# WORKSHOP TARGETS – ION SOURCES

# ION SOURCE DEVELOPMENTS AT LPSC

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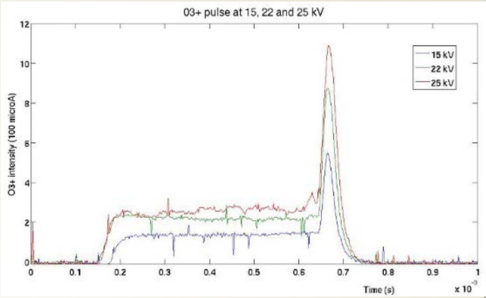
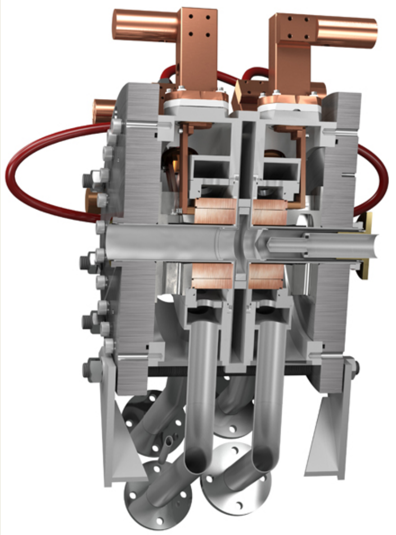
# Overview of LPSC ECRIS Team Activities

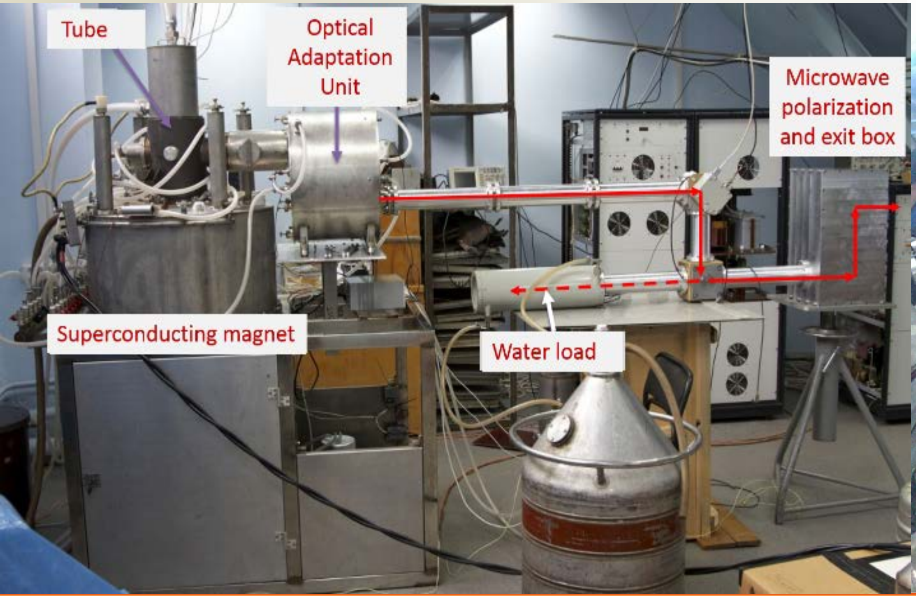
- Support national efforts to design, build and test ECR ion source with GANIL
  - Contribution to the NEWGAIN project and the ASTERICS ion source
- Support the GANIL SPIRAL1 and SPES Booster operation and developments
  - Investigations on contaminant reduction
  - Joint experiments
- Upgrade the PHOENIX-CB to a new version with a larger plasma chamber
  - Source modernization and minimization of RIB contamination
- Perform upstream research for future generation accelerators
  - 60 GHz source, PACIFICS Project
- Investigate ECR plasma physics
  - Use the 1+N+ test bench as a tool to investigate the ECR plasma
  - Train PhDs (last joint thesis with : GANIL, JYU (Finland) and LPGP (Paris-Saclay))

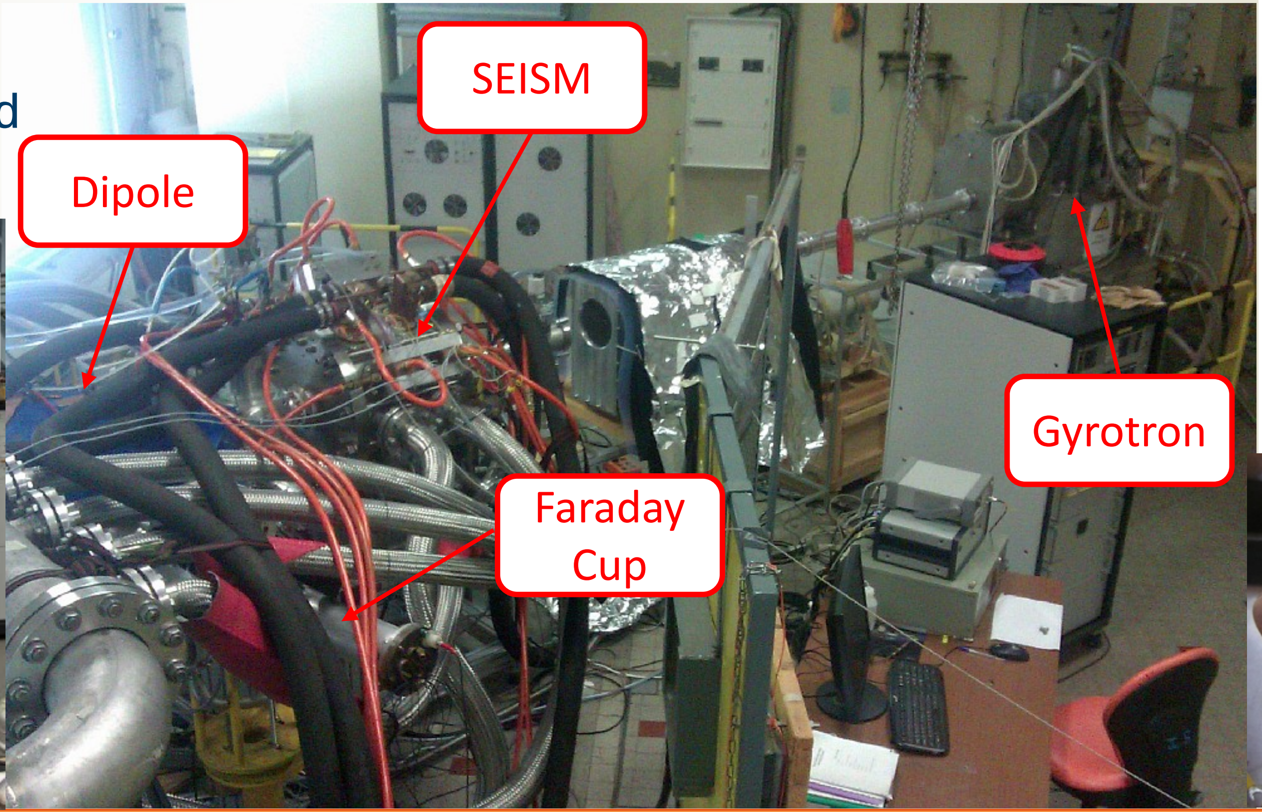
# Historical 60 GHz Project – SEISM ECRIS

