PIPERADE @ DESIR

PIEGES DE PENNING POUR LES RADIOISOTOPES A DESIR

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Pauline Ascher - NUSTAR Week - 5th March 2014

PIPERADE @ DESIR

Pieges de Penning pour les Radioisotopes à DESIR

- The DESIR facility (Presentation, Status and timeline)
- Why PIPERADE? Example of physics cases
- The PIPERADE set-up
- Isobaric separation methods
- Status and timeline of PIPERADE

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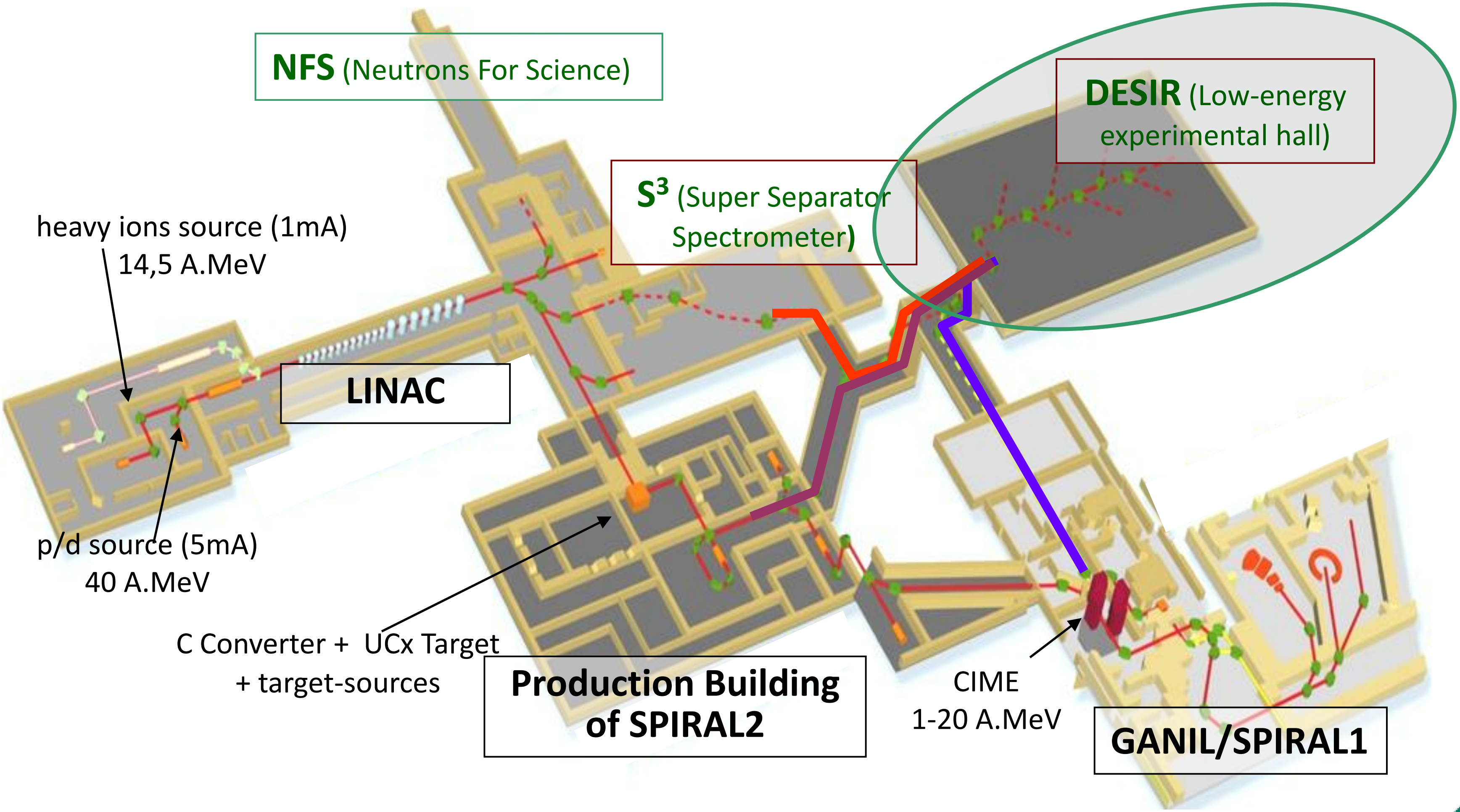
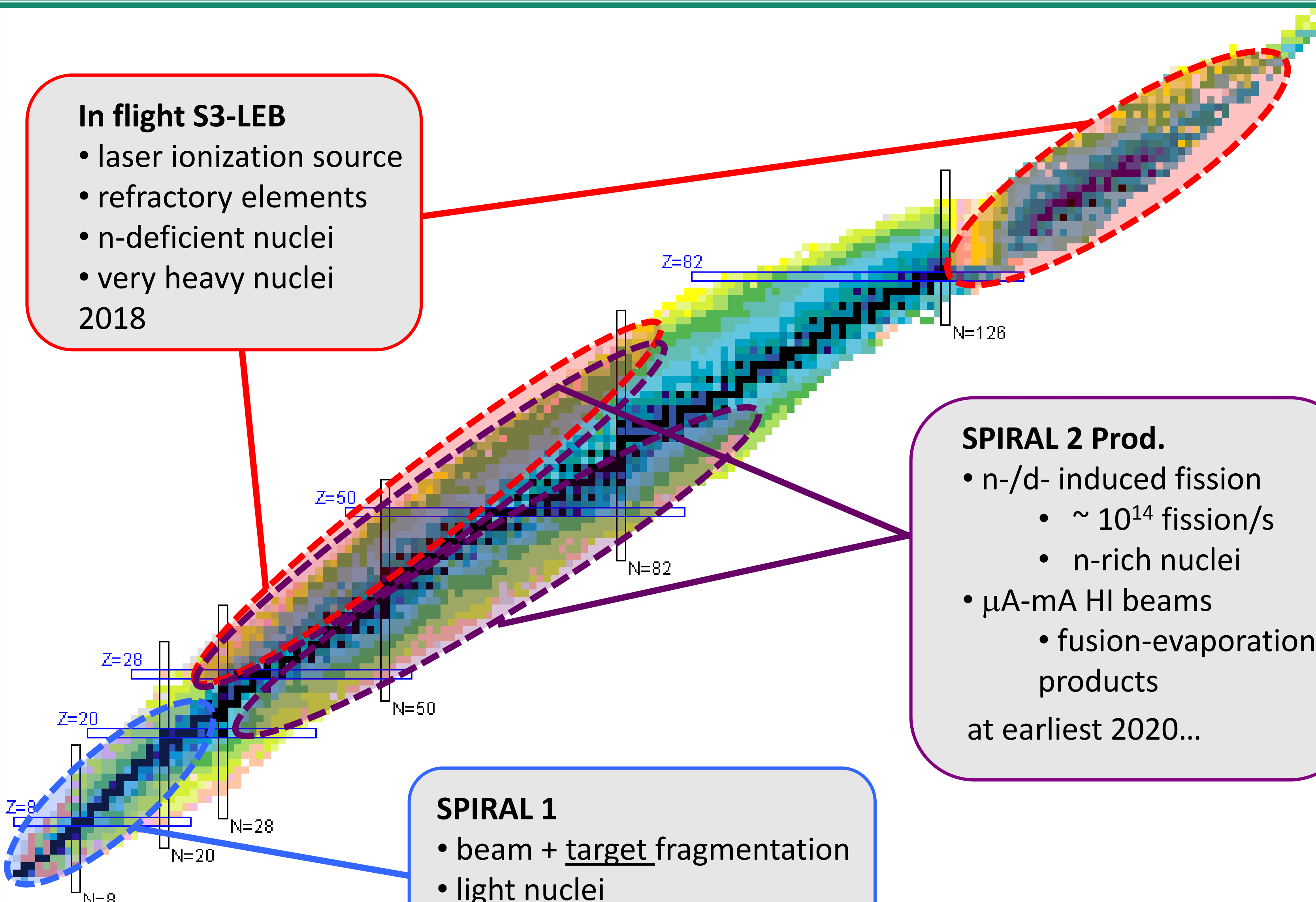
DESIR @ SPIRAL2

