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INELASTIC CROSS SECTIONS FOR POSITRON SCATTERING FROM ATOMIC HYDROGEN

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ABSTRACT:

Positronium formation (Ps) cross sections for positrons impinging on atomic hydrogen were measured in the impact energy range from $13eV$ to $255eV$ at the High Intensity Positron (HIP) beam at Brookhaven National Laboratory (BNL). The Ps-formation cross section was found to rise rapidly from the threshold at $6.8eV$ to a maximum value of $(2.98 \pm 0.18) \times 10^{-16} cm^2$ for $\approx 15eV$ positrons. By $75eV$ it drops below the detection limit of $0.17 \times 10^{-16} cm^2$ which is the present level of statistical uncertainty. The experiment was modified to enable the measurement of doubly differential scattering cross sections.

An apparatus was designed to measure inelastic scattering cross sections of positrons impinging on gaseous targets. In a central interacton region a beam of positrons intersects a beam of atomic hydrogen. With this "crossed beams" apparatus angle integrated partial cross sections for impact-ionization, resulting in a free proton, a positron, and an ejected electron, as well as for positronium (Ps) formation have been measured[1,2]. Most recently the experiment was rebuilt for the investigation of doubly differential cross sections of impact-ionization and eventually of differential elastic cross section.

Molecular hydrogen is dissociated in a Slevin-type gas discharge tube[3]. Through a thin nozzle the gas beam is directed into the interaction region. An electric field accelerates ions towards a quadrupole mass analyser (QMA), and only ions of a selected mass are detected by a channeltron electron multiplier (CEM 1) at its end. Ionization events involving H_2 can be discriminated against from the background gas with the use of the QMA. The electrostatically guided projectile beam passes through the target gas beam at a right angle. Positrons[4] as well as electrons can be used as the projectiles. The unscattered projectiles and those scattered into a forward cone of 30° apex angle are focussed onto a second detector (CEM 2) to evaluate relative cross sections dependent only on the target geometry and the gas density, both of which are kept constant during the measurements.

In addition to the two detector rates, the times between CEM 1 and CEM 2 events are recorded in an "inverted time-of-flight" spectrum. The total number of counts in its peak are proportional to the impact-ionization cross section. They will be referred to as the time correlated counts.

The ion event rate at CEM 1 is accumulated in the ion counter It is proportional to the sum of Ps-formation and impact-ionization cross sections. After comparing the relative detection efficiencies of the correlated counting method to that for total ion counting at high energies (above 100eV) Ps-formation events can be separated from the total ion rate. A more detailed description of the data analysis can be found in Weber *et. al.* [5].

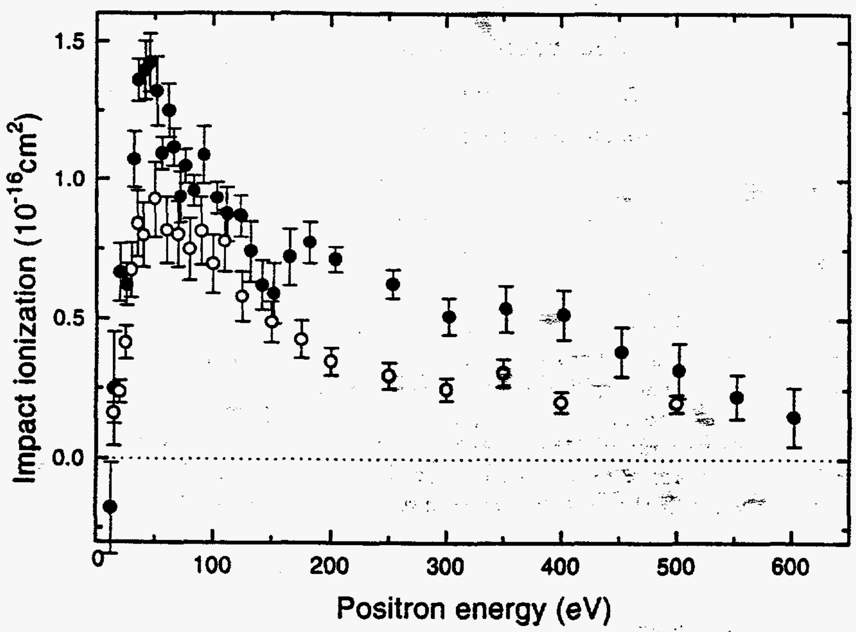

Figure 1 — Impact-ionization cross section. The reevaluated impact-ionization data of Spicher *et. al.* combined with the new data from this work (•) and the cross sections as measured by Jones *et. al.*[7] (∘).

Electron data are taken with the same apparatus and compared to published values by Shah *et. al.*[6] to obtain absolute cross sections. The cross sections for impact-ionization are displayed in figure 1 together with those by Jones *et. al.*[7]. In figure 2 the cross section for Ps-formation is displayed along with several theoretical results. The displayed uncertainties are purely statistical. Systematic errors and those due to the normalization procedure are estimated to 17.5% including an uncertainty of 6.8% in the electron data by Shah *et. al.*[6]. It should be noted that many theoretical results only calculate Ps-formation in its ground state while these measurements include all states.

The method of indirectly measuring the Ps-formation cross sections is handicapped by two systematic effects. It is possible that Ps is formed and scatteres forward to the projectile detector CEM 2. If detected it would appear as an impact-ionization event. Checks revieled that within the statistical accuracy of the experiment no such events were noticable.

