A Test Facility for High Field Magnet R&D

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CERN

Outline

- Test facility – for what ?
- A new high-field dipole as a test facility
- For discussion

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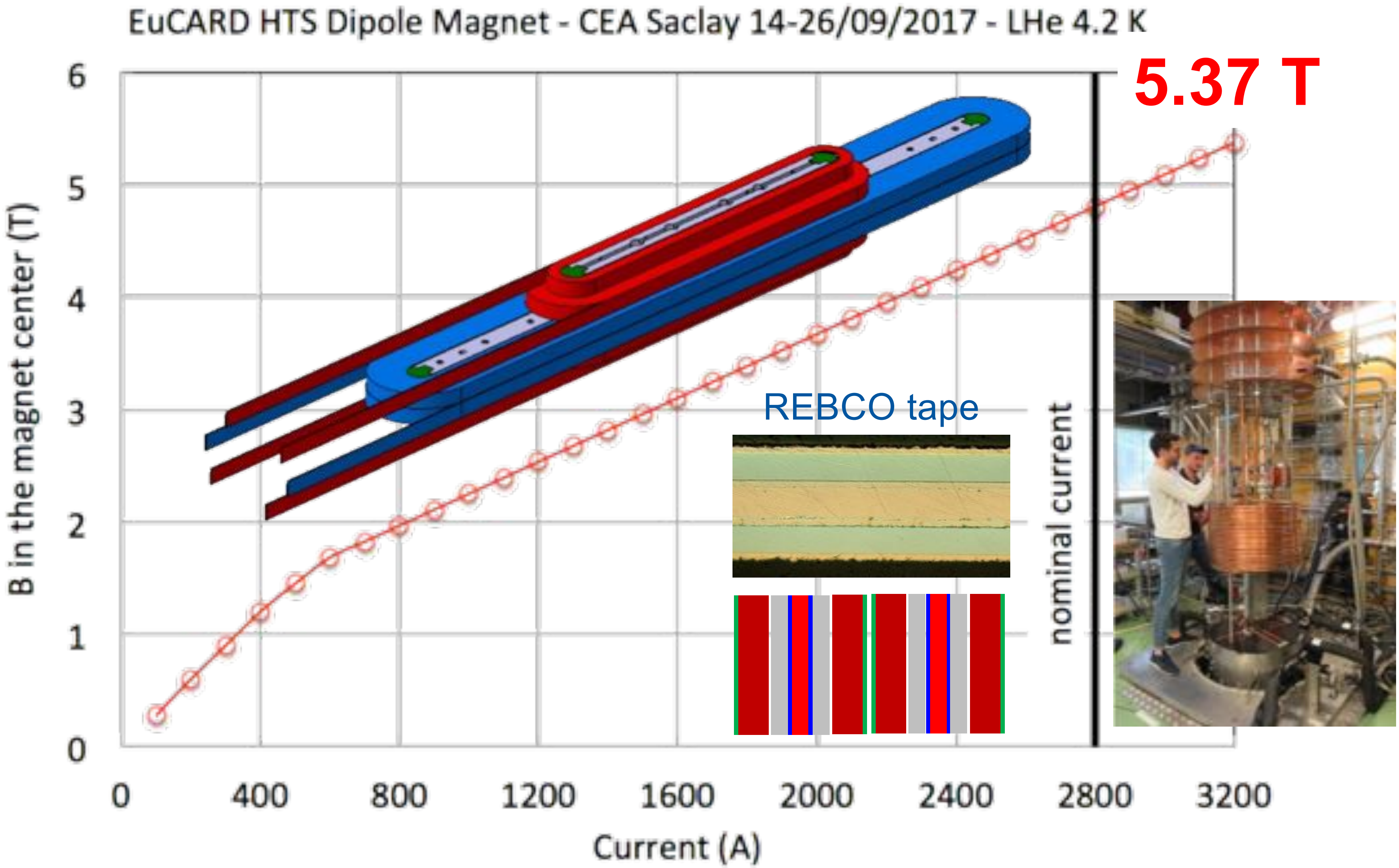
Test facilities ?

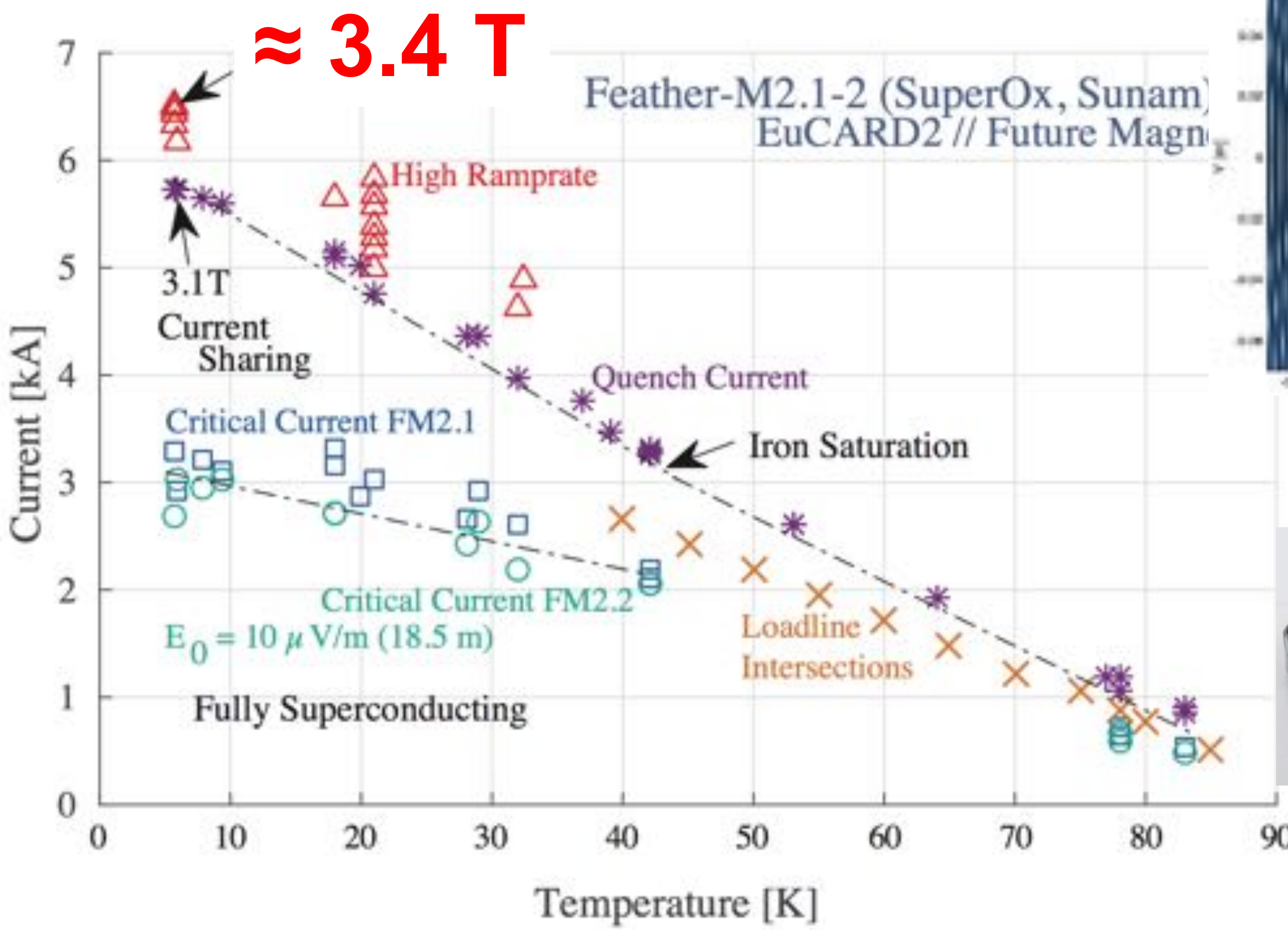
- **The usual mission of a test facility**: provide conditions of field (B, dB/dt), temperature (T), current (I, dI/dt), and force (σ, ε), as close as reasonably possible to the operation conditions of the material, cable, coil, magnet
- A matter of scales
  - The situation is **quite clear at the scale of wires**, where there is a park of test facilities operating worldwide, and a general desire to **increase and combine** the test parameters (I know this is a tricky business, I am not trying to shortchange the excellent science made within this scope)
  - The situation **at the scale of cables and small coils is much more difficult and critical**, especially when considering high fields (10 T and above) and HTS
  - Somewhat surprising, things become **much better at the next scale, the magnet itself**, with several locations worldwide that can host high-current cryogenic test of superconducting models and prototypes

