

# MEASUREMENTS OF THE STRANGENESS CONTENT OF THE PROTON THROUGH PARITY VIOLATING ELECTRON SCATTERING AT JLAB

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FOR THE HAPPEX COLLABORATION

We have measured the parity violating asymmetry in the cross section for elastic scattering of longitudinally polarized electrons from protons at 3.36 GeV incident energy and 0.48 GeV/c<sup>2</sup> momentum transfer at JLab. This asymmetry is  $-14.5 \pm 2.3$  ppm, consistent with the Standard Model with no contribution from strange quarks. We extract the combination of strange form factors  $G_E^s + 0.39G_M^s = 0.023 \pm 0.034(\text{stat}) \pm 0.022(\text{syst}) \pm 0.026(\delta G_E^s)$ , where the last error arises from the neutron electric form factor.

## 1 Introduction

This Hall A Proton Parity Experiment (HAPPEX) has measured a parity violating asymmetry, defined as  $A^{\text{PV}} = (\sigma_R - \sigma_L)/(\sigma_R + \sigma_L)$  where  $\sigma_{R(L)}$  is the elastic cross section for Right(Left) handed longitudinally polarized electrons from protons. This asymmetry arises from an interference between electromagnetic and weak neutral amplitudes and is sensitive to the contribution of strange quarks in the proton to vector matrix elements [1]. This asymmetry may be expressed in terms of the Weinberg angle  $\sin^2\theta_W$ , Fermi constant  $G_F$ , Sach's form factors, and kinematic factors as follows [2]:

$$A^{\text{PV}}(\vec{e}, P) = -\frac{G_F|Q|^2}{4\pi\alpha\sqrt{2}} \times [(1 - 4\sin^2\theta_W) - \frac{\epsilon G_E^{\text{P}}(G_E^{\text{n}} + G_E^{\text{S}}) + \tau G_M^{\text{P}}(G_M^{\text{n}} + G_M^{\text{S}}) - (1 - 4\sin^2\theta_W)\epsilon' G_M^{\text{P}} G_A^{\text{P}}}{\epsilon(G_E^{\text{P}})^2 + \tau(G_M^{\text{P}})^2}]$$

The expression contains the neutral weak axial form factor  $G_A^{\text{P}}$  which is obtainable by combining information from neutron beta decay and polarized deep inelastic scattering [3], and which is suppressed in the formula. The strange form factors  $G_E^{\text{S}}$  and  $G_M^{\text{S}}$  are measured by  $A^{\text{PV}}$ .

## 2 Experiment

The experiment was performed in experimental Hall A at the Thomas Jefferson National Accelerator Facility at an incident energy of 3.36 GeV and a momen-

tum transfer of  $0.48 \text{ GeV}/c^2$ , with a  $100\mu\text{A}$  cw beam scattered from a 15 cm long liquid hydrogen target. Two identical 5.5 msr spectrometers at a  $12.5^\circ$  angle detected the scattered electrons in total-absorption detectors in their focal plane. With their  $10^{-4}$  momentum resolution, the spectrometers focused inelastic events well away from our detectors. The polarized beam originated from a GaAs photocathode excited by a circularly polarized laser with a 30 Hz reversal frequency of the polarization line locked to the 60 Hz frequency of AC power. The helicity was structured into pairs of 33.3 msec periods of opposite helicity, where the sign of the helicity of the first in the pair was determined pseudorandomly. Custom-built ADCs integrated and digitized the data from the focal-plane detectors, as well as beam position and current monitors on the beamline.

Of paramount importance in measuring such small asymmetries is maintaining helicity correlated systematics at a level much smaller than our statistical error. Helicity correlated electronic cross talk was monitored from voltage-source and current-source signals, and were negligible. In controlling the electron beam systematics, the two main approaches were: 1) To make the two electron beams for the two helicities as identical as possible. This was achieved with a feedback loop on the helicity correlated charge asymmetry which averaged it below 1 ppm, which was sufficient to maintain small helicity correlations in other beam parameters such as energy or position. 2) We calibrated our spectrometer, beam position monitors, and energy monitor online by using a computer controlled system for modulating the beam position, angle, and energy. The energy was monitored with a beam position monitor at a point of high dispersion in the beam line. Helicity correlated corrections in the beam parameters could then be computed. The helicity correlated position differences were less than 10 nm, and the corrections were a factor of 20 smaller than the statistical error. Therefore we made no corrections and used this analysis to set an upper bound on the systematic error due to beam parameters.

