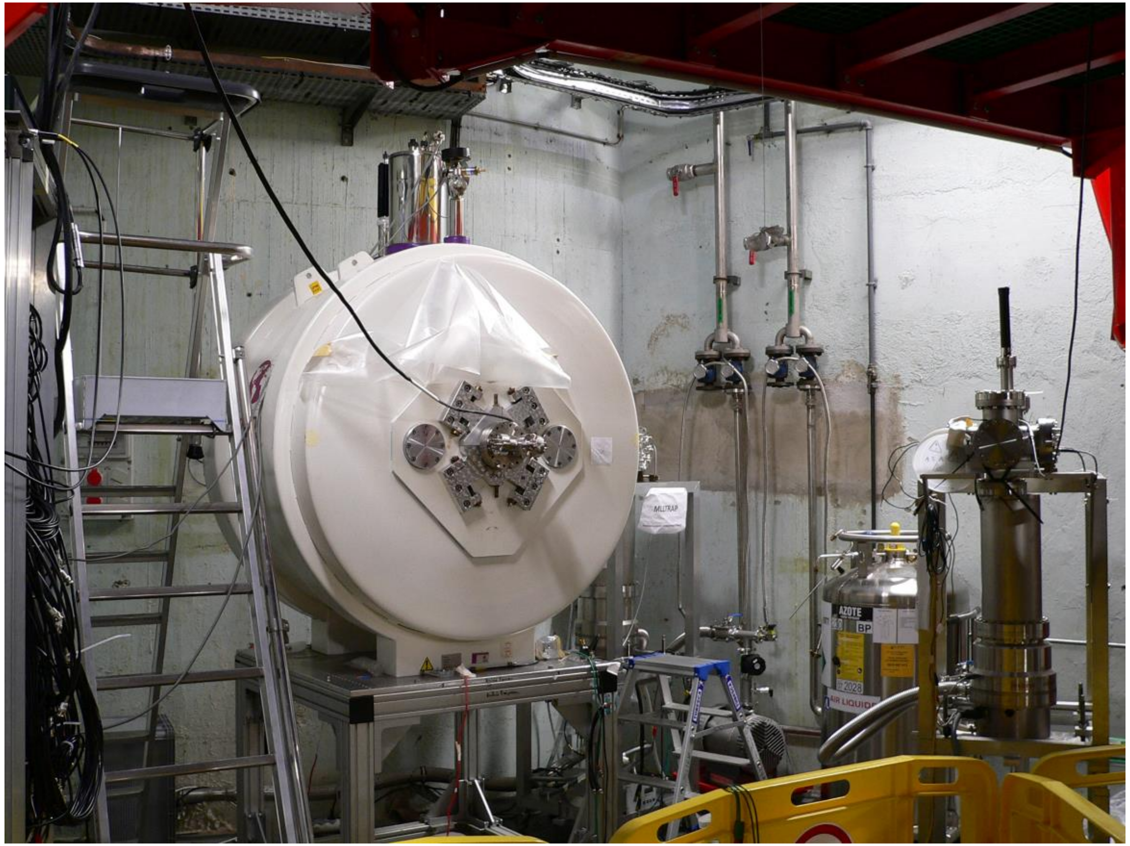
High precision mass measurements with MLLTRAP at ALTO



Elodie Morin

Supervised by Enrique Minaya Ramirez

17/05/2021

Study of N = 82 shell closure with silver isotopes high precision mass measurements (A = 124-129)

- Nuclear structure :
  - Binding Energies :

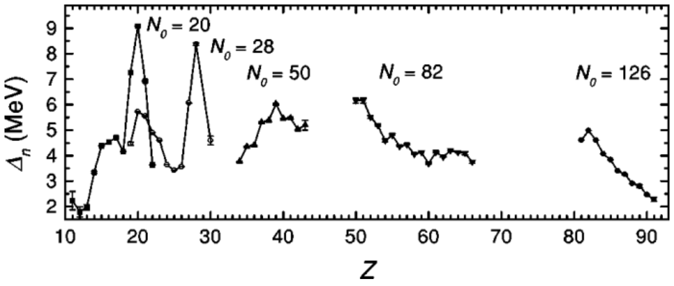
$$B(N,Z)=[N M_n+Z M_p-M(N,Z)]c^2$$

  - Two neutron separation energies :

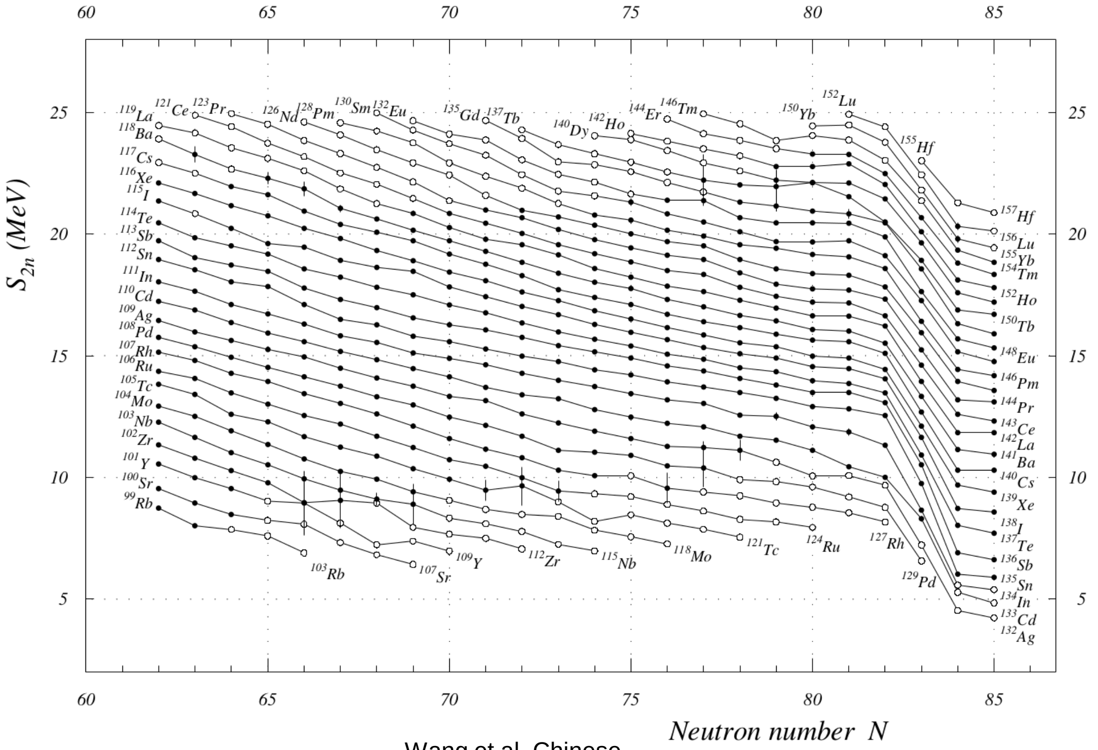
$$S_{2n}(N,Z)=B(N,Z)-B(N-2,Z)$$

  - Shell gaps :

$$\Delta_n(N,Z)=S_{2n}(N,Z)-S_{2n}(N+2,Z)$$



Lunney, Pearson, Thibault / Review of modern physics 75 (2003)



Wang et al. Chinese Physics C (2017)

