GANIL

Operation with ECR ion sources

F. Lemagnen for GCS team

SUMMARY

GANIL facilities, Ion sources

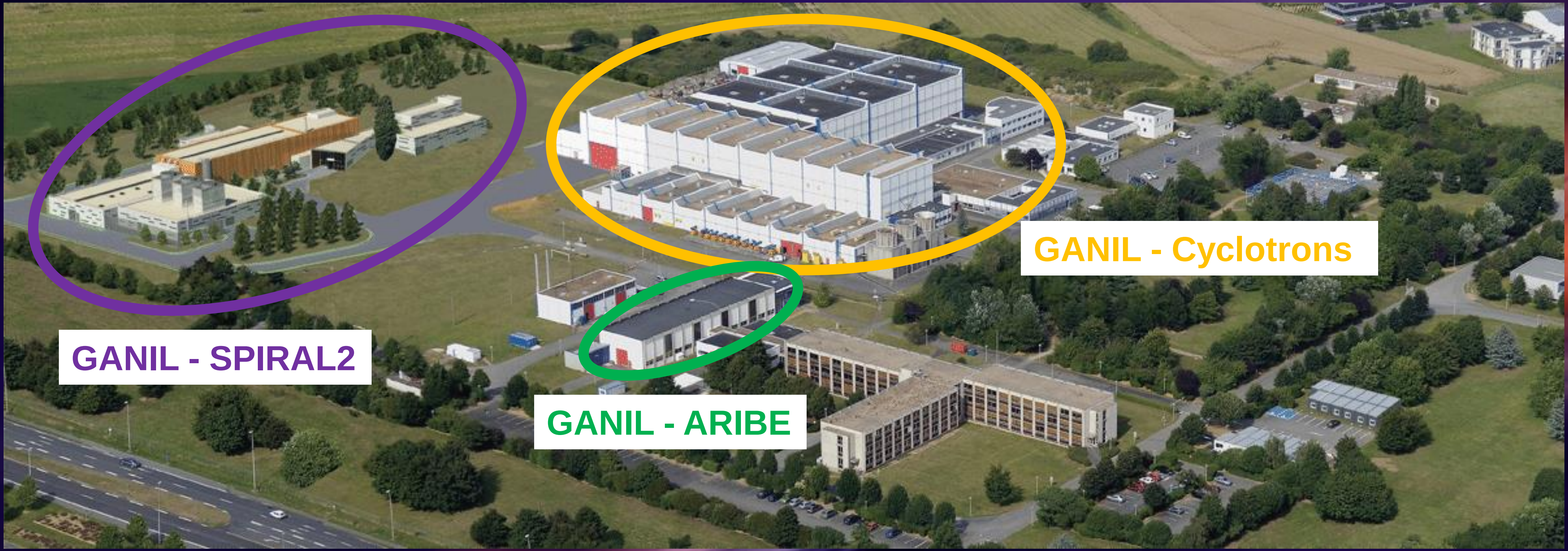
Stable beams production at GANIL

ECR ion sources : technical aspects and upgrades for operation

Challenge for the futur :

- Cyclotron
- SPIRAL2

GANIL Facilities



GANIL – Cyclotron & SPIRAL1 Facilities

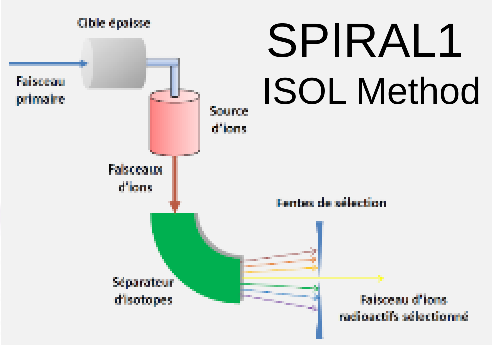
Cyclotrons (1983)

Stable beams :

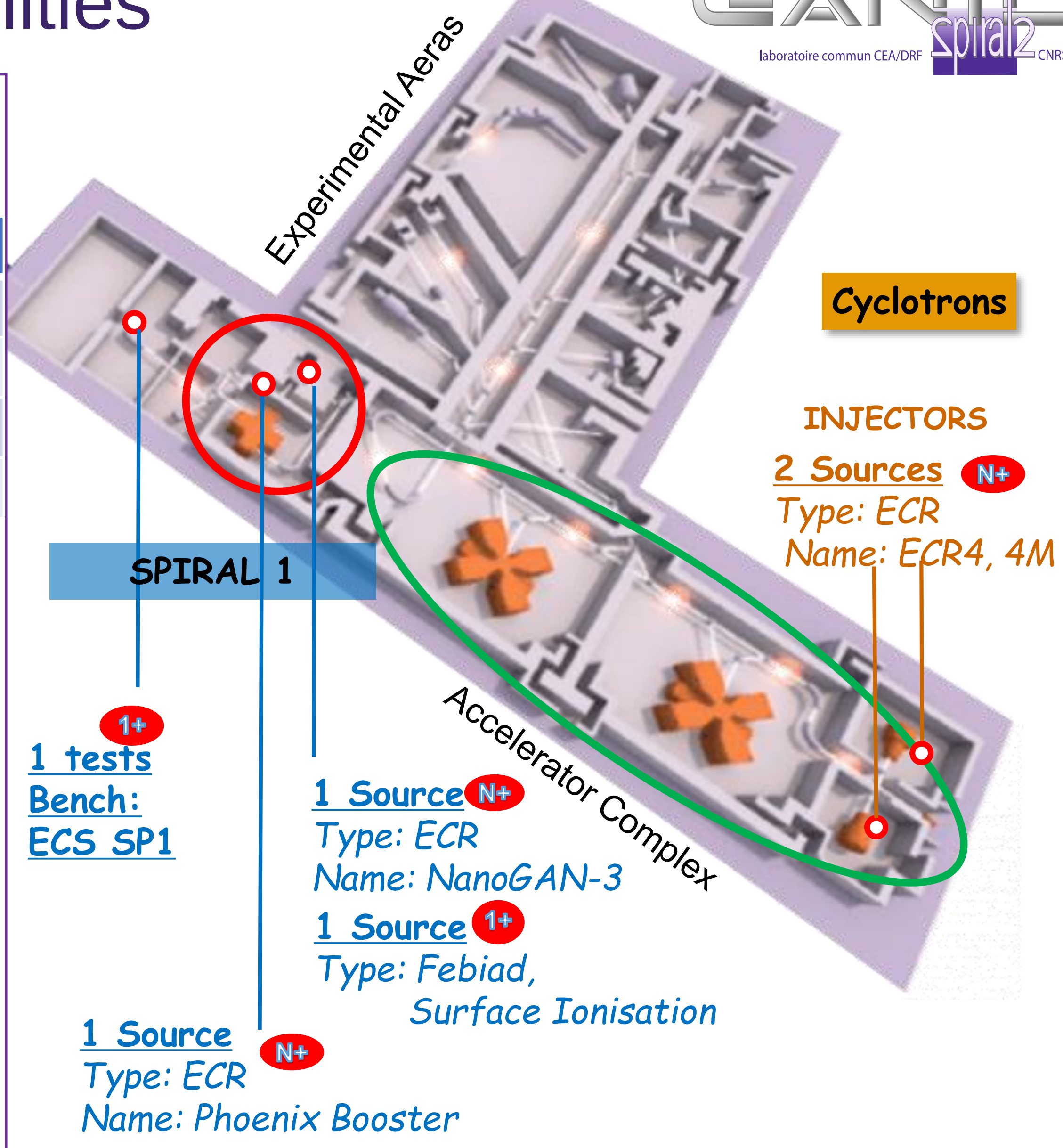
2 injectors CO (2MeV/A)
2 CSS (13MeV/A + 95 MeV/A)
α spectrometer

