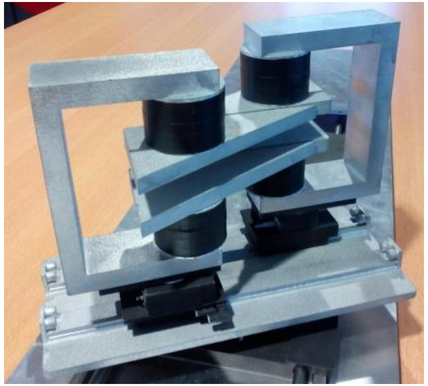
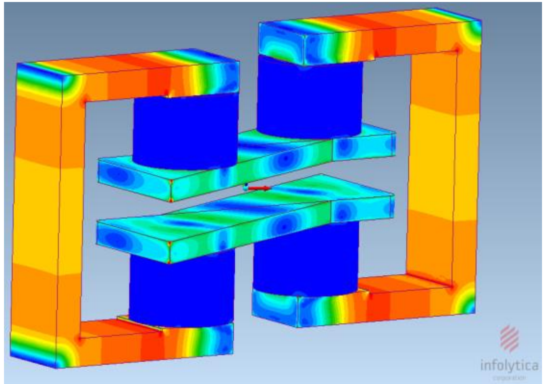
Magnetic field simulations for polarised neutron instruments





