DE LA RECHERCHE À L'INDUSTRIE

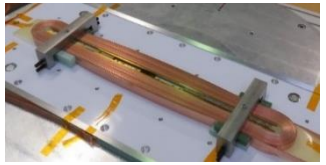
HTS magnets: Development targets and choices at CEA

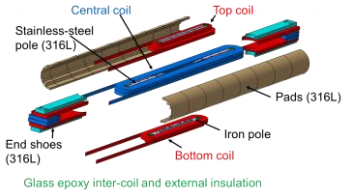
Lionel QUETTIER

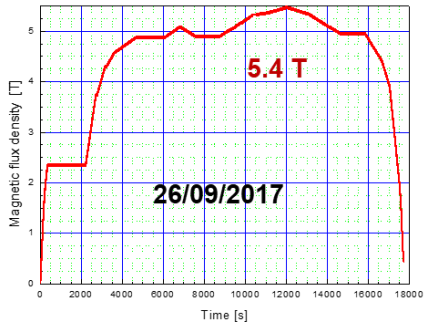
Muon Collider Collaboration Annual Meeting – October 2022

RECENT RESULTS

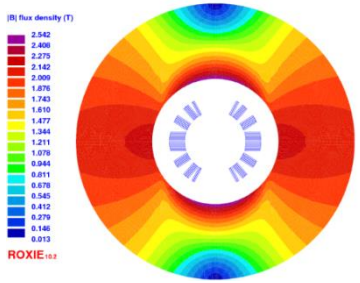
Accelerator magnets

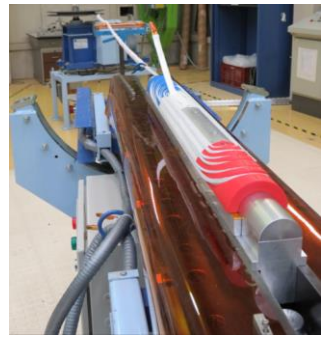






REBCO ROEBEL cable
Cos(θ) HTS dipole



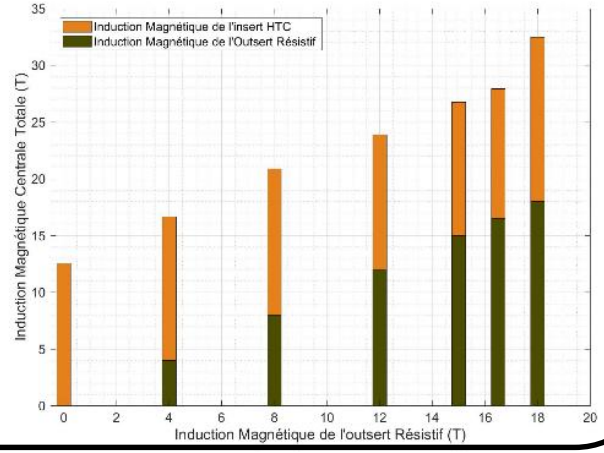


On-going cold tests at CERN

High field solenoids

NOUGAT

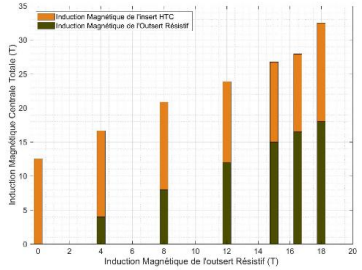
- Insert made of 9 double pancake (ReBCO) (inner diameter of 50 mm, MI insulation)
- **32.5 T obtained (14,5 T created by the HTS insert with a background field of 18T @ LCNMI Grenoble)**



HIGH FIELD HTS MAGNET PROGRAM

NOUGAT HTS insert, record 32.5 T

'NOUvelle Génération d'Aimants pour la production de Teslas'



SuperEMFL full SC 40+ T

11 european partners, 2.9 M€

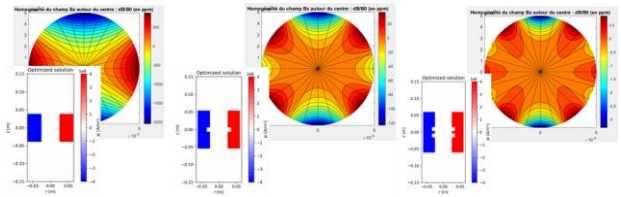
Design of a full SC 40 T+ magnet

Small-scale prototype

CEA in charge of WP4 'design'

t0 : January 2021

32 T+ pre-designs have been achieved.



Development of specific codes, MI winding and LTS/HTS interactions.

