GANIL ION SOURCES OPTIMISATION FOR OPERATION

M. Dubois and GCS Group

Operation and Development Division

Target Ion Source Group

OUTLINE

1- GANIL-SPIRAL2 Facilities

- Ion sources - Beams Production
- Challenges for the coming years

2- Cyclotron Ion sources

- Optimisation for operation
- Beam improvements

3- SPIRAL2 Ion sources

- Reliability
- Optimisation for metallic beams

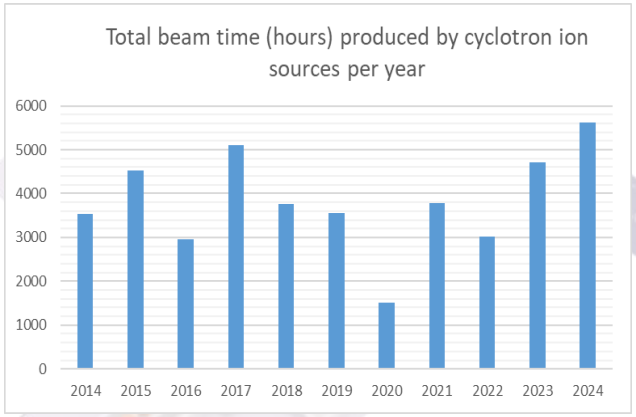
4- Conclusions and Perspectives

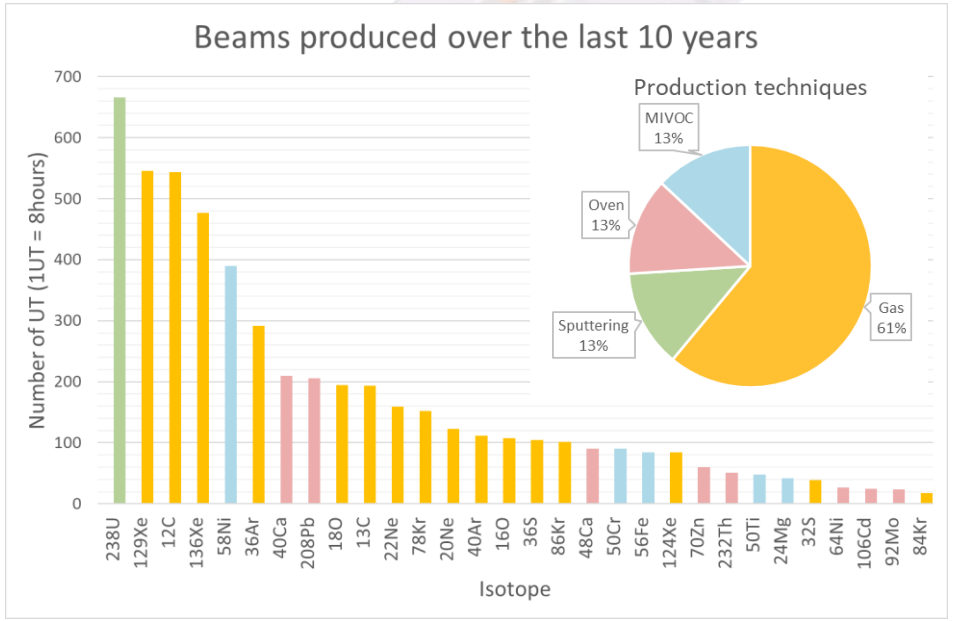
GANIL – Cyclotron & SPIRAL1 Facilities

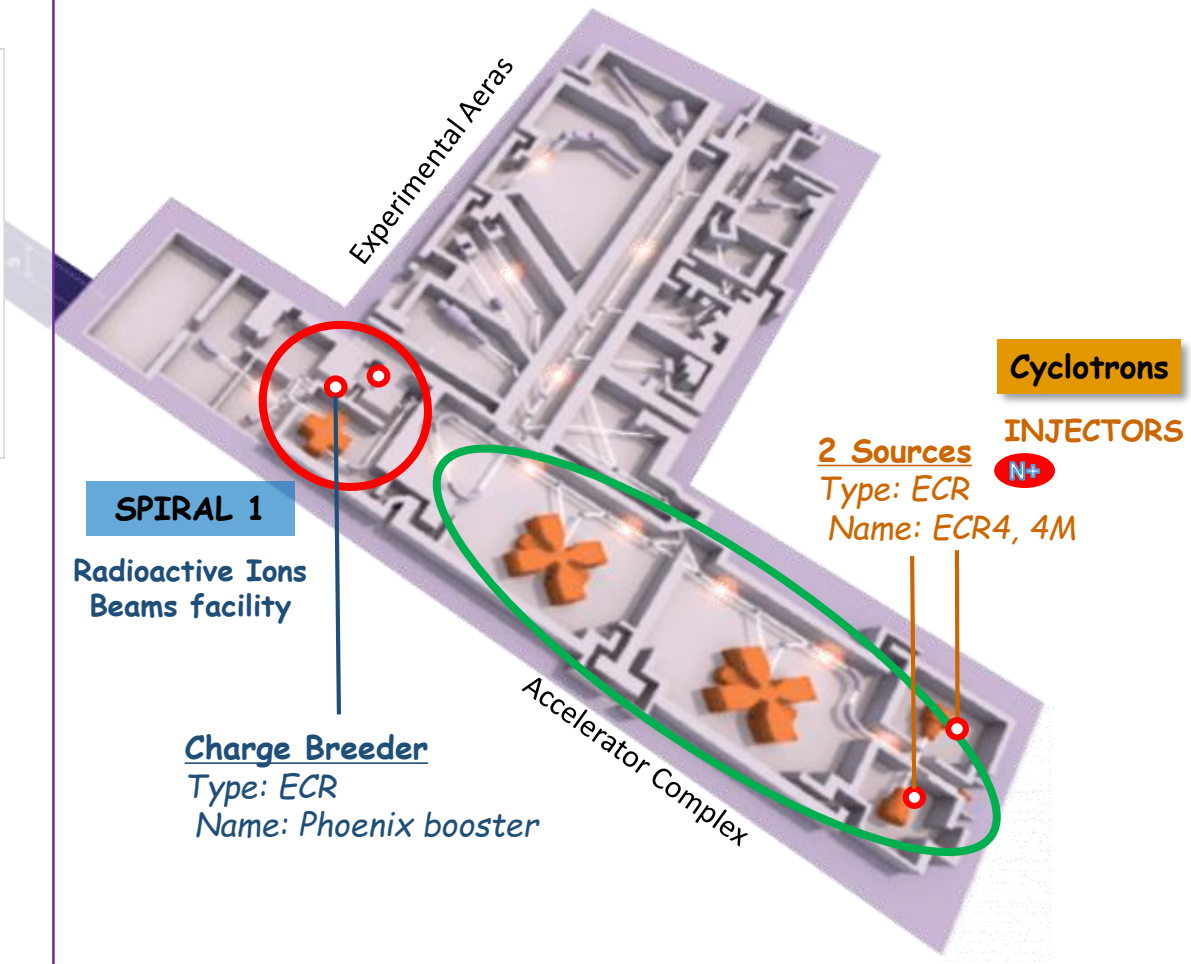
Cyclotrons (1983)

Stable beams :

Heavy ion	
Ions	^{12}C - ^{238}U
Intensity	< 2.10^{13}pps
Energy	< 95MeV/u
Power	< 3kW







GANIL – SPIRAL2

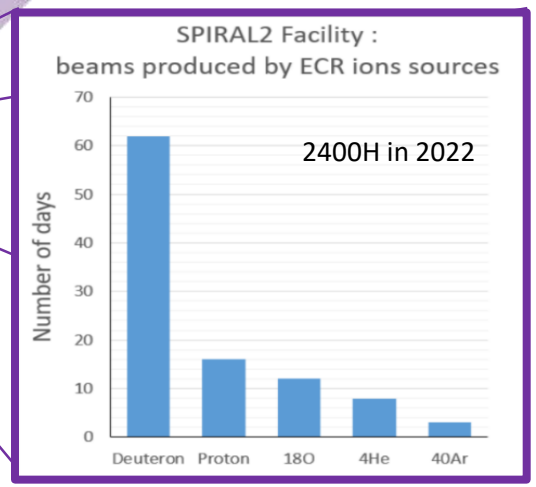
SPIRAL 2

INJECTORS

LINAC

1 Source 1+
Type: ECR
Name: SILHI

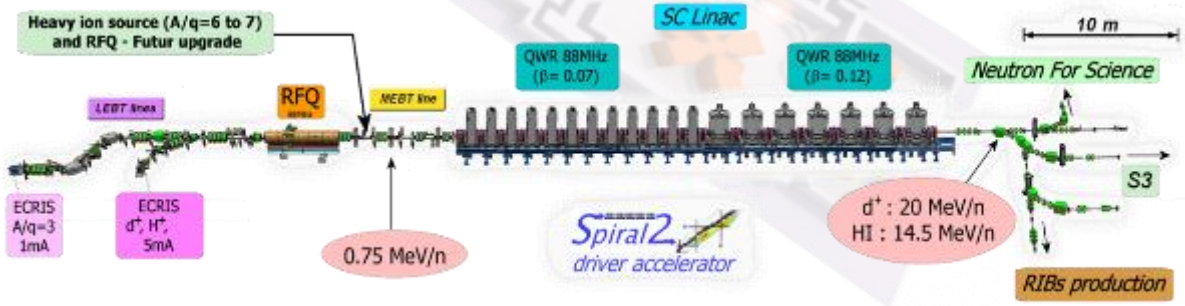
1 Source N+
Type: ECR
Name: Phoenix-V3



LINAC (2019)

Stable beams :

	Proton	Deuton	Heavy ion
A/Q	1	2	3
Particles	H+	D+	He - U
I max (mA)	< 5	< 5	<1
Max Energy (Mev/u)	33	20	<14.5
Max beam Power (kW)	165	200	44

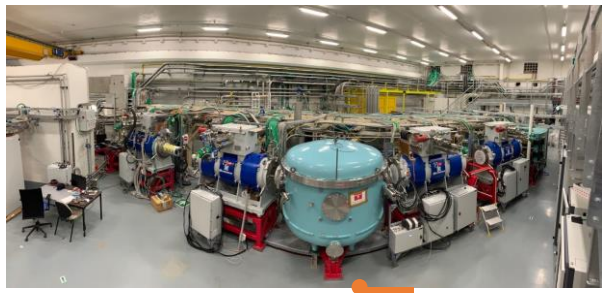


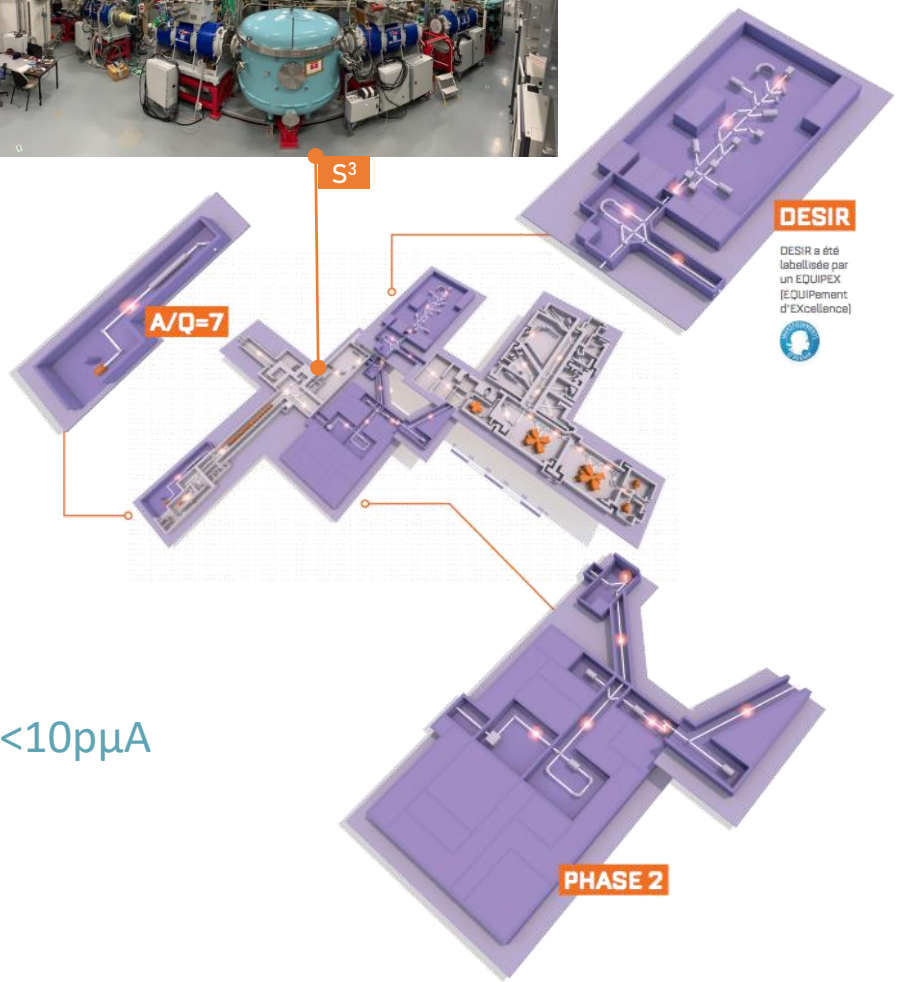
GANIL – Next steps

2026 : Super Spectrometer Separator (S^3)

