Spin Structure Measurements in the Resonance Region with CLAS

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(representing the CLAS Collaboration)

Reporting on the work of 6 graduate students:

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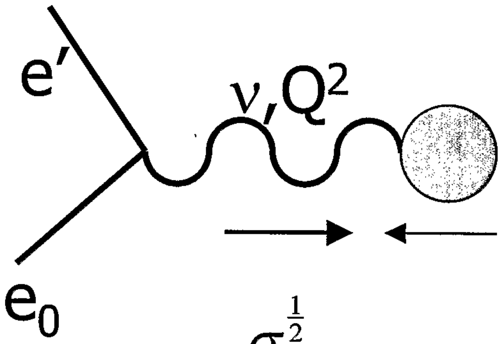
Overview

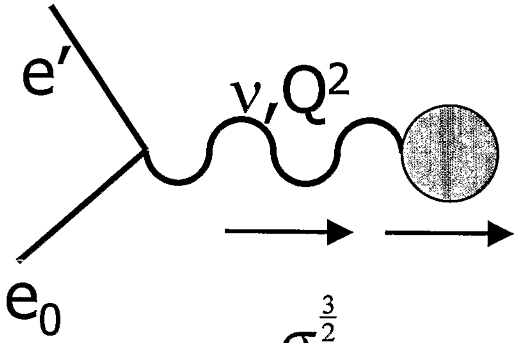
- Motivation (inclusive and exclusive)
- Experiment
  - Polarized electron scattering from polarized NH_3 and ND_3 targets
  - The CLAS detector
- Inclusive Analysis and Results
- Exclusive Analysis and Results
- Summary and Outlook

Why measure asymmetries?

Electron scattering from nucleons



$\sigma^{\frac{1}{2}}$



$\sigma^{\frac{3}{2}}$

$$A_1(\upsilon, Q^2) = \frac{\sigma^{\frac{1}{2}} - \sigma^{\frac{3}{2}}}{\sigma^{\frac{1}{2}} + \sigma^{\frac{3}{2}}}$$

High Q^2 and DIS

At high Q^2 the virtual photon couples directly to the quarks. We define the spin structure functions:

$$g_1(x,Q^2) \text{ and } g_2(x,Q^2) \quad (x = \frac{Q^2}{2M\upsilon})$$

which are related to A_1:

$$A_1 = (g_1 - \frac{Q^2}{\upsilon^2} g_2) / F_1$$

The first moment of g_1:

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

is known from DIS measurements and is related to the spins carried by the quarks.

The fundamental Bjorken integral:

$$\Gamma_1^p - \Gamma_1^n = \frac{g_A}{6} \text{ (+ QCD corrections)}$$

The GDH Sum Rule

At Q^2=0, the cross section difference is related to the anomalous magnetic moment of the nucleon:

$$I_{GDH} = \frac{M^2}{8\pi^2\alpha} \int_{thr}^{\infty} (\sigma^{\frac{1}{2}} - \sigma^{\frac{3}{2}}) \frac{d\upsilon}{\upsilon} = -\tfrac{1}{4}\kappa^2$$

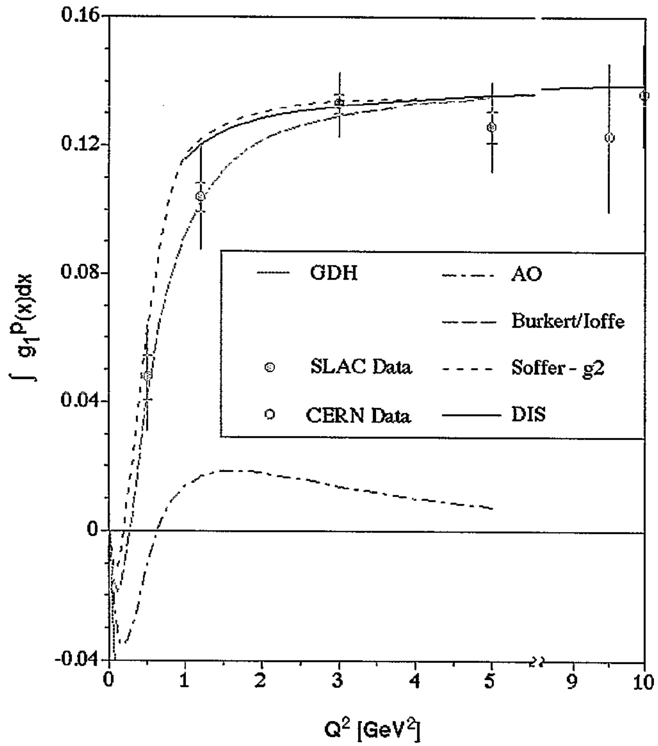
At low Q^2, the integral can be generalized:

$$\Gamma_1(Q^2) = \frac{Q^2}{16\pi^2\alpha} \int_{thr}^{\infty} (\sigma^{\frac{1}{2}} - \sigma^{\frac{3}{2}}) \frac{d\upsilon}{\upsilon} = \frac{Q^2}{2M^2} I_{GDH}$$

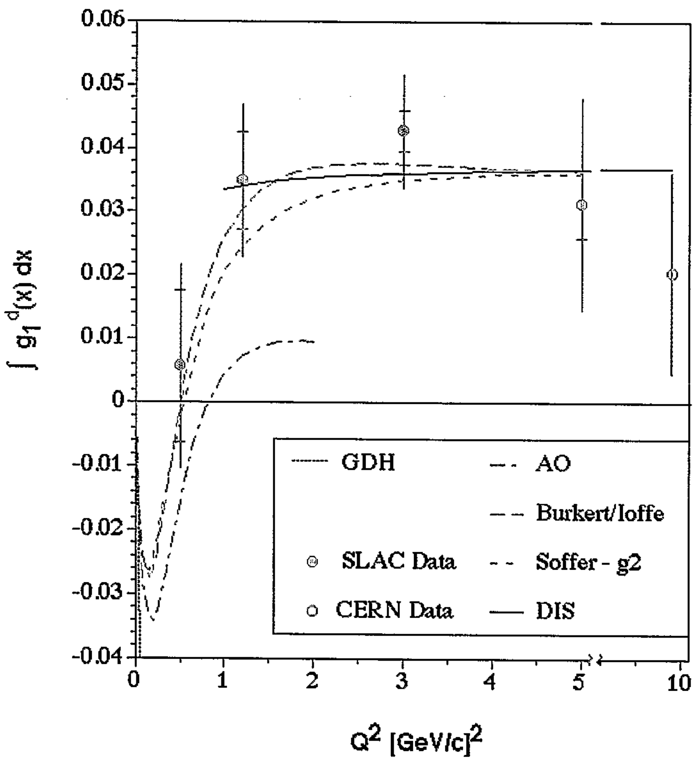
The slope of the integral at low Q^2 is predicted by the GDH Sum Rule.

