GANIL

SPIRAL1 RIB production

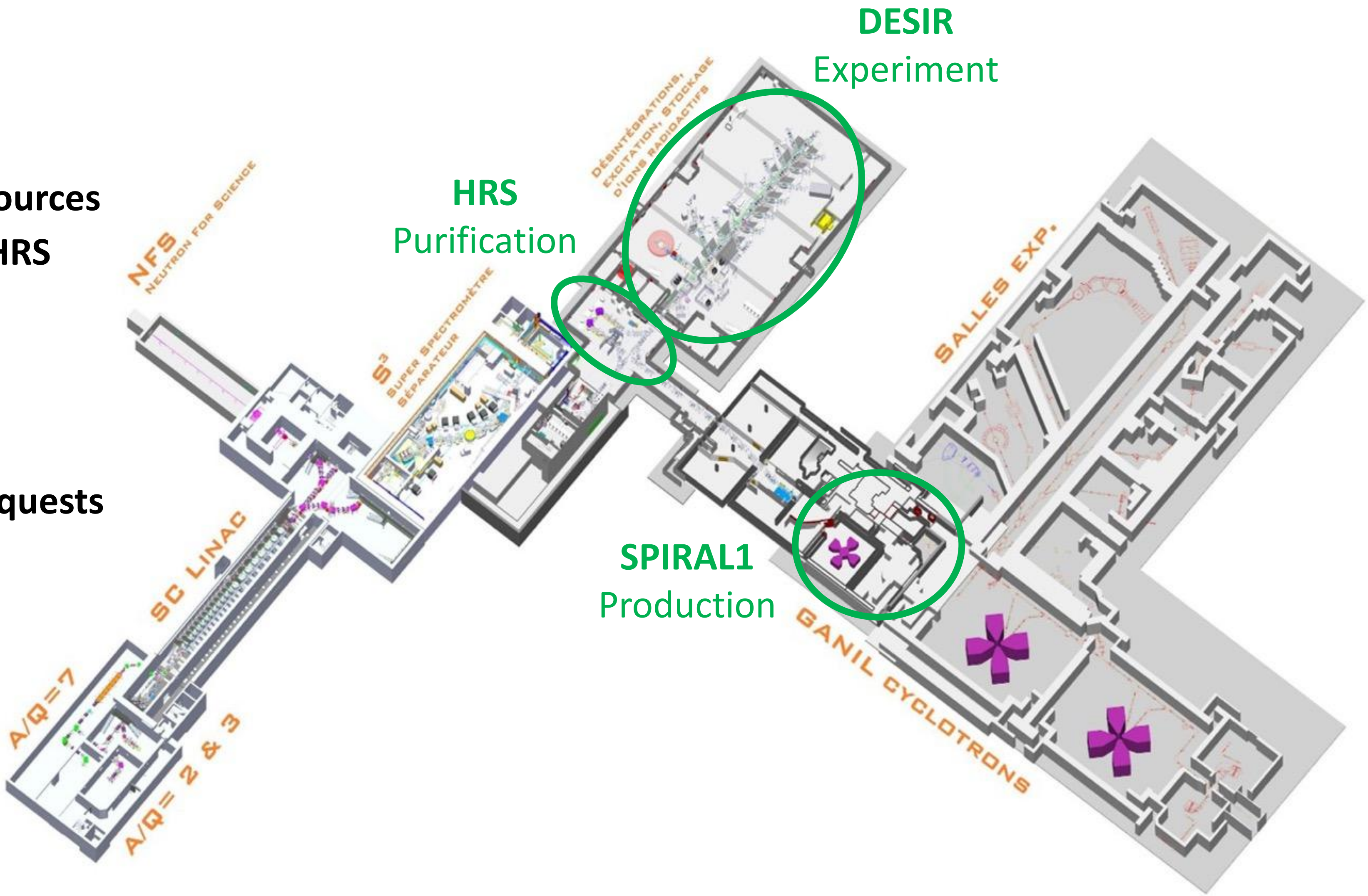
Pierre Chauveau for the Target/Ion-source group

Outline

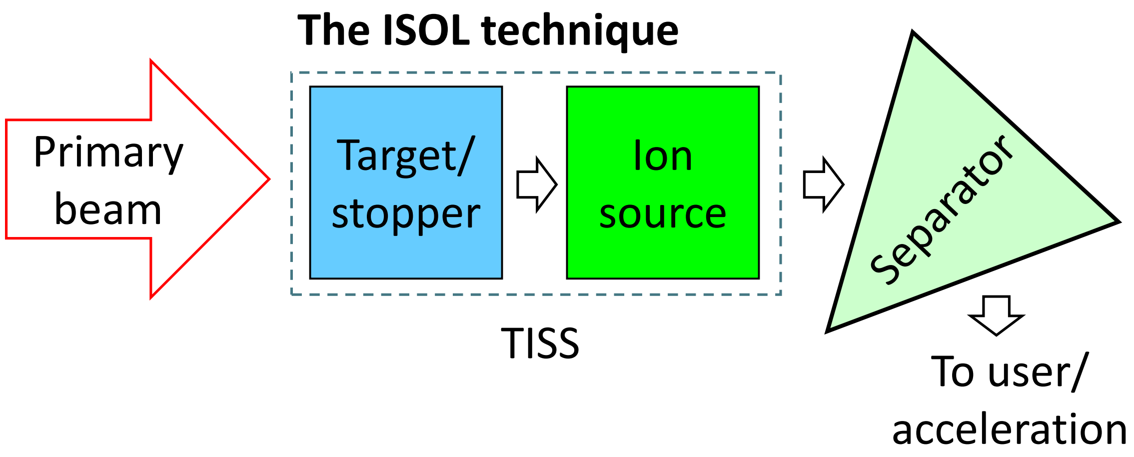
I. **The facility**
   - A. **Beam production : sources**
   - B. **Beam purification : HRS**

II. **Beam requests**
   - A. **Estimation process**
   - B. **Answer to (some) requests**

Conclusion



Beam production



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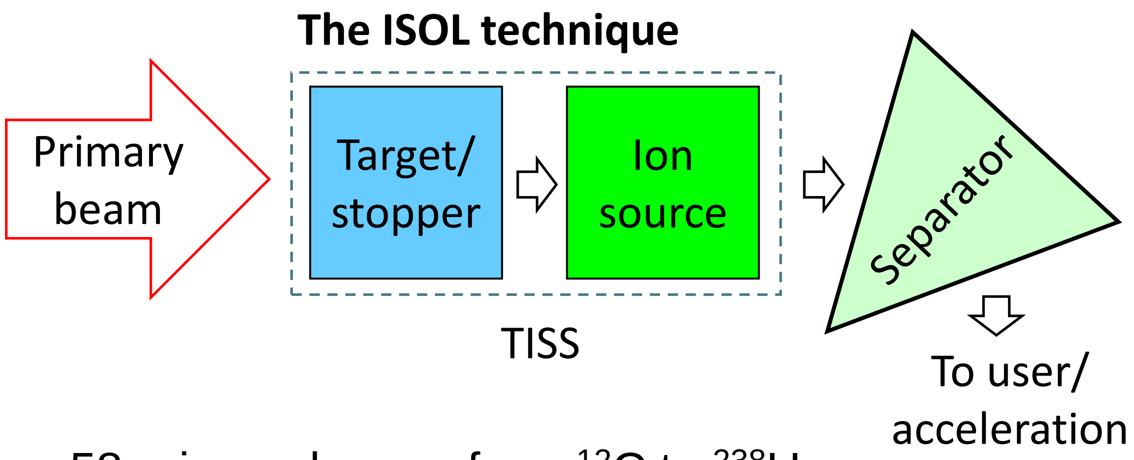
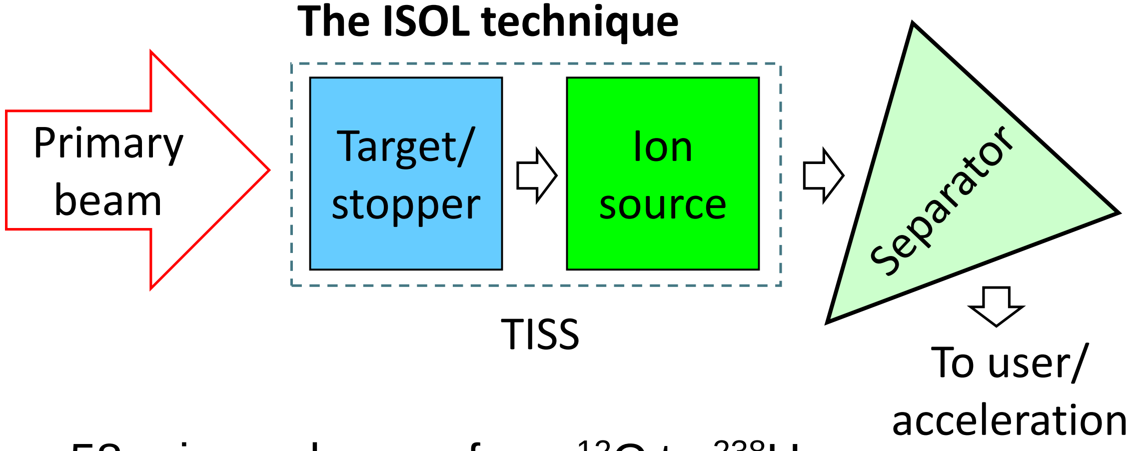


