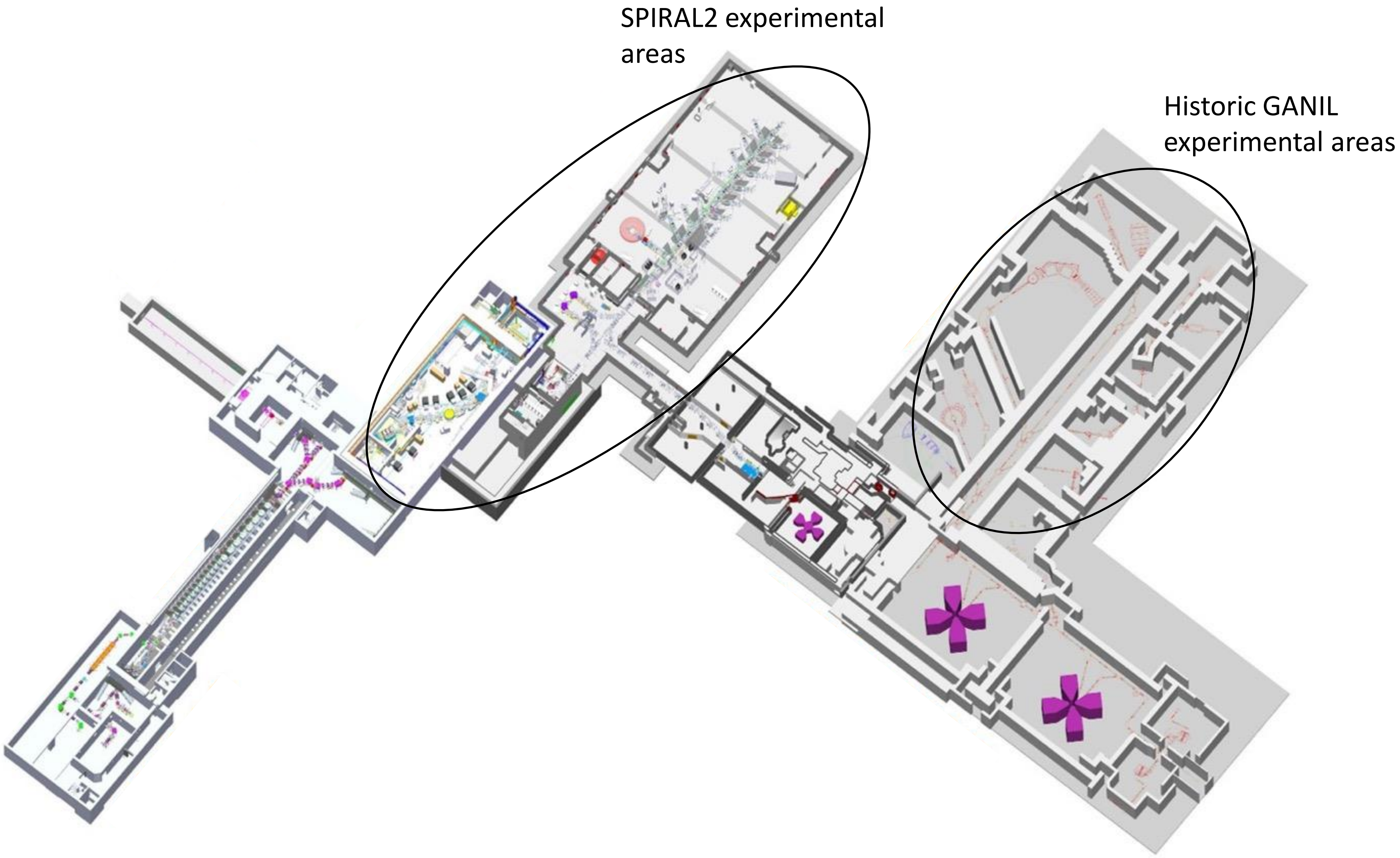
RIB development at SPIRAL1-GANIL:

Recent progress and future developments

Pierre Chauveau

Introduction



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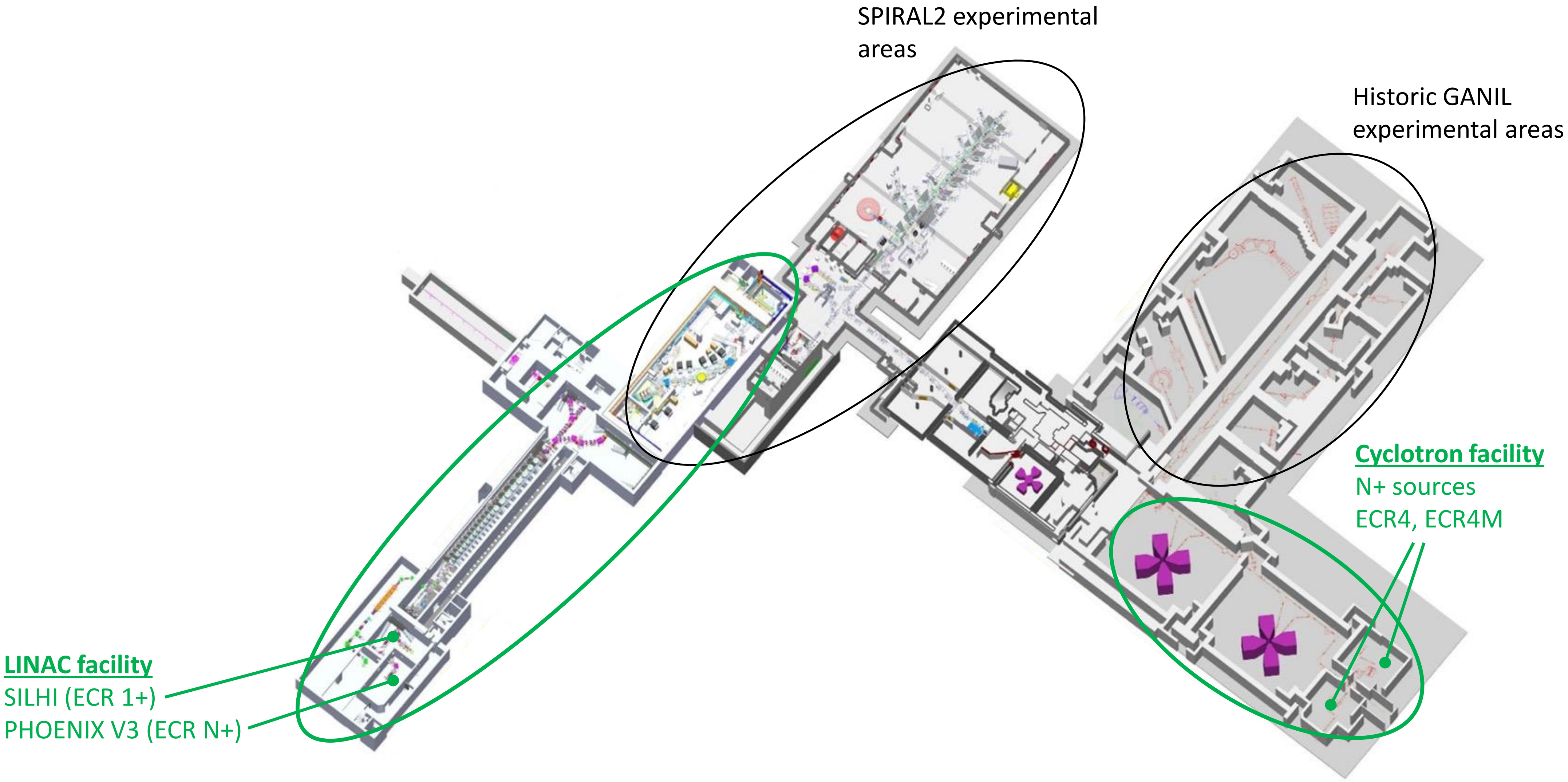
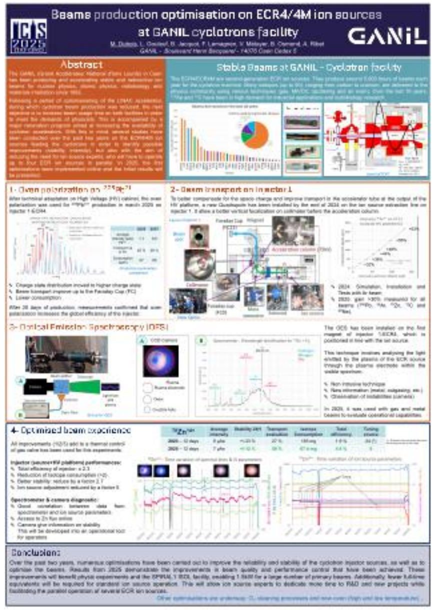
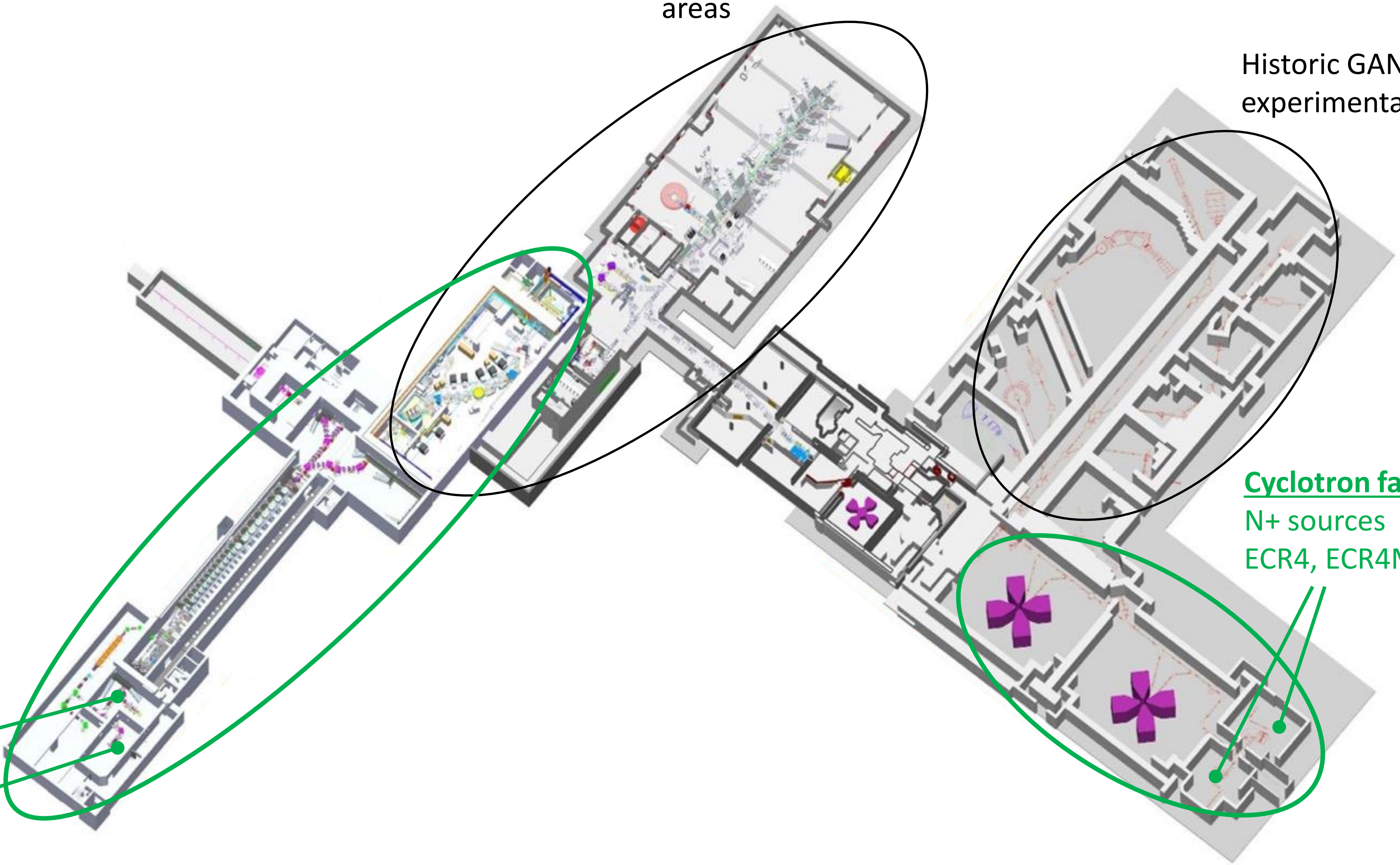


