Cryogenic Magnetic Shield Modeling & Verification

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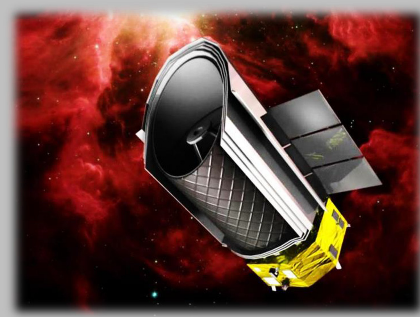
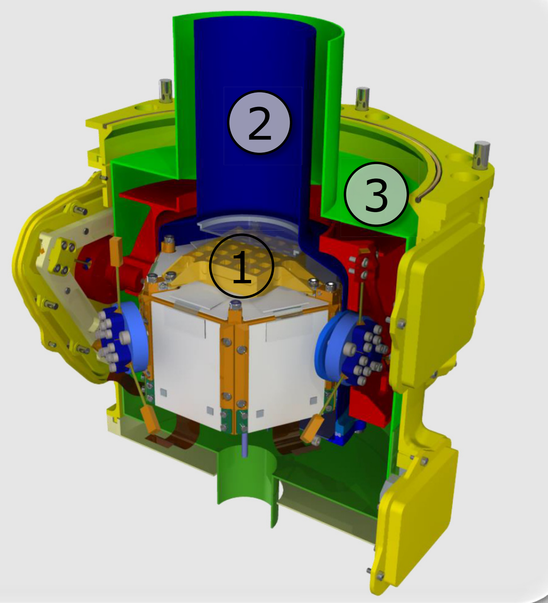


Abstract - In a European consortium led by SRON Netherlands Institute for Space Research, the SpicA FAr-infraRed Instrument (SAFARI) is being developed. SAFARI will use large-format arrays of Transition Edge Sensor (TES) bolometers read-out with Frequency Domain Multiplexing (FDM) operating at 50mK. Here we present the COMSOL Multiphysics analyses performed on the magnetic shielding.

Introduction Focal Plane Assembly (FPA)

- TES detectors (1) sensitive to absolute magnetic field: superconducting (s.c.) phase transition.
- Operation temperature of 50mK allows for use of superconducting Niobium (2) magnetic shield. This allows for an optimized shielding : mass ratio.
- S.c. Niobium shield requires additional shielding at normal to s.c. phase transition to avoid excessive flux trapping. This is provided by Cryoperm® (3) shield.



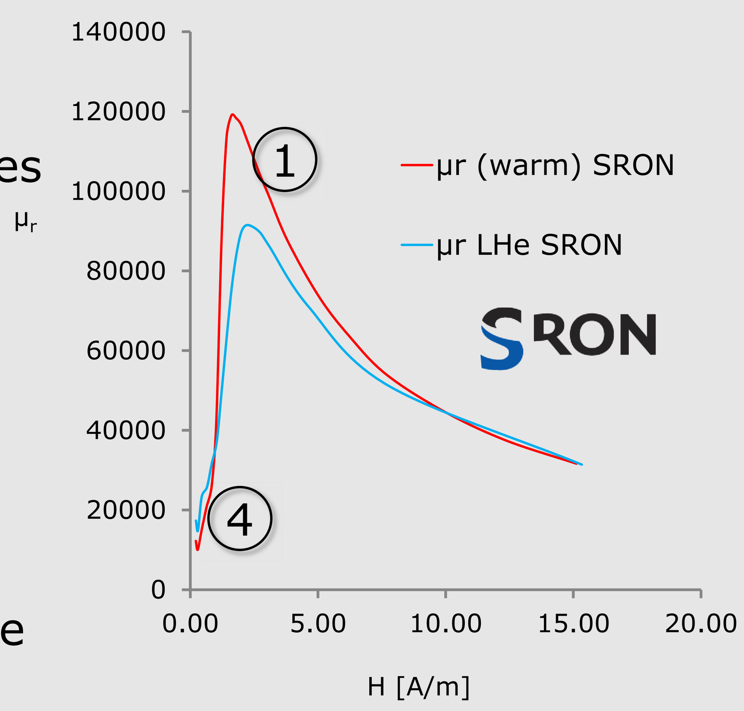
High μ_r shield (Cryoperm®) verification on simplified geometries

