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Fabrication and Results of the First MgB_2 Round Coil Superferric Magnet at LASA

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INFN — HiLumi HL-LHC PROJECT — Università degli Studi di Milano

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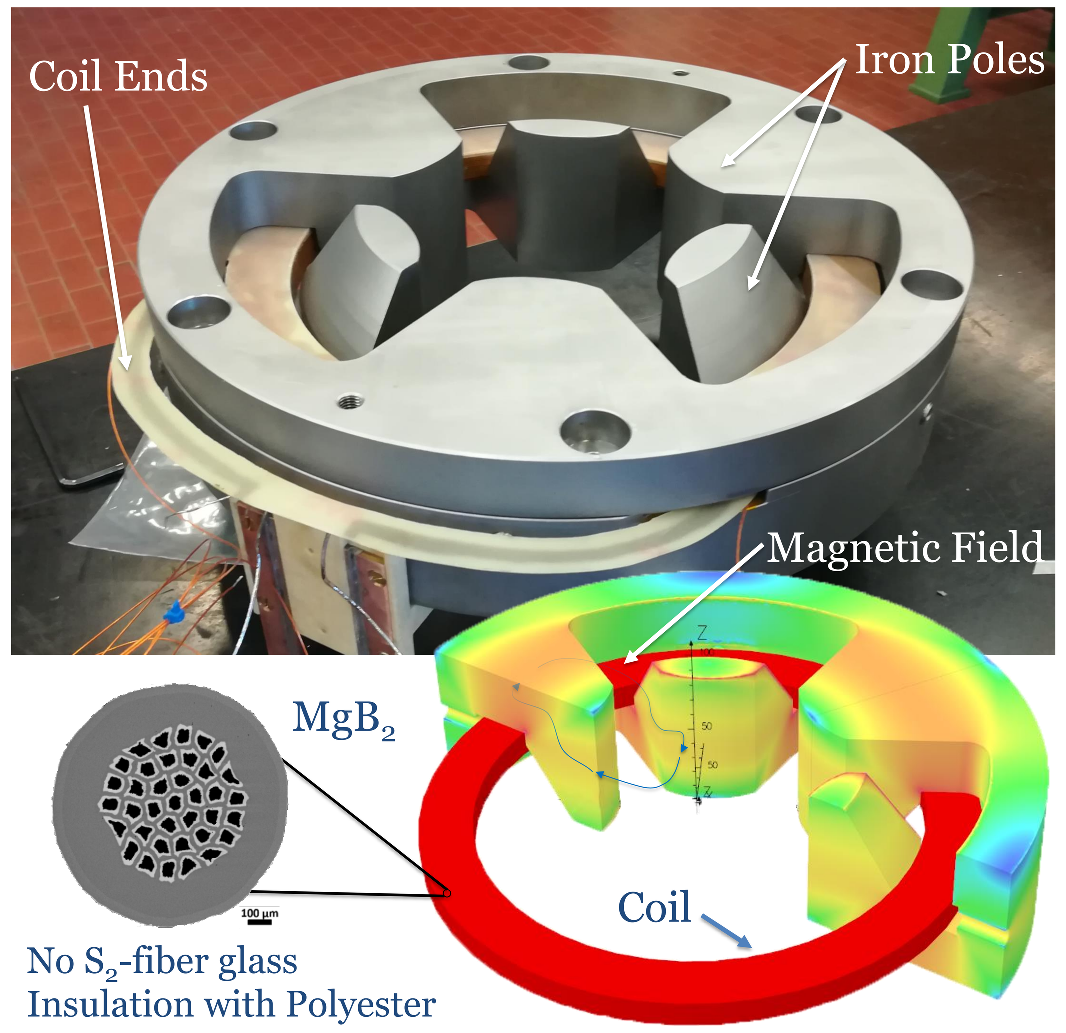
I. Introduction

Technological development and innovation in superconducting magnets for particle accelerator require new solutions in magnet's design and use of HTS materials. A new solution for the construction of Superferric High Order Corrector Magnets is proposed here by LASA laboratories called RCSM. Its design is particularly suitable for strain sensitive superconductors using only single round coils with large bending radius to create the necessary magnetic field. The arbitrary multipolar iron yoke is able to create the desired harmonic components for the magnet. The construction processes of the first successfully working prototype, which implements a single MgB_2 round coil, is presented and test results are shown and discussed.

