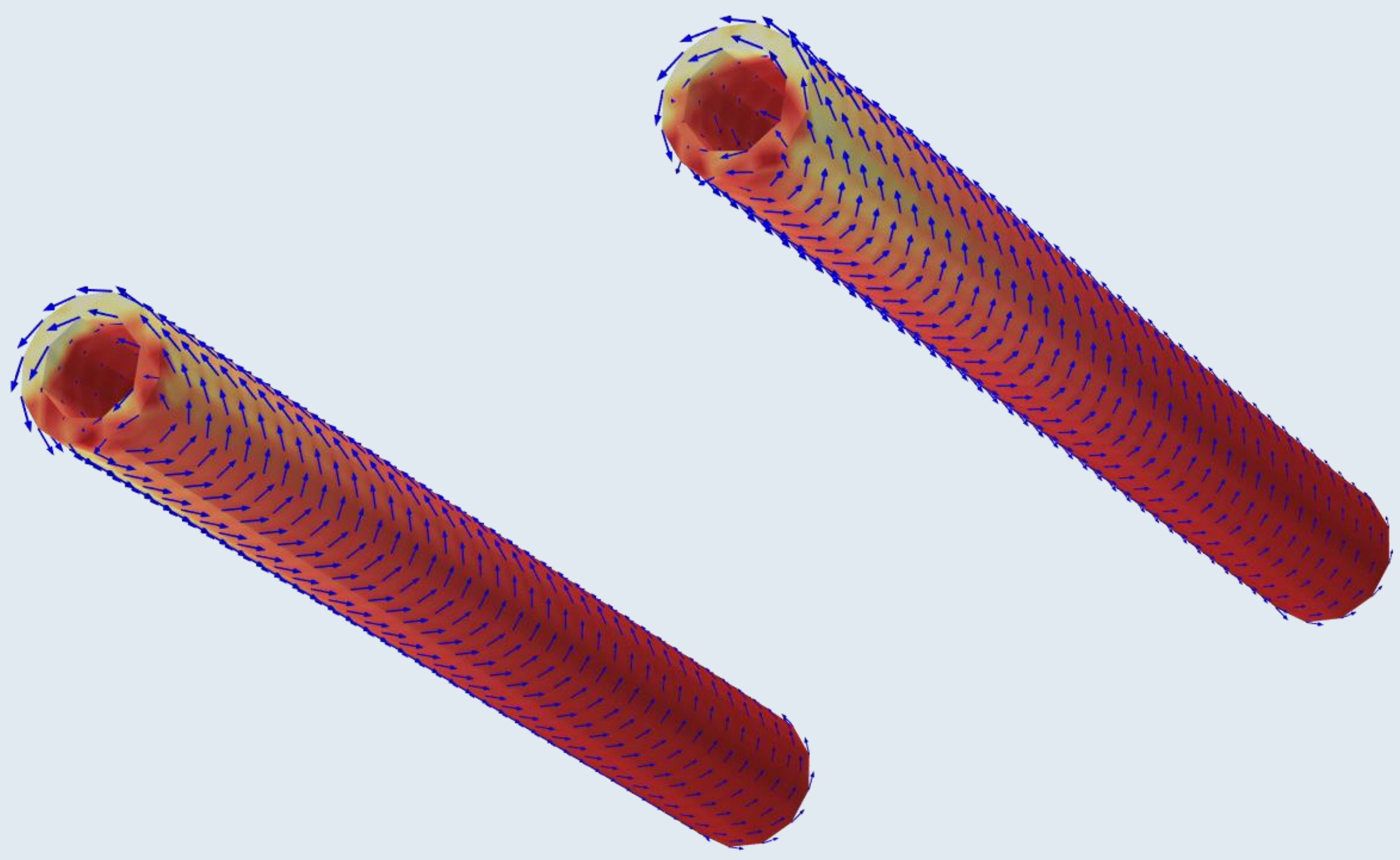

Simulating the shielding of a 3T-magnetic field with superconducting tubes deploying the A-H field formulation using COMSOL Multiphysics

We are setting up an experiment to search for the electric dipole moment (EDM) of the muon using the frozen-spin technique[1] at the Paul Scherrer Institute. The discovery of muon EDM would be a direct measurement of charge conjugation parity symmetry violation and lepton flavor universality.

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Introduction

In order to store the elementary particles muons in a fixed orbit a strong magnetic field (B ≈ 3T) and precise injection angle is required. Magnetic field of this strength would deflect incoming muons from the solenoid cavity. The aim is to design the muon injection channel, which would shield the muons from the fringe magnetic field, thus providing a high muon flux for the storage.

