GANIL

RIB development at SPIRAL1

Pierre Chauveau & the Target Ion-Source group

Introduction/outline

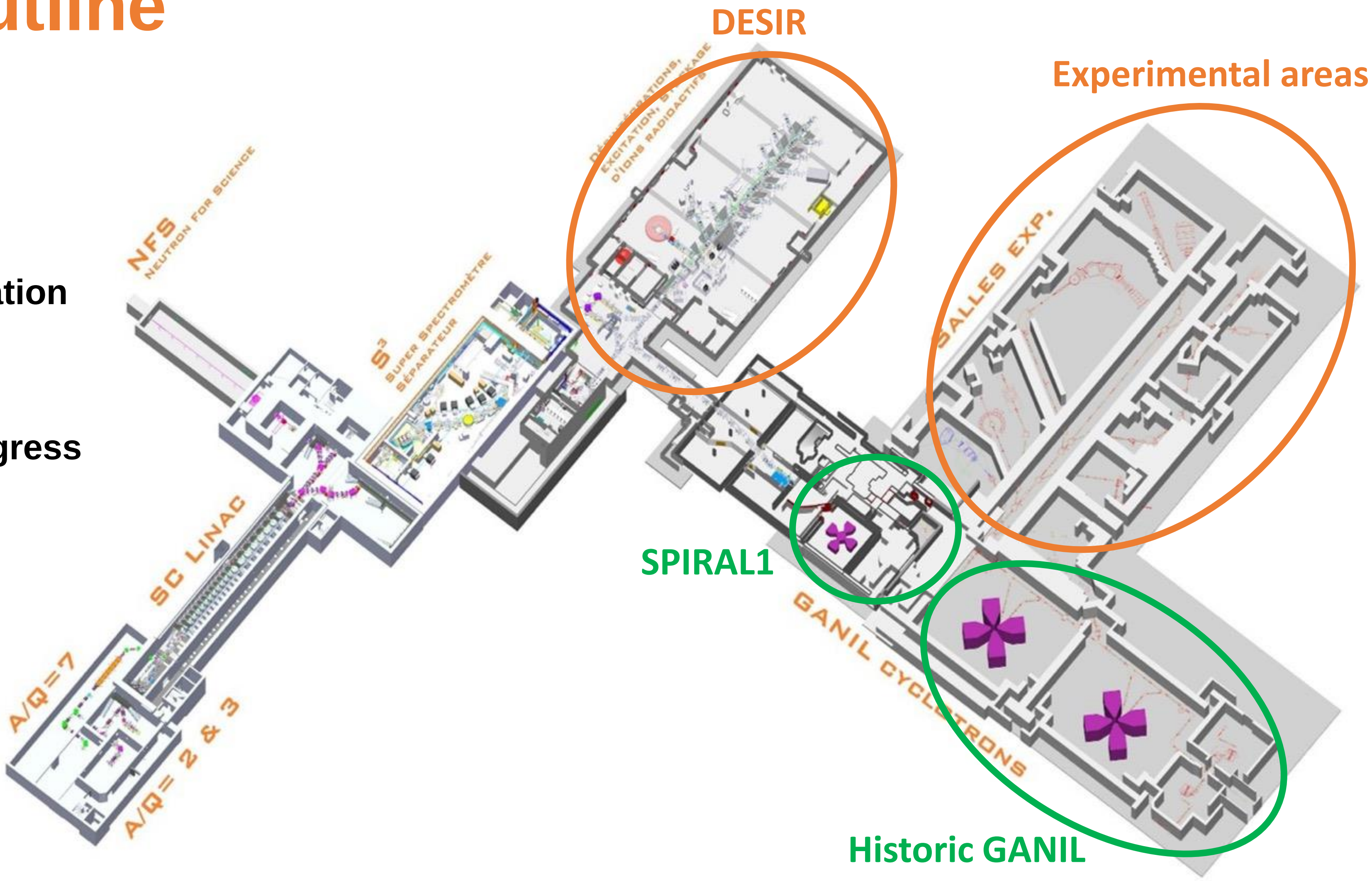
I. **Stable beams for SPIRAL1**

II. **Reminder: SPIRAL1 configuration and capabilities**

III. **Target & ion sources and progress**

- MonoNaKe
- TULIP
- FEBIAD

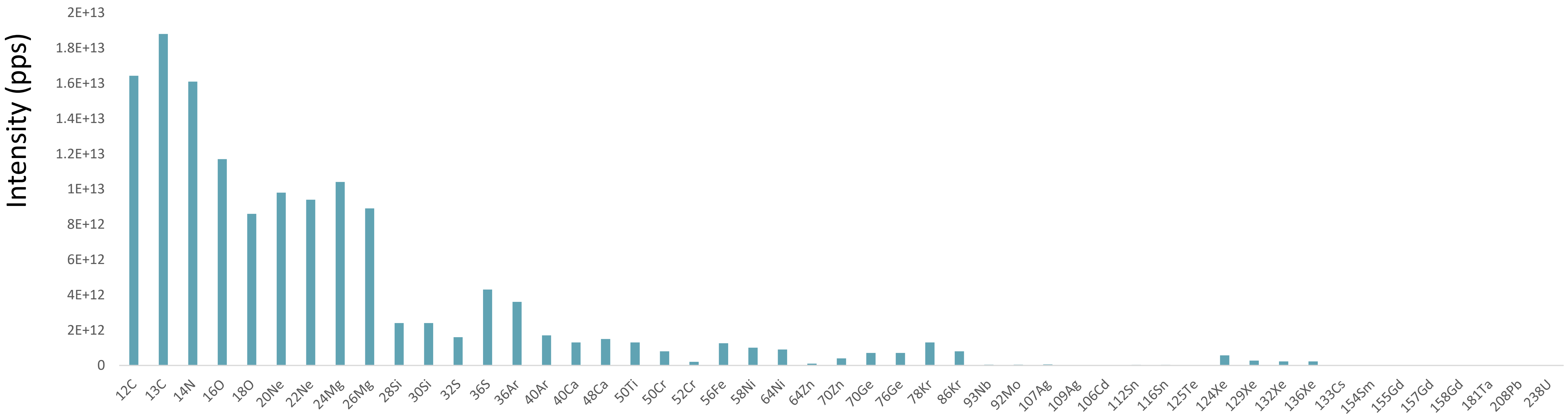
IV. **Beam Purity**



Stable beams for SPIRAL1

Possibilities

- All GANIL beams on ^{12}C target (^{12}C to ^{238}U, <95MeV/u, <2E13 pps) -> beam fragmentation
- ^{12}C beam on any target material up to Nb -> target fragmentation



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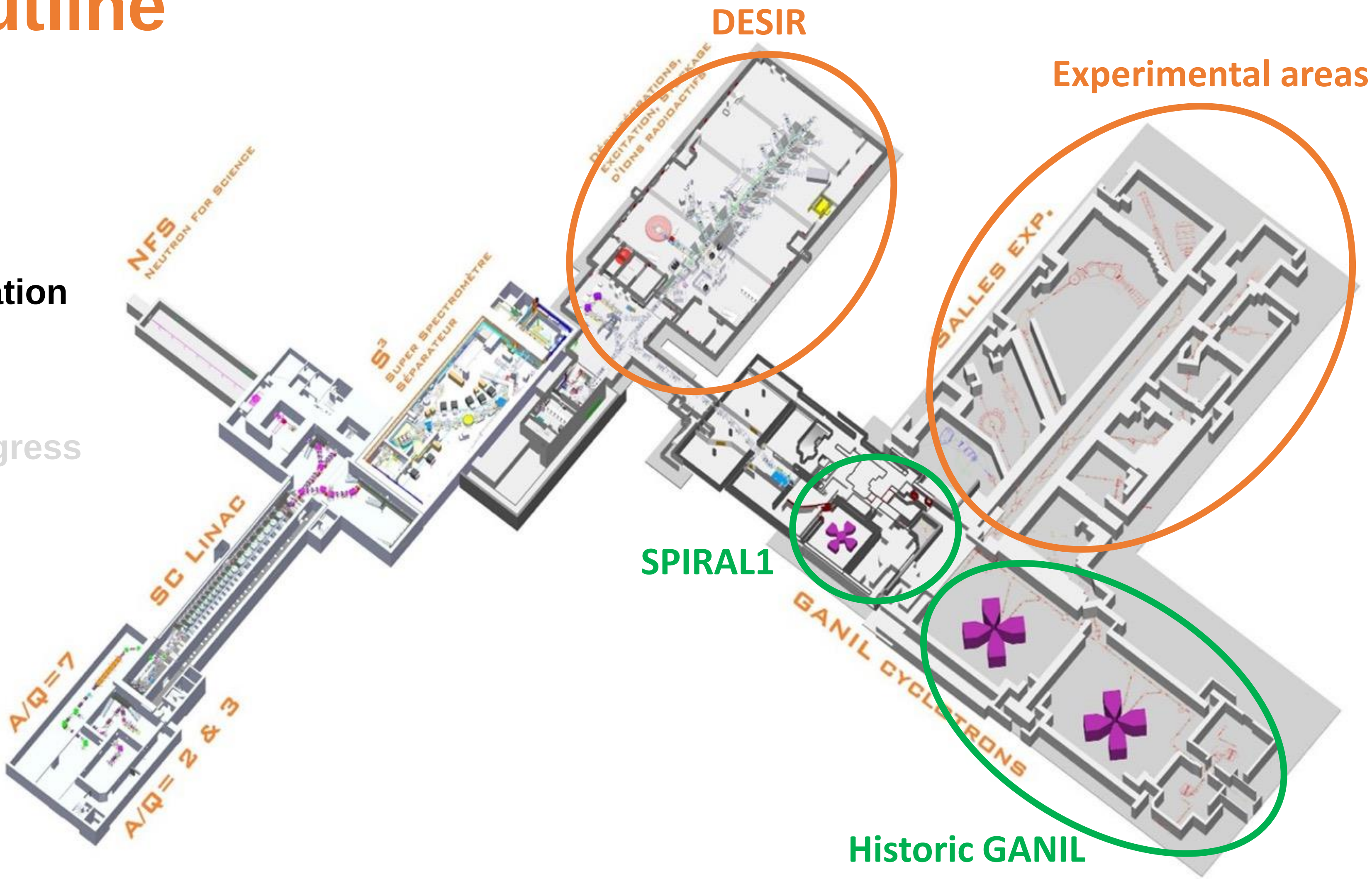
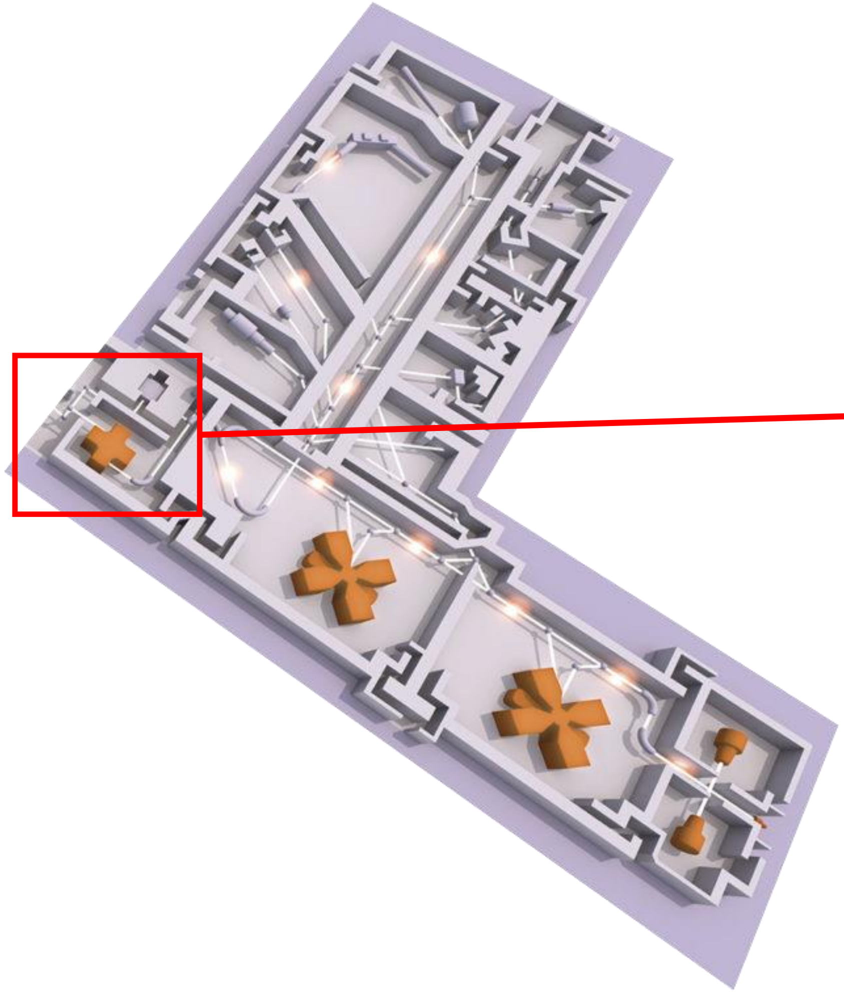
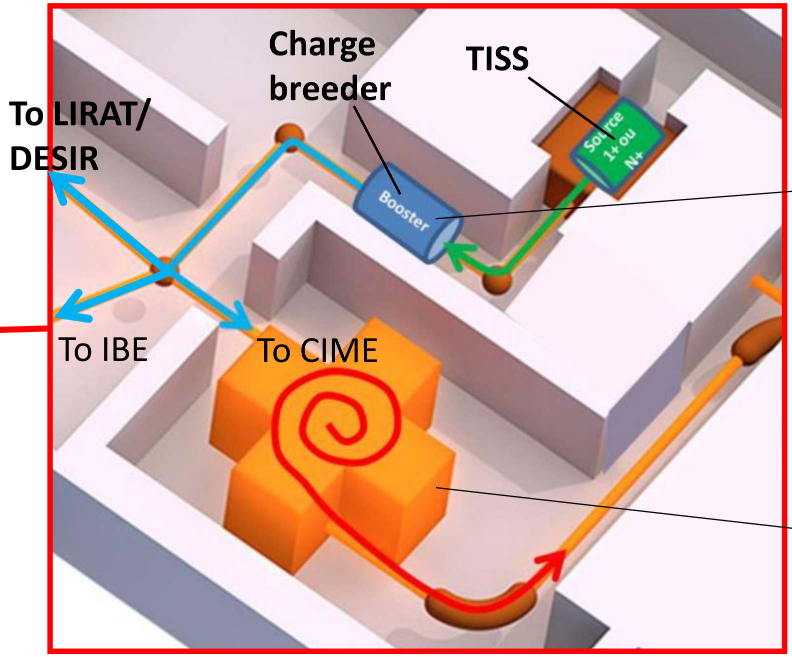
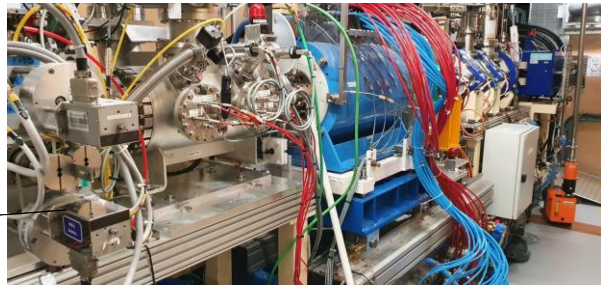


