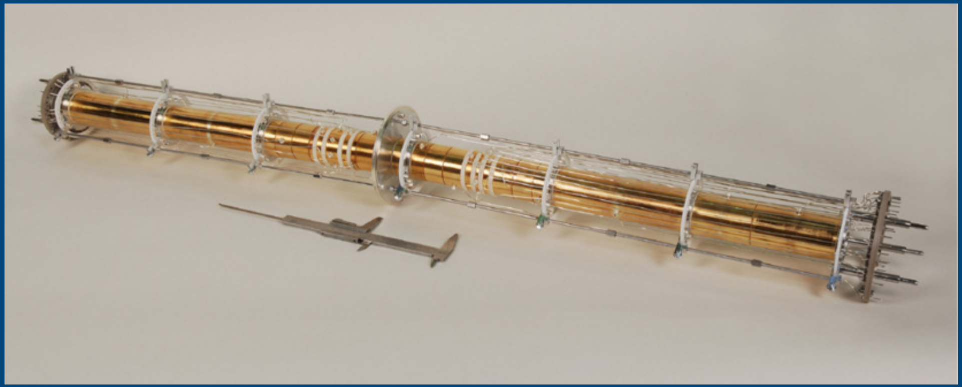
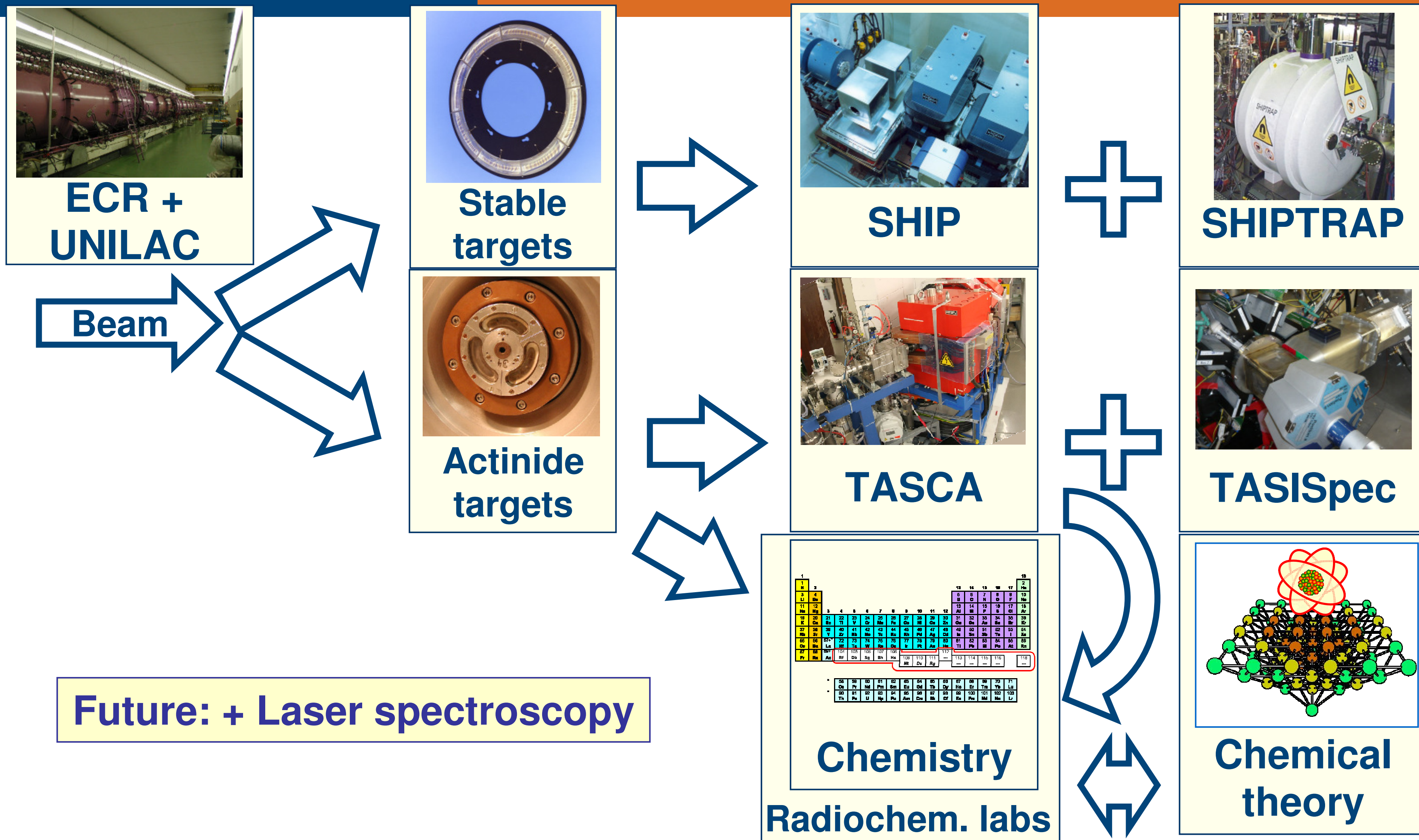
MASS MEASUREMENTS OF RARE ISOTOPES WITH THE PENNING TRAP MASS SPECTROMETER SHIPTRAP



