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"The Polarized Structure Function G_{1n} and the Q^2 Dependence of the Gerasimov-Drell-Hearn Sum Rule for the Neutron"

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By: 90

The Polarized Structure Function G_{1n} and the Q^2 dependence of the Gerasimov-Drell-Hearn Sum Rule for the Neutron

A Proposal for an Experiment using the CEBAF Large Acceptance Spectrometer

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ABSTRACT

We propose to measure the asymmetry in inclusive scattering of longitudinally polarized electrons off longitudinally polarized neutrons, using a cryogenic ND_3 target and the CLAS detector in Hall B. Together with the data of the already approved experiment 91-023 (Polarized Structure Functions of the Proton), this experiment will allow us to extract the polarized structure function $G_{1n}(\nu,Q^2)$ and the transverse photon asymmetry $A_{1n}(\nu,Q^2)$ of the neutron over a wide range of ν and Q^2.

Integration of the weighed cross section difference for parallel and antiparallel virtual photon and nucleon spin over the full range of energy transfers ν yields the Gerasimov-Drell-Hearn (GDH) sum rule for the neutron as a function of Q^2. Previous analyses of existing pion photo-production data seem to indicate some deviation from that sum rule at the photon point ($Q^2 = 0$), especially for the difference between protons and neutrons. The proposed experiment will shed light on the underlying mechanism of this discrepancy. For that purpose, a measurement at rather low Q^2 is very desirable. We propose to take data on ND_3 down to $Q^2 = 0.15$ $(GeV/c)^2$. In order to extract the polarized neutron structure functions, we will have to extend the proton measurements to the same Q^2 .

The Q^2--dependence of the GDH Sum Rule for both nucleons is also of great interest. Phenomenological models of the nucleon resonances yield predictions that differ strongly from more unconventional approaches (e.g., Chiral Pertubation Theory). The data will be especially sensitive to the QCD-structure of the Roper resonance $P_{11}(1440)$. Having data on both the proton and the neutron will help to unravel the spin-isospin structure of both resonant and non-resonant contributions.

The experimental technique is mostly a straightforward extension of the methods proposed in 91-023. Due to the smaller polarization of the deuteron in ND_3 , and due to the necessity to subtract the proton contribution, our error bars will be somewhat larger than in the proton case. Still, we show in this proposal that we will be able to make very significant measurements of $G_{1n}(\nu,Q^2)$ and $A_{1n}(\nu,Q^2)$ and the GDH sum rule.

I. INTRODUCTION

The cross section for inclusive inelastic electron scattering off the nucleon can be described in terms of two structure functions, $W_1(\nu,Q^2)$ and $W_2(\nu,Q^2)$. If the electrons are longitudinally polarized, and the target nucleon has some polarization $\mathbf{P_N}$ as well, two more structure functions become accessible, namely $G_1(\nu,Q^2)$ and $G_2(\nu,Q^2)$. These structure functions depend on the spin structure of the electromagnetic transition amplitudes and the spin wave function of the quarks inside the nucleon.

Only $G_{1p}(\nu,Q^2)$ for the proton has been measured so far [1, 2], in the deep inelastic region where both $g_1(x) = {}^{\nu}/_{m}\, G_1(\nu,Q^2)$ and $g_2(x) = ({}^{\nu}/_{m})^2\, G_2(\nu,Q^2)$ are expected to exhibit scaling behavior ($x = {}^{Q^2}/_{2m\nu}$). The results seem to indicate a violation of the Ellis-Jaffe Sum Rule (EJ) and have led to the much-debated "spin crisis". Presently, several collaborations around the world (SMC, E142, E143, Hermes) are conducting or planning experiments to measure the so-far unknown remaining deep inelastic structure functions $g_{1n}(x)$, $g_{2n}(x)$ and $g_{2p}(x)$, as well as to improve our knowledge of $g_{1p}(x)$. Comparing the data on both $g_{1p}(x)$ and $g_{1n}(x)$ will test the fundamental Björken sum rule which states that $\int_0^1 [g_{1p}(x) - g_{1n}(x)]\, dx = g_A/6$ (plus QCD corrections).

The inclusive polarized cross section can also be expressed in terms of the cross sections and asymmetries for the absorption of virtual photons, namely, σ_T, σ_L, A_1 and A_2. Here, $\sigma_T(\nu,Q^2)$ is the cross section for the absorption of a transverse virtual photon with invariant mass Q^2 and energy ν, and $\sigma_L = R\cdot\sigma_T$ is the cross section for longitudinal photons. $A_1 = \dfrac{\sigma_T^{1/2} - \sigma_T^{3/2}}{\sigma_T^{1/2} + \sigma_T^{3/2}}$ is the asymmetry for the absorption of a transverse (virtual) photon on a nucleon to a final state with total helicity 1/2 vs. 3/2, and $A_2 = \dfrac{\sigma_{TL}}{\sigma_T^{1/2} + \sigma_T^{3/2}}$ is an asymmetry coming from longitudinal - transverse interference. At low Q^2 and with an energy transfer ν in the resonance region, A_1 is directly related to the relative importance of helicity 1/2 and 3/2 resonance transition amplitudes (e.g., $A_1 = +1$ for a spin-1/2 resonance in the absence of non-resonant terms). In the scaling region (large ν,Q^2) on the other hand, A_1 is related to the likelihood of finding a quark with spin parallel vs. antiparallel to the nucleon spin. A_2 is typically assumed to be rather small, and has an upper bound of $A_2 < \sqrt{R}$. The relationship between these asymmetries and the polarized structure functions is

$$A_1 = \frac{\nu/_M G_1 - Q^2/_{M^2} G_2}{MW_1} \quad ; \quad A_2 = \frac{Q/_M G_1 - Q\nu/_{M^2} G_2}{MW_1} \tag{1}$$

The asymmetry in the cross section for positive vs. negative electron helicity is given by

$$A = \frac{\sigma_e^- - \sigma_e^+}{\sigma_e^- + \sigma_e^+} = D\left(A_1 + \eta A_2\right), \tag{2}$$

where D and η are kinematical factors depending on the direction (θ,ϕ) of the nucleon spin relative to the q-vector:

$$D = \frac{\sqrt{1-\varepsilon^2}\cos\theta}{1+\varepsilon R} \quad ; \quad \eta = \sqrt{\frac{2\varepsilon}{1+\varepsilon}}\sin\theta\cos\varphi. \tag{3}$$

In the case where the nucleon spin points in the direction of the beam, these factors simplify to

$$D = \frac{1 - E'/_E\,\varepsilon}{1+\varepsilon R} \quad ; \quad \eta = Q\frac{\varepsilon}{E - E'\varepsilon}. \tag{4}$$

Here ε is the polarization parameter of the virtual photon.

For real photons, the famous GDH sum rule [3, 4] makes a prediction for the integral

$$\int_{\nu_{thr}}^{\infty}\left[\sigma_N^{1/2} - \sigma_N^{3/2}\right]\frac{d\nu}{\nu} = -\frac{2\pi^2\alpha}{m^2}\kappa_N^2, \tag{5}$$

where κ_N is the anomalous magnetic moment of the nucleon N. The integral can be easily generalized to virtual photons, by replacing $\sigma_N^{1/2} - \sigma_N^{3/2}$ with $2A_1\sigma_T\left(\nu,Q^2\right)$. Table I gives the numerical values for the right-hand side of eq. (5) and the estimates for the GDH integral from several analyses of photo-pion data. It is clear that there is some discrepancy, especially in the difference for the GDH integrals of the proton and the neutron. This discrepancy may be due to insufficient treatment of highly inelastic contributions - all the analyses listed in table I were done for an upper limit of the GDH integral around 1.7 GeV, and contributions from multi-particle production were only estimated. In fact, extending the Björken sum rule down to low Q^2 but high ν, where it may have some relevance (see Fig. 1), indicates that there should be a positive contribution to the GDH integral in that region, which would improve the agreement with the GDH sum rule prediction. It is this region which is completely unmeasured so far, and difficult to reach with real photon experiments (since one is required to do an absorption measurement). On the other hand, inspection of the kinematical relationship between the electron asymmetry and A_1 shows that at moderately low Q^2 (0.1-0.2 GeV/c^2), the connection between electron data and the photon point is still quite close in this region, making the electron scattering experiment a good choice to gain information on this contribution to the GDH integral.

TABLE I. Various predictions for the value of the Gerasimov-Drell-Hearn Integral

Q^2 [GeV/c]^2	GDH p	GDH n	GDH p-n
GDH Sum rule	-204.5 μb	-232.8 μb	28.3 μb
Analysis by ref. [5]	-261 μb	-183 μb	-78 μb
Analysis by ref. [6]	-257 μb	-189 μb	-68 μb
Analysis by ref. [7]	-203 μb	-125 μb	-78 μb
Extended Current Algebra [8]	-294 μb	-185 μb	-109 μb

The Q^2 - dependence of the GDH integral out to higher Q^2 is rather sensitive to the (quark) structure of the low-lying nucleon resonances and thus very interesting by itself. As an example, a recent analysis [9] shows that there are quite sizable differences between predictions based on models of the Roper resonance $P_{11}(1440)$ as a hybrid quark-gluon state or as an excited 3-quark state. Our proposed measurement will clearly be able to distinguish between these models (see Figs. 11-12). Recently, a new theoretical calculation based on Chiral Pertubation Theory [10] predicted a drastically different Q^2 - dependence than more conventional models (see Fig. 11). Another approach [11] relates the rather dramatic change with Q^2 of the GDH integral below $Q^2 = 1$ (GeV/c)^2 to the contribution of the corresponding integral over G_2, and, via the Schwinger sum rule [12], ultimately to the Q^2 variation of the nucleon elastic form factors. Our data will easily distinguish between these rather different predictions.

