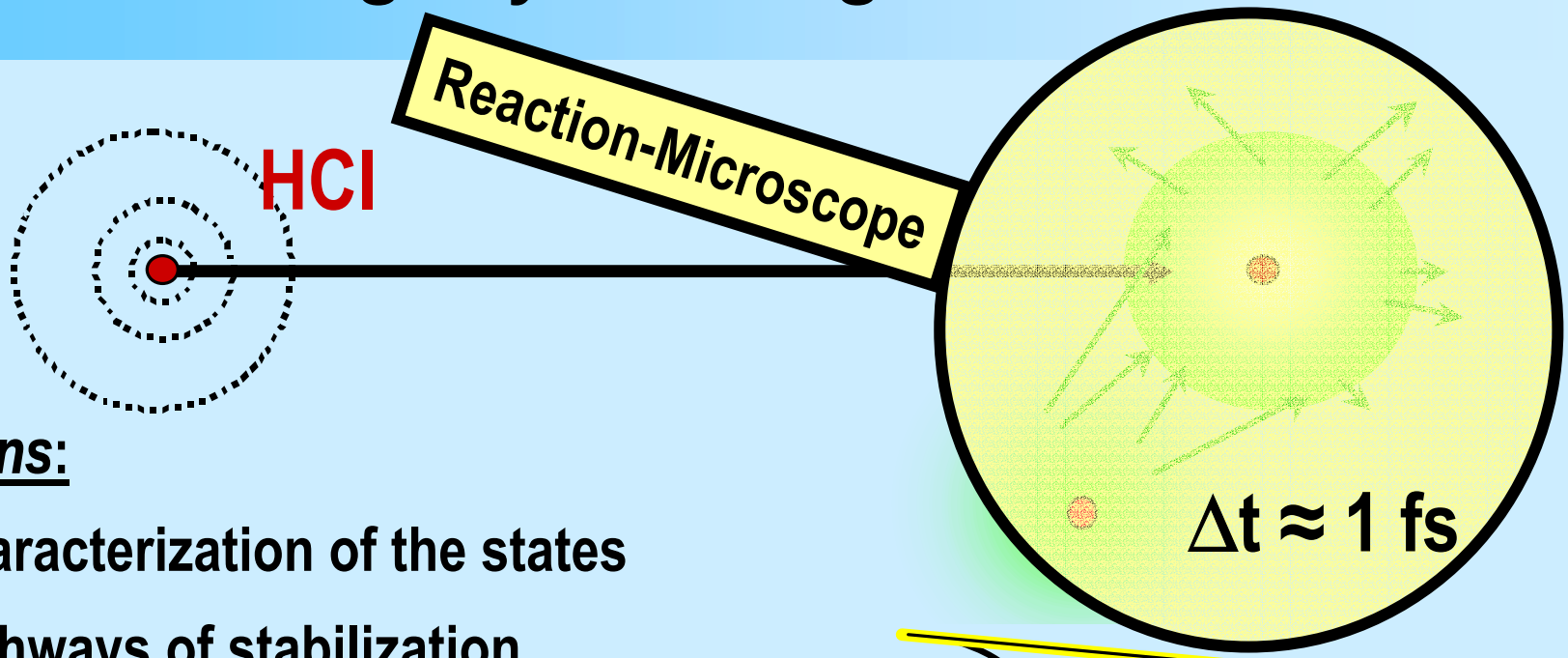
Motivation for Reaction Studies with Highly Charged Ions

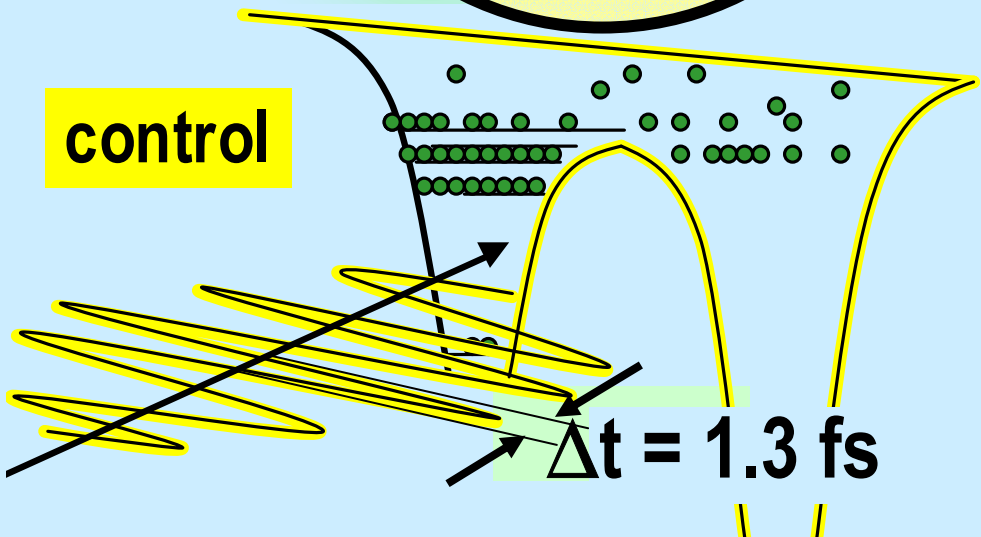


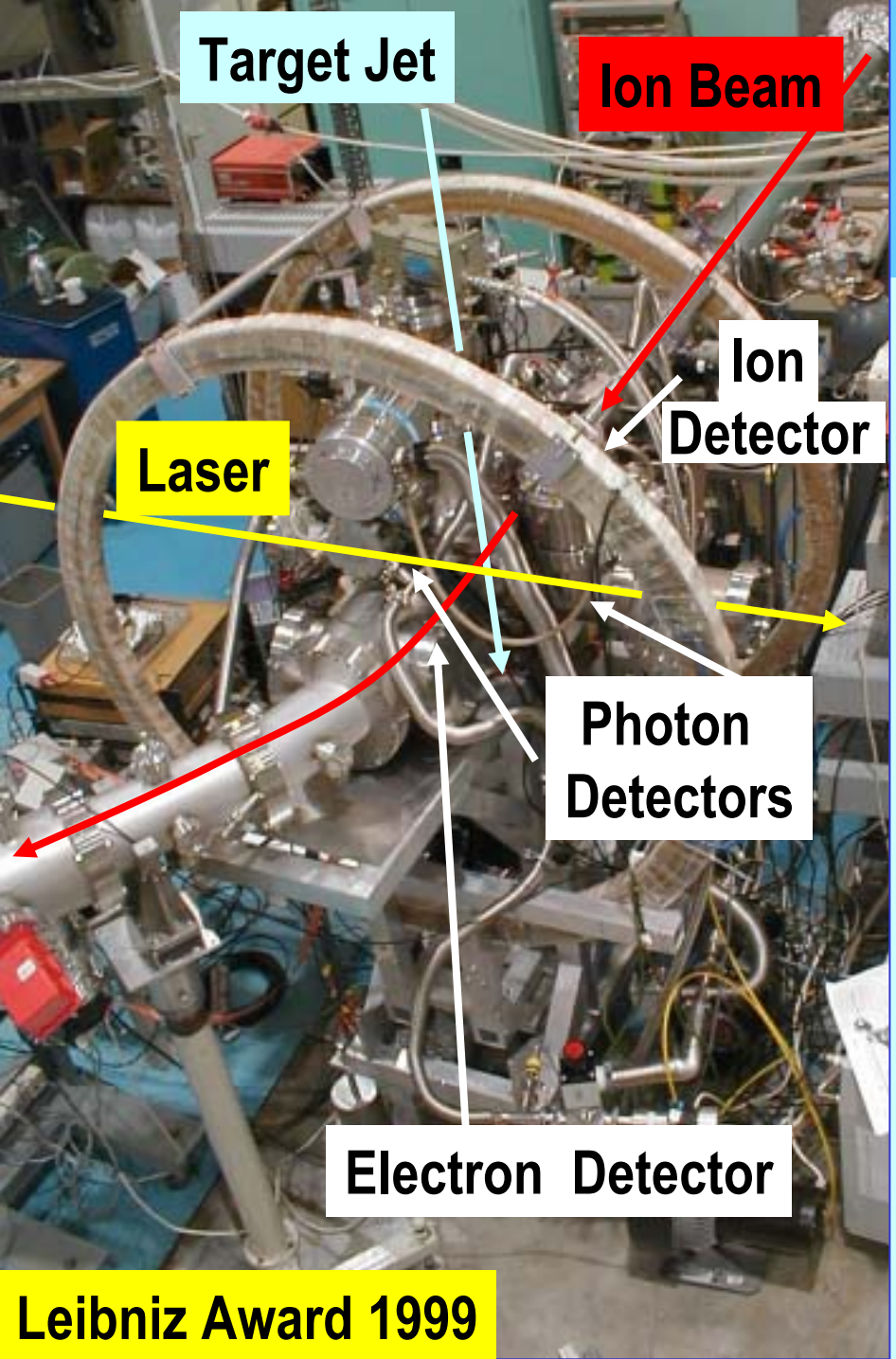
***Questions*:**

1. **Characterization of the states**
2. **Pathways of stabilization**
3. **Dynamics of formation**

femtosec. many-electron flux

- **correlated ??**
- **tunneling ??**
- **control ??**





Reaction-Microscope

Detection of:

- few ions: 100 % of 4π
- up to ten electrons: 50 % of 4π
- photons: 10 % of 4π

with high resolution

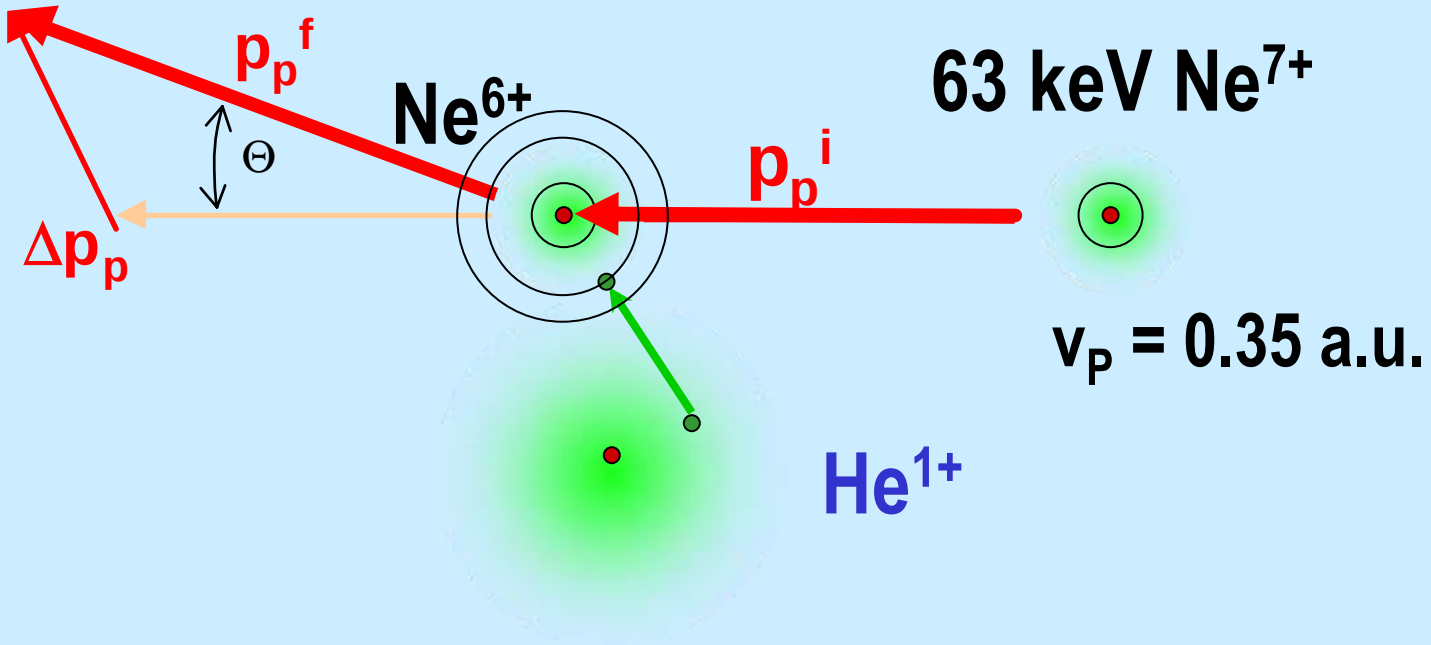
But:

- cross section: 10^{-14} cm^2
- target density: 10^{11} cm^{-2}
- efficiency: 10^{-3}
  ($2e^-$, ion,photon)

