A simple ^{3}He cell in McStas (3He_simp): (T. W. Roberts, ILL, March 1999)

This document gives the results of tests of a simple polarised 3He neutron spin filter that has been implemented in McStas. The spin filter consists of a cylindrical cell of gas at pressure `pressure` (bar), length `length` (m) and radius `radius` (m). In real life the cell consists of a glass cylinder (usually quartz), but in the simulation the cell is treated as a cylinder of gas with no walls. To first order this approximation is valid as the transmission of the glass is normally around 90 % for thermal neutrons. This approximation is used to avoid having to treat multiple scattering in the component.

The *opacity*, or effective absorption coefficient of a cell is given by $O(\lambda) = [^3\mathrm{He}] \cdot l \cdot \sigma_0(\lambda)$ where $[^3\mathrm{He}]$ is the number density of ^{3}He atoms, l is the thickness of the cell and σ_0 is the neutron absorption cross section for un-polarised neutrons. This can be expressed in terms of convenient units by the relation $O(\lambda) = 7.33 \times p[bar]l[m]\lambda[Angstroms]$.

The absorption cross section of ^{3}He for polarised neutrons depends strongly upon the polarisation of the neutron beam. The transmission of the cell for neutrons with a component of spin parallel ($\uparrow\uparrow$) and anti-parallel ($\uparrow\downarrow$) to the polarisation of the ^{3}He nuclei is given by:

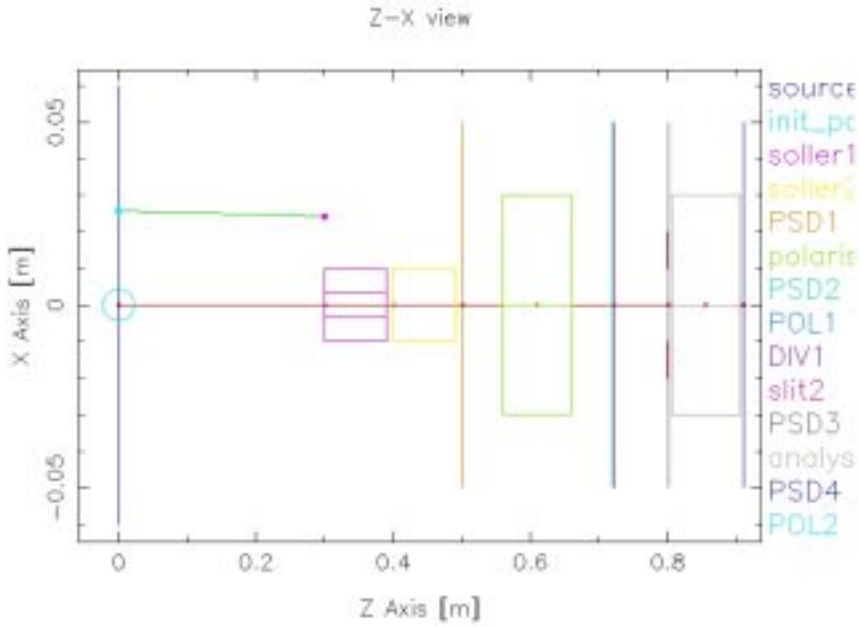
$$T_{\uparrow\uparrow} = \tfrac{1}{2}\exp\left(-O\left(1 - P_{He}\right)\right)$$
$$T_{\uparrow\downarrow} = \tfrac{1}{2}\exp\left(-O\left(1 + P_{He}\right)\right)$$

The component takes each neutron that enters the cell and calculates its path length through the cylinder. The neutron weight is then adjusted according to the equations above. The direction of polarisation of the ^{3}He nuclei is defined by the direction of the guide field denoted by `bx`, `by` and `bz` (telsa). This guide field is assumed to be constant (perfectly homogenous) and each neutron spin is precessed around its direction according to its wavelength and the field strength. The inclusion of this precession is not important for the test instrument described here and has not been tested properly yet. The guide fields outside of the cell are not considered at all.

Further reading:

R. Surkau et al, *Nucl. Instr. and Meth. in Phys. Res.* **A 384** (1997) 444-450 (and references therein).

In order to test the component a test instrument has been created containing two 3He cells as shown in the figure below:



Test instrument configuration.

The incident neutrons are produced using `source_flat()` and a random polarisation (normalised to 1) is assigned to each one by `pol_set()`. Two 40' `soller()` collimators rotated at 90° to each other around the z axis allow the vertical and horizontal divergence of the beam to be controlled. A `PSD_monitor()` follows the collimators to record the intensity of the incident beam on the first cell. The transmission of this cell (produced by `3He_simp()`) is recorded by a further `PSD_monitor()` after the cell, followed by a `polarisation_monitor()` and a `Divergence_monitor()`. A `Slit()` defines the beam entering the second cell (also produced by `3He_simp()`) followed by another `PSD_monitor()` to record measure the intensity of the beam entering the second cell. The second cell is required to analyse the polarisation created by the first cell, and has parameters that are not achievable in practice (to date anyway) but give the cell an analysing efficiency of 1 (pressure = 100 bar, length = 0.1 m, pol3He = ±1). The action of a flipper is provided by changing the sign of the polarisation of the ^{3}He gas in the second cell. A final pair of detectors (a `PSD_monitor()` and a `polarisation_monitor()`) are situated after the second cell so that its transmission can be established.

