

ILIMA Project: storage-ring isomers, lifetimes and masses

single ion => mass => isomer/isotope discovery

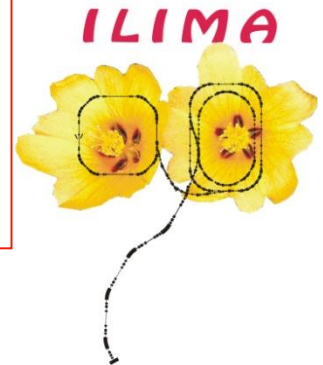
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Saitama, Japan: T. Suzuki, T. Yamaguchi
Tsukuba, Japan: A. Ozawa
RIKEN, Japan: T. Uesaka
ANU Canberra, Australia: M.W. Reed
Jammu, India: R. Devi

ILIMA Collaboration

114 scientists
 36 institutes
 20 countries



Experimental Storage Ring (ESR) at GSI



ESR at GSI

other on-line rings:

CSRe at Lanzhou

Rare RI-Ring at RIKEN

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ESR at GSI

other on-line rings:

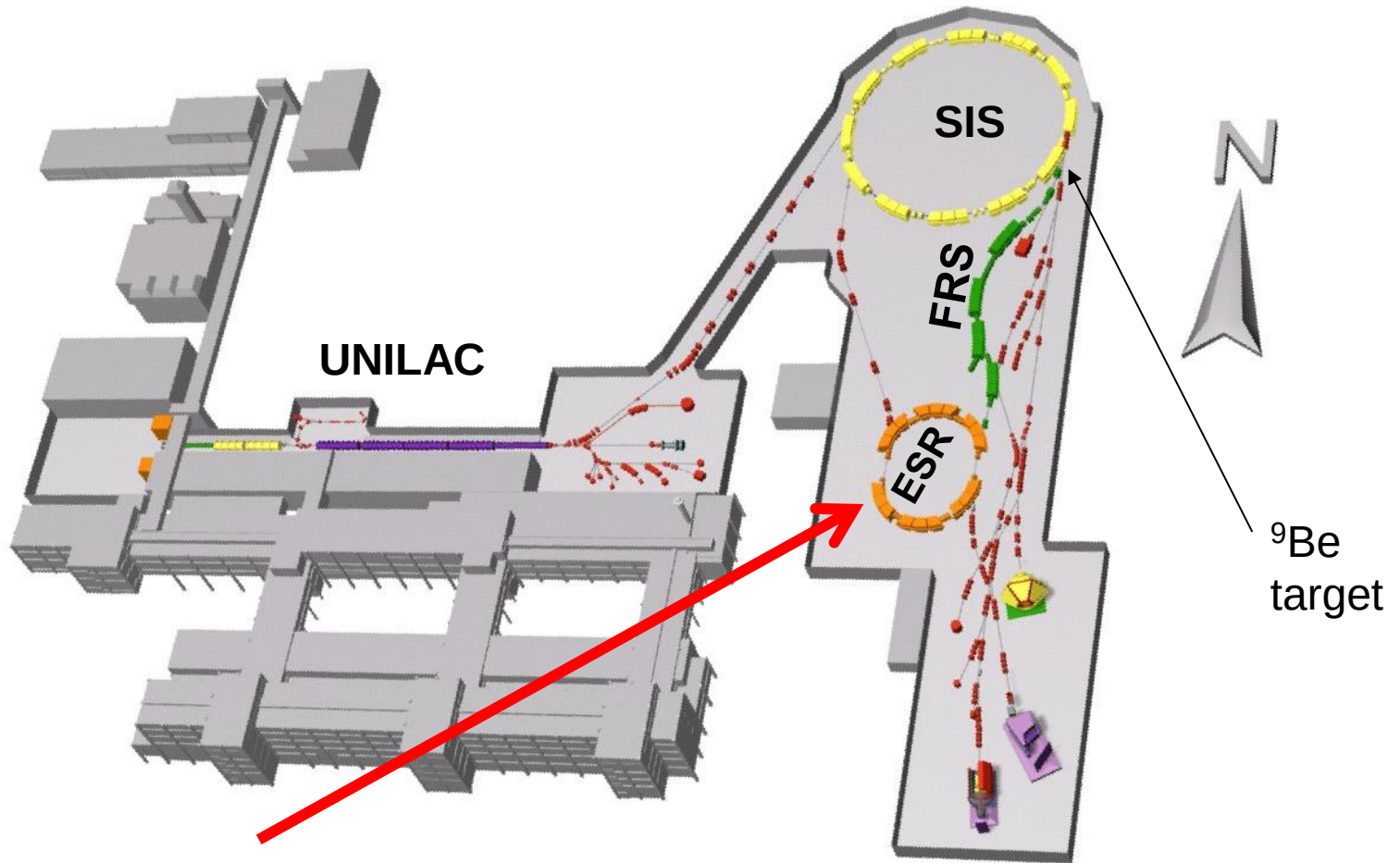
CSRe at Lanzhou

Rare RI-Ring at RIKEN

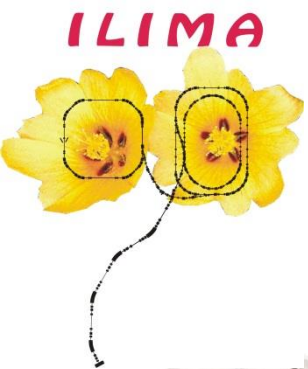


ILIMA at FAIR

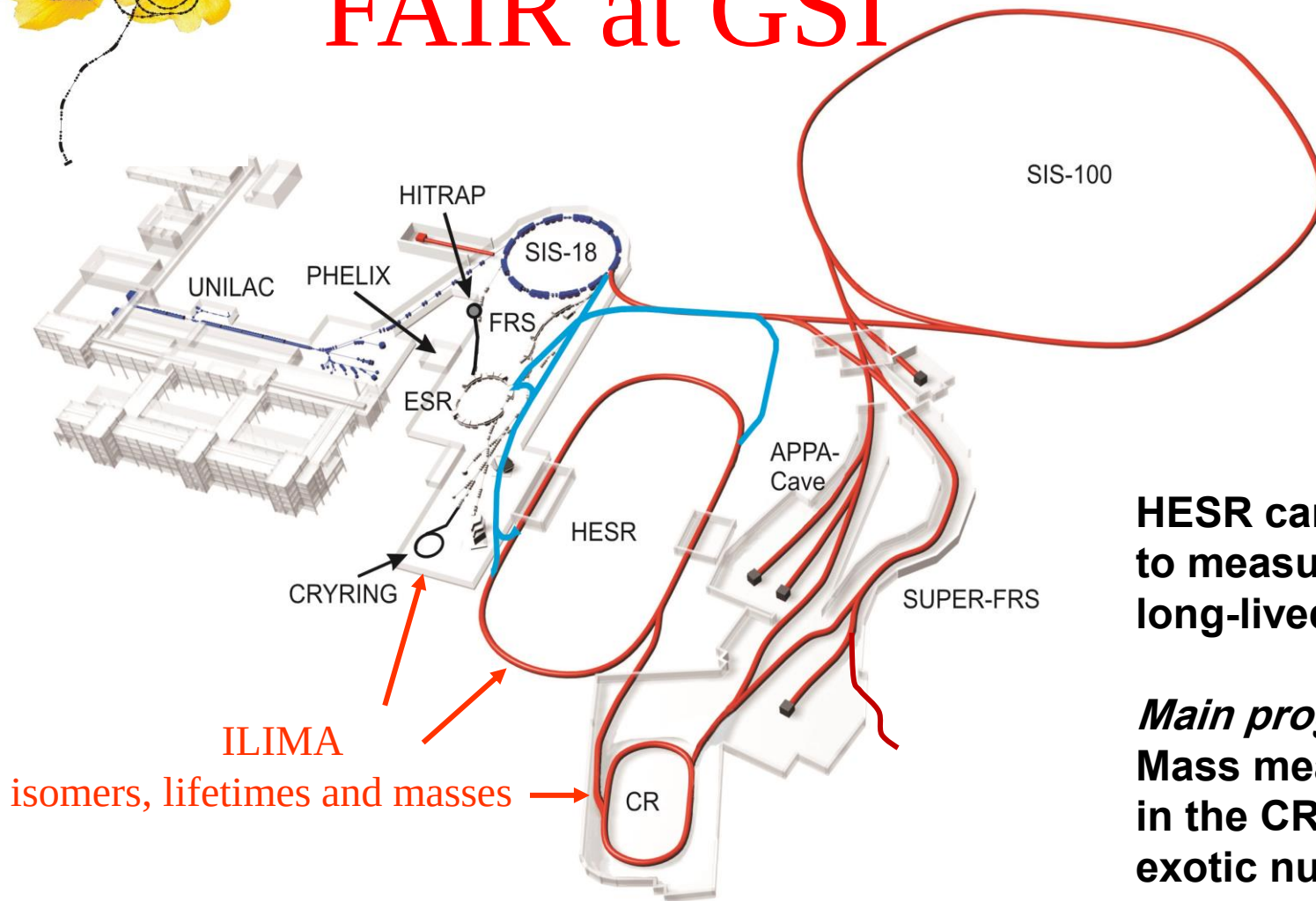
GSI accelerator complex



Experimental Storage Ring (ESR)



FAIR at GSI

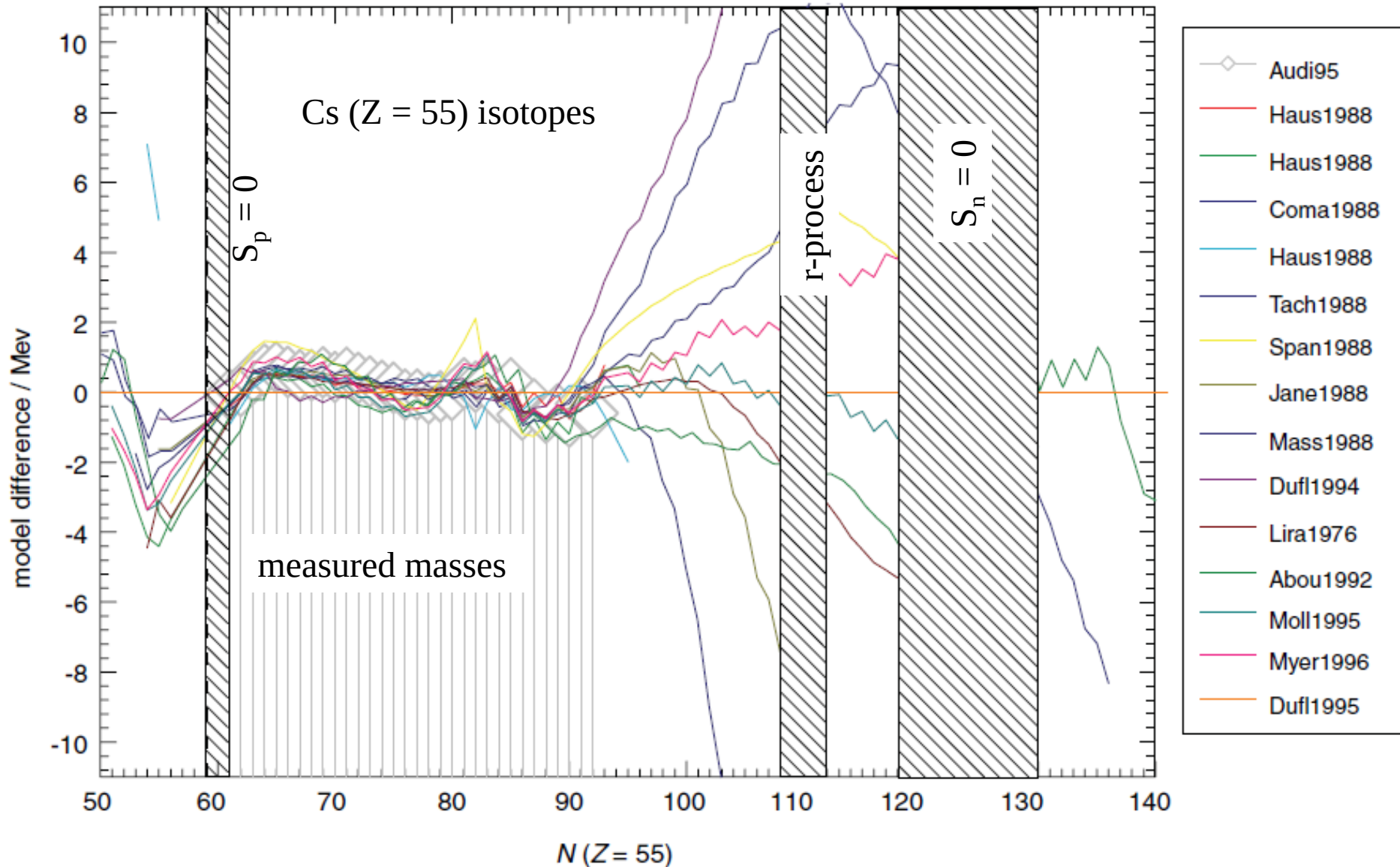


HESR can be employed to measure lifetimes of long-lived nuclides.

