LPSC activities within the framework of the EMILIE project

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LPSC Grenoble

SUMMARY

1 - Status of the 1+ ion sources development – Task 2.2

2 – Experiments with SPES, SPIRAL 1 and LPSC CBs – Task 4.2

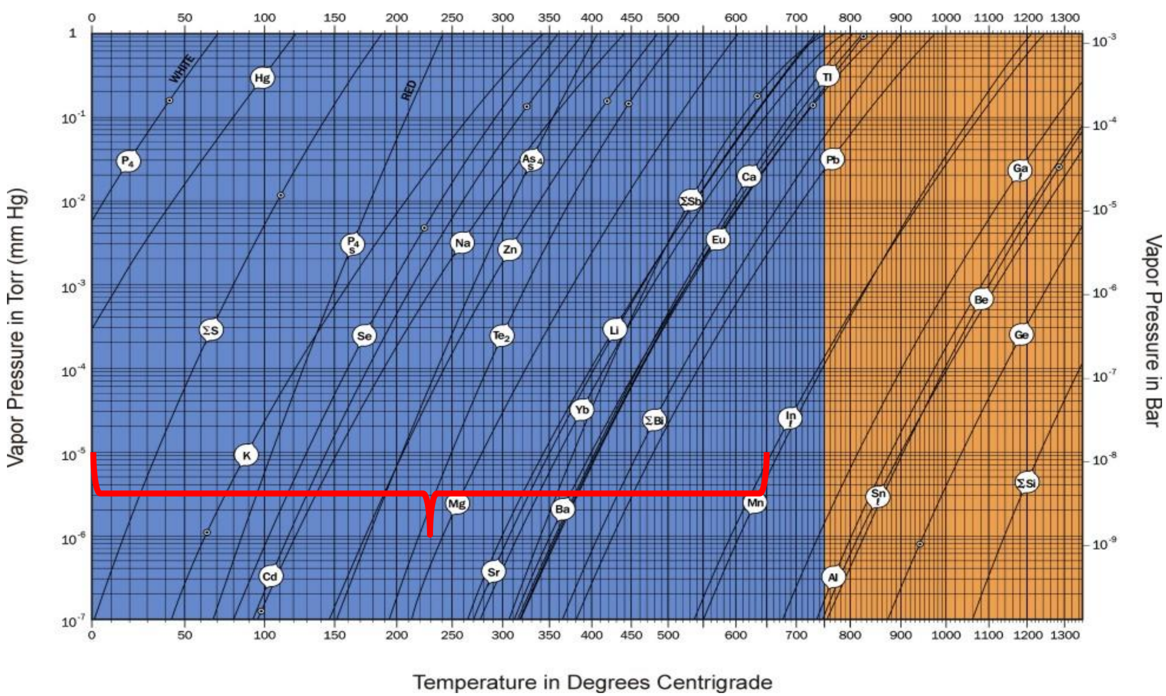
3 – LPSC Charge Breeder future plans - Task 3.1

Study of wall recycling and reduction of stable background in the PHOENIX CB

Development of a high temperature 1+ ion source

We decided to proceed in 2 steps :

- First a « Hot » version of the source to be operated up to 650°C **under progress**



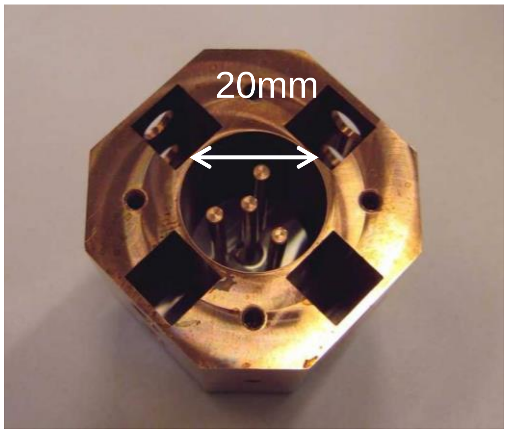
…allows to work with most of alkaline metals

- **Second step a « High temperature » version up to 1200°C studies not started yet**

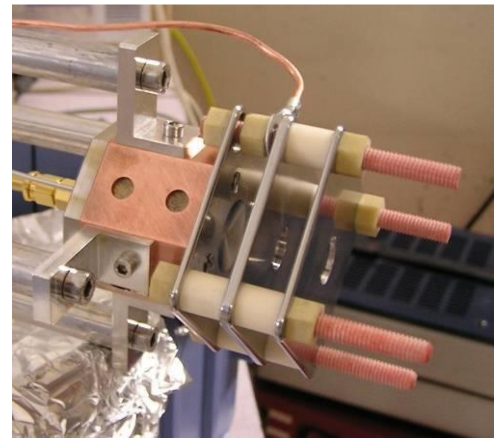
1 - Status of the 2.45GHz hot ion source – Task 2.2

The hot 2.45GHz ion source is based on the COMIC design due to its good performance (stability, beam quality, simplicity)

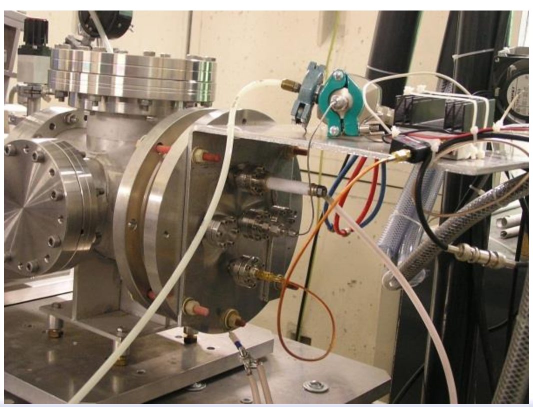
Top view of the body of the source with its cavity



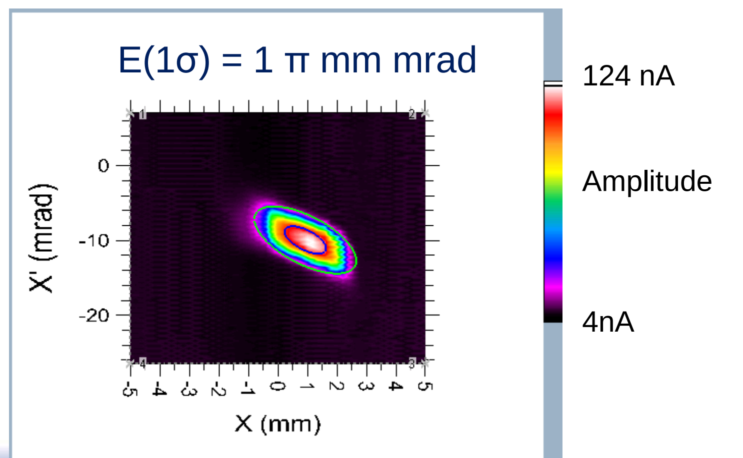
Source view with its extraction electrodes



All the feedthroughs are connected to the same flange (High voltage, gas, μw …)



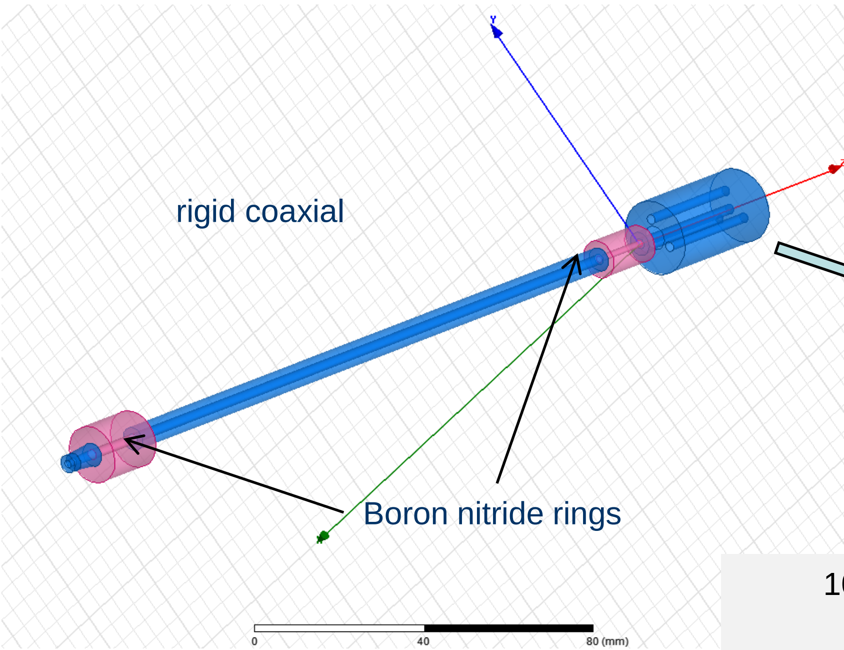
Example of Ar^+ RMS emittance measurement at 15kV



