



Beta Beams,
EUROnu WP4



60GHz Ion Source

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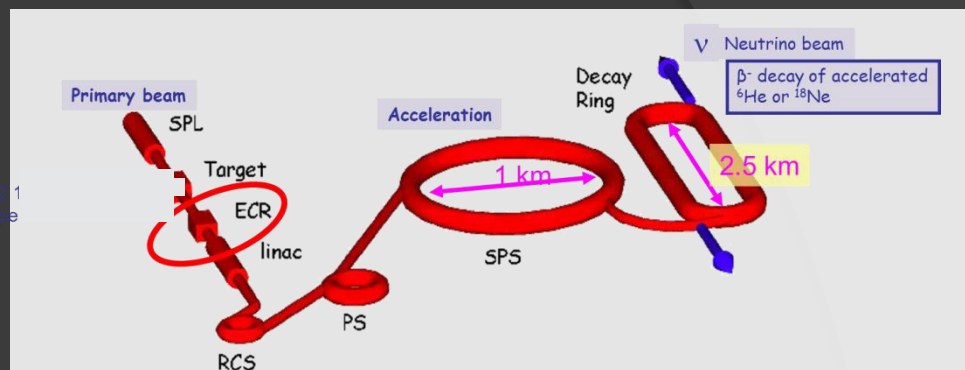
V. Zorin, I. Isotov, V. Skalyga

60 GHz Ion Source initial context

- ◎ LPSC participated to EURISOL Task 9 ‘Beam preparation’
 - EURISOL and Euronu overlap during the first year
 - Ion source Euronu R&D is (has been) the continuation of EURISOL one

60 GHz Ion Source Challenges

- 5 10^{13} atoms. s^{-1} from the target (cw)
 - 100 % ionization efficiency
 - RCS cycle 10 Hz – 50 μs
- 16 mA ${}^6\text{He}^+$ bunches to be extracted every 100 ms



- P. sortais suggested to use a 60 GHz ECR ion source (Moriond 2003)
 - Present highest frequency for an efficient 'minimum B' ECR ion source : 28 GHz ($B_{\text{ecr}} = 1\text{T}$)

ECR scaling laws

$$B_{\text{inj}} \approx 4 * B_{\text{ECR}}$$

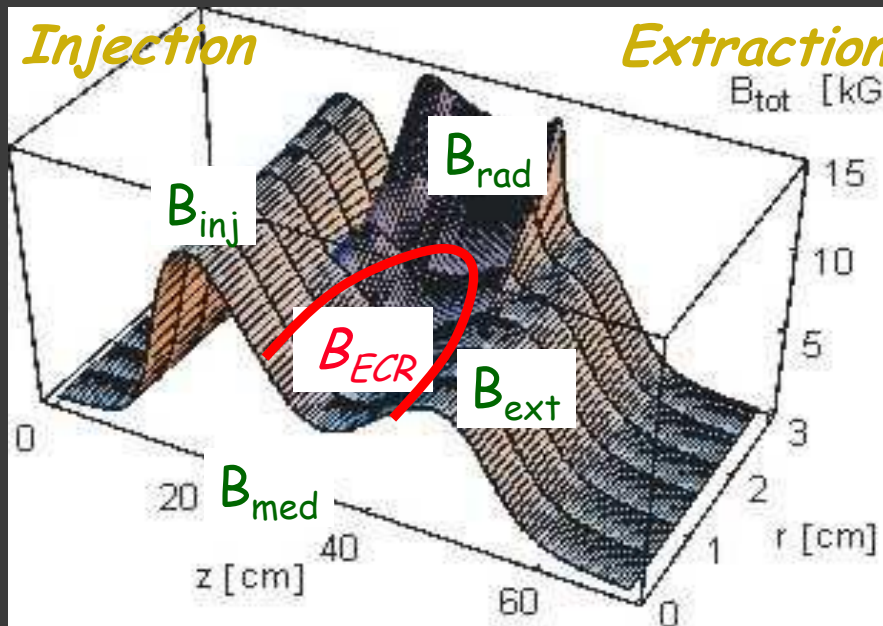
$$B_{\text{rad}} \approx 2 * B_{\text{ECR}}$$

$$B_{\text{med}} \approx 0.6 B_{\text{ECR}}$$

$$B_{\text{ext}} \approx 0.9 B_{\text{rad}}$$

28 GHz

fully superconducting sources



60 GHz

$$B_{\text{inj}} \approx 8.6 \text{ T}$$

$$B_{\text{rad}} \approx 4.3 \text{ T}$$

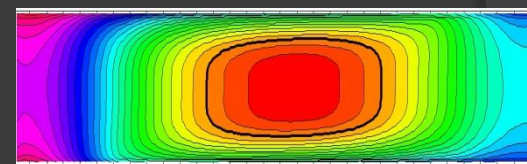
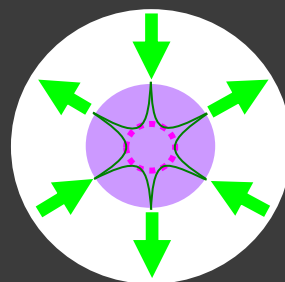
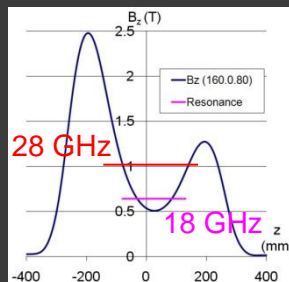
$$B_{\text{med}} \approx 1.3 \text{ T}$$

$$B_{\text{ext}} \approx 1.9 \text{ T}$$

Presently
'impossible'
to build...!

60 GHz Ion Source Strategy

- Objective : to design and build the first 60 GHz ion source prototype
 - Not possible with superconductors : technical and financial limitations (a 28 GHz source costs about 8M€)
- Strategy
 - Minimum B source : ultimate objective



$$\omega_{ce} = q_e B / M_e = \omega_{HF}$$

B axial

+

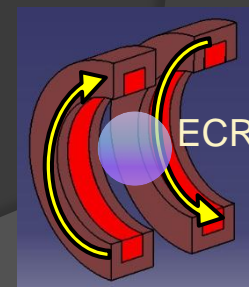
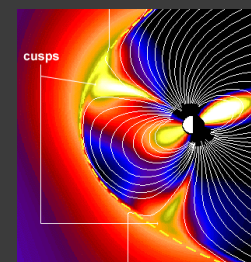
B radial

