CEBAF Program Advisory Committee Nine
Extension and Update Cover Sheet

This update must be received by close of business on Thursday, December 1, 1994 at:

CEBAF
User Liaison Office, Mail Stop 12 B
12000 Jefferson Avenue
Newport News, VA 23606

Experiment: E91-023

Check Applicable Boxes:

☒ Extension ☐ Update ☐ Hall B Update

Contact Person

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CEBAF Use Only

Receipt Date: 12/15/94

By: gp PR 94-147

... IDENTIFICATION CHECKLIST

CEBAF Proposal No.: ______________ (For CEBAF User Liaison Office use only.) Date: ______________

Check all items for which there is an anticipated need.

Cryogenics ____ beamline magnets CLAS analysis magnets ____ target type: polarized NH_3 flow rate: ____ capacity: ____	**Electrical Equipment** ____ cryo/electrical devices ____ capacitor banks ____ high voltage ____ exposed equipment Standard Hall B	**Radioactive/Hazardous Materials** List any radioactive or hazadorous/ toxic materials planned for use: None
Pressure Vessels ____ inside diameter ____ operating pressure ____ window material ____ window thickness None	**Flammable Gas or Liquids** type: ____ flow rate: ____ capacity: ____ **Drift Chambers** type: Standard CLAS flow rate: drift chambers capacity: ____	**Other Target Materials** ____ Beryllium (Be) ____ Lithium (Li) ____ Mercury (Hg) ____ Lead (Pb) ____ Tungsten (W) ____ Uranium (U) ____ Other (list below) None
Vacuum Vessels ____ inside diameter ____ operating pressure ____ window material ____ window thickness CLAS magnet + beam pipe	**Radioactive Sources** ____ permanent installation ____ temporary use type: ____ strength: ____ None	**Large Mech. Structure/System** ____ lifting devices ____ motion controllers ____ scaffolding or ____ elevated platforms Standard Hall B
Lasers type: ____ wattage: ____ class: ____ Installation: ____ permanent ____ temporary Use: ✓ calibration ____ alignment several low power lasers for PMT calibration (Standard Hall B equipment!)	**Hazardous Materials** ____ cyanide plating materials ____ scintillation oil (from) ____ PCBs ____ methane ____ TMAE ____ TEA ____ photographic developers ____ other (list below)	**General:** Experiment Class: X Base Equipment ____ Temp. Mod. to Base Equip. ____ Permanent Mod. to Base Equipment ____ Major New Apparatus Other: polarized solid state target.

Standard Hall B equipment + polarized target for experiments: E-91-015, E-91-023, E-93-009, E-93-036

CEBAF Proposal No.: ______________ Date: ______________

(For CEBAF User Liaison Office use only.)

List below significant resources — both equipment and human — that you are requesting *from CEBAF* in support of mounting and executing the proposed experiment. Do not include items that will be routinely supplied to all running experiments, such as the base equipment for the hall and technical support for routine operation, installation, and maintenance.

***Major Installations** (either your equip. or new equip. requested from CEBAF)*

Standard Hall B equipment

CLAS +

Polarized Solid State

Target

New Support Structures: No

Data Acquisition/Reduction

Computing Resources: Standard

New Software:

Major Equipment

Magnets

Power Supplies

Targets: Polarized NH_3

Detectors: CLAS in Standard Configuration.

Electronics

Computer Hardware

Other

Other

BEAM REQUIREMENTS LIST

CEBAF Proposal No.: ____________________ Date: ____________
(For CEBAF User Liaison Office use only)

List all combinations of anticipated targets and beam conditions required to execute the experiment. (This list will form the primary basis for the Radiation Safety Assesment Document (RSAD) calculations that must be performed for each experiment.)

Condition #	Beam Energy (MeV)	Beam Current (μA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Target Material Thickness (mg/cm^2)
1	6,000	0.01	polarized electrons	NH_3 +	1000. mg/cm^2
				Aluminum	

beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. For 1995, E_{Linac} = 800 MeV, i.e., available E_{Beam} are [illegible], 1600, 2400, 3200, and 4000 MeV. Starting in 1996, in an evolutionary way (and not necessarily in the order given) the following additional values of E_{Linac} will become available: E_{Linac} = 400, 500, [illegible], [illegible]00, 900, 1000, 1100, and 1200 MeV. The sequence and timing of the available resultant energies, E_{Beam}, will be determined by physics priorities and technical capabilities.

