Suppression of contaminations in radioactive ion beams at ISOLDE and ISOLTRAP

Martin Breitenfeldt

Outline

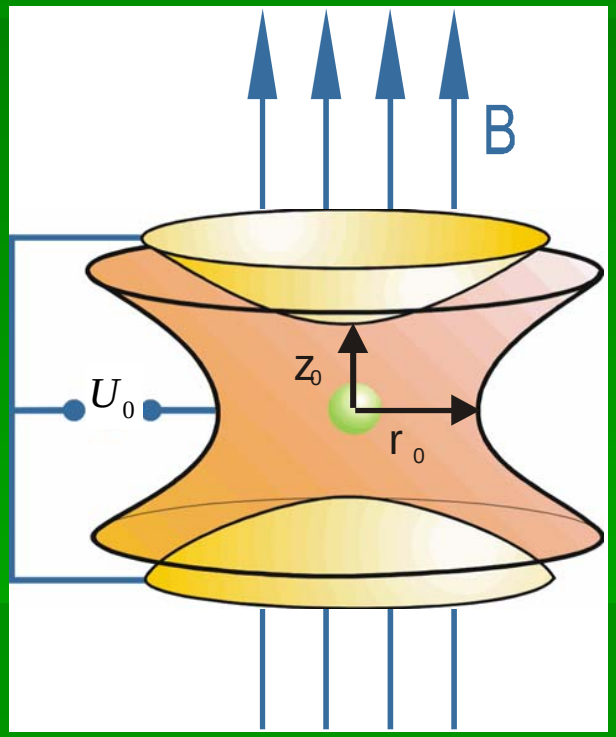
- ISOLTRAP and measurements
- ISOLDE
- Three different ways of fighting contaminations:
  - negative ions
  - electrostatic isobar separator
  - space charge effects of buffergas cooling

Penning traps

Combination of

An electrostatic Potential

$$\Phi = \frac{U_0}{2d^2}\left(z^2 - \frac{x^2}{2} - \frac{y^2}{2}\right)$$

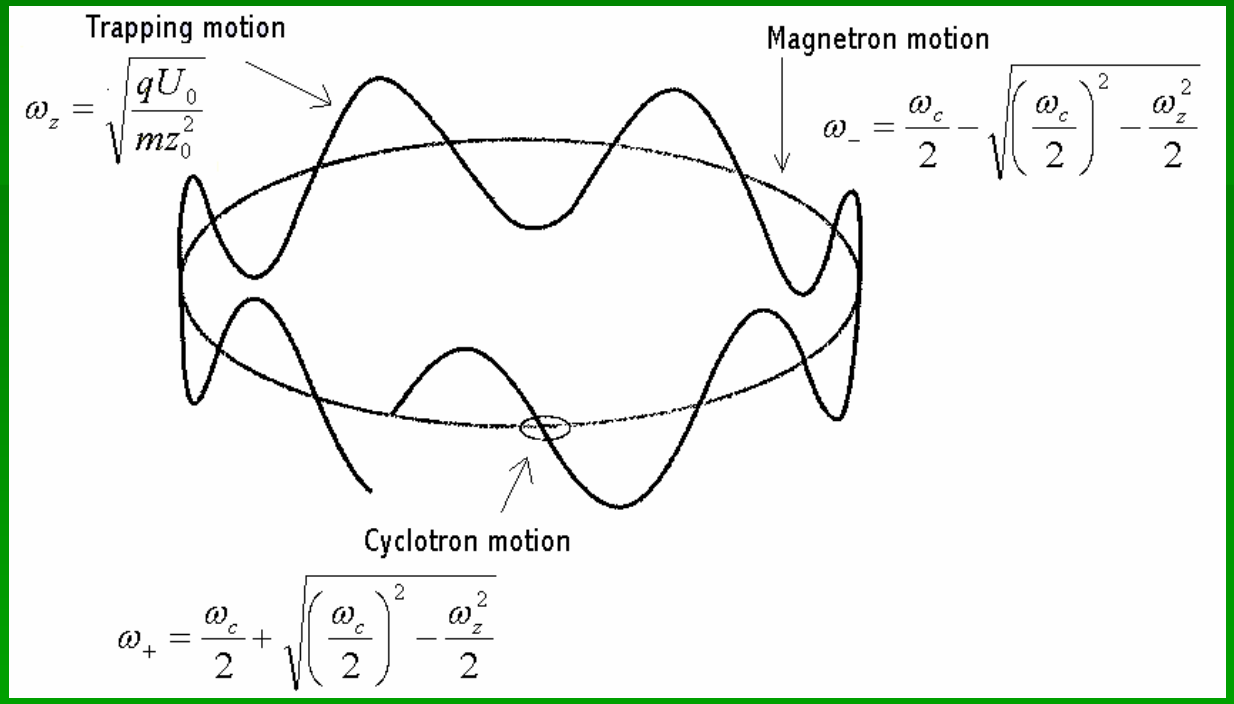


and a homogeneous magnetic field

$$\vec{B} = (0,0,B_z)$$

with: $d^2 = \frac{1}{2}(z_0^2 + \frac{r_0^2}{2})$

Eigenmotions in a Penning trap



Three independend eigenmotions:

- **axial**
- **magnetron**
- **cyclotron**

Important relation:

$$\nu_+^{\,2} + \nu_-^{\,2} + \nu_z^2 = \nu_c^{\,2}$$

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

Detection cycle

Scan QP-excitation freq. ν_{rf} about ν_c

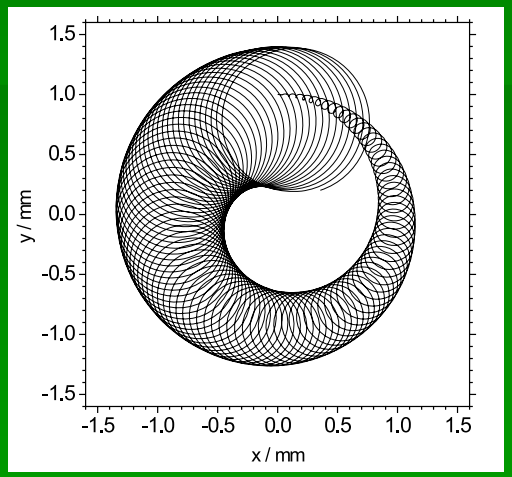
Magnetron excitation

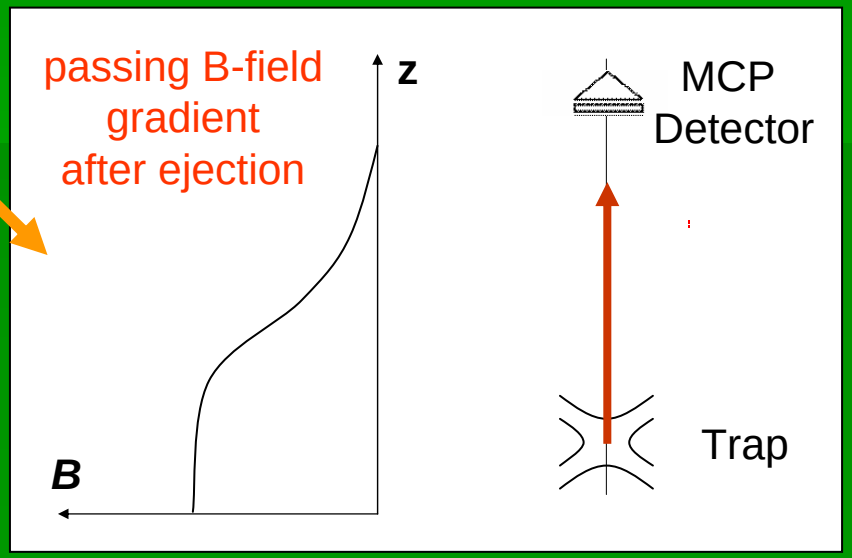
Quadrupole excitation ν_{rf}

radial ⇒ axial energy

Time-of-flight (TOF)

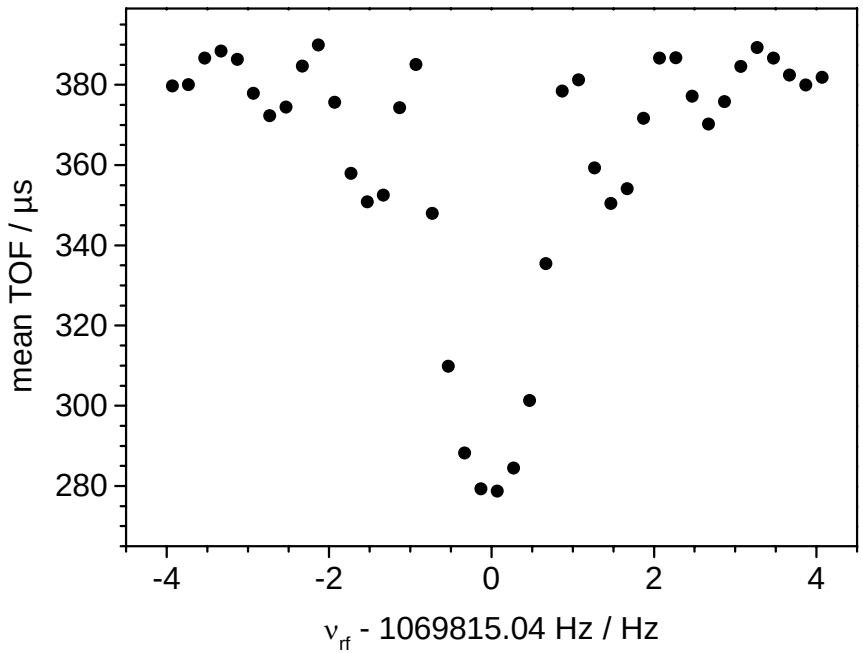
Conversion of magnetron into cyclotron motion