II. EXPERIMENTAL DETAILS

We will be using the UVa polarized $^{15}ND_3$ target (Fig. 2) which is presently being commissioned for experiment E143 at SLAC. Following the successful completion of E143, this target will first be used in an experiment in Hall C, after which it is scheduled to be moved into Hall B and adapted to the CLAS detector. The mechanical design and installation of the target as well as issues of target operation, mechanical stability, beam transport and rastering, and impact on CLAS performance and backgrounds will be virtually identical for either ND_3 or NH_3 as target material. These issues have been discussed extensively in the proposal for experiment 91-023 and in CLAS note 90-04. We will run with both the polarization vector and the magnetic field along the beam axis only. The polarization of the deuterium will be lower than for the proton. A deuterium polarization of 48% has been achieved with a 3.5 T field at 0.3 K [13]. The operation conditions for the UVa target at CLAS have not been finalized yet, but it is planned to use a higher magnetic field (5 T) which will at least partially compensate for the possibly higher temperature. We conservatively assume a target polarization of 40% for our error estimates.

In addition to the ND_3 runs, we will require measurements with nitrogen-only targets to determine the ratio between scattering rates from deuterium and the full set of target materials (see below). Also, in order to extract the lowest Q^2 point (0.15 (GeV/c)^2), we will need a proton data point at that Q^2 as well (this data point will be also very interesting in its own right, and in comparison with the neutron data). For this purpose, we propose additional running (mostly at the lower energies) on the NH_3 target, contiguous with experiment 91-023.

The CLAS detector will be used in its full configuration with EGN detectors out to 45 degrees (this is well matched to the open forward angular range of the UVa target). Space constraints for the target will require removal of the inner toroid, but the strong longitudinal field of the target will protect the first region wire chambers very effectively from low-energy background particles. The expected background level has been simulated for experiment 91-023 and was found to be comparable or smaller than in the case of an unpolarized target with same luminosity. We will use the inbending (normal) magnetic field configuration, but at 1/4 of the maximum field strength, in order to extend our measurements to the lowest Q^2 possible. The trigger will consist of a single electron track, since the proposed experiment will measure inclusive cross section asymmetries.

We will run at the maximum luminosity allowed by the data taking capacity ($2 \cdot 10^{33}$, $5 \cdot 10^{33}$ and $1 \cdot 10^{34}$ $cm^{-2}s^{-1}$, for E=1.6 GeV, 2.4 GeV, and 3.2 as well as 4.0 GeV, respectively, corresponding to 1 nA, 2 nA and 5 nA electron current). For the statistical error estimates in the present proposal, we assume a beam polarization of 75% [14]. We are quite confident that by the time of the proposed run this polarization will be available, at least for the low currents required in Hall B. The necessary technical developments (using strained GaAs cathodes) have been made at SLAC and other places.

The target polarization will be monitored and optimized using standard NMR techniques. We expect an uncertainty of 5% in the deuteron polarization. The electron beam polarization will be measured using a Möller polarimeter, which is under construction at Duke University (this is a standard method at many laboratories, with a typical relative accuracy of 5% or better). Recently, there has been a proposal by B. Norum from UVa and P. Welch from MIT to use Compton back scattering from a stored laser beam as a novel method to measure the beam polarization to even better precision.

The extracted physics asymmetry depends directly on the product of beam and target polarization, so it is very desirable to have a more direct measurement (with smaller error bars) of this product. We will use quasi elastic scattering $\vec{d}(\vec{e},e'p)$ from protons bound in the polarized deuterium for this purpose. This method is based on the fact that both the proton and the neutron inside deuterium must have the same polarization (either both parallel or, due to the D-state, both antiparallel to the deuterium polarization). A detailed study of this reaction shows that one has to choose a Q^2 of 1 - 1.5 (GeV/c)^2 to detect both the proton and the electron for all beam energies. With the proposed run plan, this yields a statistical uncertainty in the polarization product of 1% at 1.6 GeV beam energy, up to 3.3% at 4 GeV. The systematic uncertainty due to the present knowledge of the proton form factors G_E^p and G_M^p is much smaller than the statistical uncertainty in all cases, since the asymmetry is mostly determined by kinematics alone. Systematic errors from the resolution in kinematical quantities are also below 1%, according to our study. Finally, the uncertainty from the deuteron wave function is minimal if we select quasi-free kinematics (with small missing momentum and energy). In summary, this method is expected to yield a clearly superior determination of the polarization product, well below 5% for all kinematic points.

III. DATA ANALYSIS

The first step in the data analysis will be to extract the deuteron asymmetry A_d from the measured raw asymmetry:

$$A_{meas} = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}} = P_{el} P_{tar} \frac{A_d \cdot N_d}{N_d + N_{^{15}N}} = A_d \cdot P_{el} P_{tar} F \ , \tag{6}$$

where the electron and target polarization (P_{el} and P_{tar}) will be determined as described in section II, and N_d and $N_{^{15}N}$ are the count rates from the deuterium and from all other target material, respectively. The dilution factor $F = \frac{N_d}{N_d + N_{^{15}N}}$ can be determined in the following way:

We require a dedicated run on a dummy target containing all target material with exception of the deuterium (i.e., replacing the ND_3 by an equivalent amount of nitrogen only). This run will need roughly 1/5 of the beam time at each energy. Using a parametrization of the unpolarized deuterium cross section (which will be available from other CLAS experiments by the anticipated time of the proposed run), one can perform a two-parameter fit to the total observed count rate in all ν bins simultaneously as $N_{ND_3} = \alpha N_{^{15}N}{}^{meas} + \beta N_d{}^{par}$. The expression $F = \frac{\beta N_d{}^{par}}{N_{ND_3}}$ is equal to the dilution factor F. A simulation of this procedure showed that we will be able to determine the dilution factor to better than 3% with this method alone (assuming a total bin-to-bin uncertainty of ≈1% for each of the three count rate sets. The statistical uncertainty will be much smaller than that.) Fig. 3 shows the simulated total counts from ND_3 and the fitted contributions from deuterium and everything else, together with the model inputs. The accuracy of this method can be further improved by constraining the ratio of deuteron nuclei to all target material (essentially correlating the parameters α and β). This can be done by measuring the composition and total thickness of the target directly, using x-ray absorption and chemical analysis. This method is presently being developed for experiment E143 at SLAC and should be well understood by the time of the proposed run. For the experiment at CLAS, we will have another independent cross check by looking at quasi-elastic scattering from deuterium, detecting a proton in coincidence with the electron and selecting tightly constrained kinematics (both in missing mass and momentum; see section II). At small missing momentum, the contribution from deuterium (with small internal momenta) is enhanced, while at larger missing momentum (>300 MeV/c), the observed rate will be nearly exclusively due to quasi elastic scattering from nitrogen and other target material. In summary, we expect the overall systematic error due to the uncertainty in the dilution factor to be less than 6% (after proton subtraction - see below). Note that this error will only enter as an overall scale uncertainty in the extracted asymmetries.

In the next analysis step, we will extract A_n from the measured deuteron asymmetry A_d by accounting for the contribution from the proton (as measured in experiment 91-023) and the fact that the neutron has some internal momentum inside deuterium. Specifically, the asymmetry A_d can be expressed as

$$A_d = \frac{(\sigma_p A_p)' + (\sigma_n A_n)'}{\sigma_d} , \tag{7}$$

where the prime indicates that the proton and neutron cross sections and asymmetries in the numerator are for nucleons bound in deuterium. By multiplying with the same parametrized deuteron cross section mentioned above, one gets

$$(\sigma_n A_n)' = A_d \sigma_d - (\sigma_p A_p)' \tag{8}$$

(note that the dependence on σ_d cancels out to some extent, since σ_d appears in the numerator of the dilution factor F, and A_{meas} has to be divided by F to get A_d.) The second term on the right hand side of eq. (8) can be determined from the data of the approved experiment 91-023 on the proton, and unpolarized proton data, together with a realistic deuteron model. Even a rather simplistic approach, namely assuming $(\sigma_p A_p)' = 0.914 * \sigma_p A_p$, gives a satisfactory approximation, as can be seen from Fig. 4. The factor 0.914 takes the D-state of deuterium into account, yielding an average proton polarization of $P_p = 0.914 * P_d$ which has to be multiplied with the free proton data.

In order to arrive at the desired neutron asymmetry A_n, one has to divide the remaining term (the left-hand side of eq. 8) by the smeared neutron cross section σ_n' and then correct A_n' for the binding effects in the deuteron. Again, σ_n' will be well known from unpolarized measurements, while A_n can be inferred from A_n' using a realistic deuteron model. Fig.5 shows a comparison between extracted (simulated) asymmetry A_n and the theoretical input into the simulation, together with the expected statistical error bars. Although there are small differences between the structure of the extracted and the theoretical curve (especially at higher ν, where the cross section is small), the overall integral (which enters the GDH sum rule) will be very similar for both.