Introduction

Faisceaux stables

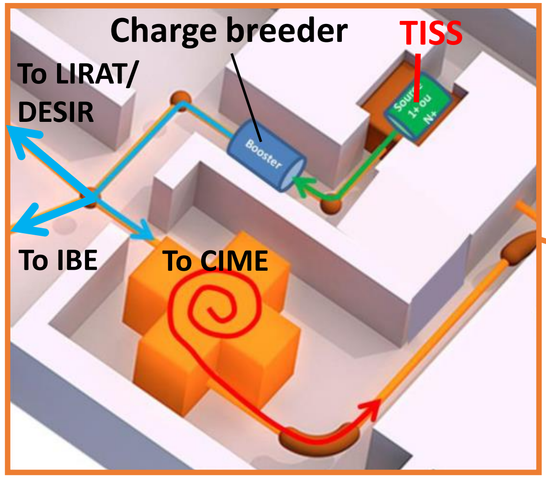


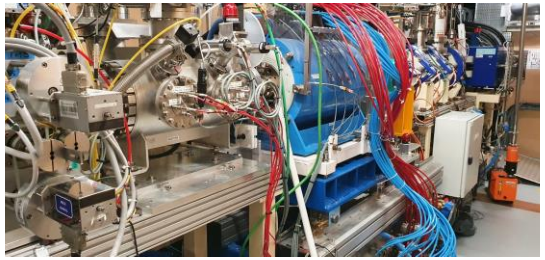
Poster #159 – Tuesday session
Mickaël Dubois et al, Beams production optimisation on ECR4/4M ion sources at GANIL cyclotrons facility