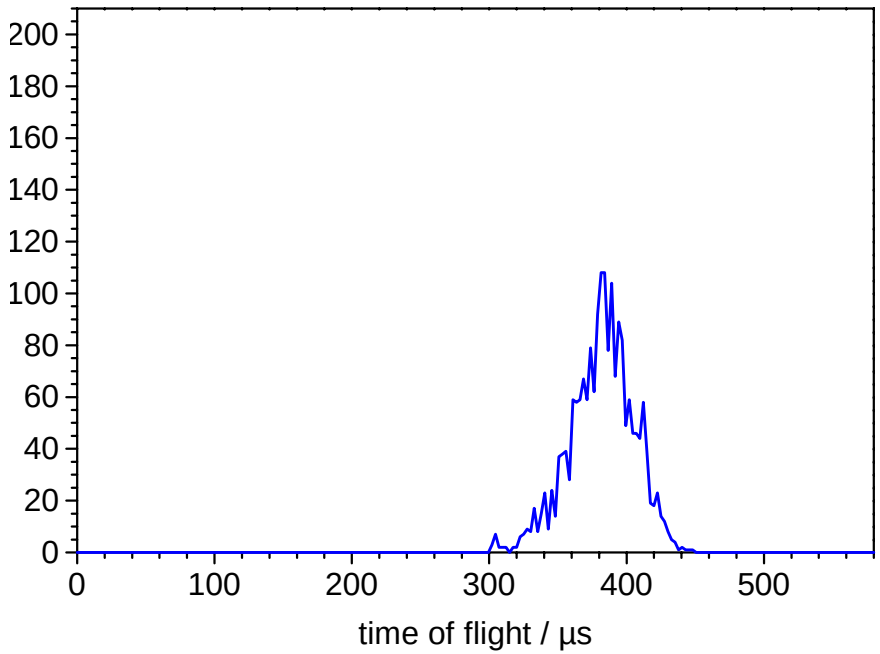


Detection cycle

mean TOF



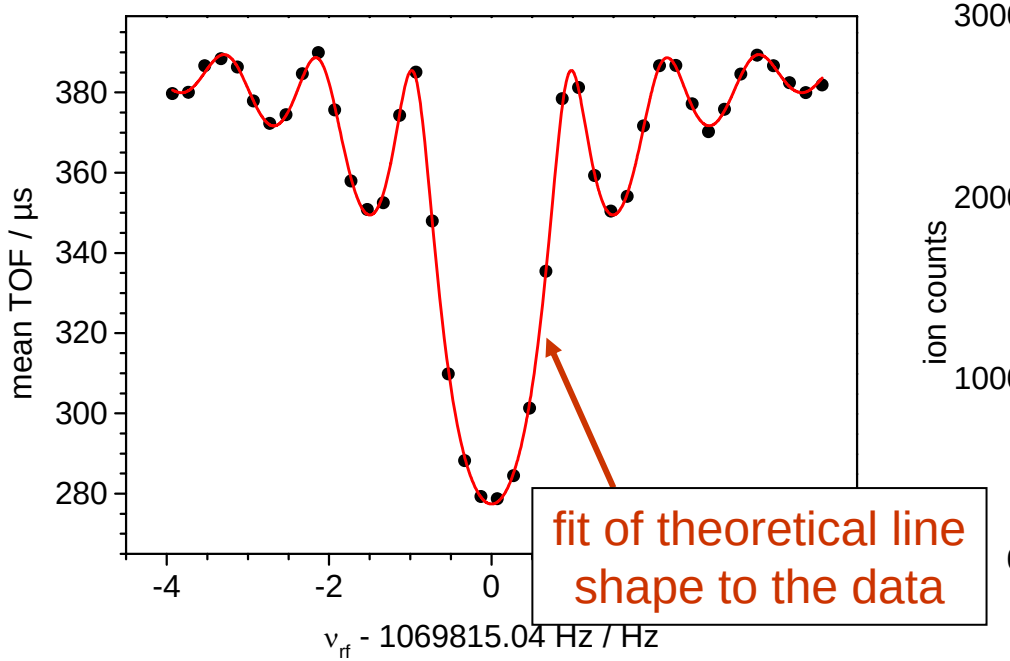
TOF spectrum



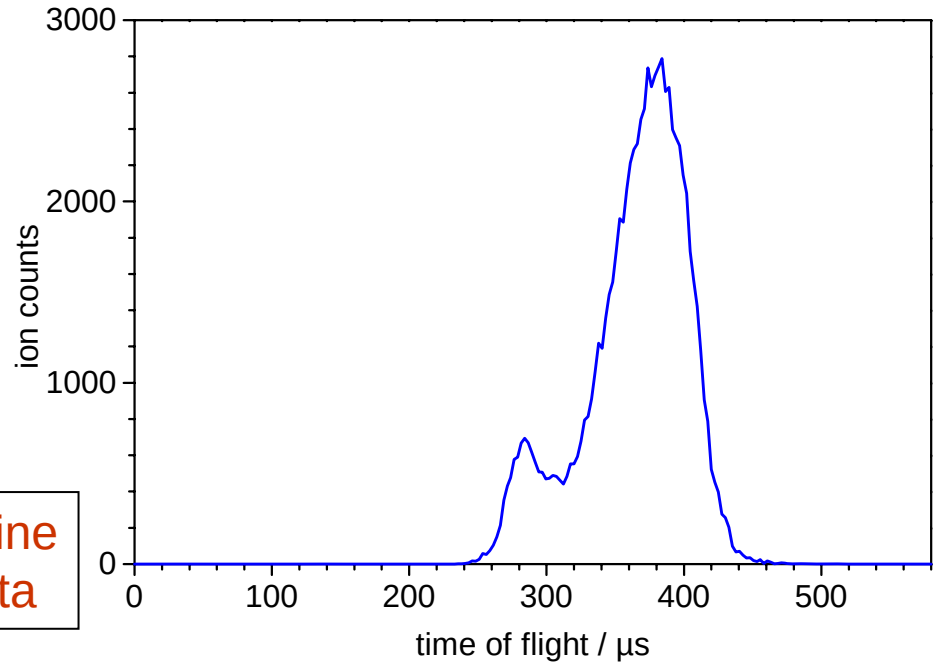
Example: ^{85}Rb (900ms excitation duration)

Detection cycle

mean TOF



TOF spectrum

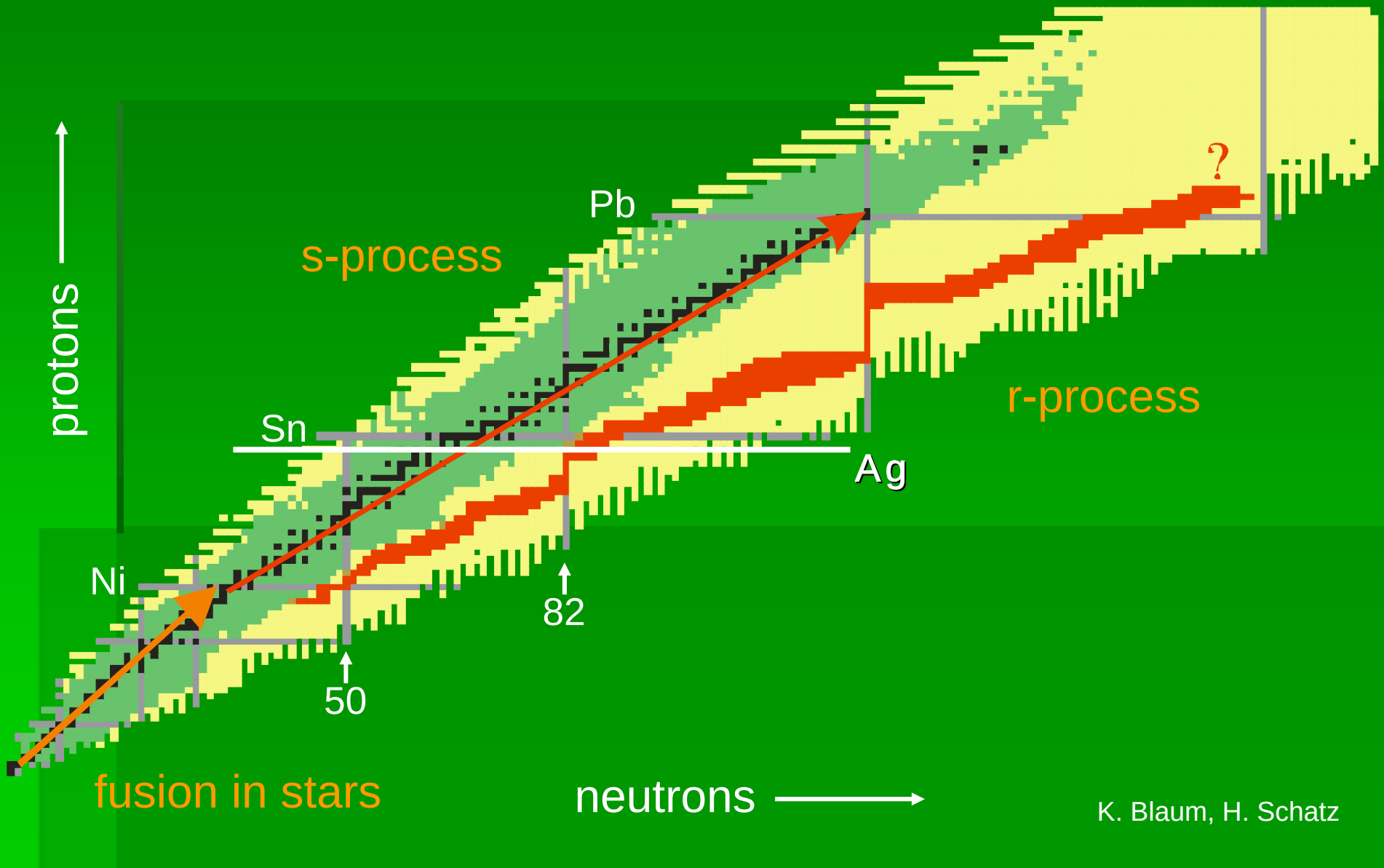


Example: ^{85}Rb (900ms excitation duration)

Frequency ratios

- measuring reference masses with very small uncertainties (^{39}K, ^{85}Rb, ^{133}Cs)
- measuring mass of interest
- measuring reference mass again
- published are the frequency ratios (for the rare case of „changing“ reference masses)

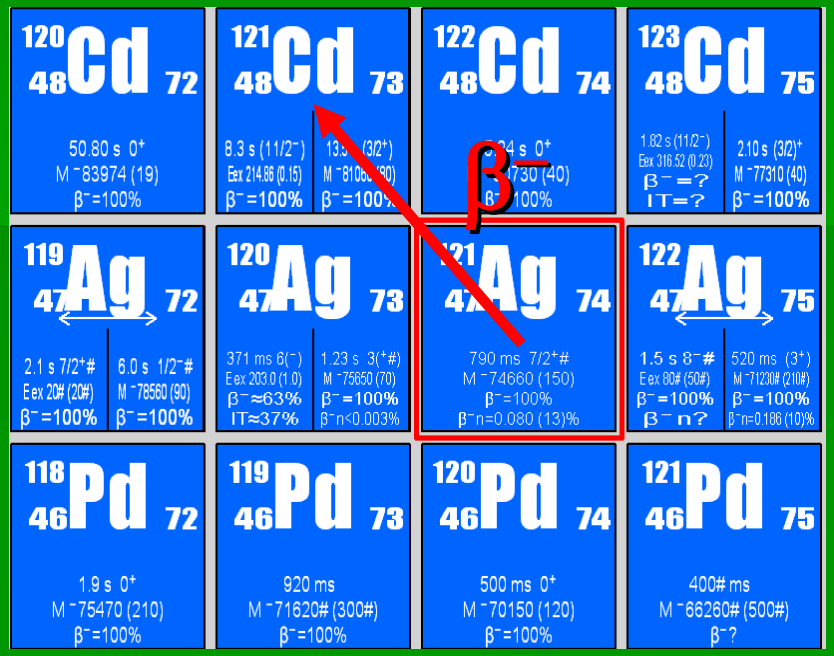
Application: Astrophysics



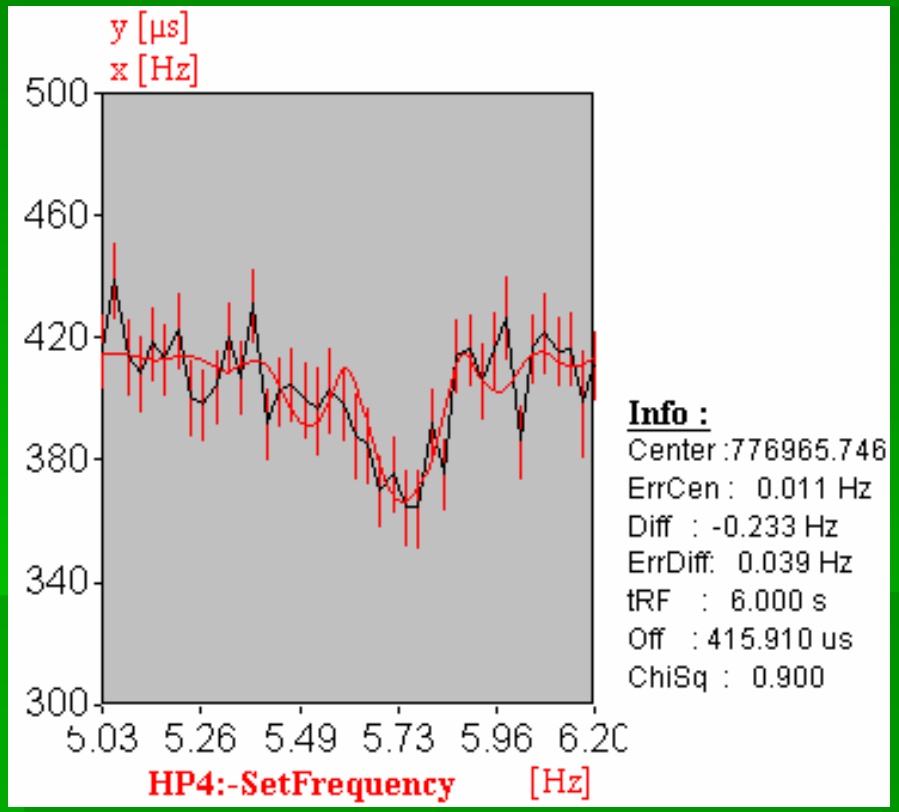
K. Blaum, H. Schatz

Q value

- The Q value gives the mass differences between the mother and the daughter nucleus of a decay.
- Uncertainty depends on the uncertainties of the measured masses.



