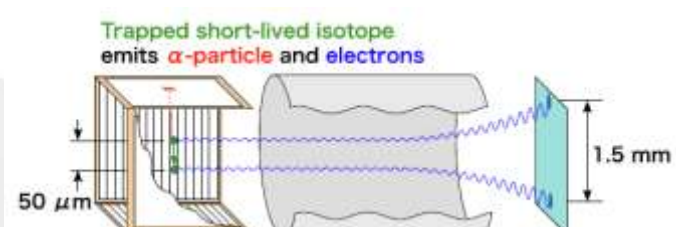
MLLTRAP : measurements at ALTO and in-trap spectroscopy studies



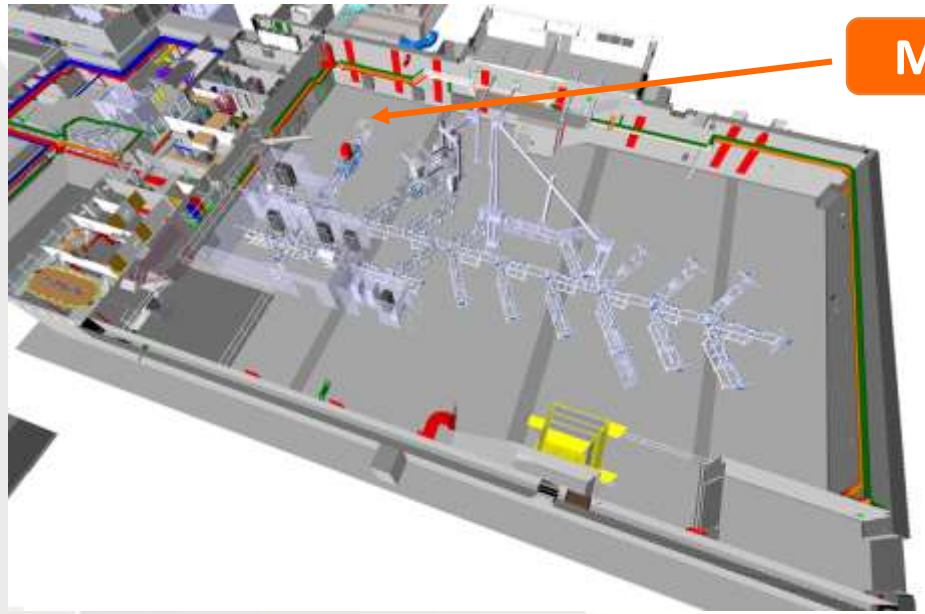
MLLTRAP Project in France

MLLTRAP → Spiral2 DESIR

Framework : "adaptation of experimental devices for their use with DESIR"

MLL LMU

GANIL Spiral2 laboratoire commun CEA/DRF CNRS/IN2P3



MLLTRAP Project in France

MLLTRAP → Spiral2 DESIR

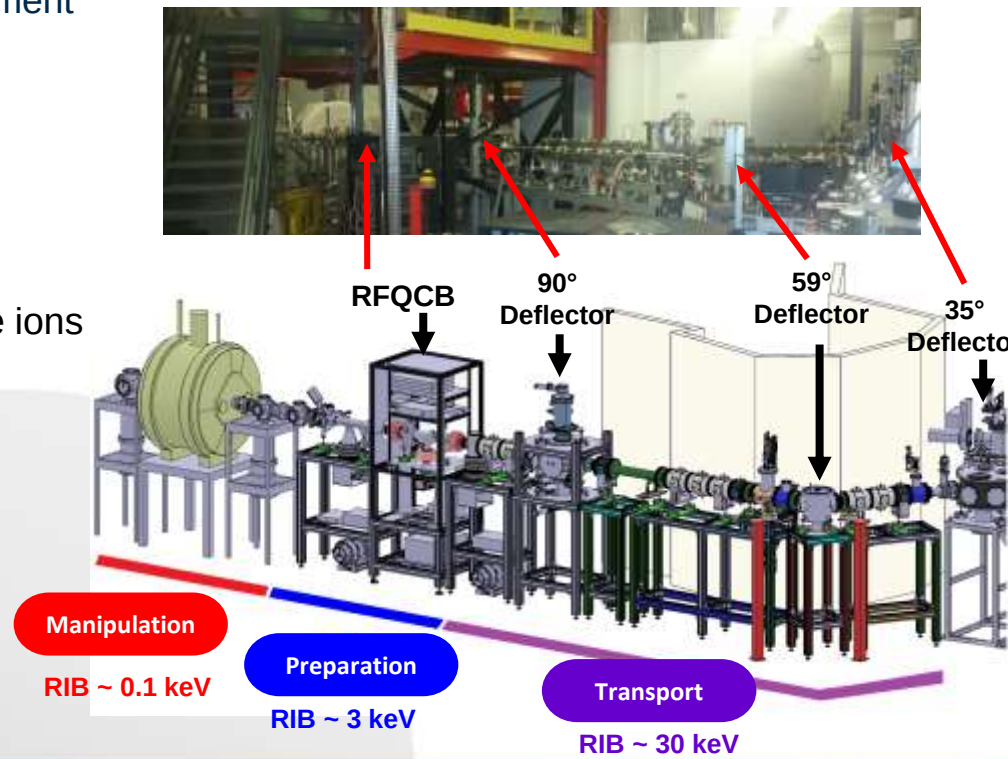
Framework : "adaptation of experimental devices for their use with DESIR"

2016 - 2026 : Commissioning and upgrade of MLLTRAP + mass measurement campaign @ ALTO

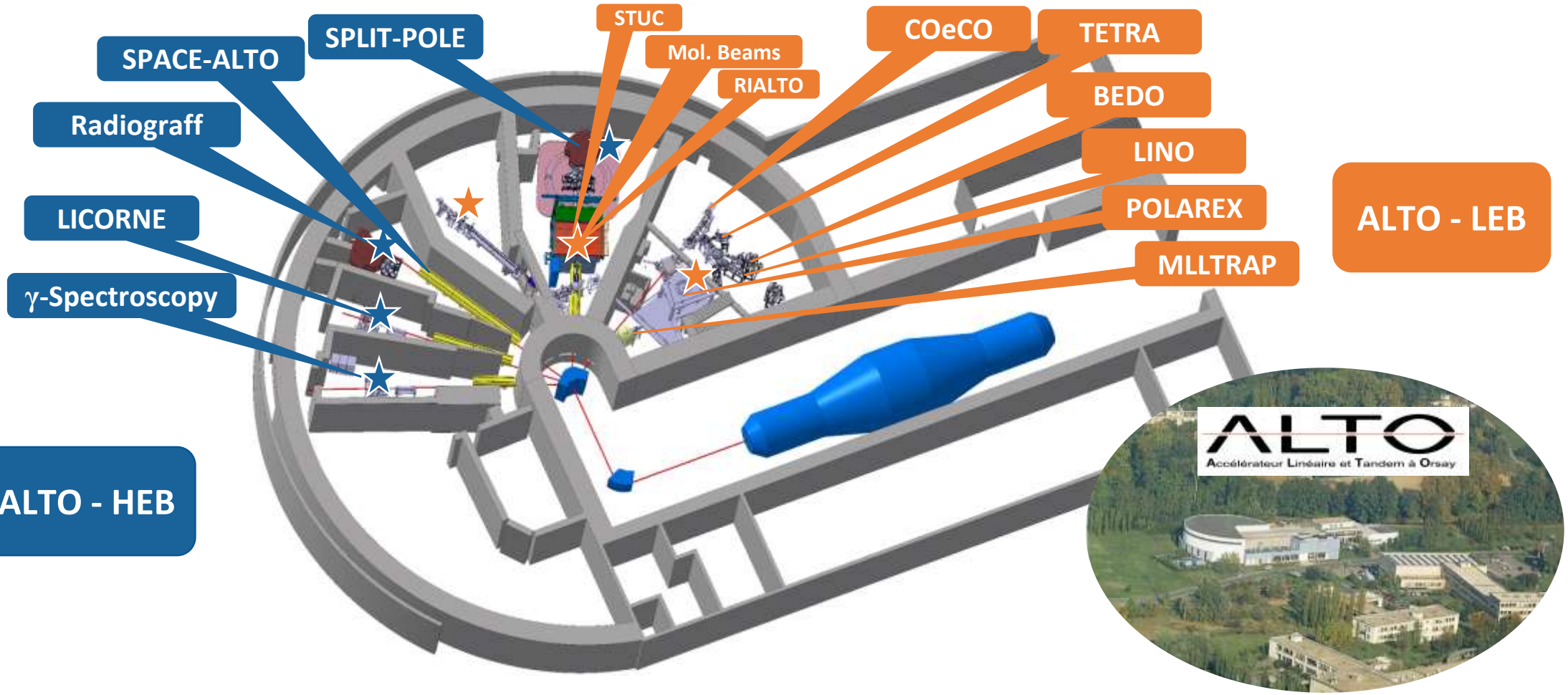
→ ***DETRAP workshop 16/06/2020***

The goal of the MLLTRAP @ ALTO is to :

- Characterize the preparation and manipulation sections with radioactive ions
- Test the resolving power of Penning traps with low production rates
- Continue the In-trap project R&D



