E05-009:HAPPEx-III Status Report

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Outline

- Quick Review:
  - Parity Violation and Strange FFs
  - Worldwide Experimental Programs
  - Motivation and Goals of HAPPEx-III
- Proposed Measurement
  - Details
  - Error Budget
- Preparations and Schedule
- Summary

Introduction to PVES

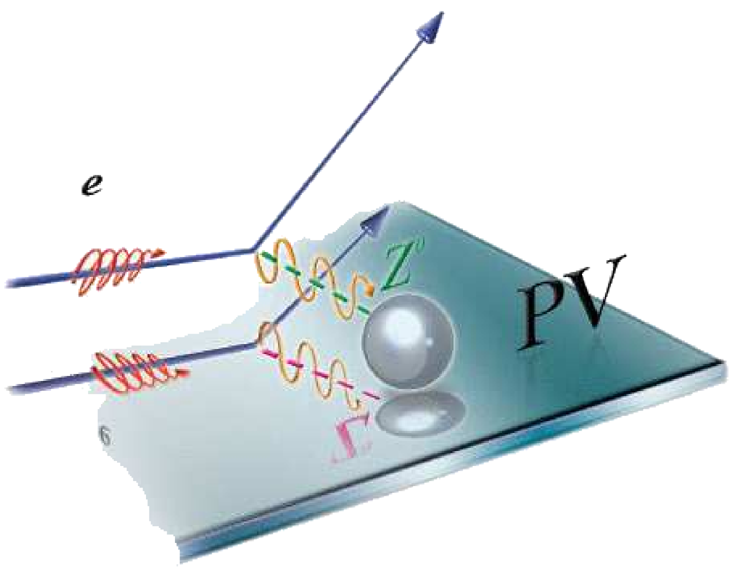
- Parity Violating Electron Scattering (PVES) allows access the the strange sea via an electroweak-interference dominated asymmetry measurement (A_{PV})
- Very challenging measurement requiring:

→ Precise matching of elec. beam charact. for Left vs. Right helicity states

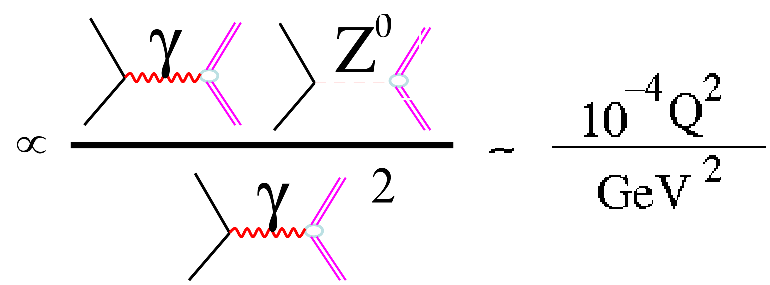
→ Precision non-invasive, continuous beam polarimetry

→ Precision knowledge of Luminosity and spect. acceptances and bkgds

- HAPPEx group very experienced in these measurements and have robust experimental technique



$$A^{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$



Neutral Current Vector Form Factors

Considering a light quark flavor decomposition...

- For electromagnetic scattering:

$\rightarrow G^{\gamma,p}_{E/M} = \frac{2}{3}G^{u,p}_{E/M} - \frac{1}{3}G^{d,p}_{E/M} - \frac{1}{3}G^{s,p}_{E/M}$

- For weak scattering:

$\rightarrow G^{Z,p}_{E/M} = (1 - \frac{8}{3}\sin^2\theta_W)G^{u,p}_{E/M} - (1 - \frac{4}{3}\sin^2\theta_W)G^{d,p}_{E/M} - (1 - \frac{4}{3}\sin^2\theta_W)G^{s,p}_{E/M}$

- Invoke charge symmetry to get the neutron FFs
- Remove $G^{u}_{E/M}$ and $G^{d}_{E/M}$ dependence from $G^{Z}_{E/M}$ and replace with the well measured $G^{\gamma,p}_{E/M}$ and $G^{\gamma,n}_{E/M}$

$\rightarrow G^{Z,p}_{E/M} = (1 - 4\sin^2\theta_W)G^{\gamma,p}_{E/M} - G^{\gamma,n}_{E/M} - G^{s}_{E/M}$

Strange Form Factor Extraction

- Measured A_{PV} is proportional to the neutral current FFs
- The relative contributions of the FFs to A_{PV} depends on experiment kinematics

$$\text{For a proton:} \quad A_{PV} = \frac{-G_F Q^2}{4\pi\alpha\sqrt{2}} \frac{A_E + A_M + A_A}{\sigma_p} \sim \text{few ppm}$$

where

$A_E = \varepsilon G_E^p G_E^Z$ ⟵ most sensitive at forward angles

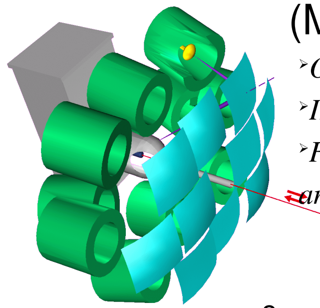
$A_M = \tau G_M^p G_M^Z$ ⟵ contributes everywhere