Heavy ion	
Ions	C - U
Intensity	< 2.10^{13}pps
Energy	3,8<E< 95MeV/A
Power	< 6kW

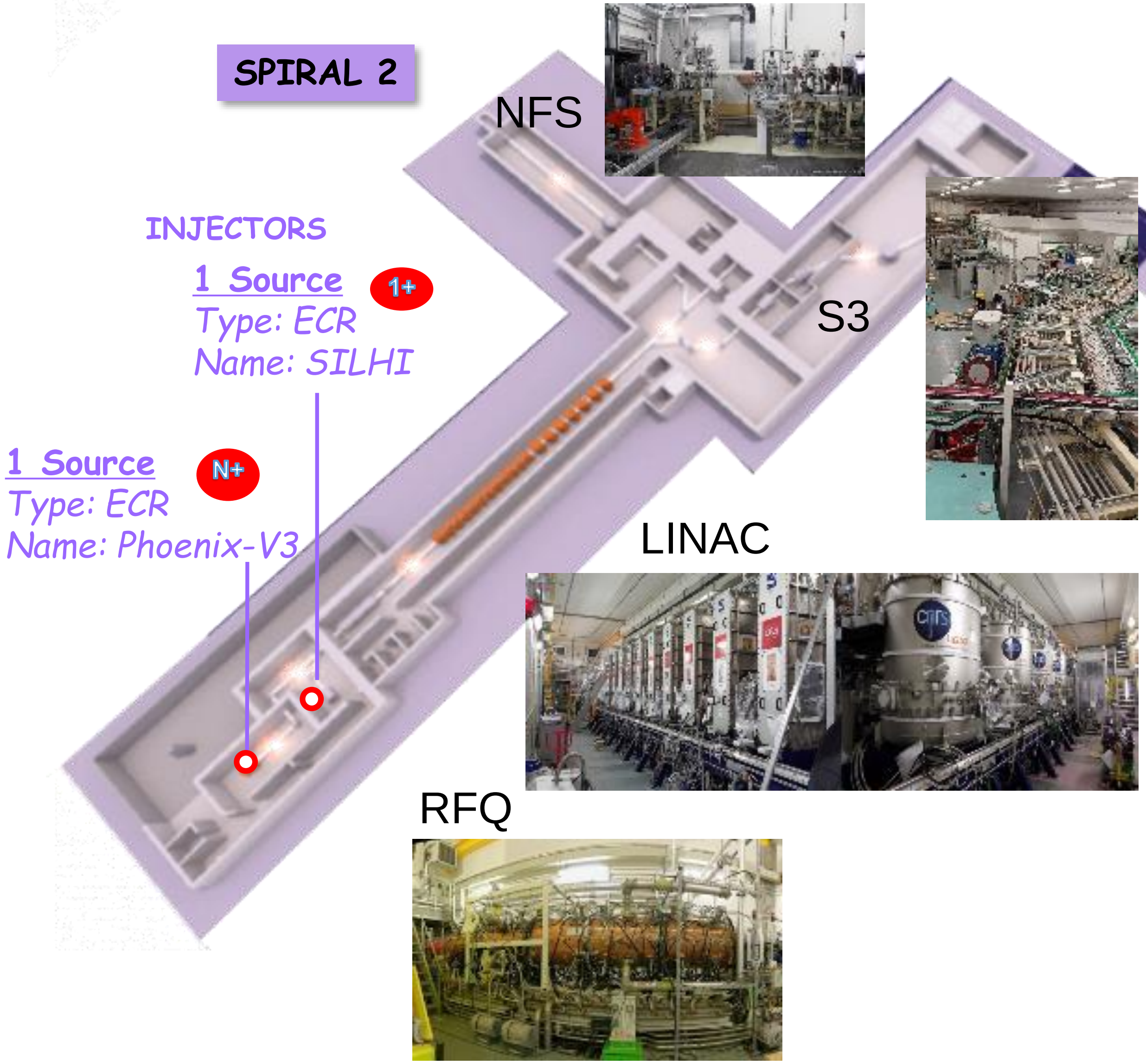
Radioactive beams :



Intensity : 10^{3}-10^{9}pps
Energy : <20MeV/A
$T_{1/2}$: 100ms (^{8}He)



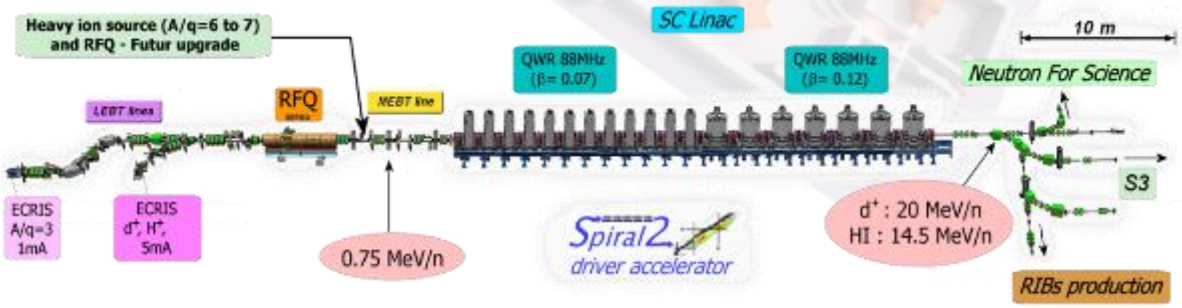
GANIL – SPIRAL2



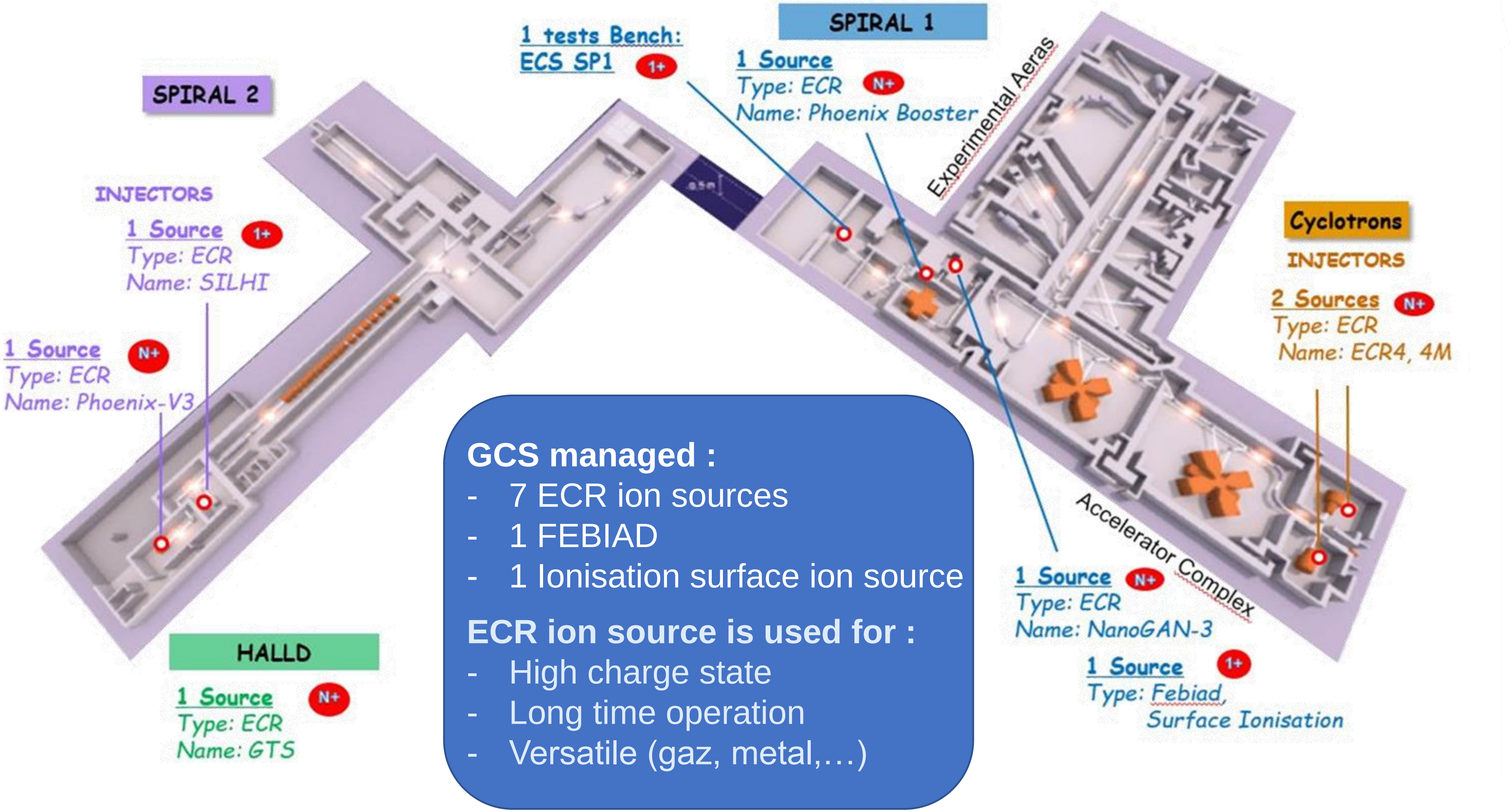
LINAC (2019)