II. Magnet Design

MAGNET PARAMETERS	
Operating Current	148.81 A
Ultimate Current	161 A
Magnet SSL @ 4.2 K	300 A
Coil SSL @ 4.2 K	333 A
Stored Energy @ I_{op}	1.1 kJ
Stored Energy @ I_{ult}	1.23 kJ
Low Current Inductance	375 mH
Differential Inductance @ I_{op}	73 mH
Semi-Module Lenght	90 mm
2 Modules Magnet Lenght	360 mm

COIL PARAMETERS	
N turns	336
Layers	28
Radial thickness	32.2 mm
Axial thickness	18 mm
Internal Radius	133 mm
Radial BTS2 Insulation	0.15 mm
Axial BTS2 Insulation	1.2 mm
Load During Winding	1 Kg

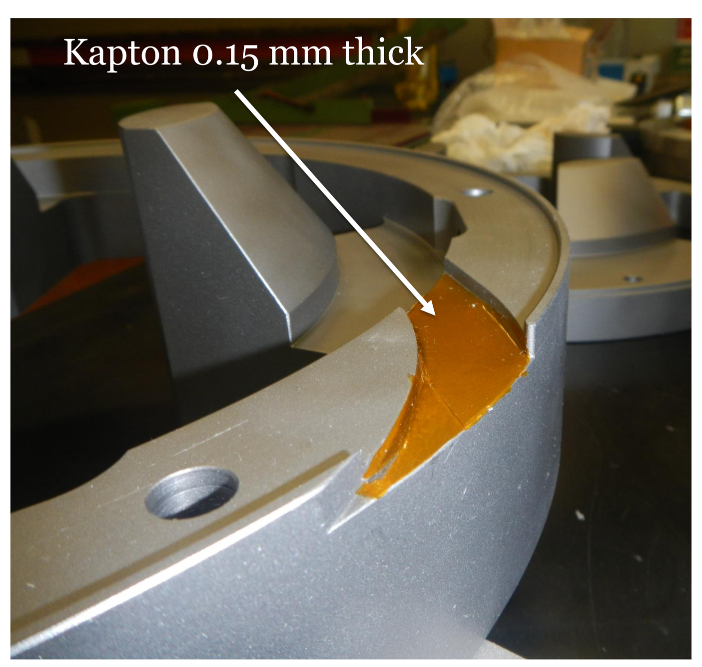


No S_2-fiber glass Insulation with Polyester

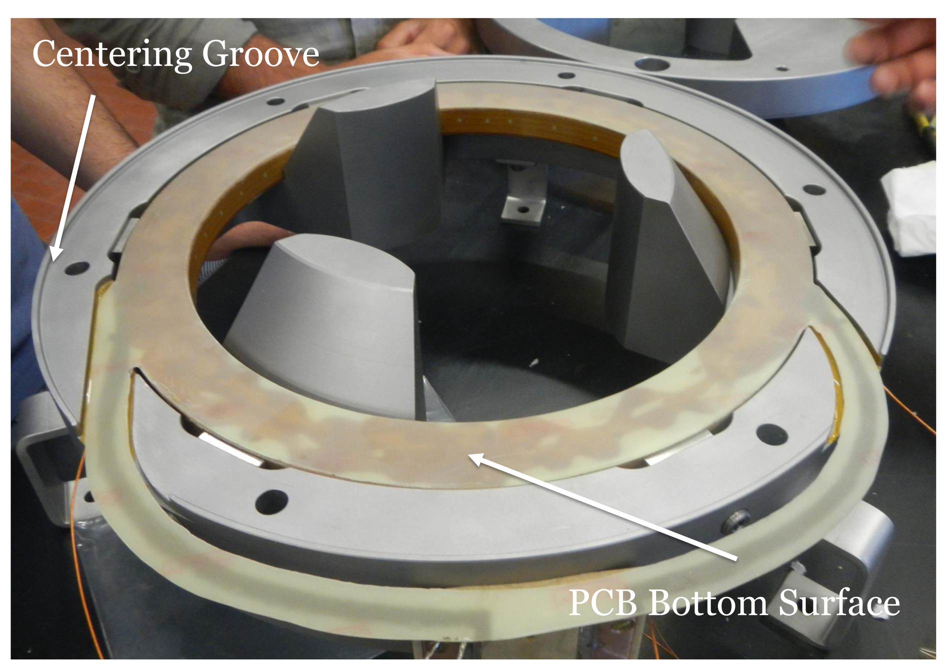
WIRE PARAMETERS			
Diameter	1±0.01 mm	Monel	46 %
N Filaments	37	Niobium	14.5 %
Filament Size	55 µm	Nickel	14 %
MgB_2	11.5 %	Copper	14 %

