Strange Quark Contributions to Nucleon Structure?
Results from the Forward G00 Experiment

Goals of G0 Experiment:

• Determine $Q^2$ dependence of a combination of $G_E^s$ and $G_M^s$ over range $0.1 \leq Q^2 \leq 1.0 \text{ GeV}^2$

• Determine $G_E^s$ and $G_M^s$ separately for 3 specific $Q^2$ values
Results from the Forward G0 Experiment

Outline

• Quark flavor contributions from parity-violating electron scattering

• Experimental setup

• Analysis

• G0 results

• Combination with SAMPLE, HAPPEX, PVA4 measurements
G0 Collaboration


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Quark flavor contributions and parity-violating electron scattering
Quark Currents in the Nucleon

- Measure $G_{\gamma,p}^Z, G_{\gamma,n}^Z, G_{\gamma,n}^Z$:
  \[
  G \sim \langle N | \sum_i e_i \bar{q}_i \Gamma_{\mu} q_i | N \rangle
  \]

  - e.g.
    \[
    G_{E,M}^{\gamma,p} = \frac{2}{3} G_{E,M}^{u,p} - \frac{1}{3} \left( G_{E,M}^{d,p} + G_{E,M}^{s,p} \right)
    \]

  - note
    \[
    \begin{aligned}
    G_{E,M}^{u,p} &= G_{E,M}^{d,n} \\
    G_{E,M}^{d,p} &= G_{E,M}^{u,n} \\
    G_{E,M}^{s,p} &= G_{E,M}^{s,n}
    \end{aligned}
    \]
    charge symmetry

  (see G. A. Miller PRC 57 (98) 1492.)

then

\[
\begin{aligned}
G_{E,M}^{u} &= \left( 3 - 4 \sin^2 \theta_W \right) G_{E,M}^{\gamma,p} - G_{E,M}^{Z,p} \\
G_{E,M}^{d} &= \left( 2 - 4 \sin^2 \theta_W \right) G_{E,M}^{\gamma,p} + G_{E,M}^{\gamma,n} - G_{E,M}^{Z,p} \\
G_{E,M}^{s} &= \left( 1 - 4 \sin^2 \theta_W \right) G_{E,M}^{\gamma,p} - G_{E,M}^{\gamma,n} - G_{E,M}^{Z,p}
\end{aligned}
\]

dropping the $p$ superscripts on the left.
Parity-Violating Electron Scattering

- $G^{Z,p}$ contributes to electron scattering

\[
\sigma \propto \left| M^\gamma + M^Z \right|^2
\]

- interference term: **large** $M^\gamma \times \text{small} \ M^Z$

- Interference term violates parity: use $(\bar{e}, e')$

\[
A^{pv} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha} \frac{A_E + A_M + A_A}{\epsilon(G_E^\gamma)^2 + \tau(G_M^\gamma)^2}
\]

where

\[
A_E = \epsilon(\theta) G_E^\gamma G_Z^Z, \quad A_M = \tau G_M^\gamma G_M^Z
\]
\[
A_A = -\left(1 - 4\sin^2 \theta_W\right) \epsilon'(\theta) G_M^\gamma G_A^e
\]

\[
\epsilon(\theta) = \left[1 + 2(1 + \tau)\tan^2(\theta/2)\right]^{-1},
\]
\[
\tau = \frac{Q^2}{4M_p^2},
\]
\[
\epsilon'(\theta) = \sqrt{\tau(1 + \tau)(1 - \epsilon^2)}
\]
## Summary of PV Electron Scattering Experiments

