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Experimental and numerical assessment of the electro-mechanical limits of state-of-the-art Nb3Sn accelerator magnets

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The development of accelerator magnets able to produce magnetic fields beyond those attained in the main magnets of the Large Hadron Collider (LHC) requires the use of conductors with enhanced superconducting properties with respect to the well-known Nb-Ti technology. In the present days, Nb3Sn has become the preferred choice for the windings of such new high-field designs, thanks to its proven large-scale industrial production. Numerous laboratory experiments, which range from tests on single wires up to full cables, have shown that the critical current of Nb3Sn conductors depends on the applied mechanical loads. However, it results very difficult to find a consensus within the magnet community on which is the maximum mechanical stress level that the brittle Nb3Sn superconductor can withstand in a magnet configuration.

Our work tries to fill this gap and reports on the results of an experimental and numerical modelling campaign devoted to understand the electro-mechanical limits of the novel MQXF quadrupoles. These magnets will be the first Nb3Sn units to be installed in a particle accelerator as a part of the High Luminosity upgrade of the LHC. On-going tests carried out in a short magnet model (MQXFS7) have confirmed the correct magnet performance up to compressive stress levels in the coils, at cryogenic temperature, in the order of 160 MPa. These results in magnet configuration are compared here with independent single-wire tests performed in a dedicated experiment at the University of Geneva. The study exploits Finite Element (FE) models reproducing both configurations to provide a complete insight into the physics of the problem. Furthermore, the MQXF FE model has been used as well to optimize the magnet assembly procedure. The refined method eliminates undesired coil stress overshoots during assembly and provides useful guidelines for future high-field designs.

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