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SLAC Proposal E-142X

A PROPOSAL FOR A PRECISION MEASUREMENT OF THE NEUTRON SPIN STRUCTURE FUNCTION

The E142 Collaboration

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ABSTRACT

An extension on the recent E142 measurement of the neutron spin structure function, g_1^n, down to x of 0.023 for Q^2 greater than 1 $(\mathrm{GeV/c})^2$ is proposed by scattering 29.1 GeV 80% polarized electrons off a polarized ^{3}He target. Such a measurement should determine the integral of the neutron spin structure function to a precision of ~ 0.008. Two short runs focussed on the measurement of the neutron spin structure function at high x and on the tranverse neutron asymmetries, $A_2^n(x)$, are also included in this proposal.

In 1988 the EMC collaboration at CERN revived an interest in an old field of physics by reporting on proton spin structure function measurements at low x using high energy muon scattering [1]. The EMC results violated a QCD sum rule of Ellis and Jaffe [2] and these results were interpreted to mean that the quarks carried little of the proton spin, and the strange sea was highly polarized ($\sim 20\%$). Hundreds of theoretical papers followed, and three experimental programs began at CERN (SMC), DESY (Hermes), and SLAC (E142 and E143). In addition, numerous low energy polarized electron and neutrino scattering experiments have been proposed to study the strange sea polarization, in particular.

In 1993 two experiments reported on first measurements of the neutron spin structure function, g_1^n. The SMC experiment extracted the neutron spin structure function using a polarized deuterium target and found the neutron integral over x to be $\int_0^1 g_1^n(x)dx = -0.08 \pm 0.04 \pm 0.04$ [3]. Soon afterwards, the E142 collaboration [4] reported a result of $\int_0^1 g_1^n(x)dx = -0.022 \pm 0.011$ in which the measured range of x was $0.035 < x < 0.6$ and the contribution to g_1^n outside the measured range came from extrapolations. A comparison of the high statistics E142 neutron measurement to the low statistics SMC/EMC neutron result is given in Figure 1. Although the two results agree, the E142 result together with the previous EMC proton integral gives a $\sim 2\sigma$ difference from the Bjorken sum rule prediction. A second almost independent $\sim 2\sigma$ difference from the Bjorken sum rule prediction comes from comparing the recent SMC deuterium results to the E142 neutron results.

In summary, from the spin structure function measurements of EMC and SLAC E142,

$$\int_0^1 g_1^p(x)dx - \int_0^1 g_1^n(x)dx = 0.146 \pm 0.022$$

and from the spin structure function measurements of SMC and SLAC E142 (note that d = 1/2 (p+n)),

$$2\int_0^1 g_1^d(x)dx - 2\int_0^1 g_1^n(x)dx = 0.09 \pm 0.05.$$

From the Bjorken sum rule, the prediction is:

$$\int_0^1 g_1^p(x)dx - \int_0^1 g_1^n(x)dx = 0.187 \pm 0.004,$$

where the uncertainty in the integral comes from the evaluation of the integral at the different Q^2 of the two experiments.

This proposal is divided into three parts. Part I is a request for one month of dedicated beam time to measure the neutron spin structure function, g_1^n, at low x. Part II is a request to run 2 weeks dedicated to a high x measurement. Part III is a request to run two weeks dedicated to the measurement of the transverse spin structure function asymmetry, A_2^n(x).

