COMSOL Simulation Of The Magnetic Field Shielding In Superconducting Tubes Using The A-H Formulation

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Abstract

Simulating the shielding of a 3T-magnetic field with superconducting NbTi and BSCCO tubes deploying the A-H field formulation using COMSOL Multiphysics

Screening of electromagnetic fields is a crucial technique for areas such as telecommunications, medical imaging, data storage and for various scientific instruments. At the Paul Scherrer insitute we develop a novel scientific instrument to search for the electric dipole moment of a muon based on the frozen-spin technique. In order to perform the measurement we need to direct muons with specific momentum, corresponding to a speed of 0.26c, into a magnetic trap.

The muons have to pass the fringe field of the solenoid to enter the trap region. Due to the magnetic mirror effect, most muons would be reflected without a magnetic field free path to the trap region. In order to improve the efficiency of the injection we use hollow superconducting tube bridging the fringe field region under a predefined angle relative to the solenoid axis. Therefore the shielding of the magnetic field is vital for an successful experiment. Based on the simulations of the muon storage, we require the transversal magnetic field components inside the tube to be less than 100mT, while the longitudinal component can remain higher, as it increases the muon transmission efficiency by forcing the muons to spiral inside the injection tube.

In order to simulate the shielding of the magnetic field in COMSOL, we use the A-H field formulation for the electromagnetic fields inside and in the close vicinity of the superconducting tubes. The superconducting properties of the Bismuth Strontium Calcium Copper Oxide (BSCCO) and Niobium-Titanium are described using critical current density dependency on the magnetic field strength and temperature. The material properties of the superconducting shield are strongly temperature dependent, so the electromagnetic model is fully coupled with a thermal one. The coupling with the mechanical model is instead performed using a segregated approach since it is assumed that the two physics can be solved independently.

In our contribution we show how the multiphysics simulations compare to test measurement using a cryogenic 12 T solenoid. For this purpose, we are going to cool the superconducting BSCCO and NbTi tubes to 4.2K using liquid helium and measure the magnetic field inside the tube at different positions using calibrated Hall sensors. This permits us to benchmark the modeling and gain confidence in the technical design deduced from the simulations.

Figures used in the abstract

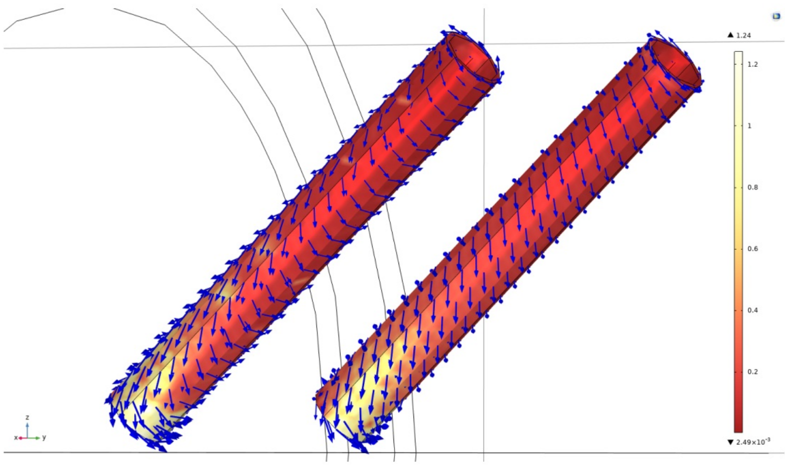

Figure 1: Simulation of the superconducting Niobium-Titanium injection tubes in 3T magnetic field. The arrows indicate the vector of the current density, while the color scheme illustrates the ratio of the critical current density and local current density the $\frac{J_c}{J}$. The ratio being larger than 1 would indicate a non-superconductive state.

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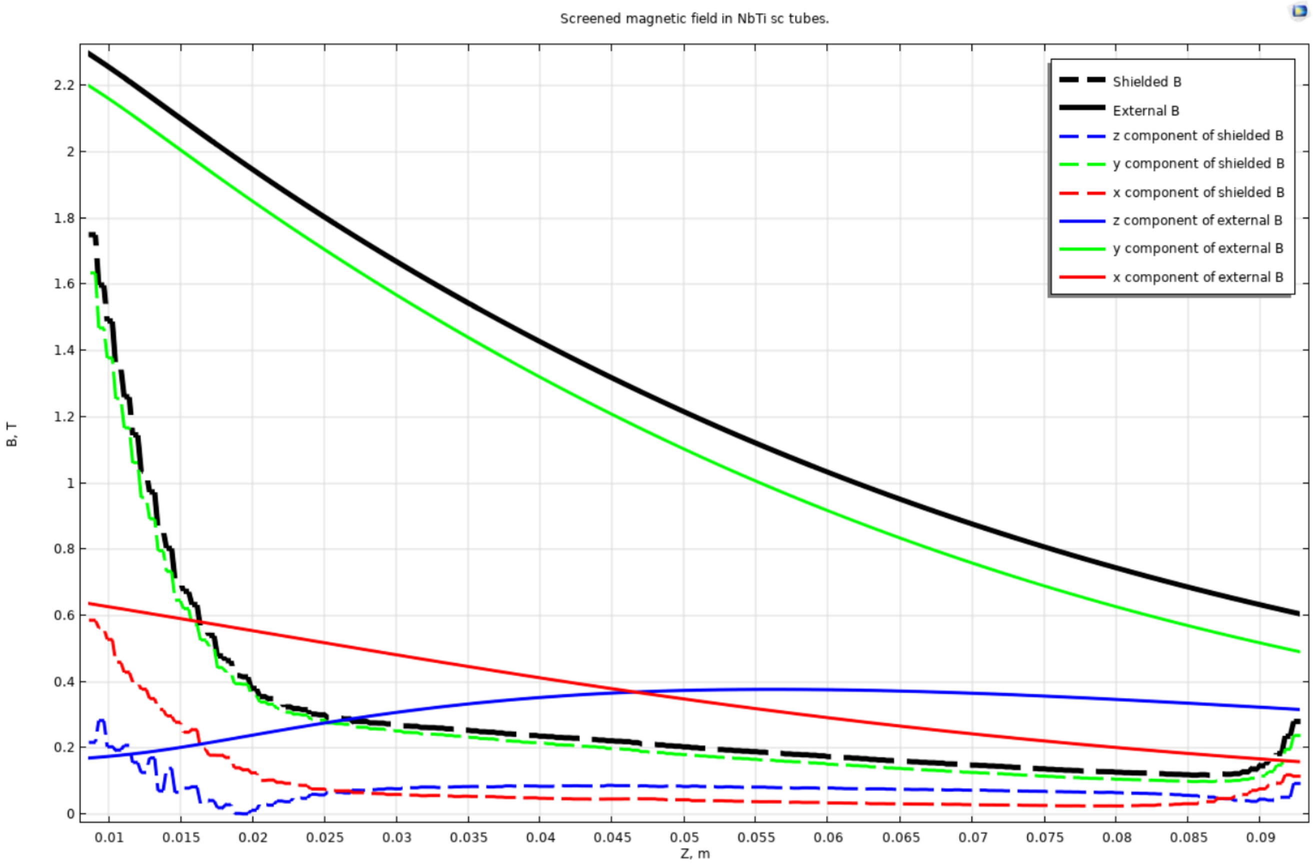

Figure 2: The simulated magnetic field shielding using A-H formulation in a superconducting NbTi tube. Note the high shielding factor on the transversal $\hat{x}$ and $\hat{y}$ components of the magnetic field.

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