Coherent treatment of transfer excitation processes in swift ion-atom collisions

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Abstract

For more than 40 years since the first ion-atom collision investigations of the two-electron process of electron transfer with excitation (TE) and its resonant (RTE) and non-resonant (NTE) features, a satisfactory quantum mechanical treatment has been lacking. Here, we present the first such comprehensive TE treatment using a three-electron atomic orbital close-coupling approach (3eAOCC), exemplified by $C^{4+}(1s^2)$ + He collisions at 0.5-18 MeV impact energies [1-4].

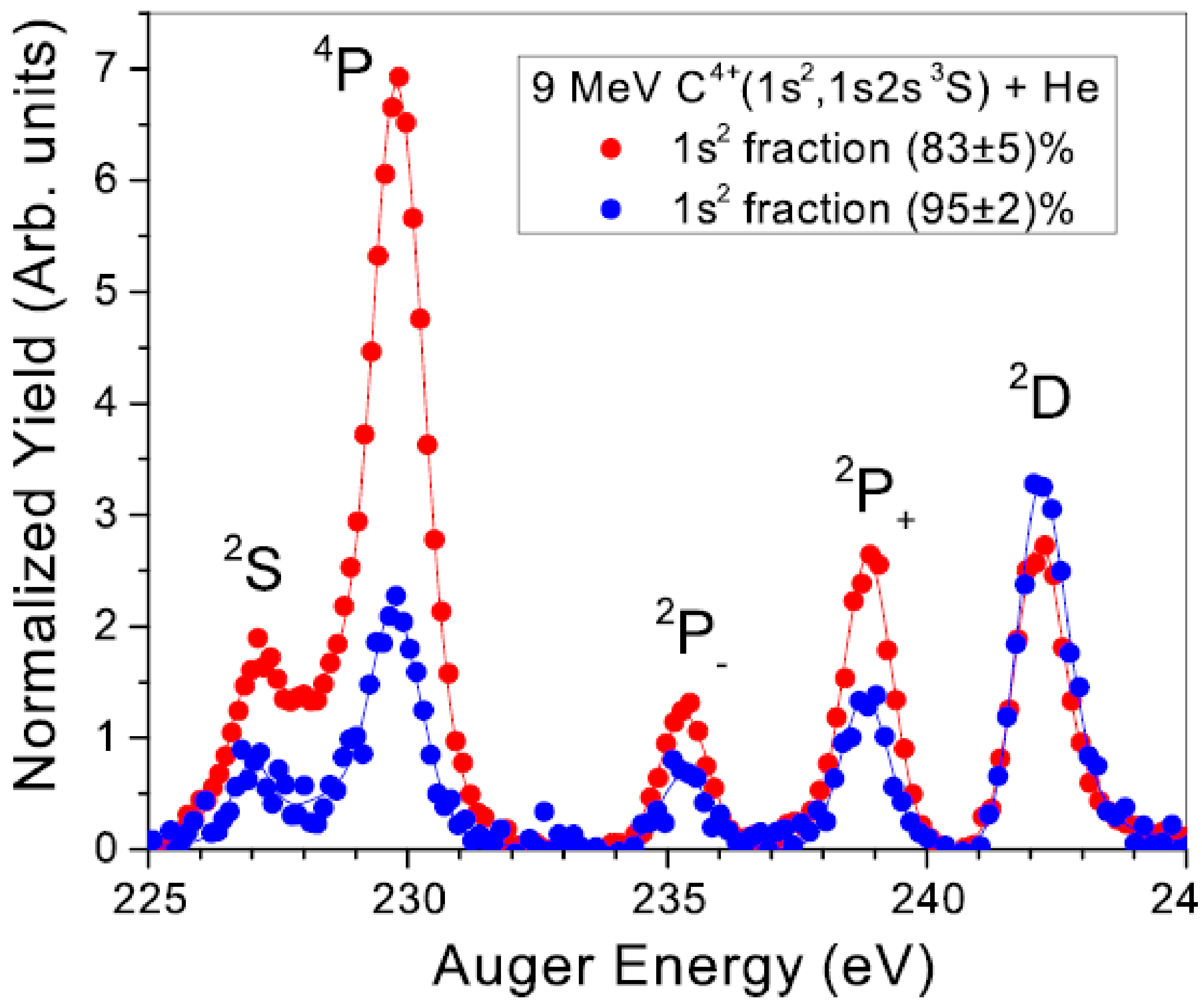


Fig. 1. Typical Auger KLL spectra obtained in collisions of mixed-state $C^{4+}(1s^2,\ 1s2s\ ^3S)$ ion beams with He. The two spectra are obtained from C^{4+} ion beams with different admixtures. The ^2D is primarily produced from the $1s^2$ component by transfer excitation, while the ^4P by single electron capture to the $1s2s\ ^3S$ component.