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/A)	33	20	<14.5
Max beam Power (kW)	165	200	44



GANIL-SPIRAL2 Ion sources



GCS managed :
- 7 ECR ion sources
- 1 FEBIAD
- 1 Ionisation surface ion source

ECR ion source is used for :
- High charge state
- Long time operation
- Versatile (gaz, metal,…)

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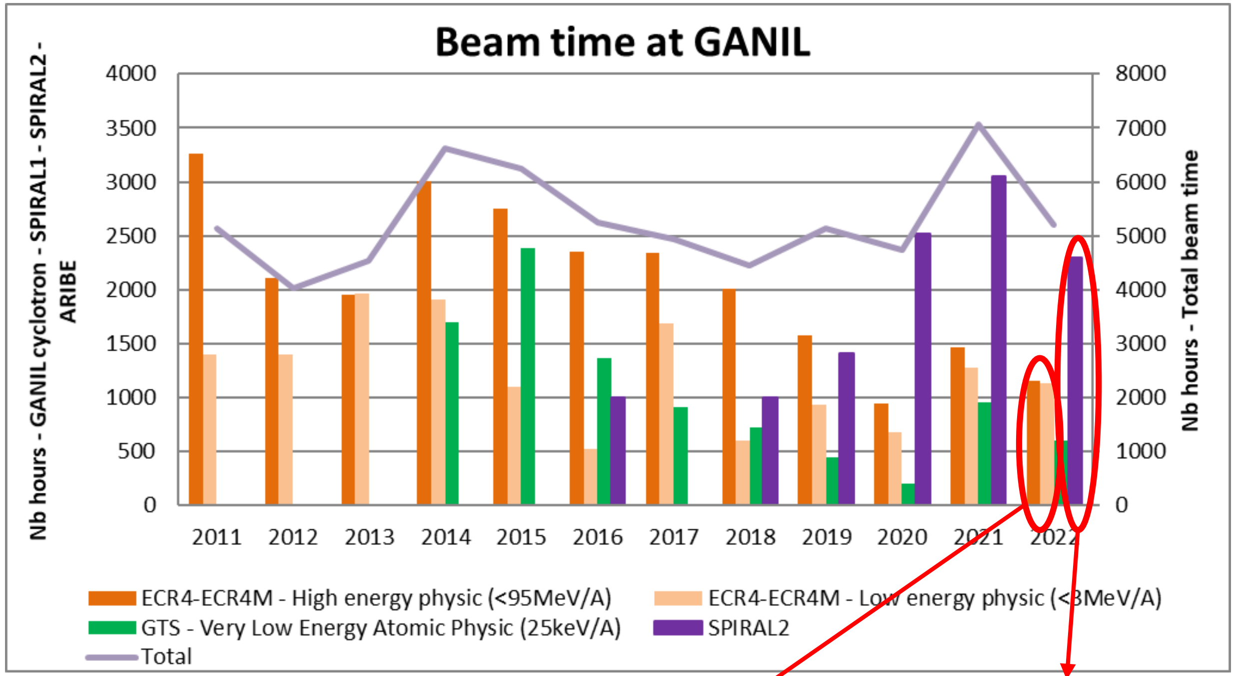
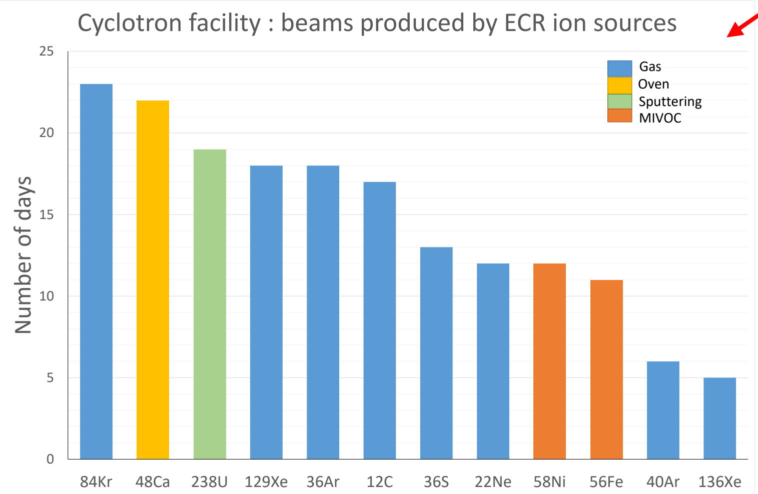
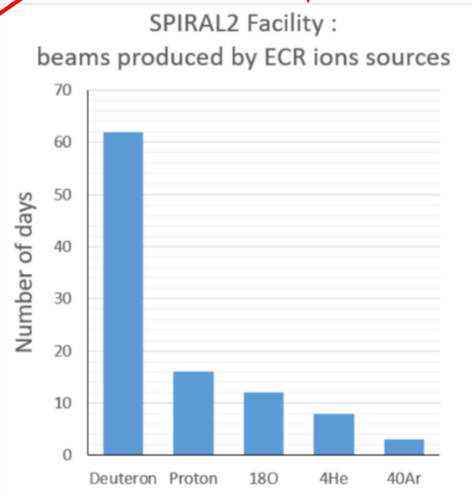
Stable beams production at GANIL







Over the past 10 years, the number of total operating hours has various in according to the installation and the commissioning of Spiral2 .The goal is to increase the operating time with 5 sources instead of 3.

⇒ Increased maintenance operation with different technologies

Several types of beams are produced, using differents techniques and requiring varying degrees of manpower.

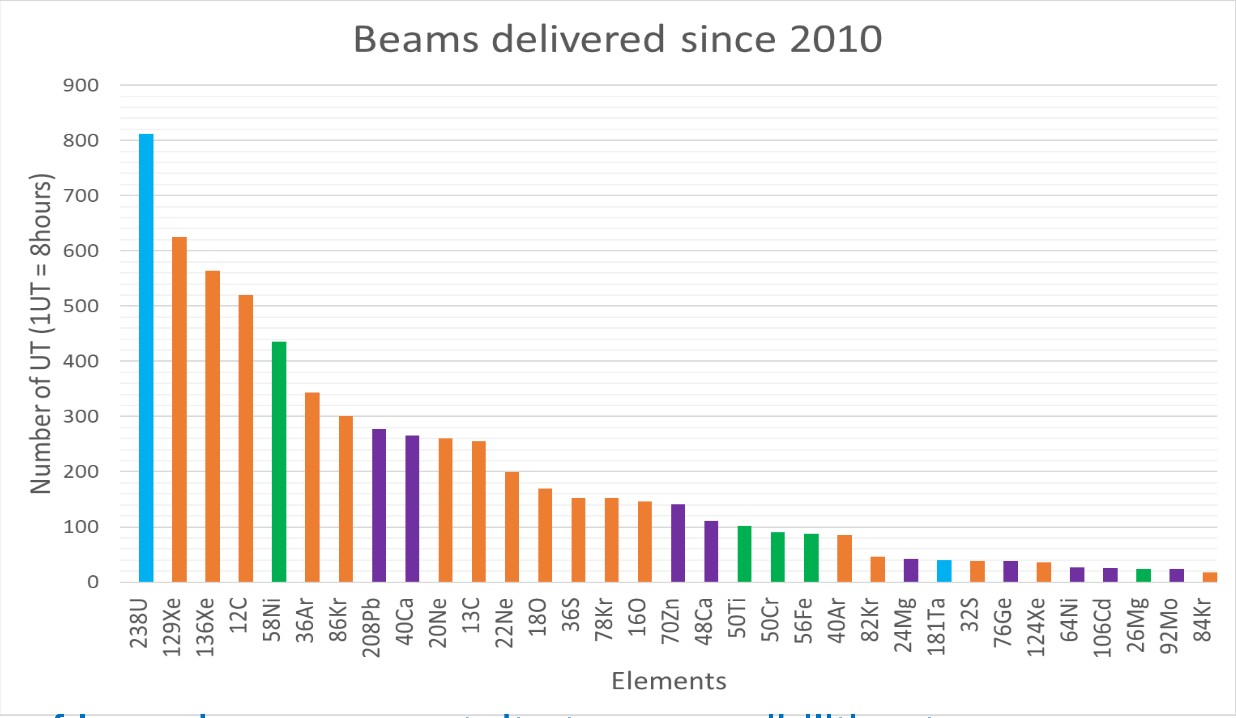
In 2022, 3 full-time equivalents (2 technicians + 1 engineer) worked on the production of beam on the 5 injectors.