Research instrumentation and R&D supported by ALTO

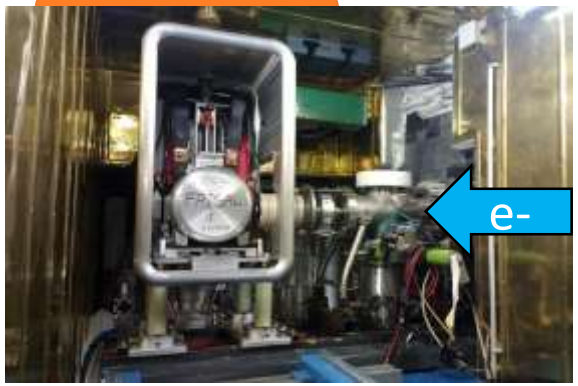


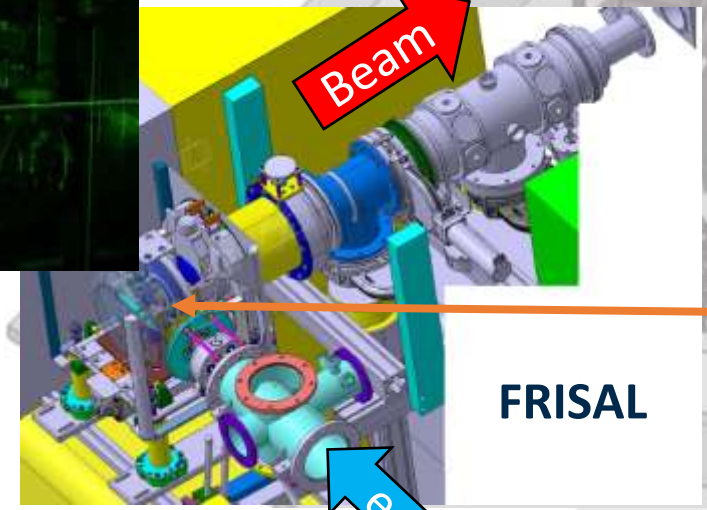
General presentation of ALTO-LEB

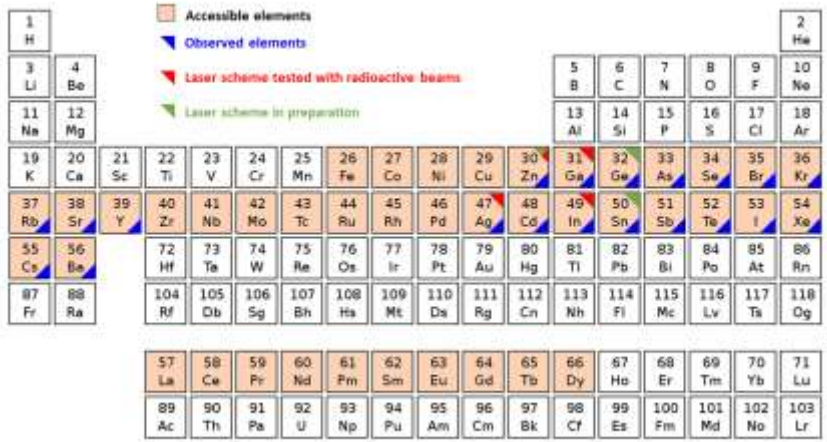
ALTO - LEB

RIALTO

ALTO-LEB : production







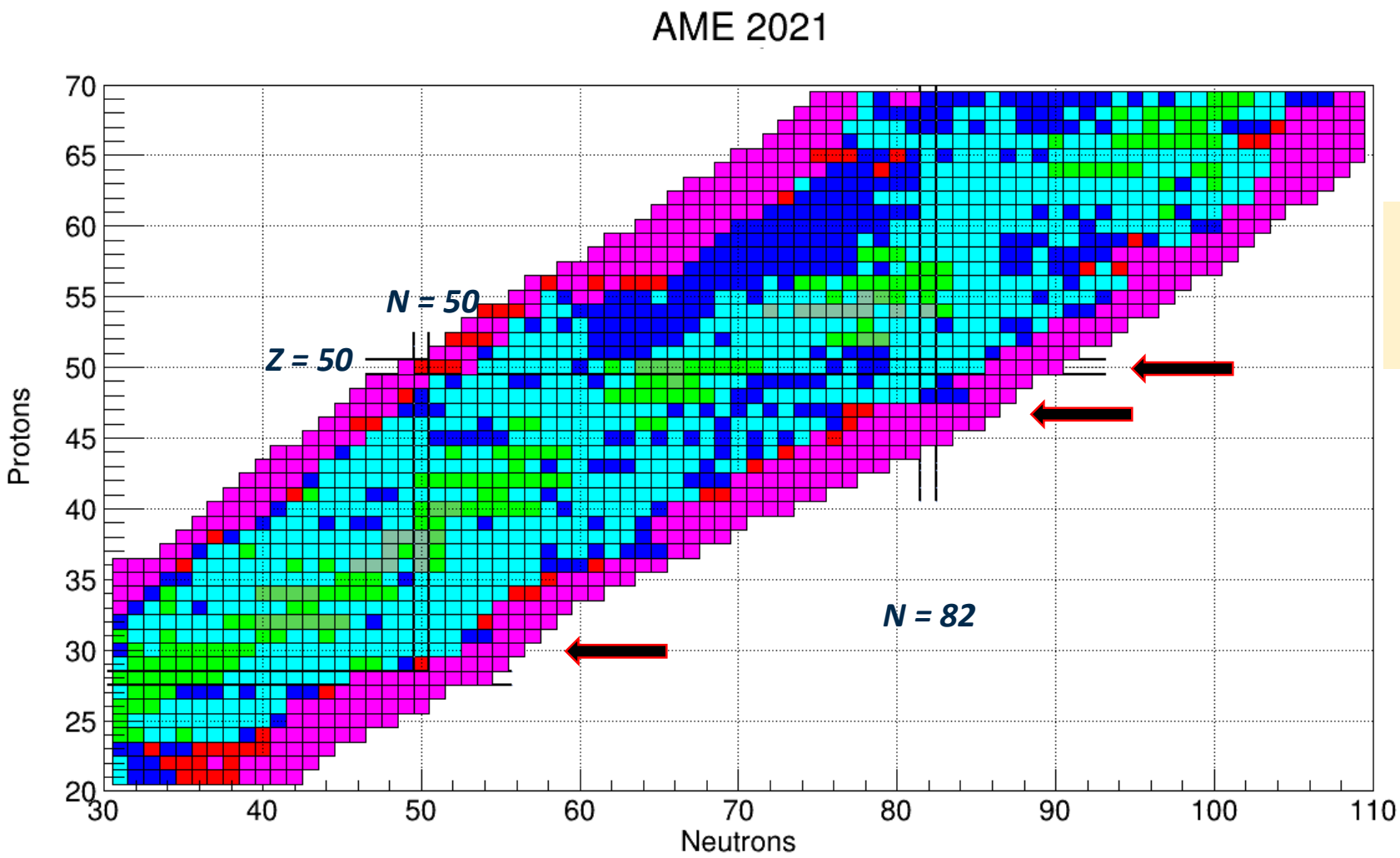
https://alto.ijclab.in2p3.fr/en/facility/alto-leb/production/

FRISAL

Target-ion source vault

Mass separator (magnet dipole)

Mass precision



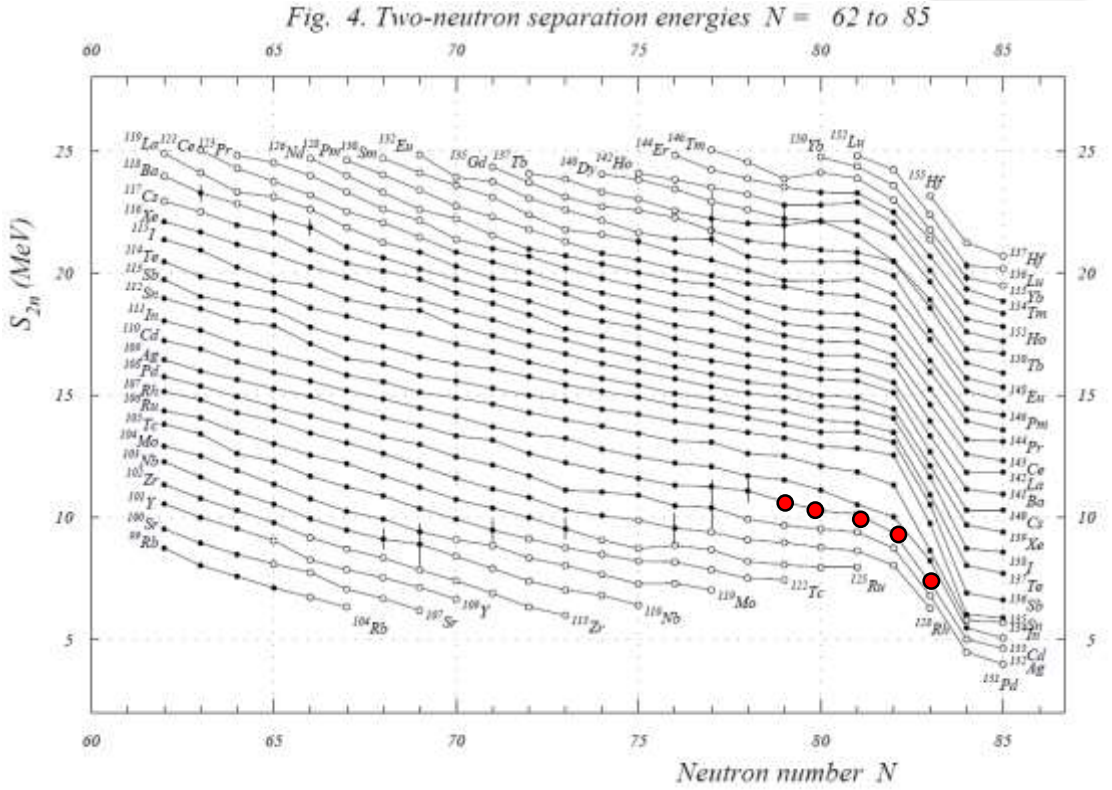
Sn(Z=50, N=86-89)
Ag(Z=47, N=78 - 84)
Zn(Z=30, N=54-55)
Ni(Z=28, N=49)

