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Experimental evidence for Young's interference effects in autoionization following 30 keV He^{2+} + H_2 collision

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Abstract. The emission of electrons from autoionizing He^{**} outgoing projectiles formed in a double capture 30 keV He^{2+} +H_2 collision has been analysed at detection angles ranging from 90° up to 162°. The autoionization cross section differential in the angle is found to oscillate. This result is attributed to a Young interference mechanism produced by the postcollisional interaction of the emitted electron with the two-centre exploding H^+ + H^+ residual target.

1. Introduction
Recently, post-collision interaction effects in the autoionization of doubly excited He** atoms in slow He^{2+} + H_2 collisions have been studied theoretically [1]. Oscillations in the angular distributions of the electrons emitted by the projectile were reported and attributed to Young's interference effects due to the interaction of the emitted electron with both H^+ residual target centres. In the present work we provide the first experimental evidence of this kind of interference pattern.

2. Experiment
The present experiment was performed at the Grand Accélérateur National d'Ions Lourds (GANIL) in Caen, France. The scattering chamber and the electron spectrometer have been described previously in full detail [2]. Here, a $^3He^{2+}$ ion beam with a kinetic energy of 30 keV collided with an effusive gas jet of H_2 molecules. Under the present conditions of target and projectile densities (~2 x 10^{11} cm^{-3} and 10^5 cm^{-3}, respectively) a single-electron condition can be assured, since the probability that two autoionization electrons from different projectiles scatter on a given H_2^{2+} residual target is exceedingly small. The emitted electrons were detected with an electrostatic parallel-plate analyser, and sorted as a function of their energy and emission angle [2]. Typical low-resolution energy distributions at observation angles of 160°, 90° and 20° are shown in figure 1. The continuously decreasing contribution originates from the direct ionization of H_2 while the superimposed structures are related to the autoionization of the He outgoing projectiles following the production of doubly excited states. Since the Auger electrons originate from moving emitters, they are influenced by

kinematics. This Doppler effect leads to a shift of the peaks associated with the projectile when changing the observation angle. The contributions originating from different autoionization states can be clearly separated at large angles. For instance, at 160° in figure 1, three different peaks are observed corresponding to $2s^2$, 2ℓ2p and 2ℓnℓ' (n ≥ 3) states, from left to right, respectively. Since the fluctuations of the beam intensity and the target density are less than ~0.3%, only the statistical uncertainties were taken into account. Whatever the detection angle, they were found to be less than 2.5%, except at electron energies larger than those found for autoionization, where they can reach ~4%.

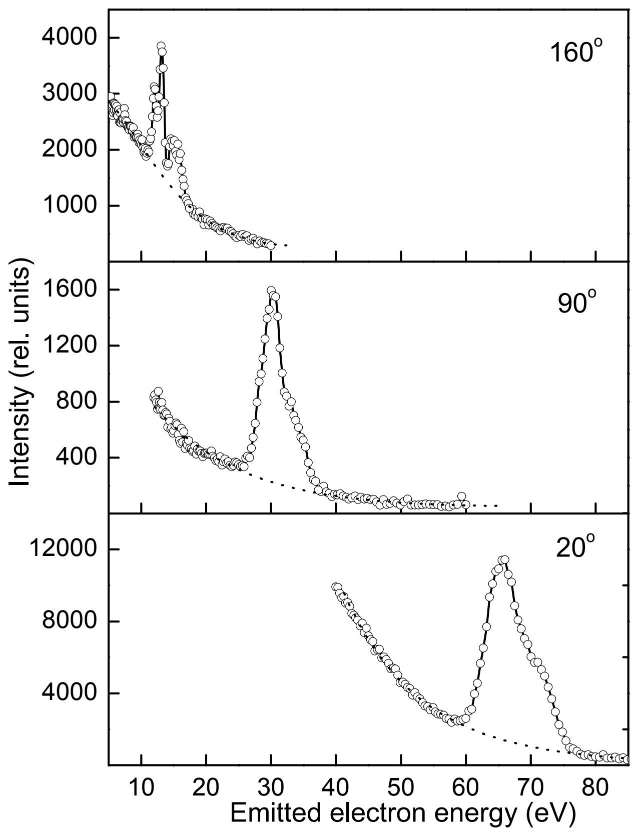

Figure 1. Energy distribution for electron emission in 30 keV $^3He^{2+}$ + H_2 collisions, at detection angles of 20°, 90° and 160° with respect to the incident beam direction. The intensity and the electron energies are given in the laboratory frame.

The autoionization contributions in these spectra were singled out by subtracting a polynomial function fitted to the direct ionization background. Finally, the resulting spectra were integrated over the emitted electron energy to obtain the angular differential cross sections for the total autoionization of the He outgoing projectiles. Figure 2 shows this cross section as a function of the detection angle in the range 90° – 162°.

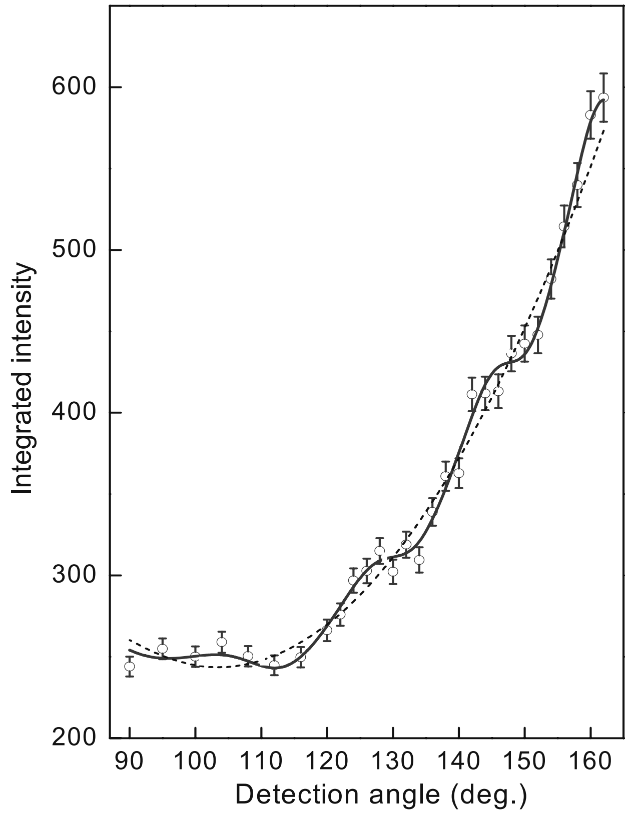

Figure 2. Total intensity for autoionization following double electron capture in 30 keV $^3He^{2+} + H_2$ collisions, as a function of the detection angle. The full curve corresponds to a fitting by the sum of a second-order polynomial (dashed curve) and a Bessel function. The curves are only intended to guide the eye and emphasize the visibility of the interference pattern.

3. Results and conclusions

A careful inspection of the data in figure 2 shows clear evidence of up to four oscillations superimposed on the main dependency. The period of the oscillations is found to be close to the theoretical estimate [1]. The experimental observation of this interference pattern provides an unprecedented realization of the famous Feynman “thought” experiment [3], by showing that a single electron interferes with itself while passing an atomic-size Young-like two-centre system.

Acknowledgments

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