

HAPPEX
parity violation experiments :
status and plans

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1. HAPPEX program overview
2. HAPPEX I (JLab 91-010): results
3. HAPPEX II (JLab 99-115): plans
4. ^4He (JLab 00-114): plans

Theory

Nucleon structure: beyond valence quarks

Strange vector form factors: $G_{E,M}^s(Q^2)$

$$\rho_s = \left. \frac{dG_E^s(\tau)}{d\tau} \right|_{\tau=0}$$

$$\mu_s = G_M^s(0)$$

where $\tau = \frac{Q^2}{4M_P^2}$

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

For the proton:

$$A = -A_0 \tau \left(2 - 4 \sin^2 \theta_W - \frac{\varepsilon G_E^0 + \tau G_M^0}{\varepsilon G_E^{\gamma p} + \tau G_M^{\gamma p}} \right) - A_A$$

$$G_{E,M}^0(\tau) = (G_{E,M}^u + G_{E,M}^d + G_{E,M}^s) / 3$$

$$\varepsilon = [1 + 2(1 + \tau) \tan^2 \frac{\theta}{2}]^{-1}$$

$$A_0 = \frac{G_F M_P^2}{\sqrt{2} \pi \alpha}$$

A_A = axial vector (small at forward scattering angles).

Predictions for Strange Form Factors

Model	ρ_s	μ_s	Reference
Poles	-2.10	-0.31	Jaffe Phys. Lett. B 229, 275 (1989)
SU(3) Skyrme	3.19	-0.33	Park, Schecter & Weigel Phys. Rev. D 43, 869 (1991)
SU(3) Skyrme	1.64	-0.13	Park, & Weigel Orsay IPNO/TH 91-57 (1991)
NJL model	3.06	-0.05	Weigel, Abada, Alkofer & Reinhardt Phys. Lett. B 353, 20 (1995)
Poles (update)	-2.93	-0.24	Hammer, Meisner & Dreschel Phys. Lett. B 367, 323 (1996)
Quark Model	0.57	0.035	Geiger & Isgur Phys. Rev. D 55, 299 (1997)
SU(3) Chiral Bag		0.37	Hong, Park & Min Phys. Lett. B 414, 329 (1997)
Lattice	1.26 \rightarrow 2.77	-0.56 \rightarrow -0.16	Dong, Liu & Williams Phys. Rev. D 58, 074504 (1998)
Poles + $K\bar{K}$	-6.0 \rightarrow +2.65	-0.51 \rightarrow -0.26	Hammer & Ramsey-Musolf Phys. Rev. C 60, 045204 (1999)

HAPPEX at Jefferson Lab: An Overview

$$E_0 = 3.35 \text{ GeV}$$

$$\theta_{\text{lab}} = 12.5^\circ$$

$$Q^2 = 0.47 \text{ GeV}^2$$

polarized source

CEBAF

Hall A

Hall A Proton Parity Experiment

$A_{\text{row}} \sim 6 \text{ ppm}$
Rate: 2 MHz

- Steering Coils
- Position Monitors
- Intensity Monitors

polarimeter

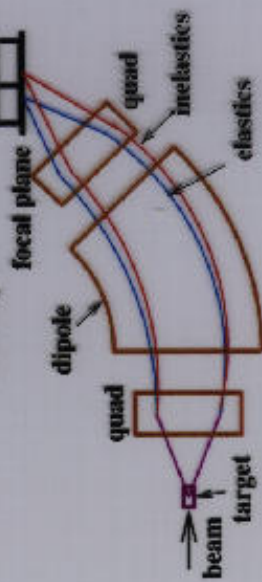
hydrogen target

spectrometers

detectors

data acquisition & control

Spectrometer Concept



HAPPEX I - Results

<i>Source of Error</i>	$\frac{\Delta A}{A}$:1998	$\frac{\Delta A}{A}$:1999
Statistics	13.3 %	7.2 %
Polarization	7.0 %	3.2 %
Q^2 Determination	1.8 %	1.8 %
Backgrounds	0.6 %	0.6 %