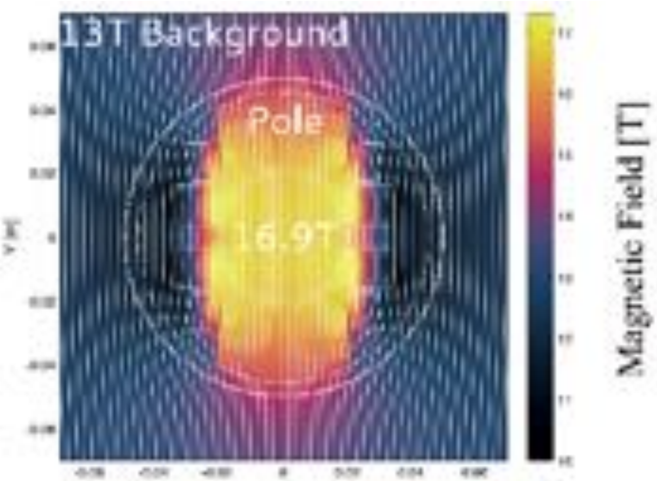
EuCARD - HTS insert



Courtesy of M. Durante, CEA

EuCARD^2 – FeatherM2.12

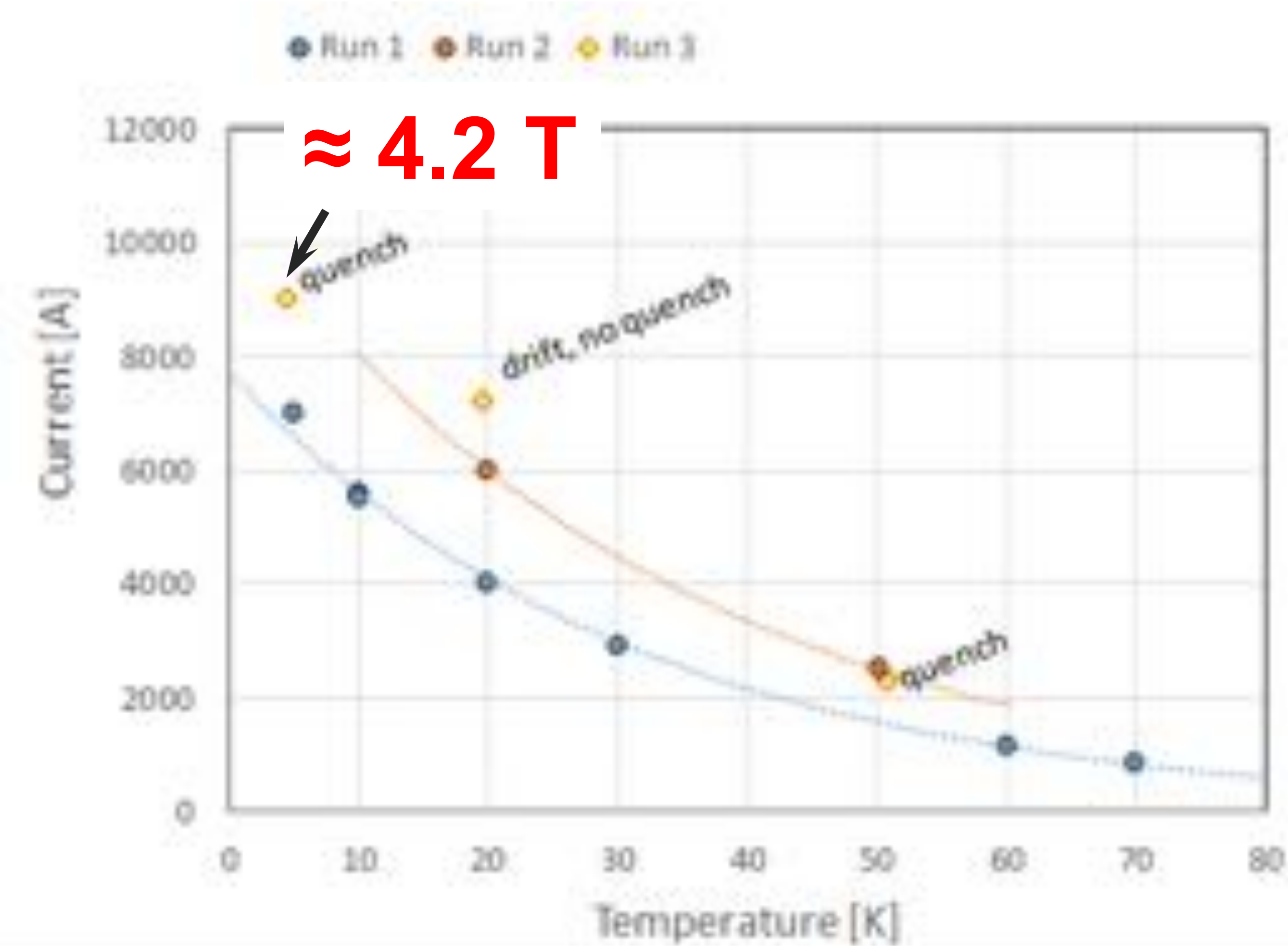




Aligned block design

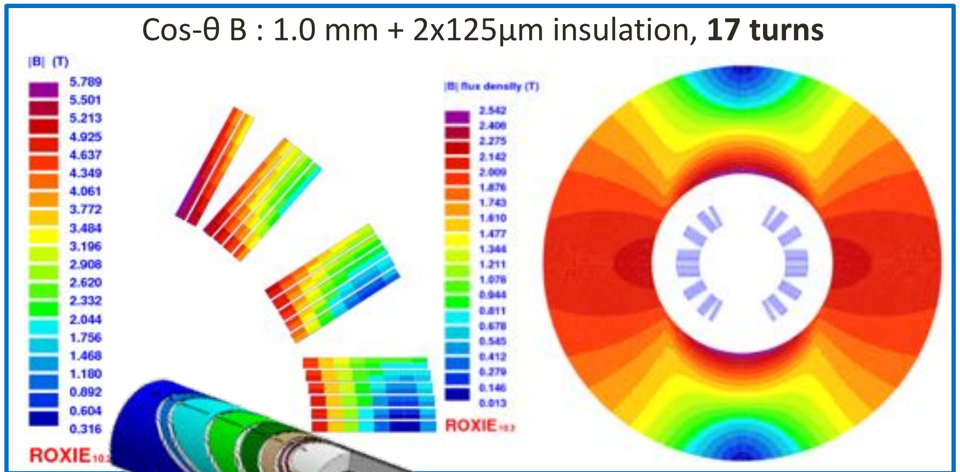
Roebel cable

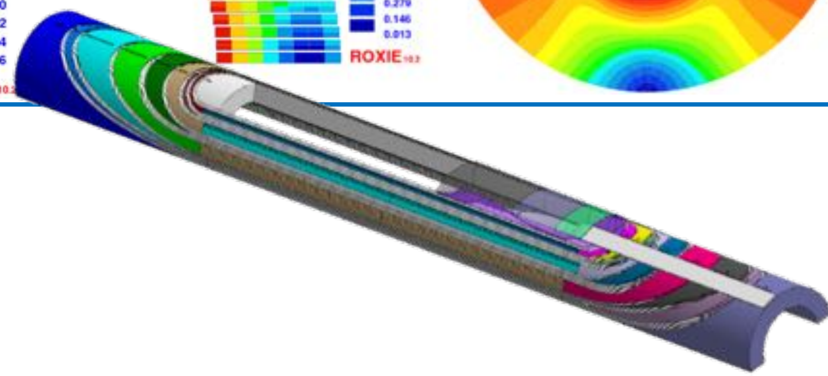
EuCARD² – FeatherM2.34

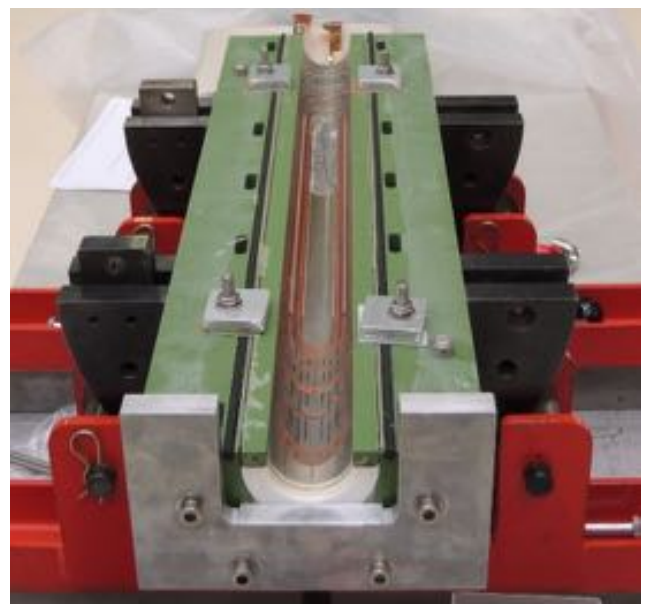


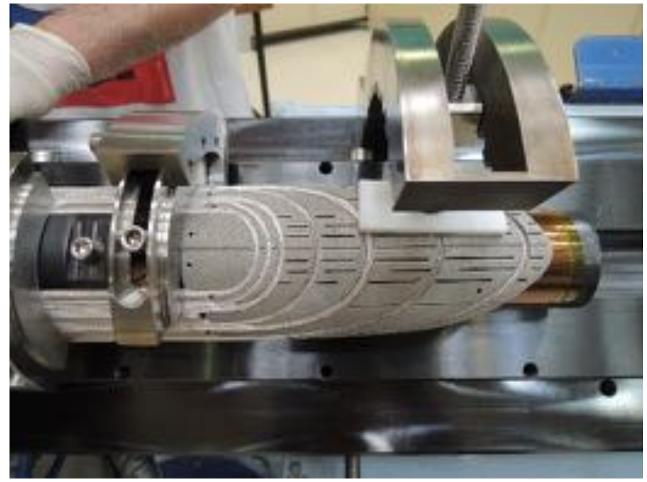
We are taking baby-steps

EuCARD^2 – cos-theta





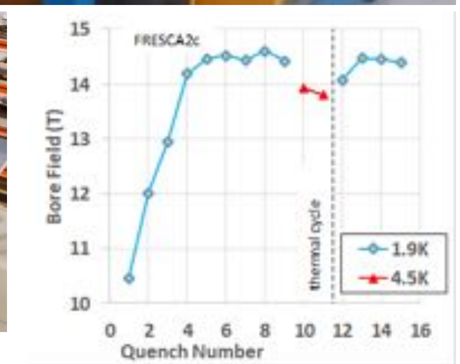




HTS-HFM R&D vehicles

- HTS requires works at all levels: material, conductor, small coils, **model coils**, and (on the longer-term) accelerator magnet design studies and construction
- HTS *short model coils* of relevant length (500 mm) and generating significant field (range of 5 T) require in the range of 0.5 … 1km of tape (12 mm equivalent). The **material value is in the range of 100 to 200 kCHF**
- A sound development program will require a few of these coils per year (see equivalent Nb_3Sn program, and EuCARD/EuCARD[2] experience)
- A test of high-field properties **forcibly requires a background field facility**. Any other plan (e.g. a full-HTS magnet) is not reasonable (2 MCHF material per 1m coil), nor technically sound (very high risk of failure)