Michael Block, GSI

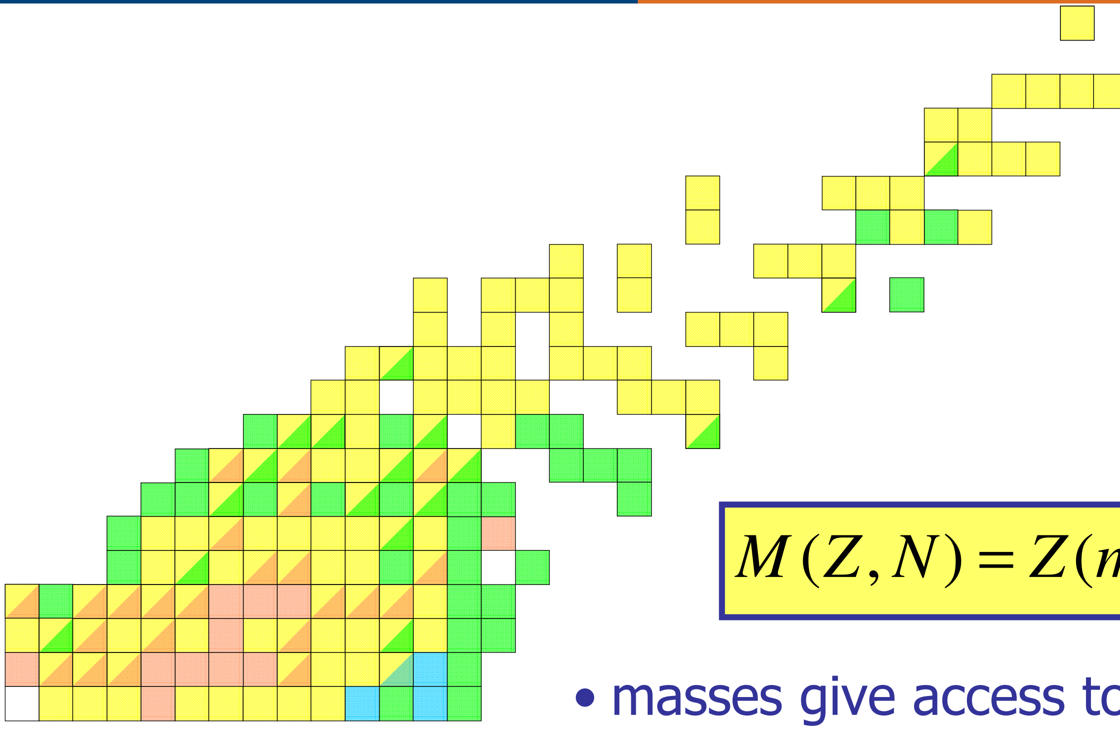
HELMHOLTZ ASSOCIATION GSI

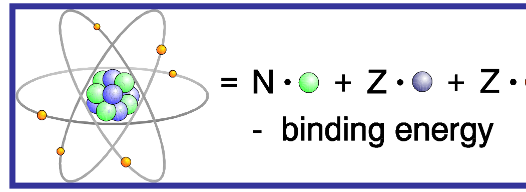
GSI: Unique Combination for SHE Studies



courtesy Ch.E. Düllmann

Importance of Masses for Z > 92

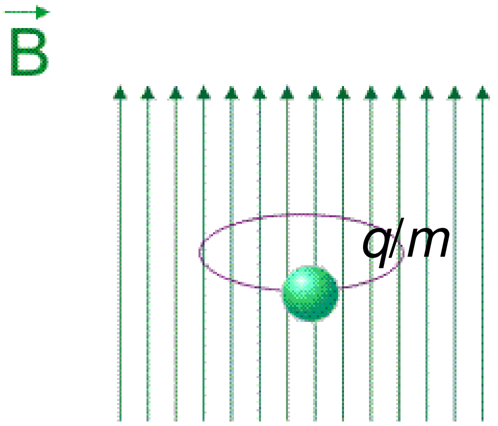




$$M(Z,N) = Z(m_e + m_p) + Nm_n - B(Z,N)/c^2$$

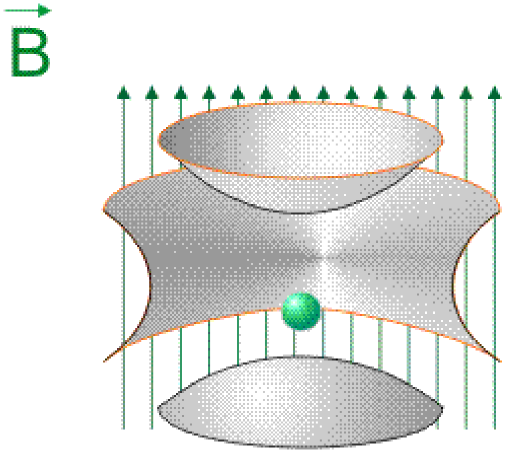
- masses give access to nuclear binding energy
- masses allow studies of the shell structure evolution
- high-precision mass measurements can provide anchor points to fix decay chains
- benchmark nuclear models

Principle of Penning Traps



PENNING trap

- Strong homogeneous magnetic field
- Weak electric 3D quadrupole field

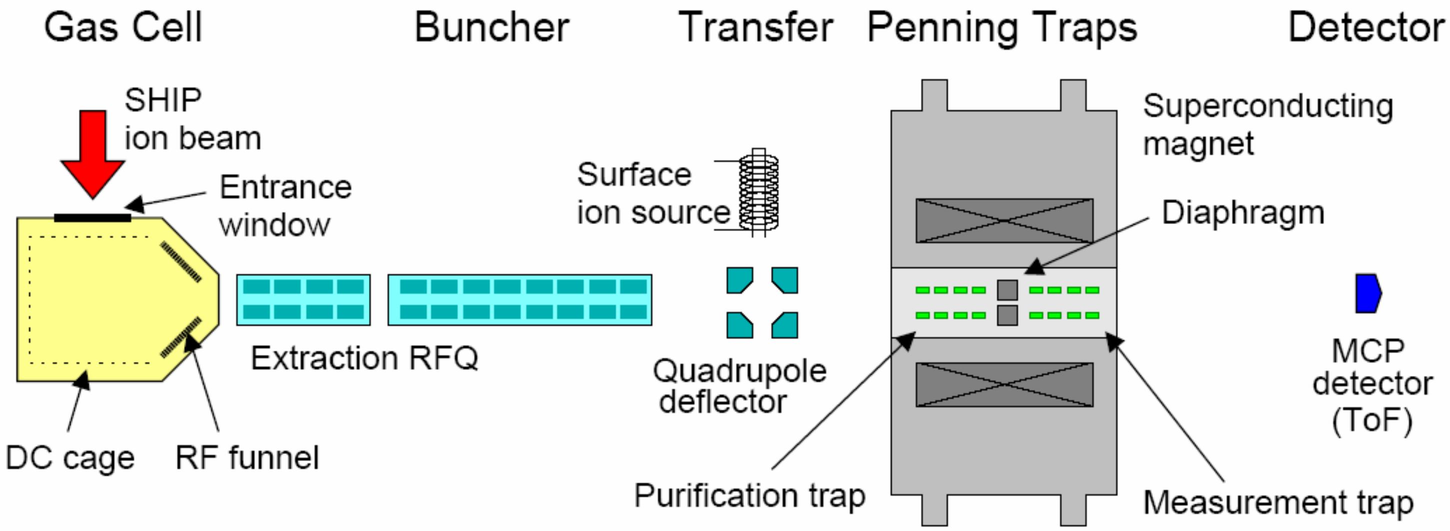


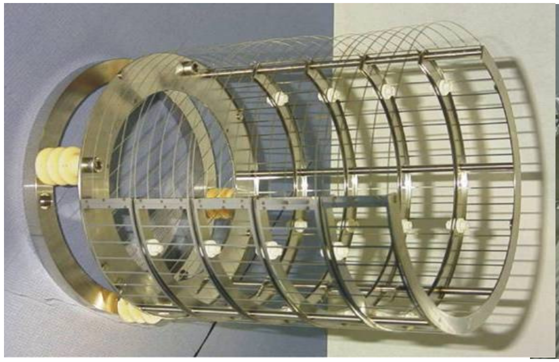
Cyclotron frequency: $$f_c = \frac{1}{2\pi} \cdot \frac{q}{m} \cdot B$$

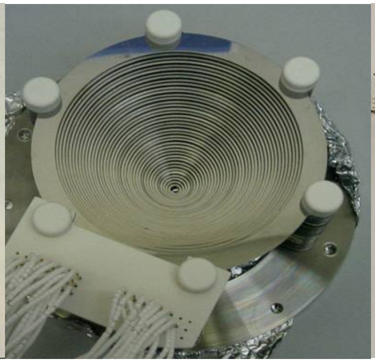
Typical values: $B = 7$ T, $A = 133$, $f_c \approx 800$ kHz

