Measurement of Charge Exchange Cross Section for HCI Collision with Atom and Molecule

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Contents

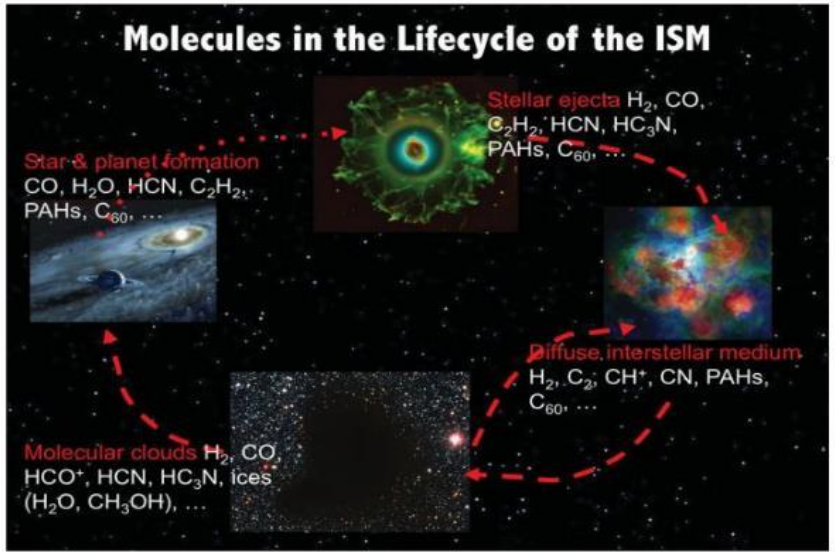
01 Motivation

Motivation

Collision experiment (atomic, molecular and cluster)

available comprehensive data and parameters

Benchmarking theory



Chem. Rev. 2012, 112, 5578

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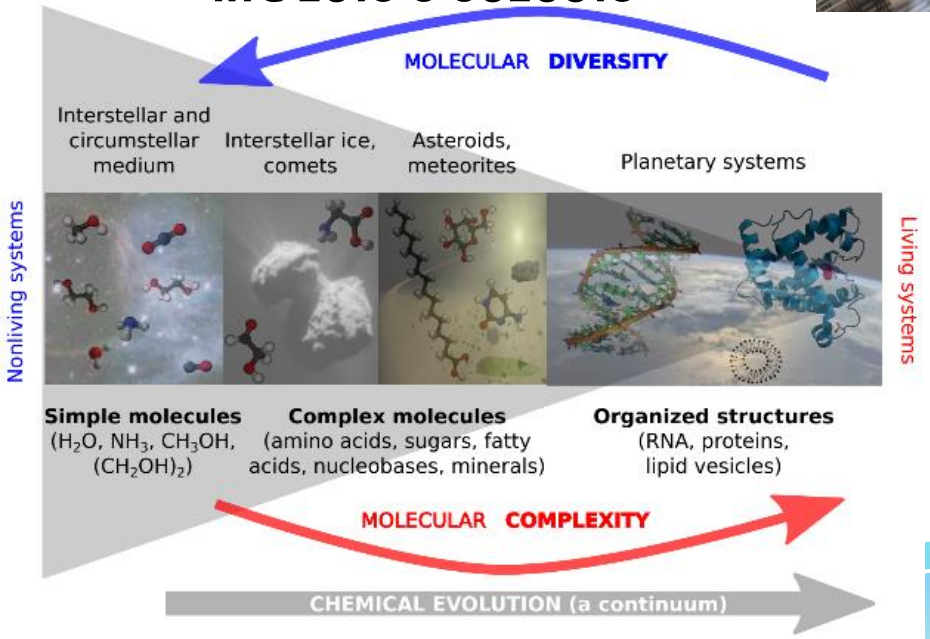
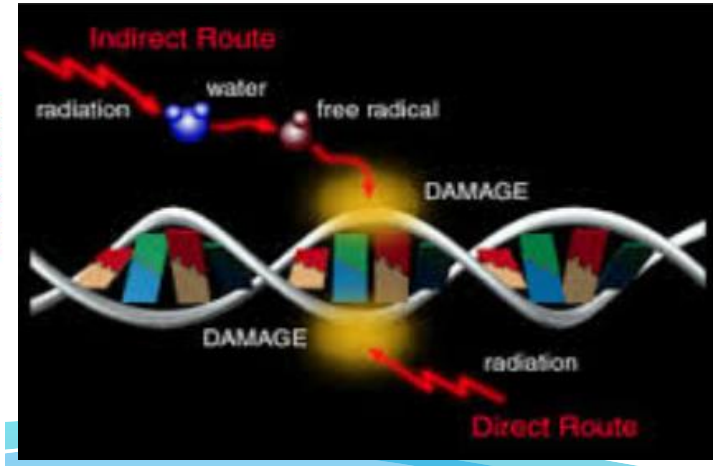
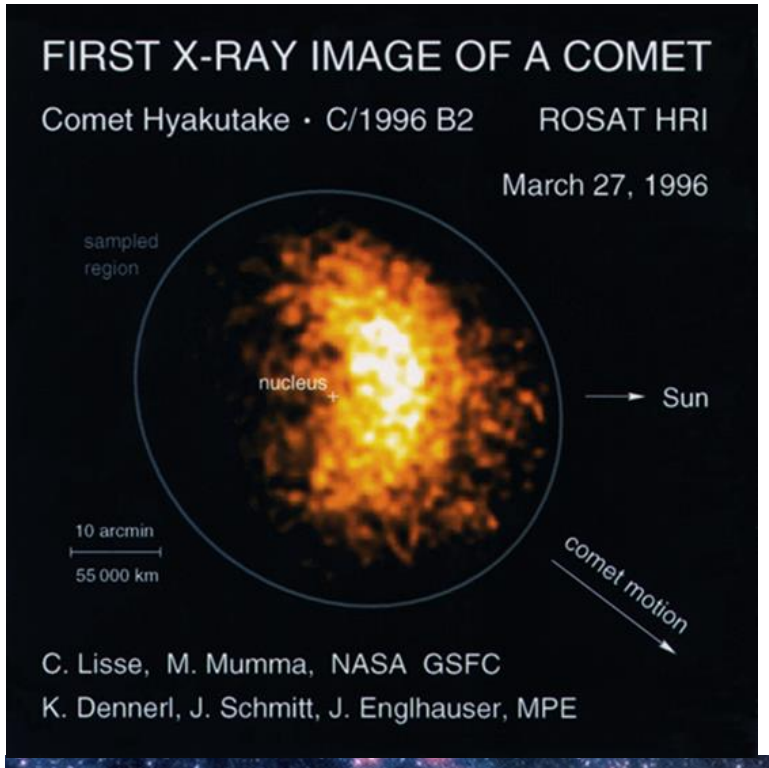
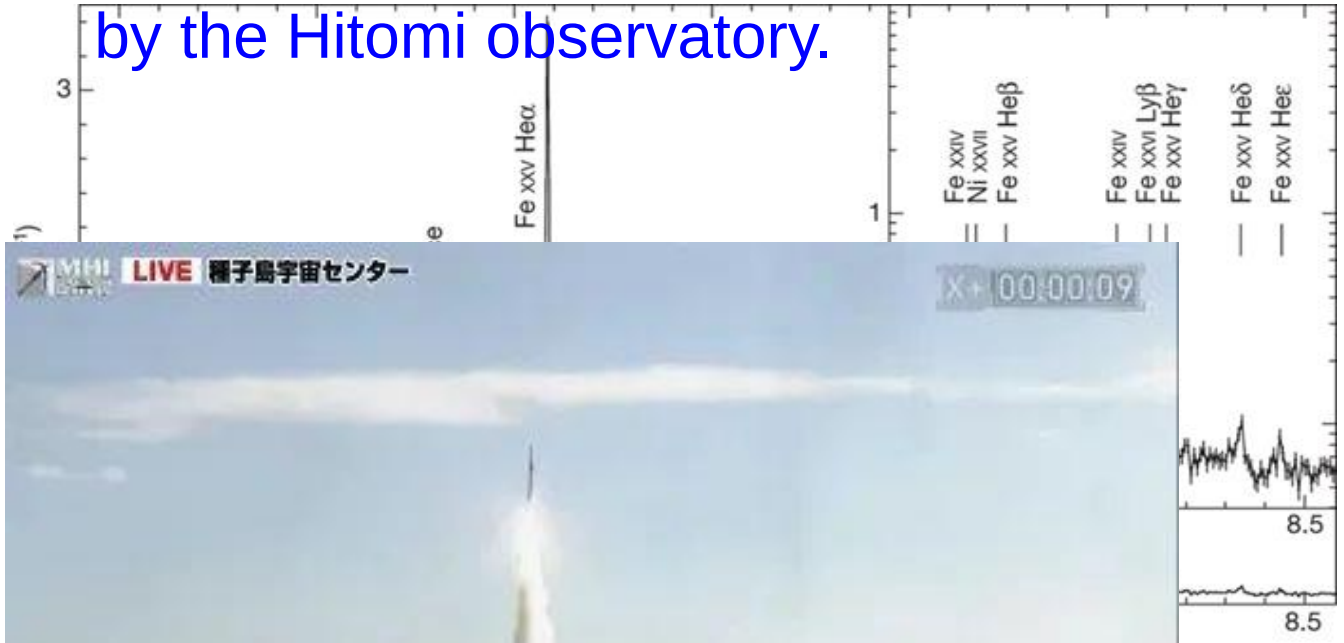


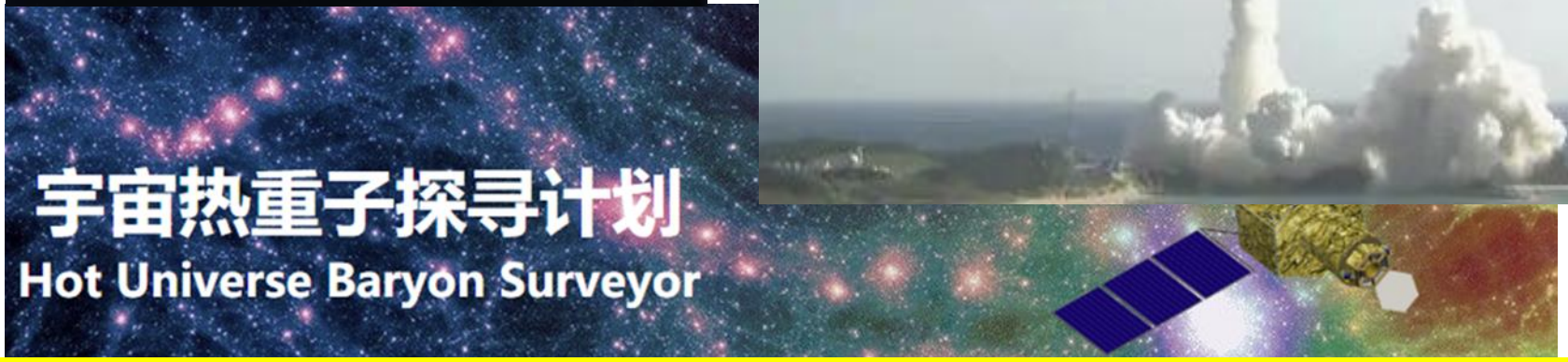


Charge Exchange Cross Section



Spectrum of the Perseus cluster obtained by the Hitomi observatory.





