Design and Tests of the 100 Tesla Triple Coil at LNCMI

Magnets:

Jérôme Béard
Julien Billette
Jean-Marc Lagarrigue

Generators:

Paul Frings
Jean-Pierre Nicolin
Tristan Moraine

Materials:

Florence Lecouturier
Nelson Ferreira

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Outline

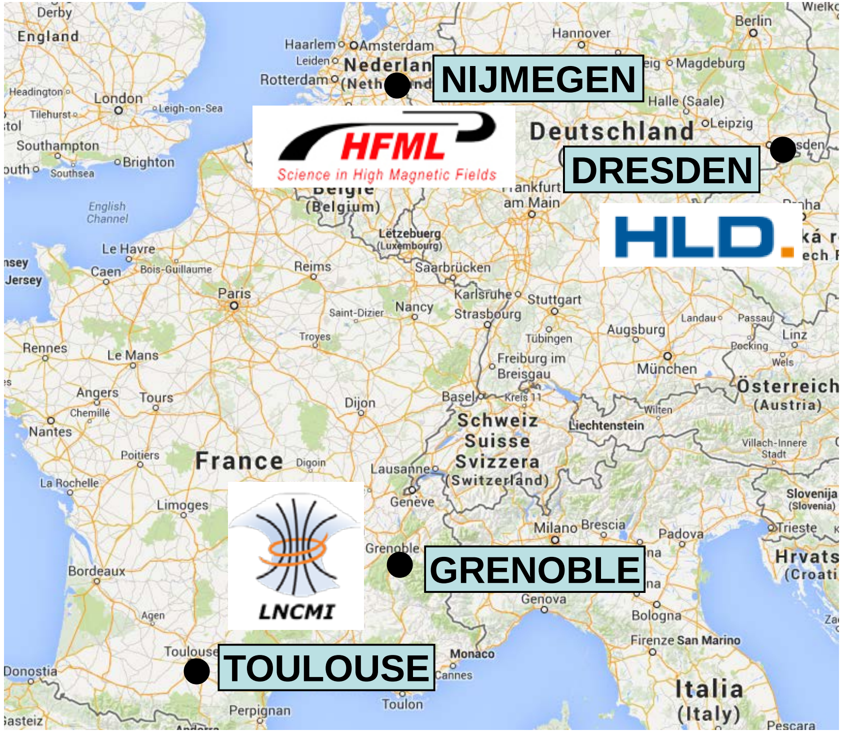
- Presentation of the LNCMI
- The 100 T Magnet
- Conclusion and perspectives

Presentation of the LNCMI

Laboratoire **N**ational des **C**hamps **M**agnétiques **I**ntenses

Host facility on two sites:

- Grenoble: static field up to 36.5 T
- Toulouse: pulsed field up to 90 T (non destructive)
  180 T (semi destructive)



The 3 missions of the LNCMI :

