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Measurement of The Deep-inelastic Spin-dependent Structure Functions of The Proton and Neutron at HERA

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ABSTRACT

It is possible to measure the deep-inelastic spin-dependent structure functions $g_1^p(x)$ and $g_1^n(x)$ for the proton and neutron using internal polarized hydrogen, deuterium, and ^{3}He targets of polarization 50% and thickness 10^{14} to $10^{15}\mathrm{cm}^{-2}$ and the 60 mA longitudinally polarized 30 GeV electron beam in the HERA electron storage ring. The measurement of the deep-inelastic spin-structure of both isospin states of the nucleon at the same kinematics and using the same apparatus allows the Bjorken sum rule to be experimentally checked. In addition, it uniquely constrains the spin distribution of the u and d quarks as a function of x in any model of the nucleon. Possible target and detector configurations are described and an estimate of the accuracy of such a measurement is presented.

Recently precise measurements have been presented of the asymmetry $A_1^p(x)$ in polarized muon–polarized proton deep inelastic scattering.[1] The spin-dependent structure function $g_1^p(x)$ was deduced from these measurements. The data indicate that the Ellis-Jaffe sum rule[2] for the proton is violated. Assuming the Bjorken sum rule[3] is valid, the data imply that the neutron must have a much larger contribution to it than hitherto assumed[4], with the asymmetry for the neutron being largely negativ e over at least part

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of the x range. No data on the neutron exist. Also the new data can be interpreted to indicate that the fraction of the proton spin carried by the quarks is small[1].

To measure the asymmetries in deep inelastic scattering of polarized electrons from polarized protons and neutrons we propose a new technique[5].

This is to use internal polarized atomic gas targets of density 10^{14} to $10^{15}\mathrm{cm}^{-2}$ and polarization 50% placed in the 60 mA circulating polarized electron beam of the HERA storage ring. To study the proton a polarized atomic hydrogen target will be used. For the neutron, polarized deuterium and ^{3}He targets will be used. The deuteron is an isoscalar target and so will measure the sum of proton and neutron asymmetries. As pointed out by Close and Roberts it also allows a precise determination of the fraction of proton spin carried by the quarks[6]. The neutron asymmetry can be deduced by subtracting the proton asymmetry from the deuteron asymmetry. ^{3}He is of interest because to a good approximation the two protons in this nucleus have opposite spins, and so the asymmetry is due to the neutron alone. Thus, the deep-inelastic neutron asymmetry can be measured in two independent ways. These measurements become possible because of both the development of a new generation of polarized hydrogen, deuterium, and ^{3}He targets based on the method of optical pumping and because of the availability of longitudinally polarized electrons in the HERA electron storage ring. In the case of the hydrogen and deuterium targets a holding field of order 1 kgauss is necessary to prevent depolarization by the intense magnetic field of the circulating beam[7]. The targets provide a luminosity of about $10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The proposed technique does not suffer the disadvantages of conventional polarized target technology. In the conventional approach, polarized deuterons in the form of deuterated ammonia would be used. Thus, the asymmetry is diluted by scattering from large amounts of unpolarized material in the ammonia target. In the internal target method, the polarized atoms are pure atomic species. In addition, because the proposed target thickness is of order 10^{-10} radiation lengths, the contribution from external radiative corrections in the target is negligible.

Development of few-body polarized internal targets by optical pumping has been in progress for some years. The common approach is to polarize atoms via optical pumping with circularly polarized light from a laser at the pumping transition. These atoms are then fed into a storage bottle[8] with pumping constrictions at each end. The pumping constrictions serve to generate the desired target density while allowing the circulating beam to pass through the target. At Argonne National Laboratory polarized hydrogen and deuterium gas targets have been under development using the technique of spin-exchange. Dissociated hydrogen (deuterium) is introduced into a cell containing a small amount ($\approx 1\%$) of potassium. The potassium is polarized by optical pumping with a dye laser, and transfers polarization to the hydrogen (deuterium) by spin-exchange collisions. The Argonne group has achieved a polarization of 25% at a flux rate of 8×10^{16} polarized atoms per second. Work is in progress to achieve a polarization of at least 50% at a flux rate of 4×10^{17} polarized atoms per second[9]. At Caltech a polarized ^{3}He target has been developed[10] for an experiment[11] at the Bates Laboratory at MIT to study the dependence of spin-dependent quasielastic scattering of polarized electrons from polarized ^{3}He. The technique used is polarization of the 2^3S metastable state via optical pumping with a laser[12], followed by polarization of the ground state through metastability exchange. Feed rates of 5×10^{17} per sec and polarizations of 40% have been achieved. Work is in progress to achieve higher laser powers.

