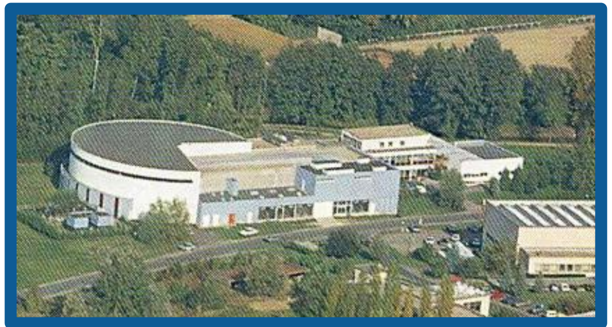
The ALTO research platform of IJCLab

Enrique Minaya Ramirez

Laboratoire de Physique des 2 infinis Irène Joliot-Curie

Outline

https://alto.ijclab.in2p3.fr/en/overview/



- User facilities
- Projects
- workshops & common platforms
- Scientific & technical platforms

- Overview of the ALTO research platform
- Current developments
- Latest results

Overview of the ALTO research platform

Joint Research Centre JRC

OCL Oslo Cyclotron Laboratory

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

TRIUMF

NPL National Physical Laboratory

UNIVERSITY OF WARSAW | HIL
Heavy Ion Laboratory

INSTYTUT FIZYKI JĄDROWEJ
IM. HENRYKA NIEWODNICZAŃSKIEGO
POLSKIEJ AKADEMII NAUK

ISOLDE

INFN Istituto Nazionale di Fisica Nucleare

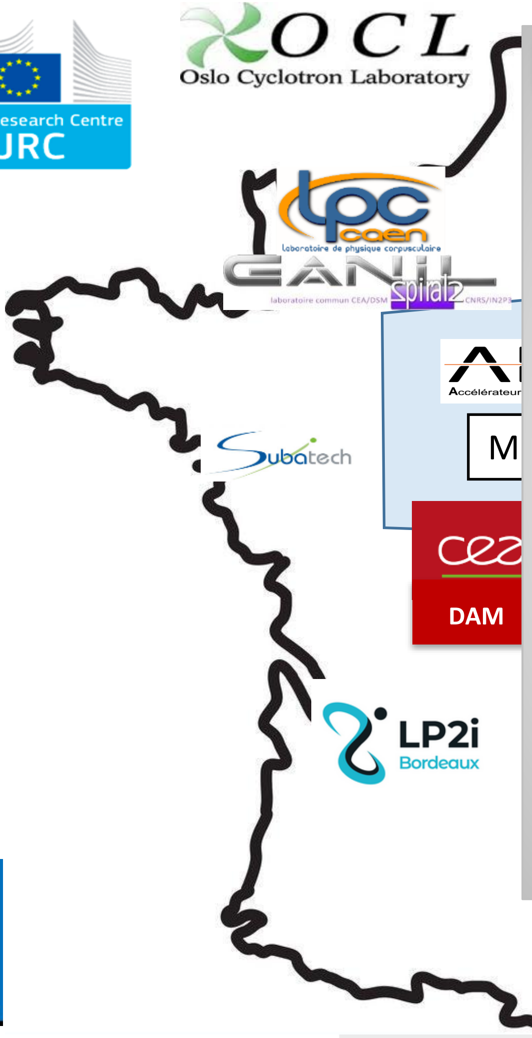
NRF National Research Foundation | iThemba LABS Laboratory for Accelerator Based Sciences

European Networks:

EURO-LABS EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

ARIEL

Overview of the ALTO research platform



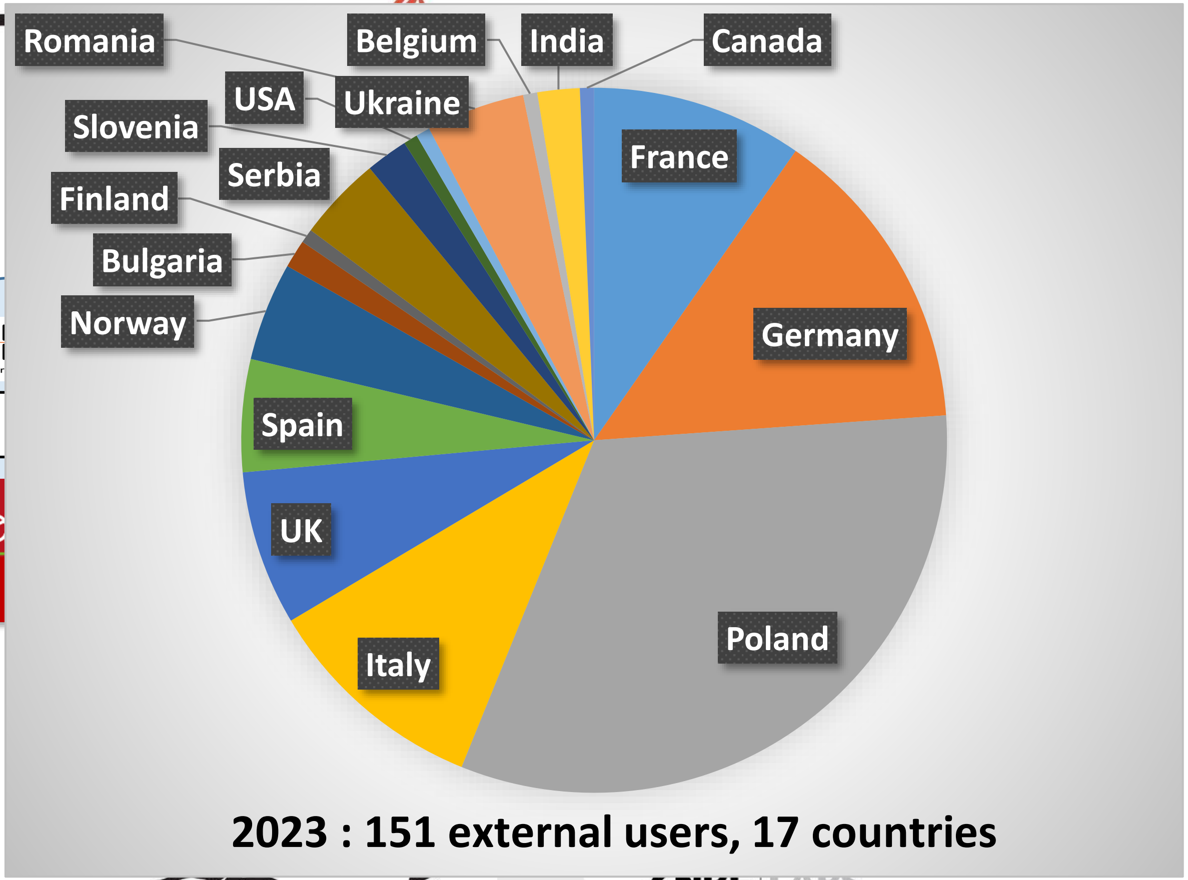
TRIUMF

NPL
National Physical Laboratory

European Networks:

EURO-LABS
EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

ARIEL



Beam time at ALTO

- Programme Advisory Committee (PAC) → access to ALTO
- Last call for proposals : November 2024 – January 2025
- Last ALTO PAC : February 2025
- The PAC has now a fixed mandate (4 years)

President

Bogdan Fornal – IFJ PAN – Krakow, Poland

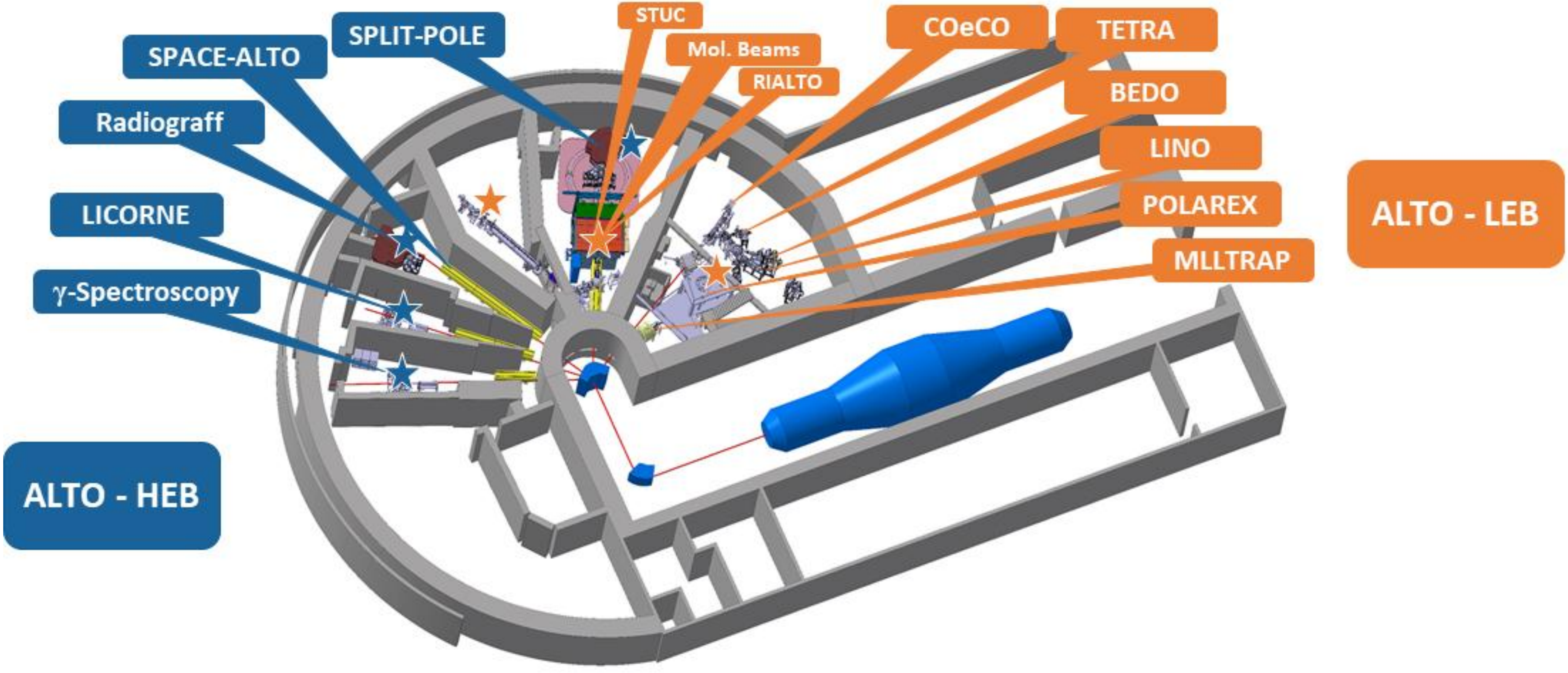
Members :

Michael Block – GSI, Darmstadt, Germany
Wilton Catford – University of Surrey, Guildford, United Kingdom
Denis Dauvergne – LPSC, Grenoble, France
Francois D'Oliveira – GANIL, Caen, France
Jean-Paul Ebran – CEA, Saclay, France
Andrea Gottardo – INFN, Legnaro, Italy
Paul Greenlees – JYFL, Jyväskylä, Finland
Beatriz Jurado – LP2iB, Bordeaux, France
Silvia Leoni – University of Milano, Italy
Caterina Michelagnoli – ILL, Grenoble, France
Marie Vanstalle – IPHC, Strasbourg, France

