laboratoire commun CEA/DRF CNRS/IN2P3

Workshop
Targets – Ions Sources
Tomorrow's technological challenges and associated skills

Beam development and platform limitations

Pierre Chauveau

Outline

Introduction : SPIRAL1

I. Beam production

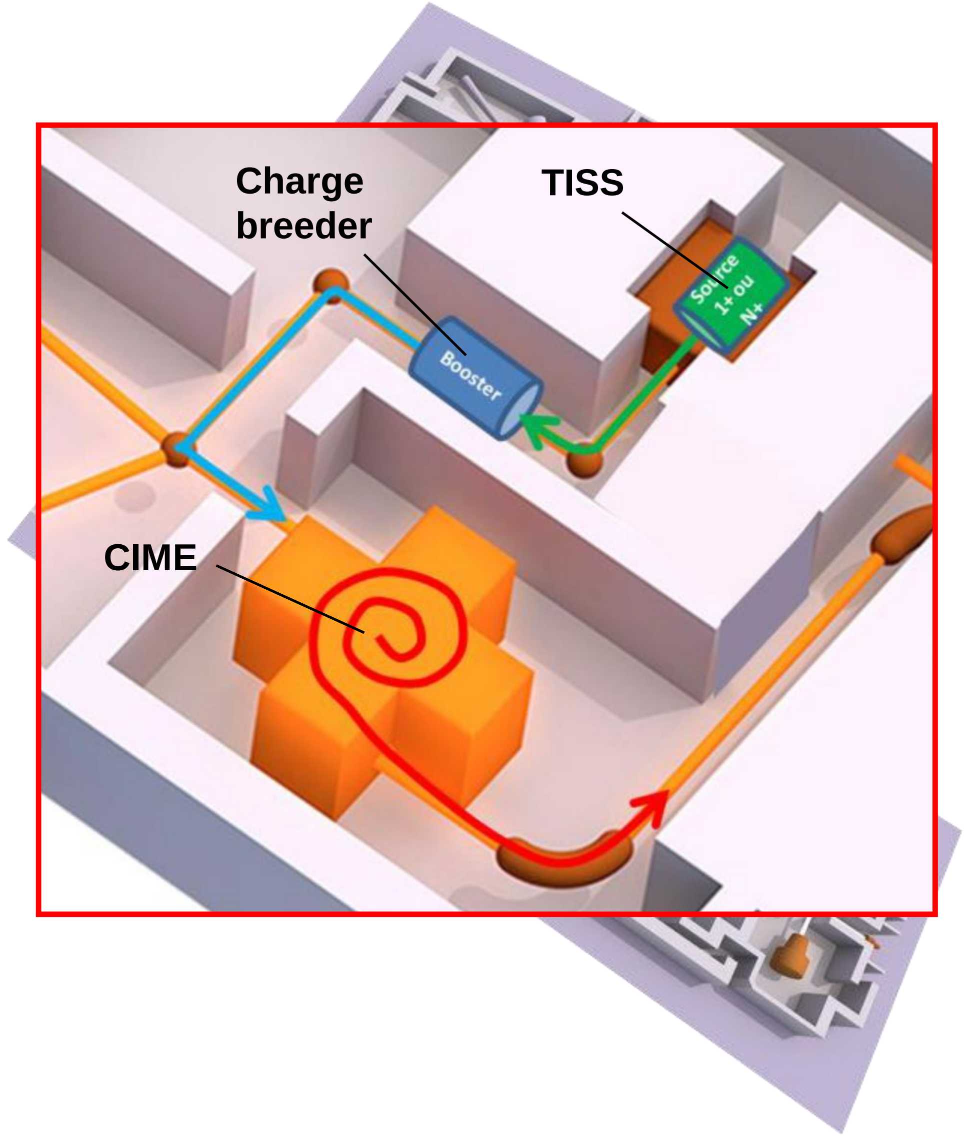
II. Acceleration

III. Beam purity

What are the limits ?

How are we improving it / How could we improve it ?

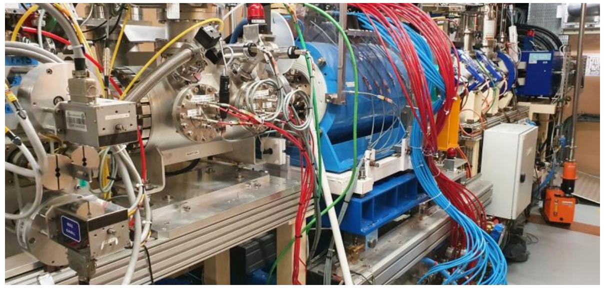
Introduction



SPIRAL1

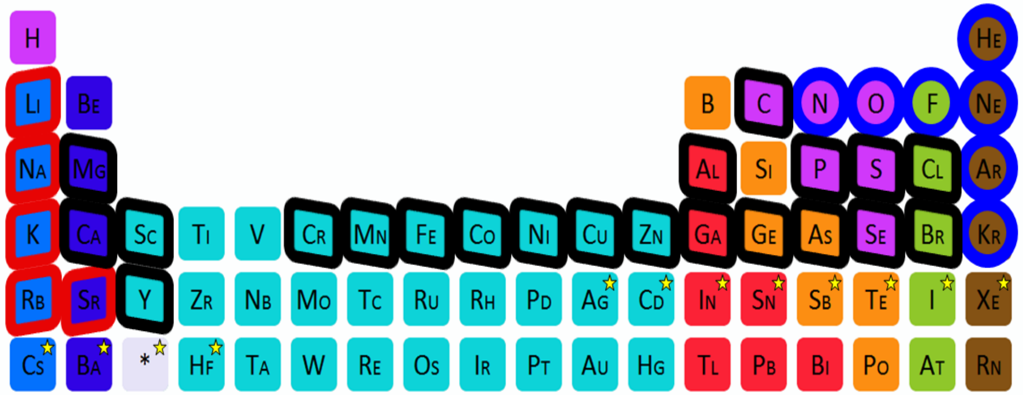
- New target Ion Source Systems (FEBIAD)

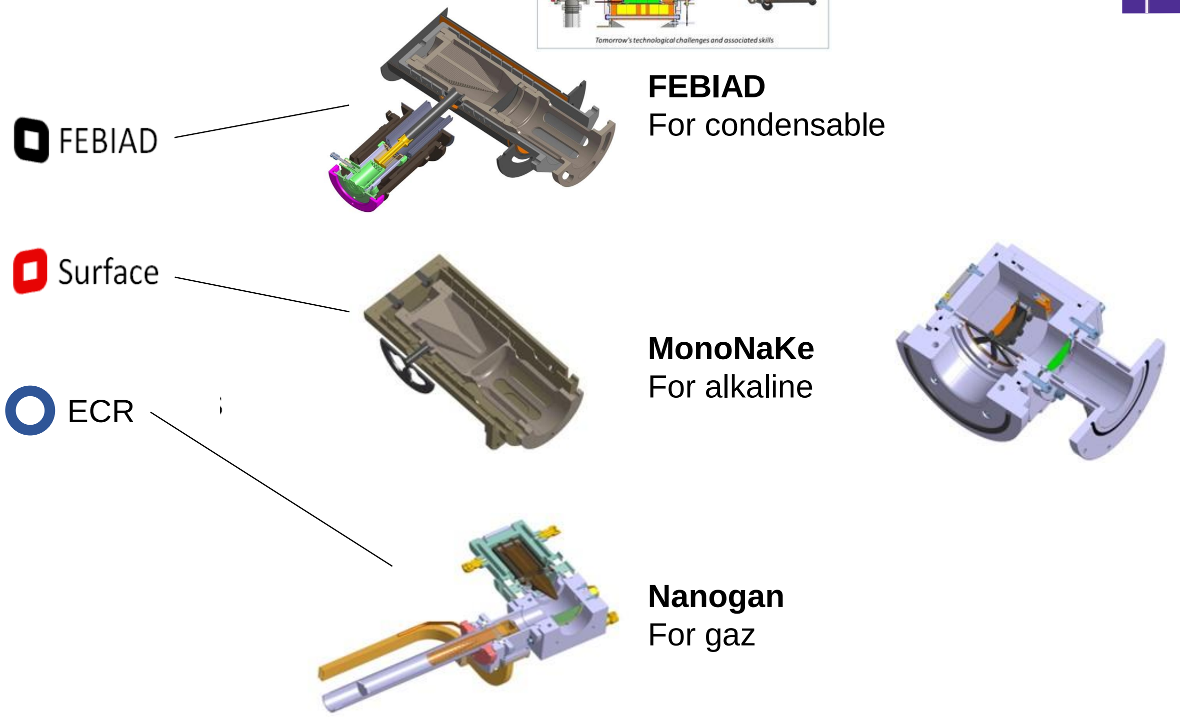
- The charge breeder



- CIME

Beam production





FEBIAD
For condensable

MonoNaKe
For alkaline

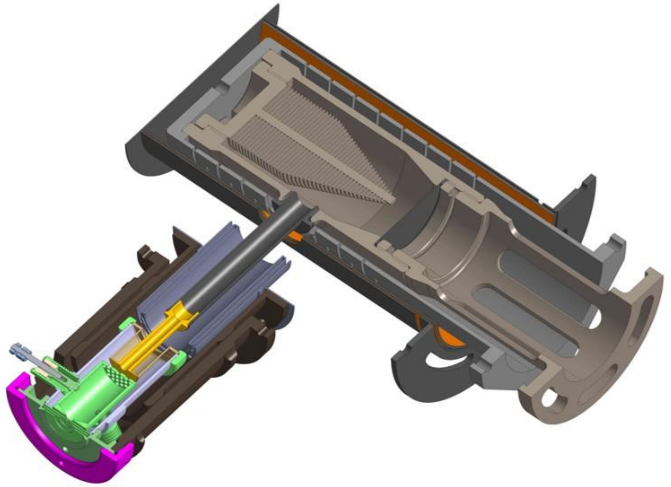
TULIP
For proton rich isotopes

Nanogan
For gaz

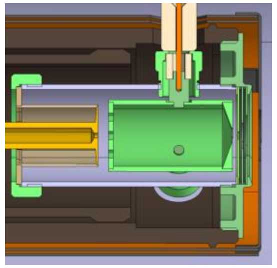
Limitations

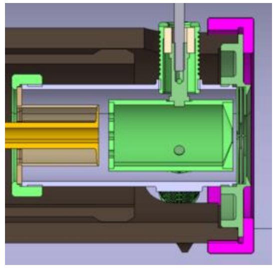
- primary beam power
- fragmentation cross-section
- diffusion/effusion time (refractory materials/short half-lives)
- ionization efficiency
- operational issues (stability, resilience)