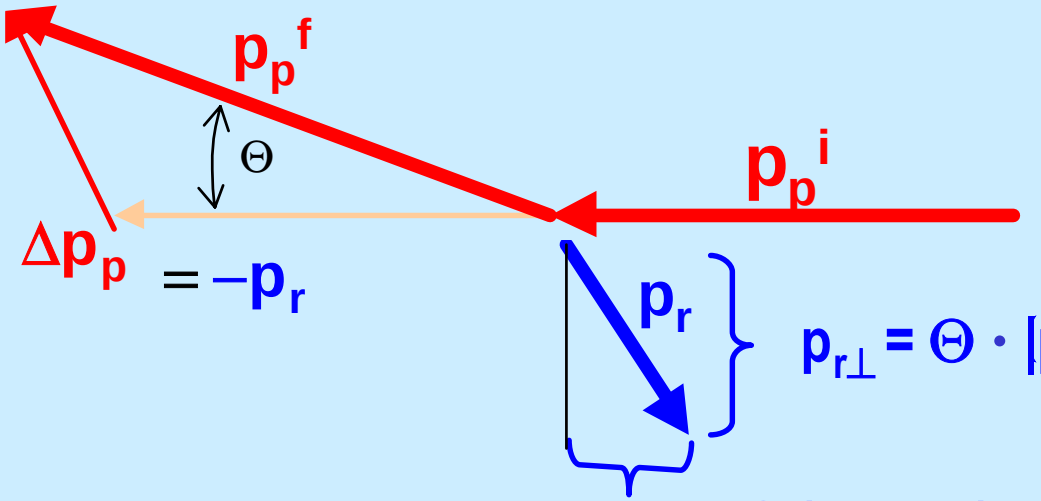
Need: 10^5 ions/second

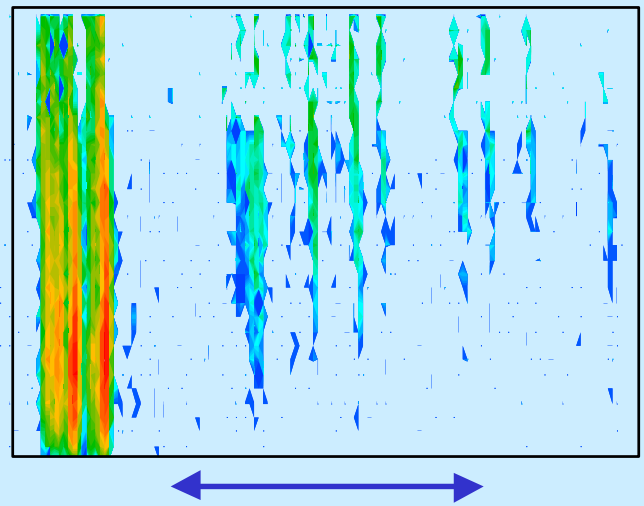
HITRAP

Kinematics: Structure & Dynamics



Kinematics: Structure & Dynamics





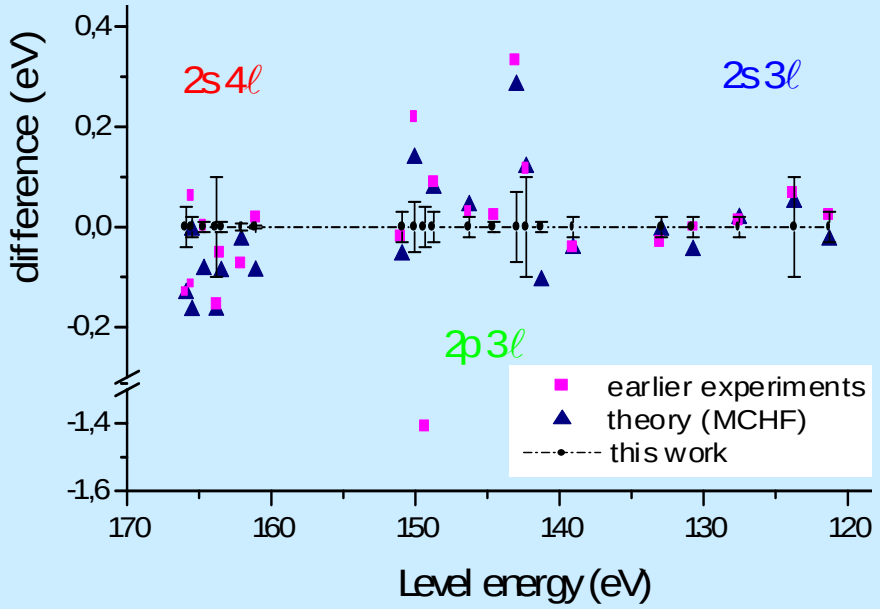
- scattering angle
- impact parameter

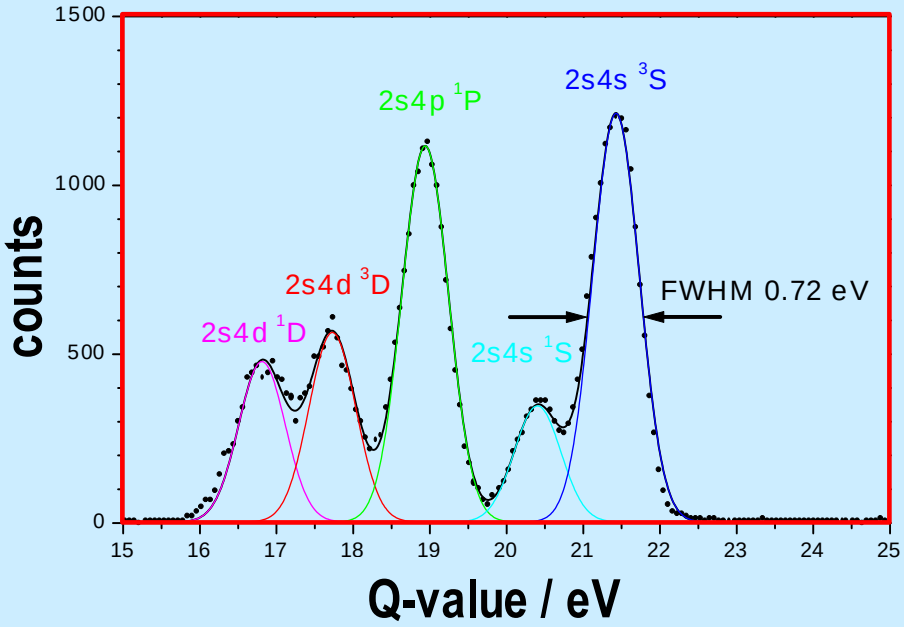
Dynamics Structure

Fischer et al.
JPB 2002

Q value: $Q = E_b^f - E_b^i$

Structure: Precision Spectroscopy





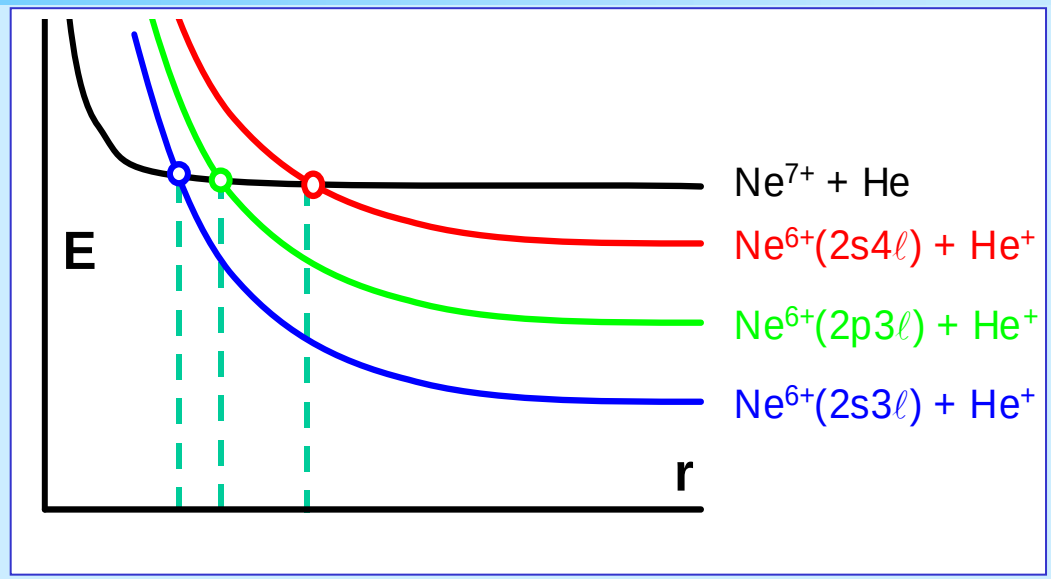
- **excellent resolution: 0.7 eV FWHM**
- **excellent precision: 3 - 300 meV**
- **many states simultaneously**
- **no selection rules <-> photons!**
- **“automatic” relative normalisation**
- **absolute normalisation feasible**

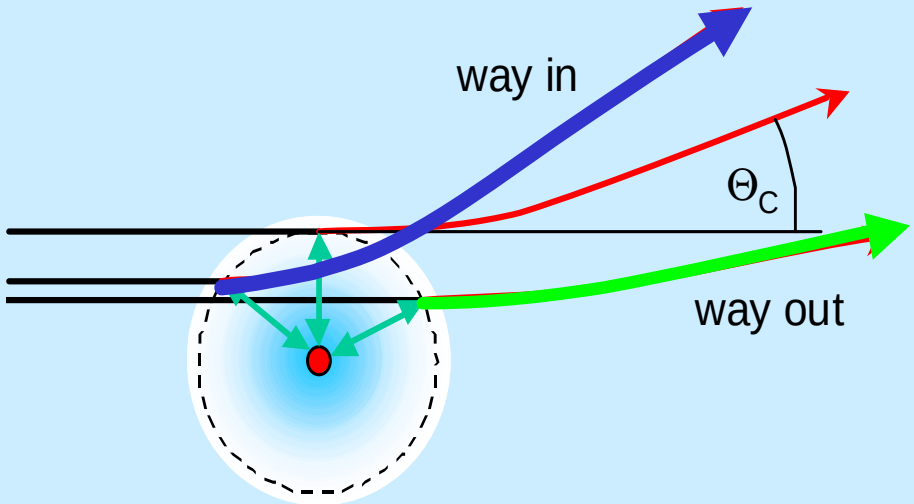
Envisaged improvement: Factor 5

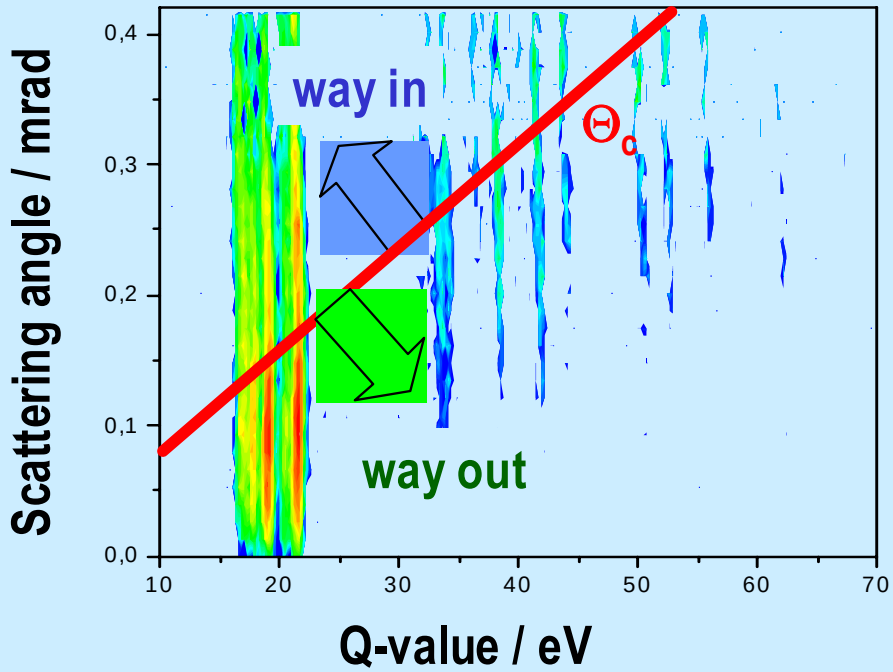
Atomic trap: MOT Factor: 30

KVI (MPI-K)