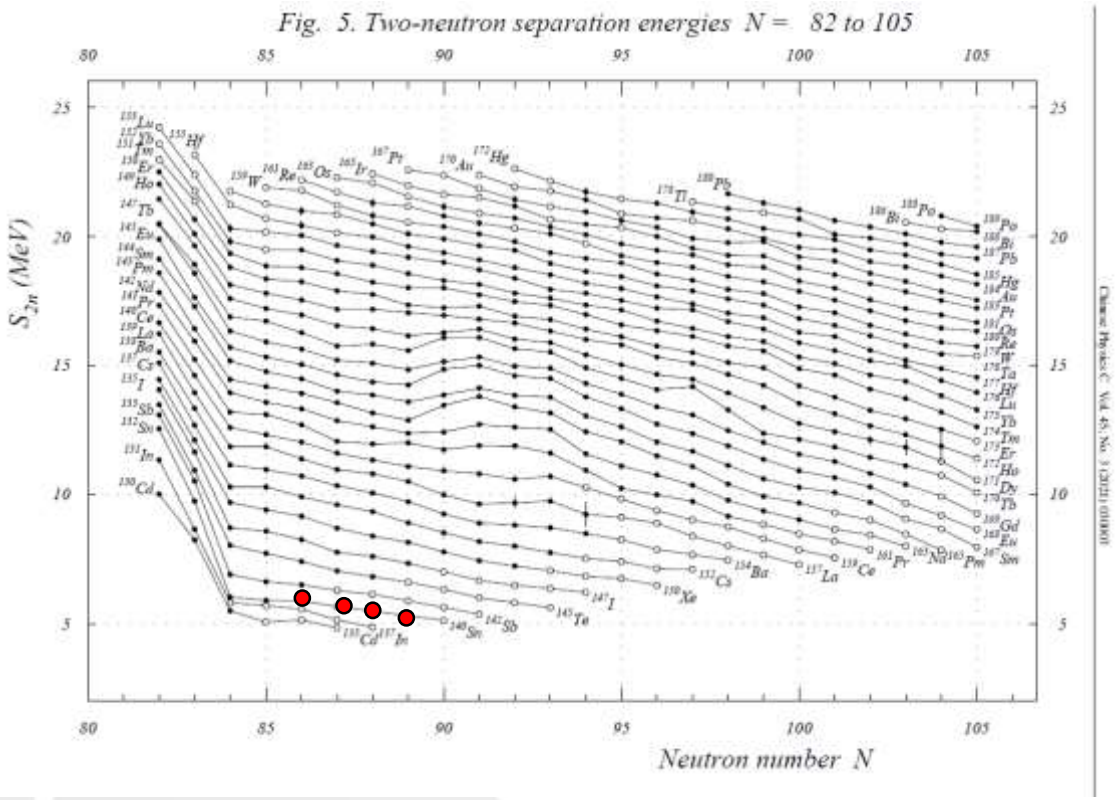
MASS EXCESS

Error keV

- $[10^{-5};10^{-4}]$
- $[10^{-4};10^{-3}]$
- $[10^{-3};10^{-2}]$
- $[10^{-2};10^{-1}]$
- $[10^{-1};1]$
- $[1;10]$
- $[10;10^{2}]$
- $[10^{2};10^{3}]$
- **Extrapolated**

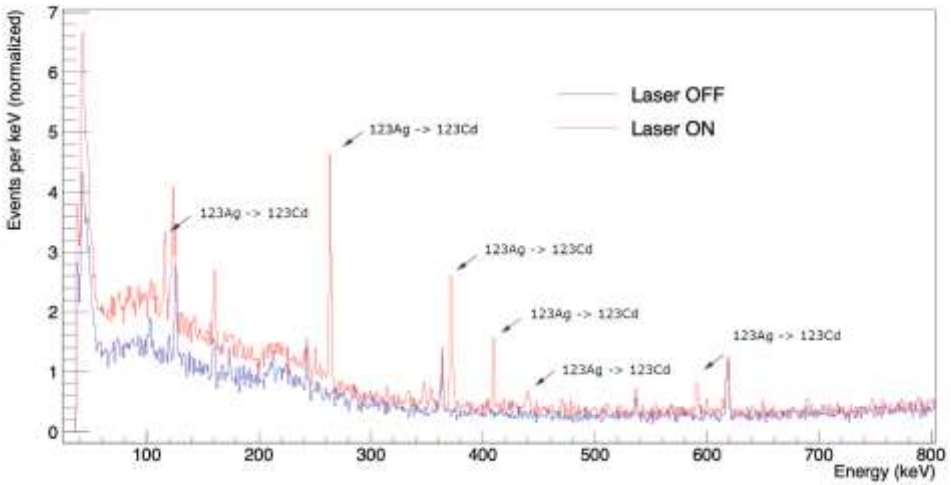
ALTO-LEB : production





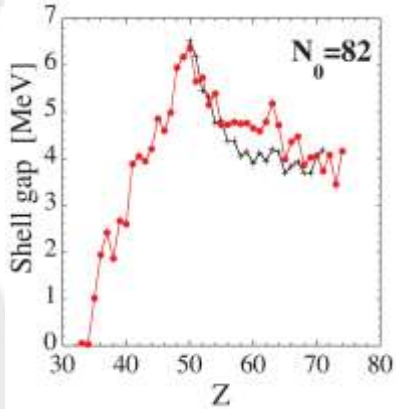
ALTO-LEB : production

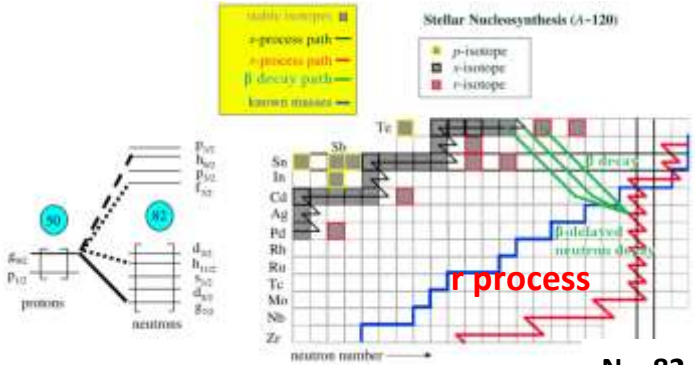
^{123}Ag decay spectrum with and without laser (November 2023)



https://alto.ijclab.in2p3.fr/en/laser-produced-ag-beams-at-alto/

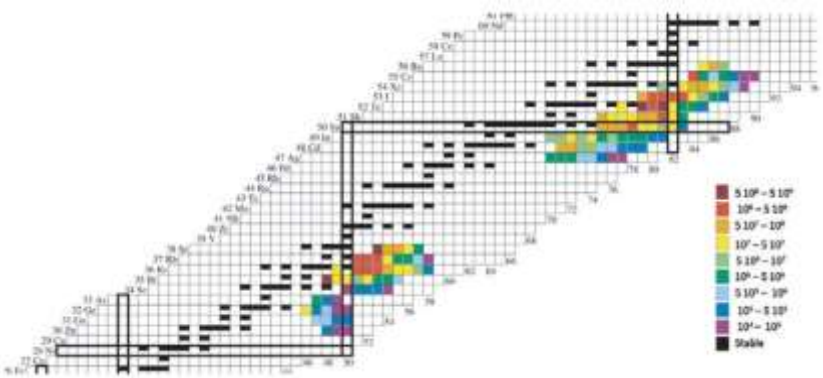
High-precision mass measurement of silver isotopes (A=113 – 129) towards the N=82 shell closure





