LOGO_INFN_CON_NOME_ESTESO.eps

INFN

Istituto Nazionale di Fisica Nucleare

INFN program on HTS R&D and 10 T dipole

Marco Statera, INFN LASA

HFM
High Field Magnets

Outline

Magnetic configuration

+

Conductor configuration

+

Modeling & Simulations

+

Mechanics and Cryogenics

→

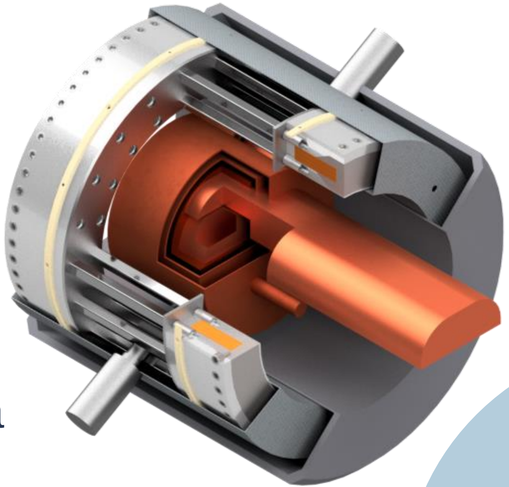
Dry HTS Magnet

Magnetic configurations – framework and background

Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani Piano Nazionale di Ripresa e Resilienza

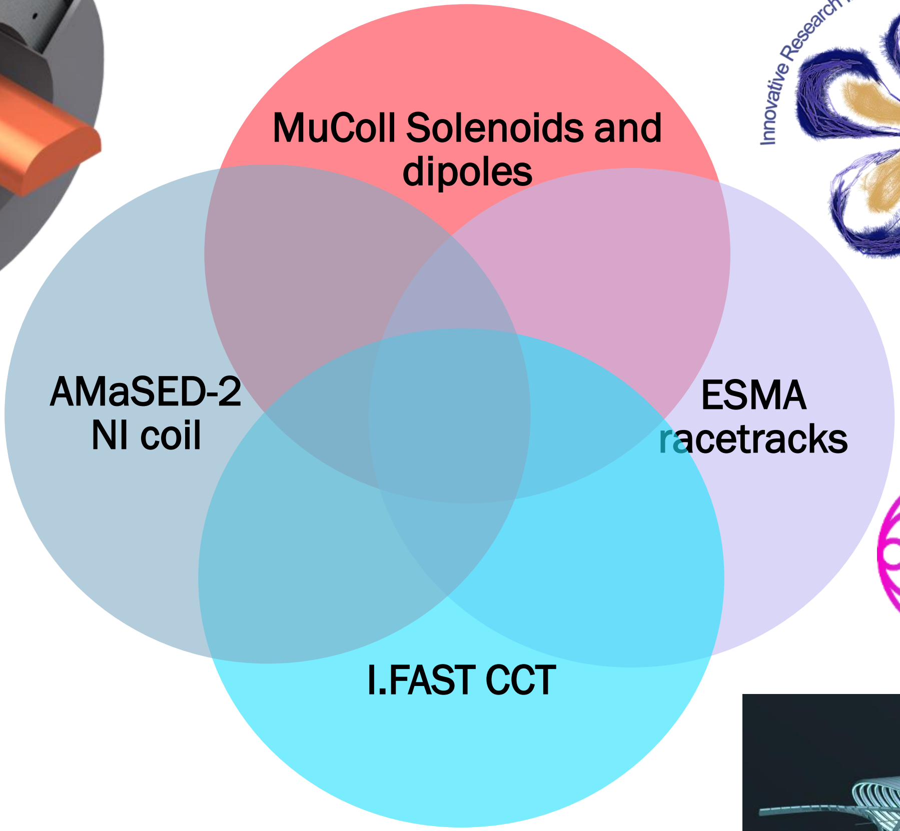
International MUON Collider Collaboration

Test stand L. Rossi
Solenoids M. Statera



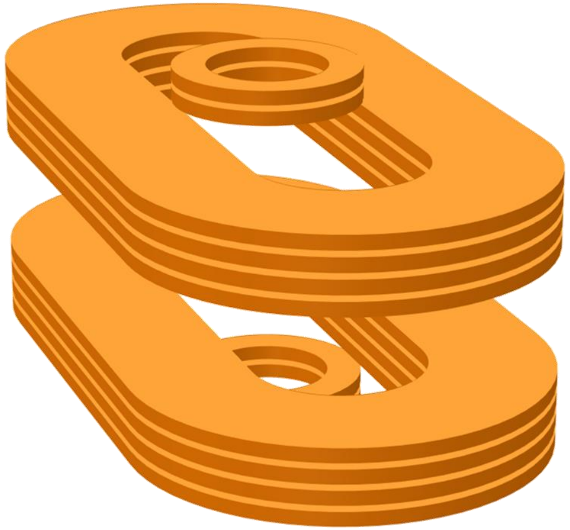
MUR

ASTROTOR
Variable T test M. Prioli



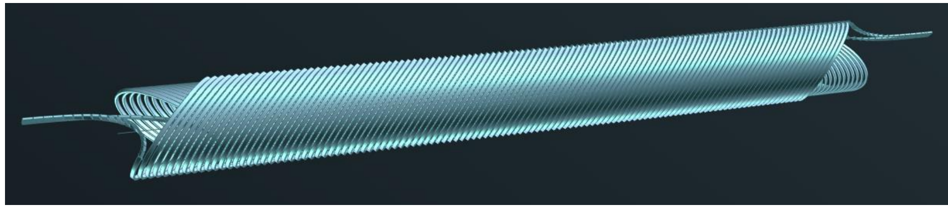
Innovative Research Infrastructure on applied Superconductivity IRIS