Previous Inclusive Measurements

Proton



Deuteron



Low to moderate Q^2 is interesting and unexplored.

Exclusive Measurements

$$\vec{e} + \vec{N} \rightarrow e' + \pi + N$$

The cross section can be written as:

$$= \sigma_0 + P_e \sigma_e + P_t \sigma_t + P_e P_t \sigma_{et}$$

P_e = electron polarization

P_t = target polarization

Polarization observables allow us to access completely new information on the helicity structure of the nucleon resonances.

Current models of the resonance region (AO, MAID) are based on unpolarized measurements.

Experiment ("EG1")

- Longitudinally polarized electrons, Jefferson Lab
  - Polarization was ~ 70% (measured by Moller Polarimeter)
  - Beam energies: 2.5 GeV, 4.2 GeV
- CEBAF Large Acceptance Spectrometer (CLAS)
  - Multi-particle final states
  - Measure large range in Q^2 and W
- Polarized solid ammonia targets
  - NH3 polarization: 70-90%
  - ND3 polarization: 10-25%
- In 1998 we ran for 2 months and recorded 3 billion events

CLAS

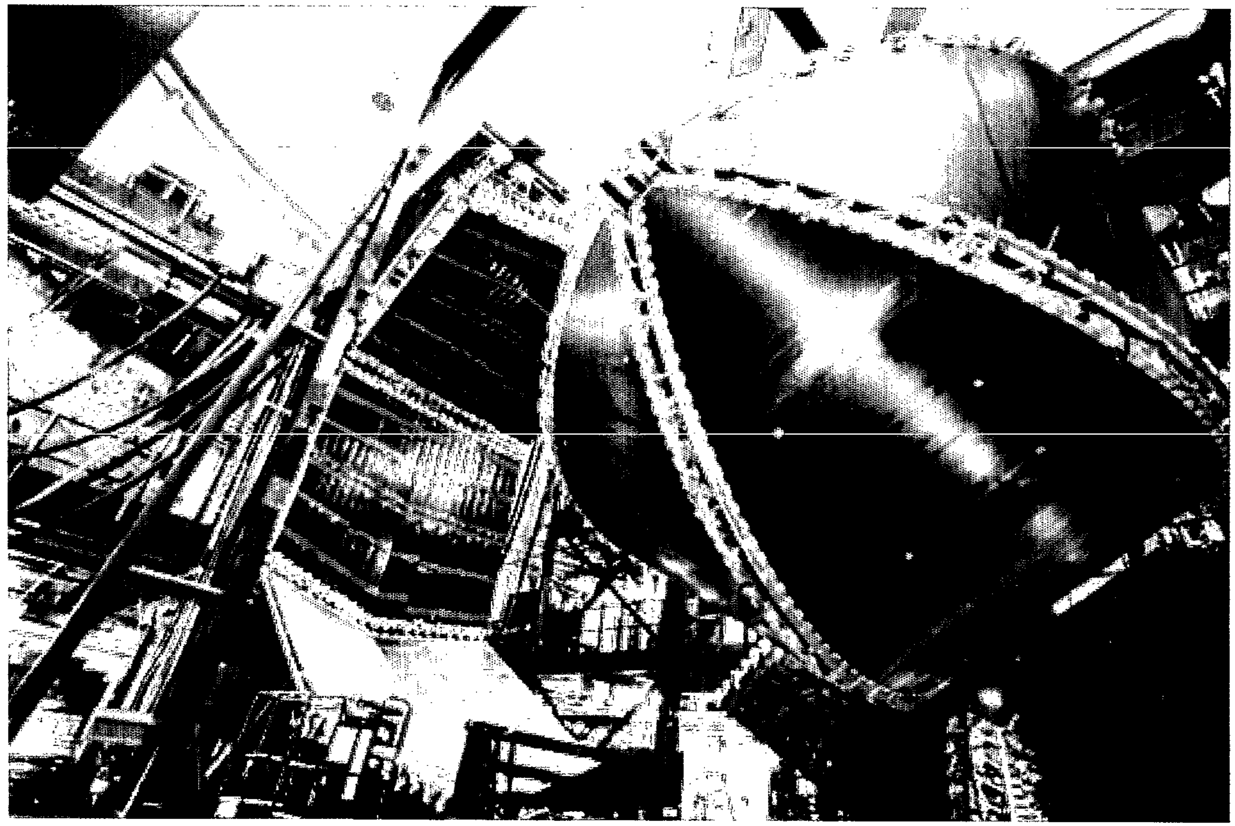
CEBAF

Large

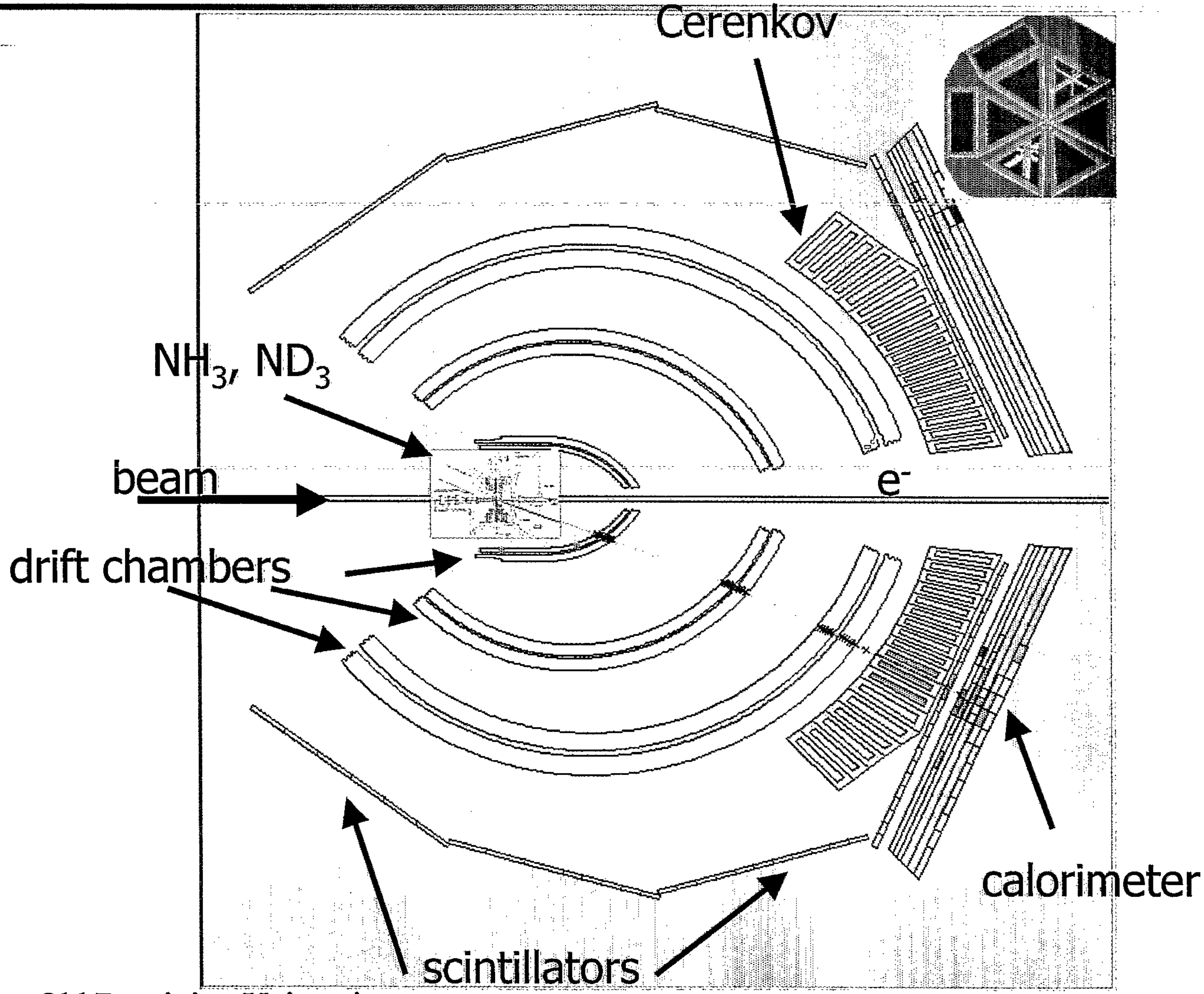
Acceptance

Spectrometer

Multi-particle final states



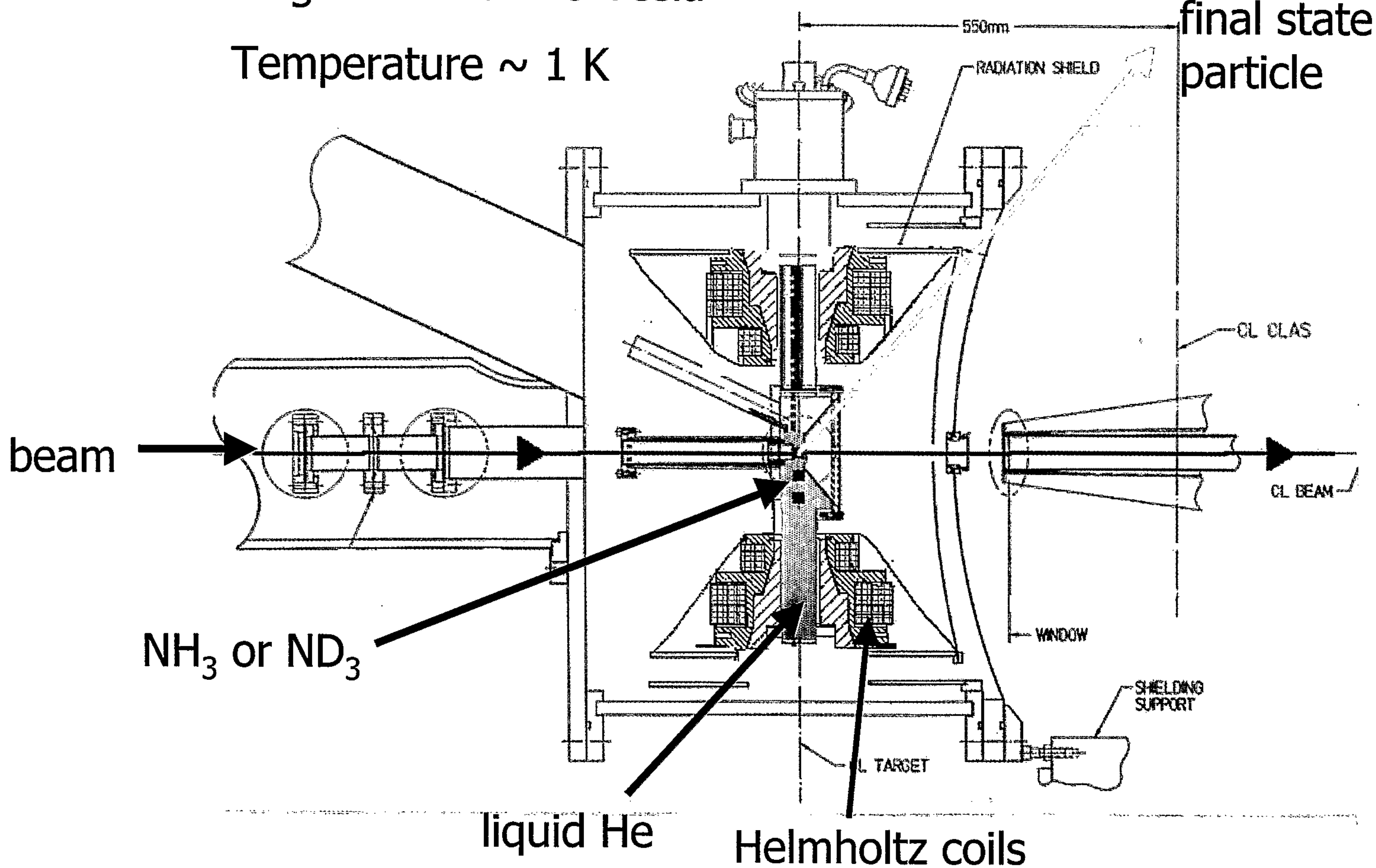
A CLAS event


Cerenkov
NH3, ND3
beam
