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Higgs and SM Physics at the LHC

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The standard model (SM) of particle physics is holding strong, accurately describing a wide range of phenomena in the subatomic realm. Despite its success, the SM exhibits notable shortcomings leaving gaps in our understanding of fundamental physics. As we enter the third year of LHC Run 3 data-taking, the experiments are measuring SM interactions with unprecedented sensitivity, searching for potential cracks in the theory. In this talk, I will present recent highlights of SM measurements from the CMS and ATLAS experiments, including measurements of the Higgs boson. The talk will explore innovative methods such as using the LHC as a photon collider, and probing quantum entanglement in top quarks.

BSM Physics at the LHC and HL-LHC upgrades

Sara Alderweireldt[1]
[1]The University of Edinburgh, UK

Despite successfully predicting the outcome of hundreds of measurements at colliders and other experiments, the standard model of particle physics cannot be the final theory of nature. Searches for beyond-the-standard model (BSM) physics are a major component of the research program of experiments at the Large Hadron Collider (LHC). This talk presents recent highlights of BSM searches at the LHC, including long-lived particles, dark matter, heavy resonances, supersymmetric particles, BSM decays of SM particles, and other exotic phenomena. Connections are made to novel experimental methodologies and analysis tools, and challenges for future data taking. The current status following the Phase 1 upgrade (Run 3) and plans for the Phase 2 upgrade (Run 4) are also discussed.

Anatomy of Hadron Collisions - And Challenges for the Future

Peter Skands[1]
[1]University of Oxford, UK

I will give an overview of our current picture of the physical mechanisms that are at play in high-energy hadron collisions and review the current state of the art of numerical models of these processes. I will explain why I believe we are on the cusp of at least two exciting revolutions, and outline some of the main challenges to realising them. I will include a few measurement highlights from the Large Hadron Collider, showcasing both successes and some (interesting) failures.

Sustainability in the subatomic sciences

Veronique Boisvert[1]
[1]Royal Holloway, University of London, UK

Abstract unavailable.

Particle Physics Strategy, the P5 Report

Christos Touramanis[1]
[1]University of Liverpool, UK

The US particle physics community has gone through a long-range planning exercise for the next ten years. The Particle Physics Project Prioritization Panel (P5) issued a report with recommendations to Department of Energy and National Science Foundation. I discuss how the report defines its scientific scope, what the major initiatives are in the next ten years, derived from a long-term vision for the field. The report also recommends creating a balanced portfolio in the program for all sizes and time scales, domestic vs international, and different subfields.

ALICE and the Heavy Ion Programme at CERN

Marco Van Leeuwen[1]
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Collisions of lead nuclei at the Large Hadron Collider energy provide the opportunity to study the Quark-Gluon Plasma, a state of matter where quarks and gluons are effectively free to move over larger distances, instead of being confined in hadrons, in the laboratory. In this presentation I will present recent highlights from the LHC heavy-ion physics program, with emphasis on the implications for multi-body QCD physics and the QGP. I will also present a brief outlook on the plans for the ongoing and future runs of the LHC.

Flavour Physics at the LHC and elsewhere

Lucia Grillo[1]
[1]University of Glasgow, UK

A rich flavour physics programme is thriving at the LHC and elsewhere. A selection of recent results including CP violation measurements, CKM metrology, lepton flavour universality tests and rare decays studies is presented.

Hidden Sector Experiments

Carl Gwilliam[1]
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A large variety of BSM theories, particularly Hidden (dark) Sectors, predict new light, weakly interacting particles. Given the lack of new physics at the LHC, such models have received growing interest since they can provide a dark matter candidate with the correct relic density and potentially address low E discrepancies. The weak nature of the interactions leads to particles with long-lifetimes that in many cases are best searches for with dedicated experiments. This talk covers the recent results from the current FASER and SND@LHC experiments, including first measurements of collider neutrinos in addition to BSM searches. It then surveys the prospects for planned/proposed future Hidden Sector experiments with UK involvement, with a focus on the recently approved SHiP experiment and the potential dedicated Forward Physics Facility (FPF).

The Proton EDM

Alex Keshavarzi[1]
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A storage ring proton electric dipole moment (EDM) experiment (pEDM) would be the first direct search for a proton EDM and would improve on the current (indirect) limit by 5 orders of magnitude. It would therefore surpass the current sensitivity (set by neutron EDM experiments) to QCD CP-violation by 3 orders of magnitude, making it potentially the most promising effort to solve the strong CP problem. This makes it manifestly one of the most important probes for the existence of axions, CP-violation in the Higgs sector and the source of the universe's matter-antimatter asymmetry. These, coupled with a new Physics reach of O(10^3) TeV and a construction cost of O(£100M), makes it one of the low-cost/high-return proposals in particle physics today. The experiment will build upon the highly successful techniques of the Muon g-2 Experiment at Fermilab, which the UK has been a leading contributor to. In this talk, I will motivate and describe the pEDM experiment, and detail how the UK can play a leading role in making it a success by building upon previous recent achievements.

Nuclear Structure with AGATA

Rosa María Pérez Vidal on behalf of the AGATA Collection[1]
[1]LNL, INFN, Italy

In April 2022, AGATA, the state-of-the-art European HPGe-array for gamma detection [1,2] was installed at LNL. It employs innovative gamma-ray tracking technology, enabling precise identification of gamma interaction points through pulse shape analysis and subsequent software-based reconstruction of individual photon trajectories (gamma-ray tracking). Shortly thereafter a physics campaign started using stable beams ranging from hydrogen to lead, delivered by the Tandem-ALPI-PIAVE accelerator complex at energies from 20-25 MeV/u (lightest ions) to about 7-8 MeV/u (heaviest ions). In its first phase AGATA has been coupled to the PRISMA heavy-ion magnetic spectrometer to investigate exotic nuclei produced in multi-nucleon transfer and fusion-fission reactions, alongside the use of different silicon detector arrays for light charged particles and ions. The nuclear structure studies with AGATA involve various physics scenarios, including shell evolution and configuration mixing in significant regions of the nuclear chart like the N=20 island of inversion and nuclei surrounding the doubly-magic ^{78}Ni. Additionally, they explore quadrupole and octupole shapes and collectivity across a broad spectrum of nuclear masses, as well as conducting measurements with astrophysical relevance. Several Coulomb-excitation experiments investigated shape coexistence along the Z=40 and Z=50 lines. This presentation will delve into the ongoing status of the physics campaign and its primary findings.

[1] A. Akkoyun et al., NIM A 668, 26 (2012).
[2] J.J. Valiente-Dobón et al., NIM A 1049 168040 (2023).

Recent advances in hadron structure at Jlab

David Hamilton[1]
[1]University of Glasgow, UK

Much has been learned about the structure of hadrons via electron scattering since the pioneering experiments at SLAC almost seventy years ago. Today, hadron structure is one of the key pillars of research at Jefferson Lab (JLab) in the USA, where researchers utilise high power polarised electron beams to study a range of reactions at the multi-GeV scale. This talk will cover a series of recent highlights from JLab experiments, including the investigation of the nucleon's exclusive electromagnetic and weak structure via measurements of elastic form factors at high momentum transfer; determination of inclusive structure functions of light mesons via the Sullivan process; and new results on the quark and gluon mechanical structure of hadrons via deeply-virtual Compton scattering and photo-production reactions.

Quantum Algorithms applied to Nuclear Structure

Paul Stevenson[1]
[1]University of Surrey, UK

Quantum computers are devices which make use of quantum properties such as entanglement and complex amplitudes to perform computation in a fundamentally different way to classical computers. Such quantum computers, once theoretical and now realised as (somewhat) practical devices, hold the promise to revolutionise many areas of research across mathematics, computers science, physical sciences and beyond.

One particular application, the simulation of quantum systems, is an especially natural way to exploit quantum computation, since the basic building blocks of the quantum computer – spin-1/2 fermions called qubits – can be tuned to directly simulate other spin-1/2 fermions such as protons, neutrons or electrons. In this talk, some different methods of quantum simulation for nuclear systems are presented, including variational algorithms applied to excited state spectra implemented on IBM cloud quantum computer systems, and more advanced algorithms for the nuclear shell model and density functional theory tested through simulation on classical hardware. Particular special cases for nuclear physics are highlighted, such as the consequences for quantum algorithms of the symmetries that nuclear systems obey, and we place the work in the context in the wider field of quantum technologies.

Further details can be found in the following recent arXiv papers: 2403.08625, 2402.10277, 2402.15577, 2402.01623

Novel Probes of Primordial Hot Quark Soup

Krishna Rajagopal[1]
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Heavy ion collisions reproduce droplets of the trillions-of-degrees-hot liquid that filled the microseconds-old universe, conventionally called quark-gluon plasma (QGP) but better thought of as hot quark soup. Over the past twenty years, data obtained via recreating this primordial liquid have shown that it is the most liquid in the universe, making it the first complex matter to form as well as the source of all protons and neutrons. After a brief look at what we have learned about the formation and properties of this original liquid from heavy ion collisions, I will focus on the road ahead, in particular on new probes being developed to answer questions like: How does a strongly coupled liquid emerge, given that what you will see if you can probe QGP with high resolution is weakly coupled quarks and gluons? How can we use jets to see the inner workings of QGP and answer this question? And how does the droplet of QGP ripple after it has been probed by a passing jet?

Dark Matter: Direct Search experiments and other approaches

Amy Cottle[1]
[1]University of Oxford, UK

This talk will provide an overview of the current status of direct detection dark matter experiments, with an emphasis on those with UK involvement. After briefly summarising the cosmological evidence for dark matter and possible candidates, I will cover the status, recent results and progress in the field. Finally, I will discuss future prospects and upcoming projects.

Gravitational Wave Astronomy

Giles Hammond[1]
[1]SUPA, University of Glasgow, UK

The field of gravitational-wave astronomy has developed rapidly since the first observations of a binary black hole coalescence by the aLIGO detectors in 2015. The worldwide network of detectors are about to begin the second part of their 4th science run, with significant astrophysical results to date, including black hole population studies, GW-EM signals from a binary neutron star, and gravitational wave transient catalogues.

The aLIGO (advanced Laser Interferometer Gravitational-wave Observatory) detectors comprise two instruments located in Hanford, WA and Livinsgton LA. These detectors are 4km long Fabry-Perot

Michelson interferometers and the most sensitive length measuring devices in the world. They are able to sense a change equivalent to 1/1000th the diameter of a proton over their 4km baseline. The interferometers utilise a 1064nm Nd-YAG laser to illuminate the cavity mirrors. The mirrors are operated as free test masses, requiring multiple stage pendulum suspensions and inertial seismic isolation to ensure that seismic noise does not limit the detector sensitivity. The final stage of the suspension is fabricated entirely from fused silica to ensure that thermal noise does not limit their sensitivity. The UK has made major contributions to the aLIGO via development of the test mass mirror suspensions.

In this talk I will describe the technology development necessary to realise the LIGO detectors, and also describe the gravitational wave signals that have been observed in the first 4 science runs. Finally I will provide a future view of the field.

Cosmic rays and cosmic neutrinos

Ryan Nichol[1]
[1]University College London, UK

The 21st century has heralded the arrival of true multi-messenger astronomy with instruments probing the universe for signals from across the electromagnetic spectrum, gravitational waves, gamma rays, cosmic rays, and neutrinos. These signals from the cosmos are being used to test the extremes of both astrophysics and particle physics. This talk will briefly review the field of 'cosmic rays', taking the broadest definition of 'rays' to include gamma rays and neutrinos, with a particular focus on those experiments or efforts with significant UK involvement. These include experiments as diverse as the Cherenkov Telescope Array, Trinity, ANITA, IceCube, P-ONE, and PUEO. As well as highlighting the current status and results the talk will also discuss where the field will be heading in the next decade.

Laser spectroscopy of the heaviest actinides

Premaditya Chhetri[1]
[1]KU Leuven, Belgium

Experimental studies to unveil fundamental properties of the heaviest actinide elements have gained increasing interest in recent years. Nuclides in this region of the nuclear chart owe their existence to the shell effects that stabilizes them against spontaneous fission. In addition, the atomic properties of these heavy elements feature an enhanced impact of relativistic effects that affect their chemical properties compared to their lighter homologes [1]. Laser spectroscopy is a powerful tool to investigate atomic structure of these heavy elements. Moreover, with information on atomic levels and their hyperfine structure, information on nuclear parameters such as the change in the mean-square charge radii and nuclear moments become accessible [2]. However, the lack of atomic structure information of these heavy elements, the low production rates and rather short half-lives makes experimental investigation challenging and demand very sensitive experimental techniques.

First experimental observations of this kind were pioneered by the dedicated RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) method in the heavy actinide element nobelium (No, Z = 102) produced in atom-at- a-time quantities at the SHIP separator at GSI [3,4]. Measurements of an atomic transition in $^{251-255}$No gave access to nuclear moments and the change in the mean-square charge radii. In recent measurements a novel mode of the RADRIS technique was established, where the desired nuclides are produced via the radioactive decay of the captured fusion products on the filament, extending the reach of this technique, for the first time, to on-line produced fermium (Fm, Z=100) isotopes. In addition, the search of an atomic transition of the next heavier element lawrencium (Lr, Z=103) has been performed.

An improvement in the experimental observation can be achieved by performing the laser spectroscopy in a hypersonic gas-jet effusing from a stopping gas cell. Low density and cold environmental condition improve the achievable spectral resolution of laser spectroscopy. For this investigation a dedicated setup, JetRIS, was developed at HIM, Mainz and commissioned at GSI [5]. In this presentation recent results and methodological advancement in view of further perspectives for the laser spectroscopy of the heaviest elements will be discussed.

[1] M. Block et al., Prog Part Nucl Phys 116, 103834 (2021)
[2] X. Yang et al., Prog Part Nucl Phys 104005 (2023)
[3] M. Laatiaoui et al., Nature 538, 495–498 (2016)
[4] S. Raeder et al., Phys Rev Lett 120, 232503 (2018)
[5] J. Lantis et al., Phys Rev Research (submitted)

In-Source Laser Spectroscopy @ ISOLDE

James Cubiss[1]
[1]University of York, UK

Laser spectroscopy is a powerful tool for studying how the structures of nuclear ground and isomeric states evolve across the chart of nuclides [1]. By measuring the isotope shifts and hyperfine structures of atomic transitions, we can deduce fundamental properties such as spins, changes in mean-squared charge radii and electromagnetic moments, in a nuclear model-independent way. Such data are an excellent testing ground for theory, and therefore are excellent benchmarks for models that attempt to describe the governing interactions within nuclei [2].

I will introduce the in-source resonance ionisation technique used at CERN's ISOLDE facility [3] – a highly efficient method, which when combined with the sensitivity of decay stations [4] or mass spectrometry devices [5], allows access to exotic nuclides with extremely low production rates. Results will be presented from studies of isotopes in the neutron deficient Pb (Z=82) region, a hot bed of nuclear structure phenomena linked to striking changes in nuclear deformation. Highlights will be given from campaigns studying gold isotopes, along with Hartree-Fock-Bogoliubov calculations that attempt to describe the charge radii across the region [6].

[1] X. F. Yang, S. J. Wang, S. G. Wilkins, R. F. Garcia Ruiz, Prog. Part. Nucl. Phys. **129**, 104005 (2023).
[2] A. R. Vernon *et al.*, Nature **607**, 260-265 (2022).
[3] M. J. Borge, B. Jonson, J. Phys. G: Nucl. Part. Phys. **44**, 044011 (2017).
[4] A. N. Andreyev *et al.*, Phys. Rev. Lett. **105**, 252502 (2010).
[5] R. N. Wolf *et al.*, Int. J. Mass Spectrom. **349-350**, 123-133 (2013).
[6] J. G. Cubiss *et al.*, Phys. Rev. Lett. **131**, 202501 (2023).

Combined gamma-ray and electron spectroscopy for studies of shape coexistence

Janne Pakarinen[1]
[1]University of Jyvaskyla, Finland

One of the goals of modern nuclear physics research is to understand the origin of coexisting nuclear shapes and exotic excitations and their relation to the fundamental interactions between nuclear constituents. Despite of huge amount of both theoretical and experimental efforts, many open questions remain [1 and references therein]. In order to verify and understand these subjects in more detail, complementary approaches are needed.

This talk will give an insight into shape coexistence studies around neutron-deficient Pb nuclei. In particular, it will focus on series of simultaneous in-beam electron and gamma-ray spectroscopy experiments employing the SAGE spectrometer [2] at JYFL, Finland. Their relation and technical developments towards complementary experiments performed at ISOLDE, CERN [3] will also be discussed.

[1] K. Heyde and J.L. Wood, Rev. Mod. Phys. 83 1467 (2011).
[2] J. Pakarinen et al., Eur. Phys. J. A 50: 53 (2014).
[3] P. Van Duppen, K. Riisager, J. Phys. G: Nucl. Part. Phys. 38, 024005 (2011).

Neutrinoless double beta decay and absolute neutrino mass

Ruben Saakyan[1]
[1]University of London, UK

The observation of neutrinoless double-beta decay (NDBD) would constitute a landmark discovery in particle physics, setting the foundations for the development of a long-sought theory of fermion masses and the explanation for why the universe contains more matter than antimatter. I will give a brief overview of the status of the field focusing on most promising developments and expectations in the next 10-15 years. I will highlight the recently formulated UK strategy for NDBD and how it fits in the highly competitive international landscape of the field.

Neutrino Oscillation Experiments: Past/Present/Future

Luke Pickering[1]
[1]Royal Holloway, University of London, UK

The field of accelerator-based neutrino oscillation experiments is in an exciting place. Current long-baseline experiments, T2K and NOvA, are making quite precise measurements of muon neutrino disappearance and seeing tantalising hints of significant CP violation in electron neutrino appearance measurements. While significant effort is now being directed to realising the next generation of long-baseline experiments, DUNE and Hyper-K, which aim to unambiguously determine the neutrino mass ordering and make 'five-sigma' measurements of neutrino sector CP violation, T2K and NOvA still have fight in them. Two long-running joint analysis efforts, NOvA-T2K and T2K-SK, have recently concluded; NOvA still has significant data in hand, with more to come; and T2K has recently overhauled the T2K near detector and is expecting to take significant amounts of new data in the newly upgrade J-PARC neutrino beam.

Meanwhile, MicroBooNE, part of Fermilab's Short Baseline Neutrino programme, has released the results of searches into a variety of possible explanations of MiniBooNE's 'Low Energy Excess'. The LEE is often highlighted as potential evidence for additional, heavier sterile neutrinos that drive oscillations over a much shorter baseline than the known neutrinos do: sub-kilometre vs. hundreds of kilometres. While this single-detector search has rightly generated great interest, the short baseline programme is just getting started. The last of the full three-detector programme, SBND, is currently commissioning and so we can expect direct, multi-detector searches for short baseline oscillations soon.

This talk will cover the status and future prospects of experiments searching for neutrino oscillations in human-made neutrino beams. It will include discussion of recent multi-experiment joint fit results as well as a brief introduction to the PRISM technique being designed into next-generation long-baseline neutrino oscillation experiments as a powerful mitigation strategy against the difficult problem of neutrino--nucleus interaction modelling.

The Muon Physics Programme: g-2 puzzle, cLFV and EDM

Saskia Charity[1]
[1]University of Liverpool, UK

Searches for physics beyond the Standard Model (SM) in the muon sector can complement direct searches for New Physics (NP) phenomena at colliders, with potential sensitivity to NP at the TeV scale. The UK is heavily involved in a number of muon experiments worldwide, which fall into three major categories: the muon g-2 “puzzle” (MUonE and g-2 experiments), the search for Charged Lepton Flavour Violation (CLFV) via the direct conversion of a muon to an electron (COMET, MEG-II, mu2e and mu3e experiments), and searches for a muon Electric Dipole Moment (EDM) with the Fermilab g-2 experiment and new muEDM experiment at PSI. Different muon experiments face similar experimental challenges including high-precision tracking detector technology and stringent systematic uncertainty requirements. This talk will provide an overview of the rich muon physics programme in the UK, recent news from the experiments and prospects for the future.

Quantum Technologies for Fundamental Physics

Ian Shipsey[1]
[1]University of Oxford, UK

Quantum Technologies for Fundamental Physics is a strategic initiative within the National Quantum Technology Programme created with £40M from UKRI’s Strategic Priorities Fund in 2019 awarded to EPSRC and STFC with STFC administering the programme. The primary purpose of QTFP is to enable advanced quantum technologies, innovated and demonstrated during the last 5-10 years to be developed, customised and refined to enable major advances in understanding of some of the greatest scientific mysteries in fundamental physics: including the origin of the universe, the nature of dark matter, neutrino mass, violation of fundamental symmetries, new forces, the cosmic neutrino background, the measurement of neutrino mass, gravity, a new gravitational window on the universe, black holes, and foundational questions in quantum mechanics. Addressing these topics is necessarily bringing together individuals, institutions and communities who have not worked together previously into powerful new multi-disciplinary scientific collaborations. QTFP initially selected seven projects with £31M of funding commencing in February, 2021 for up to 41 months. These seven projects currently comprise 101 faculty and scientists, 66 post docs, 11 Engineers and technicians, 5 administrative staff and 32 PhD students (the students are funded from other sources). Each project has built its own collaboration, including formal working agreements with leading overseas scientific teams. In 2022, a further seventeen new awards were funded.

Parallel Session I: Session A

Search for long lived ALPs that decay into diphoton in Run 3

Rebecca Irwin[1]
[1]University of Liverpool, UK

A search for long lived axion like particles (ALPs) that decay into diphoton is presented. ALPs are hypothetical light particles that may be a component of a hidden (dark) sector. ALPs arising from Higgs decays are studied, where the Higgs is produced in association with a Z boson that is reconstructed leptonically. For prompt ALP decays, a dedicated search looking for two leptons and two collimated photons (merged or resolved) has been published. Studies focusing on the case where ALPs are long lived and mostly decay within the calorimeter volume, are on-going. In this case, photons are displaced and must be identified through dedicated tools. In this talk, current and preliminary results on these ALPs searches will be presented.

Searches for the Inert Doublet Model

Edward Curtis[1], Nicholas Wardle[1], and Anne-Marie Magnan[1]
[1]Imperial College London, UK

We present our work on a search for the Inert Doublet Model. This is a Two Higgs Doublet model with a discrete, unbroken Z_2 symmetry and which introduces three new scalar particles. A notable feature of this model is that the lightest of these new particles is a viable dark matter candidate. Here we investigate this model by looking at the dilepton with missing energy final state. Specifically, we are looking for dileptons with an invariant mass corresponding to an off-shell Z, and with a reduced MET signature.

Search for dark showers in the b-parking dataset

Kai Hong Law[1]
[1]Imperial College London, UK

A first analysis was performed to search for dark quantum chromodynamics in a unique b-quark enriched dataset. The search focuses on long-lived dark mesons that decay into Standard Model particles, with a high branching fraction to muons.

The dataset was collected with displaced muon triggers and processed with delayed reconstruction. This allowed a dataset of $O(10^{10})$ unbiased B-hadron decays to be recorded with low trigger thresholds, enabling new phase space to be investigated.

A Boosted Decision Tree (BDT) is applied to discriminate between signal and background, achieving a background rejection of 10^4 while maintaining high signal efficiency. The ability of the BDT to identify displaced muon signatures is tested by studying the J/ψ resonance. Custom vertexing using muons and event categorisation are exploited to greatly improve the sensitivity, including a multi-vertex category, in which the background is greatly suppressed relative to the signal.

The mass distribution of the muon vertices is fit to extract limits for different mass and lifetime model points. The preliminary results probe the branching ratio of Higgs to dark shower decays to an expected limit of $< 10^{-3}$ at 95% confidence level. The limits are considerably tighter than the corresponding limit on Higgs to invisible, which is 0.1.

Re-thinking the CMS Level 1 Trigger with Machine Learning

Maciej Glowacki[1]
[1]University of Bristol, UK

The High Luminosity upgrade to the LHC will deliver unprecedented luminosity to the experiments, culminating in up to 200 overlapping proton-proton collisions. In order to cope with this challenge several elements of the CMS detector are being completely redesigned and rebuilt. The Level-1 Trigger is tasked with processing data from proton-proton collisions at a rate of 40MHz and subsequently reducing the read-out to 750kHz in a 12.5 microsecond window. The CMS Level-1 Trigger (L1T) is being reshaped for the HL- LHC to benefit from the various upgrades scheduled to be installed onto the detector as well as software advancement to further increase the efficiency of retaining interesting signals, even under the extreme conditions of HL-LHC. This upgraded trigger, as in the present design, will utilise an all-FPGA solution. Although rules-based algorithms have traditionally been used for this purpose, the emergence of new generation FPGAs and Machine Learning toolsets have enabled neural networks to be proposed as an alternative architecture. We present a survey of approaches leveraging machine learning for triggering tasks at the L1T and in-depth design and implementation specifics of a Convolution Neural Network (CNN) as a topological trigger running on an FPGA, demonstrating the feasibility of such an approach. Results will be presented for a baseline signal model of a pair of Higgs bosons decaying to four b-quarks. The model architecture, resource usage, latency and implementation floorplan will all be presented. Latest results will also be shown of studies to use domain-specific knowledge to enhance the network's inference capability.

The ATLAS Run III L1 calorimeter trigger

Panagiotis Bellos[1]
[1]University of Birmingham, UK

In Run III LHC has been delivering an increased instantaneous luminosity with respect to Run II. The ATLAS detector underwent a series of upgrades to deal with this increase. The upgrade focused mainly on the Level-1 trigger including improvements for both the muon and calorimeter triggers. The ATLAS Level-1 Calorimeter Trigger is a pipelined system processing signals from the calorimeters using custom hardware processors, based on FPGA technology. The new system is designed to process a higher granularity and use Feature Extractors (FEXes) which implement dedicated object-finding algorithms for electrons/photons, taus, jets and missing energy. Four UK instutes are heavily involved in the project and are almost completely responsible for the eFEX, identifying electrons and taus. The electron triggers based on the new system were exclusively used in 2023 showing a quite impressive performance. For taus a hardware implemented machine learning algorithm is planned to be used in 2024 for first time in ATLAS. An overview of the Level-1 Calorimeter Trigger will be presented, focusing on the eFEX system and its tuning and performance during the 2023 data taking period.

Parallel Session I: Session B

A search for lepton flavour violating τ →3μ decays with the ATLAS experiment

Conor McPartland[1]
[1]University of Liverpool, UK

In the Standard Model (SM), conservation of flavour is not a fundamental symmetry and has, so far, been shown to be violated in both the neutrino and quark sectors. Given these observations, and the recent intriguing results on a possible violation of lepton universality by the g-2 experiment, it is natural to question whether charged leptons also violate flavour. Although charged lepton violation (cLFV) should be possible in the SM via neutrino oscillations, this has never been observed, as the branching ratios for this are far below our current detection abilities. Therefore, any detection of cLFV would be unambiguous evidence of physics beyond the standard model, thus providing a model independent probe of new physics.

Various searches have been carried out to look for charged cLFV decays, with the branching ratio limits on the tau approximately four orders of magnitude less sensitive than those for muons. The decay that this analysis is concerned with is that of τ^±→μ^± μ^± μ^∓. Due to this much less stringent limit, and the fact that new physics may be more likely to couple to the heavier tau, it makes a good starting point to search for cLFV decays.

This project aims to search for evidence of this decay, using the large data set of 13 TeV proton--proton collisions, provided by the Large Hadron Collider to the ATLAS experiment from 2015 to 2018. The ATLAS experiment is able to detect a large number of taus produced by both heavy flavour and W production modes, with the run 2 dataset of 139fb-^{1} containing on the order of 109 taus. The aim of this analysis is to use the full ATLAS run 2 dataset, to either find evidence for this decay or to impose a stringent limit on its branching ratio.

Search for light long-lived neutral particles from Higgs boson decays via vector-boson-fusion production from proton-proton collisions at sqrt(s)=13 TeV with the ATLAS detector

Richards González[1], Yanyan Gao[1], Emily Pender[1], Cristiano Sebastiani[2], Iacopo Longarini[3], Sebastian Olivares[4], Monica D'Onofrio[2], and Anyes Taffard[3]
[1]The University of Edinburgh, Edinburgh, UK, [2]The University of Liverpool, UK, [3]University of California Irvine, USA, [4]Universidad Andres Bello, Santiago, Chile

A search is reported for long-lived dark photons with masses between 0.1 GeV and 15 GeV, from exotic decays of Higgs bosons produced via vector-boson-fusion (VBF). Events that contain displaced collimated Standard Model fermions reconstructed in the calorimeter or muon spectrometer are probed. This search uses the full LHC Run 2 (2015-2018) data sample collected in proton-proton collisions at √s=13 TeV, corresponding to an integrated luminosity of 139 inverse femtobarns. Dominant backgrounds from Standard Model processes and non-collision sources are estimated by using data-driven techniques. The observed event yields in the signal regions are consistent with the expected background. Upper limits on the Higgs boson to dark photon branching fraction are reported as a function of the dark-photon mean proper decay length or of the dark-photon mass and the coupling between the Standard Model and the potential dark sector. This search is combined with previous ATLAS searches obtained in the gluon-gluon fusion (ggF) and WH production modes. A branching fraction above 10% is excluded at 95% CL for a 125 GeV Higgs boson decaying into two dark photons for dark-photon mean proper decay lengths between 173 and 1296 mm and mass of 10 GeV.

Searching for direct stau production in the lepton-hadron final state at ATLAS using machine learning

Sebastian Rutherford Colmenares[1], Tina Potter[1], and Holly Pacey[2]
[1]University of Cambridge, UK, [2]University of Oxford, UK

Supersymmetry remains a compelling avenue to extend the Standard Model, and large gaps remain in the exclusion of the proposed stau particle in scenarios where the mass gap between the stau and the lightest supersymmetric particle (LSP) is reduced. A new ongoing search at ATLAS is presented that seeks to explore direct stau production in these moderately compressed scenarios by looking at the lepton-hadron channel to take advantage of the single-lepton triggers. New machine learning techniques are investigated to tackle the difficulties associated with this decay channel and reduce the large backgrounds.

Searching for Supersymmetry with the ATLAS Detector

Alessandro Ruggiero[1]
[1]University of Oxford, UK

This talk will cover an ongoing ATLAS effort in the search for Supersymmetry. The analysis targets a gap in current exclusion limits at small slepton - neutralino mass difference. This phase space is strongly motivated as the signal models here can explain the ongoing muon magnetic moment anomaly. The analysis exploits the presence of a jet from Initial State Radiation in order to trigger events using the Missing Energy Trigger to reach leptons at lower transverse momenta than ever before in ATLAS. The use of Boosted Decision Trees leads to significantly enhanced projected sensitivity in this interesting phase space.

A search for tri-Higgs production at the ATLAS detector

Maggie Chen[1], Todd Huffman[1], Holly Pacey[1], and William Balunas[2]
[1]University Of Oxford, UK, [2]University of Cambridge, UK

This talk will motivate and present an analysis that probes the simultaneous production of three Higgs Bosons, a signature that has never been directly probed before at the ATLAS detector. The tri-Higgs production is predicted by the Standard Model and is a promising way of constraining the trilinear and quartic Higgs self-couplings. While the SM production suffers from a small cross-section, an array of BSM models also produce three Higgs Bosons at enhanced cross-sections that are already attainable at the LHC. The current analysis at ATLAS probes both the SM-like and BSM productions, using a final state of 6 b-jet that exploits the largest branching fraction of H->bb. The analysis strategy will be presented, focusing on the physical motivations, as well as the design of machine learning methods and their synergy with the background estimation. The expected sensitivity to the SM-like and benchmark BSM signals will be presented.

ML and BSM reinterpretation - challenges and oppourtunities

Tomasz Procter[1]
[1]University of Glasgow, UK

Modern BSM searches often depend very explicitly on BDT's or Neural Nets. This can pose a real problem for interpreters - not only is the neural net data often not provided, but there may be difficulties when applying neural nets trained at reco-level to the truth-level inputs interpreters typically have to hand. I survey in detail two attempts at reinterpreting NN-based analyses, one within and without- ATLAS, and what lessons we can learn in future as analysers.

However, of course ML also offers a lot of opportunities - surrogate models may step in where straightforward reuse doesn't; and I will also show how reweighting in BSM signal grids has the potential to substantially reduce our computing load.

Parallel Session I: Session C

Beyond the standard model particle searches in MicroBooNE

Luciano Arellano[1]
[1]The University of Manchester, UK

MicroBooNE has collected the largest dataset of neutrino-argon interactions to date. Located downstream from two different neutrino beams, BNB and NuMI, this dataset has enabled a broad programme of searches for exotic beyond the Standard Model particles. I will present a detailed look into our latest published results of searches for heavy neutral mesons and dark trident processes, as well as discuss potential for future searches.

Sensitivity to HNLs with the ANUBIS detector

Anna Mullin[1]
[1]University of Cambridge, UK

Models of new physics often predict long-lived particles that would escape current Large Hadron Collider experiments unseen. Long-lived particles are predicted by extensions to the Standard Model where a new sector couples to known particles via portal interactions. Such extensions include Heavy Neutral Leptons (HNLs), axions, dark scalars and dark photons. With HNLs as an example, we evaluate the discovery potential of the ANUBIS Experiment to a rich array of final states. The ANUBIS setup places detector technology directly on the ATLAS cavern ceiling, extending our lifetime reach further from the interaction point while maintaining synergy with timing information from the main detector. Recent updates to this detector setup are showcased in our results, including a new geometry layout and improved isolation from hadronic radiation. Benchmark HNL models permit comparison with other long-lived particle experiments and provide an example of new physics with unique discovery potential at the ANUBIS Experiment.

