XIXth International Workshop on ECR Ion Sources

ECRIS 2010

LPSC Grenoble, France, August 23 – 26, 2010

Measurement of the SEISM

(**S**ixty GHz **E**CR **I**on **S**ource using **M**egawatt Magnets)

magnetic field map

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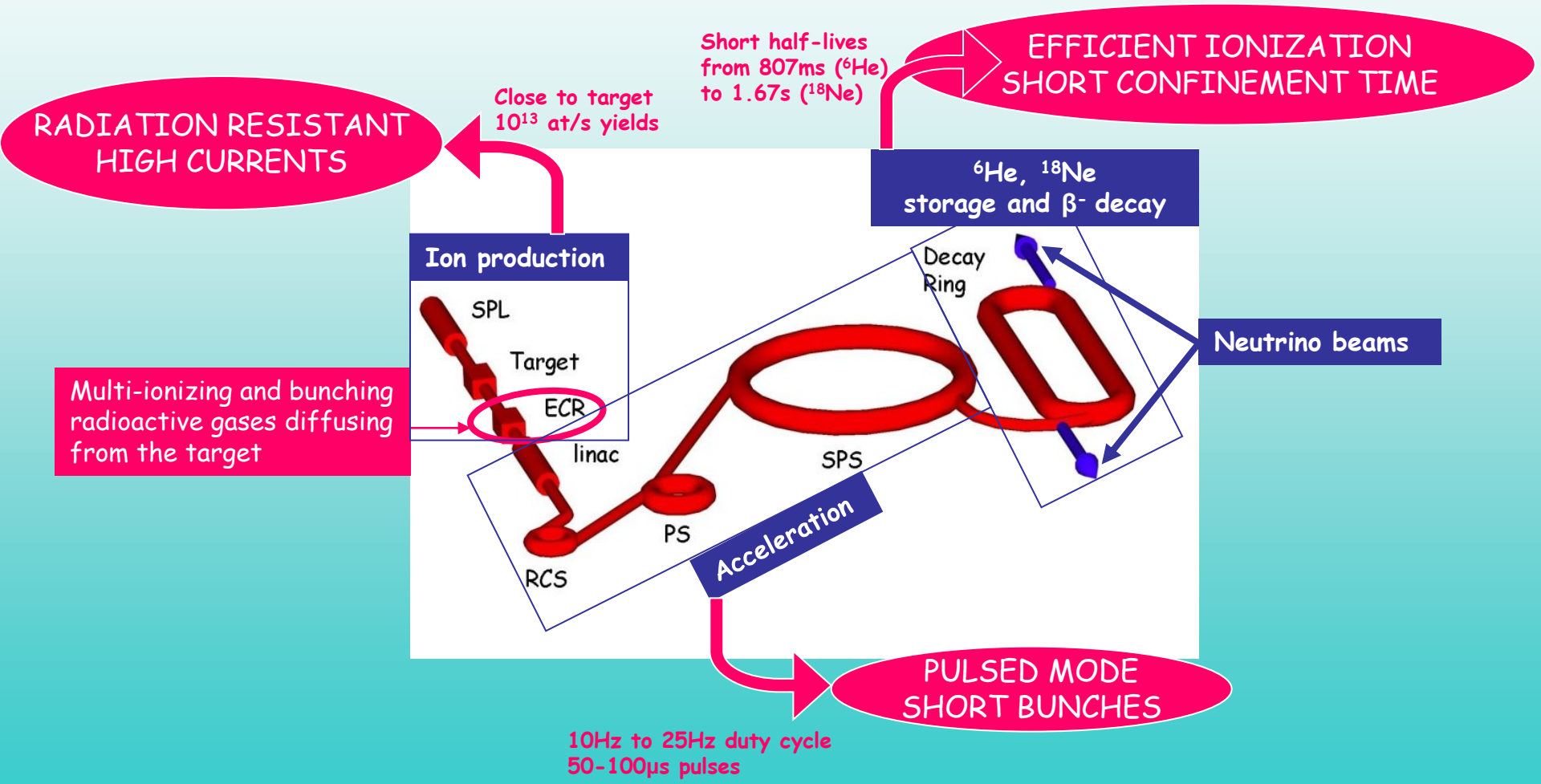
Outline

- Why a 60GHz prototype ?
- Results of the design study
- Technical challenges of fabrication
- Magnetic field measurements
- What next ?

Why a 60GHz prototype ? (1)

For the beta-beam project

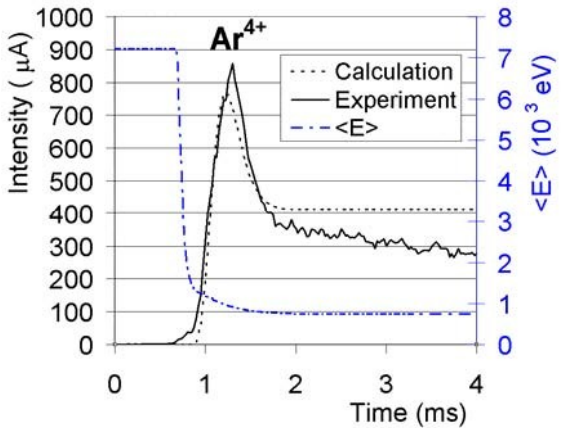


Why a 60GHz prototype ? (2)

What kind of prototype

Origins of 60GHz project: presentation by P. Sortais in Moriond - Les Arcs, March 17-22, 2003

PULSED MODE SHORT CONFINEMENT TIME	HIGH CURRENTS SHORT BUNCHES	RADIATION RESISTANT Compact (combined to target)
PREGLOW MODE	Preglow mode	
	60GHz ECRIS	60GHz high density plasma
		New ECR magnetic structures using resistive polyhelix coils