e-
drift chambers
calorimeter
scintillators

Polarized Target

Magnetic field ~ 5 Tesla

Temperature ~ 1 K

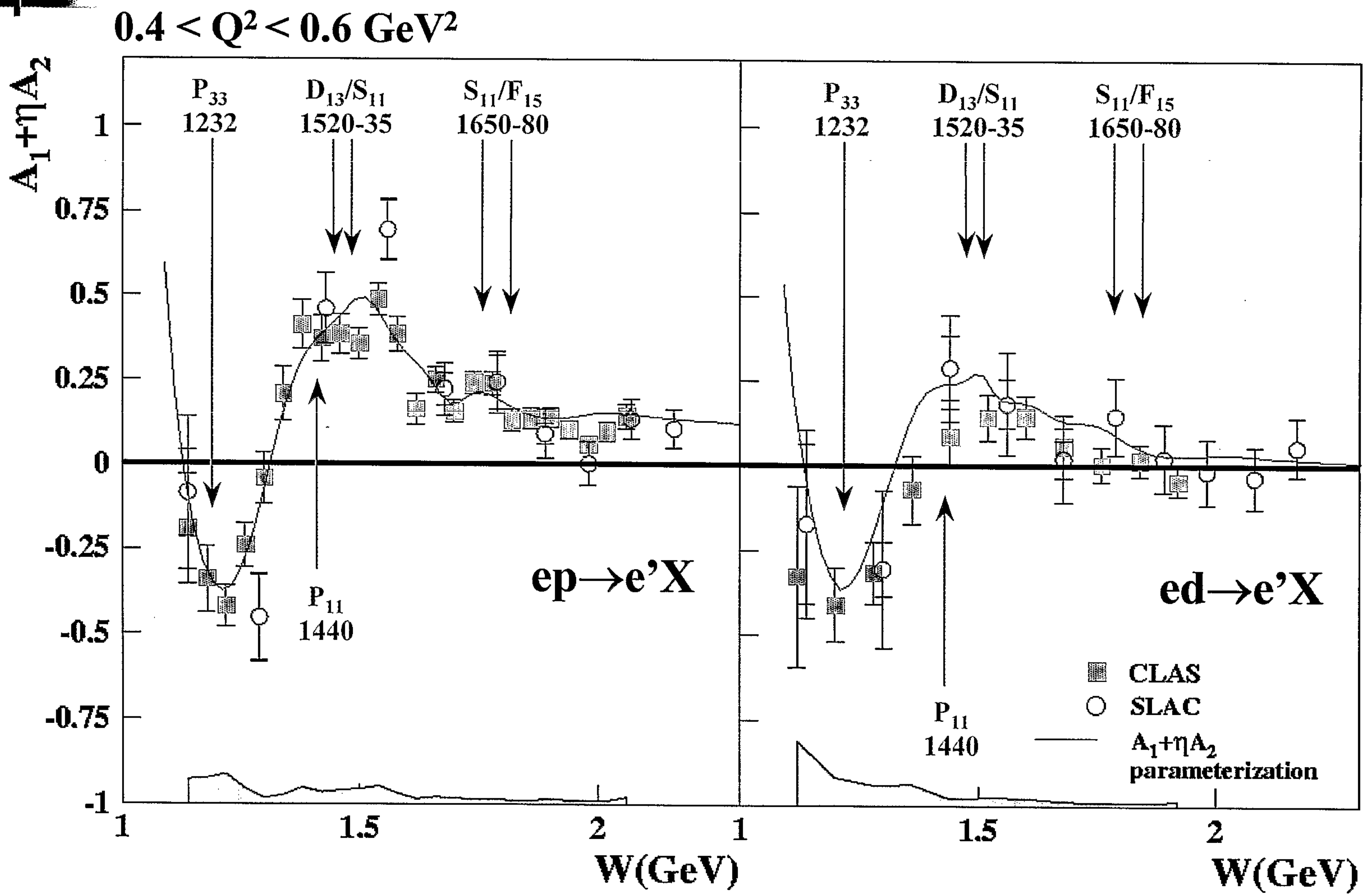


Inclusive Analysis

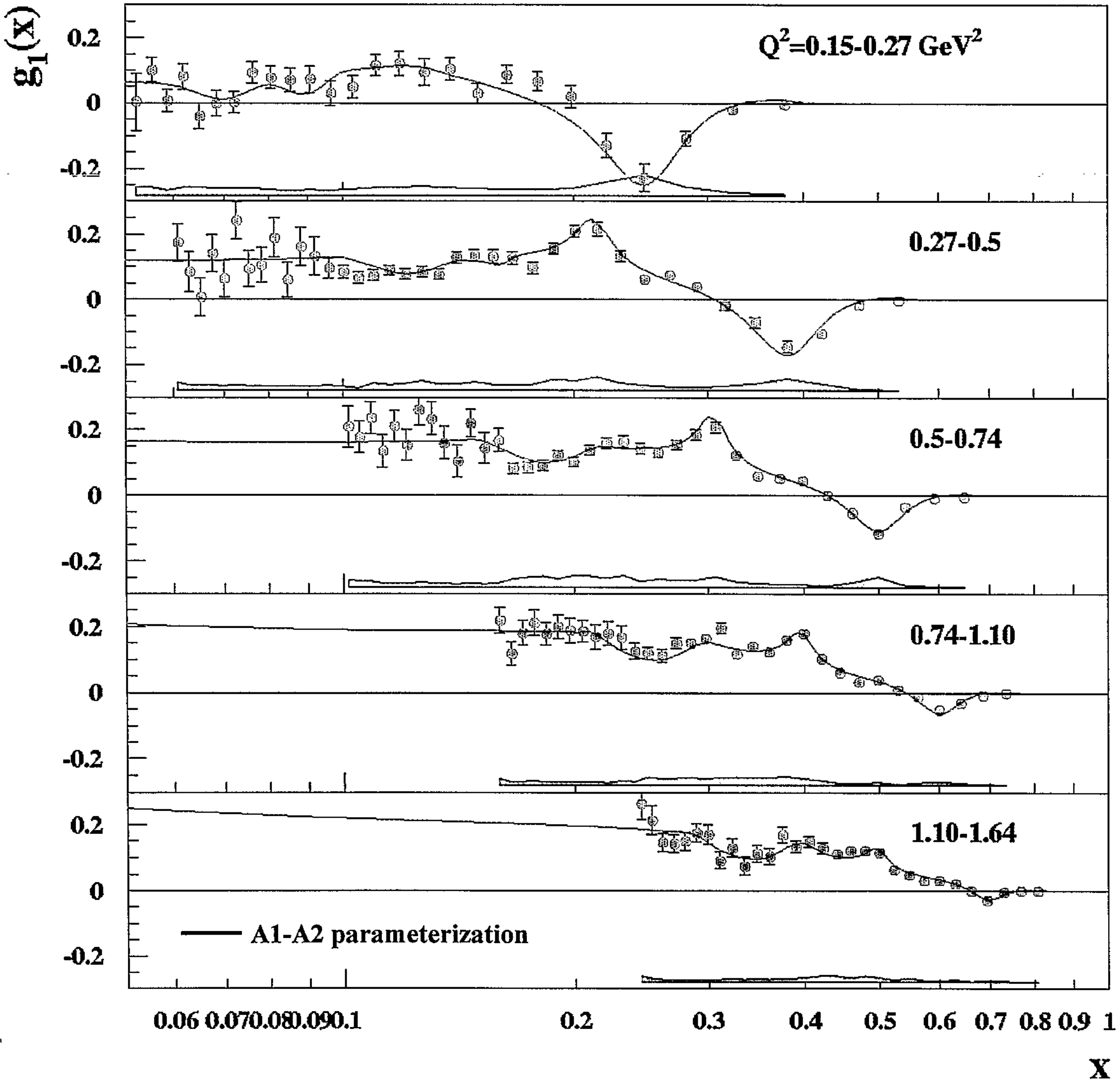
- Extract raw asymmetry, corrected for
  - Beam charge asymmetry
  - Dilution factor
- Apply radiative corrections
- P_tP_e determined from elastic asymmetry
- Extract $A_1 + \eta A_2 = \frac{1}{DP_eP_t} A_{raw}$ $\quad D = \frac{1 - E'\varepsilon / E}{1 + \varepsilon R}; \quad \eta = \frac{\varepsilon\sqrt{Q^2}}{E - E'\varepsilon}$
- Using a parameterization of world data for F_1 and A_2, extract

