Evaluation of 1s2l2l′ $^4P/^2P$, $^2P_+/^2P_-$ and $^2D/^2P$ ratios from collisions of mixed state ($1s^2$, 1s2s ^3S) He-like ion beams with H_2 and He targets

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Abstract

New results are presented on the ratio R of $^4P/^2P$ populations of Li-like 1s2s2p quartet and doublet P states formed in energetic ion-atom collisions by single 2p electron transfer to the metastable 1s2s ^3S component of a He-like ion beam. Using spin statistics, a value of R=2 is predicted, mostly in disagreement with reported measurements of R=3-10 [1-2]. A new technique is used in the evaluation of R which overcomes the need for the normalization of the measured cross sections and allows for the determination of the separate contributions of ground- and metastable-state beam components to the measured spectra. Applying to older spectra from 4.5 MeV B^{3+} [3] and 25.3 MeV F^{7+} [4] mixed state ($1s^2$ ^1S, 1s2s ^3S) ion collisions with H_2 target, we report values of R=3.5±0.4 for boron and R=1.8±0.3 for fluorine. In addition, also reported for the first time are the ratios of $^2D/^2P$ and $^2P_+/^2P_-$ populations generated by either capture and/or Transfer Excitation mechanisms, providing essential information on the active processes that can affect the overall intensities of the measured Auger spectra. They are evaluated applying the same technique and compared to previously reported results for carbon collisions on He [1].

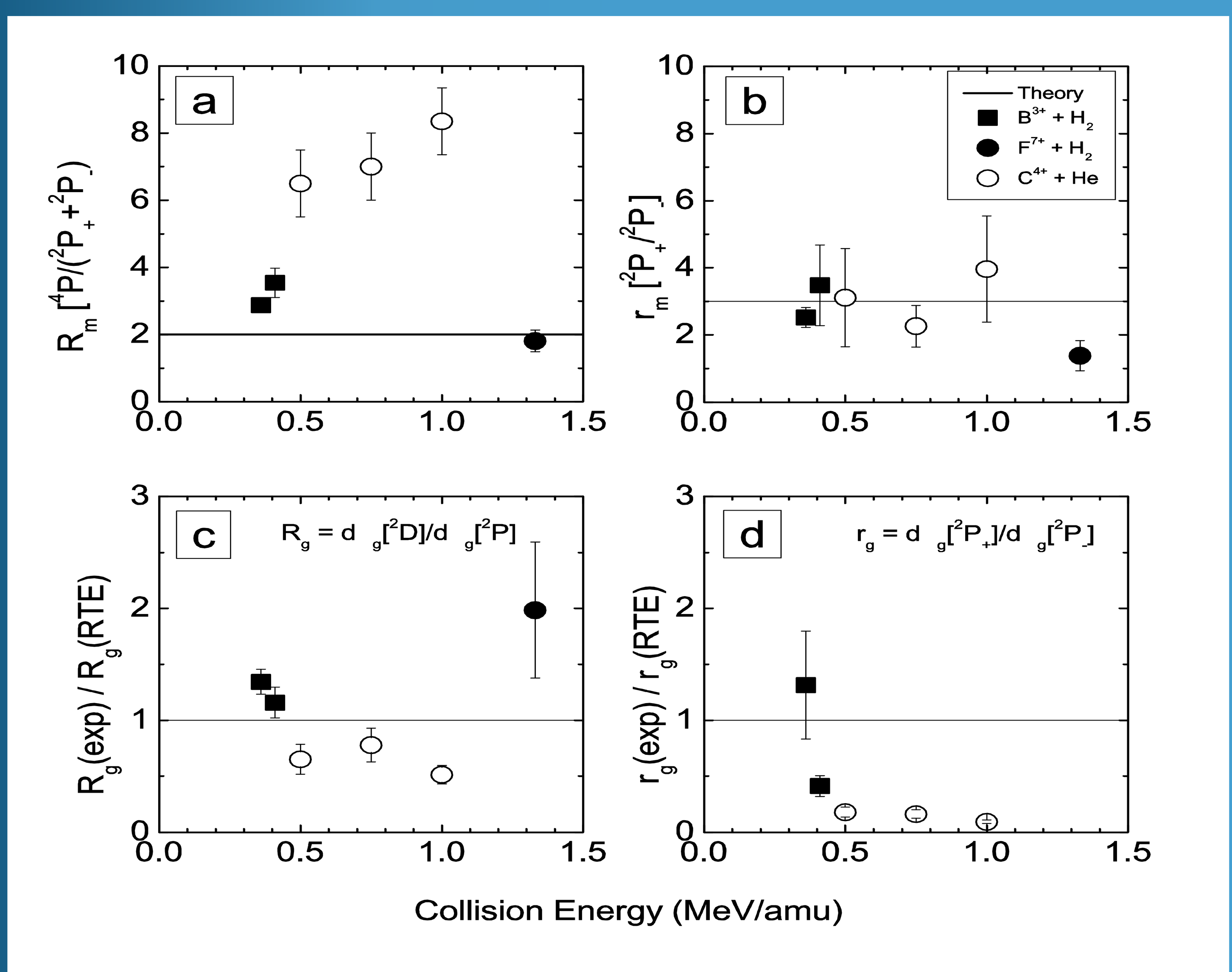

Fig. 1: Measured capture ratios along with the experimental results from applying the technique.