L. Rossi



iFAST

E. De Matteis

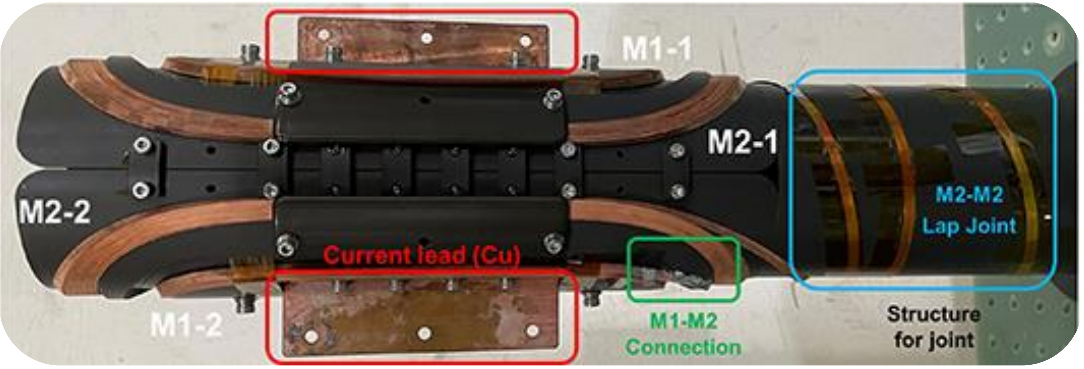


T. Lecrevisse, ''**Conceptual Design of HTS Magnet**'', IFAST WP8.3 Milestone 33, Zenodo, https://doi.org/10.5281/zenodo.6979877

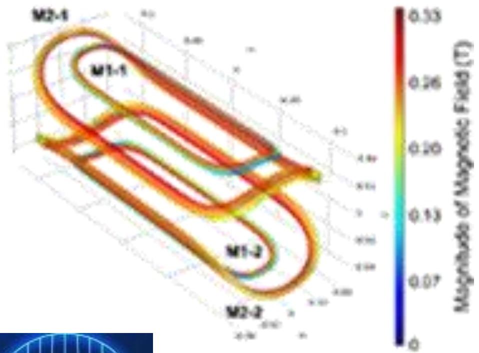
Magnetic configurations

Cosin Theta with tape in h-plane

High current density on mid-plane



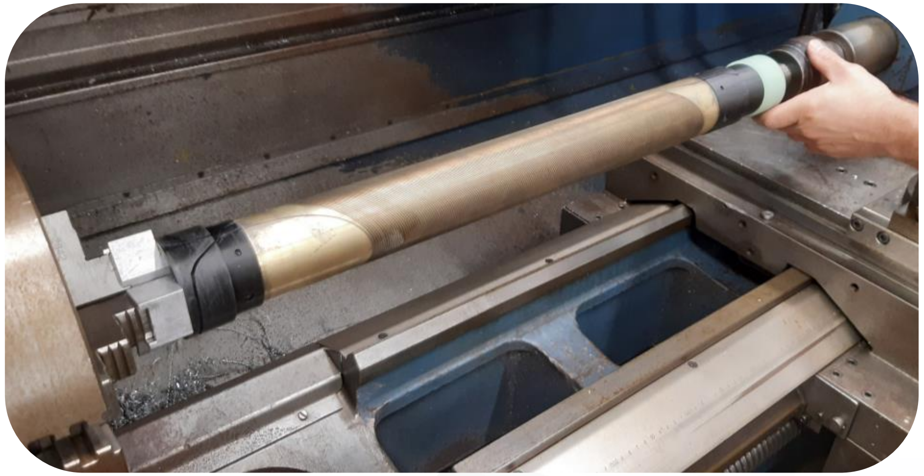
Courtesy of S. Hahn - 77 K, 77 A, 100 mT