<table>
<thead>
<tr>
<th>Lab/Expt</th>
<th>target</th>
<th>$Q^2$ GeV$^2$</th>
<th>$A_{phys}$ ppm</th>
<th>Sensitivity</th>
<th>Status</th>
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<tbody>
<tr>
<td><strong>MIT-Bates</strong></td>
<td></td>
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<tr>
<td>- SAMPLE</td>
<td>$H_2$</td>
<td>0.10</td>
<td>8.0</td>
<td>$\mu_s + 0.4 G_A^Z$</td>
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<td>- SAMPLE-II</td>
<td>$D_2$</td>
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<td><strong>JLab Hall A</strong></td>
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<tr>
<td>- HAPPEX</td>
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<td>- HAPPEXII</td>
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<td>1.5</td>
<td>$P_S + \mu p H_S$</td>
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<tr>
<td>- Helium-4</td>
<td>$^4$He</td>
<td>0.11</td>
<td>10.0</td>
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<td>- Helium-4</td>
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<td>0.60</td>
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<tr>
<td>- Lead-208</td>
<td>$^{208}$Pb</td>
<td>0.01</td>
<td>0.5</td>
<td>neutron skin</td>
<td>2006</td>
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<td><strong>Mainz</strong></td>
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<td></td>
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<tr>
<td>- A4</td>
<td>$H_2D_2$</td>
<td>0.1-0.25</td>
<td>1.0-10.0</td>
<td>$G_E^s, G_M^s$</td>
<td>published x2, running</td>
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<td><strong>Jlab Hall C</strong></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>- G0</td>
<td>$H_2D_2$</td>
<td>0.1-1.0</td>
<td>1.0-30.0</td>
<td>$G_E^s, G_M^s$</td>
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<tr>
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<td>0.3</td>
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<td><strong>SLAC</strong></td>
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<td>- E158</td>
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<td>0.02</td>
<td>0.2</td>
<td>Qw</td>
<td>published</td>
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</tbody>
</table>

K. Kumar

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Experimental setup
G0 Experiment Overview

- Measure $G_E^Z, G_M^Z$
  - different linear combination of $u$, $d$ and $s$ contributions than e.m. form factors
  $\rightarrow$ strange quark contributions to sea

- Measure forward and backward asymmetries
  - recoil protons for forward measurement
  - electrons for backward measurements
    - elastic/inelastic for $^1$H, elastic for $^2$H

- Forward measurements complete (101 Coulombs)

$E_{\text{beam}} = 3.03 \text{ GeV}, 0.33 - 0.93 \text{ GeV}$
$I_{\text{beam}} = 40 \mu\text{A}, 80 \mu\text{A}$
$P_{\text{beam}} = 75\%, 80\%$
$\theta = 52 - 76^0, 104 - 116^0$
$\Delta \Omega = 0.9 \text{ sr}, 0.5 \text{ sr}$
$l_{\text{target}} = 20 \text{ cm}$
$L = 2.1, 4.2 \times 10^{38} \text{ cm}^{-2} \text{ s}^{-1}$
$A \sim -1 \text{ to } -50 \text{ ppm}, -12 \text{ to } -70 \text{ ppm}$
G0 in Hall C

- Superconducting magnet (SMS)
- Beam monitoring girder
- Cryogenic supply
- Scintillation detectors
- Cryogenic target ‘service module’
- Electron beamline
Polarized Injector/Accelerator

- Challenging specifications – all met!
  - 32 ns pulse spacing for t.o.f.
  - 40 µA beam current
    - higher bunch charge
  - run concurrently with small energy spread for Hall A

<table>
<thead>
<tr>
<th>Beam Parameter</th>
<th>Achieved</th>
<th>“Specs”</th>
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</thead>
<tbody>
<tr>
<td>Charge asymmetry</td>
<td>-0.14 ± 0.32 ppm</td>
<td>1 ppm</td>
</tr>
<tr>
<td>x position differences</td>
<td>3 ± 4 nm</td>
<td>20 nm</td>
</tr>
<tr>
<td>y position differences</td>
<td>4 ± 4 nm</td>
<td>20 nm</td>
</tr>
<tr>
<td>x angle differences</td>
<td>1 ± 1 nrad</td>
<td>2 nrad</td>
</tr>
<tr>
<td>y angle differences</td>
<td>1.5 ± 1 nrad</td>
<td>2 nrad</td>
</tr>
<tr>
<td>Energy differences</td>
<td>29 ± 4 eV</td>
<td>75 eV</td>
</tr>
</tbody>
</table>