Finally, we will have to extract A_{1n} from A_n according to eq. (2). To do this, we will have to rely in part on a model of A_{2n}, constrained by experimental data on electromagnetic transition amplitudes in the resonance region and by the upper bound for A_{2n} of $|A_{2n}| \leq \sqrt{R}$. Again, unpolarized data in the resonance region (which are the highest priority for the N* collaboration in the first years of CLAS operation) will allow us to narrow down the reasonable range of A_{2n}. If the data available at the time of running are not sufficient to determine A_{2n} precisely enough, we may also change our proposed combination of beam energies to optimize extraction of A_{2n} from our own data. For instance, at $Q^2 = 0.35$ and in the region of the Δ resonance, we can determine A_{2n} to ±0.15 by taking data at E = 1.2 GeV as well. One can also envision a dedicated run with sideways target polarization at a later date to measure A_{2n} directly. Fig. 6 shows that even simply assuming $A_{2n} = 0$ does not lead to a gross systematic error, so that the theoretical uncertainty should be quite small. We estimate a systematical error of at most 6% in the GDH integral from this extraction procedure.

IV. EXPECTED RESULTS

We have run extensive Monte Carlo simulations of the expected experimental data and our extraction procedure. As an example, we show in Figs. 7 through 10 results of a Monte Carlo simulation (GEANT/SDA) of the CLAS acceptance in ν and Q^2, for 1/4 of the maximum magnetic field strength and including the 5T ND_3 target field. Clearly we will be able to cover a large range in ν down to $Q^2 = 0.15$ $(GeV/c)^2$ (from threshold to W = 2.2 GeV, and several data points at higher W).

Figs. 11-12 and table II show the expected precision of our data on the GDH integral at several Q^2 points, together with a number of theoretical predictions and earlier analyses of photo-pion data and electromagnetic transition amplitudes. The error bars shown are statistical only. For the neutron alone, there will be a uniform uncertainty below 7% in the overall scale for all data points from the polarization product and dilution factor, and an additional systematic uncertainty less than 6% from the extraction method. Note that there will be no systematic error from uncertainties in the CLAS acceptance and detector efficiencies, since we only measure asymmetries. Past experience with similar polarization experiments (e.g., E142 at SLAC) shows that systematic errors due to correlated changes of beam parameters with polarization are also negligible at the anticipated level of sensitivity. Those systematic errors will be further suppressed by reversing the target polarization regularly (every few hours).

Thus we estimate a maximum systematic uncertainty of ±15 μb for the proton-neutron difference, yielding a combined error bar of ≈20 μb at the lowest Q^2 point. Even so, our data would distinguish clearly between predictions from the GDH sum rule (which has a positive value for the p-n difference) and from ref. [8] and the Workman/Arndt analysis [6].

TABLE II. Expected statistical errors on the GDH integral

Q^2 [GeV/c]^2	$\sigma_{GDH(n)}$	$\sigma_{GDH(p-n)}$
0.15 ± .015	10.10	11.81
0.35 ± .035	7.01	7.78
0.80 ± .05	3.07	3.41
2.00 ± .10	0.86	0.95

V. SUMMARY AND BEAM REQUEST

We request a total of 1200 hours (50 days) of beam time. In addition, we request additional beam time for proposal 91-023 to measure an additional point at $Q^2 = 0.15$ (GeV/c)^2. These data will explore the completely unknown region of inclusive polarization observables in inelastic electron-neutron scattering for low to moderate Q^2 and will yield significant information on the Q^2 evolution of the Gerasimov-Drell-Hearn integral. Together with the proton data, we will be able to distinguish both between differing models of the nucleon resonances and between alternative predictions for the proton-neutron difference of the GDH integral near the photon point.

TABLE III. Requested Beam Time

E [GeV]	Luminosity	Target	Current [nA]	Hours
1.6	$2\cdot10^{33}$	$^{15}ND_3$	1	240
2.4	$5\cdot10^{33}$	$^{15}ND_3$	2.5	240
3.2	$10\cdot10^{33}$	$^{15}ND_3$	5	240
4.0	$10\cdot10^{33}$	$^{15}ND_3$	5	240
All	-	^{15}N	1 - 5	240
All	-	$^{15}NH_3$	1 - 5	200

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FIGURE CAPTIONS

Fig. 1) Kinematic Regime for deep inelastic electron scattering (region bounded by solid lines) and the kinematical region of the SLAC spin structure function experiment E142, in comparison with the kinematic region accessible with the CLAS at up to 4 GeV beam energy (enclosed by the dotted lines). It seems that a possible connection between the deep inelastic sum rules and the GDH sum rule at $Q^2 = 0$ should occur at higher ν, if at all, not at the lower energies (in the resonance region) considered in previous analyses of the GDH integral [6].

Fig. 2) Sketch of the UVa polarized NH_3/ND_3 target in the CLAS detector.

Fig. 3) Total number of counts expected for the ND_3 target (solid line) at $Q^2 = 0.15$ $(GeV/c)^2$ and beam energy E = 1.6 GeV. The contribution from deuterium (dotted line) and nitrogen (dash-dotted line) that entered the calculation are shown, together with the extracted contributions ("data" points) using the χ^2 minimization described in the text.

Fig. 4) Product of cross section and asymmetry for electron scattering on a proton, both free (multiplied by a factor of 0.914 - dashed line) as well as bound in deuterium (indicated by the prime - solid line). Except for minor details in the structure, the two curves agree rather well. See text for further explanation.

Fig. 5) Neutron asymmetry A_n extracted from simulated data, compared with the theoretical values that entered the simulation. The estimated error bars are statistical only. See text for explanation.

Fig. 6) Asymmetry A_{1n} times transverse photon cross section σ_T, extracted from simulated neutron events under the assumption $A_{2n} = 0$ ("data" points), compared to the full calculation (solid line).

Fig. 7) Two simulated electron events at forward angles in the CLAS detector, using GEANT. Both side views and cross sectional views are shown. The upper event corresponds to $Q^2 = 0.3$ (GeV/c)^2 at a beam energy E = 1.6 GeV, while the lower event is at $Q^2 = 1.2$ (GeV/c)^2 for a beam energy E = 3.2 GeV. The trajectories were calculated assuming 1/4 of the maximum magnetic field strength in CLAS, and including the effect of the polarized target field.

Fig. 8) Same as Fig. 7), for backward electrons of lower momentum. The effect of the target field (5T) is especially obvious for the cross sectional view of the upper event. While the field shifts all events in ϕ, it affects the acceptance only minimally.

Fig. 9) Acceptance of CLAS for electrons as function of ν and Q^2, as simulated with SDA. The 4 panels show two-dimensional plots of accepted simulated events for the 4 different beam energies proposed here. The initial events were distributed uniformly in ν and Q^2 (within the kinematical limit $x \leq 1$).

Fig. 10) Acceptance of CLAS as a function of ν for the two lowest proposed Q^2 points ($Q^2 = 0.15$ - 0.2 and $Q^2 = 0.35$ - 0.4), for the lower two beam energies. Shown are the ratios of accepted events (requiring a good track in all wire chambers, and a signal in the Cerenkov and EGN detectors), to simulated events (which were uniform in ϕ).

Fig. 11) Simulated expected data points for the GDH integral on the neutron. The error bars are statistical only; there is an overall scale uncertainty of roughly 7%, and possibly up to 6% systematic errors due to the uncertainty in the extraction procedure. The curves shown are from the program AO (based on an analysis of electromagnetic transition amplitudes in the resonance region), with different assumptions about the structure of the Roper resonance (NRQM means nonrelativistic quark model). Also shown is the prediction of a model using Chiral Pertubation Theory (ChPT) [10], and the value of the GDH sum rule at $Q^2 = 0$, together with the analysis of pion photoproduction data by Workman et al. [6].

Fig. 12) Same as Fig. 9), for the difference between proton and neutron. The curve labeled "Björken Sum Rule" is a (model-dependent) extrapolation of the Björken sum rule for deep inelastic scattering. The prediction of the model by Chang, Liang and Workman [8], using extended algebra, is indicated as well.