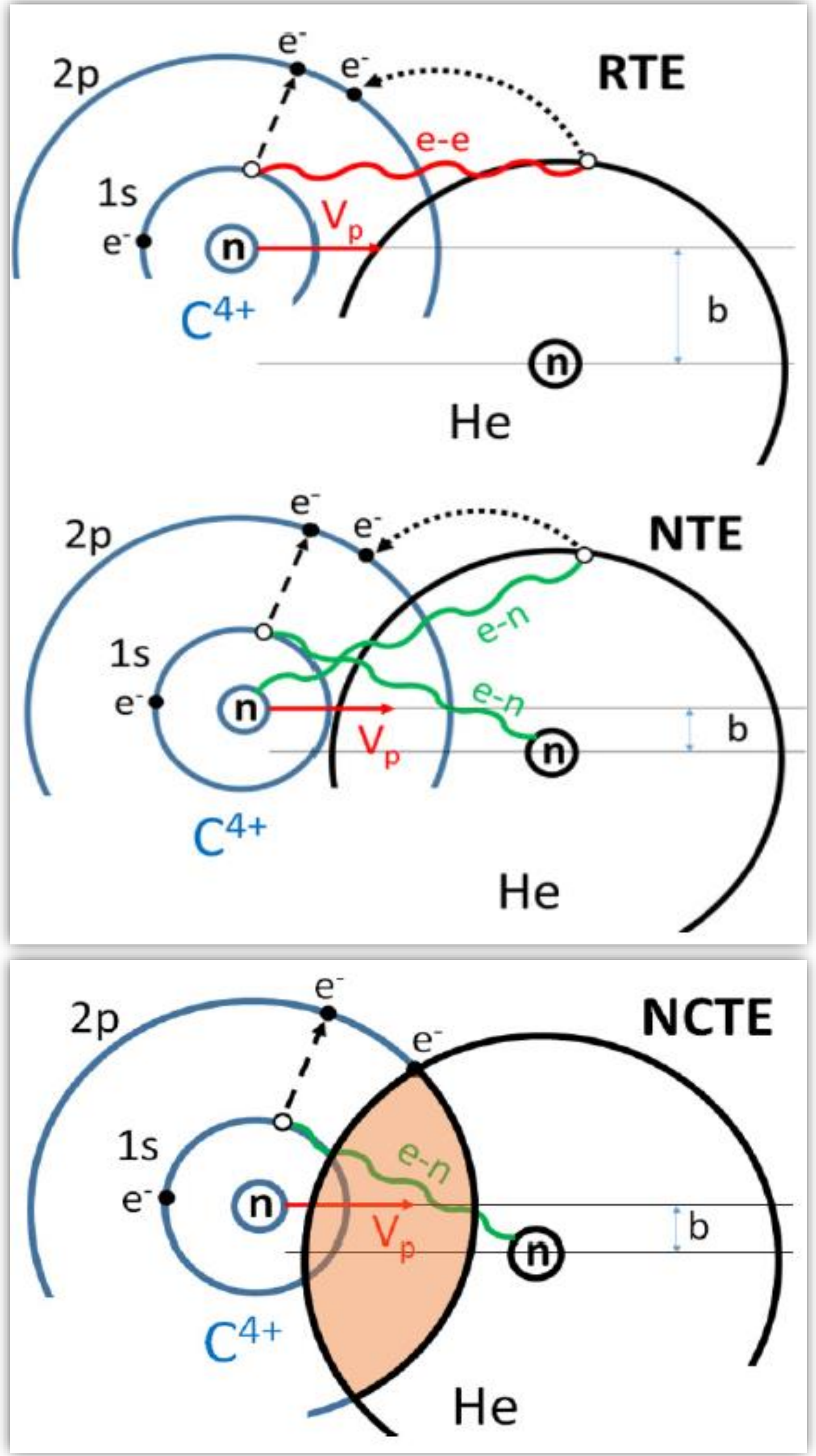
