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Novel approach for studying two-photon transitions in heavy HCI

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Synopsis In this contribution, we report on an experimental approach which allowed for a background-free measurements of the two-photon spectral shape. A number of advantages over conventional techniques lead to the ability for the first time to experimentally disentangle relativistic and non-relativistic theories with an excellent agreement to the first one.

In the early days of quantum mechanics Maria Göppert-Mayer formulated [1] a non-relativistic theory of two-photon process for hydrogen, which was later refined for the $1s2s\,^1S_0 \rightarrow 1s^2\,^1S_0$ two-photon decay in helium by Breit and Teller [2]. Since than the study of this second order transition has been of particular interest for both theory and experiment. The study of two-photon transitions (2E1) in He-like heavy ions is of particular interest due to the sensitivity of its spectral shape to electron-electron correlation and relativistic effects [3]. Numerous experimental and theoretical (references in [4]) studies have attempted to explore this process, however due to a lack of experimental accuracy, sensitivity to relativistic effects on the two-photon spectral distribution has not yet been achieved.

We developed a novel experimental approach for studying such transitions in few-electron high-Z ions. In this approach, few-electron ions with a selectively produced hole in the K-shell are used for the investigation of the transition modes that follow the decay of the excited ions. It was found that K-shell ionization is a very selective process that leads to the production of only two excited states, namely the $1s2s\ 2^1S_0$ and $1s2s\ 2^3S_1$. This can be directly applied for studying accurately the two-photon decay in He-like ions. Up to now, the experimental method in conventional $2E1$ experiments has been the photon-photon coincidence technique, which is required to separate the true $2E1$ events from the x-ray background associated with single photon transitions. In contrast, by exploiting the state selectivity of K-shell ionization, the spectral distribution of the two-photon decay could be obtained simply by a measurement of the photon emission, using only a single x-ray detector in coincidence with projectile ionization.

The method allowed for a background-free measurement of the distribution of the two-photon decay ($2^1S_0 \rightarrow 1^1S_0$) in He-like tin.

Excited He-like heavy ions were formed by K-shell ionization of initially Li-like species in collisions with a low-Z gas target, and x-ray spectra following the decay of the He-like ions were measured in coincidence with the up-charged tin ions. It is shown that for the first time a sensitivity to relativistic effects on the two-photon decay spectral shape was achieved and additionally it was possible to discriminate the measured spectrum for Sn from theoretical shapes for different elements along the He-isoelectronic sequence [5].

References

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