MEASUREMENT OF POLARIZED STRUCTURE FUNCTIONS IN INELASTIC ELECTRON SCATTERING USING CLAS

Extension of Experiment E-91-023 to 6 GeV

The N^* collaboration
and the CLAS Collaboration

Spokespersons: V. Burkert, D. Crabb, R. Minehart

Abstract

We propose to extend the kinematic range of experiment E-91-023 from $W \leq 2.\ GeV$ to $W \leq 2.7\ GeV$, and from $Q^2 \leq 2.0\ GeV^2$ to $Q^2 \leq\ 3GeV^2$ by utilizing a beam energy of 6 GeV in addition to the already approved energies ranging from 1.2 to 4 GeV. We will measure the polarized structure functions $A_1(Q^2, W)$ and $A_2(Q^2, W)$ in inclusive scattering of polarized electrons from a polarized proton target (NH_3). We propose to perform the measurements at 6 GeV with reversed polarity of the CLAS magnetic field to give improved sensitivity to A_1 at large W but small Q^2, as well as to improve the sensitivity to the structure function A_2 for all Q^2 and W. Best sensitivity is achieved if the polarized target is placed about 1 meter upstream of the normal target position. These extensions will also result in improved convergence tests of the GDH sum rule, and for the first time will allow significant measurements of the contributions to the Burkhard-Cottingham sum rule at low Q^2 in and above the resonance region. If A_2 is small at large W and Q^2, greater kinematic coverage can be achieved for A_1.

Review of approved experiment E-91-023.

Experiment E-91-023, approved for 1000 hours with the CLAS detector, will be the first measurement in the CLAS using both a polarized target and a polarized electron beam. The target consists of beads of NH_3 in liquid helium in a 5 T magnetic field produced by a pair of superconducting Helmholtz coils. The dimensions of the target are typically 1.5 cm. The polarization of the free protons achieved with a similar target at SLAC is about 90%. The purpose of the approved experiment is to measure the longitudinal scattering asymmetry at low and medium Q^2 over the resonance region. From the asymmetry we can extract proton spin structure functions. With an appropriate integration over the invariant mass, W, at fixed Q^2 one can obtain the resonant contribution to the Q^2 evolution of the Gerasimov-Drell-Hearn sum rule. It is expected that at low Q^2 this integral will be nearly saturated by the resonance part of the virtual photon absorption cross section. It is also expected that the integral will show a dramatic Q^2 dependence, changing from the negative value predicted by the GDH sum rule for real photons, $Q^2 = 0$ to the positive value observed in deep inelastic measurements of electron and muon scattering at large Q^2 ($> 3GeV^2$). Calculations shown in the proposal for E-91-023 place the cross-over in the range from $Q^2 = 0.5$ - 1 GeV^2. Other calculations[2,3] predict this cross-over to appear at even lower $Q^2 \sim 0.25$ GeV^2.

For a discussion of the motivation as well as of the status of the polarized target development we refer to the update of E-91-023 and other polarization experiments in the CLAS eg1 run period submitted to PAC9.

The differential cross section for inclusive scattering of polarized electrons off polarized protons can be expressed in terms of an unpolarized part involving both transverse and longitudinal virtual photons, and a polarization part that can be written in terms of two structure functions and kinematical terms. The structure functions, $A_1(Q^2, W)$ and $A_2(Q^2, W)$ can be separated at fixed Q^2 and W by varying the polarization direction of the target, or by measuring the cross section at different kinematics. The latter method was chosen for E-91-023. To cover a large range in Q^2, starting with as low a value as practical, and to obtain a large kinematic range for separating the structure functions, we proposed to use electron energies from 1.2 to 4 GeV. Asymmetries at fixed Q^2 and W, but different incident energies (corresponding to different angles of the proton polarization vector to $\vec{q}$, and different values of the photon polarization parameter ϵ) will be fitted to a function depending on kinematical factors and $A_1(Q^2, W)$ and $A_2(Q^2, W)$. The function A_2 is expected to be small throughout the resonance region. The accuracy of our method limited any significant measurement of A_2 to small Q^2. However, the determination of A_1 was shown to be quite good up to Q^2 of 2 GeV^2 for $W < 1.8$ to 2.0 GeV. It was also shown in the proposal that A_1 was sensitive to different choices for the resonance structures.

