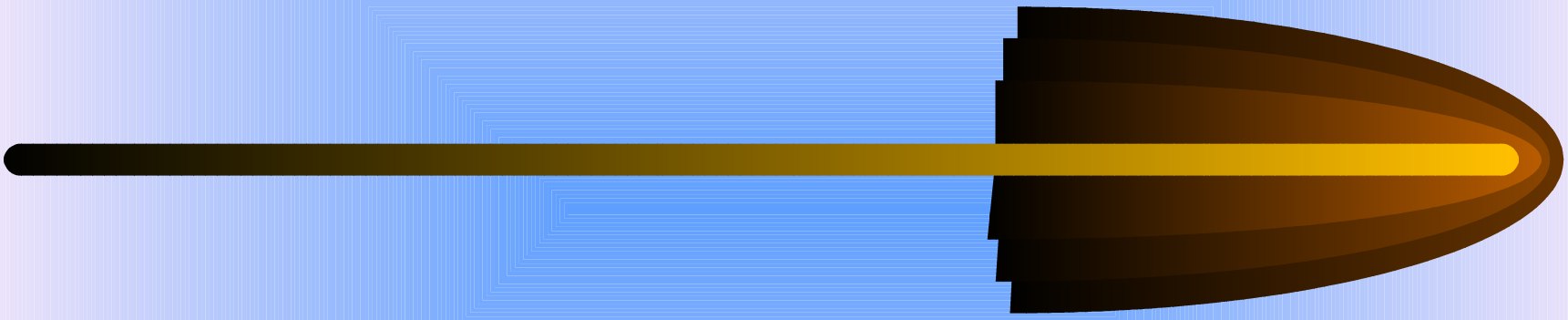
Electron transfer into metastable He-like ions: Non-statistical population mechanisms



Theo J.M. Zouros
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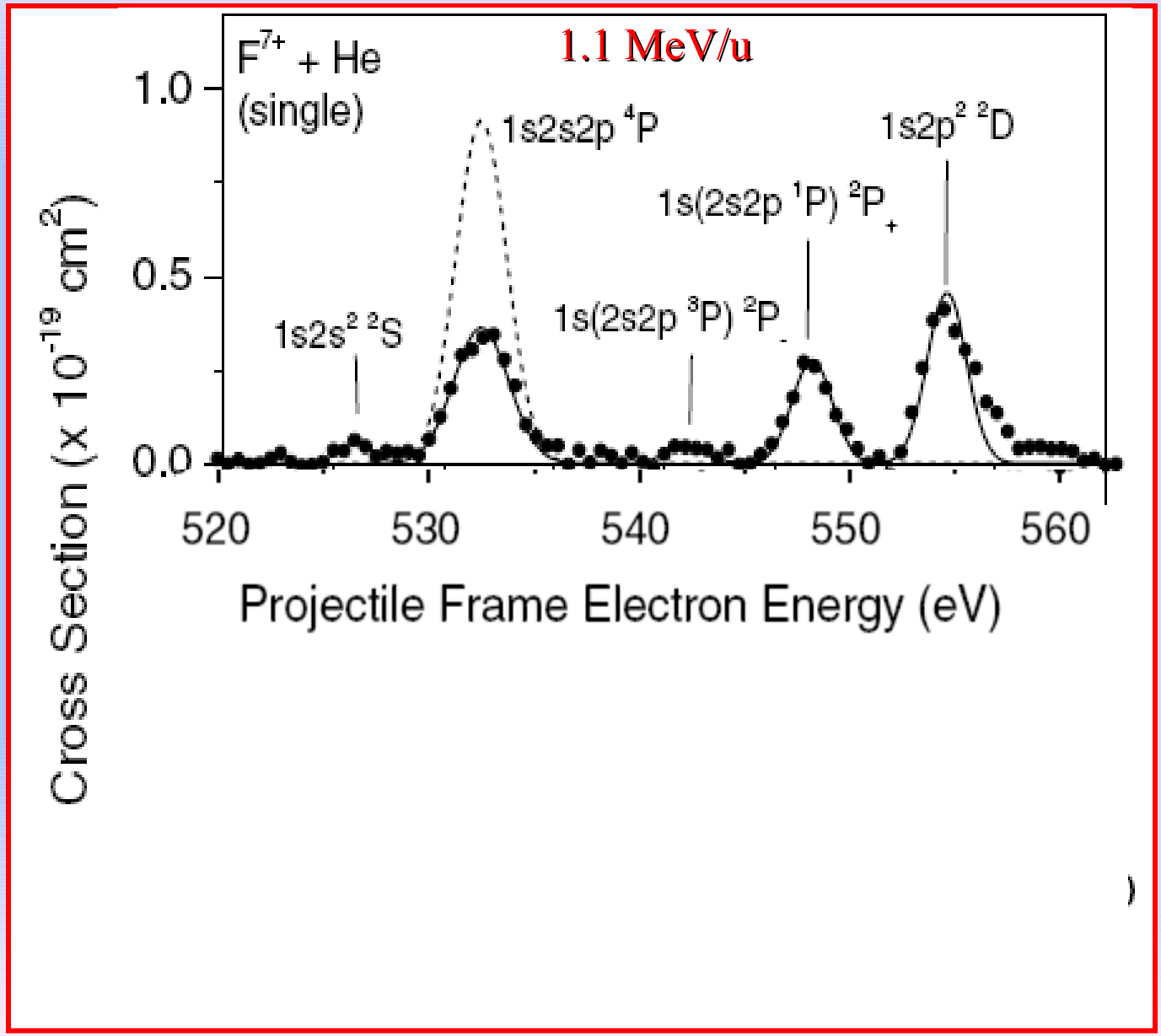
3-electron spectrum from collisions of He-like beam



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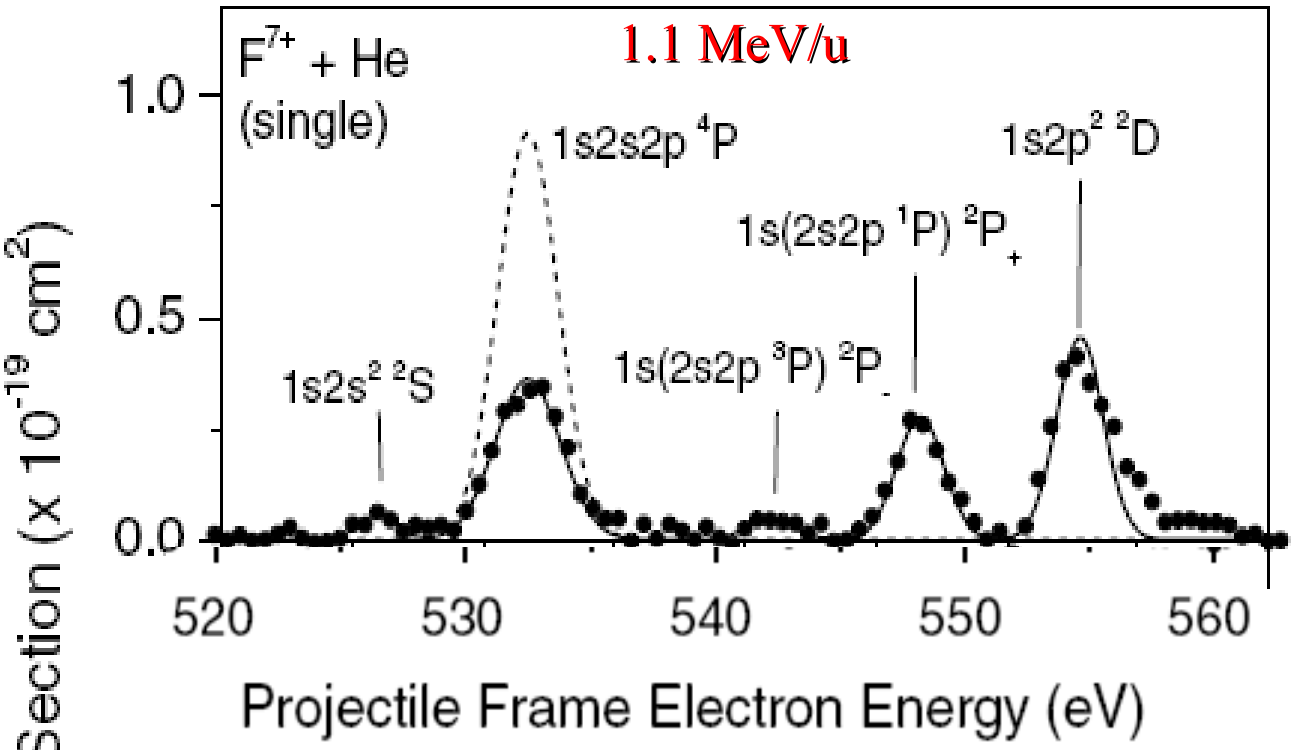