A low-energy RIB facility dedicated to the study of the fundamental properties of the nucleus in its ground and isomeric states



Collaboration Spokesperson: *B. Blank, CENBG*
Facility coordinator: *J.-C. Thomas, GANIL*

DESIR RIBs



In flight S3-LEB
- laser ionization source
- refractory elements
- n-deficient nuclei
- very heavy nuclei

2018

SPIRAL 2 Prod.
- n-/d- induced fission
    - ~ 10^{14} fission/s
    - n-rich nuclei
- µA-mA HI beams
    - fusion-evaporation products

at earliest 2020…

SPIRAL 1
- beam + target fragmentation
- light nuclei

2016

DESIR: timeline and news

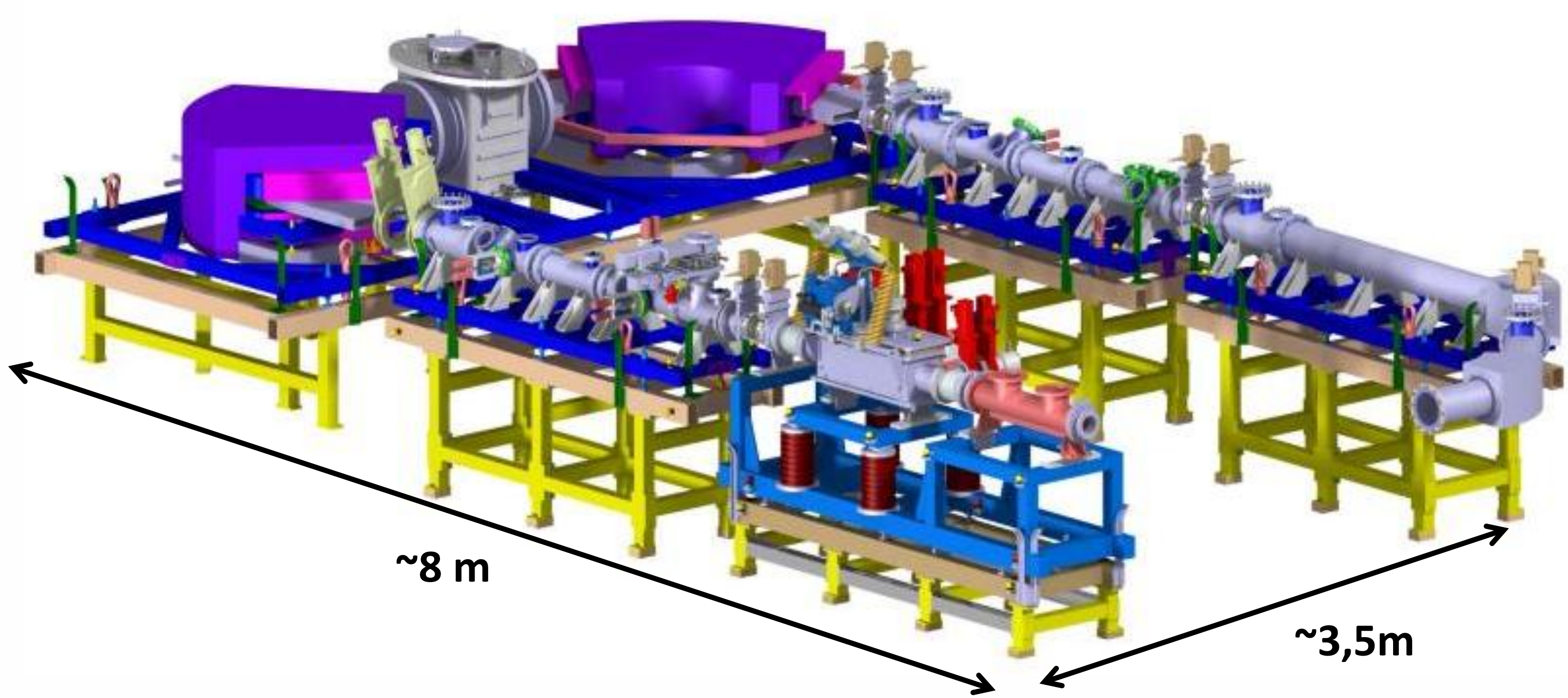
http://www.cenbg.in2p3.fr/desir/

→ **DESIR in SPIRAL2 « Phase 1+ »**

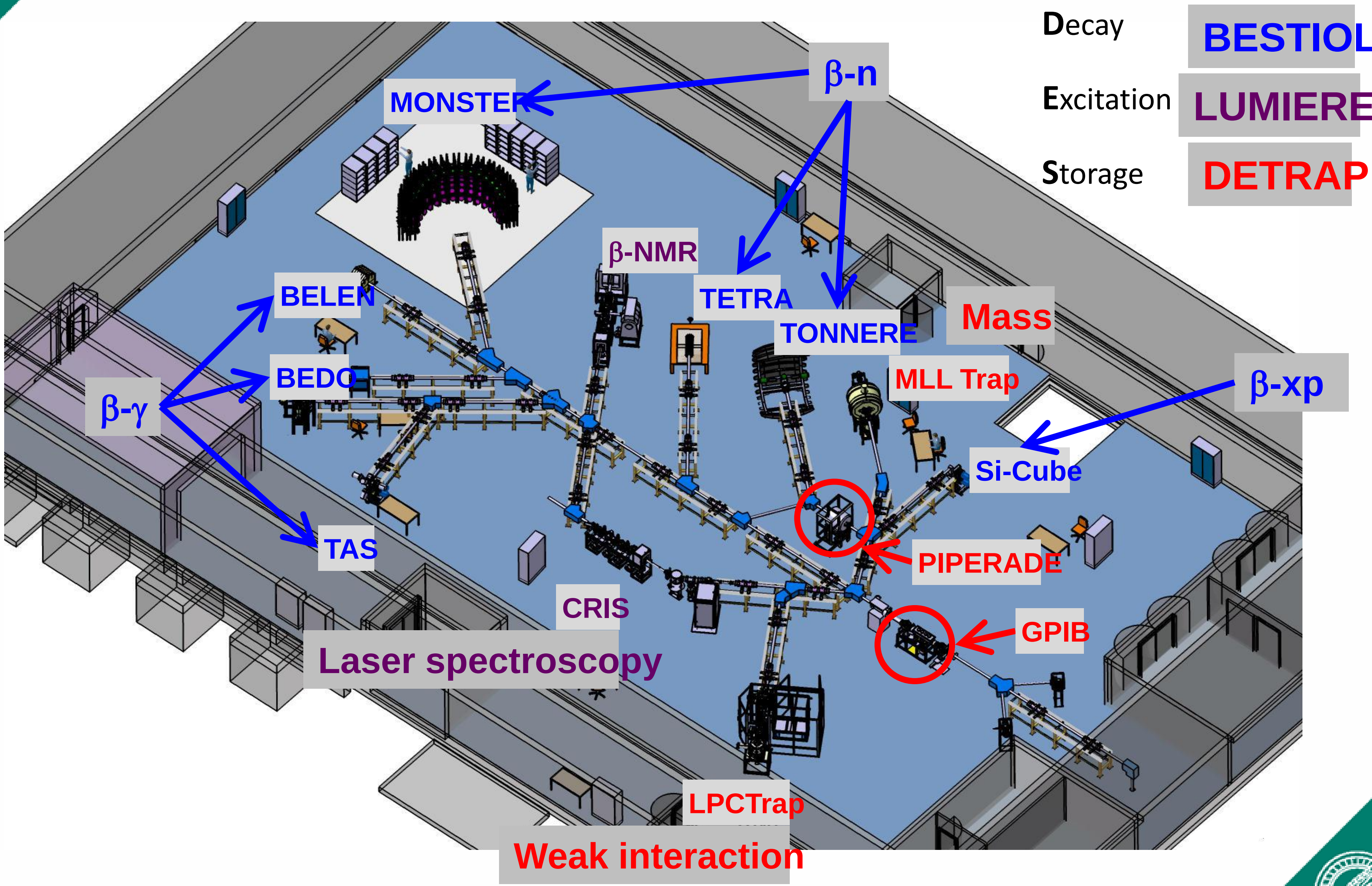
→ **Construction start in september 2015**

