# MATS – Measurements with an Advanced Trapping System

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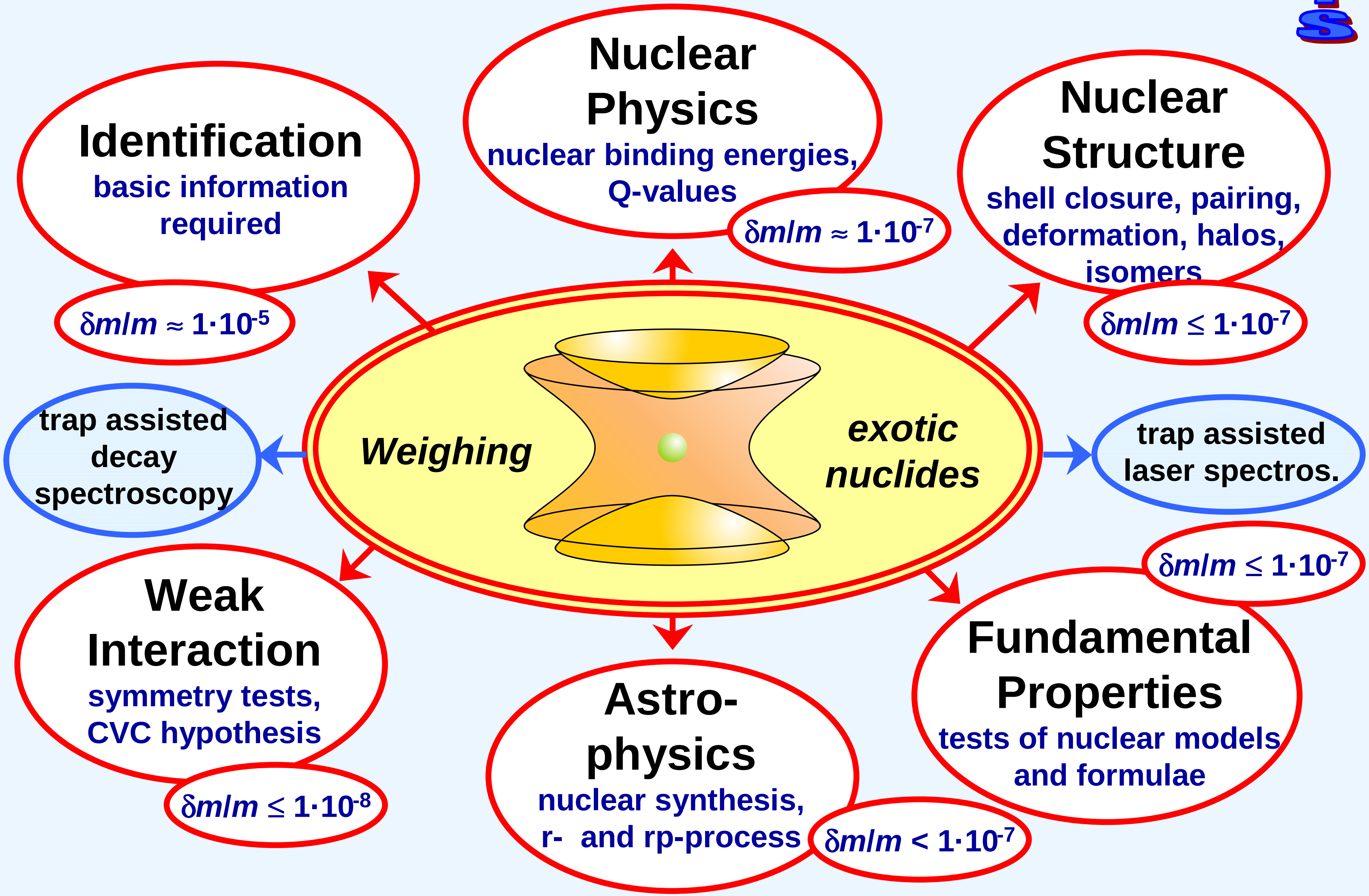
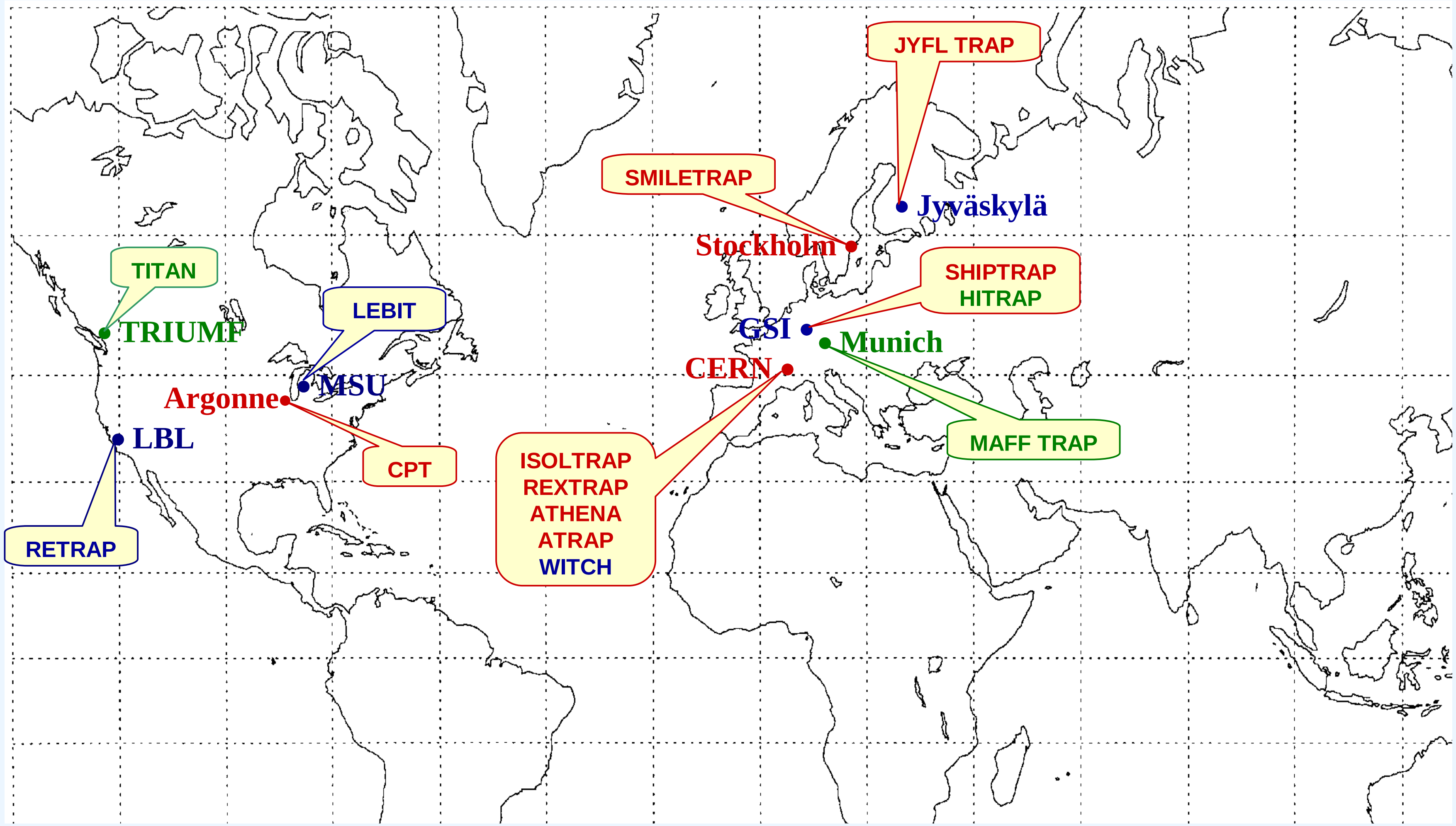
- Introduction and Motivation
- Experimental Setup
- Parameters and performance
- Collaboration

