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Spin Structure Function Physics at Fermilab

by collaborators from Fermilab E866 and additional institutions,
the SEASPIN collaboration

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Abstract. A 120 GeV polarized proton beam from the Fermilab main injector, in conjunction with modern polarized targets, offers a unique and timely opportunity to explore qualitatively new features of polarized parton structure. Far from being a disadvantage, the comparatively low-energy beam from the new main injector is *required* for study of spin structure in the large-x region. It is here where sizable polarization effects are most likely to be observed.

Measurement of the helicity asymmetry in the Drell-Yan (DY) process would allow determination of the polarization of the $\bar{u}(x)$ and $\bar{d}(x)$ structure functions in the range $0.1 \leq x \leq 0.32$. Additionally the transverse spin asymmetry in the DY process would yield the first measurements of the transversity structure functions of both quarks and antiquarks. Polarized production of the J/ψ and ψ' resonances would yield the first information about polarization of the gluon field.

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6. Experimental Assumptions

1. Introduction

The past six years have seen an enormous effort to acquire new information on the spin structure of the nucleon via deep-inelastic lepton scattering (DIS) with polarized electron and muon beams. New measurements of $g_1^p(x)$ confirm[1, 2] the earlier EMC results[3], and new data on the neutron from DIS on polarized ^2H [4] and polarized ^3He[5] add significantly to our knowledge of quark polarization in the nucleon system. The search for new understanding continues. A major effort is underway at DESY where the HERMES[6] experiment, using a polarized gas jet target in the HERA electron storage ring, will extend DIS to more exclusive channels. Experiments are also envisioned at SLAC using 50 GeV polarized electrons and at CEBAF with 4-6 GeV polarized electrons.

In spite of the large body of new data and the promise of even better experiments in the near future inclusive polarized DIS measurements have major limitations. They do not directly provide any information about antiquark or gluon helicity distributions. Neither can they probe the potentially equally interesting, and completely unknown, chiral-odd quark structure functions – the transversity[7, 8, 9, 10, 11, 12]; hence the interest in polarized hard-hadronic processes which could offer new physics insight, complimentary to polarized DIS[13].[1]

An external polarized beam from the Fermilab main injector (MI) with intensity in the range $\approx 10^{11}$/sec in conjunction with a modern polarized hydrogen target would make feasible a completely new program of polarized quark and gluon structure-function physics. The comparatively low beam energy is actually well suited to the study of spin structure at large x, just the region where polarization effects are likely to be the largest.

2. Kinematics for Polarized Drell-Yan Physics

The kinematics of parton fusion in the Drell-Yan (DY) process[14] require

$$M^2/s \equiv \tau = x_1 x_2, \tag{1}$$

where $x_1(x_2)$ is momentum fraction of the beam(target) parton. This relation and the conditions discussed below determine the optimal beam energy range for polarized DY studies.

From extensive phenomenology of experiments at CERN and Fermilab[15] it is found that continuum dilepton production with $M \geq 4\ GeV$ at low p_t is dominated by the DY mechanism. In Sect. 3 we show that polarization effects are largest when a beam quark with $x_1 \approx 0.32$ annihilates with a target antiquark. These conditions, Eq. 1, and the expression $s \approx 2m_p E_{beam}$ for fixed-target experiments, lead to

$$E_{beam} x_2 \geq 26.7\ GeV. \tag{2}$$

Thus with the 120 GeV MI beam one can explore the range $x_2 \geq 0.22$. It is shown in Sect. 3 that the range is more like $x_2 \geq 0.1$ because of the large range of values of x_1 which contribute to the production of high-mass muon pairs.

Of course higher beam energies can be employed to explore the same kinematic range, given the same range of τ. Thus the combinations, $M \geq 4\ GeV$, $E_{beam} = 120\ GeV$, and

[1] Measurement of antiquark polarization and of quark transversity via semi-exclusive DIS have been discussed in connection with the HERMES experiment[6].

$M \geq 8\ GeV$, $E_{beam} = 480\ GeV$ yield the same physics.[2] However it is not often appreciated that the scaling rule for the DY cross section,

$$d^2\sigma/d\sqrt{\tau}dx_F \propto 1/s \times \mathcal{F}(\tau, x_F), \tag{3}$$

greatly favors the lowest beam energy consistent with the production of DY pairs in the "safe" region, $M \geq 4\ GeV$. Thus the MI beam is ideal for the exploration of antiquark polarization at large x_2.

3. Antiquark Helicity Distribution Via the Polarized Drell-Yan Process

The longitudinal spin (helicity) asymmetries in DIS and the DY process have a close relation. This relation can be exploited to cast the DY helicity asymmetry into a simple form[16, 17, 18] that allows straightforward identification of its physics content.

The DY helicity asymmetry is given by[16],

$$A_{LL}^{DY}(x_1, x_2) = \frac{\sum_a e_a^2[\Delta q_a(x_1)\Delta\bar{q}_a(x_2) + \Delta\bar{q}_a(x_1)\Delta q_a(x_2)]}{\sum_a e_a^2[q_a(x_1)\bar{q}_a(x_2) + \bar{q}_a(x_1)q_a(x_2)]}, \tag{4}$$

with $\Delta q_a \equiv q_a^+ - q_a^-$. The superscripts refer to parton spin projections parallel (+) or antiparallel (-) to the parent hadron's spin projection.[3] For $x_F \geq 0.2$, the most favorable kinematic region for fixed-target experiments, the denominator of Eq. 4 is dominated by the term, $q_u(x_1)\bar{q}_u(x_2)$, allowing a substantial simplification,

$$A_{LL}^{DY}(x_1, x_2) \approx \frac{\Delta u(x_1)}{u(x_1)} \times \frac{\Delta\bar{u}(x_2)}{\bar{u}(x_2)} + \frac{1}{4}\frac{\Delta d(x_1)}{u(x_1)} \times \frac{\Delta\bar{d}(x_2)}{\bar{u}(x_2)}, \tag{5}$$

where the notation $q_u(x) \equiv u(x)$ has been introduced. Neglecting small sea-quark effects for $x \geq 0.2$, one can express the structure functions of DIS as,[4]

$$\begin{aligned} F_1^p(x) &\approx 2/9 \times u(x), \\ \Delta u(x) &= 18/15(4g_1^p(x) - g_1^n(x)), \\ \Delta d(x) &= 18/15(-g_1^p(x) + 4g_1^n(x)). \end{aligned} \tag{6}$$

