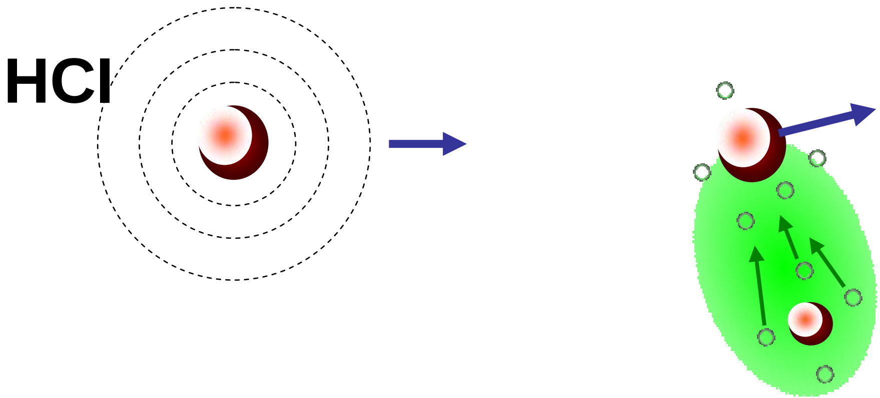
Dynamics of Electron Capture in Slow Ion-Atom Collisions

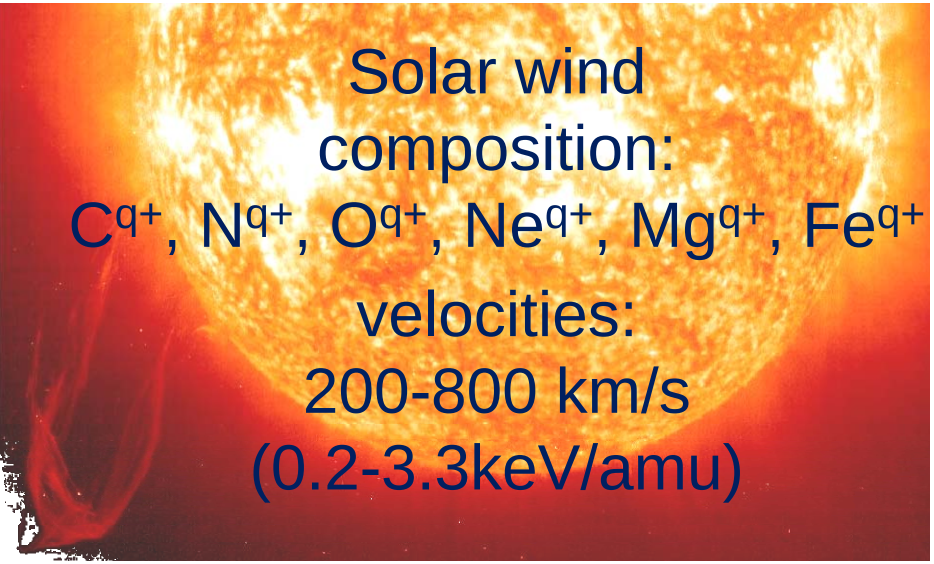


Daniel Fischer

MPIK, Heidelberg, Germany

Motivation

- **Astrophysical Reactions**



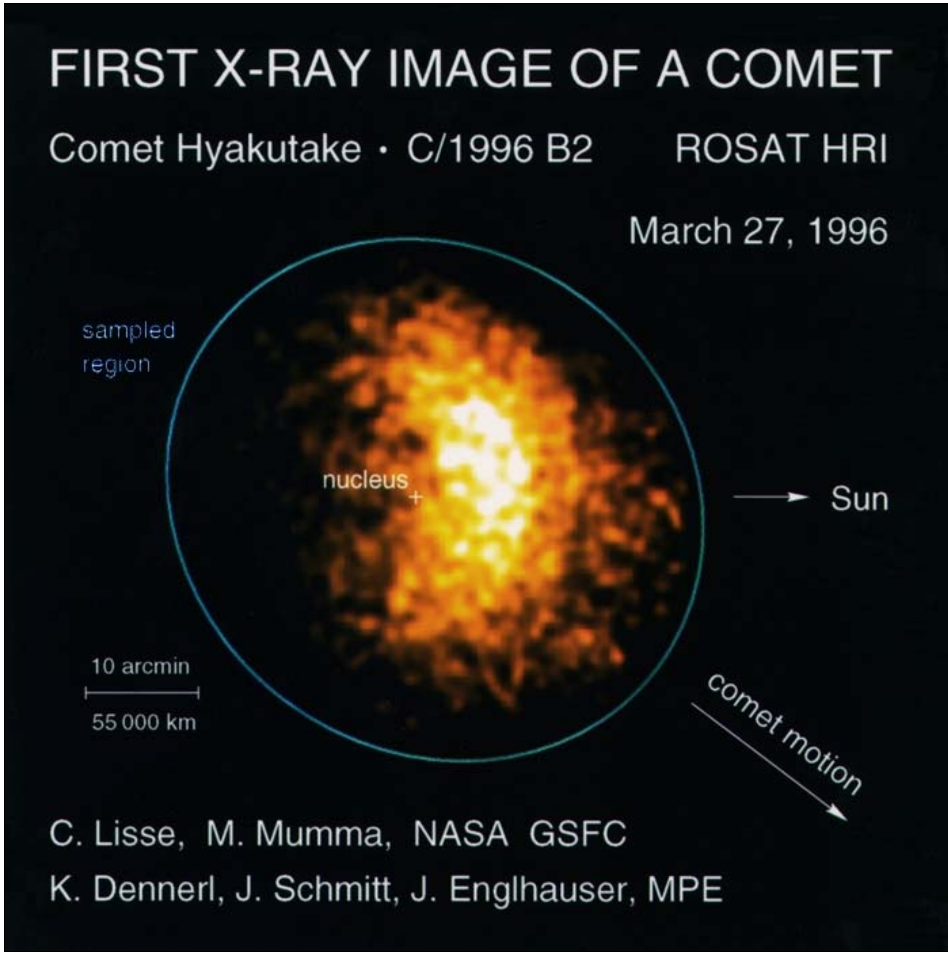
Solar wind composition:

C^{q+}, N^{q+}, O^{q+}, Ne^{q+}, Mg^{q+}, Fe^{q+}

velocities:

200-800 km/s

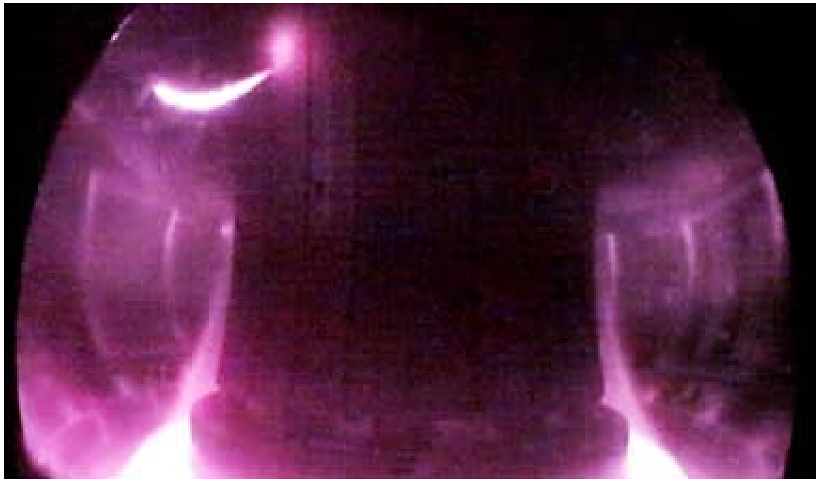
(0.2-3.3keV/amu)