# Fields of Application



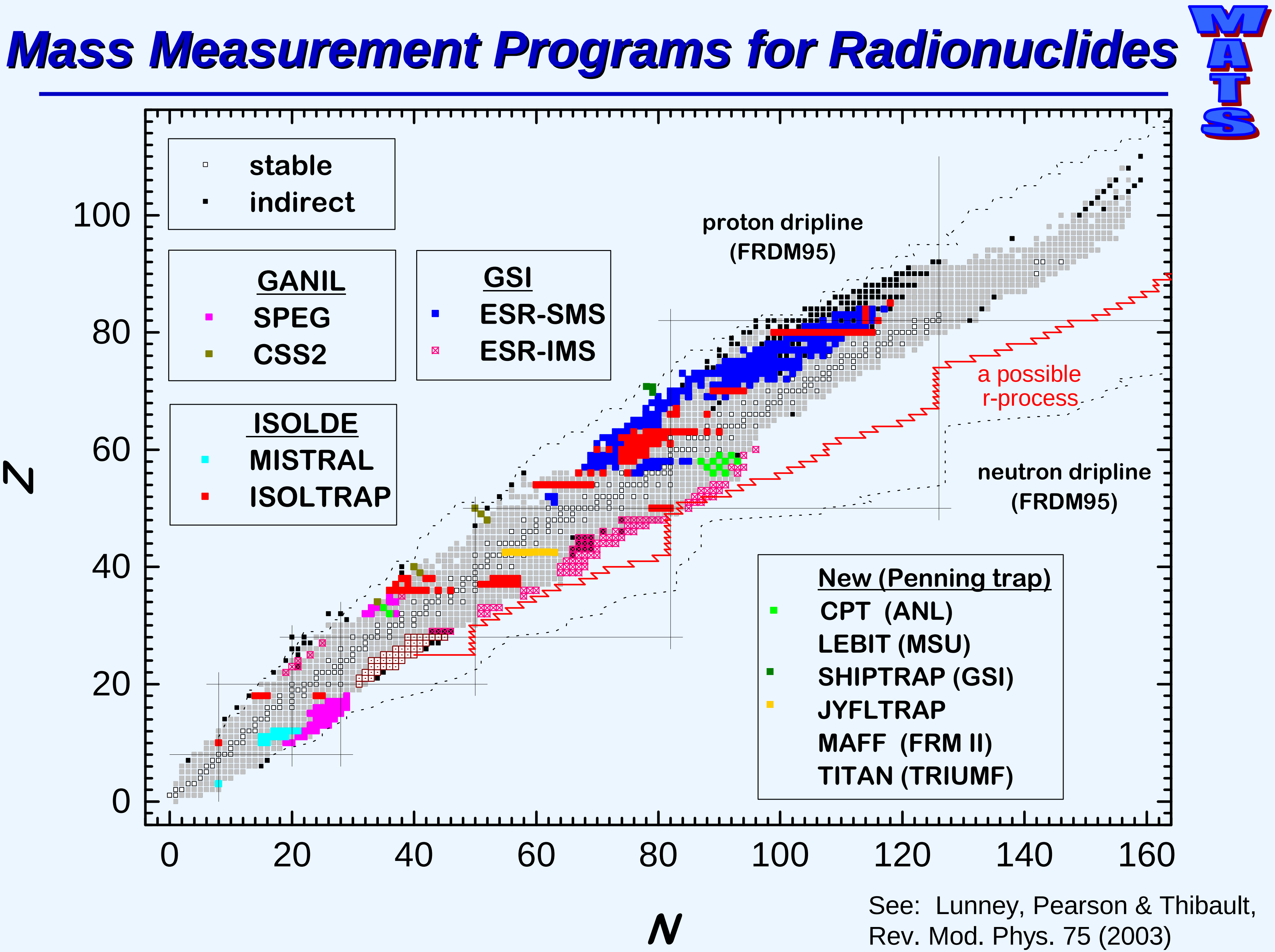
# *Penning Traps at Accelerators*

• operating facilities • facilities under test • planned facilities



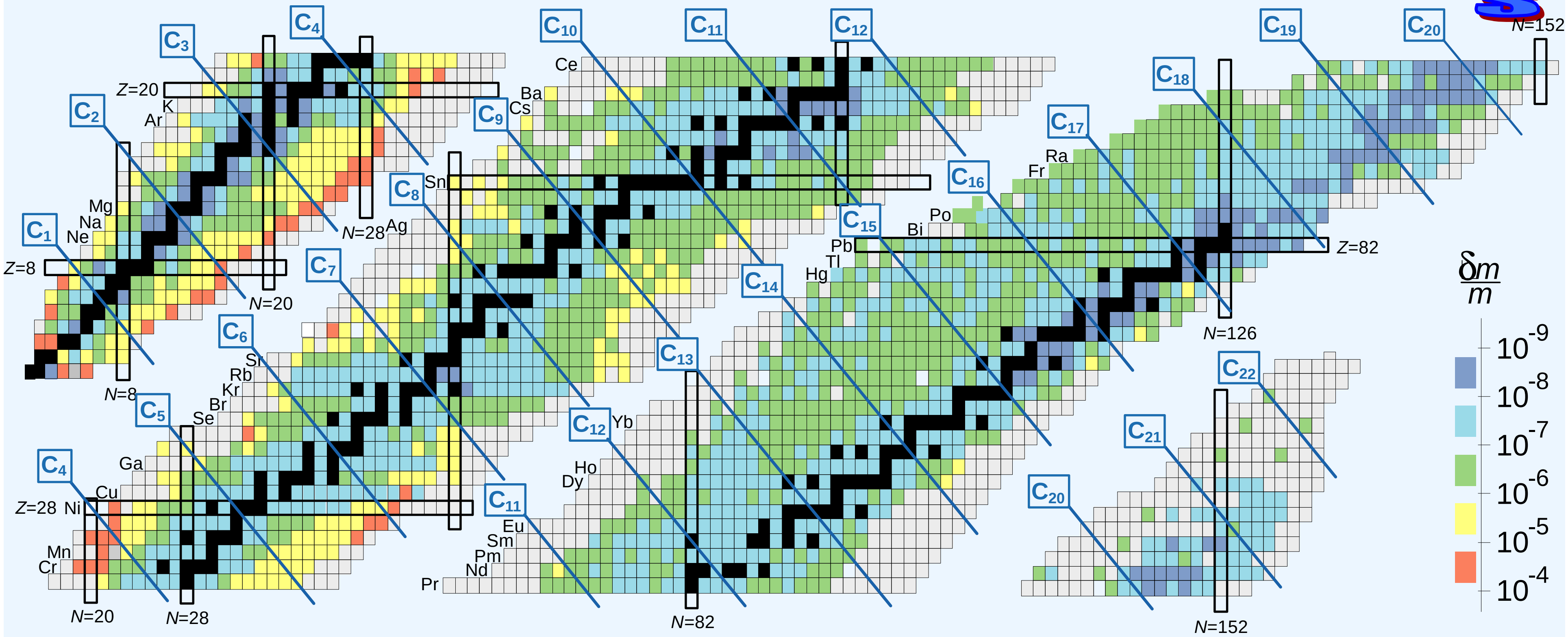

Is there a need for still another Penning trap mass spectrometer for radionuclides?

# Mass Measurement Programs for Radionuclides




See: Lunney, Pearson & Thibault, Rev. Mod. Phys. 75 (2003)

# *Present Mass Accuracy*




Status 2003 (AME2003):
G. Audi et al., Nucl. Phys. A 729 (2004) 3.

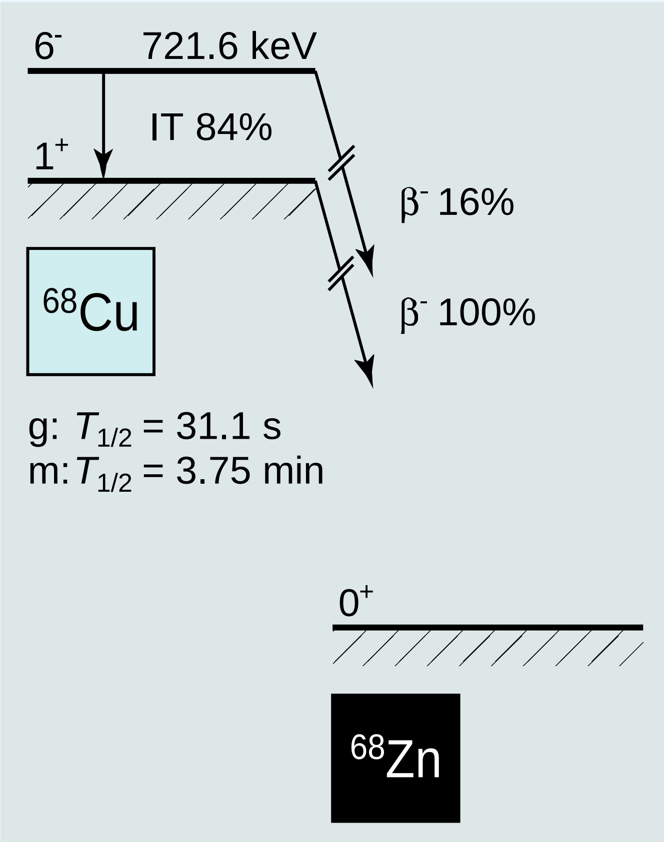
| | |
|---|---|
| Tabulated nuclides: | 3180 |
| Measured masses: | 2228 |
| Mass accuracy $\leq 10^{-7}$: | 1158 |
| Mass accuracy $\leq 10^{-8}$: | 181 |
| Mass accuracy $\leq 10^{-9}$: | 24 |