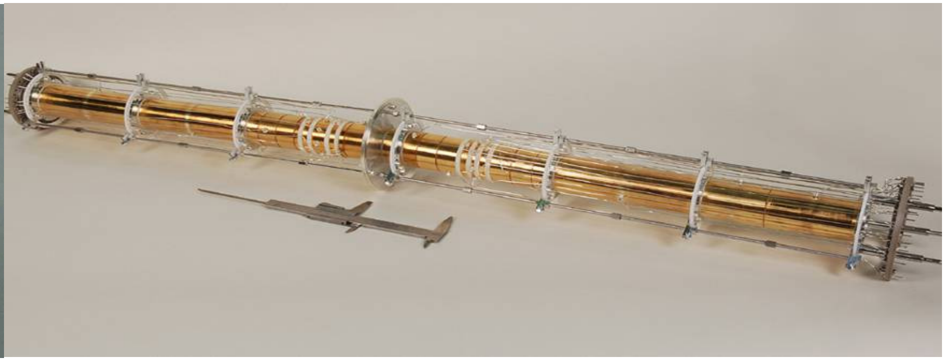
SHIPTRAP Setup

≈ 50 MeV → **≈ 1 eV**



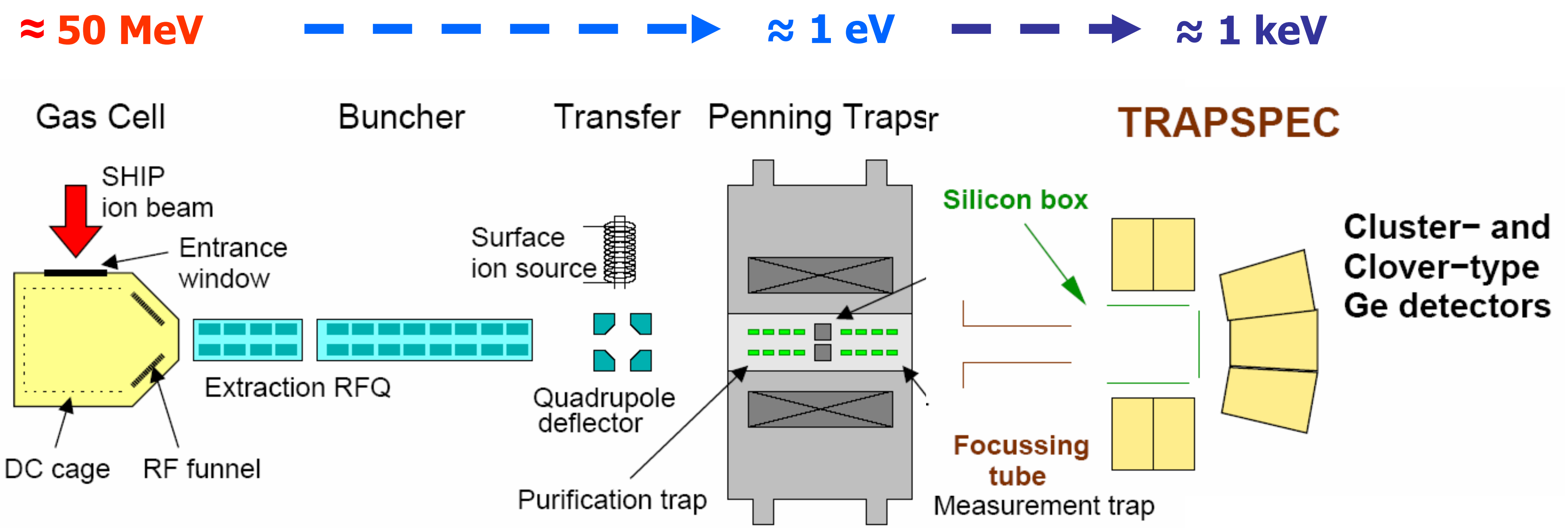


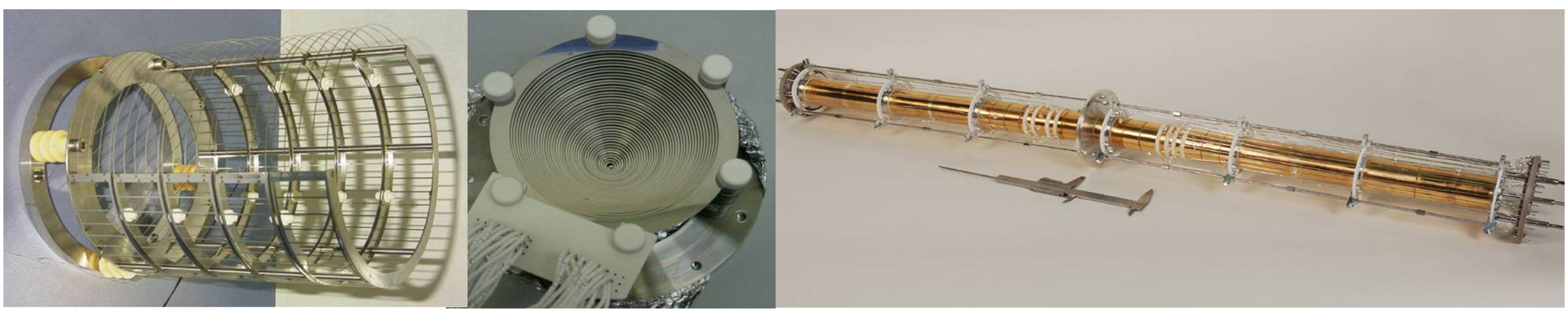




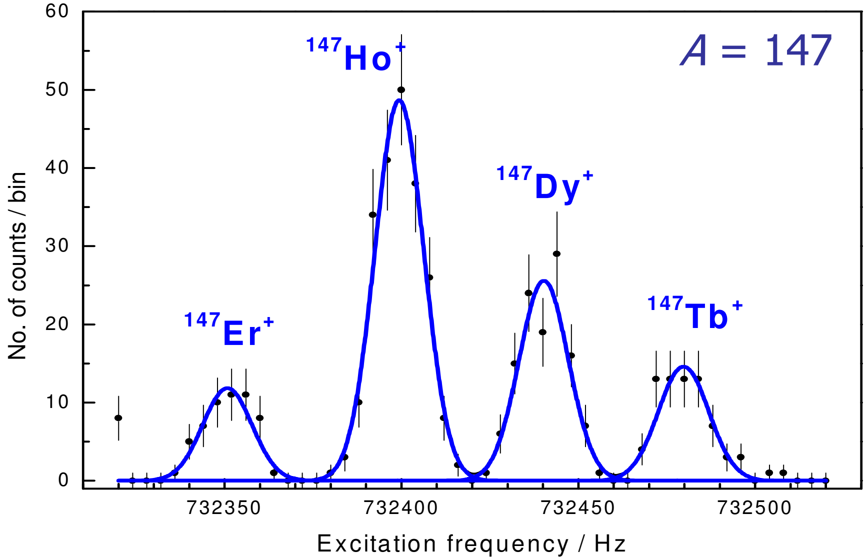
HELMHOLTZ ASSOCIATION GSI

SHIPTRAP Setup



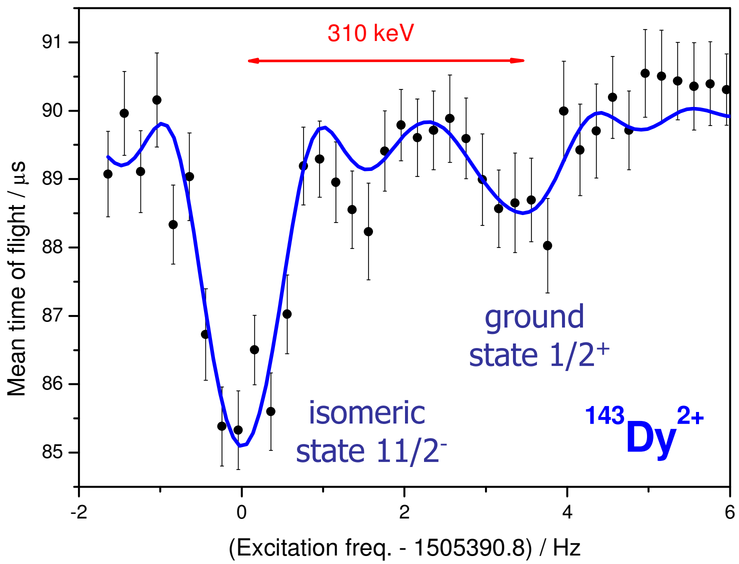


SHIPTRAP Performance



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

HELMHOLTZ ASSOCIATION GSI

Requirements for Mass Measurements $Z > 100$