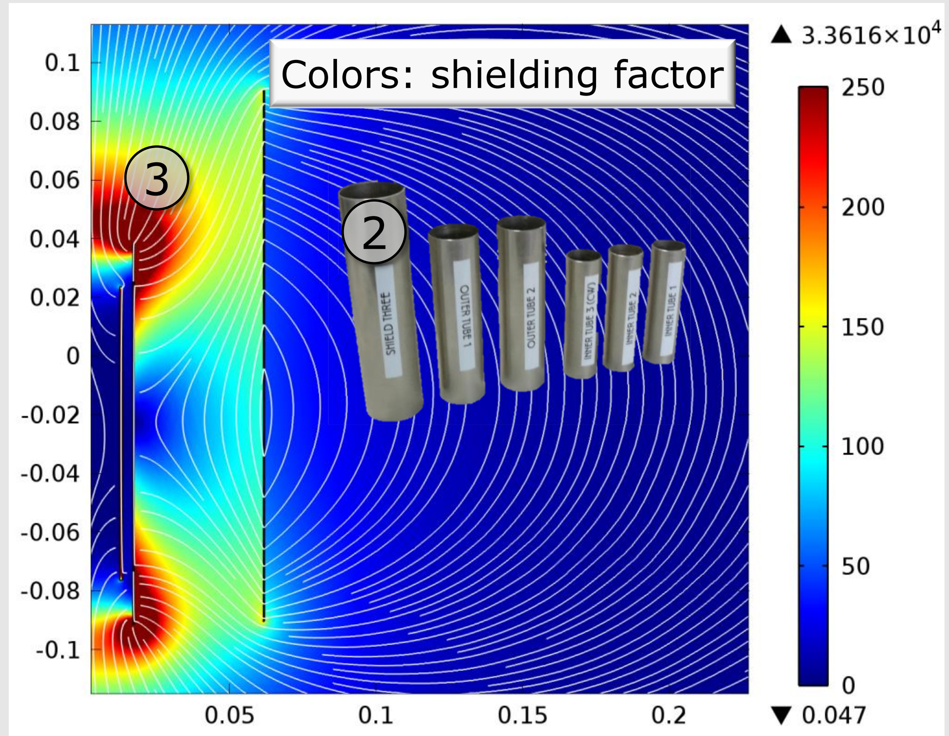
Verification method:

- Determined permeability (1) from B-H curve measurements on sample tubes (2) warm and at Liquid Helium (LHe, 4.2K) temperature.
- Performed on-axis shielding measurements on individual tubes and various combinations. Outcome compared with Comsol models (3).

Modeling and experimental results:

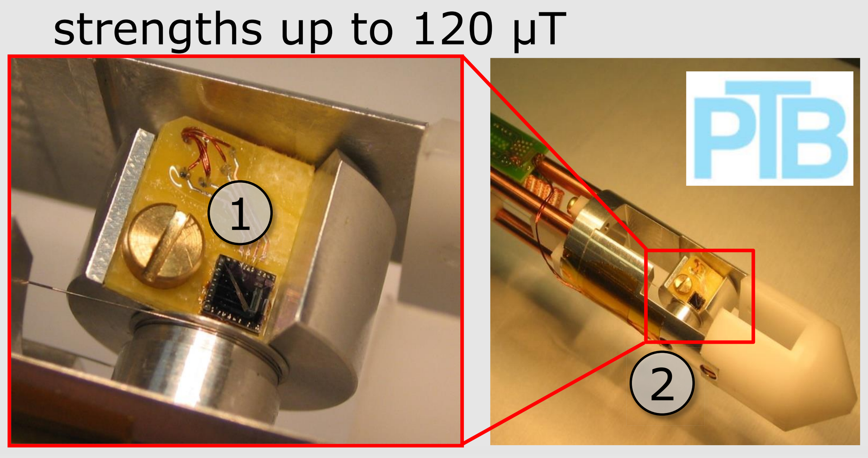
- FEM models and measurements within 15% , also for double shields with attenuations exceeding 10^3 attenuation.
- Initial permeability (4) important for correct shielding predictions on double shields. Updated permeability measurement setup accordingly.