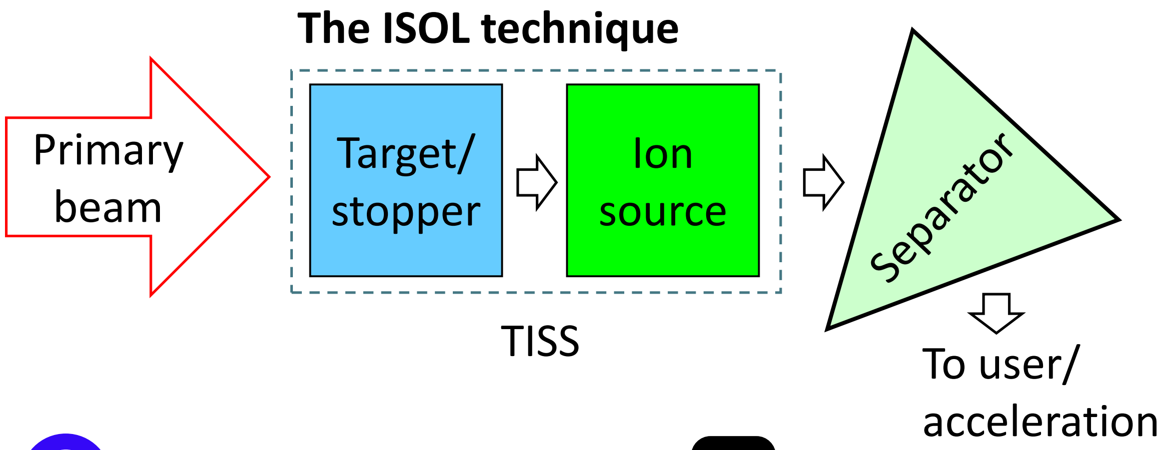
SPIRAL1



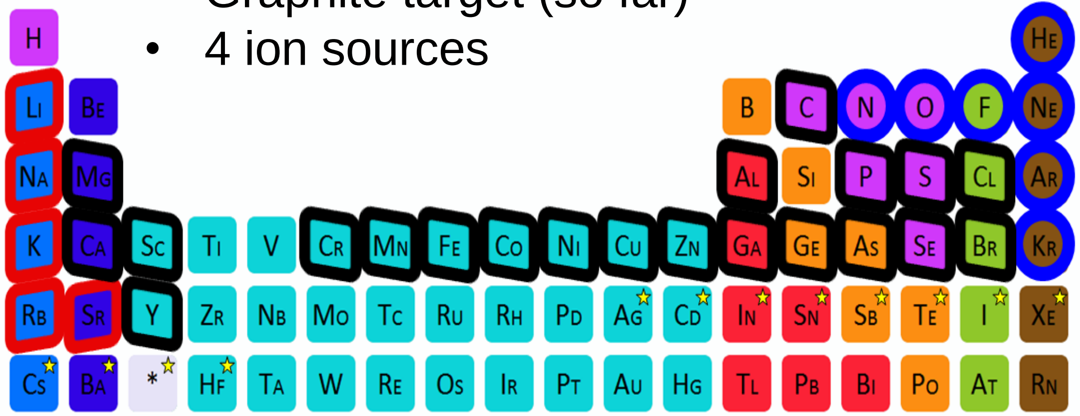




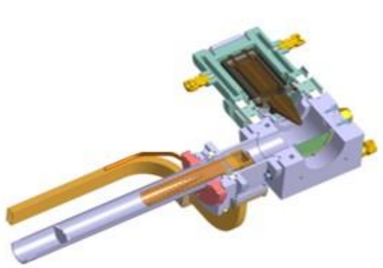
Beam production



- 58 primary beams from ^{12}C to ^{238}U
- Graphite target (so far)
- 4 ion sources

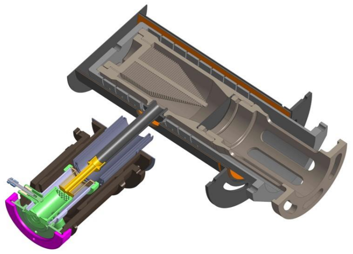


N+



Nanogan
For gaz

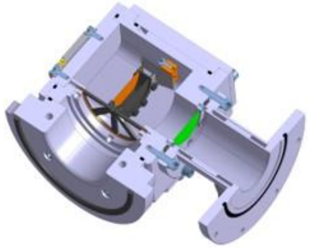
1+



FEBIAD
For condensable

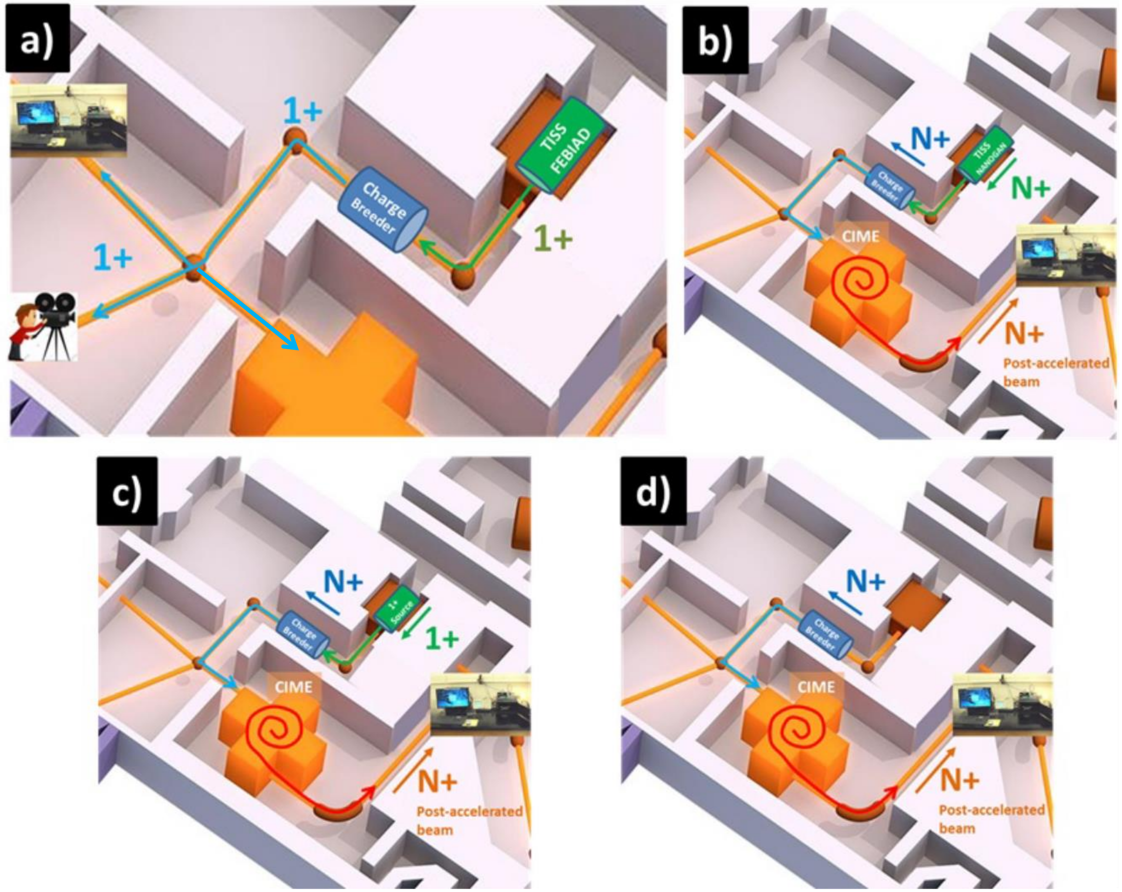
TULIP(-FEBIAD)
For proton rich isotopes

1+



MonoNaKe
For alkaline

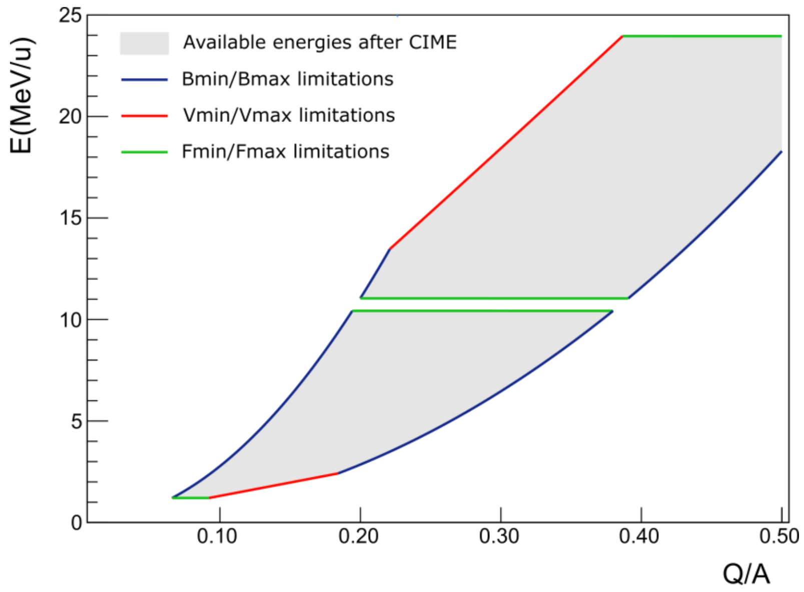
Operating modes

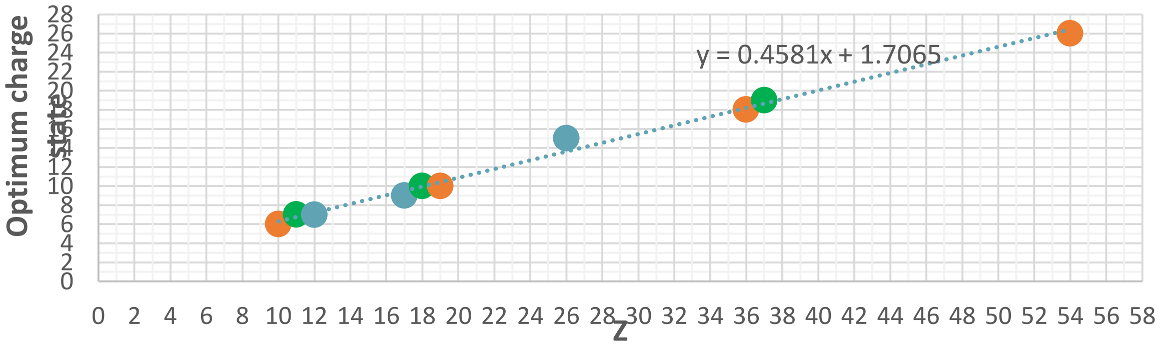


L. Maunoury *et al*, 2018 *JINST* **13** C12022

a) 1+ shooting through, for identification, low energy (10-20 keV) physics in LIRAT and since 2024, low energy (2 MeV/u) post-acceleration of very light ions (up to A≈12)
b) N+ shooting through for post-acceleration (up to 24 MeV/A)
c) 1+/N+ for post-acceleration
d) SP1CB as a source for post-acceleration tuning or experiments with stable or long-lived isotope beams (gaz only)
e) Using a 1+ TISS without primary beam as a source for stable beams (to tune CIME) or long-lived isotopes (batch mode)