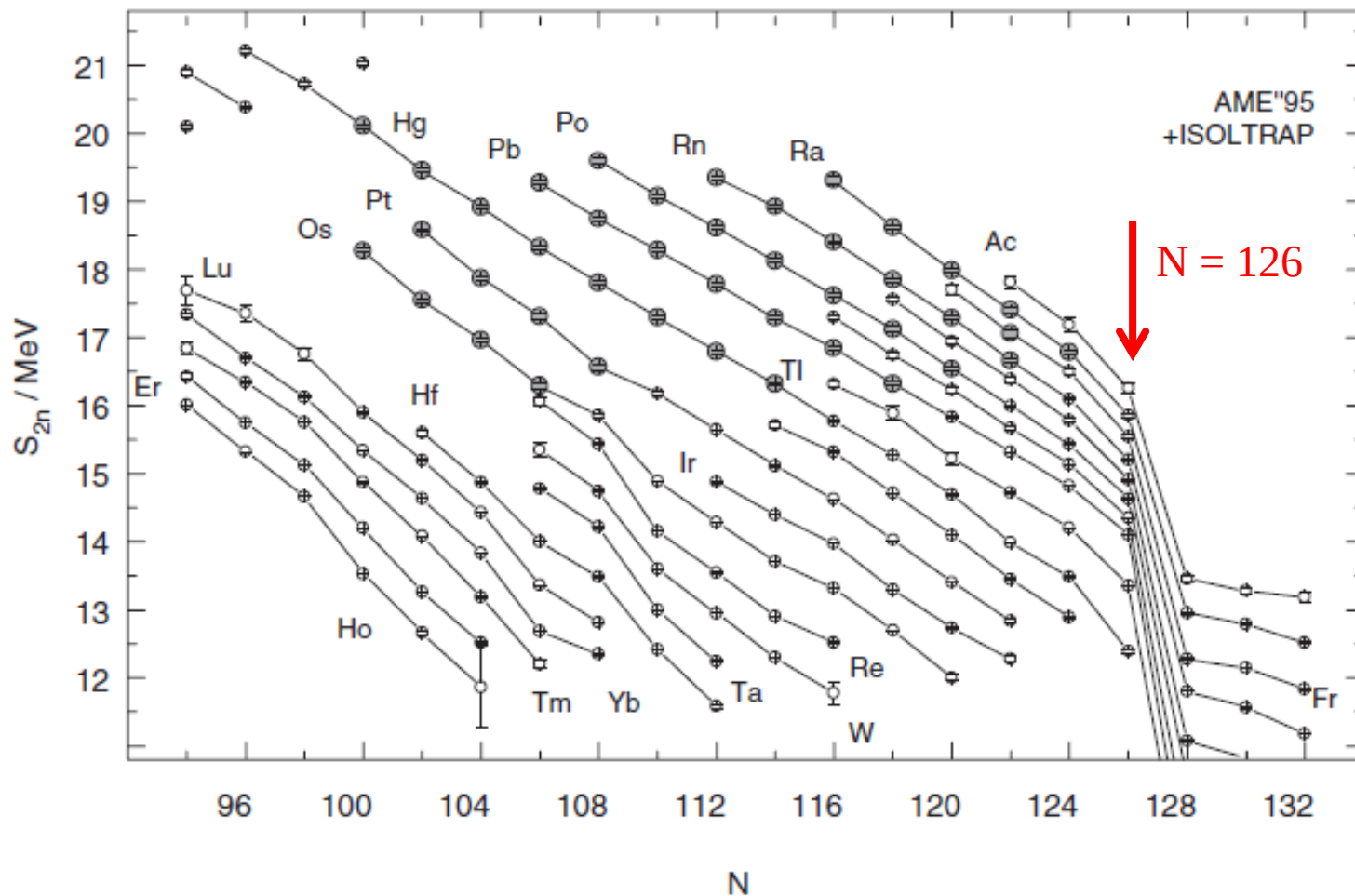
Main programme:
Mass measurements in the CR for short-lived exotic nuclei.