E. Minaya Ramirez et al., Nucl. Instr. Meth. B 463 (2020) 315

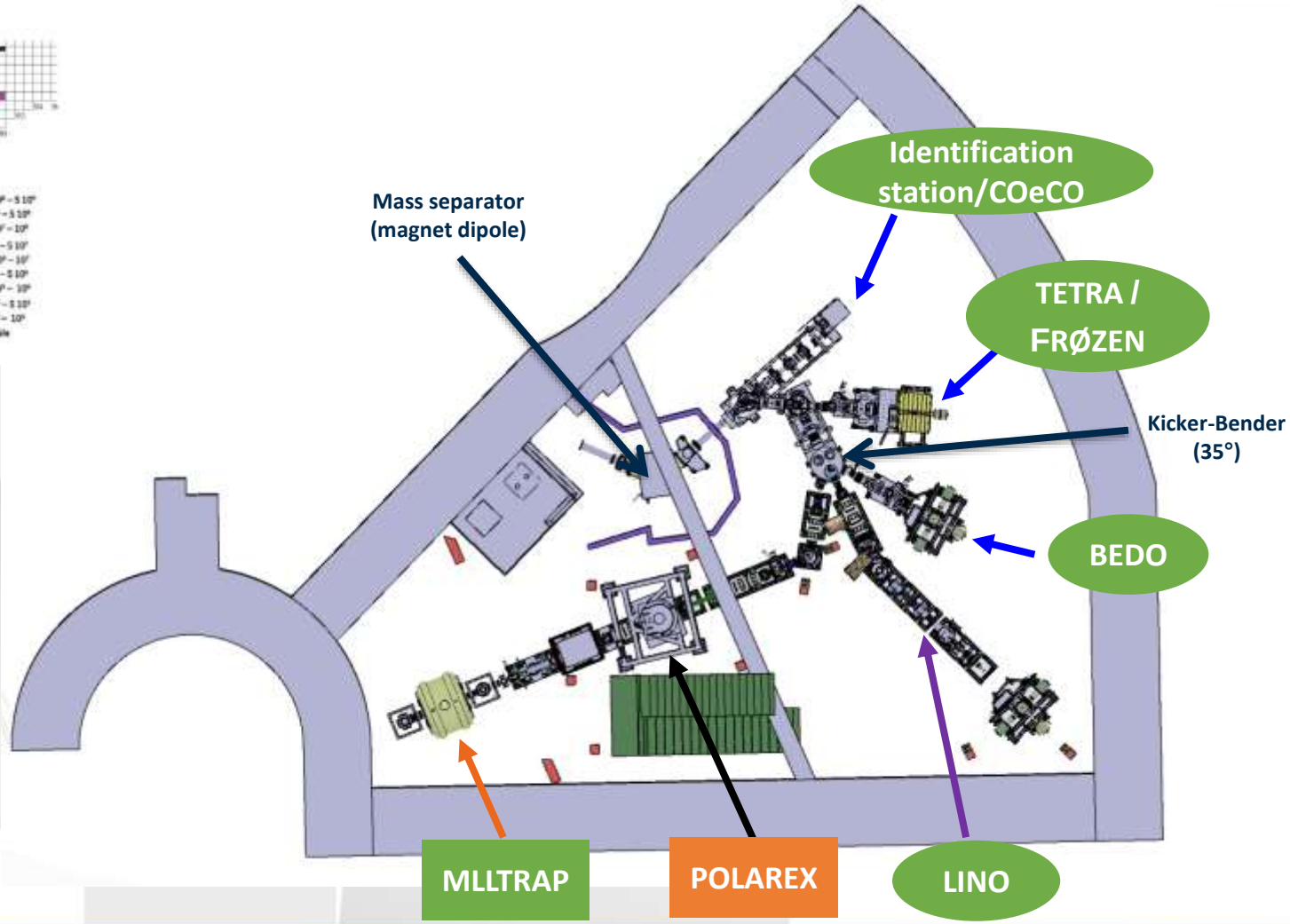
ALTO-LEB : observation



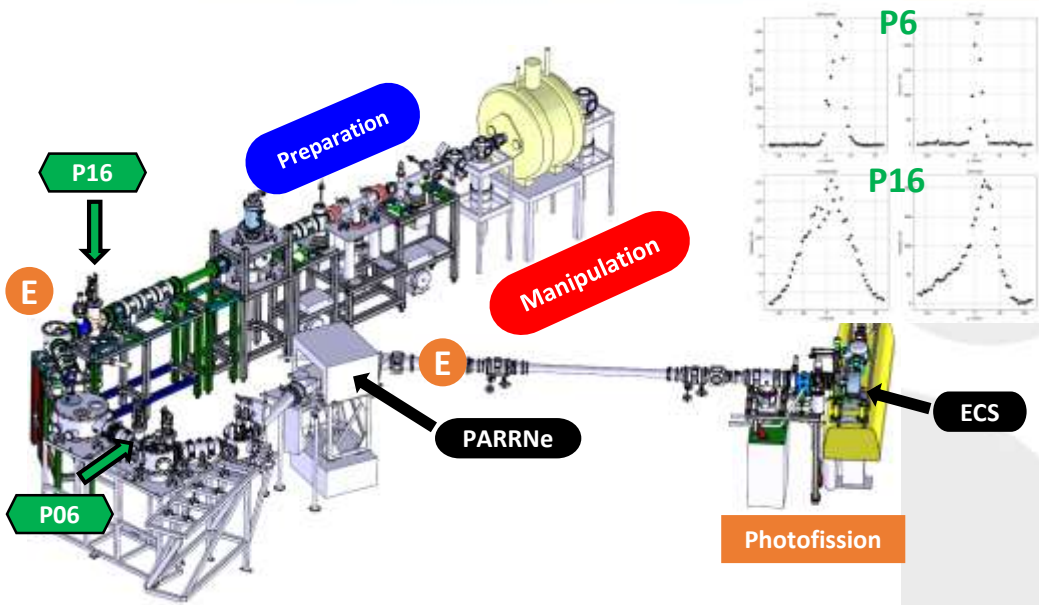
Nuclear structure studies of niche cases
→ currently 6 experiments at ALTO-LEB

They allow measuring nuclear fundamental properties of ground and long-lived isomeric states.

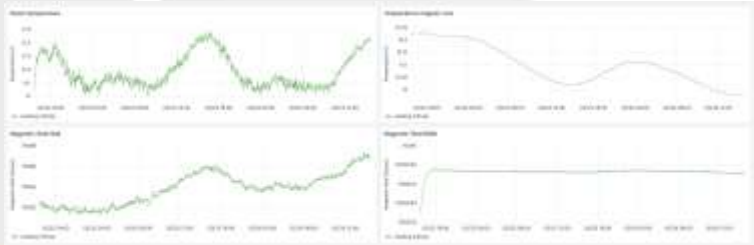
Access to fundamental observables
[I, μ, Qs, δ<r^2>, B(N,Z), β decay spectroscopy]
to test state-of-the art nuclear theories



MLLTRAP : High-precision mass spectrometer



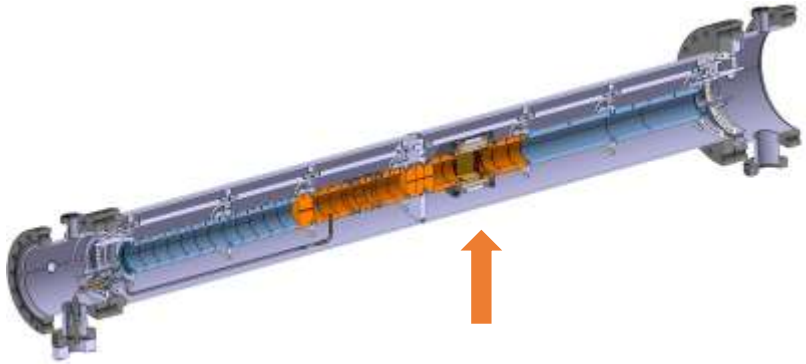
Emittancemeter



F. Osswald,
Int. Beam. Instrum. Conf (2019) tupp007 293

- Transport section under commissioning
- Preparation section connected to the transport section
- Penning traps installed under vacuum
- High voltage source under characterization
- CS++ with PI-ICR included
- Upgrades of some electronics