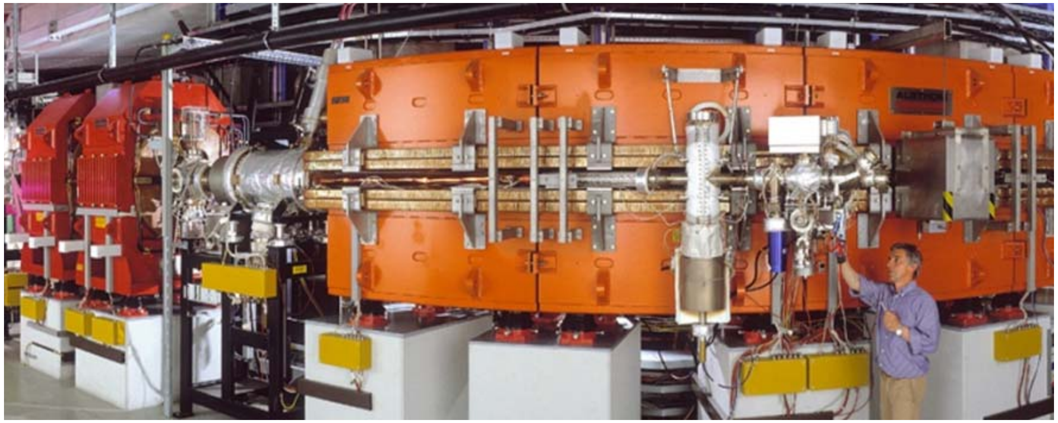
Charge-exchange reactions between HCIs and molecules are followed by X-ray emission

Motivation

- **Energy balance and transport in plasmas (e.g. Fusion)**

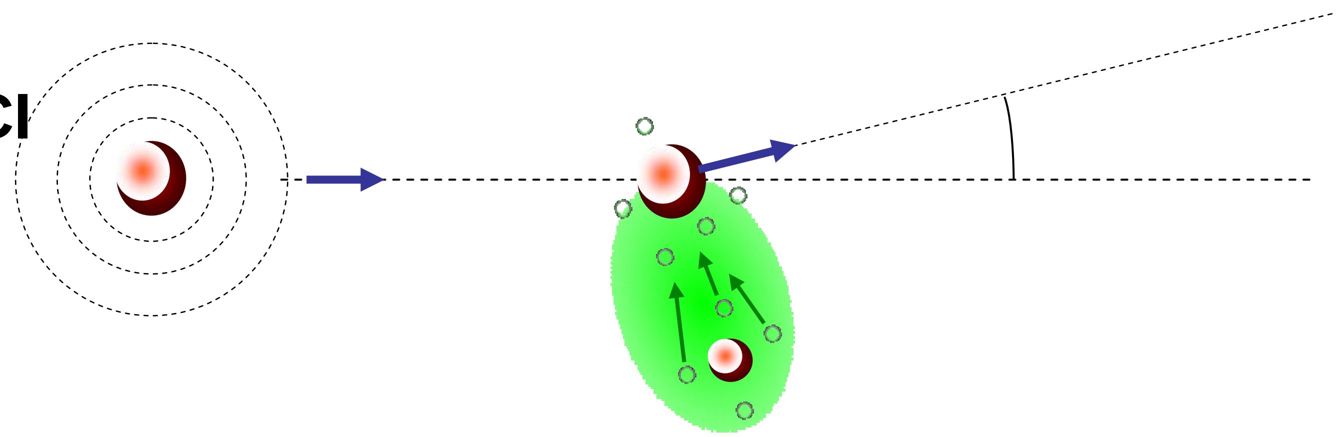


- **Storage time of highly charged ions in traps and storage rings**



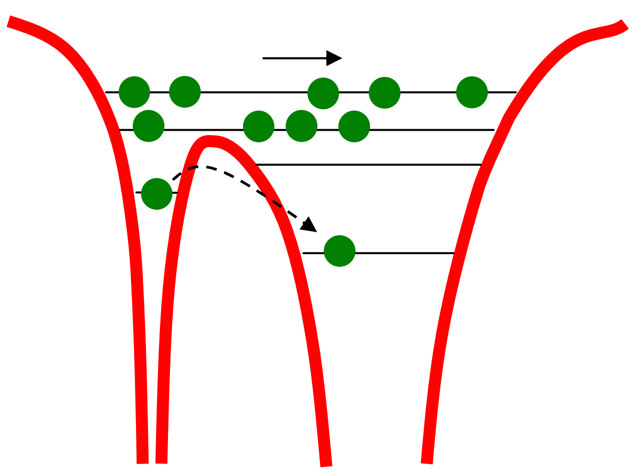
Motivation

Fundamental questions:



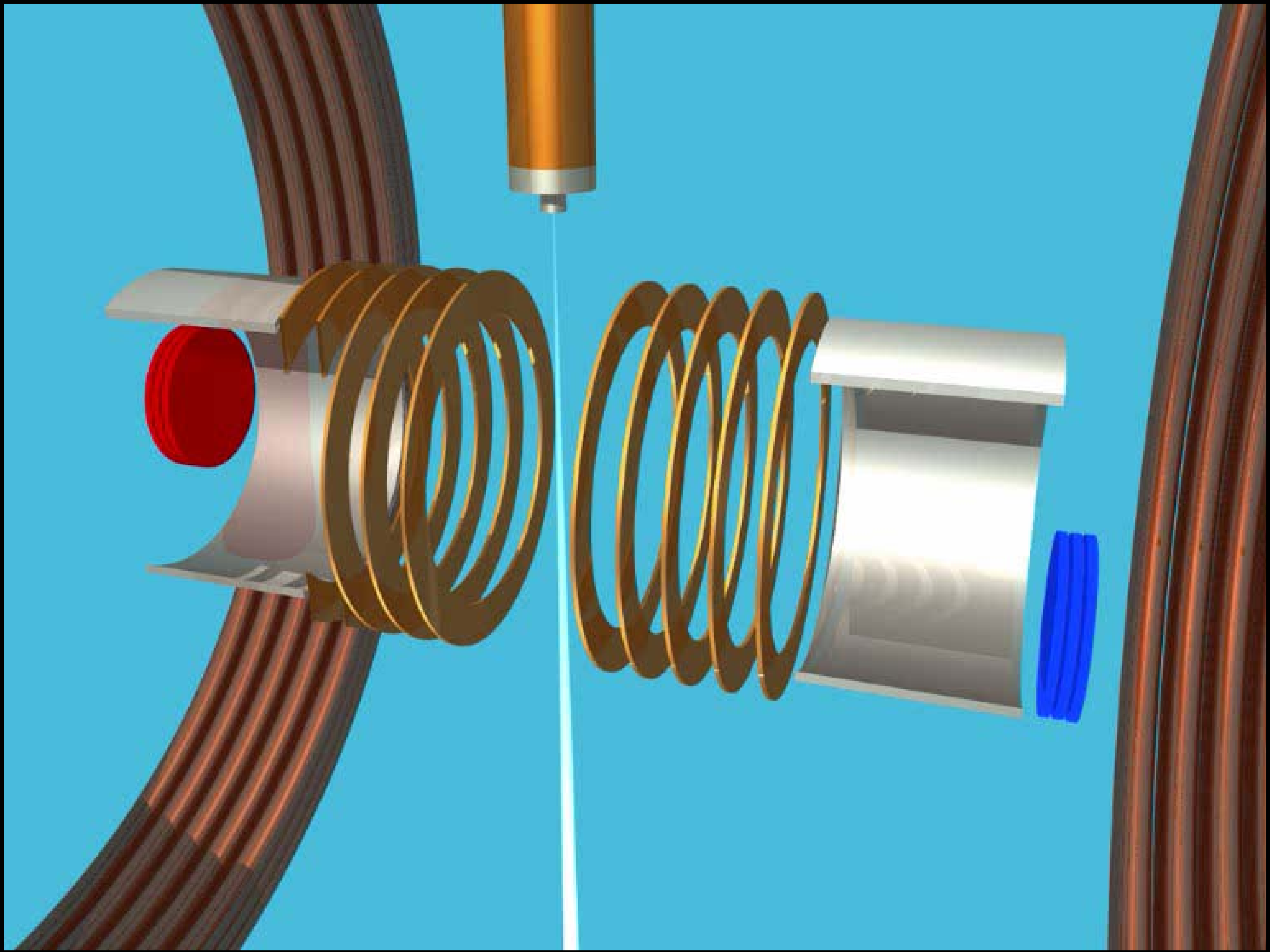
- **Populated states**
- **Pathways of stabilization**
- **Dynamics of formation**

  femtosec. many-electron flux
  - correlated?
  - tunneling?
  - control?



