High field magnets using the Nb_3Sn superconductor and a ceramic-based insulation.

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In the framework of LHC upgrades, big efforts have been provided to design accelerator magnets with the Nb3Sn superconducting alloy, in order to reach higher magnetic fields. The goal of the PhD work is to check the feasibility of a Nb3Sn high field magnet with a ceramic insulation. This innovative insulation has been developed by CEA Saclay. In high field magnets, the transverse compressive stress on the cables, due to Lorentz forces, can be higher than 150 MPa. Properties of Nb3Sn conductors are studied under pressure and magnetic field. The mechanic and magnetic behavior is finally incorporated in new methods of magnetic design.

Superconducting magnets for particle accelerators

Discover new particles…

→ Increase the energy E = cBR

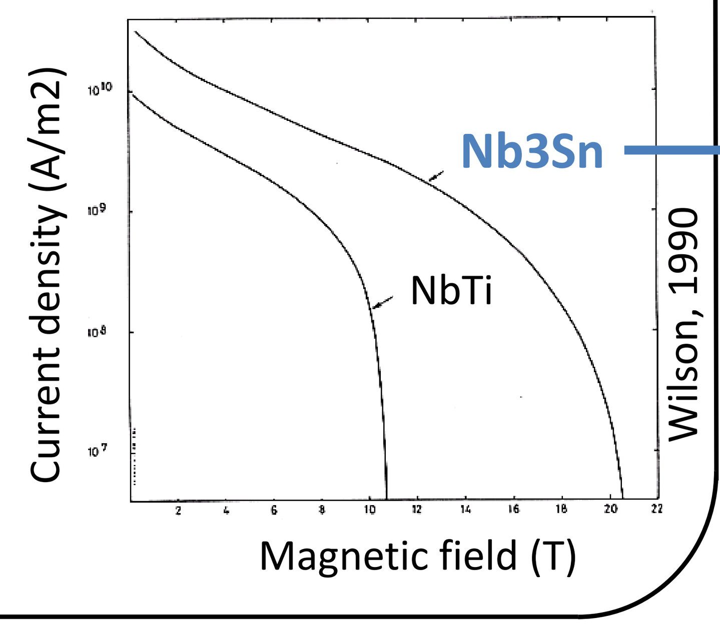
→ increase B > 12 T (beam bending)

…using superconductors.

R = 0 at low temperature

- No electrical consumption, only cryogenics
- High current density → compact
- NbTi currently limited → use Nb3Sn

→ **Constrained specifications**



Nb3Sn manufacturing issues

- **Heat treatment** (650 °C, 100h) to form the superconducting alloy.
- **Nb3Sn very brittle** after heat treatment → difficult handling
- **Electrical insulation** needed for the coil → risky process

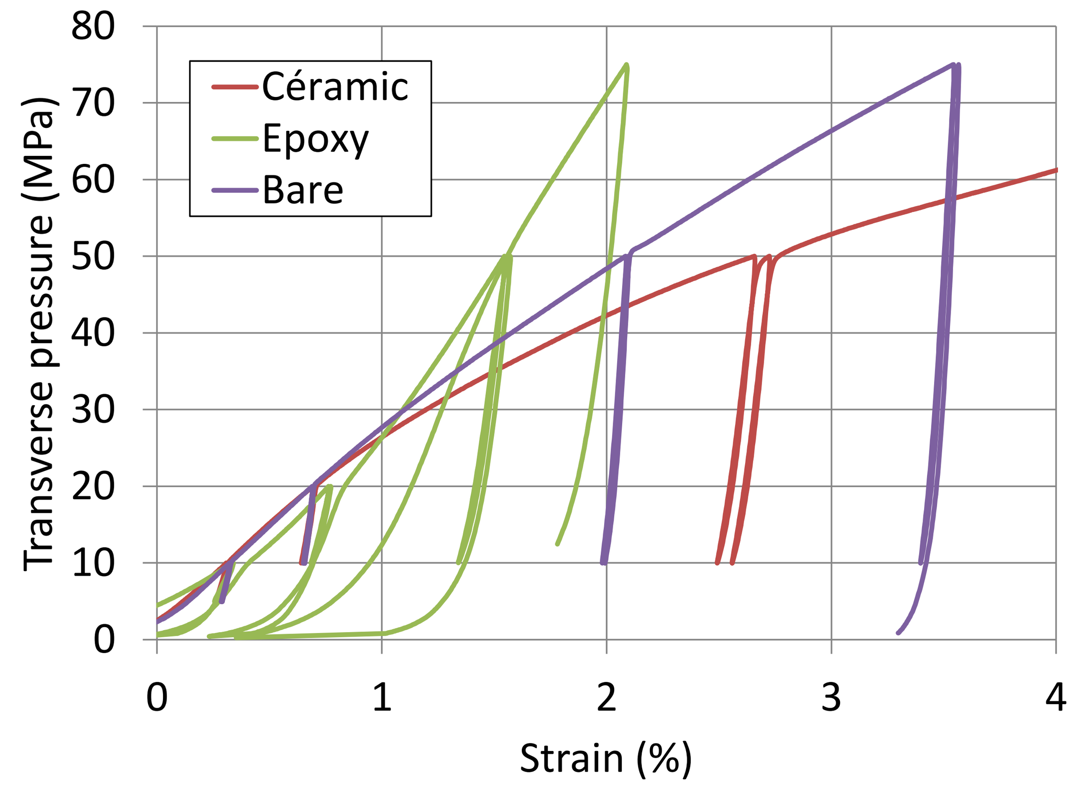
Conventional method : Coil winding → Heat treatment → Impregnation with resin ⚠