PART I

The most controversial issue in the neutron integral determination is the extrapolation of the integral to low x. For this reason, we propose to measure the neutron spin structure function at a higher energy. At an energy of 29.1 GeV, we can determine the neutron integral down to x of 0.023 for Q^2 greater than 1 (GeV/c)^2 (compared to x of 0.025 from E142). A precision measurement at lower x would decrease the range of extrapolation and place a tight constraint on the extrapolation itself. In E142 the extrapolation of the integral to low x was done applying simple Regge theory which implicity assumed that the scale of the neutron spin structure function values will not increase below x of 0.035. Criticism from the SMC collaboration has been voiced that $g_1^n(\mathrm{x})$ is getting very large just below the x range of the E142 experiment. Such behavoir could change the E142 integral result for g_1^n outside the quoted E142 error bars. A run of E142 at 29.1 GeV, however, should put this issue to rest, since we would have precision data at reasonable Q^2 for x greater than 0.023 and some lower Q^2 data (Q^2 greater than 0.7 GeV^2) for x greater than 0.015. Although a measurement down to $\sim$ 0.02 may appear at first to be only a small improvement in the precision on the neutron integral, it would be powerful for excluding large changes in the neutron spin structure function at low x.

The basic philosophy of the proposed extension would be to run at higher energy with the high beam polarization now available. The high beam polarization is critical in maintaining a good measurement for a reasonable run time without having to increase the beam current which depolarizes the target. This extension would incorporate the following improvements:

(1) A run devoted to 29.1 GeV energy

(2) A current of approximately 10^{11} electrons per pulse.

(3) A ^{3}He target with thinner windows (100 as opposed to 115 microns in E142) and higher pressure (10 as opposed to 9 atmospheres). An untested 13 atmosphere with 100 micron windows already exists.

(4) The 4.5° spectrometer acceptance opened up as much as possible (0.18 msr).

(5) TDCs on every four lead glass blocks.

(6) Greater than 2 μsec pulse length (1.2 μsec pulse length existed for E142) using the flash lamp pumped Ti:sapphire laser now being developed at SLAC [5].

(7) An extra plane of hodoscopes will exist to increase the tracking efficiency for momentum determination.

Points (1), (4), (5), (6), and (7) are already planned for E143.

With experience from experiment E142, we are confident that we can achieve the following parameters:

(1) The target polarization should be greater than 35%.

(2) The number of events per pulse in the 4.5° spectrometer will be ~ 1 (half the rate of E142).

(3) The beam polarization is expected to be $\sim 80\%$.

(4) The experiment is estimated to run at an efficiency of 50% (beam, target and spectrometer all together).

Pion contamination from the higher energy electron beam and low scattered electron energy cut (i.e. 4 GeV) should be manageable, since the longer pulse length and lower event rate, and TDCs mounted on every four lead glass blocks will improve considerably the rejection of overlays from pions. Figure 2 shows the π/e ratio as a function of E'. With a 4 (GeV/c) momentum cut on the scattered electron, the average pion rate would be about 20 per pulse. The majority of these pions would not give a shower energy above 4 (GeV/c) in the lead glass shower counter. Using an extrapolation from the E142 results, figure 3 gives an estimate of the pion contamination after simple cuts. This level of background is similar to what was found in E142.

Radiative corrections to the lowest x bin will become substantial, but not prohibitive. Figure 4 gives the size of the asymmetry corrections versus x for two different models for the neutron spin structure function.

We propose to run one week of check out followed by one month of data collection. The error bars (Figure 5) that would be achieved during a 29.1 GeV run of E142X with 300 hours on tape (25 days) would be almost a factor of two smaller than those of E142 and cover a larger range in x. Sixty additional hours on tape (5 days) would be used to do systematic studies for studying the dilution factor of the target, 'positron runs' (runs with the polarity of the spectrometer magnets reversed), and pion background studies. With these statistics, one can extend the neutron spin structure function measurement down to $x \sim 0.023$, and obtain statistics on the integral over the measured range of x of 0.004 (stat) and 0.004 (syst). Any new physics coming from large negative values of the asymmetry would be observed down to x near 0.015. The low and high x extrapolations should amount to ~ 0.004 and ~ 0.003 respectively, assuming that the asymmetries measured at low x are converging as described by Regge theory.