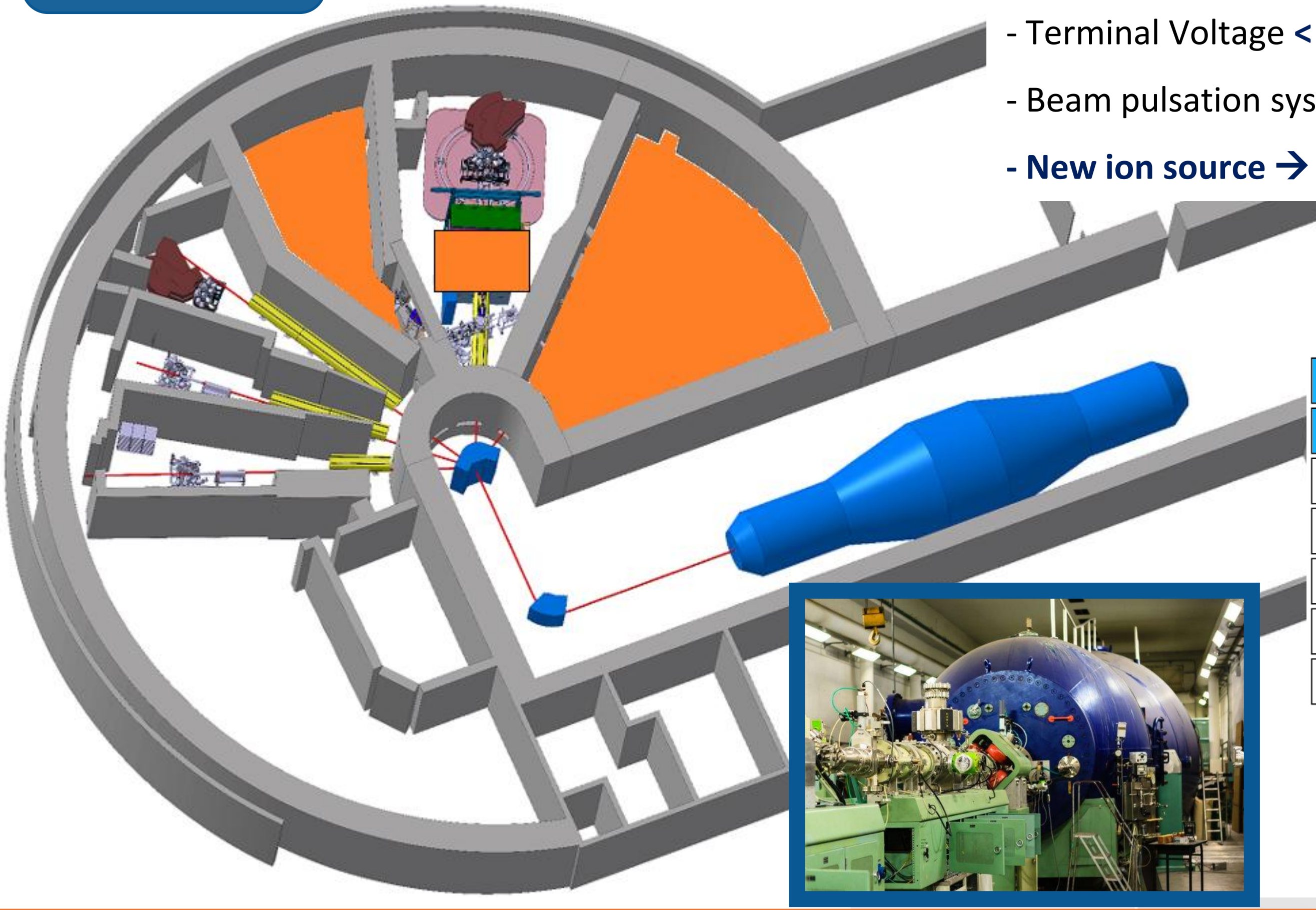
≈ 22 weeks of beamtime per year

ALTO
Accélérateur Linéaire et Tandem à Orsay

Scientific Coordinator :
E. Minaya Ramirez
Technical manager :
A. Said
Thin layers service :
E. Blanc, A. Limongi
Tandem service :
E. Borg, A. Bouafia, F. Fahy,
R. Leplat, M. Mangano, S. Semsoum
Linac service :
F. Debray, S. Jourdain, F. Lemaitre, L. Tranchard


SPACE-ALTO
SPLIT-POLE
STUC
Mol. Beams
RIALTO
COeCO
TETRA
BEDO
LINO
POLAREX
MLLTRAP
Radiograff
LICORNE
γ-Spectroscopy
ALTO - HEB
ALTO - LEB

ALTO - HEB



Tandem Accelerator Stable beams :

- **H, ^{3}He, ^{4}He, ..., ^{14}C, ...** up to **^{197}Au**
- Terminal Voltage **< 1 MV** et **14.5 MV**
- Beam pulsation system : pulse size **1 - 2 ns**; pulsation period : **100 ns - 100 µs**
- **New ion source → Intensity x5 → Difficult beams (Mg, Ca)**

1 H																	**2 He**
3 Li	**4 Be**											**5 B**	**6 C**	**7 N**	**8 O**	9 F	10 Ne
11 Na	**12 Mg**											**13 Al**	**14 Si**	**15 P**	**16 S**	**17 Cl**	18 Ar
19 K	**20 Ca**	21 Sc	**22 Ti**	23 V	24 Cr	25 Mn	**26 Fe**	27 Co	**28 Ni**	**29 Cu**	30 Zn	31 Ga	32 Ge	**33 As**	**34 Se**	**35 Br**	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	**47 Ag**	48 Cd	49 In	50 Sn	51 Sb	**52 Te**	**53 I**	54 Xe
55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	**79 Au**	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

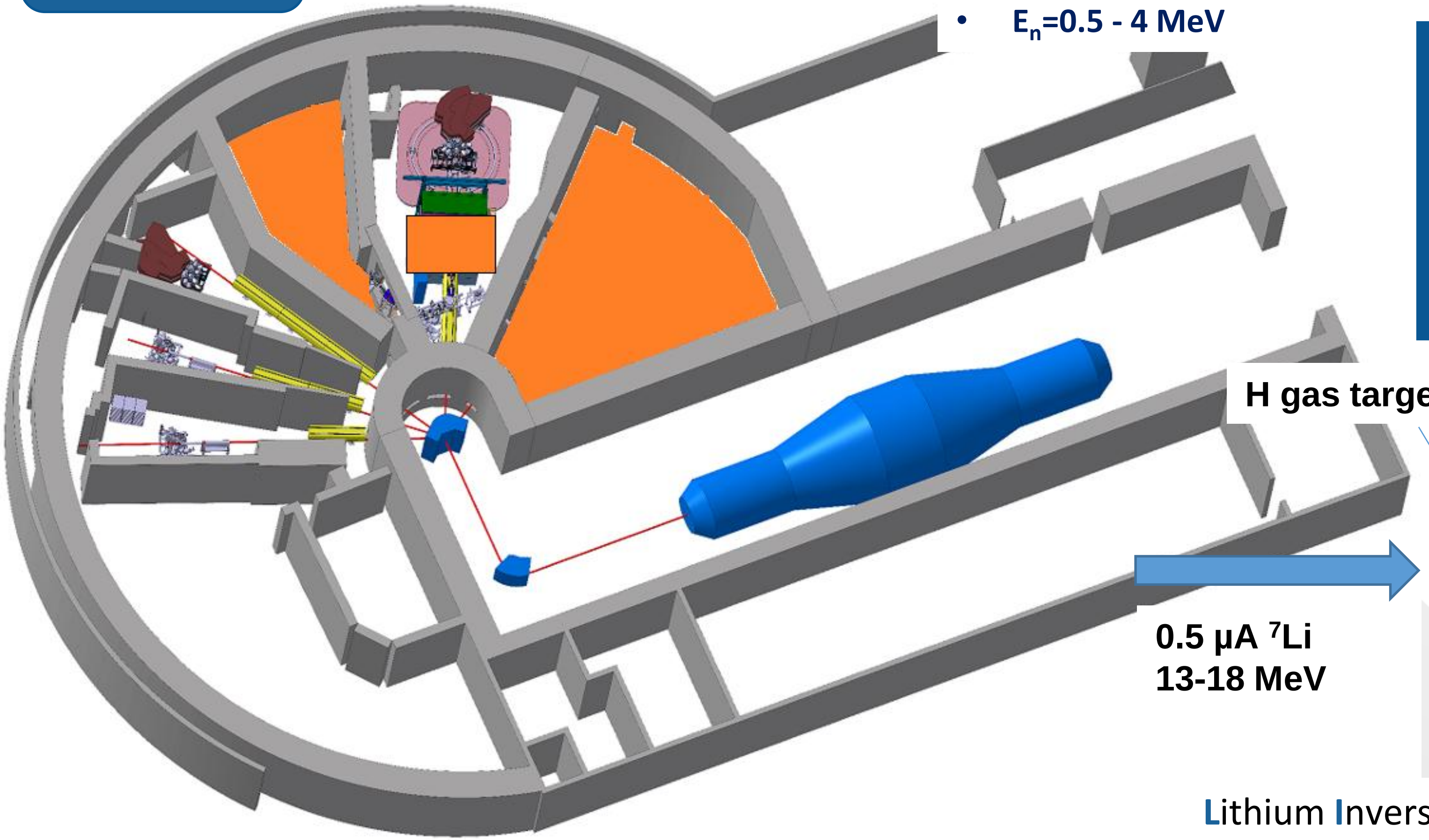
https://alto.ijclab.in2p3.fr/en/facility/alto-heb-en/heavy-ions/

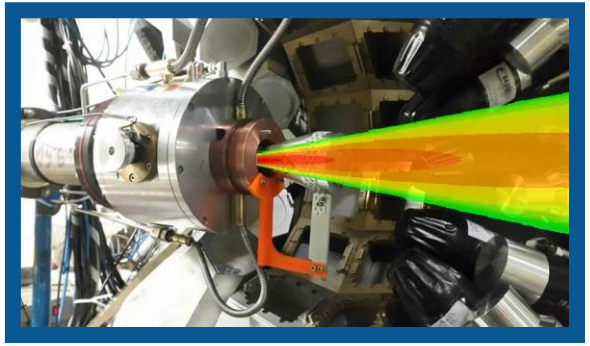
Overview of the ALTO research platform

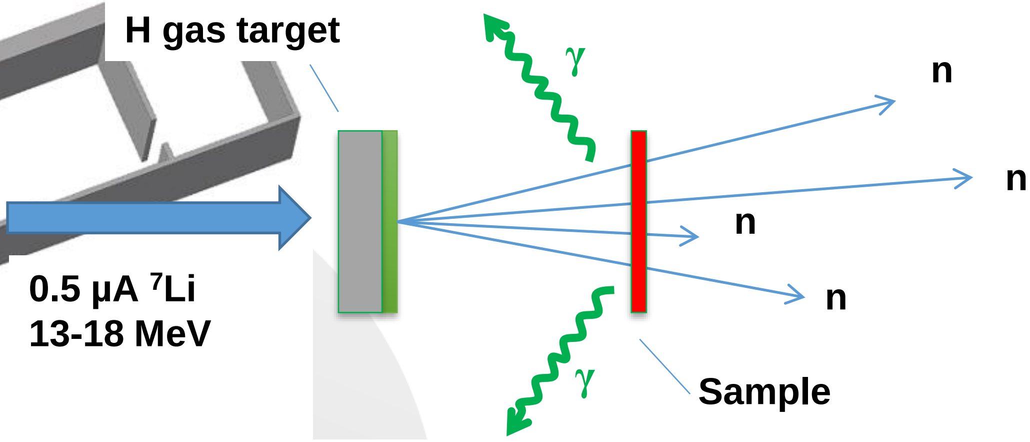
ALTO - HEB

Unique, naturally directional quasi-monoenergetic neutron source:

- Low background
- High Flux: **10^8 n/s/steradian**
- **E_n=0.5 - 4 MeV**







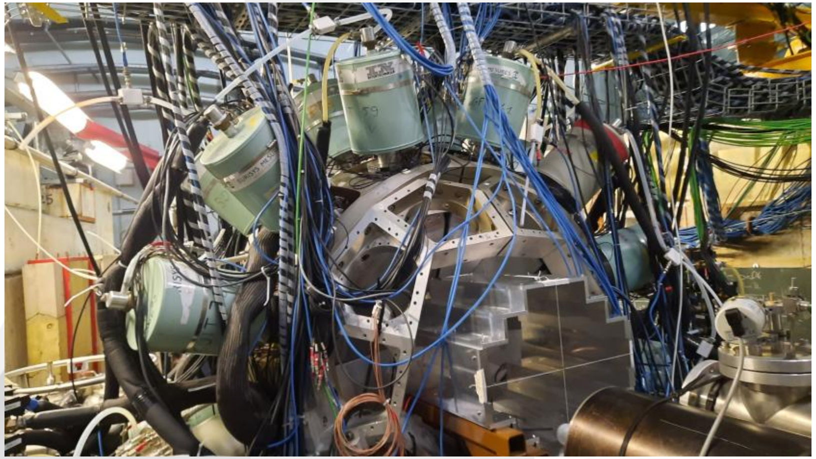
Lithium **I**nverse **C**inematiques **OR**say **N**eutron source

ν-Ball2 : campaign at ALTO

2018 – 2019 : First campaign with the high-performance ν-Ball γ-ray spectrometer

ν-Ball coupled with LICORNE : ***J.N. Wilson et al., "Angular momentum generation in nuclear fission", Nature 590 (2021) 566***

Average spins extracted for even−even nuclei produced in fast-neutron-induced fission of ^{232}Th, ^{238}U and the spontaneous fission (SF) of ^{252}Cf → fragment spins are uncorrelated, revealing the post-scission nature of the mechanism.



