INTERNATIONAL CONFERENCE ON ION SOURCES

ASTERICS, A NEW SUPERCONDUCTING ECRIS FOR SPIRAL2

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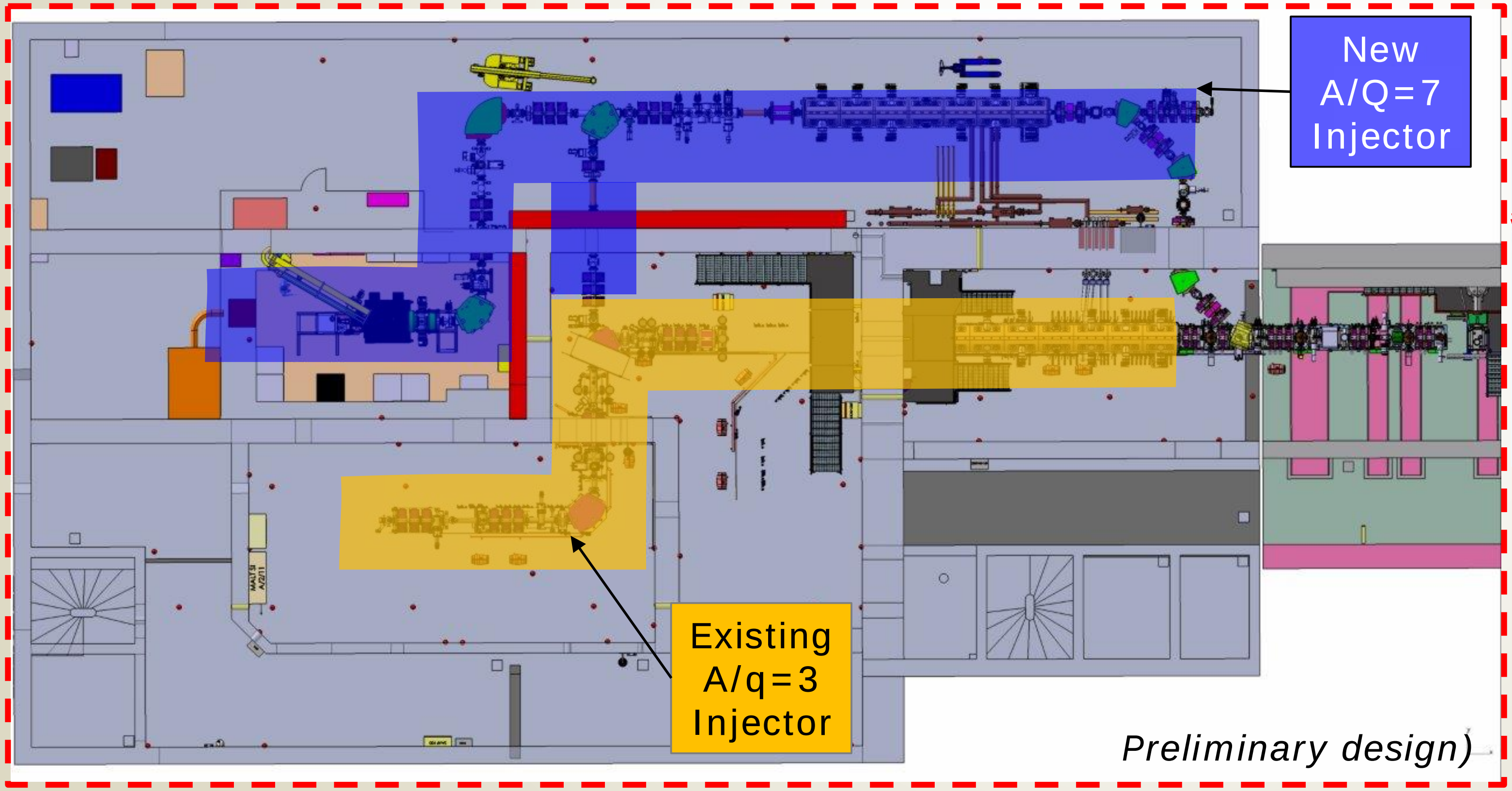
OUTLINE

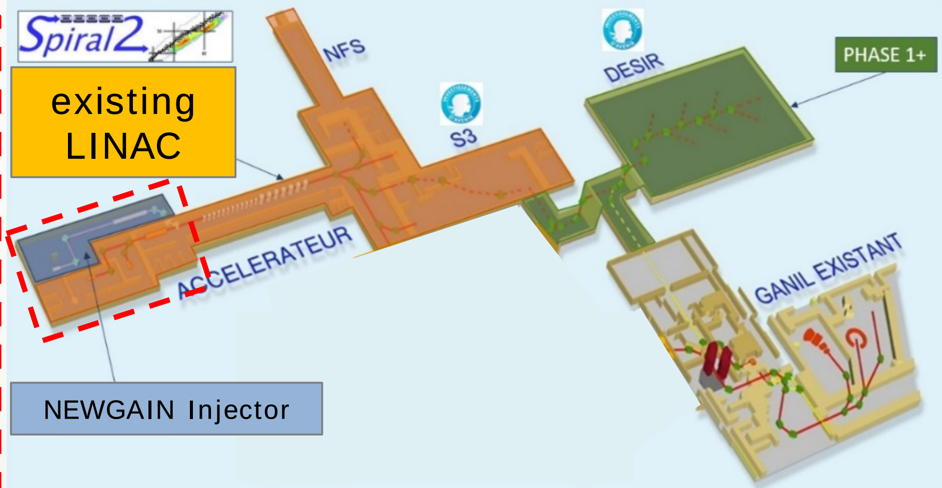
LPSC
GRENOBLE | MODANE

- NEWGAIN project, beam requirements and how to answer them
- Motivation to build a large ECR 28 GHz ECRIS
- Status of the ASTERICS design
- Concept of thick active hot liner for metallic beam operation

NEWGAIN: NEW GANil INjector

- Funded Project to design and build a M/Q=7 heavy ion injector for the SPIRAL2 accelerator at GANIL, Caen , France
- French multi-laboratory collaboration
- Project Timeline : 2023-2030





NEWGAIN Ion Source Specifications

Project Specifications

- RFQ input: 10 kV/Q with M/Q ≤ 7
- Single charge state ion beam
- Accelerate heavy ions up to uranium
  - 13 pµA for M ≤100
  - 10 pµA for M >100
- Minimize the project risk (SC magnet)

Discussion

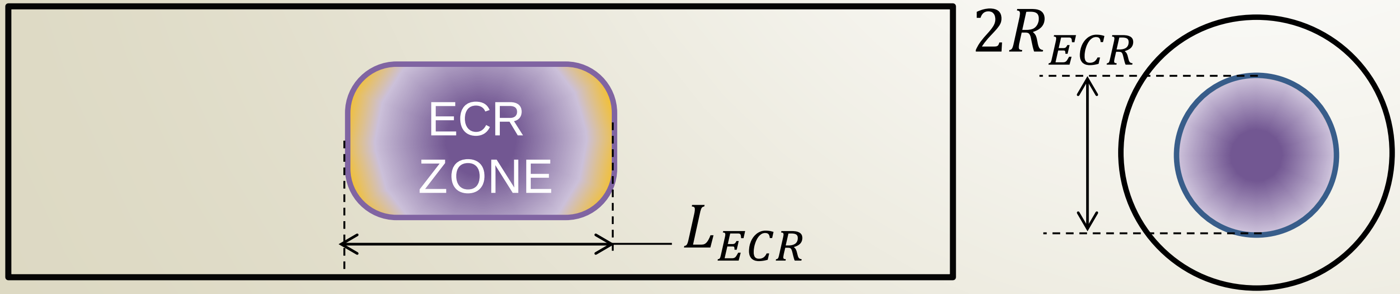
- 18 GHz plasma sufficient to make the M ≤100 beam intensities
- 28 GHz ECRIS required to produce the M > 100 beam intensities
- Practical state of the art 28 GHz U^{34+} intensity in operation: ~200 µA (6 pµA)
- How to produce 10 pµA of U^{34+} ?
- And keeping the project risk low?
- Can a larger volume ECR source @28 GHz answer the need?

