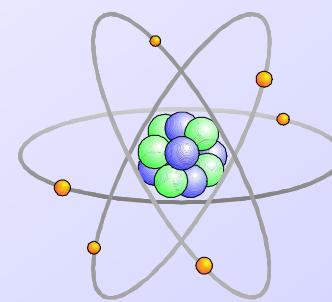
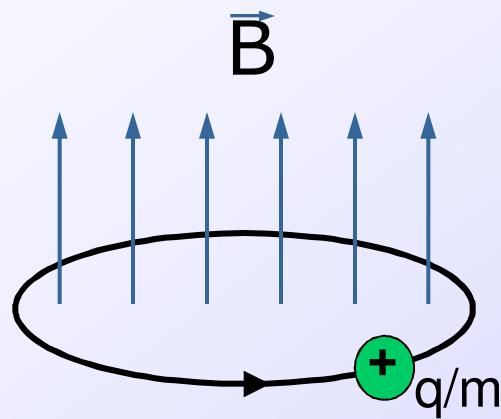


# Precision mass measurements with ISOLTRAP

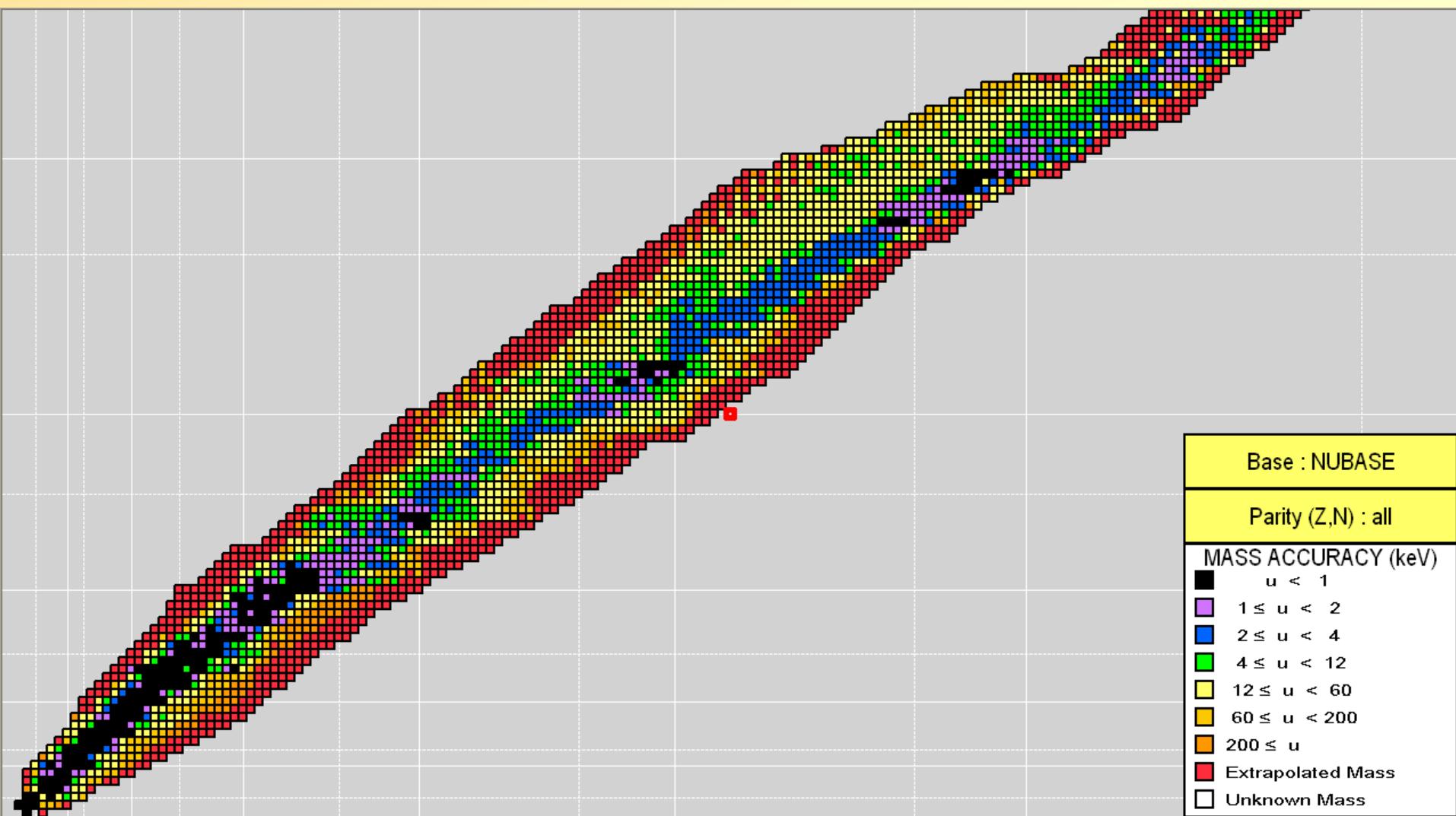
## Past, present, and future

Alexander Herlert, CERN (PH-SME-IS)



$$= N \cdot \text{green circle} + Z \cdot \text{blue circle} + Z \cdot \text{orange circle} \\ - \text{binding energy}$$

