# Precision Measurement of Parity-Violating Asymmetry in Deep Inelastic e-$^2$H Scattering (PVDIS) Using a 6 GeV Beam at JLab

— Low energy tests of the Standard Model of particle physics in the electroweak and hadronic sectors

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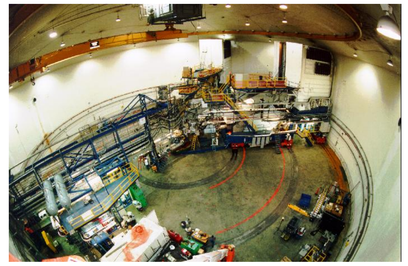


Jefferson Lab Experimental Hall A

## Introduction

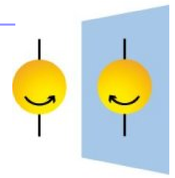
- What is parity violation?
  - The parity symmetry states that the physical laws behind all natural phenomena must be the same as those behind their mirror images.
  - It has been long confirmed that parity is conserved in strong and electromagnetic interactions. However, the postulate that parity is violated in weak interactions was proposed by Lee and Yang in 1956, and was soon confirmed experimentally by Wu.

Tsung-Dao Lee

Chen-Ning Yang

Chien-Shiung Wu

A polarized electron and its mirror image



- What is PV Deep Inelastic electron Scattering (PVDIS)?
  - For polarized electrons, the mirror image of a left-handed electron is right-handed;
  - There is a difference in scattering probability between left- and right-handed electrons, causing a cross-section asymmetry. This asymmetry comes from the interference term between the photon- and the $Z^0$-exchanges.
  - In deep inelastic scattering, the internal structure of the target nuclei or nucleon is revealed at the quark and gluon level.

$A_{PV}$ =


- PVDIS asymmetry from a deuterium target:

$$A_d = (540\ ppm)Q^2 \frac{2C_{1u}[1+R_C(x)] - C_{1d}[1+R_S(x)] + Y(2C_{2u} - C_{2d})R_V(x)}{5 + R_S(x) + 4R_C(x)}$$

$Q^2$: Four-momentum transfer squared between the electron and the target nucleon

$x$: variable relevant to the nucleon internal structure

$$C_{1u} = g_A^e g_V^u = -\frac{1}{2} + \frac{4}{3}\sin^2(\theta_W) \qquad C_{2u} = g_V^e g_A^u = -\frac{1}{2} + 2\sin^2(\theta_W)$$

$$C_{1d} = g_A^e g_V^d = \frac{1}{2} - \frac{2}{3}\sin^2(\theta_W) \qquad C_{2d} = g_V^e g_A^d = \frac{1}{2} - 2\sin^2(\theta_W)$$

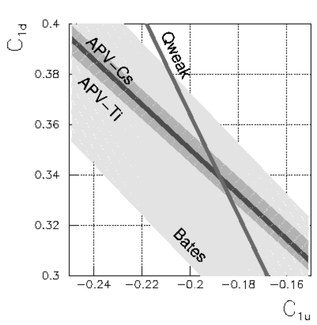
In the SM to the first order

- From $A_d$ one can extract $C_{1,2q}$ and $\sin^2\theta_W$, providing a test of the electro-weak (EW) standard model (SM);
- $R_C(x)$, $R_S(x)$, $R_V(x)$ are related to parton distribution functions, thus $A_d$ is sensitive to internal structure of the nucleon, which is described by QCD – the SM of strong interactions.

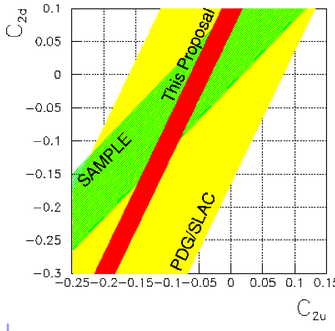
- In 1972, PVDIS result from SLAC E122 was consistent with $\sin^2\theta_W$=1/4, confirmed the Standard Model prediction; However, PVDIS measurement has not been performed again.