- Winding
- Magnetization
- AC losses
- Field quality

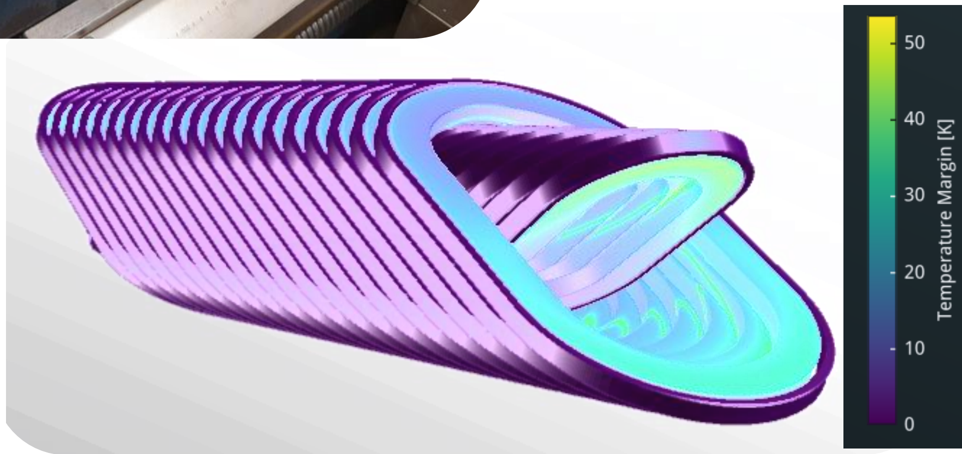
CCT based on

- Traditional machined former
- Tilted coils



- Machining
- Winding
- Curved

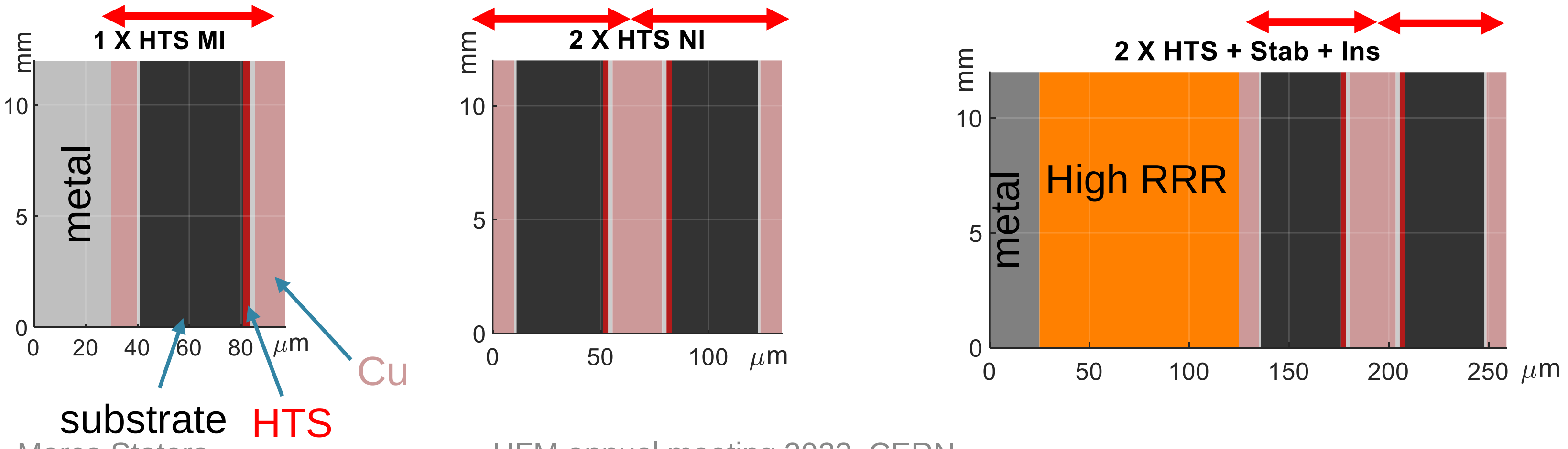
- Splicing
- Assembly



Conductor configurations

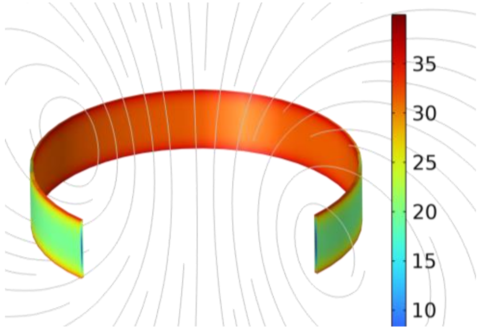
- Explore the Controlled-Insulation vs non-insulation solutions
- Multi-tape winding is foreseen, including different materials and technologies to impact the inter-turn resistance
- Both easy to bend cables and Mechanically stable conductors i.e. Roebel, tapestar/CORC and Viper like cable
- The goal of this study is to asses and improve the TRL in magnet-like conditions
- Internal splices
  - Development of technology
  - Configuration optimization for multi tape windings

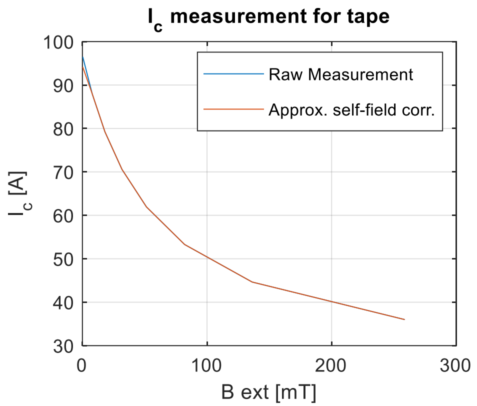
Examples of target technologies: Metal-Insulated (MI), multi-tape NI, multi-tape resistive layer + stabilizer.

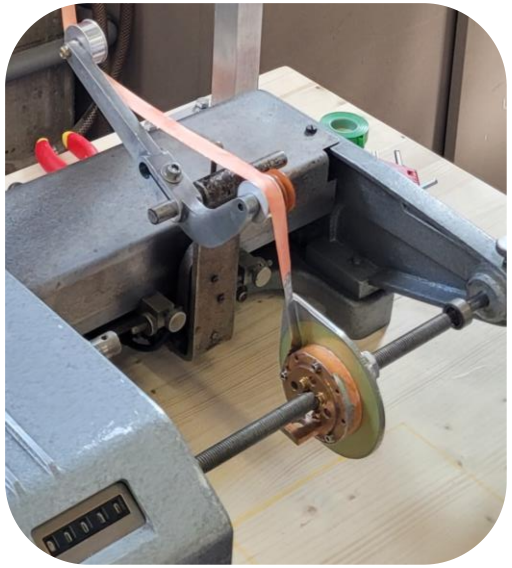


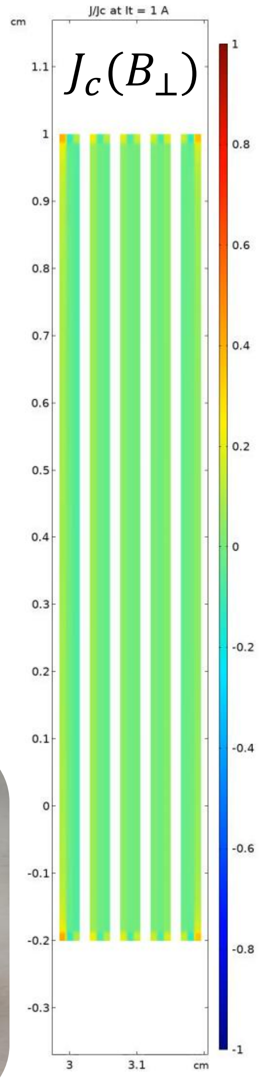
HFM
High Field Magnets

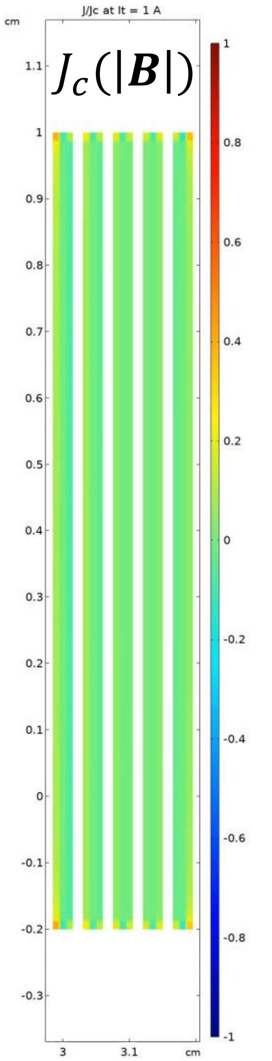
Modeling and Simulation



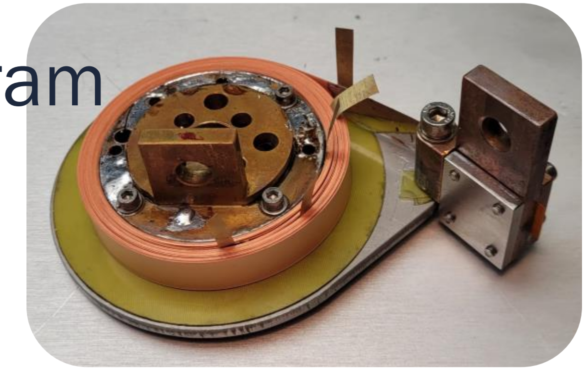








- Field calculations
- In tape critical current and current distribution
- Testing critical current and potential degradation
- 3D calculation of margin
- Probing modeling by small coils program
- Quench modeling