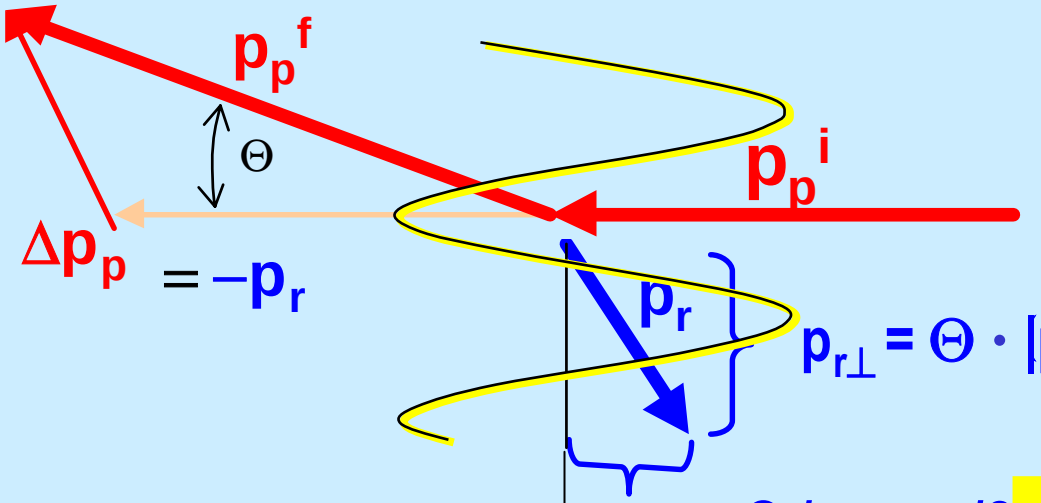
Dynamics on Femtosecond Time-Scale

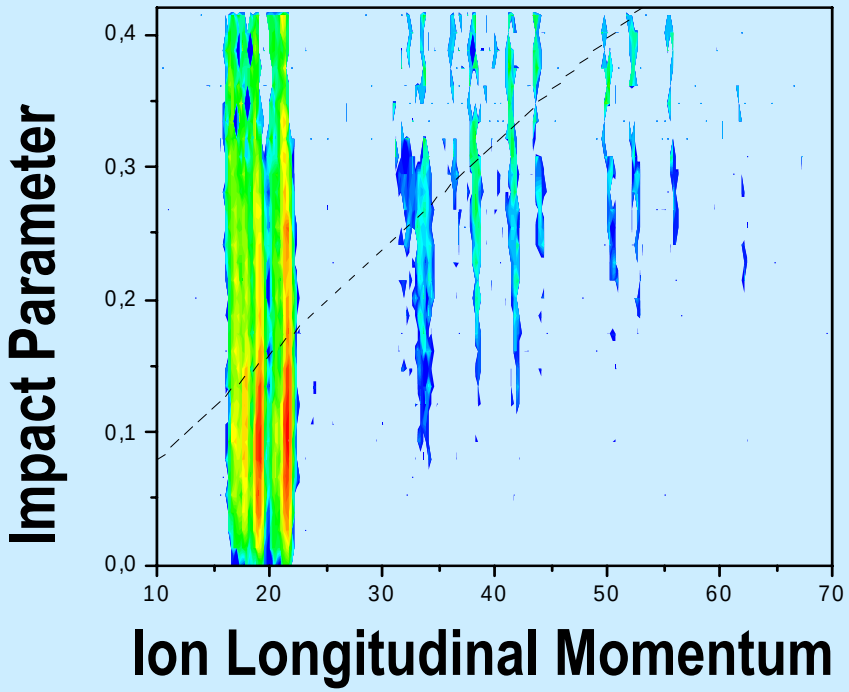


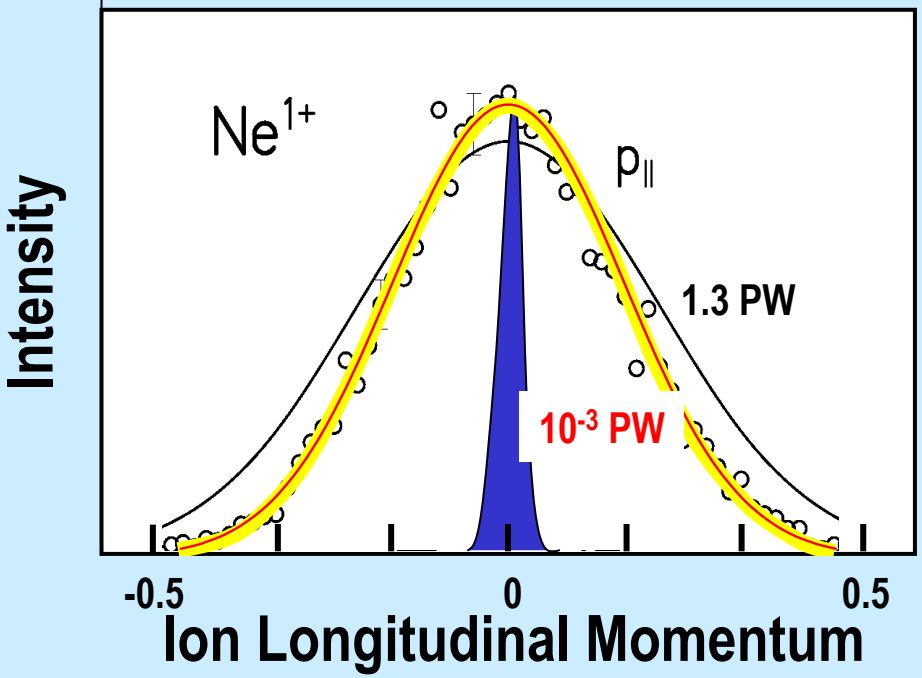




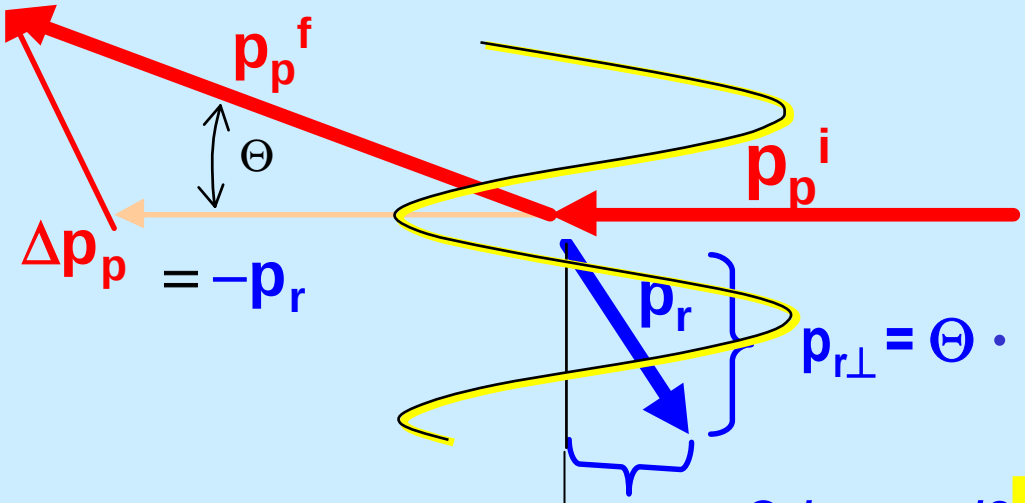
Control: Femtosecond Dynamics

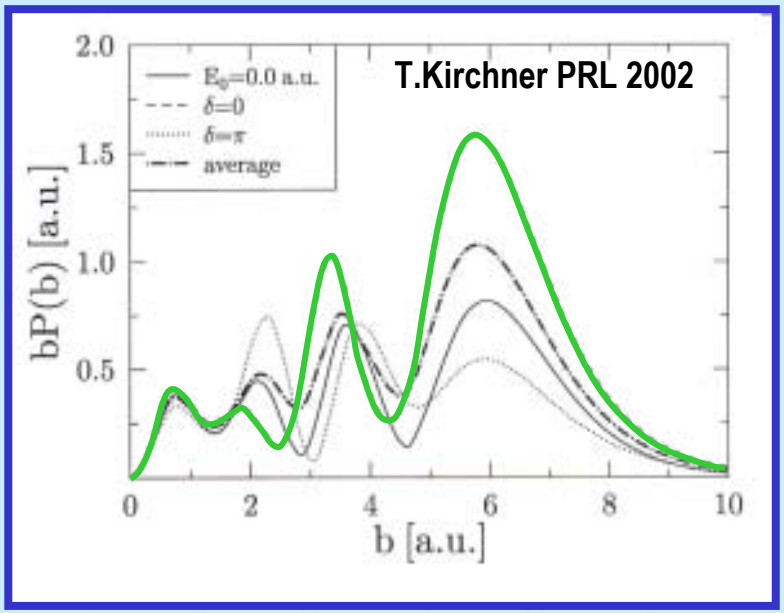