Experimental Ar4+ preglow pulse from PHOENIX V2 at 28GHz

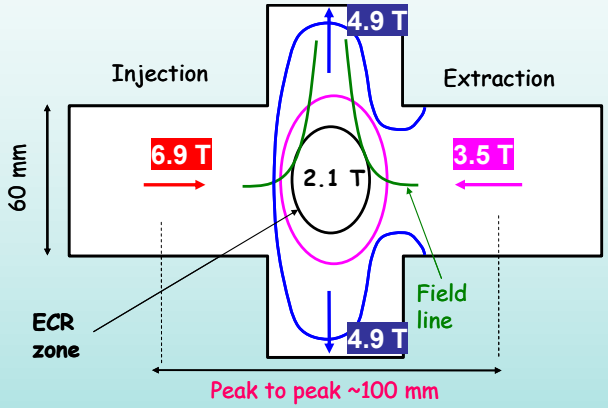
Izotov I.V., Lamy T., Latrasse L., Sidorov A.V., Skalyga V.A. et al *IEEE Transactions on Plasma Science* **36/4** (2008) 1494-1501

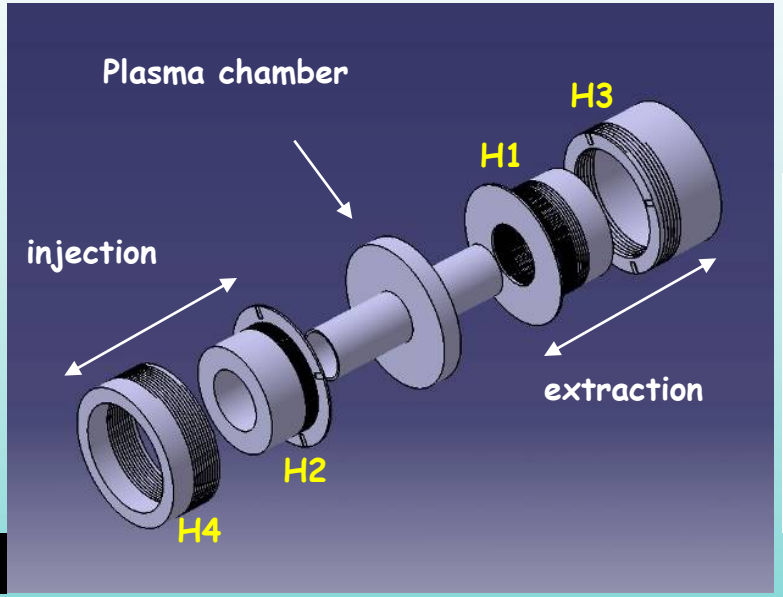
Polyhelix technology developed at LNCMI Grenoble

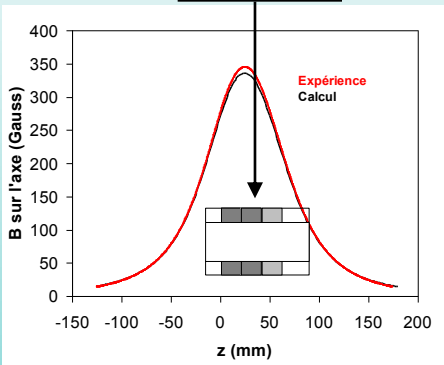
Results of the design study (1)

SEISM prototype

L. Latrasse et al., *SEISM: A 60 GHz cusp electron cyclotron resonance ion source*, **Rev. Sci. Instrum. 81, 02A324, 2010**



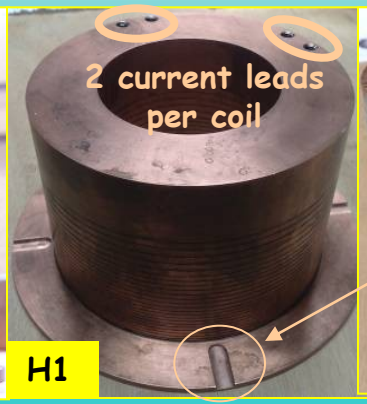




Compact CUSP magnetic structure

Magnetic field above expectations

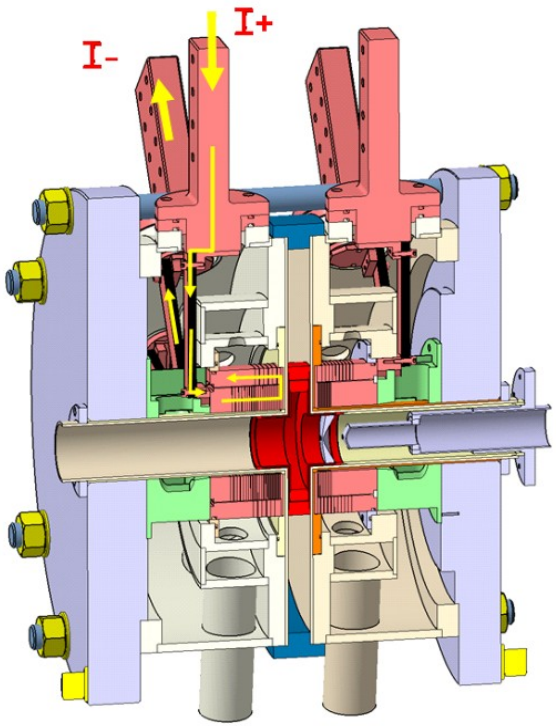
H1 aluminum prototype



Results of the design study (1)