III. Prototype Assembly

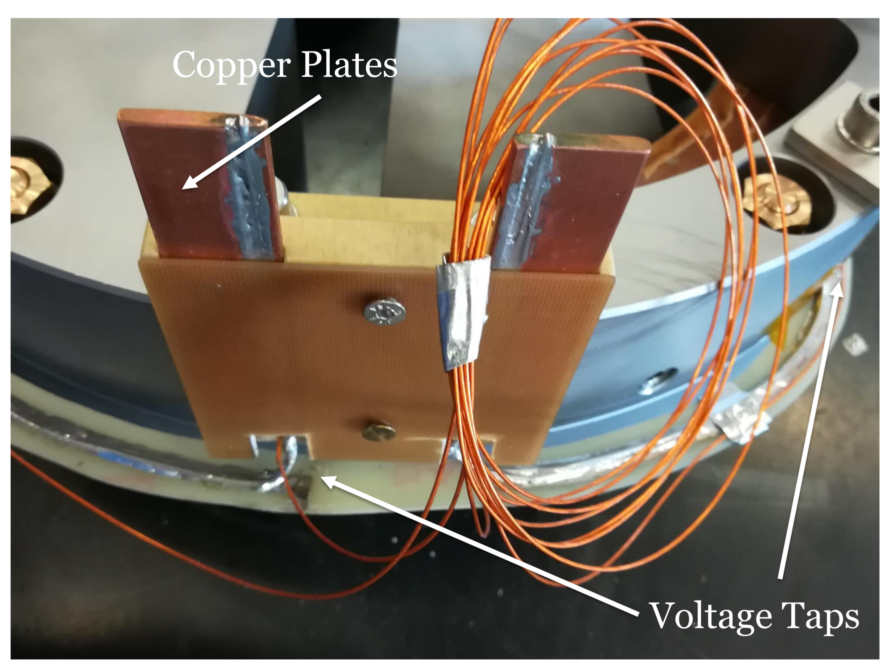
Assembly of the prototype performed at LASA laboratories. The two halfs of the prototype are centered with the external groove while rotational centering is made with Cu-Be rods which provide also compression in axial direction.



