Update to JLAB Experiment E–91–004

Measurement of Strange Quark Effects Using Parity Violating Elastic Electron Scattering from ^{4}He at $Q^2 = 0.6$ (GeV/c)^2

E. J. Beise, H. Breuer, C.C. Chang, N. Chant, J.J. Kelly, P. King, and P.G. Roos
University of Maryland, College Park, MD 20742

B. Filippone, J. Gao, K. Gustafsson, T. Ito, J. Martin, and R.D. McKeown
W.K. Kellogg Radiation Laboratory, Caltech, Pasadena, CA 91125

J.P. Chen, O. Hansen, K. deJager, J. Gomez, J.H. Mitchell,
J.J. LeRose, N. Liyanage, R. Michaels, S. Nanda, A. Saha, and B. Wojtsekhowski
Thomas Jefferson National Accelerator Facility, Newport News, VA 23606

G.G. Petratos, M. Katramatou, K. McCormick
Kent State University, Kent, OH 44242

D.S. Armstrong, T. Averett, J.M. Finn, and J. Roche
College of William and Mary, Williamsburg, VA 23187

W. Korsch and D. Dale
University of Kentucky, Lexington, KY 40506

K. Aniol, M. Epstein and D. Margaziotis
Calif. State Univ. at Los Angeles, Los Angeles, CA 90032

M. Pitt
Virginia Polytechnic Institute, Blacksburg, VA 24061

J. A. Templon
The University of Georgia, Athens, GA 30602

J. Calarco
The University of New Hampshire, Durham, NH 03824

P. Markowitz
Florida International University, Miami, FL 33199

X. Jiang
Rutgers University, New Brunswick, NJ 08854

P. Ulmer
Old Dominion University, Norfolk, VA 23529

R. Wilson
Harvard University, Cambridge, MA 02138

A Hall A Collaboration Experiment

December 12, 2000

ABSTRACT

We present an update to experiment E91–004, a measurement of parity violating elastic electron scattering from ^{4}He at the location of the first maximum of the ^{4}He charge form factor. E91–004 was approved in 1993 with an "A" rating for 85 days of beam. The experiment will use a beam energy of 3.3 GeV, a 20 cm long high pressure helium target, and the two Hall A spectrometers at 13.5° and 3.2 GeV/c to detect scattered electrons. The parity-violating amplitude is sensitive to the contribution of strange quarks to the structure of ^{4}He. In the simple one-body approximation of the helium wave function, this measurement will be sensitive to the nucleon's strange electric form factor at $Q^2 = 0.6$ (GeV/c)^2. Because ^{4}He is a (J=0, T=0) nucleus, clean information on the strange electric form factor can be determined with a single measurement with little theoretical uncertainty. In view of the anticipated performance of the polarized source of 100 μA delivery at 80% polarization, we request reapproval of 65 days of beam.

I. INTRODUCTION

In the last decade, considerable attention has been paid to developing a deeper understanding of the contribution of the sea of quarks and antiquarks to the basic properties of hadrons, such as their charge distributions and magnetic moments. Parity violating electron scattering has emerged as a powerful probe of sea-quark contributions because of its sensitivity to strange quarks. Measurements of parity-violating asymmetries at the part-per-million level, while experimentally challenging, have been successfully carried out at MIT-Bates and JLAB. These experiments were enabled by significant progress in the delivery of high quality, intense polarized electron beams. In the two recently completed experiments that measured parity violation in *e*-*p* elastic scattering, SAMPLE [1] and HAPPEX [2], systematic errors in the asymmetry due to helicity correlations in the beam were well below 10^{-7}. The expectation for the future G0 [3] and HAPPEX [4–6] programs is comparable if not better.

As a result, the ability to extract information about strange quark contributions to nucleon structure is becoming limited not by experimental errors (other than statistical) but by theoretical uncertainties in the terms that do not arise from strange quarks, such as the neutron electromagnetic form factors in the case of HAPPEX and the isovector axial form factor in the case of SAMPLE. Elastic *e*-*p* scattering is in this sense complicated by the fact that there are three weak form factors of the nucleon, electric, magnetic and axial, requiring three independent measurements for complete experimental information.

In 1999, SAMPLE experimentally determined the isovector component of the axial form factor G_A^e by combining the original *e*-*p* measurement with quasielastic *e*-*d* scattering [8], and found the radiative corrections to G_A^e, arising from anapole-like terms involving a parity-violating photon-nucleon coupling, to be significantly larger than theoretically estimated [9]. Such terms are very challenging to calculate and have large theoretical uncertainties. Because of the surprising result from SAMPLE, the G0 collaboration is considering the possibility of adding a third measurement to its program, quasielastic *e*-*d* scattering, in order to experimentally determine G_A^e. This will likely require an upgrade to the presently designed detector because of a predicted large π^- rate from the deuterium target.