The test facilities



1984: SULTAN at EPFL/SPC (Villigen)
11T at 4.5…100 K, 92x142 mm

2018: FRESCA2 (CERN/CEA) at CERN
14.6T at 1.9 K, 100 mm

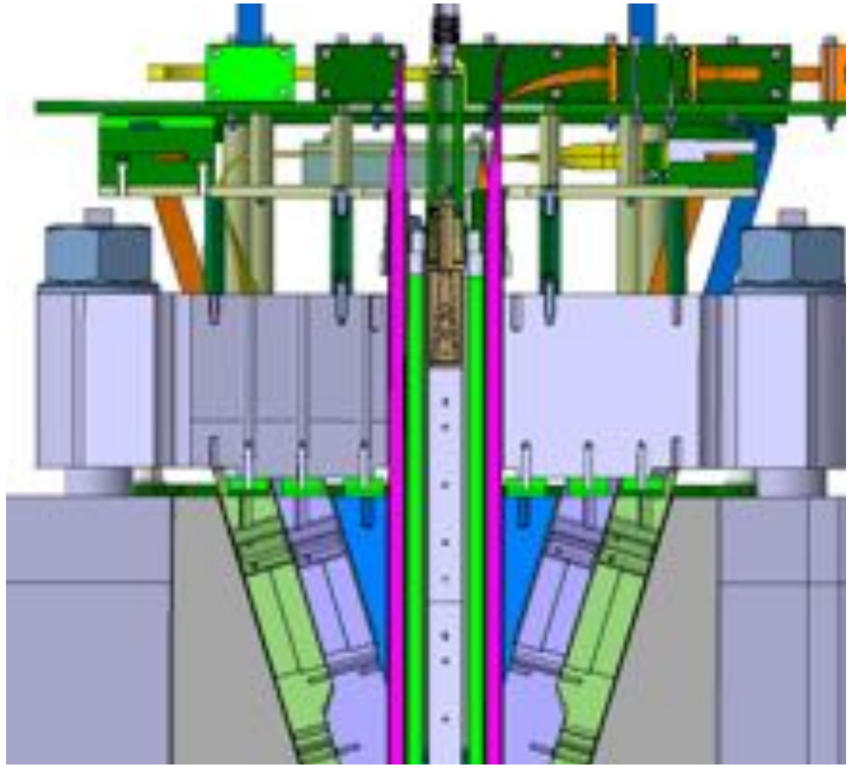
CERN interest in a new facility

- After completing testing of EuCARD and EuCARD^2 insert magnets (2…3 tests to be completed by end 2020) the FRESCA2 magnet will become part of a new cable test facility
- At this point it will no longer possible to mount HTS inserts of significant size in the magnet bore (anti-cryostat)
- The only high-field test facility left for insert testing will be SULTAN at EPFL/SPC

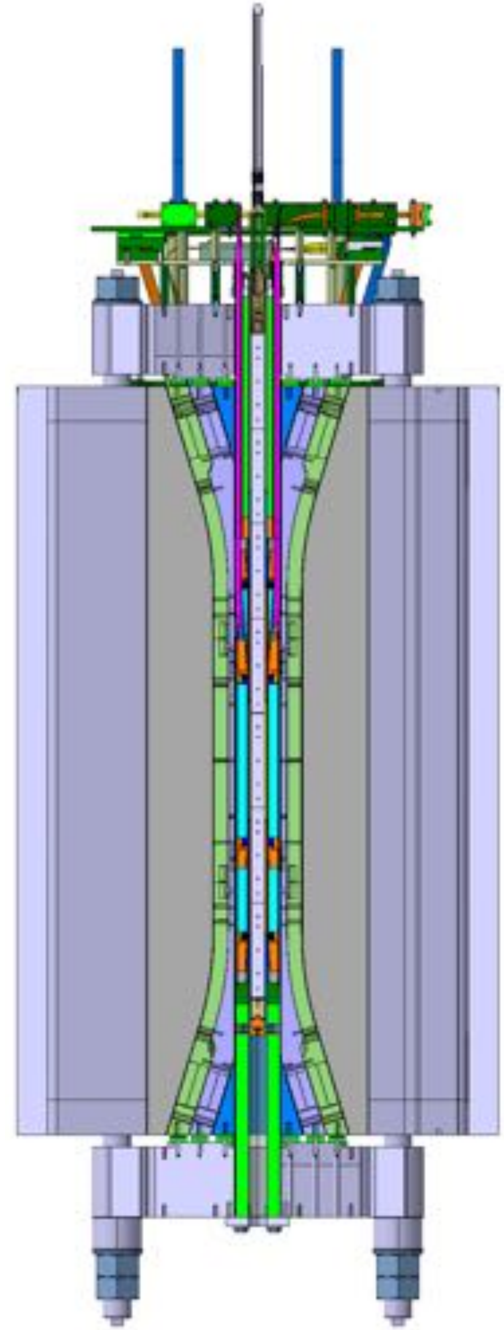
CERN

No HTS R&D without a suitable test bed

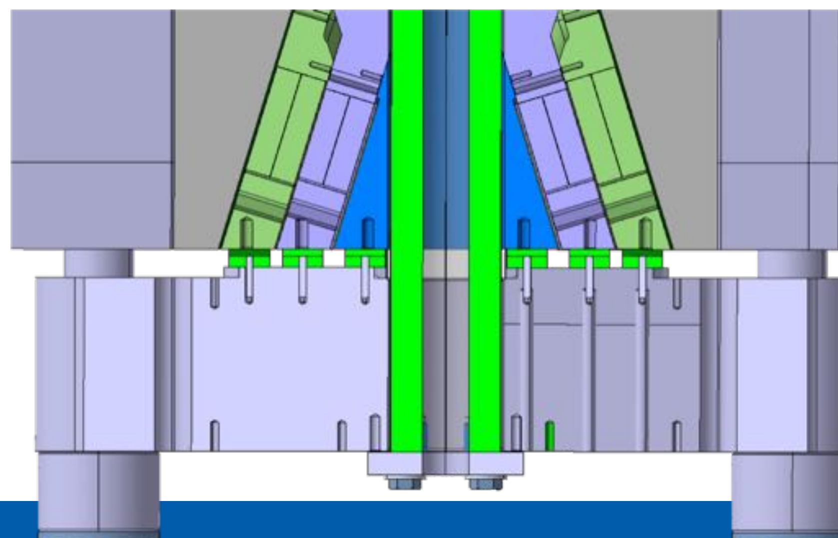
Top end, showing the mechanical support and electrical connections, as well as the integration of a shaft for magnetic measurement