Developing the Reconstruction of a Magnetised Gaseous Argon TPC for the DUNE Near Detector

Francisco Martínez López[1]
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The Deep Underground Neutrino Experiment (DUNE) is a next-generation neutrino experiment that will consist of a near detector (ND) complex placed at Fermilab, several hundred meters downstream of the neutrino production point, and a larger far detector (FD) to be built in the Sanford Underground Research Facility (SURF), approximately 1300 km away. DUNE will record neutrino interactions from an accelerator-produced beam (the LBNF multi-megawatt wide-band neutrino beam planned for Fermilab) arriving at predictable times but will also aim to detect rare events such as supernova neutrinos, potential nucleon decays and other beyond the Standard Model phenomena. The main role of the DUNE ND is constraining the systematic uncertainties in the

neutrino oscillation measurements by characterising the energy spectrum and composition of the neutrino beam, as well as performing precision measurements of neutrino cross sections. The plan for DUNE is to be built using a staged approach with two main phases. While the Phase I ND complex is sufficient for early physics goals, a Phase II upgrade is planned in order to reach the designed sensitivity for the neutrino oscillation physics. The upgraded Phase II ND will feature ND-GAr, a magnetised high-pressure gaseous argon TPC surrounded by an electromagnetic calorimeter (ECal) and a muon tagger. The gaseous argon provides low detection thresholds, which would allow detailed measurements of nuclear effects at the interaction vertex using the same material as the FD. Additionally, the magnetic field and the ECal would enable efficient particle identification and momentum and charge reconstruction. GArSoft is the simulation and reconstruction software package developed for ND-GAr. The development of this software is crucial for the task of delivering a physics-driven detector design, as it allows us to understand the impact that design changes have on the physics. This talk will present an overview of the capabilities of ND-GAr and the ongoing efforts on the simulation and reconstruction software for the detector.

A Data-Driven Extrapolation Technique for the DUNE-PRISM Oscillation Analysis

Alex Wilkinson[1]
[1]University College London, UK

The Deep Underground Neutrino Experiment (DUNE) is a next-generation long-baseline neutrino oscillation experiment that aims to measure CP-violation in the neutrino sector as part of a wider physics programme. DUNE consists of a near and far detector in a high-power wide band neutrino beam. The Precision Reaction Independent Spectrum Measurement (PRISM) refers to the capacity of part of the DUNE near detector to move off-axis from the beam to sample different neutrino energy spectra. Due to the wide range of off-axis positions, the set fluxes can be treated as an approximate basis and combined to approximate any target flux. This is used to extract oscillation parameters with little dependence on an interaction model by producing a prediction of the oscillated spectrum at the far detector directly from near detector measurements. An important part of this extrapolation is to correct for the differences in resolution and efficiency of the detectors with minimal reliance on Monte Carlo. This work presents a deep learning approach to accomplish this by predicting the far detector response given a near detector neutrino event. The problem is posed as an image-to-image translation between two domains defined by the distinct types of detector technology. The capacity for the model to accurately predict far detector reconstructed variables is demonstrated and the network is integrated in the simulation chain to conduct an initial study of its performance over Monte Carlo based smearing.

Measuring Reactor Antineutrino Oscillation at SNO+

James Page[1]
[1]University of Sussex, UK

SNO+ is a detector 2 km underground in Sudbury, whose main goal is the detection of neutrinoless double beta decay. In addition, being about 200 to 300 km away from three large nuclear power plants, it is ideally situated to measure long baseline neutrino oscillations. This should allow us to make a competitive measurement of Δm_{21}^2 in the near future, with data being collected currently. This talk will cover the basic principles of what this parameter is, and how it is to be measured. Particular attention will be paid to background reduction — including a new classifier — as well as the oscillation fit method. Some preliminary predictions and sensitivities will be shown, ahead of the SNO+ publication due later this year. Finally, a brief outlook on the related analyses to follow at SNO+ will be presented.

Parallel Session I: Session D

Stopping Effects and Sensitivity of Sub-GeV Dark Matter in QUEST-DMC

Neda Darvishi[1]
[1]Royal Holloway, University of London, UK

In this discussion, the potential for detecting sub-GeV dark matter through the QUEST-DMC experiment will be explored. The experiment employs a novel approach, utilizing superfluid Helium-3 (He-3) alongside quantum sensors. Superfluid He-3 is highlighted as an optimal medium for sub-GeV dark matter searches, particularly effective in spin-dependent interactions. The presentation will cover the experiment's projection sensitivity to diverse dark matter models and establish upper bounds on dark matter interactions due to stopping effects induced by atmospheric elements.

Cryogenic qualification of SiPM array detectors for the DarkSide-20k experiment

Alice Hamer[1]
[1]University of Edinburgh, UK

The nature of dark matter is one of the biggest mysteries of the universe. Many experiments have been built and operated to search for dark matter candidate particles and the leading technology in these searches is liquid noble detectors, with liquid argon in particular gaining momentum in recent years. The DarkSide-20k detector will search for dark matter particles using a liquid argon time projection chamber (TPC) with an active mass of 51 tons - the largest and most sensitive dark matter experiment to date. The TPC detector will be surrounded by a liquid argon veto detector in order to remove external backgrounds, with a particular focus on neutrons which are problematic for dark matter experiments. Interaction signals in the TPC and veto detectors will be recorded by arrays of silicon photomultipliers (SiPMs), an increasingly popular choice for such detectors due to their advantages over the alternatives. 25% of the SiPM units for the DarkSide-20k detector are being produced in the UK and undergoing cryogenic QA and characterisation tests at dedicated test sites. In this talk I will present an overview of these tests and the first results from the University of Edinburgh test stand.

Boosted Dark Matter Sensitivity in the DarkSide-20k Detector

Zoe Balmforth[1]
[1]Royal Holloway, University of London, UK

Boosted dark matter models offers an attractive alternative approach to traditional dark matter searches, since dark matter energies can be enhanced by a large Lorentz boost. The novel possibility that a small population of dark matter is relativistic, produced non-thermally by late-time processes, is presented in this talk, and the experimental detection potential is explored for current and future dark matter direct detection experiments, including DarkSide-20k. Boosted dark matter signals can be significantly higher in energy than traditional WIMP-induced recoil searches, and thus the inner and outer veto regions surrounding the DarkSide-20k TPC, which contain 700 tonnes of target material, offer a significant enhancement in sensitivity.

The APEX Experiment: a dark matter search at Jefferson Lab Hall A

Oliver Jevons[1]
[1]University Of Glasgow, UK

The A Prime (A′) Experiment was a search performed at Hall A of the Thomas Jefferson National Accelerator Facility (Jefferson Lab, or JLab), looking for evidence of a dark vector gauge boson (also called a 'dark photon'). The dark photon of interest, denoted as A′, is theorised to interact with the Standard Model through kinematic mixing, which is characterised by a strength parameter, ε. In February 2019, JLab's Hall A was host to the APEX experiment, which recorded e+e- production from a 2.138 GeV electron beam incident on a tungsten target. A blinded peak search was performed on 10% of the data, which did not find any evidence of the A′ within the mass range 130 − 220 MeV, and established the strongest limits on A′ production within this range. A final peak search on the full APEX data set is currently underway, and final results are expected in the near future.

Status of the LUX-ZEPLIN (LZ) Dark Matter Experiment

Sally Shaw[1], and **Ewan Fraser**[2]
[1]University of Edinburgh, UK, [2]University of Liverpool, UK

LUX-ZEPLIN (LZ) is a dark matter direct detection experiment nearly a mile underground at the Sanford Underground Research Facility (SURF) in Lead, South Dakota, USA. LZ employs a dual-phase xenon time projection chamber with 7 tonnes of active volume and a multi-component veto system for sensitive detection of particles such as Weakly Interacting Massive Particles (WIMPs), a highly motivated dark matter candidate. I will talk about the LZ experiment and its world-leading search for WIMP dark matter, as well as recent results extending the search to more exotic dark matter models and other new physics phenomena.

LZ Outer Detector: Calibration, Monitoring and Performance in Contribution to First Science Result

Sam Woodford[1]
[1]University of Liverpool, UK

The LUX-ZEPLIN dark matter experiment completed its first science run in 2022 revealing world-leading sensitivities, with further results to come in the future. The centrepiece of the experiment is a dual-phase liquid xenon time projection chamber primarily sensitive to low energy nuclear recoils, with rejection of backgrounds enhanced by a xenon skin veto detector and by a liquid scintillator Outer Detector (OD), loaded with gadolinium for efficient neutron capture and tagging. The combination of veto detectors and water tank provide active shielding for the LZ experiment. This talk will cover three main facets of the OD: calibration, monitoring of performance and data quality, and will also discuss its contribution to first science results. The calibration section will discuss two of the types used in LZ: optical calibration, and radioactive source calibration. The role of the OD Optical Calibration System (OCS) will be discussed, outlining how LEDs are used to regularly calibrate the 120 OD PMTs. OD optical calibrations include PMT response to single photoelectrons and ionic after-pulsing. LZ also uses various radioactive sources of known decay rates to ascertain the OD's response to real neutron and gamma signals. A brief description of LZ's Physics Readiness Monitor (PREM) will be provided, with a specific focus on its function in tracking overall trends in the OD, from the initial quality assurance, up to now. Finally, a summary of OD data analysis will be covered, with an emphasis on how these studies contributed to an effective background veto in the first science run.

Parallel Session I: Session E

BUTTON Simulations for the Development of WbLS

Adam Tarrant
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Gadolinium-doped Water based Liquid Scintillator (Gd-WbLS) has a lower detection threshold than traditional water fill media for detecting neutrinos. It combines the properties of water-based Cherenkov detectors with the enhanced energy resolution of liquid scintillators. Boulby Underground Testbed (for) Observing Neutrinos (BUTTON) is part of a line of detectors to assess this new fill material for its deployment in a kilotonne scale experiment. The development of BUTTON requires an understanding of the interactions expected from the experiment. Simulations will be presented that are used to understand and benchmark the potential detector performance. An important task of BUTTON will be the evaluation of the properties of WblS, this is achieved using optical and radioactive calibration source. Light diffusers currently used in Super-Kamiokande will be used in BUTTON and have the potential to measure WbLS optical properties such as attenuation. Radioactive sources such as AmBe produce neutrons allowing for the capture time on gadolinium to be measured.

The potential application of WbLS is in the observation of the next galactic core collapse will also be presented. Neutrinos from the next supernova have the potential to further our understanding of

particle physics to astronomy. WbLS is more sensitive to elastic scattering of neutrinos than typical water Cherenkov detectors. As a result, WbLS can improve supernova neutrino pointing which is vitally important for multi-messenger astronomy realising the full potential of the next core collapse event.

Vertex-finding in a DUNE far-detector using Pandora deep-learning

Andrew Chappell[1]
[1]University of Warwick, UK

The Deep Underground Neutrino Experiment (DUNE) will operate four large-scale Liquid-Argon Time-Projection Chambers (LArTPCs) at the far site in South Dakota, producing high-resolution images of neutrino interactions.

LArTPCs represent a step-change in neutrino interaction imaging and the resultant images can be highly detailed and complex. Extracting the maximum value from LArTPC hardware requires correspondingly sophisticated pattern-recognition software to interpret signals from the detectors as physically meaningful objects that form the inputs to physics analyses. A critical component is the identification of the neutrino interaction vertex, which is non-trivial due to the interaction occurring at any point within the detector volume. Subsequent reconstruction algorithms use this location to identify the individual primary particles and ensure they each result in a separate reconstructed particle.

A new vertex-finding procedure presented in this talk integrates a U-Net performing hit-level classification into the multi-algorithm approach used by the Pandora pattern recognition framework to identify the neutrino interaction vertex. The machine learning solution is seamlessly integrated into a chain of traditional pattern-recognition algorithms incorporating knowledge of the detector, demonstrating that traditional and machine learning methods need not be mutually exclusive in leveraging the potential of machine learning for neutrino physics. The technique substantially outperforms the previous BDT-based solution.

ARIADNE+: Large Scale Demonstration of Fast Optical Readout for Dual Phase LArTPCs at the CERN Neutrino Platform

Adam Lowe[1]
[1]University of Liverpool, UK

Optical readout of large scale dual-phase liquid Argon TPCs is an attractive and cost effective alternative to charge readout. Following the successful demonstration of 3D optical readout with the ARIADNE 1-ton detector, the ARIADNE+ experiment was recently deployed using the protoDUNE “cold box” at the CERN neutrino platform imaging a much larger active region of 2mx2m. ARIADNE+ uses 4 Timepix3 cameras imaging the S2 light produced by 16 novel, patent pending, glass THGEMs. ARIADNE+ takes advantage of the raw Timepix3 data coming natively 3D and zero suppressed with a 1.6 ns timing resolution. Three of the four THGEM quadrants were visible readout with the fourth featuring a VUV light image intensifier, thus removing the need for wavelength shifting altogether.

Cosmic muon events were recorded successfully at stable conditions providing the first demonstration for its use in kton scale experiments such as DUNE.

In my talk I will be discussing in detail the innovative ideas that make ARIADNE+ unique and the benefits that come with these technologies. These include, but is not limited too, TPX3Cams, the PEN wavelength shifting, a chemically etched stainless steel extraction grid, Invar support structure and a new way to manufacture glass THGEMs. I will also be presenting a gallery of cosmic muon events along with a breakdown of our mechanisms for analysis allowing us to arrive at an energy calibration and resolution.

Q-Pix: pixel-based charge readout for kton scale LArTPC

Shion Kubota[1]
[1]University of Manchester, UK

Q-Pix is a novel, pixel-based readout technology that provides a path to fully pixelated, kiloton-scale liquid argon time projection chambers. This technology enables low-energy (sub-MeV) detection thresholds that will maximize the neutrino physics potential while preserving the 3D information and keeping data rates manageable. This new solution can enhance DUNE's physics program, including beam physics, and supernova studies, as well as enable the detection of solar neutrinos. An overview of the QPix technology and the physics potential it offers will be presented in this talk.

The University of Sheffield LArTPC Test Stand for Development of Next Generation Charge Readout Technologies

Harry Scott[1]
[1]University of Sheffield, UK

The University of Sheffield Liquid Argon (LAr) Test Stand is a liquid argon time projection chamber (LArTPC) detector experiment, built for the development and optimisation of pixelated charge readout technology for the DUNE Phase-I near detector. It also has the potential to contribute to the design of the future DUNE Phase-II near detector readout system. Pixelated charge readout technology was chosen as an alternative charge readout system in the DUNE Phase-I near detector to avoid intrinsic ambiguities in event reconstruction arising from charge ionisation pile up in conventional wire plane charge readout systems used in SBND, MicroBooNE and ICARUS. The test stand setup consists of a 20 l dewar, an internal photon detector system, four external cosmic ray taggers and an electric field cage with 10 cm anode-cathode drift distance, allowing for complete reconstruction of ionisation charges and rejection of background cosmics. Sufficiently low electronegative impurity (ENI) levels are maintained by constant circulation of evaporated gaseous argon through purification systems, before cooling and condensing via proximity to circulating liquid nitrogen, keeping the percentage of argon in the dewar in liquid form at a 90% minimum. The University of Sheffield LAr Test Stand has demonstrated the ability to collect cosmic-ray muon data with continuously circulating liquid argon and nitrogen for three weeks consecutively, measuring ENI densities of the order of one part oxygen molecule per million using scintillation decay pulses deposited on the internal photon detector, comparing the results to measuring the purity through means of charge attenuation and electron lifetime measurements in the pixels.

Understanding the Off-Axis Flux of Neutrinos from Neutral Kaons

Holly Parkinson[1]
[1]University of Edinburgh, UK

The MicroBooNE experiment at Fermilab is a Liquid Argon Time Projection chamber (LArTPC) neutrino detector, able to detect neutrinos from the off-axis NuMI beam. Due to this position and its high energy (120 GeV), the beam is rich in electron neutrinos. Kaon decays are the main source of electron neutrinos in the NuMI beam, with a sizeable component coming from decays of K^0-Long (K^0L) particles produced in the beam target. This component on the flux is highly unconstrained: its prediction and the related uncertainties come from charged kaon data and arguments on isospin conservation. A method is presented to calculate a model uncertainty on the K^0L yield as a continuous function of Feynman-x and transverse momentum, using hadron production data from NA61/SHINE. This model uncertainty can be implemented in software packages for predicting flux uncertainties. Correctly estimating the uncertainty on the K^0L yield is important for measurements such as the electron-neutrino cross section on argon, beneficial for understanding neutrino interactions, and nuclear effects in future liquid argon neutrino experiments such as DUNE.

Parallel Session I: Session F

Status of the Fermilab Muon g-2 Experiment

C E Zhang[1], Elia Bottalico[1], Saskia Charity[1], and Lorenzo Cotrozzi[1]
[1]University of Liverpool, UK

The muon g-2 experiment at Fermilab (E989) recently published the measurement of the muon anomalous magnetic moment, a_μ, with a precision of 0.20 parts-per-million (ppm) with data collected in 2019 and 2020. This is in excellent agreement with and more than a factor of two more precise than the 2021 measurement. Currently the final data collected between 2021-2023 is being analysed, and the target final precision is 0.14 ppm. Our measurement will provide a strong probe of the effects of physics beyond the Standard Model (SM). While the statistical improvement will greatly improve the uncertainty, further improvement must come from the systematic uncertainties. In this talk, I will present an overview of the experiment, the developments that improved the latest experimental precision, and an outlook on the experiment's future, especially on the novel analysis techniques under development to further reduce systematic uncertainties.

Measurement of the anomalous spin precession frequency ω_a in the Muon g-2 experiment at Fermilab

Lorenzo Cotrozzi[1]
[1]University of Liverpool, UK

The Muon g-2 Experiment at Fermilab aims to measure the muon magnetic moment anomaly, a_μ = (g-2)/2, with a final accuracy of 0.14 parts per million (ppm). A 3.1-GeV muon beam is injected into a storage ring of 14 m of diameter, in the presence of a 1.45 T magnetic field. The anomaly a_μ can be extracted by accurately measuring the anomalous muon spin precession frequency ω_a, based on the arrival time distribution of decay positrons observed by 24 electromagnetic calorimeters, and the magnetic field environment using Nuclear Magnetic Resonance techniques. The experiment's first result published in 2021, based on Run-1 data collected in 2018, confirmed the previous result obtained at Brookhaven National Laboratory with a similar sensitivity of 0.46 ppm. In 2023, the experiment published a new result based on the 2019 and 2020 datasets, Run-2 and Run-3, which contain a factor of four more data than in Run-1. By improving the statistical and systematic uncertainties, the Muon g-2 Experiment reached the unprecedented sensitivity of 0.20 ppm. In this talk, I will outline the major systematic uncertainties on the ω_a frequency and discuss the improvements with respect to the Run-1 result. I will also look ahead to what we can expect in the final Muon g-2 measurement at Fermilab, based on the full statistics.

Search for an explanation to the muon anomalous magnetic moment through the non-resonant production of two additional Higgs bosons

George Uttley[1], Klitos Savva[1], Daniel Winterbottom[1], and David Colling[1]
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I will present a search for the production of two additional Higgs bosons from an off-shell Z boson, where both additional particles decay to τ lepton pairs. This is performed with a data sample collected with the CMS detector from proton-proton collisions at the LHC at √s = 13 TeV, corresponding to an integrated luminosity of 138 fb^{-1}. This is motivated by the Type X ("lepton-specific'') two Higgs doublet model which could explain the tension between the experimental and theoretical values of the muon anomalous magnetic moment. No deviation away from the standard model background is observed. Exclusion contours are placed on the Type X two Higgs doublet model alignment scenario, and the model as an explanation for the muon anomalous magnetic moment measurements is ruled out.

Status of the MUonE experiment

Riccardo Nunzio Pilato[1]
[1]University of Liverpool, UK

The muon anomalous magnetic moment exhibits a long standing discrepancy between theory and experiment. The comparison with the Standard Model prediction is currently limited by tensions in

the evaluation of the leading order hadronic contributions to the muon anomaly, aμHLO. This quantity is traditionally determined through a data-driven approach involving the measurement of e+e- annihilation cross sections into hadrons. A recent calculation of aμHLO based on lattice QCD techniques shows a 2.1σ discrepancy with the dispersive one, while a new e+e- cross section measurement disagrees with the previous results. Independent crosschecks are thus required to solve this tension and consolidate the theoretical prediction.

The MUonE experiment proposes a novel approach to determine aμHLO, based on the extraction of the running of the electromagnetic coupling constant in the space-like region from a very precise measurement of the μ − e elastic scattering differential cross section. The measurement will be performed at CERN's North Area by scattering a 160 GeV muon beam on the atomic electrons of a low-Z target. A pilot run was held in September 2023 with a reduced detector to valide the experimental proposal. The status and future plans of the experiment will be presented.

Measurement of the muon electric dipole moment at the Fermilab Muon g-2 experiment

Lucy Bailey[1]
[1]University College London, UK

The Muon g-2 experiment at Fermilab aims to measure the anomalous magnetic moment of the muon a_μ to a precision of 140ppb. This precision measurement provides a test of the standard model (SM) predictions by being sensitive to range of virtual particles. In parallel to this analysis, it is possible to perform a measurement of the muon electric dipole moment (EDM) using the straw tracker detectors.

In the SM, EDMs are predicted to be vanishingly small. A measurement of a non-zero muon EDM would constitute physics beyond the SM (BSM) and be a new source of charge-parity violation. The current limit on the muon EDM was set at the predecessor experiment at Brookhaven National Laboratory, giving $|d_\mu|<1.8\times10^{(-19)}$ e.cm – Fermilab aims to improve this by an order of magnitude. Improving the limit on the muon EDM will help to constrain BSM theories.

This talk will cover the importance and methodology of this measurement and discuss the recent improvements to the tracking algorithm giving us roughly twice the number of tracks for analysis.

Nuanced Beta Spectral Shapes and Their Role in Exploring Physics Beyond the Standard Model

Marlom Ramalho[1]
[1]University of Jyväskylä, Finland

We employ the nuclear shell model to conduct theoretical computations for the precise determination of the nuclear matrix elements, which are crucial for analysing nuclear structure-sensitive beta decays. Our research specifically addresses critical challenges in physics beyond the standard model, utilizing beta decay processes as a primary investigative tool. We first focus on the reactor antineutrino anomaly, with particular attention to the full-blown beta decay analysis of 92Rb and the decay chain of 220-222Rn leading to the 212-214Pb-Bi-Po chain, which is significant in the context of background radiation in underground experiments. Our findings highlight the issues of conventional approximations in the theoretical beta spectral shapes, especially concerning forbidden decays, and underscore the need for more sophisticated approaches that accurately incorporate nuclear structure. Through a detailed examination of computed beta spectral shapes, we reveal the limitations of existing approximations and the inherent complexities of comprehensive nuclear-structured computations. The implications of our work are particularly pertinent for enhancing the accuracy of underground Dark Matter search experiments and advancing the search for neutrinoless double beta decay, thereby contributing valuable insights to the field of rare event experiments and the physics beyond the standard model.

Parallel Session I: Session G

Silicon detector upgrades in ALICE: ITS3 and ALICE 3

Jian Liu[1]
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The new inner tracking system (ITS2) of the ALICE experiment at the LHC, upgraded during the LHC Long Shutdown 2 (2019-2021) with monolithic active pixel sensors (MAPS), known as ALPIDE, is currently taking data and demonstrates excellent performance in the LHC Run 3. A replacement of the three innermost layers of the ITS2, called ITS3, is foreseen during the LHC Long Shutdown 3 (2026-2028) to further improve its tracking precision and efficiency, particularly at very low transverse momentum (pT > 0.1 GeV/c).

The ITS3 is a cylindrically bent silicon vertex detector based on stitched wafer-scale monolithic active pixel sensors with 65 nm CMOS technology. The large stitched sensors are 28 cm in length and can be thinned down to below 50 µm, where the sensors are flexible enough to be bent into truly cylindrical detector half-barrels. An extremely low material budget of 0.05% X/X_0 per layer can be achieved in combination with air-cooling and lightweight carbon foam spacers as support structures.

Concurrently, the future ALICE 3, intended for LHC Runs 5 and 6, is set to significantly advance heavy-ion experiment technology. Its inner vertex detector, leveraging R&D efforts from ITS3, is situated within a retractable structure inside the beam pipe for optimal pointing resolution (< 10 µm), complemented by an extensive MAPS-based outer tracker with a total silicon surface of around 60 m2. Intensive R&D activities are underway to address the demanding specifications for the detectors.

This contribution will discuss the R&D status and plans for both the ITS3 and ALICE 3 upgrades, covering the detector concepts, technology challenges, detector requirements and performances, novel MAPS sensors, sensor bending, detector cooling and mechanics as well as detector integration.

Low transverse momentum jet measurements in heavy-ion collisions with ALICE

Jaime Norman[1]
[1]University of Liverpool, UK

The measurement of jets in heavy-ion collisions provides a unique probe of the strongly-interacting, deconfined state of matter created in these collisions, known as the Quark-Gluon Plasma. While the large uncorrelated background present in heavy-ion collisions is a significant challenge in the measurement of jets, precise, data-driven techniques have been developed to subtract this background in Pb--Pb collisions. This enables the exploration of medium-induced modification of jet production and acoplanarity over a wide phase space, including the low jet transverse momentum region.

In this contribution, we present novel measurements by the ALICE Collaboration employing background subtraction techniques to access unprecedented kinematic windows in heavy-ion collisions. Comparison to theoretical calculations incorporating jet quenching will be discussed.

Exploring Neutron stars EoS with coherent $\pi^0\pi^0$ photoproduction at A2@MAMI

Mihai Mocanu[1]
[1]University of York, UK

Recent measurement of coherent π^0 photoproduction on Pb leads to a most accurate determination of the neutron skin, constraining nuclear matter Equation of State (EoS) at around $\rho \sim 1\rho_0$. A natural next step is elucidating the nuclear EoS at higher densities to tune our understanding of the most violent process in the Universe - neutron star mergers. It was demonstrated that at densities above $\sim 3\rho_0$, dibaryonic degrees of freedom come into play [1]. The work presented in this talk aims to improve our knowledge of dibaryon behaviour in dense nuclear matter by measuring coherent $\pi^0\pi^0$ photoproduction of Ca-40/48 nuclei. The experiment was performed at the A2@MAMI facility in Mainz (Germany). The analysis aims to identify the first genuine hexaquark, the d*(2380), through photoproduction on nuclei. We expect to determine the medium modifications of the d*(2380) in nuclear matter and constrain its couplings [2]. These new results will further improve our understanding of the neutron stars equation of state, allow precise determination of the maximum neutron star mass, and provide critical ingredients for calculating the neutron star merger dynamics. Also, the interplay between the hexaquark, quark-gluon, and hyperon degrees of freedom in the EoS of dense nuclear matter will be discussed. The effective coupling constants obtained in this experiment can further constrain the possibility of hexaquark condensate dark matter [3].

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Probing the strange meson spectrum through the analysis of photoproduction reaction γp->K+K-ɣɣp at the GlueX experiment

Darius Darulis[1]
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The GlueX experiment at Jefferson Lab studies the hadron spectrum via photoproduction off an LH2 target. One of the experiment's primary goals is to study hybrid meson candidates -- mesons that could possess an additional gluonic degree of freedom. This talk gives an update on the partial wave analysis of reaction channel γp → K+K-γγp, looking in particular at excited ϕ meson state ϕ(1850) and hybrid meson candidate Y(2175) in the strange region of the meson spectrum.

Studying gluon GPDs at the Electron Ion Collider via DVMP

Dr Stuart Fegan[1]
[1]University of York, UK

The Electron Ion Collider (EIC) is a next-generation hadron physics facility, planned to be built in the coming decade at Brookhaven National Laboratory (BNL), with the intention of further exploring the quark and gluon substructure of hadrons and nuclei. The EIC will address fundamental questions in QCD, probing the interplay of quarks and gluons to learn how they contribute to overall nucleon properties, and how they are affected by the nuclear environment. With heavy ion beams to enable in-depth studies of nuclear matter, alongside the precision of the electromagnetic interaction and the determinative properties of polarised nucleon beams, the EIC is expected to provide scientific opportunities for decades to come.

Hard exclusive meson electroproduction processes, also known as deeply virtual meson production (DVMP), are complimentary to the deeply virtual compton scattering (DVCS) reaction. In DVMP, the scattering reaction produces a meson instead of a photon, and through the study of heavy vector meson reactions, such as J/ψ, it is possible to probe gluon GPDs and ultimately provide information about saturation when studying the evolution of gluon spatial distribution.

The work presented focuses on studies of J/ψ -> e+ e− events from ep collisions, and the evaluation of projected detector performance for DVMP measurements in ePIC, the current EIC detector concept.

Measurement of the Electric Form Factor of the Neutron

Gary Penman[1]
[1]University of Glasgow, UK

Electromagnetic form factors, which are available via elastic scattering, encapsulate information on the charge and current structure inside the nucleons. The novel Super Bigbite Spectrometer (SBS) experimental setup in Jefferson Lab Hall A seeks to extend measurements of the nucleon form factors to unprecedented high values of the four momentum transfer squared Q^2. Jefferson Lab's 12 GeV era makes this possible. The electric form factor (GEn) of the neutron is the least well understood of the four Sachs form factors, due to its small magnitude and the experimental complexity required in accessing it. The GEN-II experiment, which uses novel techniques to utilise a polarised helium-3 target, will provide results for GEn at three kinematic points 2.9 GeV^2, 5.5 GeV^2 and 9.9 GeV^2. I provide an overview of the experimental technique and present preliminary analysis from the completed kinematic points.

Parallel Session I: Session H

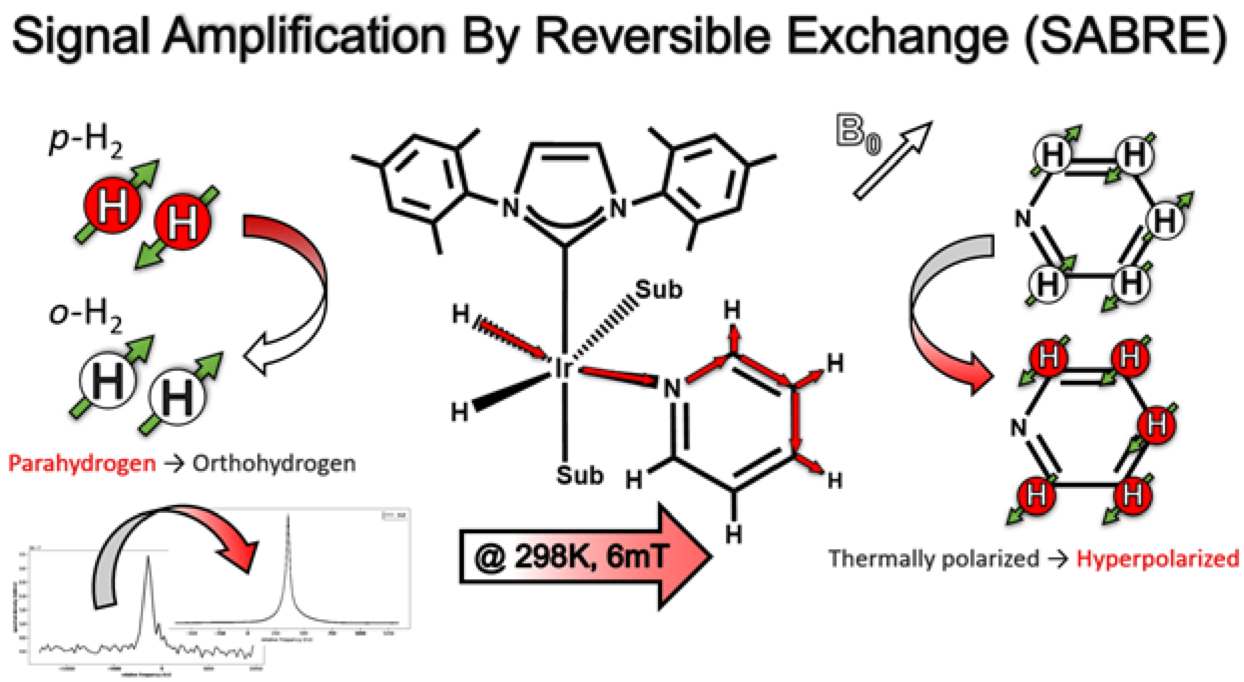
Dense room temperature spin polarized nuclear targets from SABRE chemical hyperpolarization methods – R&D status

Mr Benjamin Collins[1]
[1]University of York, UK

Spin polarized nuclear targets play a key role in nuclear and particle physics. The spin-dependent observables accessible from reactions on such targets have been crucial in improving our knowledge of the fundamental excitation spectrum of the nucleon and the partonic origin of nucleon spin. The advance in accelerator technologies mean the new intensity frontier brings such radiation and heat deposits that traditional cryogenic methods for maintaining polarized nuclear targets become challenging. For example, the Dynamic Nuclear Polarisation (DNP) methods show strong depolarization effects at these intensity frontiers.

Signal Amplification By Reversible Exchange (SABRE) is a novel nuclear hyperpolarization technique developed to enhance the sensitivity of target molecules for Nuclear Magnetic Resonance spectroscopy (NMR) and imaging (MRI). It uses parahydrogen (pH2), the singlet spin isomer of molecular hydrogen, as a polarisation feedstock and allows for the build-up of nuclear polarization through the catalytic exchange of spin order from pH2 to a target substrate whilst leaving the substrate chemically unchanged. The key advantages of SABRE are its ability to operate at room temperature and at low magnetic fields with polarization build-up times on the order of seconds. Once the media is polarized the spin orientation can be manipulated using weak magnetic fields. The SABRE method and substrates are also low-cost meaning replenishment of polarized target media in-situ is feasible.

I will present work from our ongoing R&D project aiming to transfer this exciting technology to particle and nuclear physics for the first time. Results from some of the key aims will be presented including progress in extending the achievable polarisation lifetimes and polarization yields of SABRE-derived polarization. Schemes for scaling the technology from the sub mm3 level to the cm3 scale necessary for polarized target will also be presented.