A complementary approach to elastic *e*-*p* scattering is to consider a J=0, T=0 nuclear target such as ^{4}He. In this case, only the electric contribution survives, thus only a single measurement is required to extract a single form factor. In ref. [7] Musolf and Donnelly argued that the most theoretically clean determination of G_E^s in the proton would in fact come from a combination of a low-Q^2 and a high-Q^2 measurement on ^{4}He, because of the uncertainties in calculating higher order radiative contributions to the nucleon's axial form factor.

A low Q^2 measurement of parity violation in ^{4}He(e,e') is already planned in Hall A, exp. E00–114 [5]. It will be similar in execution to the HAPPEX proton measurements and seeks to determine the slope of G_E^s at Q^2=0.1 (GeV/c)^2. Here we present an update to JLAB experiment E91–004, in which we intend to measure the parity-violating asymmetry in elastic scattering from ^{4}He at a momentum transfer $Q^2 = 0.6$ (GeV/c)^2, using the pair of high resolution spectrometers in Hall A.

Within the context of the Standard Model, the parity-violating asymmetry in elastic electron scattering from a (0^+0) nucleus is

$$A = \frac{G_F Q^2}{4\pi\alpha\sqrt{2}} \left[4\sin^2\theta_W + \frac{F^s}{F_C} \right] , \tag{1}$$

where F_C is the charge form factor of ^{4}He and F^s is the nuclear form factor associated with the matrix element $\bar{s}\gamma_\mu s$. At the kinematics of E91–004, the asymmetry in the absence of any contribution from strange quarks is 5×10^{-5} or 50 ppm, or

$$A = 50\,\mathrm{ppm}\,[1 + 100F^s] \ . \tag{2}$$

In a simple "one-body" description of ^{4}He, nuclear structure effects will cancel in the ratio of the form factors and the second term of the asymmetry can be replaced with

$$\frac{F^s}{F_C} \longrightarrow \frac{2G_E^s}{(G_E^p + G_E^n)} , \tag{3}$$

where G_E^s is the strange "electric" form factor of the proton. A statistical measurement of the asymmetry of $\delta A \sim 17$ ppm would determine F^s to an absolute error of $\delta F^s \sim 3.5\times 10^{-3}$. In the simple one-body picture this would correspond to an absolute error on G_E^s of ± 0.06. Many-body effects have been estimated [10], and at the momentum transfer of E91–004 the many-body contribution, approximately 15% of the asymmetry, is expected to be dominated by a ρ-π transition current equivalent to that known to contribute to the electromagnetic structure of isoscalar targets. This point is discussed in more detail below.

This experiment was first conditionally approved for 65 days of beam time at PAC5 in January 1992. In June 1992 it was endorsed as a Hall A Collaboration experiment. In July 1992, it was evaluated along with the HAPPEX and G0 programs by a technical advisory panel headed by B. Barish. E91–004 was given a strong endorsement by the TAP, and in Dec. 1993, it was fully approved for 85 days of beam time with an "A" rating.

The specific technical issues related to E91–004 that were highlighted by the TAP and by the subsequent PAC were those relating to luminosity: the high density ^{4}He target and the availability of high current polarized beam. Since 1993, considerable operating experience has been gained with polarized beam, with the spectrometers, and with helium gas targets. The two HAPPEX runs have demonstrated that the quality of the polarized beam is well beyond that required for the statistics limited 50 ppm asymmetry measurement of E91–004. The primary outstanding issues which have not yet been addressed in a previous experiment are the requirement for 100 μA polarized beam delivery, the need for a 20 cm long helium target, and issues associated with tracking and the trigger which are unique to this measurement.

Since the original proposal was submitted, many institutional affiliations have changed, including changes to the Hall A staff. The collaboration list is thus quite different from the original submission. We note that most members of our collaboration are also involved with either HAPPEX or G0.

II. THEORETICAL OVERVIEW

There has been significant theoretical effort towards understanding the contribution of strange quarks to nucleon structure in the last decade. At low momentum transfer, the