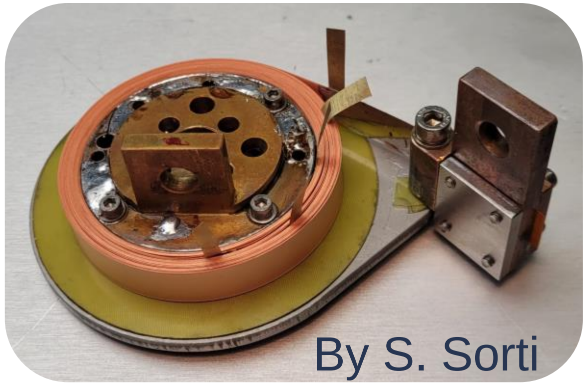
Test of small coils

- Synergies with IRIS (NextGenerationEU)
  1. Operation at T in the range 10 K – 30 K;
  2. Induction of flux densities in the tesla range
  3. Test in field up to 20+ T
  4. Non-round geometries (PNRR-IRIS project)
- The goal is to test magnet-like conditions for NI/controlled insulation coils and further validate models.
- Target time: begin 2024

Coils are tested in

CERN, INFN LASA, PSI,

CEA, SOUTHAMPTON

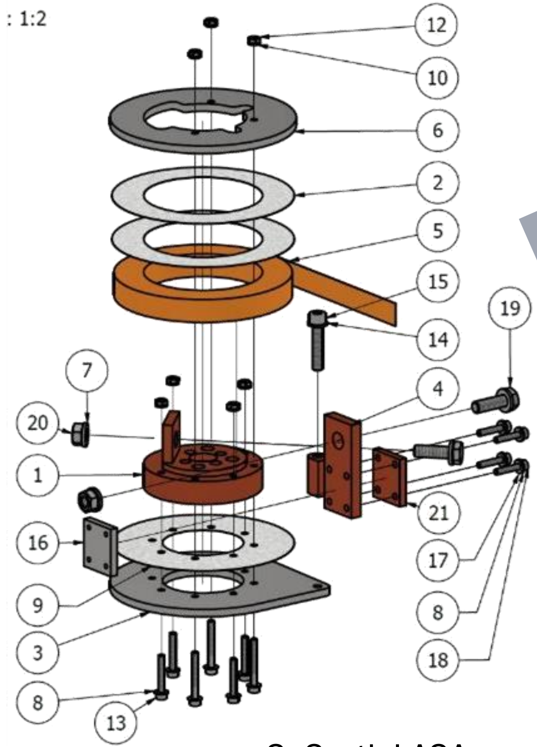


Preliminary winding and test al LASA

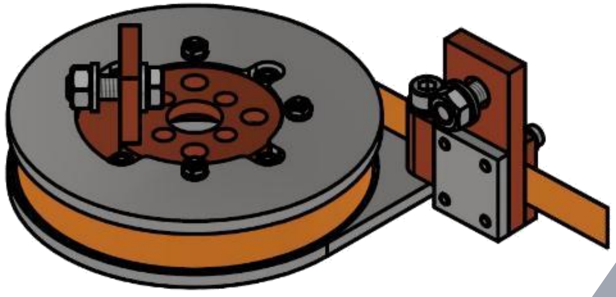
Test of small coils at LASA

R&D testing small coils (in self field or up to 8T)

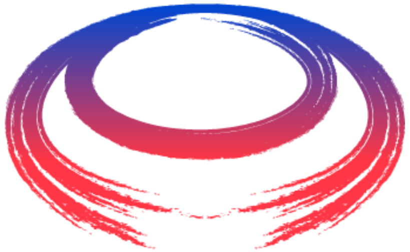
NI-partial insulated – impregnated



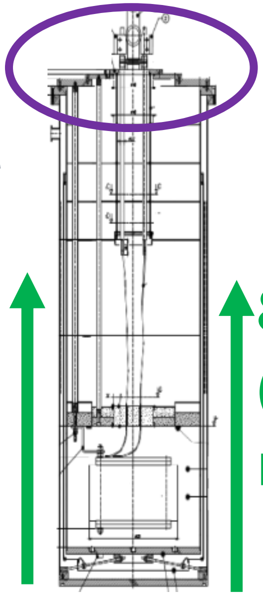
S, Sorti, LASA



NI-partial insulated – impregnated



New cooling system 20-50K Closed loop G-He (IRIS)

