

# TRIGA-TRAP

## High-precision mass measurements on neutron-rich nuclides and actinides



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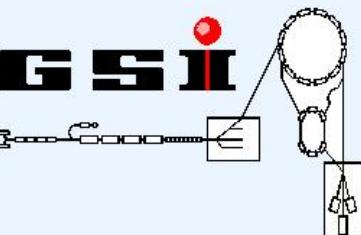
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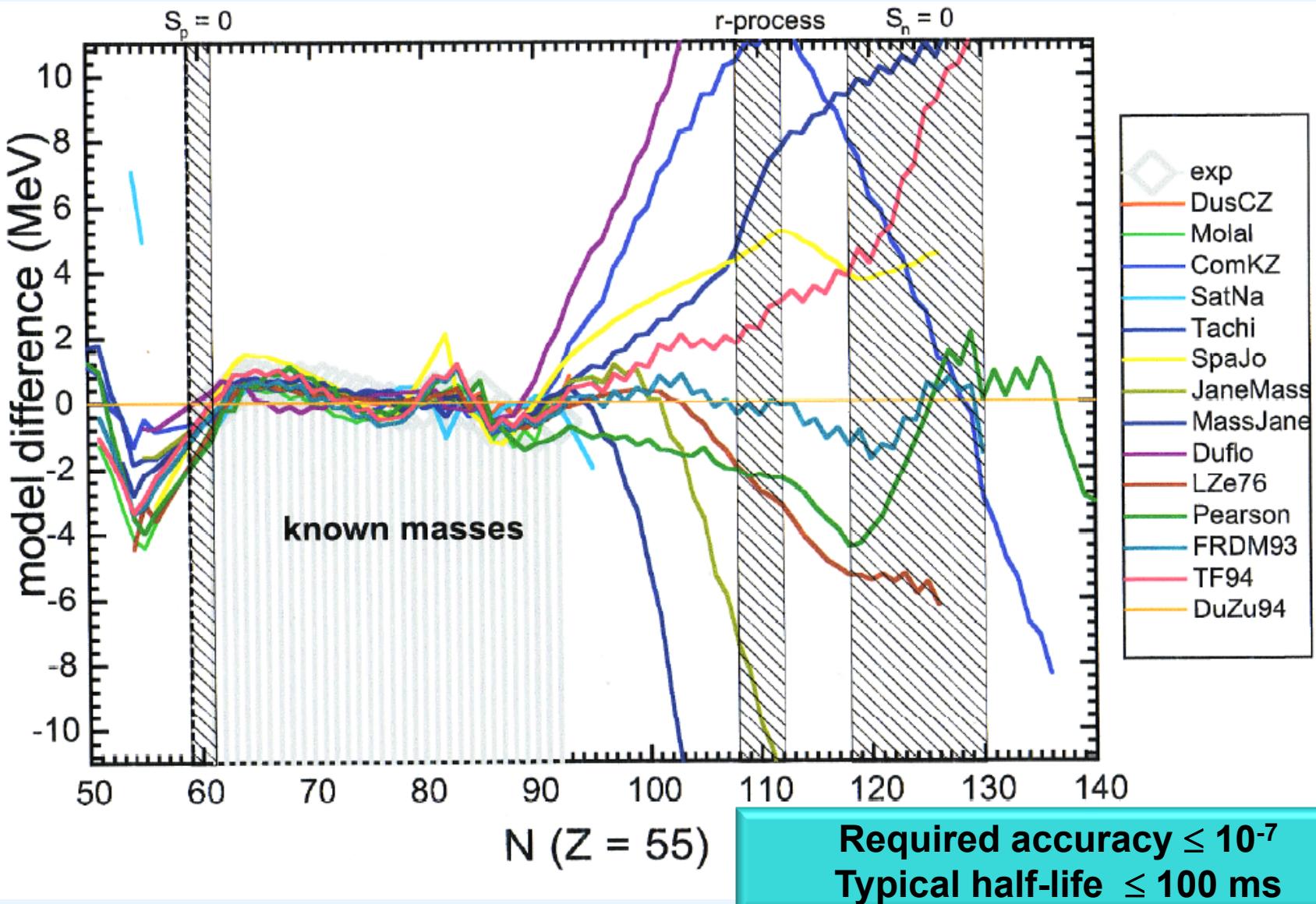
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### Outline:

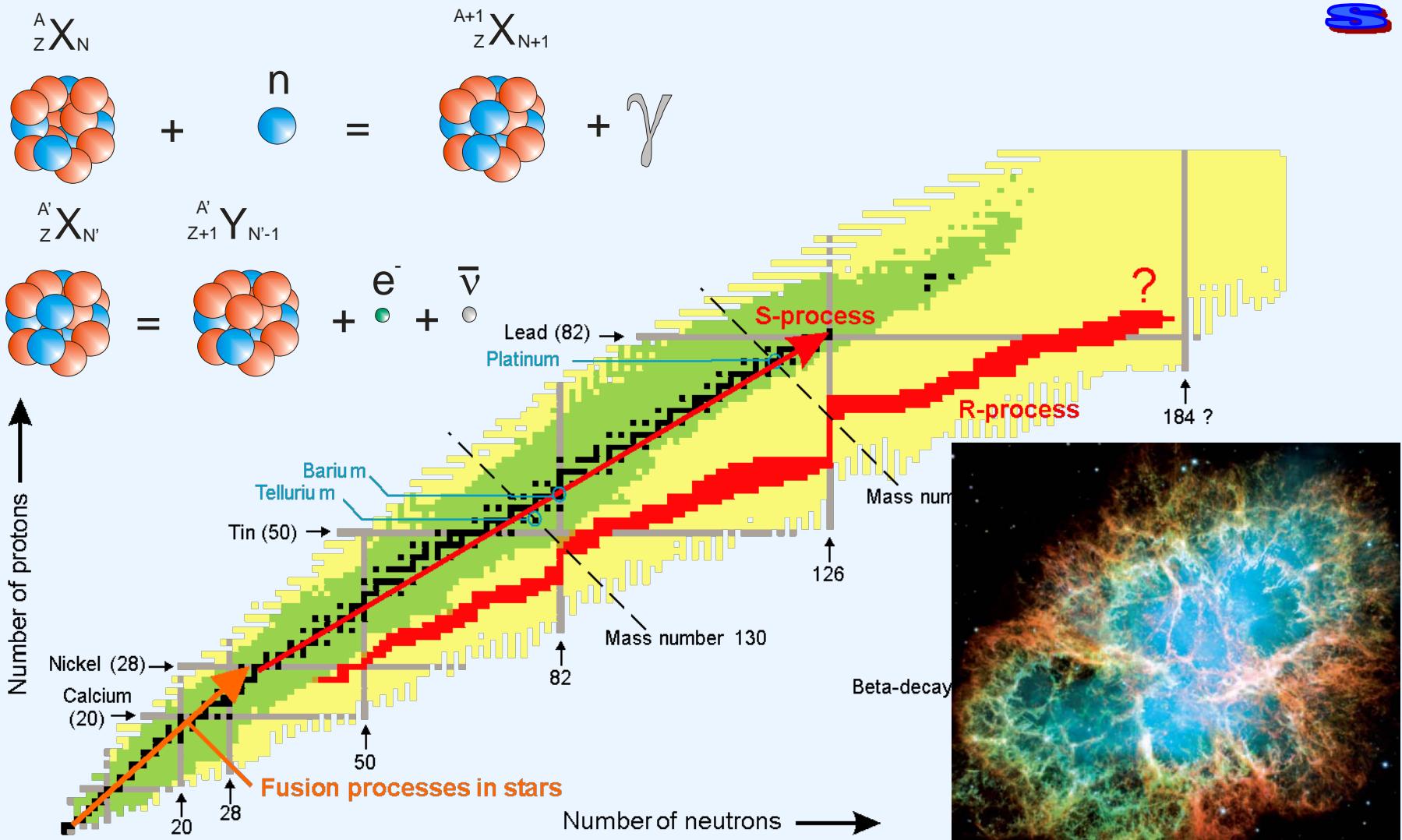
- Motivation
- Mass measurements on rare nuclides
- The TRIGA-TRAP mass spectrometer
- Present status
- Conclusions and outlook



# Motivation: Test of mass models



# Neutron capture processes



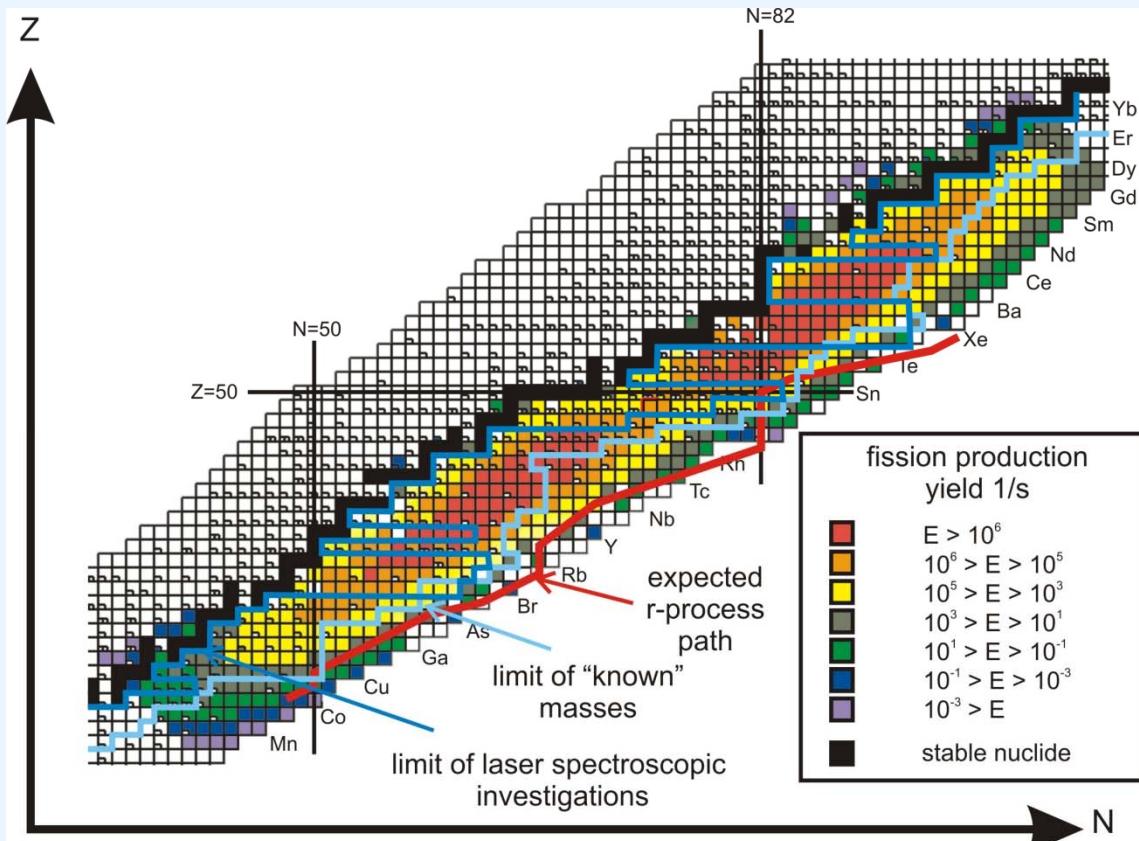
K. Blaum et al., Physik Journal 5 (2006) Nr. 2.