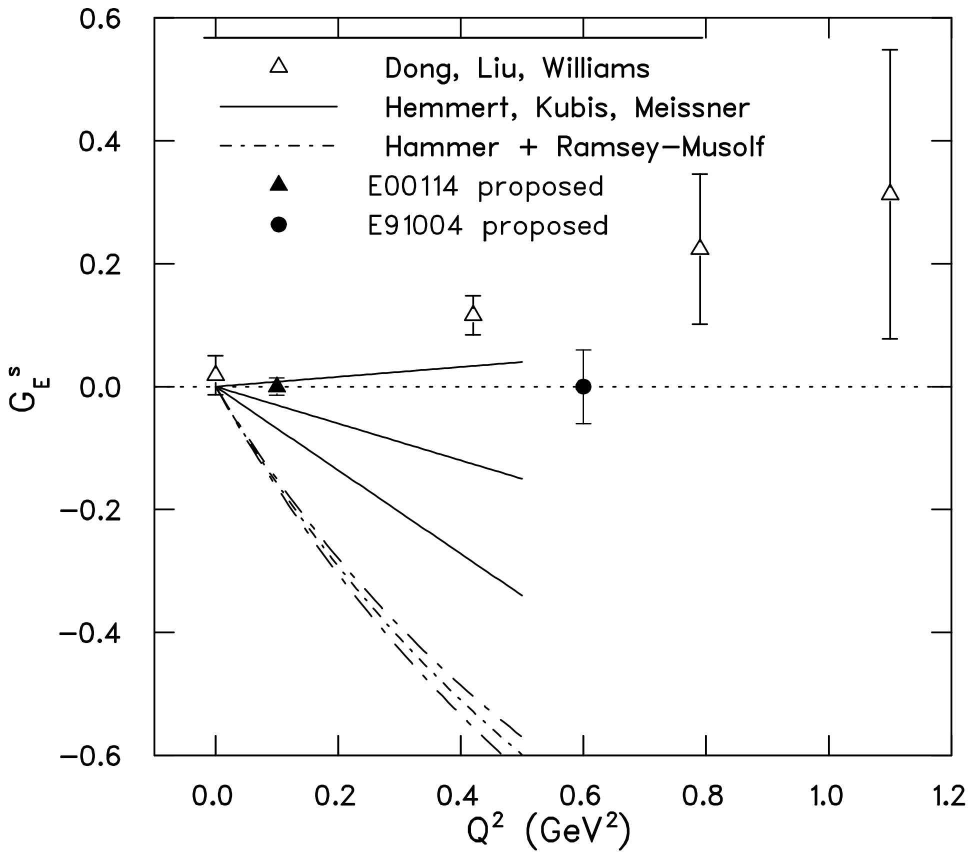

FIG. 1. Comparison between the proposed errors from E00–114 and E91–004, the lattice calculation of Dong, Liu and Williams, the dispersion analysis of Hammer and Ramsey-Musolf, and the HBCHPT calculation of Hemmert, Kubis and Meissner. Note that the authors of the latter state that the calculation is a truncated expansion and may not be valid beyond Q^2=0.5 (GeV/c)^2. The solid line is their central prediction and the dashed lines are the ranges resulting from experimental errors in HAPPEX and SAMPLE.

form factors associated with the matrix element $\overline{s}\gamma_\mu s$ are most often characterized by the strange magnetic moment μ_s and by the "strangeness radius" $\rho_s = dG_E^s/d\tau$ as $\tau \to 0$, where $\tau = Q^2/4M_p^2$. More than two dozen predictions for μ_s now exist, and about half as many for the strangeness radius. The SAMPLE experiment at MIT-Bates provided the first measurement of μ_s, with the recently published value of 0.02±0.29±0.31±0.07 [8], where the errors are statistical, systematic, and theoretical (resulting from an extrapolation to Q^2=0). The two upcoming HAPPEX measurements, one on hydrogen [4] and the other on helium [5], are focussed on determination of the two static properties.

Most calculations of the Q^2 dependence have addressed the low-Q^2 behavior of G_E^s and G_M^s. In 1989, Jaffe [11] used a vector meson dominance model where nonzero strange matrix elements arise from poles of mesons such as the ϕ and ω. This calculation was updated in [12], with essentially the same result. Musolf and Burkhardt [13] generated one of the early predictions from a "loop"-type model where the virtual $\overline{s}s$ pairs appear as strange baryon-kaon intermediate states, finding the strangeness radius to be about an order of magnitude smaller. It has been argued by several authors that the loop calculations are quite sensitive to the choice of intermediate excited meson and baryon states that are included in the calculation. Geiger and Isgur [14] considered all OZI-allowed $Y^* K^*$ intermediate states, and found that cancellations lead to a very small strangeness radius. Hammer and Musolf argued, within the context of a dispersion analysis, that OZI-violating 3π intermediate states could signficantly contribute [15].

Several authors have also commented that Jaffe's estimate results in an unrealistically large value for G_E^s at large Q^2. Cohen, *et al.* [16] attempted to link the pole and loop pictures, with a result that is not surprisingly between the two others, resulting in a value extrapolated to $Q^2 = 0.6$ (GeV/c)^2 of $G_E^s = 0.03$. The very precise HAPPEX result of $(G_E^s + 0.392 G_M^s)/(G_M^p/\mu_p) = 0.091 \pm 0.054 \pm 0.039$ at $Q^2 = 0.47$ (GeV/c)^2 tends to rule out the pure "pole-type" description, but generally, the HAPPEX result is insensitive to models that predict opposite signs for G_E^s and G_M^s.