The upgrades on the FEBIAD



Poster ICIS
V. Bosquet

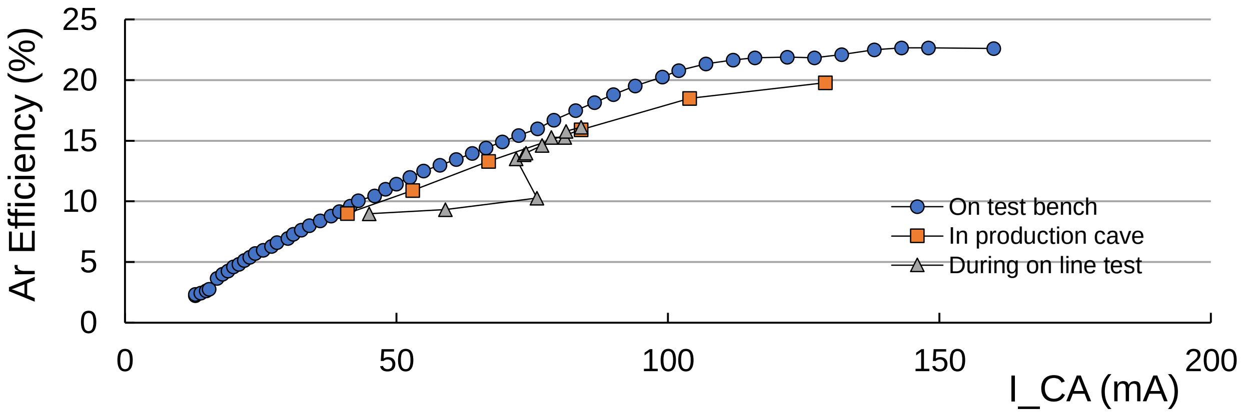




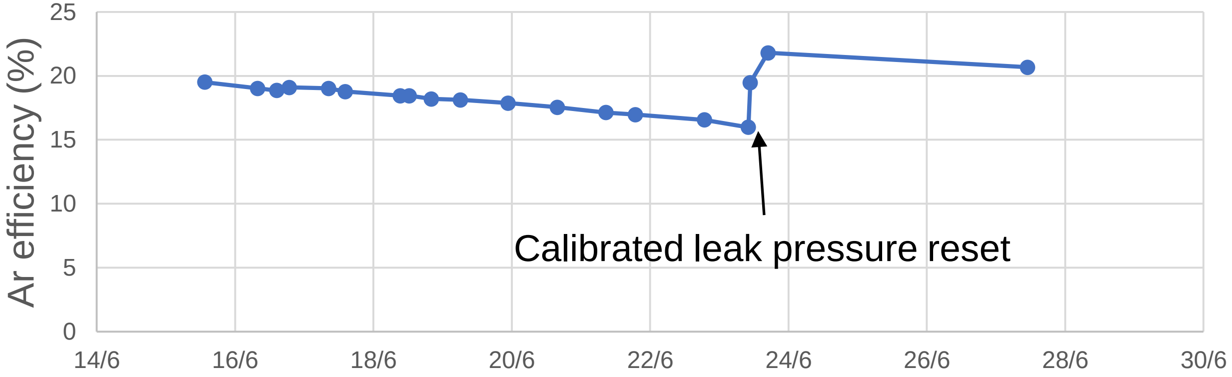
Insulator were the main point of failure.

- Increasing the size of the openings
- Pulling the insulators far from the hot anode

Progress in resilience and reliability

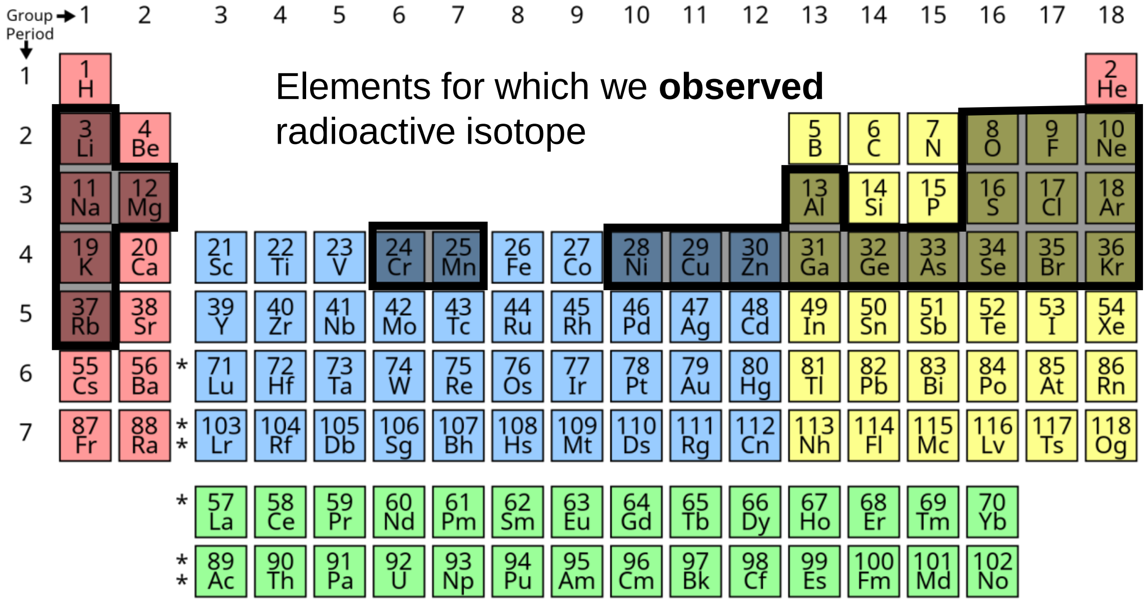


- 3 months in SPIRAL1
- 3 Machine study (2 radioactive + 1 stable)
- 10+ heating cycles
- **Efficient:** ^{40}Ar Efficiency up to 23%
- **Resilient:** 2 days of irradiation, 15 days at 20% ^{40}Ar efficiency and 10+ heating cycles without loss of performance
- **Stable over time :** same results 3 months appart
- Reliable : same results on test bench and SPIRAL and between 2 TISSes



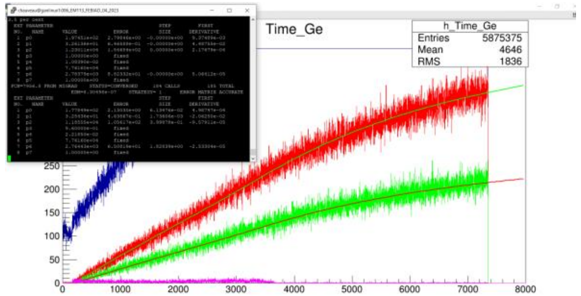
FEBIAD beams so far

- 10 tests/experiments with radioactive beams
- FEBIAD TISSes have received 36Ar (2013,2019,2022), 20Ne (2018), 40Ca (2018,2019), 48Ca (2021), 84Kr (2022) and 50Cr (2023)
- 2 post accelerated beams : ^{38m}K (2019), ^{47}K (2021)
- 90+ radioactive isotopes/isomers **seen**, including around 60 at post-accelerable intensities (>1E5pps).



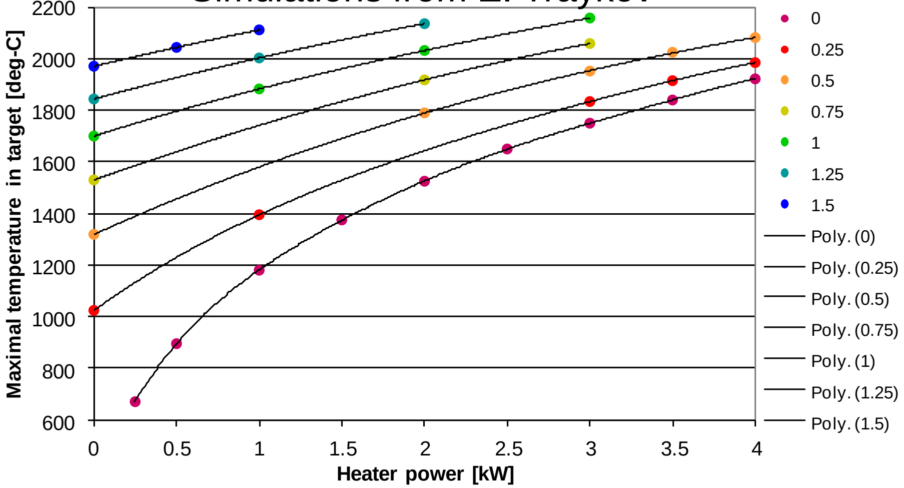
Last test (^{50}Cr beam)

^{48}Cr rate ok (1.2E4pps/W) but very slow release (46min) at low beam power (30W)