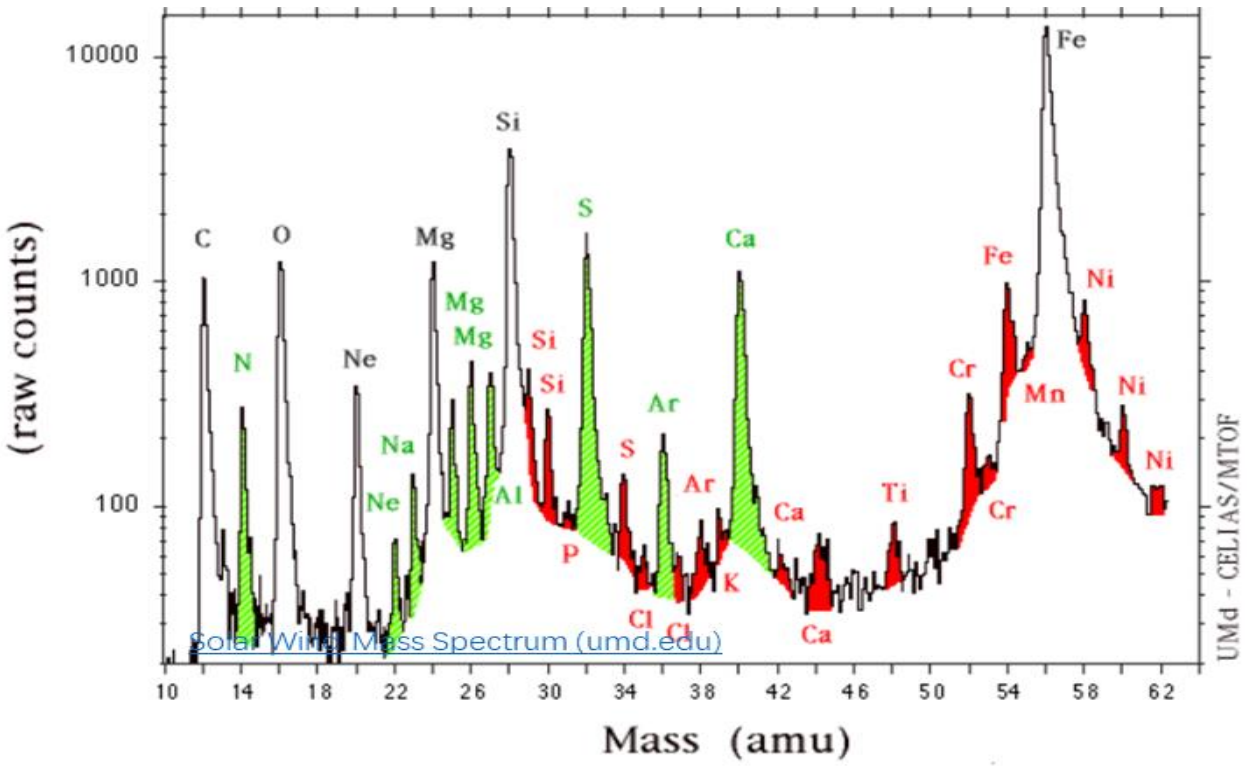
Science, 1996, 274: 205

Nature, 2016, 535: 117

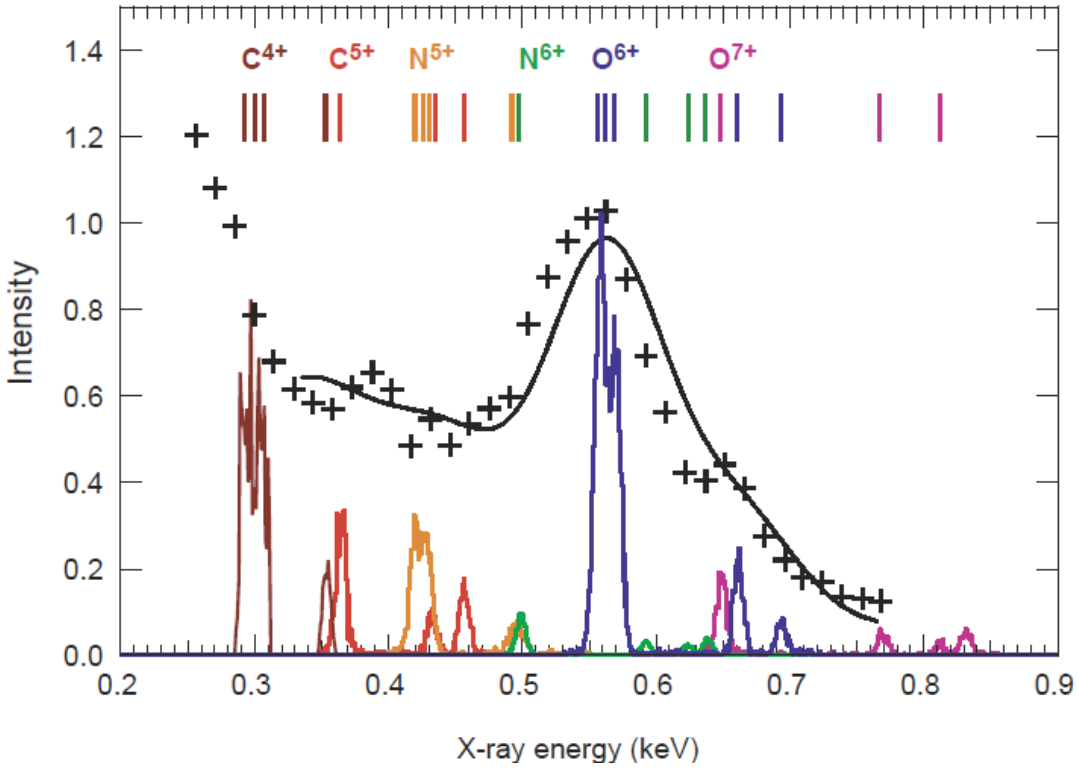
the high-resolution astrophysical spectrum needs the accurate atomic data

Charge Exchange Cross Section

Solar Wind Mass Spectrum

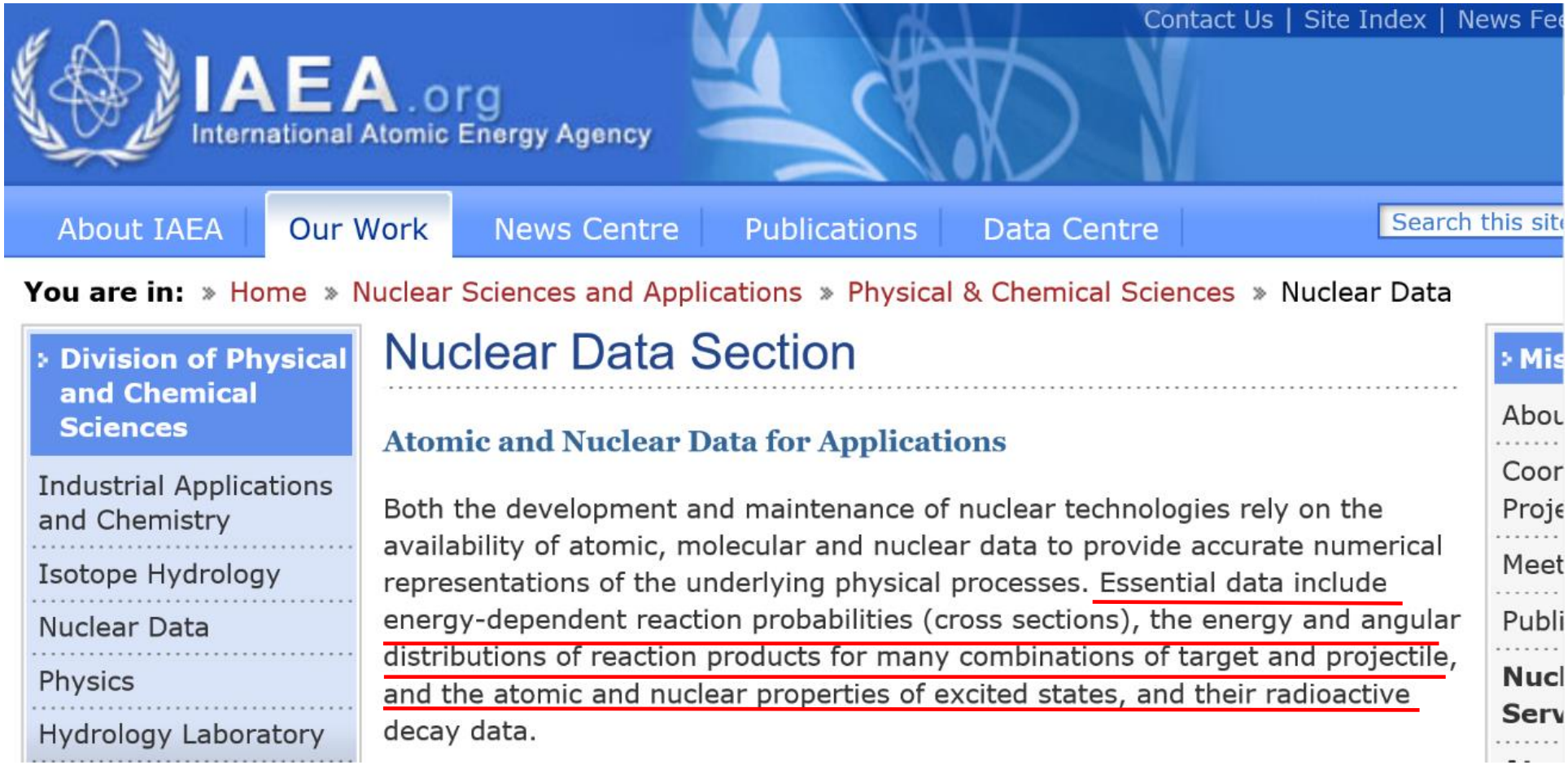


http://umtof.umd.edu/pub/full_spectrum.html



Science 300, 1558 (2003)

Motivation



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- Industrial Applications and Chemistry
- Isotope Hydrology
- Nuclear Data
- Physics
- Hydrology Laboratory

Nuclear Data Section

Atomic and Nuclear Data for Applications

Both the development and maintenance of nuclear technologies rely on the availability of atomic, molecular and nuclear data to provide accurate numerical representations of the underlying physical processes. Essential data include energy-dependent reaction probabilities (cross sections), the energy and angular distributions of reaction products for many combinations of target and projectile, and the atomic and nuclear properties of excited states, and their radioactive decay data.

Motivation

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 234:14 (4pp), 2018 January
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https://doi.org/10.3847/1538-4365/aaa02c

Measurement of Absolute Single and Double Charge Exchange Cross Sections for $Si^{(7-10)+}$ at 0.88–2.50 KeV/u Impacting He and H_2

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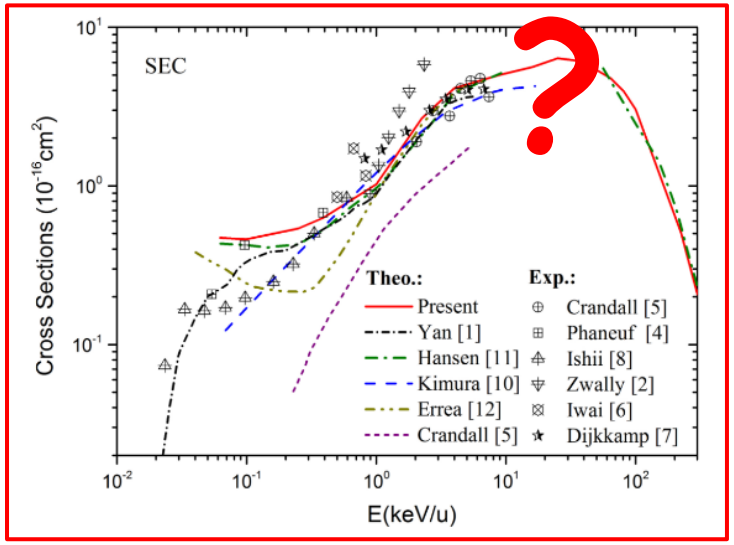
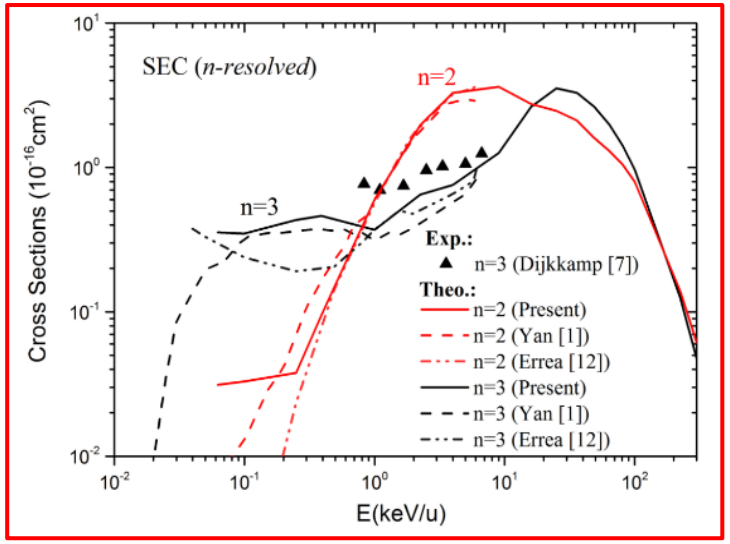
[1] Department of Science and Math, California Maritime Academy, Vallejo, CA 94590, USA