SEISM prototype

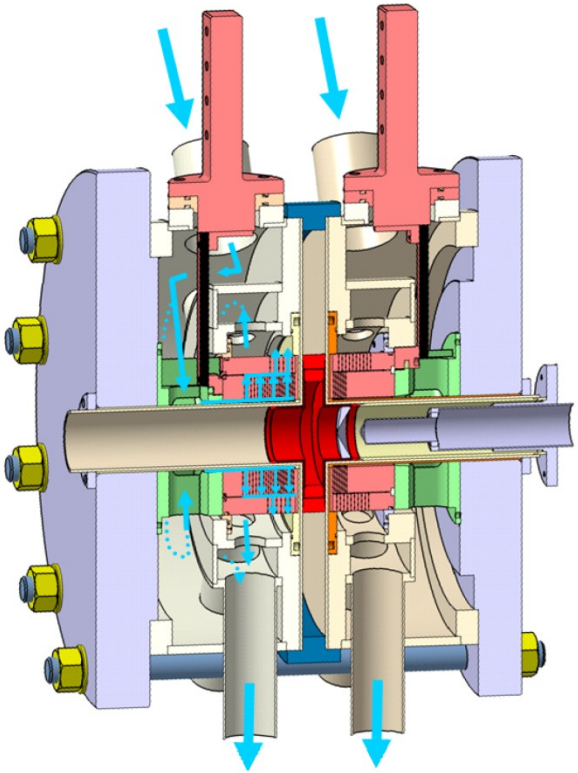
30kA current on each set of coils

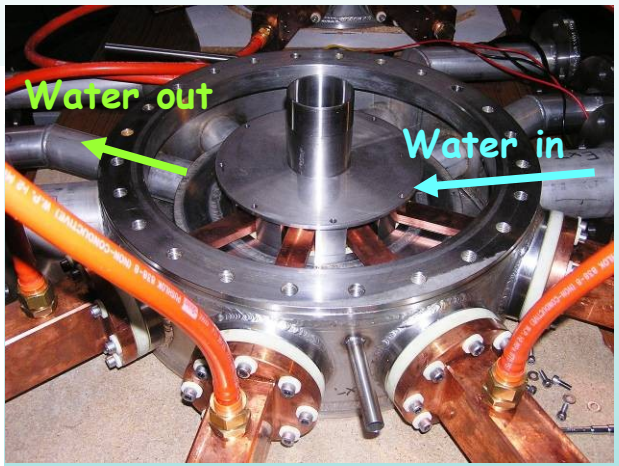


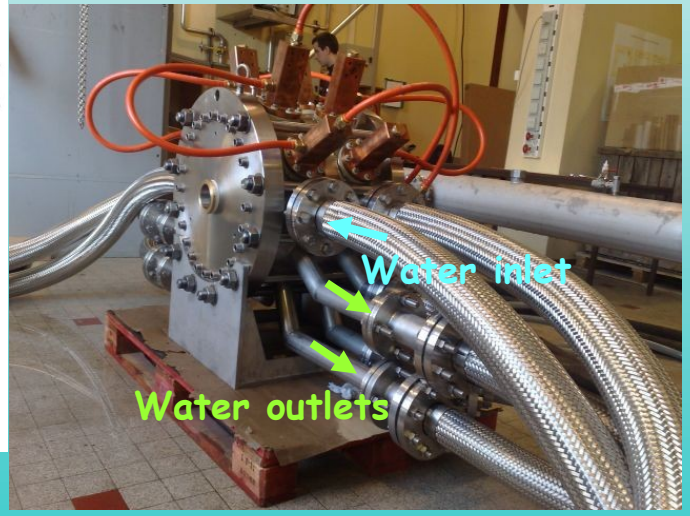
Results of the design study (1)

SEISM prototype

28l/s waterflow in each tank







Results of the design study (2)

