Investigation of 2s2p ^{3,1}P excitation and (1s2s ^{3}S)nl capture lines in 6-18 MeV C^{4+} (1s^2, 1s2s ^{3}S) collisions with gas targets*

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Synopsis

A zero-degree Auger projectile spectroscopy apparatus composed of a single stage **hemi-spherical deflector analyzer** with a **four-element injection lens** and a **2-dimensional position sensitive detector** combined with a **doubly differentially pumped gas target** has been newly set up **at the Demokritos 5.5MV tandem accelerator** in Athens for high resolution studies of **electrons emitted** from **ions colliding with gas targets**. Using this setup (see **Fig. 1**) we have started a systematic isoelectronic investigation of **projectile K-Auger electrons** emitted from pre-excited **He-like ions** in **collisions** with **dilute gas targets** [1]. The goal is to study **single electron capture** to the **He-like (1s2s ^{3}S) metastable beam component** [2,3], explore the effect of varying the metastable fraction [4] and the dependence of R_m the **ratio of ^{4}P^o/^{2}P Auger KLL line intensities** due to capture to the 1s2s ^{3}S of recent interest [5].

To obtain an independent **cross check** on the **C^{4+}(1s2s ^{3}S) metastable beam fraction**, apart from the new method recently introduced [4] based on the analysis of the KLL lines in He-like beams with different metastable fraction, we have also **explored the production** of various **Auger lines** of slightly **higher electron energy** such as the **He-like 2s2p ^{3,1}P KLL** produced by **1s-2p excitation** shown in **Fig. 2**. These lines are also of particular importance in the detailed study of fundamental **mechanisms of excitation** [6], i.e. the **electron-nucleus, electron-electron and electron-electron excitation with spin exchange** [7].

The presently **unidentified lines in Fig. 2** are most probably due to **(1s2s ^{3}S)nl Li-like states** [8] produced by direct **nl capture** with **n=3-4** to the **metastable 1s2s ^{3}S** beam component. Their existence would be further proof that these higher lying states are produced by capture as required by the proposed **cascade feeding mechanism** [3,5] leading to the observed **enhancement of the ratio R_m** [2].

Latest results on these excitation and capture cross sections and their dependence on the collision energy are presented.

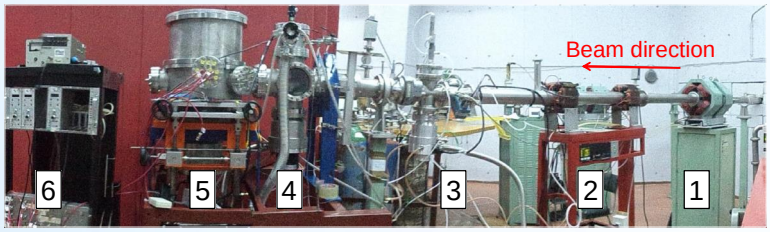

Fig. 1: Photograph of the **APAPES beam line** dedicated for **atomic collisions** physics research showing the various parts of the apparatus. From right to left: the focusing **quadrupole (1)**, a pair of **magnetic steerers (2)**, a **beam profile monitor (3)**, the differentially pumped **gas cell target (4)** inside a six-way cross and the chamber containing the electrostatic **Hemispherical Deflector Analyzer (HDA) (5)**. On the left, some of the HV voltage precision **power supplies (6)** used to bias the HDA can be seen.

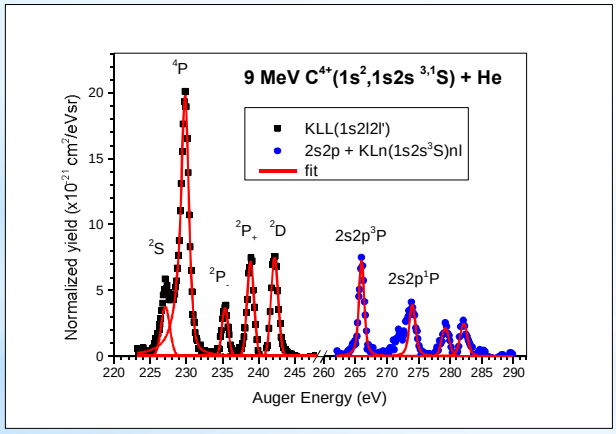

Fig. 2: Electron spectrum from **9 MeV C^{4+}(1s^2, 1s2s ^{3}S) collisions with He**. Auger Lines: **(black squares) C^{3+}(1s2l2l´) KLL**, **(blue circles) C^{4+}(2s2p ^{3,1}P) KLL** and **C^{3+}(1s2s^{3}S)nl KLn (n=3-4)**. The **C^{4+}(1s^2, 1s2s ^{3}S)** beam was produced by **gas** stripping in the accelerator terminal and subsequent **gas** post stripping of the analyzed C^{3+} ions. An average value of **C^{4+}(1s2s ^{3}S)** beam fraction f = (1s2s ^{3}S)/(1s^2,1s2s ^{3}S) defined from experimental data is determined to be **20%**.