- preparation, tuning,
- maintenance,
- on-call duty

Status of beams production at GANIL-Cyclotron

Ion sources on cyclotron facility :
- 2 injectors – 14.5GHz – 25kV (90's technology)
- Large range of beams (C => U)
- 4 methods of neutral injection elements possible
- 1 to 2 weeks for the same ion beam
- Choice of charge states flexible (3<A/Q<9)
- Intensity max usable into CO : 50-100µAe
  (not reached for many beams)
- Development of new beams in order to the request of physicists. *Possibility of 1 or 2 tests/year*

4 new ions beams availables (Si, W, Te, Th) for 4 years



Although these ion sources are old and limit the possiblity of large improvement, it stays possibilities to improve the quality and intensity of beam on some of them (On-line diagnostic@GSI, new oven, new MIVOC molecule, …)

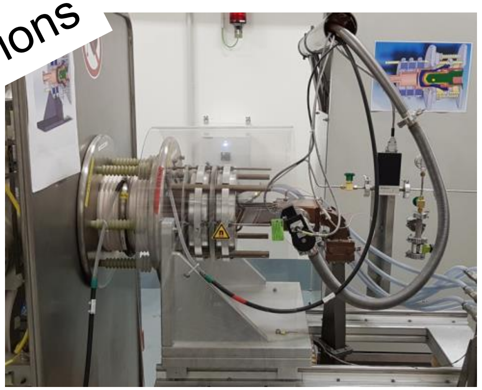
Development and fine-tuning for one beam take a long time, as equipment is not readily available.
⇒ During operation, the 2 sources are used,
⇒ During non-operation, heavy maintenance limits access to equipment (ADI, GANIL Cooling system, etc.).
⇒ No off-line dedicated R&D test bench with equivalent source.

Status beams production at GANIL - Spiral2

2 Ion sources in alternance on SPIRAL2 facility :

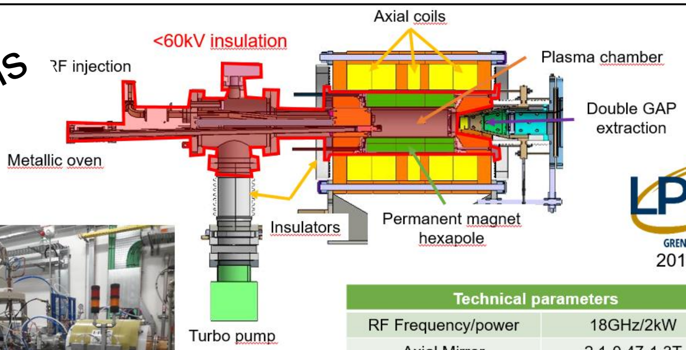
- Light Ion Source dedicated for NFS experiments
  - D^+/H^+, intensity >5mA
- Heavy Ion Source dedicated for S3 experiments
  - O to Zn beams up to 1mA for gaseous beams, 2pµA for metallic beam
  - A/Q = 3 : No flexibility for the charge states.
  - ⇒ Need for a high-performance ion source
  - Run : 3 weeks to 2 month
  - ⇒ Long R&D to optimize beams for S^3 (new LTO/HTO, Double Frequencies, Isotope preparation,…)

Light ions



In operation since 2019

Heavy ions



LPSC GRENOBLE | MODANE 2013-2019

Technical parameters	
RF Frequency/power	18GHz/2kW
Axial Mirror	2.1-0.47-1.3T
Radial magnetic field	1.28T
Plasma volume	1.4 l (x2 Phoenix V2)
HV extraction	<60kV

Gas : $^{36\text{-}40}Ar$, ^{22}Ne, ^{18}O, ^{36}S
Intensity : Up to 10pµA

Metals : ^{58}Ni, $^{40\text{-}48}Ca$, $^{50\text{-}54}Cr$, ^{50}Ti, ^{50}V, ^{70}Zn, ^{30}Si
Intensity : Up to 2pµA

Energy : 4-7MeV/A
Run : 3 weeks-2 month

Installed in 2020, in commissioning

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ECR ion sources : technical aspects and upgrades for operation

Challenge for the futur :

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ECR Ions source : technical aspects

Beam intensity available in operation is related to

Design of ion source

- Frequency / Magnetic field
- Volume of plasma chamber
- Extraction voltage
- …

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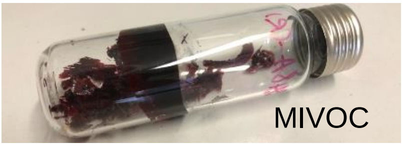
Technique used to inject neutral element



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Isotope purity

⇒ Cost / availability
⇒ Chemistry

^{48}Ca, ^{54}Cr, ^{36}S, …

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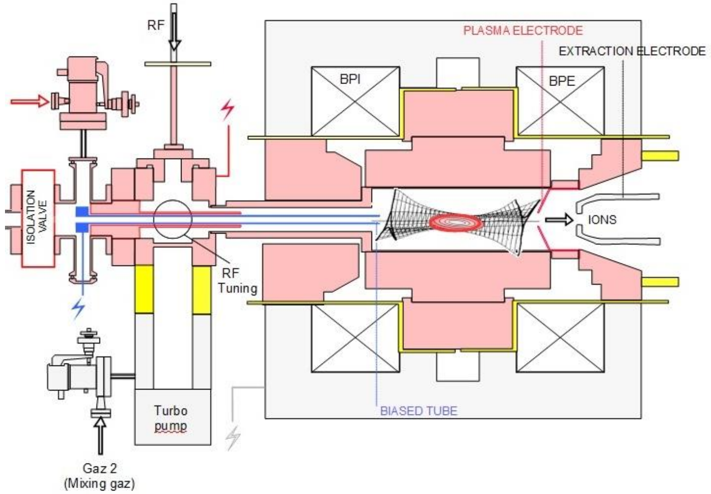
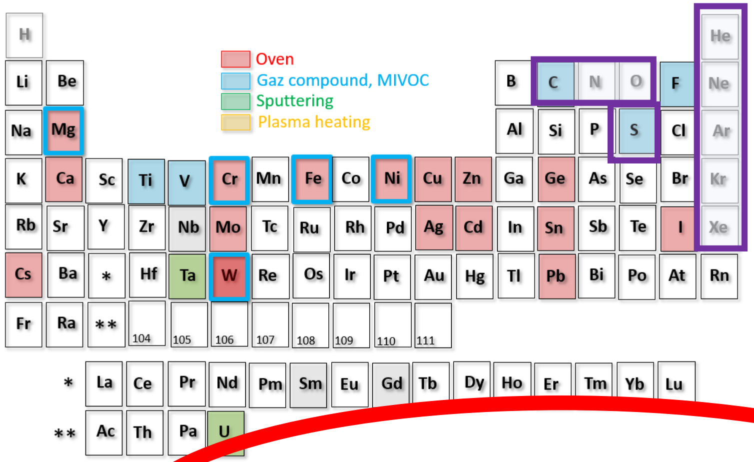
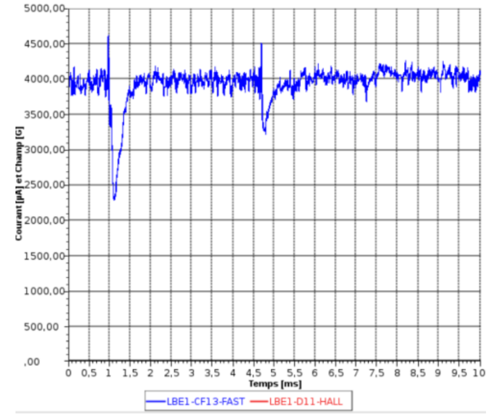


