Measurement of spin structure functions at low to moderate Q^2 using CLAS

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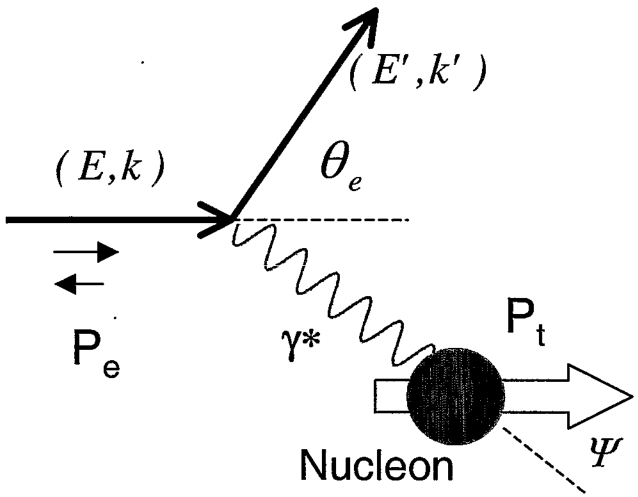
for the CLAS collaboration

OUTLINE

- Formalism
- Experimental setup
- Analysis
- Preliminary results

Double polarized inclusive electron scattering



Kinematics

$$\nu = E - E'$$

$$Q^2 = 4EE' \sin^2\left(\frac{\theta}{2}\right)$$

$$W^2 = M^2 + 2M\nu - Q^2$$

$$x = \frac{Q^2}{2M\nu}$$

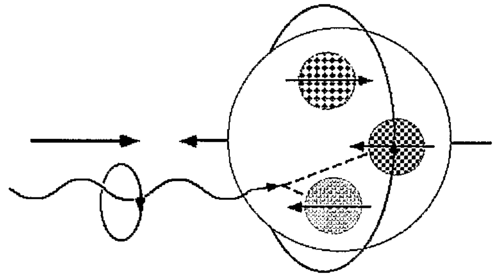
$$\frac{d\sigma}{dE'\,d\Omega} = \Gamma_\nu\left[\sigma_T + \varepsilon\sigma_L + P_e P_t\left(\sqrt{1-\varepsilon^2}\,\mathbf{A_1}\sigma_T \cos\psi + \sqrt{2\varepsilon(1-\varepsilon)}\,\mathbf{A_2}\sigma_T \sin\psi\right)\right]$$

- ❑ *Experimentally it is much easier to measure an asymmetry than it is a cross section*

- ❑ *Electron asymmetry* ⟶ $$A_{\|}(\nu,Q^2) = \frac{\frac{d\sigma}{dE'\,d\Omega}(\uparrow\downarrow) - \frac{d\sigma}{dE'\,d\Omega}(\uparrow\uparrow)}{\frac{d\sigma}{dE'\,d\Omega}(\uparrow\downarrow) + \frac{d\sigma}{dE'\,d\Omega}(\uparrow\uparrow)}$$

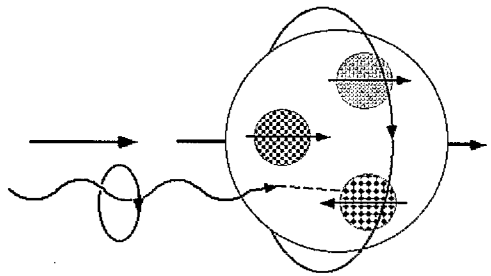
Virtual Photon Asymmetries

$$A_1(\nu,Q^2) = \frac{\sigma_T^{1/2}(\nu,Q^2) - \sigma_T^{3/2}(\nu,Q^2)}{\sigma_T^{1/2}(\nu,Q^2) + \sigma_T^{3/2}(\nu,Q^2)}$$



$\sigma_T^{1/2}(\nu)$

$$A_2(\nu,Q^2) = \frac{\sigma_{LT}}{\sigma_T^{1/2}(\nu,Q^2) + \sigma_T^{3/2}(\nu,Q^2)}$$



$\sigma_T^{3/2}(\nu)$

- *Contains information on helicity structure of resonance transition amplitudes*

$$A_1 = \frac{|A_{1/2}|^2 - |A_{3/2}|^2}{|A_{1/2}|^2 + |A_{3/2}|^2} \longrightarrow$$

A_1= - 0.5 for $\Delta(1232)P_{33}$
A_1= + 1 for $N(1535)S_{11}$

- *Longitudinal electron asymmetry can be written as a combination of A_1 and A_2*

$$\boxed{A_{\|} = D(A_1 + \eta A_2)}$$ *Where* $$D = \frac{1 - \varepsilon E'/E}{1 + \varepsilon R} \qquad \eta = \frac{\varepsilon\sqrt{Q^2}/E}{1 - \varepsilon E'/E}$$

Spin Structure Function $g_1(x,Q^2)$

$$g_1(x,Q^2)=\frac{\nu^2}{q^2}F_1(x,Q^2)\left(A_1(x,Q^2)+\frac{Q}{\nu}A_2(x,Q^2)\right)$$

First moment of g_1^N $\quad \Gamma_1(Q^2)=\int_0^1 g_1^N(x,Q^2)dx$

at $Q^2 \to \infty$

Closely related to the spin carried by quarks.

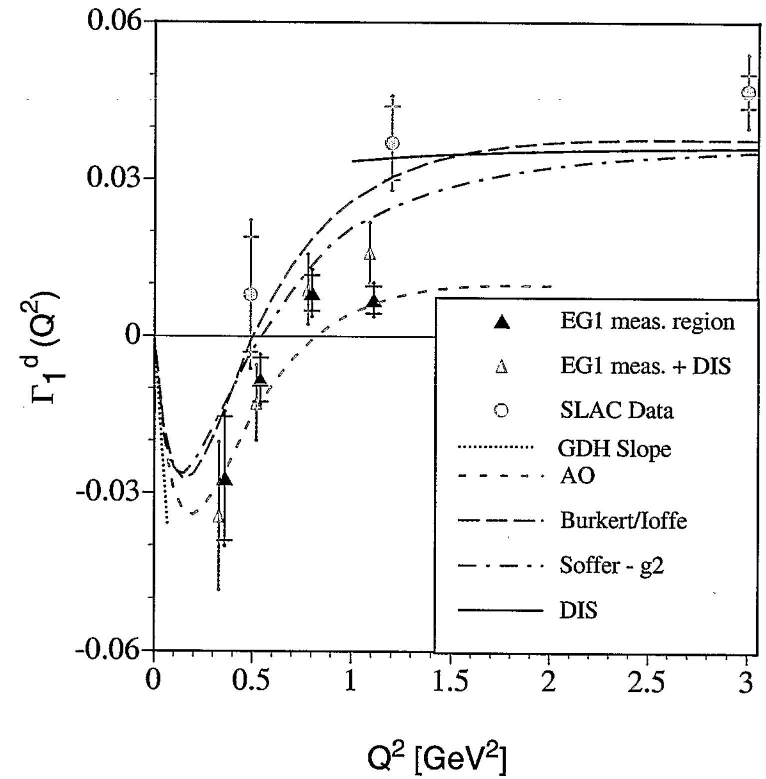
at $Q^2 \to 0$

Slope of Γ_1 is constrained by the GDH sum rule

$$I_{GDH}=\frac{M^2}{8\alpha\pi^2}\int_{\nu_{th}}^{\infty}\left(\sigma^{1/2}(\nu)-\sigma^{3/2}(\nu)\right)\frac{d\nu}{\nu}=-\frac{1}{4}\kappa^2$$

