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. ^{4}He (JLab 00-114): plans

Theory

Nucleon structure: beyond valence quarks
Strange vector form factors: $G^s_{E,M}(Q^2)$

$$\rho_s = \frac{dG^s_E(\tau)}{d\tau}\Big|_{\tau=0}$$
$$\mu_s = G^s_M(0)$$

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

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

For the proton:

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

$$G^0_{E,M}(\tau) = \left(G^u_{E,M} + G^d_{E,M} + G^s_{E,M}\right)/3$$

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

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

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**, 229 (1997)
Lattice	$1.26 \rightarrow 2.77$	$-0.56 \rightarrow -0.16$	Dong, Liu & Williams Phys. Rev. D **58**, 074504 (1998)
Poles + $K\overline{K}$	$-6.0 \rightarrow +2.65$	$-0.51 \rightarrow -0.26$	Hammer & Ramsey-Musolf Phys. Rev. C **60**, 045204 (1999)

HAPPEX at Jefferson Lab: An Overview

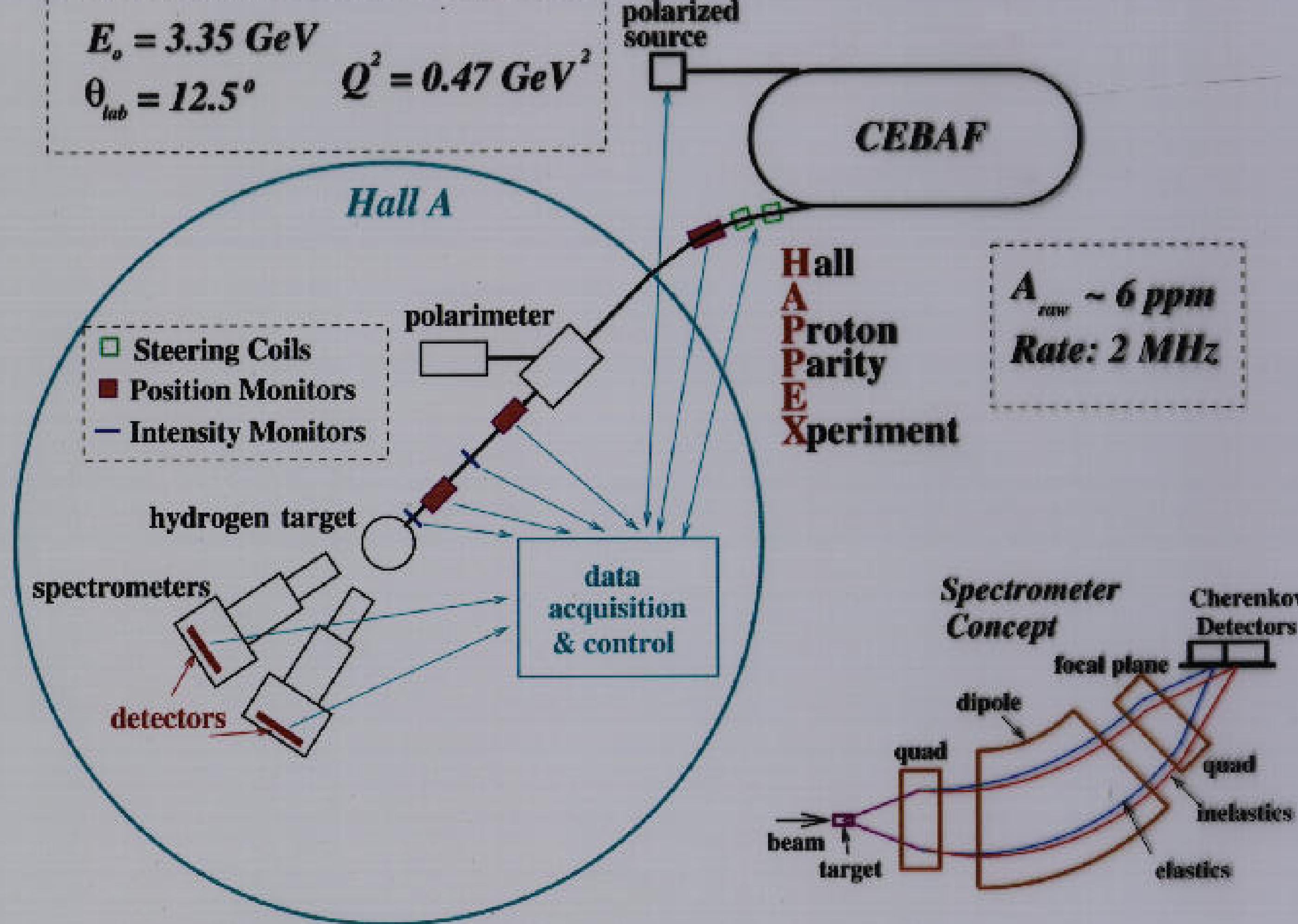
$E_o = 3.35$ GeV

$\theta_{lab} = 12.5^o$

$Q^2 = 0.47$ GeV^2

$A_{raw} \sim 6$ ppm

Rate: 2 MHz



HAPPEX I - Results

Source of Error	$\frac{\Delta A}{A}$: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: $A = (15.1 \pm 1.3) \times 10^{-6}$

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

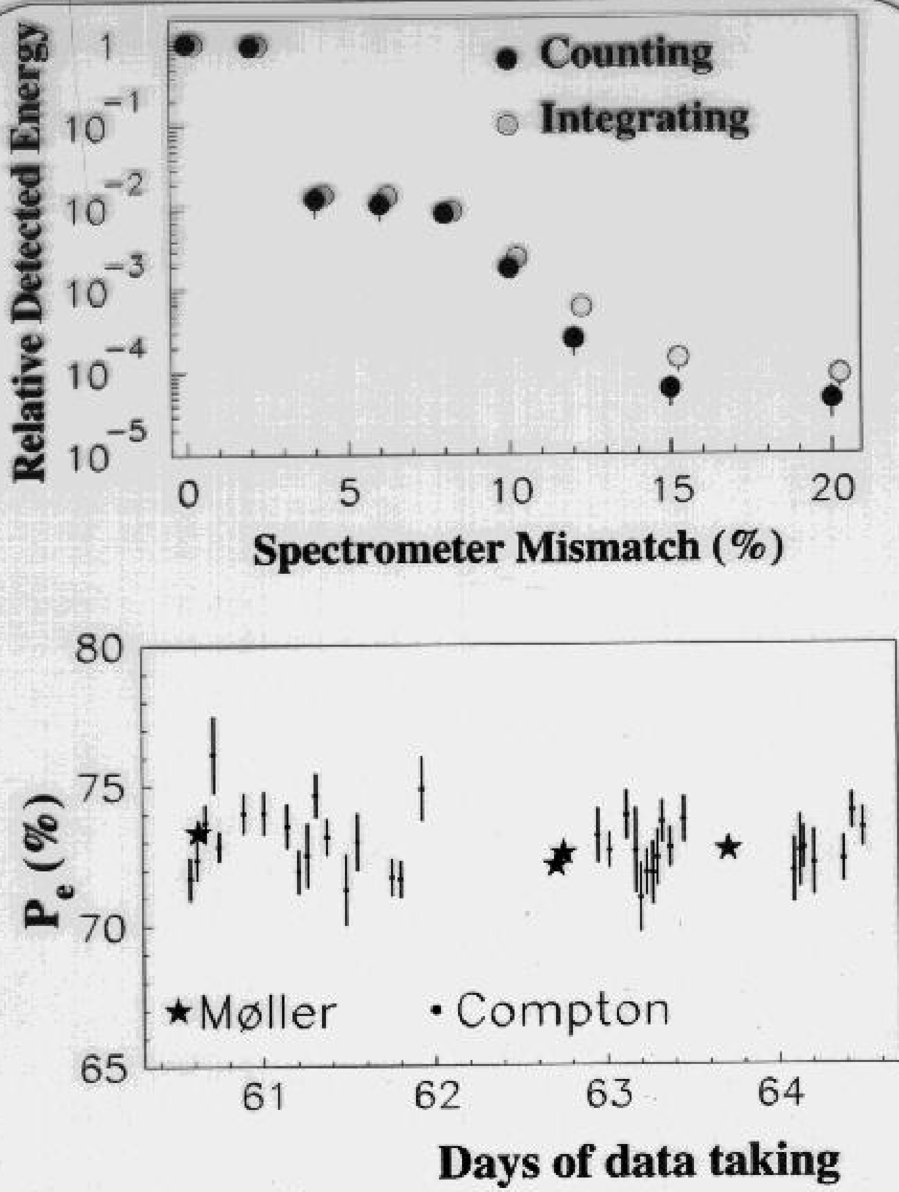
Form Factor	$\frac{\Delta A}{A}$
G_E^n	4%
G_E^p	3%
G_M^n	2%