Nuclear Density Functional Theory Calculations of Nuclear Schiff Moment of Ac-227

Herlik Wibowo[1], and Jacek Dobaczewski[1]
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Parity- and time-reversal-violating nuclear forces induce the P- and T-odd nuclear moments, particularly the nuclear Schiff moments [1,2]. The octupole deformation in the nucleus implies the presence of a partner state with the same intrinsic structure and angular momentum as the ground state but opposite parity at low excitation energy. Due to a small energy difference between the partner and the ground states, the first-order perturbation theory suggests that the dominant contributions to the Schiff moments originate from the expectation values of the Schiff operator and the PT-violating potential calculated between these two states, whereas the small energy denominator accounts for the enhancement of the Schiff moments [3]. The first term of the Schiff operator, which is proportional to the third power of charge radius, signals the possibility of correlating the intrinsic Schiff moments with the octupole moments. Indeed, the nuclear Schiff moment calculations carried out by Dobaczewski et al. [4] in the framework of nuclear density functional theory (nuclear DFT) have demonstrated a strong correlation between the octupole and Schiff moments in light actinides. They also showed that the measured intrinsic octupole moments of even nuclei can be utilized to reduce the uncertainty in the intrinsic Schiff moments of neighbouring odd nuclei.

In the present contribution, following the method described in Ref. [4], we determine the intrinsic Schiff moment of Ac-227. The deformed ground and partner states are obtained from the Hartree-Fock-Bogolyubov (HFB) calculations with broken time-reversal symmetry and parity. The uncertainty of the intrinsic Schiff moment of Ac-227 is constrained by the measured octupole moment of Ra-226, i.e., 1080(30) efm³ [5].

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[4] J. Dobaczewski, J. Engel, M. Kortelainen, and P. Becker, Phys. Rev. Lett. 121, 232501 (2018)
[5] H. Wollersheim, H. Emling, H. Grein, R. Kulessa, R. Simon, C. Fleischmann, J. de Boer, E. Hauber, C. Lauterbach, C. Schandera, P. Butler, and T. Czosnyka, Nucl. Phys. A556, 261 (1993).

Shell-model study of 58Ni using quantum computing algorithm

Bharti Bhoy[1], and Paul Stevenson[1]
[1]University of Surrey, UK

This study presents a Quantum computing approach for the comprehensive investigation into the shell-model energy levels of the 58Ni through the application of the variational eigensolver (VQE) method in combination with the unitary coupled cluster (UCC) ansatz. The variational quantum eigensolver is an algorithm to compute the ground and excited state energy of quantum many-body systems. The VQE, renowned for its efficacy in determining the eigenvalues and eigenstates of intricate systems, was adapted to operate efficiently on a quantum computing framework, thus enabling the handling of a significantly more extensive qubit array.

The primary objective is to achieve a more accurate low-lying energy level of 58Ni using the quantum algorithm, a nuclide of significant interest in nuclear physics due to its role in nuclear reactions and astrophysical processes. Additionally, we have more accurately replicated previous research findings [PHYSICAL REVIEW C 105, 064308 (2022), PHYSICAL REVIEW C 106, 034325 (2022)], which is attributable to the better construction of the UCC-ansatz and the Hamiltonian based on shell-model interaction (JUN45). The result we have reproduced is the exact value and compiled energy value for the ground state, first and second excited state. The exact value is obtained by diagonalization of the Hamiltonian after qubit mapping, and the compiled value is obtained after the diagonalization using UCC-ansatz and VQE.

By achieving a higher degree of precision and leveraging a larger quantum computational scale, our study provides an accurate depiction of the 58Ni energy spectrum and showcases the immense potential of quantum computing in conducting complex nuclear physics research.

Binding Blocks UK: A National, Inclusive Programme for Nuclear Physics Education

Joel Richardson[1], Katherine Leech[1], and Christian Diget[1]
[1]University of York, UK

The Binding Blocks project (bindingblocks.org.uk) aims to engage students aged 14 to 19 and their teachers with cutting-edge research and real world applications of nuclear physics. This STFC-funded project has been running in its current format since 2020, and includes curriculum-linked resources, online masterclasses pitched at GCSE and A-level (and equivalent Scottish and international qualifications), a practical loan kit for teachers (suitable for use with or without nuclear sources), and teacher training resources. All materials are free to schools.

The content includes topics on many areas of nuclear physics: nuclear structure, nuclear reactions, and nuclear theory; with modules on detector physics and instrumentation, nuclear astrophysics, and medical applications; exploring SM physics, dark matter, and fusion (sustainability and social challenges); and touches on hadron physics and heavy ion collisions.

The Binding Blocks project is a collaboration between universities across the UK and beyond, the STFC National Labs, international labs, and professional bodies, led by the University of York, and it has been extensively evaluated by an independent consultant. In this talk, we outline the Binding Blocks project, present the outcomes and learning from the external evaluation of the programme, and discuss how members of the nuclear physics research community can get involved with the project.

(Many!) Proton Knockout With CLAS@JLAB

Rhidian Williams[1], and Daniel Watts[1]
[1]University of York, UK

We present a new high statistics and large acceptance study of photoinduced proton knockout from Carbon 12 (up to multiplicity 6), obtained for photon energies 0.6 to 4.5 GeV. The data were obtained using the CEBAF large acceptance spectrometer (CLAS) in Hall-B of the Thomas Jefferson Laboratory in the USA. The study of photoinduced proton knockout enables a deeper understanding of the short range structure of nuclei and many-body nuclear processes. Such information is crucial for not only nuclear physics but, by corollary in the underlying nuclear processes, also for next generation neutrino facilities where detection relies of A(v,p) reactions. The first measurement of high multiplicity proton knockout data is also an important step to to benchmark the viability of a future photon induced spallation source.

Through constraint on the properties of the reconstructed recoiling system clear evidence for direct pp knockout is obtained up to previously unrealised photon energies of 2.4 GeV (previously only observed up to 0.6 GeV). Such data will provide valuable new information on the short range structure of nuclei. Cross sections and missing mass distributions are obtained for 2p, 3p, 4p, 5p and 6p knockout reactions. The viability of using this new technique to access highly exotic light nuclei is discussed. Propsects for use of the method for heavier nuclei to access currently unreachable neutron rich nuclei key to the r-process path will be outlined. The new knockout data (and additional data on 1p knockout) give valuable information on the accuracy of the GiBUU many-body model - revealing regions where the reaction and many-body modelling could be improved for both nuclear and future neutrino physics.

Cross Sections of Proton-Induced Reactions on natZn and natNi: Exploring the 67Cu/64Cu Theranostic Pair Production

Mamad Eslami[1], David Jenkins[1], Mikhail Bashkanov[1], Carl Wheldon[2], and Tzany Kokalova Wheldon[2]
[1]University of York, UK, [2]University of Birmingham, UK

The theranostic pair 67Cu/64Cu holds significant promise, but its widespread use has been hindered by the insufficient availability of the therapeutic counterpart 67Cu. Despite the growing clinical importance of this pair, the production routes for both 67Cu and 64Cu have not been thoroughly assessed. While there are various methods to produce the 67Cu/64Cu pair, both photonuclear and proton-induced routes show potential. To address this, we measured proton-induced reactions on natural zinc and nickel at the Birmingham cyclotron, employing the stacked target technique. This approach allowed us to determine cross sections from near threshold up to 27 MeV, facilitating the optimization of the production route. The experimental cross sections obtained were compared with nuclear model calculations and other experimental data, enabling the development of evaluated excitation functions for each reaction.

Parallel Session II: Session A

A Top Friendship: Measurement of ttH production in the H(bb) decay channel at ATLAS with Transformer Networks

Levi Evans[1]
[1]Royal Holloway, University of London, UK

The exploration of the Higgs boson's properties and its interactions with top quarks constitutes a pivotal aspect of the post-Higgs discovery era. Among these, the measurement of the associated production of a Higgs boson with a pair of top quarks (ttH) offers a unique window into the Yukawa coupling between the Higgs and the top quark, the heaviest known fundamental particle. This talk presents the latest results on ttH production with the Higgs boson decaying into a pair of bottom quarks (H→bb), performed by the ATLAS collaboration. A key focus is placed on the improved MVA strategy, which incorporates permutation-invariant architectures utlising attention mechanisms, for enhancements in both multi-class classification of signal and background events, and Higgs candidate reconstruction.

Search for Decays of the Higgs Boson into a Z Boson and a Light Hadronically Decaying Resonance

Chonghao Wu[1]
[1]University of Birmingham, UK

A light pseudo-scalar resonance (a), which can have a large coupling to the observed Higgs boson, is predicted by several extensions of the Standard Model, such as the 2HDM(+S) or Axion Like Particle. Several searches for the Higgs boson decaying to 2 pseudo-scalars or a Z boson and a pseudo-scalar

have been published by ATLAS and CMS, but most of them focus on mass O(10 GeV). This talk will discuss the status of the search for H→Za targeting low mass (< 4 GeV) hadronically decaying resonance using full Run2 dataset of 140 fb-1. Due to its low mass and high boost, the light resonance is reconstructed as a single jet of hadrons while the Z boson is required to decay to a pair of leptons. To simultaneously improve the modelling in all the interesting variables of the analysis a neural network is trained to estimate the multidimensional density ratio of the MC background to the data PDF. 95% CL upper limits in the range of 4% - 10% on the BR(H->Za) in the mass region from 0.5 GeV to 2.5 GeV are set.

Transformer Neural Networks for Large Radius Jet Classification and Regression for Boosted Higgs Bosons at the ATLAS Detector

Andrius Vaitkus[1]
[1]University College London, UK

Many analyses using the ATLAS detector of the Large Hadron Collider study the properties of the Higgs boson. Identifying boosted Higgs bosons decaying to a pair of b-quarks is crucial for many such analyses. The state-of-the-art algorithm, GN2X, is a transformer-based neural network designed to use charged track information to separate the large-radius jets coming from the Higgs decaying to two b-quarks from various backgrounds. GN2X has shown to significantly outperform the old approach based on a feed-forward neural network. The model is built using the Salt framework, which supports the addition of auxiliary tasks to further improve jet classification.

In my work, GN2X has been modified by an addition of two tasks, predicting truth jet mass and transverse momentum, either in conjunction with or replacing the jet classification task. Current results show an improved jet mass and pT resolution of approximately 10% and 20%, respectively, with no detriment to the classification performance. This can be further improved by providing the calorimeter and neutral particle information to the model or further tuning the model parameters.

Constraining Anomalous Quartic Gauge Couplings in Production of Three Massive Vector Bosons with the ATLAS detector

Patrick Dougan[1]
[1]University of Manchester, UK

The production of three vector gauge bosons is one of the rarest processes in the Standard Model (SM) and as a result is relatively understudied, making it an excellent avenue of exploration for stringent testing of the SM, potentially exposing New Physics. Across all LHC experiments, only the most common variant, WWW, has been experimentally observed to date. This talk will outline the ongoing search using the ATLAS detector for the still unobserved VVZ (V=W,Z) production processes in the Run 2 data. Machine Learning techniques are utilised to target WWZ, WZZ and ZZZ production across leptonic and semi-leptonic final states in order to extract signal strengths for all production modes. Using effective field theory (EFT), the SM Lagrangian can be extended to include higher dimensional operators in a model-independent manner, allowing for limits on anomalous Quartic

Gauge Couplings (aQGCs) to be extracted using the VVZ fiducial signal regions, constraining heavy new physics.

The first measurement of the ttZ->nunu cross section.

Michael Postill[1]
[1]University of Sheffield, UK

ttZ->nunu is a unmeasured process predicted by the Standard model. ttZ->nunu is the production of a top anti-top pair with the associated production of a Z boson at ATLAS. This Z boson decays into neutrinos. This process is very rare and has intense ttbar background and therefore previous studies have only focused on measuring 1L,2L,3L(L =lepton) and stayed away from the 0L. This study aims to use the 0L, 1L and 2L channels to do a combined measurement of ttZ->nunu's cross section and comparing it with the theoretical prediction. Any deviation from theory could suggest new physics beyond the standard model. Agreement with theory would allow for better background estimates of ttZ->nunu in SUSY studies and more informed EFT studies. Our study makes use of new deep neural networks and variables capable of depleting ttbar found by previous SUSY studies to enhance the measurement of ttZ->nunu.

Top quark mass measurement in the boosted lepton+jets channel in pp collisions at √s=13 TeV using the ATLAS detector at the LHC

Elliot Watton[1,2]
[1]University of Glasgow, UK, [2]Rutherford Appleton Laboratory (RAL), UK

The mass of the top-quark is an important parameter of the Standard Model, affecting the dynamics of elementary particles through radiative corrections. Precision top-quark mass measurements provide information for global fits of electroweak parameters, making it an essential tool to test the coherence of the SM and to probe its extensions. I will present a new measurement of the top-quark mass using a profile likelihood fit for $t\bar{t}$ events in the lepton (e or μ) + jets decay channel in which the hadronically decaying top-quark has high transverse momentum (referred to as a "boosted-top"). The measurement is performed using data from $p\,p$ collisions $\sqrt{s}$ = 13 TeV collected by the ATLAS detector at the Large Hadron Collider from 2015 to 2018, corresponding to an integrated luminosity of 140 fb^{-1}. In this boosted regime, the top-quark decay products become collimated in the detector leading to less ambiguity in assigning jets and allow the decay products to be captured in a single jet object through using a jet re-clustering algorithm. The reconstructed W-boson mass distribution and an additional variable sensitive to QCD radiation effects are measured in addition to the reconstructed top-quark mass to constrain the impact of systematic uncertainties.

Parallel Session II: Session B

A Search for Dark Matter in the Light of Dark-Higgs Strahlung

Tim Lukas Brueckler[1,2]
[1]University of Oxford, UK [2]ATLAS Collaboration,

The Standard Model of particle physics, while remarkably successful in describing most phenomena related to the fundamental interactions and particles, notably lacks a mechanism to account for dark matter, prompting a wealth of beyond the Standard Model (BSM) theories that propose various candidates and interactions.

This presentation describes an ATLAS search for dark matter realised through a dark-Higgs boson model with an additional vector mediator (Z'). These new heavy states decay respectively to a Higgs boson pair and invisible particles which are dark matter candidates. A first LHC search for this experimental signature of a resonantly produced Higgs pair with significant missing energy is detailed.

A specialised machine learning approach is used to provide discrimination to this unique kinematic signature whilst preserving the shape and sensitivity of the di-Higgs invariant mass distribution.

A search for high-mass resonances decaying to τν in pp-collisions at center-of-mass energy = 13 TeV with the Run-2 data of the ATLAS detector

Christos Vergis[1], and Jochen C. Dingfelder[2]
[1]Queen Mary University of London, London, UK, [2]Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany

Various theories Beyond the Standard Model predict the existence of new heavy charged gauge bosons (W'), which could manifest at the LHC. The W' bosons typically decay leptonically, yielding high-transverse momentum leptons and substantial missing momentum due to undetected neutrinos. While searches involving electron/muon in the final state are more sensitive for models with universal lepton couplings, the W' to τν searches are motivated by models favoring couplings to the third fermion generation.

This presentation will cover the latest ATLAS results for heavy spin-1 resonances decaying into a tau lepton and a neutrino, particularly in events where the tau lepton decays hadronically. This analysis used pp-collision data collected from 2015 to 2018 at center-of-mass energy = 13 TeV by the ATLAS detector at the LHC. The current exclusion limits on W' masses using the τν final state in the Sequential Standard Model and models with enhanced couplings to the third-generation fermions will be presented. Additionally, upper limits on the production cross-section times branching ratio for mono-tau signatures at ATLAS that can be used for different model interpretations will be shown.

Searching for missing mass in proton-tagged dilepton events with the AFP and ATLAS detectors

Josh Lomas[1]
[1]University of Birmingham, UK

The current status of an analysis is presented, searching for “missing mass” particles X in the channel pp -> p'p'll X using pp collision data at 13 TeV collected during 2017, with a combination of central ATLAS data and proton data from the ATLAS Forward Proton spectrometer. The process involves two protons exchanging a pair of photons without breaking up, which interact to produce a visible boson V decaying leptonically, in addition to an invisible component X which is undetected. A bump-hunt is performed in the reconstructed missing mass spectrum and a model independent search is performed, aiming to set upper limits on the signal cross section. A variety of potential signal models are also considered, including ALP decays. Studies performed in the development of this analysis are presented, alongside preliminary results using blinded data.

The Search for Axion-Like Particles with the FASER Experiment at the LHC

Lottie Cavanagh[1]
[1]University of Liverpool, UK

The Forward Search Experiment (FASER) is an experiment at the CERN Large Hadron Collider (LHC) designed to search for light, weakly-interacting new particles, in addition to studying collider neutrinos in the far-forward region. In the previous year FASER published results of the search for dark photons, for which it set new constraints and excluded previously unexplored parameter space. FASER also reported the first direct observation of collider neutrinos. FASER is currently searching for axion-like particles (ALPs) with the combined 2022 and 2023 Run 3 dataset, exploring parameter space that is unexplored by existing experiments. ALPs are long-lived dark matter particles theorised to couple to Standard Model particles, leaving a highly energetic di-photon signal in our detector.

Baler: Machine-Learning-Based Compression of Scientific Data in Real Time

James Smith[1], Fritjof Bengtsson Folkesson[2], Caterina Doglioni[1], Malena Duroux[1], Per Alexander Ekman[2], Axel Gallén[3], Elena Gramellini[1], Sam Hill[1], Pratik Jawahar[1], Marta Camps Santasmasas[1], and Nicola Skidmore[1]
[1]University of Manchester, UK, [2]Lund University, Sweden, [3]Uppsala University Sweden

The storage, transmission and processing of data from large experiments is a major challenge across particle physics, nuclear physics and astrophysics, and also in industry with the requirement of huge amounts of data for the training of AI. Traditional data compression techniques are lossless, but are limited in performance and require additional computation.

BALER [1,2] is an open-source machine-learning-based tool for the tailored, lossy compression of data across multiple disciplines. BALER provides a framework to develop and apply models based on an autoencoder architecture which can identify correlations in the input dataset and favour these variables in the compressed dataset. These models can outperform traditional data compression

techniques whilst retaining sufficient precision for use in physics analyses. BALER models can also be used online in FPGAs to compress live data from detectors and have trigger algorithms applied directly to the compressed data, potentially allowing for massive increases in event acceptance and network throughput without new hardware.

This presentation will introduce BALER, demonstrate its performance on a range of data types including a variety of particle physics data, computational fluid dynamics, text recognition, and machine vision data, and include a live demonstration.

[1] https://arxiv.org/pdf/2305.02283.pdf
[2] https://github.com/baler-collaboration/baler

Upgrading the magnetic spectrometer for electron bunch emittance and energy measurements at AWAKE.

Fern Pannell[1], AWAKE Collaboration[2]
[1]University College London, UK, [2]CERN, Switzerland

The Advanced Wakefield (AWAKE) experiment is a proof-of-principle accelerator facility at CERN (Geneva, Switzerland). Proton bunches from the CERN Super Proton Synchrotron are used to drive wakefields in 10 metres of laser-ionised rubidium plasma. Externally injected 19MeV electrons are accelerated in the wakefields and their energy is measured on a magnetic spectrometer downstream of the plasma.

Run 1 of AWAKE successfully demonstrated the self-modulation of the long proton bunch, and the acceleration of electrons to 2 GeV. The spectrometer design allowed measurements of the accelerated electron bunch energy, profile and charge, but was too resolution-limited for emittance measurements. Run 2 of AWAKE aims to demonstrate the scalability of the accelerator technology and the emittance control of the accelerated electron bunch. Current studies are investigating the use of a plasma density step and its effect on the accelerated electron bunches.

This work focuses on the upgrade of the spectrometer imaging system to facilitate emittance measurements. Preliminary results on energy gain from early Run 2 experiments with the plasma density step are also presented.

Parallel Session II: Session C

Sensitivity Studies for a Gaseous Argon Near Detector for DUNE

Naseem Khan[1]
[1]Imperial College London, UK

The Deep Underground Neutrino Experiment (DUNE) aims to study long-baseline (LBL) neutrino oscillations and make the most advanced measurements of the PMNS mixing parameters. DUNE will utilise a Near Detector (ND) around 574 m from the neutrino source and a Far Detector (FD) at around 1300 km from the source. Both detectors will, for the most part, comprise liquid argon detectors. However, as DUNE is a phased experiment, the Phase I ND complex can be used for initial oscillation physics measurements but will require upgrades to constrain the systematic uncertainties to reach its physics goals - 5σ confidence levels in CP violation measurements. ND-GAr is a magnetised high-pressure gaseous argon time projection that will make measurements of neutrino-argon interactions with greater precision. This detector technology will allow DUNE to detect much lower energy neutrino interactions and understand neutrino-nucleus interactions much better, therefore reducing these systematic uncertainties. As ND-GAr is a Phase II detector, some time is available for research and development. However, the recent P5 report recommends starting construction in the early 2030s so producing an optimised design of this detector is an urgent priority for DUNE. It is crucial to ensure that the ND-GAr design will meet DUNE's long-term physics goals for LBL oscillation physics. The LBL analysis for DUNE uses MaCh3, a Bayesian oscillation fitter utilising Markov Chain Monte-Carlo methods. To develop the physics-motivated case for the ND-GAr design, we will add ND-GAr samples into the existing LBL analysis for DUNE. In doing so, we can quantify the impact of ND-GAr on the oscillation analysis results and physics outcome. Eventually, this framework will be used to finalise the detector design. This talk will give an overview of ND-GAr in DUNE, with a significant focus on MaCh3 and the current status of the ND-GAr LBL studies.

Analysing the fast oscillations of atmospheric neutrinos at Super-Kamiokande

George Burton[1,2]
[1]King's College London, UK, [2]Rutherford Appleton Laboratory, UK

The Super-Kamiokande experiment is arguably the most successful neutrino detection experiment currently in operation. Located 1,000m underneath Mt. Ikenoyama in Mozumi mine, the detector consists of a stainless-steel tank, which is 39.3m in diameter and 41.4m tall, making Super-K is the largest water Cherenkov detector in the world. Super-K contains 50kton of ultrapure water, and since 2020 the ultrapure water has been doped with $Gd2(SO4)3$ in increasing concentrations, to vastly improve the detector's neutron capture capabilities. Super-K can detect neutrinos from many sources, but the focus of this presentation will be on atmospheric neutrinos, specifically atmospheric neutrinos with long baselines and which have an energy below about 1 GeV. Sub-GeV events with only slightly different directions and energies can have very different oscillation probabilities, due to the large L/E values. Therefore upward-going, charged-current atmospheric neutrinos which satisfy this condition undergo many neutrino oscillations, and so a special treatment is needed to analyse these types of neutrinos that is separate to the analysis of higher energy atmospheric neutrinos. My proposed solution is computationally fast and involves binning events by energy and zenith angle and using the bin width to calculate a ratio of oscillation length to bin width and calculate the oscillation probability, depending upon the value of this ratio. If the ratio is greater than one, the probability can simply be taken as an average of a few points within the bin. If the ratio is approximately one, the integral of the probability over energy and zenith angle must be found, and if the ratio is smaller than one then decoherence must be accounted for when averaging over points within the bin. This solution should overcome the current, statistically limited treatment, and correctly produce a smoother chi squared contour of the squared mass difference oscillation parameter.

Sterile Neutrino Oscillation Searches using the VALOR Fitting Framework at SBN

Beth Slater[1]
[1]University of Liverpool, UK

The Short Baseline Neutrino (SBN) programme has an extensive physics program where one of the key aims is to investigate the existence of light sterile neutrinos. It comprises 3 LArTPC detectors along the Booster Neutrino Beam (BNB), a muon neutrino ($\nu\mu$) beam. The near detector of the programme (SBND) sits at a distance of only 110m from the BNB target; this, along with the size of SBND, will result in a large neutrino flux being measured at SBND. SBND will carry the main burden of reducing systematic error for the programme. With the high statistics and excellent imaging capabilities, the detector will fully characterise the neutrino flux and neutrino-Argon cross-section and enable sensitive oscillation searches with the full SBN. Additionally, due to its short baseline, SBND is sensitive to very fast oscillations, characterised by large squared mass splittings.

The VALOR Neutrino Fitting Framework is a well established and validated framework that has been developed within T2K and used for many published results. It is fully integrated within the SBN analysis chain where it will support standalone analysis of each of the three oscillation channels available to SBND; $\nu\mu$ disappearance, νe appearance, and νe disappearance along with joint multi-channel analyses. VALOR will incorporate a combination of inclusive and exclusive samples and exploit the SBND-PRISM capabilities to provide robust systematic constraints and definitive tests of the light sterile neutrino hypothesis. This talk will cover the VALOR analysis procedure and preliminary sensitivity results along with a discussion of a novel analysis technique known as PRISM.

Improving Neutrino Energy Reconstruction with Machine Learning

Joachim Kopp[1,2], Pedro Machado[3], Margot MacMahon[4], and Ivan Martinez-Soler[5]
[1]Theoretical Physics Department, CERN, Switzerland, [2]PRISMA Cluster of Excellence & Mainz Institute for Theoretical Physics, Germany, [3]Particle Theory Department, Fermilab, USA, [4]University College London, UK, [5]Institute for Particle Physics Phenomenology, UK

Faithful energy reconstruction is foundational for precision neutrino experiments. While DUNE will offer unprecedented event reconstruction, uncertainties remain, for instance, the unknown initial-state momentum of the struck nucleon. We demonstrate that graph neural networks are highly effective in overcoming these uncertainties by estimating inaccessible kinematic variables based on the observable part of the final state. Our networks outperform conventional reconstruction algorithms both in terms of precision and of accuracy (avoiding the few per cent bias which can be present from other methods).

Joint analysis between Super-Kamiokande atmospheric and T2K accelerator neutrinos

Zhenxiong Xie[1]
[1]King's College London, UK

In the past, T2K discovered neutrino oscillation. Since the baseline of T2K is only 295 km, it is not sensitive enough to determine the mass ordering. Super-Kamiokande measures atmospheric neutrinos, which, when combined with samples from T2K, allows for the presentation of both profiled and marginalized likelihoods. In addition to the Bayesian result, which shows that δCP can be excluded at a 2σ level, the frequentist result indicates a CPC p-value of 0.030 and a preference for the normal mass ordering with a CLs of around 0.183.

Supernova triggering at DUNE from machine-learning based clustering

Dennis Lindebaum[1,2]
[1]University of Bristol, Bristol, UK, [2]DUNE Collaboration, UK

Recent results have implied that Betelgeuse might become supernova in the near future. 99.9% of the energy in a supernova burst is carried by neutrinos. Detection of these neutrinos in the next generation of neutrino experiments, including the Deep Underground Neutrino Experiment (DUNE), would provide a vast amount of information about core collapse and other astrophysical observables, neutrino mass ordering, and may be an opportunity to look for new physics.

This talk discusses the prospects for supernova detection at DUNE to supernovae far beyond Betelgeuse, including the major challenges this place on the data-acquisition system. It will cover recent innovations in machine-learning methods that may improve the sensitivity for supernova detection.

Parallel Session II: Session D

Characterising Electric Fields in LZ

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With the world-leading sensitivity for WIMP-nucleon interactions, the LUX-ZEPLIN (LZ) experiment is leading the effort in the dark matter direct detection landscape. At the heart of LZ, is the time projection chamber (TPC), responsible for the generation and imaging of light and charge signals in the detector. Charge transport in TPCs is largely defined by the various properties of the dielectric medium being studied, in combination with the electric fields that govern the dynamics equations. It is therefore vital to understand the consequences of the high voltage environment which generates the fields in our detector. As with many other dual phase xenon experiments, such as LUX, XENON & PandaX, the complex construction of the physical TPC volume along with the high voltage electrodes, can result in inhomogeneities in localised regions within the bulk volume. This is capable of affecting the xenon microphysics as well as skewing the drift path of electron clouds that constitute the ionisation signal (S2), which we rely on for position reconstruction along with the prompt scintillation signal (S1). As a result, these considerations may impact our understanding of the discrimination between electronic recoils (background-like) and nuclear recoils (signal-like). This talk explores the synergy between data-driven and simulation-based methods of deriving field and charge transport models, considering the conclusions that can be drawn on field uniformity and ER leakage, energy-position reconstruction, their combined influence on fiducialisation in the LZ TPC, future science runs and the implications for searches beyond LZ.

Multiple Scatter Neutron Background Measurements in LZ

Jo Orpwood[1]
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The LZ direct detection experiment primarily aims to detect nuclear recoils in the central time projection chamber (TPC) caused by dark matter in the form of Weakly Interacting Massive Particles (WIMPs). For this, the background of neutrons must be understood as they can give rise to identical signals to WIMPs. In this work, the fact that neutrons can scatter multiple times in the TPC detector, unlike WIMPs, is exploited to estimate the rate of single scatter neutron events. To achieve this, a new parameter space has been defined for multiple scatter events in which nuclear and electron recoils are more clearly distinguishable. This improvement in discrimination has been achieved through a method that utilises information from each of the individual scatters of the event, rather than just the summed total signal. In this talk, I will present results from the application of this analysis method to the first science run of LZ data, and additionally discuss how this analysis will be used for future science runs to enhance LZ discovery potential.

Studies of radioactive background from environment for a potential LXe dark matter experiment at Boulby

Jemima Tranter[1,2]
[1]University of Sheffield, UK, [2]Boulby Underground Laboratory, UK

Rare event searches, such as those targeting dark matter interactions and neutrinoless double beta decay (0νββ), face challenges from gamma-rays originating in rock, contributing to electron recoil background. This report presents a dual investigation: measurements of natural radioactivity in rock samples from Boulby Mine and a simulation assessing shielding thickness for a future detector. The measurements provide data for normalising conditions in prospective experiments at Boulby. The simulation studies the effectiveness of water shielding around a detector, focusing on the Weakly Interacting Massive Particle (WIMP) energy range (0 – 20 keV) and the energy range near the 0νββ Q-value (2.448 MeV).

The study design features a simplified xenon-based detector with a 70-tonne active volume, encompassed by veto systems and water shielding. Our findings indicate that gamma-ray background is unlikely to persist through analysis cuts in the WIMP energy range. However, for 0νββ decay signal searches, adjustments will be required; the sensitivity of a next-generation detector demands a background of < 1 event per 10 years, necessitating a reduction in the fiducial volume of the detector.

Searching for Low Mass Dark Matter in Silicon using the Silicon Photomultipliers in Darkside-20k.

Seraphim Koulosousas[1]
[1]Royal Holloway University of London, UK

DarkSide-20k is a liquid argon dual-phase TPC with a 51-tonne active volume that is located 1.4km underground at the Gran Sasso National Laboratory (LNGS). Darkside-20k will use a total of 26 m^2 of Silicon Photomultiplier (SiPM) arrays for photon detection in the TPC and the veto detector systems, comprising a total Si mass of 27 kg. Darkside-20k is designed to observe interactions between weakly interacting massive particle dark matter (DM) and the liquid argon (LAr) target, however, in addition, due to the low energy band gap of silicon, light and ultralight dark matter (DM) interaction could potentially be observed through DM-induced recoils on a silicon target occurring within the SiPMs themselves. This talk will explore the potential for such DM-Si interaction searches in DarkSide-20k, and report on the projected sensitivity to interactions of low-mass dark matter candidates.

Construction of the DarkSide-20k detector

Olly Macfadyen[1]
[1]Royal Holloway, University of London, UK

The dark matter direct detection experiment DarkSide-20k is now under construction at the Laboratori Nazionali del Gran Sasso (LNGS). DarkSide-20k will host 110 tonnes of ultra-pure low-radioactivity argon extracted from underground and cryogenically distilled, between the central time projection chamber (TPC) and inner veto detectors. This talk will outline the design of the detector as a whole, report on construction progress across the experiment, and focus on the initial results of operating the cryogenic system built to handle this precious target.

Muon & Antimuon Separation Using Machine Learning at MicroBooNE

Charlie Batchelor[1]
[1]University of Edinburgh, UK

The key open questions in neutrino physics such as the neutrino mass hierarchy and Charge-Parity (CP) violation in the lepton sector of the Standard Model will be addressed by the Deep Underground Neutrino Experiment (DUNE), currently under construction in the US. To determine these crucial parameters, DUNE will use huge state-of-the-art Liquid Argon Time Projection Chambers (LArTPCs) to precisely measure neutrino oscillations. To ensure DUNE's success, current experiments can provide crucial understanding of how neutrinos interact in liquid argon. The MicroBooNE experiment uses a LArTPC to detect neutrinos from the Neutrinos at the Main Injector (NuMI) beam, which offers exposure to a substantial flux of muon neutrinos and antineutrinos, thanks to MicroBooNE's highly off-axis position. In this talk, a selection process to differentiate charged-current muon neutrino and antineutrino interactions is described, which leverages advanced machine learning techniques. This talk will also present the current status of this work and plans for using it for dedicated neutrino and antineutrino cross section measurement.

Parallel Session II: Session E

Measuring muon antineutrino charged-current interactions without mesons in the final state, in the NOvA Near Detector

Kevin Vockerodt[1]
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NOvA is a long-baseline neutrino experiment based at Fermilab in the US, with the primary aim of measuring neutrino and antineutrino oscillations. This will enhance our understanding of electroweak interactions by measuring the neutrino mixing angles, CP-violating phase and neutrino mass ordering. To measure these oscillations, we first need to have a deep understanding of how neutrinos and antineutrinos interact with matter. Antineutrino interaction cross sections are, at present, particularly poorly constrained, and processes such as meson exchange currents are not well understood in the antineutrino sector. This analysis will develop a cross-section measurement of muon antineutrino interactions without mesons (e.g. pions or kaons) in the final state, in the NOvA near detector. A high-statistics, high-purity sample is obtained through a cut-based selection process implementing machine learning techniques. The sample is dominated by quasi-elastic and meson exchange current interactions which are sensitive to nuclear effects such as Final-State Interactions. The cross section will be extracted as a function of the incoming neutrino energy and the kinematics of the outgoing particles. This presentation will give an overview of the analysis and discuss progress towards obtaining the cross section measurement.