$$\Gamma_1 \to \frac{Q^2}{2M^2}I_{GDH}=-\frac{Q^2}{8M^2}\kappa^2$$

Integral $\Gamma_1(Q^2)$ for the Deuteron



- *Dramatic change of sign of Γ_1 from DIS-regime to the value at the real photon point.*
- *At low Q^2 $g_1(x,Q^2)$ is dominated by baryon resonance excitations.*

Q^2 evolution of the GDH integral

- Both Bjorken and GDH sum rules are fundamental sum rules

Small Q^2
GDH sum rule
Experiments at Mainz, Bonn, CLAS, ….
Chiral perturbation theory

?

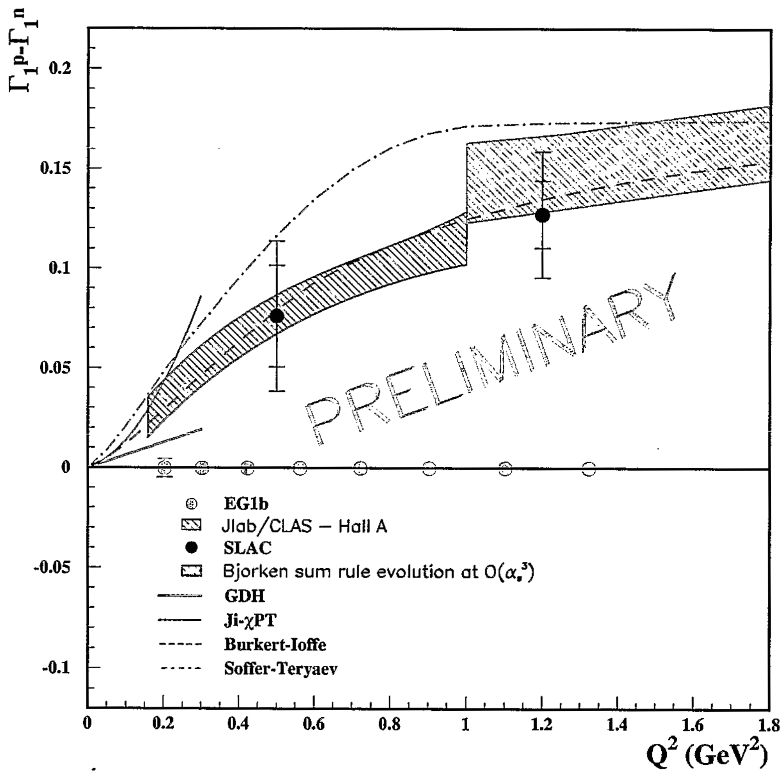
Intermediate Q^2
Extended GDH sum rule

$$I_{GDH}(Q^2) = \frac{M^2}{8\pi^2\alpha}\int_{\nu_{th}}^{\infty}\left(\sigma^{1/2}(\nu,Q^2) - \sigma^{3/2}(\nu,Q^2)\right)\frac{d\nu}{\nu}$$

What is this equal to?
Several different models
Experiments at JLAB(CLAS/Hall A/Hall C)
Provide information about the distance scale at which pQCD corrections and higher twist expansions will break down and physics of confinement dominate

Large Q^2
Bjorken Sum rule
Experiments at CERN,SLAC,DESY
Higher order QCD expansion

$$\Gamma_1^p(Q^2) - \Gamma_1^n(Q^2) = \frac{1}{6}g_A\left[1 - \frac{\alpha_S(Q^2)}{\pi} + \ldots\ldots\ldots\right] \xrightarrow{Q^2\to\infty} \frac{1}{6}g_A$$

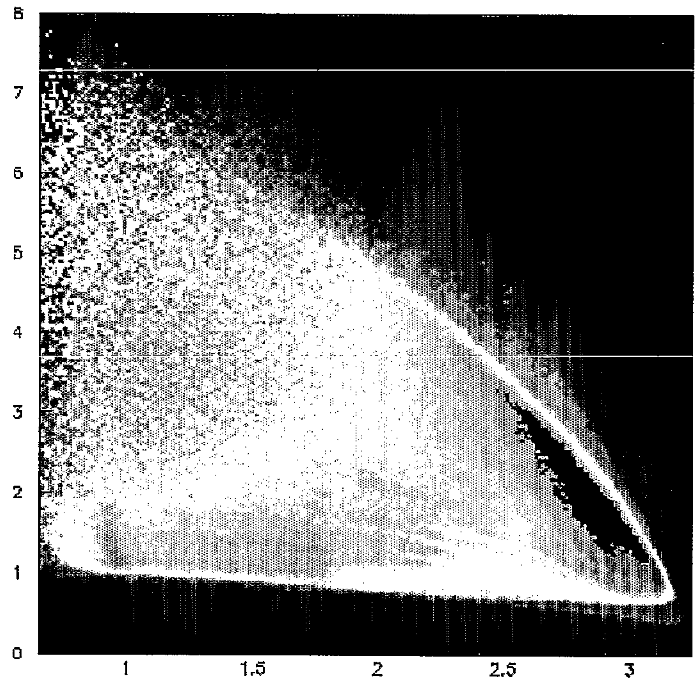


EG1b
Better precision
Wider Q^2 coverage

Kinematic Coverage

- ❑Fall 2000 to Spring 2001
- ❑23 billion events
- ❑4 different beam energies
  1.6, 2.5, 4.2 and 5.7 GeV
- ❑Q^2 coverage 0.05-4.5 GeV^2
- ❑Analysis in progress