Below about 100eV impact energy not all scattered positrons are detected at CEM 2. to prevent an underestimation of impact-ionization a correction based upon an integration of results from the First Born Approximation was made. The theoretical group in Toronto, Canada, has recently evaluated $f(E)$ based based on their more elaborate work[13]. At

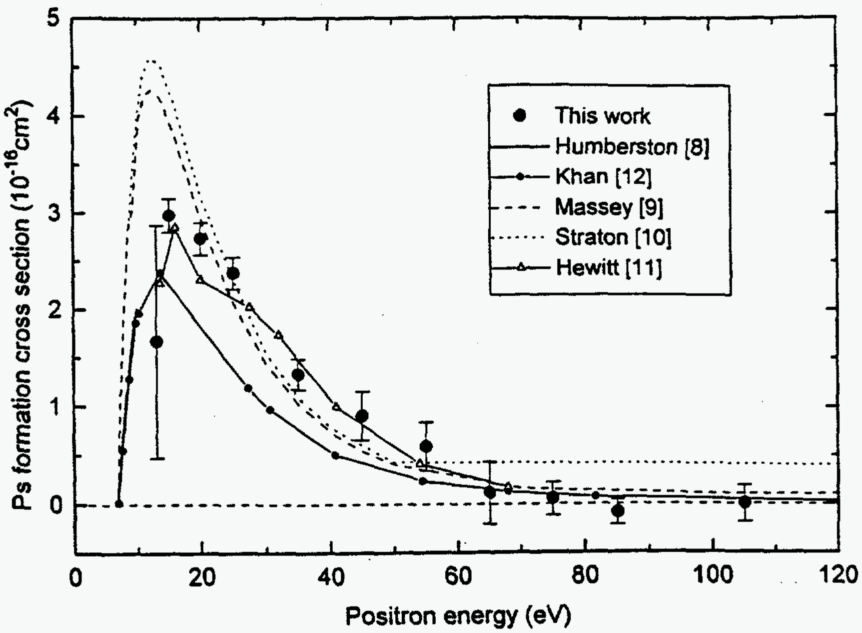

Figure 2 — Ps-formation cross section with some theoretical results. (•) denote the present results, (——) is the Kohn variational work by Humberston[8], (- - -) is the first Born result of Massey and Mohr[9], (······) field theoretical work by Straton[10], (—Δ—) stems from Hewitt's[11] close coupling calculations and finally (—·—) from Khan's work[12].

impact energies below the ionization threshold, however, only Ps-formation is possible and no correction needed.

A considerable effort was made to upgrade the experimental apparatus. A schematic is shown in figure 3. It is now possible to determine differential scattering data. The elastic cross section as well as the impact-ionization cross section will be measured. To date it was possible to check the apparatus and confirm its working conditions with an electron beam. The scattering region has been changed to a drum-like geometry. A third channeltron CEM 3 with a cylindrical energy analyser and can be rotated around the gas beam axis. Angles from −35° through 0°, the primary beam axis, to 100° are possible. The hydrogen beam can be interrupted by a beam-flag. Measurements of the "old" angle integrated type are still possible making comparisons possible. It is hoped to obtain differential positron scattering data in the near future.

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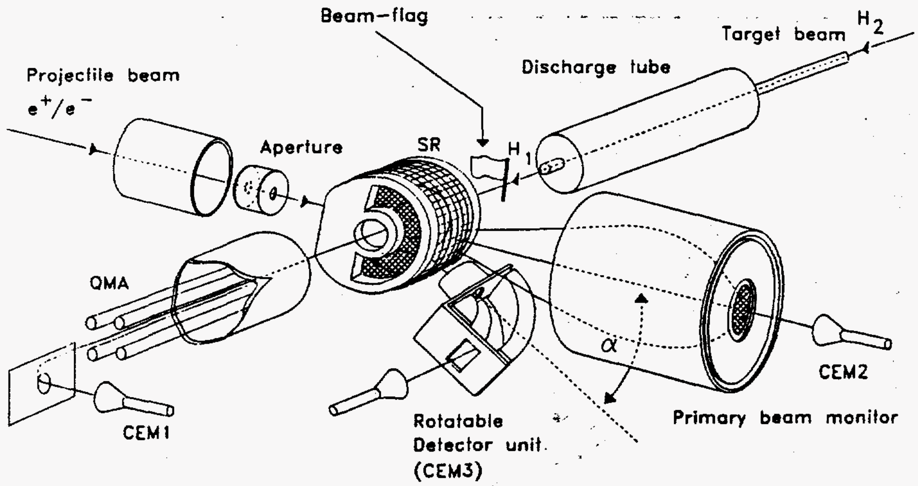

Figure 3 — The differential scattering apparatus. The positron beam passes a beam geometry limiting aperture before entering the scattering region. Around this a channeltron (CEM 3) with a cylindrical energy analyser can be rotated from −35° through the primary beam axis at 0° to 100°. The beam of atomic hydrogen emanates from a RF discharge tube and intersects the positron beam in the scattering region at a right angle. It can be interrupted with a beam-flag. Generated ions are extracted from this region by a weak electric field towards the quadrupole mass analyser and it channeltron (CEM 2). The primary positron beam is monitored at channeltron CEM 1.

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