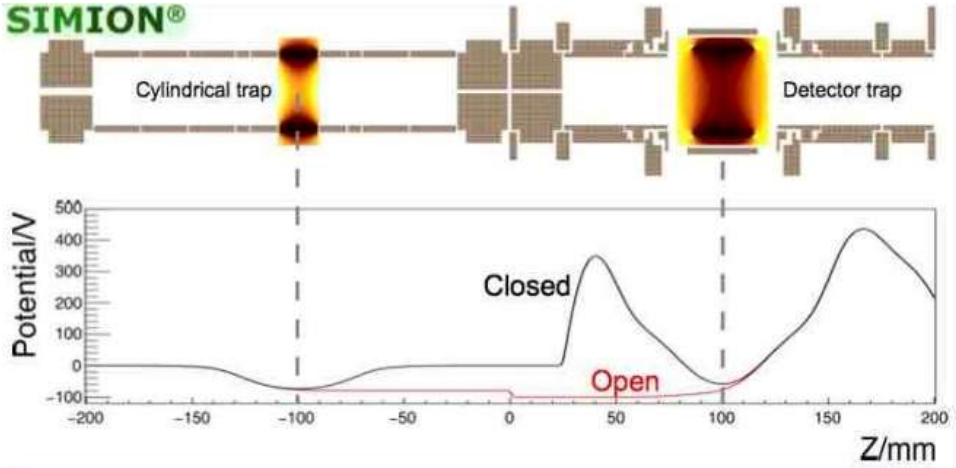
MLLTRAP – R&D for Beam manipulation

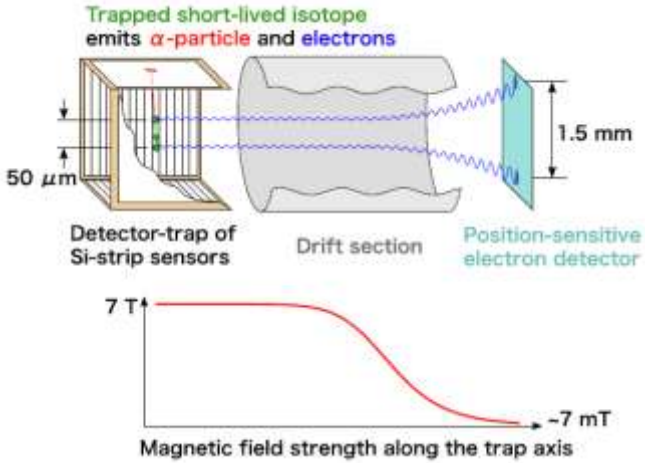


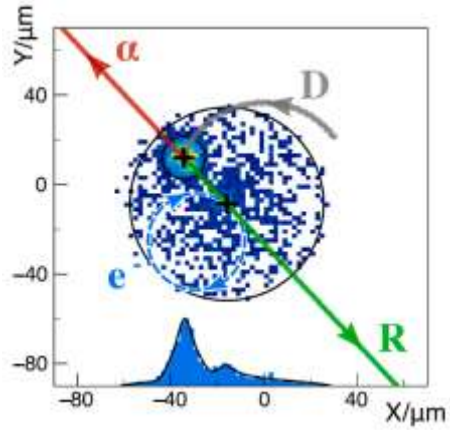
In-trap decay spectroscopy for MLLTRAP

- Decay experiments with carrier-free particles stored in a Penning trap enable studies on ideal ion samples.
- The improved energy resolution can be exploited for high-resolution α- and electron-decay spectroscopy.

DARING (Decay And Recoil imagING) technique to measure lifetimes of first excited nuclear states populated by α decay.

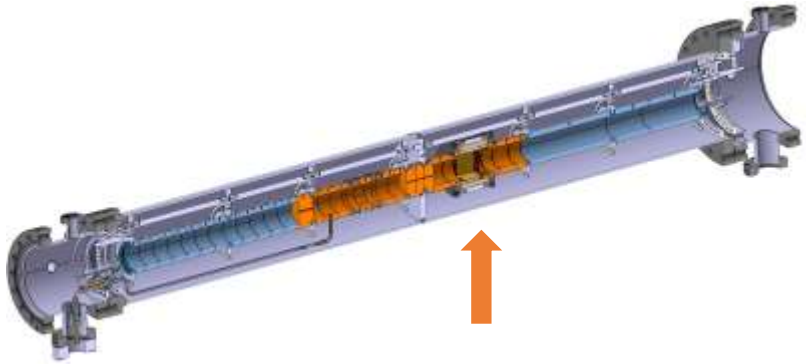






P. Chauveau et al., NIMB 982 (2020) 164508
P. Chauveau et al., NIMB 463 (2020) 371

MLLTRAP – R&D for Beam manipulation



In-trap decay spectroscopy for MLLTRAP

- Penning trap as high-resolution mass separator to prepare state-selected pure sample

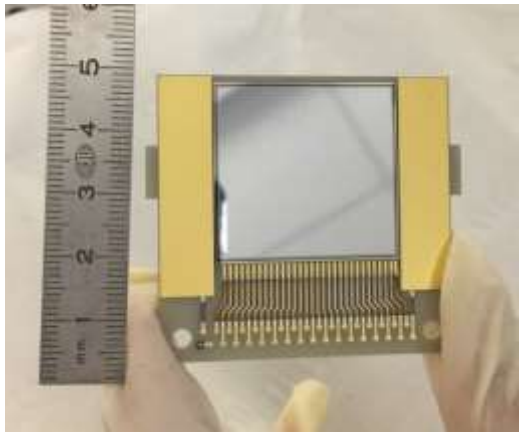
→ clean spectra

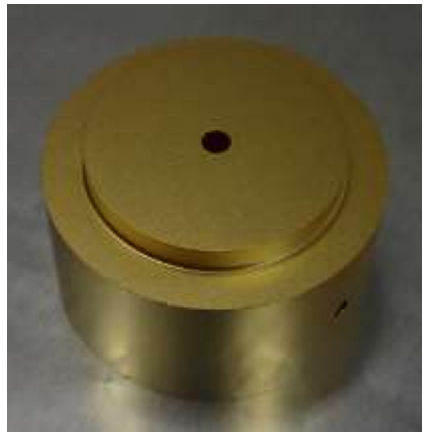
→ detailed nuclear structure information in one experiment

→ Design fixed, all mechanical parts and insulators received in 2020.

→ Gold plating of all the electrodes performed in October 2022.

→ The next step is to finalize the mechanical assembly in 2024.





Precision mass measurements of nuclei in the superheavy region at SPIRAL2

Day 1 SPIRAL2 Phase 2
(RIB in DESIR & GANIL Experimental Area)

Version 10/12/2010

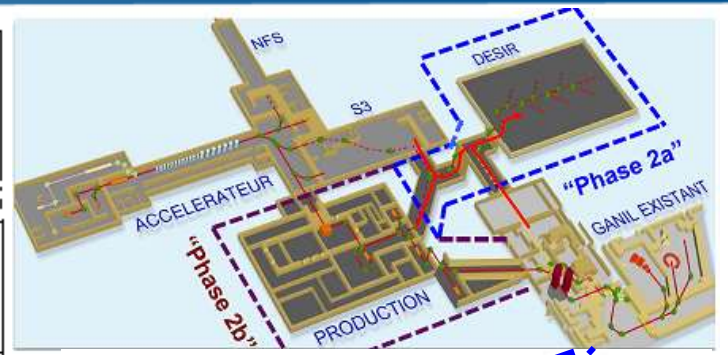
Title: Precision mass measurements of nuclei with Z ~ 104 from S^3 with MLLTRAP at DESIR

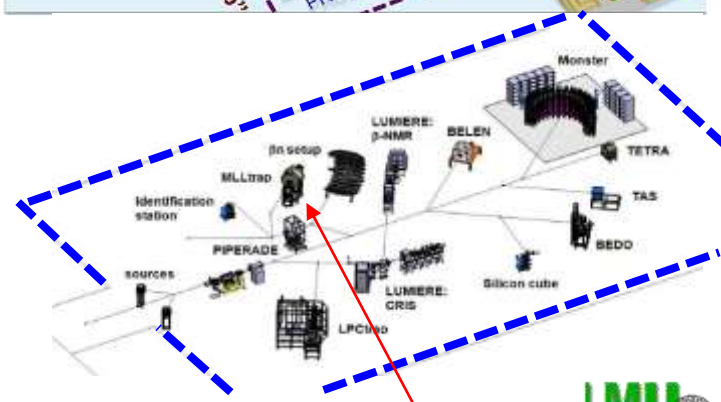
Spokespersons (if several, please use capital letters to indicate the name of the contact person):
P.G. Thirolf

Address of the contact person: Faculty of Physics, LMU Munich, Am Coulombwall 1, 85748 Garching/Germany

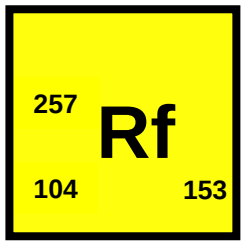
Phone: 0049-89-28914064	Fax: 0049-89-28914072	E-mail: Peter.Thirolf@lmu.de

Other Participants or Organisations: H. Savajols (GANIL), C. Weber (LMU), B. Blank (CENBG), M. Gerbaux (CENBG), J. Giovinazzo (CENBG) , S. Grevy (CENBG), D. Lunney (CSNSM), E. Minaya Ramirez (GSI)