There have been very few calculations predicting the Q^2 dependence of the nucleon's strange form factors away from the static limit. Recently, a few "first principle" calculations have been published, none of which is ruled out by existing data. The first is a lattice QCD prediction by Dong *et al.* [17]. They predict G_E^s and G_M^s to have opposite sign, and that $G_E^s(Q^2 = 0.6) \sim +0.15$. Hemmert, *et al.* [18] used heavy baryon chiral perturbation theory to predict the Q^2-dependence of G_M^s in a parameter-free calculation, although the static limit must be fixed by experiment. They used the early SAMPLE work to fix μ_s, and then used the first HAPPEX result to fix an unknown singlet counterterm and predict the Q^2 dependence of G_E^s. With these two constraints, their prediction, extrapolated to Q^2=0.6 (GeV/c)^2, would give $G_E^s \sim -0.15$, about the same magnitude as the lattice calculation but of opposite sign. Hammer and Ramsey-Musolf [19] continued with their dispersion analysis to analyze the role of the $K\overline{K}$ continuum to $G_E^s(Q^2)$ and $G_M^s(Q^2)$. When they include only the $K\overline{K}$ states, their calculation results in a positive slope for $G_E^s(Q^2)$ as in the lattice case, with a magnitude comparable to the other calculations. When they include other low-mass contributions the prediction reverses sign to the curves shown in figure 1. There is thus little agreement on even the sign of G_E^s. Figure 1 shows the comparison of the proposed error for E91–004 and E00–114 to the predictions of the above calculations.

Nuclear structure issues represent a potential theoretical uncertainty that is not present in a nucleon target. In two publications, Musolf and Donnelly [20] and then Musolf, Schiavilla and Donnelly [10] addressed this and made a prediction for the *nuclear* form factor F^s, shown in figure 2 with the specified assumed values of ρ_s and μ_s. Many-body contributions to the measured asymmetry could come either from isospin mixing or from meson exchange currents. Isospin mixing effects were estimated to be less than 1% and therefore negligible [21]. At low momentum transfer, meson-exchange contributions are also negligible. Above the first maximum in the ^{4}He charge form factor, meson exchange contributions can begin to play a role. The dominant many-body type effect is expected to come from a ρ-π "strangeness" transition current, $\langle \rho | \bar{s} \gamma^\mu s | \pi \rangle$, single meson exchange being prohibited by conservation of G-parity. In [10], the transition current was estimated to contribute about 15% to the asymmetry, however it was noted that the relative importance of this term is strongly dependent on the magnitude of the one-body strange quark contribution. The ρ-π coupling constant, $g_{\rho\pi s}$, used in the calculation was estimated from $\phi \to \rho\pi$ decay.

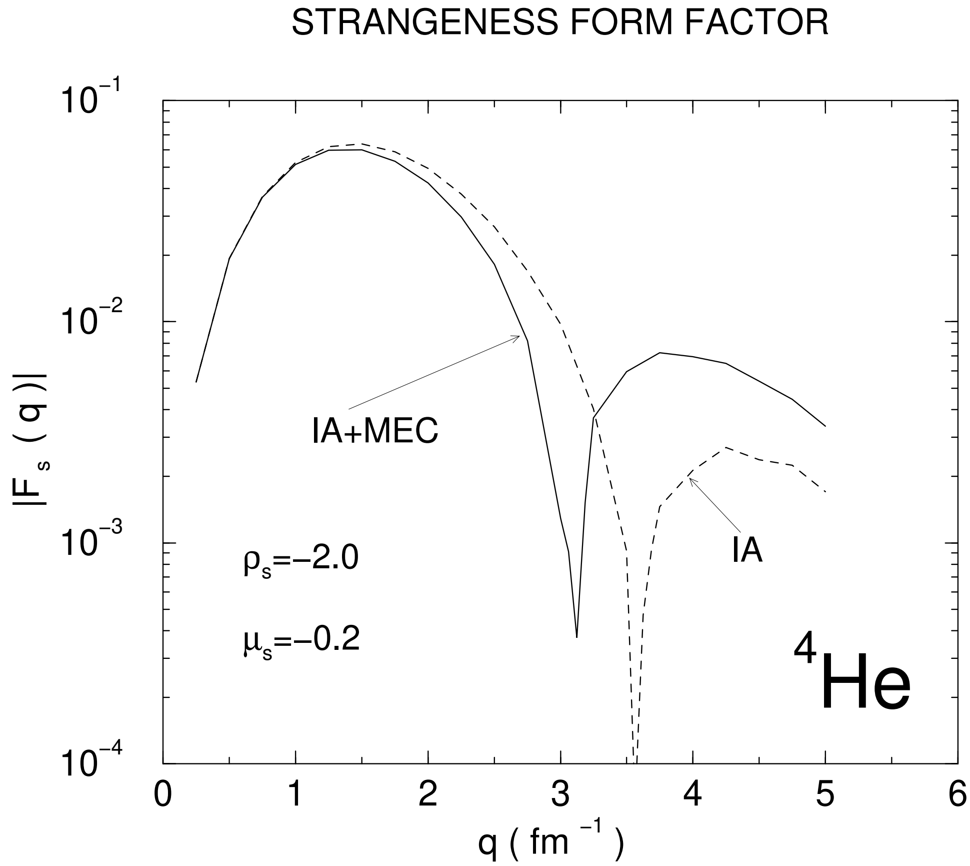

FIG. 2. Calculated F_s in ^{4}He from Musolf, Schiavilla and Donnelly (see text), assuming the specified values for ρ_s and μ_s, and showing the contribution from meson exchange.