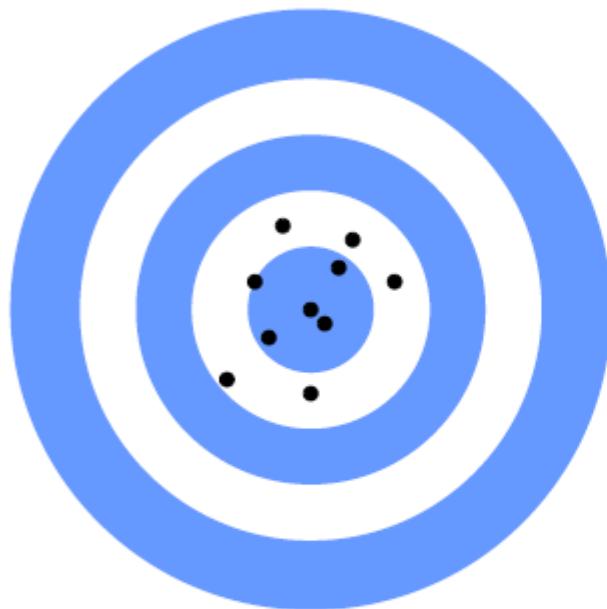
# Mass accuracy – AME2003



G. Audi, A.H. Wapstra, C. Thibault, Nucl. Phys. A 729

# Accuracy and precision ...

accurate



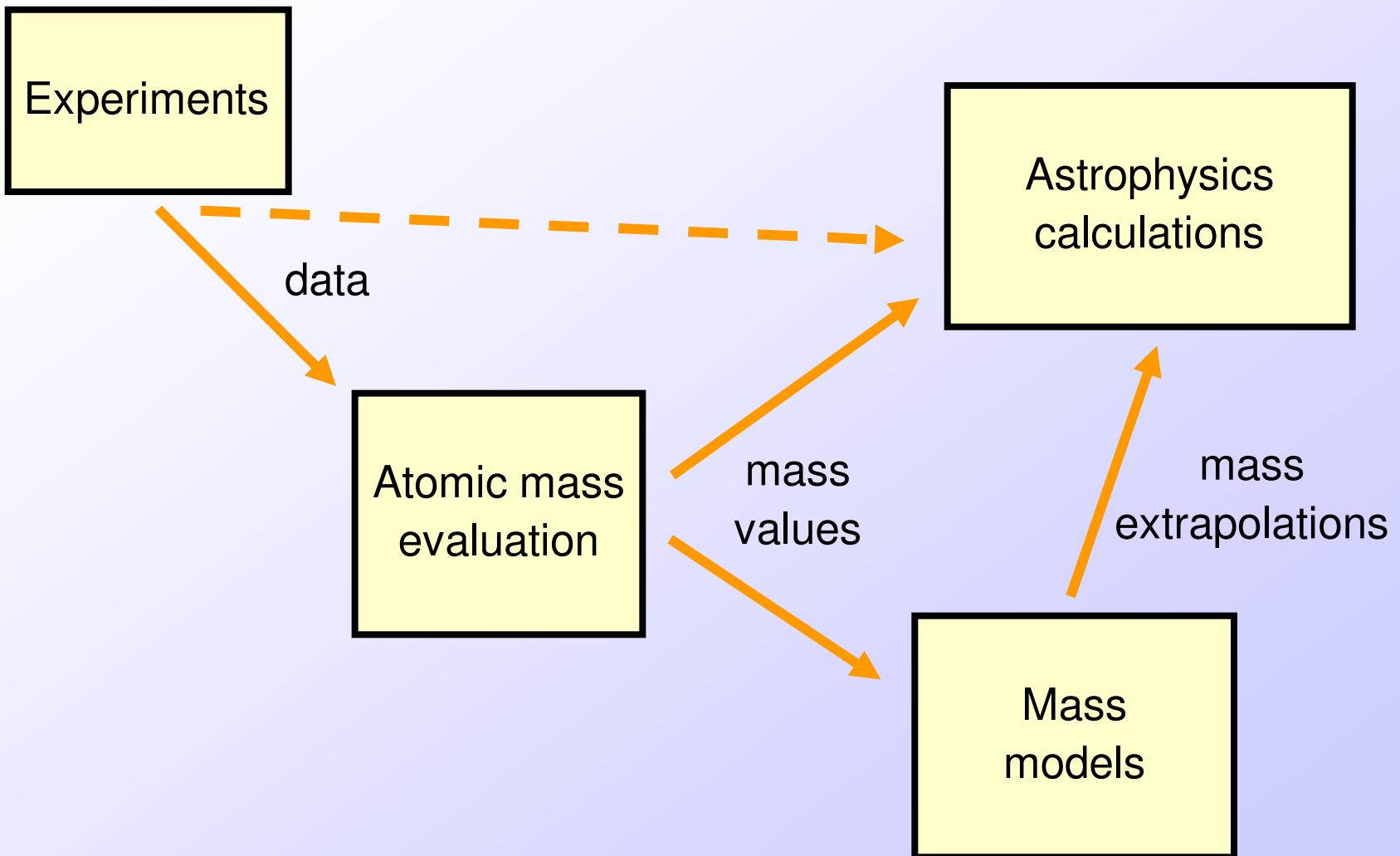
...but not  
precise

precise

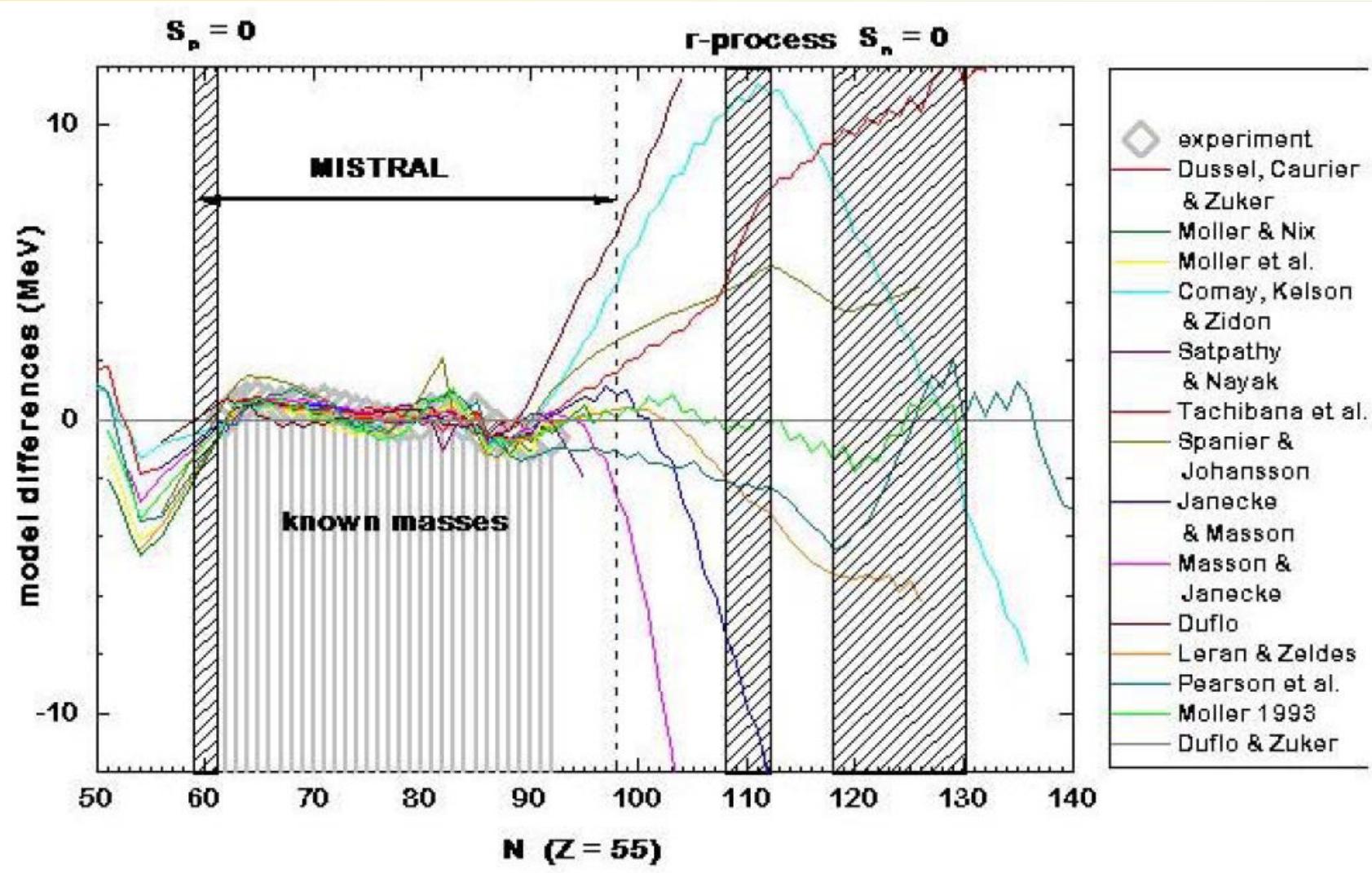


...but not  
accurate

# Mass values for astrophysics calculations

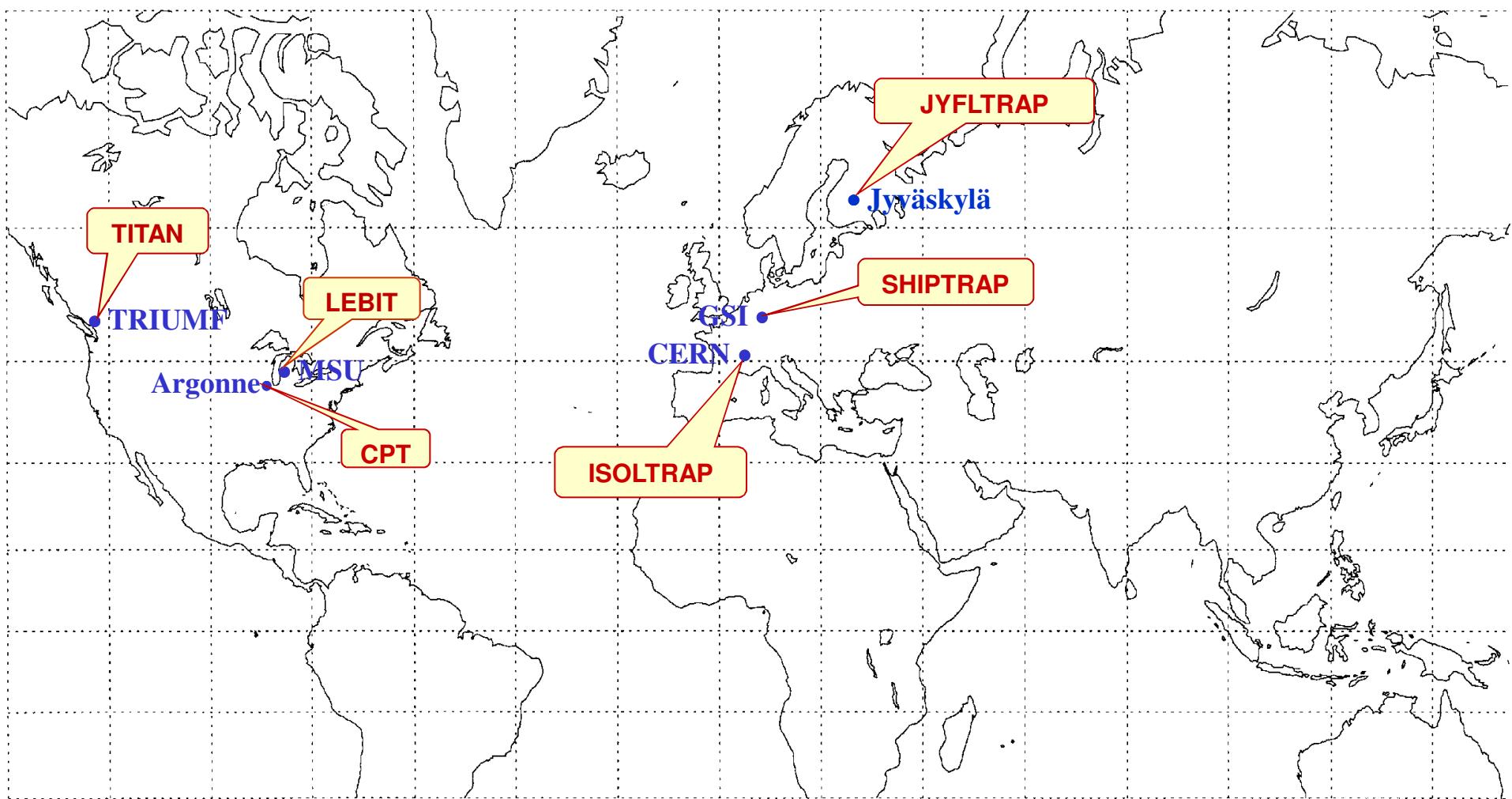


# Mass extrapolation – limitation of mass models

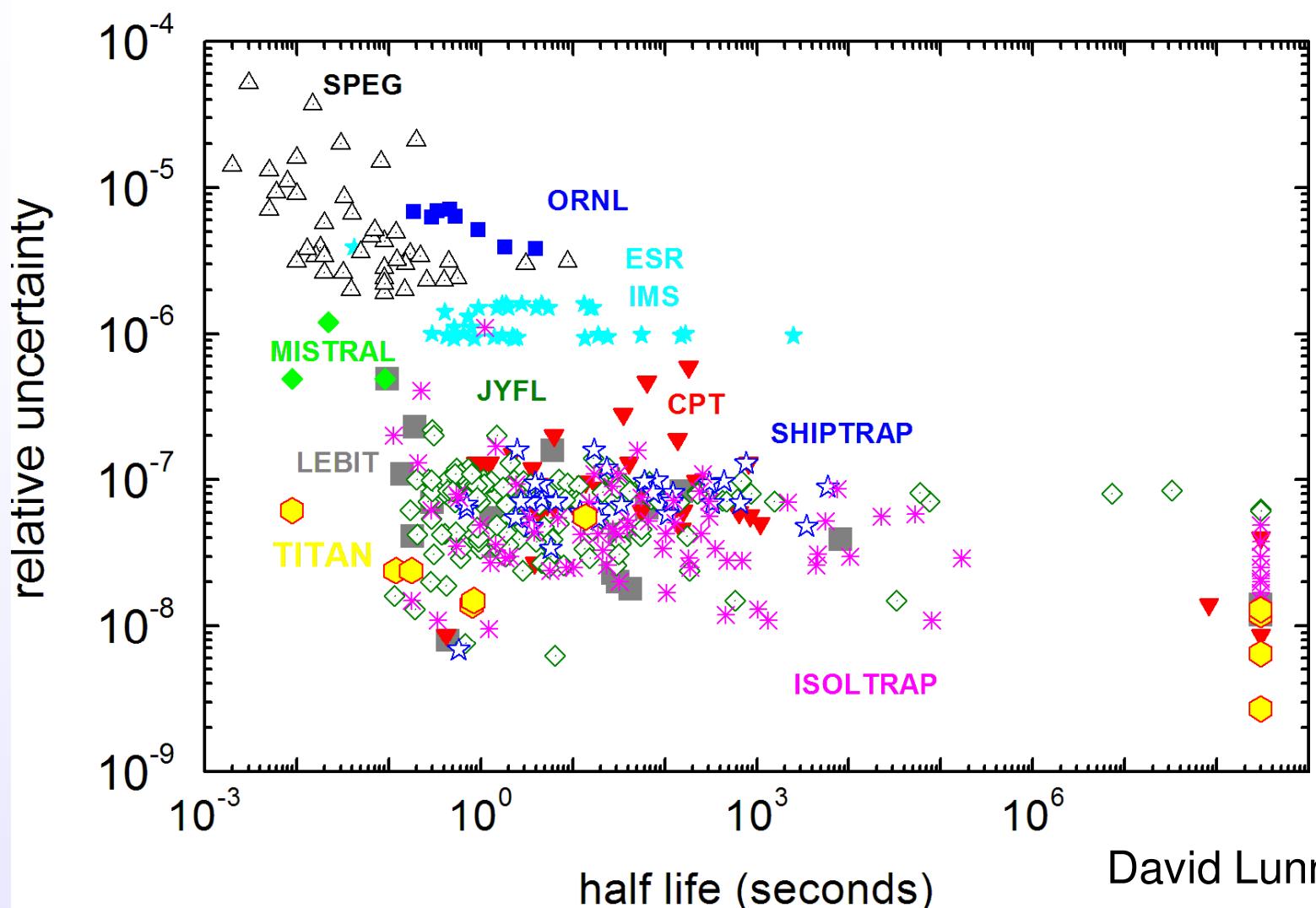


David Lunney (ENAM 1995)

# Penning traps for mass measurements on short-lived nuclides

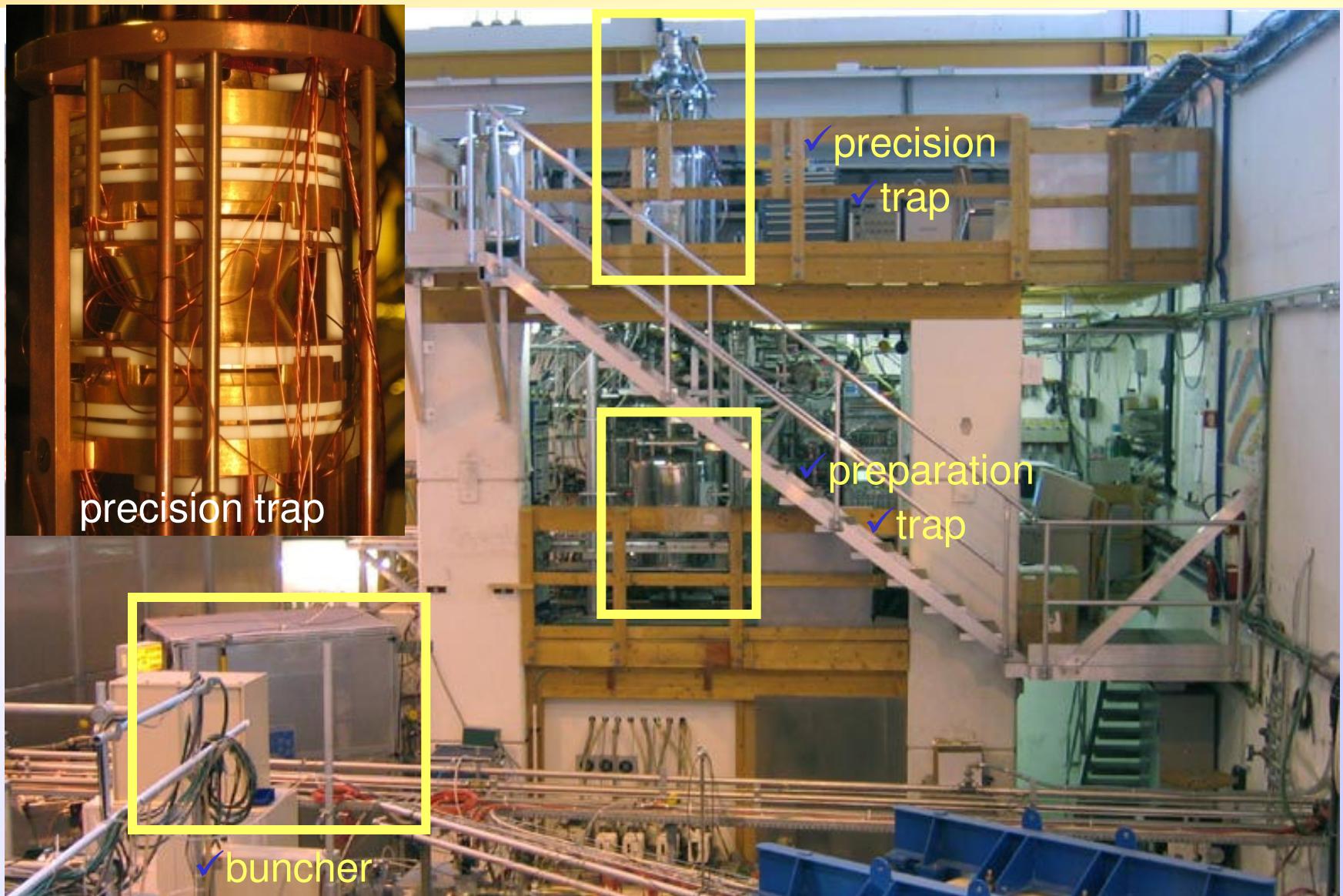


# Relative mass uncertainty vs. half life

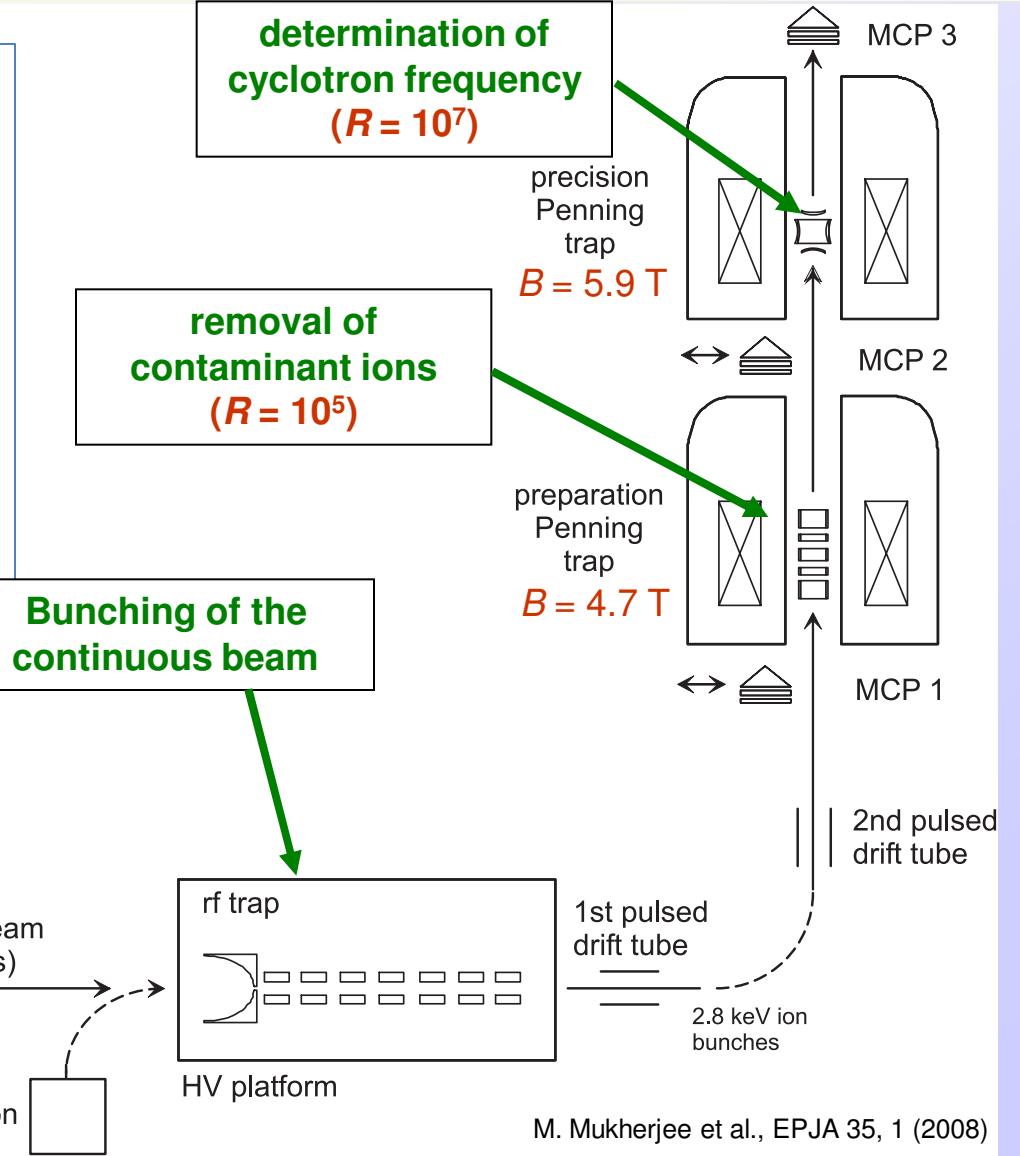
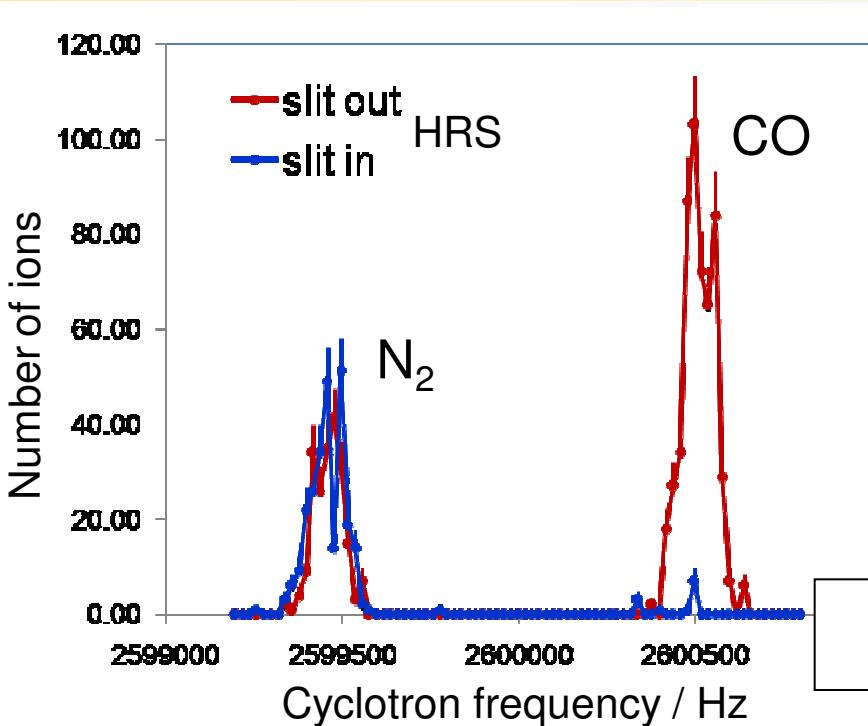


David Lunney  
(ENAM2008)