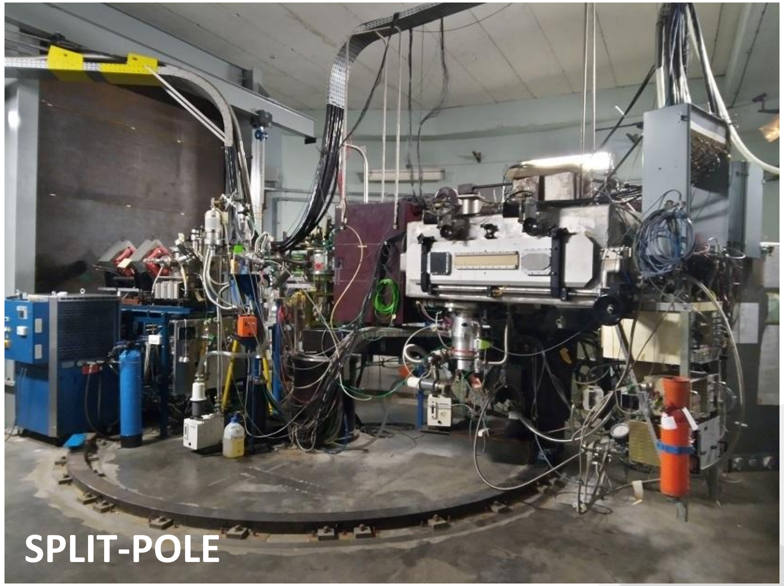
2022 (week 14) and 2023 (week 25)
Second campaign with ν-Ball

16 experiments approved, 12 completed, 8 experiments financed by EUROLABS and ARIEL, 160 international visitors

- D. Thisse, et al., «Study of N=50 gap evolution around Z=32: new structure information for ^{82}Ge"; Eur. Phys. J. A59 Letts(2023) 153
- K. Miernik, et al., «Fission of ^{215}Fr studied with g spectroscopic methods"; Phys. Rev. C108 (2023) 054608
- M. Ciemala, et al., «Feeding of the Residual States with GDR gamma Decay Studied by nuBall Coupled with PARIS»; Acta Phys. Pol. B Proc. Suppl. 16 (2023) 4-A3
- D. Gjestvang, et al., «Examination of how properties of a fissioning system impact isomeric yield ratios of the fragments", Phys. Rev. C108 (2023) 064602
- G. Pasqualato and J.N. Wilson ,"The nu-Ball2 experimental campaign at ALTO", Nuclear Physics News, 34 16-20, (2024)
- S. Leoni, B. Fornal, N. Mărginean and J.N. Wilson, ''Shape isomers: status and perspectives across the nuclear chart''; Eur. Phys. J. Spec. Top. 233, 1061–1074 (2024)
- C. Hiver, et al., "High-resolution studies of isomeric states in ^{236}U with the nu-Ball2 spectrometer"; Acta Physica Polonica 18 2A-25 (2025)

Talk by J. Wilson 23/09 at 14h40

SPLIT-POLE



The main fields of investigation addressed with the Split-Pole magnetic spectrometer are the origin of the nuclei in the Universe and the properties of atomic nuclei

Full refurbishment of the SPLIT-POLE

- New system for regulating the power supply to the spectrometer's magnets ($\Delta B/B < 10$ ppm)
- Reaction chamber repaired (new moving window, new seals, new mechanics) and coupled to the spectrometer
- All the belts driving the mechanical systems (acceptance slits, focal plane position, etc.) have been changed

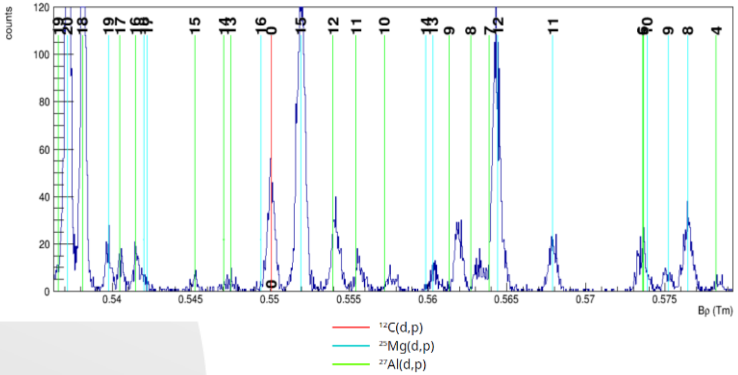
Development and testing of a gas target at the spectrometer's focal plane

- 200 mbar, 1 cm thick
- used for reactions astrophysical reactions involving gaseous species (Ne, N...)

September 2024 : What is the contribution of classical novae?

→ depends on the ^{25}Al(p,γ)^{26}Si reaction

The proposal aims at measuring the neutron spectroscopic factors for known resonances in the mirror nucleus of ^{26}Al: ^{26}Mg. These factors will constrain the values of proton widths in ^{26}Al, for which no information is available. This will improve knowledge on one of the 4 key reactions for novae: ^{25}Al(p,γ)^{26}Si.



N. de Sereville, F. Hammache, et al.

SPACE ALTO (Station Pour l'irrAdiation des Composants et systèmEs à ALTO)

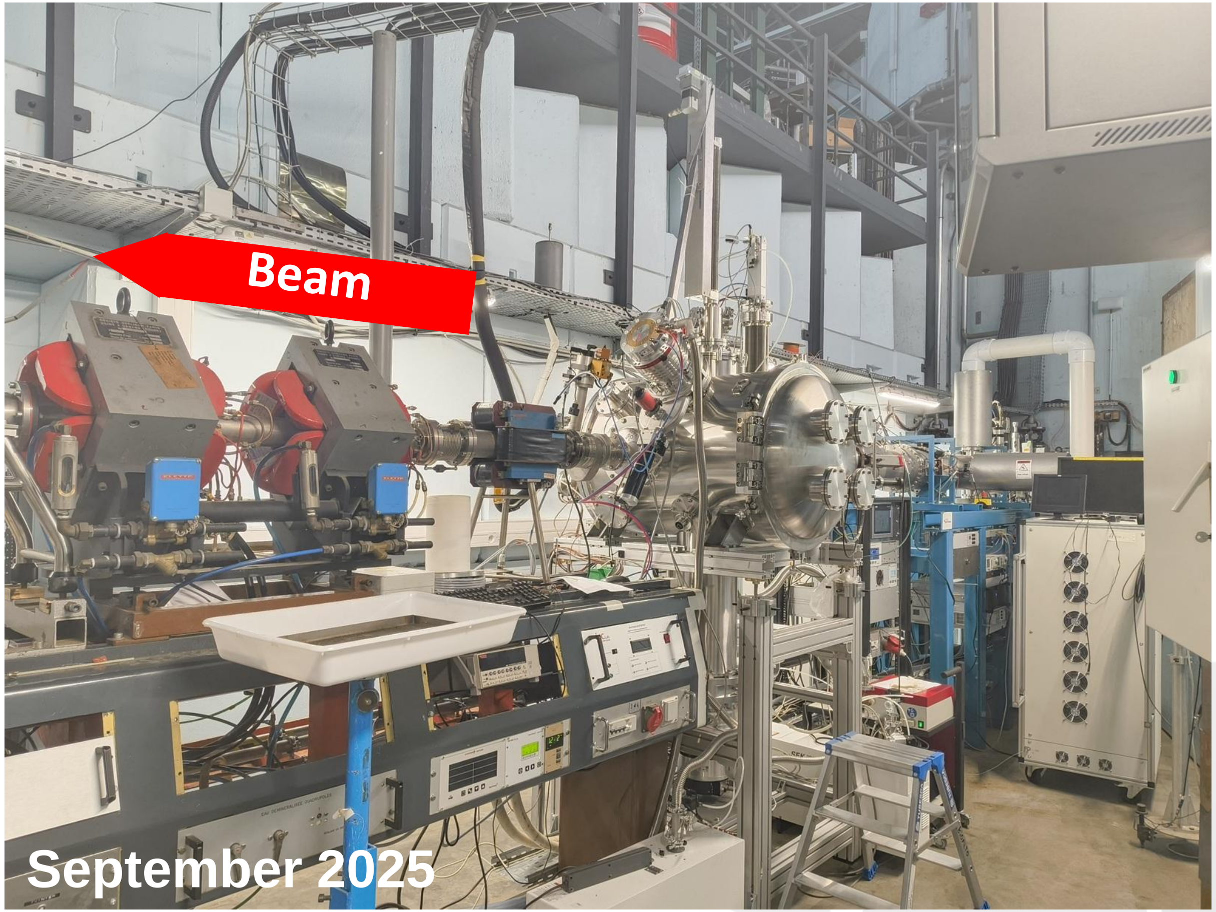
Goal : increase the added value of ALTO for industrials. First by increasing the thin targets activity and second by delivering specific beam characteristics requested by industrials clients (mostly aerospace industry) for electrons, neutrons, protons and heavy ions.

- ✓ Beam line and sweeping system installed by an external company
- ✓ Dosimetry system integrated
- ✓ A New experimental area with high-performance and exclusively dedicated to the preparation of irradiations was mandatory.

Beams	Energy (MeV)	Maximum flux	Environment test	Irradiated surface
Protons	0.02 - 30	10^{12} p/(s.cm²)	In air Under vacuum Under gas pressure -170°C to +200°C	from 20 x 20 mm² up to 30 x 30 cm²
Electrons	1 - 50	10^{12} e/(s.cm²)		
Ions	1 - 300	10^{12} ions/(s.cm²)		
Neutrons	0.5 - 8	10^{8} n/s/str	In air	up to 10 x 10 cm²

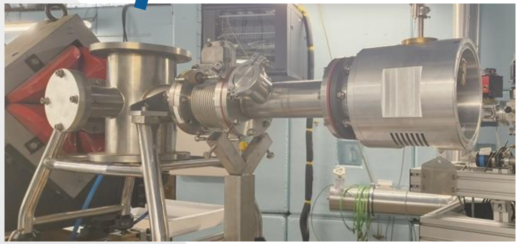
A. Said et al.

SPACE ALTO (Station Pour l’irrAdiation des Composants et systèmEs à ALTO)



Chamber for ions

LICORNE



BioALTO: new beamline @ ALTO dedicated to radiobiological studies

Motivation

- ○ Closure of Van de Graaff accelerator at IP2I and migration of RadioGraaff radiobiology setup to ALTO.
- ○ Accelerator and platform expertise at IJClab (SCALP, ALTO, …).
- ○ Increased developments in dosimetry and radiobiology at Paris-Saclay University
- ○ Develop a reference facility for hadron therapy research at IJClab in collaboration with the IP2I and the LPSC.
- ○ Promote the research activities carried out in hadron therapy in Ile-de-France.
- ○ Contribute to the network of irradiators on a national scale (Resplandir network).

Requirements of radiobiological experiments:

- ✓ Monoenergetic beams
  resolution better than 0.1 MeV
- ✓ Homogeneous irradiation field
  within 2% over ~cm^2
- ✓ Precise dose
- ✓ Precise dose rate
- ✓ Reproducibility
- ✓ Strict irradiation calendar

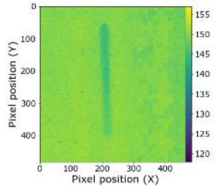
Possible available beams:

- **Protons**
- **^{4}He, ^{12}C, ^{16}O and others**
- **High dose rate beam (flash)**

- ▪ The support of the cell plates and detectors is remote controlled with a robotic arm inside a temperature-controlled enclosure.
- ▪ Possibility of irradiating multiple wells without the need to enter the controlled area
- ▪ Development in beam monitoring and micro-dosimetry

March 2024 : Characterization of 3D-microdosimeter for the BioALTO platform

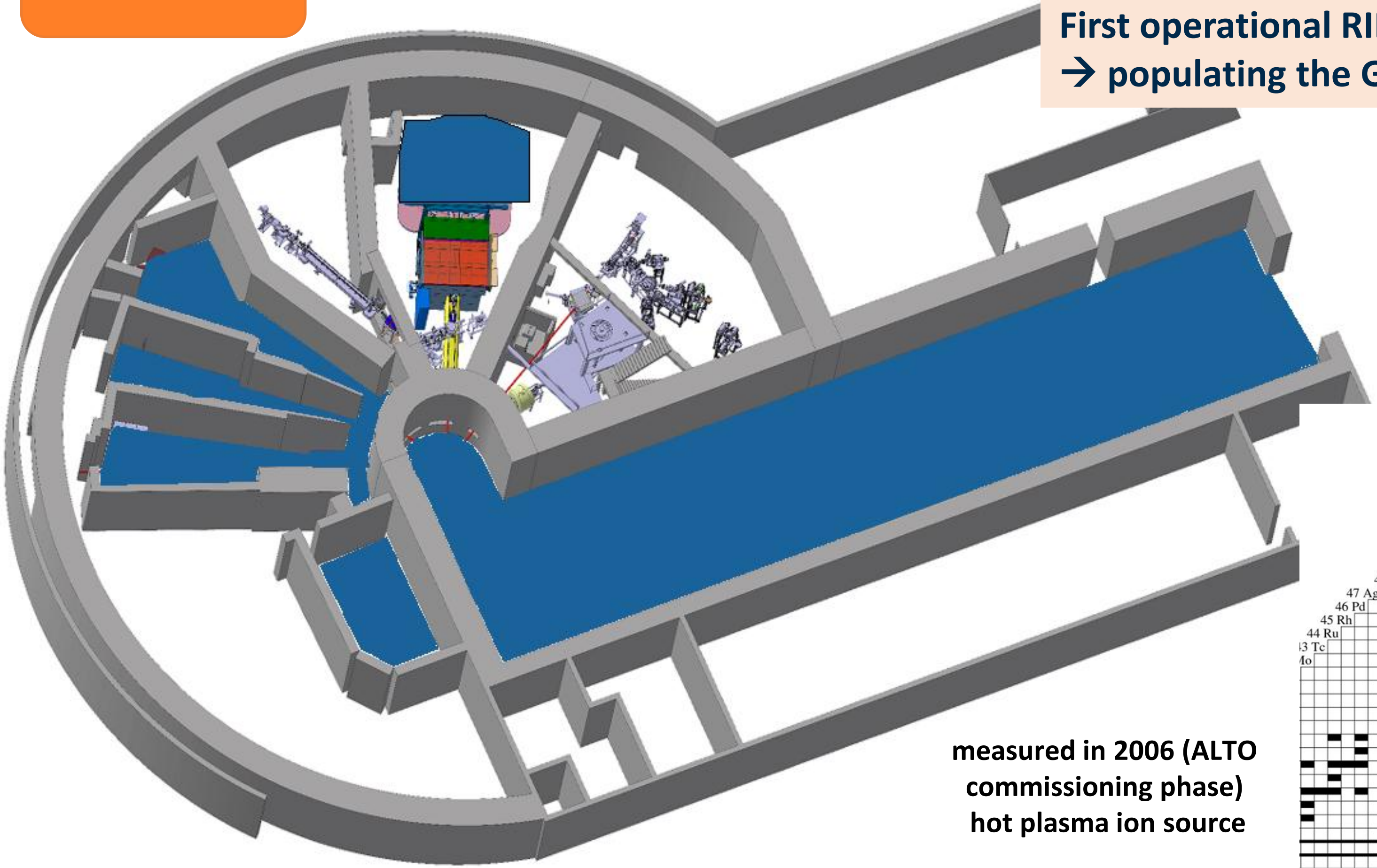
- Calibration of 3 chips (each containing 50 sets of 3D-microdosimeter)
- Monoenergetic alpha beam: from 5.75 to 20 MeV
- Validation of the calibration curve for the energies available at BioALTO
- Validation of beam visualisation and comparaison with radiochromic films