=

Minimum B

- First objective

- Cusp ion source with closed 2.14 T ECR zone

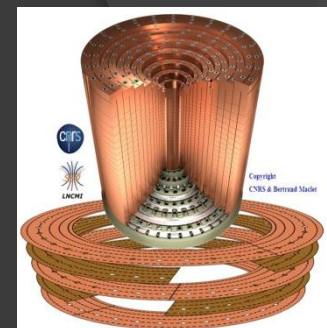


- There is no 60 GHz gyrotron in the world for ion sources

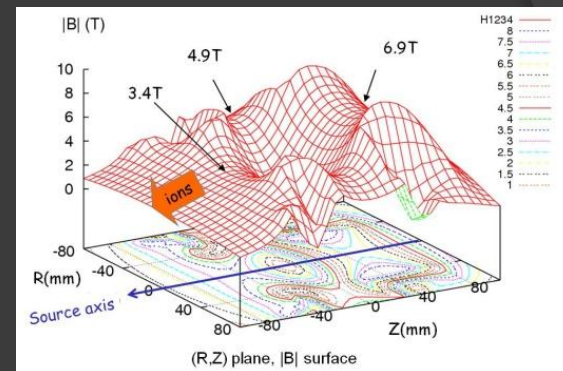
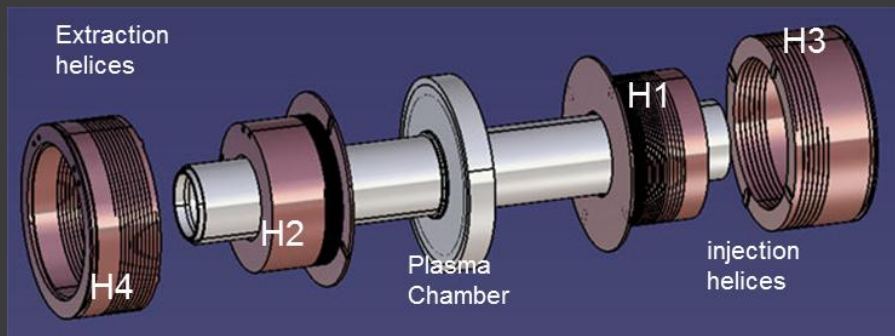
- Find the funding and build one

Euronu 60 GHz Ion Source context

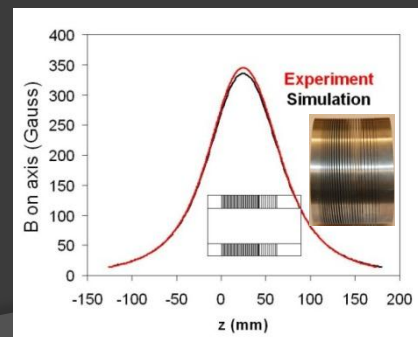
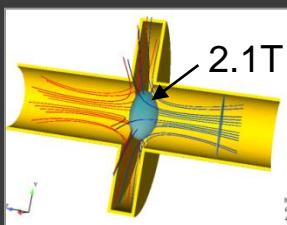
- Decisions and context to satisfy the strategy
 - Apply high field magnets technologies to ECR ion source
 - ✓ Radially cooled Helix technique
 - Develop and fund a collaboration with gyrotron specialists
- Activities in a collaborative context
 - National Laboratory for intense magnetic fields
(LNCMI) Grenoble
 - Institute of Applied Physics
(IAP) Russian Academy of Science Nizhniy Novgorod
- For the experimental program important funding required
 - ✓ Use remaining funds from EURISOL for the source
 - ✓ Establish an ISTC project with IAP for a 60 GHz gyrotron



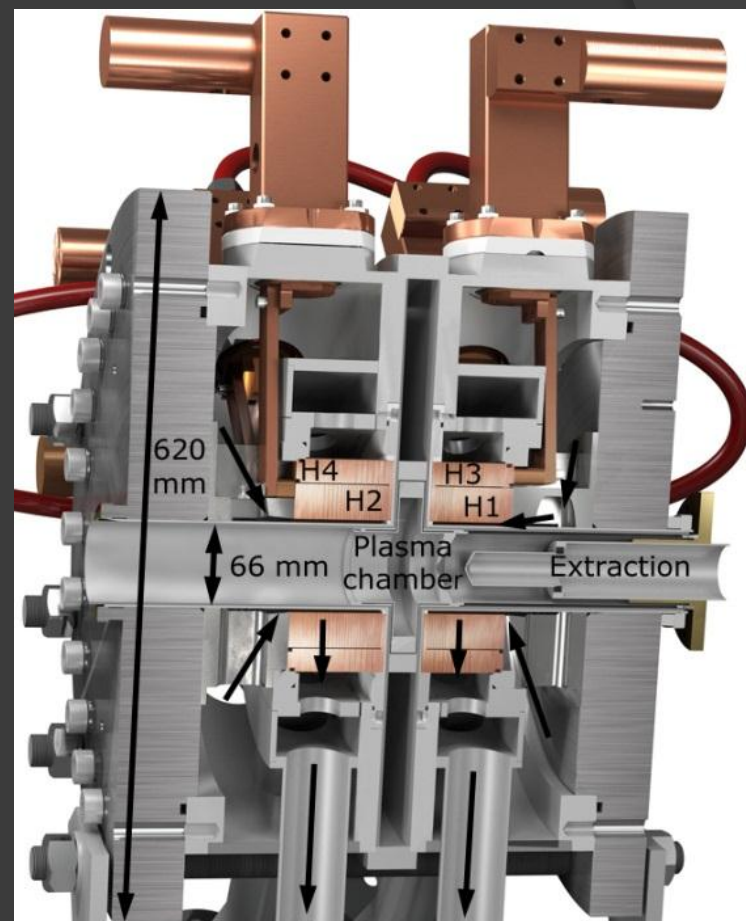
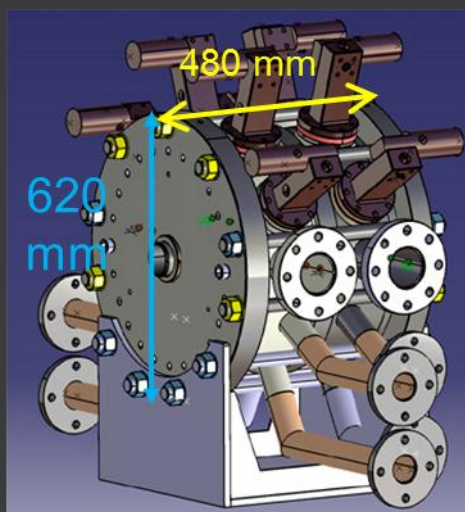
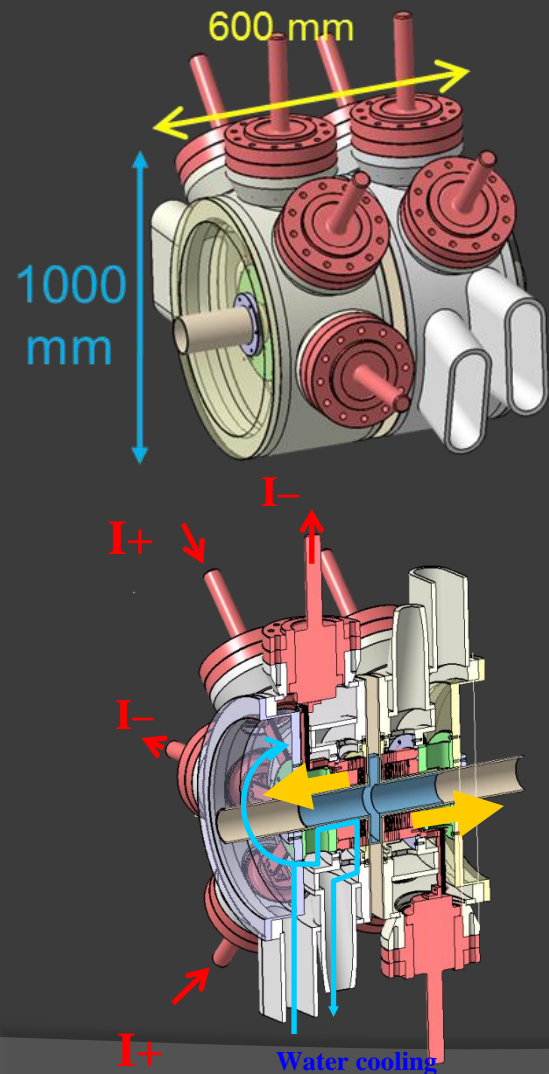
○ Magnetic simulations, experimental validation