We present our sensitivity goal, the current best experimental limit and the theoretical prediction of the muon EDM:

- *muEDM* goal sensitivity: $\sigma(d_\mu) \leq 6 \times 10^{-23}$ e · cm
- current exp. limit (BNL E821 [2]): $d_\mu \leq 6 \times 10^{-19}$ e · cm
- Standard model prediction [3]: $d_\mu \leq 1 \times 10^{-34}$ e · cm

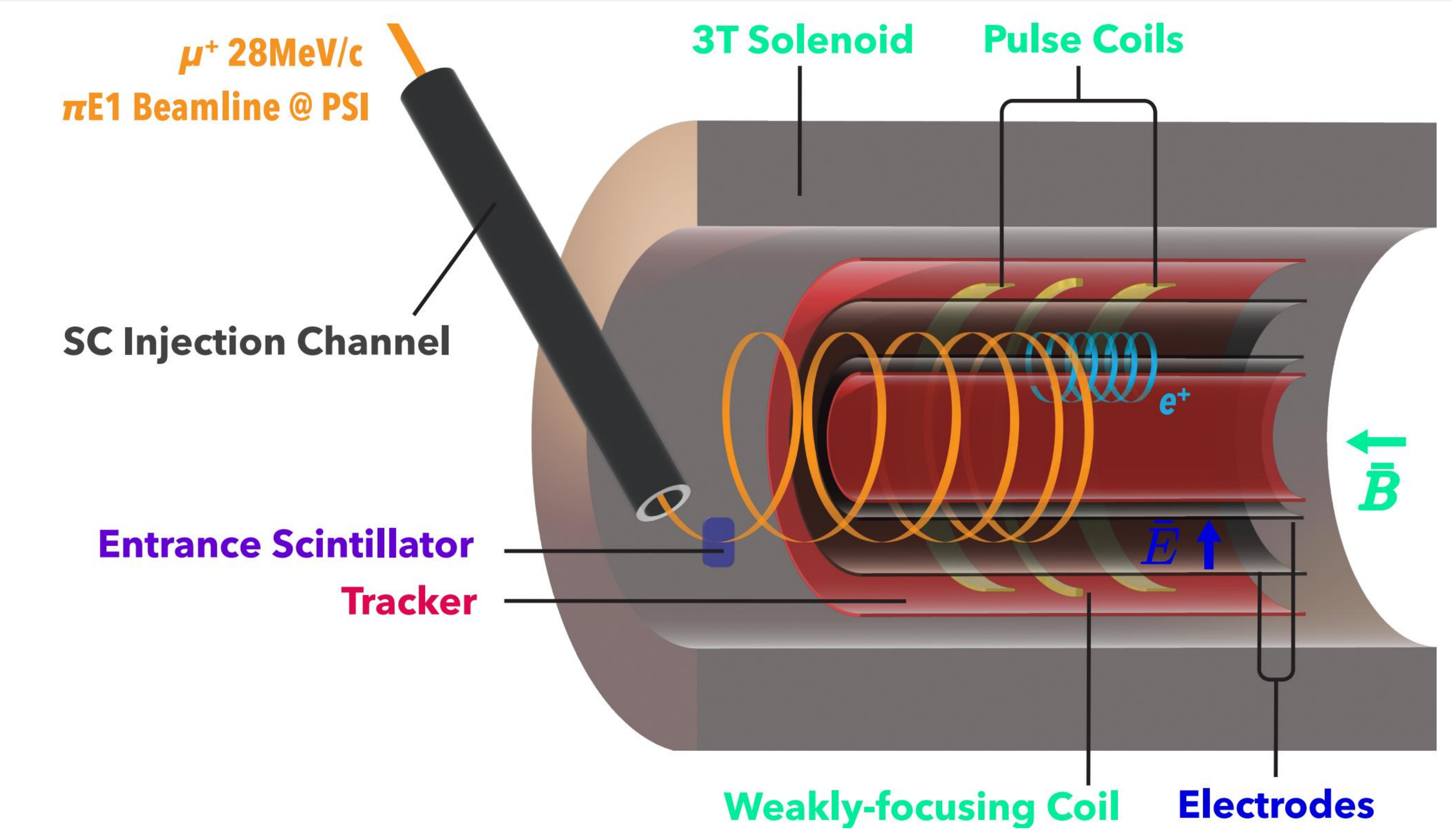

FIGURE 1. The experimental setup overview of the muon electric dipole moment measurement.

Methodology

We use superconducting hollow tubes in order to shield the incoming muons from the external fringe magnetic field. In previous injection simulations we showed that it is sufficient that the transversal components of the shielded magnetic flux density B_x and B_z are lower than 100 mT.

Due to the high current density required to shield the external magnetic field, we also simulate the Lorentz force acting on the superconductor.

$$\vec{F_L} = \int \vec{J} \times \vec{B} \, dV$$

$\vec{J}$ is the current density in the superconductor, $\vec{B}$ is the magnetic field flux density in the superconductor.