$$1998: A = (14.7 \pm 2.2) \times 10^{-6}$$

$$1999: A = (15.1 \pm 1.3) \times 10^{-6}$$

$$\text{Combined: } A = (15.0 \pm 1.1) \times 10^{-6}$$

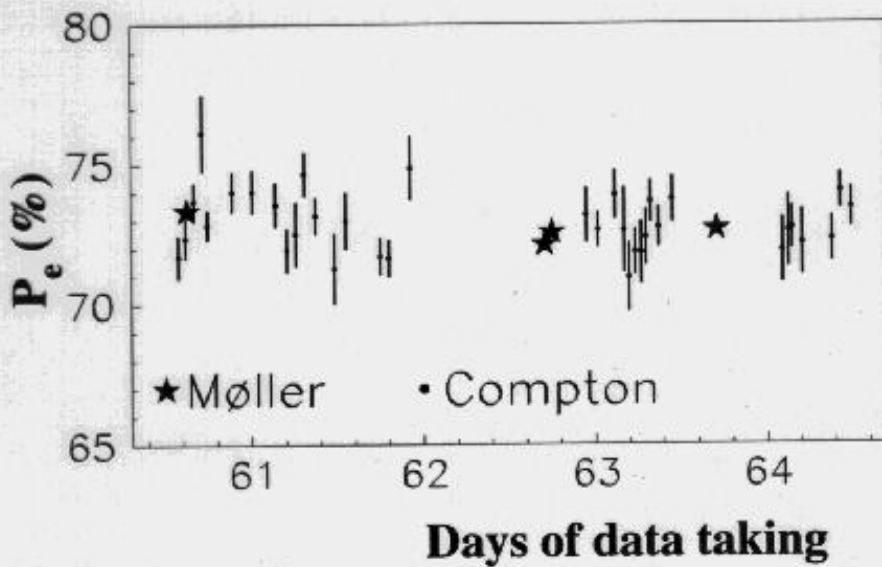
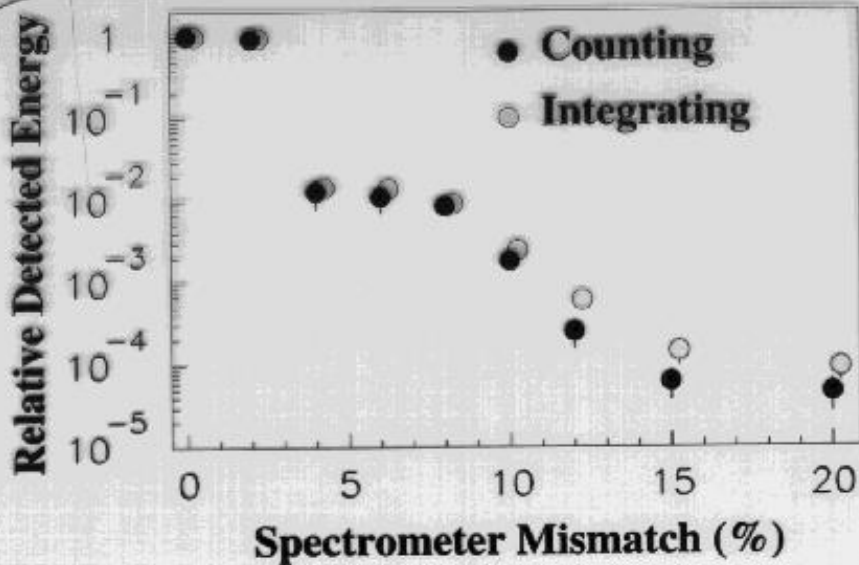
<i>Form Factor</i>	$\frac{\Delta A}{A}$
G_E^n	4%
G_E^p	3%
G_M^n	2%