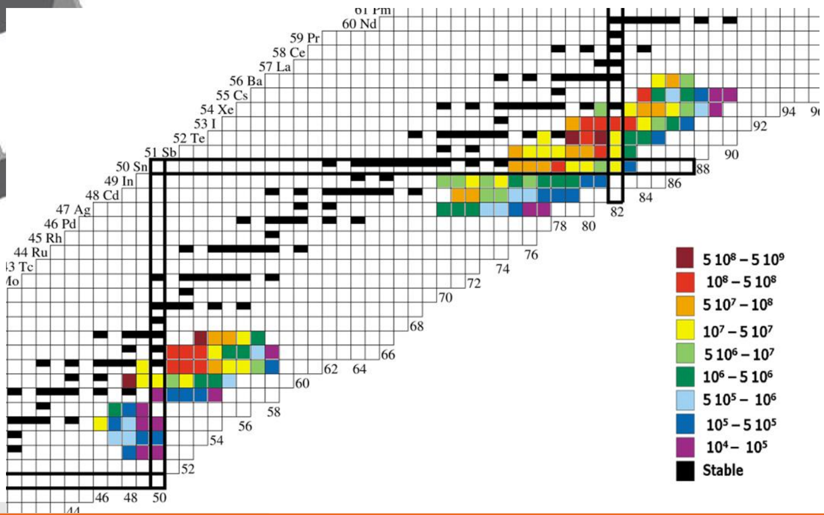


P. Laniece (IJCLab), A. Leite (IJCLab), M. Beauve (IP2I) et al.,

ALTO - LEB

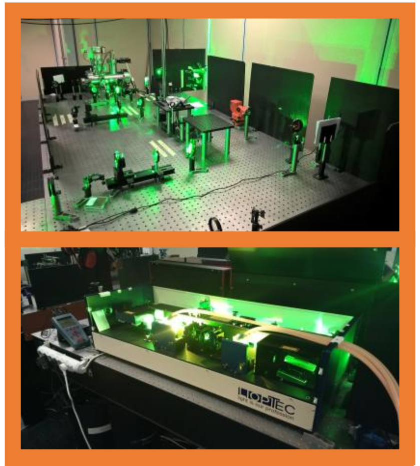
March 2012 : Operating licence from nuclear safety regulator
May 2013 : Alto Workshop
First operational RIB facility based on photo-fission
→ populating the GDR of ^{238}U(~10^{11} f/s)