Michel Thijs – DENIM 18-09-2018

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Margarine

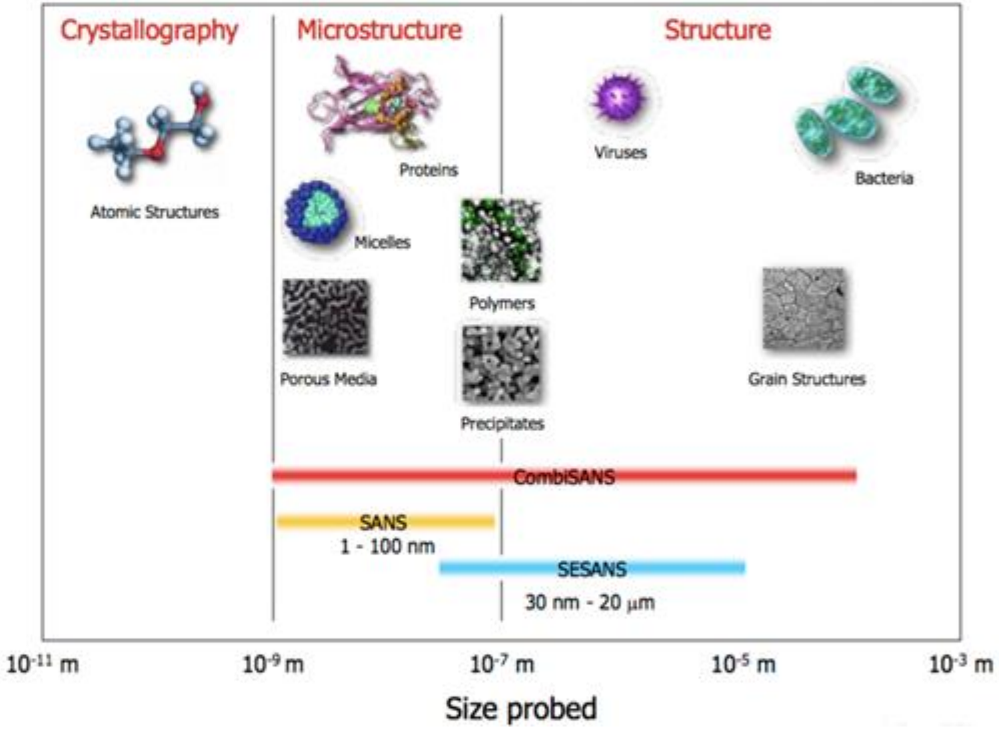

Figure from W.Bouwman – Adapted from R.Pynn

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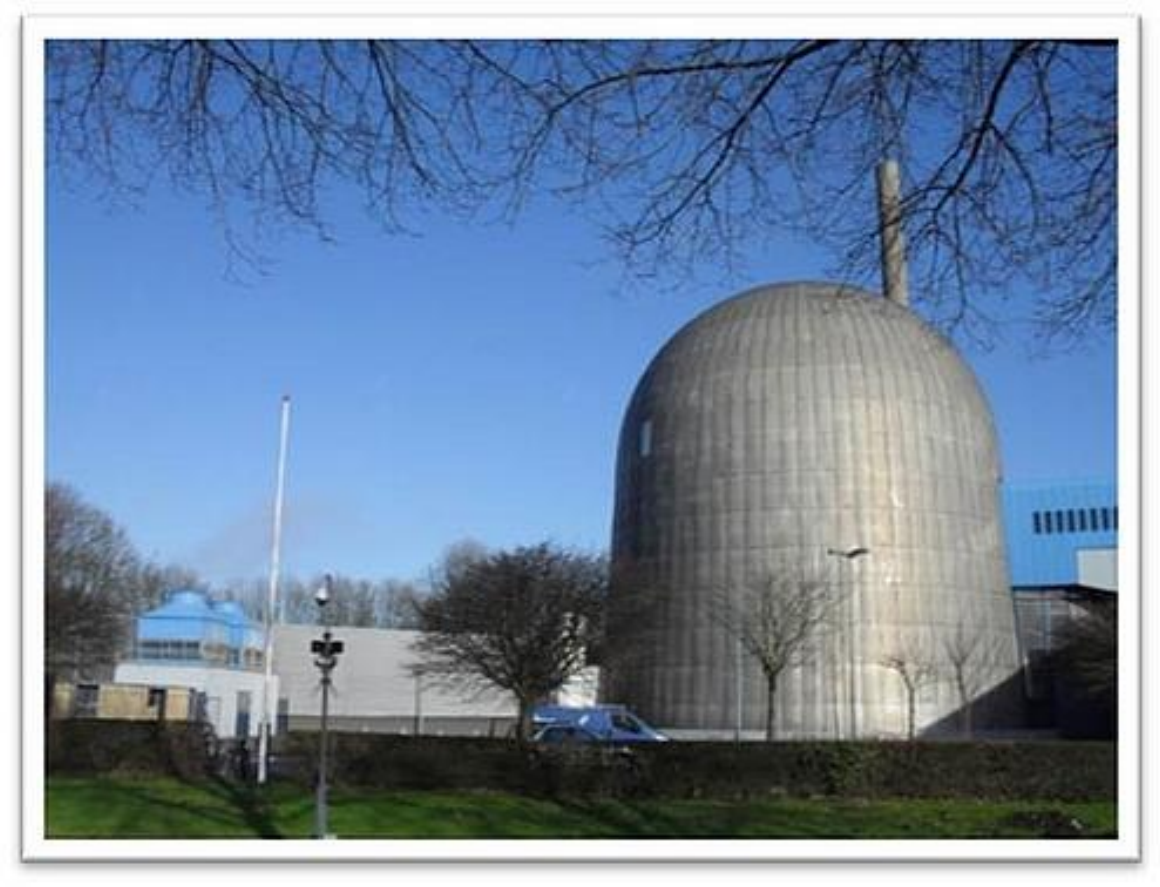
Reactor Institute Delft



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Polarised neutron instruments

- Samples with increased complexity and energy or length scales
- New instruments with polarised options

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The Neutron

- Magnetic moment
- Gyromagnetic ratio $\gamma_L = 1.83 \cdot 10^8$ rad·s^{-1}·T^{-1}
- Maintain polarisation
  - Guide field coils
- Spin manipulation tools
  - RF flipper, current screens, V-coils
- Spin Precession volume
  - Homogeneity and field line integral

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Various software packages

- First principles
  - Biot-Savart law
- Analytically:
  - Radia (from ESRF) in Wolfram Mathematica
- Finite element analysis:
  - MagNet
  - COMSOL
  - Opera

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Finite element analysis

- Accurate and realistic results
- Use actual CAD models in simulation
- Results help in designing and engineering the instrument
- Less prototypes needed

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Subjects addressed

- DC fields from permanent magnets and coils
- RF fields from coils
- Homogeneity of the magnetic fields
- Magnetic field integrals over the beam path
- Mechanical forces
- Magnetic saturation of steel in electromagnets
- High frequency current induction effects
- Simulation applicable for research areas other then neutrons