ECR Volume and Ion beam intensity (1/2)

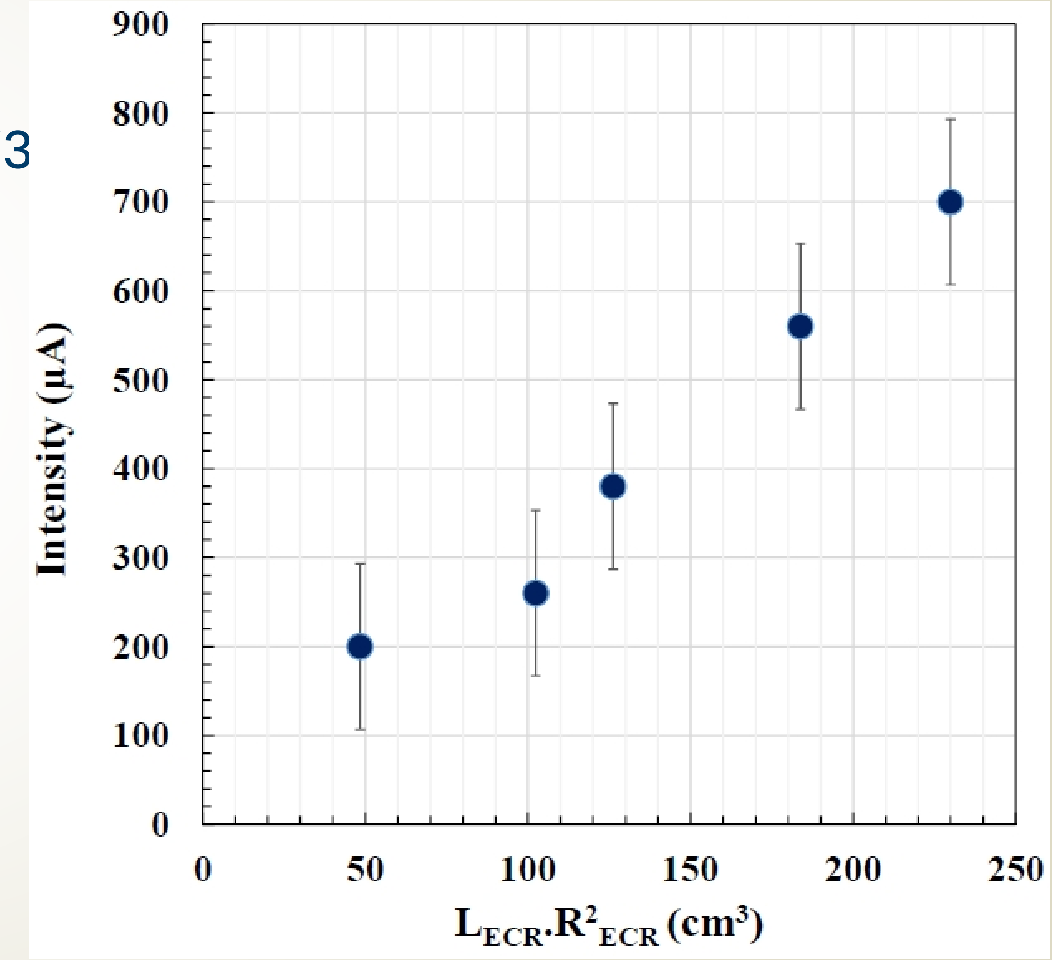
- Return of experience from the 18 GHz ECRIS
- Ploting Ar^{12+} Beam intensity vs $L_{ECR} x R^2_{ECR} (\approx V_{ECR})$
- For several ion sources : PHOENIX V2, PHOENIX V3 GTS, HIISI, SUSI
- Magnetic structures are comparable as they follow the magnetic scaling laws
- RF Power/cm³~const~0.5 W/cm³

$\rightarrow n_e$ and T_e~const

$\rightarrow I \approx V_{ECR}$

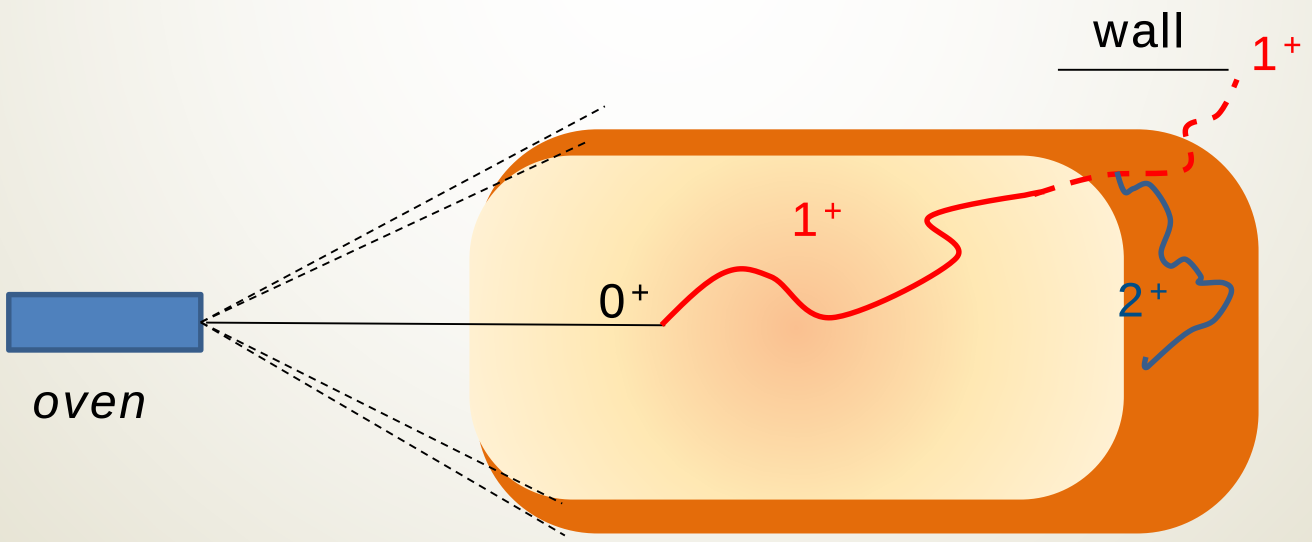


Ar^{12+} Beam intensity



ECR Volume and Ion beam intensity (2/2)

- A longer plasma will make more ion beam
- A larger plasma will boost U^{34+} intensity wrt U^{33+}
- This is the strategy chosen to target 10 pμA U^{34+} beam intensity
- Bonus: enhancement of metal vapor capture with a larger plasma volume



Minimizing risks for the SC ECRIS design

- Use the positive return of experience from VENUS, SECRAL II, RIKEN SC

=> Choose the ECR frequency at **28 GHz**

- Use the bladder and keys technique to mitigate the risk on the hexapole coil assembly

⇒ as for VENUS-FRIB and FECR

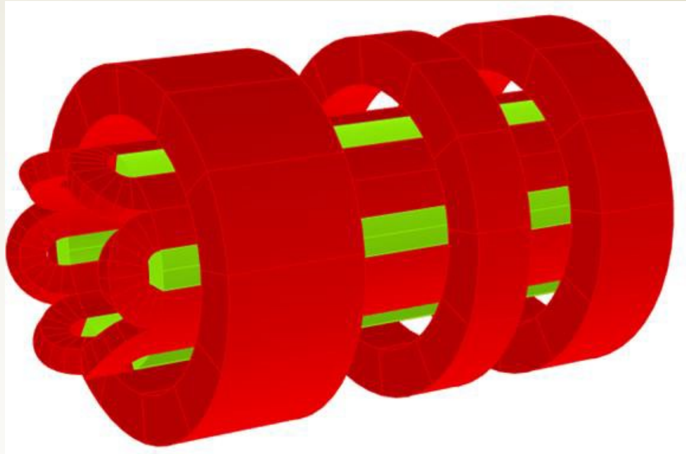
- keep the existing VENUS-FRIB magnet mechanics design system topology

