Investigation of multiple charge transfer using an ultracold target

S. Götz, B. Höltkemeier, T. Amthor, T. Mullins, R. Wester[1], M. Weidemüller

Physikalisches Institut, Universität Heidelberg

A. Sokolov, W. Quint

GSI, Darmstadt

I. Blank, R. Hoekstra

KVI Groningen

1 permanent address: Physikalisches Institut, Universität Freiburg

RUPRECHT-KARLS-UNIVERSITÄT HEIDELBERG

Center for Quantum Dynamics

Quantum Dynamics of Atomic and Molecular Systems

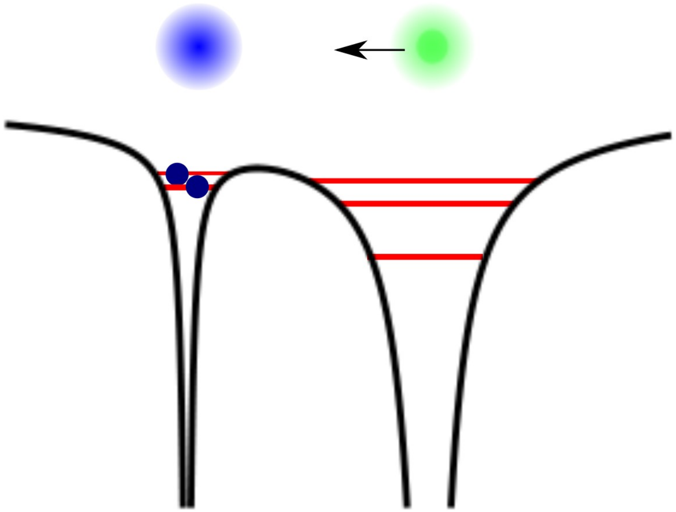
Outline

- Double charge transfer in ion-atom collisions
- Recoil Ion Momentum Spectroscopy
- Preliminary results
- Experimental setup
- Conclusion and outlook

Double electron transfer in ion-atom collision

He-Ion collisions:

- transfer of two equivalent electrons
- two different channels observed:
    - sequential transfer
    - resonant transfer



Dörner et *al*, PRA **57**, 3127 (1998), Fremont et *al*, PRA **50**, 3117 (1994), Flechard *et al*, J. Phys.B **30**, 3697 (1997)

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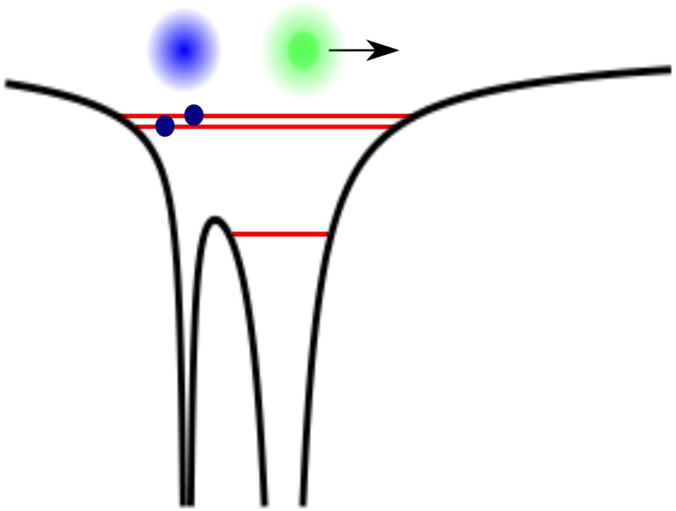

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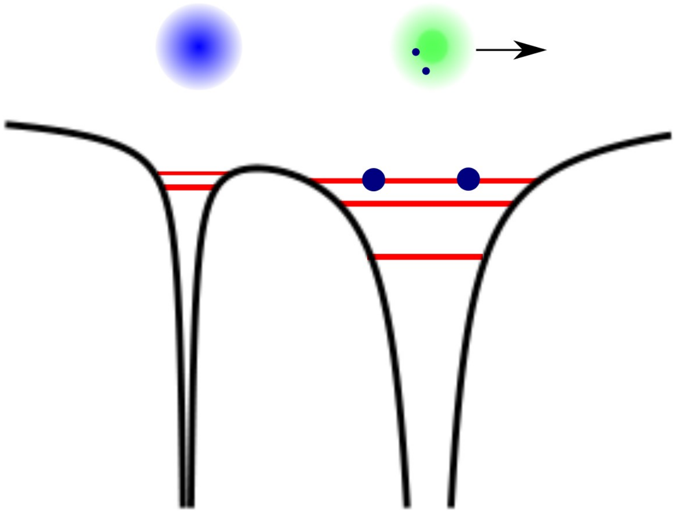

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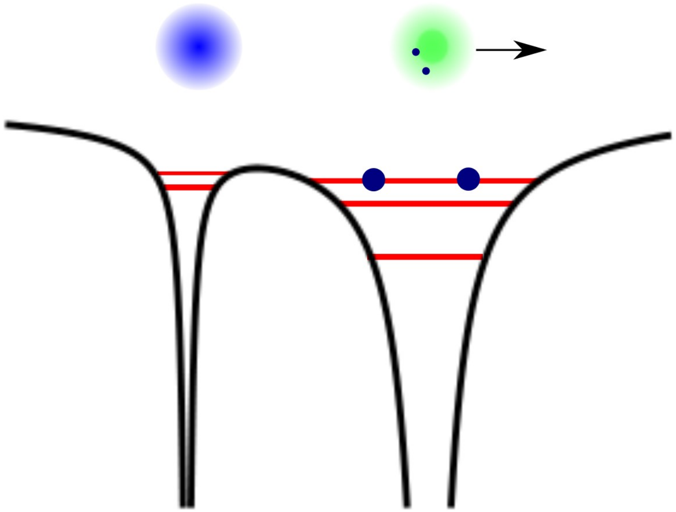

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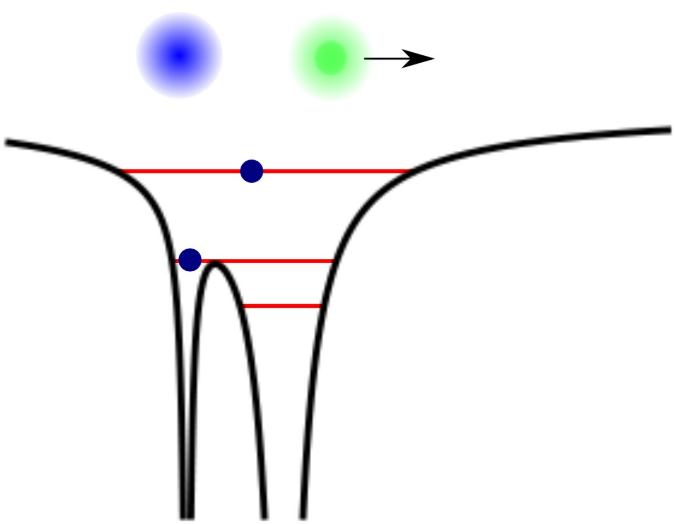
Alkali-Ion collisions:

- difference in binding energies is huge

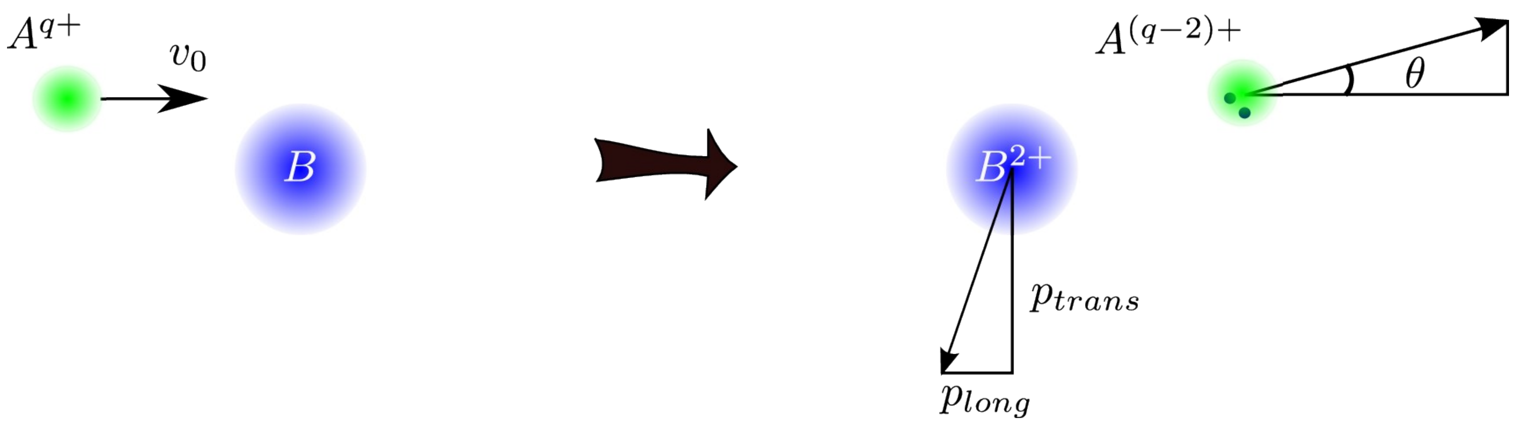


one- or two-step transfer?