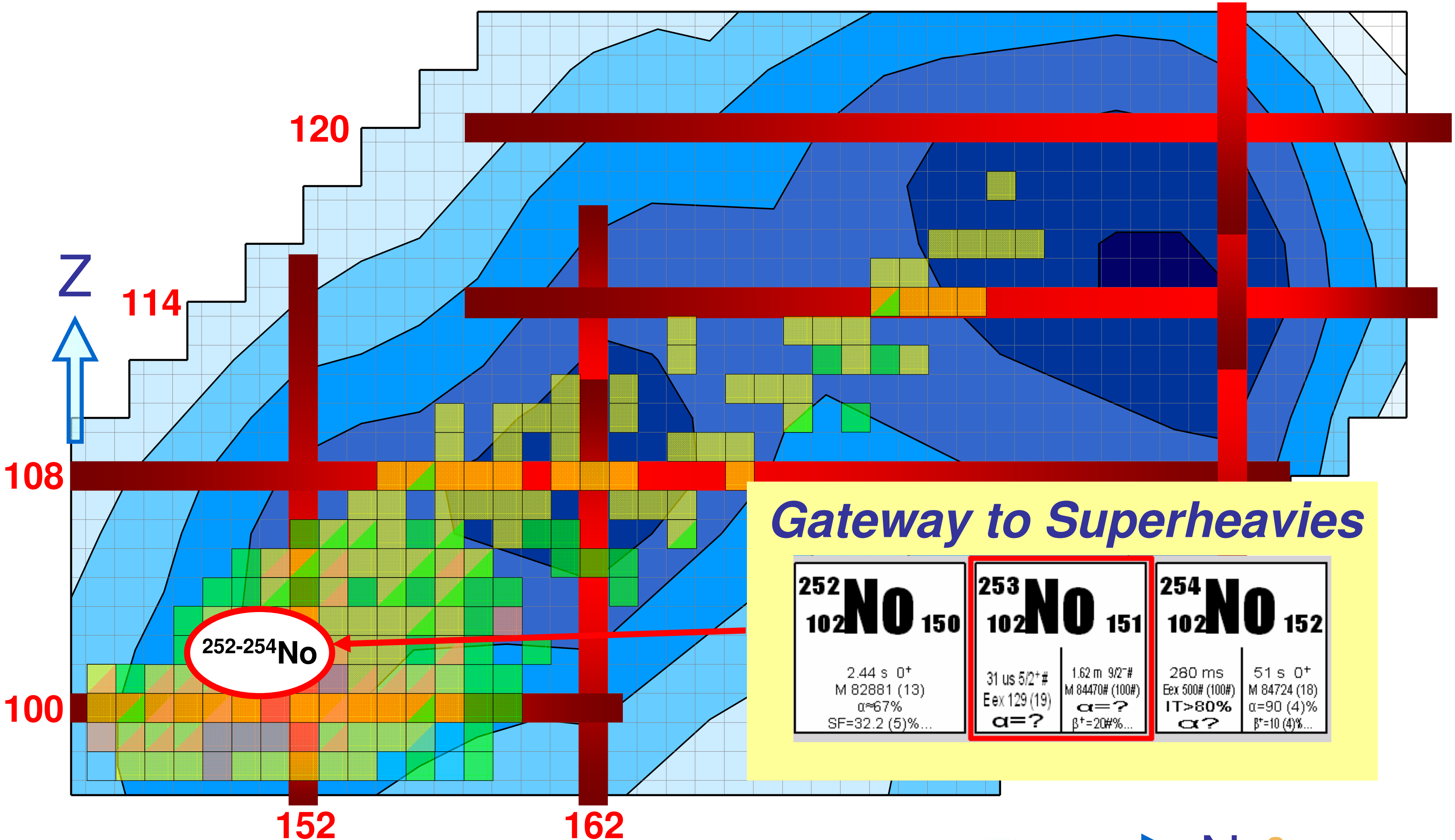
Typical production rates at present facilities:

- 1 atom/s @ Z=102 ($\sigma \approx$ 1 μb)
- 1 atom/week @ Z=112 ($\sigma \approx$ pb)
- energy matching of reaction products to trap's energy scale
- high efficiency to deal with very low production rates
- high cleanliness for low background
- stable and reliable operation over extended time

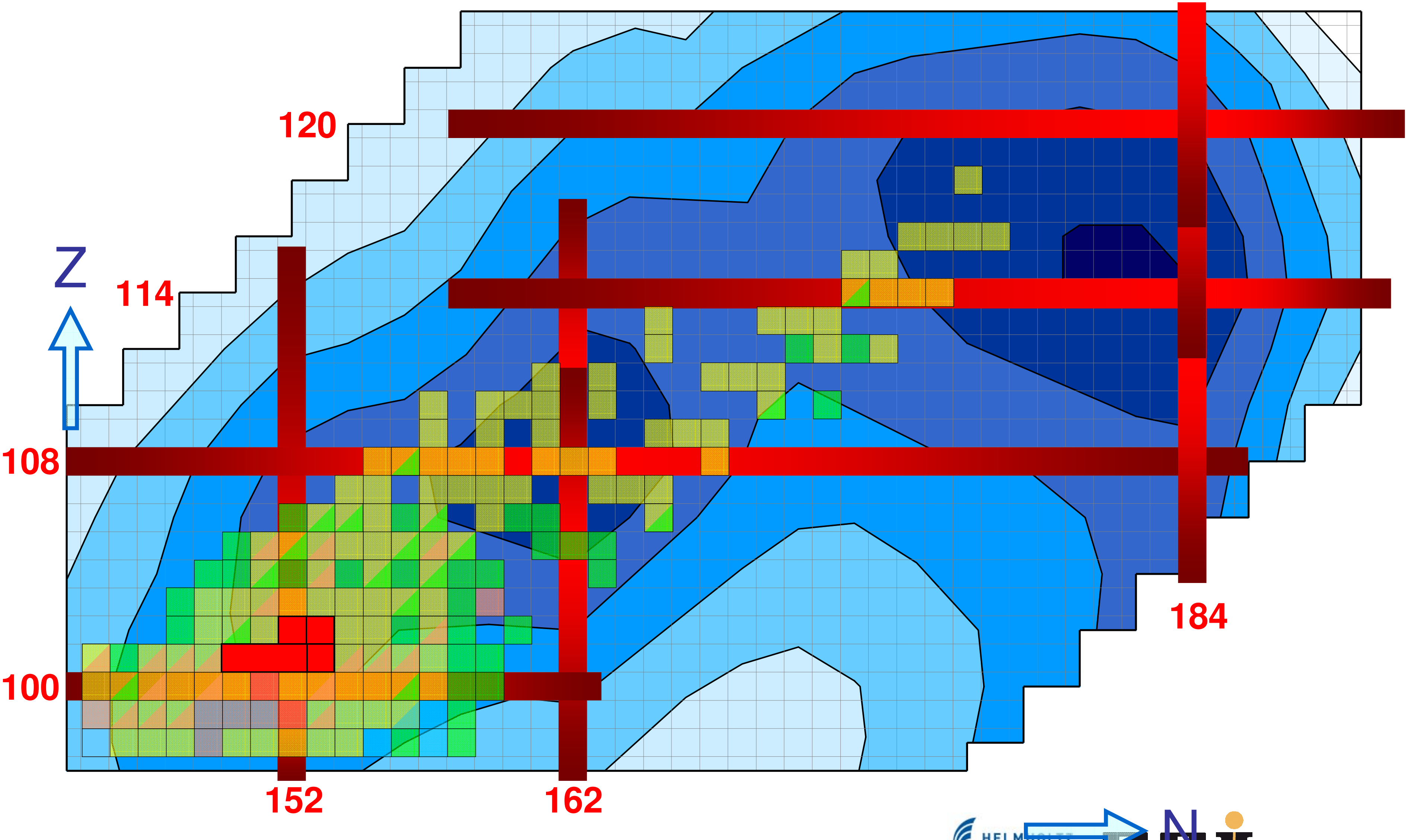
Present performance of Penning Traps for RIBs

