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Parity Violation from ^{4}He at Low Q^2: A Clean Measurement of ρ_s

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ABSTRACT

We propose to measure the parity violating asymmetry in ${}^4He(\overrightarrow{e}, e')$ elastic scattering at an incident electron energy of 3.2 GeV using the Hall A HRS spectrometers and the septum magnets to reach a scattering angle of $6°$. The average Q^2 of the experiment will be 0.1 $(\text{GeV}/c)^2$, similar to the recently approved HAPPEX II experiment. 35 days of running on ^{4}He and on a blank Al cell will result in 2.2% statistical errors. The estimated systematic errors of 2.1% are dominated by the beam polarization measurement and are similar to that expected for the approved Lead parity violating experiment. The overall combined experimental error is 3%. Recent results from the 1999 HAPPEX run indicate that the systematic errors can be achieved with anticipated improvements in the Hall A Møller and Compton polarimeters. This experiment will measure the leading strange charge coefficient $\rho_s = \frac{dG_E^s(\tau)}{d\tau}$ at $\tau \to 0$ to an accuracy of ± 0.5 which should be capable of yielding a significant nonzero result, since available models for ρ_s range from $-3 \to 3$. When combined with the results from HAPPEX II, which will measure the linear combination $\rho_s + \mu_p \mu_s$, where μ_s is the strange magnetic moment, both ρ_s and μ_s can be extracted.

Parity Violation from ^{4}He at Low Q^2

I INTRODUCTION

An open theoretical question is the role played by strange sea quarks in contributing to fundamental nucleon properties. Recent parity violation (PV) experiments in elastic $^1H(\overrightarrow{e}, e')$ by the HAPPEX [1,2] and SAMPLE [3,4] collaborations have measured the strange vector form factors $G^s_{E,M}$. Theoretical estimates differ dramatically on the size of these form factors, with most papers focusing on predictions for the leading order coefficients at low Q^2, $\rho_s = dG^s_E(\tau)/d\tau$ and $\mu_s = G^s_M(\tau)$ as $\tau = Q^2/4M_p^2 \to 0$. The spread of predictions for ρ_s is particularly large, ranging from -3 to +3 in various models. One difficulty with present measurements is that three new electroweak form factors contribute to the elastic scattering of the proton. This makes separation of strange electric and magnetic form factors $G^s_{E,M}$ and the weak axial form factor G_A difficult. Complicating the issue there is considerable uncertainty in evaluating the weak radiative corrections for the axial vector piece. Experiments are limited as well by the current state of knowledge of the electromagnetic form factors of the nucleon, $G^\gamma_{E,M}$.

In contrast, PV experiments on elastic $^4\mathrm{He}(\overrightarrow{e}, e')$ have a relatively simple interpretation. Only a single strange form factor contributes to the asymmetry and at low Q^2 this can be expanded in terms of $G^s_E \approx \rho_s \tau$ as $\tau \to 0$. We propose to carry such a low–Q^2 PV experiment on ^{4}He using the Hall A septum magnets in conjunction with the HRS spectrometers to reach $Q^2 \sim 0.1$ $(\mathrm{GeV}/c)^2$ at a beam energy of 3.2 GeV and a scattering angle of $6°$. These are the same kinematics as the approved HAPPEX II experiment [7] on $^1H(\overrightarrow{e}, e')$.The counting rate of 12 MHz/arm will require the use of an integrating detector, similar to previous HAPPEX experiments [1]. 35 days of beam time will yield the PV asymmetry to 3% combined statistical and systematic accuracy. This will allow a determination of $\delta\rho_s = \pm 0.5$. When combined with the HAPPEX II results, which will measure the linear combination $\rho_s + \mu_p \mu_s$ to an accuracy of ± 0.3, significant constraints will be placed on ρ_s and μ_s.

II THEORY

Elastic electron scattering in ^{4}He is an isoscalar $0^+ \to 0^+$ transition. Therefore there are no contributions from magnetic or axial-vector currents. At low Q^2, the PV asymmetry is given by

$$A_{He} = A_0\tau\left(4\sin^2\theta_W + \frac{G_E^s(\tau)}{G_E^{\gamma T=0}(\tau)}\right) \approx A_0\tau\left(4\sin^2\theta_W + 2\rho_s\tau\right) \quad (1)$$

$$A_0 = G_F M_p^2/\sqrt{2}\pi\alpha = 316.7\,\mathrm{ppm}, \quad (2)$$

where $G_E^{\gamma T=0} = \frac{G_E^{\gamma p}+G_E^{\gamma n}}{2}$ is the isospin-zero electric form factor and G_E^s is the electric strange quark form factor of the nucleon. Since the vector weak radiative corrections are well known, a measurement of A is a direct measurement of ρ_s at low Q^2.

For comparison, the asymmetry for elastic scattering of the proton, measured recently by HAPPEX [1,2] and SAMPLE [3,4] has contributions from weak electric, magnetic and axial vector currents:

$$A_{proton} = -A_0\tau\left(2 - \sin^2\theta_W - \frac{\varepsilon G_E^0 + \tau G_M^0}{\varepsilon G_E^{\gamma p} + \tau G_M^{\gamma p}}\right) - A_A \quad (3)$$

$$G_{E,M}^0(\tau) = \left(G_{E,M}^u + G_{E,M}^d + G_{E,M}^s\right)/3 \quad (4)$$

$$\varepsilon = \left[1 + 2(1+\tau)\tan^2\theta/2\right]^{-1} \quad (5)$$

where $G_{E,M}^{(u,d,s)}$ are the (up, down and strange) quark form factors and $G_{E(M)}^0$ is the singlet electric(magnetic) form factor of the proton, θ is the electron scattering angle, and ε is the longitudinal polarization of the photon; A_A is the axial vector contribution which is small at forward scattering angles. In the recently completed HAPPEX experiment [1,2] at Q^2 of $0.477\,(\mathrm{GeV}/c)^2$ and effective scattering angle of $\langle\theta\rangle = 12.3°$ we extracted

$$\frac{(G_E^0 + 0.392 G_M^0)}{G_M^{\gamma p}/\mu_p} = 1.550 \pm 0.046(stat) \pm 0.026(syst) \pm 0.011(theor). \quad (6)$$

The last error is due to the uncertainty in the weak radiative correction to the axial vector contribution.

