HYSPEC options for wide angle TOF neutron polarization analysis with polarized ^{3}He

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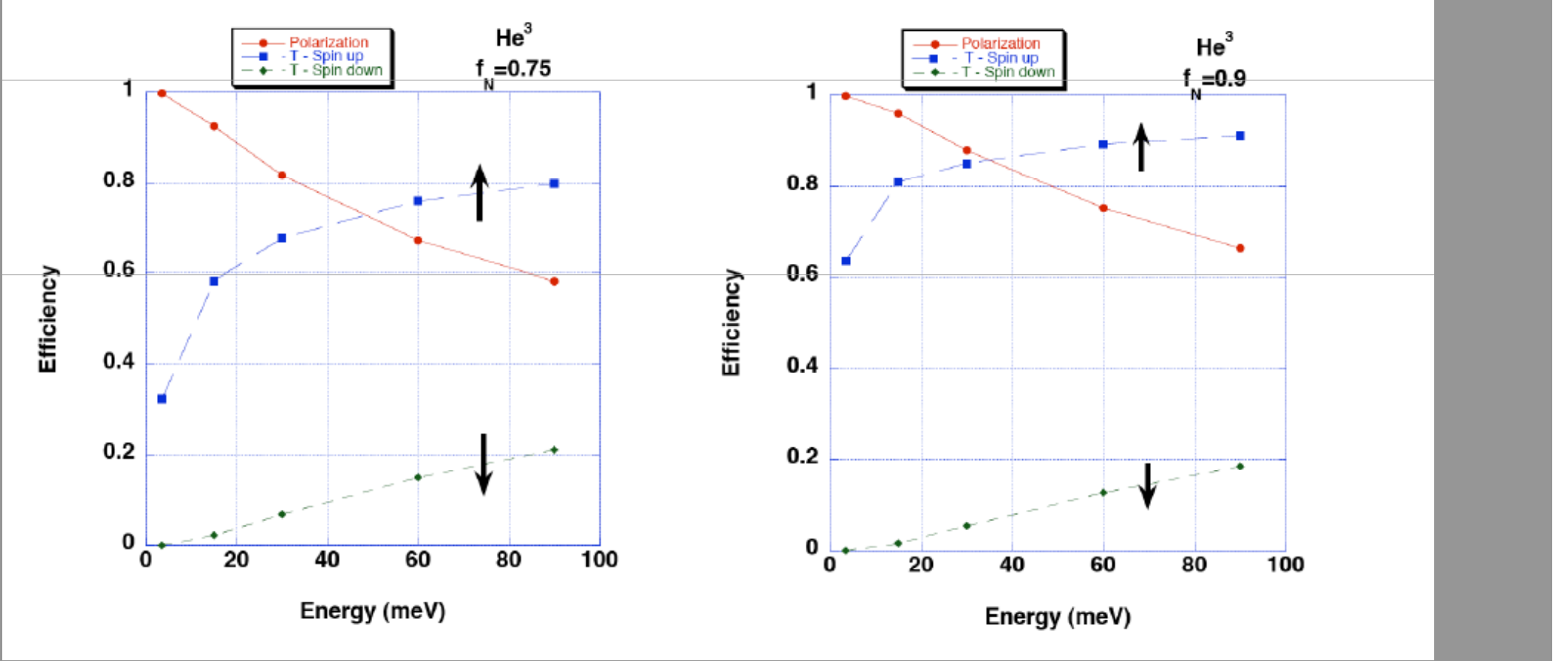
Polarized 3He Neutron polarization analyzer

Attractive Features

- Efficient thermal neutron polarization analyzer at 75 % ^{3}He polarization. Promise of even better efficiency if ^{3}He polarization can be pushed into the 80-90% range.
- Operates over a neutron energy range extending from sub-thermal to epi-thermal.
- Analyzer efficiency can be optimized at any given neutron energy by changing the 3He gas pressure.
- Does not require a highly collimated incident neutron beam.
- Potential to cover the entire active area of a wide-angular-acceptance TOF detector.