A collaboration between Argonne and Novosibirsk has been formed to study storage cells for polarized deuterium atoms in the VEPP-3 electron ring and to measure the analyzing power in electron-deuteron elastic scattering. A cell coated with drifilm has been fabricated at Argonne and has been installed in the VEPP-3 electron storage ring[13]. Tests of this cell are expected to be performed during the Summer of 1988. Design of a high density storage cell is in progress at Argonne and is to be used with the present Novosibirsk polarized atomic beam source in the VEPP-3 ring. The expected target thickness that can be achieved with the conventional source and a 30 cm long elliptical storage tube is 10^{13} cm^{-2}. In order to achieve the 10^{14} cm^{-2} target thickness required for the HERA experiment, the high flux optically pumped polarized source of the type being developed at Argonne will be necessary. In the case of polarized ^{3}He wall depolarization and beam ionization[14] problems are negligible, since it is a noble gas. Stor age times of hundreds of seconds have been obtained at Caltech. The presence of an internal target in an electron ring will give rise to multiple scattering and bremsstrahlung losses. The beam lifetime due to these effects has been estimated to be of order 100 hours[15].

Fig. 1 shows a possible detector configuration for this experiment. This is based on a detector used at SLAC in the 1970's to measure exclusive states in deep inelastic scattering[16]. Using the measured rates in the SLAC experiment, we predict a trigger rate of 400 Hz for the proposed HERA experiment, which is quite acceptable. Clearly we require that the proton beam does not pass through the target. This implies that either the experiment runs in parasitic mode with the proton beam displaced from the electron beam or that the experiment is run in dedicated mode with the proton beam turned off. The detector consists of a 1 Tm × 1 m gap dipole magnet through which both the scattered particles and the stored electron beam pass. A superconducting tube shields the electron beam from the dipole field. Planes of MWPCs allow the tracking of charged particles and a wall of lead-glass serves as a calorimeter to measure the energy. The detector should have large acceptance for electrons with scattering angles between 5° and 25°.

Figures 2 and 3 show the precision as a function of x attainable in a 240 hour run at HERA in a measurement of A_1^p(x) and A_1^n(x) on polarized proton and ^{3}He targets. It is assumed that the 30 GeV electron beam and target polarizations are each 0. 5; the electron beam current is 60 mA; the incident electron energy is taken to be 30 GeV. The polarized proton and ^{3}He target thicknesses are 10^{14} cm^{-2} and 10^{15} cm^{-2} respectively. The region in x extends from 0.02 to 0.8 and in Q^2 from 1 to 20 (GeV/c)^2. The low x limit is determined by elastic radiative tails and backgrounds at high $y = \frac{\nu}{E}$. Systematic errors of ±5% for the target polarization and ±10% for the electron polarization have been included. The value of $A_1^p(x)$ used was the measured value from the recent EMC data. The solid line in figure 3 is the prediction of a modified Carlitz-Kaur model which is in good agreement with the new EMC data and is constrained to obey the Bjorken sum rule[17]. A dilution factor of 0.33 is included in the ^{3}He estimate becaused the electron can also scatter from the two protons in the ^{3}He nucleus.

We see that the precision attainable at low x, where the main contribution to the sum rule arises, is very good. It should be possible to perform a precise test of the fundamental Bjorken sum rule, deduce the fraction of nucleon spin carried by the quarks for both isospin states of the nucleon, and contribute greatly to our understanding of the structure of the nucleon. It is important that these measurements be carried out, especially in the light of recent data, which indicate that our understanding of the spin-structure of the nucleon is very incomplete. At present we are actively pursuing the possibility of performing these measurements at DESY.