Advantages of additional 6 GeV running

In this request, we would like to demonstrate the value of additional time at 6 GeV, with the CLAS magnet set to bend electrons outward and the polarized target moved upstream by about one meter. This will not cause any change in the mounting of the target as it will be mounted to a moveable cart which is supported from the backward platform of CLAS. The benefits from including 6 GeV are:

1. Greater range in (Q^2, W) or equivalently (Q^2, x) for extracting A_1,
2. Greater range for determination of the GDH integral $\int 2A_1\sigma_T d\nu/\nu$
3. Greater accuracy in extraction of A_2,
4. Ability to determine the Burkhard-Cottingham (BC) integral $\int g_2(x, Q^2)dx$ over a larger kinematic range with reasonable accuracy.

The inclusion of 6 GeV provides a significant increase in the kinematical range available to the CLAS, and the use of electron out-bending as well as moving the target upstream, provides a significant reduction in the lower limit on Q^2 available. This turns out to be extremely useful for the higher energies. It will also allow a better overlap with the lowest energy SLAC data which were taken at 9.6 GeV.

It is important to plan such running in advance since the complexity of the polarized target makes it advisable to schedule the 6 GeV time along with the lower energies.

Expected accuracy for the separation of A_1 and A_2

In Figure 1, we show a plot of Q^2 vs. W, with the limits for 1.2, 4 and 6 GeV indicated. The limits at each energy are determined by the minimum and maximum electron angle accessible to the CLAS detector. The plot demonstrates the gains in kinematic range to be expected from increasing the incident beam energy. The reduction in minimum detectable electron scattering angle results in a significant improvement in the lower limit for Q^2 at 6 GeV incident energy.

The SLAC experiment E143 used three incident energies, 9.6, 16.2 and 29.2 GeV, and two spectrometers, one at 4.5^o and one at 7^o. Our experiment will collect much more data with a far greater acceptance in the angle of the scattered electron, essentially filling the entire kinematically accessible region with data. The resolution on W will also be much better than in E143. As described in proposal 91-023, this will allow the separation of

A_1, A_2 at fixed Q^2 and W, which is a unique feature of this experiment and essential for testing the Q^2 evolution of spin sum rules in the non-scaling regime.

The addition of 6 GeV measurements increases the range in W or x for our measurements, so that the GDH integral and the BC integral are measured over a larger range in x at a given Q^2. For the GDH integral this will increase confidence in the hypothesis that the sum rule is nearly saturated by the resonance region and also provide improved possibilities to extrapolate to high W, or small x. The expected statistical errors in the structure function A_1 are illustrated for several values of Q^2 in Figure 2. The error bars are estimates of what will be obtained by an additional 600 hours at 6 GeV with the CLAS field reversed and the polarized target moved upstream by 1 meter. We can observe that the binning used in making the graphs is somewhat arbitrary. As we did for the estimates shown in the proposal for E-91-023, for A_1 we have used W bins of 30 MeV and Q^2 bins of $\Delta Q^2 = 0.2Q^2$. If the bins are made too wide resonant specific effects as well as important Q^2 dependences could be washed out. This is especially important for A_1, which is expected to show rapid variations with W and Q^2.

A_2 is bounded by the limit $|A_2| < \sqrt{R} \sim 0.3-0.4$ in the resonance region. Calculations using AO[1] indicate that in the nucleon resonance region $|A_2|$ is typically no greater than 0.2 with significant variations with W. For a measurement of A_2 to be of much significance the statistical error should be less than 0.1. For A_2 we have increased the bin sizes for A_2 both in Q^2 and W by a factor of two, improving the statistical errors by a factor of 2. This would result in statistical errors less than 0.10 to 0.15 over the accessible W range up to $Q^2 = 2$ GeV^2 (Figure 3).

In Figure 4 we show the expected error band for the GDH integral. The improvement in Q^2 coverage over E-91-023 is apparent. In Figure 5 we show expected errors at four representative values of Q^2 for the integral of $\int g_2(x, Q^2)dx$ integrated over the range of x available to the CLAS. This is related to the BC integral, $\int_0^1 g_2(x)dx$, which is predicted to be zero. This prediction has not been tested yet. In the non-perturbative regime accessible at CEBAF this integral could be non-zero. With the additional time a significant measurement of the integral can be obtained. This experiment would be the first measurement of this integral in the resonance region. Knowledge of the Q^2 dependence of this integral in the resonance region could be significant[4], and e.g. elucidate duality arguments connecting the resonance region with the deep inelastic regime.