- 58 primary beams from ^{12}C to ^{238}U
- Thick targets: C, Nb (in development)
- Thin targets: C, Ni
- 3 ion sources: ECR, SIS, FEBIAD

Beam production

The ISOL technique



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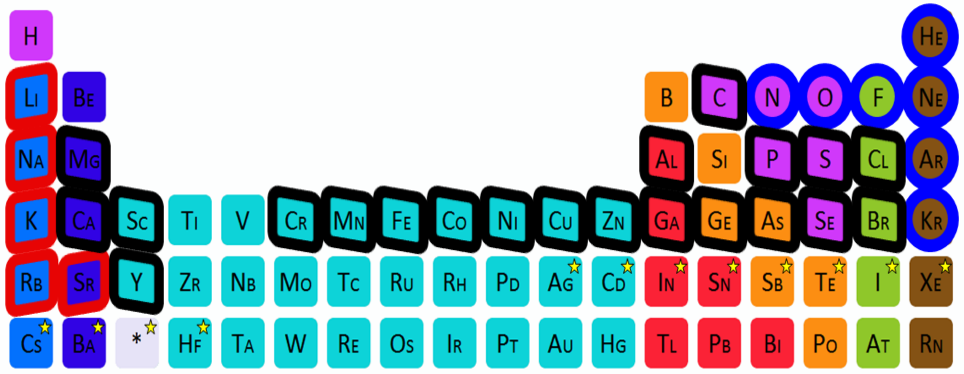

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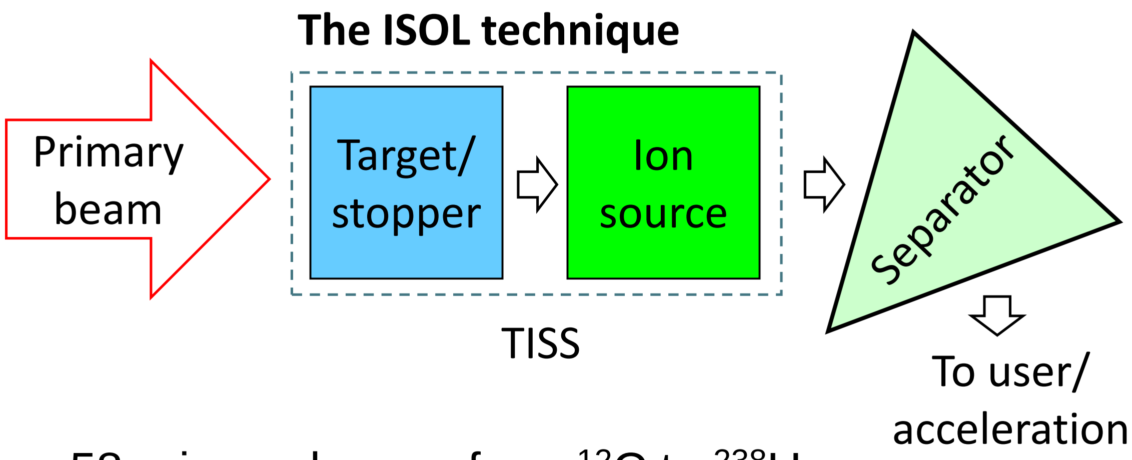

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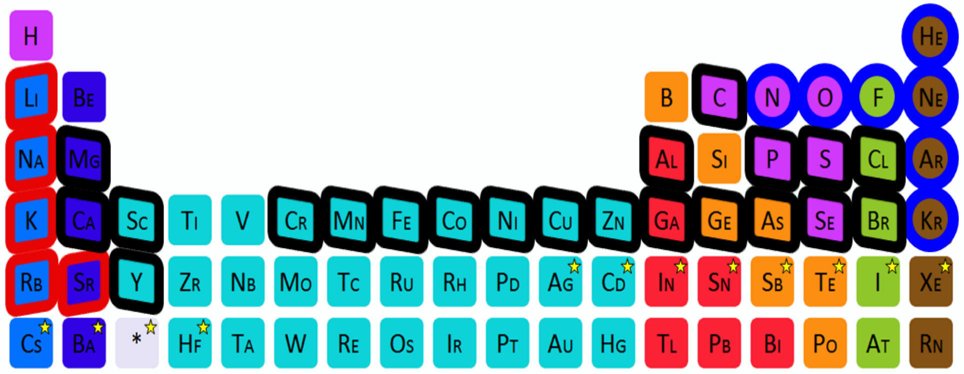
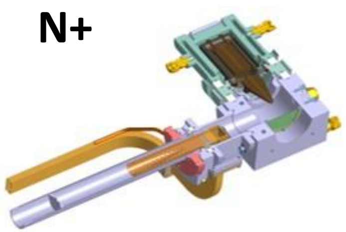
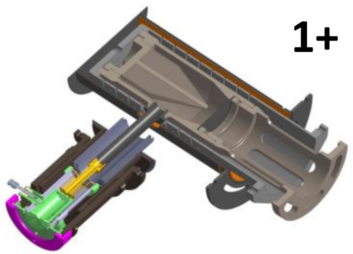
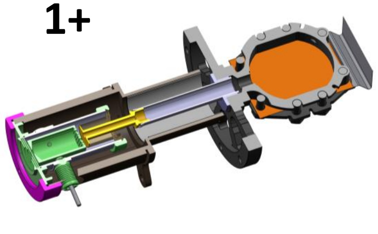
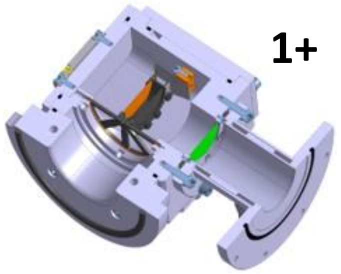
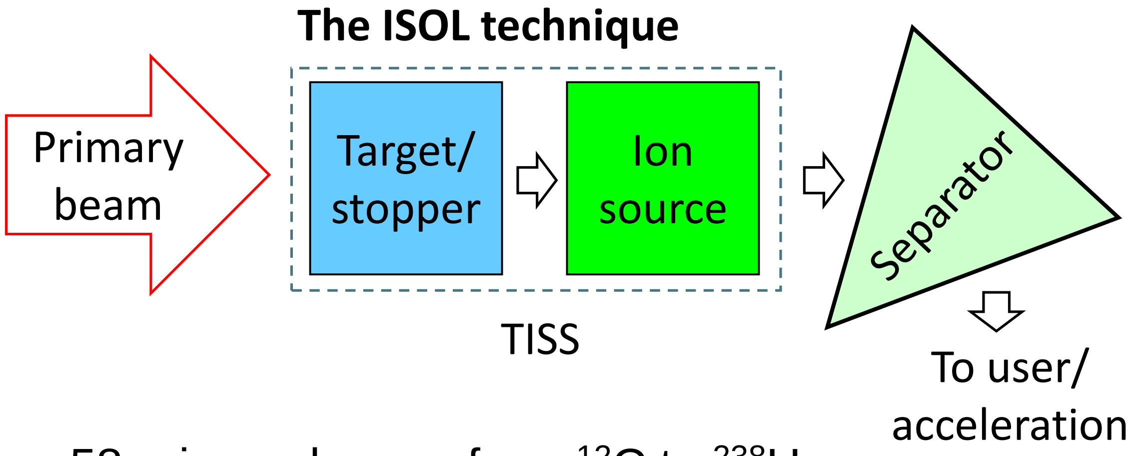