$$g_1(x, Q^2) = \frac{F_1}{1 + \frac{Q^2}{\upsilon^2}} (A_1 + \frac{Q}{\upsilon} A_2)$$

$A_1+\eta A_2$ for the Proton and Deuteron



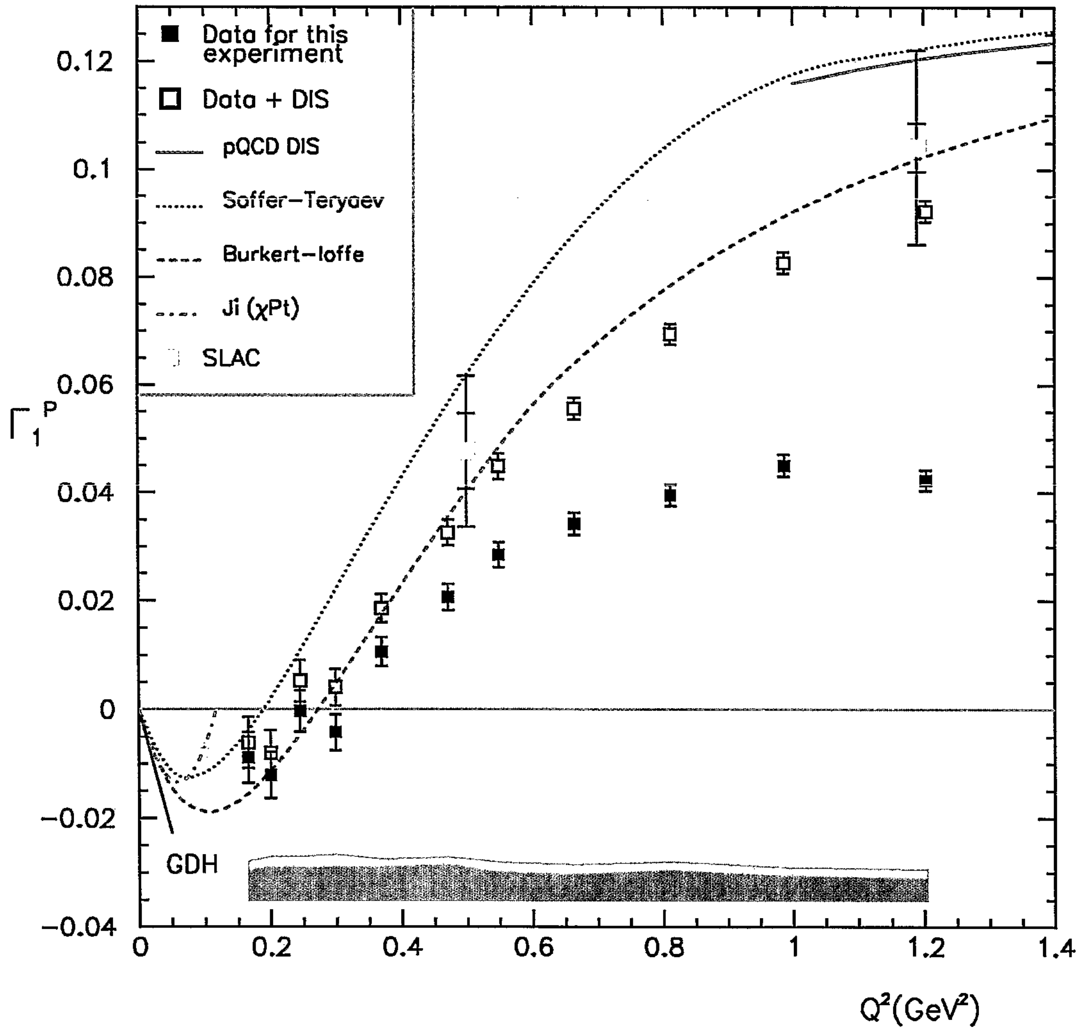
$g_1(x)$ for the proton