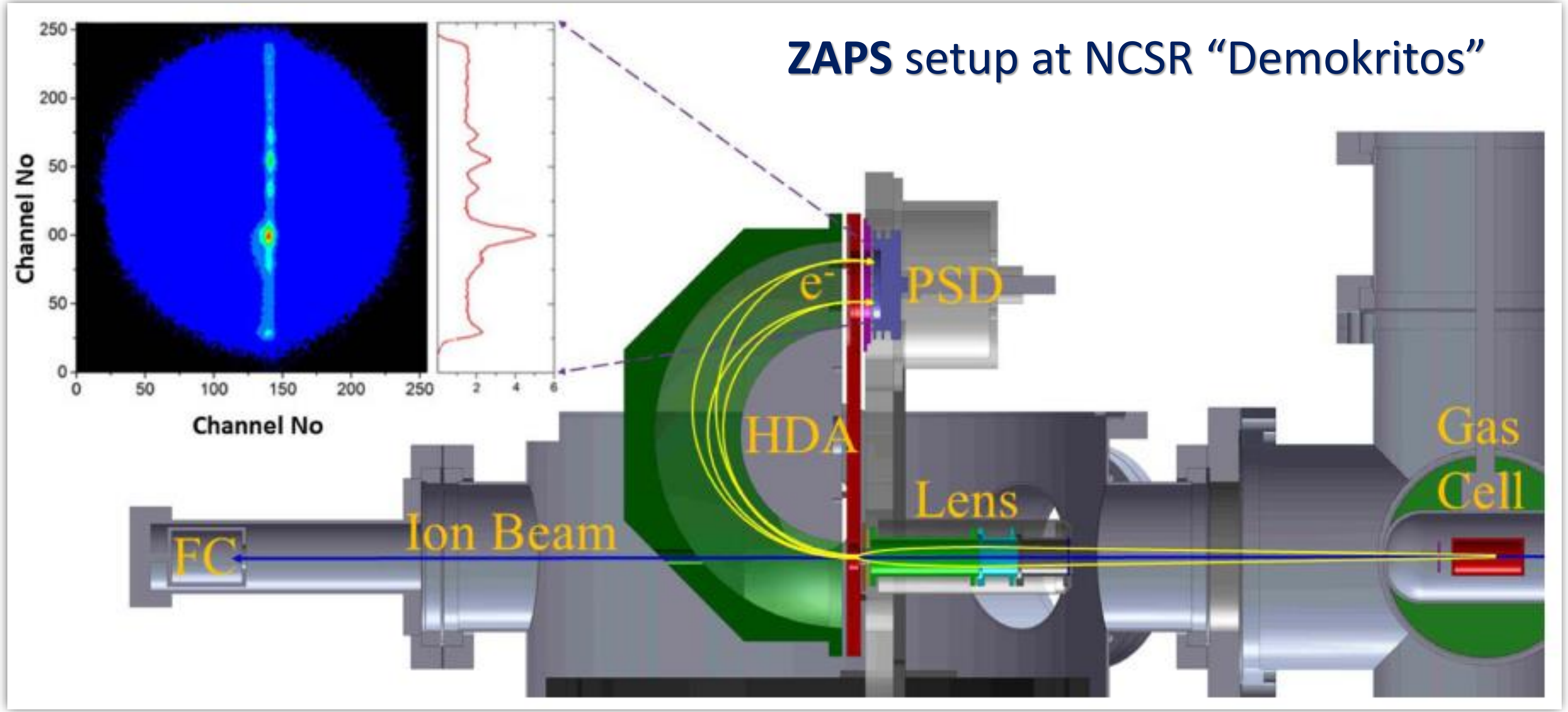