New Tiger laser system for G0

JLab polarized injector

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Leakage Beam Measurement

- Use “cut0” region in actual data to measure leakage yield, asymmetry throughout run
- Cut0 certified during test runs with only leakage beam
  - uncertainty determined in 3 ways
    - compare lumi monitor (direct) measurements to cut0
    - cut3 asymmetry independent of beam current (10, 20, 40 µA)
    - variation of corrected cut3 asymmetry (should be constant over run)
  - methods consistent at 20% level
- $\delta A_{\text{false,leak}} = -0.71 \pm 0.14$ ppm

<table>
<thead>
<tr>
<th>$I$ (µA)</th>
<th>$A_{3,\text{meas}}$ (ppm)</th>
<th>$A_{3,\text{corr}}$ (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>0.14±0.43</td>
<td>-2.5±0.43</td>
</tr>
<tr>
<td>20</td>
<td>-29.6±2.1</td>
<td>-7.2±2.1</td>
</tr>
<tr>
<td>10</td>
<td>-51.3±3.9</td>
<td>-9.5±3.9</td>
</tr>
</tbody>
</table>

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Beam Polarization

- Beam polarization measured with interleaved Møller measurements
  - std Hall C polarimeter (M. Hauger, et al. NIM A462 (2001) 382.)
  - apply for groups of runs as shown
  - average: P = 73.7%

<table>
<thead>
<tr>
<th>Source</th>
<th>Rel. uncertainty (%)</th>
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</thead>
<tbody>
<tr>
<td>Target</td>
<td>0.42</td>
</tr>
<tr>
<td>Leakage</td>
<td>0.2</td>
</tr>
<tr>
<td>Current extrap’n</td>
<td>1</td>
</tr>
<tr>
<td>Beam</td>
<td>0.52</td>
</tr>
<tr>
<td>Levchuk</td>
<td>0.3</td>
</tr>
<tr>
<td>Detection</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.32</strong></td>
</tr>
</tbody>
</table>
Timing in the Experiment

Accelerator pulse structure

Beam Helicity
+1  -1

“Quartet” Helicity + - - + or - + + - (random)

“Macropulse”

1/30 s  ~500 µs

Measurement timing

Typical t.o.f. spectrum

Det 8

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• 20 cm LH$_2$, aluminum target cell
• longitudinal flow, $v \sim 8$ m/s, $P > 1000$ W!
• negligible density change < 1.5%
• measured small boiling contribution
  – 260 ppm/1200 ppm statistical width
Spectrometer Optics

- zero magnification along beam axis
- elastic protons dispersed in $Q^2$ along focal surface
- acceptance $0.12 < Q^2 < 1.0 \text{ GeV}^2$ for 3 GeV incident beam
- detector 15 acceptance: 0.44 – 0.88 GeV$^2$
  - 3 $Q^2$ bins at 0.51, 0.63 and 0.78 GeV$^2$
- detector 14: $Q^2 = 0.41, 1.0 \text{ GeV}^2$
- det. 16: no elastic acceptance
  - important for measuring backgrounds
Detectors

- 16 detectors per octant
- Arc shape (const. $Q^2$), protons at normal incidence

- Each detector: scintillator pair
  - BC408: 0.5, 1.0 cm thick
  - 1/8 in. shielding in-between

- PMT at each end of each scintillator
  - XP2262B (NA), XP2282B (Fr)

- Signal: mean-time-front .AND. mean-time-back

- Assembled with ~ 2 mm accuracy
- Octants in light-tight enclosures
Electronics

- Measure time-of-flight target to detectors
- Counting rates $\leq 4$ MHz per scintillator pair
- Fast time encoding
  - NA: dual 500 MHz shift registers $\rightarrow$ scalers (1 ns resolution)
    - “latching time digitizer” (LTD)
  - Fr: flash TDC $\rightarrow$ DSP $\rightarrow$ scalers (1/4 ns resolution)
Electronics Deadtime Corrections

• Residual effect on asymmetry
  – scale factor
  \[ A_{\text{meas}} = \frac{R_+ (1 - \tau R_+) - R_- (1 - \tau R_-)}{R_+ (1 - \tau R_+) + R_- (1 - \tau R_-)} \]
  \[ \approx A \left( 1 - \tau \frac{R_+ + R_-}{2} \right) \]