PHYSICAL REVIEW A **96**, 052703 (2017)

Single- and double-electron transfer in low- and intermediate-energy C^{4+} + He collisions

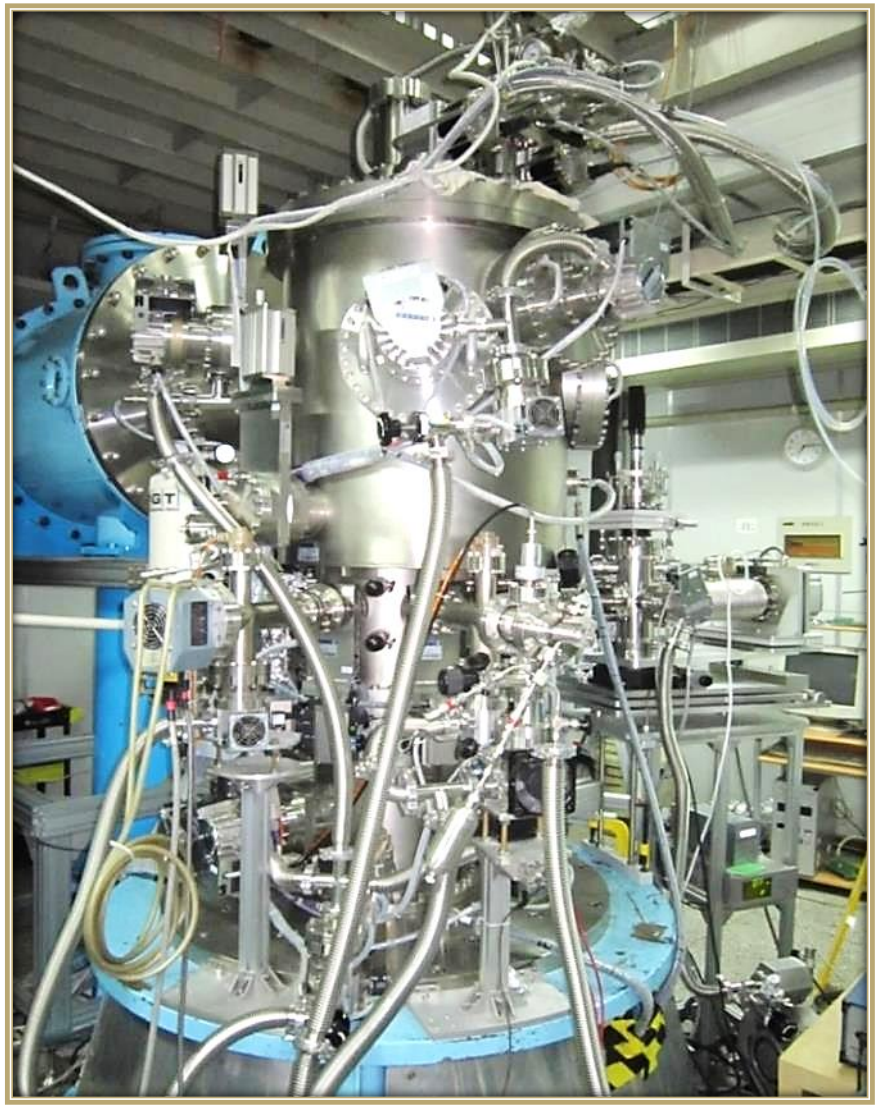
J. W. Gao,[1,2,*] Y. Wu,[1] N. Sisourat,[2] J. G. Wang,[1] and A. Dubois[2]