Fig. 6. Schematic of known TE mechanisms **RTE** (Resonant Transfer Excitation) and **NTE** (Nonresonant Transfer Excitation), as well as the proposed **NCTE** (**Nonresonant Correlated Transfer Excitation**) for the production of the $1s2p^2\ ^2D$ level in swift collisions of $C^{4+}(1s^2)$ + He.



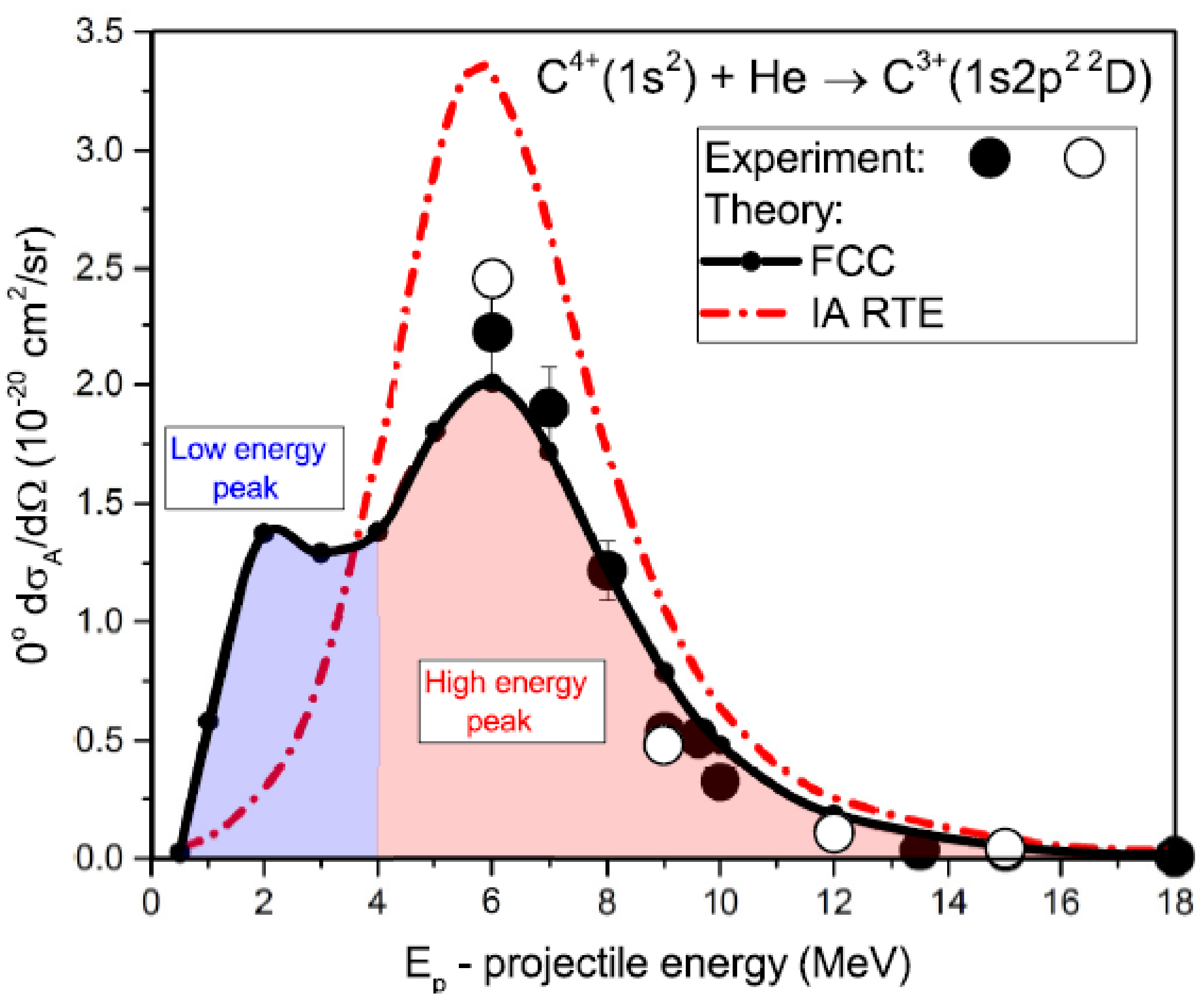


Fig. 2. Projectile energy dependence of absolute 0° Auger SDCS for the production of ^2D states by TE. **FCC**: Full 3eAOCC calculations. **IA**: Impulse approximation.