Kinematic Range for Inelastic Scattering

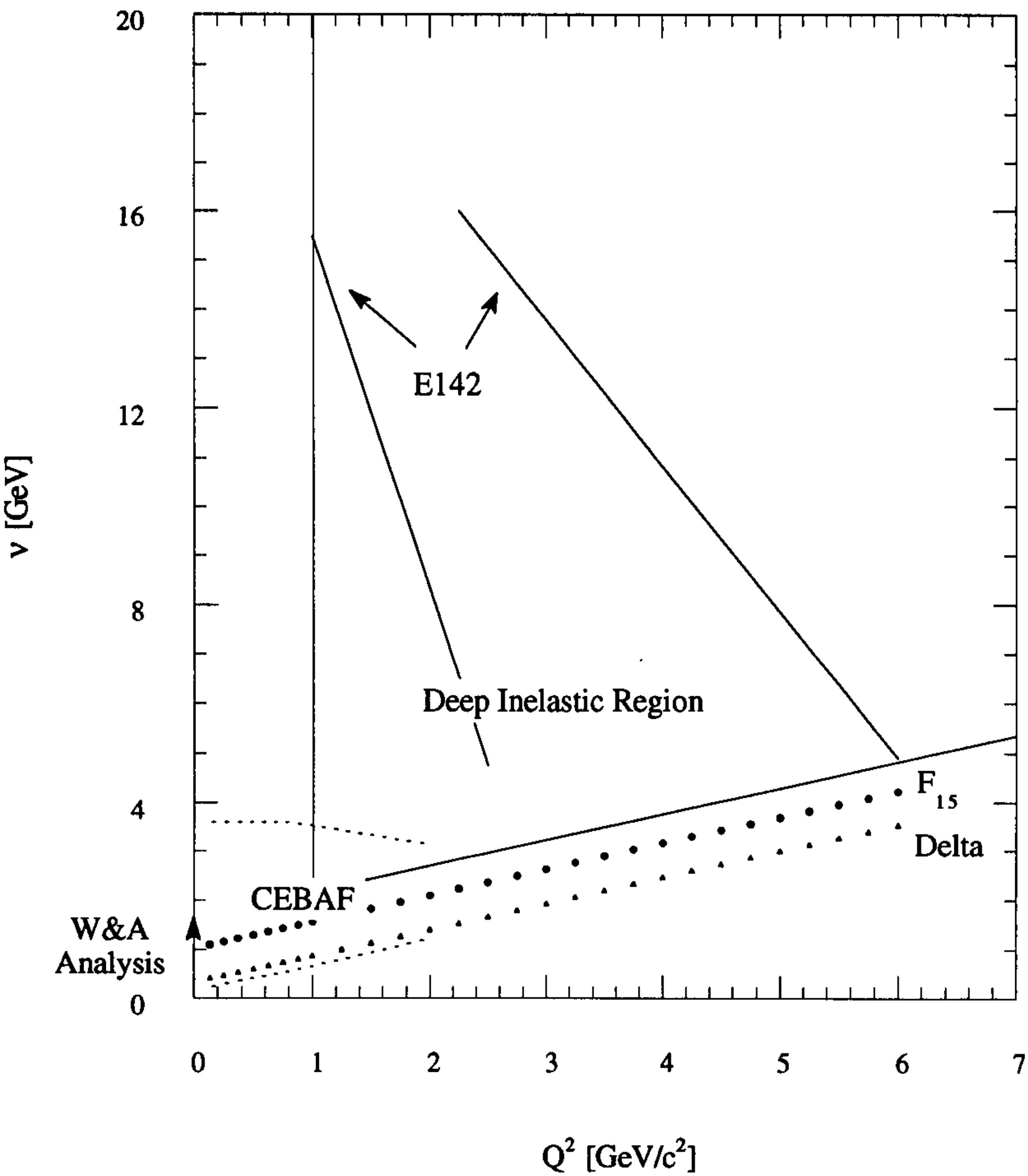


Fig. 1

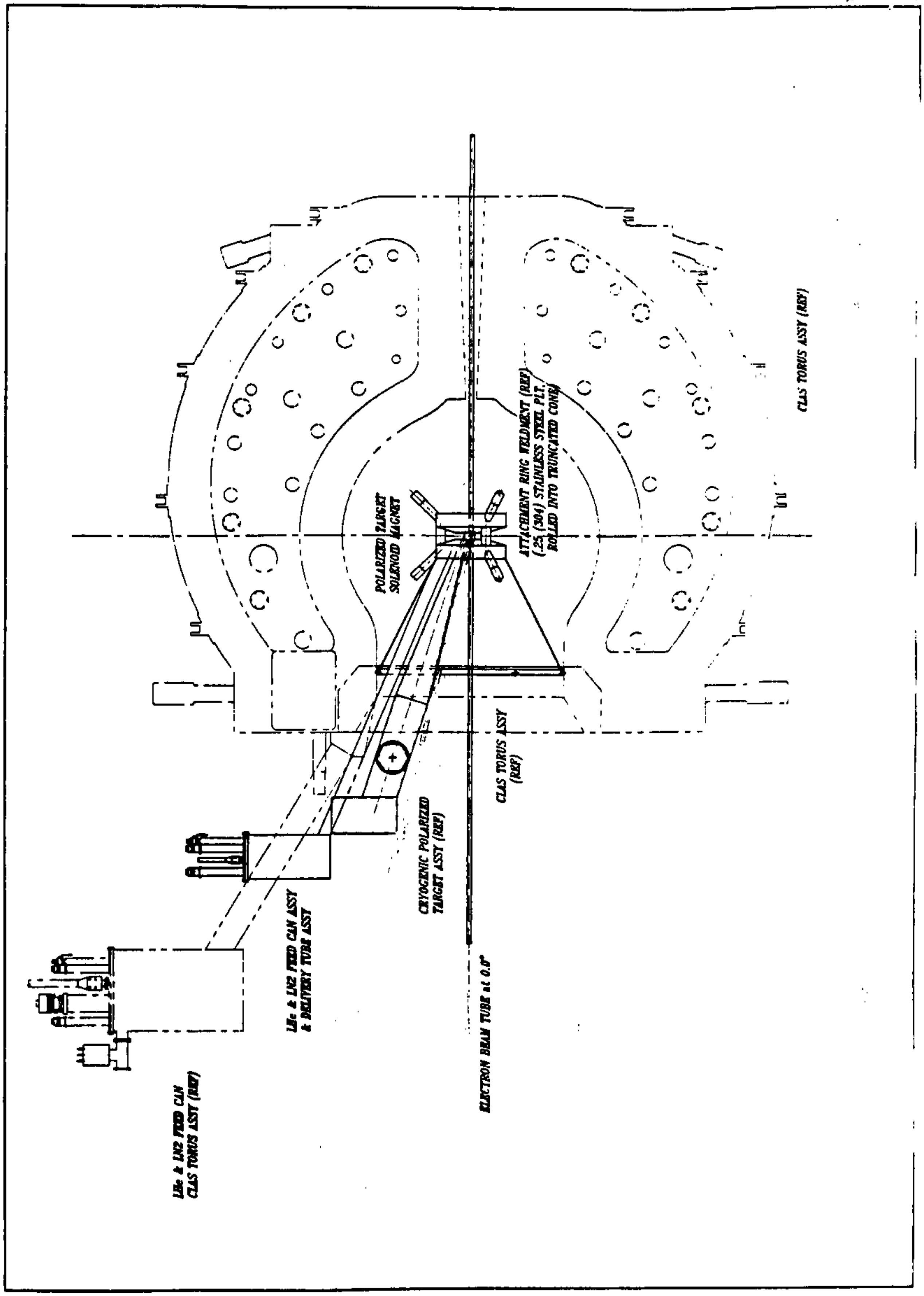

CLAS TORUS ASSY (REF)
ATTACHMENT RING WELDMENT (REF)
(.25 (304) STAINLESS STEEL PLT.
ROLLED INTO TRUNCATED CONE)
POLARIZED TARGET
SOLENOID MAGNET
CLAS TORUS ASSY
(REF)
CRYOGENIC POLARIZED
TARGET ASSY (REF)
LHe & LN2 FEED CAN ASSY
& DELIVERY TUBE ASSY
ELECTRON BEAM TUBE at 0.0°
LHe & LN2 FEED CAN
CLAS TORUS ASSY (REF)

Fig. 2

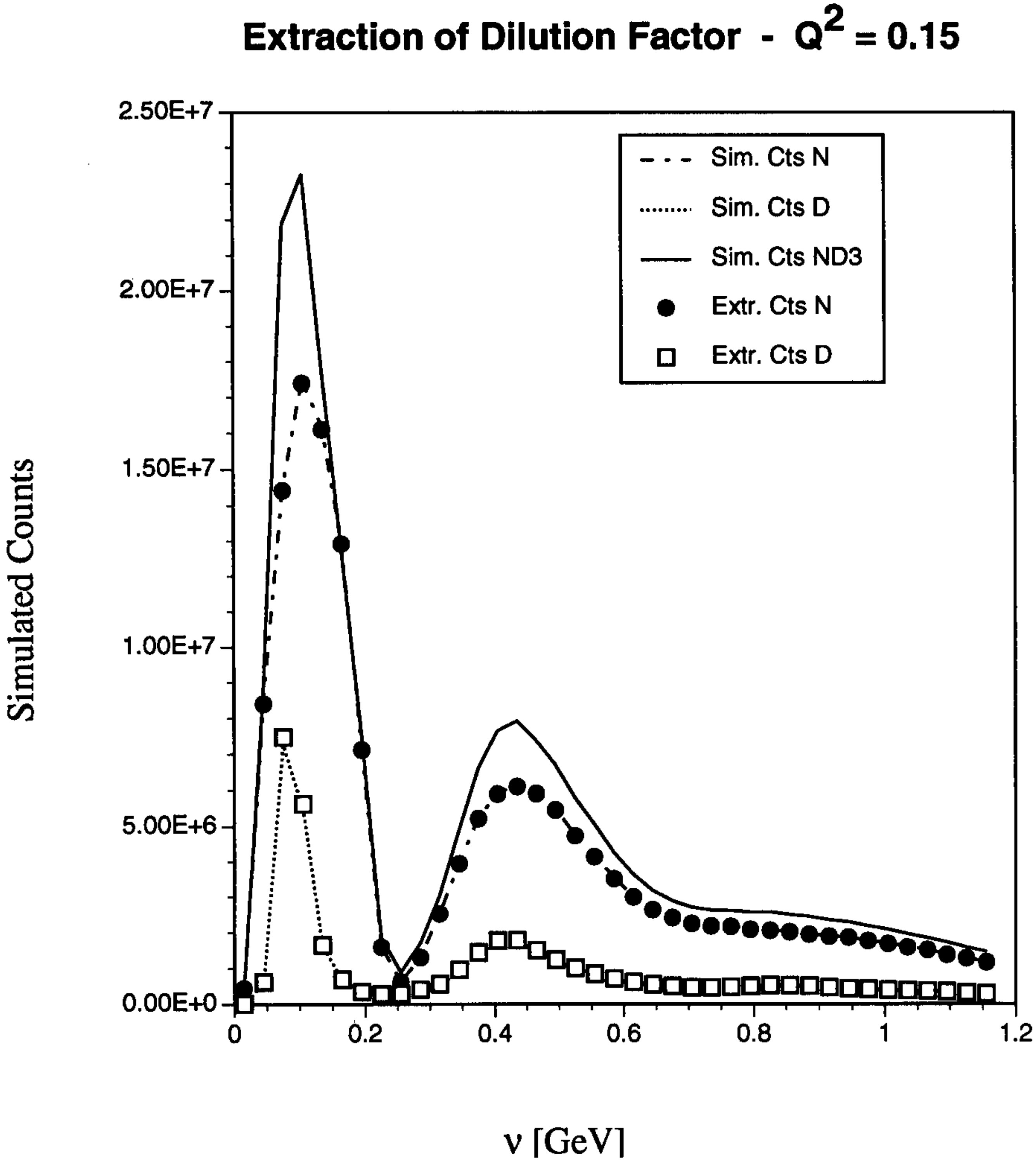

Extraction of Dilution Factor - $Q^2 = 0.15$
Sim. Cts N
Sim. Cts D
Sim. Cts ND3
Extr. Cts N
Extr. Cts D
Simulated Counts
2.50E+7
2.00E+7
1.50E+7
1.00E+7
5.00E+6
0.00E+0
0
0.2
0.4
0.6
0.8
1
1.2
ν [GeV]