*Walker, Litvinov and Geissel,
Int. J. Mass Spec. 349-350 (2013) 247*

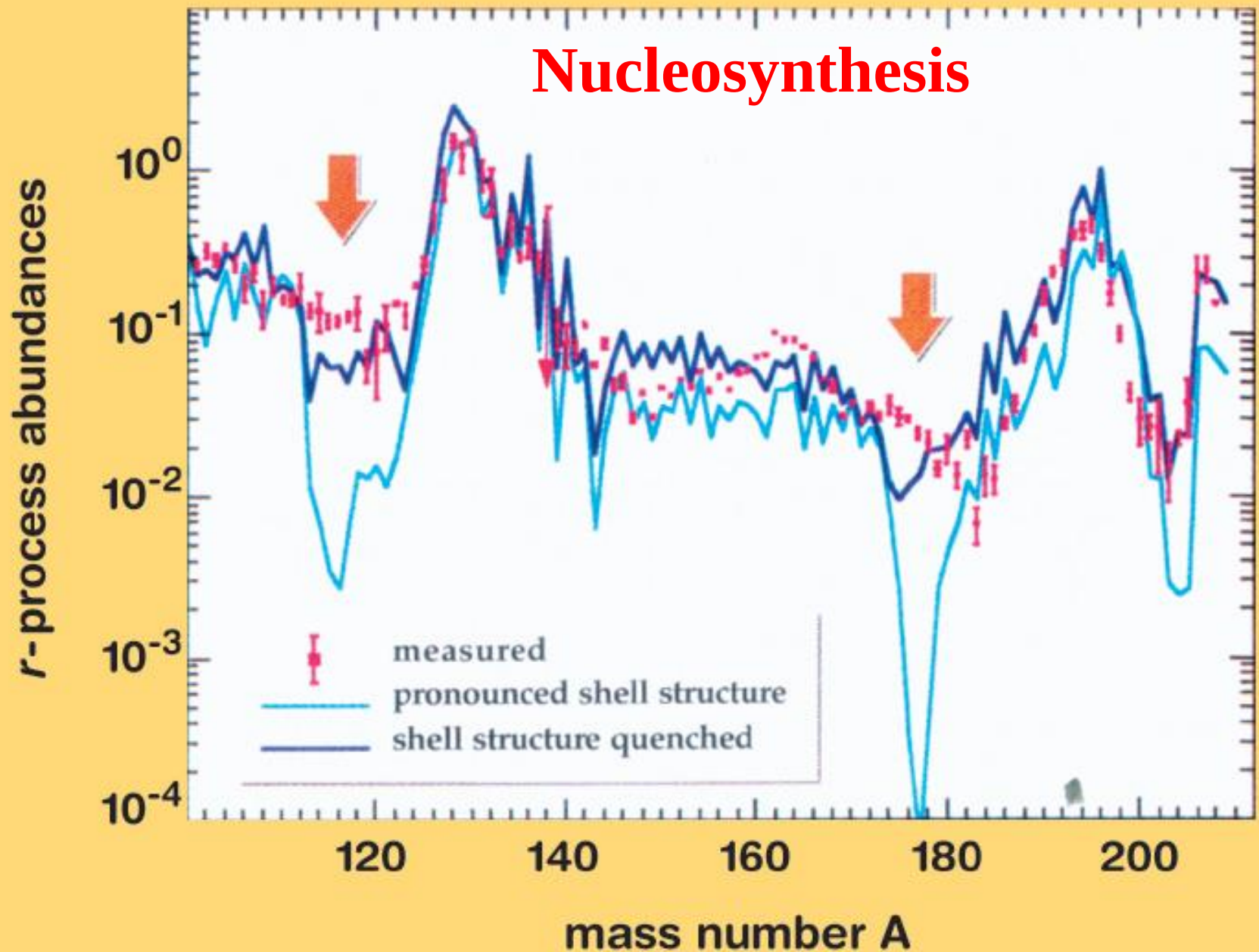
mass model differences

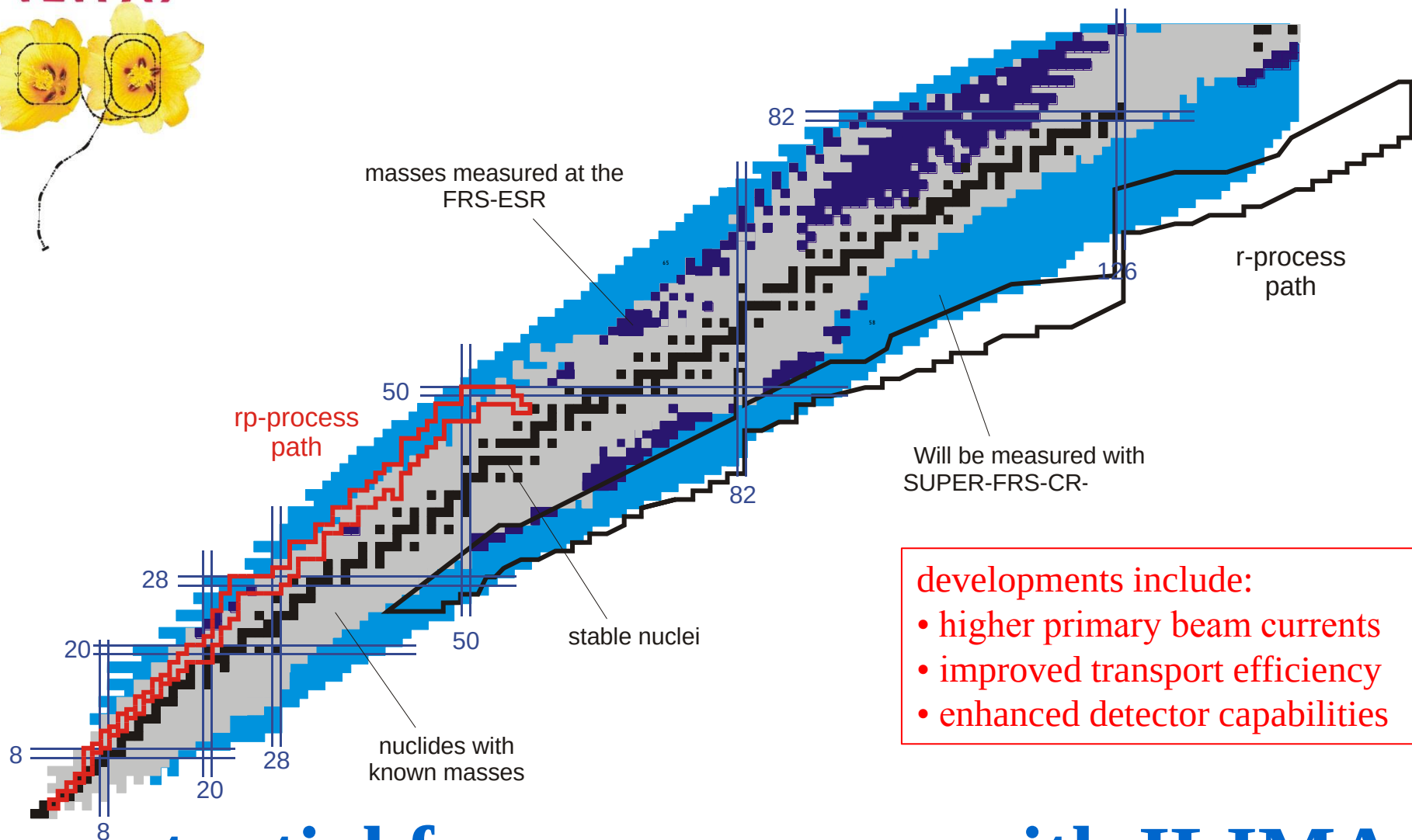


2-neutron separation energies



Nucleosynthesis





⁸potential for new masses with ILIMA

Walker, Litvinov and Geissel,
Int. J. Mass Spec. 349-350 (2013) 247

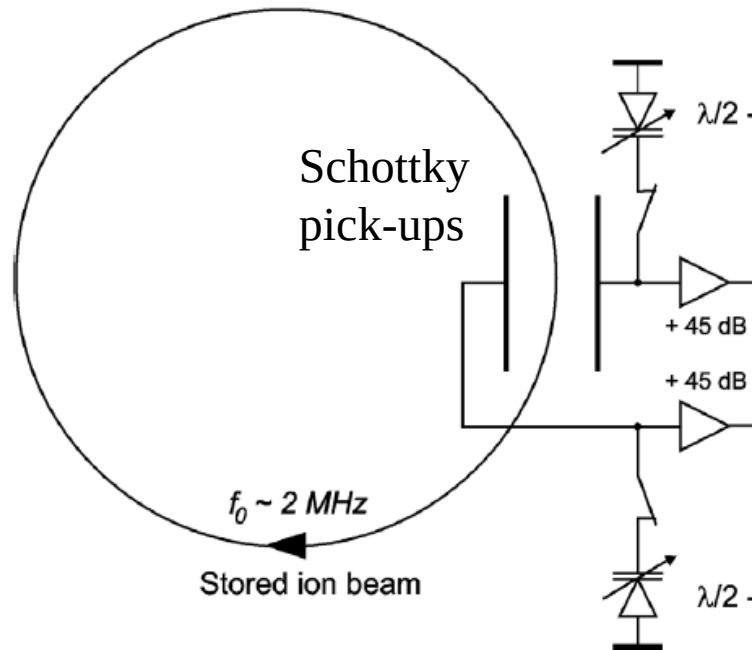
SMS and IMS

mass measurements

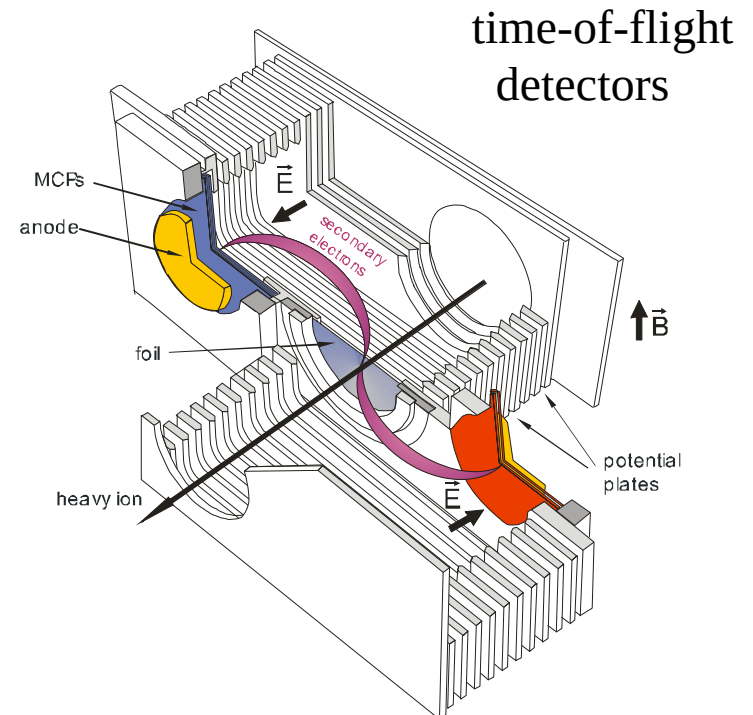
both methods have single-ion sensitivity

resolving power $\sim 10^6$ accuracy $\sim 30 \mu u$, i.e. $\sim 30 \text{ keV}$

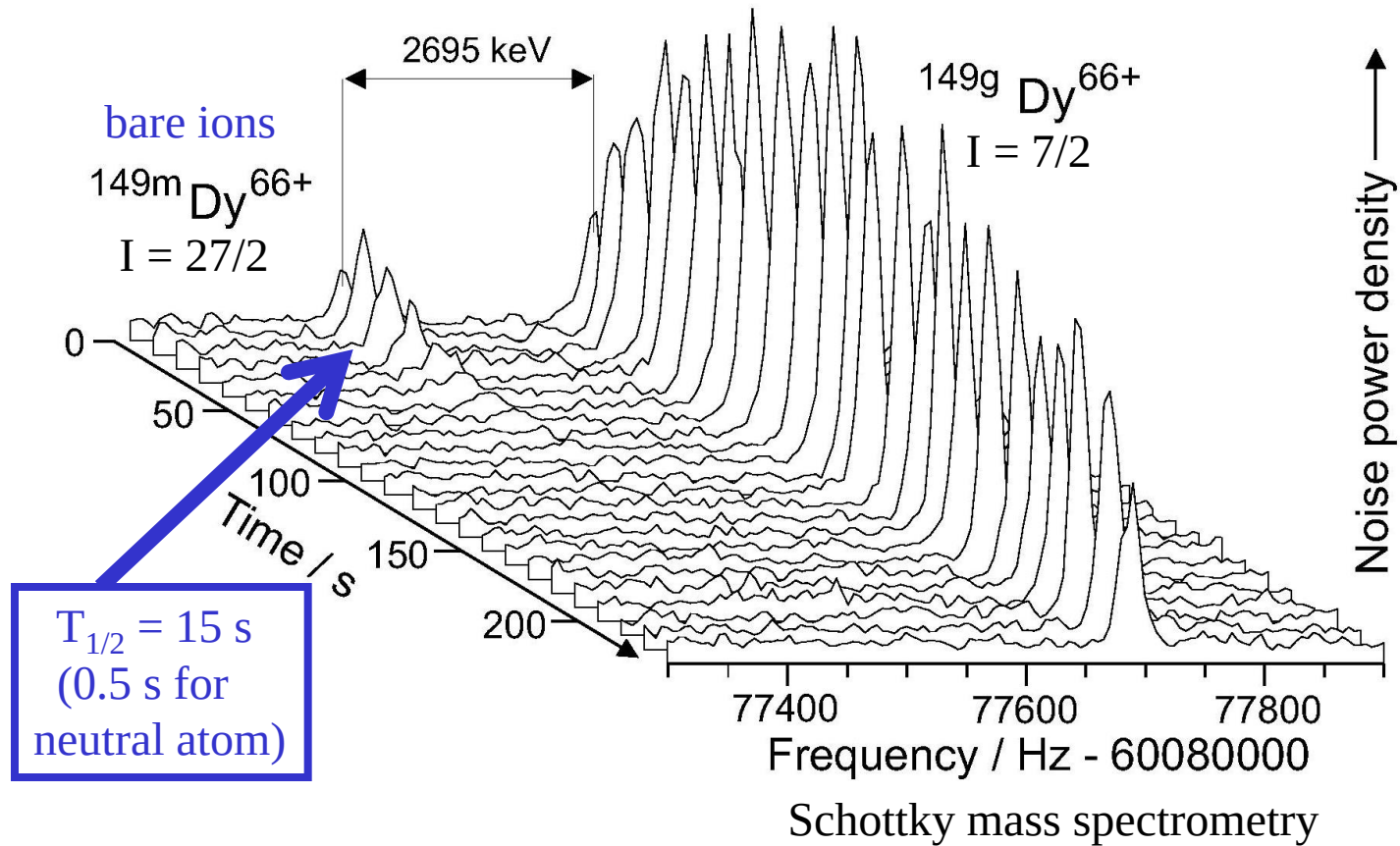
Schottky Mass Spectrometry
(with cooling): $T_{1/2} > 1 \text{ s}$



Isochronous Mass Spectrometry: $T_{1/2} > 10 \mu s$

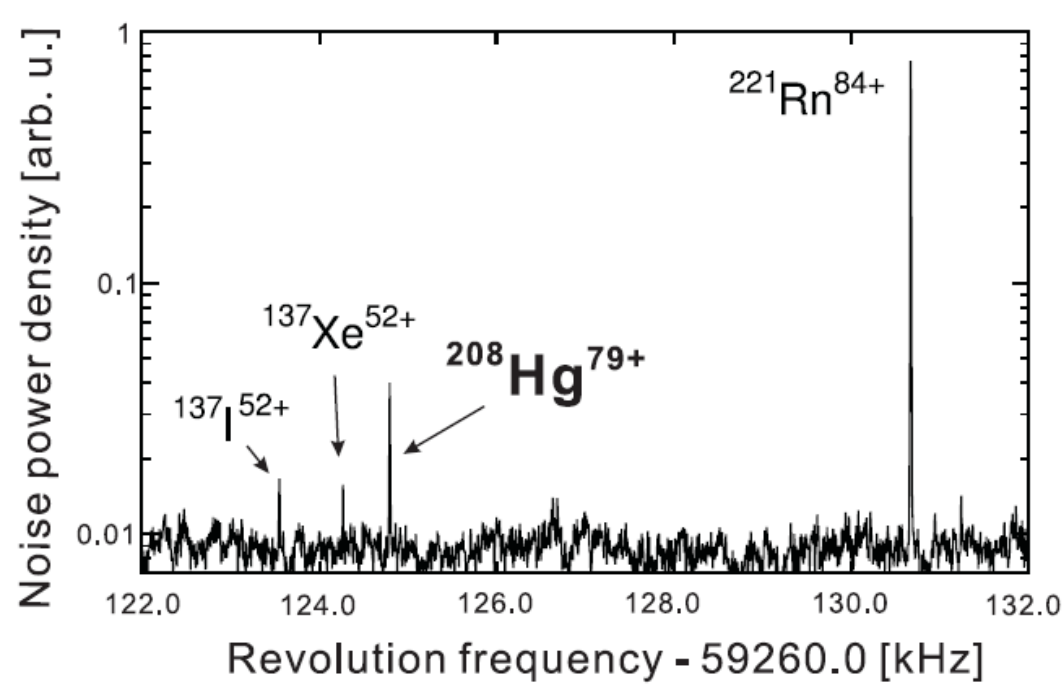


$^{149m+g}\text{Dy}$ in the ESR



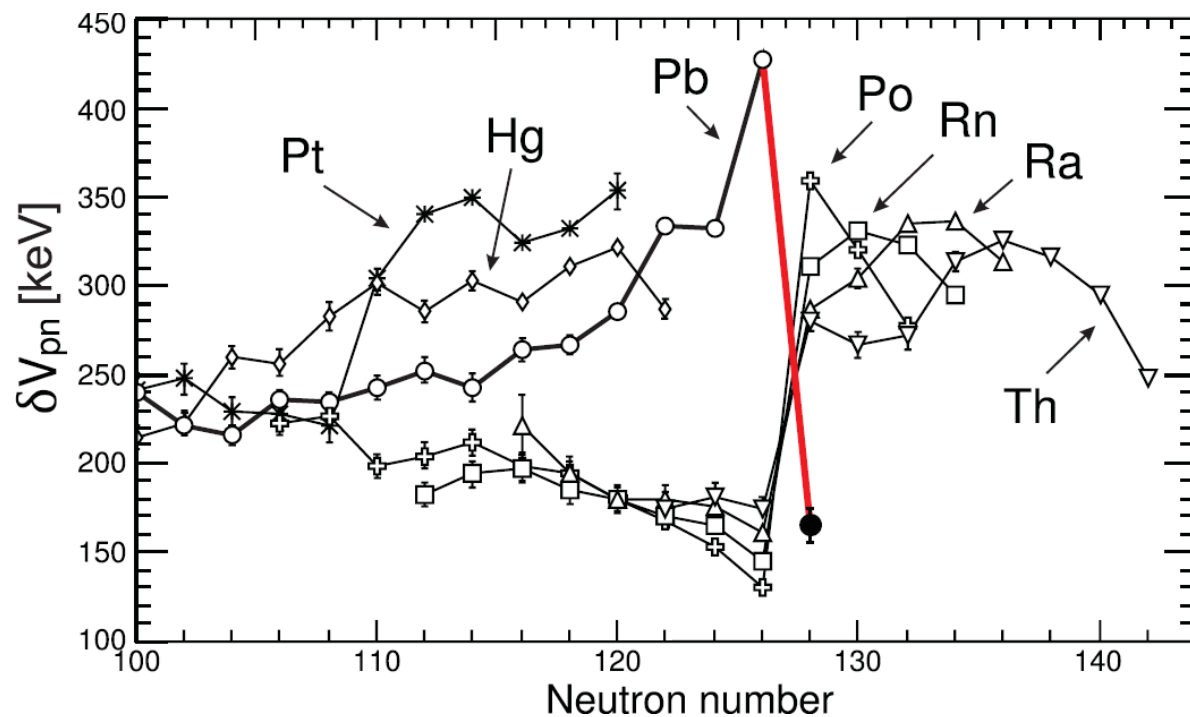
Litvinov et al., Phys. Lett. B573 (2003) 80