Using isospin symmetry we have $G^{\gamma p,n} = \frac{2}{3}G^{u,d} - \frac{1}{3}G^{d,u} - \frac{1}{3}G^s$. Therefore, the strange form factors of the proton can be determined from

$$G_{E,M}^s = G_{E,M}^0 - G_{E,M}^{\gamma p} - G_{E,M}^{\gamma n}. \quad (7)$$

provided the electromagnetic form factors of the proton and neutron are well known. Table 1 summaries some representative model estimates for ρ_s and μ_s.

Assuming that the $\tau \to 0$ limit for the ratio of form factors is valid at this Q^2, we obtain $\rho_s + 2.9\mu_s = 0.67 \pm 0.41(stat+syst) \pm 0.30$ from the HAPPEX data [2], where the second error is due to the uncertainty in the measured electromagnetic form factors. This result is plotted in Fig. 1 along with some model predictions. A more conservative estimate, suggested by the Galster parameterization is $G_E^s = \rho_s\tau/(1+\lambda^s\tau)$ with $\lambda^s \approx 5.6$. This would reduce the

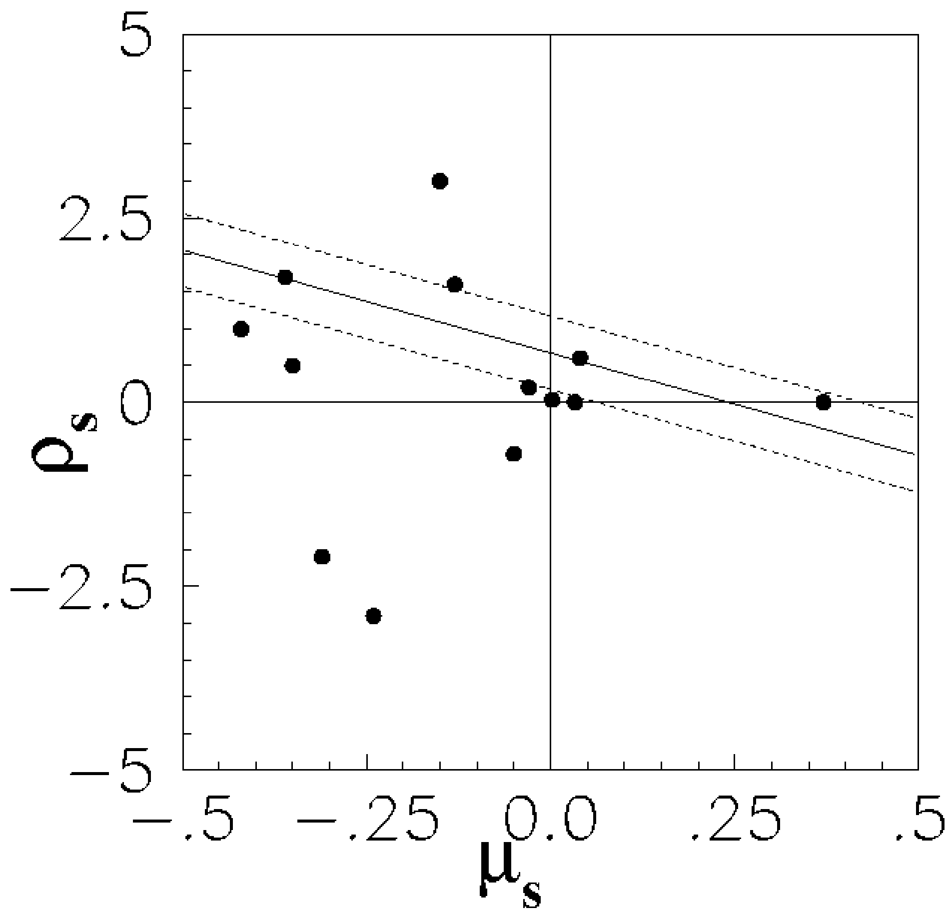

FIGURE 1. Allowed region in the ρ_s vs. μ_s plane from HAPPEX (both 1998 and 1999 data) [2]. This assumes $\lambda^s = 0$ (the strange quark Galster parameter). Increasing this parameter to $\lambda^s = 5.6$ reduces the sensitivity to ρ_s by a factor of two. Also shown are selected theoretical predictions.

TABLE 1. Various predictions of the leading moments of the strange quark form factors.

Source	ρ_s	μ_s	$\rho_s + \mu_p \mu_s$	Reference
Poles	-2.10	-0.31	- 2.97	[8]
Poles (update)	-2.93	-0.24	- 3.60	[9]
Poles + $K\overline{K}$	$-6.0 \rightarrow +2.65$	$-0.51 \rightarrow -0.26$	$-7.10 \rightarrow -1.23$	[10]
NJL model	3.06	-0.05	2.92	[11]
SU(3) Skyrme model	3.19	-0.33	2.27	[12]
SU(3) Skyrme, broken symm.	1.64	-0.13	1.27	[13]
Lattice	$1.26 \rightarrow 2.77$	$-0.56 \rightarrow -0.16$	$0.25 \rightarrow 1.76$	[14]
Quark Model	0.57	0.035	0.67	[15]
SU(3) Chiral Bag Model		0.37		[24]

sensitivity to ρ_s by a factor of two. HAPPEX II [7] will reduce our sensitivity to λ^s by measuring a point at $Q^2 \sim 0.1$ $(\mathrm{GeV}/c)^2$.

