Second Year Report

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During the second year of my PhD, I continued working with the superconducting magnets group at INFN Genova. In particular, my efforts were mainly focused on the design of superconducting magnets using FEM modelling and secondly on the realization and testing of mechanical mock-up models of accelerator magnets

ANSYS FEM code for quench simulations in superconducting magnets.

A quench in a superconducting magnet is the result of a resistive transition in a portion of the superconducting cable, leading to the appearance of voltages, a temperature increase, differential thermal expansion, electro-magnetic forces, increase in the pressure of the cryogen and its expulsion. All these phenomena have potentially destructive consequences for the magnet. Because of this the simulation of quench dynamics in superconducting magnets is essential for understanding their thermal and electromagnetic behavior during fault conditions and for designing a suitable protection strategy for the magnet. Numerically, this represents a complex multiphysics problem encompassing thermal, electrical, and magnetic phenomena. The bulk of my work this year was the realization of an advanced application developed using the ANSYS APDL program to simulate the quench behavior of superconducting magnets with a FEM (Finite Element Method) approach. The aim of the tool is to support various geometries, including cos-theta, canted cos-theta, and solenoid configurations, making it highly versatile for diverse applications. While ANSYS commonly models temperature-dependent material properties, our simulation framework extends this capability to include magnetic field-dependent material properties in the cable, such as magneto-resistivity in copper and the superconducting critical temperature during transient states. An extensive thermal model was produced to simulate the development of Joule heating in superconducting cables, heat propagation across adjacent cables, helium cooling and the effect of quench-heaters. Since simulating the behaviour of an entire magnet in an electro-thermal transient is a particularly demanding application in terms of calculation times, particular attention has been paid to developing strategies to accurately simulate magnet quench with the least possible load on the machine.

FalconD mechanical mock-up.

The Future Circular Collider-hadron-hadron (FCC-hh) project is envisioned as the successor to the Large Hadron Collider (LHC) at CERN (European Organization for Nuclear Research). The proposed particle accelerator, with a center-of-mass energy up to 100 TeV, will be housed in a tunnel approximately 100 km in circumference, representing a major leap forward in the exploration of fundamental forces and particles. A key component for the success of the project is the development of high-field dipole magnets capable of steering high-energy particle beams with precision and stability. In this context, the INFN (Istituto Nazionale di Fisica Nucleare) is involved with the FalconD (Future Accelerator post-LHC Cos Optimized NbSn Dipole) project, which focuses on the design and construction of a 12 T NbSn single-aperture cos dipole magnet. The prototype will demonstrate the feasibility of achieving the required magnetic field strength and test innovative manufacturing and assembly techniques. A distinguishing feature of the FalconD magnet is the use of the bladder and key (BK) assembly process, providing an innovative solution to the mechanical and operational challenges posed by high-field magnets in future accelerators. As a crucial step toward full-scale production, a mechanical mockup of the magnet’s straight section was constructed, as described in the Technical Design Report (TDR) published in 2021. This mockup aims to provide valuable insights into the mechanical behavior, assembly process, and cooling of the magnet under realistic conditions. I worked on assembling the magnet mock-up, on assembly operations using BK technology, and on obtaining strain measurements using strain gauges. In addition, I worked in the creation of a FEM (Finite Element Method) model of the mock-up in order to compare the measurement results with the numerical values of the stress-strain values, validating the approach followed in the creation of the real magnet model for future developments.

Workshops and Conferences

- 14^{th} HL-LHC Collaboration Meeting, Genova (IT), 7-10 October 2024.
- High Field Magnets (HFM) Annual Meeting 2025, CERN, Genève (CH), 10-12 February 2025.

- International Workshop on Coated Conductors for Applications (CCA), CERN, Genève (CH), 11-13 March 2025.
- 17th European Conference on Applied Superconductivity (EUCAS), Oporto (PT), 20-25 September 2025.

Courses attended

- *Superconducting Wires Tapes and Cables Technology*, Andrea Malagoli, CNR-SPIN

Publications

- Alessio Dellacasagrande, Andrea Bersani, Stefania Farinon, Filippo Levi, Riccardo Musenich*, Proposal of a Configuration for the Detector Magnet of the ALICE 3 Experiment at the LHC*, IEEE Transactions on Applied Superconductivity, vol.35 issue 5, doi: 10.1109/TASC.2024.3513933.