

# $\vec{e}^-$ - $^2\text{H}$ Parity Violating Deep Inelastic Scattering at Jefferson Laboratory at 6 GeV

Ramesh R. Subedi\*, Xiaoyan Deng\*, Huaibo Ding<sup>†</sup>, Robert Michaels\*\*, Paul E. Reimer<sup>‡</sup>, Diancheng Wang\* and Xiaochao Zheng\*

\*University of Virginia, 382 McCormick Rd., Charlottesville, VA 22904, USA

<sup>†</sup>Tsinghua University, Beijing, 100084, P.R.China

\*\*Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA

<sup>‡</sup>Physics Division, Argonne National Laboratory, Argonne, IL 60439, USA

**Abstract.** The upcoming parity violating deep inelastic scattering (PVDIS) experiment E08-011 in Hall A at Thomas Jefferson National Accelerator Facility (Jefferson Lab) aims to measure a combination of the axial hadronic couplings of the electron 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 will measure a  $10^{-4}$  asymmetry using polarized electron scattering from deuterium with a beam energy of 6 GeV. Recent progress on the preparation for this experiment, with an emphasis on the tests of the data acquisition system and the capability of measuring a small asymmetry, deadtime, and pileup effects are presented.

**Keywords:** parity, asymmetry, Standard Model

**PACS:** 21.10.Hw, 25.30.-c

## INTRODUCTION

Parity violating electron scattering is one of the centerpieces of Jefferson Lab's physics programs. The goal of the PVDIS experiment (E08-011) is to measure precisely the asymmetry in parity violating deep inelastic scattering of a polarized electron on an unpolarized liquid deuterium target. This asymmetry is sensitive to the effective vector electron axial quark and axial electron vector quark couplings, the former of which is extremely poorly constrained by experimental data.

With  $\sigma_+$  and  $\sigma_-$  as the left-handed and right-handed electron cross-sections, respectively, and  $Q^2$  as the negative of the square of the four-momentum transfer, the parity violating asymmetry ( $A_{pv}$ ) is given as

$$A_{pv} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} \cong Q^2 [100 \text{ ppm/GeV}^2].$$

Taking effective coupling constants  $C_{iq}$  in the context of the Standard Model as:

$$\begin{aligned} C_{1u} &= g_a^e g_v^u = -\frac{1}{2} + \frac{3}{4} \sin^2(\theta_w), & C_{2u} &= g_v^e g_a^u = -\frac{1}{2} + 2 \sin^2(\theta_w), \\ C_{1d} &= g_a^e g_v^d = \frac{1}{2} - \frac{2}{3} \sin^2(\theta_w), & C_{2d} &= g_v^e g_a^d = \frac{1}{2} - 2 \sin^2(\theta_w), \end{aligned}$$

the important possible extraction of the experiment will be a high precision effective coupling constant combination ( $2C_{2u} - C_{2d}$ ) from  $A_{pv}$ :

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

where  $G_F$  is the Fermi weak coupling constant,  $Y$  is a kinematic factor,  $R_s$  and  $R_v$  are sea- and valence-quark distribution functions (details in Ref. [1, 2]).

Another possible outcome of the experiment would be to extract an experimental result for the hadronic correction,  $c(x)$ , from 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[3].

