Results from the G^0 Forward Angle Measurement

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Abstract. The results from the G^0 forward angle experiment are reported in this talk. The parity-violating asymmetry of elastic e-p scattering has been measured within the range of the four-momentum transfer (Q^2) from 0.12 to 1.0 $(\mathrm{GeV/c})^2$, which yields linear combinations of the strange electric and magnetic form factors of the nucleon, $G_E^s + \eta G_M^s$, in the same Q^2 range. The G^0 results, combined with the measurements from other experiments, indicate that G_E^s and G_M^s are both likely non-zero.

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The strange electric and magnetic form factors of the nucleon, G_E^s and G_M^s, can be determined by combining the well-known electromagnetic (EM) form factors of the proton and the neutron, $G_{E,M}^{\gamma,p}$ and $G_{E,M}^{\gamma,n}$, with the less-measured neutral weak form factors of the proton, $G_{E,M}^{Z,p}$ [1]:

$$G_{E,M}^s = (1-4\sin^2\theta_W)G_{E,M}^{\gamma,p} - G_{E,M}^{\gamma,n} - G_{E,M}^{Z,p}. \tag{1}$$

Due to the participation of the neutral weak interaction, elastic e-p scattering carries a small parity violating (PV) asymmetry, which gives direct access to $G_{E,M}^{Z,p}$. The PV asymmetry can be expressed as

$$A_{PV} = -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\frac{\varepsilon G_E^\gamma(G_E^Z+\eta G_M^Z)-(1-4\sin^2\theta_W)\varepsilon' G_M^\gamma G_A^e}{\varepsilon(G_E^\gamma)^2+\tau(G_M^\gamma)^2}, \tag{2}$$

(with the "p" superscripts of the form factors suppressed) and

$$\tau = \frac{Q^2}{4M_p^2}, \varepsilon = \left(1+2(1+\tau\tan^2\frac{\theta_e}{2})\right)^{-1}, \varepsilon' = \sqrt{\tau(1+\tau)(1-\varepsilon^2)} \text{ and } \eta = \frac{\tau G_M^\gamma}{\varepsilon G_E^\gamma}. \tag{3}$$

In Eqn. 2, G_A^e is the axial form factor of the proton as seen by an electron. If one treats both the EM and the axial form factors as known, a measurement of A_{PV} determines $G_E^Z + \eta G_M^Z$, immediately leading to $G_E^s + \eta G_M^s$ using Eqn. 1.

G^0 is an experiment at Jefferson lab making precise measurements of these PV asymmetries [2]. A longitudinally polarized electron beam with ∼73.7% polarization, 3.03 GeV energy and ∼40 μA current was used, with micro-bunches separated by 32 ns. The helicity of the beam was alternated at 30 Hz. The target was a 20 cm long, unpolarized liquid hydrogen target, located in the center of a superconducting toroidal magnet. The scattered particles with positive charge were focused onto an array of scintillating detectors located at the focal plane of the spectrometer. These detectors covered the elastic Q^2 range of $0.12-1.0$ $(\mathrm{GeV/c})^2$. The particle identification (π^+, inelastic and elastic protons) was made via their different time-of-flight. The electronics counted individual particles from which a time-of-flight histogram for each beam helicity state was constructed. The PV asymmetry is the relative difference of the detector yields between the two beam helicities.

Careful corrections had to be made to the raw asymmetries. The two most significant corrections were due to the contaminations of the leakage beam intended for other experimental halls (with different time structure), and the background underneath the elastic peak [2, 9]. The final physics asymmetries as a function of Q^2 are plotted in Fig. 1. On each data point, the inner error bar is the statistical uncertainty, and the outer one is the combined statistical and the point-point systematic uncertainty. The upper gray band represents the global systematic uncertainty. The black curve is the non-vector-strange asymmetry, A_{NVS}, calculated by setting both G_E^s and G_M^s to zero, with the parameterizations of the nucleon EM form factors from [10]. $G_E^s + \eta G_M^s$, extracted from the difference between the measured asymmetries and A_{NVS} in Fig. 1, is displayed in Fig. 2. We note that $\eta \sim 0.94 Q^2$ for G^0 forward angle kinematics. The inner and outer error bars on the data points, and the upper gray band share the same nature as those in Fig. 1. The lower light-gray band is the uncertainty due to the electroweak radiative corrections to the PV asymmetries. The degree to which the non-vector-strange line ($G_E^s + \eta G_M^s = 0$) would shift resulting from different EM form factor parameterizations is represented by the two dashed curves (pink: [11], green: [12]). Finally, a χ^2 test based on the G^0 data, taking into account both the random and correlated errors in Fig. 2, disfavors the hypothesis of $G_E^s + \eta G_M^s = 0$ with 89% confidence level.