- technical and scientific development of experiments under high magnetic field

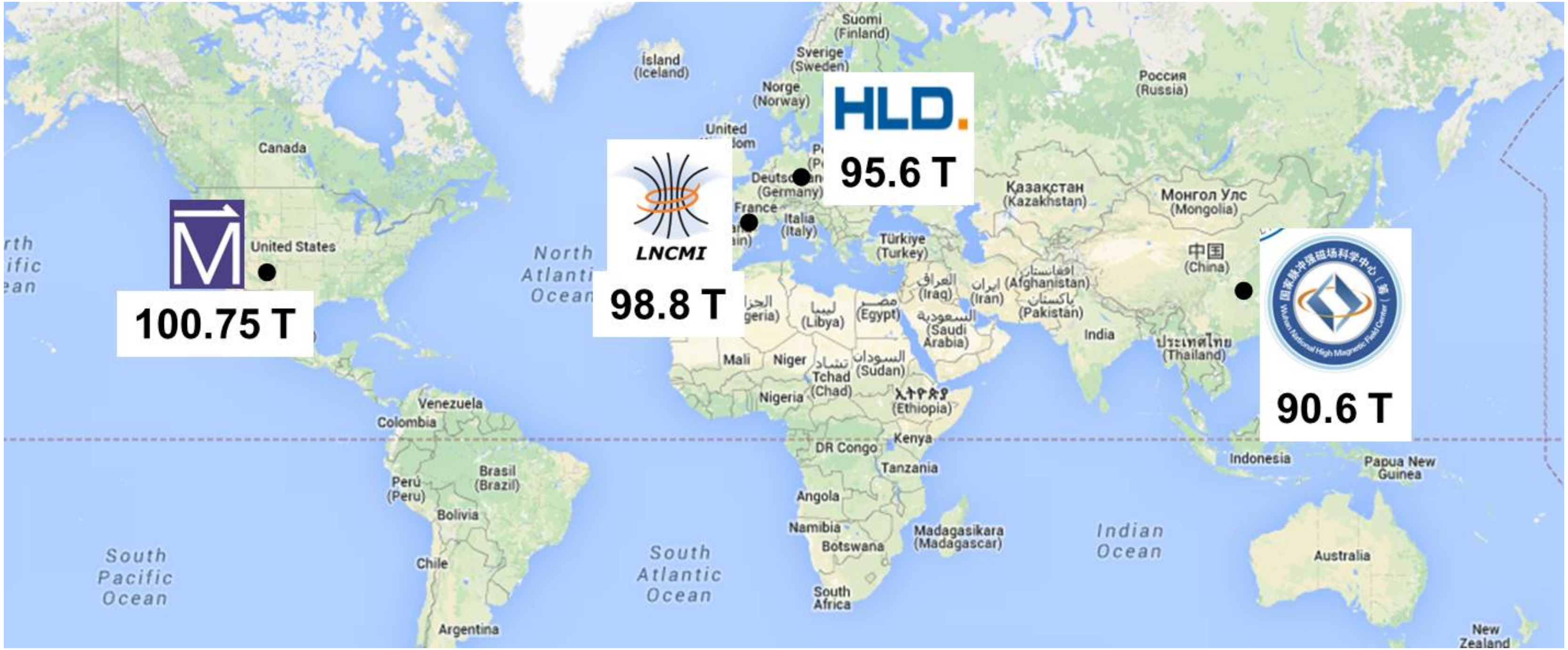
- open to scientists through collaborative agreements and contracts

- create partnerships with other installations to develop techniques

Presentation of the LNCMI

The pulsed magnetic field facility

Only few laboratories in the world with B>90 T



The pulsed magnetic field facility

8 capacitors banks from 10 kJ to 14 MJ
voltage up to 24 kV and current up to 150 kA
=> power ~GW

5 are mobile to perform experiments
in other facilities and combine magnetic field
with intense lasers, X-rays, or neutrons (LULI,
ESRF, ILL, CLIO, SLS…)

The 100 T Magnet

Mechanical stress is the main limitation to produce high magnetic field and is proportional to the density of energy.
Increase the magnetic field by increasing the size of the magnet with the same energy density requires a lot of energy.

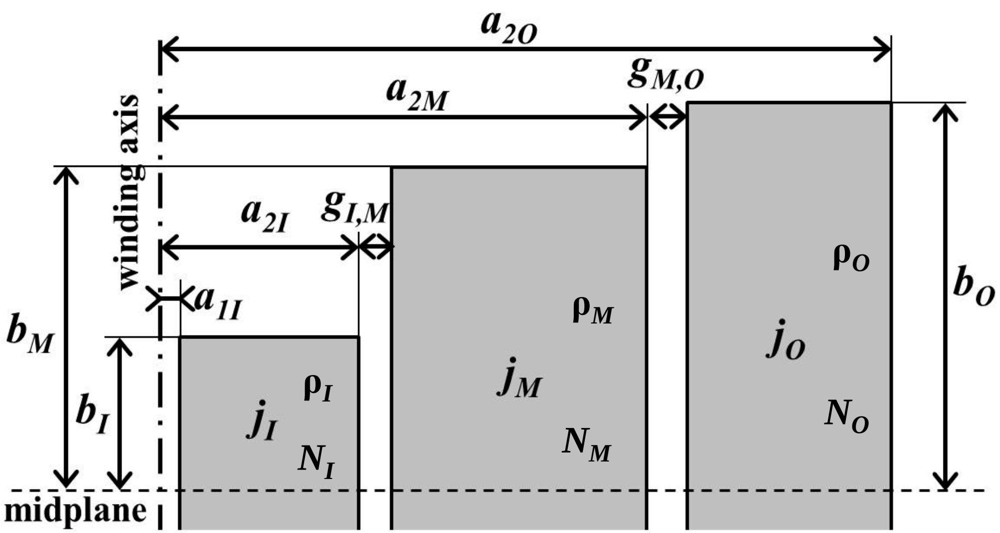
Existing system: 80/90 T Coilin/Coilex,
2 independent coils powered with 2 independent capacitor banks
12 MJ + 1 MJ