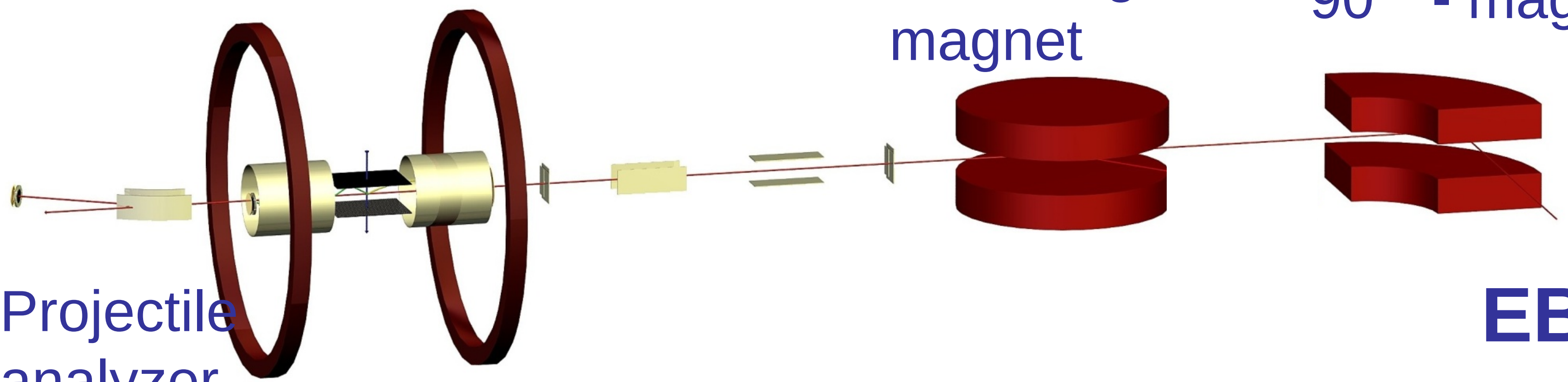
“over the barrier”

COLTRIMS / Reaction Microscopes



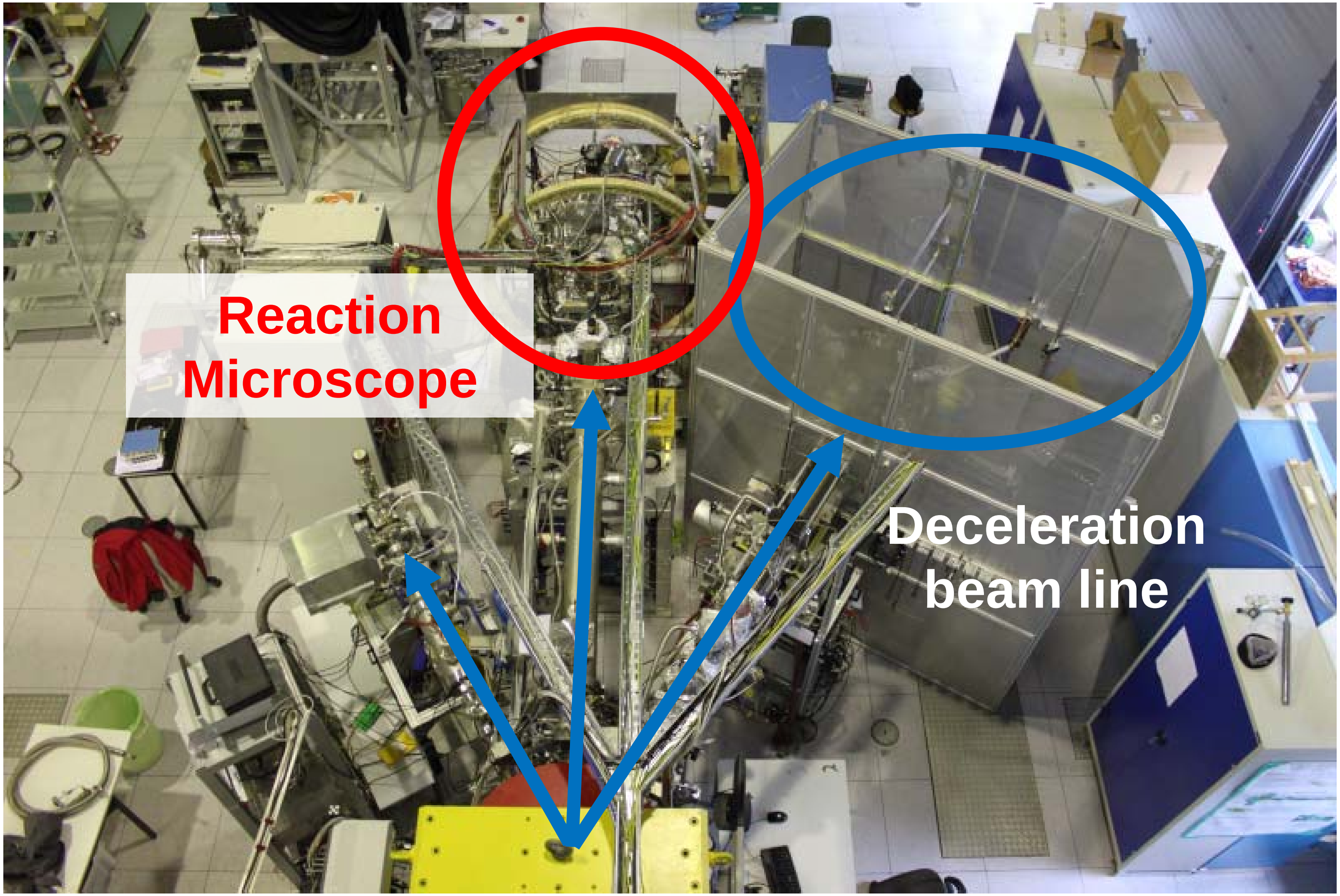
Fragmentation kinematically complete and in 3D