Recoil Ion Momentum Spectroscopy

Quantum Dynamics of Atomic and Molecular Systems

$$A^{q+} + B \rightarrow A^{(q-n)+} + B^{n+}$$



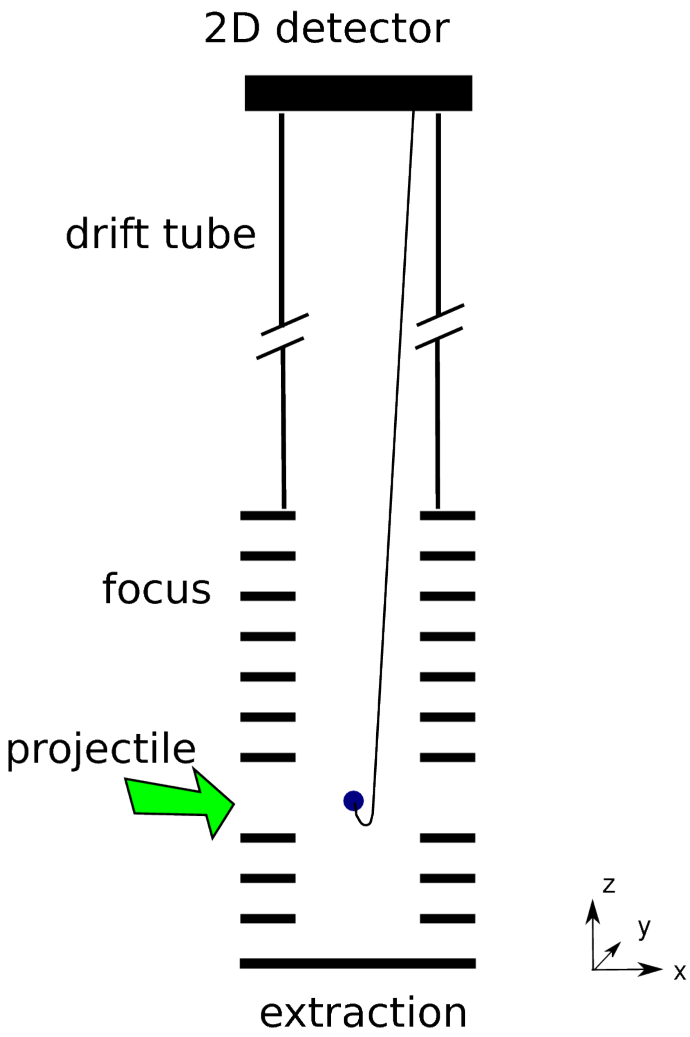
Obtain information about collision:

- scattering angle $\theta \propto p_{\mathrm{trans}}$
- energy transfer $Q \propto p_{\mathrm{long}}$

Dörner et *al*, Phys. Rep **330**, 95 (2000)

Recoil Ion Momentum Spectroscopy

- time and position focusing
- field free drift region
- position sensitive detection



DePaola et *al*, Adv. At. Mol. Opt. Phys., **55**, 139 (2008)

Recoil Ion Momentum Spectroscopy

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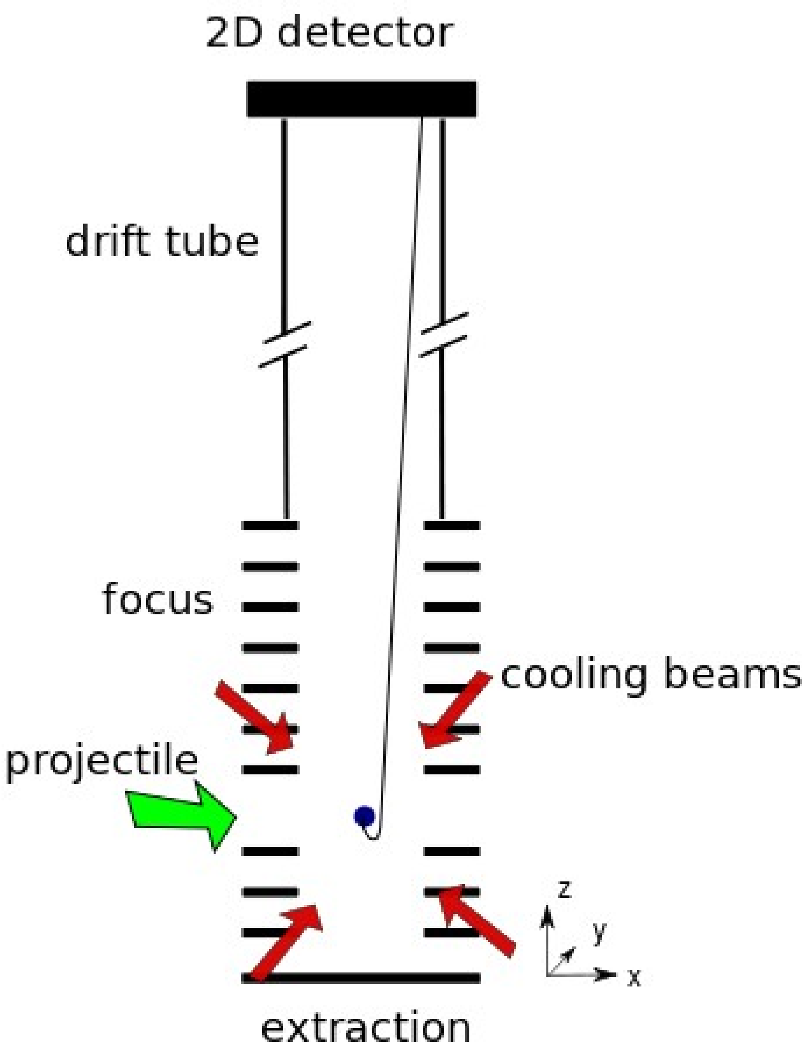
Resolution limited by:

- size of the collision region
- temperature of the target

atoms trapped in a **Magneto Optical Trap**

$$size \approx 500\mu\mathrm{m}$$
$$T \approx 100\mu\mathrm{K} \rightarrow \delta p \leq 0.01 \text{ a.u.}$$
control over internal states!



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Experiments with cold atom targets

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N. Andersen *et al.*

$$Li^+ + Na \rightarrow Li + Na^+$$

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Groningen (R. Hoekstra *et al.)*

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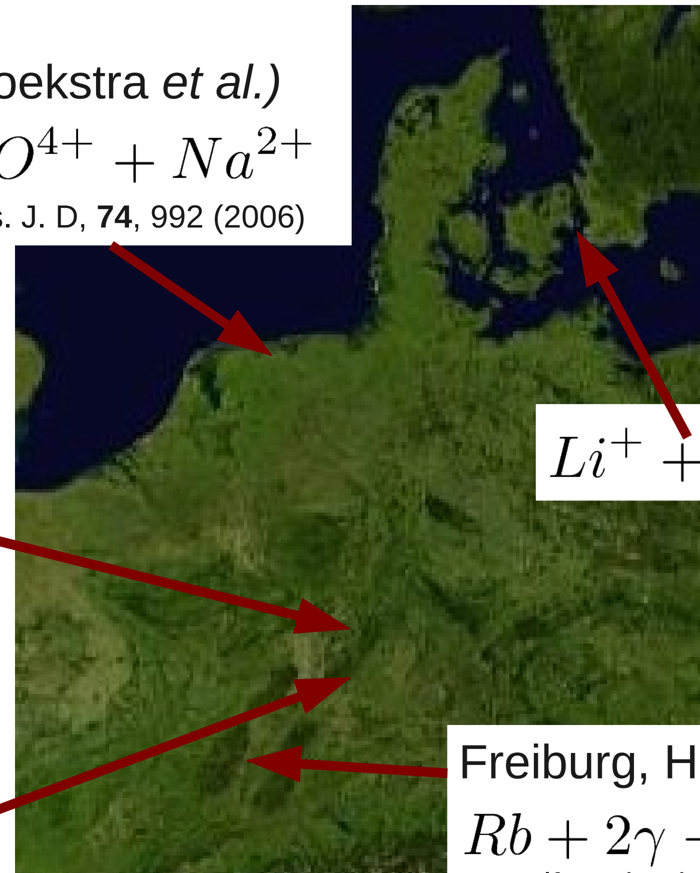
S. Knoop *et al.*, Eur. Phys. J. D, **74**, 992 (2006)