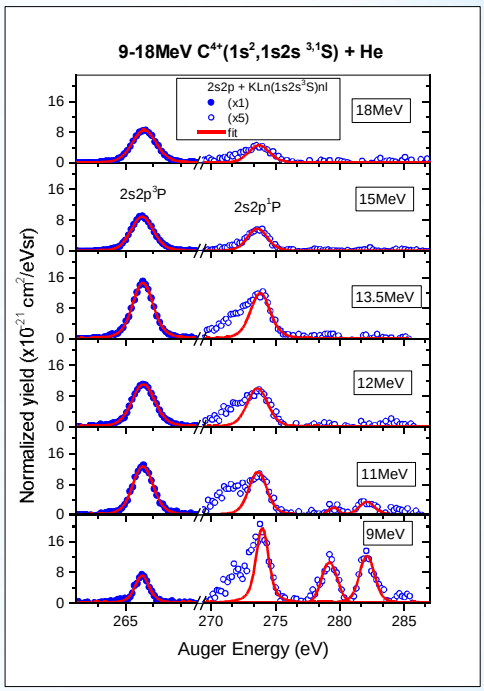

Fig. 3: Electron spectra from **9-18 MeV C^{4+}(1s^2, 1s2s ^{3}S) collisions with He**. Auger lines: **(blue circles) C^{4+}(2s2p ^{3,1}P) KLL** and **C^{3+}(1s2s ^{3}S)nl KLn (n=3-4)**. The **C^{4+} beam** was produced either by **foil stripping** in the accelerator terminal (11-18MeV) or by **gas stripping** in the accelerator terminal **and** subsequent **gas post stripping** of the analyzed **C^{3+} ions** (9MeV). An average value of **C^{4+}(1s2s ^{3}S)** fraction **f** is determined to be **20%**. The cross sections of the C^{4+}(2s2p ^{3,1}P) KLL and C^{3+}(1s2s ^{3}S)nl KLn (n=3-4) appear to depend strongly on the collision energy, particularly obvious at the lower (9-11 MeV) collision energies. Note the open blue circles (○) have been scaled by a **factor of 5** to facilitate viewing.

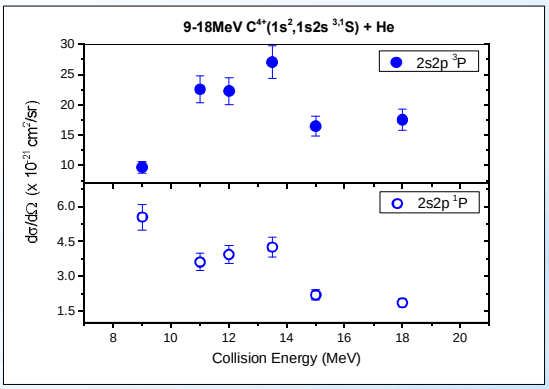

Fig. 4: **2s2p ^{3,1}P Auger electron** production **cross sections** as a function of the **collision energy**. An average overall metastable beam fraction **f=20%** was assumed. A big change in the production cross sections can be observed at collision energies lower than ~10 MeV.

Conclusions – Future projects

- A strong dependence of the C^{4+}(2s2p ^{3,1}P) KLL and C^{3+}(1s2s ^{3}S)nl KLn (n=3-4) production cross sections on the collision energy was observed which will be further investigated at lower energies in the near future.
- The production cross sections C^{4+}(2s2p ^{3,1}P) KLL and C^{3+}(1s2s ^{3}S)nl KLn (n=3-4) dependence on the stripping medium (foil or gas) for the same collision energy appears interesting and will be further investigated in the future. In this way, we expect to separate the contributions of the 1s^2 ^{1}S or 1s2s ^{3,1}S states to the production of the 2s2p ^{3,1}P states.

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