→ **Commissioning in december 2017**

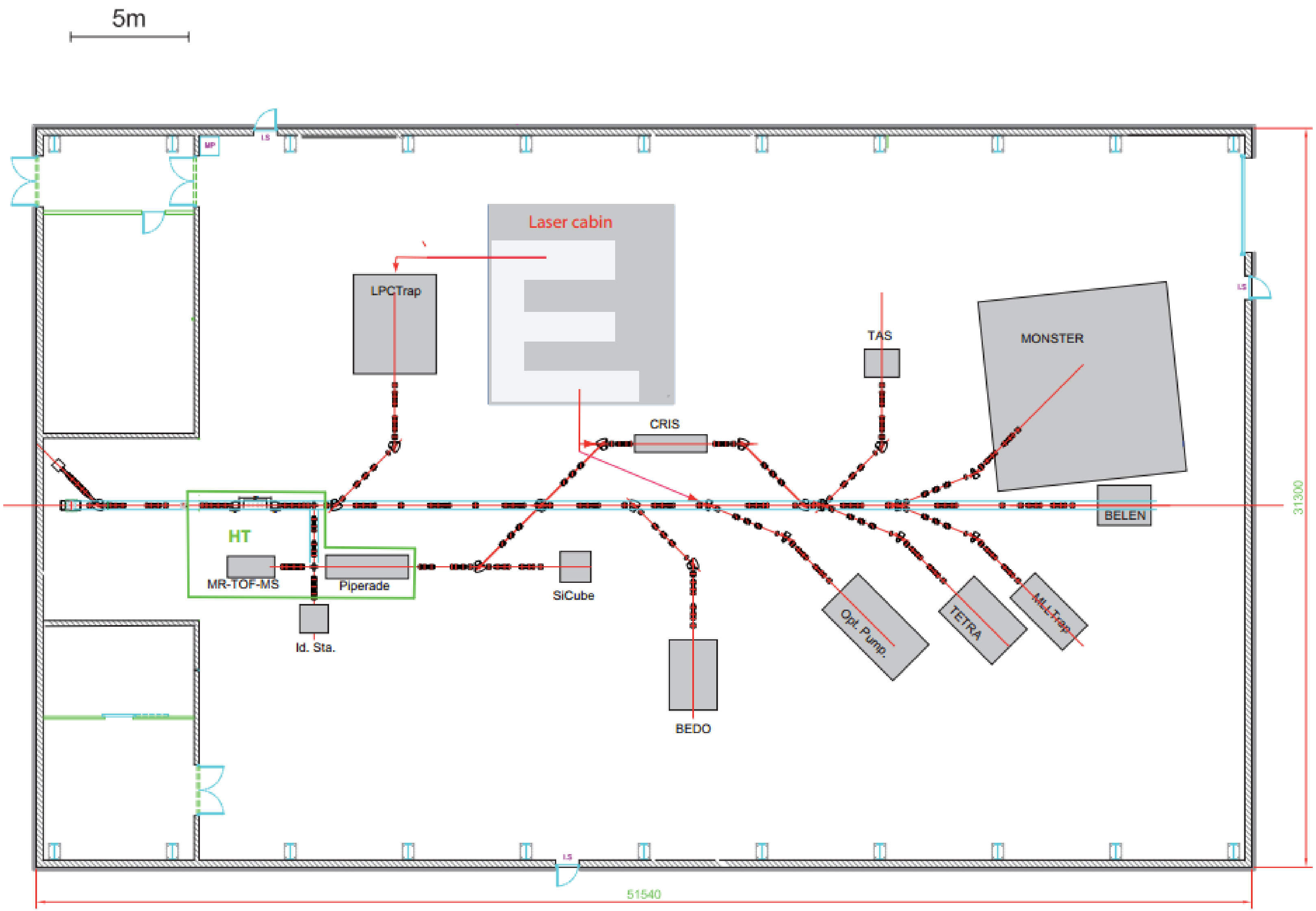
→ **New installation of SHIRAC and HRS**: end of beam transport tunnels before entering DESIR building



Experimental equipment



Experimental equipment



Examples of DESIR experiments

Trap assisted β–γ spectroscopy

High-precision measurements of $T_{1/2}$ and BR of super-allowed Fermi beta decay

→ test the CVC hypothesis and the unitarity of the CKM matrix (V_{ud} element)

(^{66}As, ^{70}Br, ^{74}Rb, ^{94}Ag, ^{98}In, ….)

TAS (Total Absorption Spectroscopy)

Reconstruction of a nucleus level scheme
Avoid the « Pandemonium » effect but need to get rid of any contaminant

→ nuclear structure, astrophysics, nuclear power

($^{80\text{-}82}$Zn, $^{98\text{-}101}$In, $^{97\text{-}99}$Cd, $^{130\text{-}132}$In, ^{130}Ag, …)

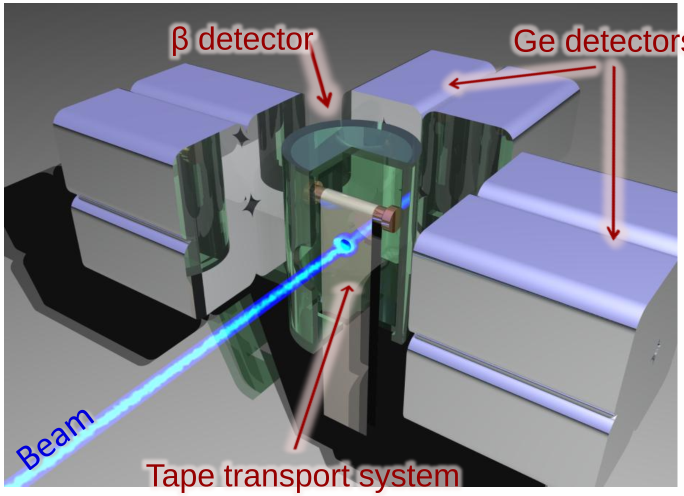
High-precision mass measurements with MLL-TRAP

→ shell closures evolution, r-process studies

(^{80}Zr, ^{100}Sn, ^{83}Zn, $^{131\text{-}133}$In, $^{129\text{-}133}$Cd, …)

→ Q values for super-allowed transitions

(^{66}As, ^{70}Br, …)