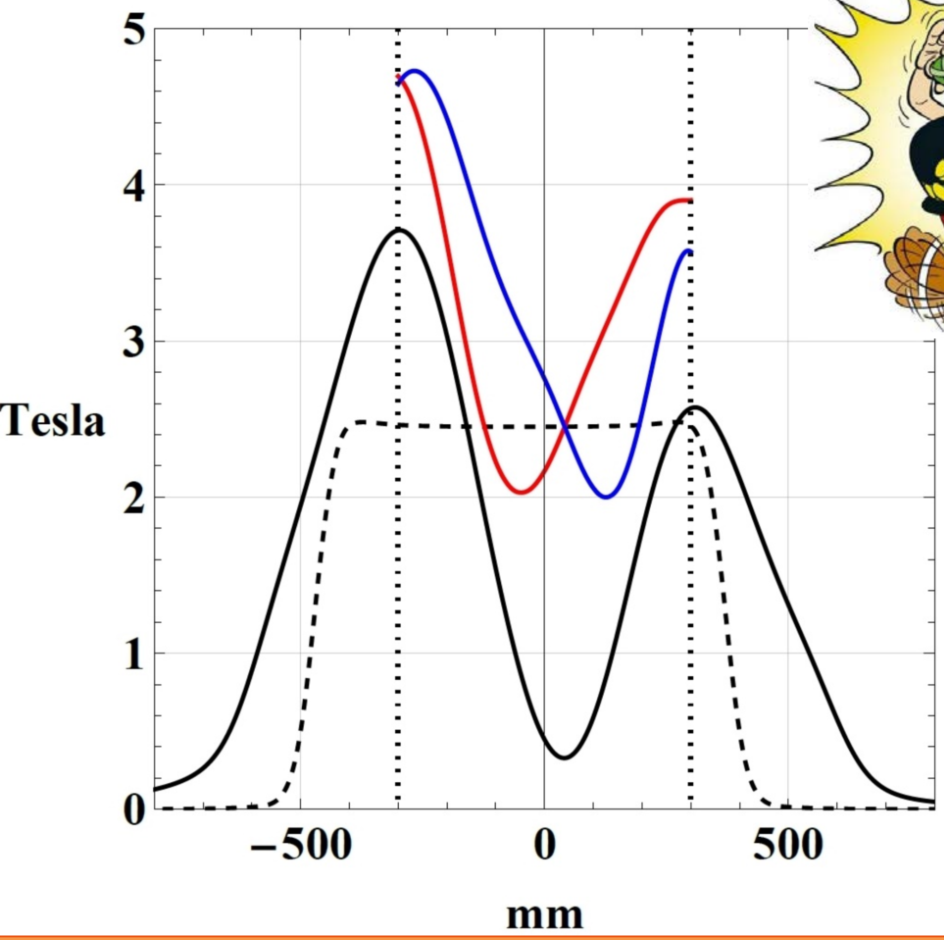
Improving beam intensities with a larger plasma volume

- Choice for ASTERICS plasma chamber : L=600 mm, r=91 mm
  - VENUS (L=500 mm, r=71 mm)
- U^{34+} Ion beam expected ≥8-9 pµA for long run operation
  - State of the art ~6 pµA (VENUS)

ASTERICS* SC magnet

- Designed by CEA Irfu
- Axial max profile 3.7-0.1-2.5 T





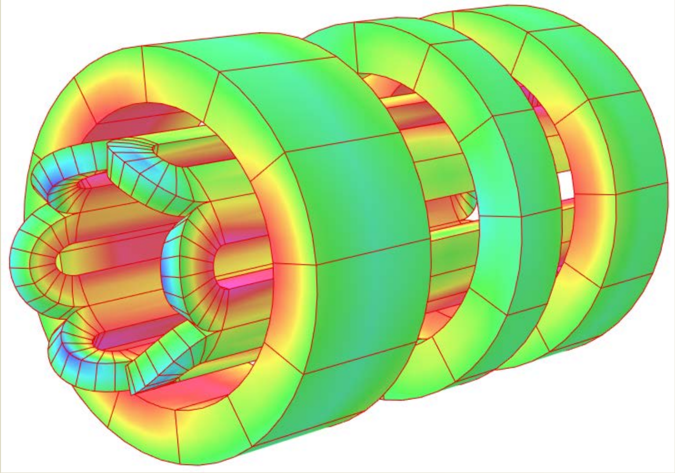
- Radial field B_r~2.45 T@ r=91 mm
- Last closed magnetic surface at wall for 3.7-0.3-2.5 T is **|B|~2T**
- Benefit of a larger ECR source is the <u>relaxation of the unwanted radial component of the axial coil magnetic field</u>
- Also relaxes forces on hexapole coils (counter-intuitive)

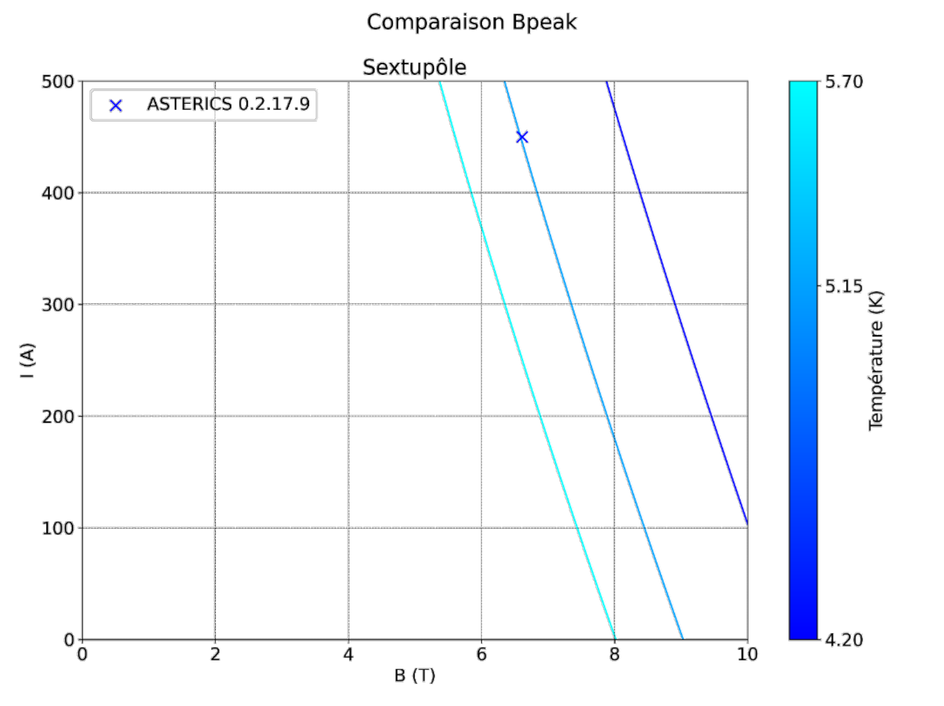
(*) ASTERICS=**A**dvanced **S**piral **T**wo **E**lectron cyclotron **R**esonance **I**on source with **S**uperconducting magnets at **C**aen

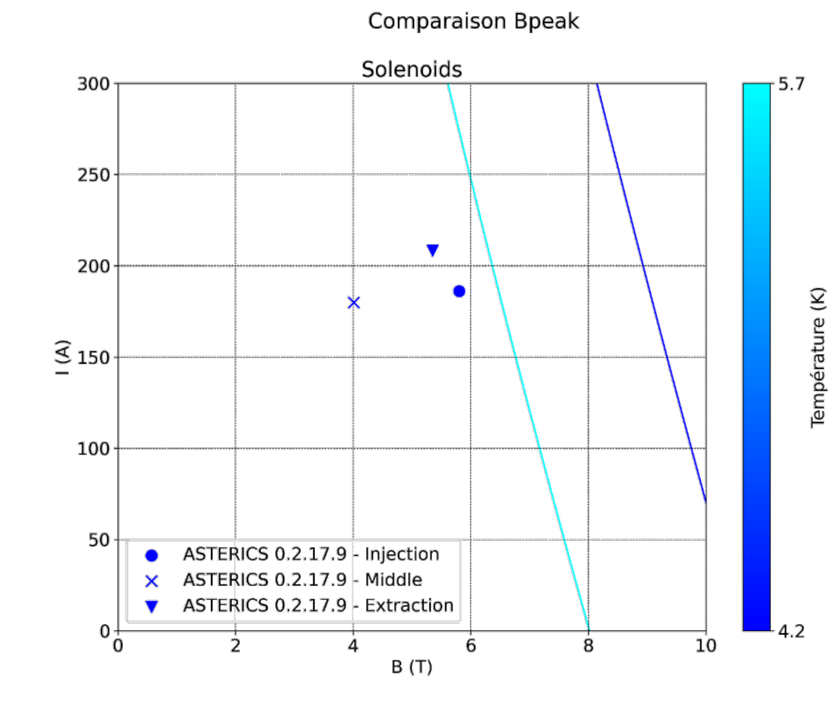
ASTERICS B Peak Fields and Temperature Margin