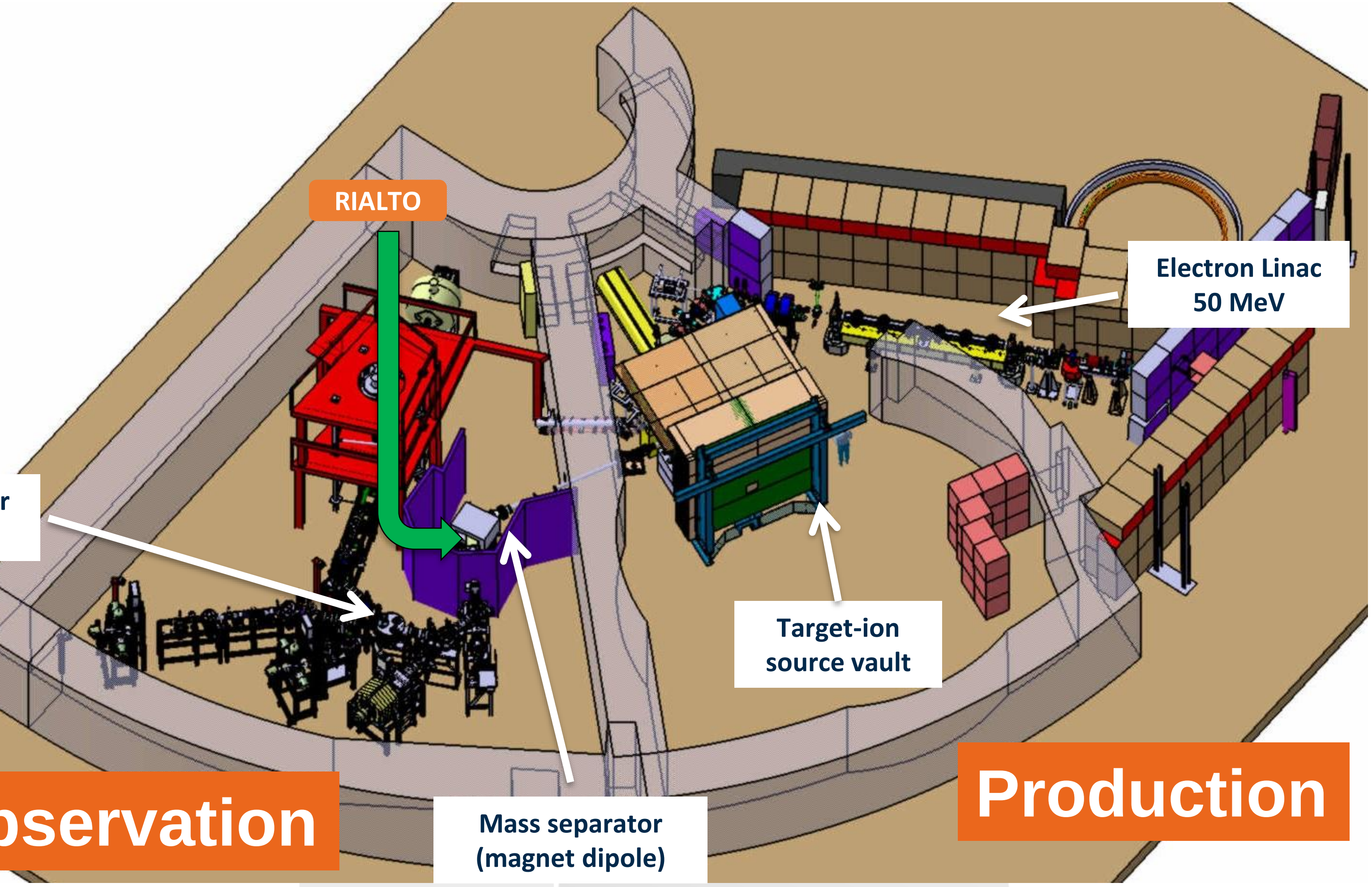


measured in 2006 (ALTO commissioning phase)
hot plasma ion source

Radioactive Ion Beams at ALTO

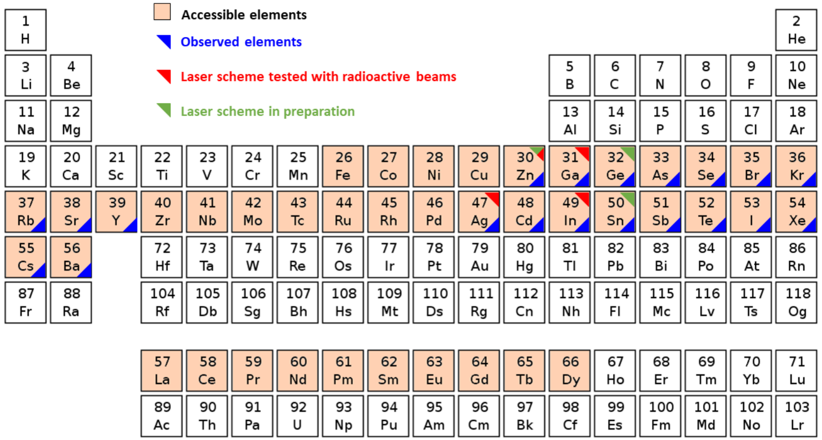


RIALTO



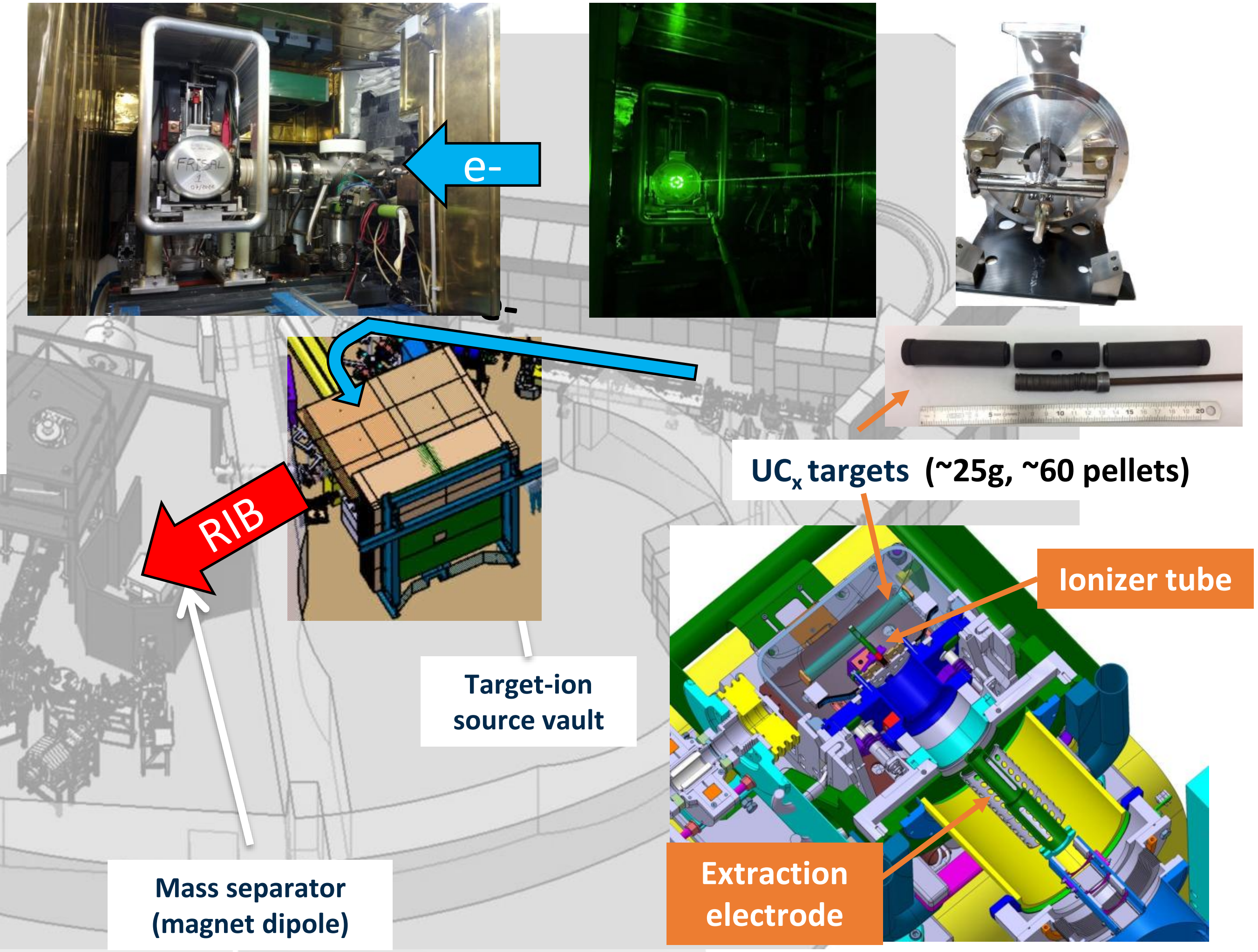
ALTO - LEB

Radioactive Ion Beams at ALTO



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

RIB produced by photofission at ALTO

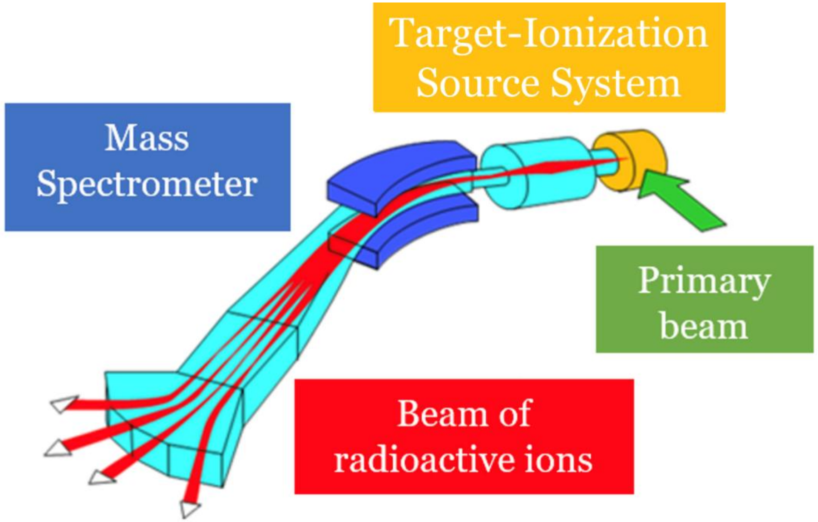


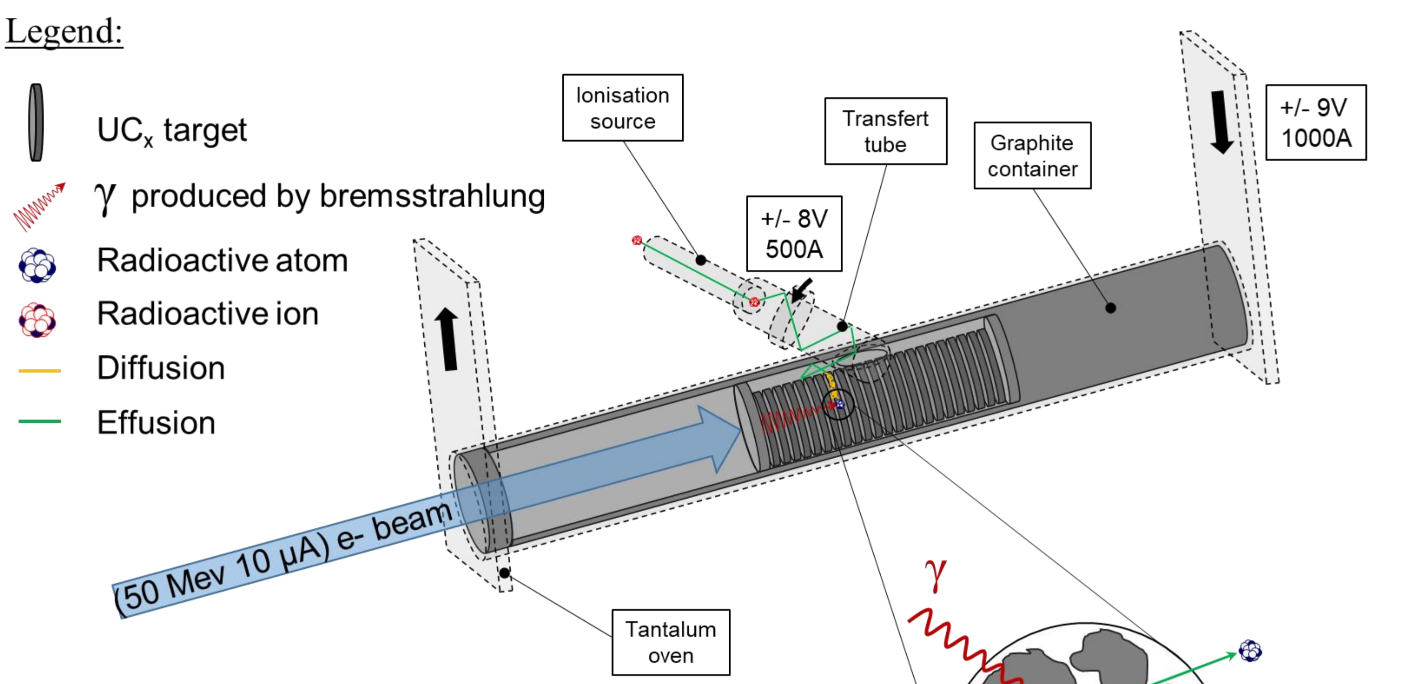
ALTO - LEB

Production of Radioactive Ion Beams at ALTO

- Strong demand from nuclear physics for exotic beams to study nuclear structure
- Production of radioactive beams at ALTO: ISOL (Isotope Separation On-Line) method

$$\mathbf{I = I_P.\,\sigma.\,N.\,\varepsilon_r.\,\varepsilon_{ion}.\,\varepsilon_{tr}}$$

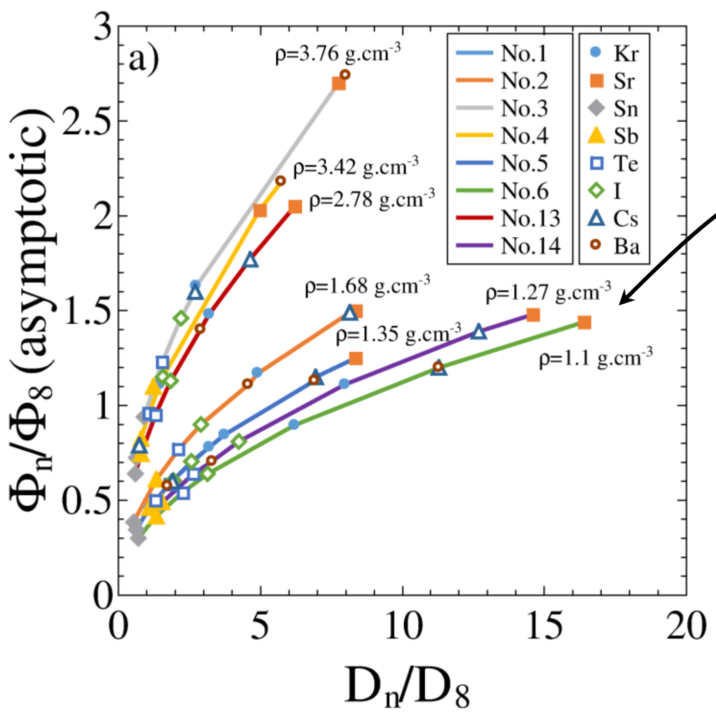


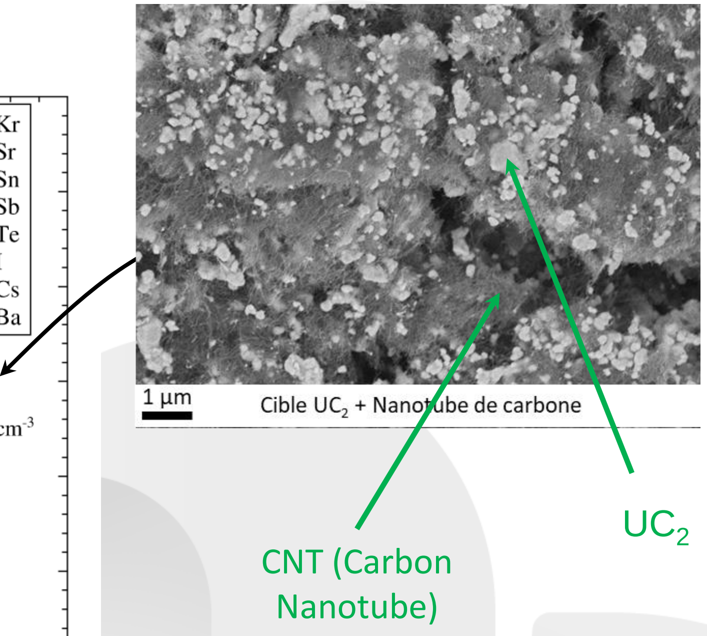


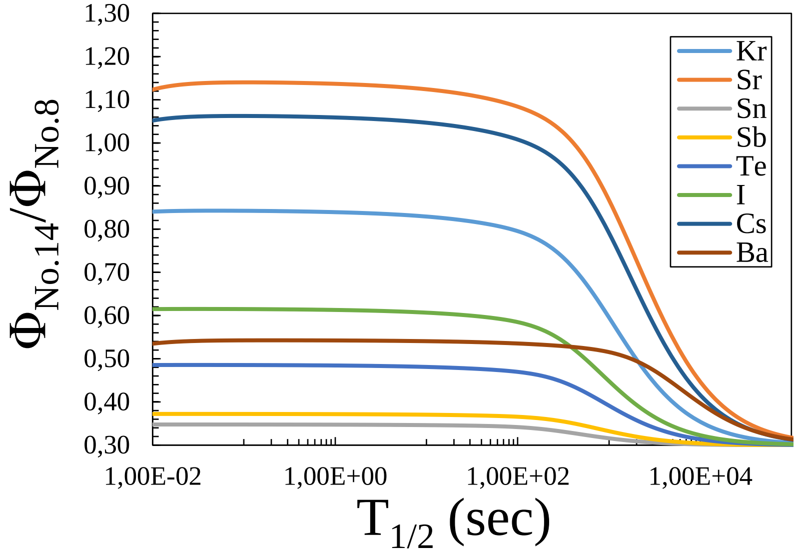
$$\boldsymbol{\varepsilon_r = \varepsilon_{(diff \rightarrow eff)}}$$

$$\varepsilon_{diff} \rightarrow C\sqrt{\frac{D}{\lambda.\,a^2}} \qquad \varepsilon_{eff} \sim \frac{1}{1+\lambda n(t_{vol}+t_{coll})}$$

Density and release properties of UCx targets on the fission product yields at ALTO







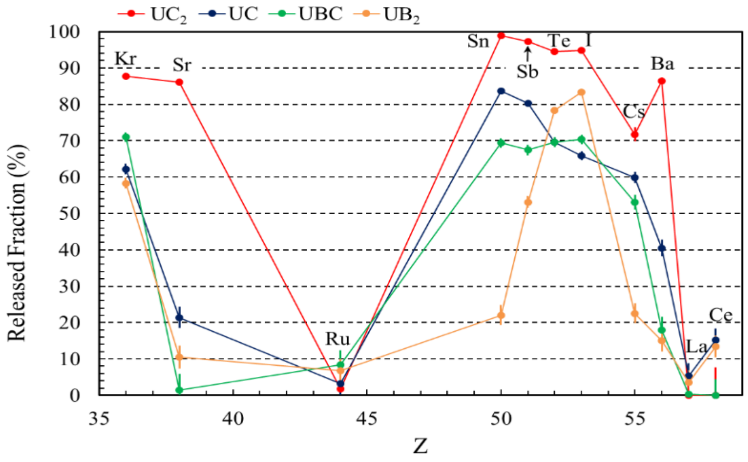
Exit rates of Kr, Sr, Sn, Sb, Te, I, Cs and Ba isotopes with half-life less than 100 seconds from targets Nos. 1 to 14 relatively to the target No. 8 as a function of the ratio of the diffusion coefficient in the target *n* over the diffusion coefficient in the conventional target. a) representation of the samples only carburized

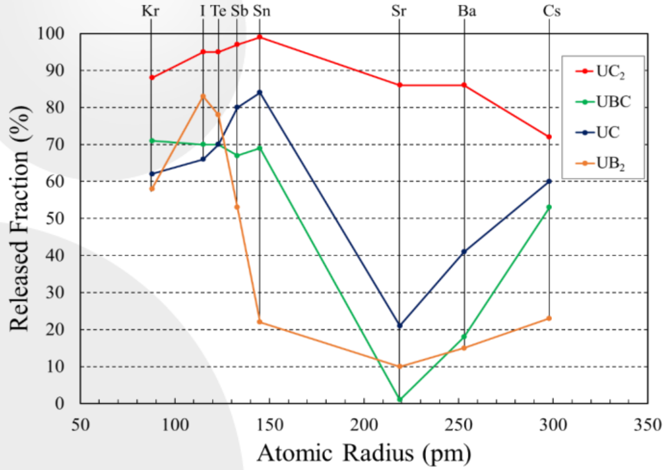
The new R&D target based on CNT is 3 times less dense than a conventional PARRNe target. For Sr, Cs and Kr the R&D target compensates its low density by its release efficiency.

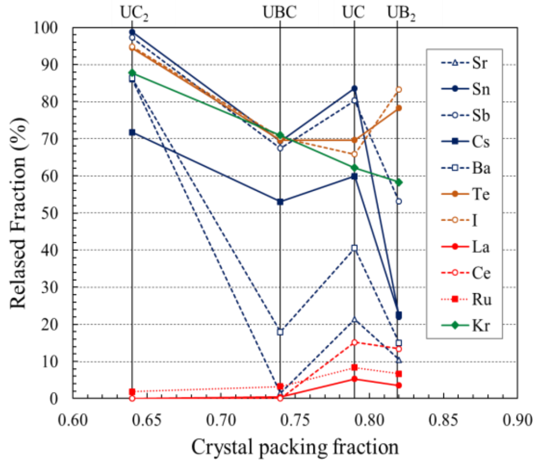
J. Guillot, B. Roussière et al., NIM B 468 (2020) 1
J. Guillot, B. Roussière et al., NIM B 440 (2019) 1
J. Guillot, B. Roussière et al., NIM B 433 (2018) 60

STudies of Uranium Compounds (STUC) → Release properties crystal structures

Experiment performed in July 2023 with protons at 26 MeV

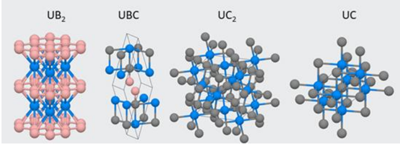






In this study, four uranium compounds (UC_2, UC, UBC and UB_2) were synthesized to investigate the release behavior of 11 fission-derived elements.

- Analysis of the experimental results showed that crystal packing fraction and atomic size influence the release of the elements.
- Krypton, a noble gas, shows a linear relationship between its release fraction and the crystal packing fraction.



In contrast, the release of the other elements is influenced in a complex way by the chemical environment and the atomic size. A study of the correlations between the physico-chemical properties of the elements revealed that chemical properties control the mobility and reactivity of elements.