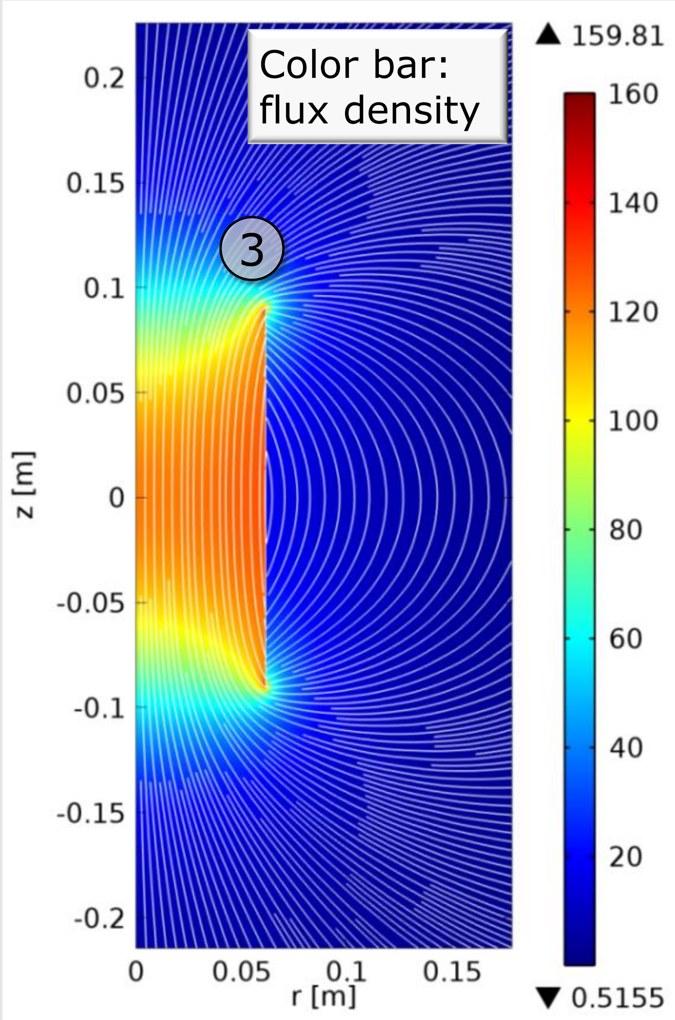


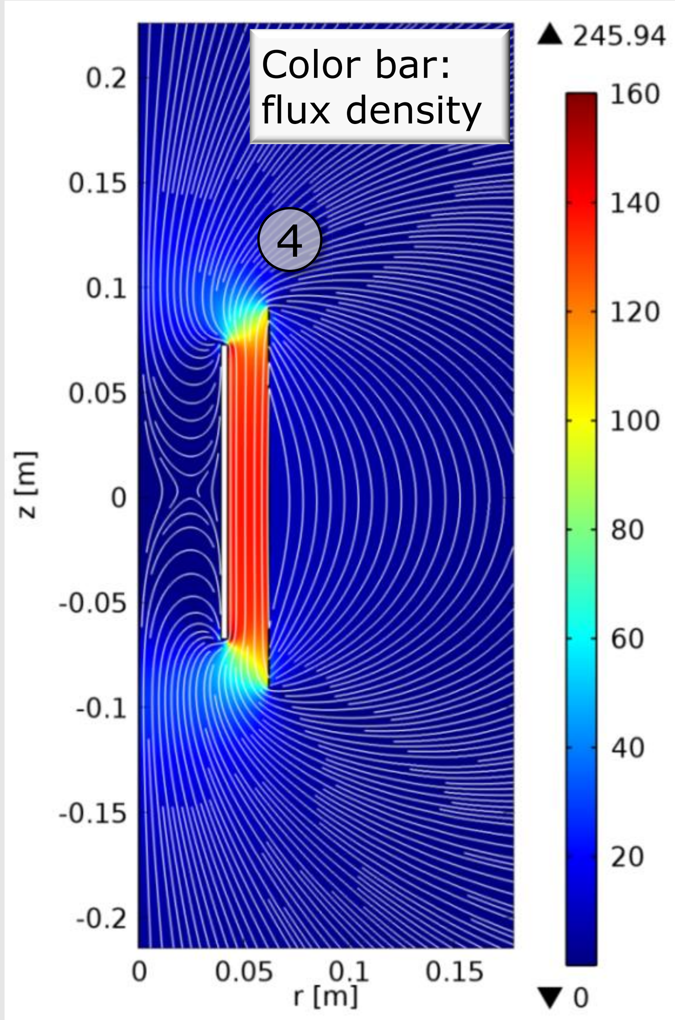