H. Schatz et al., Europhys. News 37, 16 (2006).

# Mass measurements on rarely-produced nuclides

available actinides

|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| La | Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu |
| Ac | Th | Pa | U  | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr |



High-precision mass measurements on

- *actinides*
- *neutron-rich fission products*

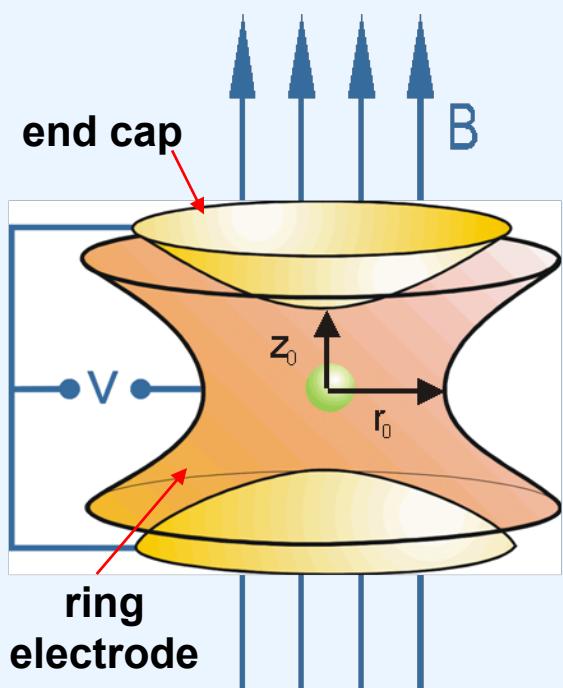
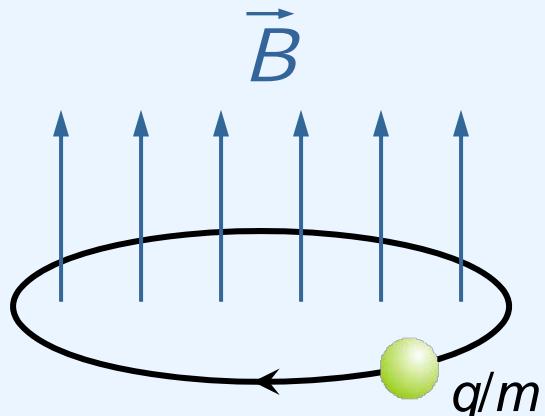
Nuclides with **very low production rates** but **half-lives in the order of seconds**



Non-destructive ion detection technique needed :

**highly sensitive FT-ICR**

# Penning trap principles

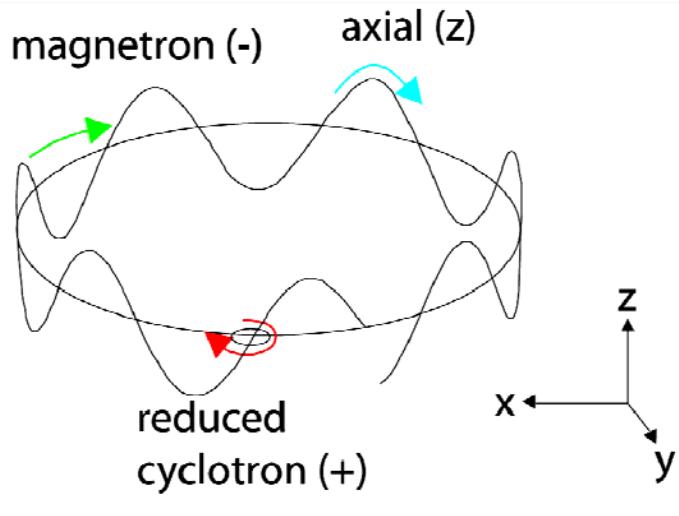


**Cyclotron frequency:**

$$\omega_c = \frac{q}{m} \cdot B$$

## Penning trap

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



$$\omega_z = \sqrt{\frac{qV}{md^2}}$$

$$\omega_+ = \frac{\omega_c}{2} + \sqrt{\frac{\omega_c^2}{4} - \frac{\omega_z^2}{2}}$$

$$\omega_- = \frac{\omega_c}{2} - \sqrt{\frac{\omega_c^2}{4} - \frac{\omega_z^2}{2}}$$

$$\omega_c^2 = \omega_+^2 + \omega_-^2 + \omega_z^2$$

Mass spectrometry

$$\omega_c = \omega_+ + \omega_-$$

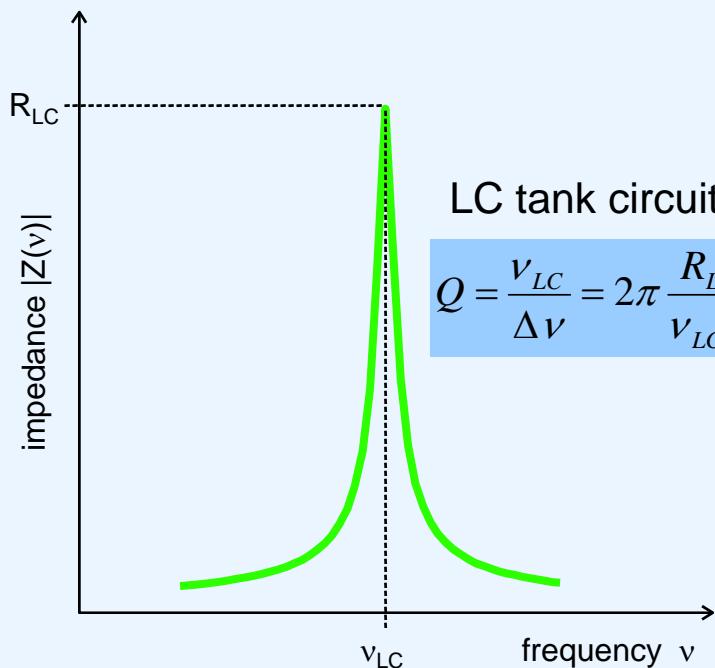
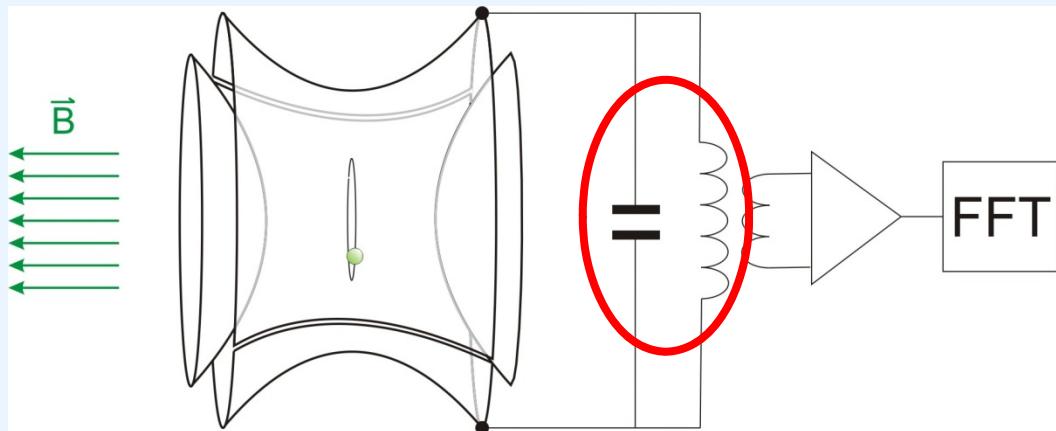
# Single-ion detection

