Nuclear Excitation by Electron Capture in Excited Ions

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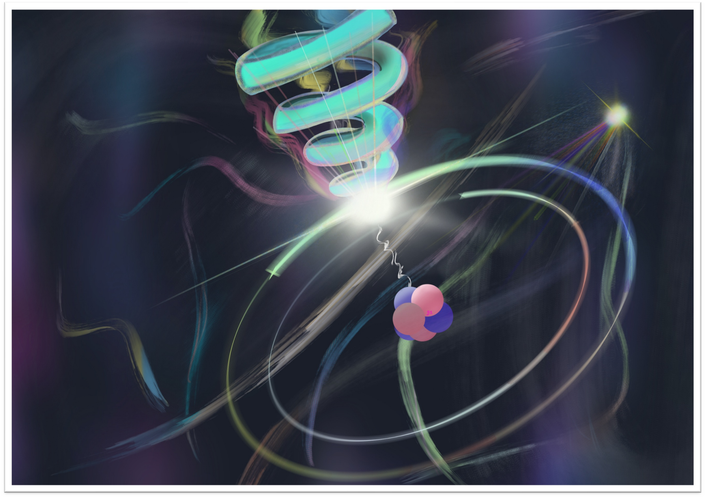
Overview



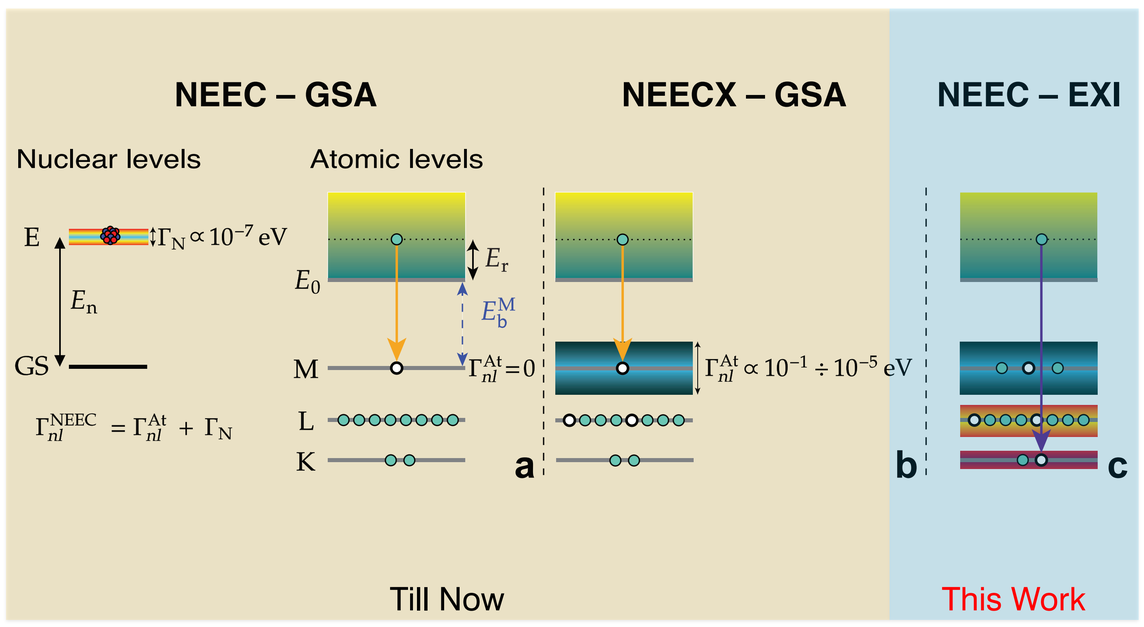
The idea that one could shine light on a nucleus releasing its stored energy is a powerful one in terms of compact and clean energy storing and also in view of climate solutions [1, 2].

Nuclear excitation by electron capture (NEEC) was initially proposed in 1976 [3] as the inverse process of the internal conversion. Since its recent observation in the ^{93}Mo isomer depletion [4], NEEC is the object of a live debate [5,6]: the unexpectedly large measured excitation probability P_{exc} differs by nine orders of magnitude from the state-of-the-art theoretical predictions [7]. A recent study [8] slightly increased this theoretical limit, accounting for the momentum distribution of the target electrons. The authors showed that the depletion probability increases by several orders of magnitude in case of the L-shell. However, these L-channels do not enhance significantly the P_{exc} because the charge state required for an L-vacancy to be present is distant from the averaged charge state (q_{mean}) at the resonance condition [7]. This circumstance is mainly determined by the fact that the ion is considered to be in its electronic ground state before the capture of the free electron.