F^{7+} $(1s^2)$ 75% $\tau_{1/2}$ = stable

F^{7+} $(1s2s\ ^1S)$ <1% $\tau_{1/2}$ = 0.198 μs

F^{7+} $(1s2s\ ^3S)$ 24% $\tau_{1/2}$ = 277 μs

Spin statistics for 2p capture to pure 1s2s ^{3}S

He-like

Initial States

$1s2s\,^3S$ + 2p

$1s2s\,^1S$

$1s^2\,^1S$

Spin statistics for 2p capture to 1s2s ^{3}S

He-like Initial States

Probability

$1s2s\,^3S$ + 2p

$1s2s\,^1S$

<1 %

$\frac{4}{6}$ $(1s2s\,^3S)2p\ ^4P$

$\frac{2}{6}$ $(1s2s\,^3S)2p\ ^2P$

$1s^2$

Spin statistics for 2p capture to 1s2s ^{3}S

He-like Initial States

Probability

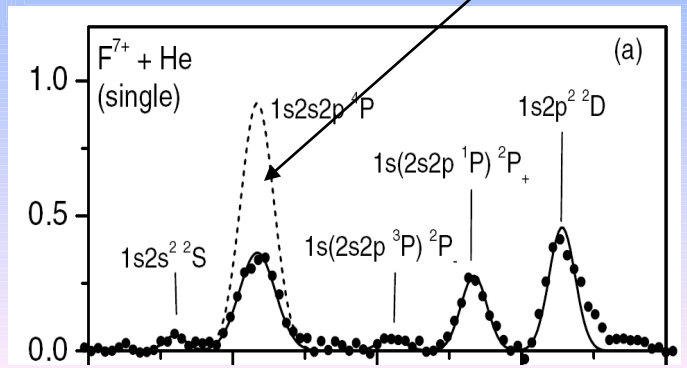
Li-like Final States

$1s2s\,^3S + 2p$

$\frac{4}{6}$ $(1s2s^3S)2p\ ^4P$ ⇢ $1s2s2p\ ^4P$

$1s2s\,^1S$

$\frac{2}{6}$ $(1s2s^3S)2p\ ^2P$



$1s^2$

Spin statistics for 2p capture to 1s2s ^3S

He-like Initial States

Probability

Li-like Final States

$1s2s\,^3S + 2p$

$1s2s\,^1S$

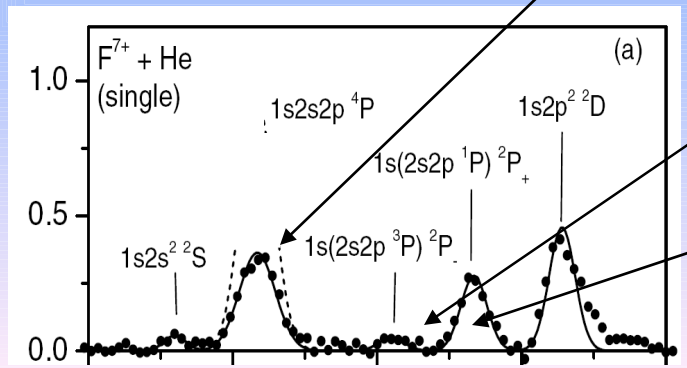
$\frac{4}{6}$ $(1s2s^3S)2p\ ^4P$ ⋯⋯▸ $1s2s2p\ ^4P$