- 2007-2014 : collaboration LPSC-LNCMI-IAP RAS (Nizhny Nov.)
  - A Cusp magnetic field source with a rough LEBT at LNCMI
  - 300 kW/1 ms/2 Hz 60 GHz Gyrotron
  - Messy experiment (30000 A cables are big and rigid)
- 900 mA/cm$^2$ beam measured (factor of 10 wrt. state of the art!)
- Afterglow peaks measured
- 2 coils damaged then exp. stopped





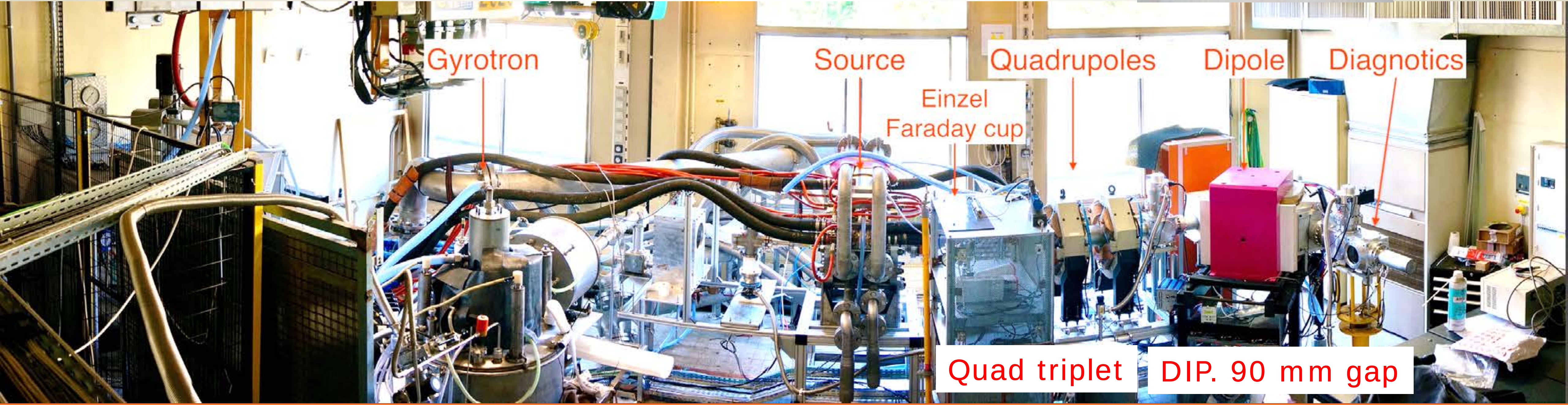



# 60 GHz Project – SEISM 2019-2024

- Project re-activated since 2019, Hiring of a Post-Doc (T. André)
- End of collaboration with IAP-RAS (Russia) since 2022 (War in Ukraine)
- Plan:
  - Fix the damaged coils, build new plasma chamber
  - Upgrade the beam transport line and the beam transport efficiency
  - Try to reproduce the former experimental results
  - Measure beam emittance