Possible results for A_1 if $A_2 \simeq 0$

A_2 is known to be small at high energies and might be consistent with zero within the expected error bars of the measurement. If we assume that A_2 is known, e.g. $A_2 = 0$, A_1 may then be determined from a measurement at fixed energy. This would increase the W and Q^2 range significantly to $W < 2.5GeV$ at $Q^2 = 4GeV^2$, and $W < 3.4GeV$ at $Q^2 = 0.25GeV^2$.

Other aspects of this experiment, such as the effect of systematic errors associated with the use of a polarized target in the CLAS, and the measurement of the product of beam and target polarization, are the same as discussed in the proposal for E-91-023.

Conclusions

Extension of experiment E-91-023 to 6 GeV, with reversed CLAS polarity and target position moved upstream by 1 meter will provide access to a significantly larger kinematic range in W and Q^2 for the separate measurement of the polarized structure functions A_1, A_2 (or g_1, g_2). This will allow the determination of the GDH integral for a larger

Q^2 range, while integrating over a larger W range. The sensitivity of the measurement to A_2 is much improved allowing a significant measurement of this quantity over the full W range and $Q^2 \leq 1$ GeV^2, which in turn allows a better determination of the BC integral throughout and even beyond the resonance region.

New beam time request

Based on the arguments presented above, we are requesting a total of 600 hours of new beam time, some 10% of which would be devoted to background measurements with N_2. This request is based on the same running conditions as the original proposal: Proton polarization = 0.9, electron polarization = 0.5, luminosity = $10^{34} cm^{-2} s^{-1}$. This additional time would be used with reversed field of CLAS and retracted target position.

References.

[1] V. Burkert and Zh. Li, Phys. Rev. D47, 46 (1993)
[2] J. Soffer and O. Teryaev, Phys. Rev. Lett.70, 3373 (1993); Phys. Rev. Lett. 71, 360 (1993)
[3] V. Bernard, N. Kaiser, U. Meisner, Phys. Rev. D48, 3062 (1993)
[4] J. Soffer and O. Teryaev, preprint, subm. to Phys. Rev. Lett. (1994)

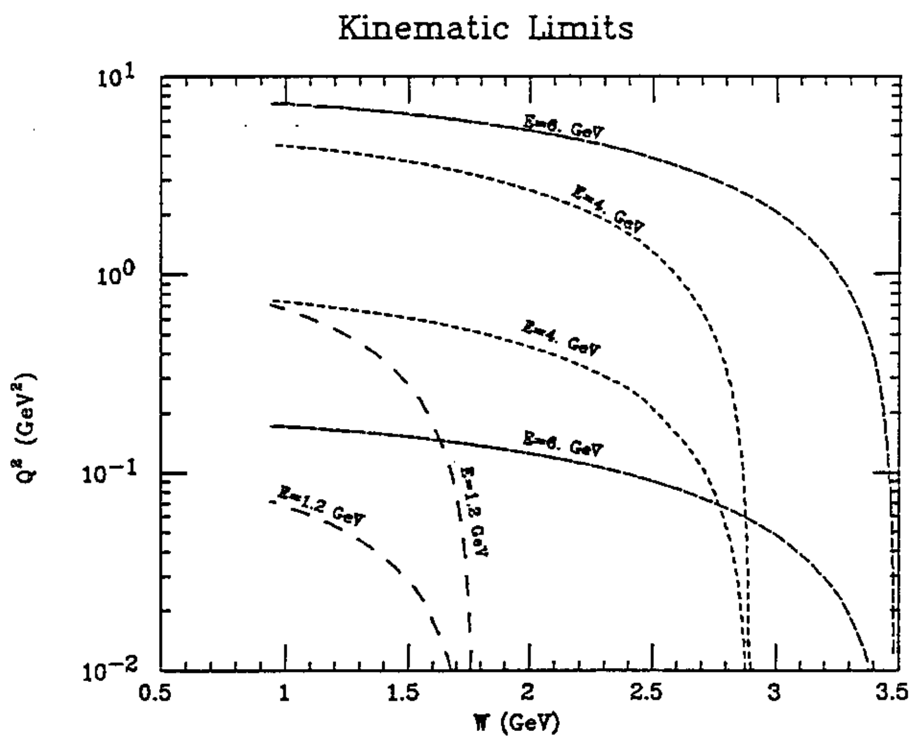

Figure 1: Kinematic limits of the proposed extension of E-91-023. The lines at fixed energy indicate the maximum and minimum electron scattering angle.

