Storage Ring Experiments with Exotic Nuclei

Yuri A. Litvinov

FRS-User-Meeting

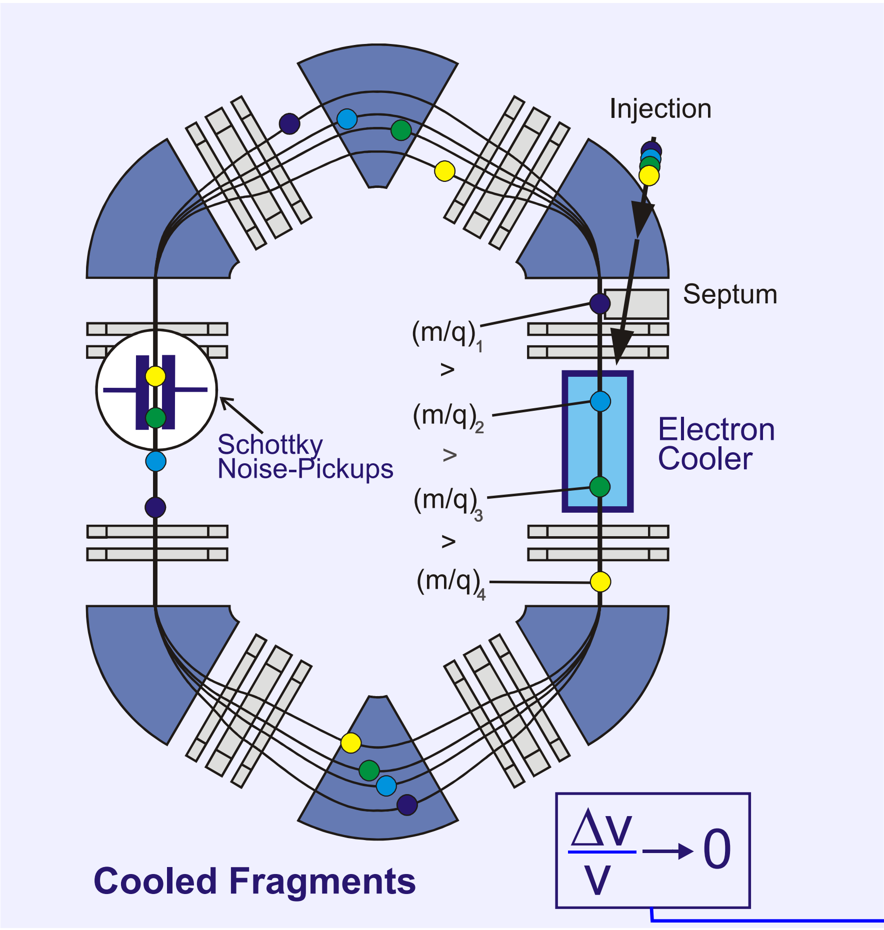
05 November 2007

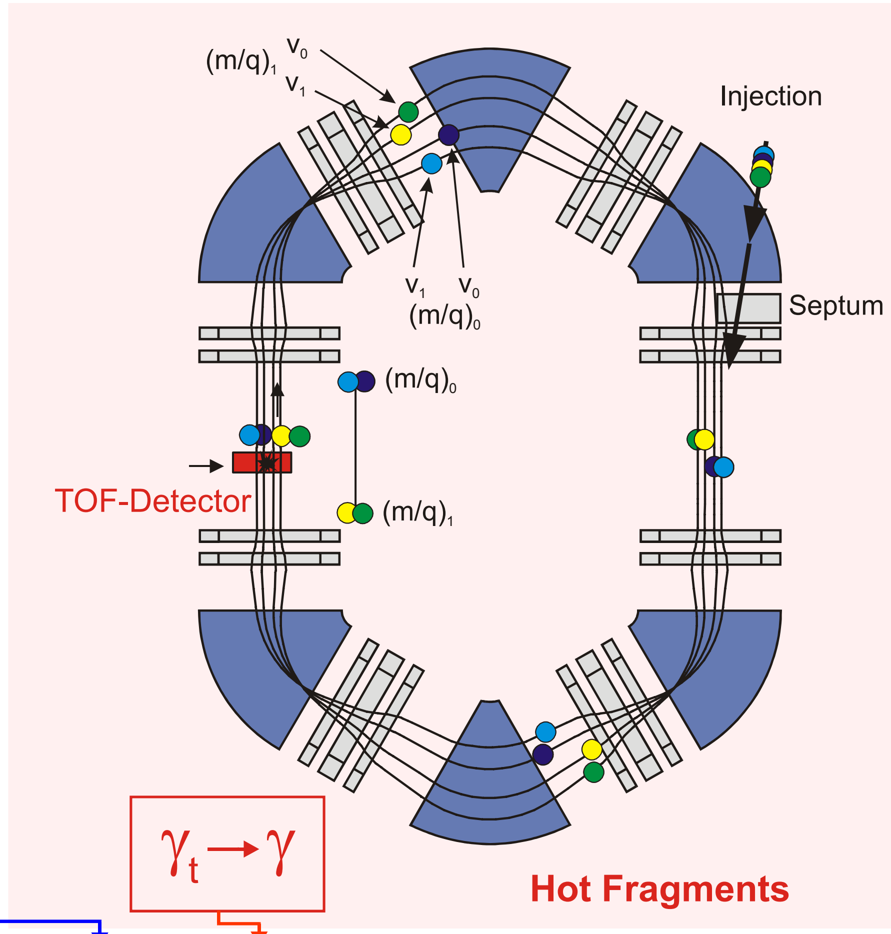
- **Mass Measurements**
- **Half-Life Measurements**
- **Summary and Outlook (after Lunch break)**

SMS and IMS

SCHOTTKY MASS SPECTROMETRY

ISOCHRONOUS MASS SPECTROMETRY



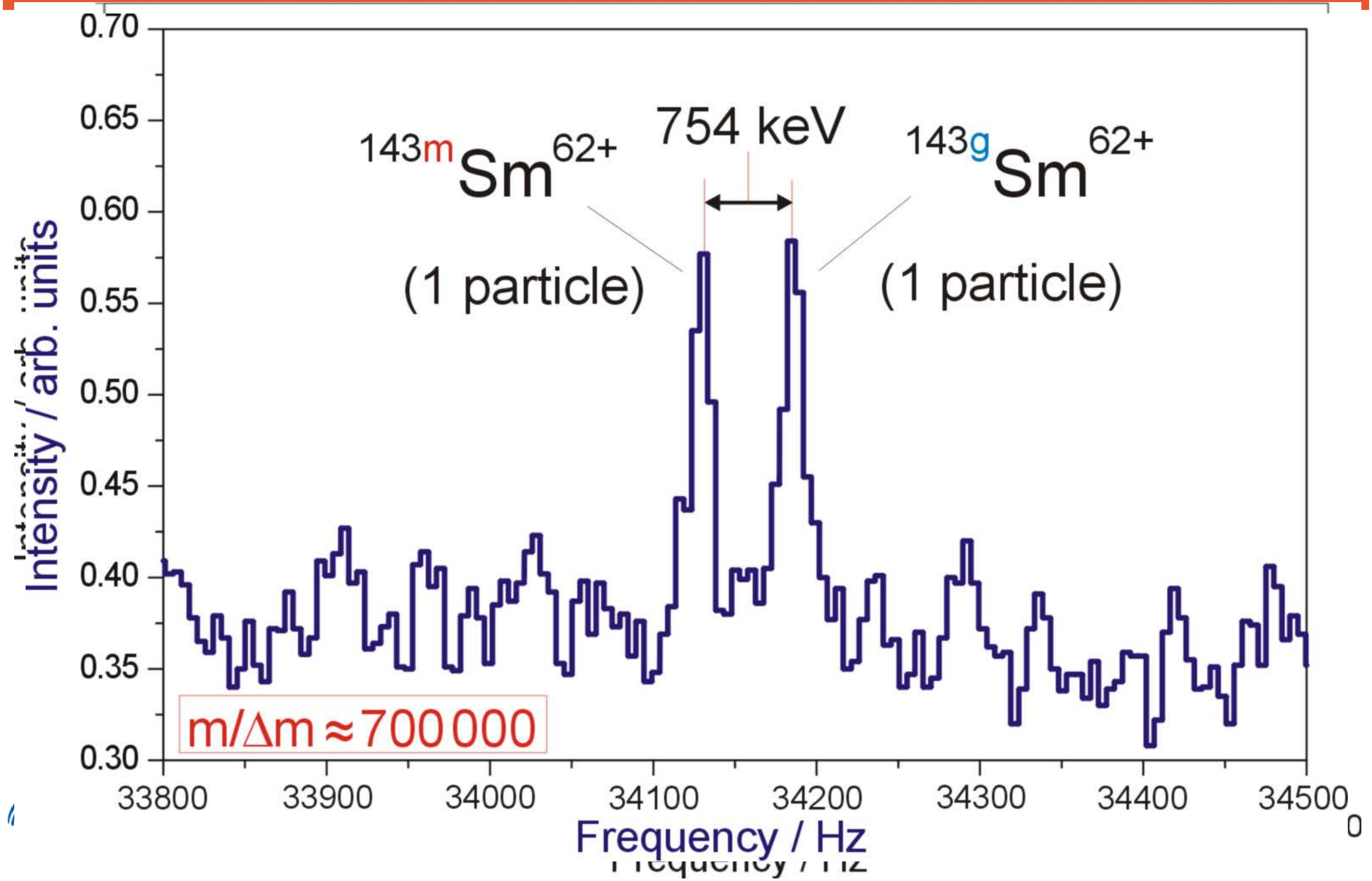


$$\frac{\Delta f}{f} = -\frac{1}{\gamma_t^2}\frac{\Delta(m/q)}{m/q} + \frac{\Delta v}{v}\left(1 - \frac{\gamma^2}{\gamma_t^2}\right)$$