- Same conductor type as VENUS FRIB , cable recently ordered (Furukawa, JP)
- Temperature Margin:
  - >1.5 K for solenoids
  - ~1 K for hexapole

	Solen. INJ			Solen. MID			Solen. EXT			**hexapole**		
	B Peak (T)	I (A)	T (K)	B Peak (T)	I (A)	T (K)	B Peak (T)	I (A)	T (K)	B Peak (T)	I (A)	T (K)
ASTERICS 0.2.17.9	5.8	186.1	6.04	4.01	-180	6.95	5.35	208.4	6.18	6.61	450	5.15

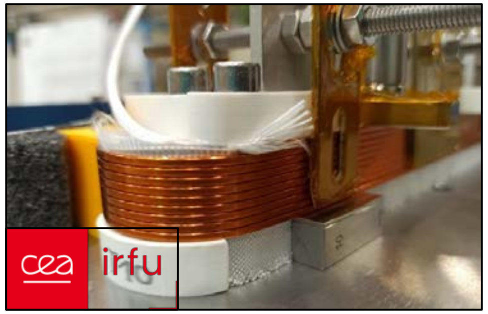




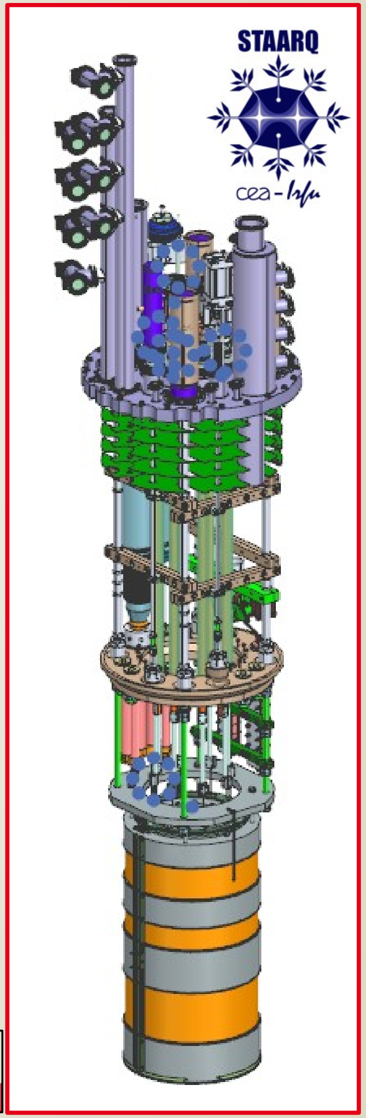


ASTERICS magnet construction strategy

- Racetrack Mock-up recently built at CEA
  - to test the winding technique and epoxy impregnation under vacuum



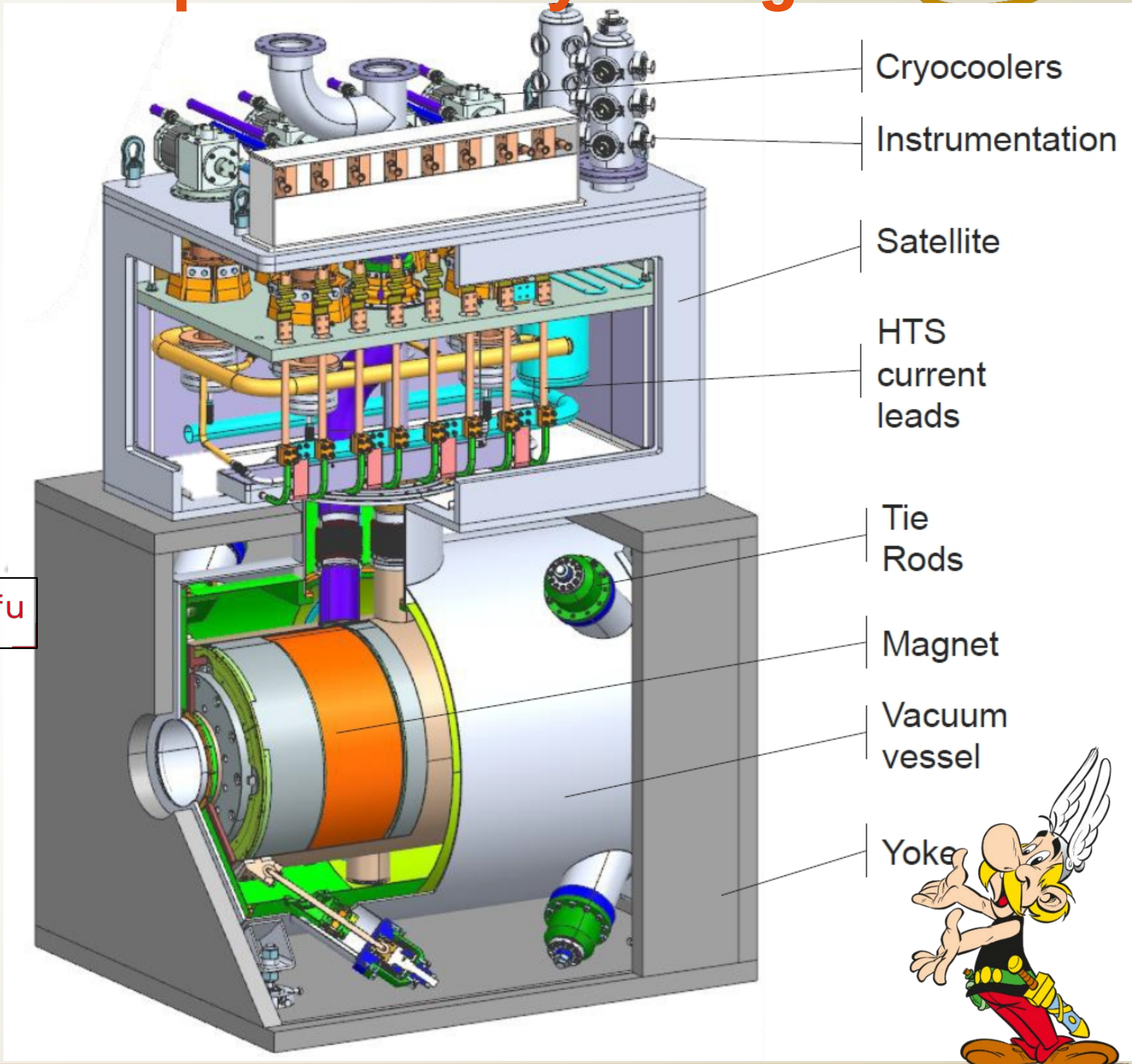
- Magnet and cryostat preliminary design done by CEA
- Construction subcontracted to the industry
- Stand alone magnet test planned at CEA before assembly in the cryostat
- 12 racetrack coils built
- 16 km of spare cable ordered