Mass measurements at ISOLTRAP



- ^{117}Ag with the isomere (ratio of 70% groundstate to 30% isomeric state)
- first direct measurement of ^{121}Ag

Welcome to Real Life

Beam time beginning May 2007:

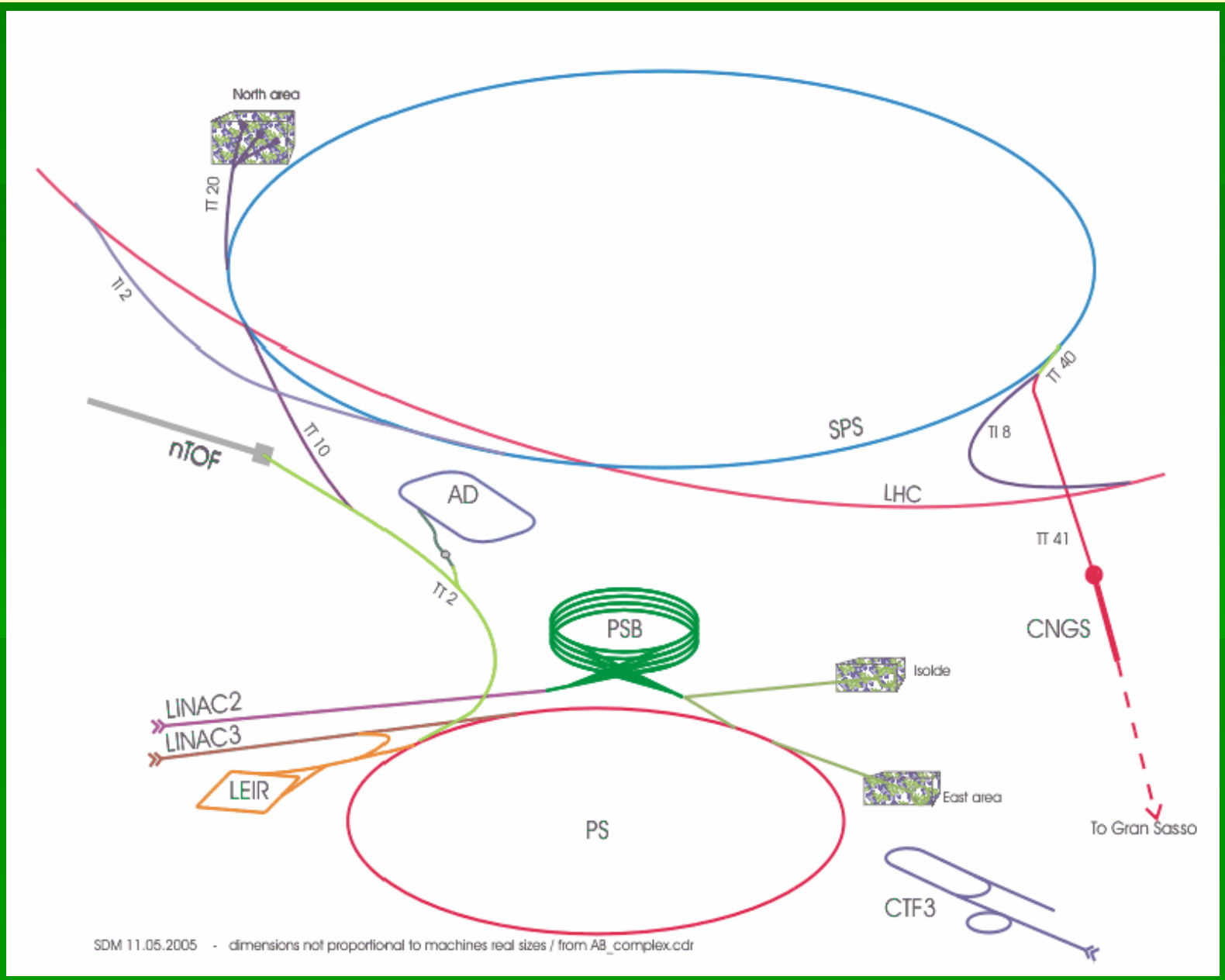
→ Aim: neutron rich silver nuclides

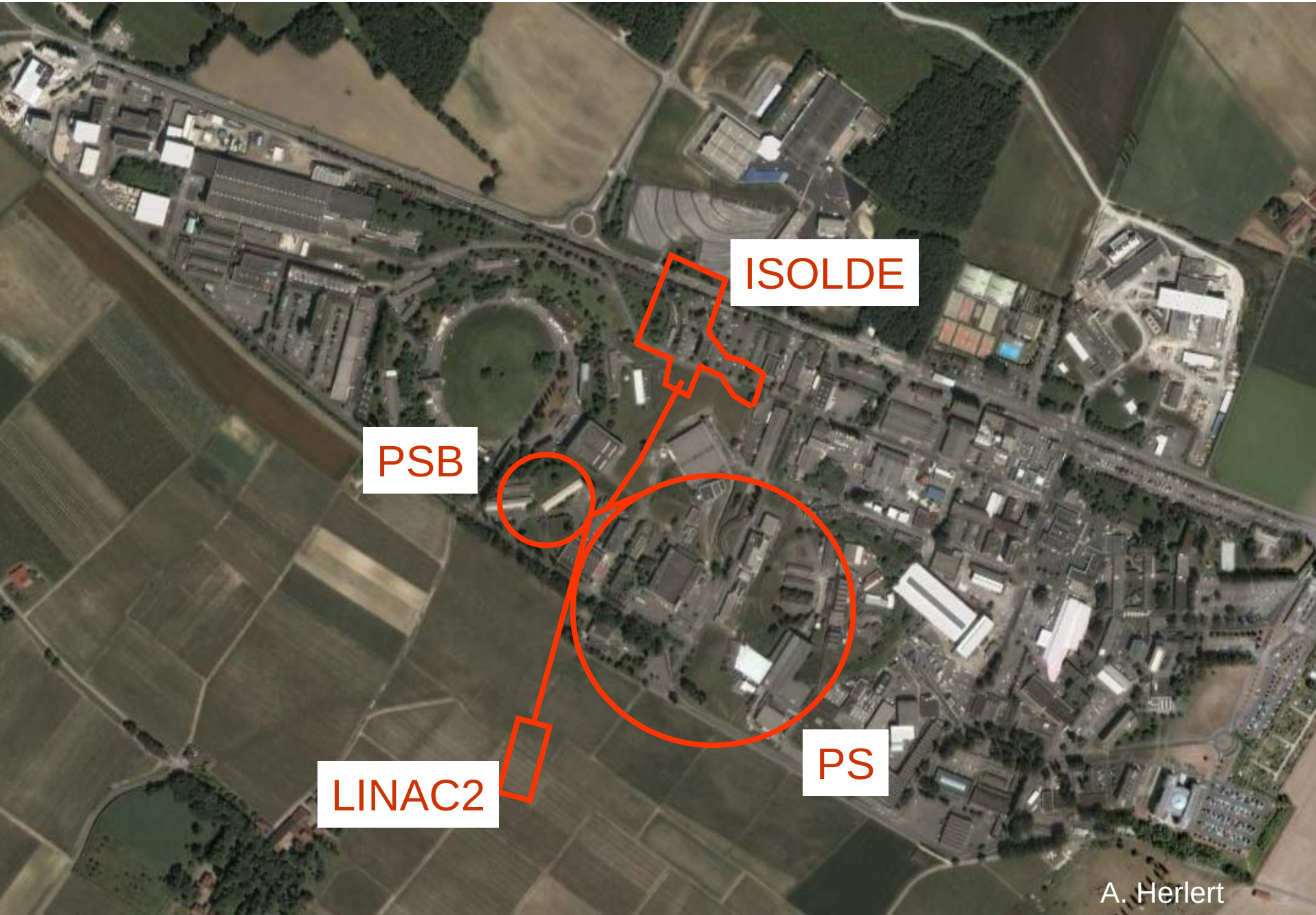
Problems:

→ ***Contaminations***

→ Thunder storm and the following power cut

Accelerators at CERN



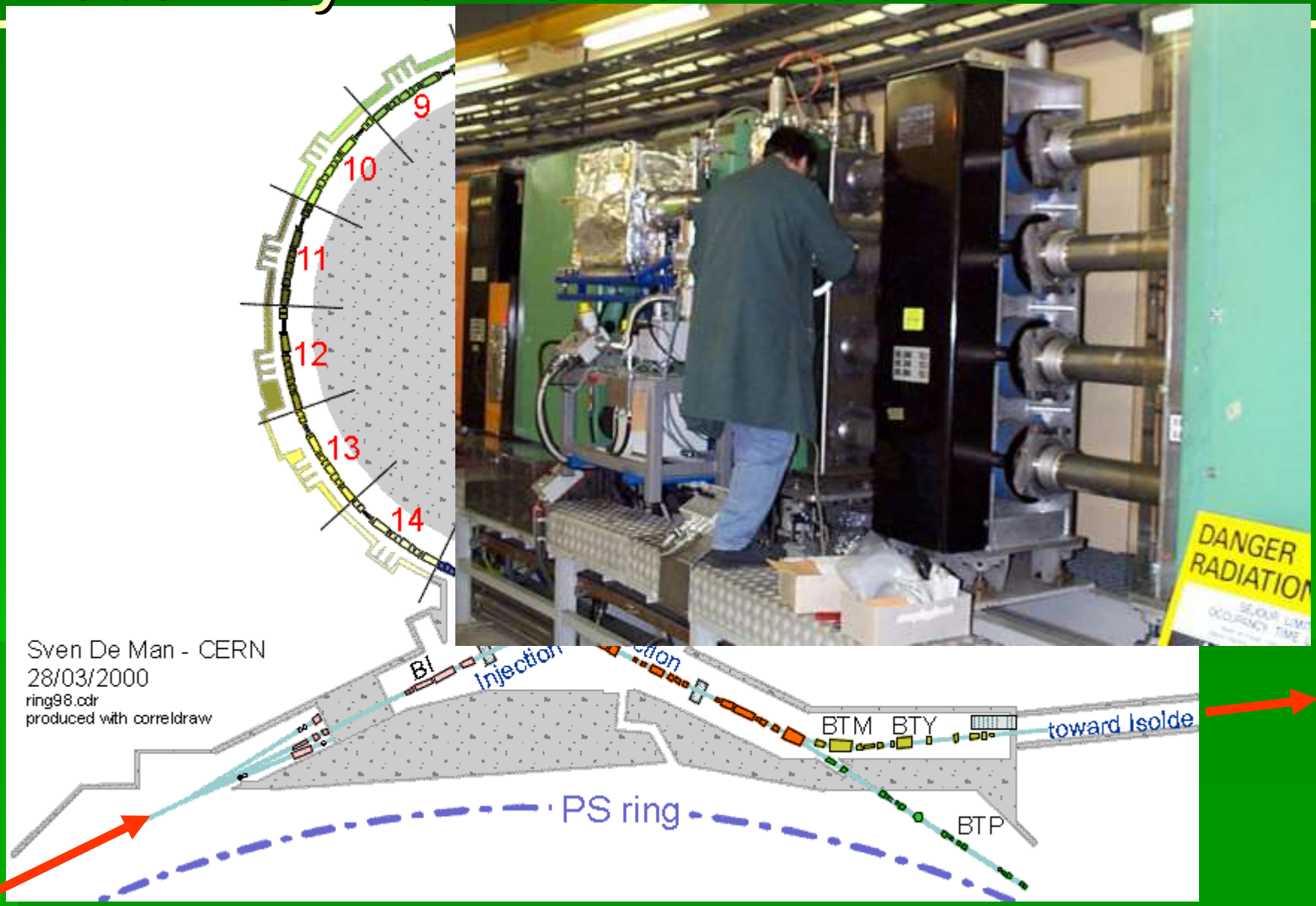

ISOLDE
PSB
PS
LINAC2
A. Herlert

Proton driver - LINAC2

It all starts with a gas bottle of hydrogen ...