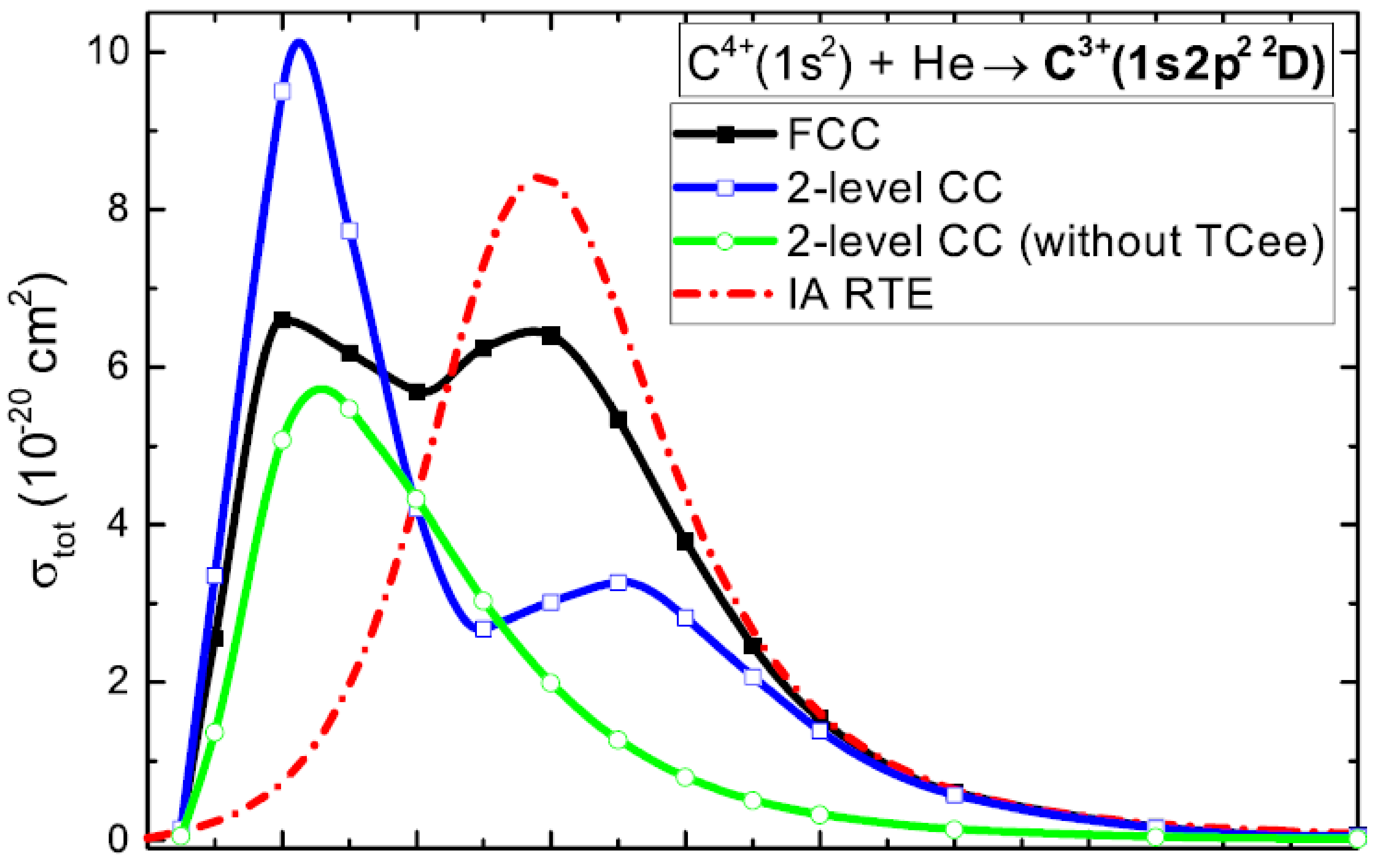


Fig. 5. Projectile energy dependence of theoretical 3eAOCC total cross sections σ_{tot} for the production of $1s2p^2\ ^2D$. **FCC**: Full 3eAOCC calculation. **2-level CC**: 3eAOCC calculation including only the initial projectile and target states. **2-level CC (without TCee)**: Same as 2-level CC calculation but omitting the two-center electron-electron interaction. The latter suggests a new one-step mechanism to account for the low energy peak.

