Polarised Neutrons & SE

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Polarised Neutrons & SE

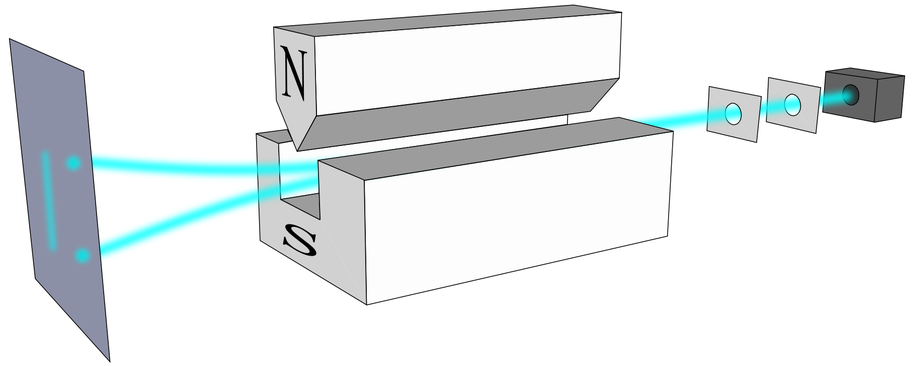
- ILL statistics
  - 40% of the +40 instruments propose a polarised neutron option
  - 25% of the total beamtime exploits a polarised beam option

- Neutron beam polarisation vector
- Spin flippers
- ^{3}He spin filters and flippers
- Zero-field polarimeters

Polarised Neutrons & SE

Introduction

- The neutron
  - no electrical charge (no Lorentz force)
  - 2-state angular momentum (Stern-Gerlach)



- The neutron beam polarisation
  - overall average of neutron angular momentums
  - behaves like a classic vector in space

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Polarised Neutrons & SE

Action of a magnetic field

- In a magnetic field, the polarisation rotates around the field in a Larmor precession with the frequency:

$$\omega_L[rad/s] = 18325\, B[Gauss]$$

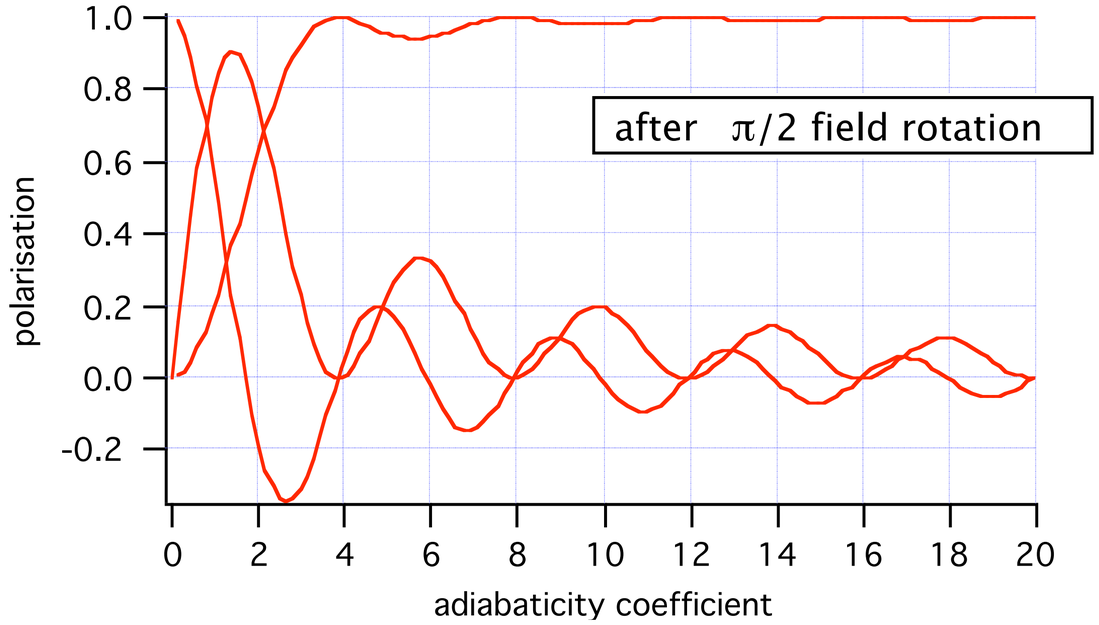
- When crossing a magnetic field region of length ℓ, the polarisation rotates by:

$$\phi[deg] = 2.65\ \lambda[\text{Å}]\ B[Gauss]\ \ell[cm]$$

Polarised Neutrons & SE

Action of a magnetic field

- If the guiding field rotates slowly compared to the Larmor precession frequency, the polarisation is transported adiabatically.



Adiabaticity rule

$$E = \frac{\omega_L}{\omega_B} \gg 30$$

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Typically, for a 90° rotation over 10 cm

λ [Å]	0.4	1	4	10
E [meV]	511	81.8	5.11	0.82
B [Gauss]	255	102	25	10

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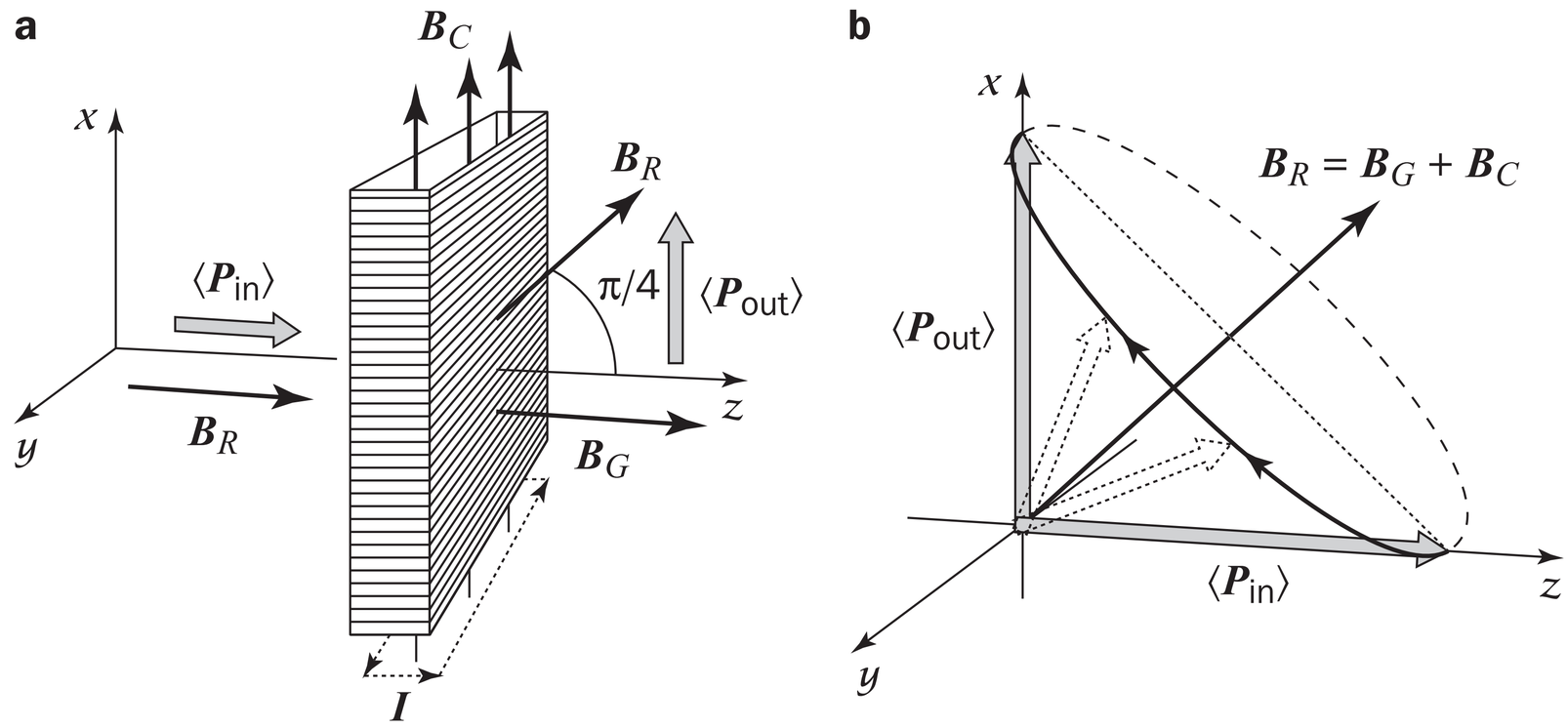
Spin flippers

- Mezei's flipper: sensitive to environmental magnetic fields, neutron wavelength dependent, for cold and thermal neutrons only



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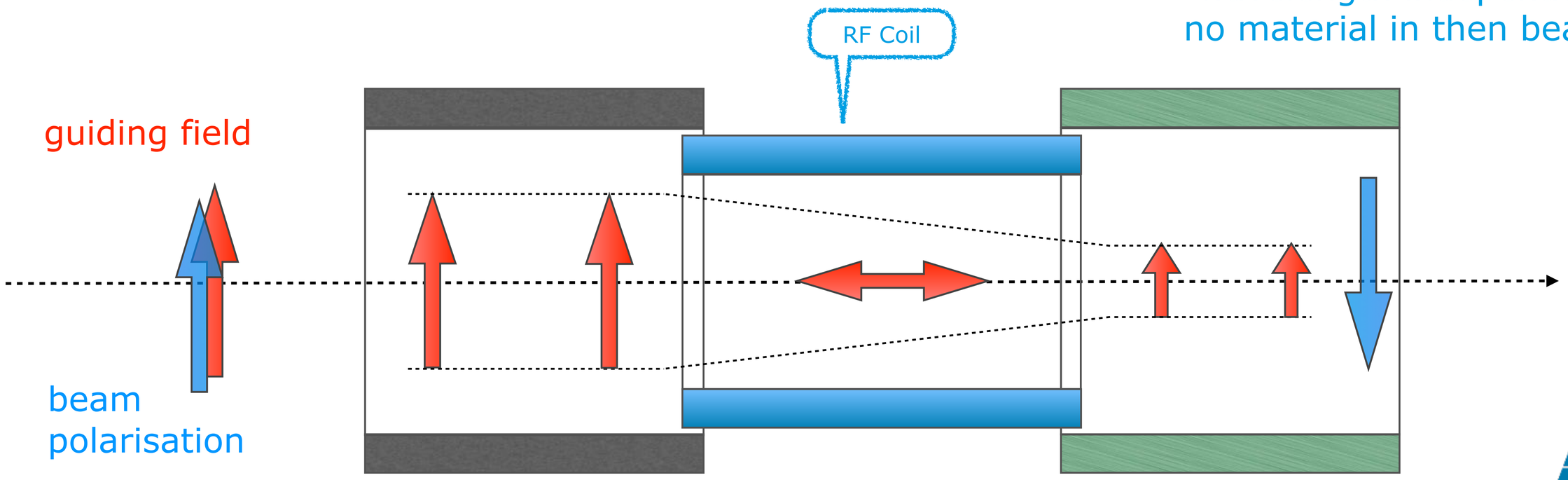
Spin flippers

- RF flipper: in the rotating frame of the neutron, the polarisation follows the effective field and rotates adiabatically.