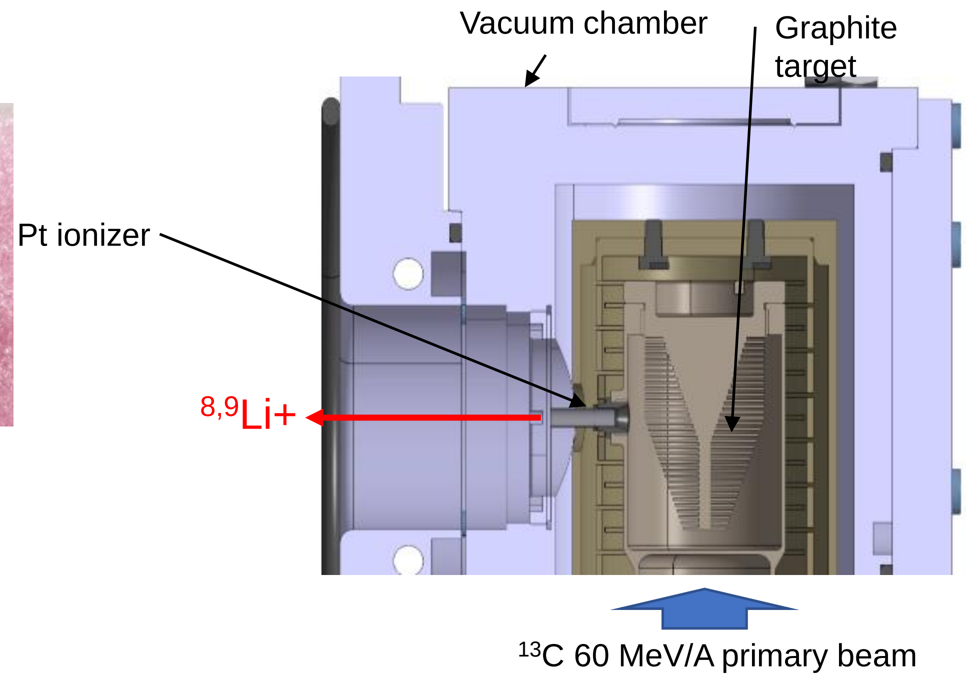
Target temperature for different heating

Simulations from E. Traykov

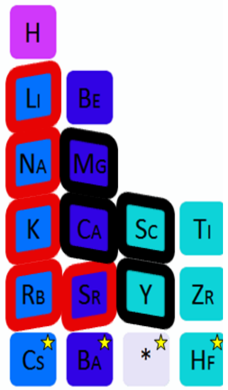


MonoNaKe (slide credit P. Jardin)

Objective: production of radioactive alkali ions



- *In-target production by target and beam fragmentation*
- *Ionization by hot surface*



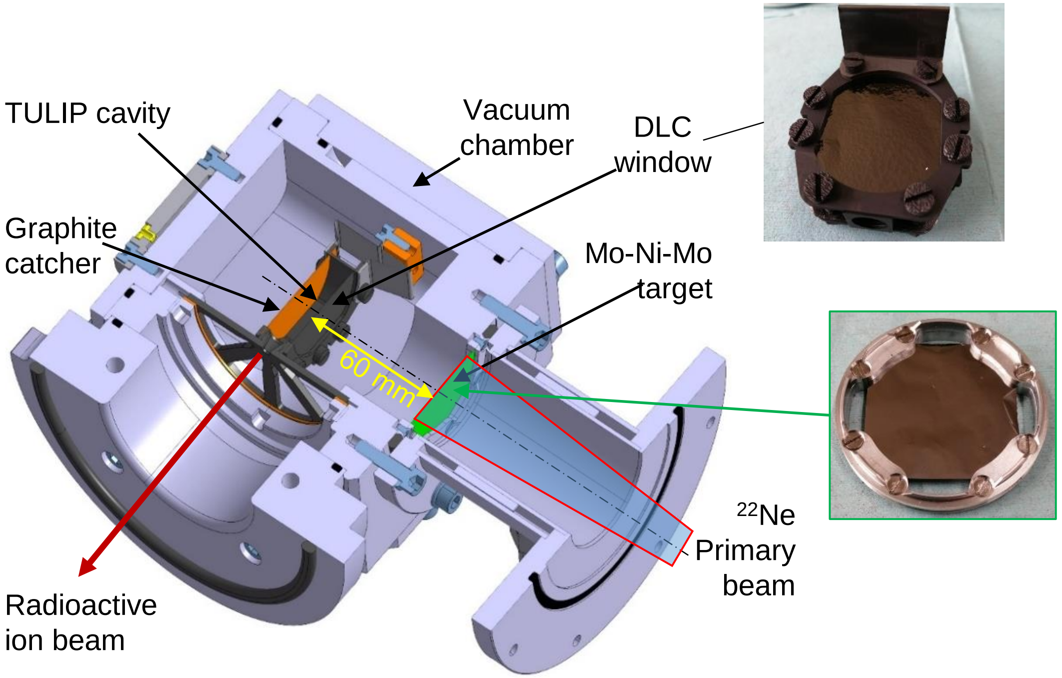
First on-line test with a Pt ionizer: $^{8}Li^{+}$ rate = 2,2.10^{4} pps (or AITefficiency~10^{-5} for 830 W of primary beam), to be compared to AITefficiency of 0,05 obtained in 2007 with a carbon ionizer.

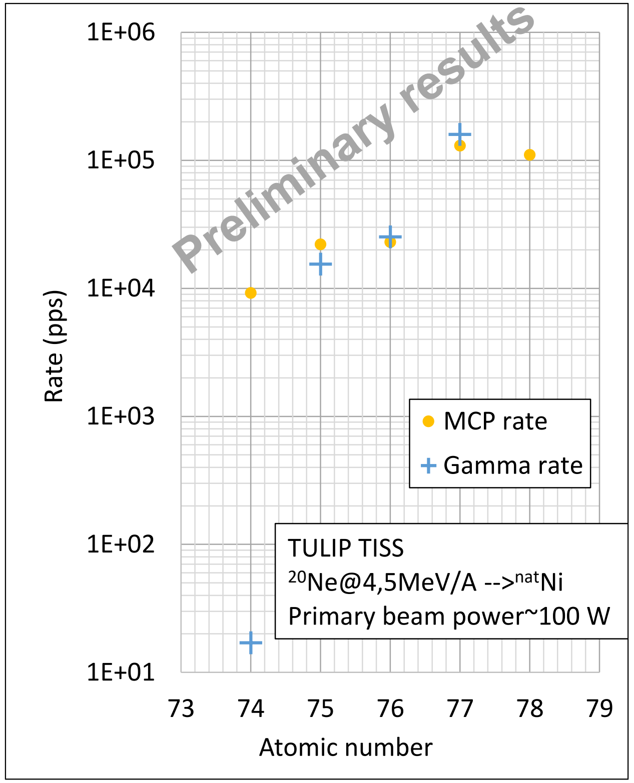
Pt and C ionizer performances will be compared during an off-line test planned in February and March 2024.

TULIP (slide credit P. Jardin)

Objective: production of neutron deficient short-lived isotopes

Proof of principle: production of $^{74-78}Rb^{+}$ ions





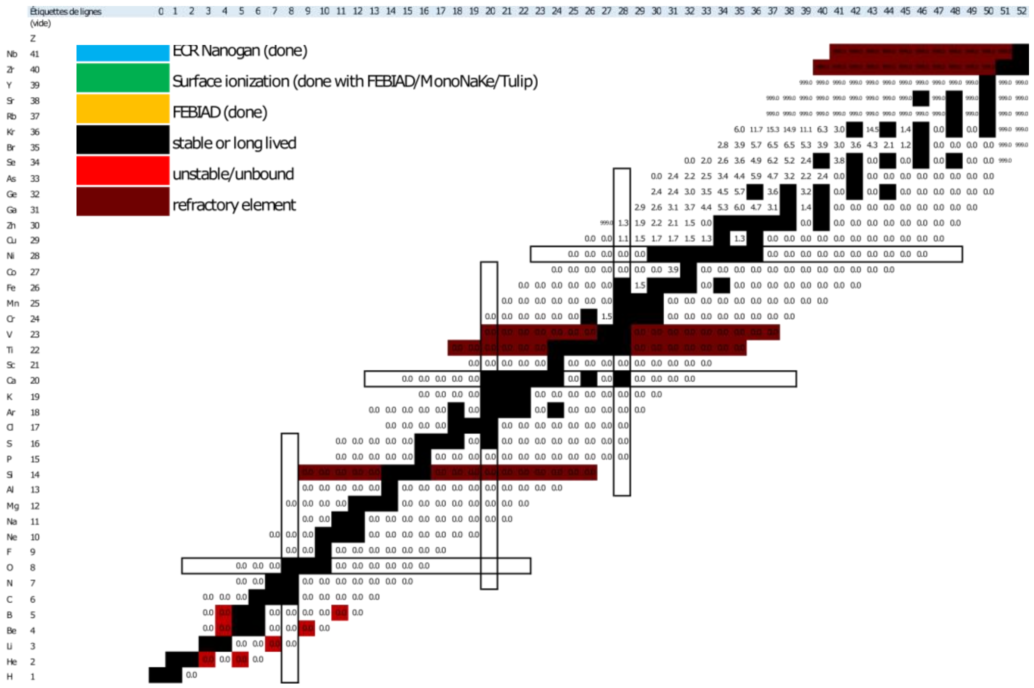
In-target production by fusion-evaporation
Short atom-to-ion transformation time

Final objective: production of metallic ions around ^{100}Sn

Next steps:

- coupling the TULIP cavity to a FEBIAD ion source. Test planned by end of 2023
- Implementation of a rotating target (production x 7).
- On-line production test of metallic ions around ^{100}Sn
- Application of the principle to the production of other elements

Beam production (status)



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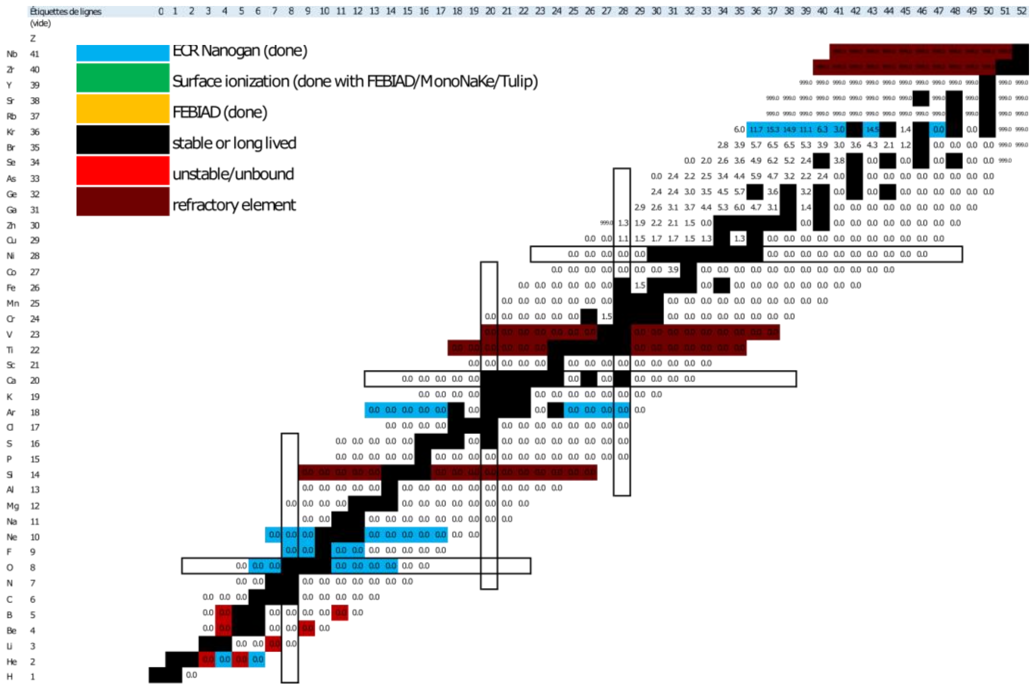