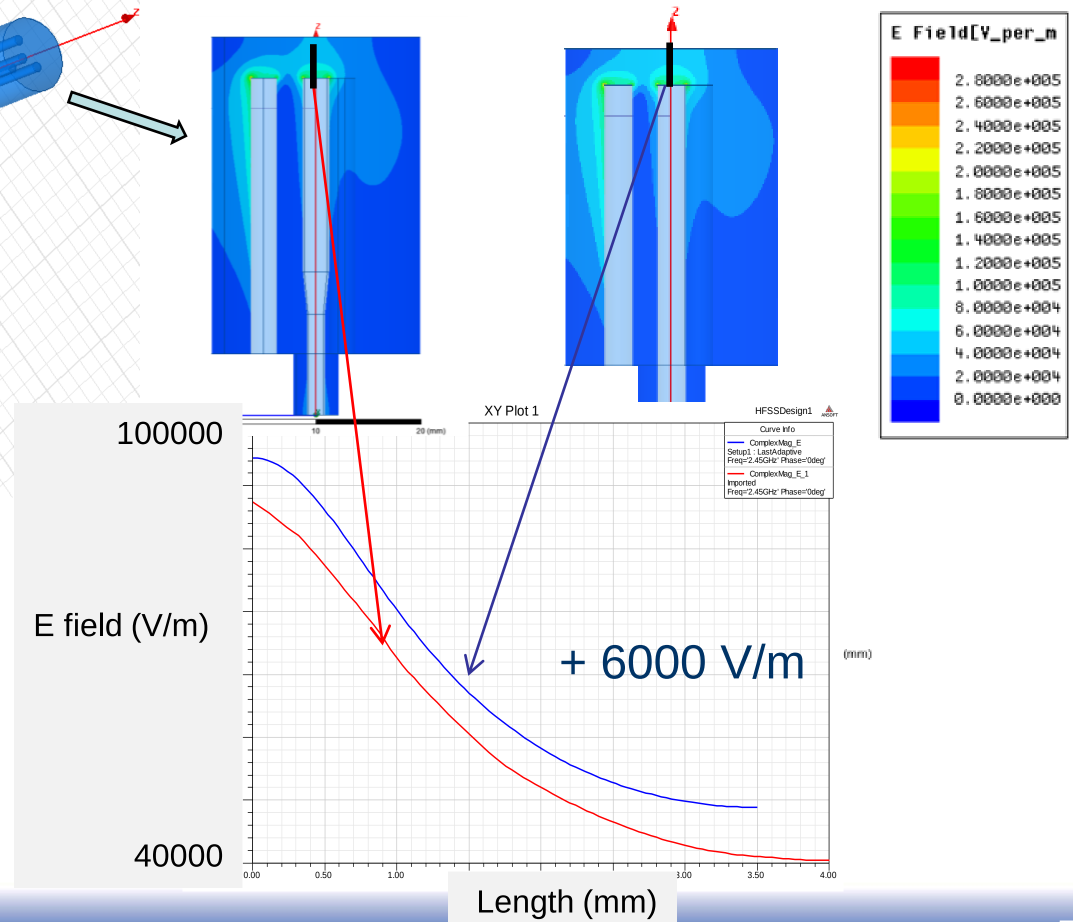
1 - Status of the 2.45GHz hot ion source – Task 2.2

Microwave coupling

Modification of the microwave circuit to replace the cable by a rigid coaxial



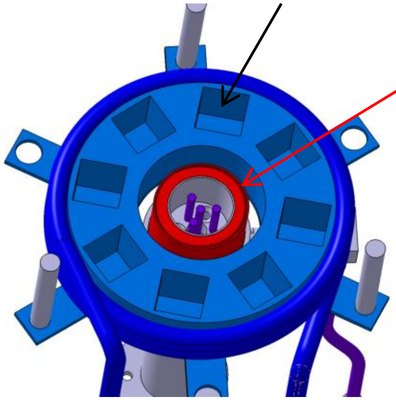
Comparison of the electric field in the plasma chamber with HFSS between the **Initial configuration** and **the new one**



Comparison of the electric field in the plasma chamber along the black lines, at the top of the antenna

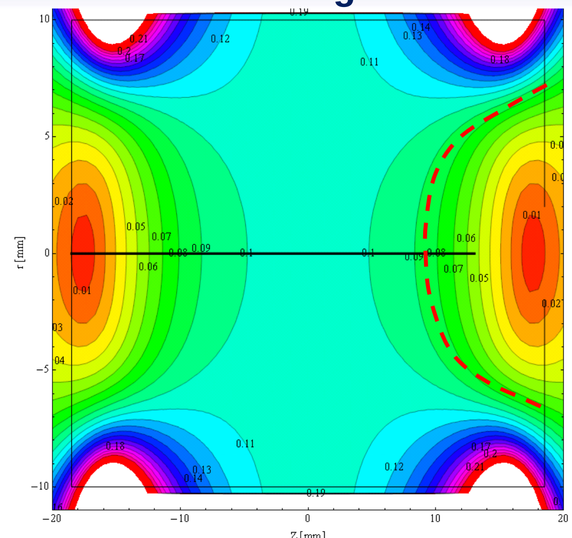
Magnetic structure enhancement

In order to protect the permanent magnets from the hot temperature, we **moved them away,** inserted a vacuum screen, water cooling and **a heater….**

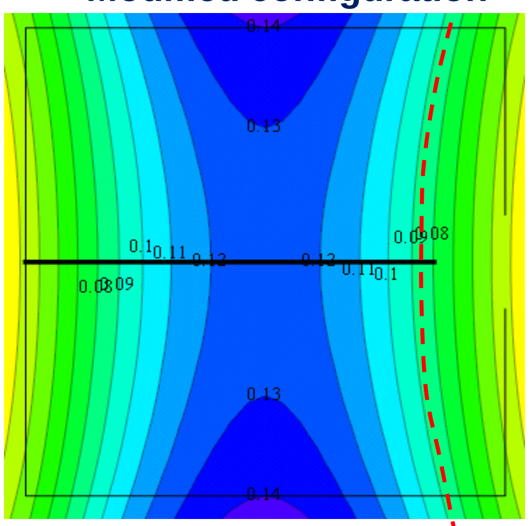


…the goal being to keep an ECR magnetic field near to the extremity of the antenna