A/Q < 3 – 2pµA

Energie : 5-7MeV/u





2027 : DESIR

Experimental hall for low energy RIBs coming from S^3 and SPIRAL1

NEWGAIN

NEW GANIL INJECTOR

2028-2030 : Newgain injector

2028 : RFQ for A/Q<7

2030 : SC Ion source for intensities <10pµA

>2030 : Futur Upgrade for GANIL

New facility for RIBs production for DESIR & GANIL

Challenges for coming years

Increase the beam time available on cyclotron-SPIRAL2

- >7 months/year on both machines by 2030,
- Industrial applications >2000H/year ➢ **(See Poster MOP13 – R. Frigot)**

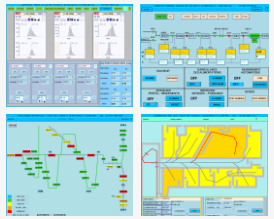
Start physics experiments on S^3, and deliver RIB's on DESIR

- A/Q <3 : 2pμA for ^{48}Ca, ^{50}Ti, ^{50}Cr,…
- Newgain : A/Q <7 : 10pμA < ^{238}U ➢ **(See talk TUB2 – T. Thuillier)**

Maintain the cyclotron facility for the next 20 years

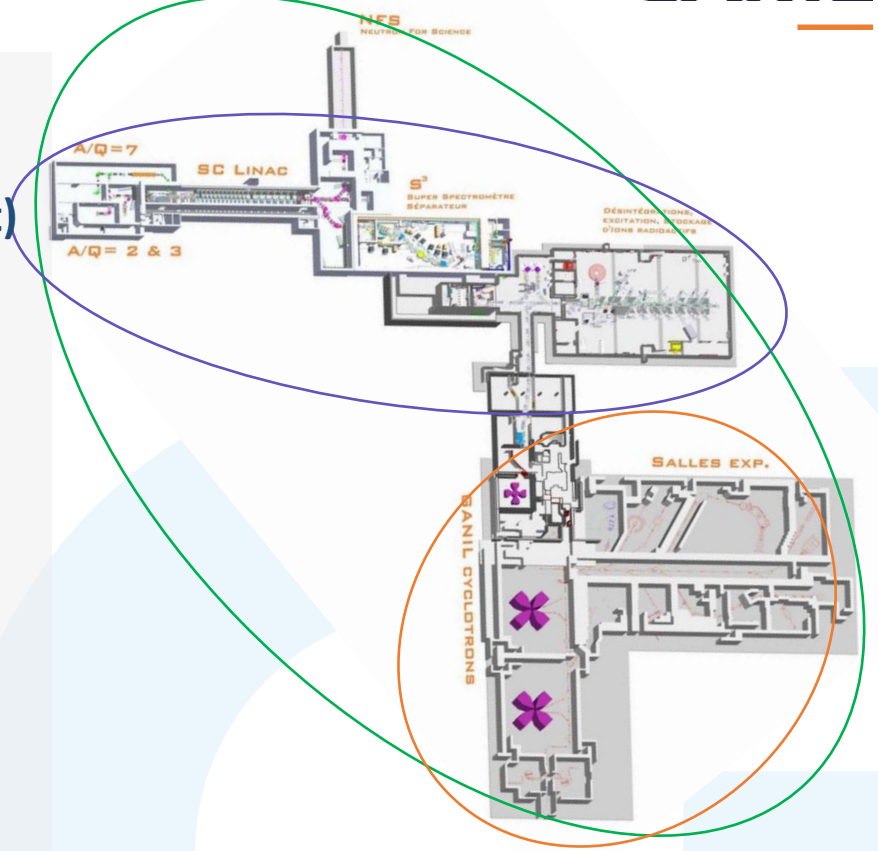
Power supplies

RF cavities



Remote control

Cooling system



Strategy for ion sources

1. Optimise ion sources for long term operation on the 4 mains injectors (reliability, stability, manpower)
2. Optimise beam production in terms of intensity and efficiency (rare isotope)
3. Continue to develop new beams requested by physicists on Cyclotron-SPIRAL2

OUTLINE

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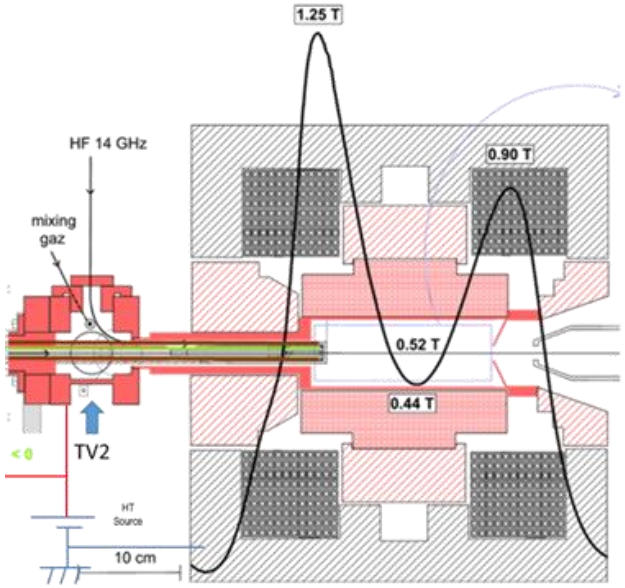
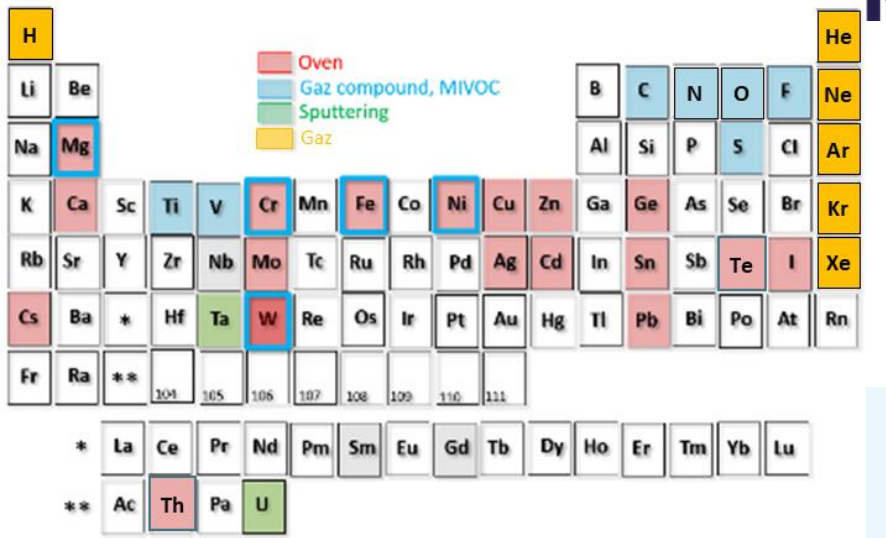
Cyclotron Ion Sources

Ion source requirements for cyclotrons accelerators

- Beam : Carbon to Uranium
- Charge states : 3<A/Q<9
- Intensities : some nAe to 50µAe (accelerator limitation)



Technical parameters ECR4/4M	
RF Frequency/power Coaxial tube	14.5GHz /600W
Axial Mirror	1.2-0.44-0.9T
Plasma volume	0.5 l – 63mm
HV extraction	<25kV



For the next 20 years :

New Ion sources ?

- Increase av… …ensities (Ni->U)
- Use sir… …ion source than SPIRAL2

Under study but not a priority

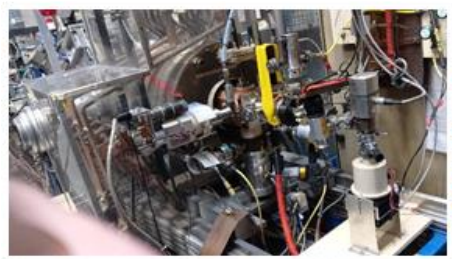
Optimisation of ECR4/ECR4M beams :

- Stability (long term)
- Diagnostic
- Intensity : Implement and adapt techniques to improve intensities available for metallic beams

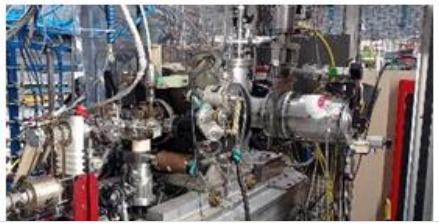
Cyclotron Ion Sources

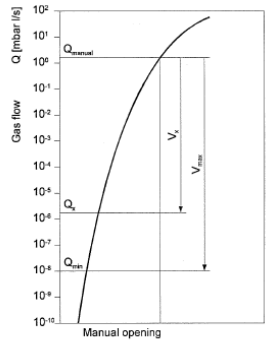
Stability – Diagnostic - Instensity

Injector 1

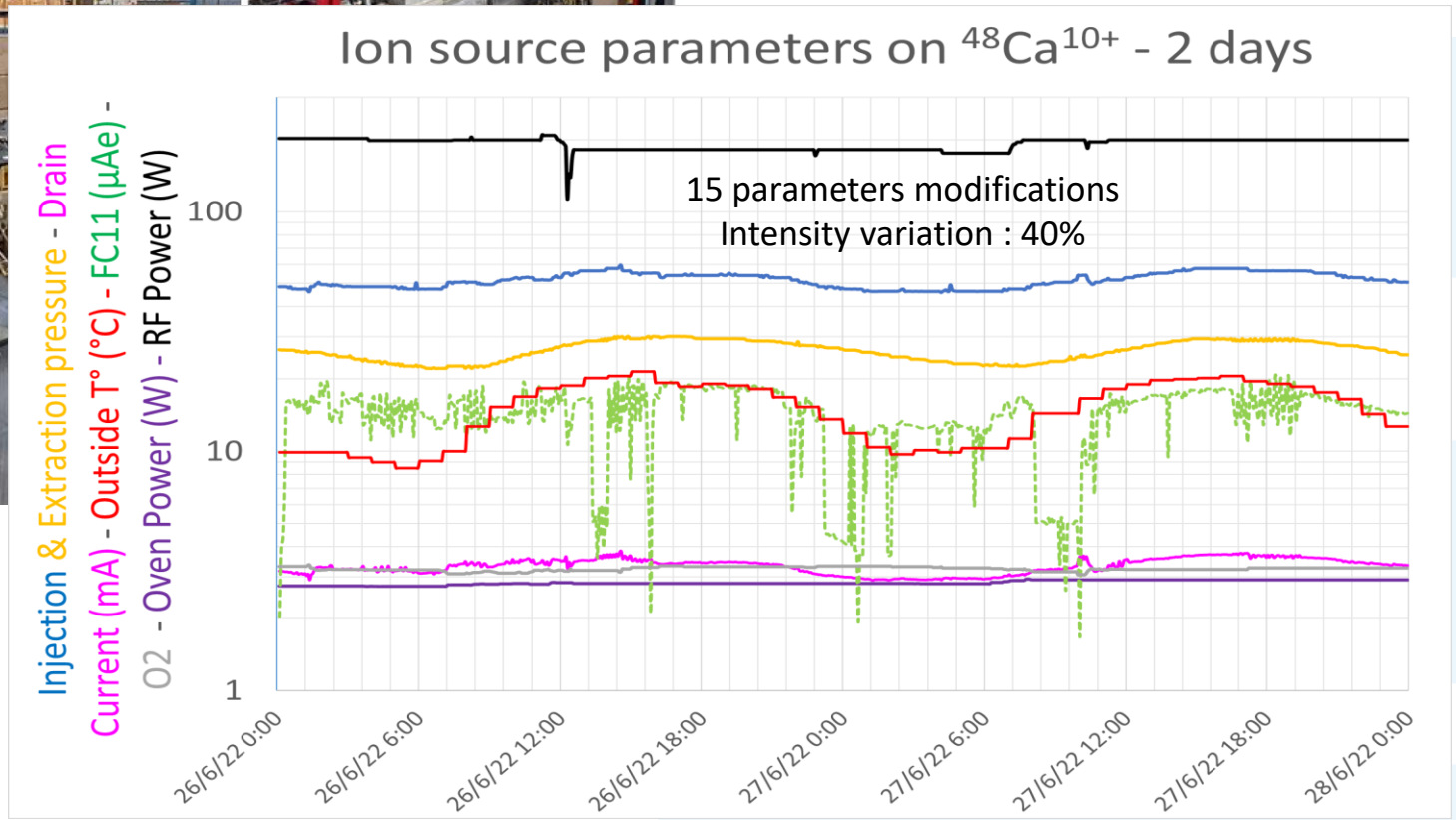


Injector 2





Typical relationship between gas flow and heater voltage (inlet pressure 1 bar)