• A is sum of physics and charge asymmetries
  – helicity-correlated beam current changes corrected in linear regression analysis
  – correction for residual effect \( \sim 0.05 \pm 0.05 \text{ ppm} \) (pt-pt systematic unc.)
Analysis
Analysis Overview

- Blinding Factor
  - Raw Asymmetries, $A_{\text{meas}}$
    - "Beam" corrections:
      - Leakage beam asymmetry
      - Helicity-correlated beam properties
      - Deadtime
      - Beam polarization
  - Background correction
  - Unblinding
    - $A_{\text{phys}}$
    - $Q^2$
    - Elastic form factors
      - $G_E^s + \eta G_M^s$
Forward Data Summary

• 101 Coulombs of parity-quality beam
  – cuts on helicity-correlated beam parameter are
    4 x std. dev. for given run:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>charge asymmetry</td>
<td>600 ppm</td>
</tr>
<tr>
<td>x, y position differences</td>
<td>8, 10 μm</td>
</tr>
<tr>
<td>x, y angle difference</td>
<td>0.6, 1.1 μrad</td>
</tr>
<tr>
<td>energy difference</td>
<td>7.5 keV</td>
</tr>
</tbody>
</table>

• Includes running with both Hall A and Hall B (leakage beam asymmetry measured satisfactorily)

• Corresponds to: 701 h at 40 μA
  19 x 10^6 quartets
  76 x 10^6 MPS
Statistical Properties of the Data

- Asymmetry distributions very clean over range of $10^5$

- Measured and expected widths agree at few % level
Helicity-Correlated Beam Parameters

- Response of spectrometer to beam changes well understood
- Average helicity-correlated beam parameters very small
- False asymmetries due to helicity-correlated beam parameters very small
  - overall about -0.02 ppm
  - largest is 0.01 ppm from residual charge asymmetry
  - uncertainties small as well: 0.01 ppm
Background Overview

- Measure yield and asymmetry of entire spectrum
- Correct asymmetry according to

\[ A_{\text{meas}} = (1 - f) A_{\text{el}} + f A_{\text{back}} \]

where \( A_{\text{el}} \) is the raw elastic asymmetry,

\[ f = \frac{Y_{\text{back}}}{Y_{\text{meas}}} \]

- Actual analysis: \( f = f(t) \)
  - det. 1-14
    - fit \( Y_{\text{back}} \) (poly\(^4\) of degree 4), Gaussian for elastic peak
    - then fit \( A_{\text{back}} \) (poly\(^2\) of degree 2), constant \( A_{\text{el}} \)
  - det. 15
    - interpolate over detectors for \( Y_{\text{back}}, A_{\text{back}} \)
    - fit 3 constants for \( A_{\text{el}} \)
Det 1-14 Background

• Results of 2-step fitting procedure: det 8
  – fit $Y_{\text{back}}$ (poly' of degree 4), Gaussian for elastic peak
  – then fit $A_{\text{back}}$ (poly' of degree 2), constant $A_{\text{el}}$
  – example fits
    • yield: $\chi^2 = 31.1/40$
    • asym: $\chi^2 = 37.5/44$
  – f determined from $Y_{\text{back}}$, $Y_{\text{meas}}$ in subsequent analysis
    • don’t use detailed shape of elastic peak

• Det 14 similar except it has 2 elastic peaks
  – $Q^2 = 0.41, 1.0 \text{ GeV}^2$
Det. 1-14 Background Uncertainty

• Statistical uncertainty includes that from $A_{el}$ and from $A_{back}$

\[ A_{meas} = (1 - f)A_{el} + fA_{back} \]

• Systematic uncertainty: general philosophy
  – vary background yield and asymmetry over plausible ranges
  – consider distributions of results for $A_{el}$
    • unweighted
    • weighted by $\chi^2$
    • systematic uncertainty is average of std. dev. of these two distributions
Det. 1-14 Background Uncertainty

- Background yield varied within “lozenge”
  - use a variety of shapes

- Similar approach for asymmetry
  - vary throughout range
Correlations in Det 1-14 Backgrounds

