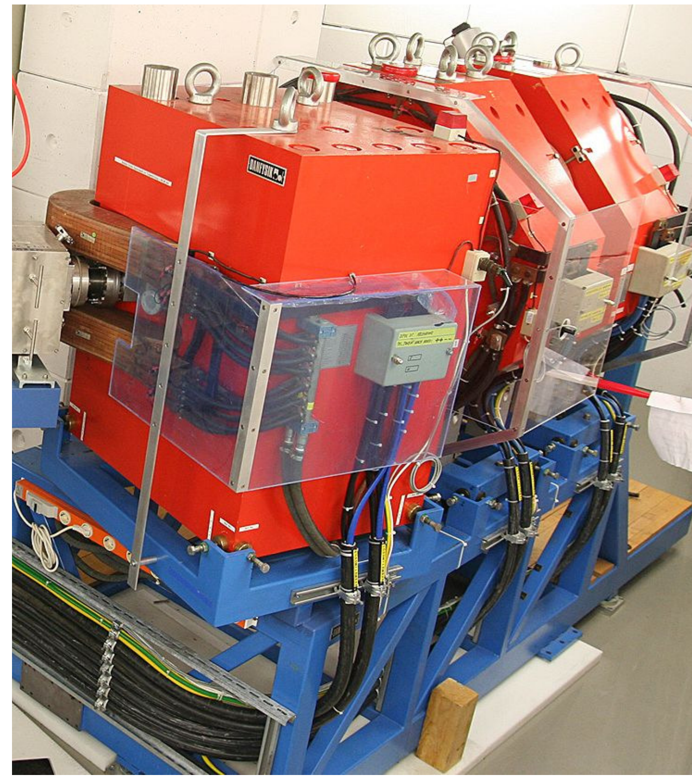
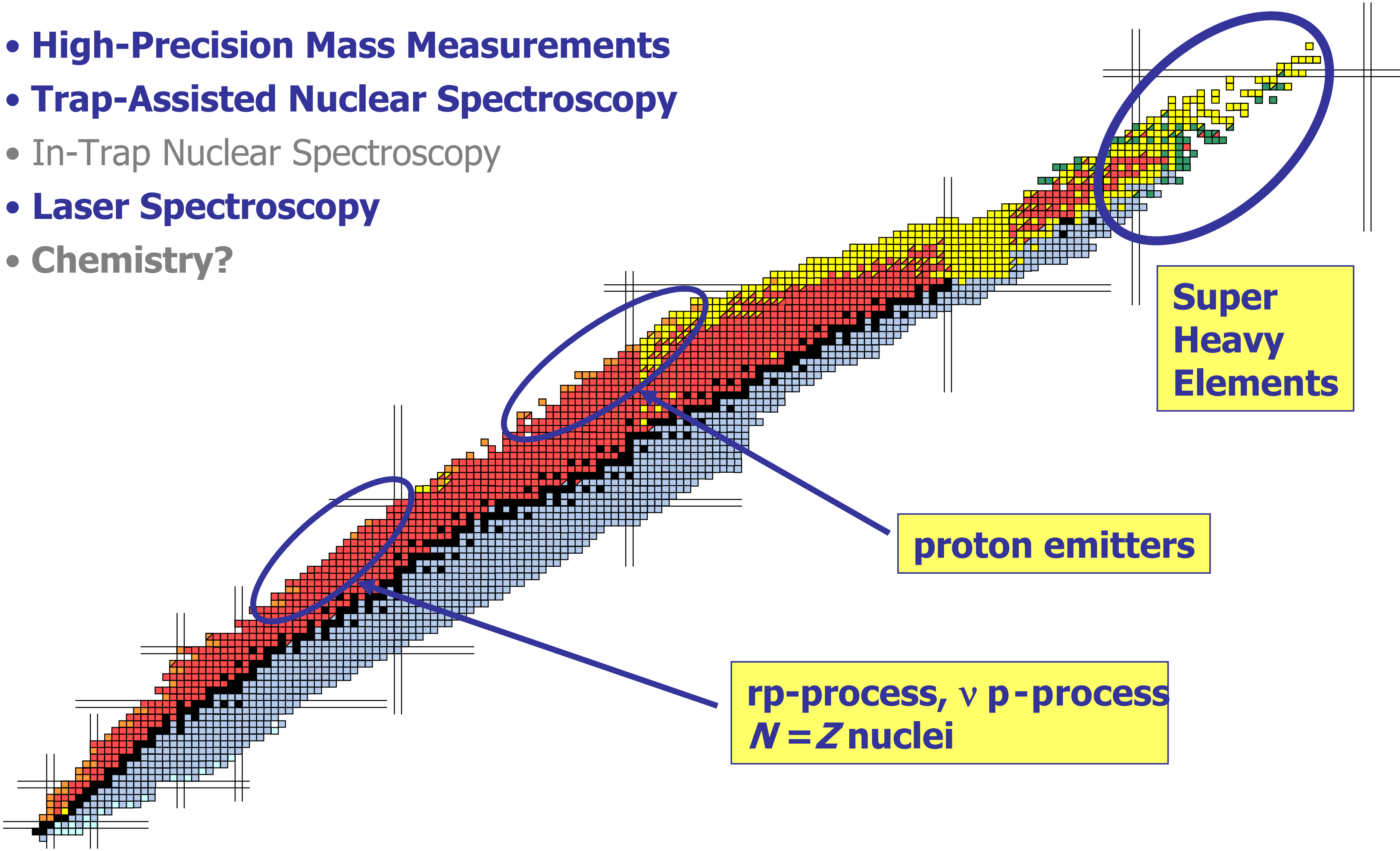
Towards
SHIPTRAP @ TASCA



