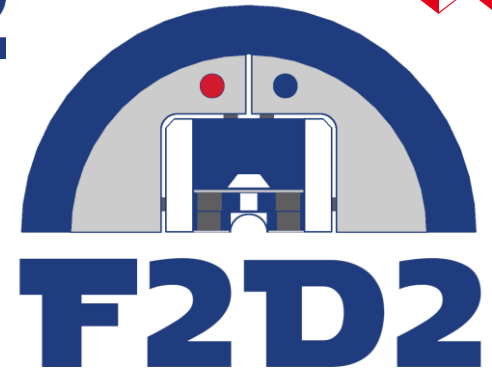
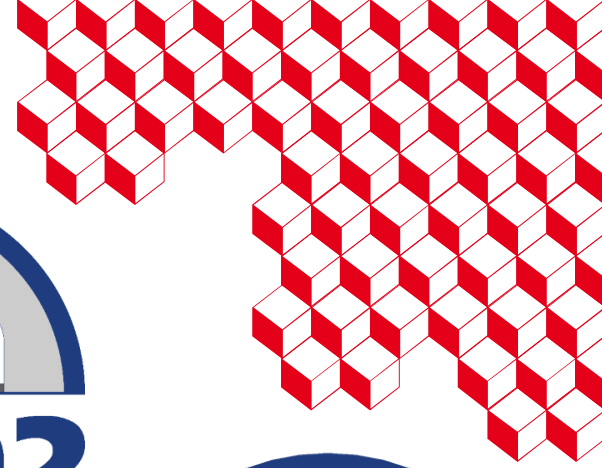
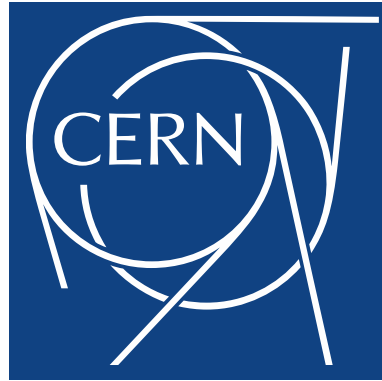


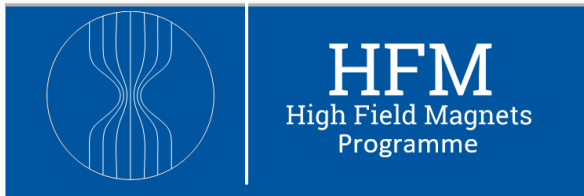


irfu



Status of HFM development at CEA - LTS and HTS

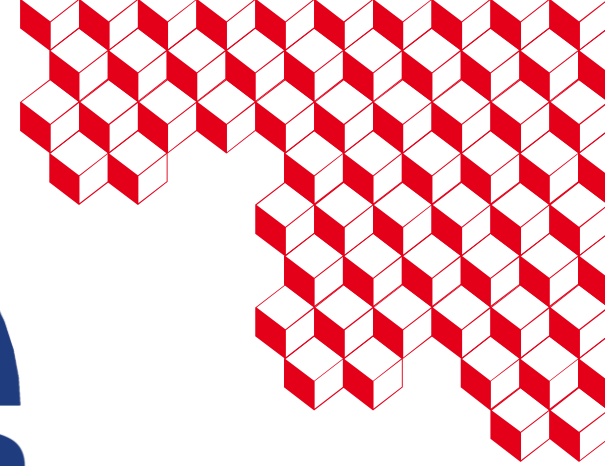
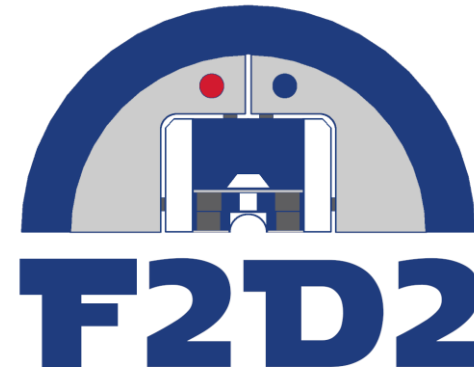
E. Rochepault, T. Lécresse - CEA Paris-Saclay



FCC week 2025 – 22/05/2025



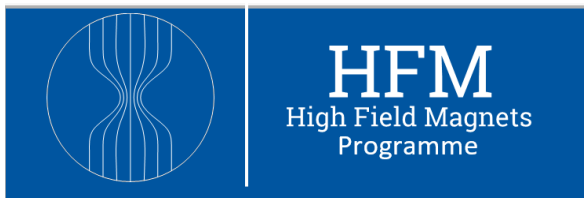
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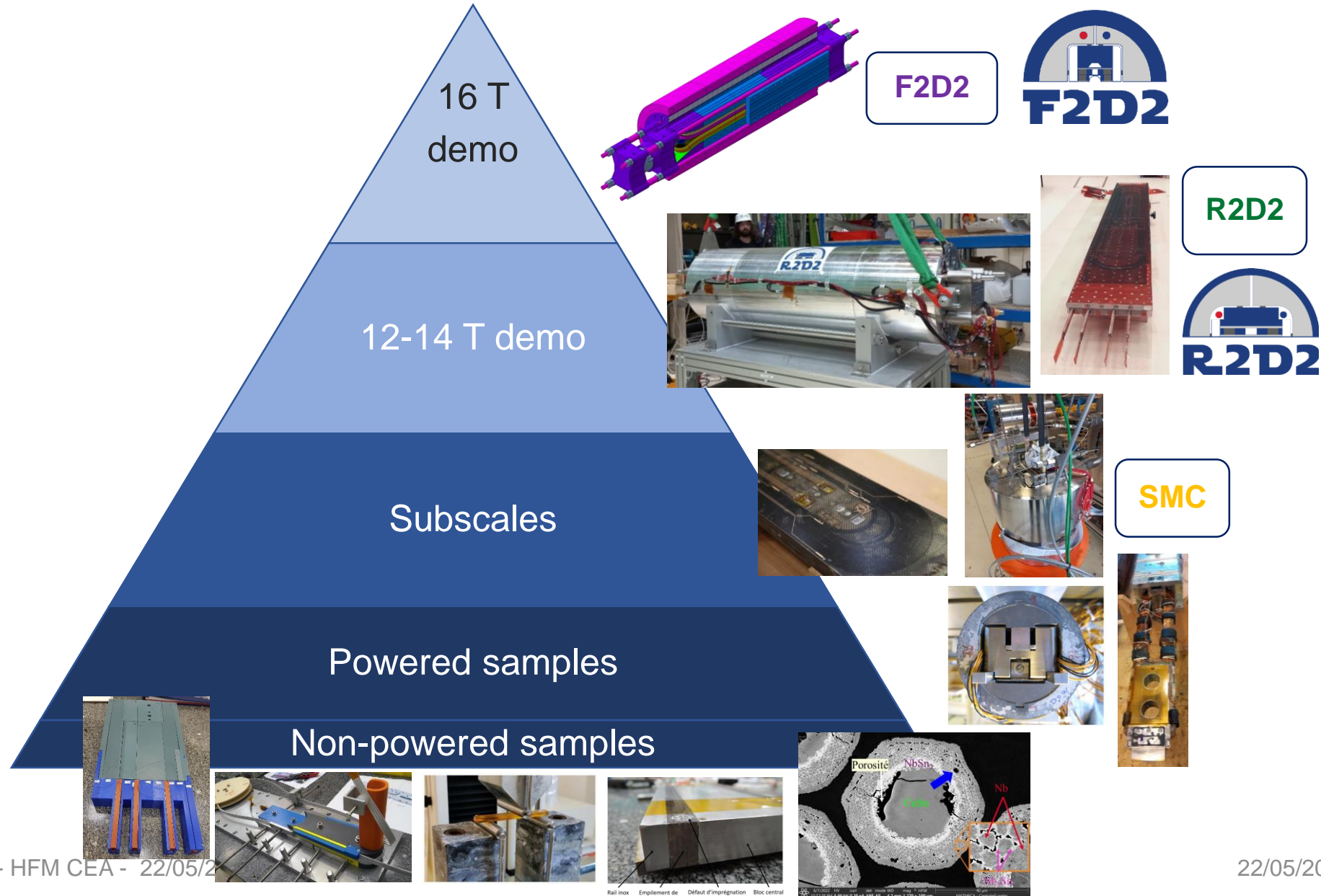
Nb₃Sn magnet program - R2D2 and F2D2 (Part I)