E = 5.6 GeV

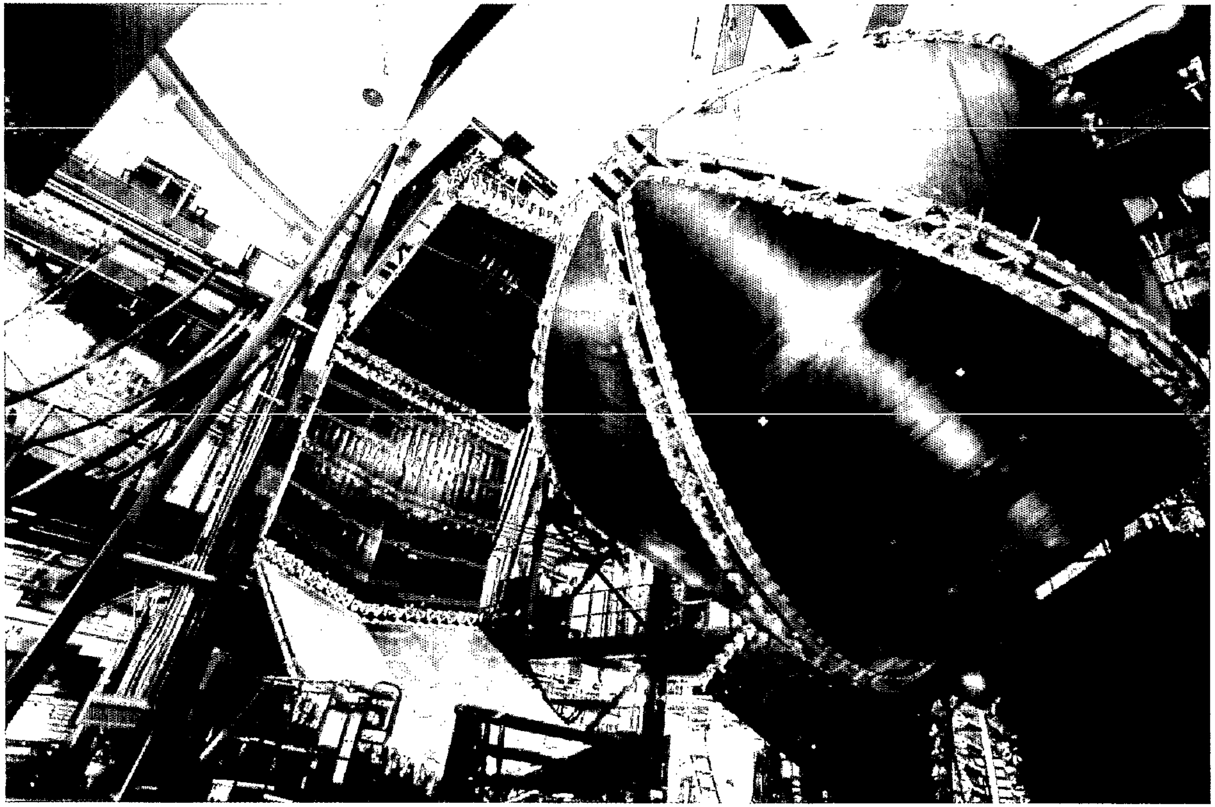


Q^2 (GeV^2)

W(GeV)

CLAS

CEBAF
Large
Acceptance
Spectrometer

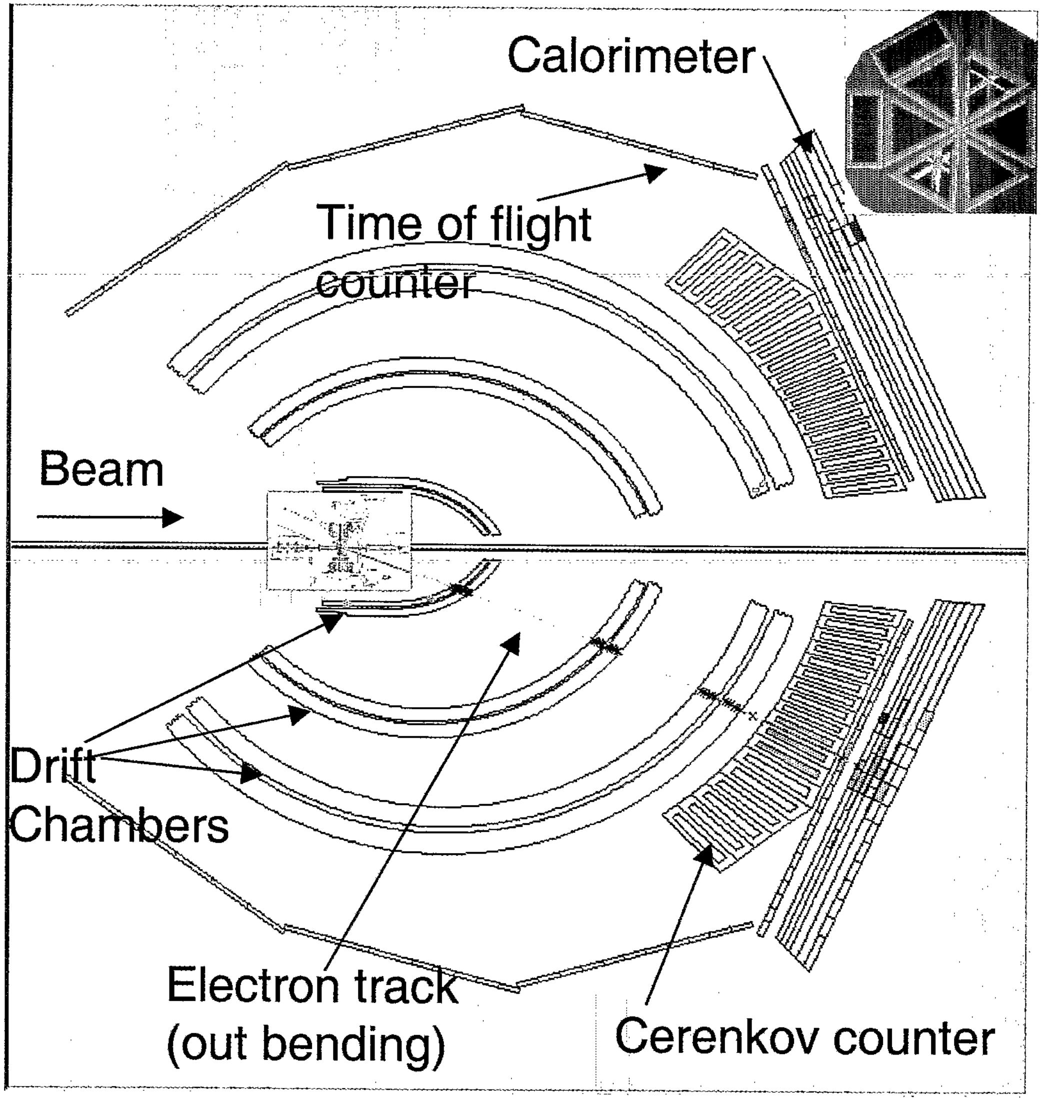


- Large kinematic coverage
- Detection of charged and neutral particles
- Multi particle final states