Image current of single ion:

**10-100 fA**



**High-Q resonator,**  
superconducting coil



**$Q \approx 1000$**

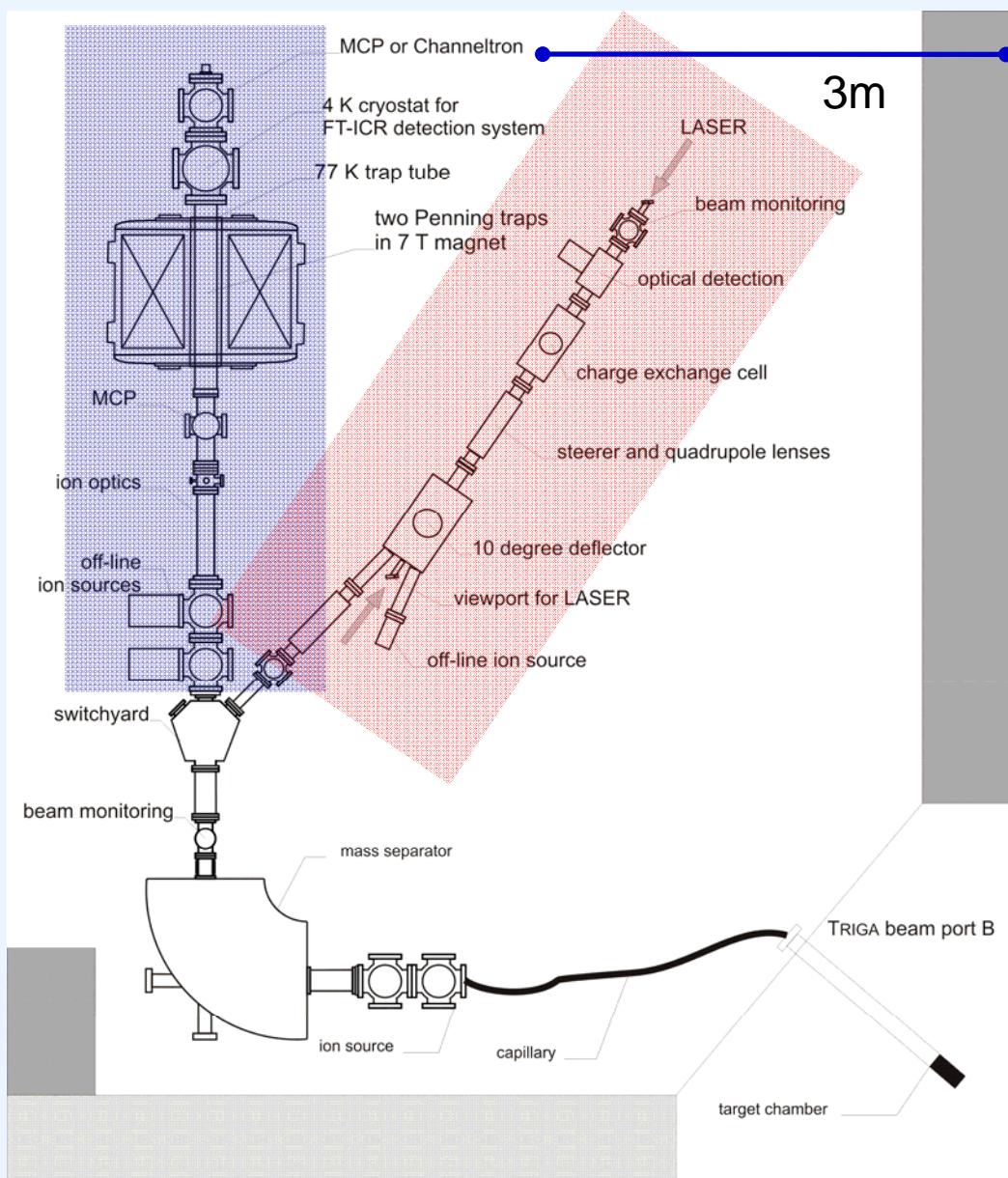
signal-to-noise ratio

$$\frac{S}{N} \approx \sqrt{\frac{I_0^2 G_{amp1}^2 R_p^2 / \gamma^2}{[(4k_B T R_p / \gamma^2 + U_{amp1}^2) G_{amp1}^2 + U_{amp2}^2] \cdot \Delta\nu}}$$