E. Rochepault, V. Calvelli, G. Campagna, M. Durante, H. Felice, J. Faucheux, D. Djetten, G. Lenoir, G. Minier, S. Perraud, Y. Perron, F. Rondeaux, E. Pepinter, R. Correida Machado, T. Barabé, M. Lefèvre, S. Somson, B. Maloeuvre - CEA

J.C. Perez - CERN

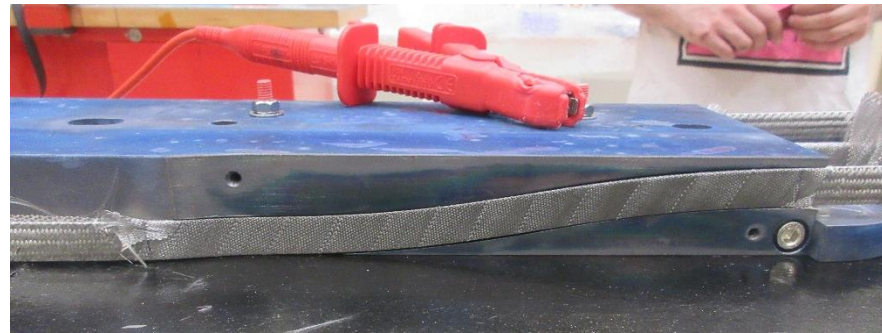
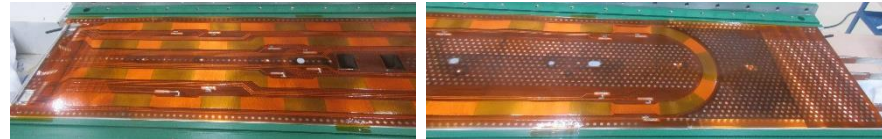
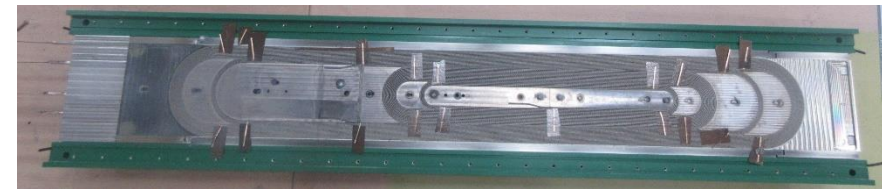
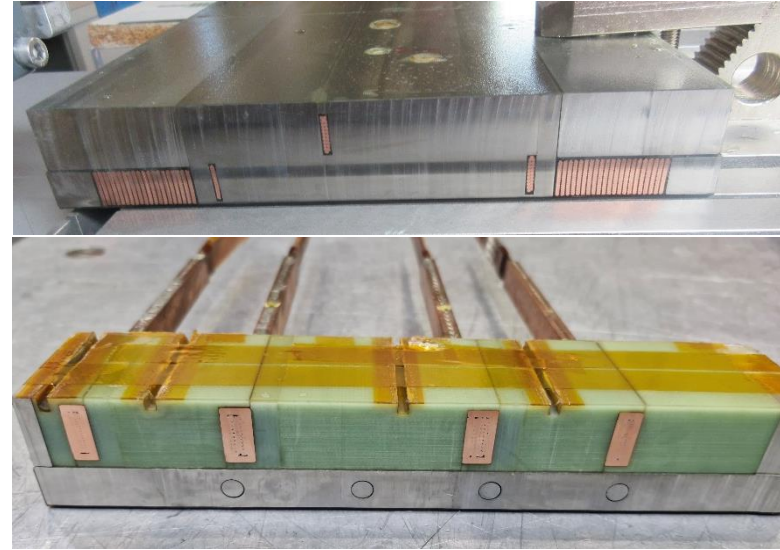