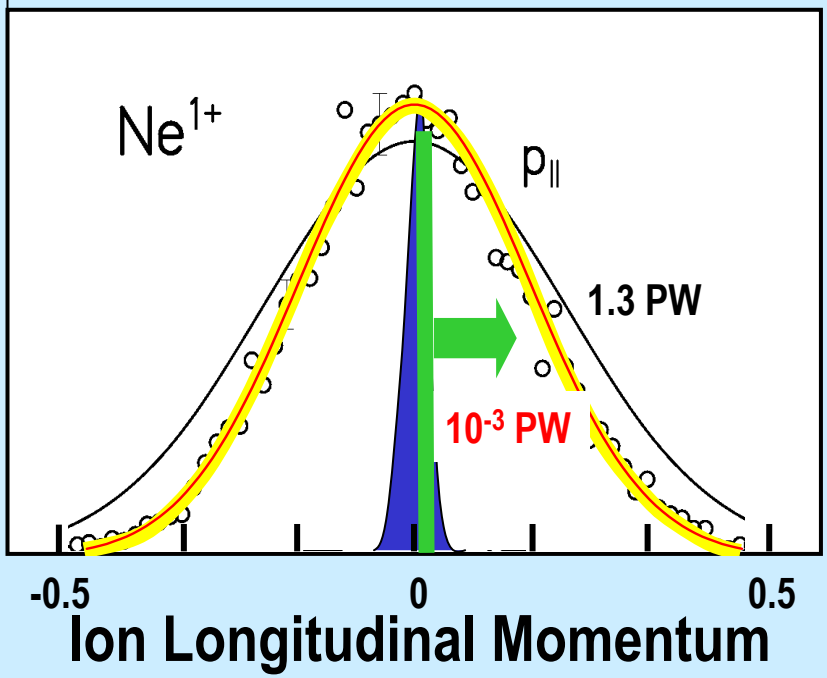




Control: Femtosecond Dynamics







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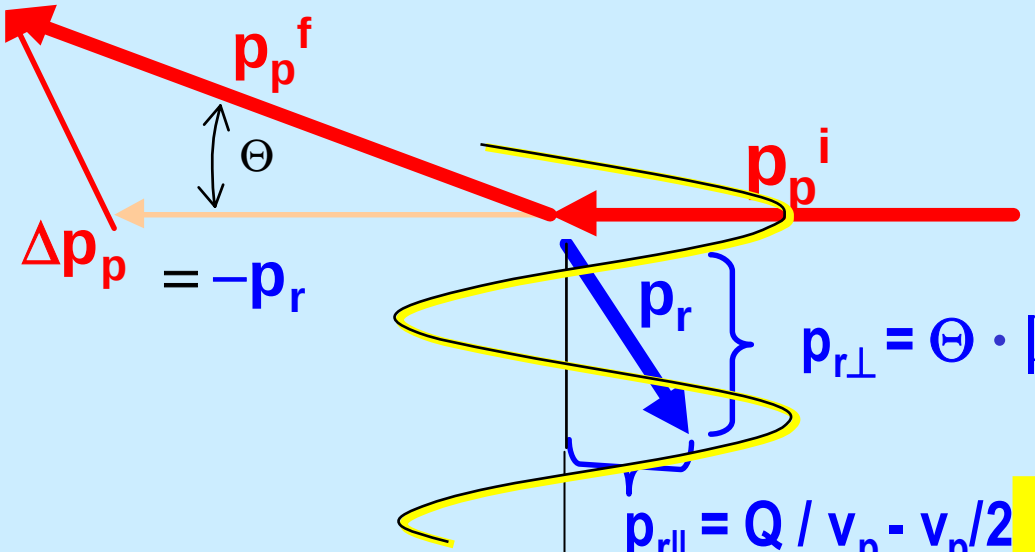
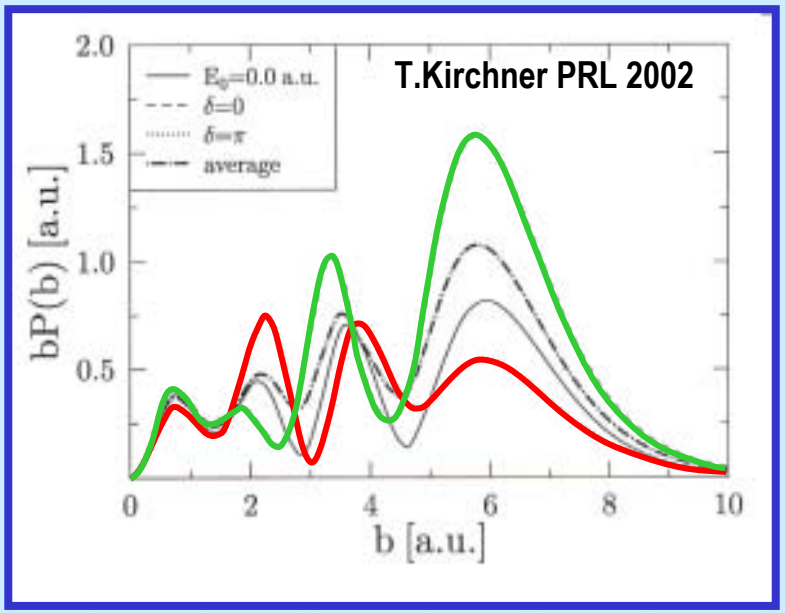
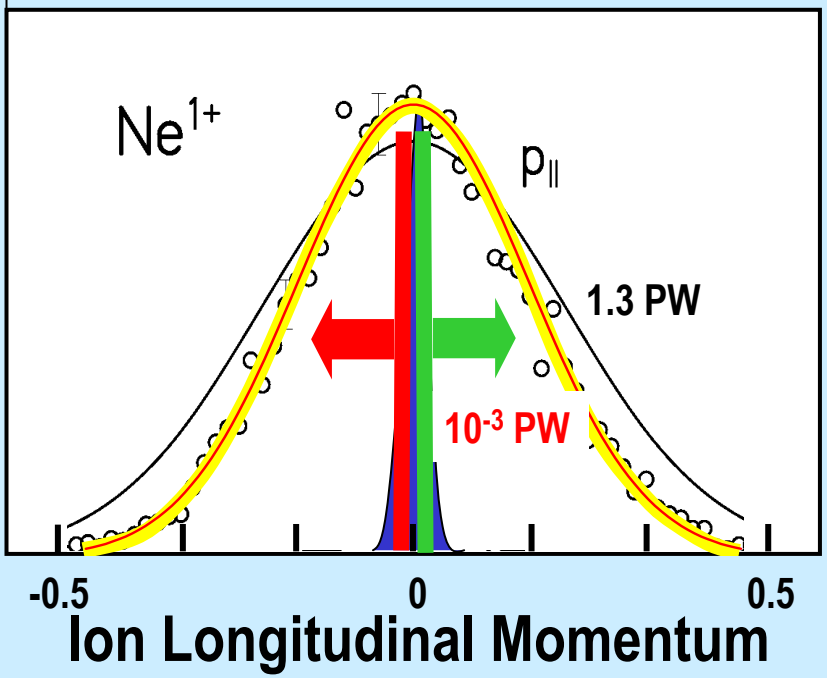
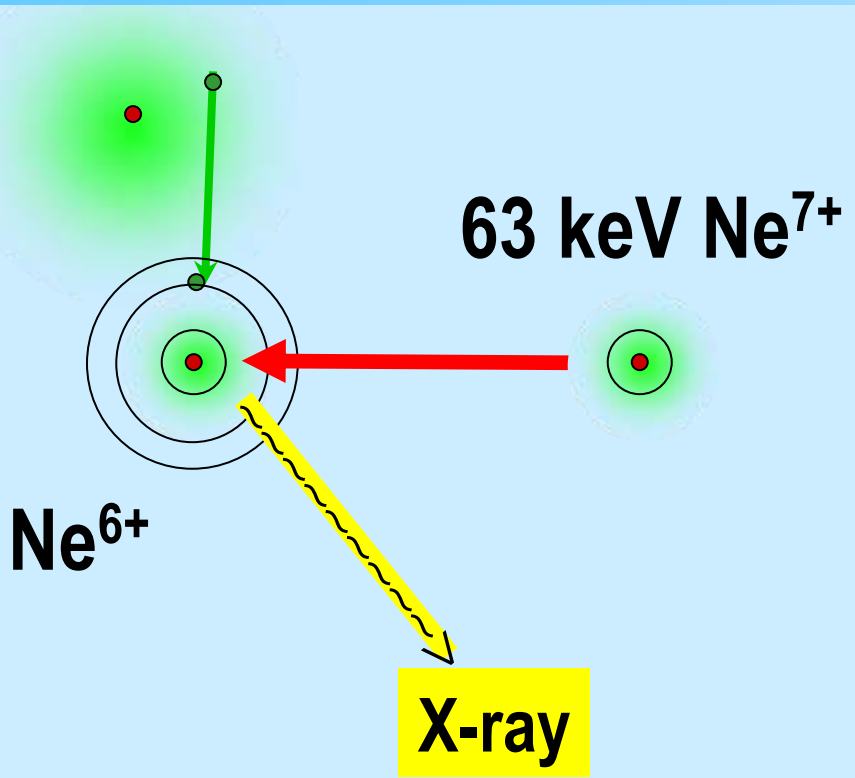