However, neither the sign nor the Q^2 dependence of this coupling is known, resulting in an uncertainty in the estimated contribution to the asymmetry of also $\pm 15\%$. The transition current was estimated again in a loop-type calculation [22], with a somewhat larger resulting contribution. The $g_{\rho\pi s}(Q^2)$ form factor was also calculated within the framework of a chiral quark model [23], and found to be about 25% smaller than that used in [10]. A theoretical uncertainty of $\pm$ 15% on our measured asymmetry corresponds to an additional uncertainty in G_E^s of $\delta G_E^s \sim \pm 0.022$.

In summary, despite possible theoretical uncertainties arising from meson exchange, a high-Q^2 asymmetry measurement in helium will be able to provide substantive information on the contribution of s-quarks to nucleon structure well away from the static limit. In the event that both HAPPEX and G0 find very small values for G_E^s, E91-004 may be able to provide a constraint on meson-exchange contributions to nuclear strangeness. This measurement would therefore complement E00–114, and, because of the very different theoretical issues involved and different experimental technique used, will also be complementary to the planned G0 program.

III. EXPERIMENTAL UPDATE

The basic goal and method of the experiment has not changed since it was approved, and both the original proposal and the 1993 update are for the most part still relevant. The only significant changes have been related to the polarized beam parameters, and to the spectrometer settings because of the requirement that the right-side HRS not go above 1100 Amps, corresponding to a momentum of 3.25 GeV/c.

We assume 100 μA of available 80% polarized beam, incident on a 20 cm long gaseous helium target with a density of 0.15 g/cm^2. For consistency, these parameters are identical to the other recently approved low-Q^2 helium parity violation experiment, E00-114. The target parameters are identical to those required for E00-118 [24]. We propose to add collimators to eliminate events from the target windows, resulting in an effectively viewable length of helium of about 15 cm.

A. Target

The existing helium target loop in Hall A contains a 10 cm diameter vertical flow cell ("tuna can" geometry) that in Oct. 2000 operated at 5.8 K and 15 atm with up to 100 μA of beam current incident. For this experiment, as well as for E00–114 and E00–118, the helium target will be upgraded to a 20 cm long vertical flow cell. The new cell, developed by the Cal State Los Angeles group, is constructed of 7075-T6 Al, with 13 mil walls. It has been successfully pressure tested to over 30 atm at room temperature. Additional R+D is underway to try to decrease the wall thickness to 10 mils, although further upgrades are not necessary for E91–004. Design of the cell block that will attach to the existing target loop is underway. The helium loop heat exchanger was recently upgraded for high current running and has operated successfully with a total power deposition of 500 watts, of which 350 watts was from the 100 μA beam. It is estimated that an additional 100 watts could be gained by increasing the target temperature by 0.5 K, which has little impact on the density. The actual performance of the new target cell will not be known until it has been tested with beam. In the existing target, the helium gas density was studied as a function of incident beam current (with a 2 mm by 2 mm rastered beam), and found to drop by approximately 6% with 100 μA incident beam. Again, the new target may behave differently and these studies, as well as a study of possible helicity correlated density changes, will be carried out prior to production running.

B. Spectrometers

We will use a beam energy of 3.3 GeV and scattering angle of 13.5°. The acceptance-weighted cross section will be 1 nb/sr and $\langle Q^2 \rangle$=0.58 (GeV/c)^2, assuming no entrance collimator in the spectrometers. We assume a solid angle of 6.5 msr per spectrometer, and reduction factors coming from radiative losses (20%), dead time (20%) and tracking inefficiencies (10%). Rates were calculated assuming these values.

Due to the low elastic count rate and the kinematic broadening of both the elastic and inelastic events, the elastically scattered electrons are not cleanly identified in any of the individual hardware elements or in the raw trigger. Therefore, rather than use the integration technique of the HAPPEX experiments, we plan to use the standard HRS detector packages in order to take advantage of its excellent tracking capabilities.

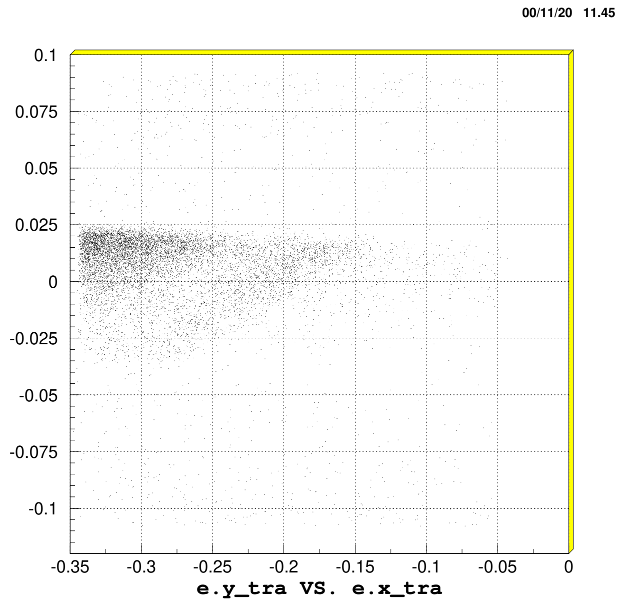

FIG. 3. Elastic data from E97–111, showing the distribution of transverse (Y) vs. dispersive (X) coordinates at the focal plane, perpendicular to the central ray, with geometrical cuts corresponding to one scintillator in each of the S1 and S2 planes. Events in the right band are from elastic scattering. Aluminum windows have not been subtracted.