The EBIT Reaction Microscope

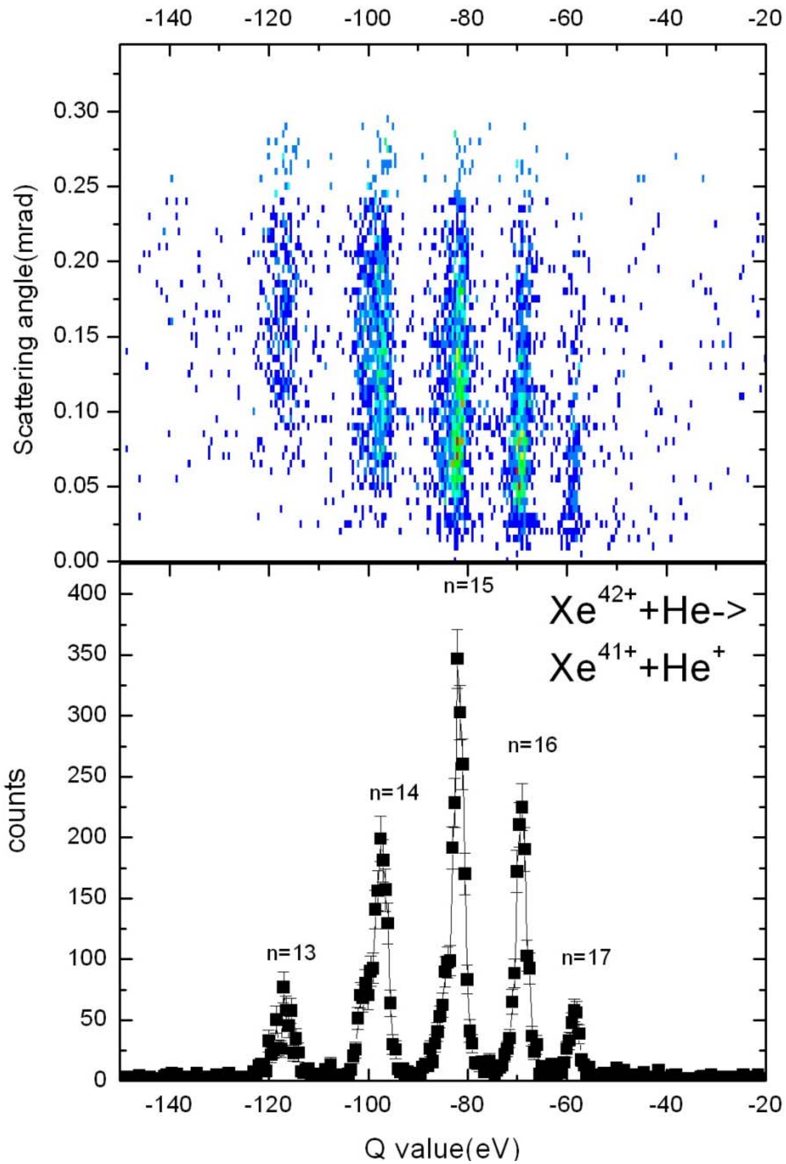


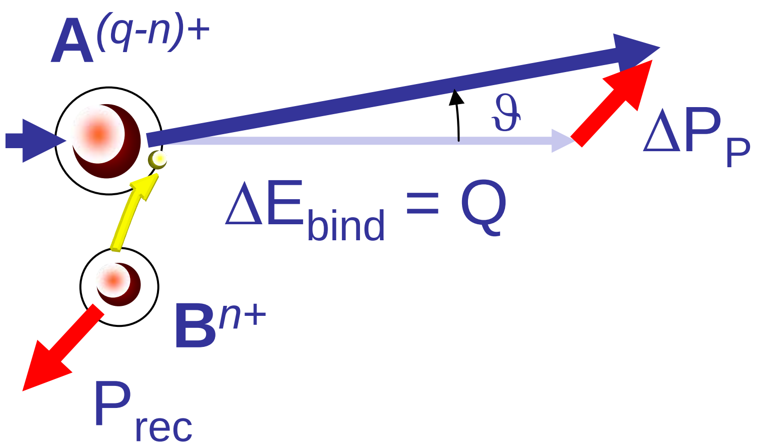
Projectiles: Charge q < 64 (e.g. Ar^{18+}, Xe^{44+}, U^{64+})
energy ~ 10 keV/q (with HV platform up to 300 keV/q)

The EBIT Reaction Microscope



Kinematics





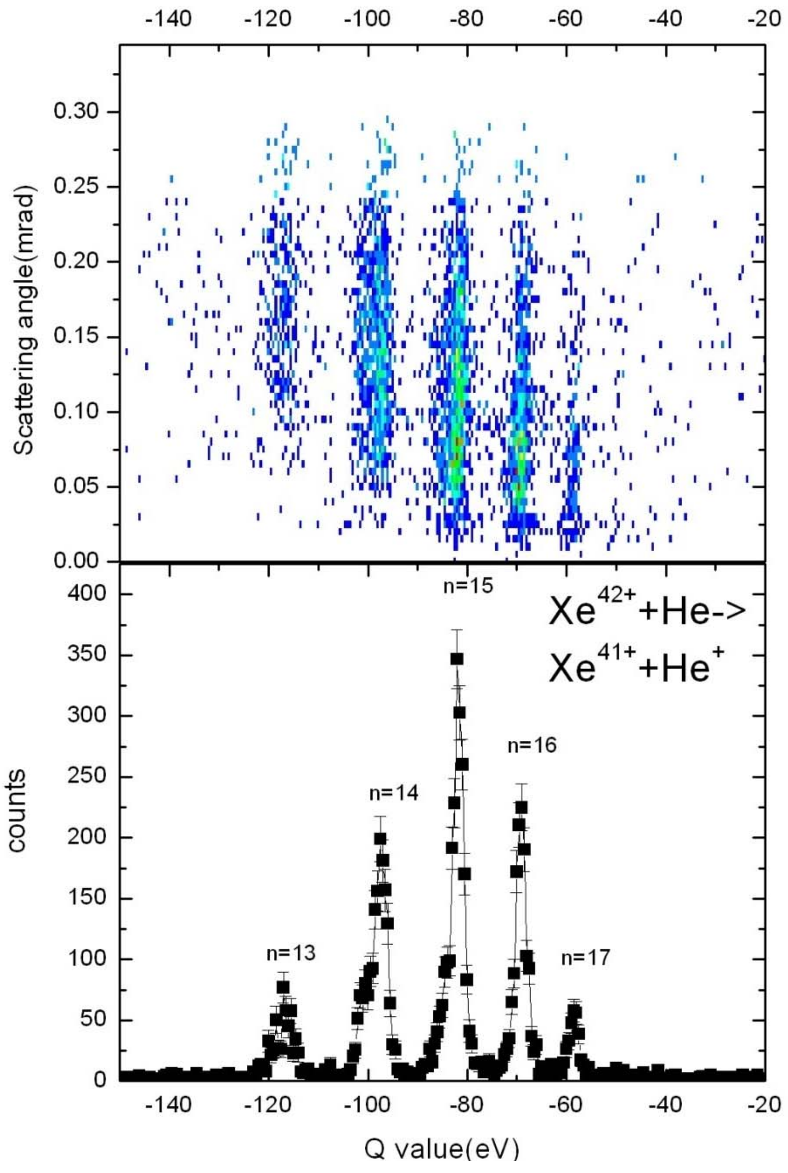
Energy conservation: $\Delta E_{kin} = Q$