	ECR	SIS	FEBIAD
Thick target	N+  **Nanogan** For gaz	1+  **FEBIAD** For condensable	1+  **MonoNaKe** For alkali
Thin target (TULIP)		1+  **TULIP**(-FEBIAD) For neutron-deficient isotopes	1+  **TULIP** For alkaline

Beam production



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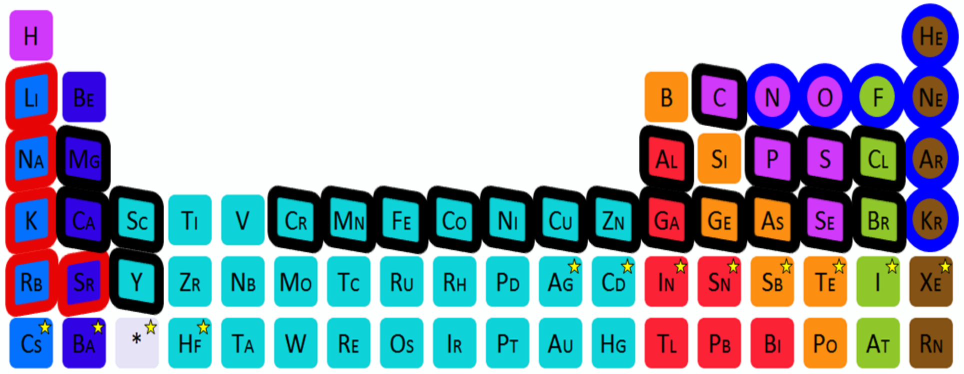
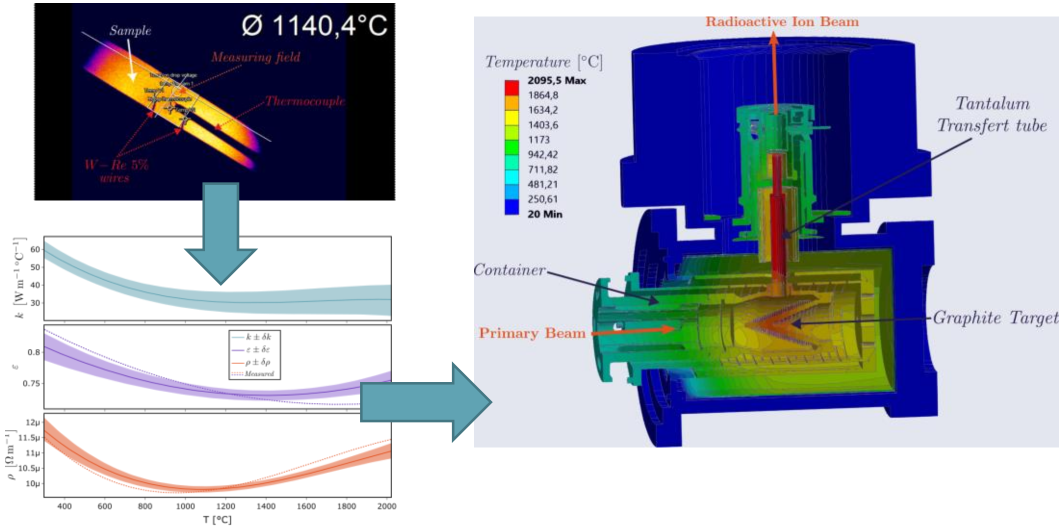


	ECR	SIS	FEBIAD
Thick target	N+ **Advantages** • Intensity (directly N+ beam) • Purity (gases only) **Disadvantages** • Lower charge states (and energy) • Gases only — Nanogan For gaz	1+ **Advantages** • Intensity (high efficiency for most alkali) • Purity (low ionisation energies only) **Disadvantages** • Only alkali — FEBIAD For condensable	1+ **Advantages** • Broadband **Disadvantages** • Non selective — MonoNaKe For alkali
Thin target (TULIP)		1+ **Advantages** • Intensity (high efficiency for most alkali) • Purity (low ionisation energies only) • Fast release **Disadvantages** • Only alkali • Low in-target production — TULIP (FEBIAD) For neutron-deficient isotopes	1+ **Advantages** • Broadband • Fast release **Disadvantages** • Non selective • Low in-target production — TULIP For alkaline

Recent R&D work – thick targets

PhD
E. Le Villain

- New target design to optimize the release of Fe-Co-Ni isotopes (and others)
  - **Gathering material data** ✓
  - Building a parametric model for simulations
  - Optimizing the geometry for high and homogeneous temperature ✗
  - Building and testing ✗



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S. Hurier

- New target material to improve the production rate of many isotopes
  - Production calculations : GANIL beams → graphite **VS** Carbon beam → new material (<Nb) ✓
  - Investigating and chosing materials (Nb, ZrO^2) ✓
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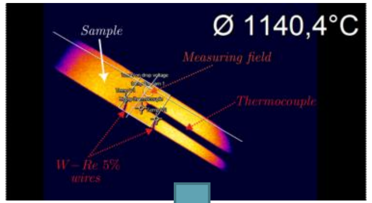

