Measurement of the g_1 Structure Function of the Proton and Deuteron with CLAS

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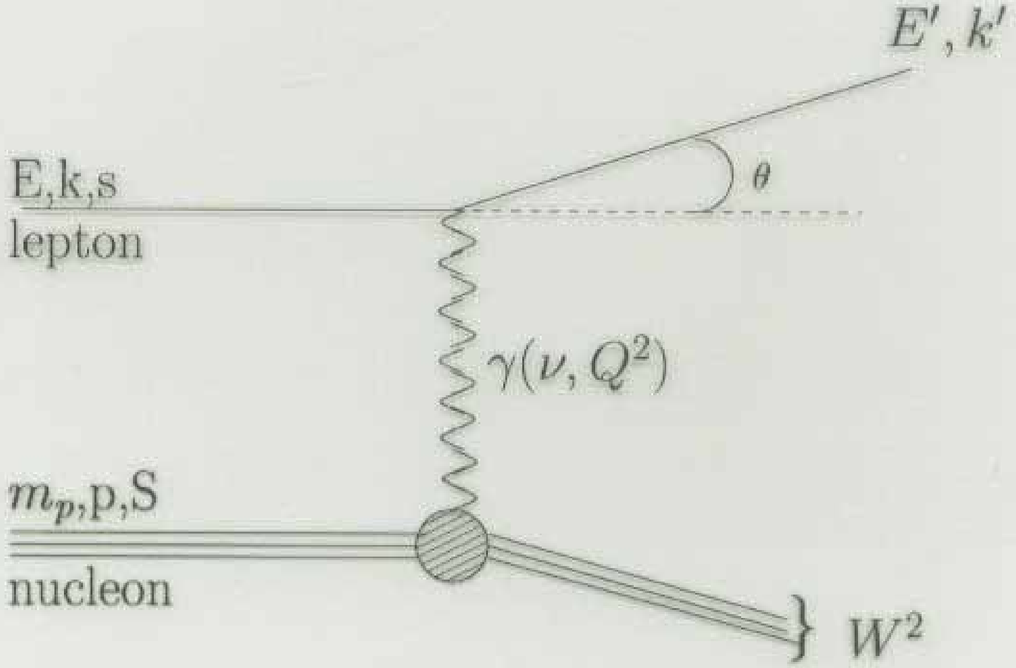
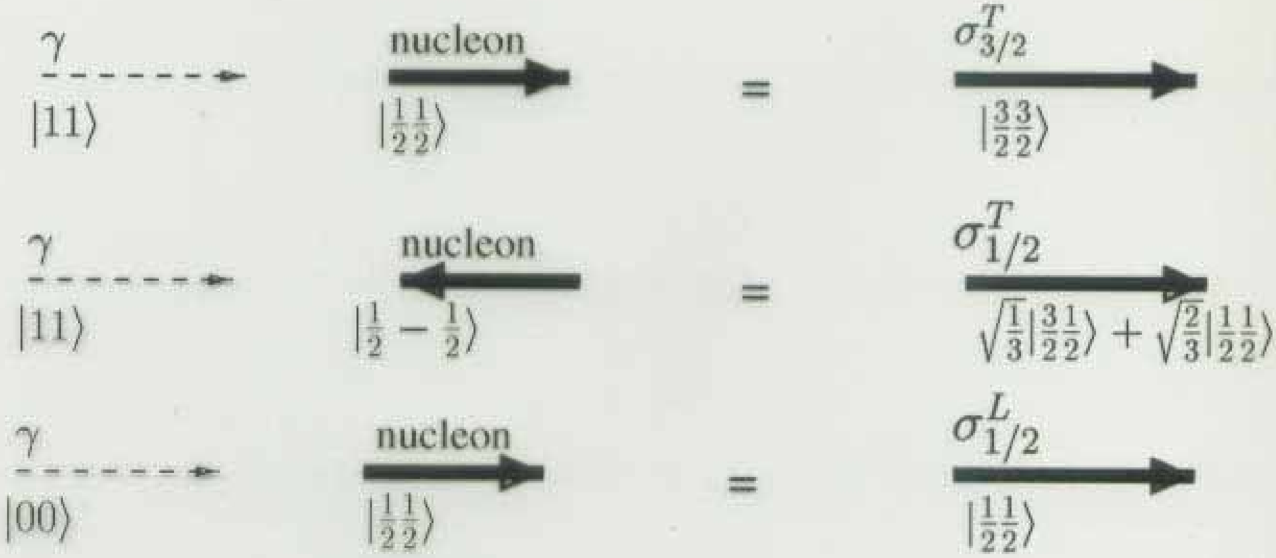
on behalf of the
CLAS Collaboration

Inclusive Deep Inelastic Scattering



- θ : scattering angle
- Q^2: 4-momentum transfer squared
- ν : energy transfer
- $x = \frac{Q^2}{2M\nu}$: Bjorken scaling variable
- $W^2 = m_p^2 - Q^2 + 2m_p\nu$: Mass of the final state

Measurements of the spin dependent cross sections will allow the extraction of the spin structure function $g_1(x)$



$$A_1(x,Q^2) = \frac{\sigma^T_{1/2} - \sigma^T_{3/2}}{\sigma^T_{1/2} + \sigma^T_{3/2}} = \frac{g_1(x,Q^2) - \gamma^2 g_2(x,Q^2)}{F_1(x,Q^2)}$$