• Half-life	> 10 ms
• Rate of trapped ions	> 1 / h
• Rel. uncertainty	$\approx 10^{-8}$

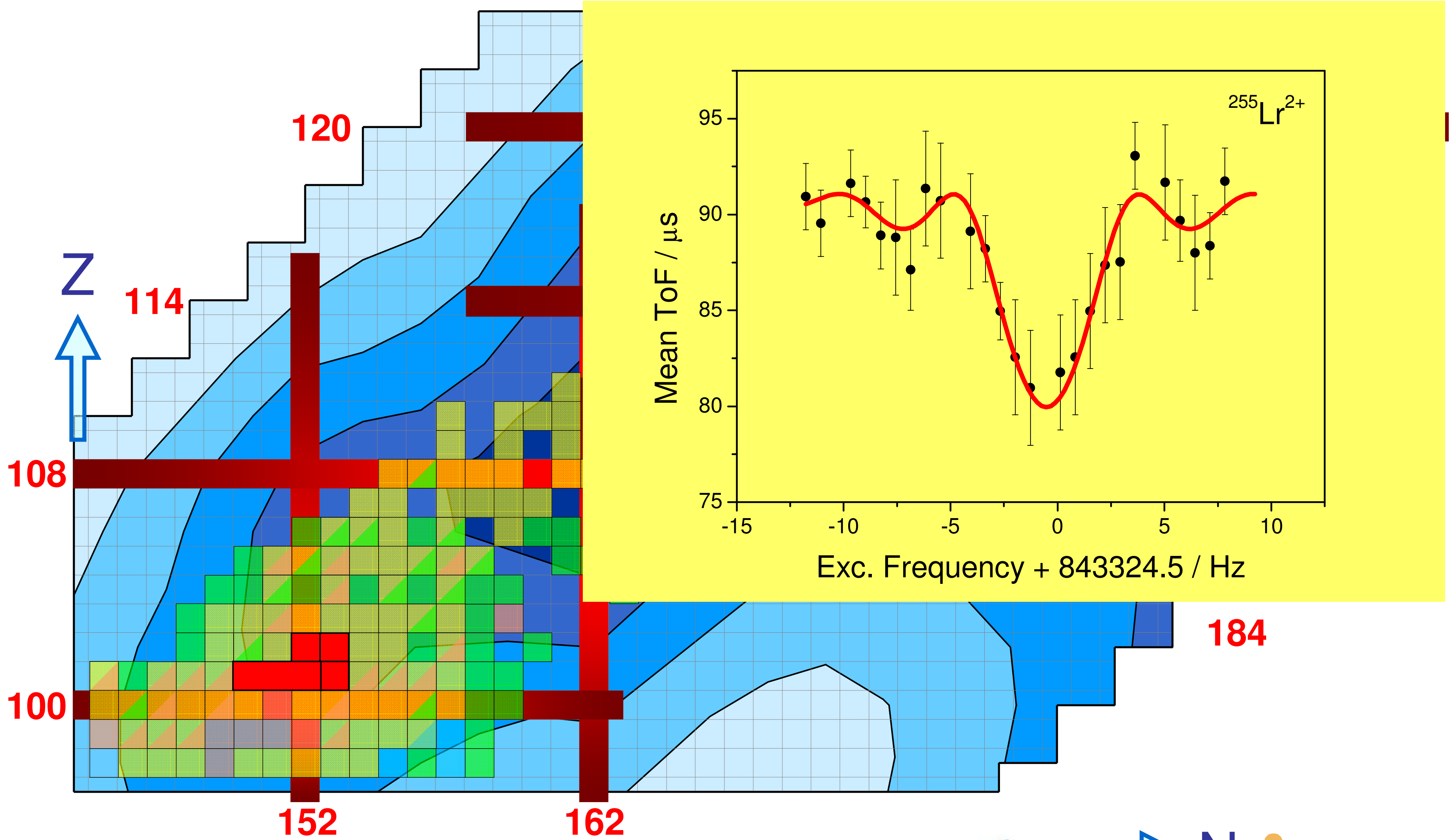
Direct Mass Measurements of $^{252-254}$No



