Li-like carbon Auger KLL measurements of mixed-state $C^{4+}(1s^2\ ^1S,\ 1s2s\ ^3S)$ ions in 6-15 MeV collisions with He and comparison to 3eAOCC calculations†

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Abstract

New state-resolved Li-like carbon Auger KLL measurements of mixed-state $C^{4+}(1s^2\ ^1S,\ 1s2s\ ^3S)$ ions in 6-15 MeV collisions with He are presented. Results of three-electron semiclassical atomic orbital AOCC coupled channel (3eAOCC) calculations are also presented and compared.

State-resolved cross sections for the production of $1s2s^2\ ^2S$, $1s2s2p\ ^4P$, $1s2s2p\ ^2P_{\pm}$ and $1s2p^2\ ^2D$ C^{3+} states were determined using our zero-degree Auger projectile spectroscopy (ZAPS) setup at the 5.5 MV tandem accelerator at Demokritos [1]. These states are populated predominantly by transfer-excitation processes from the $C^{4+}(1s^2)$ and/or by single electron transfer processes from the $C^{4+}(1s2s\ ^3S)$ metastable components.

Using our recently reported dual measurement technique [2], we have separated ground state from metastable state KLL contributions in collisions of mixed-state $C^{4+}(1s^2\ ^1S,\ 1s2s\ ^3S)$ ions in 6-15 MeV collisions with He.

For the interpretation and understanding of the experimental results we also performed calculations over the 0.5-18 MeV range using a semiclassical atomic orbital close-coupling approach, based on an asymptotic (atomic) description of the neutral and charged collision partners [3,4]. The electronic dynamics is then treated quantum mechanically solving the three-electron time-dependent Schrödinger equation with full configuration interaction (CI).

To describe electron excitation and transfer to doubly excited states on the carbon center, **three active** electrons are taken into account: **two** of them are reserved initially for the He-like C^{4+} projectile, while the third is initially on the He target, accounted for by a He^+ model potential binding a unique electron which can be transferred in the collision to C^{4+} to describe 1-, 2- and 3-open-shell electronic configurations of the C^{3+} ions. Illustration of our results are shown in Figs. 1 and 2 for the production of various KLL states.

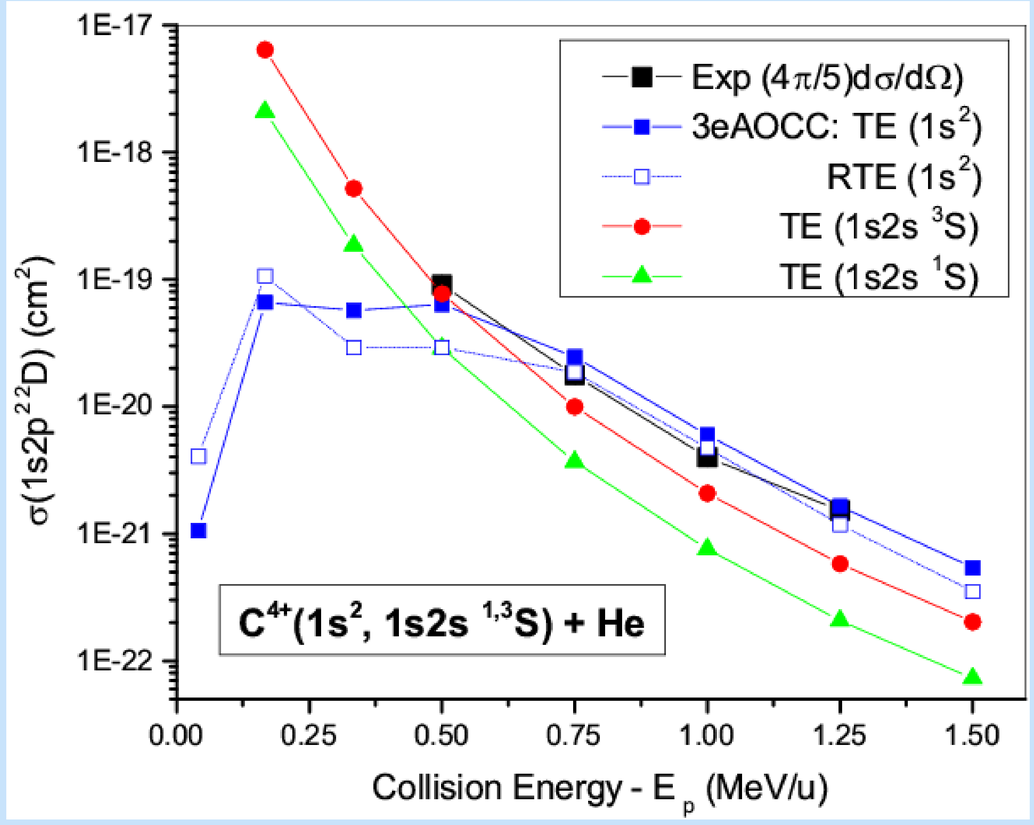

Figure 1. Cross sections for the production of the $C^{3+}(1s2p^2\ ^2D)$ state in collisions of $C^{4+}(1s^2\ ^1S,\ 1s2s\ ^{1,3}S)$ ions with He. ZAPS measurements (black squares), 3eAOCC results from: (squares) $1s^2$ ground (circles) $1s2s\ ^3S$ and (triangles) $1s2s\ ^1S$ metastable states beam components, respectively. One-step RTE assessment (open squares) is also indicated. Both TE and RTE from the ground state are seen in good overall agreement with experiment. Contributions to TE (mostly two-step NTE) from the 1s2s metastable components is seen to become large at the lowest collision energies for which, however, no experimental data exist.