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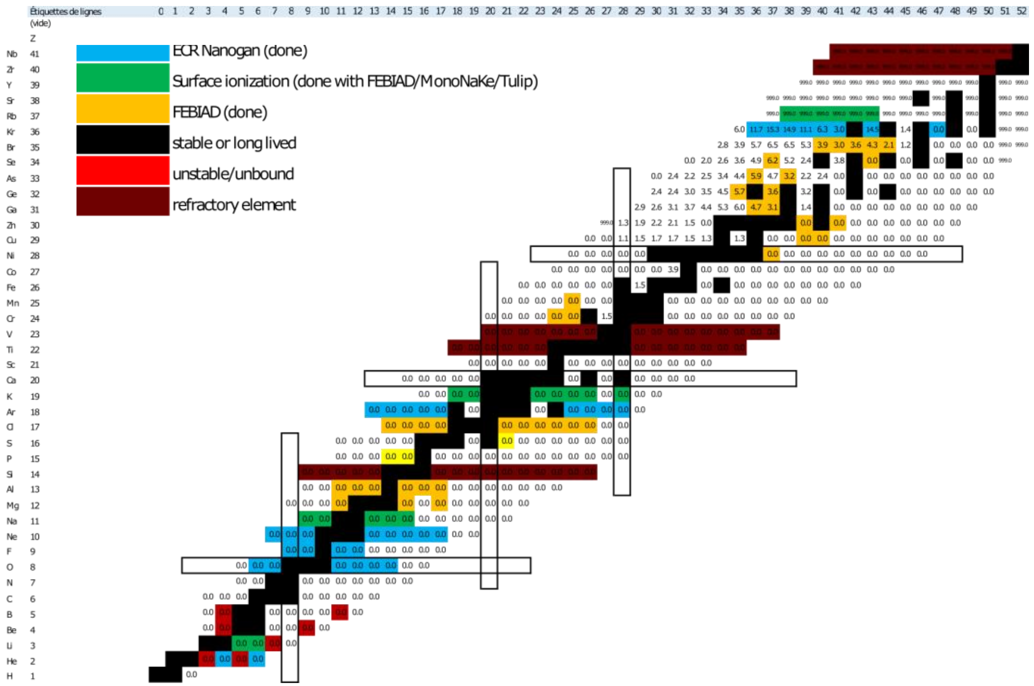
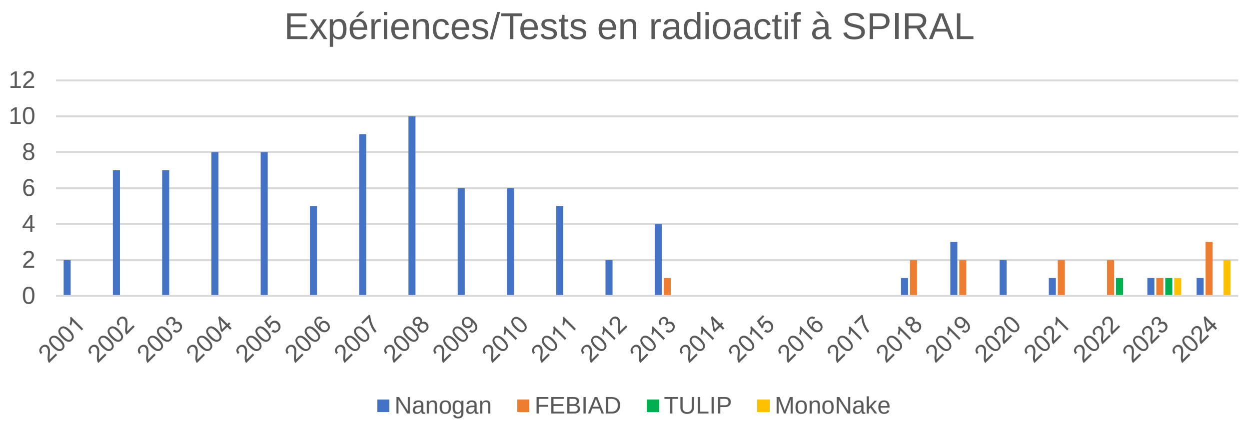
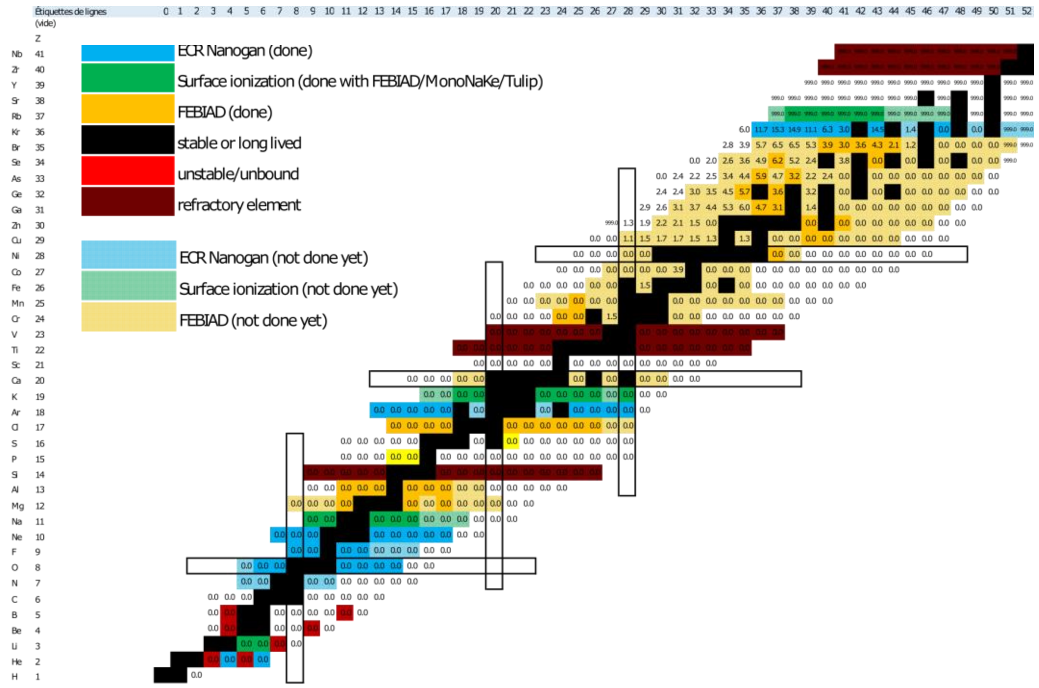
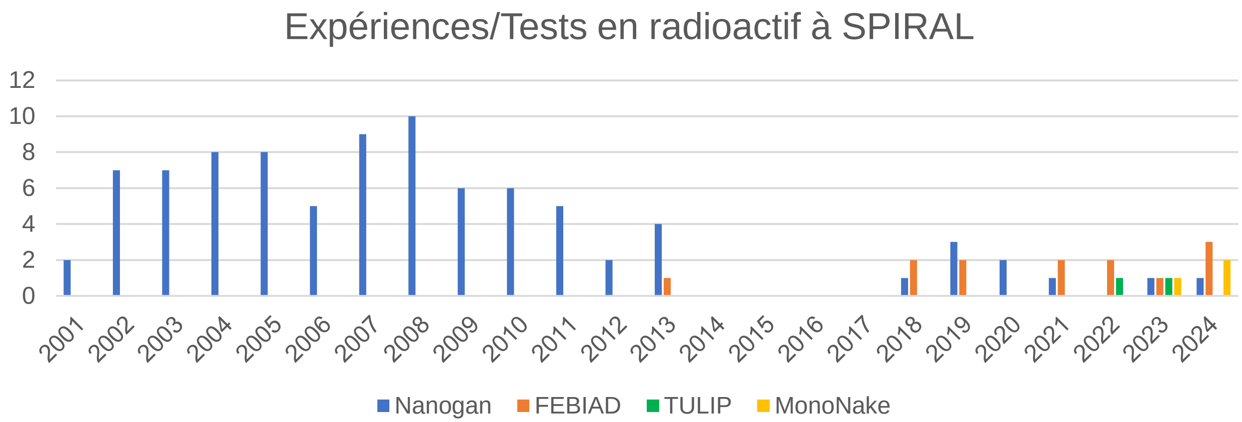




Beam production (status)





Developments

- MonoNaKe-Pt
- Fe-Co-Ni beams (hot target)
- New Target(s) + ^{12}C beam
- Molecular extraction
- Tulip-FEBIAD