$N\tau$=3.14 x10^{20} atoms/cm^2



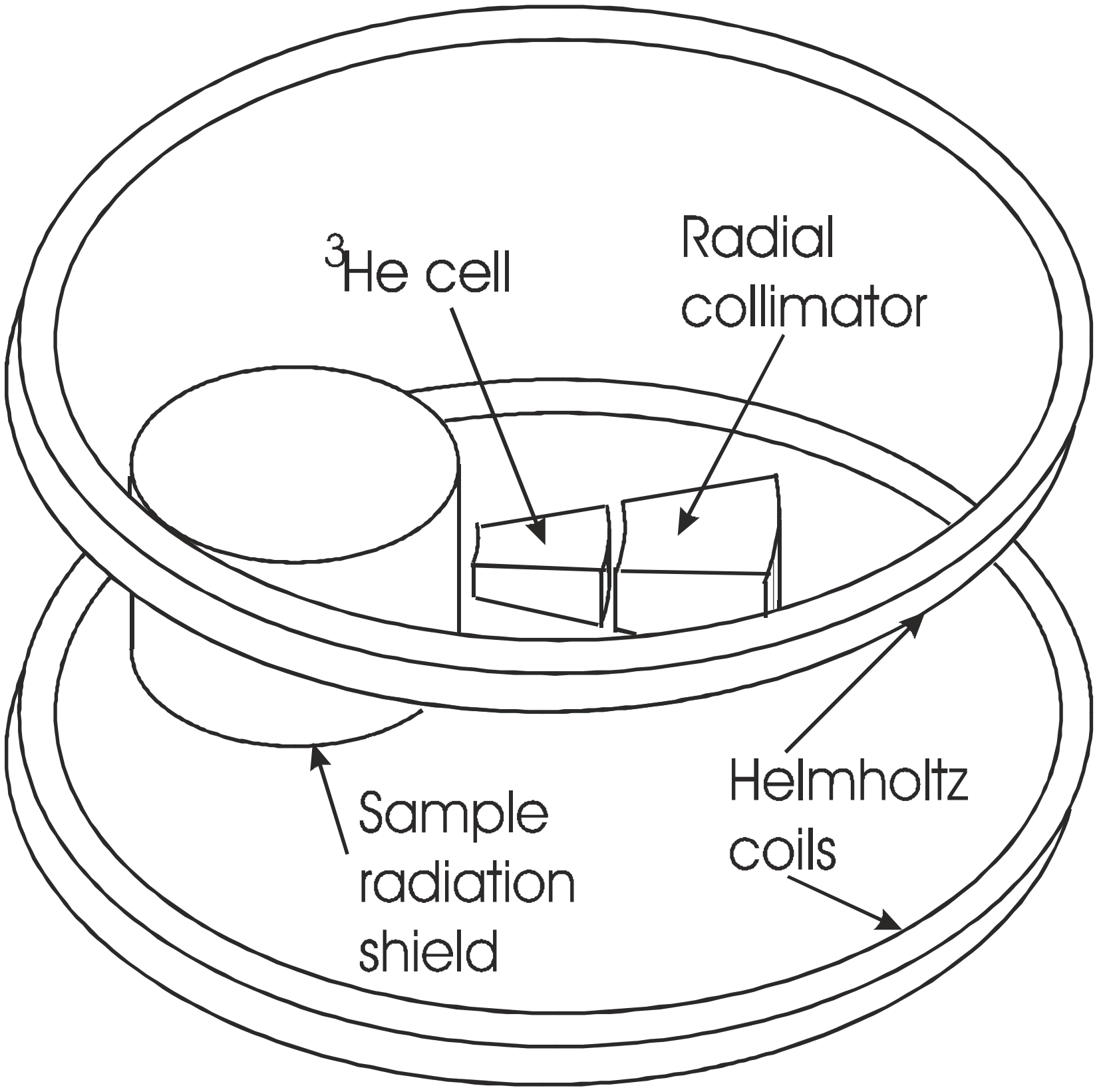
Design Constraints

- Design issues relating to influence of guide and holding field configurations on incident neutron beam polarization
- Wide angular acceptance applications require substantial volumes of polarized 3He gas that will have to be supplied by a central optical pumping facility
- Wide angular acceptance applications require the fabrication of large-volume, kidney-shaped gas cells which must operate as both vacuum and pressure vessels
- Cell lifetime sensitive to holding magnetic field uniformity. Necessary to screen stray magnetic fields and provide field uniformity ΔH/H<10-4/cm over cell volume. Also sensitive to power supply and field coil vibration-induced fluctuations
- Design and fabrication issues relating to influence of cell wall material on cell lifetimes
- Design issues relating to the possibility of in-situ optical pumping and to the choice of optical pumping method
- Design issues relating to quick, easy and convenient interchange of gas cells

Small sample field Hs< 0.1 T

Both sample and ^{3}He cell fields are provided by the same pair of Helmhotz coils. An arrangement of three pairs of orthogonal coils (so called PASTIS geometry) is possible.

Ref: J.A. Stride, K.A. Andersen, A.P. Murani, H. Mutka, H.S. Schober, and J.R. Stewart - Physica B356, 146 (2005)