$A_A = (1 - 4\sin^2\theta_W)\varepsilon' G_M^p \widetilde{G}_A^Z$ ⟵ most sensitive at backward angles

$$\tau = Q^2/4M^2 \qquad \varepsilon = [1 + 2(1+\tau)\tan^2(\theta/2)]^{-1} \qquad \varepsilon' = [\tau(1+\tau)(1-\varepsilon^2)]^{-1/2}$$

- For spinless isoscalar target(such as ^{4}He or ^{12}C), A_{PV} only sensitive to G_E^s (HAPPEx-^{4}He measurement)
- For backward angle scattering with Deuterium target, A_{PV} dominated by the axial FF (G0 backangle measurement)

Worldwide Experimental Programs



SAMPLE
(MIT Bates)

- *Open geometry.*
- *Integrating DAQ.*
- *Forward & back angle meas., H & D.*

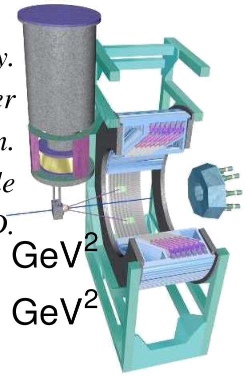
G_E^s , (G_A) at Q^2 = 0.1 GeV^2

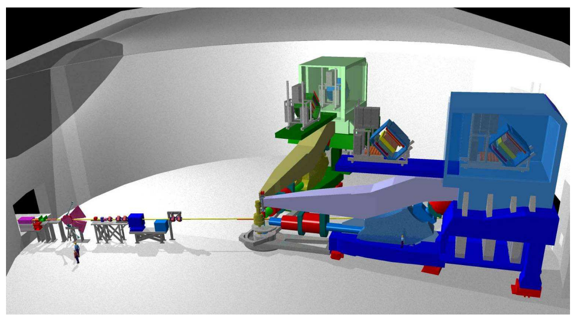
(Mainz)

- *Open Geometry.*
- *Fast counting calorimeter for background rejection.*
- *Forward & back angle meas., H & D.*

$G_E^s + 0.23 G_M^s$ at $Q^2 = 0.23$ GeV^2

$G_E^s + 0.10 G_M^s$ at $Q^2 = 0.10$ GeV^2





HAPPEX
(Jlab)

- *Precision spectrometers.*
- *Integrating DAQ.*
- *Forward angle meas., H & He.*

$G_E^s + 0.39 G_M^s$ at $Q^2 = 0.48$ GeV^2

$G_E^s + 0.08 G_M^s$ at $Q^2 = 0.10$ GeV^2

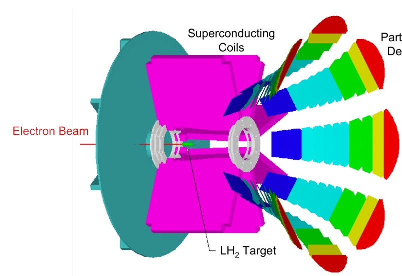
G_E^s at $Q^2 = 0.10$ GeV^2 (^{4}He)

G0 (Jlab)

- *Open geometry.*
- *Fast counting with magnetic spectrometer plus Time of Flight background rejection.*
- *Forward & back angle meas., H & D.*