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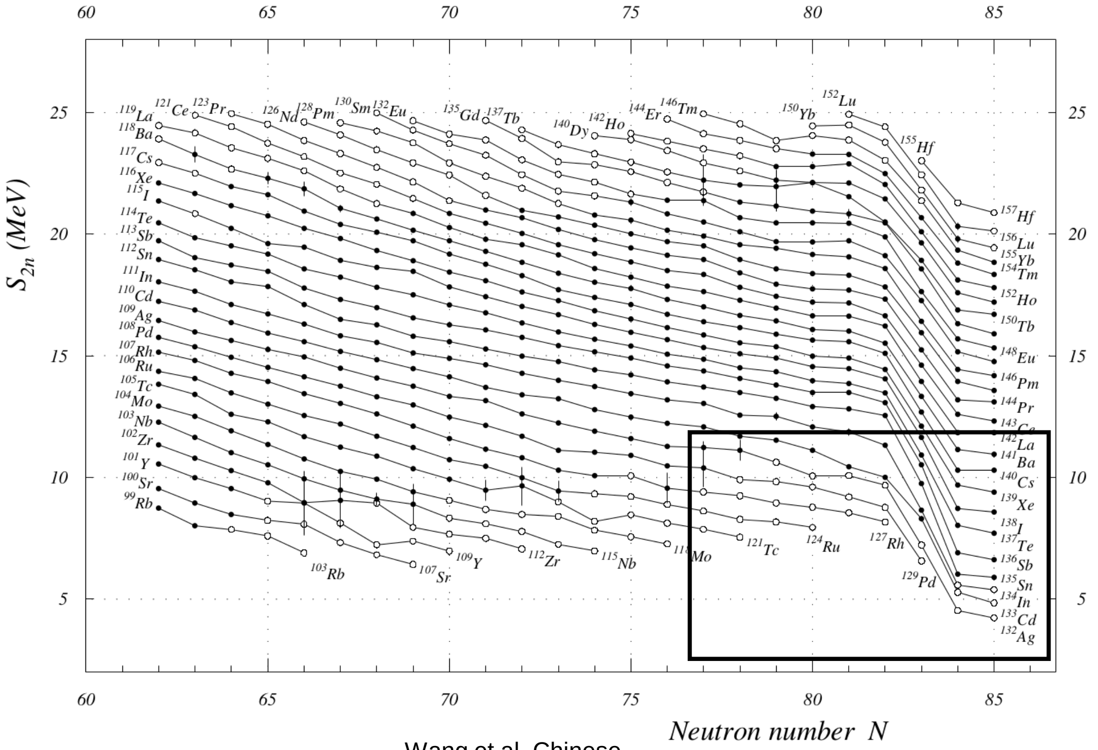
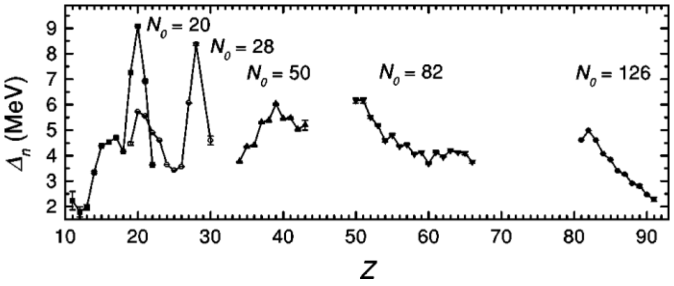


Wang et al. Chinese Physics C (2017)



Lunney, Pearson, Thibault / Review of modern physics 75 (2003)

Scientific context - Motivations

Study of N = 82 shell closure with silver isotopes high precision mass measurements (A = 124-129)

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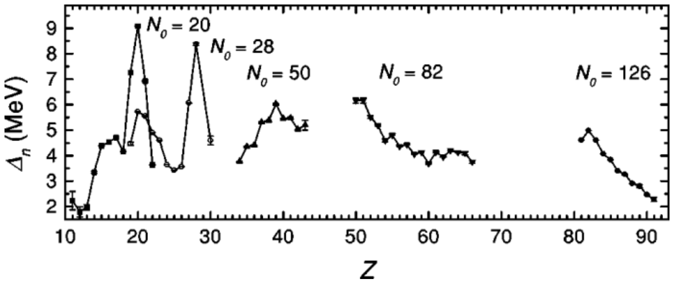

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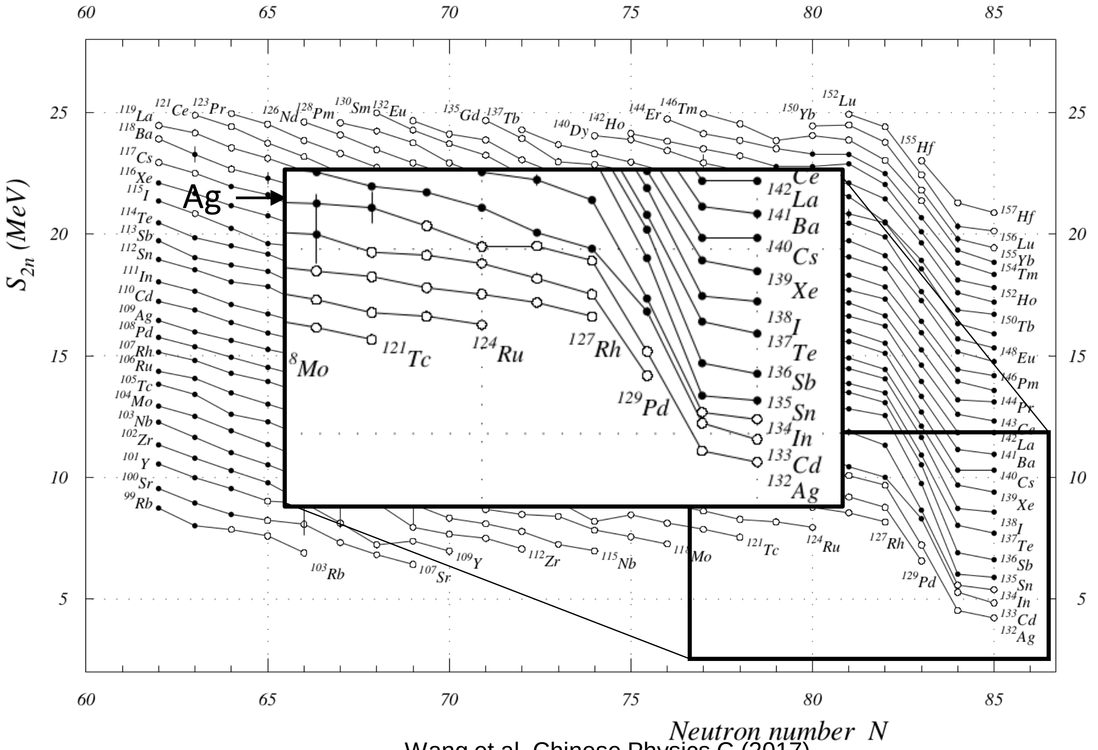
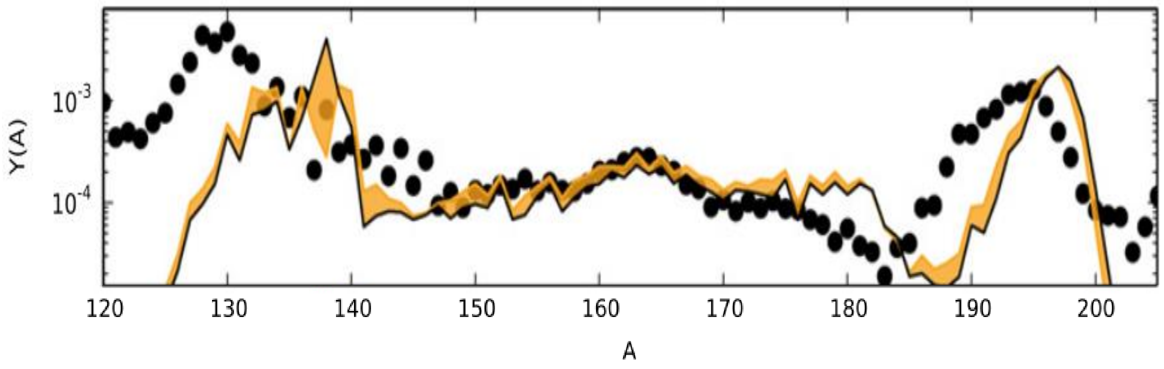