One issue in the HAPPEX results [2] is that μ_s might have the opposite sign as ρ_s, leading to a partial cancellation in the measurement. Ideally one would like to have independent measurements of the leading electric and magnetic contributions, as is being proposed by the G0 collaboration [6]. However forward and backward scattering measurements at two angles do not, by themselves, allow a complete separation, due to the axial vector contribution which may be the limiting source of systematic error. Therefore this experiment is being proposed to complement the HAPPEX II proposal [7] also at $Q^2 \sim 0.1$ $(\mathrm{GeV}/c)^2$. The ^{4}He experiment directly measures the strange electric form factor while being insensitive to uncertainties in measured EM form factors and weak axial vector corrections. Figure 2 shows how a new ^{4}He experiment would complement the HAPPEX II proposal [7].

In principle, these results can be combined with backward scattering angle data to further constrain μ_s. Figure 3 shows the error band on G_M^s from SAMPLE [4]. Using the current theoretical value for G_A and assigning a nearly 100% uncertainty to the axial vector radiative corrections gives $G_M^s(Q^2 = 0.1\,(\mathrm{GeV}/c)^2) = 0.61 \pm 0.17(stat) \pm 0.21(syst) \pm 0.19$, where the final error is due to the weak radiative correction. This yields a value for $\mu_s \approx 0.79 \pm 0.43$, which would be off scale on Fig. 2. Their results are inconsistent with a negative value of μ_s, as is favored by most models (See Table 1). A recent calculation using an SU(3) chiral bag model yields a positive value of $\mu_s = 0.37$ [24]] which would be more consistent with their results. To reduce the uncertainty due to the axial vector corrections, the SAMPLE collaboration is presently measuring the quasielastic asymmetry from deuterium [4].

The model-dependence of a ^{4}He PV experiment due to isospin-mixing in the ^{4}He ground state is known to be negligible [18]; Donnelly and co-workers calculated the effects at our Q^2 to be two orders of magnitude smaller than their model predictions for the effects due to G_E^s. The model-dependence due

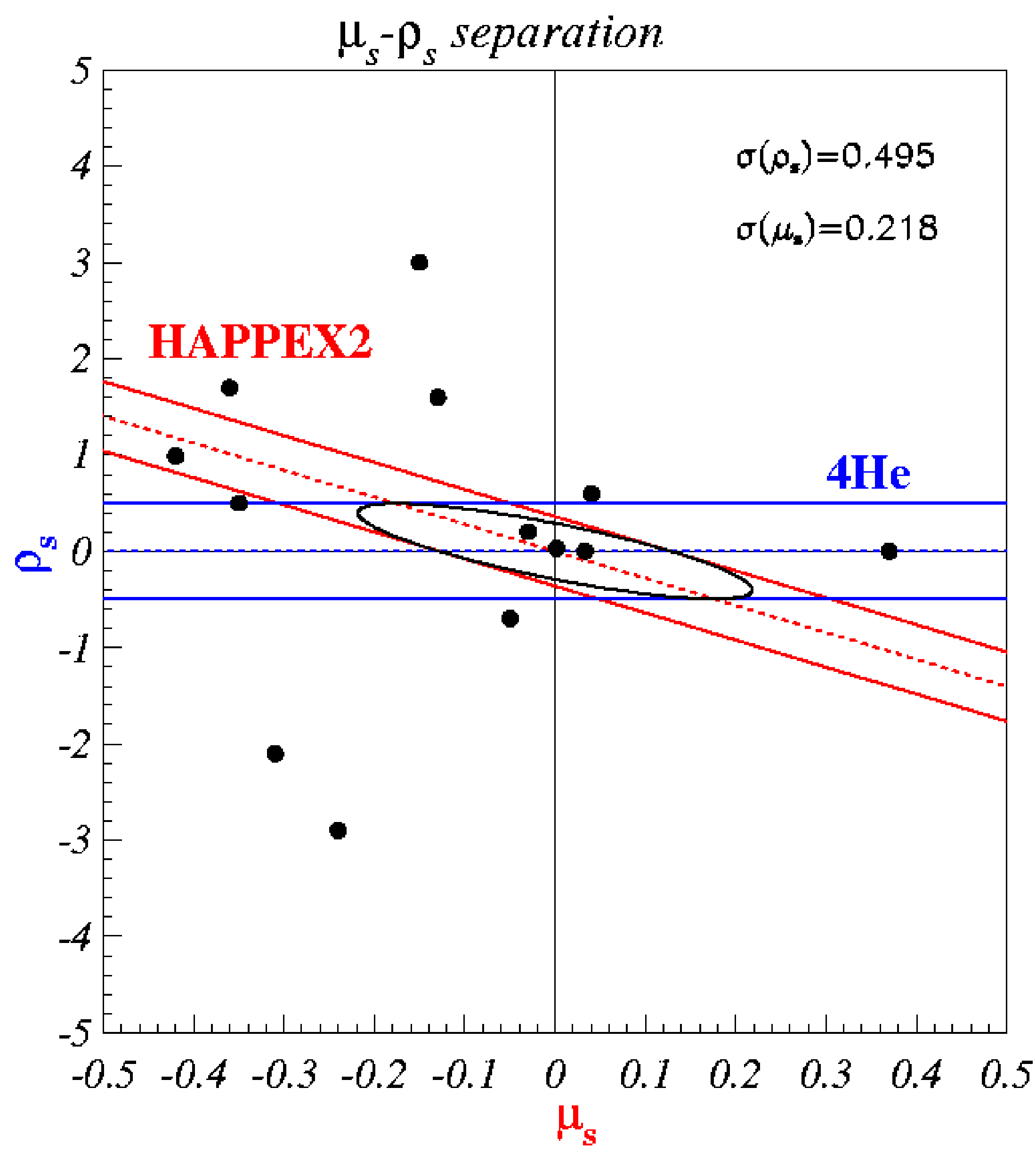

FIGURE 2. Sensitivity of the present experiment in the ρ_s vs. μ_s plane (horizontal band) along with the projected error from HAPPEX II (dashed lines), along with selected theoretical predictions.