Development Plan towards 16 T Nb₃Sn Dipoles



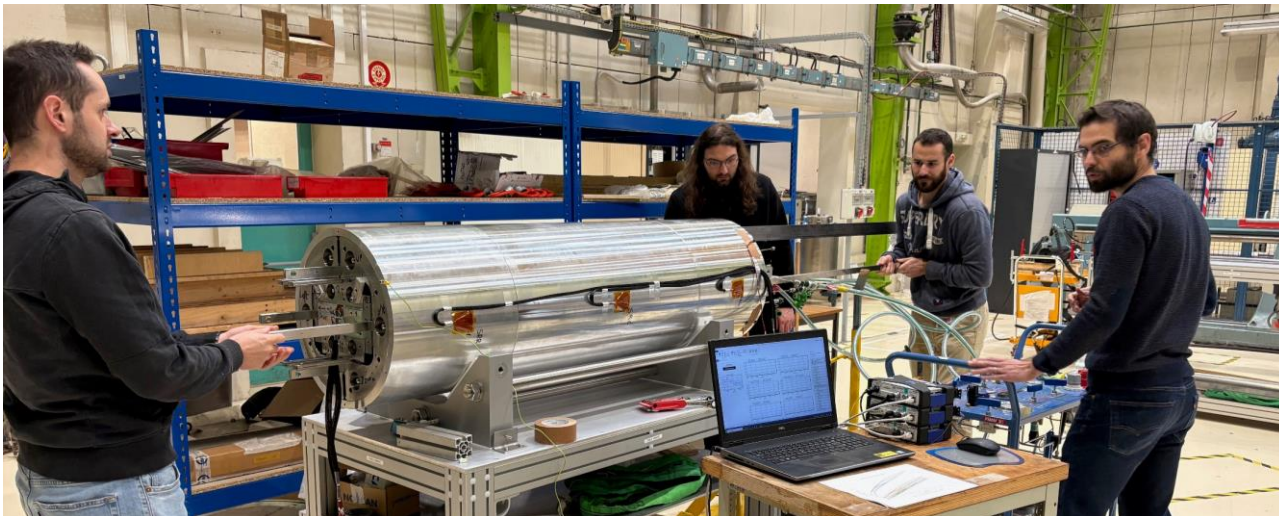
Fabrication of R2D2 coils

1. CC01: Cu Practice coil
 - Cuts for inspection
 - **Validation of the process**
2. CR01: Nb₃Sn Practice coil
 - **Electrical shorts in the exit jumps**
 - **Issue identified: composition of the fiber used**
3. CR02: final Nb₃Sn coil
 - **Wound and unwound**
 - **Fiber replaced**
 - **Manufacturing validated**
4. CR03: final Nb₃Sn series coil
 - **Wound and reacted**
 - **Manufacturing ongoing**



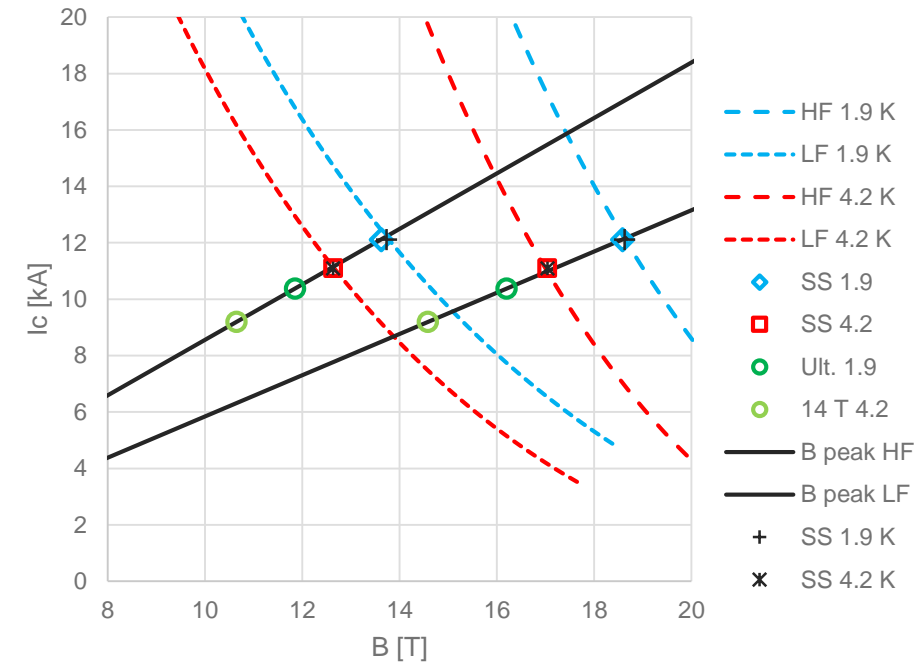
Assembly of the R2D2 mechanical structure

- Mechanical structure assembled with a dummy coil block
- Mechanical tests to validate the behavior:
 - Different room temperature preloads
 - Cool-down to 77 K
 - Analysis ongoing
- Goal: get ready for the final assembly with the Nb₃Sn coils

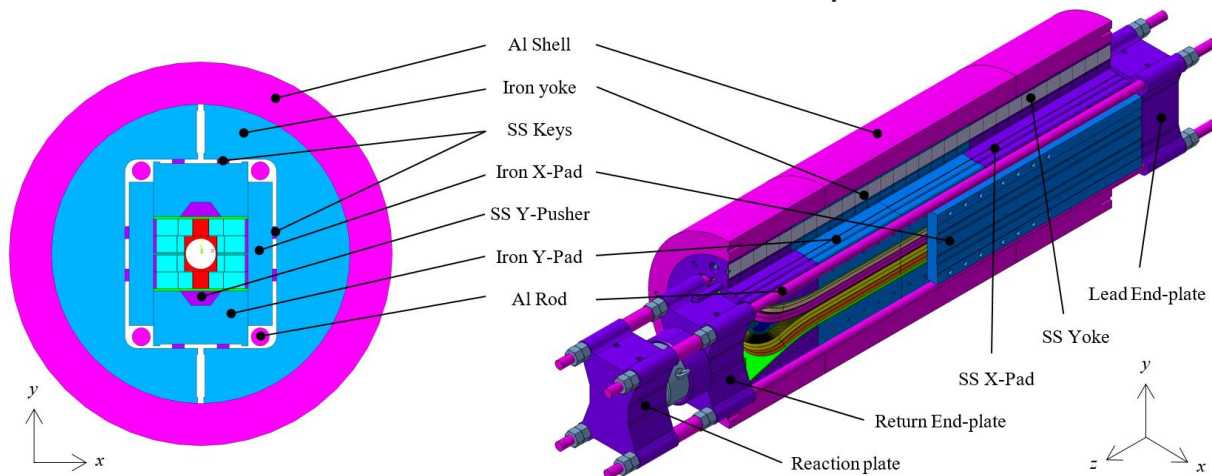


Overview of the F2D2 design

- **Conceptual design done, detailed engineering ongoing**
- Fabrication, assembly and pre-stress at Saclay
- Tests at cold at CERN
- **Main goal: demonstrate all technologies**
 - Representative of high field magnets: grading, joints, flared-ends, high field and high stress
 - Representative of accelerator magnets: 50 mm bore, field quality