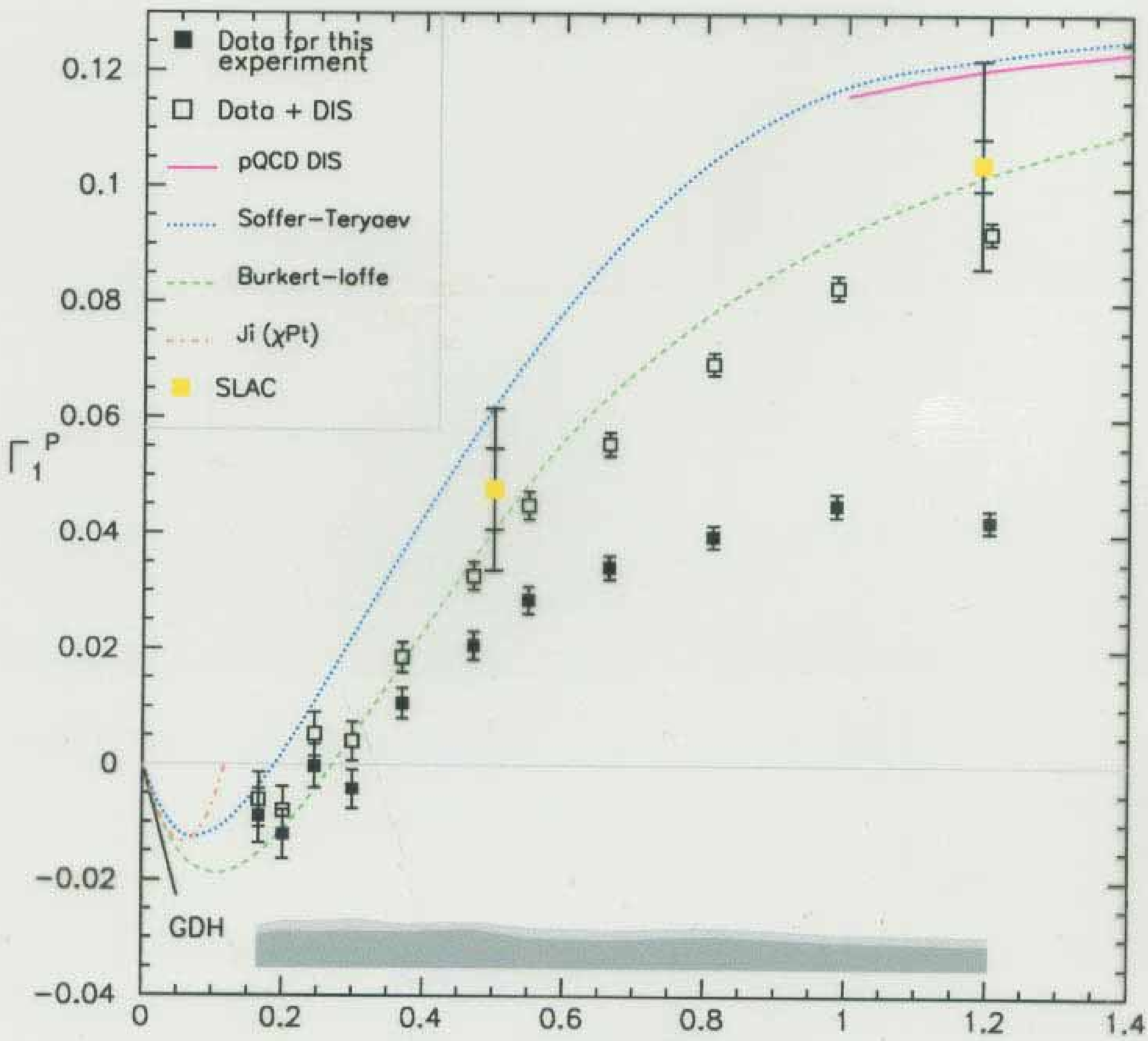
$$A_2(x,Q^2) = \frac{2\sigma^{TL}}{\sigma^T_{1/2} + \sigma^T_{3/2}} = \gamma\frac{g_1(x,Q^2) + g_2(x,Q^2)}{F_1(x,Q^2)}$$

$$\gamma^2 = Q^2/\nu^2 \qquad\qquad R = \frac{2\sigma^L_{1/2}}{\sigma^T_{1/2} + \sigma^T_{3/2}}$$

The GDH Sum Rule is generalized at low Q^2

$$\Gamma_1^p(Q^2) = \frac{Q^2}{16\pi^2\alpha_{em}} \int_{\nu_{th}}^{\infty} (\sigma_p^{3/2} - \sigma_p^{1/2})$$

$$\Gamma_1^p(Q^2) \rightarrow -\frac{Q^2}{8M_p^2}\kappa_p^2$$



The first moment of $g_1(x, Q^2)$

$$\Gamma_1(Q^2) = \int_0^1 g_1(x, Q^2)dx$$

$Q^2 \rightarrow \infty$

The Bjorken Sum Rule relates the first moments to the coupling constant from neutron beta decay

$$\Gamma_1^p(Q^2) - \Gamma_1^n(Q^2) = \frac{g_a}{6}$$

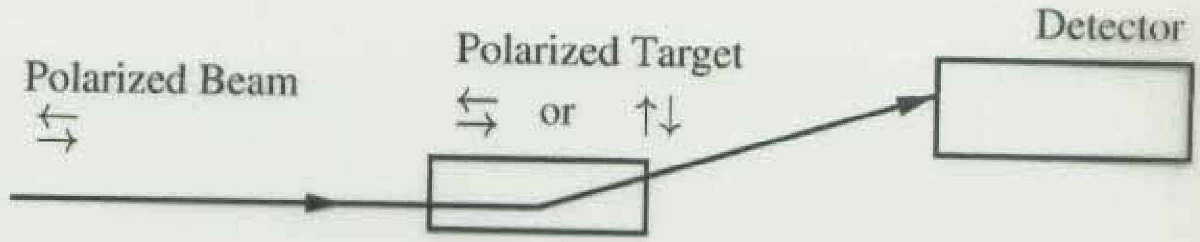
+QCD corrections

$Q^2 \rightarrow 0$

The GDH Sum Rule relates the spin-dependent photonucleon cross sections to the anomalous magnetic moment of the target nucleon

$$\int_{\nu_{th}}^{\infty} \frac{d\nu}{\nu}(\sigma^{3/2} - \sigma^{1/2}) = \frac{2\pi^2\alpha_{em}\kappa^2}{M^2}$$

Polarized Cross-section Asymmetries



$$A_{\parallel} = \frac{\sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}}{\sigma^{\downarrow\Uparrow} + \sigma^{\uparrow\Uparrow}} = D(A_1 + \eta A_2)$$

$$A_{\perp} = \frac{\sigma^{\downarrow\Leftarrow} - \sigma^{\uparrow\Leftarrow}}{\sigma^{\downarrow\Leftarrow} + \sigma^{\uparrow\Leftarrow}} = d(A_2 - \zeta A_1)$$

$$D = \frac{1 - \epsilon E'/E}{1 + \epsilon R} \qquad \eta = \frac{\epsilon Q/E}{1 - \epsilon E'/E}$$

$$d = D\sqrt{\frac{2\epsilon}{1+\epsilon}} \qquad \zeta = \eta\frac{1+\epsilon}{2\epsilon}$$

$$\epsilon = \frac{1}{1 + 2[1 + \nu^2/Q^2]\tan^2(\theta/2)}$$

$$\mathbf{g_1} = \frac{\mathbf{F_1}}{\mathbf{1} + \gamma^{\mathbf{2}}}[\mathbf{A_{\parallel}/D} + (\gamma - \eta)\mathbf{A_2}]$$

$$A_{\parallel} = D(A_1 + \eta A_2)$$

$$A_{\parallel} = \frac{1}{1 + \epsilon R}[\epsilon(Q/E)A_2 + (1 - \epsilon E'/E)A_1]$$

low E (small ϵ): $A_{\parallel}$ more sensitive to A_1
high E (large ϵ): $A_{\parallel}$ more sensitive to A_2

Measurements at fixed Q^2 and W and different beam energies will allow the separation of A_1 and A_2

$$A_{\parallel} = A_{exp}\frac{1}{P_b P_t f} + \Delta_{RC}$$

$$A_{exp} = \frac{N^{\downarrow\Uparrow}/N_e^{\downarrow\Uparrow} + N^{\uparrow\Uparrow}/N_e^{\uparrow\Uparrow}}{N^{\downarrow\Uparrow}/N_e^{\downarrow\Uparrow} + N^{\uparrow\Uparrow}/N_e^{\uparrow\Uparrow}}$$