Initial configuration

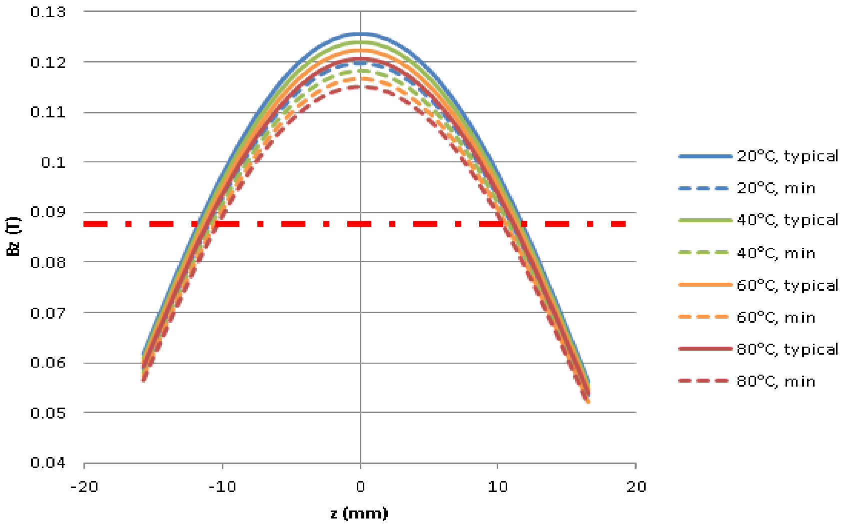


Modified configuration



- - - ECR magnetic field

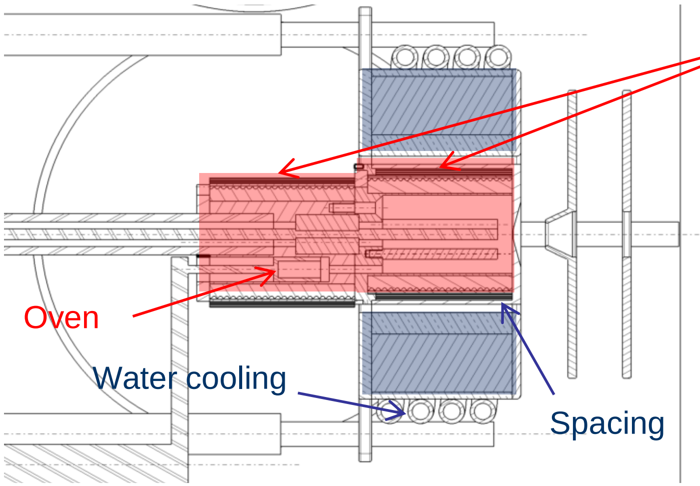
Magnetic field simulations for several magnetization values (manufacturer tolerances) and several temperatures



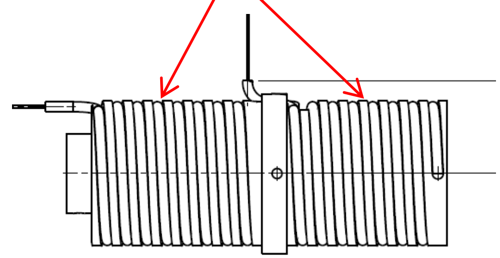
1 - Status of the 2.45GHz hot ion source – Task 2.2

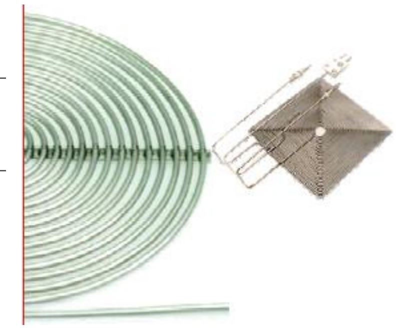
Heating and thermal simulations

The goal is to get a positive temperature gradient between the oven and the chamber

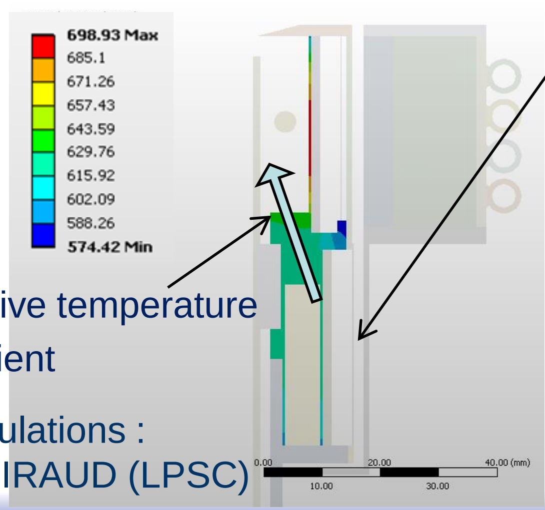


2 x Thermocoax heaters brazed around the chamber





Ansys thermal simulations → additional screens needed



positive temperature gradient

Simulations :
J. GIRAUD (LPSC)

Simulation outputs

Designation (units)	Value
Plasma chamber heating (W)	90
Crucible heating (W)	60
Plasma chamber temperature (°C)	667
Crucible temperature (°C)	627
Vacuum chamber external surface maximum temperature (°C)	38
Screen temperature (°C)	130
Maximum temperature of permanent magnets and box (°C)	24.4
Temperature of the gasket on the flange (°C)	22
Transmitted power to the cooling (magnets side) (W)	75
Transmitted power to the flange cooling (W)	11.3

1 - Status of the 2.45GHz hot ion source – Task 2.2

Presently, the source is assembled and ready for experiments on the 1+ N+ test bench

Tentative planning (2016… ?)

- Make experiments for gaseous ion beams: room temperature source tests
- Test the Heating with thermocouples measurements and compare it with simulations
- Make experiments with heating + alkali ions production

1 - Status of the 5.8GHz – Task 2.2

Version 1 source design

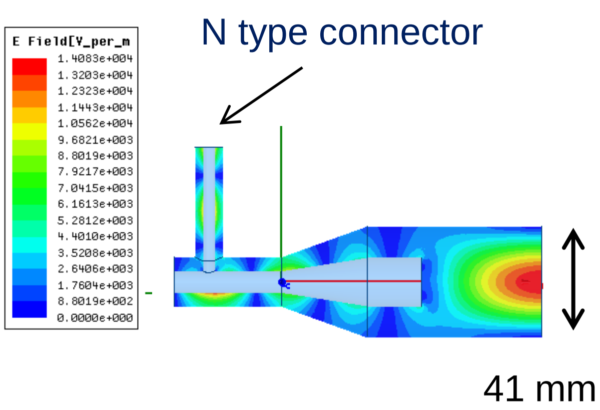
The goal of this source is to produce low charge state ion beams to study the dynamic of the capture process in the CB

The first design (version 1) is based on

- A full under vacuum design, like the COMIC ion source
- The use of a coaxial microwave coupling
- The production of a strong axial electric field in the plasma chamber
- The use of a 5,8GHz solid state amplifier for stability

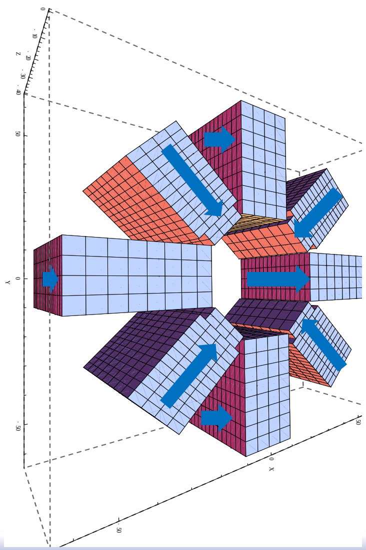
HFSS microwave simulations

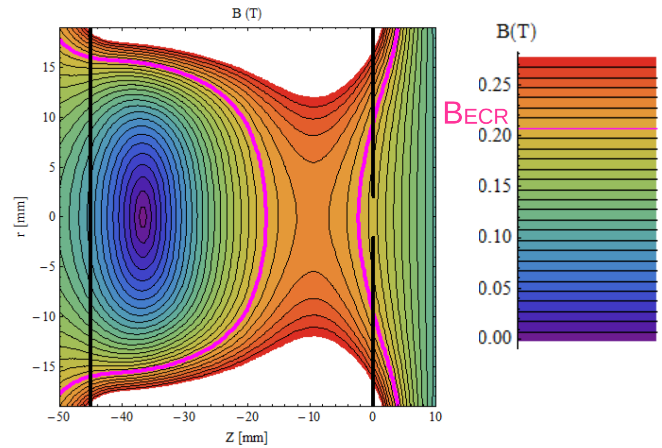
Coaxial cavity resonator designed to obtain a strong electric field near to the plasma electrode



Magnetic field simulations : Radia – Mathematica (ESRF)

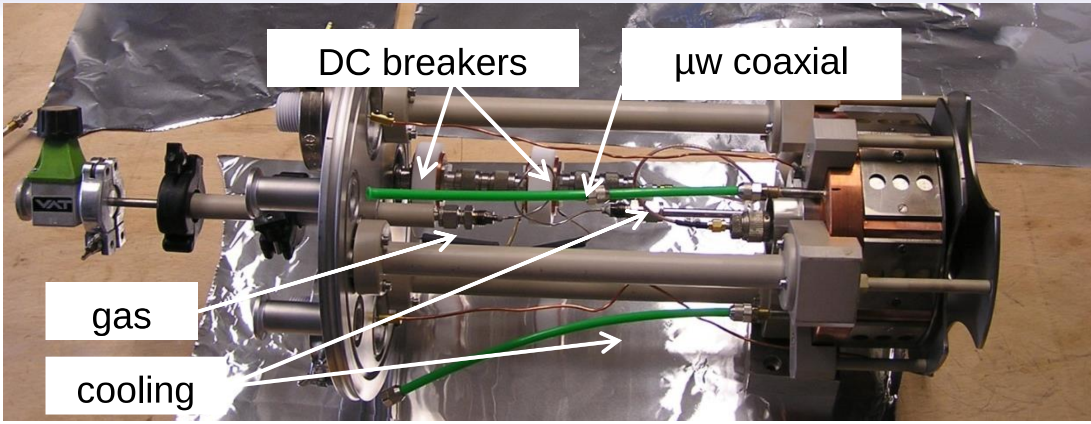
- Built up with standardized permanent magnets (low cost, modularity)
- 2 resonances in the cavity