$$G_E^s + 0.392G_M^s = 0.025 \pm 0.020 \pm 0.014$$

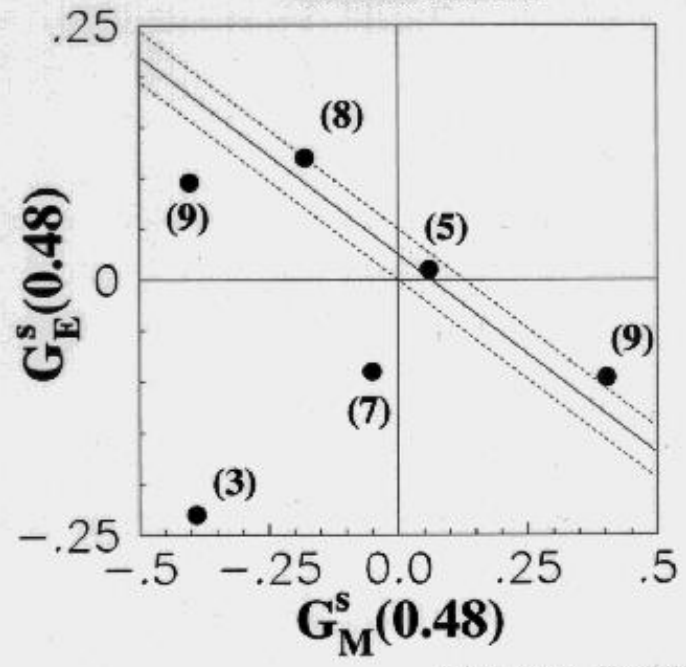
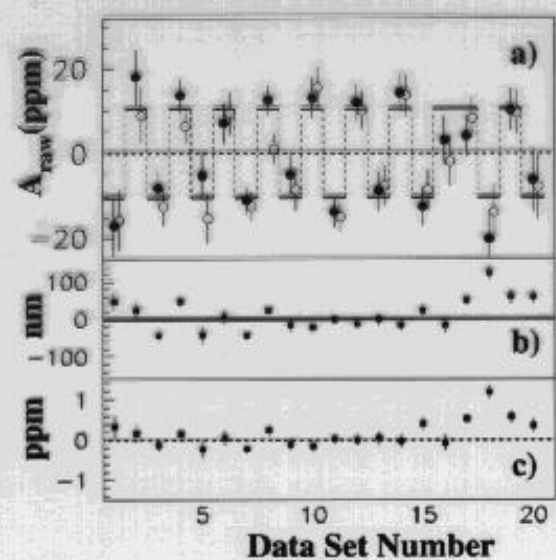
K.A. Aniol et al., PRL **82**(1999)1096

K.A. Aniol et al., Phys. Lett. **B509**(2001)211

HAPPEX I



HAPPEX I: results



HAPPEX II (proton) and ^4He

- JLab, Hall A
- Use HRS ($3.7 \text{ msr} \times 2$) & septum magnets $\rightarrow \theta = 6^\circ$
- $\langle Q^2 \rangle = 0.1 (\text{GeV}/c)^2$ [$E_0 = 3.2 \text{ GeV}$]
- $100 \mu\text{A}$, 80% polarization, 30 ms helicity-flip
- Polarimetry: Hall A Møller & Compton (2%)
- Integrating; total absorption Cerenkov counters

	HAPPEX II	^4He
Rate/arm	65 MHz	11.9 MHz
$\langle A \rangle$	1.63 ppm	8.43 ppm
$\delta A/A$	5.4%	3.0%
Backgrounds ($\delta A/A$)	0.75%	0.2%

Theory - ${}^4\text{He}$

$${}^4\text{He}(\bar{e}, e') : 0^+ \rightarrow 0^+$$

→ charge scattering only - no G_M^s, G_A^Z

$$A = \frac{G_F M_P^2}{\sqrt{2}\pi\alpha} \tau \left(4 \sin^2 \theta_W + 2 \frac{G_E^s(\tau)}{[G_E^{\gamma p}(\tau) + G_E^{\gamma n}(\tau)]} \right)$$

$$\approx \frac{G_F M_P^2}{\sqrt{2}\pi\alpha} \tau (4 \sin^2 \theta_W + 2\rho_s \tau)$$

for τ small; here, $\tau = 0.03$

Model Dependence

- Spin-orbit effects:
(from D-state admixture in ^4He ground state)
negligible

[Musolf & Donnelly Phys. Lett. **B318** 263, (1993)]