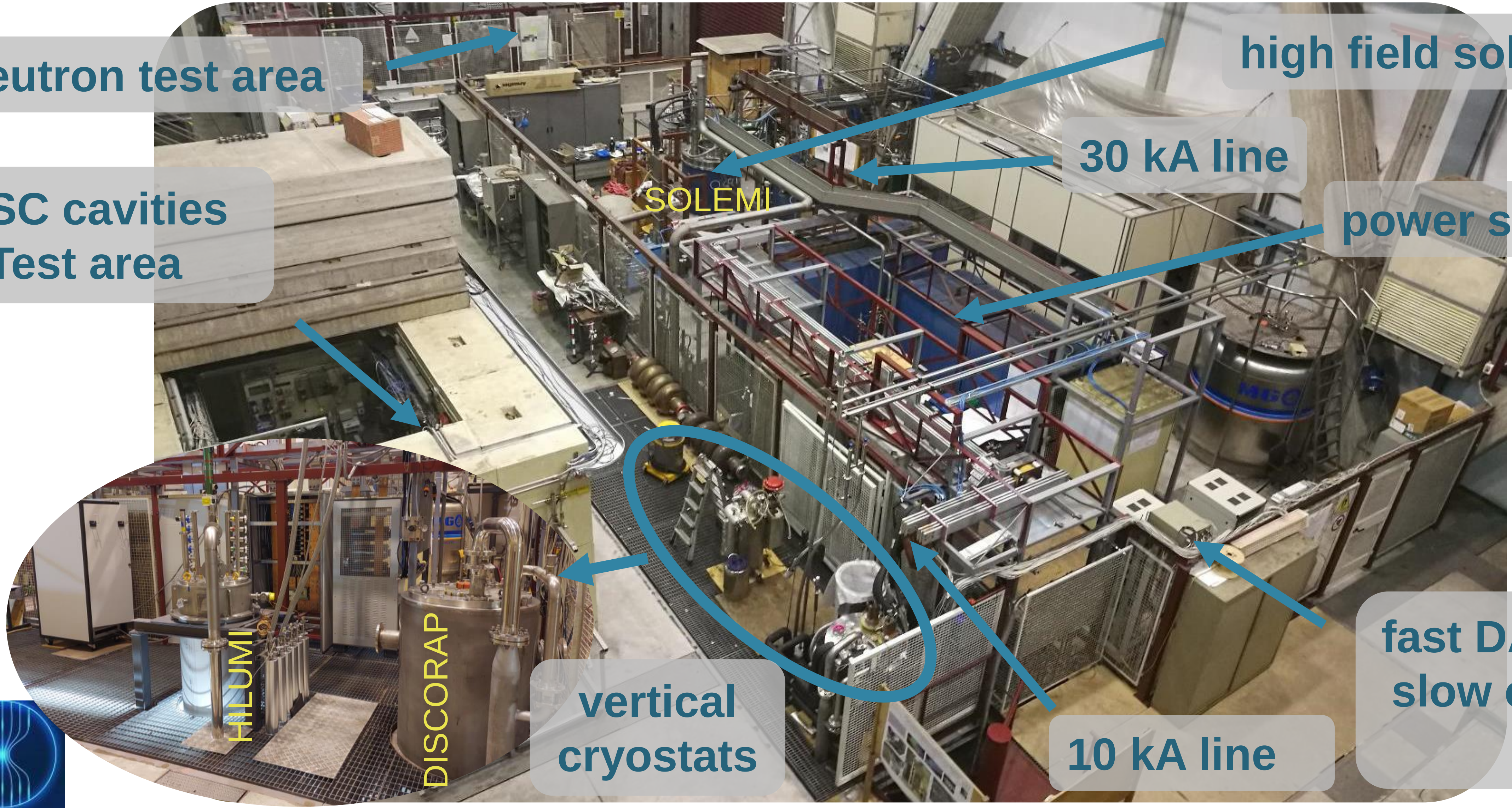


SOLEMI Insert
D 480 mm
h 1200 mm
4.2 K and 2.17 K
500 A

8 T field by solemi (refurbished and recommisisoned by IRIS)

HFM
High Field Magnets

LASA overview



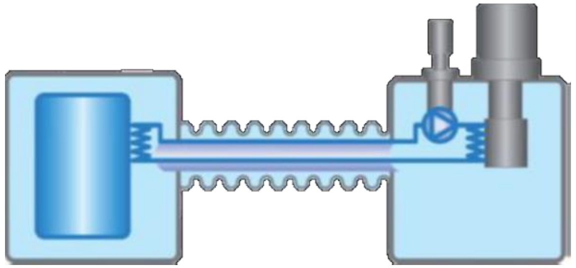
LASA test facility upgrade

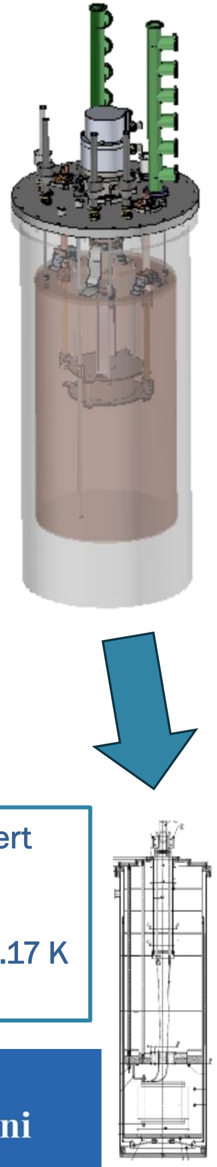
INFN LASA

Innovative Research Infrastructure on applied Superconductivity IRIS

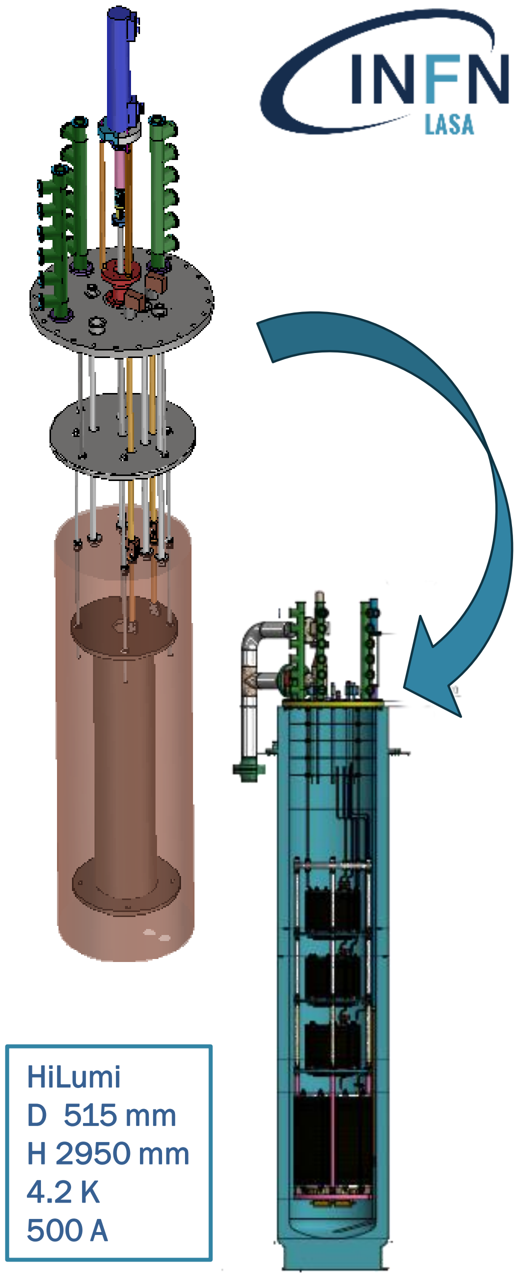
- Two new cold masses to test HTS magnets
  - Solemi insert
  - Hilumi
- Conduction cooled (cryocooler or closed loop He gas)
- New closed loop G-He cooling
  - Cooling power by cryocooler
  - Gas Helium circulation
  - Easy to move, no liquid helium required
  - 20 W at 20 K – 200 W at 55 K