Wang et al. Chinese Physics C (2017)

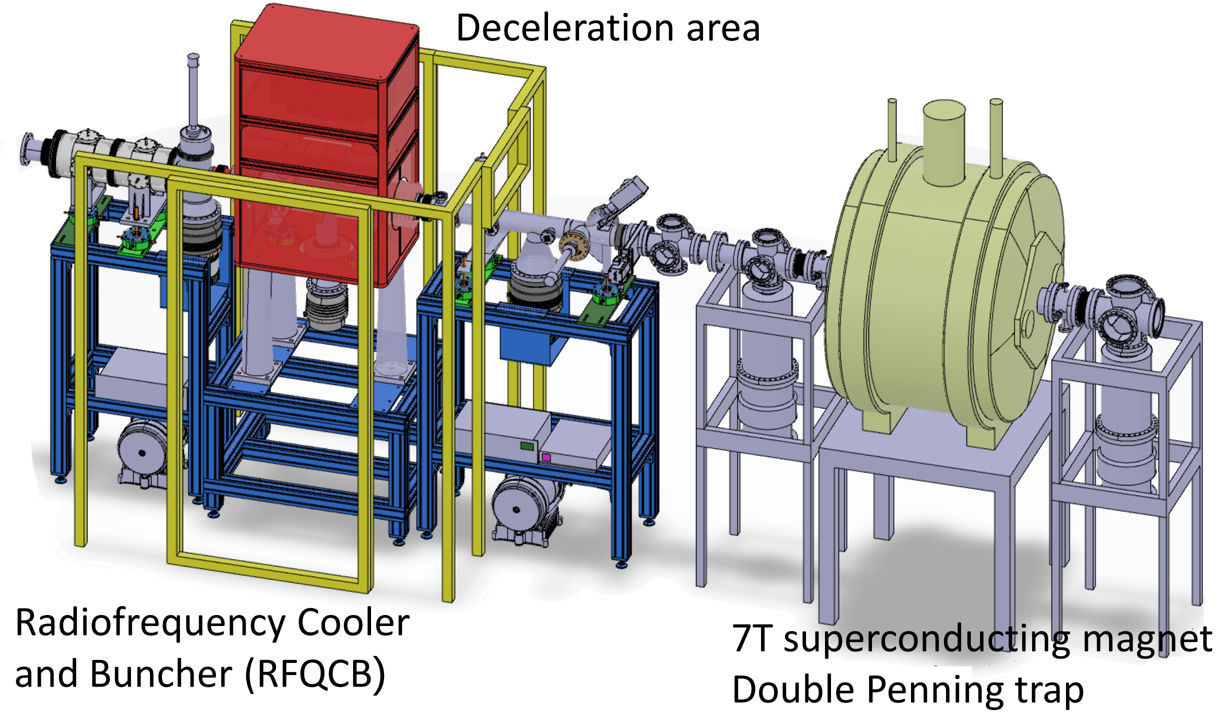
Study of N = 82 shell closure with silver isotopes high precision mass measurements (A = 124-129)

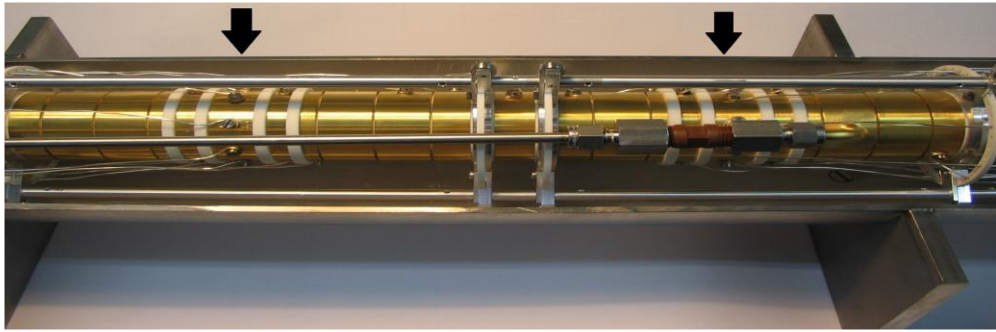
- Nuclear astrophysics
  - N = 82 could be linked to A = 130 solar abundance peak :
    - Balance between neutron capture and beta decay
    - Fission recycling
  - Nuclear informations including nuclear masses are important inputs for r-process path evolution models



M.R. Mumpower et al. / Progress in particle an nuclear physics 86 (2016)

With ion traps



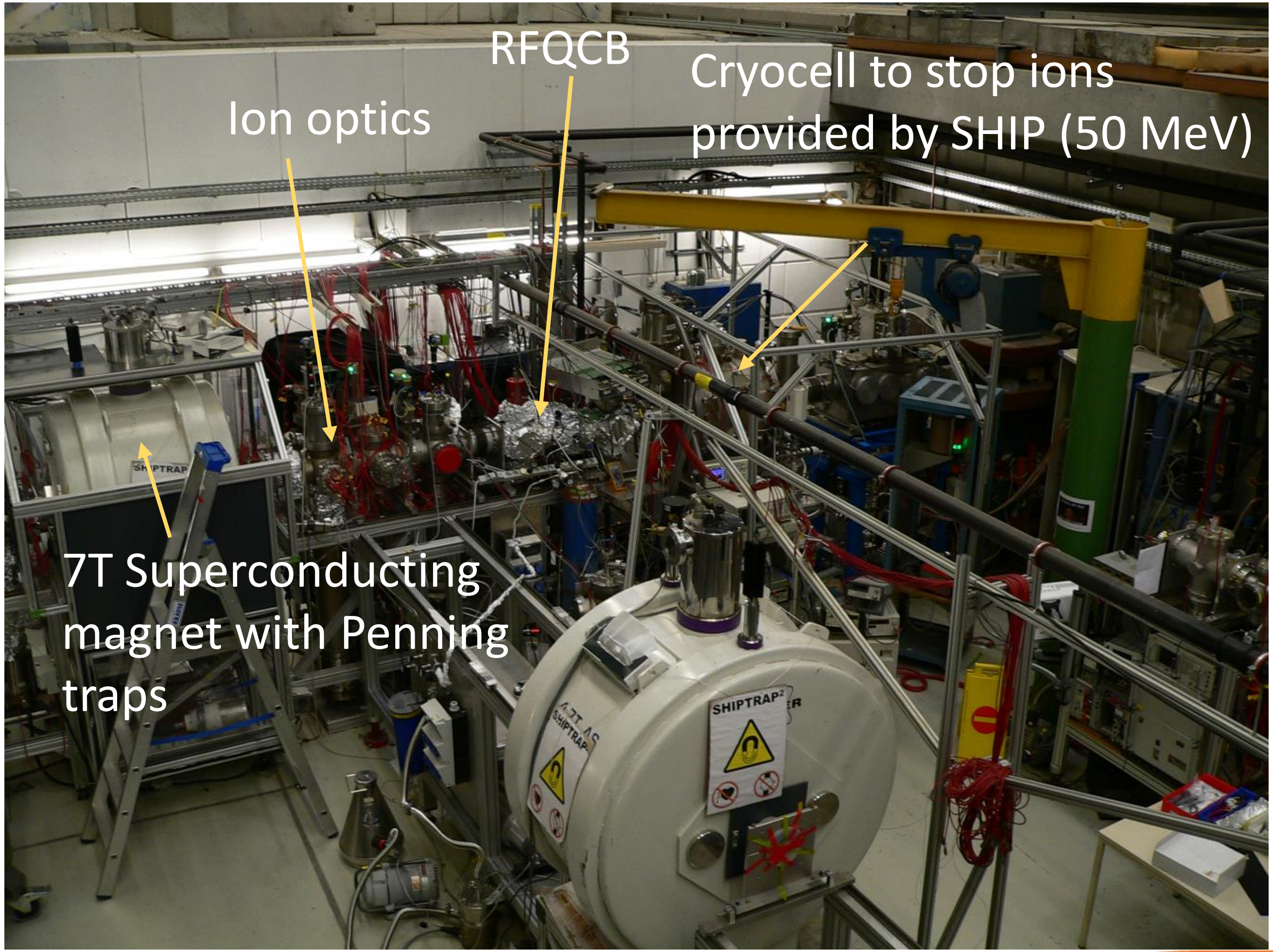


- RFQCB : cools the beam as a good quality of the beam is necessary to inject it in the Penning traps
- Cyclotron frequencies measurements with Penning traps (rf excitations) :