wavelength independent
no material in then beam

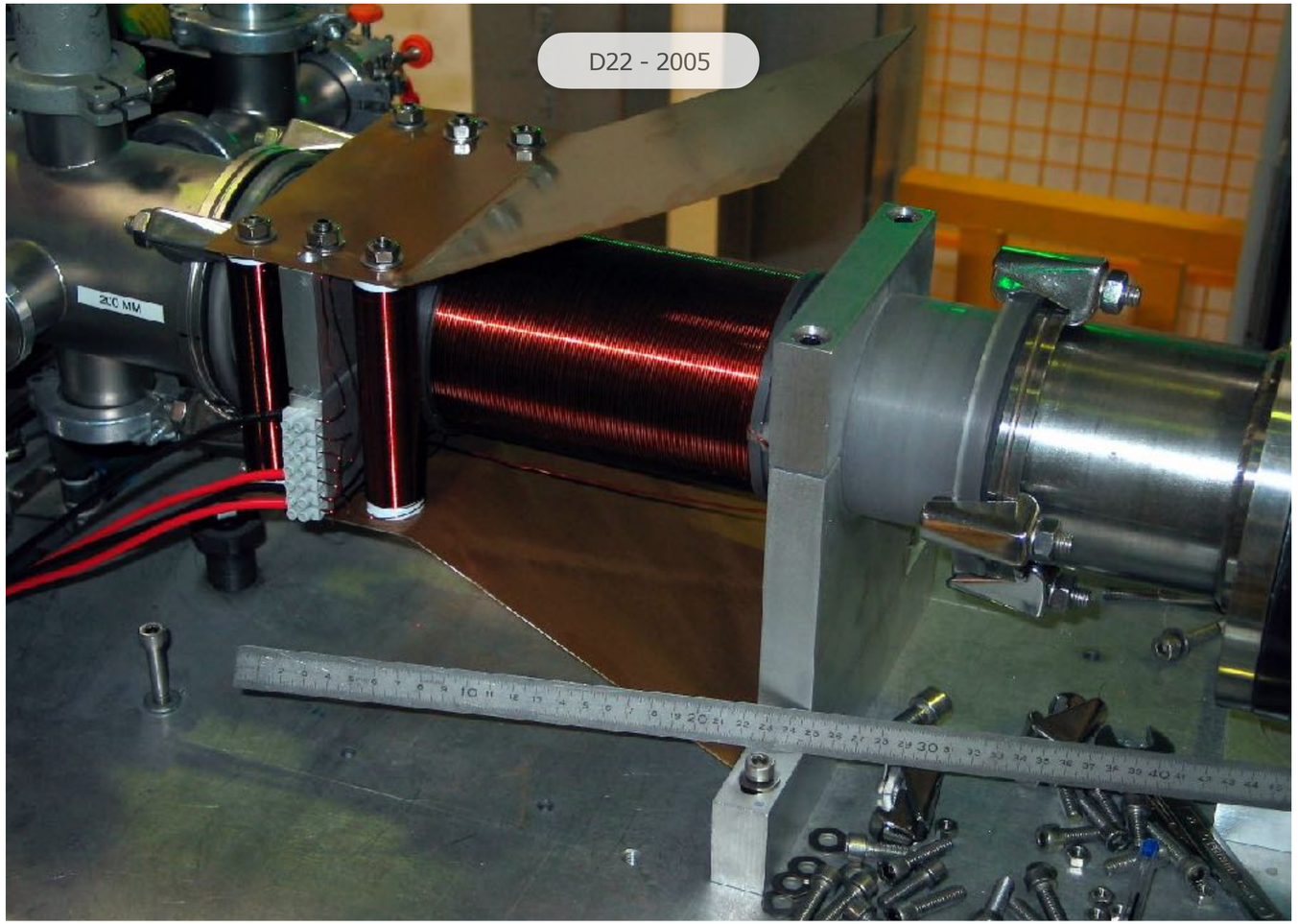


NEUTRONS FOR SOCIETY

Polarised Neutrons & SE

Spin flippers

- RF flipper
  - compact
  - wavelength independent
  - no material in the beam
  - +99.4% efficiency
  - but depend on environmental field

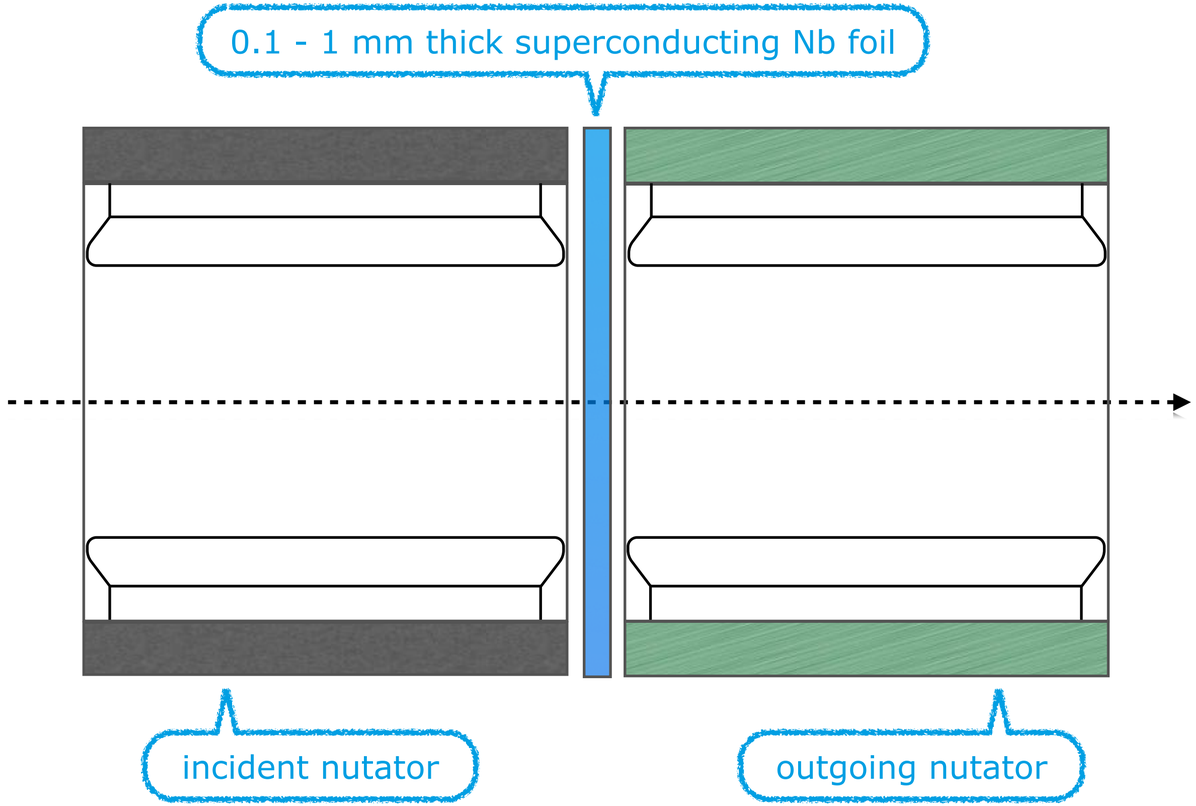


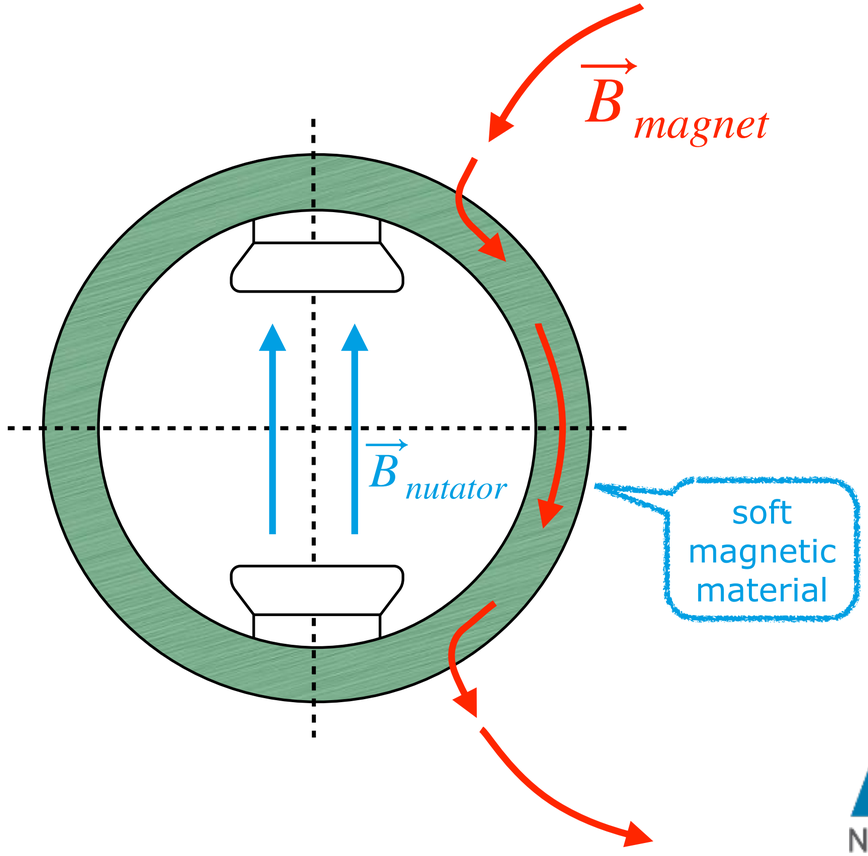
NEUTRONS FOR SOCIETY

Polarised Neutrons & SE

Spin flippers

- Cryoflipper (Tasset's flipper): neutron wavelength independent, operates in 400 G stray field, 99.9% efficiency down to 0.3 Å





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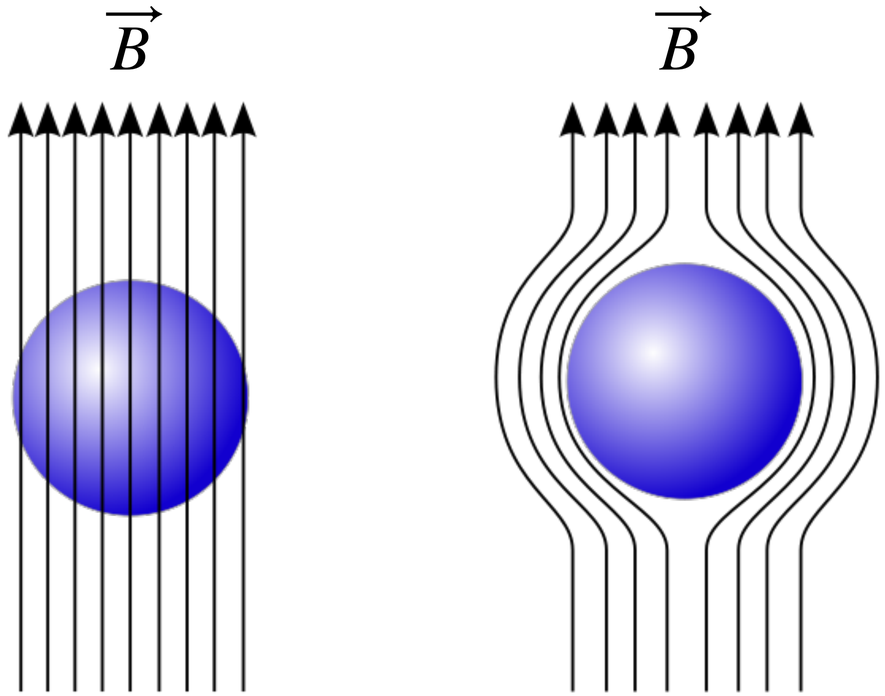
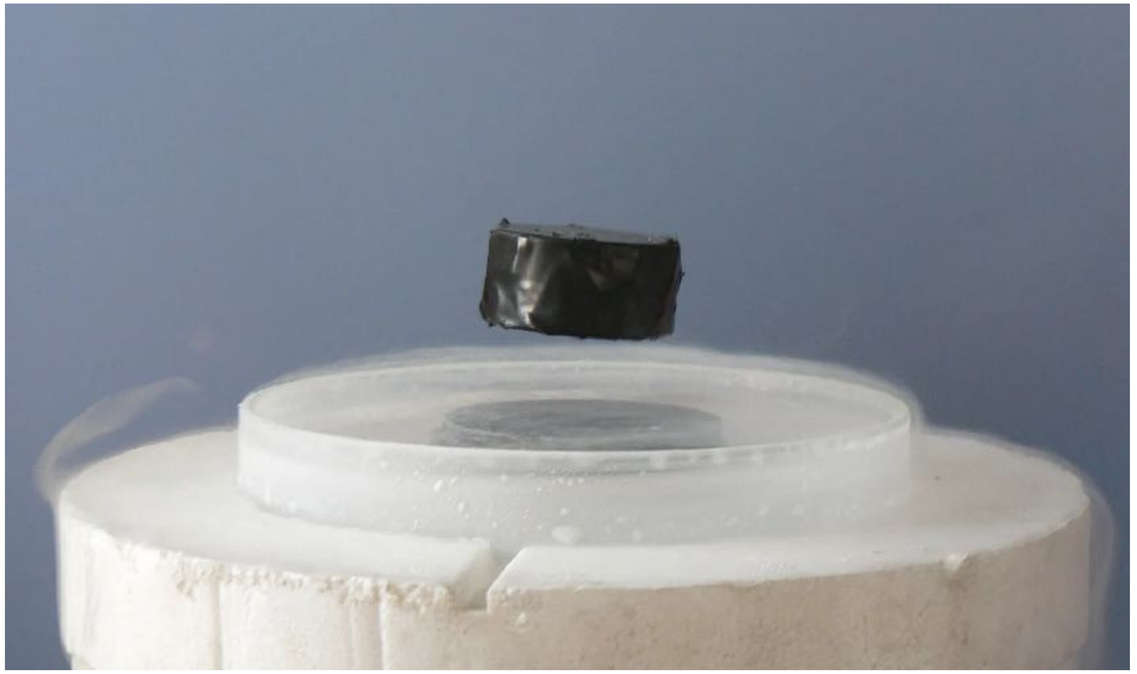