TPC Calibration in the Short Baseline Near Detector (SBND)

Robert Darby[1]
[1]University of Sussex, UK

SBND is a Liquid Argon Time Projection Chamber (LArTPC) based at Fermilab. It is currently undergoing commissioning, with first data expected in summer 2024. In addition to mm-scale reconstruction afforded by LArTPC technology, SBND also employs a sophisticated photon detection system (PDS) allowing for ns-scale timing resolution and effective charge and light calorimetry. SBND is surrounded by 7 cosmic ray tagger (CRT) panels which can act as a veto for cosmic ray muons with ns precision. SBND lies 110m from the Booster Neutrino Beam (BNB) target and will characterise the BNB in tandem with the far detector ICARUS to investigate the low energy excesses seen by LSND and MiniBooNe. To ensure accuracy of these data-driven results, SBND must be calibrated. I will report on development of a framework for calibrating the e-/ADC ratio of the TPC anode planes using the dQ/dx spectra of simulated stopping cosmic ray muons. Stopping muons are tagged using a combination of light flashes and CRT hits, then a delayed Michel electron flash. To produce an accurate measurement of the Michel electron energy spectra, a study of the TPC reconstruction performance of Michel electrons using the Pandora framework has been performed. In addition, a flash-matcher was developed to match scintillation light signals with TPC tracks to aid in cosmic ray rejection, yielding >90% accuracy in both neutrino selection and cosmic rejection which is in use in several ongoing studies in SBND. The development of these tools will allow for efficient calibration of SBND, thus enabling a swift transition from calibration to physics data-taking, as well as providing analysis tools to help with cosmic ray rejection and reconstruction of low-energy neutrino interactions.

Modelling Cosmic Ray Muon Spallation for a Hyper-Kamiokande DSNB Analysis

Jack Fannon[1]
[1]University of Sheffield, UK

Hyper-Kamiokande (HK) will be a 260 000 tonne water Cherenkov detector located in the Gifu Prefecture of Japan. The primary research topic of HK is the neutrino, a neutral particle that rarely interacts with matter. As such, neutrinos from specific sources are challenging to detect in the presence of overwhelming backgrounds. One background of specific interest is events caused by cosmic ray muon spallation, particularly the decay of radioactive isotopes caused by the spallation of oxygen nuclei in the HK water. High-energy muons are produced in the upper atmosphere when pions, created by interactions between the atmosphere and cosmic rays, decay to a muon and its corresponding neutrino. Even though the HK overburden of 1750 m.w.e will reduce the flux of cosmic ray muons by a factor of ~60 000, it is still expected that 45 muons per second will cross the detector where there is approximately 1 spallation interaction per muon. Although many daughter isotopes of the spallation process are stable or decay in ways that do not produce Cherenkov radiation, 16 nuclei can be created that cause a significant background in analyses focused in the 0-20 MeV range. One such analysis is the search for diffuse supernova background neutrinos (DSNB). These are the cumulative neutrinos created by all past core-collapse supernovae in the universe, the detection of which would provide information into the mechanisms behind star formation and the rate at which they are created. Presented here is the development of an MC simulation, combining output from multiple particle physics simulations, to model the spallation background at HK and its predecessor, Super-Kamiokande (SK). Current results for SK show a good agreement between simulation and data, and preliminary results from training a machine learning classification display a good reduction power of a gradient-boosted algorithm.

Constraints on the Cosmic Neutrino Background from NGC1068

Jack Franklin[1]
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We investigate IceCube's ability to constrain the neutrino relic abundance using events from the recently identified neutrino source NGC1068. Since these neutrinos have large energies ≥ 1 TeV and have propagated through large distances, they make a great probe for overabundances of the cosmic neutrino background.

The propagation of neutrinos from NGC1068 was simulated by solving a transport equation, which takes into account the SM neutrino-neutrino interactions. The final fluxes produced are then analysed using publicly released IceCube data. Our preliminary results indicate that IceCube is able to improve the current bounds on a relic neutrino overabundance by 3 orders of magnitude compared to current experimental bounds, i.e. to less than ~ 10^{10} cm^{-3} at the 2σ confidence level.

The SNO+ Neutrinoless Double Beta Decay Programme

Benjamin Tam[1]
[1]University Of Oxford, UK

The SNO+ Experiment is a versatile multipurpose neutrino detector situated at SNOLAB, with the primary goal of searching for neutrinoless double beta decay ($0\nu\beta\beta$). After a successful operating phase as a water Cherenkov detector, the SNO+ target medium was switched to liquid scintillator to increase the light yield of the detector, thereby enabling a much richer physics programme.

The SNO+ experiment is now preparing for the deployment of tellurium within the scintillator using a novel chemical loading technique, thereby enabling a $0\nu\beta\beta$ search. Numerous underground chemical purification plants are being commissioned to ensure that this technique is carried out with expected purification efficiency, stability, and process performance. Meanwhile, the scintillator backgrounds in the $0\nu\beta\beta$ region of interest are being investigated prior to the addition of tellurium – a major advantage of the SNO+ experiment. This presentation will discuss the status of the SNO+ $0\nu\beta\beta$ programme.

Cold Atoms, Cool Physics: Progress in the AION Project

Elizabeth Pasatembou[1], Charles Baynham[1], Oliver Buchmuller[1], David Evans[1], Richard Hobson[1], Ludovico Iannizzotto Venezze[1], and Alice Josset[1]
[1]Imperial College London, UK

The Atom Interferometer Observatory and Network (AION) project aims to harness state-of-the-art quantum technology to develop a next-generation differential atom interferometer for the detection of ultra-light dark matter and mid-frequency range gravitational waves, complementing the peak sensitivities of other experiments such as LISA, LIGO, and Virgo. The project is comprised of various stages, starting with a 10 m baseline atom interferometer paving the way to a 100 m detector and eventually a km-scale terrestrial detector, with the final stage being the development of a satellite-based detector. The project is a multidisciplinary initiative bringing together researchers from seven institutions from all over the UK.

Long-baseline atom interferometers, like the one to be built by the AION collaboration, require ultra-cold atomic clouds. These are produced by trapping the atoms in Magneto-Optical Traps (MOTs) using high-power, narrow-linewidth lasers. In this work, I present an overview of the AION project and the progress made to date. I will focus on the role of my team at Imperial College London in this collaboration, which is to cool down Sr-87 atoms to sub-micro-Kelvin temperatures and improve the sensitivity of the detector using spin squeezing. I will present the first results produced at Imperial,

demonstrating the production of a Sr-88 atomic cloud at a temperature of 812 ± 43 nK in a narrowband red MOT, and report on the current status of the project.

Parallel Session II: Session F

Characterization of irradiated Silicon Photomultipliers for LHCb Upgrade II

Constantinos Vrahas[1,2], Stefania Ricciardi[1], and Franz Muheim[2]
[1]STFC RAL, UK, [2]University of Edinburgh, UK

The LHCb detector will be upgraded in 2032 to operate at about an order of magnitude higher than its current nominal luminosity. As the occupancy in the detector will increase dramatically, it will be necessary to increase its granularity. This can be achieved in the Ring-Imaging Cherenkov radiator (RICH) by installing new photo-detectors with smaller pixel size as well as improved timing resolution. Silicon Photo-Multipliers (SiPMs) are promising candidates because of their excellent photo-detection capabilities and resolution. However, it is critical to mitigate their high thermal noise, which is significantly increased after irradiation due to their low radiation hardness, by cooling them to low temperatures. The objective of my research at RAL is to characterize SiPMs to determine suitable operational conditions for their use in LHCb by studying their behaviour across a wide temperature range and different levels of irradiation.

Amplitude Analysis of B 0 → D 0 D ̄ 0 K + π − decays with the LHCb experiment

Jake Amey[1], Kostantinos Petridis[1], Jonas Rademacker[1], and Mark Whitehead[2]
[1]University of Bristol, UK, [2]University of Glasgow, UK

The B 0 → D 0 D ̄ 0 K + π − decay was first observed in 2020 at the LHCb experiment, and is a particularly promising decay mode for two main reasons. The first is to search for exotic states such as tetraquarks and pentaquarks in the charm sector. The second is to study charm-loop contributions to b → sμμ processes by studying the amplitude structure of the D 0 D ̄ 0 system, which will shed light on the apparent deviations from the SM in B→K(∗)μ+μ−B→K(∗)μ+μ− decays. These two avenues can be simultaneously explored by performing an amplitude analysis of B 0 → D 0 D ̄ 0 K + π − decays. This talk will present work done toward this goal using the full Run I and Run II datasets of LHCb.

Search for rare Bd -> phi phi decays in the full Run 1 + Run 2 dataset from the LHCb experiment

Mary Richardson-Slipper[1]
[1]University of Edinburgh, UK

I will present the status of the first dedicated search for Bd -> phi phi decays at LHCb using Run 1 and Run 2 data. Decays of Bd -> phi phi are rare and highly suppressed. They have never been observed, however the branching fraction of this decay may be enhanced by both standard model and beyond standard model effects. An observation of these decays would be a subtle test of the calculations that are used to predict the branching fraction as the values presented in the literature vary by up to an order of magnitude, from 0.21e-8 to 3e-8. A previous study using LHCb data up to 2016 set the limit on the branching fraction at < 2.7e-8 at 90% C.L. In this dedicated analysis, sensitivity to this decay mode is enhanced using a novel method of removing background events that originate from prematurely interacting kaons in the Bs -> phi phi decay. These events contribute significantly to the background present in the signal region of the Bd -> phi phi decay. With this novel background rejection technique and more careful treatment of the other backgrounds present, and utilising the full Run 1 + Run 2 data set, it is anticipated that the presented analysis is sensitive to a branching fraction of 2e-8, where 3sigma significance is expected. This analysis is a factor of 2 more sensitive than the previous study. This analysis is currently still blinded and we anticipate results before the summer.

Angular analysis of rare Bs decays involving electrons at the LHCb Experiment

Lorenzo Paolucci[1]
[1]University of Warwick, UK

The Standard Model of particle physics (SM) has been challenged in recent years by measurements from the LHCb collaboration involving rare B meson decays. These processes, involving a b->sll quark transition, are highly suppressed, happening less than once in a million decays. Thus, they offer an ideal testing ground for the flavour sector of the SM, as any enhancements in their rates would be a smoking gun for New Physics (NP) phenomena. So far, most of these discrepancies have been reported in decays involving muons, while processes involving electrons are still largely unexplored experimentally. If NP is behind the current anomalies, b->see decays, with their unique experimental signatures, can independently probe this. This talk will cover the experimental challenge of decays with electrons in their final state, focussing on an ongoing LHCb measurement of the rare decay Bs->Φee and how it can improve our understanding of the so-called "flavour anomalies".

Test of lepton flavour universality using B+ -> K+l+l− processes at high dilepton invariant mass

James Herd[1,2]
[1]Imperial College London, UK, [2]LHCb Collaboration, CERN, Switzerland

Decays of beauty mesons into a final state consisting of a kaon and two leptons are heavily suppressed in the Standard Model (SM), since their leading order Feynman diagram must contain loops. For this reason, they are expected to be a sensitive probe for new physics contributions that could interfere with the suppressed SM process. One way in which new physics could alter such decays is by breaking the symmetry of lepton flavour universality (LFU), whereby each generation of lepton has identical coupling to the vector gauge boson of the SM. One important consequence of this symmetry is that the ratio of branching fractions for B->Kμμ and B->Kee decays is precisely predicted to be unity in the SM. Hence a measured deviation of the ratio of branching fractions - known as R_K - from unity would be a unambiguous sign of new physics. A recent result by the LHCb collaboration found R_K to be consistent with SM expectation in the dilepton invariant mass squared range $1.1 < q^2 < 6.0$ GeV^2/c^4. The upper bound for this measurement is chosen to veto the J/Ψ and Ψ(2S) charmonium resonances, which are not expected to be sensitive to new physics. However, no competitive measurement has been made in the high q^2 region above the charmonium resonances. In this talk, I will present the status of the measurement of R_K at high q^2 using the combined Run 1 and Run 2 data sets (which have an integrated luminosity of 9 fb-^{1}) collected by the LHCb detector.

Search for Right-Handed Weak Decays with the LHCb Detector

James Brown[1]
[1]University of Liverpool, UK

My research features the analysis of a unique and rare decay channel (B^0 -> K_1^0μμ) that is theoretically produced from proton-proton collisions at the Large Hadron Collider. The primary objective is to quantify the branching fraction associated with this process using the LHCb detector at CERN. Moreover, I aim to use this measurement to investigate the existence of right-handed weak interactions.

Analysis of LHCb Run 2 data, which has been refiltered for this decay mode, is underway. Furthermore, a dedicated trigger for this channel has been implemented ready for Run 3 data collection later this year. Given the assumed rarity of this decay channels production in proton-proton collisions and its composition involving a seldom detected neutral particle, it is optimal to partially reconstruct the decay to improve reconstruction efficiency that is lost during neutral particle reconstruction. An initial sensitivity study of these triggers provided promising insights for the analysis.

If right-handed weak interactions are to exist, they are anticipated to be an exceptionally rare phenomenon to be consistent with prior experimental findings. To meet the challenge posed by the exceedingly rare nature of the search I am implementing a method known as parity doubling to increase the search precision. With this technique comparing two channels of opposite parity effectively cancels out the prevalent left-handed contributions, leaving a much cleaner right-handed signal, should it exist.

Parallel Session II: Session G

Comparing Post Processing Nucleosynthesis (PPN) codes: An investigation into the impact that different reaction rate libraries and PPN codes can have on a variety of different astrophysical environments

Alexander Hall-Smith[1], Alison Laird[1], Chris Fryer[2], Sophie Abrahams, Sam Jones[2], Christian Diget[1], Matthew Mumpower[2], and Richard Longland[3]
[1]The University of York, UK, [2]Los Alamos National Laboratory, USA, [3]North Carolina State University, USA

Post Processing Nucleosynthesis (PPN) codes are used to study a variety of different astrophysical scenarios, ranging from long lived stellar hydrogen burning to short lived explosive scenarios such as X-ray burst or type 1a supernovae. These types of codes rely heavily on the input physics that dictate the interactions between neutrons, protons, alpha particles and isotopes included in the network. There is a large choice of PPN codes that have been independently developed using different techniques for electron screening and solving the differential equations, as well as taking reaction rate information from a variety of sources. This presentation will show four different astrophysical scenarios modelled in four different PPN codes; Nugrid [1], PRISM [2], SkyNet [3] and a newly developed code from Richard Longland at North Carolina State University. A similar study was previously conducted by Lippner et al. [2] as a benchmark for SkyNet. The resulting abundances can show significant variations depending on the PPN code used. This presentation will also examine the impact that different generations of reaction rate libraries have on resulting mass fraction distributions, calling attention to the importance of keeping regularly updated reaction rate libraries for these codes.

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[2] Mumpower M. R., Kawano T., Sprouse T., Vassh N., Holmbeck E., Surman R., Möller P., 2018, The Astrophysical Journal, 869, 14
[3] Lippuner J., Roberts L. F., 2017, The Astrophysical Journal Supplement Series, 233, 18

Constraining the NiCu cycle in X-ray bursts: Spectroscopy of 60Zn

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Type-I X-ray bursts are interpreted as thermonuclear explosions in the atmospheres of accreting neutron stars in close binary systems. During these bursts, sufficiently high temperatures are achieved (T ~ 0.8 – 1.5 GK) such that "breakout" from the hot CNO cycle occurs. This results in a whole new set of thermonuclear reactions known as the rp-process. This process involves a series of

rapid proton captures resulting in the synthesis of very proton-rich nuclei up to the Sn - Te mass region.

Various sensitivity studies have highlighted the $^{59}Cu(p,\gamma)^{60}Zn$ reaction as significant in its impact on energy generation along the rp-process path within X-ray bursts, and hence, the resultant light curve and final isotopic burnt ashes composition. In particular, competition between the $^{59}Cu(p,\alpha)^{56}Ni$ and $^{59}Cu(p,\gamma)^{60}Zn$ reactions within the NiCu cycle directly determines whether the pathway of nucleosynthesis flows towards higher mass regions. At present, stellar reaction rates for both of these astrophysical processes are based entirely on statistical-model calculations.

Recently, however, an indirect study of the nucleus ^{60}Zn has surprisingly shown a plateau in the level-density of states in the region of interest, contrary to the usual expectation of exponential growth with increasing excitation energy. As a result, a statistical-model approach of the $^{59}Cu(p,\gamma)$ reaction rate may be insufficient, and it is therefore now essential to explore the properties of excited states in ^{60}Zn, that influence the astrophysical $^{59}Cu(p,\gamma)^{60}Zn$, reaction. Specifically, the $^{59}Cu(p,\gamma)$reaction is expected to be dominated by resonant capture to excited states above the proton-emission threshold in ^{60}Zn, Sp = 5105.0(4) keV, that lie within the Gamow energy window, E ~ 0.7 - 1.5 MeV.

In this work, we aim to utilise the $^{59}Cu(d,n)$ reaction in inverse kinematics at the Facility for Rare Isotope Beams (FRIB) to obtain the first measurement of single-particle properties of resonances in the $^{59}Cu(p,\gamma)$ reaction. Specifically, ^{60}Zn ions separated within the S800 spectrometer and identified prompt with respect to γ-rays detected by the GRETINA array will be used to determine the energy and angle-integrated cross sections of key resonance states, while neutrons detected at backward laboratory angles by the LENDA array will be used to constrain the distribution of spin-parity assignments across the relevant excitation energy region of Type-I X-ray burst nucleosynthesis.

A new Measurement of 16O(p, α)13N reaction rate using MUSIC detector at the energies relevant to SNIa

May Alruwaili[1], A Laird[1], H Jayatissa[2], N de Séréville[3], M Avila[2], C Fougères[3], B Kay[2], S Chakraborty[1], C Barton[1], C Diget[1], A Hall-Smith[1], W Ong[4], E Rehm[2], E Bravo[5], and C Badenes[5]
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The $^{16}O(p,\alpha)^{13}N$ reaction plays a key role in controlling the Ca/Si and Ca/S ratios synthesized during α-rich oxygen burning in Type Ia supernovae (SNIa). This reaction feeds the α-rich burning branch by converting ^{16}O into ^{12}C via the chain of ^{16}O (p, α)$^{13}N(\gamma,p)^{12}C$. Moreover, the ^{16}O (p, α)^{13}N rate is highly sensitive to the progenitor white dwarf metallicity. However, substantial uncertainties (factors >2) have existed in current $^{16}O(p, \alpha)^{13}N$ rates, presenting challenges for reliably modeling Type Ia supernova nucleosynthesis.

Therefore, a new direct experimental measurement of the ^{16}O (p, α)^{13}N reaction cross section at center-of-mass energies E_{cm} = 6.9-5.6 MeV using the MUSIC active-target detector at the ATLAS facility at Argonne National Laboratory was performed. The measured cross sections are used to compute the ^{16}O (p, α)^{13}N reaction rate at the relevant temperatures for SNIa models.

The new reaction rate shows that the range of observed isotopic ratios cannot be reproduced by the SNIa models if all other rates still at their standard value. Existing models would however give reasonable agreement with observations, if the ^{12}C+^{16}O reaction rate is lower than currently assumed.

Neutron irradiations at the University of Birmingham High Flux Accelerator Driven Neutron Facility (HF-ADNeF)

Jack Bishop[1], Patrick Galvin[1], Tim Williams[1], Carl Wheldon[1], Tzany Kokalova[1], and Ben Phoenix[1]
[1]University of Birmingham, UK

The newly-commissioned HF-ADNeF (High Flux Accelerator Driven NEutron Facility) [1] at the University of Birmingham provides a world-leading accelerator-driven neutron intensity. Using a >30mA beam of protons at 1.912 MeV incident onto a thick lithium target, a neutron energy spectrum with a Maxwellian shape of kT=25 keV can be achieved. In this way, Maxwellian Averaged Cross Sections (MACS) can be directly measured for s-process nuclei at temperatures relevant for nuclear astrophysics.

An initial study of the beam characterisation and verification of the 59Co(n,g) MACS have been performed in tandem with GEANT4 simulations, the results of which will be presented alongside details of the planned 60Co(n,g) MACS measurements which have not been previously measured.

[1] C. Wheldon 2022 JINST 17 C10010

Spectroscopy of 23F Following a One-Neutron Removal Reaction

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The structure of the neutron-rich 23F nuclide was investigated via high-resolution in-beam γ-ray spectroscopy following a one-neutron removal reaction using the γ-ray energy tracking array GRETINA coupled to the S800 spectrometer at the NSCL facility. Several new transitions and excited states have been identified, which in tandem with a γ-γ coincidence analysis, allows for the construction of an updated level scheme for 23F. The relative populations and branching ratios of the excited states were studied using detailed Monte Carlo GEANT4 simulations, and the spin and parities of the states were inferred from the analysis of the γ-ray angular distributions. The findings were compared to phenomenological USD-type shell-model calculations; it was found that the USDB calculations were consistently reproducing the experimental data on the structure of 23F.

Coulomb Excitation in 80Sr

Reuben Russell[1], J. Henderson[1], J. Heery[1], C. Andreoiu[2], D.W. Annen[2], A. Avaa[3], G. Ball[3], V. Bildstein[4], S. Buck[4], C. Cousins[1], S.A. Gillespie[5], B. Greaves[4], A. Grimes[3], G. Hackman[3], R. Hughes[6], D. Jenkins[7], M. Martin[2], C. Müeller-Gatermann[8], J.R. Murias[3], S.M. Morales[3], S. Pascu[1], D. Rhodes[3], J. Smallcombe[9], P. Spagnoletti[2], C. Svensson[4], B. Wadsworth[7], B. Wallis[7], J. Williams[3], C.-Y. Wu[6], and D. Yates[3]
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The structure of deformed nuclei is known to greatly differ from that which is predicted by an independent particle model. 80Sr lies in the region of N=Z=40, which is a region displaying strong quadrupole deformation. Therefore, to further the understanding of deformation in nuclear structure, it is important to examine nuclei in regions exhibiting this feature. Coulomb excitation of 80Sr with a 208Pb target at TRIUMF was carried out in early September 2023 using TIGRESS and two annular S3 detectors. Early results including preliminary B(E2; 2+1→ 0+1) and Qs(2+) found from this experiment will be presented.

Parallel Session II: Session H

Tracing two-neutron halos in N=28 isotones: A three-body adventure

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The latest generation of radioactive ion beam facilities provides unparalleled access to neutron-rich unstable isotopes. One of the areas of active investigation is the study of the shell evolution near the neutron magic numbers N=20 [1-4] and N=28 [5-6] for such unstable nuclei. The nuclei near these magic numbers display exotic structural features such as dampening of shell gaps, formation of halos, and deformed structures.

Recently, the 29F system, a light neutron-rich N=20 isotone, was identified as the heaviest two-neutron Borromean-halo nucleus found till date [1-4]. Motivated by this observation, it is interesting to explore the “N=28” shell closure for nuclei with a small proton number as well, to see whether we can find similar Borromean structure formation.

In this talk, I will compare and contrast the shell evolution across the neutron magic numbers N=20 and 28 within a three-body (core+N+N) framework based on the hyperspherical harmonics formalism by using an analytical-transformed harmonic-oscillator basis. New three-body results will be presented for the ground state structural properties of putative two-neutron Borromean halos in Na and Mg isotopes with N=28 [7].

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Two-centre harmonic oscillator basis for Skyrme Hartree Fock: alpha clustering in 8Be and 24Mg ->12C+12C as a proof of principles calculations

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Fission is one of the most challenging processes to describe in nuclear physics. Contrary to most of the nuclear properties, which can be explained in terms of a smaller set of valence nucleons, in fission all the particles are involved. To link the properties of the nascent fragments with the structure of the initial compound nucleus, it seems adequate to consider the two-centre harmonic oscillator basis to build the many-body wave functions. In the present work, symmetry-unrestricted two-centre harmonic oscillator states are used — within the density functional solver HFODD — to solve the Hartree-Fock equations. The separation between fragments as well as their deformation are explored, comparing the results with the classical one-centre calculations. Particular emphasis is given to the post-scission configuration, where the Coulomb interaction is well-reproduced both in the exact direct and exchange terms.

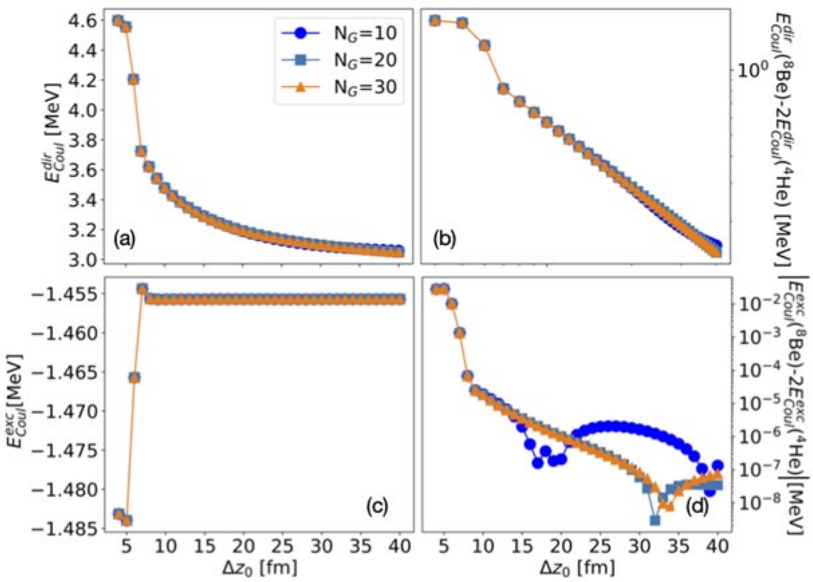

Fig 1. Electrostatic repulsion between two alpha particles after splitting 8Be determined for different numbers of Gaussians used to approximate the 1/r form factor. Panels (a)-(b) show the direct term of the interaction in linear and double-logarithmic scale. Panels (c)-(d) show the exchange contribution in linear and logarithmic scale. The TCHO basis was adapted to spherical 4He.

Finding Excitation Spectra Using a Quantum Computer

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Quantum Computers will allow for simulation of larger nuclear models, since the model space of a quantum computer doubles for each additional qubit. However, current quantum computers are noisy, error prone, and only have a small number of quantum bits (qubits). Algorithms must be developed with these limitations in mind. Variational algorithms have gained popularity recently; these are hybrid algorithms, which utilize a quantum and a classical computer in the same algorithm to reduce the load on the quantum computer. There are many variational algorithms that are applicable to nuclear physics such as the Variational Quantum Eigensolver (VQE) and the Variational Quantum Imaginary Time Evolution (VarQITE) algorithms. However, these algorithms often only focus on finding the ground state of a system whereas it is generally more useful to find the full excited state spectrum of a system. We present work that builds upon the VarQITE algorithm by minimising the variance of the Hamiltonian. This extends the existing VarQITE algorithm to be able to find the full excitation spectrum of a nuclear model using a quantum computer.

Shape coexistence in neutron-deficient 190-Pb

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Shape coexistence is a broad phenomenon with manifestations all over the nuclear chart [1]. In the neutron-deficient lead region when approaching the neutron mid-shell N = 104, collective intruder configurations give rise to oblate and prolate shapes competing with the spherical ground-state, in particular in 190-Pb. Wealth of information on the nuclear structure is connected to these different potential well minima. We present two complementary experiments that we have performed to study this nucleus' deformation.

Simultaneous measurement of internal conversion electrons and γ rays was achieved employing the SAGE spectrometer [2] within the first campaign where is was used coupled to the MARA (Mass Analysing Recoil Apparatus) vacuum mode recoil separator [3,4]. The desired nucleus was produced via the fusion-evaporation reaction 159-Tb(35-Cl,4n), at beam energy of 165 MeV, in the Accelerator Laboratory at the University of Jyväskylä (JYFL) [5]. We have measured strong E0 components for the inter-band transitions, which is a clear sign of states associated with different mean-square charge radii.

Previous experimental studies have assigned the yrast band with a spherical shape [6], while theoretical calculations beyond mean-field and within the interacting boson model (IBM) have shed light on a possible oblate configuration dominance [7,8]. In order to clarify this and to investigate the shape mixing at low-spin, an additional experiment was conducted in March 2023 at JYFL, via the Recoil Distance Doppler-Shift (RDDS) method, using the recently-developed APPA plunger device. The lifetimes obtained are directly related to nuclear shapes via the B(E2) values. Monopole transition strengths and shape mixing amplitudes can be calculated for the inter-band transitions with the

combination of both datasets' results. In addition, spectroscopic information for the structures above the 11- and 12+ isomeric states has also been gathered.

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Investigation of quadrupole and octupole states in Zr chain using TDHF and QRPA

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As fundamental collective excitations of atomic nuclei, giant resonances (GR) carry information about key aspects of nuclear structure and dynamics. The time-dependent Hartree-Fock (TDHF) method and the small amplitude limit of TDHF, known as the (quasiparticle) random phase approximation (QRPA), are recognized as standard tools for studying these excitations. In this work, we investigate quadrupole (2^+) and octupole (3^-) excitations in nuclei using the TDHF method with Skyrme-type interactions. Firstly, the TDHF method is extended to perform calculations for octupole excitations, and the results are benchmarked against calculations using the quasiparticle random phase approximation (QRPA) for spherical nuclei. Then, extensive calculations are performed in the Zr chain to study the characteristics of quadrupole and octupole excitations. The results for deformed nuclei using the TDHF and QRPA methods have been compared and discussed. We also investigate the validity of the octupole magic number (N = 64) for the Zr isotopic chain, assessing the strength of the first octupole state in relation to the mass number.

Suppressed electric quadrupole collectivity in ^{32}Si

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Lying between ^{16}O and ^{40}Ca, the sd-shell is well described by robust phenomenological and ab initio nuclear theories. In this talk, I will describe a recent sub-barrier Coulomb excitation experiment performed on the radioactive nucleus ^{32}Si. The results from this experiment find that the oblate nature of the deformation is well-reproduced, whilst the absolute scale of quadrupole deformation, however, is inhibited by approximately a factor of two compared to theoretical predictions. Through comparison with shell-model and ab initio calculations, a number of possible explanations for this inhibited E2 strength are presented. By comparing the results of these calculations to multiple observables, it is concluded that there is a reduced role for out-of-space excitations in ^{32}Si, resulting in a reduction in the corrections normally applied to both models.

Parallel Session III: Session A

UKRI-MPW1: Simulations and preliminary Evaluations of an HV-CMOS sensor optimised for high radiation tolerance

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As the LHC and future collider experiments probe higher energies and luminosities, detector systems must improve with the changing landscape. Tracking systems, typically made of silicon and placed millimetres from the beampipe, are indispensable to modern particle physics. These sensors are exposed to high levels of radiation at bunch crossing rates in the GHz range; this is set to increase further with the next generation of experiments. High Voltage-CMOS (HV-CMOS) pixels are an excellent candidate for use in the next generation of detector experiments. This radiation tolerant, monolithic solution can achieve fine spatial and temporal granularity with a low material budget: not limited by bump bonding. Although the sensors are already being developed for Mu3e and LHCb's Mighty Tracker, more development is needed to meet future targets.

The UKRI-MPW is a series of proof-of-concept HV-CMOS pixel chips designed in the LFoundry 150 nm node with the goal of improving radiation tolerance of the technology through backside biasing and high breakdown. UKRI-MPW1 is the next chip which builds on the already tested MPW0: The former chip reached breakdowns of ≈ 600 V with a sensing region of 50 μm after 1×10^{16} 1 MeV neq cm2. However, the sensor suffered from a high leakage current and poorly isolated pixels. The new chip refines the design with a specialised p-layer, jointly developed with the manufacturer. The new layer, a high substrate resistivity, 3.0 kΩ cm; improved ring structure, and backside biasing scheme, is predicted to better isolate the pixels and reduce the leakage current without sacrificing the high radiation tolerance.

This contribution presents the simulations of the chip with comparison to a former chip, and preliminary IV and eTCT measurements of the new sensor, delivered in early 2024.

Pre-clinical Investigations of Spatially Fractionated Radiotherapy

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LhARA (Laser-hybrid Accelerator for Radiobiological Applications) is conceived as a novel, uniquely flexible facility dedicated to the study of the biological response to ionising radiation. The design for LhARA offers versatility, allowing for the production of spatially fractionated radiation therapy (SFRT) at the in-vitro and in-vivo end stations.

Background

SFRT aims to minimise radiation exposure to healthy tissues by separating the incident beam into fractions. The delivery of SFRT and the measurement of the dose distribution present a variety of challenges that must be explored to optimise the design of the LhARA end stations.

Methods

A preclinical study was conducted to compare a systematic review and in-silico study of critical parameters surrounding SFRT. The systematic review evaluates the tumour control and tissue sparing properties of SFRT. The in-silico study uses linear-quadratic models via TOPAS to investigate the same responses. Correlations between parameter values and experimental outcomes were studied and a follow up in-vitro experiment was designed to investigate the discrepancies.

Results

Both the systematic review and in-silico study present very agreeable results with the exception of a few discrepancies, notably with PVDR. A reason for this could be the radiation bystander effect. If this is occurring in the unirradiated regions, it may have an impact on these parameters that is not accounted for in the linear quadratic in-silico model. A preliminary in-vitro SFRT investigation saw evidence of this, though more experiments are required to provide a concrete theory. This will be concluded ahead of the conference.

Conclusions

In conclusion, the systematic review and in-silico study reveal similar parameter correlations with sparing and tumour control. A potential bystander effect underscores the need for further investigation in order to improve the in-silico linear-quadratic model for more accurate pre clinical investigation. This is to be completed by April 2023.