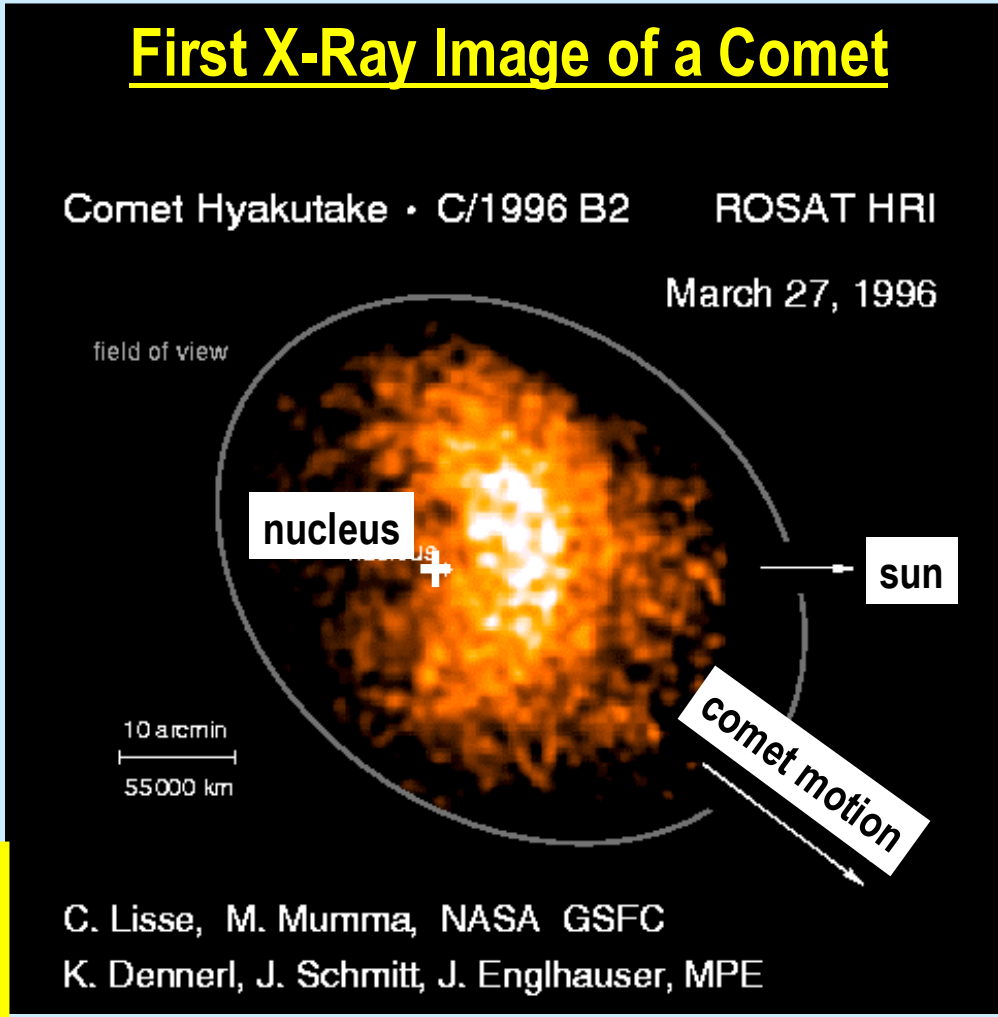


Some Useful Application



Composition of solar wind

Velocity distribution



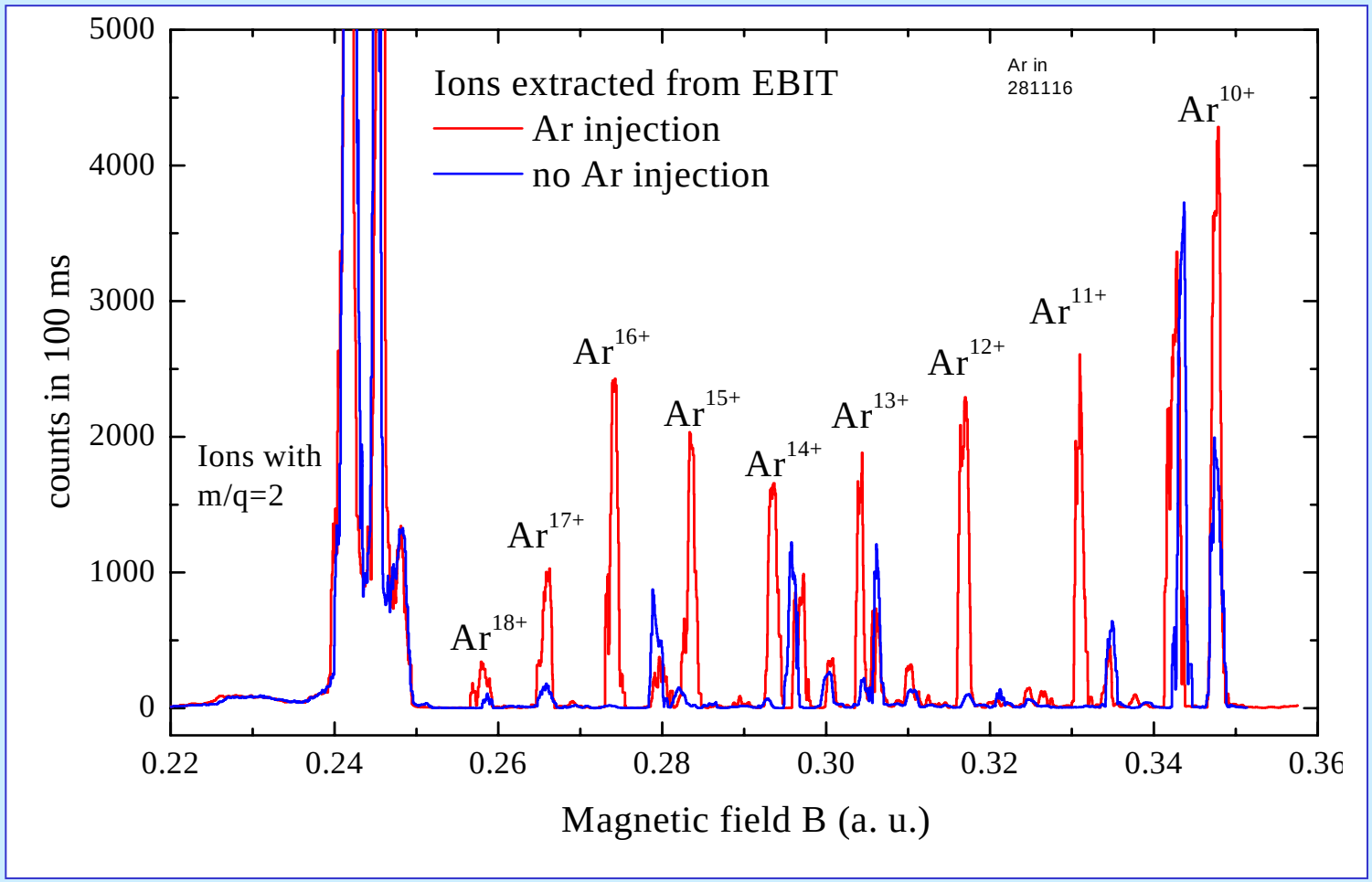
Present Status and Milestones

Extraction: **- beam-line is ready**

Present Status and Milestones

Extraction: **- beam-line is ready**

- started 2 weeks ago: Ar^{18+}

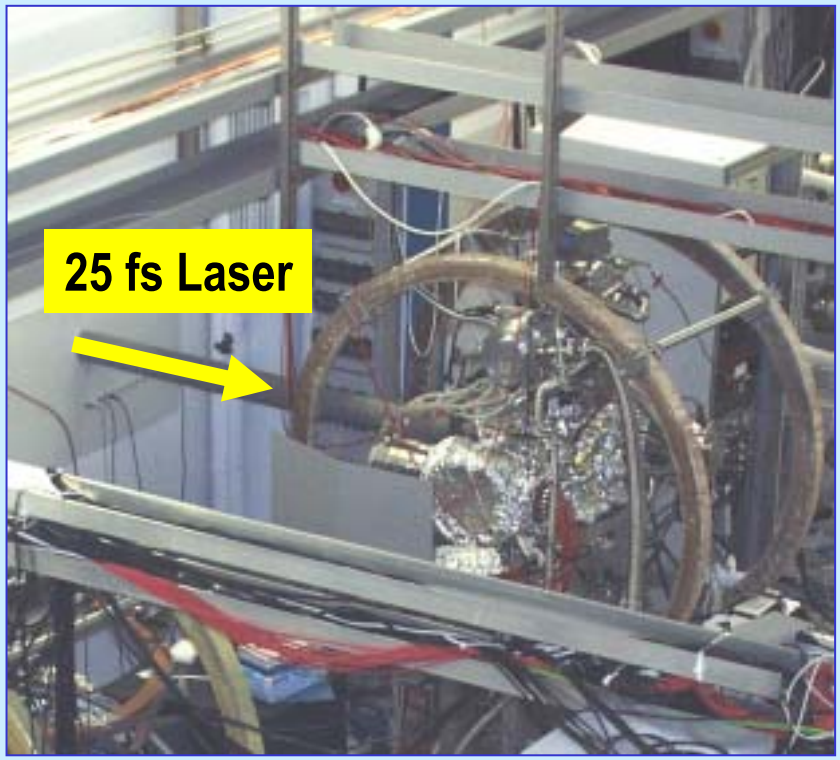


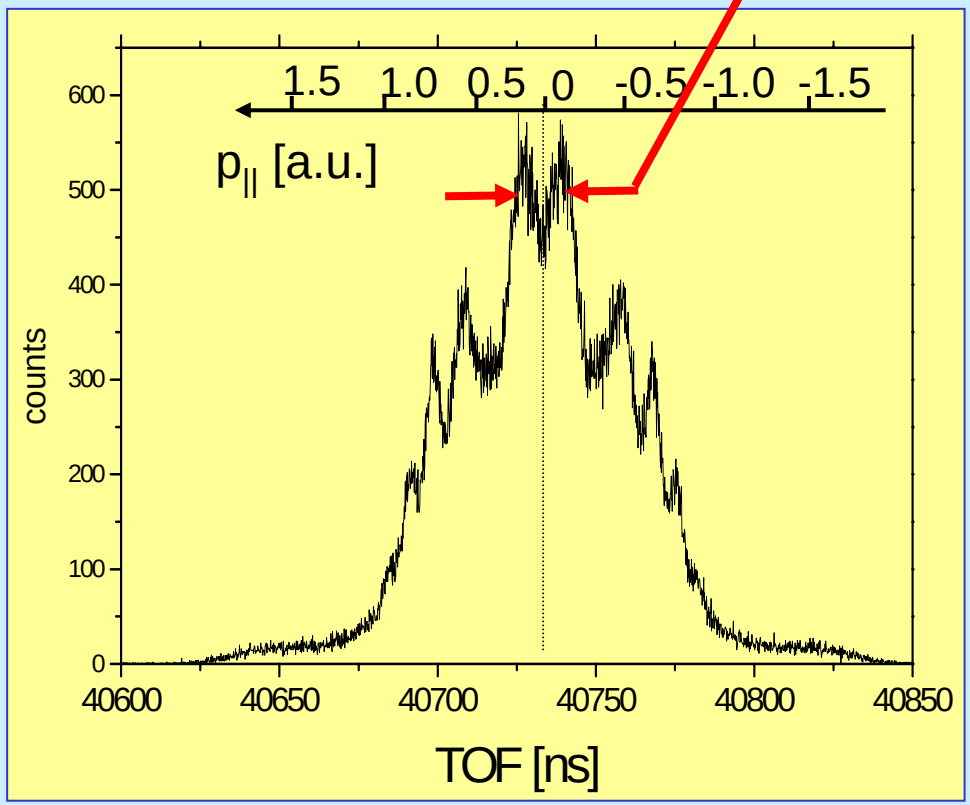
Present Status and Milestones

Extraction: - beam-line is ready

- started 2 weeks ago: Ar^{18+}

Reaction Microscope: - ready & tested: $\Delta E_R = \pm 460$ neV





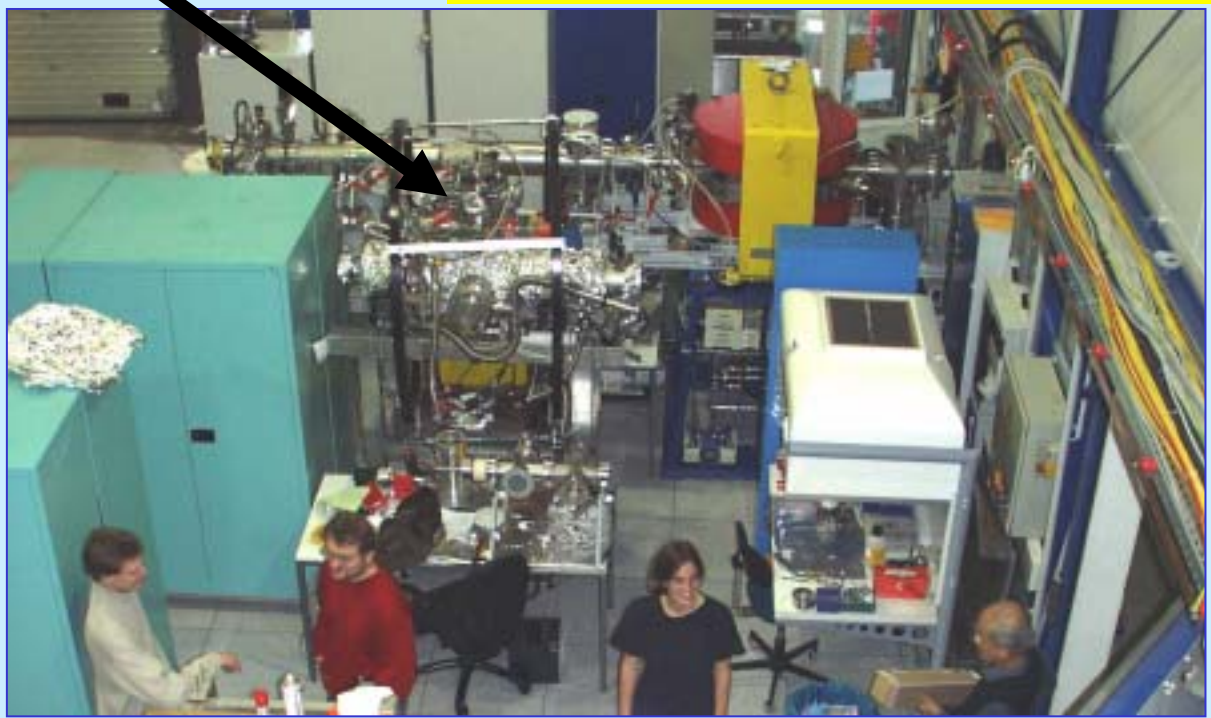
Present Status and Milestones

Extraction: - beam-line is ready

- started 2 weeks ago: Ar^{18+}

Reaction Microscope: - ready and tested

- January: moved to beam line



Present Status and Milestones

Extraction:

- beam-line is ready
- started 2 weeks ago: Ar^{18+}

Reaction Microscope:

- ready and tested
- January: moved to beam line
- projectile spectrometer: ready
- February: mounted at beam line

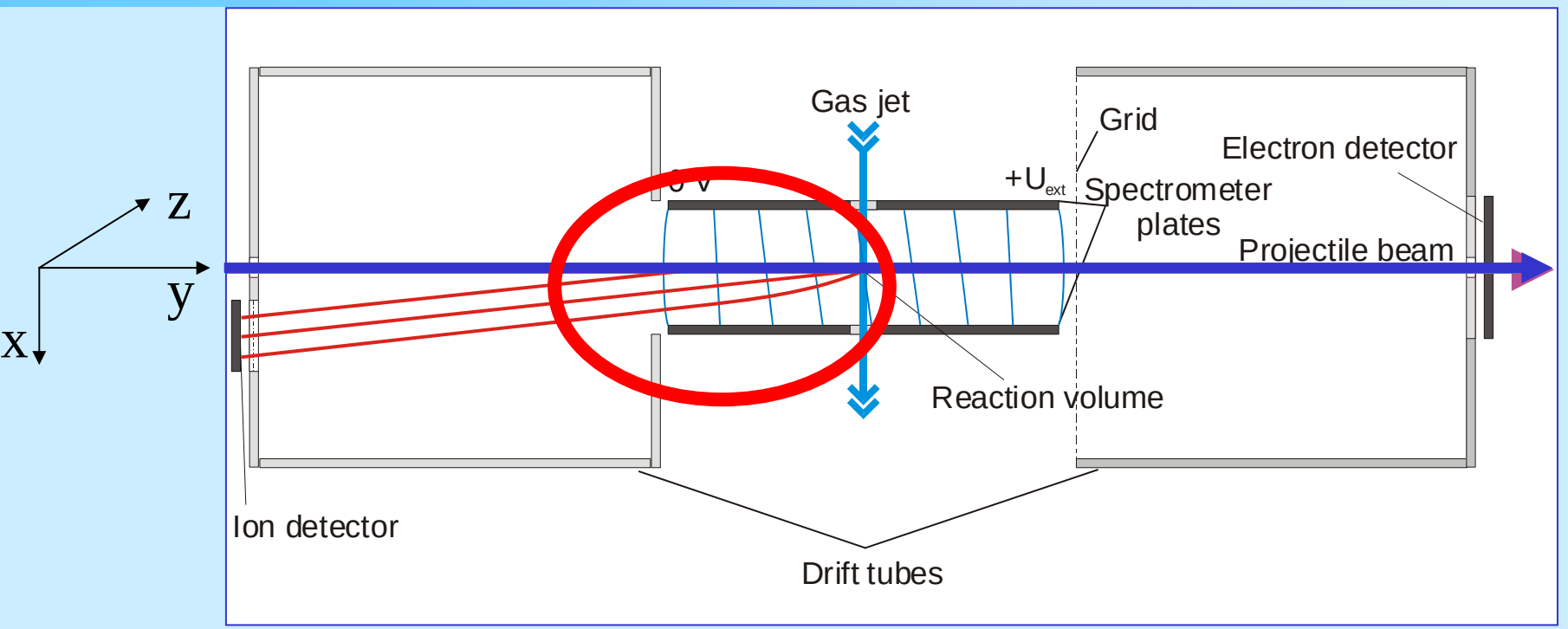
• • • • •

- start single capture experiments
- electron coincidences
- implementation of photon detect.
- Laser assisted single e^- transfer

Project Leader EBIT: J. Crespo Lopez-Urrutia

• *Spectroscopy (visible):*	*I. Draganic*	*PhD Student*
	R. Soria	*Diploma Stud.*
• *Spectroscopy (x-ray):*	*J. Braun*	*Diploma Stud.*
	H. Bruhns	*PhD Student*
• *Laser-Spectroscopy:*	*J. Crespo*	*Scientist*
• *Laser-Ion-Source:*	*M. Trinzcek*	*Postdoc*
	A. Werdich	*Diploma*
	P. Guo	*Postdoc*
• *Electron Capture:*	*D. Fischer*	*Diploma*
	Ch. Dimopoulou	*Postdoc*
	B. Feuerstein	*Postdoc*
	B. DuBois	*Guest*
	R. Moshammer	*Scientist*
• *Extraction / Beamline:*	*V. Mironov*	*Postdoc*
	H. Tawara	*Guest*
• *Dielectronic Recombination:*	*Y. Zou*	*Guest*
	A. Gonzalez	*Diploma Stud.*
Technicians:	*Müller, Busch, Bechberger*	

The HITRAP Reaction Microscope

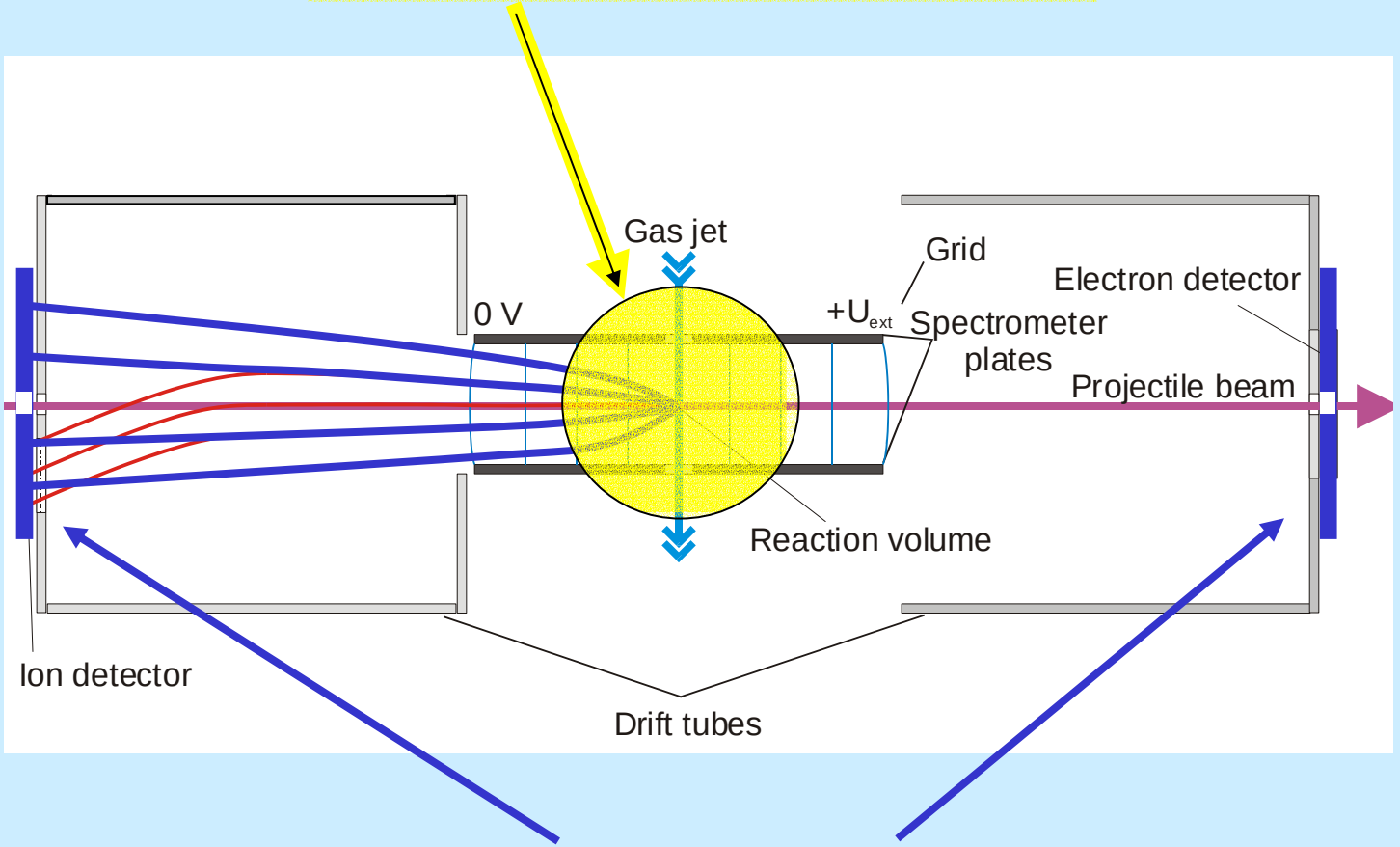


!! Remaining Problem: Electric Field !!