Motivation

The use of pre-excited long-lived 1s2s ^3S states has been particularly attractive to Zero-degree Auger electron Projectile Spectroscopy (ZAPS) technique since they can provide a unique and simple excited atomic system for testing atomic theory models as in Electron Transfer (T), Resonant (RTE) and Non-resonant (NTE) Transfer Excitation, among others. Mixed state ($1s^2$ ^1S, 1s2s ^3S) ion beams, provided by heavy ion accelerators and highly charged ion sources, have been used in such experiments, however, the fraction of the ^3S over the total mixed beam is necessary information.

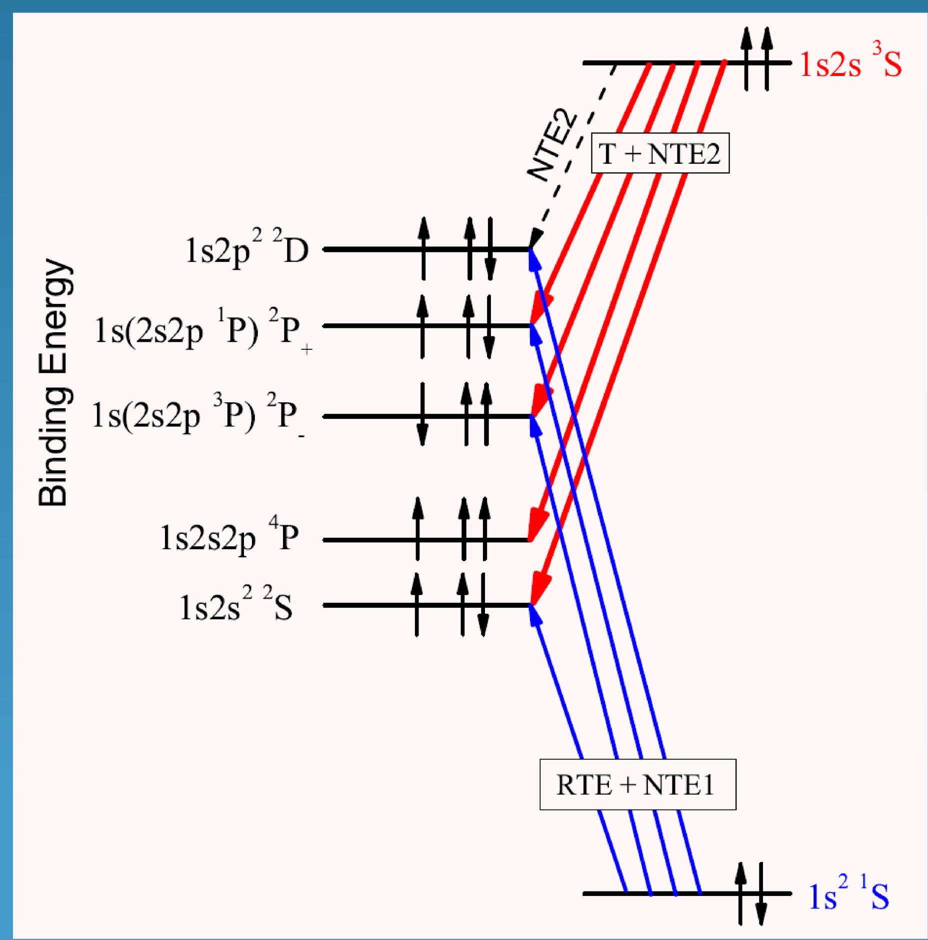

Fig. 2. Energy level diagram showing the dominant mechanisms for the production of the 1s2l2l′ $^{(2S+1)}L$ doubly excited states formed in collisions of energetic He-like mixed beams with H_2 targets. Single 2p or 2s electron transfer or NTE2 to the metastable state (m) in red, RTE and NTE1 from the ground state (g) in blue.

Furthermore, in the ZAPS technique the long lifetime of the ^4P states should be considered. Compared to the ^2P and ^2D whose lifetime is short, from which electrons are emitted promptly after the formation of these states inside the gas cell, the ^4P Auger electrons are emitted all along the path of the ions towards the spectrometer. This problem has been treated recently by calculating G_τ - a solid angle correction factor - with the use of Monte Carlo simulation and the well known SIMION program[5].