100 T Magnet:

3 independent capacitor banks
to power 3 independent concentric coils.
14 MJ + 6 MJ + 1 MJ

The 100 T Magnet

Magnet optimization



A lot of parameters: dimensions, materials, current density (reinforcement), number of turns (wire section), …

some of them can be chosen:

• Same inserts dimensions as in the existing 80/90 T Coilin-Coilex system
a_{1I} = 9.5/2 = 4.75 mm ; a_{2I} =170/2 = 85 mm; $g_{I,M}$ = 10 mm

• Mechanically reasonable: $g_{M,O}$ = 10 mm

• Maximum feasible winding diameter: a_{2O} = 520/2 = 260 mm and maximum efficiency $a2/b = 1.675$ so b_O = 150 mm

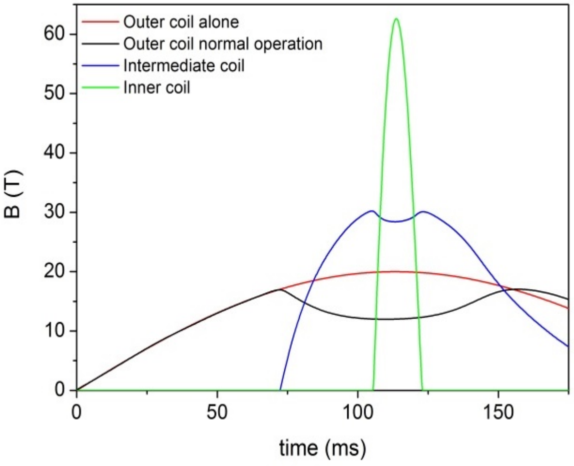
• …

• The other parameters are chosen by optimizing the use of the energy that will give the lower mechanical stress for the best efficiency.