• Separate point-to-point (pt-pt) uncertainties in background correction from global uncertainties
  – e.g. changing from linear to quadratic model for background asymmetry changes all det.1 -14 asymmetries downward on average

• Again using the distributions of results for $A_{el}$
  – calculate ~ correlation coefficient
  – correlated uncertainty is change in centroid of distribution for given background model compared to width of overall distribution ($\equiv$ total systematic uncertainty)

• For det. 1-14

$$\Delta^2 A_{el,sys} = \Delta^2 A_{el,pt-pt} + \Delta^2 A_{el,lob}$$

$$\Delta^2 A_{el,pt-pt} = \frac{1}{4} \Delta^2 A_{el,sys}$$

$$\Delta^2 A_{el,lob} = \frac{3}{4} \Delta^2 A_{el,sys}$$
Det. 15 Background Yields

- Elastic protons shifted to lower t.o.f.
- Elastic peak broadened because of increased $Q^2$ acceptance
- Interpolate over detector range 12-14, 16
  - take out changing acceptance first
Positive Background Asymmetries

- Det. 12-16 see smoothly varying peak in background asymmetries
  - maximum magnitude ~ +45 ppm

- Source is protons from hyperon weak decay scattering inside spectrometer
  - GEANT simulation with generator for hyperon production based on CLAS data
  - simulate both $\Lambda$ and $\Sigma^{+,0}$ decays
    - $\Lambda$ polarization transfer 100%
    - $\Sigma^{+,0}$ asymmetry scaled by further factor of -1/3 (CG coefficient)
  - simulation explains source; use measured data for actual analysis
Positive Background Asymmetries: GEANT

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Det. 15 Background Asymmetry

• Use smoothed interpolation of $A_{\text{back}}$ from det. 12-14, 16
• Uncertainties are ± 1 detector AND ± 0.5 ns time shift
Det. 15 Asymmetry

- Compare interpolated background asymmetry and data
Correlations in Det. 15 Backgrounds

- Separate point-to-point (pt-pt) uncertainties in background correction from global uncertainties
  - in det. 15, correlations larger because bins are contiguous

- Consider distributions of results for $A_{el}$
  - for variety of randomly generated models determine correlation coefficient

- For det. 15

\[
\Delta^2 A_{el,sys} = \Delta^2 A_{el,pt-pt} + \Delta^2 A_{el,glob}
\]
\[
\Delta^2 A_{el,pt-pt} = \frac{1}{2} \Delta^2 A_{el,sys}
\]
\[
\Delta^2 A_{el,glob} = \frac{1}{2} \Delta^2 A_{el,sys}
\]
Dilution factor and Background Asymmetry

- Smooth, systematic progression
  - dilution factor
  - background asymmetry
  - both averaged over t.o.f.
    for demonstration

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G0 results
Where Were We?

- From HAPPEX H preprint nucl-ex/0506011

![Graph showing data points and error bars with labels for different experiments: MAMI A4, MAMI A4, HAPPEX-I, and HAPPEX-II. The x-axis represents $Q^2 (GeV^2)$ and the y-axis represents a function involving $G_E$, $G_M$, and $\eta(Q^2, E_i)$. The graph includes data points and error bars for each experiment, indicating variations in the measured values.](image-url)
## Experimental Results