In addition one has $A_{LL}^{DIS}(x) = g_1(x)/F_1(x)$. These relations and the measured values of $g_1^{p,n}$, shown in Figs. 1 and 2, allow even further simplification. For $x \geq 0.2$ one sees that $g_1^n \approx 0$, and with the above relations Eq. 5 becomes

$$\begin{aligned} A_{LL}^{DY}(x_1, x_2) &\approx A_{LL}^{pDIS}(x_1) \times [\frac{16}{15}\frac{\Delta\bar{u}}{\bar{u}}(x_2) - \frac{1}{15}\frac{\Delta\bar{d}}{\bar{u}}(x_2)], \\ &\approx A_{LL}^{pDIS}(x_1) \times \frac{\Delta\bar{u}}{\bar{u}}(x_2). \end{aligned} \tag{7}$$

[2]For this discussion we ignore the well-established scaling violation of QCD.

[3]Next-to-leading order QCD corrections to Eq. 4 have been evaluated[19] and found to be very small.

[4]The approximate forms for the structure functions of DIS used here are, $F_1(x) = 1/2\sum_a e_a^2 q_a(x)$ and $g_1(x) = 1/2\sum_a e_a^2 \Delta q_a(x)$.

The second step follows if $\Delta\bar{u} = \Delta\bar{d}$. Equation 7 has the familiar form of an experimentally measured asymmetry determined by the product of a beam polarization and the asymmetry of a physical process. Thus for the DY process with $x_F \geq 0.2$, a longitudinally polarized proton can be thought of as a beam of *polarized* u quarks with $P_u(x) \approx A_{LL}^{pDIS}(x)$. It is apparent from the large measured values of $A_{LL}^{pDIS}(x_1 \geq 0.2)$ that the longitudinal spin asymmetry in the DY process will be a sensitive measure of the polarization of the $\bar{u}$ quark distribution of the proton. The figure of merit of a polarized beam experiment is $P^2\sigma$. For a polarized proton beam Fig. 3 shows that this quantity, $[A_{LL}^{DIS}(x)]^2 \times u(x)$, peaks near $x = 0.32$.

A polarized u-quark beam may also be used to measure the $\bar{u}$ polarization of the neutron which, by charge symmetry, is the $\bar{d}$ polarization of the proton. This requires a polarized neutron target, feasible with either polarized ND_3[2] or ^3He[5]. For the p+n DY process, Eq. 7 becomes,

$$A_{LL}^{DY}(x_1, x_2) \approx A_{LL}^{pDIS}(x_1) \times \frac{\Delta\bar{d}}{\bar{d}}(x_2). \tag{8}$$

Equations 7 and 8 permit estimates to be made for actual experimental conditions.

Until recently little guidance could be found on the subject of antiquark polarization beyond an indication that the strange quark sea might contribute significantly to the proton's spin[1]. Bourrely and Soffer[21] have presented a phenomenological analysis of data related to nucleon spin and isospin polarization which leads to definite predictions of the polarizations of antiquarks. Their model predicts simple relations connecting the spin and isospin asymmetries of the proton. For $\bar{u}$ quarks the relation is

$$\Delta\bar{u} = \bar{u}(x) - \bar{d}(x). \tag{9}$$

Two recent experiments[22, 23] strongly suggest $\bar{u} \neq \bar{d}$ in the proton. From the ratio of DY cross sections, σ_p/σ_D, experiment NA51 at the CERN SPS has determined the surprisingly large asymmetry, $\bar{u}/\bar{d}(x = 0.18) = 0.51 \pm 0.04 \pm 0.05$; this result and Eq. 9 yield $\Delta\bar{u}/\bar{u}(0.18) = -0.96$. The phenomenology of Ref. [21] also predicts (with little discussion) $\Delta\bar{d}_p = 0$.

An analysis of the new polarized DIS data has been used recently by Gehrmann and Stirling[24] to generate a set of polarized quark and gluon structure functions. Their interest was primarily in assessing status of the gluonic polarization (See discussion in Sect. 5). Their constraints include an isospin symmetric sea with $\Delta\bar{u} = \Delta\bar{d} = 0$ at $Q_0^2 = 4\ GeV^2$. QCD evolution then transforms gluon polarization to antiquark polarization at larger values of Q^2. The analysis gives $\Delta\bar{u}/\bar{u} = \Delta\bar{d}/\bar{d} \approx +[20 - 40]\%$ (opposite sign to that of Bourrely and Soffer for $\Delta\bar{u}/\bar{u}$) in the range $0.1 \leq x \leq 0.3$ at $Q^2 = 30\ GeV^2$.

In order to characterize a measurement of antiquark helicity at 120 GeV, we have designed an experiment capable of yielding $\approx 10^6$ DY dimuons with $M \geq 4$ GeV with an integrated beam-target luminosity $L = 1.2 \times 10^{42} cm^{-2}$. The beam, polarized target, and spectrometer, all based on existing technologies, are described in detail in Sect. 6. Figure 4 shows the predicted $\bar{u}$ polarization with the above structure functions and the errors achievable (plotted on the Bourrely-Soffer curve) with a 10^6 DY pair data set. Clearly measurements achieving the proposed design goal would be able to characterize antiquark polarization in the range $0.1 \leq x \leq 0.32$. It is important to note that the experimental errors are independent

of $\Delta\bar{u}/\bar{u}$. Thus whether the antiquark polarization is close to unity or zero, the use of a polarized u-quark beam ensures a significant measurement.