- Meson Exchange Currents:

$$\text{eg. } \langle \rho | \bar{s} \gamma_\mu s | \pi \rangle$$

$$\text{@ } Q^2 = 0.1 \text{ GeV}^2: \quad < 1\% \text{ of } G_E^s$$

$$\text{@ } Q^2 = 0.6 \text{ GeV}^2: \quad \text{can be large}$$

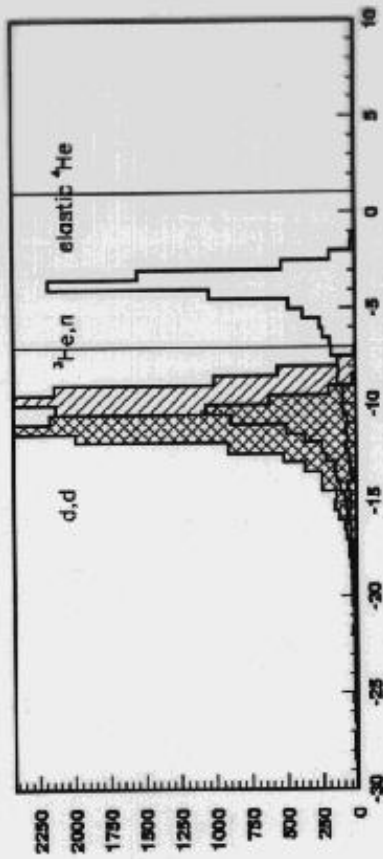
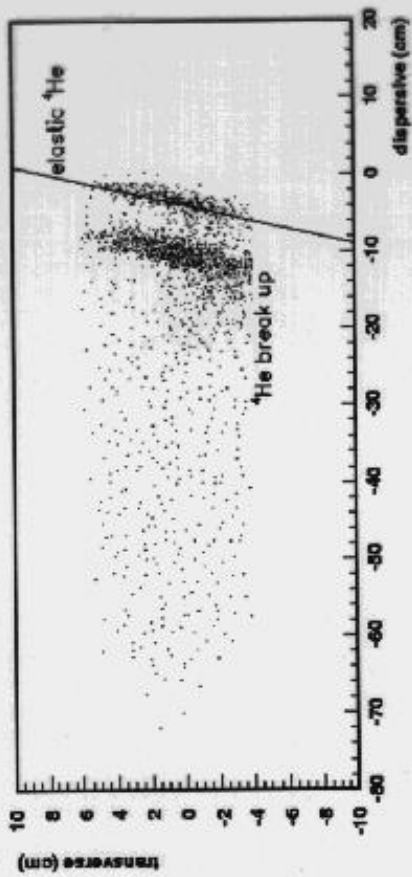
[Musolf, Schivavilla & Donnelly Phys. Rev. C **50**, 2173 (1994)]

- Isospin mixing: $\ll 1\%$

[Ramavatarm, Hadjimichael, & Donnelly Phys. Rev. C **50**, 1174
(1994)]

- Vector weak radiative corrections:
order 1% effects

Focal Plane Distributions



Error Budget - HAPPEX II

<i>Source of Error</i>	$\frac{\Delta A}{A}$ (%)
Polarization	2.0
Radiative Corrections (mainly G_A^Z)	1.0
Backgrounds	0.75
Q^2 Determination	0.6
Beam Systematics	0.2
G_E^n	1.4
Total Systematic Error	2.8
Statistics	4.6
Total Experimental Error	5.4