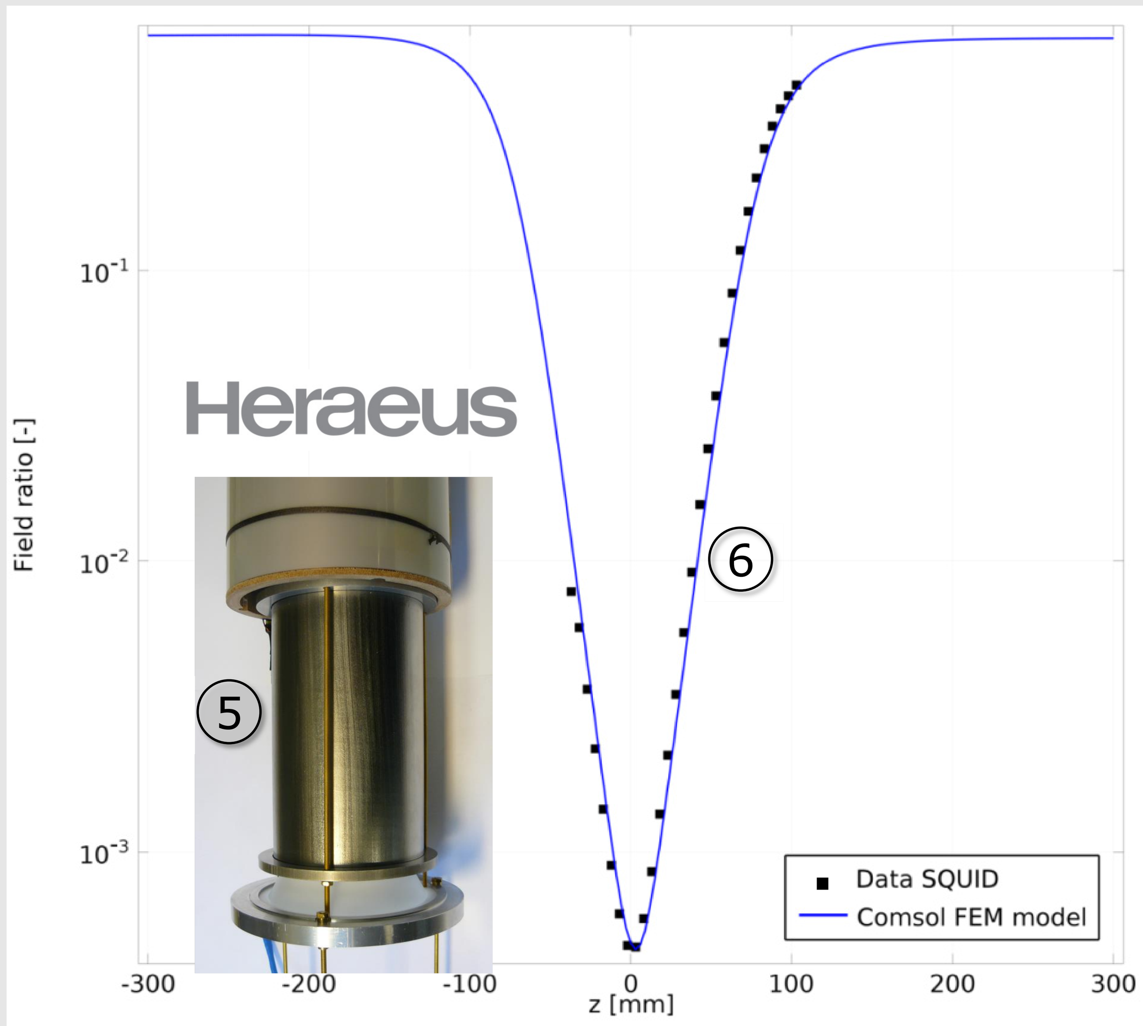
Superconducting shield (Niobium) model verification using SQUID probe