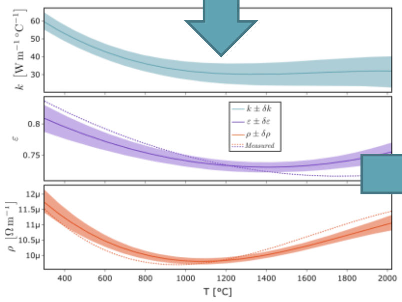

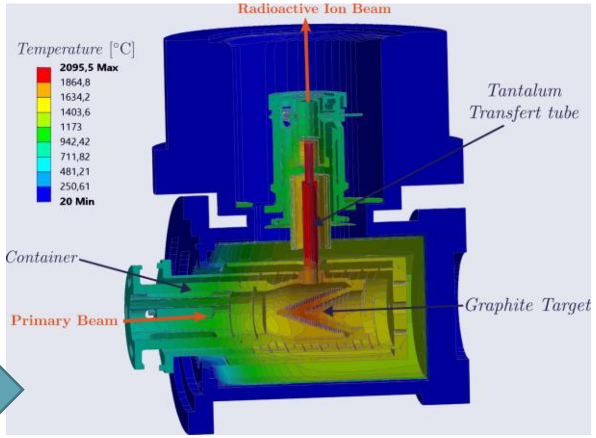

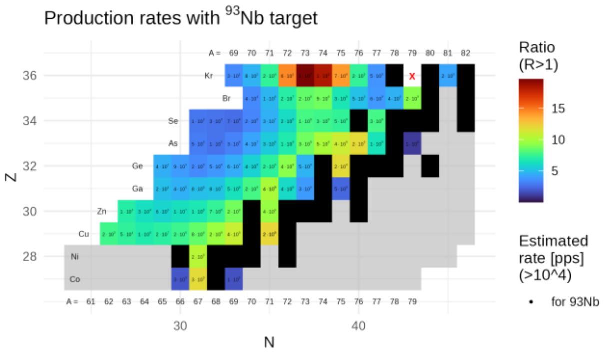

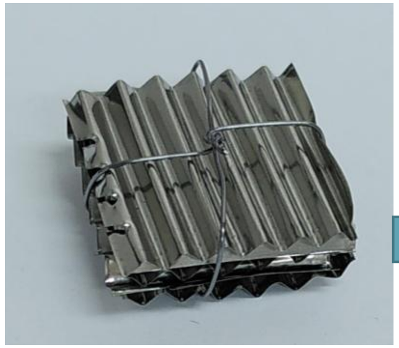

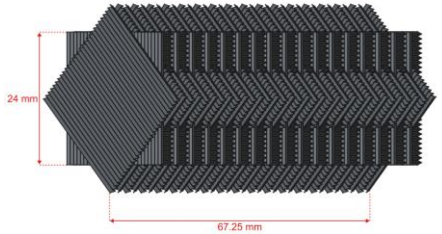

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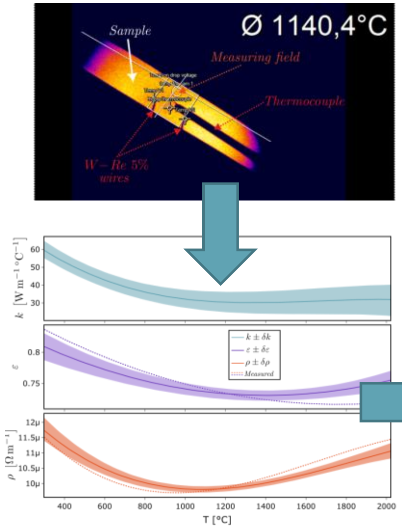
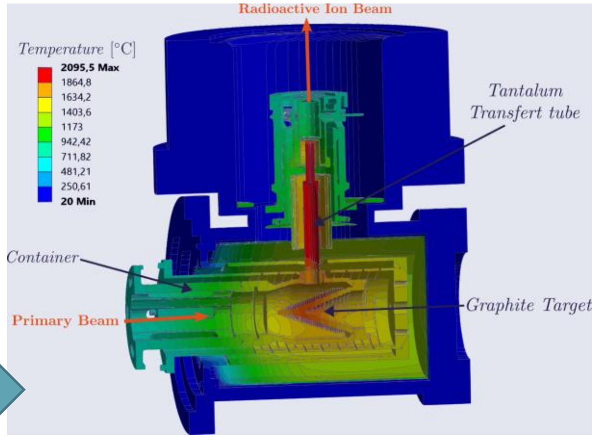
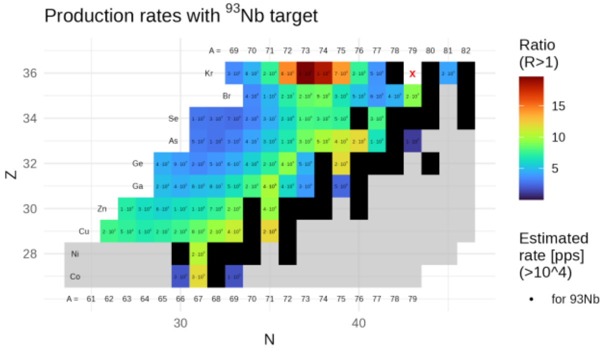
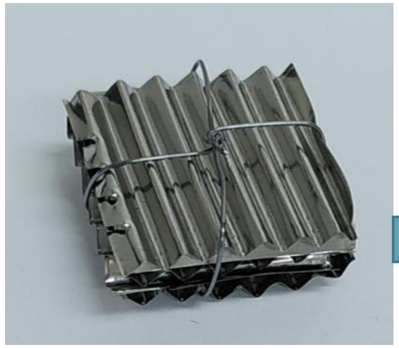
M2+PhD
C. Pfeffer

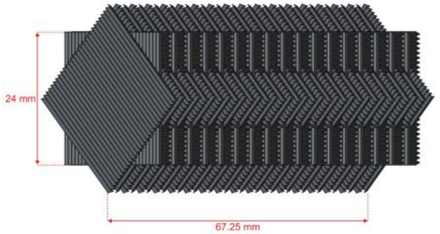
- New TISS for intense 39Ca beams
  - Preliminary investigation (production method, target materials, source)
  - …





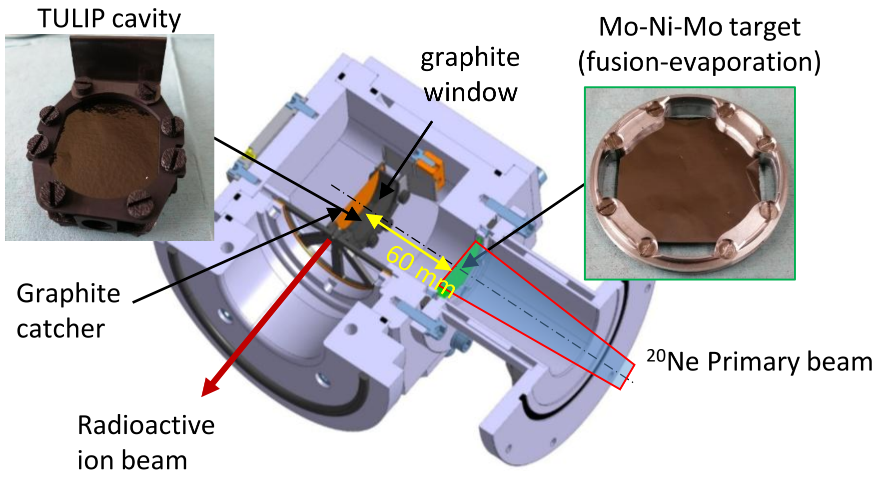






Recent R&D work – TULIP

TULIP SIS



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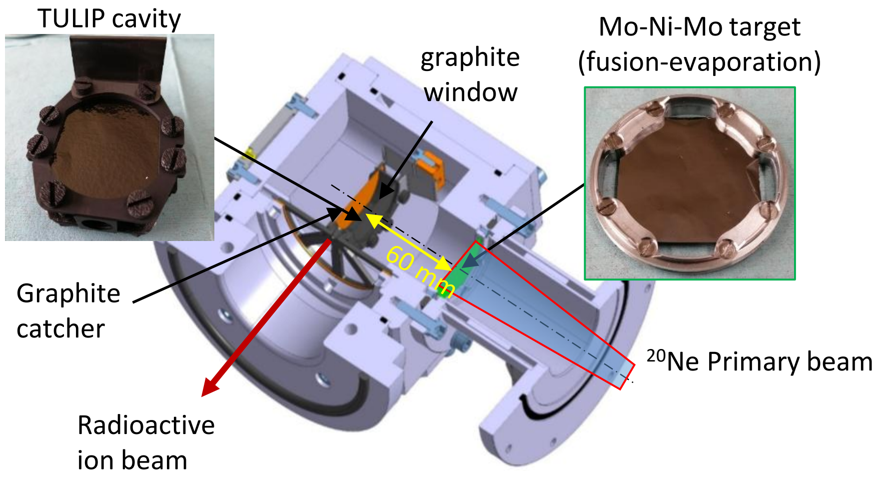
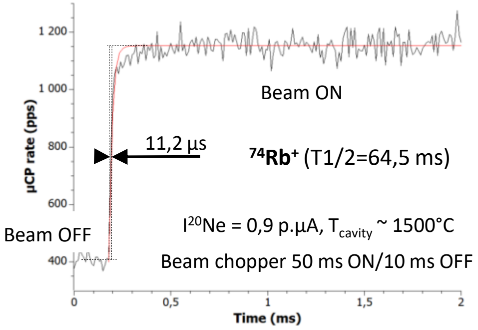
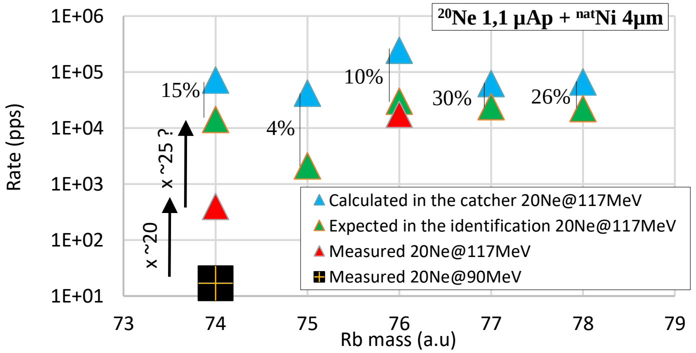


- Proof of principle with Rb isotopes
- Several experiments (2022,2023,2024)
- Improved rate for 74Rb ($T_{1/2}$ = 65ms)





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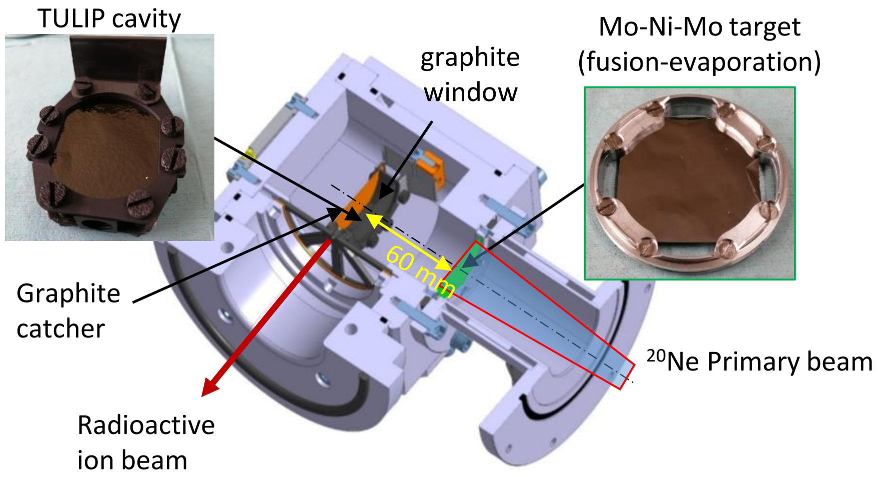