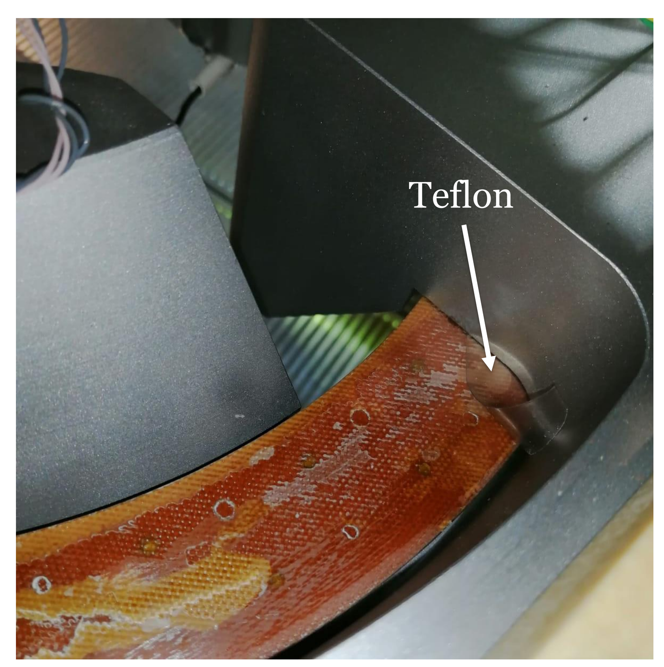
GROUND INSULATION for coil ends



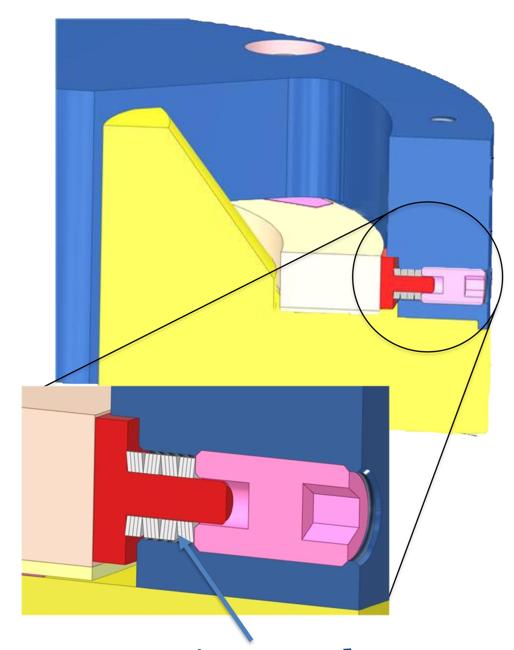
COIL INSTALLATION



ELECTRICAL CONNECTIONS



COIL-POLE CONTACT SURFACE



Spring Washers

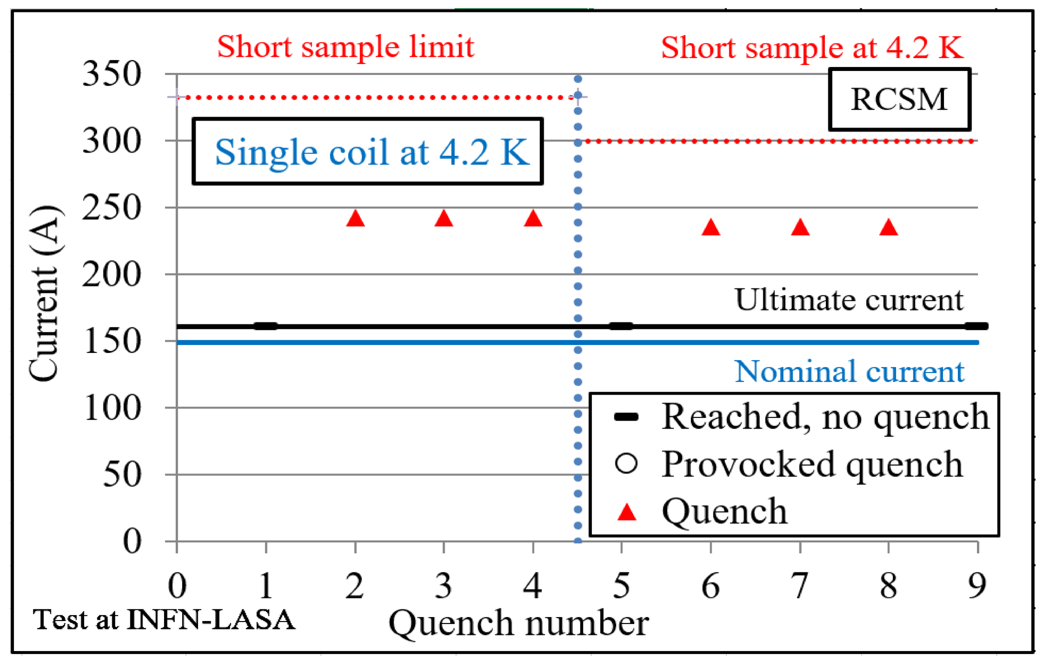
IV. Powering Test

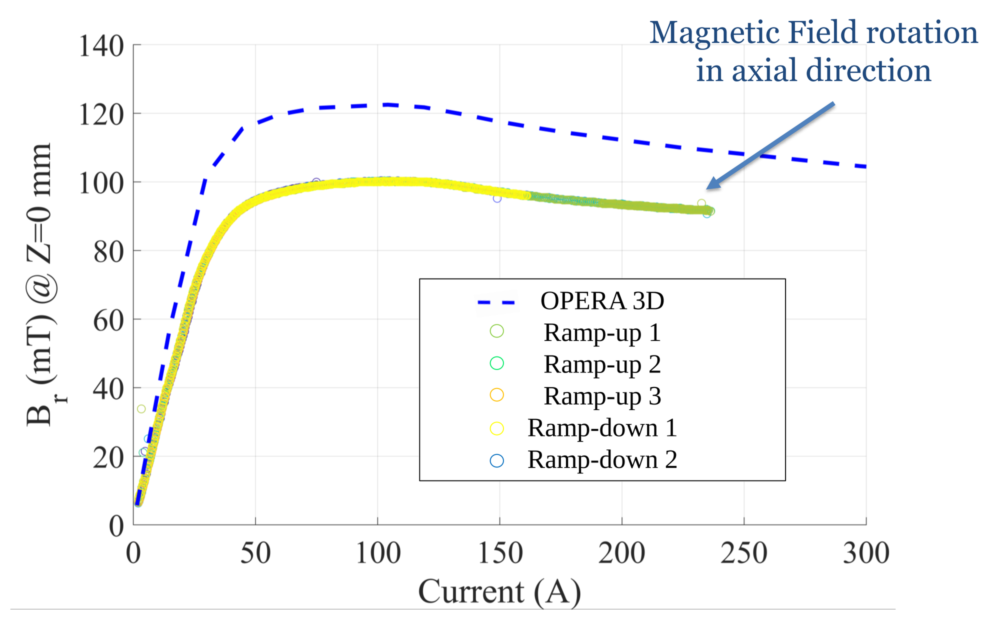
Plan:

- 4.2 K ramp rate 0.2 A/s until I=75 A (limited by protection threshold on coil total voltage)