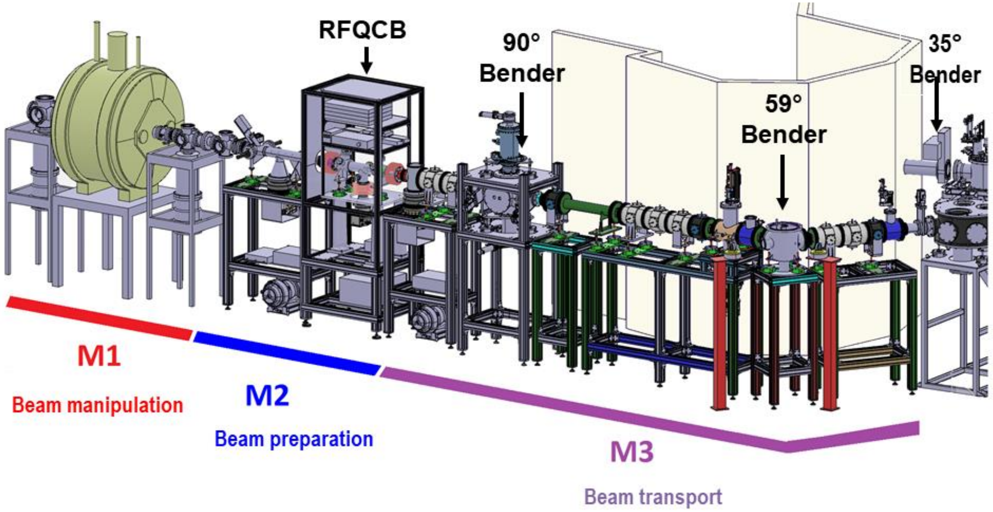
$$\nu_c = \frac{q\,B}{2\,\pi m}$$

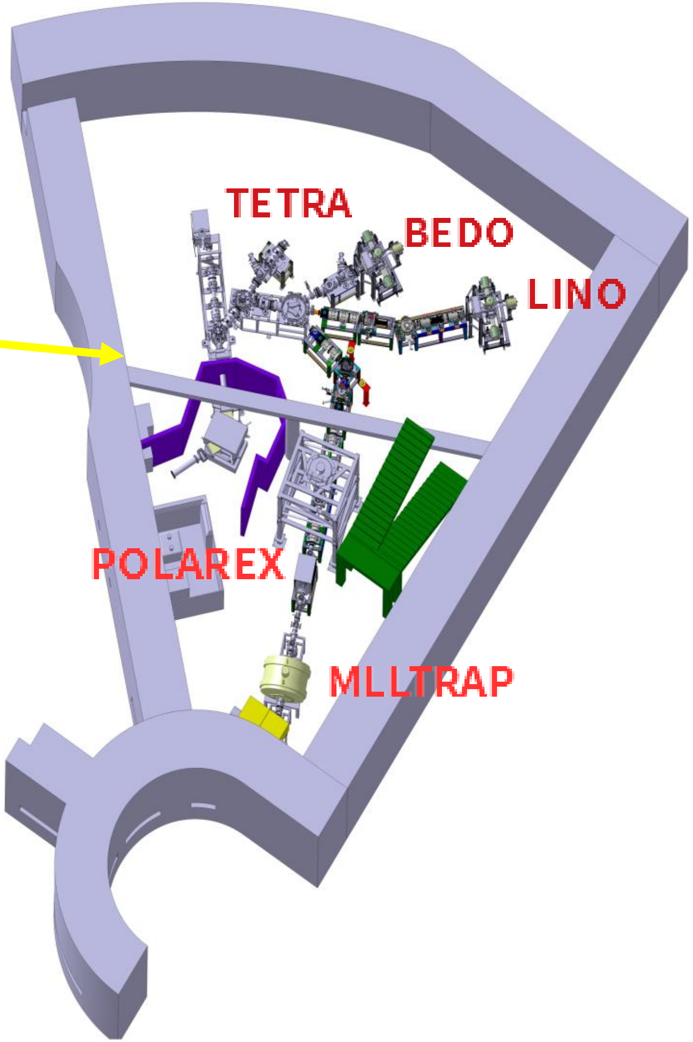
SHIPTRAP/GSI/Germany

- Studies on heavy and superheavy isotopes, ground and isomeric states (N = 152-162)
- Parasitic beamtime
  - At GSI, the accelerator is able to provide a small fraction of the beam to a second experiment
  - -> Some measurements of already known masses (^{254}No ; $^{271, 273}$Cf ; $^{201, 202}$At ; $^{196, 198}$Bi ; $^{204, 206}$Fr ; ^{215}Th…)
  - They also permetted to make some adjusments on the system
- Main beam (for ^{257}Rf and ^{258}Db) is now !