2.45/10/14,5/18 GHz



Stability



Reliability

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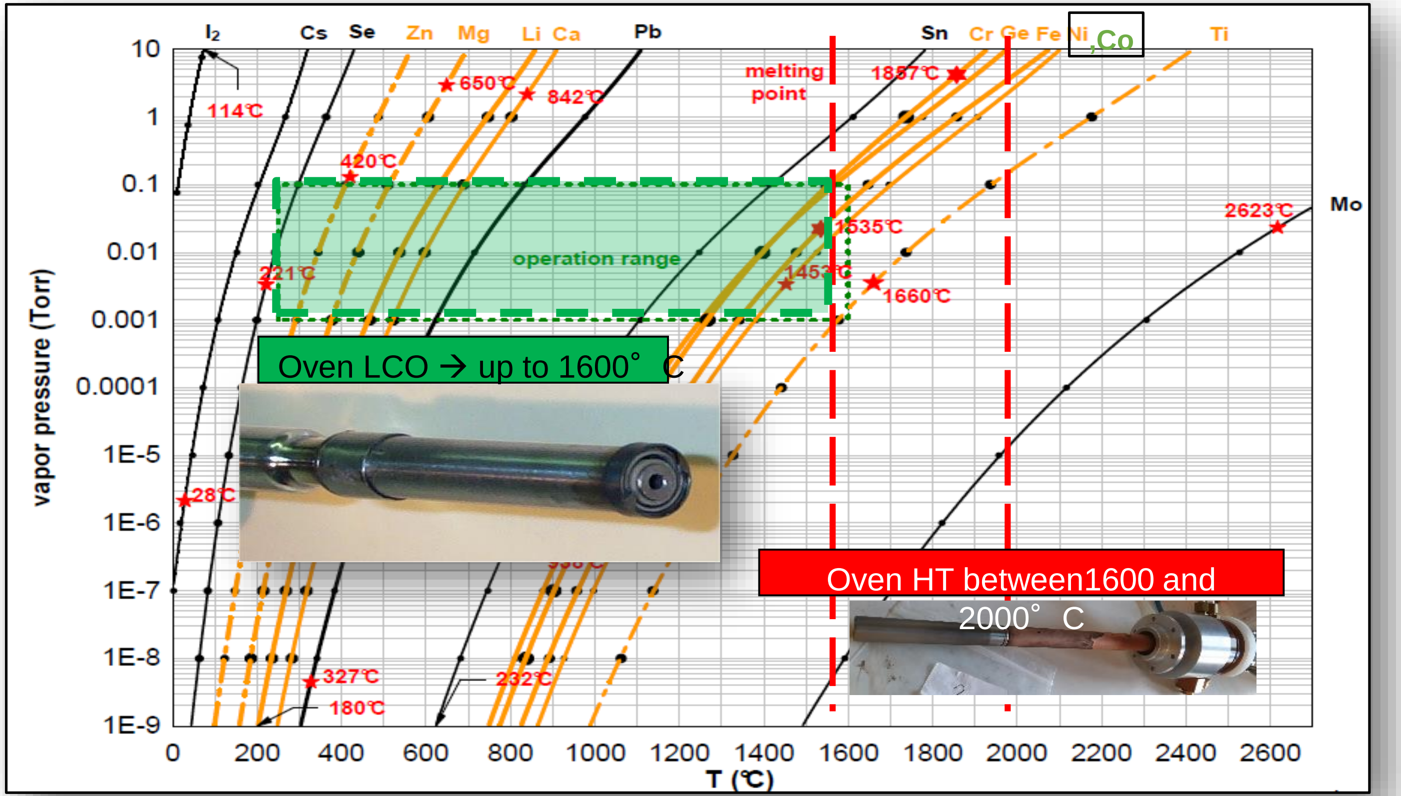
Technical of the ions beams production with ECR ion sources

❖Oven method

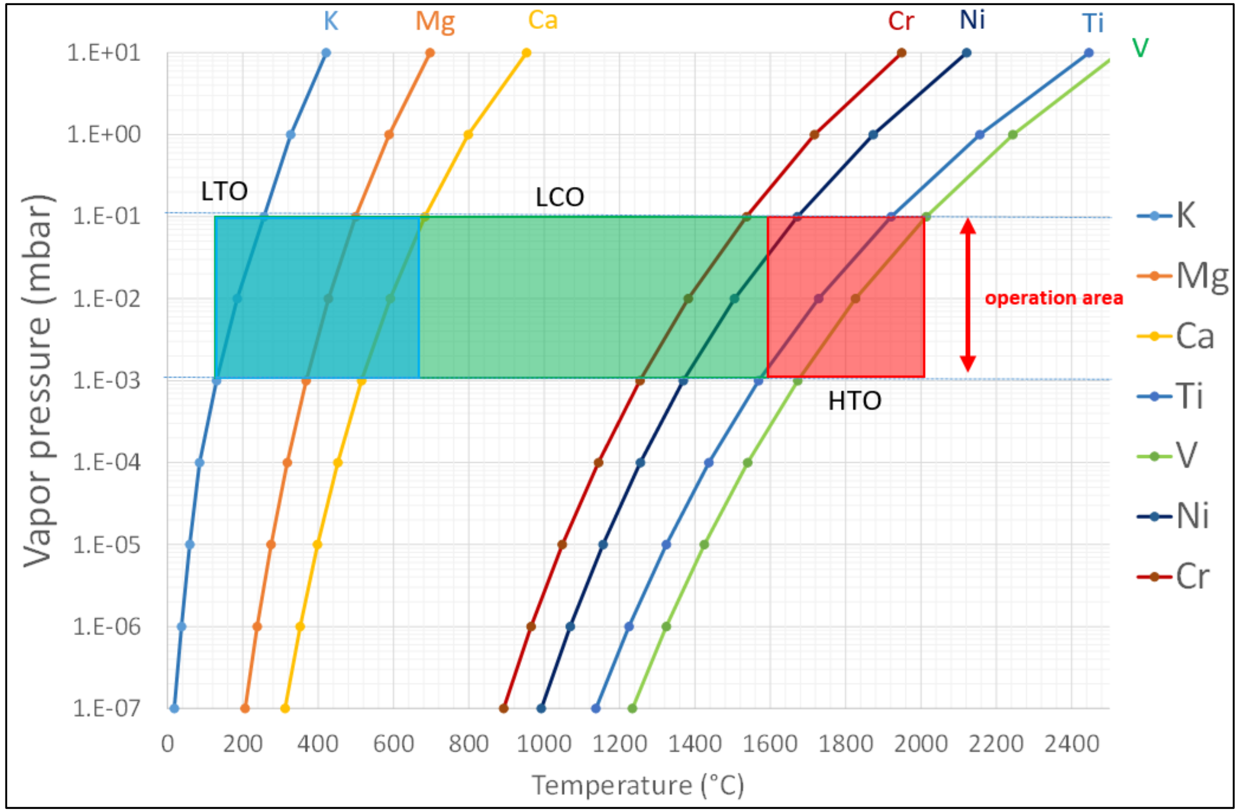


Advantages:

- A lot of isotopically enriched elements are evaporated by oven (oxyde and metallic form)
- High charges states can be optimized by the control of evaporation

Disadvantages:

- Start and tuning of beam for a long time (>6h)
- Difficulties to control the evaporation for T° <500° c with LCO
- Low ionization efficiency (<10%)
- Low capacity (stop the Run to replace the sample)



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Large Capacity Oven

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High Temperature Oven

IPHC Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

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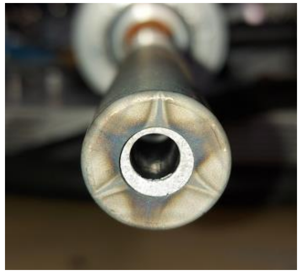
Low Temperature Oven

LPSC Grenoble



High temperature oven GANIL On-line in ECR4M –First beam of ^{238}U

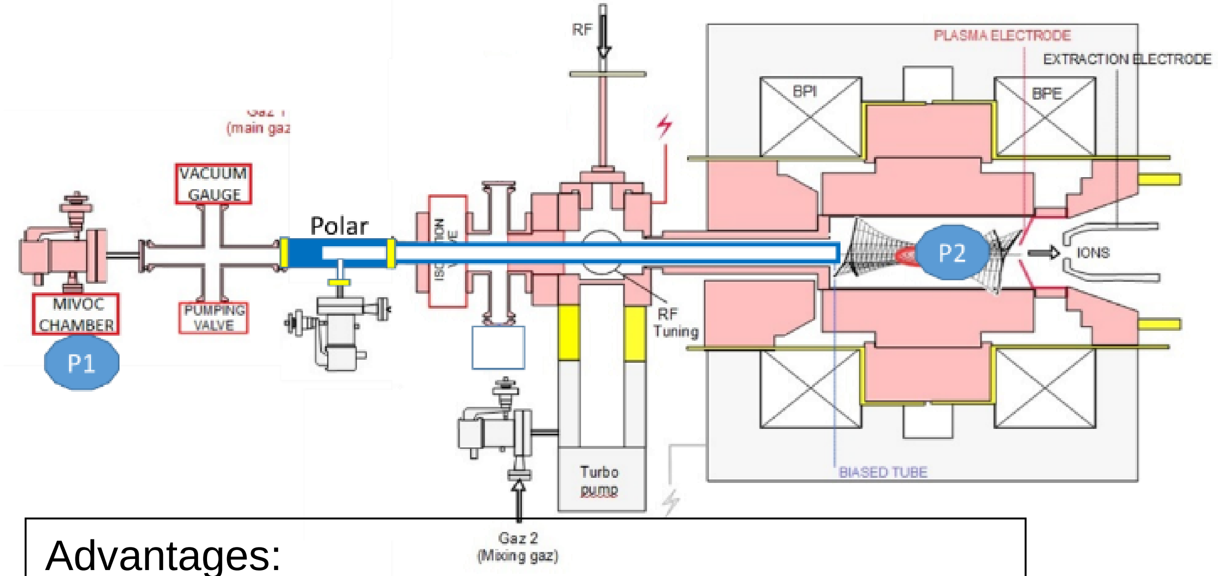
❖ MIVOC method

<u>Metallic beams with MIVOC at GANIL:</u>
Ni, Fe, Mg, Cr, Ti, Ru, Va…

For natural elements : Several Commercial compounds can be found.