- Fast discharge → Test of QDS system
- 4.2 K ramp rate 0.2-0.5 A/s until I_{OP} and I_{ULT}
- 4.2 K 1h @ I_{ULT}
- Training with ramp rate ≤ 0.3 A/s
- 4.2 K ramp rate 0.2-0.5 A/s until I_{ULT} (to assure no degradation)

TEST RESULTS

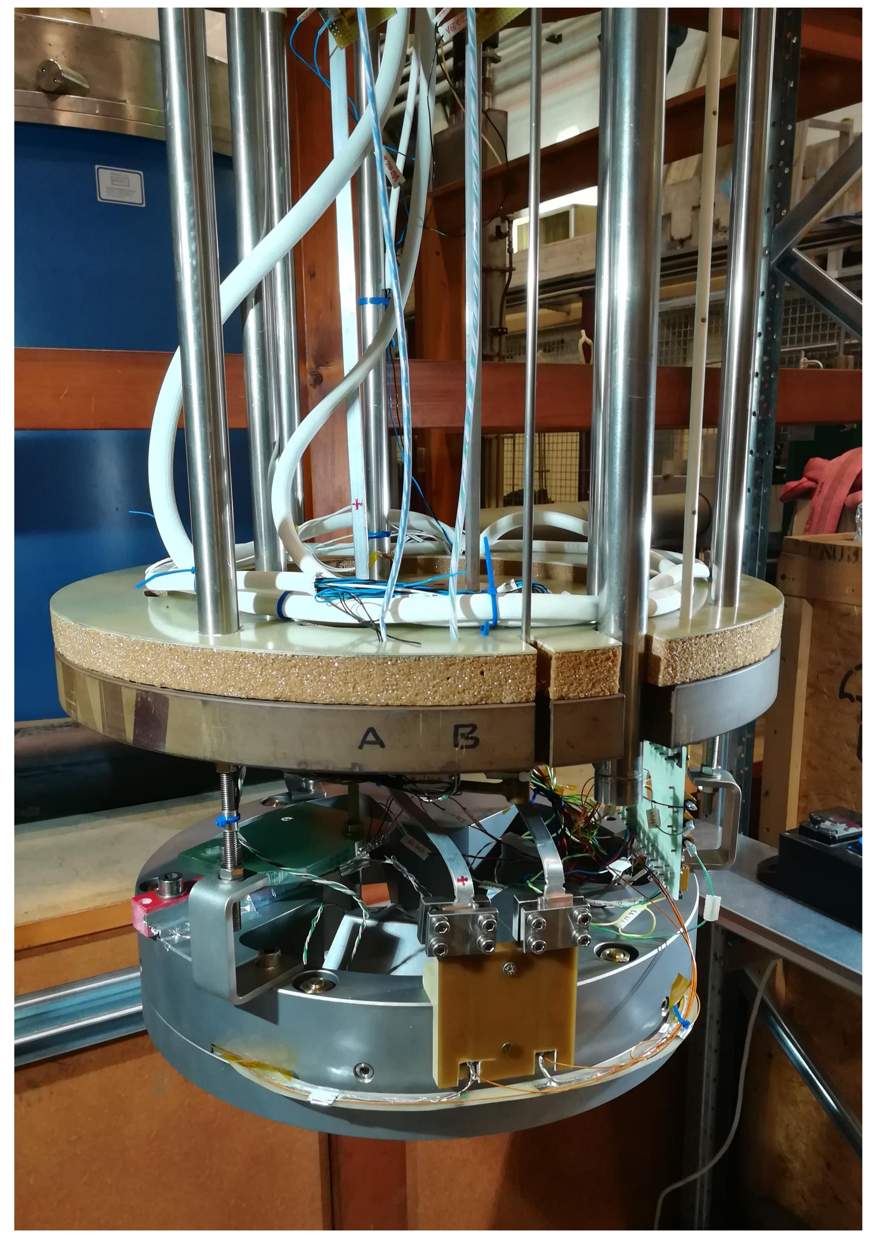
- Ultimate Current reached without any training
- 3 different spontaneous quenches occured at the same maximum current of 236 A