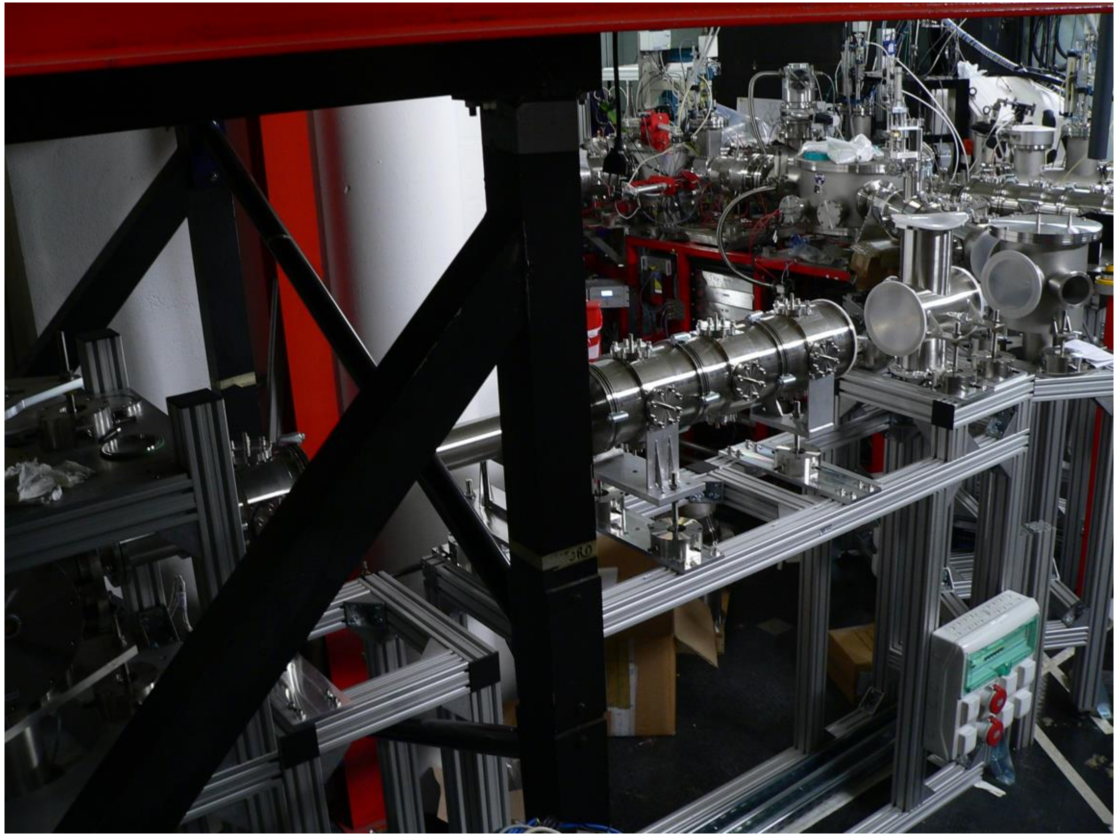


MLLTRAP at ALTO

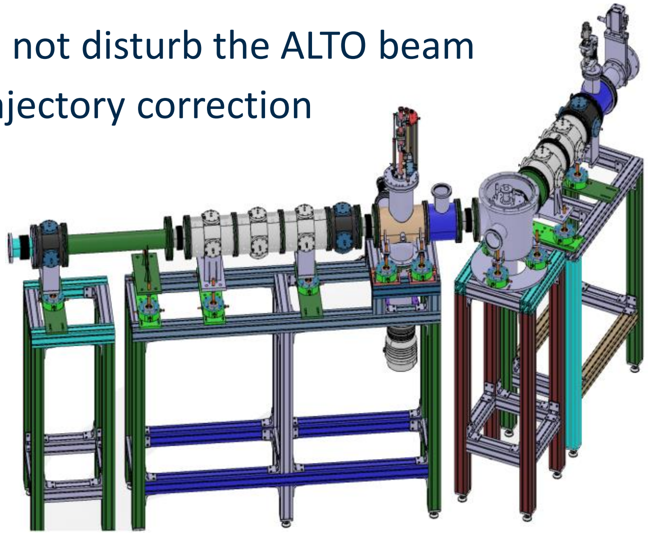




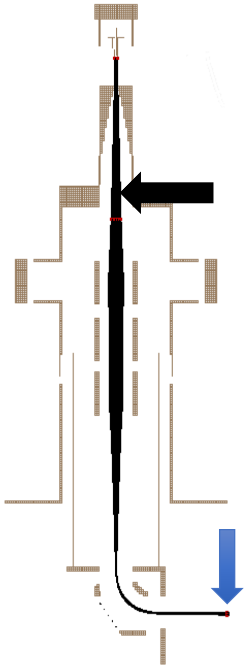
M3 Section - High voltage Ion source (50 kV)

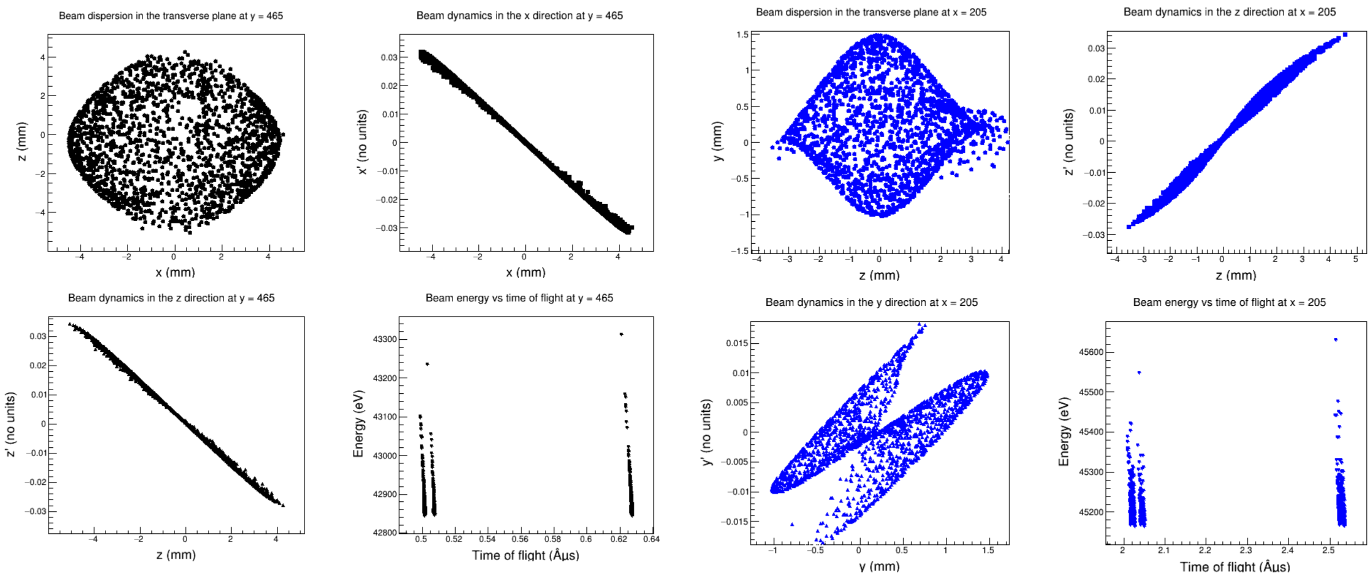


- Ion source (Rb and Cs) designed to characterize the traps (RFQCB+Penning traps) at different energy ranges for the ions
- Technical requirements :
  - Injection from top
  - Fixed electrodes
  - Do not disturb the ALTO beam
  - Trajectory correction



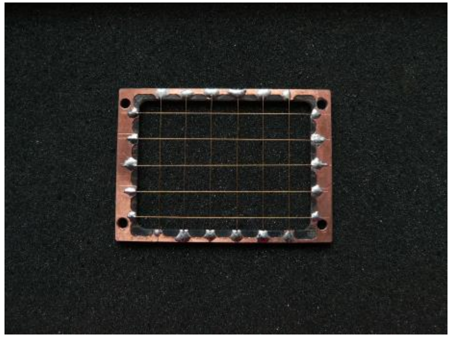
M3 Section - High voltage ion source

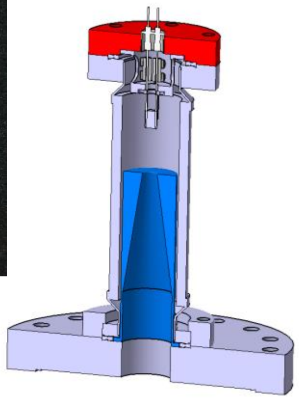


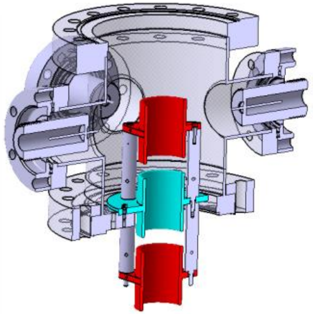


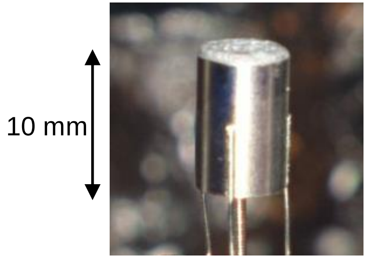
- Simulations with Simion® to test different designs and improve them to choose the best one
- Simulation tests at 1, 10, 30, 50 kV to validate that it works at different energy ranges
- Work with the design office to fix the final design

