The 1s Lamb Shift in H-like Uranium Measured on Cooled and Decelerated Ion Beams

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By using intense beams of cooled and decelerated uranium ions, the ground-state transition energies of hyrogenlike uranium were measured in an x-ray spectroscopy experiment conducted at the ESR gas-jet target (Fig. 1). The main purpose of this study is the *accurate* determination of the binding energy of the 1s level where effects of QED are strongest. Here we report on the current status of the data evaluation of this experiment exploiting the deceleration capability of the ESR storage ring for the first time in such investigations. For a detailed description of the experimental techniques used we refer to Ref. [1].

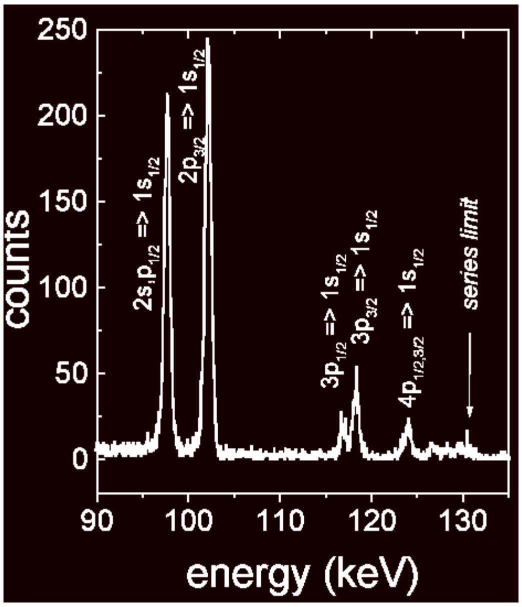

Figure 1: The ground-state transitions in H-like uranium as observed at 48^O by one strip of the segmented detector: The spectrum was recorded at a beam energy of 68 MeV/u.

For the experiment, the gas-jet area was surrounded by four Ge(i) x-ray detectors mounted at observation angles of 48^0, 90^0, and 132^0 with respect to the predicted ion-optical beam axis whereby at 48^O and 90^O segmented x-rays detectors were used. When knowing precisely the relative angles between all the detectors the individual position of each x-ray detector can be determined by assuming that the origin of the radiation is the same for all detectors. This procedure is required, as the absolute position of the interaction zone between gas jet and ion beam is not precisely known.

The whole detector arrangement, i.e. the detector positions relative to each other, were measured by laser assisted trigonometry just before and after the experiment. From a comparison of both measurements, a mean angular stability of the set-up of 0.015^O was deduced. Beside the mechanical stability, the control over possible electronic drifts was most important. For this purpose, all detectors were calibrated frequently during the experiment by using ^{169}Yb and ^{182}Ta standard calibration lines. For the data analysis, the collected data were subdivided into various groups and evaluated separately. Thereafter, the centroid energies of the ground-state transition lines of each detector were fitted with Gaussian distributions. Since the line shapes might be influenced by the Doppler effect, the appropriateness of the applied fit procedure was checked by Monte Carlo calculations. Typically, an accuracy for the determination of the centroid energies of 10 to 20 eV was achieved. The latter turned out to be limited by calibration uncertainties rather than by counting statistics. Finally, the centroid of the Lyα transitions in the projectile frame were determined. by means of an uncertainty minimizing procedure, including all centroid energies of the individual segments at the various observation angles and considering the known relative positions of each detector. For the case of the Lyα_1 transitions, the resulting uncertainties are given in the table. Also, the uncertainty in the knowledge of the absolute beam velocity has to be considered. As it has been established recently, the latter is caused by a systematic uncertainty in the cooler voltage of 10 V, leading to an $\Delta\beta/\beta = \pm1.7\times10^{-4}$ at 49 MeV/u and of $\Delta\beta/\beta = \pm1.2\times10^{-4}$ at 68 MeV/u. However, the latter affects only slightly the overall accuracy of the experimental results (see Table 1).

Table 1: *The preliminary result for the energy of the Lyα_1 line of U^{91+} along with its experimental uncertainties. All values are given in eV.*

	geometry	**$\Delta\beta$**	**fit**	**Lyα_1**
49 MeV/u	±8	±3	± 13.2	102 162 ± 15.7
68 MeV/u	±9	±2.3	± 14.3	102179 ± 17.0
Mean value	±8.5	±2.6	± 9.7	102170 ± 13.2

Table 2: *Preliminary experimental Lamb Shift value for the 1s ground-state in H-like uranium in comparison with the theoretical prediction.*

experiment	469 eV ± 13 eV
theory	465.9 eV [2]

The preliminary experimental result for the Lyα_1 transition energy and the deduced 1s Lamb Shift value is summarized in the tables. It agrees well with the most recent theoretical prediction [2,3] and with a former experiment conducted at the electron cooler device [4] where an absolute precision of ±16 eV was achieved. In order to obtain a significantly improved precision, future experiments must focus on the application of high-resolution x-ray detection devices such as crystal spectrometers or bolometers which presently are under construction. Currently, also the potential of the absorption-edge technique [5] is being investigated.

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