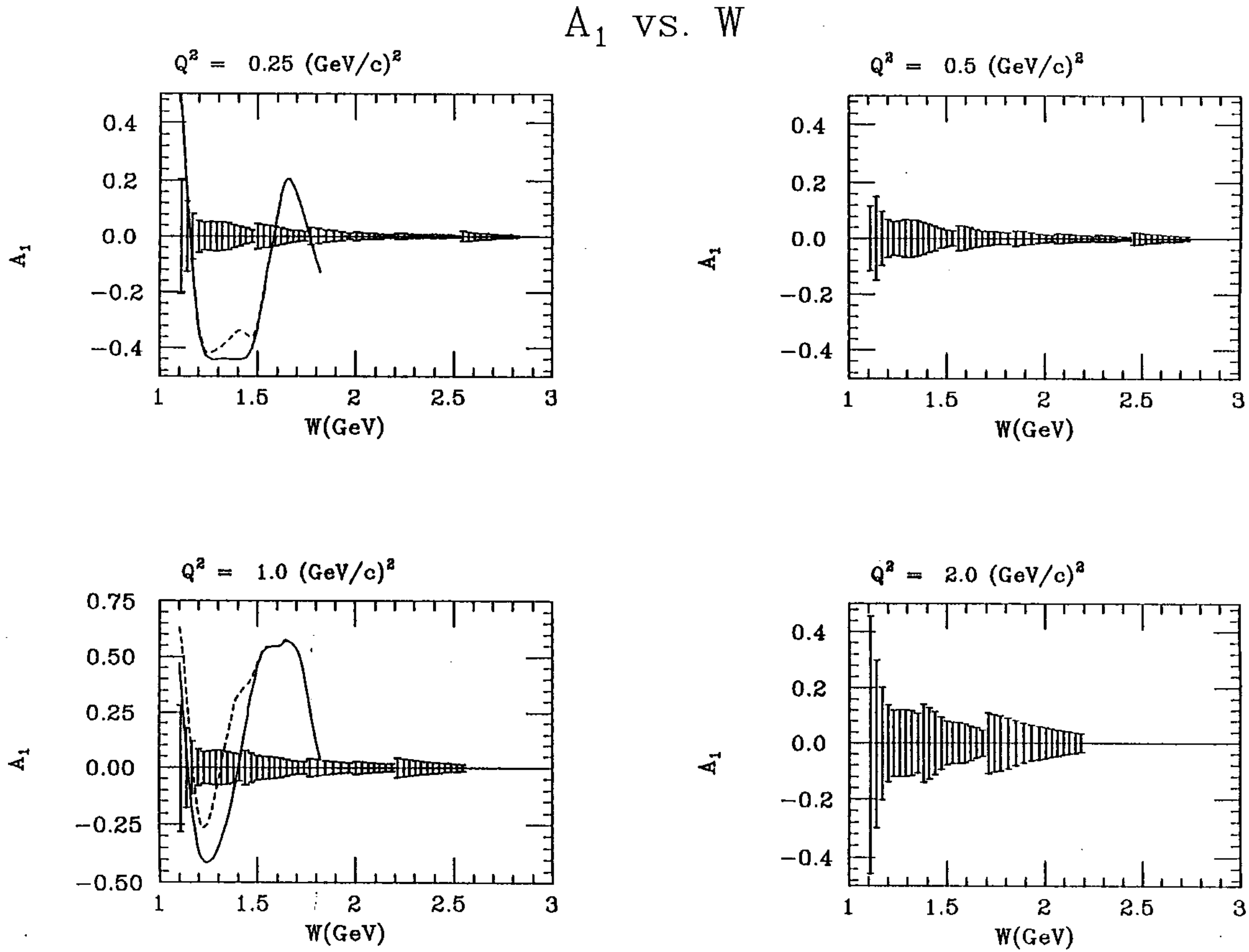

Figure 2: Expected accuracy in A_1 for different Q^2. The lines are predictions using AO[1] amplitudes for different assumptions about the structure of the Roper resonance.