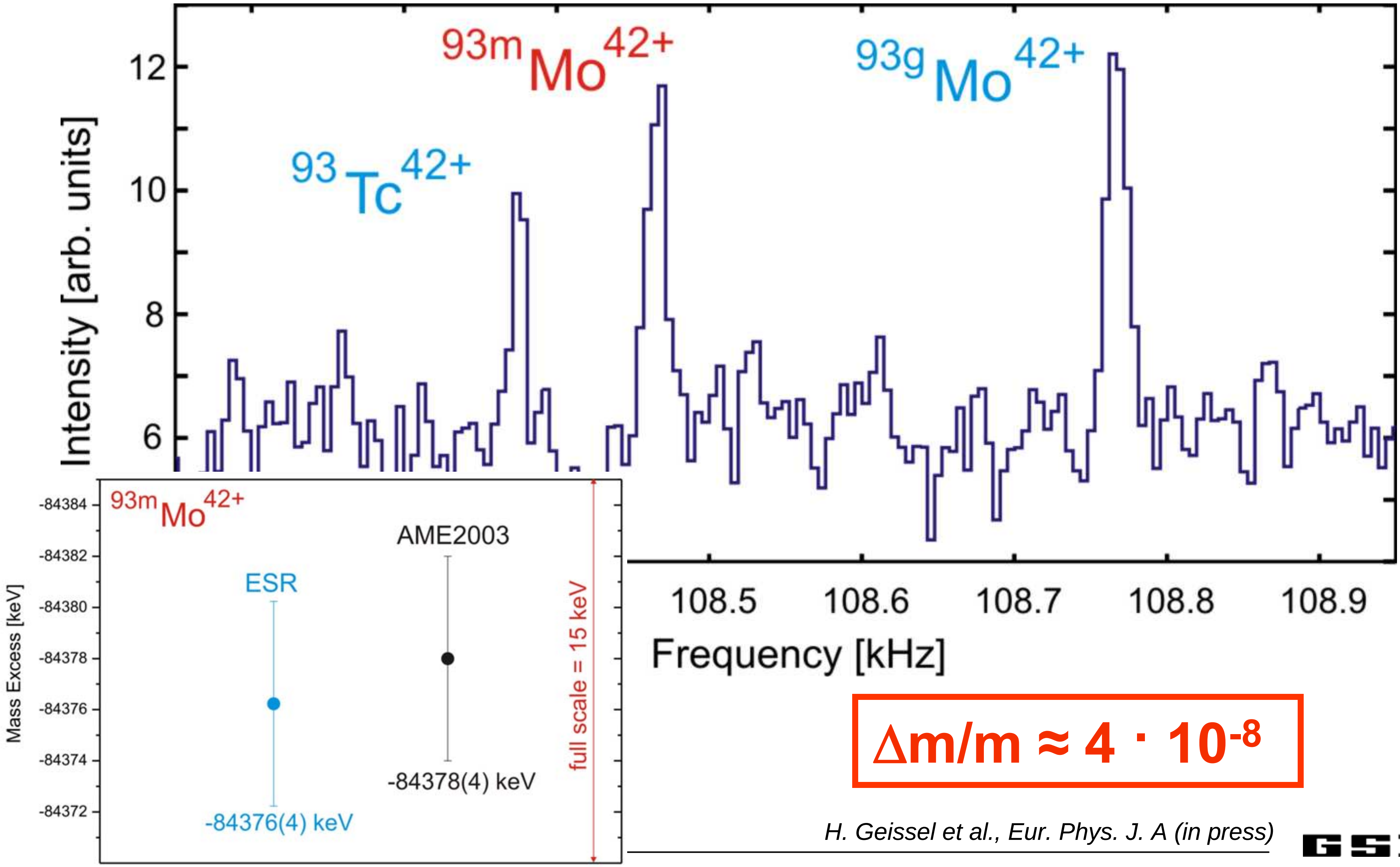
HELMHOLTZ | GEMEINSCHAFT

GSI

SMS: Broad Band Frequency Spectra (E036)



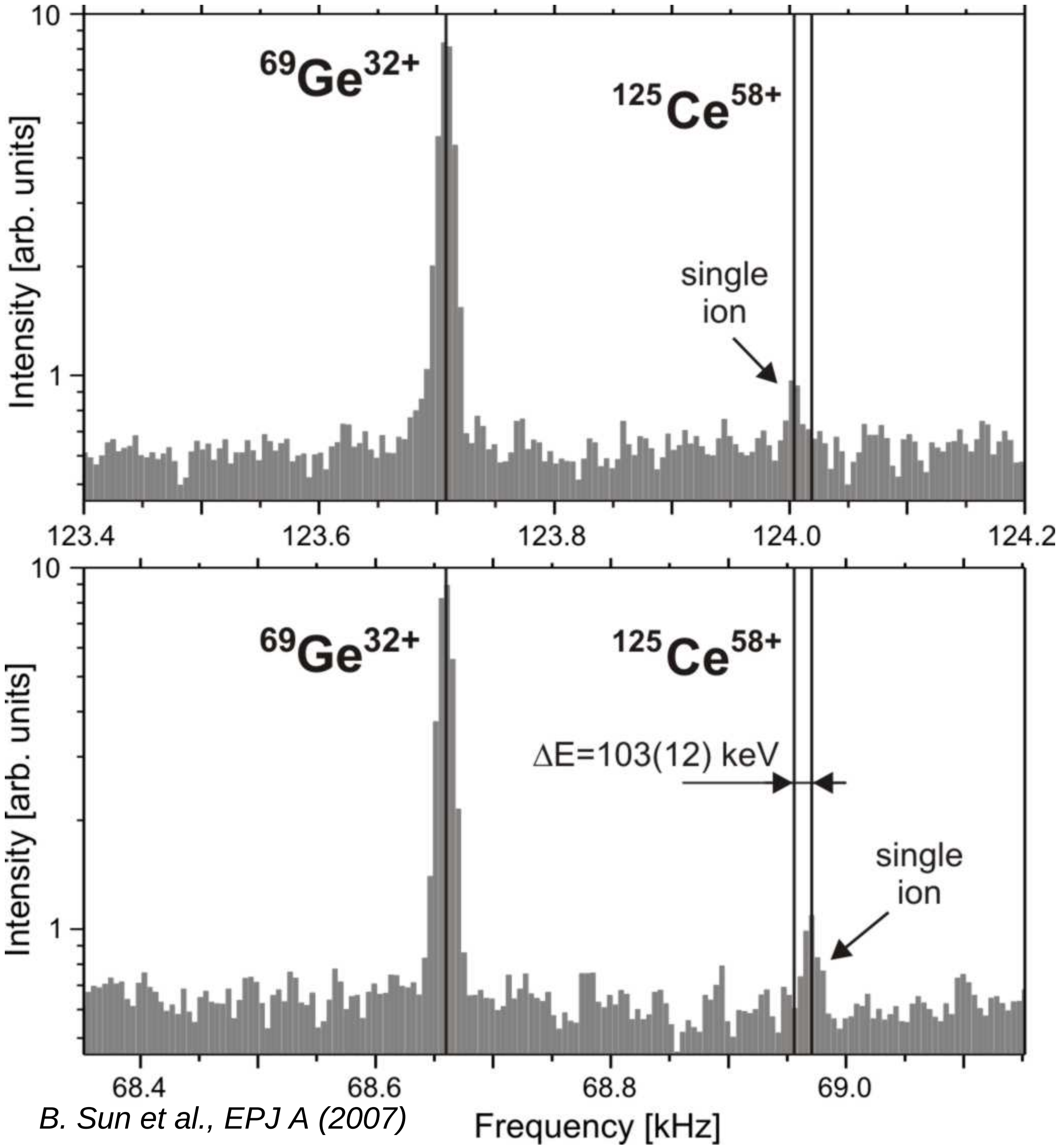
SMS: Accuracy (E077)