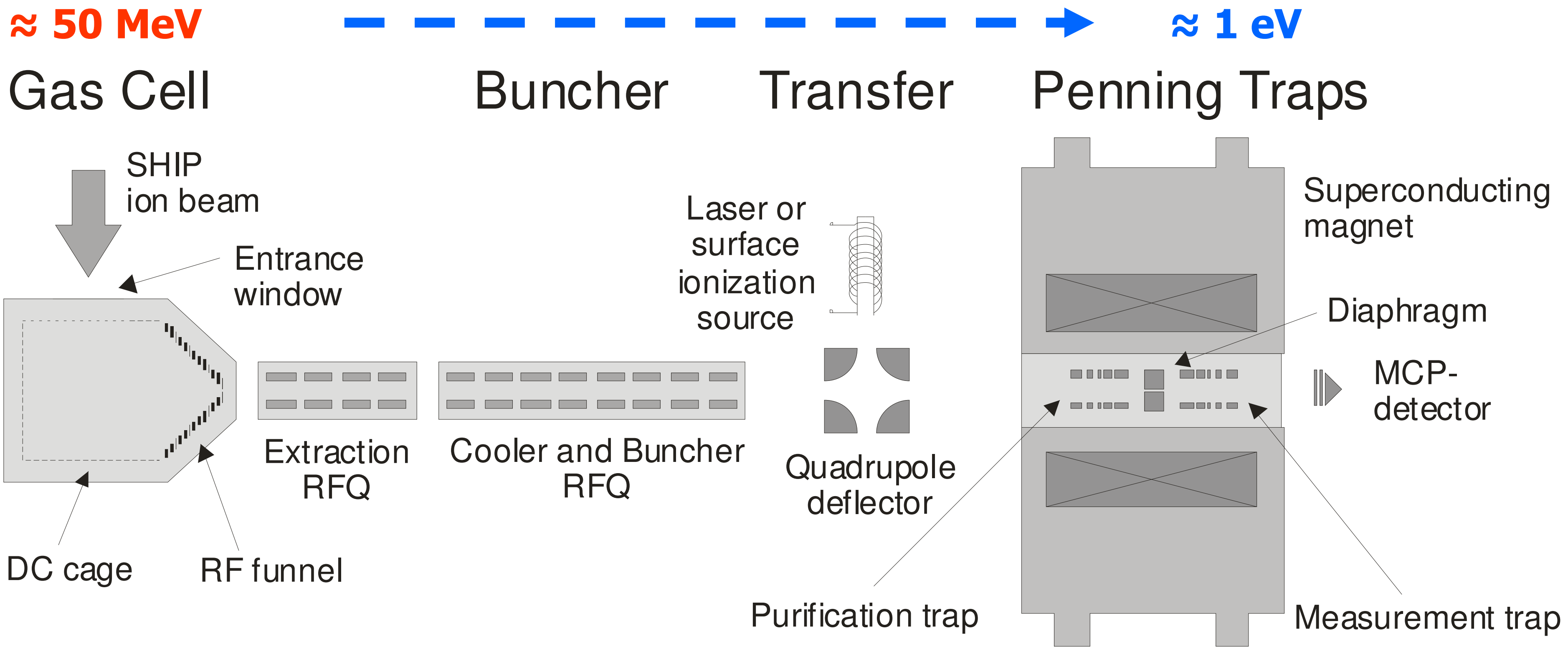
Michael Block

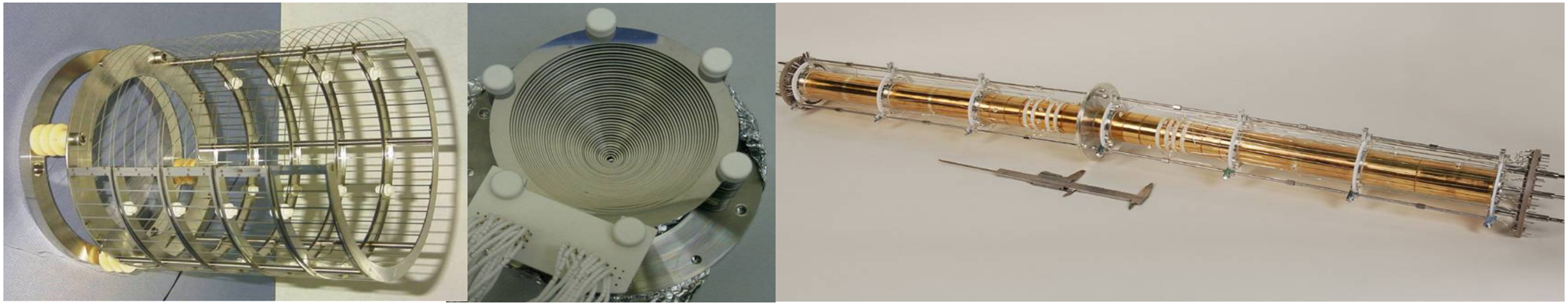
SHIPTRAP Physics Program

- **High-Precision Mass Measurements**
- **Trap-Assisted Nuclear Spectroscopy**
- In-Trap Nuclear Spectroscopy
- **Laser Spectroscopy**
- **Chemistry?**

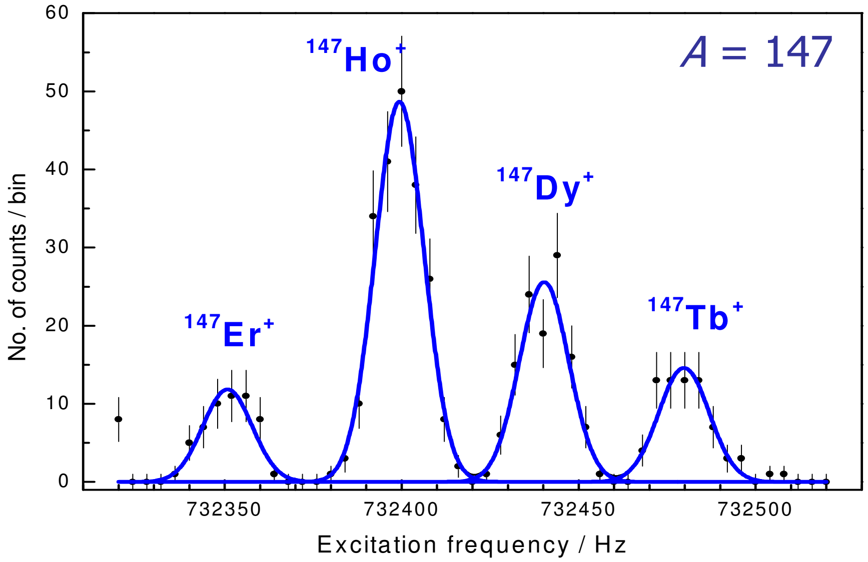


SHIPTRAP Setup



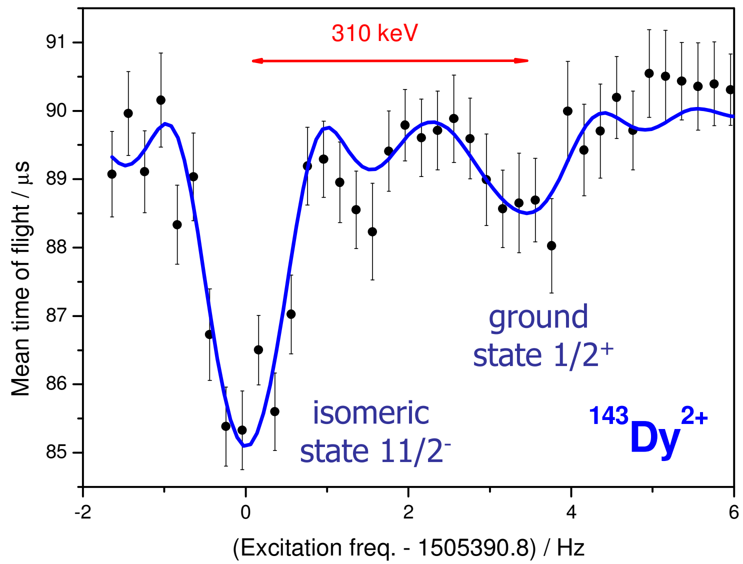


SHIPTRAP Performance



Mass resolving power of
m/ δm ≈ 100,000
in purification trap:

⇒ separation of isobars



Mass resolving power of
m/ δm ≈ 1,000,000
in measurement trap:

⇒ separation of isomers

Requirements for Mass Measurements

- high overall efficiency
- high cleanliness for low background
- stable and reliable operation over long time

Present reach of SHIPTRAP

• Half-life	> 100 ms
• Rate of trapped ions	> 0.01 / s

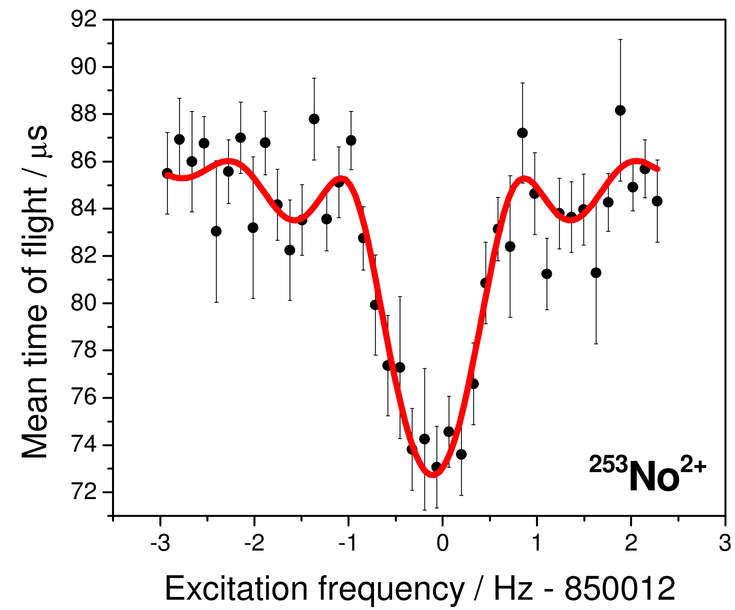
- mass measurements with 0.3 pps ($\sigma \approx$ 200 nb) demonstrated

Direct Mass Measurements of $^{252-254}$No

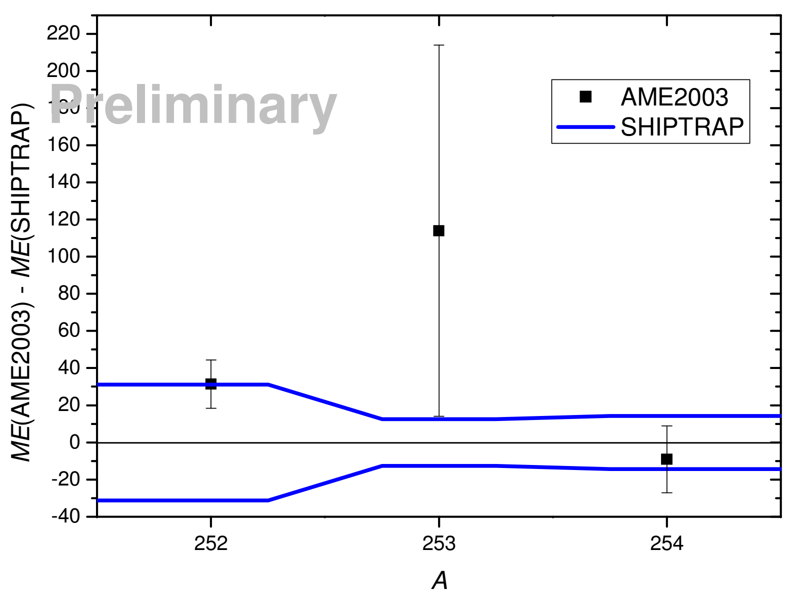
August'08:

$^{206-208}$Pb(^{48}Ca,2n)$^{252-254}$No

- doubly-charged nobelium ions extracted
- production rates ≈ 1 / s



First direct mass measurements in the region *Z* > 100



April'09:

- ^{209}Bi(^{48}Ca,2n)^{255}Lr
- rate of incoming ions of ^{255}Lr only 0.3 pps
- singly and doubly-charged ions extracted

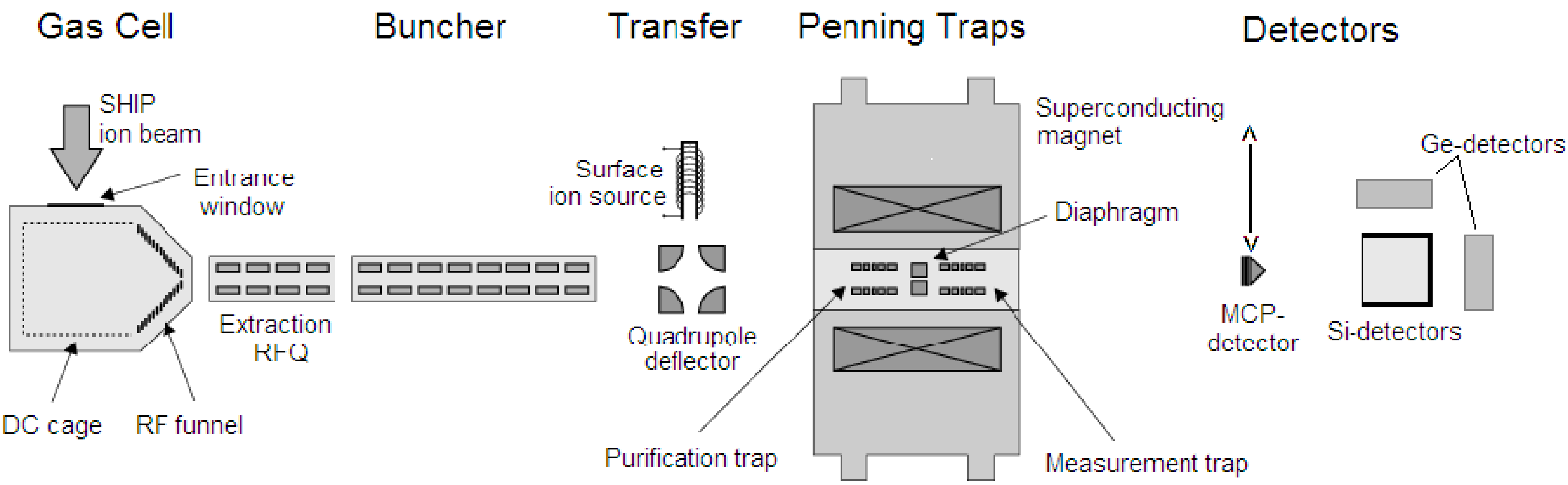
TRAPspec: Trap-assisted Spectroscopy

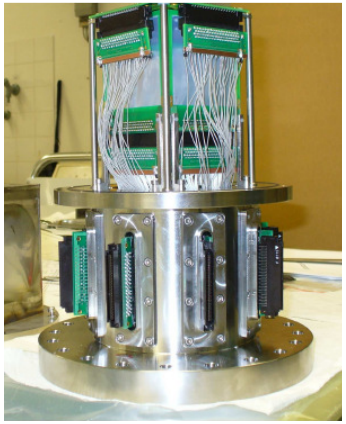
Idea: combine high mass resolving power of Penning traps with decay spectroscopy

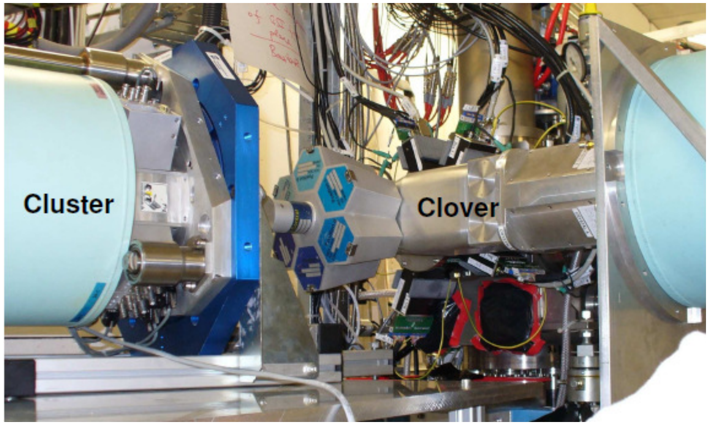
Benefits:

- only one nuclide - clean spectra
- detailed nuclear structure information in one experiment
- great potential for studies of isomers
  - isomeric beams possible

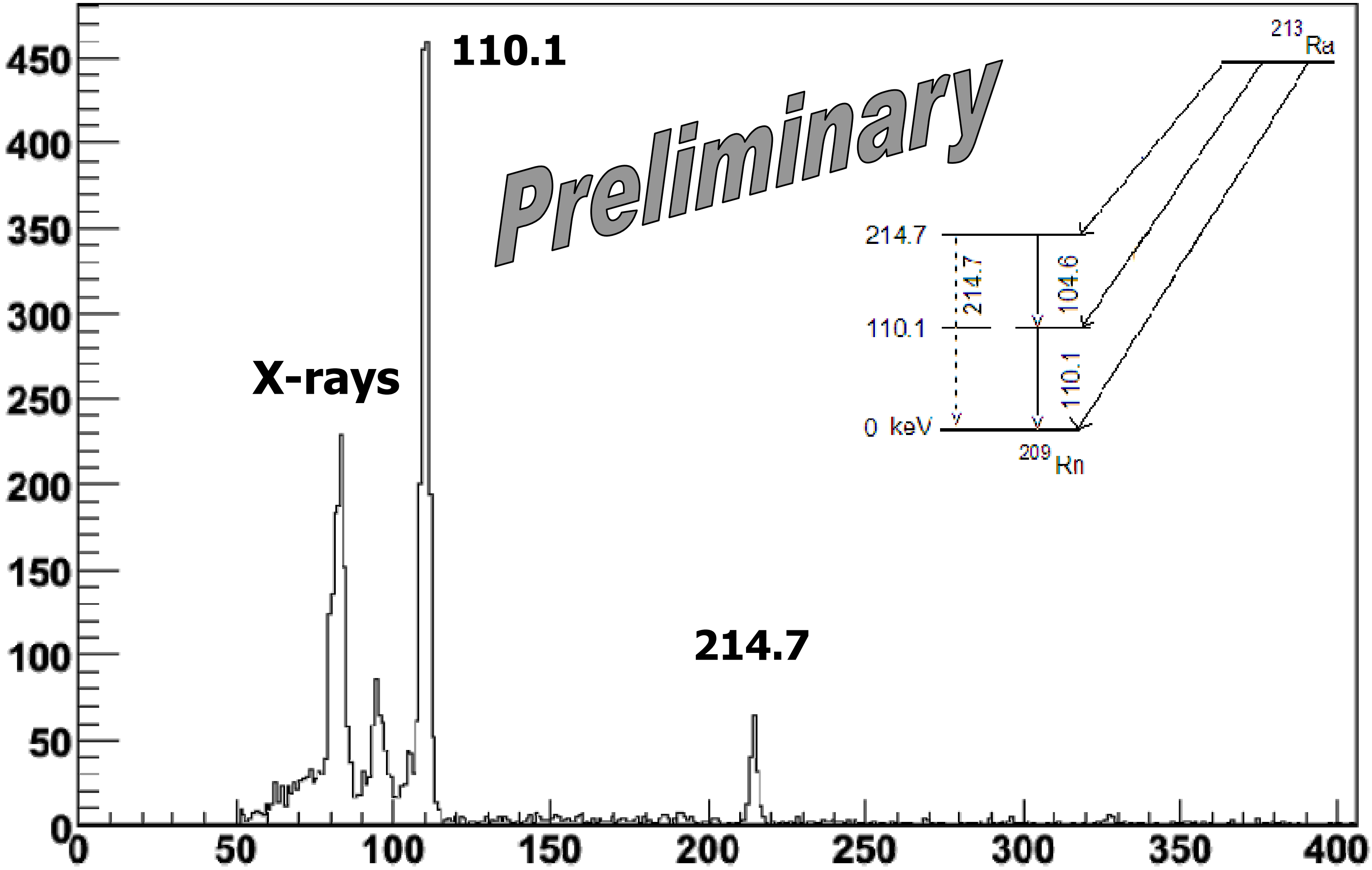
TRAPspec Setup





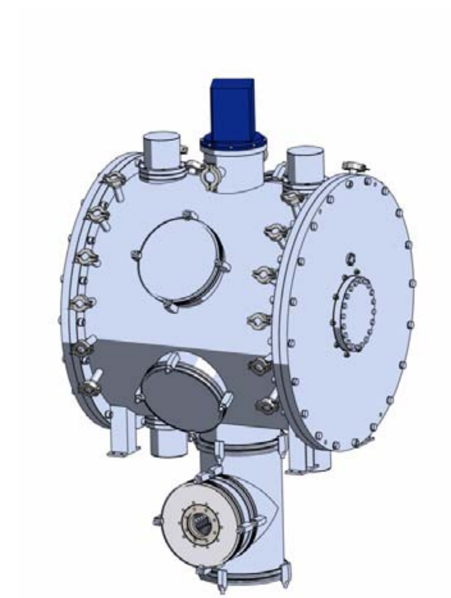


TRAPspec commissioning experiment



The Route to higher *Z*

- **improve production rates and targets**
  - cw accelerator for SHE research
- **increase sensitivity and efficiency**
  - non-destructive detection system with single-ion sensitivity
  - cryogenic gas stopper for high cleanliness and higher efficiency
- **extend reach to more neutron-rich nuclides**
  - hot-fusion reactions with actinide targets
  - connection to gas-filled separator TASCA