Fig. 3

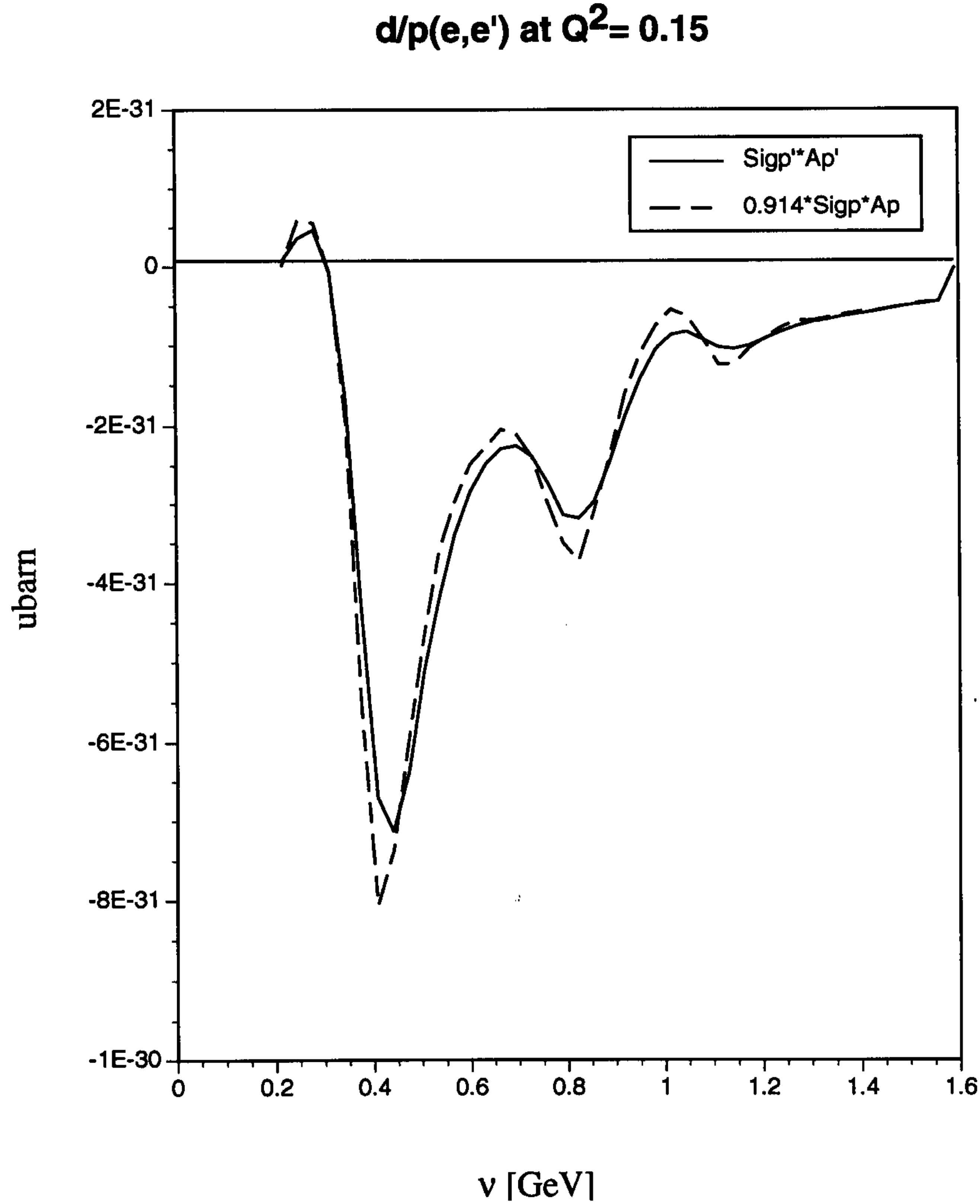
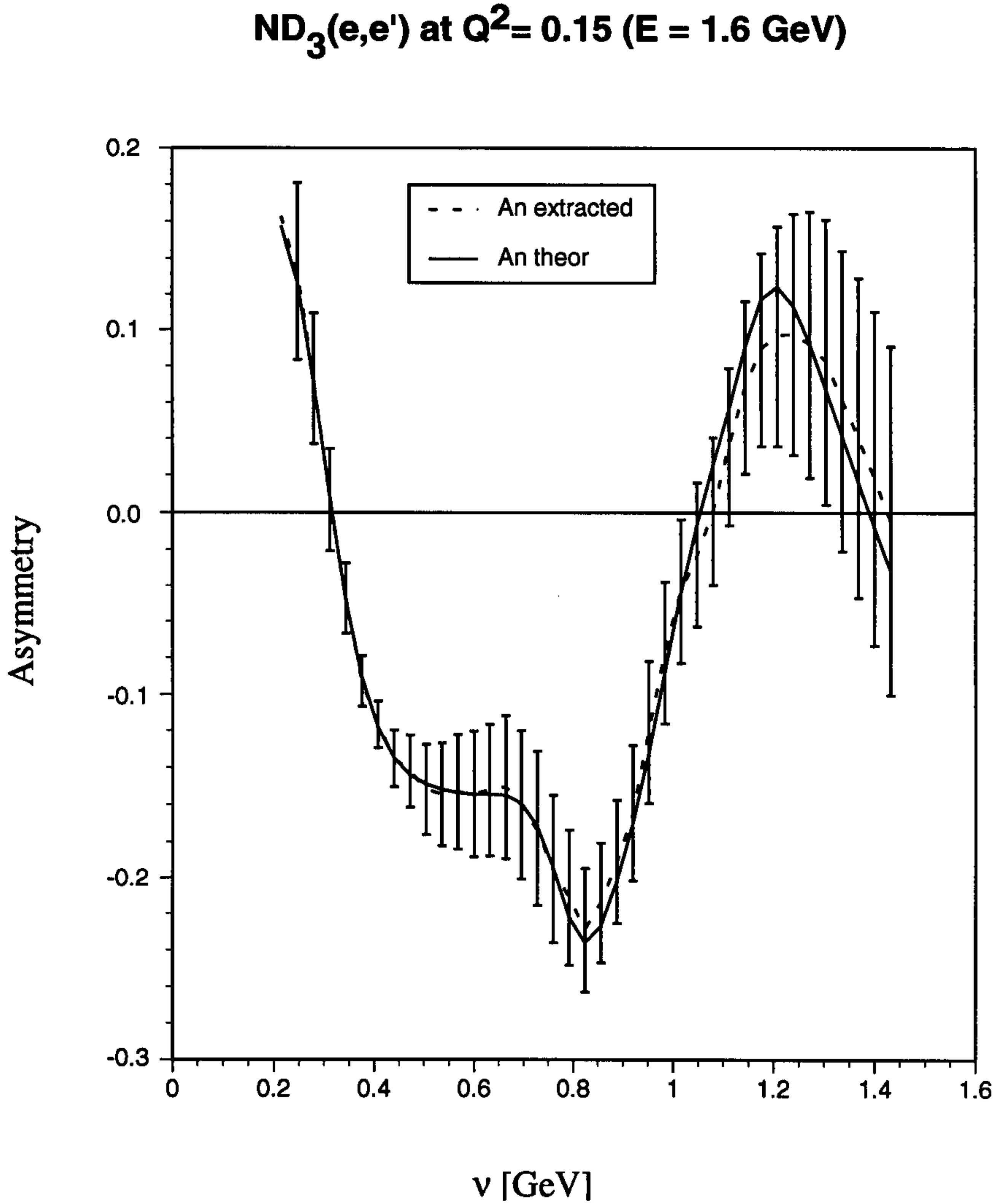

d/p(e,e') at Q2= 0.15
2E-31
0
-2E-31
-4E-31
-6E-31
-8E-31
-1E-30
ubarn
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
ν [GeV]
Sigp'*Ap'
0.914*Sigp*Ap

Fig. 4



ND$_3$(e,e') at Q^2= 0.15 (E = 1.6 GeV)
An extracted
An theor
Asymmetry
0.2
0.1
0.0
-0.1
-0.2
-0.3
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
ν [GeV]