2024





SOLEMI insert
D 480 mm
h 1200 mm
4.2 K and 2.17 K
500 A



HiLumi
D 515 mm
H 2950 mm
4.2 K
500 A

Finanziato dall'Unione europea NextGenerationEU
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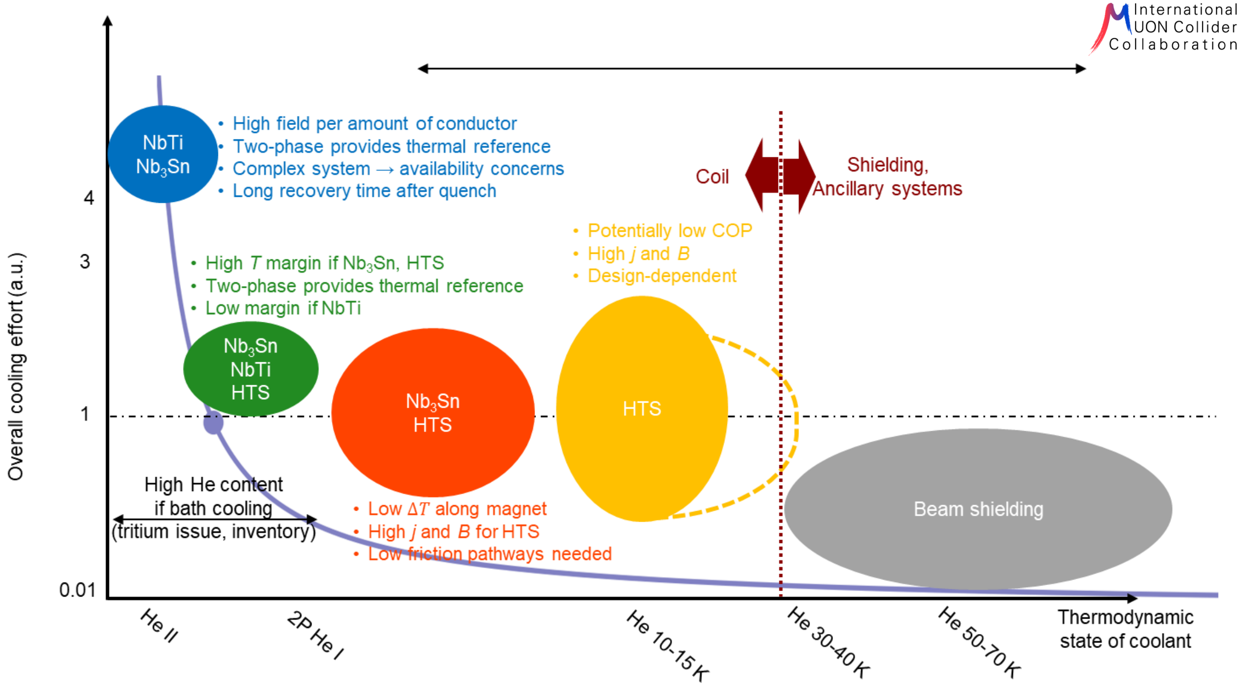
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

Why dry magnets?

- Target temperature 20 K – 50 K
  Depending on performance
- HTS have great performance at high field above 10 K
- Less expensive and complex cryogenics
- Looking at the sustainability of science and societal applications



P. Borges de Sousa, 2022

Performance (field and field quality)

Cost

Sustainability

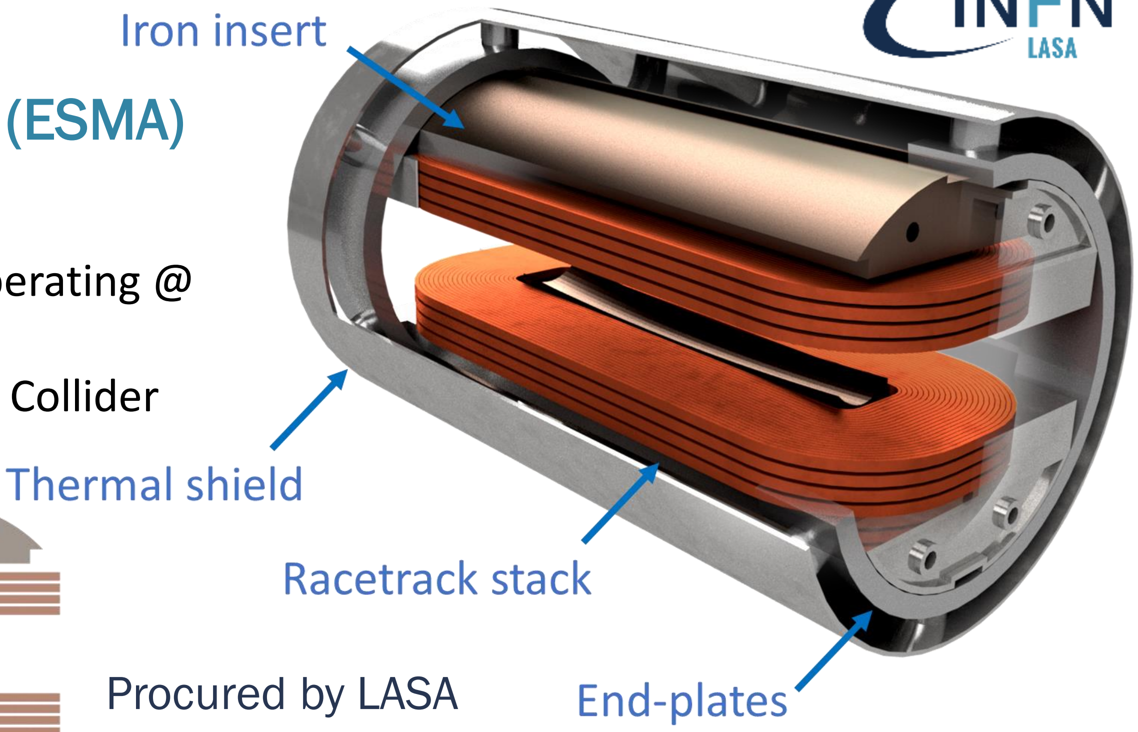
10 K to 20 K

operating temperature

ESMA by IRIS

Energy Saving HTS Magnet for Sustainable Accelerators (ESMA)