$\frac{2}{6}$ $(1s2s^3S)2p\ ^2P$

Spin recoupling

$\frac{1}{4}$ $1s(2s2p\ ^3P)\ ^2P_-$

$\frac{3}{4}$ $1s(2s2p\ ^1P)\ ^2P_+$



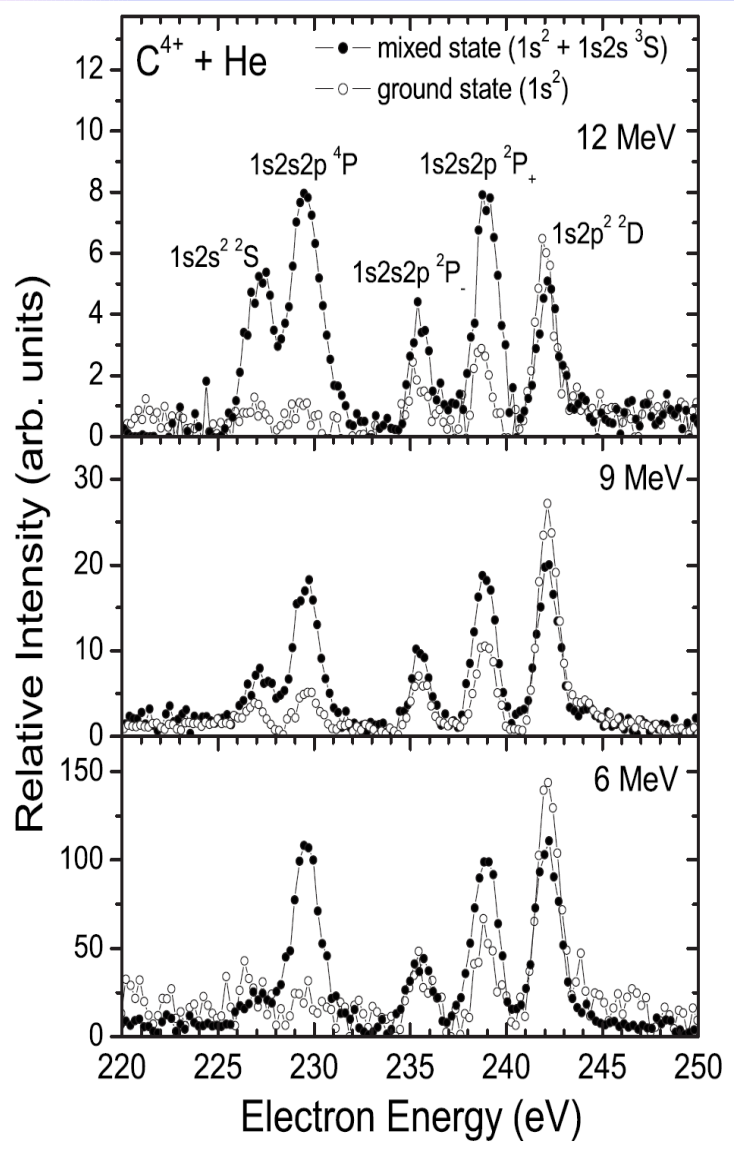
$1s^2$

Final breakdown

$^4P : {}^2P : {}^2P_+$

$\frac{8}{12} : \frac{1}{12} : \frac{3}{12}$

Obtaining pure metastable beam contributions



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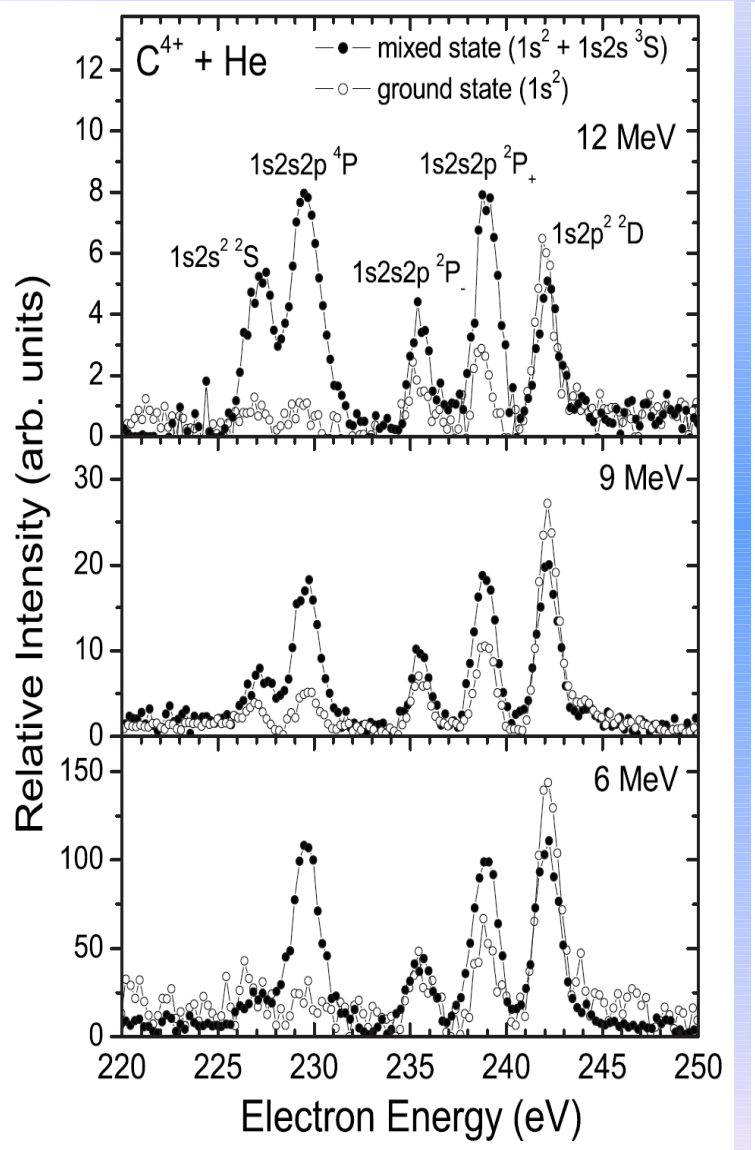
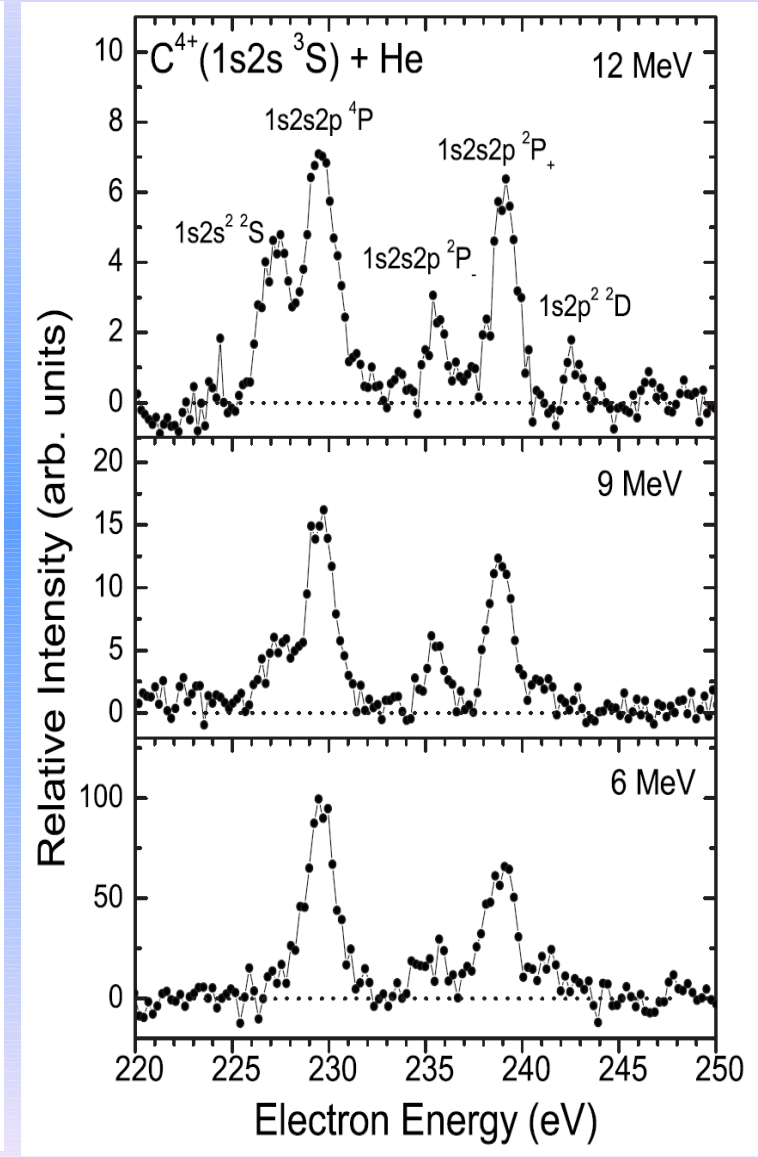
Obtaining pure metastable beam contributions

Pure metastable = Mixed - Ground





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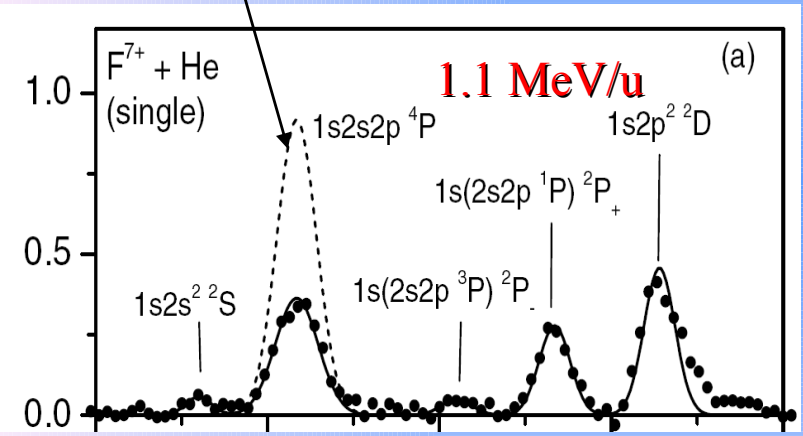
Yield corrections due to ^4P_J metastability

Important
Yield correction



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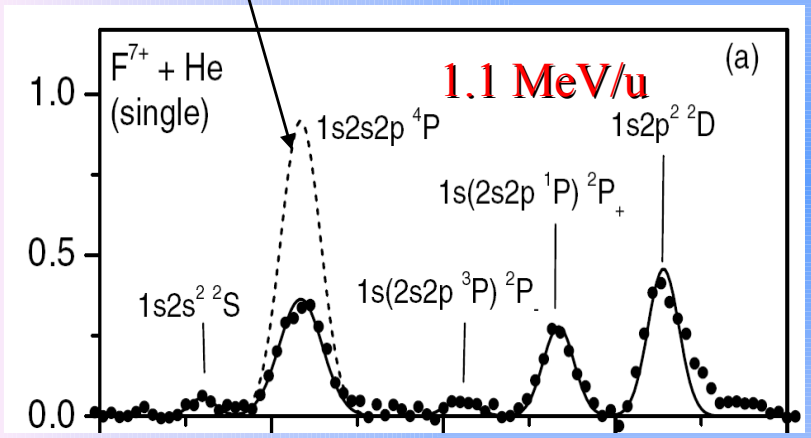