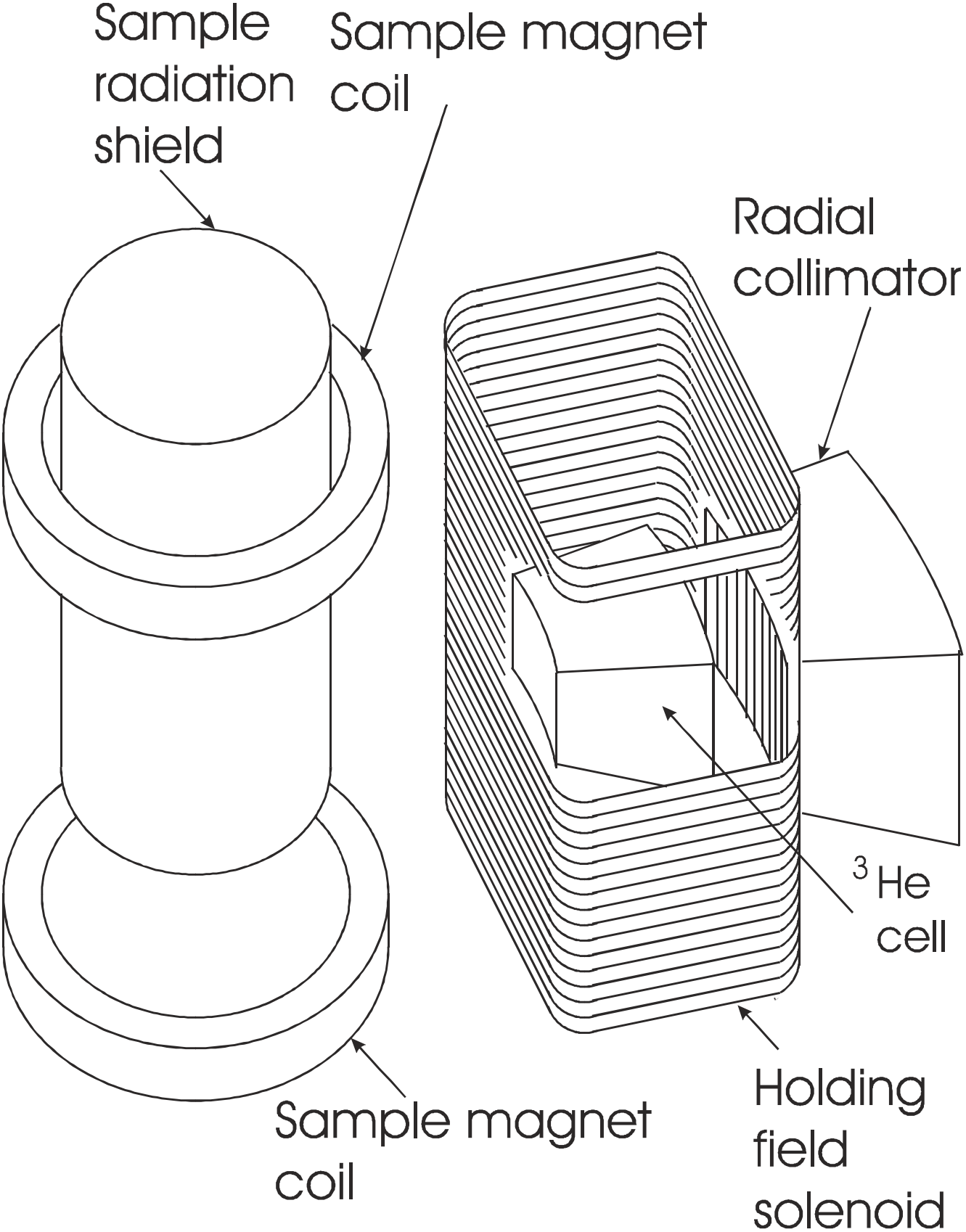


Intermediate sample field Hs ~ 1-3 T

Sample fields generated by 1-3 T magnets

^{3}He cell field by separate Al-wire solenoid

Magnetic shielding will be required to screen the cell solenoid from the sample magnet field