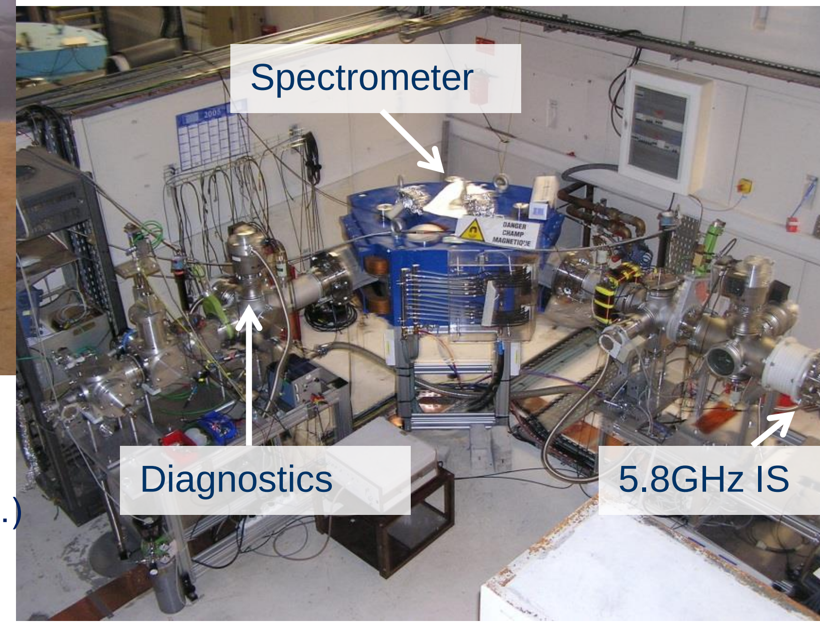


1 - Status of the 5.8GHz – Task 2.2

Version 1 results



Experiments on the LHI beam line

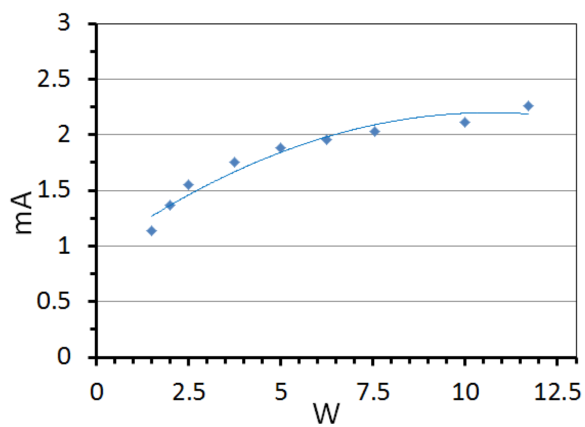


+ operates at low HF power operation
+ we tested several HF couplings (simple antenna, add of couplers…)

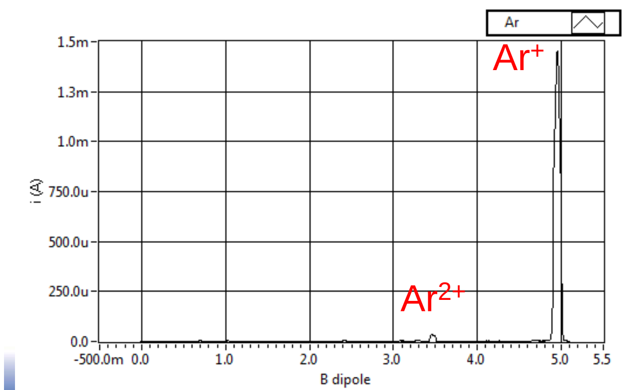
- Production of 1+ ions
- High pressure operation
- Original design to be improved (flange at HV, sparks, melted antenna, breakdowns…)

➢ **new version of the source with**
  + Min B structure
  + design improvement

Extracted current, plasma hole 6mm, 40kV, Ar gas $2x10^{-4}$ mbar



Argon spectrum, plasma hole 6mm, 40kV, 10W, $8x10^{-5}$ mbar

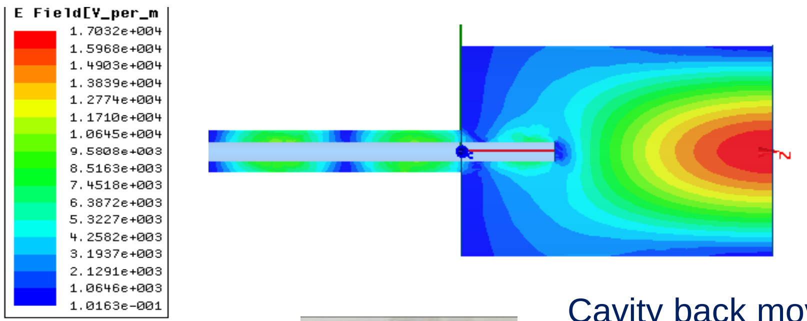


1 - Status of the 5.8GHz – Task 2.2

Version 2 source design

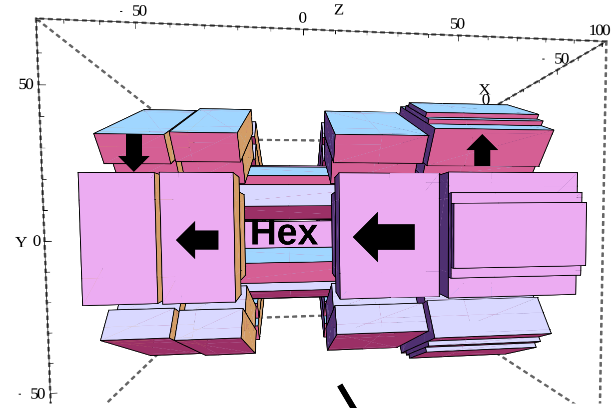
HF circuit improvement

- New coupling
- Water cooled semi rigid-coaxial RG 401
- Cavity length adjustable from outside
- Triple stub tuner
- Feedthrough flange at HV (no DC breakers)



Magnetic structure modification

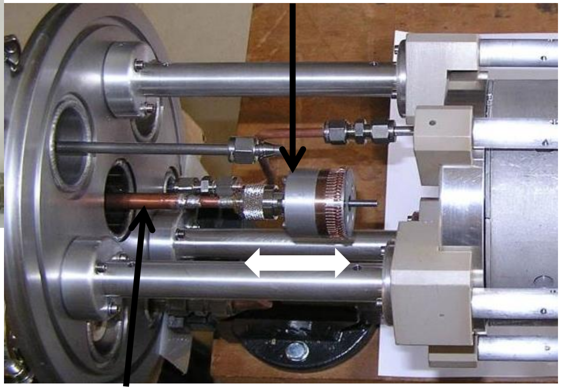
Design of a new min B structure with low cost permanent magnets (cubic 12x12x12 mm^3)