Characterization of Secondary Neutrons in Carbon Ion Beam Therapy Using TOPAS Monte Carlo Simulations

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Particle therapy, particularly carbon ion beam therapy, has emerged as a promising approach for cancer treatment due to its capacity to deliver precise doses to tumors while sparing normal tissues. However, the potential health impact of secondary radiation poses a concern, as it may elevate the integral dose, leading to secondary cancer risks in patients. This study employs the TOPAS Monte Carlo toolkit to investigate the characteristics of primary particles and secondary neutrons generated during carbon ion irradiation. The focus is on understanding these characteristics before employing the Dark Matter Particle Explorer experiment (DAMPE) detector to measure energy deposition in air and water, with the aim of comparing simulation results with experimental data.

Through TOPAS Monte Carlo simulations, we explored the interactions between carbon ion beams and a water phantom, representing human tissues. Two silicon strip detectors, positioned behind the water phantom, were used to measure scattering angles and reconstruct particle positions. Analysis of the simulated data provided valuable insights into energy deposition profiles and scattering patterns secondary neutrons. This information is crucial for evaluating potential biological effects of secondary radiation and optimizing treatment planning.

Scattering angles for secondary neutrons were calculated and plotted, alongside the dose deposited in each detector. The simulation results exhibited good agreement with previous studies utilizing different Monte Carlo codes. These findings contribute to the refinement of treatment planning accuracy, ongoing advancements in particle therapy techniques, and optimization of detector design. Furthermore, this work assesses the applicability of the TOPAS Monte Carlo toolkit for comprehensive studies in carbon ion beam therapy, paving the way for further developments in this dynamic field.

Design of an Ion-Acoustics Proof-of-Principle Experiment for LhARA

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LhARA, the Laser-hybrid Accelerator for Radiobiological Applications, is a proposed facility dedicated to the study of radiation biology using proton and ion beams. The accelerator has been designed to deliver a variety of ion species over a wide range of spatial and temporal profiles at ultra-high dose rates. The variable nature of the ion yield requires that the deposited dose distribution be measured in real-time.

Due to the short pulses (10—40 ns) delivered by LhARA, the thermal expansion generated by the almost instantaneous energy deposition satisfies the stress confinement criterion necessary for the efficient generation of acoustic (pressure) waves. A proposed proof-of-principle experiment is presented that exploits these induced waves to obtain a 3D calibrated dose map.

The experiment targets the Laser-Driven Ion Accelerator (LION) in Munich, which produces protons up to 25 MeV at a repetition rate of 10 Hz. A water-based phantom has been designed that features a beam entry window sealed with a 50 µm Kapton membrane. Three ports located on three orthogonal sides mount transducer arrays for detecting the acoustic waves. To calibrate their acoustic response, a liquid scintillator will be added to the water and its luminescence arising from the energy deposited by the ion beam is imaged by two cameras, positioned orthogonally to each other. To evaluate the performance of the proposed experiment, a series of simulations have been developed. The accelerator beamline and beam parameters have been simulated in BDSIM, the acoustic wave generation and detection have been simulated in Geant4 and k-Wave, and the optical system in OpticStudio.

The simulations indicate a high degree of precision in reconstructing the three-dimensional energy deposition profile through the combined use of the acoustic and optical detection systems, and therefore, this integrated approach is expected to yield an accurately calibrated dose map in the proposed experiment.

A feasibility study using an array of LaBr3(Ce) scintillation detectors as a Compton camera for prompt gamma imaging during BNCT

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Boron Neutron Capture Therapy (BNCT) is a binary cancer therapy where a low energy neutron beam is incident upon a patient who has been administered a tumour-seeking 10B loaded compound. The neutron capture reaction on 10B results in the production of two short range particles, 7Li and 4He, that deposit all of their energies within the targeted cell. However, accurate, online dosimetry during BNCT is challenging as it requires knowledge of both the neutron fluence and 10B concentration in cells. An additional product in the neutron capture reaction on 10B is a 478 keV prompt gamma ray, and if the production vertices of these gamma rays could be imaged by an external camera, the density of the vertices could be used to infer the dose delivered to the patient. In this study, the feasibility of using an array of LaBr3 scintillators as a modified Compton camera for prompt gamma imaging during BNCT was investigated using Geant4 simulations. The camera design investigated was based on an existing array of 1.5 inch lanthanum bromide (LaBr3(Ce)) scintillator detectors at the University of Birmingham, with a hemispherical configuration. The simulations demonstrated that a phantom containing a 3 cm diameter region of 400 ppm 10B could be reconstructed using clinically relevant neutron fluences. Results from this study have been accepted for publication in Frontiers in Physics. These results will be presented along with the methodology associated with the novel Compton camera, details of the reconstruction algorithm and future plans for assessing the dose delivered during BNCT treatment and the impact for patients.

Parallel Session III: Session B

Fiducial differential measurement of the production of the Higgs boson through Vector Boson Fusion in the τ+τ− channel with the ATLAS Detector

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This talk will present an overview of the present state of the first unfold fiducial differential measurements of the Higgs boson decaying into a ditau final state in a Vector Boson Fusion (VBF) phase space with the ATLAS detector. This analysis is made in parallel of a Simplified Template Cross-Section (STXS) approach and is based on a previous STXS analysis.

In the fiducial approach, former events are categorized by only their kinematic properties to create a framework which is more model independent than STFX framework, which relies on the Standard Model properties of the VBF production mode. While fiducial measurements still rely on SM simulated samples to derive unfolding matrices, this approach does not separate the different production modes, but a region of phase space is defined which is dominated by VBF events and the properties of these events are then measured. Several variables are unfolded including the difference in the azimuthal angle between the jets, Δϕjj , the Higgs transverse momentum, pT(H), and the leading jet pT. The goal is to investigate the kinematics and the charge Conjugation and Parity symmetry properties (CP properties) of the Higgs boson but also search for new physics by using an effective field theory which is sensible to those new explored kinematics variables.

Preliminary results using MonteCarlo produced data have been finalised and data obtained during the Run2 of the LHC has started to be used to measure the final results of our analysis.

Differential Cross-Section Measurement of Inclusive W^± (→l^± ν)γ Process in proton-proton collision at √s=13 TeV with the ATLAS Detector

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The ATLAS Collaboration is performing the differential cross-section measurement of inclusive W^± (→l^± ν)γ at √s=13 TeV, using the full Run2 data set collected during 2015-2018, with an integrated luminosity of 140 fb^(-1). This analysis follows on the inclusive W^± γ analysis of ATLAS in Run 1 at √s=7 TeV [1]. The W^± γ process provides a direct and precise test of the SM properties and is sensitive to the O_W̃ and O_(HWB)̃ operators in dimension-six Standard Model Effective Field Theory (SMEFT) that induce CP-violating effects in weak-boson self-interactions. Events with one electron or muon, one photon and missing transverse momentum are selected.
Backgrounds are estimated using data-driven methods and the data are corrected for detector effects. Differential cross sections are presented for a variety of observables sensitive to CP-violation.

[1] arXiv:1302.1283 [hep-ex]

Studies on Z-gamma Scattering at 13 TeV with ATLAS Detector

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Vector boson scattering (VBS) processes serve as a robust means to test the Standard Model (SM) by providing insights into anomalous quartic gauge couplings. The exploration of Zγ VBS is particularly crucial as it delves into neutral quartic couplings forbidden at the lowest order of the SM.

At the LHC, Zγ VBS materializes as a final state comprising a Zγ pair and two jets (Zγjj). However, additional gauge-invariant electroweak (EW) processes contribute to the same state. Therefore, a comprehensive study of Zγ VBS at the LHC necessitates an examination of the entire EW-Zγjj production.

This presentation highlights the analysis (https://doi.org/10.1016/j.physletb.2023.138222) that achieved the first observation of EW-Zγjj production with the ATLAS detector, utilising proton-proton collision data recorded from 2015 to 2018. Furthermore, the study explores the total Zγjj production, encompassing EW-Zγjj, QCD-Zγjj, and their interference. This investigation complements the recent ATLAS Zγ+jets analysis by quantifying the total Zγjj process in a VBS-like region, advancing our understanding of the process within a region sensitive to new physics.

Uncertain systematics in combinations

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The Gamma Variance Model (GVM) [1, 2] is a statistical model that implements uncertainties in the assignment of systematic errors (informally called "errors-on-errors"). This is becoming an increasingly important issue as many LHC measurements either already or will soon be dominated by systematic uncertainties. However, the values assigned to quantify these uncertainties often emerge from methodologies that are themselves quite uncertain, such as two-point systematics and theoretical errors. In this talk, we present how uncertain error parameters can be incorporated into combinations. Specifically, we illustrate some properties of our model by applying the GVM formalism to the recently published 7-8 TeV Atlas-CMS top quark mass combination [3]. This application demonstrates how the Atlas and CMS combination is robust to the presence of uncertain systematics, with both the central value and the confidence interval remaining stable under different assumptions regarding the potential values of "errors-on-errors". We also explore the hypothetical scenario of including an outlier in the combination, which could become relevant in the future, by artificially adding a fictitious measurement to the combination. This example highlights a key feature of the GVM: results become sensitive to the internal consistency of the input data. In a standard combination, the presence of an outlier would bias the central value of the combination without affecting the size of the confidence interval. However, if some of the systematic errors are uncertain, the GVM mitigates the effect of outliers, while treating the internal inconsistency of the input data as an additional source of uncertainty.

[1] https://doi.org/10.1140/epjc/s10052-019-6644-4
[2] https://doi.org/10.1140/epjc/s10052-023-12263-7

[3] https://arxiv.org/pdf/2402.08713.pdf

First measurement of high-mass ttll and LFU-inspired EFT interpretations with the ATLAS detector

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The large dataset of high centre-of-mass proton-proton collisions recorded by the ATLAS detector in Run 2 of the LHC provides the unprecedented possibility to study rare Standard Model processes and to measure potential discrepancies to the SM predictions. The top quark, being the heaviest fundamental particle, has a unique role in testing the SM. This can be done by measuring the top quark coupling to other fundamental particles, through the measurement of the inclusive and differential cross-section of these processes. Another more generic way to probe for possible BSM contributions is in the context of the Effective Field Theory, which provides a powerful tool to obtain sensitivity to new physics beyond the reach of the current collider energies. EFT operators targeting the ttll coupling are currently poorly constrained. The impact of such operators strongly increases with energy, a dedicated ttll analysis is performed with the ATLAS experiment, targeting a high-mass regime. The measurement is aiming to constrain the relative rate of ttll production for different lepton flavours at large di-lepton masses in the context of the EFT framework for the first time in ATLAS, testing the Lepton Flavour Universality (LFU) of different four-fermion operators, probing a top-quark sector equivalent to the B-anomalies.

Measurement of Higgs boson properties via the H-> ττ decay channel

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For my PhD thesis, I am working on a Higgs boson data analysis using the full Run 2 dataset recorded by the ATLAS detector at the LHC. This analysis aims at measuring the first fiducial differential cross-sections in the Vector Boson Fusion phase space using the H-¿τ τ decay mode. These differential cross-sections allow us to study the kinematic and CP properties of the Higgs boson and to probe for new physics beyond the Standard Model. At this point, I set up a fiducial volume and an unfolding method, optimized the event selection, and extracted the signal using a fit to the reconstructed di-tau mass. Currently, I am finalizing a study on normalizing flows to improve the template shapes of the main background process in this analysis, Z → τ τ .

Monte Carlo simulations depict behaviours of complex processes. However, predicted distribution often deviated from the corresponding observed ones due to approximations. To correct the simulated distributions and adjust them to better match the recorded data, several methods strategies have been developed. Normalizing flows employ morphing strategies that correct the overall distribution of an observable to match better the data. Normalising Flows (NFs) transform simulated event by employing a deep learning based Machine Learning (ML) method to estimate the probability density function to to better match the data.

Parallel Session III: Session C

SoLAr: A novel technology for solar neutrino detection

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The SoLAr concept introduces a novel liquid-argon neutrino detector technology to enhance sensitivity in the MeV energy range, broadening the scope to include solar and supernovae neutrinos. This technology is based on a monolithic light-charge pixel-based readout, offering a low energy threshold, exceptional energy resolution (approximately 7%), and effective background rejection through pulse-shape discrimination. The primary objective is to observe solar neutrinos in a 10-kiloton-scale detector, ultimately leading to precise measurements of the 8B flux, improved solar neutrino mixing parameters, and the first observation of the hep neutrino flux. It is also a timely technology choice for the DUNE "Module of Opportunity", which could serve as a next-generation multi-purpose observatory for neutrinos from the MeV to the GeV range. A staged prototyping program is in progress to validate the viability of this detector concept, with a prospect to build a medium-sized demonstrator in the Boulby Underground Laboratory. Here, we present preliminary results from the prototype run in July 2023, showcasing cosmic muon tracks detected for the first time with an integrated light and charge readout.

Towards a NCπ0 cross section measurement in the Short-Baseline Near Detector

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The Short-Baseline Near Detector (SBND) is a Liquid Argon Time Projection Chamber scheduled to begin operations later this year on the Booster Neutrino Beam at Fermilab. As the near detector for the Short-Baseline Neutrino program, SBND is part of a multi-detector search for a variety of new physics signatures such as oscillations driven by eV-scale sterile neutrinos. As a result of its large mass and location 110m from the beam target, SBND will collect world leading statistics for neutrino-Argon interactions enabling a wide program of precision cross section measurements. NCπ0 interactions are of particular interest due to their experimental signature being easily confused with the electron producing events looked for in electron neutrino appearance searches. Neutral pions also provide a useful calibration via the standard candle of their invariant mass. This work presents a mature event selection developed on SBND Monte Carlo in preparation of first data, and work towards a first NCπ0 cross section measurement.

First results from a relativistic mean field theory implemented in the NEUT neutrino interaction event generator

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Neutrino oscillation experiments, such as the Tokai to Kamioka (T2K) experiment, are limited by their simulation of accurate neutrino-nucleus interactions. More in-depth theoretical knowledge of neutrino-nucleus interactions are paramount; however, implementing such knowledge in existing event generator frameworks is just as imperative. To evaluate neutrino-nucleus interactions a general framework for the relativistic nuclear many-body problem is required; this framework can be calculated to arbitrary accuracy and compared with experimental measurements.

A relativistic nuclear model containing interacting nucleons with mesons was proposed by Walecka [J.D. Walecka, Annals Phys. 83 (1974) 491-529] and is based on quantum field theory. The model is complex and computationally expensive; however, it can be approximated at higher densities by using a mean field approach in which the meson field operators are replaced by their respective expectation values. The resulting model, relativistic mean field theory (RMF), can be used to describe medium to high density nuclei through Dirac-Hartree calculations [C.J. Horowitz, Brian D. Serot, Nucl. Phys.A 368 (1981) 503-528] of the nuclear bound state. This method can be exactly solved for spherically (nearly-spherically) symmetric nuclei such as 12C, 16O and 40Ar—the target nuclei used in neutrino experiments. The RMF model [R. González-Jiménez et al., Phys. Rev. C 100 (2019) 4, 045501] [R. González-Jiménez et al., Phys. Rev. C 101 (2020) 1, 015503] has already been used to evaluate electron and neutrino scattering on different nuclei. The RMF bound state model can then be coupled with the nucleon scattered state (the solution of the Dirac equation with a complex optical potential) to predict the hadronic current in lepton-nucleus scattering.

As a final year student, this talk presents my work in implementing an RMF neutrino interaction model into the NEUT neutrino interaction event generator framework. This can provide a first glimpse into calculating an exclusive cross section using an neutrino interaction event generator and can provide the T2K experiment with a more theoretically robust model upon which to study systematic uncertainties.

First look at the background of the LEGEND-200 experiment

George Marshall[1]
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The discovery of neutrinoless double beta decay would definitively prove both that lepton number is not a fundamental symmetry in nature and that neutrinos are their own antiparticles. LEGEND is a ton scale program using the isotope 76Ge to search for this decay. The first phase of which, LEGEND-200, utilising up to 200kg of Germanium detectors and based at the Gran Sasso underground laboratory in Italy, has now been operating stably and taking data for over a year. This talk will give an overview of the LEGEND-200 experiment, presenting some initial results on the background from this first year of data taking.

LEGEND-1000

William Quinn[1], and Matteo Agostini
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The discovery of neutrinoless double beta decay would definitively prove both that lepton number is not a fundamental symmetry in nature and that neutrinos are their own antiparticles. Furthermore as a purely matter creating process it could provide a mechanism for the observed prevalence of matter over antimatter. LEGEND (Large Enriched Germanium Experiment for Neutrinoless double beta Decay) is a ton scale program using the isotope Ge-76 to search for this decay with an eventually sensitivity of $>10^{28}$ years covering the inverted hierarchy region. In this talk the design and discovery potential for the next generation experiment LEGEND-1000 will be presented.

Sub-GeV particle identification and tagged photon beam for the Water Cherenkov Test Experiment

Alie Craplet[1]
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The Water Cherenkov Test Experiment (WCTE) will be installed in CERN's recently upgraded T9 "Test Beam" Area in Summer 2024. The upgrade to the East Area, completed in 2022, allows the T9 beamline to reach lower beam momenta than previously possible, now down to ~100MeV/c. The WCTE has three goals: to prototype photosensor and calibration systems for Hyper-Kamiokande, to develop new calibration and reconstruction methods for water Cherenkov detectors and to measure lepton and hadron scattering on Oxygen.

The WCTE collaboration performed a 3-week-long beam test in July 2023 to test WCTE's beam telescope in the momentum range of 200-1000MeV/c. The collaboration uses newly developed aerogel Cherenkov counters with an index of refraction between 1.006 and 1.15 to perform an efficient separation of pions from muons in the sub-GeV range, which had not been done before. This makes a test beam where pions and muons are tagged with good efficiency without having to rely on a tertiary beam.

Additionally, the collaboration developed a new compact tagged photon beamline composed of a Neodymium (N52) Halbach array permanent magnet with a peak magnetic field of 1.7T and a hodoscope array placed downstream of the magnet. The combination of the aerogel Cherenkov threshold counters and tagged photon beamline provides sub-GeV p, e, pi, mu and gamma test beams with momentum between 200 and 1000MeV/c. Using this setup, the collaboration was able to estimate the beam flux of the CERN T9 beam.

Parallel Session III: Session D

Production and performance of first DarkSide-20k Photo Detector Units

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One of the most challenging open problems in physics is the direct detection of dark matter candidates. Several low-background underground experiments are currently involved in the search of Weakly Interacting Massive Particles (WIMP) employing noble liquids like xenon or argon that have very good scintillation properties. Using underground sources of argon, it is possible to limit the contamination of radioactive ^{39}Ar significantly down to 0.5 mBq/kg. High-performance single-photon detectors are required to acquire the faint signals emitted by the expected interaction of such candidates in the detector.

This talk presents the production and the performance of the first Photo Detector Units (PDUs) of DarkSide-20k (DS-20k) detector, under construction in Laboratori Nazionali del Gran Sasso (LNGS), Assergi, Italy.

DS-20k detector is a double-phase Time Projection Chamber (TPC) containing 20 tons of ultrapure liquid argon in the fiducial volume. The scintillation light emitted by particles interacting with argon in the TPC will be read out by custom cryogenic Silicon Photo Multipliers (SiPMs) that will cover two 10.5 m^2 optical plane surfaces located on the top and bottom of the TPC. The latter is surrounded by an active veto as shield against the external environment to improve background rejection.
The PDU is a radiopure photodetector designed to work in liquid argon composed by 16 tiles, each of them containing 24 SiPMs. The tiles will be assembled and tested inside Nuova Officina Assergi (NOA) at LNGS before to be integrated on the PDUs. The first DS-20k PDUs are going to be characterized in a dedicated cryogenic test facility in Naples University and the preliminary results will be reported.

The QUantum Enhanced Space-Time (QUEST) experiment

Abhinav Patra[1]
[1]Cardiff University, UK

The QUantum Enhanced Space-Time (QUEST) experiment is currently being commissioned at Cardiff University. QUEST consists of a pair of co-located tabletop power-recycled Michelson interferometers, each targeting a displacement sensitivity of 2 x 10^{-19} m/rtHz at 100 MHz. To achieve this sensitivity, the interferometers utilize high circulating power (10 kW) and squeezing. The main science goal of QUEST is to be sensitive to sub-shot noise stochastic signals. These stochastic signals can be a result of spacetime fluctuations due to quantum gravity, interactions of dark matter with the interferometer optics or ultra-high frequency stochastic gravitational waves.

Overview of the Technology of MAGIS and AION Atom Interferometry Experiments Towards Ultra-light Dark Matter Searches

Gedminas Elertas[1]
[1]Department of Physics, University of Liverpool, UK

MAGIS and AION are experiments based on quantum sensors aiming to explore fundamental physics with atom interferometry, particularly the search for the ultra-light dark matter fields at a mass range of 10-22 eV – 10-15 eV and develop the technology for a future kilometre-scale detector that could be sensitive to gravitational waves at a mid-band frequency range of 0.1-10 Hz. MAGIS is a vertical 100 m strontium interferometer under construction at Fermilab, while AION is a sister UK project. It has established five strontium atom interferometry laboratories nationwide and is planning to build a 10 m prototype at the University of Oxford, leading to a 100 m sensor, potentially at Boulby Underground Laboratory.

Both projects are collaborating in developing atom interferometry technology to meet the high sensitivity requirements needed by dark matter searches such as shot-noise limited detection, high repetition rate, ultracold atom samples, large atom numbers, the ability to launch atoms for tens of meters, maintaining record-breaking spatial separation of the matter wave packets, and accounting for multiple systematic uncertainties.

The leading contribution of the University of Liverpool is the development of a phase-shear detection platform for both experiments. Phase-shear detection is a technique that imprints the interference fringes spatially across the atom cloud, allowing single-shot measurements of the phase and contrast, plus compensation for the Coriolis effect, which is one of the largest systematics. The platform is an ultra-high vacuum chamber housing the primary ultra-flat mirror used to retroreflect the interferometer beam. The mirror angle is controlled with amplified piezoelectric actuators to achieve the phase-shear and Coriolis compensation. The platform design, specifications, and status are presented.

Low energy electron recoil searches within LZ and using FlameNEST for future work

Harkirat Riyat[1]
[1]Univesrtiy of Edinburgh, UK

LUX-ZEPLIN (LZ) is a direct dark matter (DM) detection experiment utilising a 7-tonne active target of liquid xenon, searching primarily for WIMP candidates that produce nuclear recoils (NR) of xenon nuclei. LZ recently published results from the 60 live-day science run one (SR1), producing new world-leading limits for the upper bound of the spin-independent and neutron spin-dependent WIMP-nucleon cross-sections. In 2023, LZ published results in a search for new physics in low-energy electron recoils from the first LZ exposure, which looked for signals from exotic physics models that produce electron recoils, such as DM candidates that couple to electrons. The search included solar axions, axion-like particles, hidden photons, and solar neutrino magnetic moment and millicharge. This talk will discuss the results featured in this paper, the work done to calculate projected limits by combining SR1 with planned exposures from SR3 to estimate future sensitivity and discuss using

FlameNEST, a statistical framework being developed within LZ, to produce improved sensitivity results for these models compared to previous statistical methods used by LZ.

Optimisation of fast likelihood functions for dark matter and rare event searches

Joshua Green[1]
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Flamedisx provides a unique method of calculating likelihoods for rare event searches in liquid xenon time-projection chambers, like LUX-ZEPLIN, without the need for exhaustive monte-carlo simulations. Rather than random sampling of underlying parameters, flamedisx evaluates the range of possible parameters that could have significantly contributed to an observed event allowing for faster evaluation of more observables and shape varying parameters. This is represented in a large tensor calculation optimised with differential programming in TensorFlow. The implementation of Noble Element Simulation Technique (NEST) Xe response models in flamedisx, necessary to model light and charge response of Xe in a way consistent with other experiments, resulted in a more complex model which significantly increased memory consumption and execution time. Various optimisations made inference with more observables possible but the memory and time issues restrained possibilities with shape varying parameters. This work resolves the complexity of the NEST models through manipulation of the tensors and gives examples of where introducing shape varying parameters can improve analyses.

Parallel Session III: Session E

Development of the MAGIS-100 atom interferometer primary imaging system

Daniel Wood[1]
[1]University of Oxford, UK

The Matter-wave Atomic Gradiometer Interferometric Sensor (MAGIS) program is leading the development of long-baseline atom interferometry with the goal of exploration of fundamental physics. MAGIS-100 is a novel 100-metre baseline interferometer under construction at Fermilab which will utilise techniques developed in state-of-the-art 10-metre baseline interferometers and technological advances in the world’s leading atomic clocks, in order to search for ultralight dark matter candidates, probe quantum mechanics in new regimes, and serve as development for a future, kilometre-baseline interferometer which will be sensitive to gravitational waves from known sources in the previously unexplored 0.1Hz to 3Hz range.

Such a complex and powerful instrument as MAGIS-100 requires a leading imaging system, to precisely capture the interference patterns that compose the science signal. In order to capture these interference patterns, the atom cloud will be fluoresced with light at 461nm, presenting a novel and challenging imaging problem. Here we present the development of the primary science imaging

system for MAGIS-100, which will constitute up to ten CMOS camera and optical assemblies. The imaging environment is described, and simulations of the photon distributions are presented which include realistic intensity, diffraction and depth-of-field effects. Results of camera characterisation tests are described including linearity, quantum efficiency, and sensor MTF measured both through a conventional 'knife-edge' method and the use of laser speckle. A method of optical testing is outlined which uses lateral-shear interferometry to measure the lens pupil function. All of this simulation and experimental work is combined to lead the characterisation and calibration of the proposed baseline MAGIS-100 science imaging system.

Superfluid Helium-3 Calorimetry with Quantum Sensor Readout in the QUEST-DMC experiment

Rob Smith[1]
[1]Royal Holloway, University of London, UK

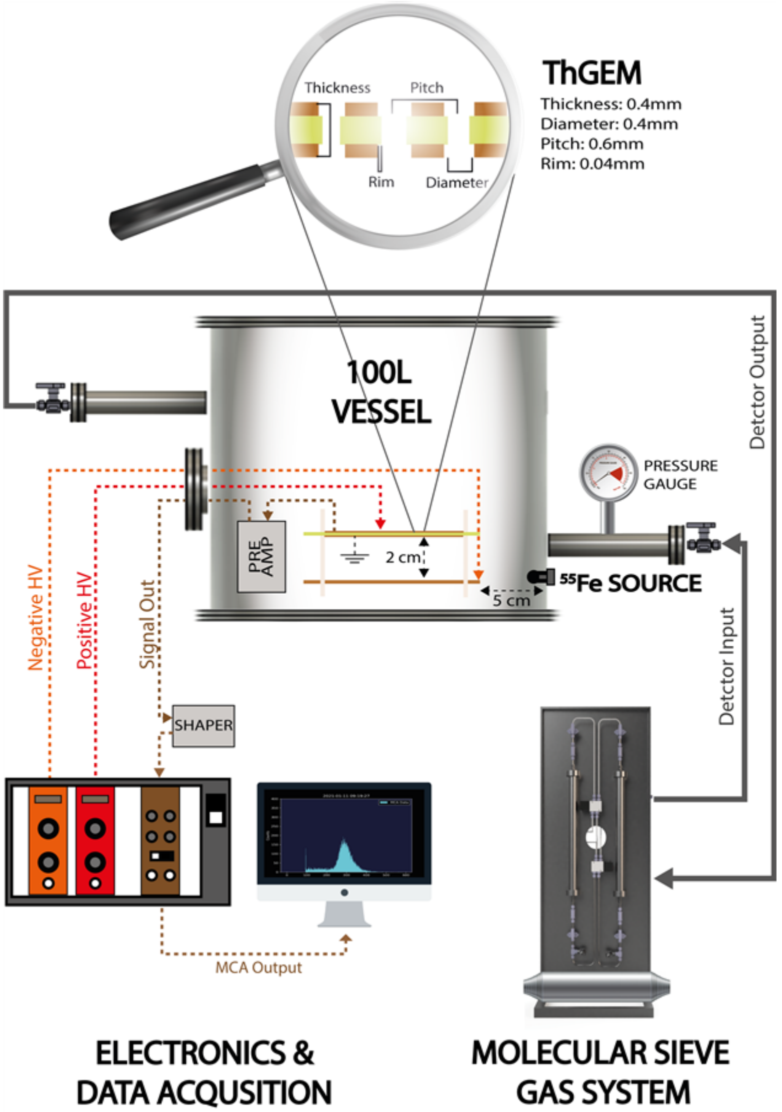
QUEST-DMC (QUantum Enhanced Superfluid Technologies for Dark Matter and Cosmology) is an experiment searching for dark matter particle interactions in a superfluid ^{3}He target. QUEST-DMC aims to be sensitive to dark matter particle interactions in the GeV to sub-GeV mass range with recoil energies in the eV to keV range. Extremely low energy threshold is required to probe this parameter space, pushing the need for innovation in detector and readout technologies. QUEST-DMC employs bolometers consisting of vibrating nanowire resonators submerged in superfluid ^{3}He, coupled with a quantum sensor readout, to achieve resolution at the eV scale. This talk will describe the experimental methods for bolometry, highly sensitive quantum readout and energy calibration in QUEST-DMC.

Molecular sieve vacuum swing adsorption purification and radon reduction system for gaseous dark matter and rare-event detectors

Robert Renz Marcelo Gregorio[1,2], Neil Spooner[2], Ferdos Dastgiri[3], Alastair McLean[2], Greg Lane[3], Kentaro Miuchi[4], and Hiroshi Ogawa[5]
[1]Queen Mary University of London, UK, [2]University of Sheffield, UK, [3]Australian National University, Australia, [4]Kobe University, Japan, [5]CST Nihon University, Japan

In the field of directional dark matter experiments SF6 has emerged as an ideal target gas. A critical challenge with this gas, and with other proposed gases, is the effective removal of contaminant gases. This includes radon which produce unwanted background events, but also common pollutants such as water, oxygen and nitrogen, which can capture ionisation electrons, resulting in loss of detector gas gain over time. We present here a novel molecular sieve (MS) based gas recycling system for the simultaneous removal of both radon and common pollutants from SF6. The apparatus has the additional benefit of minimising gas required in experiments and utilises a Vacuum Swing Adsorption (VSA) technique for continuous, long-term operation. The gas system's capabilities were tested with a 100 L low-pressure SF6 Time Projection Chamber (TPC) detector. For the first time, we present a newly developed low-radioactive MS type 5Å. This material was found to emanate radon at 98% less per radon captured compared to commercial counterparts, the lowest known MS emanation at the time of writing. Consequently, the radon activity in the TPC detector was reduced,

with an upper limit of less than 7.2 mBq at a 95% confidence level (C.L.). Incorporation of MS types 3Å and 4Å to absorb common pollutants was found successfully to mitigate against gain deterioration while recycling the target gas.



Direct search for scalar field dark matter with LIGO

Alexandre Göttel[1], Aldo Ejlli[2], Kanioar Karan[2], Sander Vermeulen[3], Lorenzo Aiello[4,5], Vivien Raymond[1], and Hartmut Grote[1]

[1]Cardiff University | Gravity Exploration Institute, UK, [2]Max-Planck-Institute for Gravitational Physics and Leibniz University, Germany, [3]California Institute of Technology, Department of physics, USA, [4]Università di Roma Tor Vergata, Italy, [5]INFN, Sezione di Roma Tor Vergata, Italy

Laser interferometers have in recent years not only revolutionized astronomy through a variety of gravitational-wave detections, but have also shown promise in the search for new physics, such as dark matter, even without gravitational wave mediation. In the case of LIGO, a scalar dark matter field would lead to oscillations in the size of interferometer optics, leaving a distinct and measurable signature in their strain data. We analyse the coupling between these size oscillations and

gravitation-wave strain. Using detailed optical simulations, we achieve this in a way that considers effects not just from the beamsplitter, but also from the arm mirrors, for the first time, and considers the effects from finite light travel time. We apply advanced search techniques, newly-developed to maximise the sensitivity to such signals, establishing stricter upper limits on the coupling strength of scalar field dark matter. Our results surpass those from earlier direct searches by up to four orders of magnitude in a mass range from 5e-14 eV to 1e-12 eV.

IWAVE a novel adaptive filtering method and its application to short and long duration gravitational wave searches

Ian Hollows[1]
[1]The University of Sheffield, UK

The remnant of a binary neutron star coalescence is expected to emit transient gravitational wave (CW) signals with spin down times of 10-3-105 s after merger to form a black hole. CW signals have not yet been directly detected.

The evolving oscillation of CW signals is at a very low signal-to-noise ratio (SNR) and so the frequency evolution of such signals in ground based gravitational wave interferometers cannot be inferred from the raw data as is necessary for successful tracking with a conventional phase locked loop (PLL). The IWAVE (Iterative Wave Action-angle Variable Estimator) technique is a new type of PLL addressing the dynamic characterization of evolving pseudo-sinusoidal signals. The algorithm has just two input parameters: the initial frequency and the response time. A theoretical optimal value of the IWAVE response time based on the signal frequency and its rate of change corresponds well with values determined from simulations. The algorithm has a low computational load so that results are obtained rapidly and may be used to reduce the search parameter space before applying matched filtering methods. IWAVE has been applied to LIGO strain data and the study of violin modes in ultralow loss fused silica suspensions [1].

The IWAVE technique is being applied to study simulated magnetar signals similar to those used in [2] and short-duration signals using the CoRe database simulations of binary neutron star merger waveforms [3] injected into LIGO data. The talk will present an overview of the IWAVE approach, recent work on the dynamic characterisation of CW signals and future challenges.