# Ion traps at ISOLTRAP

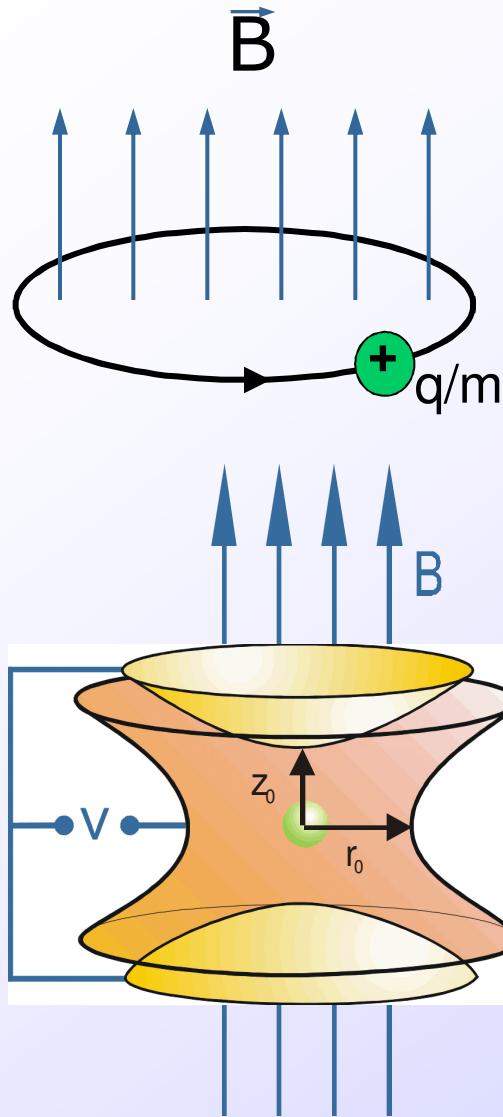


# Mass purification - isobaric separation



Buffer gas cooling with QP excitation:  
Savard et al., Phys. Lett. A 158, 247 (1991)

# ISOLTRAP measurement trap



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

determination of cyclotron frequency ( $R = 10^7$ )

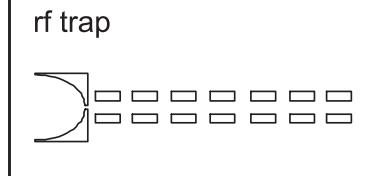
precision Penning trap  
 $B = 5.9$  T

removal of contaminant ions ( $R = 10^5$ )

preparation Penning trap  
 $B = 4.7$  T

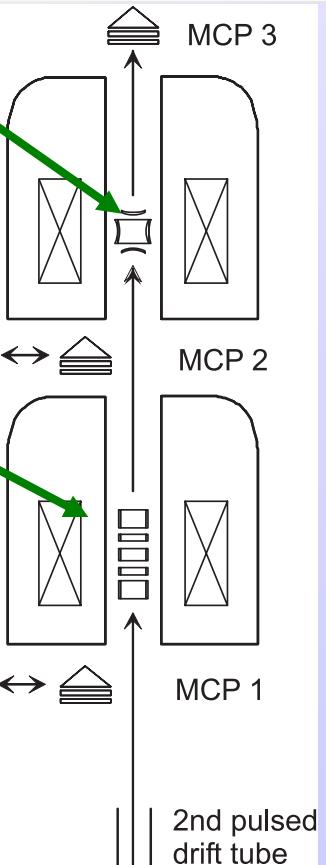
Bunching of the continuous beam

ISOLDE beam (continuous)  
60 keV  
stable alkali reference ion source



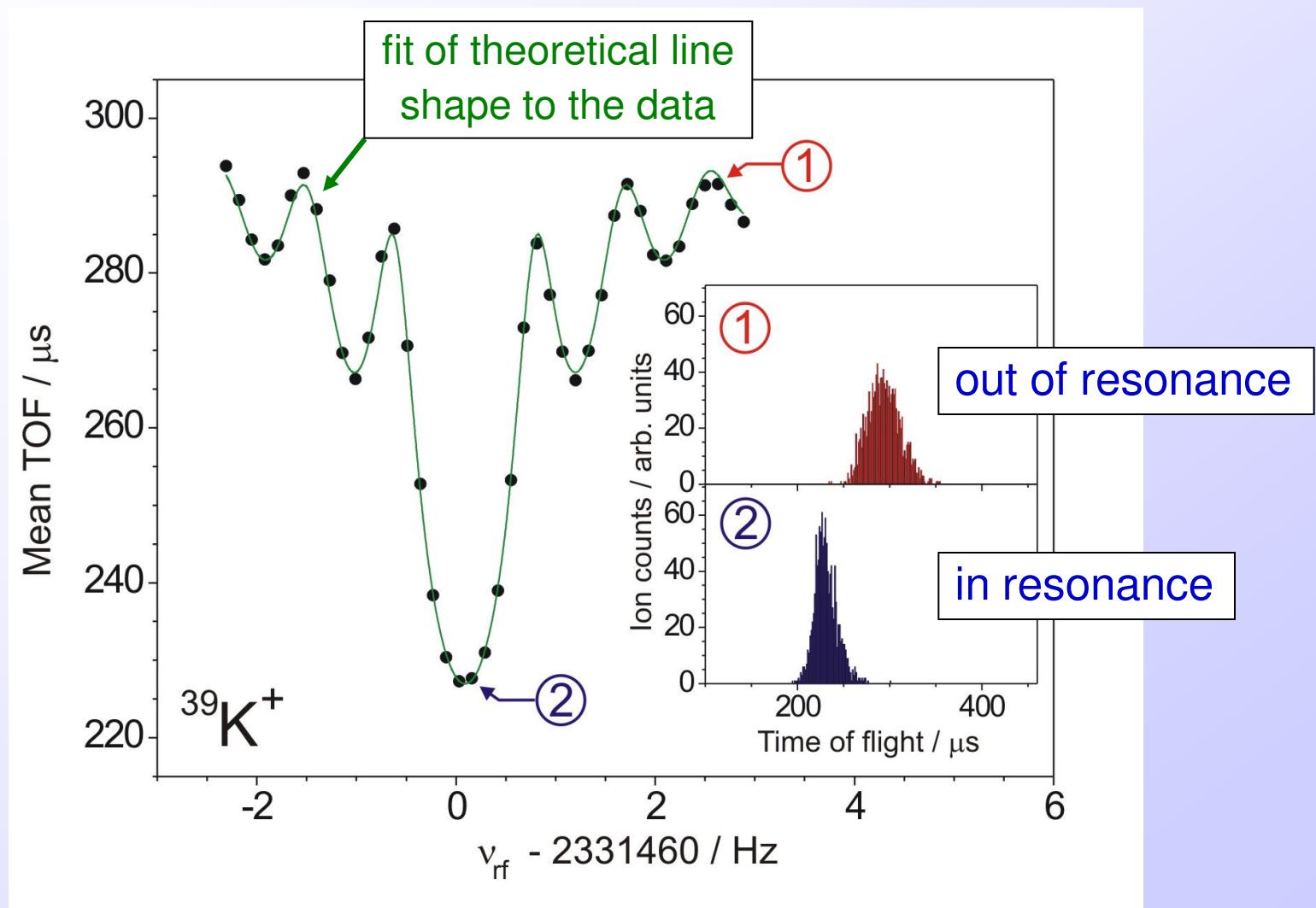
HV platform

1st pulsed drift tube  
2.8 keV ion bunches



M. Mukherjee et al., EPJA 35, 1 (2008)

# Cyclotron frequency determination



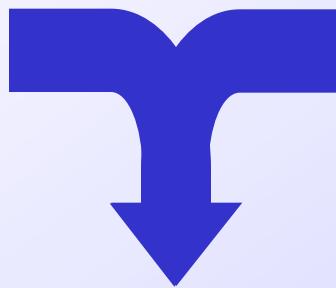
# Principle of mass determination

cyclotron frequency  
of "unknown" nuclide

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

cyclotron frequency  
of well-known nuclide

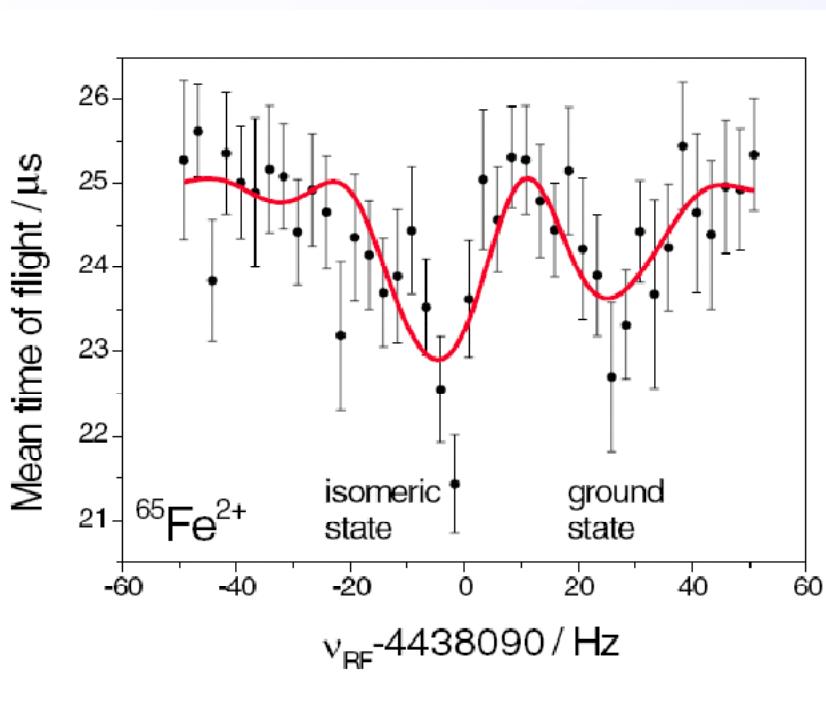
$$\nu_{c,ref} = \frac{1}{2\pi} \frac{q}{m_{ref}} B$$



$$\frac{\nu_{c,ref}}{\nu_c} = \frac{m}{m_{ref}}$$

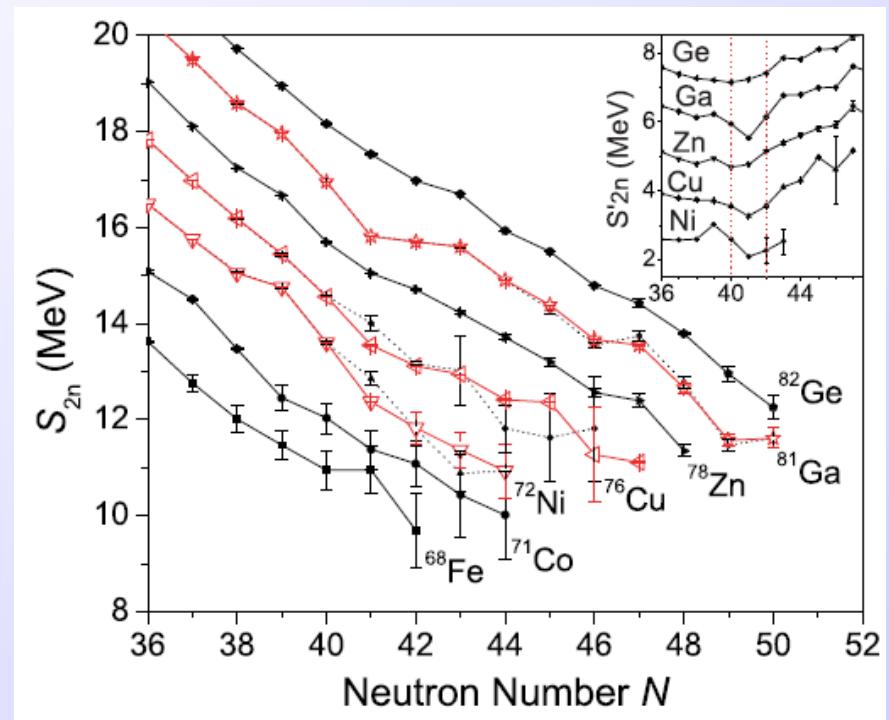
determination of mass ratio

# Motivation to investigate Mn and Fe nuclides



Mass measurements at LEBIT experiment

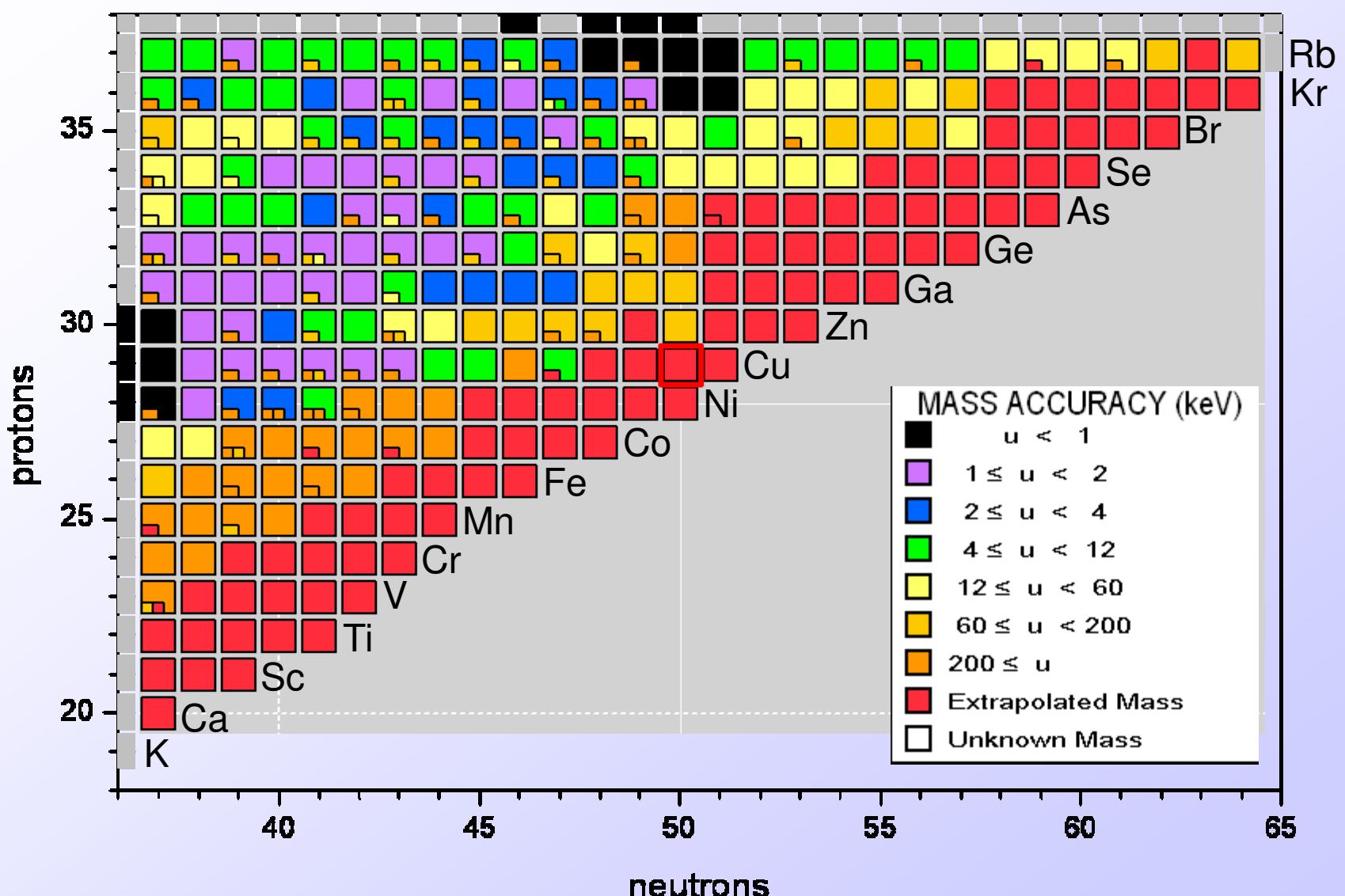
M. Block et al.,  
Phys. Rev. Lett. 100, 132501 (2008)