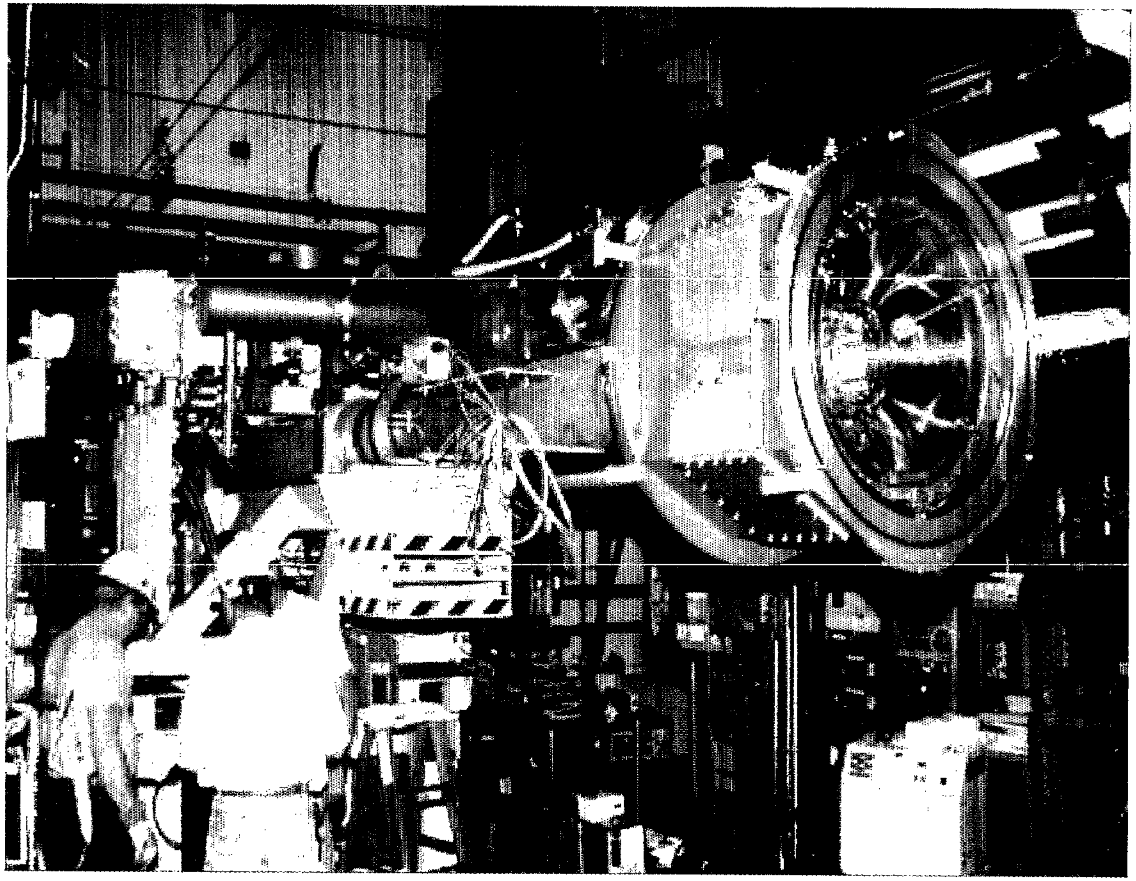
Event in CLAS

❑Electrons are detected as a coincidence in the Electromagnetic Calorimeter and the Cerenkov Counter

❑Electron momentum is reconstructed from trajectory in Drift chambers



EG1 Target



- Dynamically polarized $^{15}NH_3$ and $^{15}ND_3$
- 5 Tesla Magnetic field
- 1K LHe cooling bath
- NH_3 polarization: 75-85%
  ND_3 polarization: 25-35%
- ^{12}C, ^{15}N and ^{4}He targets to measure the dilution factor

Background subtraction : ^{15}N *simulation*

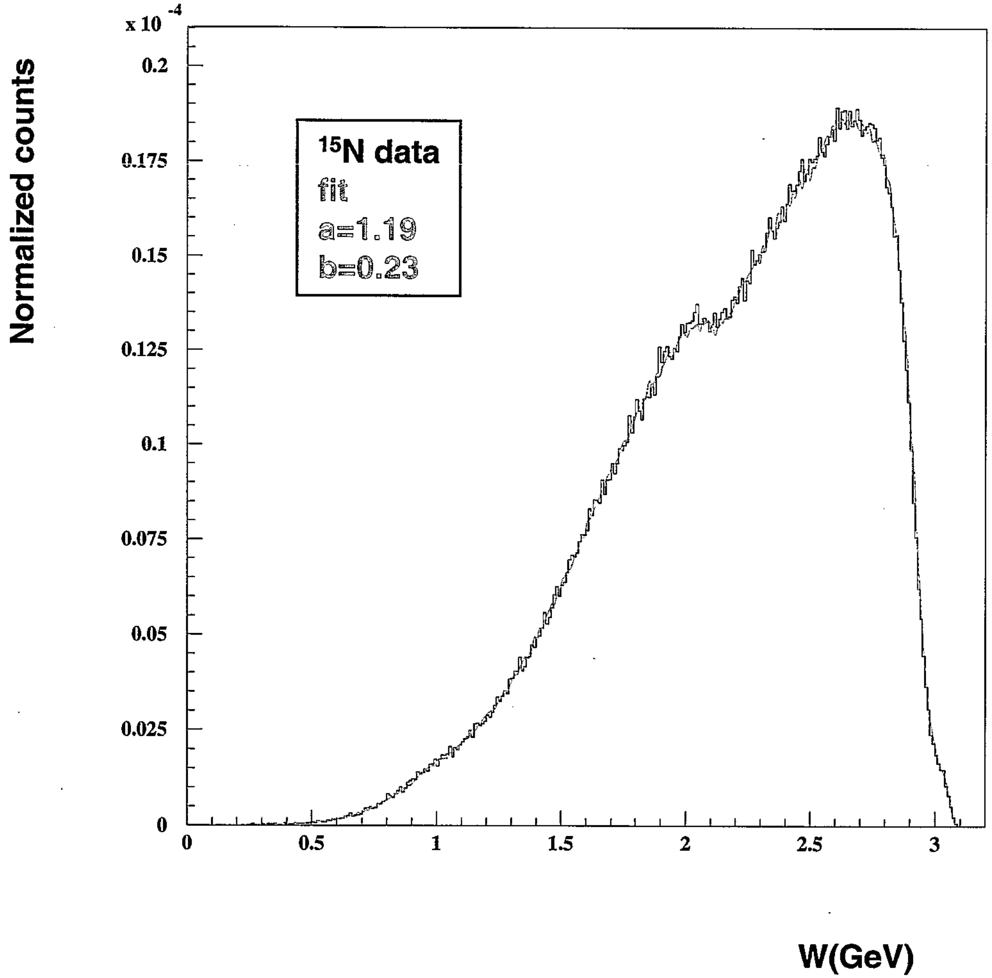
❑^{12}C data were used to simulate ^{15}N background

❑Limited statistics ^{15}N data were fitted with high statistics ^{12}C data.