In the interest of obtaining this result rapidly, we propose to do essentially no spectrometer improvements beyond those of E143. *We consider it important that this extension of E142 occur soon, so as to obtain unambigously a new low* *x neutron spin structure function.* Our focus is to make some precision low x measurements on the neutron spin structure function in order to investigate the claim that the structure function gets very large at low x.

PART II

In Part II, we propose to run a dedicated high current exposure (2.5 x 10^{11} electrons/pulse) at 22.66 GeV. With a 80% polarized beam, a higher event rate and the smaller dilution factor target, this two week run *alone* would give a measurement of the high x data in the 7° spectrometer with a precision almost twice as good as the E142 measurement. The data in the high x region is completely dominated by statistical errors. The data will allow for the first time a determination of the crossing point from negative to positive asymmetries, since it is expected that A_1^n approaches one as x approaches one [6].

Finally, it should be stressed that half of the statistical error on the neutron integral came from the highest x bin measurement. In order to improve the integral determination of g_1^n, it is important to measure the high x values significantly better.

PART III

A dedicated two week run with a stable transverse polarized target would do an exploratory check of A_2^n(x). The transverse asymmetries have essentially not been measured. At present, E142 found the asymmetries to be less than ±25%. However, during the A_2^n measurements of E142 the ^{3}He target depolarized since the measurement was done without the aid of the optical pumping of the lasers to keep the cell polarized. The ^{3}He target lost polarization when it was not optically pumped at a rate of about $\Delta P_t = 1\%$ per hour. Only about 24 hours were used to measure A_2^n with this method for experiment E142.

In this part of the E142X proposal, we propose to change the optical path of the laser light so that it can enter the ^{3}He cell transverse to the electron beam. This will allow for a measurement of A_2^n in which the cell is kept polarized. A two week run at 22.66 GeV with the stated values for polarizations and target densities would determine A_2^n(x) to a precision per bin in x of ± 0.05 over the x range up to 0.3. Above this, the statistical errors increase as in the A_1^n measurement. This measurement would be a powerful test to see whether the transverse asymmetries have any non-zero values comparable to the longitudinal measurements. Large A_2^n(x) asymmetries (greater than 10%) would be regarded as a discovery and would open up a field of physics for studying higher twist effects (the expected origin of non-zero A_2^n values).

It should be noted that if a 50 GeV program in End Station A is approved, then the E142 collaboration would submit a proposal to run a ^{3}He target to measure the Q^2 dependence of the neutron spin structure function.

REFERENCES

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Figure 1. Comparison of neutron spin asymmetries, $A_1^n(x)$ versus x, for the SLAC E142 experiment and the CERN SMC experiment.

Figure 2. Calculated pion/electron ratio as a function of scattered electron energy in the 4.5° spectrometer.

Figure 3. Estimated pion background contamination in the electron sample as a function of scattered particle momentum. The contamination is estimated using just the shower counter energy deposisition and timing to reject pions. Hodoscope tracking is used to measure this contamination.

Figure 4. Radiative corrections to the asymmetries as a function of scattered electron energy.

Figure 5. Estimated error bars on the asymmetry measurement as a function of x from the main 29.1 GeV run and the high x 22.66 GeV run. A comparison to the existing data is also presented.