R&D to obtain synthesis with the isotopically enriched element.
=> B.GALL’s team IPHC- Strasbourg

Several syntheses could be developped to replace the evaporation of element with high vapor pressure (difficulties of evaporation control with oven)



Advantages:

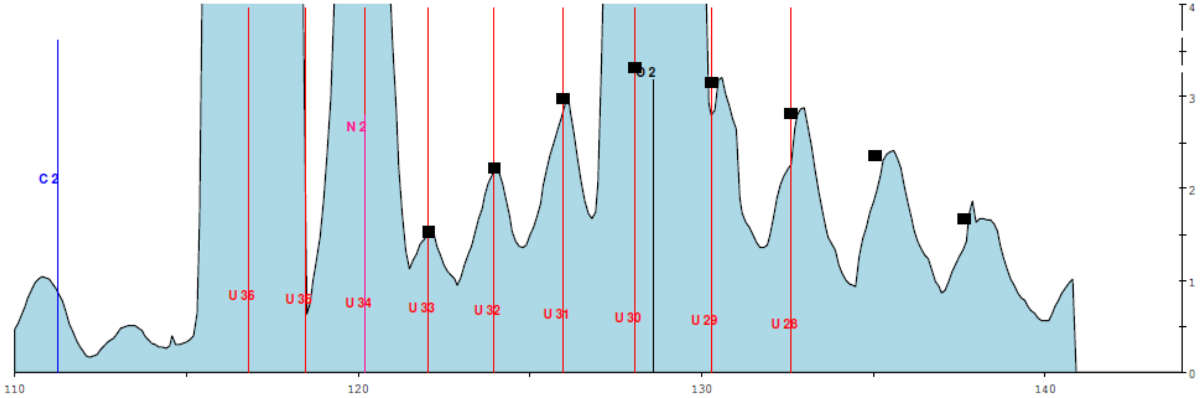
- Tuning is easy and good beam stability
- Level of intensity more important than oven
- No change of sample during the run

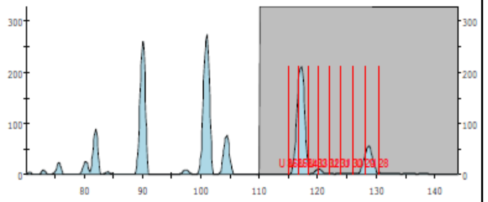
Disadvantages:

- No possible to optmize the high charge states
- Can’t used for A/Q=3
- ionization efficiency between 20%
- Need to develop syntheses

❖ Sputtering method

Metallic beams : ^{238}U, ^{181}Ta.





$^{238}U^{31+}$=3µA.e
Realized by ECR4M

Advantages:

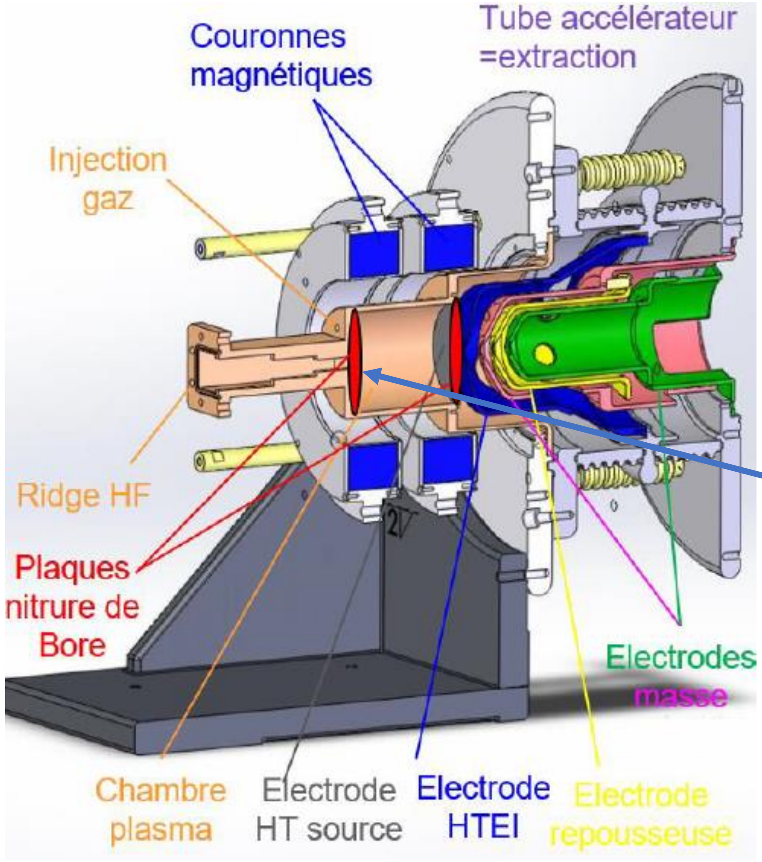
- ➢ Production of refractory elements
- ➢ Good stability of beam (<+/-5%)
- ➢ Optimisation of high charge states
- ➢ No change of sample during the run

Disadvantages:

- ➢ Low ionization efficiency (<8%)
- ➢ Low intensity (with ECR4/ECR4M)

Upgrade of Spiral2's ion sources for operation mode

❖ Ion source H^+/D^+

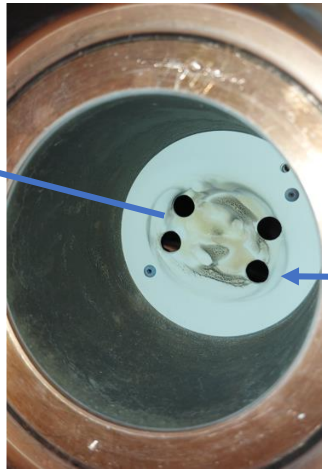


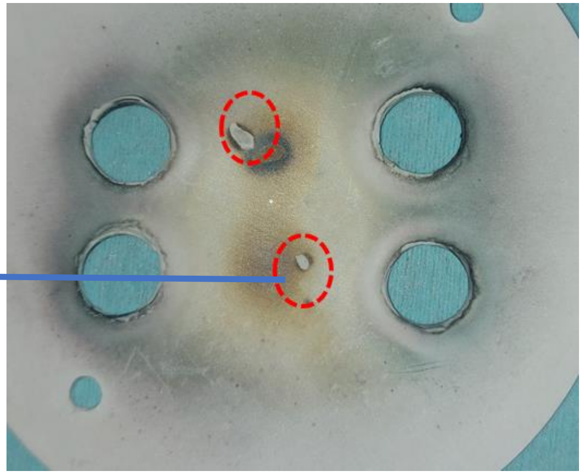
- Very stable ion source with the good intensity – stability

- But deterioration of boron nitride plates inside the plasma chamber

Need maintenance to change them after 500 hours for D^+ or 1000 hours for H^+

Need to increase the lifetime of plates to reduce maintenances and increase availability of the machine (represent around 10% downtime)





A collaboration with CEA/IRFU will start soon to fixe this issue

Upgrade of Spiral2’s ion sources for operation mode

❖ PHOENIX V3 : upgrade in collaboration with LPSC-Grenoble

Long term operation at 60kV require ion source upgrade :

⇒ New Injection

- Bias disc in aluminium : reduce pollution
- Cooled system and insulators protection
- Wave guide 8-18GHz to use double frequencies
- Ø25mm hole oven diameter for High Temperature Oven