4. Transversity Measurements in the Polarized Drell-Yan Process

The transversity structure function has recently received a great deal of attention[12, 13] as a potential source of qualitatively new insight into the spin structure of the nucleon: it is not measurable in inclusive DIS experiments. The transversity is defined in a fashion similar to Δq_a, specifically $\Delta q_a^T \equiv q_a^+ - q_a^-$, but with $\pm$ denoting the spin projection perpendicular to the momentum of the nucleon. It is measured in the DY process with a transversely polarized beam and target. Specifically,

$$A_{TT}^{DY}(x_1, x_2) = \frac{sin^2\theta cos2\phi}{1 + cos^2\theta} \frac{\sum_a e_a^2[\Delta q_a^T(x_1)\Delta\bar{q}_a^T(x_2) + \Delta\bar{q}_a^T(x_1)\Delta q_a^T(x_2)]}{\sum_a e_a^2[q_a(x_1)\bar{q}_a(x_2) + \bar{q}_a(x_1)q_a(x_2)]}. \tag{10}$$

where θ is the polar angle of either lepton in the rest frame of the virtual photon, and ϕ is the angle between the direction of polarization and the normal to the plane of the dilepton decay.

Unlike $\Delta q_a(x)$, very little is known about $\Delta q_a^T(x)$. Estimates using the MIT bag model[12] indicate $\Delta q_a^T(x) > \Delta q_a(x)$ in the large-x region where valence quark polarization predominates. A very recent calculation[25] of the valence Δu^T using a QCD sum-rule approach differs significantly from the bag-model estimate, but confirms the above inequality. No estimates are available for the antiquark transversity, $\Delta\bar{q}_a^T(x)$. We assume that optimization of the experimental conditions for $A_{TT}^{DY}(x_1, x_2)$ is similar to that presented previously for $A_{LL}^{DY}(x_1, x_2)$. The major differences are in the angular dependencies of Eq. 10. The dipole spectrometer described in Sect. 6 has maximum efficiency in the region where $sin\theta \approx 1$, thereby optimizing measurement of $A_{TT}^{DY}(x_1, x_2)$.

5. Gluon Polarization Effects Via J/ψ and ψ' Production

Polarization of the gluon field has attracted considerable attention, in connection with the axial anomaly,[5] as a possible source of the "missing" spin of the proton. A variety of models have been published on the subject of gluon polarization[24, 27, 28, 29].

Quarkonium[30, 31, 32, 33] production has been considered as a possible means for the delineation of gluon polarization effects. It has the merit that its decay through dimuon channels is large and easily detectable. In general one can write[13],

$$A_{LL}(x_1, x_2) = \frac{\Delta G}{G}(x_1) \times \frac{\Delta G}{G}(x_2) \times \hat{a}_{LL}(\hat{s}, \hat{t}, \hat{u}), \tag{11}$$

where $\hat{a}_{LL}(\hat{s}, \hat{t}, \hat{u})$ is the parton level asymmetry for a particular gluon fusion process.[6] The asymmetry for J/ψ production is usually discussed in terms of parton fusion models which

[5] See, for example, the discussion by Jaffe and Manohar[26].

[6] Next-to-leading order corrections to the equations used in this section have not been completely evaluated[33]. There is, of course, the possibility that these corrections could substantially modify the polarization relations.

rely on bound-state phenomenology[34] for identifying various possible production mechanisms. Two paths that are likely to contribute to J/ψ production are.

$$g + g \rightarrow \chi_2 \rightarrow J/\psi + \gamma, \tag{12}$$

and

$$g + g \rightarrow J/\psi + g. \tag{13}$$

One expects the ψ' resonance to be produced primarily via the second path since its mass lies above the χ region. The parton-level asymmetry for indirect production via the χ_2 state is maximally large and independent of kinematics, $\hat{a}_{LL}^{\chi_2} = -1$. Theoretical evidence[31, 34] and experimental data from hadron production of the J/ψ [35] suggest that $\sim 30-50\%$ of the cross section is via this path at fixed-target energies. Unfortunately the asymmetry for the three-gluon mechanism has the opposite sign to the χ_2 production path, resulting in partial cancellation[31, 33]. Nevertheless it is found[33] that the net asymmetry remains rather large and constant over a wide energy range. In order to establish the level of sensitivity to gluon polarization achievable by 120 GeV data, we make the simplifying assumption $\hat{a}_{LL} = 0.28$ for both J/ψ and ψ' production independent of kinematics.

At comparatively low energies and large x_F quark-antiquark fusion can also contribute to quarkonium production. Using the semi-local parton duality model[34] we have estimated the contribution from the $q\bar{q}$ term to be a factor of 3-5 lower than that from gluon fusion and will therefore neglect it.

For $x_F \neq 0$, quarkonium production measures the product of gluon polarizations at two different values of x. For example at $x_F = 0.4$, one has $x_1 \approx 0.5$ and $x_2 \approx 0.1$. Figure 5 compares the errors achievable for A_{LL} with the predictions of several polarized gluon structure functions. An integrated luminosity $L = 1.2 \times 10^{41} cm^{-2}$ (factor of 10 less than for DY production, see Sect. 6D for discussion) was assumed. The large number of J/ψ events would, under the above model assumptions, clearly permit one to distinguish between large and small values of $|\Delta G/G|$ in the range $0.15 \leq x \leq 0.75$. The ψ' may be useful as a confirmation if its production mechanism is simpler than that of the J/ψ. It would clearly be desirable to have additional data on the issue of gluon polarization from reactions which may be theoretically cleaner, e.g. direct photon production. Such measurements are planned using the PHENIX and STAR detectors at RHIC[13].

6. Experimental Assumptions

A. Polarized Beam

The detailed operation of the booster and MI for polarized protons has been described by the SPIN collaboration in a recent report[36]. Here we recount only the assumptions essential to justify the polarized proton beam intensities.