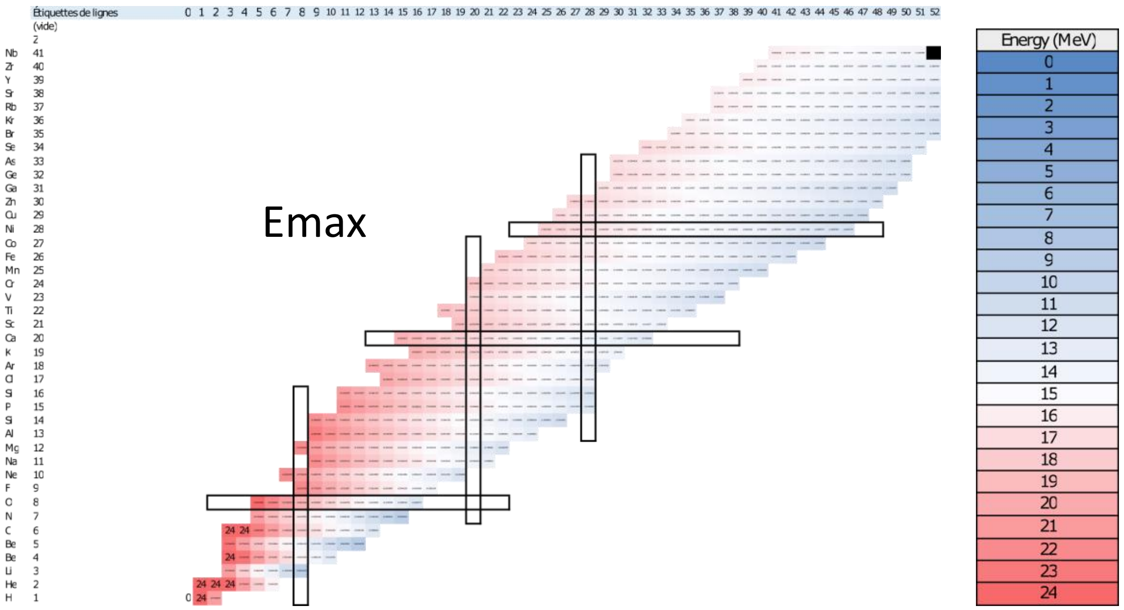
Acceleration





Up to 24 MeV/u, limited by:

- charge state distribution at the output of the charge breeder
- platform limitations



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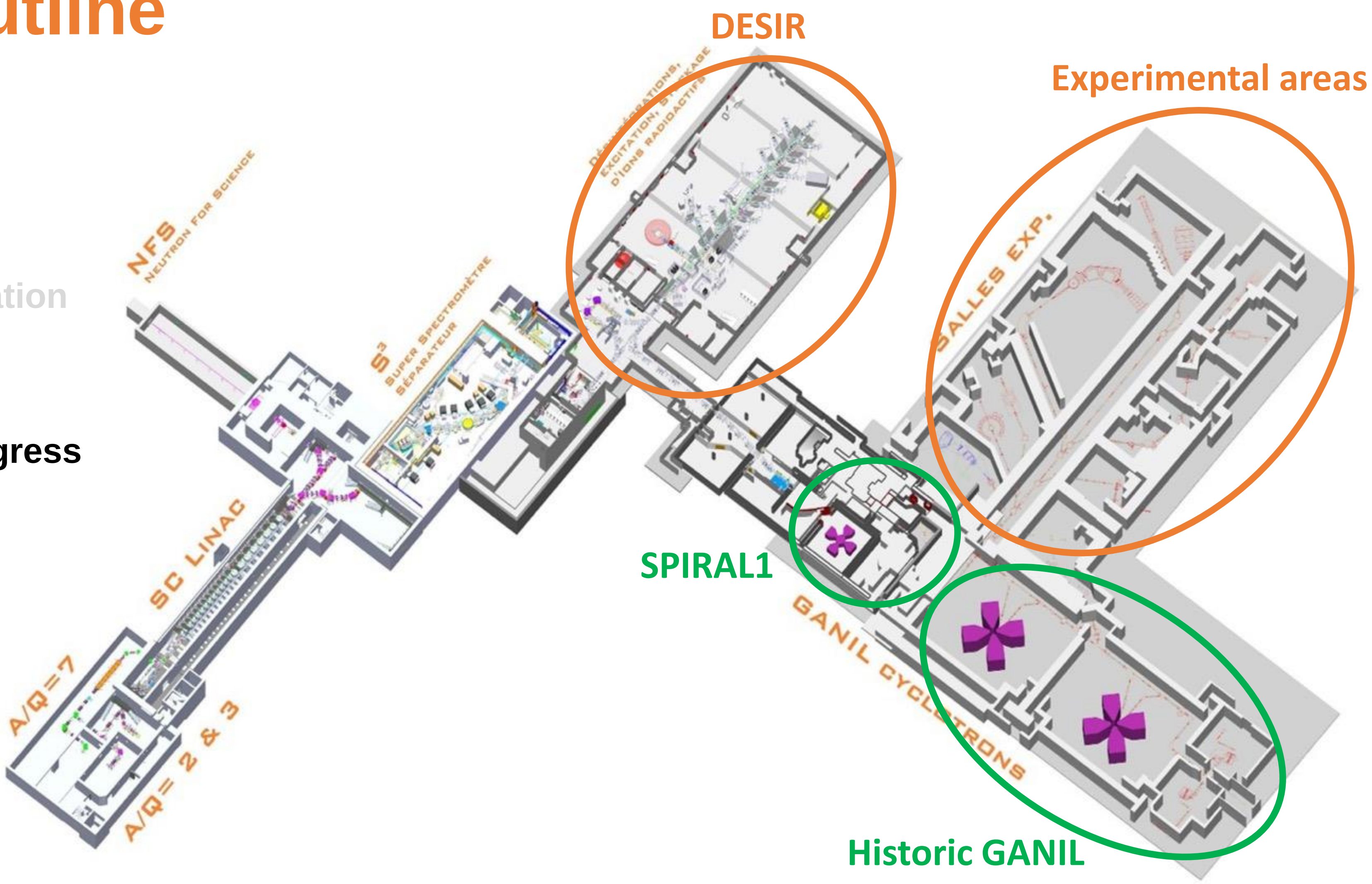
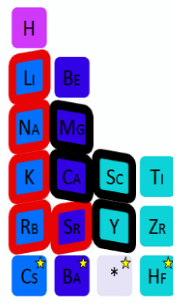


MonoNaKe (credit P. Jardin) Thick target + SIS



Low ionization potential atom
+
High work function surface
= Surface ionization

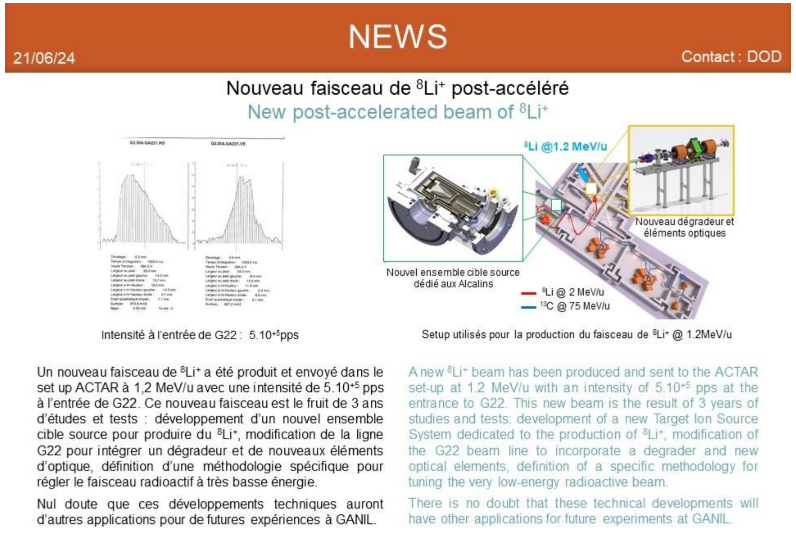
Designed and tested in 2006

Recently, interest for Li beams

- Successful production test of ^{8}Li (**2e7pps**) and ^{9}Li (**1e5pps**) at low energy in 03/2024
- Successful experiment with post-acc. ^{8}Li (**5e5pps** at 1.2MeV/A) in 06/2024

In the future

- Development and tests with Re ionizer to enable other elements



NEWS

21/06/24 Contact : DOD

Nouveau faisceau de $^{8}Li^{+}$ post-accéléré

New post-accelerated beam of $^{8}Li^{+}$

Intensité à l'entrée de G22 : 5.10^{+5}pps

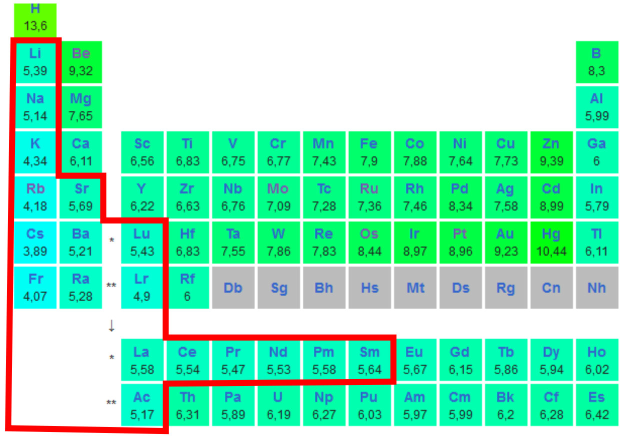
Setup utilisés pour la production du faisceau de $^{8}Li^{+}$ @ 1.2MeV/u

Un nouveau faisceau de $^{8}Li^{+}$ a été produit et envoyé dans le set up ACTAR à 1,2 MeV/u avec une intensité de 5.10^{+5} pps à l'entrée de G22. Ce nouveau faisceau est le fruit de 3 ans d'études et tests : développement d'un nouvel ensemble cible source pour produire du $^{8}Li^{+}$, modification de la ligne G22 pour intégrer un dégradeur et de nouveaux éléments d'optique, définition d'une méthodologie spécifique pour régler le faisceau radioactif à très basse énergie.

Nul doute que ces développements techniques auront d'autres applications pour de futures expériences à GANIL.

A new $^{8}Li^{+}$ beam has been produced and sent to the ACTAR set-up at 1.2 MeV/u with an intensity of 5.10^{+5} pps at the entrance to G22. This new beam is the result of 3 years of studies and tests: development of a new Target Ion Source System dedicated to the production of $^{8}Li^{+}$, modification of the G22 beam line to incorporate a degrader and new optical elements, definition of a specific methodology for tuning the very low-energy radioactive beam.

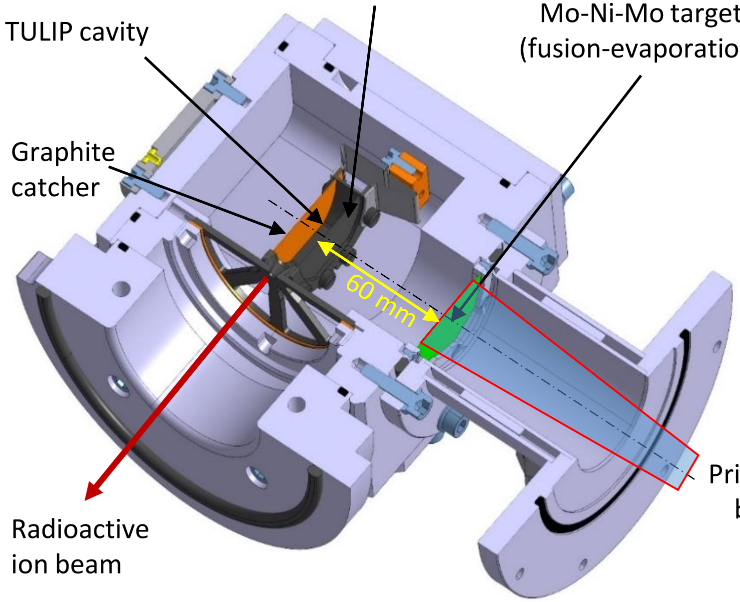
There is no doubt that these technical developments will have other applications for future experiments at GANIL.



TULIP (credit P. Jardin) Thin ^{58}Ni target + SIS

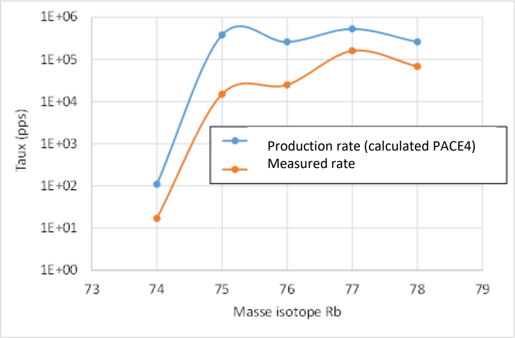
TULIP cavity

Mo-Ni-Mo target
(fusion-evaporation)



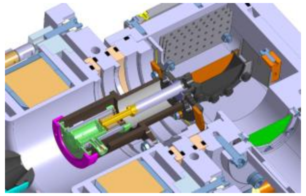
On-line test 2023: production of $^{74-78}Rb^+$ ions (≈10%)

Isotope mass	T1/2	LE rate (pps)	
	s	mars-22	juillet 23
74	64,76 ms		1,7E+01
75	19 s		1,5E+04
76	36,8 s	3,80E+03	2,5E+04
77	3,78 m		1,6E+05
78	5,74 m/ 17,66 m	5,80E+04	6,8E+04



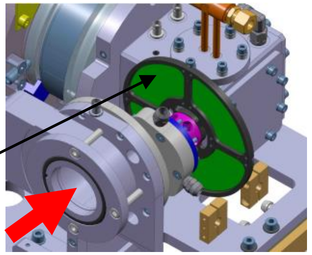
Ongoing

- Off-line test of the TULIP-FEBIAD coupling (metallic ions) + rotating wheel (production x7)



In the future

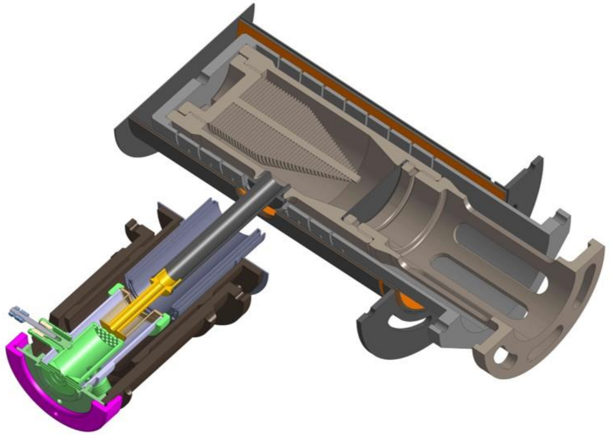
- Off line test of Re ionizer
- On-line production of ^{74}Rb (2025?)
- On-line test of the TULIP-FEBIAD with a ^{54}Fe target and a ^{14}N beam (2026?)