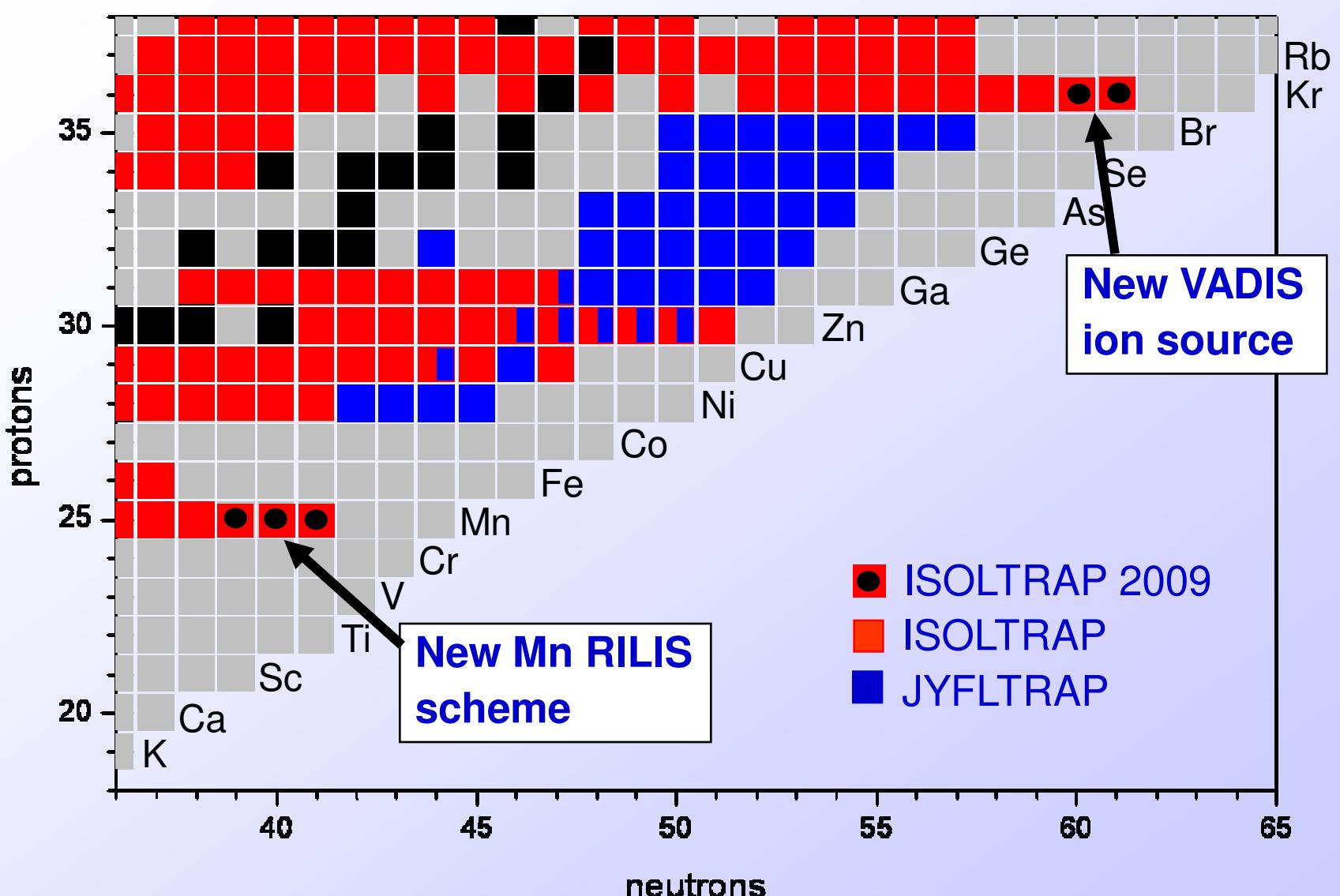
Nuclides around  $N=40$

C. Guenaut et al.,  
Phys. Rev. C 75, 044303 (2007)

# Mass accuracy – AME2003

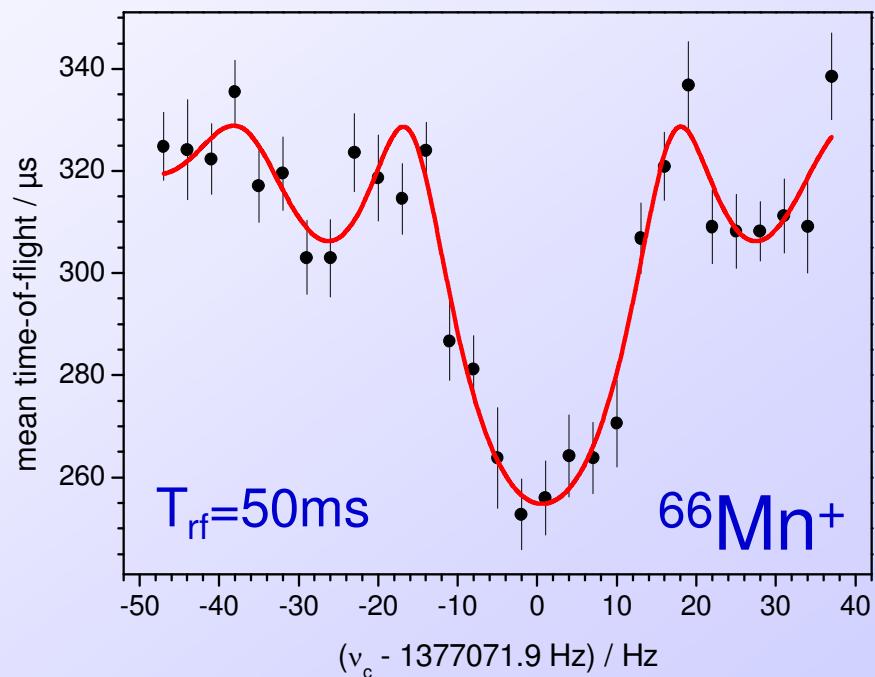


# Mass measurements - plus new cases explored in 2009



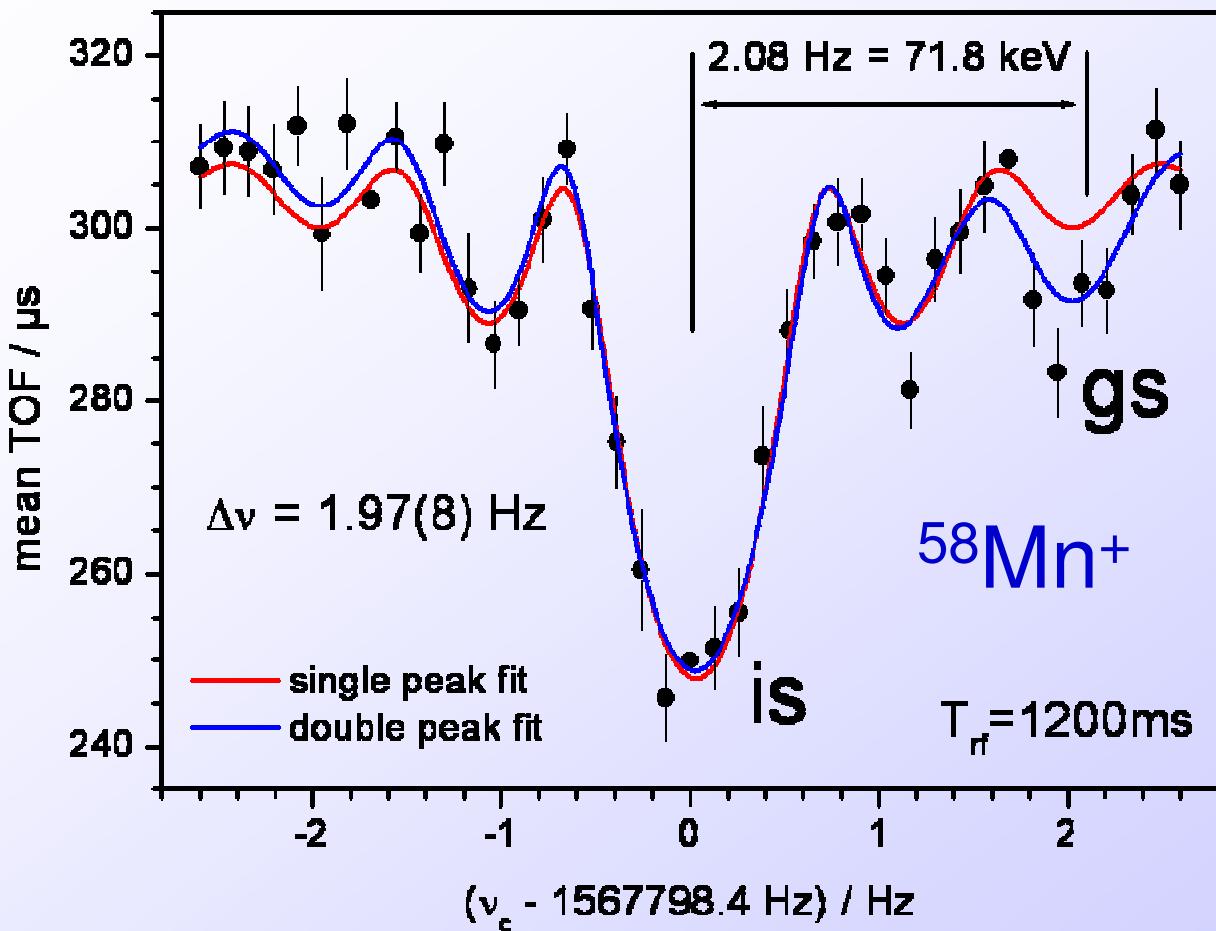
# Neutron-rich manganese isotopes 2009

Very good data for  $^{64-66}\text{Mn}$   
 $(T_{1/2}(\text{ $^{66}\text{Mn}$ }) = 64.4\text{ms}$   
new ISOLTRAP record)



See talk of Sarah Naimi

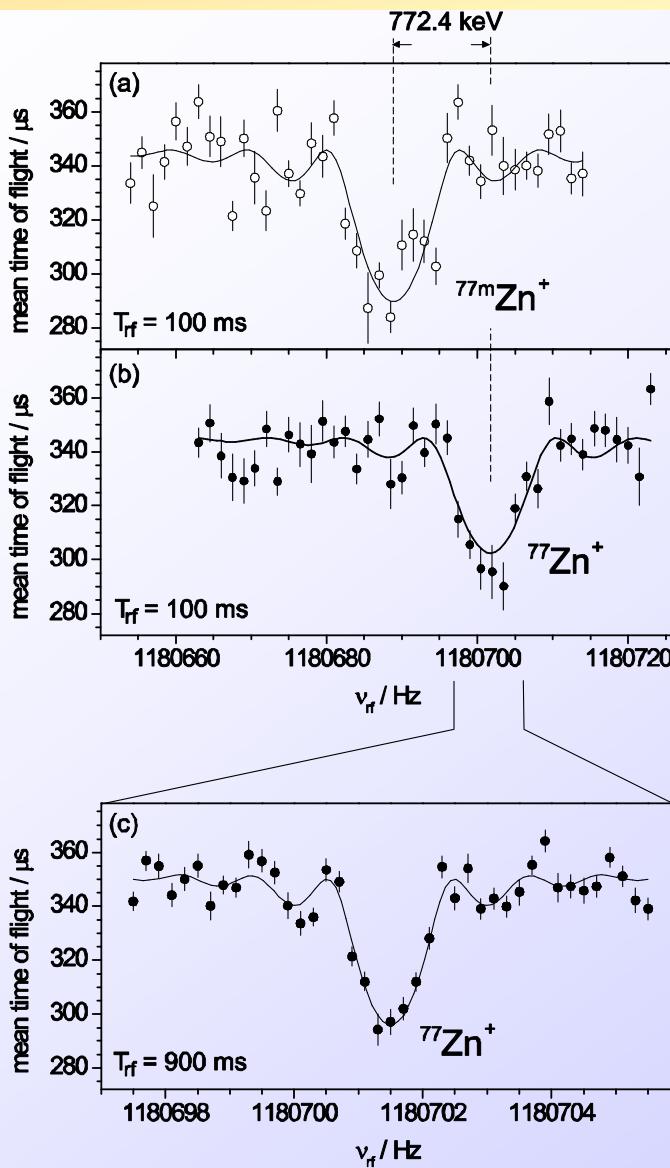
# Limitation: Resolving isomers



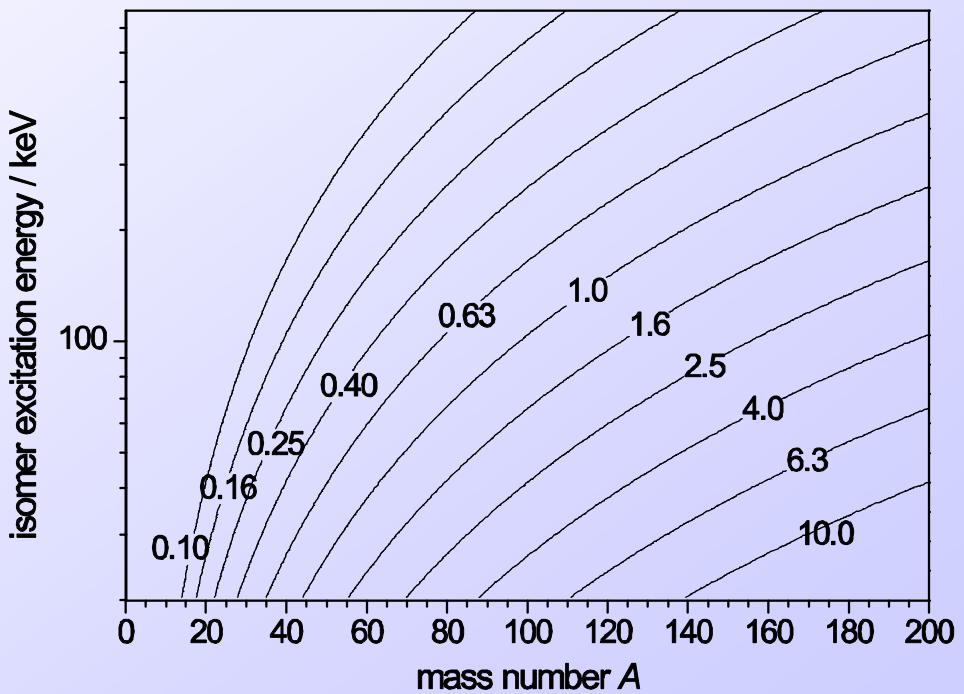
At 1.2s excitation duration both states are resolved