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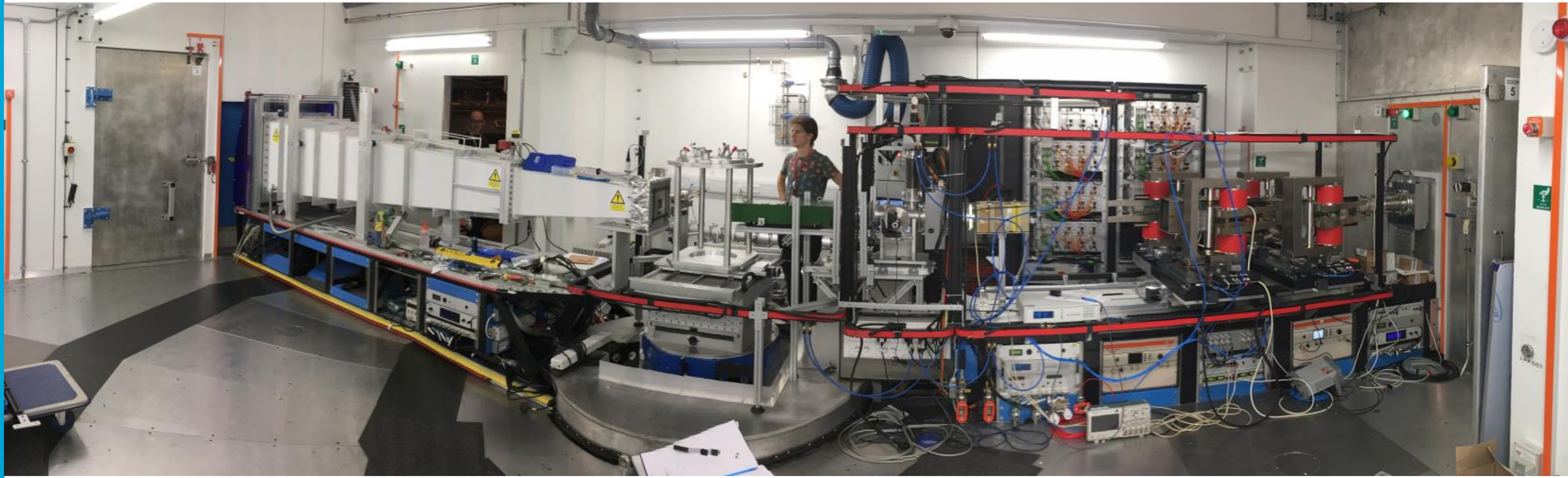
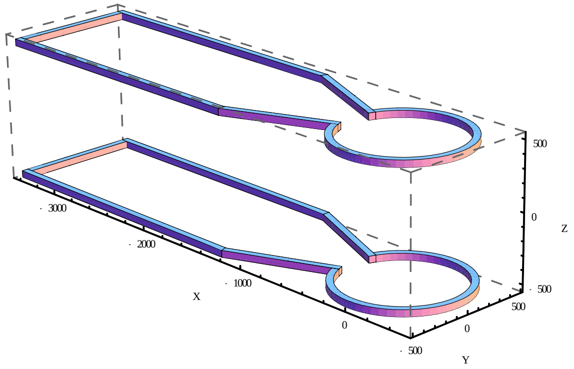
LARMOR instrument @ ISIS

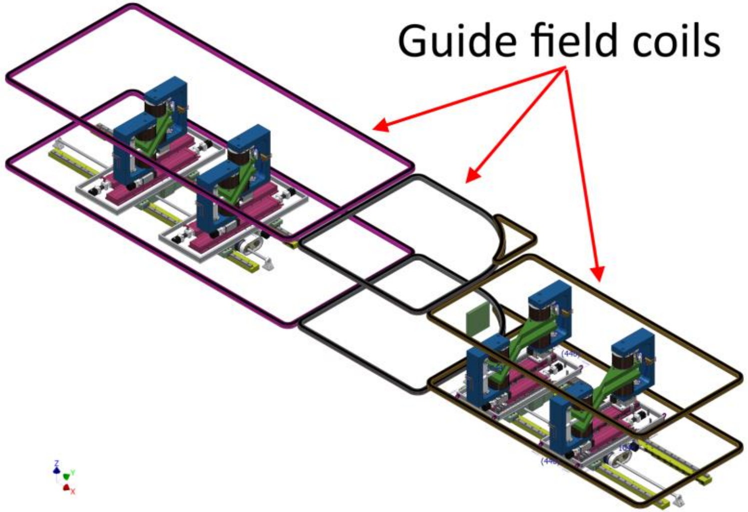
- Collaboration between TU Delft RID and ISIS
- TUD-RID developed the ‘neutron spin-echo’ components
- Magnetic field simulations used extensively