➡ Master Projet Ions radioactifs
1 PhD + 1 Postdoc

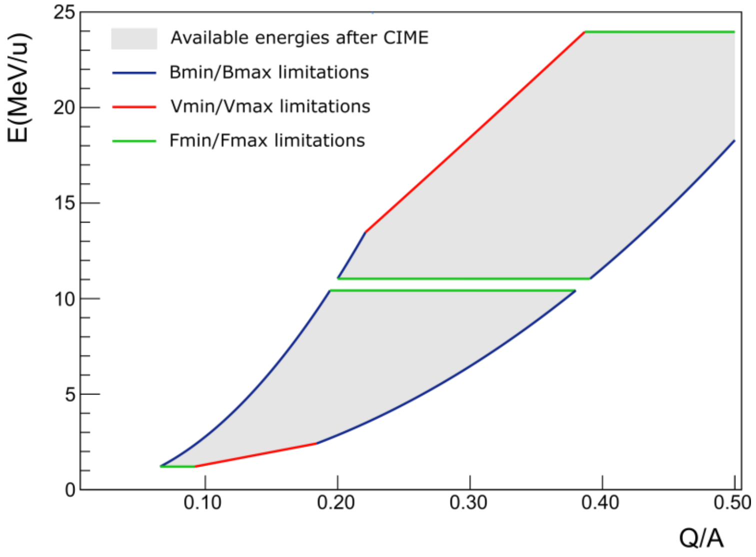
Limitations

- primary beam power
- fragmentation cross-section

^{12}C on new target(s)

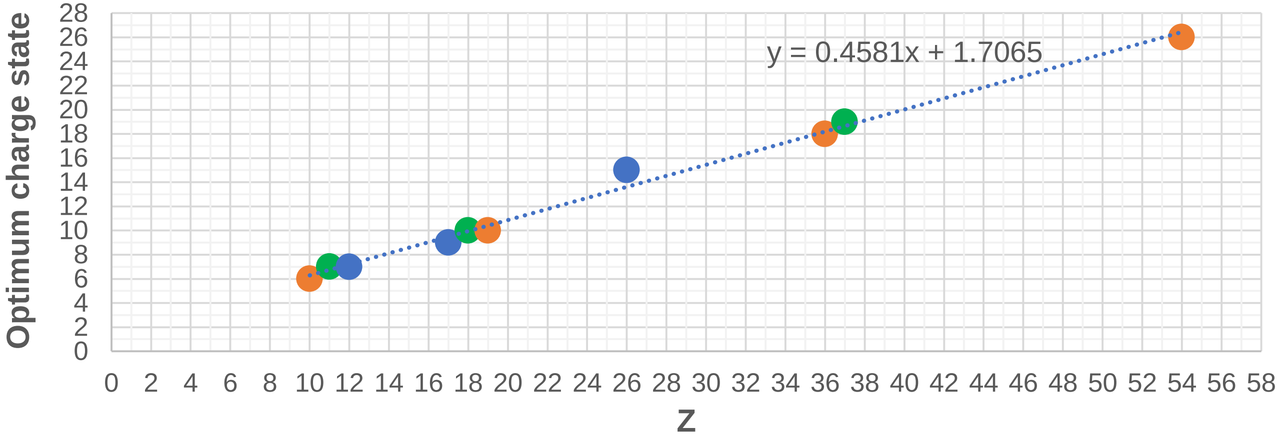
- diffusion/effusion time (refractory materials/short half-lives) -> Target heating, TULIP, Molecular extraction
- ionization efficiency -> MonoNaKe-Pt, FEBIAD source heating, target outgasing
- operational issues (stability, resilience) -> modifications to keep the insulators cold

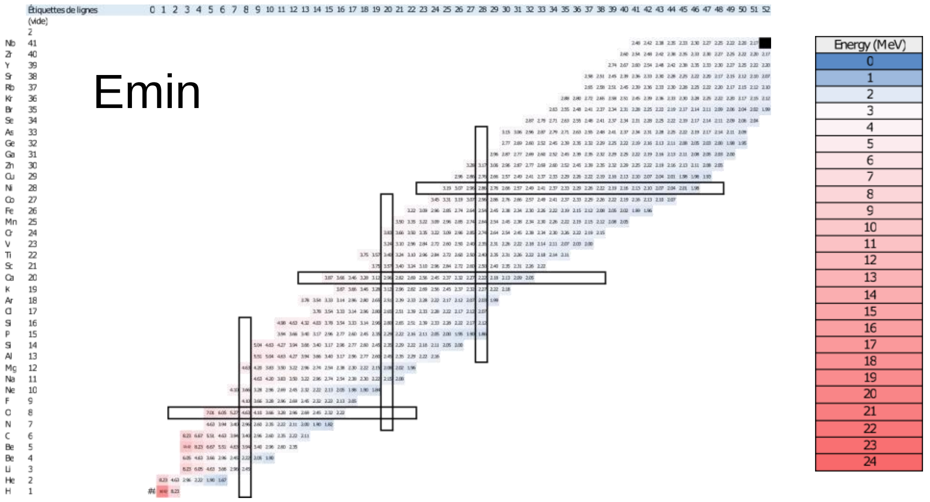
Acceleration

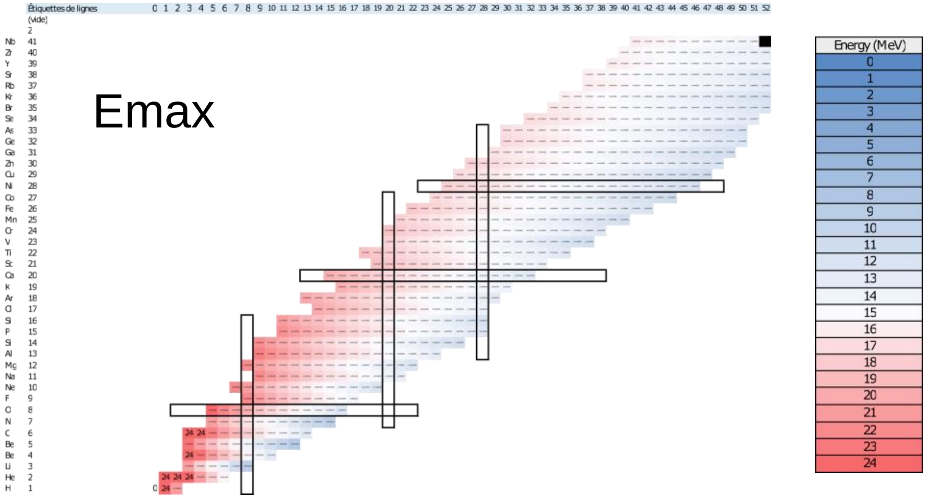


Limited by:

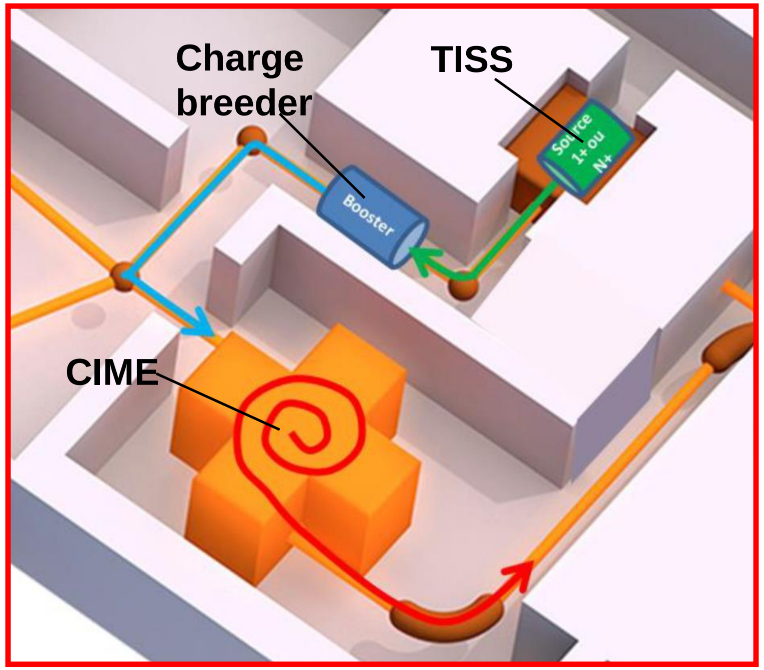
- charge state distribution at the output of the charge breeder
- platform limitations