- Developed rotatable SQUID (1) magnetometer for cryogenic H-field magnitude and direction measurements (2).
- Replaced s.c. domain with boundary conditions and modeled field generated by excitation coil (3) and attenuated (4) field.
- On-axis data from open tube (5) compared to model (6).
- Excellent agreement for field strengths up to 120 μT



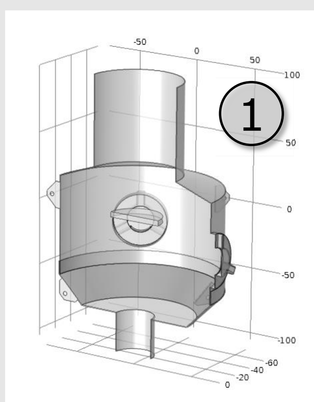


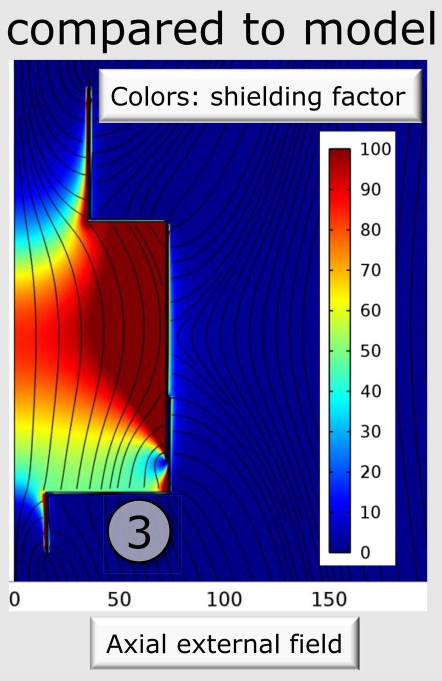


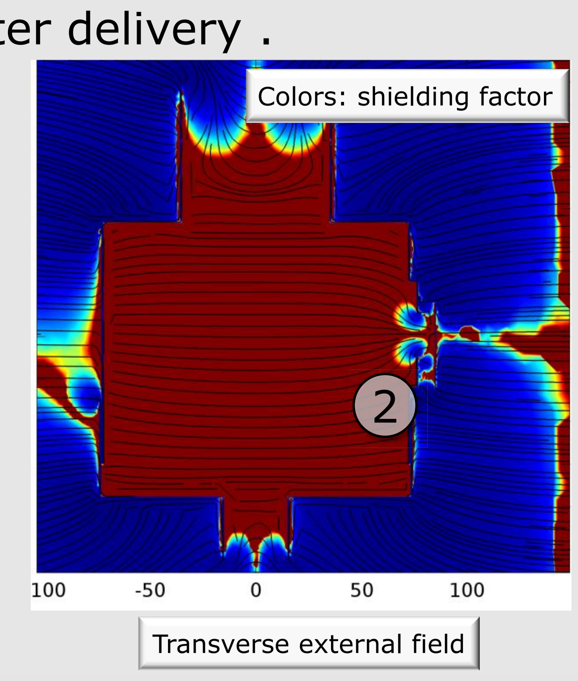


High μ_r shield (Cryoperm®) engineering model optimization

- Extended model to 3D to study influence of mounting holes (2) and top- to bottom-shield interface (3).
- Mounting holes (2) less critical, interface (3) optimized to avoid shielding degradation. Prototype design changed accordingly (4).
- Engineering model currently in production at Sekels GmbH, magnetic properties will be compared to model after delivery .