J. Ketelaer et al., Eur. Phys. J. A, submitted (2008).

R. Ferrer et al., Eur. Phys. J. Special Topics 150, 347–348 (2007).

# The TRIGA-TRAP mass spectrometer



Part of the **TRIGA-SPEC** facility

## TRIGA-TRAP :

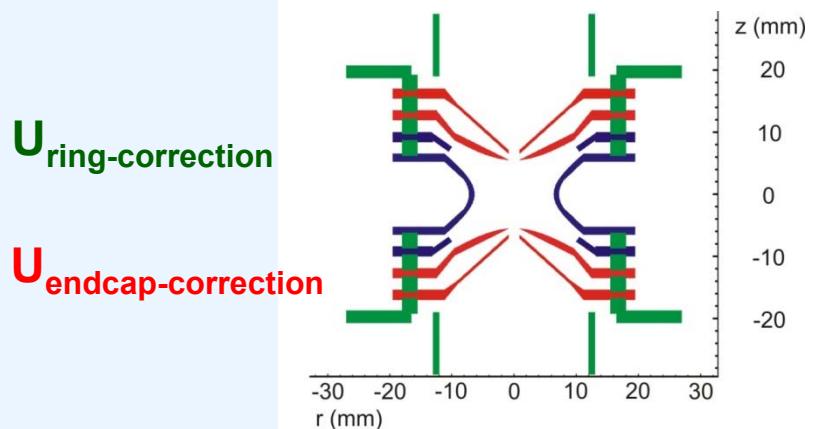
high-precision mass measurements on heavy and exotic nuclides

trap-assisted decay spectroscopy

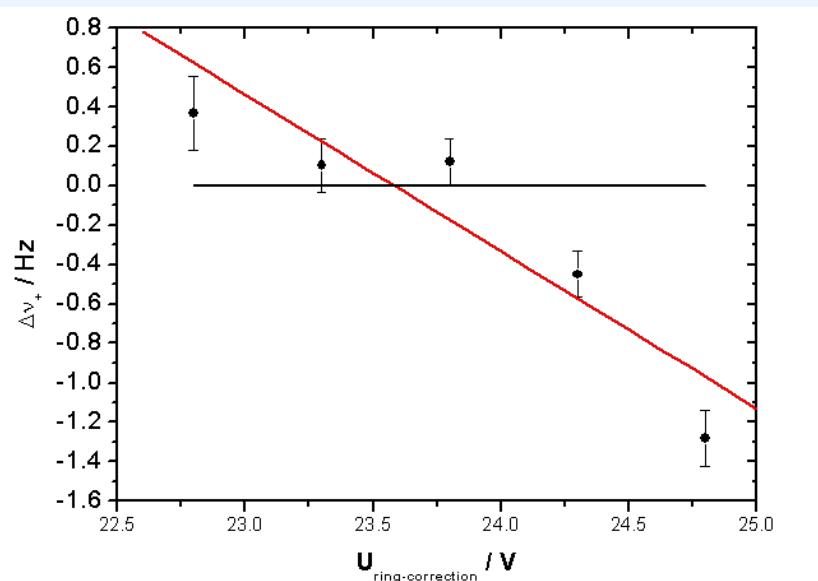
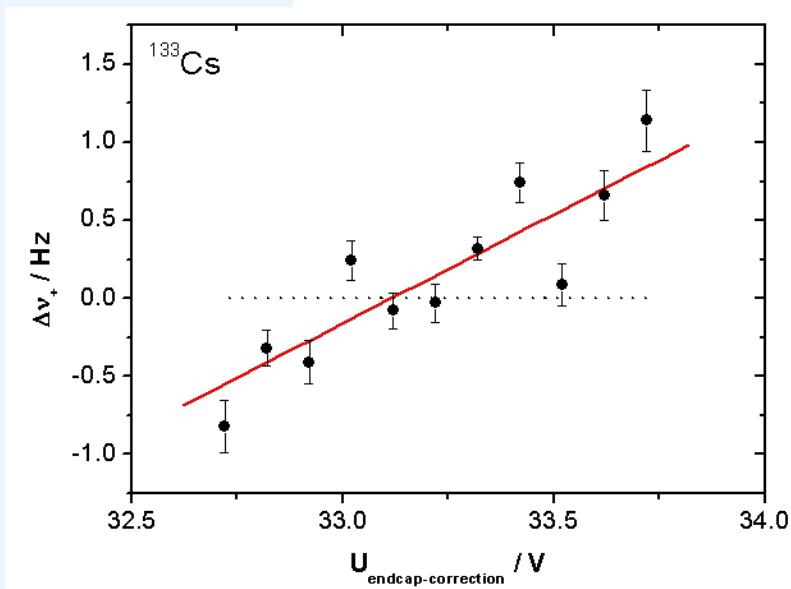
## TRIGA-LASER :

collinear laser spectroscopy on neutron-rich nuclides

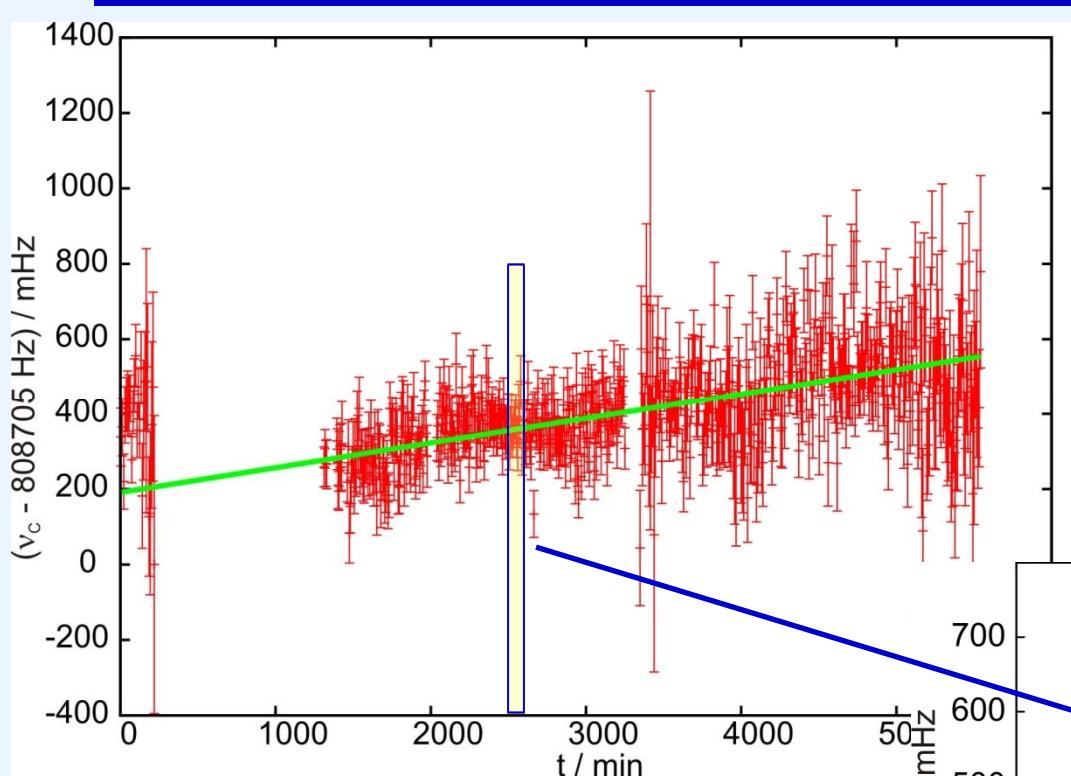
# Electric-field optimization of the trap