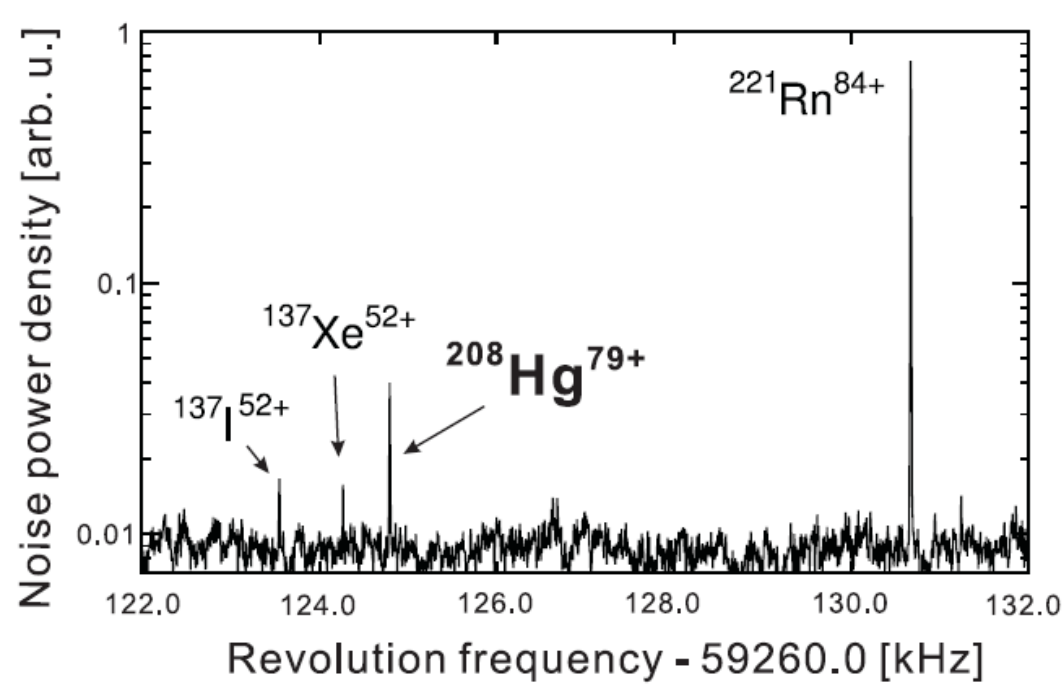
[isomers up to $I = 55/2$ seen in fragmentation:
Denis Bacelar et al., Phys. Lett. B723 (2013) 302]



neutron-proton
interactions
from ^{208}Hg mass

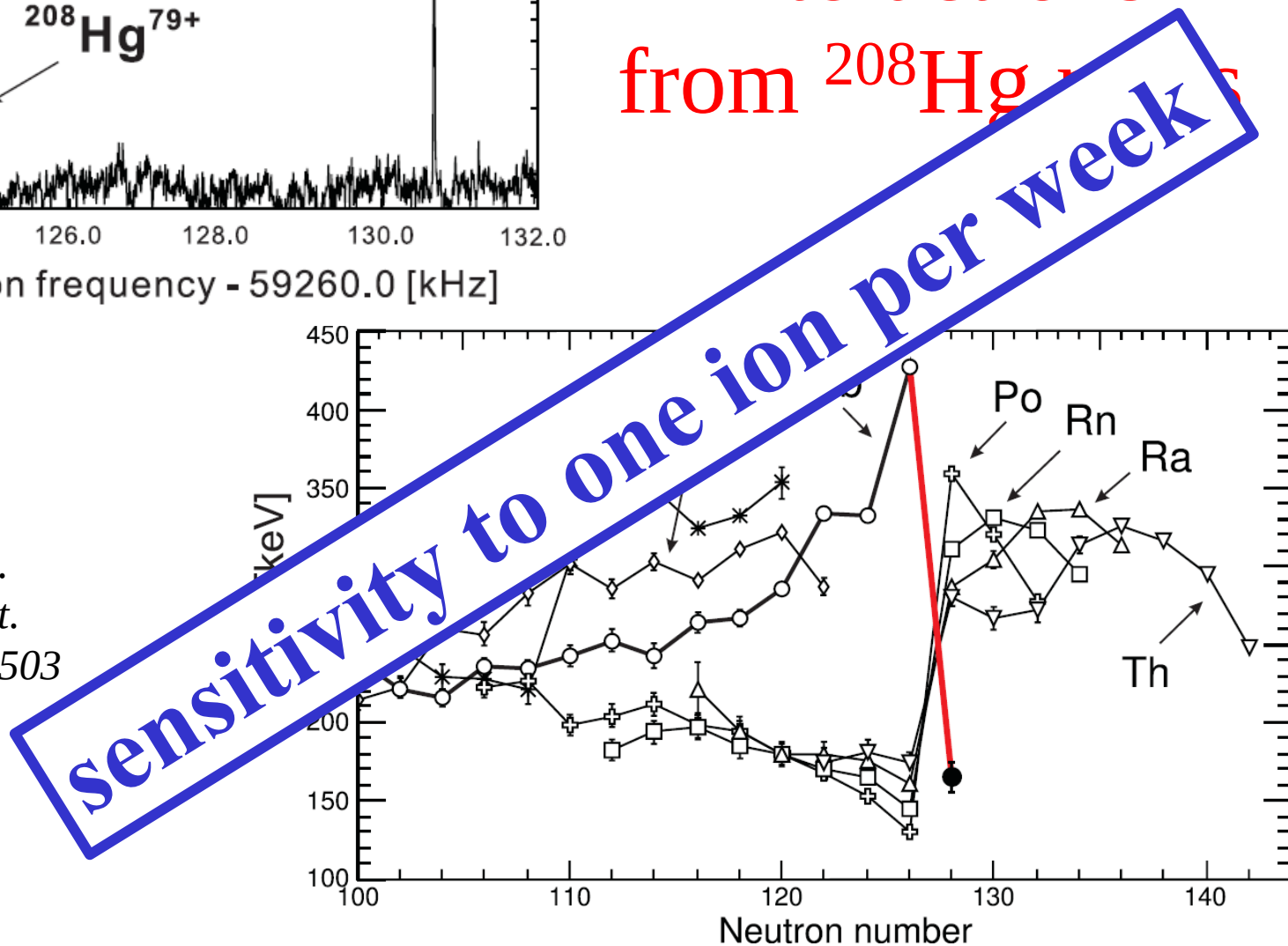
L. Chen et al.
Phys. Rev. Lett.
102 (2009) 122503





neutron-proton
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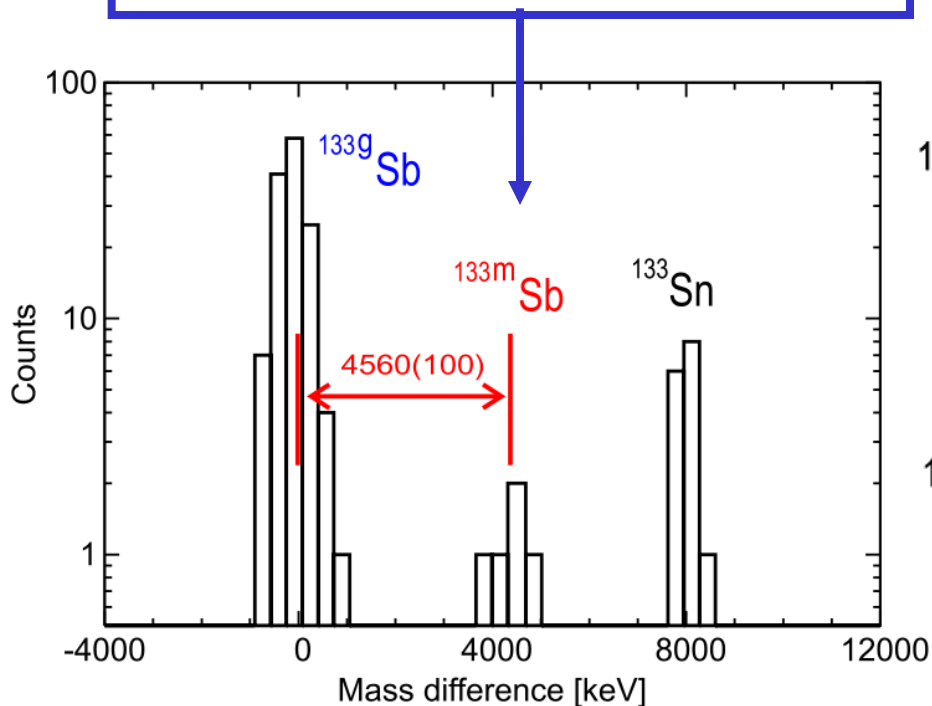
L. Chen et al.
Phys. Rev. Lett.
102 (2009) 122503



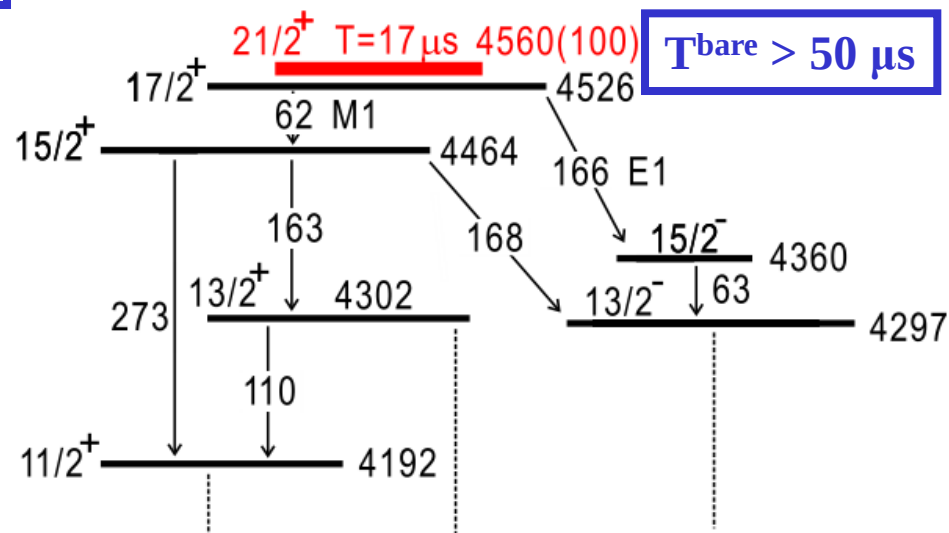
sensitivity to one ion per week

Shell-model isomer in n-rich ^{133}Sb

- first direct observation of this isomer
- shortest-lived stored ion



^{238}U fission
isochronous mass spectrometry



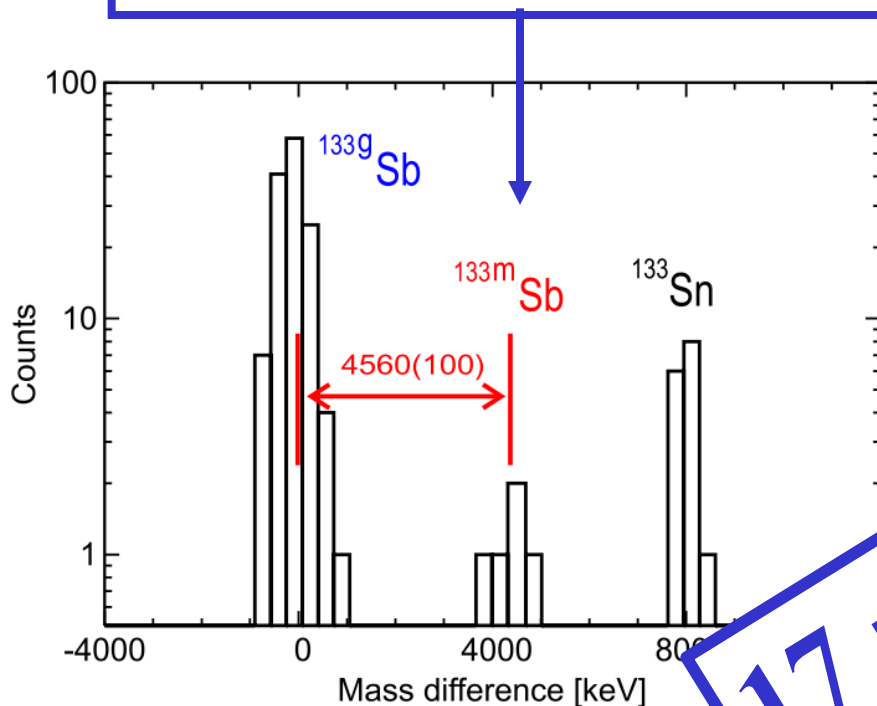
$T_{\text{bare}} > 50 \mu\text{s}$

consistent with shell-model calculations: *Urban et al., Phys. Rev. C62 (2000) 027301*