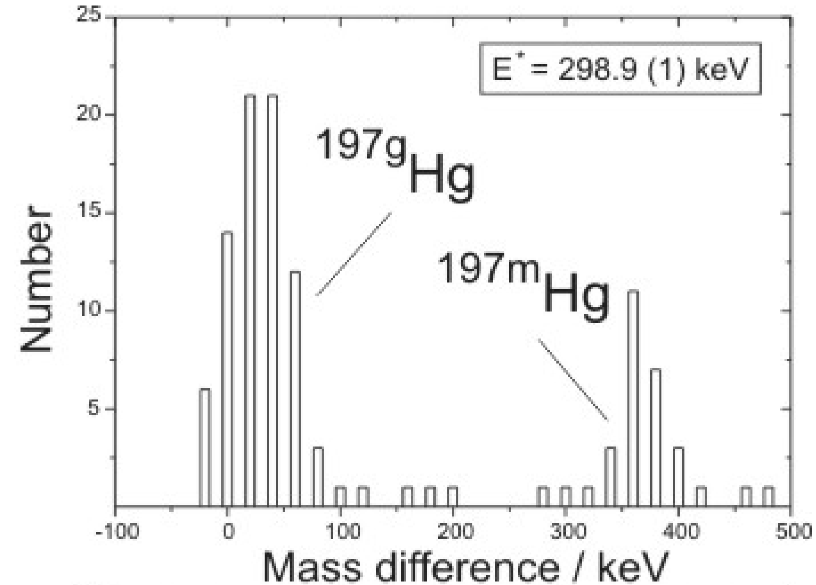


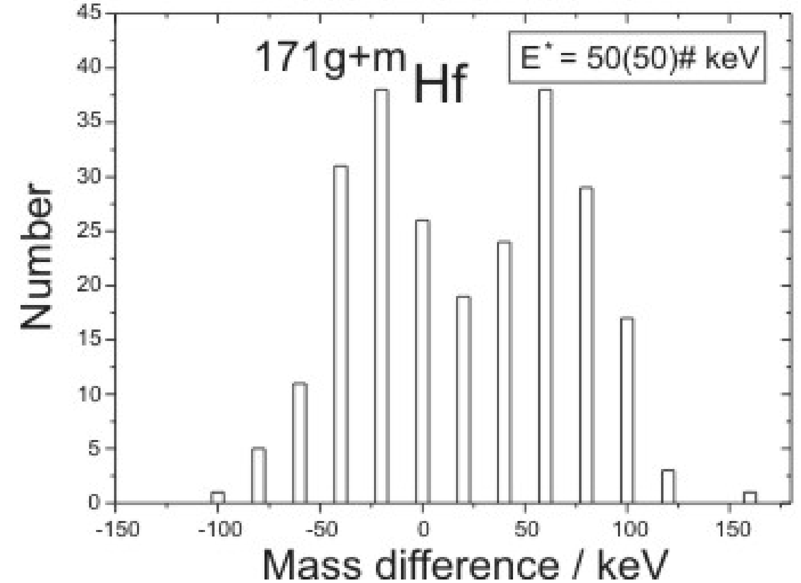
$\Delta m/m \approx 4 \cdot 10^{-8}$

H. Geissel et al., Eur. Phys. J. A (in press)

Mass Distributions from Single Ions

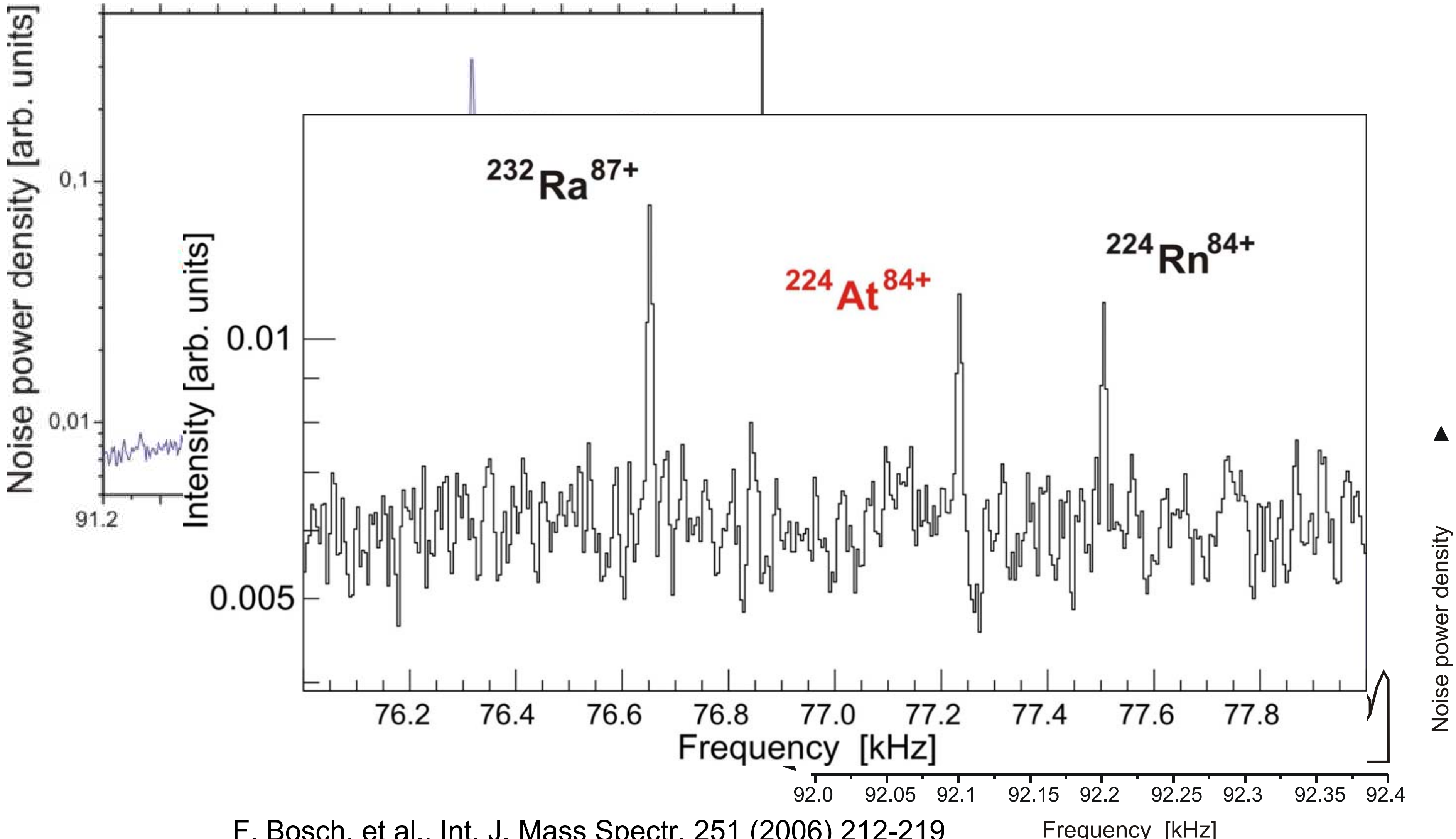






B. Sun et al., EPJ A (2007)

Identification of New Isotopes (E048+E055)



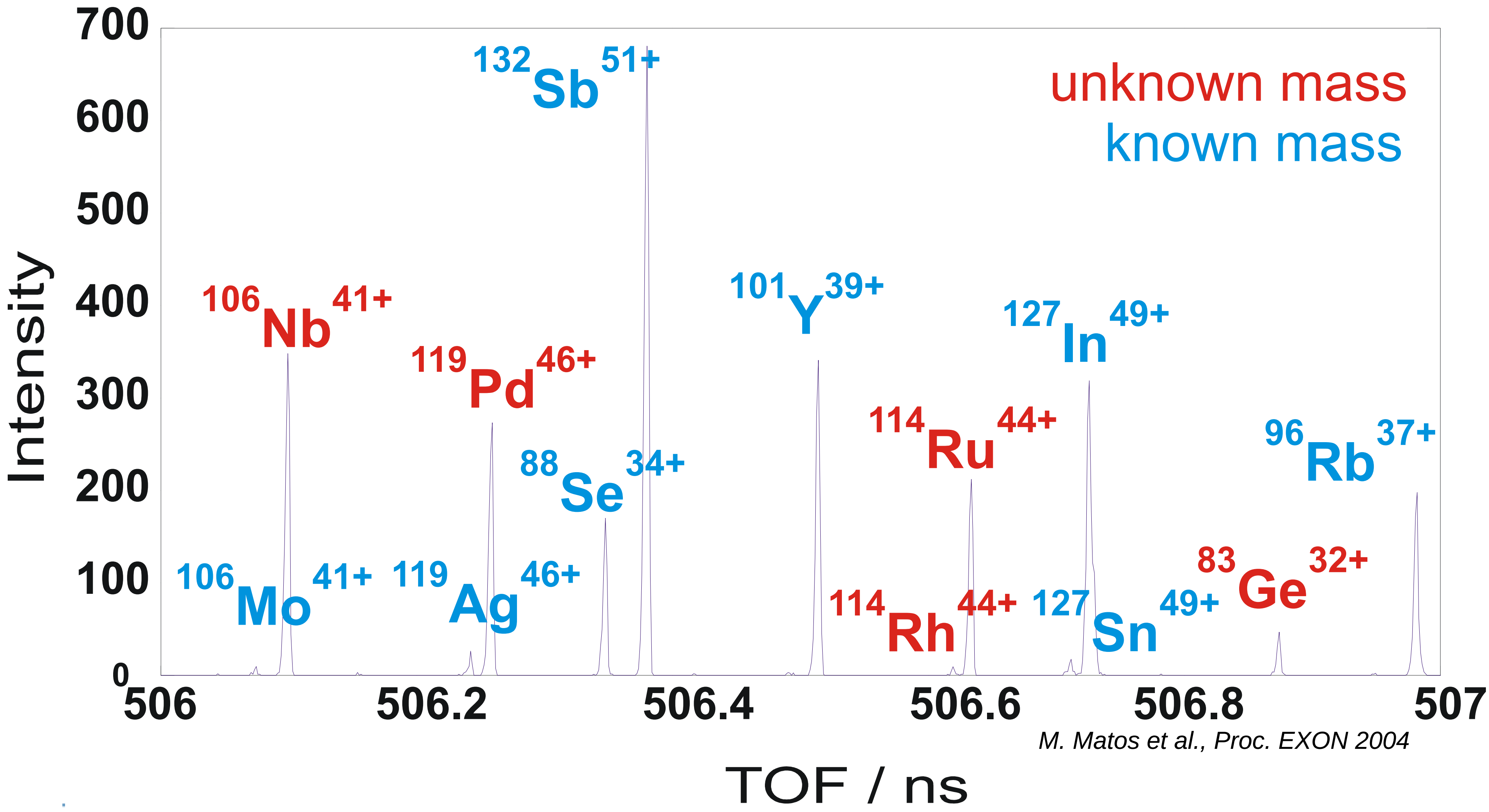
F. Bosch, et al., Int. J. Mass Spectr. 251 (2006) 212-219
L. Chen, et al., in preparation