strong Q^2 dependence

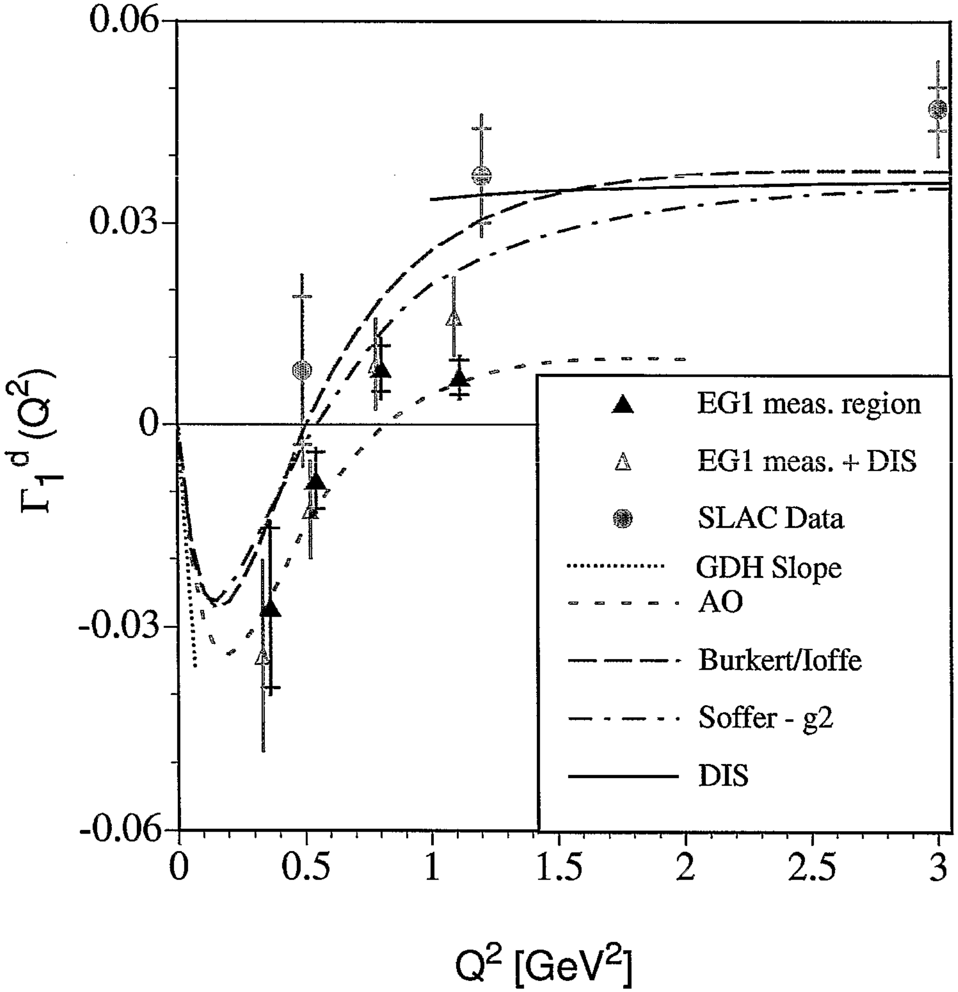
evident resonance structures

Proton Integral: $\int g_1(x,Q^2)dx$



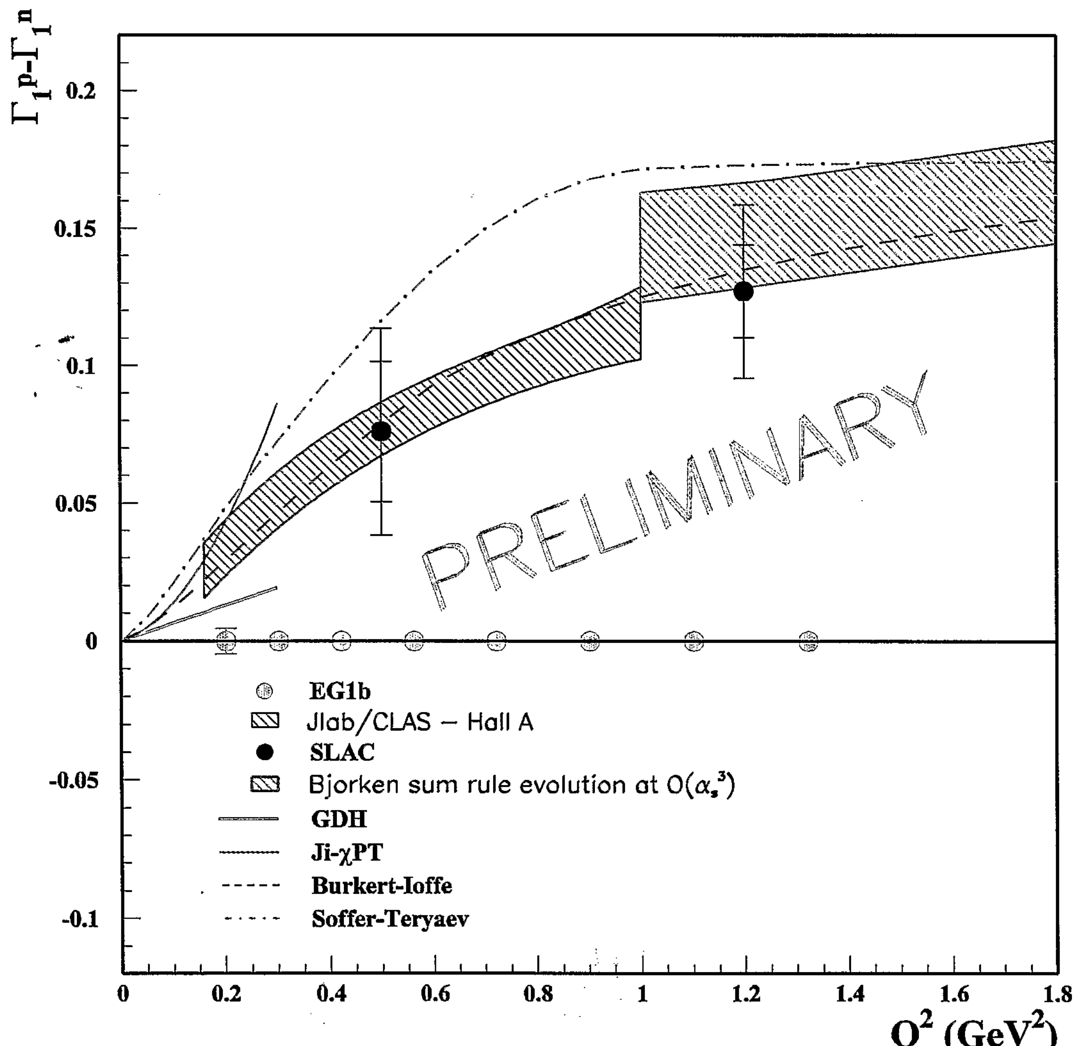
Ph.D. work:
R. Fatemi – UVa
A. Skabelin - MIT