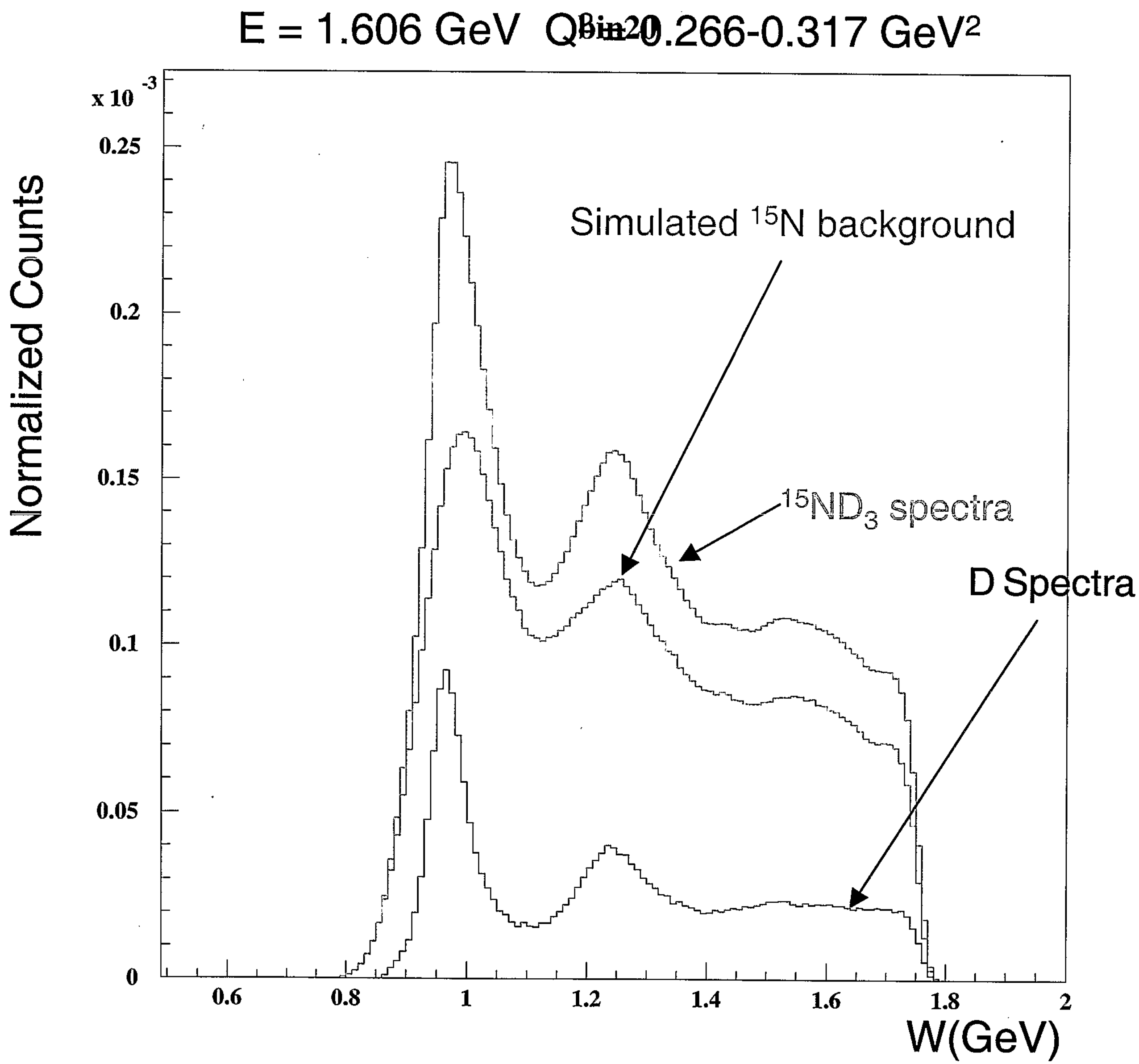
$$\sigma_{^{15}N} = \left(a + b\frac{\sigma_n}{\sigma_D} \right)\sigma_{^{12}C}$$