Guide field coils

- Create a well defined, homogeneous field
- Maintain the beam polarisation

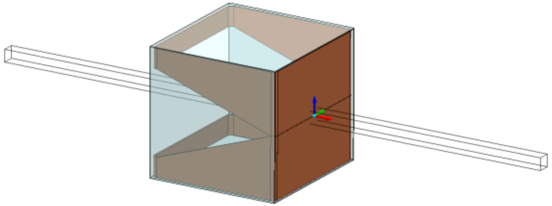


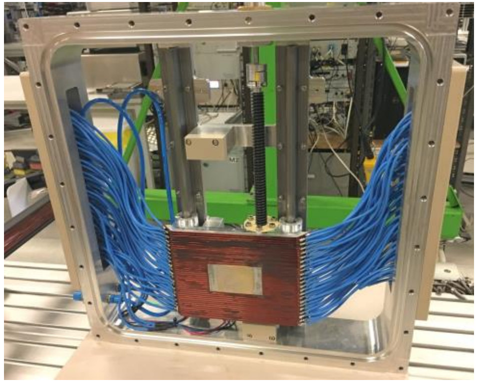


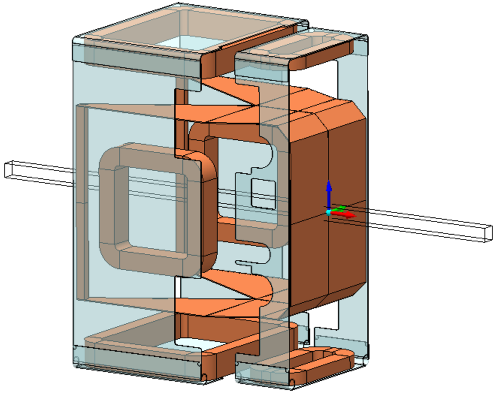

CAUTION

Current sheets, V-coils

- Start and stop neutron precession
- Reverse precession direction
- Combine smooth and sudden field transitions

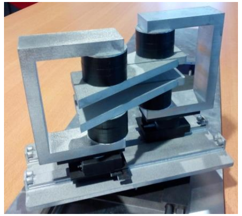


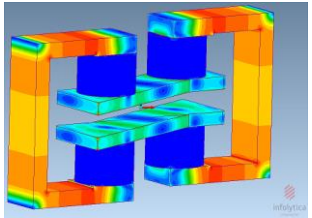


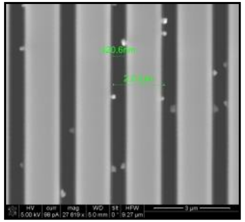


SESANS magnets

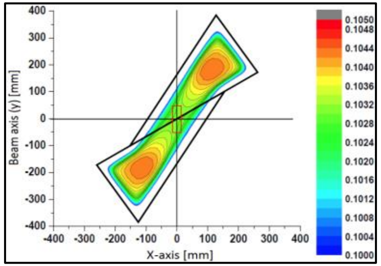
- Neutrons manipulated by field between the pole shoes
- Angle tunes the wavelength sensitivity and what length scales in the sample are being probed
- Field homogeneity very important

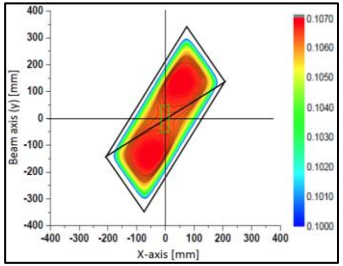


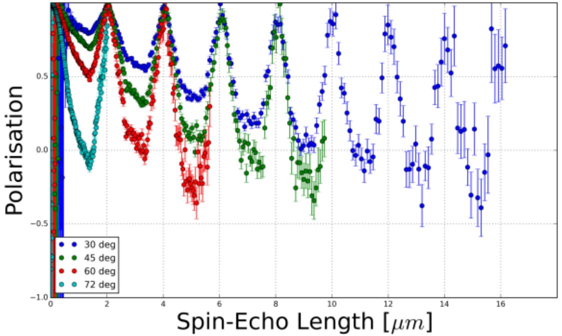




Microscopy image of silicon grating with 2μm pitch
Grating fabrication curtesy of N. Lavrik, ORNL