The HITRAP Reaction Microscope

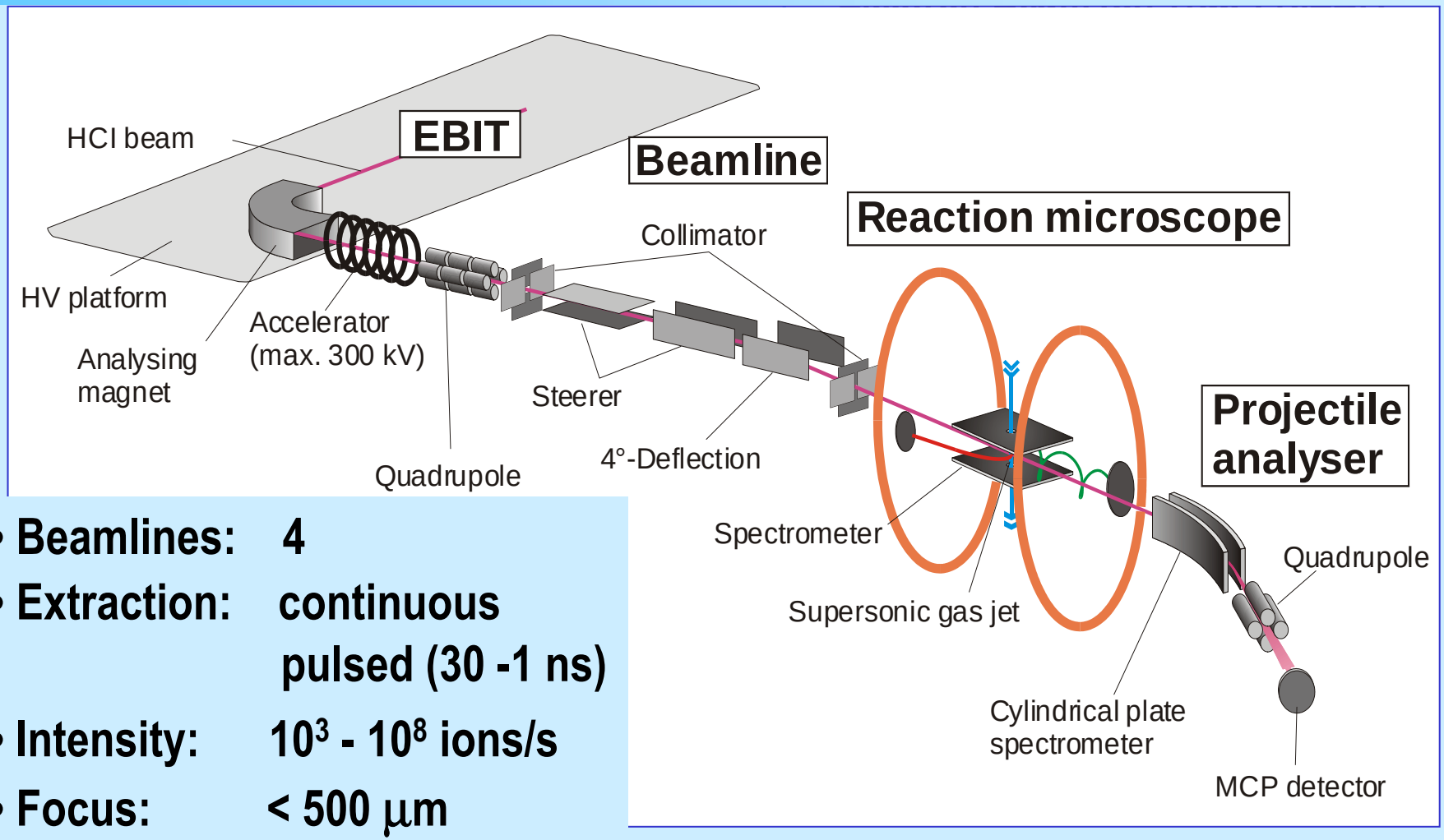
- **Optimizing the Q-Value Resolution & Acceptance**

future solution: large area photon detectors



future solution: large area (∅ 120 mm) MCPs with hole

HCIs from the Heidelberg EBIT



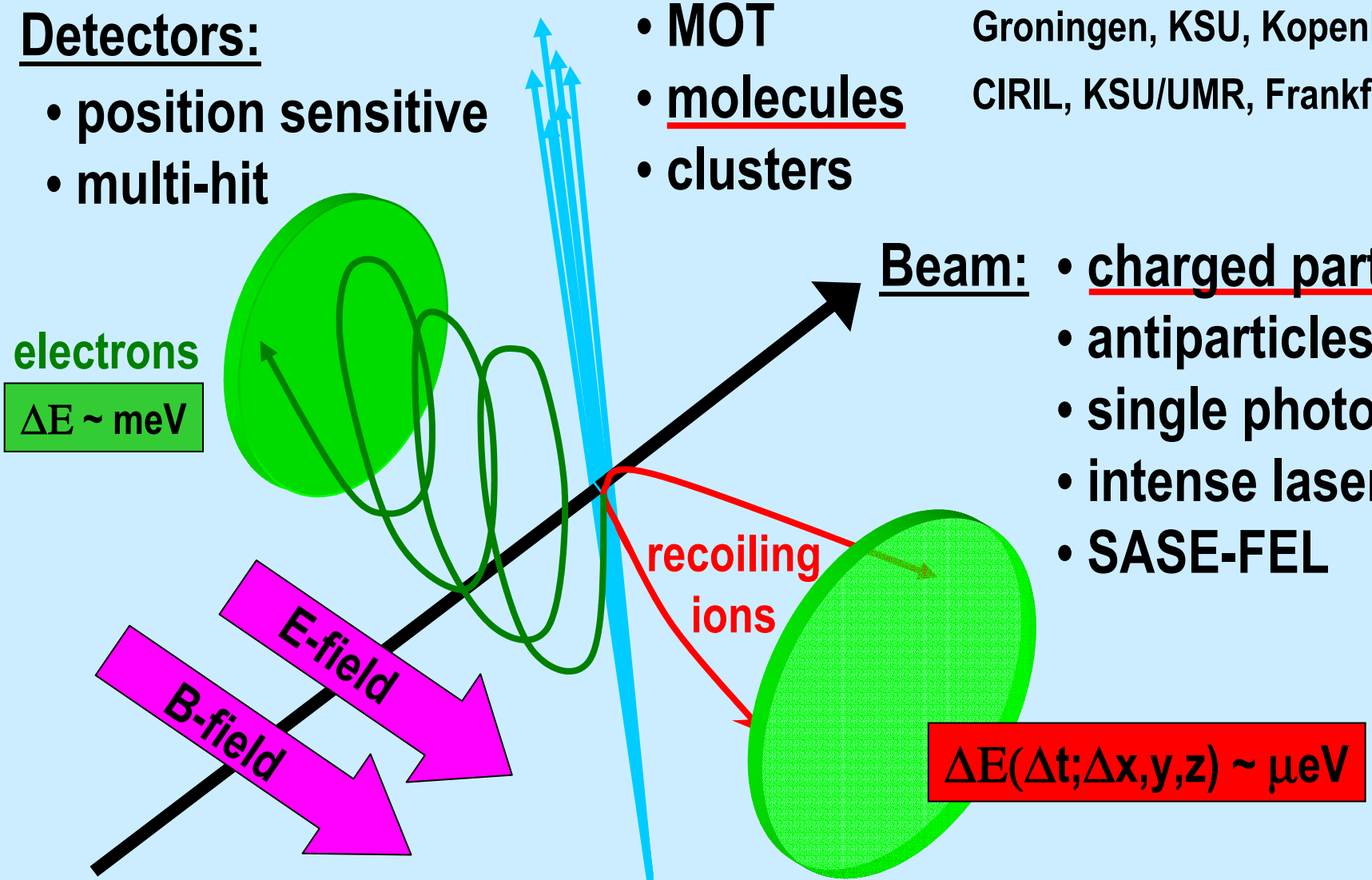
- **Beamlines: 4**
- **Extraction: continuous pulsed (30 -1 ns)**
- **Intensity: 10^3 - 10^8 ions/s**
- **Focus: < 500 μm**
- **Energies: (10-350 kV) • q**
- **Future: 2 MeV/u (RFQ injection TSR?**

Reaction Microscopes

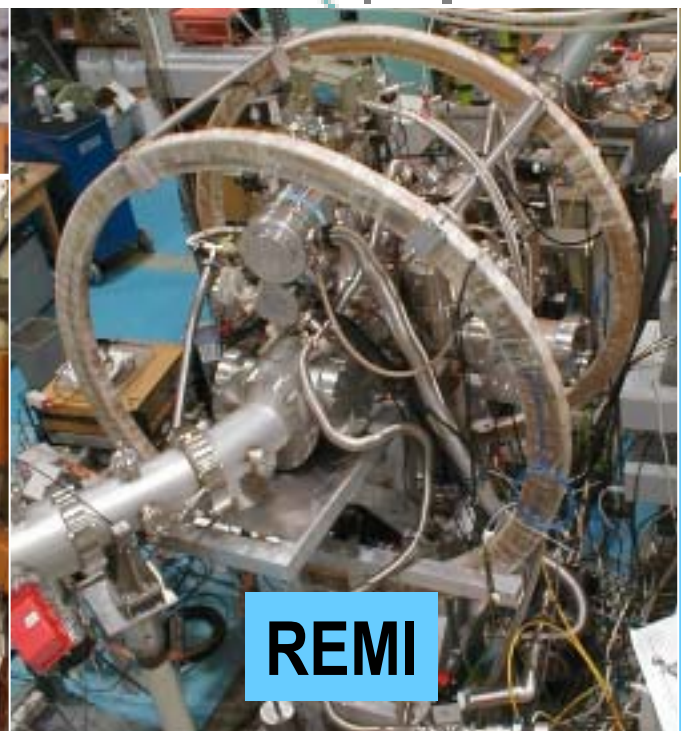
Target:
- supersonic atomic jet
- MOT — Groningen, KSU, Kopenhagen
- molecules — CIRIL, KSU/UMR, Frankfurt
- clusters

Detectors:
- position sensitive
- multi-hit

Beam:
- charged particles
- antiparticles
- single photons
- intense lasers
- SASE-FEL



Max–Planck–Institut
für Kernphysik



Highly Charged Ions:

Physics of Strong Fields