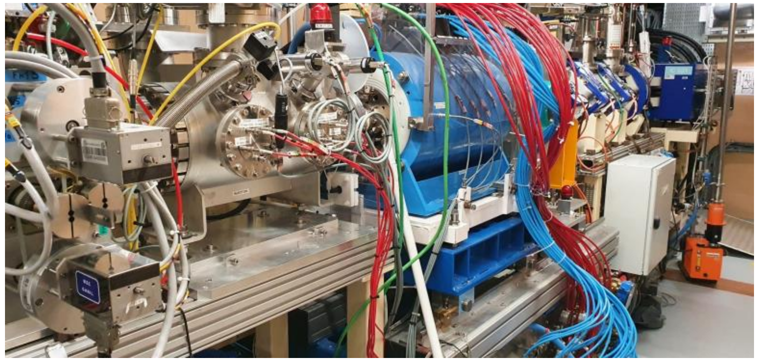




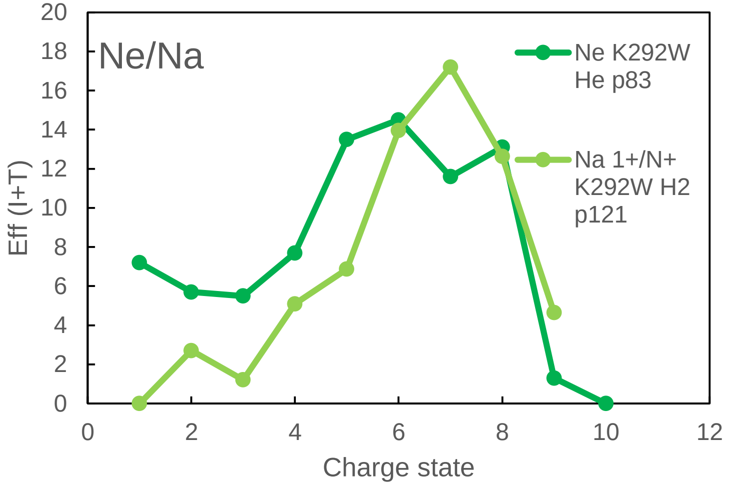


Charge breeding status

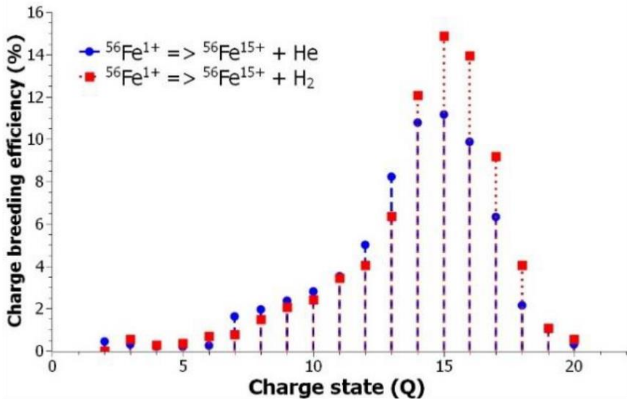




Gaz & Alkali ions



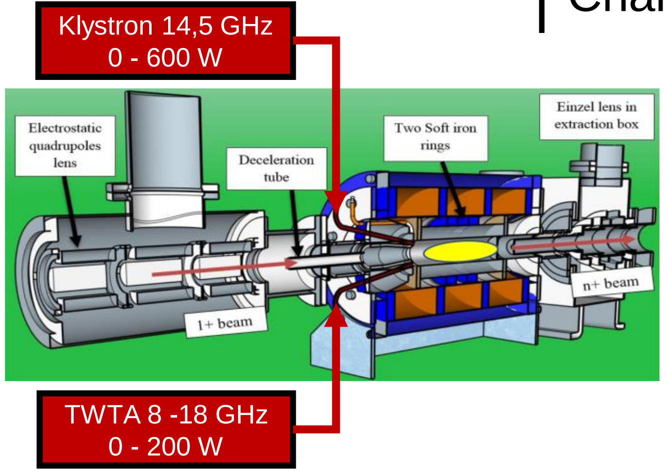
Metalic ions

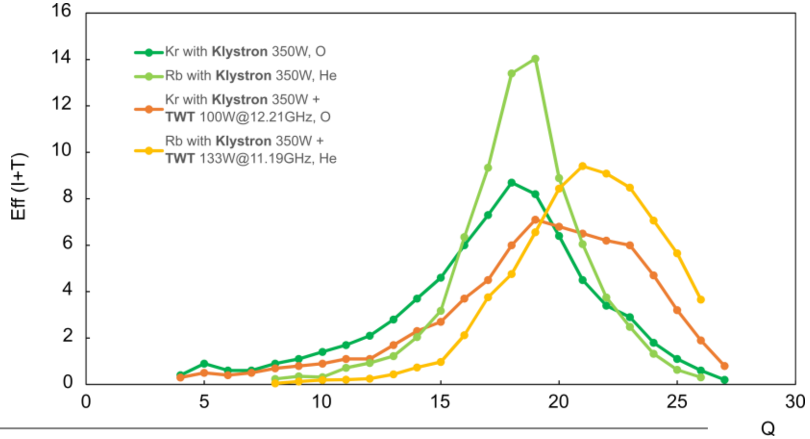


L. Maunoury et al, Journal of Physics: Conference Series 2244 (2022) 012066

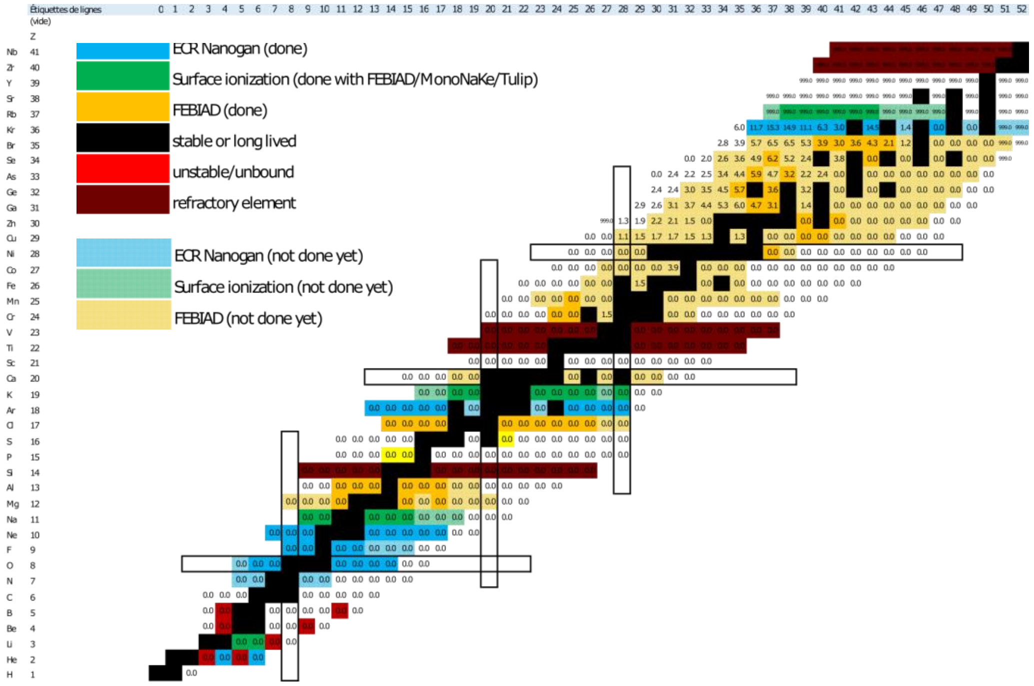
The charge breeder works

Total efficiency >70%
Charge state efficiency 5-20% depending on Z

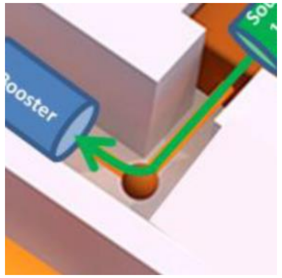


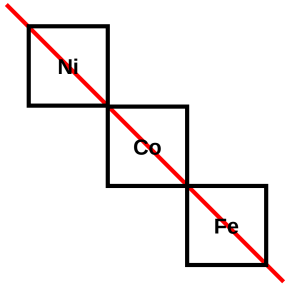


Purity



A selection -> Isobaric contaminants





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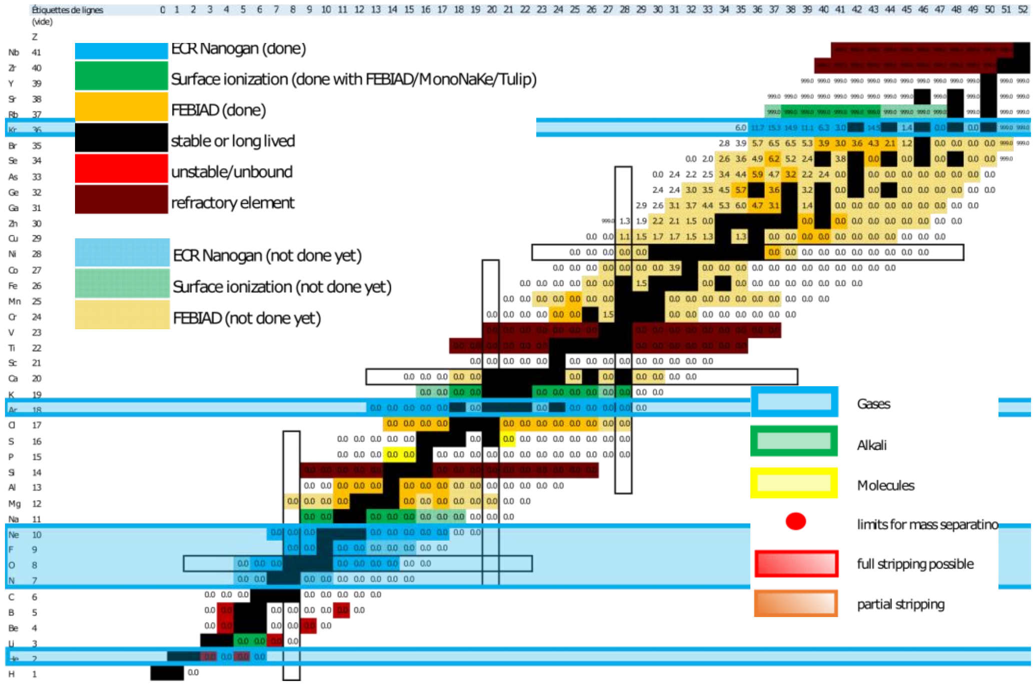