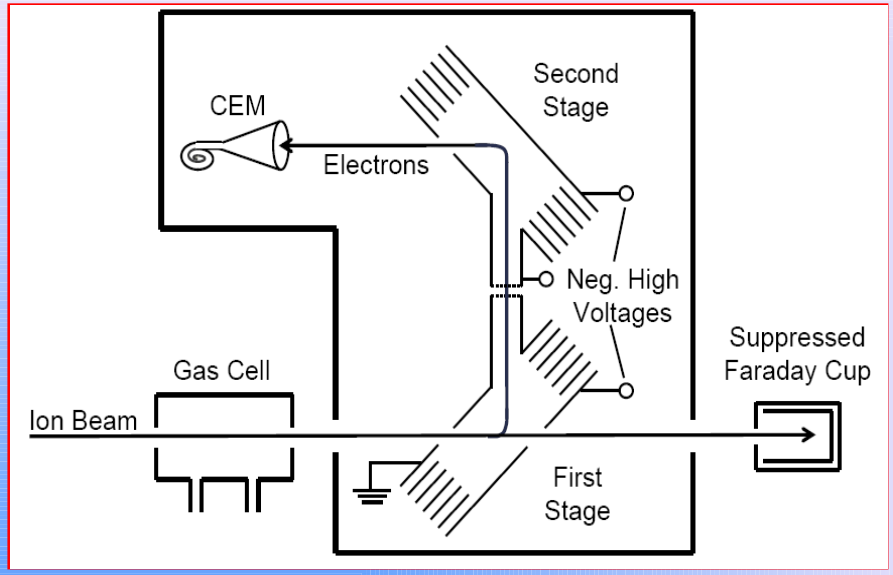

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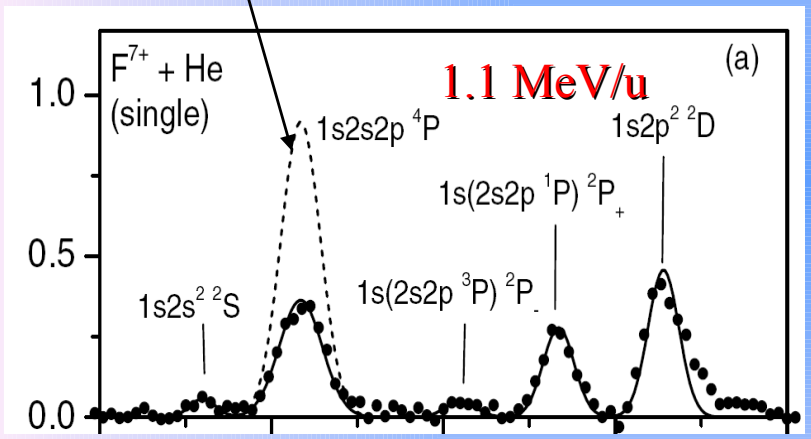
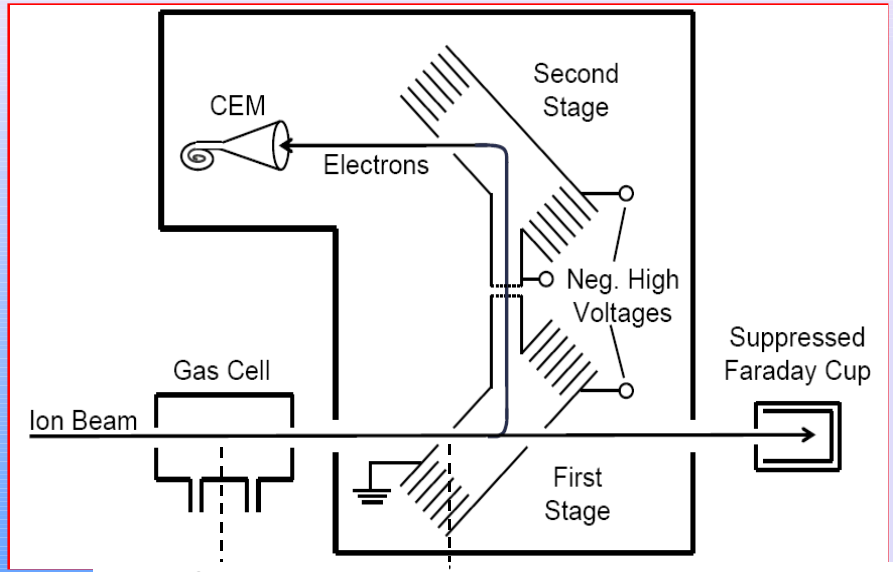
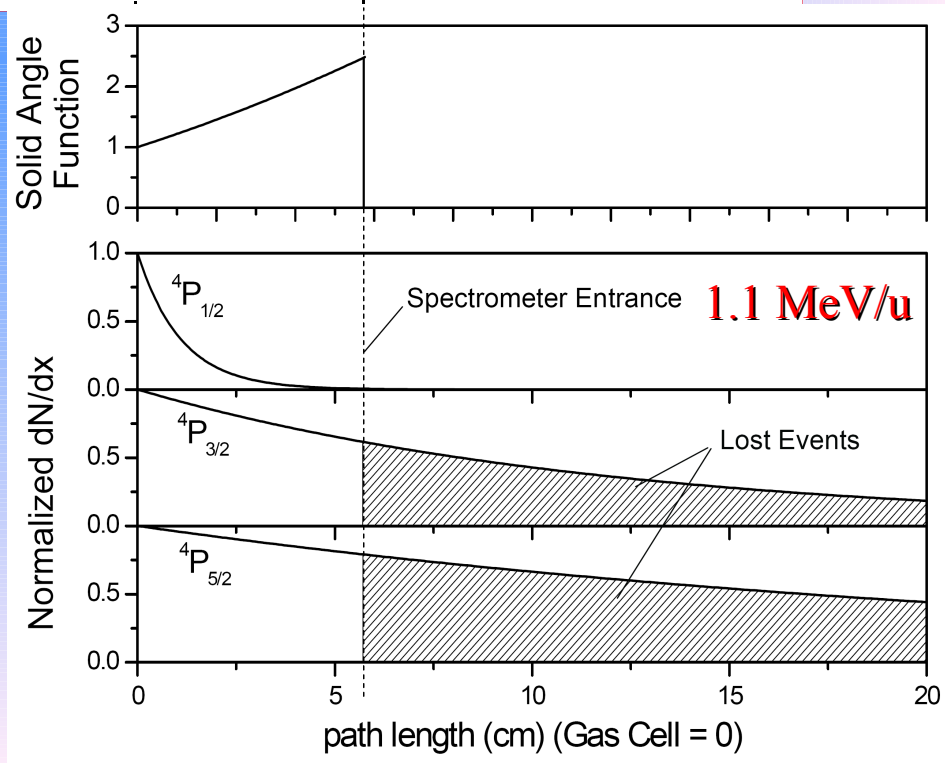
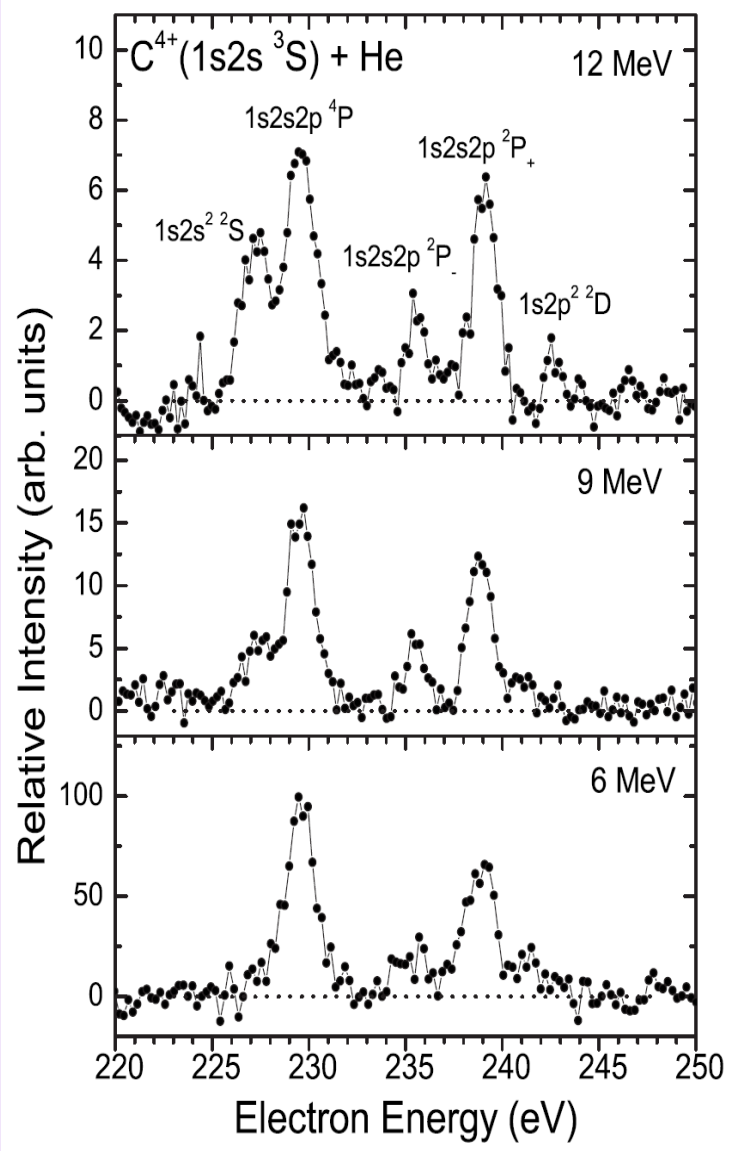