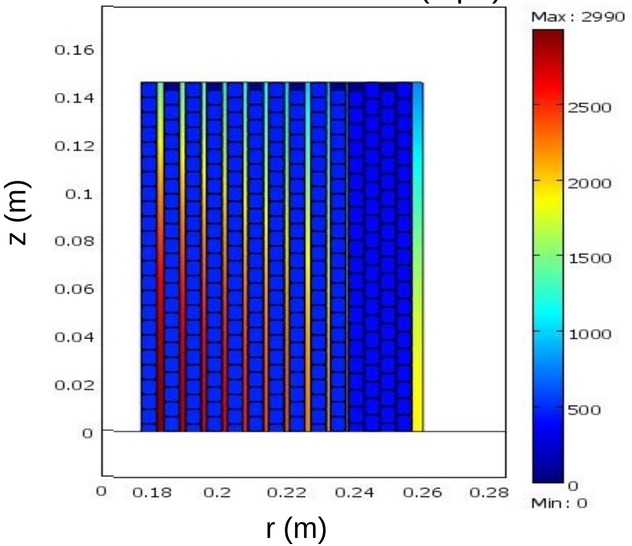
The outer coil, mechanical modeling

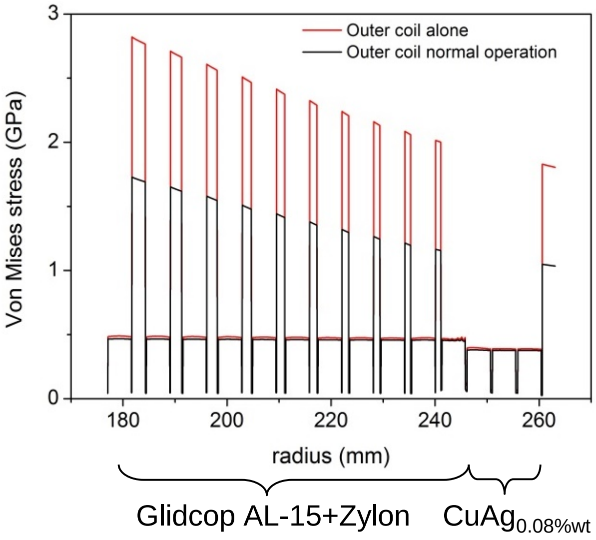
~20 T in ø350 mm but strong magnetic coupling with the middle coil

Based on our experience with the Coilin/Coilex system:
GLIDCOP AL-15 reinforced with Zylon fibers (11 first layers), $CuAg_{0.08\%wt}$ (3 last layers)



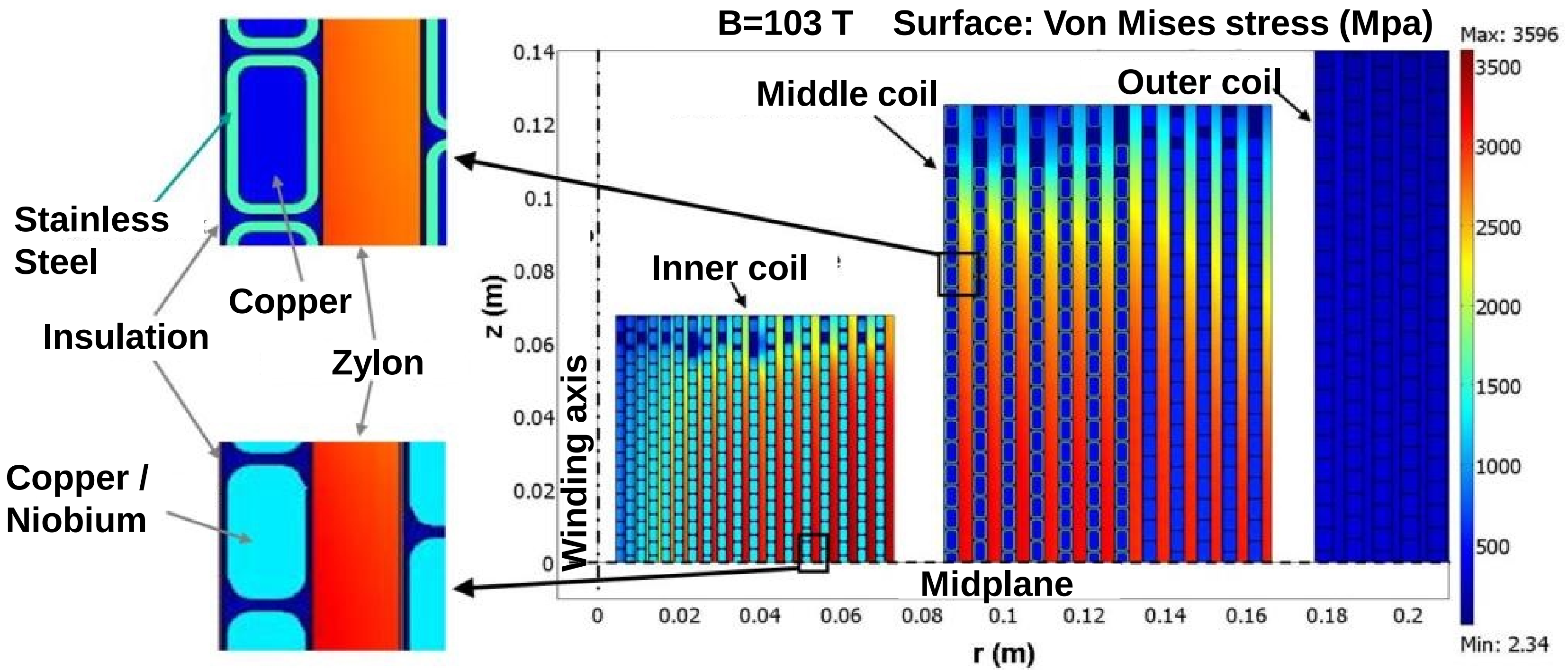
B=21 T Surface: Von Mises stress in the outer coil (Mpa)