LMU

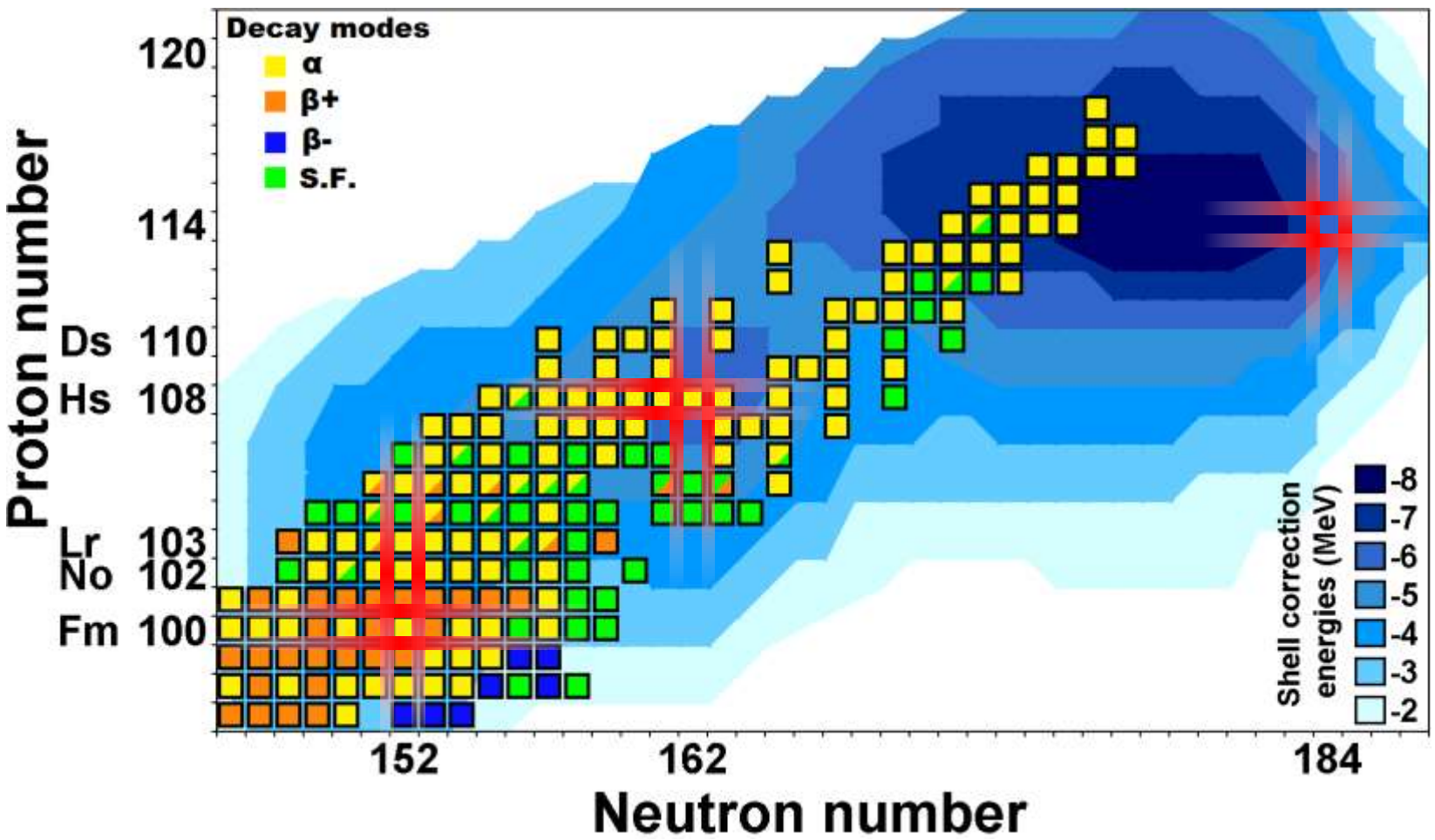


$^{208}Pb(^{50}Ti,1n)^{257}Rf$

$T_{1/2}$ (g.s.)	σ (nb)
4.7 s	~40

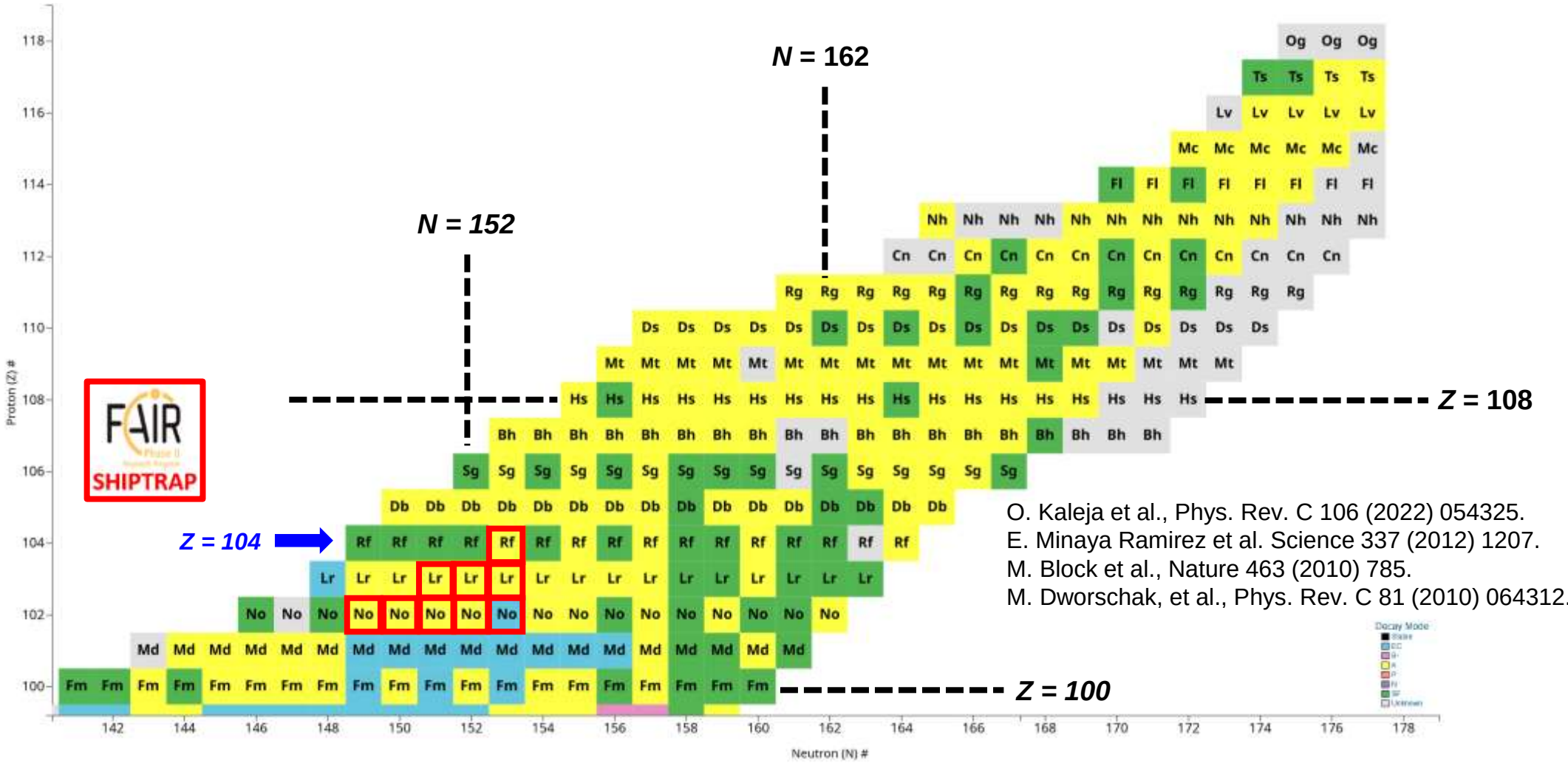
Anchor point for ^{269}Ds (Z=110, N=159)

Studies in the SHE region



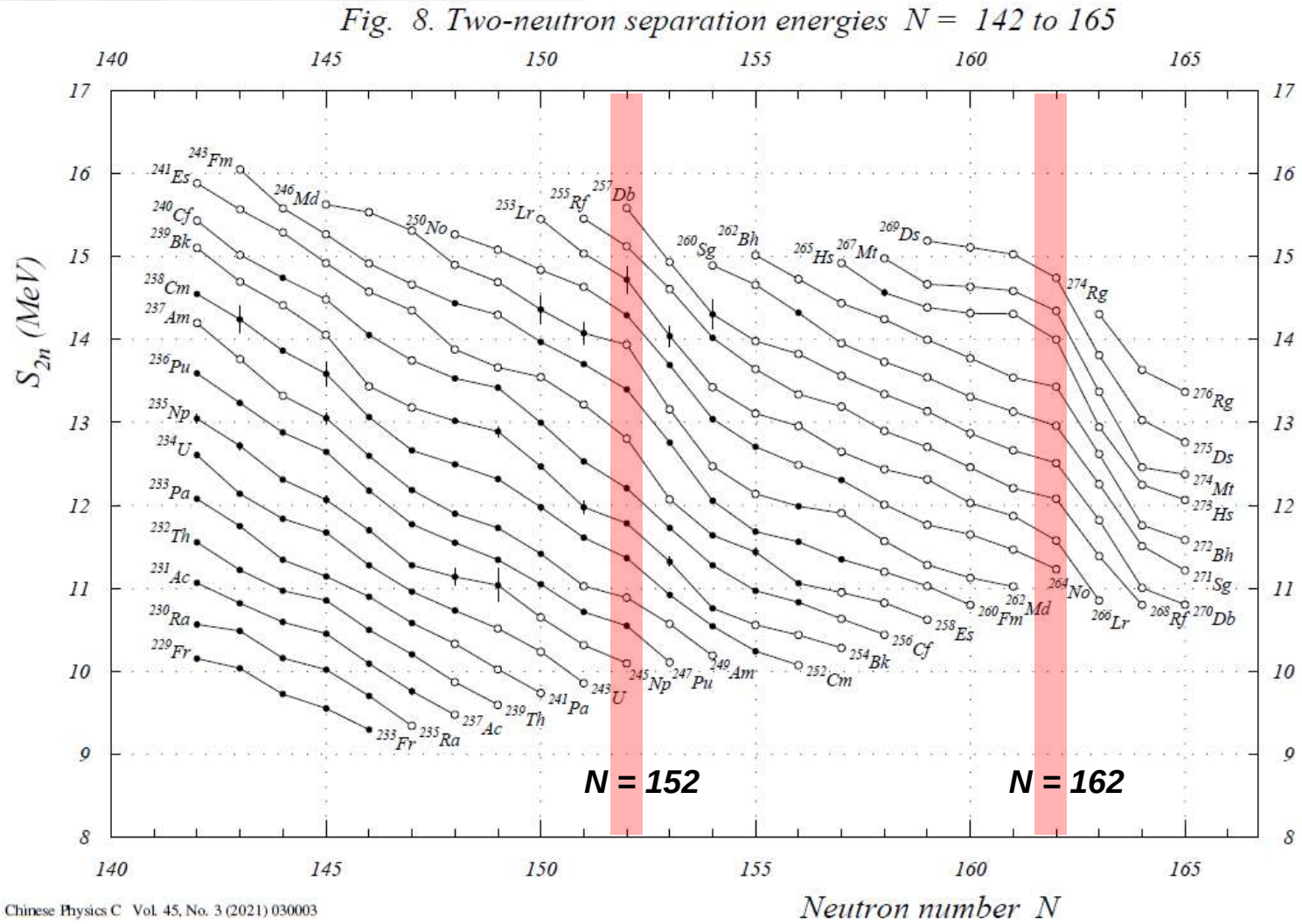
- Island of stability
- New Elements
- Laser Spectroscopy
- Nuclear Spectroscopy
- Nuclear Reaction studies
- Nuclear Chemistry
- Nuclear Structure
- High Precision Mass Measurements