Equipex FASUM 40 T

Fundings 3.6 M€

Partners : Université Grenoble-Alpes, LNCMI

Full SC magnet of 40 T

Realisation of the HTS insert, LTS outsert from the industry.

Cryocooler 2W@4K, winding machine.
500 k€ for manpower.

ISABEL –high-field network (EMFL)

18 europeans partners, 4.9 M€

Survey about means of calculations and design center.
Pre-study of a 60 T hybrid magnet.

CEA in charge of t4/WP9 'design center'

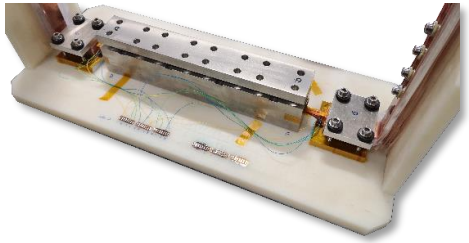
t0 : November 2020

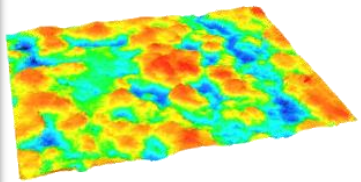
Survey has been conducted, analysis in progress.

NUMERICAL AND EXPERIMENTAL STUDIES FOR THE OPTIMIZATION AND PROTECTION OF NI-MI HTS COILS

Experimental measurements contact resistivity R_{ct} :

- ✓ as a function of the mechanical stress
- ✓ as a function of the number of mechanical cycles
- ✓ for different types of insulation (NI, MI...)

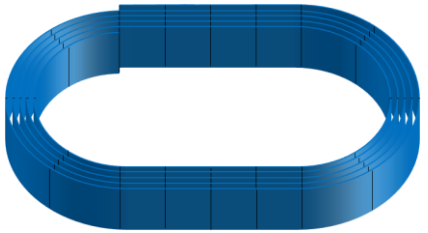


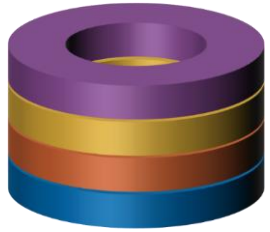


Surface condition of superconducting tape

Detailed microscopic study of R_{ct}

New simulated geometries with PEEC model : racetrack and multi-pancake





Quench protection :
voltage limitation
Experimentally tested with success

Objective : R_{ct} control with atomic layer deposition (ALD)

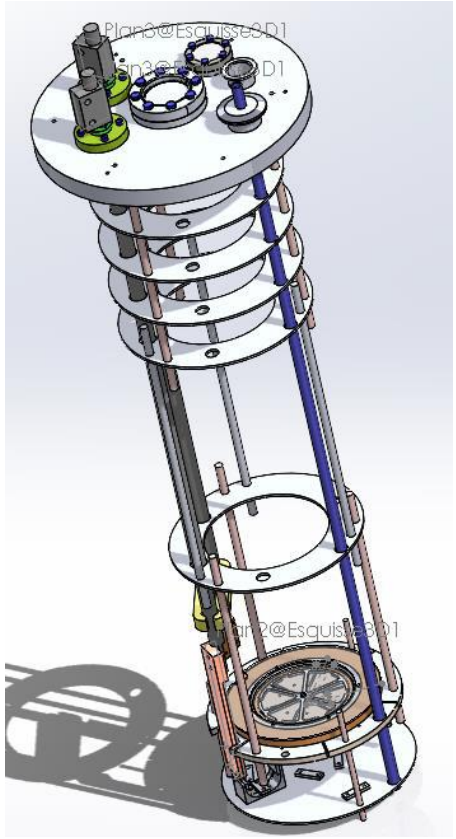
PhD thesis – Clément Genot
Defended in October 2022

MECANICS OF METAL-AS-INSULATED WINDINGS

✓**Analytical formulation** of mechanical stresses and displacements.