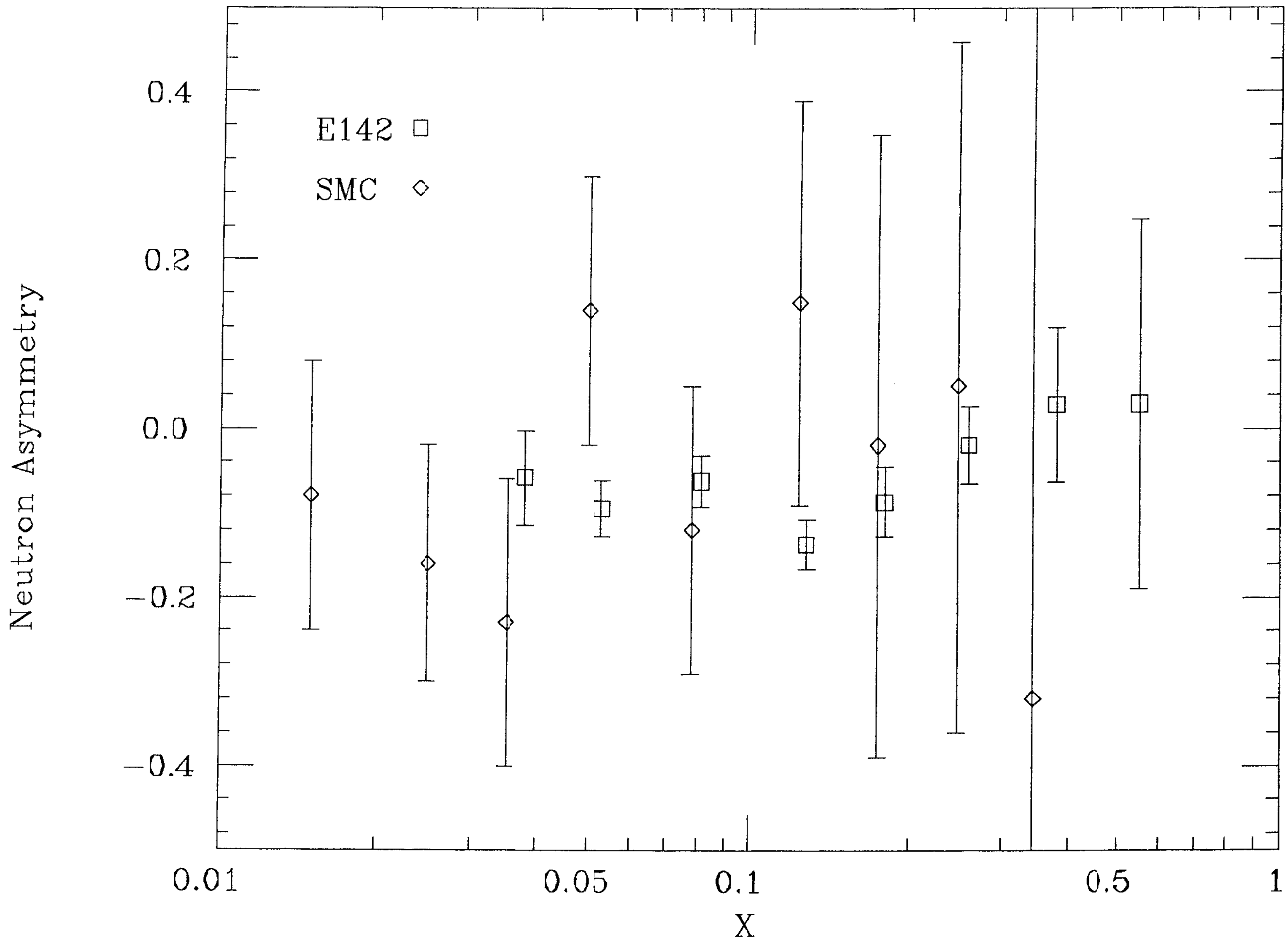