Mass measurements in the SHE region



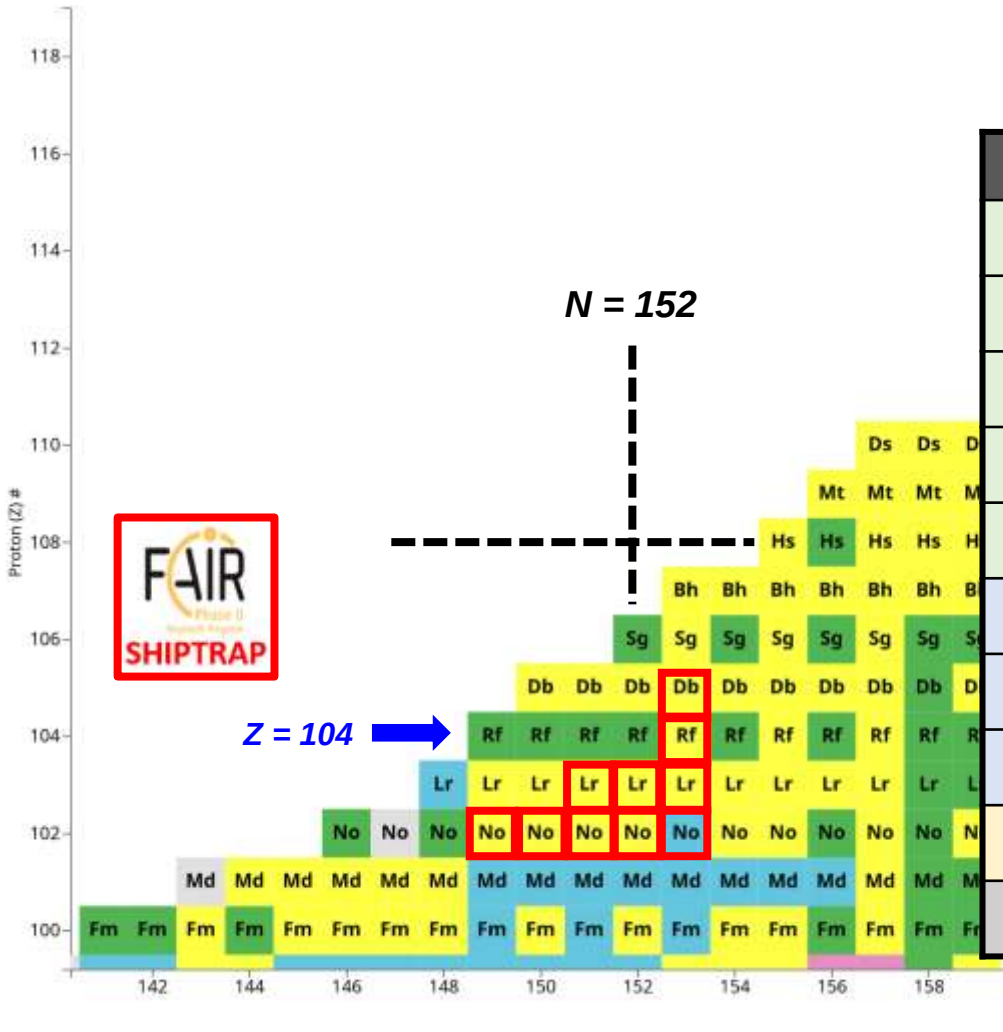
O. Kaleja et al., Phys. Rev. C 106 (2022) 054325.
E. Minaya Ramirez et al. Science 337 (2012) 1207.
M. Block et al., Nature 463 (2010) 785.
M. Dworschak, et al., Phys. Rev. C 81 (2010) 064312.

Mass measurements in the SHE region



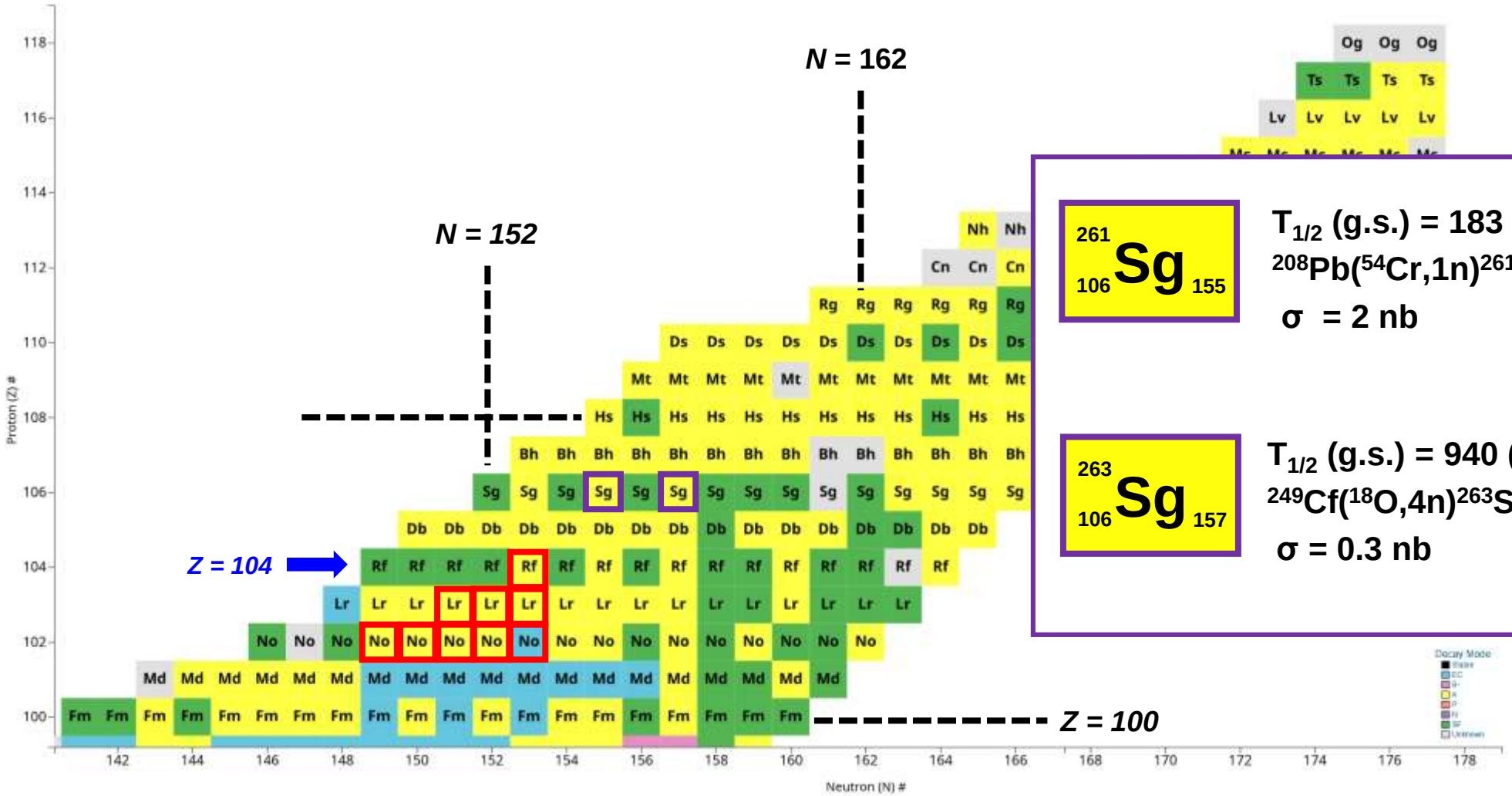
Chinese Physics C Vol. 45, No. 3 (2021) 030003

Mass measurements in the SHE region



Element	$T_{1/2}$ (g.s.)	σ (nb)
^{251}No	800 (10) ms	30
^{252}No	2.44(4) s	400
^{253}No	1.62(15) min	1800
^{254}No	51(10) s	2000
^{255}No	3.1(2) min	140
^{254}Lr	17.1 (1.8) s	25
^{255}Lr	30(4) s	250
^{256}Lr	28(3) s	60
^{257}Rf	4.82 (0.13) s	15
^{258}Db	4.5 (0.4) s	4

