6 GeV Parity Violating Deep Inelastic Scattering at Jefferson Laboratory

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Abstract. The 6 GeV Parity Violating Deep Inelastic Scattering (PVDIS) experiment has measured a 10^{-4} level asymmetry through polarized electron scattering off a liquid deuterium target with a beam energy of 6 GeV. This experiment has a goal of measuring a combination of the product of the weak neutral couplings of the electron and the quark with a factor of six improvement in precision over world data. Precise data for the couplings are essential to search for physics beyond the Standard Model. The experiment took place in Hall A at Thomas Jefferson National Accelerator Facility (Jefferson Laboratory) and data collection was completed in the end of 2009. A highly specialized counting data acquisition system with an inherent particle identification was developed and utilized. We have taken data at two Q^2 points in order to possibly address the hadronic correction due to higher twist effects. An overview of the experiment will be presented.

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INTRODUCTION

Nature distinguishes between left and right. That is where parity violation experiments, like PVDIS, find their scope. The objective of the 6 GeV PVDIS experiment (E08-011) is to measure the coupling constant combination $2C_{2u} - C_{2d}$ with an unprecedented accuracy by measuring the PVDIS asymmetry better than 4% statistical accuracy using a polarized electron beam on an unpolarized liquid deuterium target. Here $C_{2q} = g_V^e g_A^q$, with $q = u, d$ indicating an up or a down quark, is a coupling constant, g_V^e is the electron vector coupling and g_A^q is the quark axial coupling. The coupling constant combination appears in the expression for the parity violating asymmetry (A_{PV}) for deep inelastic scattering (DIS) of electrons from a liquid deuterium target as shown below:

$$\begin{aligned} A_{PV} &= \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} \\ &= \left(\frac{3G_F Q^2}{\pi\alpha^2\sqrt{2}}\right) \frac{2C_{1u}[1+R_c(x)] - C_{1d}[1+R_s(x)] + Y(2C_{2u} - C_{2d})R_v(x)}{5 + R_s(x) + 4R_c(x)}, \end{aligned}$$

where σ_+ and σ_- are the left-handed and right-handed electron scattering cross-sections, respectively, Q^2 is the negative of the four-momentum transfer squared, G_F is the Fermi weak coupling constant, α is the fine structure constant, Y is a kinematic factor, $R_{S,C}$ and R_V are related to sea- and valence-quark distribution functions, and x is the Bjorken scaling variable (for details see Ref. [1, 2, 3]). The magnitude of this asymmetry is approximately Q^2 times 100 parts per million.

The data taking of the experiment took place in experimental Hall A at Jefferson Laboratory and was completed in December 2009. The experiment was performed by using two high resolution spectrometers, with their standard settings [5], at two Q^2 points: the first Q^2 point being 1.1 (GeV/c)^2 with incident electron energy $E = 6.0$ GeV, scattered electron energy $E' = 3.66$ GeV, Bjorken $x = 0.25$, and scattered electron angle $\theta = 12.9°$, and the second Q^2 point being 1.9 (GeV/c)^2 with $E = 6.0$ GeV, $E' = 2.63$ GeV, $x = 0.30$, and $\theta = 20.0°$. Both Q^2 points used about 89% polarized electron beam about $90 - 115$ μA on a 20 cm long deuterium target. The two Q^2 data points can be used to extract experimental results for the hadronic correction, $c(x)$, due to higher-twist effects

$$A_{pv}(x,Q^2) = A_{pv}(x)(1 + c(x)/Q^2),$$

whose value is believed to be impossible to get from the first principles [4]. The plan is to find asymmetry at low Q^2 point and then set a limit on higher twist there. Next, use that higher twist while measuring asymmetry at the high Q^2 point.

INSTRUMENTATION

The experiment utilized the standard Hall A instrumentation consisting of Compton and Moller polarimeters for measuring (and monitoring) beam polarization, target chamber consisting of a production target (liquid deuterium) along with other calibration targets, and two high resolution spectrometers. Each spectrometer had a detector package comprising of two vertical drift chambers for tracking, two scintillator planes for main triggers, and a set of particle identification detectors made up of a gas-cerenkov and two layers of lead-glass detectors. The tracking chambers were used only for some calibration runs at low event rate to check tracking efficiency, and they were turned off during production runs suspecting that they could not take a high event rate without being damaged. Lumi monitors, installed downstream of the target, were also used to monitor beam and target noise.

DEADTIME AND ASYMMETRY MEASUREMENT

This was the first time that a scaler based counting data acquisition (DAQ) system was implemented at Jefferson Lab for an experiment bearing an expected high event rate of about a mega hertz. The particle identification capability for identifying electrons and pions was included in the DAQ hardware. The main purpose of the counting DAQ was to take a high event rate data by keeping the deadtime negligible (<1%) with about $< 0.3\%$ accuracy so that it may not contribute anything significant to the accuracy in the physics asymmetry of the experiment.

For the deadtime measurement, two different resolution times of the electronic modules were used: 30 ns (“narrow path”) and 100 ns (“wide path”). Subsequent events falling within the resolution time of the previous events cannot be recorded by the DAQ, causing a counting loss due to the deadtime.

As a specific method to study deadtime, a 10 kHz gate generator signal (called a tagger) was combined with all lead-glass (preshower and total shower) signals using analog summing modules producing a total input rate as R_i. The signal, after passing through a chain of electronics modules including discriminators that define both “narrow path” and “wide path”, was then ANDed with the delayed tagger signal, giving R_o as the output. Now the fractional loss due to deadtime (D) is obtained as $D = 1-(1-p)R_o/R_i$, where p is a correction factor for a pileup effect: when the tagger signal follows closely a detector signal, the DAQ output caused by the detector signal would coincide with the tagger signal, causing a false count that should have been lost due to deadtimes. Fastbus TDCs were used to measure pileup effect, with the pileup factor p being measured by using a TDC spectrum.

In the deadtime analysis, we find that the “wide path” signals appear to be about 100 ns wide as expected, whereas the “narrow path” signals appear to be about $60-80$ ns wide instead of being 30 ns wide. The observation that the “narrow path” signal being unexpectedly wide is due to the reason that the input signal to the “narrow path” was $60-80$ ns wide by itself. The deadtime from the “wide path” boils down to a 0.1% value with a relative uncertainty of 1.2%.

The expected physics asymmetry of this experiment is about 90 ppm for the low Q^2 point and about 170 ppm for high Q^2 point. In the preliminary asymmetry analysis we find that asymmetry plots appear gaussian as expected, the asymmetry values also agree with expectation within statistical errors and flip sign under the flip of polarization direction by using a beam half wave plate. The asymmetry analysis is still in a very preliminary stage, since other ingredients (pileup, deadtime, polarization, etc.) that involve in revealing the accuracy of the asymmetry are being analyzed.

SUMMARY

The Jefferson Lab experiment $E08-011$ has measured the parity violating asymmetry in deep inelastic scattering from a liquid deuterium target. The preliminary result on deadtime analysis shows that the deadtime is well below one percent with a relative accuracy of about a percent. Very preliminary asymmetry analysis shows that the measured asymmetry has met expectation. Active data analysis is underway and final results could be out in about a year.

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