Nuclides available at FAIR with proper yield and half-life: ≈ 3000

*There is a huge potential for high-precision mass measurements*

# Resolution and Isolation of Isomers

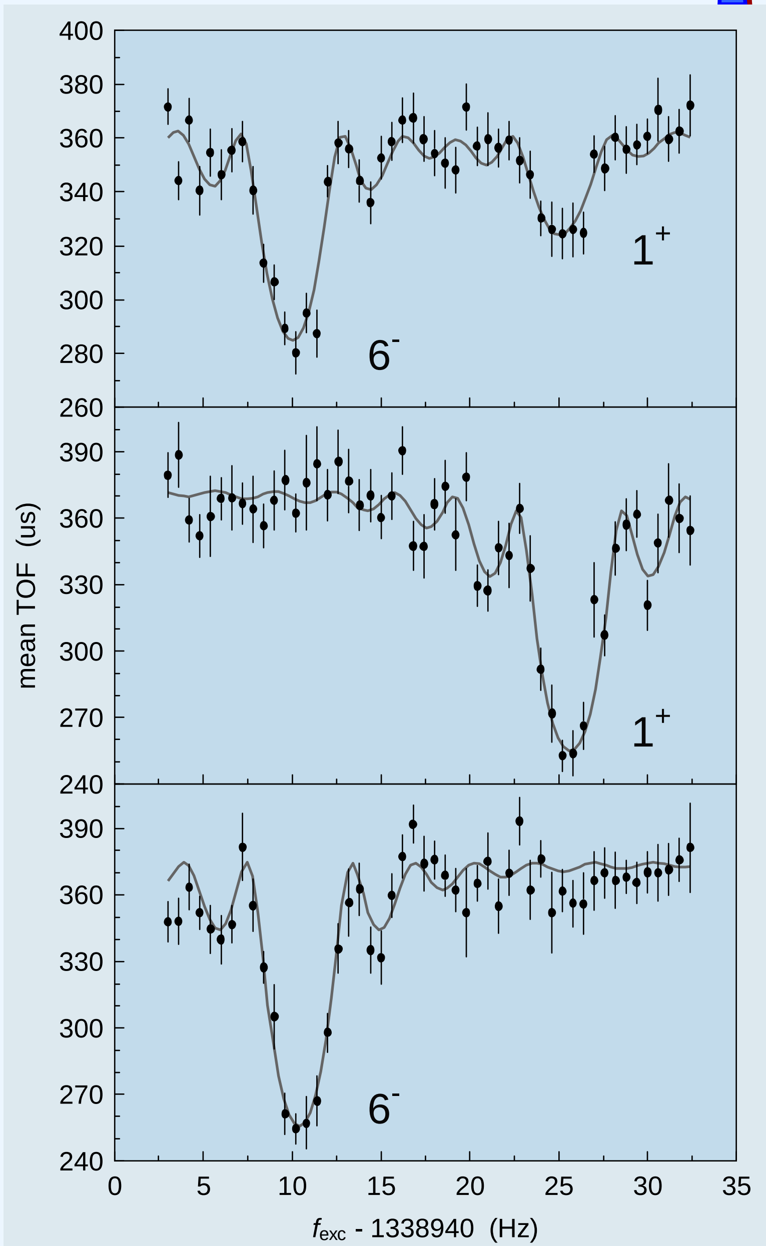
Isomerism in $^{68}$Cu:




as produced by ISOLDE

isolation of the 1⁺ ground state

isolation of the 6⁻ isomeric state



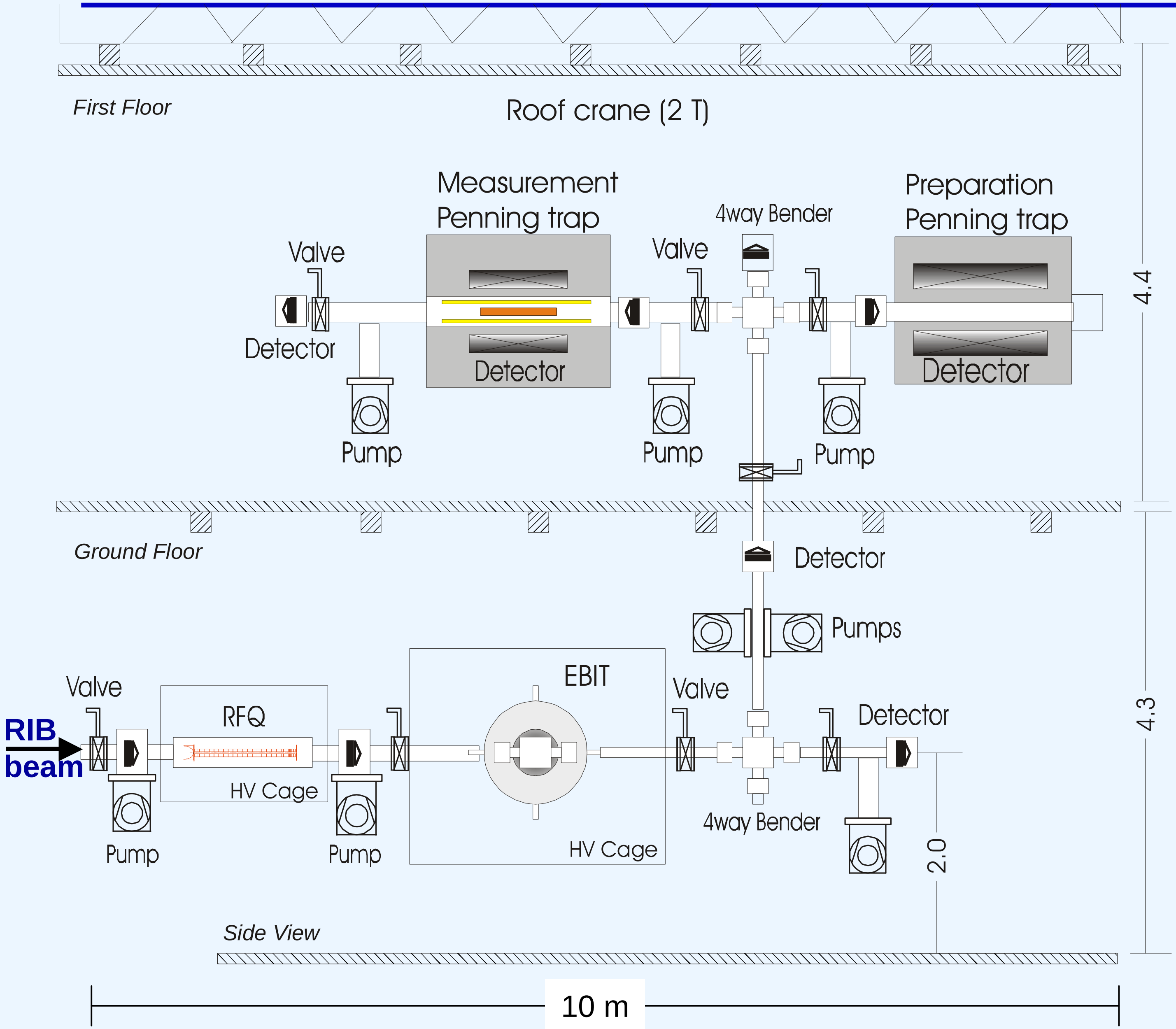

**Resolving power of excitation: $R \approx 10^7$**

**⇒ Preparation of an isomerically pure beam**

**⇒ 100 keV isomers could be resolved ($^{70}$Cu)**

K. Blaum *et al.*, Europhys. Lett. 67, 586 (2004)

# MATS Experimental Setup




Detectors:
- FT-ICR
- TOF-ICR
- Si(Li) electron

Precision trap:
measurements

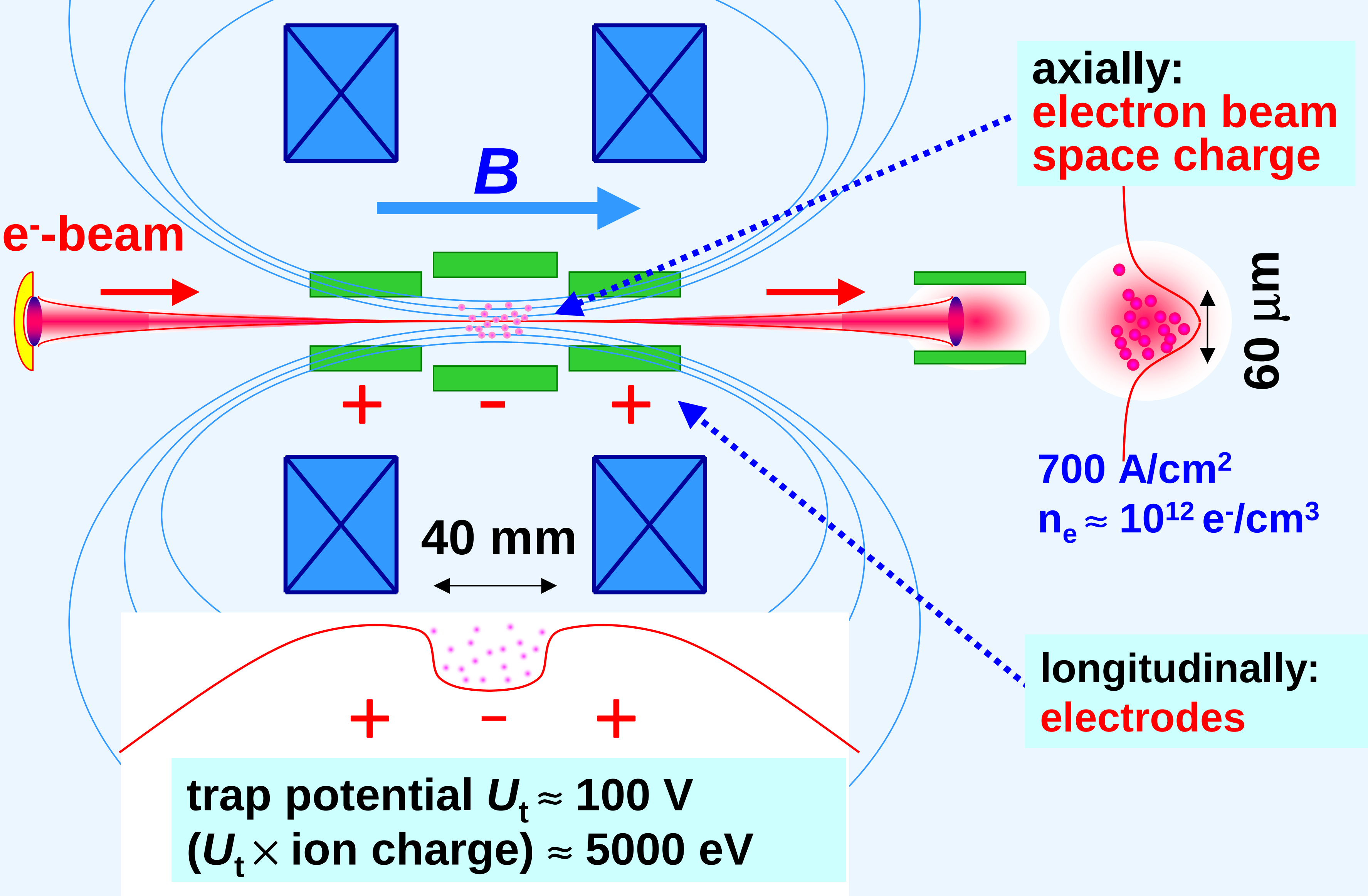
Cooler trap:
beam preparation

q/m selection:
separation

EBIT:
charge breeding

$$f_c = \frac{1}{2\pi} \cdot \frac{q}{m} \cdot B$$

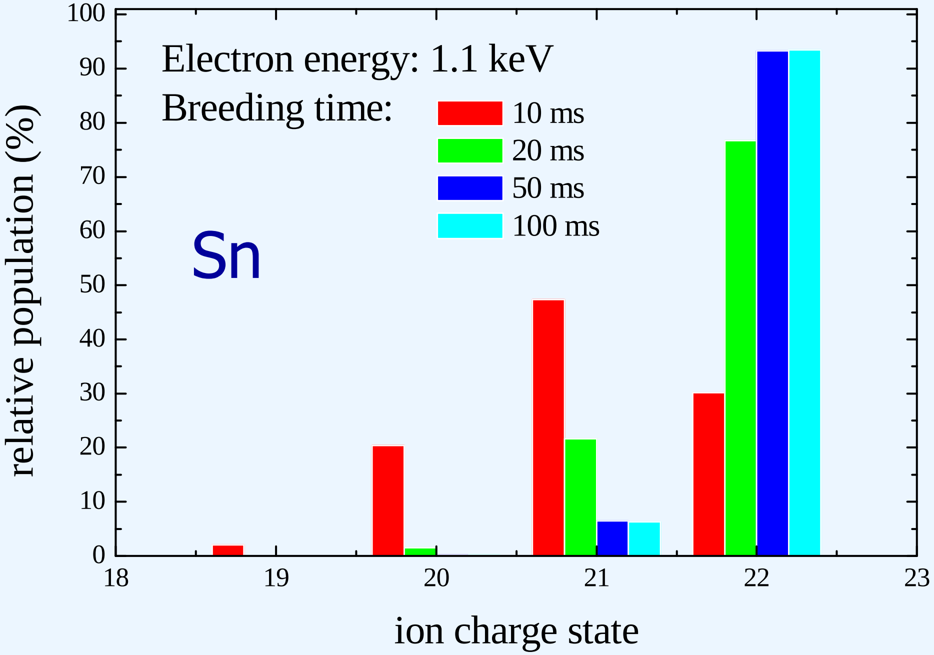
# *Principles of an EBIT (electron beam ion trap)*




trap potential $U_t \approx 100$ V

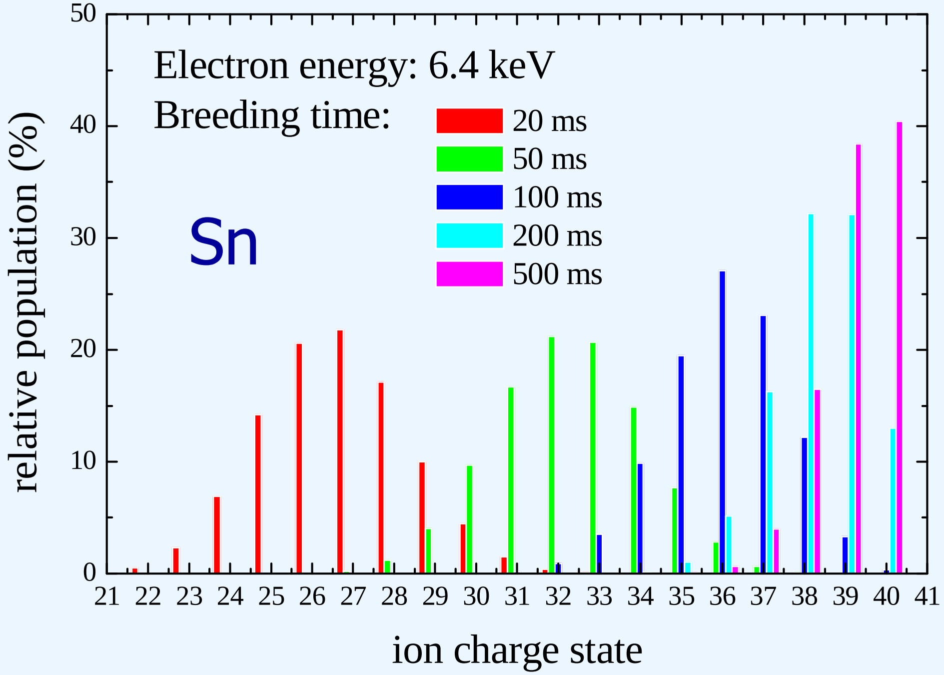
($U_t \times$ ion charge) $\approx 5000$ eV

# The EBIT Performance




## Charge breeding of Sn

Parameters:
- up to 6.5 keV beam energy
- 700 A/cm$^2$ current density
- $10^{-9}$ mbar residual gas pressure