$T > T_C$ $T < T_C$



Meißner effect

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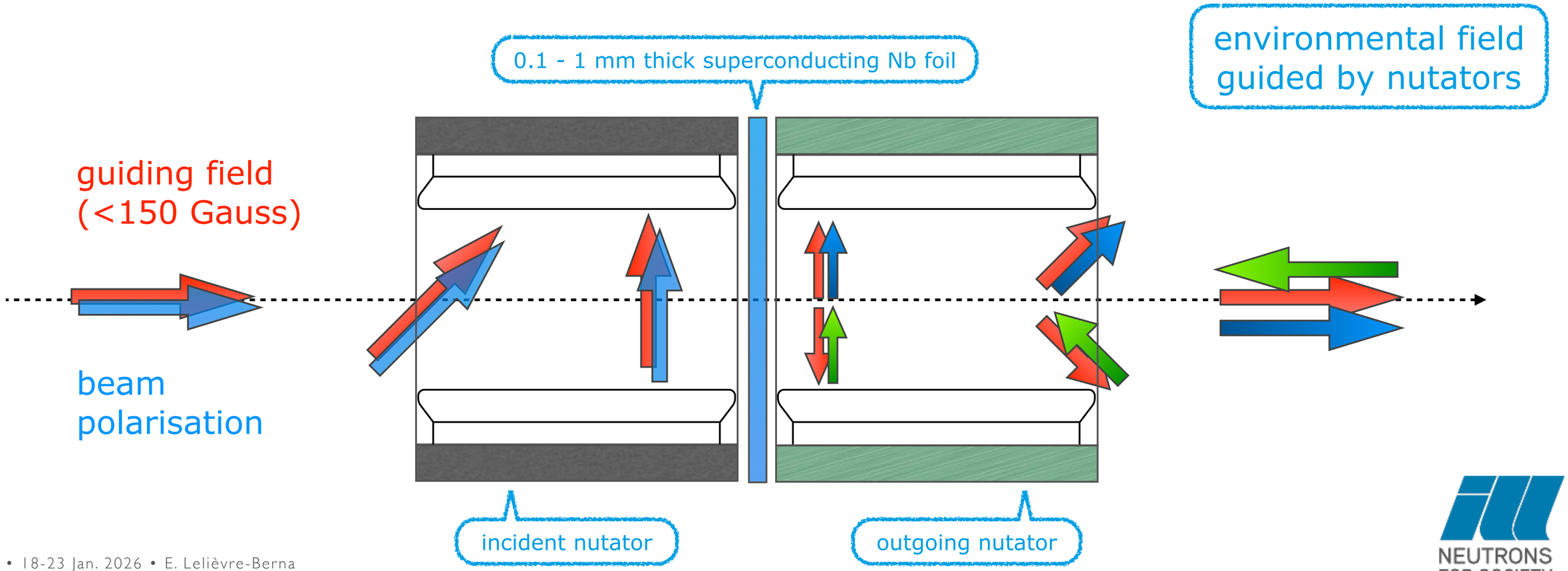


NEUTRONS FOR SOCIETY

Polarised Neutrons & SE

Spin flippers

- Cryoflipper (Tasset's flipper)
  - 3-week autonomy with 10 litres of liquid He
  - 24-h autonomy with 10 litres of liquid N_2 (auto-refill)
  - must be cooled down in zero-field!
  - high-T_c version with cryocooler possible but limited in beam size and field strength

Polarised Neutrons & SE

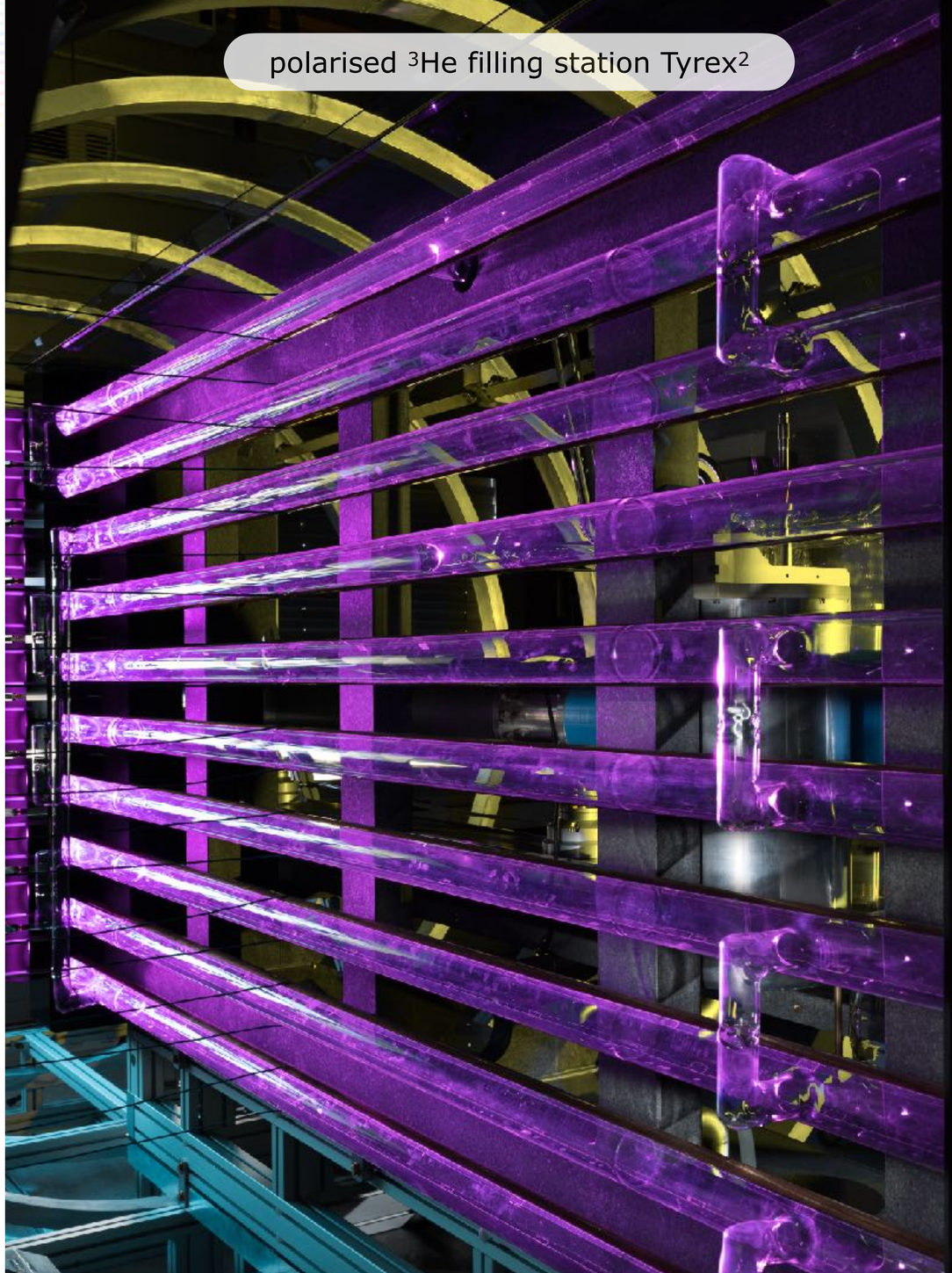
^{3}He spin polarisers & flippers

- Spin dependent absorption
- ^{3}He spin filters are characterised by their opacity:

$$\mathcal{O} = N \ell \sigma_{\uparrow\downarrow}$$
$$\simeq 0.0732\ p[\text{bar}]\ \ell[\text{cm}]\ \lambda[\text{Å}]$$

- The total transmission and polarising efficiency are:

$$T_n \propto \cosh\left(\mathcal{O} P_{^3\text{He}}\right)$$
$$P_\epsilon = \tanh(\mathcal{O} P_{^3\text{He}})$$



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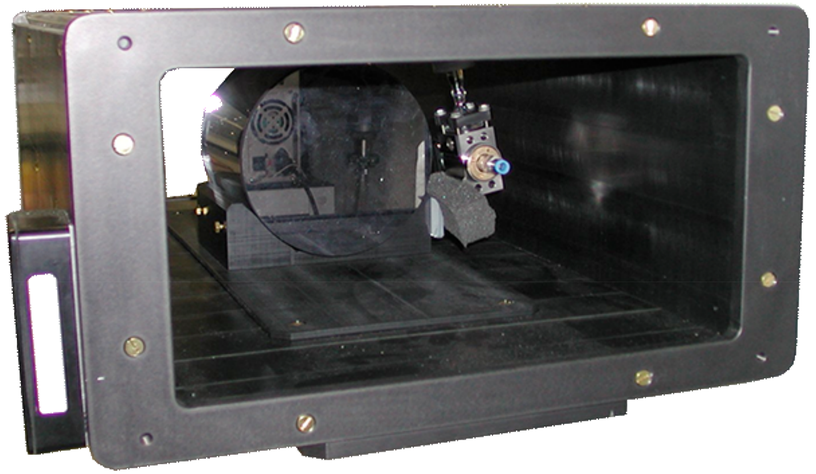
Banna-shaped Quartz cell

Quartz cell

Si-windowed cell



magneto static cavity

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Polarised Neutrons & SE

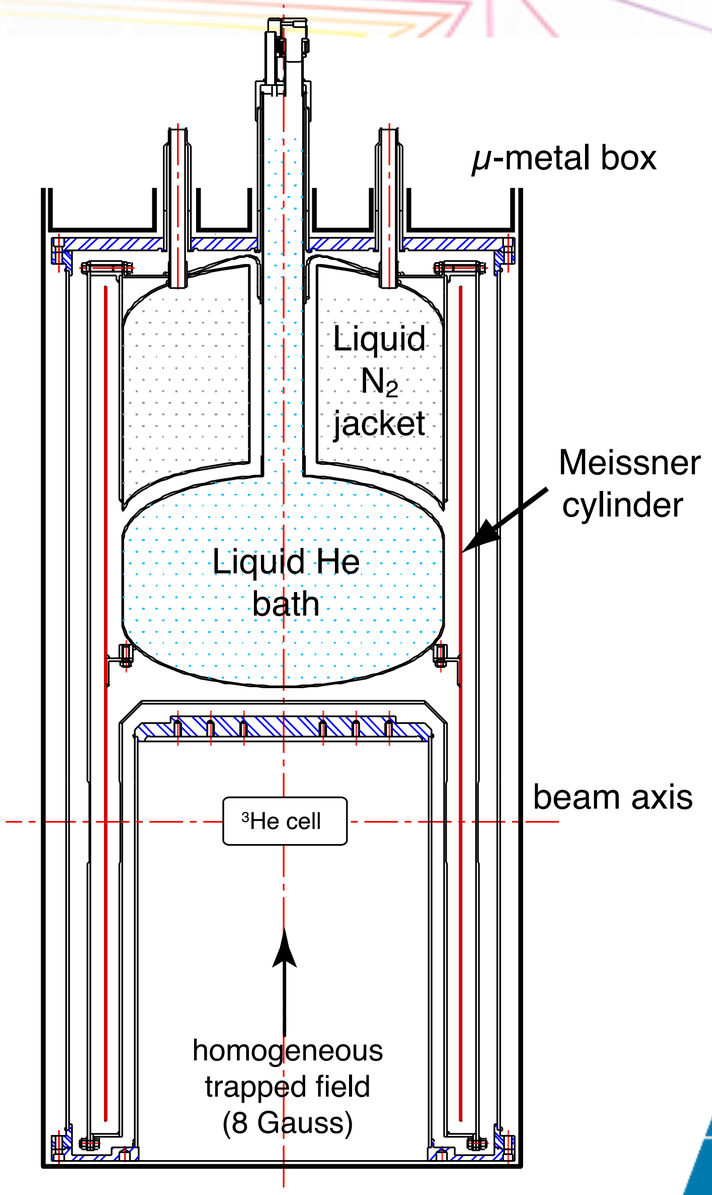
^{3}He spin polarisers & flippers

- 3 T HTS Magnet
  - horizontal field ∥ or ⊥ to beam
  - for SANS and reflectometry
  - Ø81 warm bore
  - Ø42 dual heat-exchanger cryostat
  - 40 mK to 300 K
  - optimised for polarisation analysis with a ^{3}He spin filter