Fig. 5

n(e,e') at Q^2= 0.15

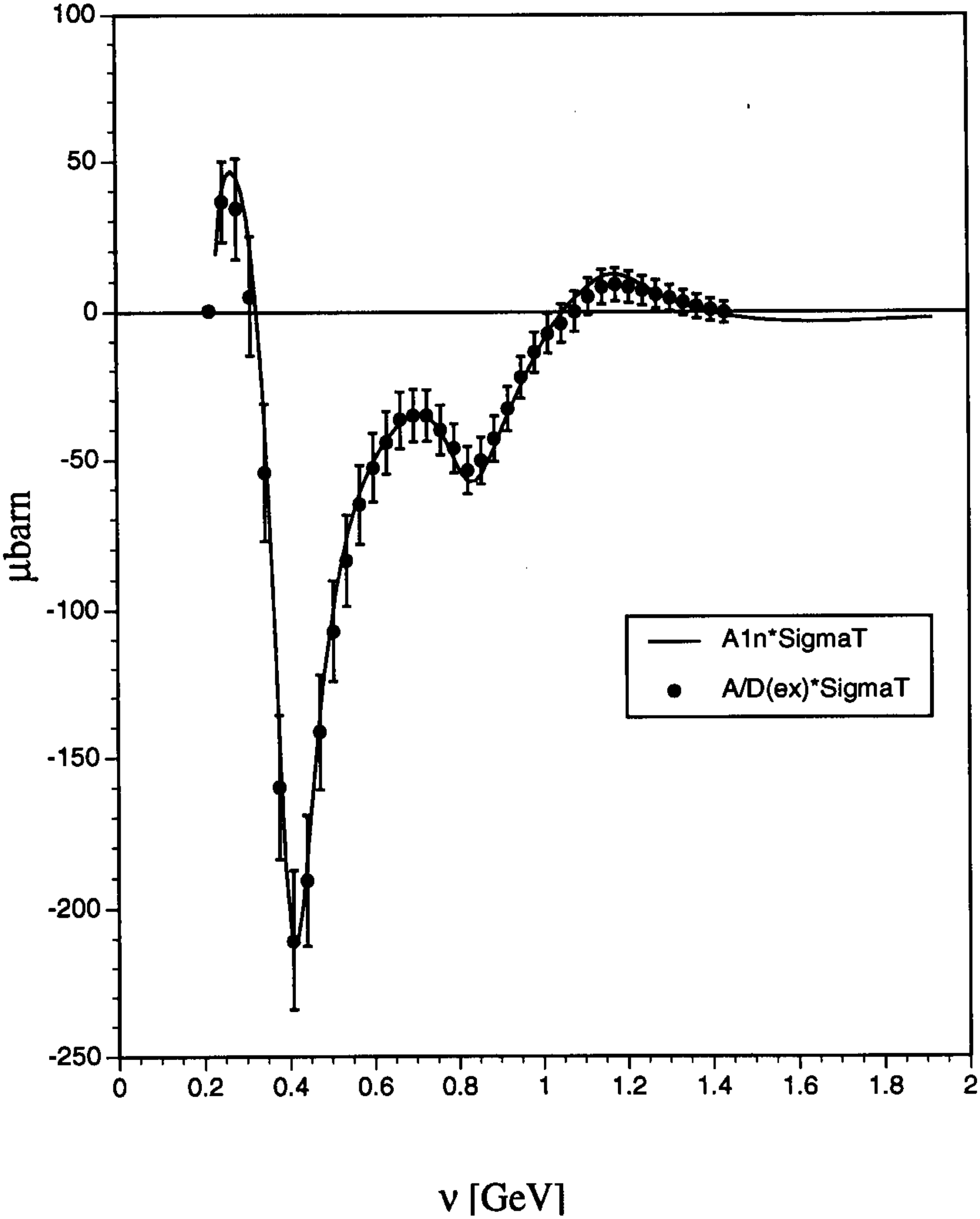


Fig. 6

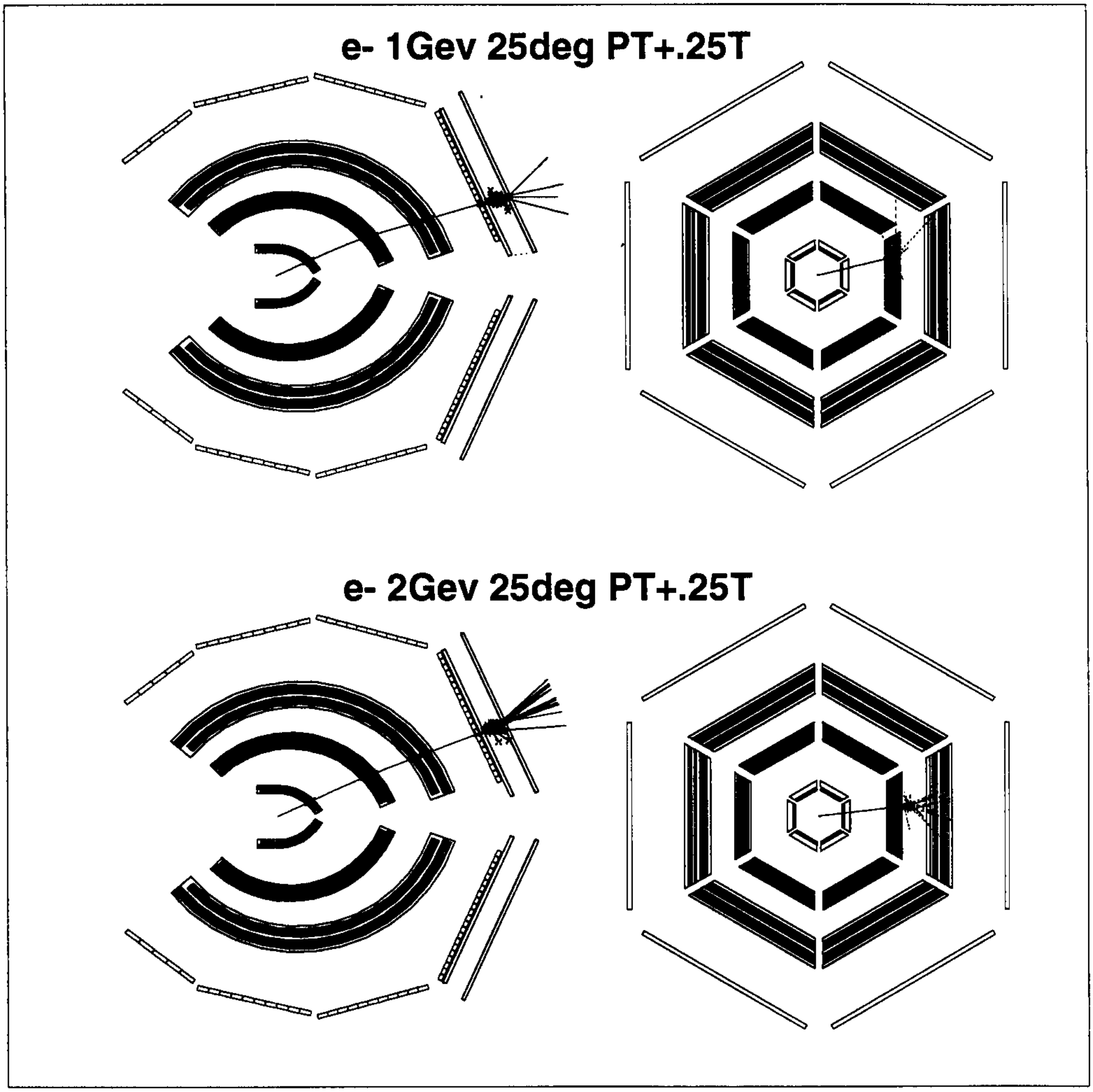


Fig. 7