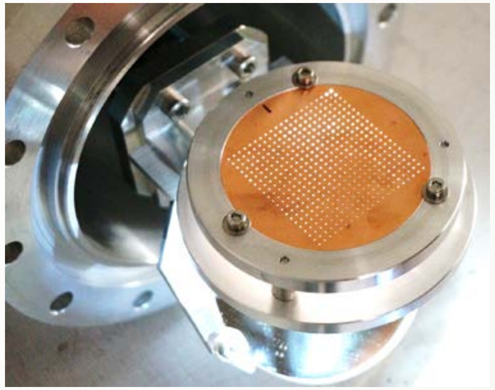
Additive Plasma chamber fabrication

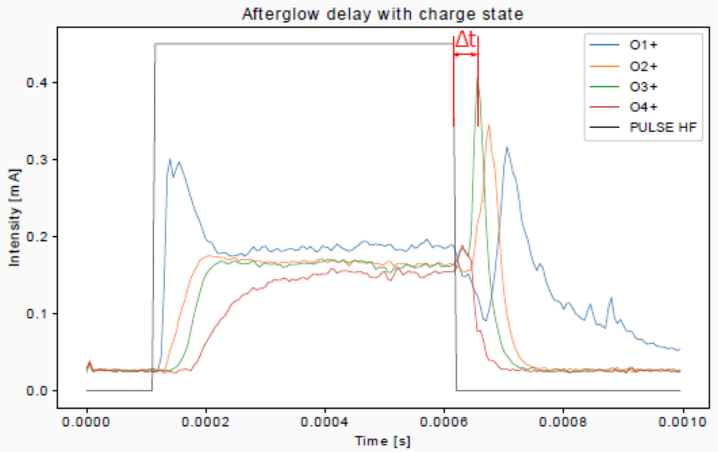
Cold spray Raw coil

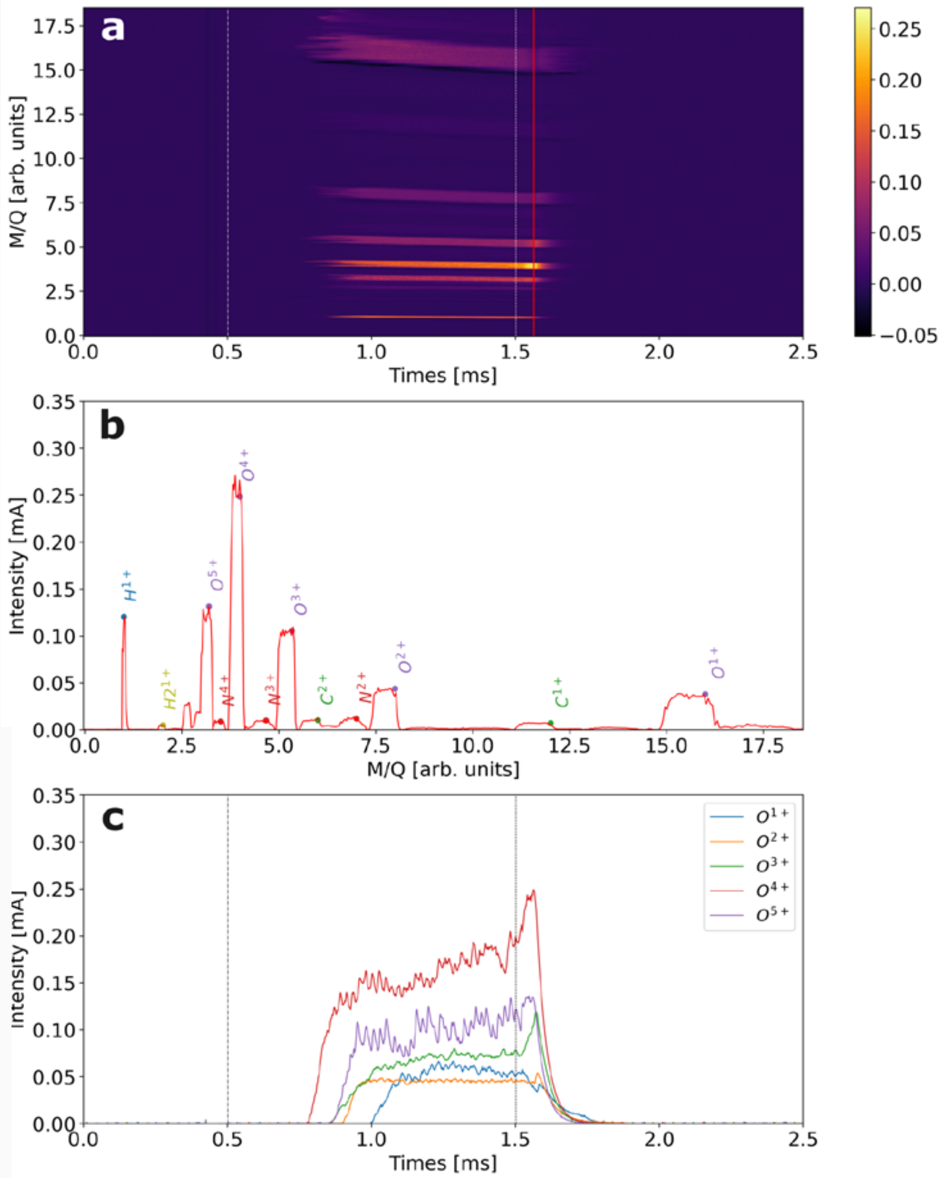


# SEISM Preliminary results as of 2023

- Many Experimental Difficulties
  - Several coils failure or bad machining, which required 3 reparations in total.
  - LNCMI is an ESRFI and time of operation is limited to a few hours / day for <6 weeks/year
- Beam Transmission improved to 65 % (a few % before)
- Current density up to 200 mA/cm2 (below expectation, under investigation)
- Observation of a weird asynchronous afterglow peak, function of the charge state
- Emittance yet to measure
- A new coil is being machined and last fruitful experiments hoped in 2024