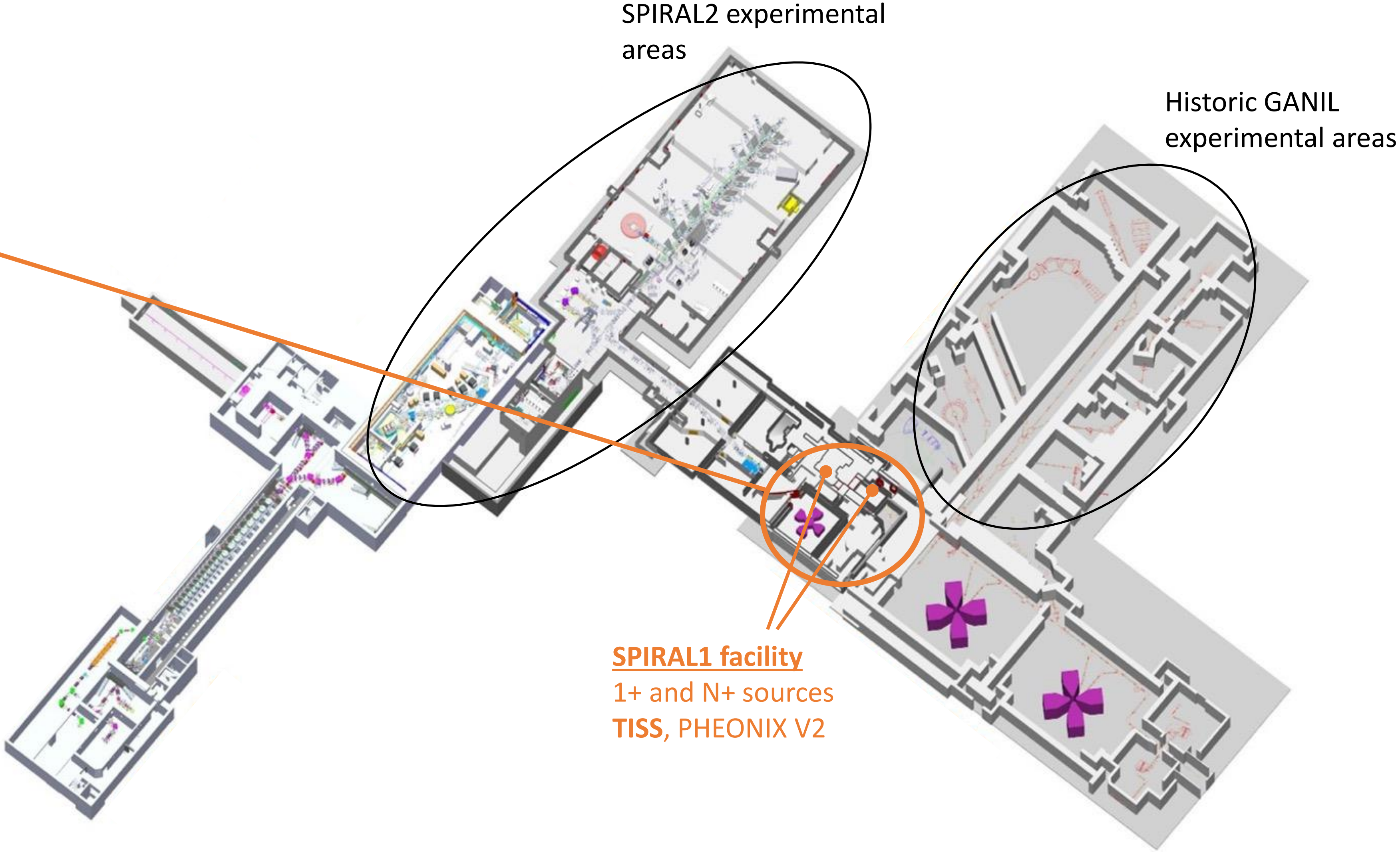


Introduction

Faisceaux radioactifs







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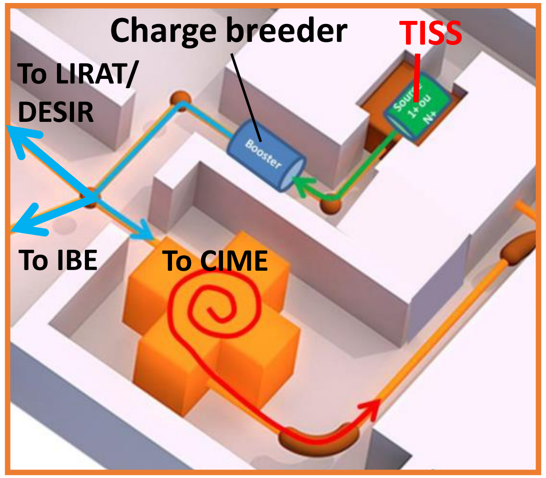
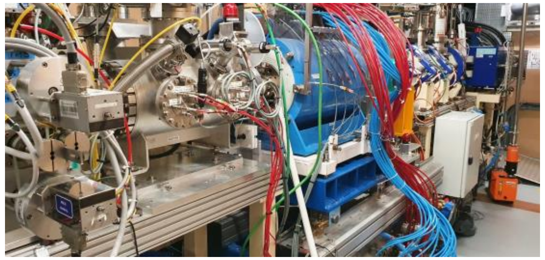




I. **Beam production and sources**

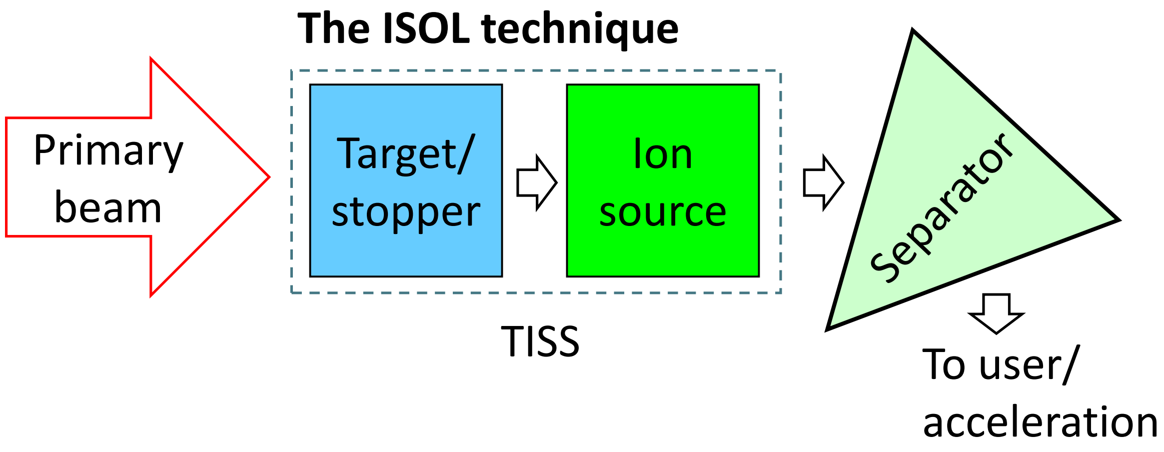
II. **FEBIAD**

III. **MonoNaKe**

IV. **TULIP**

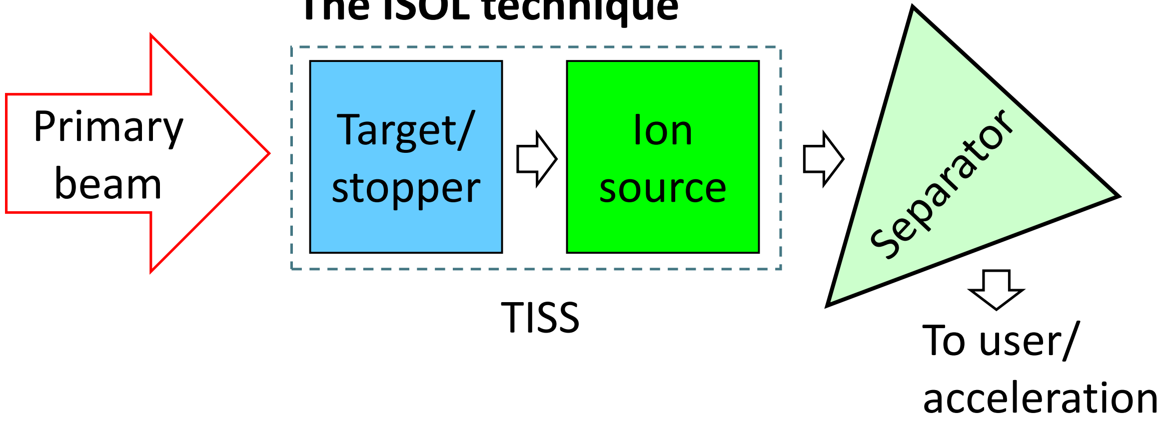
Conclusion and future works

I. Beam production

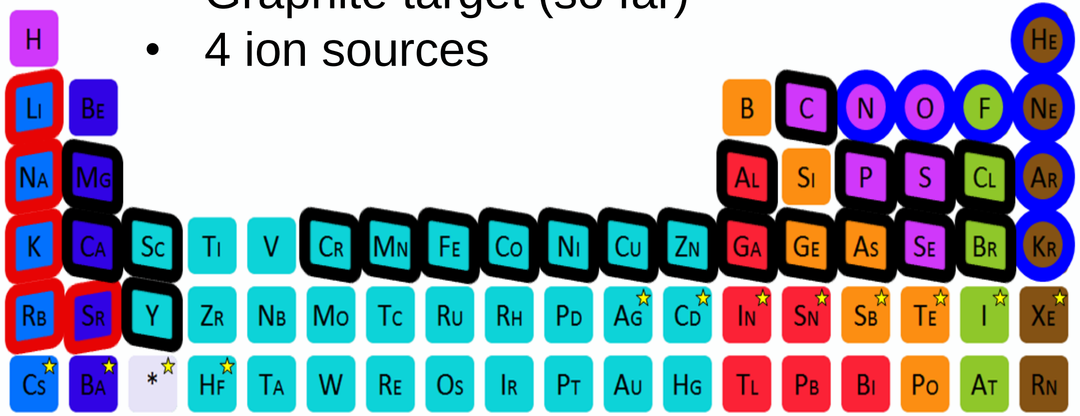


I. Beam production

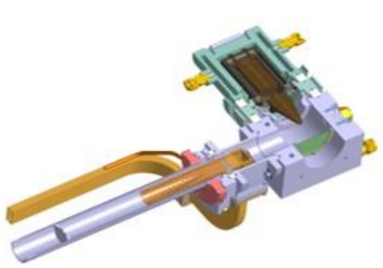
The ISOL technique



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

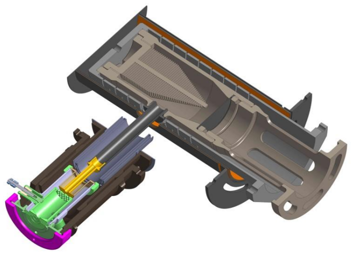


N+

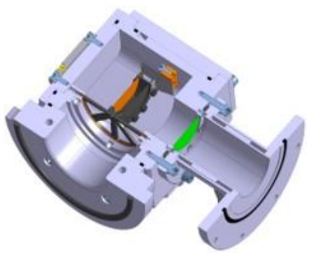


Nanogan
For gaz

1+



FEBIAD
For condensable



TULIP(-FEBIAD)
For proton-rich isotopes

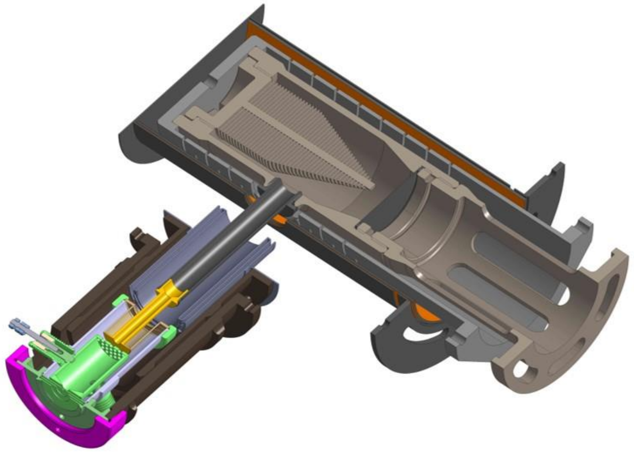
1+

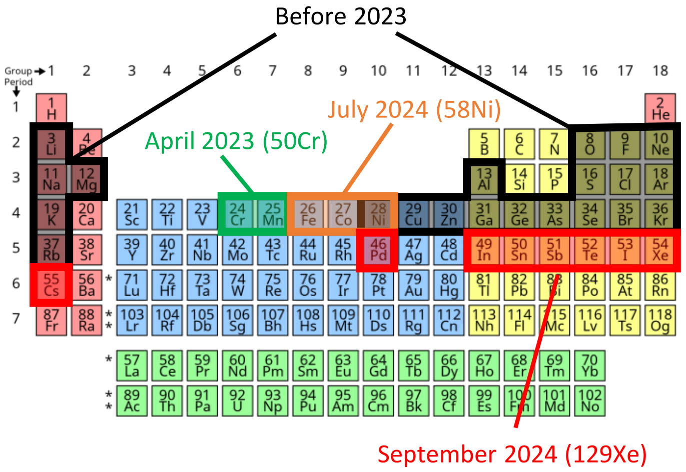
MonoNaKe
For alkaline

II. FEBIAD (1/3) – recent experiments

GANIL

Objective: production of radioactive metallic ions





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).