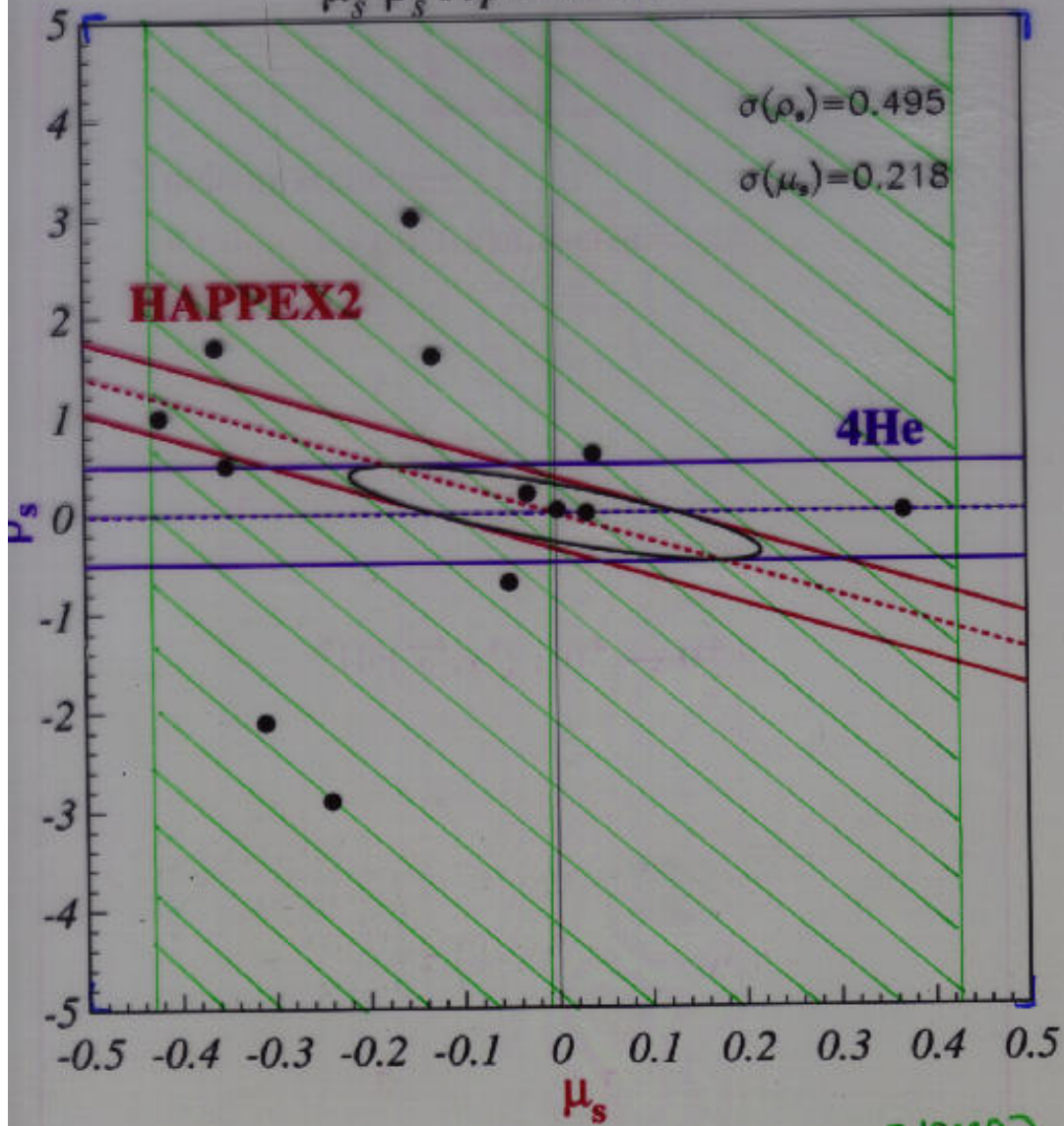
Measure $\rho_s + \mu_p \mu_s$ to ± 0.31
in 700 hours

Error Budget - ^4He

<i>Source of Error</i>	$\frac{\Delta A}{A}$ (%)
Polarization	2.0
Q^2 Determination	0.3
Finite Acceptance	0.3
Beam Systematics	0.2
Backgrounds	0.2
Total Systematic Error	2.1
Statistics	2.2
Total Experimental Error	3.0

Measure ρ_s to ± 0.5
in 700 hours

$\mu_s - \rho_s$ separation



2AMPLE

R. Harty et al. Science 280 (3000) 2117

$\mu^2 = 0.01 \pm 0.24 = 0.24 \pm 0.05$

$50.0 \pm 12.0 = 22.0 \pm 10.0 = 2\mu$

Summary and Outlook

- HAPPEX I

- no *large* strange quark contributions

$$G_E^s + 0.392G_M^s = 0.025 \pm 0.024$$

at $Q^2 = 0.48 \text{ (GeV/c)}^2$.

- Uncertainty due to electromagnetic form factors significant.

- HAPPEX II and ^4He

- Will measure at $Q^2 = 0.10 \text{ (GeV/c)}^2$
- Should provide precise values of ρ_s and μ_s
- Complementary to SAMPLE (same Q^2)
- Schedule (*Tentative*): Late 2002/Early 2003
→ run back-to-back

In the next few years, HAPPEX, along with SAMPLE (Bates), G^0 (JLab) and A4 (Mainz) should provide a definitive picture of the strange vector form factors of the nucleon.

–*merci beacoup*–