The elastic rate into each spectrometer will be approximately 780 Hz. If the full acceptance of the focal plane were used, there would be a significant additional rate from breakup and quasielastic ^{4}He(e,e') bringing total rate to about 50 kHz. In both spectrometers, each of the two planes of scintillators is segmented into six paddles with phototubes at both ends. The momentum acceptance of the spectrometer can thus be limited by triggering on only one or possibly two scintillators per plane, turning off the other detectors. This will reduce the quasielastic trigger rate by at least a factor of 10. The remaining quasielastic rate will be further reduced by placing a 3rd scintillator along the diagonal elastic scattering acceptance at the S1 plane. With this strategy the rate from quasielastic scattering can be reduced to approximately the elastic rate, keeping the total rate into each arm below 2.5 kHz.

In October 2000, as part of the calibration data for experiment E97-111, several sets of data were acquired with approximately the correct kinematics for E91-004. With these data we have been able to study the proposed technique by placing software cuts corresponding to the scintillator geometry. The target was a 10 cm diameter "tuna can" with 13 mil 7071 Al walls and a target density of 0.14 g/cm^2. There was no target collimator so events

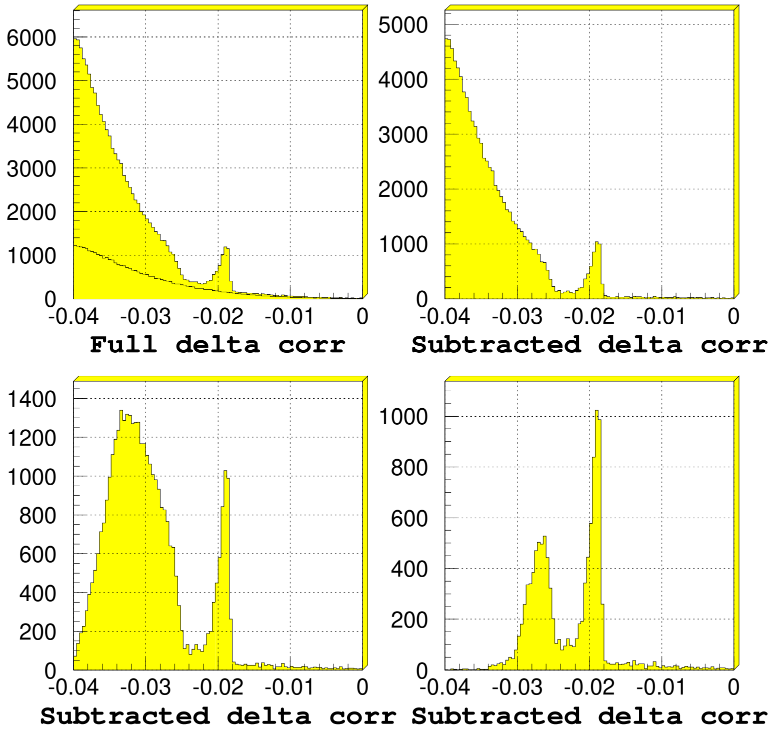

FIG. 4. Elastic ^{4}He data from E97-111. (a) (upper left): Kinematically corrected momentum spectrum of the full focal plane, with empty target spectrum overlaid. (b) (upper right): same spectrum again, but with aluminum walls subtracted. (c) (lower left): same spectrum, placing geometrical cuts simulating the width of one scintillator paddle in S1 and S2. (d) (lower right): addition of a third cut simulating a scintillator along the elastic peak at the location of S1.

from the aluminum walls are present in the spectrum. Figure 3 shows the distribution of scattered electrons perpendicular to the central ray of the spectrometer at the focal plane after the S1/S2 cuts. Although elastic events, which are in the band near the center of the distribution, are reasonable well-separated from quasielastic events, there is sufficient scatter in the two distributions that it would be difficult to cleanly separate out the elastic events in hardware as is done in the HAPPEX experiments.

Figure 4(a) (upper left) shows a kinematically corrected momentum spectrum with all scintillators turned on, with the equivalent empty target spectrum overlaid. It can be seen that there is a contribution from the aluminum walls under the elastic peak. Figure 4(b) (upper right) shows the effect of subtracting the target walls. The elastic peak can now be cleanly separated from quasielastic events. Figure 4(c) (lower left) shows the effect of removing all but one scintillator from S1 and S2, and figure 4(d) shows the effect of a geometry cut simulating a third scintillator along (but wider than) the elastic acceptance. These cuts reduce the overall count rate to an acceptable level with minimal loss of elastic rate.