IMS: Time-of-Flight Spectra (E055)

Nuclei with half-lives as short as 20 μs

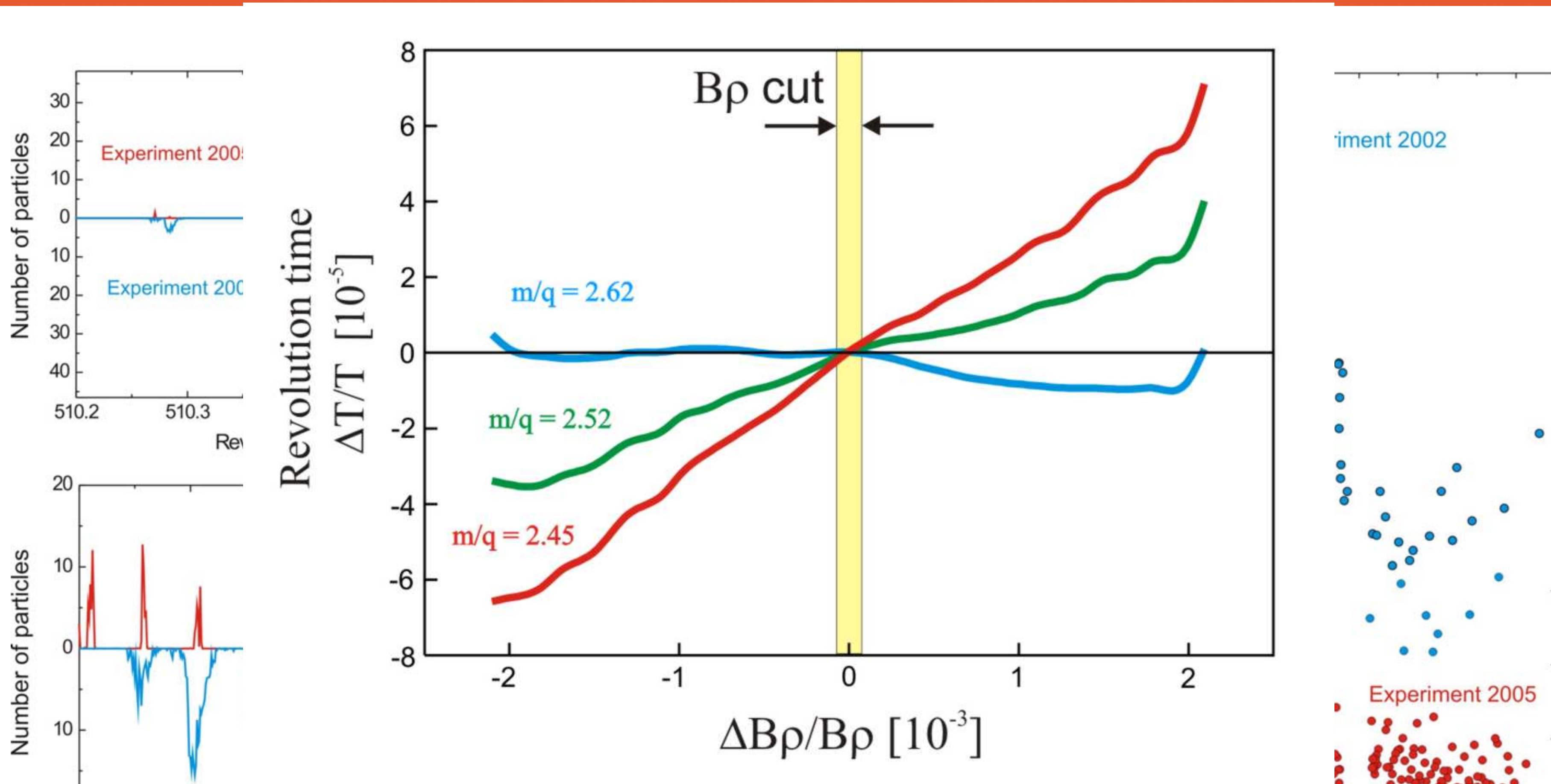
About 13% in mass-over-charge range

m/q range: 2.4-2.7



M. Matos et al., Proc. EXON 2004

IMS: Bρ Tagging (E055)



Good isochronous conditions are fulfilled only in a small range

Solution: measurement of *Bρ* or *v* in addition

H. Geissel et al., Eur. Phys. J. A (in press)

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GSI

Measured Mass Surface

Masses of more than **1100** Nuclides were measured

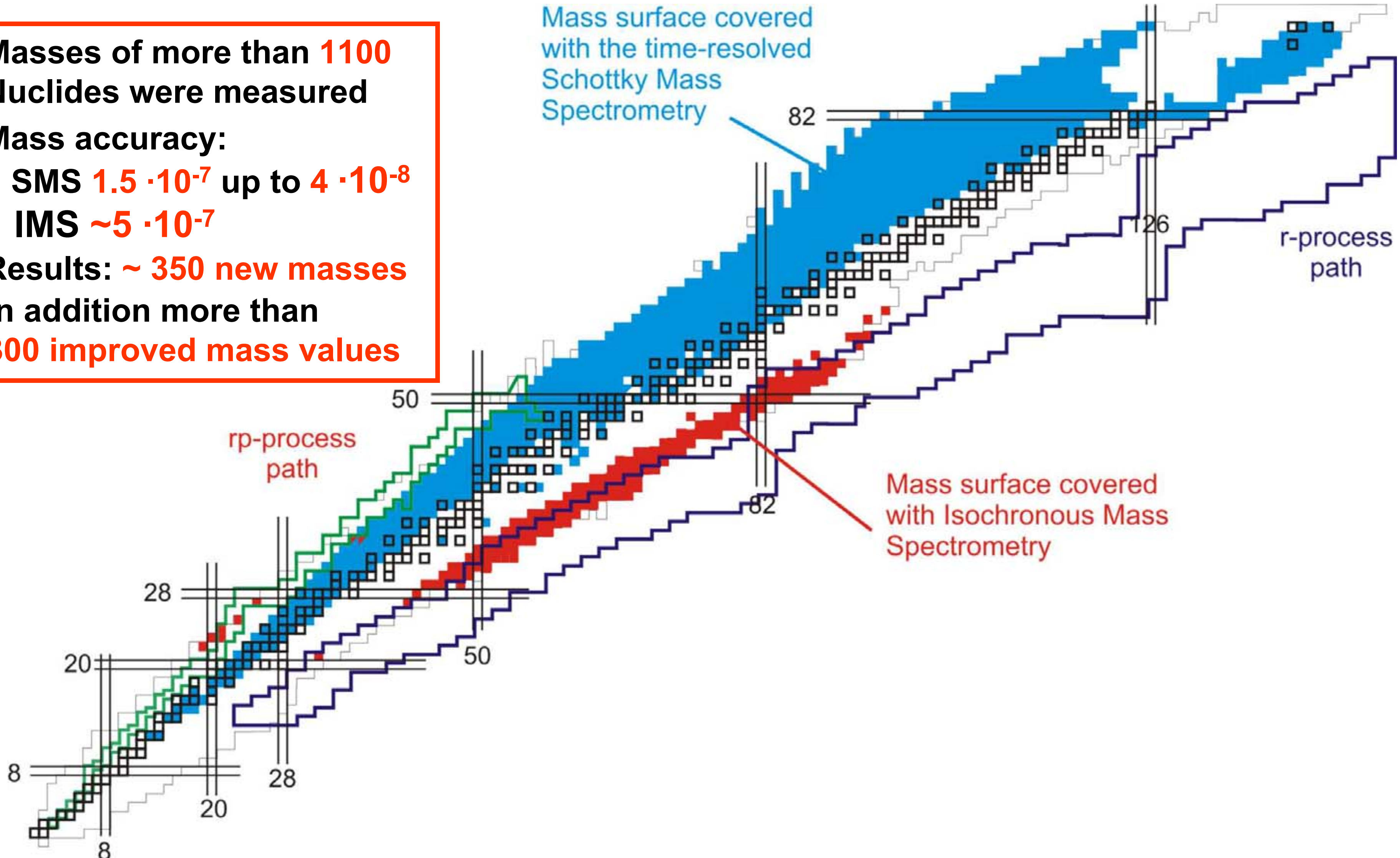
Mass accuracy:

