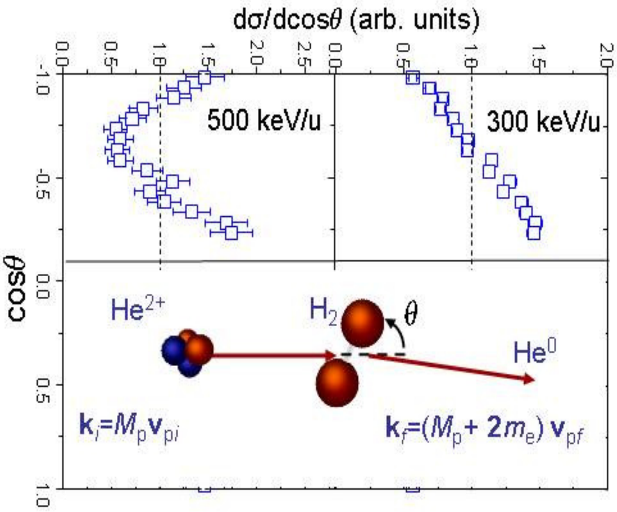
Particle-Wave Duality in Electron-Capture from Atoms and Molecules

Reinhold Schuch
Department of Physics, Stockholm University, SE 106 91 Stockholm, Sweden

The particle-wave duality, inherently fundamental to quantum mechanics, is often illustrated by double slit and diffraction experiments. In energetic atomic collisions the heavy particles and even the active electrons were successfully described as classical particles, diffraction and interference effects were usually irrelevant. Illustrative examples are the kinematic capture and Thomas mechanism, where the heavy particles seem to play billiard with the electrons to get them transferred. Clear evidence for features of this billiard type capture were seen in experiments by our group[1-2].

By means of recoil-ion momentum spectroscopy at the gas-jet target in the storage ring CRYRING we managed to separate the kinematic and Thomas processes in capture of an electron from He by a proton. The cross sections scale in the high energy limit with the projectile velocity as v^{-11} [3] as predicted by the classical Thomas mechanism.

With a molecular target, in contrary, we have seen strong interference effects of the proton or He^{++} ion capturing an electron or two from e.g. H_2 [3-5] (see inserted figure). This is the so far highest momentum where matter-wave interferences were seen. With the molecular target, the interference phenomena allow to check the localization of electron capture in terms of a double slit experiment. The outgoing hydrogen waves[3] or the He wave[5] are shown to be super-positions of contributions from the vicinities of either protons in H_2.



In view of this strong quantum interference in capture we also consider a diffraction of the de Broglie waves for the proton capturing an electron from atomic He. We find, this could also shape the angular differential cross section[6]. The experiments reported here elucidate the quantum interference in the final projectile state after reactions necessarily involving one or two active electrons in a one- and two-center scatterer.

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[5] D. Misra et al. Phys. Rev. Lett. 102, 153201 (2009)
[6] M. Gudmundsson et al. J. Phys. B43, 185209 (2010)