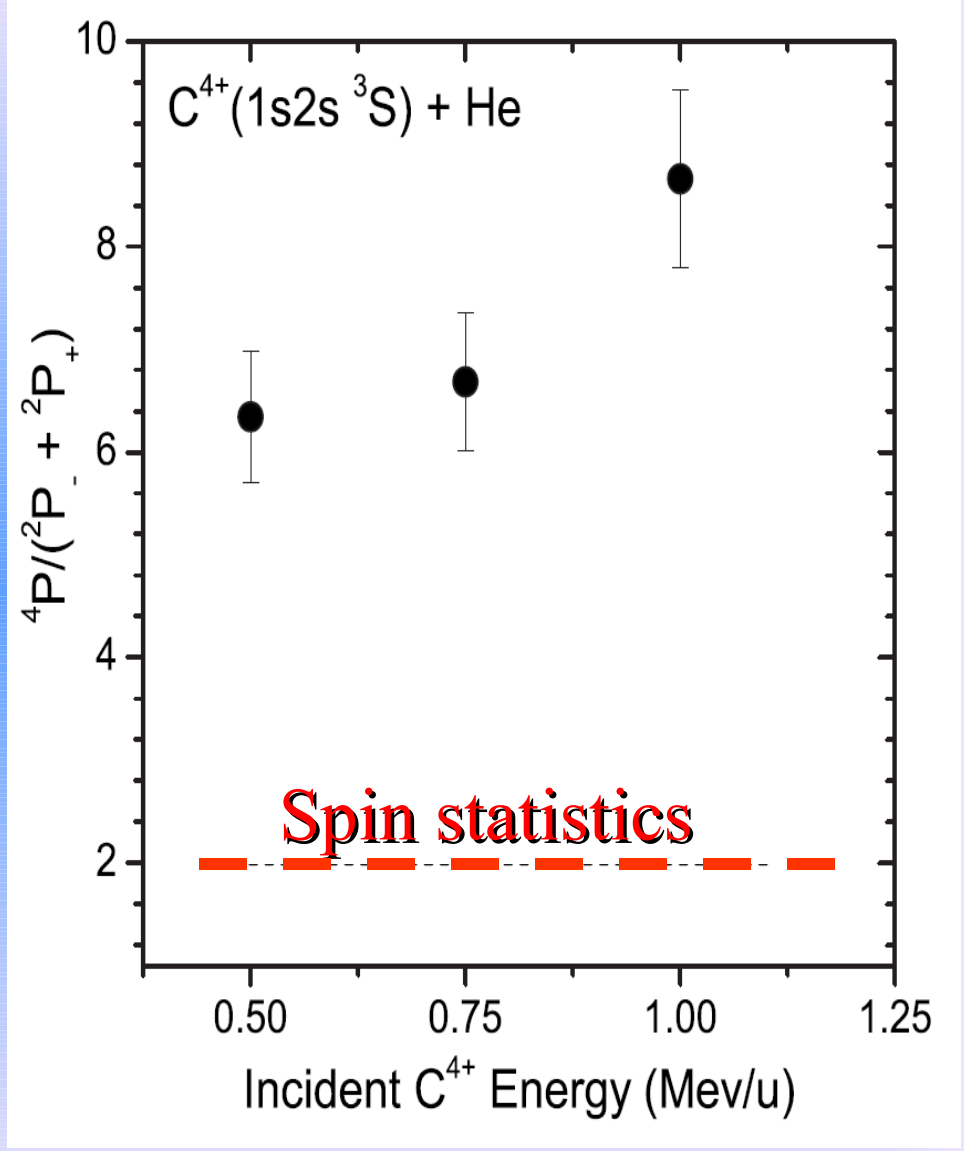






Obtaining pure metastable beam contributions





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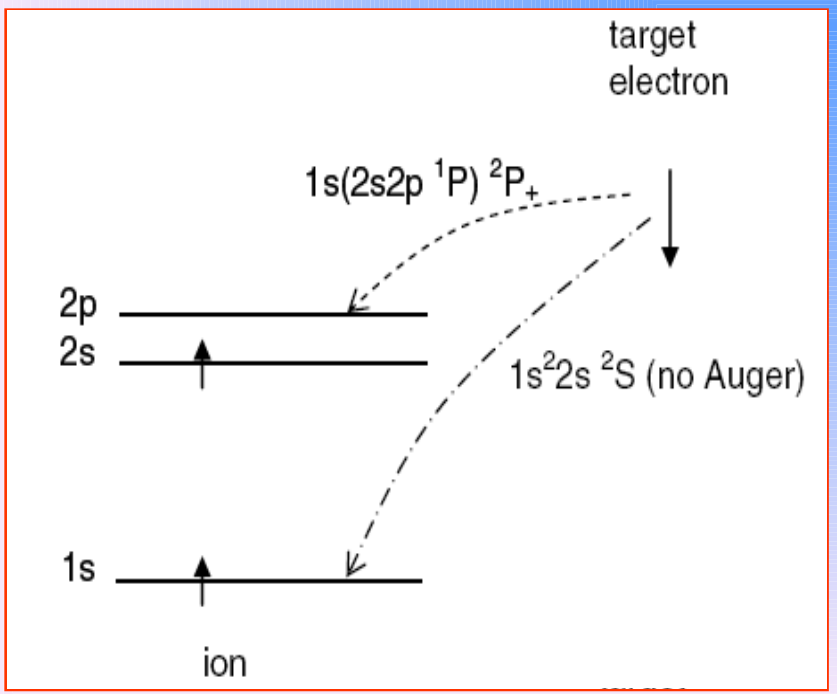
Pauli exchange interaction