Our Results

NEEC is a process in which the capture of a **free electron** by an ion results in the resonant **excitation of a nucleus**.

Energy conservation requires that the kinetic energy of the free electron, E_r, equals the difference between the nuclear transition energy, E_n, and the atomic binding energy released through electron capture, E_b(i.e., $E_r = E_n - E_b$).

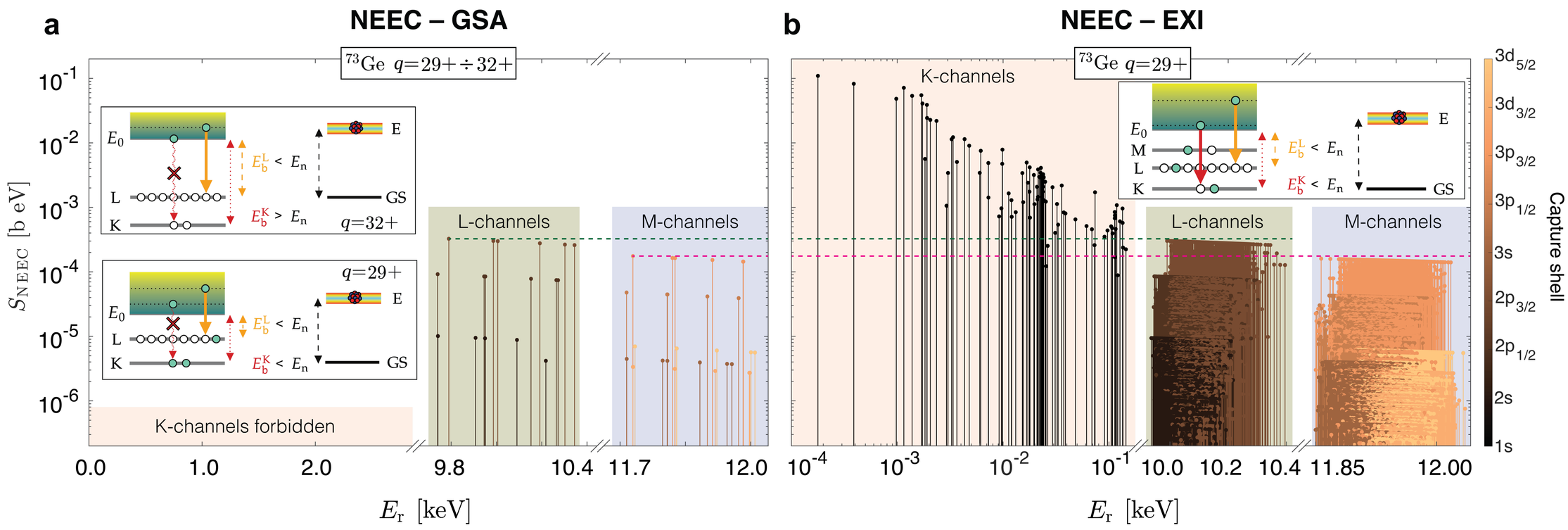


So far, the evaluation of the NEEC cross section has been carried out widely using the assumption that the ion is in its **electronic ground state prior to the capture** (for brevity, GSA), inhibiting the capture in the innermost-shells as soon as the atomic orbitals fill up.

By lifting this restriction and considering NEEC in excited ions (**NEEC-EXI**), we show for ^{73}Ge [9], that many more capture channels emerge.

Moreover, excited electronic configurations present in NEEC-EXI make K-capture possible, revealing new channels with resonance strengths S_{NEEC} (that is the integrated cross-section) larger than for any channel obtained under GSA [9].

$$S_{\mathrm{NEEC}}^{q,\alpha_r} = \int \sigma_{\mathrm{NEEC}}^{q,\alpha_r}(E)\, dE$$



Outlook

In out-of-equilibrium scenarios, excited electronic configurations might be more likely to occur and the same can hold true for the beam-based ^{93}Mo isomer depletion. Here, the presence of vacancies in the L-shell at the resonance condition — even for lower charge states than q_{mean} — could make the contribution of L-channels no longer insignificant for the total excitation probability. This could in principle reduce the discrepancy between theoretical predictions and experimental results. Furthermore, these findings heralds the possibility of a re-evaluation of the isotopes prematurely disregarded for NEEC.

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