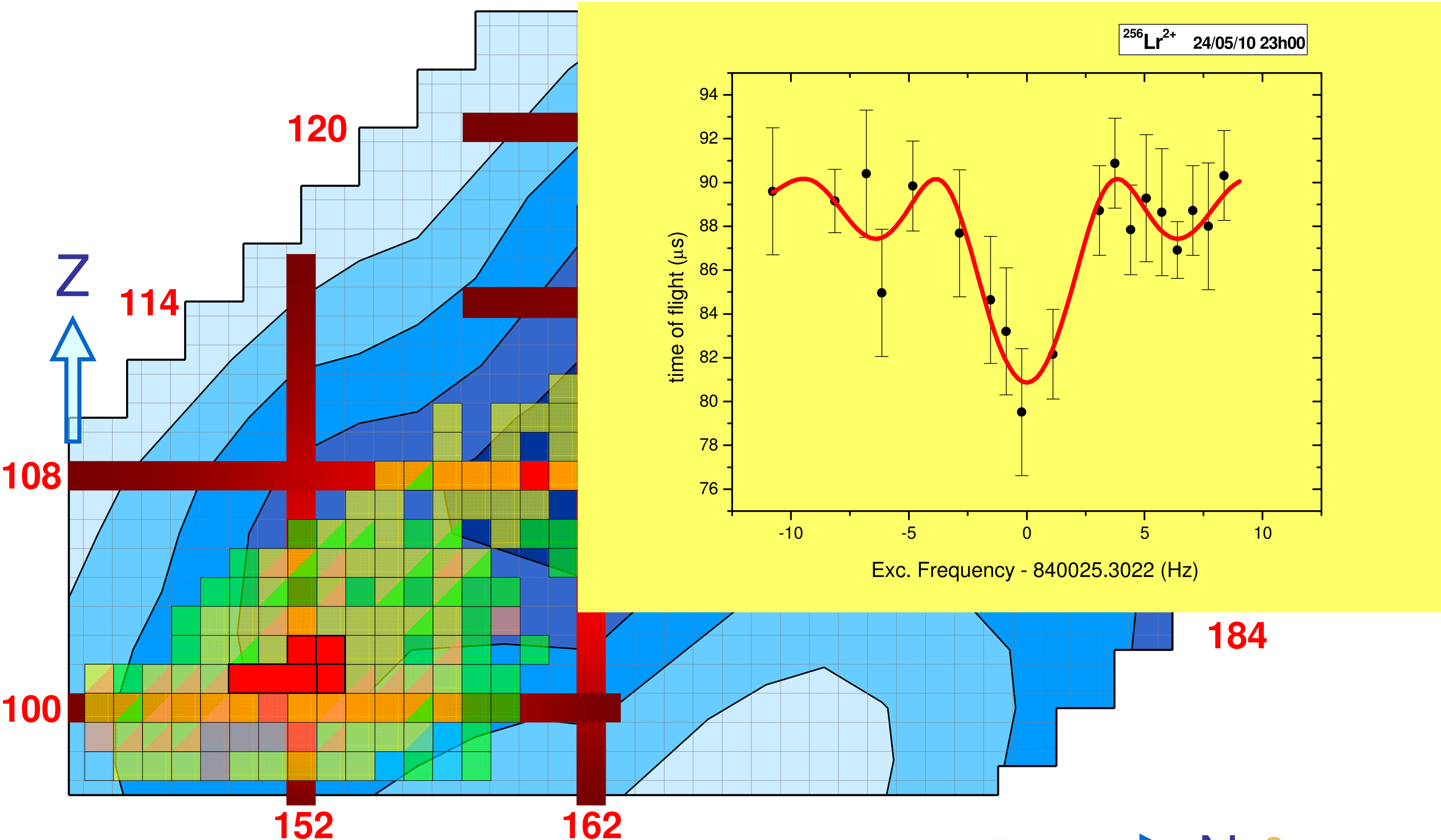
Towards Mass Measurements of SHE



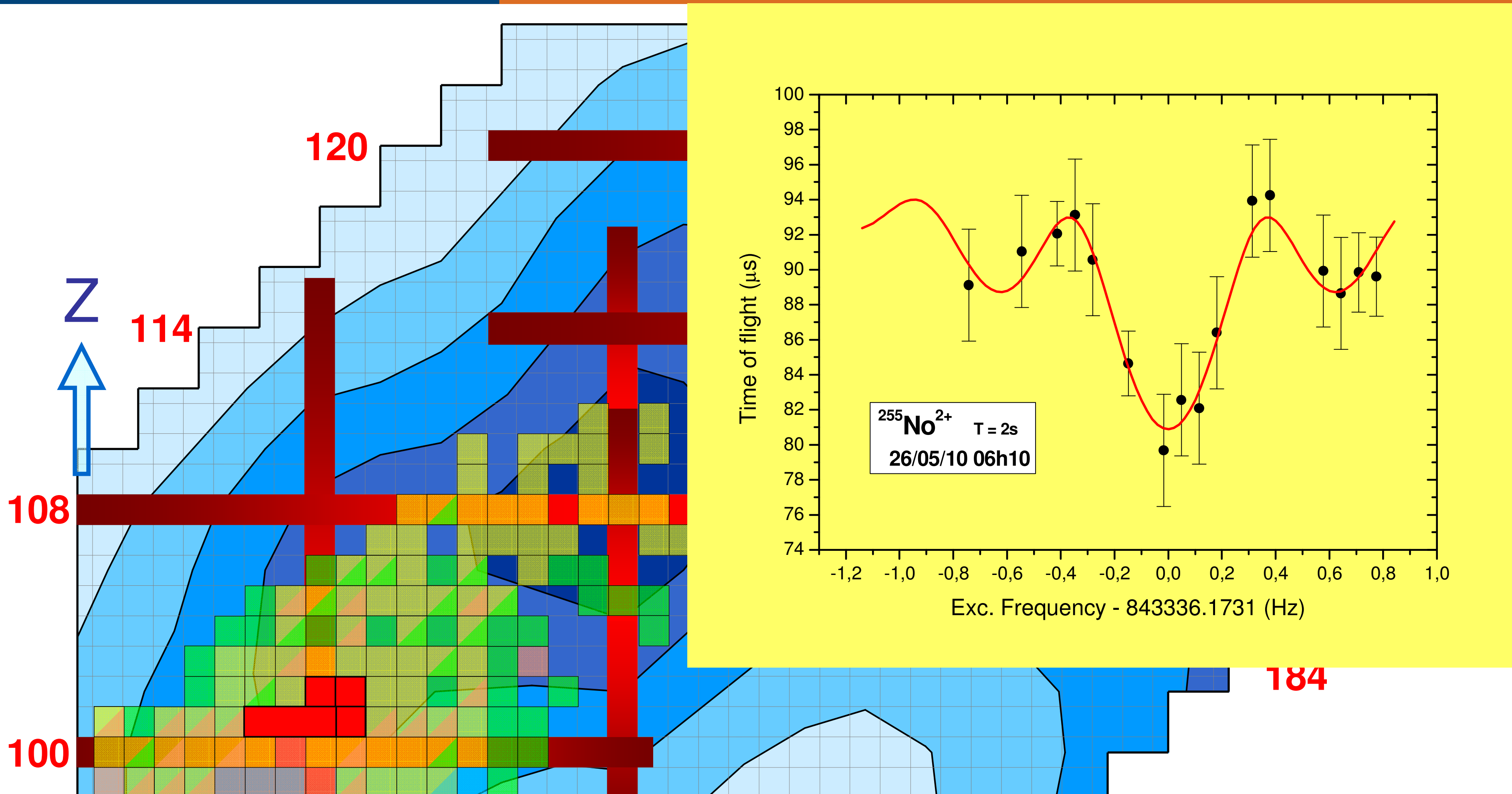
Towards Mass Measurements of SHE



Towards Mass Measurements of SHE

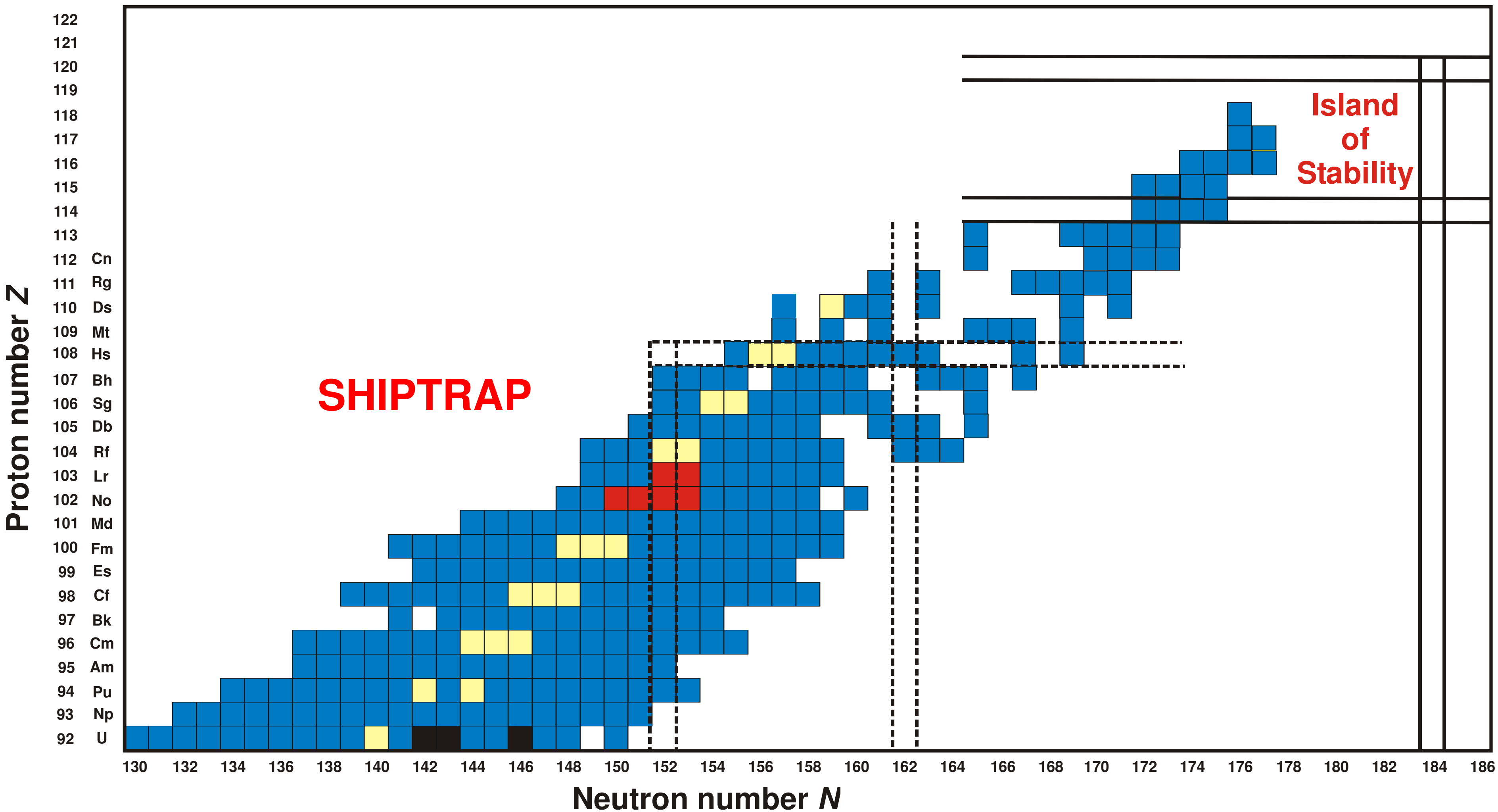


Towards Mass Measurements of SHE



- ^{256}Lr radionuclide with lowest yield ever measured in a Penning trap (2 ions/minute)

