Status of Design and Manufacturing of PENeLOPE neutron trap

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Visit also talk by R. Picker, TRIUMF, Wen, 30 August, 17:15
PENeLOPE: testing of a one-of-a-kind neutron storage magnet

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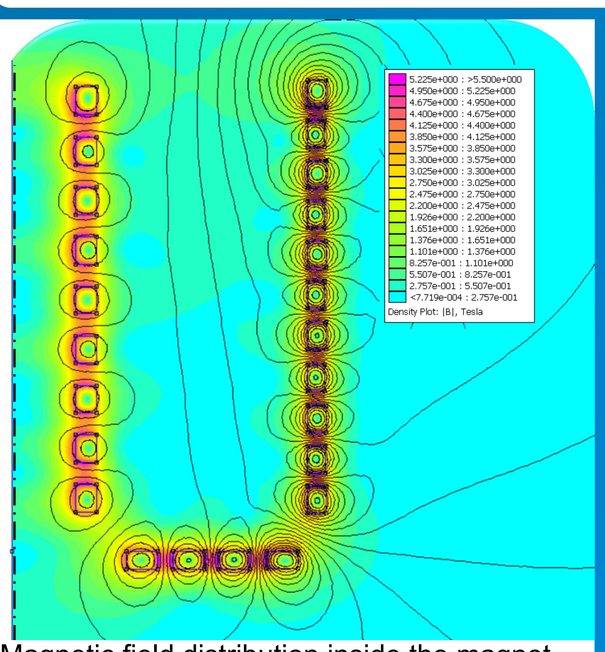
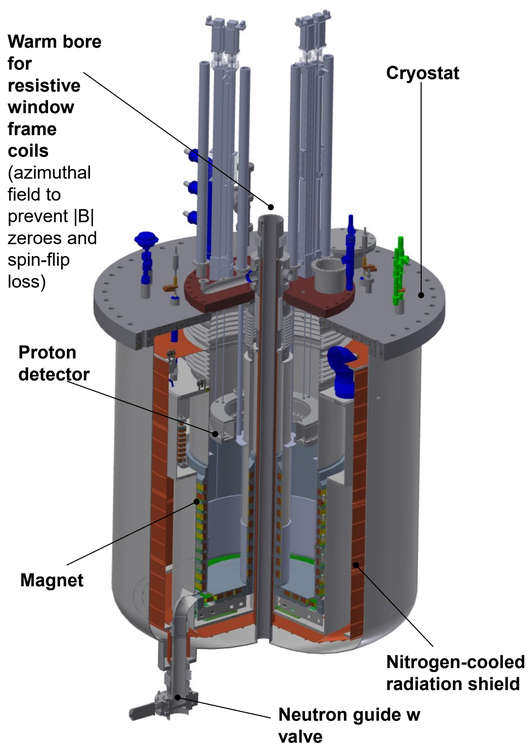
PENeLOPE (*P*recision *E*xperiment on *N*eutron *L*ifteime *O*perating on *P*roton *E*xtraction) is a novel neutron lifetime precision experiment devised by TUM, currently being designed, manufactured and tested in close cooperation of TUM and BNG, funded by Deutsche Forschungsgemeinschaft DFG.
Ultra cold neutrons produced by the experimental reactor facility FRM II in Garching will be stored in a large volume magnetic bottle and held confined for periods of several minutes , where a combination of magnetic and electric fields allows basically all protons emerging from neutron decay to be captured by a high efficiency detector. Thus, the decay curve can be measured with unprecedented precision. The magnetic bottle is formed by an array of 24 pairwise oppositely poled solenoids with local fields up to 5.4 T, providing magnetic confinement for neutron energies up to 110 neV, while maintaining an essentially field free trapping volume.