$G_E^s + \eta G_M^s$ at Q^2 = [0.12, 1.0] GeV^2

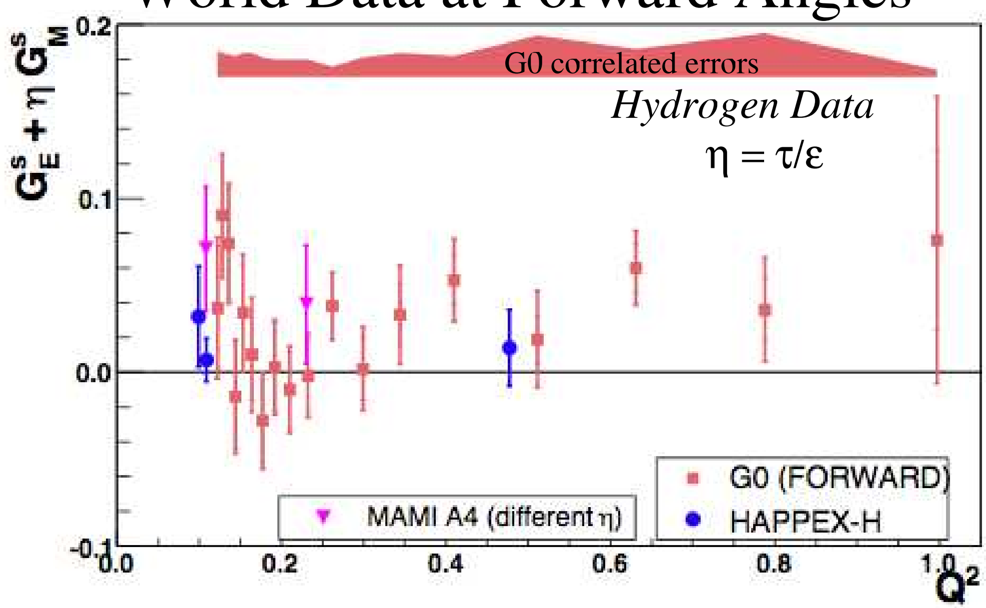
G_M^s , G_A^e at Q^2 = 0.23, 0.62 GeV^2 (results coming soon)



Motivation and Goals of HAPPEx-III

- A definitive probe of nucleon Strangeness at high Q^2 (~ 0.6 GeV^2)
  $\rightarrow$ significant non-zero world data average for $Q^2 > 0.5$ GeV^2
  $\rightarrow$ HAPPEx capabilities–high stats, low syst. errors, and nearly bkgd-free
  $\rightarrow$ Precision meas. interpretable without assumptions regarding Q^2 evol.
- Extract $G_E^s + \eta G_M^s$ from experimental A_{PV}: $(\delta A_{PV}/A_{PV}) \sim 4$ % total
- Anticipated precision: $\delta(G_E^s + 0.48 G_M^s) \sim 0.011$ total

World Data at Forward Angles



HAPPEx-III Proposed Measurement

Configuration:

- 20 cm cryogenic Hydrogen Target
- $100\mu A$ I_{beam}
- 80% polarization

Kinematics:

- E$= 3.4$ GeV, $\theta \sim 13.7^\circ$ (both arms), $E' = 3.1$ GeV $Q^2 \sim 0.6$ GeV^2

Rate:

- 1.1 MHz per arm (3700 ppm width per arm, 2600 ppm per pair at 30Hz)

A_{PV} (assuming no strange vector FF):

- $A_{PV} \sim -22.1 \pm 0.62$ ppm (2.9%)

Anticipated results:

- $\delta A_{PV} = 0.55\ \mathrm{ppm(stat)} \pm 0.33\ \mathrm{ppm(syst)}$
- $\delta(G_E^s + 0.48 G_M^s) = 0.0070(\mathrm{stat}) \pm 0.0042(\mathrm{syst}) \pm 0.0079(\mathrm{FF})$

Experimental Error Budget

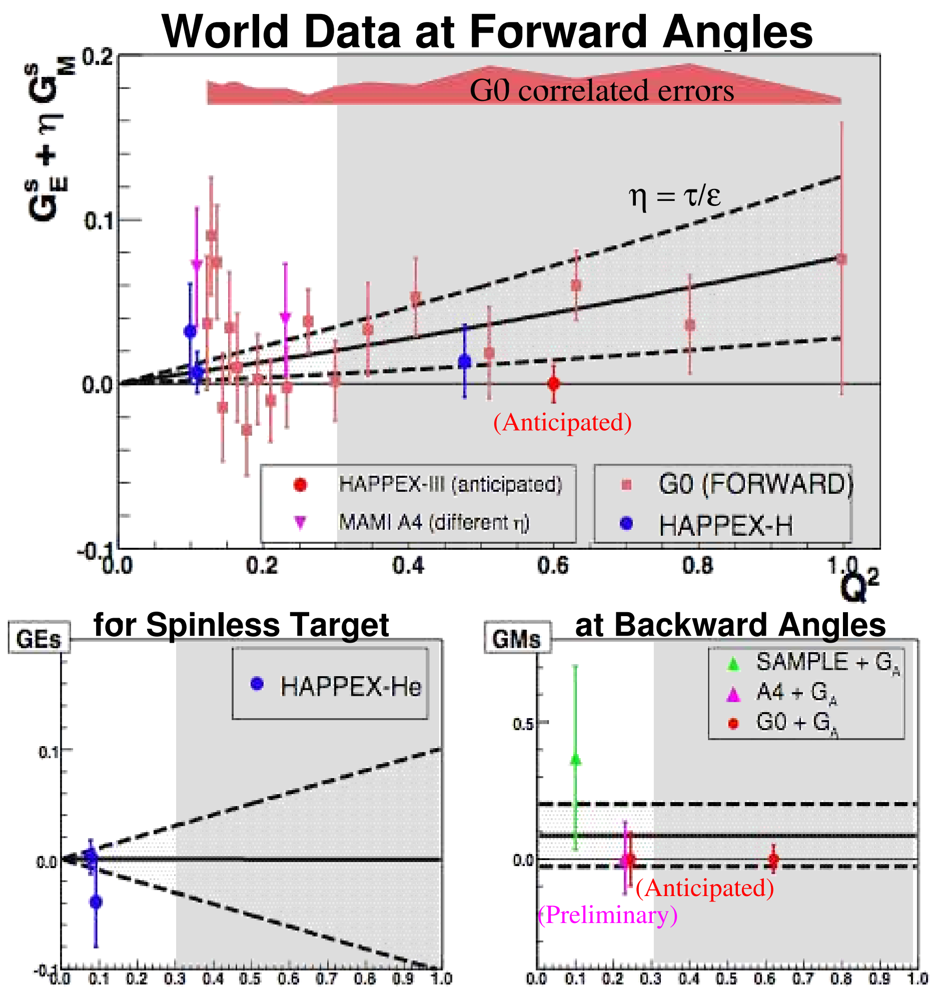
	$\delta A_{PV}/\langle A_{PV}\rangle$	$\delta(G^s_E+0.48G^s_M)$
Polarization	1.0%	0.0028*IR=hard
Q^2 Measurement	0.8%	0.0022*
Backgrounds	0.3%	0.0009*
Linearity	0.6%	0.0017*
Finite Acceptance	0.3%	0.0009*
False Asymmetries	0.3%	0.0009*easy
Total Systematic	1.5%	0.0042
Statistics	2.5%	0.0070
Total Experimental	2.9%	0.0082