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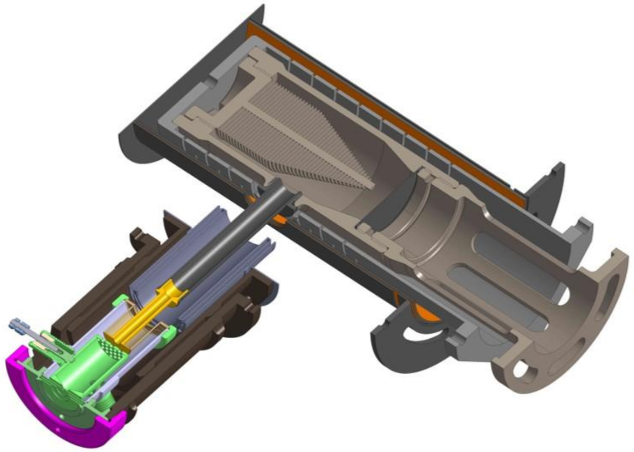

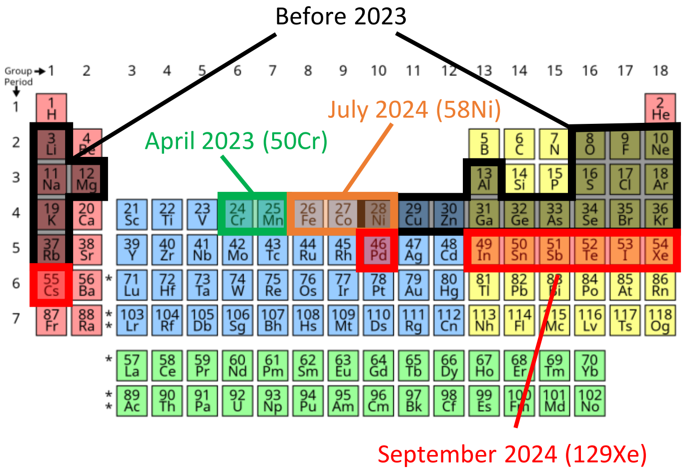

58Ni @ 74.5AMeV ≈600W		
Isotope	HL	measured rate (pps)
59Cu	82 s	5.03E+05
58Cu	3.205 s	1.60E+05
57Ni	35.6 h	2.52E+07
56Ni	6.081 d	1.99E+06
58Co	70.883 d	9.40E+07
57Co	271.8 d	2.21E+08
56Co	77.236 d	1.11E+08
55Co	17.53 h	2.33E+07
54mCo	1.48 min	2.39E+05
53Fe	8.51 min	7.80E+06
53mFe	2.54 min	2.39E+06
52Fe	8.273 h	4.80E+06
52mFe	45.9 s	6.47E+04
57Mn	85.4 s	4.10E+04
56Mn	2.5788 h	1.09E+06
52Mn	5.591 d	1.19E+08
52mMn	21.4 min	3.10E+07
51Mn	45.84 min	3.90E+07
50mMn	1.75 min	1.80E+06

129Xe @ 50AMeV ≈200W		
Isotope	HL	measured rate (pps)
117Xe	61 s	8.72E+03
117I	2.22 min	3.41E+05
117Te	62 min	1.64E+05
117Sb	2.8 h	7.42E+05
109Sn	18.1 min	4.30E+04
117In	43.2 min	1.05E+04
109In	4.159 h	7.00E+05
109mIn	1.34 min	3.33E+04
109mPd	4.694 min	8.86E+02

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49Cr	42.3 min	5E+05
48Cr	21.56 h	3E+05

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- Fe/Co/Ni beams produced for the first time in 07/2024
- « Heavy » ions produced in 09/2024

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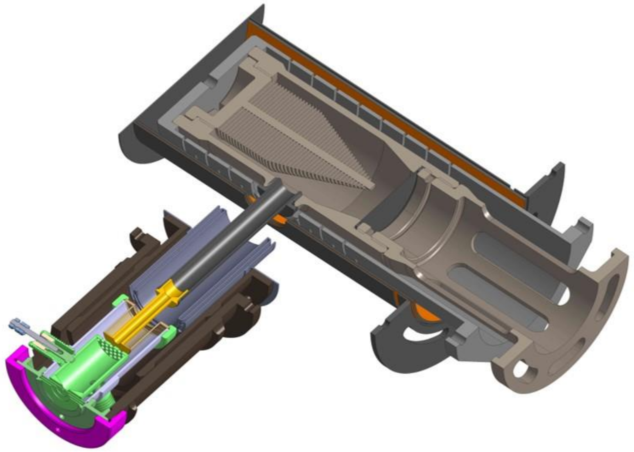

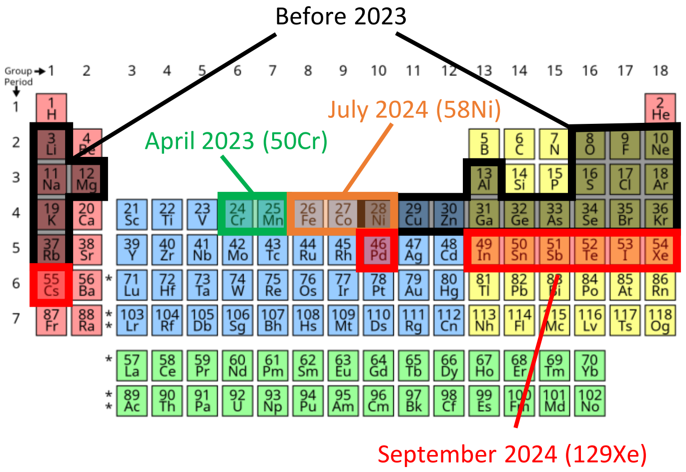

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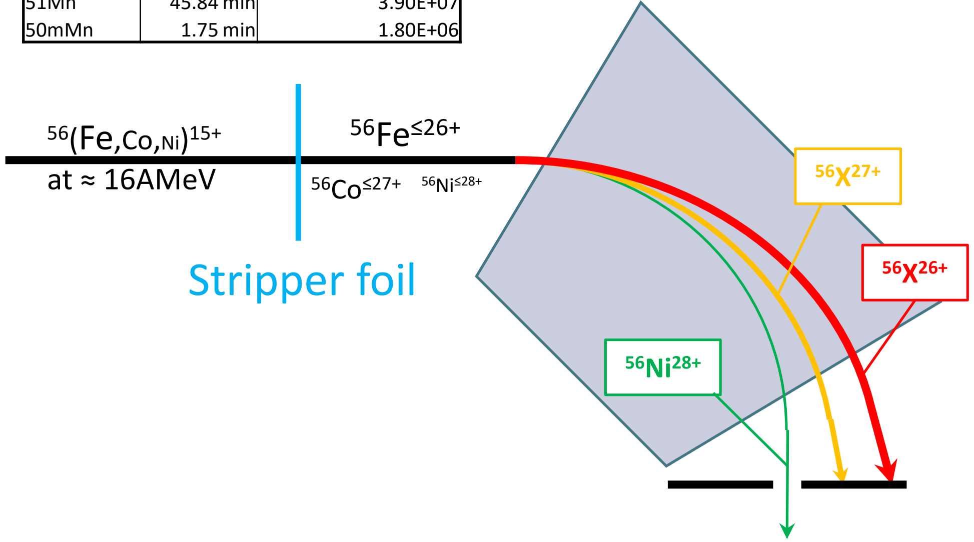
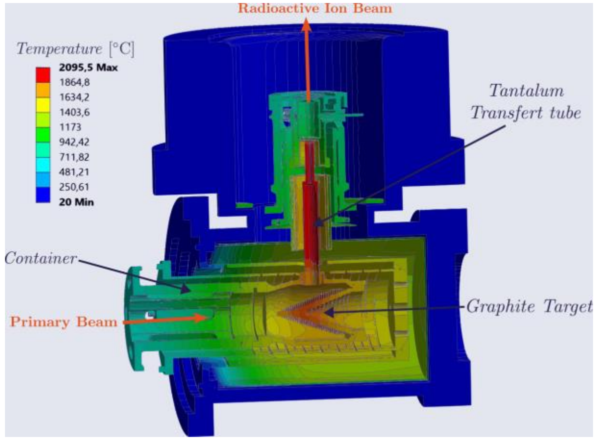


Upcoming experiment (october 25?): post-acceleration and purification of 56Ni !