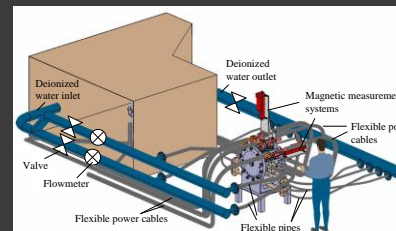
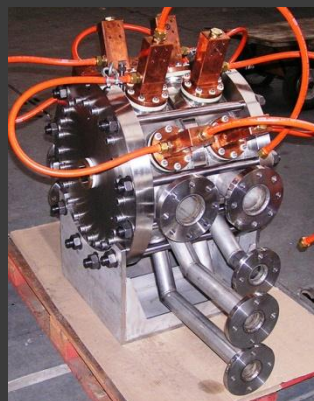
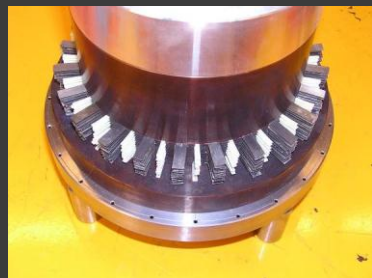
- Use of radially cooled Helix technique to ECR ion source
- Intensive use of numerical modeling
- Compact design
- Short time between design and prototype construction



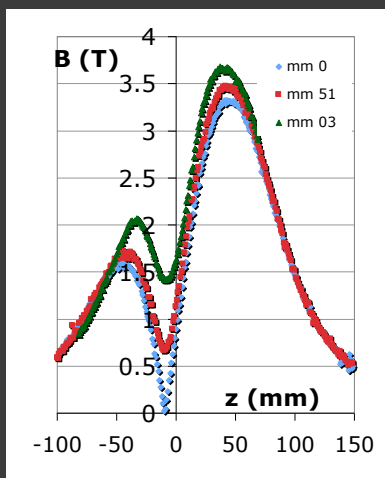
- Mechanical design and optimization of the magnetic structure prototype



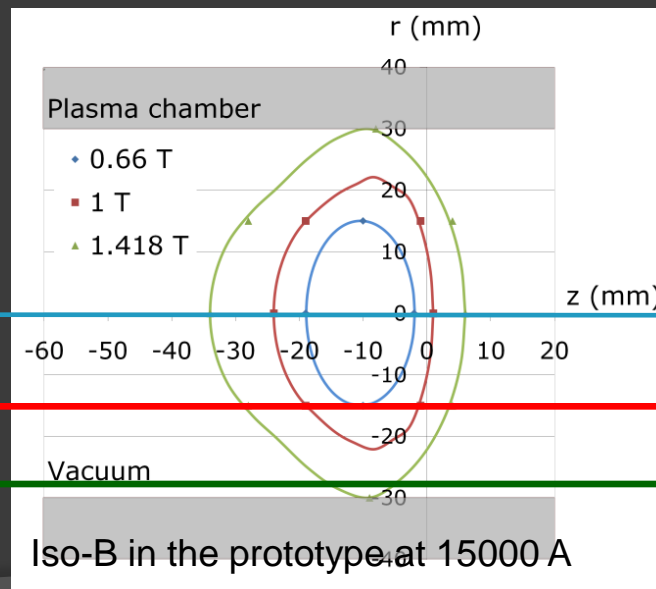
- Magnetic field structure prototype construction and installation on the M5 LNCMI site



- Magnetic field measurements from 1500 up to 15000 A



Magnetic field along 3 axis at 15000 A

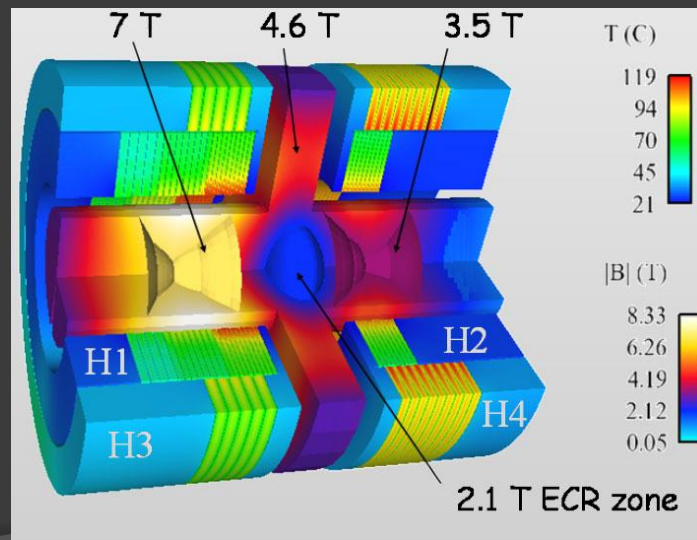
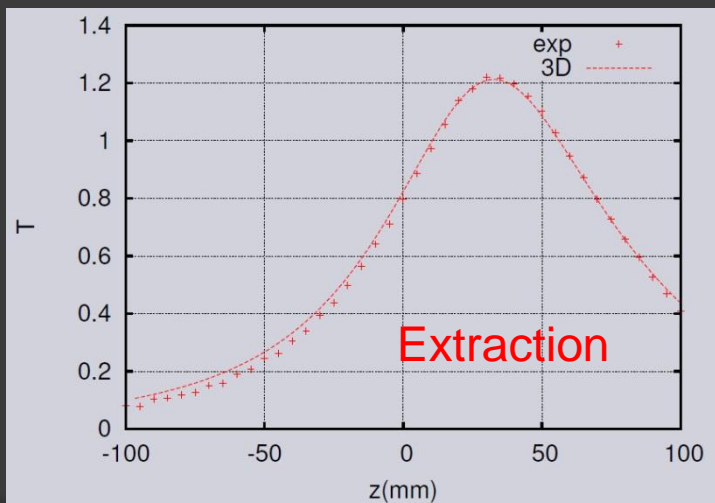
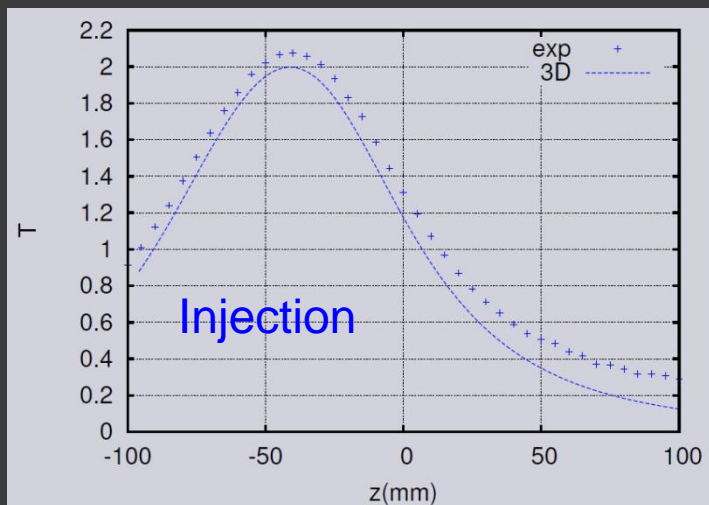