Penning trap mass spectrometry

Mass via cyclotron frequency measurement

$$\nu_C = \frac{1}{2\pi}\frac{qB}{m}$$

reference ion to calibrate magnetic field

$$\nu_{ref} = \frac{1}{2\pi}\frac{q_{ref}\cdot B}{m_{ref}}$$

Primary experimental Result: frequency ratio

$$\frac{\nu_{\mathrm{Re}\,f}}{\nu_C} = \frac{m}{m_{ref}}$$

$\Rightarrow$ Atomic mass

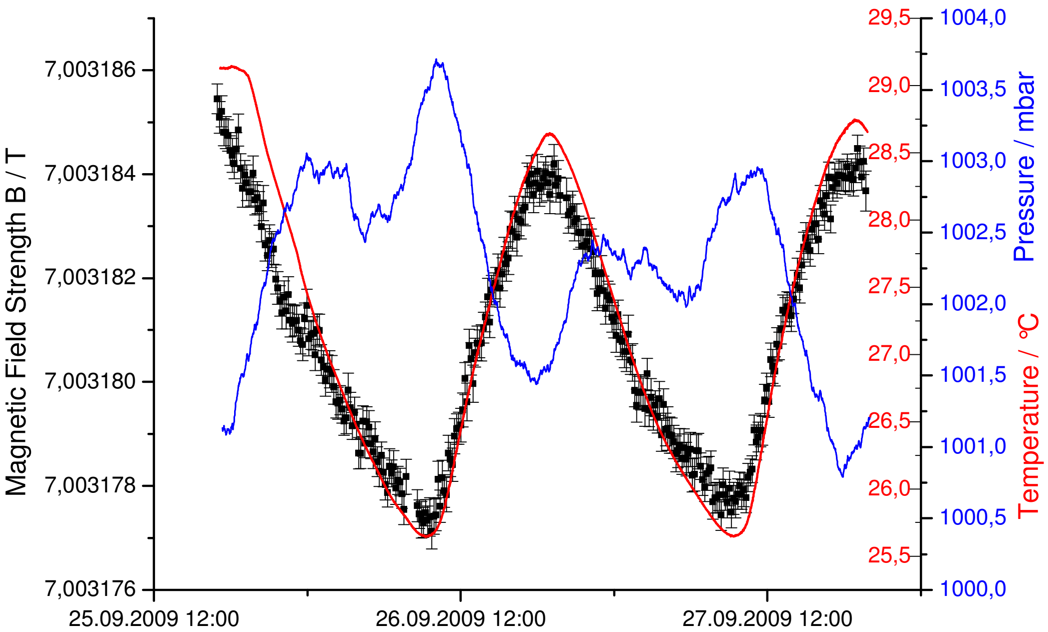
$$m = \frac{q}{q_{ref}}\left(m_{ref} - q_{ref}\cdot m_e\right)\frac{\nu_{ref}}{\nu_c} + q\cdot m_e$$

Limitations for Mass Measurements

• with present technique about 100 ions have to be detected

→ several hours measurement time for low production rates

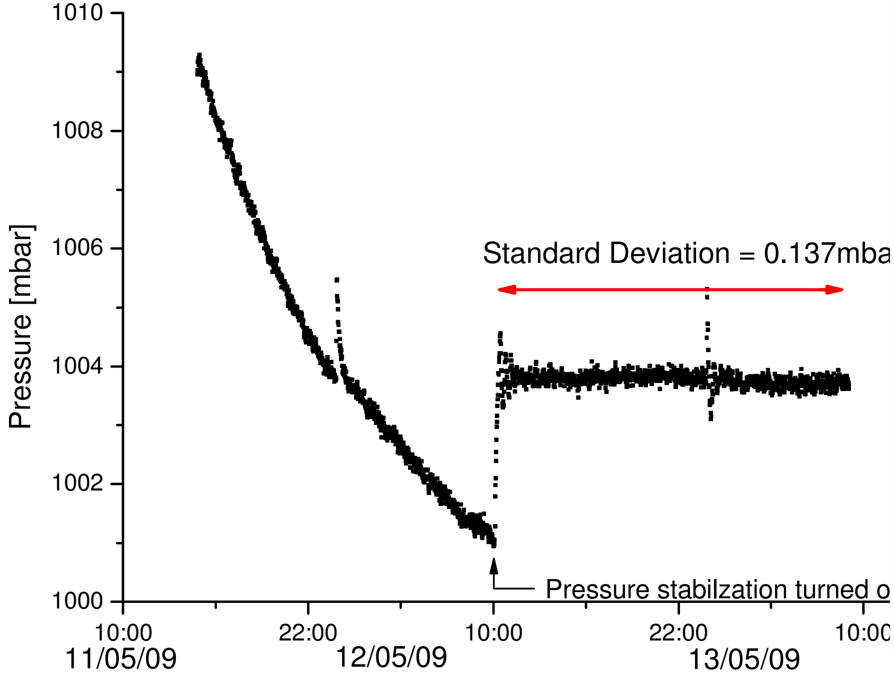
• measurement time limited by temporal magnetic field fluctuations