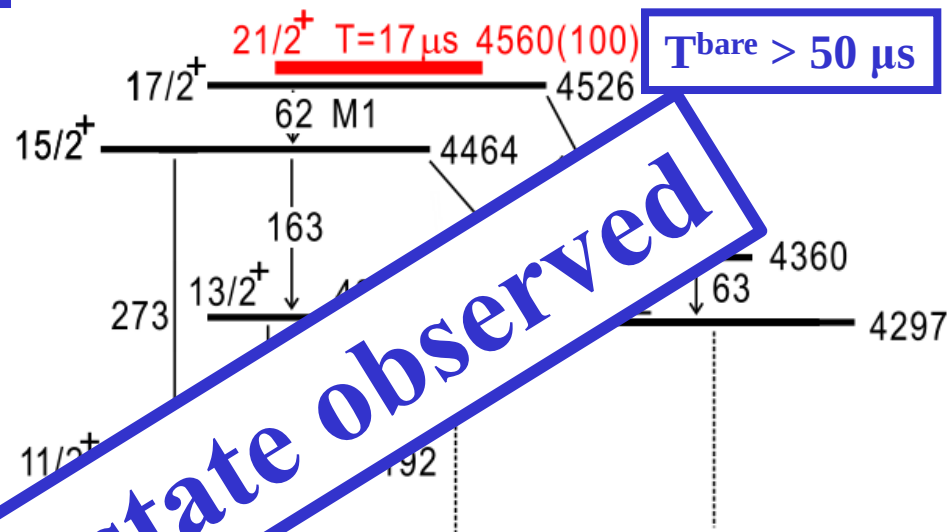
Sun et al., Phys. Lett. B688 (2010) 294

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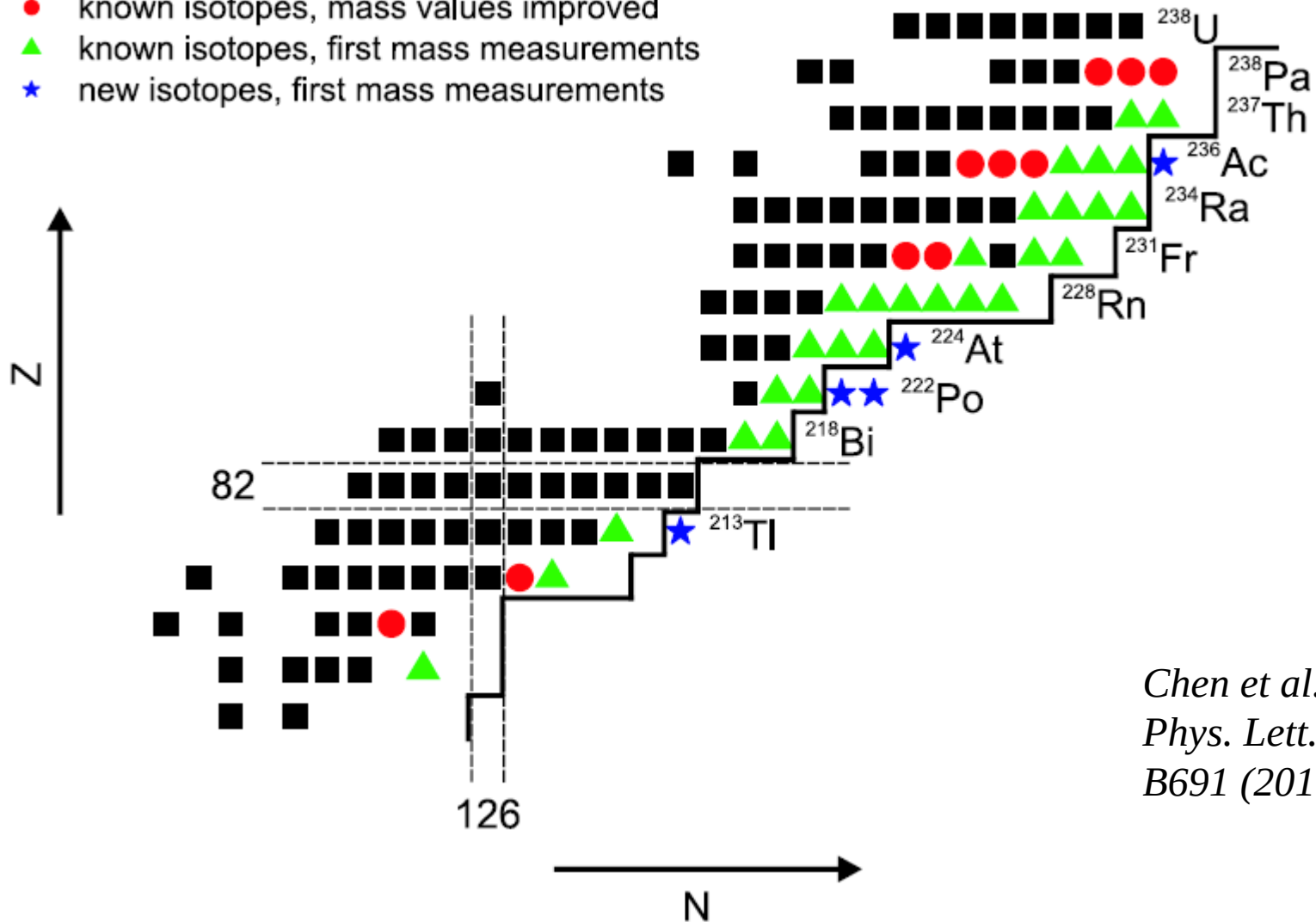
17 μs state observed

consistent with shell-model
calculations: *Urban et al.,
Phys. Rev. C62 (2000) 027301*

Sun et al., Phys. Lett. B688 (2010) 294

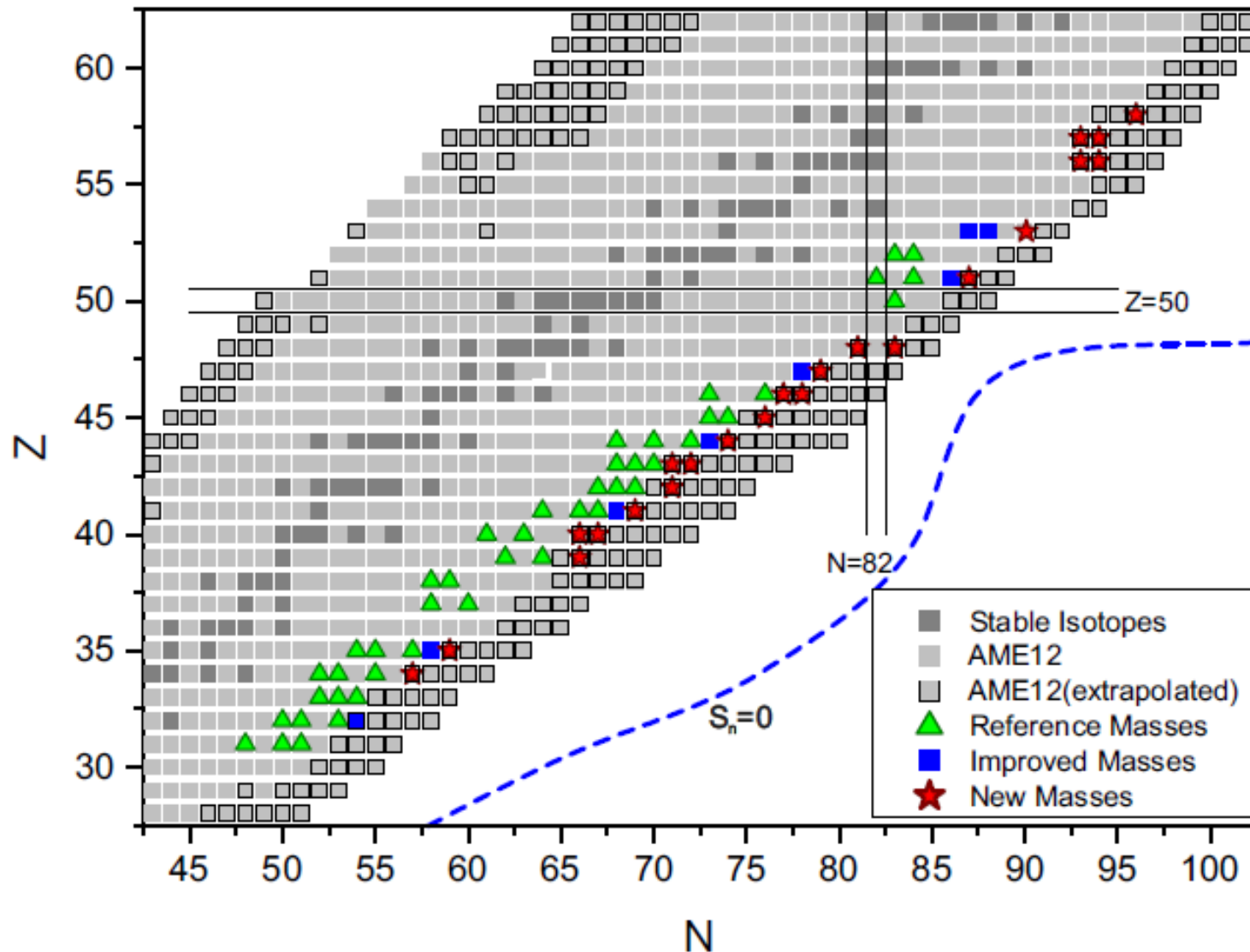
New isotopes (SMS)

- isotopes with well-known masses
- known isotopes, mass values improved
- ▲ known isotopes, first mass measurements
- ★ new isotopes, first mass measurements