Iso-B in the prototype at 15000 A

Prototype axis

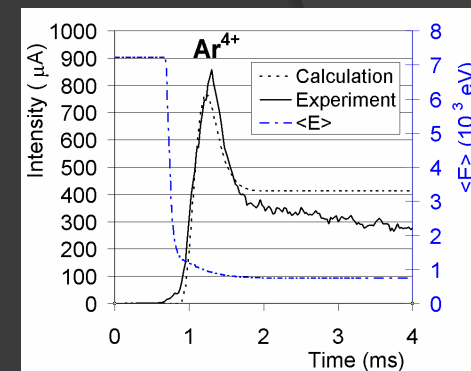
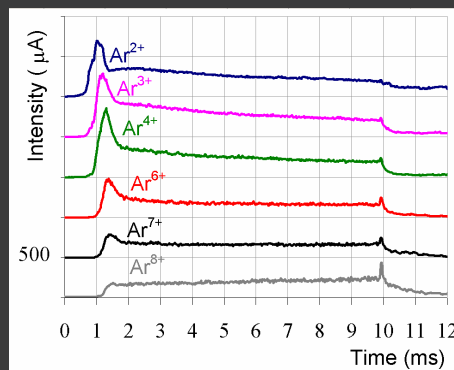
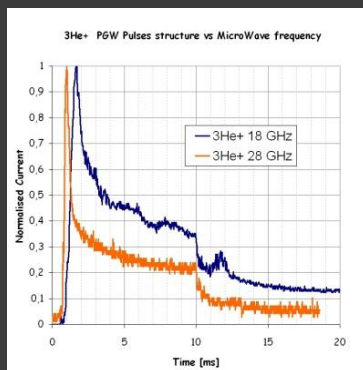
○ Magnetic field profile : experiments-simulations mismatch

- Due to thermal behavior of helices mechanical positioning, ...?
- Improve the reliability of our model (error estimation)
- Improve the performance (parametric studies)



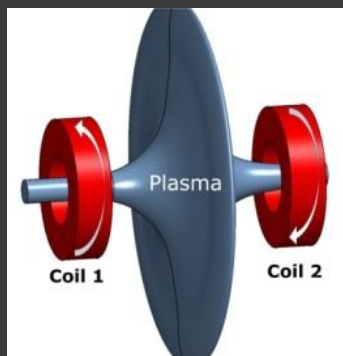
- Experimental preglow studies in a 'Min B' source (PHOENIX V2) at 18 and 28 GHz

Preglow Efficiency About 10 to 30 %



60GHz Ion source : to be done (short term)

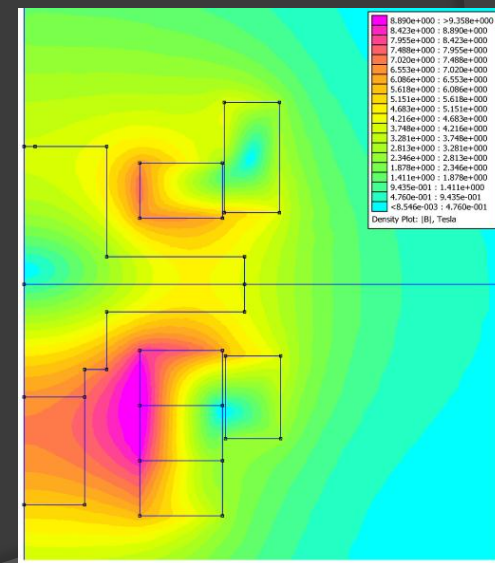
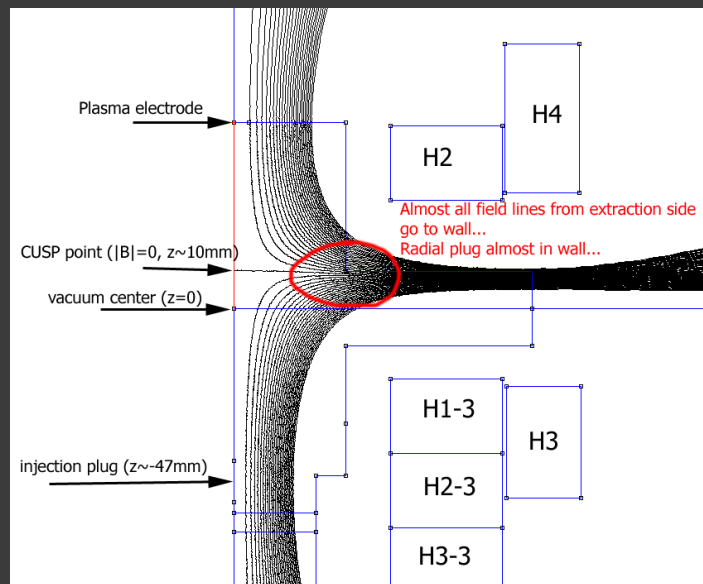
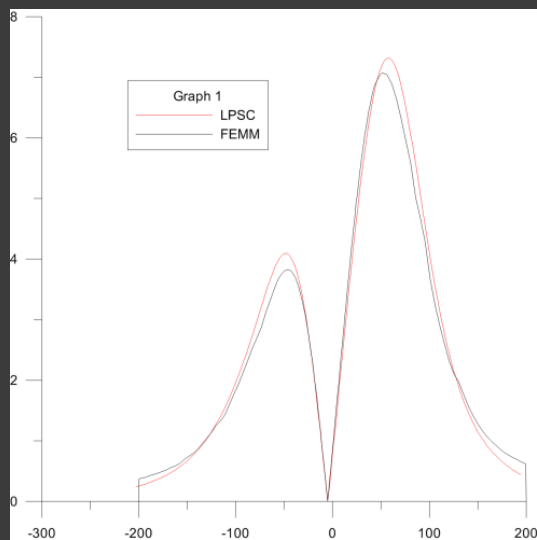
- Experimental results have to be evaluated in the CUSP configuration