Hall probe signal taken from different ramps of the powering test. High repetibility of the magnet with no degradation at high value of current. 20% difference from simulations

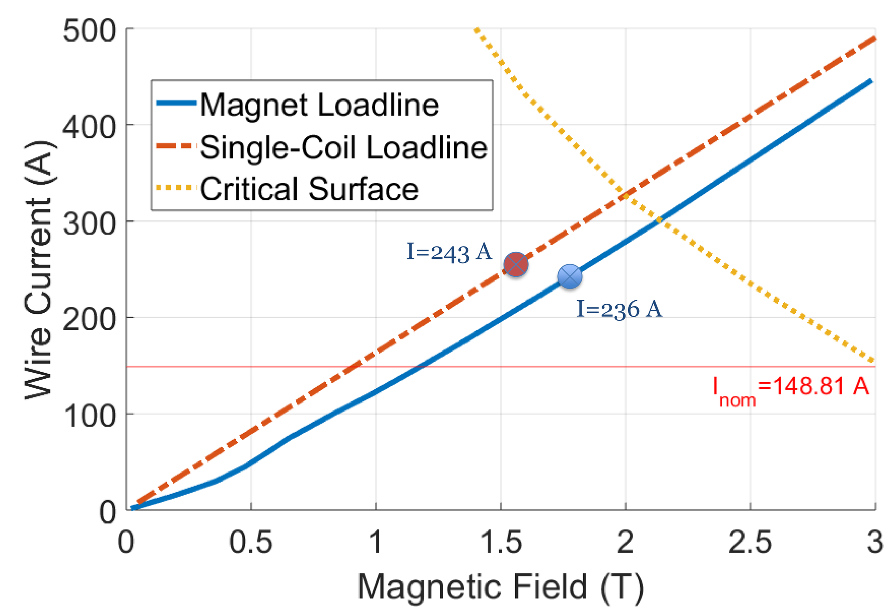
- Probably due to Hall probe positioning → Currently under Study



Magnet connected to mechanical support and electrical link to bus-bars. Coil ends are soldered with a MgB_2-NbTi junction on a PCB glued on the lower coil's face.