The SPIN collaboration assumed a polarized source intensity of 150 microamps which yields $\approx 10^{11}$ protons per booster pulse. Here we assume a somewhat simpler operation of the booster and MI not requiring "slip stacking". Five out of six of the MI's pulses are polarized with the sixth unpolarized at high intensity for antiproton production. In this manner the

operation of the MI is compatible with its primary function of providing antiprotons for the Tevatron Collider. With the addition of a 0.5 second flattop, this corresponds to $\approx 5 \times 10^{11}$ protons per 2.8 seconds. For rate calculations we assume 2×10^{11} per spill would be available to this physics program.

The beam would be transported to the current meson area. Beam polarization would be $\approx 75\%$ following the report of the SPIN collaboration. Horizontal bends in the meson area dipoles could form part of a general spin orientation system to provide both transverse and longitudinal polarization at the target location.

We have not considered polarimetry in detail. Continuous polarization monitoring would likely be achieved by upstream thin-target polarimeters using one or more of the techniques described by the RHIC spin collaboration[13].

B. Polarized Targets

Significant developments in the physics and technology of dynamically pumped polarized targets have led directly to the recent successes of the SMC[1] and E143[2] experiments. The SMC targets (two identical ones for canceling systematic errors) were 60 cm long containing butanol pellets. The E143 target was 4 cm long but scalable to much longer dimensions[37]. To achieve the luminosity of the following section we assume a version of the E143 $^{15}NH_3$ target with length ≈ 6 cm (7% λ_n). This provides an instantaneous luminosity $L = 1.2 \times 10^{35} cm^{-2} sec^{-1}$, comparable to E143. We also assume the target dilution factor of E143.

C. Spectrometer, Luminosity, and Estimated Errors for the DY Process

A schematic layout of a possible spectrometer configuration is shown in Fig. 6. It follows the design of the current 800 GeV Fermilab Meson-East spectrometer, which uses two dipole magnets to focus opposite sign dimuons onto three downstream tracking stations shielded by a thick hadron absorber. The first magnet containing a beam dump and hadron absorber sweeps low momentum particles away from the tracking stations; the second magnet provides momentum analysis. An aperture accepting $\pm 8°$ in the bendplane and $\pm 4°$ in the orthogonal plane yields an acceptance of $\approx 4.5\%$ for pair masses above 4 GeV. The central $\pm 1°$ in both planes is not included in the acceptance since target dimuons cannot be distinguished from those originating in the beam dump. The layout of Fig. 6 uses components from the current Meson-East spectrometer thereby minimizing construction costs. The ME spectrometer has run with beam-target (+beam dump) luminosities up to $10^{36} cm^{-2} sec^{-1}$[38], comparable to what is proposed here.

Calculation of DY production rates listed in table 1 assumes $L = 1.2 \times 10^{42} cm^{-2}$; this can be achieved with a beam of 2×10^{11} protons per 2.8 sec spill on a 0.07 λ_n thick target or with lower beam intensity on a somewhat thicker target. Experience with past high luminosity "beam-dump" dimuon physics obtained in E772 and E789 has demonstrated the feasibility of high-mass high-x_F dimuon physics with interaction-length targets. The principal limitation of longer targets is a degradation in the mass resolution; $\sigma_{J\psi} \approx 80 MeV$ with a 0.07 λ target, adequate for separating the J/ψ and ψ' resonances from the DY continuum.

Table 1. Number of Drell-Yan dimuons detected in an experiment with an integrated luminosity $L = 1.2 \times 10^{42} cm^{-2}$. The entry labeled P_u is the effective u-quark polarization as determined by $A_{LL}^{pDIS}(x_1)$.

$< M >$	$< x_2 >$	$< x_1 >$	$< x_F >$	$< P_u >$	DY pairs
4.10	0.095	0.79	0.697	0.892	1.66×10^4
4.26	0.132	0.627	0.495	0.794	3.31×10^5
4.46	0.175	0.520	0.344	0.711	3.46×10^5
4.60	0.223	0.452	0.229	0.648	1.84×10^5
4.82	0.271	0.417	0.146	0.611	6.75×10^4
5.37	0.320	0.450	0.130	0.646	1.56×10^4

In order to estimate errors we return to the measurement of A_{LL}^{DY} where $\Delta\bar{u}/\bar{u}$ is readily related to number of DY events and polarizations. Using Eq. 8 one finds

$$\sigma_{\Delta\bar{u}/\bar{u}} = \frac{1}{\sqrt{N_{DY}}} \times \frac{1}{f P_t P_b P_u}, \tag{14}$$

with $P_t = 0.65$, $f = 0.15$[2], $P_b = 0.75$[36], and $P_u = A_{LL}^{pDIS}(< x_1 >)$. Errors evaluated from Eq. 14 and the yields of Table 1 are shown on Fig. 4.

D. J/ψ and ψ' Running Conditions

Optimization of the running conditions for DY pairs with $M \geq 4$ GeV requires a configuration where the dominant rate from J/ψ production is diminished by moving the resonance region well off the peak of the acceptance[38]. Thus recording J/ψ and ψ' events is best accomplished in separate run. To evaluate errors we take $L = 1.2 \times 10^{41} cm^{-2}$, i.e. a factor of 10 less than for DY running. Using the cross section parameterization of Vogt[39] and the error relation

$$\sigma_{A_{LL}} = \frac{1}{\sqrt{N_{c\bar{c}}}} \times \frac{1}{f P_t P_b}, \tag{15}$$

yields the results given in Table 2 and Fig. 5.

Table 2. Cross sections times dimuon branching ratio and yields for J/ψ and ψ' production at 120 GeV with an integrated luminosity $L = 1.2 \times 10^{41} cm^{-2}$.