Cyclotron Ion Sources

Stability – Diagnostic – Intensity

New gas valves under evaluation

External T° regulation at 40°

Exemple on stability on $^{129}Xe^{23+}$ (4 days) - April 2024

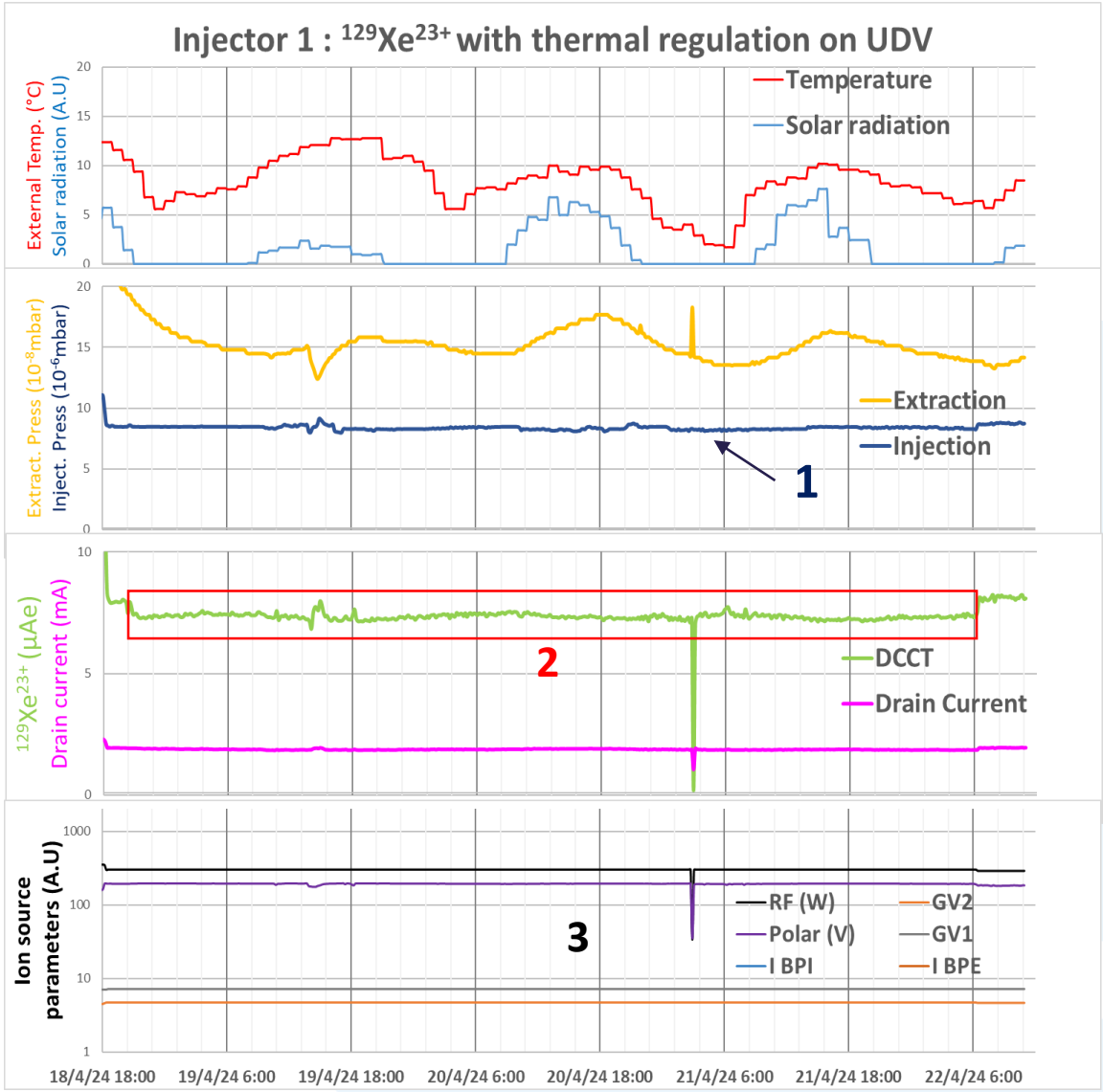
1- Injection pressure become less sensitive to T°

2- Intensity variation : 5% on 4 days

3- No parameter adjustments

Comparison 2023/2024 - Similar RUN (U, Zn, Xe, C, O,…)

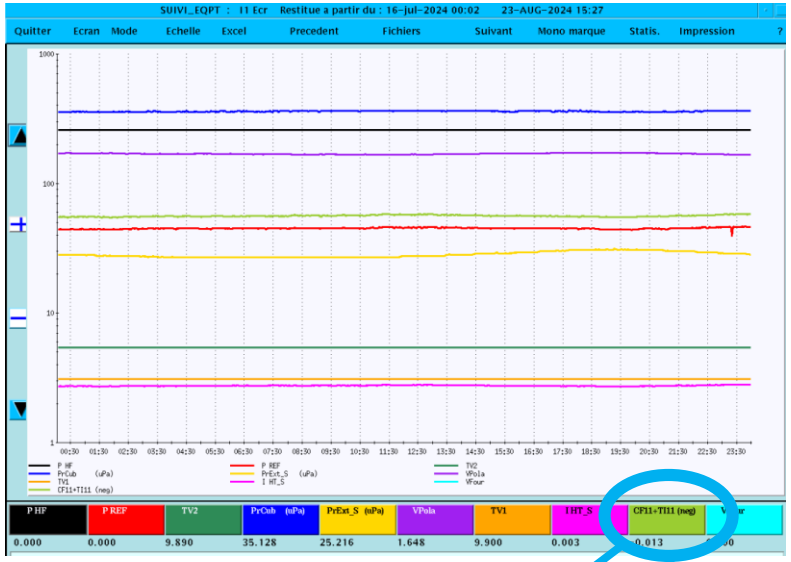
- Better stability : variation <10% (gas)
- Reduction on parameter adjustments :
  - $^{238}U^{31+}$: 3/day (2023) – 5/14days (2024)
- On call intervention for adjustments (night/WE) : 4->1

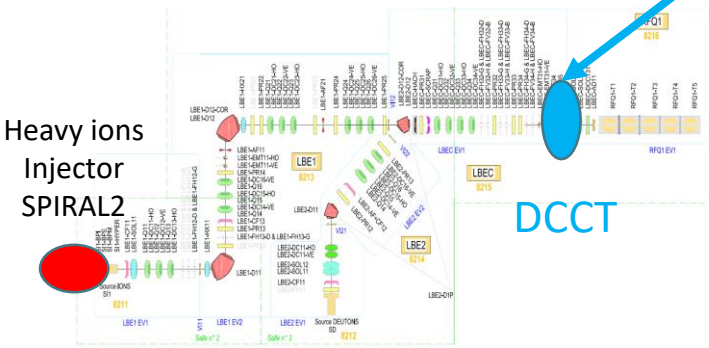


Cyclotron Ion Sources

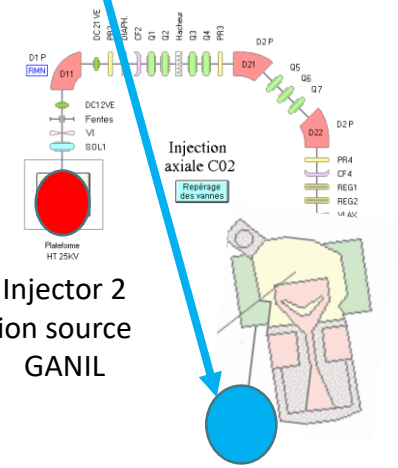
Stability – **Diagnostic** – Intensity

Tools for tuning ion source / monitoring ion source





Heavy ions Injector SPIRAL2



Injector 2 ion source GANIL

OPTICAL EMISSION SPECTROSCOPY

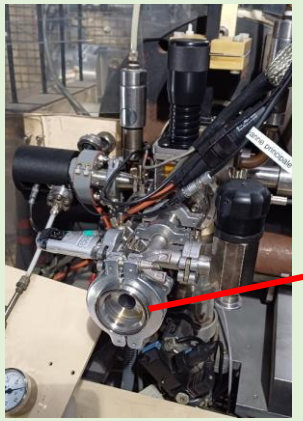
20th International Conference on Ion Sources IOP Publishing
Journal of Physics: Conference Series **2743** (2024) 012048 doi:10.1088/1742-6596/2743/1/012048

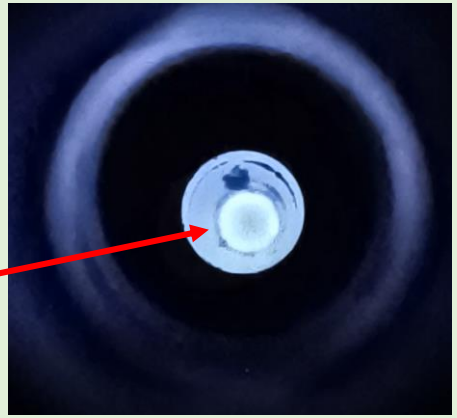
Research and development activities to increase the performance of the CAPRICE ECRIS at GSI

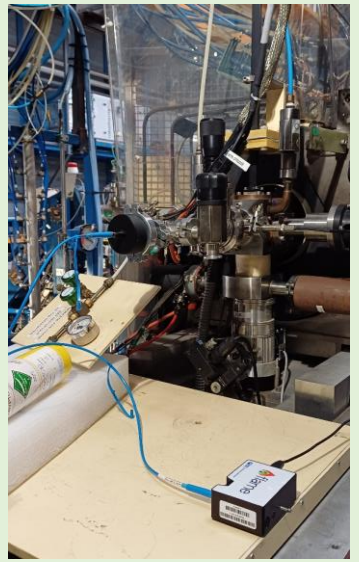
F. Maimone, A. Andreev, M. Galonska, R. Hollinger, R. Lang, J. Mäder, P.T. Patchakui

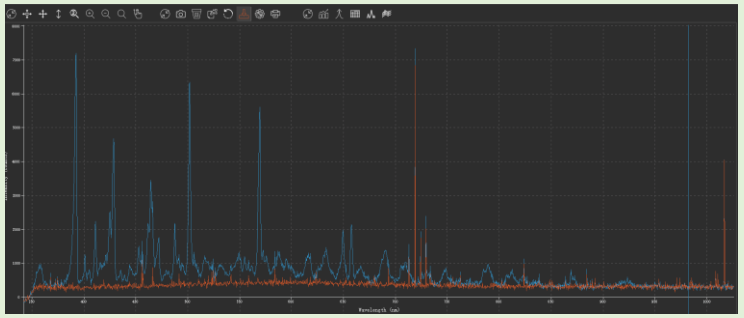
GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstrasse 1, 64291 Darmstadt, Germany