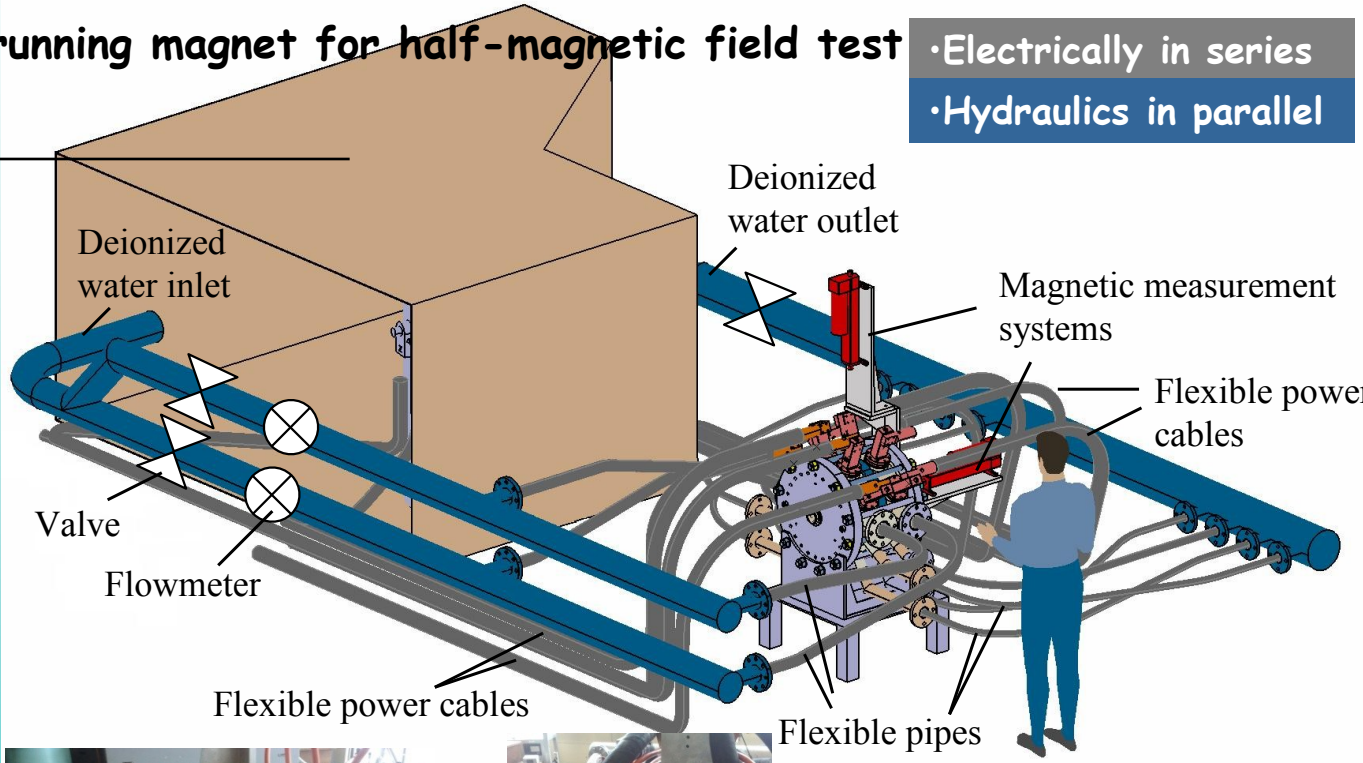
Test bench at LNCMI Grenoble

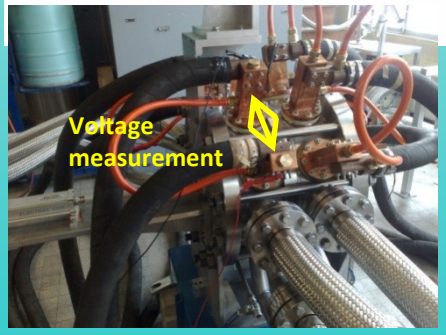
On-site connection to a running magnet for half-magnetic field test

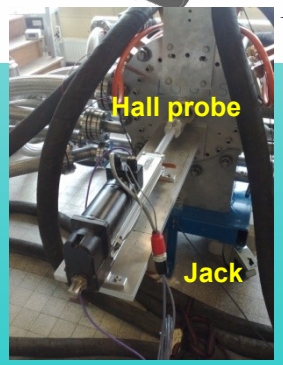
- Electrically in series
- Hydraulics in parallel

13T – 10MW magnet
2x13000A applied

- Electric parameters
  - I = 15000 A
  - P = 0.75 MW (one coil set)
- Cooling parameters
  - Q = 22 l/s
  - P_{in} = 20 bars
- Max coil temperature
  - T_{mean} = 50 °C
  - $T_{Max.\ loc.}$ 70 °C.







Visit LNCMI on Thursday !

Technical challenges (1)

Insulating between the helices windings

- Narrow insulators (2mm wide) to minimize local heating
- Height calibration (0.32mm height)
- 24 sectors on inner coil, 32 sectors on outer coil to avoid contact between the windings

→ « prepreg » for pre-impregnated composite fibres

G11 dry woven glass fabric impregnated with epoxy resin

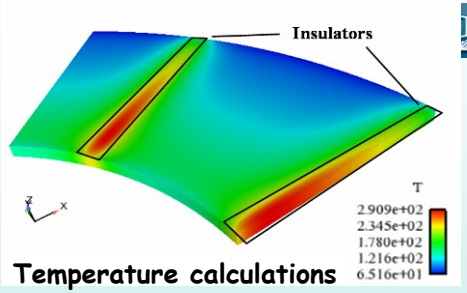
Specified maximum continuous operating temperature: 165°C

Specified breakdown voltage condition: 35kV/mm

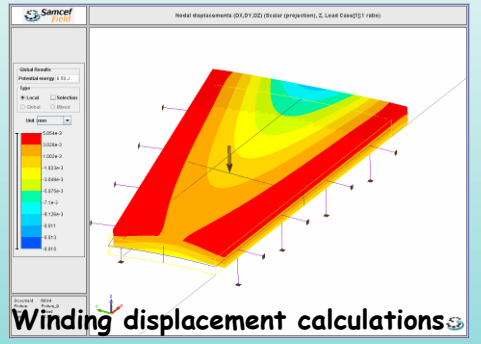
Out of stock ! Tests with frozen out-of-date prepreg

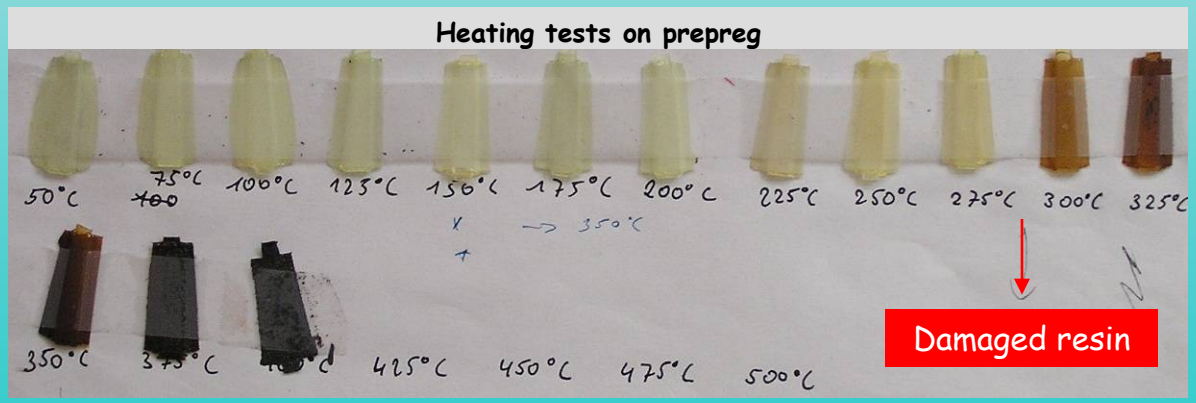
20MPa at room temperature

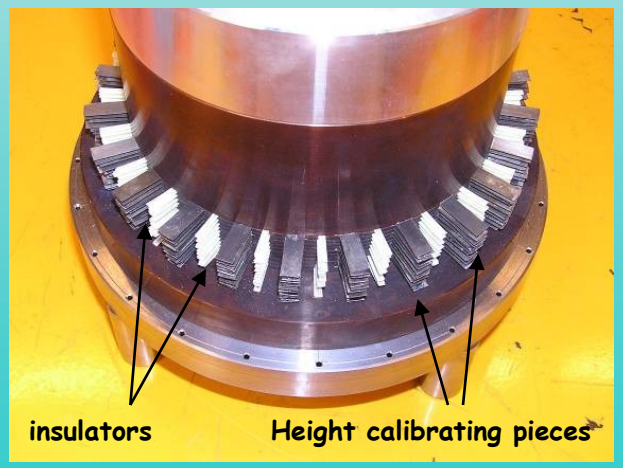
Resin damaged for local temperatures around 300°C