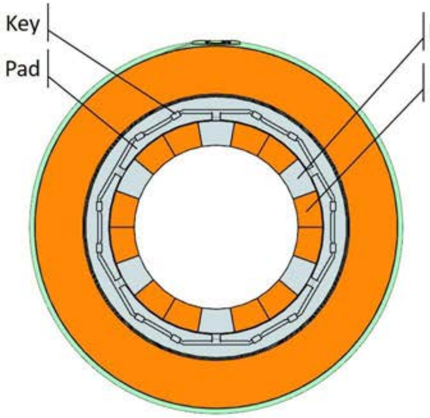


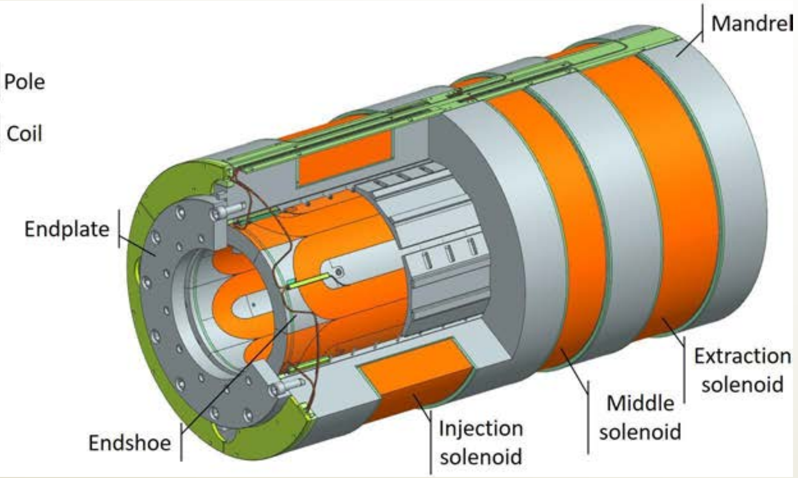
cea irfu

ASTERICS Magnet and Cryostat preliminary design

- Bladder and keys technique
- LHe bath, 6 GM-JT crycoolers
- 8 HTS leads
- Redundant instrumentation
- Preliminary design under progress
- Active quench system (to dump coils energy in ext. resistors)

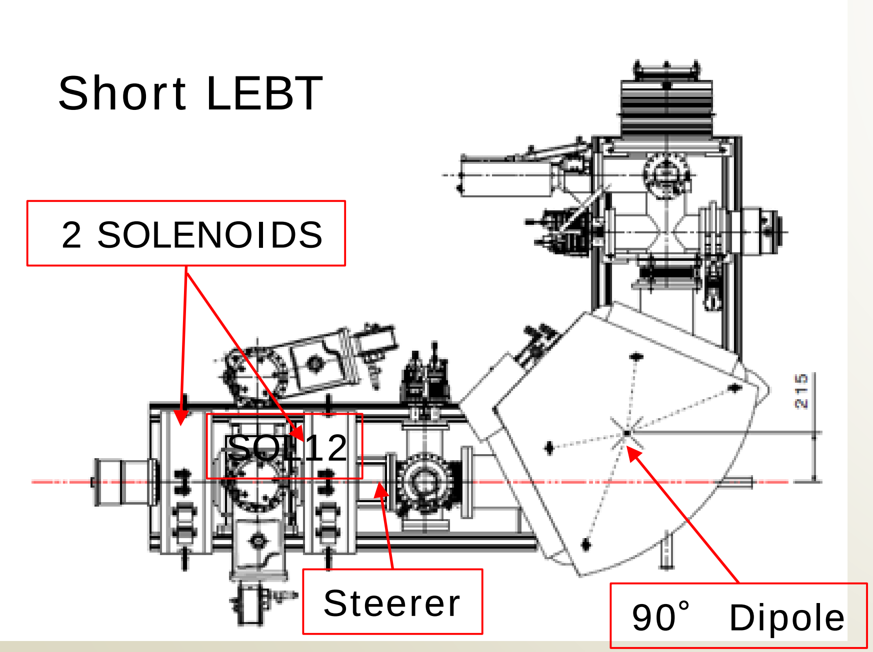


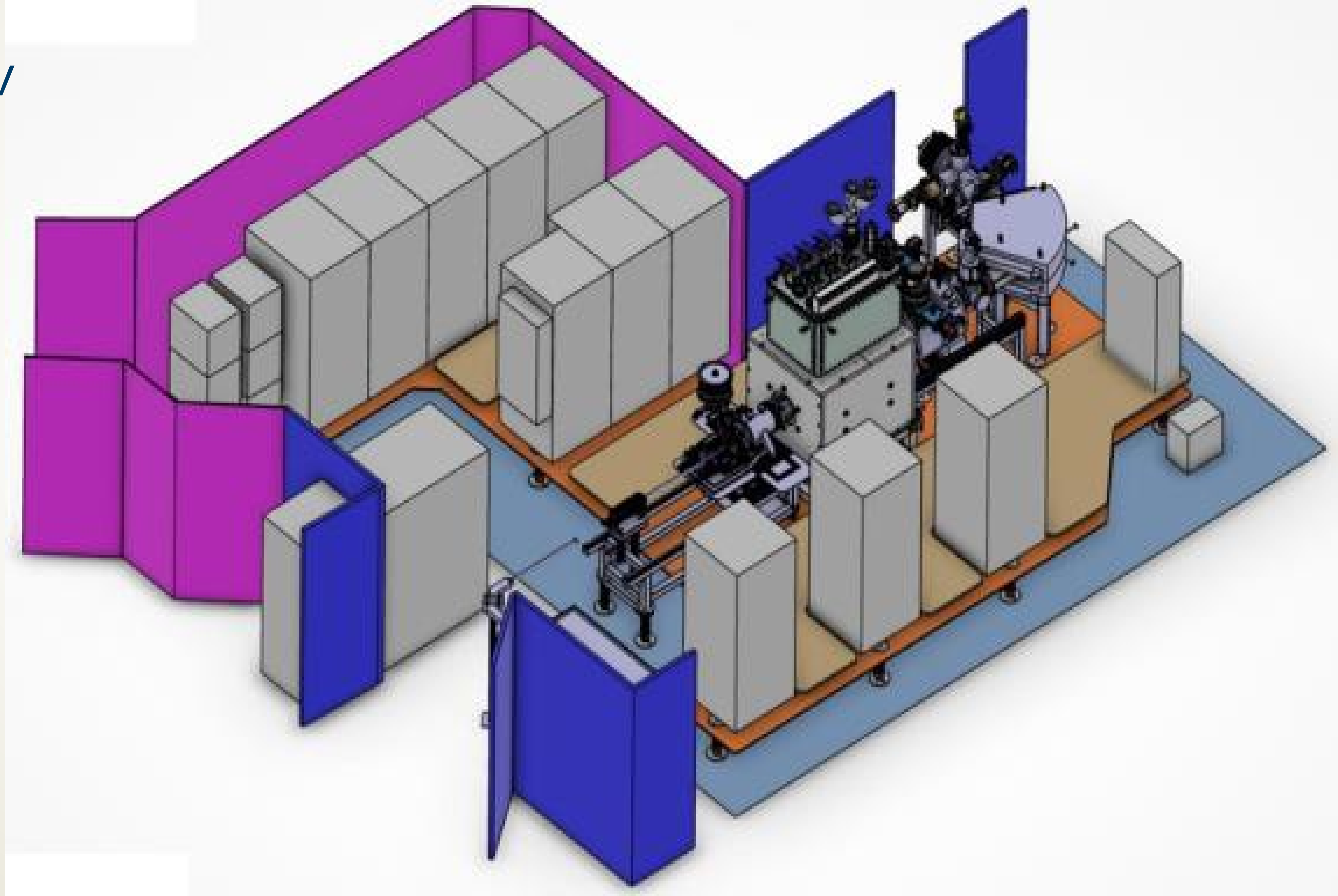




Source and platform preliminary design (under progress)