SMS $1.5 \cdot 10^{-7}$ up to $4 \cdot 10^{-8}$

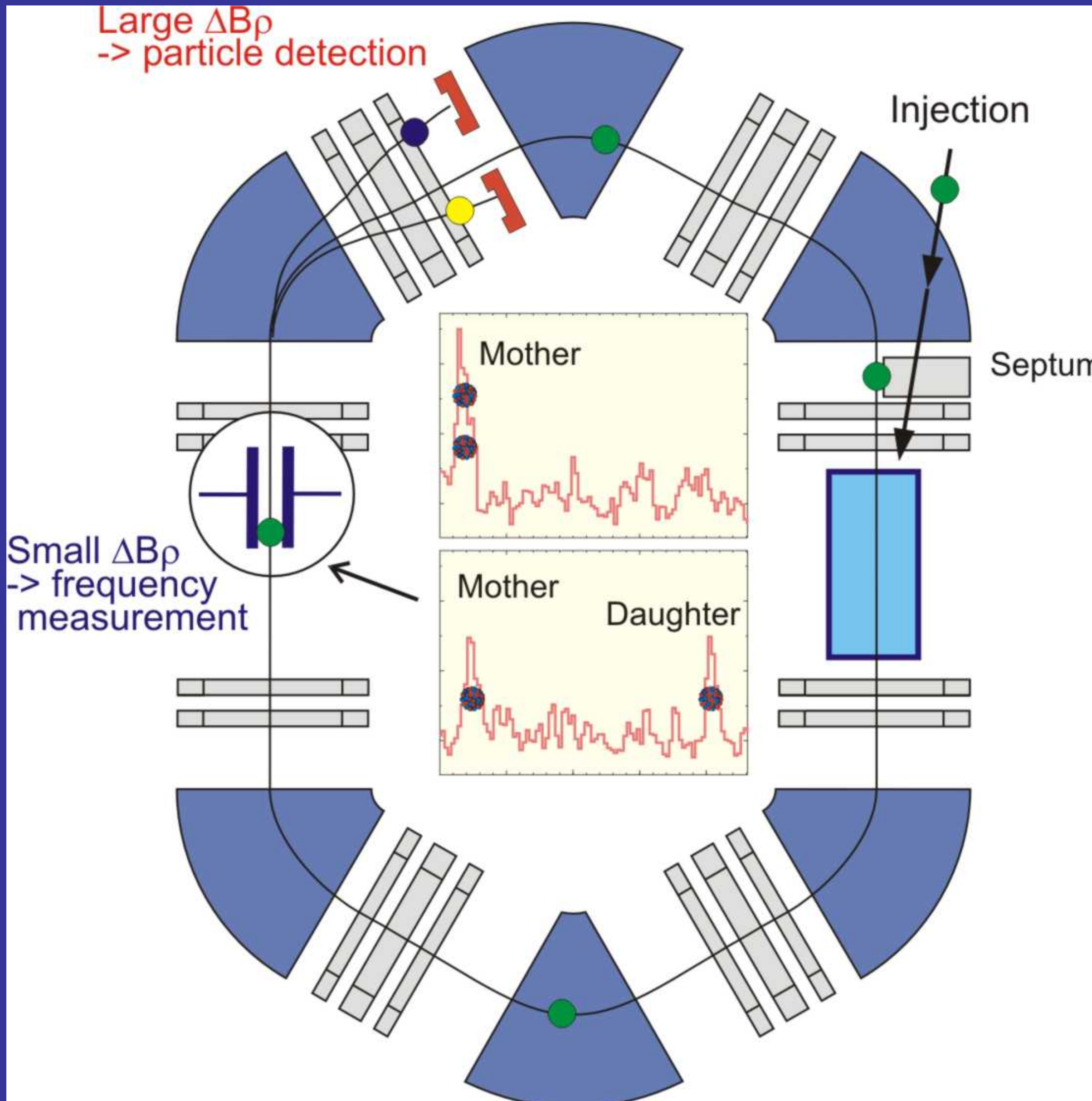
IMS $\sim 5 \cdot 10^{-7}$

Results: **~ 350 new masses**

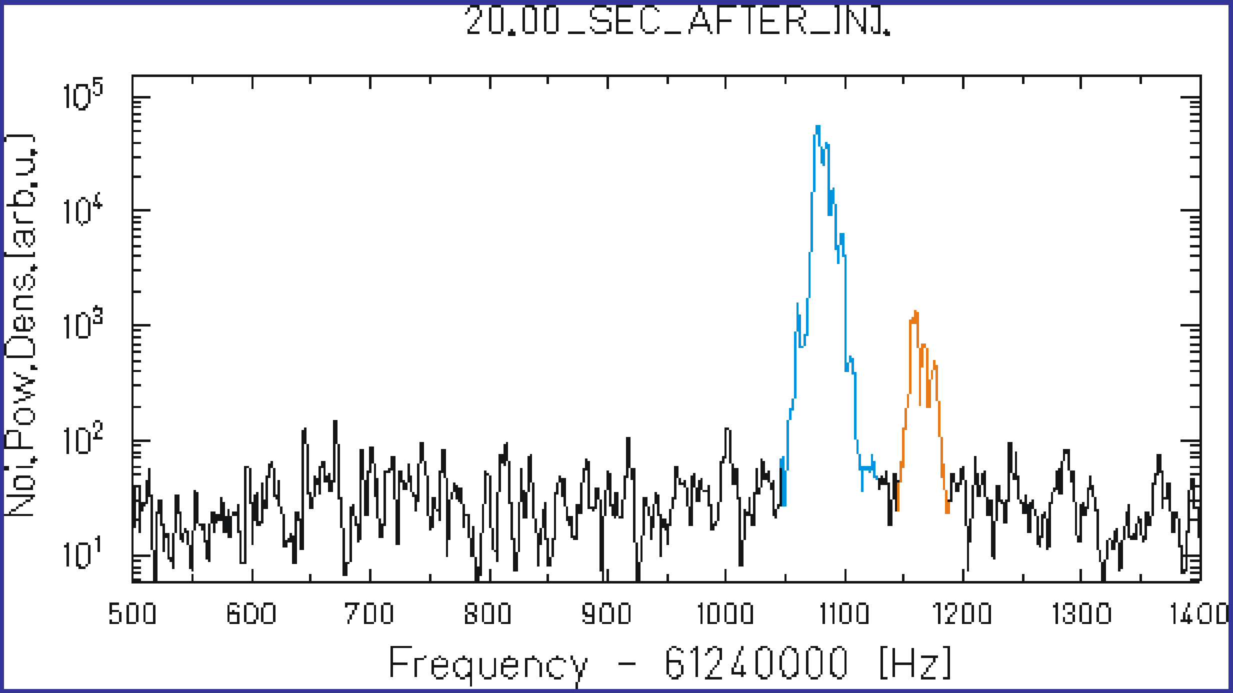
In addition more than **300 improved mass values**



Half-life Measurements



Stochastic + Electron Cooling



D. Boutin, PhD Thesis, JLU Giessen, 2005

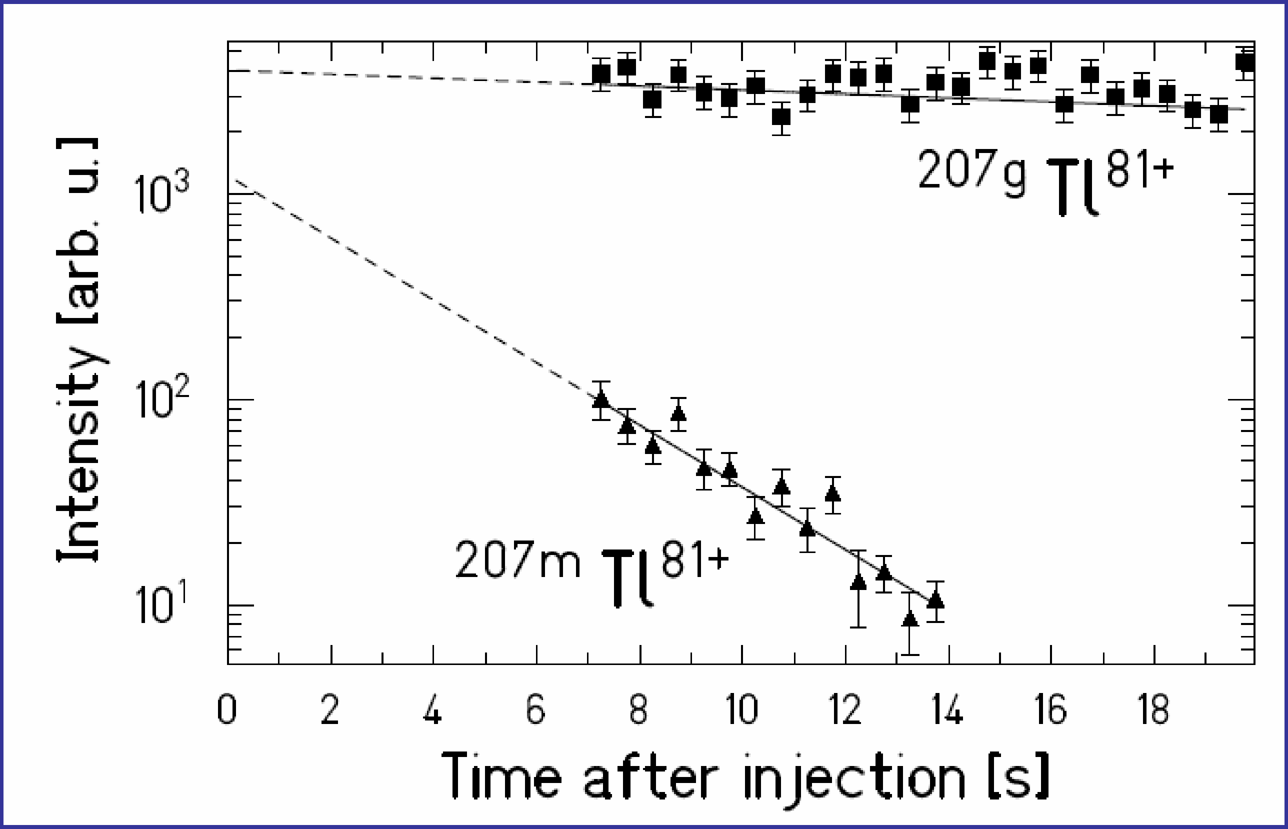
Half-life of Fully-Ionized $^{207m}Tl^{81+}$

^{207m}Tl ($E^* = 1348$ keV)