- Highest magnetic field cusp with a closed ECR zone
- 28 then 60 GHz experiments
- Experiment accepted for 20 days
 - Shifted from May to July (LNCMI PS failure...)
 - We just finalized the safety document

60 GHz launch under design (Yvan Isotov IAP-RAS Nizhny Novgorod)

- Evaluation of the consequences of the 9 mm experimental shift from center
- Measurements performed with the same current in all helices
- Slight unbalanced intensities should shift back the null value at the center



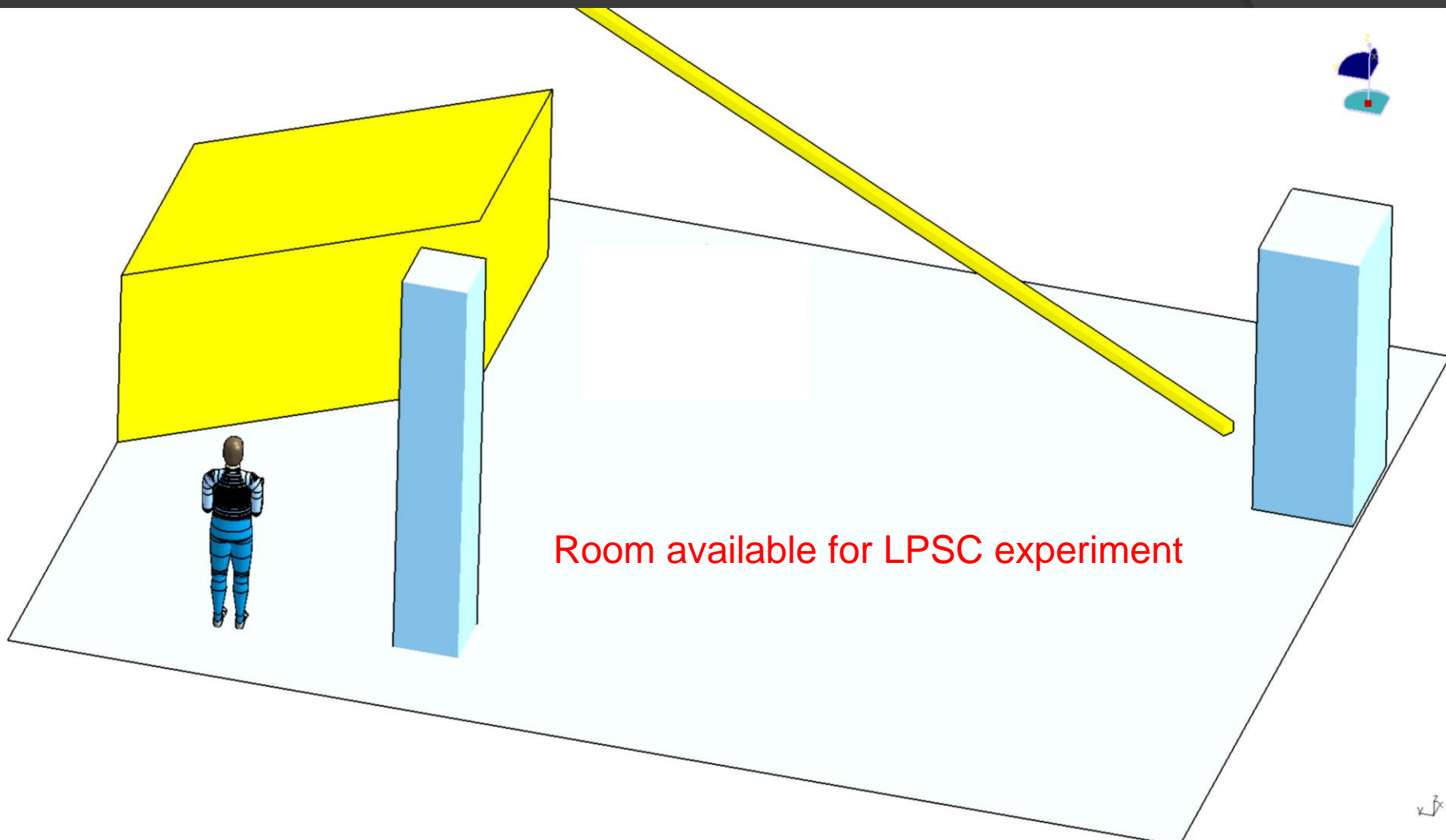
Previous experiment : M5



A new dedicated room : M3

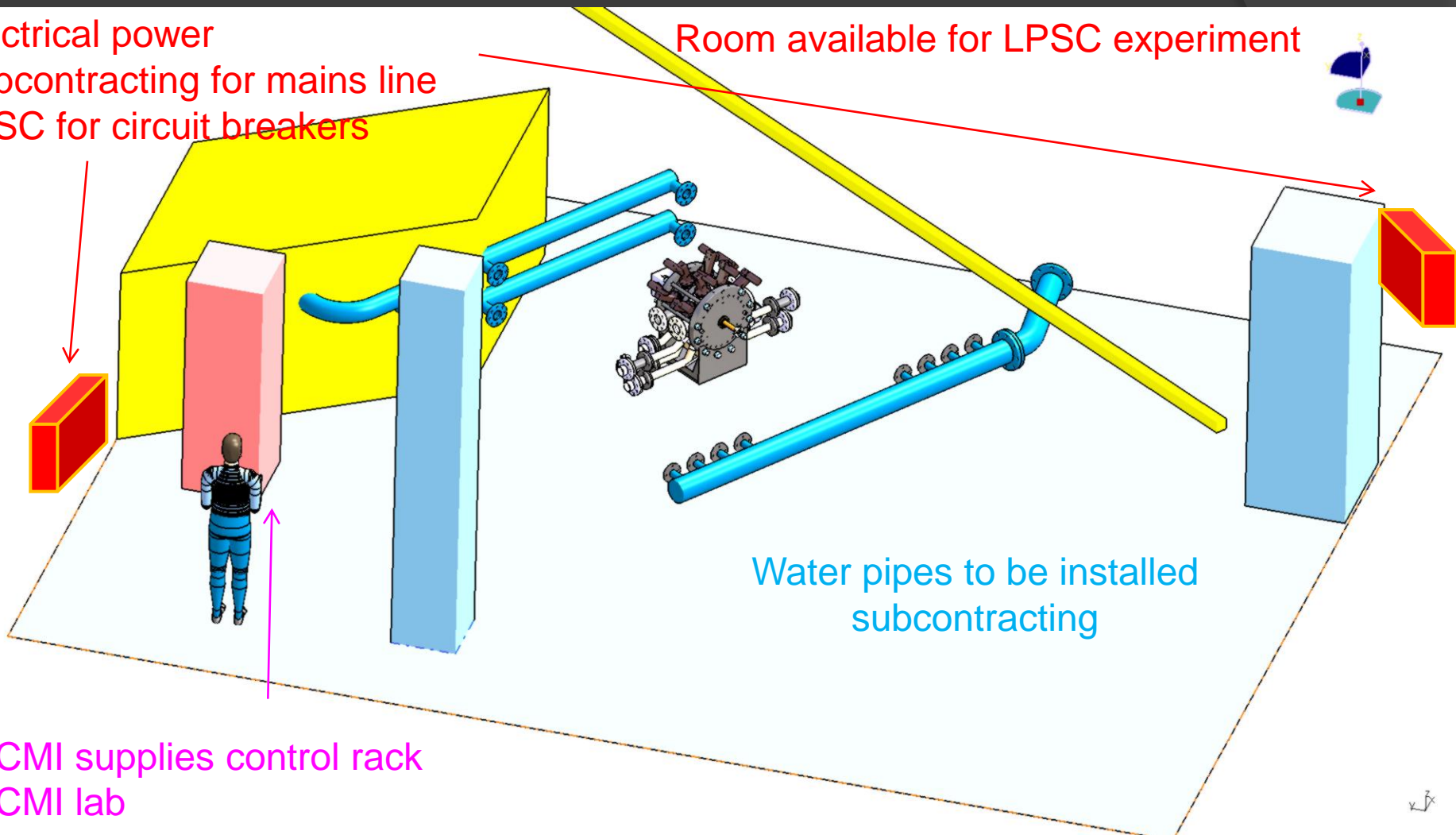


Former cooling circuit has to be reinstalled on the new site



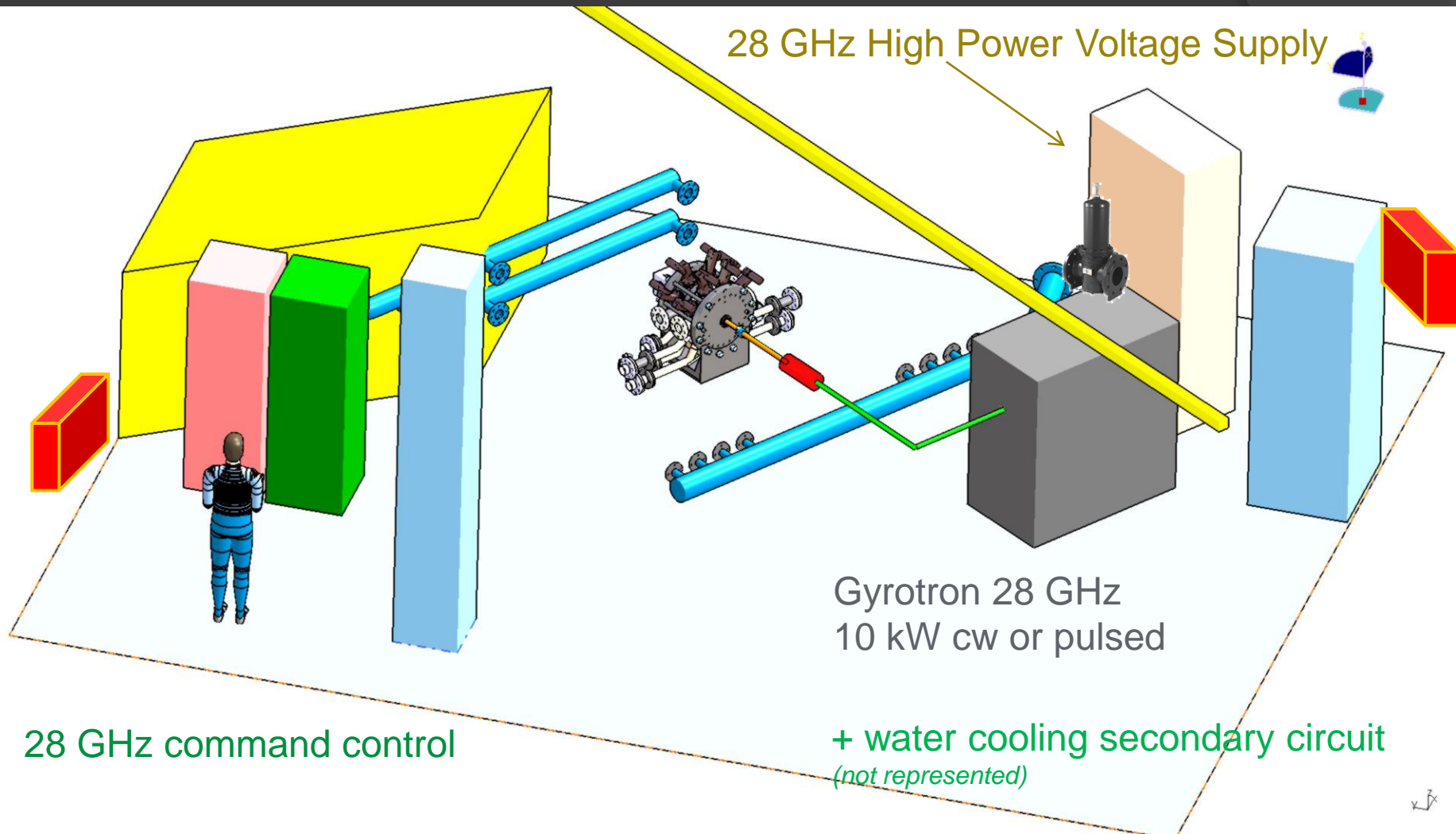
Electrical power
Subcontracting for mains line
LPSC for circuit breakers