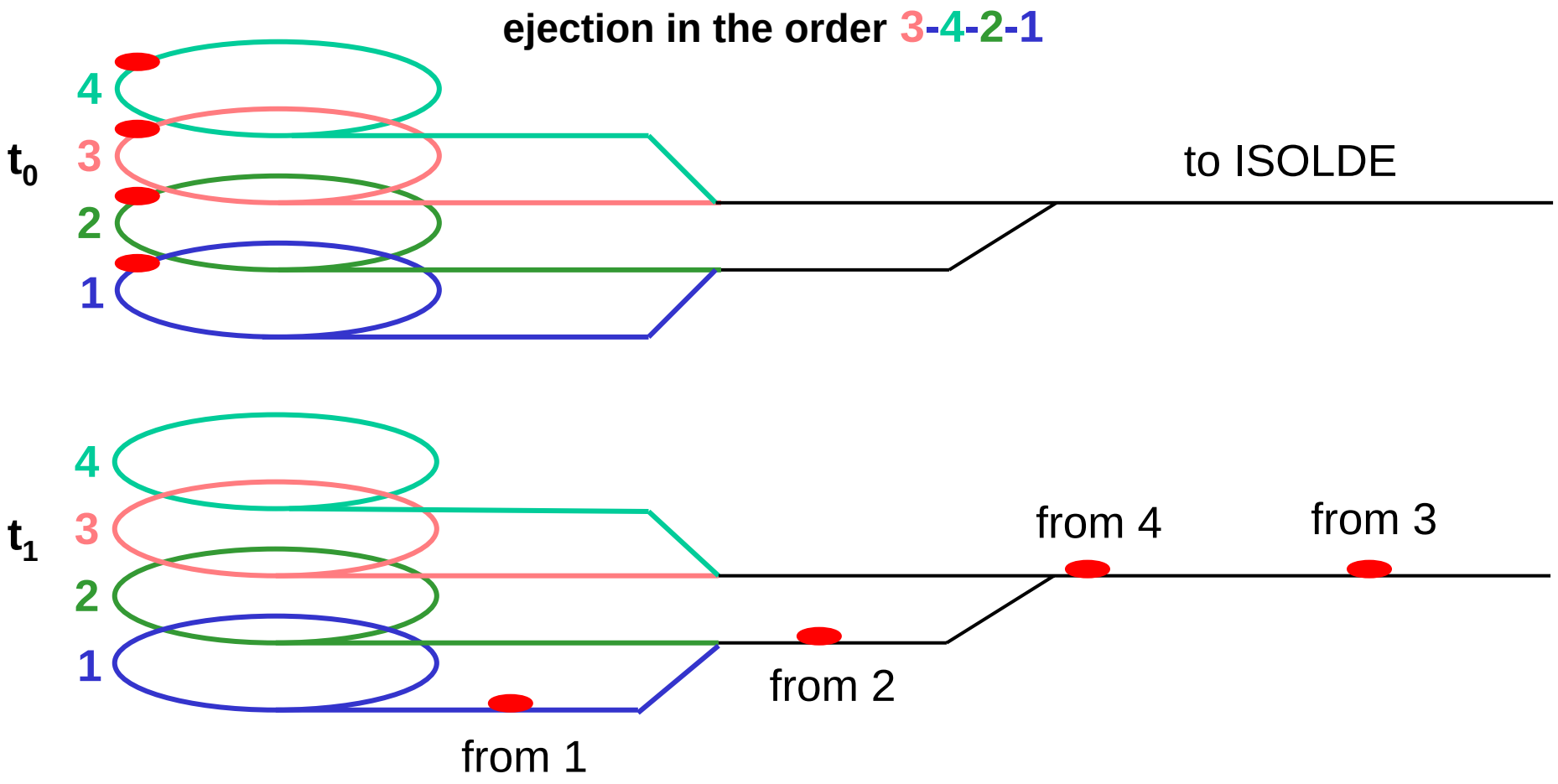
... delivery of 50MeV protons to the PSB