FEBIAD

GANIL

Thick target + Ionization by electron impact (non selective) / surface ionization

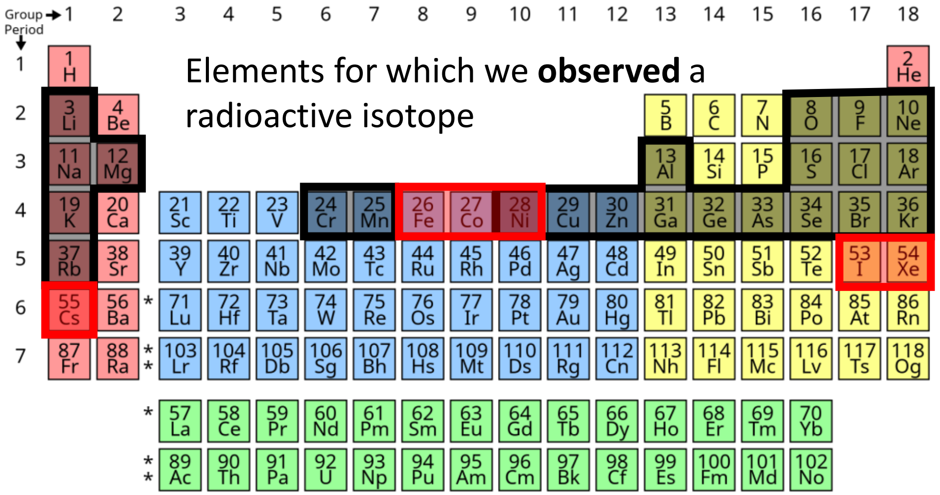


Since 2021

- Irradiated with ^{48}Ca (2021), ^{36}Ar, ^{84}Kr (2022), ^{50}Cr (2023), ^{58}Ni (2024), ^{129}Xe (2024)
- 100+ radioactive isotopes/isomers **seen**, including around 60 at post-accelerable intensities (>1E5pps).
- ^{48,49}Cr produced for the first time in 2023
- Fe/Co/Ni beams produced for the first time in 2024
- « Heavy » ions produced in 09/2024

Isotope	Masse	lambda	T1/2(s)	taux
56Ni	56	1,31928E-06	525398,4	1,62E+06
55Co	55	1,09835E-05	63108	1,40E+07
57Ni	57	5,40845E-06	128160	2,23E+07
53Fe	53	0,001357515	510,6	1,66E+07
53Fe_m	53	0,00454821	152,4	1,44E+06
53Fe_m -> 53 Fe	53	0,00454821	152,4	1,27E+06

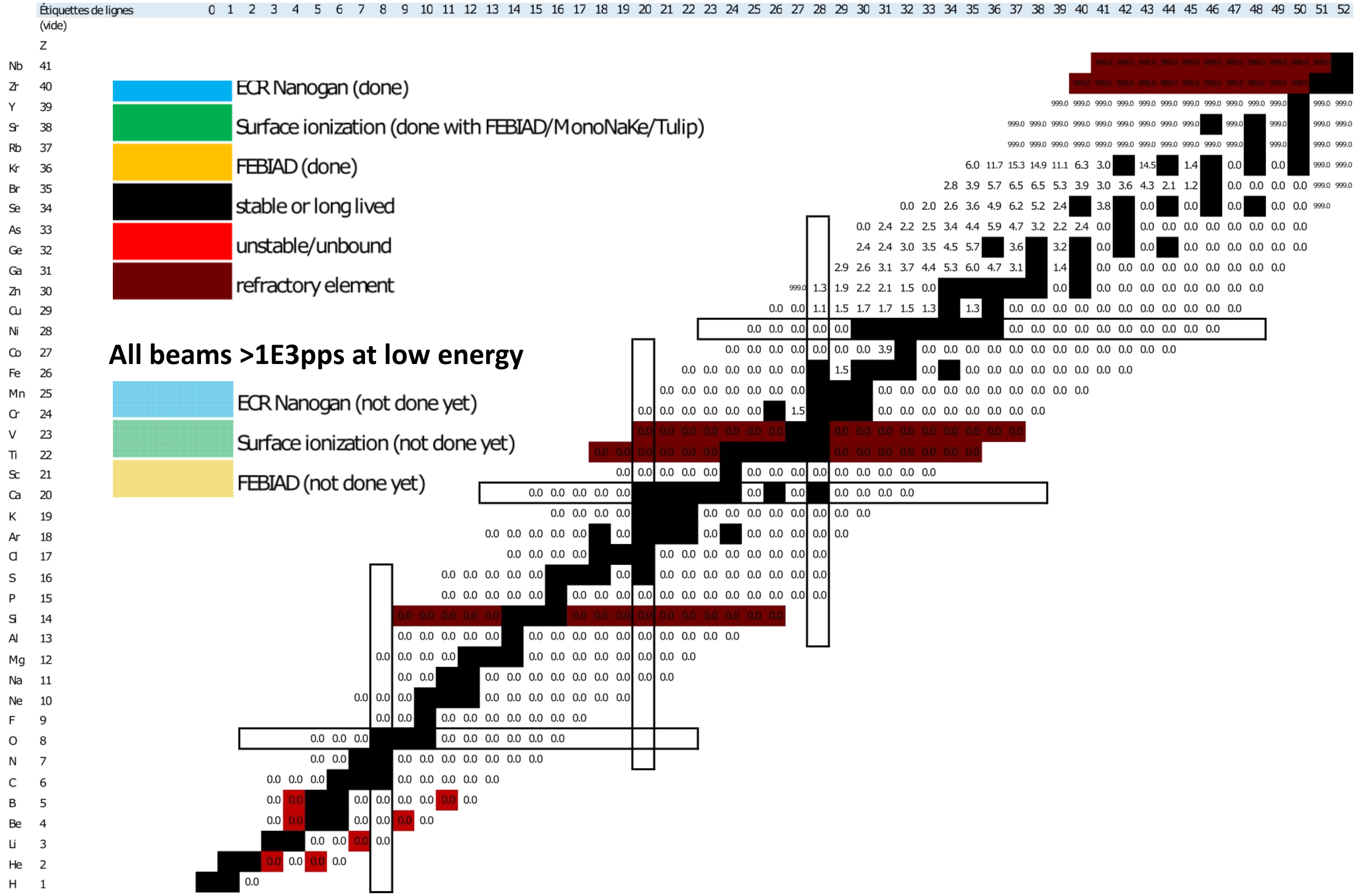
Credit: E. Le Villain. Preliminary results



In the future

- Experiment with post accelerated ^{48}Cr in 2025
- PhD project (E. Le Villain, started this month)
  - Optimized FEBIAD for Fe-Co-Ni beams
  - Purification by acceleration+stripping+spectrometer (09/2025)
- Post-doctoral project (S. Hurier, started this month)
  - New target development (Y, Zr, Nb ?) for ^{12}C irradiation
  - Proof of production

Production summary



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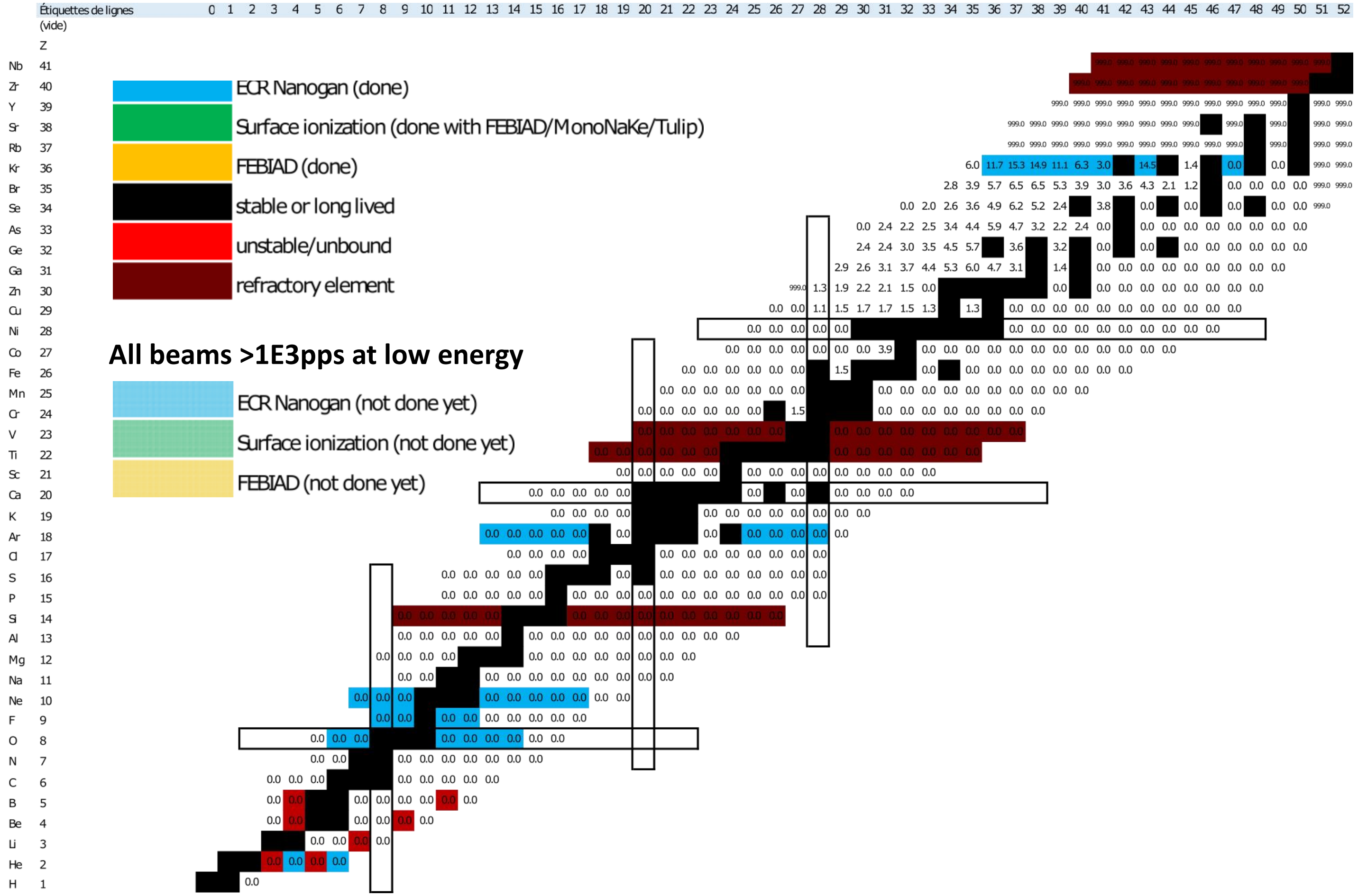

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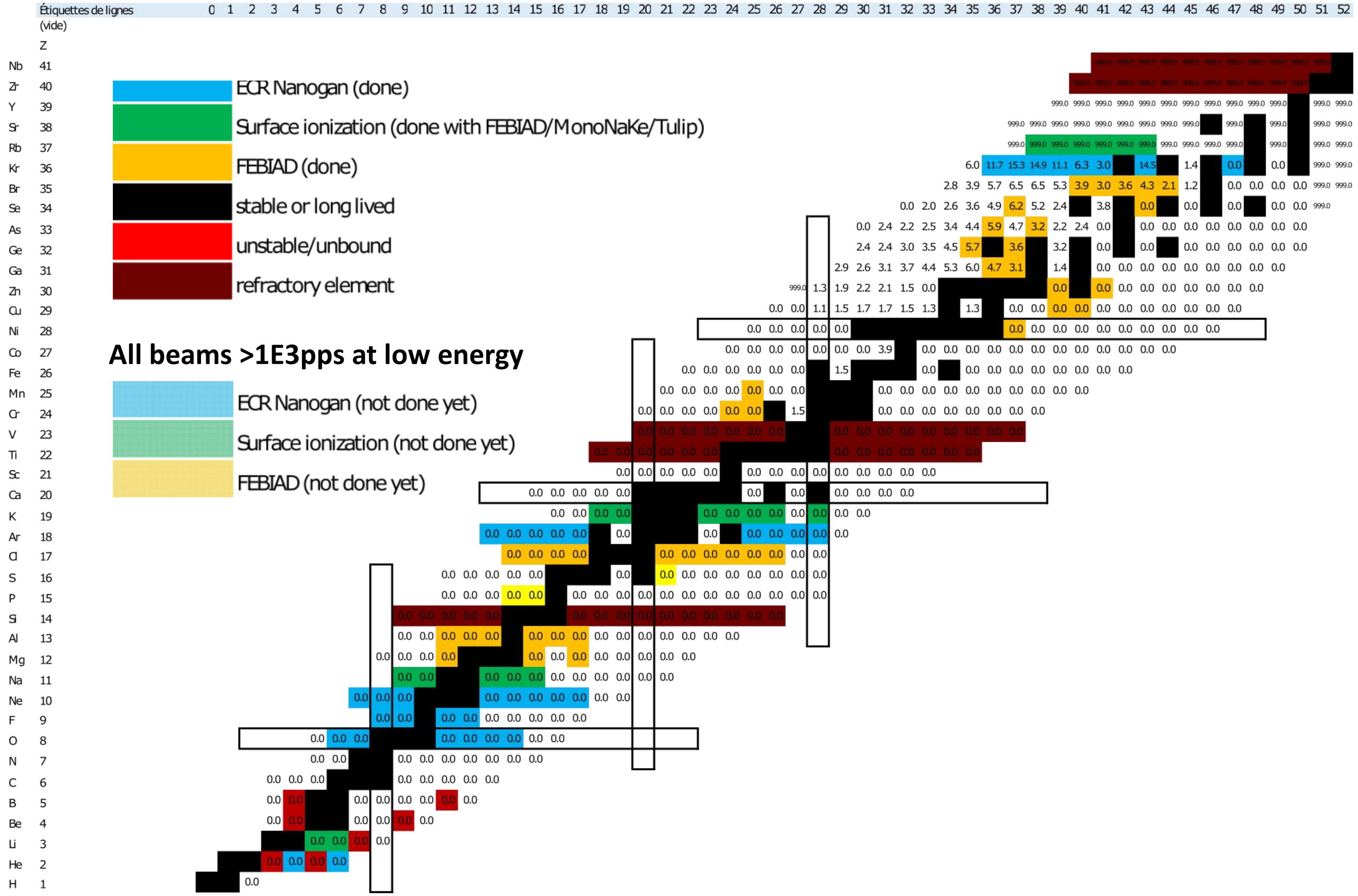