Polarised Neutrons & SE

^{3}He spin polarisers & flippers

- With high-field magnets
  - Cryopol-1 (Cryogenic polariser)

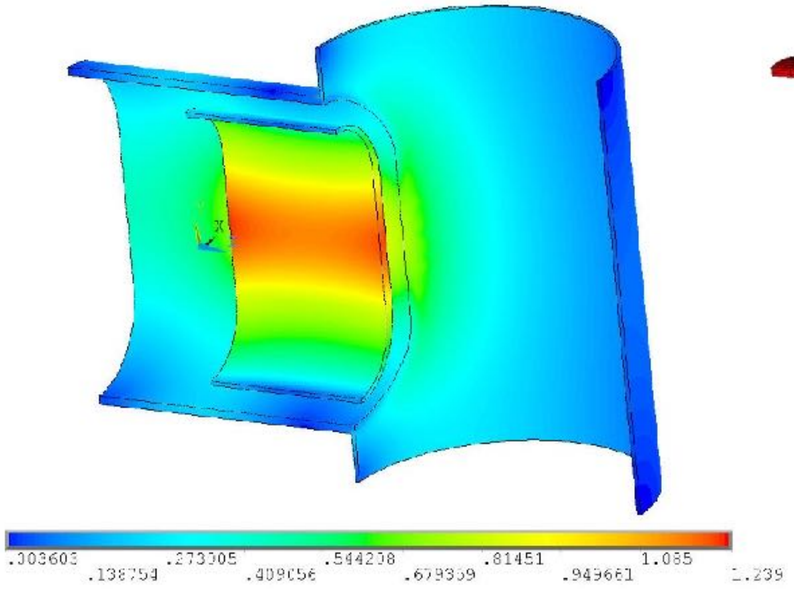


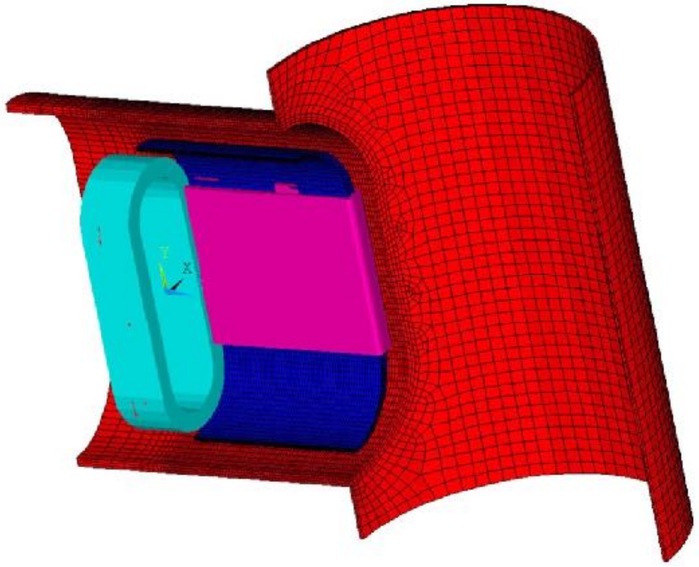
NEUTRONS FOR SOCIETY

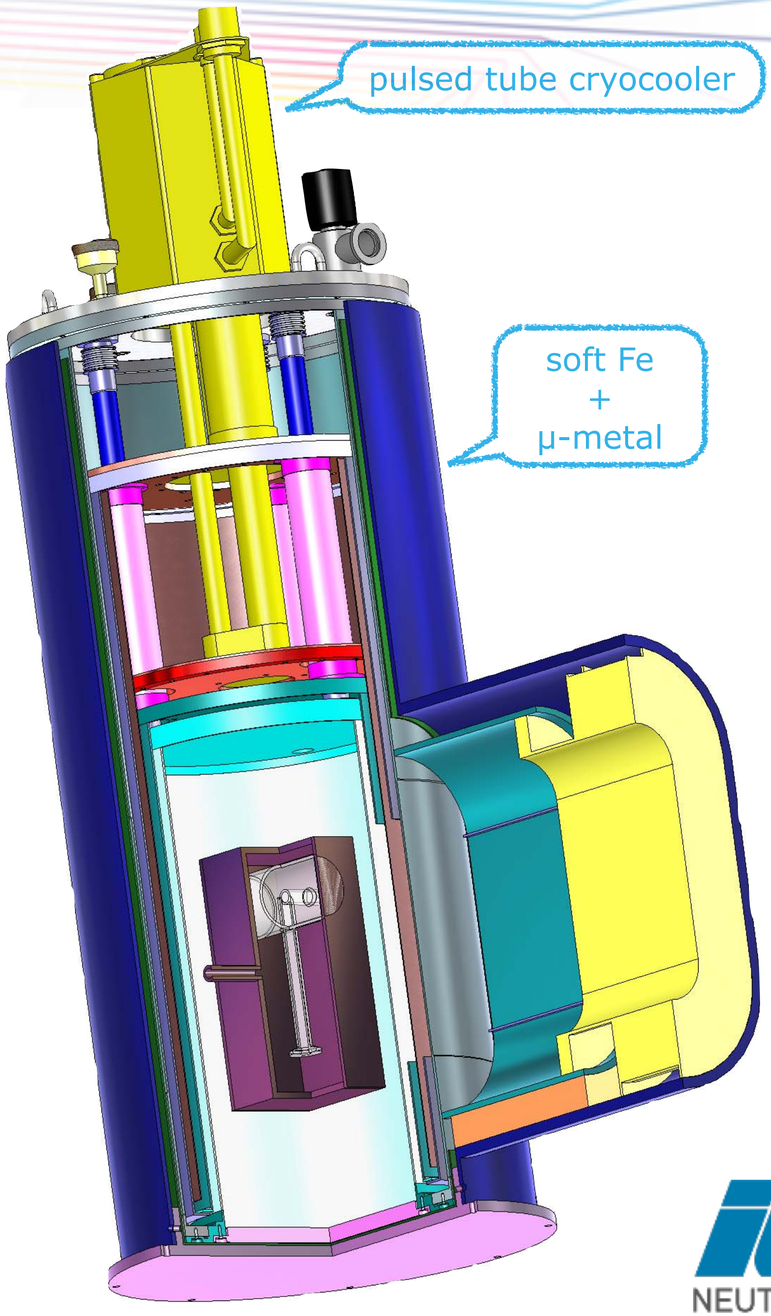
Polarised Neutrons & SE

^{3}He spin polarisers & flippers

- With high-field magnets
  - Cryopol-2: 20x7 cm² beam section







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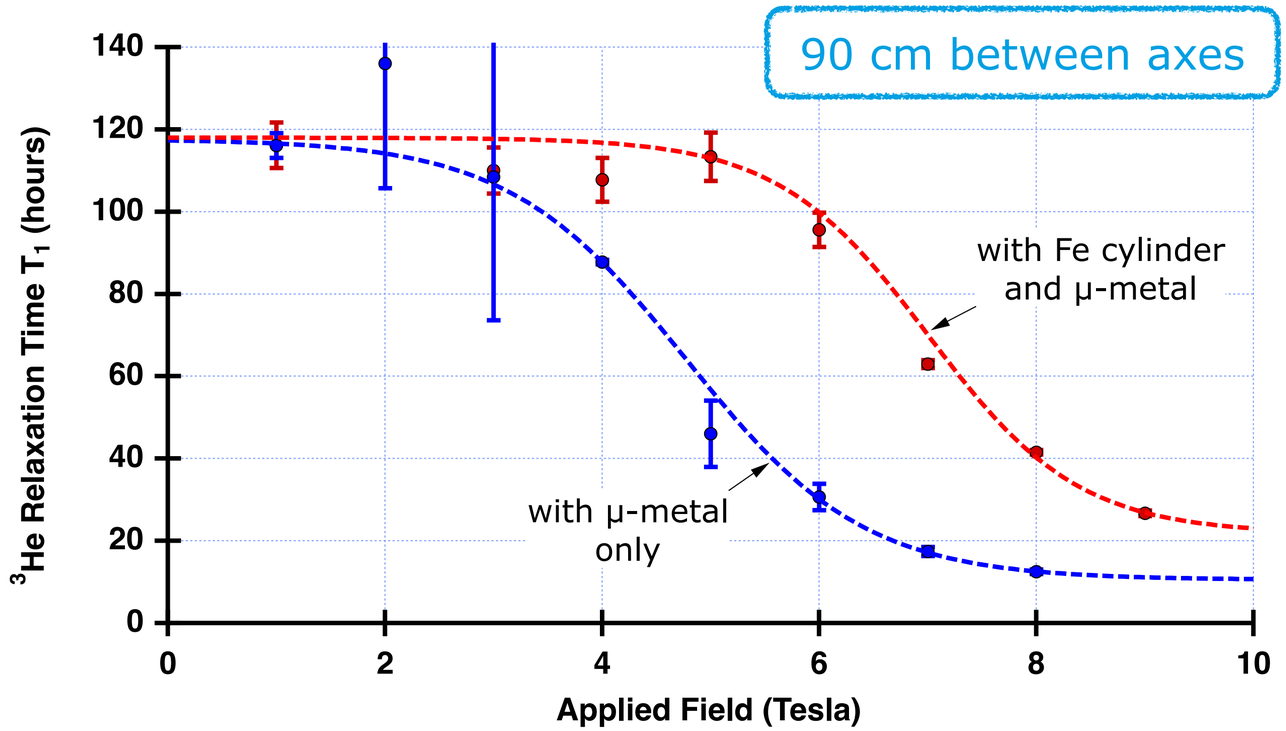
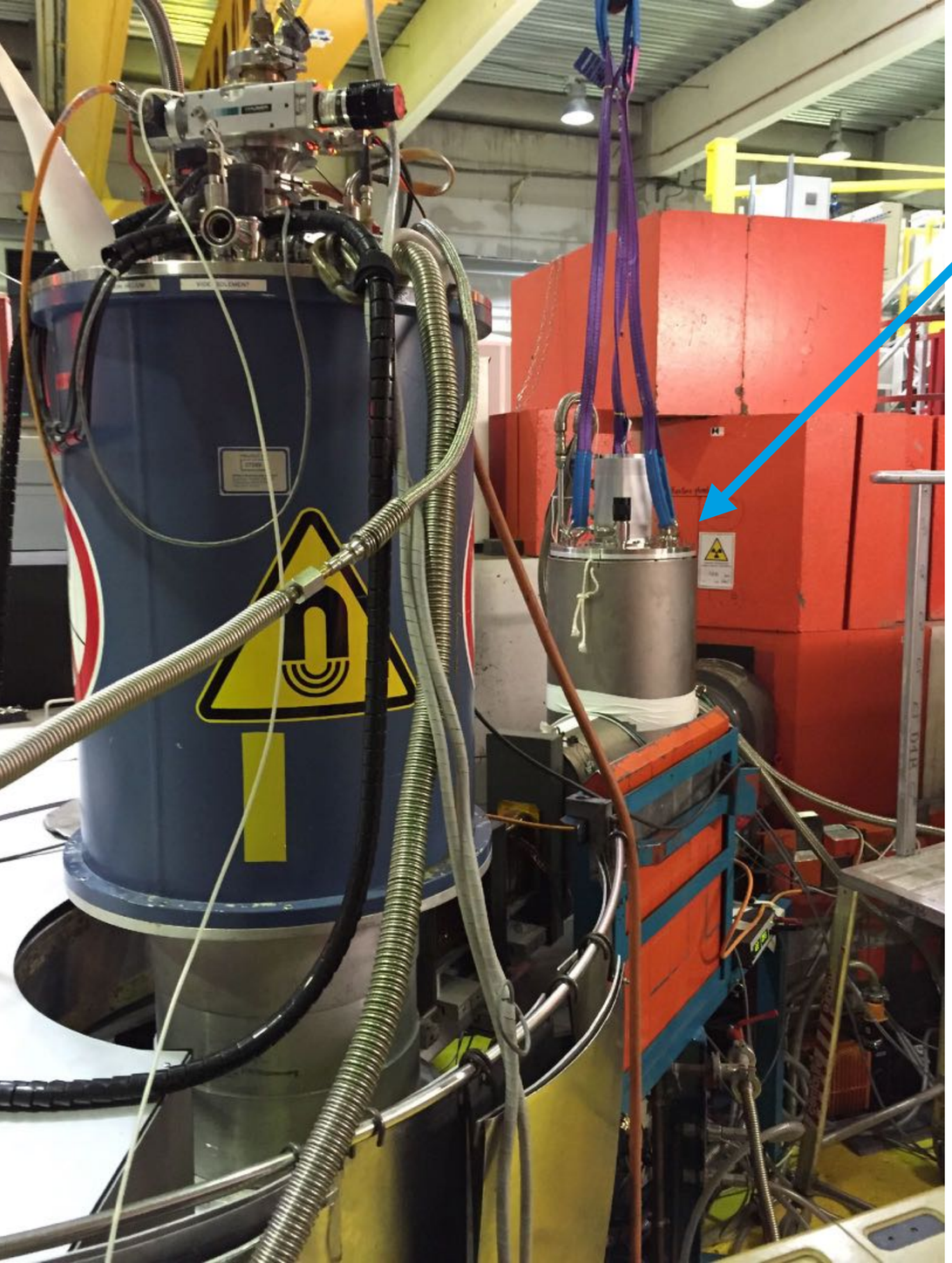
Polarised Neutrons & SE