Proton Synchrotron Booster

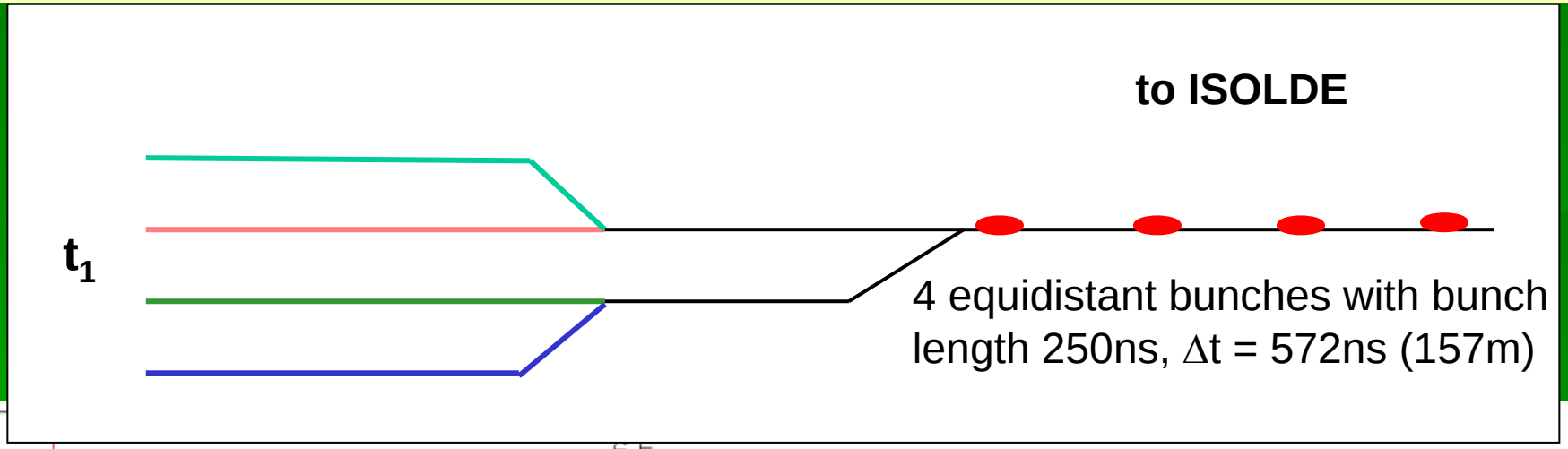


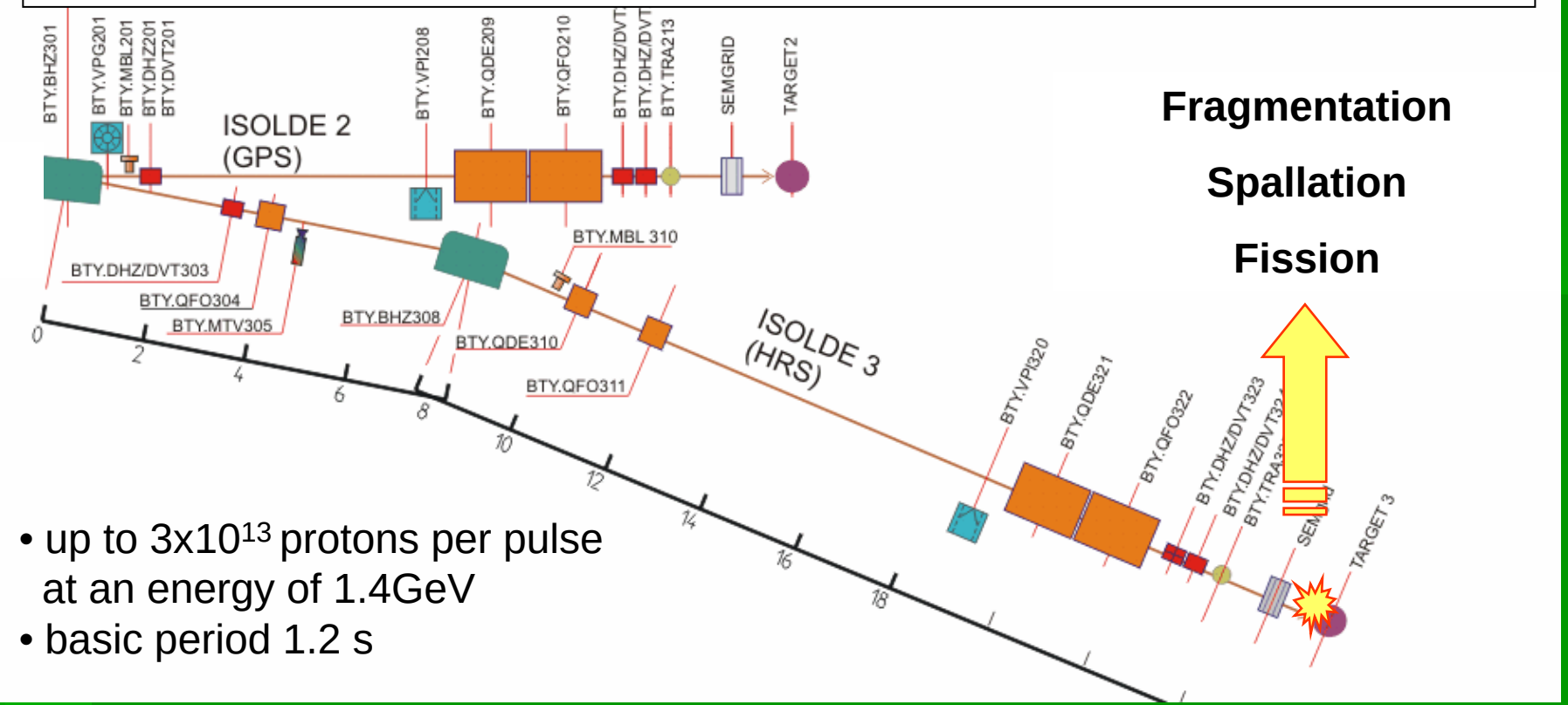
protons from LINAC2

Delivery to the ISOLDE targets



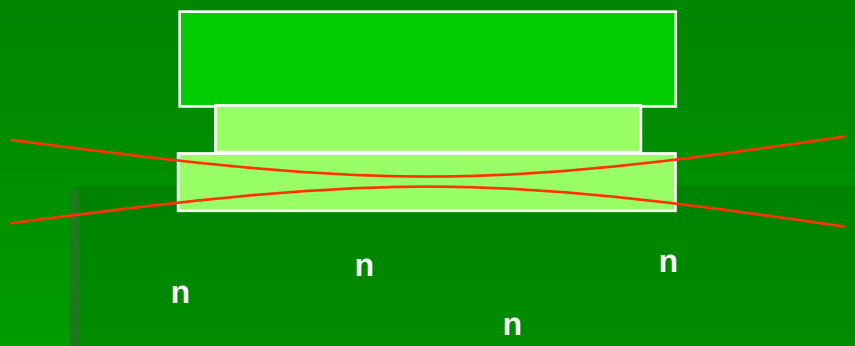
Delivery to the ISOLDE targets

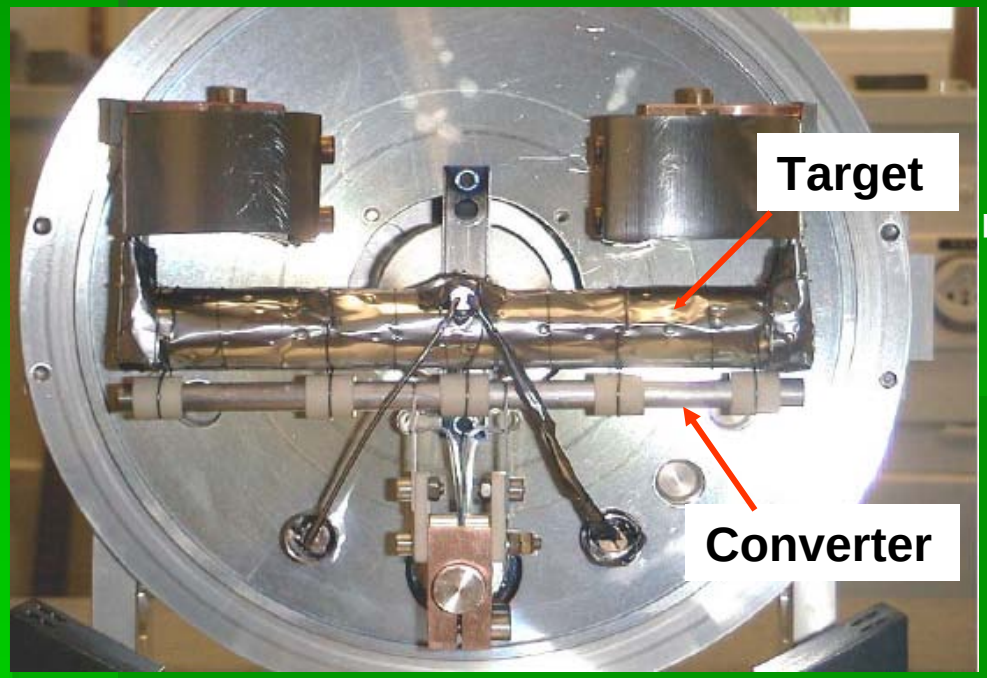




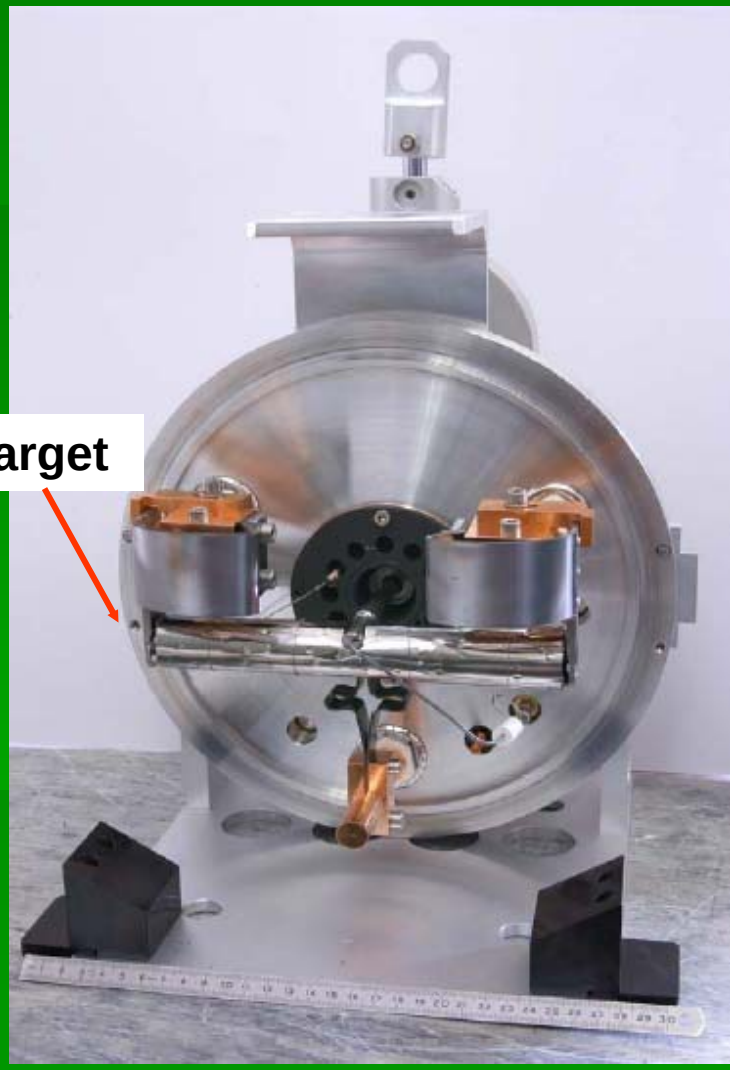
- up to 3×10^{13} protons per pulse at an energy of 1.4GeV
- basic period 1.2 s

Focussing of protons on target





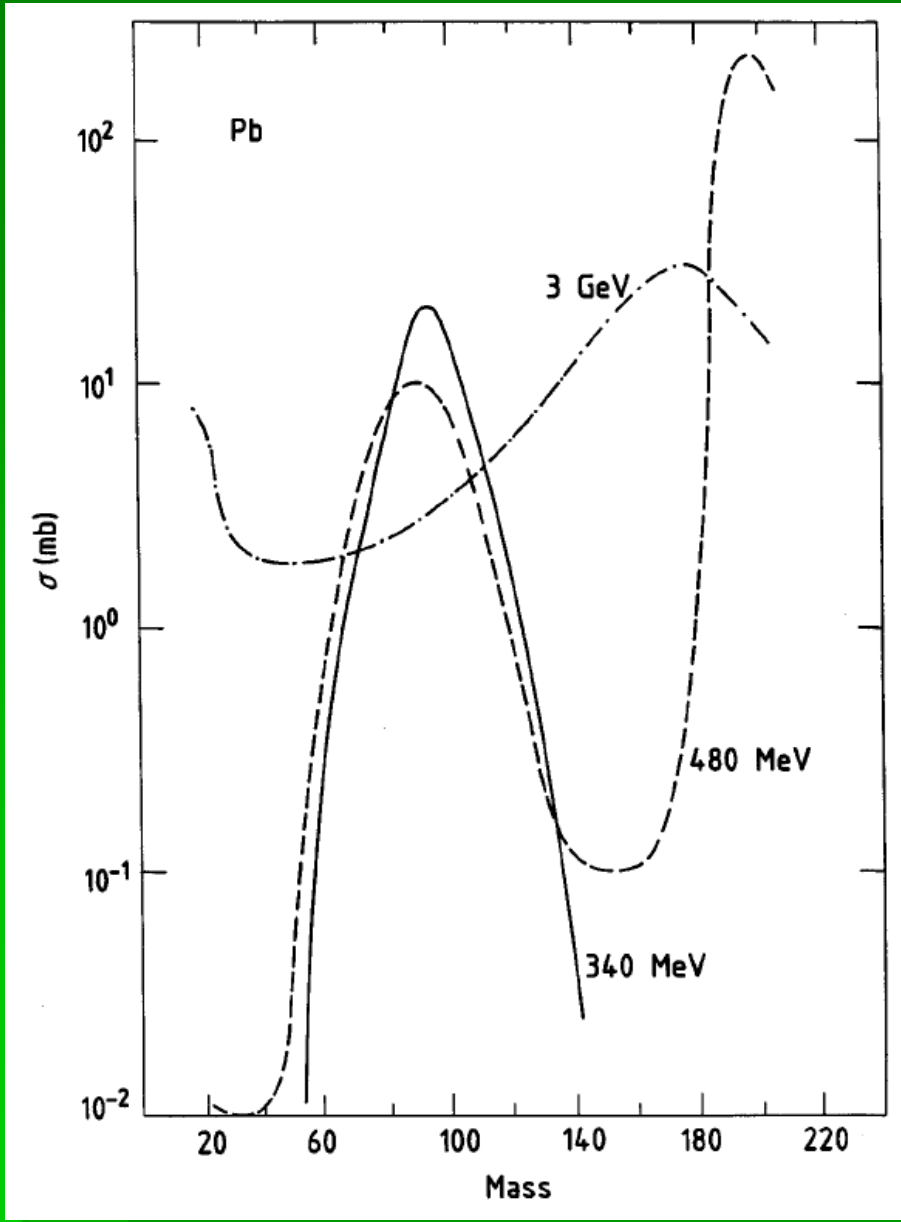
Converter Target



Standard

E. Siesling

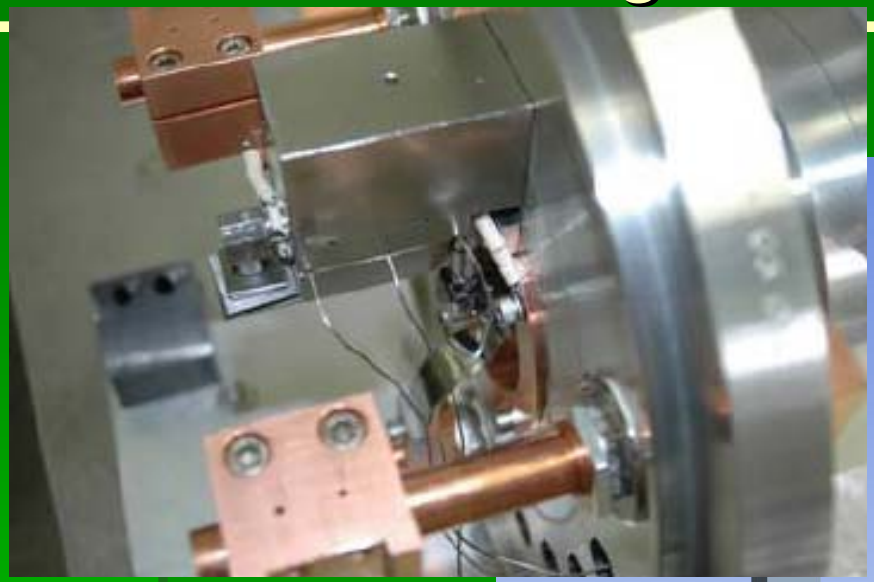
Dependence on proton energy



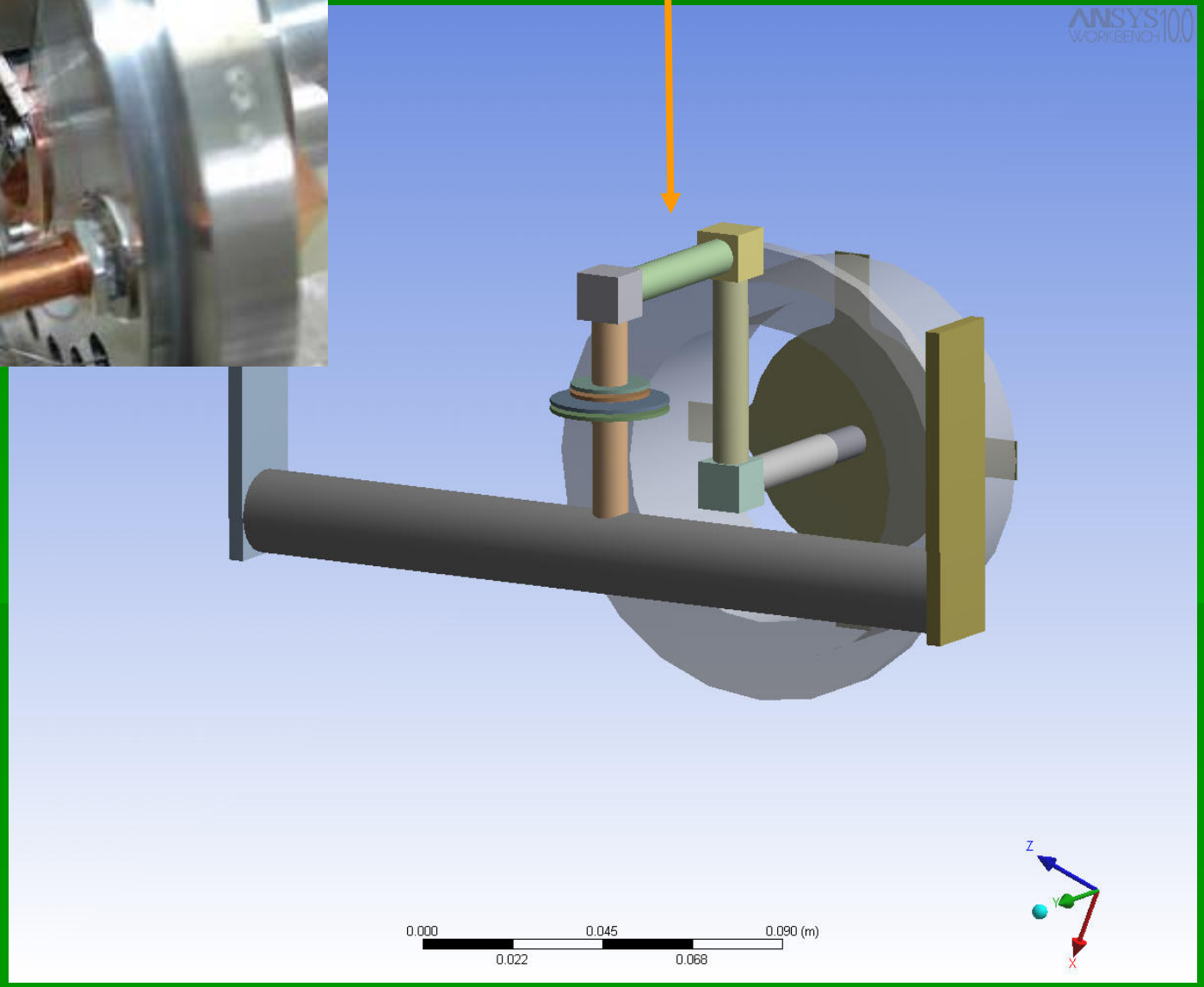
Mass-yield curve for reactions of protons with different energies on Pb target

H.L. Ravn,
Phil. Trans. R. Soc. Lond. A 356, 1955 (1998)