II. FEBIAD (2/3) – ongoing R&D

Objective: optimized production of Fe-Co-Ni beams (PhD work of Erwan Le Villain)



Measurements and thermal simulations revealed that the target temperature was:

- Relying too much on beam heating
- Low : max 1500°C without beam / 1900°C with 1kW beam)
- Inhomogeneous : >500°C ΔT in the target cavity

This impacts the release efficiency

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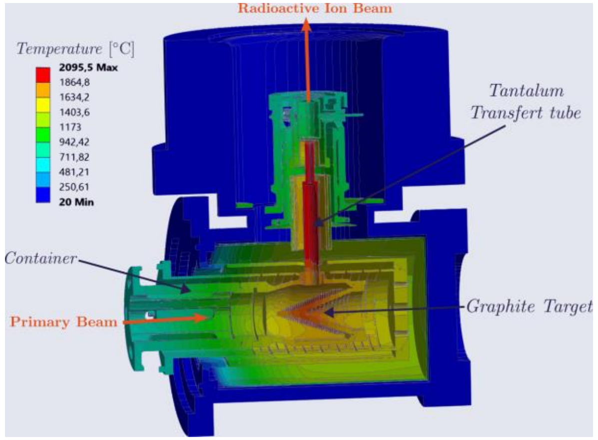

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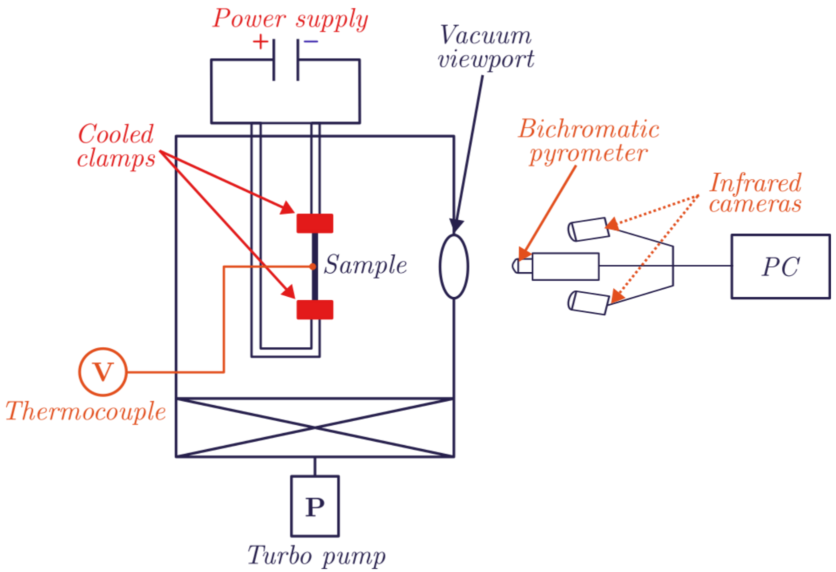
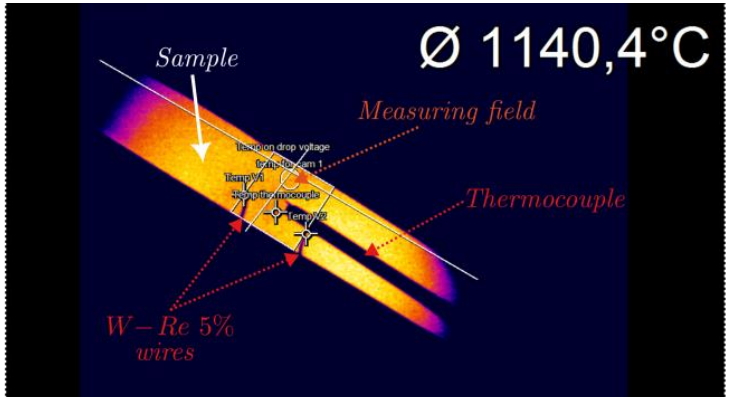
- Gathering material data ✓





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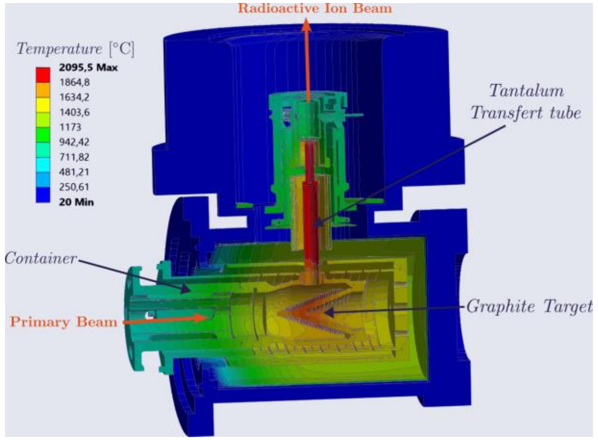

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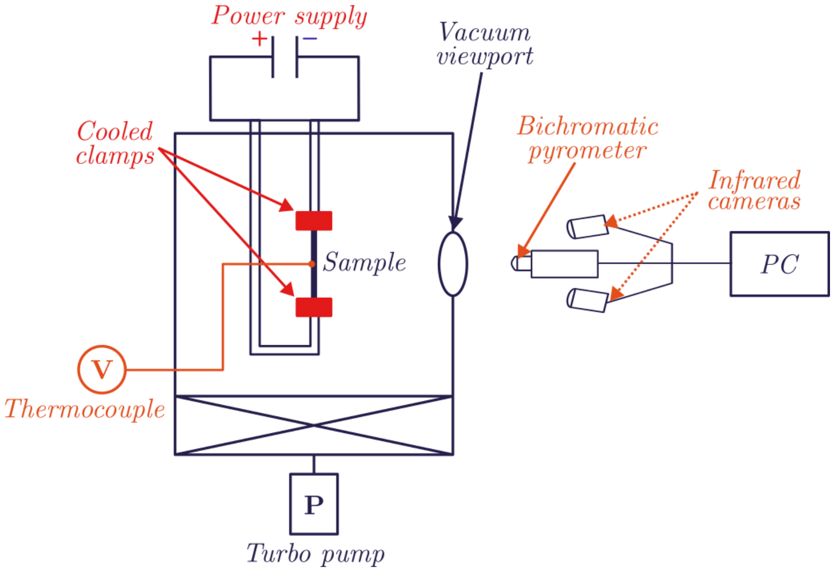
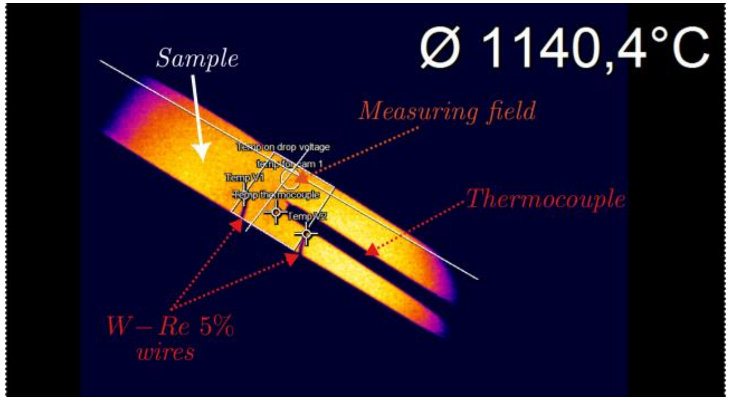
This impacts the release efficiency

- Gathering material data ✓
- Building a parametric model
- Optimizing the geometry for high and homogeneous temperature ✗
- Building and testing ✗





II. FEBIAD (3/3) – ongoing R&D

Objective: new target material for new beams (Post-doc work of Sophie Hurier)

Beam fragmentation loses interest at higher masses (lower beam energy and intensity). Above Ni, target fragmentation could be better, **but never done in SPIRAL1**