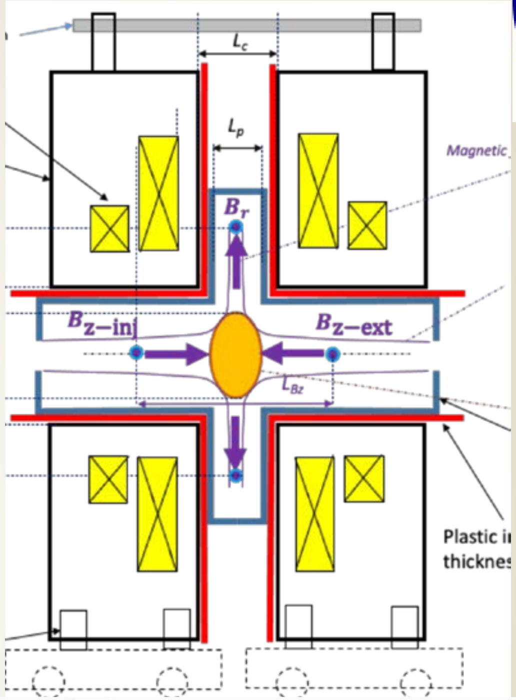


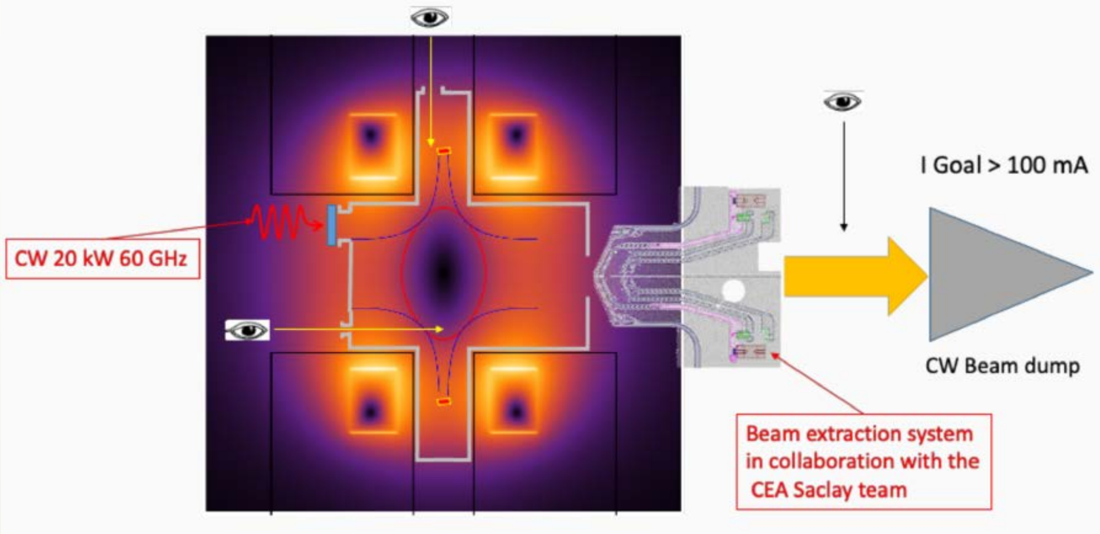


# 60 GHz Prospects with PACIFICS

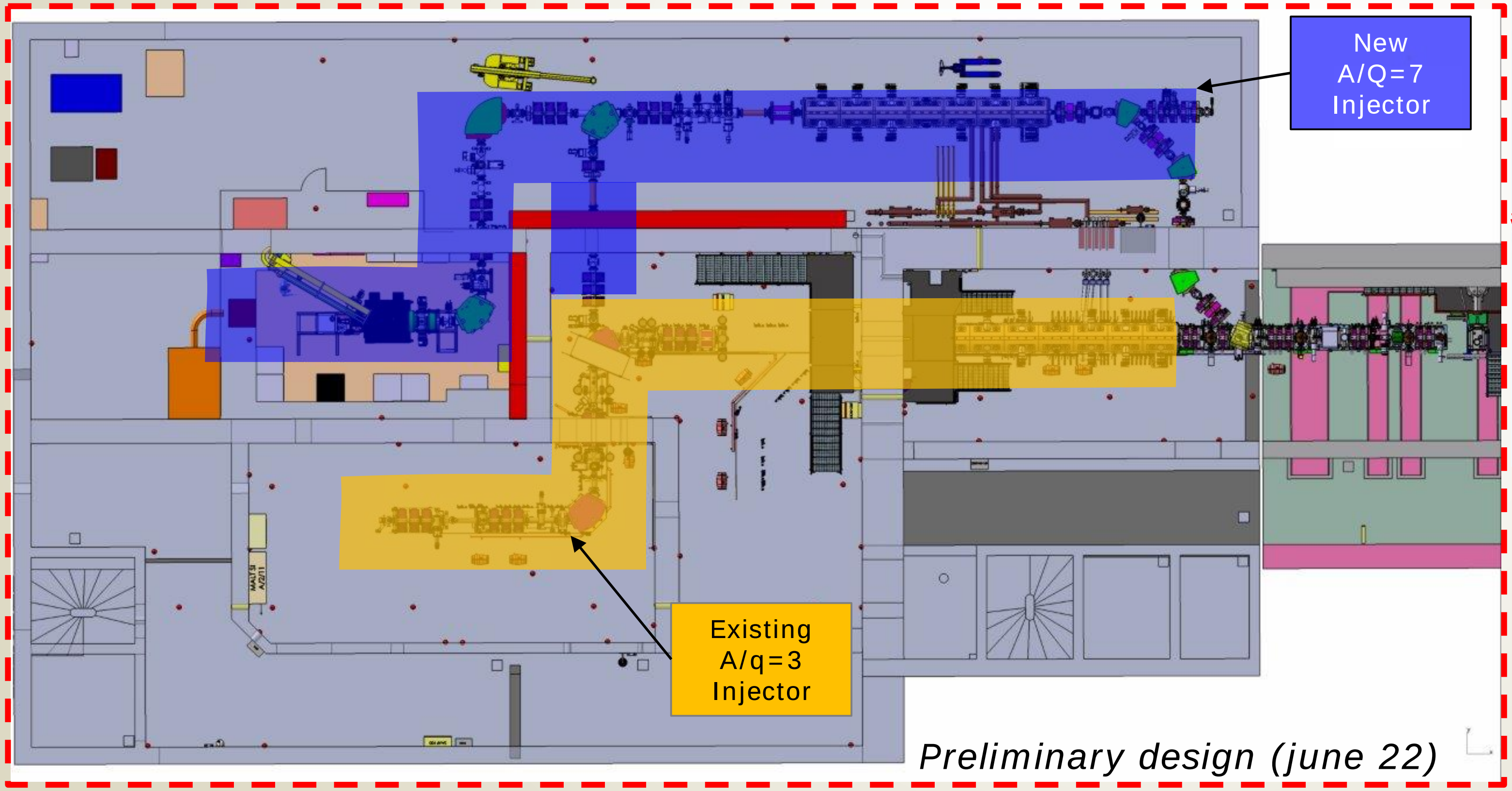
- Project Funded by the French ANR, under contract #21-ESRE-0049 EQUIPEX+PACIFICS
  - 700k€ for the 60GHz program
  - 2022-2028
- Procurement of a superconducting magnet to generate the CUSP field
  - Call for tender published, about to be settled with Scientific Magnetics LTD (UK)
  - Large(r) plasma with view ports. ∅ 200 mm L~250 mm. Bz=3.5 T Br=4 T
- Gyrotron upgrade from pulsed to 20 kW CW
- Relocation of the source at LPSC
- Construction of a new extraction system able to manage 100 mA of ion beam
- Amazing research coming!



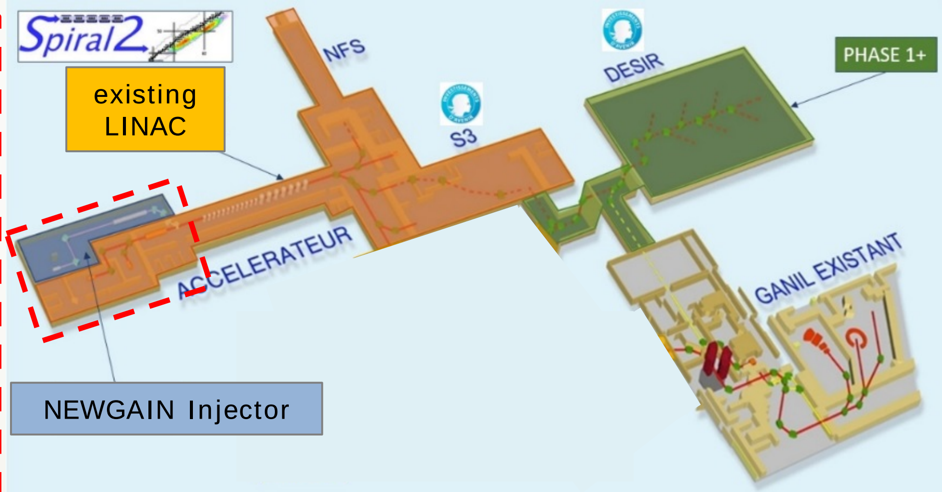



# ASTERICS ION SOURCE

- NEWGAIN Injector (A/Q=7) Funded by ANR contract # 21-ESRE-0018 EQUIPEX+
- LPSC involved in the national effort to design and build a 28 GHz Superconducting ECRIS
- The team manages 2 WP:
  - HV platform and Ions source (TT)
  - Project System management (CP)




*Preliminary design (june 22)*




NEWGAIN
NEW GANIL INJECTOR

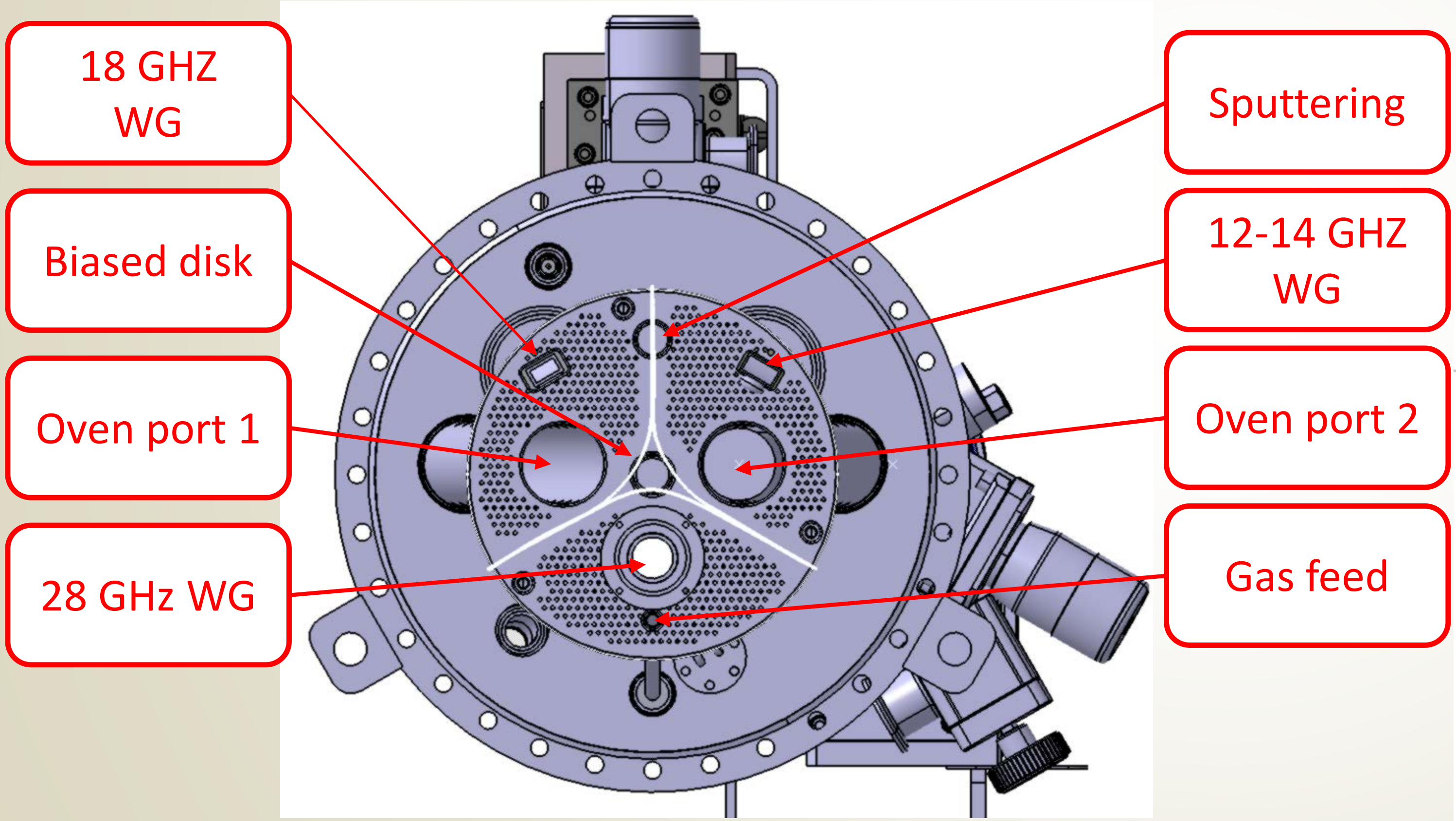
# Collaborative effort to design and build the ASTERICS ECRIS and its HV platform