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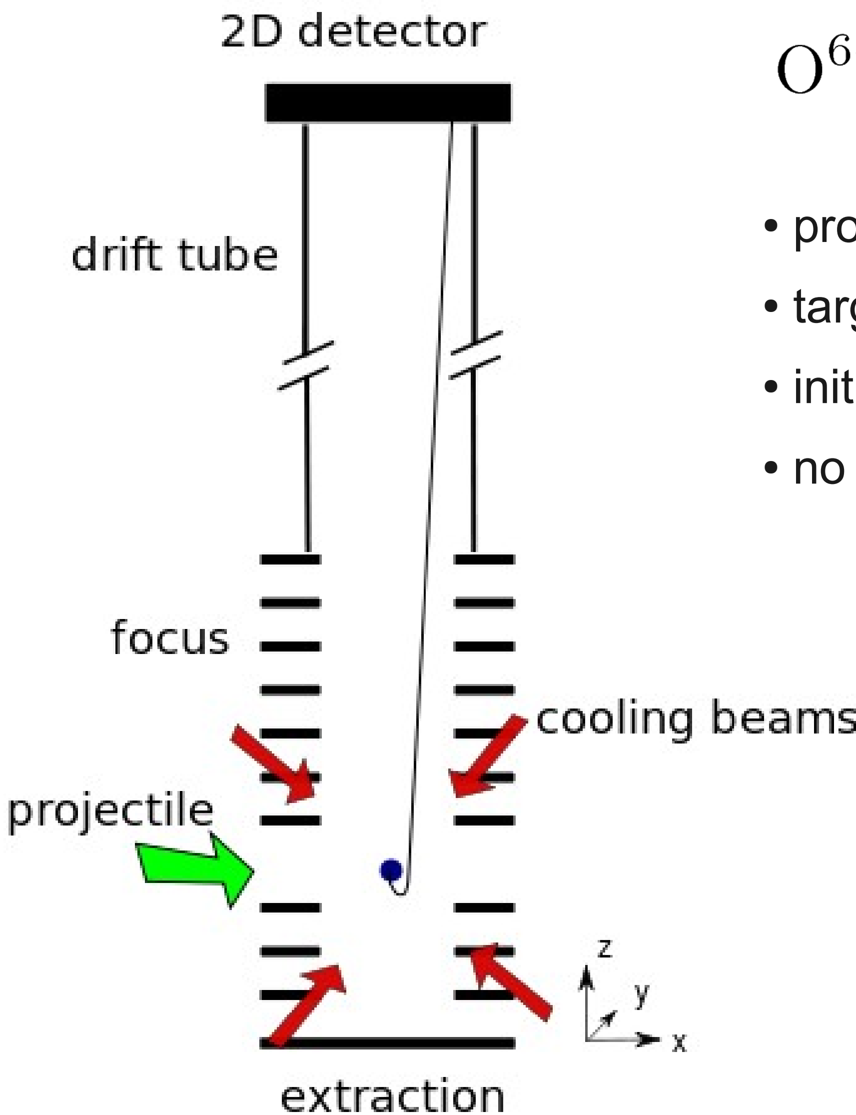
Experiments at KVI



$$O^{6+} + Na(3s) \rightarrow O^{4+}(1s^2nln'l') + Na^{2+}$$

- projectile velocity between 0.3 a.u. and 0.7 a.u.
- target atoms are all in the ground state
- initial transverse momenta ~ 0.01 a.u.
- no detection of the projectile

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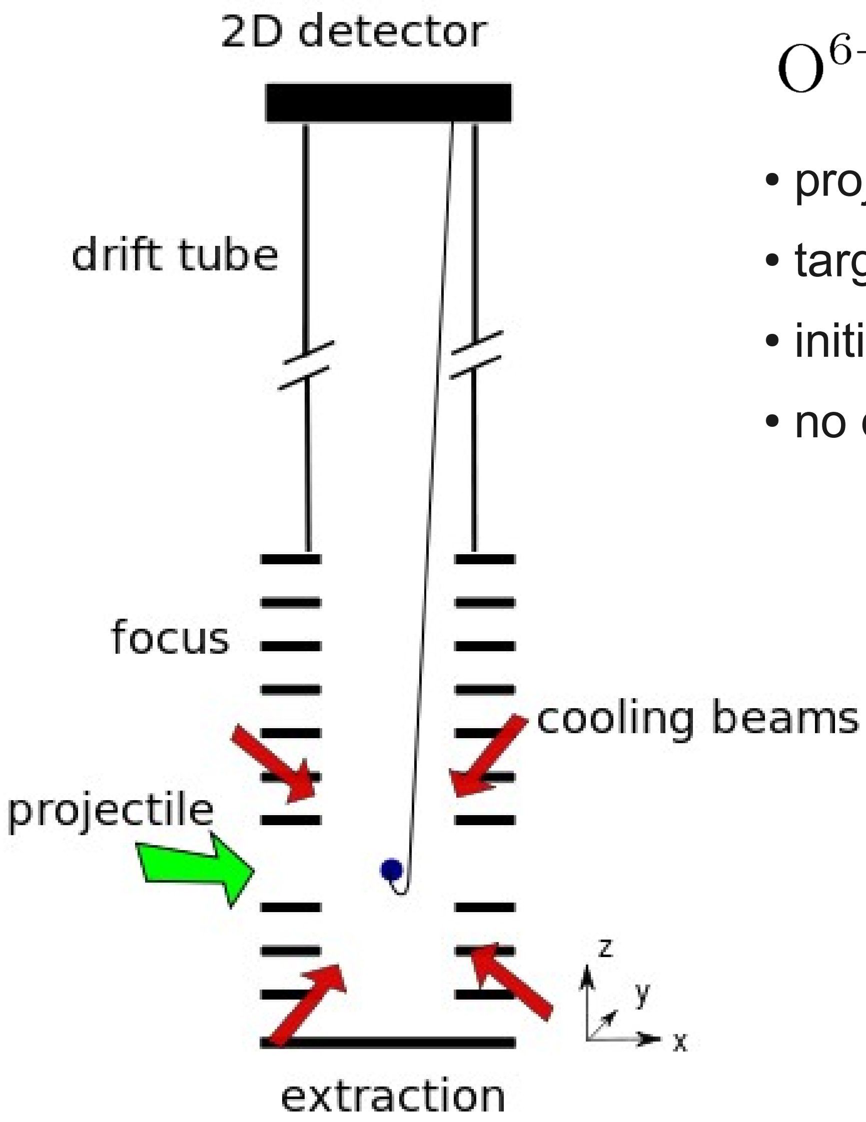

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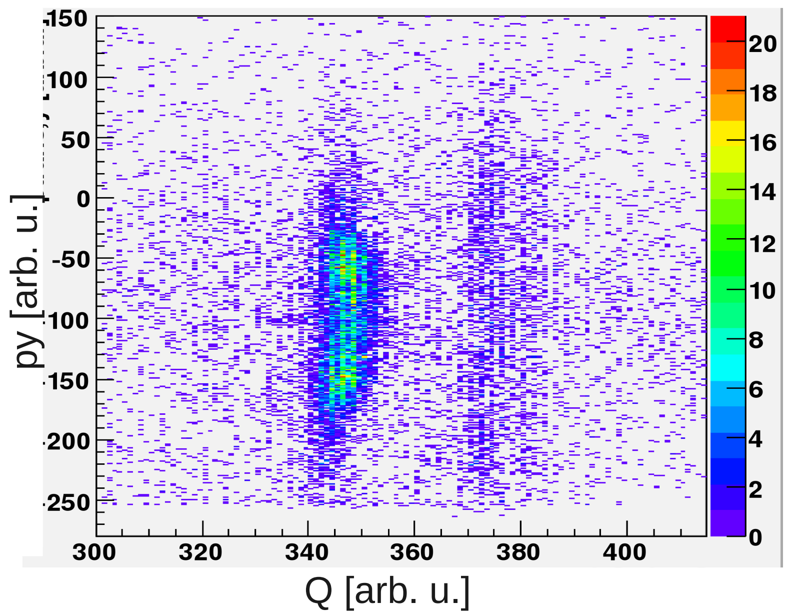
v =7.5 keV/amu