Innovative method : Coil winding → Impregnation with a **ceramic solution** → Heat treatment ✓

Improvements of the ceramic insulation

- **Heat extraction** : better than resins
- **Mechanical strength** : lower than resins

Ceramic-insulated cable



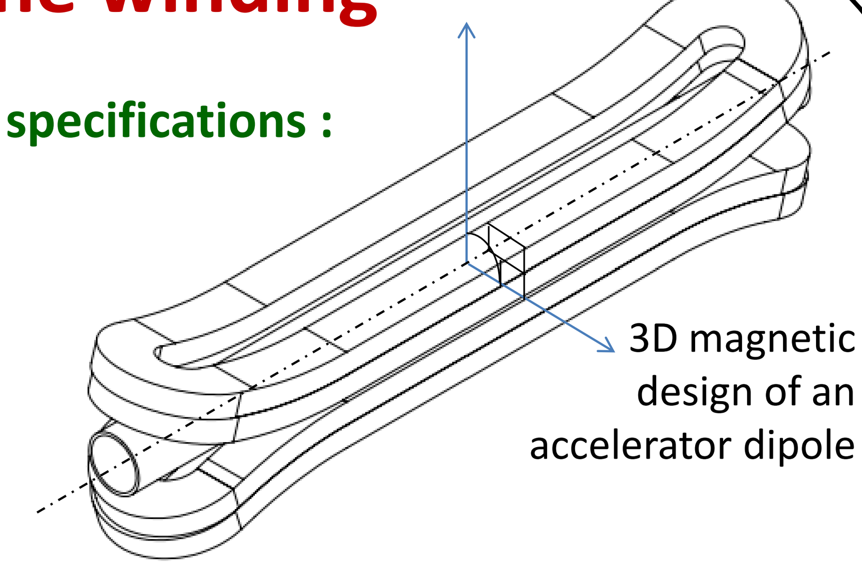
- High B, high current → high Lorentz forces

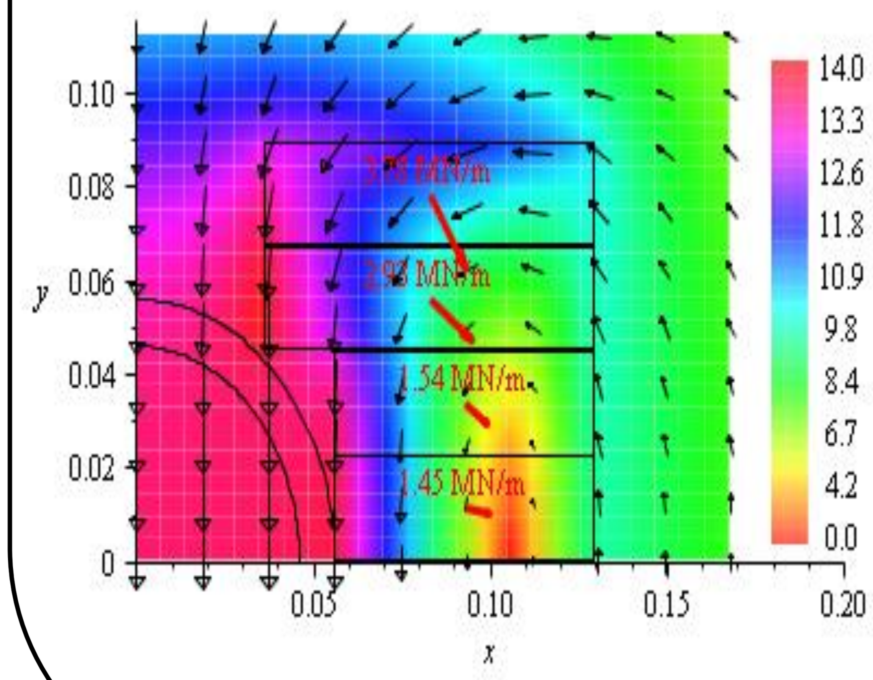
→ The insulation has to support **high compressive stresses**