$T_{1/2}$(neutral) = 1.33(11) s

$T_{1/2}$(bare) = 1.47(32) s

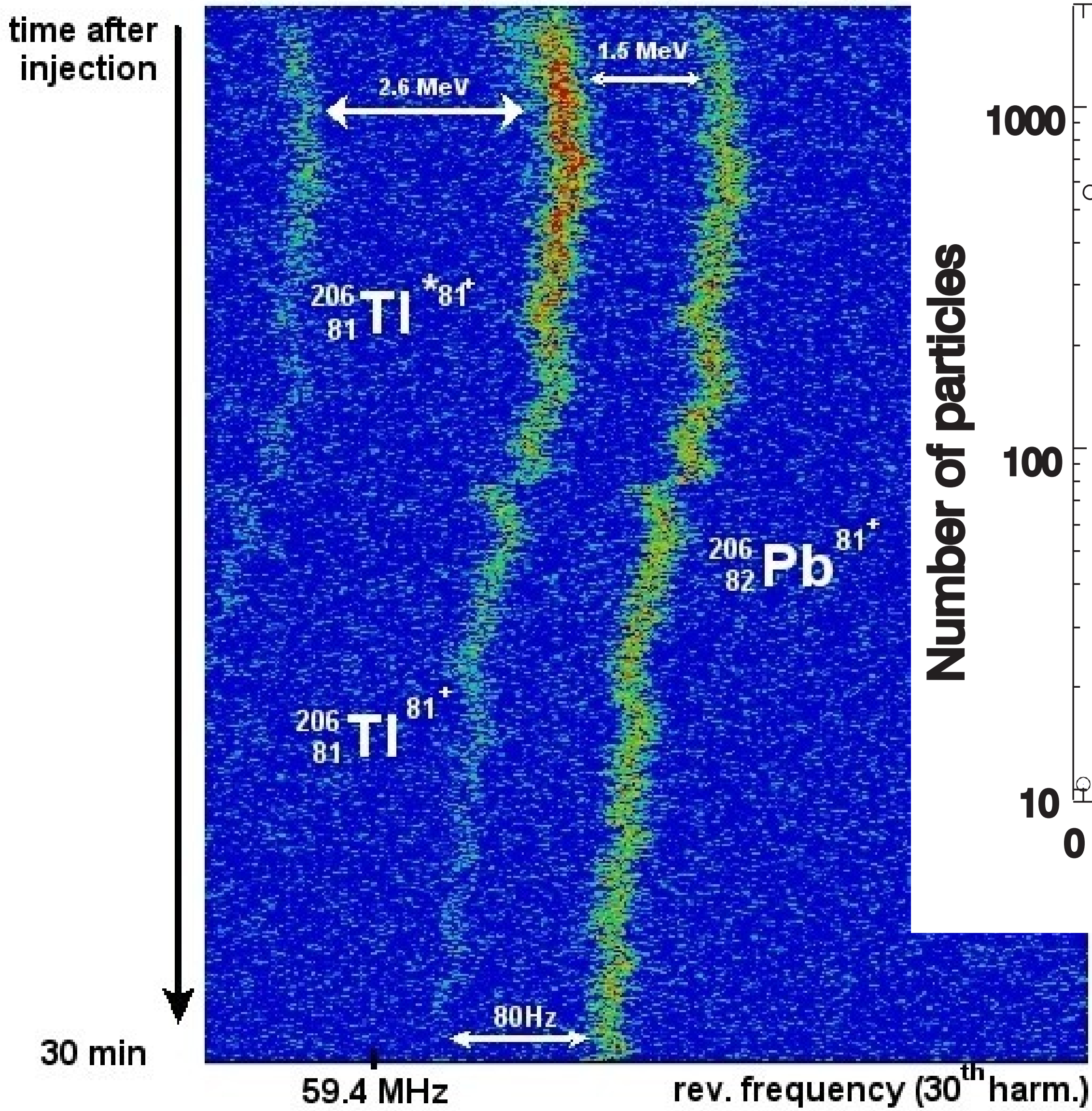
$T_{1/2}$(theory) = 1.52(12) s

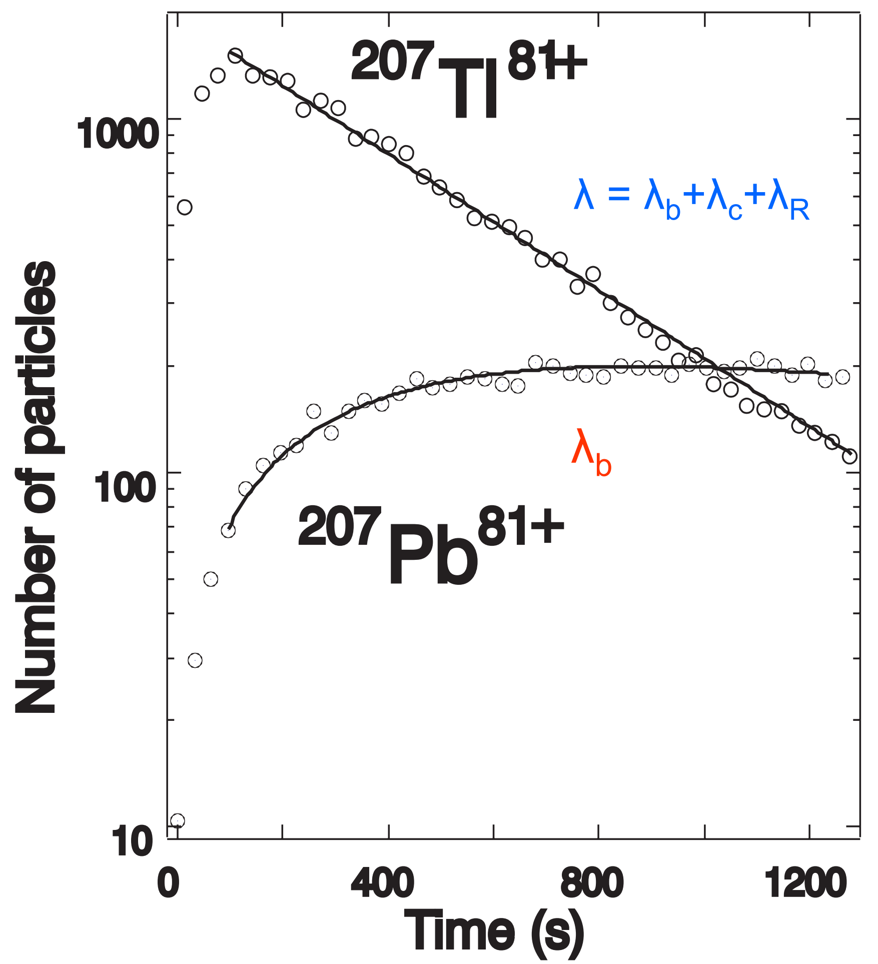


D. Boutin, PhD Thesis, JLU Giessen, 2005

T. Ohtsubo et al., Phys. Rev. Lett. 95 (2005) 052501

Bound-State β-decay in $^{206,207}Tl$





bound/continuum branching ratio

T. Ohtsubo et al., Phys. Rev. Lett. 95 (2005) 052501

Electron Capture in Hydrogen-like Ions (E078)

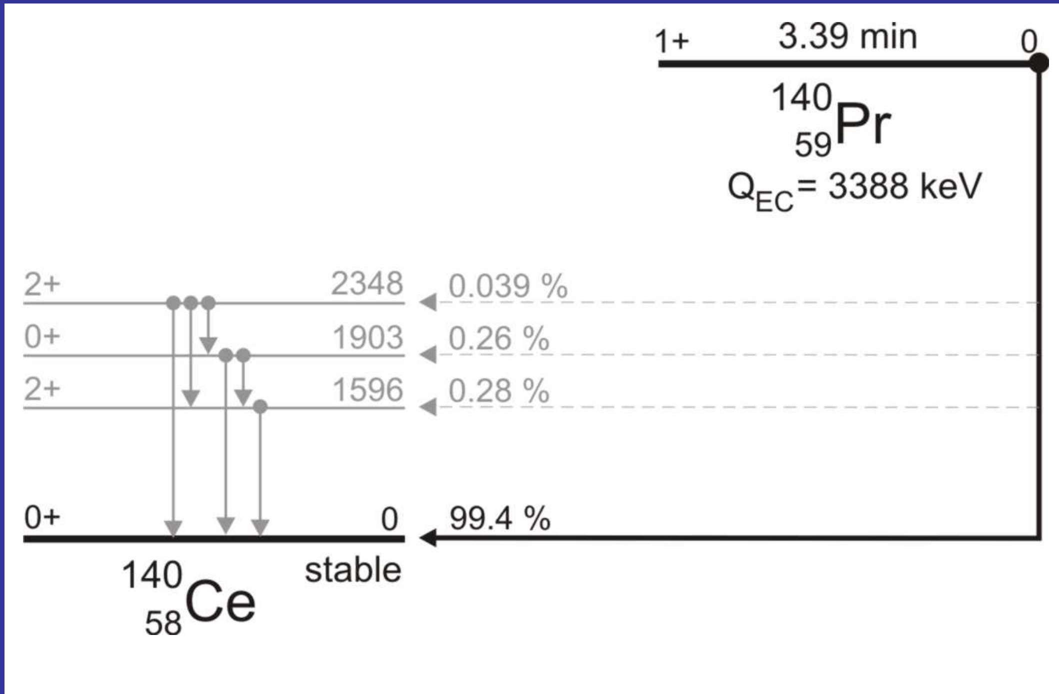
Classical EC-theory:

Gamow-Teller allowed transition $1^+ \rightarrow 0^+$

β+ to EC branching ratio:

$\lambda_{\beta+}/\lambda_{EC}$ **(neutral atom) ≈ 1**

W.Bambynek et al., Rev. Mod. Phys 49, 1977



S-electron density at the nucleus:

$|f_S(0)|^2 \propto 1/ n^3$

P_{EC} **(neutral atom)** $\propto 2 \sum 1/ n^3 = 2.4$

P_K **(H-like)** $\propto 1 * 1/ 1^3 = 1$

$\lambda_{\beta+}/\lambda_K$ **(H-like) ≈ 2.4**

Conclusion:

H-Like ion should have 41% longer half-life

M. Campbell et al., Nucl. Phys. A283 (1997) 413

$\lambda_{\beta+}/\lambda_K$ **(He-like) ≈ 1.37**

$\lambda_{\beta+}/\lambda_K$ **(H-like) ≈ ? ≈ 2.74 ?**

EC in Hydrogen-like Ions

Expectations:

$\lambda_{\beta+}/\lambda_{EC}$ (neutral atom) ≈ 1

EC(H-like)/EC(He-like) ≈ 0.5

$\lambda_{\beta+}/\lambda_{K}$ (H-like) ≈ 2.4

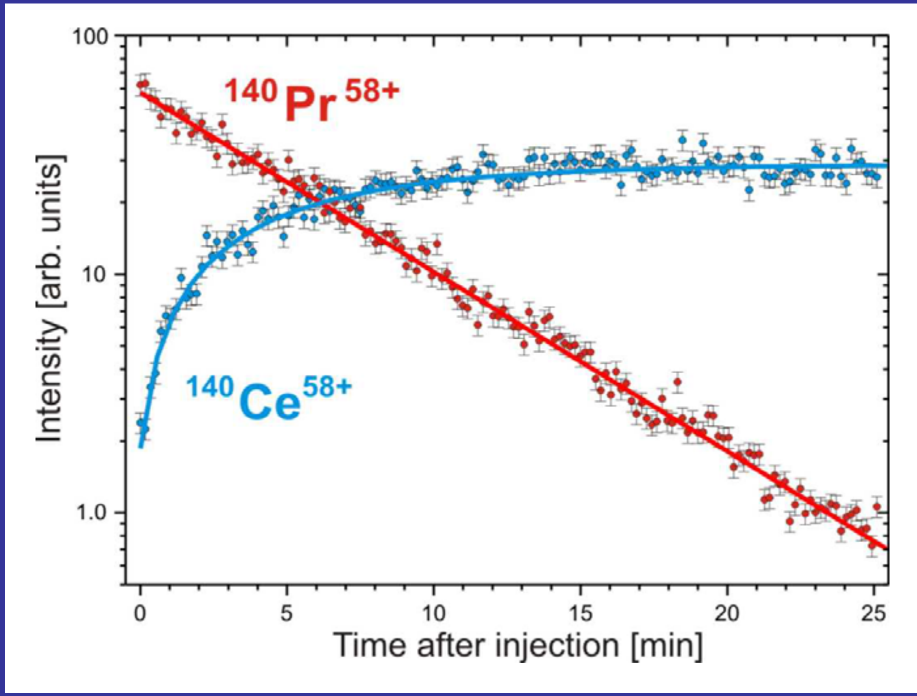
FRS-ESR Experiment

λ(neutral) = 0.00341(1) s^{-1}
G.Audi et al., NPA729 (2003) 3

$\lambda_{\beta+}$(bare) = 0.00158(8) s^{-1} *(decay of $^{140}Pr^{59+}$)*

λ_{EC}(H-like) = 0.00219(6) s^{-1} (decay of $^{140}Pr^{58+}$)

λ_{EC}(He-like) = 0.00147(7) s^{-1} (decay of $^{140}Pr^{57+}$)



EC(H-like)/EC(He-like) = 1.49(8)

$\lambda_{\beta+}/\lambda_{EC}$(H-like) = 0.72

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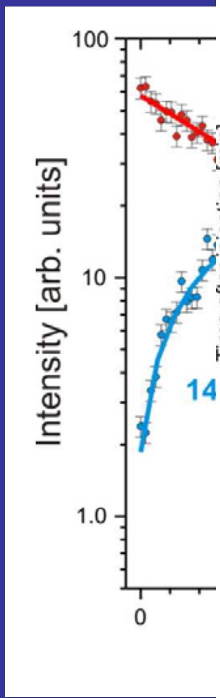
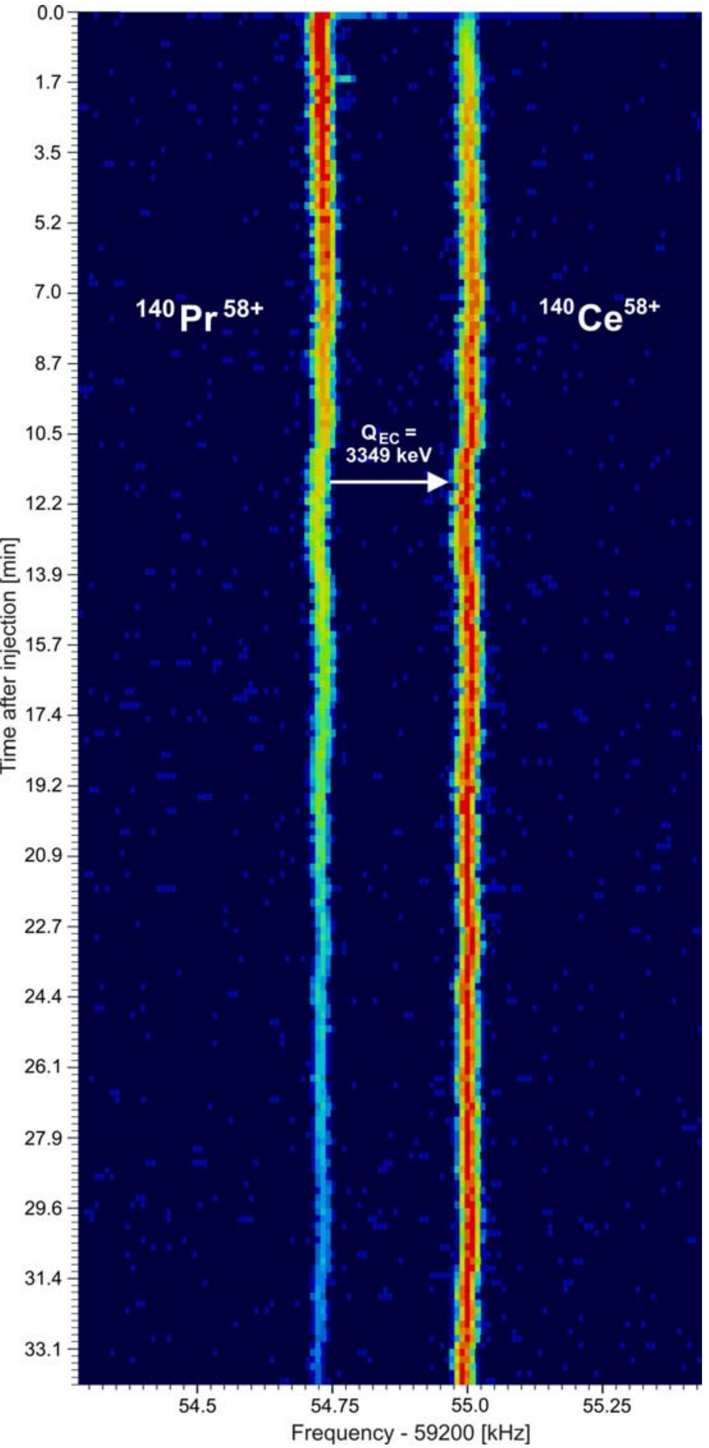
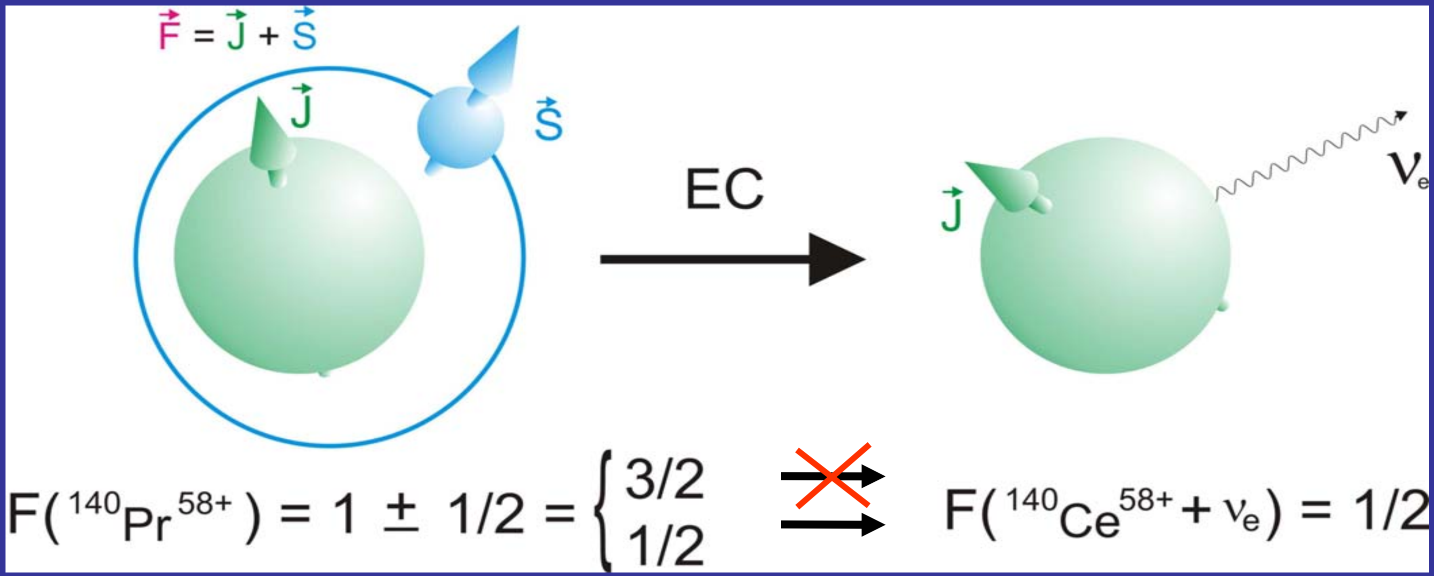




