JAN 02 1991

PNL-SA--18538

DE91 005557

CORRELATIONS BETWEEN CHARGED
PARTICLES EMITTED IN ION-
MOLECULE COLLISIONS

R. D. DuBois
R. Herrmann^(a)
J. Feng^(b)
R. Dörner^(a)
J. Euler^(a)
K. Ullmann^(a)

September 1990

Prepared for the
Vth International Conference
on the Physics of Highly
Charged Ions
Giessen, West Germany
September 10-14, 1990

Work supported in part by the
Office of Health and Environmental
Research (OHER), U.S. Department
of Energy under Contract
DE-AC06-76RLO 1830 and the Fulbright
Commission and the Bundesminister
für Forschung und Technologie
grant 060F/73 (741336476)

Pacific Northwest Laboratory
Richland, Washington 99352

^(a)Institute für Kernphysik
University of Frankfurt
West Germany

^(b)University of Lanzhou
Lanzhou, Gansu
Peoples Republic of China

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Abstract:

A new experimental apparatus for studying correlations between charged particles emitted in ion-atom collisions is described. The apparatus consists of two channelplate detectors, each equipped with position sensitive anodes. Time correlated events in both detectors provide information about correlated charged particle emission. Initial test studies of dissociative double ionization for H_2 and N_2 targets are reported here.

I. Introduction:

From numerous experimental and theoretical studies during the past decade it is well established that multiple ionization of target atoms, particularly for highly charged ion impact, is a common event. This results in the emission of two, or more, electrons. For molecular targets, the emission of two or more electrons can also result in the creation of energetic ionic fragments due to coulomb explosion of the resultant molecular ion. In all cases, investigating the energy and angular distributions of the emitted particles can be used to study multi-electron transition events.

In the case where only two particles are emitted, identifying and studying these events can be done by looking for correlated signals recorded by two detectors that can be positioned relative to each other. Unfortunately this typically means extremely small signal rates because of solid angle limitations for each detector. Thus an obvious way to improve the signal rate is to increase the detection solid angle while still maintaining a reasonable energy and angular resolution.

II. Experiment:

At the University of Frankfurt we have constructed an apparatus which is capable of detecting charged particles emitted into a solid angle of nearly 1.5π for each of two detectors. By using two-dimensional position sensitive anodes, information about the angular distributions of the emitted particles can be preserved. The apparatus, as used for test studies involving dissociative ionization of H_2 and N_2 , is shown schematically below.

The detectors (D1 and D2) are located at plus and minus 90° with respect to the beam direction. A point source target, approximated by a gas jet, is located between the two detectors. Due to physical restrictions, the detectors could not be positioned closer to the beam path. Thus an ion transport system (T) was used to increase the solid angle with respect to what could be achieved due to physical limitations. By applying a negative voltage to the transport system, low energy ions emerging from the target region through the first grid could be swept towards the detector. Thus particle emission between roughly 15 and 165° in both the theta and phi directions could be detected. Hence the probability of detecting correlated events is rather large, provided that the particles are emitted into opposite hemispheres.

Data were collected in the following fashion. Low intensity, collimated beams of H^+ and He^+ ions passed through the target region, thus inducing target ionization. The projectile beam was then charge state analyzed and one of the components was deflected onto a movable surface barrier detector. Amplified and discriminated signals from this detector served as stop pulses for two time-to-amplitude

converters with the start signals being the target ions detected by either detector 1 or 2. Thus time-of-flight spectra were recorded for each detector.

In principle, energy information is obtainable from these time-of-flight spectra. However locating the detectors as close as possible to the beam axis in order to maximize the detection solid angle meant sacrificing time-of-flight energy information. It is possible however to identify energetic (eV) fragment atomic ions resulting from dissociative ionization events from low energy (meV) molecular ions resulting from simple ionization of the molecule. This is demonstrated in the following figures for 0.5 MeV H^+ and He^+ impact on H_2 .

Time-of-flight spectra were collected in List Mode fashion for both detectors and stored in a computer. By replaying the experiment, time correlated events between the two spectra could be investigated. An example of this is shown in the next figure where events detected by detector D2 were searched with the condition that they were time correlated with the energetic atomic ions (H^+ ions) detected by detector D1. These events are directly proportional to the dissociative double ionization cross section of H_2 .

In principle, the angular distributions of these correlated events are available due to the two-dimensional detection used, but for the examples shown limited statistics prohibited investigating this feature.

III. Conclusions:

The capabilities of investigating correlated charged particle emission have been demonstrated. Using dissociative ionization of molecular hydrogen and nitrogen as a test example, it was found that dissociative ionization with respect to simple ionization of the molecule is too small to be studied using the present device. However, for He^+ impact adequate intensities were obtained. Therefore, experimental studies, including investigating the angular distributions, using highly charged ion impact appear to be feasible.

Experimental difficulties that need to be overcome or improved upon include a better approximation to a point source. The simple hypodermic needle used does not provide an adequate target/background gas ratio. The test data also showed that weak electric fields were present in the target region; these fields influence the very low energy molecular ion emission which are useful for normalization purposes. Lastly, the field configurations of the ion transport systems need to be altered to eliminate possibilities of secondary electrons created along the flight path between the target region and the detector from reaching the other detector.

Acknowledgments:

This work was funded in part by the Office of Health and Environmental Research (OHER) under contract DE-AC06-76RLO1330, the Fulbright Commission and the Bundesminister für Forschung und Technologie grant 060F/73 (741336476).

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