Magnetic design of the winding

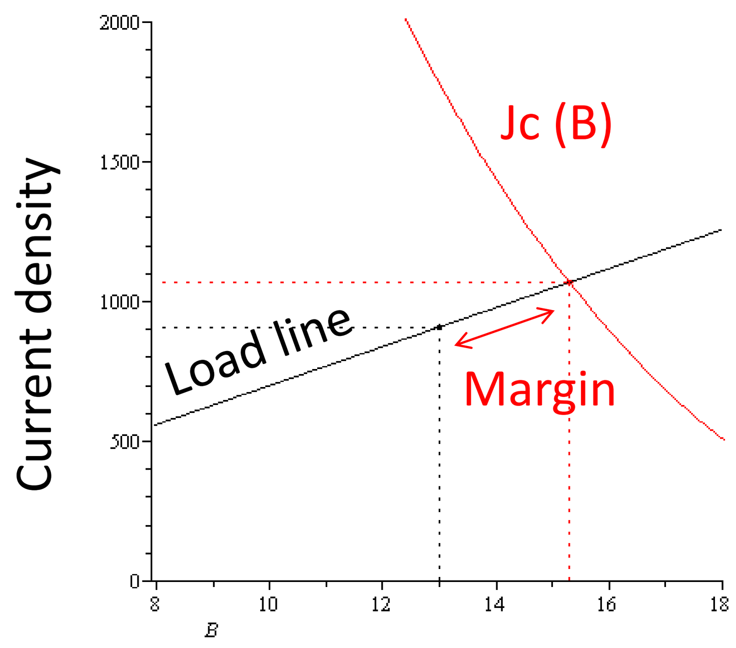
The winding shape must fulfill the specifications :

- Central B
- Field harmonics
- Maximum forces
- Operating margins





2D magnetic design (cross section)