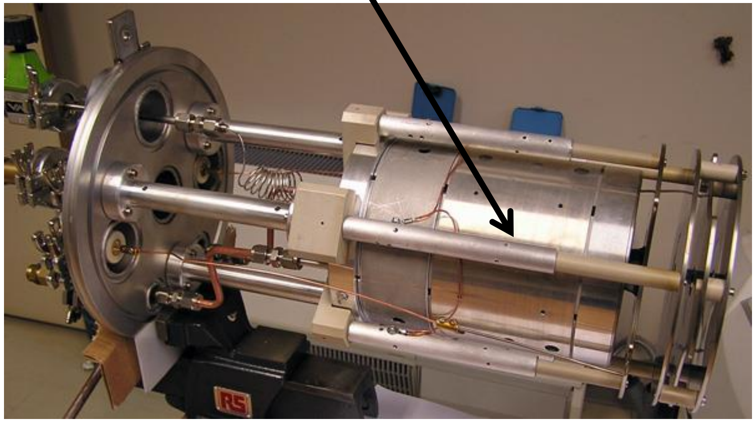
100W amplifier
SS 5,8 GHz

Triple Stub tuner

Cavity back movable from air



RG401 coaxial inside a water cooled copper tube

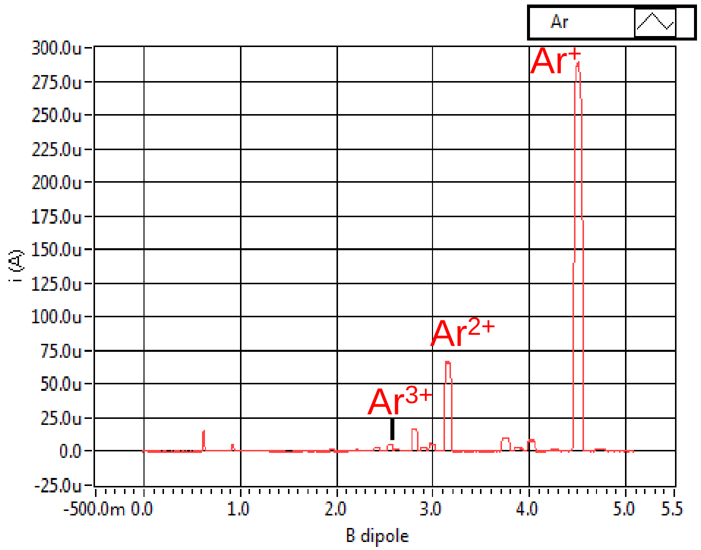


1 - Status of the 5.8GHz – Task 2.2

Version 2 : results

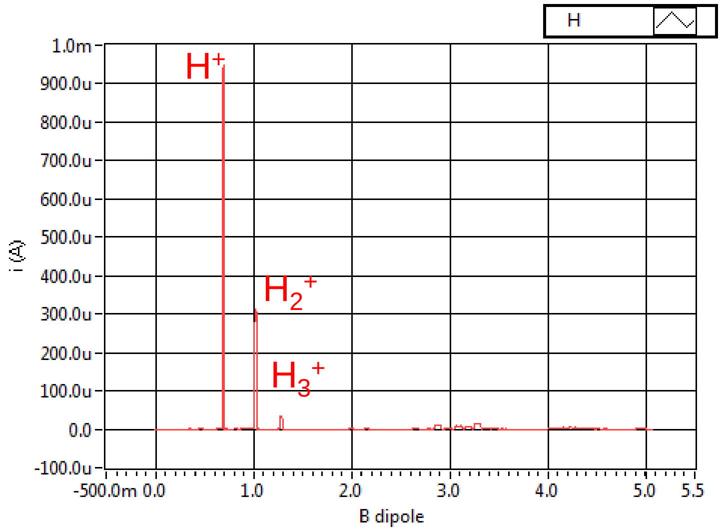
The 5,8GHz IS is installed on the LHI test bench since July 2015

Ar spectrum (optimized for Ar^{+})



HV 30kV/0.77mA ,HF 30W
Plasma electrode hole Ø 4mm

H_2 spectrum (optimized for H^{+})



HV 30kV/2.49mA,, HF 63W,
Plasma hole Ø 4mm

- The experiments have to be completed :
  - Plasma electrode hole reduction (decrease the current)
  - Optimization of medium charge states
  - Emittances measurements
- Installation on the 1+N+ test bench to study the capture of low charge states ion beams

- A copy of the source will be installed on the GeNePI 2 accelerator at LPSC : accelerator based fast neutron source for multipurpose applications (nuclear physics experiments, irradiation platform, neutron detector calibration)
- The permanent magnets being difficult to assembly, a new configuration will be calculated by a trainee (June 2016)

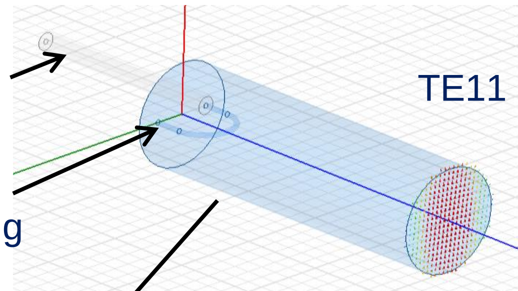
1 - Status of the 5.8GHz – Task 2.2

Version 2 soon

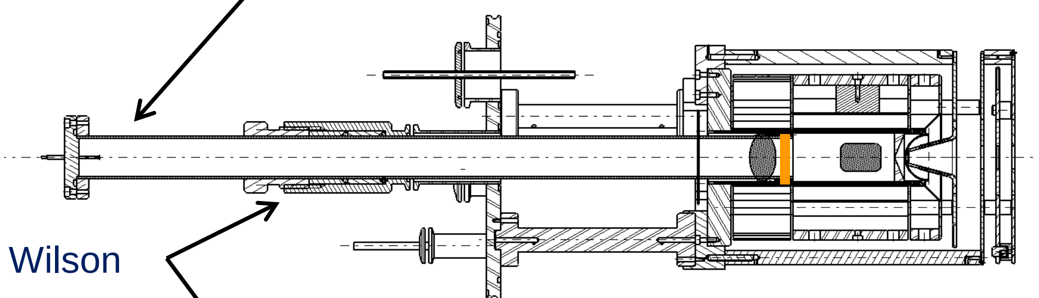
Circular waveguide coupling to :

- Remove the coaxial teflon parts close to the chamber
- Test a new coupling
- Increase the HF power (above 100W)

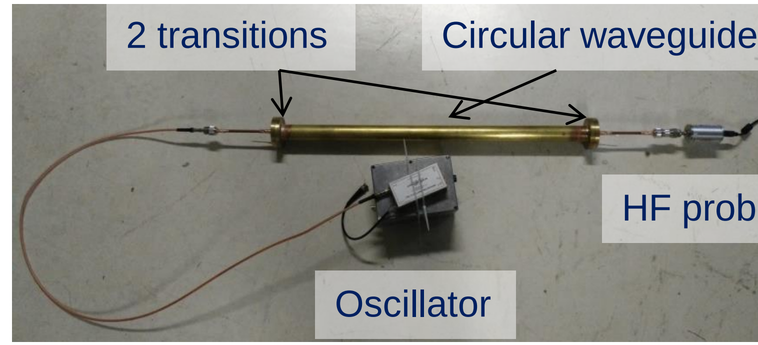
HFSS coaxial to waveguide transition calculation



Transmission = 97%



Coupling test at low level

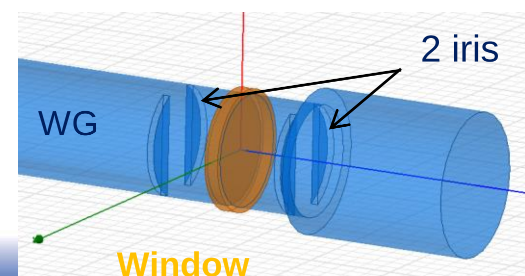


Meas .transmission = 85% with 2 transitions, N connectors … **design validated**

2 configurations:

- Without window (WG under vacuum), parasitic resonances…
- With BN vacuum window ,WG at atm pressure Design of the window with 2 iris