- \( A_{\text{phys}} \) corrected for all beam, electronics, background factors

<table>
<thead>
<tr>
<th>Det</th>
<th>( Q^2 ) (GeV(^2))</th>
<th>( A_{\text{phys}} ) (ppm)</th>
<th>( \Delta A_{\text{stat}} ) (ppm)</th>
<th>( \Delta A_{\text{sys,pt}} ) (ppm)</th>
<th>( \Delta A_{\text{sys,glob}} ) (ppm)</th>
<th>( f ) (ppm)</th>
<th>( \Delta A_{\text{meas}} ) (ppm)</th>
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<tr>
<td>1</td>
<td>0.122</td>
<td>-1.513</td>
<td>0.436</td>
<td>0.224</td>
<td>0.176</td>
<td>0.061</td>
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<td>2</td>
<td>0.128</td>
<td>-0.972</td>
<td>0.409</td>
<td>0.198</td>
<td>0.173</td>
<td>0.084</td>
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<td>3</td>
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<td>-1.298</td>
<td>0.424</td>
<td>0.174</td>
<td>0.170</td>
<td>0.085</td>
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<td>4</td>
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<td>0.077</td>
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<td>0.324</td>
<td>0.234</td>
<td>0.100</td>
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<td>7c</td>
<td>0.177</td>
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<td>0.205</td>
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<td>-3.850</td>
<td>0.485</td>
<td>0.218</td>
<td>0.192</td>
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<td>0.505</td>
<td>0.301</td>
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<td>0.136</td>
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<td>0.780</td>
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</table>

[http://www.npl.uiuc.edu/exp/G0/Forward](http://www.npl.uiuc.edu/exp/G0/Forward)
Experimental Asymmetries

- “no vector strange” asymmetry, $A_{NVS}$, is $A(G_E^s, G_M^s = 0)$
- inside error bars: stat, outside: stat & pt-pt

http://www.npl.uiuc.edu/exp/G0/Forward
Strange Quark Contribution

- Strange quark contribution to asymmetry

\[ G_E^s + \eta G_M^s = \frac{4\pi\alpha\sqrt{2}}{G_F Q^2} \frac{\tau G_E^p}{\epsilon G_E^p (1 + R_V^{(0)})} \left( A_{\text{phys}} - A_{\text{NVS}} \right) \]

\[ \eta(Q^2, E_i) = \frac{\tau G_M^p}{\epsilon G_E^p} \]

http://www.npl.uiuc.edu/exp/G0/Forward
Strange Quark Contribution to Proton

http://www.npl.uiuc.edu/exp/G0/Forward

DHB, 17 June 2005
Strange Quark Contribution to Proton

http://www.npl.uiuc.edu/exp/G0/Forward
Are the G0 Data Consistent with Zero?

• Test hypothesis $G_E^s + \eta G_M^s = 0$
• Simple $\chi^2$ incorrect because of correlated uncertainties

• Instead, generate many copies of data set
  – each data value:
    • value from normal distribution with width = random uncertainty
      PLUS
    • value from normal distribution with width = correlated uncertainty
  – use new choices for each data point for random uncertainty
  – for each data set, use single random number for correlated uncertainty, scale according to our global uncertainty

• Result
  – 11% of resulting $\chi^2$ values for test data sets are larger than that for our data
    • ~ independent of uncertainties used to calculate $\chi^2$
Combination of G0 with SAMPLE, HAPPEX, PVA4
G0 With Other Experiments

• Show all uncertainties
  – short dash: statistical
  – long dash: statistical & overall systematic
  – solid: statistical & overall systematic & model

• Kelly form factors

• \( Q^2 = 0.1 \text{ GeV}^2 \)
  – extrapolate G0 using simple average of \( A_i/Q^2_i \) for first 3 \( Q^2 \) points
    • \( Q^2 = \{0.122, 0.128, 0.136\} \)
    • uncertainties are those of average
  – contours
    • simple prescription (PDG §32.1.2, Eqn. 32.11) using likelihood function
    • \( 1\sigma, 2\sigma \) shown

• \( Q^2 = 0.23 \text{ (PVA4-I)}, 0.477 \text{ (HAPPEX-I) GeV}^2 \)
  – average \( (A - A_{\text{NVS}})/Q^2 \) for three nearest G0 points
    • essentially averaging \( G_E^s + \eta G_M^s \)
    • \( Q^2 = \{0.210, 0.232, 0.262\} \)
    • \( Q^2 = \{0.410, 0.511, 0.631\} \)
World Data @ $Q^2 = 0.1$ GeV$^2$