The excited state isomer has a higher production yield

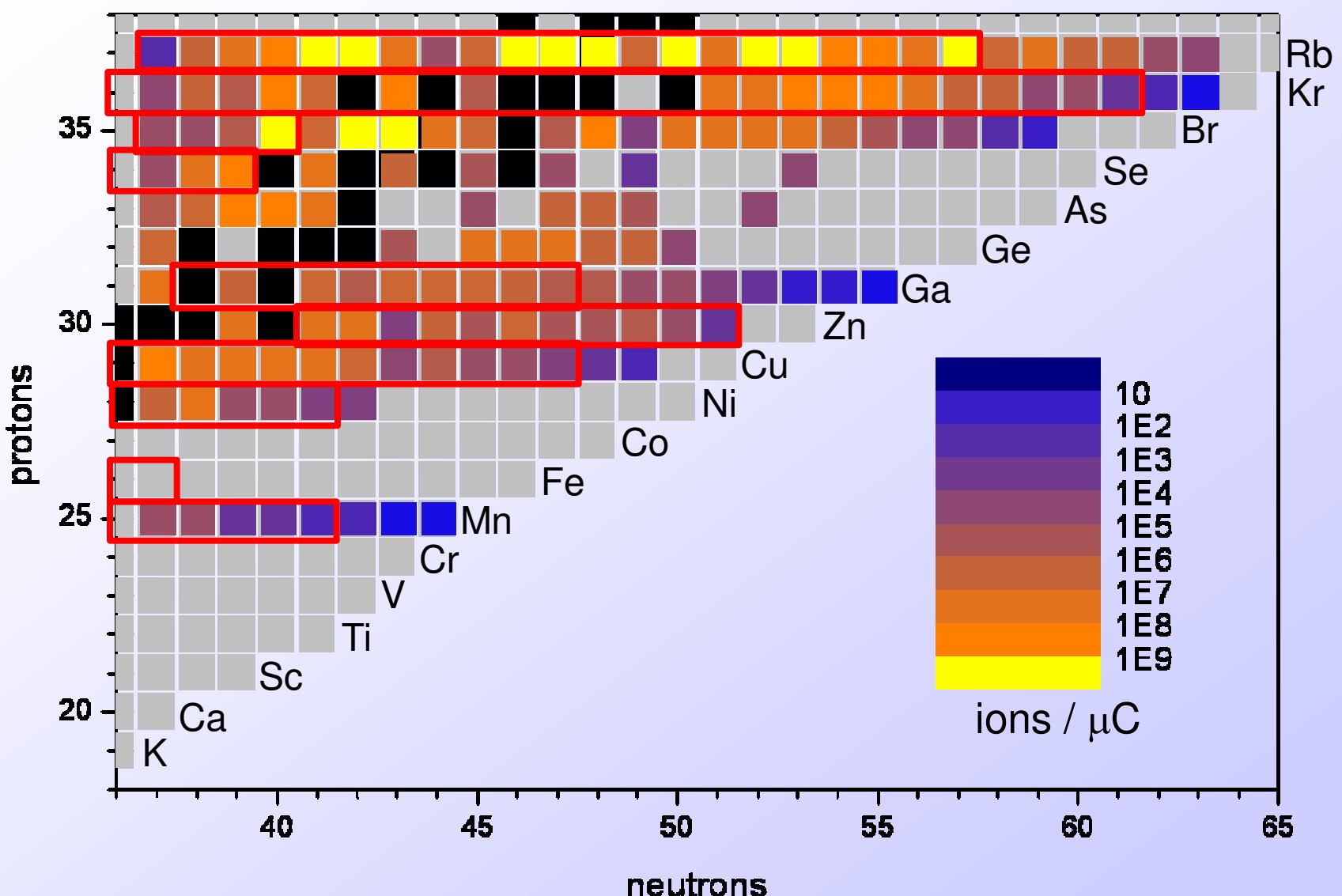
# Isomer selection/cleaning



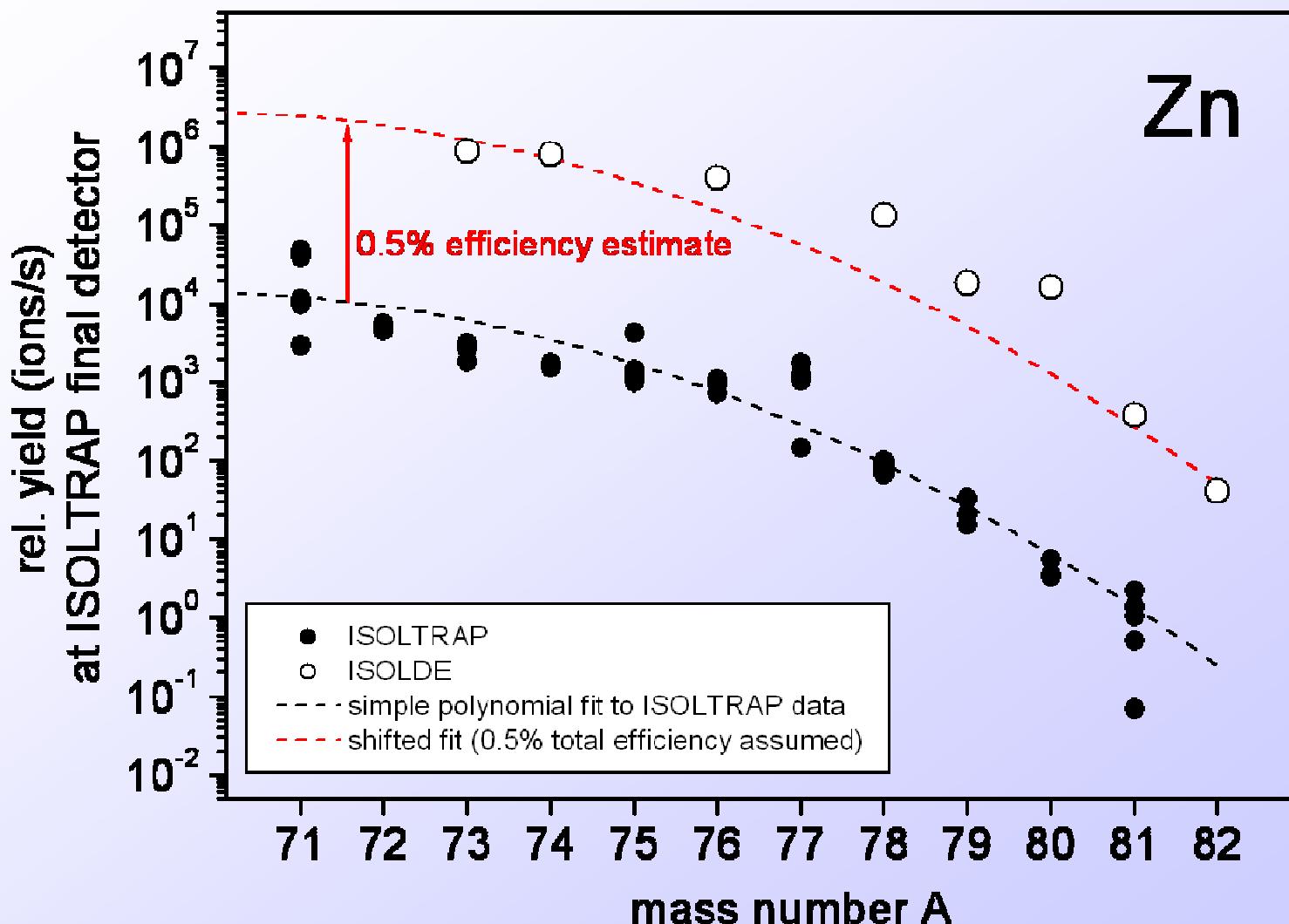
Excitation duration required



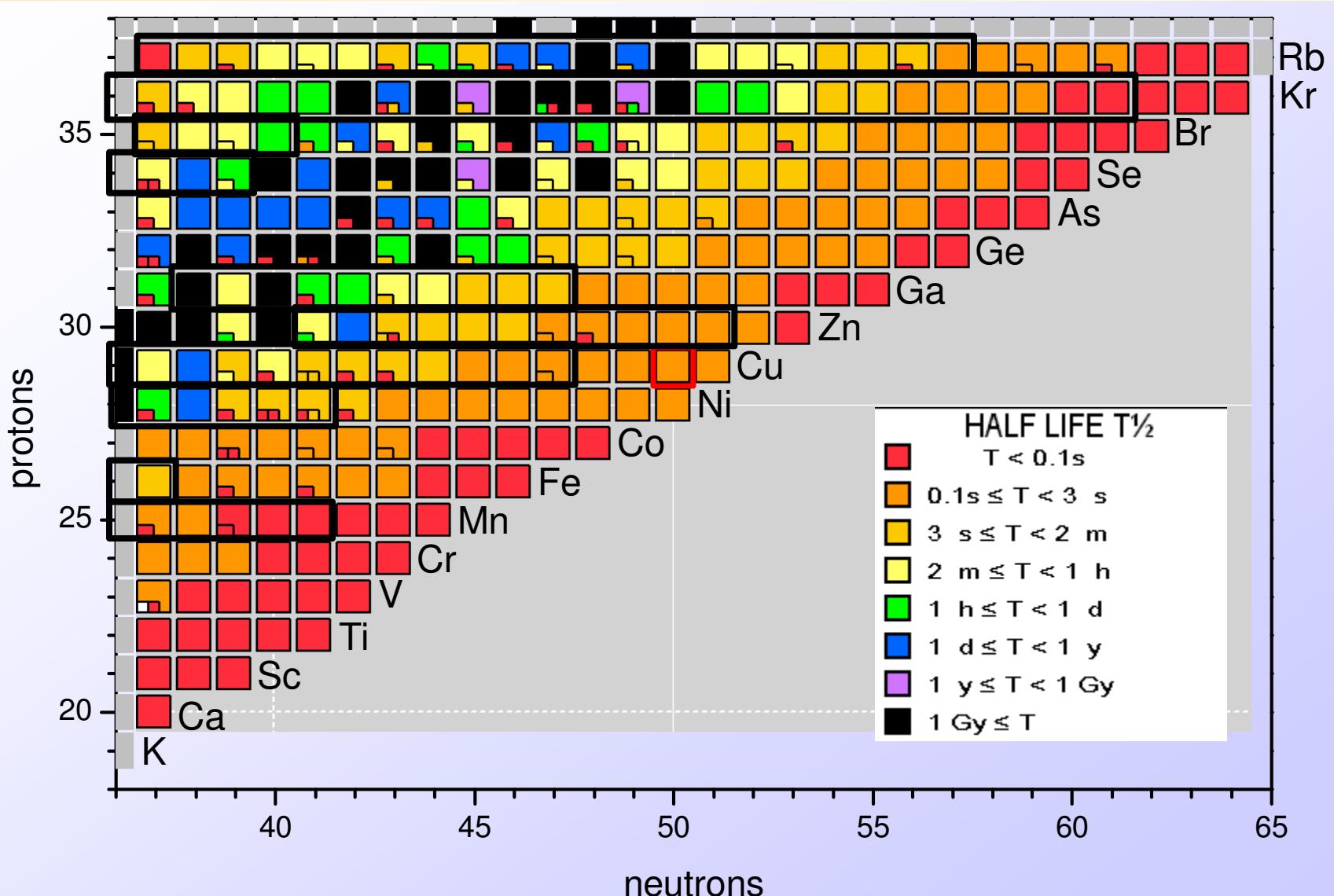
# Limitation: Ion yields



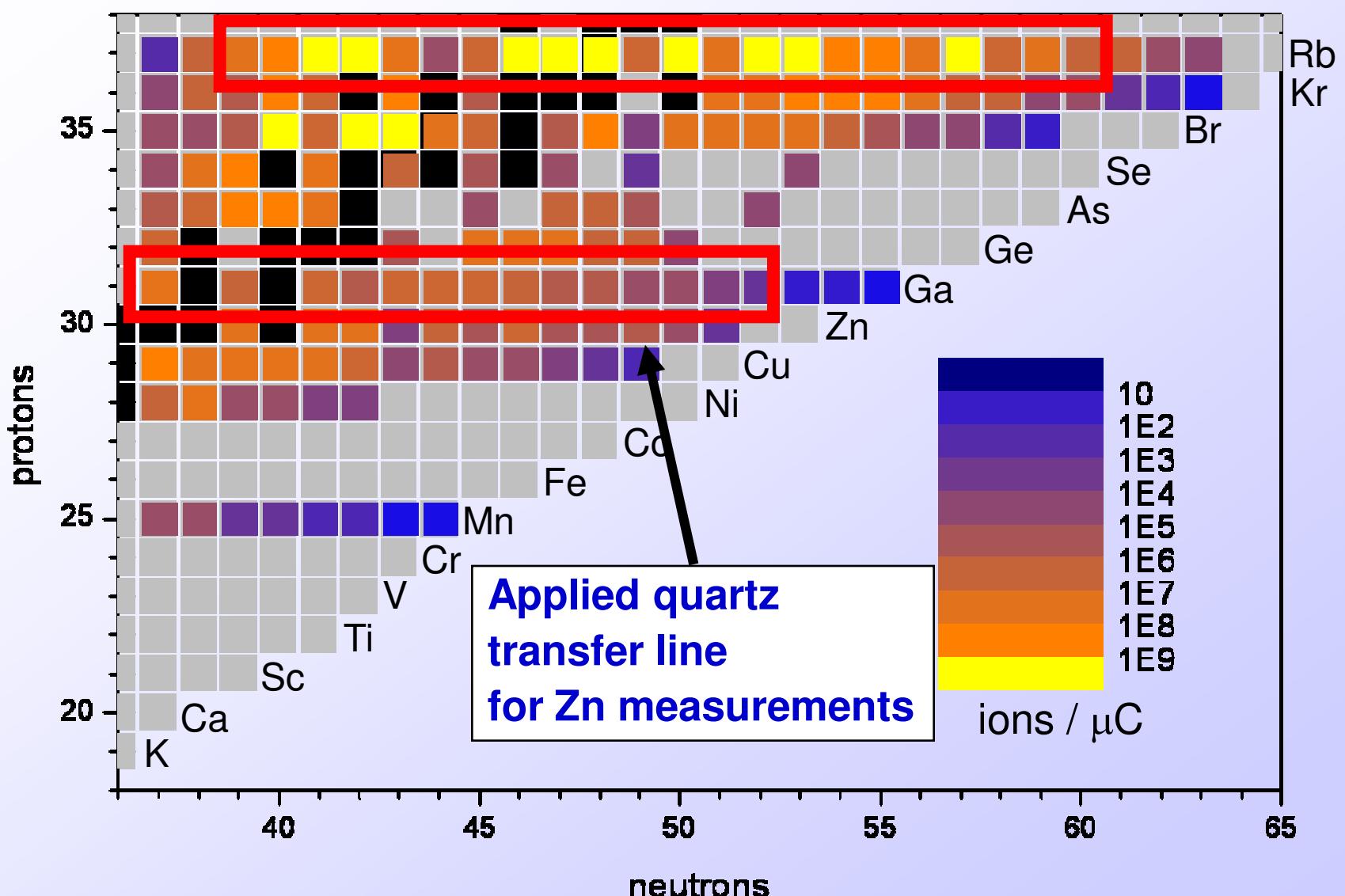
# Yield ISOLDE vs. ISOLTRAP



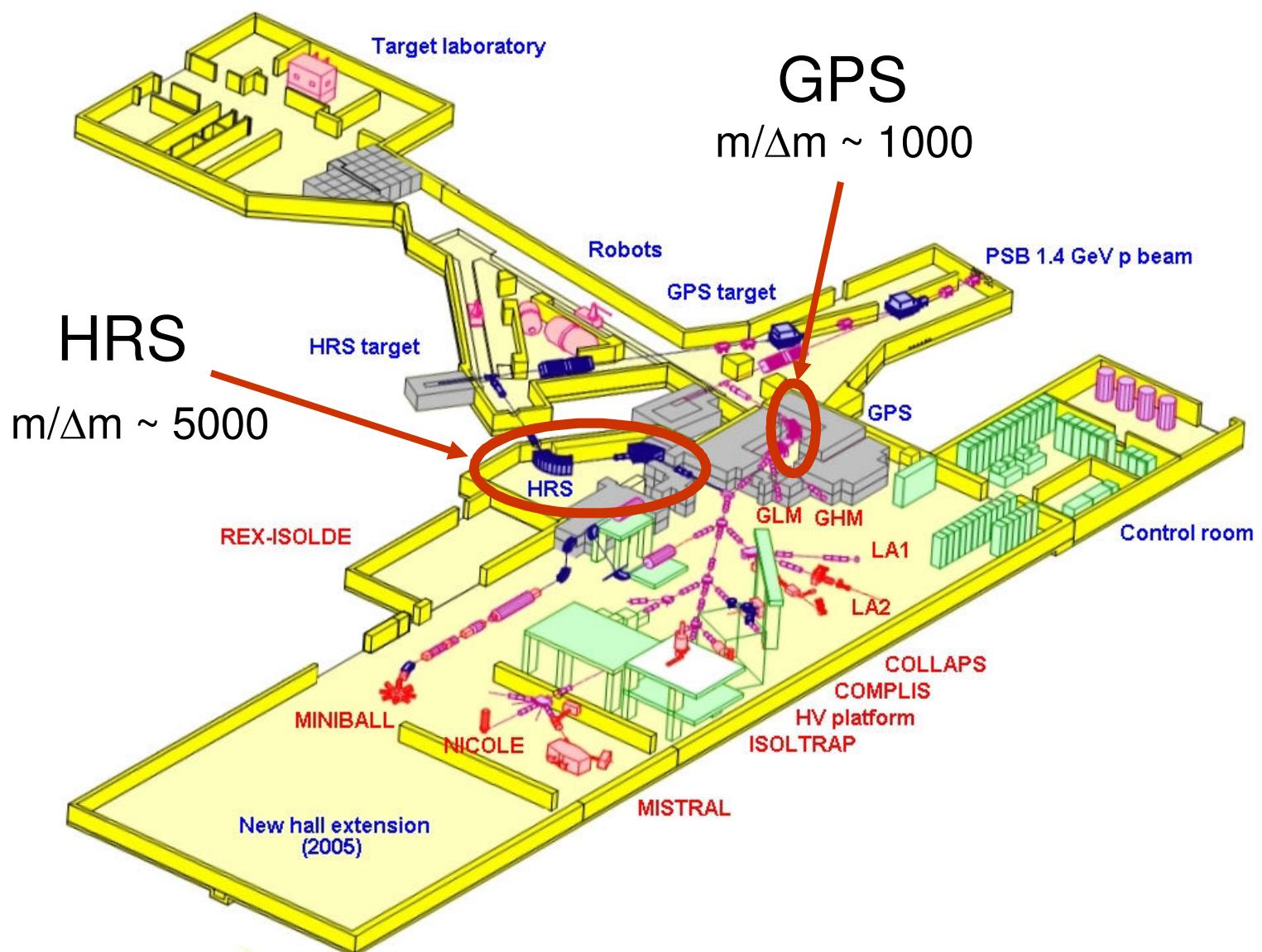
# Limitation: Half-life of short-lived nuclides