Momentum cons.: $\Delta P_P = -P_{rec}$

$$P_{\parallel rec} = Q / v_p - n\, v_p / 2$$

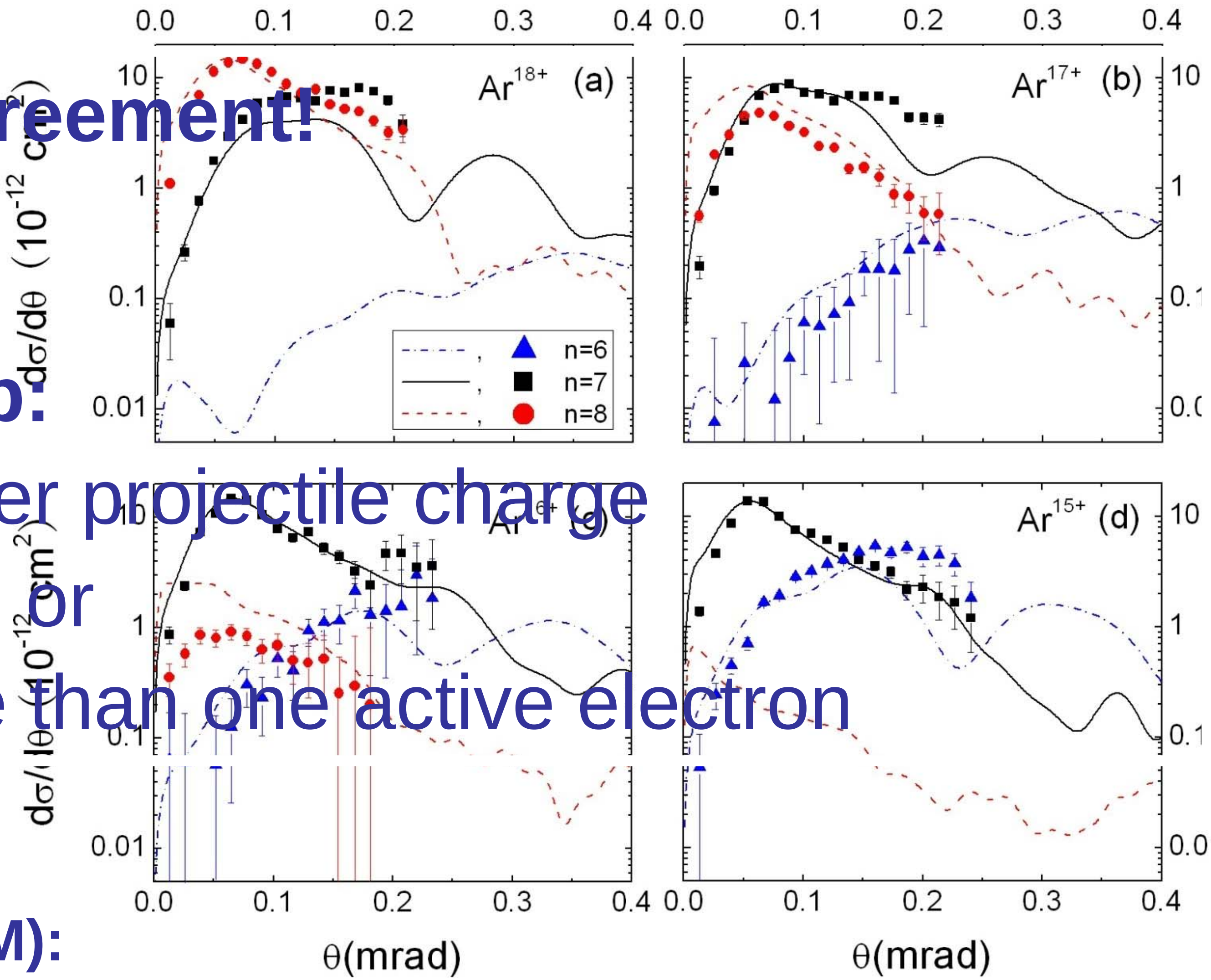
$$P_{\perp rec} = P_P \cdot \vartheta$$

Kinematics



Sensitive test for theoretical cross sections

Single electron capture



Good agreement!

Next step:

- Higher projectile charge

  or

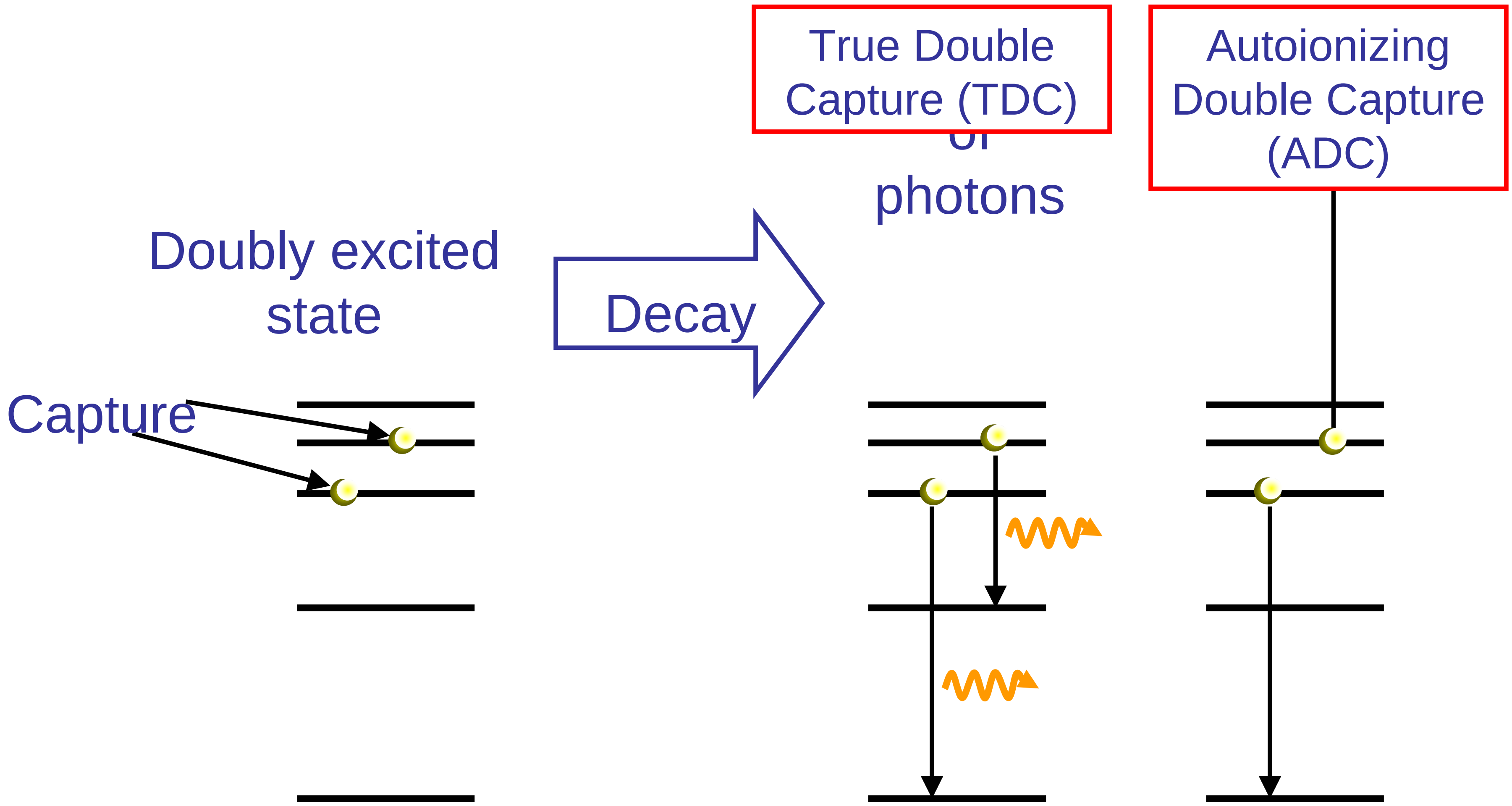
- More than one active electron

Theory (TC-BGM):
two center – basis generator method
(T. Kirchner, M. Zapukhlyak)