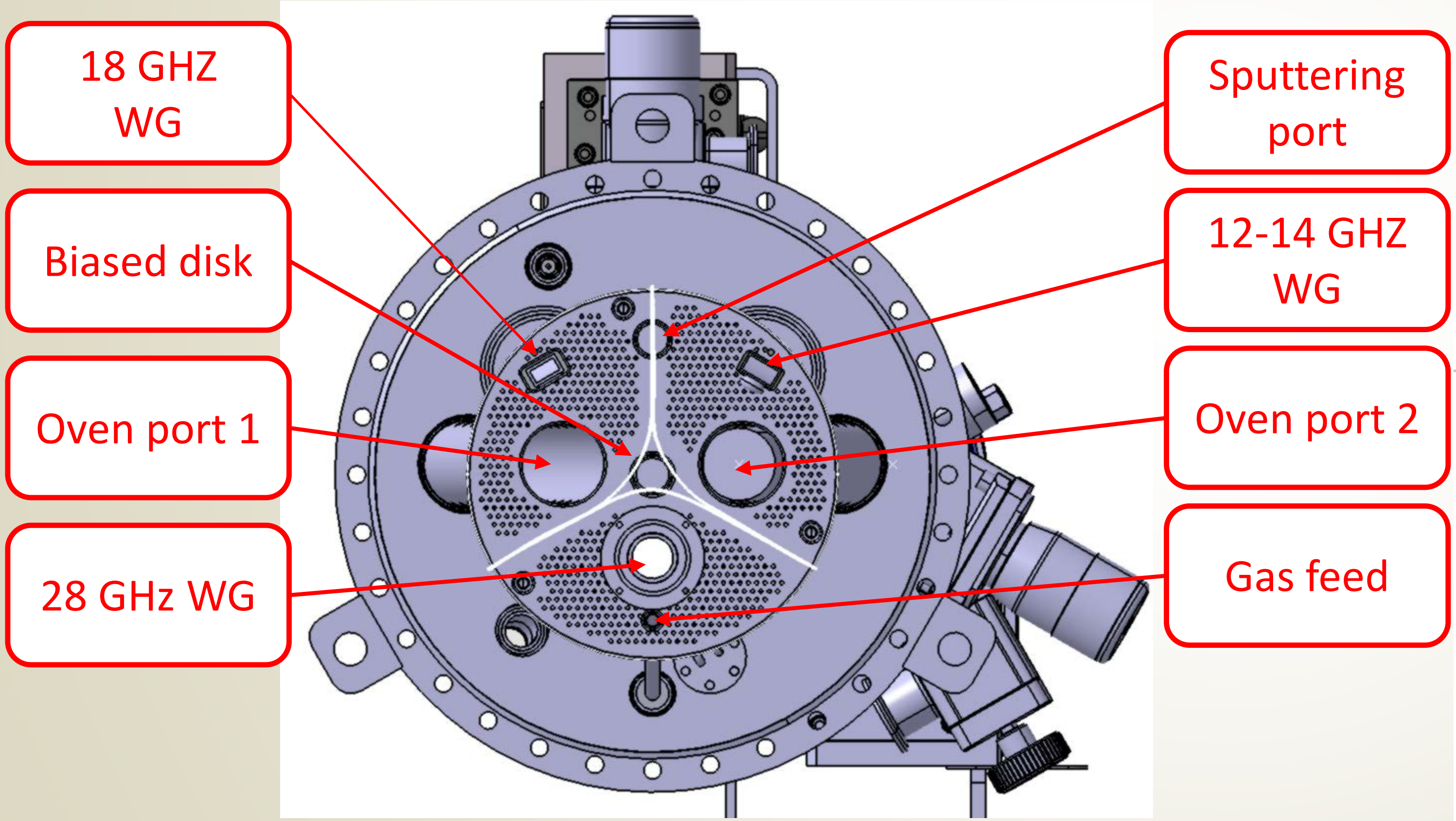
- 50 KV HV platform
- Source HV tunable: 20-40 kV
- LEBT on platform
- 28 GHz gyrotron @ ground



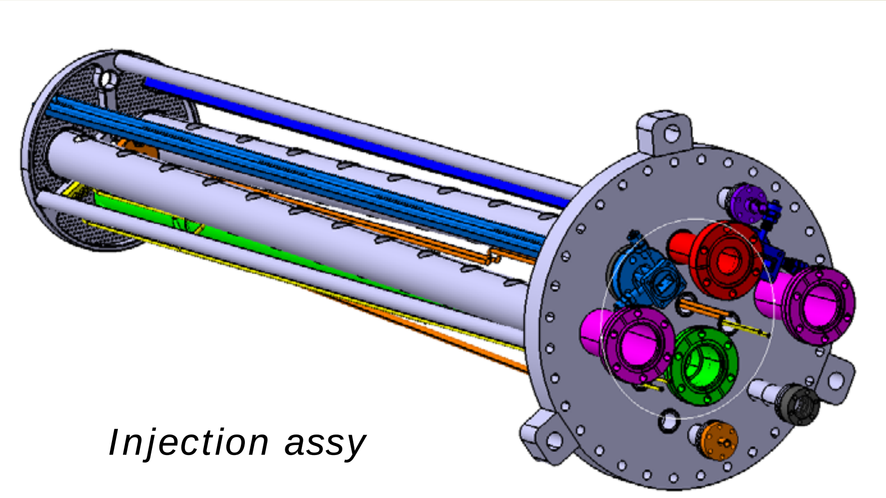


Source mechanics preliminary design

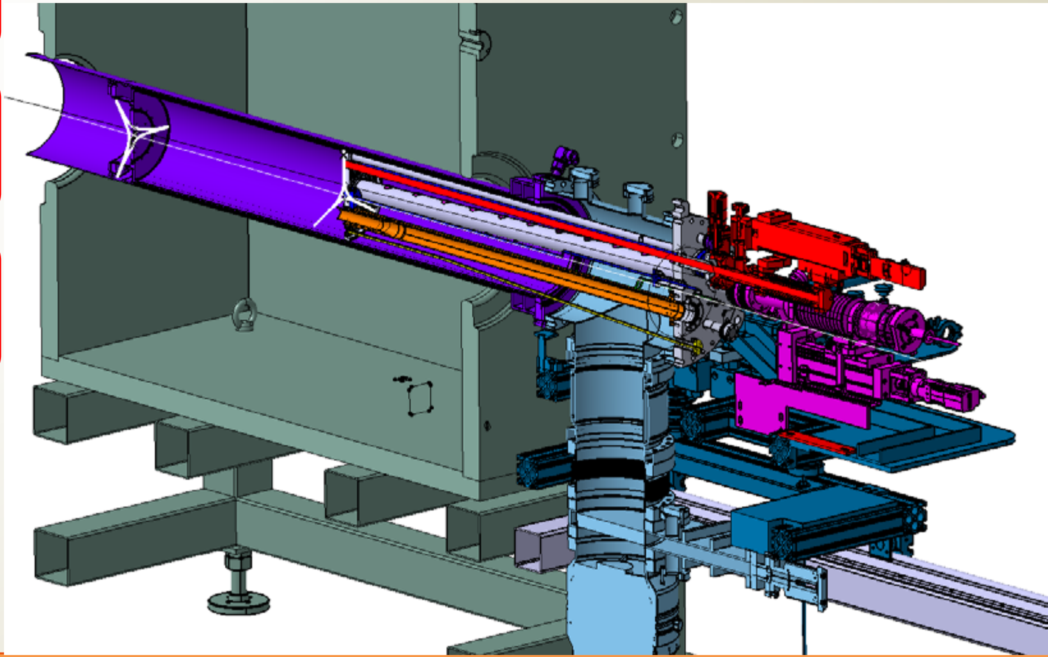
- The large chamber diameter allows to pass many feedthroughs



ASTERICS Injection assy preliminary design

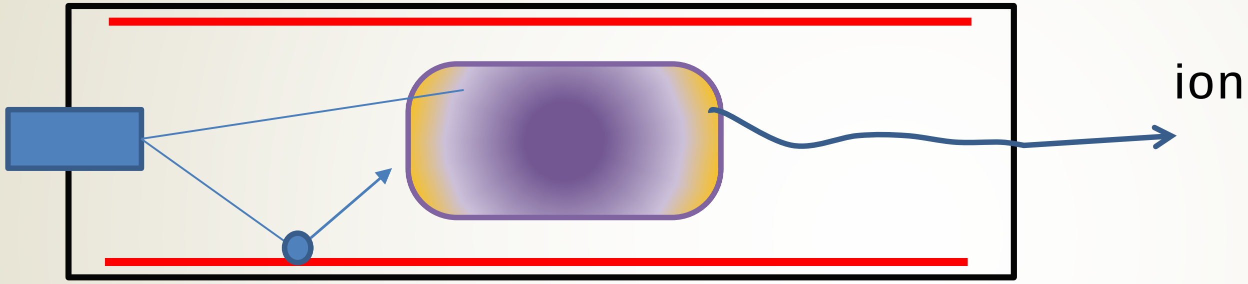


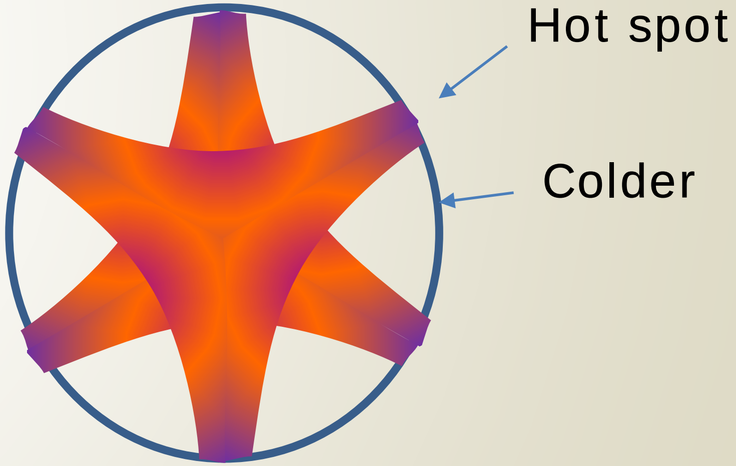
Injection assy



Motivation to develop a new generation of ECRIS hot liners

- Liner used to enhance the production yield of high vapor pressure metal beams like Ca
- Today hot liners in ECRIS are usually thin foils (~0.1 mm) directly heated by the plasma