EG2000 Experimental Overview

CEBAF electron beam

- Laser driven photoemission source
- Strained GaAs cathode
- Polarization measured by the Moller polarimeter
- Typical beam polarization $\sim 75\%$
- Beam current 1-10 nA

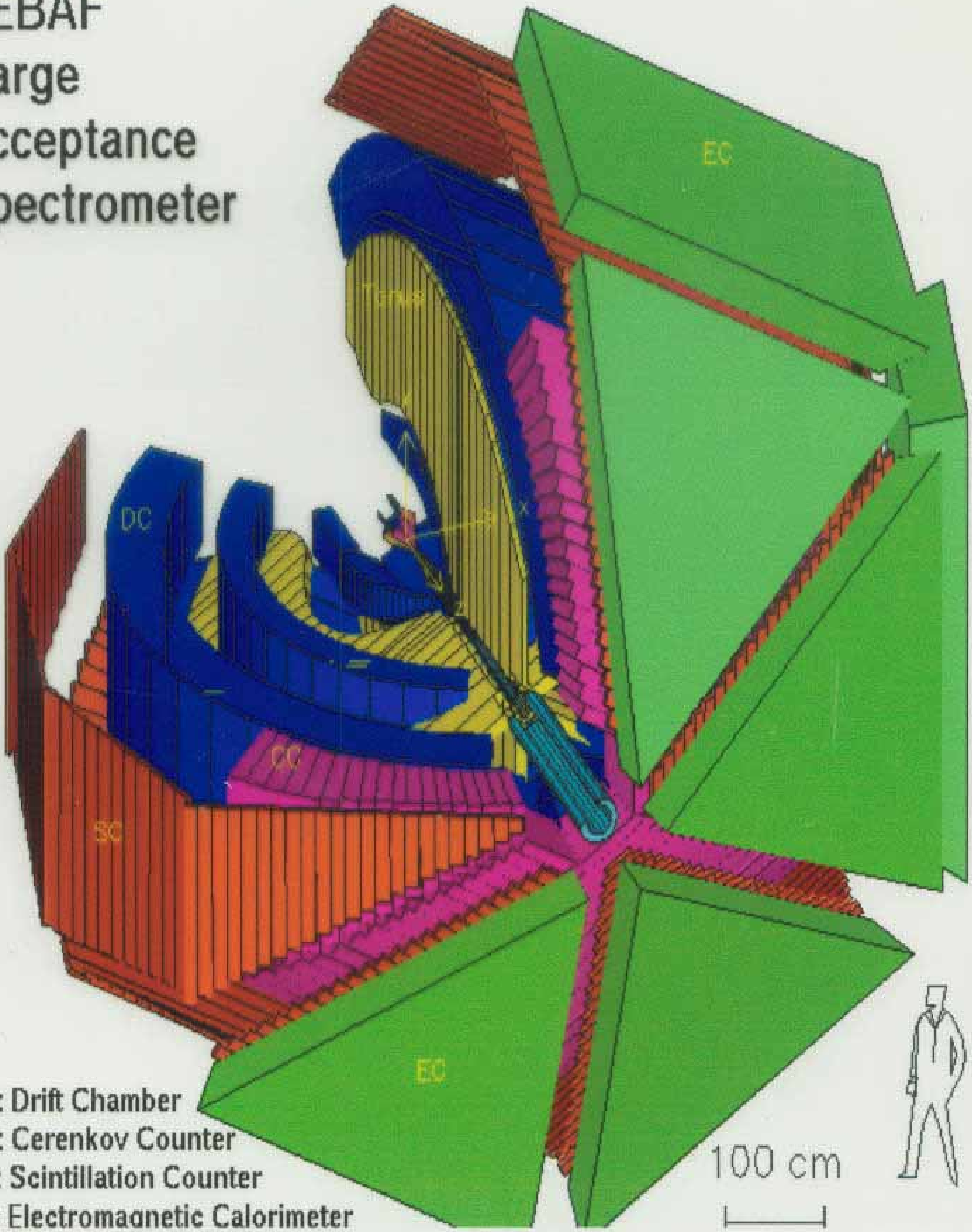
Longitudinally Polarized Targets

- Dynamic Nuclear Polarization
- 5T, 1K, microwave radiation
- Frozen NH_3 and ND_3 granules
- Polarization is monitored by the NMR system

CEBAF Large Acceptance Spectrometer

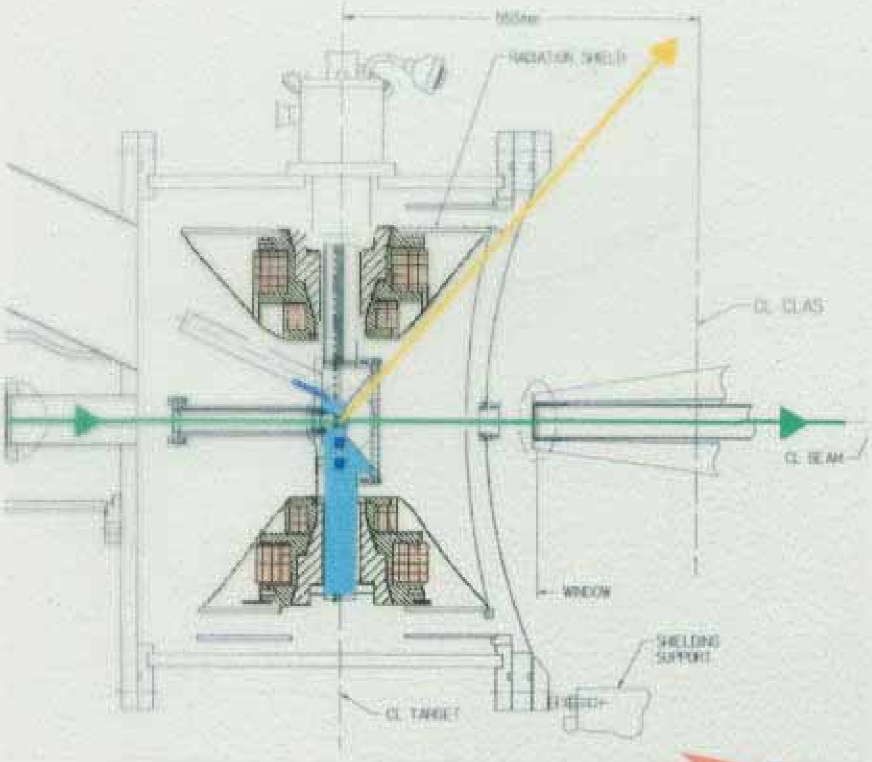
- Magnetic Toroidal Spectrometer
- Nearly 4π acceptance
- Multi-particle final states