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References

[1] J. Ashman *et al.* [The EMC Collaboration], submitted for publication
[2] J.Ellis and R.Jaffe, Phys. Rev. **D9**, 1444 (1974)
[3] J.D.Bjorken, Phys. Rev. **148**, 1467 (1966)
[4] R.Carlitz and J.Kaur, Phys. Rev. Lett. **38** 673 (1976)
[5] Memorandum to DESY Research Director, R.G. Milner and T. Sloan, September 1987; Letter to HERA Physics Research Committee, Caltech-Argonne collaboration, January 1988
[6] F.E. Close and R.G. Roberts, Phys. Rev. Lett. **60**, 1471 (1988)
[7] R.D. McKeown, *Proceedings of the Workshop on Electronuclear Physics with Internal Targets*, SLAC 1987, p.99
[8] M.D. Barker *et al.*, *Polarization Phenomena in Nuclear Physics* edited by G.G. Ohlsen *et al.* American Institute of Physics, 1981
[9] L. Young *et al.*, Nucl. Instr. and Meth., **B24**, 963 (1987)
[10] R.G. Milner, R.D. McKeown, and C.E. Woodward, *to be published*
[11] Bates experiment 88-02, Caltech-MIT-Harvard-NBS
[12] C.L. Bohler, L.D. Schearer, M. Leduc, P.J. Nacher, L. Zachorowski, R.G. Milner, R.D. McKeown, and C.E. Woodward, to be published
[13] R. Holt, *Proceedings of the International Conference on Spin Observables in Nuclear Physics*, Telluride (1988)
[14] R.G. Milner, R.D. McKeown, and C.E. Woodward, Nucl. Instr. and Meth. **A257**, 286 (1987)
[15] T. Weiland, DESY, private communication
[16] J.F. Martin *et al.*, Phys. Rev. D **20**, 5 (1979)
[17] Andreas Schäfer, Caltech preprint MAP-104, *to be published*

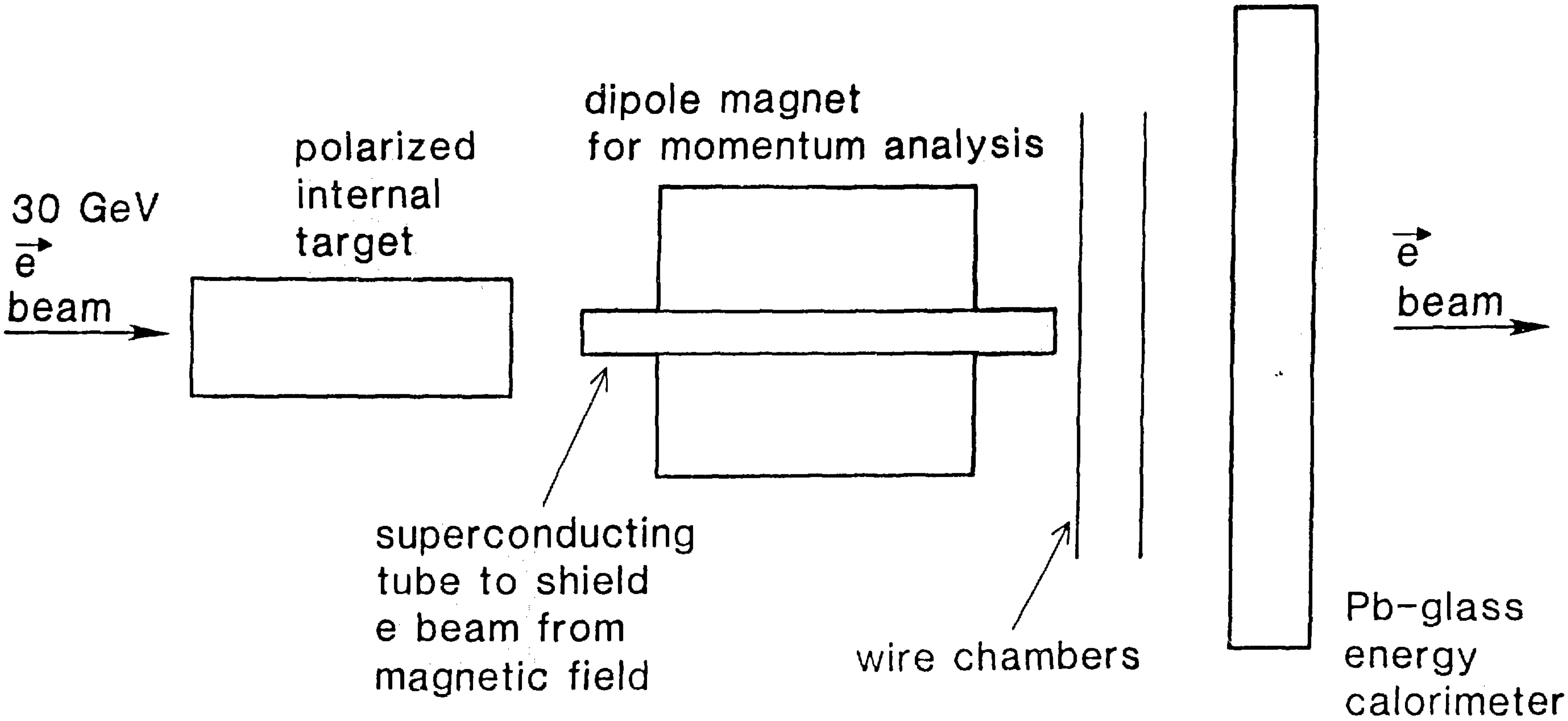
30 GeV
$\vec{e}$
beam
polarized
internal
target
dipole magnet
for momentum analysis
superconducting
tube to shield
e beam from
magnetic field
wire chambers
Pb-glass
energy
calorimeter
$\vec{e}$
beam