PIPERADE requirements

Goal of PIPERADE: deliver **very pure** and **large samples** of exotic nuclei to the DESIR set-ups

Requirements for the device

- **Mass resolution > 10^5** (Isobaric cleaning)
- Purify very large samples of ions **(> 10^5 ions/bunch)**
  (Large ratio contamination/ions of interest, high relative intensity also for the molecules)
- "**Fast**" cleaning process (50 – 500 ms)

➔ **Penning trap system**

PIPERADE set-up

Ion Source (FEBIAD)

calibrate the system
perform off-line measurements
deliver stable beams to DESIR

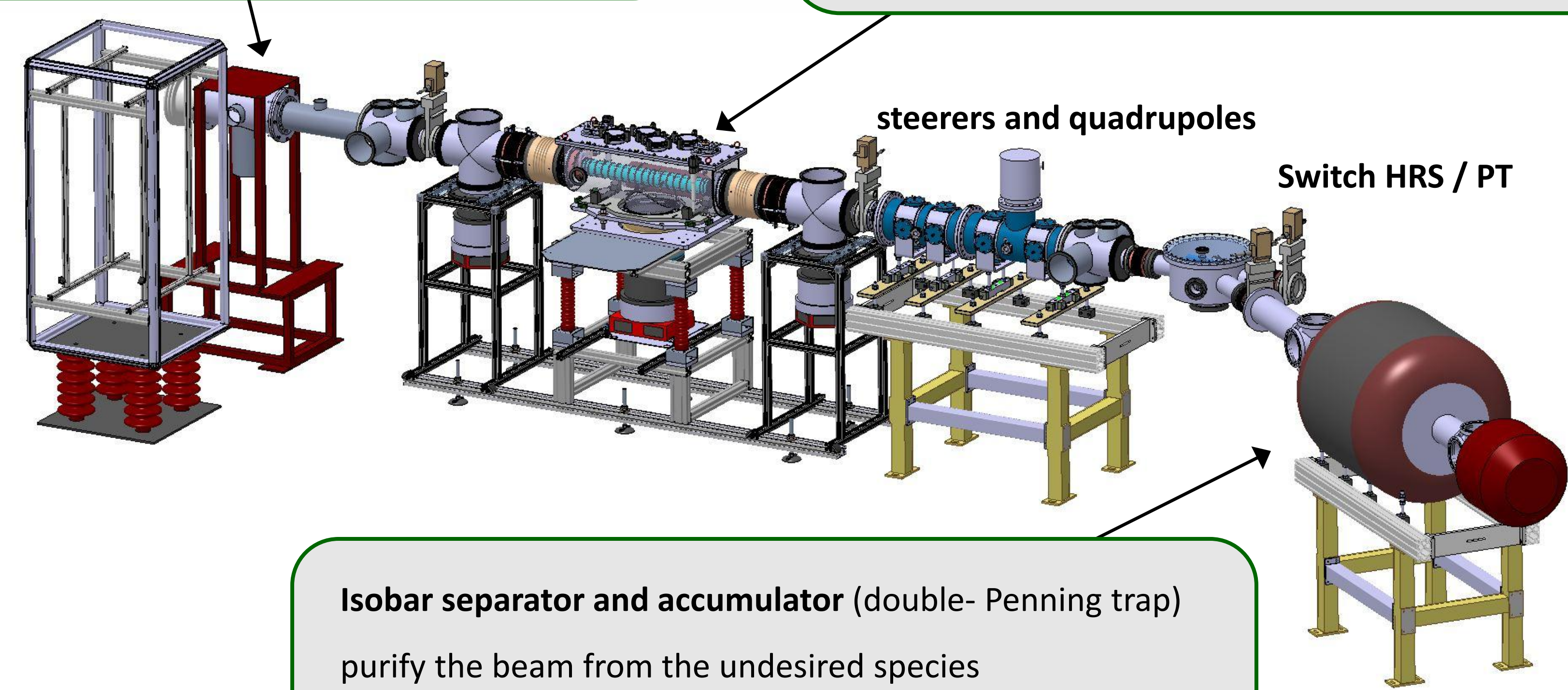
already in operation at CENBG

Radiofrequency Quadrupole (RFQ/GPIB)

cool and bunch the beam

under construction at CENBG

tests in 2014 -2015



Isobar separator and accumulator (double- Penning trap)

purify the beam from the undesired species
accumulate the ions of interest

design under study at MPIK

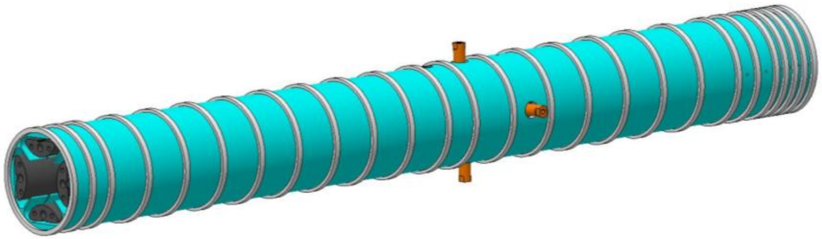
GPIB (General Purpose Ion Buncher)

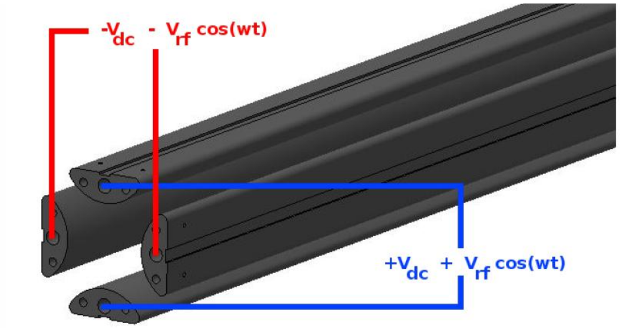
Aim: cool and bunch the beam

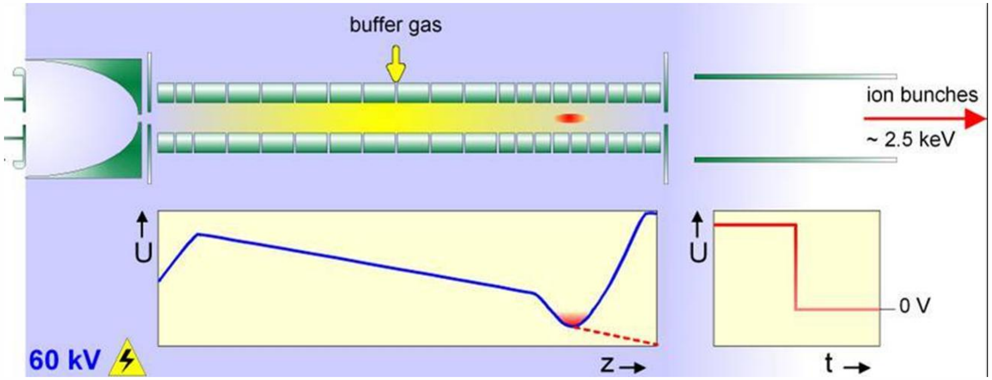
- for injection into Penning trap
- DESIR experiments might need bunched beam (e.g. collinear laser spectroscopy, LPCTrap)
- will be placed in the central beam line

Status:

- construction of the mechanical part done (ISCOOL mechanical design)
- RF circuit under study
- first exp. tests in the next months







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Status and timeline of the project