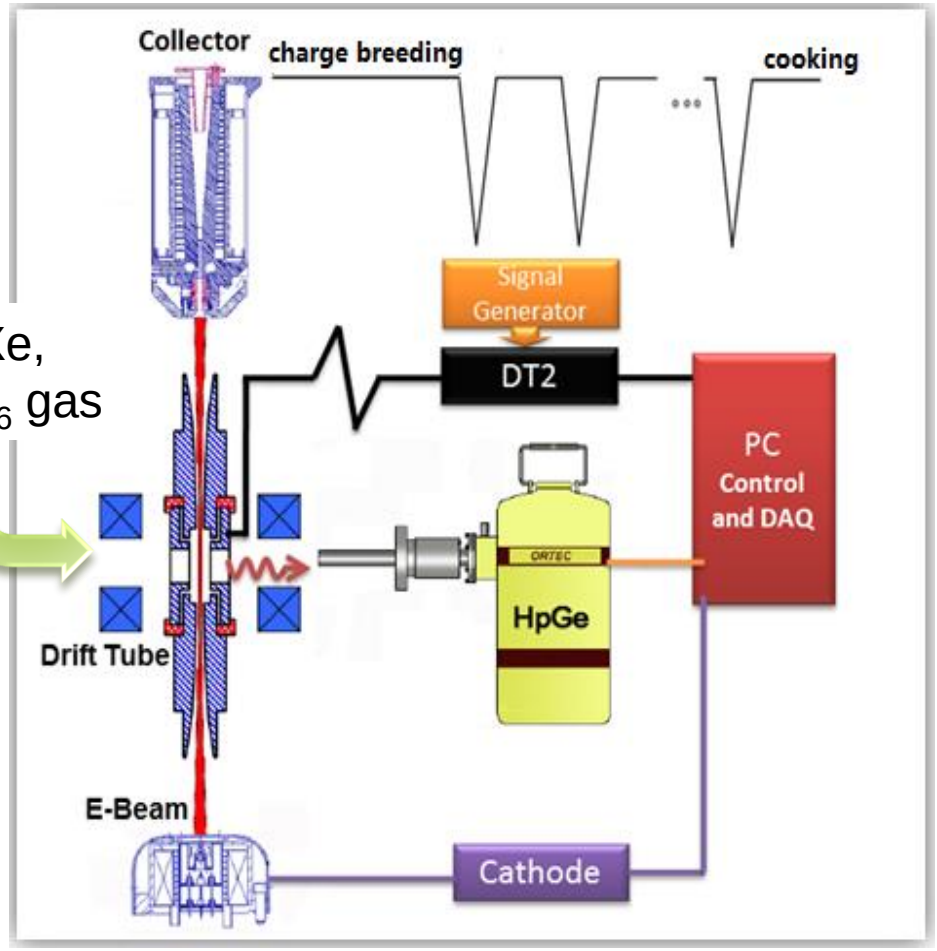


02 Experiment setup

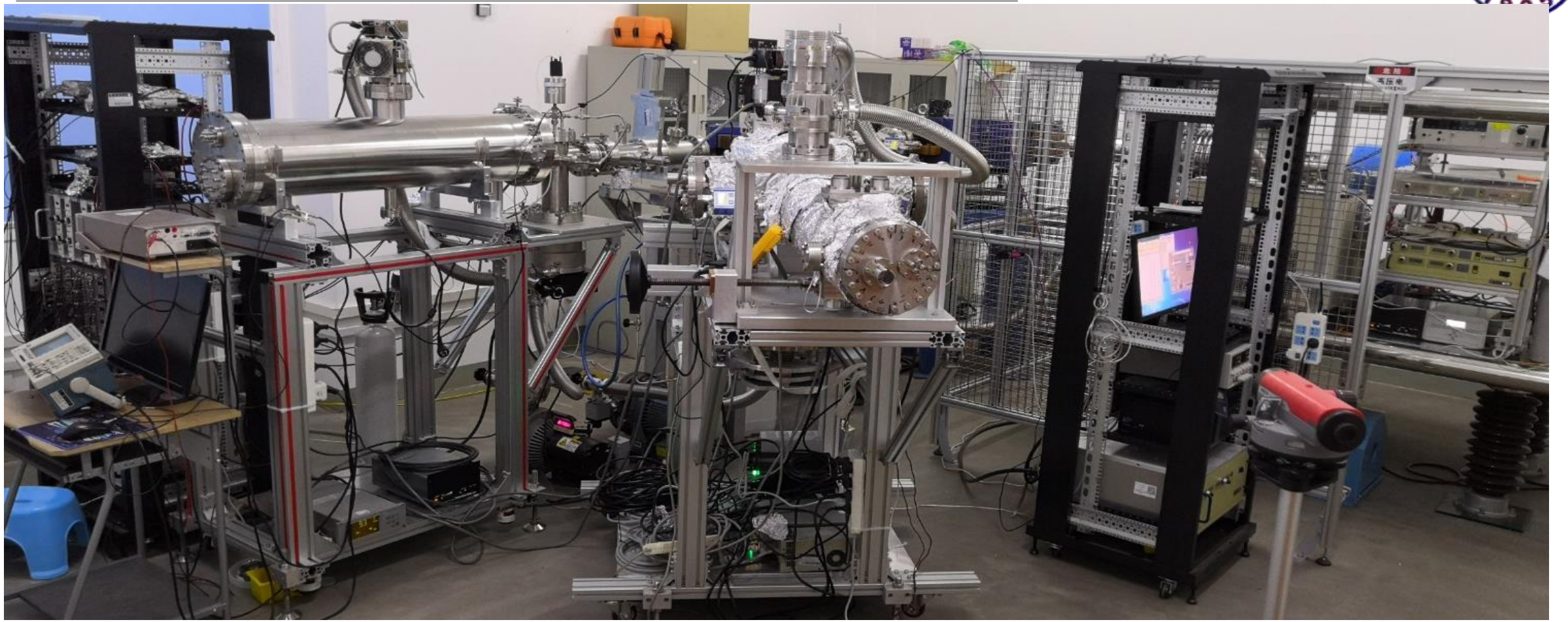
Shanghai EBIT



Data acquisition system



Setup: 150 kV HCI platform



Molecular fragmentation

Collision cross section

Surface irradiated interaction

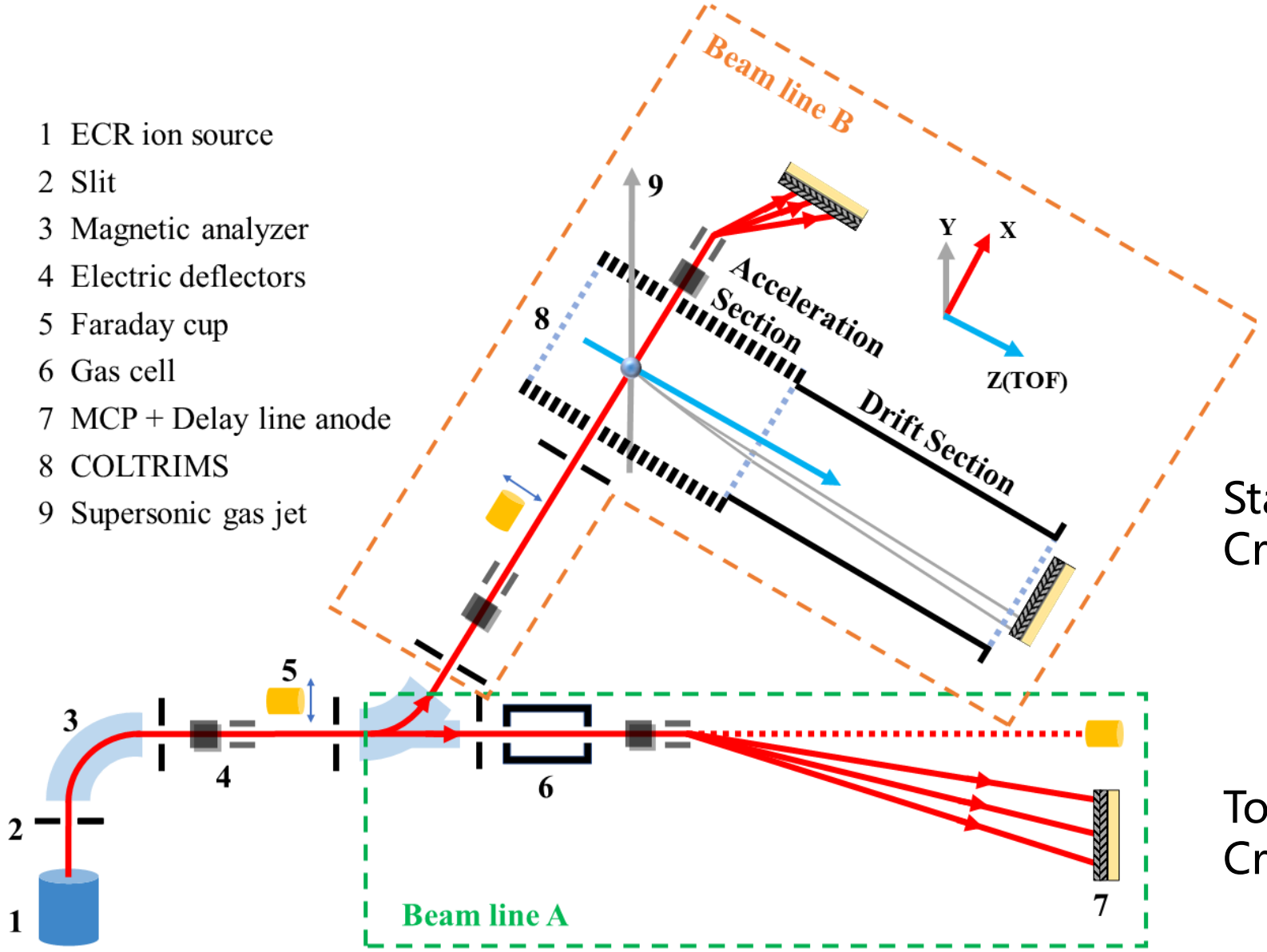
COLTRIMS

CS measurement device

……

Setup: 150 kV HCI platform

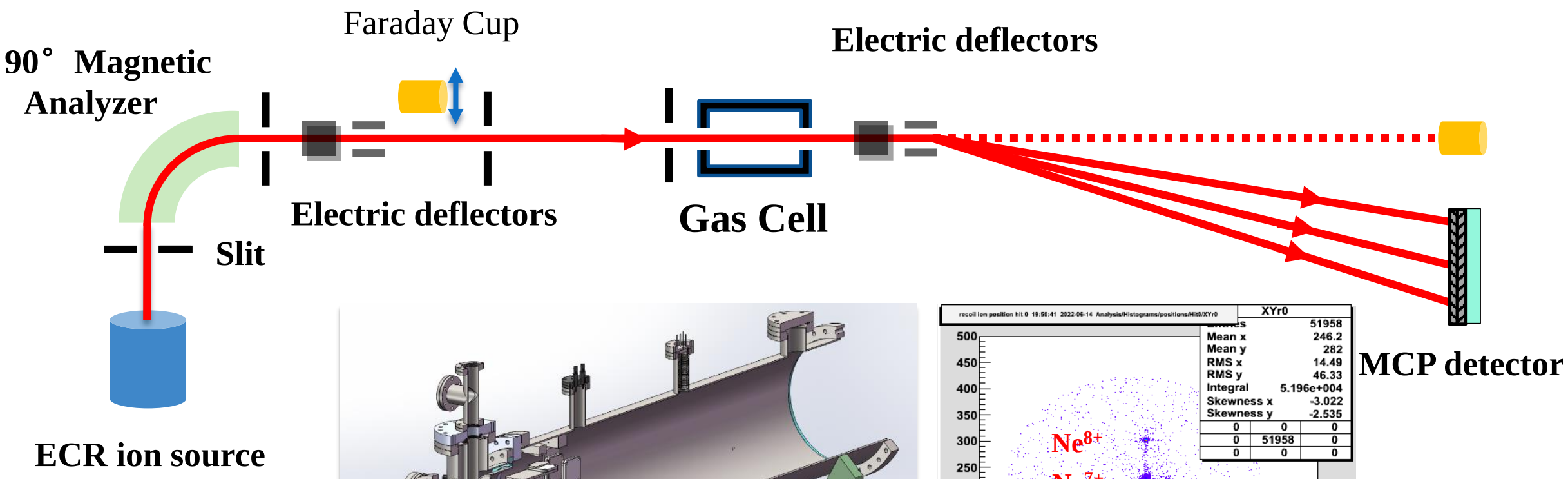
1 ECR ion source
2 Slit
3 Magnetic analyzer
4 Electric deflectors
5 Faraday cup
6 Gas cell
7 MCP + Delay line anode
8 COLTRIMS
9 Supersonic gas jet