Direct Mass Measurements above Uranium



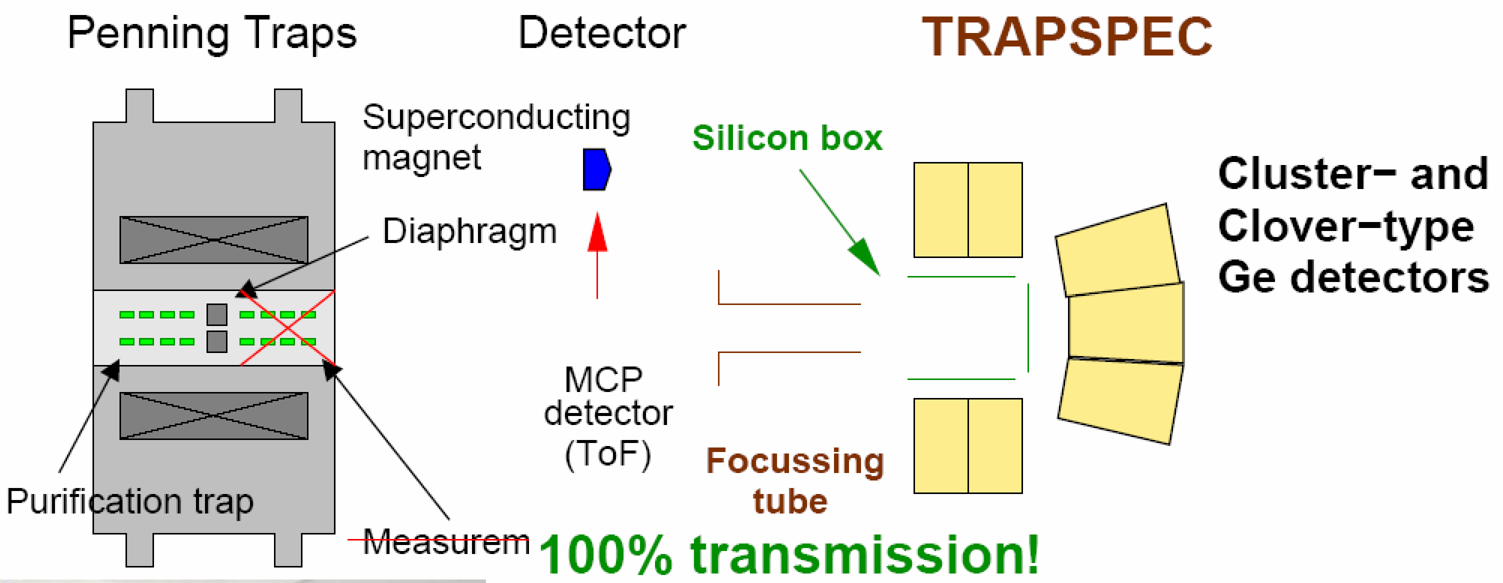
TRAPSPEC: Trap-assisted Spectroscopy

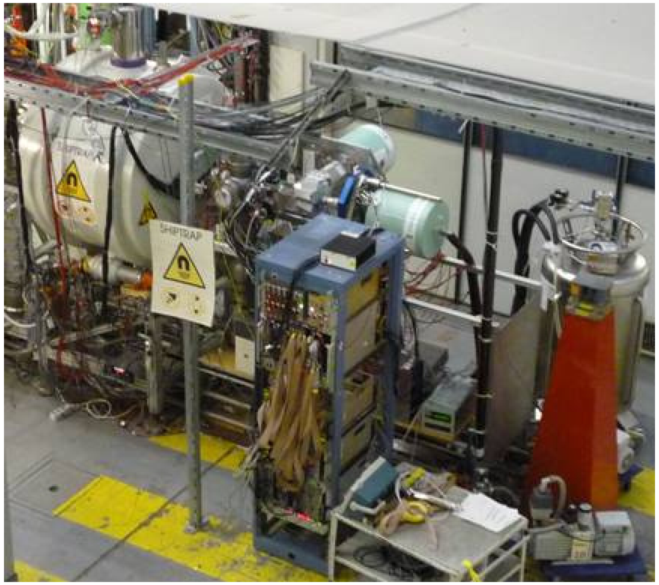
Idea: use Penning traps as high-resolution mass separator for isotope-selected decay spectroscopy

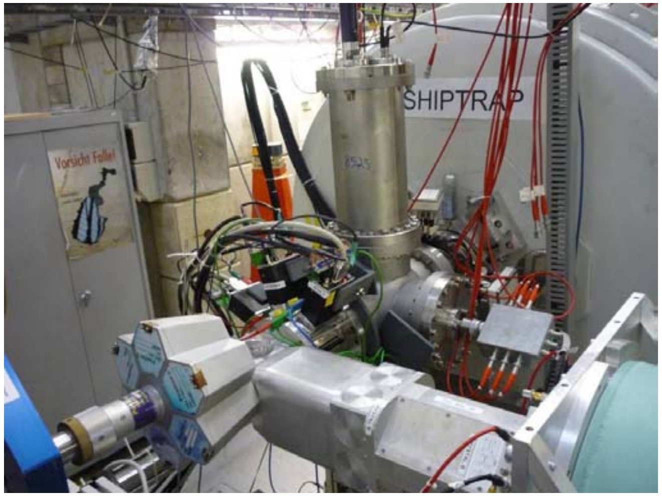
Benefits:

- clean spectra
- detailed nuclear structure information in one experiment
- great potential for studies of isomers
- future option for SHE identification