Ion Source (FEBIAD)

calibrate the system
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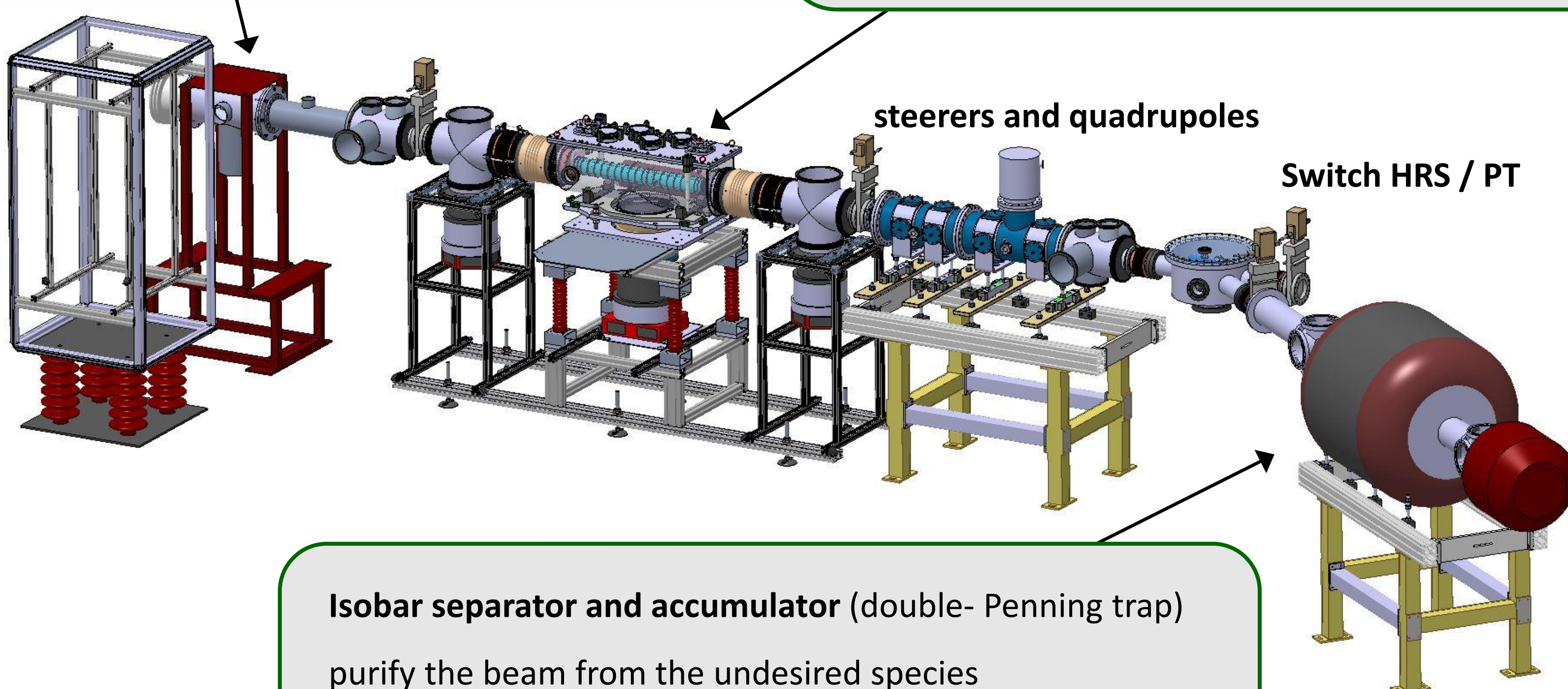

Isobar separator and accumulator (double- Penning trap)

purify the beam from the undesired species
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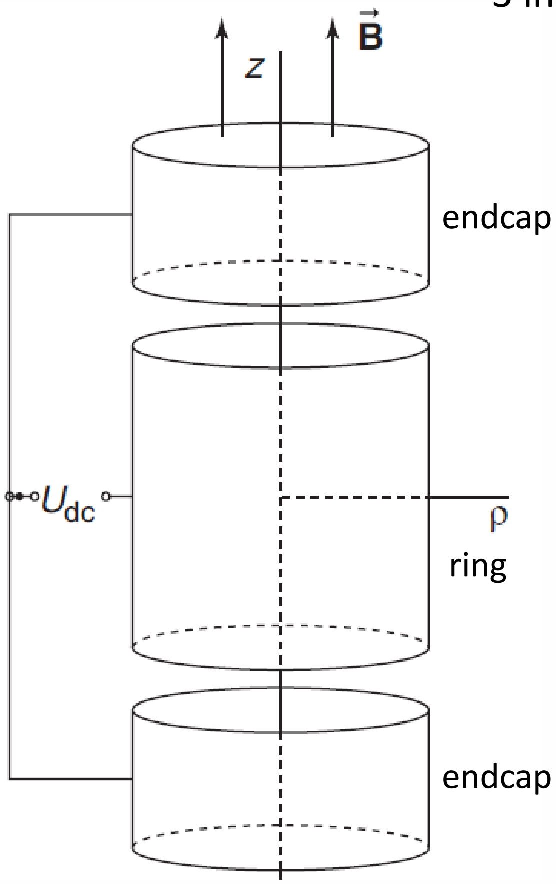
design under study at MPIK

Penning trap

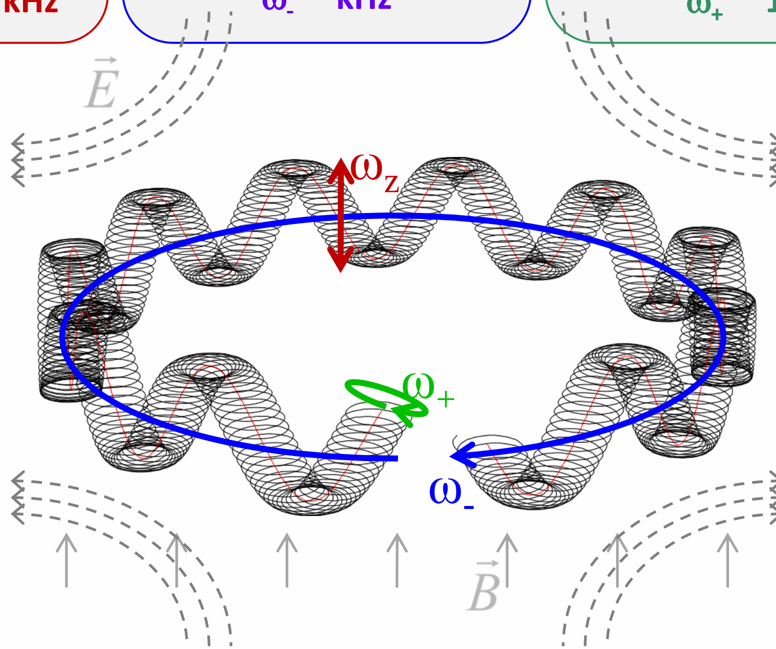
Trapping (i.e. confinement in all 3 dimensions) obtained by:

- electrostatic quadrupolar field (axial confinement) $\Phi(z,r) = \frac{U_{\mathrm{dc}}}{2d^2}\left(z^2 - \frac{1}{2}r^2\right)$
- homogeneous magnetic field (radial confinement)