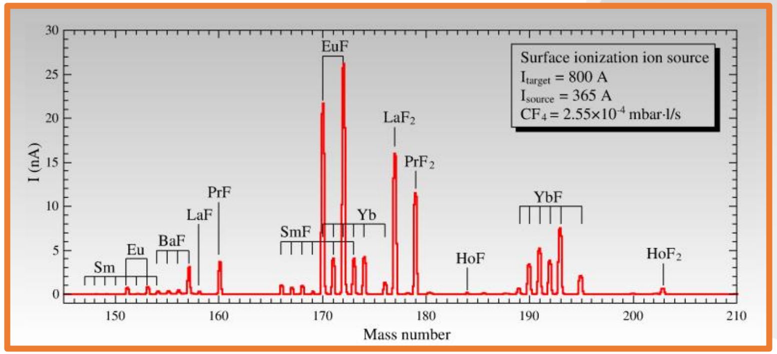
J. Guillot, B. Roussière et al., NIM B 559 (2025) 165600

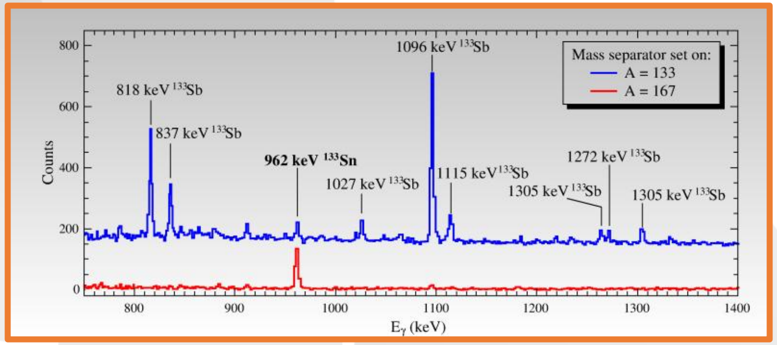
Interest of the molecular beam technique:

- ✓ To improve the release of refractory elements by forming molecular compounds more volatile than the elements
- ✓ To purify by mass-separation a beam by forming a chemical compound with only one of the isobars
- ✓ To reduce the effusion time

Experimental procedure

Molecular beams are obtained at ALTO by adding CF4 or S in gaseous form into the graphite container well adapted to the short target configuration and composed of three parts: the gas inlet section, the target chamber and the tube.CF4 is introduced using a gas-inlet system composed of four calibrated leaks manually adjustable, without any electronic component inside and thus resistant to the hard on-line running conditions. S is introduced using an ancillary oven located inside the target + ion-source system.





B. Roussière, et al.

FRISAL project : Robotic Frontend for ALTO-LEB

- **Objectives of phase 1**
  - Increase Frontend reliability for RIB production
  - Upgrade of the RIB acceleration from 30 kV to 60 kV
  - New Frontend mechanics adapted to the robot
  - 2023 upgrade of high power cables
    → stability of the temperature applied on the oven

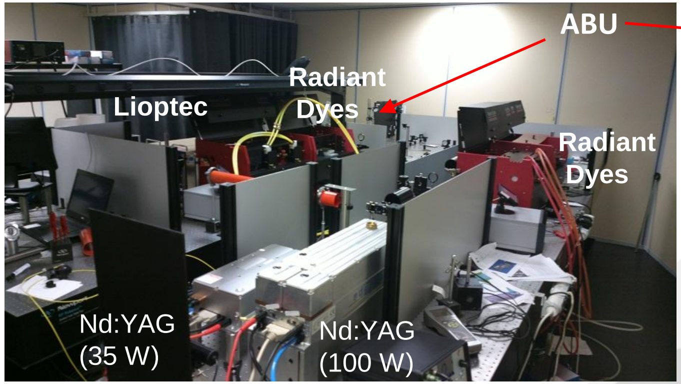
2019

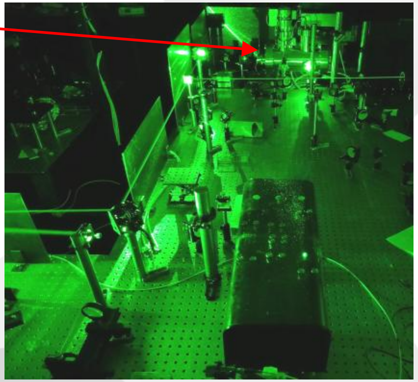
October 2022 : online commissioning

- **Objectives of phase 2**
  - Implementation of the Robot at ALTO-LEB
  - Increase the number of RIB experiments
  - 2023 : main movements validated
    → advanced tests at ALTO
  - Summer 2024 : first test in area of the target-ion source vault

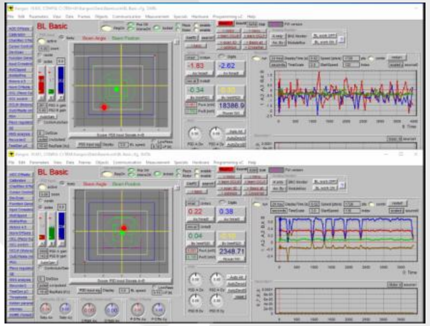
RIALTO : Laser Resonance Ionization Technique

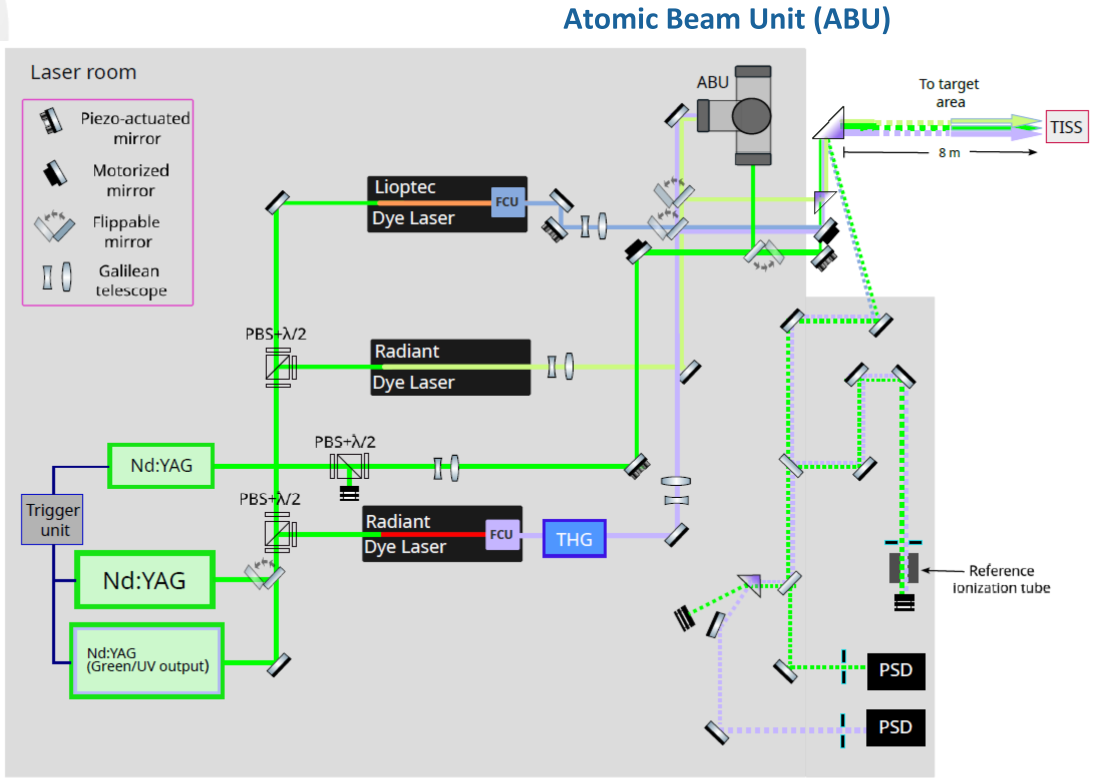
- 3 Edgewave Nd:YAG pumping laser (532 nm – 355 nm, 100W-32W-80W, 10 kHz rep rate, 10 ns pulse width)
- 2 Radiant Dyes + 1 Lioptec dye laser (540-900 nm), up to 5 W@20 W pumping, 10 ns pulse and 3 GHz linewidth
- 2 BBO doubling and tripling units (200- 475 nm), < 1 W





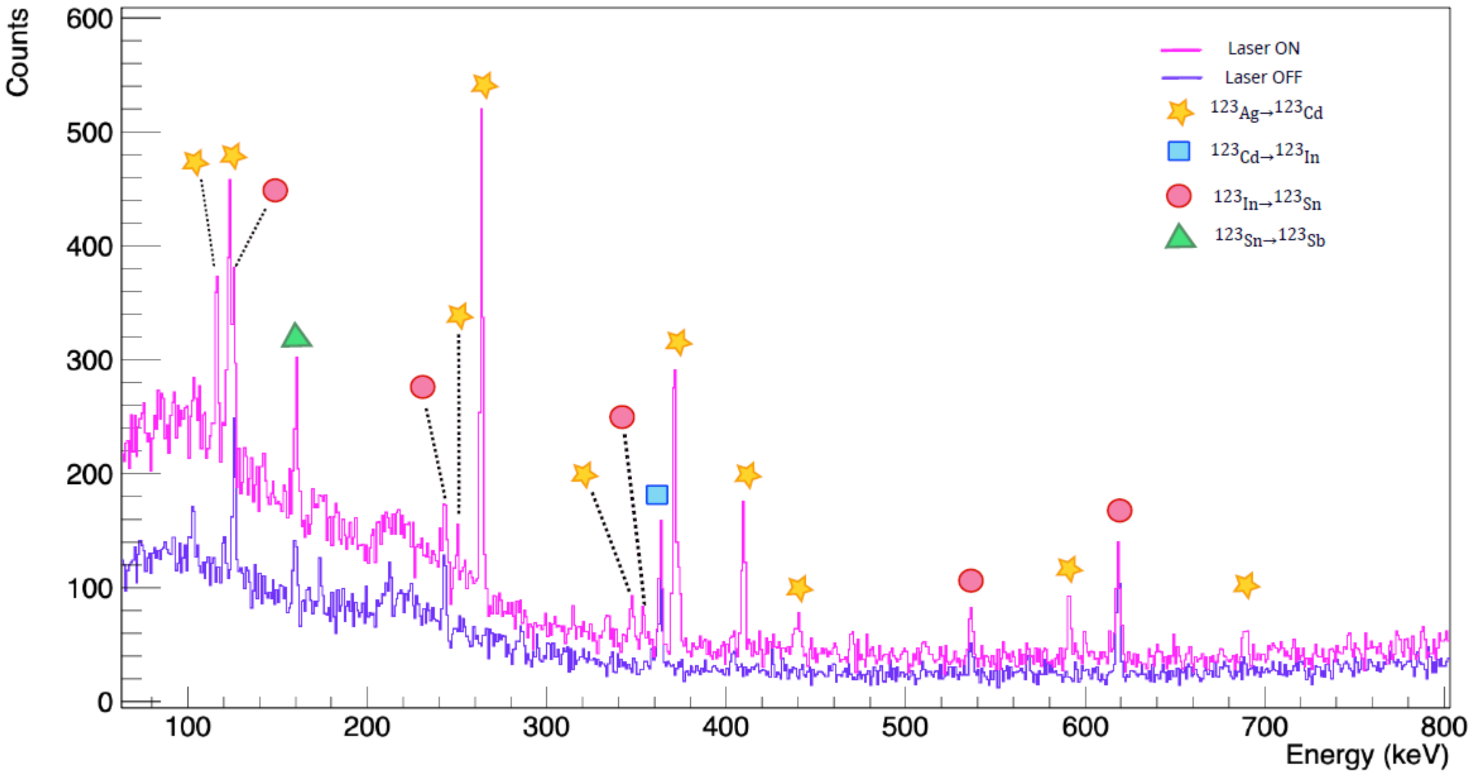
- Beam Distribution System upgraded
- Beam Stabilization System upgraded
- Tripling frequency for Zn, Sb
- Switch between both laser schemes performed