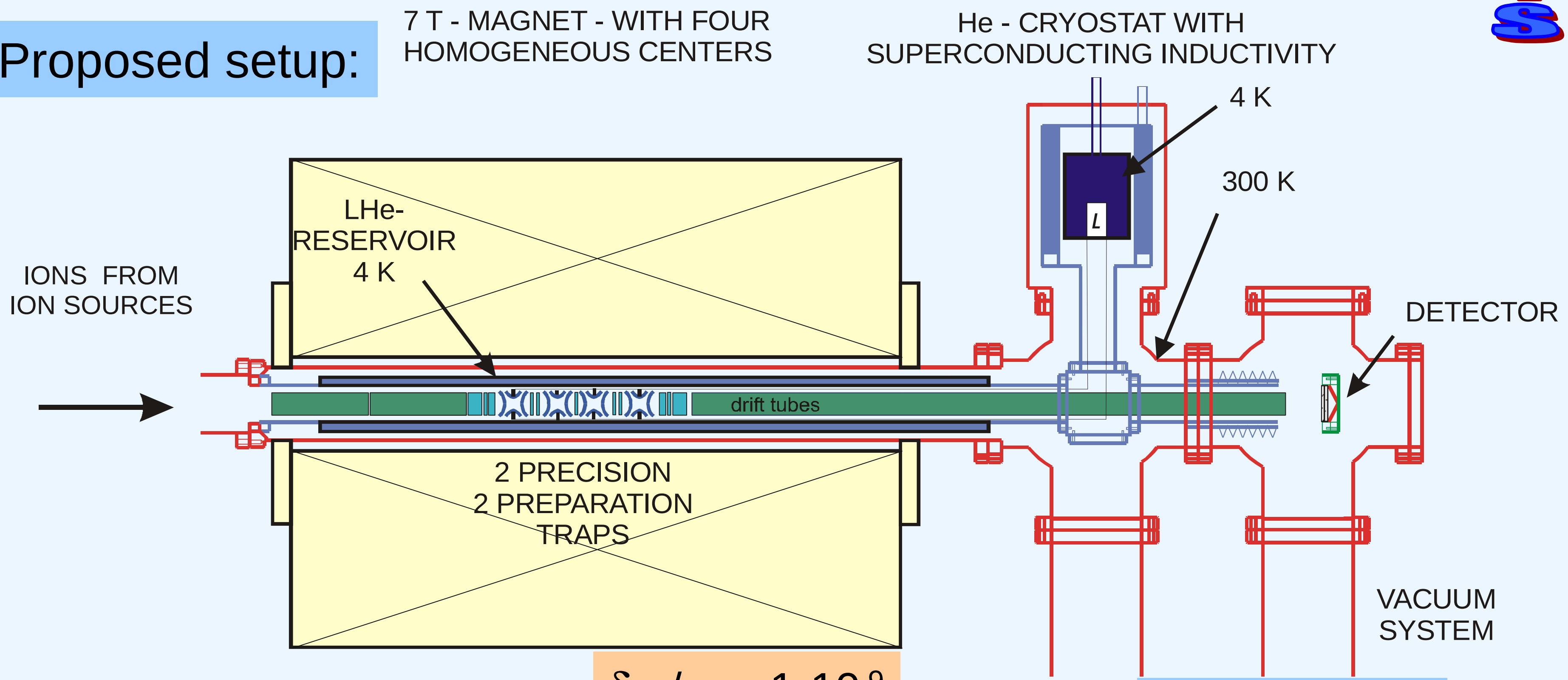



Peak charge state after 20 ms breeding time

| Element | Charge state |
|---|---|
| $_{8}$O | 7+ |
| $_{12}$Mg | 9+ |
| $_{18}$Ar | 11+ |
| $_{20}$Ca | 12+ |
| $_{36}$Kr | 16+ |
| $_{51}$Sb | 19+ |
| $_{54}$Xe | 21+ |

# The Measurement Penning Trap

Proposed setup:




$\delta m/m \approx 1 \cdot 10^{-9}$

$T_{1/2} \approx 10$ ms

Timing scheme:

Simultaneous storage of two ion species in two precision traps and measurement of $\nu_c$ at the same time.

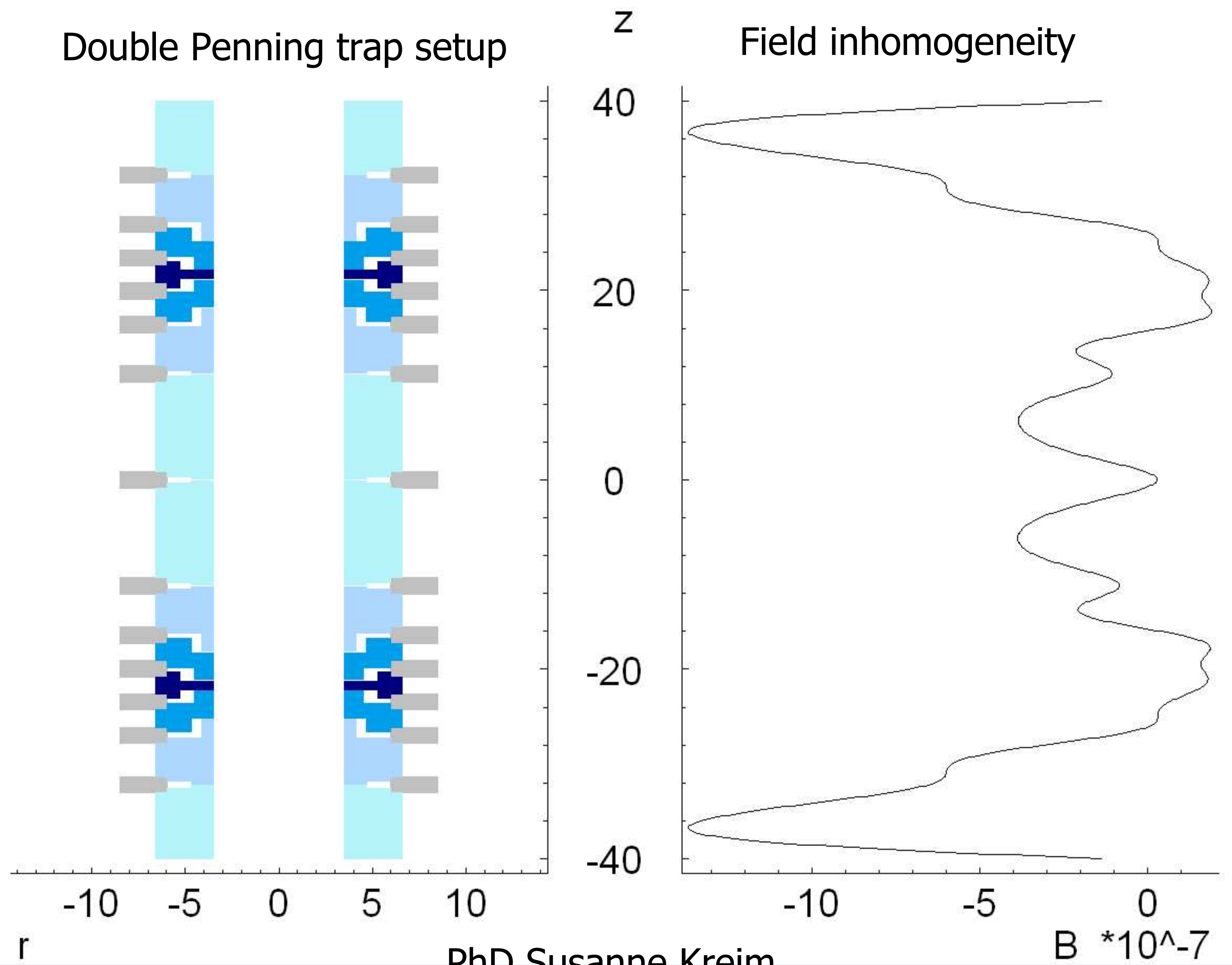
Advantages:

Direct mass doublet measurement.

No ion-ion interaction.

Simultaneous measurement process.