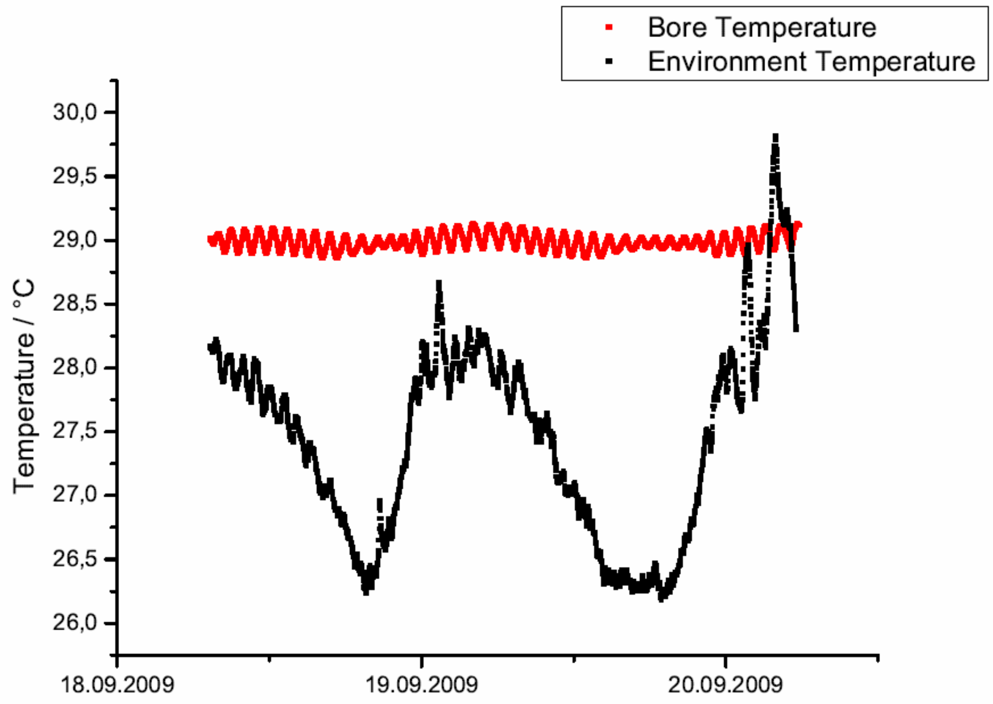
Diplomarbeit C. Droese

Improvements for Rare Isotopes

Stabilize pressure in LHe cryostat



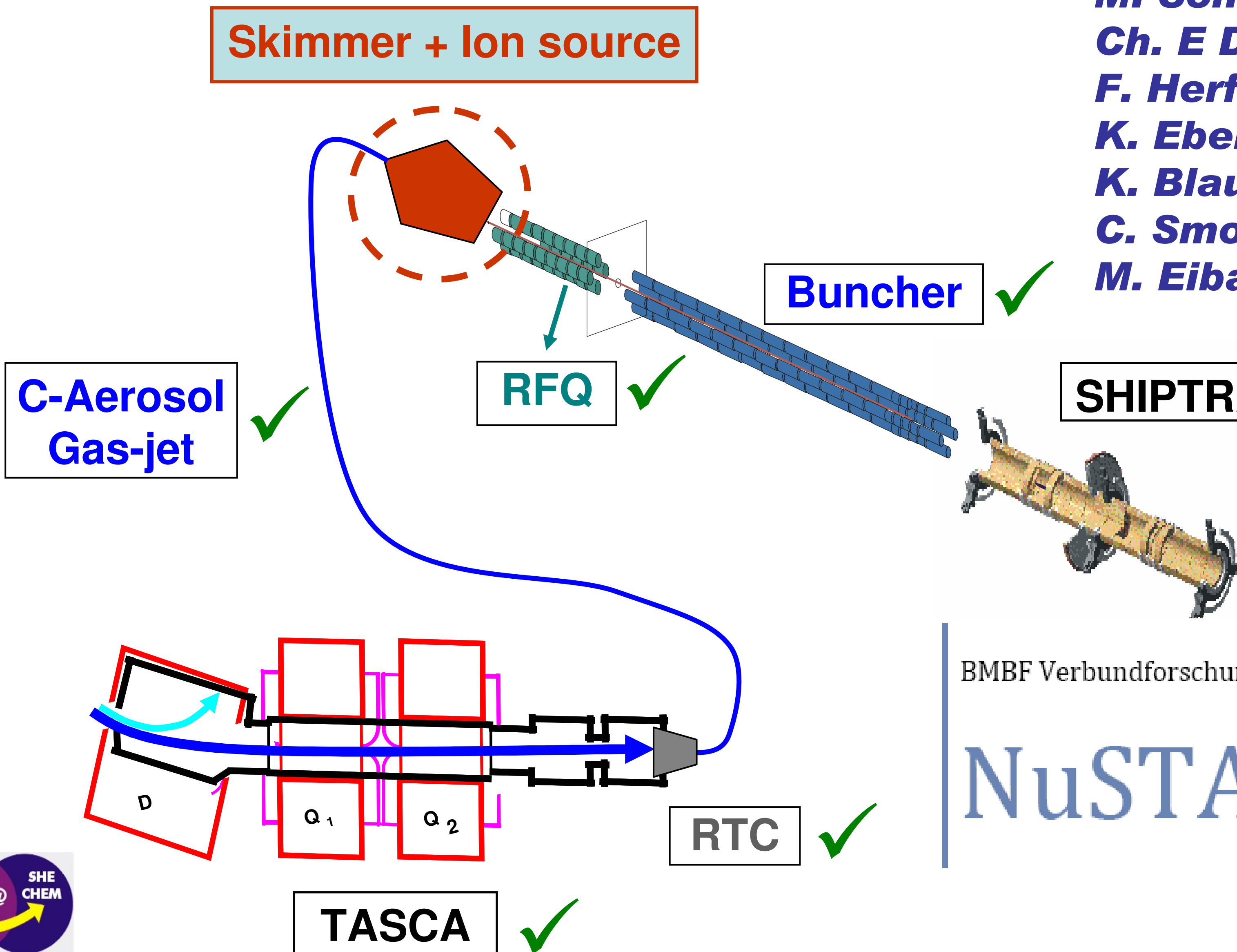
Stabilize temperature in bore



Diplomarbeit C. Droese

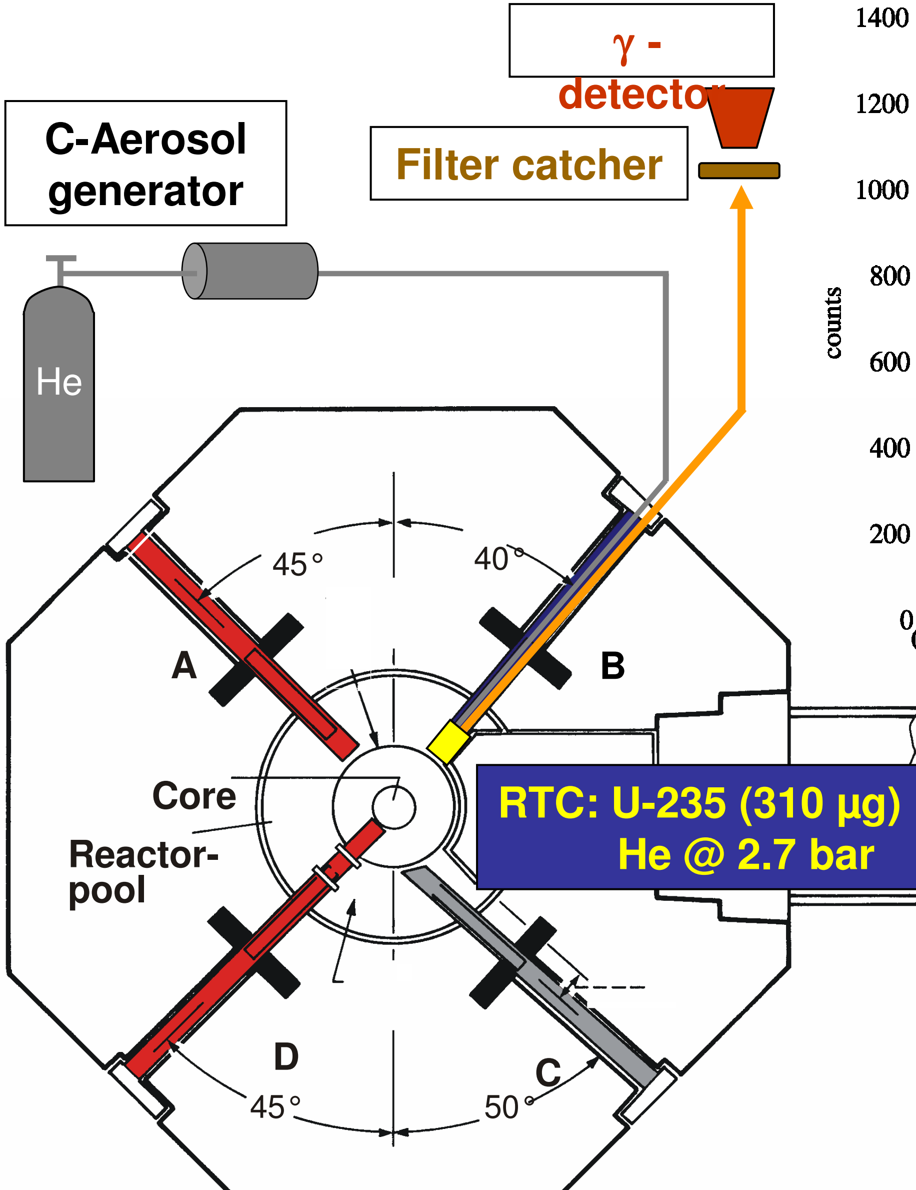
Coupling of TASCA and SHIPTRAP

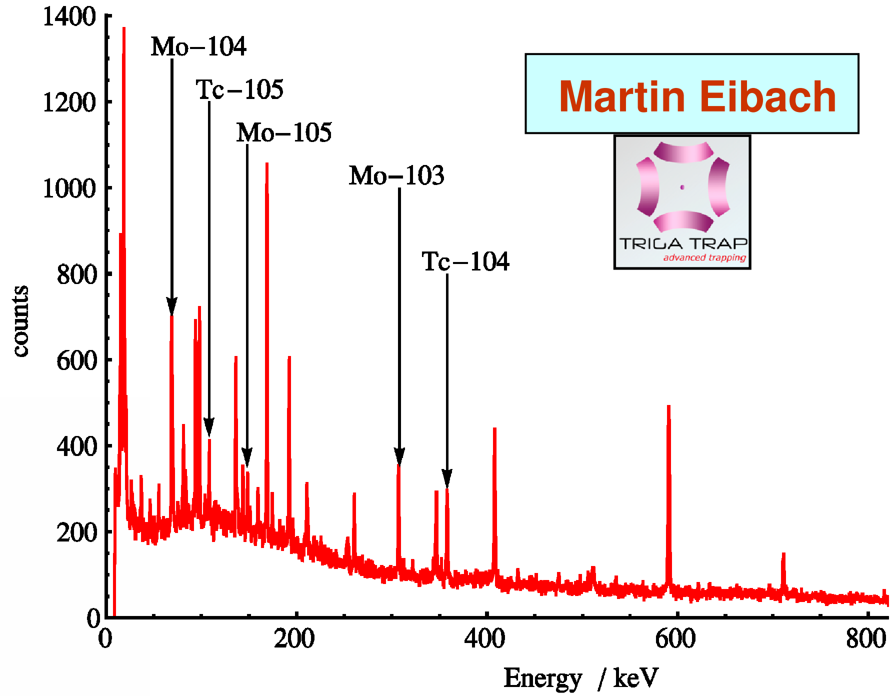
M. Schaedel
Ch. E Duellmann
F. Herfurth
K. Eberhardt
K. Blaum
C. Smorra
M. Eibach