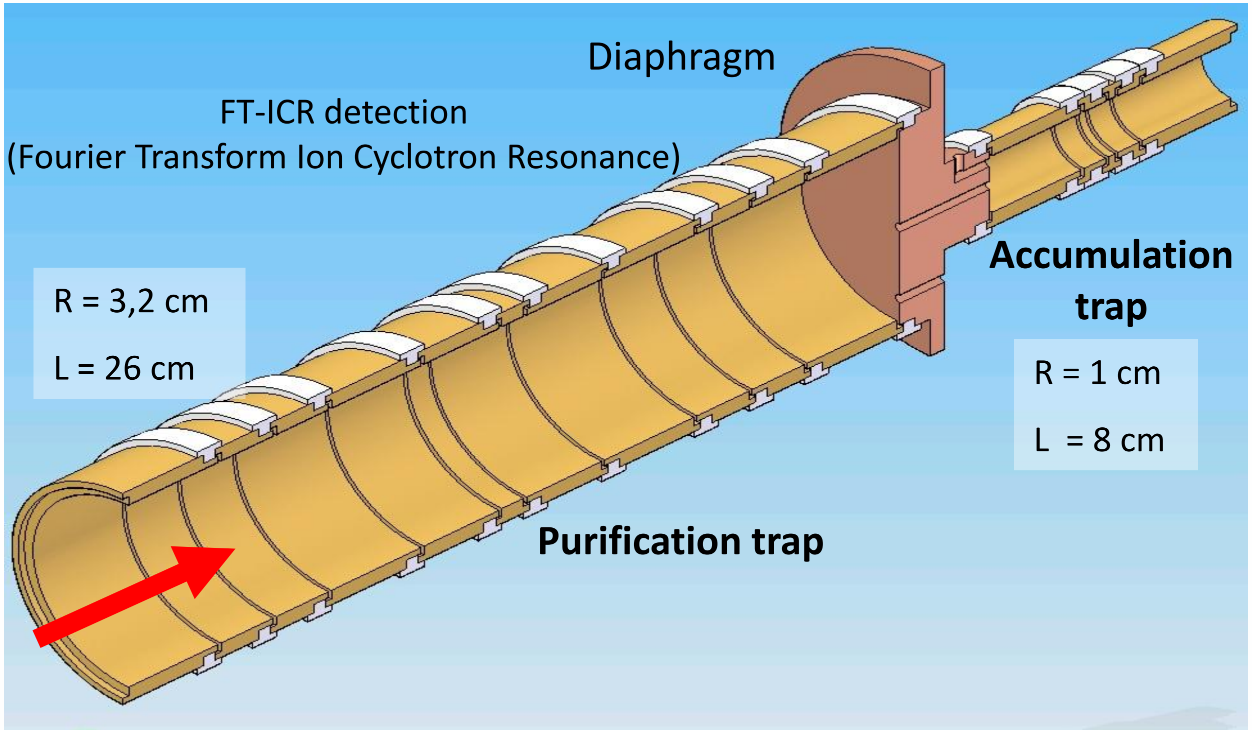


3 independent motions at 3 eigenfrequencies

axial motion	magnetron motion	modified cyclotron motion
$\omega_z = \sqrt{\frac{qU_{\mathrm{dc}}}{md^2}}$	$\omega_- = \frac{\omega_c}{2} - \sqrt{\frac{\omega_c^2}{4} - \frac{\omega_z^2}{2}}$	$\omega_+ = \frac{\omega_c}{2} + \sqrt{\frac{\omega_c^2}{4} - \frac{\omega_z^2}{2}}$
ω_z ~ 100 kHz	**ω_- ~ kHz**	**ω_+ ~ 10MHz**

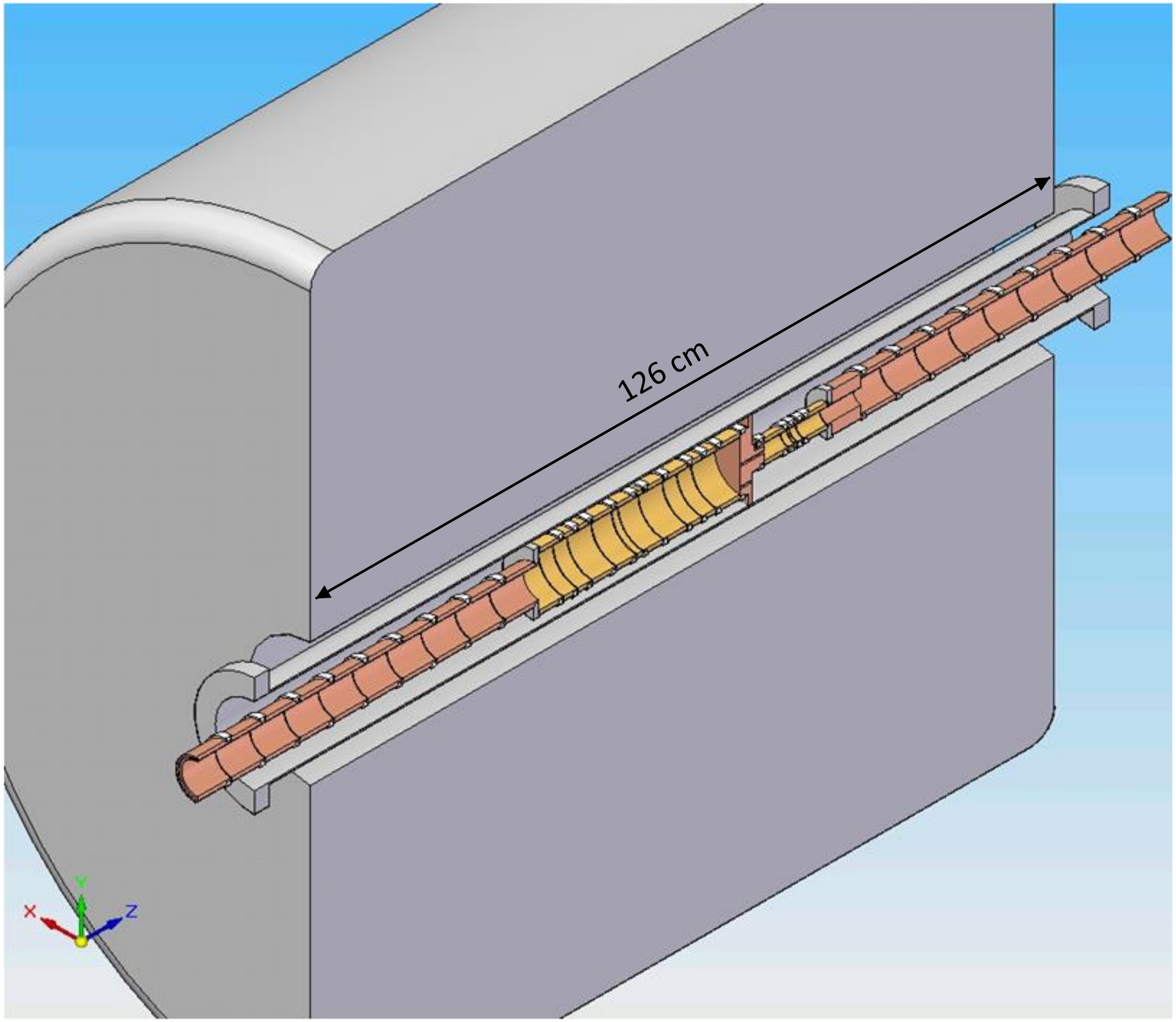


The double Penning trap



- Many cycles (purification + storage) + final cleaning (decay products) before sending large samples to experiments
- A diaphragm will be placed between the two traps to act as a pumping barrier and to eject selectively the ions of interest which are centered

The double Penning trap



Isobar separation in a Penning trap

Sideband buffer gas cooling:

- Dipolar excitation at the magnetron frequency $\omega_- \approx \frac{U_{\mathrm{dc}}}{2d^2 B}$