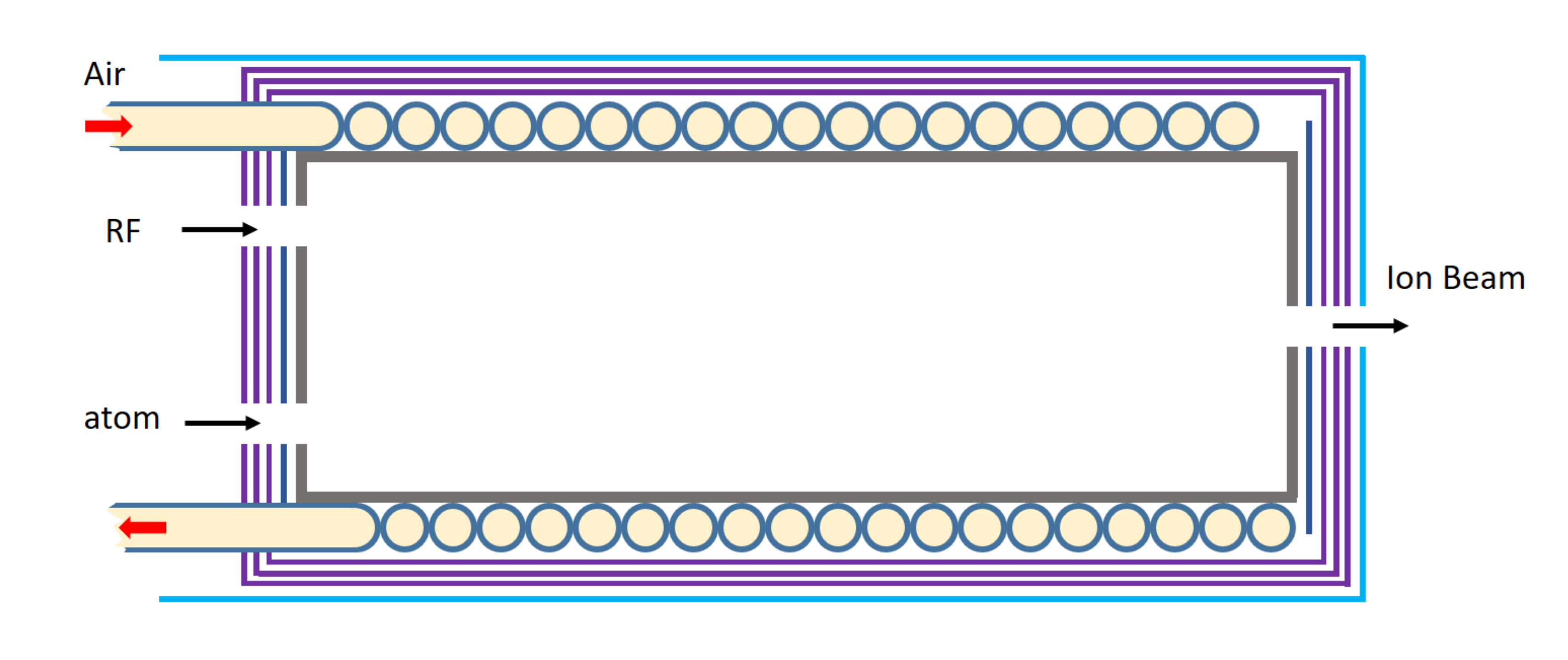




- No control of the liner temperature and evaporation rate
- Thin liner=>poor thermal conduction in the liner
=> hot spots=> easy to melt
- If RF power is OFF while oven is ON => accumulation of metals on the liner
=> overshoot of metal vapor when RF is resumed