F2D2 = Future Flared Dipole Demonstrator

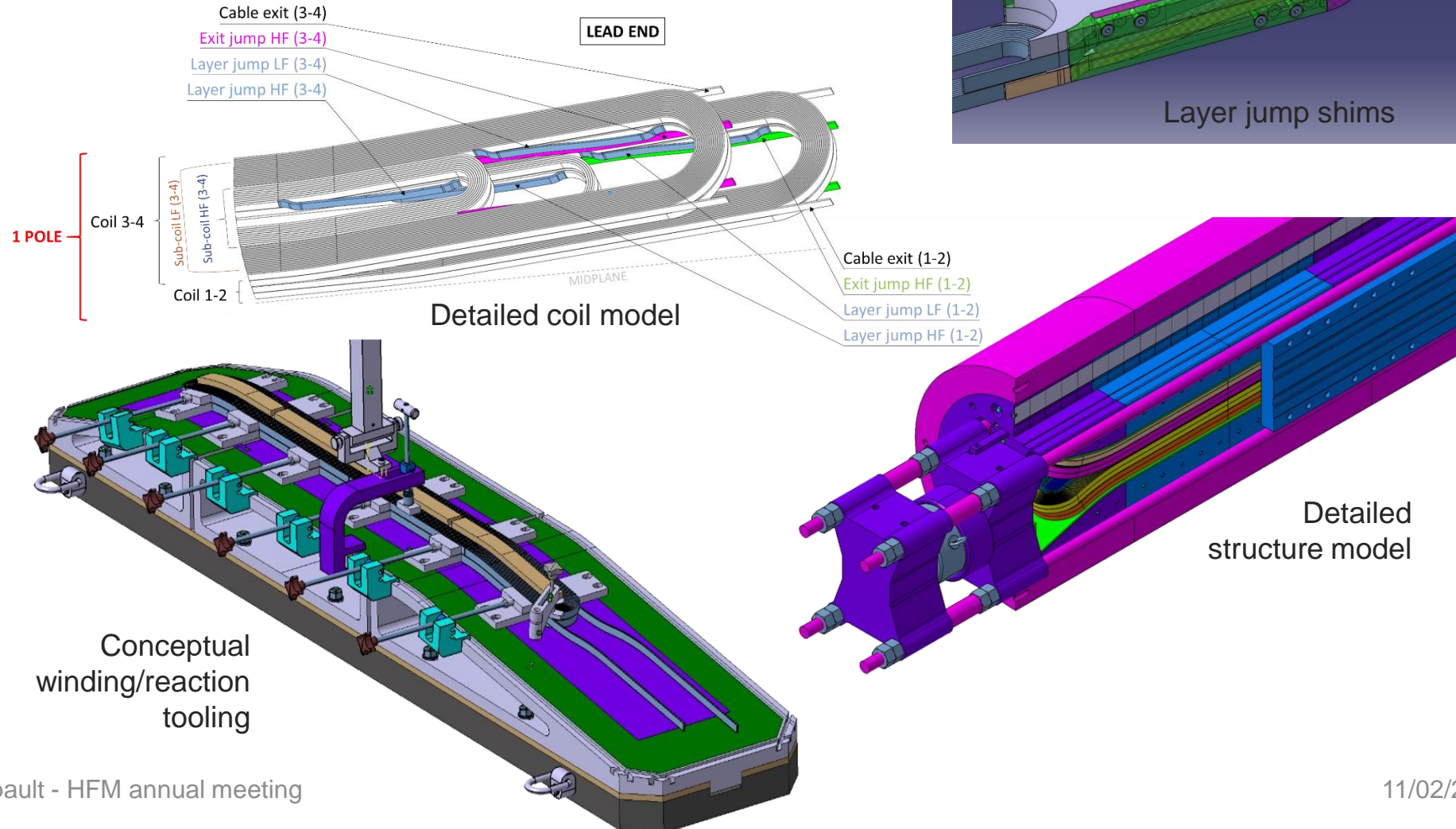


Aperture	50 mm
Outer diameter	650 mm
Total length	2.0 m
Central field @76% LL	14.0 T
SS central field	17.8 T

@1.9 K

F2D2 conceptual engineering design

- Conceptual design finalized
- Detailed design ongoing



Conclusion: plan towards ultimate-field Nb₃Sn

- SMC coils as a learning tool
 - **Nb₃Sn coil fabrication experience acquired at CEA Saclay**
- R2D2 as a 1st demonstrator
 - Demonstrator for **grading in block-coils**
 - Simplified design → **single-layer, flat racetracks, no bore**
 - ~12 T @1.9 K with 20 % margin on the load-line
 - **Fabrication of the coils ongoing**
 - **Structure validation ongoing**
- F2D2: the final goal
 - Demonstrator for **accelerator magnets**
 - **double-layers coils with layer jumps, grading, 50 mm bore, field quality**
 - 14 T @1.9 K with 25 % margin on the load-line
 - 15.5 T @1.9 K with 15 % margin on the load-line
 - **Detailed design ongoing**



irfu



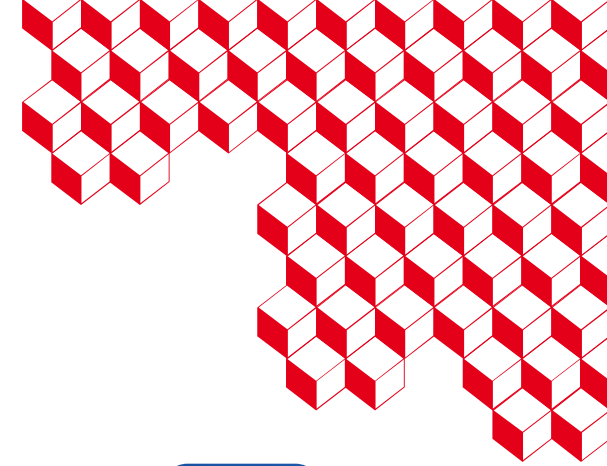
T. Lécrevisse

Metal-insulated REBCO Racetracks last results (part II)

CEA-CERN HFM collaboration W2-11 agreement on HTS MI racetracks developments

Thibault Lécrevisse (CEA) on behalf of CEA team

Amalia Ballarino, Algirdas Baskys (CERN)



