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A Search for Wigner Cusps and Resonances in Positron Scattering by Atoms and Molecules

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Synopsis: Detailed elastic cross-section measurements in the vicinity of the positronium (Ps) formation threshold for He, Ne, Ar, Kr and Xe show a cusp-like feature, made visible by a small and localised depression of between (2 to 15%) of the cross-section value. Other near-threshold structures such as scattering resonances have been demonstrated in close-coupling and convergent-close-coupling calculations for helium. This investigation is undertaken to explicitly search for the presence or otherwise of scattering structures using a high efficiency (~ 1 % statistical uncertainty) and high resolution (< 70 meV) transmission based apparatus.

In 1948, Wigner showed that, in principle, abrupt changes should appear in all scattering cross-sections which are open below the threshold of a new scattering channel [1]. The probability of observing a Wigner cusp or simply a "cusp" in practice depends, amongst other things, on the rate-of-increase of the cross-section for the newly opening channel. Positronium (Ps) formation appears to be a perfect case as the cross-sections rise rapidly in the near-threshold region.

Recent, detailed high resolution measurements of the elastic cross-section for positron scattered by helium and heavier rare gases by our group have shown a cusp-like feature very close to the Ps formation threshold for all the rare gases [2, 3]. Each cusp manifests as a small, but rapid, reduction of the elastic cross-section (up to 15%). This 'absorption' effect is attributed to cross-channel-coupling between the elastic and Ps formation channels.

In the case for positron-helium interactions, resonant-like structures have been reported by two successful theories, namely, the Close-Coupling (CC) calculations of Campbell et al. [4] and the Convergent Close-Coupling (CCC) calculations of Utamuratov et al. [5]. In both cases these resonance-like features are found in the 2\(^1\)S and 2\(^3\)P excitation cross-sections, between the 2\(^3\)P(21.2 eV) and the 3\(^3\)S(22.9 eV) excitation thresholds. In the case of the CCC theory, these structures are reported to rise approximately 10% above the background cross-section. The beamline at the ANU is perfectly poised to investigate the existence or otherwise of these structures and other possible threshold effects.

References


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