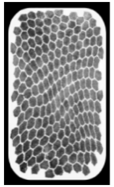
The inner and middle coils

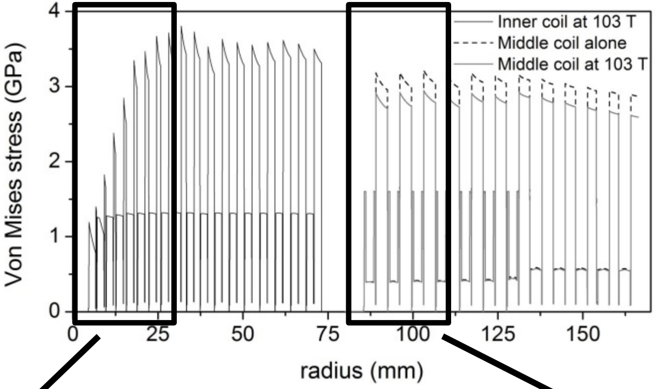
CuNb microcomposite in the inner coil reinforced with Zylon layers
Copper/Stainless steel macrocomposite and GLIDCOP AL-60 reinforced with Zylon layers



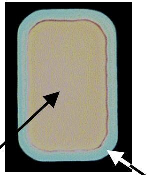
The inner and middle coils

2 x 3.5 mm² Copper/Niobium micro-composite Nanoelectro. UTS ~ 1.3 GPa



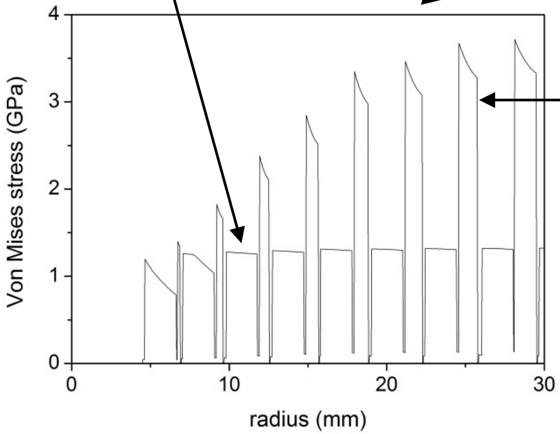


3.35 x 5.6 mm² Copper/Stainless steel macro-composite produced at LNCMI. UTS ~ 1 GPa

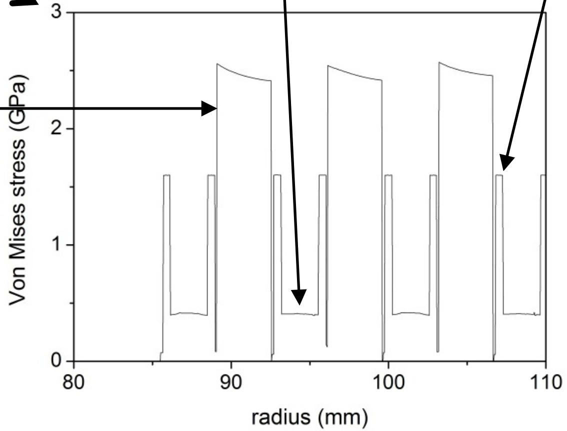


Copper core (60%)
Low strength, high electrical conductivity

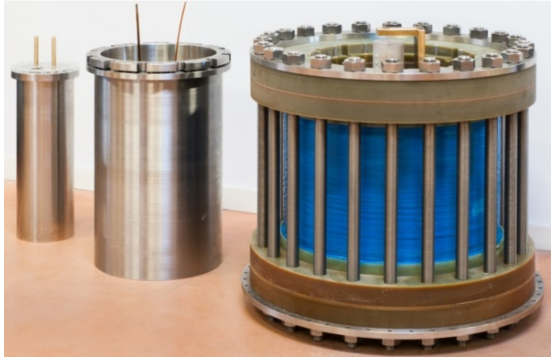
Steel sheath (40%)
High strength, low electrical conductivity



