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Normalization of the NPDGamma data

Forrest Simmons

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Student: Forrest Simmons
Faculty Mentor: Christopher Crawford

The goal of the experiment is to measure the parity-violating asymmetry in the npdgamma reaction. The npdgamma reaction is when a polarized neutron strikes a proton to form a deuterium nucleus, and emit a gamma ray. The NPDGamma collaboration at Oak Ridge National Lab is measuring the asymmetry of the angle of the emitted gamma rays relative to the neutron spin. The value of the asymmetry in the npdgamma reaction can tell us the value of f_π, one of six coupling constants which tell us about the hadronic weak interaction. These six constants can tell us about the nucleon structure.

The asymmetry exists because there is an asymmetry in the weak force. An asymmetry is possible because the angle of the emitted gamma ray is parity odd. If the x, y, and z coordinates were flipped, the direction of the gamma ray would be flipped, but the spin of the neutron would be going the same direction. The reaction can be mediated by the strong force or the weak force. Since the strong force is much stronger than the weak force, most of the interactions are mediated by the strong force. Since only the weak force is parity-violating, the asymmetry of the reaction is thought to be very small. This experiment has been done before and the asymmetry measured was smaller than the statistical error. This new experiment should be able to measure the asymmetry more accurately. Since randomness is involved in the experiment, there is a probability that an asymmetry could occur by chance. As more measurements are taken, this probability decreases as the inverse square root of the number of events recorded. In order for a non-zero asymmetry to be accepted, it has to be five standard deviations away from zero, so the value measured must be five times as large as the uncertainty. This corresponds to less than a one in a million probability that the asymmetry was due to chance.

The neutrons produced at the source are first polarized with supermirrors. Then a pair of spinning choppers limits the time frame where the neutrons can get through. Each chopper has a hole in it that allows neutrons to get through. The only way a neutron can get through is if it reaches each chopper when its opening aligns with the beam. This restricts the length of time the neutrons spend between the two choppers, and thus regulates the speed of the neutrons reaching the target. Next, the neutrons are sent through a spin-flipper. The spin-flipper uses a time-varying magnetic field in order to flip the neutrons from spin-up to spin-down. It must be time-varying because the neutrons have a range of speeds. The faster neutrons are there for less time than the slower ones, so they require a stronger magnetic field. The purpose of the spin-flipper is to prevent false asymmetries of the equipment from entering the data. If something due to the equipment were to cause the gamma rays to go up rather than down, this would add an equal number of counts to both directions and the asymmetry would cancel itself out. The spin-flipper is turned on and off at a high frequency in order to prevent asymmetries due to time as well. After passing through the spin-flipper, the neutrons strike a parahydrogen target. Parahydrogen is a hydrogen molecule with it's protons' spins in opposite directions. The target is surrounded by 3 rings of 12 cesium-iodide detectors. When a photon hits one of the detectors, it scintillates (flashes). 1010 interactions per second is too frequent for each one to be counted directly. Instead, the light produced is converted to a voltage, which is then stored in a file. The voltage shows how frequently these interactions occur. This can later be integrated to tell how many photons hit a given detector.

Over the summer, noise runs were taken to check that there wasn't a false asymmetry due to the equipment. During the noise runs, everything is turned on, but the neutron beam is blocked. The statistical error from the noise runs was on the order of 10^-8 and was larger than the measured asymmetry, which means the result is consistent with zero. The experimental error is much smaller than the statistical error, so this means that if there is a false asymmetry due to the equipment, it is smaller than the level at which we are trying to measure the asymmetry

The asymmetry is predicted to be about 5x10-8. Since the statistical error decreases as the inverse square root of the number of measurements taken, so about 1016 neutron interactions need to be measured in order to decrease the error to be lower than the spin. Since there are about 3x 107 seconds in a year, at 1010 interactions per second, this will take about a month. Due to other factors, it will actually take longer and the experiment will run for about a year. Data will continue being taken during the fall.

The neutrons are produced at a spallation source, which means they are produced in pulses by firing protons at a spinning liquid mercury target. Different pulses have different amounts of neutrons, so the gamma ray detector signals need to be normalized with the number of neutrons produced. There are two ways to do this. The first way is to measure the neutrons with detectors at our target. This is currently being done, but is indirect and could cause false asymmetries. The other way is to measure the number of protons before they collide with the mercury target by measuring the proton current. This can be converted directly to the number of neutrons going through the hydrogen target. My project for the summer was to get the proton current into our experiment's data stream.

There is a neutron pulse every sixtieth of a second and the proton current needs to be measured for each pulse. There are several VMEbus cards that data was being read from, one of which gets the proton current for each pulse every sixtieth of a second. There is a VMEbus card which gets data from the spallation neutron source every 1/60 seconds. Among this data is the proton current that is needed from the file. Before I started, there was a program that counts pulses, then reads values for several other cards at each pulse. I modified this program so that it reads all the data on the card that has the proton current.

Another card generates a signal every time there is a pulse. The program counts out each pulse. It sits in a loop waiting until it gets the signal that represents a pulse.

When a pulse is received, the main program calls a function for each card consecutively. The function creates a memory map to the address space containing the data for each card. It then copys the data from the card, word at a time, into an array reserved for its data. When the function exits, it copies the data from the card-specific function into a larger array used to combine the data from each card. From this main array, the data is copied into a file.

The program can also be modified to get the proton current as it updates. The program is currently relying on pulses from another card to tell it when to grab data. This should work, but it would be more reliable to use the card with the proton current to find out when it updates. This would make sure it is updating and make sure data is read exactly one time per update. The beam is currently off, so there will be no real data until August. The program will be tested and used in the production runs this fall.