Fig. 1

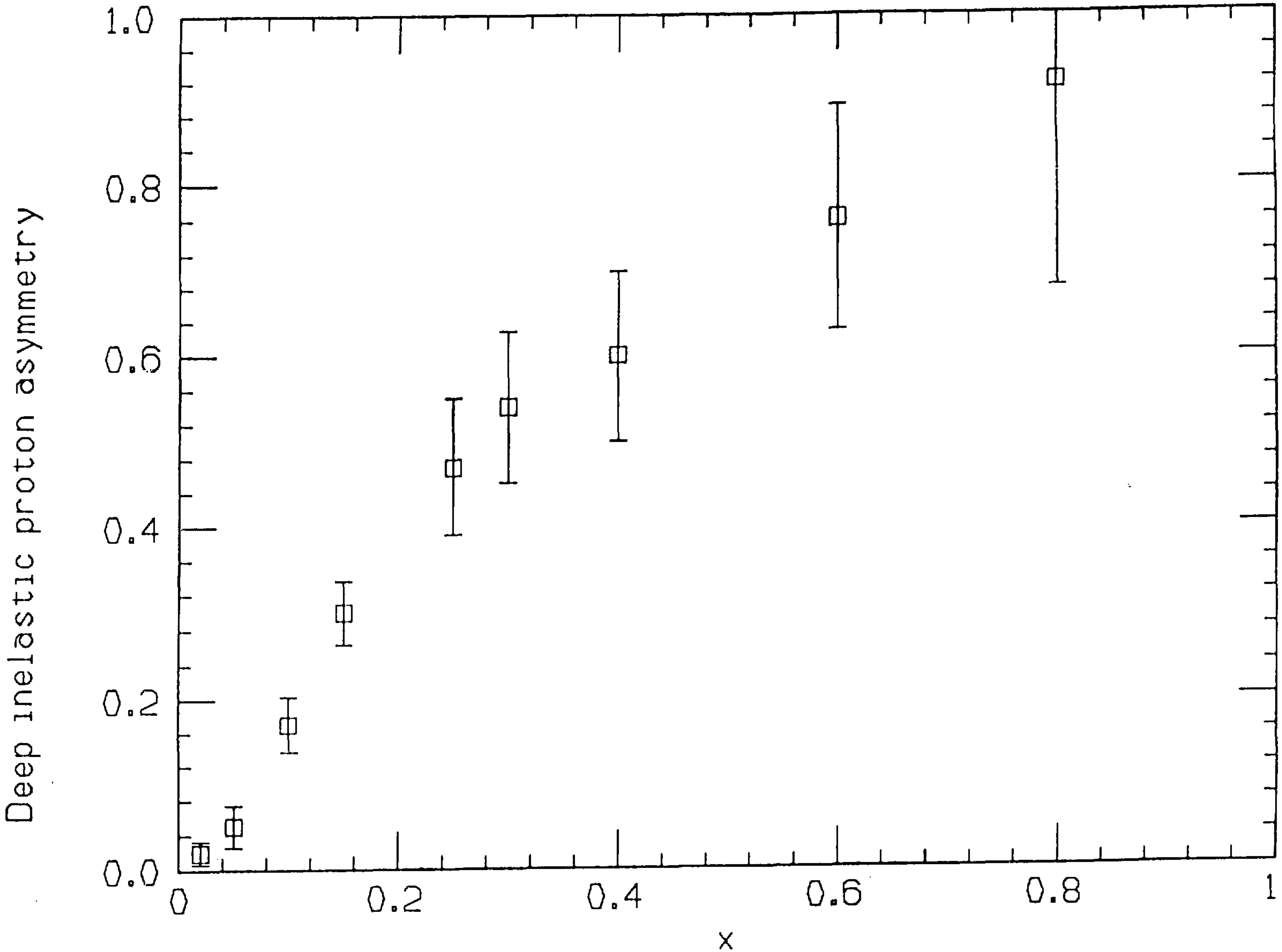
Deep inelastic proton asymmetry
0.0
0.2
0.4
0.6
0.8
1.0
0
0.2
0.4
0.6
0.8
1
x