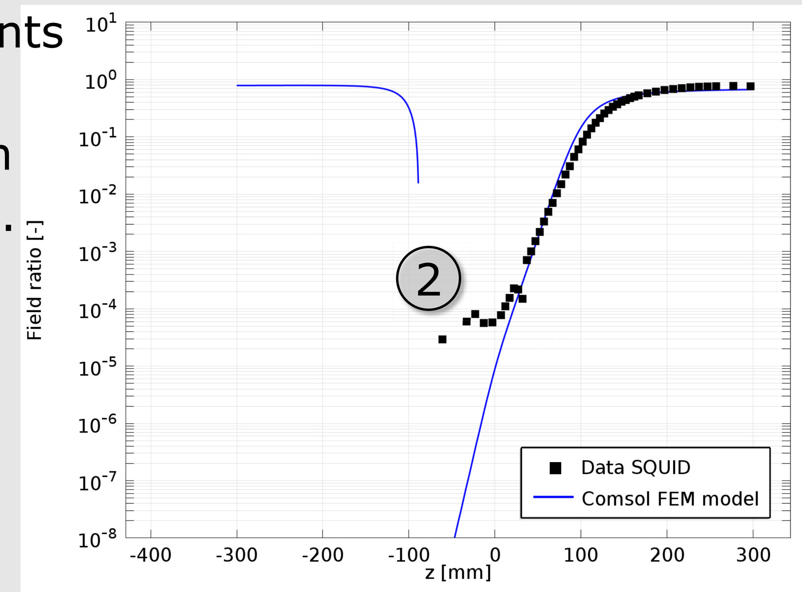


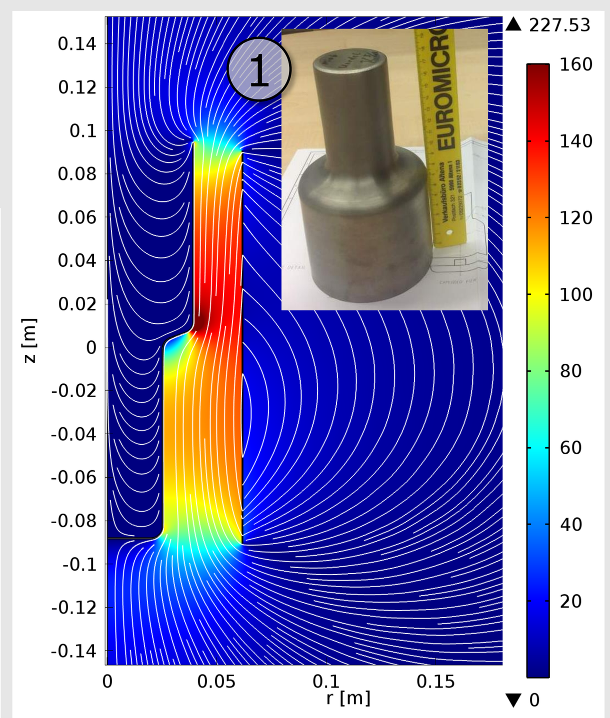




Superconducting shield (Niobium) engineering model first tests

- Thin walled Nb shield (1) produced at Hereaus.
- Effects close to the bottom of the shield (2) might be an indication of flux trapping.
- Measurements and model optimization ongoing (3).





Conclusions:
COMSOL Multi-physics is used frequently during the ongoing development of the SAFARI Focal Plane Assembly. Magnetic models are used to optimize the shielding ratio while minimizing the required mass and volume. Both high-permeability and superconducting shield models have been validated and correspond well to experimental data. The developed models are now used extensively to predict the implications of design alternatives and are an essential tool for further system optimization. Also for other FPA related subsystems COMSOL is used extensively as an engineering design tool.

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