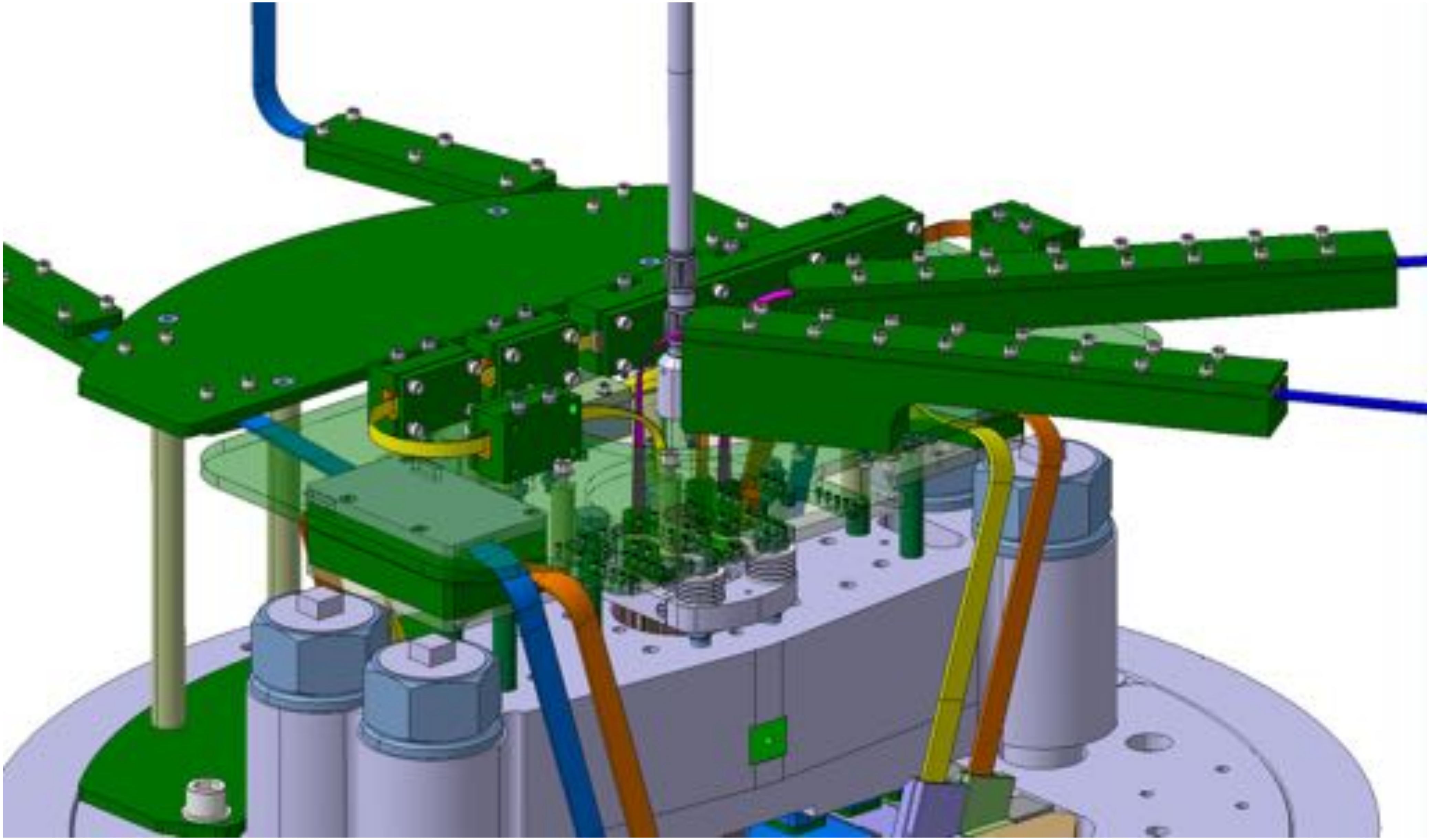
Feather.M2 integration in FRESCA2



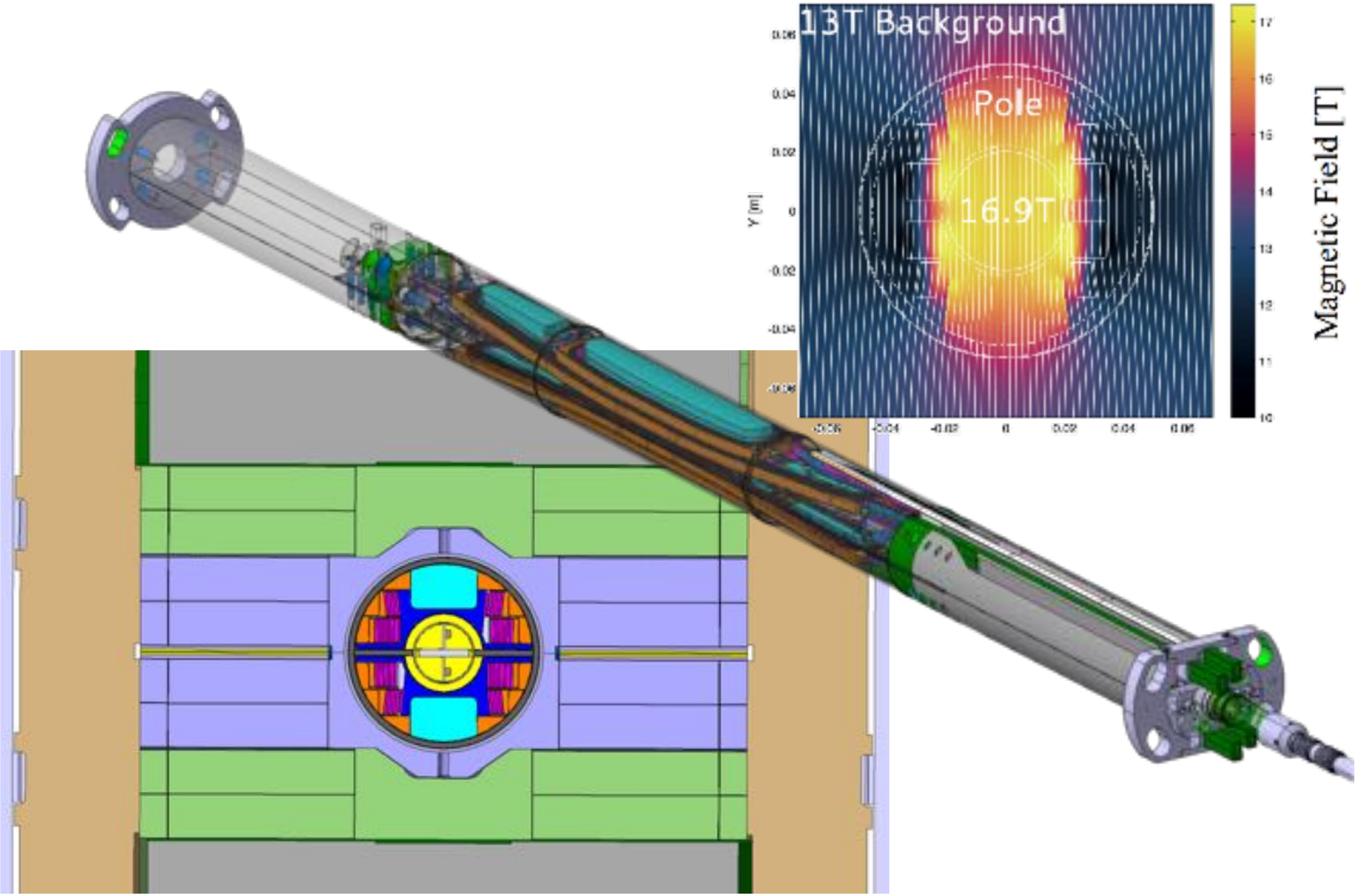
Bottom end, showing the mechanical support of the insert structure (additional pipe)



Feather.M2 magnet integration in FRESCA2 for test in SM18



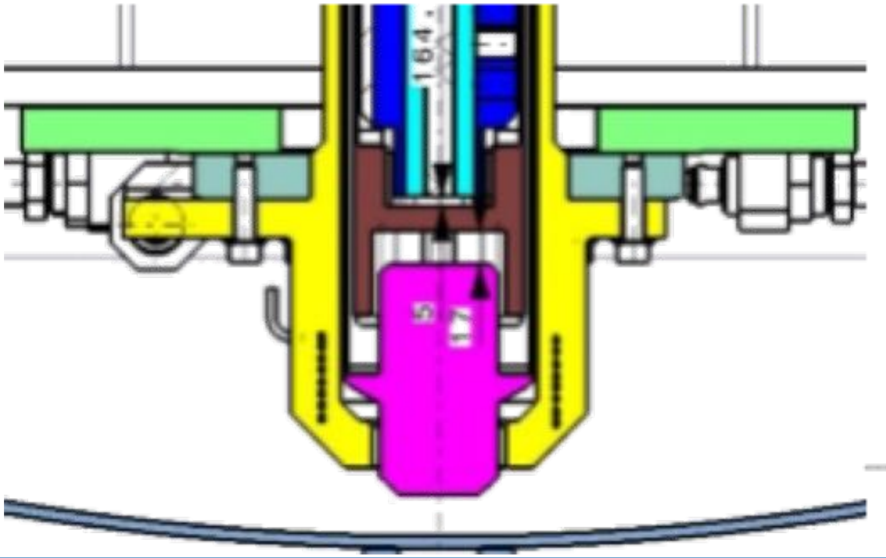
Integration of HTS inserts in FRESCA2 for test in SM18