Fig. 2

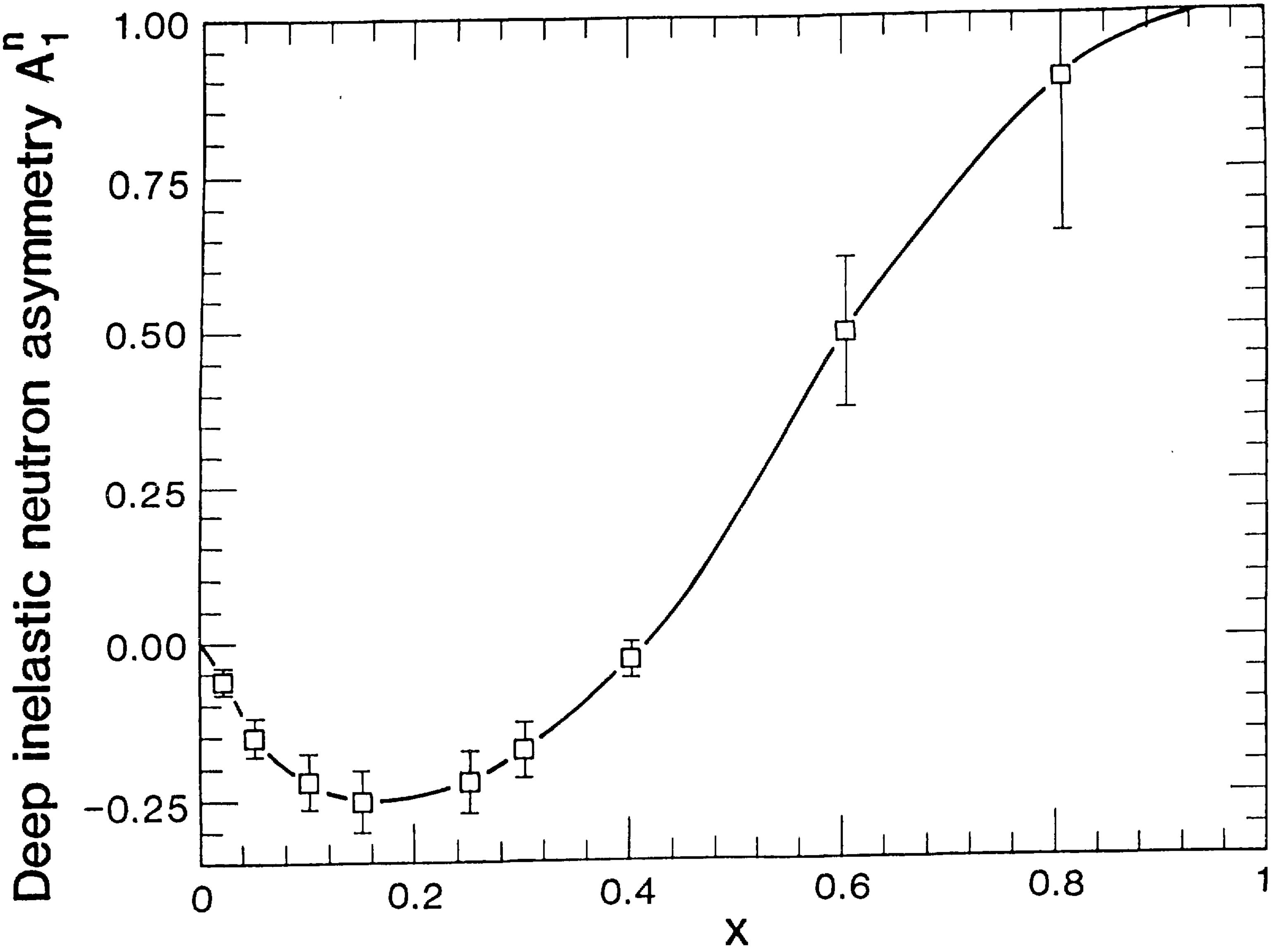
Deep inelastic neutron asymmetry A_1^n
1.00
0.75
0.50
0.25
0.00
−0.25
0
0.2
0.4
0.6
0.8
1
X

Fig. 3