# 2D momentum distribution of electron in transfer ionization of helium atom by fast proton



2014 J. Phys.: Conf. Ser. 488 082002

(http://iopscience.iop.org/1742-6596/488/8/082002)

# 2D momentum distribution of electron in transfer ionization of helium atom by fast proton

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**Synopsis** 2D distribution of momentum components of the ejected electron in the reaction $H^+ + He \to H + He^{2+} + e$ at 630 keV proton is studied both theoretically and experimentally. This allows to unambiguously identify contributions from the shake-off and binary encounter mechanisms of transfer ionization. It is shown that the results are highly sensitive to the quality of the initial-state wave function.

We present the experimental 2D momentum distribution of the escaped electron in the scattering plane and the corresponding Plance Wave First Born Approximation (PWFBA) calculations. This is the most sensitive test of the theory and provides an unprecedented insight into the physical mechanisms at play. By comparing these calculations to our high-resolution experimental data, we separate ionization due to shake-off (SO) or binary encounter (BE) collision leading to distinct islands in the momentum space. These data are extremely sensitive to the initial-state correlation.

We have used the COLTRIMS reaction microscope technique to determine the momentum vectors of all final-state products. From the positions of impact on the detectors and the time-of-flight we can derive the initial momentum vectors of the $He^{++}$ and the electron. A momentum resolution of 0.1 a. u. was achieved for all particles in all directions. Energy and momentum conservation were used for off-line background suppression. Furthermore the high resolution data allow to distinguish data where hydrogen is found in an excited state from those, where the hydrogen is in its ground-state [1].

The corresponding triple differential cross section (TDCS) takes the form

$$\frac{d^3\sigma}{dk_x dk_z d\phi} = \frac{m^2}{(2\pi)^5} \int_{\theta_i}^{\theta_{i+1}} \theta_p d\theta_p \int_{-\infty}^{\infty} dk_y |T|^2. \quad (1)$$

In the presented experiments, the scattering plane $\{z, x, y = 0\}$ formed by the momentum vectors $\vec{p}_p$ ($z$-axis) and $\vec{p}_H$ is fixed in space, and we put its polar angle $\phi = 0$. Here $(\theta_i, \theta_{i+1})$ is the scattering angle domain and $(k_x, k_y, k_z)$ the electron momentum components. The PWFBA amplitude includes the matrix elements describing both shake-off and binary encounter mechanisms. One sees that the FBA even with highly correlated trial helium wave function overestimates the experiment for $k_z > 0$. We need higher Born terms to correctly reproduce this BE domain.

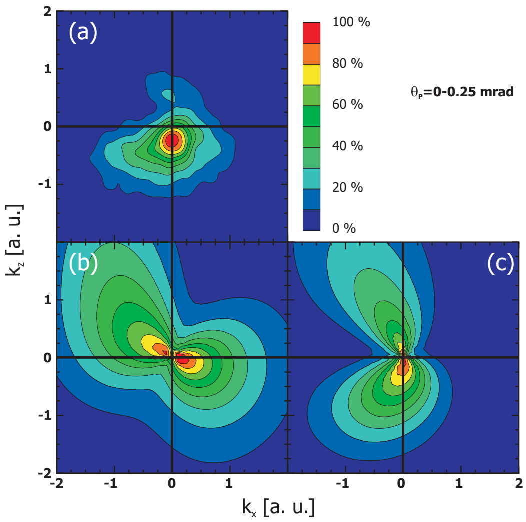


**Figure 1.** Experimental and theoretical data for 630 keV proton energy and for $\theta_p \leq 0.25$ mrad. (a) experiment, (b) calculations with $1s^2$ trial helium wave function, (c) the same with highly correlated wave function

## References

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