E. Benoist



A. Blondelle



A. Caunes



M. Durochat



C. Genot



G. Lenoir



S. Somson



B. Maloeuvre



T. Barabe

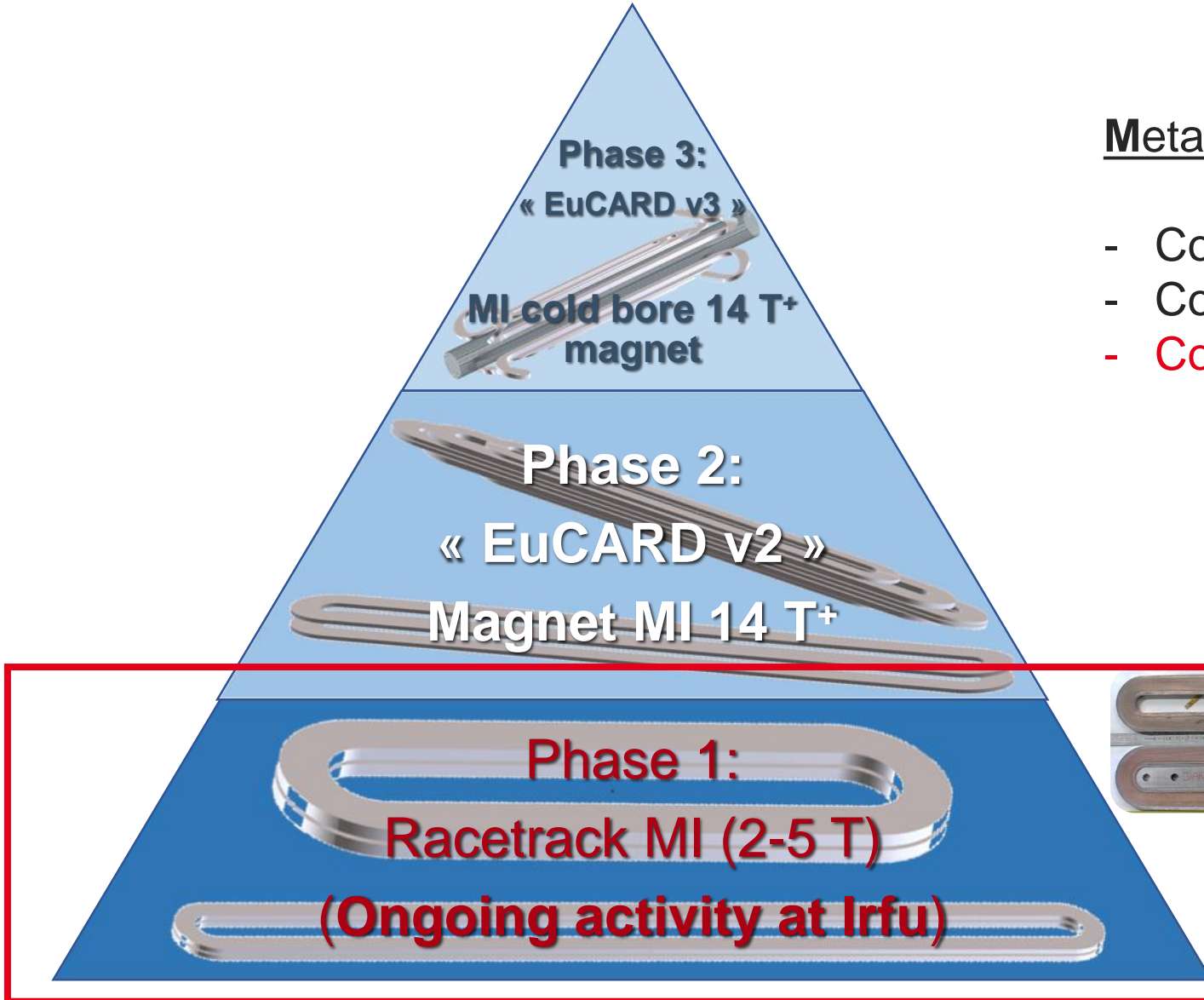


E. Pepinter

+ Many thanks to CNRS Néel Institute for helping in 4.2 K tests (A. Badel, J. Vialle & P. Tixador)

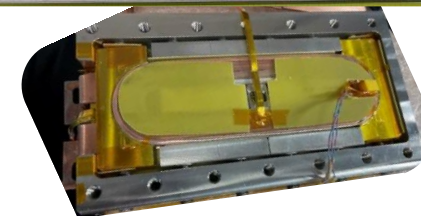


1. Agreement Status : Development main phases



Metal Insulated (NI steel co-winding) for :

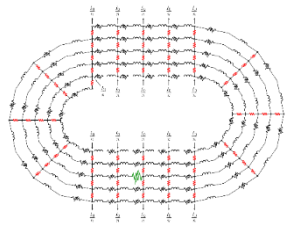
- Costs / risks reduction
- Conductor and design **limit exploration**
- **Compact 14 T+ REBCO** mock-ups



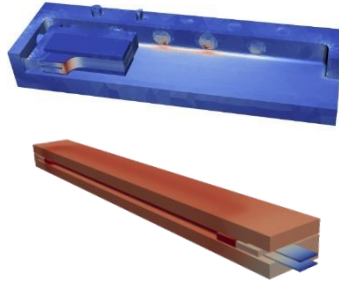
2023-2025

2. Development blocks

Modeling



PEEC-R



3D FEM

R&D / Characterization

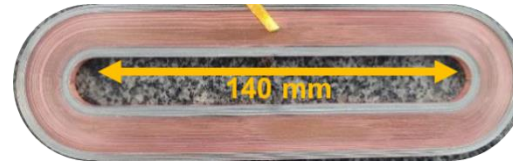


Electrical connections

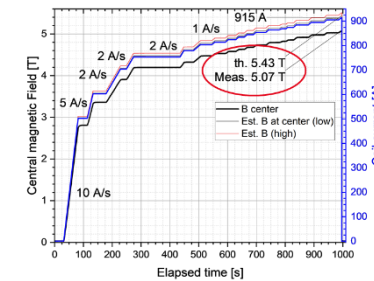


Radial thermal conductivity

MI Racetrack fabrication, assembly and tests



Winding & assembly



Test and analysis

4. Racetrack coils : Samples overview

- 26 mm inner width, 140 mm straight part
- Shanghai Superconductor Technology (SST), 4 mm wide and 73-75 μm thick
- Co-winding of :1 REBCO tape with a 30 μm thick Durnomag®
- ~54-59 m of single 4 mm tape per Racetrack

REBCO tape provided
by CERN

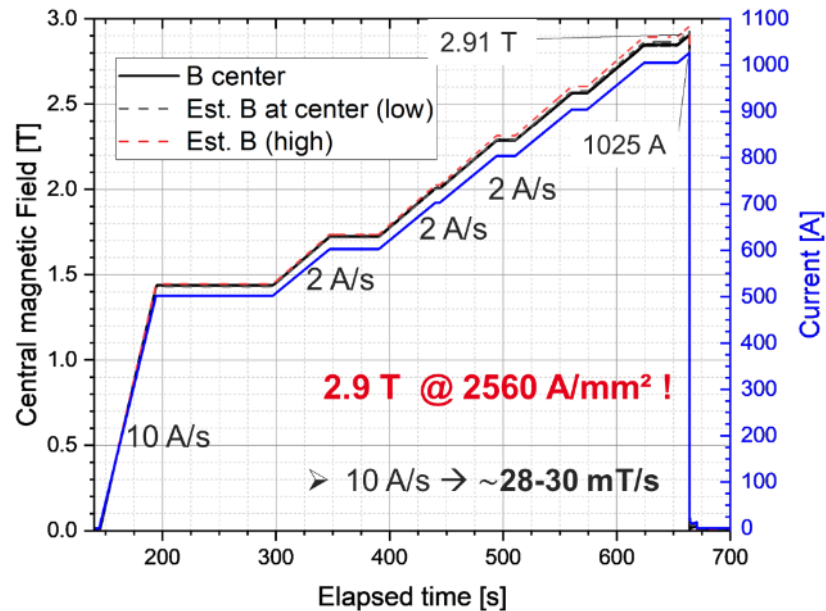
- Dummy winding (copper stainless steel)
- 11 RaceTracks (RT) with copper rings built (RT1, ..., RT9, RT10 & RT11)
- 3 Double RaceTrack (DRT) assemblies (DRT78, DRT75 & DRT10-11)
- 77 K tests (LN2 bath)
- 4.2 K tests (LHe bath)

2 tests campaigns : November 2024 (DRT78 and DRT75) → learning

March 2025 (RT9 and DRT10-11) → Promising results ([HFM forum: metal insulated HTS coil](#))