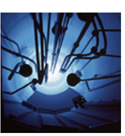
BMBF Verbundforschung
NuSTAR.de

Gas-jet with Carbon-Aerosols at the TRIGA Mainz





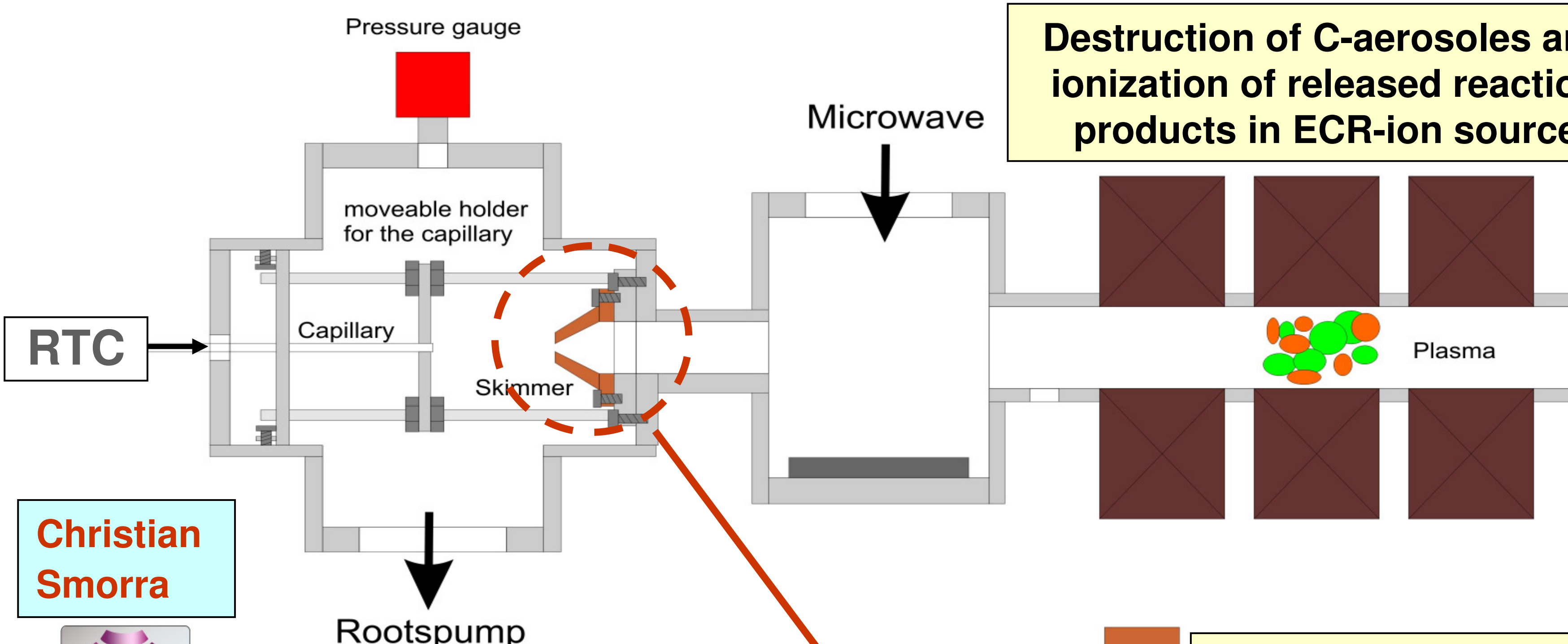
Martin Eibach



Coupling of TASCA and SHIPTRAP: Ion Source (I)

High-pressure ECR source ⇒ currently developed at TRIGA Mainz

Destruction of C-aerosoles and ionization of released reaction products in ECR-ion source

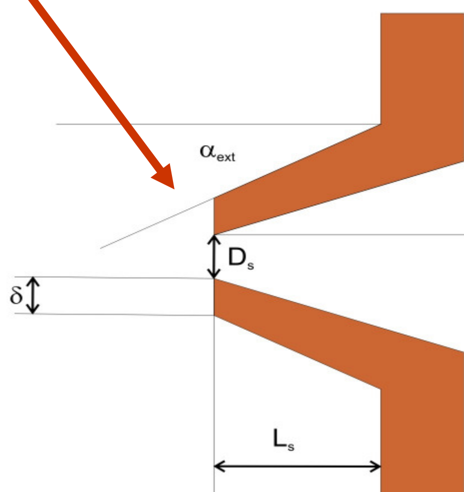


Christian Smorra

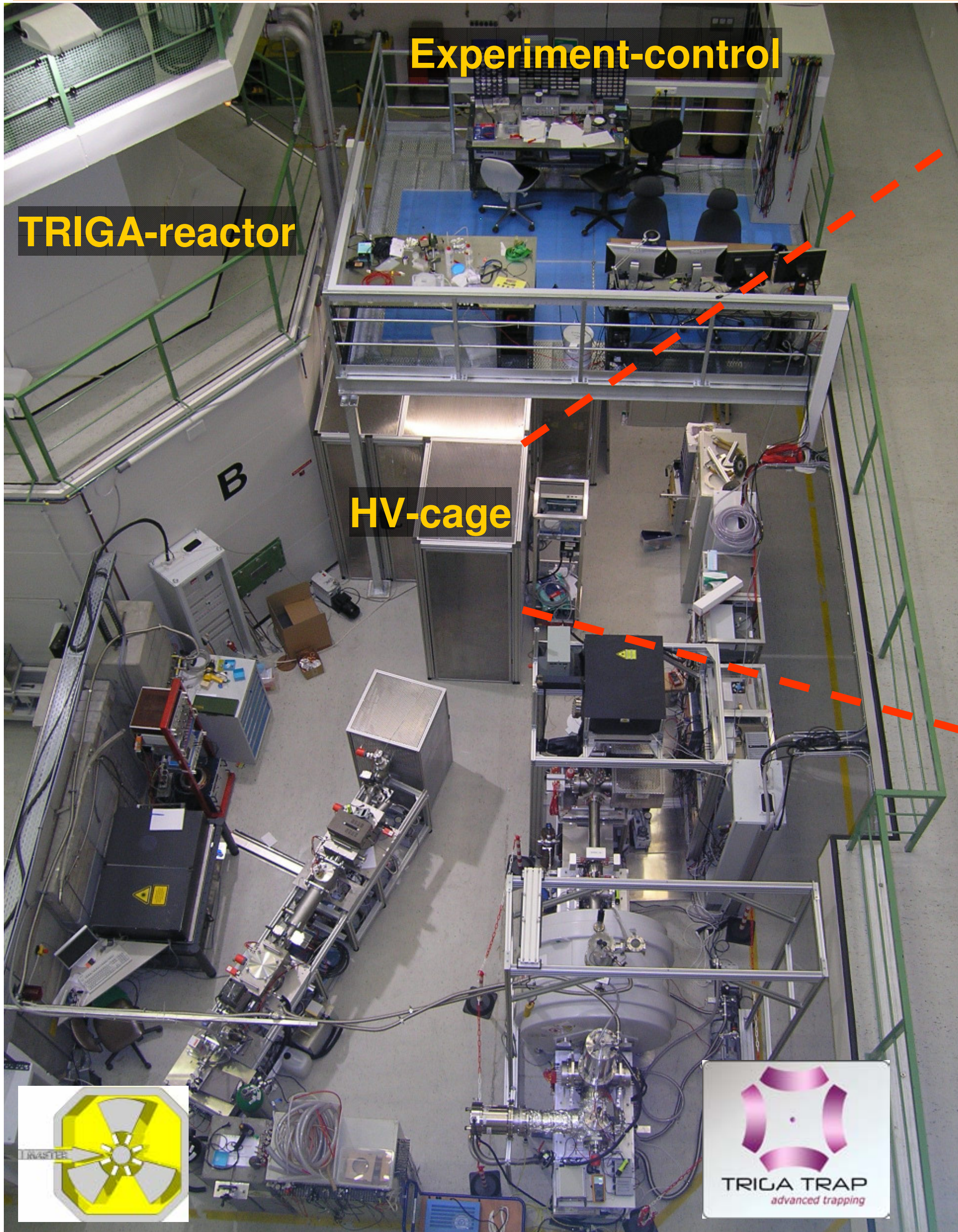
Separation of aerosol from transport gas with skimmer

skimmer parameters:

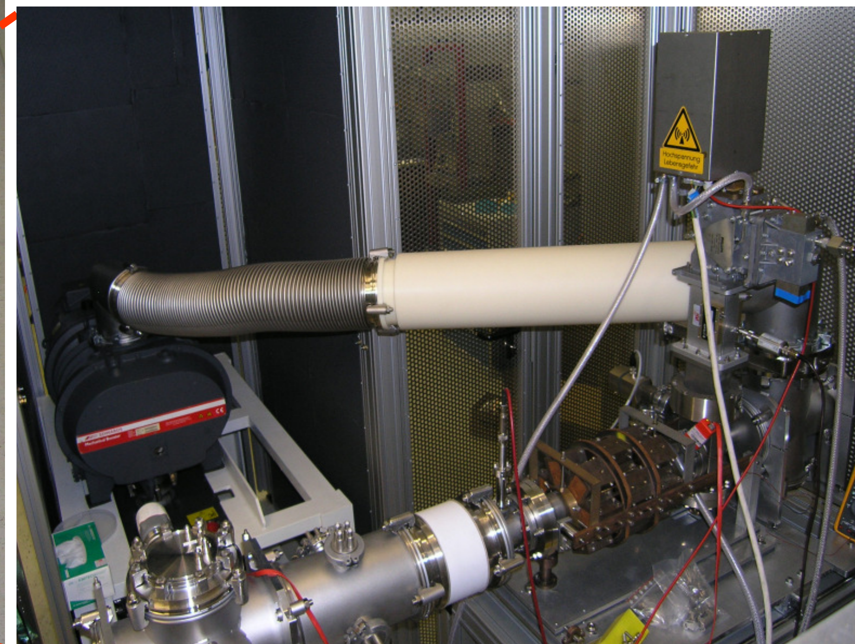
δ = 2 µm (as small as possible)
α_{int} = 45°
α_{ext} = 55°
L_s = 20 mm
D_s = ???



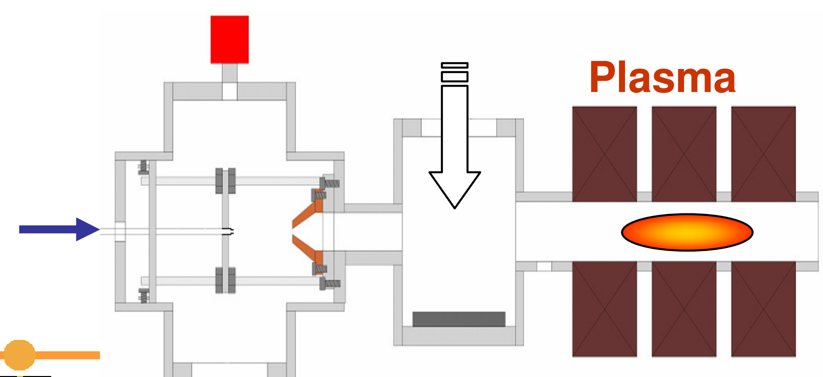
TRIGA-SPEC Experiment



Skimmer-Ionensource-unit at 60 kV

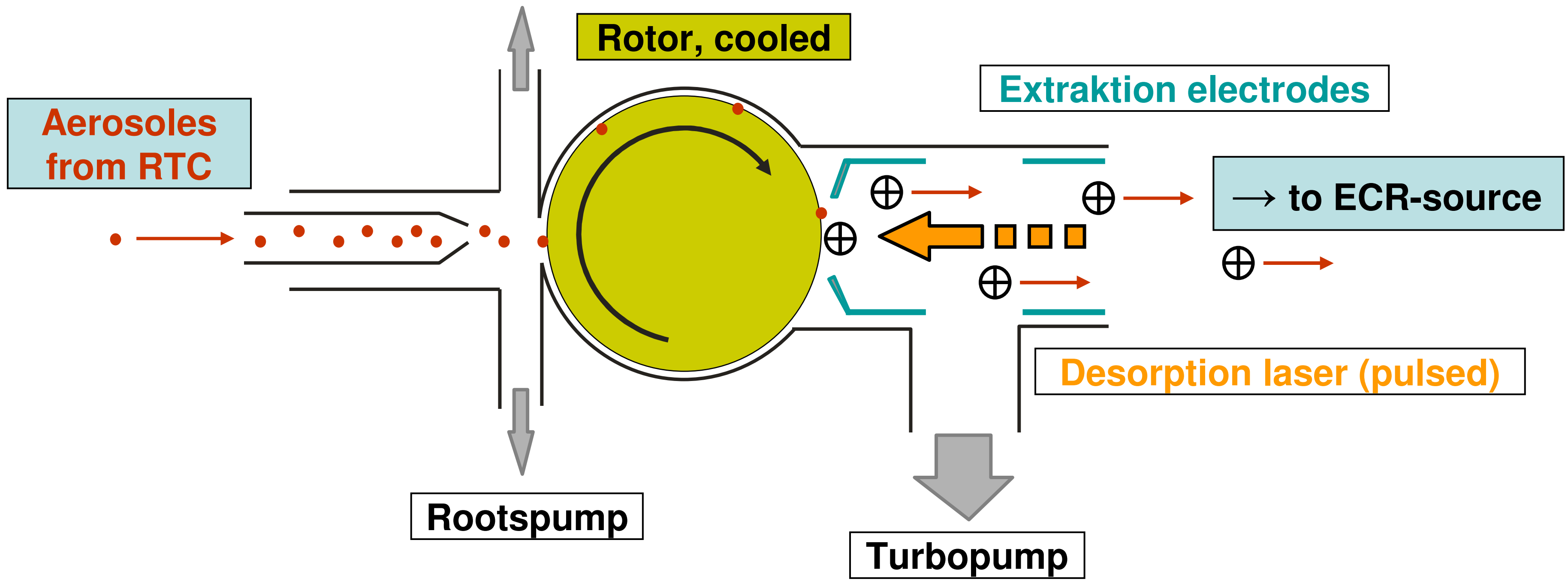


Skimmer MW-inlet ECR-magnet



Coupling of TASCA and SHIPTRAP: Ion Source (II)

Alternative approach ⇒Laser ablation



BEARS-Projekt (LBNL): Powell et al., NIM A455 (2000) 452

Summary and Outlook

- first direct mass measurements of nobelium isotopes performed
- high-precision mass measurements of stopped rare isotopes with production rates of only 0.1 per second demonstrated
- trap-assisted decay spectroscopy successfully established at SHIPTRAP
- synergy with TRIGA-SPEC project for gas jet
- connection to TASCA will widen the range of accessible nuclides

Thank you for your attention !

Collaborators

C. Breitenfeldt, D. Ackermann, K. Blaum, C. Droese, M. Dworschak, S. Eliseev, E. Haettner, F. Herfurth, F. P. Heßberger, S. Hofmann, J. Ketter, J. Ketelaer, H.-J. Kluge, G. Marx, M. Mazzocco, D. Nesterenko, Yu. Novikov, W. R. Plaß, A. Popeko, D. Rodríguez, C. Scheidenberger, L. Schweikhard, S. Stolze, P. Thirolf, G. Vorobjev, C. Weber

For TRAPspec:

D. Rudolph, L. Anderson, U. Forsberg, R. Hoischen, H. Schaffner, I. Kojouharov, …

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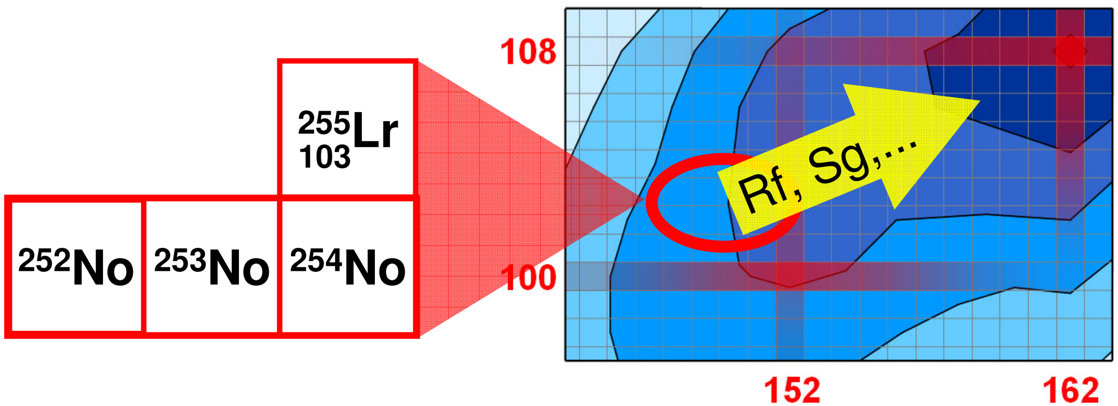
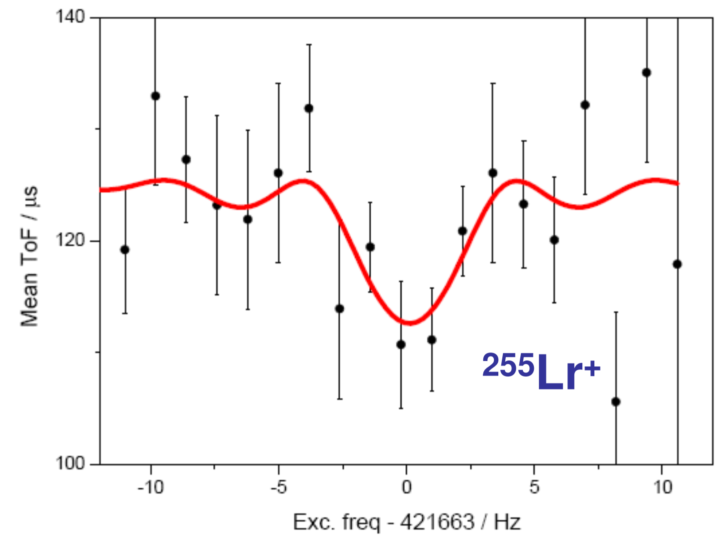
Connecting SHIPTRAP to TASCA