	$\sigma \times$ BR ($10^{-33} cm^2$)	Yield
J/ψ	6.87	5.1×10^7
ψ'	0.058	4.3×10^5

7. Summary

Dimuons from DY and charmonium production with 120 GeV polarized protons on polarized targets offer unique opportunities for extending our knowledge of the spin structure of the nucleon in the large-x region. Measurements include:

- Determination of the antiquark helicity asymmetries $\Delta\bar{u}/\bar{u}$ and $\Delta\bar{d}/\bar{d}$. Estimates of errors for these measurements are particularly robust as they rely on the close connection between the DY process and polarized deep-inelastic lepton scattering.
- Drell-Yan production with transversely polarized beams and targets, yielding the first determinations of the transversity structure functions of the nucleon.
- Large statistics J/ψ and ψ' production, leading to the first measure of polarization in the nucleon's gluon field.

The measurements proposed require acceleration of beam from a high-intensity ($\geq$ 150 μamp) polarized-ion source through the injector, booster, and MI, followed by extraction from the MI to the existing ME experimental area. A polarized beam of 2×10^{11}/per 2.8 second spill impinging on a polarized NH_3 target of the SLAC E143 type yields a luminosity $L = 1.2 \times 10^{35} cm^{-2} sec^{-1}$. A close-aperture spectrometer, capable of operating at this luminosity, could be constructed largely from components of the existing ME spectrometer.

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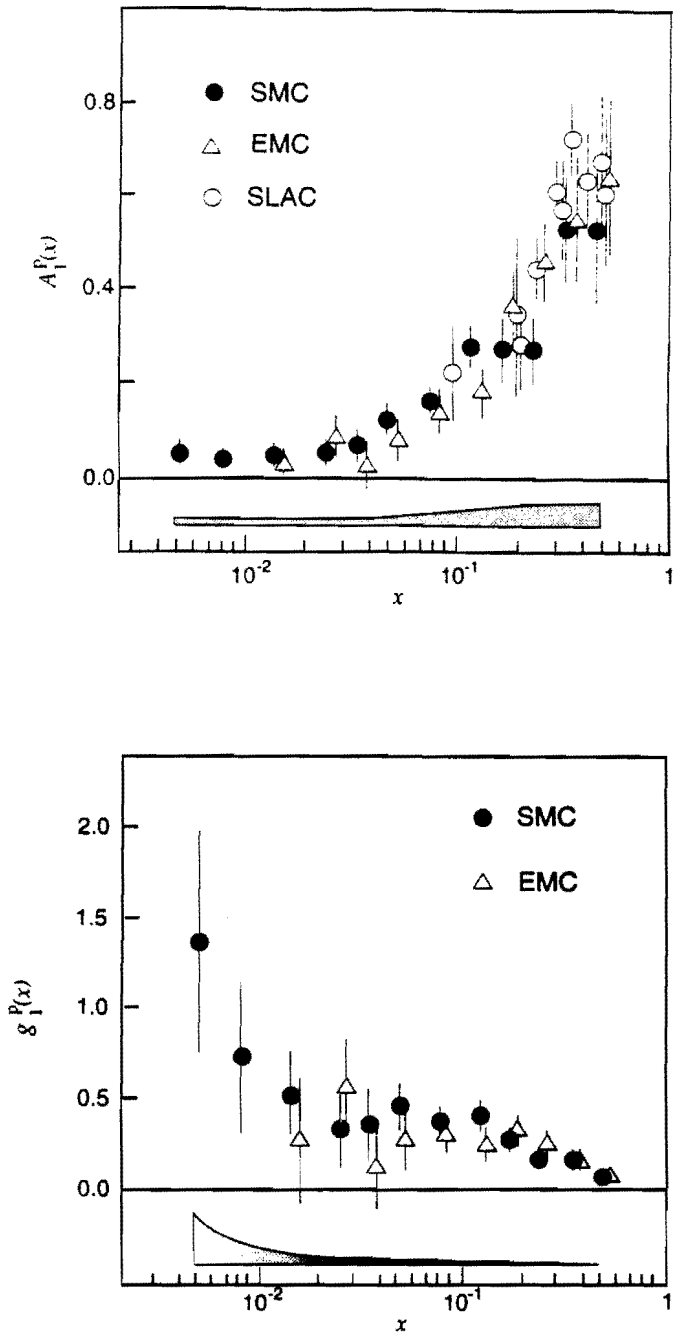

Figure 1. Longitudinal asymmetry and $g_1(x)$ structure function for deep-inelastic lepton scattering from the proton from CERN[1, 3] and SLAC[20].