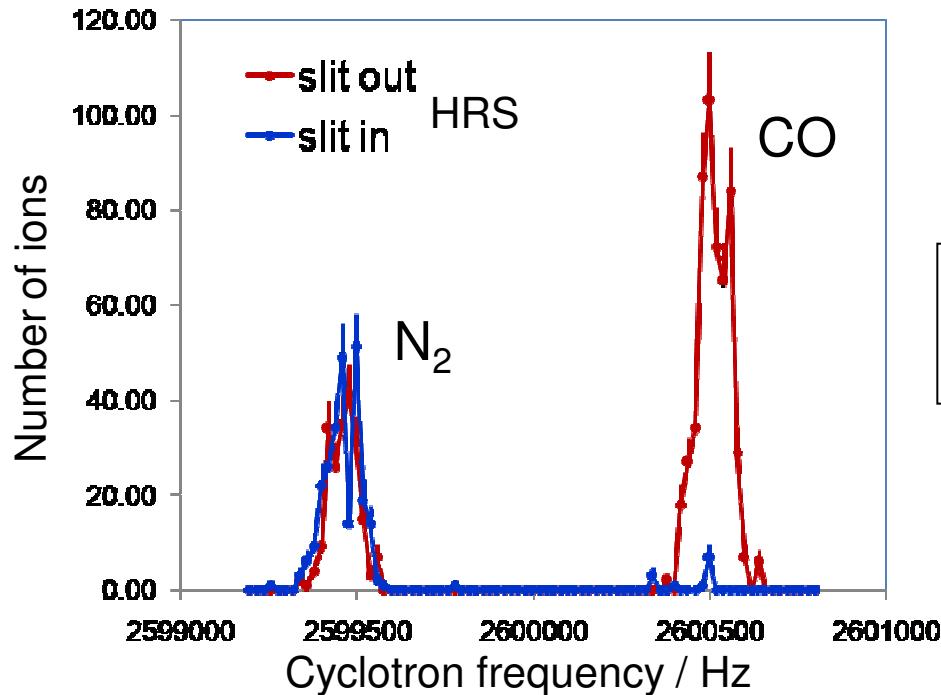
# Limitation: Isobaric contamination



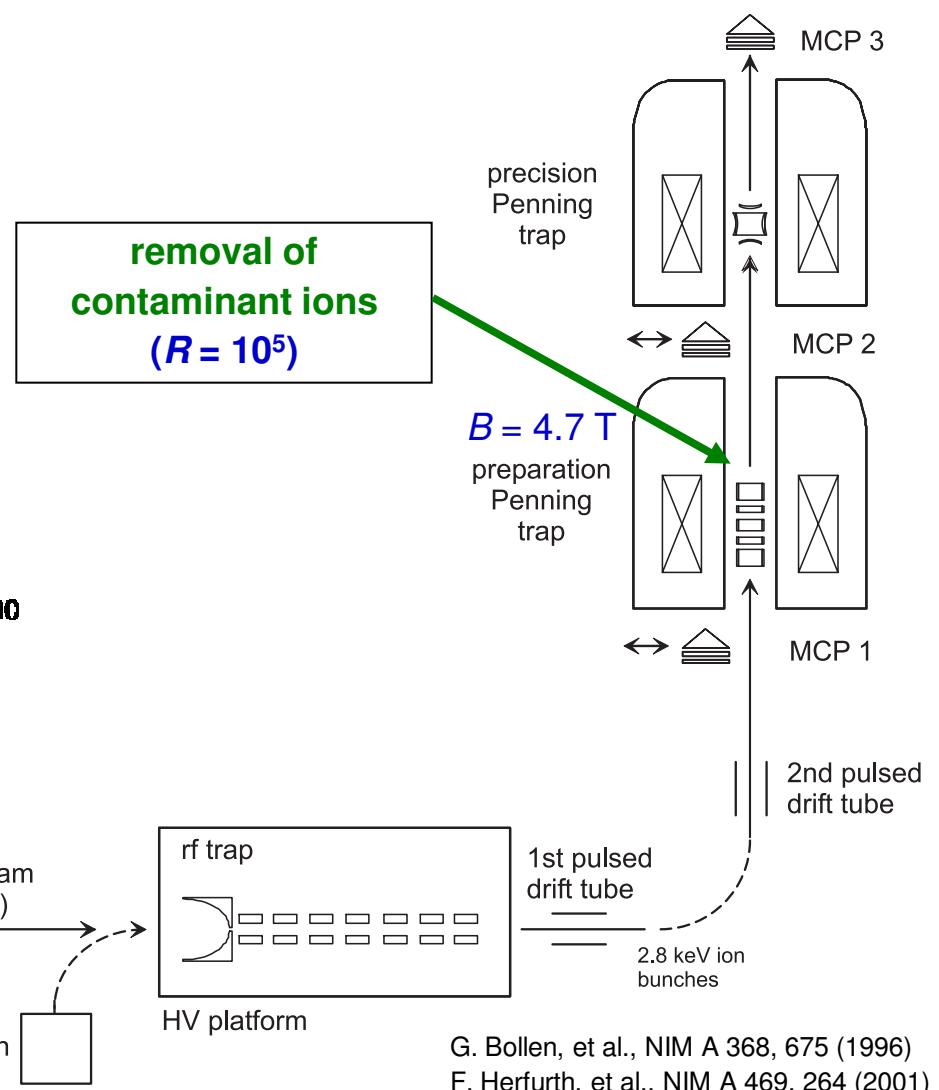
# ISOLDE mass separators



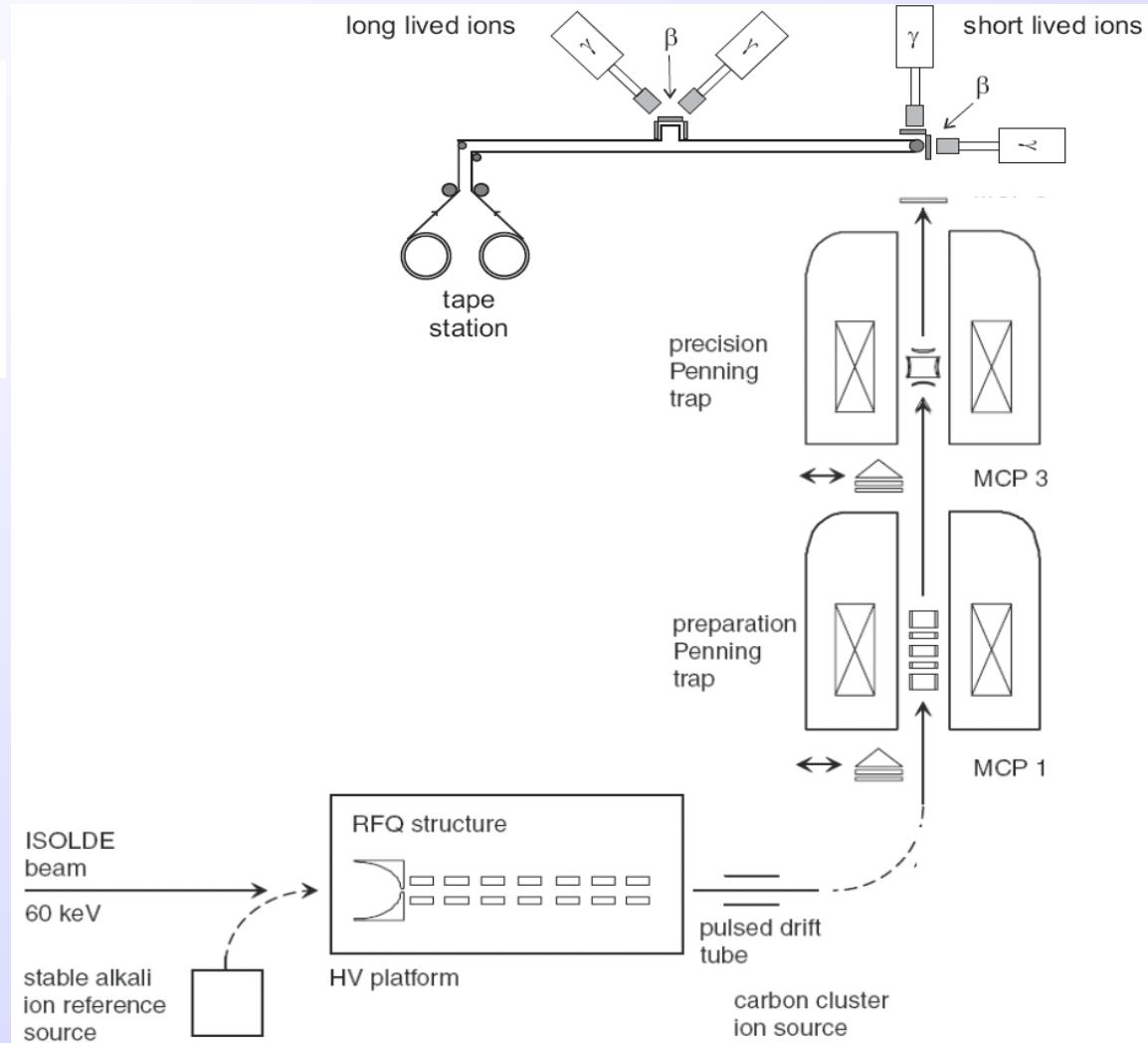
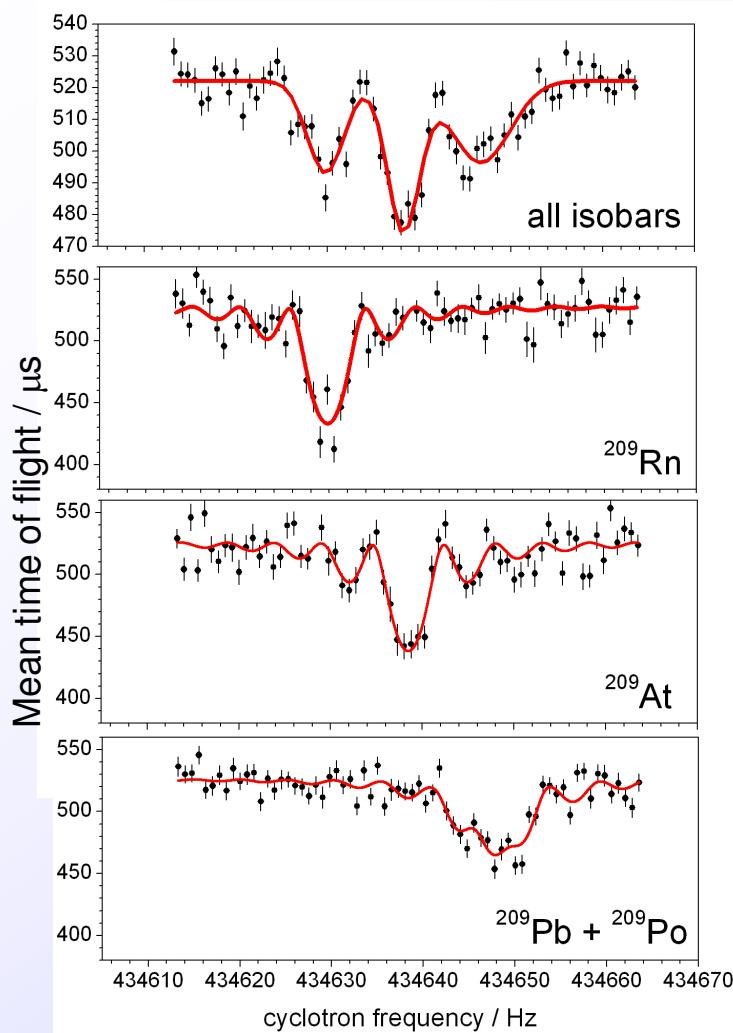
# Mass separation in Penning trap



Buffer gas cooling with QP excitation:  
Savard et al., Phys. Lett. A 158, 247 (1991)

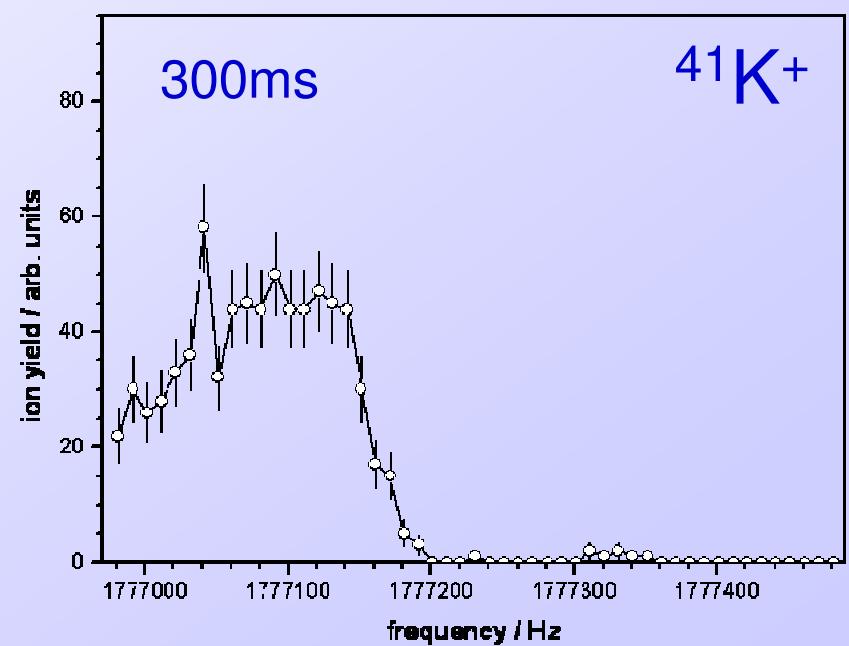
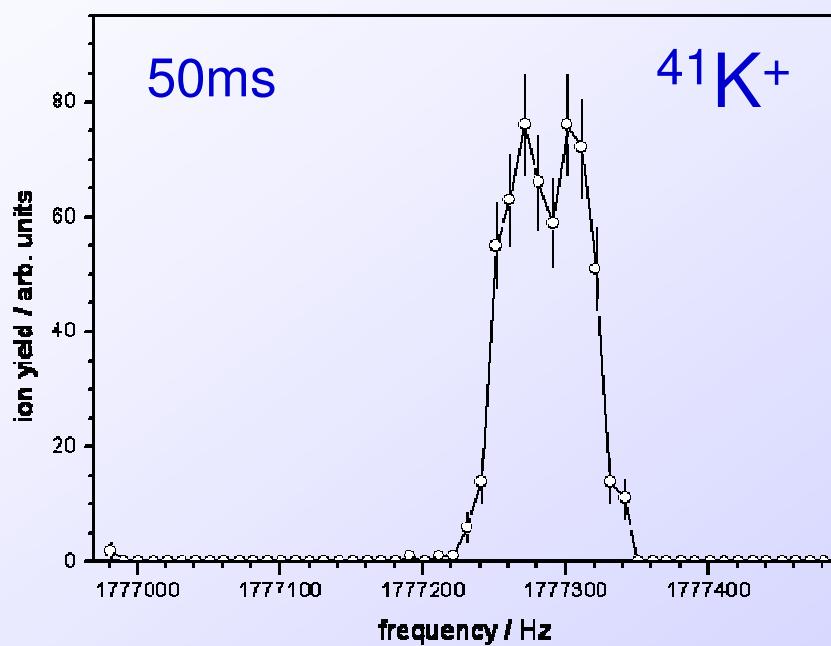
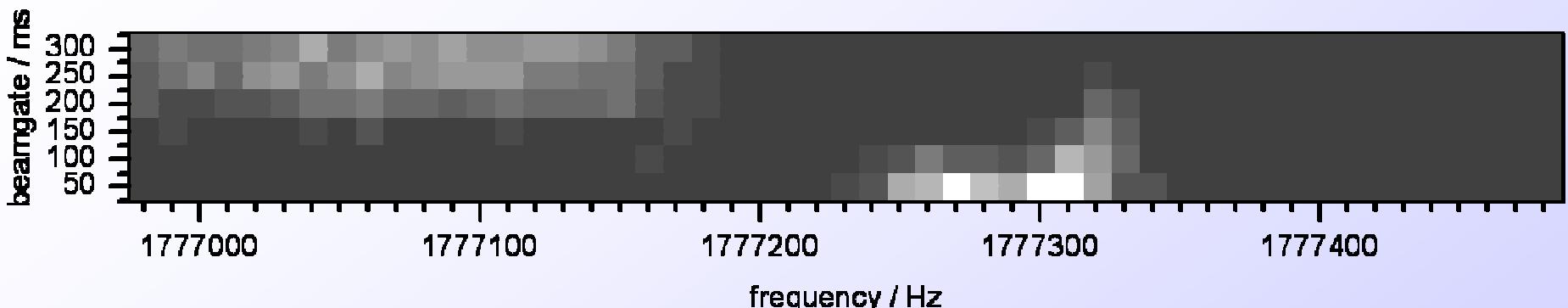