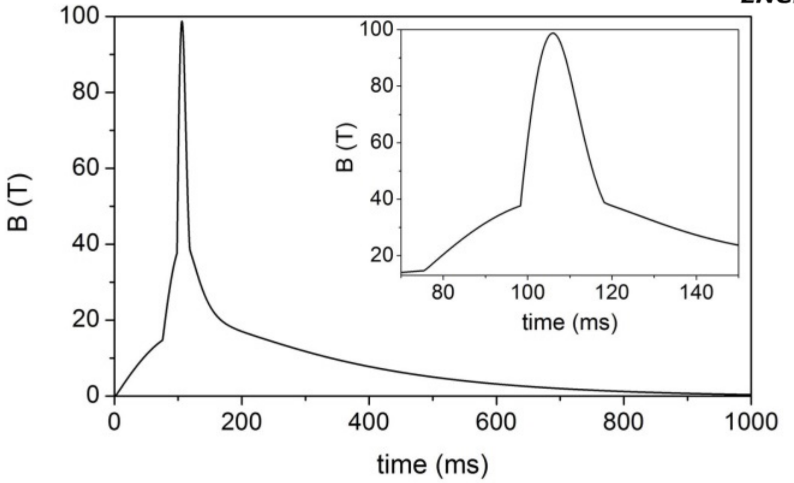
Zylon fibers
High strength, insulating



Mechanical construction and first tests



The three coils mechanically and electrically independent and the final assembly

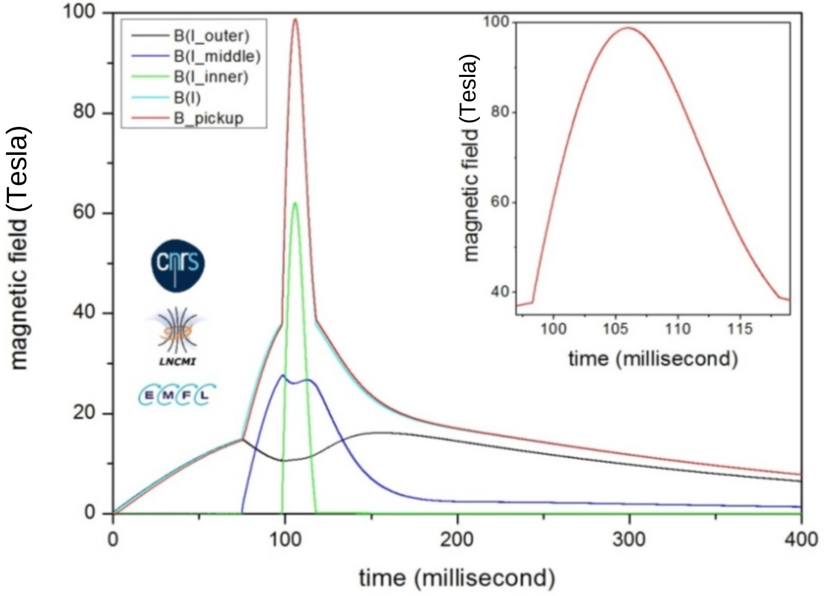


New European record: 98.8 T

A capacitor bank failure forced us to stop the tests.

But there is no sign of weakness in the magnet and tests will continue after repair.

Conclusion and perspectives



- Perfect behavior of the mechanical construction

- Plug and play system and simple user interface:
automatic selection of generators, voltages, delays (charge and discharge)

- High magnetic field not so far from the objective,
New European record: 98.8 T
Capacitor bank failure but tests will continue after repair (No sign of weakness in the magnet)

- Long pulse duration and less than 2 hours of cooling
Will be a tool for scientific research once in operation

Some possibilities exist to increase the field:

- to generalize the use of Copper/Stainless steel in the middle and outer coils
- increase the total amount of energy thanks to the renewal of the facility

(- reduce safety margin i.e. shorter lifetime and/or reduce gaps between coils)