Separate tests at lower beam energy where the scattered rate was high were performed prior to the experiment to verify that the non-statistical fluctuations in the detected flux were small compared to counting statistics. Data were cut only when there was  $\leq 3\mu\text{A}$  of beam current or when the some equipment like magnets was not functioning. Insertion of a half-wave plate in the laser beam was an important test of false asymmetries. The half-wave plate reverses the sign of the electron beam helicity, and hence the physics asymmetry, while leaving several other kinds of systematics (such as electronic cross talk) unchanged. The half-wave plate was inserted and withdrawn repeatedly during the experiment, and data taken in 1-2 day intervals with each state.

Fig. 1 shows a clear correlation between the half-waveplate state and the raw asymmetry, for which the average was  $-5.64 \pm 0.75$  ppm. The beam polarization of  $40 \pm 2\%$  was measured with a Mott scattering apparatus at the low energy end of the accelerator and by a Møller apparatus in front of our target. The resulting experimental asymmetry was  $A = -14.5 \pm 2.0(\text{stat}) \pm 1.1(\text{syst})$  where the main systematic error came from the polarimetry. Further details of this experiment may be found in a forthcoming publication [4].

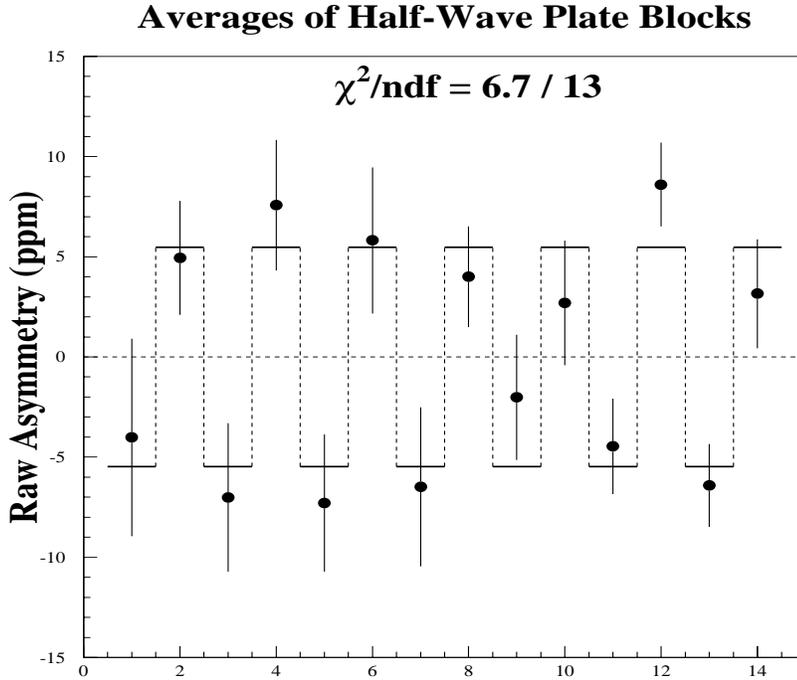


Figure 1: The parity violating asymmetry for different states of the half-waveplate.

### 3 Implications and Outlook

To extract the contribution of strange quarks, we must compare our result with the theoretical expression using parameterizations of the electromagnetic form factors. The biggest uncertainty was in  $G_E^n$  for which we assumed a

50% experimental error corresponding to a 9.6% error in the asymmetry. For the other form factors, a dipole fit was used, and the uncertainty was about 4% in the asymmetry. Radiative corrections were applied. From our data we extract the following combination of strange form factors:  $G_E^s + 0.39G_M^s = 0.023 \pm 0.034(\text{stat}) \pm 0.022(\text{syst}) \pm 0.026(\delta G_E^n)$ . We have listed the error due to  $G_E^n$  separately in anticipation of anticipated improvements in  $G_E^n$ .

This experiment rules out a large strangeness contribution but still allows for a few percent effect. We plan to reduce our error by a factor of 2 in 1999. Jefferson Lab, with its very stable beam conditions and excellent control of systematic errors, has a bright future for parity violation experiments.

## References

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3. R. M. Barnett *et al.*, *Phys. Rev. D* **54**, 1 (1996); K. Abe *et al.*, *Phys. Rev. Lett.* **74**, 346 (1995)
4. These results are being submitted to *Phys. Rev. Lett.*