Chen et al.,
Phys. Lett.
B691 (2010) 234

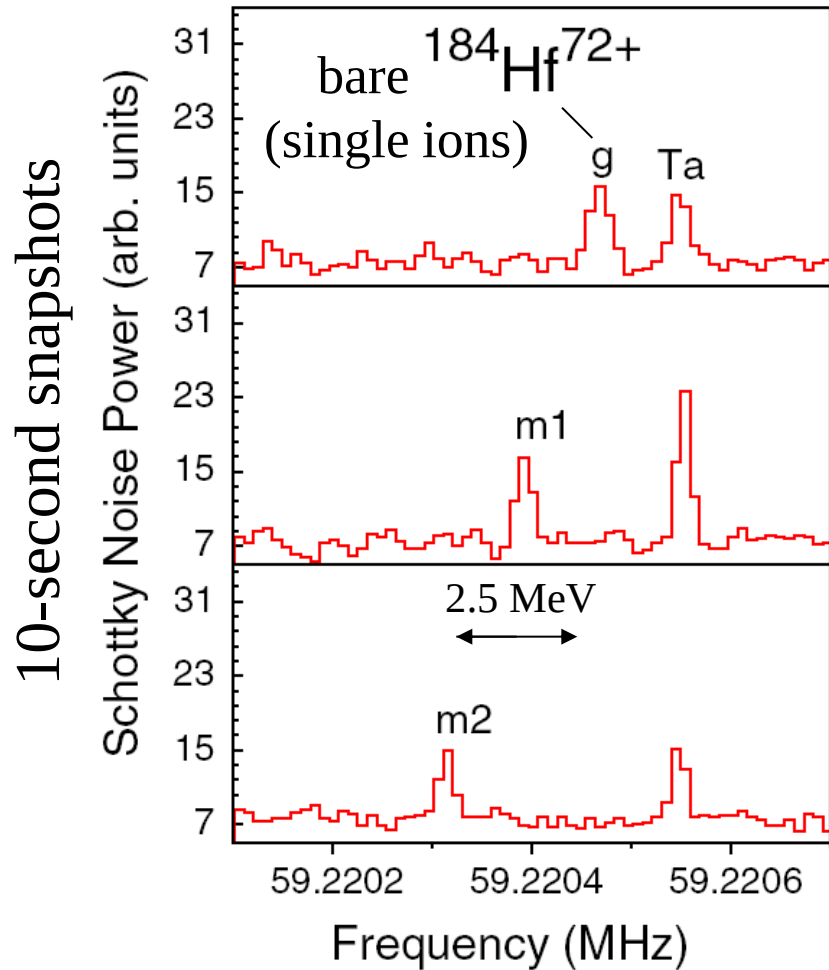
New masses (IMS)



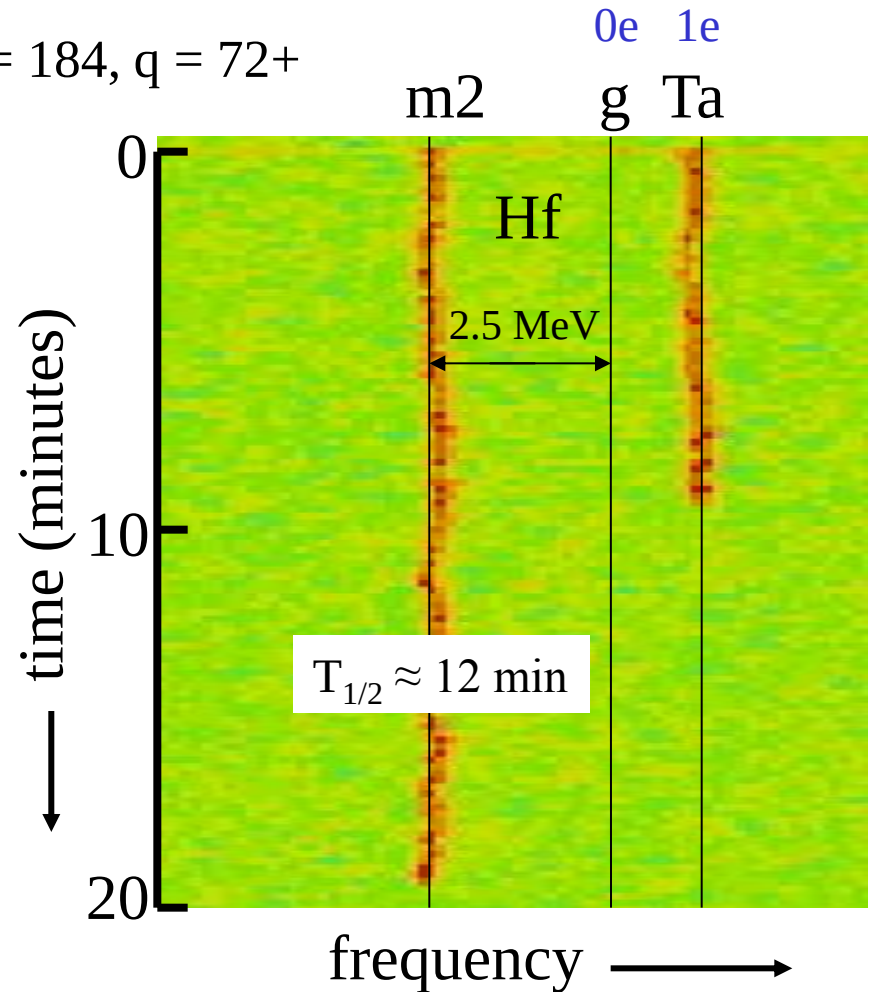
New isomers (e.g. $^{184m2}\text{Hf}$)

- first observation of $m2$ isomer
- long-lived β -decaying isomer

Schottky mass spectrometry ^{197}Au fragmentation



$A = 184, q = 72+$



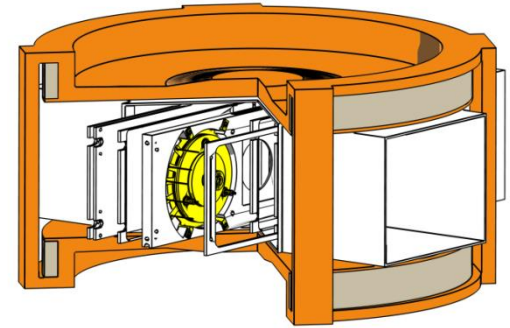


Preparations for ILIMA at FAIR

Design of a Dual TOF Detector System for the CR

Main challenges for new detector:

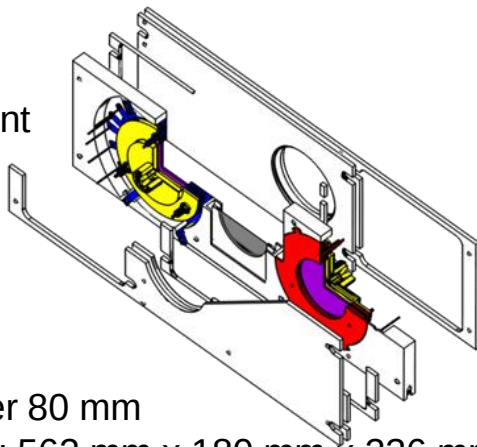
- Active area x 4 required
- Very limited space in the ring
→ scaling up the detector not possible



Achievements:

- Simulations for the CR and the TOF detector
(M.Diwisch PhD Thesis, University Gießen, in preparation; GSI Scientific Report 2012, p. 212)
- Simulated performance of the TOF detector even surpasses the performance parameters of the existing detector
- CAD drawings exist

2 detectors
for velocity
measurement



Foil diameter 80 mm
Dimensions: 562 mm x 180 mm x 236 mm
Electron transport efficiency $\approx 98\%$
Timing accuracy ≈ 35 ps

CR
(two detectors)

slide from Marcel Diwisch (Giessen)

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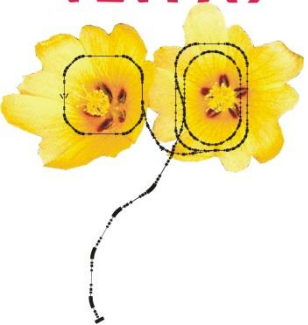
Foil diameter 80 mm
Dimensions: 562 mm x 180 mm x 236 mm
Electron transport efficiency $\approx 98\%$
Timing accuracy ≈ 35 ps

two detectors, each x4 area

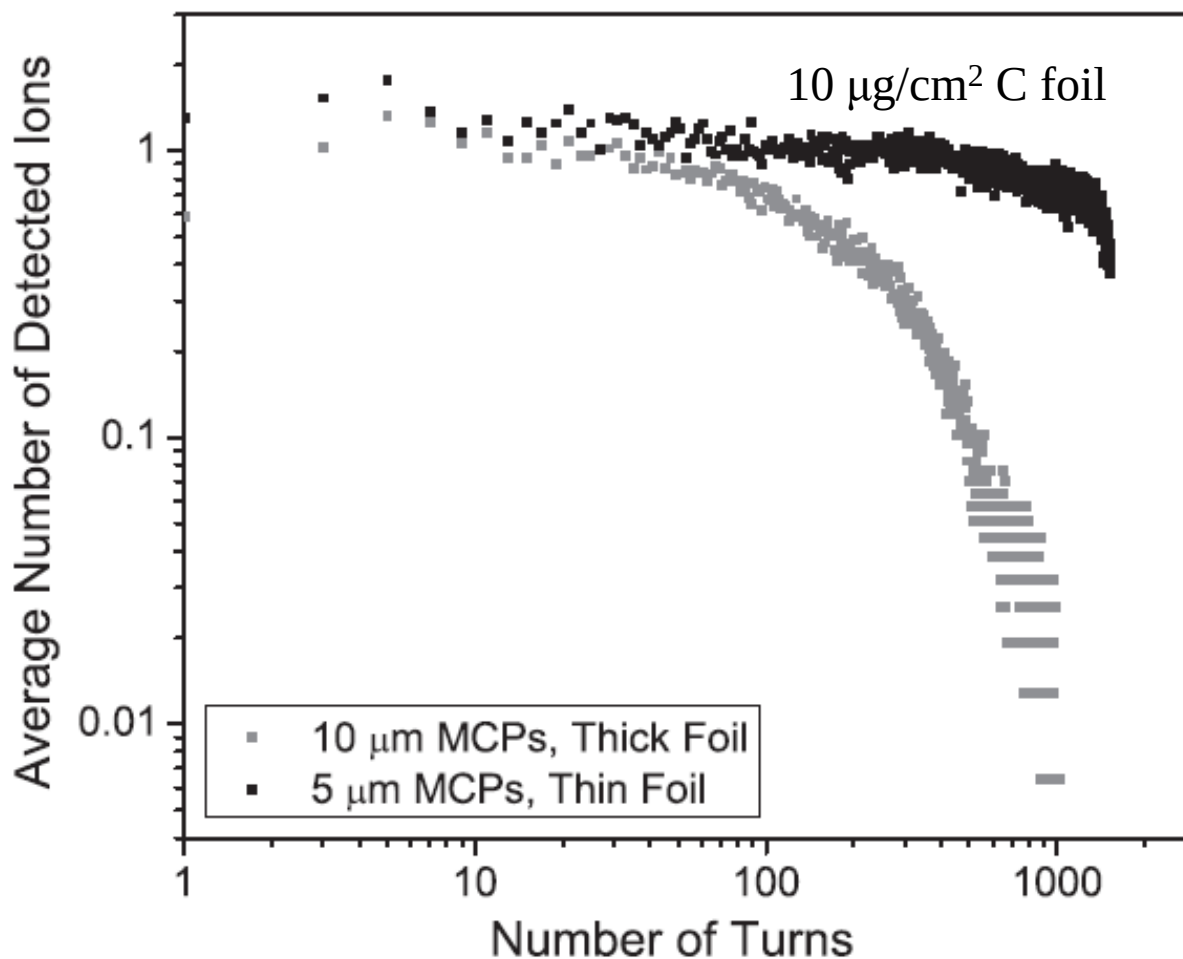


CR
(two detectors)