❑*a* and *b* are in good agreement with the expected numbers; a=7/6, b=1/6

E = 5.627 GeV



Background Subtraction



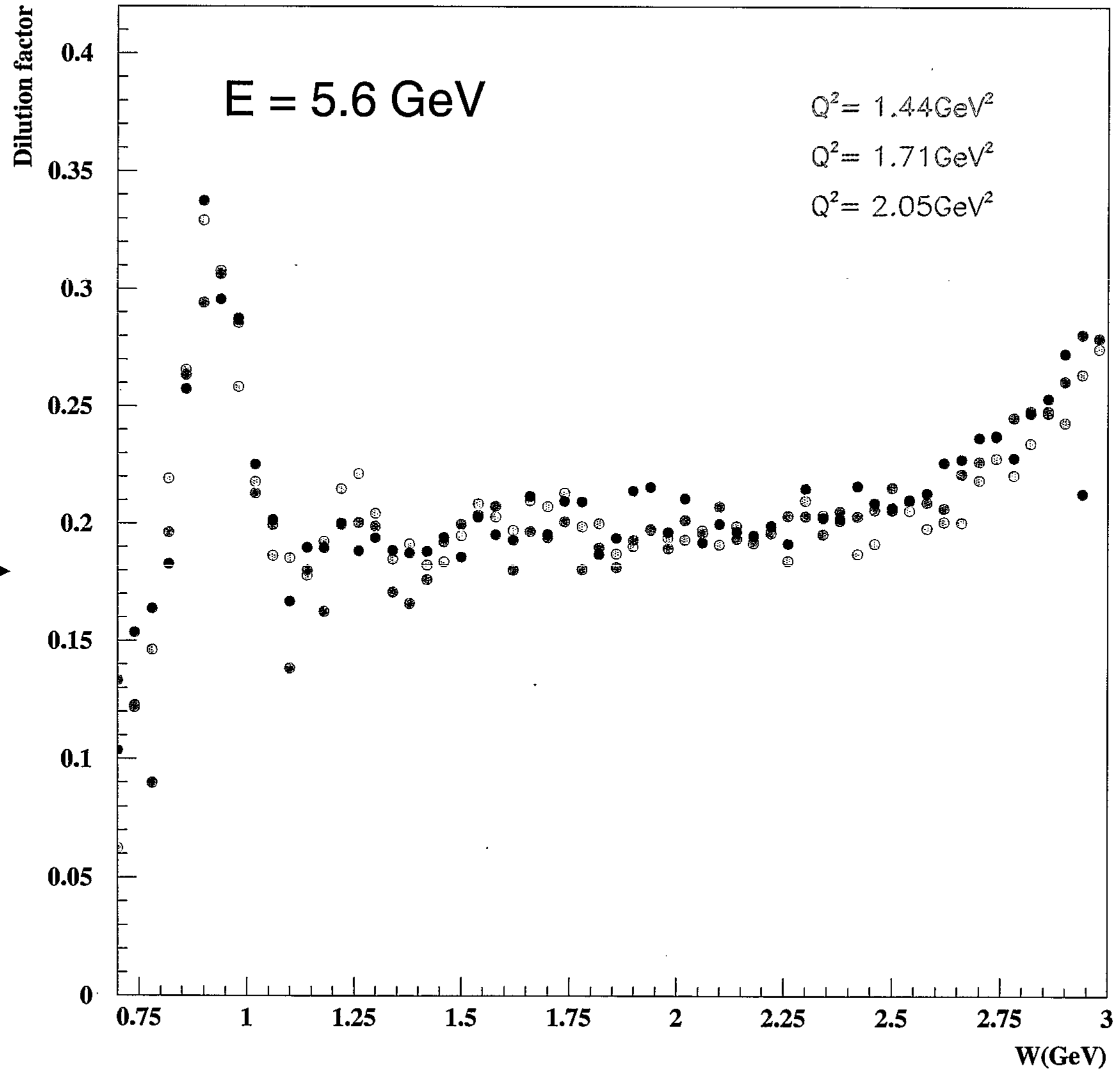
Dilution Factor

- Gives the contribution to the count rates from unpolarized target constituents

$$DF = \frac{{}^{15}ND_3 - {}^{15}N}{{}^{15}ND_3}$$

- No Q^2 dependence

Dilution factor for $^{15}ND_3$

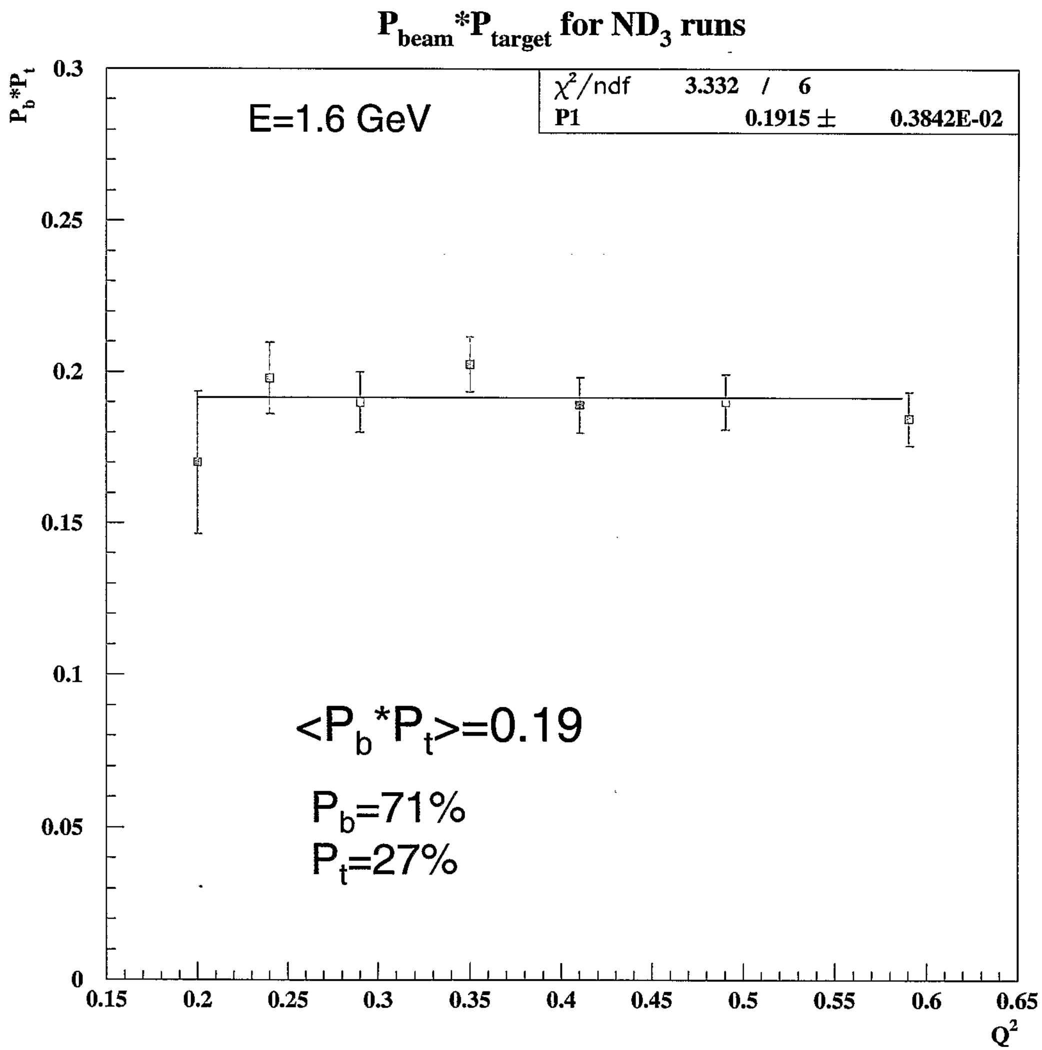


Polarization

- NMR was used to monitor polarization during data taking
- Asymmetry for proton is very well known
- Elastic asymmetry was used to extract the product of target and beam polarization

$$P_b * P_t = \frac{A(\,elastic\,)_{measured}}{DF * A(\,elastic\,)_{theoretical}}$$

DF: Dilution factor



Asymmetry Analysis

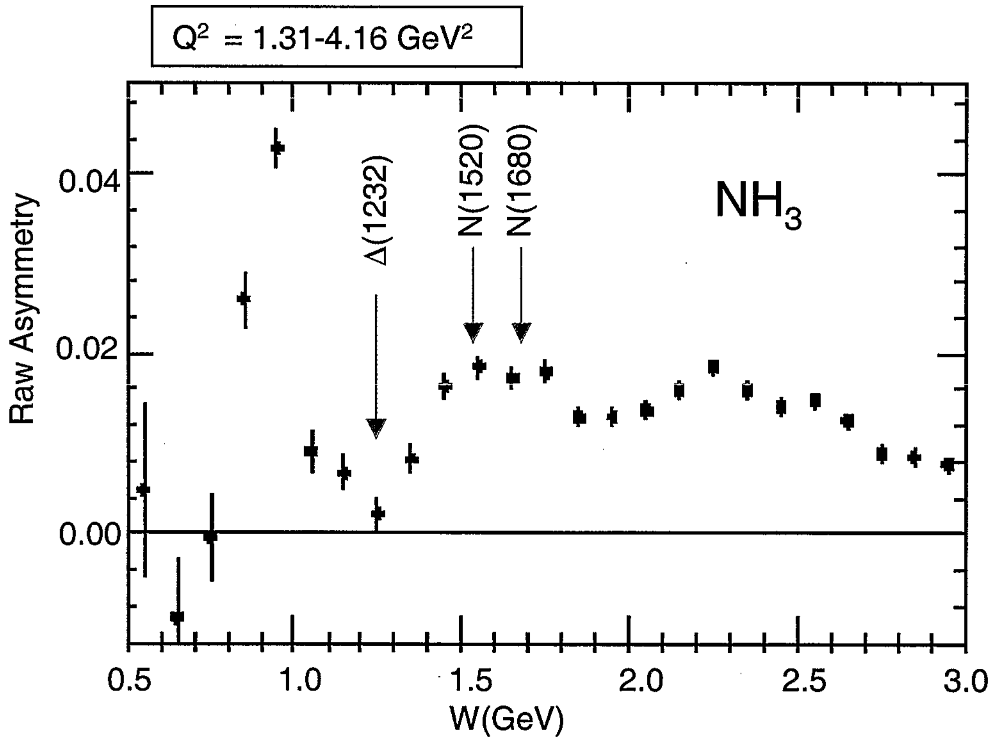
- In an asymmetry analysis acceptance and detector efficiency of the cross sections cancel out

