Measuring the Fifth Structure Function in $D(\vec{e}, e'p)n$

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for the CLAS Collaboration

1. Introduction and Background.
2. Event Selection and Corrections.
3. Extracting the Fifth Structure Function.
4. Preliminary Comparison with Theory
5. Conclusions.

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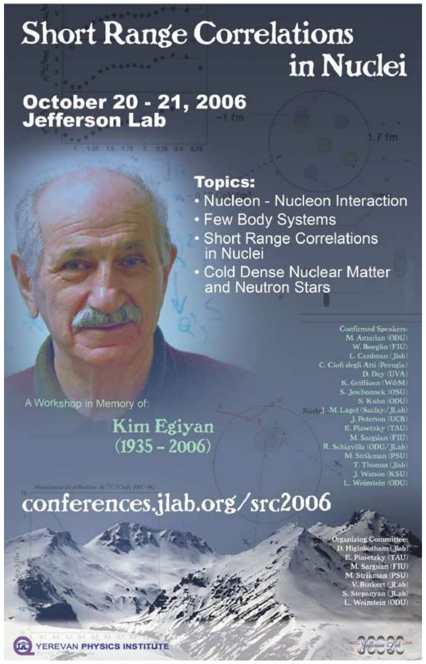
Scientific Motivation

- Establish a baseline for the hadronic model to meet. The deuteron is an essential testing ground because it is the simplest nucleus. On the theory side see also Deuteron Benchmarking Project.[a]

- Differing mix of relativistic corrections (RC), meson-exchange currents (MEC), final-state interactions (FSI), and isobar configurations (IC) depending on kinematics.



- Learn more about FSI in quasielastic kinematics.
  - The fifth structure function is zero in PWIA and is dominated by FSI.
  - Short-Range Correlations (SRC).
  - Deuteron as neutron target, N^*N interaction ...

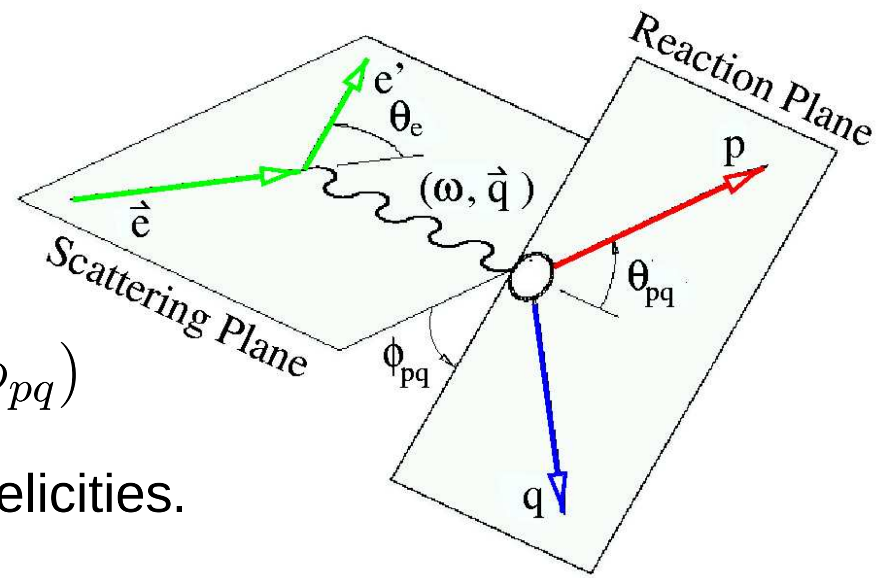
[a] http://hule.fiu.edu/highnp/deubenchmarking.htm

Introduction

- Goal: Measure the imaginary part of the LT interference term (the fifth structure function) of $D(\vec{e}, e'p)n$ at $Q^2 \approx 1\ (GeV/c)^2$.

- The cross section is

$$\frac{d^3\sigma}{d\omega d\Omega_e d\Omega_p} = \sigma^{\pm} = \sigma_L + \sigma_T + \sigma_{LT}\cos(\phi_{pq}) + \sigma_{TT}\cos(2\phi_{pq}) + h\sigma'_{LT}\sin(\phi_{pq})$$



where $\pm$ refers to different beam helicities.

- Asymmetry requires polarized beam.

beam helicity

$$A'_{LT} = \frac{\sigma^+_{90} - \sigma^-_{90}}{\sigma^+_{90} + \sigma^-_{90}} = \frac{\sigma'_{LT}}{\sigma_L + \sigma_T - \sigma_{TT}}$$