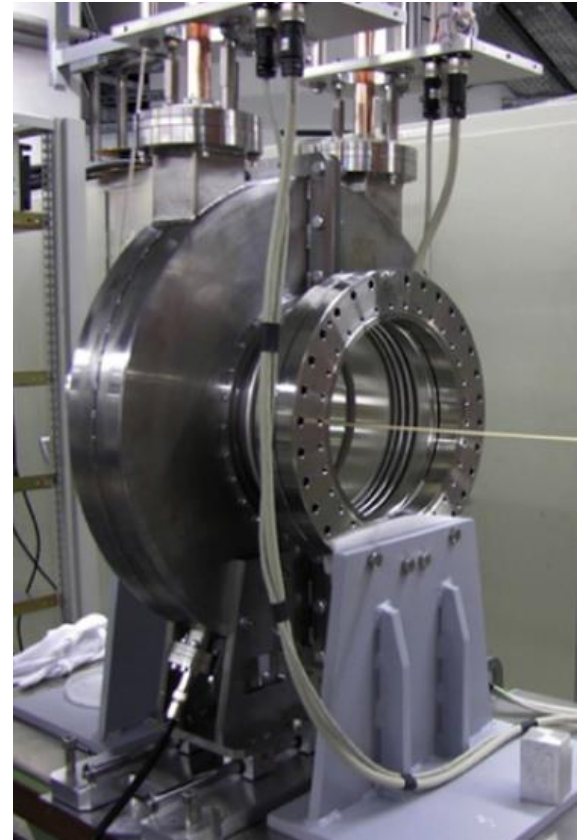
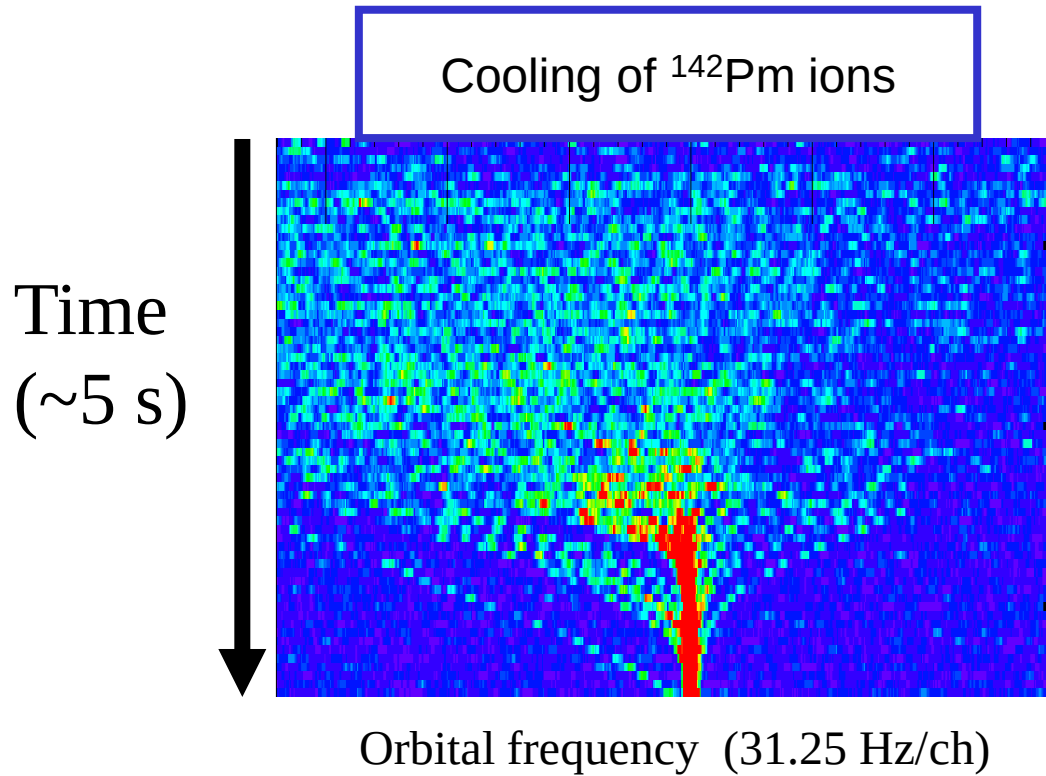
slide from Marcel Diwisch (Giessen)



ToF detector optimisation



Schottky Mass Spectrometry: resonant pickup

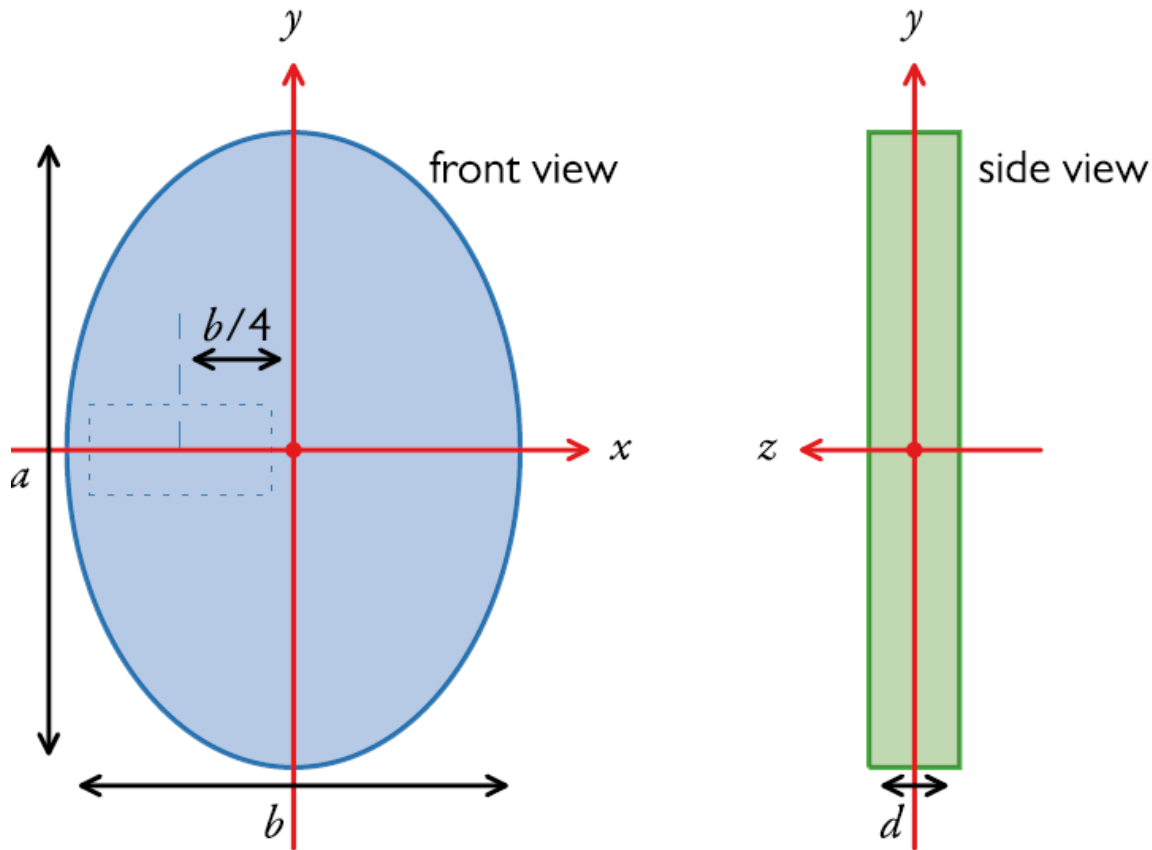


Nolden et al., NIM A659 (2011) 69
Bosch et al., PPNP 73 (2013) 84



Schottky Mass Spectrometry

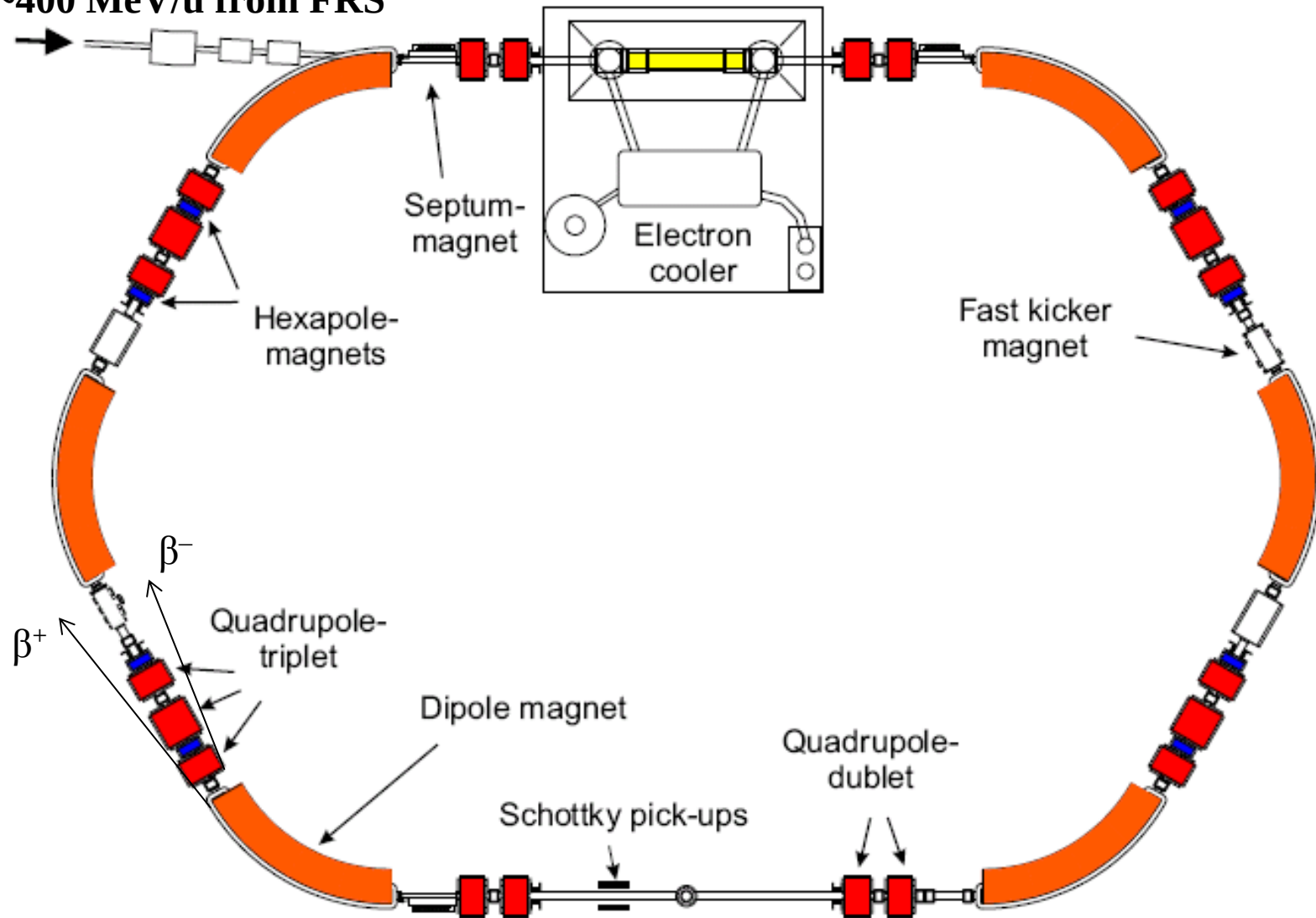
Isochronous mode in CR: need position information