Room available for LPSC experiment

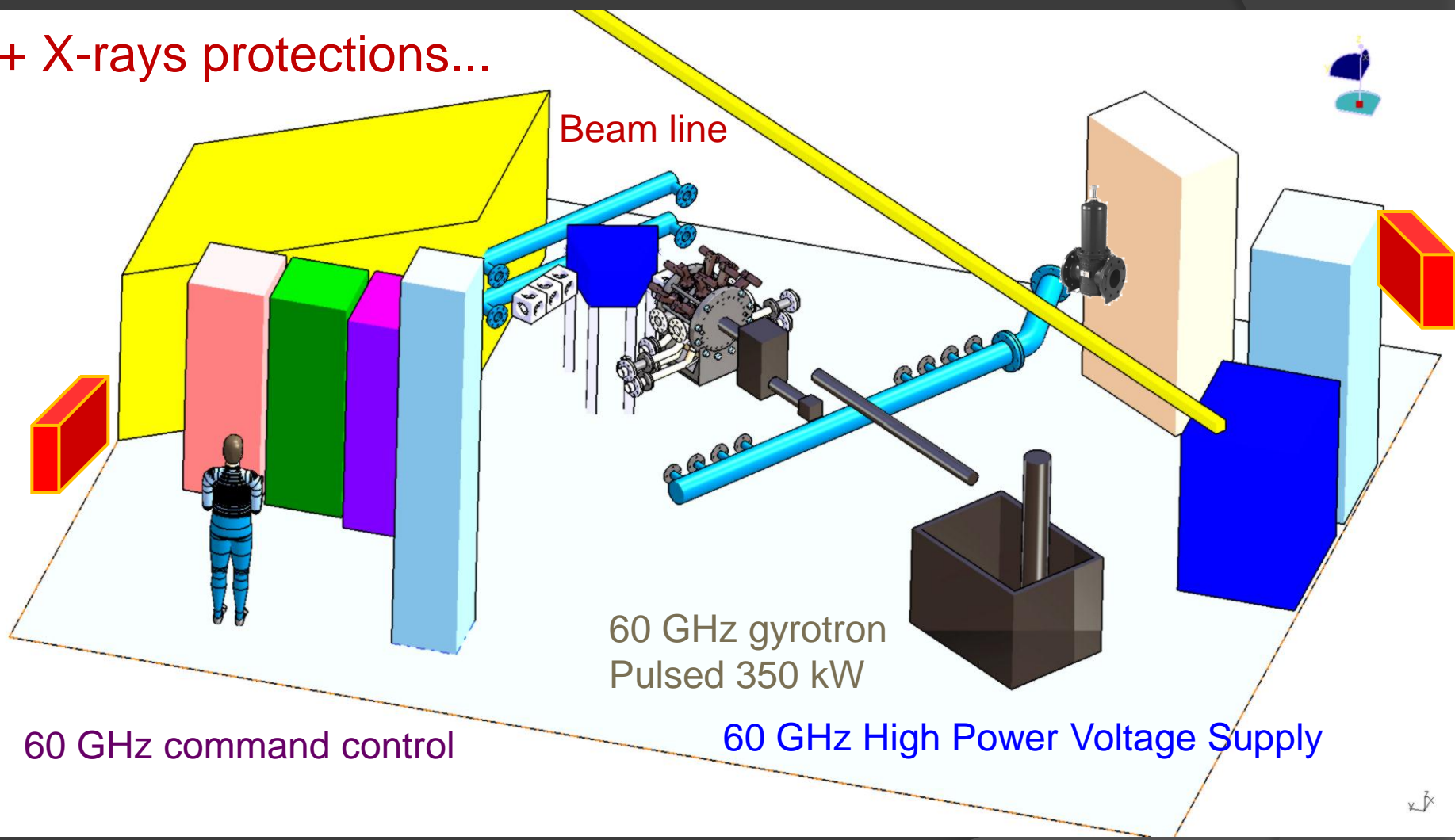


Water pipes to be installed
subcontracting

LNCMI supplies control rack
LNCMI lab



+ X-rays protections...



Beam line

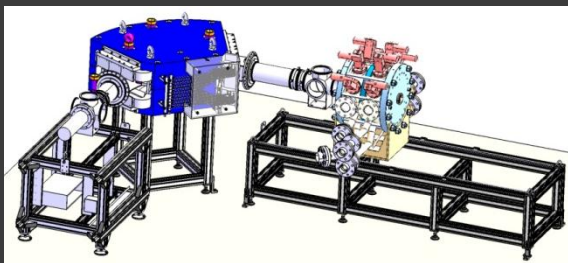
60 GHz gyrotron
Pulsed 350 kW

60 GHz command control

60 GHz High Power Voltage Supply

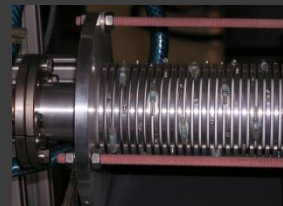
Internal parts of the source to be installed in 2 weeks

- The source will be a VERY HIGH intensity ion source
 - So High intensity beam line necessary (2 tons spectrometer)
 - Construction almost finished



- Not presently installable at LNCMI due to the low resistance of the concrete slab...

- A lighter LPSC magnet to be used (back from ISOLDE)



A 60 kV DC breaker copy under construction



A 28 GHz HF window ordered to GYCOM (> 6000 €...) Not delivered yet...

- LPSC 28 ghz Gyrotron failure
 - 28 GHz Gyrotron removed from LPSC experimental hall

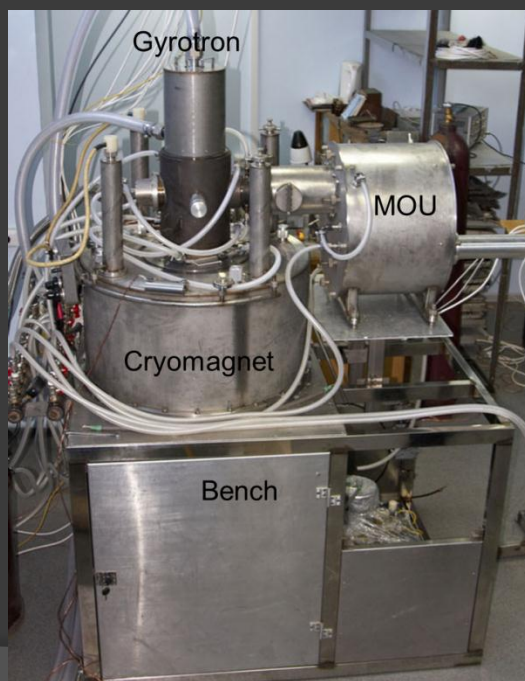
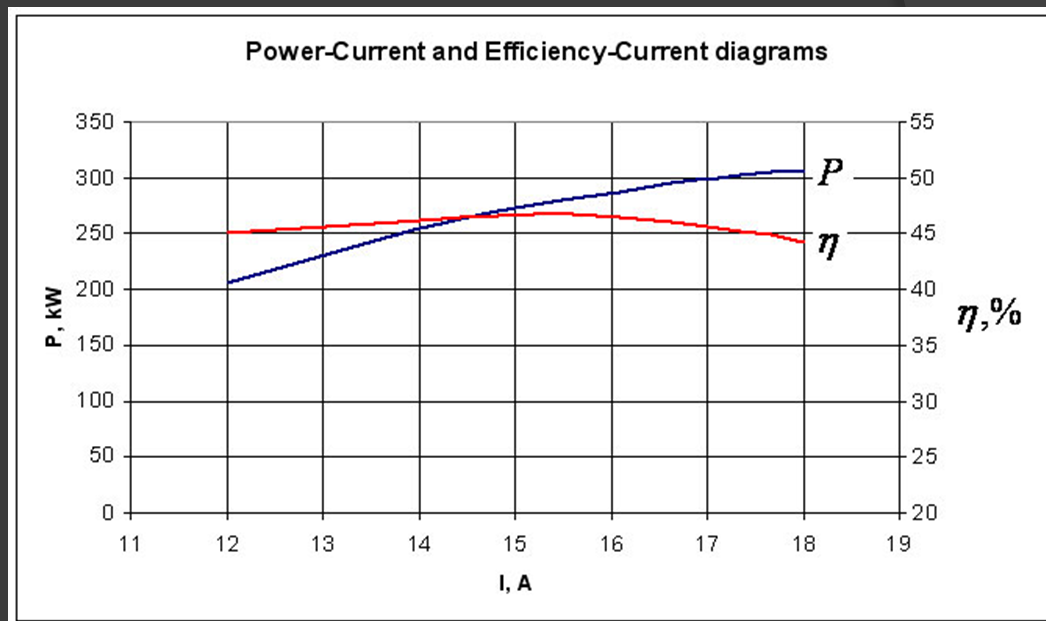