✓Measurement of displacements by **Digital Image Correlation,** brazilian tests of several pancakes at room temperature**.**

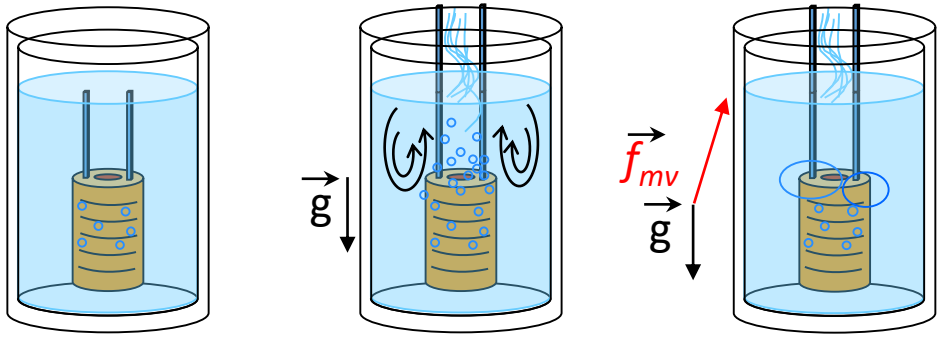
✓Measurement of displacements and stresses of a superconducting **pancake under different loadings** by DIC (tension during winding, cooling down at liquid helium temperature, Lorentz foces) ; **still in progress.**



PhD thesis Mohmad Al Harake, defended in March 2022

STUDY OF CRYOGENIC FLUID COOLING DISTURBANCES DUE TO MAGNETO-GRAVITATIONAL VOLUME FORCES IN SUPERCONDUCTING MAGNETS

Problematics: Heat transfert disturbances due to diamagnetic forces



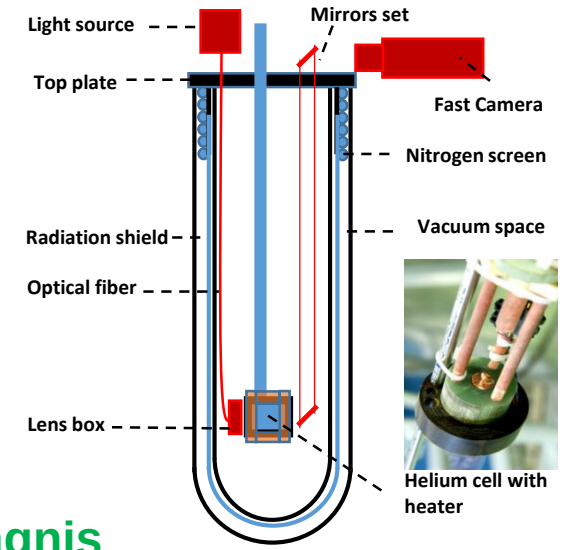
Objectives:

- Quantify the heat transfert and fluid flow modifications due to diamagnetic forces, coupled to gravity and capillary forces, in SC magnets.
- Develop new technologies to cancel or control the cooling disturbances linked to this phenomenon.

$$\overrightarrow{f_{mv}} = \frac{1}{2\mu_0}\chi_m \overrightarrow{grad} B^2$$

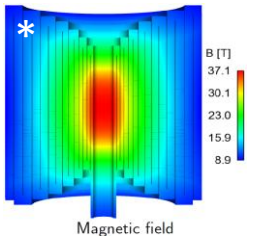
Experiment:

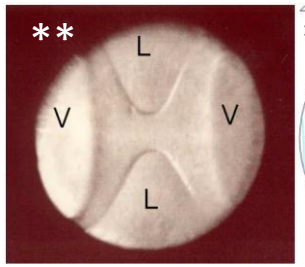
Design and fabrication of experimental cells to analyze in a high field test station of 36 T (LNCMI) the cooling behaviour in magnet-like configuration (bath cooling or small channel cooling).

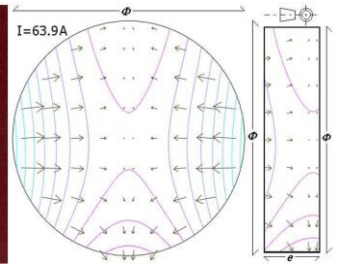


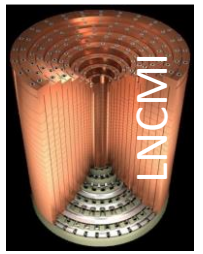
Numerical simulations:

Multiphysics simulation of the heat transfert in the cell to investigate our experimental results with extrapolation to full scale magnet modelling.









*C. Darversin et al., Full 3D MultiPhysics Model of High Field PolyHelices Magnets, MT24
**C. Lorin et al, Magnetogravitational potential revealed near a liquid-vapor critical point, JAP,106 (2009)

PhD thesis – Simon Bagnis
On-going work

FROM RESEARCH TO INDUSTRY

cea

THANK YOU FOR YOUR ATTENTION !