- Produce high metallic ion beam intensity on target (10 pμA)
- Up to the uranium ($U^{34+}$)
- Requires a 28 GHz ion source
  - produce 10 pμA $U^{34+}$ on a single charge state is challenging
- Choice to use the VENUS RFIB design as a starting point (bladder & keys, see D. Simon talk) and amend it to a larger volume plasma chamber to boost the beam intensities

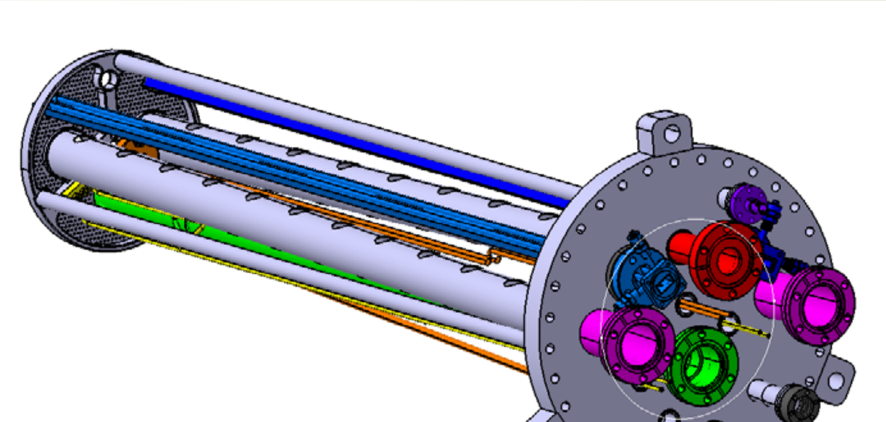
| element | intensity (p$\mu$A) | intensity ($\mu$A) | ion | $\epsilon^*_{1\sigma RMS}$ |
|---|---|---|---|---|
| calcium | 13 | 143 | $Ca^{11+}$ | $\leq 0.2$ |
| chromium | 13 | 143 | $Cr^{11+}$ | $\leq 0.2$ |
| titanum | 13 | 143 | $Ti^{11+}$ | $\leq 0.2$ |
| nickel | 13 | 130 | $Ni^{10+}$ | $\leq 0.2$ |
| zinc | 13 | 156 | $Zn^{12+}$ | $\leq 0.2$ |
| xenon | 13 | 336 | $Xe^{28+}$ | $\leq 0.15$ |
| bismuth | 12 | 360 | $Bi^{30+}$ | $\leq 0.15$ |
| uranium | 6-10 | 204-350 | $U^{34+}$ | $\leq 0.15$ |

# ASTERICS hardware under design

- Plasma chamber dimensions: L600xR91 mm (VENUS ~L500xR71)
- ECR plasma volume V~1.9 l (VENUX ~1.2 l)