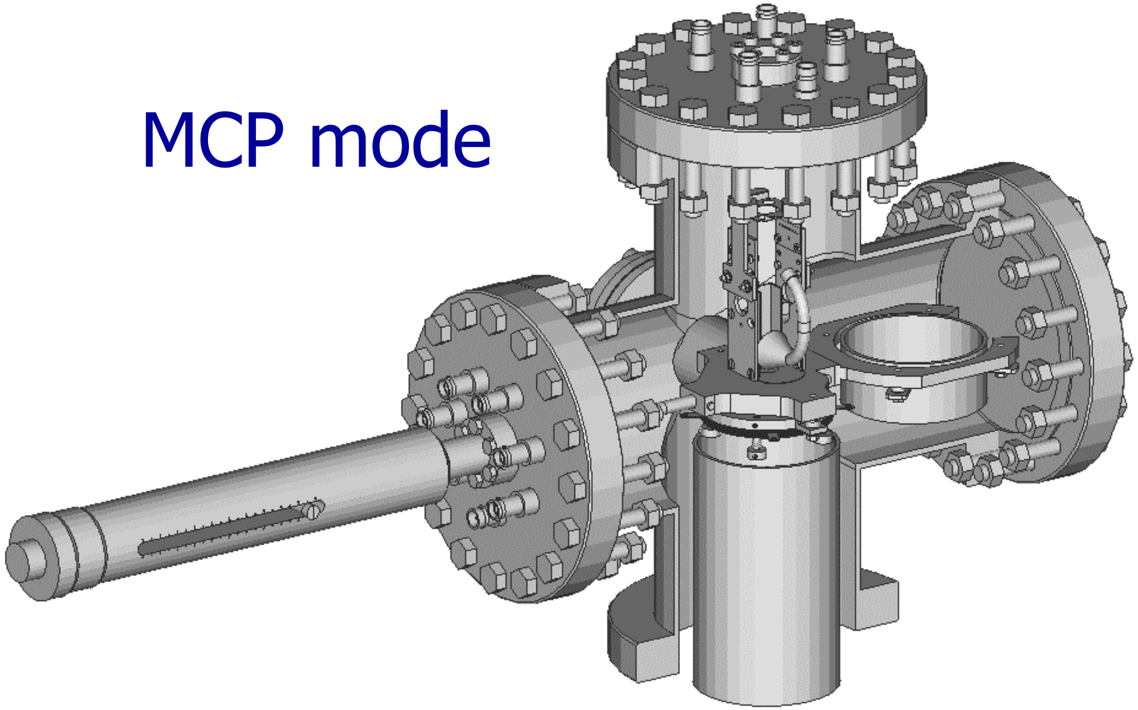
# Optimization of the Trapping Field



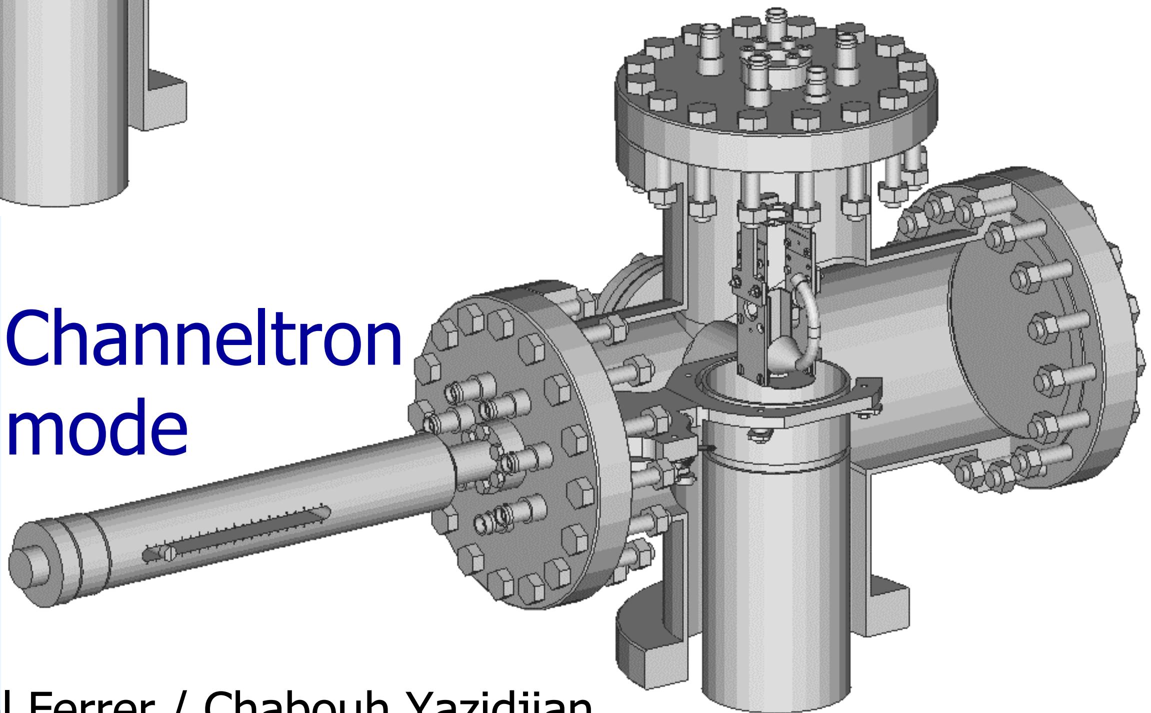

PhD Susanne Kreim

# *Destructive Ion Detection: TOF-ICR*

MCP mode



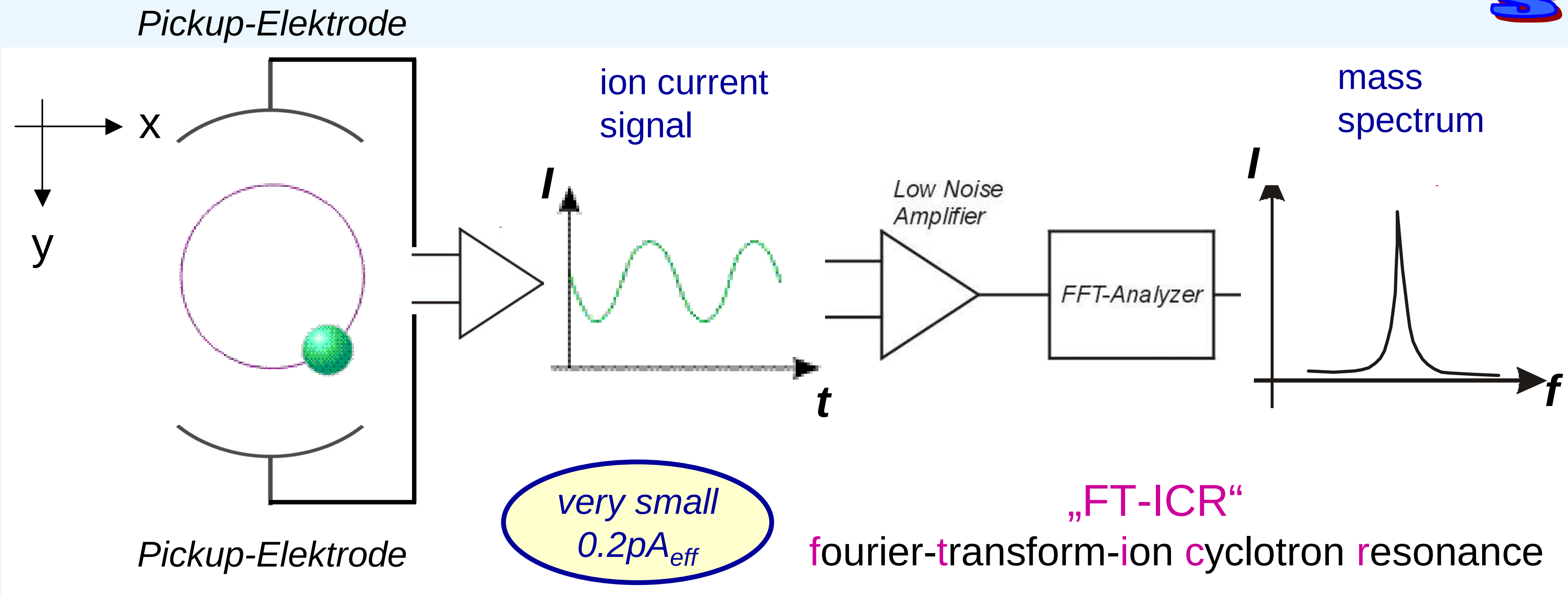
Channeltron mode



Detection efficiency: ~100%
Low background: <10 mHz
Deadtime: ~ 10ns

PhD Rafael Ferrer / Chabouh Yazidjian

# Non-Destructive Ion Detection: FT-ICR



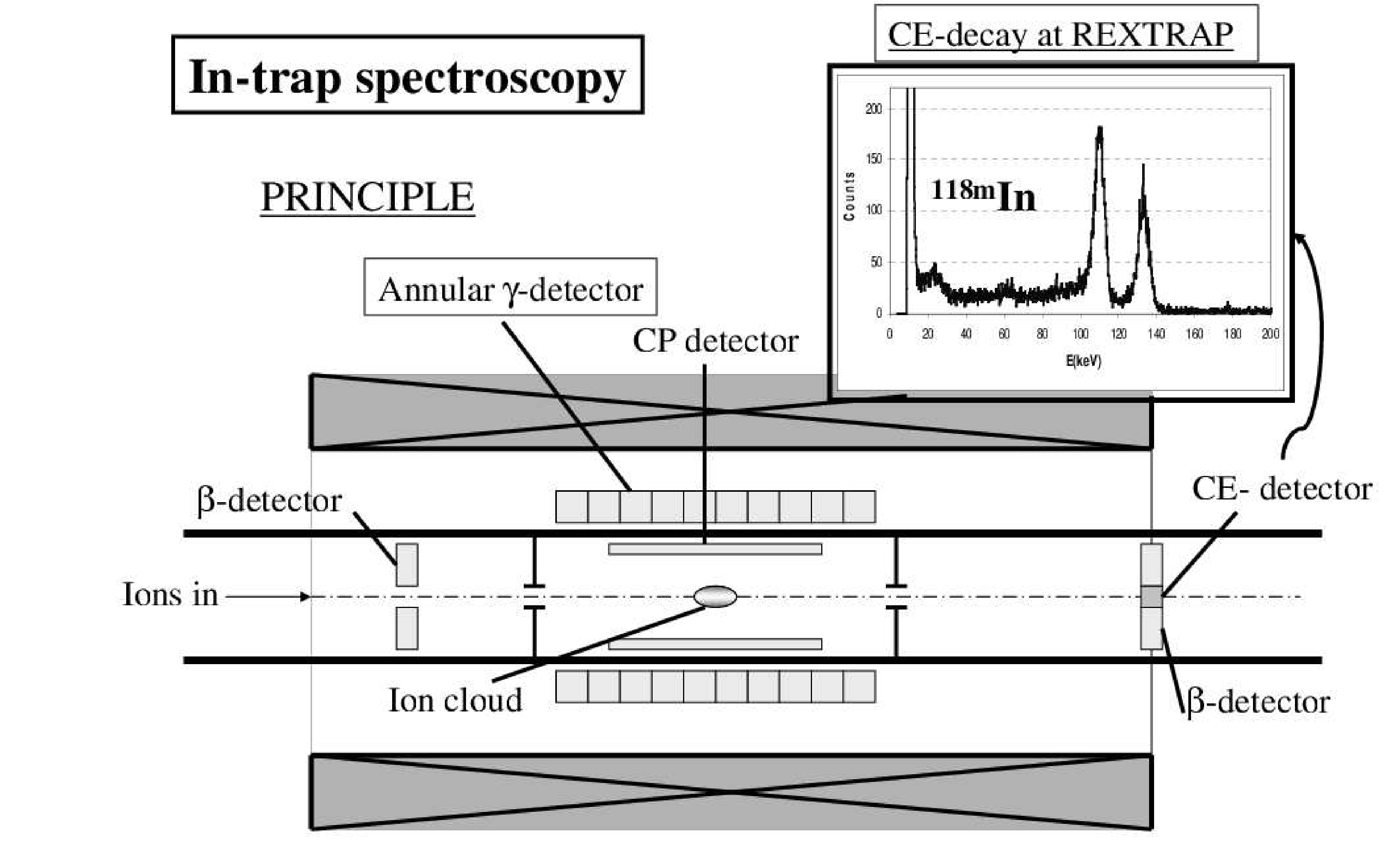

## Applications

– Mass measurements on long-lived rare elements (SHIPTRAP)

– Ultra high-precision mass measurements on “stable” ions

C. Weber *et al.*, PhD Thesis, Heidelberg (2004).

# In-Trap Spectroscopy Detector



# Conclusions

***Ion traps are an ideal tool to perform nuclear physics precision experiments!***

- Unique combination of an EBIT and a Penning trap for mass spectrometry and trap assisted decay spectroscopy