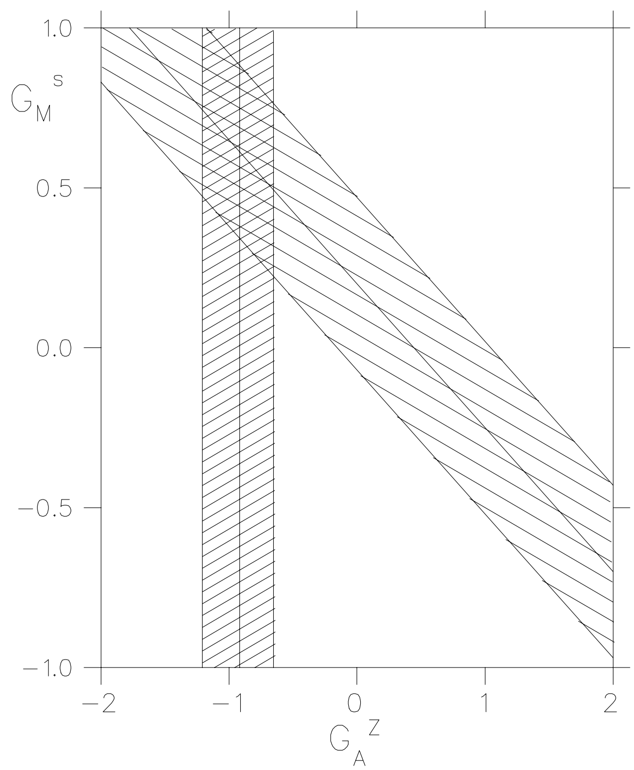

FIGURE 3. Error band (statistical and systematic) for G_M^s from the Sample experiment [4], along with the theoretical value of the axial form factor G_A^Z.

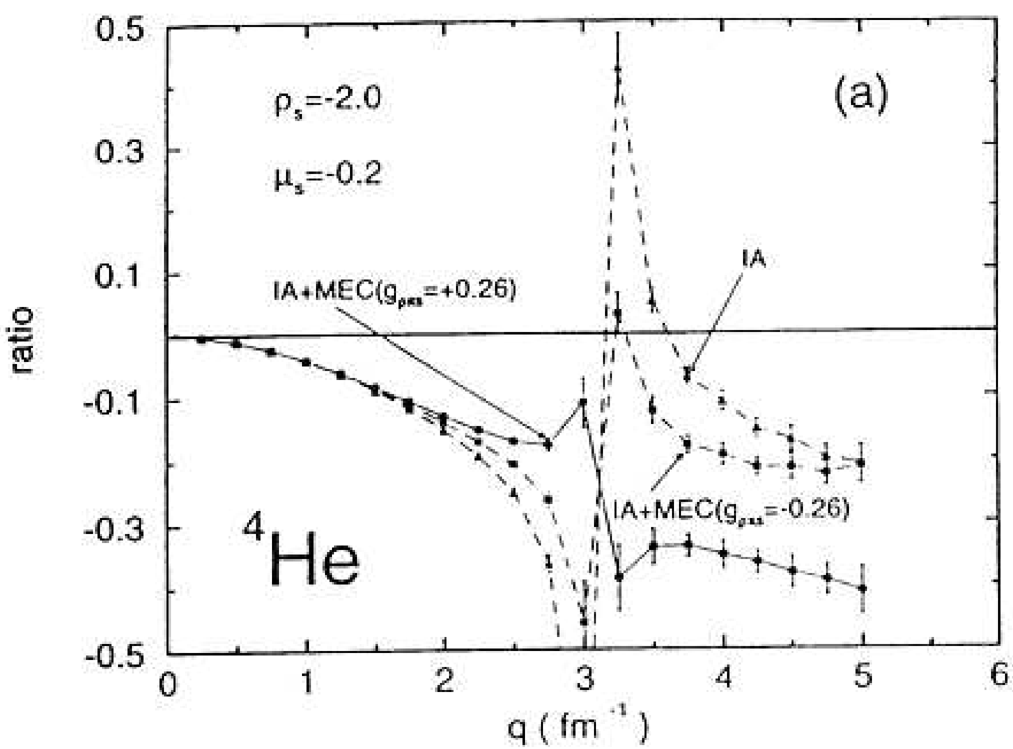

FIGURE 4. Effects of meson exchange currents (MEC) [17]. The elastic strangeness to electromagnetic form factor ratio is plotted vs. q for impulse approximation (IA) and for two choices of possible MEC contributions. At the present kinematics ($q = 1.6\text{fm}^{-1}$), the effects of MEC are negligible.