TRAPSPEC: Trap-assisted Spectroscopy

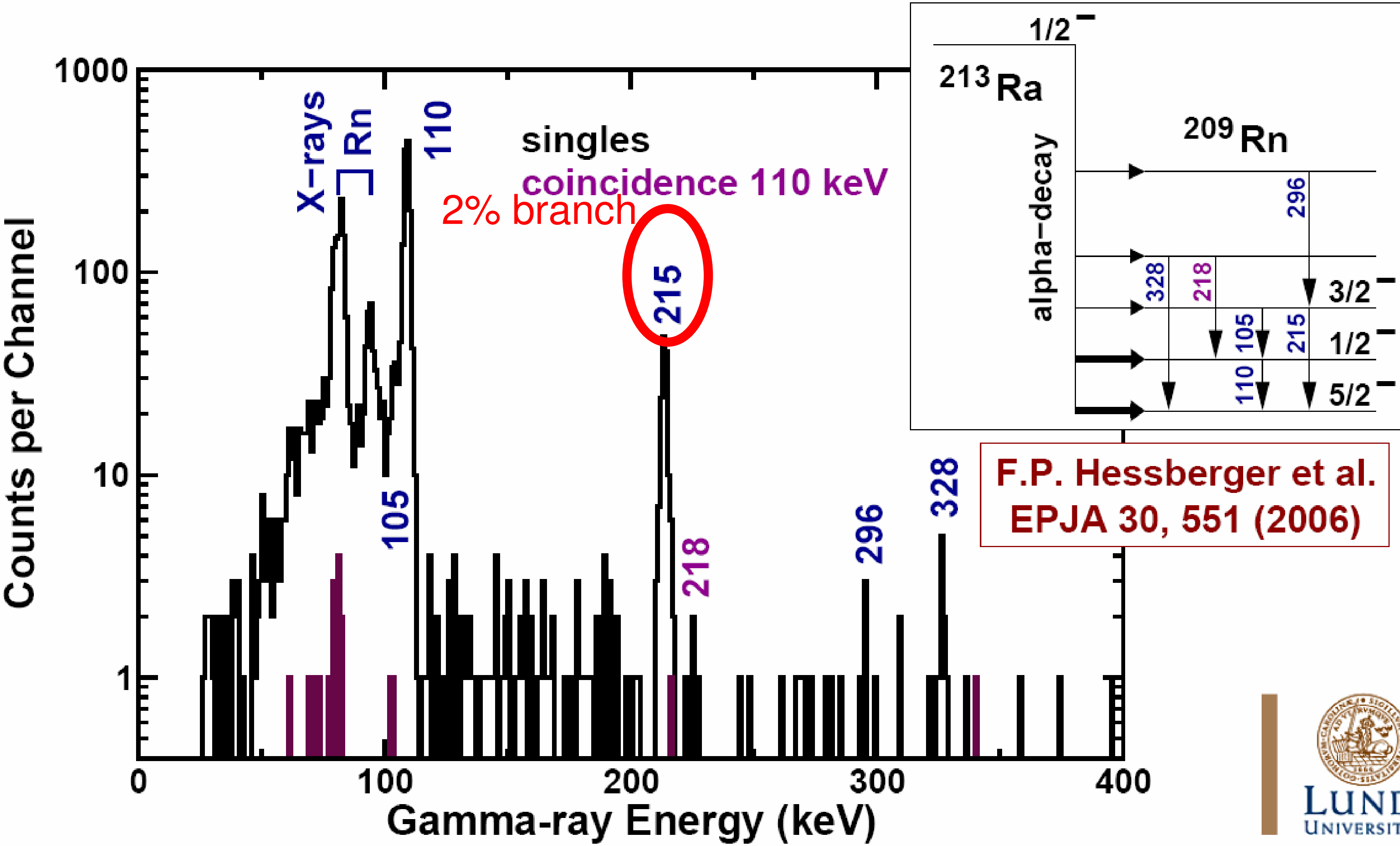






M. B.
D. Rudolph
et al.

TRAPSPEC Commissioning

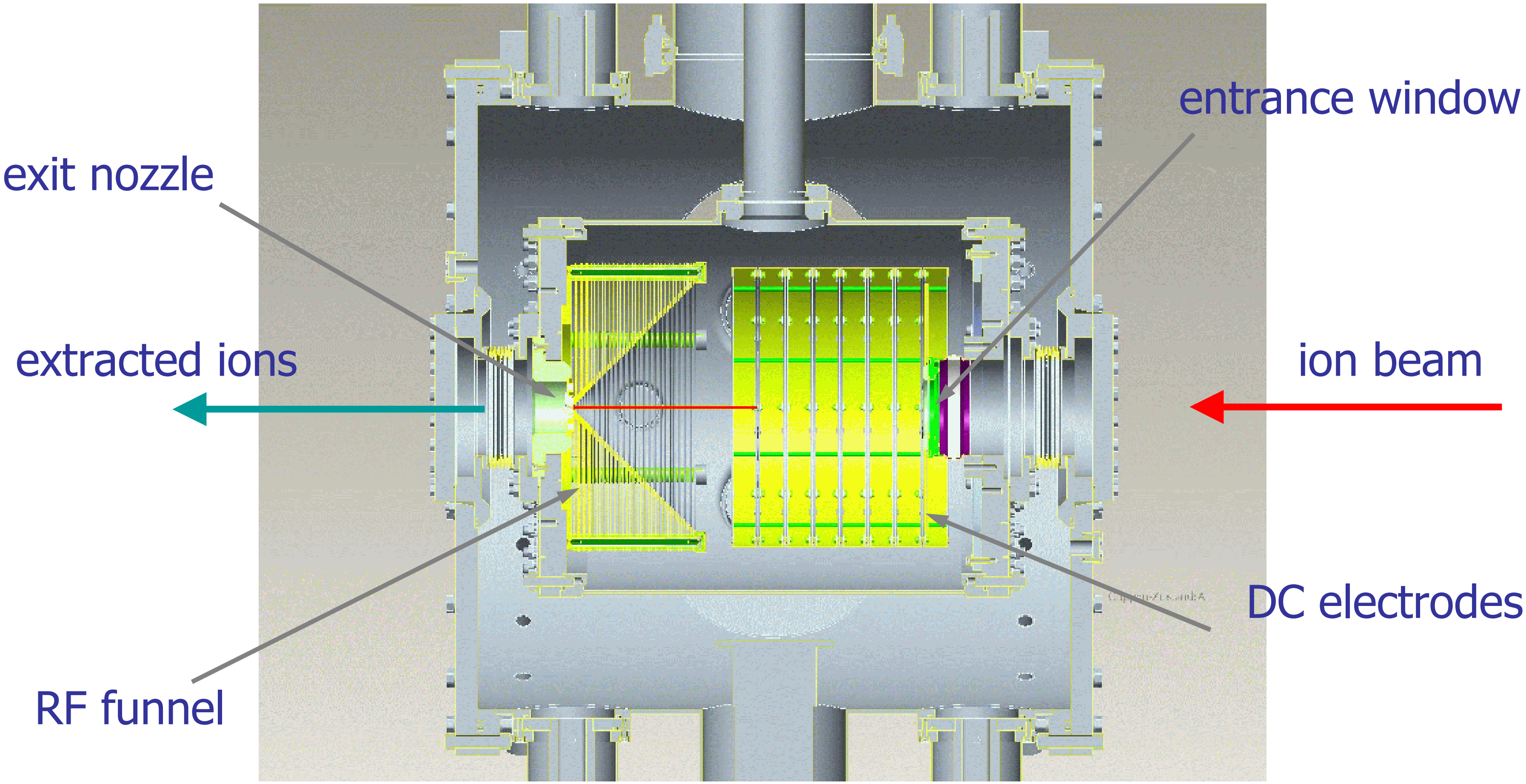


F.P. Hessberger et al. EPJA 30, 551 (2006)

LUND UNIVERSITY

ASSOCIATION

Conceptual design of a cryogenic gas stopper



Summary and Outlook

- first direct mass measurements above uranium performed
- high-precision mass measurements of stopped rare isotopes with production rates of only 1 per minute demonstrated
- opened the door for novel experiments with heavy elements
- trap-assisted decay spectroscopy successfully established at SHIPTRAP
- technical developments and new techniques will pave the way towards heavier elements $Z > 104$

Thank you for your attention !

The SHIPTRAP collaboration 2010

GSI

HELMHOLTZ | Institut Mainz

LUND UNIVERSITY

LMU

Max-Planck-Institut für Kernphysik

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

ugr Universidad de Granada

JG|U JOHANNES GUTENBERG UNIVERSITÄT MAINZ

HELMHOLTZ | ASSOCIATION

GSI