Figure 1

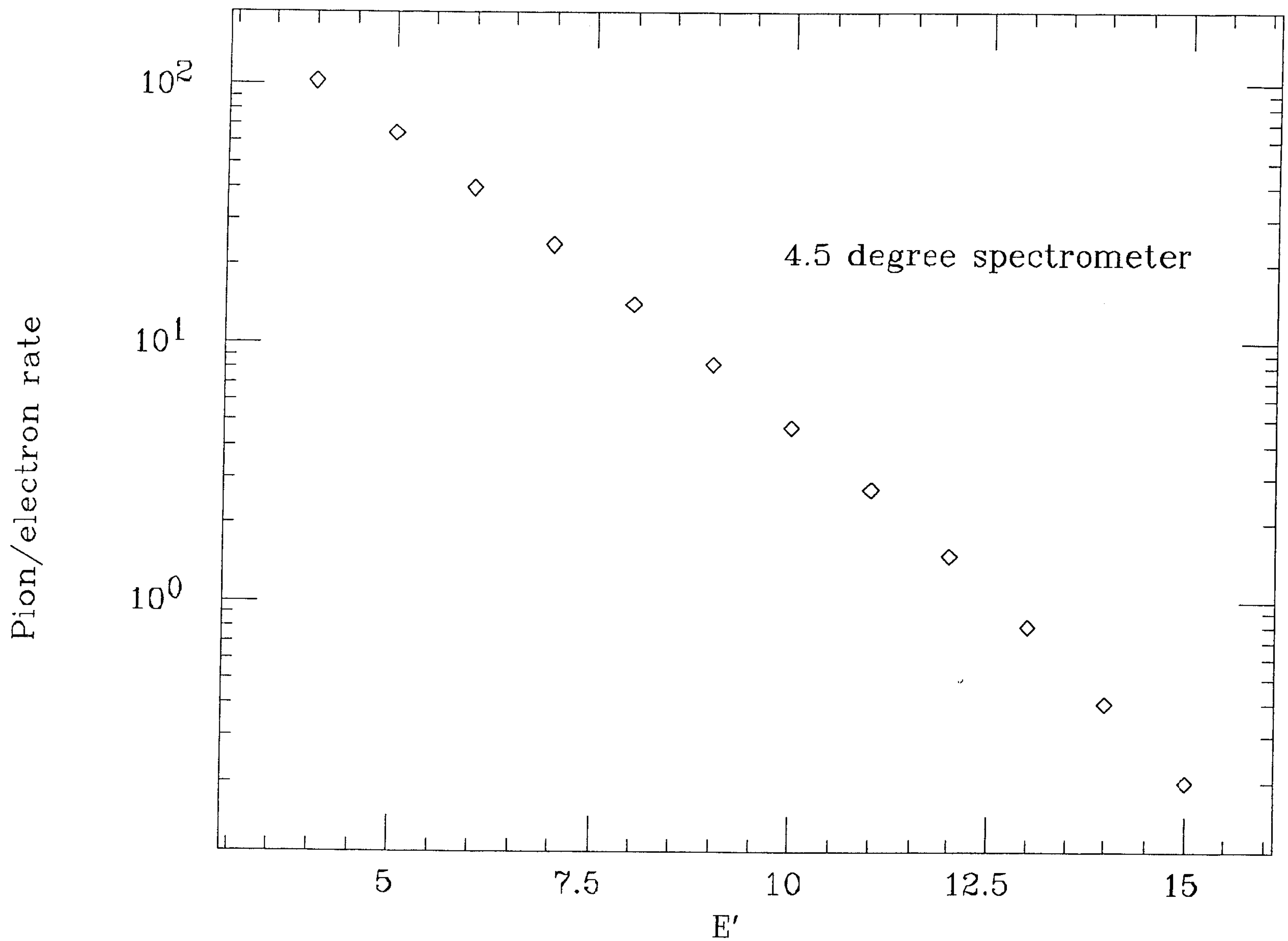