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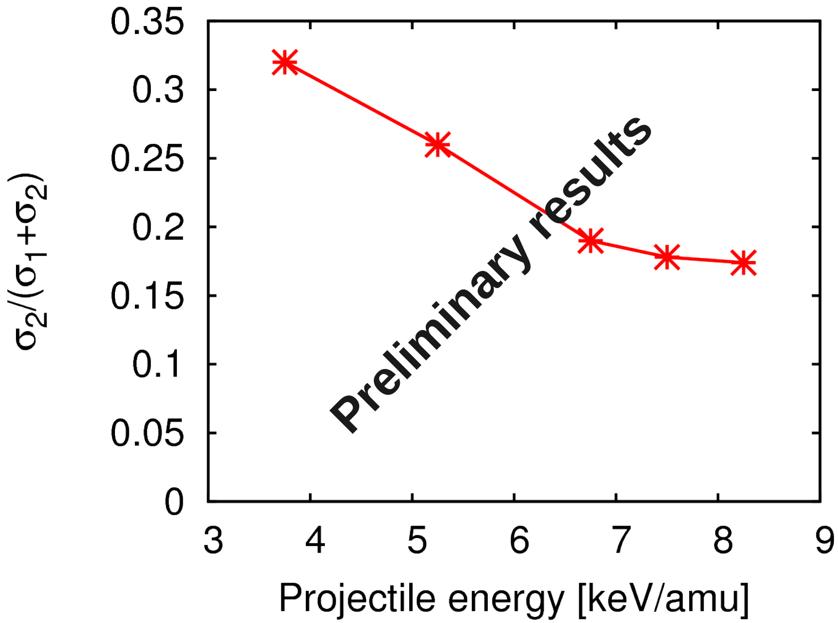

➔ different channels show strong **energy dependence**

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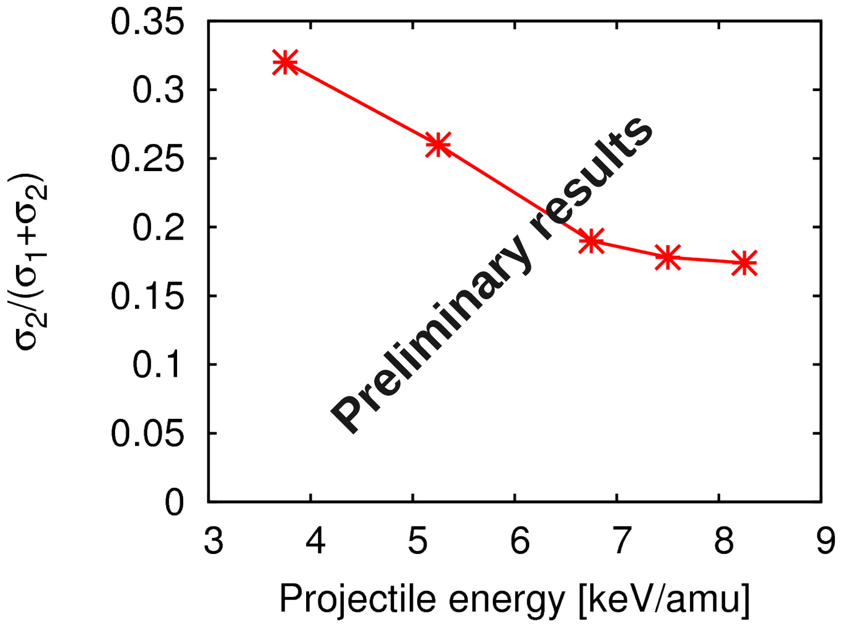
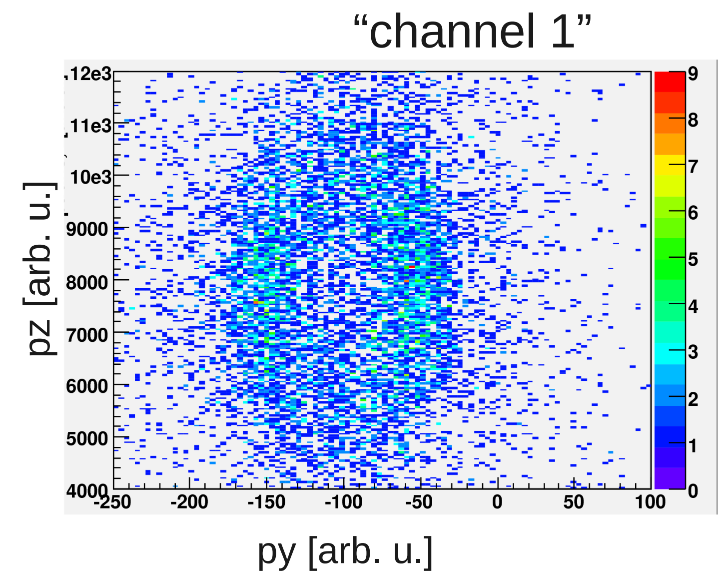
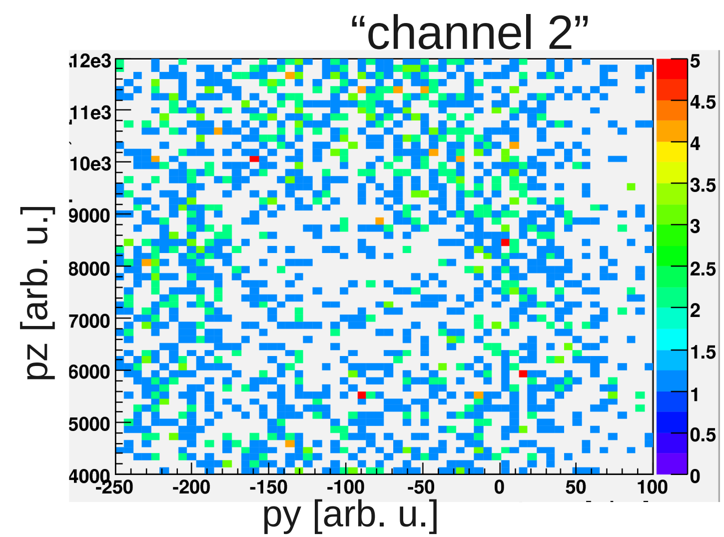






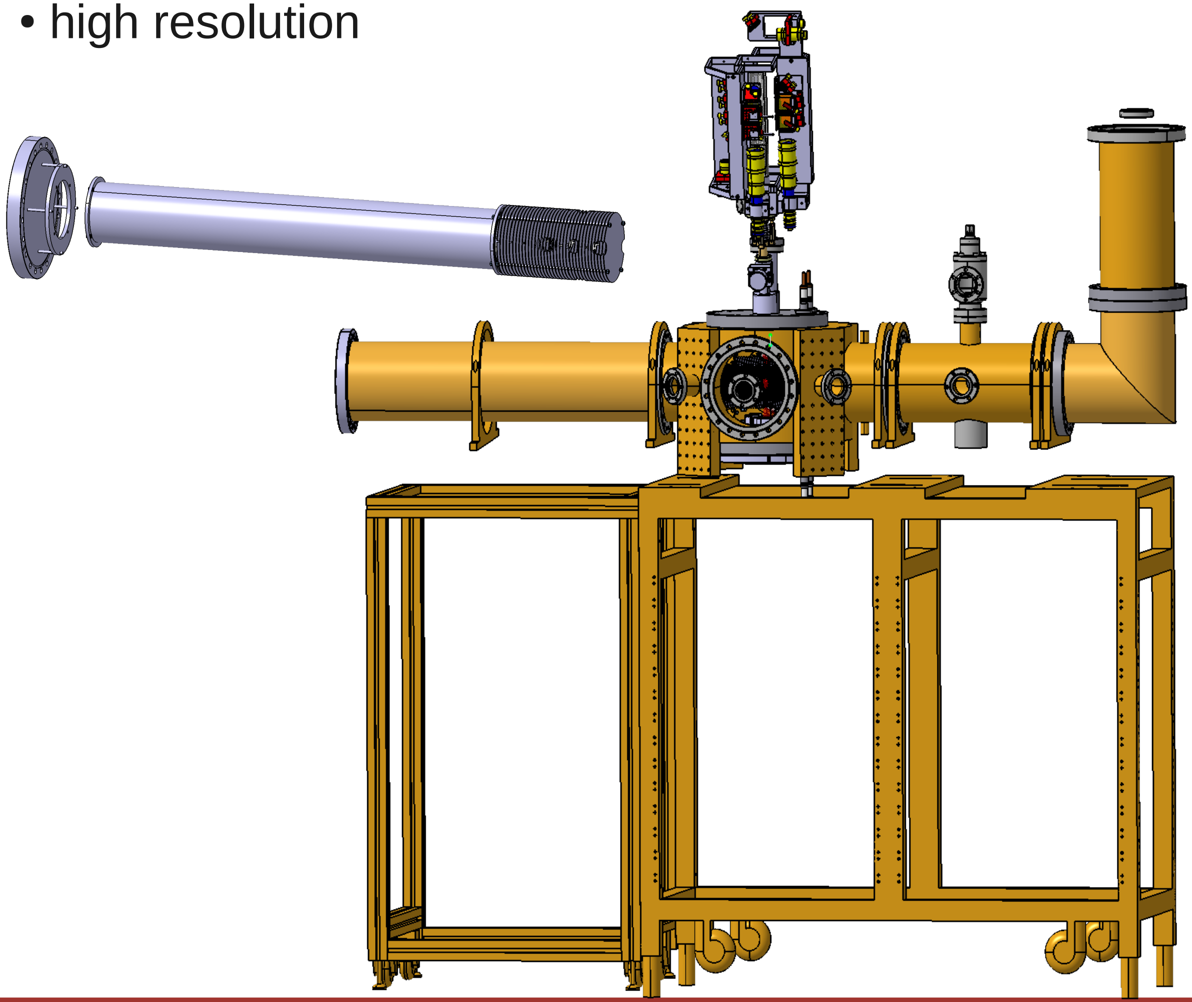
→ different channels show strong **energy dependence**

