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Polarised neutron capabilities at ACNS

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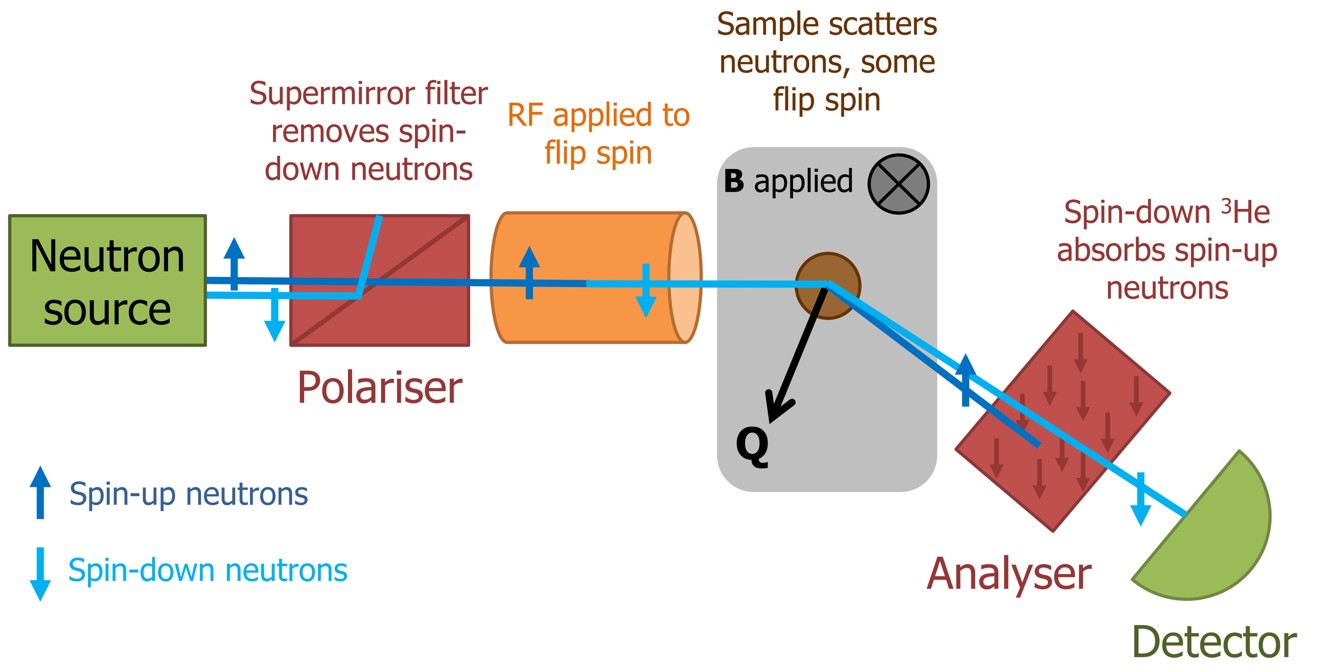
Spin-polarised neutrons are a valuable tool for obtaining unique information in neutron scattering experiments, allowing detailed study of magnetic effects or the separation of coherent and incoherent scattering. The Australian Centre for Neutron Scattering (ACNS) offers neutron spin filters for six instruments, using a combination of supermirrors and polarised ^{3}He cells. A variety of capabilities for polarised neutron scattering experiments are available for user experiments, including compatible sample environments such as the new 7 T compensated vertical magnet.