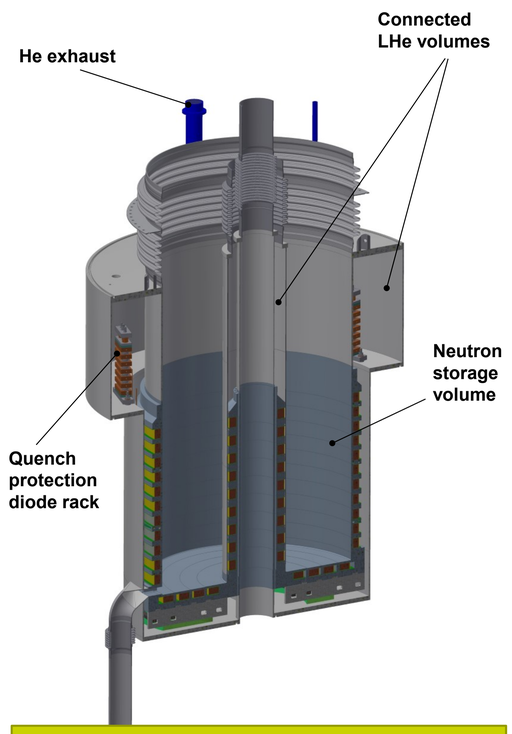


Magnetic field distribution inside the magnet. The steep field gradient close to the coils repels the neutrons to prevent any contact with material walls and avoids parametric heating during field ramp-up. Gravity hinders upward escape.