Corresponding Author: Fabio Maimone, f.maimone@gsi.de





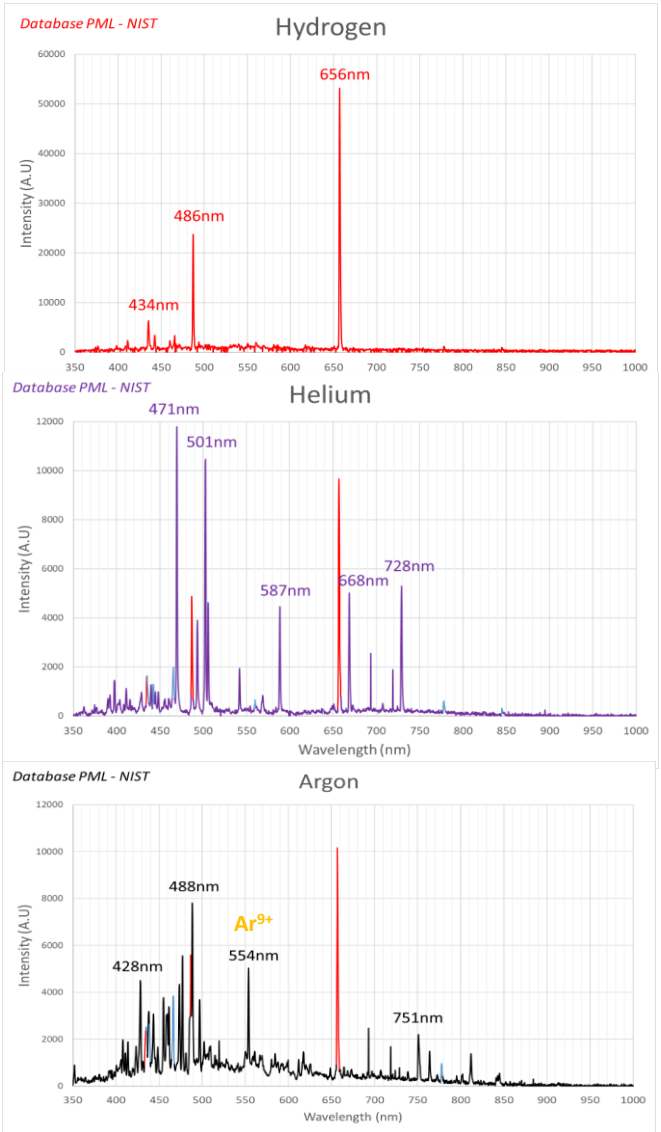




Cyclotron Ion Sources

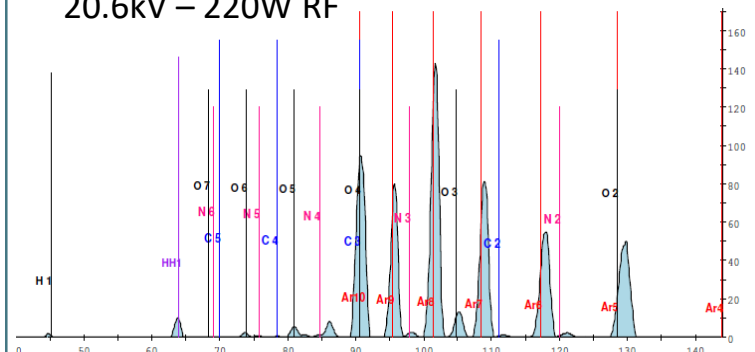
Stability – **Diagnostic** – Intensity

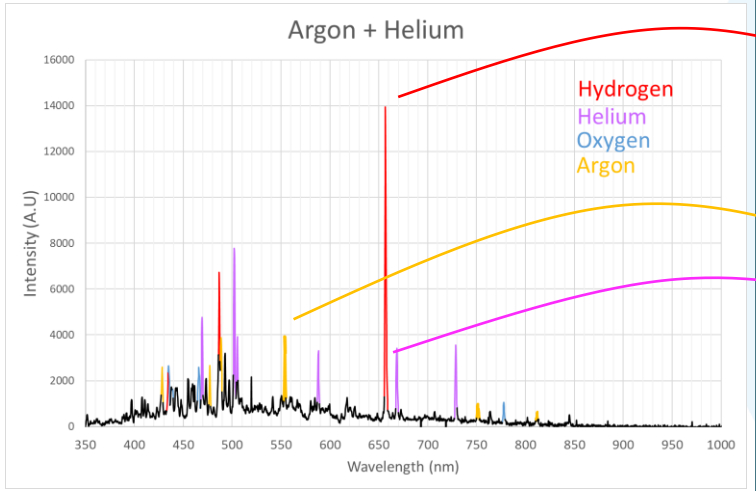
Wavelenghts identification



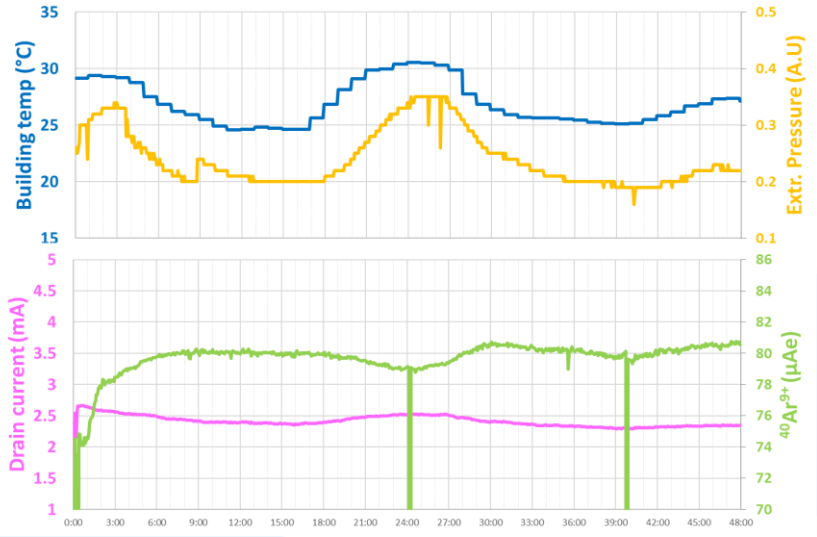
OES diagnostic with Ar+He plasma

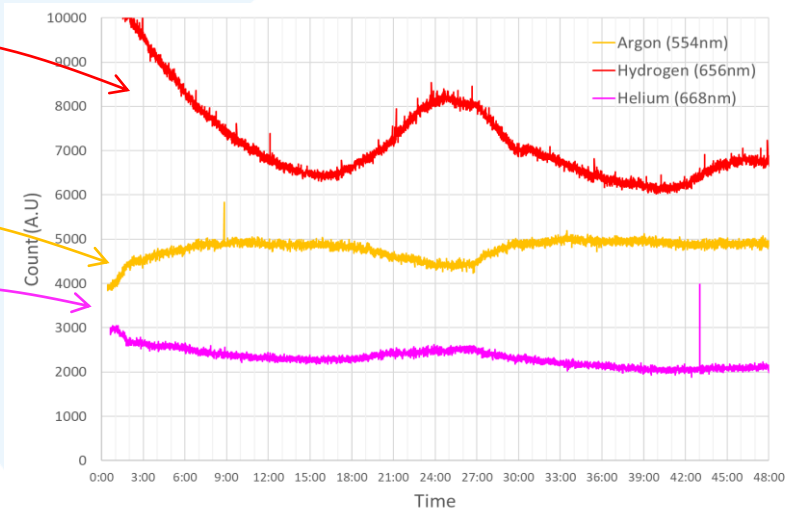
20.6kV – 220W RF





48-Hours Parameters tracking



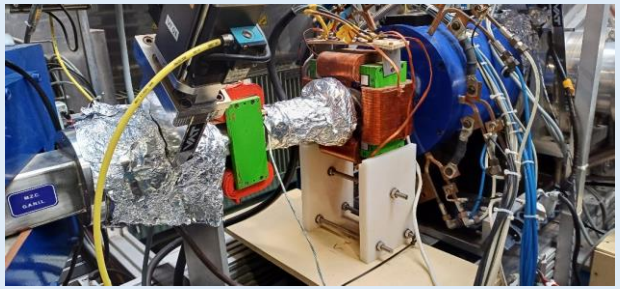


Cyclotron Ion Sources

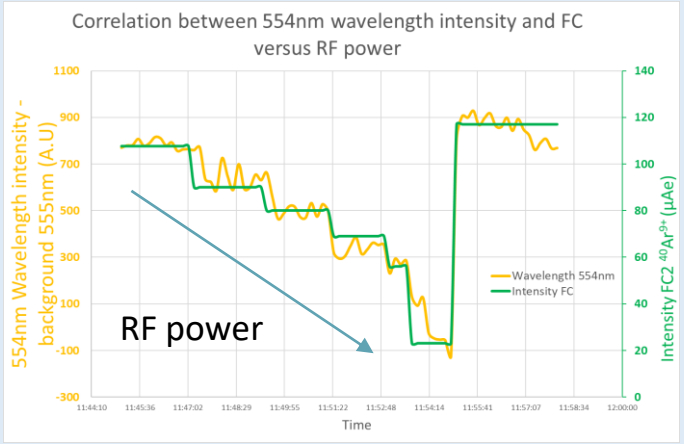
Stability – **Diagnostic** – Intensity

Remarks :

1- Diagnostic : outgasing

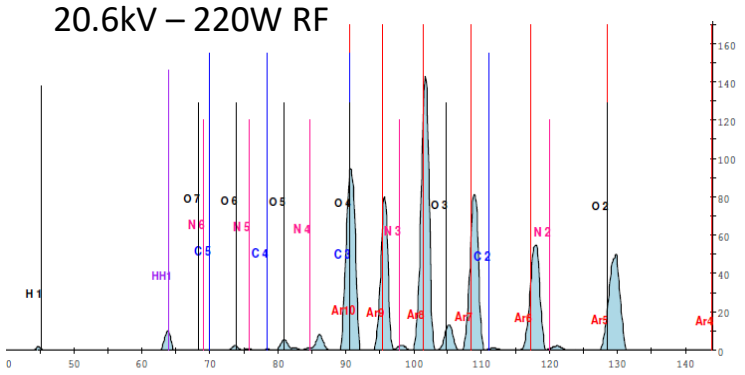


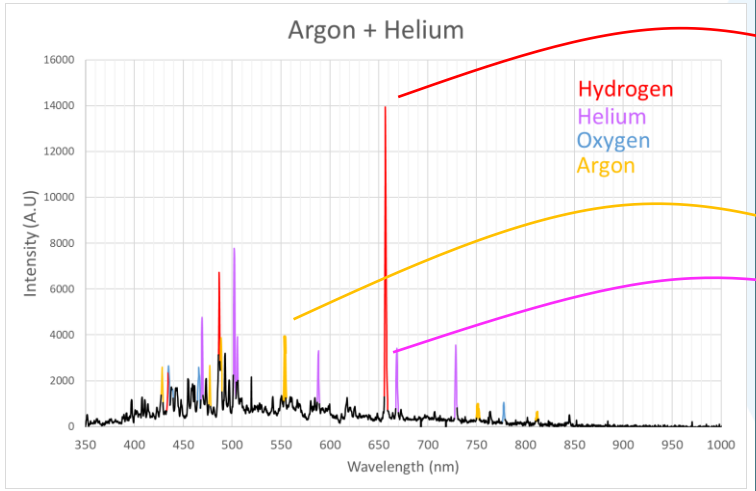
2- Tracking charge state ($^{40}Ar^{9+}$)