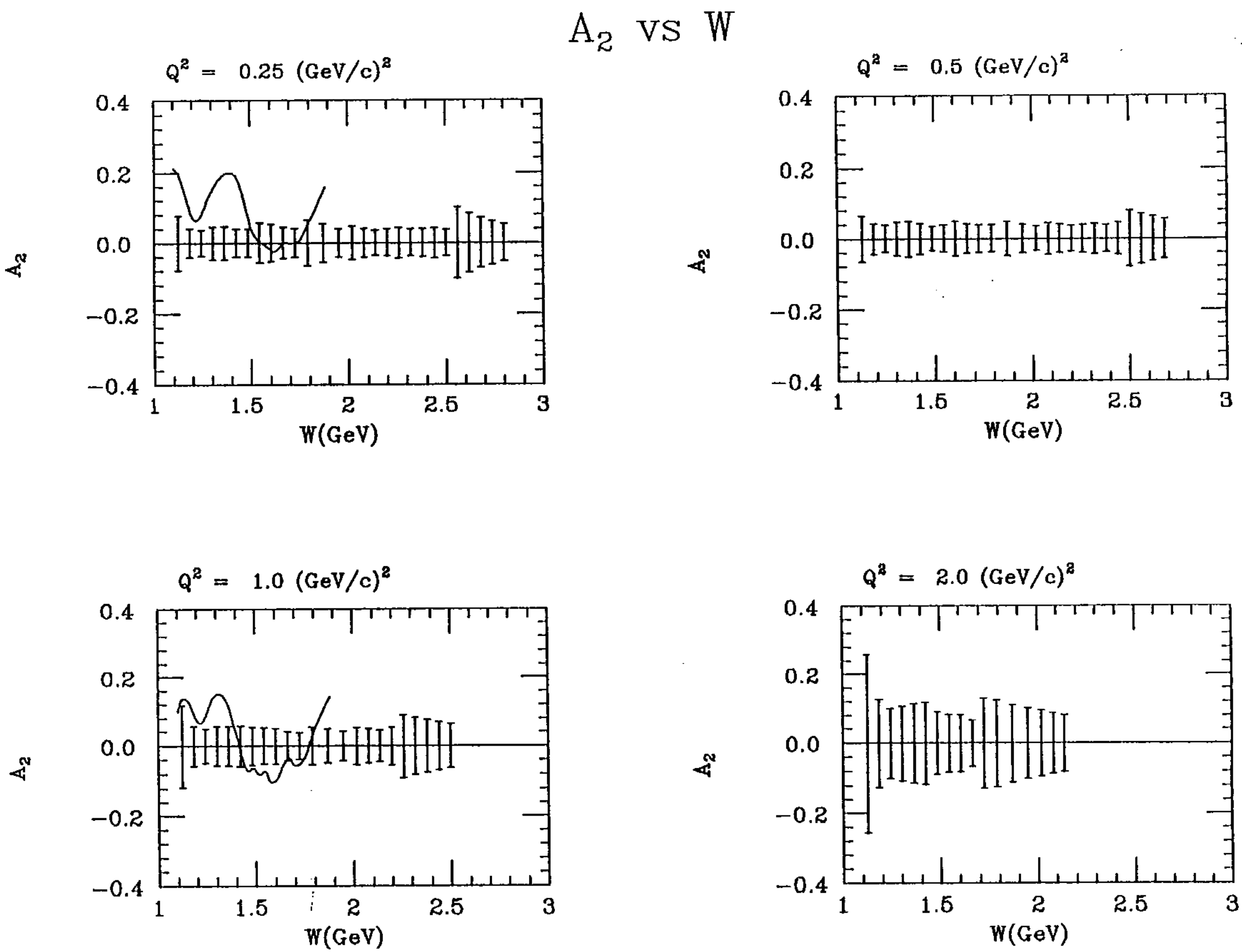

Figure 3: Expected accuracy in A_2 vs W, for different Q^2. The lines are predictions using AO amplitudes.