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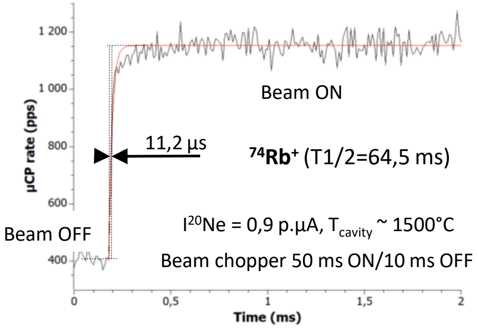
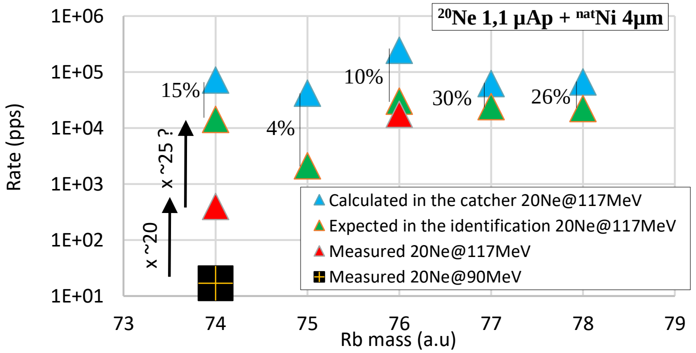
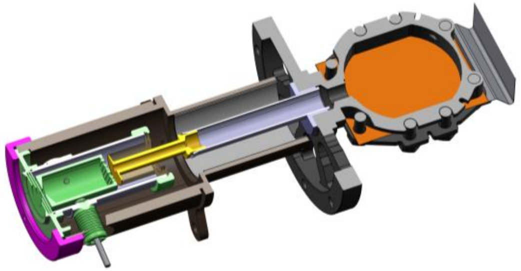
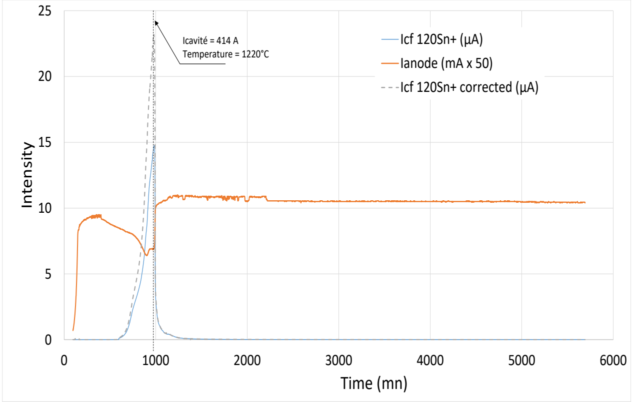




TULIP FEBIAD





- Fully tested offline
- Efficiency measurement with tracers (Ar, Ag, Sn, In, Eff≈9-15%)
- First online test in 04/2026 aiming to produce Sn isotopes

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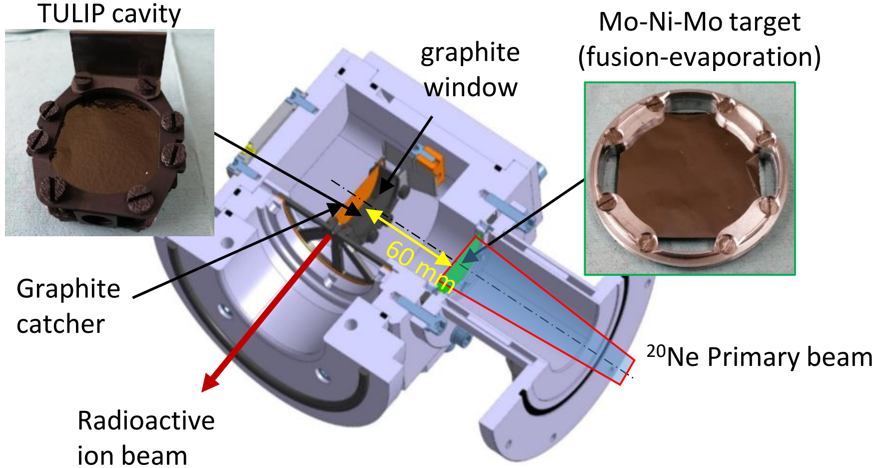

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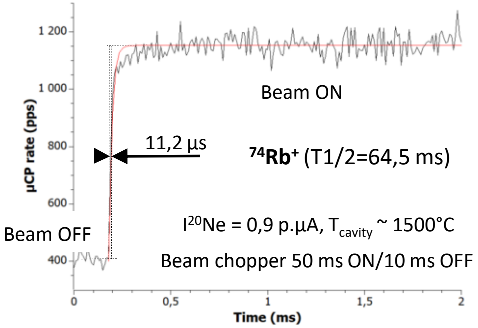

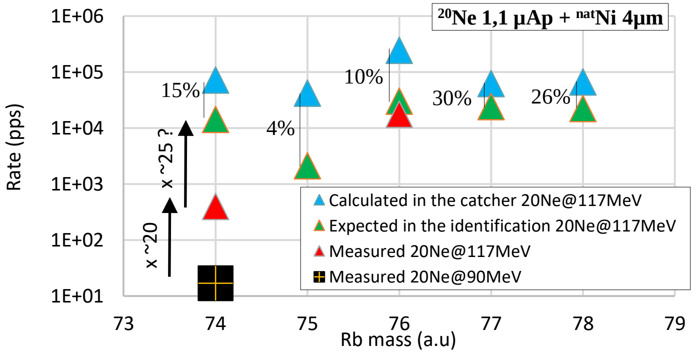

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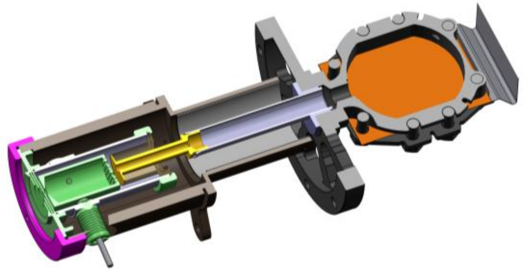

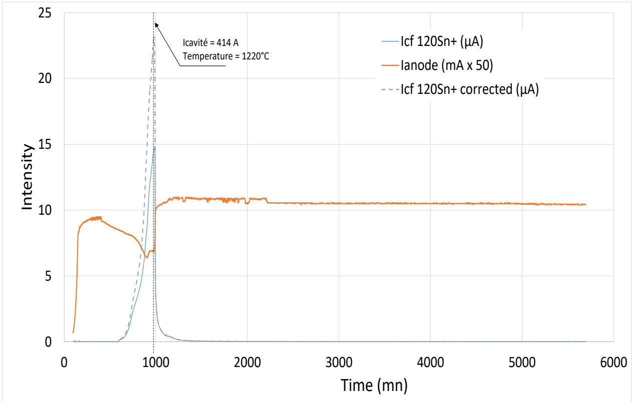

- Fully tested offline
- Efficiency measurement with tracers (Ar, Ag, Sn, In, Eff≈9-15%)
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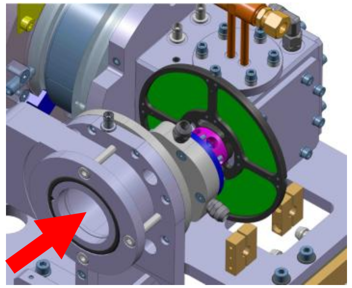
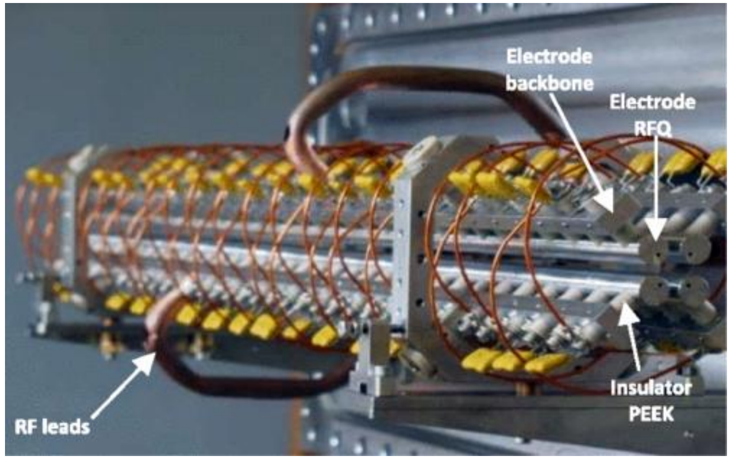
Rotating target (increased beam power)