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

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

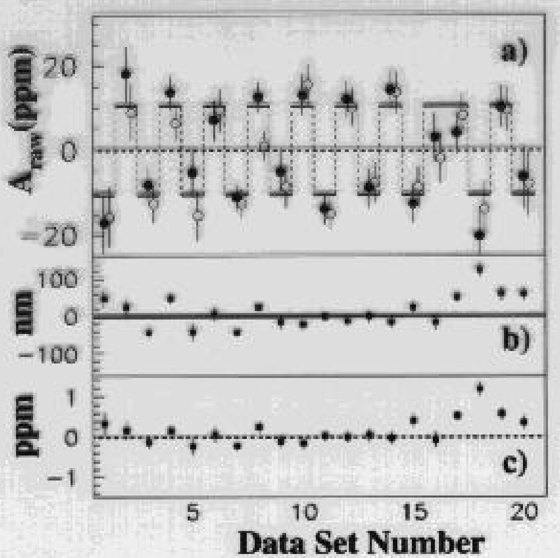
K.A. Aniol *et al.*, Phys. Lett. **B509**(2001)211

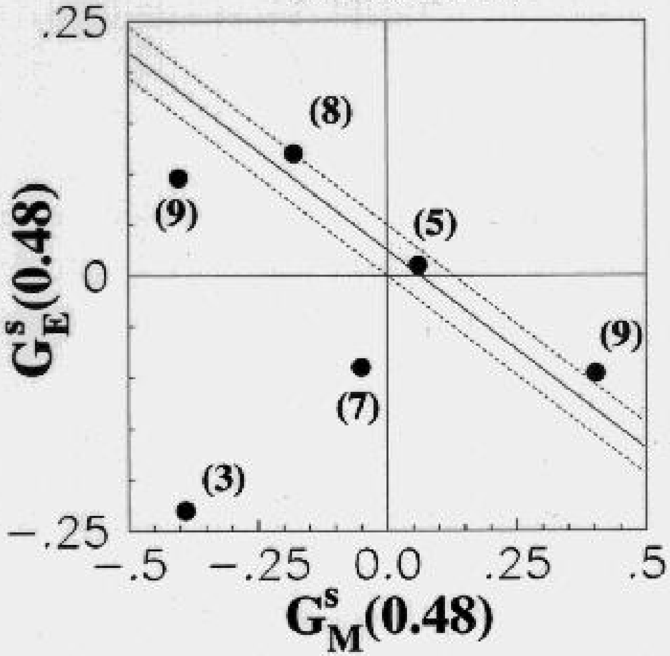
HAPPEX I



Relative Detected Energy
Counting
Integrating
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
5
10
15
20
Spectrometer Mismatch (%)
P_e (%)
80
75
70
65
★Møller
• Compton
61
62
63
64
Days of data taking

HAPPEX I: results





Phys. Lett. B509(2001)211.