# ISOLTRAP tape station

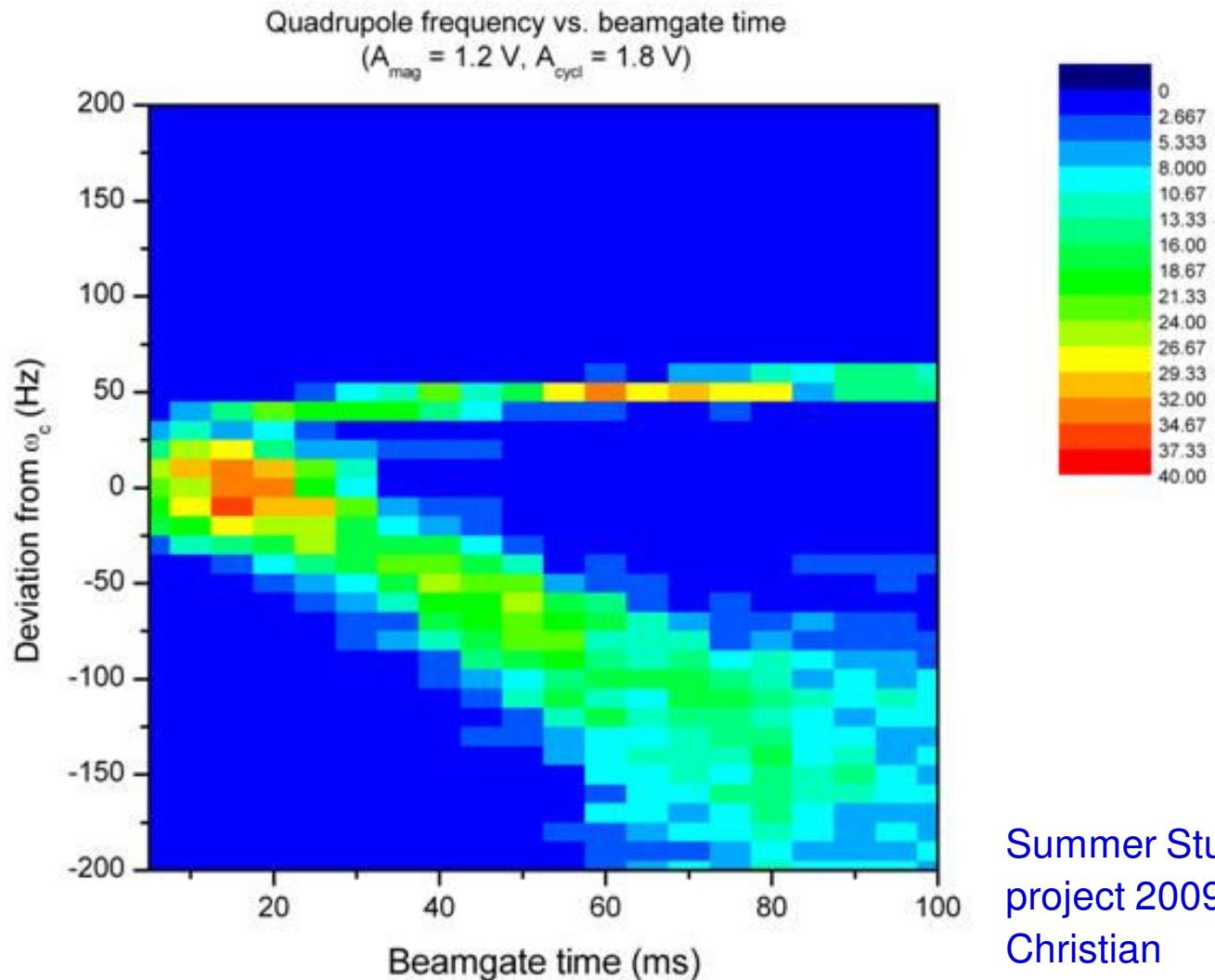


See talk of Magda Kowalska

# Limitation: Space-charge effects

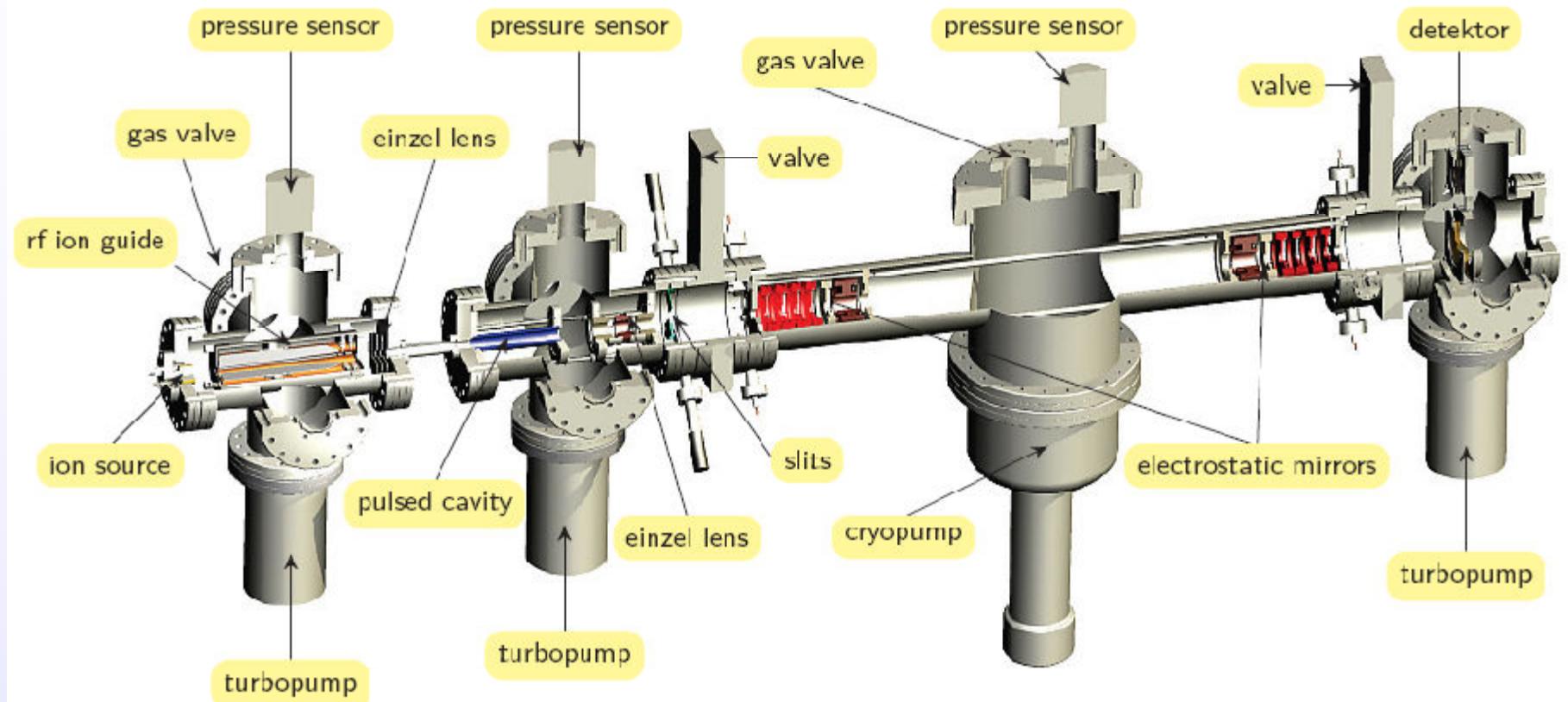


# Space-charge effects: $^{85,87}\text{Rb}$



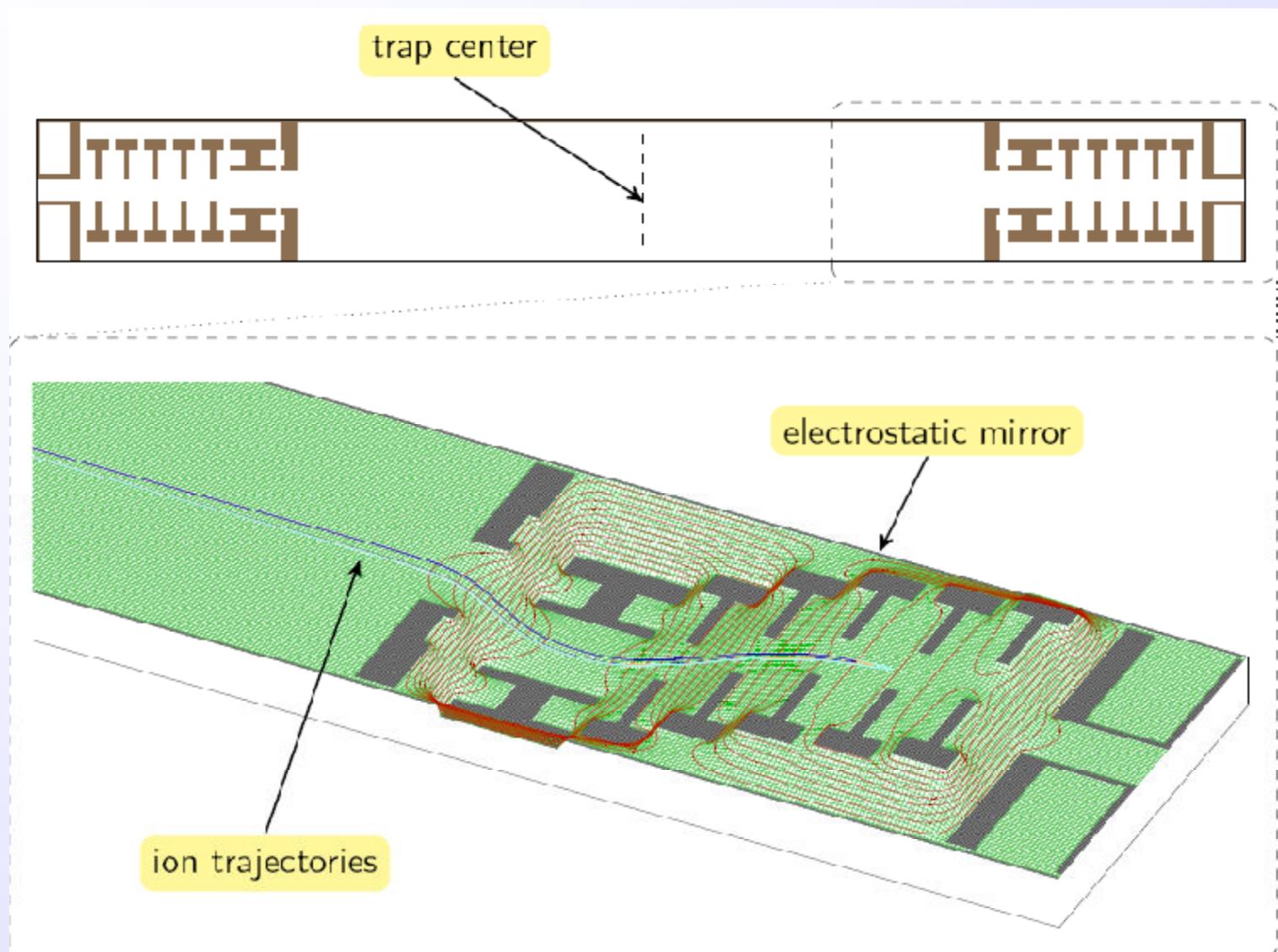
# Possible solution: Electrostatic ion trap

- Test-setup at University Greifswald **in operation**
- To be shipped and installed at ISOLTRAP **during the 2009/2010 shutdown**