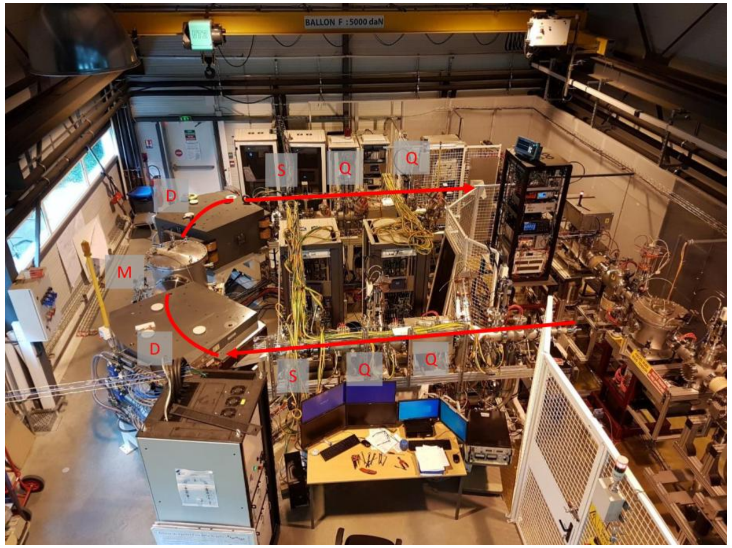
- Simple and radiation hard
- Water wheel/magnetic coupling
- Works but rotation speed limited by eddy currents



Purification: SHIRAC & HRS



R. Boussaid, Phys. Rev. ST Accel. Beams **18**, 072802



Expectations:

- SHIRAC: ΔE down to 1eV
- HRS: R_{FWHM} up to 24000

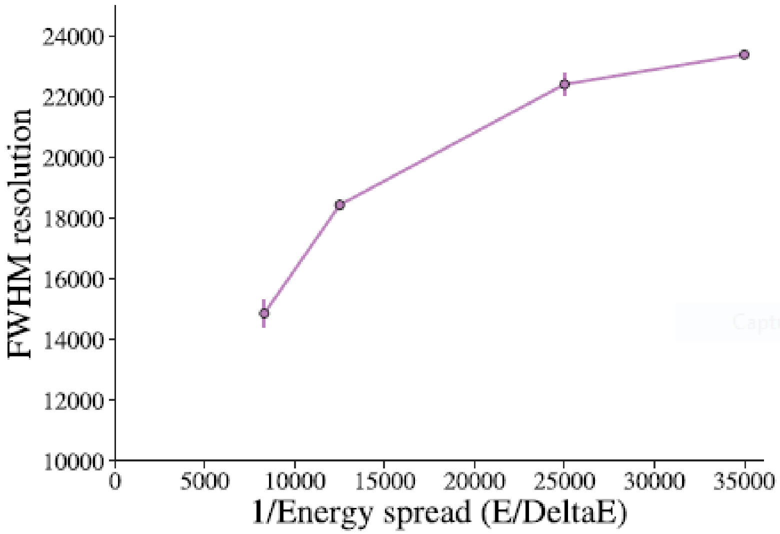


Fig. 6. HRS FWHM resolution as a function of the beam energy spread. The energy spread was introduced by adding a noise on the acceleration voltage by means of an arbitrary waveform generator in the acceleration chain.

J. Michaud et al, NIMB 541 (2023) 161-164

Estimation process (DESIR)

1. Gathering radioactive ion data (rates for all measured $^{A}Z^{Q+}$) for each source (either measured or estimated)
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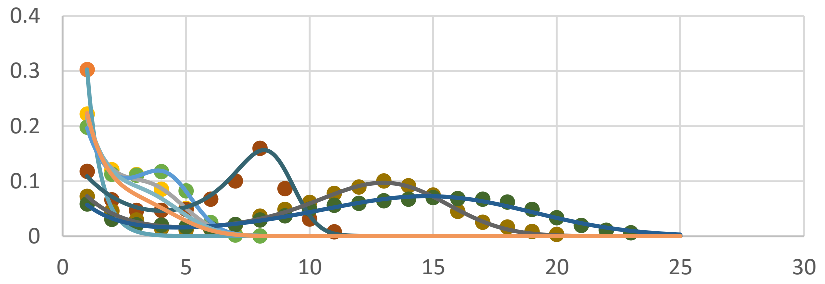
   - Nanogan -> charge state distribution model



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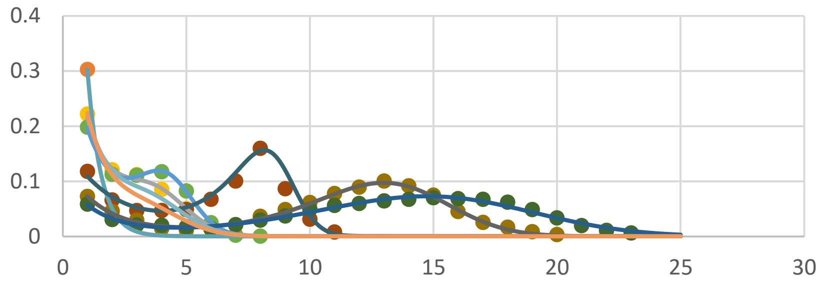

4. Predicting contamination after spectrometer (D1P, HRS)
   - Create a simulated mass spectrum, with each $^{A}Z^{Q+}$ given by a gaussian
     - Centroid : mass from AME
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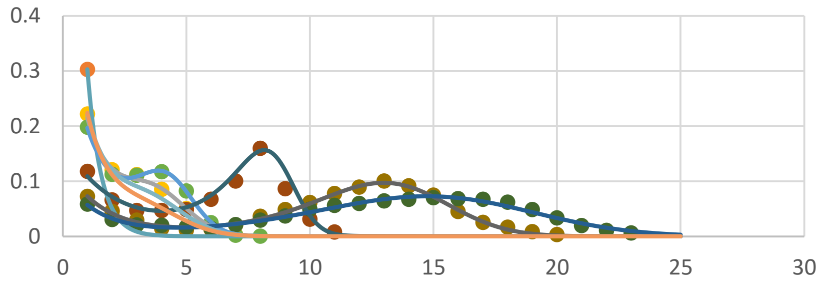

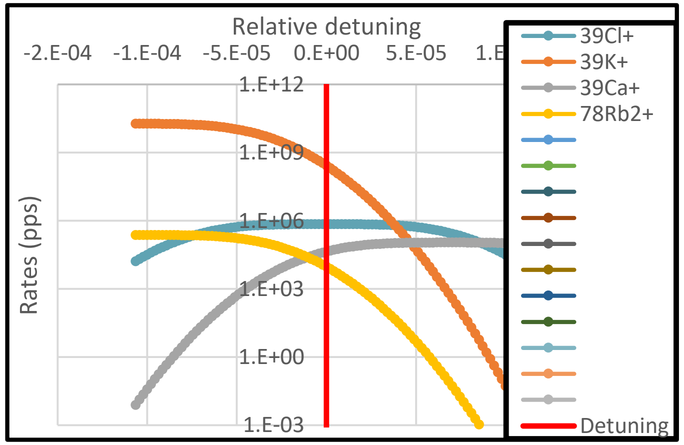

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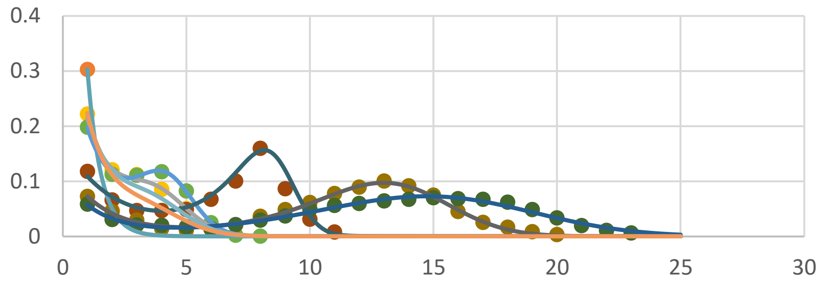