CEBAF
Large
Acceptance
Spectrometer



DC: Drift Chamber
CC: Cerenkov Counter
SC: Scintillation Counter
EC: Electromagnetic Calorimeter

Dynamic Nuclear Polarization (DNP) NH_3 and ND_3 target



B=5 Tesla

$\frac{dB}{B} \approx 10^{-4}$

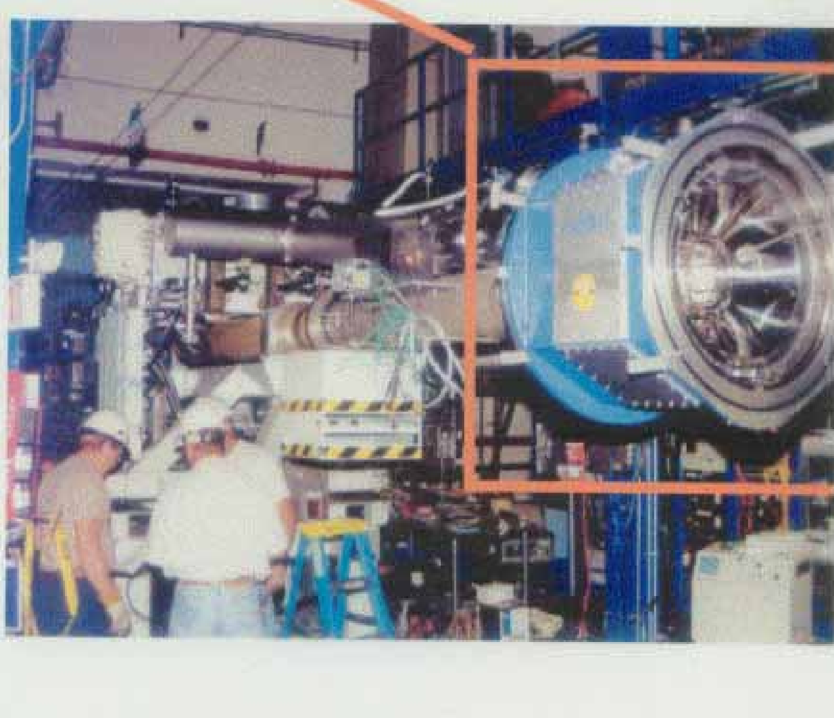
1^oK ^4He cooling bath

^{12}C and ^{15}N targets

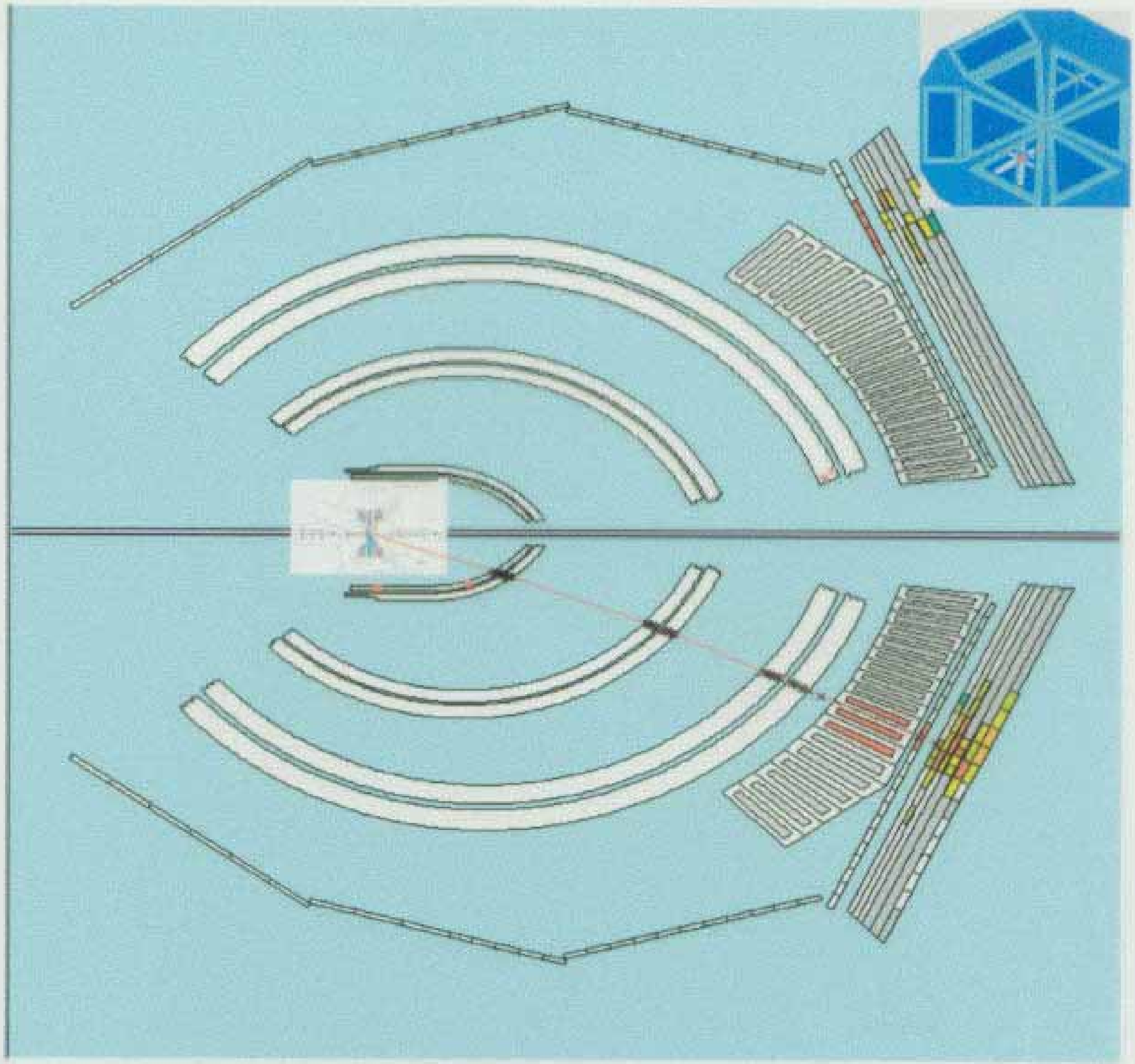
$P_{NH_3} \approx 75 \rightarrow 85\%$

$P_{ND_3} \approx 25 \rightarrow 35\%$

