I will be introducing you to the NPDGamma experiment goals, theoretical motivation, the Spallation Neutron Source Facility, NPDGamma apparatus, asymmetry calculation, and the current status of data taking.
The goal of NPDGamma is to use the weak interaction to probe the strong interaction at low energy by measuring the parity violating asymmetry of the emission of gamma rays from the capture of a transversely polarized cold neutron beam on protons in a liquid hydrogen target. The measured asymmetry is a combination of a parity violating up down and a parity conserving left right asymmetry from which we will extract the parity violating asymmetry.
In the standard model of subatomic physics the interaction between particles is modeled as the exchange of virtual bosons between the fundamental particles. Gluons are the strong force carriers and the $W^\pm$ and $Z^0$ are the weak force carriers. For composite hadrons such as protons and neutrons the exact nature of the strong interaction at low energies is not known. We try to exploit the interference between the strong and weak interaction, and the corresponding PV signal, to learn about the strong interaction at low energy. QCD calculations of the HWI are not possible, so effective theories that reparameterize the interaction in effective degrees of freedom are used. Meson exchange pictures such as the DDH model parameterize the hadronic weak interactions in terms of 6 coupling constants, $h$, and with coefficients $a$ related to the exchange of virtual mesons between the hadrons. There is a great deal of uncertainty in the value of these parameters, so it is an ongoing experimental effort to accurately measure the parameters.
The asymmetry to be measured by NPDGamma is related to three of the parameters, but due to the relative size of the parameters and their coefficients is primarily sensitive to $h_{\pi}^1$. The electromagnetic signature of the parity violation in the gamma ray asymmetry arises due to the mixing of strong interaction states caused by the weak interaction perturbation to the system. This is a difficult measurement as the asymmetric signal is very small, but the simplicity of the two body system makes for an easy theoretical interpretation of the results.
A parity transformation is a transformation that can be done by flipping the sign of all three spatial coordinates in a system. A parity transformation will change the sign on vectors such as momentum, but not pseudovectors such as spin. A parity transformation of the NPDGamma experimental setup would reverse the beam direction and gamma ray emission direction while leaving the neutron polarization unchanged. It can be seen that an equivalent transformation can be made by reversing the neutron polarization and leaving the other vectors unchanged.
The Spallation Neutron Source is located at the Oak Ridge National Lab in Tennessee. It uses a pulsed proton beam on a mercury target to provide a 60 hertz pulsed neutron beam simultaneously to multiple beam lines. NPDGamma is located at the fundamental neutron physics beamline.
(30 seconds) This is a comparison of a calculated and measured neutron flux spectrum at the FnPB. The high energy neutrons from the spallation target are thermalized with a liquid hydrogen moderator so that the neutron exiting the moderator have a maxwell-boltzmann distribution of energies, rising to a peak and dropping off through a tail. There are two dips near the top of the peak where the bragg scattering from the Al beam pipe has removed neutrons from the beam. more slides later on chopped beam profile
Exiting from the moderator the thermalized neutrons pass down a beam pipe through two choppers. A beam monitor M1 is used to measure the beam flux into the experiment. The supermirror mirror polarizer transmits roughly a third of the beam intensity polarized to approximately 97%. A set of helmholtz coils provide a holding field to maintain the beam polarization down stream from the polarizer. A second beam monitor measures the flux exiting the super mirror polarizer. A spin flipper is used to reverse the neutron polarization in a 8 step pattern to control for systematic effects. The proton target is liquid parahydrogen. Positioned around this is an array of 48 CsI detectors for measuring the gamma rays emitted from the target, and finally a third neutron beam monitor for measuring the flux out of the target.
Here is an image of the installed NPDGamma experiment with all of the shielding in place. The concrete shielding over the SMP is visible, as are the helmholtz coils, and a safety barrier.
As it is required to know the number of neutrons entering into the experiment for counting statistics, I performed a calibration calculation for the M2 monitor using data gathered at a separate beam line with a provided low efficiency nitrogen monitor to measure the neutron flux. A proportionality factor was calculated to related the current from the M2 monitor to the number of neutrons entering it at a given wavelength range, and the calibration is shown here for a chopped pulse compared to a boron plate measurement of the neutron flux.
To control for systematics an eight step spin sequence is used that will cancel drifts in the detector efficiency up to quadratic order. For efficient spin flipping it is required to know the neutron velocity at each time of flight so that the amplitude of the spin flipper signal can be varied to achieve a maximum spin flipping efficiency.
To get to the physics asymmetry a raw asymmetry is calculated in each time bin $t_i$ for each detector pair $p$ for every good 8 step spin sequence $j$. A series of simulated and measured correction factors are then used to extract the physics asymmetry from the raw asymmetry. The geometry factors $G_{UD}$ and $G_{LR}$ are calculated for each detector and target to account for the relative position and physical dimensions of each detector block, the target, and neutron capture distribution. Other factors are related to the detector gain, beam flux, noise, polarization, spin flipping efficiency, and neutron deplorization inside the target.
As an initial measurement a Cl asymmetry was taken to test the experimental apparatus as Cl has a large well known asymmetry. Al asymmetry measurements were taken using an Al target as this is one of the larger background due to Al in the experimental apparatus. A noise asymmetry measurement is required to ensure that there is not a false asymmetry in the electronics. Hydrogen data began last year in September, and has continued since then with down time for facility maintenance.
This shows a Raw Cl asymmetry. Over each of the 4 rings in the detector array you can see a cosine like dependence on the magnitude of the asymmetry starting at theta=0 going to 180. The LR asymmetry sin theta factor is two orders of magnitude smaller so it is not not visible. A measurement of this known asymmetry served as a test for systematic effects, false asymmetries and backgrounds.
This is an uncorrected plot of the measured Al asymmetry. It is two orders of magnitude smaller than the Cl asymmetry, and the error bars are proportionally larger.
This shows a subset of the current hydrogen data. This plot shows a detector asymmetry so each ring has 12 instead of 6 points, and it is not background corrected.
In conclusion the NPDGamma experiment has completed commissioning and is in the process of taking hydrogen data.