Exotic Radiative Decay Modes in Heavy Few Electron Ions

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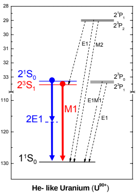
Introduction and motivation

In relativistic collisions with gaseous targets the process of *K*-shell ionization of Li-like high-*Z* ions has proven to be a highly-selective mechanism for the population of excited (*n*=2) *s*-states [1]. This process allows one to measure the undistorted two-photon energy distribution for the 2E1 decay of the [1s2s] ($^1S_0$) state, which is of particular interest for a decisive test of theoretical predictions. Extending our previous experiment on He-like uranium to the medium-*Z* regime, we present first data of the two-photon decay energy distributions in He-like tin (Z=50). Further, these investigations were extended to initially Be-like uranium allowing us to produce almost exclusively the $1s(2s)^2$ level in the Li-like species which is expected to undergo predominantly an exotic two-electron one-photon (TEOP) decay. Recently at low-*Z*, similar studies have been performed for Li-like aluminum ions [2] and for the process of dielectronic recombination [3]. The decay properties of the $1s2s^2\ 2S_{1/2}$ state are of particular interest for atomic structure investigations because of the sensitivity of the TEOP transition to electron correlation.



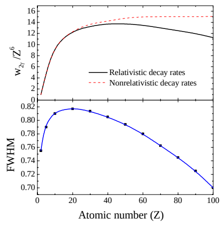
2S states in the He-like ions can decay to the ground state by the following transitions:

M1: ($2^3S_1 \rightarrow 1^1S_0$) – magnetic dipole transition

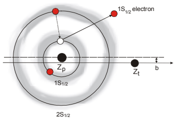
2E1: ($2^1S_0 \rightarrow 1^1S_0$) – two-photon transition

Comparison of the relativistic and nonrelativistic decay rates for the 2^1S_0 state [4].

Full width at the half maximum of the two-photon energy distribution of the 2^1S_0 state as function of Z [5].

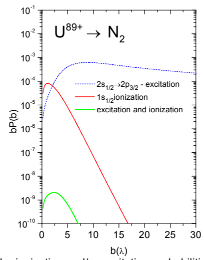


Production of excited states by ionization (gasjet target) [6].



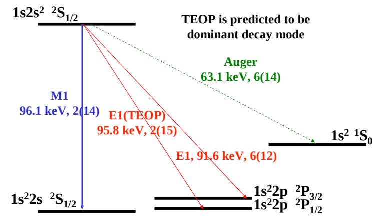
Probability for a simultaneous ionization and excitation:

$$p_{nlj}^{ion-exc}(b) \approx p^{ion}(b)\, p_{nlj}^{exc}(b)$$

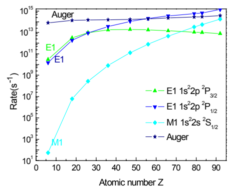


The ionization and/or excitation probabilities as a function of an impact parameter b(λ-Compton wavelength) [7].

Decay modes of the $1s2s^2\ ^2S_{1/2}$ in U^{89+}
The Two-Electron One-Photon Transition (TEOP) [8].

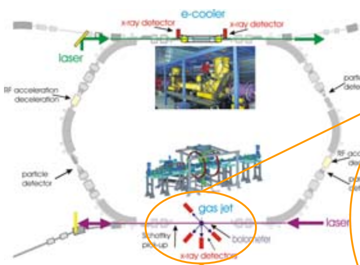


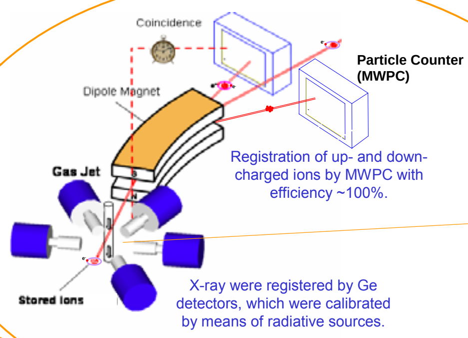
- In low Z region (Z<30), Auger decay is a the dominant decay channel. The Auger rate is nearly constant along all the sequence.
- In the range of 30<Z<80, the E1 TEOP decay to the $1s^22p\ ^2P_{1/2}$ becomes as important as the Auger decay.
- At *Z* close to 90, the M1 decay to $1s^22s\ ^2S_{1/2}$ becomes also very important.