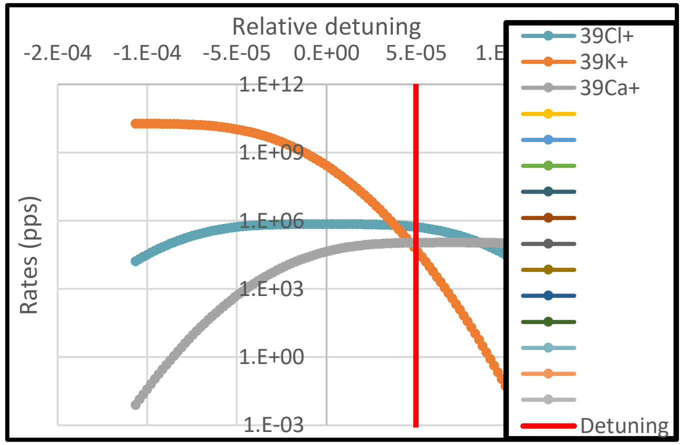

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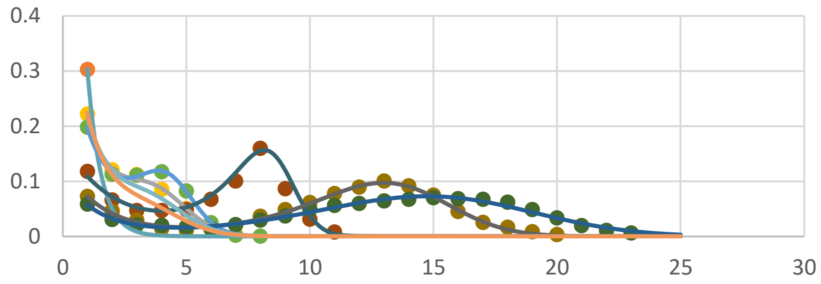
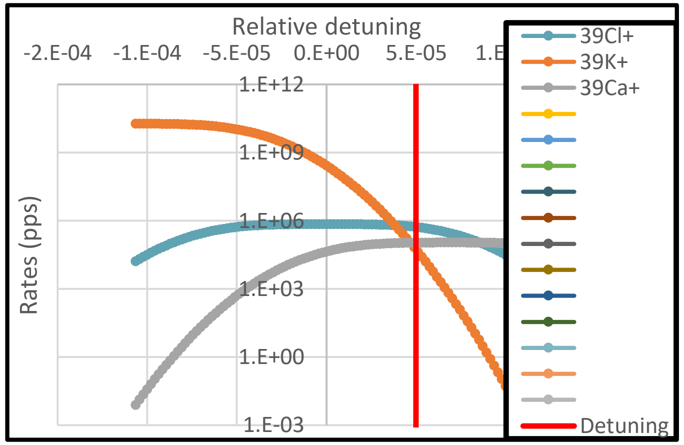


4. Predicting contamination after spectrometer (D1P, HRS)
   - Create a simulated mass spectrum, with each $^{A}Z^{Q+}$ given by a gaussian
     - Centroid : mass from AME
     - Hight : rate
     - Width : FWHM = $\delta m = m/R_{FWHM}$ (R_{FWHM} = 200 for D1P, R_{FWHM} = 20000 for HRS)
   - Cut the spectrum at +/- 3σ around the chosen mass : mass of the isotope of interest + detuning if necessary



Limits :

- Source data not perfect (rate estimations/CSD model/reproducibility)
- Purity estimates rely on peak shape

Beam requests

Workshop R&D ISOL beams

- 15 LOI (LEB & PAB), 136 beam requests → several months to gather data, build the model and provide « beam sheets »

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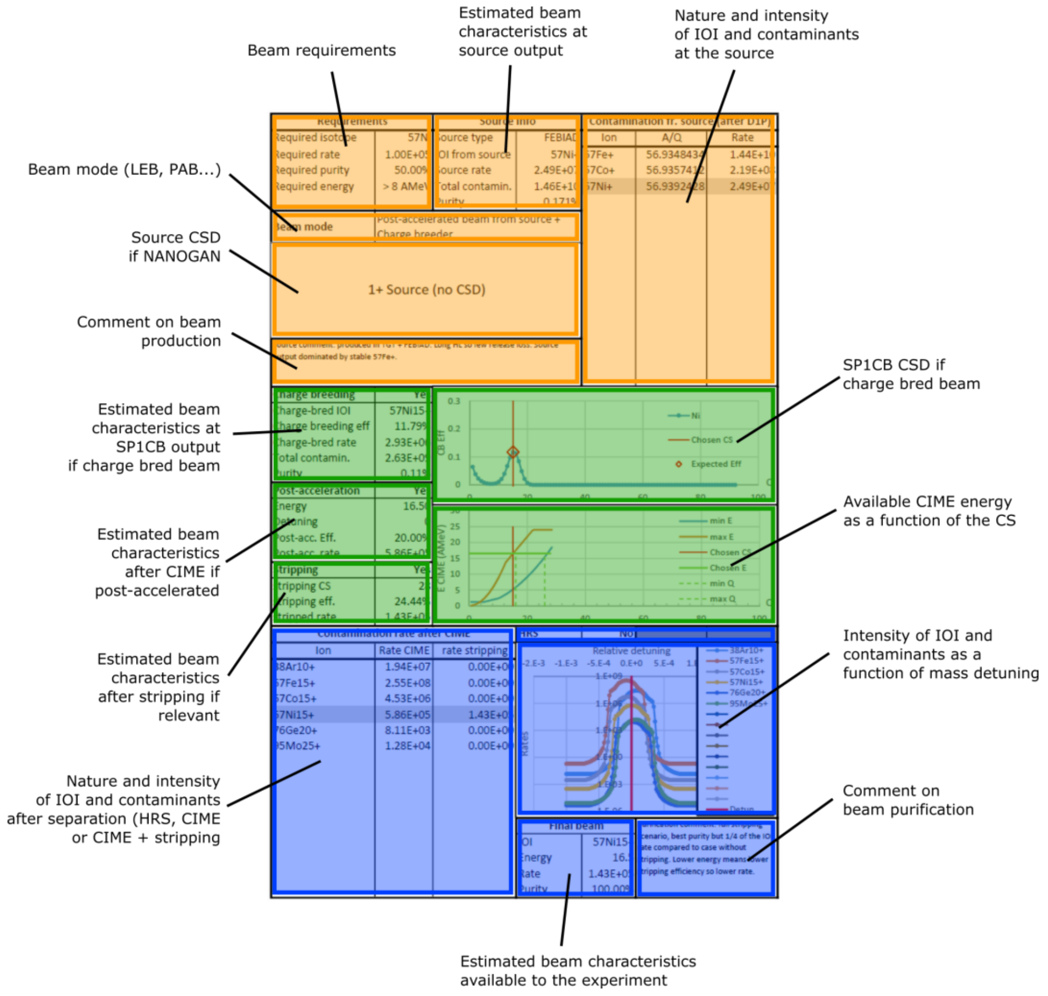