*Injection assy*



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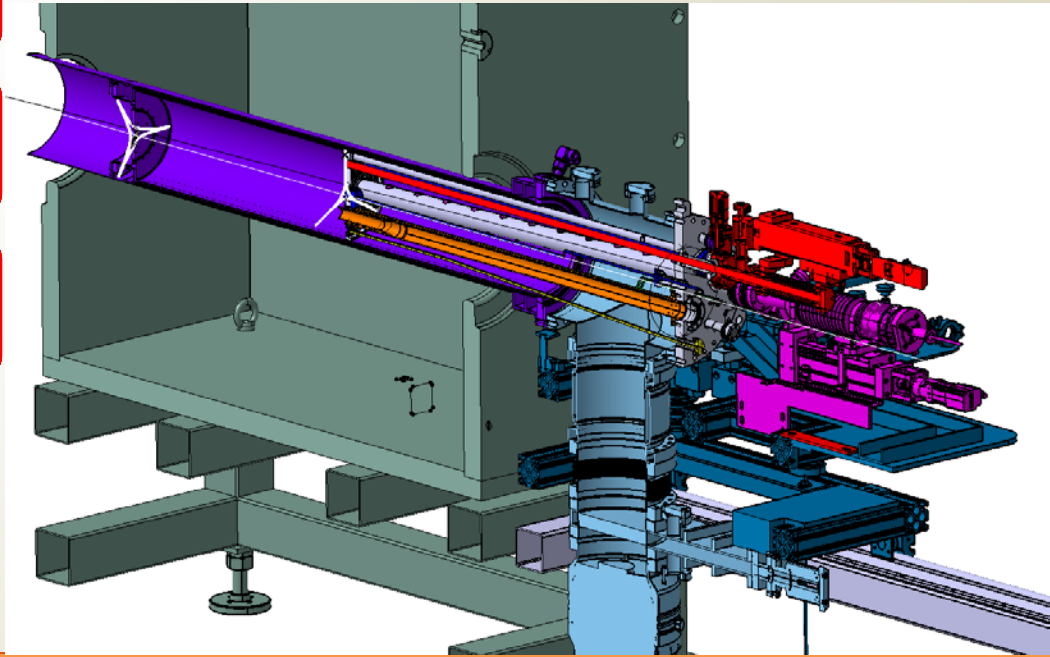
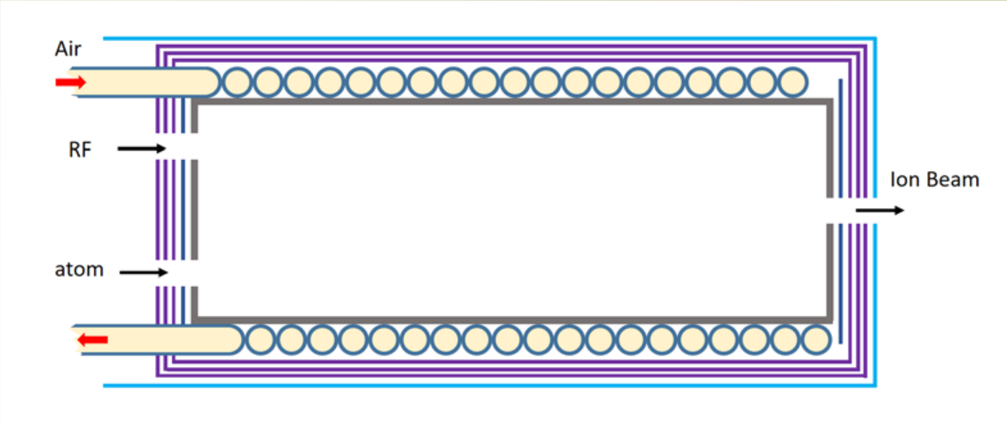
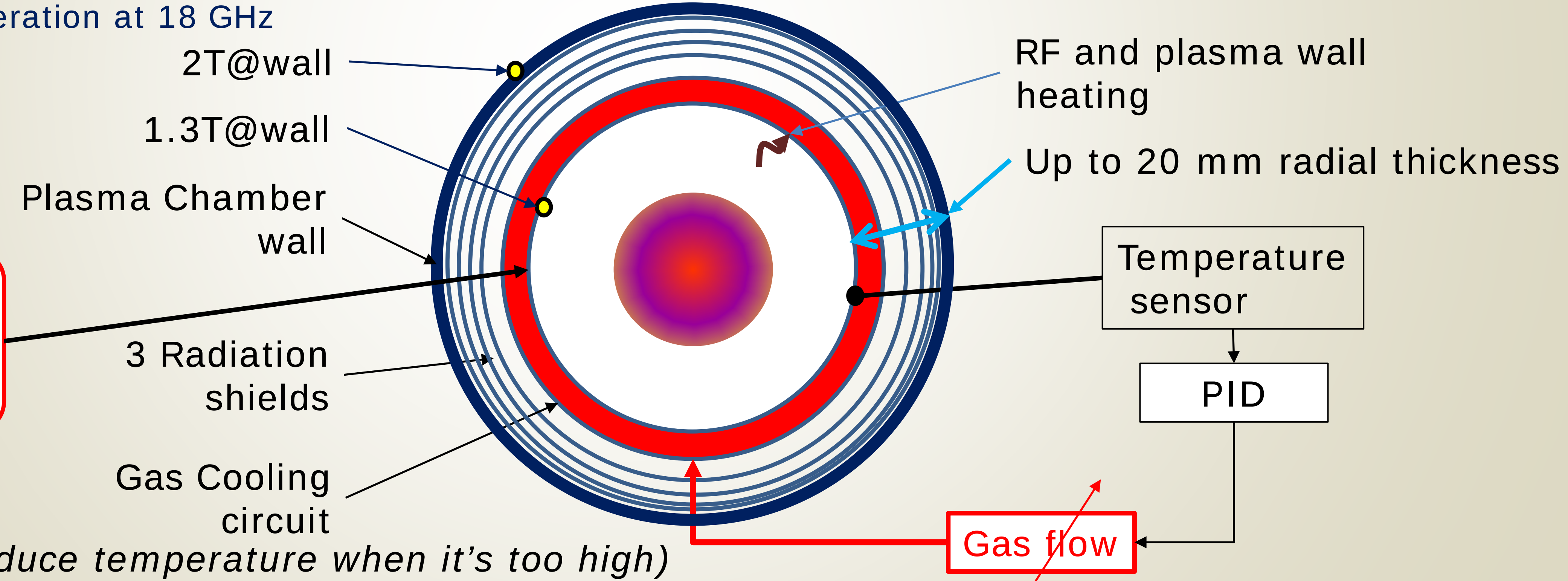


CNRS IN2P3 Les deux infinis

# ASTERICS Metallic beam production

- Requires large high temperature metallic ovens
  - See Benoit Gall presentation
- R&D planned on new generation thick thermo-regulated liners
  - Able to cool down the hot liner with a tunable air flow
  - Range of operation 350°C-800°C
  - Source Operation at 18 GHz

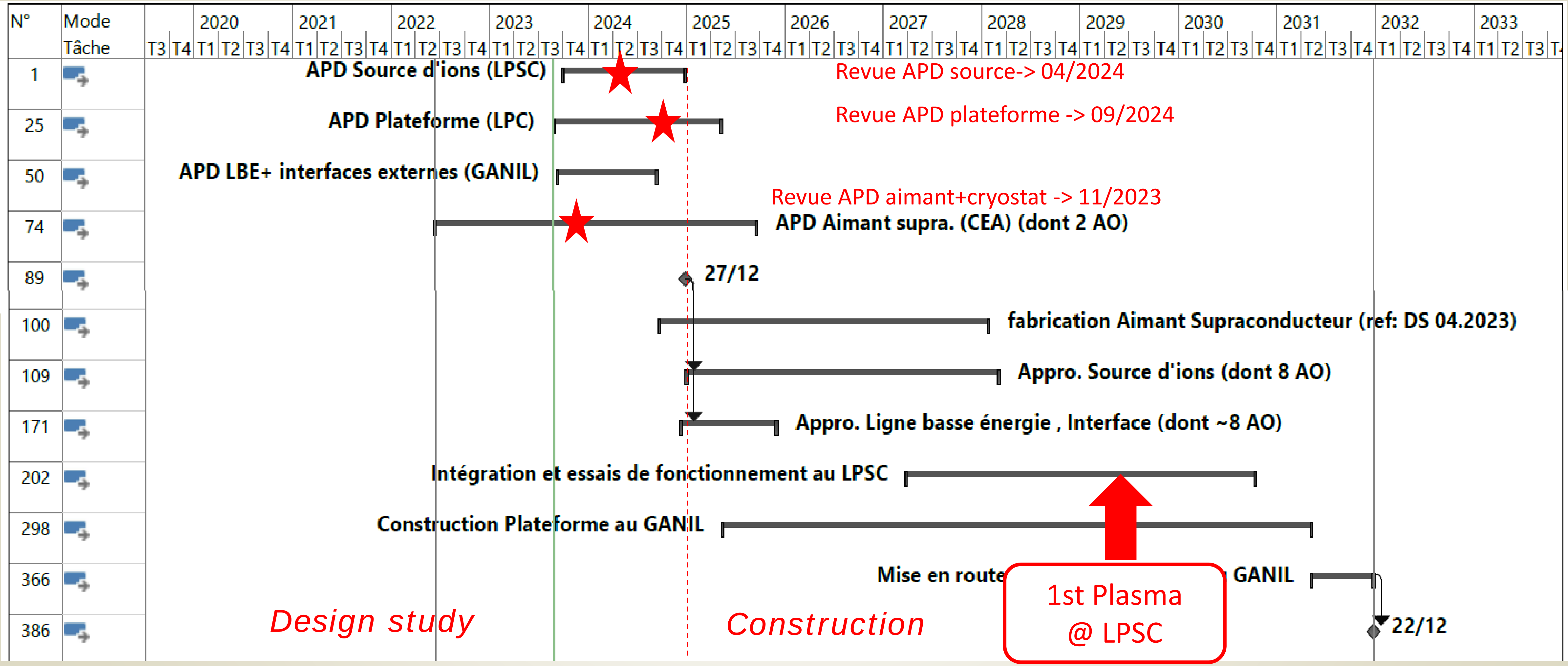



Source radius
With the liner is
71 mm
(like VENUS)