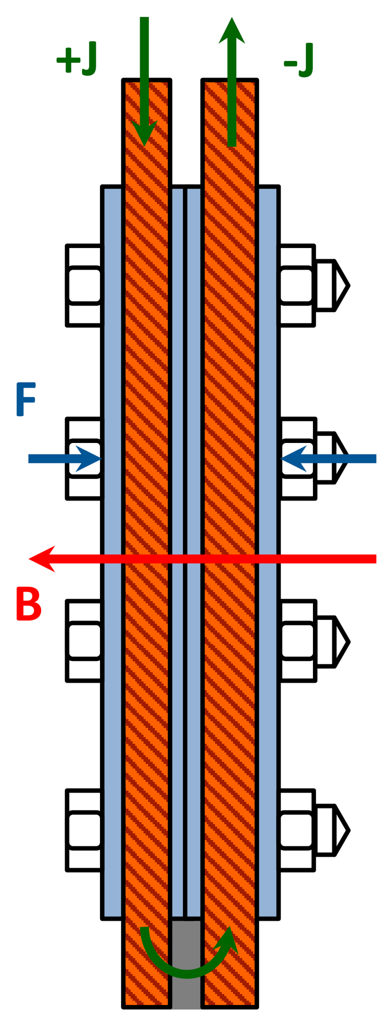


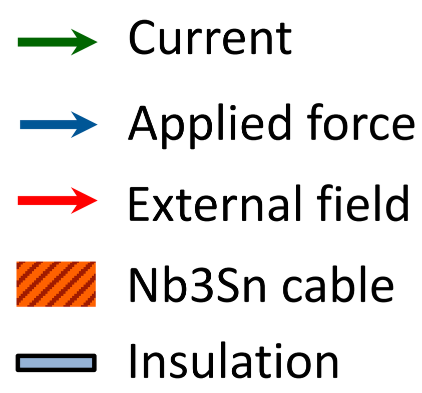
Operating point

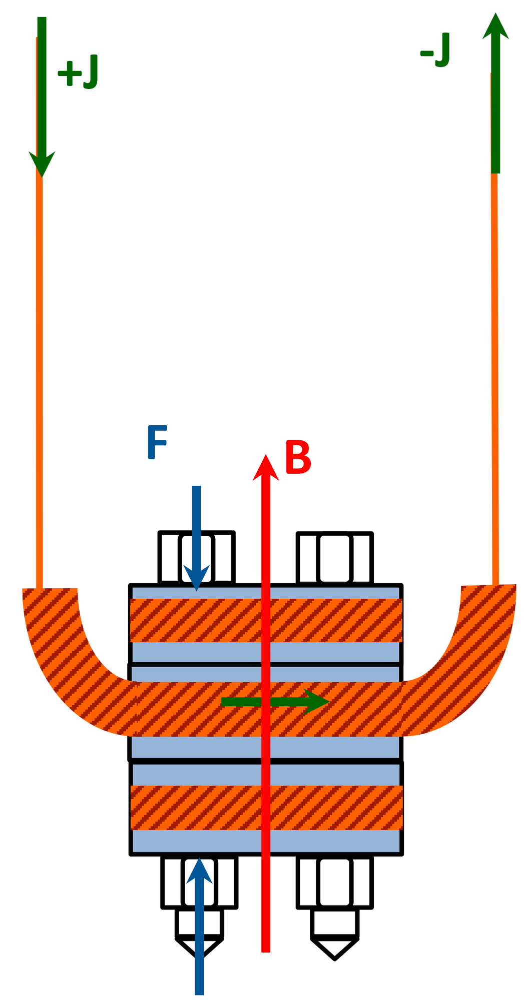
Characterization of the electrical properties under stress

- **2 experiments :**

→ Test the conductor with ceramic insulation, under pressure, in magnetic field







CERN :

→ 14 strands cable

→ Current supply : 32 000 A

→ Max. external field : 9 T

→ Max. pressure : 50 MPa

CEA :