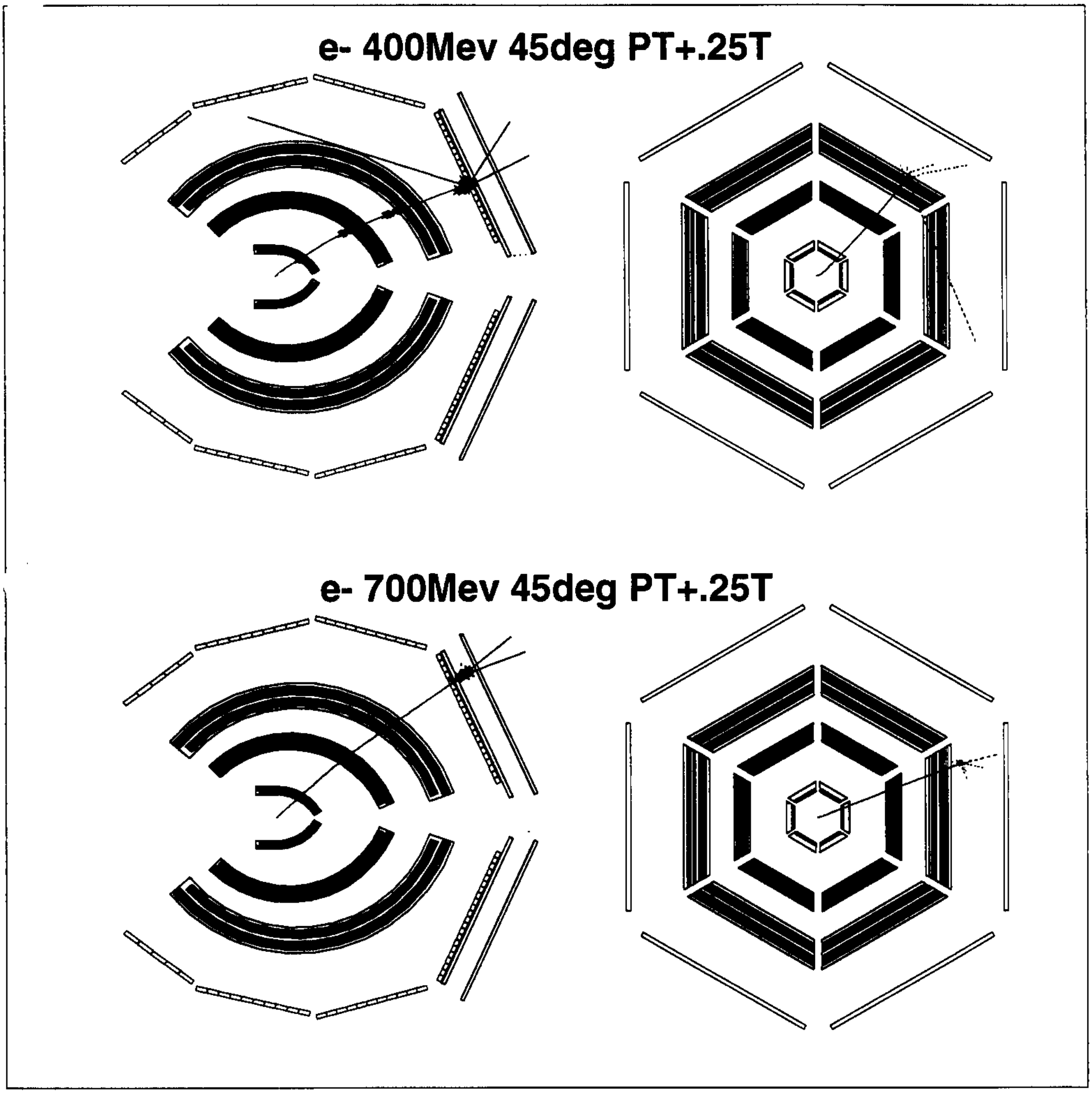
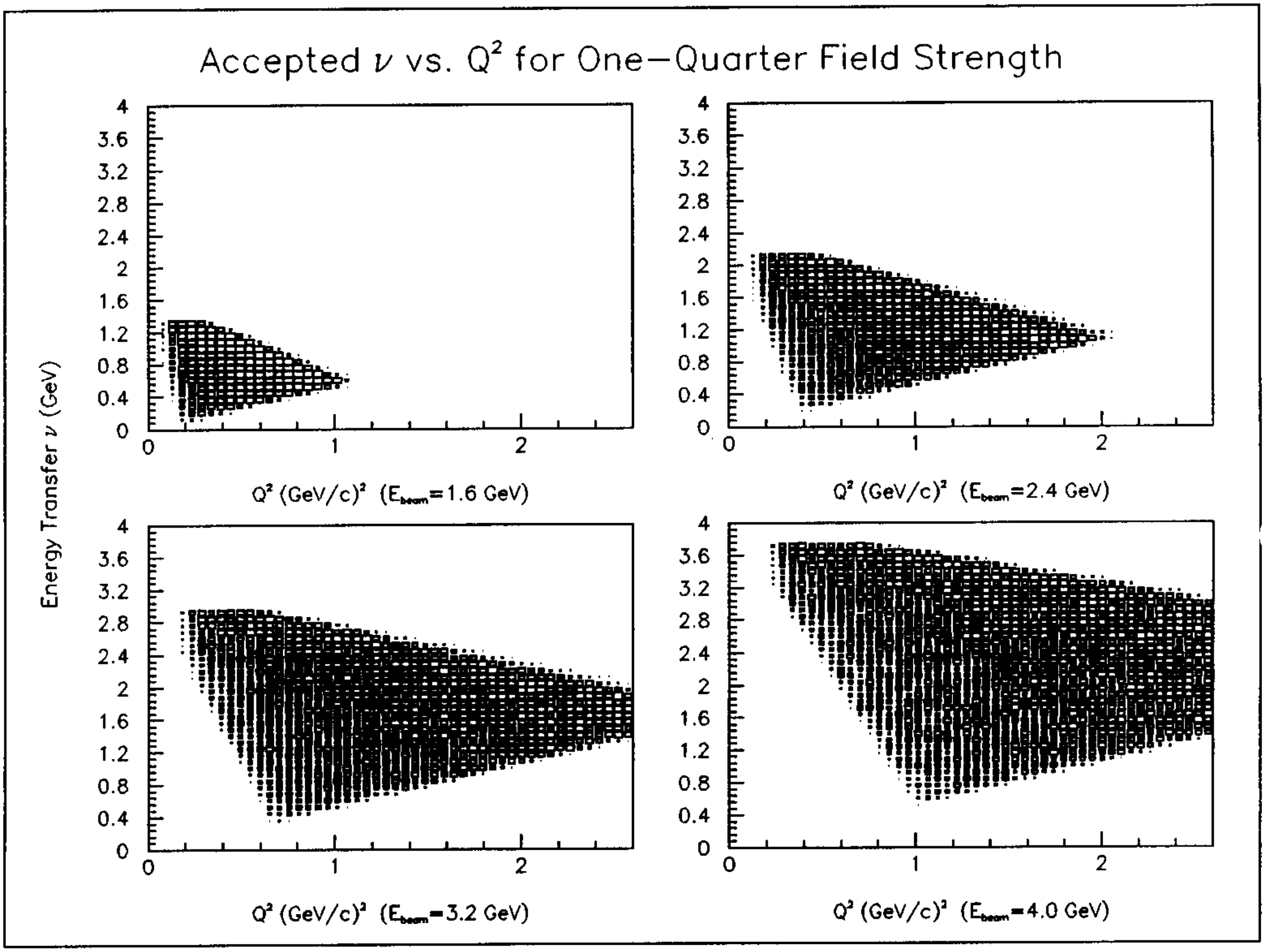
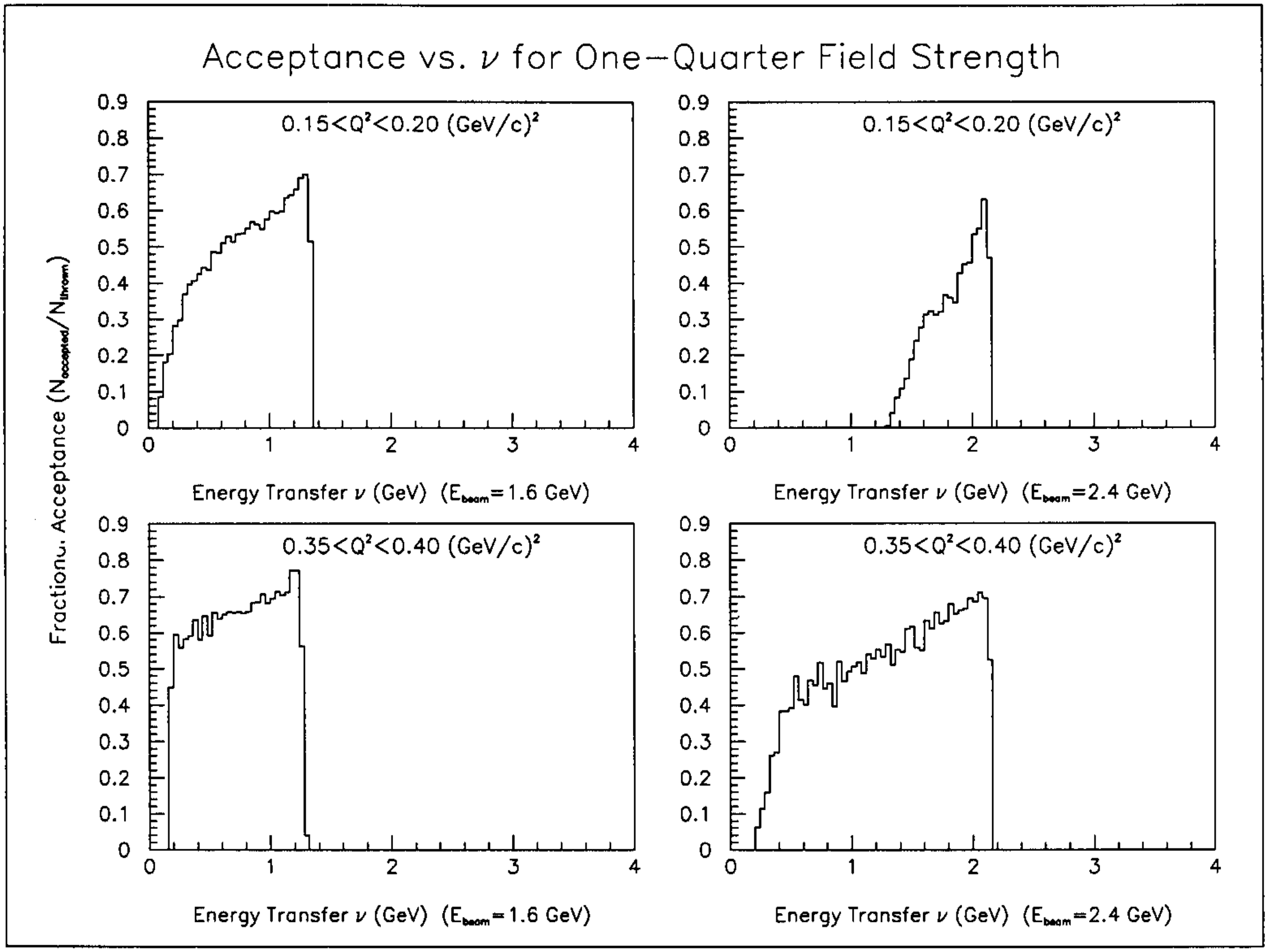