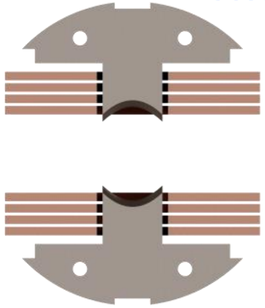
- Scope: superconducting cables test up to 8 T (10 T)
- **Deliverale: 8 T – 70 mm aperture HTS conduction cooled dipole** operating @ 10-20 K
- Goal: increase of the TRL for 15 T – 20 K magnets for FCC and Muon Collider

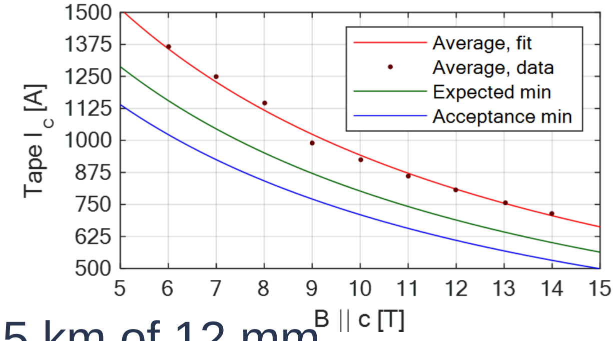


Procured by LASA
Installed in INFN Genova

S. Sorti and L. Balconi
Univ. of Milano & INFN-LASA

Parameter	Unit	Value
Central field	tesla	10
Free bore dimensions	mm	H80 x V50
Magnet length	mm	1000
Good field region uniformity	N/A	1.5%
Good field region extension	mm	H50xV30xL400
Operating temperature	K	20
Minimum op. temper. for test	K	10
Maximum current	A	<1000





Dimensions	12 mm × 67 µm
Substrate	40 µm of Hastelloy C276
Copper stabilizer	2 × 10 µm, RRR>20
Easy-way minimum bend	10 mm
Allower longitudinal strain	-0.4 % to 0.3 %
I_c, 77 K, self-field Ic, 20 K, 15 T	Min. 400 A, average 470 A Min 500 A

Tape procured by LASA: 15 km of 12 mm FARADAY tape

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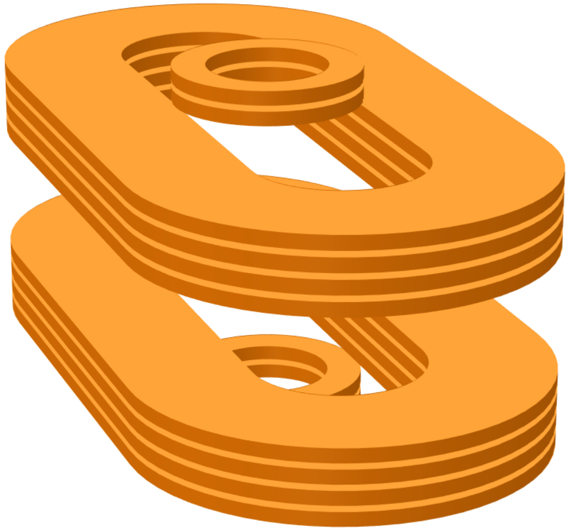
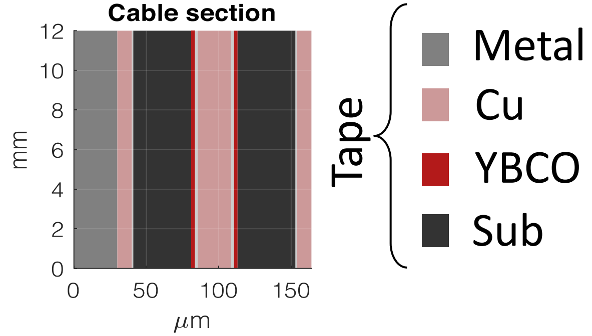
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