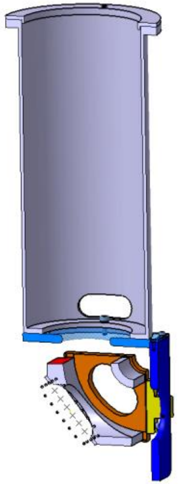
M3 Section - High voltage ion source

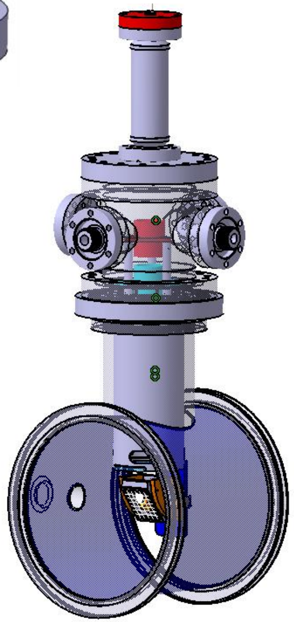


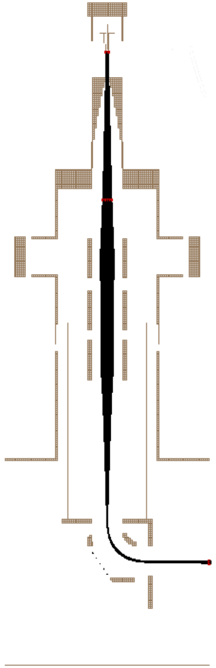






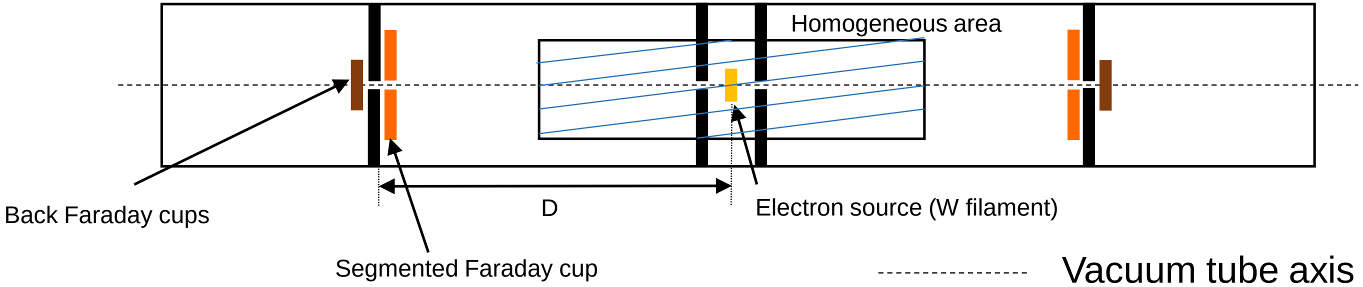






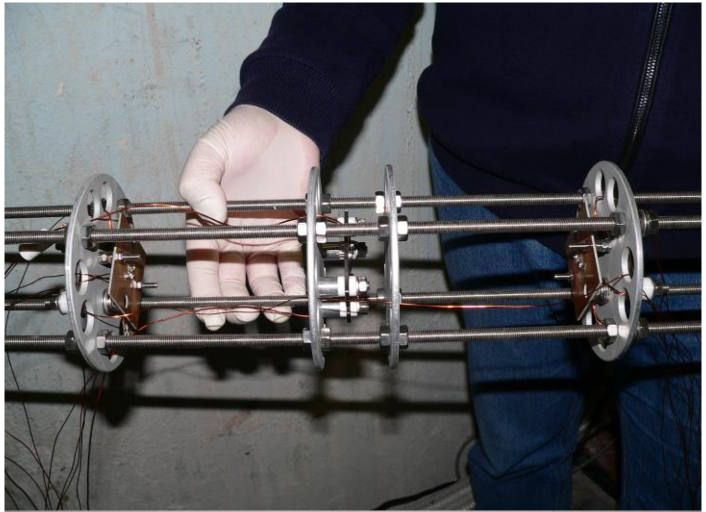
M1 Section - Vacuum tube

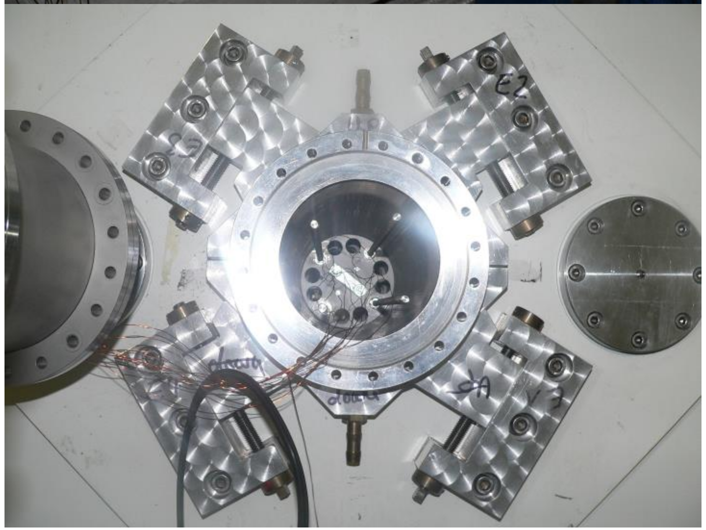
- Alignment of the vacuum tube axis with magnetic field lines in the homogeneous area (magnet center) using an electron gun
- Reduce the misalignment



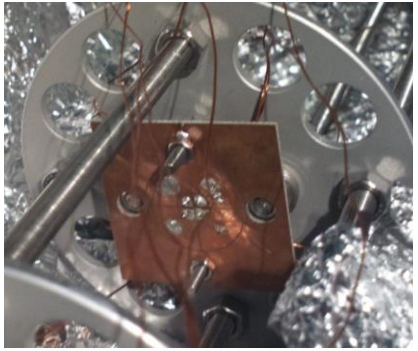
------------ Vacuum tube axis

—— Magnetic field lines





- Movable Faraday cups
- Two positions checked :
  - D = 160 mm
  - D = 100 mm
- Final tests will be done to validate the alignment



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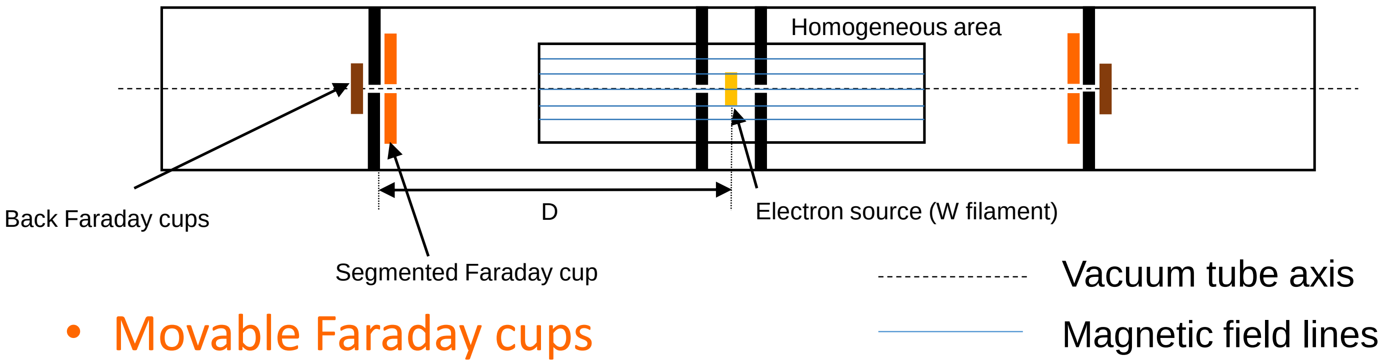