$$A_{raw} = \frac{N^+/Q^+ - N^-/Q^-}{N^+/Q^+ + N^-/Q^-}$$

$$A_{\parallel} = \frac{A_{raw}}{DF\ P_b\ P_t}$$

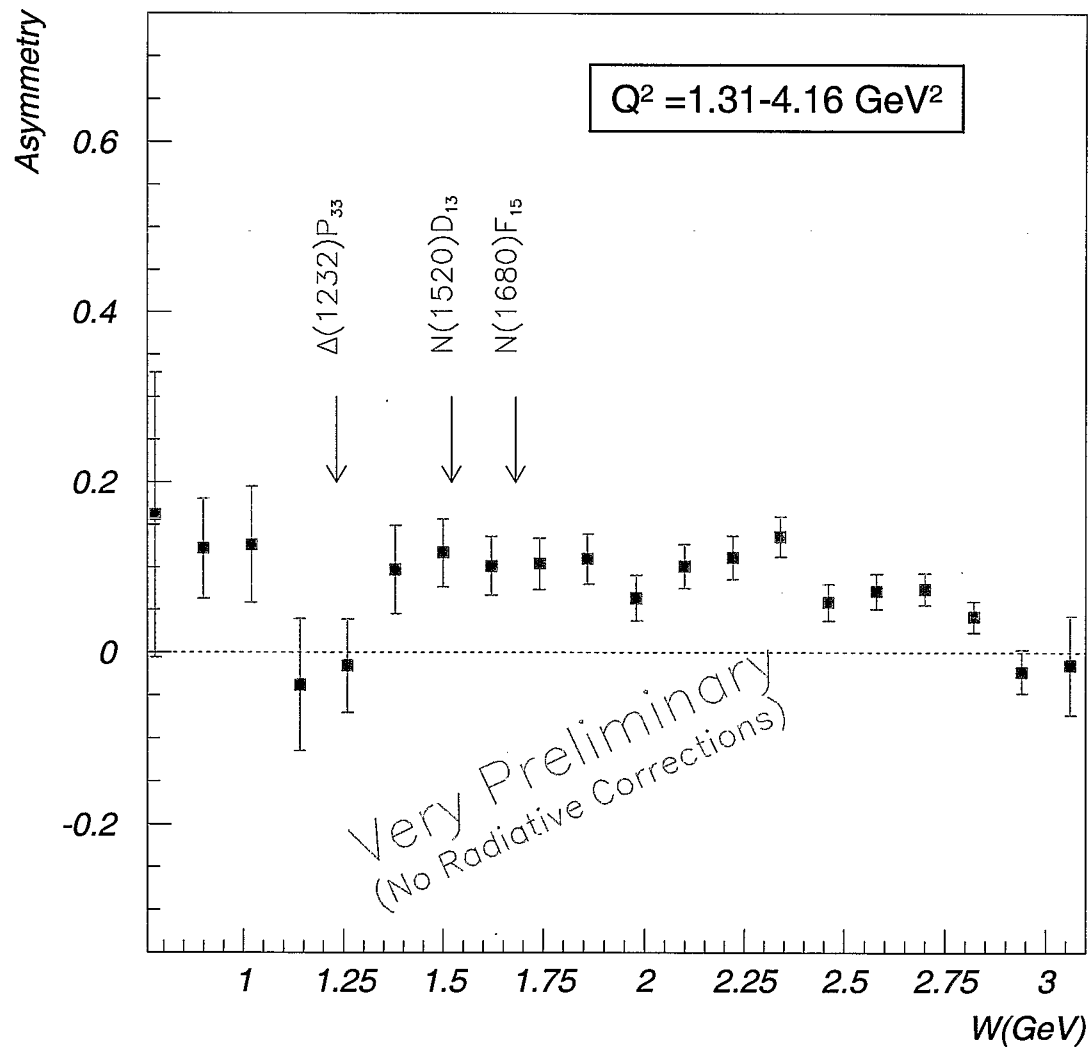
- $N^{+/-}$ are the counts
- $Q^{+/-}$:Integrated beam charge
- P_b:Beam Polarization
- P_t:Target Polarization
- DF: Dilution factor

Raw asymmetry for NH_3 at
E = 5.627 GeV



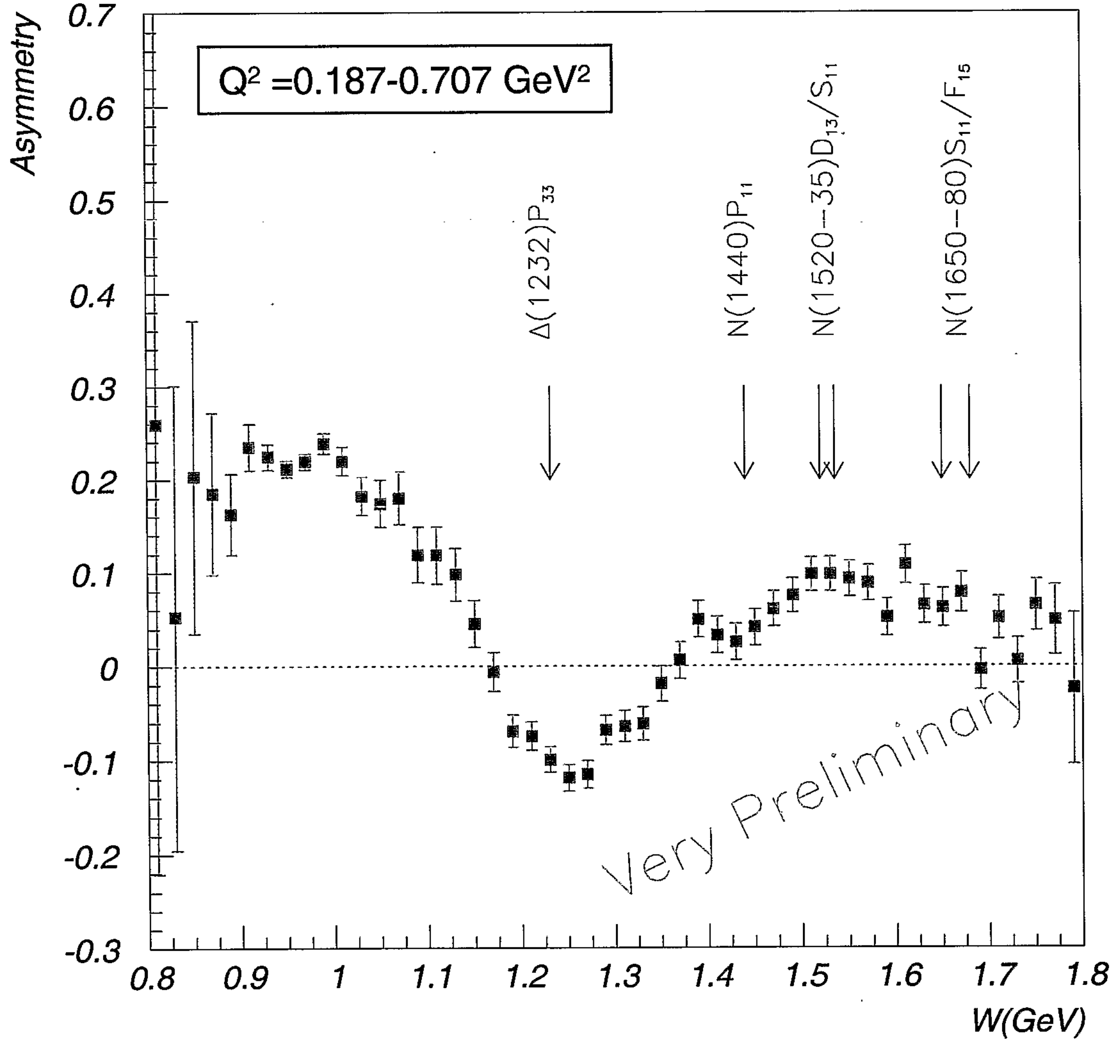
Electron asymmetry $A_{\parallel}$ in $\vec{D}(\vec{e}, e')$ at $E = 5.627$ GeV