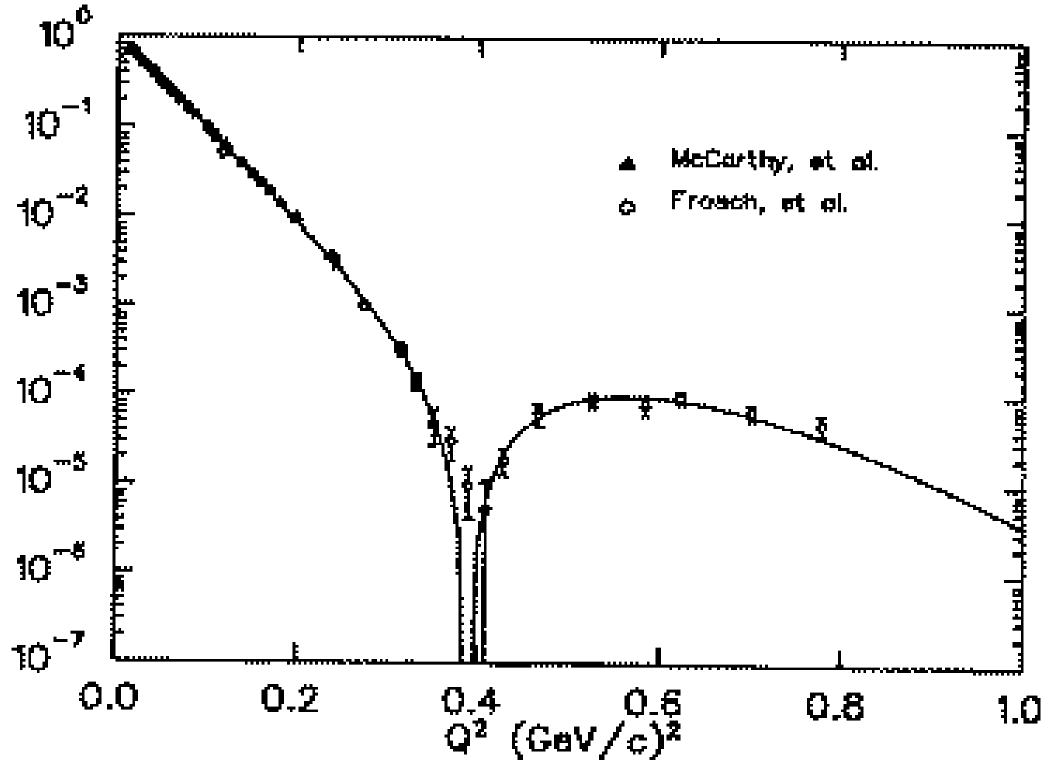

FIGURE 5. ^{4}He charge form factor

to D-state admixtures is also negligible [19]. Furthermore, at small Q^2, meson exchange current contributions are also expected to be small [17] as depicted in Fig. 4.

We note that a measurement of parity-violating elastic scattering from ^{4}He at this Q^2 was a component of the original HAPPEX proposal (JLab proposal 91-010, "Parity Violation in Elastic Scattering from the Proton and ^{4}He").

Another ^{4}He PV experiment [5], approved for running in Hall A, differs from this proposal in both physics motivation and methodology. In that proposal, a higher Q^2 (on the second maximum of the elastic form factor; see Fig. 5) is adopted The experiment then becomes sensitive to meson-exchange currents [17]. It is a low counting rate experiment which proposes to use focal plane detectors to reconstruct the particle trajectories for background subtraction, while the present experiment, like the previous HAPPEX efforts, uses integrating Cerenkov detectors and makes use of the kinematical separation of the inelastic processes at low Q^2. We view the two experiments as complementary.

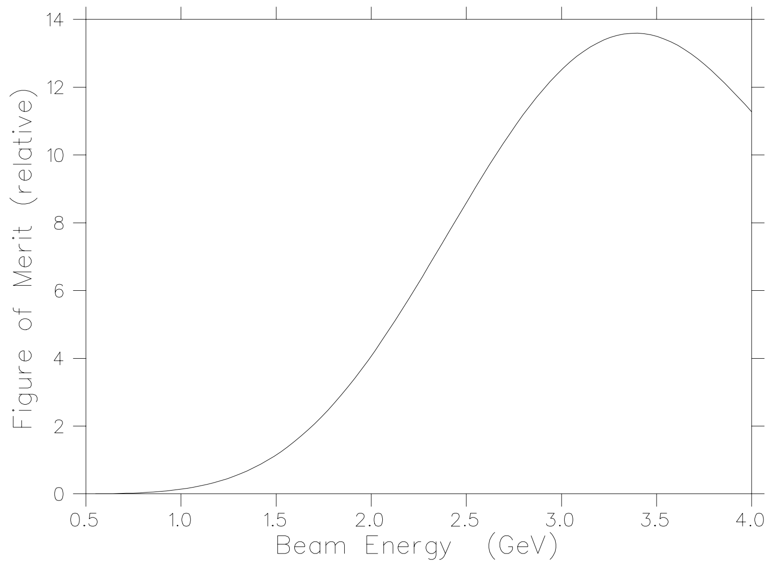

FIGURE 6. Relative Figure of Merit as a function of beam energy, at a 6° scattering angle.

III CHOICE OF KINEMATICS AND COUNTING RATE ESTIMATE

To maximize the Figure of Merit we plan on using the septum magnets in conjunction with the HRS spectrometers to reach a mean scattering angle of 6°. We define the figure of merit $FOM = \frac{d\sigma}{d\Omega}(A\tau)^2$ to maximize sensitivity to ρ_s. For the elastic form factor, we adopt the Frosch *et al.* parameterization [25]. As shown in Fig. 6, this figure of merit has a broad peak around an incident electron energy of 3.4 GeV and $Q^2 \sim 0.1$ $(\mathrm{GeV}/c)^2$. Fortuitously, this is very nearly the same Q^2 as planned for the HAPPEX II proposal [7]. Figure 7 shows the hardware separation of the inelastic breakup channels in the focal plane. There is 20.2 MeV separation to the first inelastic level, which is also an isoscalar $0^+ \to 0^+$ transition. The neutron emission threshold occurs at 20.6 MeV (Fig. 7). The elastic and quasielastic peaks from the Al target walls are also kinematically separated. Assuming a $\Delta\omega = \pm 15$ MeV acceptance gives an 8 cm wide detector. The required detector is similar to that needed for the approved Lead parity experiment [20]. The previous HAPPEX [1] detectors were similar in width (10 cm wide).

We plan to use a new ^{4}He cryotarget under construction for Hall A which will be 20 cm long and have a target density of 0.14 gm/cm^3. Assuming a spectrometer acceptance of 3.7 msr using the septum magnets and a $100\,\mu A$ 80% polarized beam, yields a 12 MHz counting rate per spectrometer. Results from the Monte Carlo estimate assuming no strange quarks are summarized in Table 2. Acceptance averaging reduces the effective cross section by 36%; radiation, by another 33%. The effective point scattering angle corresponding to the acceptance–averaged value of Q^2 is 5.72°.