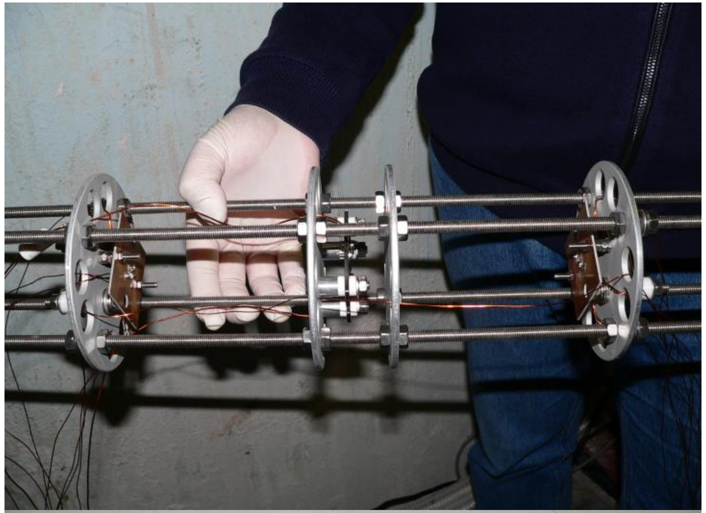

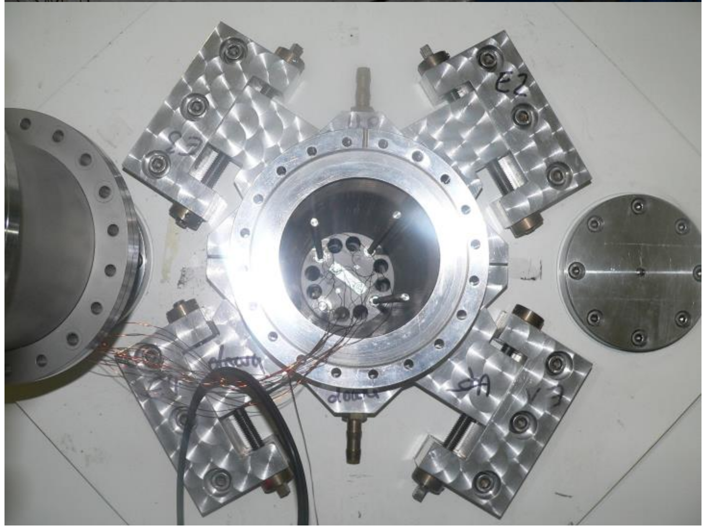

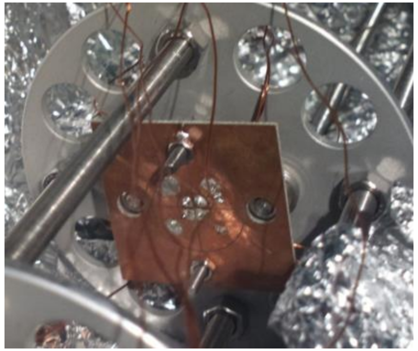

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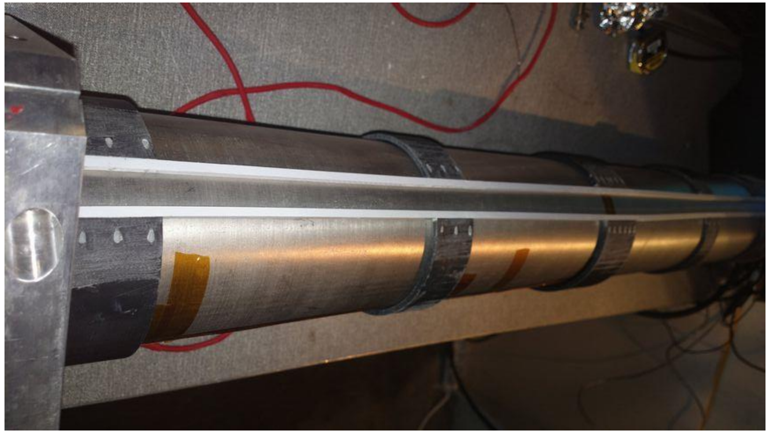
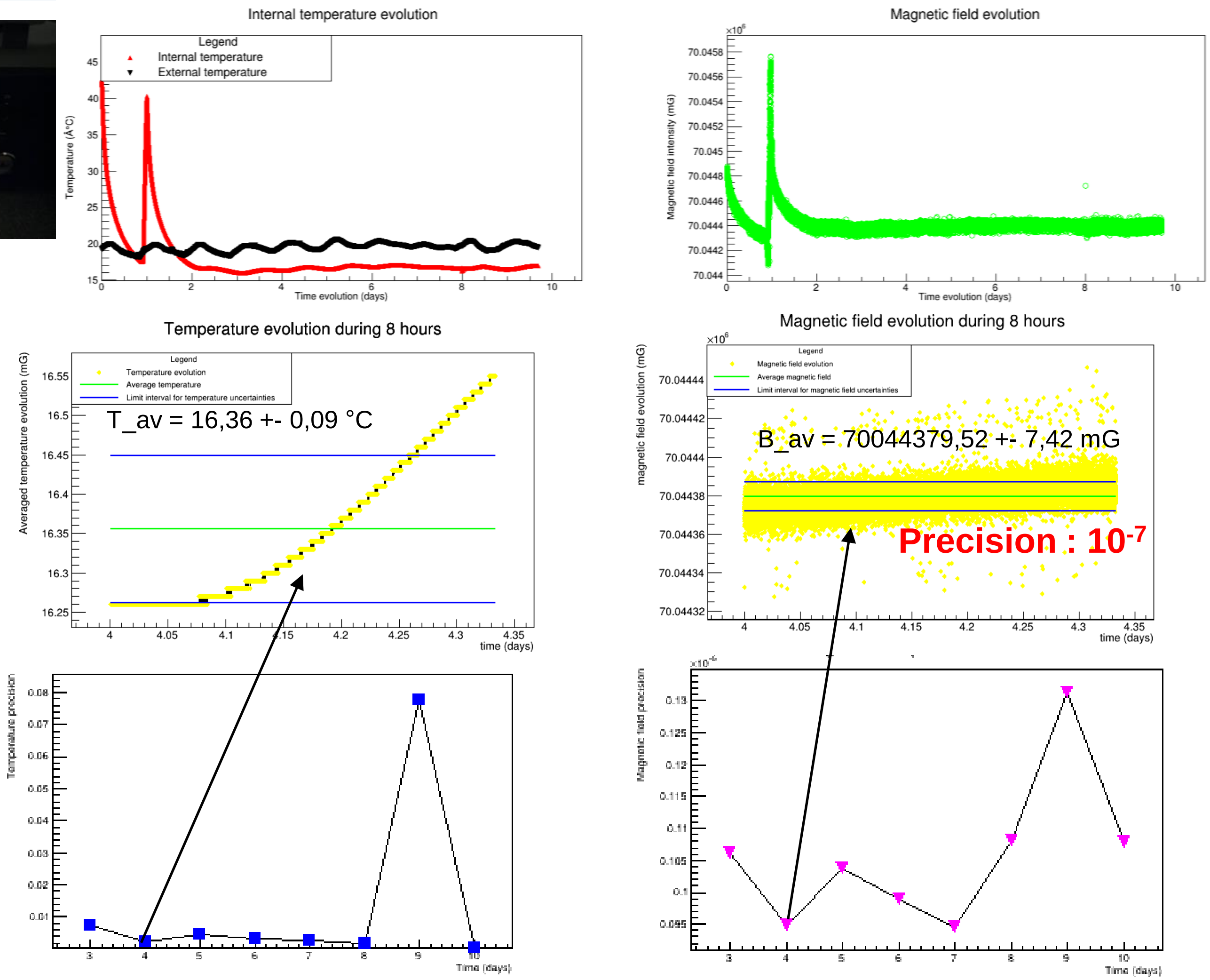
M1 Section - Magnetic field monitoring

- Magnetic probe developped by Caylar to track magnetic field evolution in real time
- Coupled to the bore temperature





Conclusion and perspective

What's already done

- MLLTRAP experiment « in construction »
- Stable ion source designed to caracterise the traps
- Magnetic probe to have a monitoring of the magnetic field validated
- Vacuum tube alignment almost finished