$v_+$  is sensitive to electric potential  
 $v_+$  is constant for a harmonic trap potential  
determine  $v_+$  for two capture timings ( $t_{1,2}$ )

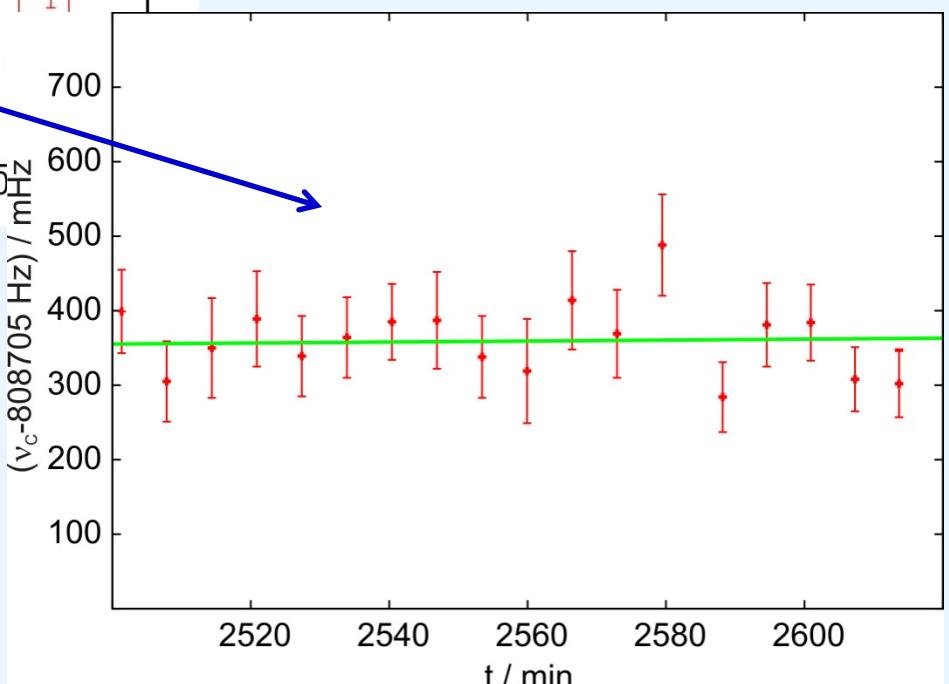


# Test of stability

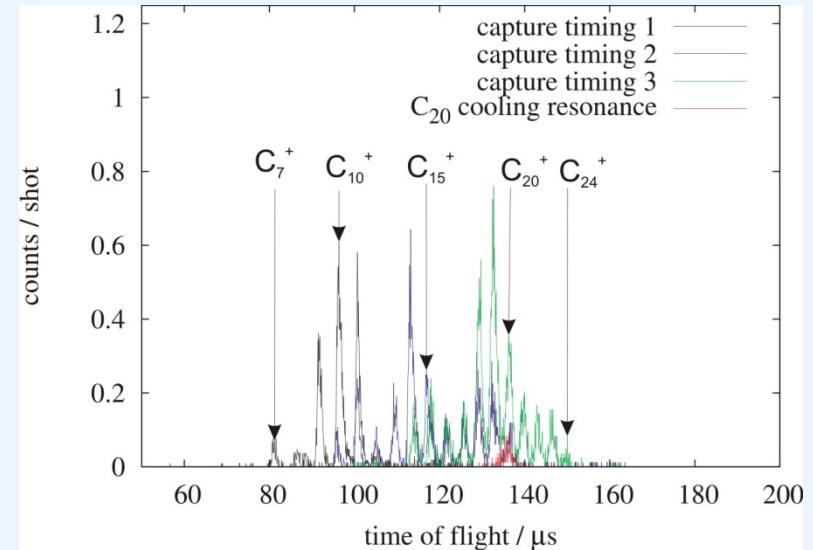
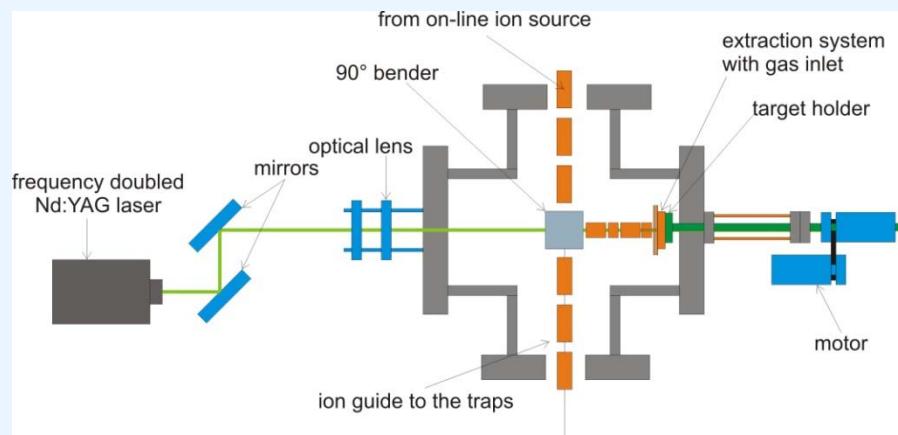