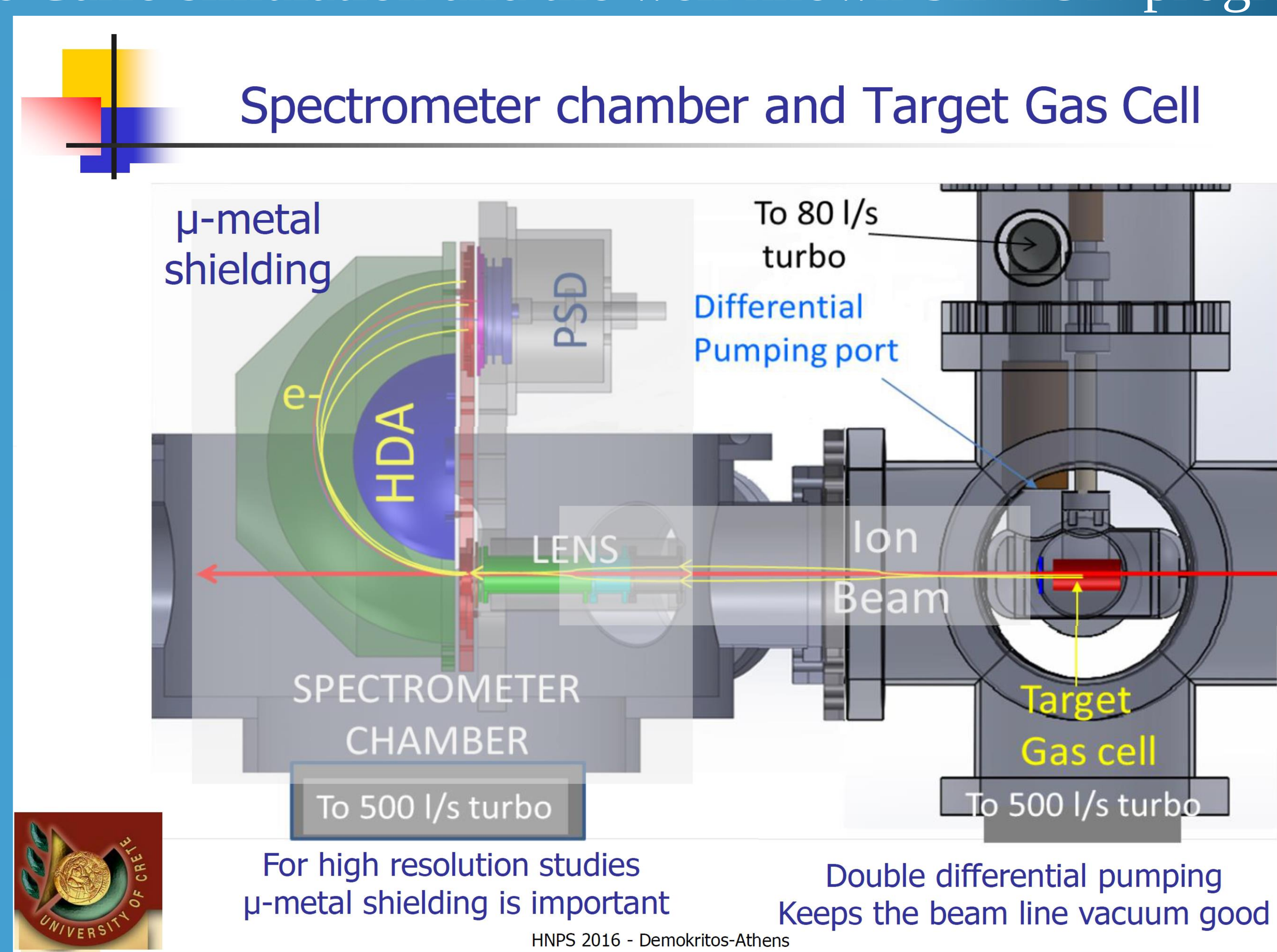

Fig. 3. Double Differential pumped target gas cell, along with Paracentric Hemispherical Deflector Analyser (HDA), 4-element input lens and 2-D Position Sensitive Detector (PSD). Each color denotes a different voltage. The 1s2s2p ^4P de-excitation takes place along the ion beam path requiring a solid-angle detection correction factor G_τ[5].

Here, a new approach is reported for the evaluation of R, which involves the use of two independent measurements that differ only in the fraction of the 1s2s ^3S metastable part of the ion beam, eliminating the need of pure ground state beam, the need of detection solid-angle correction factors, and the common normalization factors typically needed.

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