

Parity Violation in Neutron Spin Rotation

W.M. Snow

Indiana University Cyclotron Facility, Bloomington, IN

We are preparing an experiment to search for parity violation in neutron spin rotation in liquid ^4He . A transverse rotation of the neutron spin vector about its momentum manifestly violates parity [1] and can be viewed from an optical viewpoint as due to a helicity-dependent neutron index of refraction. For ^4He , the calculated PV neutron spin rotation is $\phi = (-0.1 \pm 1.5) \times 10^{-6}$ rad/m using the DDH best values [2]. To measure the small parity-odd rotation, a neutron polarimeter is used to measure the $+\hat{y}$ polarization component of a neutron beam initially polarized along the \hat{z} axis and traveling in the \hat{x} direction. The challenge is to distinguish small PV rotations from rotations that arise from residual magnetic fields. See the diagram in Fig. 1.

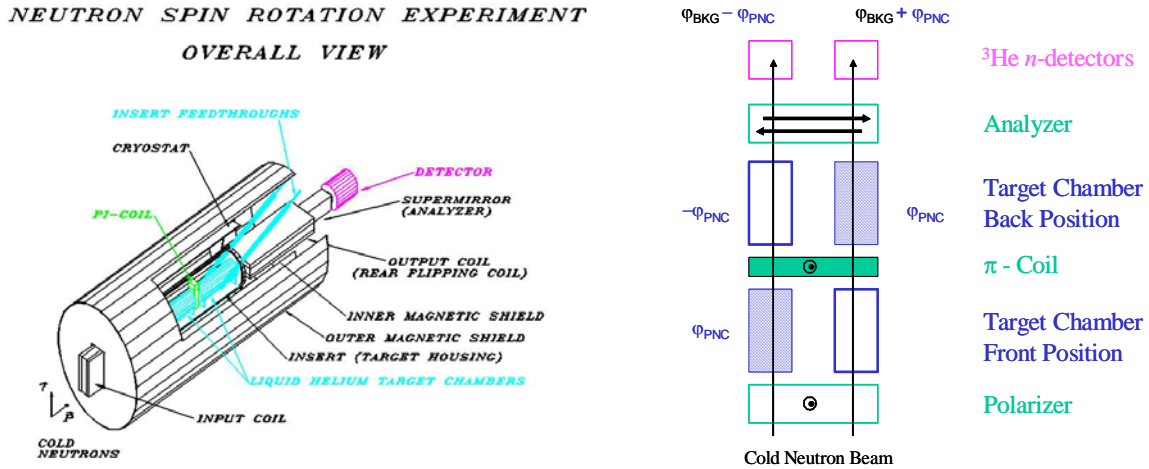


Figure 1. Conceptual diagram of the apparatus to measure PV neutron spin rotation in helium, in perspective on the left and a top view on the right. In the latter view, neutrons polarized out of the plane pass through a segmented target region. The upstream-downstream segmentation in combination with the π -coil and the motion of the liquid helium allows the PV component of spin rotation to be separated from the much larger parity-even component from residual magnetic fields. The left-right segmentation eliminates extra noise from reactor intensity fluctuations. The polarization analyzer and oscillating guide field converts the in-plane polarization component into an intensity difference measured by the segmented current-mode ion chamber.

The first measurement by the Washington group achieved a sensitivity of 14×10^{-7} rad/m at NIST [3], a factor of two from the precision needed to provide new information about f_π . We are modifying the apparatus originally built at Washington in several ways: (1) use of more magnetic shielding, (2) incorporation of a 2K superfluid helium target chamber, (3) use of a new ion chamber for measuring the beam transmitted through the supermirror analyzer, (4) improvement of the neutron beam optics. In addition, we have conducted an extensive series of neutron transport simulations to verify our insensitivity to neutron scattering effects in the helium.

All of the systematic effects in the experiment are coupled to the presence of a longitudinal magnetic field, which rotates the neutrons by Larmor precession by an angle much larger than the expected parity-odd signal. It is therefore essential to suppress longitudinal magnetic fields as much as possible. Figure 2 shows our measurement of the residual longitudinal magnetic field in the magnetic shield after adding a third magnetic shield made of Cryoperm, which has a larger magnetic permeability at low temperatures. The residual magnetic field is lower than achieved in the previous experiment by one order of magnitude and is less sensitive to changes in the external magnetic field due to the third shield.