- High-precision mass measurements can provide valuable input to nuclear structure and fundamental studies
- Preparation of isomerically pure beams for further experiments, e.g. decay and laser spectroscopy
- Great potential for further measurements with even increasing sensitivity and precision and yet shorter half-lives!

# *The MATS Collaboration*

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*Universite Libre de Bruxelles:* P.-H. Heenen

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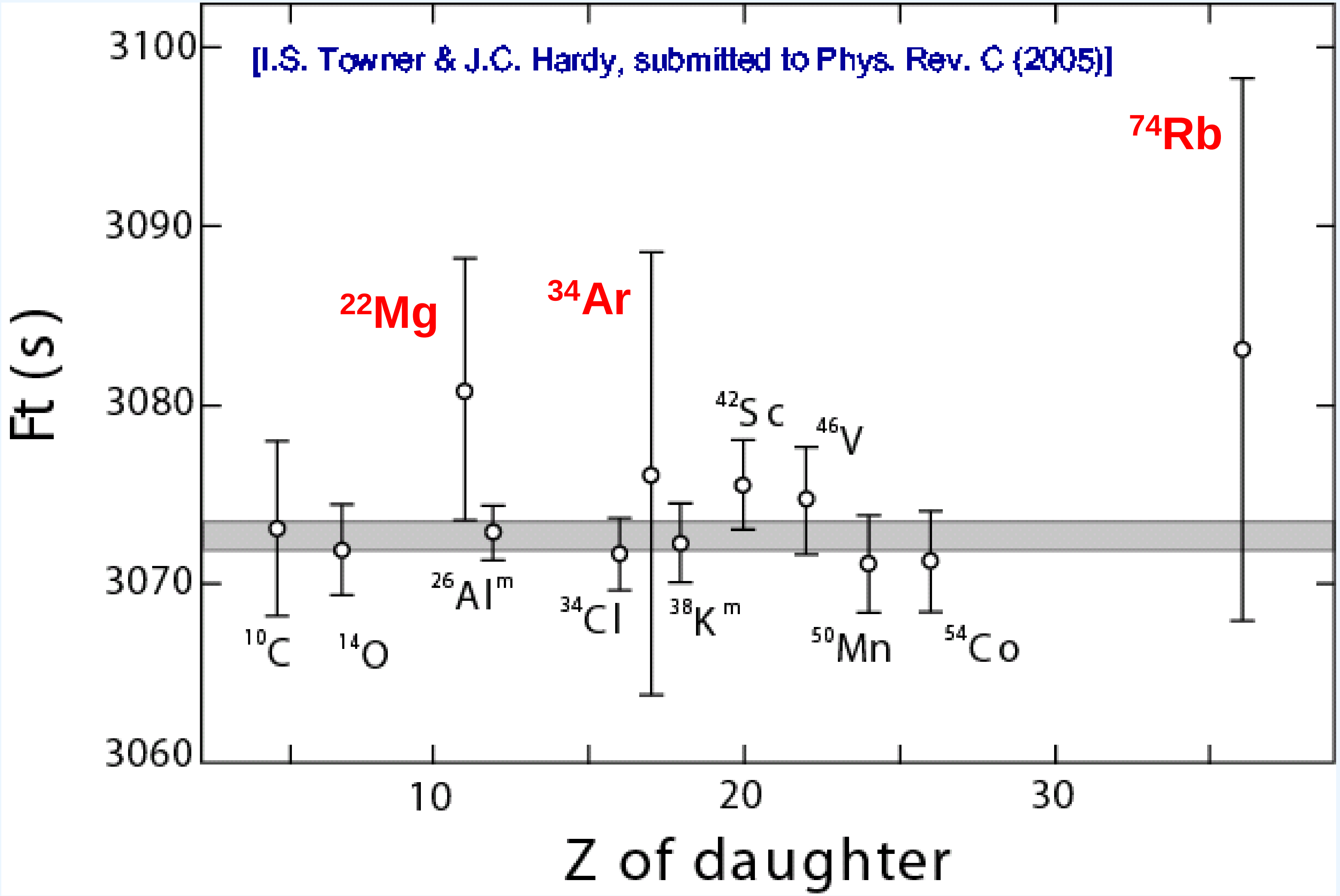
*University of Tübingen:* W. Nörtershäuser

*Kolkata India:* A. Ray

**16 Institutes**
**52 Members**

# Fundamental Studies

*Test of the conserved-vector-current hypothesis and the CKM unitarity.*




F. Herfurth *et al*., Eur. Phys. J. A 15, 17 (2002)
A. Kellerbauer *et al*., Phys. Rev. Lett.93, 072502 (2004)
M. Mukherjee *et al*., Phys. Rev. Lett. 93, 150801 (2004)