Temperature calculations


Winding displacement calculations





Technical challenges (2)

Hydraulic circulation from the inner to the outer coil

- Tests with fake aluminum helices

→ water circulation up to 18bars – 18l/s in each tank

→ cavitation noises, small damage marks on aluminum

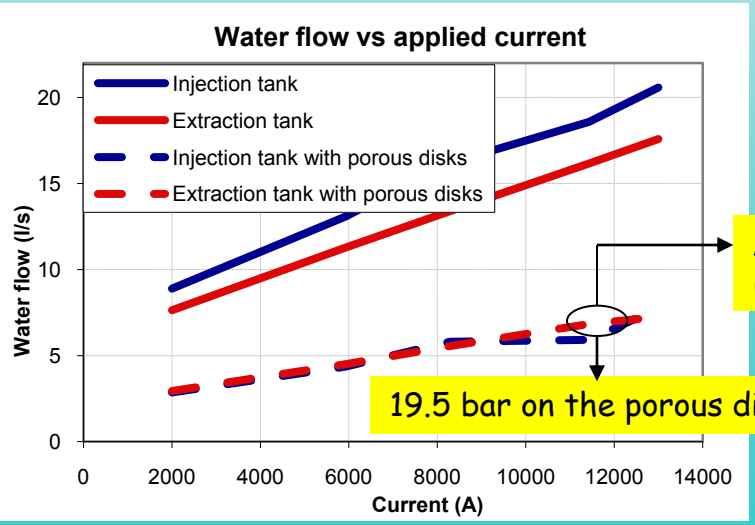
- Tests with copper helices and measurements up to 7000A

→ 10bar - 12l/s in each tank _ water speed up to 14m/s in the radial helices slit

→ cavitation noises

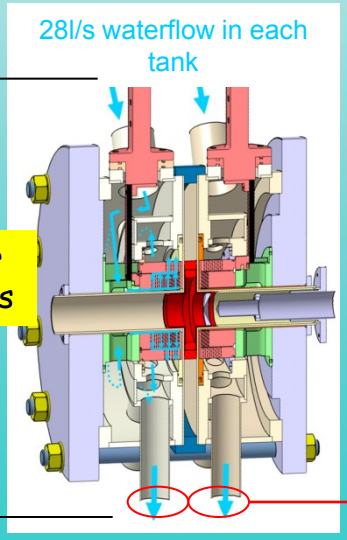
- Porous discs to slow down the flow in SEISM, but not in the LNCMI magnet running in parallel

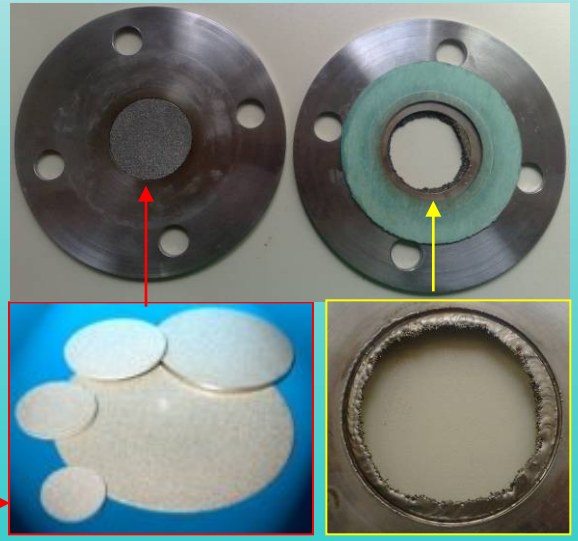
→ no more cavitation, but a filter damaged after 24 hours of run



ΔP ~ 0.5 bar in the helices

19.5 bar on the porous disc

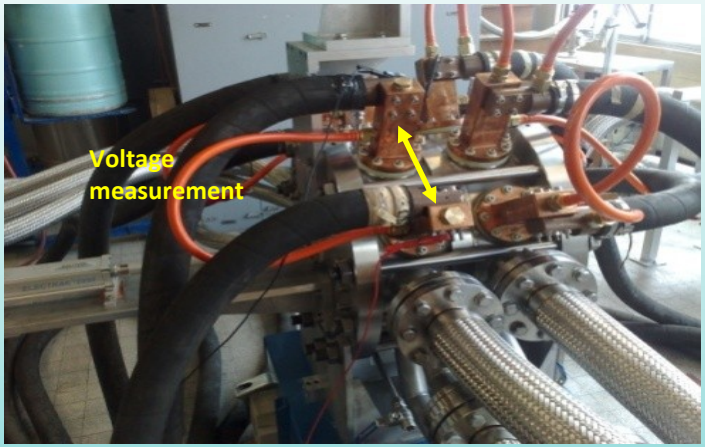


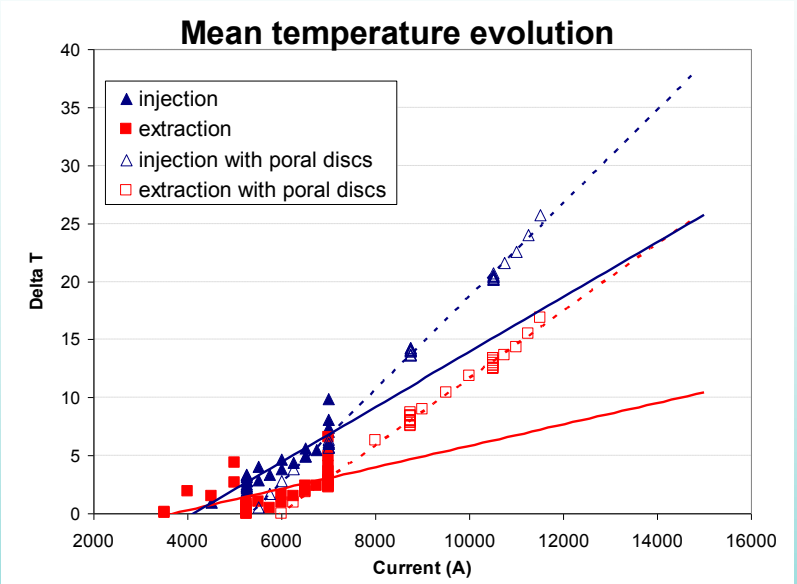


Technical challenges (3)