→ transverse momenta indicate different **transfer mechanism**

Experimental Setup at Heidelberg

New spectrometer:

- improved optical access
- high resolution



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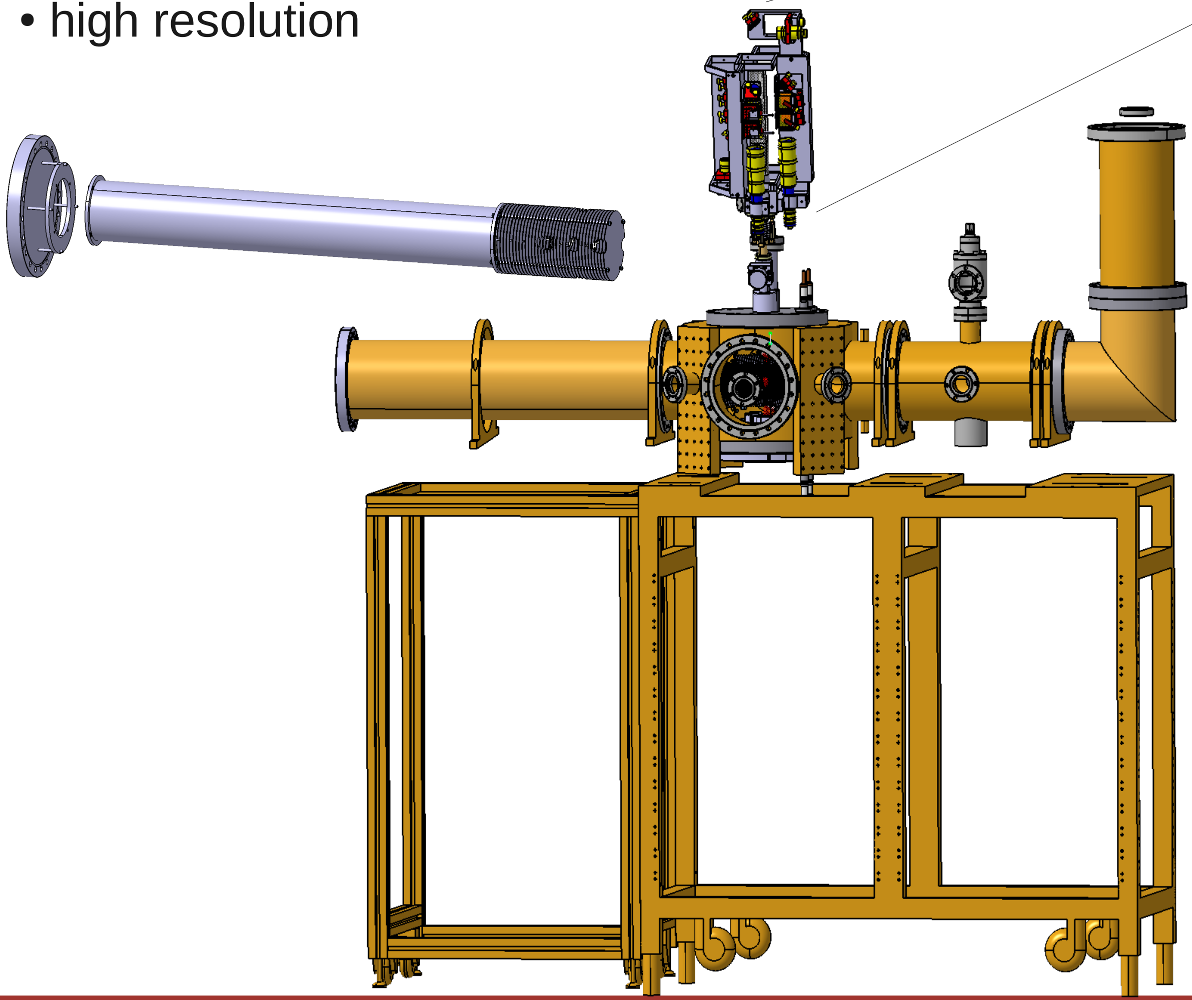

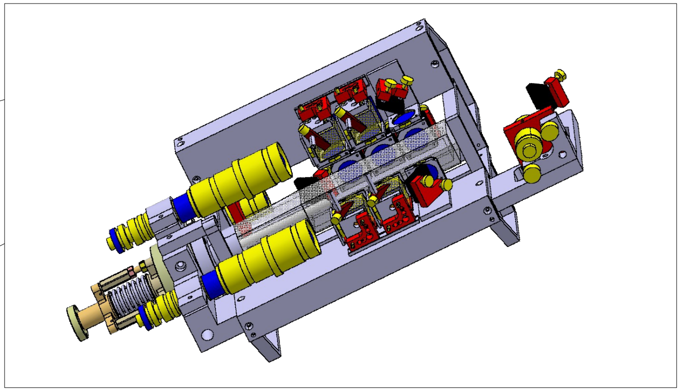

New source of atoms:

- atom beam precooled in two dimensions
- low background ions
- high loading flux of 10^9 atom/s
- low beam divergence

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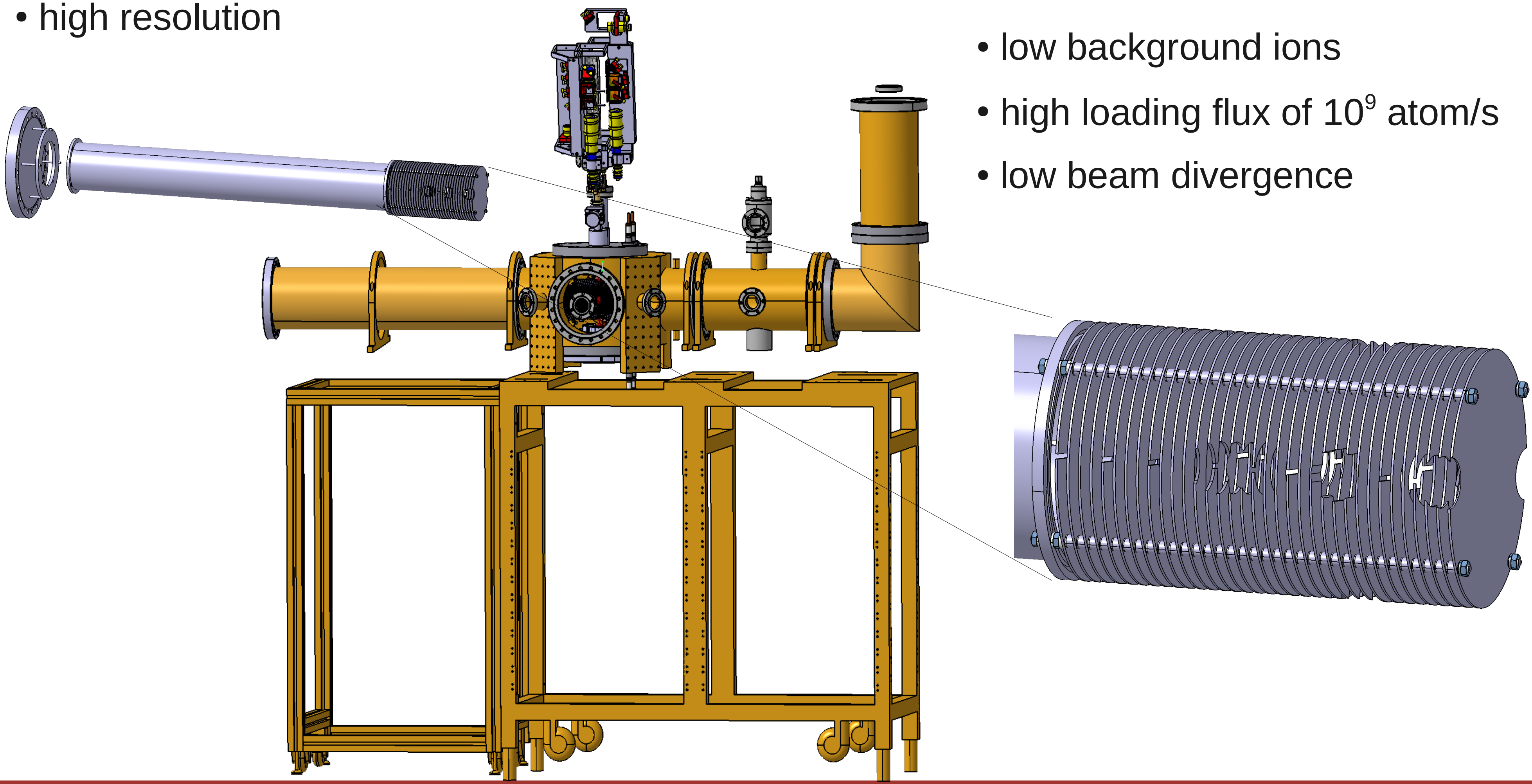