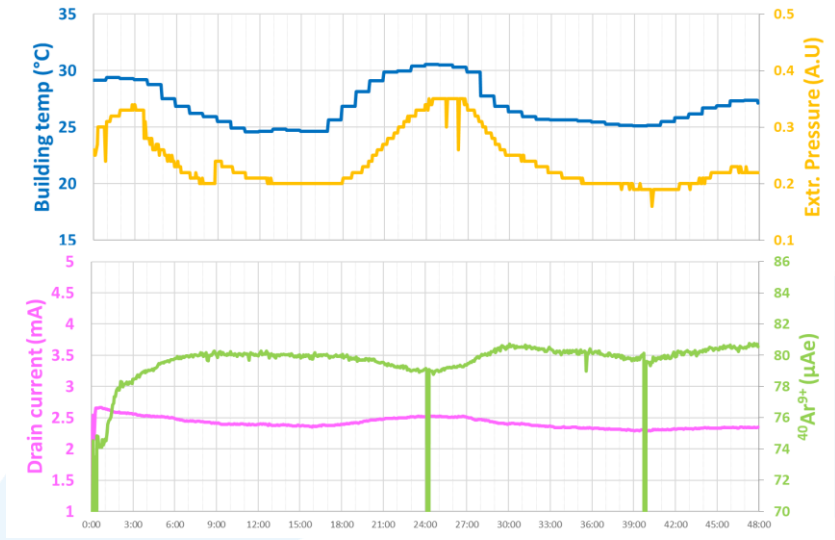
3- Neutral evolution (gas, vapor)

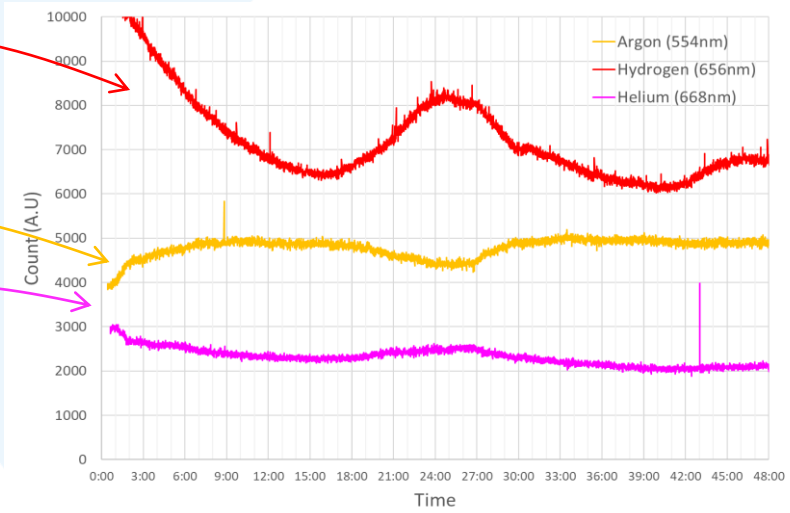
OES diagnostic
with Ar+He plasma





48-Hours – IS Parameters

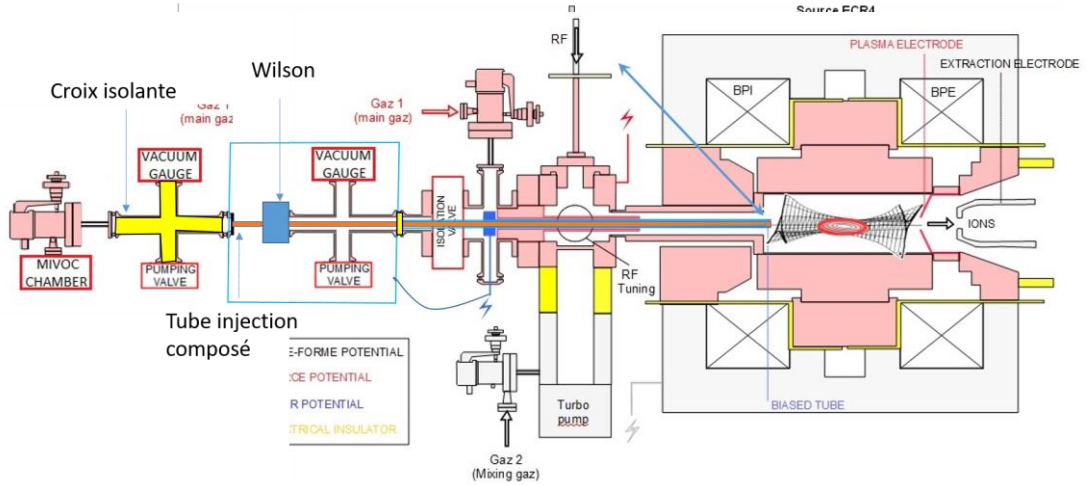




Cyclotron Ion Sources

Stability – Diagnostic – **Intensity**

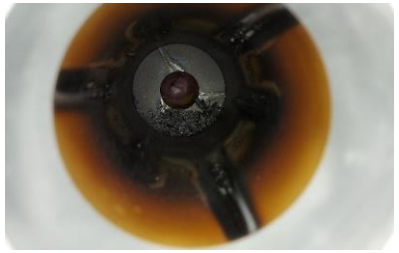
Ion source configuration (ECR4/4M)

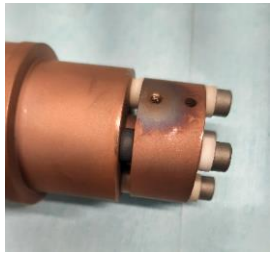


Easy to switch from gas to sputtering, oven, MIVOC

But some inconvegnients :

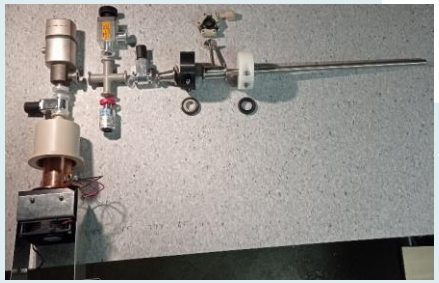
- MIVOC: Conductance limited of the injection tube
- OVEN : diameter limited by the coaxial tube
- Plasma chamber is replaced after metal beam production

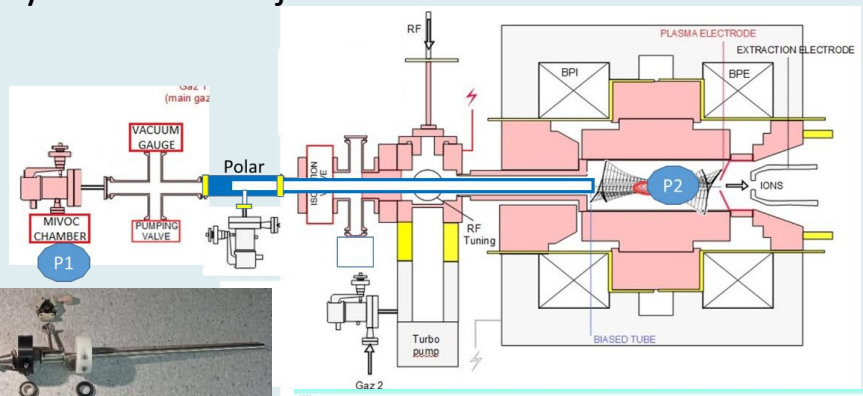


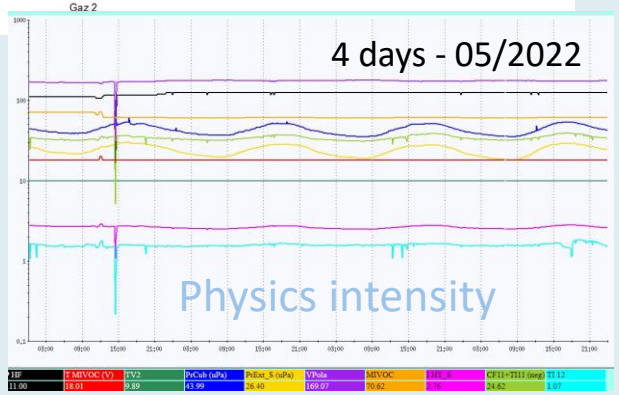


Metal Ion from Votatil Compound

- Internal diameter injection tube : 14mm (8mm previously)
- Thermal regulation of sample
- Possibility to bias the injection tube







Results for $^{58}Ni^{11+}$:

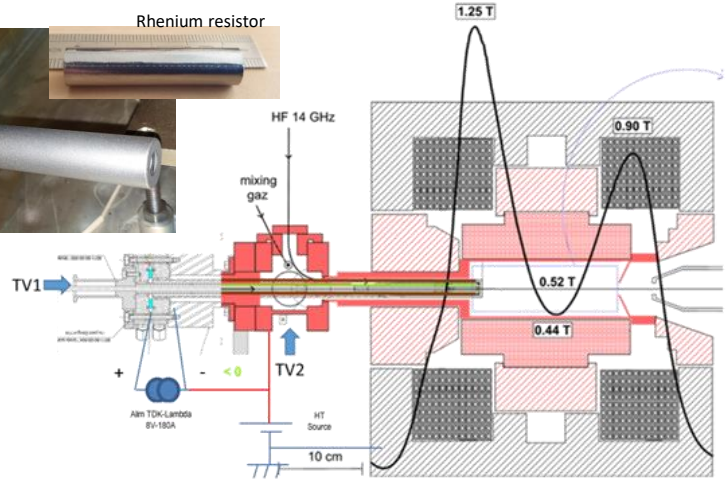
- More stable beam
- Better intensity online (up to 25µAe $^{58}Ni^{11+}$)
- Operated for more than 2 weeks with no technical problems

Cyclotron Ion Sources

Stability – Diagnostic – **Intensity**

Ion source configuration with high temperature oven

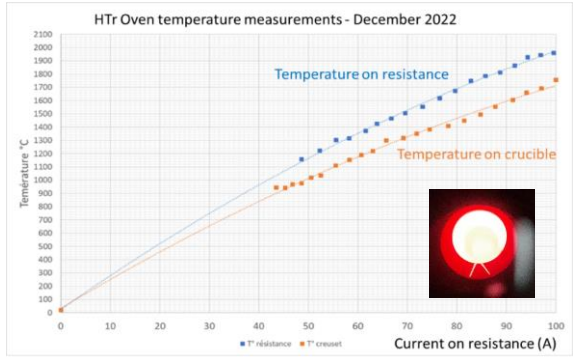
O. Bajeat. ICIS 2021



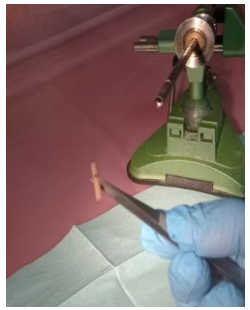
Configuration :

- Outer diameter : **20mm**

High temperature oven for Uranium Beam

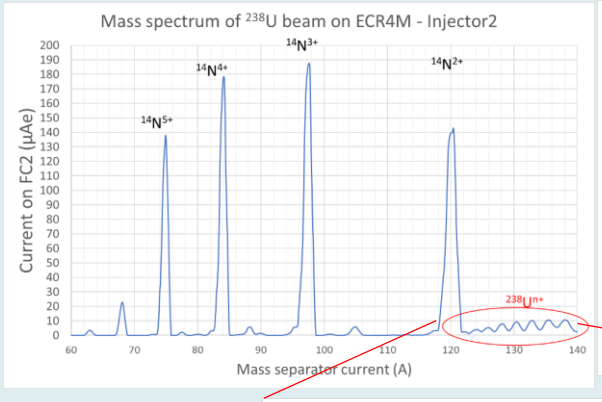


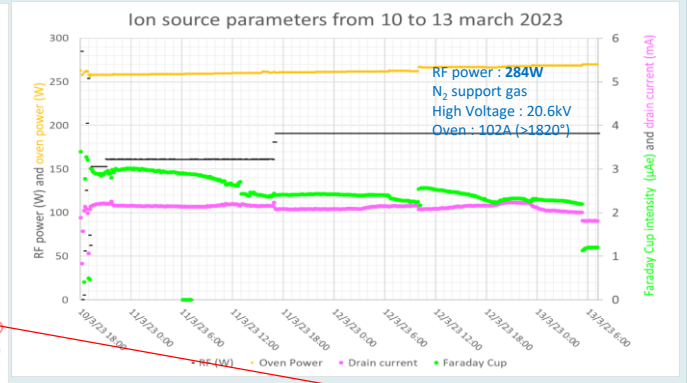
Oven temperature measurement



UO_2 sample into WL_{20} crucible

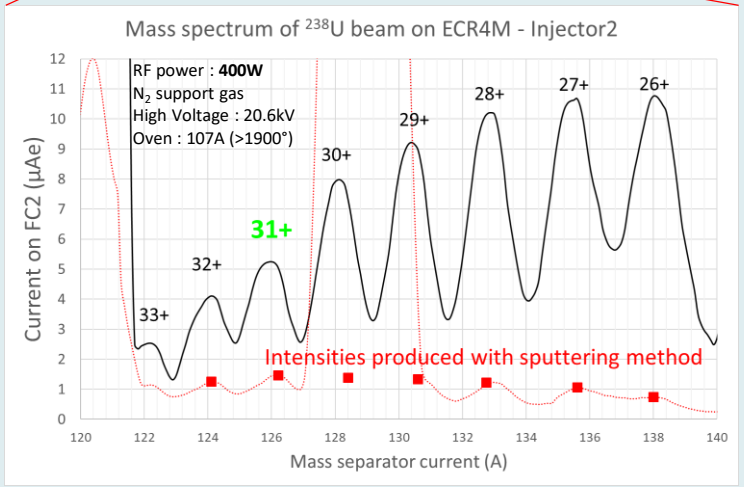
Results for $^{238}U^{31+}$ beam with HTr Oven