## JLab Experiment 05-007

- The ultimate, long term goal of the JLab PVDIS program is to study both the Standard Model of EW interactions and hadronic phenomena.
- Our first step is to use a 6 GeV beam -- JLab E05-007 (planned for 2009):
  - Use 85μA, 6 GeV, 80% polarized beam on a 25-cm LD2 target;
  - Two Hall A High Resolution Spectrometers detect scattered electrons;
  - Measure $A_d$ at $Q^2$=1.10 and 1.90 GeV$^2$ to about 2% (stat.), with similar systematic uncertainties.
- Assuming hadronic effects are small and using the expected known values for $C_{1q}$'s, we can extract $2C_{2u}$-$C_{2d}$; Will also provide crucial guidance to the 12 GeV program.

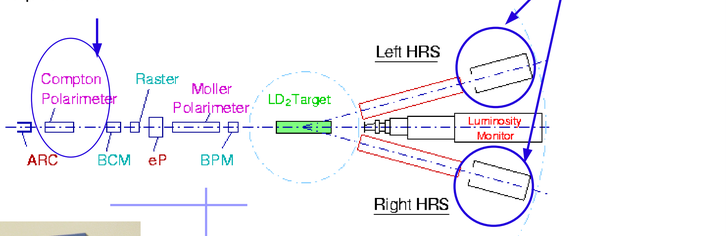



Expected best knowledge on $C_{1u}$ and $C_{1d}$ after completion of the future Qweak experiment. This will be used to extract $C_{2q}$'s from E05-007 results.



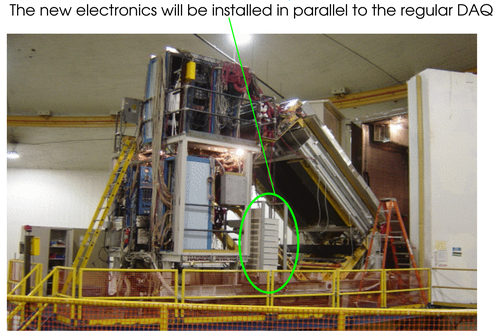

Expected results on $2C_{2u}$-$C_{2d}$ from E05-007, assuming hadronic effects are small

- Experimental upgrade needed:
  - upgrade from IR to green laser to provide 1% precision
  - upgrade to flash-ADC based DAQ to count at ~1MHz rates



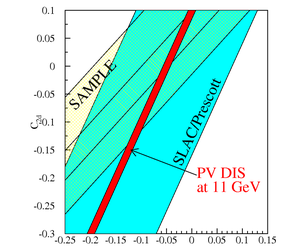

Electronics being assembled at JLab

The new electronics will be installed in parallel to the regular DAQ



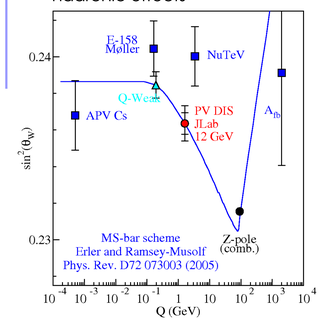
## PVDIS at JLab 12 GeV


- Provide precision test of the Electroweak Standard Model, complementary to other experiments:
  - High-energy direct searches (such as LHC) may discover new particles. However to study their coupling properties we must use low- and medium energy experiments;
  - Moller (SLAC E158, completed): pure-leptonic;
  - Qweak (JLab Hall C, future): only $C_{1q}$'s;
  - Only PVDIS is sensitive to $C_{2q}$'s (new physics in the quark axial coupling).

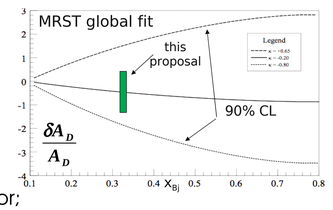



Expected results on $2C_{2u}$-$C_{2d}$ from PR12-07-102, assuming small hadronic effects

Expected results on $\sin^2\theta_W$ from PR12-07-102, assuming small hadronic effects




Expected constraint on CSV from PR12-07-102




- Provide possible direct observation of:
  - Non-perturbative QCD effects in the EW sector;
  - Charge symmetry violation at the quark level.

(All these are not yet calculable in QCD ! Direct observations will be very exciting.)

## References

1 R. Michaels, P.E. Reimer, X. Zheng, et al, JLab Proposal PR05-007.
2 K. Paschke, P.E. Reimer, X. Zheng et al., JLab 12 GeV Proposal PR12-07-102.
3 JLab 12 GeV electroweak physics meeting, Initiative on the large acceptance solenoid device, October 11, 2007.

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