$\frac{\delta(P_b \cdot P_t)}{P_b \cdot P_t} \approx 3\% for NH_3$



CLAS Detector



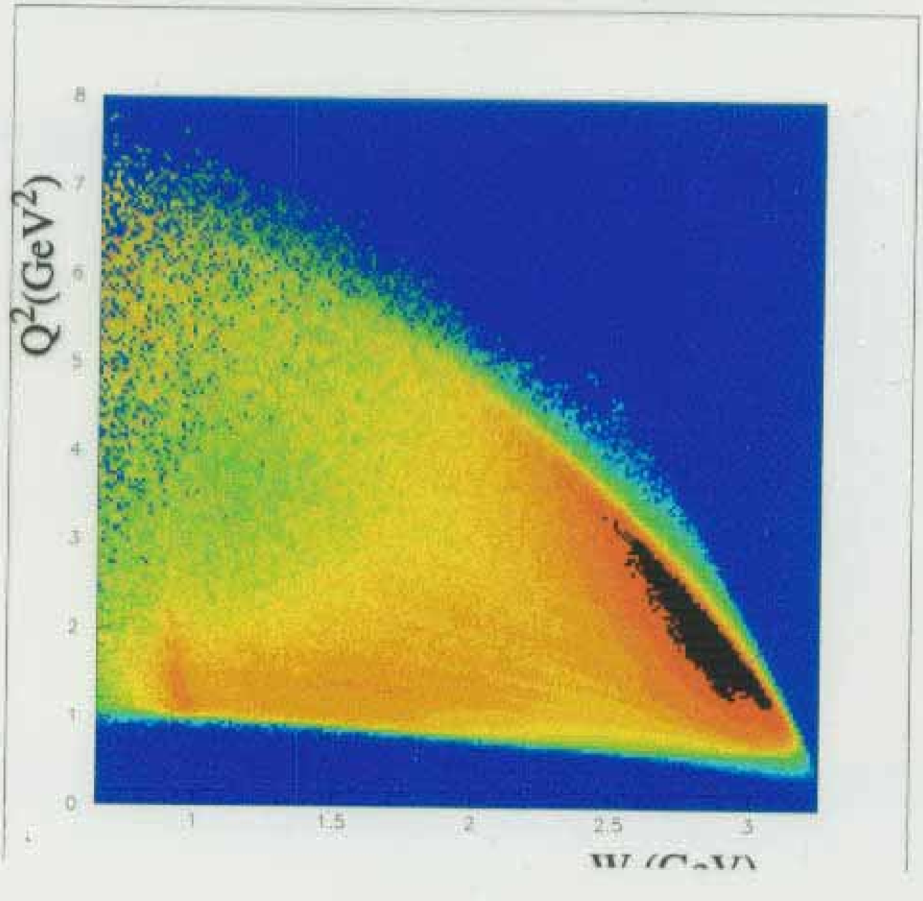
- Drift chambers
- Cerenkov counters
- Scintillation counters
- Electromagnetic calorimeter

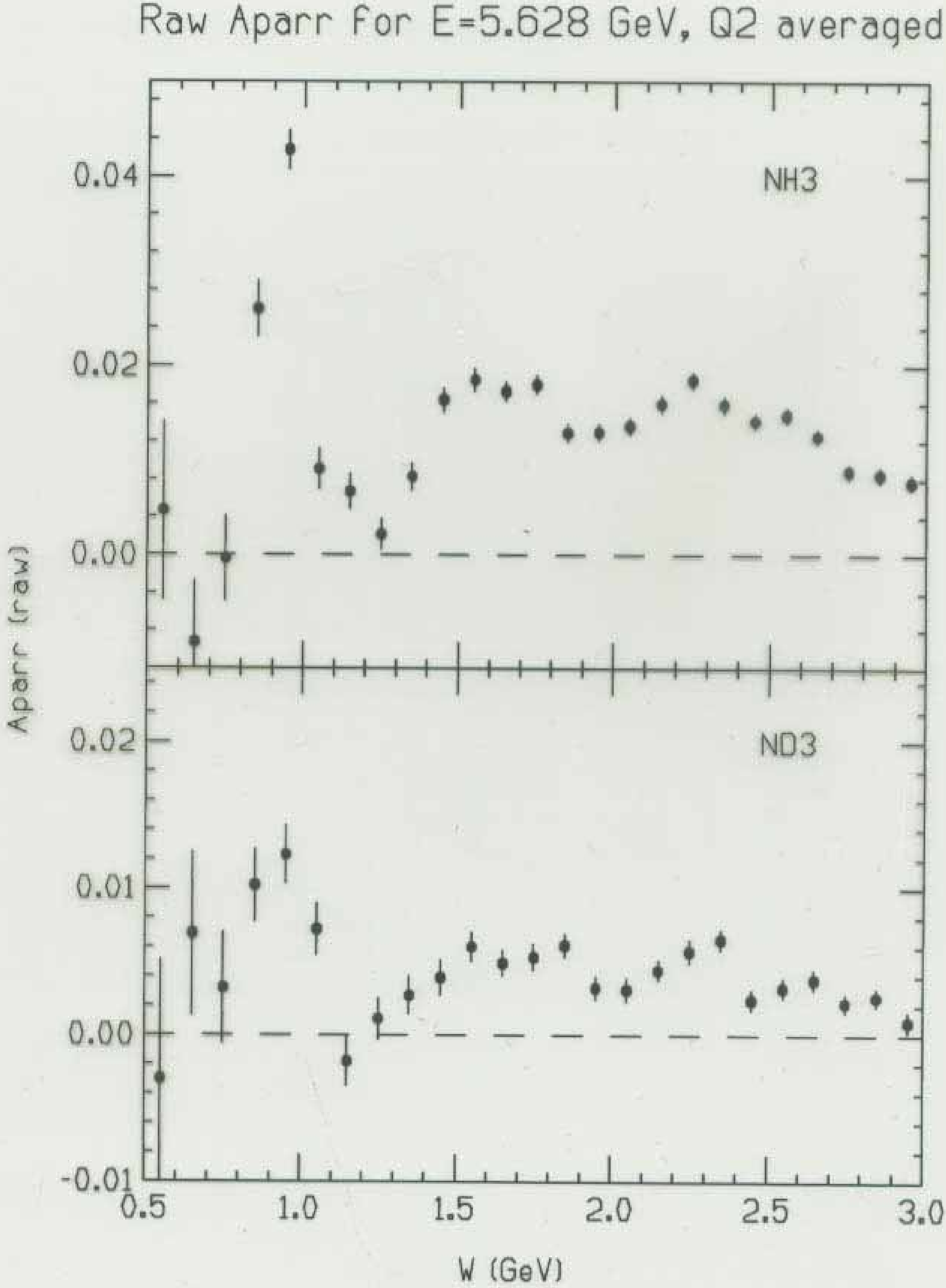
- Experiment ran from Sep, 2000 to April, 2001
- Over 20 billion triggers accumulated
- Beam Energy= 1.6, 2.5, 4.2, 5.7 GeV
- $0.05 < Q^2 < 4.5\ GeV^2$
- $0.8 < W < 3.0\ GeV$