HAPPEX II (proton) and ^{4}He

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

	HAPPEX II	^{4}He
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}He

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

$\rightarrow$ charge scattering only - no G_M^s, G_A^Z

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

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

for τ small; here, $\tau = 0.03$

Model Dependence

- Spin-orbit effects:

  (from D-state admixture in ^{4}He ground state)

  negligible

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

- Meson Exchange Currents:

  eg. $< \rho|\bar{s}\gamma_\mu s|\pi >$

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

  @ $Q^2 = 0.6$ GeV^2: can be large

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

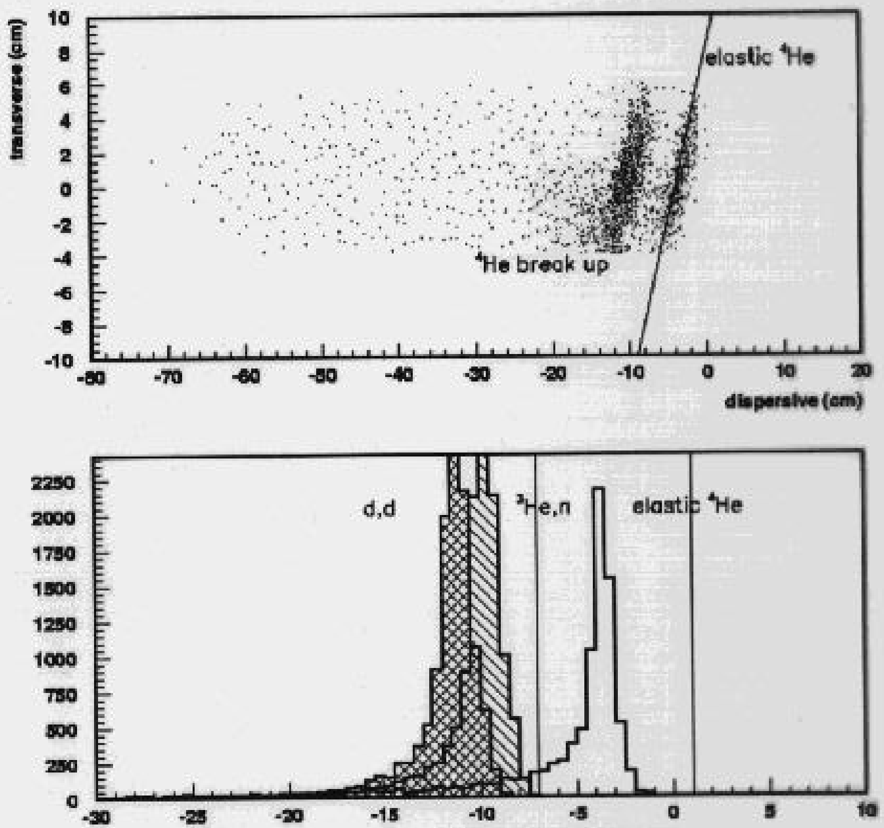
- Isospin mixing: $<< 1\%$

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

- Vector weak radiative corrections:

  order 1% effects

Focal Plane Distributions



Error Budget - HAPPEX II

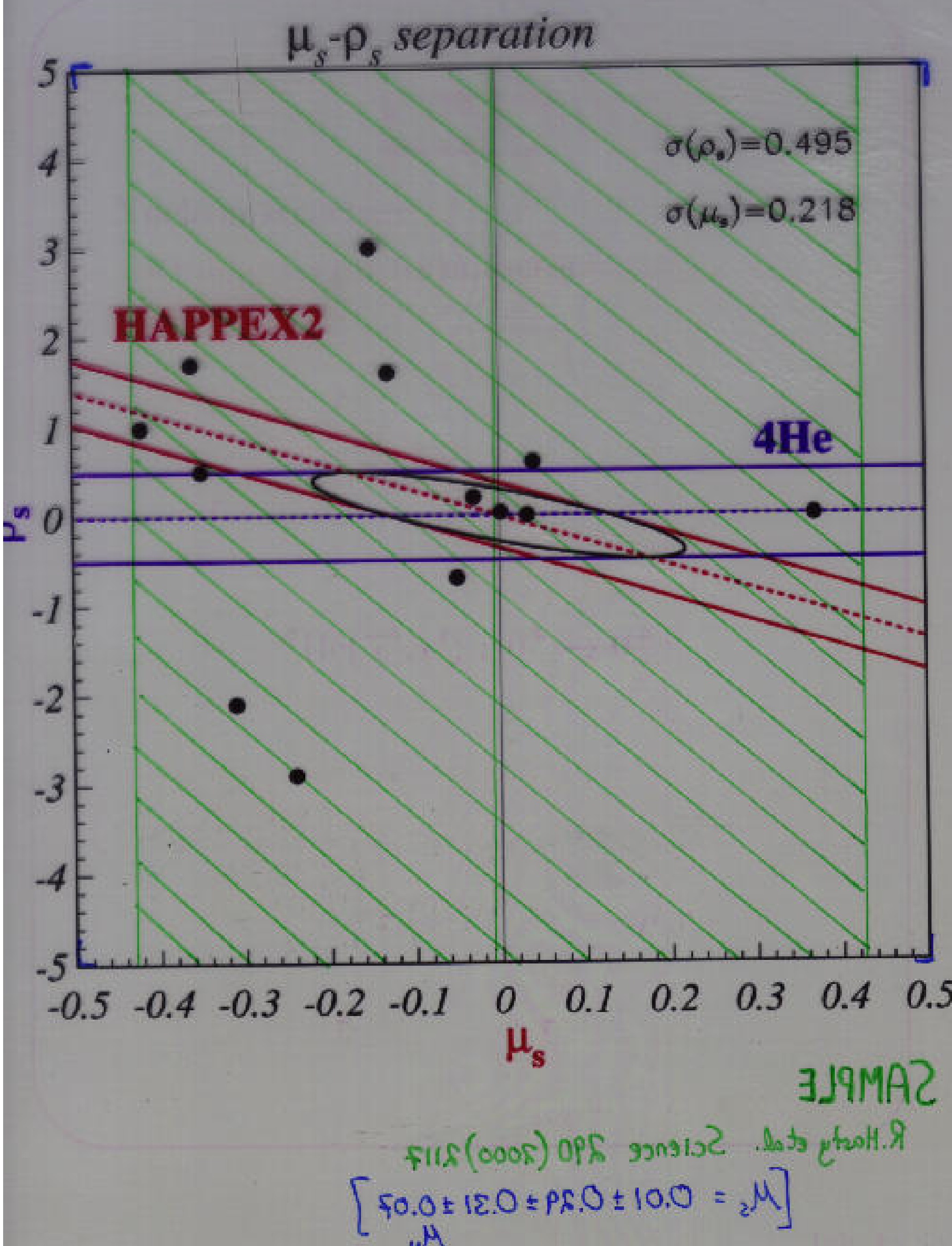
Source of Error	$\frac{\Delta A}{A}$ (%)
Polarization	2.0
Radiative Corrections (mainly G_A^Z)	1.0
Backgrounds	0.75
Q^2 Determination	0.6
Beam Systematics	0.2
G_E^n	1.4
Total Systematic Error	2.8
Statistics	4.6
Total Experimental Error	5.4

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

Error Budget - ^{4}He

Source of Error	$\frac{\Delta A}{A}$ (%)
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 $\pm$ 0.5
in 700 hours



μ_s-ρ_s separation
$\sigma(\rho_s)$=0.495
$\sigma(\mu_s)$=0.218
HAPPEX2
4He
ρ_s
μ_s
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5
5 4 3 2 1 0 -1 -2 -3 -4 -5
SAMPLE
R.Hasty et al. Science 290 (2000) 2117
[μ_s = 0.01 ± 0.29 ± 0.31 ± 0.07 μ_N]

Summary and Outlook

- HAPPEX I
  - no *large* strange quark contributions
    $G_E^s + 0.392 G_M^s = 0.025 \pm 0.024$
    at $Q^2 = 0.48$ (GeV/c)^2.
  - Uncertainty due to electromagnetic form factors significant.
- HAPPEX II and ^{4}He
  - Will measure at $Q^2 = 0.10$ (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–