- high transmission for asymmetric reactions
- actinide targets available
- highest separation not crucial
- long-lived chemistry isotopes suitable for SHIPTRAP
- gas jet transport routinely used

Entering the Gateway to the Transactindes

Extend direct mass measurements to higher Z



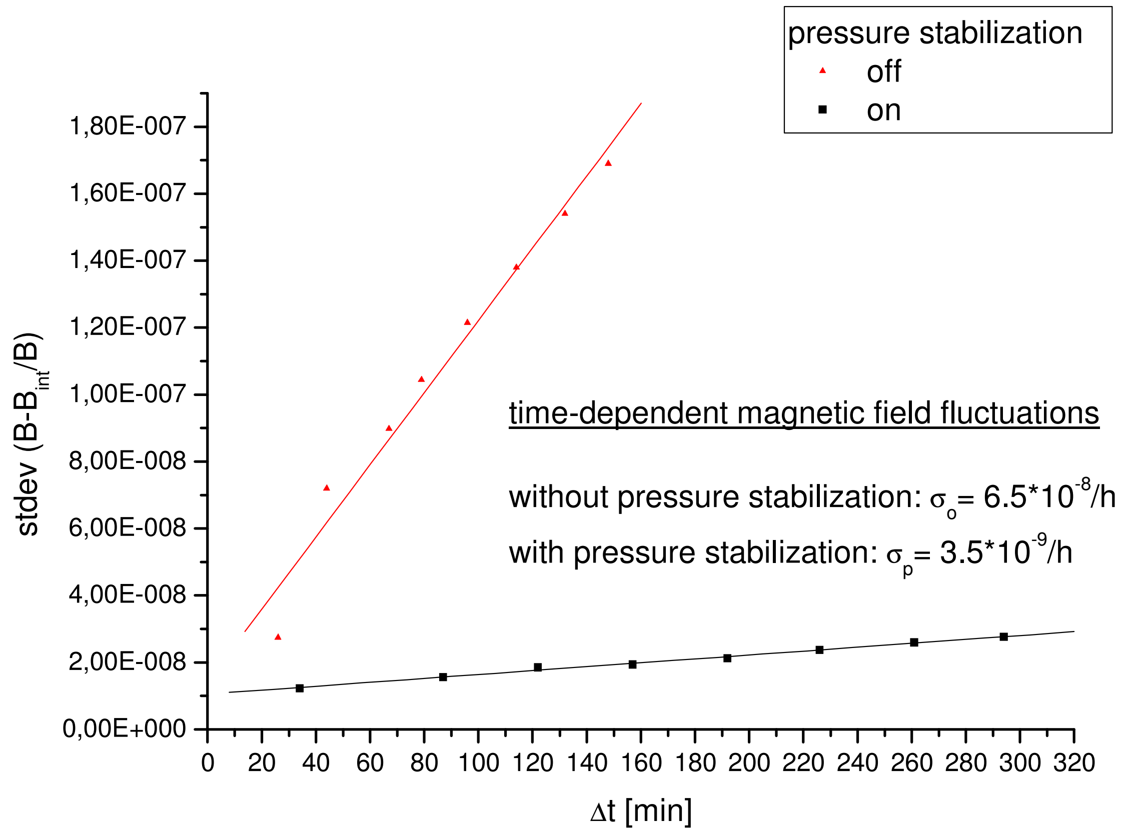


April'09:

- $^{209}Bi(^{48}Ca,2n)^{255}Lr$
- rate of incoming particles for ^{255}Lr only 0.3 ions/s
- singly and doubly-charged ions extracted

^{255}Lr nuclide with lowest rate ever measured in a Penning trap

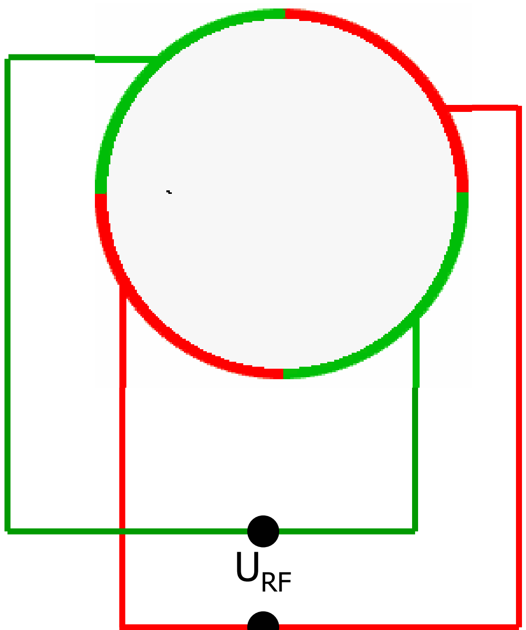
Long time Measurements



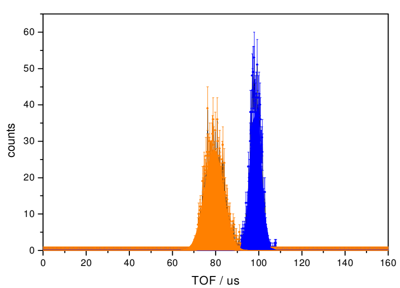
Diplomarbeit C. Droese

Cyclotron Frequency Measurement

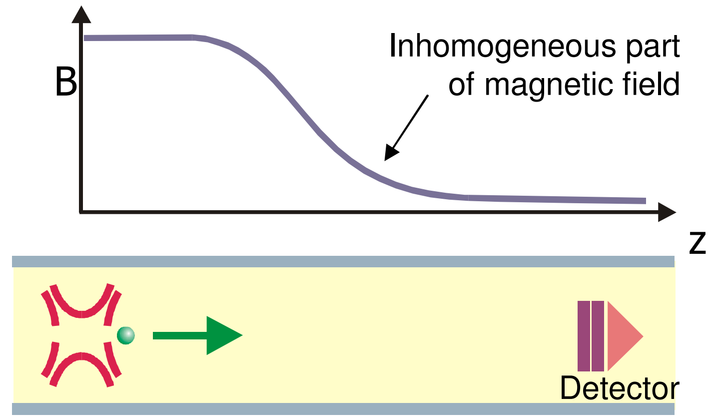
Step1: Excite radial motion



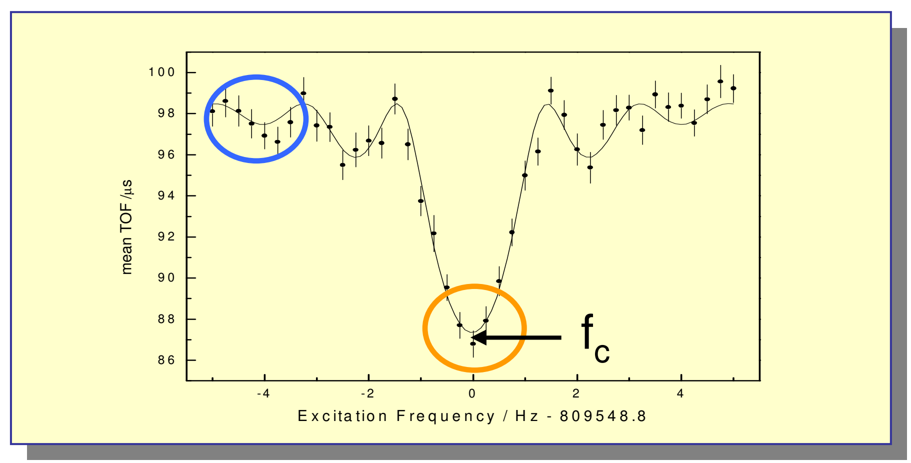
$E_{-} \sim 1meV \Leftrightarrow E_{+} \sim 1eV$



Step 2: Convert E_{rad} into E_{axial}, measure TOF



Record TOF as function of excit. frequency $\Rightarrow$ Resonance



G. Bollen et al. J. Appl. Phys. 68 (1990) 4355

M. König et al., Int. J. of Mass Spectr. and Ion Proc. 142 (1995) 95