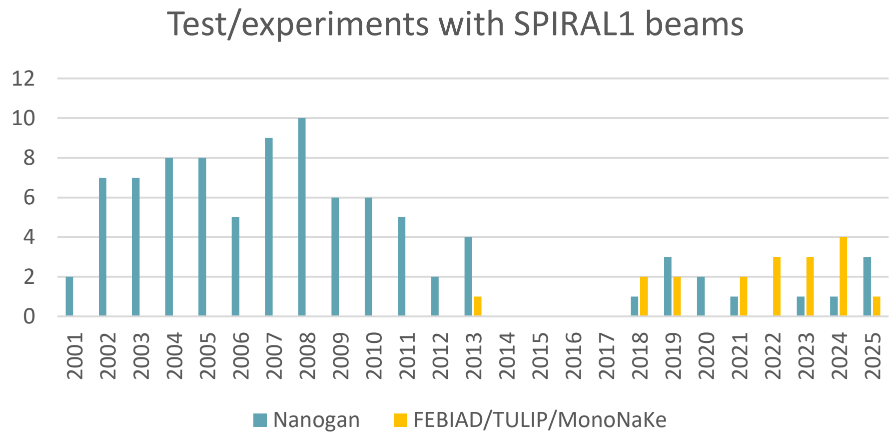

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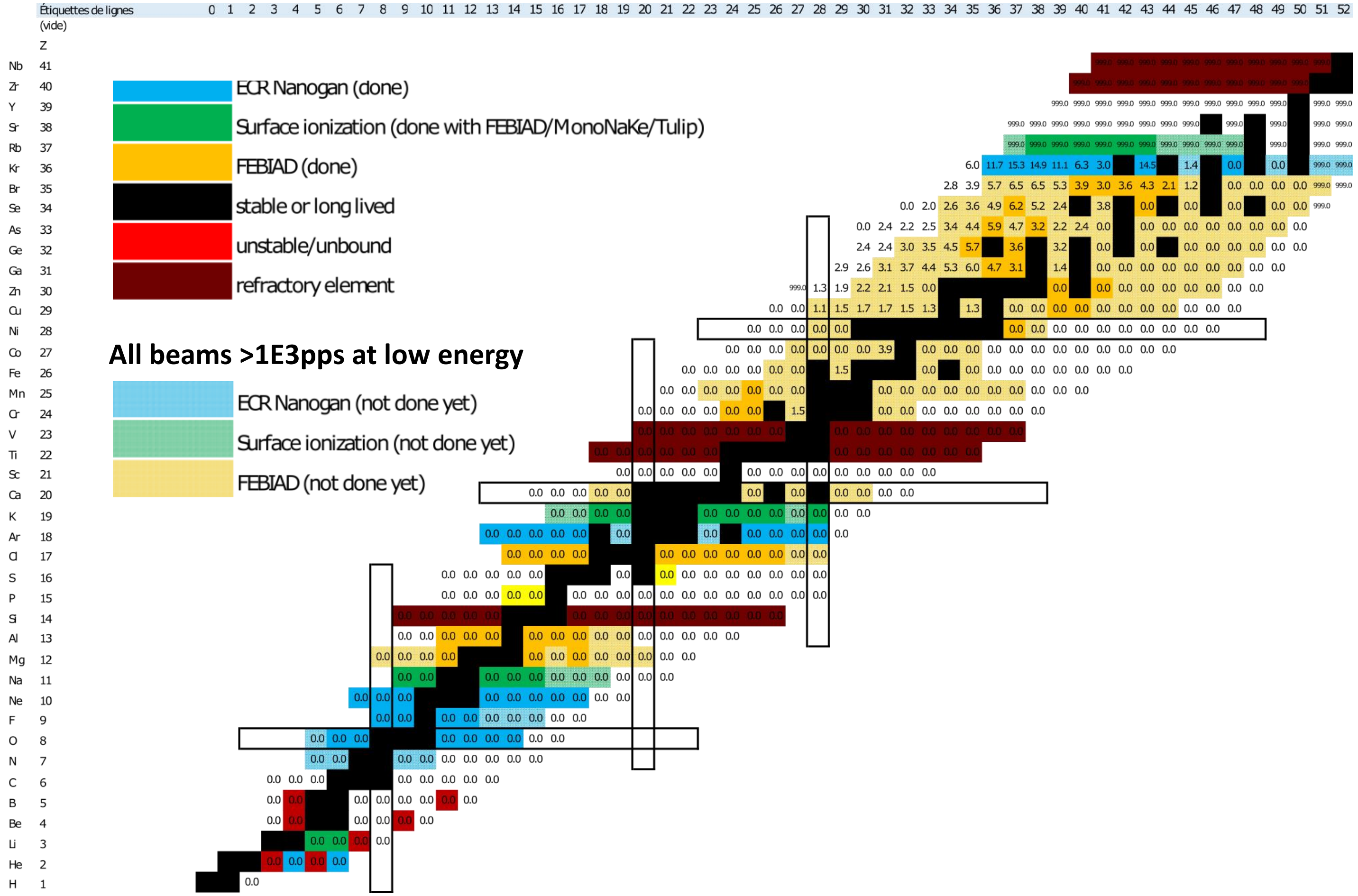

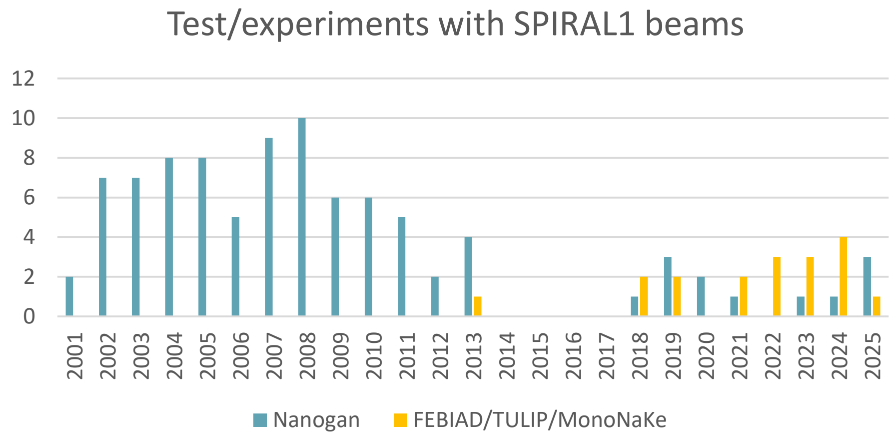

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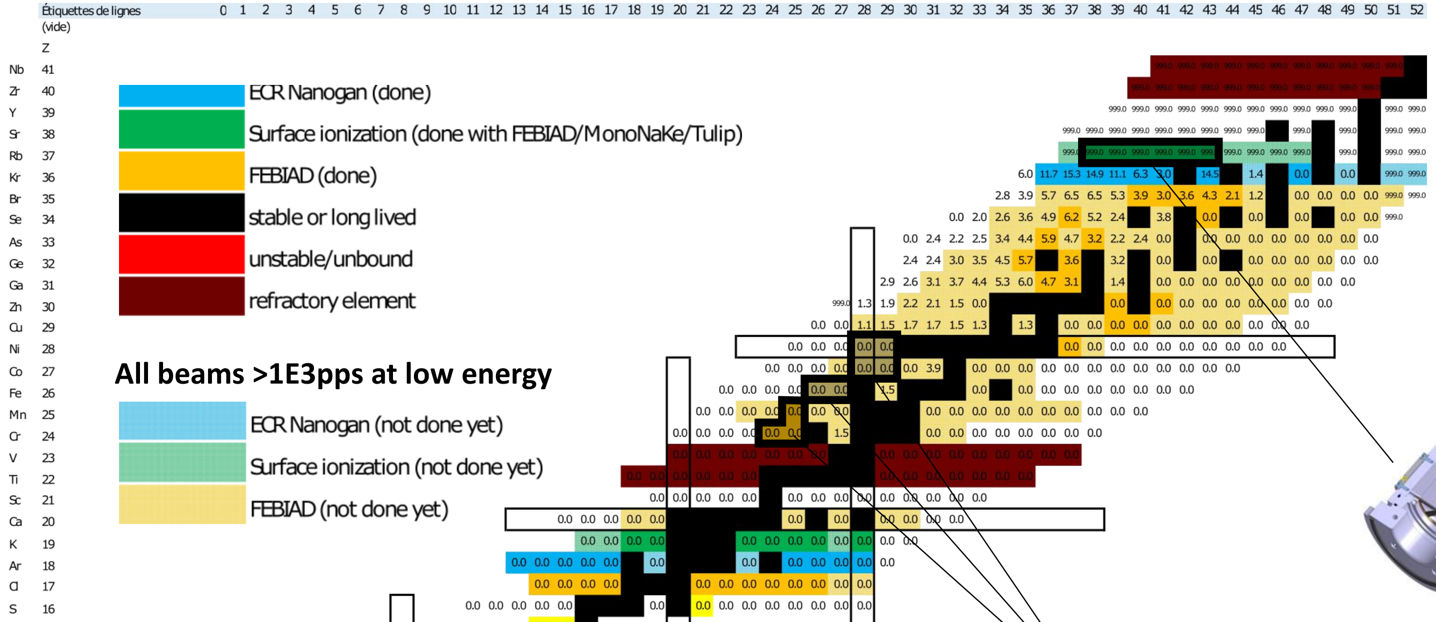
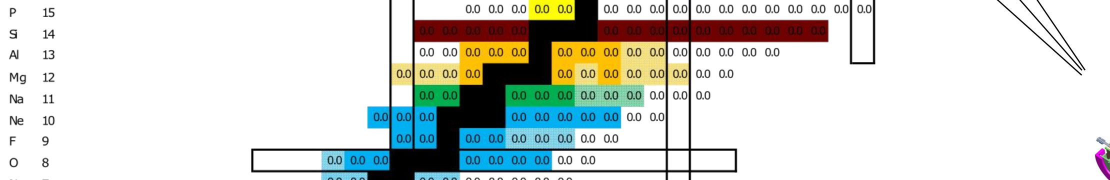
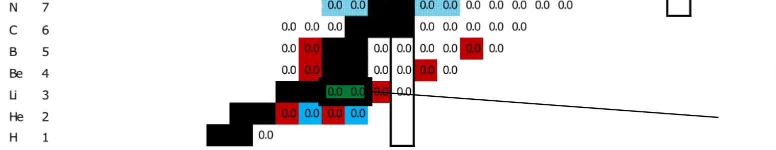
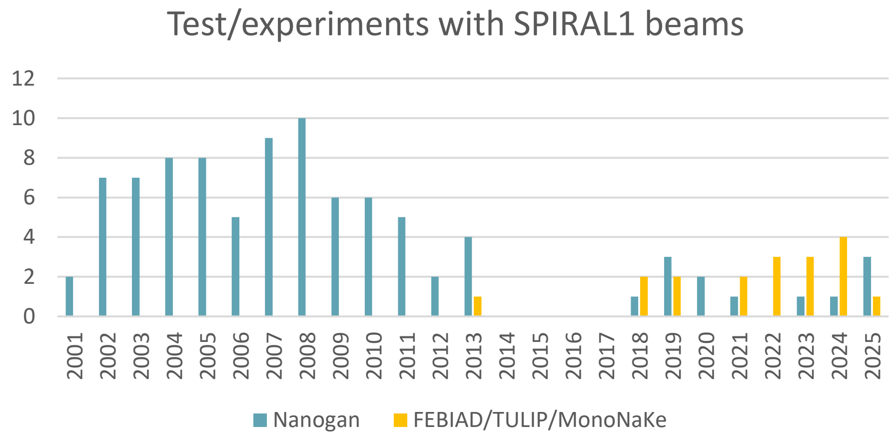
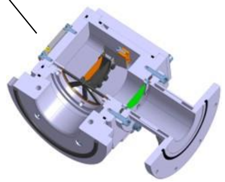
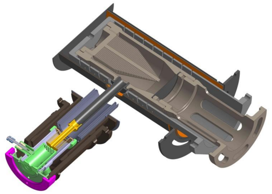








- n-deficient Rb isotopes



- ^{48,49}Cr, ^{50}Mn, $^{53m/g}$Fe ^{55}Co, ^{56,57}Ni, Cs isotopes down to A=117,
- Other isotopes (ongoing analysis)

- ^{8,9}Li

We can/could do many exotic beams !