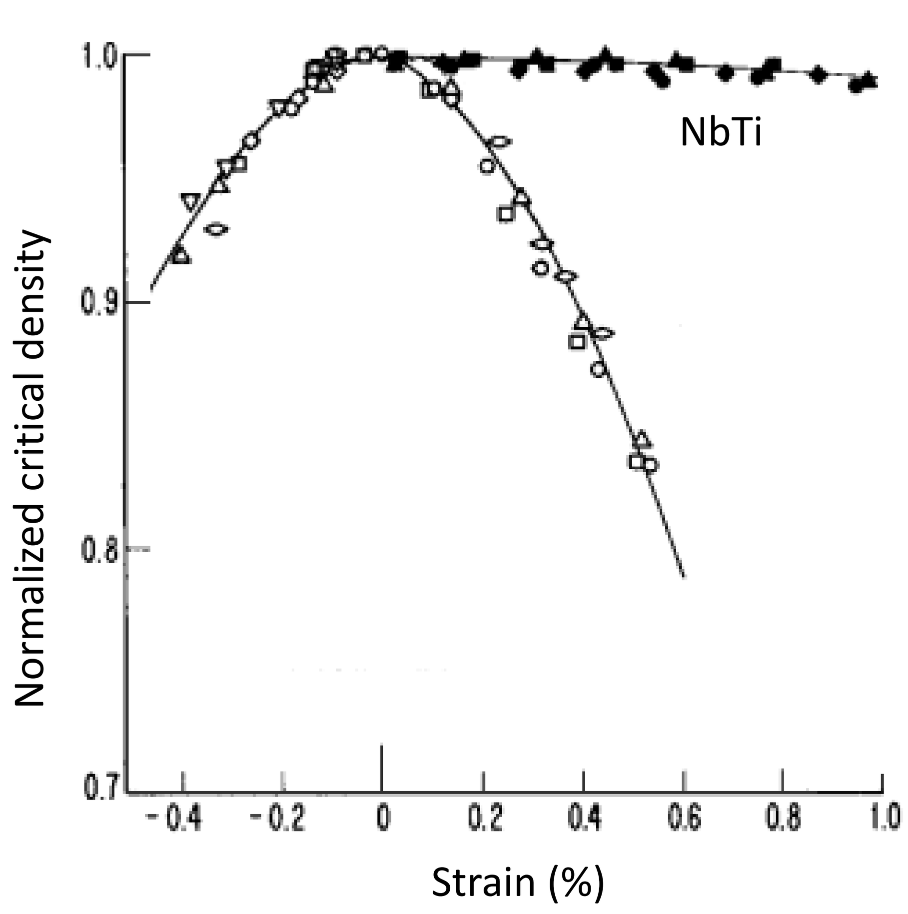
→ 1 strand in its cable

→ Current supply : 2000 A

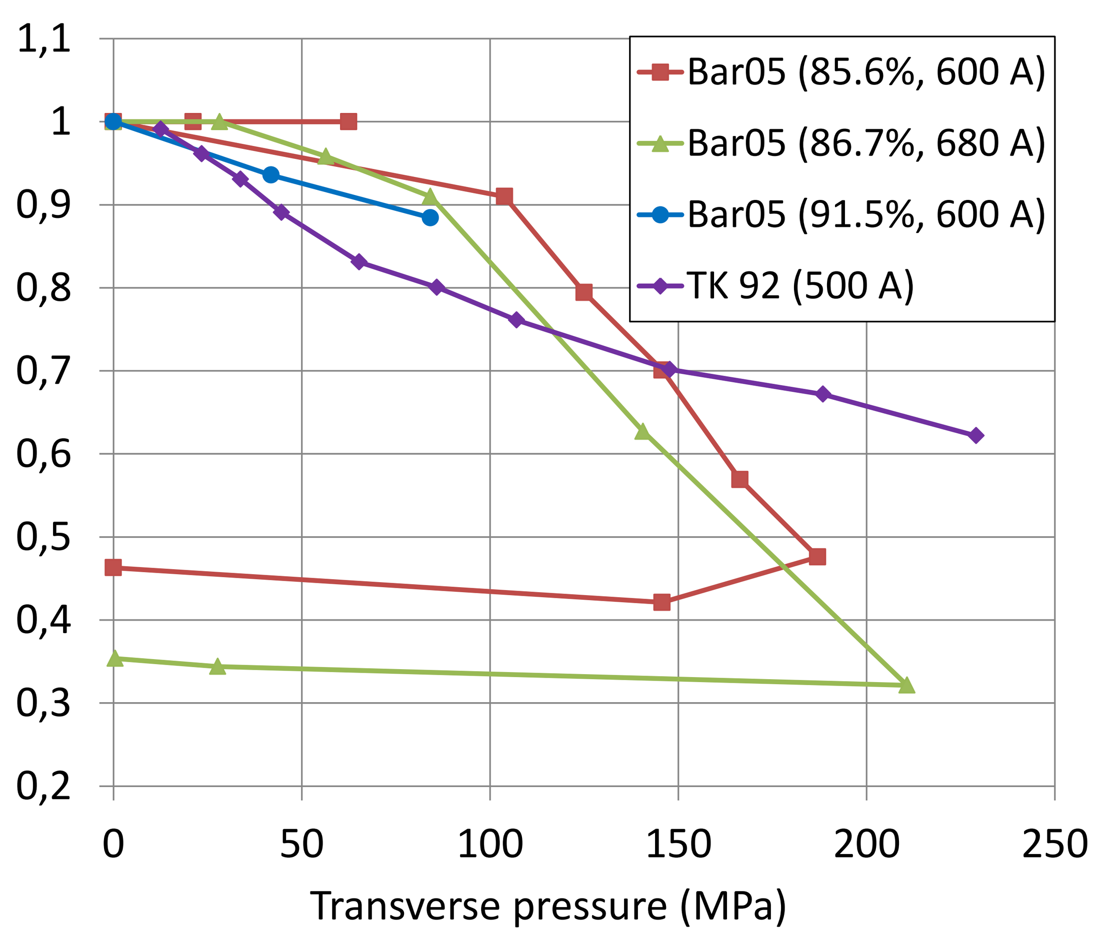
→ Max. external field : 11 T

→ Max. pressure : 200 MPa

- **Nb3Sn very sensitive to strain**



What stress limit to keep a high Jc ?



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