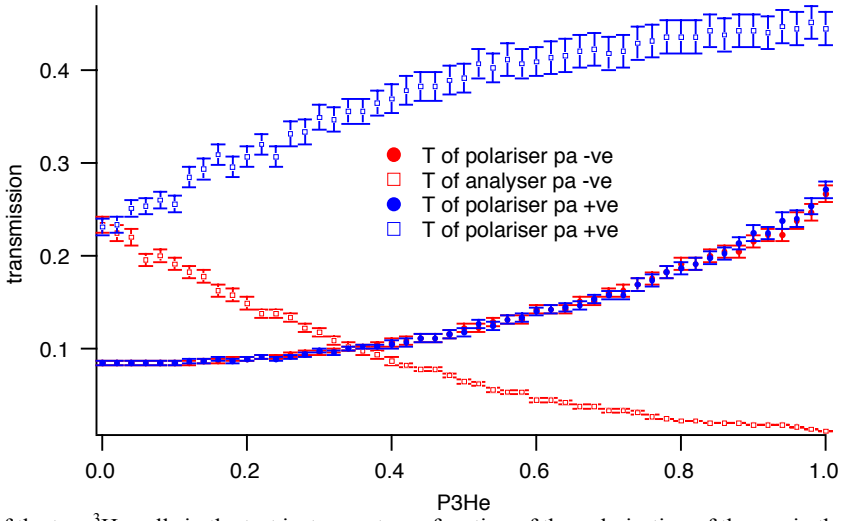
The instrument takes the following parameters:

en = incident neutron energy (meV), den = energy spread (meV, pol = polarisation of the ^{3}He in the first cell, p = pressure of the 3He in the first cell, l = length of the first cell (m), pa = polarisation of the ^{3}He in the second cell.

The instrument was run using the following two scans:

```
gscan 51 1e5 ./3He_test testp.dat pol=0,1.0 pa=1.0 l=0.1 en=100 den=0.01 p=2.7
gscan 51 1e5 ./3He_test testm.dat pol=0,1.0 pa=-1.0 l=0.1 en=100 den=0.01 p=2.7
```

The transmission of each of the two cells for both signs of the polarisation of gas in the analyser cell was then calculated from the resulting data and is plotted in the graph below as a function the polarisation of the gas in the polariser cell:



Transmission of the two ^{3}He cells in the test instrument as a function of the polarisation of the gas in the polariser cell. The polariser cell was filled with 2.7 bar of gas, is 0.1 m long with a radius of 0.03 m. The incident neutrons were collimated to 40' both horizontally and vertically and had an energy of 100 meV ± 0.01 meV. The red points are the results obtained with pa = -1.0 and the blue points are those obtained with pa=+1.0. Squares relate to the analyser and circles to the polariser.

The transmission for the polariser is independent of that of the analyser because the analyser occurs after the polariser. The transmission of the analyser depends strongly upon the sign of `pa` for all points other than where `pol` is zero. This shows that the polariser is polarising the neutron beam as expected.

The polarisation of the beam after the first cell and the equivalent transmission of the first cell for unpolarised neutrons are calculated using the following relations:

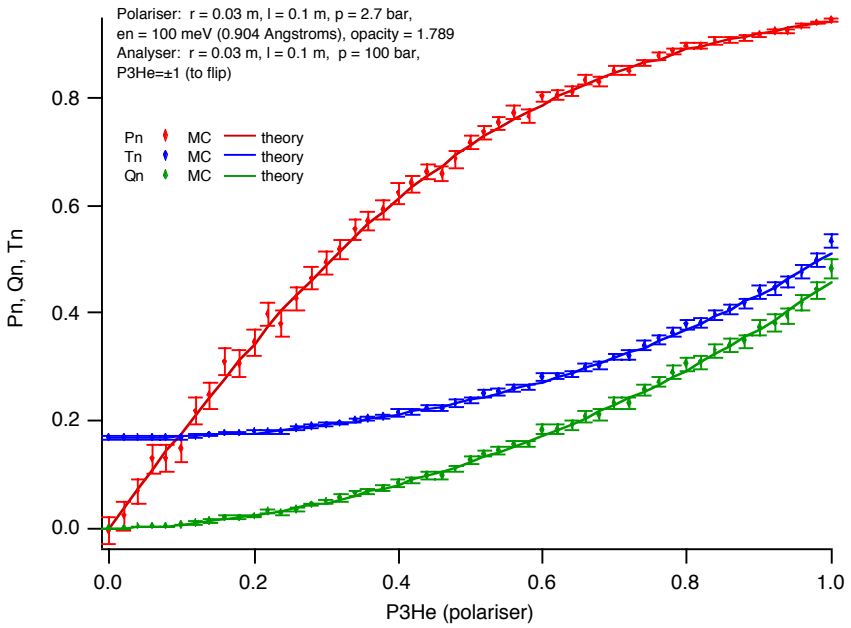
$$P_n = \frac{{}^{analyser}T_{\uparrow\uparrow} - {}^{analyser}T_{\uparrow\downarrow}}{{}^{analyser}T_{\uparrow\uparrow} + {}^{analyser}T_{\uparrow\downarrow}}$$

$$T_n = {}^{polariser}T_{\uparrow\uparrow} + {}^{polariser}T_{\uparrow\downarrow}$$

These can be compared to the analytical relationships given by:

$$P_n = \tanh\left(O(\lambda)P_{^3He}\right)$$

$$T_n = \exp\left(-O(\lambda)\right)\cosh\left(O(\lambda)P_{^3He}\right)$$



The analytical and Monte Carlo results are shown in the figure above. The analytical curves are the solid lines and the MC results are given as points with error-bars. The quality factor $Q = P^2T$ has also been plotted in green. The analytical results were produced by inserting the same cell parameters as those used in the simulations into the relevant formulae with no fitting. The correspondance between the two is excellent and the differences for the polarisation and transmission are shown in the figure below.