*small improvement over H-II

*significant improvement over H-II

Estimated Precision

	$\delta A_{PV}/<A_{PV}>$	$\delta(G_E^s+0.48G_M^s)$
Total Systematic	1.5%	0.0042
Statistics	2.5%	0.0070
Total Experimental	2.9%	0.0082
Axial FF	1.5%	0.0042
EM FF	2.4%	0.0067
Total FF	2.8%	0.0079
TOTAL	**4.0%**	**0.011**



- Simple fits (to 1st order in Q^2): Only includes data for $Q^2 < 0.3$ GeV^2

$$G_E^S = \rho_S \tau \qquad\qquad G_M^S = \mu_S$$

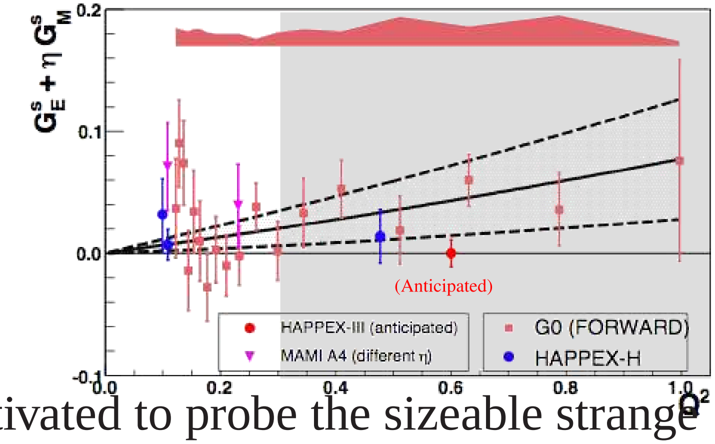
Preparations

- Detectors - Examine HAPPEx-I detectors, refurbish or rebuild (W&M)
- Polarimetry - Review e- analysis, will use IR system
- Linearity - LED studies of phototubes/bases and Jan 2008 beam studies
- Q^2 - verify cross sections and plan angle mesurement
- Finite Acceptance - simulations (HAMC)
- backgrounds - simulation and target design (HAMC)
- Rapid Flip - $>$ 200 Hz flip rates are considered for QWeak, PREx. HAPPEx-III may benefit as well.

Schedule

- Start Installation: 6/1/2009
- Beam Restoration: $\sim$mid August 2009
- Commission and run until: 10/26/2009

Summary



- HAPPEx-III motivated to probe the sizeable strange quark effects at higher Q^2 which are not ruled out by current world dataset
- Precision data at middle Q^2 can finish the question of large contributions to the static properties, in a way that backangle measurements cannot independently do.
- Experiment Scheduled to run late summer through mid Fall 2009.
- CSB effects in proton could be as large as stat. error of high-precision HAPPEx data (at low Q^2) are are not well constrained at higher Q^2.
- The current uncertanties in the EM FFs (including 2-photon exchange effects) limit precision to a few percent at higher Q^2.