VOLUME 92, NUMBER 13 PHYSICAL REVIEW LETTERS week ending 2 APRIL 2004

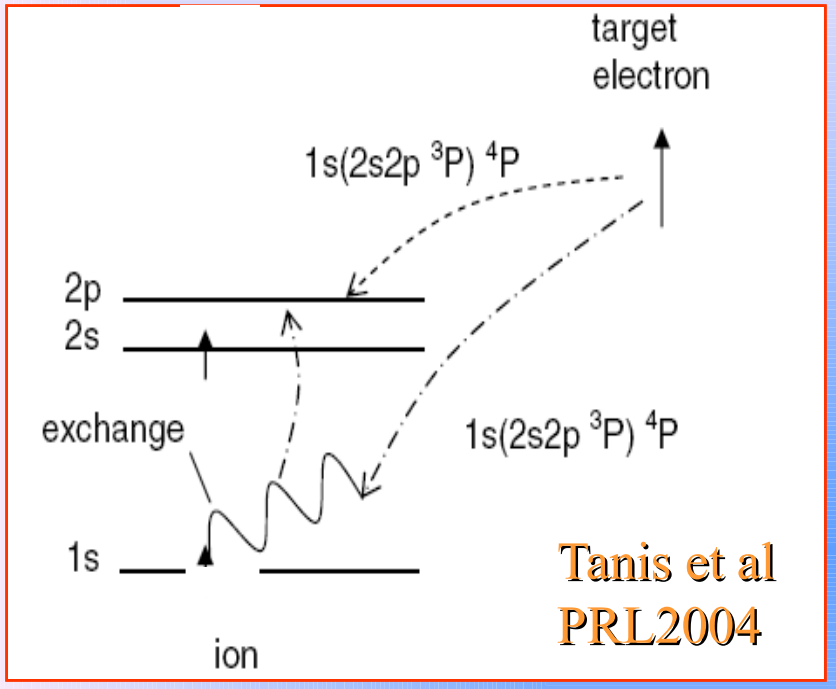
Evidence for Pauli Exchange Leading to Excited-State Enhancement in Electron Transfer

J. A. Tanis,[1] A. L. Landers,[1] D. J. Pole,[1] A. S. Alnaser,[1] S. Hossain,[1] and T. Kirchner[2]
[1]*Department of Physics, Western Michigan University, Kalamazoo, Michigan 49008, USA*
[2]*Institut für Theoretische Physik, Technische Universität Clausthal, Leibnizstrasse 10, D-38768 Clausthal-Zellerfeld, Germany*
(Received 26 June 2003; published 2 April 2004)



- An electron with antialigned spin can populate either the 1s, 2s or 2p levels, in the later case giving rise to the $^2P_+$ state

Pauli exchange interaction



Tanis et al
PRL2004

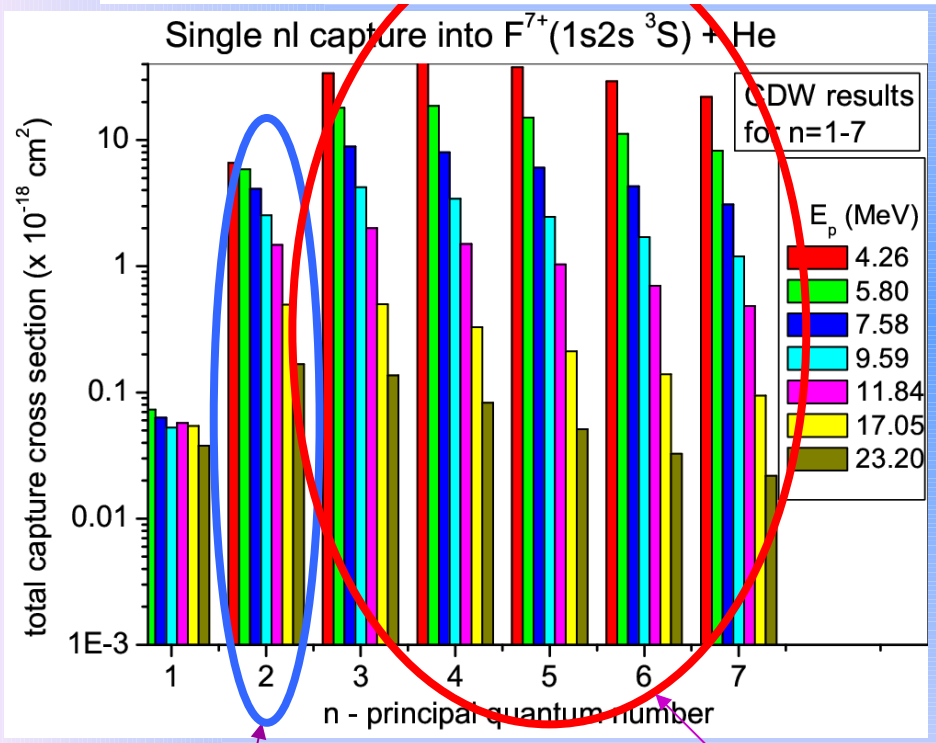
- An electron with a spin aligned with the spin of the 1s projectile:
  a) can be captured into the 2p directly to form the ^{4}P state

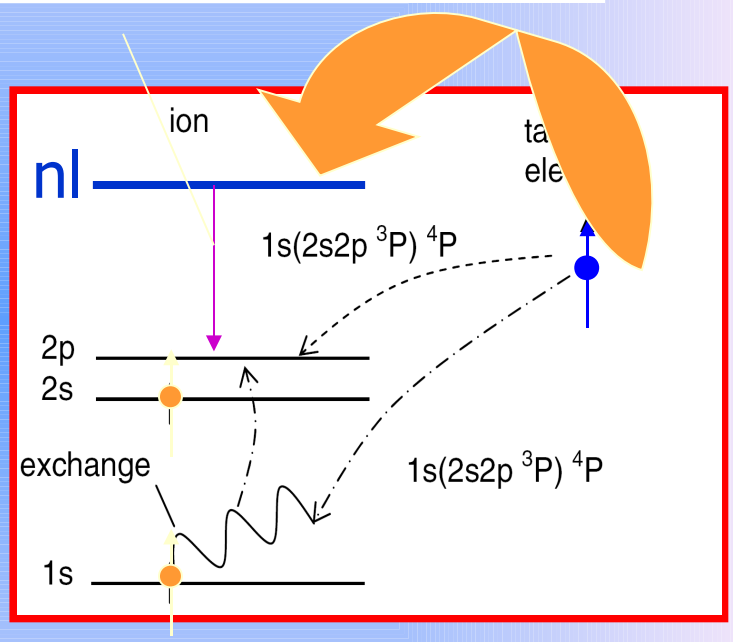
b) cannot be captured into the 1s (or 2s) due to Pauli exclusion.
So instead it interacts with the 1s (or 2s) via a
Pauli Exchange Interaction
so that one of them is transferred to the 2p forming additional ^{4}P states

PHYSICAL REVIEW A 77, 050701(R) (2008)

Selective enhancement of $1s2s2p\ ^4P_J$ metastable states populated by cascades in single-electron transfer collisions of $F^{7+}(1s^2/1s2s\ ^3S)$ ions with He and H_2 targets

T. J. M. Zouros,[1,2] B. Sulik,[3] L. Gulyás,[3] and K. Tőkési[3]
[1]*Department of Physics, University of Crete, P.O. Box 2208, 71003 Heraklion, Crete, Greece*
[2]*Institute of Electronic Structure and Laser, FORTH, P.O. Box 1385, GR-71110 Heraklion, Crete, Greece*
[3]*Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI), H-4001 Debrecen, Hungary*
(Received 24 December 2007; published 9 May 2008)