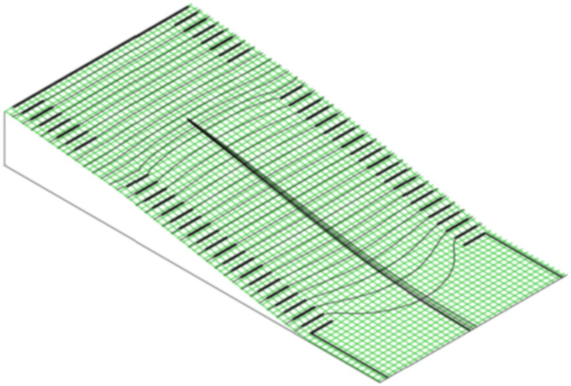
Simulations

example: $Rb + Ar^{16+} \rightarrow Rb^{2+} + Ar^{14+}$

values taken from Abdallah et *al*, PR**A 58**, 2911 (1998), NIST

initial conditions:

- $\text{MOT size} = 600\,\mu\text{m}$
- $Q = 190\ \text{eV}/191\,\text{eV}$
- $\theta = 0.3\ mrad, 0.5\ mrad$
- $v = 0.3\ a.u.$



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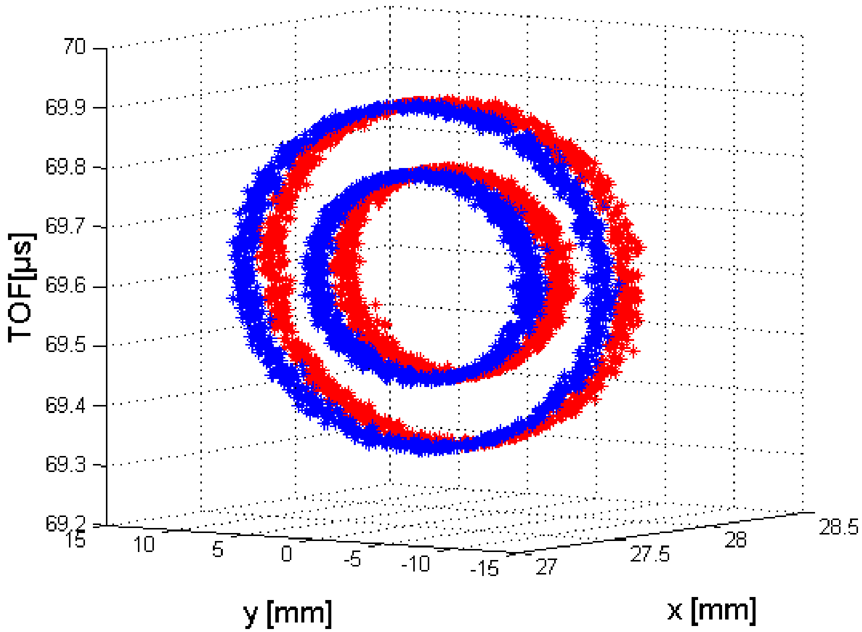

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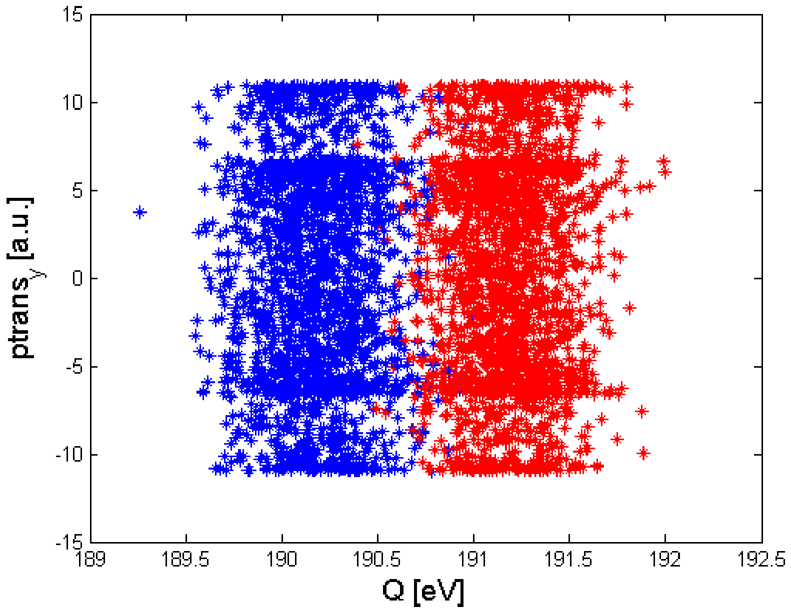