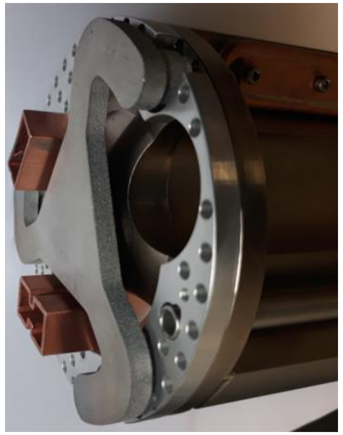
⇒ Upgrade of insulator system

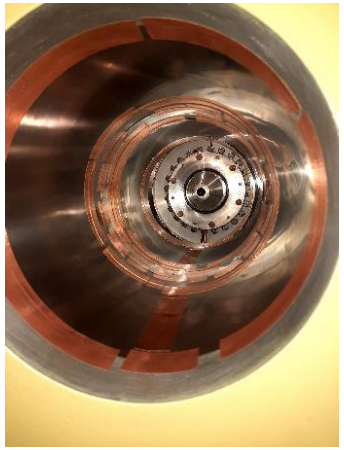
⇒ Adaptation of extraction system

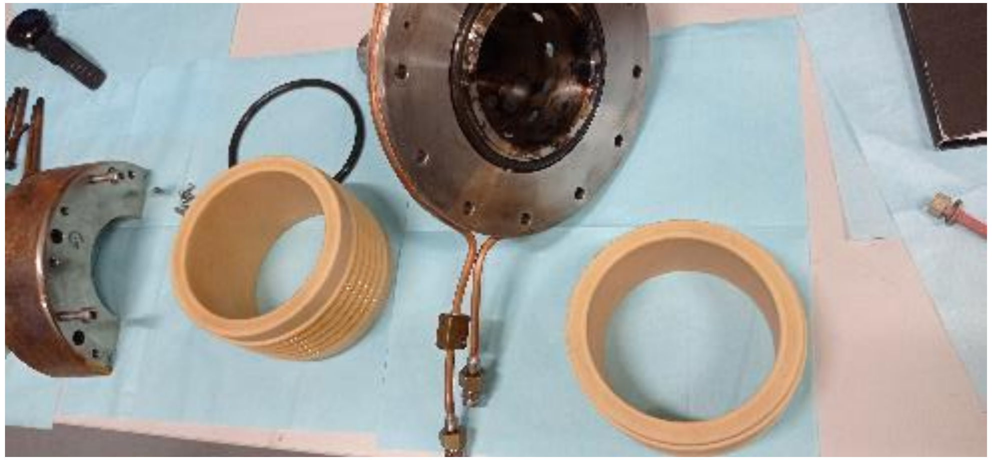
=> Major maintenance program for winter 2023 - 2024 -

- Hexapolar magnetic field checking
- New injection
- New insultors

1.5 full time equivalent in 2022







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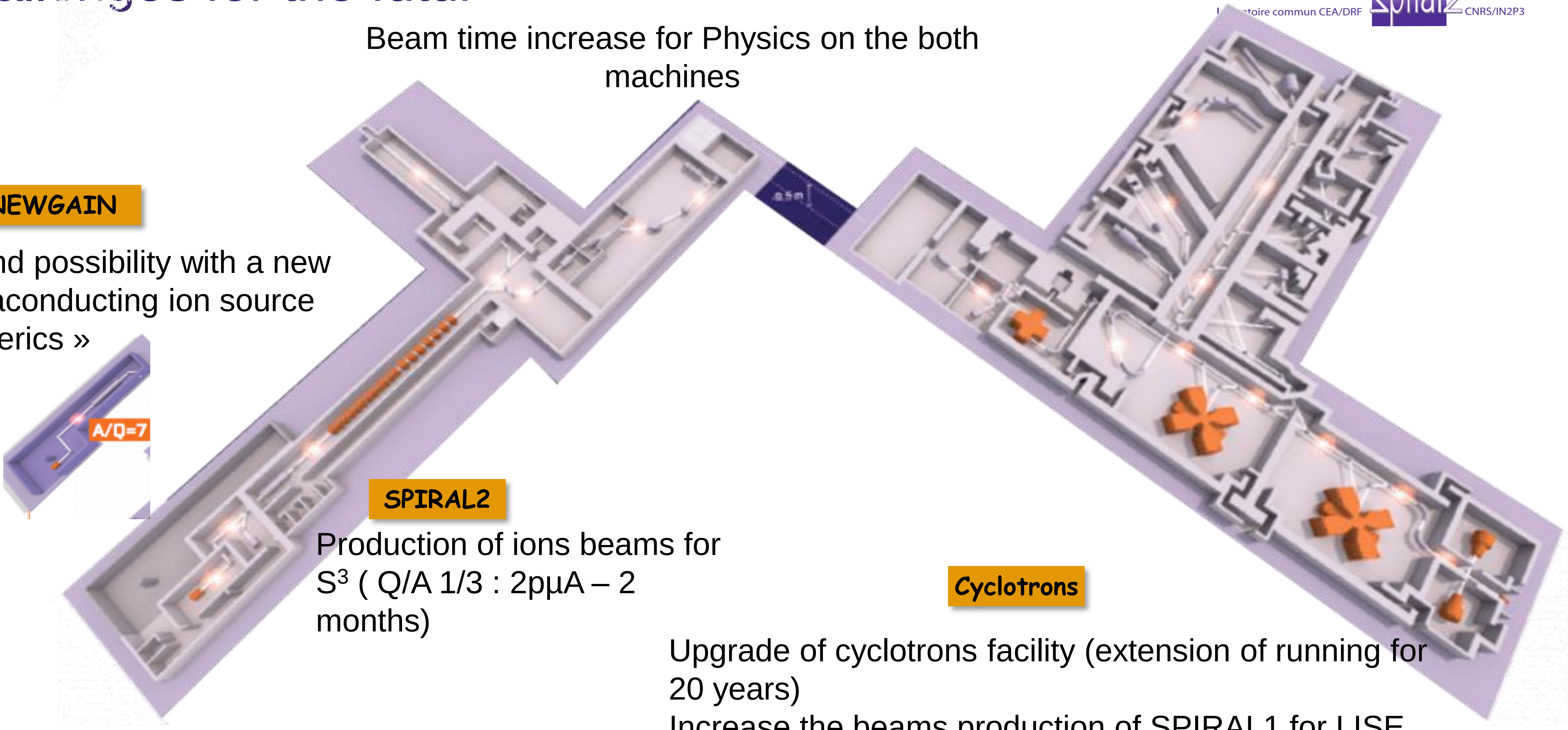
Challenges for the futur

Beam time increase for Physics on the both machines



NEWGAIN

Extend possibility with a new supraconducting ion source « Asterics »

SPIRAL2

Production of ions beams for S^3 (Q/A 1/3 : 2pμA – 2 months)

Cyclotrons

Upgrade of cyclotrons facility (extension of running for 20 years)
Increase the beams production of SPIRAL1 for LISE

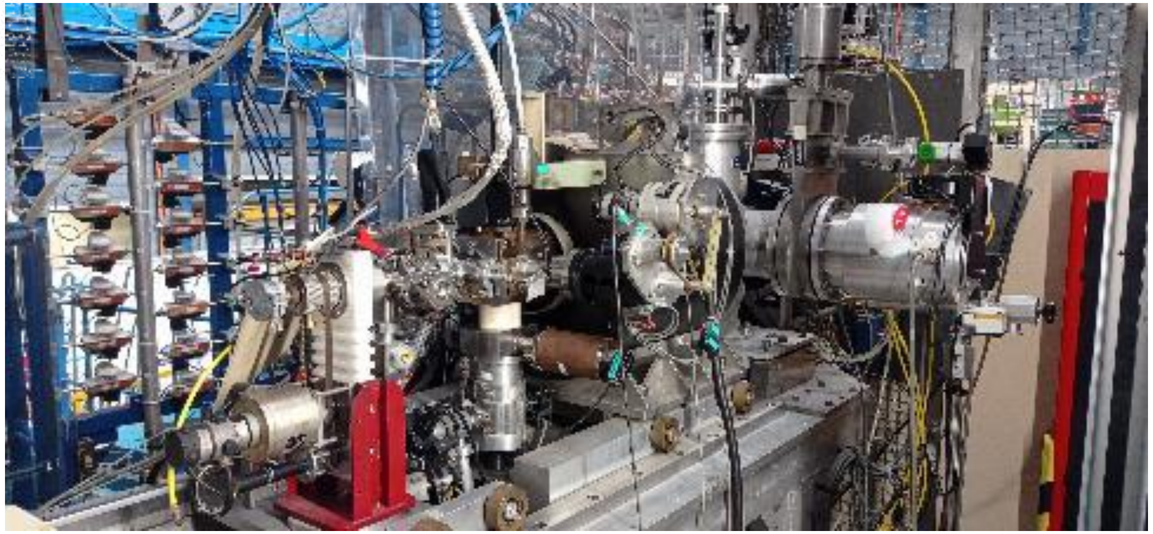
Cyclotrons – Challenges for the futur

ECR4/ECR4M ion sources :