Limitation of the mass measurement due to stability of the magnetic field

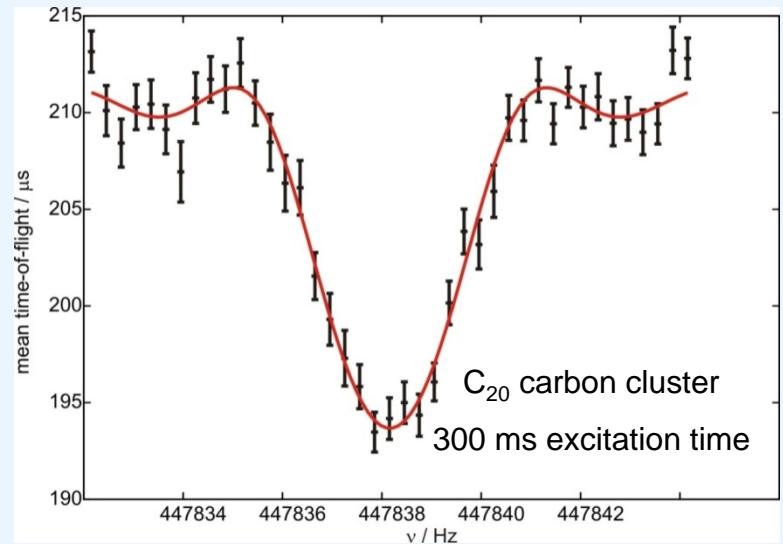
Linear magnetic field drift:  
 $\Delta B/B * 1/\Delta t = 6.4(4) 10^{-11} / \text{min}$



# Carbon cluster cross-references



Check of systematic effects  
with carbon clusters of  
different size  $C_n$



## ***Conclusions and outlook***

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- Many of the **actinide masses above uranium** have not been directly determined yet, but are important for **nucleosynthesis calculations**.
- Heavy and superheavy elements yield only **very low production rates** (~1 / sec.) but **rather long half-lives** ( $\geq$ 1 sec.). Therefore, the **non-destructive FT-ICR detection technique** is ideally suited.
- The use of the **cryogenic narrow-band FT-ICR technique** combined with a **77 K cold trap** enables single-ion sensitivity.
- TRIGA-TRAP aims for direct mass measurements on **elements heavier than uranium** as well as on neutron-rich fission **products**.
- The non-destructive FT-ICR detection method will be applied for the first time in an on-line facility for high-precision mass measurements on heavy nuclides.

# *Thanks a lot for your attention!*

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T  
S

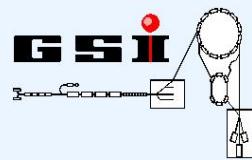


Funding:



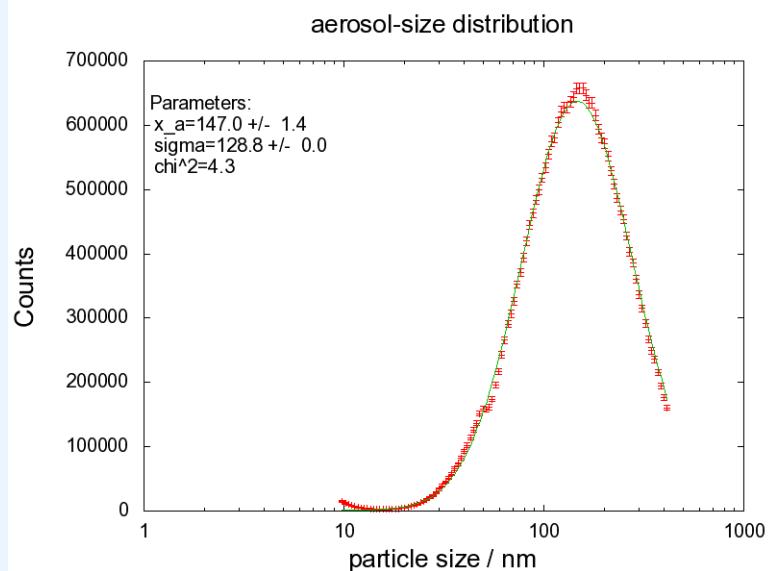
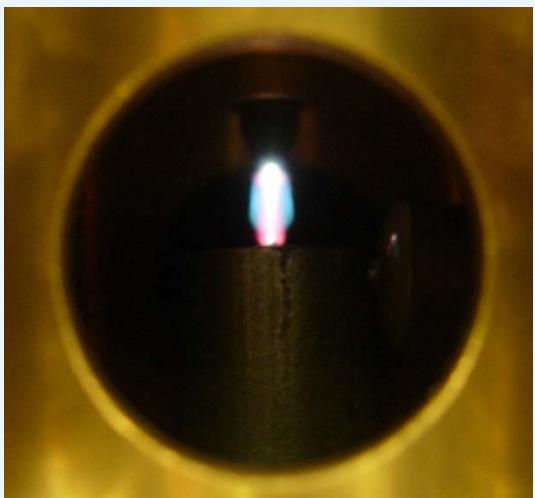
**854**