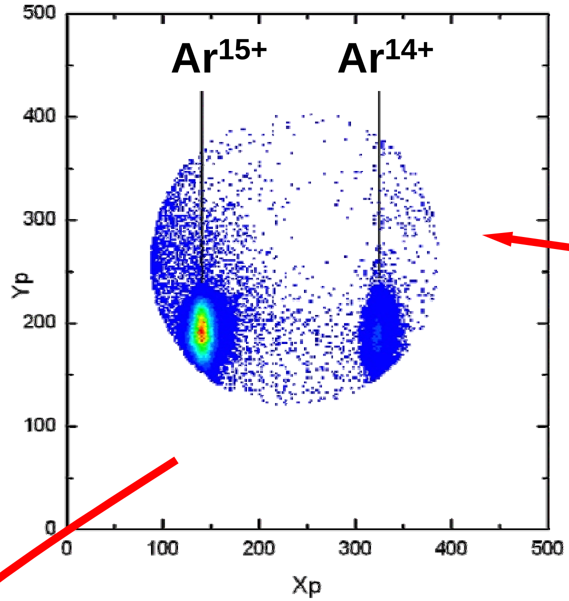
S. Knoop, R. Hoekstra
(*KVI, Groningen*)

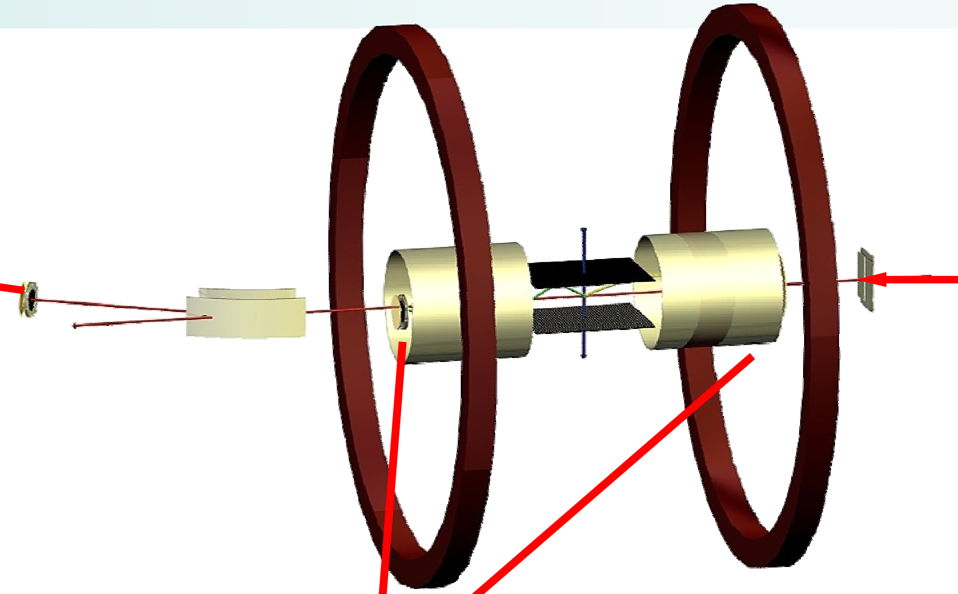
Double electron capture

$$A^{q+} + B \rightarrow A^{(q-2)+ \,**} + B^{2+}$$



Double electron capture





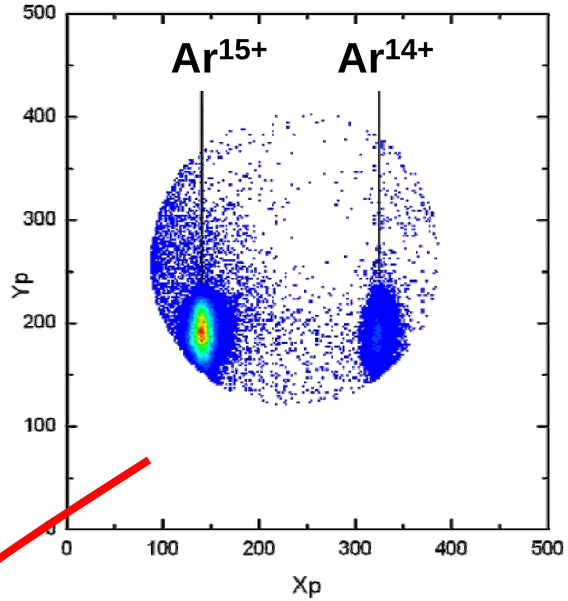
HCIs from EBIT

$$Ar^{16+} + Ne \rightarrow Ar^{14+\,**} + Ne^{2+}$$

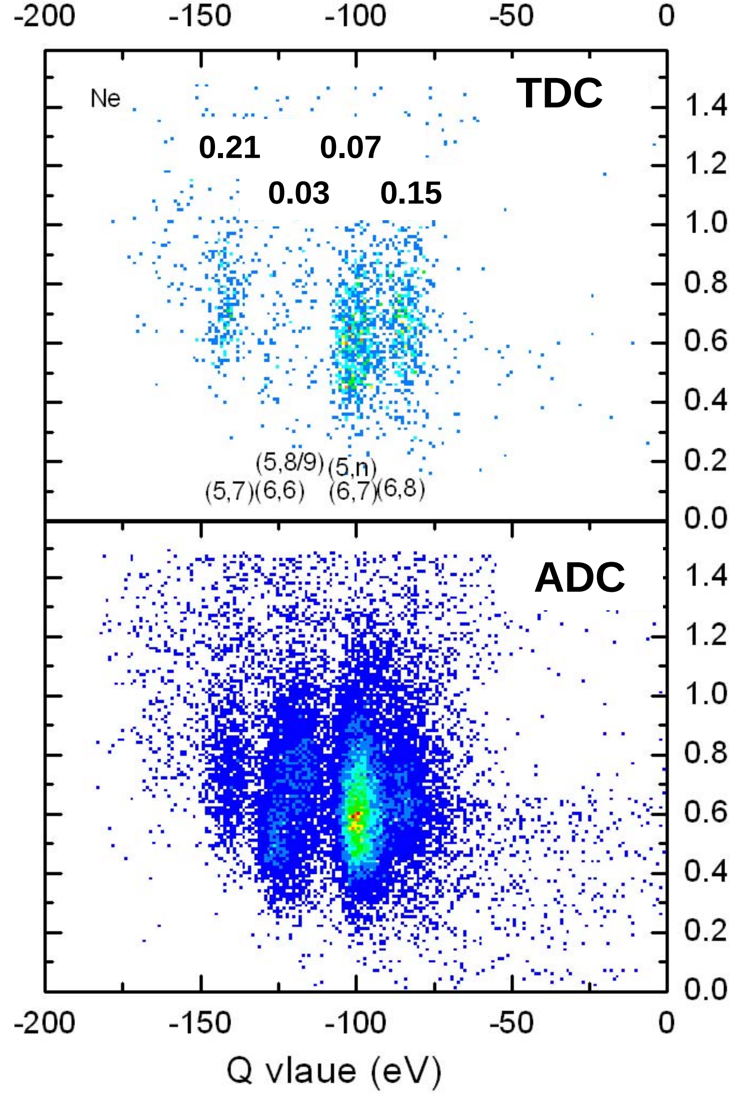
$\quad\rightarrow Ar^{15+(*)} + e^-$

$\quad\rightarrow Ar^{14+(*)} + \gamma$

Double electron capture



Q-value vs. projectile scattering angle

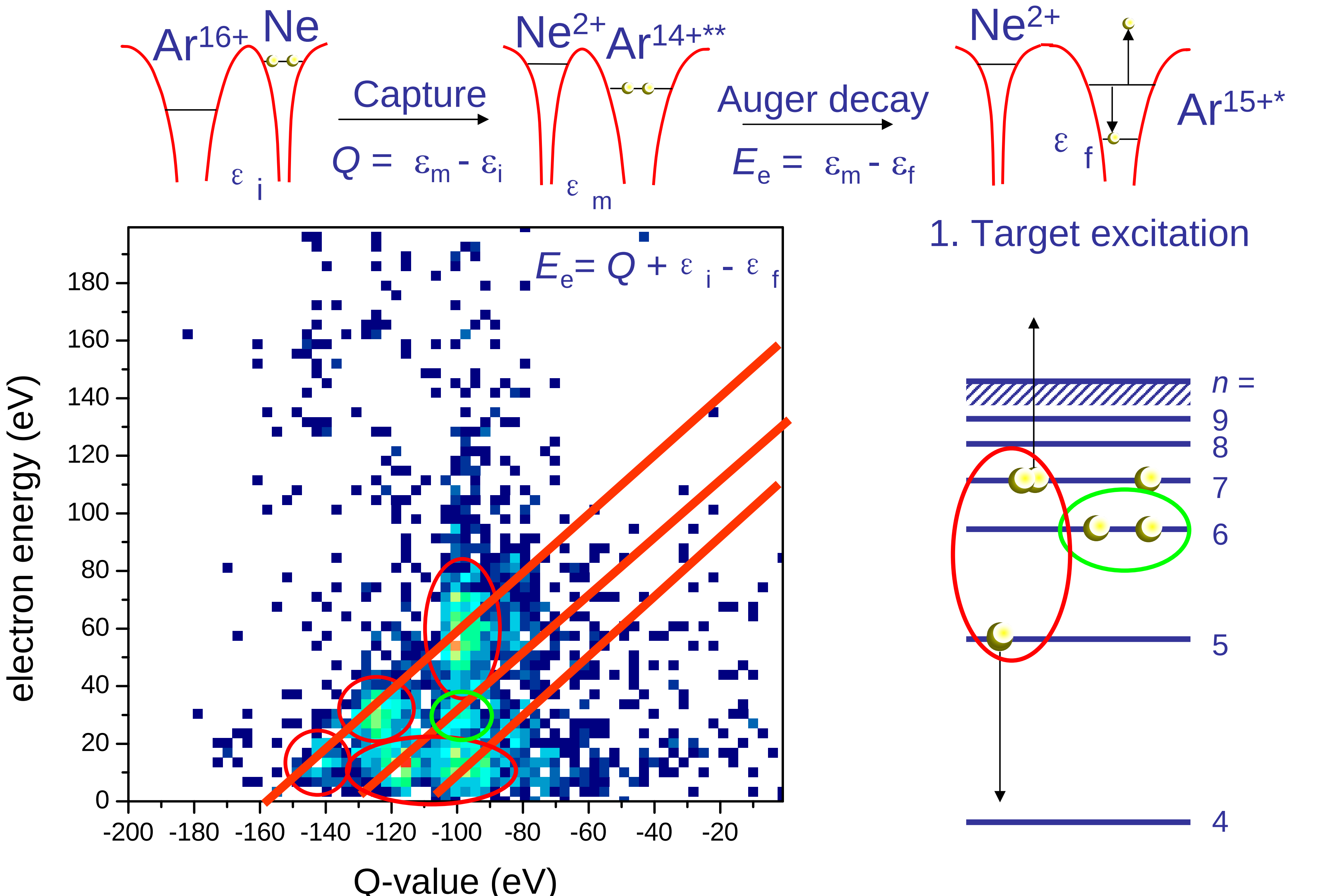


$Ar^{16+} + Ne \rightarrow Ar^{14+**} + Ne^{2+}$

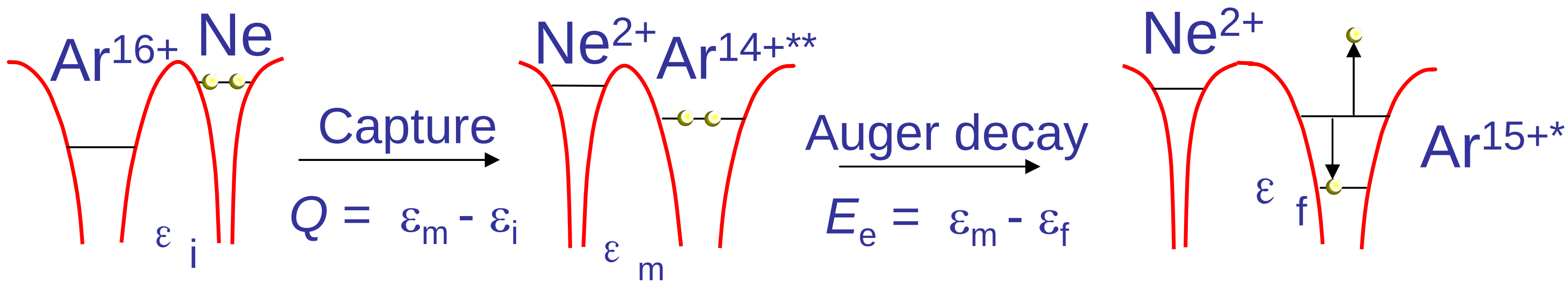