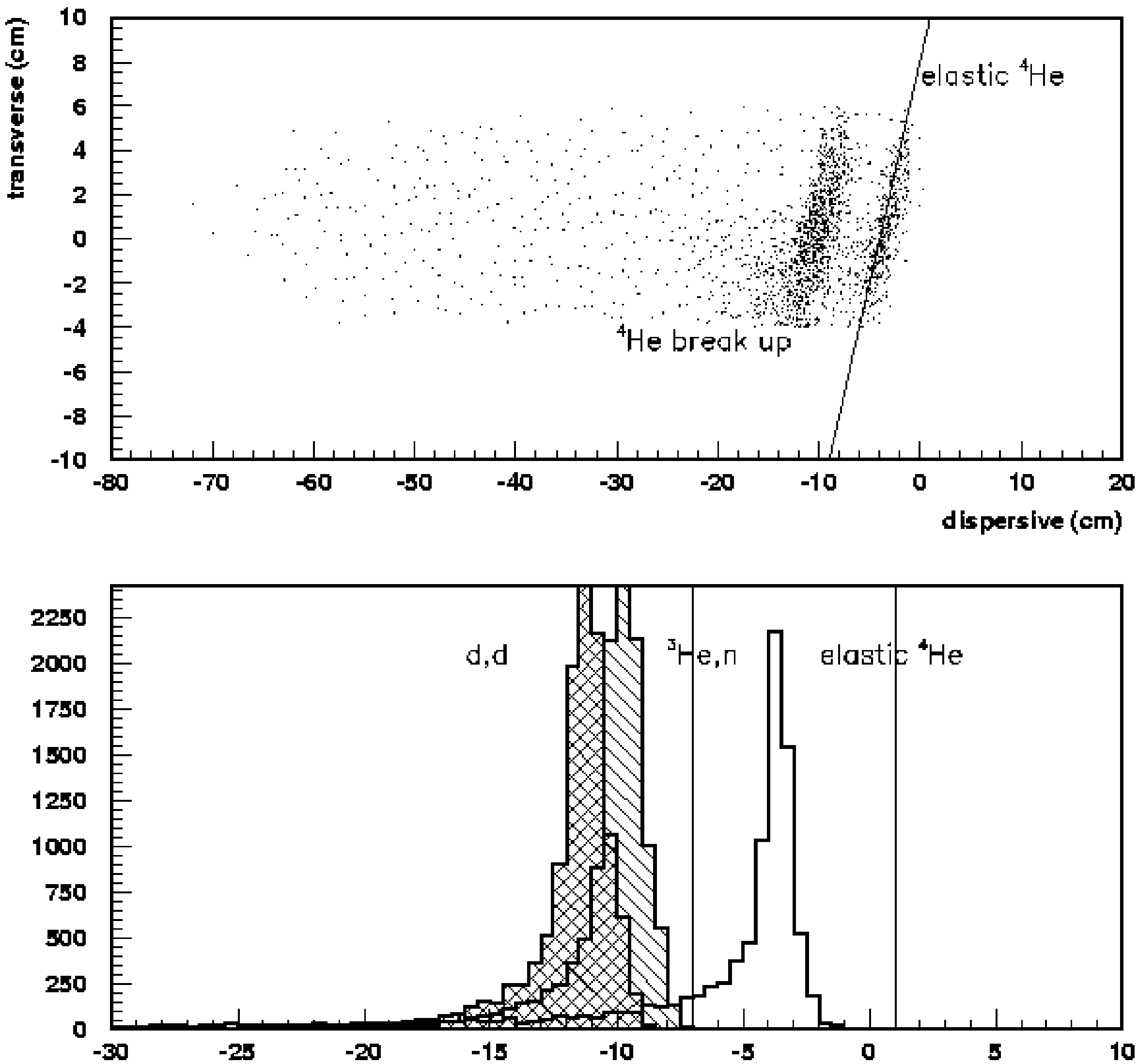

FIGURE 7. Elastic and breakup distributions on the focal plane (top) and events projected onto the elastic line (bottom). The detector size indicated corresponds to a window of ± 15 MeV in missing energy. The events were *not* weighted by their relative cross section.

A 700 hr run will produce a 1.9% error for the asymmetry from the ^{4}He target. Assuming that the error correction due to the Al cell wall background is no bigger than half this error, leads to a predicted overall 2.2% statistical error.

TABLE 2. Kinematics and Rates

$\left\langle E_0 - \frac{dE}{dx} \right\rangle$	3198 MeV
$\left\langle Q^2 \right\rangle$	0.101 $(\mathrm{GeV}/c)^2$
$\langle\theta\rangle_{eff}$	5.72°
$\left\langle \frac{d\sigma}{d\Omega}^{rad} \right\rangle$	0.00125 fm^2
$\langle A \rangle$	8.43 ppm
Rate/arm	11.9 MHz

IV APPARATUS

A Overview

Much of the experimental technique used in HAPPEX [1] and proposed for the approved HAPPEX II [7] experiment and the Lead Parity Experiment [20] will also be used here. The two identical 3.7 msr spectrometer systems consisting of the Hall A septum magnets plus HRS spectrometers will focus elastically scattered electrons onto total-absorption detectors in their focal planes. With their 10^{-4} momentum resolution, the spectrometers will focus inelastic events far away from our detectors (Fig. 7). The detectors will integrate the elastic peak in each 30 msec helicity period. A 100μA, 80% polarized beam with a 30 Hz helicity reversal will scatter from the Hall A cryogenic ^{4}He target. Ratios of detected flux to beam current integrated in the helicity period are formed and the parity–violating asymmetry in these ratios computed from the helicity–correlated difference divided by the sum: A = $(\sigma_R$ - $\sigma_L)$ / $(\sigma_R + \sigma_L)$, where $\sigma_{R(L)}$ is the ratio for right(R) and left(L) handed electrons. Separate studies at lower rates are needed to measure backgrounds, acceptance, and Q^2. Polarization is measured once a day by the Møller polarimeter, and monitored continuously with the Compton polarimeter.