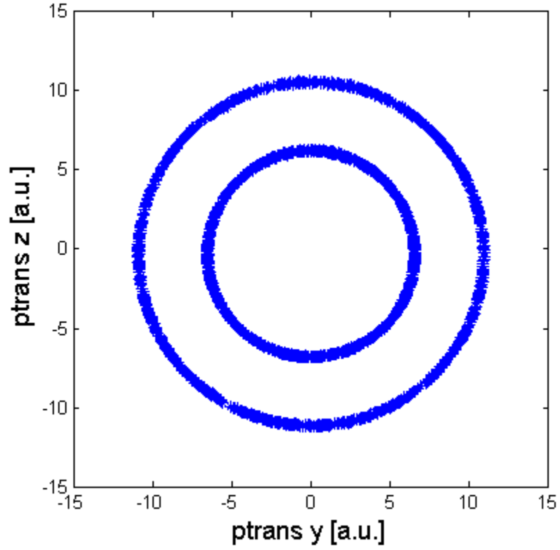

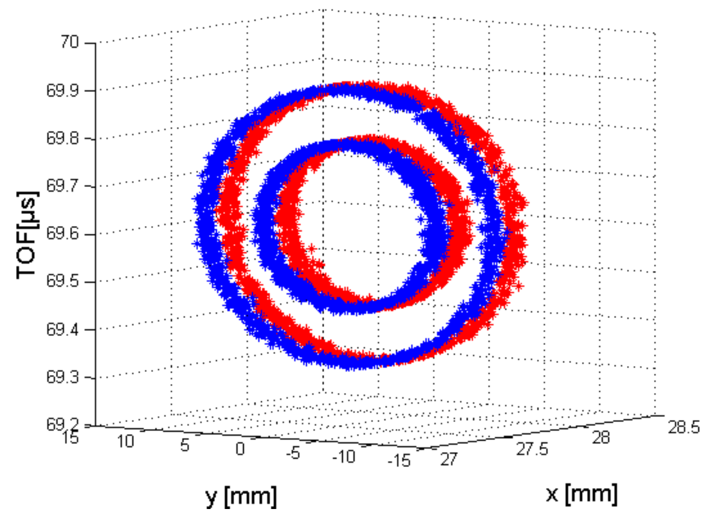

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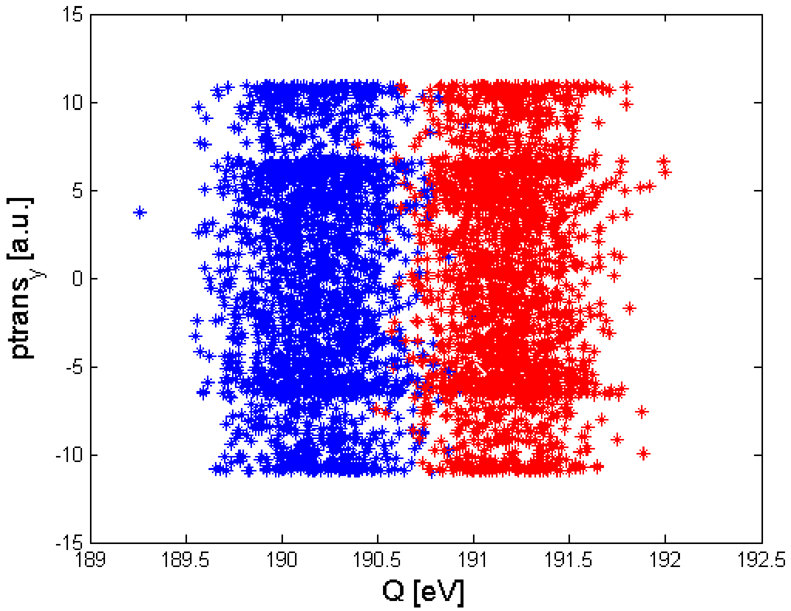

initial conditions:

- $\mathrm{MOT\ size} = 200\,\mu\mathrm{m}$
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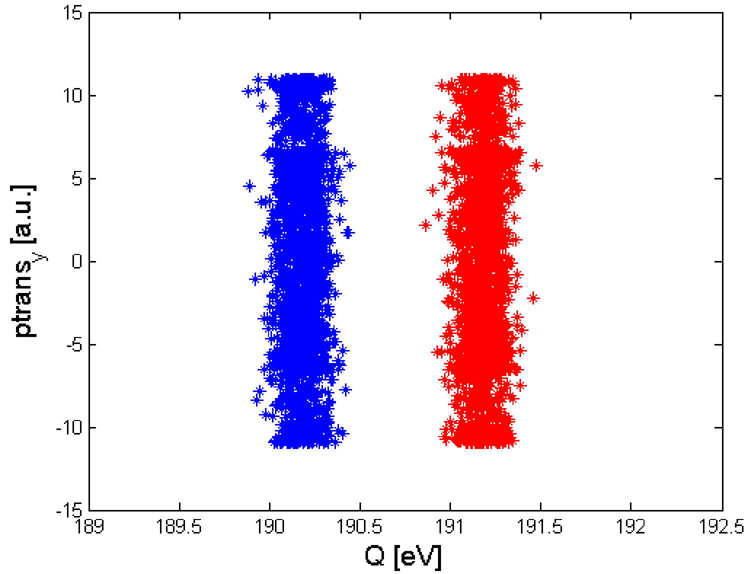

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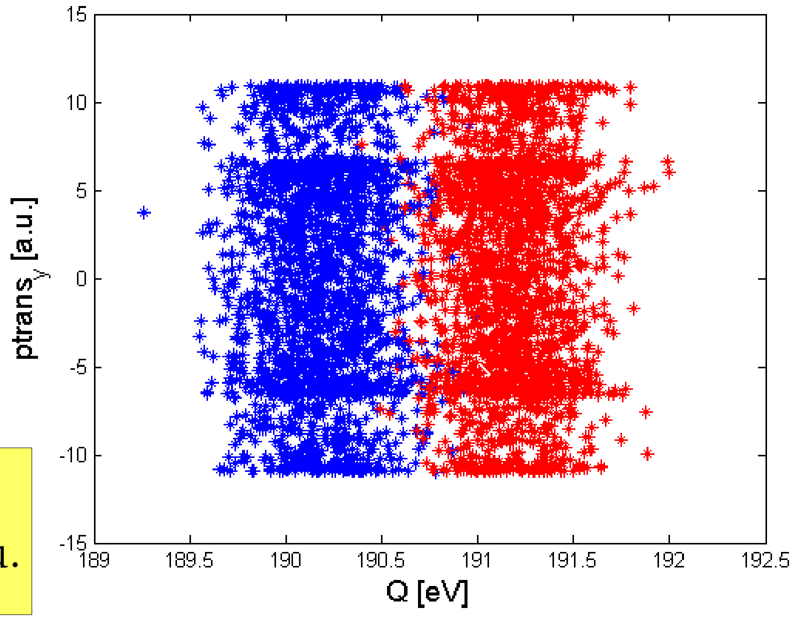
resolution

$\delta p_{long} < 0.04\ \text{a.u.}$
$\delta p_{trans} < 0.05\ \text{a.u.}$



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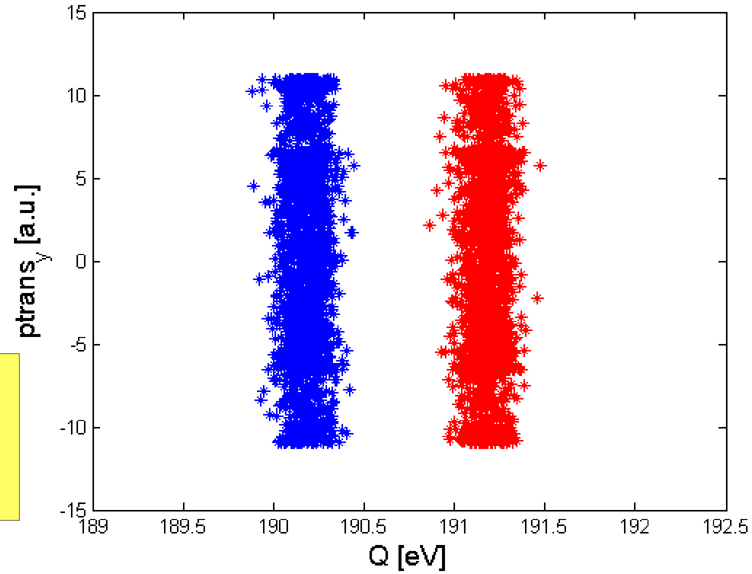

Quantum Dynamics of Atomic and Molecular Systems

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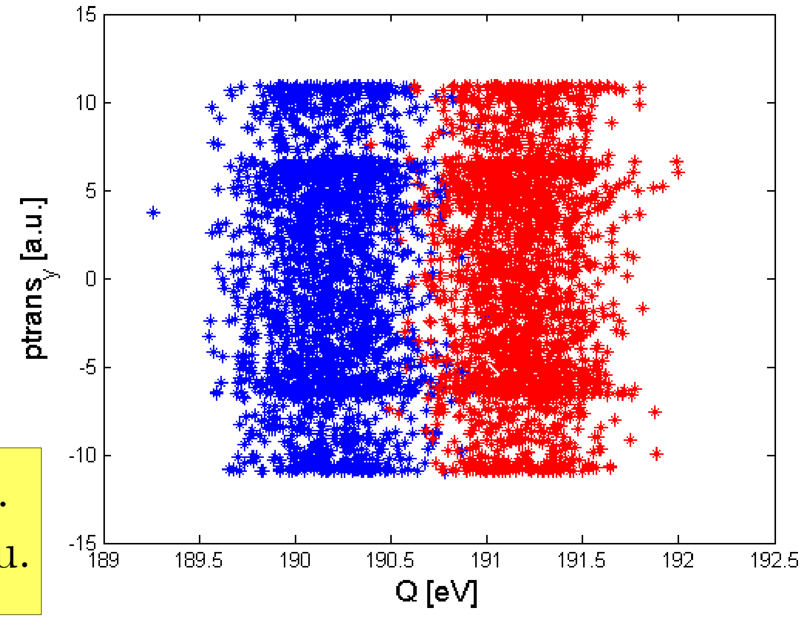