Electron Capture in Hydrogen-like Ions

Gamow-Teller transition $1^+ \rightarrow 0^+$



S. Typel and L. Grigorenko

$\mu = +2.7812\mu_N$

Z. Patyk

Probability of EC Decay

Neutral ^{140}Pr: **P = 2.381**

He-like ^{140}Pr: **P = 2**

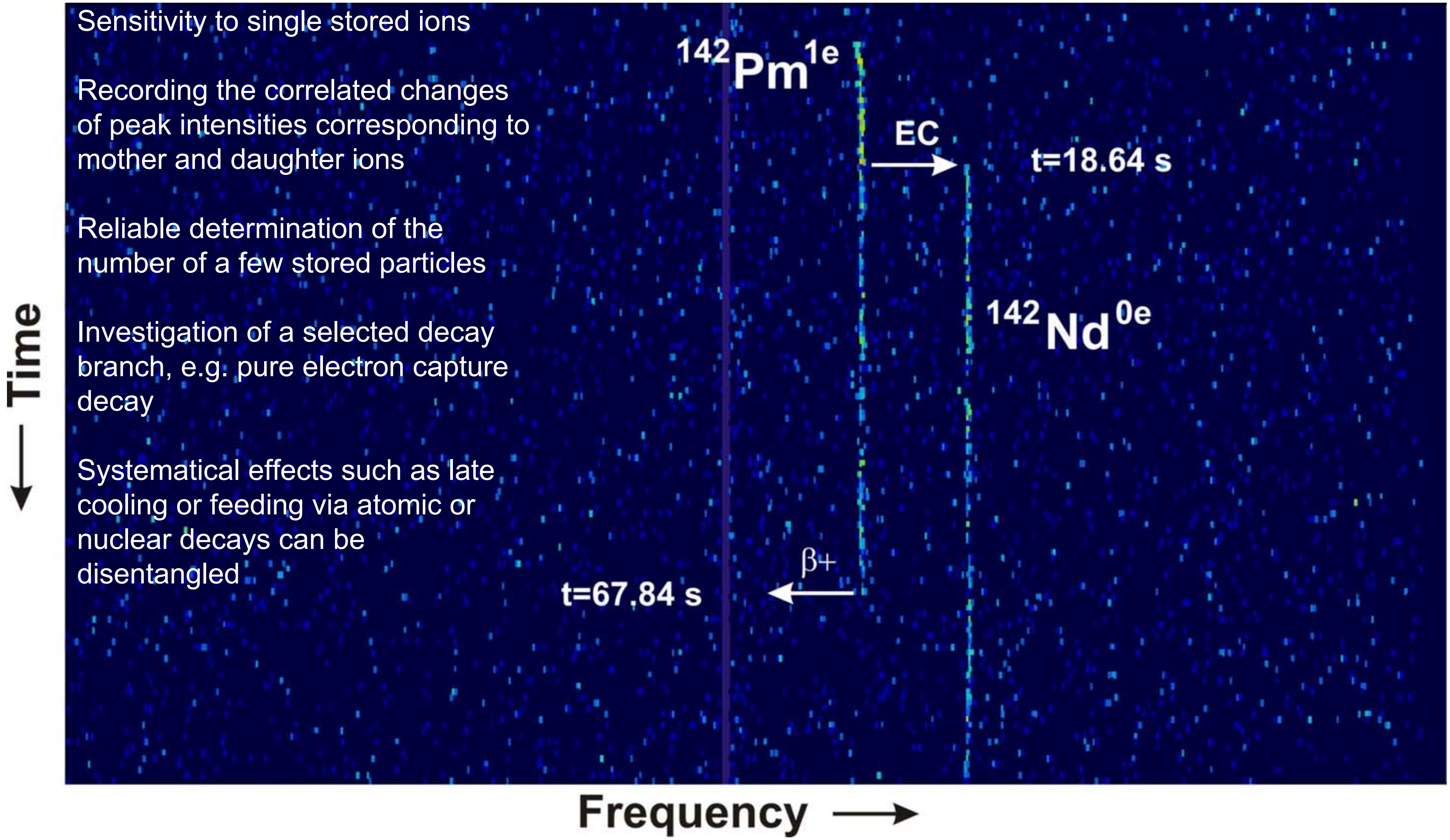
H-like ^{140}Pr: **P = 3**

Theory:

The H-Like ion should really decay 20% faster than neutral atom!

(2I+1)/(2F+1)

Single-Particle Decay Spectroscopy (E077)



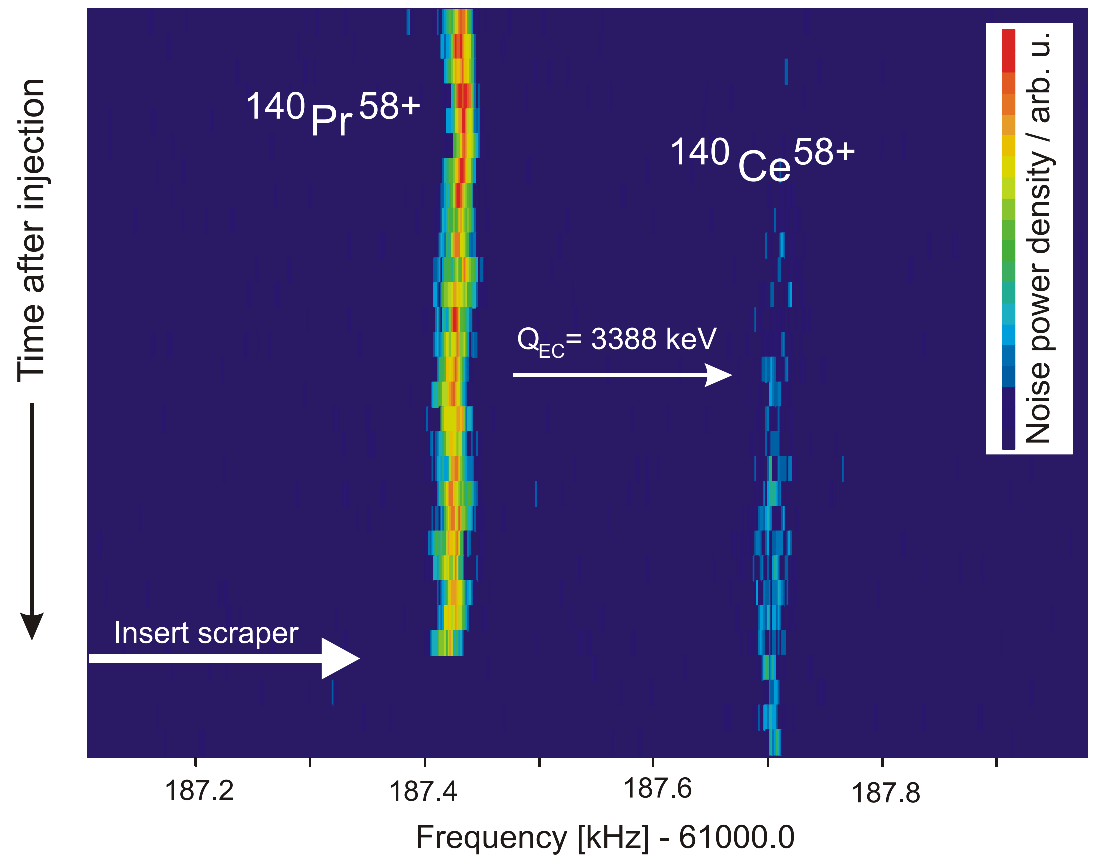
F. Bosch et al., Int. J. Mass Spectr. 251 (2006) 212

ILIMA: Towards Isomeric Beams (E051)

1. Pure isomeric beams can be prepared if the half-life of the corresponding ground state is much shorter.

2. For isomers with large excitation energies a spatial separation by means of a fast micrometer scraper is possible. In the first experiment the isobars with a Q-value of 3.388 MeV were successfully separated.

Pure beams of ions in the isomeric or ground state can be prepared alternatively.



Injection length 170 s

ILIMA Collaboration

FRS-ESR Half-Life and Mass Measurements

Collaboration

G.Audi, K.Beckert, F.Bosch, D.Boutin, C.Brandau, T.Bürvenich, L.Chen, I.Cullen, C.Dimopoulou, A.Dolinskii, B.Fabian, T.Faestermann, B.Franzke, H.Geissel, E.Haettner, M.Hausmann, P.Kienle, O.Klepper, R.Knöbel, C.Kozhuharov, J.Kurcewicz, Y.Litvinov, S.Litvinov, Z.Liu, L.Maier, M.Mazzocco, F.Montes, G.Münzenberg, A.Musumarra, S.Nakajima, C.Nociforo, F.Nolden, T.Ohtsubo, A.Ozawa, Z.Patyk, W.Plass, T.Radon, H.Schatz, C.Scheidenberger, M.Shindo, J.Stadlmann, M.Steck, T.Stöhlker, B.Sun, T.Suzuki, P.Walker, H.Weick, N.Winckler, M.Winkler, H.Wollnik, T.Yamaguchi