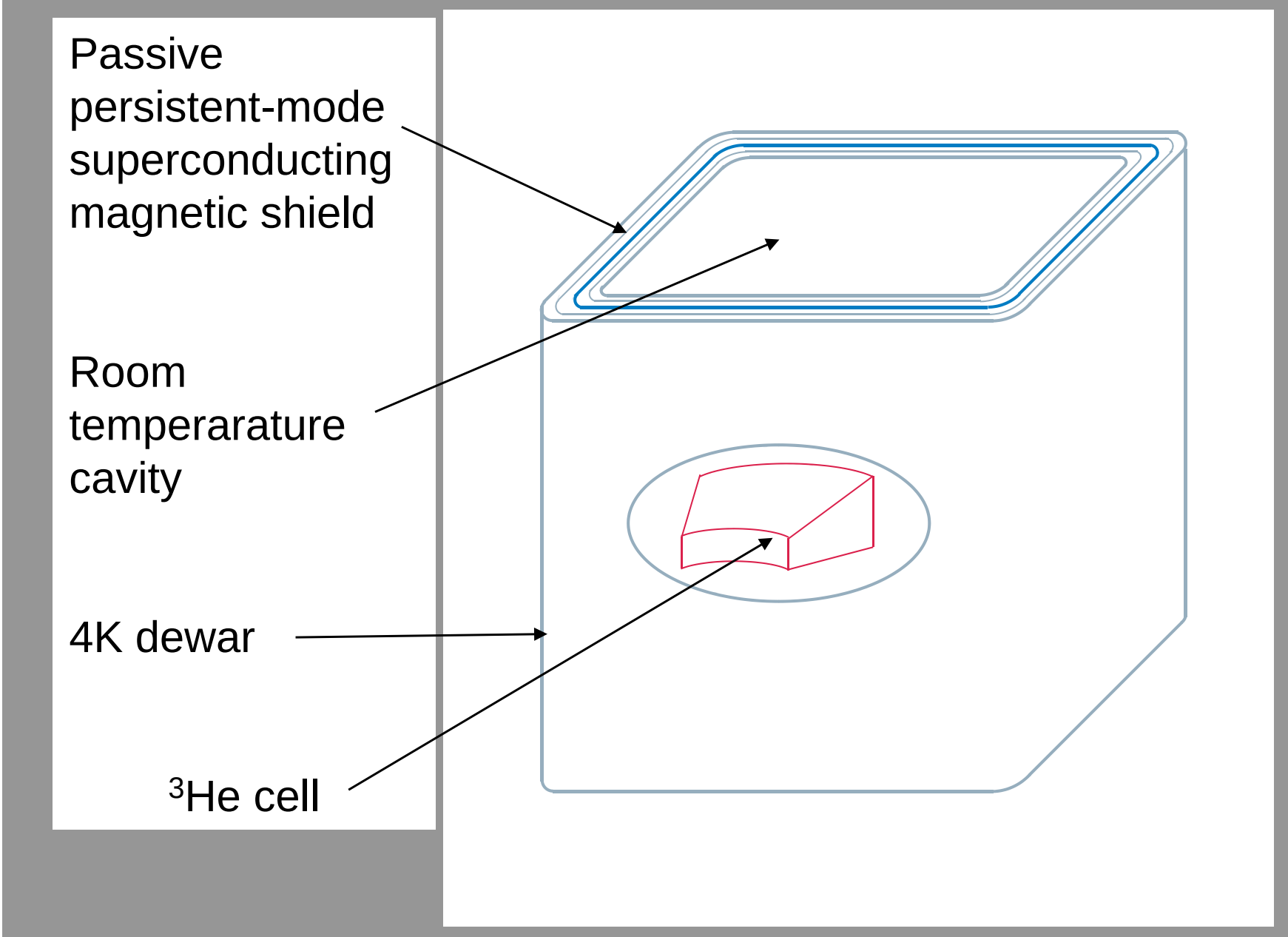
High sample field Hs ~ 10-15 T

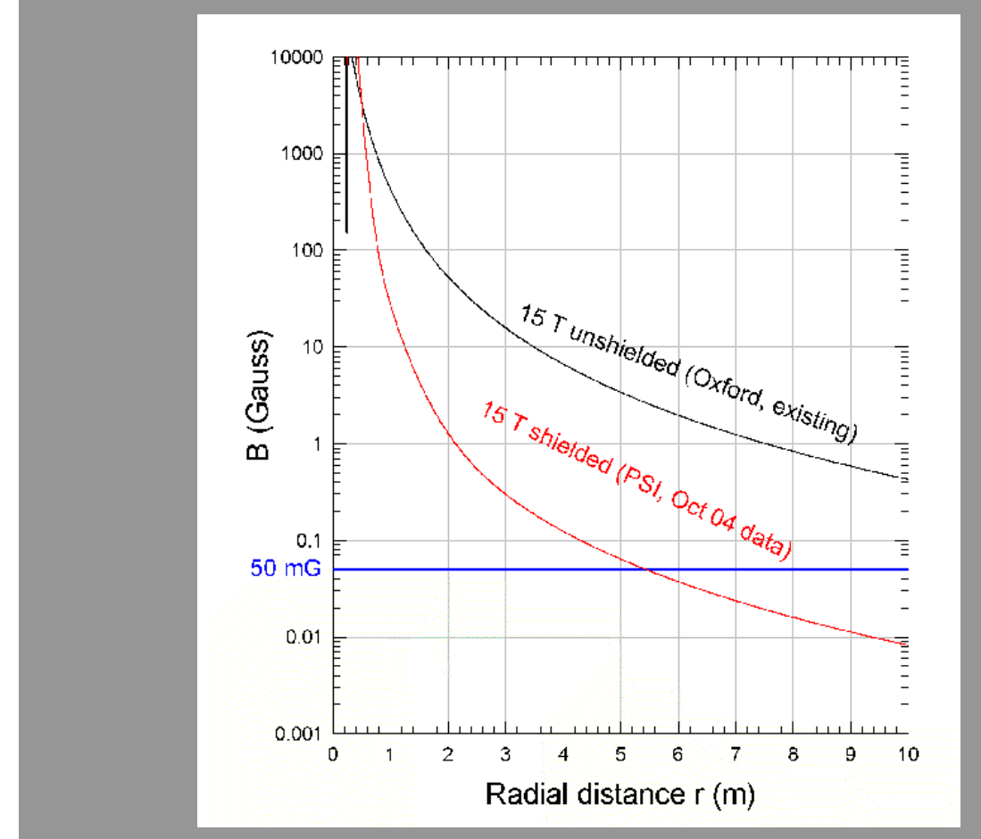
Sample field provided by 10 -15 T split pair superconducting magnet

A CRYOPAD-like superconducting magnetic shielding is required to screen out the 0.5-1T fringe field of the sample magnet.

A passive, persistent-mode superconducting sleeve will both screen the fringe field from the sample magnet and provide the holding field for the ^{3}He cell.