^{3}He spin polarisers & flippers

- With high-field magnets
  - Cryopol-2 on D3, D1B, D20 at ILL



D20 - Cryopol - July 2008



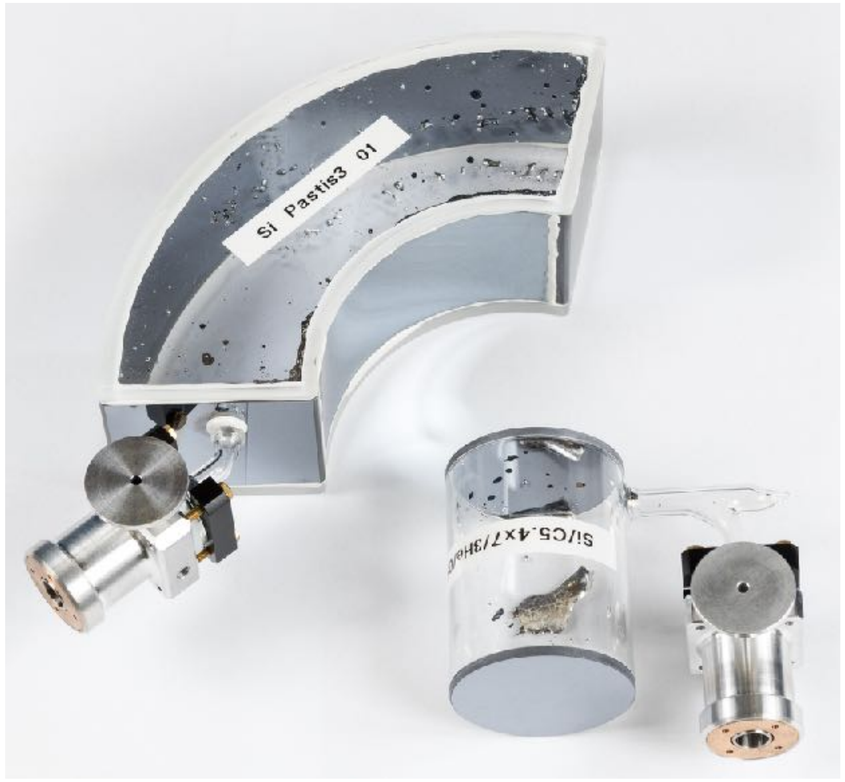
Cryopol
on D1B

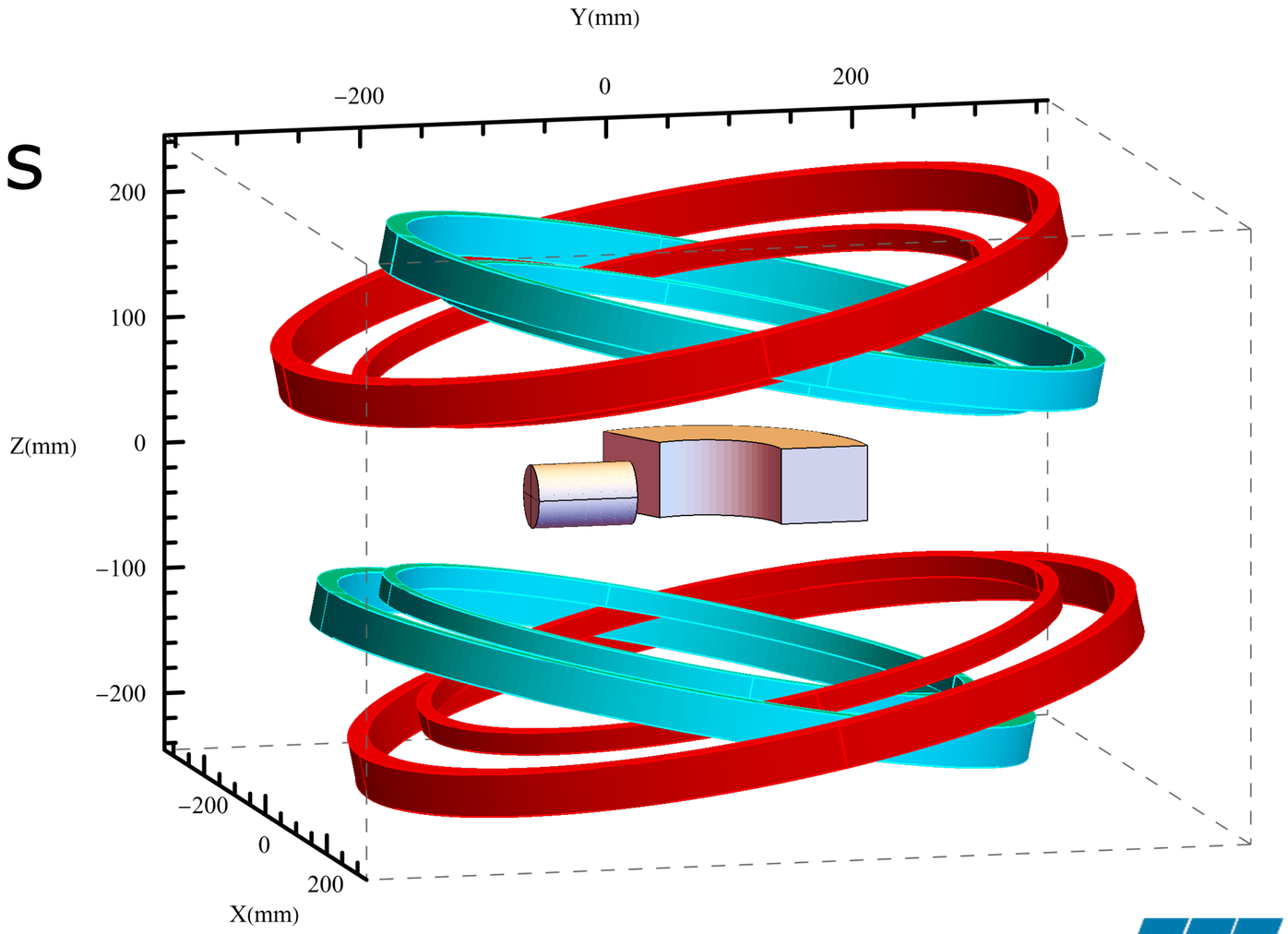
"Tetrapack"
^{3}He cell

Polarised Neutrons & SE

^{3}He spin polarisers & flippers

- Wide-angle spin analysis





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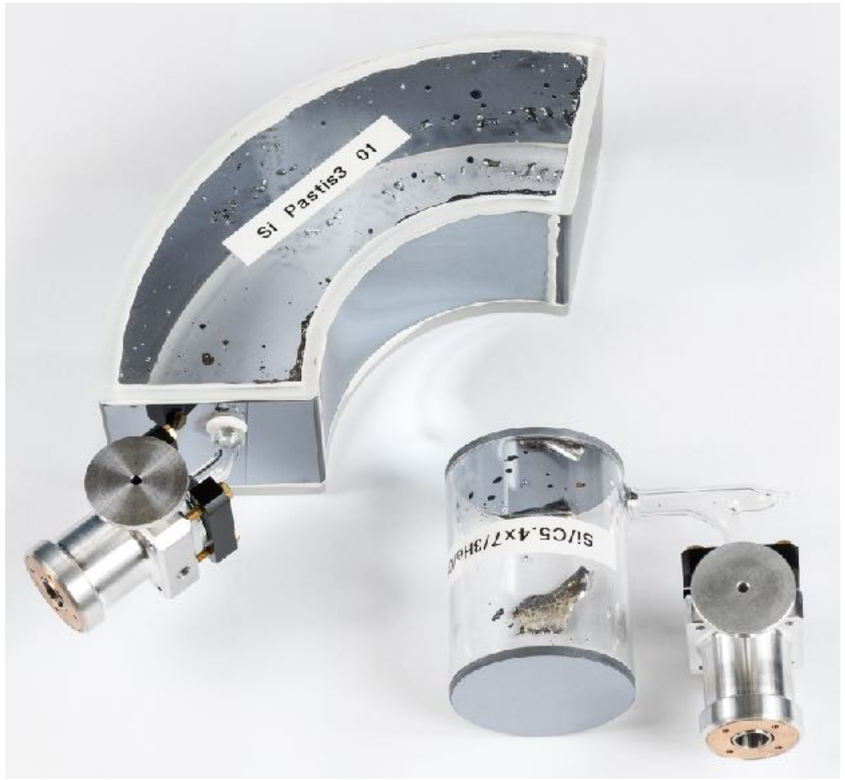
Polarised Neutrons & SE