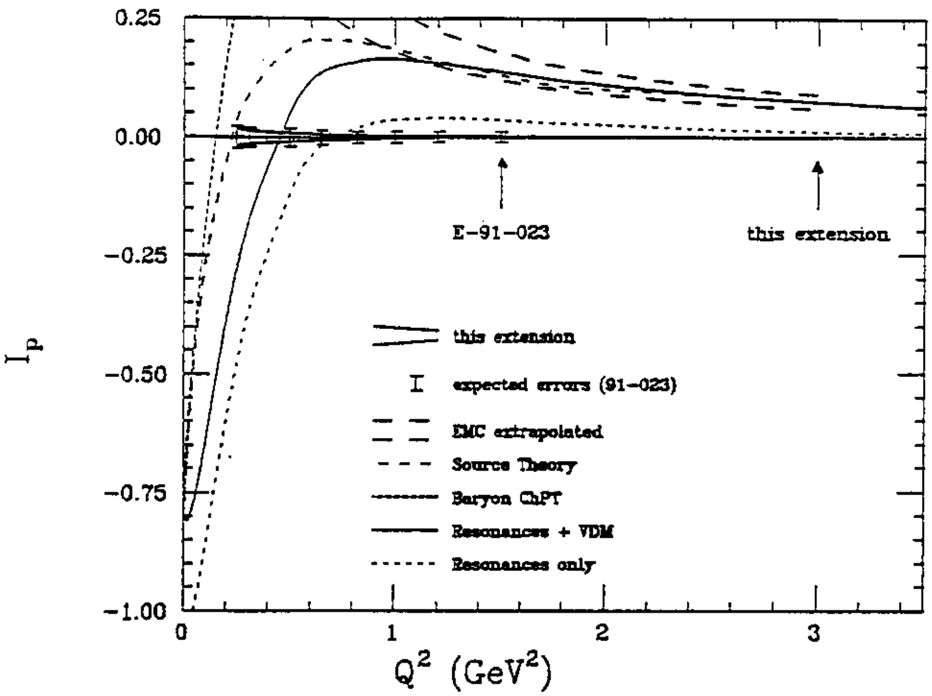

Figure 4: Expected accuracy and coverage of the GDH integral vs Q^2. The curves are predictions of various models.

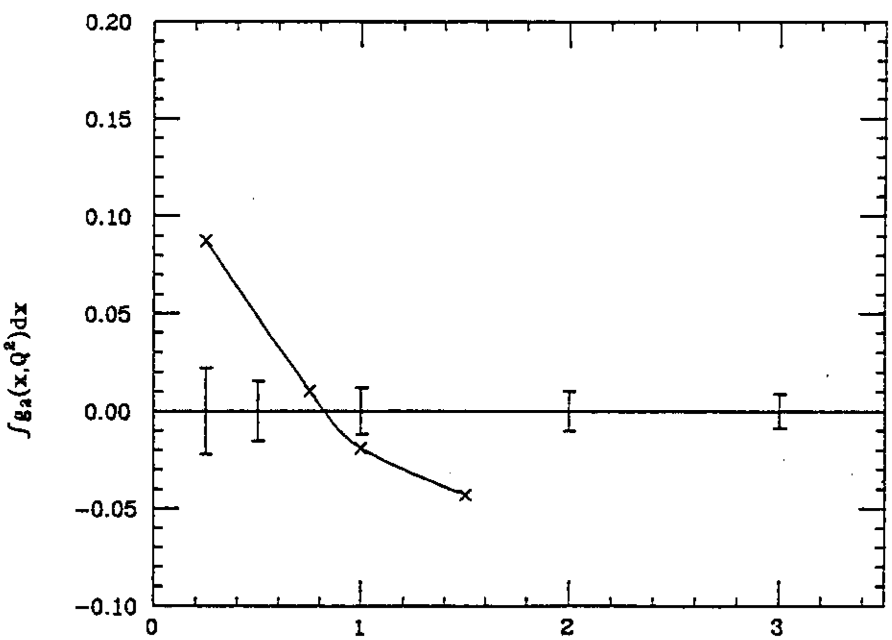

Figure 5: Expected accuracy for the Burkhard-Cottingham integral vs *(* curve is a prediction using AO amplitudes integrated from 1.08 to 1.8 Ge