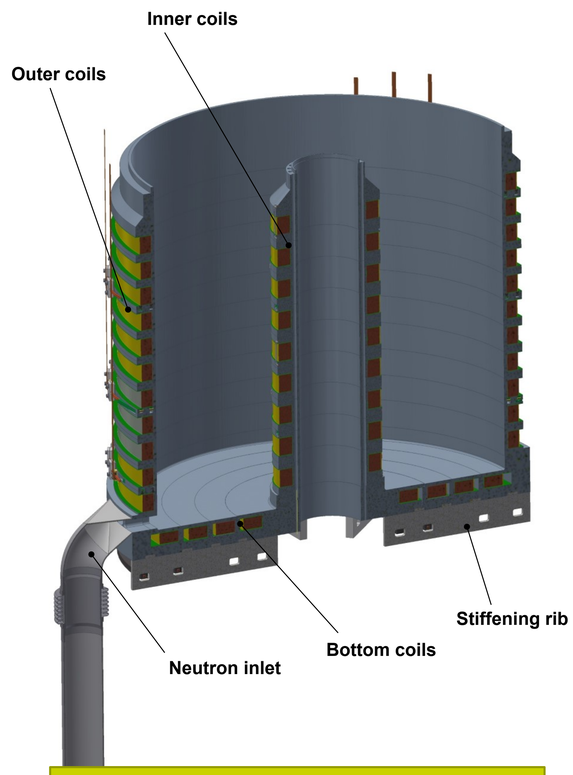
Coils and magnetic field



Superconducting magnet assembly in cryostat



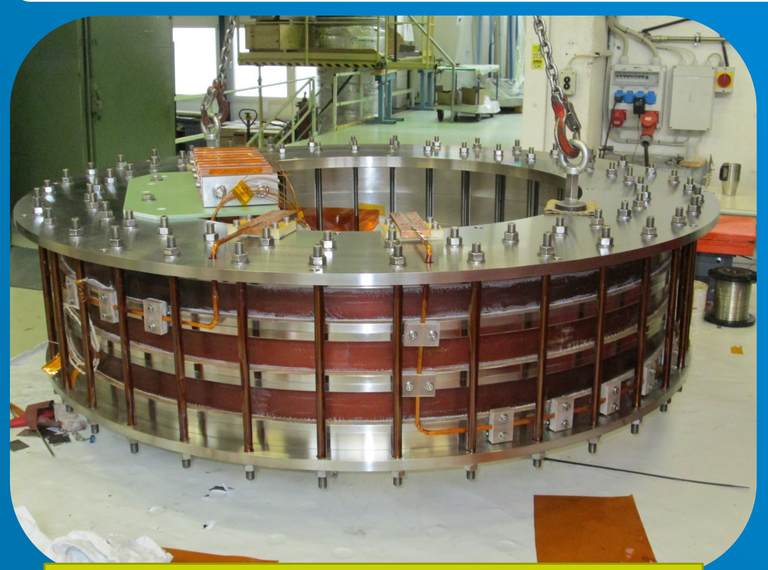
LHe vessel and coil structure



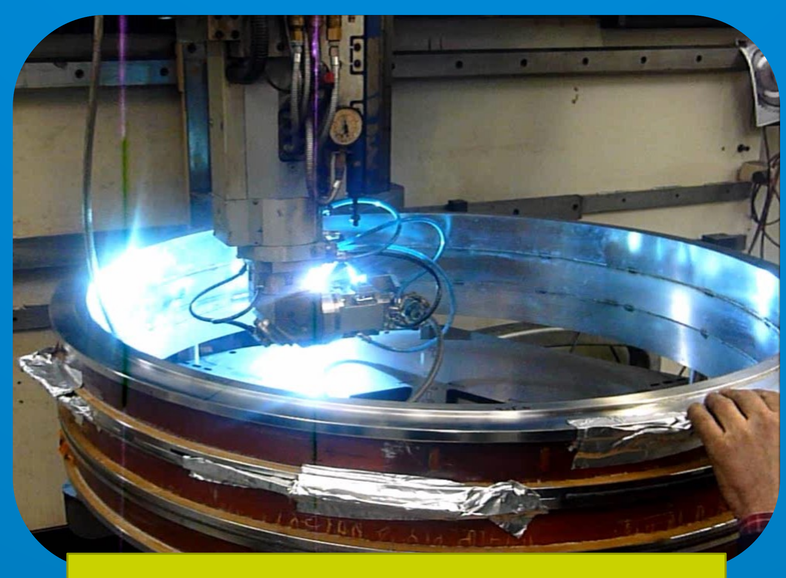
Coil assembly

The coil formers made of 1.4429/SS 316LN constitute the wall between experimental vacuum and the LHe bath. This material exhibits low permeability and superior mechanical strength at low temperatures.
For reasons of a viable manufacturing scheme, the coils are wound and potted on individual formers, which are then assembled to the full magnet structure by laser welding. This structure must bear the repelling forces between the coils which can rise to above 1000 kN in certain quench scenarios. High force density on the coils required stress management by careful choice of winding pre-tension to avoid separation from former.

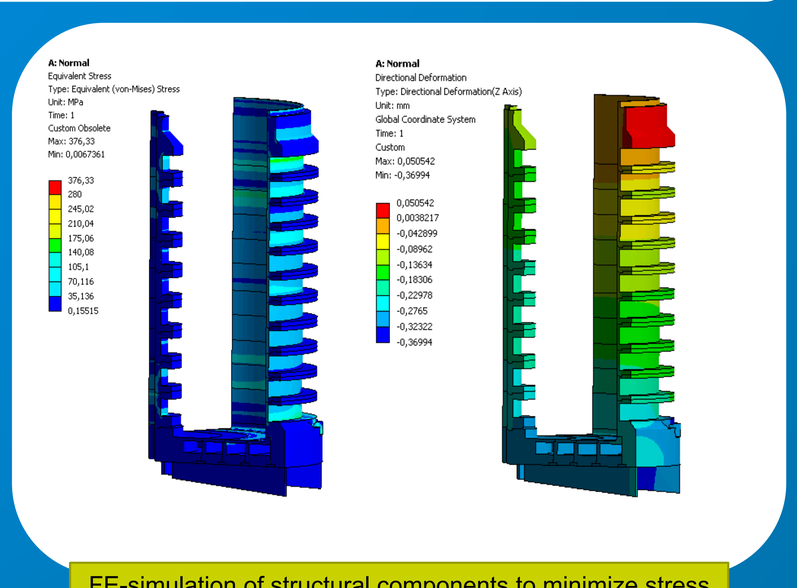
Due to spatial constraints, there is no additional support structure and the welds do not only provide a seal between experimental UHV and LHe bath, but transmit the full inter-coil forces as well.
In cooperation with specialized companies, we were able to produce 6 mm deep vacuum tight and load bearing structural welds without raising the temperature at the coils' windings above 180°C, which is considered the maximum acceptable temperature for insulation and potting resin.
In the past months, two sub assemblies have undergone extensive testing and training at TUM's test facility.