Results

We have successfully simulated the magnetic field shielding using COMSOL and showed that we can expect sufficient magnetic field shielding (see FIGURE 2).

We have simulated the force acting on the superconductor with perfect magnetic field shielding using COMSOL and independent ring model [4], thus gaining the upper limit of the expected forces. The radial component of the Lorentz force integrated on half of the hollow cylinder F_r≈ 10 kN (corresponding to 11 GPa) and the axial component integrated on the whole volume F_y≈ 1.4 kN (corresponding to 26.2 MPa).

We are planning an experiment to measure the magnetic field shielding and forces acting on the superconductor to verify the simulation results.

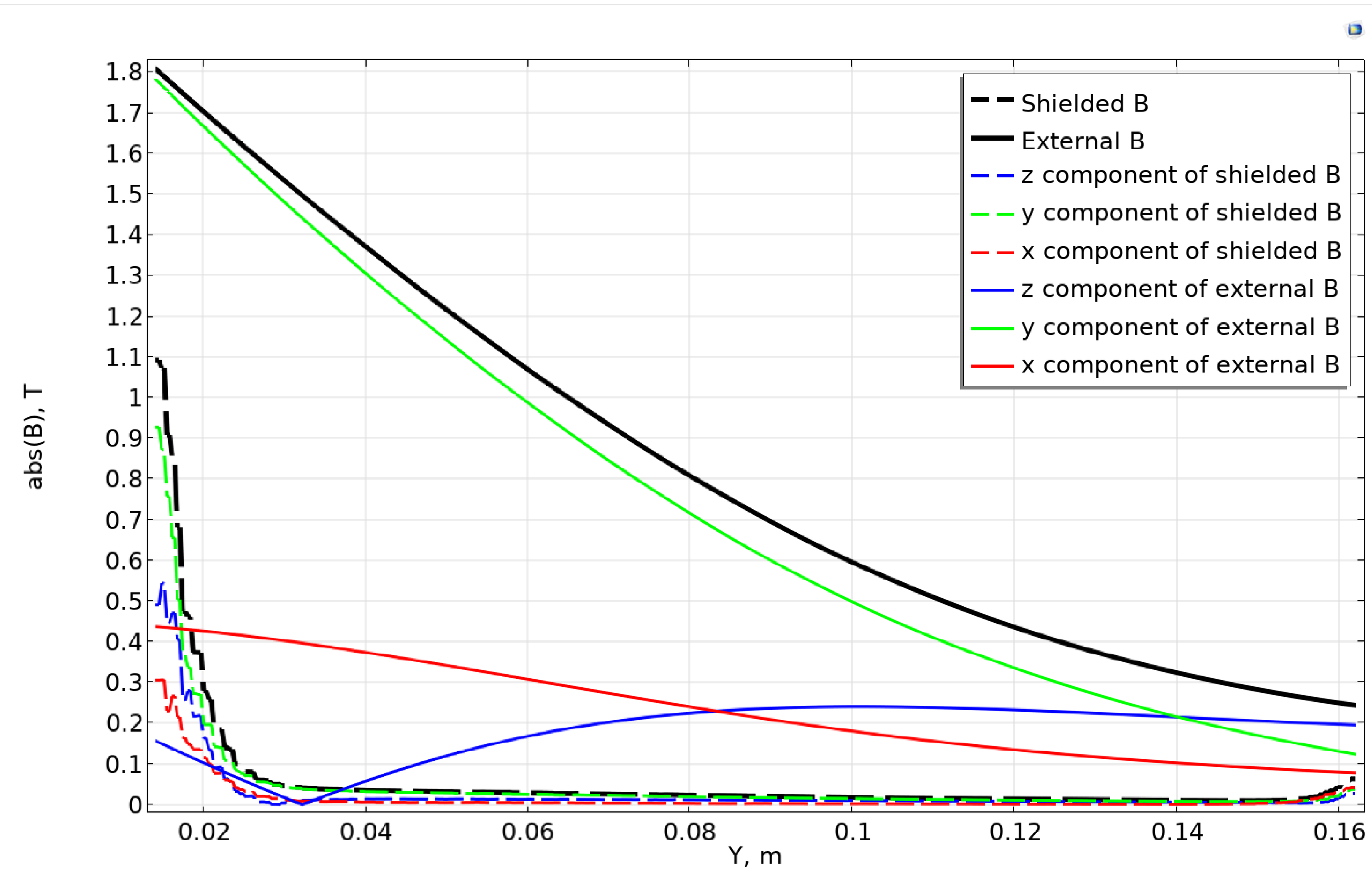

FIGURE 2. The components of the external and shielded magnetic field flux density in the local frame of the superconducting tube. Y axis is oriented along the principal axis of the tube.

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PSI Center for Neutron and Muon Sciences

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FNSNF Swiss National Science Foundation

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Excerpt from the Proceedings of the COMSOL Conference 2024 Florence