



Beitrag ID: 6

Typ: Poster

Testing Strong-Field QED to Second-Order in Highly Correlated Berylliumlike Pb^{78+} by Electron-Ion Collision Spectroscopy

Montag, 15. September 2025 16:30 (1 h 30m)

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Using the experimental technique of electron-ion collision spectroscopy at the electron cooler of the heavy-ion storage ring CRYRING@ESR [1] we have measured merged-beams rate coefficients for electron-ion recombination of berylliumlike Pb^{78+} ions. In the electron-ion collision energy range 12-16.5 eV, we have observed $2s2p\ (^3P_1)\ 19l_j$ dielectronic recombination (DR) resonances associated with a $2s^2\ ^1S_0 \rightarrow 2p2p\ ^3P_1$ core excitation and a simultaneous capture of the initially free electron into the $n = 19$ shell of the boronlike Pb^{77+} product ion. A careful analysis of the systematic experimental errors reveals that the uncertainty of the measured resonance positions amounts to ~ 30 meV. This uncertainty is lower than the theoretical uncertainty of the calculation of the $2s^2\ ^1S_0 \rightarrow 2p2p\ ^3P_1$ excitation energy by Malyshev et al. [2]. By considering second order QED effects and electron-electron correlation effects, which are particularly strong in berylliumlike ions, these authors obtained $E_{\text{exci}} = 244.942(52)$ eV. Within the uncertainties this agrees with our experimental finding [3], which thus constrains second order strong-field QED.

[1] C. Brandau et al., Chin. Phys. C **49**, 064001 (2025),
<https://doi.org/10.1088/1674-1137/adbf81>

[2] A. Malyshev et al., Phys. Rev. A **110**, 062824 (2024),
<https://doi.org/10.1103/PhysRevA.110.062824>

[3] All authors of this abstract, Phys. Rev. Lett. (submitted),
<https://arxiv.org/abs/2502.15433>

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Sitzung Einordnung: Poster Session