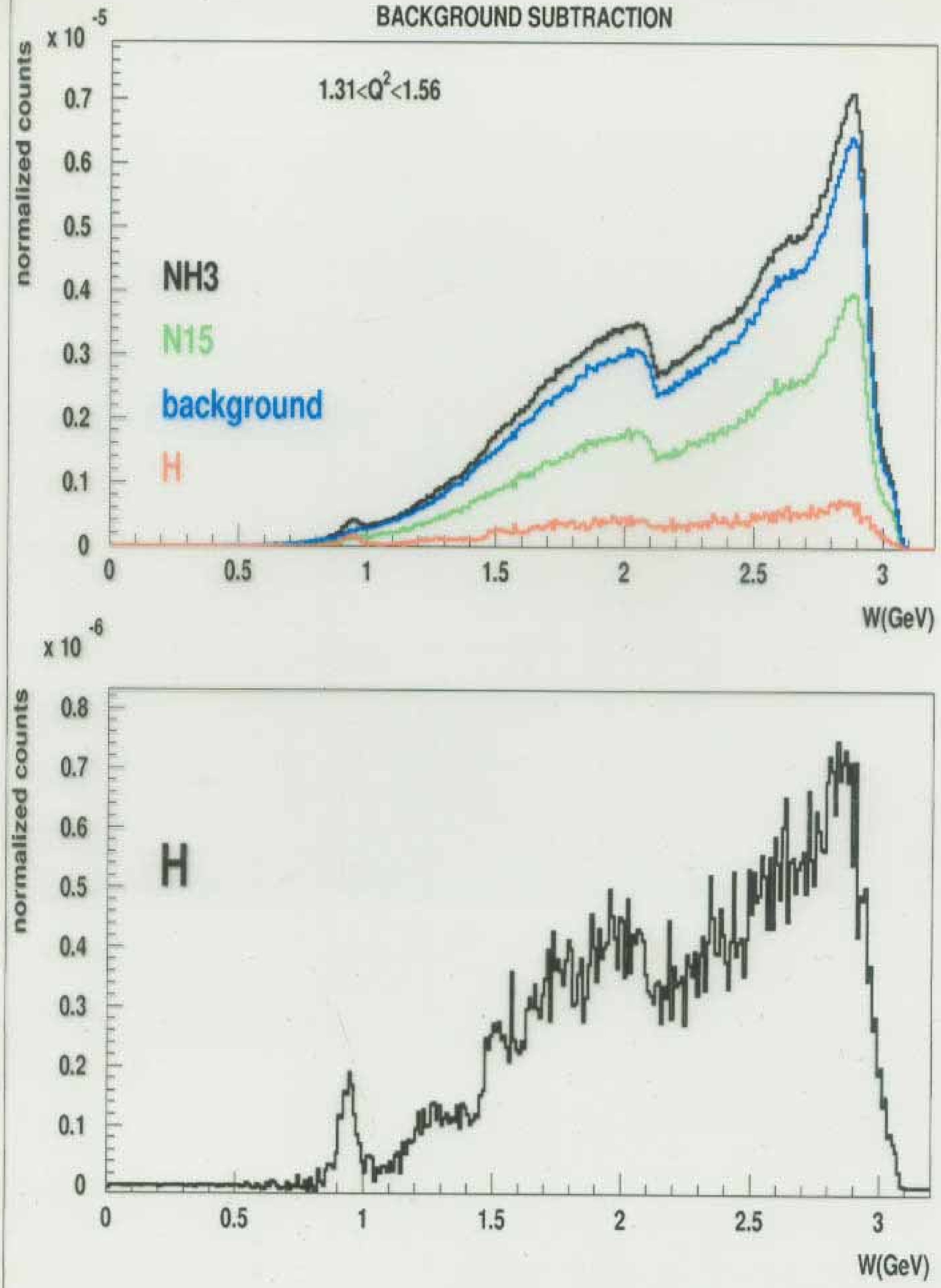
EG1b Kinematics

CLAS/E91-023

$\vec{e}\vec{N}H_3 \rightarrow eX \qquad E = 5.65\ GeV$

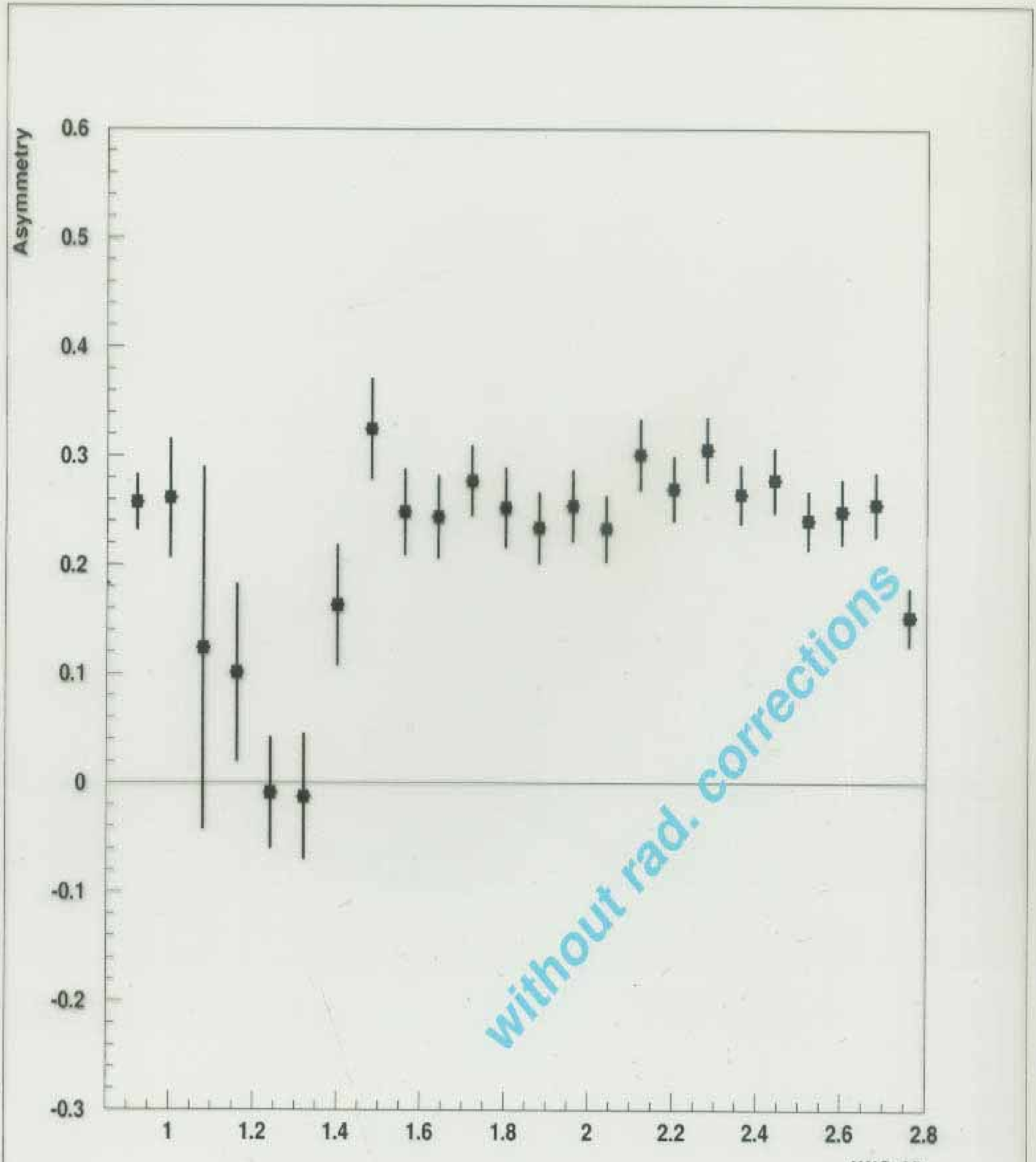



Raw Aparr for E=5.628 GeV, Q2 averaged
NH3
ND3
Aparr (raw)
W (GeV)
0.04
0.02
0.00
0.02
0.01
0.00
-0.01
0.5
1.0
1.5
2.0
2.5
3.0