C. Data Acquisition and Trigger

Because the standard detector packages will be used rather than an integrating technique as utilized in HAPPEX, there is the possibility of a helicity-correlated detection efficiency, including both data acquisition dead time and tracking efficiency. These could result in false asymmetries in the yield if there is a significant helicity-correlated change in beam intensity.

Computer and electronic deadtime have been extensively studied in the HRS setup and are now well-predicted with a simple model using conversion and readout times for the various crates. We intend to run the two spectrometers in single arm mode with separate data acquisition systems. The high resolution TDCs (model 1875) would be replaced with faster modules, and several of the beam line ADCs would be removed from the data stream. Finally, the shower counter and aerogel detectors would not be read, since for the elastic kinematics the pion rate is expected to be negligible. In this mode, the dead time per spectrometer is estimated to be 20% with a 2.5 kHz trigger rate per spectrometer [25]. This estimate is based on tests carried out with the above proposed reconfiguration of the data acquisition system.

The effect of nonzero deadtime on the measured asymmetry enters if there is a helicity-correlated change in count rate coming either from the real parity-violating asymmetry or from a helicity-correlated beam intensity change. The measured helicity-correlated intensity change in the most recent HAPPEX run was 1 ppm, much smaller than the expected PV asymmetry. Any helicity-correlated dead time effects will thus be most likely a result of the real asymmetry. This effect has been seen in other Hall A experiments in which the physics asymmetry was on the order of one percent, and has been shown to be correctible. The dead time for each helicity state will be measured with scalers. The helicity averaged deadtime will result in an increase in the statistical error of the final asymmetry by $1/(1-\lambda)$, where λ is the fractional dead time. As long as $\lambda < 0.3$, the error of the asymmetry is optimized by maximizing the raw elastic rate.

Similar arguments can be given for the effect of helicity-correlated intensity changes on the tracking efficiency. In E91–004, the rate of tracks crossing the vertical drift chambers (VDCs) will be about 50 kHz, spread across about half of the chambers. A large range of VDC trigger rates have been studied in the HRS, and one particular example where the rates were carefully studied was E94–004 [26], where several data sets were acquired at different track rates crossing the vertical drift chambers (VDCs). As the electron rate changed from 70 kHz to 380 kHz (total across the whole chamber), the coincidence tracking efficiency dropped from 0.7 to 0.5, so one can estimate the rate-dependent component of the tracking efficiency to be 0.65 ppm/Hz. The change in rate resulting either from a 1 ppm helicity-correlated change in beam current or from the real 50 ppm parity-violating asymmetry is much less than 1 Hz. Any false asymmetry due to this effect will be negligible.

As in the case of dead time, of more concern is the overall low tracking efficiency. In the analysis of the E94–004 data, the low efficiency was apparently due to multiple tracks rather than missing hits: the missing hit efficiency was greater than 90%. The tracking algorithm was rather crude, requiring only one cluster per plane on each of the 4 wire planes. An improved tracking algorithm that can accept multiple tracks and perform a chi-squared analysis would likely significantly improve the efficiency. In the case of E91–004, because the trigger scintillators will be physically restricted to the region of the elastic peak, the track rate seen by the data acquisition should be significantly lower than 50 kHz and the multiple track rate should also be low. Our goal is to reach a tracking efficiency of 90% or better in each spectrometer.

D. Helicity Correlated Beam Properties and Systematic Errors

To estimate the contribution to the asymmetry from helicity correlated beam effects, we use the experience gained from the HAPPEX program. HAPPEX reported a total correction due to helicity correlated position and current differences to be $(3 \pm 3) \times 10^{-8}$. Because of the large physics asymmetry in E91–004 and the moderate statistical error, this magnitude of correction would exceed the needs of E91–004 by a factor of at least 100.

We intend to flip the beam helicity at the nominal 30 Hz rate used in most of the other JLAB polarized beam experiments. The statistical error per spectrometer in a 30 msec window is 18%, making the experiment very insensitive to short term jitter. The electronic jitter in the beam monitors seen by HAPPEX on this time scale was 30 ppm for beam current and 20 μm for beam position, the latter representing a factor of 25 better than required for E91–004. The relative accuracy of the beam energy determination is $1{\times}10^{-4}$.

The required measurement accuracy of the beam parameters in a 30 msec period are reproduced here from the earlier proposal. A detailed outline of how these requirements were determined can be found in the original proposal. The dependence of the cross section on energy and angle leads to

$$A_{false}(E) = \left| \frac{1}{\sigma} \frac{\partial \sigma}{\partial E} \right| E \left(\frac{\delta E}{E} \right) \sim 4 \frac{\delta E}{E} \,. \tag{4}$$

and

$$A_{false}(\theta) = \left| \frac{1}{\sigma} \frac{\partial \sigma}{\partial \theta} \right| \delta\theta \sim 17\, \delta\theta \,/\mathrm{rad} \,. \tag{5}$$

These, and the assumption that the beam parameters should be measured to a precision of no more than 10% of the statistical error in 30 msec, were the baseline for calculating the required precision on beam parameter measurements in the table.