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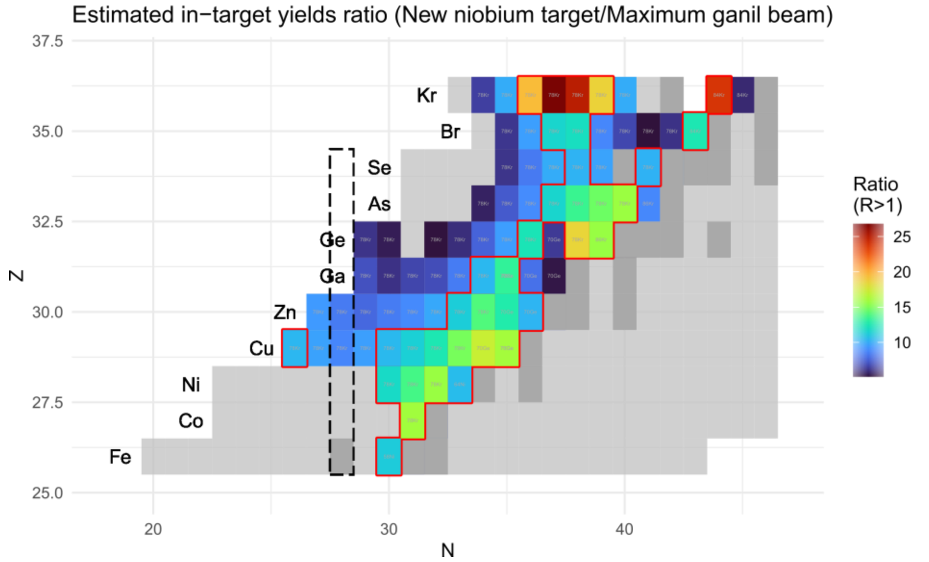
- Investigating and chosing materials (Nb, ZrO^2) ✓



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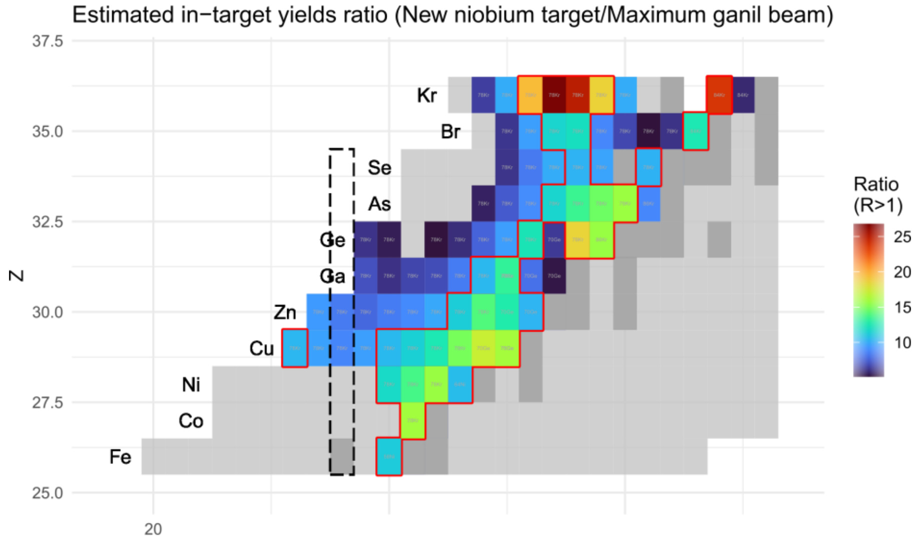
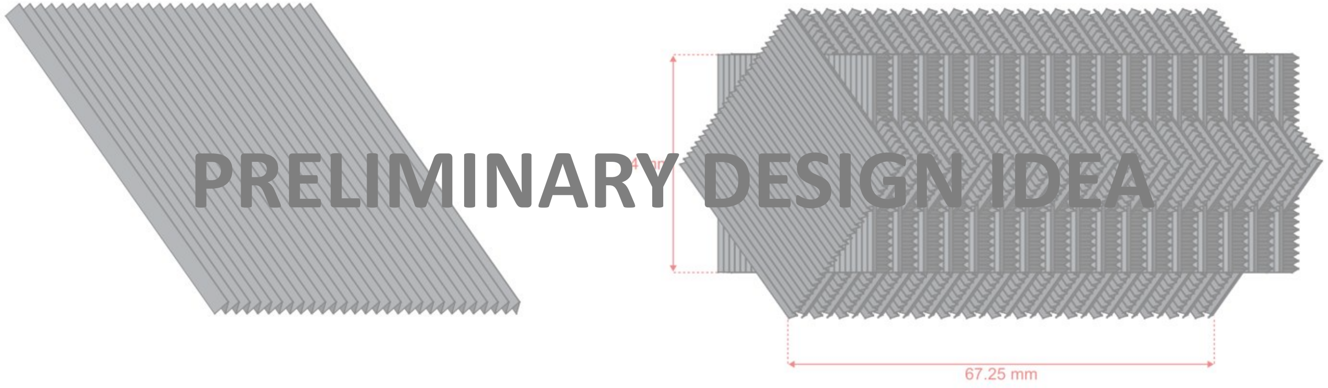
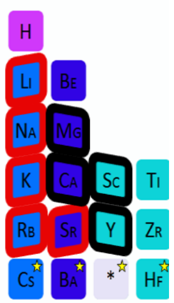
- Production calculations : GANIL beams → graphite **VS** Carbon beam → new material (<Nb) ✓
- Investigating and chosing materials (Nb, ZrO^2) ✓
- Testing material properties ✗
- Designing and simulating a target ✗
- Testing the target ✗





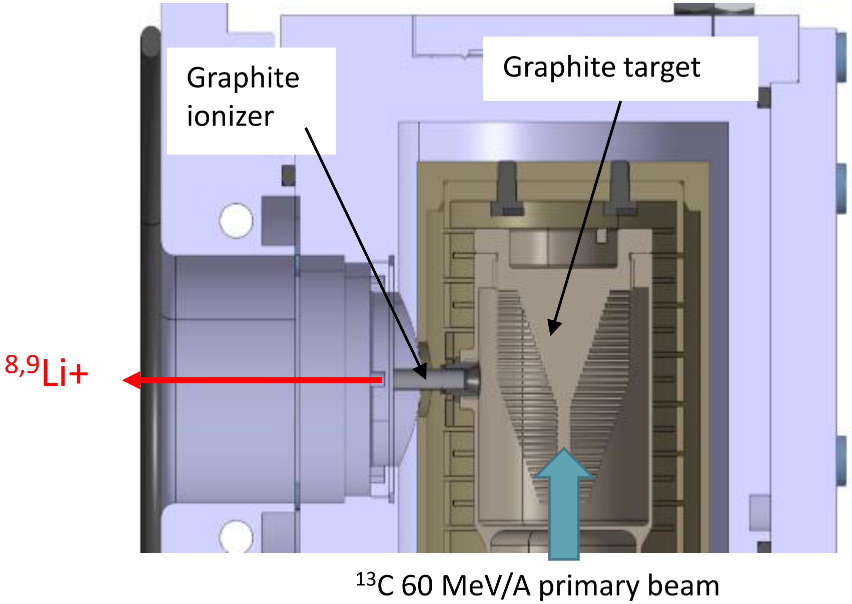
III. MonoNaKe

Objective: production of radioactive alkali ions (slide credit Pascal Jardin)



Low ionization potential atom
+
High work function surface

= Surface ionization



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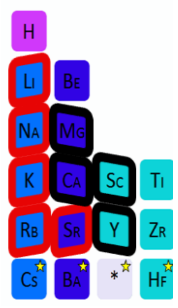

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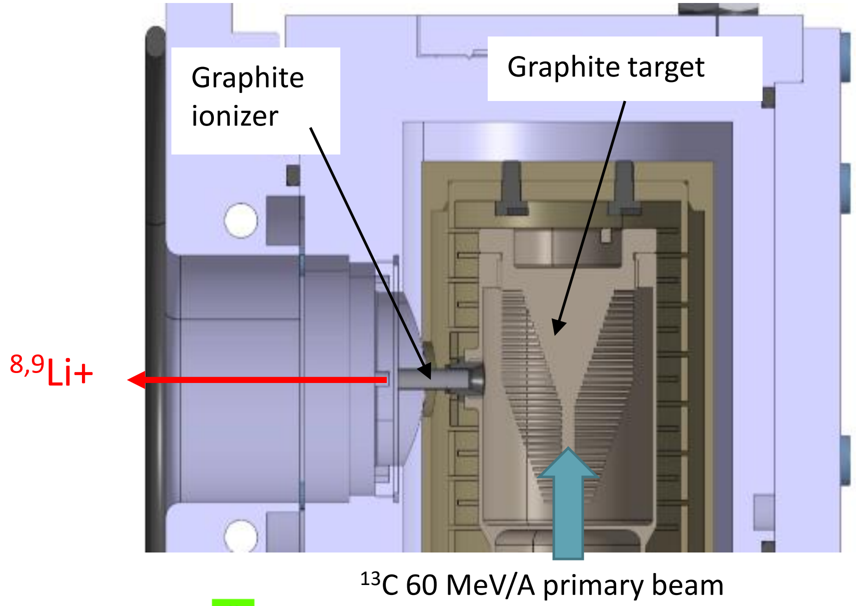