Transmission = 94%



2 – CB experiments on the 1+N+ test bench - Task 4.2

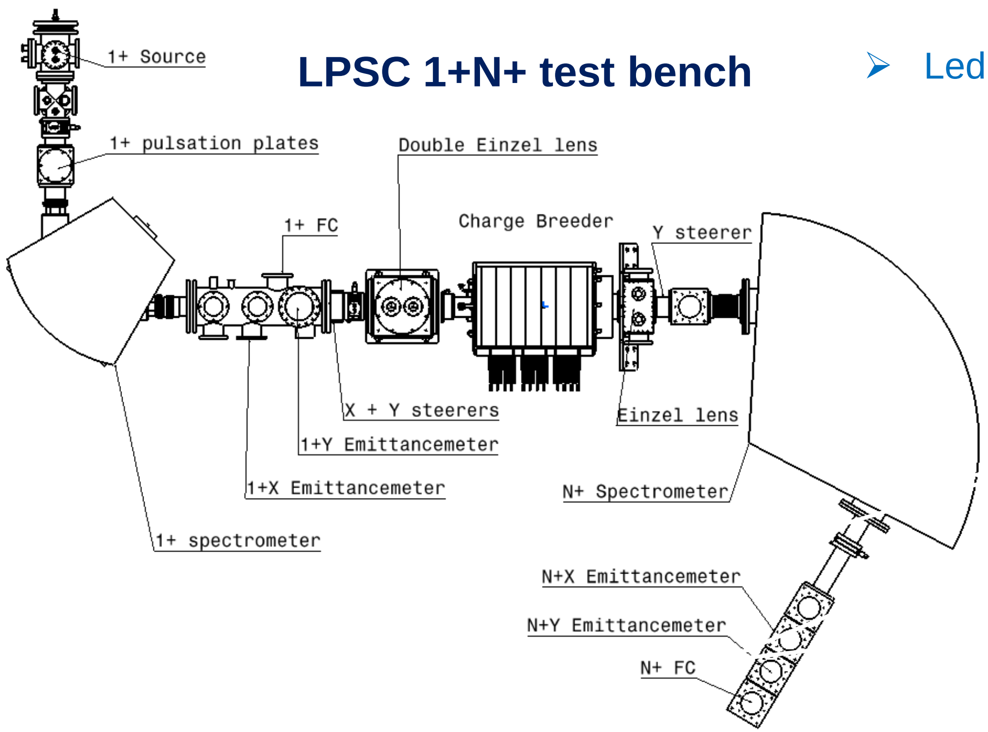
LPSC – SPES and SPIRAL 1 charge breeders experiments
Emilie experiments with the LPSC CB

2013-2014 : 6 weeks of experiments with Ar Na Rb Cs to study the beam capture

For Ar : the COMIC 1+ ion source was used

For Na, Rb, and Cs : 1+ ion gun using thermionic pellets from HeatWave Labs and extraction optics developed at LPSC

LPSC 1+N+ test bench



- ➢ Led to a paper publication in the « PSST » journal

IOP Publishing — Plasma Sources Science and Technology

Plasma Sources Sci. Technol. **24** (2015) 035014 (12pp) — doi:10.1088/0963-0252/24/3/035014

Injected 1+ ion beam as a diagnostics tool of charge breeder ECR ion source plasmas

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CrossMark

Abstract

Charge breeder electron cyclotron resonance ion sources (CB-ECRIS) are used as 1+ → n+ charge multiplication devices of post-accelerated radioactive ion beams. The charge breeding process involves thermalization of the injected 1+ ions with the plasma ions in ion–ion collisions, subsequent ionization by electron impact and extraction of the n+ ions. Charge breeding experiments of ^{85}Rb and ^{133}Cs ion beams with the 14.5 GHz PHOENIX CB-ECRIS

- ➢ Presentation of H. Koivisto just before

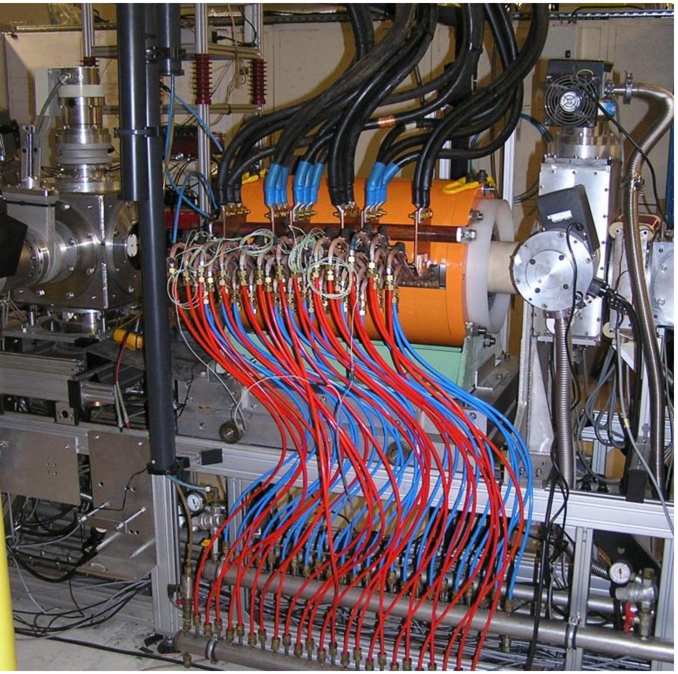
2 – CB experiments on the 1+N+ test bench - Task 4.2

SPES charge breeder

Research collaboration agreement between CNRS and INFN signed in June 2014
For the construction and experimental validation of the SPES project Charge Breeder

- Design based on the LPSC CB
- original hexapole permanent magnet shade no more available : Choice of one close to the LPSC CB
- ➢ The goal was to get the same performances

SPES CB on the 1+N+ test bench



- **Assembly end of 2014 with the LPSC plasma chamber**
- **Installation on the test bench with LPSC electrodes and optics**
- **4 weeks of experiments in March – April 2015**

	Eff (%)	CB Time (ms per charge)
$^{40}Ar^{8+}$	15.2	9.2
$^{85}Rb^{19+}$	7.8	28.5
$^{132}Xe^{20+}$	11.25	16.8
$^{133}Cs^{26+}$	11.7	17.7

- **2H Stability tests, in the range ± 5%**

➢ A. GALATA presentation on Wednesday

2 – CB experiments on the 1+N+ test bench - Task 4.2

Spiral 1 charge breeder

Research collaboration agreement between CNRS and GANIL signed in January 2015
Experiments and qualification of the SPIRAL 1 Charge Breeder on the 1+N+ test bench

- CB : Modified version of the Phoenix CB
- Equiped with SPIRAL1 original design Injection and extraction electrodes and optics

SPIRAL 1 CB on the 1+N+ test bench

- **Installation in April 2015**
- **Experiments between May 2015 and November 2015**
- **Very good efficiencies and fast CB times measured**
- **No double frequency heating experiments (TWTA breakdown)**

  - L. MAUNOURY presentation on Wednesday

3 – LPSC CB future plan - Task 3.1

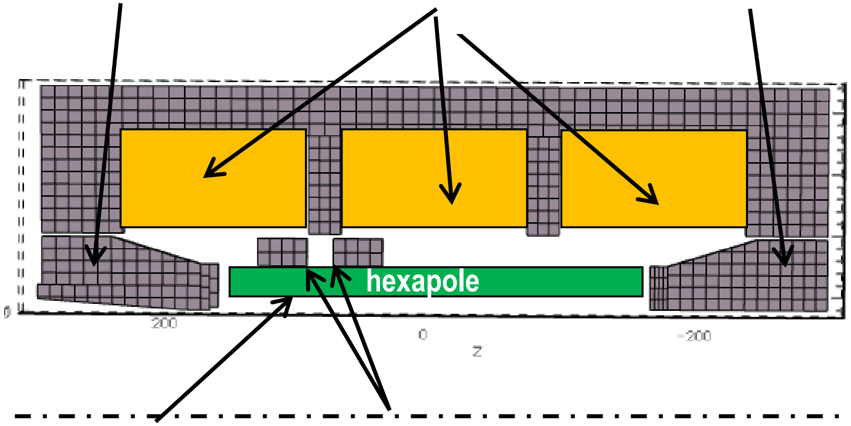
Reproducibility of the PHOENIX CB performances