Monitoring of Temperature:

- Two Carbon Glass probes (CGR-500) for temperature on magnet ends to have temperature gradient < 100 K/m and <40 K/h

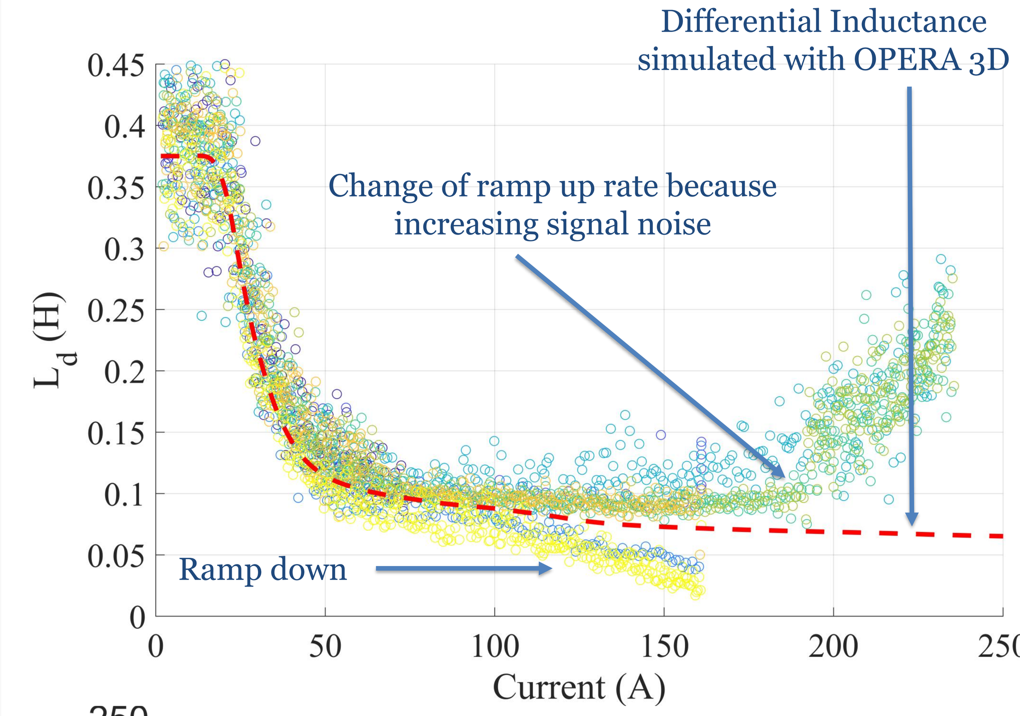


Comparison between loadlines and wire critical surface:

- Single Coil → 73% of loadline
- Magnet → 78% of loadline

Compatible with wire degradation during winding

V. Quench Study



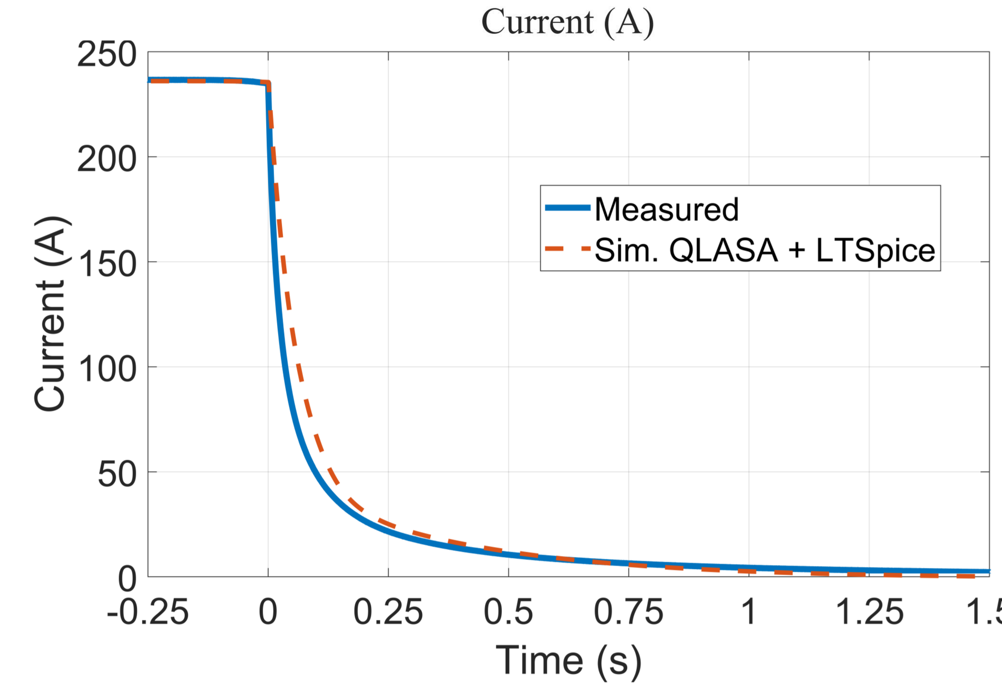
Simulations in static electromagnetic solver