B Polarized Beam

Polarized electrons are produced by photoemission from a strained GaAs crystal. The laser light is circularly polarized by a Pockels cell providing voltage–controlled optical phase retardation that is reversed at 30 Hz. The helicity is structured into pairs of 33.3 msec periods of opposite helicity, where the sign of the first in the pair is determined pseudorandomly. Experience has shown that most of the helicity correlations in the electron beam originate from control of the laser light.

A great deal of effort is being put into upgrading the polarized source, including control of the systematics, and increases in the product P^2I. With increased laser power, a 100μA beam of ≈80% polarization is expected to be available. Techniques to purify the laser light polarization to high degree should reduce the need for feedback to control the helicity– correlated intensity asymmetry. [16].

C Spectrometer and Detector

The septum magnets being built by the INFN group [21] will extend the angular range of the HRS down to 6°. Monte Carlo simulations show a solid angle acceptance of 3.7 msr per spectrometer. During running of the early septum magnet experiments, we will study issues of acceptance, backgrounds, and the systematics of Q^2.

The focal-plane detector will be similar to the HAPPEX detector, which was a sandwich of lead and lucite. For HAPPEX [1], custom built 16-bit ADCs integrated the signal in each 30 msec helicity window. The ADCs were also used to integrate beam position and beam current monitor signals. To reduce the noise from pickup on the long cable runs from our detectors, we will explore the possibility of using high frequency ($\geq$ 60 MHz) V-to-F converters to convert the analog signals, and transport the frequency signals via fiber optic cables to 200 Mhz scalers in the DAQ crate. We expect that most, if not all, of the detector and DAQ components for this proposal will be the same as will be used for the HAPPEX II [7] and Lead Parity [20] experiments.

For the focal-plane detector we plan to use amorphous silicon or "quartz" as the radiating element. One possible technology is the use of quartz fibers. They can be obtained as thick as 880 μm and cost \$20/m in bulk. The detector would have about 10 layers of fibers between 1 radiation length sheets of lead. Due to our simple geometry, an air lightguide is sufficient to transport the light to the phototube. Another possibility is to use quartz plates. Since the detector is small, light collection is no problem. We will investigate this possibility. The detector will be easy to install in the focal plane above the VDC drift chambers. The rate in the spectrometer hut should not harm the other detectors, which will be turned off during normal data-taking.

V SYSTEMATICS

A major challenge in measuring such small asymmetries is maintaining helicity–correlated systematics at a level much smaller than the statistical error. In addition, one must measure the systematic errors. We note that the present proposal places less stringent requirements on most systematics than either the HAPPEX II [7] or Lead Parity [20] experiments. The present goal is an absolute error on the asymmetry of ± 0.3 ppm, compared to ± 0.09 ppm for HAPPEX II and ± 0.016 ppm for the Lead experiment.

There are several issues here:

1. The main issue affecting the experimental systematic error is the control

of false asymmetries associated with helicity–correlated beam parameters such as intensity, energy, and position. In controlling these, the goals are to make the two electron beams for the two helicities as nearly identical as possible, and to calibrate the apparatus by modulating the beam position, angle, and energy, thus allowing us to compute any corrections.

2. The statistical error in each 30 msec window will be 1180 ppm. All other noises, e.g. instrumental noise, must be kept well below this.

3. The normalization of the asymmetry must be better than 3%. We expect to be able to measure Q^2 to 0.3%. The polarimetry groups have stated they can measure polarization to 2% by the time of HAPPEX II.

4. Since we must integrate our detected signal, the backgrounds must be measured separately. Also, pedestals and nonlinearities need to be controlled at the few tenths of percent level.

5. Electronic cross-talk must be minimized. During HAPPEX, techniques were deployed that kept this effect less than 2×10^{-8}.

A Helicity–Correlated Beam Parameters

In the past year, techniques have been developed to reduce the helicity–correlated intensity and beam position in the injector by minimizing the sensitivity of the laser optics to changes associated with the Pockels Cell used to produce polarized light. These developments will continue in collaboration with the polarized injector group, the G0 experiment [6], and HAPPEX II experiment.

During HAPPEX, the correction due to beam parameters was $(3 \pm 3) \times 10^{-8}$. These were negligible for HAPPEX but we want to reduce both the size of this correction and its error. We already have a goal of a factor of 10 for the Lead Parity experiment [20], and this will more than suffice for the present proposal.

The position correlations for the running using the strained GaAs for HAPPEX were larger than desired. The main reason was that the beam tune had unnecessarily large beta functions. This tune resulted from a need to have a tight beam in the Compton polarimeter together with a lack of appropriate quadrupoles in the Hall A beam line. With the new quadrupoles that were installed in January 2000, we should be able to develop ideal tunes which will significantly reduce the helicity–correlated position differences on target. In addition, new controls of systematics are being developed for the polarized source. These include improving the degree of circular polarization of the laser, and helicity–correlated deflections using a piezoelectric mirror. We believe we can solve the position correlation problem, making the corrections at most comparable to the statistical error.

The error in the position corrections was due to 20μm position jitter in the beam at the target. However the true noise in position is the electronic position monitor noise. One of our monitors showed 0.8 μm noise, presumably due to the small beta function at that point. This provides a measure of the intrinsic monitor noise which is 25 times smaller than the value used to compute the HAPPEX error, or 1×10^{-9} for the same sensitivity. Prior to HAPPEX II we plan to measure with the LH_2 target to measure these sensitivities, study the monitor noise, and see where we stand. A possible upgrade is to use the cavity monitors being developed for G0 [6].