Temperature monitoring

Voltage measurement to monitor the coils resistance / temperature:



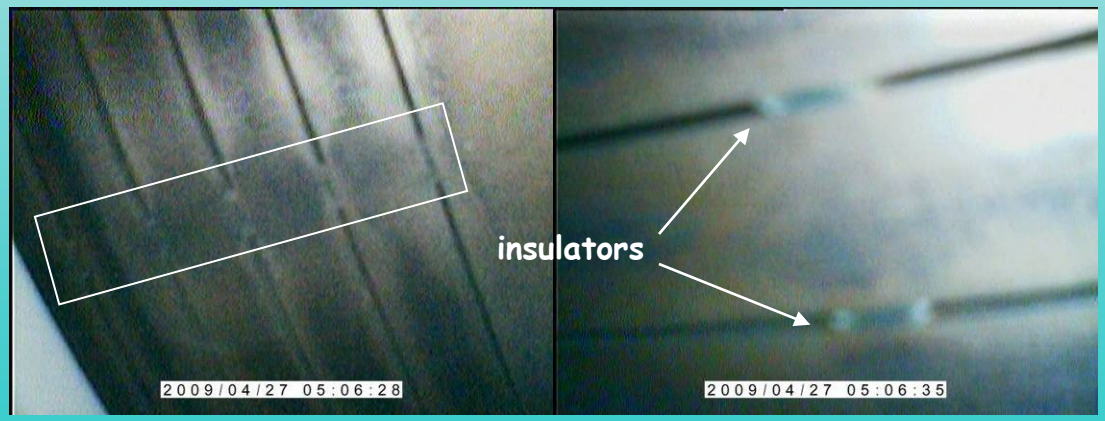


Inserting a camera to have a look:

++ insulators still aligned !

-- color indicates local temperature is higher than expected

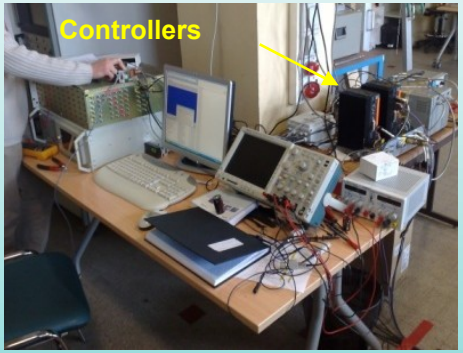
Snapshot of the outer coil insulators after 40 hours of run up to 7000A

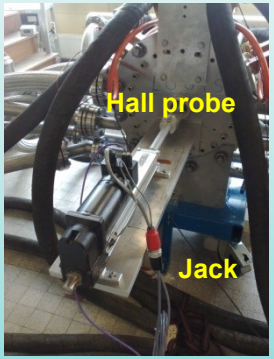


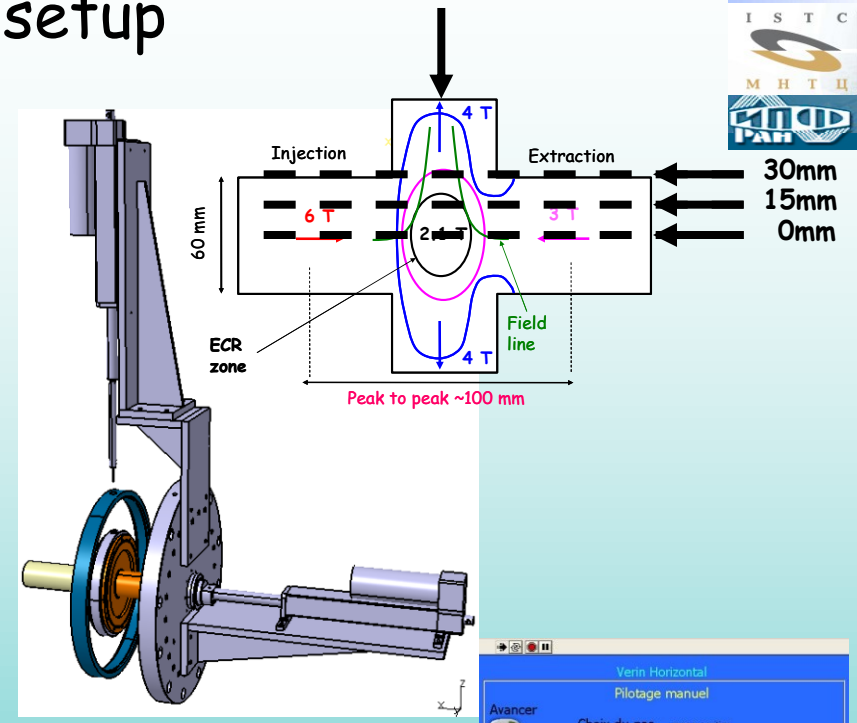
Magnetic field measurements (1)

Measurement setup

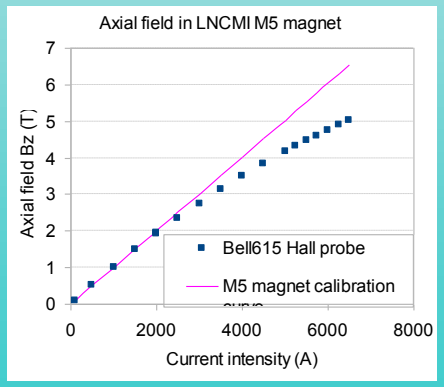
- Measurement on 3 horizontal axes along z and on one radial axis
- 300mm-course jacks with a step-by-step motor equipped with a probe holder