ISOLDE target for neutron-rich Zn



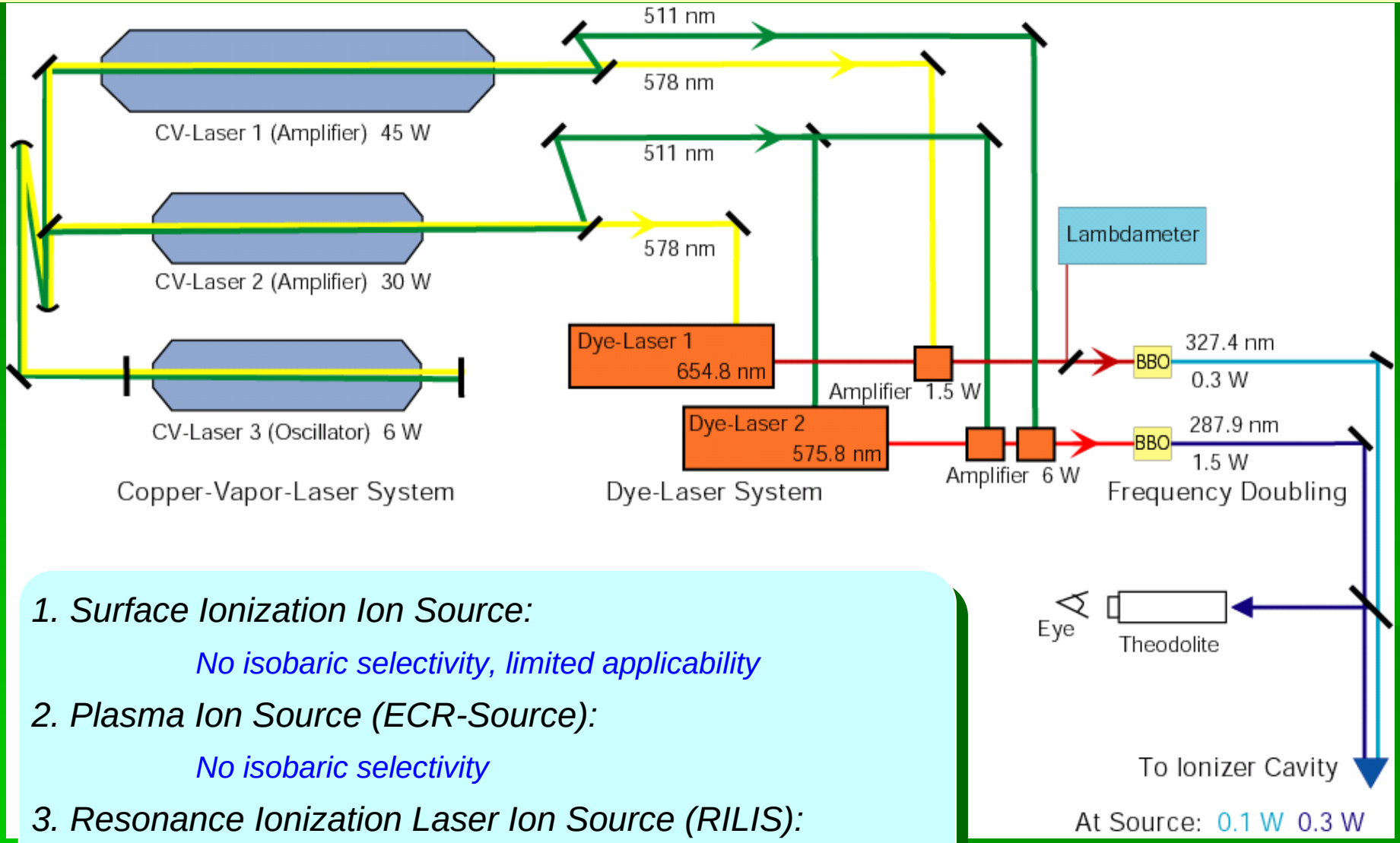
quartz transfer line



- cooled transfer line
- temperature controlled
- reduction of alkali ions

T. Stora, E. Bouquerel

Ionization mechanisms



1. *Surface Ionization Ion Source:*

   No isobaric selectivity, limited applicability

2. *Plasma Ion Source (ECR-Source):*

   No isobaric selectivity

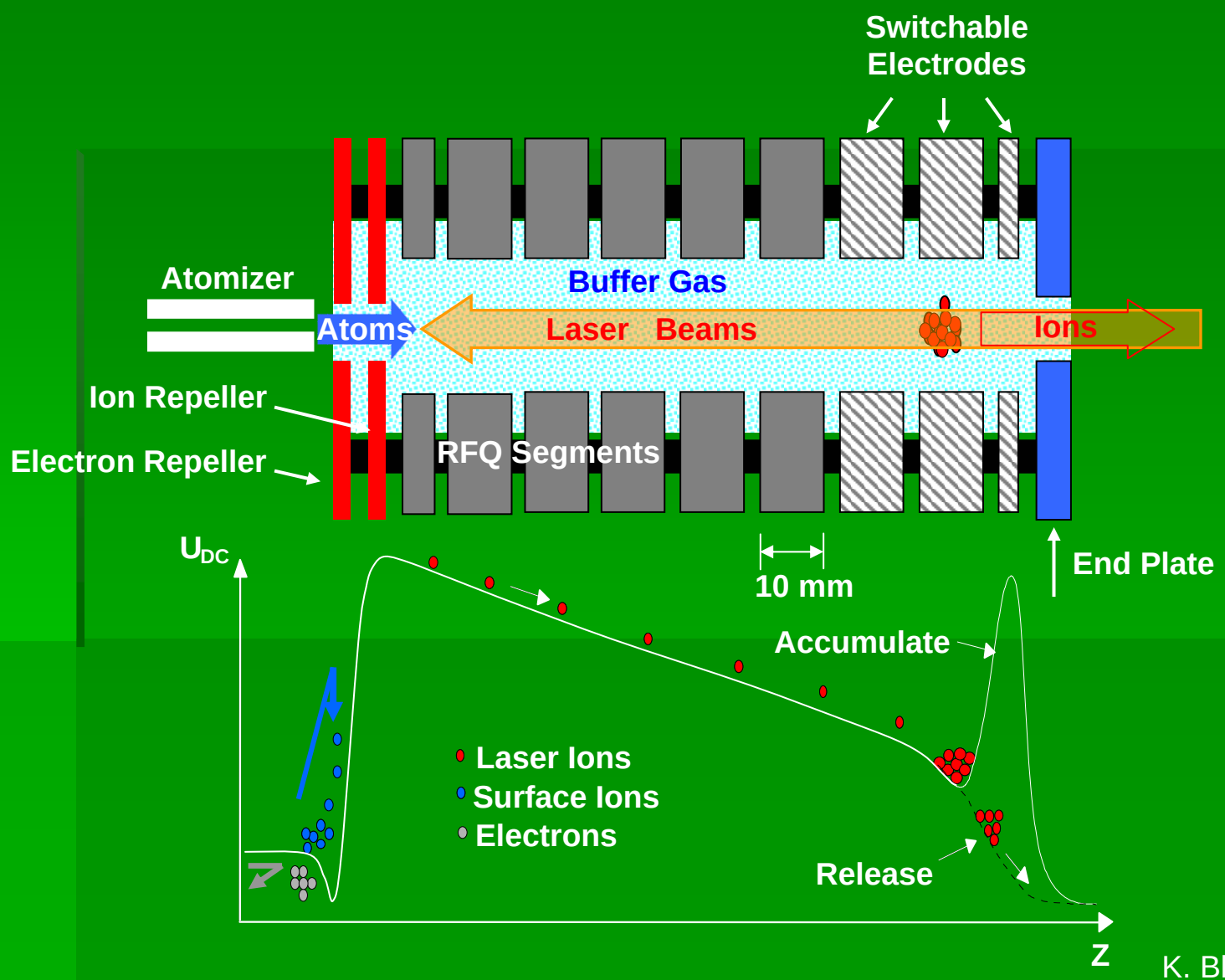
3. *Resonance Ionization Laser Ion Source (RILIS):*

   High isobaric selectivity by resonant laser ionization

   Limitation by surface ionized isobars

K. Blaum

Laser ion source trap (LIST)



K. Blaum et al., NIM 2003

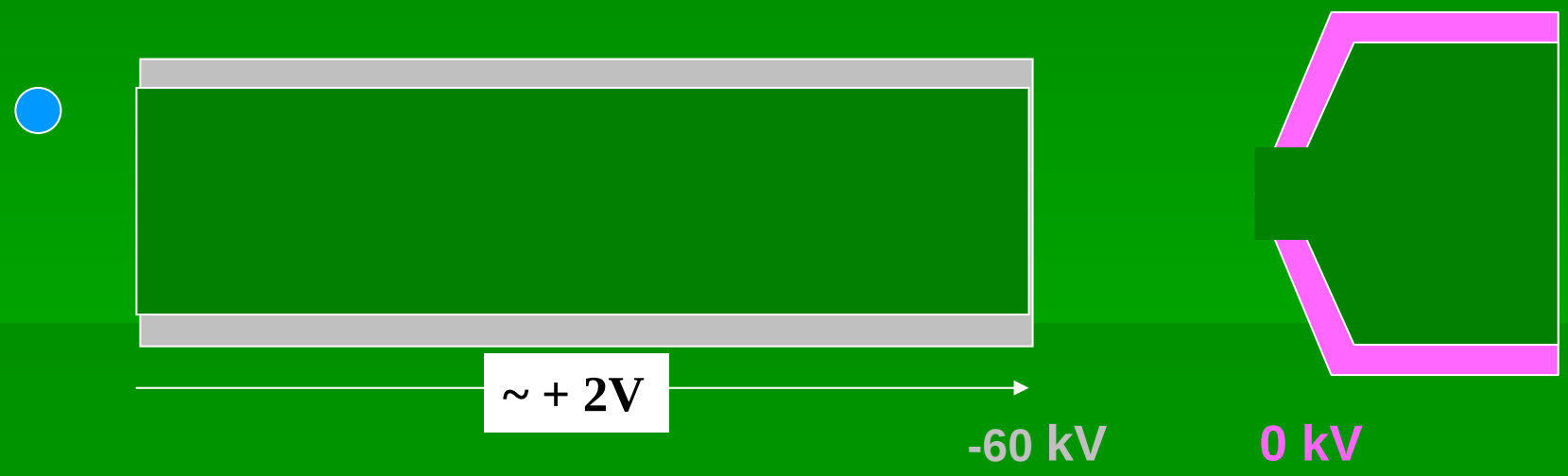
Molecular ions

- reactions in the ion source with S and F
- not all elements perform all chemical reactions
- recent example: measurement of half-live and mass of ^{38}Ca by creating $^{38}Ca^{19}F$ to get out of the regime of mass 38u

Negative ion source

An electron is added to the neutral atom as it drifts and bounces along the ionizer tube

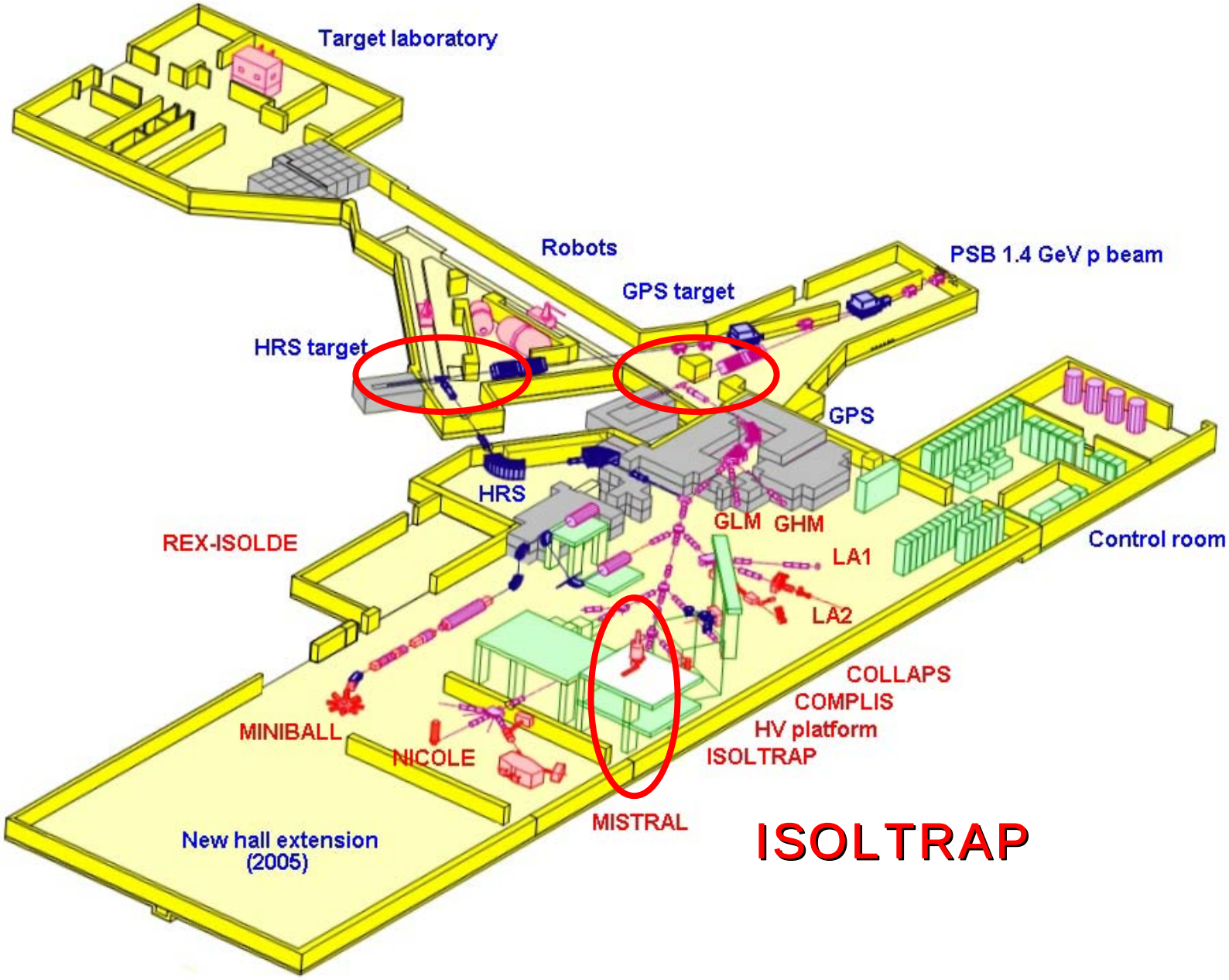
(Part of the effusion process followed by ionization)



