Contribution ID: **25** Type: **not specified**

Towards testing three-loop effects of bound-state QED in He-like uranium

Wednesday, 1 June 2022 15:05 (5 minutes)

We propose here an evolution of the past E125 proposal that uses H-like scandium as reference line and a smaller gas-jet target (from 5 to 1 mm) to measure the $1s_{1/2}2p_{3/2}$ J=2 $\rightarrow$ $1s_{1/2}2s_{1/2}$ J=1 intrashell transition in He-like uranium. This improvement will allow to reach the accuracy of 10~meV for the 4.5~keV line, sufficient to start to be sensitive to three-loop and more QED effects in such bound system, which are estimated to contribute with about 17~meV. The X-ray Bragg spectroscopy experiment E125 that took data in 2021 at ESR successfully measured $1s_{1/2}2p_{3/2}$ J=2 $\rightarrow$ $1s_{1/2}2s_{1/2}$ J=1 intrashell transition in He-like uranium with an accuracy of 0.17~eV, providing the most accurate test of QED in heavy He-like systems, enough to be sensitive to two-loop QED effects evaluated to 0.20~eV in such a transition. This result was however strongly limited by the accuracy of similar Li-like and Be-like uranium transition used as reference and measured in the past with an uncertainty of 0.21~eV. By using the Lyman-α line of H-like scandium ($Z = 21$) as a reference line from moving ions, an accuracy in the energy difference of 10~meV can be obtained. Differently from such heavy ions, Lyman-α H-like scandium H-like scandium could be precisely measured in lower energy facilities such EBIT or ECRIT ion plasma sources. As an alternative, theoretical predictions can be trustfully used for such a low-Z H-like ion. Two-loop QED contribution amount to only 1.7~meV in such low-Z ion and the largest uncertainty contribution comes from its hyperfine structure with only 5~meV.
Moreover, by reducing the target width from 5 to 1 mm, as planned at ESR, a gain a factor five on the statistical uncertainty is expected, with a reduction to about 7~meV only. Differently from E125 experiment, where a nitrogen gas-jet target with a relatively low-density was implemented to reduce possible double electron capture indistinguishable in by the CCDs spectrometer detectors, the reduction of the gas-jet target (and the possible use of heavier gas target to increase the induced photon flux) will requires the use time-coincidence position-sensitive detectors. The use of arrays of timepix3 detectors is planned for this purpose.
A total amount of 50 shift will be required (33 of high-intensity H-like uranium beam, 3 of bare scandium and 14 for beam preparation).

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Session Classification: ESR