Present magnetic configuration of the CB

Extraction plug

3 pairs of coils

Injection plug



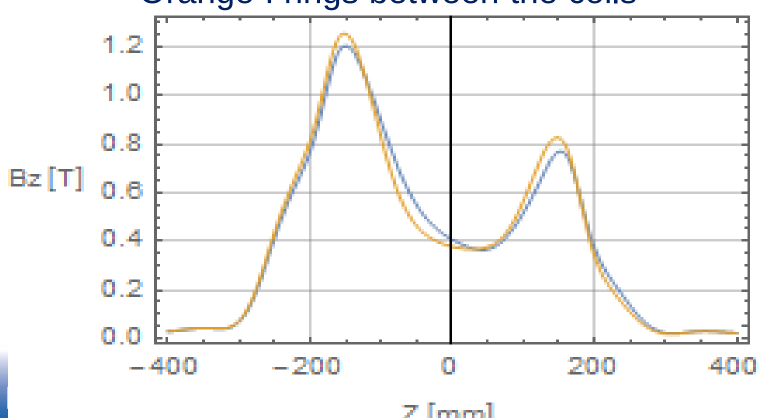
Hexapole 0.8T on plasma chamber wall

2 movable soft iron rings

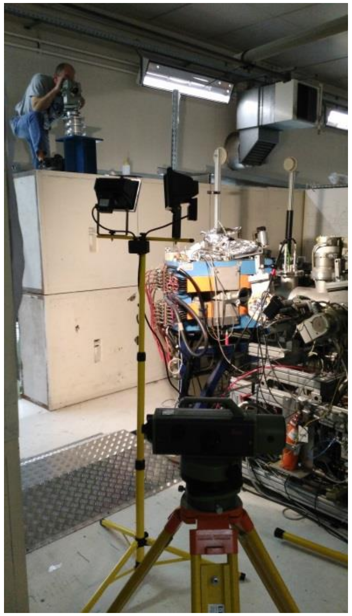
Axial B field 1200/241/634 A

Blue : rings at extraction (picture)

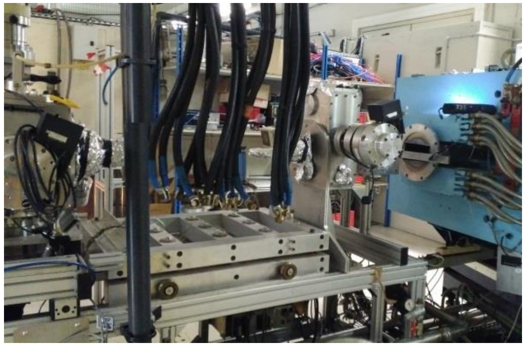
Orange : rings between the coils



Status of the test bench



Injection and extraction vacuum chambers aligned



CB dismounted to allow precise adjustment of new parts

… for step 1

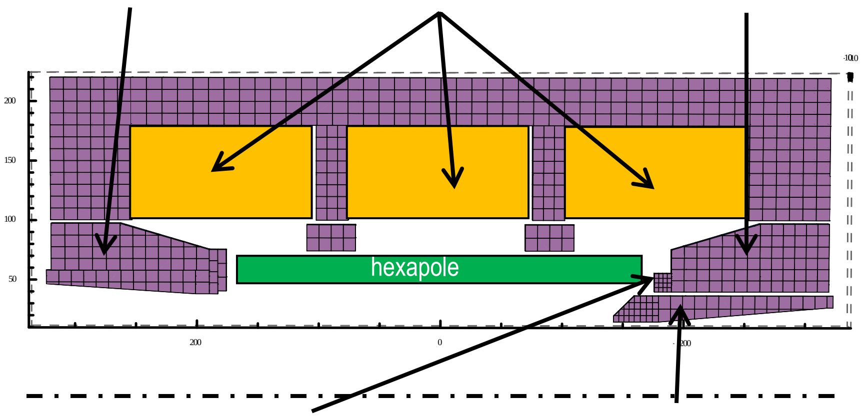
3 – LPSC CB future plan - Task 3.1

Reproducibility of the PHOENIX CB performances

- Step 1 : additional plug under vacuum at injection

Sectional view of the CB magnetic configuration

Extraction plug **3 pairs of coils** **Injection plug**



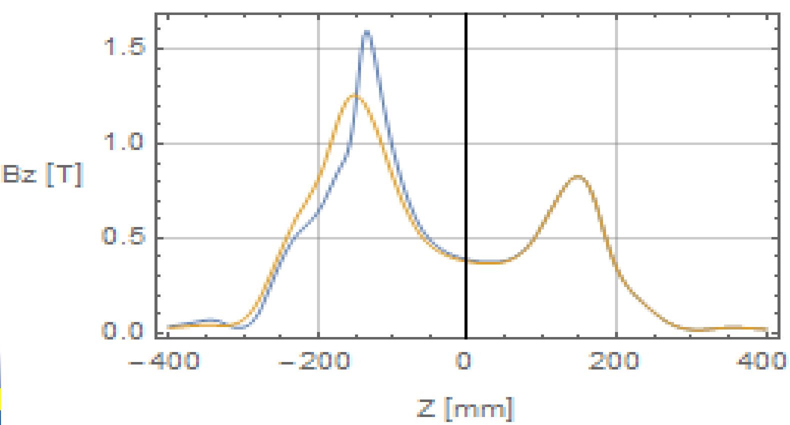
New injection plug end

New additional injection plug inside the plasma chamber

Axial B field 1200/241/634 A

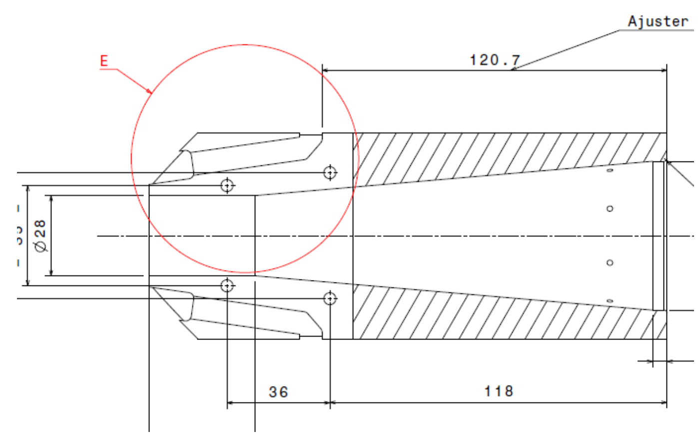
Blue : add of the iron plug under vacuum

Orange : present configuration



Benefits

- Increase of the axial magnetic field at injection (1.2 to 1.6T)
  - ➢ increase the field gradient and the mirror ratio
    - ➢ Improve the ions confinement
    - ➢ reduce the ion leak rate on the injection side
- Redirect the waveguide toward the plasma
- Study of the soft iron rings axial position around the hexapole on the 1+N+ yield (=> B gradient modification)



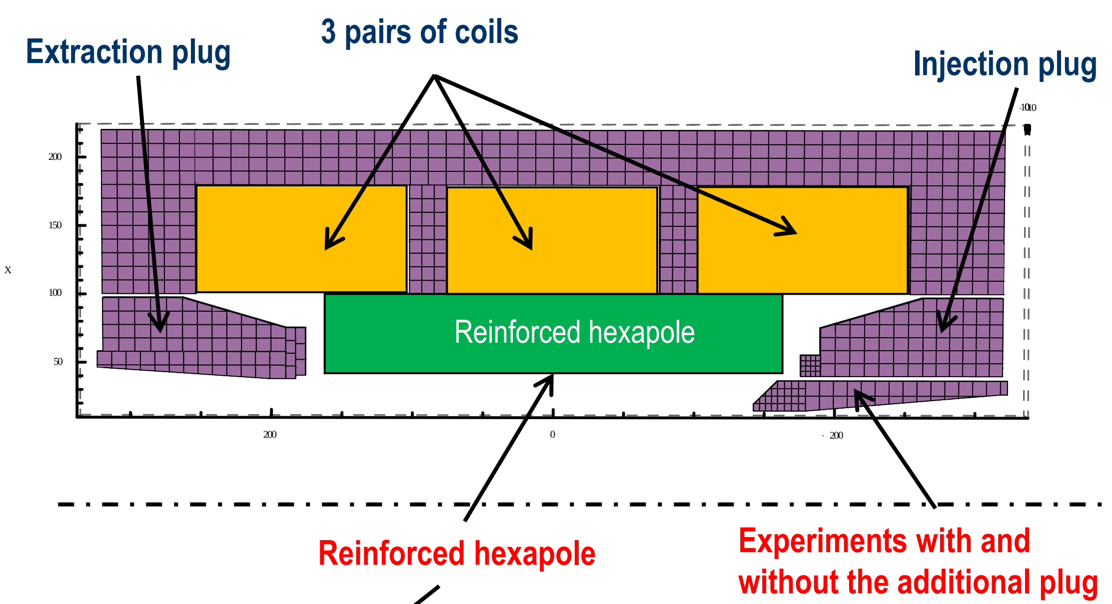
- **The parts are designed and ordered**
- **Experiments by July 2016**