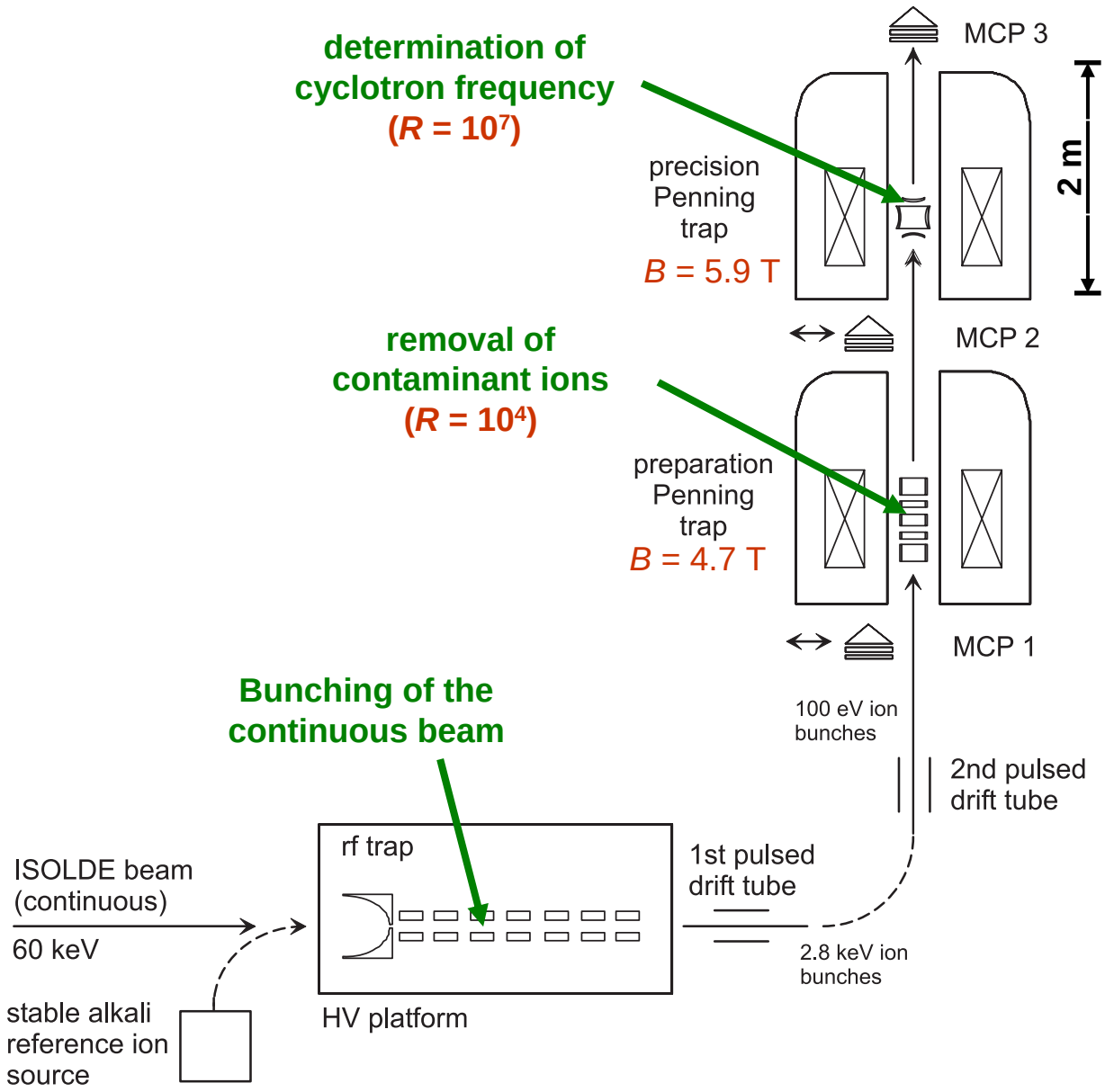
The negative ion is accelerated at 60 kV

M. Menna

Layout of ISOLDE



ISOLTRAP



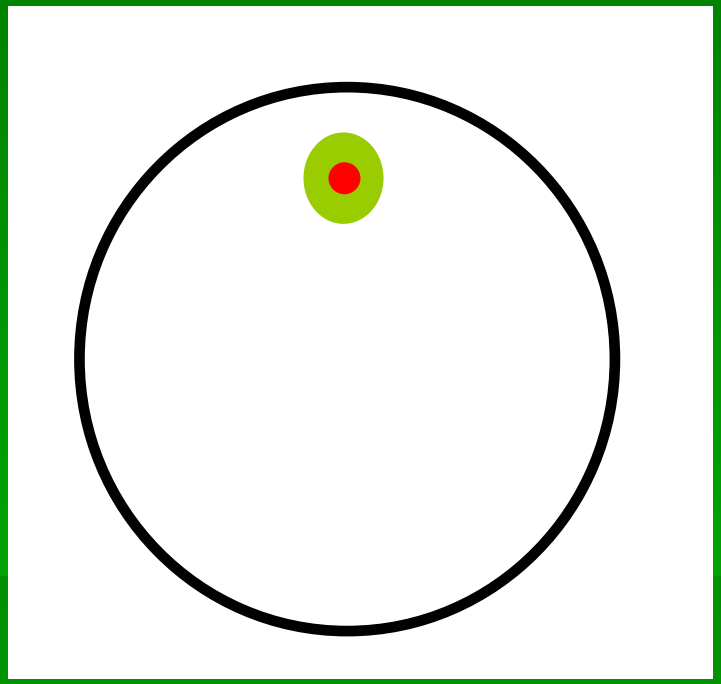
Tripple trap mass spectrometer:
bunching cooling
purification
measurement

G. Bollen, et al., NIM A 368, 675 (1996)
F. Herfurth, et al., NIM A 469, 264 (2001)

Fights at ISOLTRAP

- using combination of quadrupolar excitation and buffergas cooling for a mass selective centering
- possible to resolve isobars (Resolution up to 40000)
- two problems:
  - → closer masses
    (only a few keV away)
  - → ratio of ion numbers
    (contermination to ion of interest)

