Study of dissociative capture in p+H_2 collisions using COLd Target Recoil Ion Momentum Spectroscopy (COLTRIMS) and its application to sterile neutrino search

B R Lamichhane[1,2 *], T P Arthanayaka[2], A Hasan[3], M Dhital[2], T Voss[2], R Lomsadze[4], and M Schulz[2 †]

[1] Department of Physics, Temple University, Philadelphia, Pennslyvania, 19122, USA
[2]Department of Physics, Missouri University of Science and Technology, Rolla, Missouri, 65409, USA
[3]Department of Physics, UAE University, P.O. Box 15551, Al Ain, Abu Dhabi, United Arab Emirates
[4]Tbilisi State University, Tbilisi 0179, Georgia

Synopsis We study fully differential cross-sections (FDCS) for the dissociative single capture and Coulomb explosion through double capture in p + H_2 collisions. In this study, we used projectile coherence effects as a tool to sensitively analyze the few-body dynamics of the scattering processes.

The key role of the projectile coherence properties has been studied in several ion-atom scattering processes [1-4], which suggested that cross sections could be significantly affected by these properties, especially for fast, heavy ions. To this end, kinematically complete experiments were performed using COLTRIMS to study the fragmentation of H_2 by 75 keV proton impacts. Three fragmentation channels were studied as illustrated in Figure 1. The first channel proceeds through vibrational excitation of the nuclear motion, in which, dissociation of H_2 proceeds through vibrational excitation to a continuum state. The second pathway is a capture of one electron accompanied by excitation of the second electron to a repulsive electronic state. The third path is Coulomb explosion induced by double capture where an H^- projectile ion is generated.

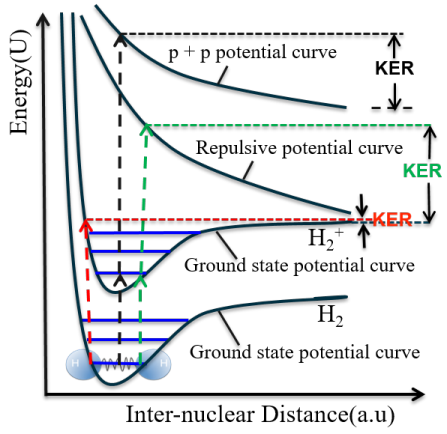

Figure 1. Transitions shown by red, green, and black color indicates vibrational dissociation, dissociation due to electronic transitions, and Coulomb explosion due to double capture simultaneously.

A novel approach was used to analyze coherence and interference effects in the observed cross-sections. The idea was to measure cross sections for coherent and incoherent projectiles simultaneously under otherwise identical experimental conditions.

FDCS were extracted for a fixed kinetic energy release and for two different fixed molecular orientations as a function of scattering angle. The coherent to incoherent FDCS ratios, which represents the interference term, revealed two distinct types of interference, single- and two-center interference. In the first fragmentation channel, an unexpected phase shift of π was found in the pronounced oscillations observed in the interference term. In the other two channels, no clear signatures of single-center interference were observed for either process. Two-center interference was identified for dissociative transfer excitation and no π phase shift was observed for this process. Only a very weak two-center interference structure at most was found for double capture.

The COLTRIMS technique, which provides a coincident multi-fragment imaging method for eV and sub-eV fragment detection has many applications in physics. The Heavy Unseen Neutrinos from Total Energy-Momentum Reconstrution (HUNTER) collaboration is utilizing COLTRIMS in a sterile neutrino search experiment using 131-Cs in a magneto-optical trap [5].

References

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* E-mail: basu.lamichhane@temple.edu
† E-mail: schulz@mst.edu