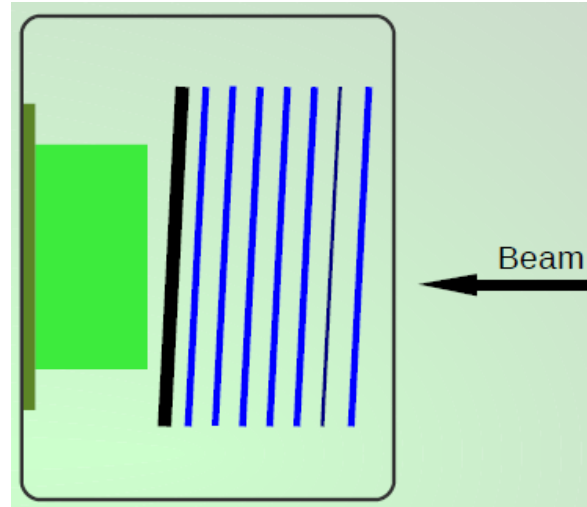
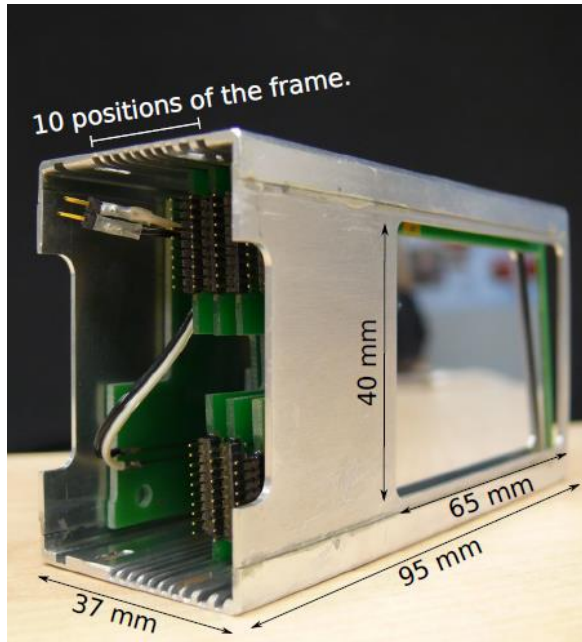
Design off-set elliptical
(or rectangular) cavity

detector for in-ring decay

ions ~ 400 MeV/u from FRS



CsISiPHOS detector for in-ring decay

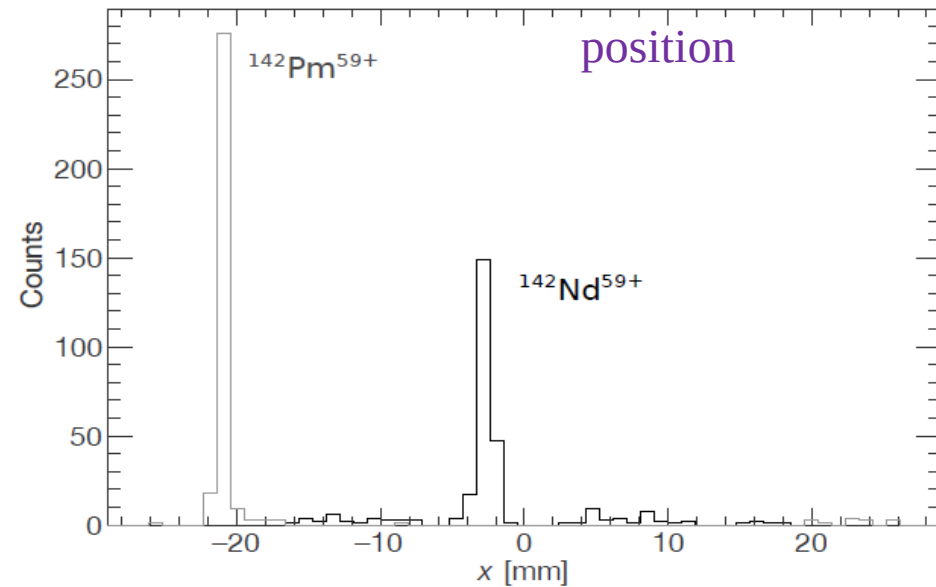
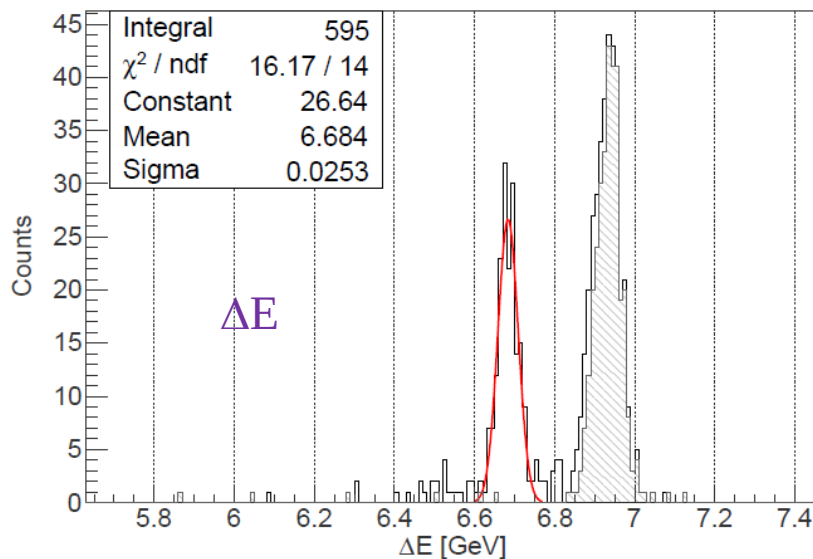


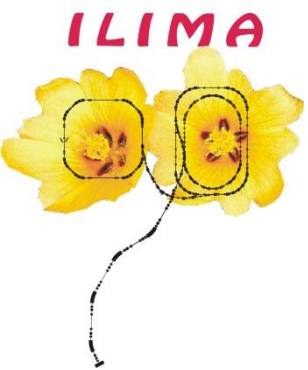
DSSD stack for ΔE -E
 active area 40mm x 60mm
 also with CsI calorimeter
 + Si photo diode,
 to identity Z and A.

Prototype tested in the ESR:

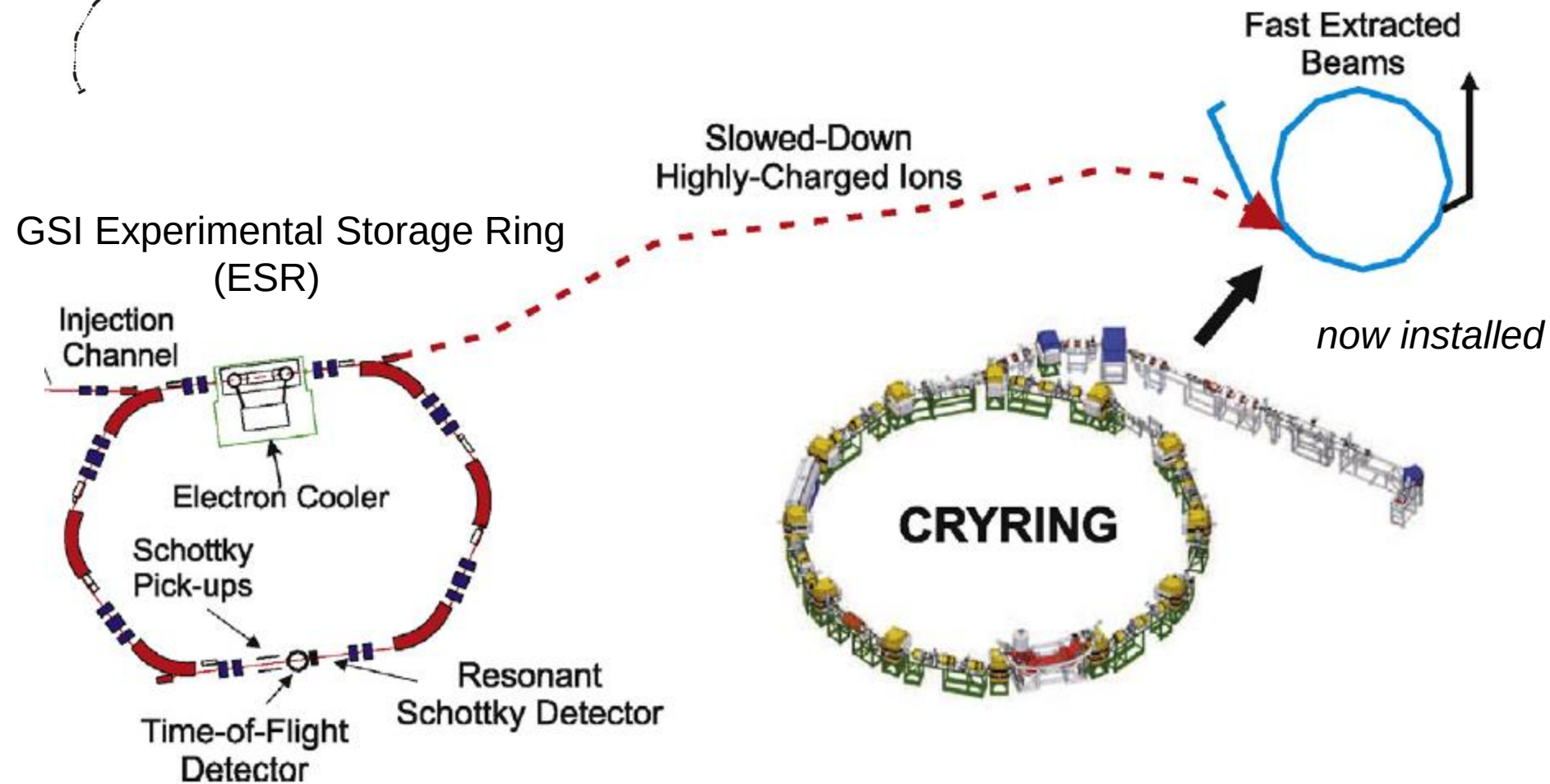
Najafi et al., NIM A836 (2016) 1

β^+ decay: $^{142}\text{Pm}^{60+} \rightarrow ^{142}\text{Nd}^{59+}$, atomic electron capture $\rightarrow ^{142}\text{Pm}^{59+}$



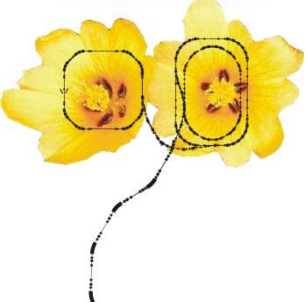


Possibility to prepare <100 keV bare ions



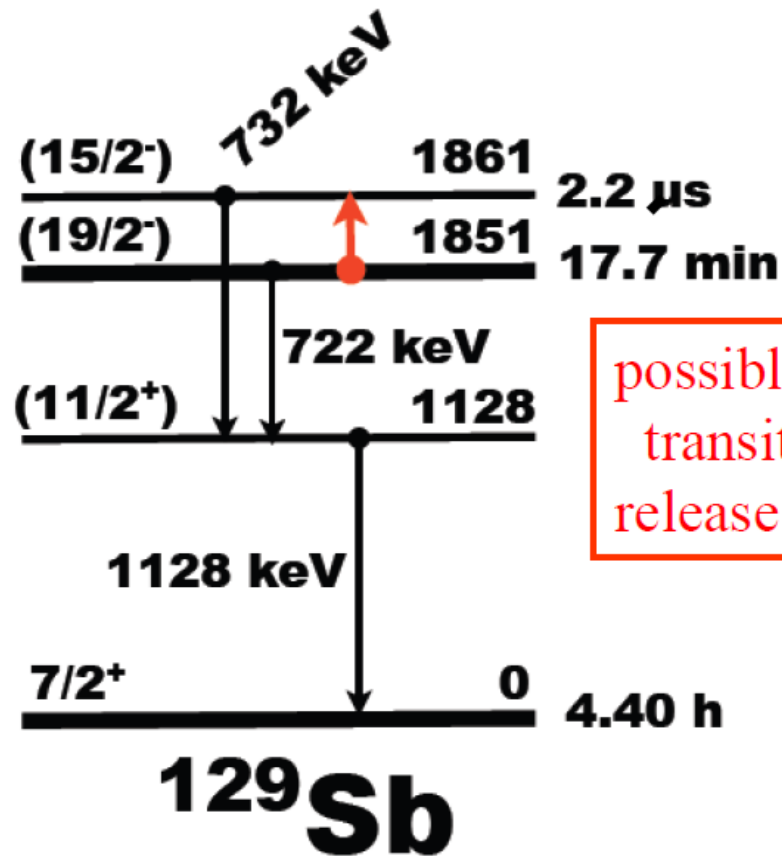
Walker, Litvinov and Geissel, *Int. J. Mass Spec.* 349-350 (2013) 247
Lestinsky et al., *Eur. Phys. J. Special Topics* 225 (2016) 797

ILIMA



Possibility to prepare <100 keV bare ions

=> **NEEC* opportunities**



possible 10 keV
transition to
release 1.9 MeV



physics at the atomic
-nuclear interface

Walker, Litvinov and Geissel, *Int. J. Mass Spec.* 349-350 (2013) 247
Lestinsky et al., *Eur. Phys. J. Special Topics* 225 (2016) 797

* NEEC: Nuclear Excitation by Electron Capture

Highly-charged exotic nuclei in storage rings

Current:

ESR at GSI

CSRe at Lanzhou

Commissioning:

Rare-RI ring at RIBF

Installation:

CRYRING at GSI (very low energies)

Preparation:

Ring Branch at FAIR

ILIMA collaboration:
isomers, lifetimes and masses

accuracy ~ 30 keV, half-life limit ~ 20 μ s, sensitivity to one ion per week