Improvement of MCP detectors to achieve a dead-time-free measurement of groups of charged particles

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Synopsis Actual MCP detectors with hexagonal delay-line anodes and TDC readout reach a resolution about 40 µm FWHM and 40 to 150 ps FWHM. If too many particles hit the detector simultaneously a reconstruction becomes difficult. Different readout methods and new types of anodes will be introduced and compared.

Microchannel plates (MCP) convert one incoming particle (e.g. electrons, ions and higher energetic photons) into 10^6 to 10^7 secondary electrons. The leaving electron cloud's centre is at the same spot as the impacting particle (in 2D). An anode measures the electron cloud and the particle's original position can be estimated. Several types of anodes can be used (for a short summary see [1]).

The voltage drop at the MCP is used for precise timing information. A resolution better than 150 ps FWHM is possible.

State-of-the-art hexagonal delay-line anodes (hex-anode) with a time-to-digital-converter (TDC) as readout can obtain a spatial resolution about 40 µm FWHM [2]. If too many particles hit the detector in a short time window not all particles can be reconstructed with a simple TDC readout (see Figure 1).

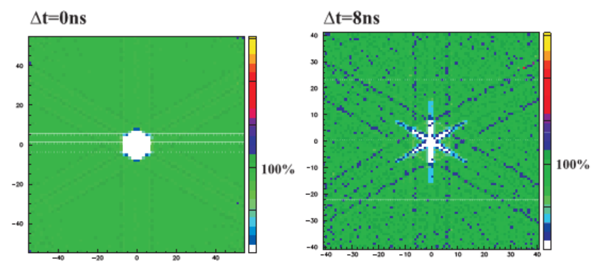

Figure 1. Theoretical comparison of the detection efficiency for a second electron after the first one hits the center of the detector (hex-anode with TDC readout). Left simultaneous, right 8 ns later. Modified from [3].

Instead of only measuring the time of the two signals it is better to digitalize the whole signal with an analog-to-digital-converter (ADC). Adroit algorithms are able to determine the positions of more particles.

But the delay-line anode has a physical multi-hit limit which no readout can overcome. Other anodes have to be used to get a nearly dead-time-free detector.

A first attempt replaces the long wound wires by a couple of short wires. Each wire collects a small amount of the charge and the charge distribution correlates to a 1D position [4]. Time and spatial resolution are as good as before but more particles could be detected.

Another option to determine the impact position is to use a circuit board with coated parts. The charge is directly picked up, amplified and then measured with ADCs [5]. A version with a chessboard-like pattern is shown in Figure 2.

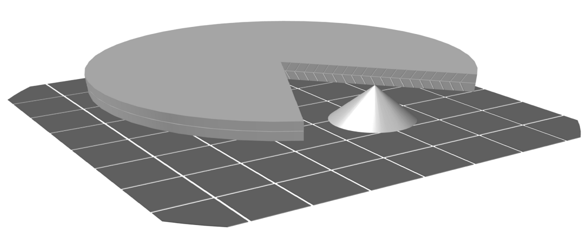

Figure 2. Gashed model of a MCP stack and a chessboard-like anode. The cone represents the trajectory of an electron cloud. Modified from [3].

At this point no detector reached the goal of a good time (< 500 ps FWHM) and spatial (< 100 µm FWHM) resolution together with an adequate multi-hit capacity.

References

[1] O. Jagutzki, 2011, Handbook for Highly Charged Ion Spectroscopic Research, page 121-149

[2] T. Bauer, 2015, Koinzidente Photoelektronenspektroskopie an Kuprat-Hochtemperatursupraleitern (dissertation, Goethe University Frankfurt)

[3] A. Czasch, private conversation

[4] O. Siegmund *et. all*, 2009, *Nuclear Instruments and Methods in Physics Research A*, Microchannel plate cross-strip detectors with high spatial and temporal resolution, doi:10.1016/j.nima.2009.05.116

[5] C. Janke, 2014, Entwicklung einer segmentierten Anode zur orts- und zeitaufgelösten Detektion von Teilchen (master thesis, Goethe University Frankfurt)

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