Deuteron Integral: $\int g_1(x,Q^2)dx$



Ph.D. work:
J. Yun – ODU

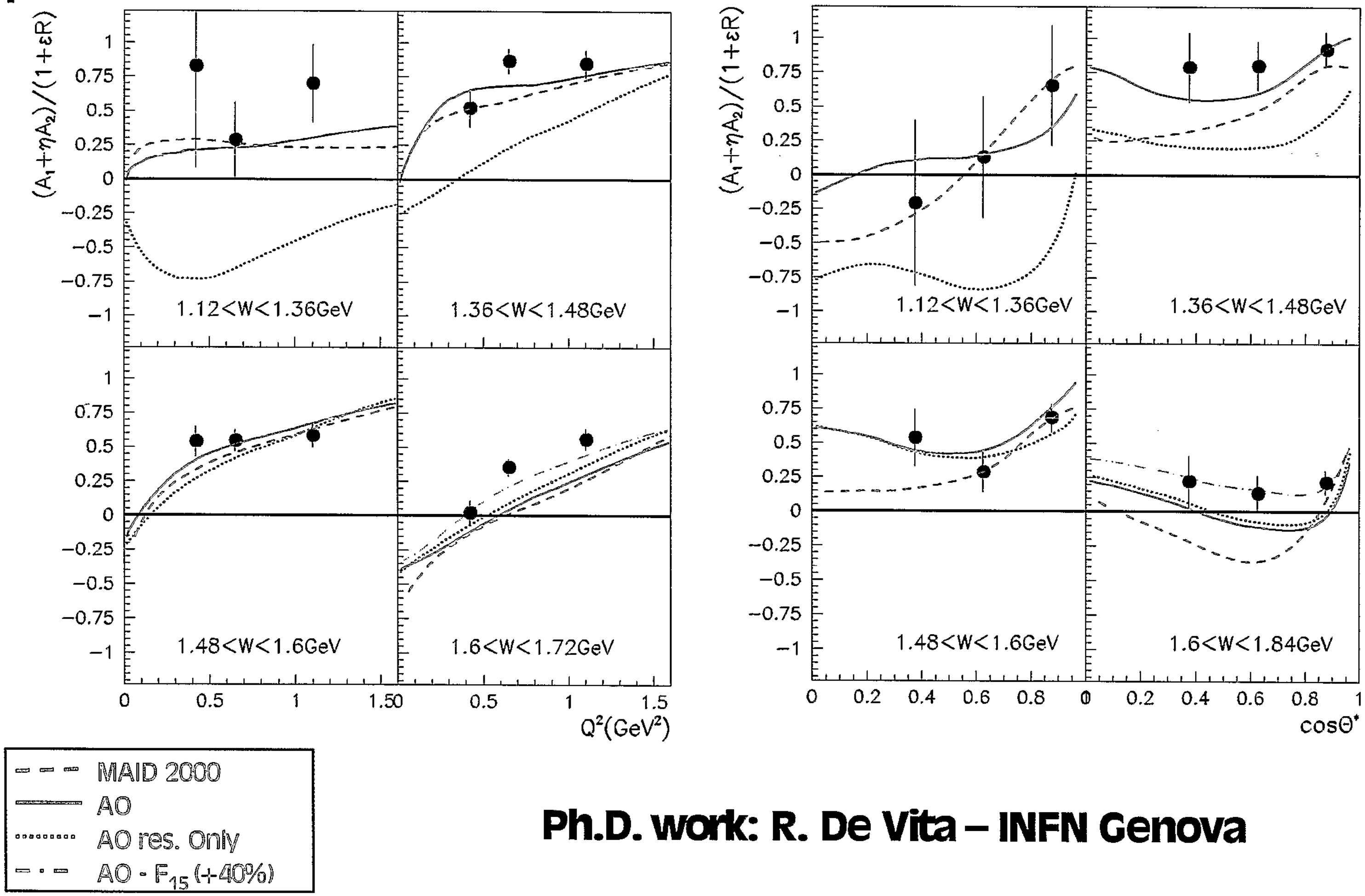
Bjorken Integral



Exclusive Analysis

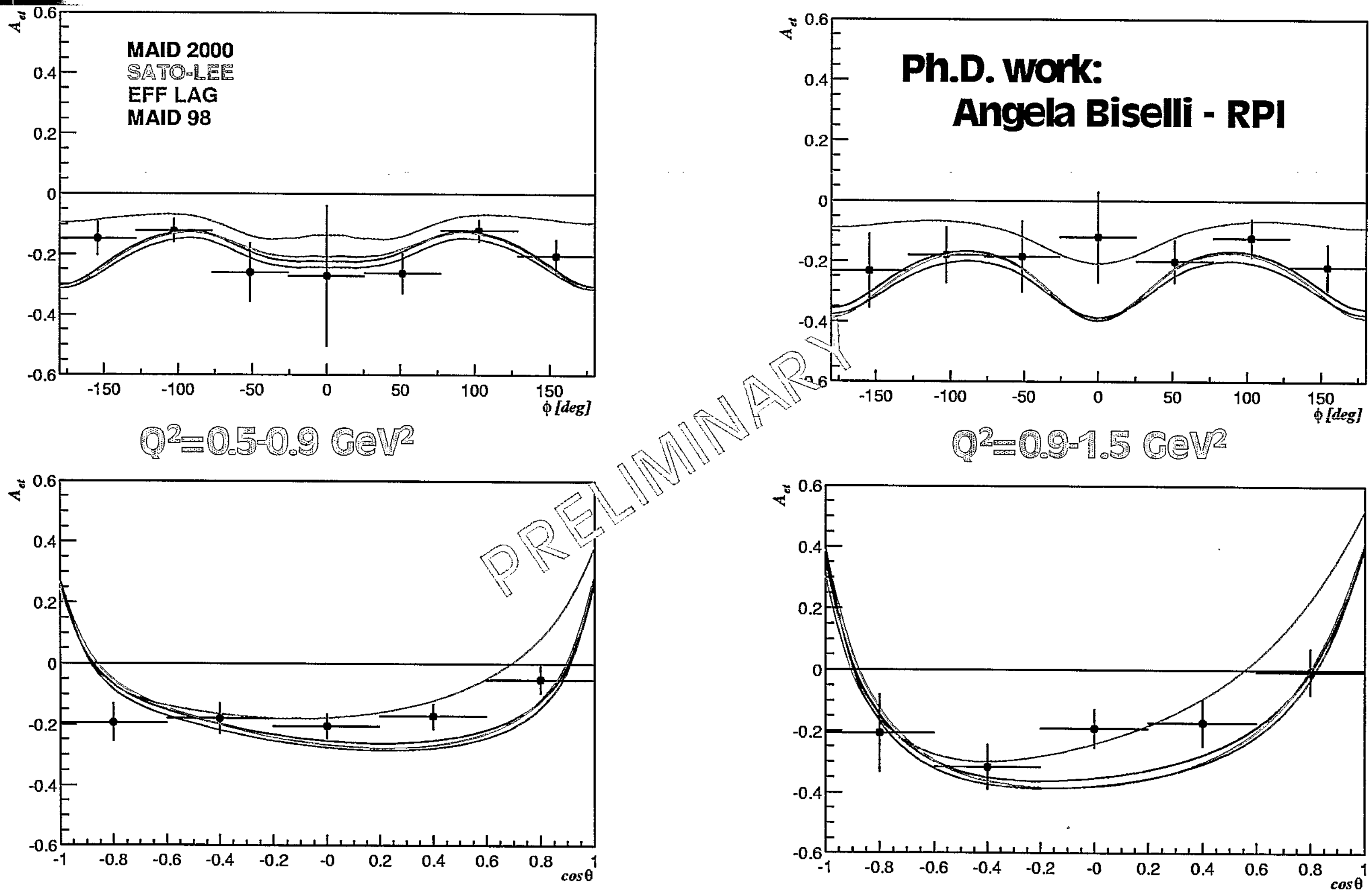
- Identify channel using missing mass technique
  - $ep \rightarrow e'\pi^+ n$
  - $ep \rightarrow e'\pi^0 p$
  - $en \rightarrow e'\pi^- p$ (using ND_3 data)
- Correct for dilution factor and beam charge asymmetry
- $P_t P_e$ determined from elastic asymmetry
- Extract $A_{et} = \frac{\sigma_{et}}{\sigma_0}$
- Compare with phenomenological models: A0 and MAID