$G_E = -0.013 \pm 0.028$

$G_M = +0.62 \pm 0.31$

$\pm 0.62$ 2$\sigma$

Contours

1. $1\sigma$, $2\sigma$
2. 68.3, 95.5% CL

Theories

1. Leinweber, et al.
   PRL 94 (05) 212001

2. Lyubovitskij, et al.
   PRC 66 (02) 055204

3. Lewis, et al.
   PRD 67 (03) 013003

   PRD 65 (01) 014016

http://www.npl.uiuc.edu/exp/G0/Forward

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$G_M = +0.55 \pm 0.28$

$G_E = -0.01 \pm 0.03$

This result
World Data @ $Q^2 = 0.23$ GeV$^2$

- PVA4 measurement at $Q^2 = 0.23$ GeV$^2$
  - consistent probable value for $G_M^s$
  - supports negative $G_E^s$

http://www.npl.uiuc.edu/exp/G0/Forward
World Data @ $Q^2 = 0.477$ GeV$^2$

http://www.npl.uiuc.edu/exp/G0/Forward

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Speculation
Simple Fits to World Hydrogen Data

• Fit

\[ G^s_E(Q^2) + \eta(Q^2, E_i)G^s_M(Q^2) = \]
\[ \frac{4\pi\alpha\sqrt{2}}{G_FQ^2} \left( \frac{\epsilon G^p_E + \tau G^p_M}{\epsilon G^p_E(1 + R_V^{(0)})} \right) \left( A_{phys} - A_{NVS}(Q^2, E_i) \right) \]

with simple forms for \( G^s_E \), \( G^s_M \)

\[ G^s_E(Q^2) = \frac{c_2Q^4}{1 + d_1Q^2 + d_2Q^4 + d_3Q^6} \]

à la Kelly

\[ G^s_M(Q^2) = \frac{G^s_M(Q^2 = 0)}{\left(1 + Q^2/\Lambda^s_M^2\right)^2} \]

with

\[ G^s_M(Q^2 = 0) = 0.81 \]

from \( Q^2 = 0.1 \text{ GeV}^2 \) plot, dipole ff

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“Fit” to World Hydrogen Data

- $\chi^2 = 31/20$
“Fit” to World Hydrogen Data

\[ c_2 = -0.51 \pm 0.25 \]
\[ d_1 = -8.5 \pm 0.9 \]
\[ d_2 = 24 \pm 6 \]
\[ d_3 = 1 \]
\[ \Lambda_M^2 = \Lambda^2 / 1.3 \]

Remember the factor of \(-1/3\)
G0 Backward Angle Measurements
G0 Backward Angle Measurements

- Match forward angle range with measurements at 3 momentum transfers

<table>
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<th>$Q^2$</th>
<th>Beam Energy</th>
<th>Target</th>
<th>Rate</th>
<th>Asymmetry</th>
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<td>(MHz)</td>
<td>(ppm)</td>
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<td>D$_2$</td>
<td>0.274</td>
<td>-72</td>
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</table>

- New detectors (scintillator array, Cherenkov): commissioning
- New electronics assembly (tested previously)
- Trigger change to run with standard beam (499 MHz)

Scheduled: Dec 05 – May 06

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Prospective G0 Data @ $Q^2 = 0.8, 0.23 \text{ GeV}^2$

- Run in Dec ’05 at $Q^2 = 0.79 \text{ GeV}^2$ (H and D targets)
- Possible run at $Q^2 = 0.23 \text{ GeV}^2$ next (H alone?)
G0 Summary

• First measurement of parity-violating asymmetries over broad $Q^2$ range
• Excellent performance of accelerator, experimental equipment
• Conservative estimates of uncertainties
  – careful assessment of backgrounds

• Results consistent with previous measurements
• Emerging picture
  – $G_M^S > 0$ at low $Q^2$
  – $G_E^S < 0$ at medium $Q^2$ a possibility
  – $G_E^S + \eta G_M^S$ positive at higher $Q^2$
Acknowledgements

• We gratefully acknowledge the support of our funding agencies
  – DOE (US), NSF (US), IN2P3-CNRS (Fr) and NSERC (CA)

• We would also like to extend sincere thanks to the very strong technical support from many groups
  – Caltech, Illinois, LPSC-Grenoble, IPN-Orsay, TRIUMF

  – especially: JLab Accelerator
    JLab Hall C