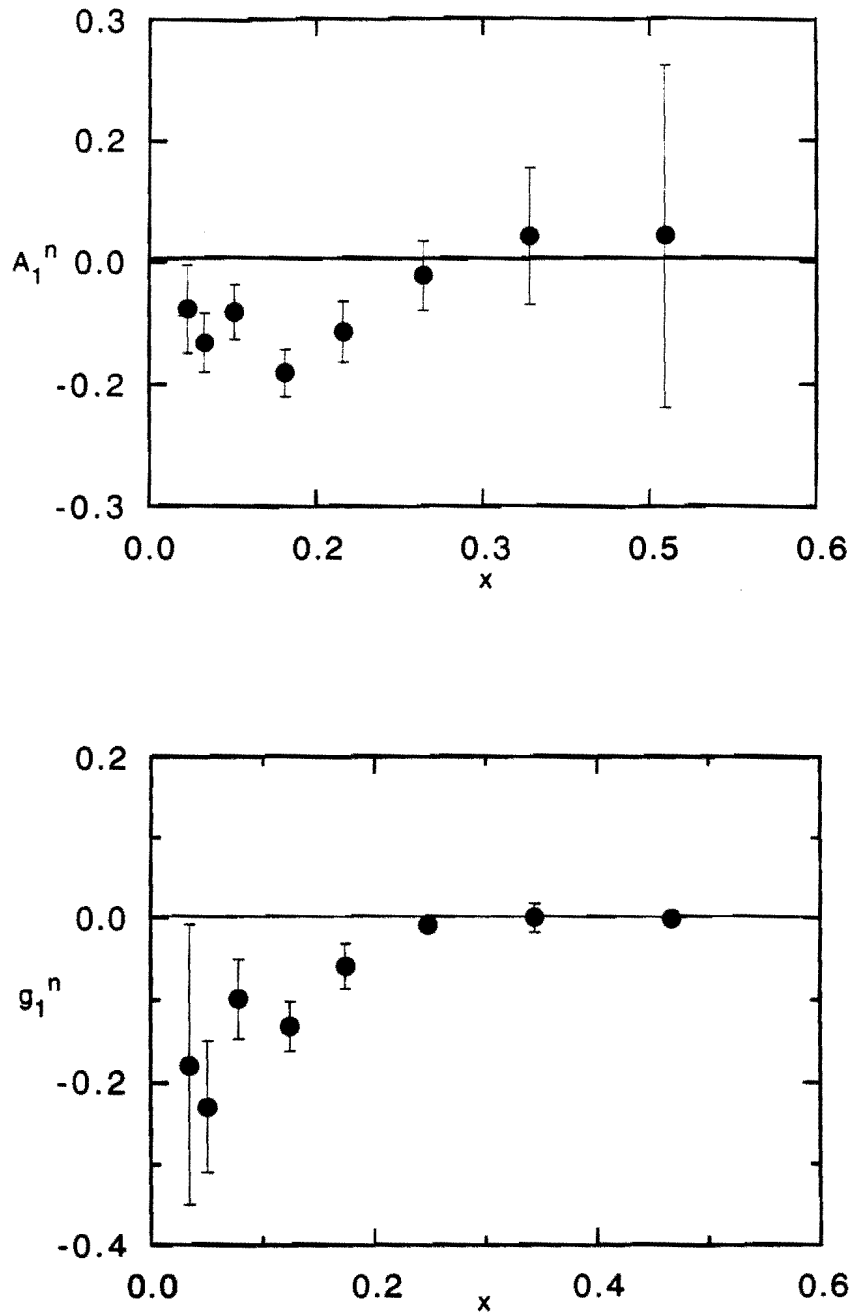

Figure 2. Longitudinal asymmetry and $g_1(x)$ structure function for deep-inelastic lepton scattering from the neutron (^3He) from SLAC[5].

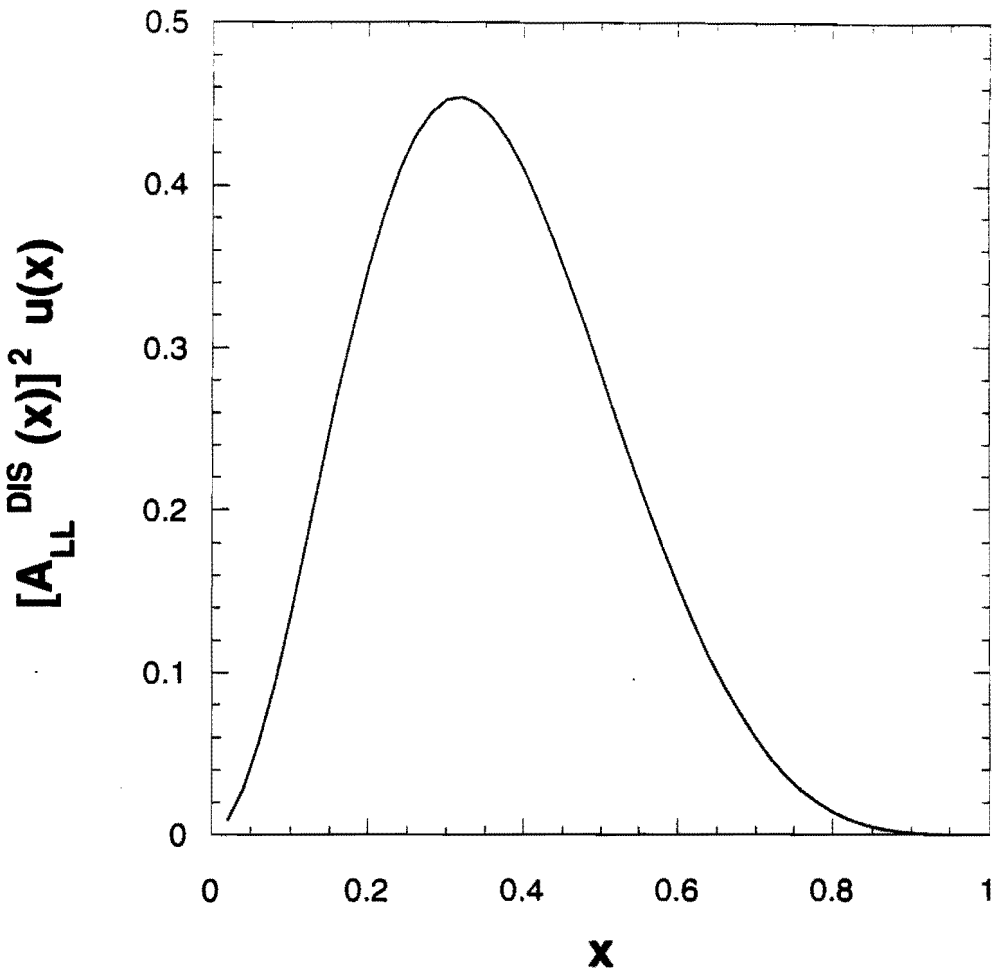

Figure 3. Figure of merit for a "beam" of polarized up quarks.