Ref: J. Dreyer, L.P. Regnault, E. Bourgeat-Lami, E. Lelievre-Berna, S. Pujol, F. Thomas, M. Thomas, F. Tasset - Nuclear Instruments and Methods A449, 638 (2000)





Magnetic fields in the vicinity of the OXFORD 15 Tesla superconducting magnet

On-line optical pumping

There are two potentially viable approaches to maintaining near-constant gas polarization in 3He cells:
- in-situ optical pumping
- batch gas transfer from an externally pumped cell to the working cell.

Continuous in-situ optical pumping using the spin exchange optical pumping (SEOP) method can be used for the low sample field configuration. The cell will have to be heated to about 200 C to maintain the Rb vapor pressure needed for efficient Rb-3He spin exchange. For a PASTIS-type arrangement of three orthogonal Helmholtz coil pairs, however, continuous in-situ pumping would be more of a challenge because the circularly polarized pumping light has to enter the cell parallel to the holding field which, in this case, would shift from one direction to another depending on what is regarded as the most experimentally advantageous sample field orientation.

Batch gas transfer from an externally pumped cell connected via capillaries to the working cell would also work for the low sample field configuration. In this case the approach would be a closed loop arrangement involving either metastable exchange optical pumping (MEOP) or SEOP. MEOP is the faster of the two methods but the gas has to be optically pumped at low pressure and then compressed and stored under pressure for periodic exchange with gas in the working cell. At the present time MEOP looks to be the less attractive alternative for batch transfer in part because compressors that can compress the gas without significant loss of polarization are are still in the development stage and in part because they are almost certain to be costly and require maintenance on a regular schedule. SEOP, on the other hand, although slower, is not constrained to low pressures and gas exchange could probably be accomplished without any mechanical components other than the valves controlling the gas flow and would be comparatively maintenance-free. But whatever the choice of pumping method, issues relating to providing the necessary holding field uniformity in the connecting capillaries will need to be addressed.

Given the more demanding nature of the intermediate and high sample field cases, it is likely that 3He polarization analyzers, if employed, will, at least initially, be optically pumped off-line and manually interchanged as the need arises. On-line optical pumping by either the in-situ or batch method, although not ruled-out, would require a significant developmental effort because of the geometrical constraints imposed by cells inside either solenoids or hollow-center dewars.