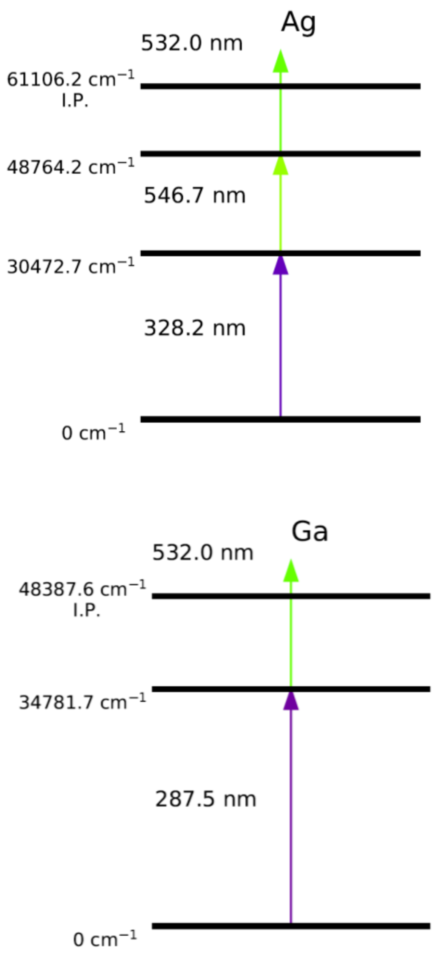




F. Le Blanc et al.

RIALTO : Laser Resonance Ionization Technique



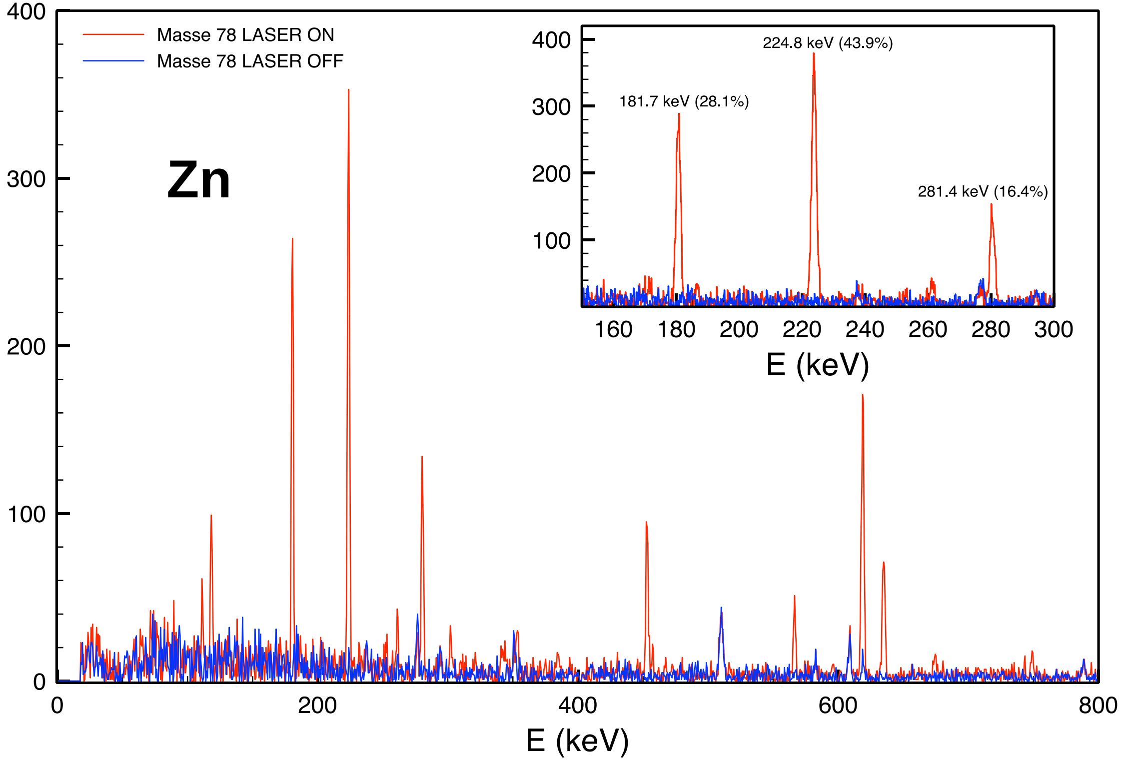


Experiment performed in November 2023

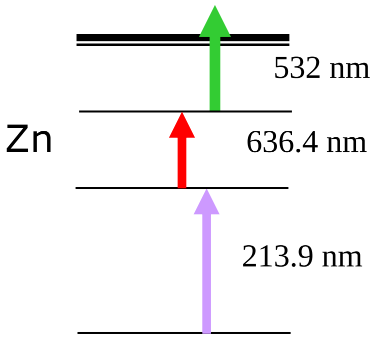
A. Segovia-Miranda et al., "Upgrades of the RIALTO facility and recent laser-ionized beams of radioactive gallium and silver isotopes", Nuclear Instruments and Methods in Physics Research A 1080 (2025) 170785

RIALTO : Laser Resonance Ionization Technique

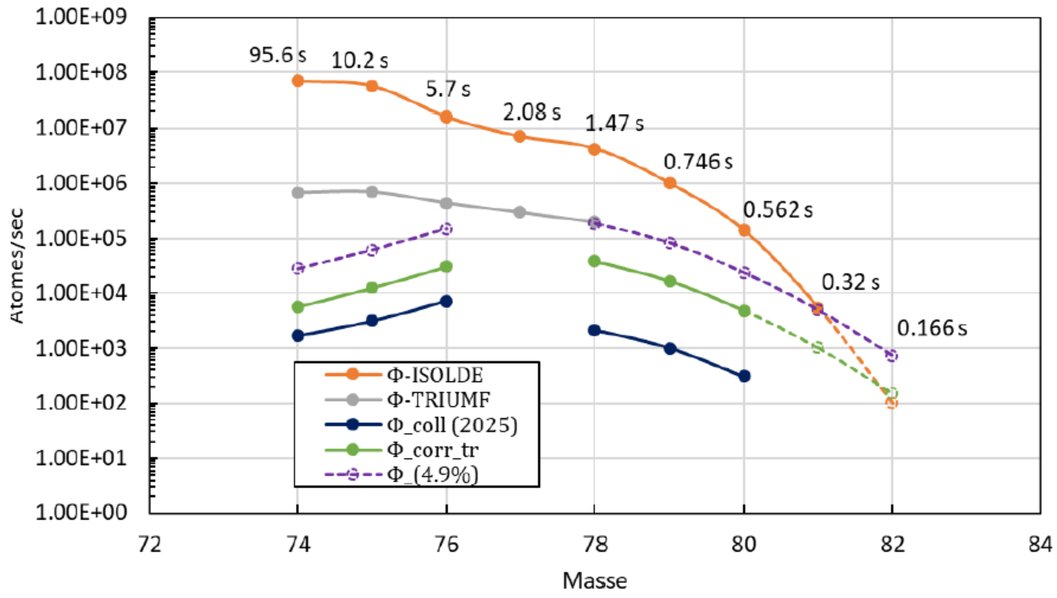
Radioactive beams of Zn and Ga at ALTO



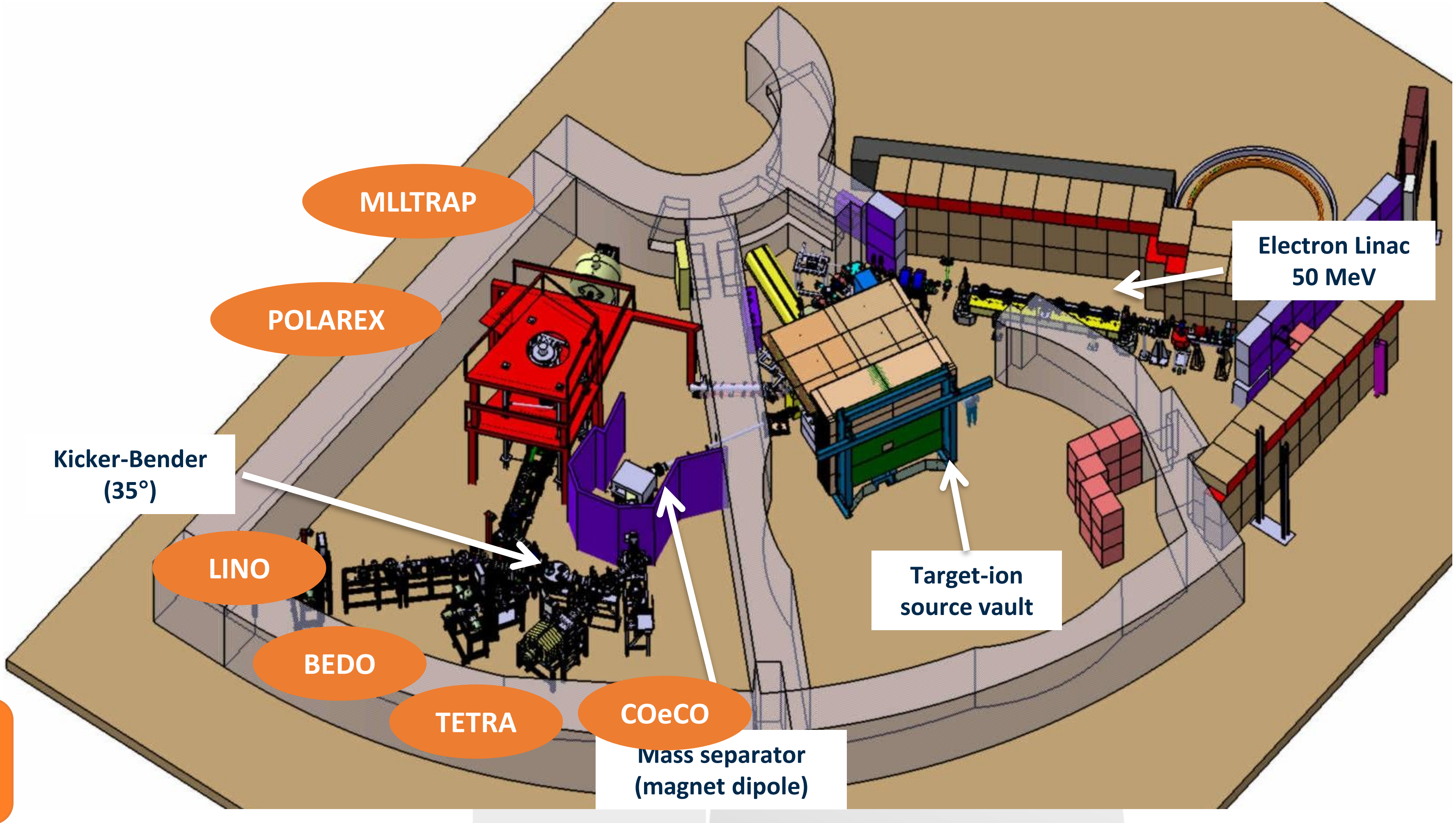
Experiment performed in February 2025



Zinc production



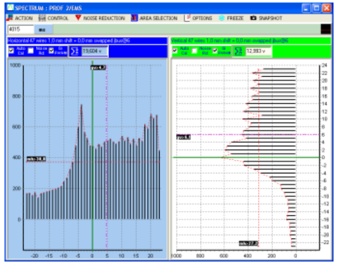
J. Guillot

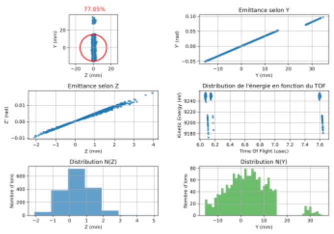

MLLTRAP
POLAREX
Kicker-Bender
(35°)
LINO
BEDO
TETRA
COeCO
Mass separator
(magnet dipole)
Target-ion
source vault
Electron Linac
50 MeV

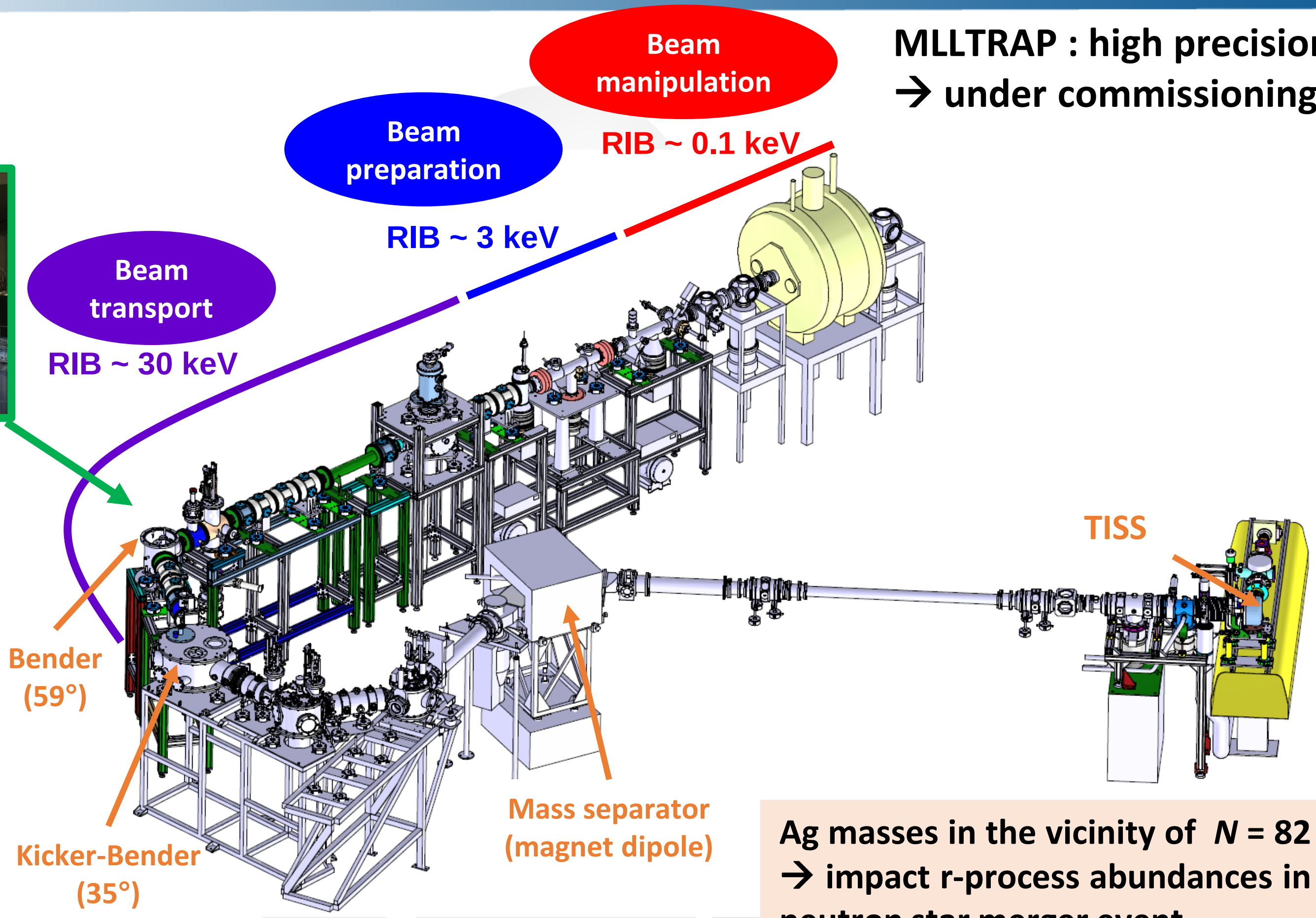
ALTO - LEB

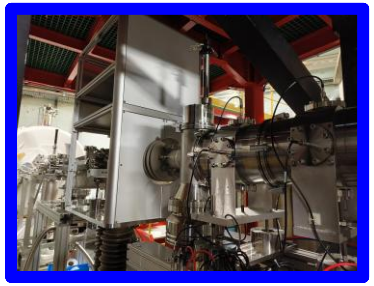
ALTO-LEB : MLLTRAP

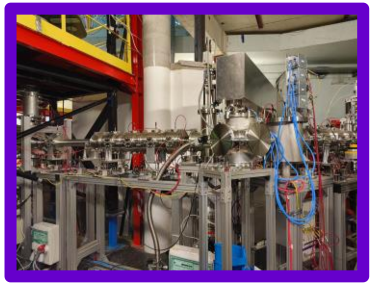
MLLTRAP : high precision mass measurements
→ under commissioning