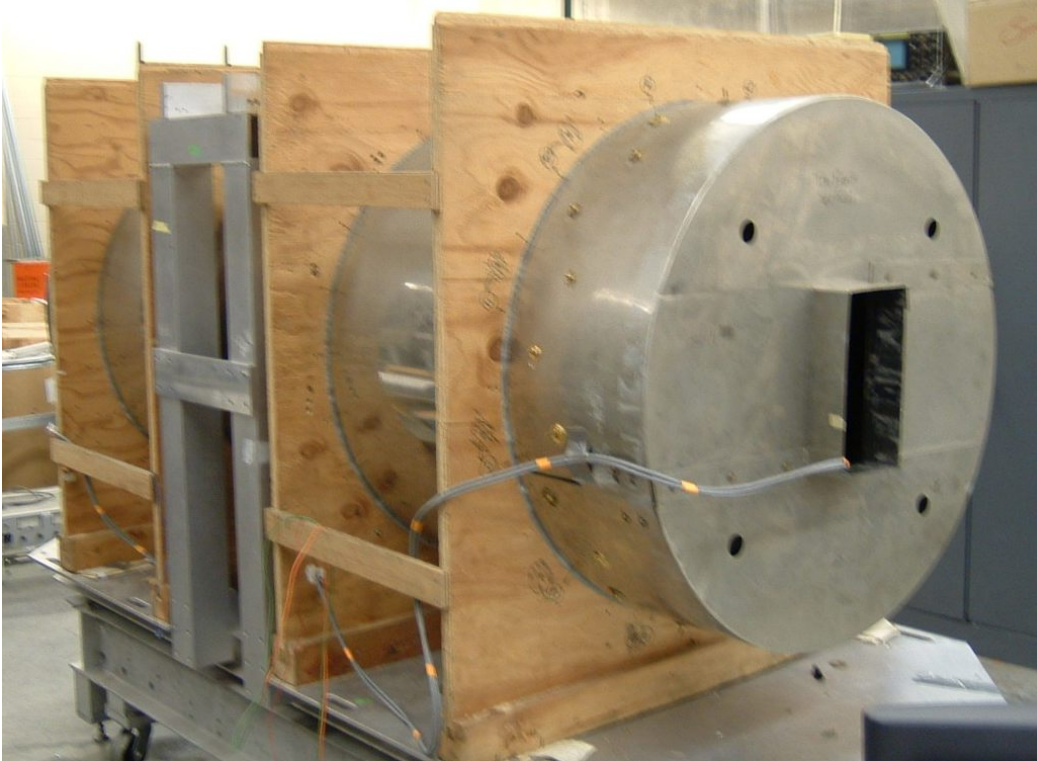


Figure 2: *External magnetic shielding for the superfluid helium target cryostat for the n - ^4He spin rotation experiment. A third cylindrical shield made of Cryoperm is also installed inside the cryostat. We have achieved internal fields of less than 5 microGauss over the 10 cm x 10 cm x 1 m volume of the liquid helium target.*

We have made significant progress in the design and construction of the new 2-K superfluid target chamber. The new target consists of a new superfluid tight insert thermally isolated from the 4-K cryostat with a ^4He evaporation refrigerator and associated roots pump and gas handling system, new fluxgate magnetometers, new target chambers, new low temperature valves for filling the target from the main helium bath, new room temperature feedthroughs to access the superfluid pump, valve, and magnetometers, and new nonmagnetic electrical feedthroughs. Washington supplied the roots pump, fluxgate magnetometers, and several other items. Indiana designed the new target chamber that was machined at Washington, designed and

machined the new 2-K insert and room temperature feedthroughs, tested the pumps, and is now constructing the remainder of the system.

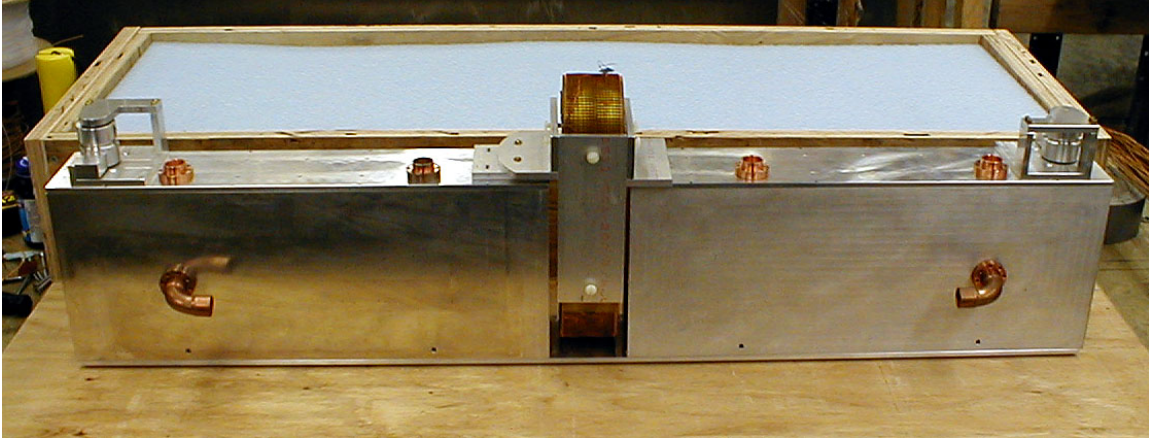


Figure 3: The superfluid helium target chamber for the $n\text{-}^4\text{He}$ spin rotation experiment, designed at IUCF and machined at Washington. Approximately 1 meter long, it possesses 4 internal chambers for the 2 parallel neutron beams, a central “pi-coil” to precess the neutron spins by 180 degrees about the vertical axis to isolate the parity-odd signal, and two fluxgate magnetometers above the neutron beam.

The new ^3He ion chamber is similar in design to the original Washington ion chamber but is constructed out of UHV bakeable materials. It was successfully tested in a neutron beam at Los Alamos and its operation was in agreement with simulations.

Considerable effort has been directed toward the development of a Monte Carlo simulation of the neutron interactions in superfluid helium. Small angle scattering in the liquid helium coupled with target motion and the different solid angles subtended by the two target positions can lead to a systematic effect in the presence of the residual longitudinal magnetic field. We developed a neutron scattering kernel based in part on the model of Morishima but extended to small angles using recent data from the ILL [4]. This model calculates the neutron angular distribution and energy loss spectrum for neutron scattering in the helium and also performs the neutron transport through the apparatus. The model shows that neutron scattering systematic effects are negligible for our experiment and also predicts that we will be able to increase the statistical accuracy of the experiment using supermirror optics in the input and output guides between the polarimeter elements.

1. F.C. Michel, Phys. Rev. B **133**, 329 (1964).
2. V. Dmitriev, V.V. Flambaum, O.P. Shuskov, and V.B. Telitsin, Phys. Lett. **125**, 1 (1983).
3. D.M. Markoff, Ph.D. thesis, University of Washington (1997).
4. Yu.M. Tsipenyuk and R.P. May, arXiv:cond-mat/0207278.