OBK approximation $\left| -i \int_{-\infty}^{+\infty} dt\ \langle \Psi_f | W | \Psi_i \rangle\ e^{-i\Delta E_{if} t} \right|^2$

$$W = V^T(r_i) + V^T(r_j) - \frac{Z_p}{r_k} + \frac{1}{r_{ik}} + \frac{1}{r_{jk}}$$

$$\boxed{\sqrt{2} W_{fi} = \langle 2p | V^T | 1s \rangle \langle 2p' | \underline{1s} \rangle + \langle 2p2p' | \frac{1}{r_{ik}} | 1s\underline{1s} \rangle}$$

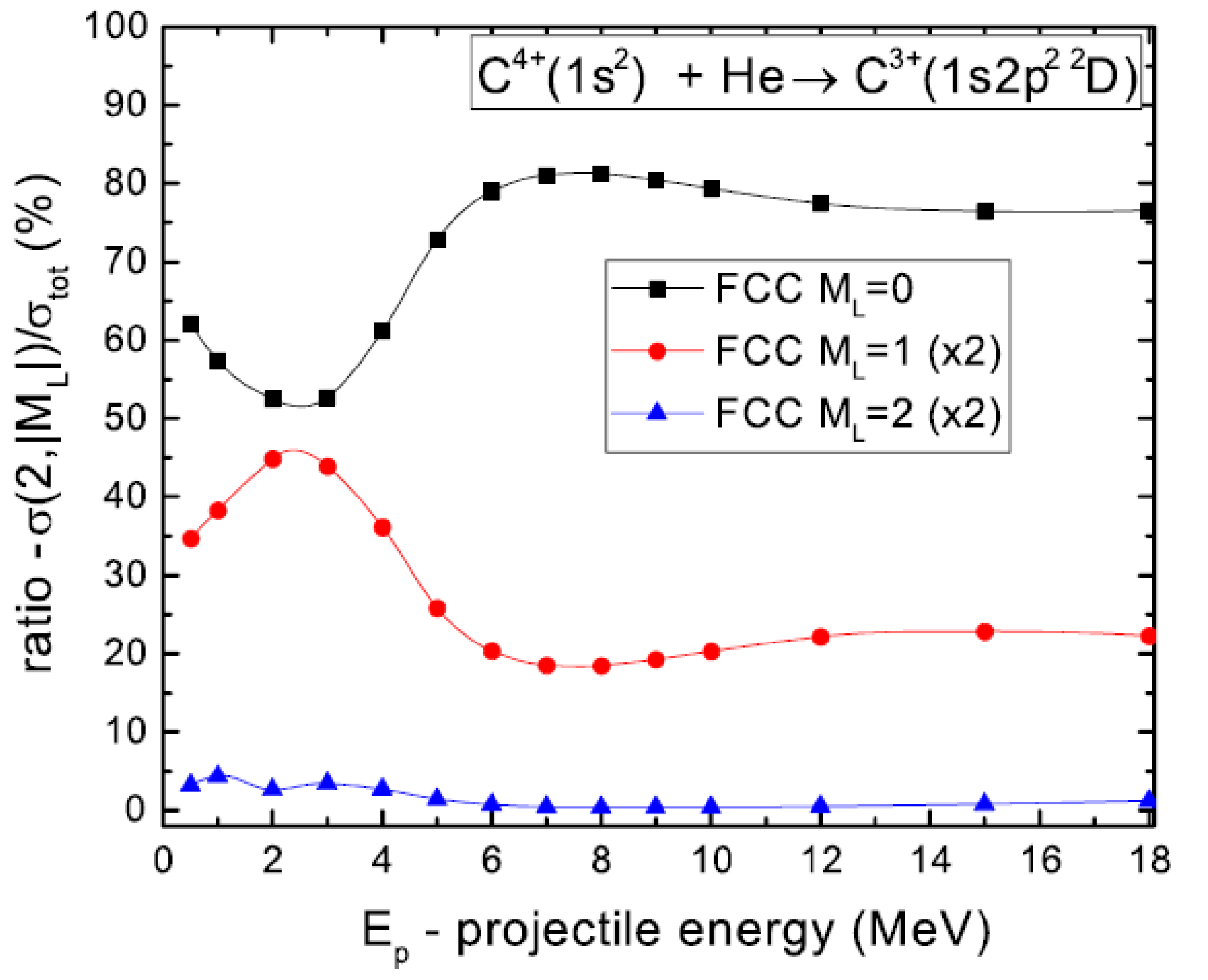


Fig. 3. FCC results of ratios of partial to total cross sections $\sigma\ (L{=}2,\ |M_L|)/\sigma_{\text{tot}}$ as a function of projectile energy. A strong $M_L{=}0$ contribution is observed for collision energies above 6 MeV where the high-energy peak lies.