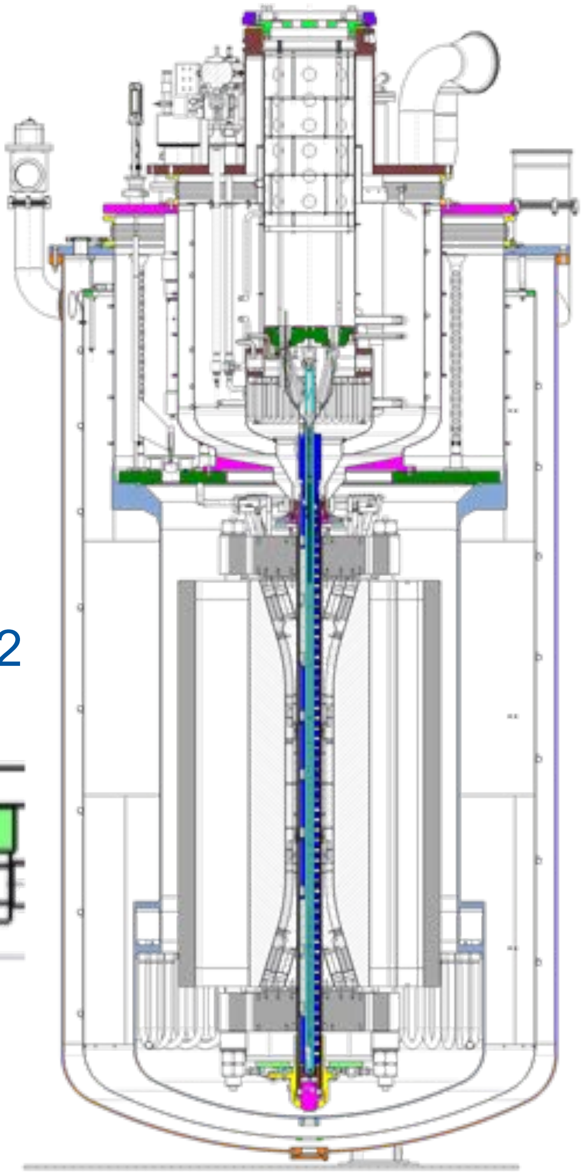


Feather.M2 magnet integration in FRESCA2 for test in SM18

Top end, showing the sample penetration in the anti-cryostat and the torque locking mechanism with fixed features mounted on the magnet

Cable sample integrated in FRESCA2





Bottom end, with the torque support mechanism through the wall of the variable temperature cryostat

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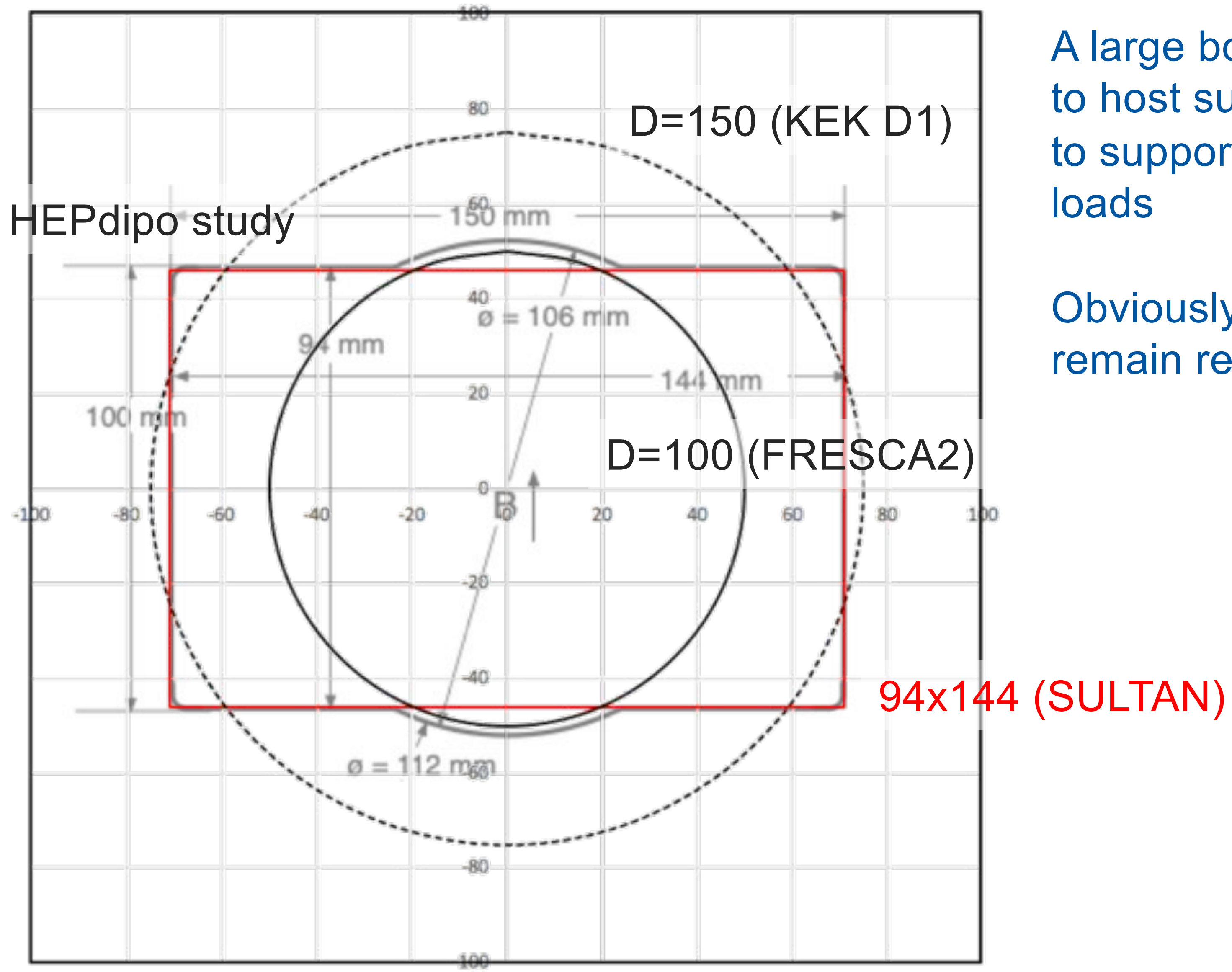
Specification for a new test facility

- Approach operating conditions (B, I, T) set as target for the development of **future accelerator HTS magnets**:
  - $B_{bkg} \approx 15$ T
  - $I_{op} > 20$ kA
  - $T_{op} \approx 1.9$ K … 100 K
  - Large aperture (≈ 150 mm)
- A test-bed for **HTS inserts** (possibly cables, and obviously also relevant to LTS) of different configurations (wound samples, hairpin samples, pressure/temperature controlled samples), targeting peak (total) field of the order of 20 T