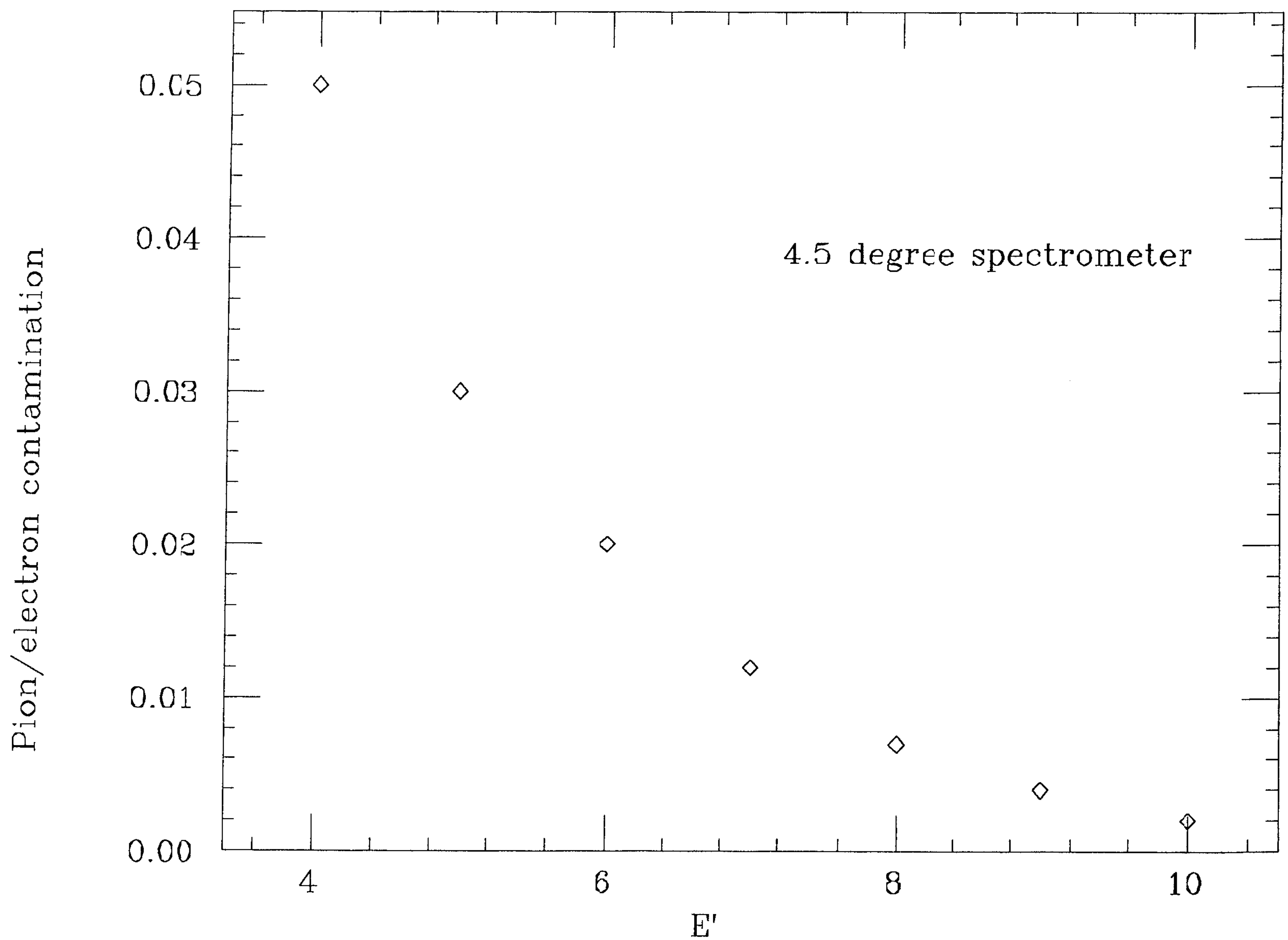