State-selective EC
Cross Section Measurement

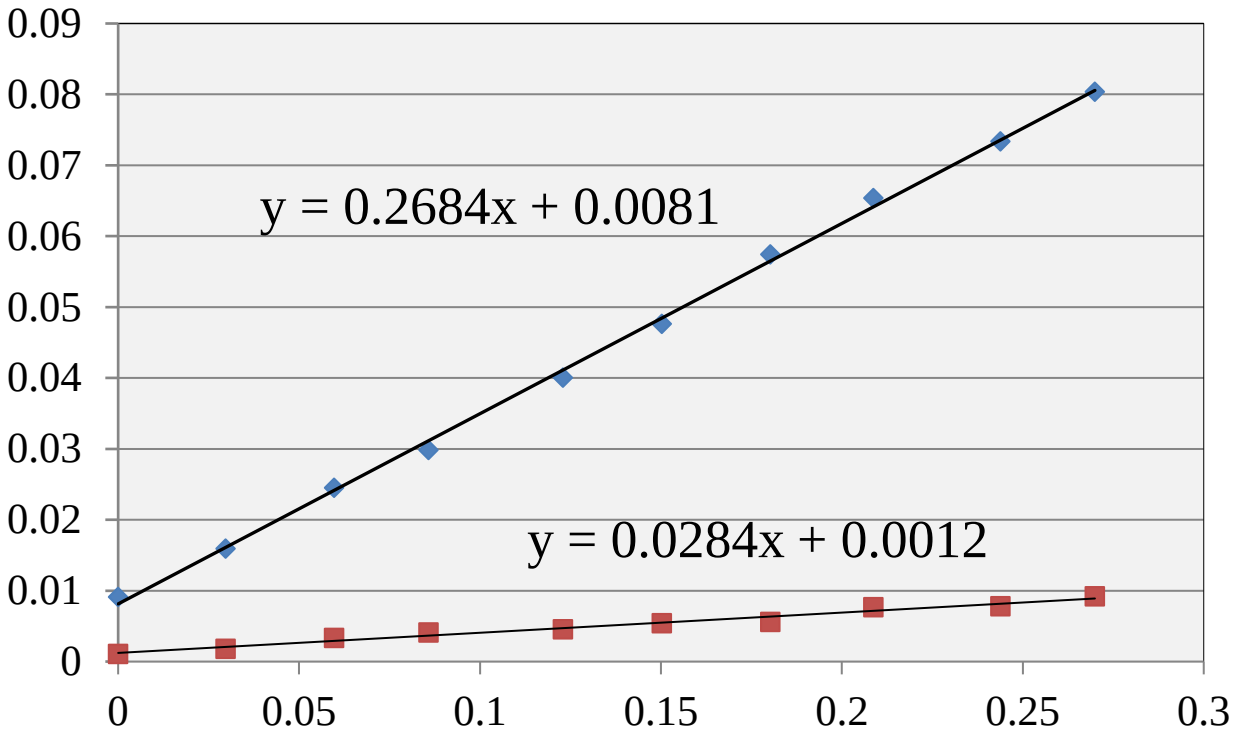
Total EC
Cross Section Measurement

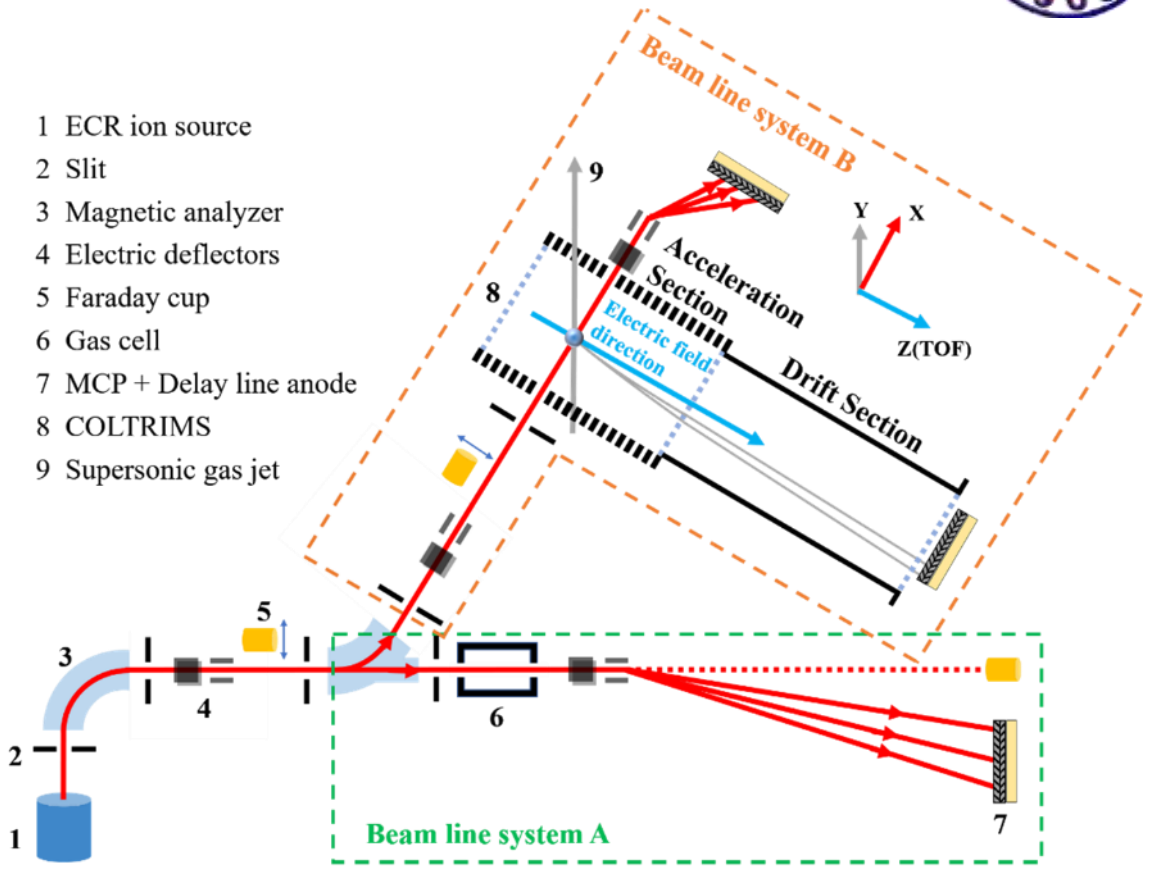
Charge Exchange Cross Section



Charge Exchange Cross Section

$O^{6+} + He \rightarrow O^{5+}(1s^2nl) + He^{+}(1s)$



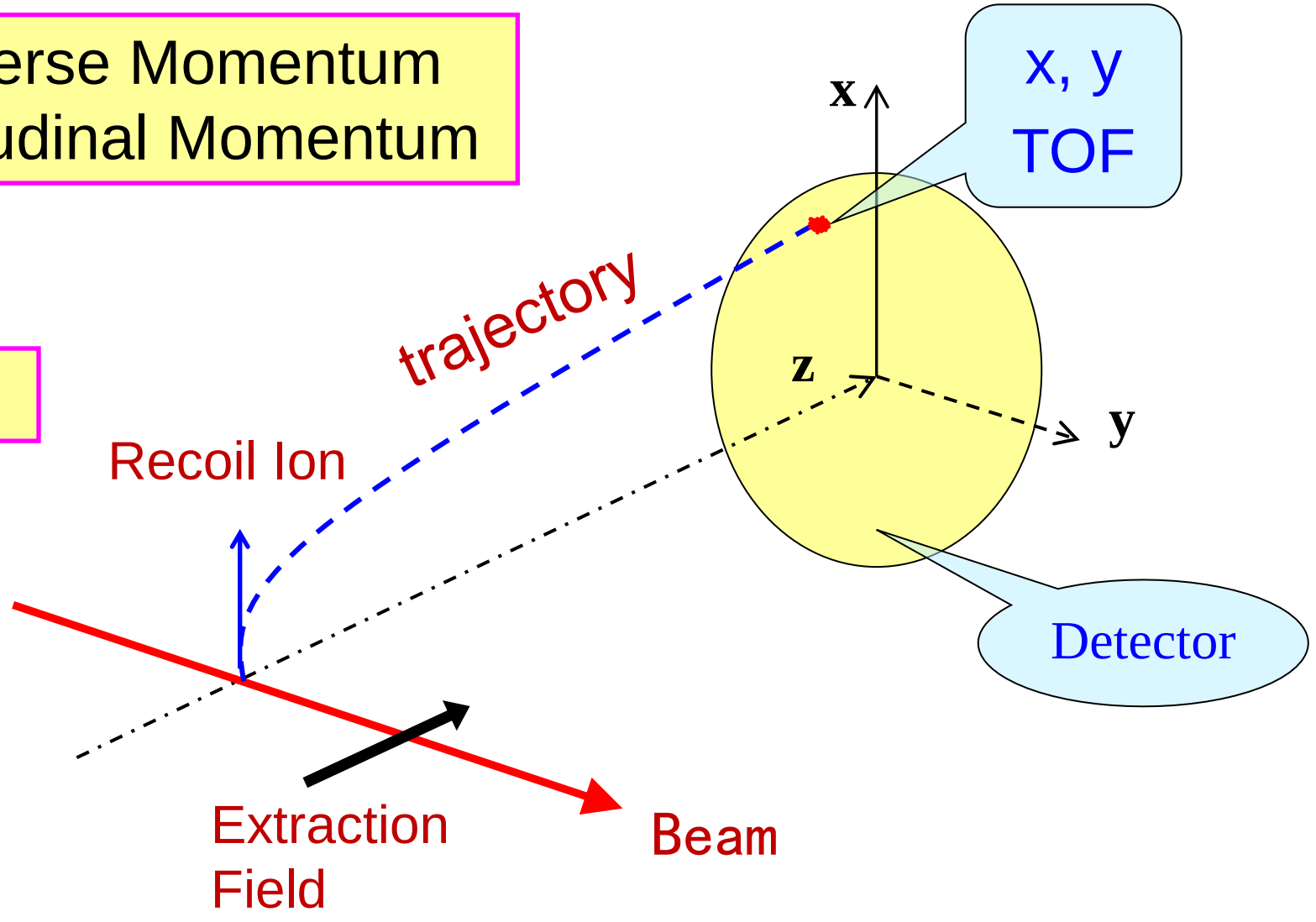


$$\sigma_{q,q-j} = \frac{kT}{PL}\frac{qI_{q-j}}{(q-j)I_q}$$

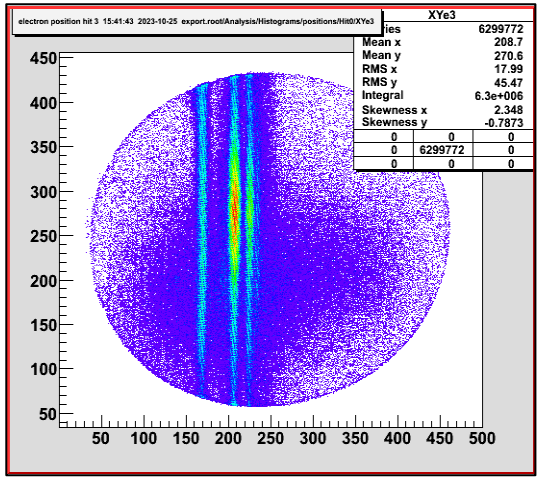
Setup: COLTRIMS

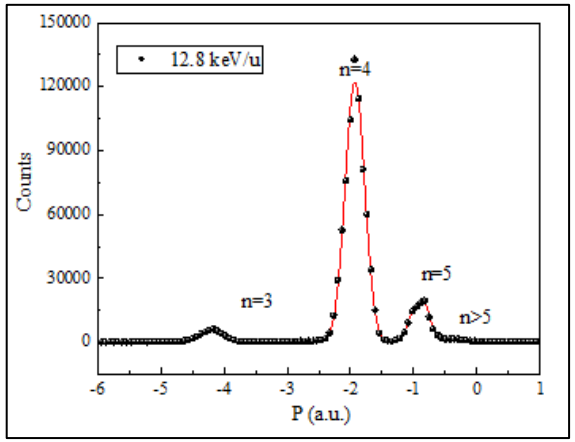
x, y → Transverse Momentum
TOF → Longitudinal Momentum

Q Value (eV)



Setup: COLTRIMS





ECR ion source

Slit

90° Magnetic Analyzer

Faraday Cup

45° Magnet

Supersonic gas jet

MCP detector

Electric deflectors

Y

X

Z(TOF)