[1] E. J. Daw, I.J. Hollows, E.L. Jones, et al., Rev. Sci. Instrum. 93, 044502 (2022)
[2] L. Sun and A. Melatos, Phys. Rev. D 99, 123003 (2019)
[3] T. Dietrich, D. Radice, et al., Classical and Quantum Gravity 35, 24LT01 (2018)

Parallel Session III: Session F

Search for the very rare $B^+ \rightarrow \pi^+ e^+ e^-$ electroweak penguin decay at LHCb

Richard Williams[1]
[1]University of Cambridge, UK

Rare beauty quark decays provide tests of the standard model and allow the search for new particles with masses that exceed the capabilities of any past or present particle collider. The Large Hadron Collider beauty (LHCb) experiment at CERN allows precise measurement of beauty quark decays, being purpose-built for the study of 'flavour physics', owing to it's unique ability to resolve decay vertices and identify different species of particles in the detector. Recent measurements at LHCb have revealed flavour anomalies – deviations from the standard model's predictions for the universal behaviour of electrons, muons, and taus. In this presentation I will discuss the search for the as-yet unobserved $B^+ \rightarrow \pi^+ e^+ e^-$ decay, focusing on the methods used in the analysis.

Search for the Lepton Flavour Violating Decay Λb → Λ(1520)μe at the LHCb Detector

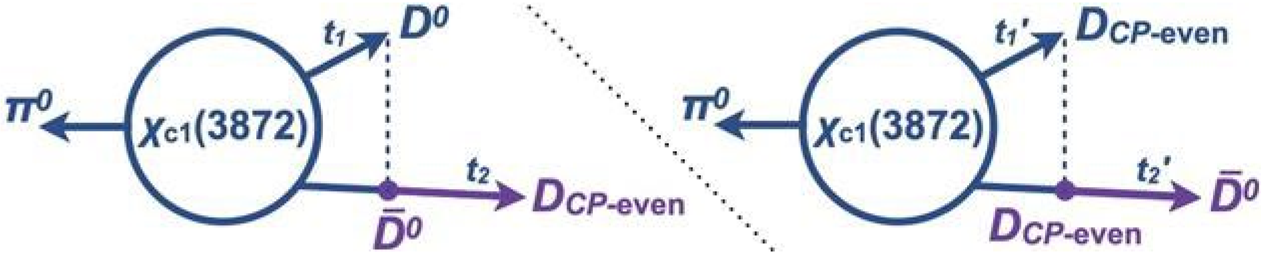
Daniel Thompson
[1]University of Birmingham, UK

Lepton flavour violation (LFV) is forbidden in the charged lepton sector of the Standard Model. Searches for LFV decays are therefore an important way of looking for new physics (NP) and complement precise measurements of Lepton Flavour Universality at the LHC. While multiple LFV searches have been recently published in the decays of b-mesons, there are no equivalent results from decays of b-baryons. The mode Λb -> Λ(1520)μe provides a new, independent search for LFV and builds on recent efforts to find NP involving the Λ(1520) baryon at the LHCb experiment. This presentation will review the first search for the Λb->Λ(1520)μe mode at LHCb, including the strategy and important components vital to this near-complete analysis.

Novel sources and uses of quantum-correlated charm systems

Paras Naik[1]
[1]University of Liverpool, UK

Quantum-correlated (entangled) systems of charmed mesons have been a focus area for flavour physicists, providing input for measurements of the CKM phase gamma and for studies of charm oscillations. Considered previously only from a single source, there is a novel opportunity to perform additional types of analyses with these systems, in several experimental environments [JHEP 03 (2023) 038]. For systems from charmonia decays, it is advantageous to isolate these systems in their C = +1 components for studies of lineshapes and, within b-hadron decays, amplitude analyses. Studies of T and CPT conservation in C = +1 correlated charm systems can be performed with more easily reconstructible final states, when compared to C = -1 correlated charm systems, leading to an opportunity for flavour physics experiments — understanding the C = +/− 1 correlated charm components from chi_c1(3872) exotic meson decay samples is crucial to this task.



Measurement of the Z Mass at LHCb with 2016 pp collision data

Emir Muhammad[1]
[1]University of Warwick, UK

The Z Mass is an important fundamental parameter of the Standard Model of Particle Physics, which has been measured precisely by the LEP experiments using electron-positron collisions. None of the four LHC experiments have yet released a measurement of the Z Mass with proton-proton collisions that would corroborate or challenge the LEP result. The LHCb collaboration has recently released a measurement of the W mass with 2016 data, so it is a natural follow up to extend this measurement to the Z boson. This talk will cover the ongoing measurement at LHCb to measure the Z Mass using Z->μμ decays from proton-proton collision data at sqrt(s) = 13 TeV recorded during 2016, the experimental challenges in the momentum calibration using J/ψ and U1S and transporting their momentum information to a higher energy scale, and the precision currently achievable at LHCb.

CMS Run 3 RK measurement and di-electron triggers

Jay Odedra[1]
[1]Imperial College London, UK

LHC's Run 3 at CMS provides a valuable opportunity to explore Lepton Flavour Universality Violation (LFUV), through the RK observable. Utilizing a variable rate/threshold trigger strategy, which aggressively uses spare L1 bandwidth and new di-electron triggers, CMS may be able to provide a precision measurement of this ratio. This talk will outline the previous results, trigger strategy used to collect data during Run 3 in 2022 & 2023, the commissioning of the triggers and a preliminary look at the expected precision on CMS's measurement using this data.

Parallel Session III: Session G

Laser Spectroscopy of Cobalt isotopes at IGISOL

Elliot Wood[1]
[1]University of Liverpool, UK

Laser Spectroscopy was performed on isotopes of cobalt at the IGISOL facility at the University of Jyvaskyla Accelerator Laboratory (JYFL), Finland. This allows the magnetic dipole moment, electric quadrupole moment and change in the mean-square charge radius to be extracted for isotopes via analysis of each isotopes hyperfine splitting spectrum and other methods. Some of these quantities are measured here for the first time, particularly the mean square charge radius. The isotopes observed were 58Co, 57Co, 55Co, and 54Co, with 59Co used as a reference isotope, its hyperfine constants already known from literature. This is part of an ongoing programme which required an upgrade to the apparatus. Ultimately the goal is to measure the charge radius of a proton emitting state, 53mCo, for the first time. Analysis of these isotopes is ongoing and the progress of which is reported on here.

The New MARA-LEB Facility and Experimental Prospects

Jorge Romero[1]
[1]University of Liverpool, Liverpool, UK

The Low-Energy Branch (LEB) for the MARA separator is a facility in development and construction at the Accelerator Laboratory of the University of Jyväskylä. The facility will be used to perform complete spectroscopy (decay spectroscopy, mass measurements and laser spectroscopy) on exotic nuclei far from stability to investigate their ground-state properties and decay modes.

The MARA-LEB facility will stop and neutralise reaction products selected in flight by the MARA separator in a small-volume buffer gas cell. A state-of-the-art titanium:sapphire laser system allows for re-ionisation of selected species and for laser spectroscopic analysis. Re-ionised recoils can be extracted and accelerated by the ion transport system and further mass- and velocity-selected before being directed either into specialised detector stations for decay spectroscopy, or a dedicated cooler-buncher and Multi-Reflection Time-of-Flight Mass Spectrometer (MR-TOF-MS) for high-precision mass measurements.

The facility was designed for self-conjugate nuclei close to the proton drip line, especially those in the regions around 80Zr, 94Ag and 100Sn. Experiments performed utilising the MARA separator have resulted in increased interest in new regions of the chart of nuclides, including the actinide elements, among others. The use of non-fusion reactions such as multi-nucleon transfer (MNT) has been proposed as a way to enhance access to this region of the nuclear chart and thus improve the prospects of laser ionisation of the actinides, which has proven challenging in the past.

A status update of MARA-LEB will be presented, alongside a discussion of the regions of interest for the facility and the feasibility of experiments involving the different techniques available at MARA-LEB.

Lifetime measurements in 53Ca

Sidong Chen[1], Marina Petri[1], Stefanos Paschalis[1], and Ryo Taniuchi[1]
[1]University of York, UK

The structure of neutron-rich Ca isotopes has attracted interest from both experimental and theoretical side for more than a decade. With 20 protons (Z=20) forming a closed proton shell, the structure evolution in Ca isotopes is dominated by the neutrons. In the neutron-rich side, signatures of new magic numbers or sub-shell closures have been found at N=32 and 34 [1,2], and interpreted as a consequence of the absence of a tensor attraction between valence protons and neutrons. Experimental evidence for these sub-shell closures were presented by the measurements of the E(2+1) [2], the atomic mass [1,3] and the cross sections in direct reactions [4,5]. Transition probabilities between low-lying excited states would further our understanding of the microscopic forces that drive the shell evolution in this region. We therefore performed an experiment to study the transition probabilities in neutron-rich Ca isotopes by lifetime measurements at the RIBF facility of the RIKEN Nishina Center.

Excited states of 53Ca were populated by multi-nucleon removal reactions of a Sc secondary beam on C and CH2 targets. The HiCARI (High-resolution Cluster Array at RIBF) array was used to perform in-beam gamma-ray spectroscopy measurements and excited-states lifetimes have been extracted through line-shape analysis (taking advantage of the high-resolution of this array). In this contribution, first experimental results will be presented and compared with the latest theoretical calculations in the region.

[1] F. Wienholtz et al., Nature, 498, 346, (2013).
[2] D. Steppenbeck et al., Nature, 502, 207, (2013).
[3] S. Michimasa et al., Phys. Rev. Lett. 121, 022506 (2018).
[4] S. Chen et al., Phys. Rev. Lett. 123, 142501 (2019).
[5] M. Enciu et al., Phys. Rev. Lett. 129,262501 (2022).

High-Spin Gamma-Ray Spectroscopy at the Proton Drip Line: The Study of 131Eu

Conor Sullivan[1], David Joss[1], and Holly Tann[1]
[1]University of Liverpool, UK

In the mass-130 region, a host to some of the most deformed nuclei, phenomena such as shape coexistence, superdeformation, and isomerism challenge our understanding of nuclear behavior. At the proton drip line, a frontier of nuclear stability, nuclei become unbound to direct proton emission. While spherical proton emitters are well-understood through the WKB tunnelling approach, describing proton emitters with significant quadrupole deformation (β_2) is more complex. 131Eu, with one of the largest predicted ground-state deformations (β_2=0.36) in this region, exemplifies this complexity. Contemporary theoretical approaches have yielded precise calculations of experimental observables for 131Eu, such as half-lives, branching ratios, and even decay schemes of rotational bands.

The Liverpool group studied 131Eu at the University of Jyvaskyla using recoil-decay spectroscopy. In addition to measuring those fundamental observables used in comparison to theoretical models, the fine-structure proton decay of this nucleus was measured to an unprecedented precision, resulting in the first observation of the 2+ → 0+ transition in the 130Sm daughter nucleus. Finally, we showcase the first excited states measured for 131Eu. This was achieved through the effective utilization of proton decay tagging, which allowed clear separation of the signals of 131Eu - despite its low production cross-section - from the dominant gamma-ray emissions resulting from the decay of other nuclides.

Among numerous gamma rays, the yrast rotational band for 131Eu was identified and characterized as an $h_{11/2}$ [532]5/2- orbital by comparison with cranked shell model calculations and systematic comparison. However, limited gamma-gamma counting statistics precluded assigning other observed gamma rays to any band, leaving open questions about the observed band's absolute excitation energy, the potential isomerism of its bandhead, and the reconciliation of observed excited states with theoretical predictions.

Octupole correlations in neutron deficient plutonium isotopes

Hamid Ayatollahzadeh[1]
[1]University of the West of Scotland, UK

The extent of the well-established region of octupole correlations in the light-actinide region has recently been brought into question by new theoretical calculations. The new calculations suggest that the region extends into the neutron deficient plutonium (Z=94) and curium (Z=96) nuclei, and to even higher values of Z. In order to test these new predictions, an experiment has been performed using the AGATA spectrometer at the Legnaro National Laboratory to study the onset of octupole correlations in previously unstudied neutron-deficient plutonium (Z=94) isotopes. The primary goal of the experiment was to identify excited states in the isotopes Pu-232 and Pu-234, through the technique of gamma-ray spectroscopy, for which there are presently none known. Using multi-nucleon transfer reactions, the cross sections for these reaction channels, taking prompt fission into consideration, were predicted to be 0.4 (Pu-232) and 0.7 mb (Pu-234). The nuclei of interest were populated using a beam of Sn-112 at an energy of 808 MeV, delivered by the Tandem-XTU and ALPI accelerators, incident on a thin U-238 target. The AGATA gamma-ray spectrometer, in conjunction with the DANTE charged-particle detector array and the PRISMA mass spectrometer were used to select the populated nuclei of interest. The identification of low-lying negative-parity states and E1 transitions in the level schemes of the nuclei of interest would be indicative of octupole correlations. Analysis is currently ongoing. Preliminary results will be presented.

Electromagnetic moments of ground and excited states calculated in nearly spherical and well-deformed odd nuclei

Jacek Dobaczewski[1,2], Paolo Sassarini[1], Karim Bennaceur[3], Gauthier Danneaux[4], Anu Nagpal[1], and Herlik Wibowo[1]
[1]School of Physics, Engineering and Technology, University of York, UK, [2]Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Poland, [3]Univ Lyon, Université Claude Bernard Lyon 1, France, [4]Department of Physics, University of Jyväskylä, Finland

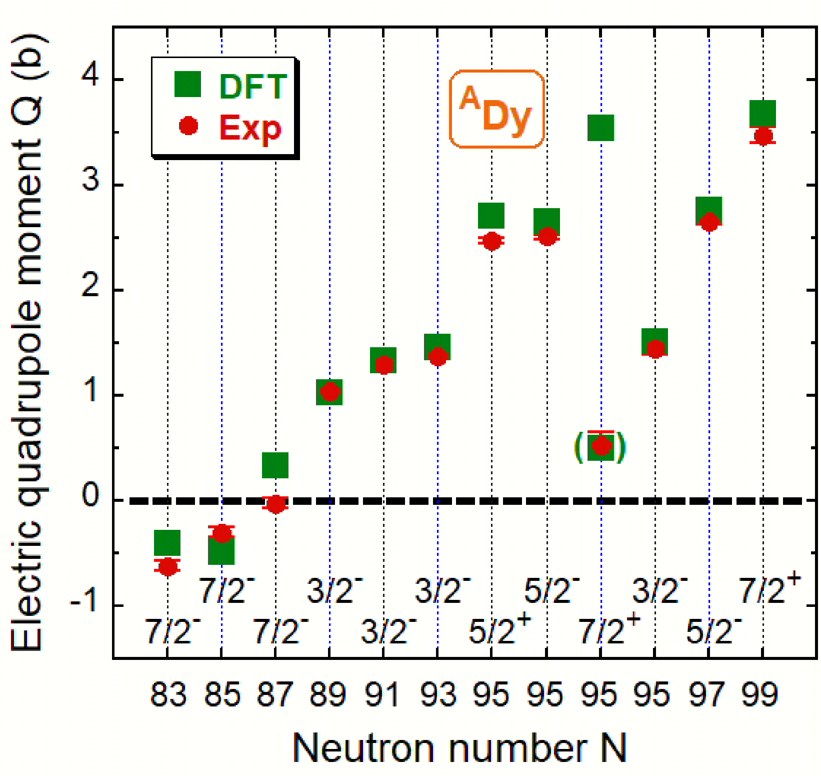
Nuclear electromagnetic moments provide essential information in our understanding of nuclear structure. Observables such as electric quadrupole moments are highly sensitive to collective nuclear phenomena, whereas magnetic dipole moments offer sensitive probes to test our description of microscopic properties such as those of valence nucleons. Although great progress was achieved in the description of electromagnetic properties of light nuclei and experimental trends in certain isotopic chains, a unified and consistent description across the Segré chart of nuclear electromagnetic properties remains an open challenge for nuclear theory.

In our nuclear-DFT methodology [1,2], we align the total angular momenta of odd nuclei along the intrinsic axial-symmetry axis with broken spherical and time-reversal symmetries. We fully account for the self-consistent charge, spin, and current polarizations, in particular through the inclusion of the crucial time-odd mean-field components of the functional. Spectroscopic moments are then determined for symmetry-restored wave functions without using effective charges or effective g-factors and compared with available experimental data.

In the present contribution, I will present the results of calculations performed for the ground and excited states of odd near doubly magic nuclei and for open-shell odd-N isotopes of even-Z nuclei between Gd and Os. The excited states were determined using the tagging technique that allows us to find in each nucleus self-consistent solutions for 22 deformed quasiparticle states blocked in the 82<{N}<126 major shell. Those states can then be followed through the chains of isotopes across the shell and the neutron numbers where they approach ground states can be identified.

The figure shows the calculated spectroscopic electric quadrupole moments in dysprosium isotopes compared with the available experimental data [3]. We used the standard UNEDF1 Skyrme functional with no parameters (re)adjusted here. For 161Dy, the parentheses indicate the value obtained for the 7/2+ member of the rotational band based on the 5/2+ [642]5/2 bandhead.

[1] P.L. Sassarini et al., J. Phys G 49 (2022) 11LT01
[2] J. Bonnard et al., Phys. Lett. B 843 (2023) 138014
[3] N.J. Stone, At. Data Nucl. Data Tables 111-112 (2016) 1



Parallel Session III: Session H

In-source Laser Spectroscopy Studies of Neutron-rich Thallium at IDS/ RILIS-ISOLDE

Zixuan Yue[1]
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Laser spectroscopy is one of the most powerful tools for studying ground and isomeric state nuclear properties. By observing small changes in atomic transitions, we can deduce the nuclear spin, electromagnetic moments, and changes in mean-square charge radii across long chains of isotopes. This allows us to study how the shapes and the configurations of the nuclei vary along the chain and hence to test our models that attempt to describe how nuclear structures evolve across the chart.

In this contribution, I will present the results from hyperfine structure and isotope shift studies of neutron-rich 207-209Tl performed at the ISOLDE Decay Station (IDS), combined with the application of the Laser Ion Source and Trap (LIST) to suppress the isobaric contamination typical to this mass region. Therefore, the changes in the mean-square charge radii and magnetic dipole moments were extracted. The results display a kink [1] in the mean-square charge radii along the Tl isotopic chain when crossing the N=126 shell closure, which is the same phenomenon observed from other elements around this region [2, 3, 4]. The magnetic dipole moments for 1/2+ thallium ground states have a large jump at N=126. Theoretical calculations including particle-vibrational coupling with the self-consistent theory of finite Fermi systems based on energy density functional are used to model the data [5].

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Shape studies in neutron-rich cerium isotopes

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Octupole correlations are the result of the long-range octupole-octupole interaction between nucleons occupying pairs of orbitals which differ by ΔL = ΔJ = 3. This interaction gives rise to an asymmetric pear-shaped form that can be manifested by the appearance of low-lying negative-parity states [1]. The presence of octupole deformation has only been observed in localized regions of the nuclear chart and more specifically in the mass region around Z=88, N=134 [2,3,4,5] with the next promising region to be around Z=56, N=88 [6]. Isotopes with their Fermi surfaces close to these particle numbers are predicted to possess an octupole collectivity [7] which can be characterized by enhanced B(E3) values, as observed in recent experiments on 144,146Ba [8,9]. The neighbouring cerium isotopes with 146 ≤ A ≤ 152 are also considered to be excellent candidates to study this kind of deformation [10,11]. Studying the electromagnetic properties of excited states is essential in our understanding of the magnitude and mode of deformation, whether it is static or vibrational in nature [3].

A β-decay experiment has been performed at the radioactive ion beam facility ISAC-I at the TRIUMF particle accelerator center in Vancouver, Canada, aiming to look for low-lying negative-parity states in neutron-rich cerium isotopes. Beams of Cs were initially produced from a UCx target and implanted on an aluminized mylar moving tape collector. The population of states in 146,148,150,152Ce was possible through the decay of the grand-daughter La isotopes. Spectroscopy measurements have been performed using the GRIFFIN spectrometer, which consists of an array of 16 Compton-suppressed HPGe clover detectors for the detection of gamma-rays, 5 scintillators for conversion electron spectroscopy and 8 LaBr3 detectors to allow for fast-timing measurements of excited-state lifetimes.

In this talk, preliminary results of this experimental campaign will be presented including the identification of new excited levels in 150Ce. Additionally, from angular distribution measurements, the assignment of spin and parity of the proposed low-lying 1- and 3- states in 146,148Ce [12] will be discussed.

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Decay spectroscopy of isomerically pure 178Aug,m at the ISOLDE Decay Station, CERN

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In the region around the Z = 82 shell closure and the N = 104 midshell, competition between spherical and deformed configurations leads to the phenomenon of shape coexistence due to the delicate balance between single-particle and collective effects [1,2]. Previous work (e.g. [3]) has sought to understand the properties of isotopes of platinum (Z=78) and gold (Z=79) to establish the extent to which this competition dictates their structures. In a recent study [4], the mean squared charge radii for a long chain of neutron-deficient gold isotopes were measured using in-source laser spectroscopy. This revealed a pattern in ground-state deformation that is so far unique in the nuclear chart. During this study, the deformed ground state of 178Au, 178Aug, was found to coexist with a strongly deformed isomer, 178Aum [5].

As part of a long-term programme investigating gold isotopes, a decay spectroscopy experiment was performed at ISOLDE, CERN in August 2021 [6]. By exploiting the unusually broad hyperfine structure, laser-ionised isomerically pure beams of 178Aug or 178Aum were produced using RILIS. This allowed for detailed α- and β+/EC-decay studies to be performed. In this contribution, I will summarise the experimental techniques used to collect these data and present the results obtained from the decay of 178Aug,m. These include separate α- and β+/EC-decay schemes for each decaying state of 178Au which give insight into the structure of 174Ir and 178Pt, respectively.

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Onset of deformation in the neutron-rich krypton isotopes with the ISOLDE Solenoidal Spectrometer

Annie Dolan[1]
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In the A = 100 region, a dramatic shape change is observed at N = 60 for the Zr [1-3] and Sr [4-7] isotopes (Z = 40 and 38, respectively). This is in contrast to the Kr (Z = 36) isotopes where the 2_1+ energies and the B(E2; 2_1+ → 0_1+) values vary smoothly as N approaches 60 [8-10]. Previous studies in this region have shown a smooth onset of deformation in the neutron-rich Kr isotopes at N = 60 [9, 10], and evidence of a new oblate structure coexisting with the prolate ground state [11].

The νg7/2 orbital is filled in the ground states of the Kr isotopes around N = 59 and is thought to lower the energy of the πg9/2 orbital, which helps to drive deformation in this region. Accurately predicting ground-state spins and parities of odd-mass isotopes in this region is challenging due to the large valence space, and lack of ESPE data and accurate shell- model interactions. The single-particle energy differences and spectroscopic factors extracted from neutron-adding transfer reactions will provide a more complete experimental picture of the underlying single-particle configurations, allowing for comparison to modern shell-model calculations [12] that try to describe the onset of deformation around A = 100.

The neutron single-particle properties and their role in the onset of deformation towards N = 60 in the neutron-rich 93Kr isotope has been studied via the one-neutron transfer reaction 92Kr(d,p), performed in inverse kinematics at an energy of 7.35 MeV/u using the ISOLDE Solenoidal Spectrometer at ISOLDE, CERN. Spectroscopic factors of the low-lying states of 93Kr have been determined. Results obtained from the October 2022 experiment will be presented.

Decays of K isomers in the extremely deformed neutron-deficient A = 130 region

Andy Briscoe[1]
[1]University of Liverpool, UK

Nuclear isomers offer a unique experimental probe of the nuclear structure factors that govern the decay properties of nuclei very far from stability. In the neutron-deficient A = 130 region at large prolate deformations, the extruding high-Ω component of the g9/2 orbital traverses the N = 50 shell gap. The presence of such orbitals at the Fermi surface gives rise to isomeric states that are hindered by many order of magnitude due to the necessary reorientation of the angular momentum vector. Complex detector systems coupled to the state-of-the-art vacuum-mode recoil separator MARA, have allowed for the study of the decays of several novel isomeric states produced in fusion-evaporation reactions. In this talk, recent recent results from experiments performed at the University of Jyväskylä concerned with the spectroscopy of 122,125,126La, 127,128,129Pr and 129Nd will be presented.

Investigating nucleon-nucleon correlations through QFS reactions

Ryo Taniuchi[1], Luke Rose[1], Stefanos Paschalis[1], and Marina Petri[1]
[1]University of York, UK

Several properties of atomic nuclei are known to be sensitive to the neutron-to-proton (isospin) asymmetry. In particular, the evolution of the single-particle strength as a function of isospin has been the subject of experimental and theoretical debate.

Quasi-free scattering (QFS) reaction is an established method to probe the structure of atomic nuclei. This reaction in inverse kinematics using radioactive-ion beams at relativistic energies has been successfully employed as an effective tool to study very exotic nuclei with high luminosity. Recent studies [1, 2] reported on the evolution of the proton single-particle strength as a function of isospin asymmetry using (p,2p) QFS reactions along the Oxygen isotopic chain and found a weak or no dependence. The reduction of the single-particle strength has been attributed to nucleon-nucleon correlations and a recent phenomenological study [3] has quantified the long and short-range part of these correlations and their dependency on isospin. The QFS result is at variance with nucleon-removal reactions with heavy targets [4] where they report a single-particle strength is strongly correlated with isospin.

To shed light on this puzzle, we performed a systematic study of (p,2p) and (p,pn) cross-sections along the calcium isotopic chain (from 39Ca to 50Ca) at 500 MeV/nucleon using proton and carbon targets. The experiment was performed with the large acceptance spectrometer GLAD with the R3B setup at GSI-FAIR. The difference in reactions with the targets and the identification of reactions with recoil protons are investigated. The results of the analysis and comparison to the theoretical calculations will be discussed in this contribution.

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Plenary Session: Thursday I

The 2024 NuPECC Long Range Plan

Eberhard Widmann[1]
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NuPECC, the Nuclear Physics European Collaboration Committee, publishes every 6-7 years a Long Range Plan. This document is prepared in a bottom-up process from inputs of the community and presents the view of nuclear physicists in Europe about the priorities and opportunities of the field in the next decade. The work on the next edition of Long Range Plans has started in 2022 and is close to being concluded. The talk will give an overview on the science topics as well as other subjects that are addressed in the draft.

2023 IOP APP Early Career Prize winner's talk

Patrick Knights[1]
[1]University of Birmingham, UK

The precise nature of dark matter, despite making up the majority of matter in the universe, remains one of the great unanswered questions in modern physics. The NEWS-G collaboration is searching for light dark matter candidates using a novel gaseous detector concept, the spherical proportional counter. Access to the mass range from 0.05 to 10 GeV is enabled by the combination of low energy threshold, light gaseous targets (e.g. H, He, Ne), and highly radio-pure detector construction. Recent advancements in the detector instrumentation and understanding will be presented, along with first results from the current NEWS-G detector, S140 - constructed at LSM (France) using 4N copper with 500 µm electroplated inner layer. The detector has since been installed and is taking data in SNOLAB (Canada). The potential to achieve sensitivity reaching the neutrino floor in light dark matter searches with a next generation, fully electroformed detector, DarkSPHERE, situated in the Boulby Underground Laboratory, will also be presented. Current efforts underway towards DarkSPHERE will be discussed, for example, establishing a high-purity copper electroforming facility in Boulby.

The future of Fermilab

Bonnie Fleming[1]
[1]Fermi National Laboratory, USA

Abstract unavailable.

CERN: The Future Programme

Mike Lamont[1]
[1]CERN, Switzerland

CERN, the European Laboratory for Particle Physics, presently has wide ranging physics program serving a community of around 12000 users from around the world. Besides, its flagship machine, the LHC, it also fully exploits the potential of the injector complex through a number of well-solicited facilities such ISOLDE (nuclear physics and radioisotopes), n TOF (neutron-induced reactions) and AD-ELENA (antimatter).

CERN's future scientific programme rests on three pillars: (1) full exploitation of the LHC, including its high-luminosity upgrade, HL-LHC, currently under preparation; (2) a compelling and diverse scientific programme at the injectors, complementary to the collider; (3) preparations for future projects, with vigorous accelerator, detector and computing R&D programmes and design studies for future colliders.

The main foundation of CERN's longer term future is a reinforced accelerator R&D programme aimed at developing the technologies needed for a Future Circular Collider (FCC), as well as alternative options. An FCC Feasibility Study is currently under way with the final report to be submitted in 2025.

CERN will continue to leverage its position as nexus of an impressive collaborative ecosystem, with sustainability and societal impact, outreach and education as key components of its overall mission.

Plenary Session: Thursday II

The future programme at JPARC

Takashi Kobayashi[1]

[1]High Energy Accelerator Research Organisation, Japan

Abstract unavailable.

The future programme at BNL

Joanne Hewett[1]

[1]BNL, USA

Abstract unavailable.

The ECFA DRD Programme

Chris Parkes[1]
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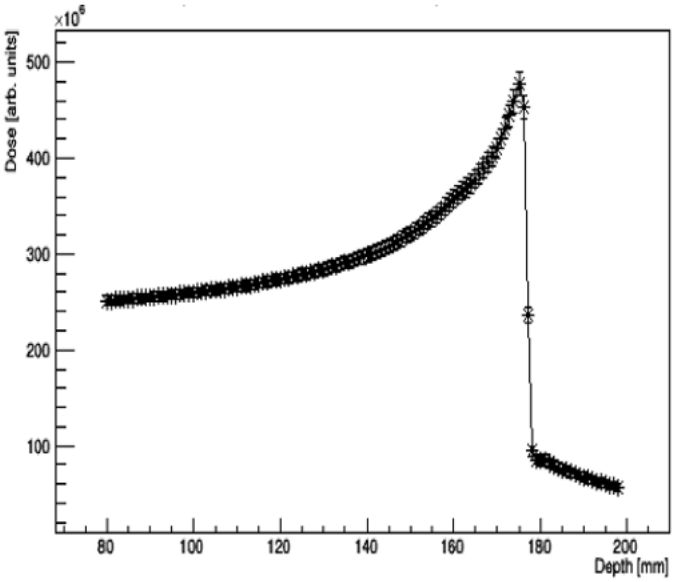
An international organisation for strategic R&D activities is being setup, under the auspices of ECFA and hosted by CERN, to serve the needs of the future experimental programmes in particle, particle astro-physics and related nuclear physics areas. The necessary national infrastructure, training and industrial support will form part of this activity. The UK is fully engaged in this process and is organising its activities in alignment to the international DRD collaboration and major international partners. The current status and UK plans will be presented.

Poster Session 1

P1.1. A Study on Dose Monitoring in Carbon Therapy Using Secondary Protons

Shaikah Alsubayae[1]
[1]The University of Liverpool, UK

Attaining precise radiotherapy through carbon therapy relies on accurately monitoring the distribution of radiation doses within a patient's body, which is crucial for targeted tumor treatment while preserving healthy tissues. In our investigation, Monte Carlo (MC) simulations were employed to monitor dose of carbon ion using a 3.720 GeV carbon ion beam. Initially, Geant4 simulations identified various secondary particles (protons, gamma rays, alpha particles, neutrons, and tritons) generated during interactions between carbon ions and water. We explored the relationship between the carbon ion beam and these particles. Interaction Vertex Imaging (IVI) proved to be valuable in monitoring dose distribution, particularly with protons, by revealing the locations and abundances of secondary particles. IVI utilizes charged particles from ion fragmentation to reconstruct particle trajectories, providing range information from their origin, known as the vertex. Our simulations demonstrated a strong correlation between certain secondary particles and the range of carbon ions. We observed an increase in generated protons as the target depth increased due to the expanding inelastic cross-section with decreasing energy. However, our results revealed substantial discrepancies between the reconstructed path of the proton and the primary beam, especially noticeable at lower energy levels, attributed to scattering effects induced by multiple Coulomb interactions. To analyze trajectories as straight lines, we utilized Si detector positions and developed a beam back-projection algorithm to reconstruct vertices, highlighting a correlation between reconstructed and actual positions. The significance of our research lies in the utilization of thin silicon detectors for detecting both the primary ion beam and secondary particles.we utilize thin silicon detectors to detect both the primary ion beam and secondary particles



P1.2. A Time-Dependent Wave-Packet Approach to the 12C + 12C Reaction Using DC-TDHF Potentials.

Grant Close[1], Alexis Diaz-Torres[1], and Paul Stevenson[1]
[1]University of Surrey, UK

The 12C + 12C reaction plays an important role in the fate of massive as it can determine the path in stellar evolution. The behaviour of this reaction at astrophysical energies is still actively debated. To reproduce the resonant structure seen in the astrophysical S-factor of the 12C +12C reaction we focus on the novel combination of tried and tested techniques in the field, the Time-Dependent Wave-Packet (TDWP) and Density Constrained Time-Dependent Hartree-Fock (DC-TDHF) method. The former controls the dynamics of the reaction and the latter describes the inner mechanisms of the nucleus in the form of extracted ion-ion potentials. This methodology aims to take advantage of microscopic description of the nucleon-nucleon interactions involved in the collision of the deformed nuclei. The implementation of the TDWP method includes phenomena that DC-TDHF can't reproduce, such as quantum tunnelling.

We use a 5 dimensional collective coordinate system to express the position and orientation of the individual nuclei. As the orientation of the incoming nuclei plays an important role in fusion. Theoretical studies have shown that the Equatorial-Equatorial orientation of the reaction facilitates fusion while the Pole-Pole orientation is the configuration in which the nuclei undergo fusion. This is confirmed by the resonance structure that has been experimentally observed in the astrophysical S-factor. From the ion-ion potentials extracted from the DC-TDHF simulations, it has be shown that there are alternative configurations that can also undergo fusion. Results are given in the form of the astrophysical S-factor and aims produce resonance structure seen in experimental observations.

P1.3. An overview of the Miniball spectrometer at ISOLDE

Frank Browne[1]
[1]University of Manchester, UK, [2]CERN, Geneva, Switzerland

Over the last two years, a revamped Miniball has been conducting physics experiments across the nuclear chart. Comprising eight assemblies of three electronically-segmented high-purity germanium crystals, the spectrometer measures gamma-rays emitted from fast-moving nuclei following various nuclear reactions. As well as being refurbished with new endcaps, cryostats, and AGATA-like pre-amplifiers, a new digital data acquisition for Miniball has been successfully installed to allow for a triggerless readout and to easily integrate ancillary detectors.