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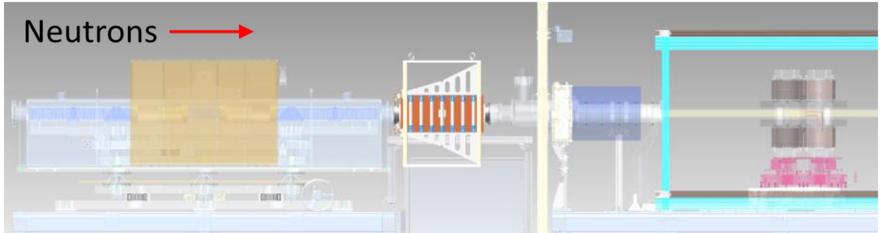
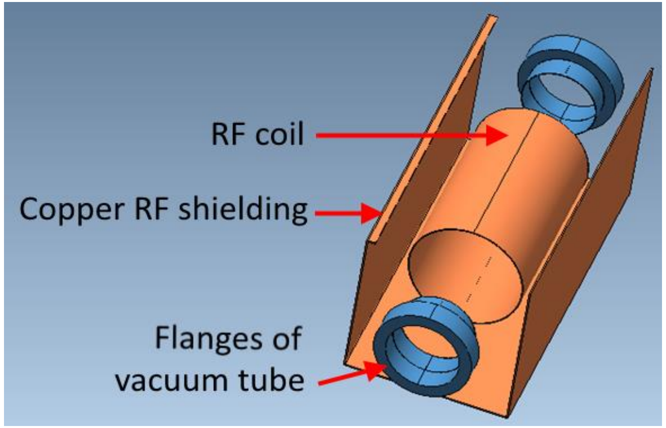
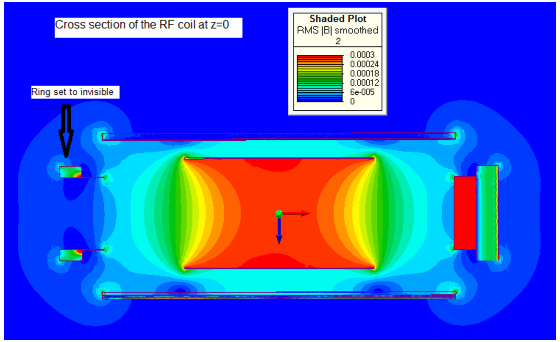
White beam flipper using static and high frequency fields >99.8% efficient all wavelength







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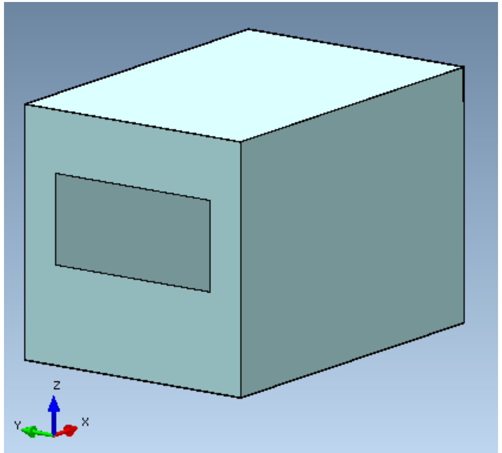
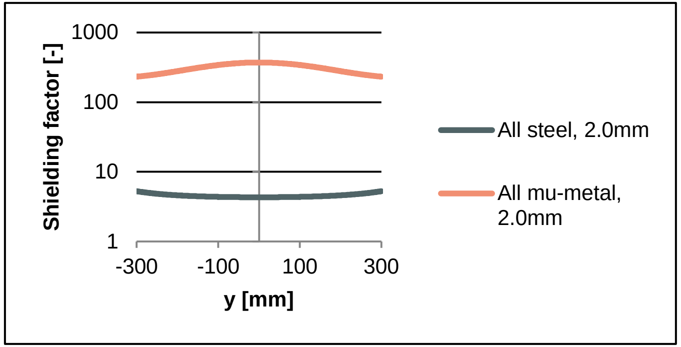
Mu-metal shielding of photo multiplier tubes (PMT)