Acceleration

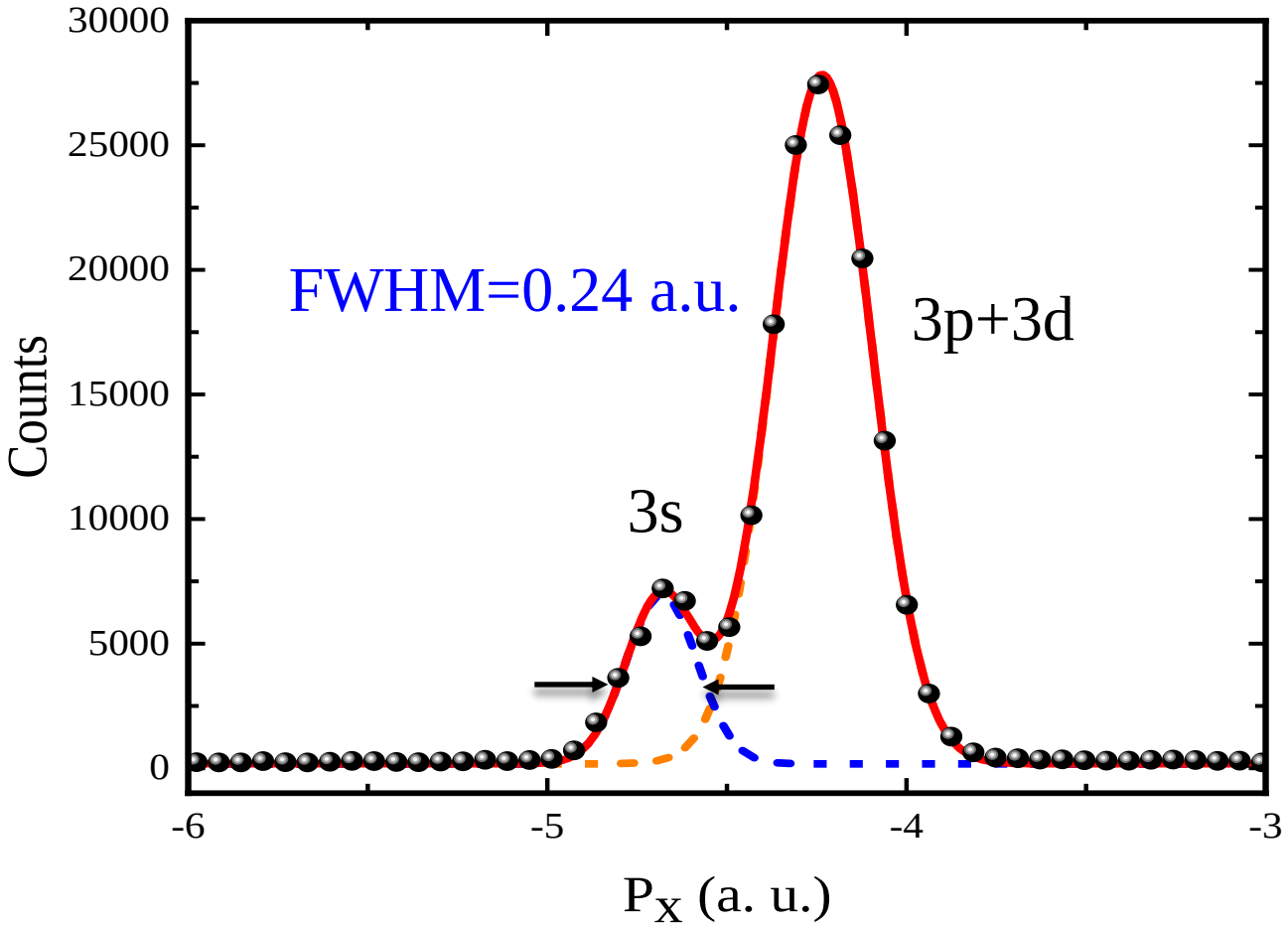
TOF tube

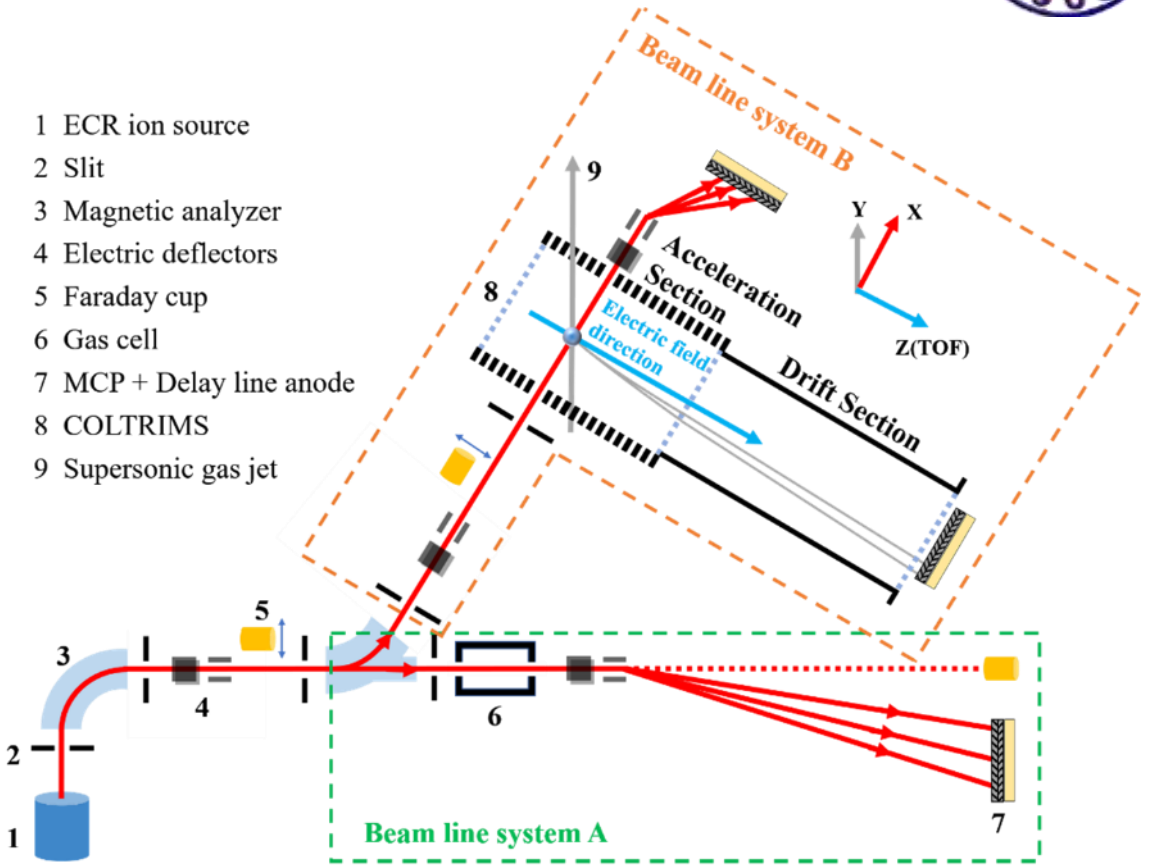
Field-free drift

MCP detector

Setup: COLTRIMS

$O^{6+} + He \rightarrow O^{5+}(1s^2nl) + He^{+}(1s)$





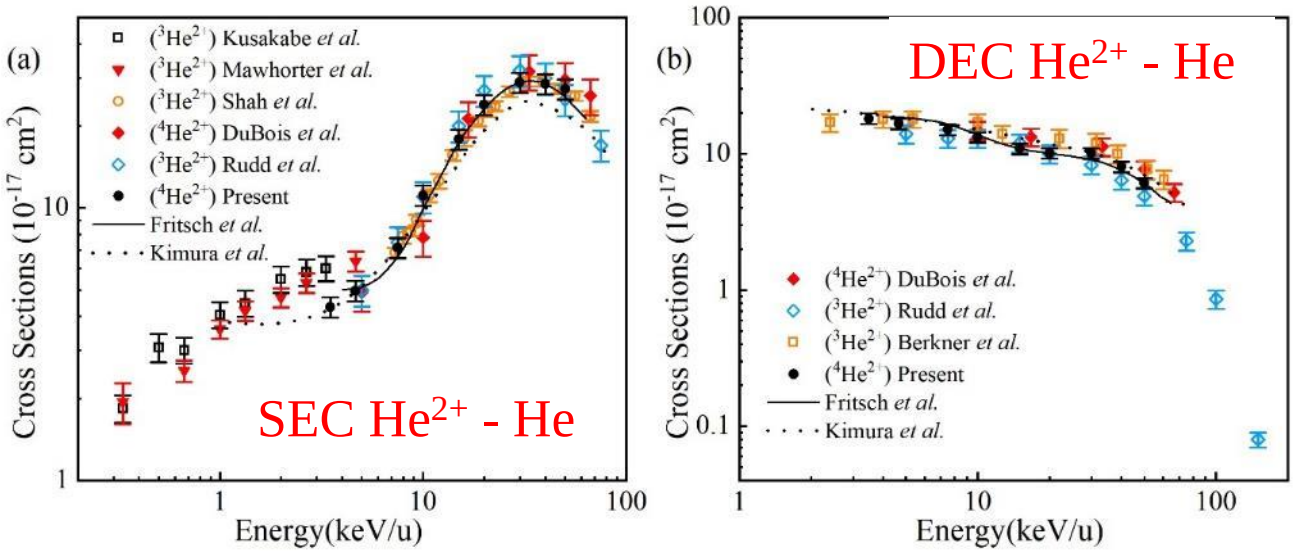
03 Charge Exchange Cross Section

Charge Exchange Cross Section

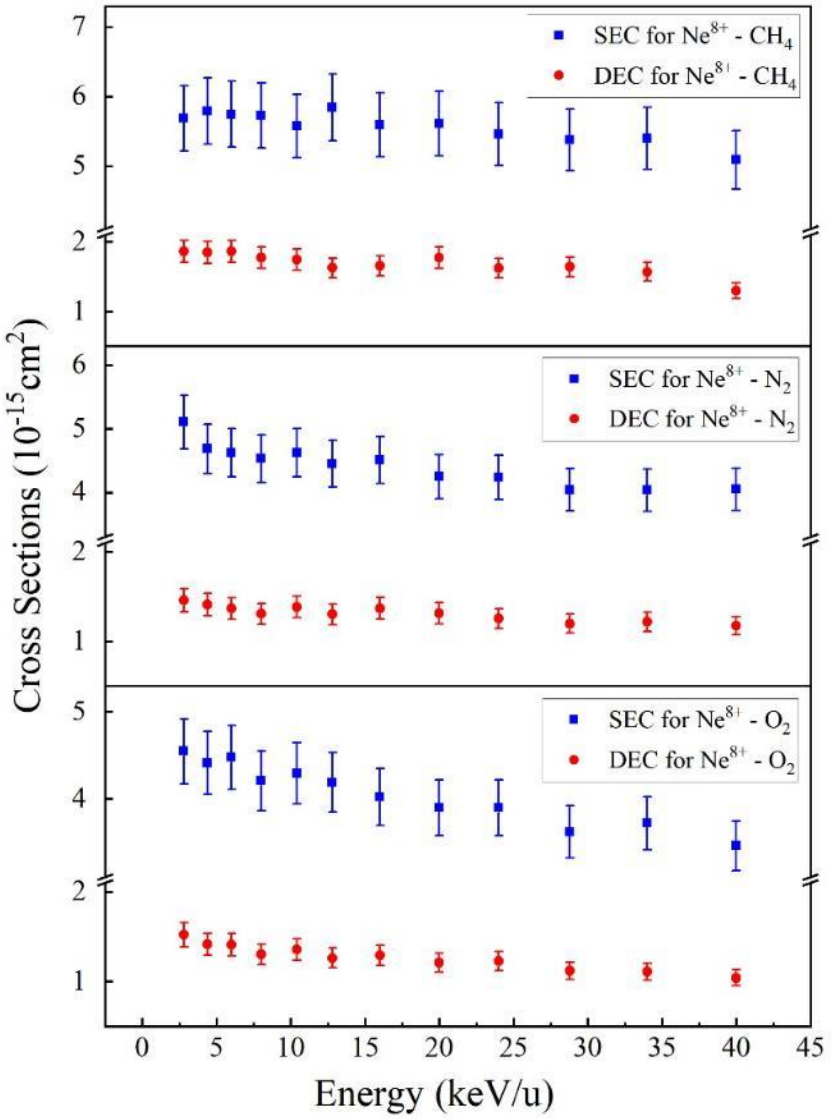
What do we want to measure?

- Absolute total cross section √
- *n* state-selective cross sections √
- *n,l* state-selective cross sections (harder) √
- Full *n,l,j,s* state-selective cross sections (even harder)
- The photon emission spectra depend strongly on l, so it's really important to test calculations of state-selective cross sections
- For every neutral target except H, also need to worry about multiple capture!
- (radiative cascades are easy, right?)

Charge Exchange Cross Section



Source of Error	Relative error (%)
Error in temperature	1
Error in pressure	3
Error in effective collision length	2
Error in detection efficiency of PSD	5.8
Statistical error N_{q-1}	1.8
N_{q-2}	3.8
Stability of beam	4
Total error $\sigma_{q,q-1}$	**8.2**
$\sigma_{q,q-2}$	**8.7**



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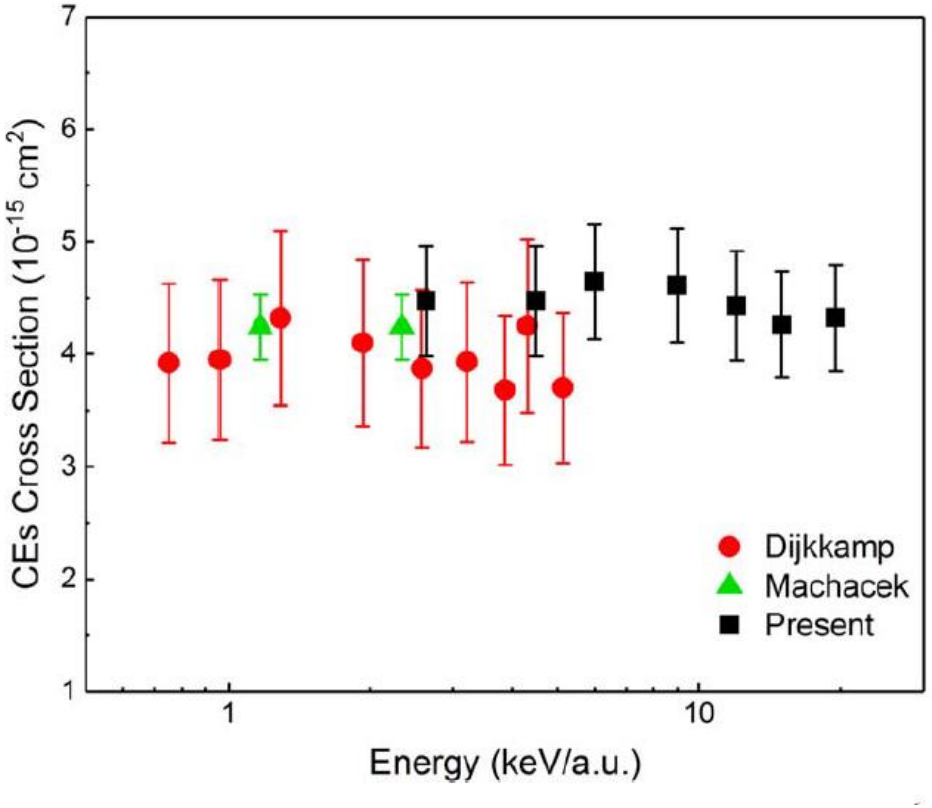
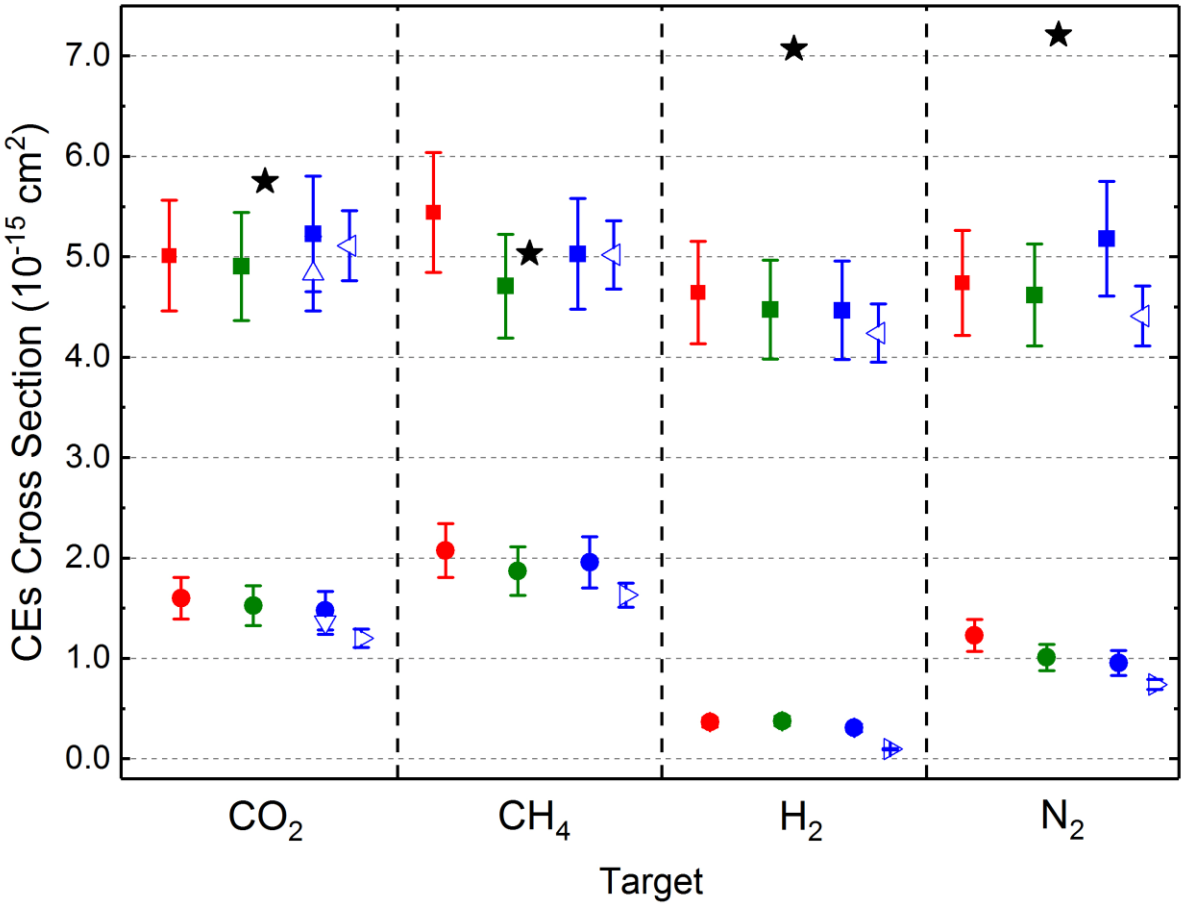
Charge Exchange Cross Section