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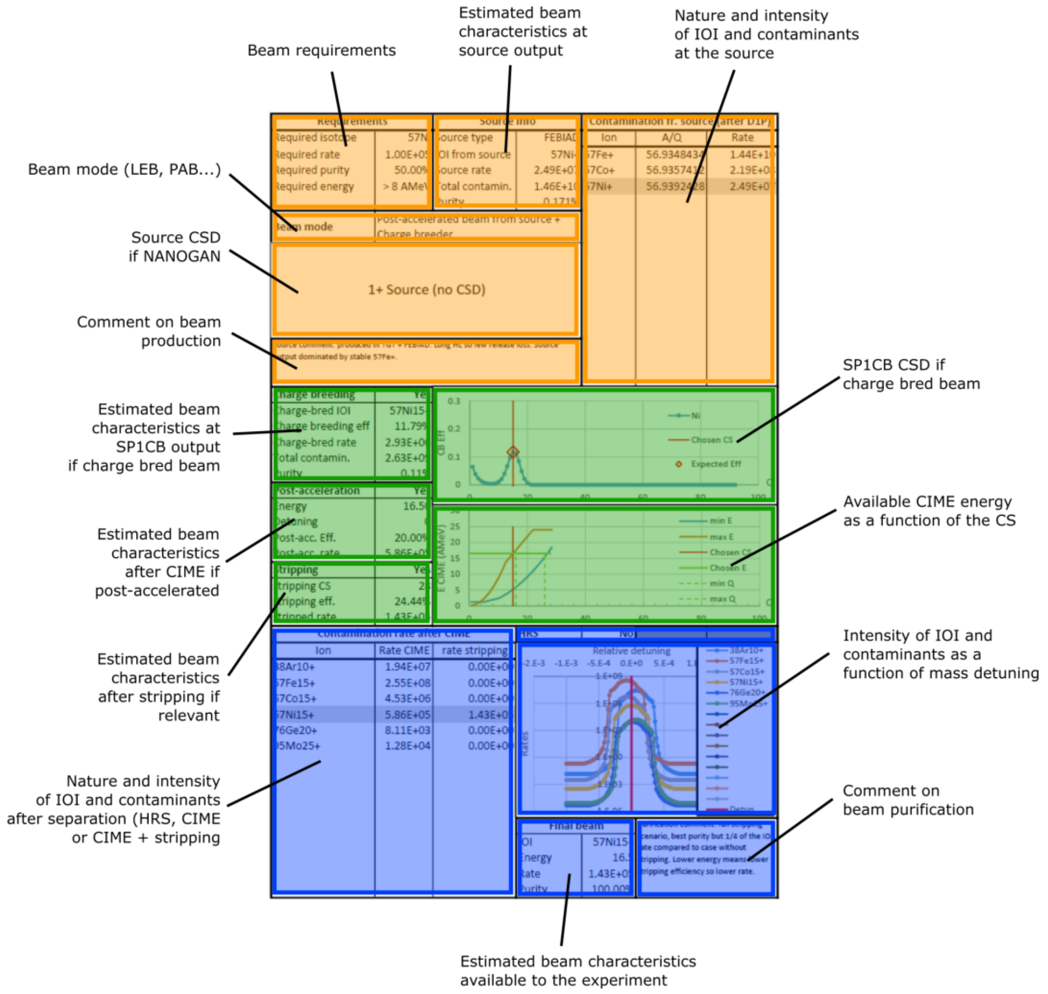
- 52 LOI, 375 beam request (just LEB), but…
- …147 beams flagged for S3-LEB, some beams requested twice, redundancy with the last WS.
- Many beams we have never produced, including 52 beams from elements we have never seen
- 87 beams from TULIP (1 beam + 1 target → 1 isotope)



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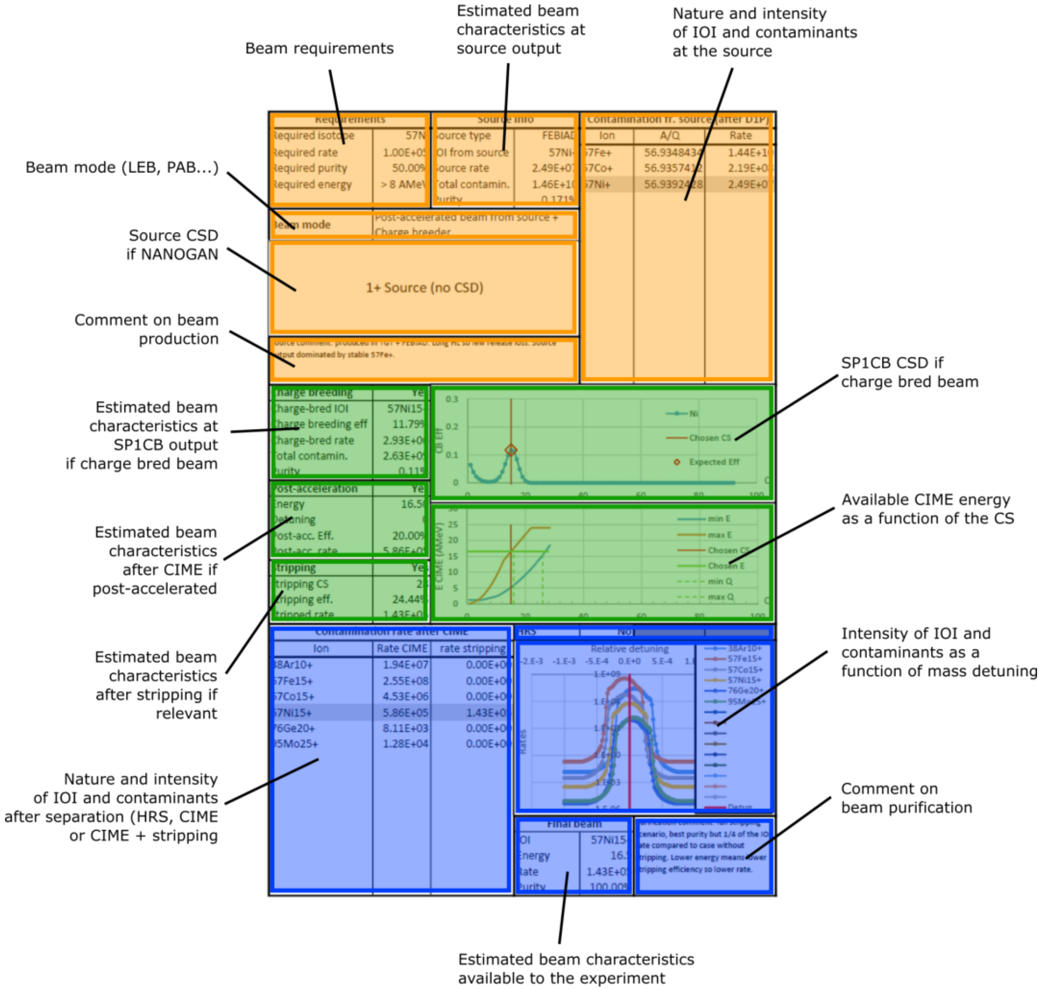
A lot of work remains to be done

- Beams sheets for every new beam
- Checking the specifics of LOIs for each beam
- **We need : minimum rate/minimum purity for each request (not on every LOI)**



Answer to some requests

Very difficult, not considered with the ISOL technique.
Never produced, to be tested. Need a specific development
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	  ○ Beams of refractory metals or carbides (^{23}Si, $^{41-43}$Ti, ^{44}V, ^{43}Cr)
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Never produced or with a lower rate, production to be tested
	• In-target production rates have been calculated for TULIP beams but ion rates remain to be calculated
	  ○ For isotopes of known elements -> extrapolation of the $T_{1/2}$-dependant release efficiency
	  ○ For unknown elements -> offline/online tests necessary.
	• Many beams require more test to assess feasibility
	• Several beams left to estimate and classify, on going work

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Rates estimates

In-target production	Bulk diffusion	Effusion (free-flight) + sticking	Ionization
Fragmentation -> EPAX V2 **Fusion-Evaporation** • Target-beam optimization and basic estimate with LISE++ • Target choice limited to commercially avaliable C foils (35µm and 65µm), already developped 4µm Ni target, and possibly Re for heavy isotopes • New materials or thicknesses require lengthy target development • Better estimate after pre-selection of some beams by a scientific comitee	• Highly depending on the diffusing element, the matrix and the temperature. • Many information in diffusion database (PostDoc work of A. Ribet), but there are gaps in the database	• Sticking time highly dependant on the sticking atom, the surface and the temperature • No bibliographic study carried out yet • A rough estimate of effusion time and sticking times can be achieved by introducing a sample offline and measuring the rate of exhaustion of a sample at a given temperature.	Ionization efficiency can be measured on stable isotopes • Online by re-ionizing the primary beam implanted in the target • Offline by introducing a sample and integrating the output current overtime (1-2weeks/sample)
	Diffusion-effusion-ionization losses can be difficult to decorelate but information on the overall atom-to-ion transformation (AIT) process can be gathered with online tests • AIT efficiency from measured ion rate and calculated production rate for each isotope • AIT release profile from beam-ON/beam-OFF measurements.		

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Talk to us:

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Thank you for your attention