(Operational limit at 1 TISS/month)

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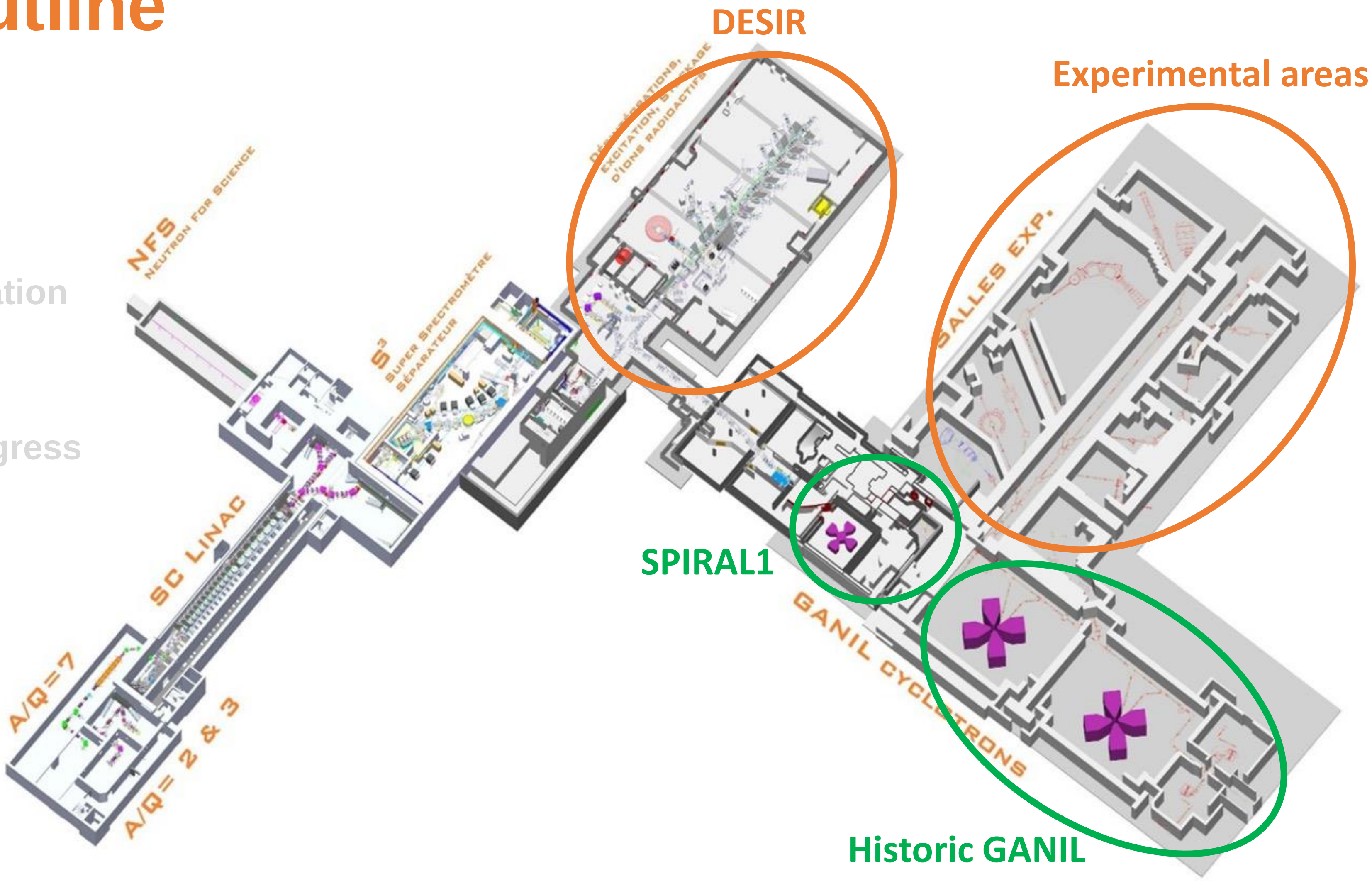
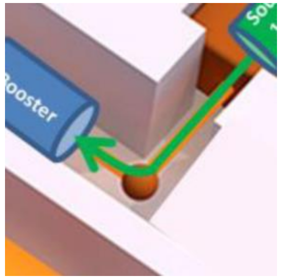
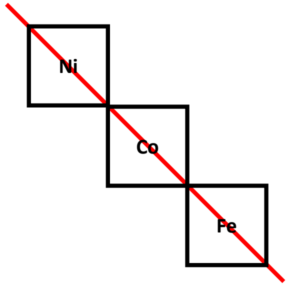


Purity





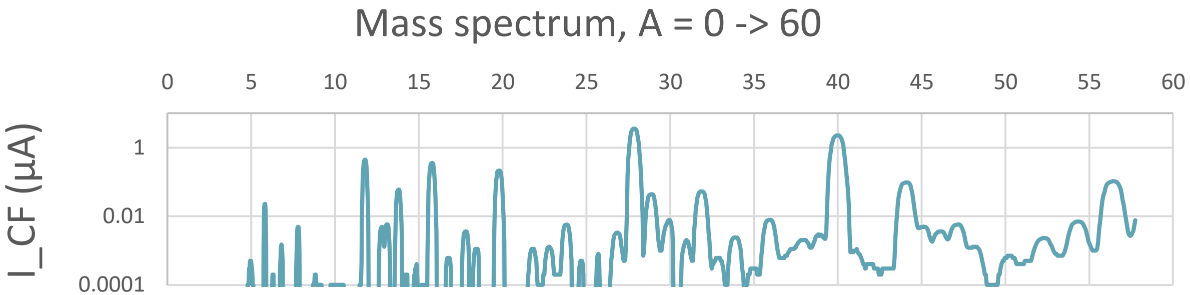
A selection -> Isobaric contaminants

Low energy

- Z selection
  - gas (Nanogan)
  - alkali (MonoNaKe/TULIP/FEBIAD)
  - molecules (reactive gas injection)
- Isobar separation in DESIR (resolution 5.10^{-5})

High energy

- Isobar separation in CIME (best resolution 3.10^{-4})
  - Light ions only (A<40)
  - Best res. in energy range 2.7-5.8 MeV/A
- Stripping
  - n-deficient only
  - Max energy mandatory (12-16 MeV/A)
  - Z<30



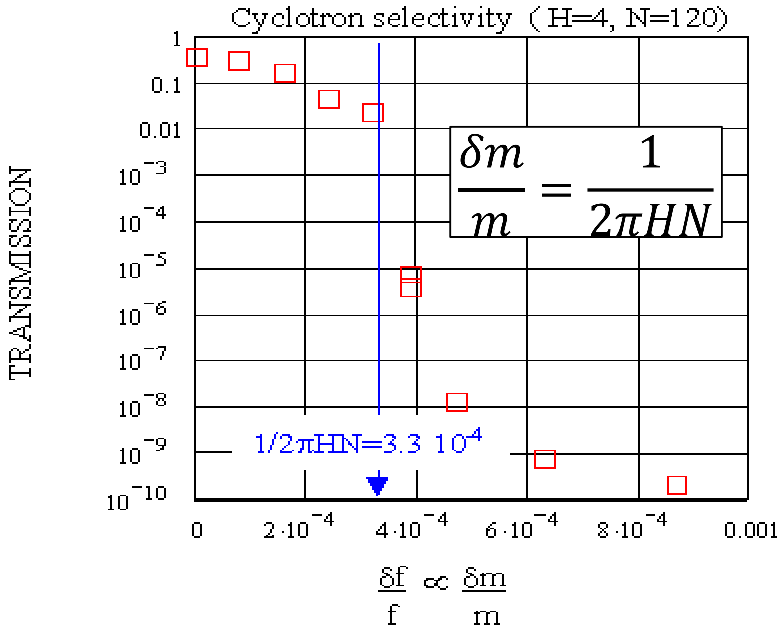
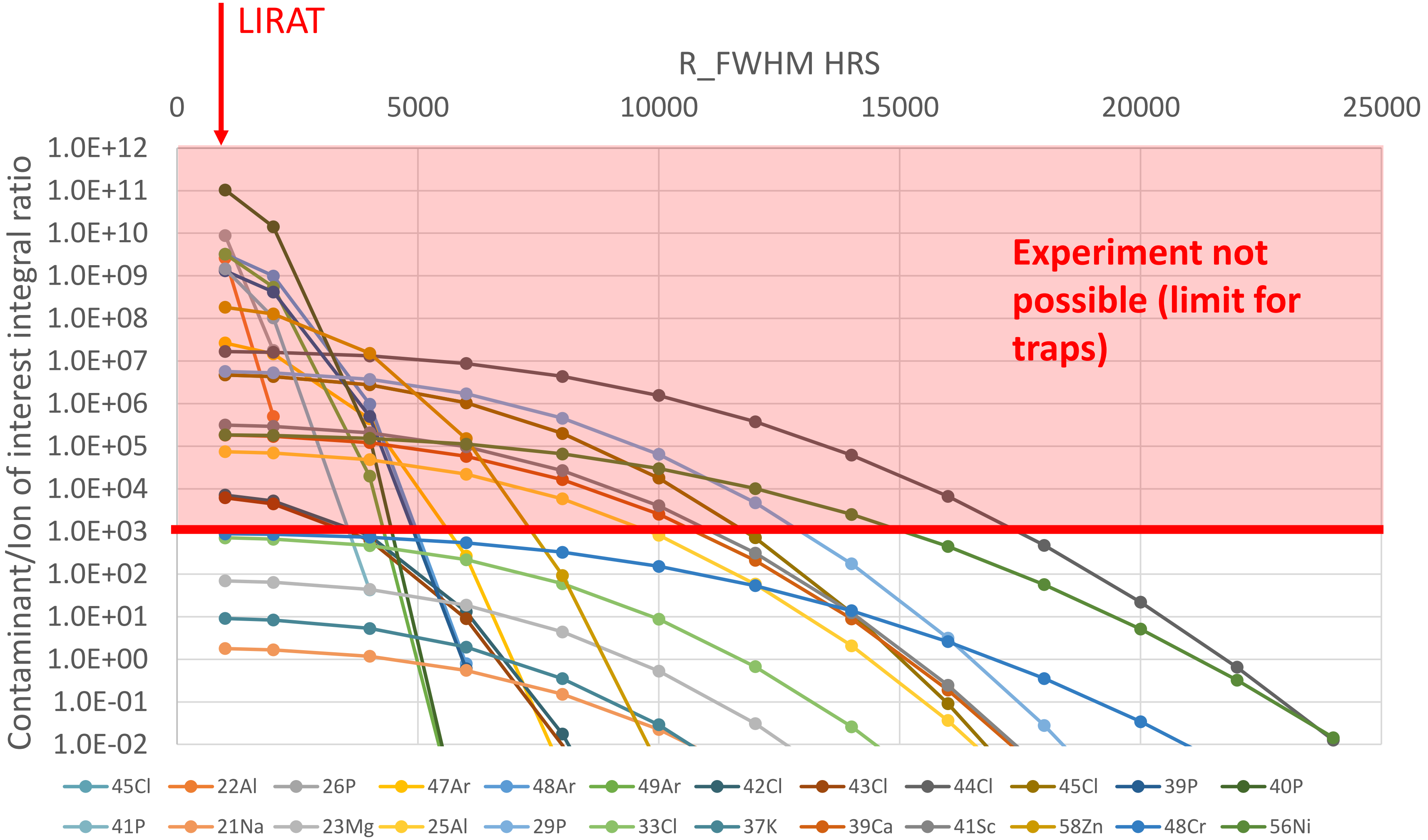
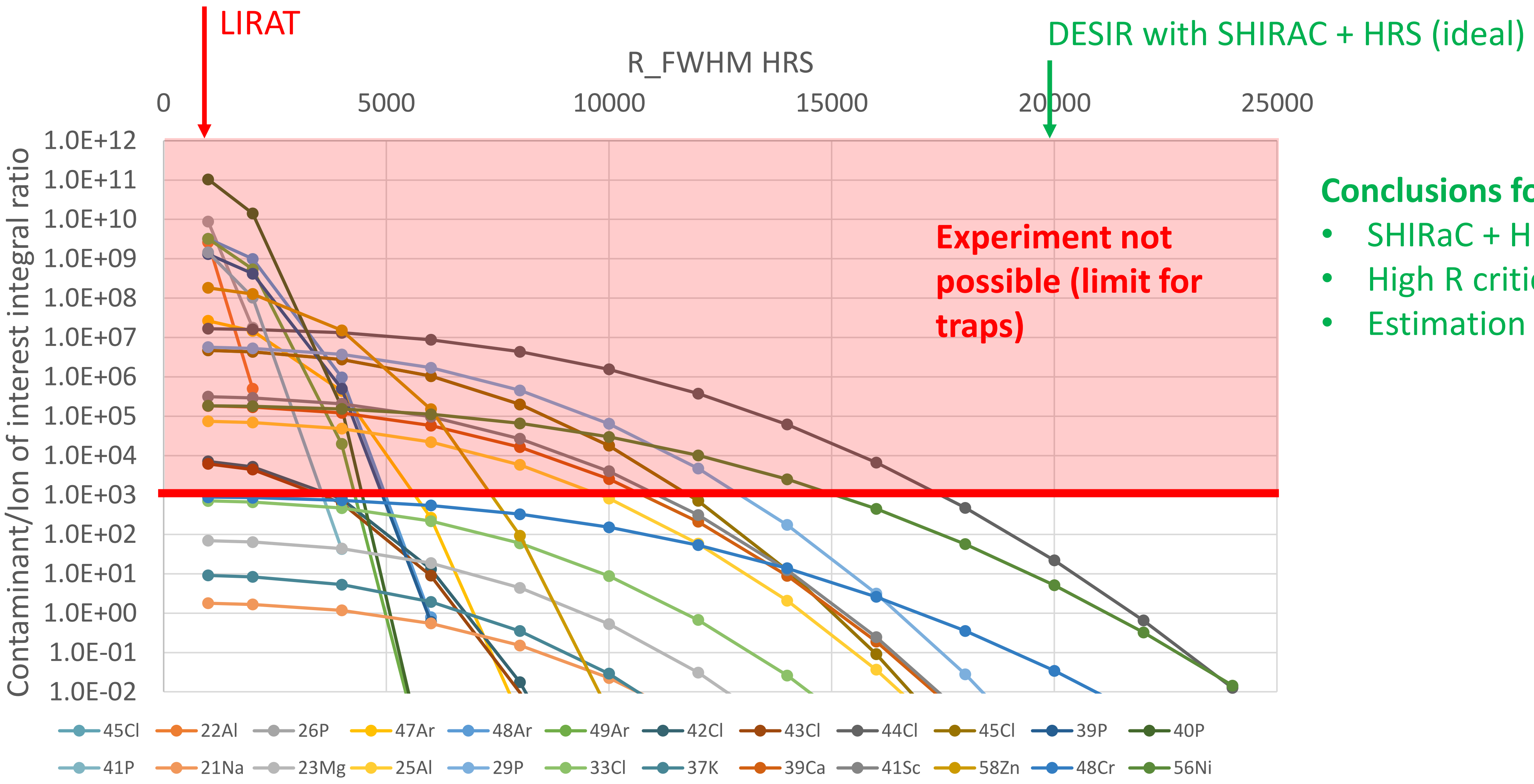