$^{238}U^{28+}$: x5

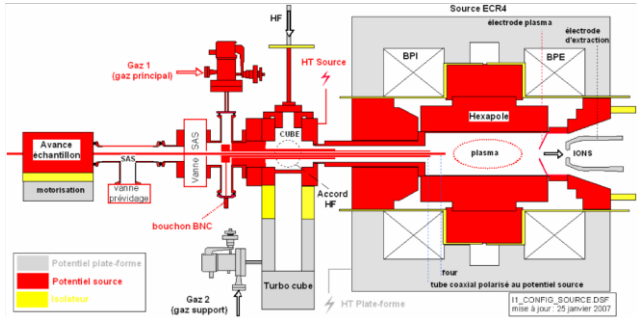
$^{238}U^{31+}$: x3.3



- HT oven can be used on ECR4M and it's possible to produce ^{238}U beam with higher intensity than sputerring method
- Stability was measured for 3 days - Consumption : 1.47mg/h

Cyclotron Ion Sources

Stability - Diagnostic – **Intensity**-



High Voltage : 20.6kV
Drain current : 1.96mA
RF power : 342W
O_2 support gas : 2.95V
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STATUS REPORT ON METALLIC BEAM PRODUCTION AT GANIL/SPIRAL 2

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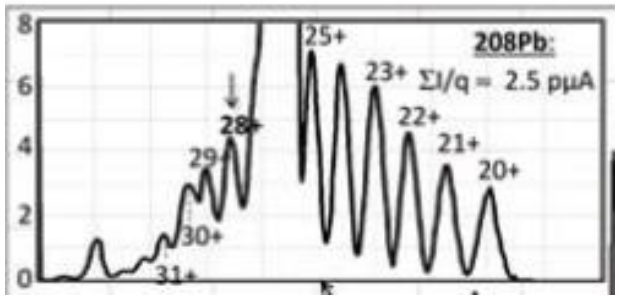

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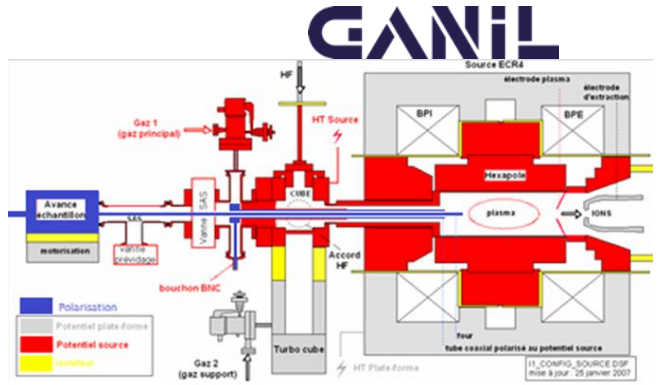

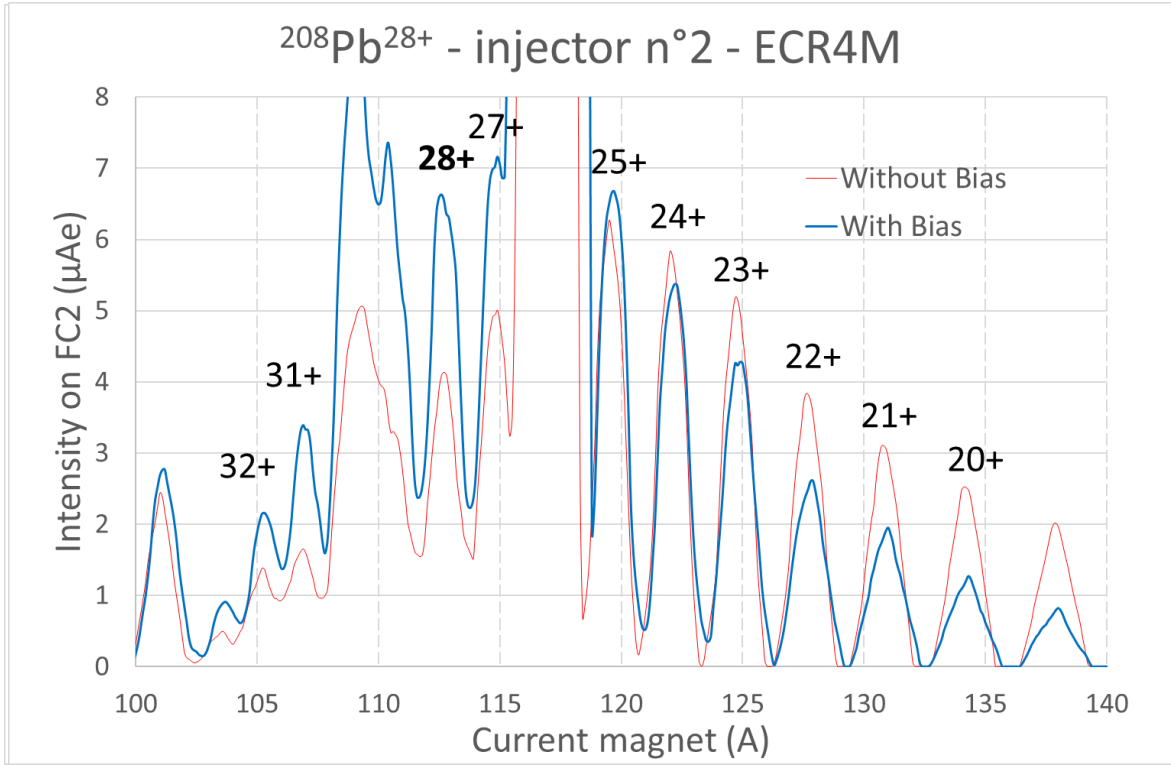

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RF power : 294W
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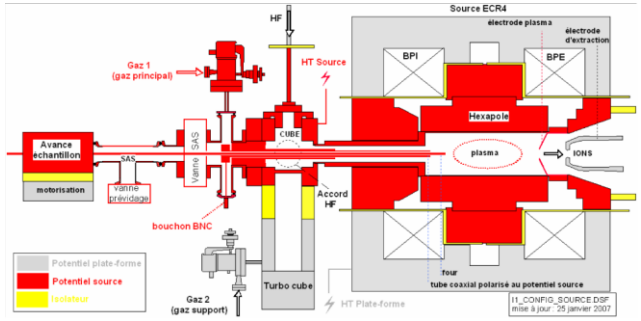
Cyclotron Ion Sources

Stability - Diagnostic – **Intensity**-



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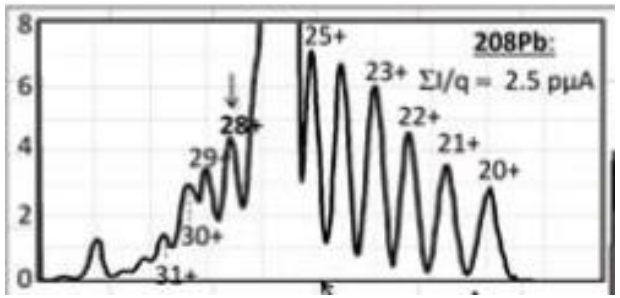

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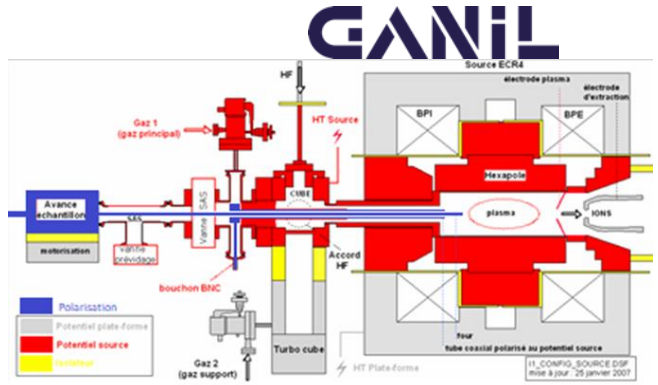

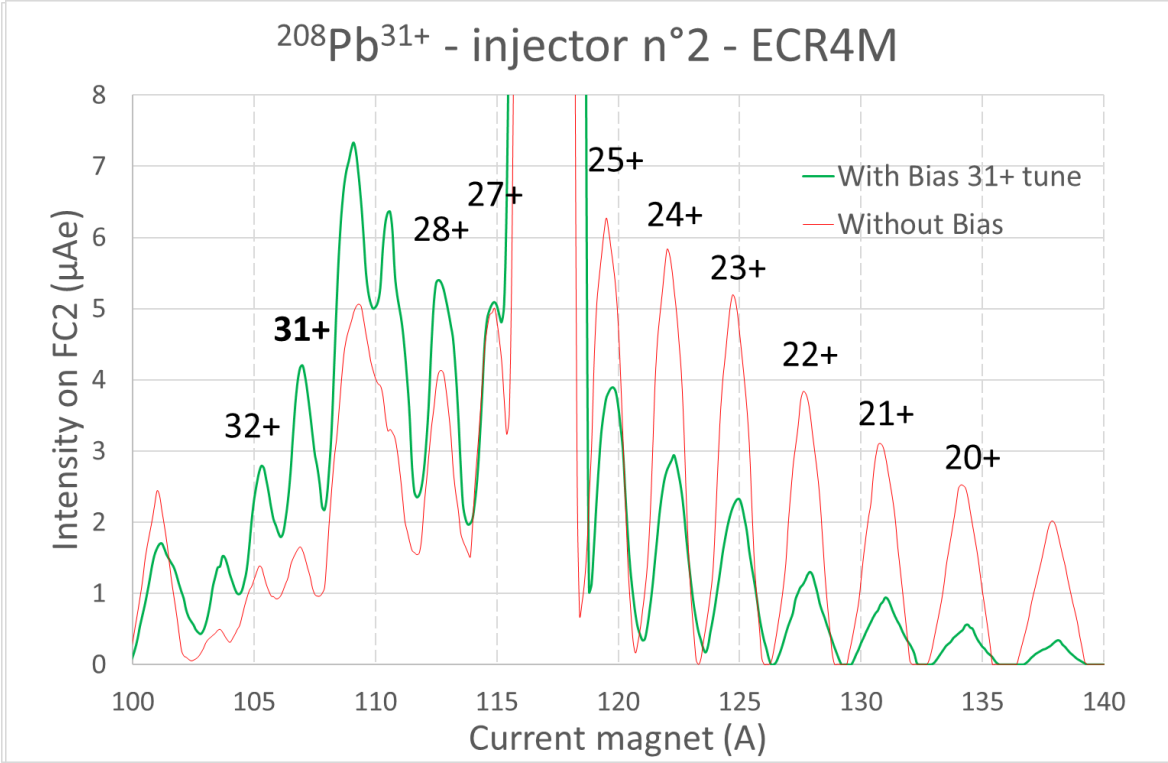

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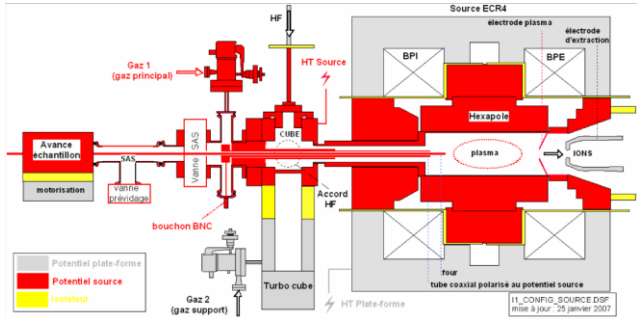