Pion/electron rate
10^2
10^1
10^0
4.5 degree spectrometer
5
7.5
10
12.5
15
E′

Figure 2



4.5 degree spectrometer
Pion/electron contamination
0.05
0.04
0.03
0.02
0.01
0.00
4
6
8
10
E'

Figure 3

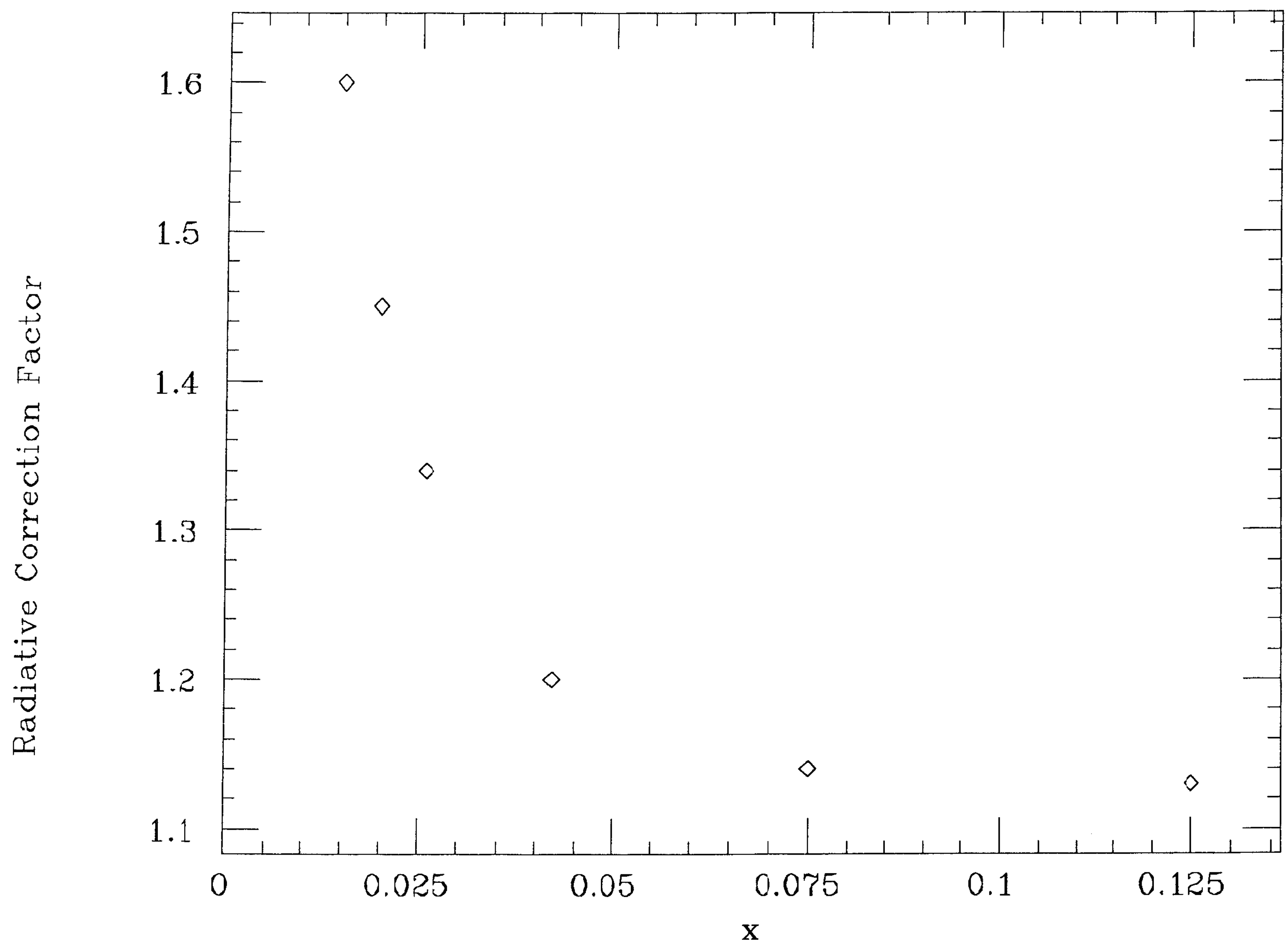

Radiative Correction Factor
1.6
1.5
1.4
1.3
1.2
1.1
0
0.025
0.05
0.075
0.1
0.125
x