Double Spin Asymmetry in $\vec{e}\vec{p} \rightarrow e'\pi^+ n$

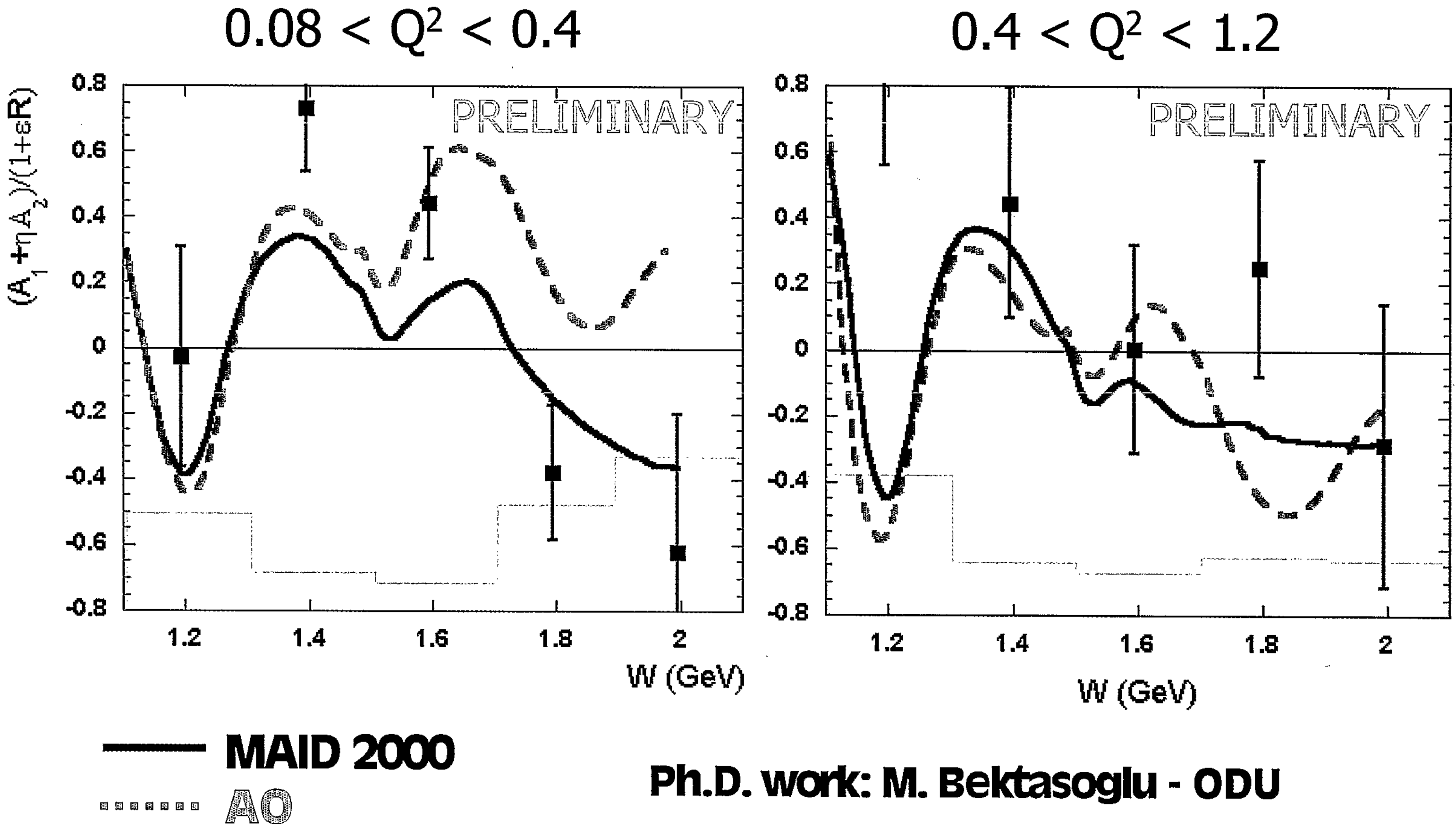


Ph.D. work: R. De Vita – INFN Genova

Double Spin Asymmetry in $\vec{e}\vec{p} \rightarrow e'\pi^0 p$



Double Spin Asymmetry in $\vec{e}\vec{n} \rightarrow e'\pi^- p$



Ph.D. work: M. Bektasoglu - ODU

Summary

- Our data on the proton and deuteron provide the first detailed look at spin structure functions in the resonance region at low to moderate Q^2
  - Γ_1^p changes sign at ~ $Q^2=0.25$ for the proton
  - Γ_1^d changes sign at ~ $Q^2=0.6$ for the deuteron
  - Bjorken integral shows interesting behavior
- The double spin asymmetry for single pion production has been studied for the first time with polarized electron beam and target
  - Three channels:
    - $p \rightarrow n\pi^+$
    - $p \rightarrow p\pi^0$
    - $n \rightarrow p\pi^-$
  - Rough agreement with phenomenological predictions
  - Sensitive to the details of individual resonance contributions

Outlook

- Last year we finished the second phase of the experiment - EG2000 (or EG1b)
  - 23 billion events (7 months of data)
  - Data at 1.6, 2.5, 4.2 and 5.7 GeV
  - Extend measurements to higher and lower Q^2
  - Better target polarization, better statistics

Next Talk: Preliminary Results

- Jefferson Lab upgrade to 12 GeV