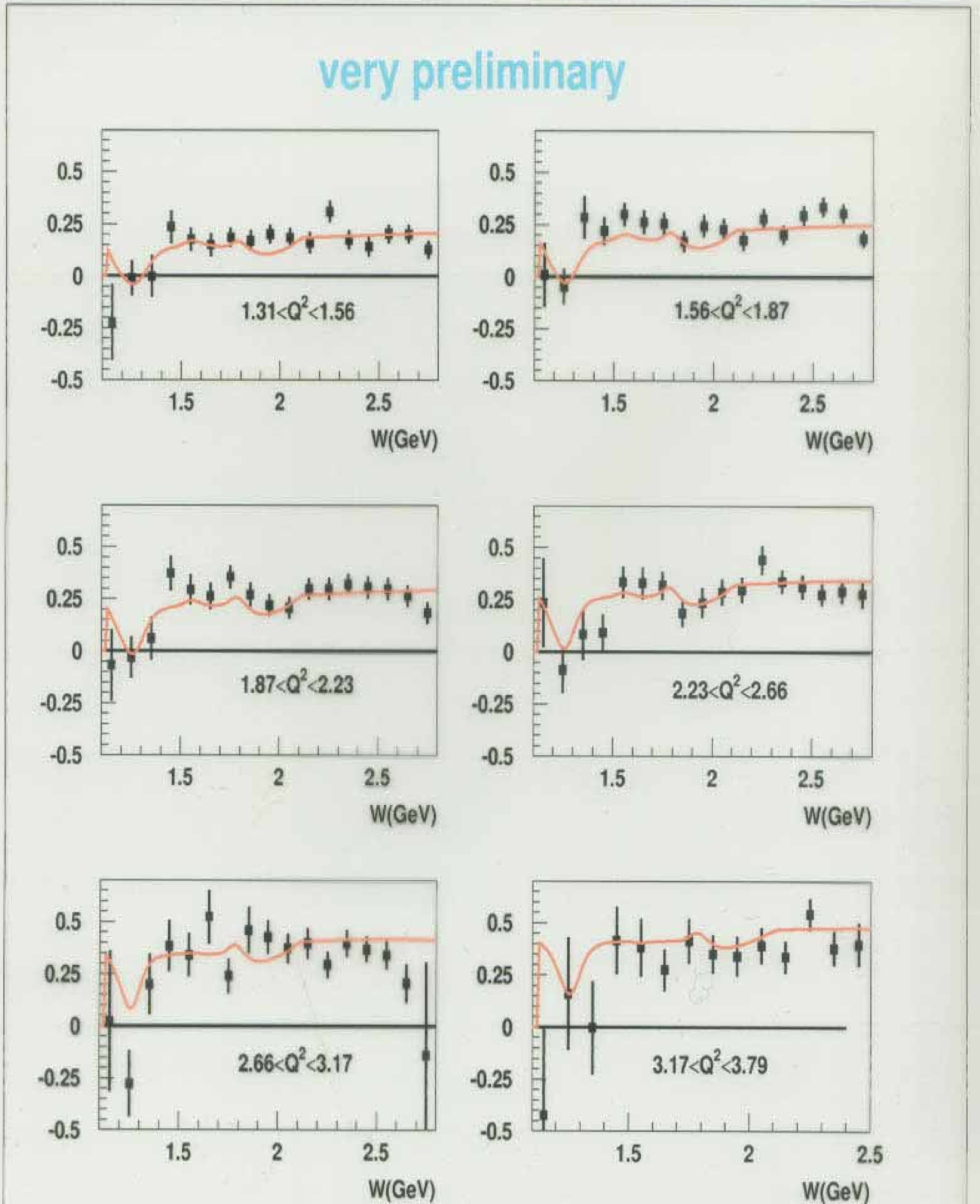


BACKGROUND SUBTRACTION
x 10^-5
normalized counts
1.31<Q^2<1.56
NH3
N15
background
H
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
0.5
1
1.5
2
2.5
3
W(GeV)
x 10^-6
normalized counts
H
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
0.5
1
1.5
2
2.5
3
W(GeV)