- Diffraction detector with wavelength shifting fibres
- PMT's are sensitive to magnetic fields
- Mu-metal 'instrument box' and 'shield tubes' around PMT





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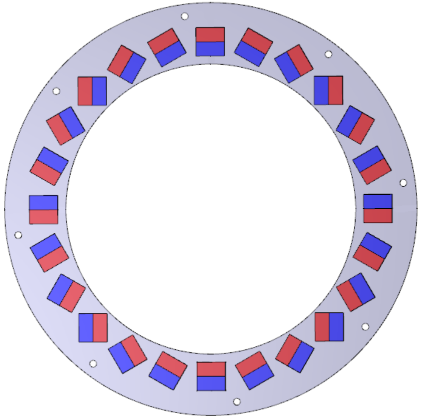
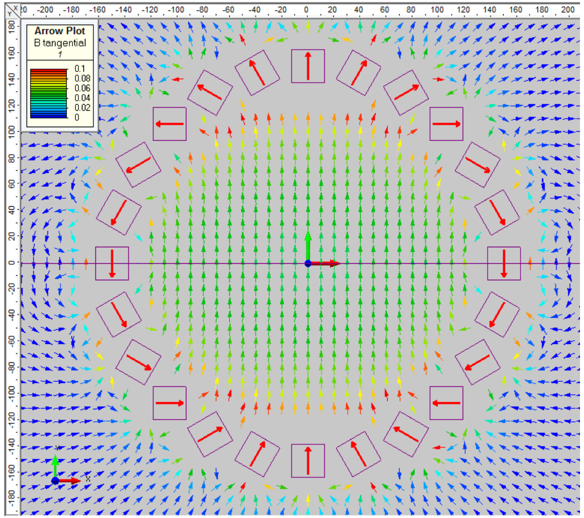
Other applications

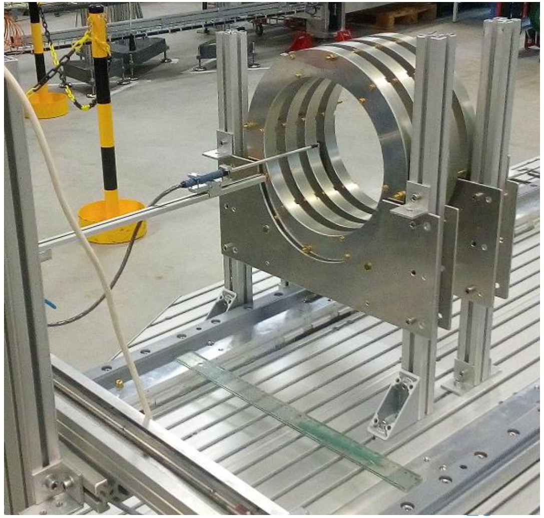
- Magnetic enclosures for He3 polarisers and analysers
- MRI system using permanent magnets in a halbach array
- Magnetic field shielding for a positron beamline
- Magnetic nanoparticles behaviour
- Revolving permanent magnets for magnetocaloric cooler

Low budget MRI using Halbach array

- Study babies (e.g. for hydrocephalus) in developing countries
- Magnetic field and mechanical forces







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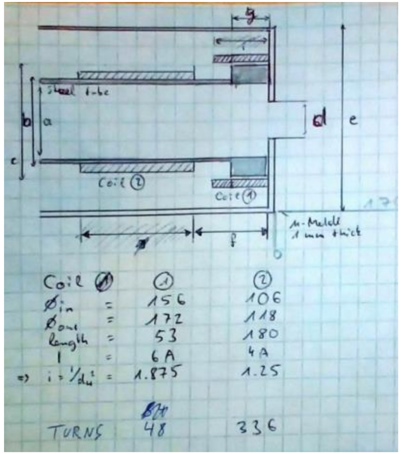
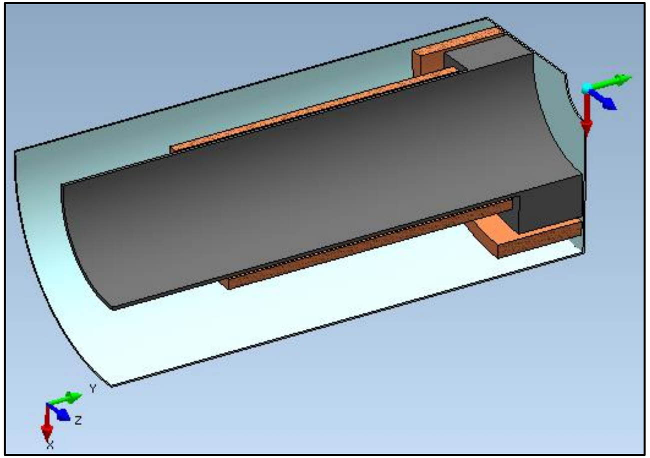
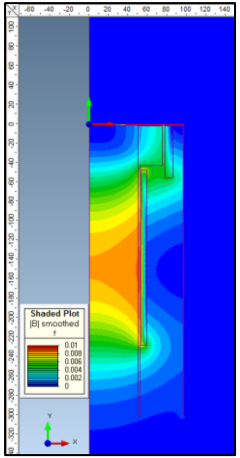
Magnetic shielding for positron beam