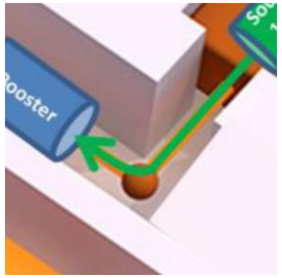

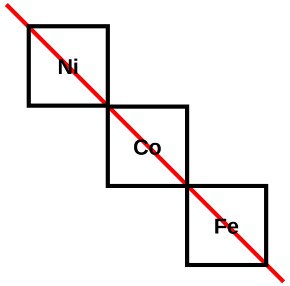

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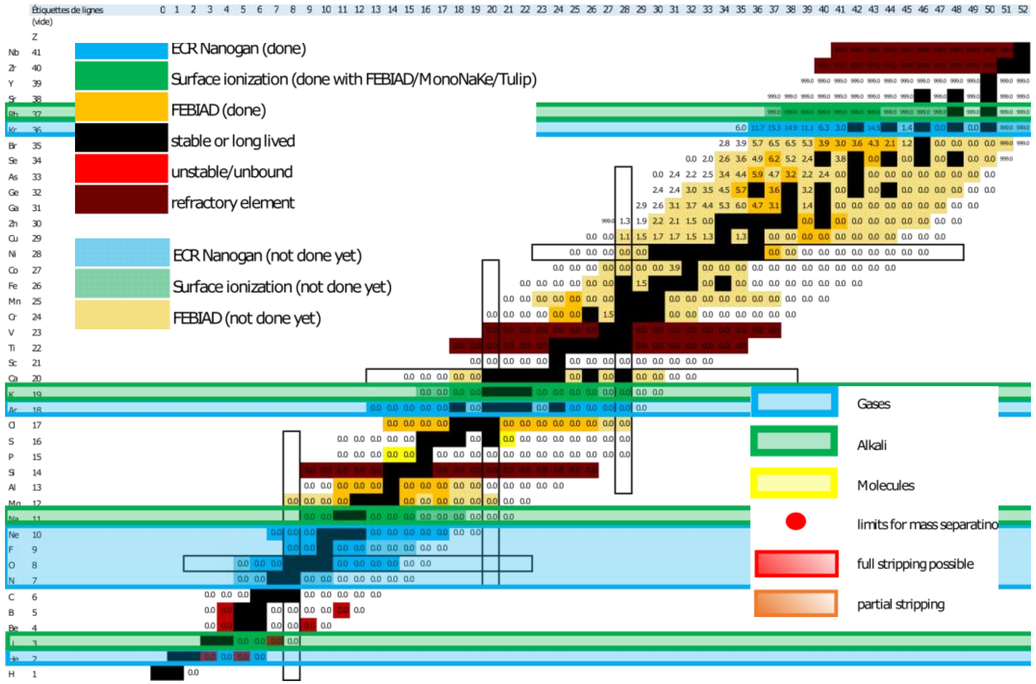
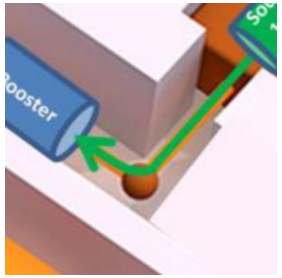
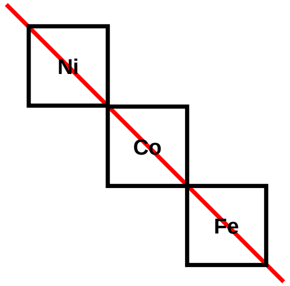
- Z selection – gaz (Nanogan)

Purity







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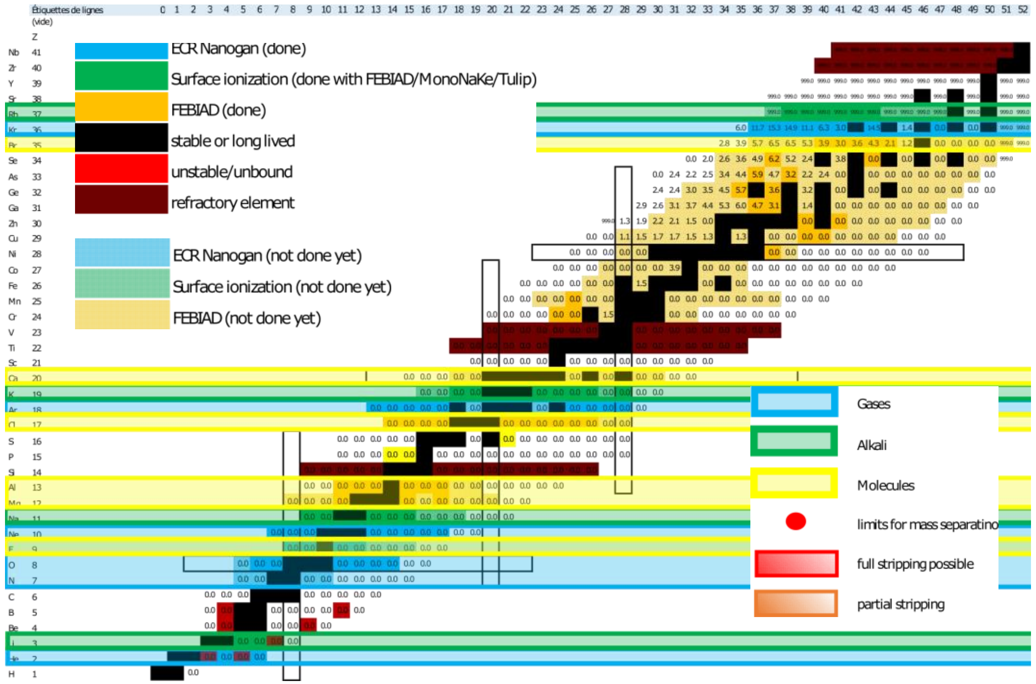

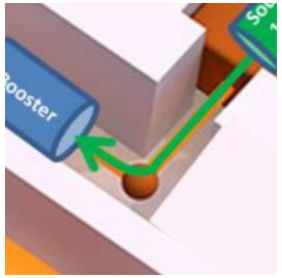

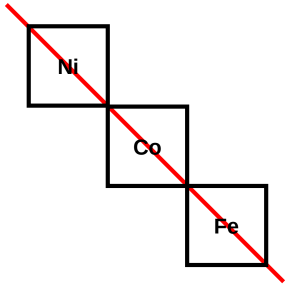

A selection -> Isobaric contaminants

- Z selection – gaz (Nanogan)
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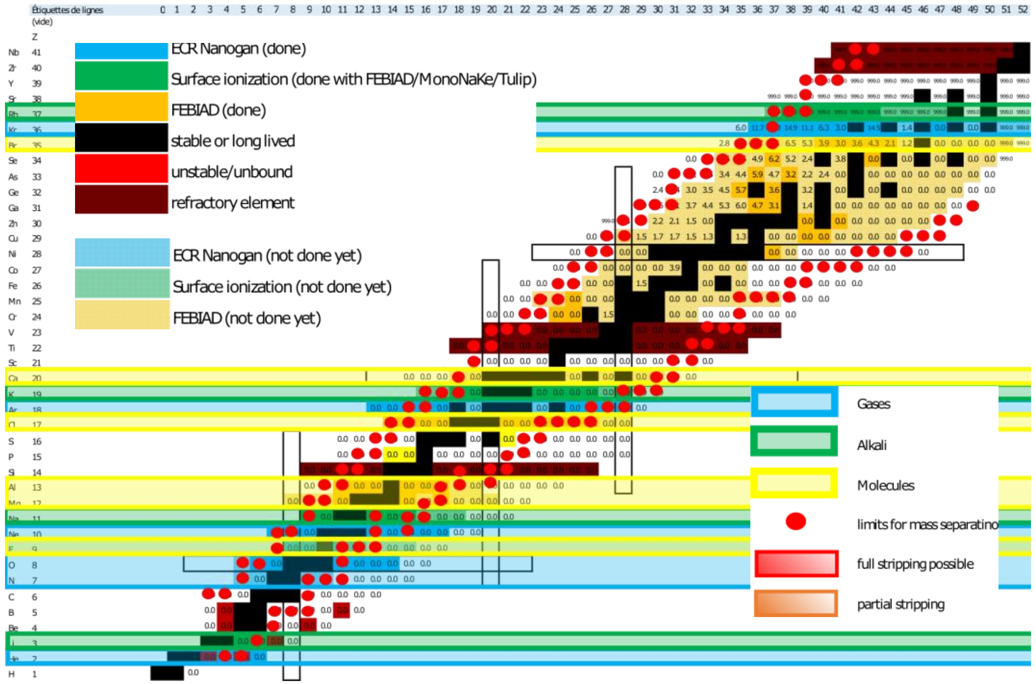
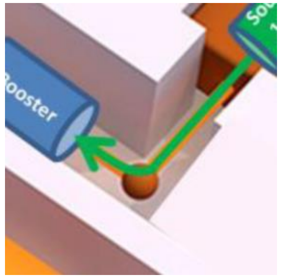
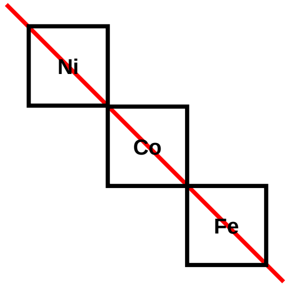
Purity







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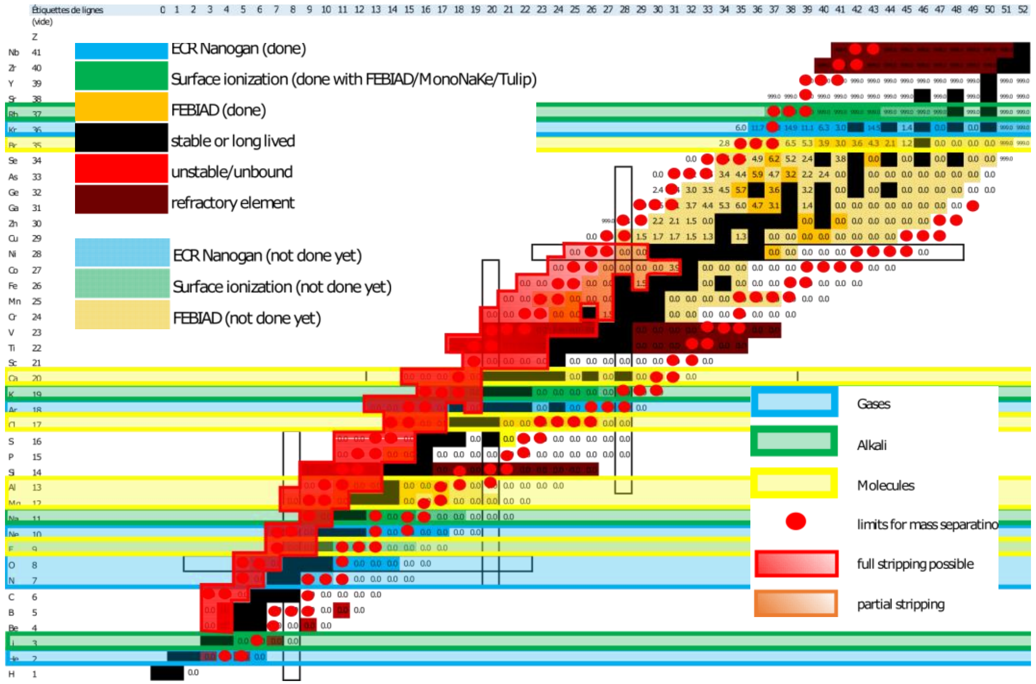