Conventional magnetic shielding

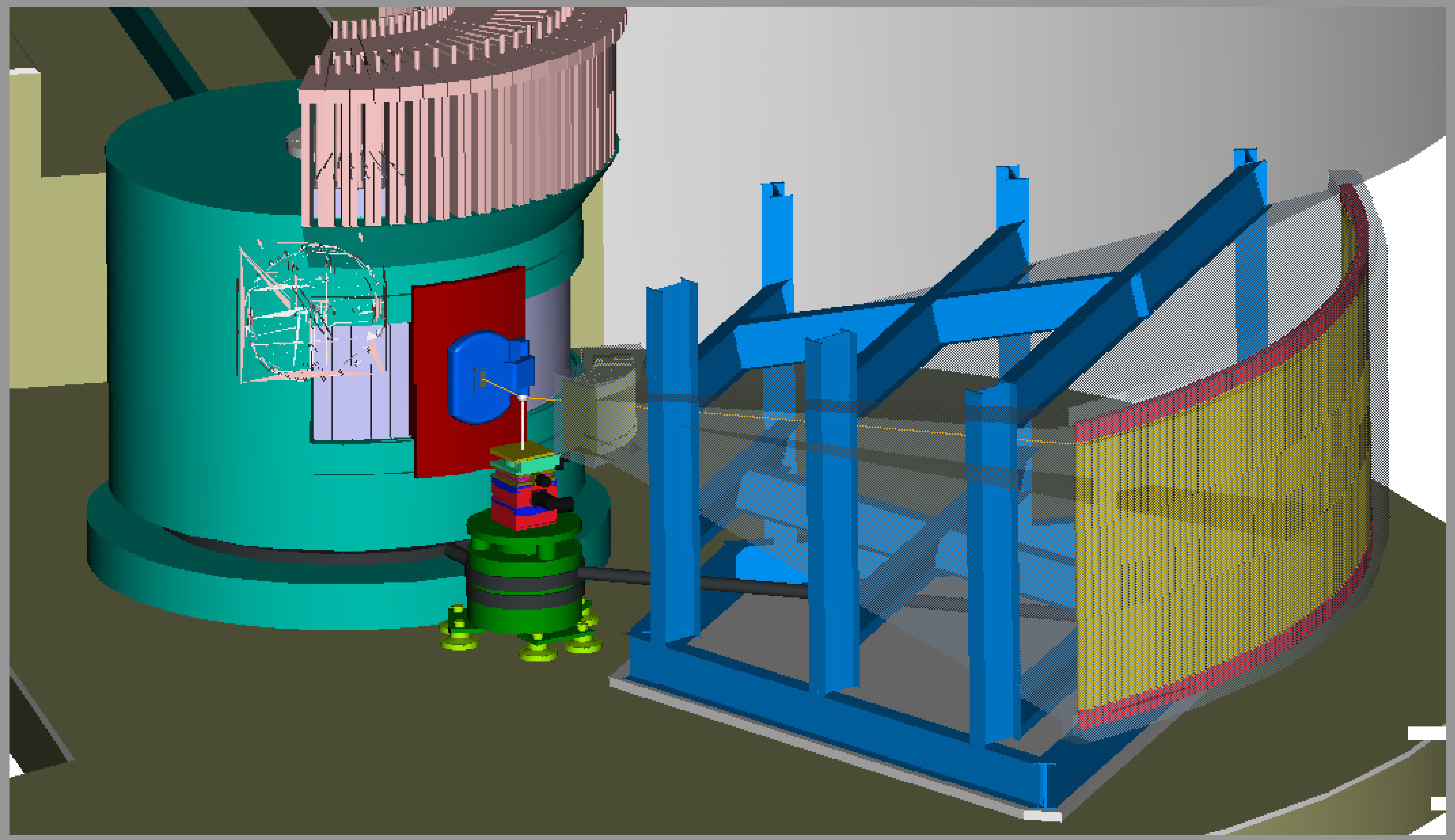
Material	Mechanical properties	Field that can be shielded (Gauss)
High grade μ metal Fe0.2Ni0.8	annealed susceptible to heat and stress	~10
Mid-grade μ metal FexNi(1-x)	partly-annealed or not annealed	~10
Fe0.97Si0.03		~100