→ $Ar^{15+(*)} + e^-$

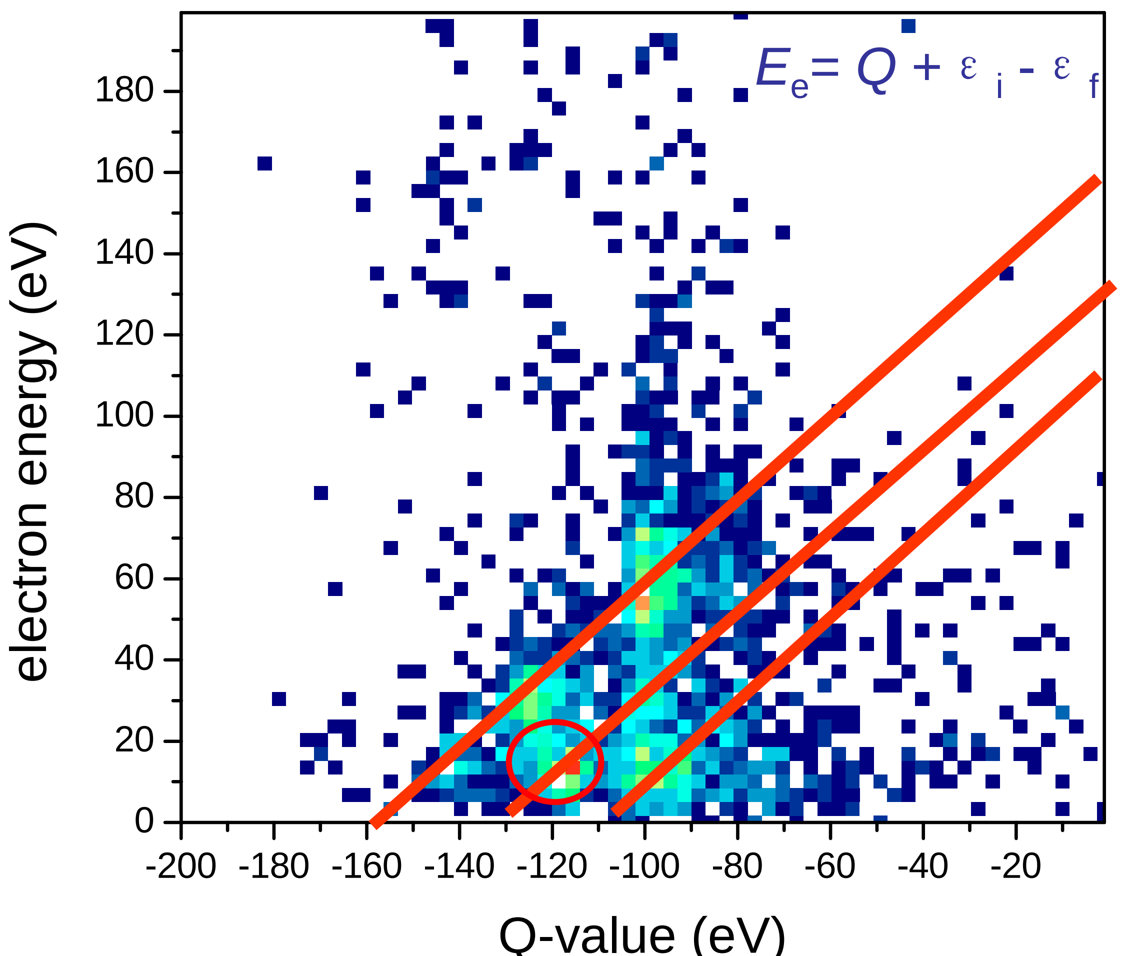
→ $Ar^{14+(*)} + \gamma$

ADC decay channels



ADC decay channels





1. Target excitation
2. Photon emission

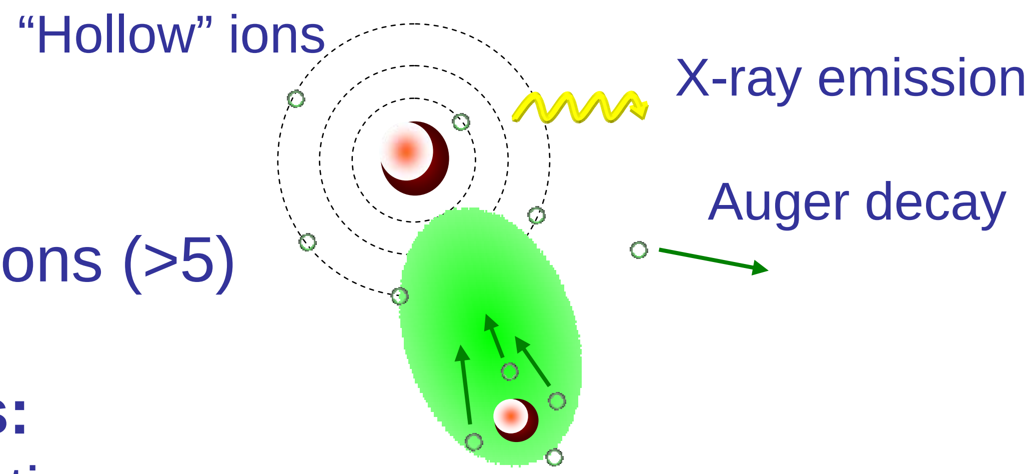
Life times:

Auger ~0.1-1 ps

Radiative ~10 ps

Theoretical state-selective capture cross sections required

HITRAP: Towards higher charge states and lower collision-energies



Higher charge states:

⇒Transfer of many electrons (>5)

Lower collision energies:

⇒ "narrower" (*n*,*l*) distributions

⇒ longer collision duration

- **Dynamics of formation and relaxation**
  - Correlation in femtosec. many-electron flux