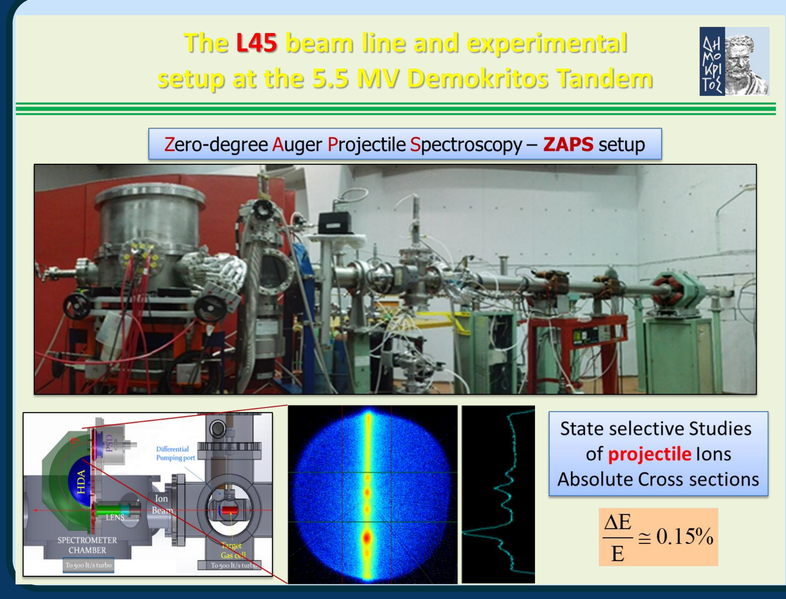

Figure 3. Zero-degree Auger projectile spectroscopy (ZAPS) experimental setup at the L45 beam line at the Demokritos 5.5 MV tandem accelerator. The experimental setup includes doubly differentially pumped target gas cell and a 101mm mean radius hemispherical deflector analyser (HDA) with a 4-element injection lens and 2-D position sensitive detector (PSD).

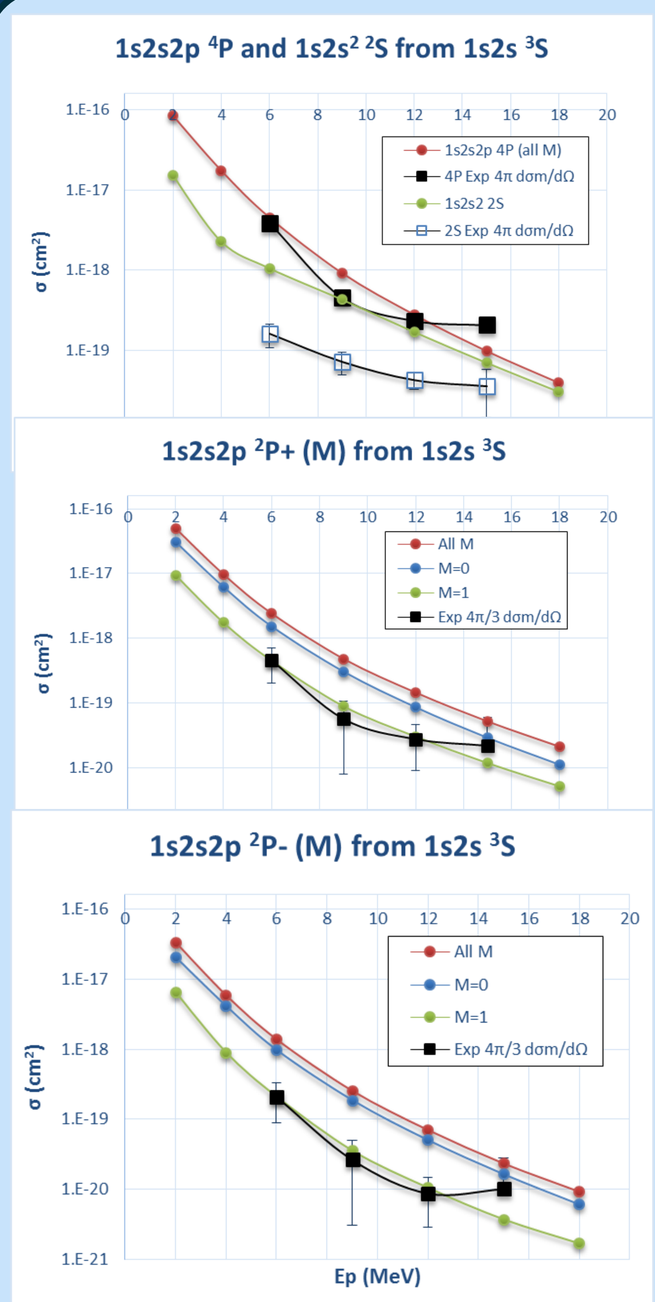

Figure 2. Cross sections for the production of the C^{3+} $1s2s^2\ ^2S$, $1s2s2p\ ^4P$ (top), $1s2s2p\ ^2P+$ (middle) and $1s2s2p\ ^2P-$ (bottom) states extracted for collisions of **$C^{4+}(1s2s\ ^3S)$** ions with He.

ZAPS measurements (black squares) determined for **$C^{4+}(1s2s\ ^3S)$** beam component as discussed in Ref. [2]

3eAOCC theory [3-4]: circles (red – sum of all M), (blue – M=0) and (green – M=1) sub states where available.

References

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