Image credit: B. Jacquot

Purity in DESIR



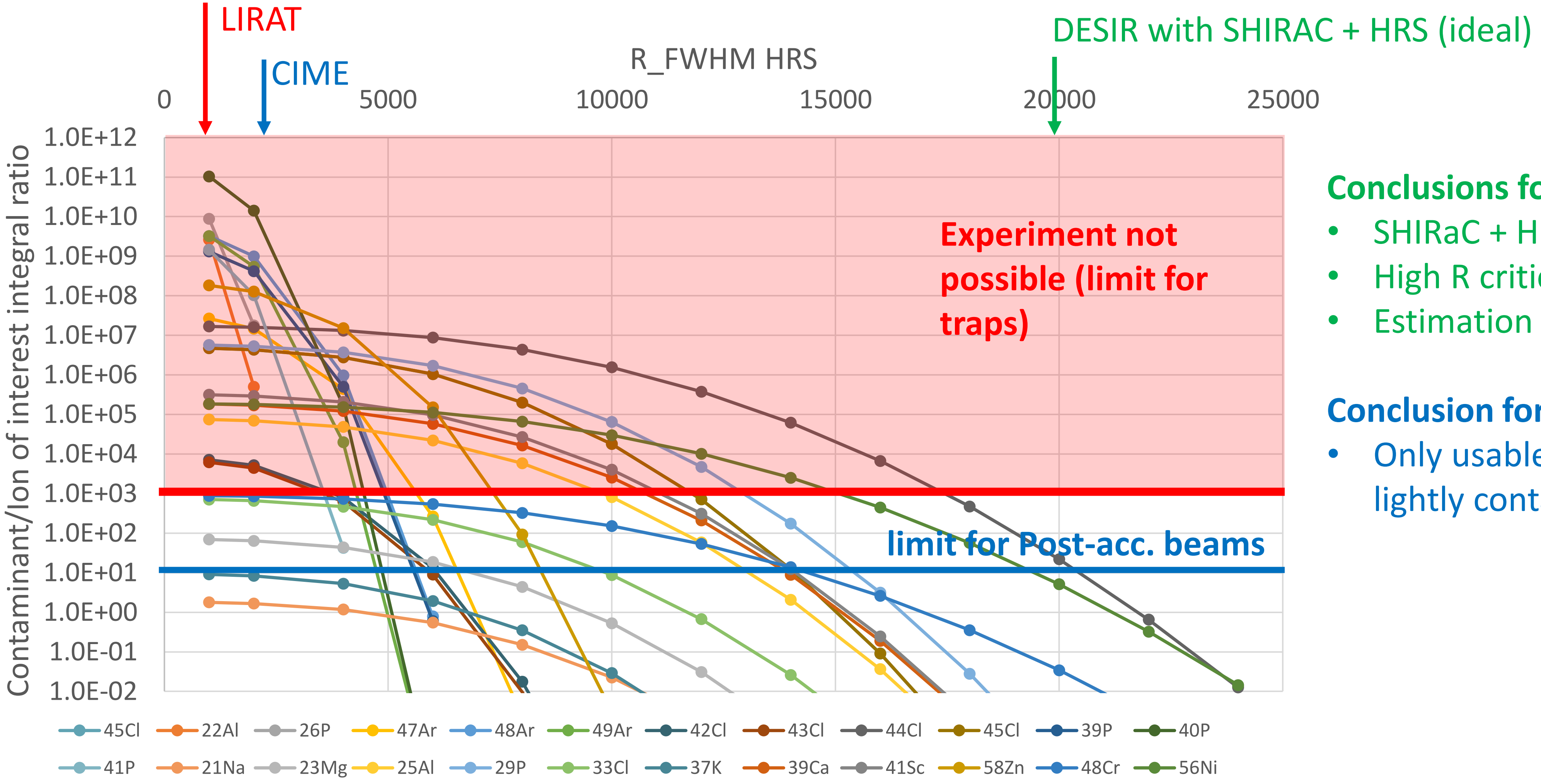
Purity in DESIR



Conclusions for DESIR

- SHIRaC + HRS is necessary
- High R critical
- Estimation **very** tail-dependant

Purity in DESIR



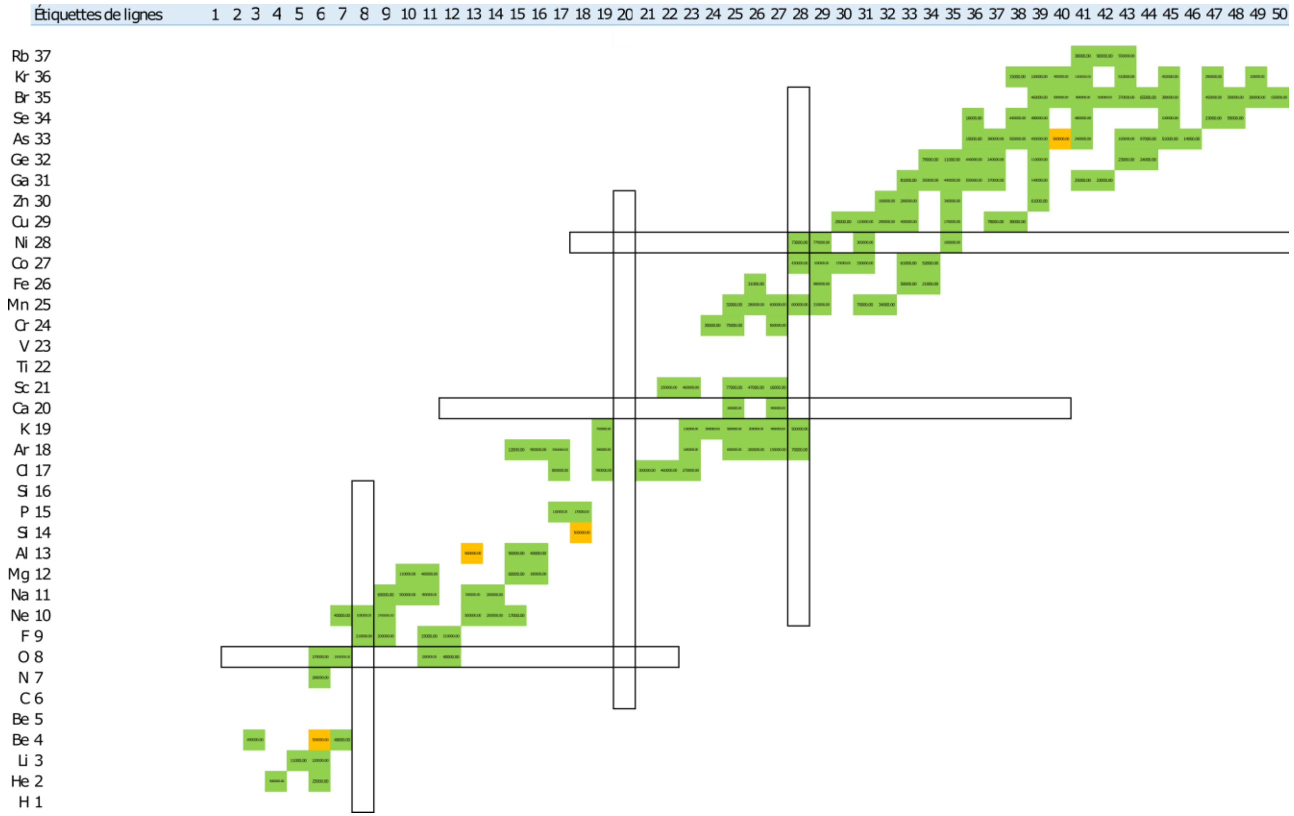
Conclusions for DESIR

- SHIRaC + HRS is necessary
- High R critical
- Estimation **very** tail-dependant

Conclusion for CIME

- Only usable for light masses and lightly contaminated beams

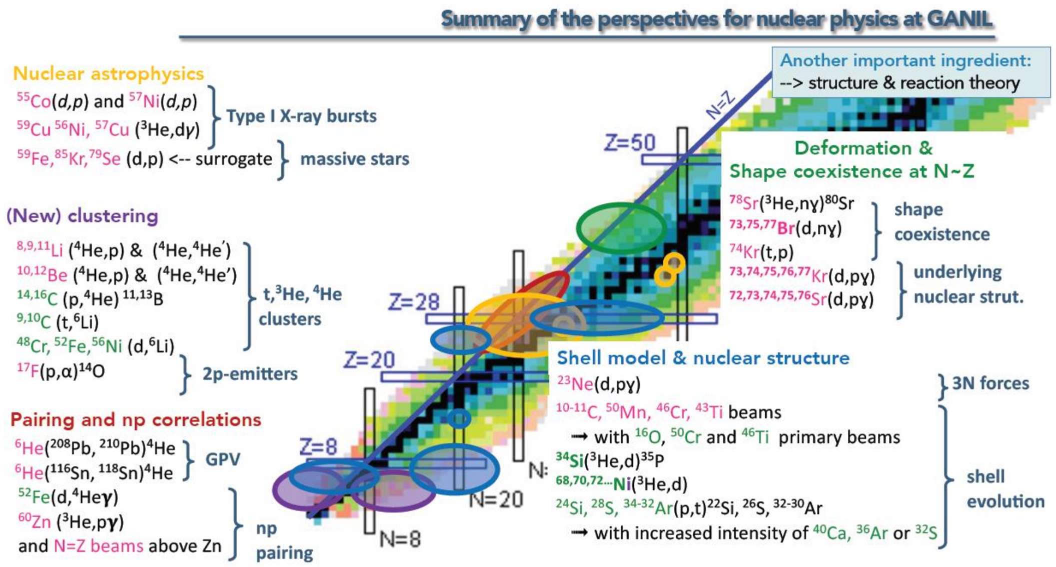
Post accelerated FEBIAD beams - intensity



172 isotopes + possible batchmode beams

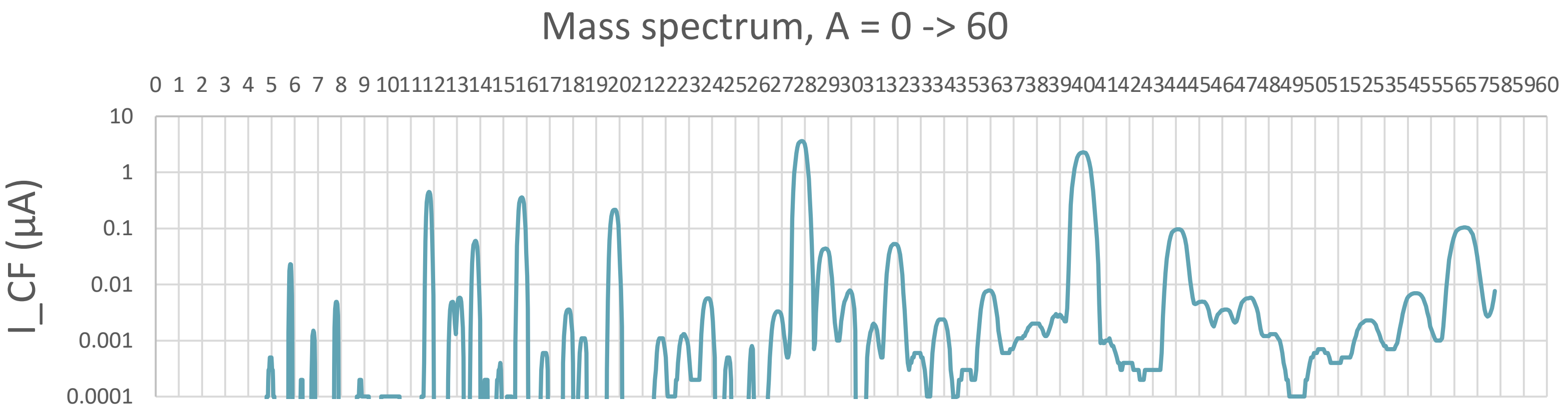
All radioactive beams > 10^4 pps after acceleration