B Fluctuations in the Asymmetry

Integrating a total of 12 MHz (per arm, 24 MHz total) leads to a counting statistic error of 1180 ppm in each 30 msec helicity window. In order to have our error dominated by counting statistics all other sources of noise must be much smaller than this. Again, the HAPPEX experiment can be used as an indication of the magnitude of the problems. The following contributions to noise in HAPPEX are relevant: 1) Electronic noise of beam current monitors, 30 ppm; 2) Electronic jitter in the detected flux contributed 100 ppm, but this was caused mainly by long cable runs to our ADCs. We are presently studying the possibility to deploy 60 MHz V-to-F converters in the detector huts, to convert the analog signals, then run the frequency signals via fiber optics to scalers in the counting room. We anticipate this will reduce the error to about 30 ppm. and 3) Beam jitter of about 20 μm corresponding to 20 ppm in the asymmetry (for the LH_2 target).

These and other sources of noise can be studied during engineering runs prior to the experiment.

C Normalization Errors - Q^2 and Polarization

The two main normalization errors are Q^2 measurement and beam polarization. Since the beam energy and the scattered momentum can each be measured to better than 0.1%, we expect to measure Q^2 for elastic scattering to 0.1%. We can make a cross check using the scattering angle, for which a systematic error of 0.3 mrad from a careful survey is achievable. The asymmetry is approximately proportional to Q^2 and it should therefore be possible to keep this systematic error ≤ 0.3 %.

We plan to measure the polarization once a day using the Møller polarimeter. We expect to use the Compton polarimeter to monitor the polarization online in a non-invasive manner between Møller measurements. At present the Compton polarimeter has a systematic error in the absolute polarization of 3.2% at 3.3 GeV. In the future, a 2% error is expected to be possible at 3.2 GeV. One major improvement being made is the implementation of a recoil-electron detector. Considerable experience with Compton is being gained during this year's running of the N-to-Δ experiment.

For the Møller polarimeter, 2% is within reach by the time we run, the main limitation being due to knowledge of the target foil polarization. Cross checks against the Compton and against the Hall C Møller polarimeter are planned.

D Backgrounds

Separate measurements at low rates, as well as Monte Carlo studies, need to be performed to understand the backgrounds. Such studies have been done for the HRS spectrometers [22] and need to be repeated for the septum magnet setup. Early data from running the septum magnet can also be used to study backgrounds. The relevant results from the HRS study and the implications for this proposal are:

1. Inelastically scattered electrons, or those from the radiative tail, can rebound inside the spectrometer and strike the detector. The inelastics were a 0.2% contribution during HAPPEX and should be less of a problem for this proposal because the ratio of inelastic to elastic is very small.

2. Some electrons may scatter from the magnetized iron in the spectrometer and strike the detector. This is a potentially serious problem because Møller scattering from polarized electrons in the iron creates an asymmetry. For the HAPPEX setup pole–tip scattering was measured to be a $\leq 10^{-5}$ contribution to our detected flux implying $\leq 10^{-9}$ to the asymmetry. Simulations confirmed this. For the present proposal it should be an even smaller problem because the septum magnet collimates more strictly the trajectories that come near pole tip faces. Lower energy electrons that rebound in the spectrometer do not see the pole tips.

3. Contributions from inelastic states in ^{4}He and target impurities are a negligible systematic.

4. Target wall contribution: Both the elastic and quasielastic Al contributions kinematically separate, but there are a number of weaker levels in the region of the elastic ^{4}He peak. Therefore measurements will have to be made under our experimental conditions to determine the running time needed to correct for the target-cell wall background. The rate from Al elastics is about 0.8% of the ^{4}He elastic rate. We estimate that the tail of the quasielastic peak will contribute about a 3.3% background. The blank target has thicker walls than the gas target, thus we are currently estimating that no more than 10% of the running time will have to be devoted to Al background measurements.

TABLE 3. Error Budget

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

E Pedestals and Nonlinearity

During HAPPEX we found that measuring ADC pedestals once a day reduces the error in them to 0.1% while their drift was 1% over a 1 day period. Nonlinearities can be measured once per day to 0.1% and are probably stable at the 0.2% level. The effect of pedestal errors or nonlinearity is to produce a systematic which is approximately the product of the error times the largest asymmetry in the devices they affect. For example, a 0.1 ppm beam current monitor asymmetry with a 1% nonlinearity produces a $\approx 1 \times 10^{-9}$ systematic. If we run with adequately low noise in the beam parameters, similar to what was observed during HAPPEX, and if we achieve the aforementioned pedestal errors and nonlinearities, the effects on this proposal will be acceptable.

F Error Budget

A summary of the experimental errors which we will need to achieve are given in Table 3.

VI BEAM TIME REQUEST

We request **35 days of beam allocation**. The breakdown, summarized in Table 4 is **770** hours to achieve **2.2**% statistical accuracy with **100** μA of **80%** polarized beam. This includes approximately 70 hours for running on the blank Al cell 2) A two hour Møller polarimeter measurement once per 24 hours of beam–on–target, hence a total of **34** hours for Møller. 3) **36** hours for setup, checkout of the detector alignment, and auxiliary measurements of beam energy, Q^2 and non target-wall backgrounds. All time estimates assume 100% efficiency.

We plan to study the systematics of the strained GaAs polarized beam parasitically; this work was already begun in 1999 and will continue as preparation for HAPPEX II [7] and G0 [6]. If successful, these beam studies will

TABLE 4. Beam Request

Measurement	Time
He data-taking	700 hr
Blank target cell data	70 hr
Møller polarimetry measurements	34 hr
Energy calibrations and spin dances (2)	8 hr
Q^2 calibration (weekly)	8 hr
Measurements of other backgrounds	4 hr
Setup, detector alignment, linearity tests	16 hr
Total (35 days)	840 hr

demonstrate that the beam and beam line instrumentation are adequate in advance of our beam-time.

We will participate in the commissioning of the septum magnet and will use data from that commissioning as well as early experiments to examine issues of acceptance, backgrounds, and systematics of Q^2. Prior to our production run, we'll need to set up the septum magnet.

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