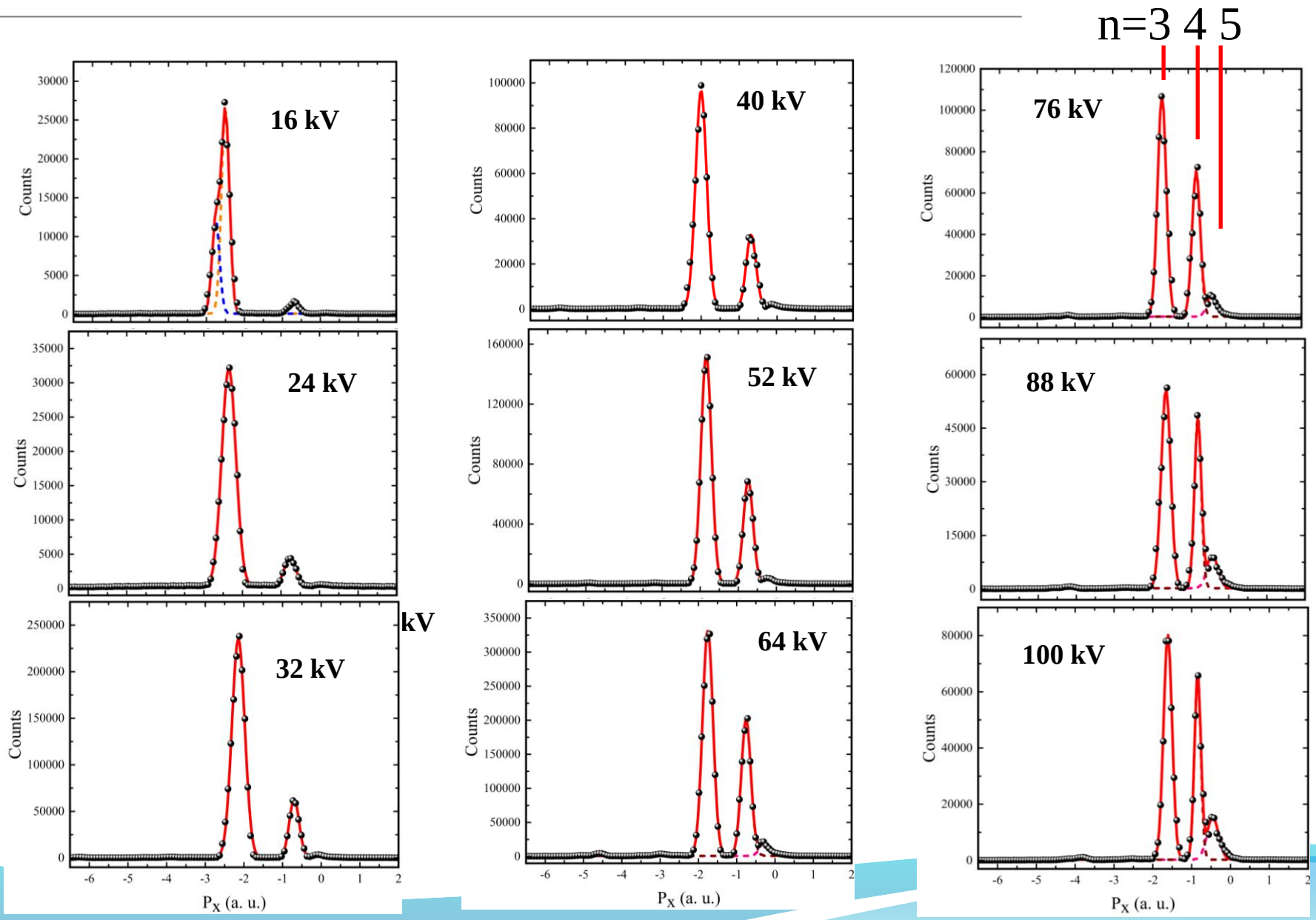
Single Electron Capture Cross Section of O^{6+} - H_2