This poster shall provide an overview of the Miniball spectrometer, its ancillary detectors, and data acquisition at ISOLDE, CERN. The experimental setup, detector performances, and selected preliminary results shall be shown.

P1.4. Analysis of particle/nuclei cross sections within neutrino generator final state interaction models

Tom Peacock[1], and Patrick Stowell[1]
[1]University of Sheffield, UK

Neutrino event generators play a vital role in neutrino oscillation experiments, bridging the gap between the theory of neutrino interactions and the experimental data. Interactions with atomic nuclei, especially secondary interactions of hadrons within the nuclei after leaving the primary interaction vertex (deemed the final state interaction cascade), need to be modelled to high precision in generators. This is in order to fully understand the detectable hadronic component of an event and successfully recreate the primary interaction of the neutrino.

In this presentation, recent analyses of predicted nuclei/particle interaction cross-sections from the event generators NEUT and NuWro for different final state interaction models will be explored. Predicted cross section data is then compared to real nuclei/particle cross sections to demonstrate how different implementation choices for the final state interaction cascade model can modify the outgoing particle predictions.

P1.5. Assembly and QA/QC of the readout electronics for the DarkSide-20k veto photodetector modules

Ioannis Manthos[2], Konstantinos Nikolopoulos[1,2], and Giovanni Rogers[1]
[1]School of Physics and Astronomy, University of Birmingham, UK, [2]Institute for Experimental Physics, University of Hamburg, Germany

Darkside-20k is the next-generation detector of the Global Argon Dark Matter Collaboration, currently under construction at the Gran Sasso National Laboratory (LNGS). The main aim of this detector is to search for the interaction of Dark Matter particles with the liquid argon (LAr) target, with sensitivity down to the neutrino fog. Towards this goal, the detector utilises novel technologies including underground Ar depleted in the radioactive 39Ar and novel cryogenic Silicon Photomultiplier (SiPM) photodetectors. These bespoke SiPM structures, assembled into photodetector modules, can meet the required resolution, signal-to-noise and strict radiopurity requirements of DarkSide-20k and will instrument both the TPC and veto systems. In this contribution the status of the UK's production of the photodetector modules for DarkSide-20k's veto detectors will be outlined. With a focus on the assembly of front-end boards at The University of Birmingham, which is now well advanced. Alongside this QA/QC procedures and current results of testing will be presented.

P1.6. Beam Studies using a Cherenkov Diffraction based Beam Position Monitor in the AWAKE common beamline

Bethany Spear[1], Philip Burrows[1], Collette Pakuza[2], Manfred Wendt[2], Stefano Mazzoni[2], and Thibaut Lefevre[2]
[1]John Adams Institute, University of Oxford, UK, [2]CERN, Geneva, Switzerland

A beam position monitor based on Cherenkov diffraction radiation (ChDR) is being investigated as a way to disentangle the signals generated by the electromagnetic fields of a short-pulse electron bunch from a long proton bunch co-propagating in the AWAKE plasma acceleration experiment at CERN. These ChDR BPMs have undergone renewed testing under a variety of beam conditions with proton and electron bunches in the AWAKE common beamline, at 3 different frequency ranges between 20-110 GHz to quantify the effectiveness of discriminating the electron beam position with and without proton bunches present.

P1.7. Calculation of Neutron Production in (alpha, n) Reactions with SOURCES4 and ONYSC

Piotr Krawczun[1]
[1]University of Sheffield, UK

Neutron yields and spectra from alpha radiation need to be calculated to account for backgrounds in undergrounds experiments. We present in this work the results obtained with the modified SOURCES4 code. This program was used with updated database files and some extensions of functionality. The changes involve increasing the size of arrays which became necessary as the database files became larger. An option of working with multiple input files was added so the code can now calculate neutron yields for a number of materials in one running job. Since there are multiple datasets per certain nuclides in database files, the input file format was modified in order to be able to select a specific dataset. The input files written in the new format will still work correctly if used on older versions of SOURCES4 where this update was not implemented. A new code was written, called ONYSC, which allows the calculation of yields for a large number of energies so that a continuous yield vs energy plot can be created which is not feasible with SOURCES4. The new code can potentially be developed further to also calculate the spectra and this is possibly going to be implemented in the future.

The two codes are using the same libraries of cross-sections and branching ratios, and the same equations, hence, returning the same neutron yields. The differences are in implementation where the former was written in Fortran and the latter in C++.

P1.8. Commissioning the Isolde Solenoidal Spectrometer with a measurement of the (d,p)23Ne reaction

Mr Ben Jones[1]
[1]University of Liverpool, UK

The ISOLDE Solenoidal Spectrometer (ISS) is a large bore magnetic solenoid used as a particle spectrometer. The device allows for the study of radioactive nuclei by direct reactions in inverse kinematics. Ejectiles from reactions are transported in helical orbits back the magnetic axis. The ISS silicon array placed along the magnetic axis makes position and energy measurements of the ejectiles. Using these measurements, the excitation energy spectrum and differential cross sections can be obtained. This technique overcomes the problems associated with kinematic compression encountered in conventional detector setups when working in inverse kinematics.

ISS has already successfully performed several experiments with radioactive ion beams of a large mass range. In order to benchmark the performance of the detector system, a (d,p)23Ne commissioning experiment was also carried out. I intend to show the results from this experiment by comparing the measured differential cross sections with previous work done in normal kinematics. I also intend to outline the corrections we apply to obtain the correct excitation energy spectrum across the silicon array.

P1.9. Elucidating Strangeness with electromagnetic probes

Asli Acar[1]
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The Very Strange experiment is a Jefferson lab project studying the photoproduction mechanisms of doubly and triply strange baryons utilising the CLAS12 detector. Isgur and Capstick [1] predicted a total of 44 cascade states below 2.5 GeV. Currently, there are only six Ξ states that have at least three-star ratings in the PDG [2], with the production mechanism of these states still remaining mostly elusive. The goal for the Very Strange project is to bridge this gap in our excited hyperon spectroscopy knowledge by studying the quasi-real photoproduction of cascades, with the possibility of extracting the quantum numbers of the new and missing Ξ states. The new data would make it possible to measure for the first time the beam polarisation transfer and induced polarisation of the Ξ - baryon as a kinematical variable function. Additionally, cascade studies look promising as a tool to differentiate genuine quark states from hadronic molecules due to the symmetry from two heavy s-quarks. This work focuses on the development of realistic simulations of reactions involving the photoproduction of very strange baryons that will guide the high-level analysis of the collected CLAS12 data. Extensive research will be conducted on the production mechanisms and decays. A key component of enabling the determination of quasi-real photoproduction reactions is the Forward Tagger. As high precision calibration is absolutely necessary to measure these rare cascades, efforts have been undertaken to produce an electron energy correction for the Forward Tagger to sufficiently suppress the background.

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P1.10. Examining the north-west limit of octupole correlations in the light-actinide region using alpha decay spectroscopy

Ben Hogg[1]
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Octupole collectivity describes the behaviour of atomic nuclei which have adopted a reflection-asymmetric shape, said to resemble the shape of a pear. Theoretical and experimental studies of octupole correlations in nuclei have been reviewed in Refs. [1, 2]. The microscopic conditions for octupole correlations to develop are favourable amongst the light-actinide nuclei, leading to a region of octupole-deformed nuclei, centred around the nucleus Ra-224. There is a wealth of evidence for experimentally accessible octupole-deformed nuclei in this region, particularly in the radon (Z=86), radium (Z=88), thorium (Z=90) and uranium (Z=92) nuclei, however recent theoretical calculations in Ref. [3] indicate that the region may extend to higher values of Z than previously thought. There is, therefore, significant motivation to study nuclei with Z>92 to determine the extent of octupole correlations in the light-actinide region. For this reason, an experiment has been carried out at the Accelerator Laboratory at the University of Jyväskylä. The experiment used a beam of Ne-22 with a maximum intensity of 260 pnA on thin Pb-208 and Bi-209 targets to produce U-223, Np-225 and Np-227 nuclei. Recoiling evaporation residues were transported by the recoil spectrometer RITU and were implanted into a double-sided silicon strip detector (DSSD) behind the RITU focal plane. The subsequent alpha decays of the implanted evaporation residues were studied using the DSSD as well as a PIN-diode box and an array of HPGe detectors. The data collected will allow alpha-gamma coincidence spectroscopy to be performed following the decays of the implanted uranium and neptunium nuclei. This will help to assign the ground-state spins and parities to these nuclei which can be compared to calculations. The data will allow assignment of single-particle configurations and possible identification of distinctive parity-doublet states, indicative of octupole deformed odd mass nuclei. The analysis is ongoing, and the preliminary results will be presented.

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P1.11. Experimental Investigation of High-K Isomer Decays in Neutron-Rich 183,184Hf isotopes Using the KISS Facility

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A prolate-to-oblate shape/phase transition is predicted in neutron-rich A ~ 180–190 nuclei which is expected to result in prolate high-K isomers decaying to oblate low-K states.1,2) However, the production of heavy neutron-rich nuclei beyond the limits of the current nuclear chart proves to be challenging, compounded by their refractory chemical properties especially in the hafnium (Z=72) to platinum (Z=78) range, constraining possibilities for comprehensive studies.

Recent advancements in experimental techniques have led to the discovery of long-lived (T1/2→ 1 s) isomers in isotopes such as 183,184Hf, and 186,187Ta using projectile-fragmentation reactions at the GSI experimental storage ring (ESR).3) Moreover, details of the structure of the tantalum isomers have recently been obtained with multi-nucleon transfer (MNT) reactions and electron-γ spectroscopy at KISS.4,5)

In order to further examine the decay from the high-K isomers in 183Hf and 184Hf an experiment was conducted with the KISS facility using a 136Xe beam incident on a natural tungsten target. Recoiling reaction products were stopped in a high-pressure argon gas cell, followed by laser ionization and mass separation. Data analysis is ongoing and preliminary results indicate the successful production of neutron-rich 183,184Hf+ ions. Further analysis will investigate the decay from the isomeric structures which could provide valuable insights into the nuclear properties of this region The presentation will give a progress report on the state of the analysis.

[1] P.M. Walker and G.D. Dracoulis, Nature 399 (1999) 35; Hyp. Int. 135 (2001) 83.
[2] H.L. Liu, F.R. Xu, P.M. Walker and C.A. Bertulani, Phys. Rev. C 83 (2011) 067303.
[3] M.W. Reed et al., Phys. Rev. Lett. 105 (2010) 172501; Phys. Rev. C 86 (2012) 054321.
[4] P.M. Walker et al., Phys. Rev. Lett. 125 (2020) 192505.
[5] Y.X. Watanabe et al., Phys. Rev. C 104 (2021) 024330.

P1.12. Exploring Proton Structure: Gluon TMDs at ATLAS

Alina Hagan[1]
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In an attempt to improve an understanding of proton structure, we explore the extension of conventional collinear Parton Distribution Functions (PDFs) to encompass the transverse dynamics of gluons in the proton. This is of particular relevance at the LHC, where gluon interactions dominate the hard scattering processes. After an overview of current theory and the landscape of Transverse Momentum Dependent (TMD) PDF measurements, the methods of performing such measurements at the ATLAS detector is presented. Using novel techniques to overcome backgrounds from non-prompt and double-parton-scattering contributions, a measurement of the unpolarised gluon TMD in the proton, f_1^g, is obtained.

P1.13. Exploring unphysical quadrupole triaxiality in 200,202Hg using Coulomb Excitation

Gregory Willmott[1]
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Presently the quadrupole triaxiality parameter, γ, for 200,202Hg based on theory and previous experimental data has unphysical results for both nuclei. These isotopes currently have values for γ beyond the oblate limit of cos(3γ) = -1 which are not accounted for by uncertainty. This, in conjunction with the importance of nearby nucleus 199Hg in nuclear structure for determining limits on a permanent atomic electric dipole moment, was the motivation for experimental work carried out in December 2023 at Argonne National Laboratory.

For this Coulomb excitation experiment, beams of 200,202Hg were impinged on natural Ti and 120Sn targets. The chosen beam energy of 777 MeV corresponds to the 'safe' Coulomb excitation limit. Within the ATLAS facility, Gammasphere in conjunction with a S3 DSSD were utilised for coincident γ-ray and ion detection respectively. Simulations using the CERN toolkit Geant4 are forming part of the analysis. Preliminary results of this experiment will be shown.

P1.14. First operation of an ACHINOS equipped Spherical Proportional Counter with individual anode read-out

Lex Millins[1,2]
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The multi-anode sensor ACHINOS has been transformative to the capabilities of the spherical proportional counter by enabling higher pressure operation and larger detectors. Another advantage is the additional event localisation capability brought by having several, generally eleven, anodes. To date, the anodes are typically read in one or two channels due to read-out hardware constraints. We present the first measurements with an ACHINOS with individual anode read-out. Previous implementations of ACHINOS will be discussed and how this led to the development of individual-

anode read-out. Experimental results with an individually read out ACHINOS, demonstrating significant energy resolution improvement will also be presented. Extensive simulation studies were performed to understand the origin of anode-by-anode response differences, including from the design of ACHINOS and construction imperfections, which will be presented, along with mitigation and calibration methods to overcome them. This development is transformative for many applications of the spherical proportional counter, from direct dark matter searches to fast neutron spectroscopy, and the advantages brought will be discussed.

P1.15. Investigating Charge Sharing Effect in HVCMOS Silicon Detectors during Carbon Ion Beam Therapy

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In the field of radiation therapy, carbon ion beams provide better dose conformity than traditional methods, which has great potential to improve the results of cancer treatment. The accurate characterization of the interaction between carbon ions and silicon detectors is crucial for optimizing treatment strategies. Using the Allpix2 simulation framework, this work focuses on the charge sharing effect in HVCMOS silicon detectors during carbon ion beam therapy simulations.
Detailed simulations have been conducted using the Allpix2 framework to model a HVCMOS silicon detector exposed to carbon ion beams. The flexible Allpix2 framework captures the complex physics of particle interactions with matter, offering a realistic simulation platform. To fully investigate the charge sharing phenomenon, different incident bias voltage values and angles were used in the simulations.

Under different conditions, preliminary results show significant charge sharing effects in the pixel silicon detector. The impact of charge sharing on spatial resolution and energy deposition within the detector is explained by an analysis of the gathered charge distribution patterns. These results advance our knowledge of the detector's reaction to carbon ion beams and help optimise detector design for higher accuracy in clinical settings.

By addressing a crucial component of silicon detector performance during carbon ion beam therapy, this work clarifies the complex mechanisms of charge sharing. The knowledge gathered from these simulations could improve particle therapy's accuracy and dependability, which would ultimately benefit patients. Our research supports developments in state-of-the-art cancer treatment modalities by adding important knowledge to the field of medical physics.

P1.16. Light simulation optimisation for the DarkSide-20k detector

Andrzej Gawdzik[1]
[1]University of Manchester, UK

The DarkSide-20k detector, featuring a 51 tonne dual-phase liquid argon time projection chamber, is designed for the direct identification of Weakly Interacting Massive Particles (WIMPs). Such searches require precise simulation and modelling of 128 nm photon generation, propagation, and detection for both background and signal events inside of the detector, ensuring a comprehensive replication of the detector's responses in S1, S2, and time— key variables for discriminating β/γ background. The poster presents the simulated light detection efficiency for the neutron veto, and methods to optimise the simulation to improve the accuracy and efficiency of the modelling process.

P1.17. Measurement of Nuclear Schiff Moment in 199Hg

Dylan White
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This talk will present preliminary data and theoretical background from a recent experiment performed at HIGS facility at the Triangle Universities Nuclear Laboratory at Duke University. The aim of the experiment was to investigate the low-energy dipole response of 200Hg up to the neutron-evaporation threshold which made it possible to measure the Pigmy Dipole Resonance (PDR). The Schiff moment [1], associated with the creation of a permanent electric dipole moment in an odd-A atom, has been theorised [2,3] to be proportional to the inverse energy-weighted sum of the isoscalar dipole strength distribution of the neighbouring even-even nuclei. Therefore, a measurement of the PDR of 200Hg allows for a measurement of the Schiff moment of 199Hg. This nucleus was investigated, as it currently provides the lowest known upper limit for a permanent electric dipole moment [4].

[1] L. I. Schiff Physical Review, vol. 132, pp. 2194-2200, Dec. 1963.
[2] N. Auerbach and V. Zelevinsky Phys. Rev. C, vol. 86, p. 045501, Octo. 2012.
[3] N. Auerbach, C. Stoyanov, M. R. Anders, and S. Shlomo Phys. Rev. C, vol. 89, p, 014335, Jan. 2014
[4] B. Graner, Y. Chen, E. G. Lindahl, and B. R. Heckel Phys. Rev. Lett., vol. 119, P. 119901, Sept. 2017

P1.18. Measurement of the production cross section for the single top quark in association with a Z boson at the ATLAS detector

Alberto Plebani[1], and Sarah Williams[1]
[1]University of Cambridge, UK

My analysis focuses on the single top quark production in association with a Z boson (tZq). This process is one of the latest additions to the Standard Model, being observed only in 2019, due to its electroweak (EW) nature which makes it rare to observe. The tZq process can be obtained by either having a WW->Z vertex, which can probe the EW coupling of the vector bosons, or by having the Z boson radiated by any quark, mainly the top. The latter is of particular interest because it allows to probe the EW coupling between the top and the Z boson. Furthermore, tZq is one of the backgrounds for the tHq production, which is the only process that allows to measure the sign of the Top-Higgs Yukawa coupling.

The process was observed with a measured cross section of 97fb, with a 15% uncertainty dominated by statistics (12%). In my work, carried out during my two theses, I firstly worked on increasing the signal acceptance, by improving the event selection, and then I focused on improving the control of the backgrounds. This was obtained by using Machine Learning techniques to improve the separation between the signal and the backgrounds, as well as doing data-driven estimation of specific background sources. The blind cross section, obtained by a Maximum Likelihood Estimator fit, has an uncertainty of 12%, which represents an expected 20% improvement with respect to the previous analysis, using the same dataset. In addition to this, I have performed the first measurement of the ratio between top and antitop cross sections in the tZq production, and we are also in the process of presenting the first differential measurement.

P1.19. Measurement of the |Vcb| element of the CKM matrix in ttbar decays with the ATLAS detector

Mohammed Ghani[1], and Paul Harrison[1]
[1]University of Warwick, UK

The |Vcb| element of the CKM matrix, a fundamental parameter of the standard model, describes the coupling strength of weak charged currents to charm-beauty quark pairs. Historically, |Vcb| has only been measured using either inclusive or exclusive B-meson decays, which occur at an energy scale much below that of the weak scale. Measurements made using these two techniques have been shown to disagree, with a tension of 2.4σ, which motivates the need for a new method of extracting |Vcb| that does not face the same limiting factors. This analysis attempts to make the first measurement of |Vcb| by studying the semileptonic decays of top-antitop pairs, which are mediated by on-mass shell W-bosons at the weak scale. Unlike existing |Vcb| measurements, this methodology can produce a value of |Vcb| which is not heavily impacted by theoretical calculation uncertainties, and could be sensitive to new physics contributions due to this presently unexplored energy scale. The method is, implicitly, a test of the weak decay paradigm for top decays, and is potentially sensitive to deviations from it.

P1.20. Neutron Beams at Birmingham: HF-ADNeF

Alex Brooks[1], Carl Wheldon[1], Tzanka Kokalova[1], Jack Bishop[1], Ben Phoenix[1], and Martin Freer[1]
[1]University of Birmingham, UK

The High-Flux Accelerator Driven Neutron Facility (HF-ADNeF) is the latest particle accelerator facility to be housed at the University of Birmingham and marks a significant point in the University's extensive history of accelerators [1]. Capable of achieving a nominal flux of up to 10^12 neutrons/cm^2/s [2], HF-ADNeF is currently one of the highest flux accelerator-driven neutron facilities in the world. This high flux is accomplished through the utilisation of a 30-50 mA 2.6 MeV proton beam producing neutrons via the 7Li(p,n)7Be reaction with a maximum energy of 0.9 MeV. With a diverse array of applications into areas such as materials research, medical physics and nuclear astrophysics [2], this state-of-the-art facility boasts the potential to further probe and evolve our understanding in a multitude of fields making it an exciting opportunity for the future of nuclear research. This poster will provide an overview of the operation of the facility and the physical processes which enable the high neutron flux, as well as highlighting a variety of the research topics which the facility enables.

[1] D. Parker and C. Wheldon, Nucl. Phys. News 28, 15, (2018), DOI: 10.1080/10619127.2018.1463021
[2] C. Wheldon, JINST 17 10, C10010 (2022), DOI: 10.1088/1748-0221/17/10/C10010

P1.21. OpenMC simulations of the UoB HF-ADNeF for Medical Isotope Production

Max Conroy[1], Tony Price[1], Martin Freer[1], Bethany Slingsby[2], and Robert Mills[2]
[1]University of Birmingham, Birmingham, UK, [2]National Nuclear Laboratory, Warrington, UK

The demand for medical radioisotopes in the UK is ever growing, yet the country lacks the capability to produce many of these domestically, instead depending on aging research reactors around the world. Resultantly, there is a critical need to investigate alternative isotopes and new methods of production. The High Flux Accelerator-Driven Neutron Facility (HF-ADNeF) at the University of Birmingham presents an exciting opportunity to conduct this work, with neutron fluxes up to 10^{12} n cm^{-2} s^{-1}. Presented is the application of OpenMC to simulate this facility, with the aim to explore the production of novel radioisotopes for medicine. A detailed model of the facility has been developed in an easily adaptable framework, allowing for both rapid prototyping and detailed analysis. This includes modelling detector responses, examination of neutron angular distributions and prediction of radionuclide activities resulting from neutron activation. To maximise the yields of relevant isotopes, moderators will be designed and tested. Comparative analyses will be conducted with other established tools such as MCNP, Geant4 and Serpent, with the simulated results being validated through neutron activation analysis experiments at the HF-ADNeF throughout the course of the project.

P1.22. Optimising Phenomenological Optical Model Parameters to Reproduce Reaction Cross Sections using Particle Swarm Optimisation and a Feed-Forward Neural Network

Samuel Sullivan[1], Paul Stevenson[1,2], James Benstead[1,2], Lee Morgan[1,2], and Payel Das[1]
[1]University of Surrey, UK, [2]AWE, Aldermaston, UK

Optical Model (OM) calculations are often a prerequisite for the complete description of nuclear reactions. The theory describes the total, elastic, and non-elastic reaction channels between a projectile and nucleus, and informs subsequent calculations required to estimate specific non-elastic channels. Phenomenological OMs have successfully reproduced experimentally measured cross sections and been used to describe reactions involving exotic nuclei. These models require geometric form-factor and energy-dependence parameters informed by experimental data. Nuclear reaction codes, such as TALYS, provide a global set of these parameters, as well as local sets defined for certain nuclei. However, these parameterisations do not universally reproduce experimental results.

This presentation describes a methodology used to optimise the nucleon parameters of the Koning-Delaroche phenomenological optical model to best fit experimental cross sections from the EXFOR nuclear data library. Particle Swarm Optimisation was applied to the parameter space, minimising a χ^2 metric which quantified the goodness-of-fit for a particular set of parameters. This metric was calculated by generating cross sections at incident-energy values matching the available EXFOR data. The optimisation procedure was enhanced by substituting on-line cross section calculations with a Feed-Forward Neural Network (FFNN). Using training data consisting of many stochastic parameterisations and an energy grid covering 1 - 23 MeV, the network generated cross sections an order of magnitude faster than equivalent TALYS calculations.

This optimisation framework produces OM parameterisations which fit experimental data well, though a future consideration of angular distributions as well as further reaction channels is necessary. The use of a FFNN for substituting explicit on-line calculations suggests an effective method of reducing code runtime and improving overall efficiency when many calculations are required. Additionally, a FFNN is shown to be a practical approach to estimating cross sections where appropriate for training data to be generated from theoretical calculations rather than real-world measurements.

P1.23. Progress on designing a beta-gamma detection system for criticality monitoring of spent nuclear fuel rods and operational nuclear reactors

Sifa Elizabeth Poulton[1,2], Patrick Regan[1,2], Steven Bell[2], Robert Shearman[2], and Matthew Ryan[3]
[1]University Of Surrey, Guildford, UK, [2]National Physical Laboratory, Teddington, UK, [3]National Nuclear Laboratory, Cumbria, UK

The International Monitoring System (IMS) measures atmospheric radioxenon concentrations to monitor for nuclear tests [1] by measuring the ratio between different isotopes and metastable states to distinguish between civil and weapons test emissions [2]. This project uses this principle to design a beta-gamma detection system for real time criticality monitoring of spent nuclear fuel and active nuclear reactors as part of the UK's decommissioning strategy. This is an update on the project's progress to date and an overview of future work.

[1] Goodwin, M. A. (2024) J. Env. Rad.
[2] Kalinowski, M. B. (2010) Pure Appl. Geophys.

P1.24. The 2023 MUonE Test Run

Clement Devanne
[1]University of Liverpool, UK

The MUonE experiment aims at an independent and competitive determination of the leading hadronic contribution to the muon anomalous magnetic moment, aμHLO. Tensions in the current

evaluations of this quantity are limiting the comparison between theoretical and experimental value of the muon g-2, which exhibits a long standing discrepancy and could hint at New Physics effects. MUonE proposes to determine aμHLO through a very precise measurement of the shape of the μ-e elastic scattering differential cross section. The experiment will be carried out at the M2 beamline at CERN North Area, where the high intensity 160 GeV muon beam available will impinge on a low-Z fixed target. A test run was performed this summer, where multiple tracking stations and a prototype electromagnetic calorimeter connected to a triggerless readout system were operated for the first time. The experimental apparatus and preliminary results from the test run will be presented.

P1.25. The current status of Jet measurements from Run 3 at ALICE

Daniel Jones[1]
[1]University of Liverpool, UK

When nuclear matter experiences extreme temperatures and pressures, it exists in a new phase known as the quark-gluon plasma (QGP), where partons (quarks and gluons) are free to propagate in a near perfect fluid. The QGP is investigated at experiments such as A Large Hadron Collider (ALICE) at the CERN LHC, where heavy ions such as lead are collided at high energies to create a QGP for a small fraction of time. As a result of the recent upgrades of the ALICE experiment and the LHC we are entering a new era of data collection, which makes this an exciting time to be working with ALICE.

Produced in both heavy-ion collisions and proton-proton collisions are jets - collimated streams of high energy hadrons originating from a high-energy parton created in a hard scattering process. As heavy ion collisions also result in the generation of a QGP, it is expected that the properties of jets will be modified when they are produced in it. The modifications can include an increase or decrease in the jet energy, a change in the jet shape or substructure or a deflection from its propagation axis when produced in a vacuum. Phenomena which demonstrate such modifications include “jet quenching” in which even the jet topology is lost. Thus, measurements of jet production can be expected to yield critical information which relates to the collective behaviour of the QGP which is manifest as a perfect fluid. This poster will present an update on the current status of jet measurements in ALICE, including the validation of Run 3 Monte Carlo productions which are used for unfolding detector level effects in real data.

P1.26. The VELO Monitoring during the Run-III

Lanxing Li[1], David Friday[1], Marco Gersabeck[1], and Eva Gersabeck[1]
[1]University of Manchester, UK

The upgraded LHCb vertex detector, upgrade I VELO, has been designed to operate with Run 3 collision data at 40 MHz with a raised operational luminosity of $2\times10^{33}/cm^2s$. It utilises new hybrid-pixel technology and geometry to maintain optimal physics performance in very high occupancy and pile-up conditions. With this upgrade, the VELO is expected to provide the precise tracking of particle trajectories and accurate reconstruction of primary and secondary vertices. Monitoring conditions inside the VELO during collision is vital to provide insight into the status of the whole VELO system, as well as a better understanding of the behaviour of the corresponding algorithms to commission the VELO.

During this talk, I will give an overview of the new monitoring algorithms used for the VELO detector, which uses unbiased events from the detector in real time to monitor detector performance. It focuses on understanding the properties of reconstructed tracks and monitoring the distribution of clusters reconstructed in the firmware and using a novel 'Superpixel' readout. Two specific studies will be presented, including tracking asymmetry between the two halves of the VELO detector, based on track monitoring, and a study on the detector time alignment based on cluster monitoring.

P1.27. Using U-nets for the Application of Machine Learning to Improve Acquisition Times for Muography

William O'Donnell[1,2], David Mahon[1,2], Paul Naidoo[2], and Guangliang Yang[1,2]
[1]University of Glasgow, UK, [2]Lynkeos Technology, UK

Muography, a non-invasive detection technique centred around imaging objects through the utilisation of natural cosmic ray muons, employs a technique called muon scattering tomography to construct three-dimensional density maps. However, the reliance on a natural source imposes a constraint on the muon flux, resulting in prolonged acquisition times and somewhat noisy images, thereby limiting the widespread industry adoption of muography. Machine learning techniques offer a potential solution to these challenges as they can be used to learn and identify complex patterns or features in data that would otherwise not be possible. The proposed approach consists of the transformation of under-sampled muography images into their higher sampled counterparts, using a convolutional-based supervised learning model called a U-net. Unlike traditional convolutional neural networks, U-nets excel in preserving information that might be lost during the convolutional process. Their interconnected layers play a pivotal role in maintaining the resolution of muography images, ensuring that denoising and enhancement tasks do not compromise the crucial features. Preliminary results from a novel U-net design, using training data simulated in Geant4, are presented to address challenges related to image quality and acquisition time.

P1.28. Isomeric and Beta Decays in the Neutron-Rich N=126 Region

Gee Bartram[1]
[1]University of Surrey, UK

As part of the May 2022 campaign at GSI Darmstadt, Germany, a high-intensity, 208Pb primary beam of 1 GeV/u was fired at a 9Be target to populate neutron-rich fragmentation products at N~126. The study of such nuclei forms an important part of our understanding of nuclear structure and the testing of nuclear shell model predictions. Fragmentation products from GSI's fragment separator were implanted in two AIDA active silicon stoppers and two scintillating beta plastic detectors, surrounded by eight newly developed DEGAS high-purity Ge detectors as well as two EUROBALL germanium detectors.

The main aim of this experiment was to study the structure of N=126 nuclei, through the observation of isomeric and beta decays. In 202Os, isomers are predicted with Iπ=10+, 7- and 5-, while in 203Ir a long-lived 11/2- state is expected. Furthermore, the beta-decay half-lives of several nuclei in this

region are being analysed, in addition to information on excited states in their daughter nuclei. GSI's fragment separator was centered on 203Ir and 202Os for one day and three days, respectively. The knowledge gained from this experiment is valuable for understanding potential shell evolution at N=126, and also to contribute to the theoretical predictions of r-process path properties in this region.

Preliminary analysis has identified all previously observed isomeric states in 203Pt, 204Pt, and 203Ir [1]. In addition, known gamma lines following the beta decays of Pt and Hg isotopes were observed [2]. The collected statistics on neutron-rich nuclei such as 203Ir are much higher than in previous experiments, revealing new internal decay channels. The isomeric decays observed in this experiment will be presented with their lifetimes, alongside beta-gamma correlations using the beta plastic and germanium detectors.

[1] S. J. Steer et al., Phys. Rev. C 84, 044313 (2011)
[2] A. I. Morales et al., Phys. Rev. C 88, 014319 (2013)

Poster Session 2

P2.1. Search for μ+ → e+e+e− at the Mu3e experiment and the Commissioning of the Pixel Tracker.

Charles Kinsman[1]
[1]University of Liverpool, UK

Mu3e is an experiment dedicated to observing the lepton flavour violating decay of a muon to two positrons and an electron. The experiment is situated around the πE5 beam at the Paul Scherrer Institut, which produces a muon rate of 108 Hz. The aim of the experiment is to observe the decay, or more specifically to improve the limits on the branching ratio to greater than 10−16 at a 90% confidence level.

To achieve this, there must be 1 · 1017 muons stopped in the detector, with a reconstruction efficiency of 20%. In addition to this, the background, which is made up of combinatorial and internal conversion effects, must be suppressed to below the 10−16 level. The focus of this research is in the pixel tracking detector of the experiment and understanding the effect the efficiency has on the physical output of the experiment. To do this the the research is combined from two parts. Firstly the development of tracking algorithms to measure and analyse the tracking and vertex reconstruction performance of the pixel detector. From this, the expected performance of the experiment will be presented. Secondary to this the tracking algorithms must be optimised under realistic detector conditions, such as inefficient or noisy pixel sensors, with the purpose of increasing the reconstruction efficiency. Due to the rarity of the decay, a high reconstruction efficiency is required and thus an algorithm that is capable of both calculating and working with inefficiencies in the detector is required. The performance of these algorithms are presented.

P2.2. Iluminating the 12C(a,g)16O cross section with gamma beams

Kristian Haverson[1]
[1]Sheffield Hallam University, UK

The carbon to oxygen ratio (C/O) remaining after stellar helium burning has a significant impact on stellar evolution models. For example, the C/O ratio affects the mass threshold that determines whether a Type II supernova will collapse into a black hole or form a neutron star.

At this stage in a star's life cycle two main reactions determine this ratio, the well constrained triple alpha process and the carbon-12 alpha capture reaction, denoted 12C(a,g)16O. The latter has large uncertainties in the cross section approaching the Gamow window, resulting in a poorly constrained C/O at astrophysical energies.

This work details a new measurement of the 12C(a,g)16O capture reaction, by measuring the reverse photo-dissociation reaction, 16O(g,a)12C, using intense mono-energetic gamma beams produced at the HIGS facility and an Optical Time Projection Chamber.

By utilising this background-free technique with high angular resolution, accurate angular distributions were measured over the 1− resonance at Ecm ∼ 2.4 MeV. For the first time measurements of the E1 and E2 mixing angle, phi12, are shown to be in agreement with elastic scattering data.