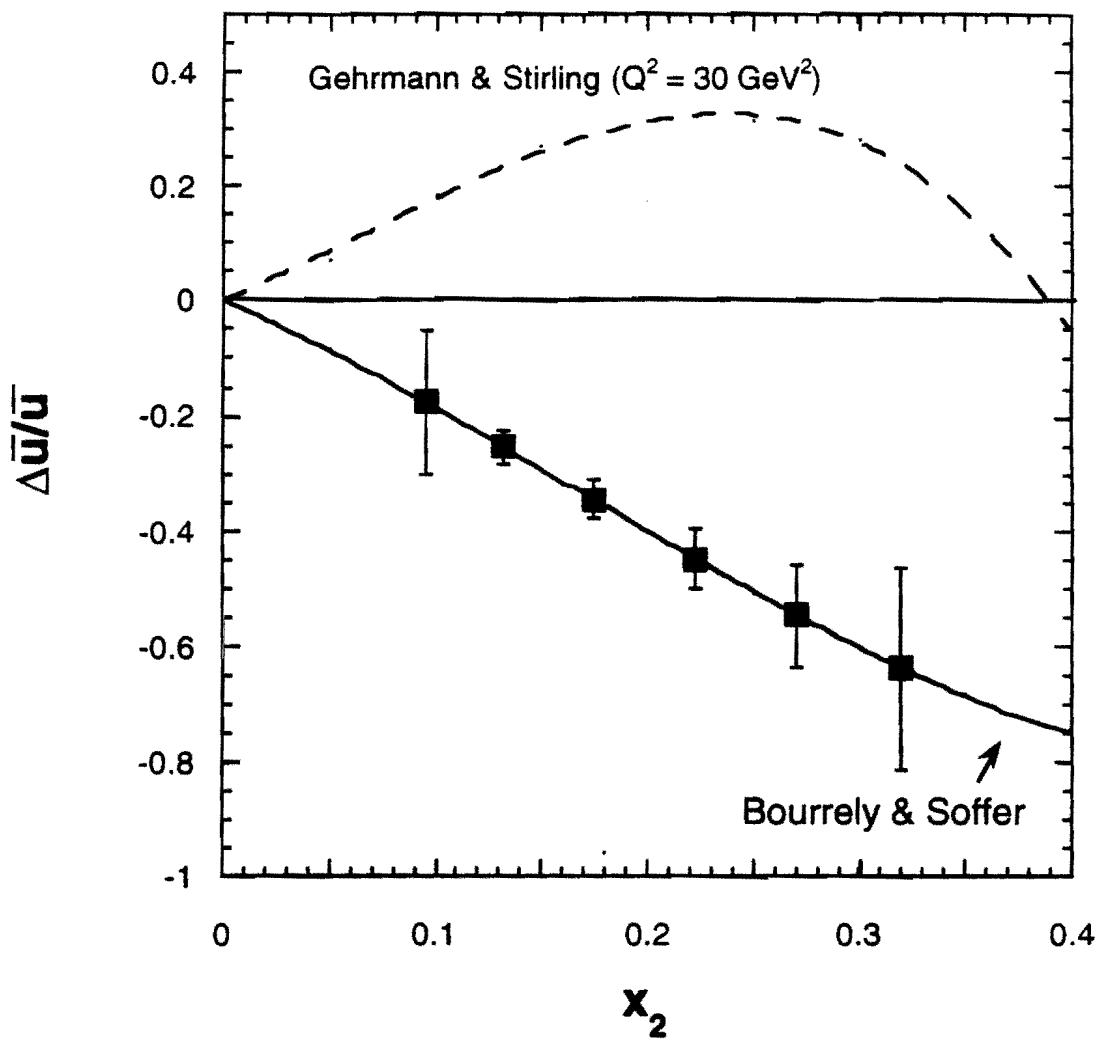

Figure 4. Errors achievable for $\Delta\bar{u}/\bar{u}$ with an integrated luminosity $L = 1.2 \times 10^{42} cm^{-2}$ on a SLAC E143-style target. The errors are plotted on the prediction of Bourrely-Soffer[21] model. Also shown is a prediction from the model of Gehrmann and Stirling[24].