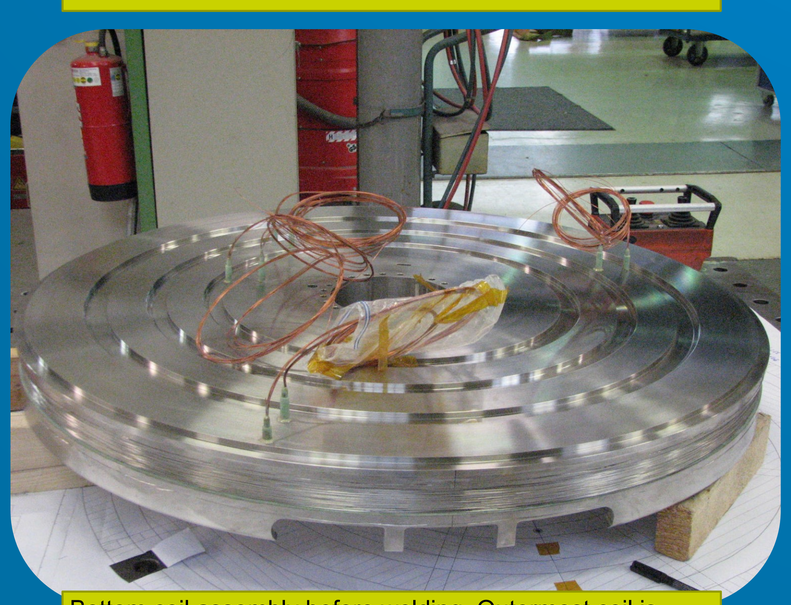
Assembly of three outer coils in test fixture



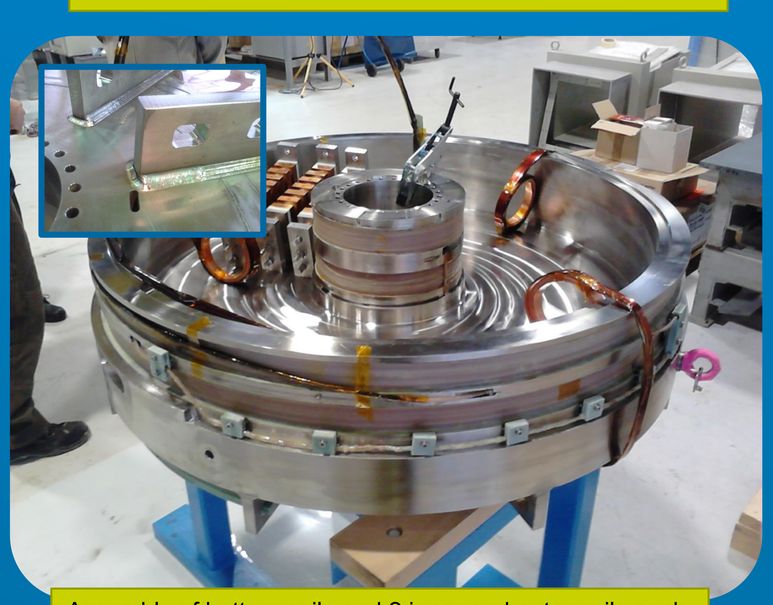
Laser welding of outer coil stack



FE-simulation of structural components to minimize stress and deflections under load



Bottom coil assembly before welding. Outermost coil is reinforced with a pre-loaded wire bandage to contain the extreme radial forces.



Assembly of bottom coils and 2 inner and outer coils each, prior to shipment for testing at TUM

Design Goals

- 24 solenoids
- 108 cm maximum coil Ø
- Ø0.9 mm NbTi-wire Cu:SC 60:40
- 283.5 A operating current
- 316 A/mm² eng. curr. density
- 5.4 T maximum field @ coils
- 1.8 T usable trap field (110 neV)
- 100 s ramp-up time
- 8.5 kV coil proof voltage
- 1.2 MN max. axial coil force (quench)
- 30.8 H series inductance
- 1.24 MJ magnetic energy
- 30 – 110 neV neutron energy (< 1 mK!)