Spectroscopy of Ly-α Lines at Storage Rings by Absorption-Edge Technique

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QED is very well tested in the case of light atoms. However, a test in the strong-field domain of highly charged heavy atoms with strongly pronounced higher order effects in $\alpha \cdot Z$ is still missing.

Sophisticated experiments have been devised to test QED in the high-Z region by the accurate determination of the ground-state Lambshift in hydrogenlike ions which recently has been calculated with an accuracy of the order of 10^{-5} of the ground-state binding energy of typically ($60 - 130$) keV [1]. The experiments are aimed to measure the Ly-α energies with comparable accuracy and therefore require instruments with high spectral resolution in the hard x-ray region. The absorption-edge technique fulfills this condition as has been demonstrated by a preliminary experiment [2, 3]. The experimental uncertainties of that "one-detector experiment" introduced by the Doppler-effect can be reduced by a measurement at several ion velocities β, x-ray observation angles Θ and absorbers.

The Doppler shift continuously depends on the ion velocity β and the angle of observation Θ while the energies of the K-edges discretely vary with the atomic number of the absorber. Since only a few fixed angles of observation at the gasjet target of the ESR are accessible, the number of suitable combinations of β, Θ and absorbers for a measurement on a certain ion is strictly limited.

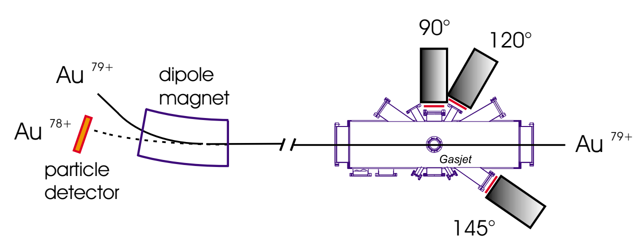

Figure 1: Experimental setup for the absorption-edge technique. Three position-sensitive drift chambers measure - in coincidence with downcharged ions - the intensity variations resulting from the shift of x-ray energies of H-like Au^{78+} which are due to the angle-dependent Doppler-effect over the absorption edges of heavy absorbers.

In the case of hydrogenlike gold such a combination could be found for $\beta = 0.253$ and 0.4196, $\Theta = 90°$, $120°$ and $145°$, and Sm, Tb, Ho, Tm, Lu and Ta as absorbers. The setup of an experiment performed in August 2000 is shown in Fig. 1. In this experiment, three position-sensitive drift-chambers [3, 4] were used for the measurement of the intensity variation of the Ly-α2 line across the K-edges of the absorbers due to the angle-dependent Doppler shift. The line with the sharp peak at the right in

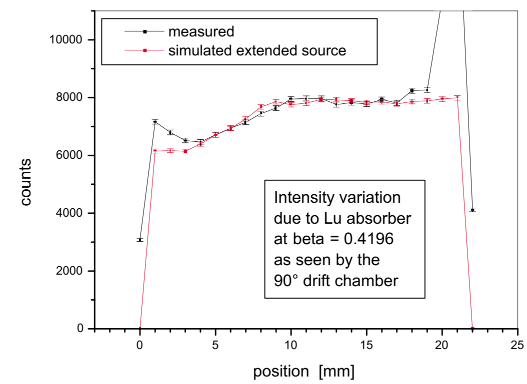

Figure 2: Measured and simulated intensity variation of the Ly-α2 line along the Lu absorption edge at 90° emitted by H-like Au ions at $\beta = 0.4196$. The sharp peak results from the inner geometry of the drift chambers. The calculation corresponds to an extended source.

Fig. 2 shows the experimental result for $\beta = 0.4196$ and $\Theta = 90°$ with Lu as absorber. Plotted is the observed intensity along the horizontal coordinate in the central plane of the detector, integrated over height and depth. The peak results from geometrical effects of the detector.

In order to analyse the experimental data, a program has been written which simulates the intensity variation of the detected photons. Here, the energies, widths and steps of the K-edges are fixed and the only free parameters are the observation angle Θ, the size of the emitting volume and the photon energy in the rest frame.

The line without sharp peaks in Fig. 2 shows preliminary results of the simulations for a 2 mm in diameter and 5 mm long emitting volume assuming $\Theta = 90°$ and the theoretical energy of the Ly-α2 transition [1] in comparison with the experimental data. Since the width of the observed absorption edge is sensitive to the spatial distribution of the emitting volume, it turns out that the extended source is close to the chosen values. The final results will be obtained from a combined fit of the simulations to the experimental data for all K-edges observed.

References

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