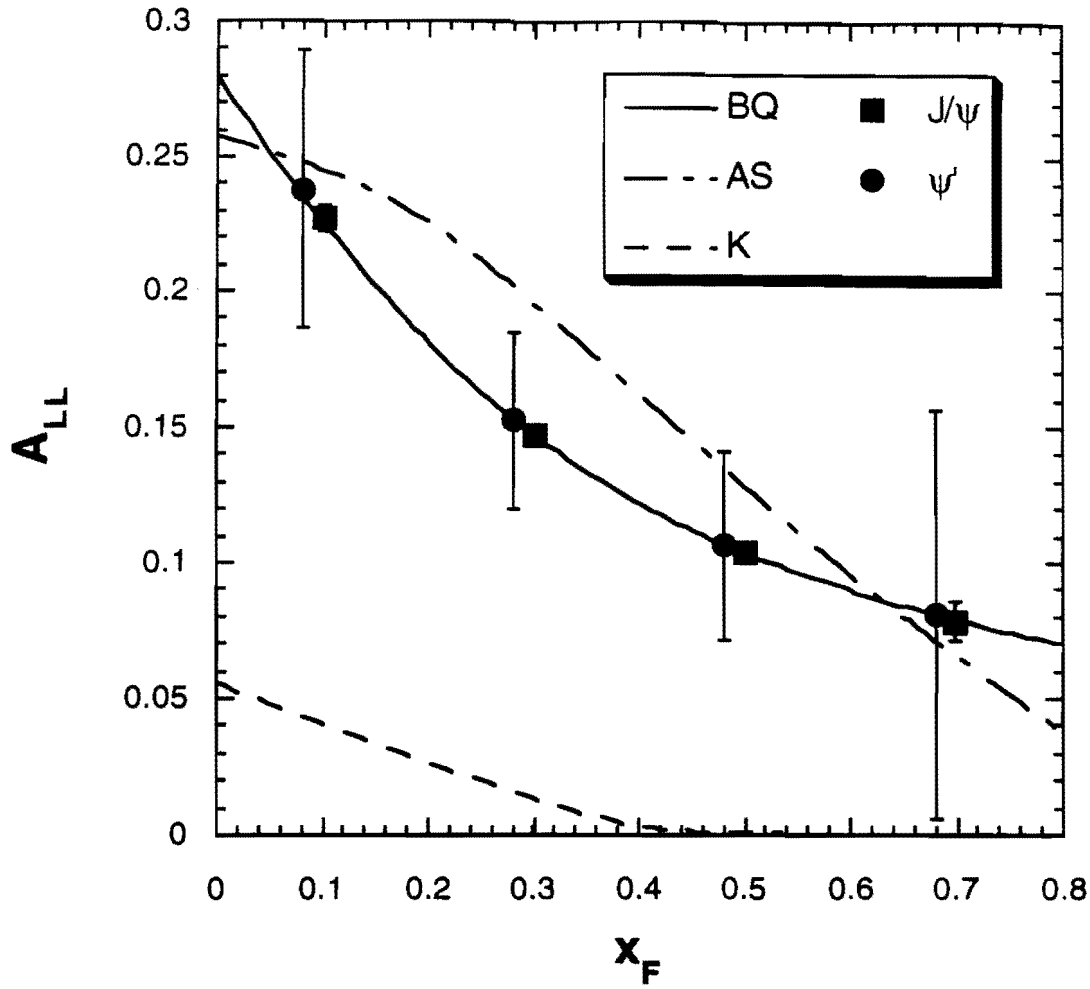

Figure 5. Errors achievable for helicity asymmetries in J/ψ (squares) and ψ' (circles) production with an integrated luminosity $L = 1.2 \times 10^{41} cm^{-2}$ on a SLAC E143-style target. Also shown are helicity asymmetries calculated with the polarized structure functions of Ref. [27] BQ , Ref. [28] K, and Ref. [29] AS. A parton-level asymmetry, $|\hat{a}| = 0.28$ has been assumed in calculating A_{LL} from Eq. 11. The errors estimated from Eq. 15 are plotted on the curve of Ref. [27].

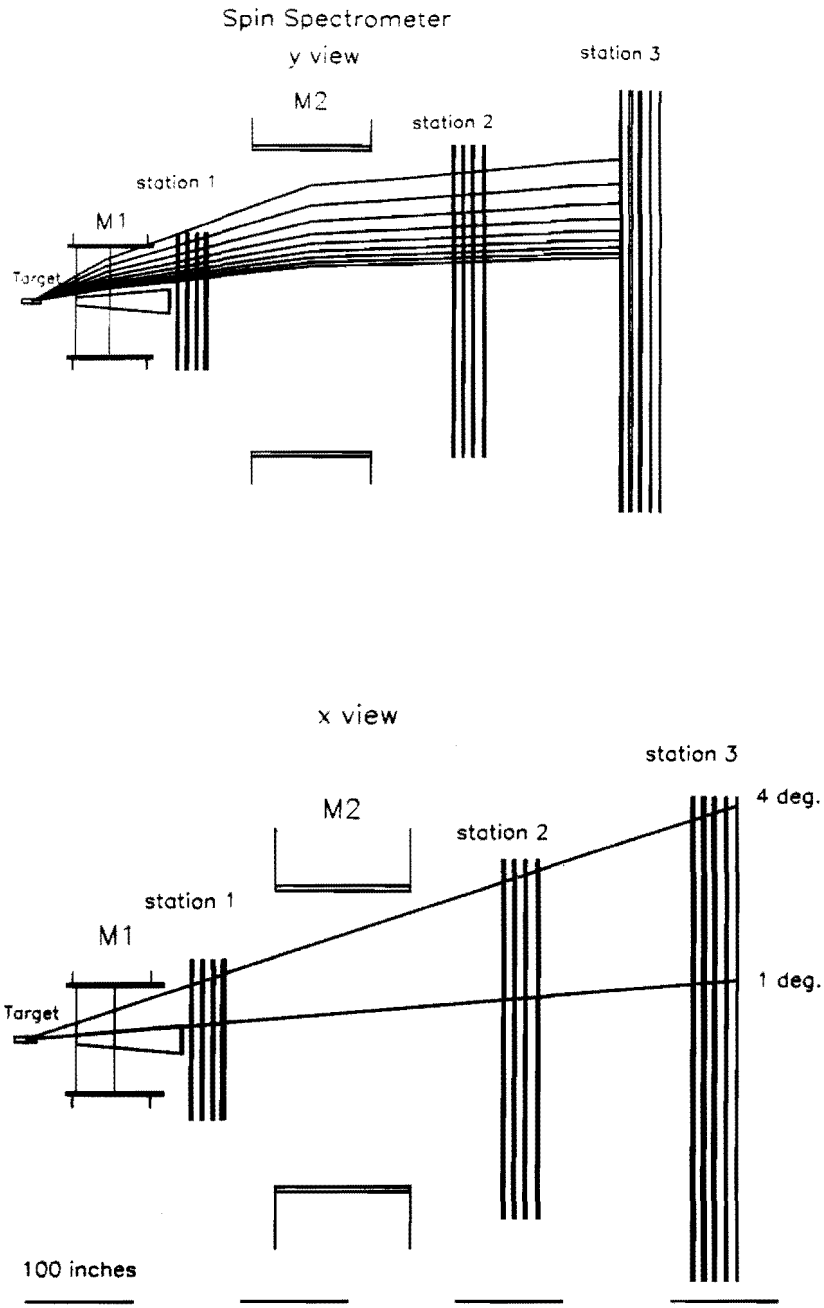

Figure 6. Schematic view of a two-dipole spectrometer using components (M2 and tracking stations 1-3) from the existing ME spectrometer. The beam enters from the left and is absorbed by a beam dump (wedge shape) inside M1. The aperature of M1 is closed with a 10 λ_n hadron absorber.