It should be noted that the small helicity correlated beam properties achieved in HAPPEX were done so with feedback, in particular between the beam intensity and the Pockels cell voltage that determines the helicity. We intend to implement the same system. In addition, a feedback system to eliminate helicity-correlated position differences is being investigated. This technique was used in the SAMPLE experiment where a glass plate was wiggled in a helicity-correlated way to counteract helicity correlated position differences in the experimental hall. The components for such a system at JLAB exist, and tests are underway to decide whether to implement it for future HAPPEX and G0 running. Both the possible position feedback and the intensity feedback systems would run independently of the spectrometer data acquisition using either the HAPPEX or injector DAQ systems.

The requirements for the beam polarization measurement are not very stringent, and a relative error on the average polarization of 5-10% would be sufficient. A combination of the Compton polarimeter for on-line measurements and periodic Moller polarimeter measurements will easily achieve this goal.

Energy	$\delta E/E$	1×10^{-3}
Position	δx	0.5 mm
Angle	$\delta\theta$	0.3 mrad
Intensity	$\delta I/I$	5×10^{-3}
Radius	δr	1 mm (do not measure)

TABLE I. Required *relative* measurement accuracy of beam properties in 30 msec.

IV. SCHEDULE AND BEAM REQUEST

If E91–004 is reapproved by this PAC, we will request to be put on the schedule at the next available opportunity. The remaining hardware tasks to be completed prior to running are construction of the third trigger scintillator, design and construction of the target collimator, and assembly and testing of the helium target with the 20 cm cell.

The experiment was approved for 85 days of beam time. If the beam and target parameters assumed here are achievable, then 60 days of production beam would result in a statistical error on the physics asymmetry of 17 ppm, or 35% of the “no-strange quark” value. The resulting statistical error on F^s would be $\delta F^s \sim 3.5 \times 10^{-3}$. If the one-body assumption is used, this would correspond to $\delta G_E^s \sim 0.06$. We therefore request 65 days of beam for reapproval, with a breakdown of 60 days for production running and 5 days for target checkout, polarization measurements and empty target measurements. E91–004 is a Hall A collaboration experiment.

[1] D.T. Spayde *et al.*, Phys. Rev. Lett. **84**,1106 (2000).
[2] K. Aniol, *et al.*, Los Alamos preprint /nucl-ex/0006002 (2000). See also K. Aniol, *et al.*, Phys. Rev. Lett. **82**, 1096 (1999.)
[3] "G0", JLAB experiment E00–006, D. Beck, contact.
[4] JLAB experiment E99–115, K. Kumar and D. Lhuillier, contacts.
[5] JLAB experiment E00–114, D. Armstrong and R. Michaels, contacts.
[6] JLAB experiment E99–003, R. Michaels, P. Souder and G. Urciuoli, contacts.
[7] M.J. Musolf and T.W. Donnelly, Nucl. Phys. **A546**, 509 (1992).
[8] R. Hasty *et al.*, accepted for publication in *Science*, 2000.
[9] S.L. Zhu, S.J. Paglia, B.R. Holstein and M.J. Ramsey-Musolf, Phys. Rev. **D62**, 033008 (2000). See also M.J. Musolf and B.R. Holstein, Phys. Lett. **B242**, 461 (1990).
[10] M.J. Musolf, R. Schiavilla and T.W. Donnelly, Phys. Rev. **C50**, 2173 (1994).
[11] R.L. Jaffe, Phys. Lett. **B229**, 275 (1989).
[12] H.-W. Hammer, U.-G. Meissner, D. Drechsel, Phys. Lett. **B367**, 323 (1996).
[13] M.J. Musolf and M. Burkardt, Z. Phys. **C**,433 (1994).
[14] P. Geiger and N. Isgur, Phys. Rev. **D 55**, 299 (1997).
[15] H.-W. Hammer and M.J. Ramsey-Musolf, Phys. Lett. **B416**, 5 (1998).
[16] T. Cohen, H. Forkel, and M. Nielsen, Phys. Lett. **B316**, 1 (1993).
[17] S.J. Dong, K.F. Liu and A.G. Williams, Phys. Rev. **D55**, 074504 (1998).
[18] Hemmert, Kubis and U.-G. Meissner, Phys. Rev. **C60**, 045501 (1999).
[19] H.-W. Hammer and M.J. Ramsey-Musolf, Phys. Rev. **C60**, 045205 (1999). Erratum: *ibid.* **C62**, 049902 (2000).
[20] M.J. Musolf and T.W. Donnelly, Phys. Lett. **B 318**, 263 (1993).
[21] S. Ramavataram, E. Hadjimichael and T.W. Donnelly, Phys. Rev. **C50**, 1175 (1994).
[22] J.L. Goity and M.J. Musolf, Phys. Rev. **C53**, 399 (1996).
[23] H. Ito and M.J. Musolf, Phys. Rev. **C58**, 2595 (1998).
[24] JLAB proposal E00–118, G.G. Petratos, contact.
[25] R. Michaels, private communication and Hall A internal report.
[26] P. Ulmer, private communication.