# *Nuclear Structure Studies*

MATS

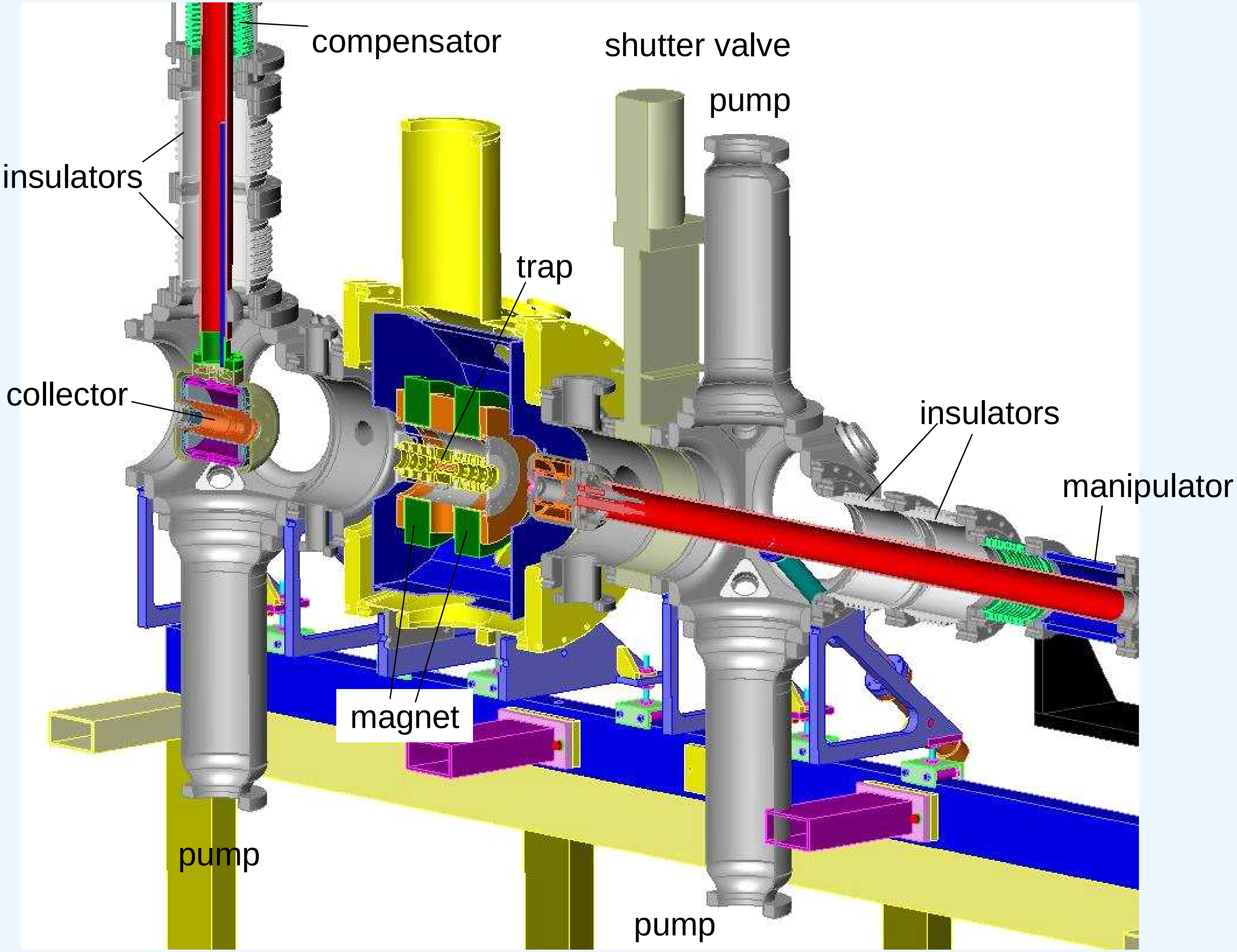
*Proton-neutron interactions and the new masses*

[R.B. Cakirli *et al.*, submitted to Phys. Rev. Lett. (2004) and private communication.]

$$\delta V_{pn}(Z,N) = \tfrac{1}{4}\,[\{B(Z,N) - B(Z,N-2)\} - \{B(Z-2,N) - B(Z-2,N-2)\}]$$

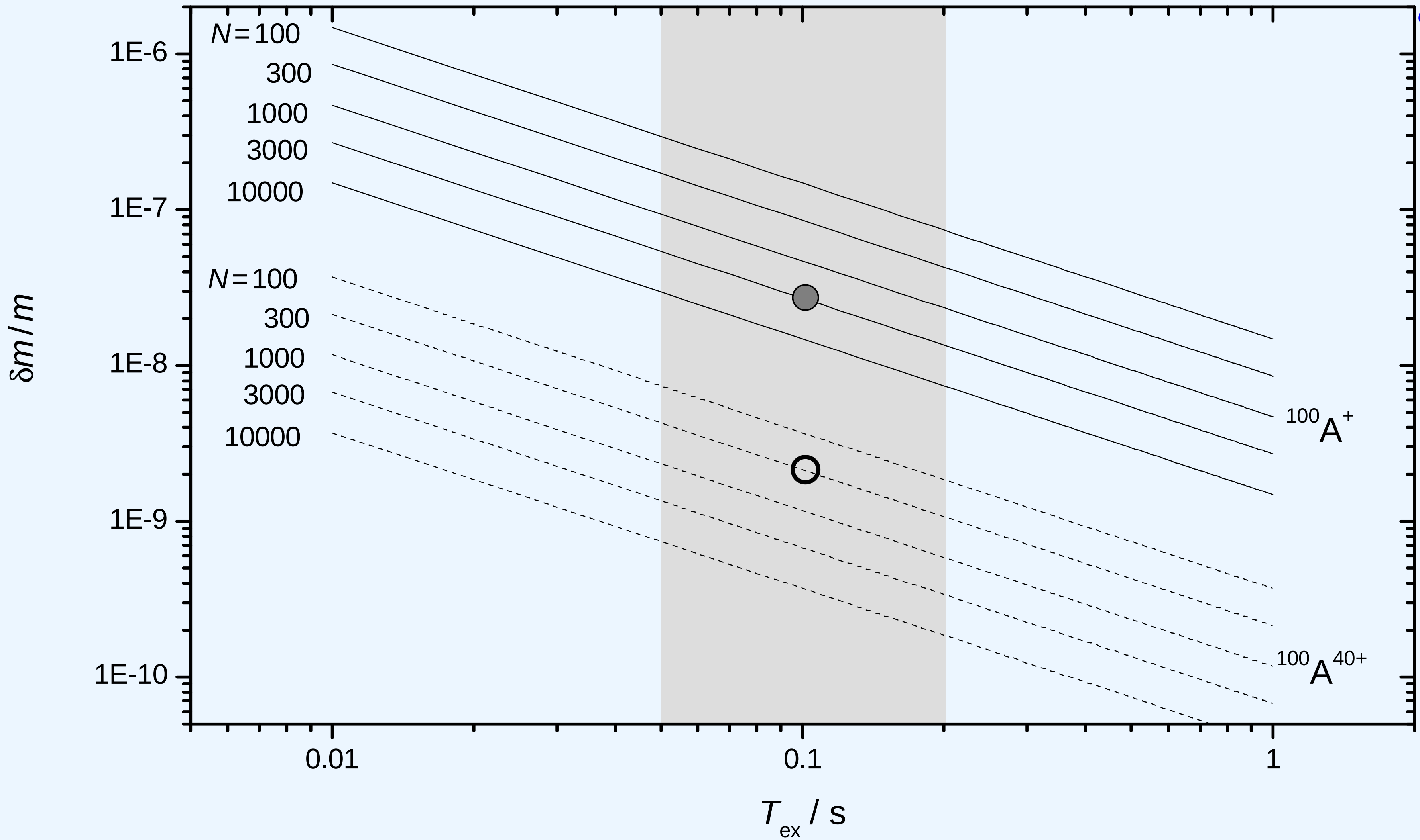
A given $\delta V_{pn}(Z,N)$ value for even-even nuclei refers to the interaction of the $(Z-1)$ and $Z^{th}$ protons with the $(N-1)$ and $N^{th}$ neutrons.

# The EBIS



compensator
shutter valve
pump
insulators
trap
collector
insulators
manipulator
magnet
pump
pump

# The Advantage of Highly Charged Ions




- much higher resoving power and accuracy
- saving in beam time requirement