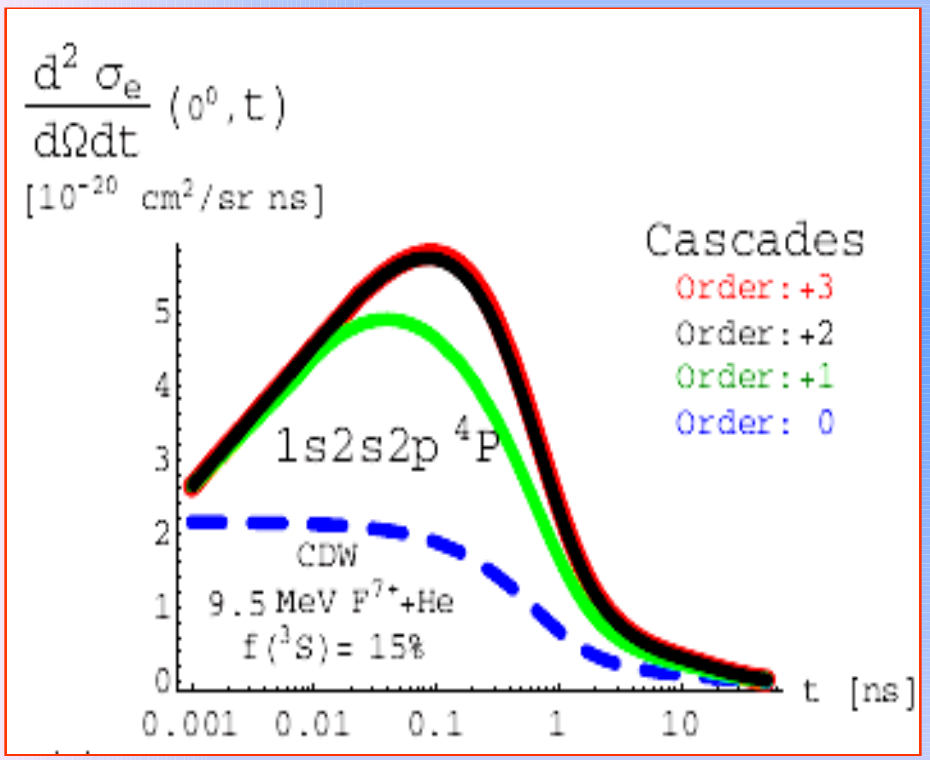
Overlooked channel:
Radiative cascade Feeding!

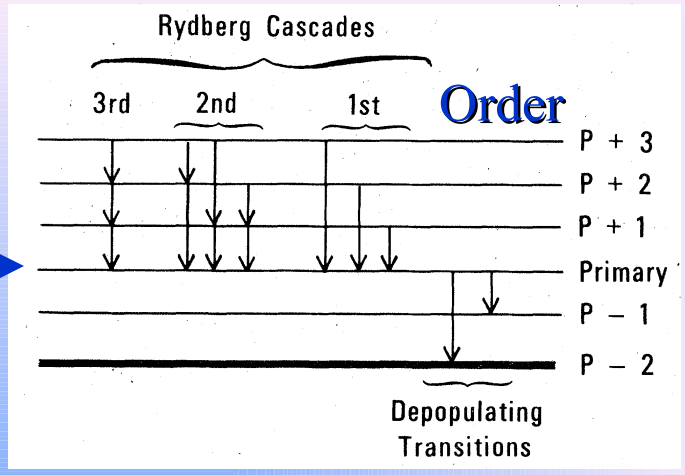
Tanis et al considered capture only to n=2

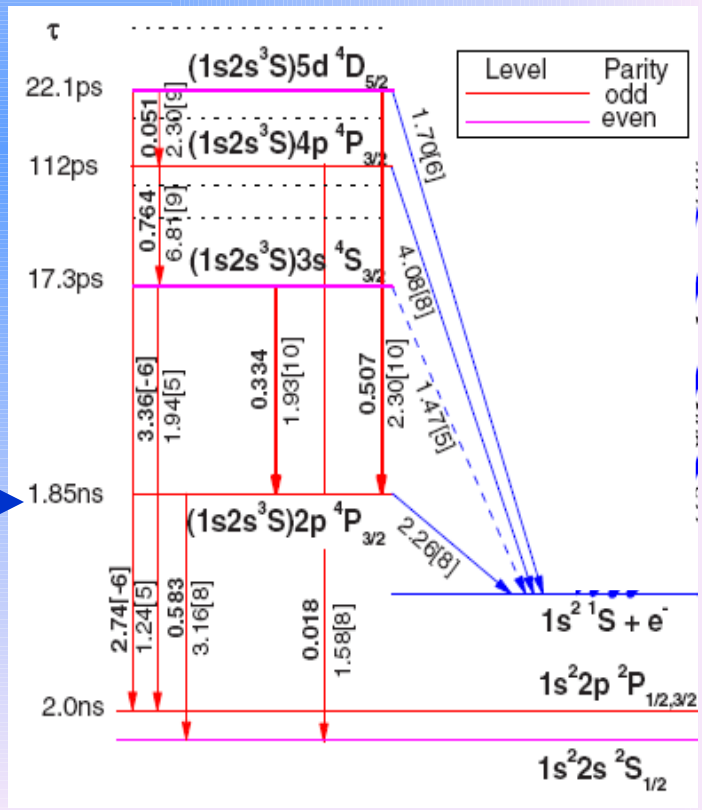
Significant capture to higher n=3-7 indicated by our CDW calculations

Cascade feeding 1s2s2p ^{4}P analysis

$$\frac{dN_p}{dt} = -N_p(t)\sum_{q=1}^{p-1} A_{pq} + \sum_{i=p+1}^{\infty} N_i(t)A_{ip}$$