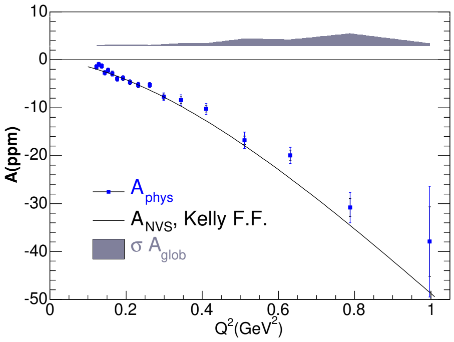


FIGURE 1. The physics asymmetry vs. Q^2 measured in the G^0 forward angle experiment. The black curve is the non-vector-strange asymmetry. See text for details.

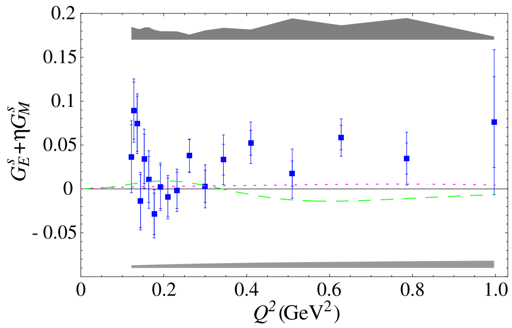
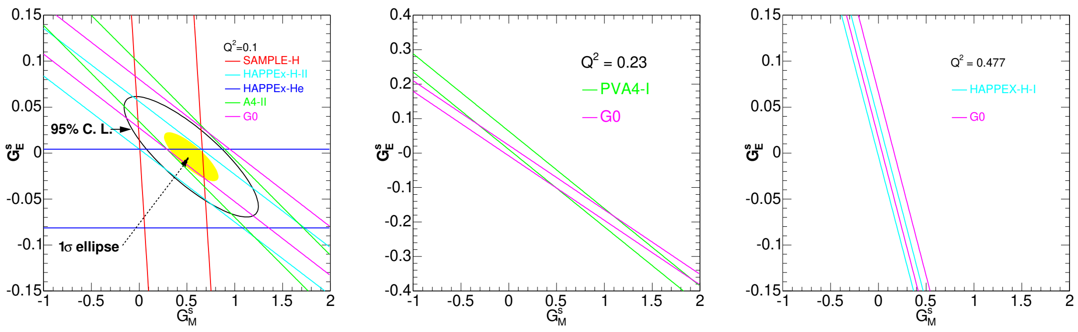


FIGURE 2. The extracted $G_E^s + \eta G_M^s$ vs. Q^2. The dashed lines shows the impact of different parametrization of the EM form factor of the nucleons. See text for details.

The Q^2 range of G^0 overlaps with other existing measurements at 0.1, 0.23 and 0.477 $(\mathrm{GeV/c})^2$. The data at $Q^2 = 0.1$ $(\mathrm{GeV/c})^2$ from G^0 [2], SAMPLE [3], HAPPEx [7, 8] and PVA4 [5] are shown Fig. 3(a). All five measurements agree, and in combination they lead to $G_M^s = 0.55 \pm 0.28$ (G_E^s is consistent with zero within precision), leading to an approximately -10% contribution of strange quarks to the proton's magnetic moment at the 2σ level. The 1σ and 95% confidence contours are also drawn in the figure.

The world data at Q^2 =0.23 (GeV/c)^2 (G^0 [2] and PVA4 [4]) and 0.477 (GeV/c)^2 (G^0 [2] and HAPPEx [6]) are shown in Figs. 3(b) and 3(c), respectively. Although more measurements are needed at these two points to independently determine G_E^s and G_M^s, the existing data are also in excellent agreement.



(a) $Q^2 = 0.1$ *(GeV/c)*^{2} (b) $Q^2 = 0.23$ *(GeV/c)*^{2} (c) $Q^2 = 0.477$ *(GeV/c)*^{2}

FIGURE 3. *The constraints of the world data in* (G_M^s, G_E^s) *space at three* Q^2*s. See details in [9].*

In Fig. 2, the positive data in the lowest Q^2 bins are in accord with a *positive* G_M^s indicated by Fig. 3(a). The decreasing trend of the data around 0.2 (GeV/c)^2 (with an increasing η) suggests that G_E^s might be *negative* around this region. The results in Fig. 3(b) also provide some support to this speculation. There is a positive trend of $G_E^s + \eta G_M^s$ at higher Q^2, consistent with HAPPEx (Fig. 3(c)). The experiments together indicate that both G_E^s and G_M^s are non-zero and Q^2-dependent.

G^0 backward angle experiment will be started in 2006 to measure the PV asymmetries on both hydrogen and deuterium at Q^2 =0.23 and 0.63 (GeV/c)^2. The programs of PVA4 and HAPPEx are also continuing. These measurements will allow clean separations of G_E^s and G_M^s at different Q^2 values in the near future.

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