These are the specifications for the HEPdipo study

On the magnet bore



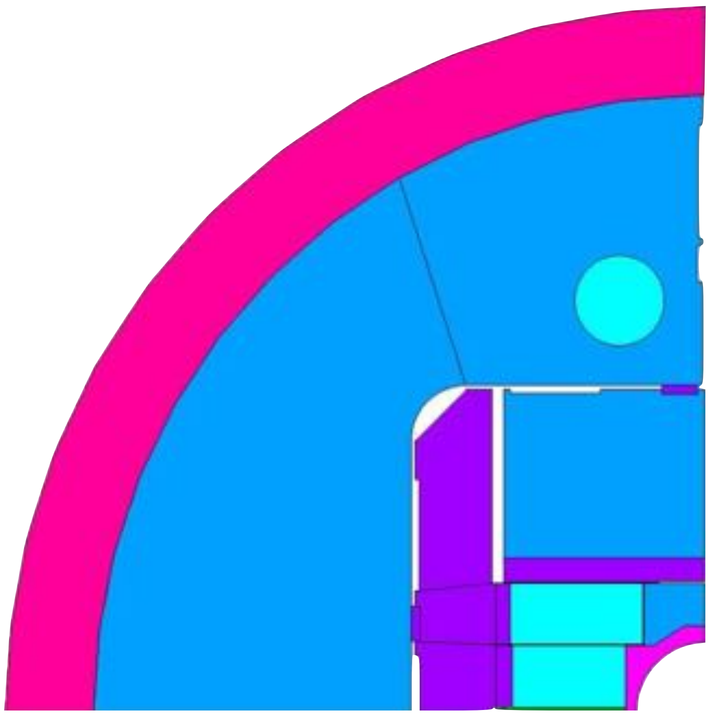
A large bore is necessary to host sufficient structure to support electromagnetic loads

Obviously, we need to remain reasonable…

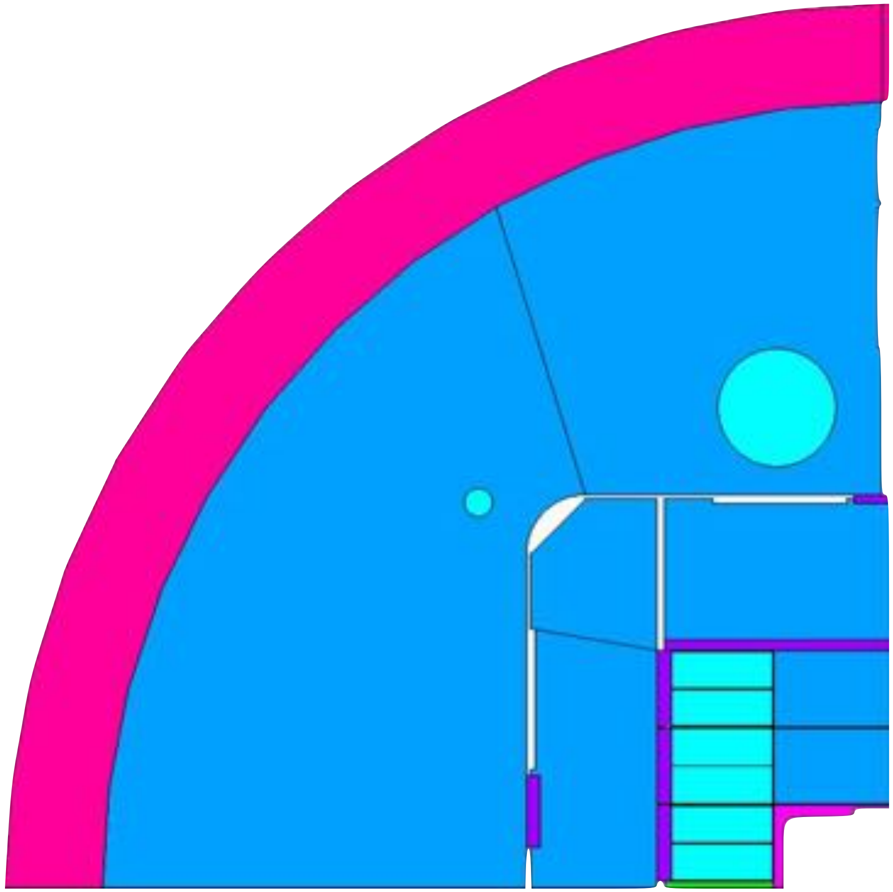
Additional benefits

1. **Exploit the investment** made in the technology developed for block magnets (SMC, RMC, FRESCA2)
2. **Mutualize the effort** with the sequence of model magnets planned towards high-field Nb_3Sn accelerator magnets of the next generation (the CERN DEMO)
3. Use this construction as an **additional R&D vehicle**, to implement and test variants that are deemed appropriate and ready for such realization, and leave a significant heritage