P2.3. A microscopic study of 12C+12C fusion interactions

Khlood Alharthi[1], and Paul Stevenson[1]
[1]University of Surrey, UK

The study of 12C+12C fusion interactions was performed using time-dependent Hartree-Fock (TDHF) approximation. The cross-section reaction has been computed with SKI3 Skyrme force at different orientations. The Sky3D TDHF code has been used to calculate static proper- ties, and fusion reaction of the 12C+12C system. Our findings produced reasonable resonances at each center of mass energy. The structures of the resonances appear explicitly in the fusion cross section for 12C+12C, due to overcoming angular momentum fusion barriers. Our results are compared to those obtained experimentally via several techniques. It is observed that, at low energy, our data is in a good agreement with the experimental data. The disagreement be- comes visible with increasing incident energy, where the TDHF approximation begins to break down.

P2.4. Progress towards Strontium Atom Interferometry at RAL Space

Kamran Hussain
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AION (Atom Interferometer Observatory and Network) and MAGIS (Matter-wave Atomic Gradiometer Interferometric Sensor) are a consortium of strontium atom interferometry experiments, with the science goals of probing gravitational waves in the mid-band detection region between 0.1-10 Hz and to search for ultra-light dark matter candidates. MAGIS is currently constructing the 100 m vertical baseline in the MINOS access shaft at Fermilab. AION plans to build the 10 m detector at the University of Oxford, with prospects of setting up the 100 m baseline in Boulby Underground Laboratory.

The University of Liverpool is responsible for developing the phase-shear detection platform for MAGIS. This system employs a piezo-driven retro reflection mirror inside the ultra-high vacuum chamber to correct for the Coriolis and induce phase shear on atom cloud. To track the position of the retro mirror, two types of position feedback are being developed. Electronic feedback via a strain gauge which is to be initially implement during commissioning, then ultimately an optical feedback system using an optical lever.

Rutherford Appleton Laboratory hosts one of five strontium labs in the AION consortium with a 1m interferometer. This is a testbed to understand and further develop cold atom technologies that required for the 10 m AION tower. Currently a 2D Magneto-Optical Trap (MOT) has been formed, with progress towards setting up the next cooling stage for the 3D MOT. The goal is to achieve strontium interferometry with the potential to test the out-of-vacuum phase-shear imaging platform in collaboration with the University of Liverpool.

P2.5. ATLAS Run 3 Search for New Physics in the Dielectron Channel

Tom Elliot[1]
[1]Royal Holloway, University of London, UK

The ATLAS detector is currently in its third run of data taking; the last chance to search for new physics at the energy frontier before a three-year shutdown at the LHC. The di-electron channel is an interesting place to look for such new physics owing to its distinctive signature in the detector, the stability of the electron, and the absence of QCD effects. Presented is an ongoing analysis of run 3 Monte Carlo datasets, simulating the decay of the elusive Z' bosons to electrons, aimed at reducing several measurement backgrounds. Making use of the ATLAS trigger system, an efficiency study has been made, considering electron triggers that are maximally efficient on the Z' signal, but fail to trigger on the reducible backgrounds. This novel approach facilitates background reduction before data selection, which may help to improve signal isolation overall.

P2.6. Calibrating the Short-Baseline Near Detector with Cosmic-Ray Muons

Anna Beever[1]
[1]University of Sheffield, UK

The Short-Baseline Neutrino programme at Fermilab makes use of a series of Liquid Argon Time Projection Chambers (LArTPCs) downstream from the Booster Neutrino Beam target, a muon neutrino beam source, to search for eV-scale sterile neutrinos and to advance liquid argon detector technology. The Short-Baseline Near Detector (SBND), an 112-ton LArTPC, lies 110 m from the source, with ICARUS, the far detector, positioned 490 m further along the beam. SBND will measure the unoscillated neutrino flux, and is uniquely positioned to make precise measurements of neutrino-argon interactions, since as the near detector it will collect more than two million neutrino interactions per year. Crucial to extracting physics from a LArTPC is calibration, producing precise position and energy measurements by correcting for detector effects. Calibration with cosmic-ray muons primarily accounts for space charge effects, drift electron lifetime, electron cloud diffusion, non-uniform charge deposition across a detector, and defining the absolute energy loss per unit length scale. This allows full advantage to be taken of the mm-scale resolution capabilities of the LArTPC technology employed by the SBN detectors. This poster will show the measurement of electron lifetime in SBND using Monte Carlo simulation of cosmic-ray muons, and the resulting correction of charge deposition values. This will contribute to the overall calibration effort ahead of the first data in early 2024.

P2.7. Cocktail Beam Coulomb-Excitation of 50Cr and 50Ti

Christopher Cousins[1], Jacob Heery[1], Jack Henderson[1], Stanimir Kisyov[2], Ching-Yen Wu[2], Laetitia Canete[1], Scott Carmichael[3], Daniel Doherty[1], Liam Gaffney[4], Kasia Hadyńska-Klęk[5], Heshani Jayatissa[3], Daniel Lascar[6], Claus Müller-Gatermann[3], Sorin Pascu[1], Charlie Paxman[1], Connor O'Shea[1], Ben Reed[1], Walter Reviol[3], Elizabeth Rubino[7], Reuben Russell[1], Darek Seweryniak[3], Marco Siciliano[3], Gemma Wilson[3], and Kasia Wrzosek-Lipska[5]
[1]University of Surrey, UK, [2]Lawrence Livermore National Laboratory, USA, [3]Argonne National Laboratory, USA, [4]University of Liverpool, UK, [5]Heavy Ion Laboratory, Poland, [6]Northwestern University, USA, [7]Michigan State University, USA

Chromium-50 and Titanium-50 are located in a region of the nuclide chart, where as N→28, the increased excitation energy of the deformed bands result in less mixing with lower-lying states. Therefore, these nuclei are described well with simple shell model calculations. Experimental measurements of the spectroscopic quadrupole moments (Qs) for these low-lying states is performed to verify the use of a simplistic configuration space.

The experimental data was collected at Argonne National Laboratory in 2022, where the CHICO2 and GRETINA arrays worked in conjunction, such that de-excitation γ rays could be observed in coincidence with scattered projectile-target events. The 50Cr-50Ti cocktail beam was impinged onto a 208Pb target up to the “safe” Coulomb-excitation limit (4.55 MeV/u).

A modified χ2 GOSIA minimizer allows for simultaneous analysis of both 50Cr and 50Ti, where reduced transition probabilities (B(E2)) and Qs can be extracted. Since this is the first instance the minimizer has allowed for multiple species in the beam, the performance of the modified minimizer is tested, as well as the possibility of expanding it further. Re-measurements of Qs for the 2_1+ states in 50Cr and 50Ti are performed, as well as a first measurement of Qs for the 4_1+ state in 50Cr. Preliminary results are presented in this work.

P2.8. Commissioning of the MIGDAL detector with fast neutrons at ISIS/NILE

Lex Millins[1,2]
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Many dark matter experiments are exploiting the Migdal effect, a rare atomic process, to improve sensitivity to low mass WIMP-like dark matter candidates. However, this process is yet to be directly

observed in nuclear scattering. The MIGDAL experiment aims to make the first unambiguous measurement of the Migdal effect in nuclear scattering. A low pressure optical Time Projection Chamber is used to image in 3-dimensions the characteristic of a Migdal event: an electron and a nuclear recoil track sharing a common vertex. Nuclear recoils are induced using fast neutrons from a DD source which scatter in the gaseous volume of the detector. The experiment is operated with 50 Torr of CF4 using two glass GEMs for charge amplification. Both light and charge are read-out and these measurements are combined for full track reconstruction. In this talk I will present the results of the commissioning of the experiment with fast neutrons at the Neutron Irradiation Laboratory for Electronics (NILE) at Rutherford Appleton Laboratory in the UK.

P2.9. Construction, Installation, and Commissioning of the SFGD Detector

Jake McKean[1]
[1]Imperial College London, UK

The Super Fine-Grained Detector (SFGD) plays a crucial role in the Tokai to Kamioka (T2K) experiment's near detector upgrade, specifically in reducing systematic uncertainties in cross-section analyses and enabling neutron tagging. The SFGD is an active mass scintillator detector composed of over two million 1cm cubes with full 3D readout. This poster showcases the comprehensive efforts undertaken for the construction, installation, and commissioning of the SFGD.

Accurate calibration of the Multi-Pixel Photon Counters (MPPCs) and electronics is crucial for precise measurements. The poster extensively discusses the high gain and pedestal calibrations, highlighting the steps taken to ensure a precise calibration for accurate measurements. Additionally, it briefly outlines the significance of the low gain and time over threshold calibrations in optimizing the SFGD's performance for higher energy event.

P2.10. Decay Spectroscopy of 152Tb as a Theragnostic Radionuclide

Edward O'Sullivan[1,2], Professor Patrick Regan[1,2], Doctor Jack Henderson[1], Doctor Robert Shearman[2], Sean Collins[1,2], Doctor Jacob Heery[1], Doctor Sorin Pascu[1], Doctor Thomas Parry[1], Ulli Koester[3], Caterina Michelagnoli[3], Jean-Michel Daugas[3], and Lorenzo Domenichetti[3]
[1]University of Surrey, UK, [2]National Physical Laboratory, UK, [3]Institut Laue-Langevin, France

The Terbium Theragnostic Quartet is a set of four terbium isotopes (149,152,155,161Tb) that show potential application in personalised nuclear medicine [1, 2]. 152Tb, decaying by β+ and EC to excited states in 152Gd (QEC =3.99 MeV, T1/2 =17.9 hours [3]), shows promise in positron emission tomography (PET) as demonstrated in clinical trials [2]. Routine use of this radionuclide requires improved nuclear data for patient dosimetry [4], involving precision measurements of beta feeding strengths and gamma-ray emission probabilities. Preliminary results of a decay spectroscopy study of 152Tb are presented, using sources prepared at CERN-ISOLDE. Gamma-ray coincidences were measured using the Fission Product Prompt γ-ray Spectrometer (FIPPS) [5] at the Institut Laue-Langevin, Grenoble, supported by measurements taken using a bespoke Si(Li)-HPGe decay setup for electron-gamma coincidences using sources created in the same ISOLDE production run. This project aims to establish a decay scheme for the isotope with a metrological approach to traceability, with particular emphasis on weakly populated, high-excitation energy states in the 152Gd daughter nucleus. Preliminary gamma-gamma coincidence analysis has suggested the existence of a number of previously unreported states at Ex >3 MeV. Angular correlation and electron-gamma coincidence analysis aid in the construction of the final level scheme, providing information on the multipolarities and mixing ratios of discrete transitions. A progress report on the analysis on these data to date will be presented.

[1] Muller et. al., Journal of Nuclear Medicine 53, 2012
[2] Muller et. al., EJNMMI Research 9, 2019
[3] S.M.Collins et al., Applied Radiation and Isotopes (2023)
[4] Adam et. al, European Physical Journal A - Hadrons and Nuclei 18, 2003
[5] C.Michelagnoli et. al., EPJ Web Conf. 193, 2017

P2.11. Designing Calorimeters for the Luminosity Monitoring System at the Electron-Ion Collider

Alex Smith[1], and Nick Zachariou[1]
[1]University of York, UK

The electron-ion collider is a next generation facility that enables the precise study of the structure of nucleons and the mechanisms of the strong nuclear force. Aiming to be operational in the 2030s, the EIC will allow collisions at a range of centre-of-mass energies, from 20 to 140 GeV, with polarised beams, and a large range of ion species. Crucial to meeting the scientific goals of the experiment is a high luminosity, which has to be measured to a high degree of accuracy: less than 1% absolute uncertainty and less than 10E-4 relative uncertainty.

To achieve this, a three-part luminosity monitoring system will be constructed, providing the means to underpin systematic uncertainties. The three subsystems utilise the well-known bremsstrahlung process. The low Q2 tagger counts the electrons which lose energy and drop out of the beam line as it leaves the detector region. Simultaneously, the direct photon calorimeter will measure the energy of the majority of the bremsstrahlung photons and produce an estimate of their number. Finally, the pair spectrometer system will detect electron-positron pairs that are produced from 1% of the photons at a converter and steered to a pair of calorimeters and trackers.

This presentation will introduce the EIC and give an overview of the luminosity monitoring system. Focus will be on the design of the calorimeters for the system and studies on their use for the pair spectrometer system.

P2.12. Exploring nuclear shapes and sizes of Thulium using laser spectroscopy (On behalf of the COLLAPS collaboration)

Jack Hughes[1]
[1]University of Liverpool, UK

High resolution laser spectroscopy has been used to study the atomic hyperfine structure of thulium isotopes (Z=69). This technique results in a model independent measurement of the nuclear

magnetic dipole and electric quadrupole moments, as well as the change in mean-square charge radius, with respect to the stable 169Tm. Collinear laser spectroscopy measurements were performed using the COLLAPS experiment based at ISOLDE, CERN. From a preliminary study to measure isotope yield and assess the chosen transition, measurements of thulium isotopes ranging from 155 – 175 were taken and have been analysed, with these results being the focus of the presentation. This paves the way for studying the more neutron-deficient isotopes of thulium, with the eventual goal of obtaining the first laser spectroscopy (and charge radius) measurement of a proton emitter, 147Tm.

P2.13. Exploring Tau Identification in $t\bar{t}$ dilepton final state with ATLAS 2022 Data

Sudev Pradhan
[1]University of Sheffield, UK

A study of the measurement of the Tau Identification efficiency and correction factors in the $t\bar{t}$ dilepton (e+τ, μ+τ final state is presented. The study is conducted using 30 fb^{-1} of proton-proton collisions at $\sqrt{s}$ = 13.6 TeV recorded with the ATLAS detector at the LHC in 2022. An efficiency measurement covering a wider range of transverse momentum values compared to the existing measurement in the Z → ττ is presented. Additionally, Run-3 $\bar{t}$t plots with Recurrent Neural Network (RNN) score and lepton η values are presented. The studies are carried out using analysis frameworks provided by TauCP both for the ntuple production and the data analysis.

P2.14. Gaussian Processes: Machine Learning for Observable Interpolation and Data Analysis

Ryan Ferguson[1]
[1]University of Glasgow, UK

Current studies of the hadron spectrum are limited by the accuracy and consistency of datasets. Information derived from theory models often requires fits to points at specific values of kinematic variables, which needs interpolation between measured points. In sparse data sets the quantification of uncertainties is problematic.

Machine Learning is a powerful tool that can be used to build an interpolated dataset, with quantification of uncertainties. The primary focus here is one type of machine learning called a Gaussian Process (GP). By calculating the covariance between known datapoints, the GP can predict the mean and standard deviation of other, unknown, datapoints. The model built here is checked and tested using Legendre polynomials to ensure it is unbiased and gives accurate predictions. This is then demonstrated on two datasets; one sparsely and one densely populated.

Whilst this model is only demonstrated on polarisation observables, it could easily be adapted to provide information on other measured quantities, such as cross-sections.

P2.15. Improving the Performance and Reliability of High Purity Germanium (HPGe) Detectors through the monitoring of trace signals

Thomas Wonderley[1]
[1]University of Liverpool, UK

High-Purity Germanium (HPGe) detectors embody unparalleled spectroscopic performance, delivering unmatched sensitivity and precision in gamma radiation measurements. These detectors are useful across a wide range of fields from security, nuclear decommissioning, scientific research in nuclear physics, and ensuring the safety of food, water, soil, and air quality. It is thanks to their reliability and unrivalled energy resolution that they have so many uses across multiple fields. Therefore, any issues within a detector must be found and dealt with quickly and efficiently, especially in cases such as security and decommissioning. By monitoring the trace data from HPGe detectors, we can allow quicker responsive action to fix any detector issues and optimise the key performance criteria.

My work aims to train a neural network to monitor the trace data collected by a Mirion Lynx Digital Signal Analyser to investigate the presence of abnormal pulses. This information can be passed to the user which will allow for easier identification of potential faults or badly tuned parameters that could be affecting the performance of the detector.

The training data for such a model includes the collection of trace data through a series of controlled measurements, in which the detector is detuned in specific ways. This includes shaping times as well as detector bias voltage and pole-zero correction. This work will be extended to cover common issues such as signal noise from electronics, microphonics and ground loop feedback, for example.

By systematically introducing these issues to a working detector, with known calibration sources, a generous dataset of trace data can be generated which will be used as training data for a neural network. The network will then be tested to determine its performance.

P2.16. Kaon Cross Section Measurement with NuMI Beam at MicroBooNE

Natsumi Taniuchi[1]
[1]University of Cambridge, UK

The existence of Grand Unified Theories describing the unification of the electromagnetic, weak, and strong forces is still an open question. One of the notable features of these theories is the prediction of protons decaying into lighter particles with long lifetimes in the order of 10^{30}-10^{40} years. Although many studies have been conducted assuming various decay channels so far, such decays have yet to be observed. In particular, the sensitivity to decay modes involving kaons in Cherenkov detectors is hampered by the fact that kaons produced in proton decay are under detection threshold due to their heavy mass. The Deep Underground Neutrino Experiment (DUNE) is a state-of-the-art international experiment aiming to reveal the nature of neutrinos and proton decay amongst other BSM topics. DUNE's far detector will utilise a liquid argon time projection chamber (LArTPC) with an active volume of 40 kt. While DUNE's LArTPC is still under construction, another LArTPC has been operating in two neutrino beams, namely the MicroBooNE experiment. The analysis of kaons produced by neutrino interactions in the MicroBooNE LArTPC will provide useful information to understand the behaviour of kaons in the DUNE LArTPC and constrain their production cross section in atmospheric neutrino data -- one of the major backgrounds for proton decay searches in DUNE. In this presentation, a novel event reconstruction algorithm for K^+ daughter particles and the event selection method using machine learning techniques for neutrino-induced charge current K^+ production at MicroBooNE LArTPC will be described.

P2.17. Measurement of the electric dipole moment of the muon at the Fermilab g-2 experiment

Katie Ferraby[1]
[1]University of Liverpool, UK

The g-2 experiment at FNAL has finished data taking, and using the complete dataset will publish the world's most precise measurement of the anomalous Magnetic Dipole Moment (MDM) of the muon. The Electric Dipole Moment (EDM) of the muon, which is CP violating, is also measured at the g-2 experiment. The EDM is predicted to be extremely small in the SM, so any signal would be a clear sign of CP-violating New Physics. I will present the status of the EDM analysis, which searches for an oscillation in the average vertical angle of decay positrons as measured by the tracking detectors. The predicted sensitivity with the complete dataset from the g-2 experiment will also be presented.

P2.18. Measuring the lifetimes of low-lying 146Ba energy levels using fast-timing techniques

Faye Rowntree[1], Liam Gaffney[1], Alejandra Diaz Varela[2], Allison J Radich[2], Robin Coleman[2], Fuad Ali[2], James Smallcombe[3], John F Smith[4], Adam B Garnsworthy[3], Mustafa M Rajabali[5], Ben K Luna[5], Corina Andreoiu[6], Costel Petrache[10], Pietro Spagnoletti[4], James Keatings[4], Konstantin Mashtakov[4], Nikita Bernier[3,7], Mike Bowry[3], Bruno C Olaizola Mampaso[3], Roger Cabellero-Folch[3], Lewis Sexton[3,8], Paulina Siuryte[3,8], S S Bhattacharjee[3], Yukiya Saito[3,7], Elena Timakova[3], Kenneth Whitmore[6], Daniel Yates[3,7], Carl Svensson[2], Ryan Lefleur[2], Fatima H Garcia[6], Gwen Grinyer[9], M P Hladun[9], and J L Mitchell[9]
[1]University of Liverpool, UK, [2]University of Guelph, Canada, [3]TRIUMF, Canada, [4]University of the West of Scotland, Scotland, [5]Tennessee Technological University, USA, [6]Simon Fraser University, Canada, [7]University of British Columbia, Canada, [8]University of Surrey, UK, [9]University of Regina, Canada, [10]Paris-Sud University, France

Recently, Coulomb excitation experiments of radioactive beams of even-even 144Ba and 146Ba have found direct evidence of octupole deformation through the measurement of large B(E3) values. The region centered around 144Ba is expected to present strong octupole deformation, where in addition to the pear-shape appearance of the nucleus, a displacement between the centres of mass and charge cause strong electric-dipole transitions. Thus the low-lying negative-parity states of these nuclei must be studied further to better understand the shape and structure of nuclei in this region at low energy and spin. A potential insight is through the measurement of lifetimes of the low-lying energy levels using the fast-timing technique for lifetimes of the order of picoseconds. The fast-timing technique is a well-known and reliable tool to determine lifetimes of nuclear excited states.

Knowing the lifetime of an excited state of a nucleus can allow for the extraction of the reduced transition probability between two excited states that indicate potential deformation.

A β-decay experiment has been performed at the radioactive ion beam facility ISAC-I at TRIUMF in Vancouver, Canada. Beams of caesium isotopes were initially produced from a UCx target and implanted on an aluminized mylar moving tape collector. Fast-timing γ-γ and β-γ measurements are possible using the GRIFFIN spectrometer, which contains 8 $LaBr_3(Ce)$ detectors and a zero-degree fast scintillator β-detector.

In this talk, preliminary results of the lifetimes of low-lying excited states in 146Ba results will be presented and compared to currently accepted values.

P2.19. Novel Techniques for α/β Pulse Shape Discrimination Using Silicon Strip Detectors

Olivia Tindle[1]
[1]Sheffield Hallam University, UK

It is well known that the 9Be nucleus exists as a cluster of two α-particles bound together by a valence neutron – a nuclear molecule. Examination of how this cluster structure changes as the internal energy of the nucleus increases will lead to new and crucial insights into the nature of the nuclear force.

An experiment is planned at the HIγS facility to explore the 9Be(γ,n)αα photo-dissociation reaction for γ-ray energies between 8 to 16MeV. Reaction reconstruction will be made possible by utilising an array of position-sensitive double-sided silicon strip detectors (DSSDs).

However, due to the experimental conditions, the energies of the α-particles will be low, and are expected to overlap with Compton electrons, leading to high backgrounds. Therefore, as a prerequisite, a method of pulse shape discrimination (PSD) is required to accurately separate the α-particles from the low-energy electron noise.

This work introduces the testing and development of novel α/β pulse shape discrimination techniques with DSSD's based on the exploitation of both detector and particle characteristics and subsequent analysis of pulse rise-times.

P2.20. Studying displacement damage in silicon detectors with the University of Birmingham MC40 Cyclotron

Eric Liu[1]
[1]University of Birmingham, UK

In future collider programs, there is an increasing requirement on the radiation hardness of detectors to maintain performance over their operational lifetime. For silicon detectors, the displacement damage is related to non-ionising energy losses (NIEL) of incident radiation in the silicon bulk, leading to changes in detector's electrical and charge collection properties. This displacement damage is dependant on numerous factors of the incident radiation, including particle species and energy. However the damage characteristics are expected to scale with the NIEL and thus irradiation fluences are often quoted in terms of the equivalent dose for 1 MeV neutrons. The factor relating the displacement damage cross-section for an arbitrary beam species and energy to 1 MeV neutrons is known as the hardness factor. This quantity is important in predicting the radiation exposure of detectors in future collider environments.

The MC40 cyclotron facility at the University of Birmingham is routinely involved in proton irradiations for several detector R&D projects. Proton beams of energy up to 38 MeV and maximum currents in the µA range allow fluences up to a few 10^{15} n_eq/cm² to be supplied in one day.

A recent study investigates the hardness factors at several beam energies up to 27 MeV. Silicon pad diodes were irradiated across a range of fluences and their change in leakage currents were measured. The extracted hardness factor is then compared with the current theoretical predictions.

P2.21. The 2x2 DUNE Near Detector Demonstrator

Akeem Hart[1]
[1]Queen Mary University of London, UK

'DUNE (Deep Underground Neutrino Experiment) is an under-development next-generation long baseline neutrino experiment. It features a Near Detector (ND) complex at Fermilab and a Far Detector (FD) based on Liquid Argon Time Projection Chambers (LArTPC), with a 40kt fiducial volume, 1.5km underground at Sanford Underground Research Facility (SURF), spanning 1300 km. The ND, particularly its LArTPC module, is crucial for constraining uncertainties in neutrino flux, interactions, and detector models. The ND LArTPC aims to utilise several key innovations like pixelated charge readout, modularization and high-performance light readout. The 2x2 demonstrator is a fully integrated prototype consisting of modules very similar to those we aim to use at the ND but smaller in scale. Positioned along the NuMI neutrino beam, it will be the first demonstration of a modular LArTPC in a high-intensity neutrino beam and by utilising components of the MINERvA experiment to assist with particle tracking, it will have a strong ability to perform physics analyses in its own right.

P2.22. The effect of kinematic-specific calibrations on the timing resolution of the the BigBite Timing Hodoscope for the GMn experiment at Jefferson Lab.

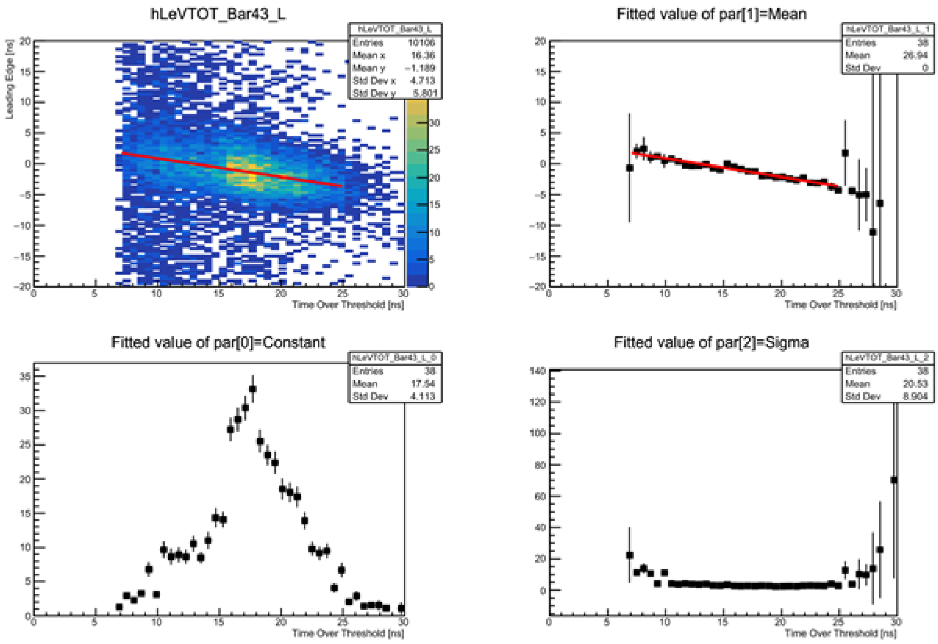
Andrew Cheyne[1], Rachel Montgomery[1], David Hamilton Hamilton[1], Gary Penman[1], Ralph Marinaro III[2], and Oliver Jevons[1]
[1]University of Glasgow, UK, [2]Christopher Newport University, USA

Electromagnetic form factors describe the spatial distribution of charge and magnetism. One of the main goals at Jefferson Lab is to measure these magnetic and electric form factors for the proton and neutron across a wide range of Q^2.

The GMn experiment makes use of the Super BigBite Spectrometer (SBS) and is designed to obtain values for the magnetic form factor of the neutron at values of Q^2 beyond what has been done before using a ratio-method that relies on measuring recoil protons and neutrons. To obtain the range of proposed Q^2, a number of data runs were performed at various kinematic settings by changing beam energies and scattering angle. The Hadronic physics group at Glasgow are responsible for the timing-hodoscope (TH) for SBS experiments in Hall A at Jefferson Lab. The raw data from the timing hodoscope has a number of unwanted contributions such as timewalk (see attached image) and alignment. These unwanted timing effects must be subtracted in order to accurately obtain the arrival time of the particle. Until now, the calibration was done with cosmic ray data on one kinematic setting. The calibration data from this was then used on analysis for all data.
For the past 2 months I have been working on performing kinematic-specific calibrations for all 6 kinematic settings that took place for the GMn experiment.

It is anticipated that by performing kinematic-specific calibrations like this, we hope to see an improvement in the timing resolution of the hodoscope.

If the new calibration settings do not show any marked improvement it would still allow us to quantify how much performing such a kinematic-specific calibration would benefit any future studies. Preliminary results show a small improvement but more detailed comparison is still in progress - planned to be completed by the end of February 2024.



P2.23. The MUonE experiment: a novel way to measure the hadronic contribution to the muon g-2

Giorgia Cacciola[1]
[1]University of Liverpool, UK

The MUonE experiment aims to measure with very high precision the leading-order hadronic contribution to the muon anomalous magnetic moment g-2, aμHLO. Tensions in the evaluation of this quantity using different techniques are currently limiting the comparison between the theoretical and experimental value of the muon g-2, which exhibits a long-standing discrepancy and could hint at New Physics effects. It follows that it is crucial to resolve the current tensions in the calculation of aμHLO. MUonE proposes to determine aμHLO through an innovative method, based on the extraction of the effective electromagnetic coupling from the shape of the differential cross section of μ-e elastic interactions. The measurement will be performed by scattering a 160 GeV muon beam, currently available at CERNs North Area, on the atomic electrons of a low Z target. The main challenge of MUonE resides in the control of the systematic effects to an unprecedented level of precision for a fixed target experiment, both on the theoretical and on the experimental side. The main concepts and challenges of this new proposal will be presented.

P2.24. The QUantum Enhanced Space-Time experiment poster

Abhinav Patra[1]
[1]Cardiff University, UK

The QUantum Enhanced Space-Time (QUEST) experiment is currently being commissioned at Cardiff University. QUEST consists of a pair of co-located tabletop power-recycled Michelson interferometers, each targeting a displacement sensitivity of 2×10^{-19} m/rtHz at 100 MHz. To achieve this sensitivity, the interferometers utilize high circulating power (10 kW) and squeezing. The main science goal of QUEST is to be sensitive to sub-shot noise stochastic signals. These stochastic signals can be a result of spacetime fluctuations due to quantum gravity, interactions of dark matter with the interferometer optics or ultra-high frequency stochastic gravitational waves.

P2.25. Unfolding Jet Observables with Machine Learning

Nicodemos Andreou[1]
[1]University of Derby, ALICE Collaboration, UK

The ongoing Run 3 at the Large Hadron Collider marks a new era in data production for heavy-ion collisions. A Large Ion Collider Experiment (ALICE) recently completed a data collection phase, recording an unprecedented 12 billion Pb-Pb collisions over five weeks, surpassing the combined periods of Run 1 and Run 2 by a factor of 40. Operating at $\sqrt{s}$ = 5.36 TeV with an interaction rate reaching 50 kHz, this vast data production allows a more differential analysis to be performed.

Jets are cascades of hadrons originating from the fragmentation of hard-scattered partons within high-energy collisions, often referred to as a spray of particles. In heavy-ion collisions, when jets are formed, they interact with the quark-gluon plasma medium, providing crucial insights into its

properties and therefore, serving as a significant probe for it. Transverse momentum, jet radius, and pseudorapidity are among the most common jet observables that one can focus on; however, it is essential to correct any observables for instrumental effects.

In high energy physics, unfolding refers to the ensemble of statistical techniques employed to solve the inverse problem, often referred to as deconvolution. In particular, unfolding allows the reconstruction of the true distribution of an observable from the measured data, with estimates as close as possible to the true value. Omnifold, is a machine learning unfolding framework designed to address challenges faced by conventional unfolding techniques, such as binning limitations and dimensionality constraints imposed by binning, while enabling control over auxiliary features for detector response corrections.

This research aims to integrate machine learning into the unfolding process of jet observables from ALICE data using the Omnifold framework. This poster will showcase the initial testing of Omnifold conducted in one dimension, with the potential for expansion into multiple dimensions.

P2.26. Wavelength Shifting Plates to Improve the Photon Detection Efficiency for the Southern Wide-Field Gamma-Ray Observatory

Jazmin Stewart[1], and Jon Lapington[1]
[1]University of Leicester, UK

The Southern Wide-Field Gamma-Ray Observatory (SWGO) marks a groundbreaking initiative in ground-based observation in the southern hemisphere. SWGO's wider field of view unlocks previously inaccessible areas of the southern sky, thereby enhancing our understanding of transient and variable multi-wavelength and multi-messenger phenomena. This observatory will complement other experiments such as the Cherenkov Telescope Array (CTA), the High-Altitude Water Cherenkov Gamma-Ray Observatory (HAWC), and the Large High Altitude Air Shower Observatory (LHAASO). Its heightened sensitivity, wide field of view, distinct location, and high-duty cycle make SWGO a unique and vital component of the high-energy gamma-ray observation in the southern hemisphere.

SWGO will comprise 6 to 8 thousand water Cherenkov tanks and is exploring various configurations, with the double-layered tank design emerging as the primary option. In this setup, the upper section of the tank houses a large-sized photomultiplier tube (PMT) oriented upwards, aimed at capturing particle timing and energy data with high sensitivity. The tank's lower section features a smaller PMT facing downwards, enveloped in a highly reflective material like Tyvek, designed for muon-tagging purposes. It is this lower chamber for which the proposed configuration with wavelength shifting (WLS) plates is being developed.

Research is currently underway to explore a novel method for use in SWGO, which entails integrating wavelength-shifting (WLS) materials to enhance photon detection efficiency, with a specific focus on smaller-sized photomultiplier tubes (PMTs). Monte Carlo simulations are being used to investigate the performance of embedding the lower PMT within a WLS plate, which shifts the wavelength of incident photons to match the optimal efficiency range of the PMT. Additionally, WLS materials can emit multiple photons per absorption event, potentially increasing the overall photon detection efficiency. Overall, the WLS plate will serve the purpose of trapping and guiding the photons towards the PMT's photocathode, increasing the light capture area of the smaller PMT. Although the lower chamber does not require the same level of time sensitivity as the upper chamber, these simulations will also assess the impact of WLS plates on the time resolution of detected Cherenkov photons.

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