Actual design

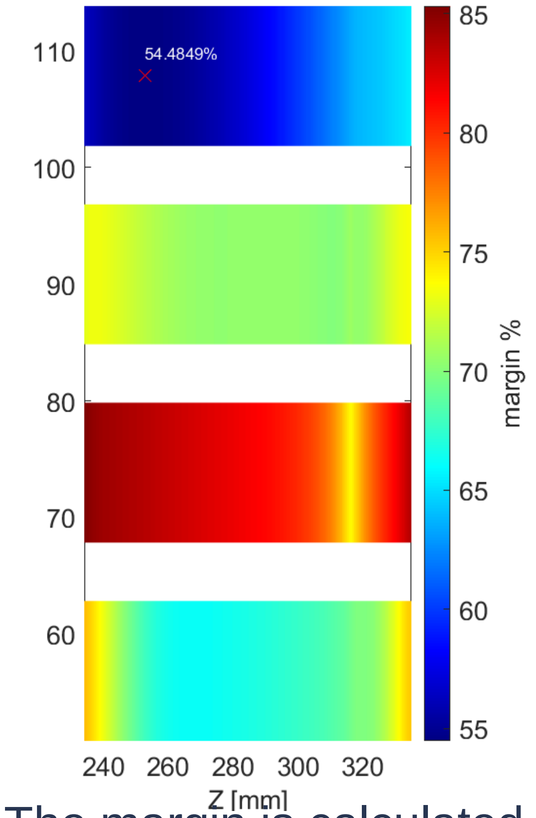




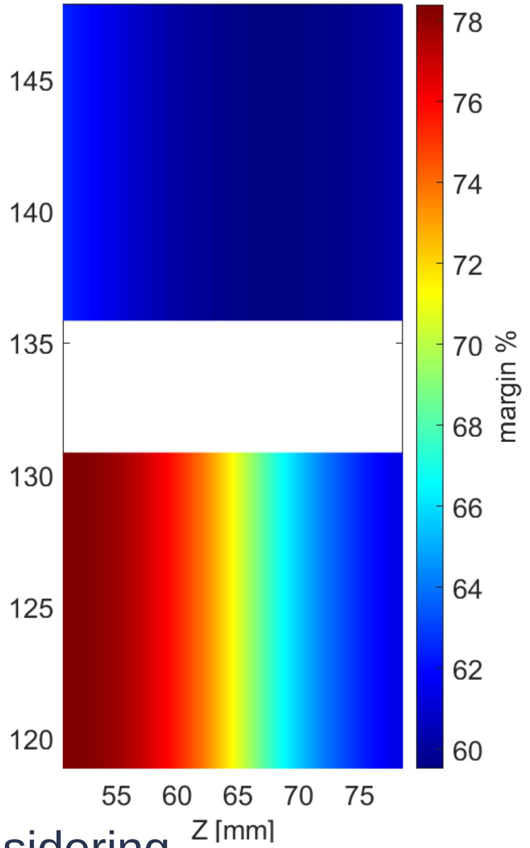
~13.9 km of tape

Central field B_0	tesla	10
Minimum central field B_{0min}	tesla	8
Free aperture	mm	Ø70
Good field region uniformity	N/A	±1.5%
Good field region extension	mm	H50xV30xL350
Operating temperature	K	20
Operating Current	A	810

Racetrack coils margin



correction coils margin



The margin is calculated considering Temperature and field angle
For safety this calculation includes the case of a 100% current sharing between the tapes.

Synergies on ongoning studies

Magnetic configuration

+

Conductor configuration

+

Modeling & Simulations

+

Mechanics and Cryogenics

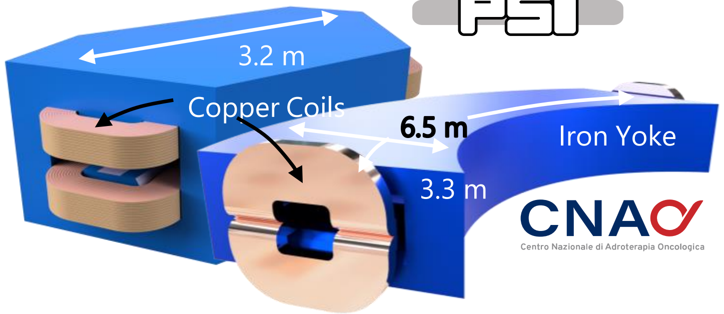
Activities in strong synergy with HFM

- Development of multitape flat coils
- Contact resistance modeling
- Impregnation (YES/NO/WHAT)
- Mechanics optimization for conduction cooled magnets
- Cryogenics optimizations
- Current leads

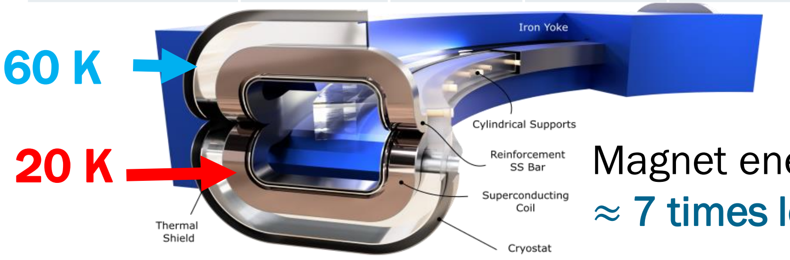
HF and UHF HTS solenoids will be in an upcoming INFRA-TECH EU call

Energy Saving Magnets - ESABLIM

- Revamp of common resistive magnets for heavy particle beam lines with Cryogen-free superconducting magnets
- Use of MgB_2 or HTS conductors reusing iron yoke
- Current < 300 A
- Work @ T=8-20 K with conduction cooling by cryocoolers



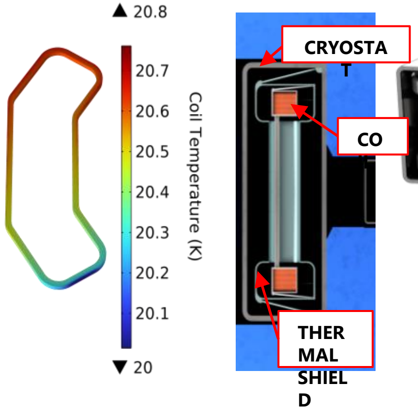
	Nominal Field	Weight	Air Gap	Max. Current	Max. Power	Cond. Dimensions	Energy Consumed
PSI (Steady State)	1.45 T	50 tons	100 mm	1 kA	95 kW	18.5 x 18.5 mm^2	715 MWh/year
CNAO (Ramped)	1.74 T	75 tons	200 mm	2.28 kA	700 kW	39.8 x 14.3 mm^2	262 MWh/year

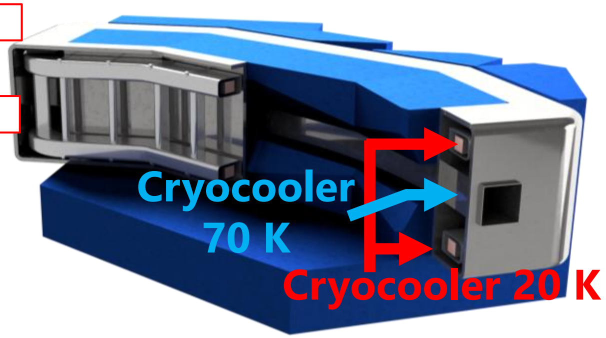


CNAO Option

Magnet energy consumption **4.3 kW** (vs **30 kW** DC).

≈ 7 times lower with MgB_2 rope conductor





PSI Option

Power consumption of **5 kW** (vs **190 kW DC** resistive design)

- ≈ 40 times lower with MgB_2 rope conductor
- **HTS Design on-going @ T > 20 K**

Summary

- Ongoing R&D to increase TRL of HTS magnets
- Started a program for small HTS coils production and test
- INFN is building and testing HTS magnets in next two years
- Update the test stations for variable temperature
- Several synergies in developing HTS magnets have yet to be fully exploited
- HF and UHF HTS solenoids will be one of the leading themes in an upcoming INFRA-TECH EU call
- Dedicated R&D for MgB_2 conductor for new magnets, refurbished ones and sustainability (see IRIS by L. Rossi on Thursday)

HFM
High Field Magnets

THANK YOU

INFN
Istituto Nazionale di Fisica Nucleare

Ph. by G. Fornasier