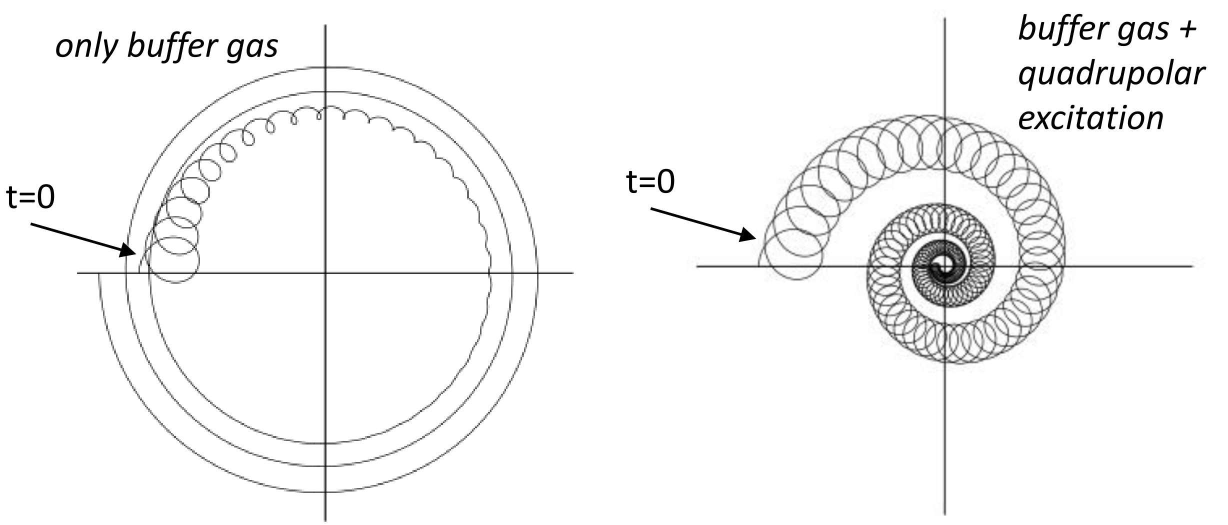
(in first order mass independent, all the ions are brought to a higher radius)

- Combining the effect of buffer gas and the use of a quadrupolar excitation at ($\omega_+ + \omega_-$)

  - quadrupolar excitation: coupling the two radial modes
  - buffer gas: cyclotron motion is cooled, magnetron motion increases

-> radii of both motions are cooled

-> mass-selective centering



G. Savard et al, Phy.Lett. A 158, 247-252 (1991)

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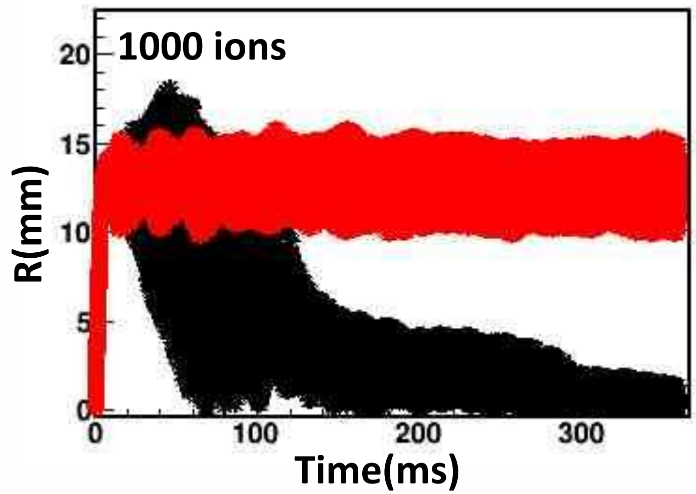
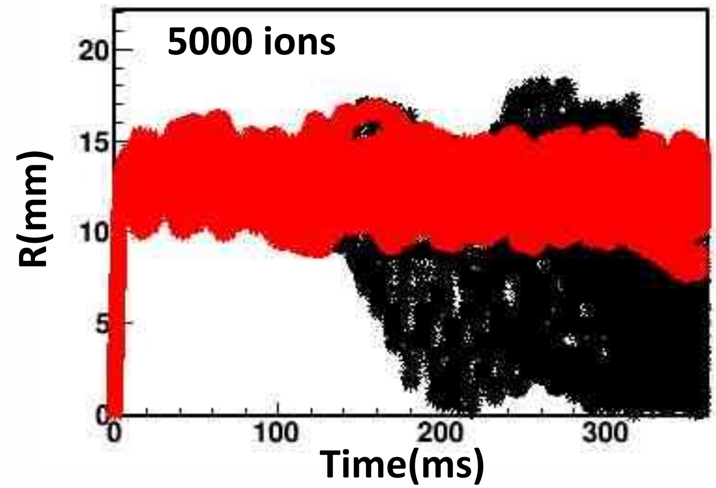
Space charge effects

SIMBUCA code, *S. Van Gorp et al., NIM A 638, 192200 (2011)*

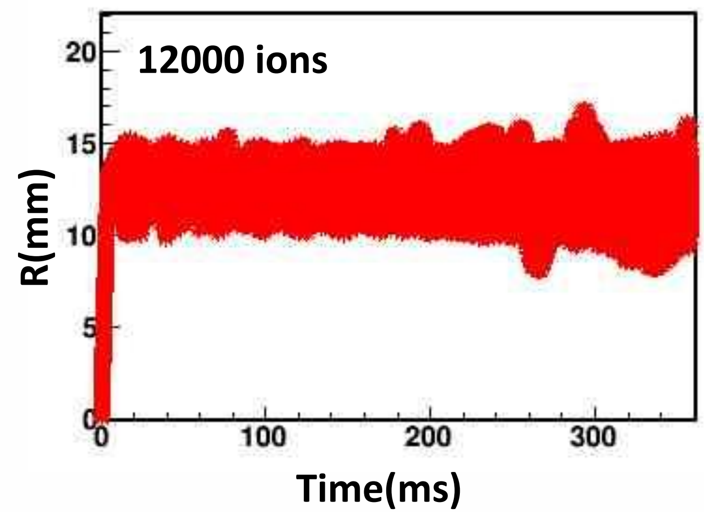
90% ^{136}Te, 10% ^{136}Sb **P = 10^{-4} mbar**