Mass measurements in the SHE region @ DESIR



$^{261}_{106}Sg_{155}$

$T_{1/2}$ (g.s.) = 183 (5) ms

$^{208}Pb(^{54}Cr,1n)^{261}Sg$

σ = 2 nb

$^{263}_{106}Sg_{157}$

$T_{1/2}$ (g.s.) = 940 (140) ms

$^{249}Cf(^{18}O,4n)^{263}Sg$

σ = 0.3 nb

Mass measurements in the SHE region @ DESIR

B. Streicher et al., Eur. Phys. J. A 45 (2010) 275–286.

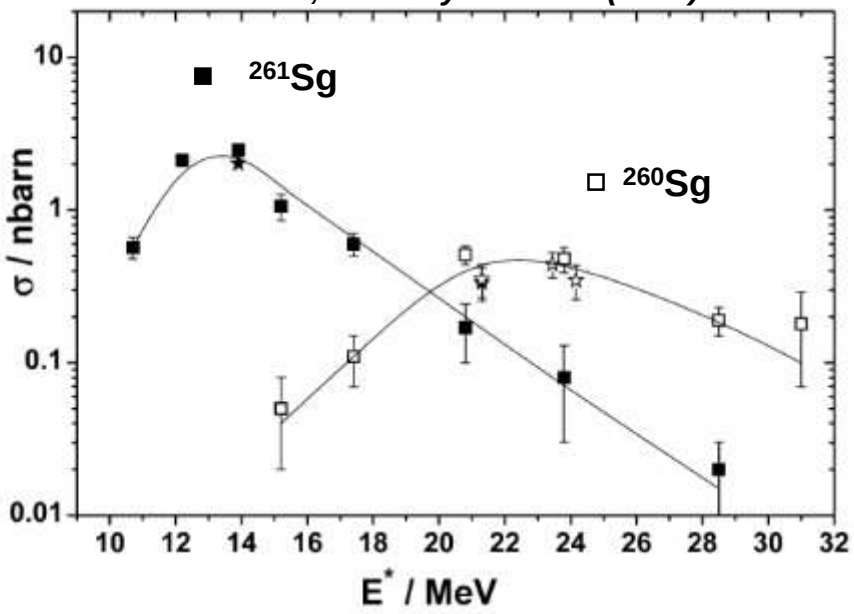


Fig. 1. Excitation function for the production of ^{261}Sg (full symbols) and ^{260}Sg (open symbols) by the reaction ^{208}Pb(^{54}Cr, xn)$^{262-x}$Sg ($x = 1, 2$). The squares represent irradiations using metallic Pb targets, the stars irradiations using PbS targets. The lines are to guide the eye.

A. Ghiorso et al., Phys. Rev. Lett. 33 (1974) 1490.

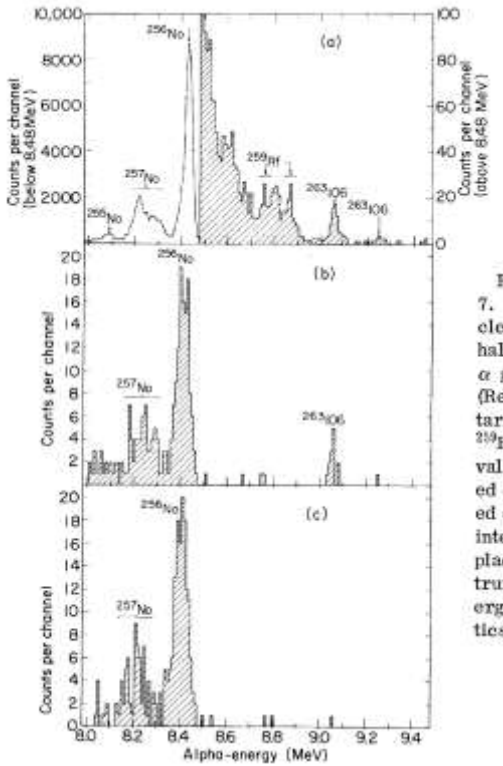
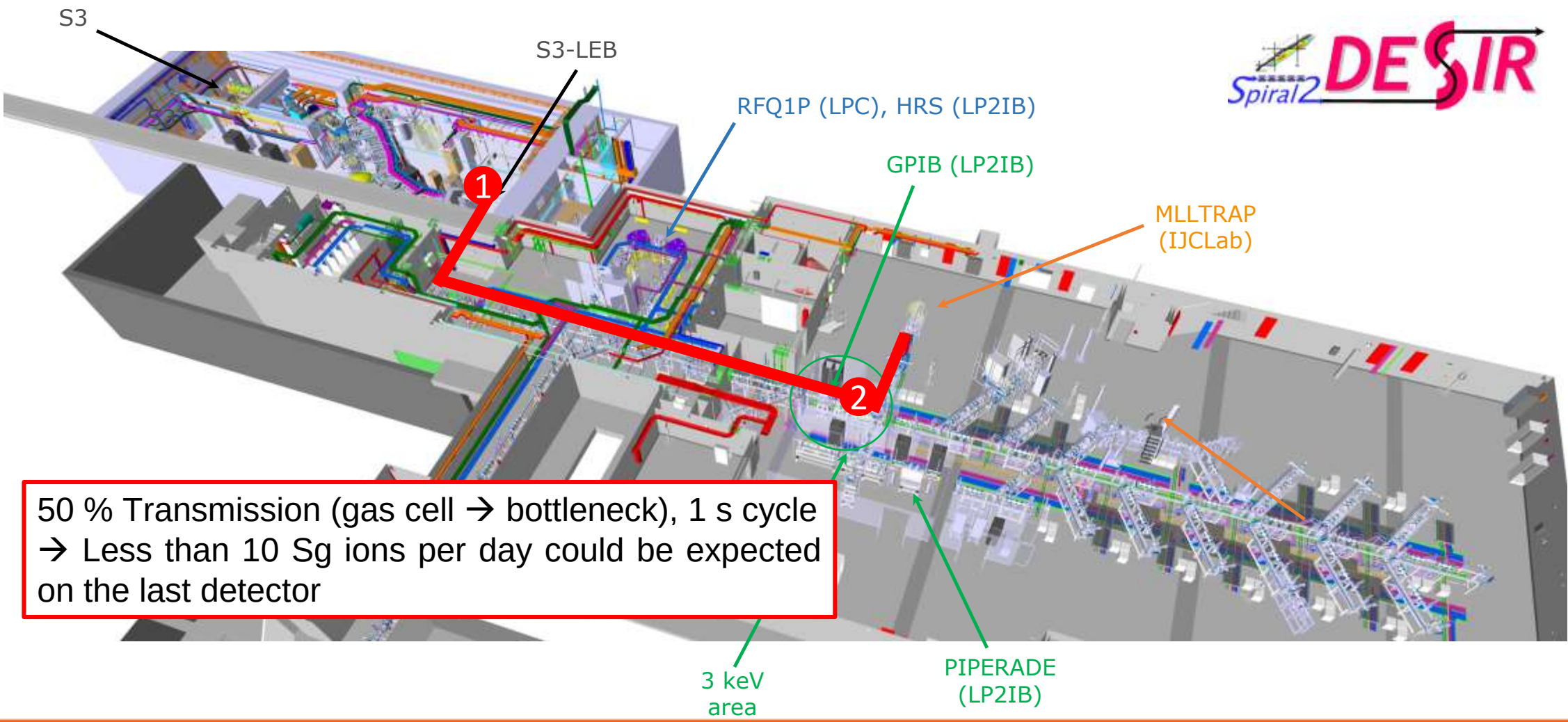


FIG. 2. (a) Sum of α spectra from stations 1 through 7. The integrated beam intensity was 1.34×10^{18} particles of ^{18}O. The peak at 8.81 MeV, which has a long half-life (> 5 sec) and is not time-correlated with any α group above 8 MeV, is probably ^{214}At fed by ^{222}Ac (Ref. 10), produced from trace amounts of Pb in the target. (b) α events in the 0–12-sec interval preceding ^{259}Rf events (8.65 to 8.91 MeV). The 12-sec time interval represents four ^{259}Rf half-lives. Thirteen correlated events were observed at 9.06 MeV and one correlated event at 9.25 MeV. (c) α events in the 50–62-sec interval preceding ^{259}Rf events. A 50-sec time displacement was chosen to determine the accidental spectrum. Only one α event was found within the ^{263}106 energy region, as had been expected from Poisson statistics.

Development of Cr beams required
→ **σ = 2 nb**

Development of Cf targets required
→ **σ = 0.3 nb**

Mass measurements in the SHE region @ DESIR



50 % Transmission (gas cell → bottleneck), 1 s cycle
→ Less than 10 Sg ions per day could be expected on the last detector

Perspectives

- Radioactive silver ions have been produced at ALTO up to mass 125.
- A detailed study of the beam transport from the ion source of ALTO to the entrance of the RFQCB is ongoing. The commissioning of the preparation and manipulation sections is scheduled for 2024.
- The goal of the development of in-trap at MLLTRAP is to offer a new instrument able to perform simultaneously spectrometry and spectroscopy studies in the SHE region. This program can start by measuring the mass of ^{261}Sg and then move to ^{263}Sg. Support on development of beams and targets will be required.

Thank you for your attention !

Scientific poles at IJCLab: Accelerator and Nuclear Physics :
E. Minaya Ramirez, A. Leite, L. Perrot, D. Lunney, A.Lopez-Martens, K. Hauschild, V. Manea

PhD students : E. Morin (2019 – 2022) / S. Morard (2022 – 2025)
Postdocs : P. Chauveau (2017-2019) / New postdoc position in 2024

+ strong support Mechanical engineering from Engineering pole and ALTO platform

GSI-IN2P3 Collaboration n°19-81:
M. Block, F. Giacoppo, M. J. Gutiérrez,