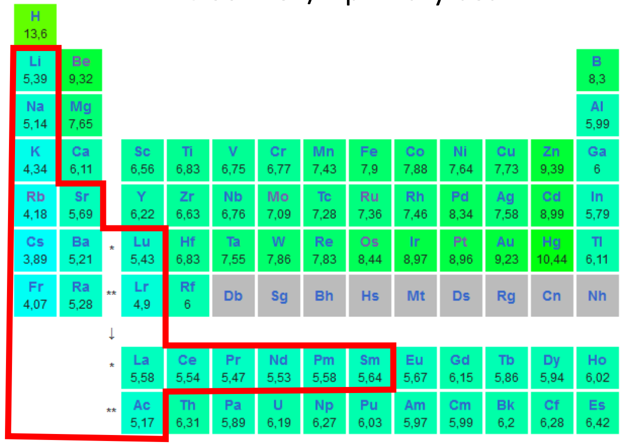
Designed and tested in 2006

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

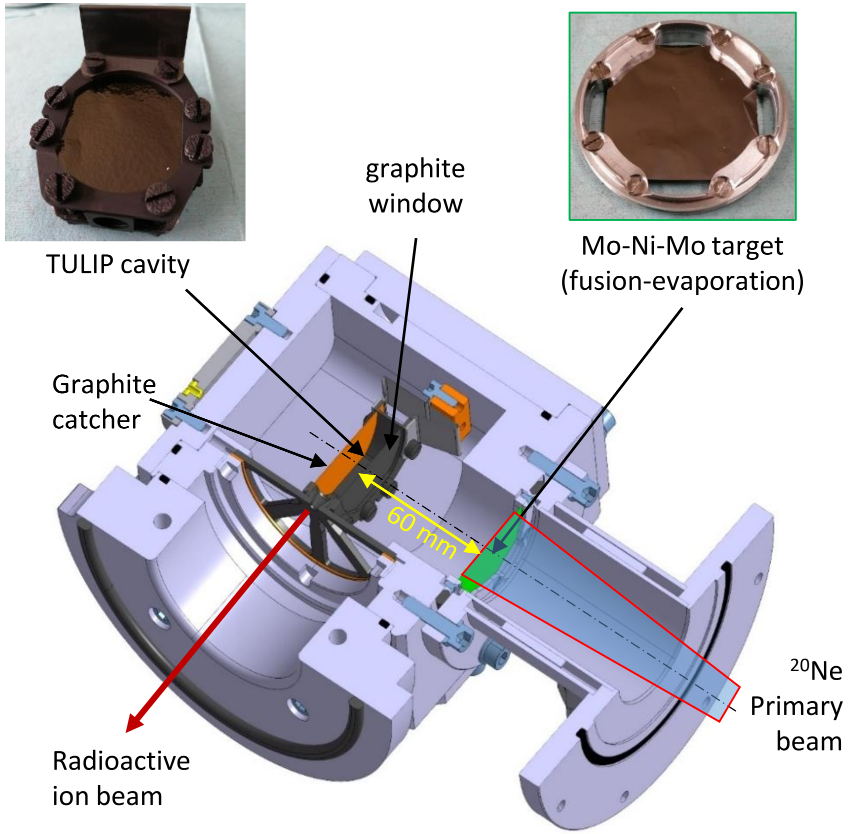
In the future

- Development and tests with Re ionizer to enable other elements



IV. TULIP (1/2) concept and first results

Objective: production of short-lived neutron deficient isotopes (slide credit Pascal Jardin)



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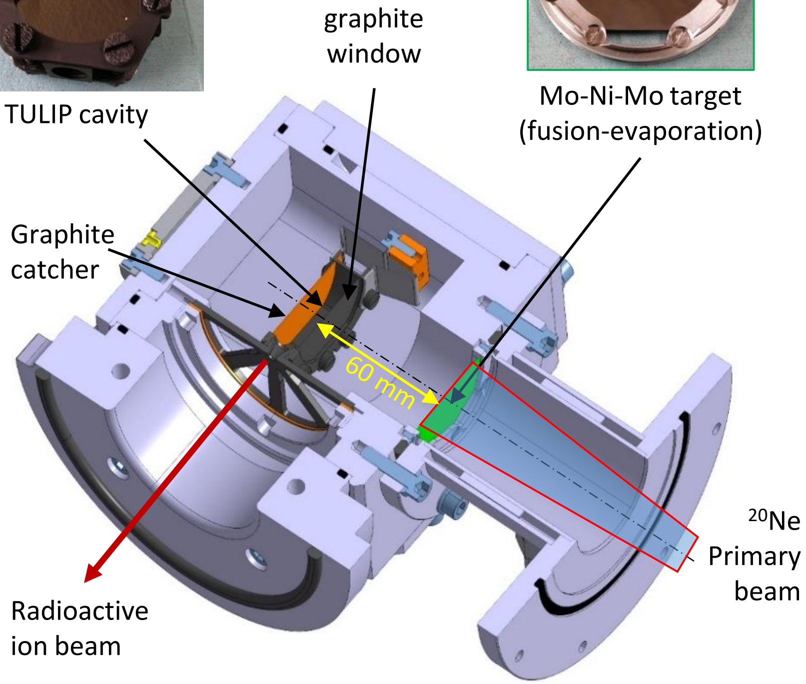
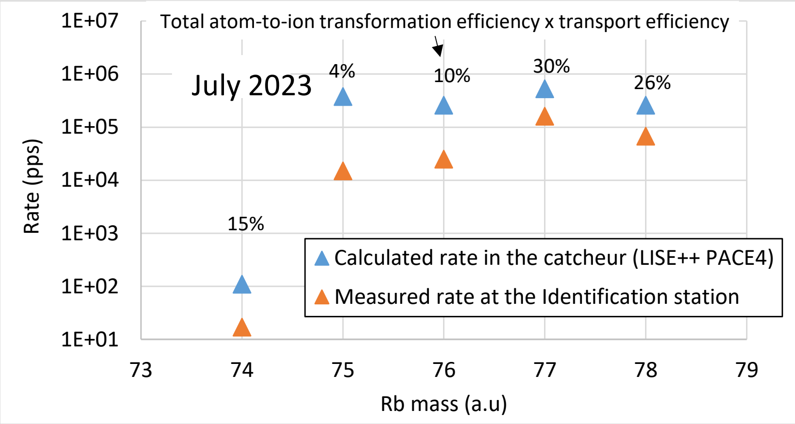
TULIP cavity

Mo-Ni-Mo target (fusion-evaporation)



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

Rb Mass	$T_{1/2}$	ID station rate (pps)	
		March 22 $^{22}Ne+^{nat}Ni$	July 23 $^{20}Ne+^{nat}Ni$
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	5,74m/ 17,7 m	5,80E+04	6,8E+04



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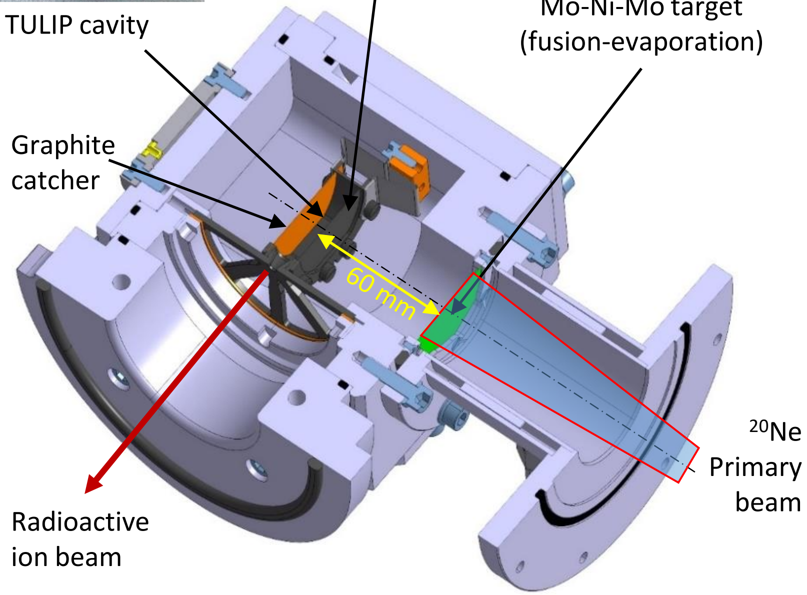

anr®

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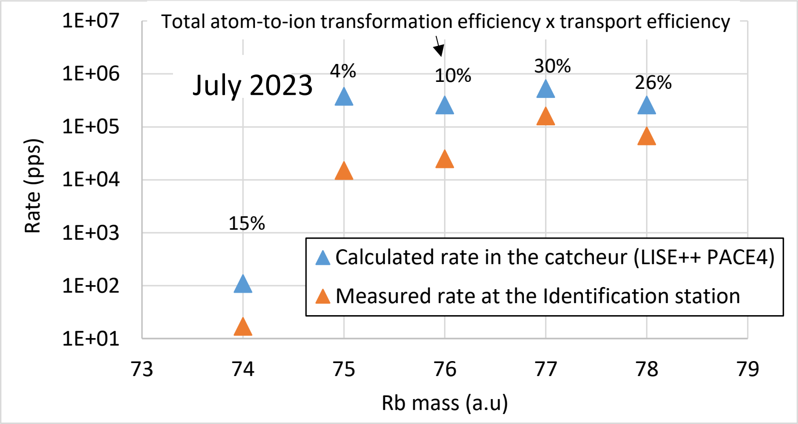