- ❑Radiative corrections underway
- ❑To do:
  extract g_1 and Γ_1
- ❑About 50% of 5.6 GeV data



Electron asymmetry $A_{\|}$ in $\vec{D}(\vec{e},e')$ at $E = 1.606$ GeV

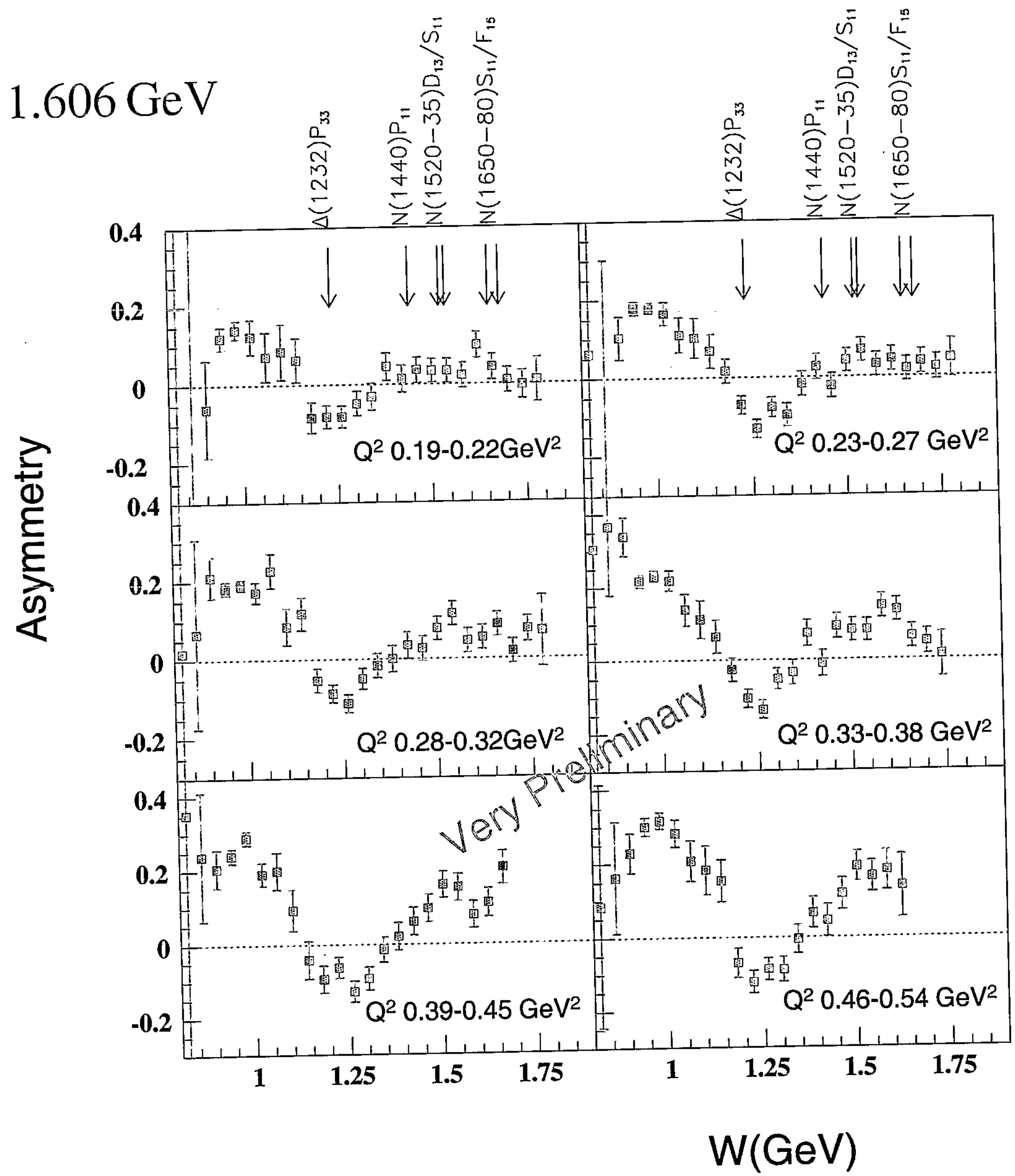
- ❑Evident resonance structure
- ❑Negative Δ(1232) asymmetry
- ❑Positive asymmetry for higher resonances



Electron asymmetry $A_{||}$ – Q^2 dependence

$\vec{D}(\vec{e},e')$ at $E = 1.606$ GeV

- Q^2 dependence at higher resonances



Summary & Outlook

- A broad physics program to study the spin structure of the proton, neutron and their excited states in progress at Jefferson Lab Hall B.

- Preliminary results for 1.6 GeV and 5.6 GeV data show strong Q^2 dependence and have better precision than existing data

- Present data set still being analyzed
  - 5.6 GeV
    Evaluation of radiative corrections and systematic errors underway
  - 1.6 GeV
    Asymmetry analysis in progress
  - 4.2 GeV and 2.5 GeV
    Calibrations are in progress

- Extract g_1, Γ_1, I_{GDH} for the proton and deuteron STAY TUNED!