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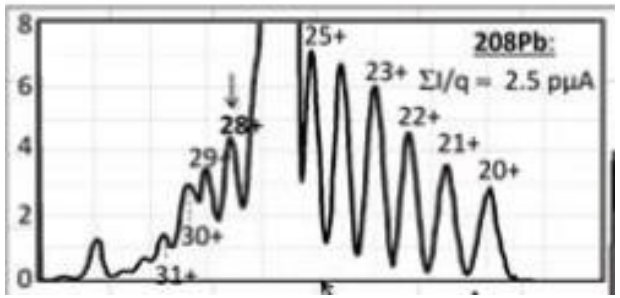

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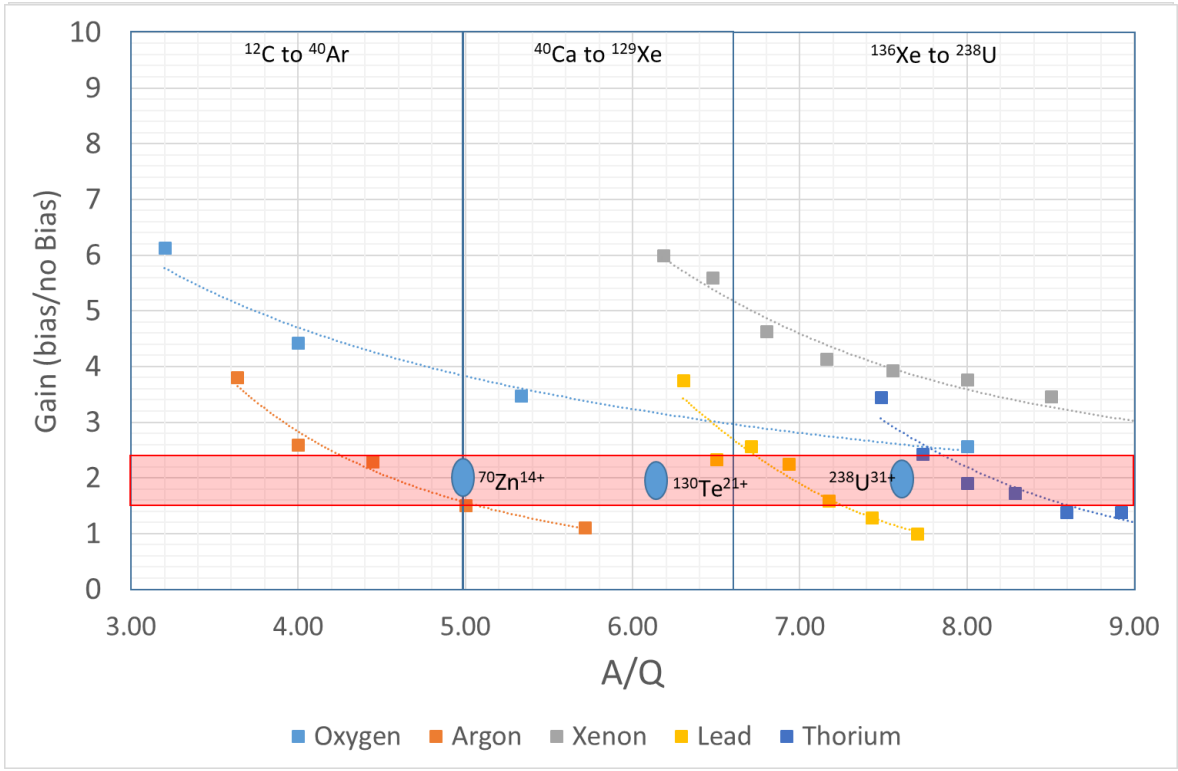

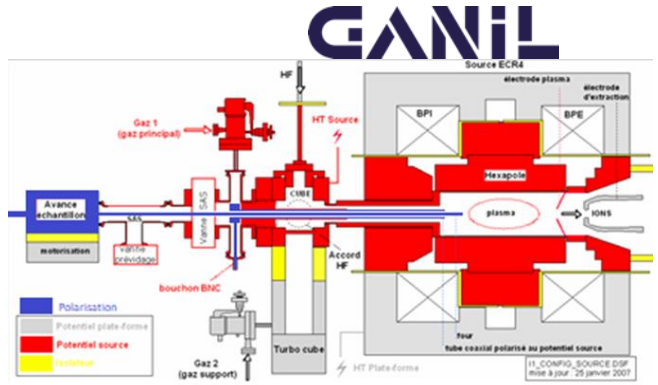

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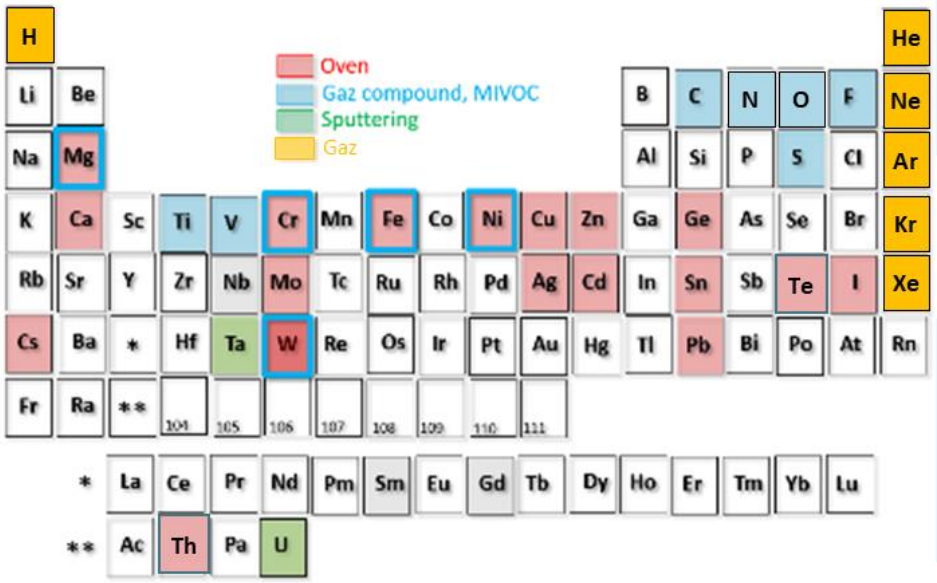
Cyclotron IS optimisation : summary

1. **Beam stability improved for all beams**
   - ❑ H_2 pollution has to be analysed and controlled

2. **Diagnostic OES has to be developped**
   - ❑ Preliminary OES tests have shown that this could be an interesting on-line diagnostic
   - ❑ Next step : Use with metallic beam
   - ❑ Specific tools have to be developed for operation

3. **Adaptation of the injection source is necessary**
   - ❑ New Oven with polarisation = improvement GANIL metallic beams
   - ❑ MIVOC : Better stability, more reliable than previous version



- *New valve + OES + Bias HT oven : $^{238}U^{31+}$ (x5 ?)*

- *New valve + OES + Bias LT oven + Liner : Ca, Zn, Se*
  Higher intensity (x2 expected), better stability, T° control

OUTLINE

1- GANIL-SPIRAL2 Facilities

- Ion sources - Beams Production
- Challenges for the coming years

2- Cyclotron Ion sources

- Optimisation for operation
- Beam improvements

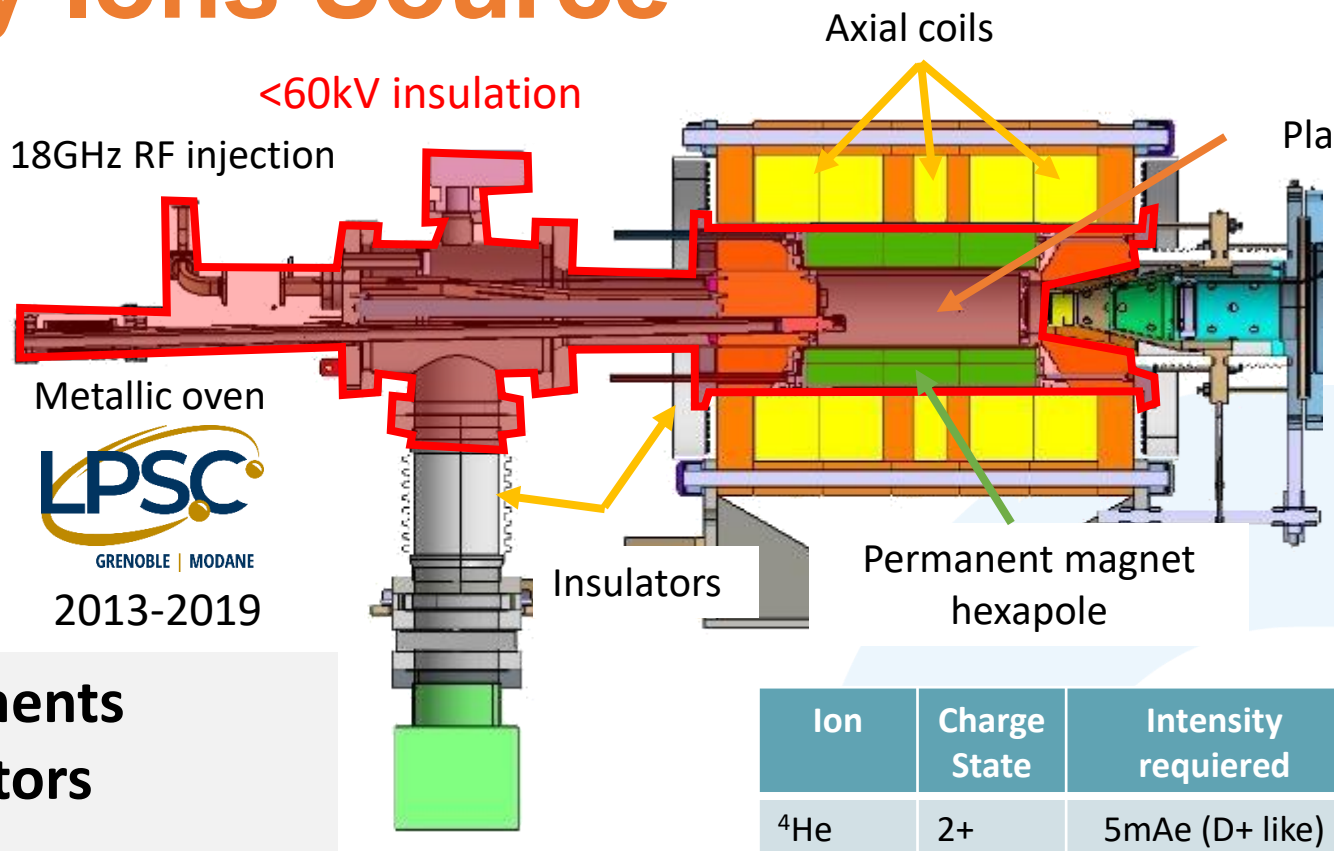
3- SPIRAL2 Ion sources

- Reliability
- Optimisation for metallic beams

4- Conclusions and Perspectives

SPIRAL2 Heavy Ions Source

Technical parameters	
RF Frequency/power	18GHz/2kW
Axial Mirror	2.1-0.47-1.3T
Radial magnetic field	1.15T
Plasma volume	**1.4 l** – 89mm
HV extraction	**<60kV**



LPSC GRENOBLE | MODANE

2013-2019

Double GAP extraction

Ion source requirements for LINAC accelerators

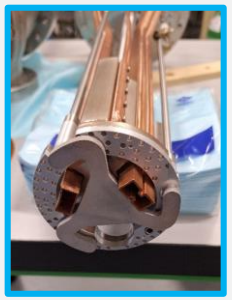
- A/Q <3 – 60kV extraction double GAP
- Gas : $^{36-40}$Ar, ^{22}Ne, ^{18}O, ^{36}S – (<10pμA)
- Metals : ^{58}Ni, $^{40-48}$Ca, $^{50-54}$Cr, ^{50}Ti, ^{50}V, ^{70}Zn (< 2pμA)
- Run : 3 weeks-1.5 month