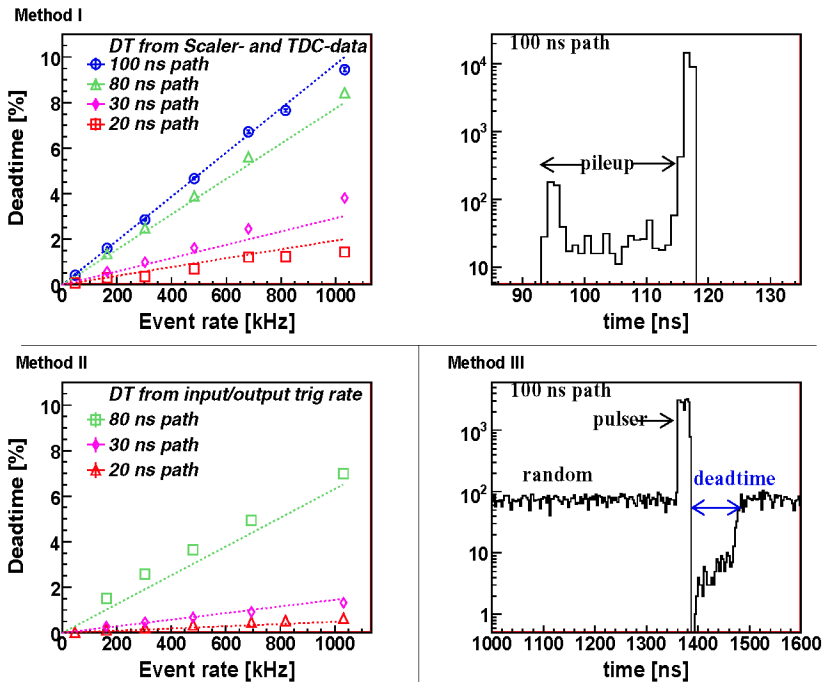
The data will be taken in Hall A using two standard spectrometer setups[4] at two  $Q^2$  points of 1.10 (with incident electron energy  $E = 6.0$  GeV, scattered electron energy  $E' = 3.66$  GeV, Bjorken  $x = 0.25$ , and scattered electron angle  $\theta = 12.9^\circ$ ) and 1.90 (with  $E = 6.0$  GeV,  $E' = 2.63$  GeV,  $x = 0.30$ , and  $\theta = 20.0^\circ$ ) ( $\text{GeV}/c$ )<sup>2</sup> using an 80% polarized electron beam of 85  $\mu\text{A}$  on a 25-cm long deuterium target. The lowest expected physics asymmetry from the experiment is about 100 parts per million (ppm).

## DEADTIME AND ASYMMETRY MEASUREMENTS

This experiment is introducing a scaler-based counting data acquisition (DAQ) system for the first time at Jefferson Lab. The new counting DAQ is essential, since the expected event rate of the experiment is about 0.5 MHz for each spectrometer and the background rate from pion electroproduction is high. The use of the conventional counting DAQ, which handles rates up to 4 kHz, is impossible. And the integrating DAQ used by previous parity violation experiments at JLab cannot reject pion backgrounds. The new DAQ will perform online particle identification and count electron events for a period of 30 msec helicity window in the scaler-readout. The scaler-readout is virtually deadtime-free, the only deadtime involved is from the electronic modules used.

The DAQ system has been assembled and a series of tests have been performed to determine its deadtime and to evaluate its performance in measuring small asymmetries. For the deadtime measurement, two different resolution times of the electronic modules were used: 20 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 counting losses due to the deadtime.

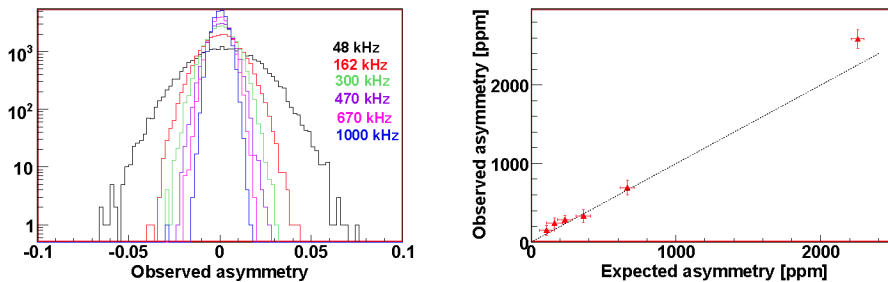
Three methods were employed to measure the deadtime. The results are shown in Fig.1. In method-I, a pulser signal (called a tagger) with rate  $R_i$  was mixed (ORed) with a high rate random pulse ranging from a few Hz to a few MHz obtained from a photomultiplier tube (PMT). The mixed signal was then input to the PVDIS DAQ. The output trigger from the PVDIS DAQ was ANDed with the tagger giving  $R_o$  as the output. The fractional loss due to deadtime ( $D$ ) was obtained as  $D = 1 - (1 - p)R_o/R_i$ , where  $p$  is a correction factor for the pileup effects: when the tagger signal follows closely a random PMT signal, the DAQ output caused by the PMT signal would co-incide with the tagger