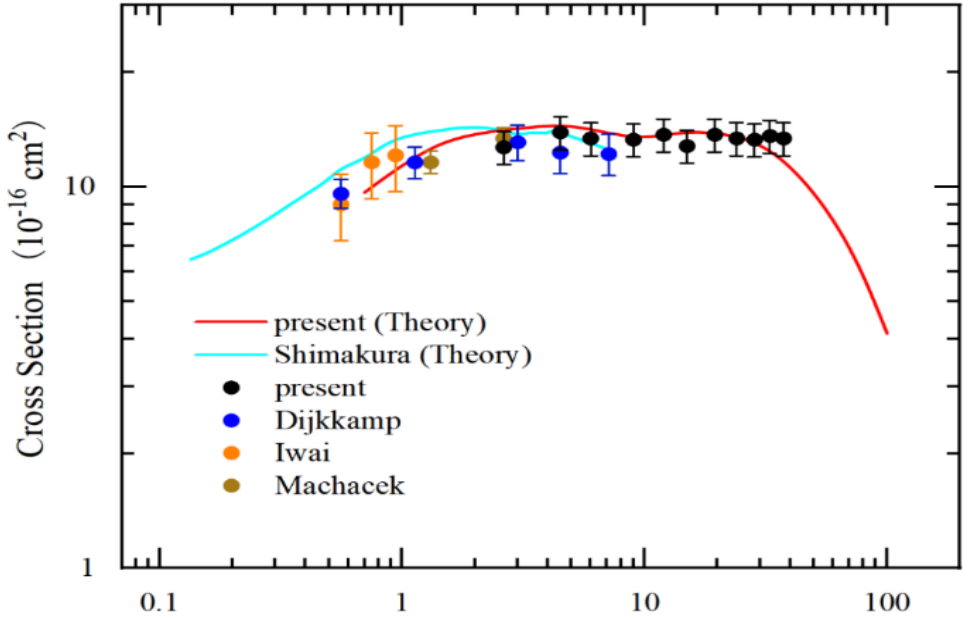


Astrophys. J. Supp. Series (2021) 253:6

Charge Exchange Cross Section O^{6+}-He



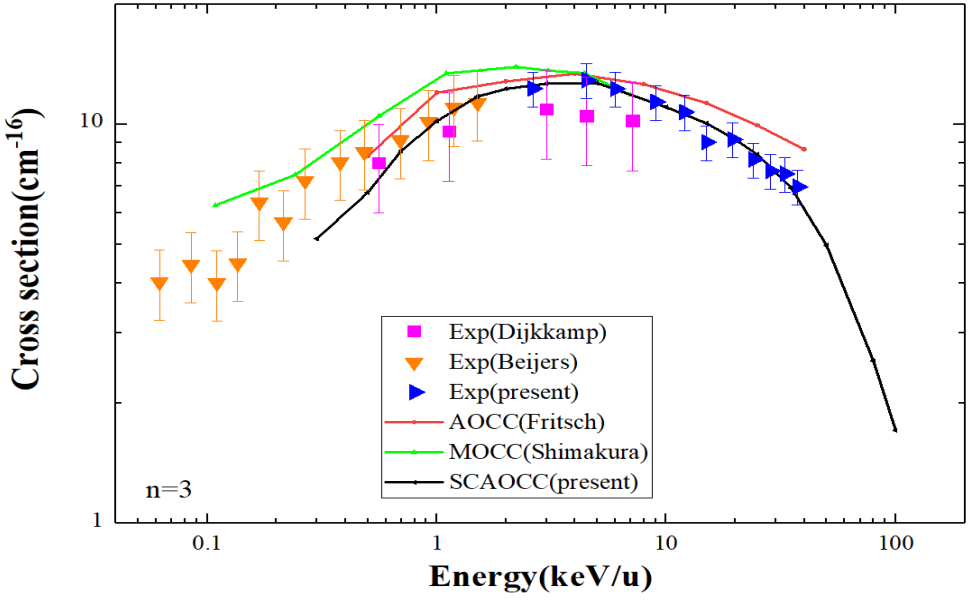
Charge Exchange Cross Section

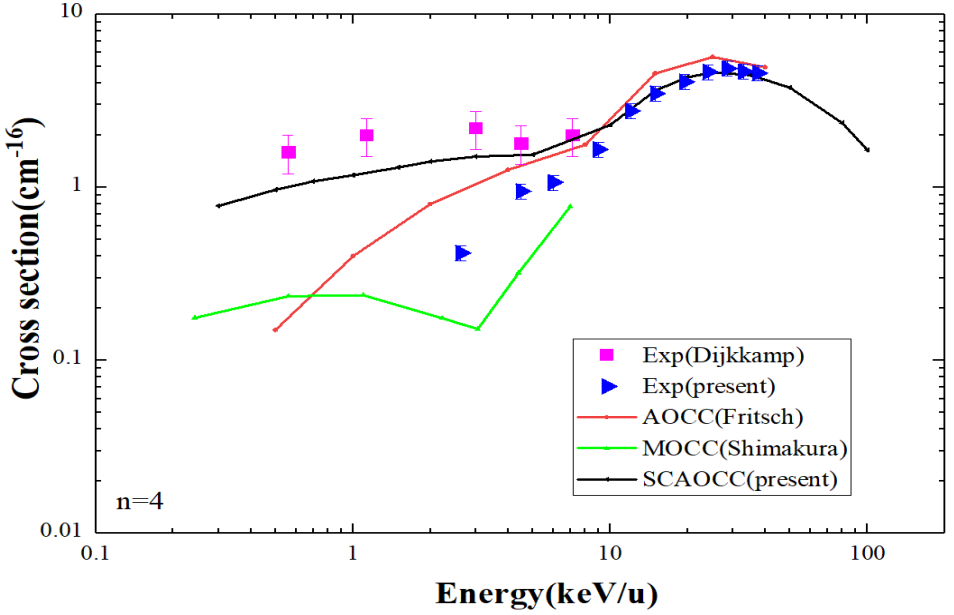


$O^{6+} + He \rightarrow O^{5+}(1s^2nl) + He^{+}(1s)$

Two-electron semiclassical atomic orbital close-coupling method

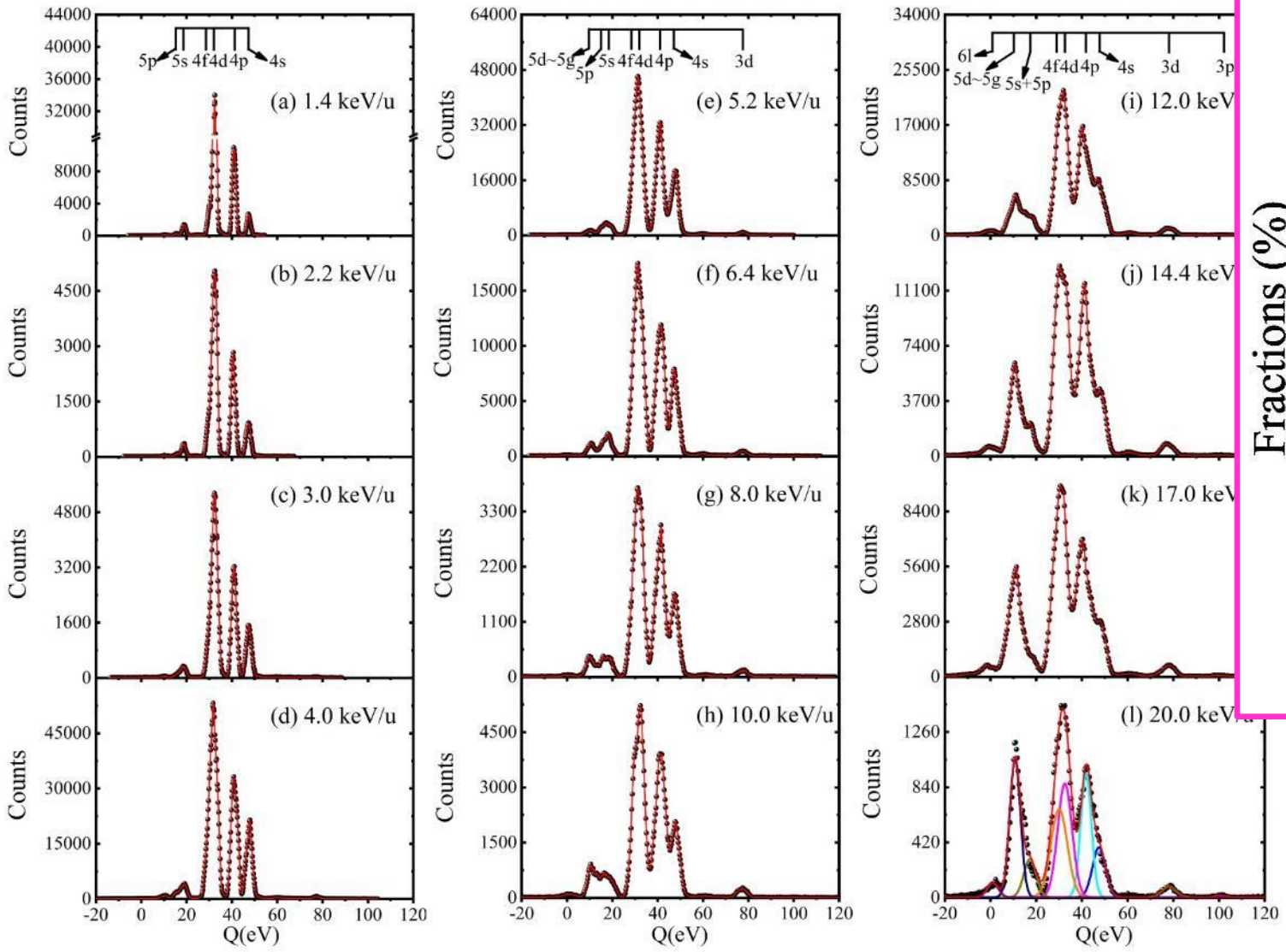
New J. Phys. 25 (2023) 093026

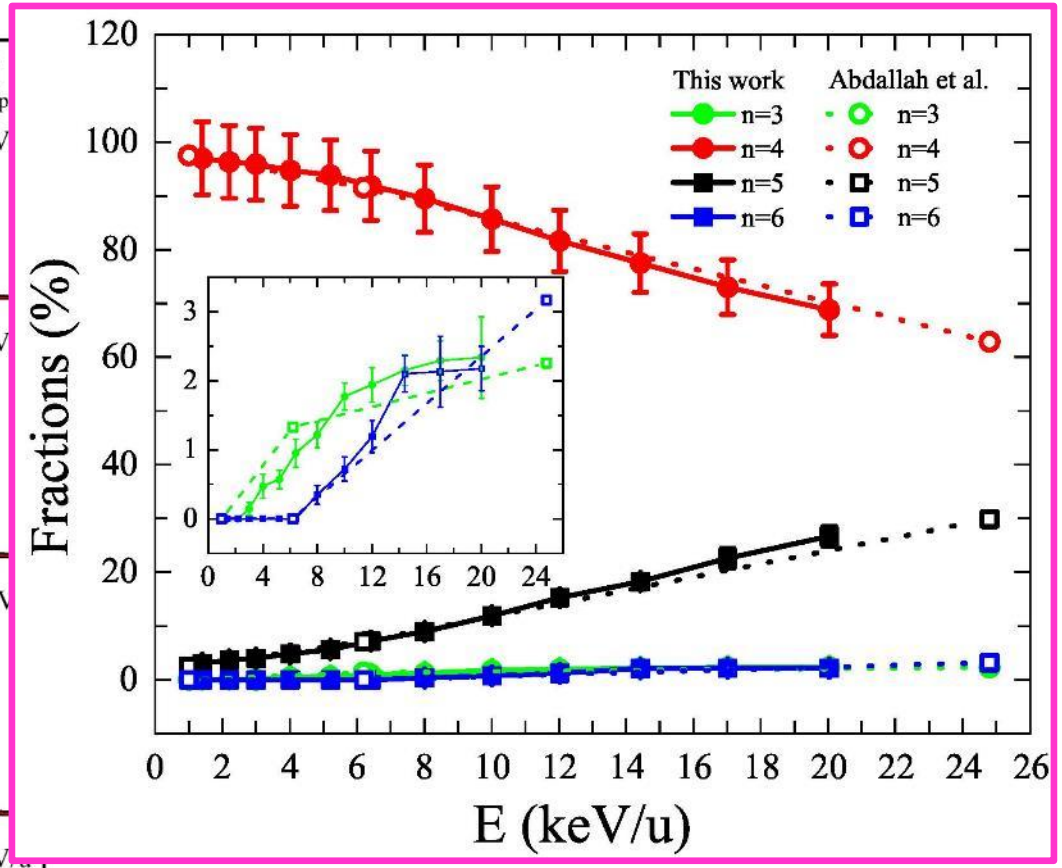




Charge Exchange Cross Section

Ar^{8+} + He

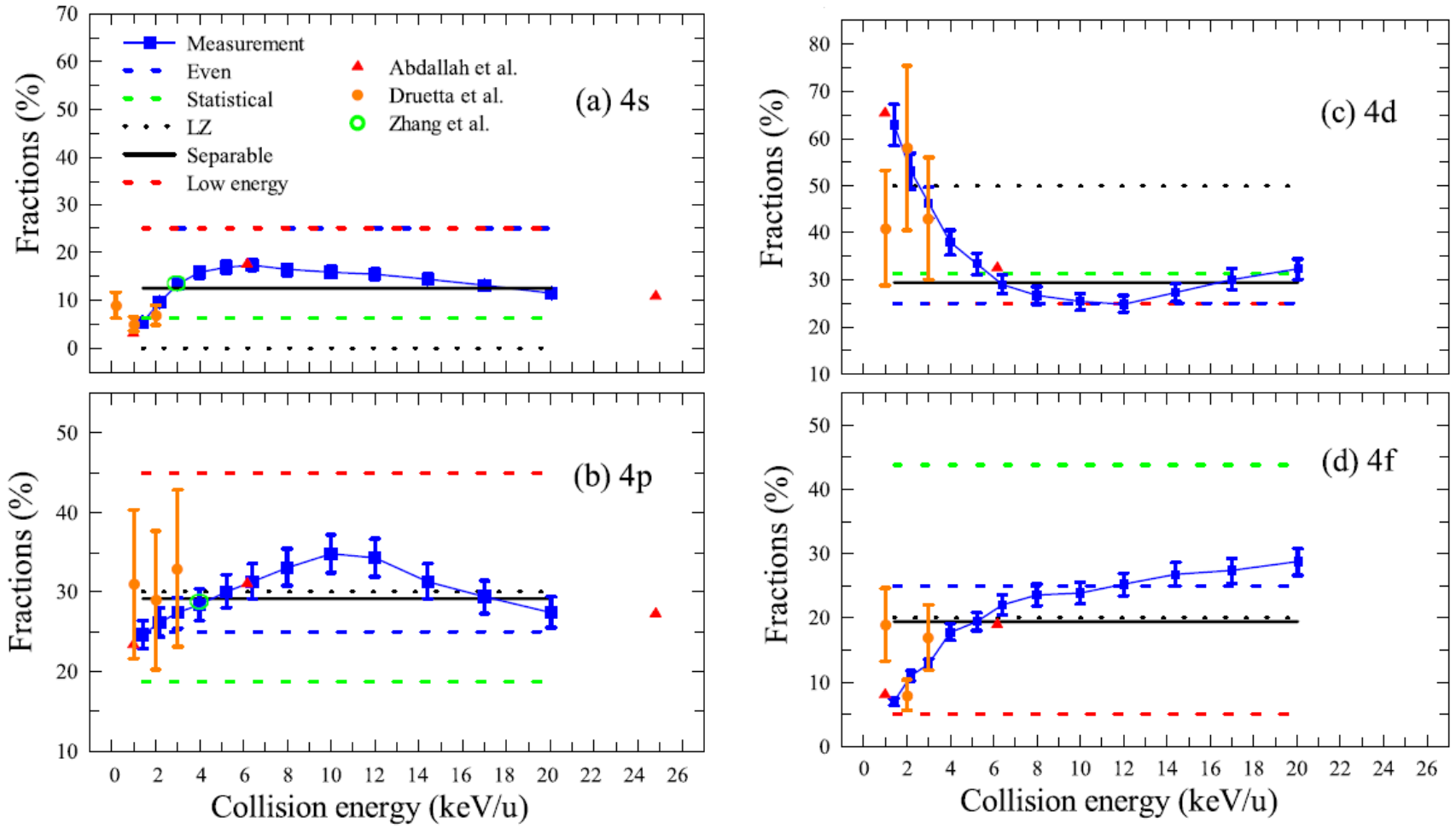




Astrophys. J., 933:207 (2022)

Charge Exchange Cross Section

Ar^{8+} + He

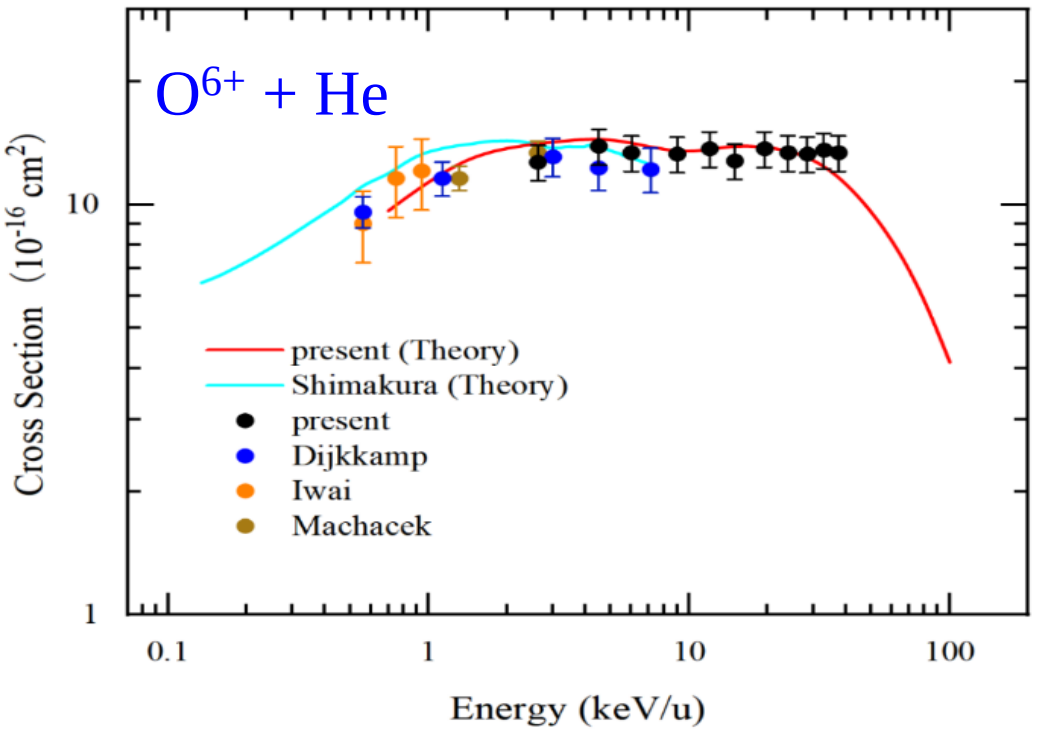


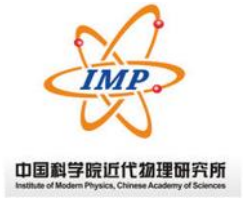
Astrophys. J., 933:207 (2022)

04 Summary and Outlook

Summary and Outlook

- A HCI platform for the charge exchange process studying in a wide energy range.
- The absolute electron capture CS and State-selective Charge Exchange CS have be measured.
- The energy range could be extended.
- It is still a challenge for complicated collision system in theory.





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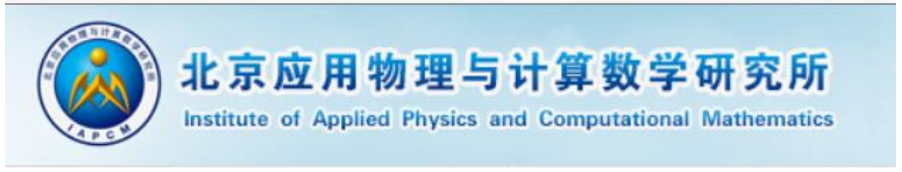

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Tianting Meng
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Mingxuan Ma
Jun Xiao
Ke Yao
Yang Yang
Bingsheng Tu
Yaming Zou
Baoren Wei

Thank you for your attention!