Zouros et al,
Phys. Rev. A Rapid Comm. 2008

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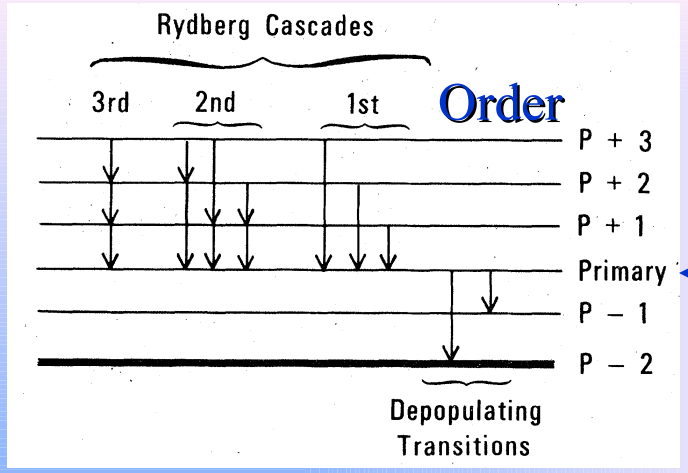
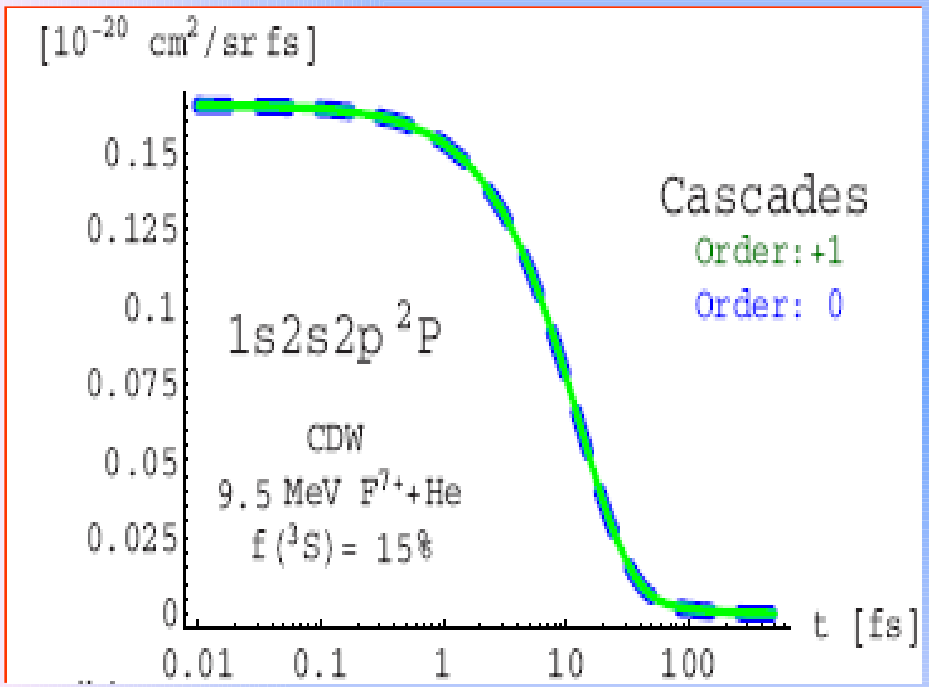
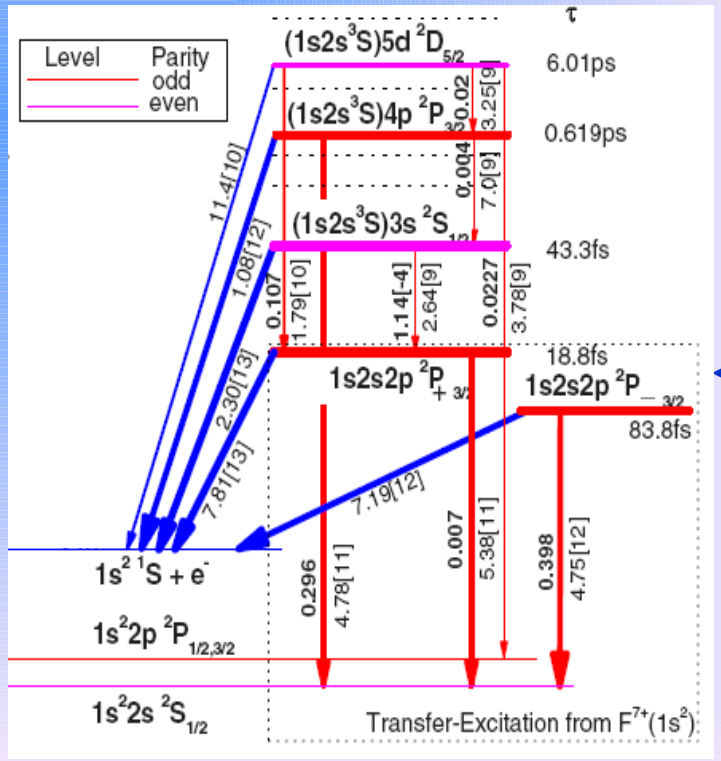
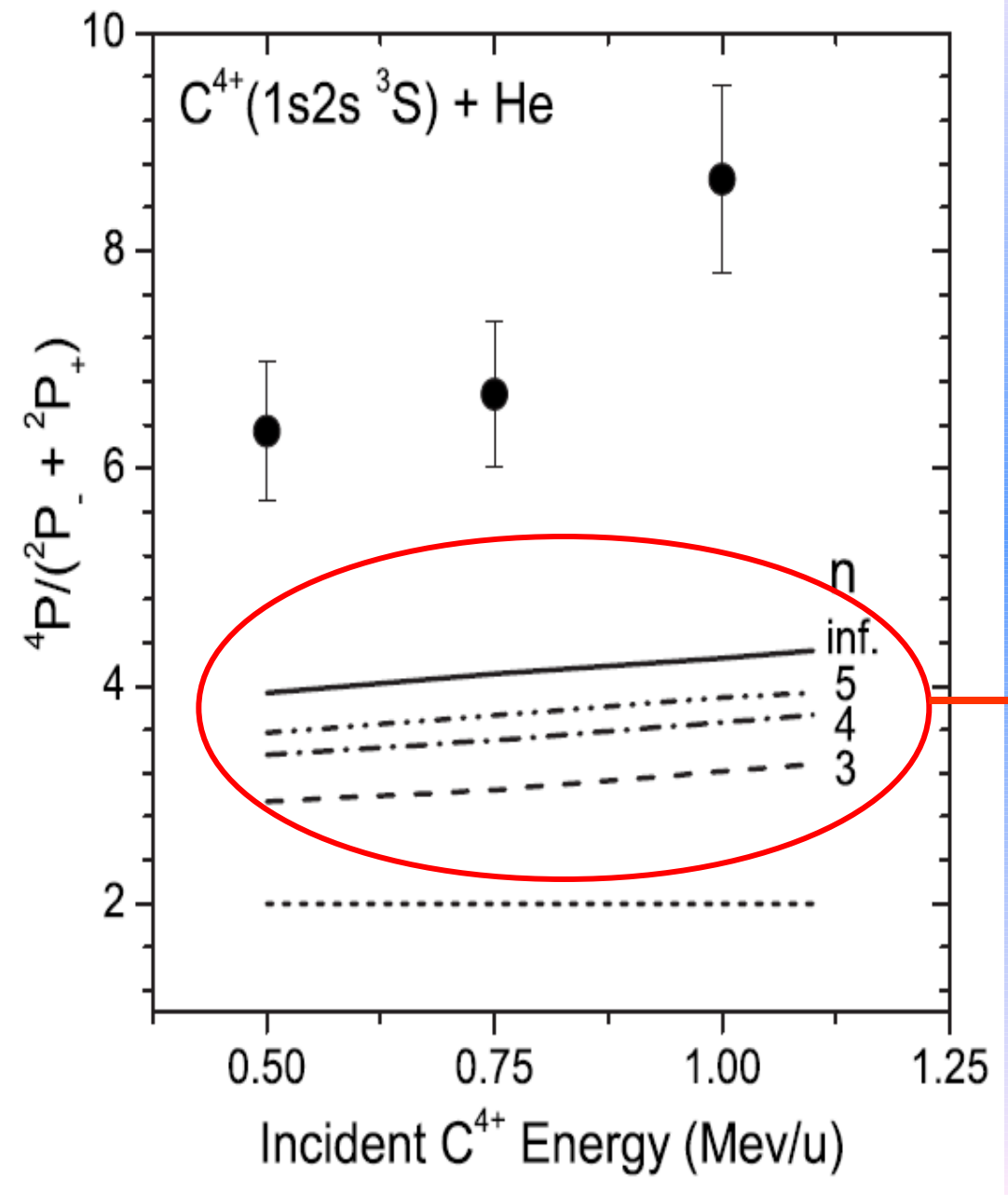






Zouros et al,
Phys. Rev. A Rapid Comm. 2008

Final verdict



Cascade feeding accounts for about 50% of the observed enhancement

So what is the rest due to?

Proposal

- Isoelectronic sequence study using He-like ions from Li^{+} to F^{7+} in the 0.1-0.5 MeV/u where capture is strongest and effect seems to be the largest

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- Needed: terminal gas stripper to produce pure ground state He-like beams – otherwise need to calculate ground state contribution

The end – thank you for listening

References

Non-statistical results

- Tanis et al. PRL 92 (2004) 133201
- Zouros et al. PRA 77 (2008) 050701
- Strohschein et al. PRA 77 (2008) 022706

Production of pure ground state He-like ion beams

- Benis & Zouros, PRA 65 (2002) 064701

Contact: tzouros@physics.uoc.gr