**FIGURE 1.** Results of deadtime measurements from three methods. Dotted lines show the expected fractional count loss due to deadtime as a function of the event rate. *Top-left:* results from method-I. *Top-right:* pileup appearing in the timing spectrum of the output trigger with respect to the reference tagger signal. *Bottom-left:* results from method-II. An intrinsic 15 ns deadtime in the input rate measurement was added to each point. *Bottom-right:* results from method-III.

signal, causing a false count that should have lost due to deadtimes. The pileup factor  $p$  was measured by the TDC spectrum as shown in the top-right pad in Fig.1. If there was no pileup, only the right-side peak would show up, hence the integral of the events other than this peak would correspond to the pileup amount. In method-II, the input trigger rate  $r_i$  and the output trigger rate  $r_o$  of the PVDIS DAQ were measured directly in the scaler module. The deadtime was obtained as  $D = 1 - r_o/r_i$ . In method-III, tagger signals are mixed with random PMT signals and then sent to a TDC. Following each tagger signal there exists a “dead-zone” region in the TDC spectrum during which the system does not respond to the random PMT signals, as shown in the bottom-right pad in Fig.1. This dead-zone region provides a measurement of the deadtime. The deadtime measured by these three methods were consistent with each other.

An artificial asymmetry signal, with a magnitude of a few ppm, was prepared using an asymmetry module locally made at Jefferson Lab. This asymmetry signal was mixed (ORed) with a high rate PMT signal and then sent as inputs to the PVDIS DAQ. Shown in Fig.2 are our test results from a few to a thousand ppm and the measured asymmetries agreed with the expected values within their statistical uncertainties.



**FIGURE 2.** *Left:* width of asymmetry-histograms for different event rates. The rate of the innermost trace is the highest and goes decreasing as we march outwards. They agree with the expected width  $\sqrt{\frac{1}{RT}}$  where  $R$  is the trigger rate and  $T$  is the integration time of a helicity window pair. *Right:* Expected and the observed asymmetries. The expected asymmetry of the experiment is in the region of 100 – 200 ppm.

## SUMMARY

Jefferson Lab experiment E08 – 011 will measure the parity violating asymmetry in deep inelastic scattering from a deuterium target. Significant efforts have been used to design, assemble and bench-test the fast-counting DAQ system needed by this experiment. Our tests provided the confidence that the different methods used for the deadtime determination and the technique for asymmetry measurement were working. The new DAQ is currently being tested by taking parasitic data with the electron beam.

## ACKNOWLEDGMENTS

This work is supported in part by the U.S. National Science Foundation and the U.S. Department of Energy (DOE), under Contract No. DE-AC02-06CH1135.

**Notice:** Authored by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177. The U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce this manuscript for U.S. Government purposes.

## REFERENCES

1. R. Michaels, P. Reimer, and X.-C. Zheng,  *$\bar{\nu}$ - $^2H$  Parity Violating Deep Inelastic Scattering at CEBAF at 6 GeV*, Jefferson Lab Hall A Proposal E08-011.
2. X. Zheng, *Parity Violation in Deep Inelastic Scattering at JLab 6 GeV, in PAVI 2006 May 16-20: From Parity Violation to Hadronic Structure and more... (Part III) (Springer, Milos, Greece, 2006)*
3. K. S. Kumar, *Eur. Phys. J. A* **24**, s2, 191-195 (2005).
4. J. Alcorn, et al., *Nucl. Instr. and Meth. A* **522**, 294 (2004).