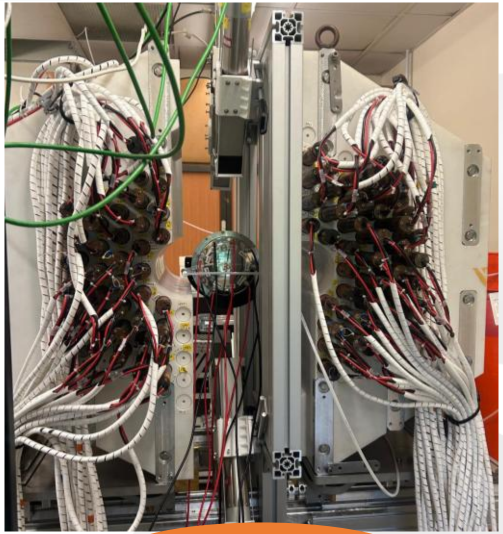


Ag masses in the vicinity of $N = 82$
→ impact r-process abundances in neutron star merger event

High voltage alkali ion source
Measurement campaign with the Emittancemeter from IPHC Strasbourg

ALTO-LEB : BESTIOL

COeCO



TETRA

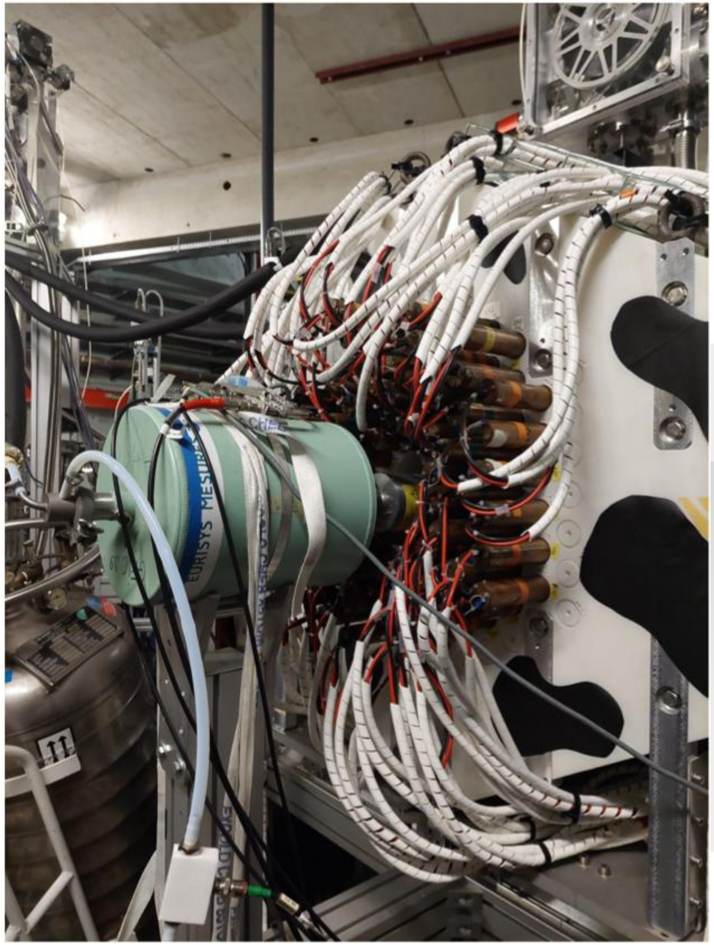
BEDO / MONSTER

COeCO : identification station → conversion electron spectroscopy (COeCO)
G. Tocabens et al. PRC 111 (2025) 034306 → Extraction of E0 transition strengths and their use in a two-state mixing model to deduce changes in mean-square charge radii in Zr.

TETRA : neutron detection / 80 ^{3}He tubes $\varepsilon(^{252}Cf) = 53\%$ borated polyethylene shielding
2023 → Probability measurements of β-delayed neutron emission (P_n) for silver isotopes

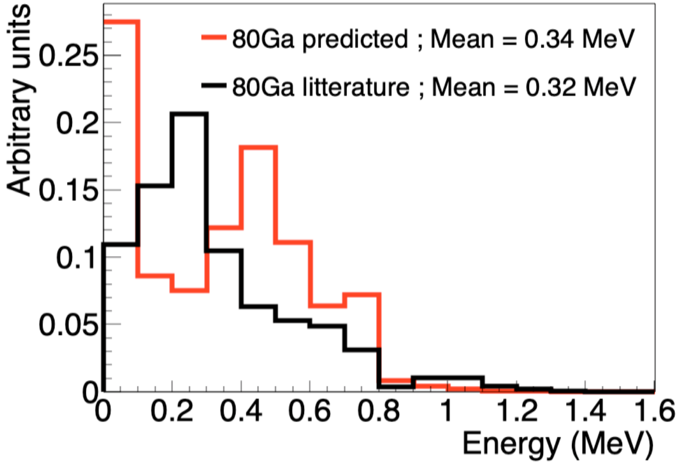
BEDO : (**BE**ta **D**ecay studies in **O**rsay) / up to 5 Ge detectors (ε = 5-6%) 4π β trigger /Fast-timing studies using $LaBr_3$ detectors
In February 2025 : Installation of the **MO**dular **N**eutron time-of-flight **S**pectrome**TER** (MONSTER) → Zn beam

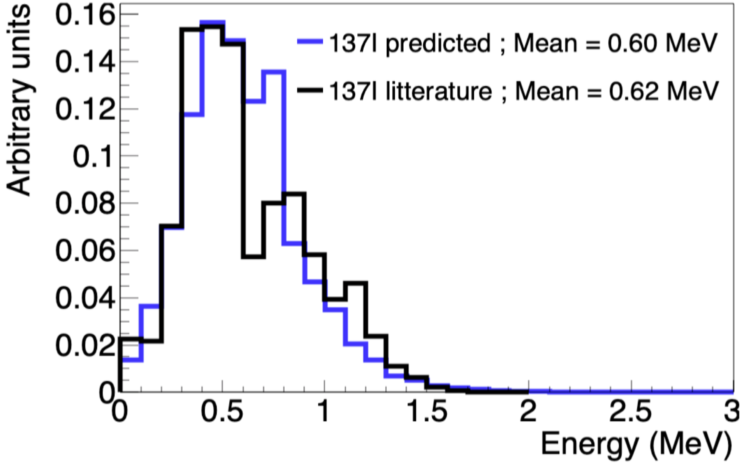
TETRA



Nov. 2023 Measurements of P_n et P_{2n} for silver isotopes, ^{84}Ga and ^{84}Ge:

Measurement of the average neutron energy





Reconstruction of the emission spectrum:

Bayesian method for deconvolving the TETRA response

E. Cantacuzène *et al.,* N.I.M. in preparation

ALTO-LEB : COeCO

Conversion electron spectroscopy was performed in two Zr isotopes in the transitional region around N = 60, ^{98}Zr and ^{100}Zr, in a decay spectroscopy experiment using the COeCO setup at the ALTO facility. This experiment enabled to reinvestigate electric monopole transitions from the first excited 0+ states to the ground-state of said isotopes.

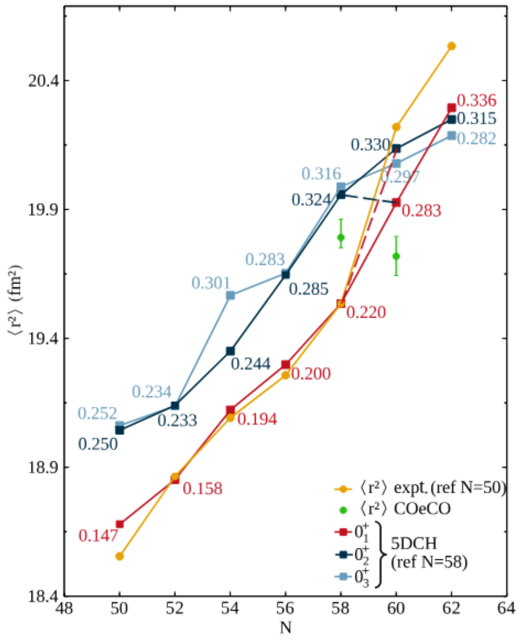


FIG. 7. Comparison between experimental (yellow full circles) and theoretical values—computed within the 5DCH model using the Gogny D1M interaction—(full squares) for the mean-square charge radii of Zr isotopes as a function of neutron number. The values for the first excited 0^+ states obtained in this work are reported as green full circles. Computed values for the β_2 deformation parameter are indicated in color. Theoretical values are normalized to the experimental value for ^{98}Zr, at $N = 58$; see text for details and explanations on the dashed lines.

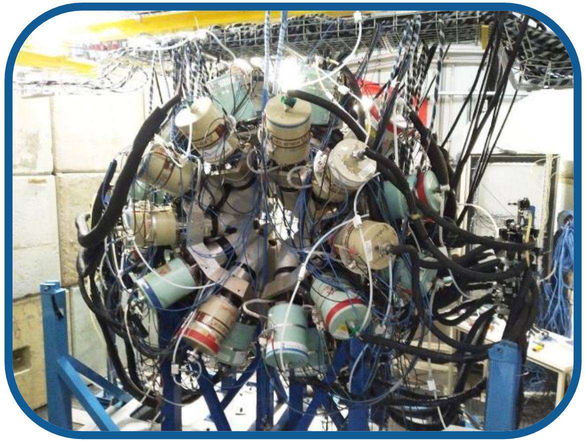
A new value for the half-life of the first excited state in ^{98}Zr as well as new branching ratios for the two transitions depopulating the first excited 0+ state in ^{100}Zr were reported.

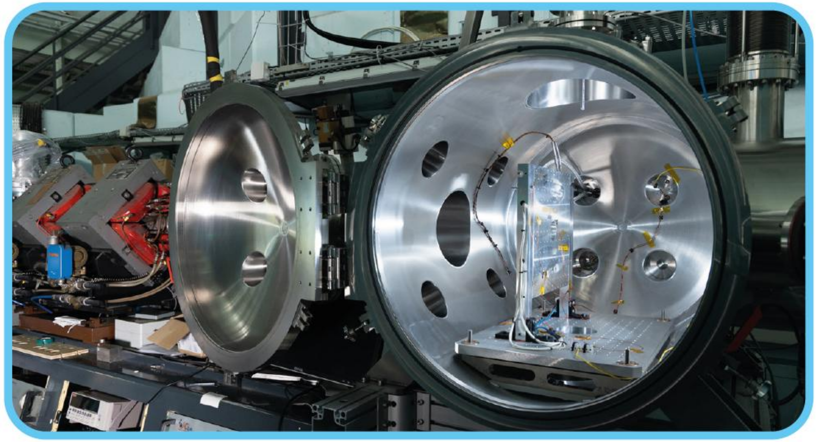
These new measurements allowed to extract two new values for the strengths of the E0 transitions, ρ2 ($0^+_2 \rightarrow 0^+_1$), lower than reported values in literature. Validation and comparison with beyond-mean-field (5DCH-D1M) theoretical calculations, which qualitatively support the experimental findings but show limitations in deformation predictions.

G. Tocabens et al. Phys. Rev. C 111 (2025) 034306

Talk by G. Tocabens 22/09 at 17h40

Conclusion





- Project of reliability and sustainability of ALTO ongoing
- R&D on stable and radioactive beams
- SPACE ALTO is now in operation
- Installation of new instruments for short and long periods
- Next call for proposals winter 2025 / Next PAC ALTO February-March 2026

Thank you for your attention !