Decay rates for the $1s2s^2$ state, as functions of atomic number [8].

Experimental setup at the ESR storage ring





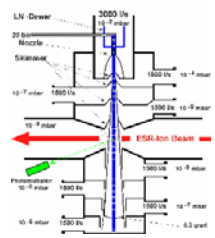
Registration of up- and down-charged ions by MWPC with efficiency ~100%.

X-ray were registered by Ge detectors, which were calibrated by means of radiative sources.

The time coincidence information between x-rays and up-, down-charged particles was used to separate different radiative processes, such as radiative capture, ionization and excitation of the projectile.

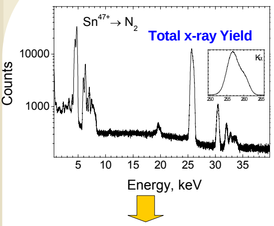
No x-x coincidence

Gasjet target

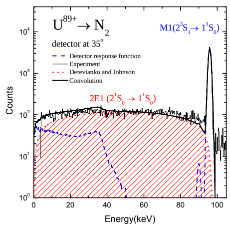


Gas target areal density of about 10^{12} particles/cm².

Two-photon decay (2E1)



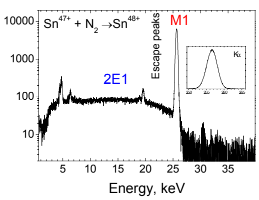
Coincidence registration of x-rays and down charged ions (He-like)



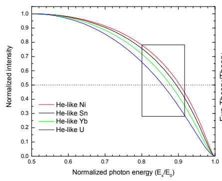
Comparison of the two-photon energy distribution with fully relativistic calculation [5].

The continuum is caused by the **2E1** decay of the **[1s2s]** $^1S_0$ state whereas the Kα line results from the **M1** decay of the **[1s2s]** $^3S_1$ level

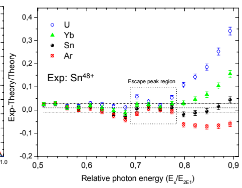
The experimental technique allows one to measure the spectral distribution with enough precision to disentangle different elements



Preliminary x-ray spectra recorded at the observation angle of 35⁰ for 300 MeV/u $Sn^{47+} \rightarrow N_2$ collisions

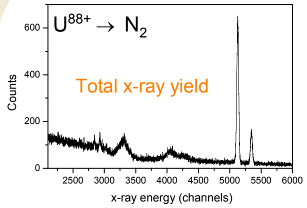


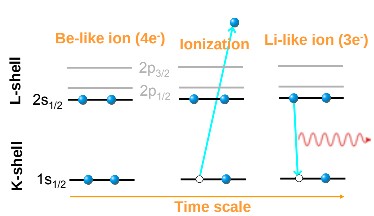
Fully relativistic calculations for the two-photon energy distribution for He-like ions [9].



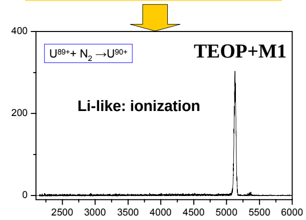
"Experiment-theory/theory" ratio for He-like Ar, Sn, Yb and U theoretical values as a function of relative photon energy.

Two-electron One-photon transition (TEOP)





Coincidence registration of x-rays and down charged ions (Li-like)



Preliminary x-ray spectra recorded by the detector at the observation angle of 35⁰ for 90 MeV/u $U^{88+} \rightarrow N_2$ collisions

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Only one single x-ray line stemming from the decay of the $1s(2s)^2$ state (TEOP) and M1.

The TEOP and M1 are separated by 280 eV with branching ratios ~90% and ~10% (theory)[8].

The data analysis is under evaluation aiming on a precise determination of the centroid of the peak.

Summary:

The experimental study of the production of the low-lying excited states in He-like (Li-like) Tin and Uranium produced by the selective K-shell ionization of initially Li-like (Be-like) species has been performed. This technique allows for a background-free study of the spectral shape of the two-photon decay with possible disentanglement of different He-like ions. In addition the selective formation of excited states in high-Z ions was used to populate the $1s(2s)^2$ state of Li-like species which can decay via an exotic transitions, namely two-electron one-photon transition. The data analysis is currently in progress.

References:

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