^{3}He spin polarisers & flippers

- Wide-angle spin analysis



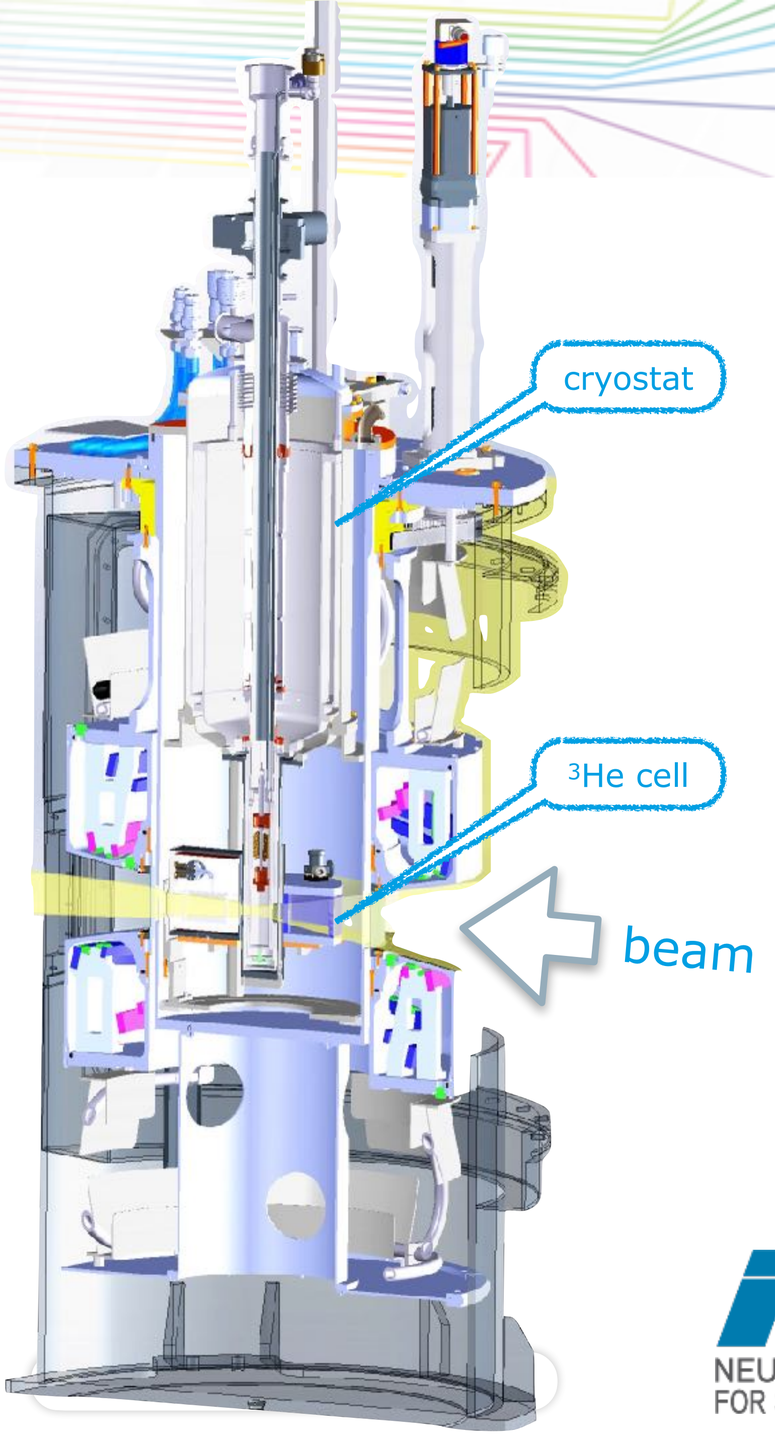
PASTIS 3 on IN20 with FlatCone - 2021

Polarised Neutrons & SE

^{3}He spin polarisers & flippers

- Wide-angle spin analysis

Time-of-Flight version in construction for PANTHER



NEUTRONS FOR SOCIETY

Polarised Neutrons & SE

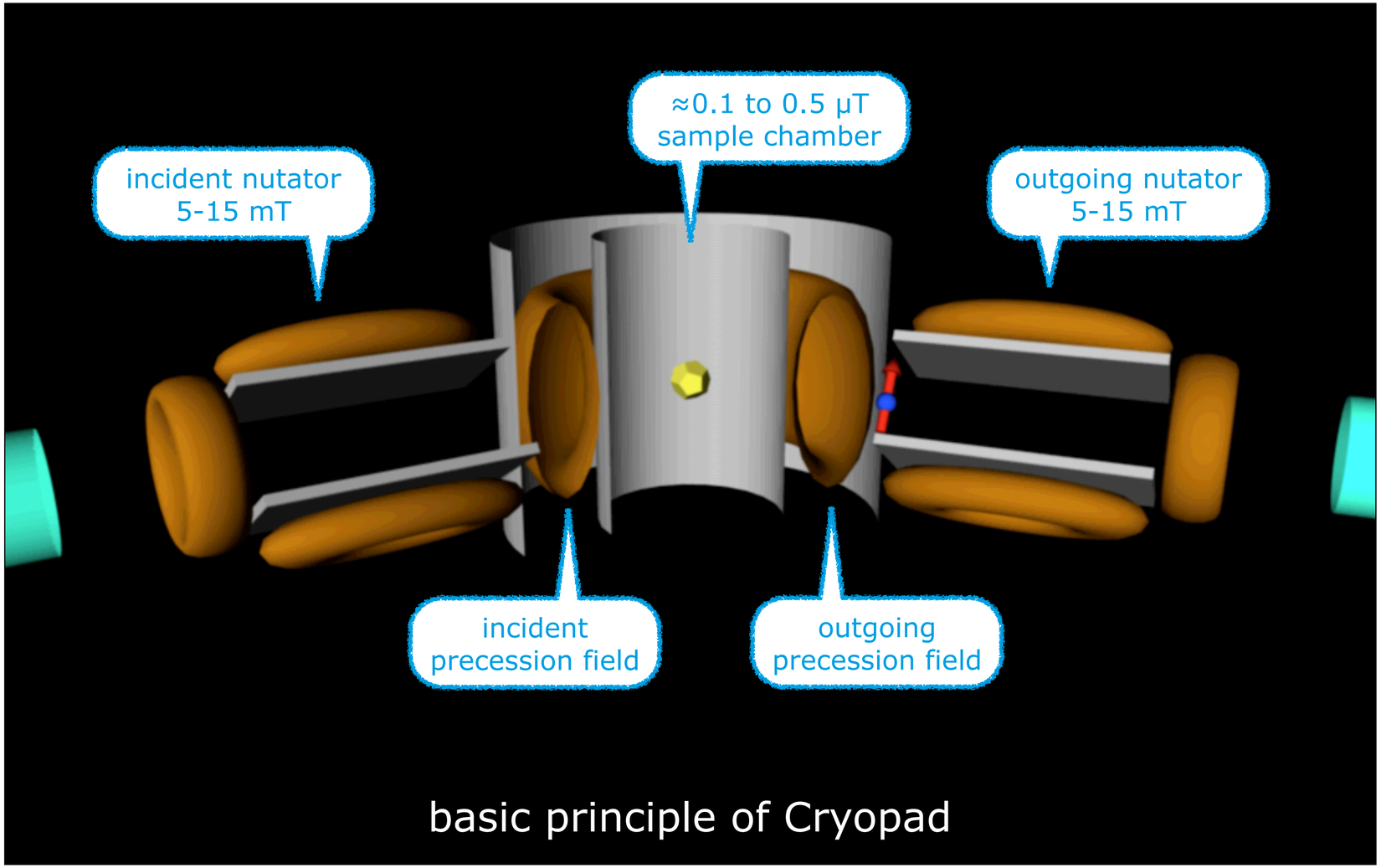
Manipulation of the beam polarisation

- Cryopad (Cryogenic Polarisation Analysis Device)
- sample in zero field, typically between 0.1 to 0.5 μT
- manipulates the polarisation before and after the sample
- 1° absolute precision without special care, 0.1° with fine tuning
- hot, thermal and cold neutrons

Cryopad-III - January 2003

Polarised Neutrons & SE

Manipulation of the beam polarisation



basic principle of Cryopad

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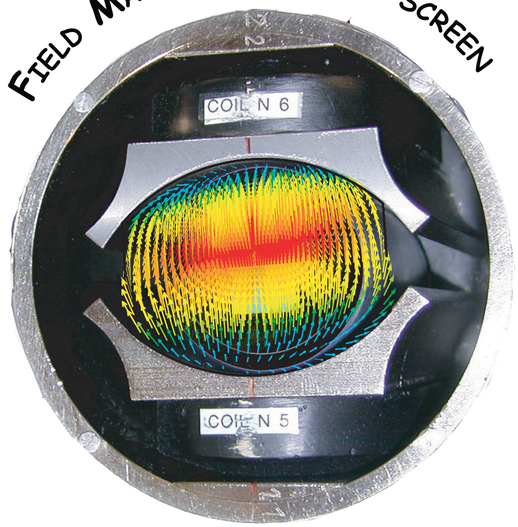
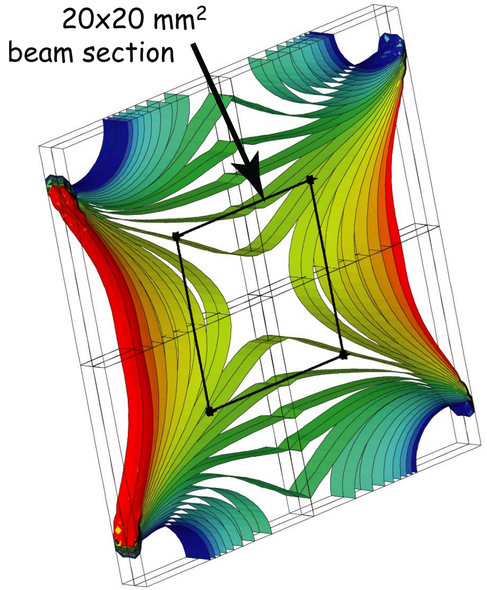
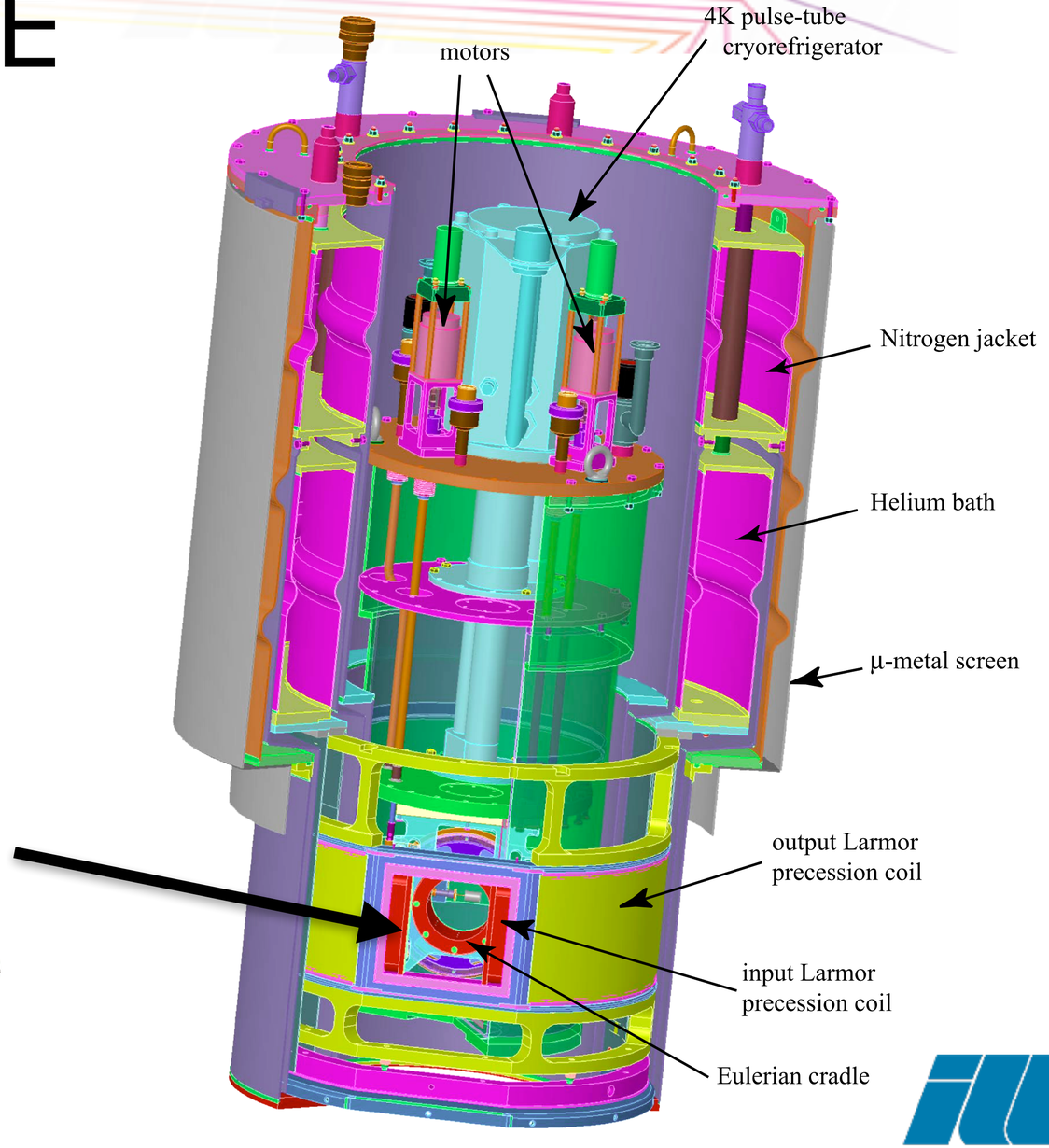
Manipulation of the beam polarisation