❖ **R&D to optimize the beams:**
- Improve the stability
- New oven for the low temperatures
- News syntheses for MIVOC
- Increase efficiency with the metallic beam (hot screens)

❖ **Replace ECR4M by more perform ion source ?**

	ECR4	ECR4-M
Frequency	14.5GHz	
Power	<500W	
Type	Coaxial injection	
HV plateform	75kV + 25kV	25kV
Q/A	3 to 9	



Spiral2 – Challenges for the futur

S³ : High priority beams

Large Capacity Oven

Low Temperature Oven

Gas : $^{36-40}$Ar, ^{22}Ne, ^{18}O, ^{36}S
Intensity : Up to 10pµA

Metals : ^{58}Ni, $^{40-48}$Ca, $^{50-54}$Cr, ^{50}Ti, ^{50}V, ^{70}Zn, ^{30}Si
Intensity : Up to 2pµA

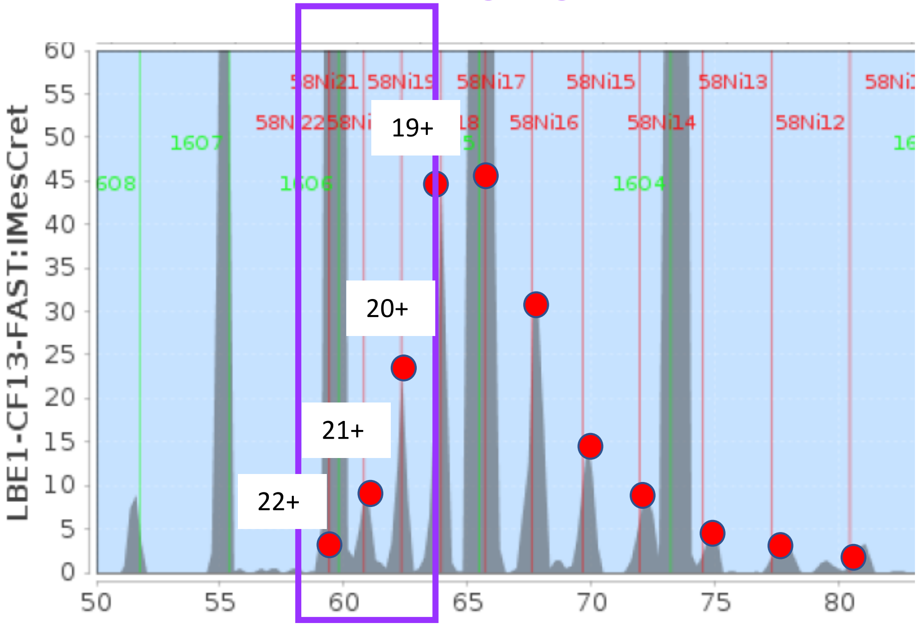
Energy : 4-7MeV/A
Run : 3 weeks-2 month

High Temperature Oven

Inductive

Resistive

A/Q<3 working region



Intensities decrease a lot in accordance with high charge states

Chose an high purity metal to optimize intensity

Z=28	^{58}Ni	^{60}Ni	^{61}Ni	^{62}Ni	^{64}Ni
Isotopic abundance	68%	26%	1%	3.6%	0.9%
€/mg for 99% isotope purity	1.87			11.6	65
30days@1mg/h	1346€			8352€	46800€

A strategy have to be defined for the supply, the stock, the chemistry, the budget request for using theses isotopes

SPIRAL2 : NEWGAIN

NEW GANIL INJECTOR

GANIL spiral2 laboratoire commun CEA/DRF CNRS/IN2P3

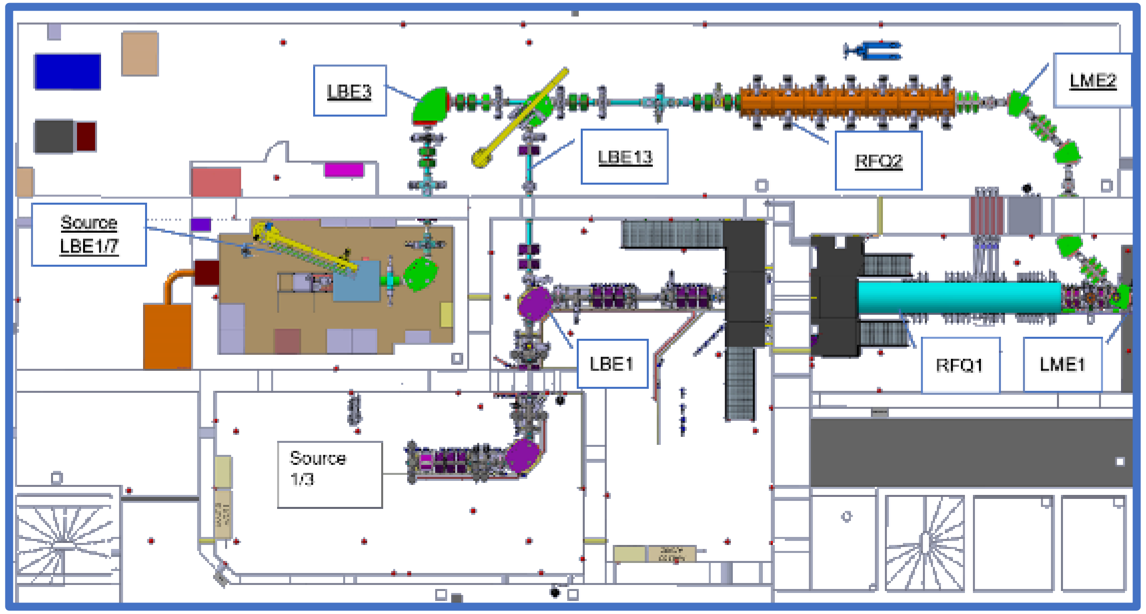
Design and build a second injector at SPIRAL2 with A/Q=7

Budget obtained by ANR/France in 2021

Planning : 2021-2030

Element	A/q	Operational Beam Current (µA)	Particle Current (pµA)	1 σ RMS normalized (π.mm.mrad)
$^{48}Ca^{11+}$	4.36	150	15	0.25
$^{238}U^{34+}$	7	170	5	0.10

Beams of reference for ions source and plateform design

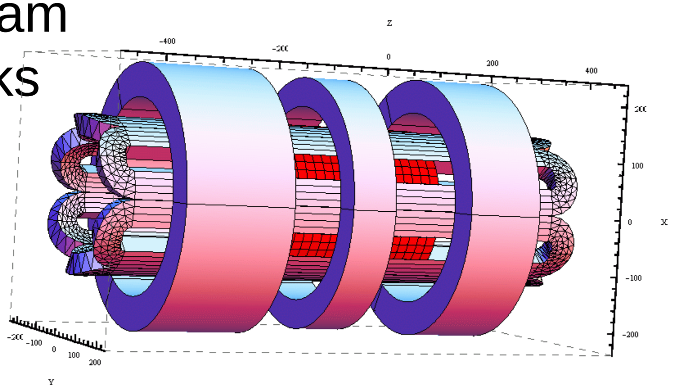


LPSC Grenoble Laboratoire de Physique Subatomique et de Cosmologie

cea cnrs

GANIL spiral2 laboratoire commun CEA/DRF CNRS/IN2P3

- New technology (supraconductor) : Formation for GCS's team
- Product the ions beams in continuous during severals weeks
- No manpower in GCS 's team to participate in this R&D



Conclusion:

laboratoire commun CEA/DRF CNRS/IN2P3

- ❑ Cyclotrons facility:
- Large variety of beams
  - → Requires to use all techniques availables
  - → Requires R&D specific to optimize all parameters
- Short experiments
  - → Involves more tuning and Manpower

- ❑ Spiral2 facility:
- Upgrades for operation of ion sources
  - → Reduce breakdowns and maintenance
  - → R&D specific to optimize the beam stability
- Long experiments
  - → Increase the capacity of ovens's samples
  - → Increase the efficiency ionisation

- ❑ Challenges for the futur:
- cyclotrons
  - → R&D to reduce the re-tuning time (stability , new oven for the low temperature.....)
  - → New ion source?
- Spiral2
  - → Beams for S^3
  - → Supply of all enriched isotopes
  - → Commissioning of the new supraconducting ion source

Thank you for your attention