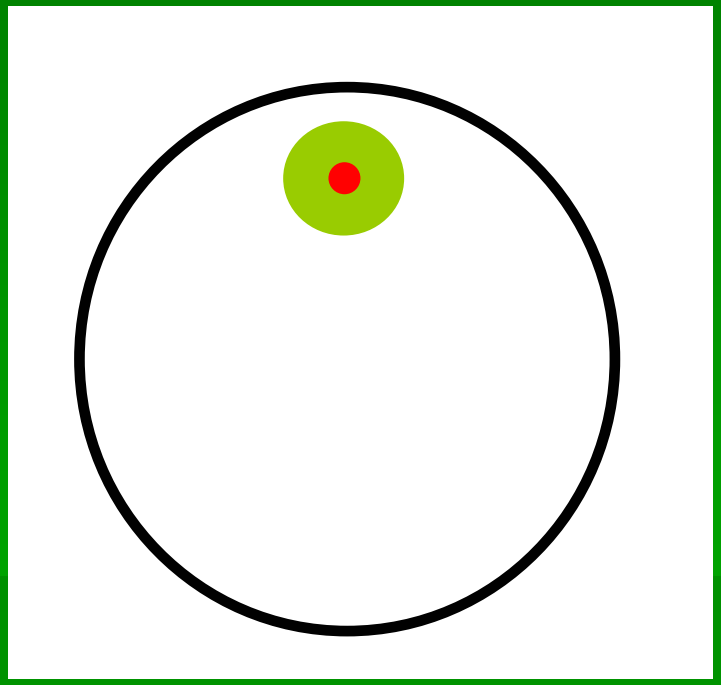
Buffergas Cooling



applying a quadrupolar rf field with $\omega_{rf} = \omega_c$

centering only the mass of interest

Buffergas Cooling

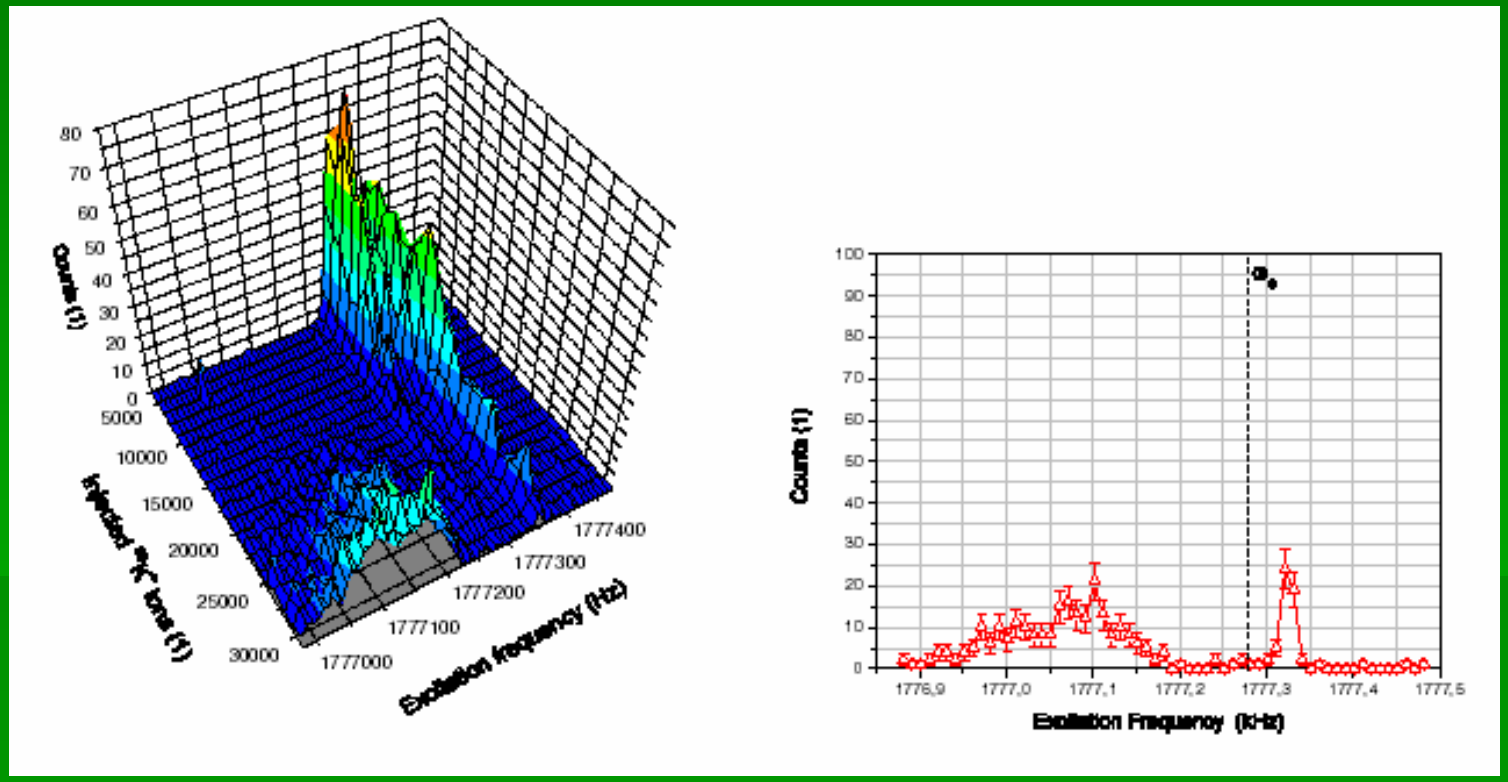


applying a quadrupolar rf field with $\omega_{rf} = \omega_c$

centering only the mass of interest

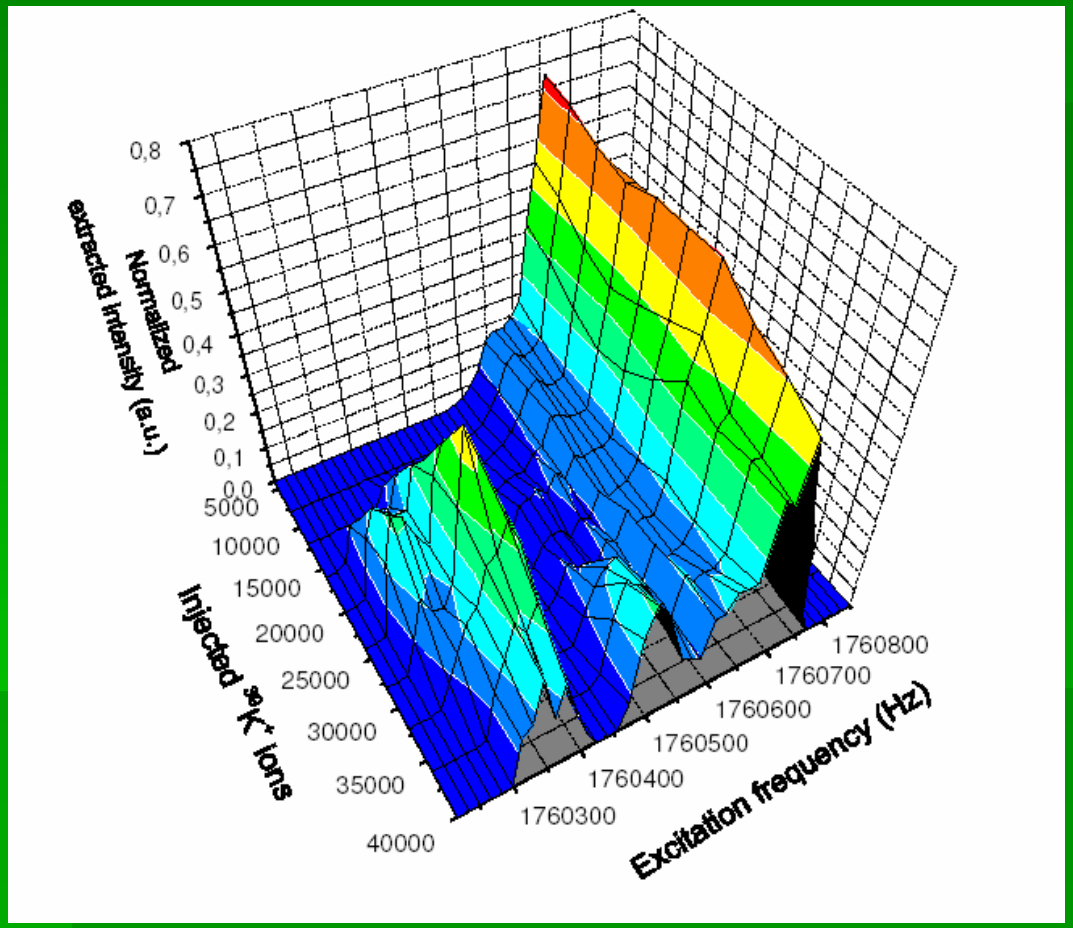
Space Charge measurement

results of buffergas cooling with large ion numbers ^{41}K in ^{39}K:



ratio of natural abondance: ^{39}K / ^{41}K ~ 13 / 1

Space Charge effects (simulation)



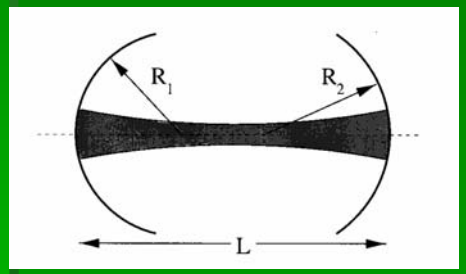
Numerical calculations of the ion trajectories of ^{41}K in an ion cloud of ^{39}K

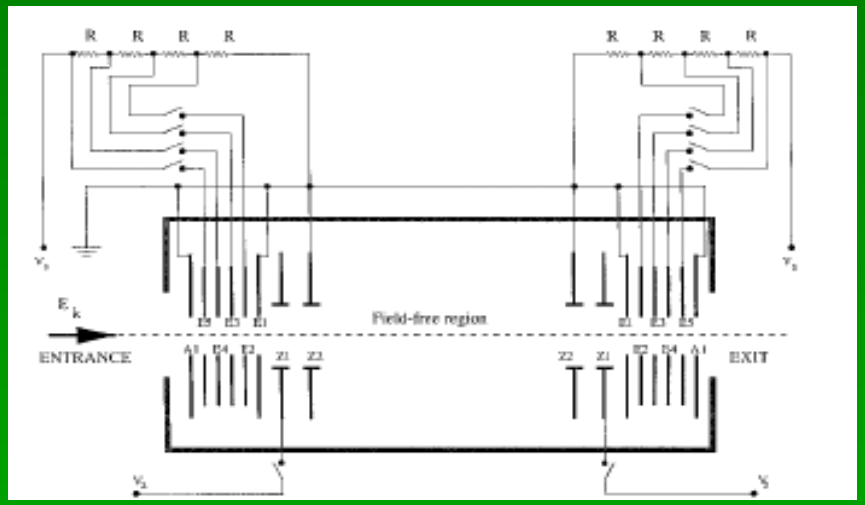
S. Sturm

Electrostatic Isobar Separator

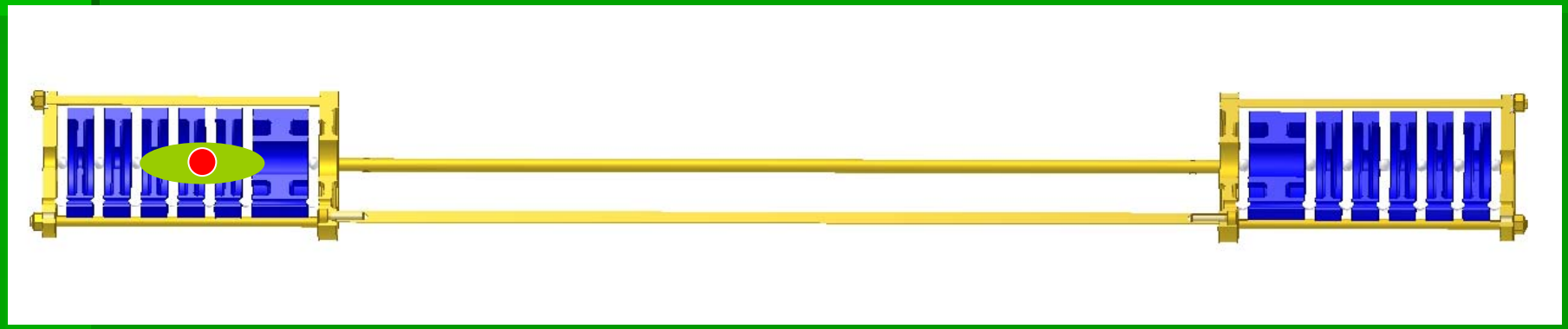
→ Isobaric separation with resolution of up to 100 000

→ Comparable with optics:





M. Dahan et al., A New Type of Electrostatic Ion Trap for Storage of Fast Ion Beams, Rev. Sci. Instrum., pp. 76-83, 69 (1998)

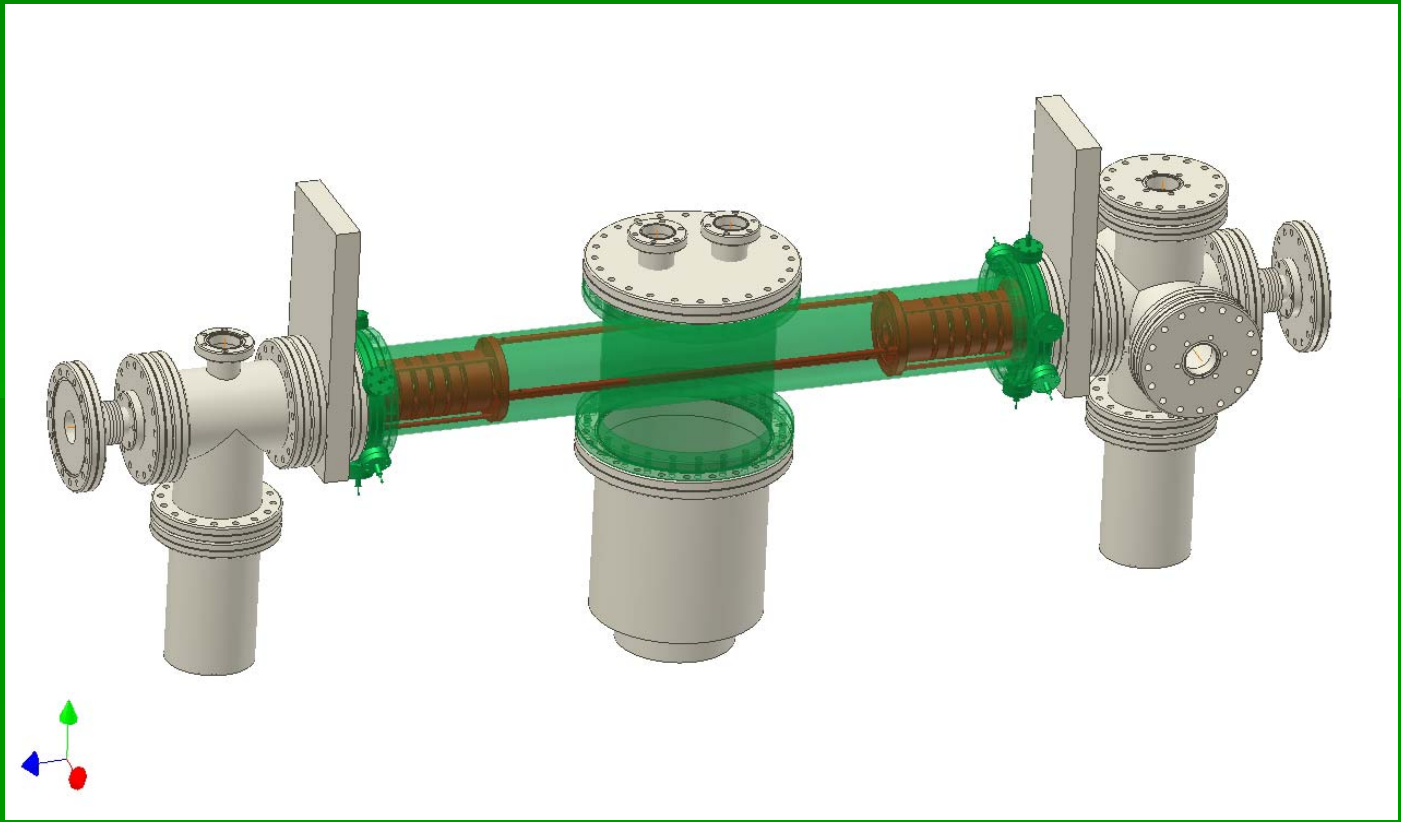


M. Eritt

Electrostatic Isobar Seperator: scheme

Experimental parameters:

- beam energy 2.5keV
- vacuum of $10e^{-11}$mbar
- separation N_2 and CO
- increasing the ratio of conterminants to ions of interest



M. Eritt

Schedule this year

- Beam time beginning of May (neutron rich silver)
- Finished beam time on neutron rich lead (not successful due to conterminations)
- Next beamtime is this weeks (neutron deficient Cd)
- Beamtime on test of a target with a cooled transfer line and neutron rich Cd end of August

Thanks

- Alexander Herlert, Magda Kowalska, Dennis Neidherr and Romain Savreux (ISOLTRAP crew)
- Lutz Schweikhard and Gerrit Marx
- Sven Sturm and Markus Eritt
- for your attention