1. FRESCA2 vs. HEPdipo.1

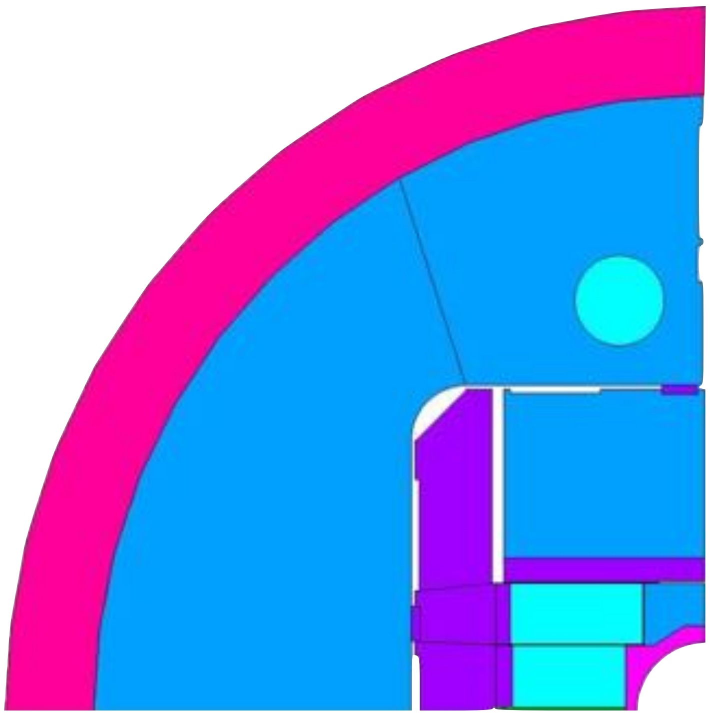


FRESCA2

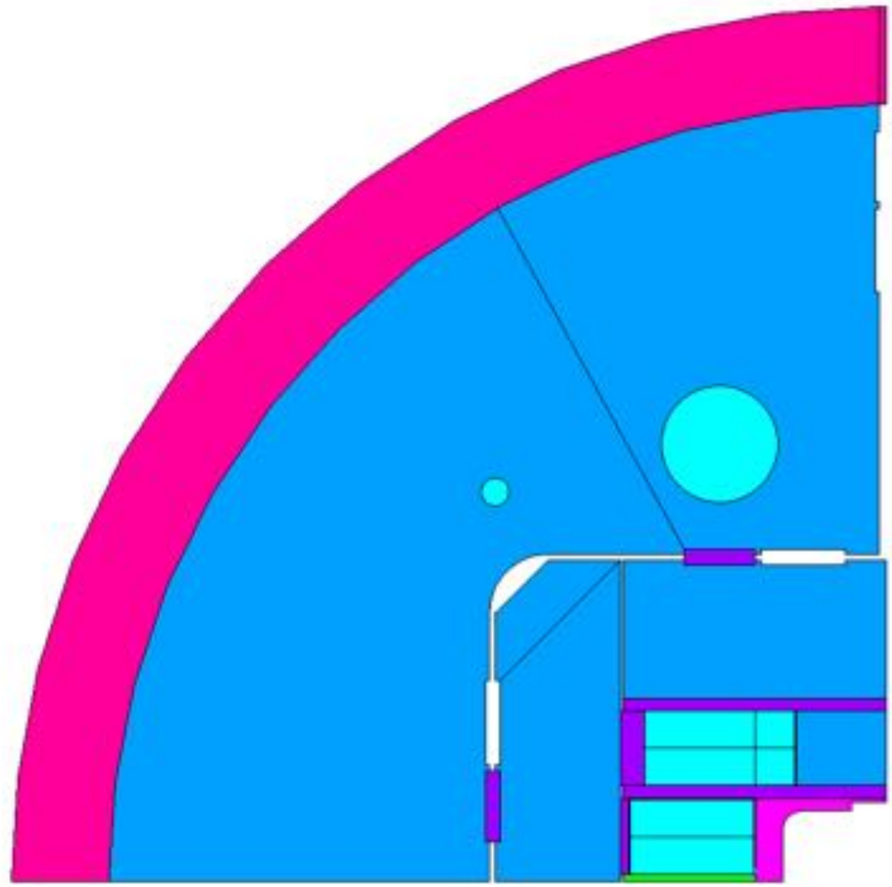


HEPdipo Baseline

1. FRESCA2 vs. HEPdipo.2

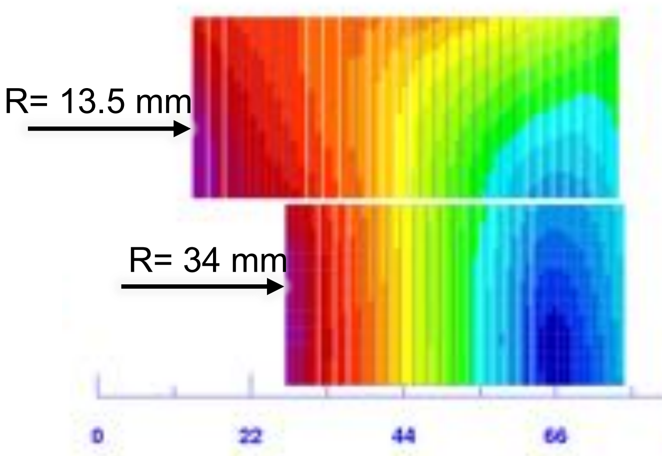


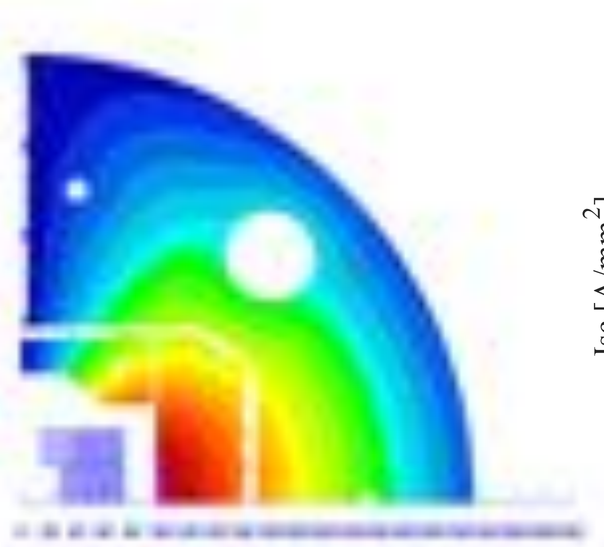
FRESCA2

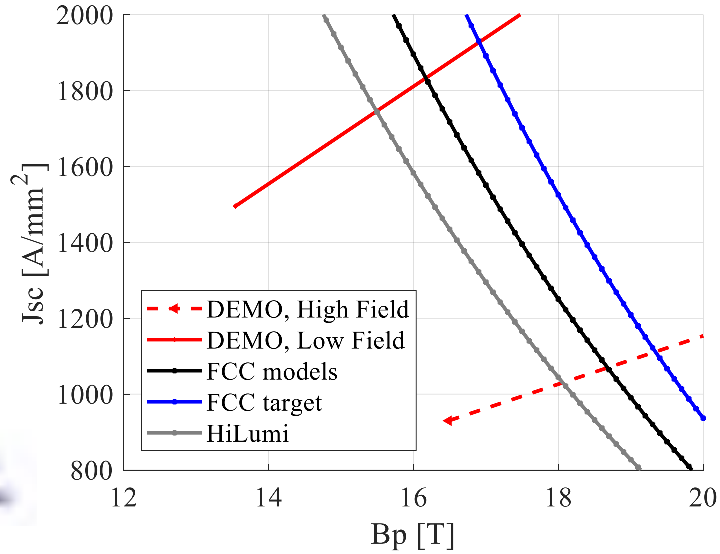


HEPdipo Option

2. relevance to DEMO







		Strands	D_{strand}	CU/SC	Width	Thickness
		(-)	(mm)	-	(mm)	(mm)
Option 1: Same width LF and HF	DEMO HF	44	1.10	0.8	25.700	2.002
	DEMO LF	56	0.85	1.2	25.700	1.547
Option 2: Best width LF and HF	DEMO HF	44	1.10	0.8	25.958	2.002
	DEMO LF	56	0.85	1.2	25.475	1.547

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- Test facilities – for what ?
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For discussion

- I see a strategic and long-term interest for a new very high-field test facility
  - Mainly for HTS magnet development, but also relevant to cable tests in ultra-high fields
  - The interest is shared through communities
- This work should start rapidly, it will take years to complete
  - Even with an aggressive plan the timeline for magnet construction and test is 5 years
  - In the meantime there is a gap for testing HTS inserts
- Next step is to complete the magnet design, possibly using the same geometry (see e.g. QXF). This is the work presently on-going in the scope of the HEPdipo collaboration
- Remember that the operating costs of one such facility is significant

1984…

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THE FORCED FLOW HIGH FIELD TEST FACILITY SULTAN

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Résumé - La construction de SULTAN I, un projet conjoint de ENEA (I-Frascati), ECN (NL-Petten) et SIN (CH-Villigen), a été terminée. Le champ magnétique et le diamètre intérieur sont de 8 Tesla et 105 cm, respectivement. Dans ce papier le montage, le refroidissement et la mise en marche du système sont decrits. L'équipement SULTAN offre un grand nombre de possibilités (p.ex. variation des paramètres, tels que le champ magnétique, le courant et le type de refroidissement du supraconducteur) pour étudier le comportement statique ou la stabilité d'un supraconducteur en conditions nominales.