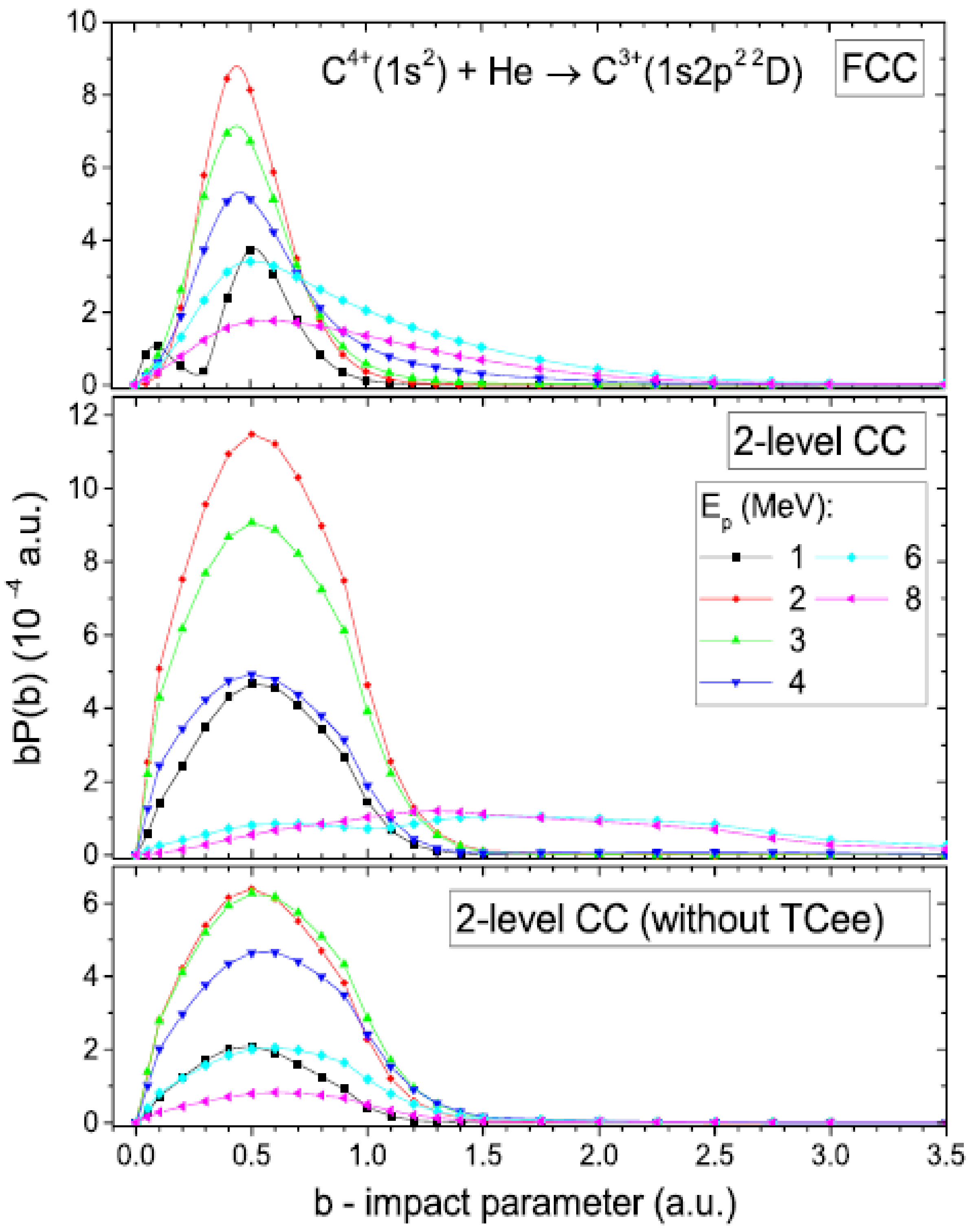


Fig. 4. Impact parameter-weighted TE probabilities $bP(b)$ as a function of impact parameter b for the $1s2p^2\ ^2D$ state.

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References

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