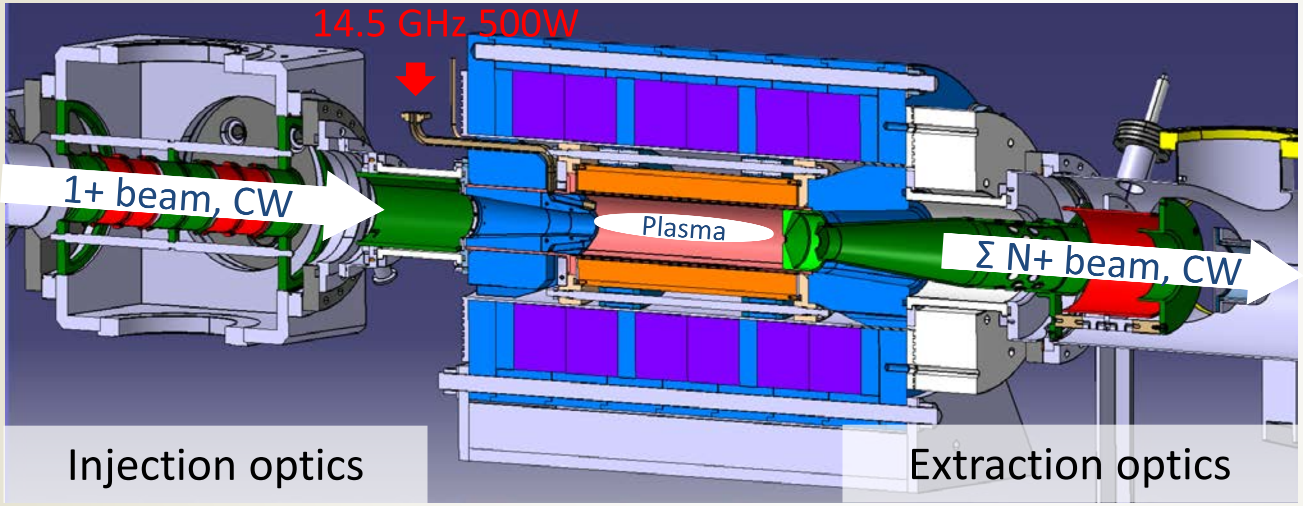
*(To reduce temperature when it's too high)*

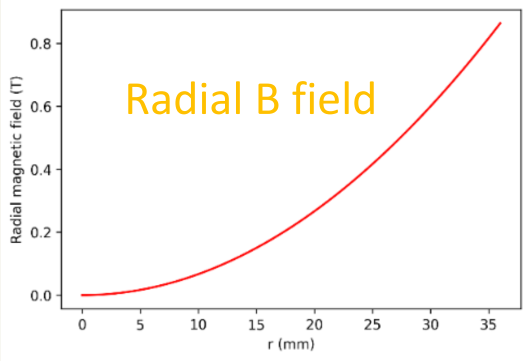
# ASTERICS Timeline

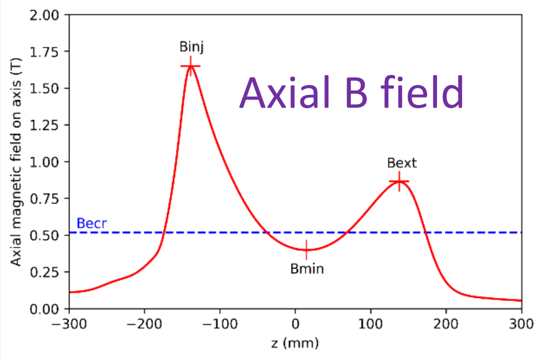


# ECR Charge Breeding activity at LPSC

- LPSC historical inventor of the ECRIS CB technique (R. Geller)
- Development of the PHOENIX CB since 2000
- 4 boosters used : SPIRAL1, SPES, TRIUMF, LPSC




- Ion Capture process based on the slowing down by electrostatic potential and Coulomb collisions with the plasma ions (studies under progress)
- Performances characterized by efficiency (10-20%) A/q 3-5, CB time (10-30 ms/q), and contamination ratio

# RIB Contamination with ECRIS

**Wall sputtering**
$\sim 10^9 - 10^{10}\ pps$ whole ion spectrum
$\sim 10^4\ pps$ within $\frac{M}{\Delta M} \sim 400$
$\sim 10^2\ pps$ within $\frac{M}{\Delta M} \sim 5000$

**Buffer gas**
$\sim 10^{16}\ pps$

**Gases contaminants**
$\sim 10^9 - 10^{13}\ pps\ whole\ spectrum$
$\sim 10^4\ pps$ within $\frac{M}{\Delta M} \sim 400$
$\sim 10^2\ pps$ within $\frac{M}{\Delta M} \sim 4000$

**1+ signal**
*up to* $10^{13}\ pps$

14 GHz ECR

contaminants

Itotal~1 mA
($\sim 10^{15} - 10^{16}$ pps)

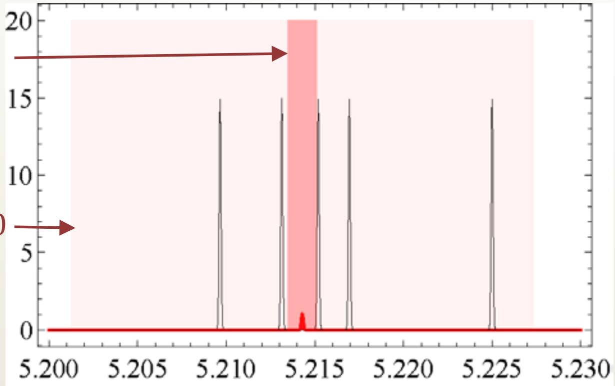
N+ signal

**SIGNAL TO NOISE RATIO IS CRITICAL**

**DOWNSTREAM MASS SEPARATION IS CRITICAL:**

$\frac{M}{\Delta M} \sim 6000$

$\frac{M}{\Delta M} \sim 300$




Key parameters :

