Projectile coherence effects in simple atomic systems

M. Schulz[1], A. Hasan[2], T. Arthanayaka[1], B. Lamichhane[1], M. Dhital[1], and R. Lomsadze[3]

[1]*Department of Physics and LAMOR, Missouri University of Science and Technology, Rolla, MO 65409, USA*
[2]*Dept. of Physics, UAE University, P.O. Box 15551, Al Ain, Abu Dhabi, UAE*
[3]*Tbilisi State University, Tbilisi 0179, Georgia*

A rich body of data on atomic collision cross sections illustrates that our understanding of the few-body dynamics even for basic processes occurring in simple atomic systems is still rather incomplete. A prominent example is offered by fully differential cross sections (FDCS) for ionization of helium by 1.2 GeV C^{6+} impact. Due to the very small projectile charge to speed ratio this collision system should be amenable to even simple perturbative approaches like the first Born approximation. Yet, qualitative discrepancies between experiment and even sophisticated theoretical models were reported [1].

A major breakthrough was achieved by the realization that the projectile coherence properties can have an important impact on measured cross sections [2]. C^{6+} ions with an energy of 1.2 GeV tend to have a very large intrinsic momentum spread due to their very small deBroglie wavelength, making the collision incoherent with respect to the effective dimension of the target atom or molecule. The impact of the coherence properties on the cross sections was first investigated by measuring double differential cross sections (DDCS) for ionization in $p + H_2$ collisions as a function of the projectile scattering angle for coherent and incoherent projectile beams. Since then a large number of experiments for a variety of collision systems and different processes have confirmed the findings of [2] that indeed collision cross sections can sensitively depend on the coherence properties, at least for low- and intermediate-energy collisions.

In this talk two recent projects investigating the role of the projectile coherence properties will be presented. In the first, FDCS for dissociative capture in $p + H_2$ collisions were measured simultaneously for coherent and incoherent projectiles [3]. In the ratio of the coherent to incoherent FDCS, which represents the interference term, pronounced signatures of molecular two-center interference were observed. However, the interference pattern is afflicted with a π phase shift which is currently not understood. In the second project coherent and incoherent FDCS were measured for ionization of He by proton impact [4]. The results show that even for a single-center atomic target the comparison between coherent and incoherent FDCS can reveal the presence of interference effects, to which we refer as single-center interference. These experimental findings were confirmed by several theoretical studies.

While for intermediate-energy proton collisions the importance of coherence effects has been demonstrated in a number of experimental and theoretical studies, further work is necessary to clarify to what extent such effects are responsible for the aforementioned discrepancies in the case of high-energy C^{6+} impact. This explanation did not go unchallenged and critical views will also be addressed.

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