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Design and Digital Twin of INFN's main Nb3Sn 15T Dipole for CERN's FCC

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CERN is currently investigating the feasibility of a future collider - the Future Circular Collider (FCC)- as a potential successor of the Large Hardon Collider (LHC), providing scientists in the field of high energy physics with a powerful discovery tool. A 100 km tunnel hosting a circular electron–positron collider as a first stage towards a 100 TeV proton–proton collider would probe new phenomena coupled to the Higgs and electroweak sectors with unparalleled precision.
To construct such a high center-of-mass energy HC in a tunnel of ˜100km in length, dipole magnets with a nominal operation field of ˜16T and ˜15% margin are necessary. At the state of current available technology, only coil strands made of Nb3Sn can provide such nominal field levels. Key requirements for the realization of an accelerator of this magnitude are the ability to demonstrate that accelerator-quality magnets can indeed produce such a magnetic field and a substantial reduction of the costs of building and operating superconducting magnets to produce a cost-effective design. INFN developed the main 16T Nb3Sn dipole of the FCC based on the cos-theta coil design. The baseline design of the superconducting magnet includes a welded stainless-steel skin based on the bladder-and-key concept.
The scope of this work is FEAC, as a third-party, to validate and further study the baseline design in collaboration with INFN and CERN. This paper describes the design concept and the fully parametric multi-physics finite & boundary element (FEM & BEM) model used in the detailed design optimization. The optimized assembly parameters are presented, and the effect of the manufacturing tolerances are studied via a sensitivity analysis performed on geometrical, material and assembly parameters.

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