- RI production yield and CB efficiency
- Downstream MS resolution

# Joint R&D to mitigate the RIB contamination

- Work done in collaboration with GANIL, LNL (res. collab. agreement), with fruitful discussions with ANL
- Task 1: Improve the low beams intensity measurements to better identify contaminants and measure the production rates
  - Enhancement of the spectrometer resolution
  - Enhancement of the beam intensity dynamics (command control, slits, detector with channeltron,etc)
  - Development of an isotope identification computer code
- Task 2: Decrease the contamination
  - Perform comparative measurements using different liners made of high purity material (Nb, Ta, graphite) or with high purity coating ( $Al_2O_3$ as prev. proposed by ANL)
  - Empirically search for contaminant emitting surfaces, develop cleaning technics
- As a first result: Large amount of species identified (Pb, Zn, Hg, I, Br, Cl, F..) and emitting surface neutralized (e.g. injection plug cone)

# ECR Charge Breeding : performances improvement

- Research project included in the « Radioactive Ions » IN2P3 master project, in collab. with GANIL
- At LPSC : development plan in 3 steps to improve the PHOENIX Booster performances
  - Improve plasma confinement ➔ Modified 6 coils configuration
    - Reinforcement of the injection axial B field with additional injection plug
    - 2017 ➔ 2022
    - Efficiency for metal ions : 3 – 11 % ➔ 10 -20 % , similar CB time

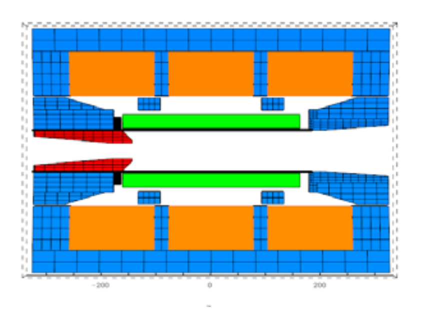
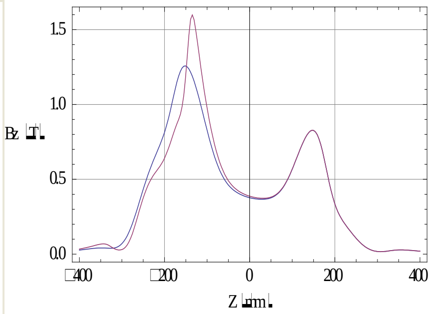
**DONE**

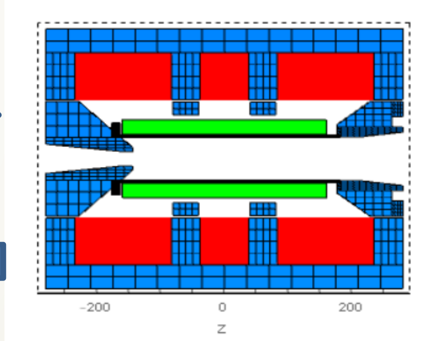
  - Ease the tuning, stabilize the plasma ➔ 5 coils configuration
    - Improve the magnetic profile, decrease the crosstalk between the coils
    - Assembled at the end 2022 ➔ End 2023
    - Characterization of the source under progress

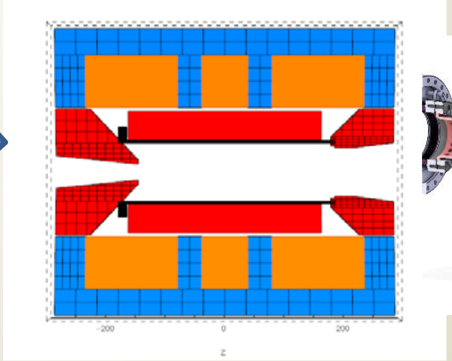
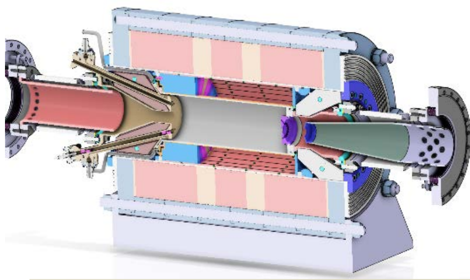
**ONGOING**

  - Increase the high charge state production & decrease the density of contaminants ➔ Large diameter configuration
    - Plasma chamber diameter increased from 72 to 100mm
    - UHV sealing
    - 2 frequency heating, 18 GHz operation
    - Design finished, parts being manufactured

**TO BE DONE IN 2024**
**Next applicable to facilities**

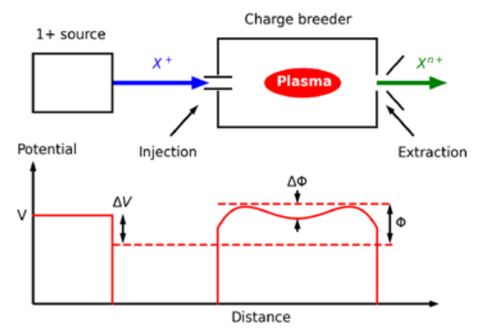



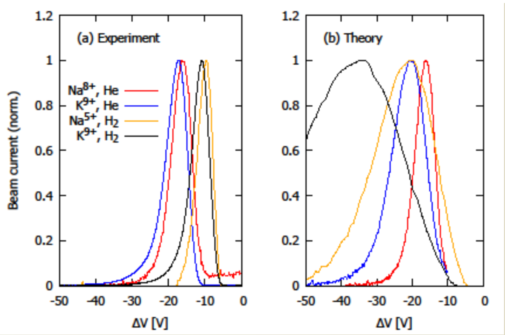


# ECR Charge Breeding : Plasma studies

- The ECRIS Charge breeder is a gold mine to investigate the ECR plasma
- The injection of ions in the booster and its interaction with the plasma allows to probe the ECR plasma behaviour and measure many physics parameters



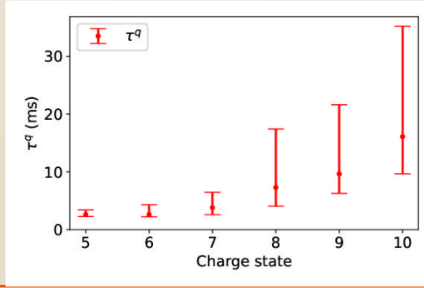




## 1) Investigation of 1+ beam capture dynamics (LPSC, GANIL, RAL, JYFL)

- Upstream Injection of K+ and Na+ in H2 and He plasma
- Measure of N+ beams energy spread downstream with a Ret. Field Analyser
  - Low contribution of mass ratio
  - Slowing down mainly due to electrostatic forces (Φ), then ionization to 2+ and thermalization by Coulomb interaction or trapping in potential dip ΔΦ

## 2) Indirect measurements (of *Te*,*ne*) by studying the transient N+ pulse temporal responses to an input pulse (LPSC, RAL, JYFL)

- Comparison of Measurements with a 0-dim. ion dynamics model simulation code
  - Provides extra values of various collision rates
  - Confinement time not linear with charge state giving credit to electrostatic confinement of high charge state ions in the potential dip



# MERCI POUR VOTRE ATTENTION