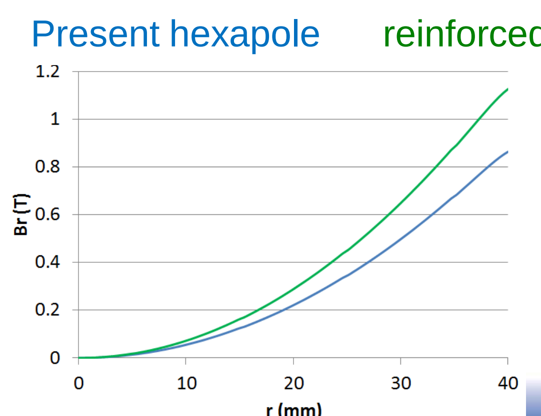
3 – LPSC CB future plan - Task 3.1

Reproducibility of the PHOENIX CB performances

- Step 2 : reinforced hexapole

Sectional view of the CB magnetic configuration





Modifications

- Mounting of a reinforced hexapole (0.8 T → 1.0 T at plasma chamber wall)
- Use of an existing reinforced hexapole ready to be assembled in the CB

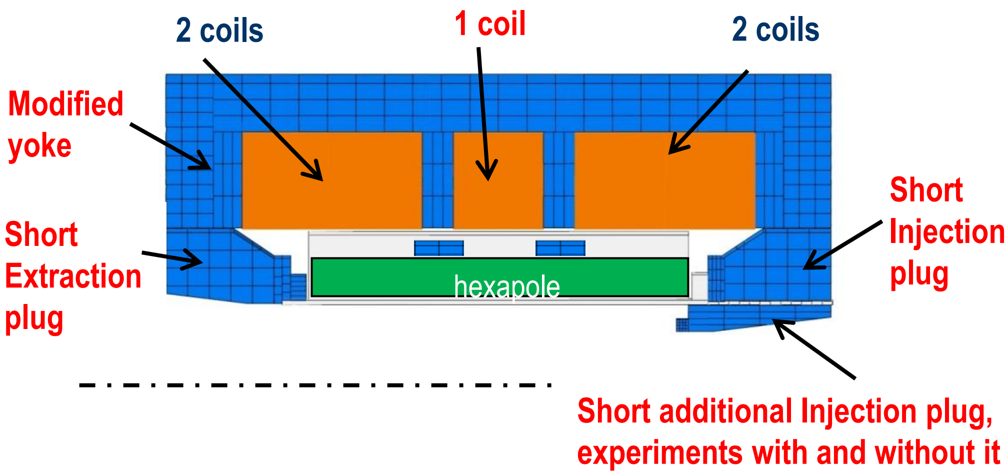
Benefits

- Radial confinement improvement
- Possibly 18GHz experiments

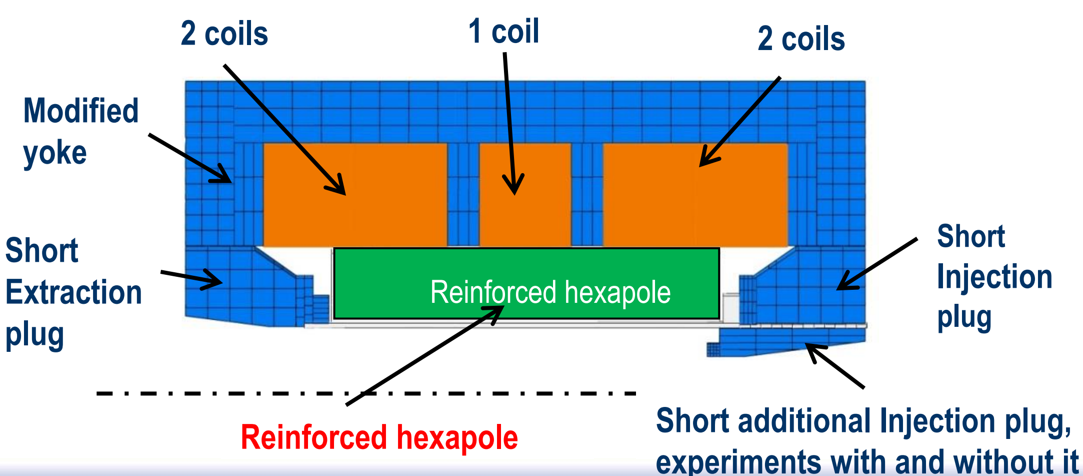
- **Experiments planned in September 2016**

Reproducibility of the PHOENIX CB performances

- Step 3 : modified yoke + coils configuration



- Step 4 : with the reinforced hexapole



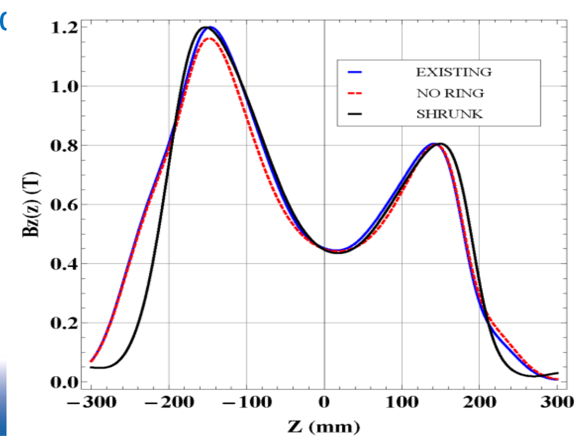
Modification of the coils and the yoke, like done on the Phoenix V2 ion source

Modifications :

- Removal of a central coil,
- central iron rings thickness increased
- extremity iron rings thickness decreased
- plugs length reduction

Benefits

- Reduction of the coils coupling :
  - ➢ ease of tuning
- CB length reduction (-80mm) :
  - ➢ should improve the injection and extraction of ions
- Keep a high mirror ratio and field gradient (with the additional injection plug)
- Possibility to mimic the existing axial magnetic fiel

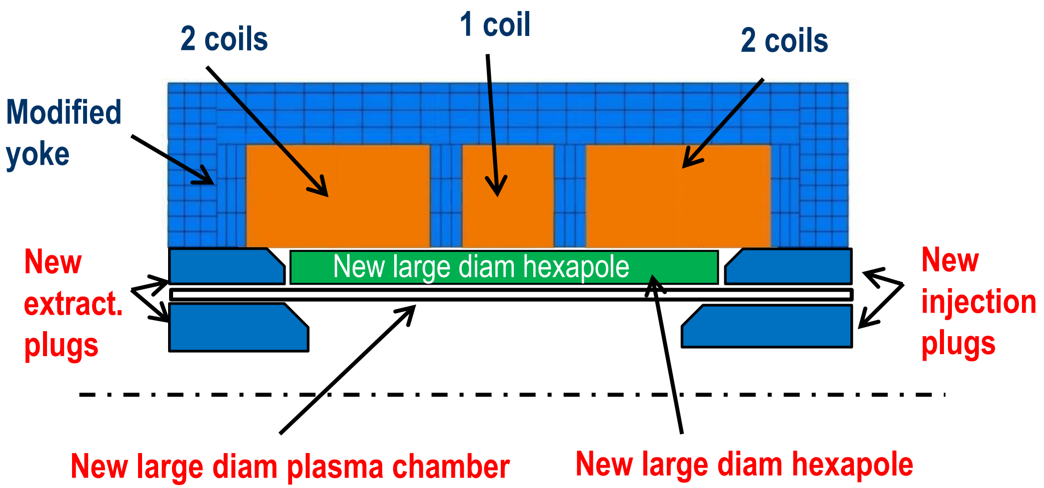


3 – LPSC CB future plan - Task 3.1

Reproducibility of the PHOENIX CB performances

- Step 5 : increase the plasma chamber volume

Sectional view of the CB magnetic configuration



Modification

- New large internal diameter hexapole (1.1T on plasma chamber wall Ø~90 mm)
- New large internal diameter plasma chamber

Benefits

- Plasma volume increase
- Higher ion confinement time, higher charge states, lower operating pressure

Hexapole calculation in spring

Order of permanent magnets in 2016

Thank you for your attention