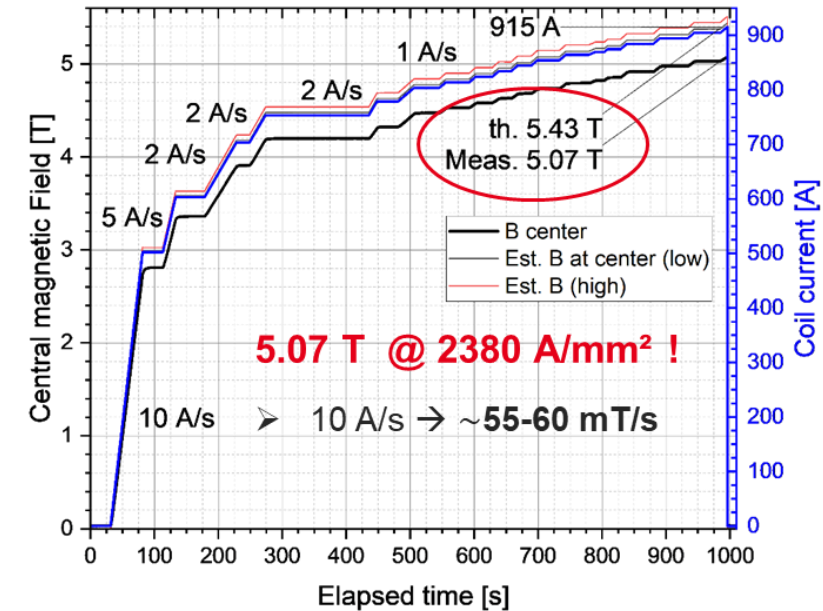
5. RT and DRT promising results

RT9 tests



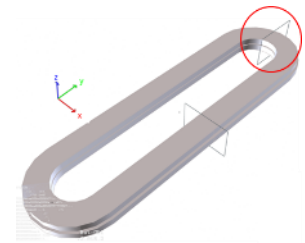
- High current density ($j_{\text{overall}} > 2500 \text{ A/mm}^2$)
- **Peak field** on REBCO tape **> 8 T**
- **2.9 T at center** (at quench current)
- 20-30 mT/s reached
- Survived to quench... **BUT damaged**

DRT10-11 tests

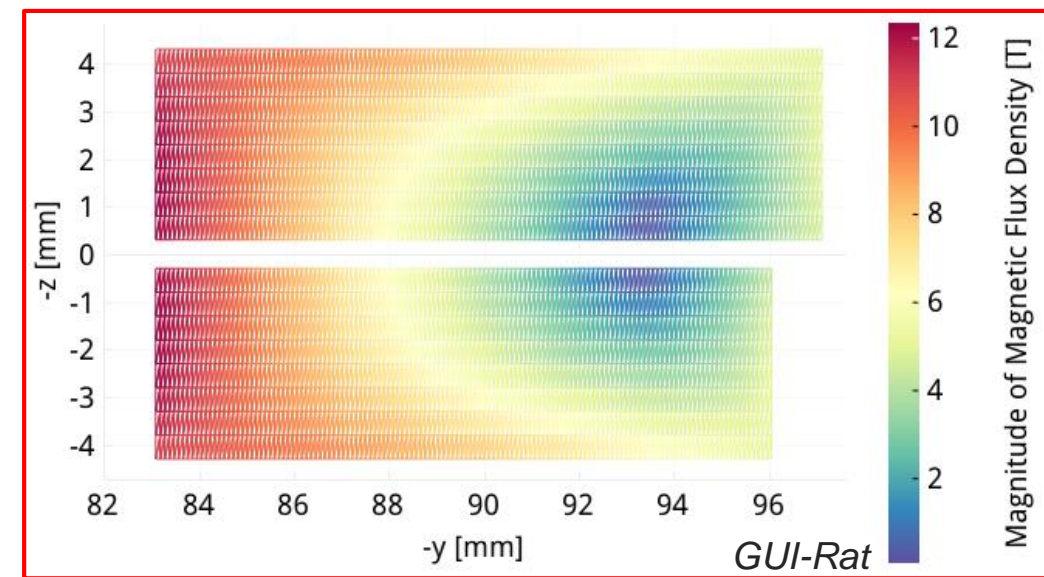


- High current density ($j_{\text{overall}} > 2300 \text{ A/mm}^2$)
- Peak field on REBCO tape **> 12 T**
- **> 5 T at center** (at quench current)
- **55-60 mT/s** reached
- Survived to quench **without visible damaged** (2 quenches above **2100 A/mm²**)

5. DRT10-11 promising results : details

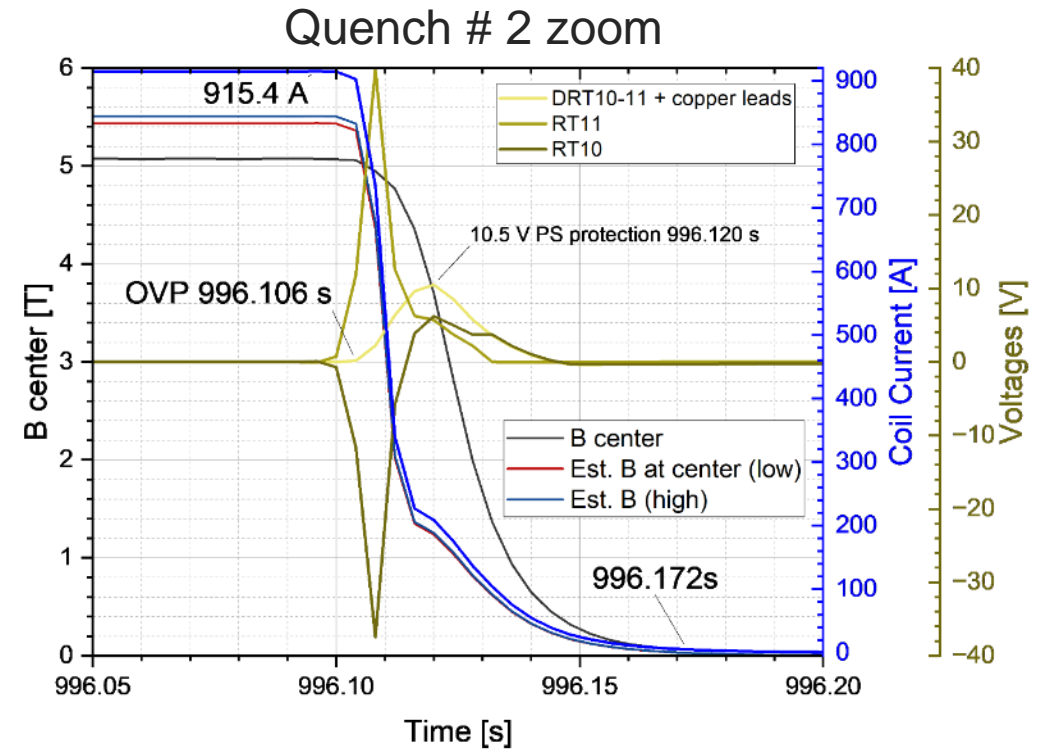


DRT10-11 @ 915 A



Peak Field on **REBCO tape** ~ 12.3 T (without SCIF*)