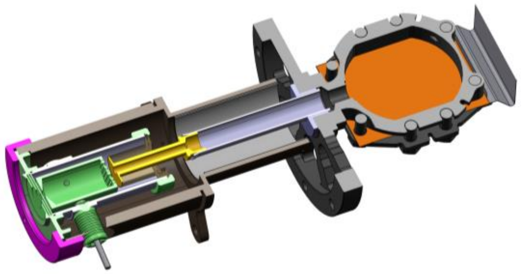
On-line test last week

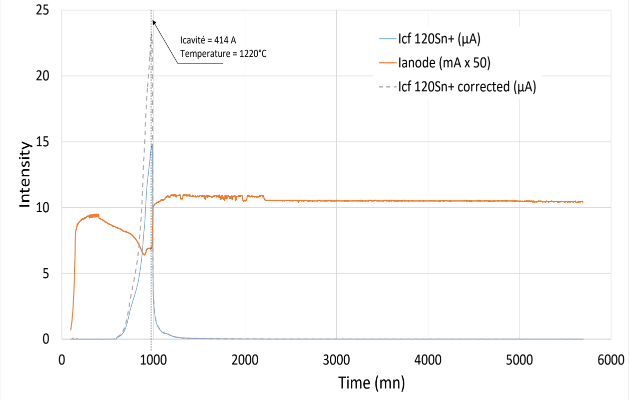
- At least 100pps of 74Rb (65ms)
- The source survived (>5kW for >48H) but maybe not the window
- Release time in the ms range

IV. TULIP (2/2) ongoing R&D

Objective: expand the concept to other elements (slide credit Pascal Jardin)

TULIP FEBIAD





Tested offline in 2024-2025

- Calibrated Ar leak : Eff_{Ar} > 6% (stable) and up to 17%
- Ag, In, Sn tracers : Eff = 9-15%

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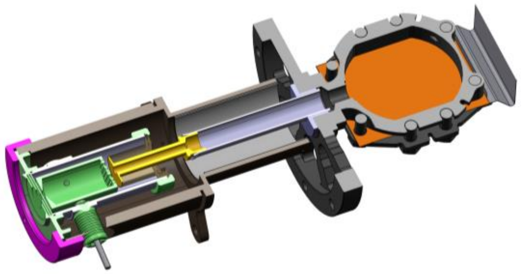
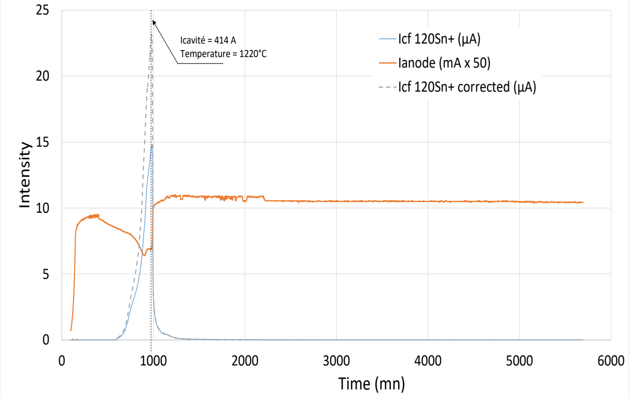
TULIP FEBIAD

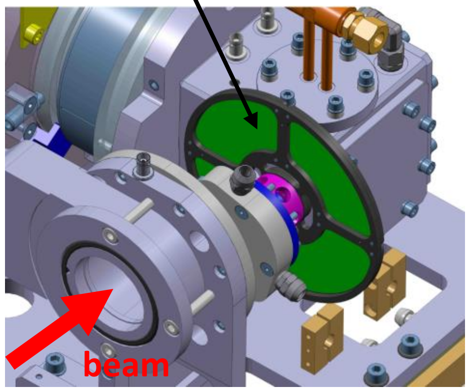




Tested offline in 2024-2025

- Calibrated Ar leak : Eff_{Ar} > 6% (stable) and up to 17%
- Ag, In, Sn tracers : Eff = 9-15%

Rotating target



To increase the maximum primary beam power x7. Must be simple and radiation hard.

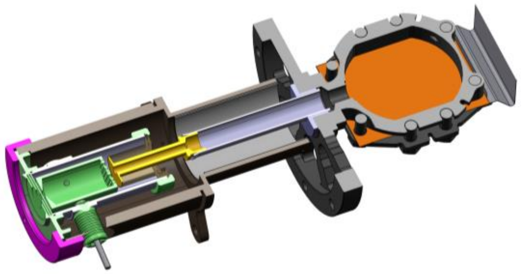
- Graphite bearing
- waterwheel drive
- magnetic coupling

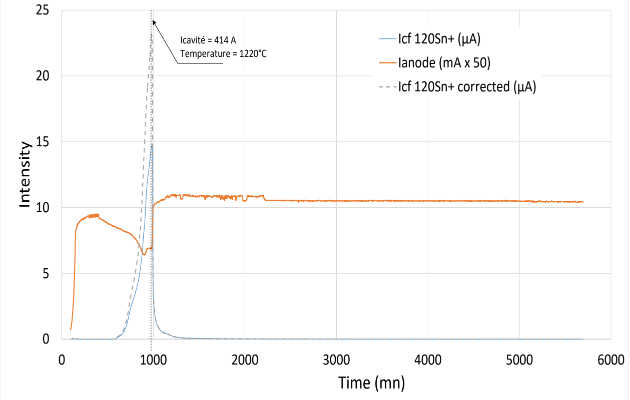
Works but rotating speed limited by eddy current. New design ongoing.

IV. TULIP (2/2) ongoing R&D

Objective: expand the concept to other elements (slide credit Pascal Jardin)

TULIP FEBIAD





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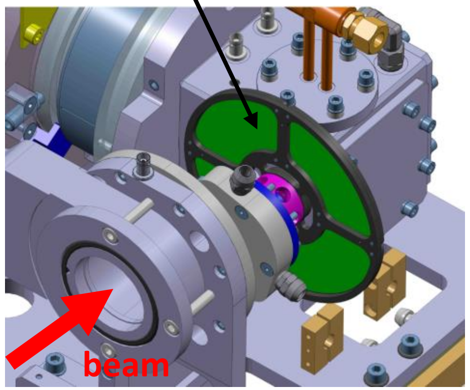

To increase the maximum primary beam power x7. Must be simple and radiation hard.

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« Intense » production of metalic isotopes in the ^{100}Sn region.

Expanding the number of primary beam/target/source combinations to produce new RIBs

Conclusion and future works

- Recent progress with the FEBIAD, MonoNaKe and TULIP TISS
  - Improvement of performances, reliability
  - Test/development of specific beams ($^{7\text{-}8}$Li, neutron-deficient Cr and Fe-Co-Ni, **very-neutron-deficient Rb**)
- Ongoing development on the FEBIAD and TULIP
  - Upcoming post-acceleration/purification experiment
  - New graphite target design for optimized Fe-Co-Ni beams
  - New target materials for Cu → Rb beams
  - High intensity TULIP-FEBIAD TISS for short-lived neutron-deficient metalic isotopes

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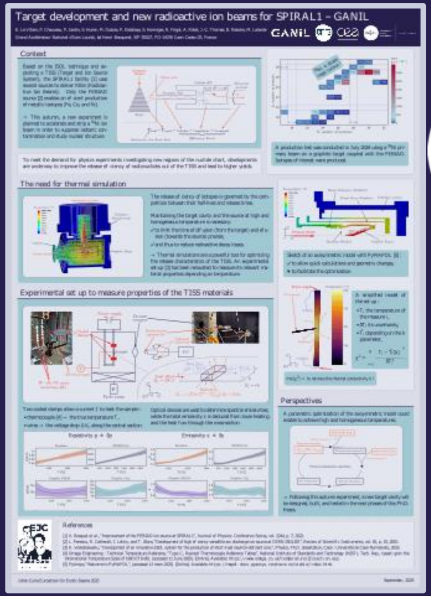
If you are going to EMIS:



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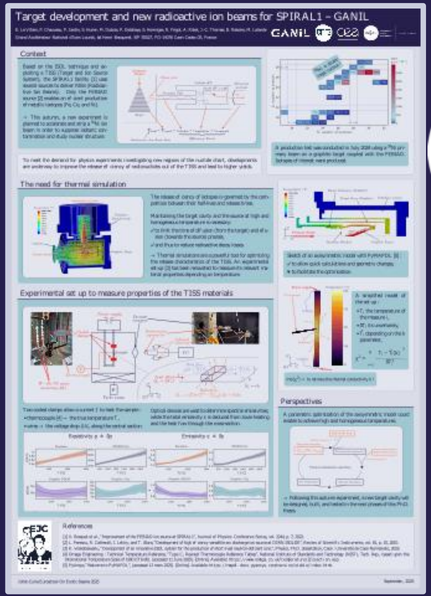

Thank you for your attention