Increasing the number of ions

makes the re-centering inefficient



Additional potential created by the cloud itself

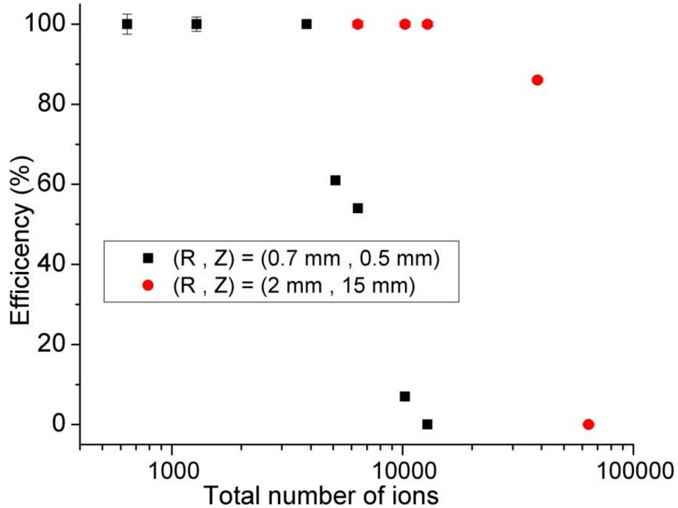
→ f-shifts

→ peak broadening

→ screening effects

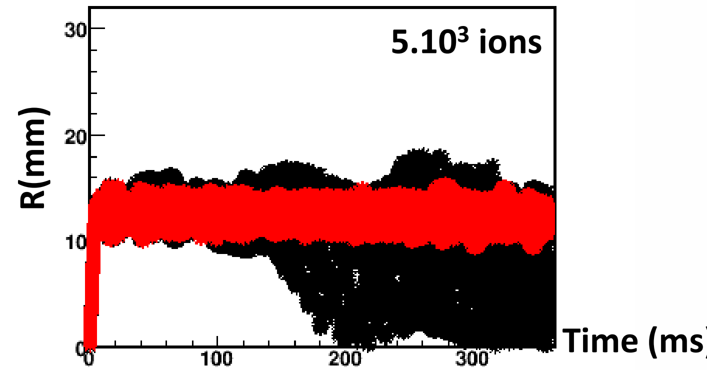
Space charge effects

10% ^{136}Sb / 90%^{136}Te B = 7 T

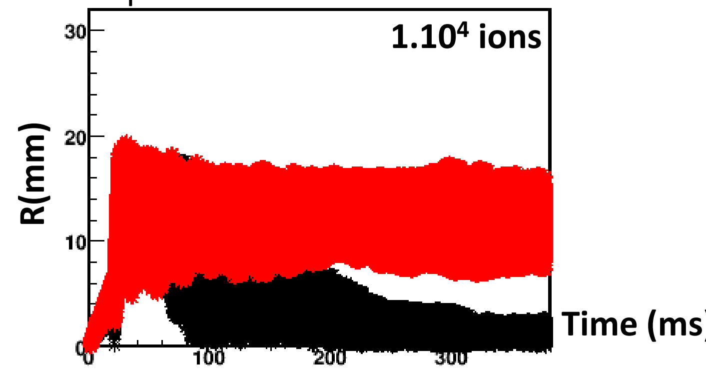


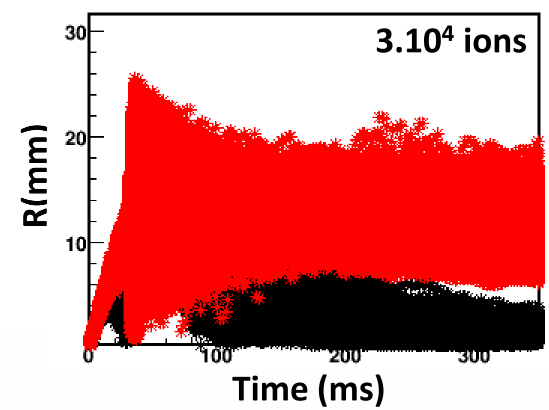
Antisymetric Rotating Wall technique, SWIFT, …

under study at CSNSM Orsay



With a pre-excitation at ν+ of contaminant





Other techniques:

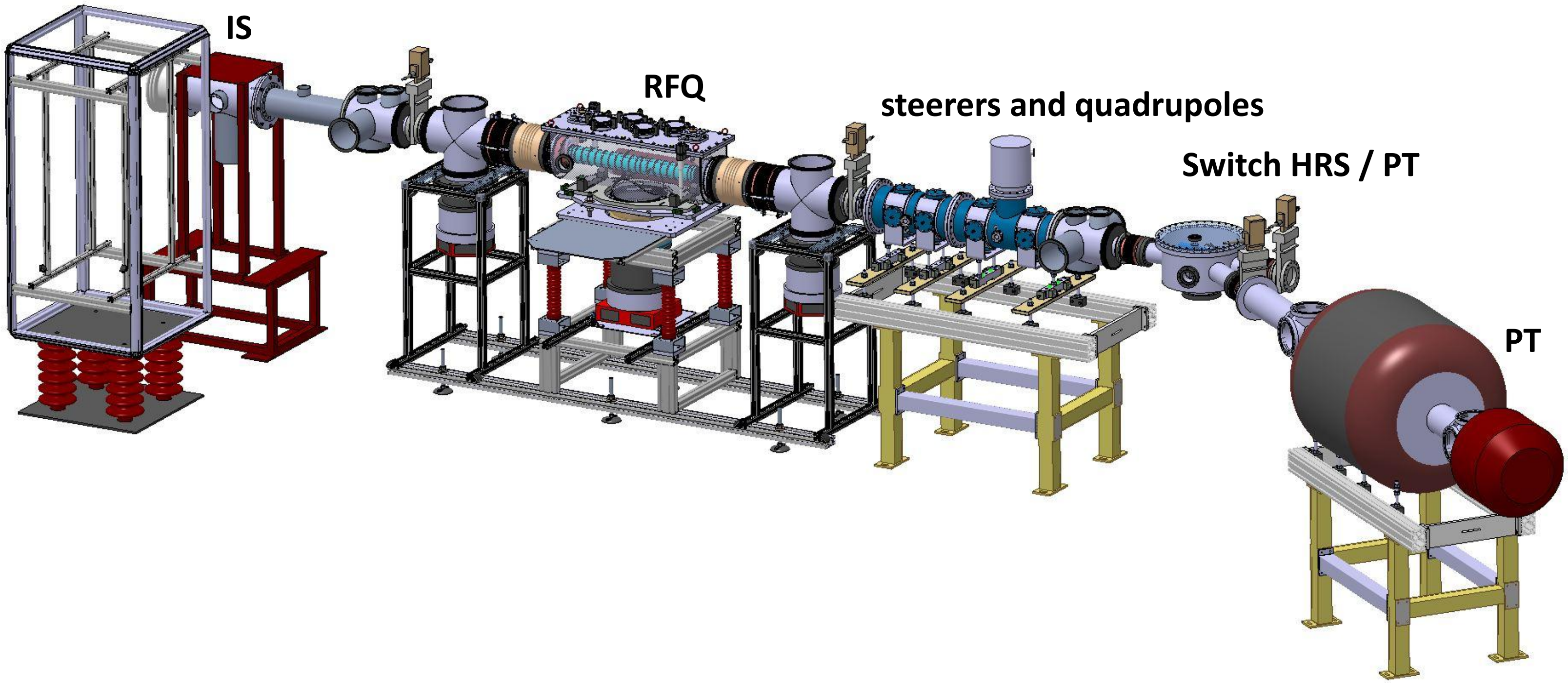
Axial coupling, SWIFT technique, SIMCO Excitation,…

Experimental tests of the methods and investigation of the dependence on the number of ions

Development of an electrospray ionization (ESI) ion source to test it with isobars **(DESIR offline source)**

Timeline of the project

• Tests of the RFQ built in Bordeaux	2014 – mid 2015
• Separation methods tests at MPIK	2014
• Construction and test of the PT at MPIK	2014 - mid 2015
• Test the complete PIPERADE system in Bordeaux	mid 2015 - 2016
• Installation at DESIR	2017-2018



PIPERADE collaboration

G. Ban, B. Blank, K. Blaum, J.- F. Cam, P. Delahaye, F. Delalee, P. Dupré, S. El Abbeir, M. Gerbaux, S. Grévy, G. Grinyer, H. Guérin, E. Liénard, D. Lunney, S. Naimi, L. Perrot, A. de Roubin, L. Serani, B. Thomas and J.-C. Thomas

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DESIR / S3-LEB Meeting @ GANIL, 24th-26th March 2014

abstract submission deadline: 6th March

http://pro.ganil-spira2.eu/events/workshops/desir-s3-nfs

yields of S3 and SPIRAL beams on the web page

Agence Nationale de la Recherche ANR

Thank you for your attention!

Alexander von Humboldt Stiftung/Foundation

PIPERADE

Pieges de Penning pour les Radioisotopes à DESIR

Spiral2 DESIR