Observation of electron back-to-back emission from the quasifree mechanism of helium at 800 eV photon energy

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Synopsis: We investigated the angular distribution of the correlated two-electron emission originating from the quasifree mechanism at 800 eV incident photon energy.

Single-photon double ionization for helium due to electron-correlation is a well explored phenomenon and has been described within the picture of the two-step-one (TS1) and shake-off (SO) mechanisms. Here the electrons interact with each other, either before (SO) or after (TS1) the photon absorption takes place. More than four decades ago a third, the so-called quasifree mechanism (QFM), has been predicted for photo double ionization by Amusia et al. [1]. For QFM the photon couples directly to the electron pair and the mechanism manifests itself in a back-to-back emission of electrons with the same energy, leaving the nucleus at rest. Therefore the QFM is dipole forbidden; it precedes only at high photon energies, where quadrupole components from the field come into play. Just recently, in 2013, the first experimental observation was reported in the He^{2+} ion momentum distribution [2]. The QFM's observation is experimentally challenging due to the very small cross section (≈ 0.02 barn at 800 eV) and the prerequisite of detecting highly energetic electrons. This is the reason, why it has only been observed in the ion distribution at p = 0 until now, which is not accessible with TS1 and SO. Therefore the data that allowed its confirmation left some aspects of the unique fingerprint in the dark. Also inelastic scattering of a photon by an electron leads to ion momenta close to zero. Even though the cross section to create a He^{2+} via Compton scattering is, at this photon energy, orders of magnitude smaller than the QFM, a differential view of the electrons allows a more solid distinction.

We used the COLTRIMS reaction microscope technique [3] and intersected a cold supersonic helium gas jet with a beam of 800 eV circularly polarized photons from beamline P04 at PETRA III (DESY, Hamburg). Electrons and ions were projected with a weak electric field towards time- and position sensitive detectors. Additionally a strong magnetic field of ≈35 Gauss was applied to guide the high energetic electrons towards the detector. The outstanding photon flux of P04 combined with an increased target density made this experiment a full success. Figure 1. (a) shows the angle between the two emitted electrons with the same kinetic energy. The major contribution at 90° originates from the still very strong TS1 component, which can also be seen for a slightly asymmetric energy sharing in the inset. The QFM, which requires back-to-back emission of the electrons, is clearly visible at 180°. Figure 1. (b) shows the same angle with more asymmetric energy sharing, which makes the QFM disappear.

This clear finger print allows a clear identification of the QFM, ruling out other processes, such as Compton scattering.

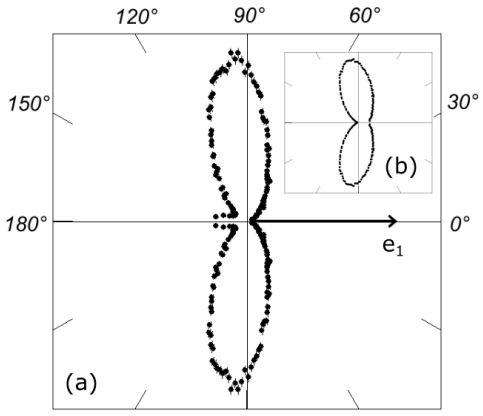

Figure 1. Angle between emitted electrons for electron energies of 360 ± 60 eV in **(a)** and 80 ± 10 eV in **(b)** . The polar plot is mirrored horizontally since the shown angle runs only from 0 to 180°.

References

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