Ion	Charge State	Intensity requiered	Intensity measured
^{4}He	2+	5mAe (D+ like)	4mAe
^{18}O	6+	60μAe	1mAe
^{22}Ne	8+	80μAe	220μAe
^{40}Ar	14+	140μAe	130μAe
^{40}Ca	14+	28μAe	70μAe
^{48}Ca	16+	32μAe	35μAe (*)
^{58}Ni	20+	40μAe	18μAe

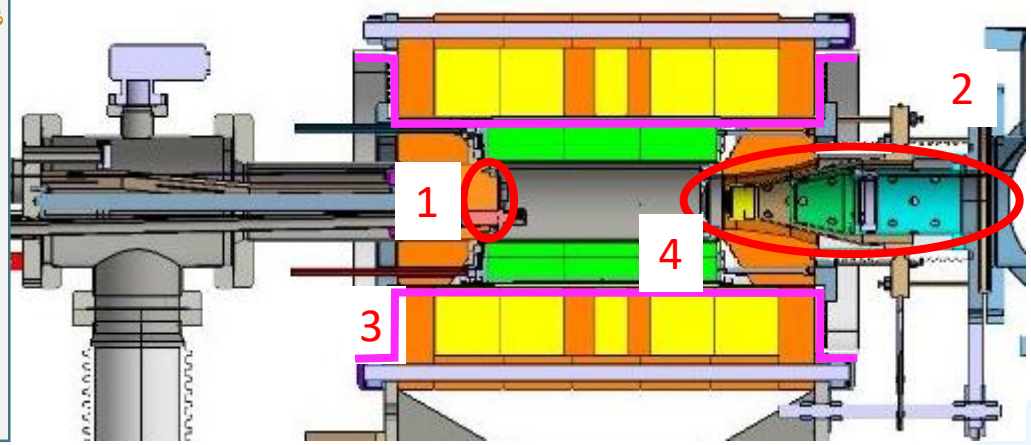
(*) Expected if enriched isotope can be used

SPIRAL2 Heavy Ion Source : Reliability

1 – Injection



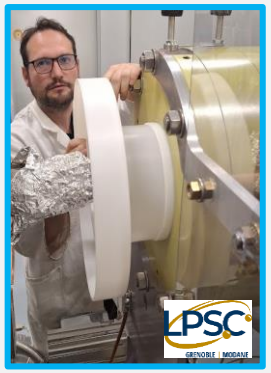
- Protection bias disc insulators
- Ø 25mm access for HT oven



2- Extraction

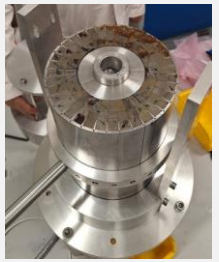
- extraction electrodes (shape + lenght)

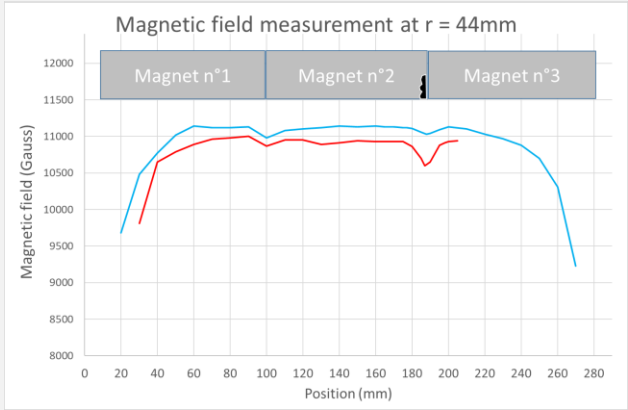
3 – 60kV insulation



Coils protection with metal liner + Kapton layer
New design to garantee 3mm thickness insulation

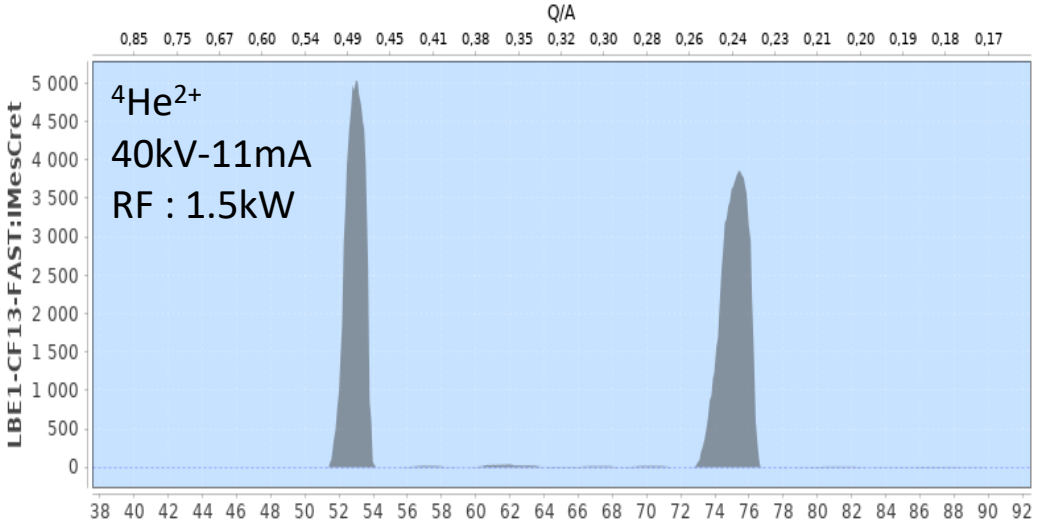
4 – Magnetic field

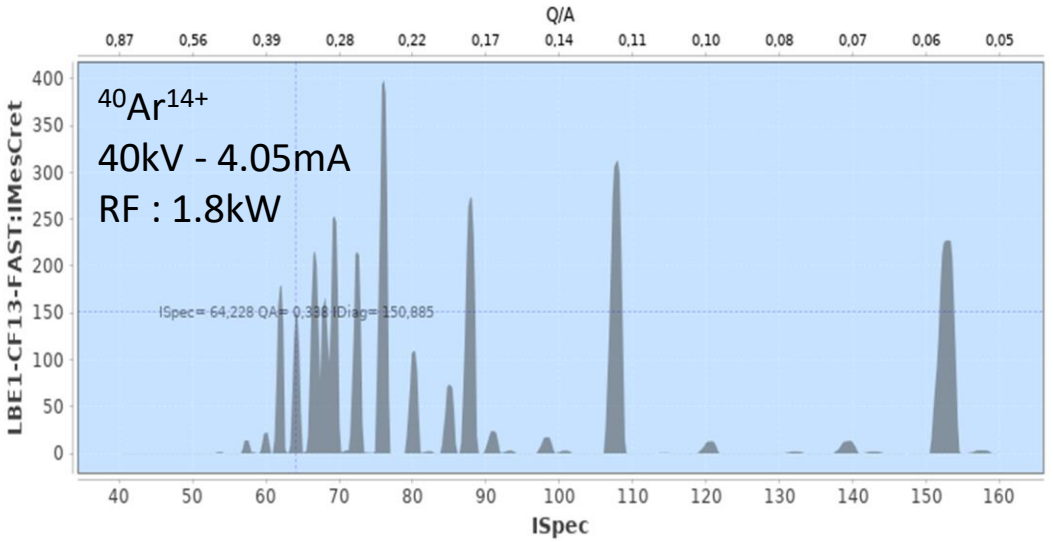




SPIRAL2 Heavy Ion Source

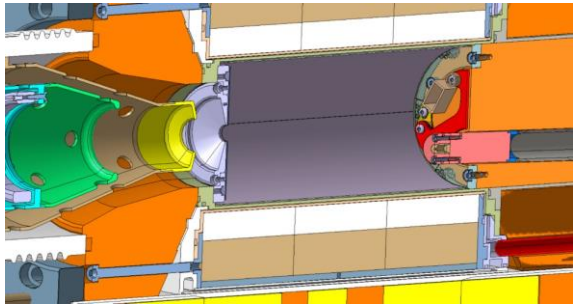
First results (summer 2024) :

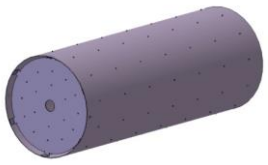


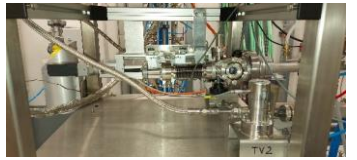


Ions	Best reference at GANIL	New result (summer 2024)	Gain
$^{4}He^{2+}$ @ 40kV	4.2mA	5.03mA	**+19.7%**
$^{40}Ar^{14+}$ @ 40kV	130µA	156 µA	**+20%**

Next step : Metallic beams production and optimisation







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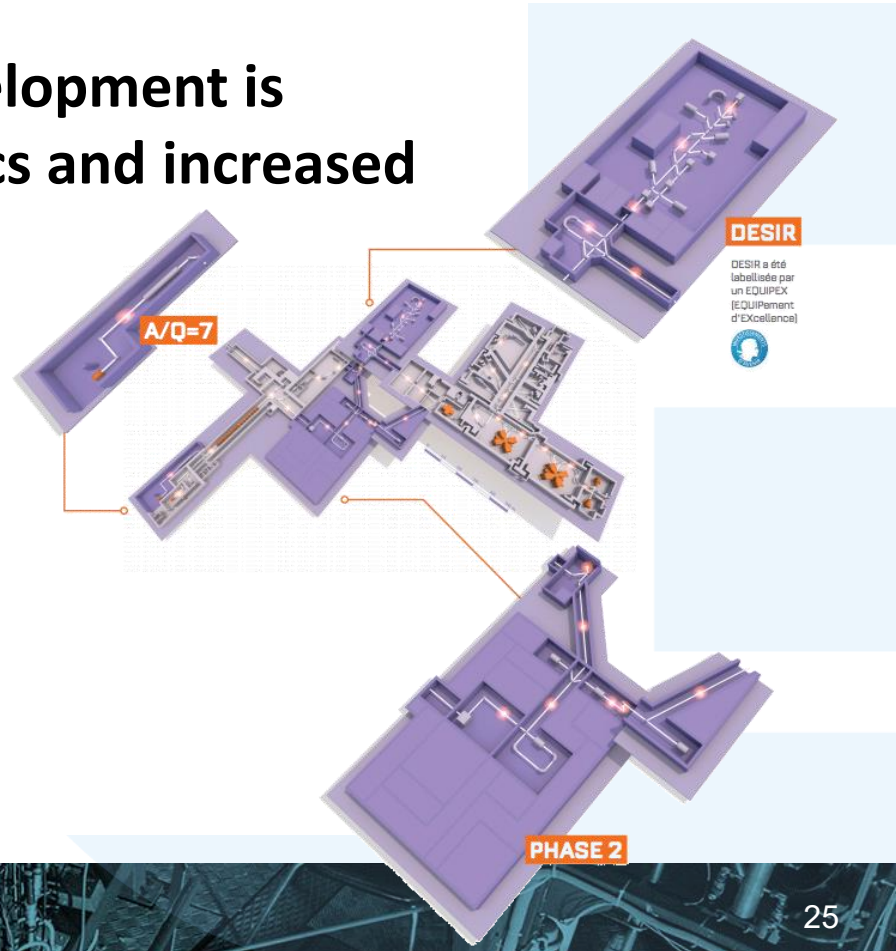
Conclusions and perspectives

The GANIL-SPIRAL2 facility is evolving and investing for the future.

- ❑ New installations : S^3, DESIR, Newgain
- ❑ Refurbishment of the cyclotron machine

For ion source group, a programme of optimisation and development is underway on ion sources to meet the requirements of physics and increased beam times :

- ❑ Cyclotron beams optimisation
- ❑ Development of SPIRAL2 heavy ion beams
- ❑ Improving the reliability of Deuton-Proton
- ❑ Reception and installation of SC ion source



We currently have a limited manpower.

If you would like to join us, please contact me.

THANK YOU FOR YOUR ATTENTION