Fig. 8



Accepted ν vs. Q² for One–Quarter Field Strength
Energy Transfer ν (GeV)
4
3.6
3.2
2.8
2.4
2
1.6
1.2
0.8
0.4
0
0
1
2
Q² (GeV/c)² (E_beam=1.6 GeV)
Q² (GeV/c)² (E_beam=2.4 GeV)
Q² (GeV/c)² (E_beam=3.2 GeV)
Q² (GeV/c)² (E_beam=4.0 GeV)

Fig. 9



Acceptance vs. ν for One-Quarter Field Strength
Fractional Acceptance (N_accepted/N_thrown)
0.15<Q²<0.20 (GeV/c)²
0.15<Q²<0.20 (GeV/c)²
0.35<Q²<0.40 (GeV/c)²
0.35<Q²<0.40 (GeV/c)²
Energy Transfer ν (GeV) (E_beam=1.6 GeV)
Energy Transfer ν (GeV) (E_beam=2.4 GeV)
Energy Transfer ν (GeV) (E_beam=1.6 GeV)
Energy Transfer ν (GeV) (E_beam=2.4 GeV)

Fig. 10

Gerasimov-Drell-Hearn Sum Rule for the Neutron

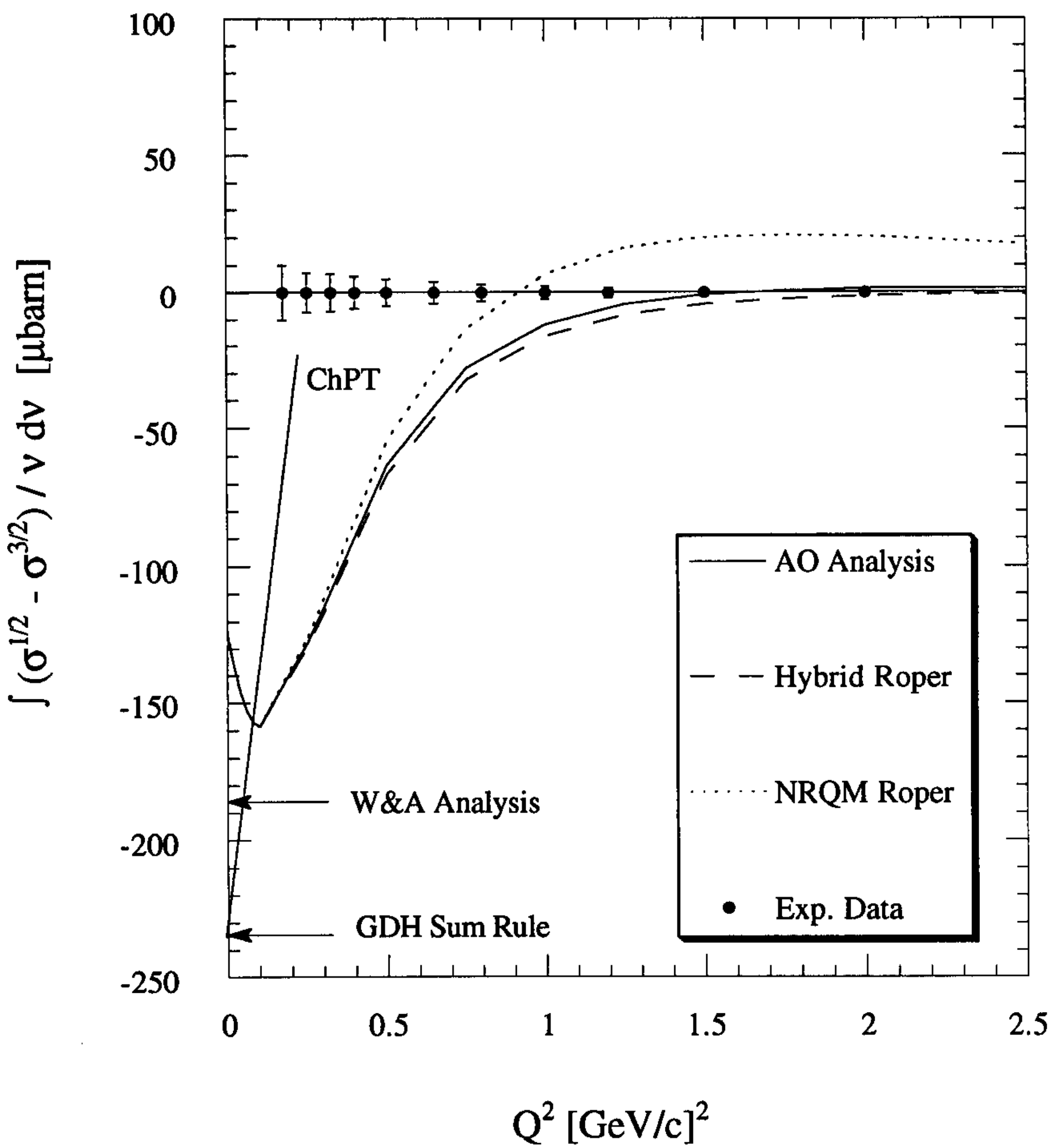


Fig. 11

Gerasimov-Drell-Hearn Sum Rule: Proton - Neutron

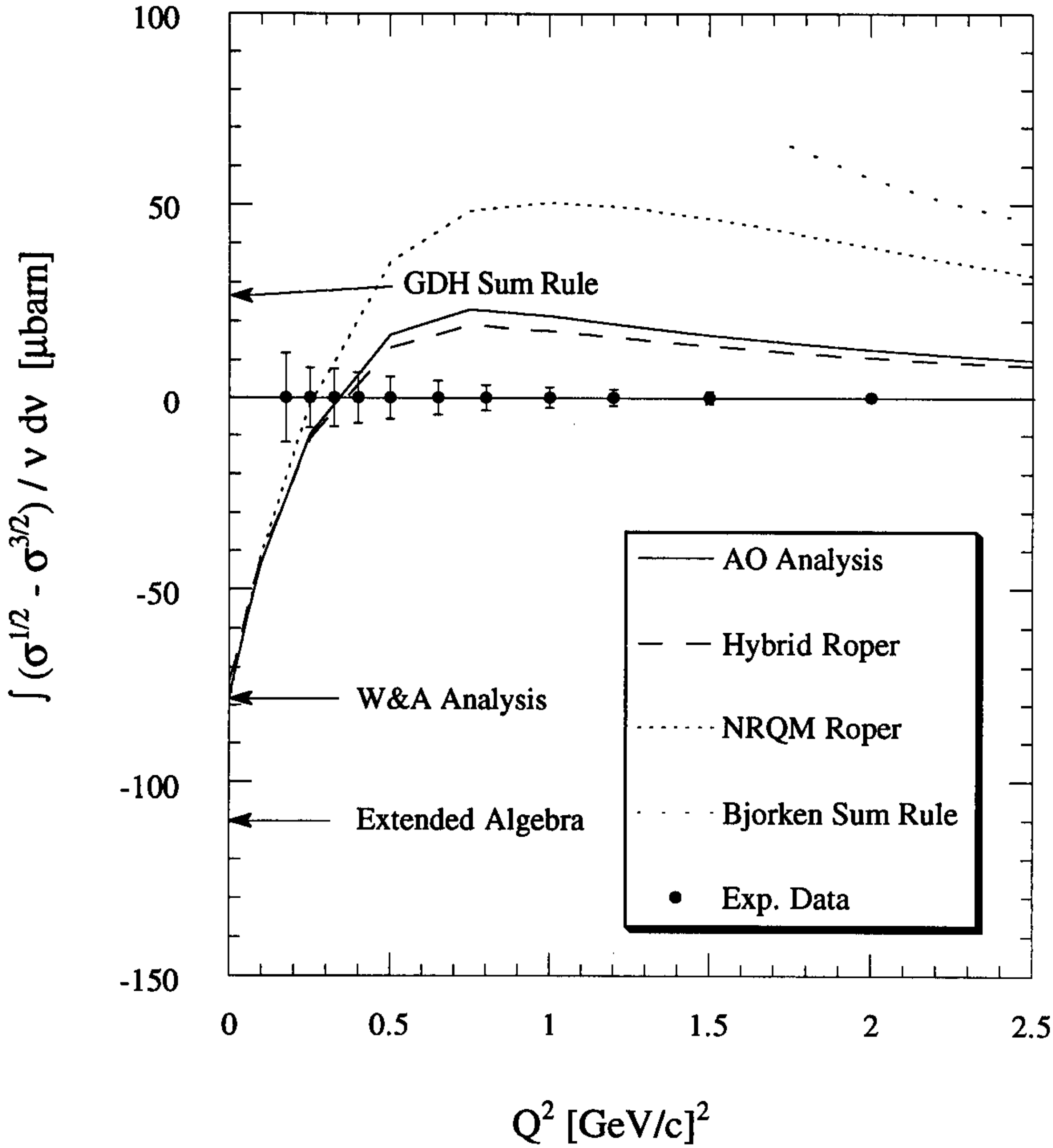


Fig. 12