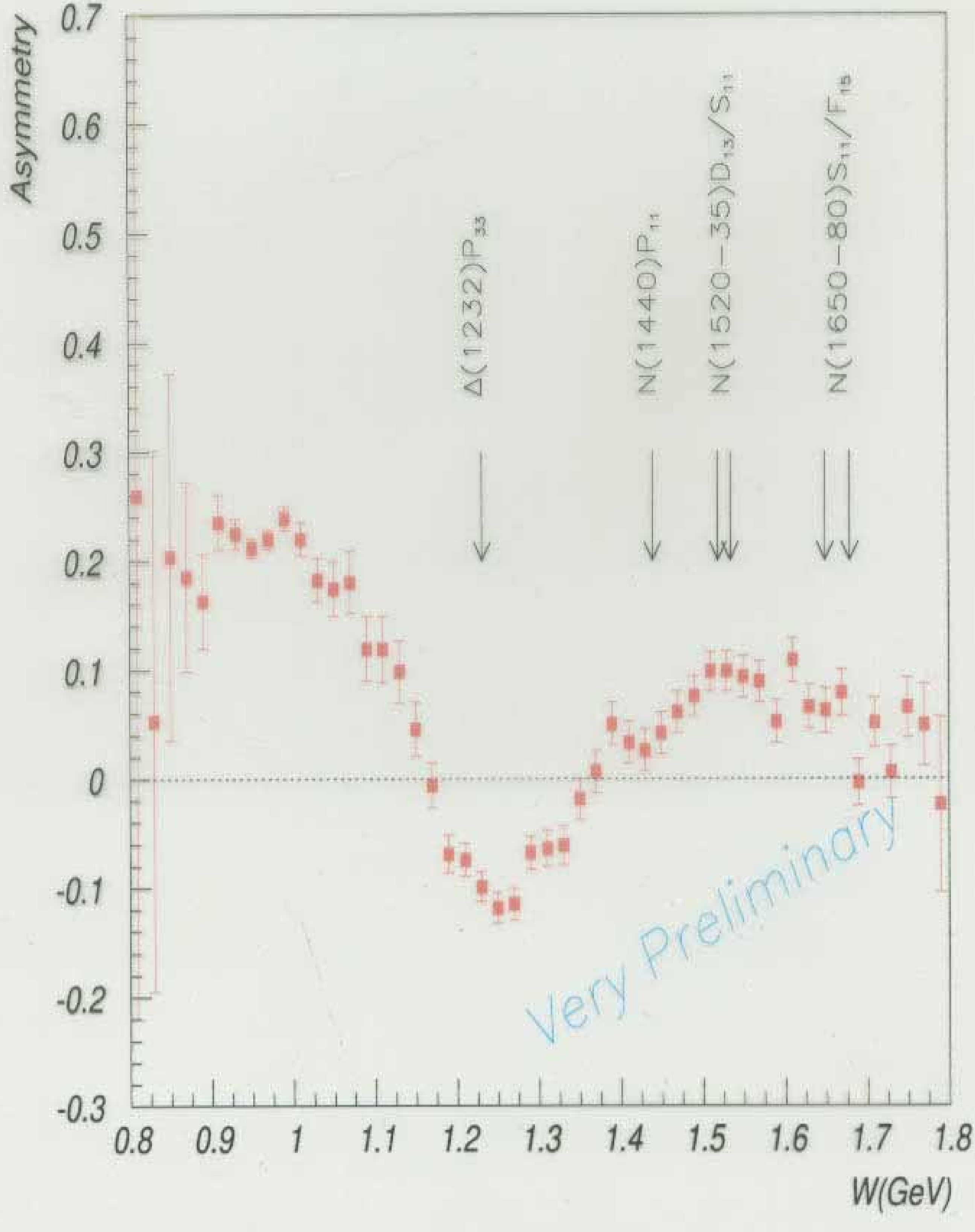
Electron Asymmetry in $\vec{H}(\vec{e}, e')$ at E=5.628 GeV



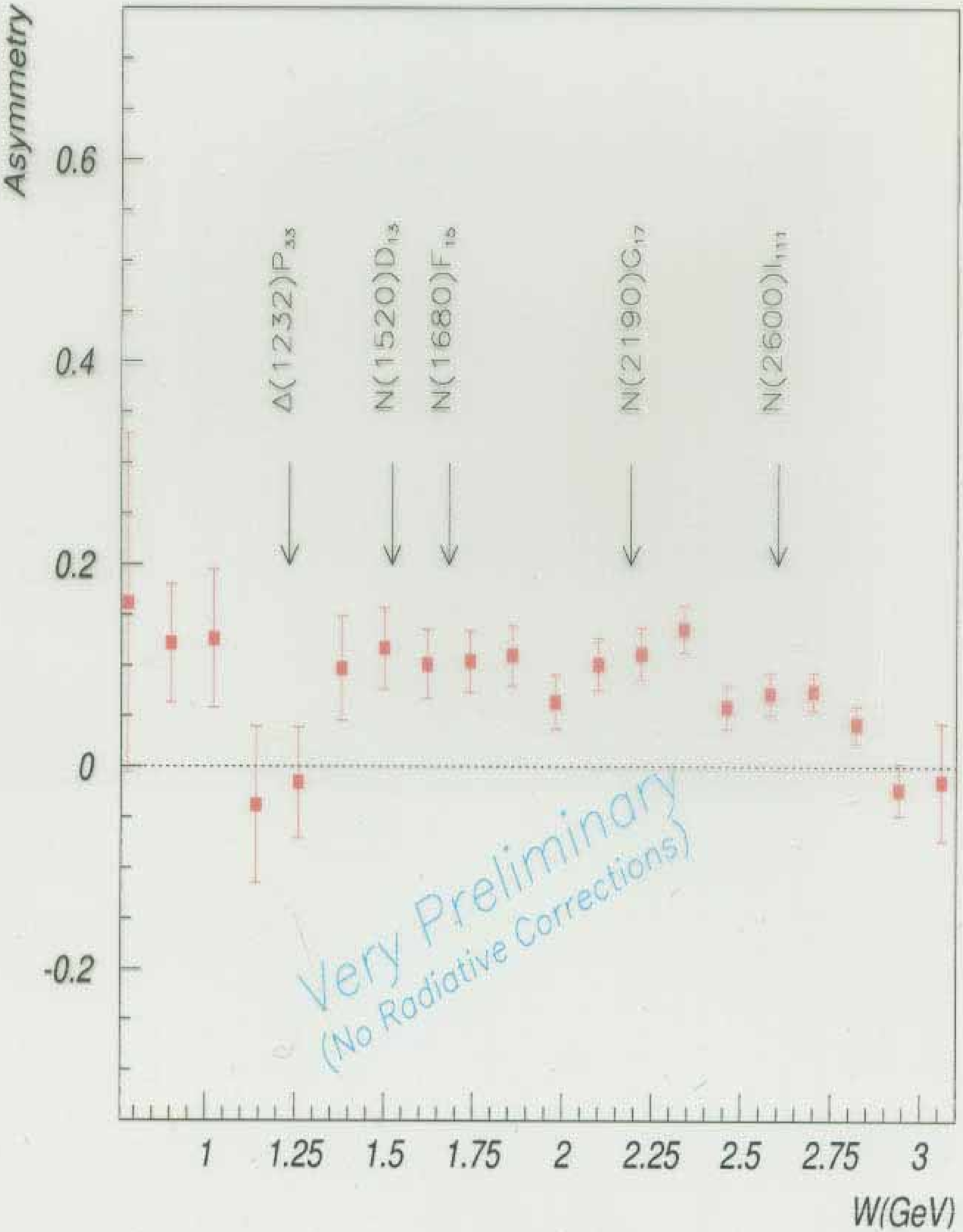
Electron Asymmetry in $\vec{H}(\vec{e}, e')$ at E=5.628 GeV



Electron Asymmetry in $\vec{D}(\vec{e}, e')$ at E=1.6 GeV



Electron Asymmetry in $\vec{D}(\vec{e}, e')$ at E=5.628 GeV



Summary and Outlook

- Polarized double asymmetry has been measured at the beam energies of 1.6 GeV, 2.5 GeV, 4.2 GeV, 5.6 GeV
- Measurements have been extended to lower and higher Q^2, complimenting the existing data
- Target polarization has been improved in comparison with the first part of the experiment
- Preliminary results have better statistical accuracy than the existing data
- Asymmetry analysis is in progress for the 1.6 GeV and 5.6 GeV data
- Calibrations are in progress for the 2.5 GeV and 4.2 GeV data
- Improved radiative corrections and pair-symmetric corrections need to be applied to the analyzed data
- Systematic errors need to be evaluated
- g_1, Γ_1 and I_{GDH} for the proton and the deuteron will be extracted.