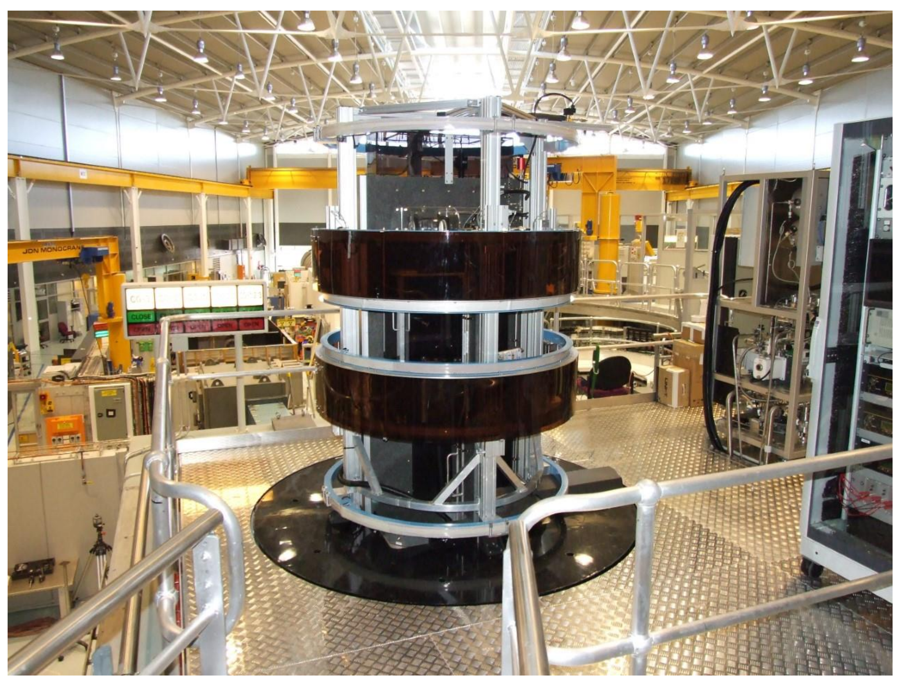
Why use polarised neutrons?

By using both a polarising and analysing filter, each with their respective spin flipping mechanisms, longitudinal polarisation analysis experiments can be performed. This enables studies which distinguish coherent and incoherent scattering, as the probability that a neutron scattered off a sample undergoes a spin-flip depends on whether the scattering is isotope coherent, isotope incoherent or spin incoherent.

Separating spin-flipping from non-spin-flipping scattering processes also allows magnetic scattering to be investigated in detail. For a given sample with magnetic moment **M**, if the neutron polarisation **P** and scattering vector **Q** can be controlled independently to extend the longitudinal analysis to a full XYZ setup, then given that probability of spin flipping depends on the relative orientation of the three vectors **M**, **P** and **Q**, very precise measurements of magnetic behaviour in the sample can be achieved.



Example of a polarisation analysis experiment



MEOP polarisation station

How to polarise beams for neutron scattering experiments

There are several ways to polarise the spin of neutron beams, which combine to enable polarisation analysis studies across a wide range of experimental conditions.

Polarising supermirrors are best suited to collimated beams of cold neutrons, and the simplicity of their use makes them the ideal choice for polarising the incident beam of Quokka, Pelican and Platypus, and for analysing specular reflections on Platypus. These setups have the distinct benefit of requiring little preparation or maintenance for use on user experiments.

Conversely, cells containing spin-aligned ^{3}He gas allow a wider beam divergence and wavelength range, making them ideal for polarising incident beams for Sika, Taipan and Wombat, and the analysers for each of these six instruments. The gas is prepared by a Metastable Exchange Optical Pumping (MEOP) station located in the Neutron Guide Hall at ACNS, and is stored in glass cells which are transported to each instrument.

Polarisation capabilities on neutron scattering instruments

Each of Quokka, Pelican, Platypus, Sika, Taipan and Wombat are capable of polarisation analysis experiments (please not that Pelican is not yet available for user experiments, but we aim to offer this in late 2021). The ancillaries are categorised by their location: the polariser after the instrument neutron source; the sample position; and the analyser in front of the detector.

Quokka, Pelican and Platypus have supermirror source polarisers and RF spin flippers built into the instrument on a translatable stage, while other instruments (Sika, Taipan and Wombat) can install a helium spin-filter cell inside a Magic box, which provides a homogeneous magnetic field as well as the ability to invert the spin of the helium gas without loss using pulses of RF radiation.