  - Relaxation of highly charged quasi-molecules

People

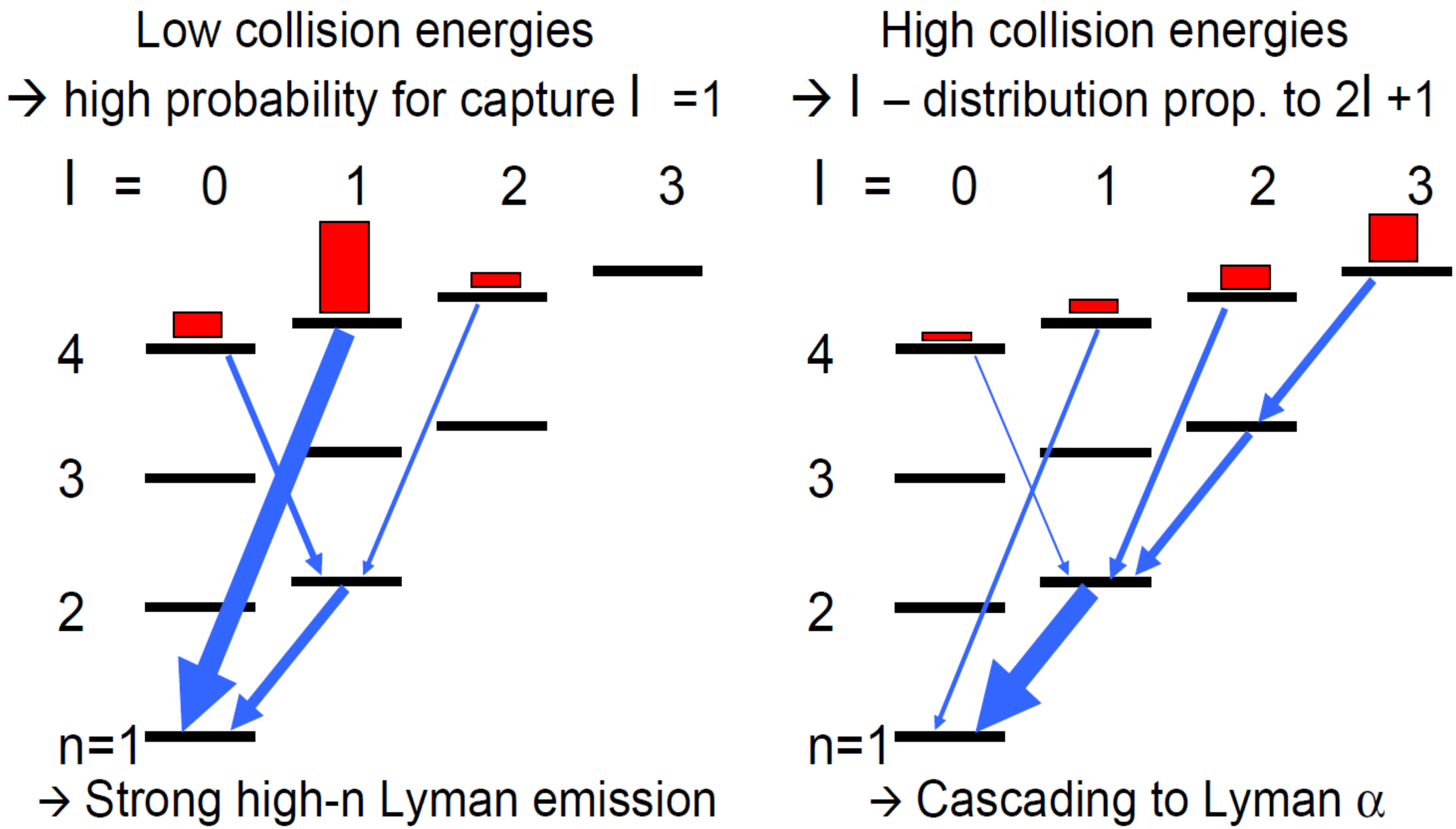
D. Fischer
D. Globig
R. Hubele
A. Kelkar
A. LaForge
D. Misra
M. Sell
K. Schneider
Xincheng Wang
Yingli Xue (pres. Lanzhou)

S. Bernitt
J. Crespo
R. Ginzel
K.-U. Kühnel
R. Moshammer
J. Ullrich

Conclusion I

- State selective, differential cross sections for single and double-electron capture
- coincident energy- (and momentum-) resolved information of electron emission (Auto-ionization)
- Insight in femtosecond transfer and stabilization mechanisms in slow collisions between HCIs and atoms in great detail

Towards lower collision energies and higher charge states



Zerfallskanäle