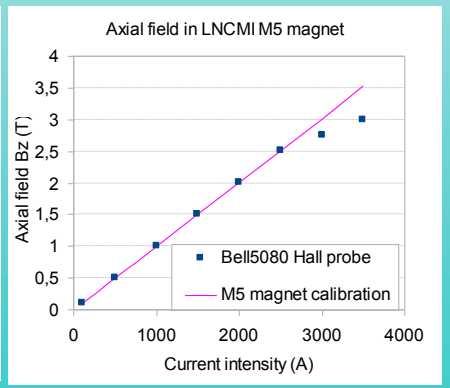




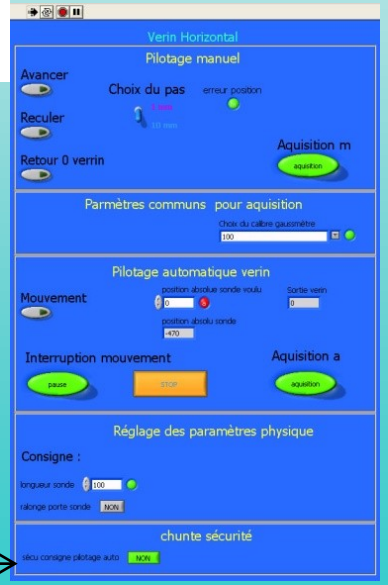


- Two gaussmeters equipped with single-axis axial and radial Hall probes



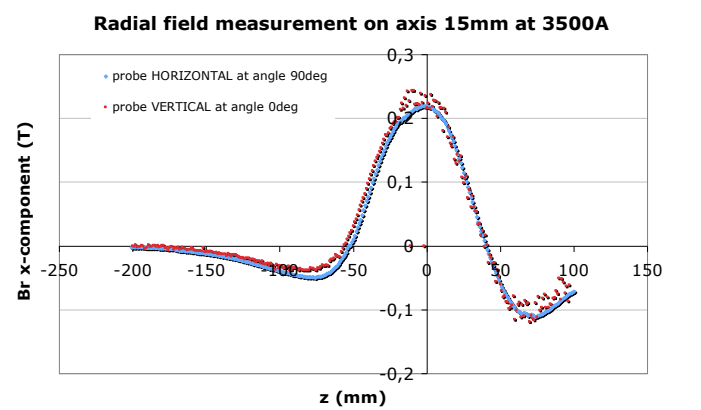


- LabView interface to move jacks and acquire data



Magnetic field measurements (2)

Preliminary results vs simulations

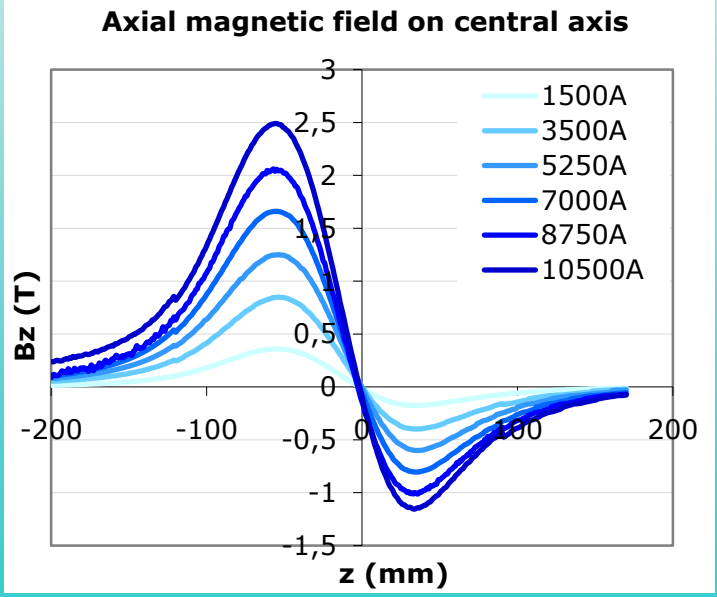


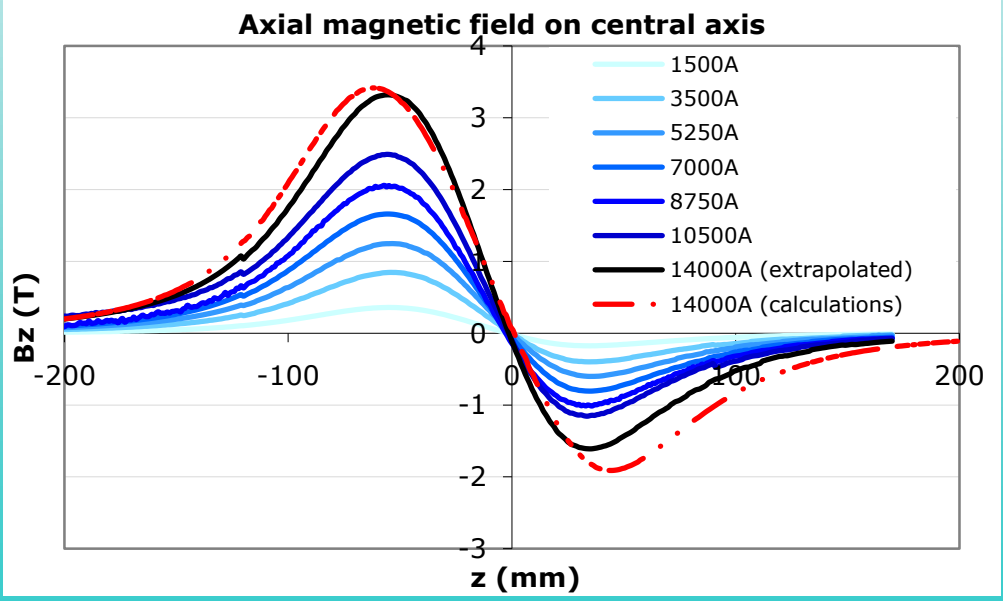
As expected:

- Axisymmetric field
- Increase with distance to central axis
- Scaling with increase of the intensity

Unexpected:

- Shift in maxima positions
- Lower amplitude on extraction side

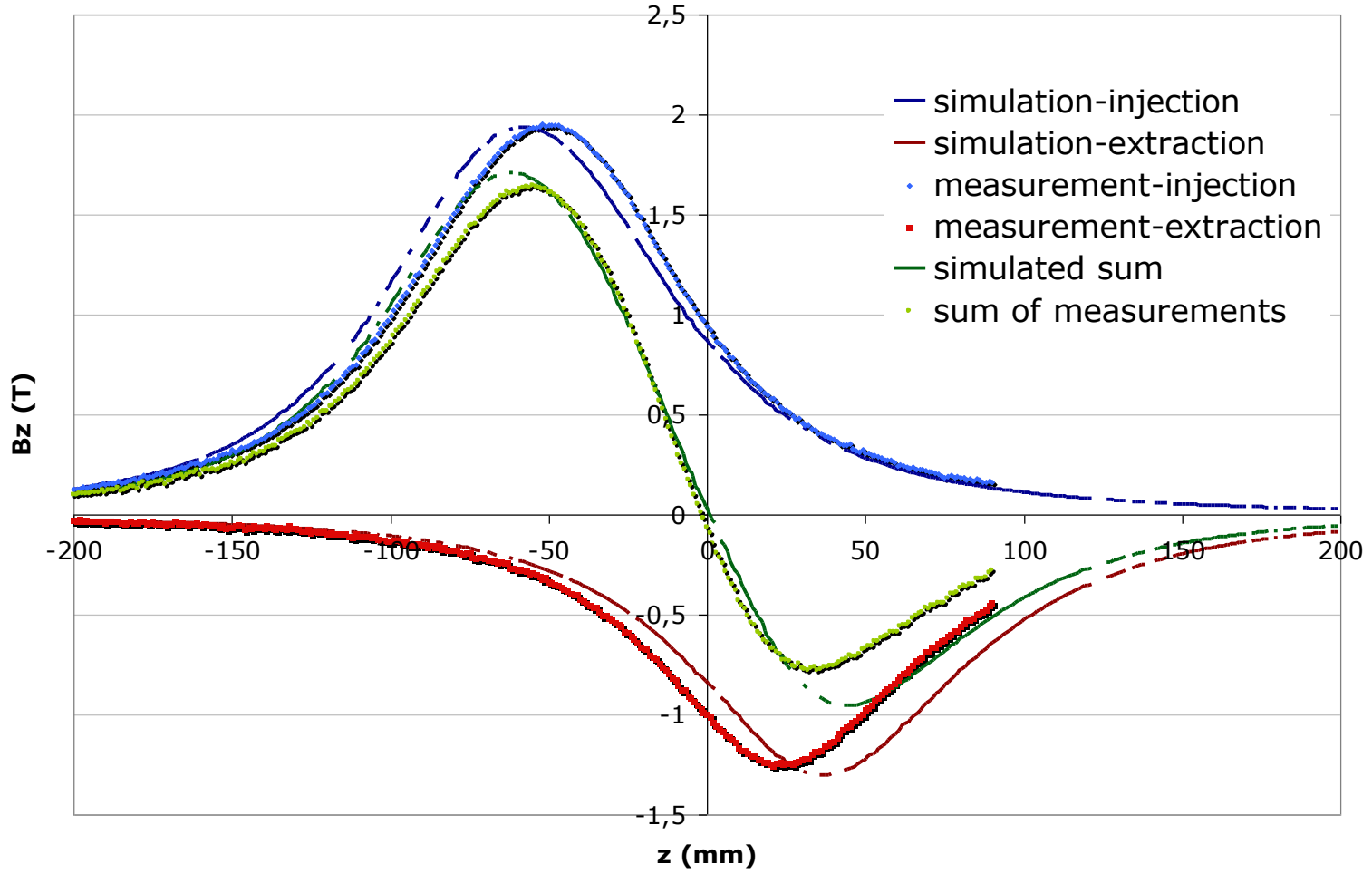




Magnetic field measurements (2)

Preliminary results vs simulations

Axial field on central axis at 7000A



Magnetic field measurements (3)

Possible explanations

- Mechanical error (tank dimensions, helix positioning)

Injection and extraction coil sets are too close

Sum of the amplitudes is modified

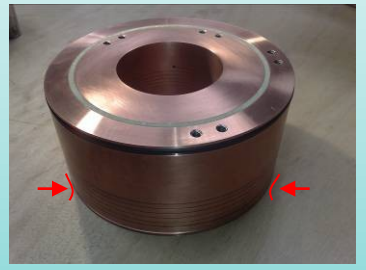
→ Not likely to cause 10mm difference, tanks dimensions were checked and within tolerances

- Misplaced magnetic center because helix shape is wrong

Electric discharge machining with a 0.25mm wire

For example real split is 0.37mm instead of expected 0.32mm

→ Magnetic centers can be checked individually for each helix after dismounting



- Calculation error

Considered heat transfer is wrong

Copper resistance is higher, current density is lower, and resulting magnetic field is lower

→ Comparative simulations should be performed

Conclusion

- The SEISM magnetic structure was built and set up on a test bench at LNCMI Grenoble
- Continuous magnetic field has been produced on-site for 70h up to now
- Results show an axi-symmetric field map with a lower amplitude and closer maxima than expected from the simulations
- Possible explanations involve mechanical errors in the fabrication of the polyhelix coils or the water tanks, and are still under investigation

What next ?

- Right now:

→ Damaged poral disc to be replaced
→ Gaussmeter with triple-axis Hall probe to be bought
→ **Magnetic field measurements up to 14000A (2 weeks run to be scheduled in automn 2010)**

- Next year:

→ Plasma chamber design
→ **permanent room at LNCMI is under funding request for first tests at 28 GHz**

- In a near future:

→ Preparation to raise the current to full intensity (30kA)
  → Adding direct voltage reading on each individual helix
  → Adding temperature reading on local non-cooled parts (insulators)
  → Insulators replacement ? What kind ?
→ **60 GHz gyrotron is currently under construction at IAP-NN (ISTC contract)**

Acknowledgements

To numerous people from the SERM-LPSC workshop

To the LNCMI Magnet Group