- Direct measurements (19, mostly Nanogan)
- Extrapolation from direct measurements (46)
- Estimates (107, FEBIAD only)



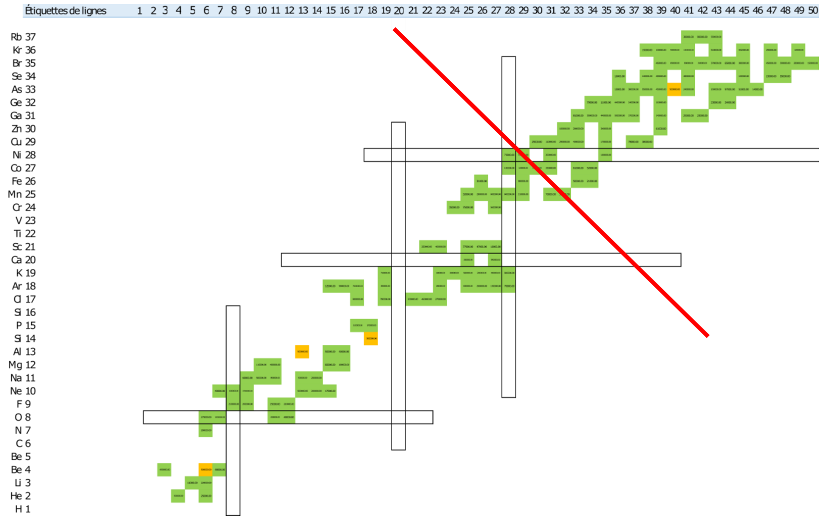
M. Assié, WS Cible-Source, 09/2023

Post accelerated FEBIAD beams - purity



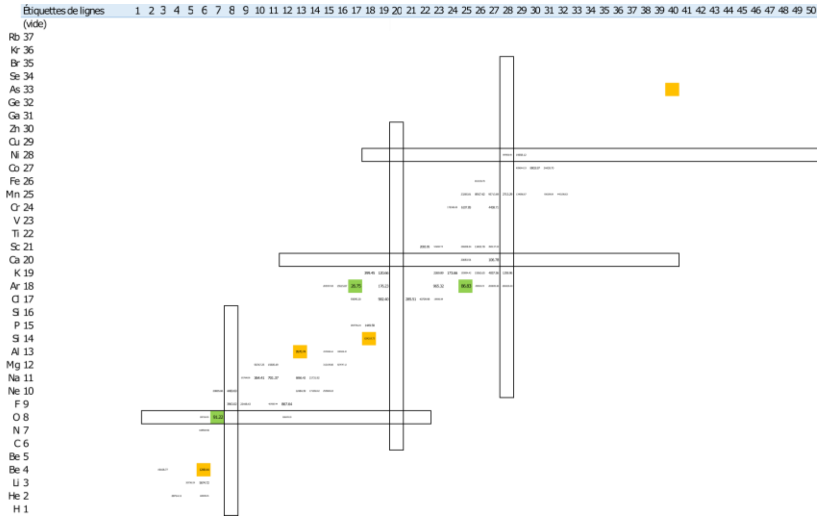
Disclaimer

- contaminants not measured for A>57
- Contaminants not formally identified
- Other possible contaminants



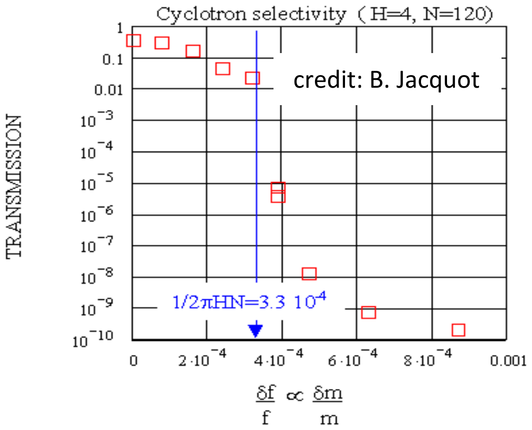
172 isotopes

Usable without any purification



3 isotopes

Post accelerated FEBIAD beams - purity

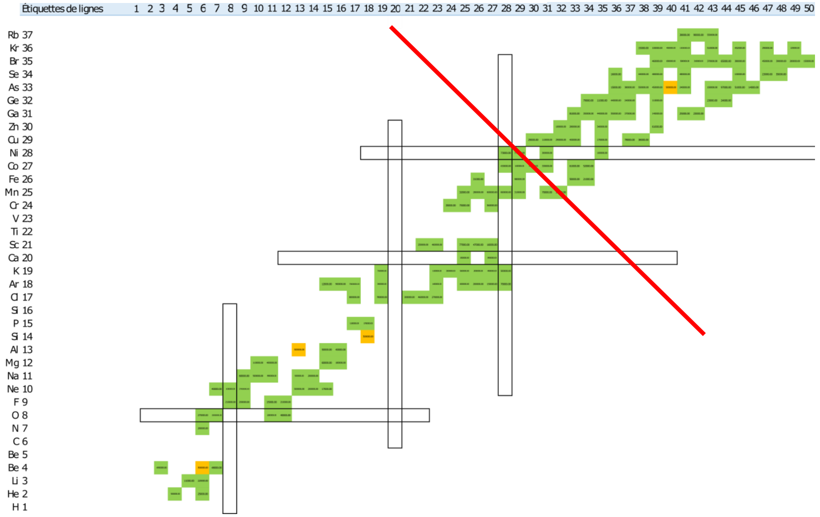


Using CIME as a mass spectrometer

$$\frac{\delta m}{m} = \frac{1}{2\pi HN}$$

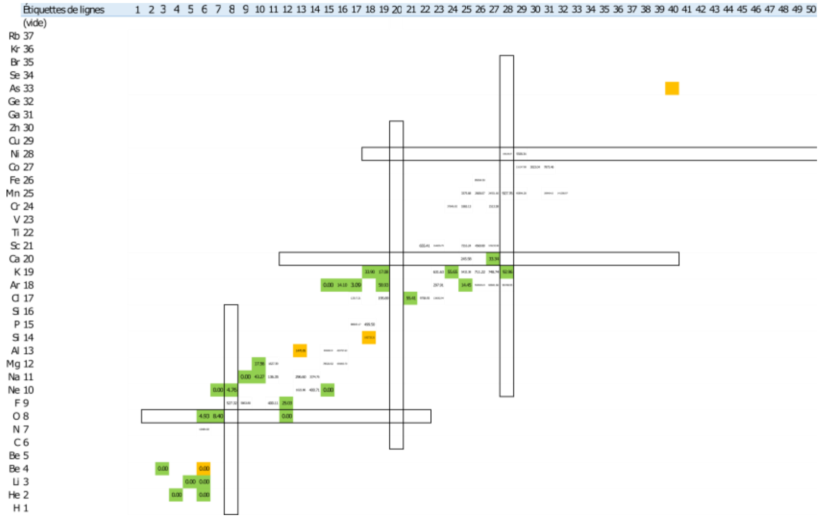
- Best resolution for H=4 (Energy range 2.7-5.8 MeV/A)

- Higher energies possible at the cost of more contamination
- Less contamination possible at the cost of lower intensity



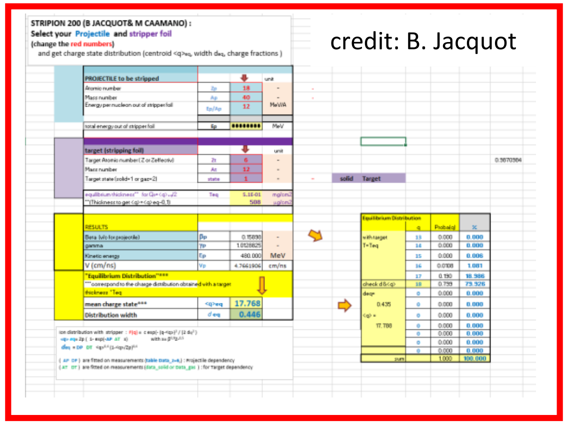
172 isotopes

Usable after mass separation in CIME



26 isotopes

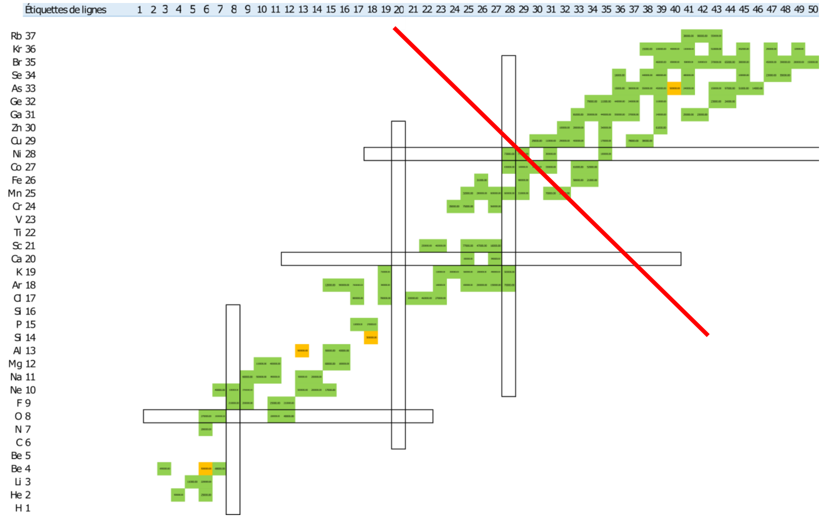
Post accelerated FEBIAD beams - purity



credit: B. Jacquot

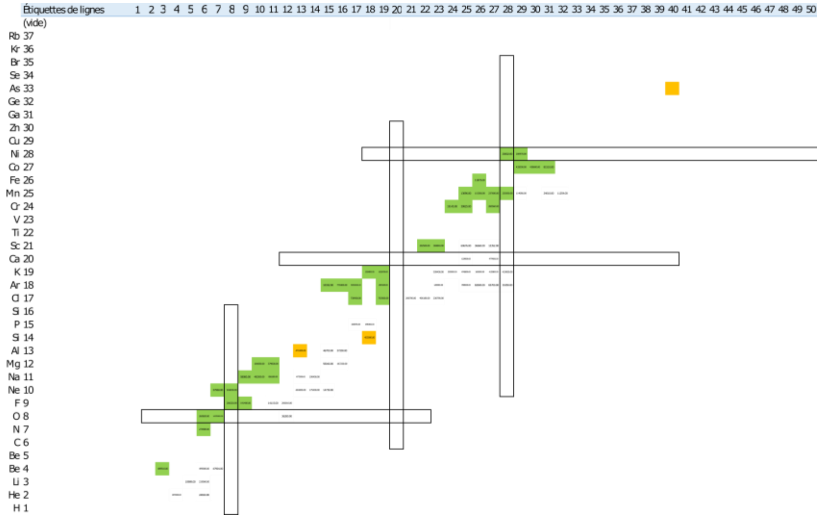
Stripping at high energy

- n-deficient only
- Max energy mandatory (12-16 MeV/A)
- Model, not measurement
- Low energy tail of the contaminant not accounted for



172 isotopes

Usable after stripping at max E

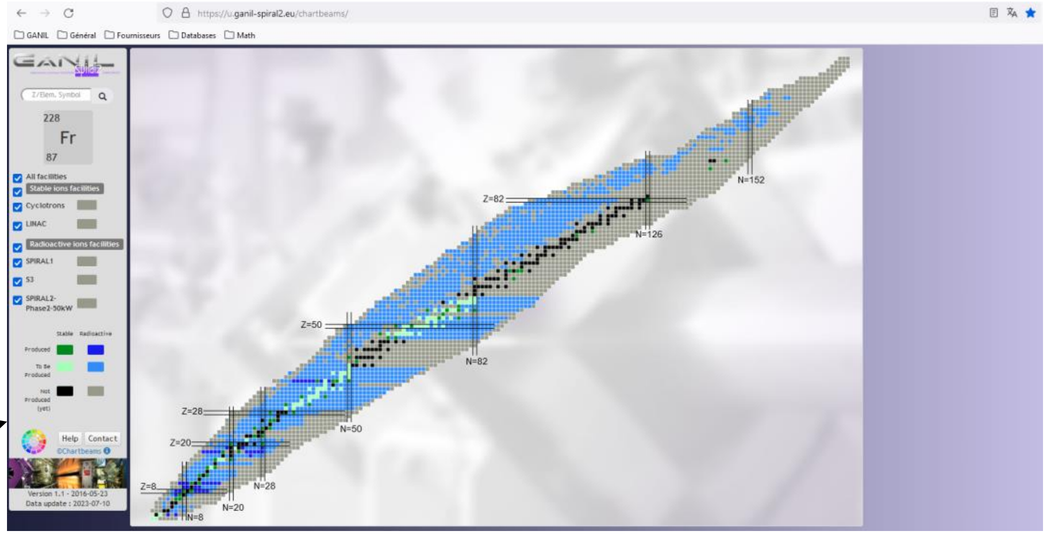


36 isotopes

Takeway messages

- High variety of beams (elements, isotopes, energy)
- Broadband estimates are not guaranteed or easy to deliver due to :
    - Release uncertainties
    - Primary beam
    - Low RIB intensities (affects beam tuning)
    - Contamination
- Study should be done on a beam-by-beam basis (time-costly)
- The beam chart can be the first source of information…
- … but the target ion-source group should be the second.
- Higher uncertainty for shortlived species
- Purity: the earlier, the better

Basic information on beams: https://u.ganil-spiral2.eu/chartbeams/



inquiries to be sent at chartbeams-spiral1@ganil.fr

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Thank you for your attention