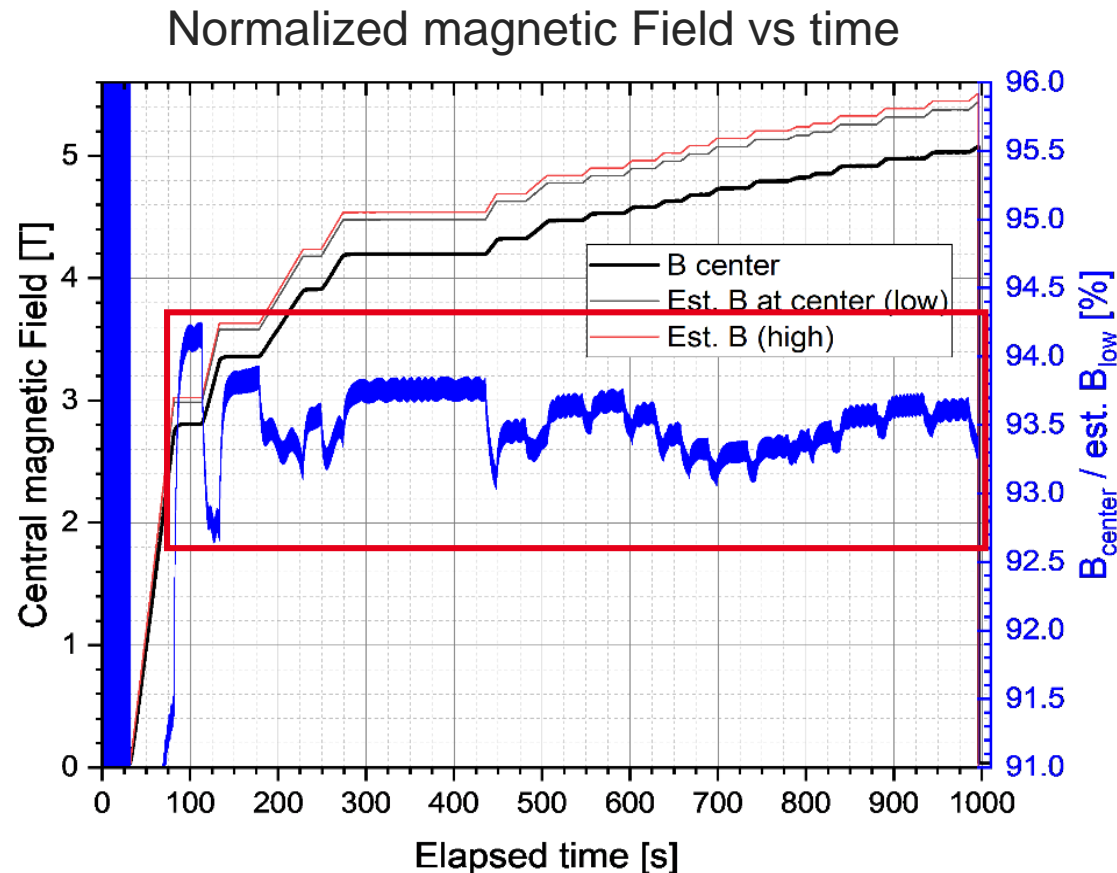
* Screening Current Induced Field



- B_0 measured ~ 5.07 T (5.43 T calc. **without SCIF***)
- Very high current density at quench :
 - $j_{\text{overall}} \sim 2300$ A/mm²
 - $j_{\text{REBCO tape}} \sim 3400$ A/mm²
- Coil **self discharge** (~ 5.1 kJ) in ~ 80 ms

NO DAMAGES

5. DRT10-11 promising results : details



- Magnet transfer function fluctuation **within ~ 1 %** (steps) or 1.5 % (incl. transient)
- **Fine analysis required** to understand the magnet behavior
- **SCIF might be responsible** for the 6-7 % lower magnetic field measured in plateaus

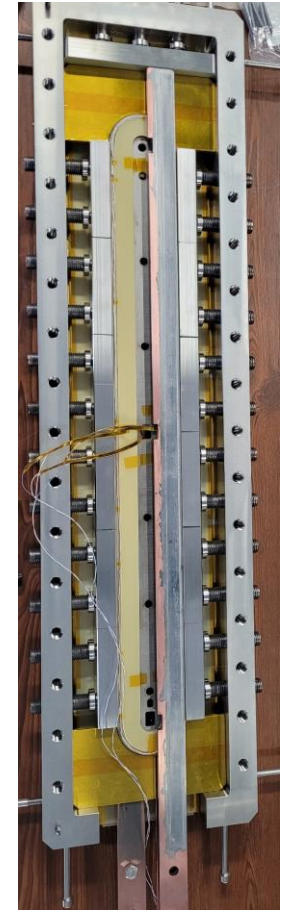
Very promising setup for getting experimental data for numerical models benchmark

* Screening Current Induced Field

6. NARSIL toward 14 T dipole magnet

- Many open question and lot of data to try to answer them
- Nice setup to test different kind of windings
- Possibility to compare measures to models