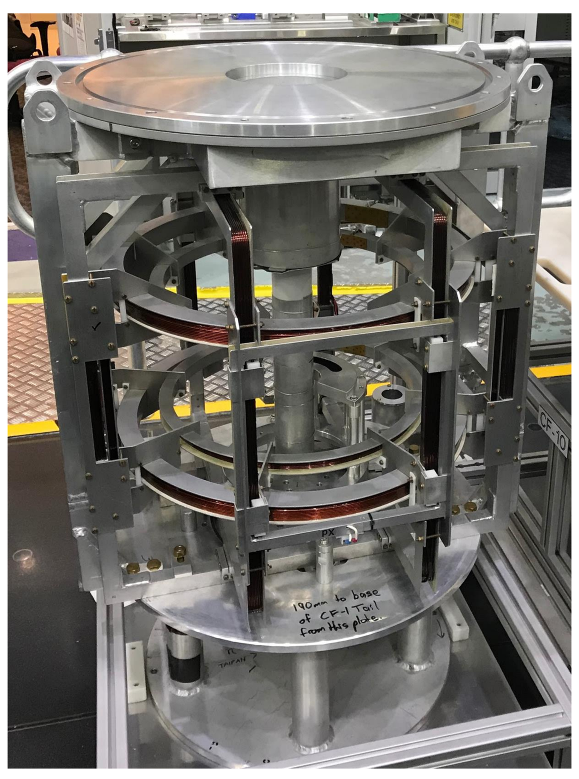
At the sample position, a variety of options are available to create the magnetic field applied to the sample which also maintains the neutron polarisation. These range from static permanent magnets, to controllable uniaxial superconducting magnets, to 3D Pastis coils. These setups are also compatible with a variety of cryofurnaces, including those which can accommodate a dilution refrigerator, to allow sample temperatures between 50 mK and 800 K. Other complementary environments such as electric fields are also possible for some setups.

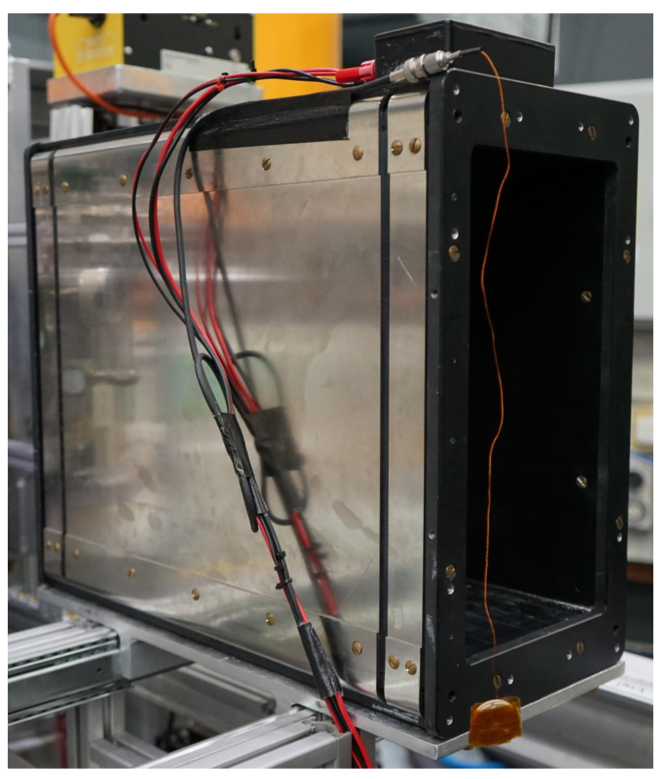
Quokka and Platypus also offer the ability to translate ^{3}He spin filters in Magic boxes into the beam after the sample to analyse the scattered signal. These cells are mounted inside each instrument's detector tank, and can be recharged remotely using a portable local filling station. Sika and Taipan can use a second standard Magic box and flat-windowed cell as an analyser, while Pelican and Wombat use wide-angle cells housed in the Pastis coils to analyse beams scattered over an angle of 120°.

A new setup which is of particular importance to polarisation experiments is the compensated 7 T vertical magnet, which ensured that spin transport is achieved over its entire field range without reducing the polarisation lifetime of the spin-filter cells. Recent commissioning tests have successfully verified the performance of this setup on Quokka.

Every polarised neutron scattering setup also includes the required guide fields to transport the neutron spin adiabatically from the polariser to the analyser, using arrangements of permanent magnets in most cases.

7 T compensated vertical magnet installed on Quokka





Pastis coils (left) and a Magic box (right)

How to use polarised neutrons for your experiment

Using polarised neutrons requires additional considerations when designing an experiment. The most pronounced of these are the significant loss of flux due to the spin filters, the installation of extra ancillaries on the neutron scattering instrument, and the finite spin-polarisation lifetime of ^{3}He cells and consequent need to recharge these cells once per day. Each of these extend the time required to complete a neutron scattering experiment.

If you are interested in planning for a polarisation neutron experiment, especially one requiring the use of ^{3}He spin filters, please discuss this well in advance with the polarised helium instrument scientist (andrewm@ansto.gov.au) and the instrument scientist on your preferred instrument.

More information can also be found on the ANSTO website: www.ansto.gov.au/helium-3-polariser