The abBA Experiment

Submitted on behalf of the abBA collaboration by W.S. Wilburn

We are developing an experiment (the *abBA* experiment) for the SNS FNPB which will determine four neutron decay parameters to greater precision than previous measurements. These parameters are the three time-reversal allowed correlations A (correlation between electron momentum and neutron spin), B (correlation between anti-neutrino momentum and neutron spin), and a (correlation between electron and anti-neutrino momenta), and the Fierz interference term b. These measurements will provide a redundant determination of $\lambda = g_A/g_V$. Previous experiments on determinations of λ in neutron decay have focused on measuring only one parameter, mostly A. Also these experiments have been limited in precision primarily by two effects: large backgrounds and uncertainty in neutron polarization. The *abBA* approach addresses the first of these limitations by observing coincidences between the decay proton and electron in high-quality silicon detectors, greatly reducing the background. It also decreases the uncertainty in neutron polarization through the use of a polarized ^{3}He neutron spin filter which allows precision neutron polarimetry. The experiment consists of a broad-spectrum cold neutron beam (provided by the FNPB), a polarized ^{3}He neutron polarizer, an electromagnetic spectrometer, and large-area silicon detectors to detect the charged particles from the decays.

The neutron beam is polarized by passage through a polarized gas of ^{3}He. A cell containing ^{3}He gas and a small amount of rubidium is polarized by first polarizing the Rb with circularly polarized laser light. Spin exchange between Rb and ^{3}He transfers the polarization. Because the cross section for neutron absorption on ^{3}He is strongly spin-dependent (5.3 kbarn for spins anti-parallel and 3 barn for spins parallel at 25.3 meV), the polarized ^{3}He acts as a spin filter, preferentially transmitting neutrons of one spin state. In addition, the $n{-}^3$He cross section scales very accurately with the inverse of the neutron velocity. For any neutron energy, there is then a parametric relation between neutron polarization and neutron time-of-flight $P_n = \tanh{(t/\tau)}$ where $\tau = P_3 L/n_3\sigma_v v$, with the ^{3}He polarization and thickness given by P_3 and n_3, the flight path length given by L, and the $n{-}^3$He cross section at neutron velocity v given by σ_v. A similar relationship also holds for the neutron transmission through a polarized ^{3}He gas. This relationship has been used to measure absolute neutron polarization to an accuracy of 0.3% for neutron energies from 40 meV to 10 eV in a dedicated measurement which was statistics limited. Present knowledge of the $n{-}^3$He interaction indicates the relationship holds to at least the 10^{-4} level and can thus be used as the basis for a precision neutron polarimetry technique at cold ($<$ 25 meV) neutron energies.

The spectrometer is a highly efficient, 4π charged particle detector that guides both the electron and proton from a neutron decay event to opposing detectors, allowing one detector to see all particles emitted parallel to the neutron spin, and the other to see the particles emitted anti-parallel to the neutron spin. The detectors are ion-implanted silicon detectors, with active area greater than 100 cm^2 and a thickness of 2 mm. Specially preparation of the implant layer provides an entrance window of less than 100 nm, allowing detection of the decay protons, after acceleration to 30 keV. The detectors are cryogenically cooled and operate at high internal electric field to provide ~ 1 ns timing resolution, allowing for the reconstruction of electron backscatter events.