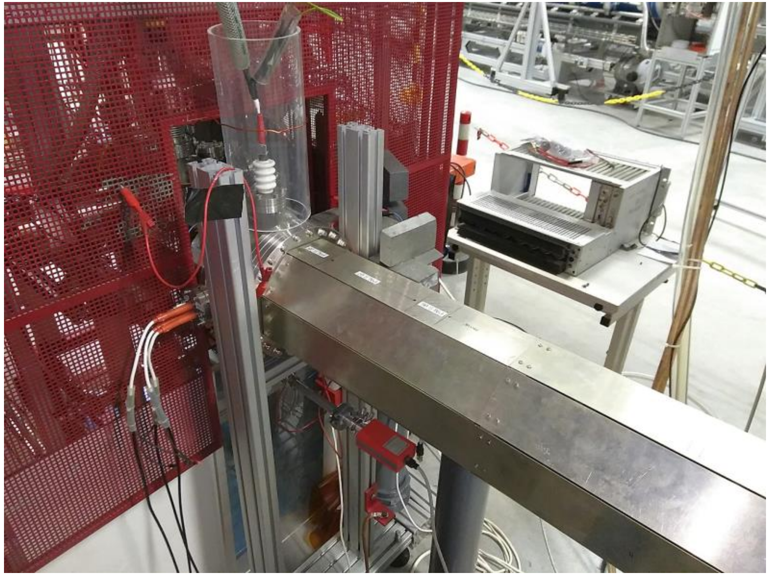
- Goal: no magnetic field outside
- Mu-metal shielding
- Optimise coil positions and currents

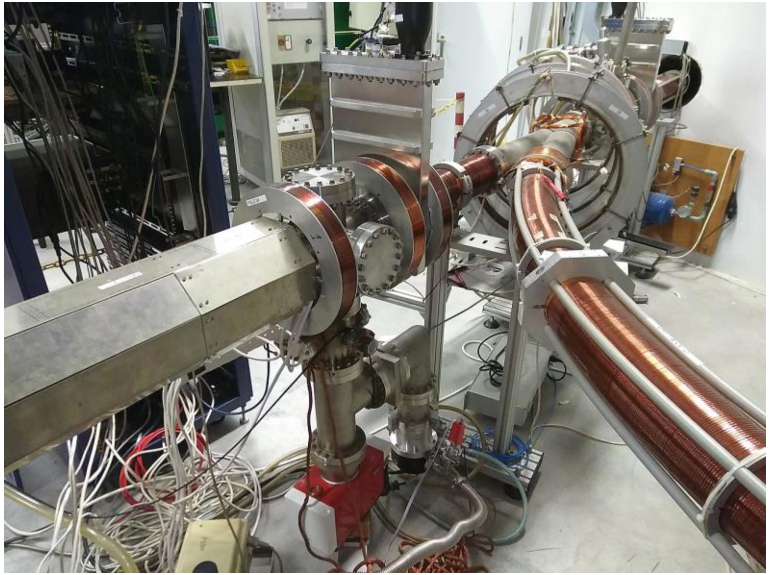






Magnetic shielding for positron beam





Conclusion

- Powerful tool
- Accurate results and user friendly software
- Great benefits for development time and instrument performance for the Design and Engineering of Polarised Neutron Instruments

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