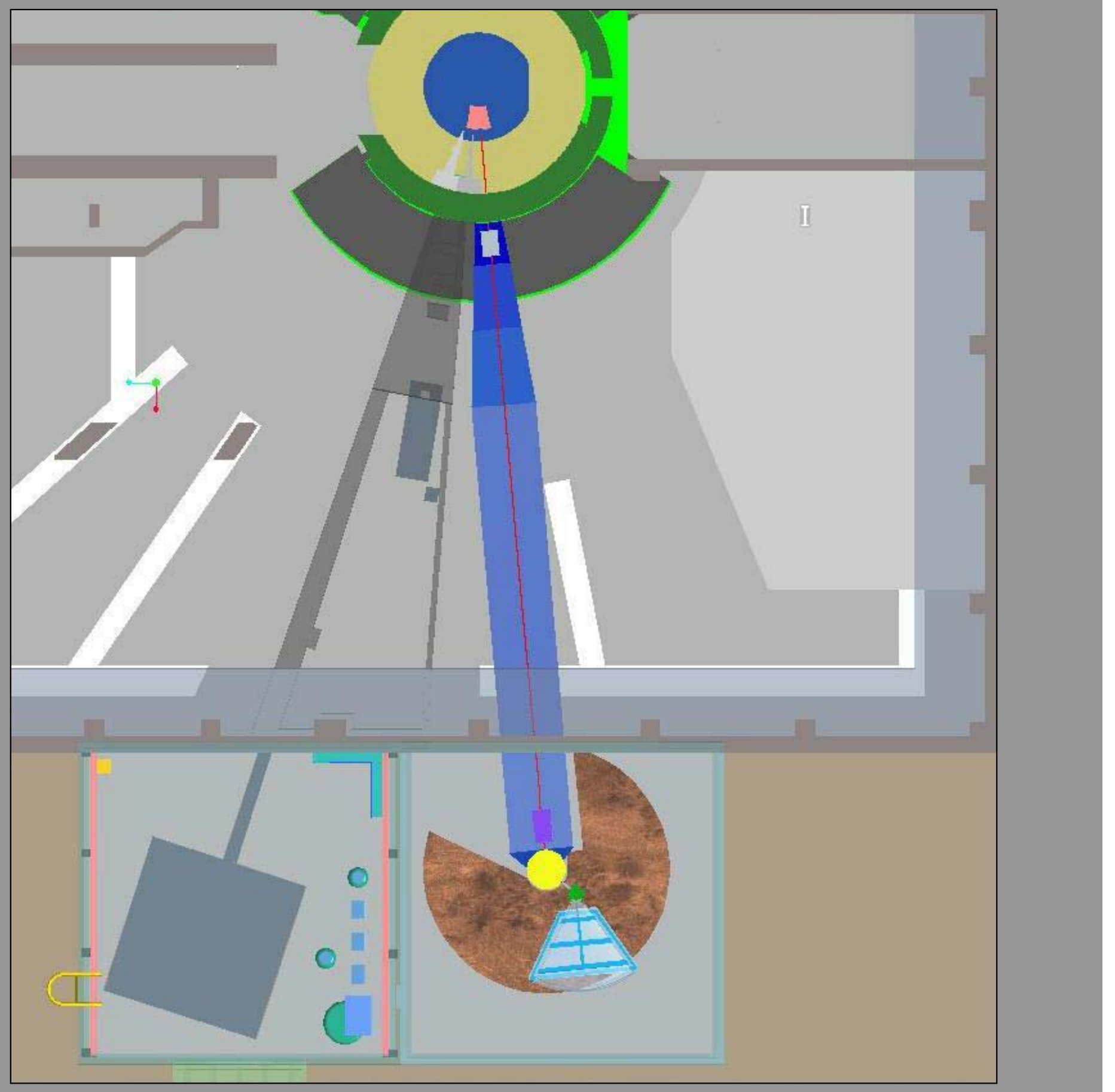
Gaps or windows would be required in the for beam entrance and exit

Passive, persistent-mode, superconducting magnetic shielding

Superconductor	Density (g/cm3)	properties	Field that can be shielded by 1 mm thick foil (Tesla)
Nb	8.5	good strength and rigidity electron beam weldable	~0.2
Al clad Nb0.37Ti0.63	6.02	good strength and rigidity	~1.0
Al clad Nb_3Sn	8.9	very brittle	?

No entrance and exit windows will be required – the beam will be transmitted through the shielding. Foil thickness is limited to 1mm to allow for adequate transmission.





HYSPEC PARAMETERS

Beamline: 14B at the Spallation Neutron Source, ORNL

Moderator: Cryogenic coupled H2 moderator

Moderator-monochromator distance 35-40m

Monochromator-sample distance 1.4-1.8m

Sample-detector distance 4.5m

Incident energy range: 3.6meV < EI < 90meV

Incident energy resolution: ΔEI/EI ~ 1.5%

Final energy resolution: ΔEF/EF ~ 5% - 8%

Wavevector transfer range: ~0.1Å-1 < Q < 8Å-1

A large beam (150mm x 40mm) from the SNS Moderator is compressed (focused) down to a 2cm by 2cm sample area using (focusing) Bragg crystal optics.

A curved supermirror guide is used to lower the background by going out of the line of sight of the source.

There is a large area around the sample for specialized and/or bulky sample environment equipment.

Brookhaven National Laboratory is managed by Brookhaven Science Associates for the U.S. Department of Energy. For more information on HYSPEC please see the website http://neutrons.phy.bnl.gov/CNS/hyspec/index.htm