A collective ECC Cusp observed in Multi-electron Continua excited via Strong Field Ionization

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We have measured doubly differential ionization cross sections (DDCS) for continuum electron production from He and Ar targets via strongly perturbing projectiles $I^{23+,26+}$ and $F^{8+,9+}$. The angular distribution for multiple ionization of electrons from the target, detected in coincidence with recoiling target ions, exhibits a strong enhancement in a narrow cone around the forward direction. For high emission multiplicities electrons have condensed around the ECC Cusp; the ECC is inconspicuous for single ionization but dominates the spectrum for high emission multiplicities. Electrons emitted in the target zone with $\theta = 0°$ to $\theta = \pm 180°$ are analyzed with an electrostatic toroidal electron analyzer while recoils are extracted from the target zone with a ns-fast high voltage pulse [1]. In Fig. 1 we compare three doubly differential ionization cross sections $d^2\sigma/dv_e d\Omega_e$ for electron emission coincident with Ar recoil ions in three different final charge states between q_R=1+ and q_R=12+. The Sommerfeld parameter of the perturbation is $s = q_{Proj}/v_{Proj} = 6.1$.

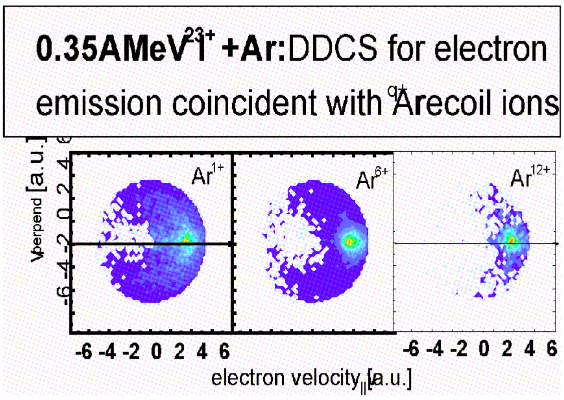

Figure 1: Coincident doubly differential cross section for 0.35AMeV I^{23+} + Ar.

Very clearly visible at $v_e = v_{Proj}$ and $\theta = 0°$ is the ECC Cusp of electrons captured into low continuum states of the projectile. In those electron spectra which are taken in coincidence with very high recoil charge states virtually all electrons not captured into bound states of the projectile have *condensed into a very low momentum continuum state of the projectile.* The observed dependence of the coincident cross sections of electrons with high multiplicities on the recoil charge state (see Fig. 2) leads to the conclusion that electron emission with high multiplicity may occur with an effectively lower momentum transfer ΔQ than single ionization.

Whereas ECC capture of a single electron from the target into a projectile of 0.35AMeV requires a momentum transfer [2] $\Delta Q_1 = v_{Proj}$ =3.75 a.u. , for n-fold transfer at least $\Delta Q_n = n(\Delta Q_1)$ is necessary.

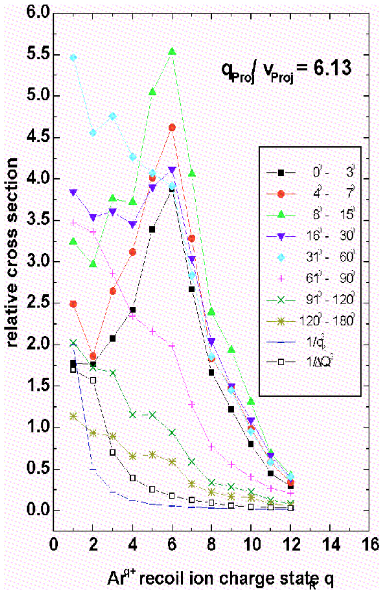

Figure 2: Coincident multi-electron emission for selected directions of emission for 0.35AMeV I^{23+} + Ar. Open squares give the estimate for minimum momentum transfer.

Thus the cross section, which in perturbation theory depends on the momentum transfer at least with $(\Delta Q_1)^{-2}$, is expected to decrease with increasing emission multiplicity, contrary to the experimental finding which shows for charge states up to $q_{Rec} = 7+$ a higher cross section than for single ionization.

A qualitative argument of a collective ECC transfer may explain the observed cross sections: the outer electrons of the Ar target are considered a quasi-free swarm of electrons interacting in the strong time dependent field of the projectile. As a result a fraction of these electrons - all initially with momentum v_{Proj} with respect to the projectile - find themselves collisionally "cooled" to nearly $v \approx 0$ barely above the continuum threshold in the projectile frame. The role of the hot evaporating electrons in this model of "capture cooling" is assumed by those electrons of the swarm which in this interaction have acquired a momentum appropriate for quasi-resonant capture into the projectile- they will be captured into bound states without a large momentum transfer.

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[1] S. Hagmann et al., to be published.

[2] J. Burgdörfer, *Lect. Notes in Physics* **213** 32 (1984), Springer Verlag, Berlin.