And now : reproduce the results on 600 mm **NARSIL*** DRT



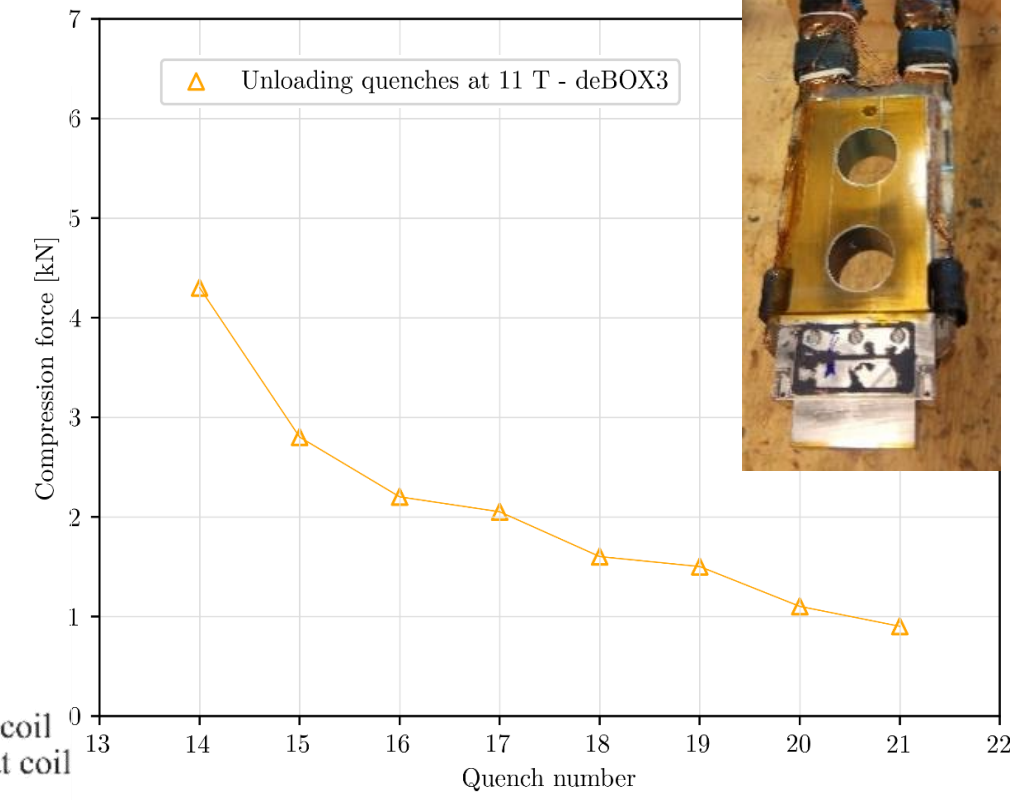
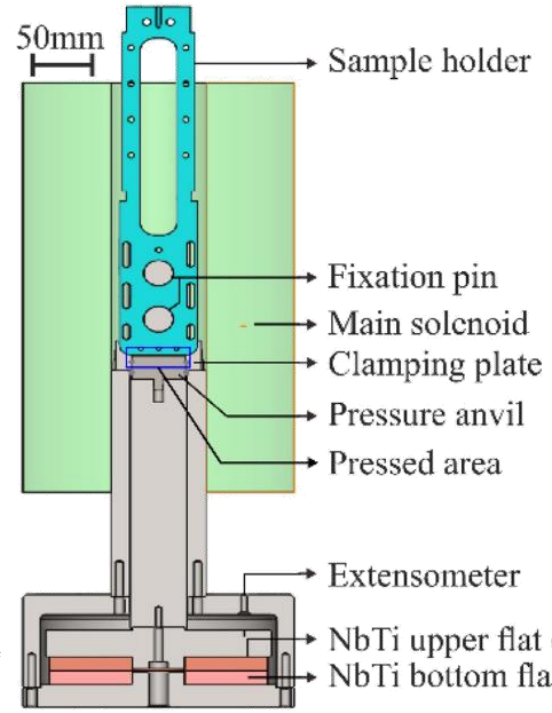
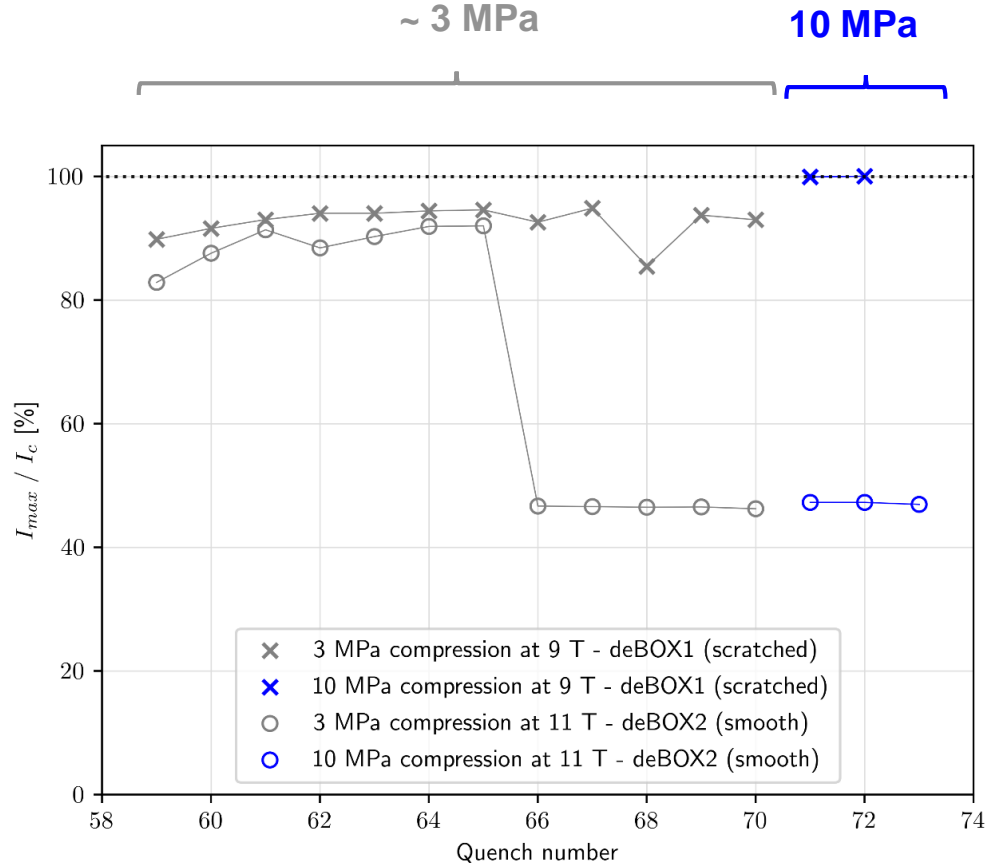
Est. current limit @ 4.2 K : 1000 A → **4.5-5 T**
at center and >10 T peak field

* Next generation of Accelerator HTS RacetrackS with metal Insulation at Lab-scale



Thank you for your attention !

Training of Nb₃Sn a low compression force (PhD Guillaume Campagna)



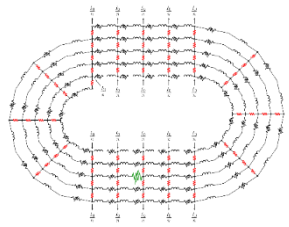
At low compression:

- The small **detraining** can be reversible.
- The large **degradation** is not reversible.

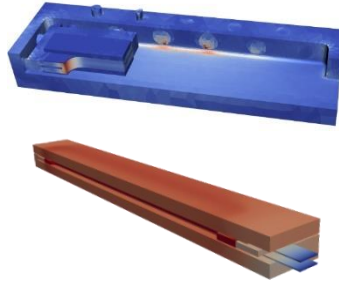
- **Unloading quenches: A quench can be triggered just by changing the compression force!**

3. Modeling and small R&D

Modeling



PEEC-R



3D FEM

- Magnetic model (RAT-GUI, OPERA, CASTEM)
- Transient PEEC-R without magnetization (MATLAB)
- Thermo-mechanical model (CASTEM / ANSYS)
- ➔ **Need to be compared to measurements**
- PEEC-R with magnetization : started

R&D / Characterization

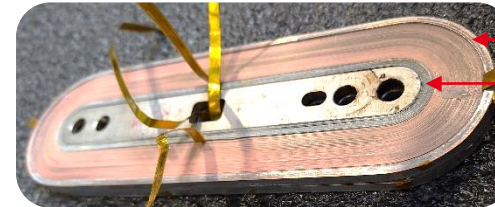


Electrical connections



Radial thermal conductivity

- Study on copper to copper electrical contacts resistance
 - For contacts between racetracks and/or leads



Inner copper ring
Outer copper ring

- Study on turn to turn thermal conductivity in MI windings