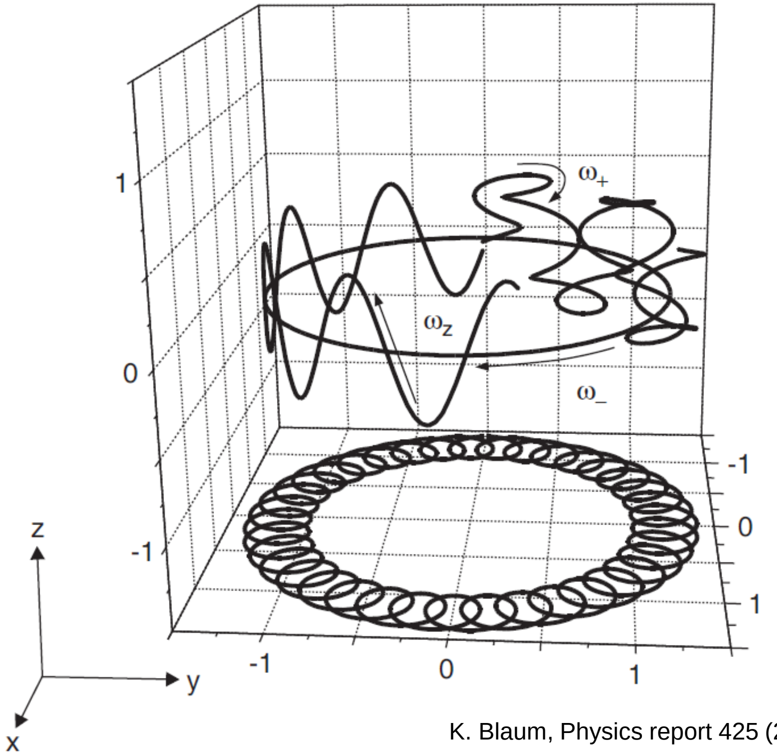
Perspectives

- Put the traps inside the magnet when alignement finished and validated
- Building up and tests of the ion source
- Construction of the RFQCB (when pieces delivered)
- Offline tests of RFQCB and Penning traps with the ions source
- M3 Section almost closed -> vacuum tests

Thank you for your attention !

Ion motions in a Penning trap

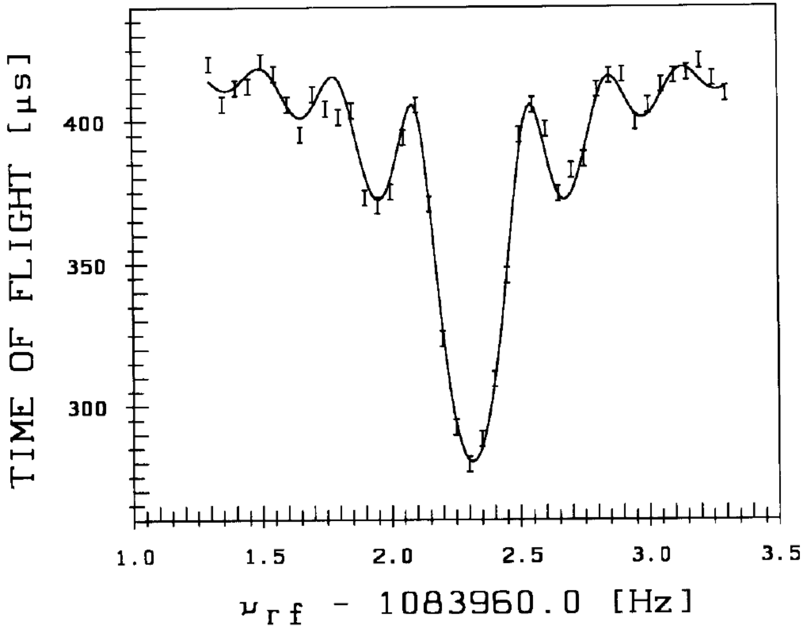
- Global motion contains 3 eigenmotions :
  - An axial motion of frequency ω_z
  - A slow radial motion called magnetron motion of frequency ω_-
  - An fast radial motion called reduced cyclotron motion of frequency ω_+
- Cyclotron frequency :
  - $\omega_c = \omega_+ + \omega_-$
  - $\omega_c^2 = \omega_+^2 + \omega_-^2 + \omega_z^2$



K. Blaum, Physics report 425 (2006)

TOF ICR

- Ion excited with RF at frequencies around its own cyclotron frequency :
  - The excitation makes the ion axial energy increase (motion radius increases)
  - Scan on several frequency values around its eigenfrequency
  - Time of flight measurement made for each frequency value scanned
  - Conversion from radial energy to kinetic energy
  - Radial energy accumulated is maximum at the eigenfrequency (minimum TOF)



M. König et al., International Journal of Mass Spectroscopy and Ions Processes 142 (1995)

$$T(\omega) = \int_{z0}^{z1} \left(\frac{m}{2(E_0 - qV(z) - \mu(\omega)B(z))} \right) dz$$

z0 : measurement trap center position
z1 :detector position
E_0 : initial energy of the ion

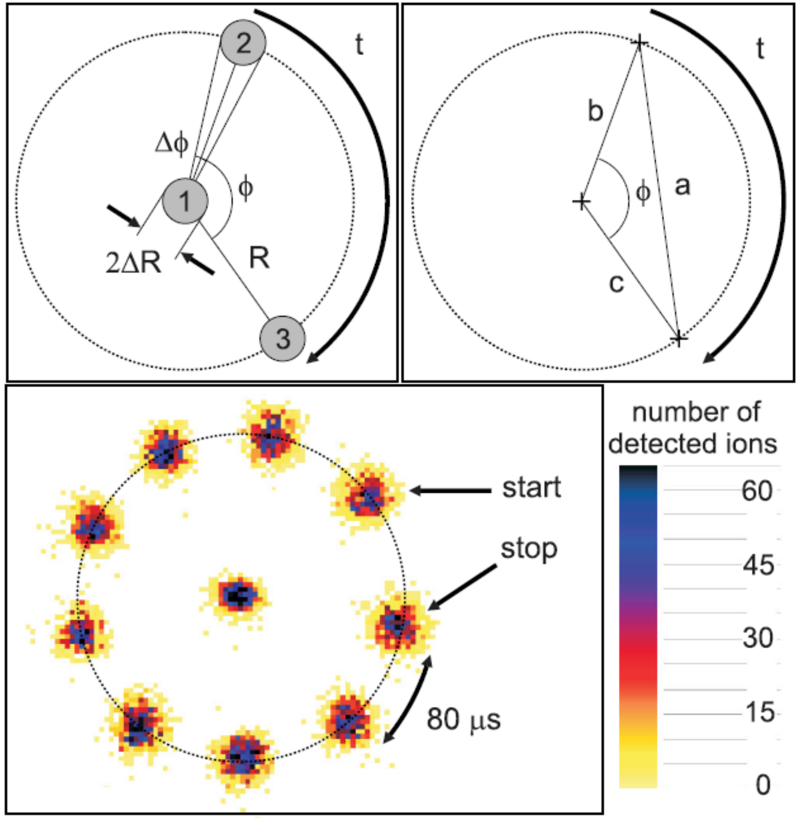
V(z) : electric field at z
B(z) : magnetic field at z
$\mu(\omega)$: magnetic moment of the ion excited at ω

PI ICR

- Ion excited at its eigenfrequency (almost)
  - A first excitation (with one of the eigenfrequencies ω_+ or ω_-) is applied to prepare the ions on an average radius R with an initial phase
  - The ions radial motion accumulates a phase during a free evolution time on this « orbit » :

$$\phi + 2\pi n = \omega t$$

with n the number of full revolutions performed by the ion during the time t and ω the pulsation the radial motion studied



S. Eliseev et al., Physics Review Letter 110 (2013)