- Cryopad (version 3)
  - small and large models at ILL, J-RR3 and FRM-2

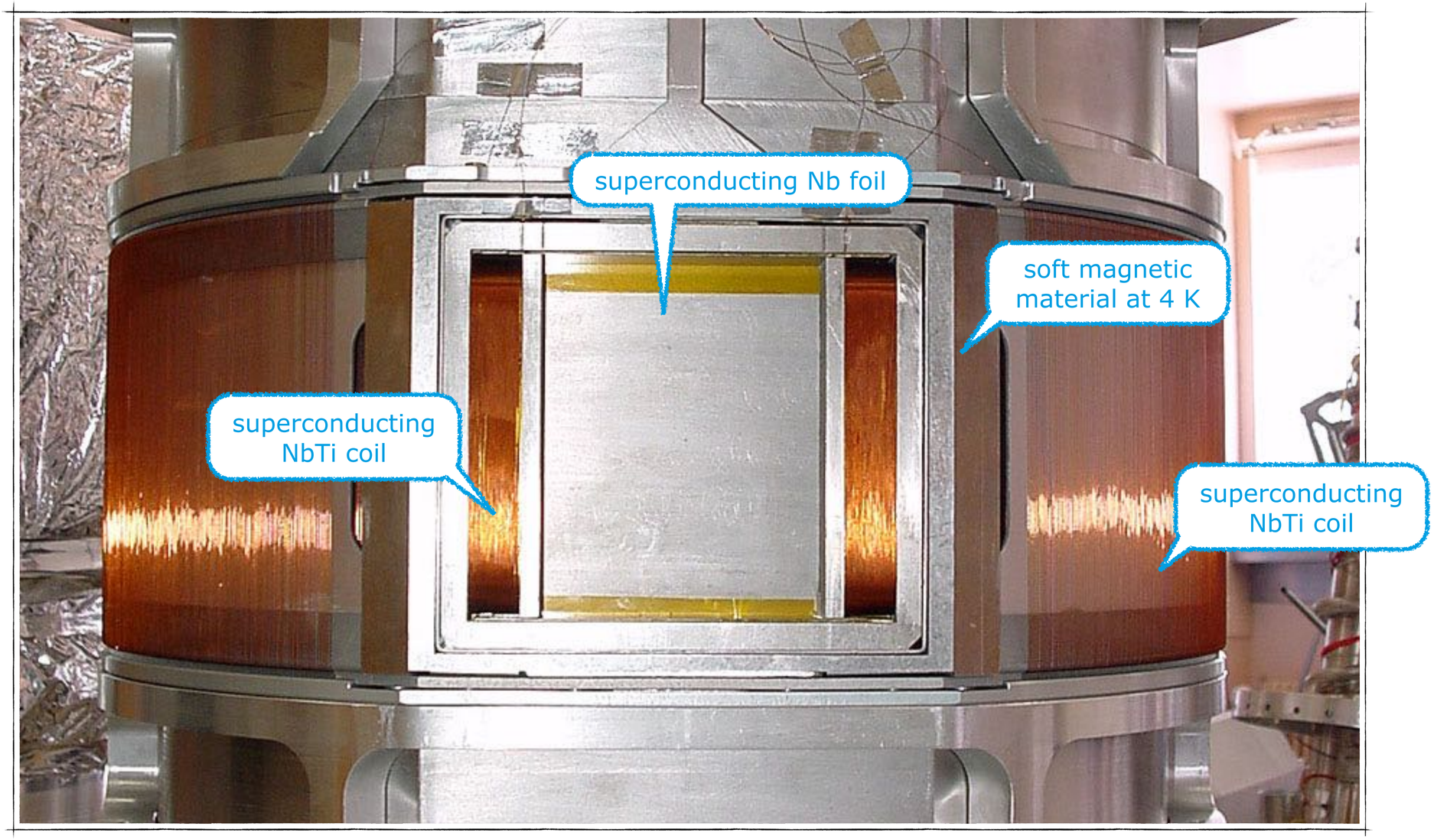






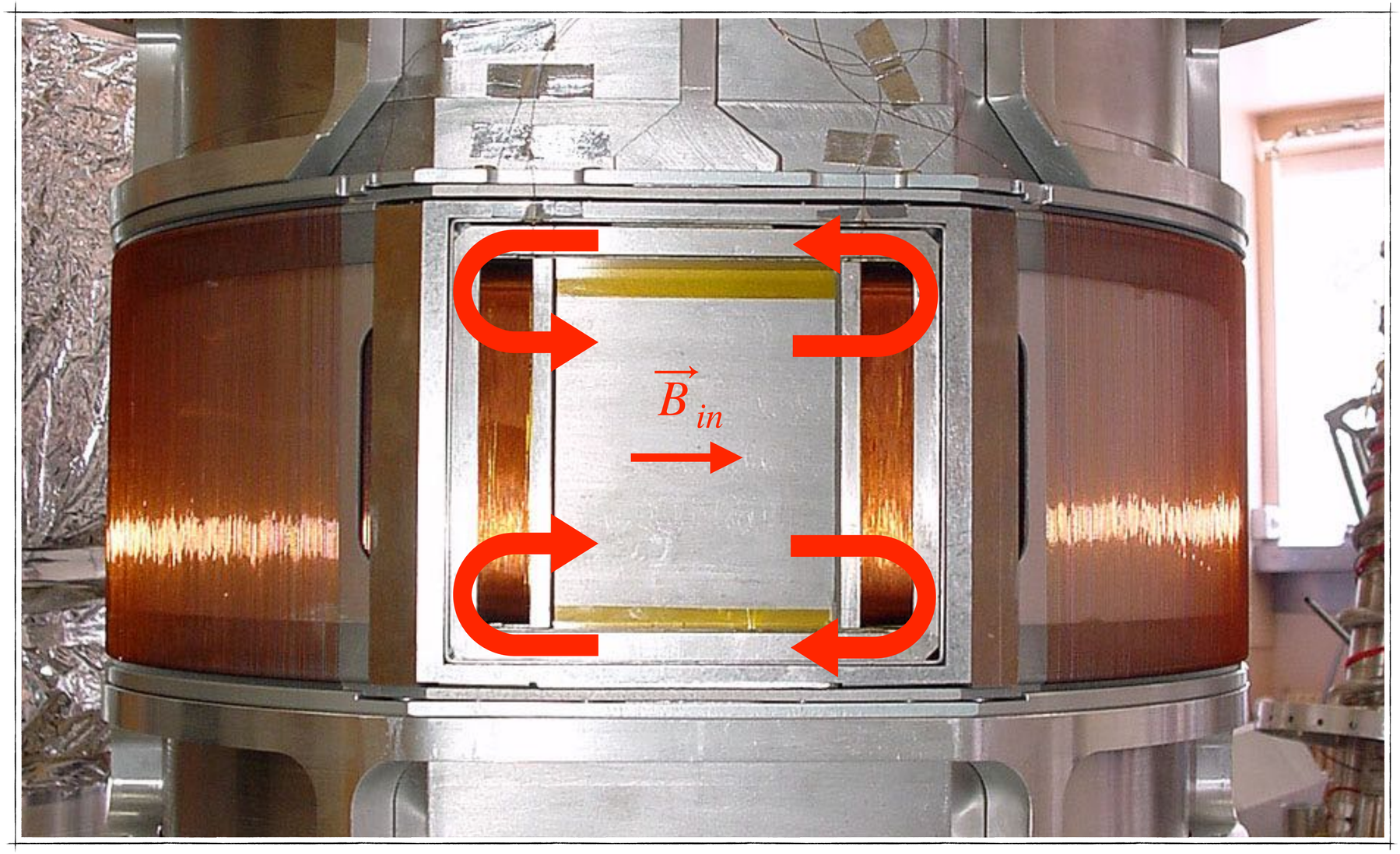
NEUTRONS FOR SOCIETY

Polarised Neutrons & SE

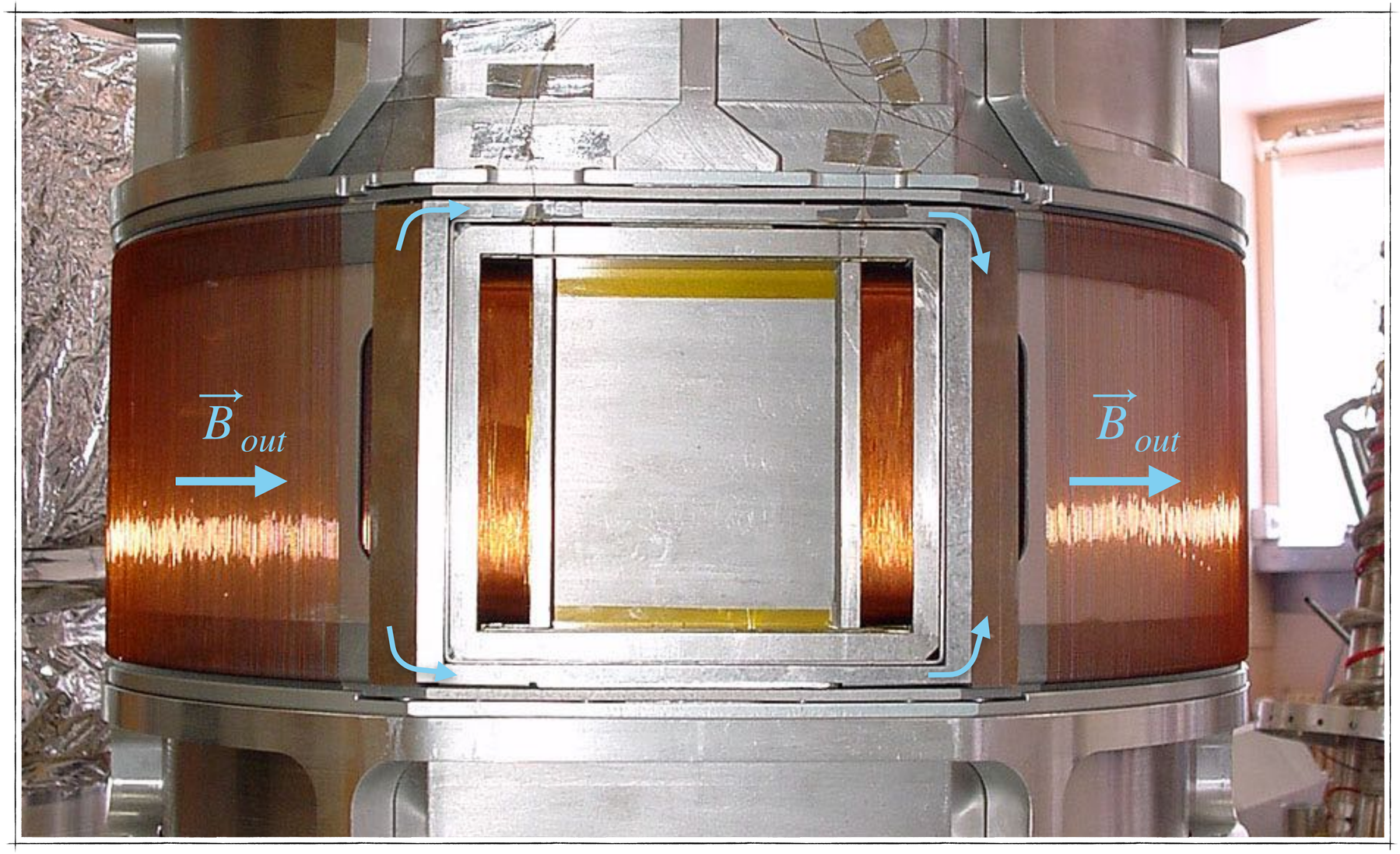


NEUTRONS FOR SOCIETY

Polarised Neutrons & SE



Polarised Neutrons & SE



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Sample orientation inside Cryopad