- Has to be reinstalled at LNCMI then repaired with GYCOM Ru support

60 GHz gyrotron
(Gycom Ltd, Nizhny Novgorod, Russia)

2010-2012 ISTC project #3965
(225 k€ LPSC - CNRS + 490 k€ EU)

- Should have been delivered March 2011... Assembly finished end of May
- Tests have just begun)
- Deliver July, August...Customs...?



Ion source

Additional research needed

Time scales for a realistic implementation

- ⊙ Perform as soon as possible the experiments at 28 and 60 GHz !!

- ⊙ After the first experiments taking place in July, or August-September
 - **Modify (improve) the magnetic structure**
 - 6 months
 - **Possibly to add a strong radial component (for a minimum B ECRIS)**
 - 1 year
 - **Design and Construction**
 - 10 months
 - **Commissioning** (depends on the availability of high current supplies, a pulsed power supply may be installed at LPSC)
 - 9 month
 - **Project (necessity...)** : a joint PhD between LPSC (IN2P3) and LNCMI (INP)

- ⊙ **Time scale for realistic implementation : 3 years**

But there is work for more than 10 years in the ECR ion source science...

2006:

ANR ECR60 for gyrotron and prototypes constructions 1 M€ *unfortunately not accepted*

2009

For gyrotron construction

ISTC project #3965 (225 k€ CNRS + 490 k€ EU) *Success !!*

2010:

CePIT Equipex project submitted by F. Debray LNCMI and T. Lamy LPSC)

Dense plasmas, intense ion beams, CW intense THz radiation – 6.5 M€

unfortunately not accepted

2011:

COLOSSECRIS Equipex project submitted by T. Lamy

4 laboratories (LPSC, GANIL, LNCMI, IPNL)

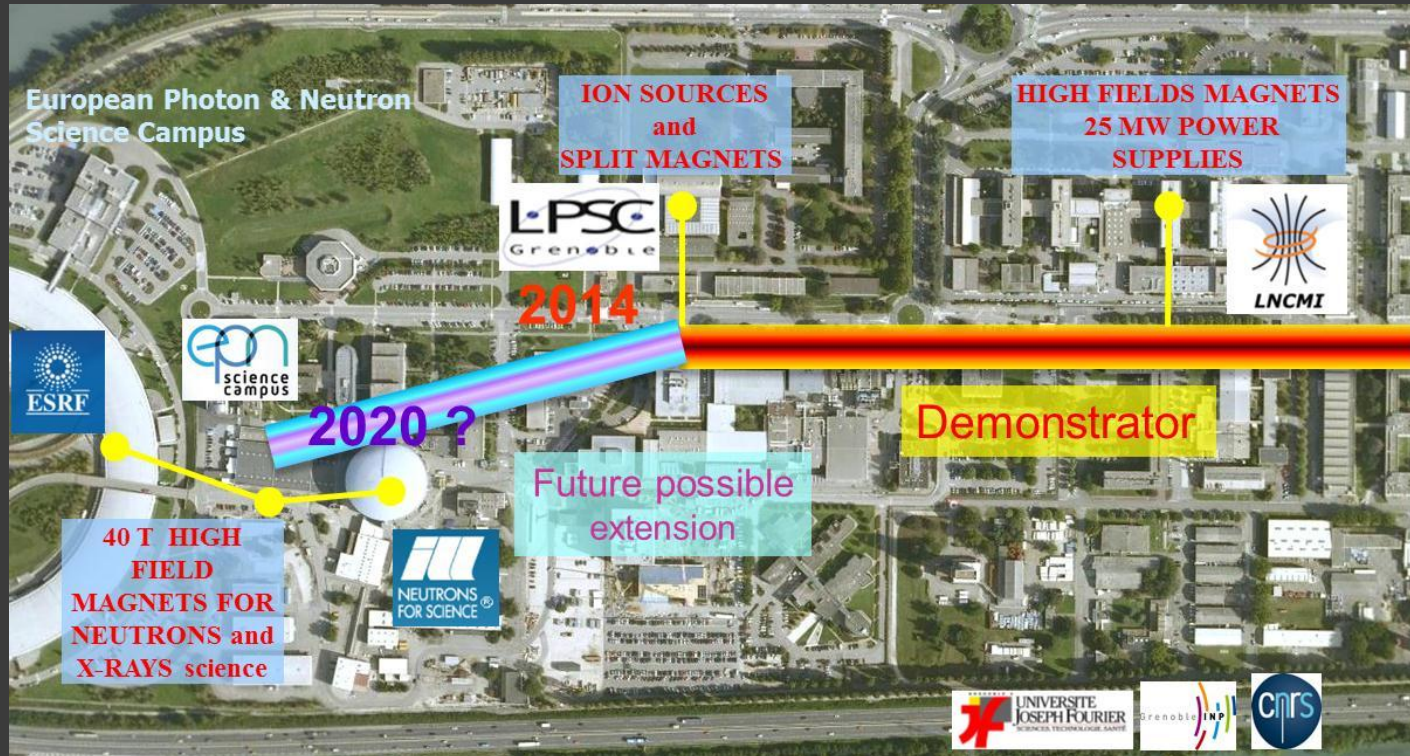
for the intense magnetic fields applications (X-rays, neutrons, ion sources ...) – 12 M€

unfortunately not accepted

But under strong reactivation...

COLOSSECRIS LNCMI + LPSC +(ESRF + ILL) ?

(4*15000 A) allowing future 28 and 60 GHz ion sources R&D, experimental studies on split magnets for ESRF and ILL



2 cryostats 600 meters long
Diameter PHI 163 mm