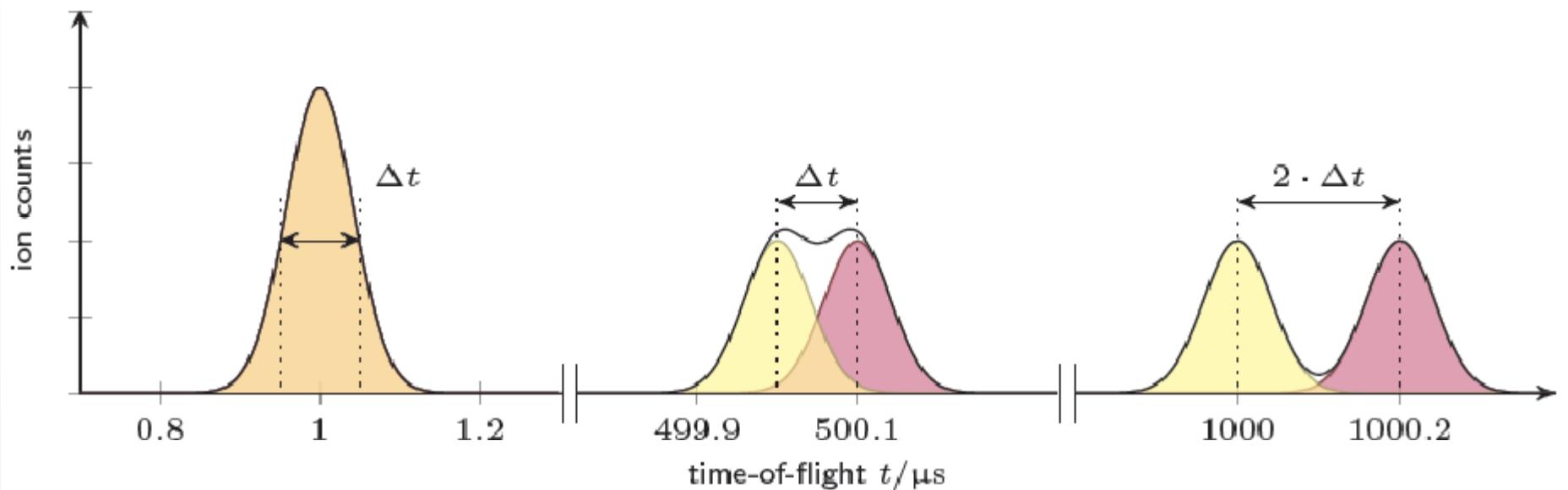


Robert Wolf

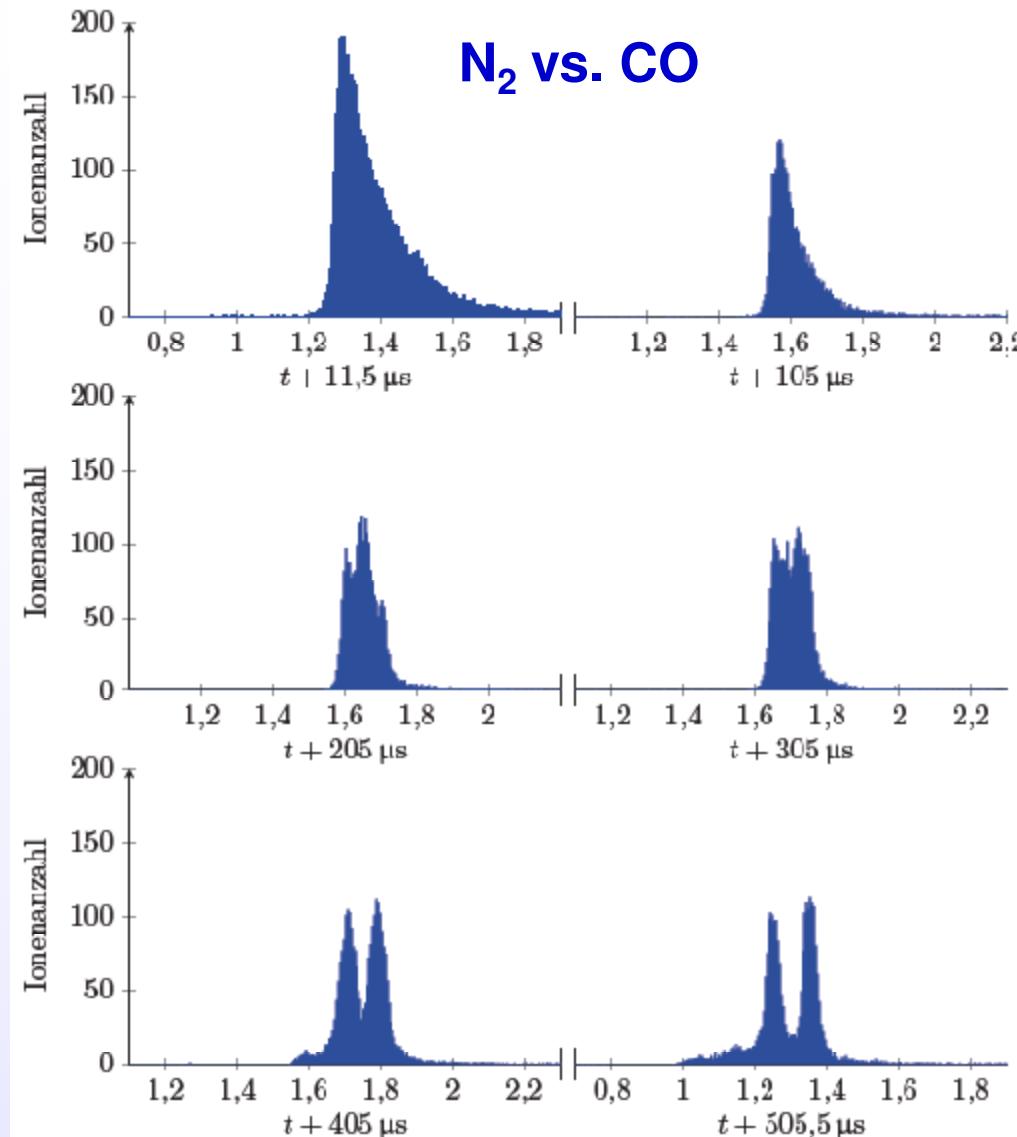
# Electrostatic ion trap layout



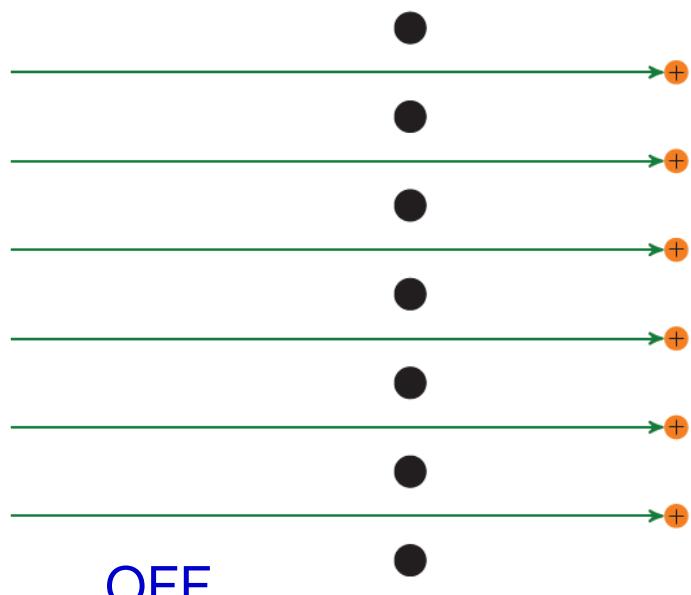
# Mass separation principle



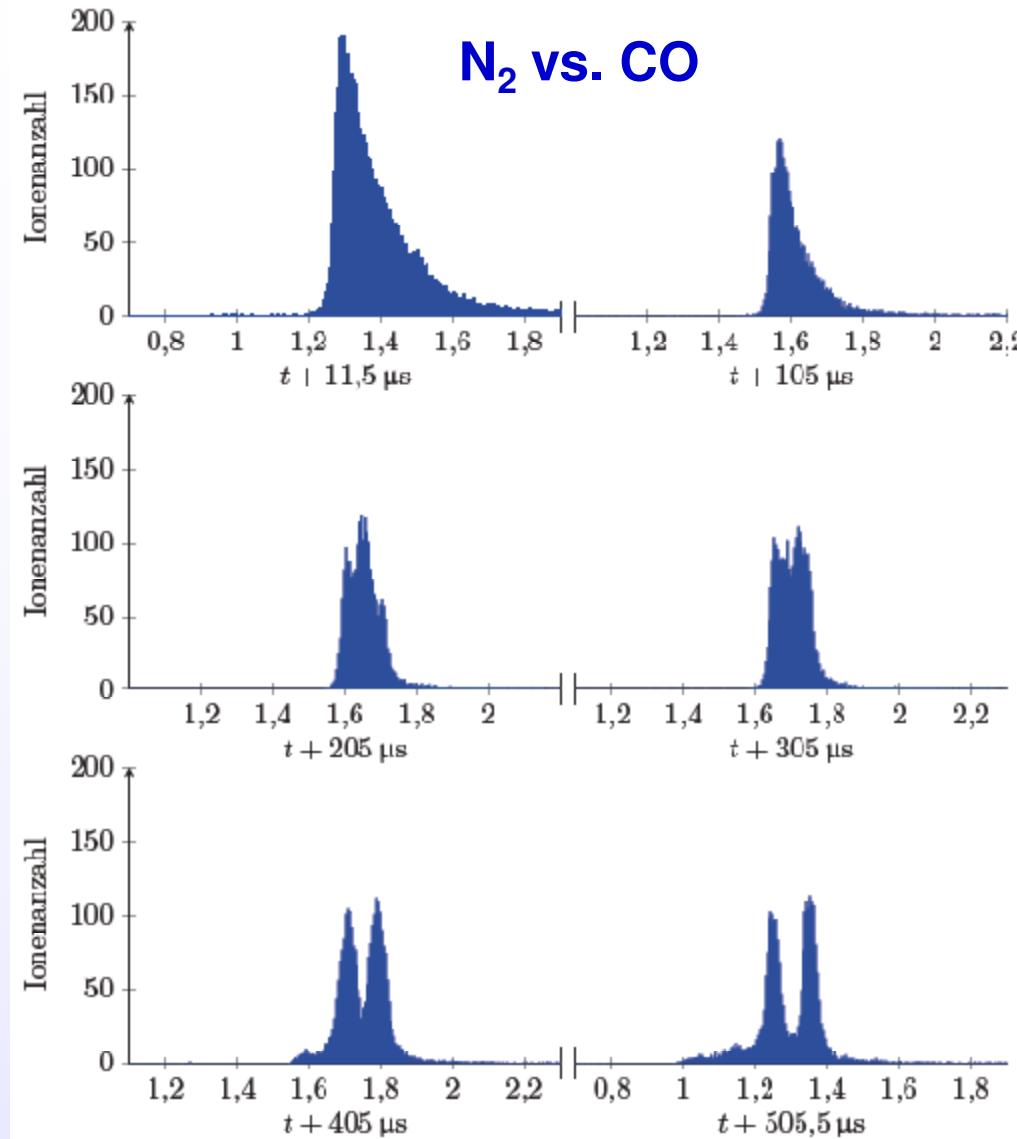
# Time-of-flight gating and ion removal



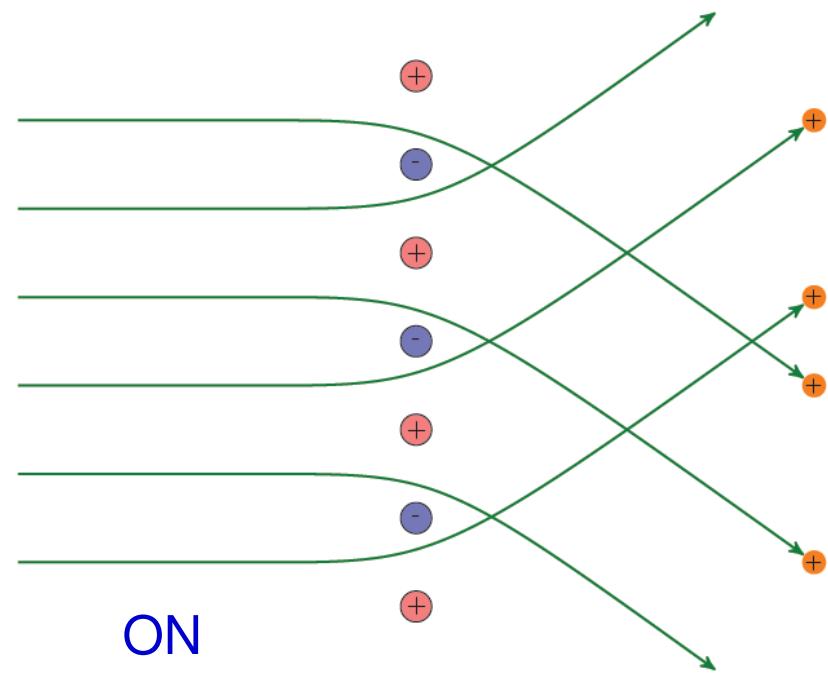
# Bradbury-Nielsen-Beamgate



# Time-of-flight gating and ion removal

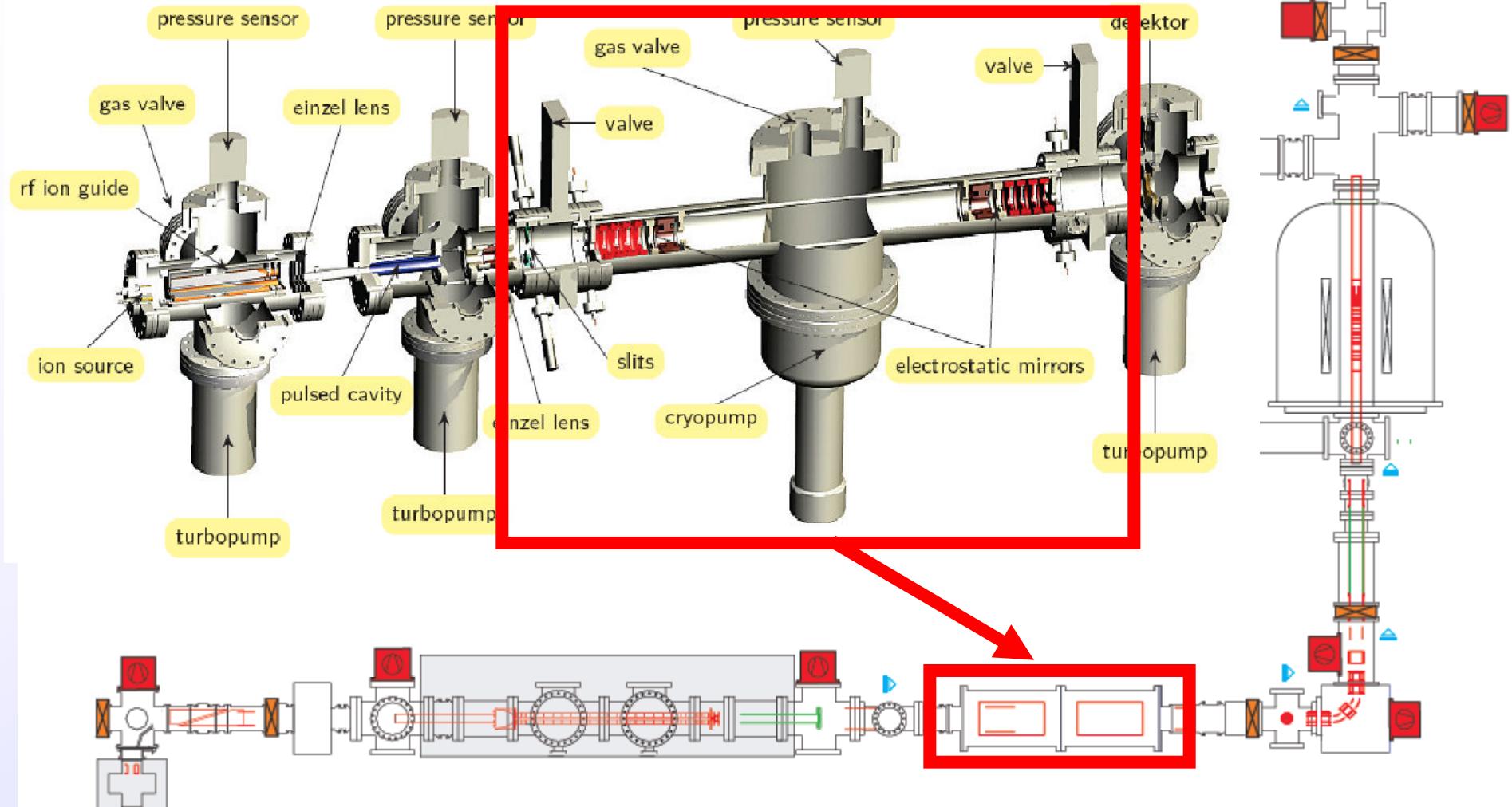


Bradbury-Nielsen-Beamgate



# Installation at ISOLTRAP 2009/2010

## 4th ion trap at ISOLTRAP !



# Summary

- ISOLTRAP allows one to obtain accurate and precise mass values of short-lived isotopes
- Limitation due to purity, yield, and half-life
- Recent developments at ISOLDE:
  - ISCOOL RFQ buncher and cooler – lower beam emittance
  - Quartz transfer line target – better beam purity
  - New VADIS arc discharge ion source – higher ionization efficiency
  - New RILIS lasers and schemes – higher ionization efficiency
- Recent developments at ISOLTRAP:
  - Ramsey type excitation – faster measurement
  - New electrostatic ion trap – faster purification and contamination suppression
  - New ion detectors – higher detection efficiency



## Thanks to ...



G. Audi, S. Baruah, D. Beck, K. Blaum, Ch. Böhm,  
**Ch. Borgmann**, M. Breitenfeldt, B. Cakirli, P. Delahaye,  
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U. Hager, F. Herfurth, A. Kellerbauer, H.-J. Kluge,  
**M. Kowalska**, **S. Kreim**, D. Lunney, M. Marie-Jeanne,  
M. Mukherjee, **S. Naimi**, **D. Neidherr**, Y. Novikov,  
**M. Rosenbusch**, R. Savreux, S. Schwarz, L. Schweikhard,  
Ch. Weber, U. Warring, **R. Wolf**, C. Yazidjian, K. Zuber



The ISOLDE Collaboration and the ISOLDE  
technical group