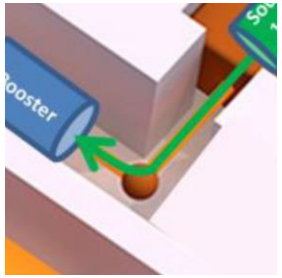

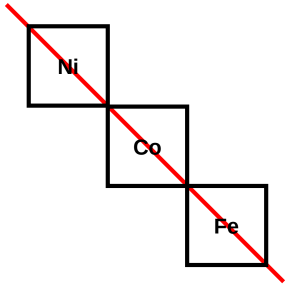

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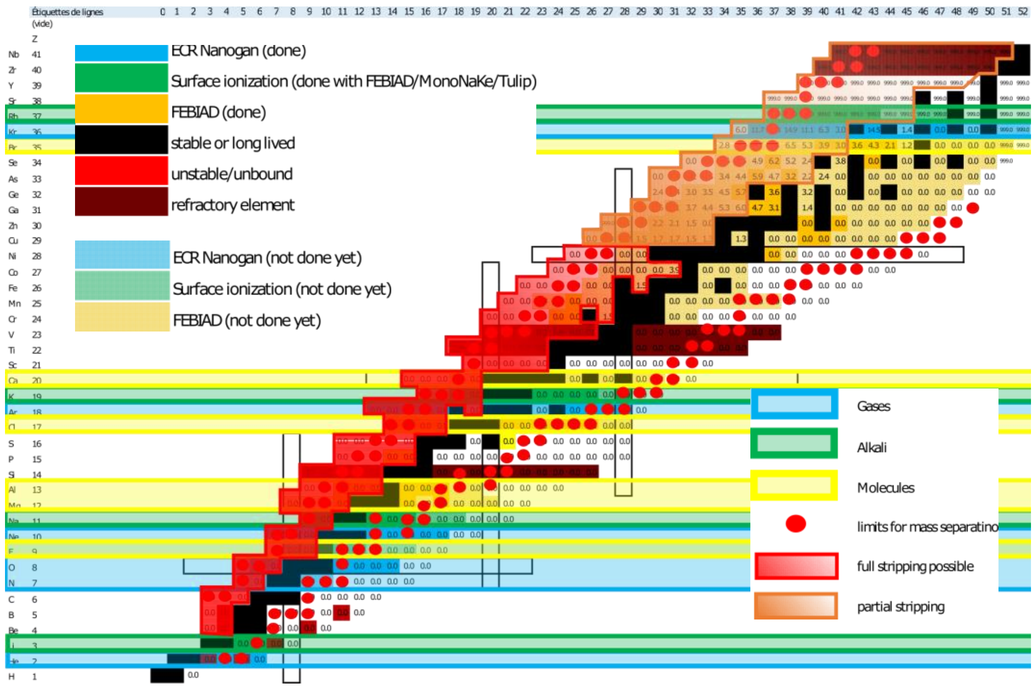
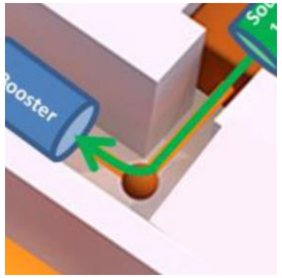
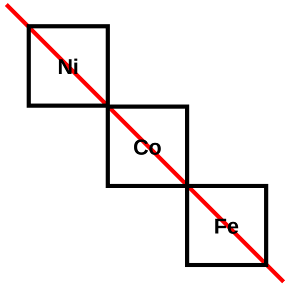
Purity







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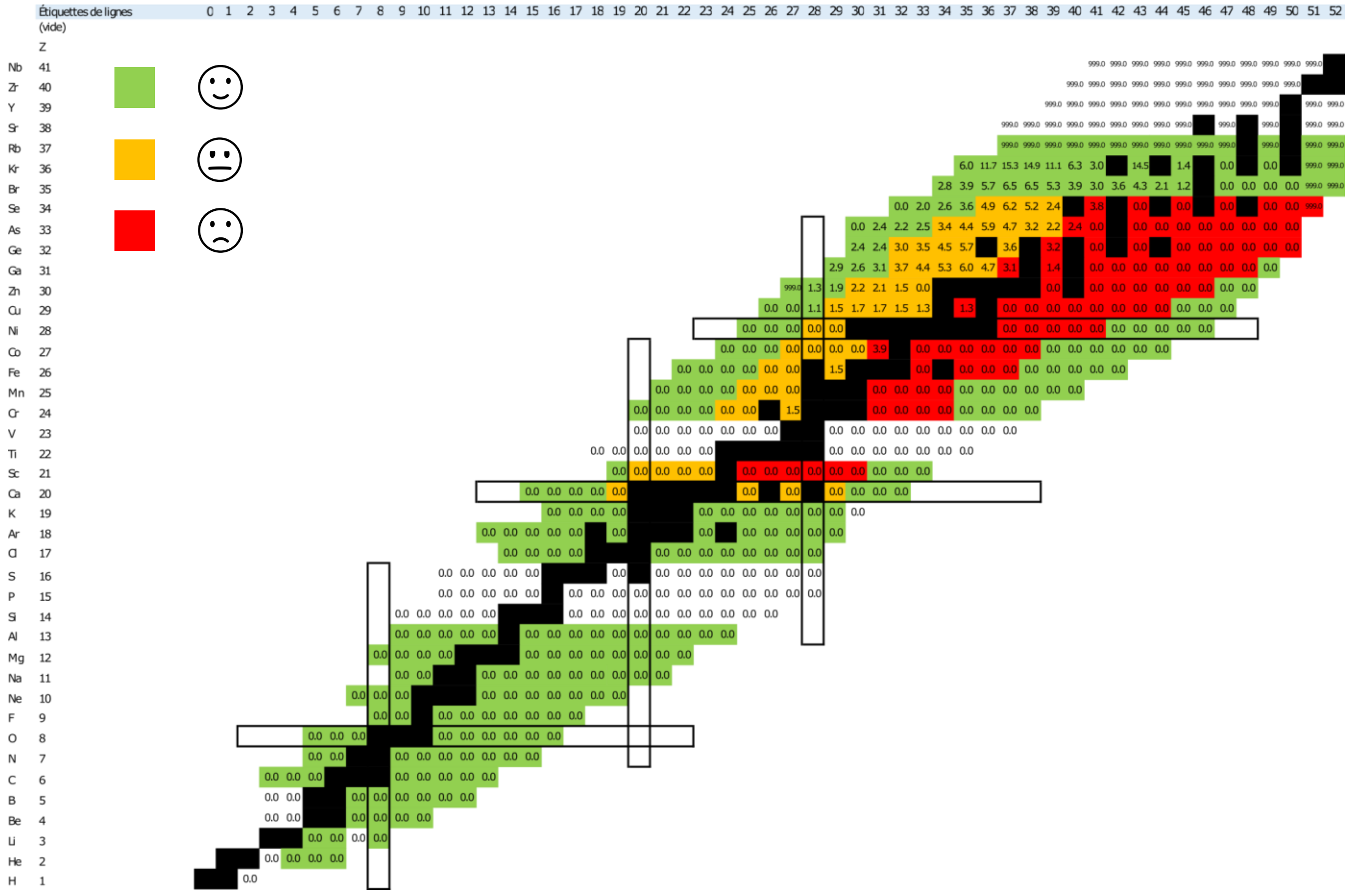
- Partial stripping : limited

Purity



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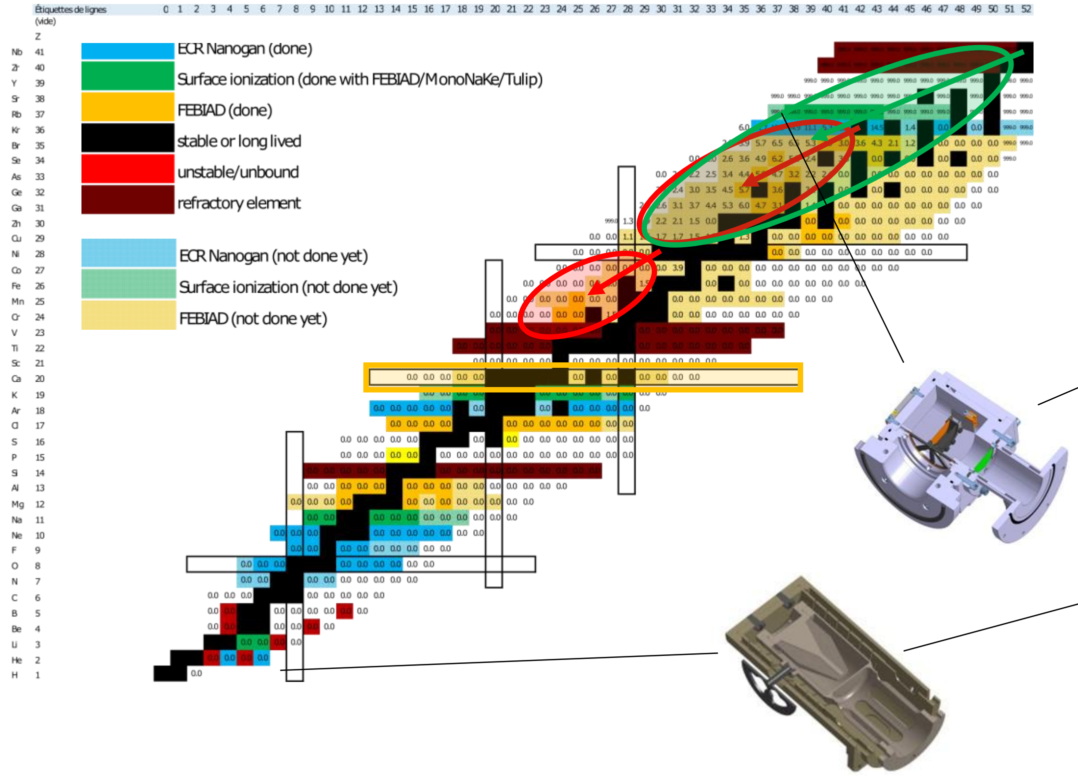
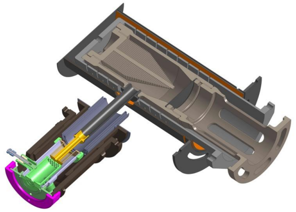
RILIS worth it or not ?

Conclusion



Source development

- New beams (2024)
- New target (2026?)
- Molecular CaF ?



- N-deficient Rb

- $^{8\text{-}9}$Li

Main limitations of Spiral1

- Diffusion/effusion time
- Purity (RILIS?)

Thank you for your attention!