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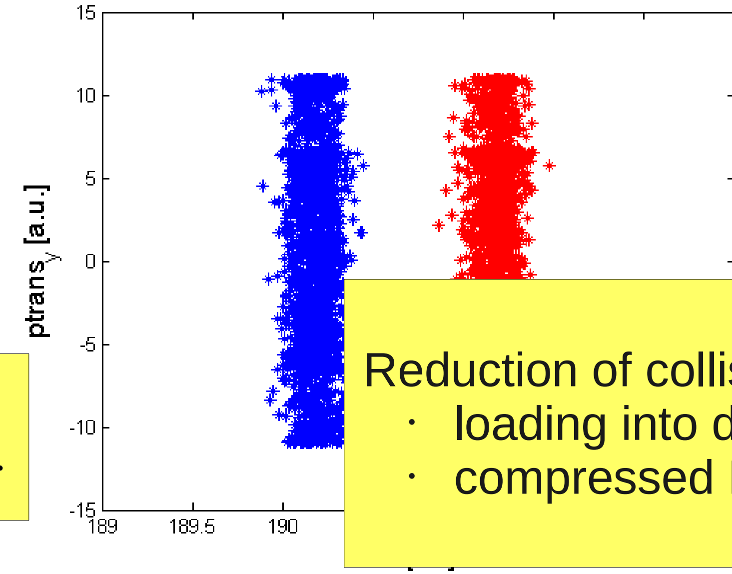


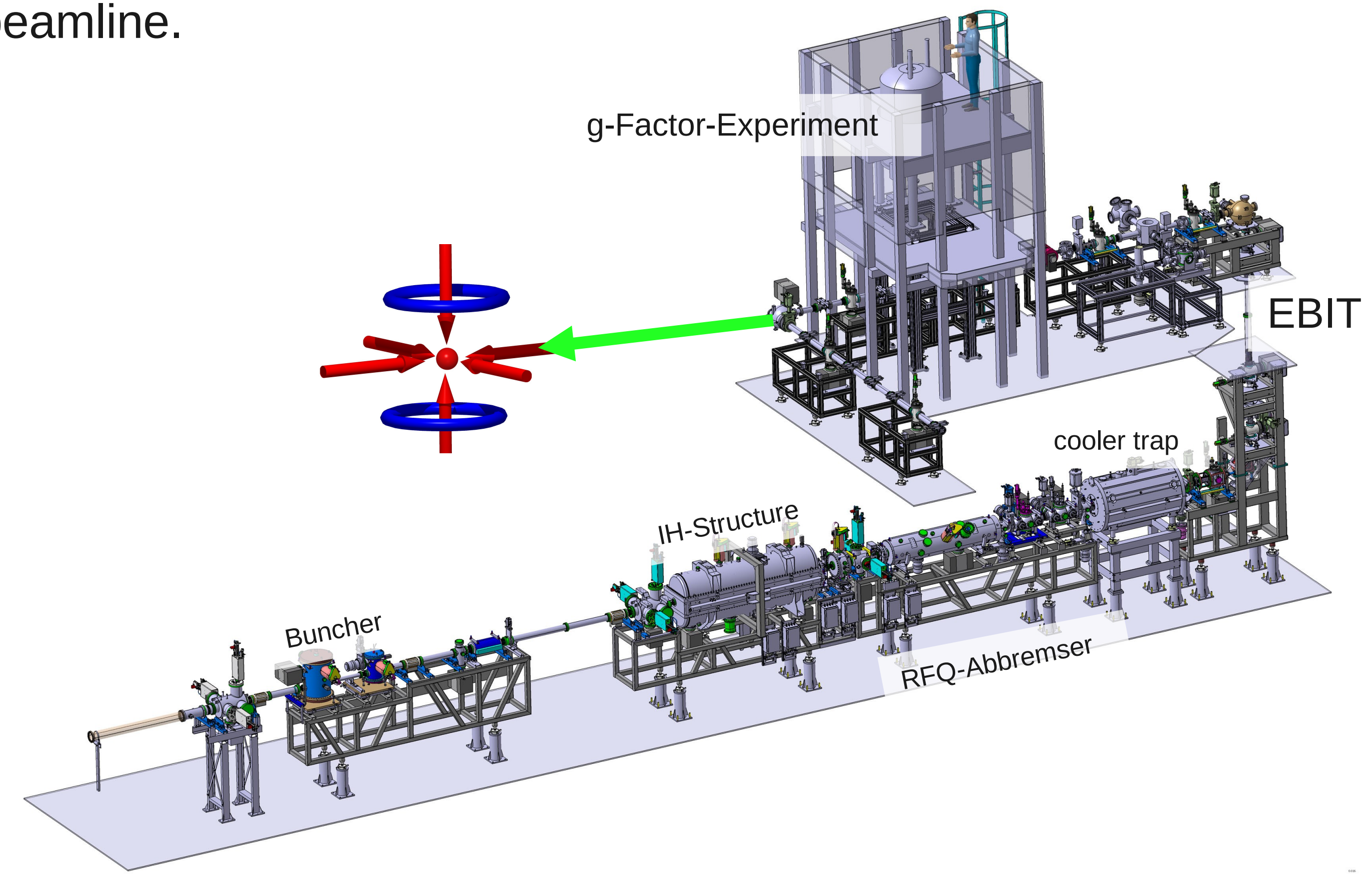
Reduction of collision size:

- loading into dipole trap
- compressed MOT

MOTRIMS at HITRAP

Which mechanisms come into play when many electrons are transferred?

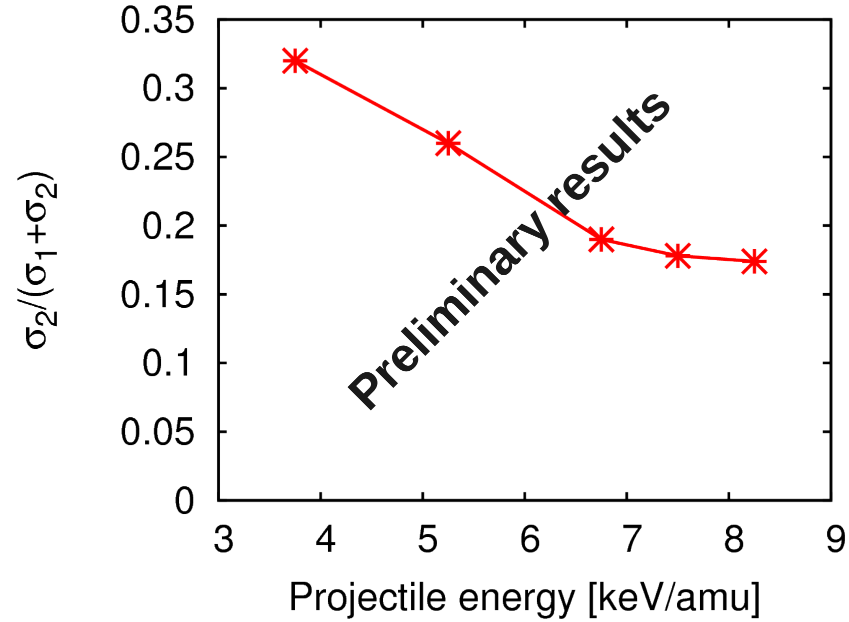
Low energetic highly charged ions up to U^{92+} available at the HITRAP beamline.



Conclusion and outlook

Conclusion:

- first results on double charge transfer



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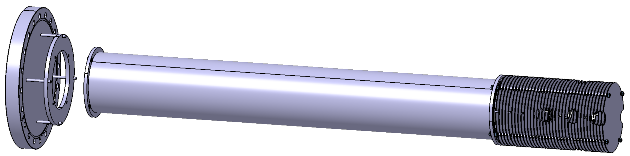

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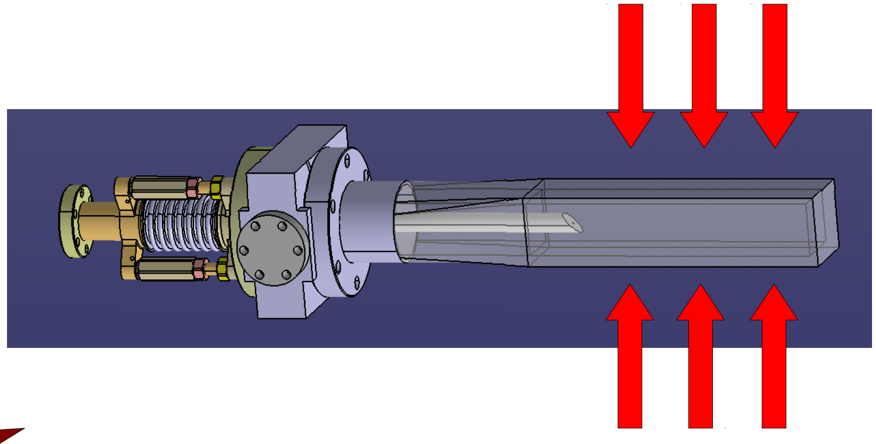

See poster B. Höltkemeier tonight!

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Outlook:

- understand different transfer mechanisms for double electron transfer
- commissioning of the upgraded setup
- implementation of coincidence detection of projectile and recoil ion
- investigation of charge transfer between alkalis and highly charged ions