- Needs of transient electromagnetic simulations

Effect at High Current visible also in the Single Coil Test

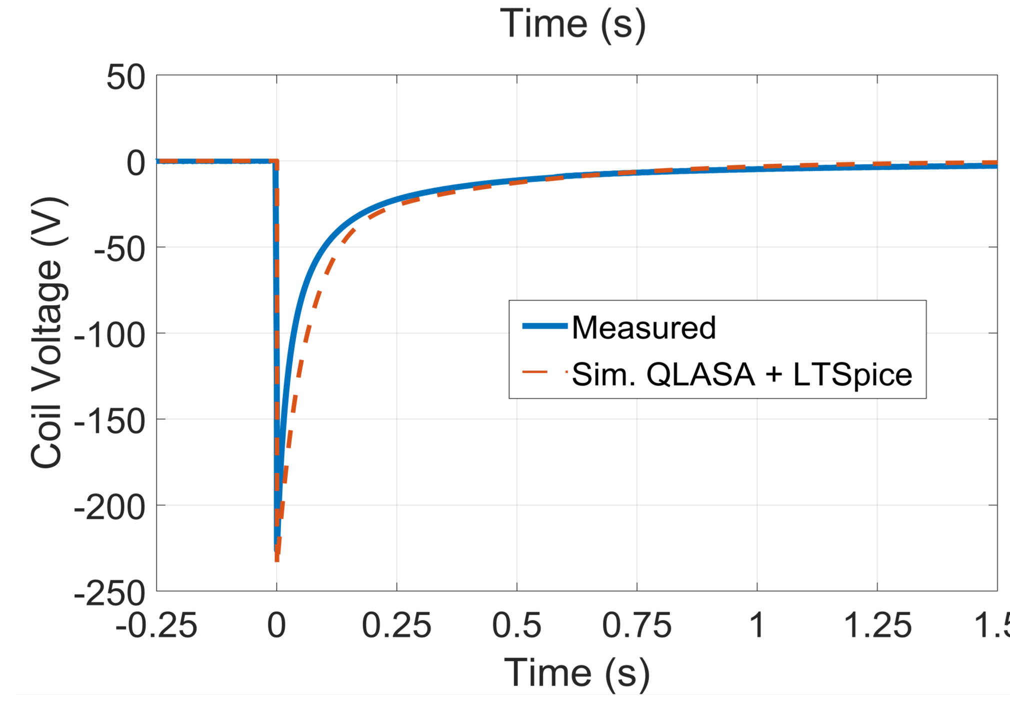
Hypothesis:

- Eddy currents in superconductor
- Eddy currents in non laminated ARMCO Iron
- Resistance development in stabilized coil ends



Protection Scheme Design

- Voltage Threshold: 100/150 mV for $I \geq I_{op}$
- Validation Time 20 ms
- Ultimate current (161 A), R_{DUMP}=1 Ω
- Coil ends



STEAM

Quench Analysis

QLASA & LTSpice

I=236 A (159% I_{nom})

- Maximum Voltage 236 V at dump
- T_{MAX} simulated = 270 K

Measured decay is faster than simulated

ANALYSIS STILL ONGOING

VI. Conclusions

The First RCSM prototype, in the sextupole semi-module configuration, has been constructed and successfully tested. The magnet reached, firstly, the nominal current and, secondly, the ultimate one without any quench. The maximum current reached is equal to 236 A (78% of S.S.L. @ 4.2 K) which is compatible with wire degradation seen during the Single Coil test and reasonably due to winding process. Further analysis of the magnetic field produced has to be done in order to verify the magnet efficiency. Quench analysis showed that experimental decay is faster than the simulated one. Different hypothesis are still under discussion and analysis. Results of the RCSM prototype test are encouraging and they open to the construction of the full modular operating magnet.

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