$3 < T < 320K$

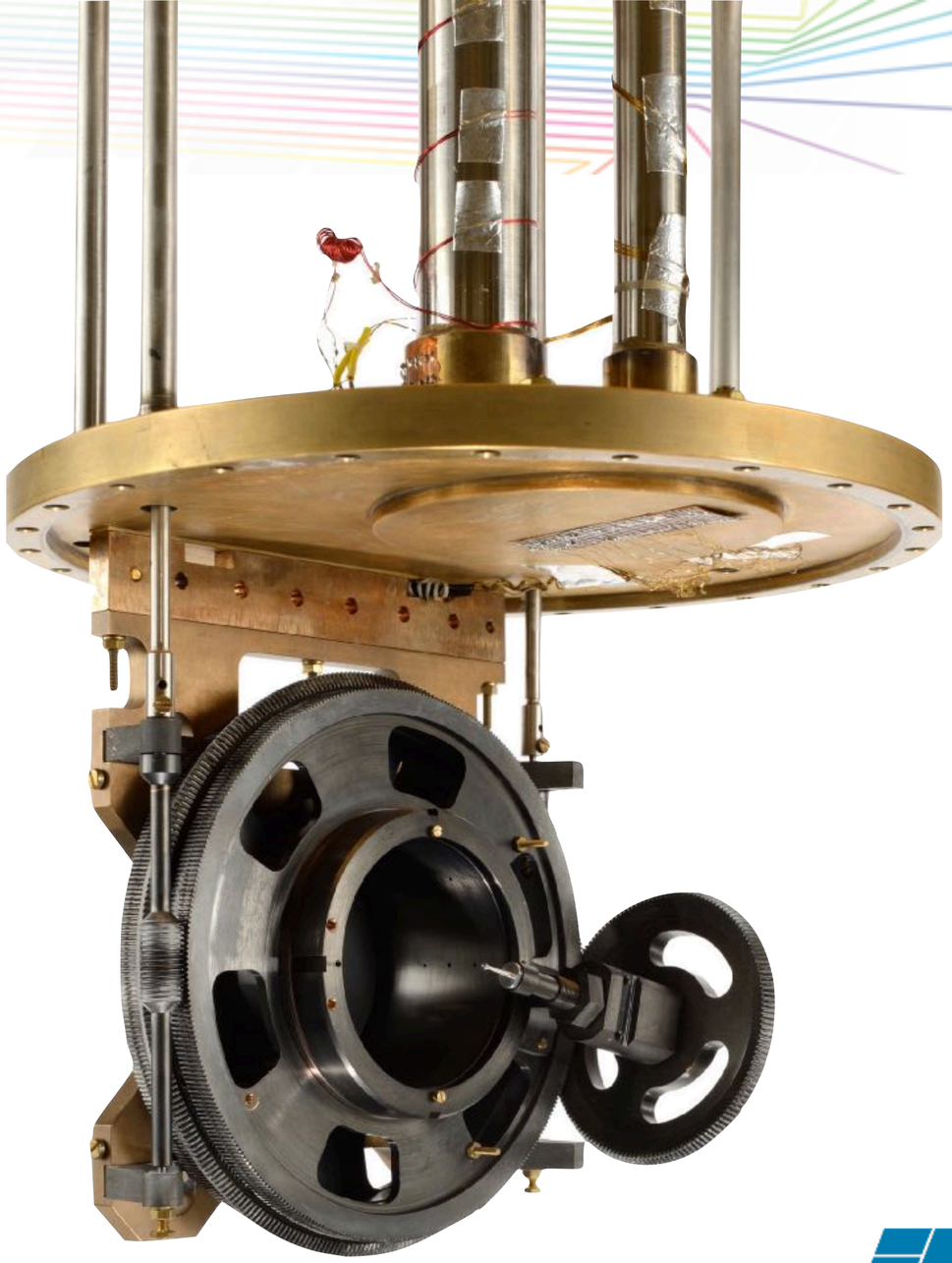
$-30 < \chi < +210°$

$-180 < \varphi < +180°$

$-40 < 2\theta < +120°$

$\approx 0.1°$ reproducibility

- remotely controlled
- 2 units exchanged between experiments



Polarised Neutrons & SE

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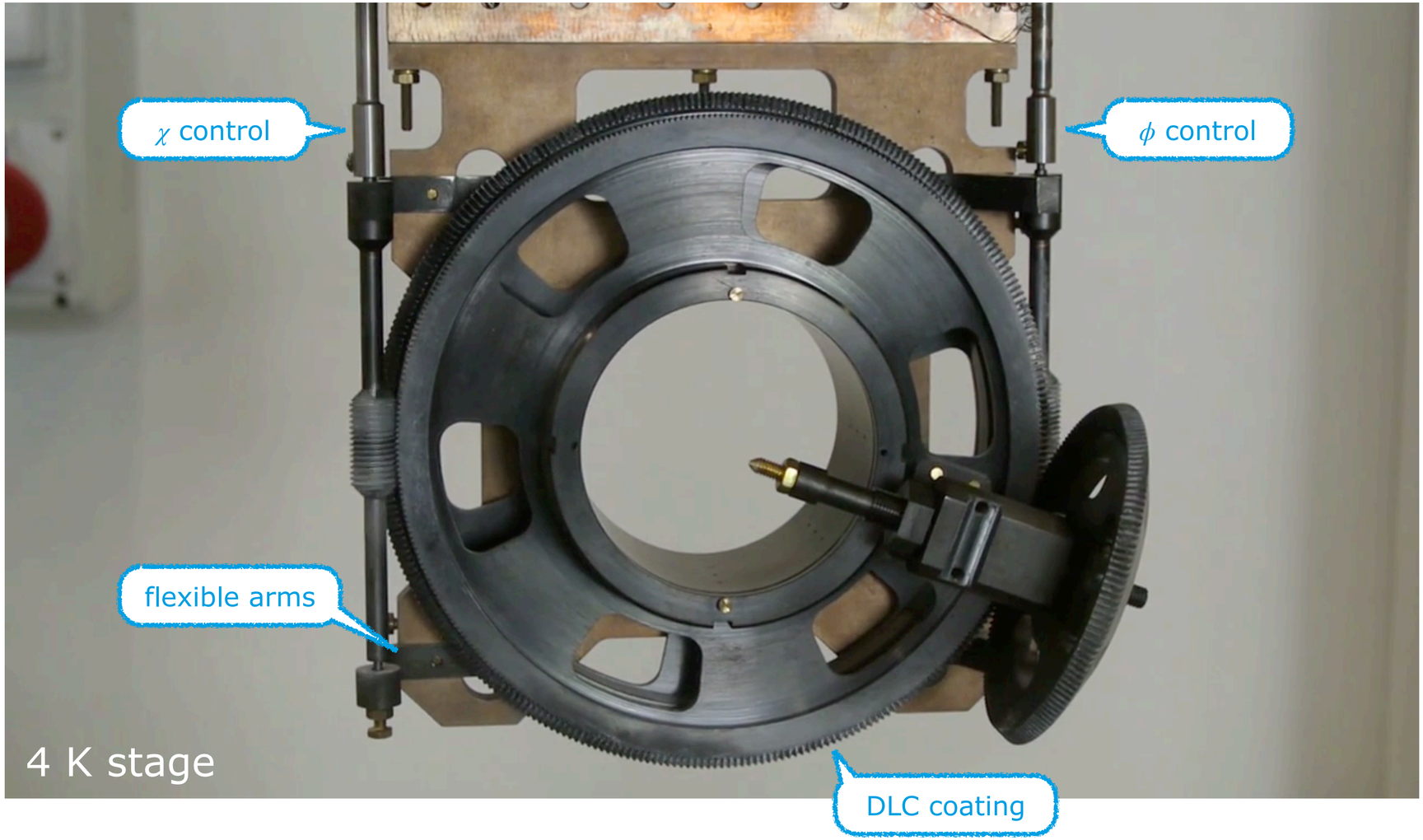

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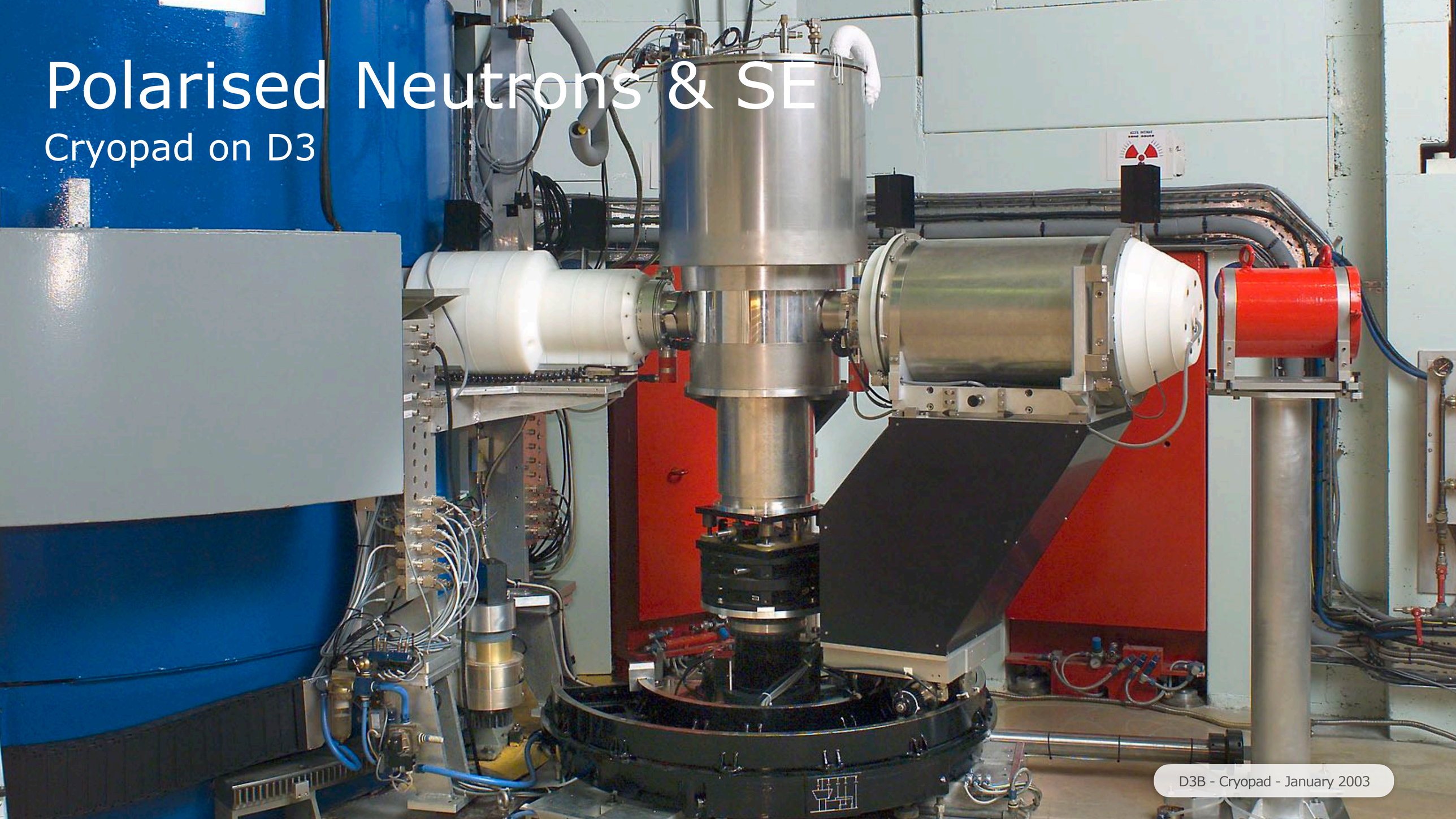
Cryopad on D3



D3B - Cryopad - January 2003

Polarised Neutrons & SE

Cryopad on IN22

IN22 - Cryopad - 2003

Many Thanks
for your Attention

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