Stiftung  
Rheinland-Pfalz  
für Innovation

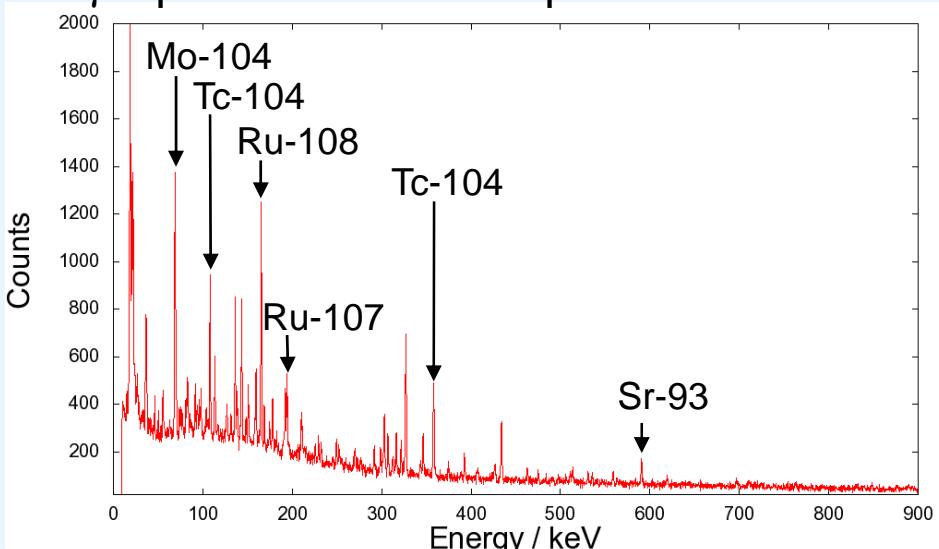


# Aerosol production at TRIGA-TRAP

M  
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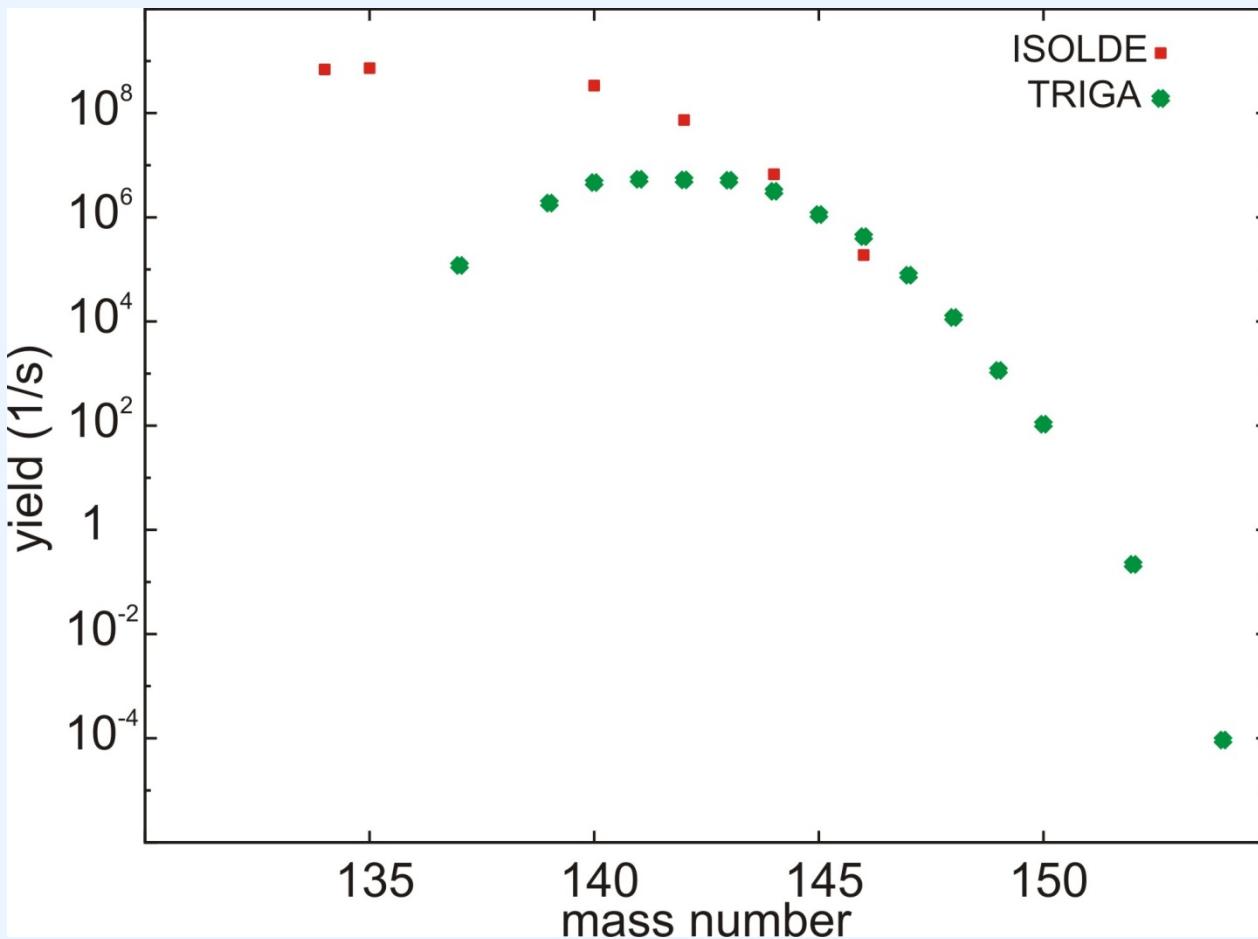
$\gamma$ -spectrum of fission products of Cf-249



Candidates for mass measurements

| Nuclide | $T_{1/2}$ | $\Delta m / \text{keV}$ |
|---------|-----------|-------------------------|
| Tc-104  | 18.3 min  | 50                      |
| Tc-105  | 7.6 min   | 60                      |
| Mo-104  | 60 s      | 50                      |
| Ru-107  | 3.75 min  | 120                     |
| Ru-108  | 4.6 min   | 120                     |

# *Yield comparison TRIGA / ISOLDE*



Yield comparison  
between ISOLDE  
and TRIGA  
  
Example: Barium