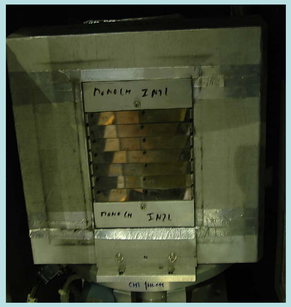
Neutron Sciences

NEUTRON SCIENCES

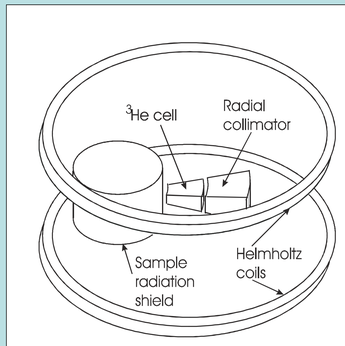
Polarizing the incident beam - Heusler Focusing Crystal Array

In order to polarize the incident beam on HYSPEC we propose to use an array of vertically focusing Heusler (Cu_2MnAl) crystals. The flux gain from vertical focusing on HYSPEC is much greater than the flux gain from horizontal focusing and thus using a vertically focusing array is much the better choice. This does mean that the polarization will need to be rotated between the Heusler crystals and the sample but this will not be a problem. On the right we show a photograph of the IN22 Heulser monochromator which is a very similar design to the device we propose to use.

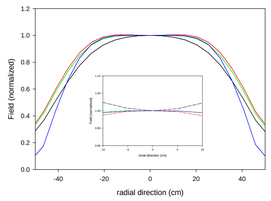


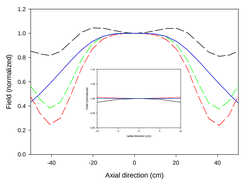
Analyzing the scattered beam - a ^{3}He Filter Analyzer

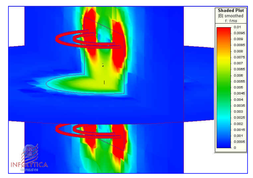
We propose to use a nuclear spin polarized ^{3}He filter analyzer of the PASTIS type to analyze the spin state of the scattered neutrons in the thermal energy range. A sketch of our proposed set-up is shown to the right along with preliminary field calculations. Below the concept behind a ^{3}He filter is explained and at the very bottom photographs of our first (test) filter analyzer cell are shown.



2 pairs of coils with diameter 400 mm & 350 mm separated by 400 mm. By applying appropriate currents to the coils, field uniformity similar to a pair of 400 mm diameter Helmholtz coils can be obtained.







Neutron Spin Filter

The absorption cross-section σ for polarized ^{3}He is highly spin dependent. For neutrons with wavelength λ=1 Å, anti-aligned neutrons see a thick absorption target:, $\sigma_{\uparrow\downarrow}$=5931 barns, and aligned neutrons see a thin target: $\sigma_{\uparrow\uparrow}$~5 barns. The transmission T_n and analyzing power P_n are

$$T_{n\uparrow\uparrow} = T_e e^{-(1-P_{He})n\sigma_0\lambda l}$$

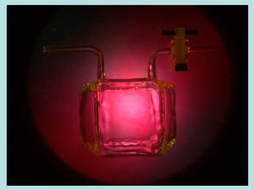
$$T_{n\uparrow\downarrow} = T_e e^{-(1+P_{He})n\sigma_0\lambda l}$$

$$P_n = \tanh(P_{He} n\sigma_0\lambda l)$$

$\sigma_0 = \sigma_{\downarrow\uparrow}$ since $\sigma_{\downarrow\uparrow} >> \sigma_{\uparrow\uparrow}$
T_e = neutron transmission through glass cell
P_{He} = ^{3}He polarization
l = cell length
λ = neutron wavelength
n = number density of ^{3}He

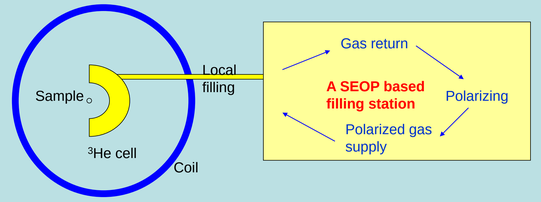
First Test Cells

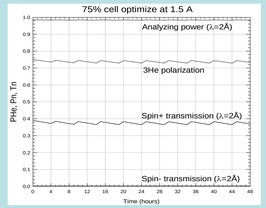
As the first step on our development of a wide angle polarization analyzer we have constructed a 45° test cell (HYSPEC needs 60°) which we are currently testing for ^{3}He polarization lifetime. The photograph on the left shows the valved cell, while the photograph on the right shows the cell under polarized light, used to search for flaws in the glass.



SEOP Filling Station

The Spin Exchange Optical Pumping (SEOP) method (see box) for polarizing ^{3}He gas produces a high polarization of the ^{3}He. However the large cell proposed for the HYSPEC filter analyzer is too large to directly pump via SEOP. Instead we propose to develop a "filling station" of smaller SEOP cells whose output can be accumulated to refill the filter cell. Some preliminary rate calculations for the filling station are shown below.





Optical pumping may be difficult due to the shape of the cell. Refilling may be the solution.

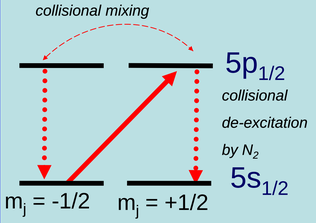
Filling station example:
Max ^{3}He polar. =0.75, optimized at 1.5 Å. T1=200 hours, refill 75% volume every 5 hours. (Plot: for 2 Å neutrons)

Spin-Exchange Optical Pumping

^{3}He nuclei are polarized in a 2-step process. First Rb atoms are polarized by optical pumping. Then spin is transferred from the Rb electron to ^{3}He nuclei during collisions.

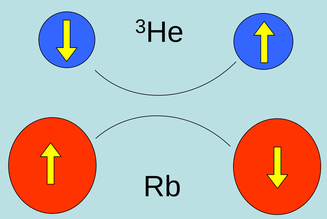
Optical Pumping

- pump Rb D1 line with circularly polarized light (795 nm)



Spin-Exchange

- spin is transferred between Rb electron and ^{3}He nucleus during collisions



$$P_{He}(t) = \frac{\gamma_{SE} P_{Rb}}{\gamma_{SE} + \Gamma}\left[1 - e^{-(\gamma_{SE}+\Gamma)t}\right]$$

P_{He} – ^{3}He polarization
P_{Rb} – Rubidium polarization
γ_{SE} – spin-exchange rate
Γ – ^{3}He relaxation rate

Polarization Analysis at the SNS and HFIR

The development of polarized neutron techniques at the Spallation Neutron Source and High Flux Isotope Reactor in Oak Ridge is coordinated and lead by the Instrument Development Group (Dr. Lee Robertson, Dr. Wai-Tung Lee and Dr. Dennis Rich) in the Neutron Facilities Development Division. The development of the 3He wide angle polarization analyzer for HYSPEC is a collaboration with the Instrument Development Group, which we hope will provide a useful foundation for developing polarization analyzers for a range of SNS and HFIR beamlines. For more information on the overall development of polarization analysis at SNS/HFIR please contact Dr. W.T. Lee (leewt@ornl.gov).

HFIR SNS SPALLATION NEUTRON SOURCE OAK RIDGE National Laboratory