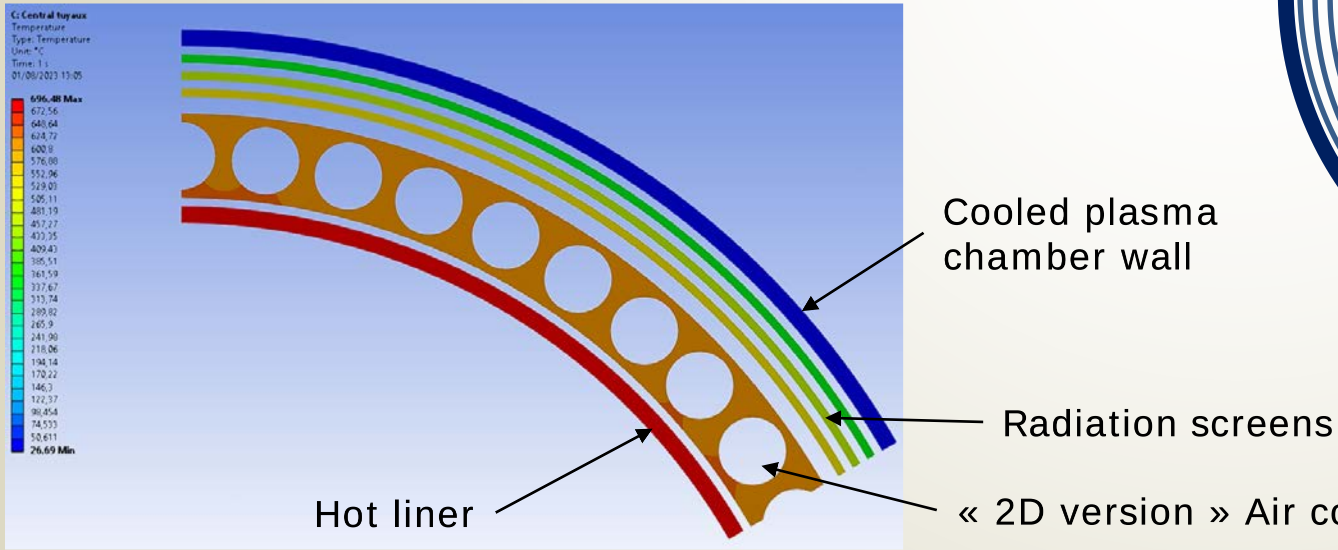
Concept of thick active liner for ECRIS

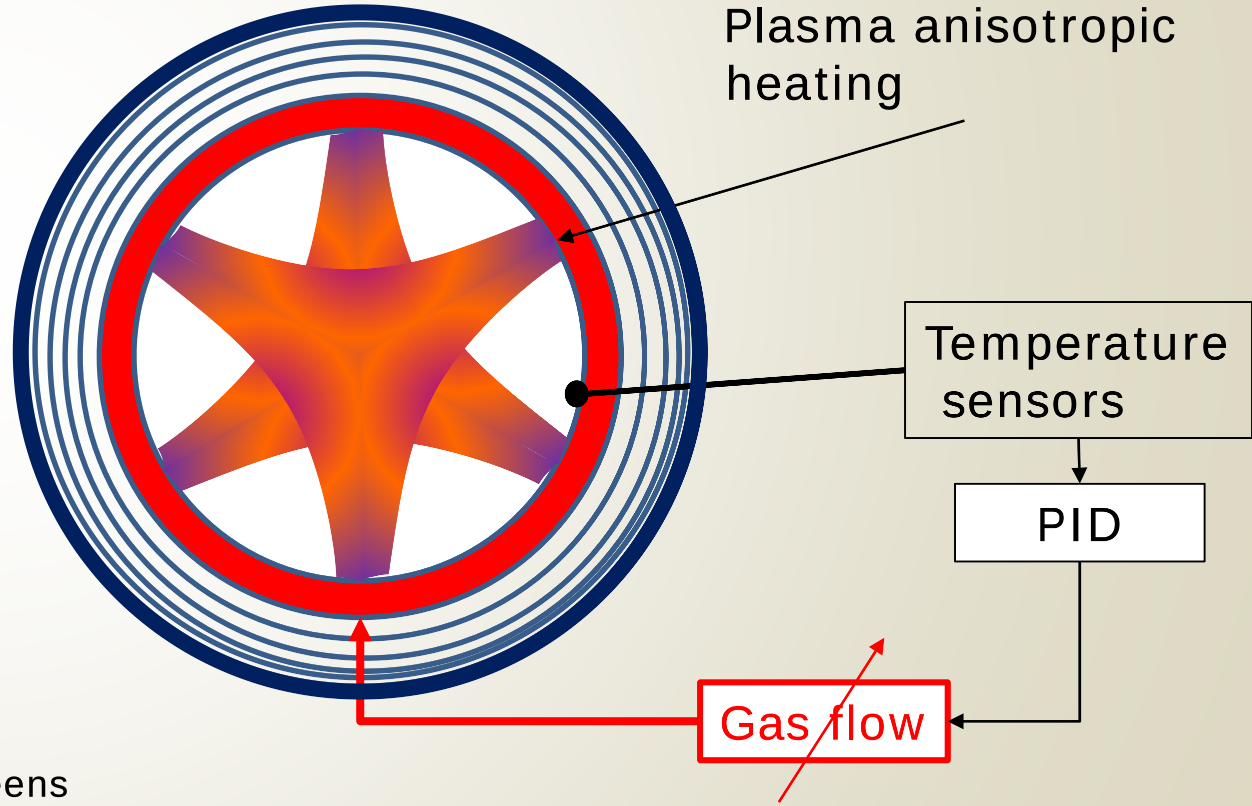
- Use a thick hot liner to homogenize its temperature
- Add radiation screens to increase the mean liner temperature
- Add a stainless steel helically wrapped tube in which compressed air can flow, acting as a radiation screen
- The air flow reduces the liner temperature



Active hot liner simulation

- Thermal Simulation with Ansys 2D
- Anisotropic power flux
- Air forced convection and thermal radiation modelled
- radiation screens
- 0 or 12 m3/h airflow
- Center of plasma chamber (6 loss lines)
- Edge of plasma chamber (3 loss lines)





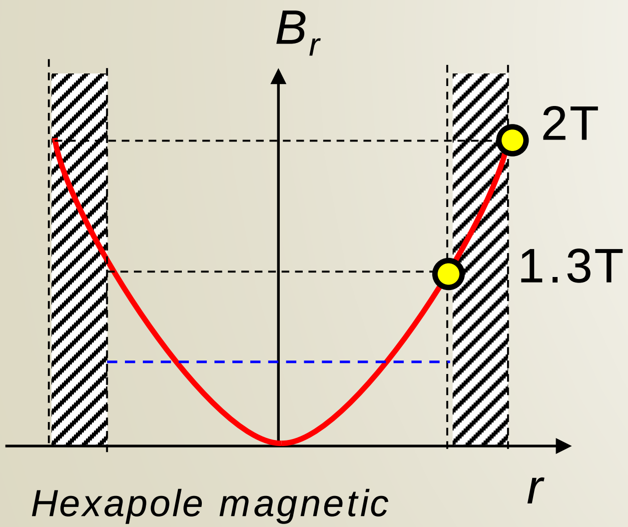
Simulation results and discussion

- Max reachable temperature with 2 kW RF is 800° C with 3 screens
- Max temperature with 2 kW RF is 700° C without screens
- Thick liner wall => temperature homogeneity at wall +- 12° C
- Air cooling can **remove 200° C** for a 12 m^3/h air flow => partial control of the evaporation

- The temperature range of liner operation can be adapted by changing the number of screens
- The Air cooling allows to keep the liner temperature constant while changing other source parameters (gas glow, RF)
- The Air cooling helps to mitigate overshoots of evaporation after a RF shutdown

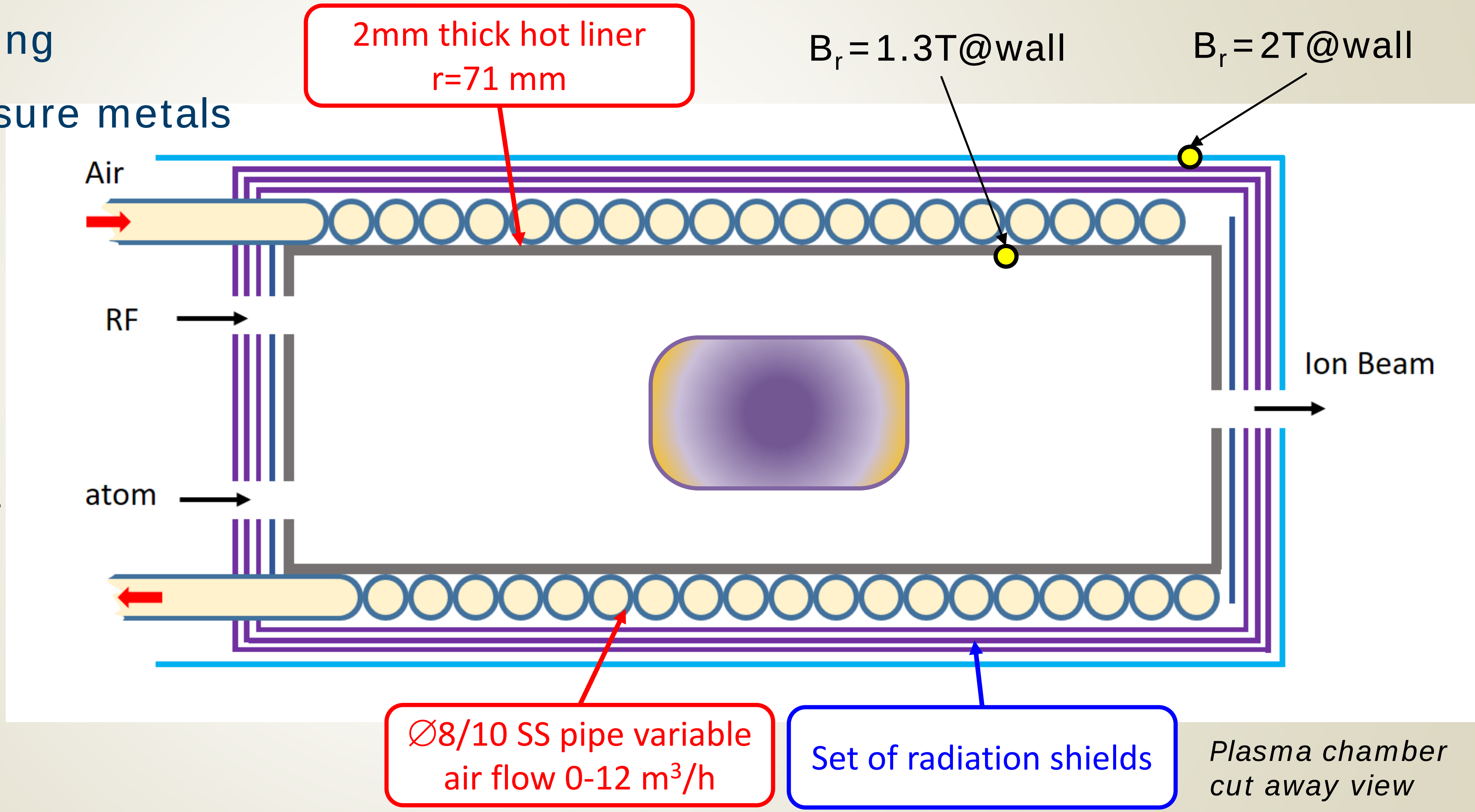
A thick active hot liner for ASTERICS

- ≤20 mm radial thickness (R=91 to R=71 mm)
- For 18 GHz RF heating
- For high vapor Pressure metals



Hexapole magnetic Field intensity

$B_{ECR}=0.64\ T$



Plasma chamber cut away view

THANK YOU FOR YOUR ATTENTION

Any question?