Figure 4

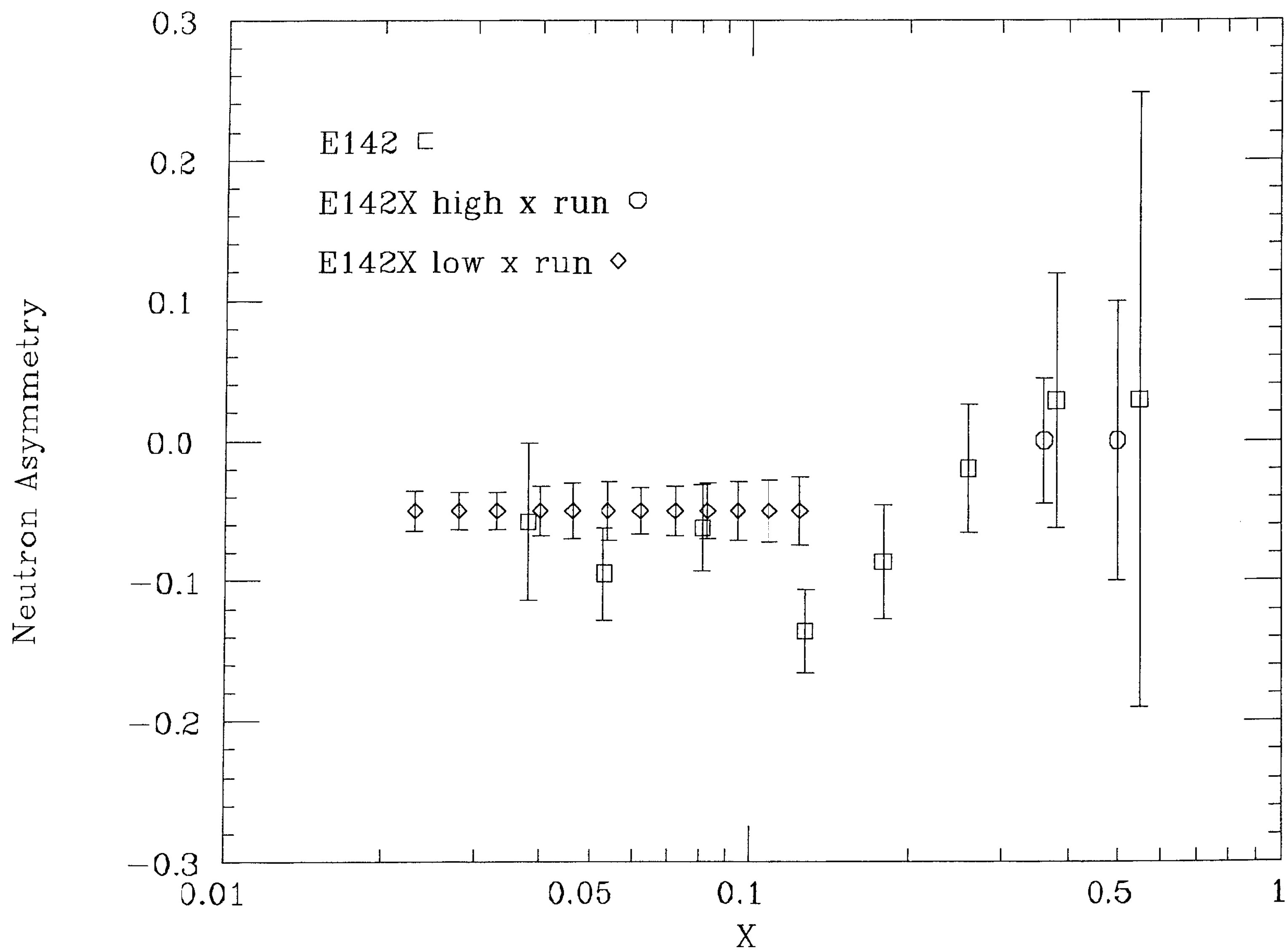

0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0.01
0.05
0.1
0.5
1
X
Neutron Asymmetry
E142
E142X high x run
E142X low x run

Figure 5