ϕ_{pq}

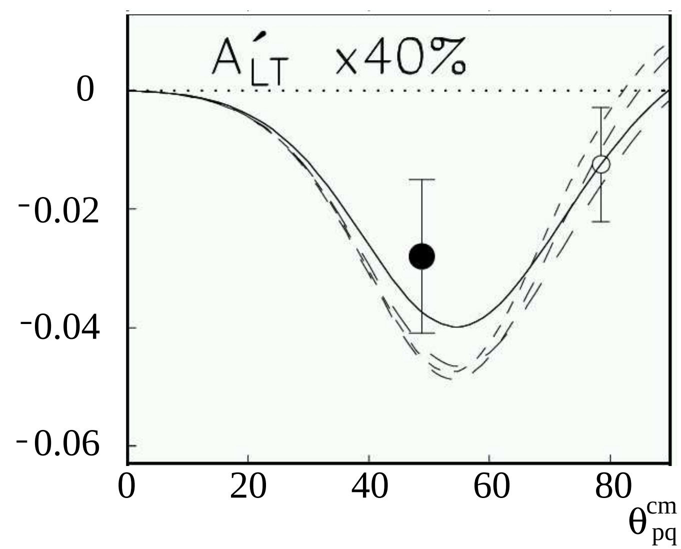
$$\sigma'_{LT} \propto Im(J^z_{fi}(\vec{q})^* J^y_{fi}(\vec{q}))$$

$$\vec{p}_m = \vec{q} - \vec{p}_p$$

This asymmetry is for single angles only!

Existing Measurements of Structure Functions of the Deuteron

- Several results from Bates in the 1990's for different structure functions and kinematics (*i.e.*quasielastic, 'dip' region) using the Out-Of-Plane Spectrometer. See S.Gilad, *et al.*, NP **A631**, 276c, (1998) and references therein.

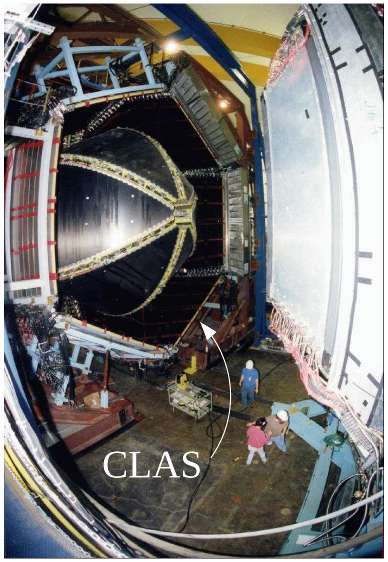


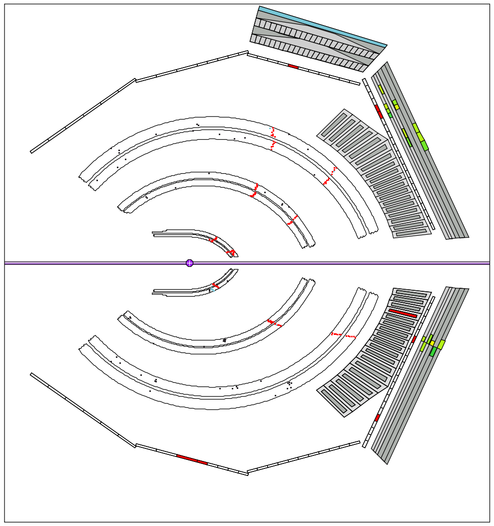
- Existing efforts at JLab to measure deuteron structure functions in quasielastic kinematics.
  - W. Boeglin, Hall A experiment E01-020 - measure R_{LT}.
  - This report.

Data Collection with CLAS

- CEBAF is the 7/8-mile-long, racetrack-shaped electron accelerator at JLab that produces continuous electron beams up to 6 GeV.

- CLAS is a 45-ton, six-sector detector covering most of 4π, with drift chambers to measure trajectories, scintillators for TOF, Cerenkov counters to identify electrons, and calorimeters to measure energy. A toroidal magnetic field determines momentum.





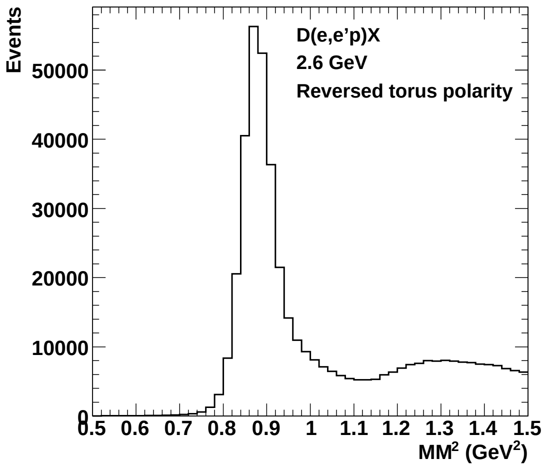
The Data Set

- Analyze data from the E5 run period in Hall B.
- Two beam energies, $4.23\, GeV$ and $2.56\, GeV$, with normal torus polarity (electrons inbending).
- One beam energy $2.56\, GeV$ with reversed torus polarity (electron outbending) to reach lower Q^2.
- Recorded about 2.3 billion triggers, $Q^2 = 0.2 - 5.0 (GeV/c)^2$.
- Dual target cell with liquid hydrogen and deuterium.
- Beam polarization: 0.736 ± 0.017

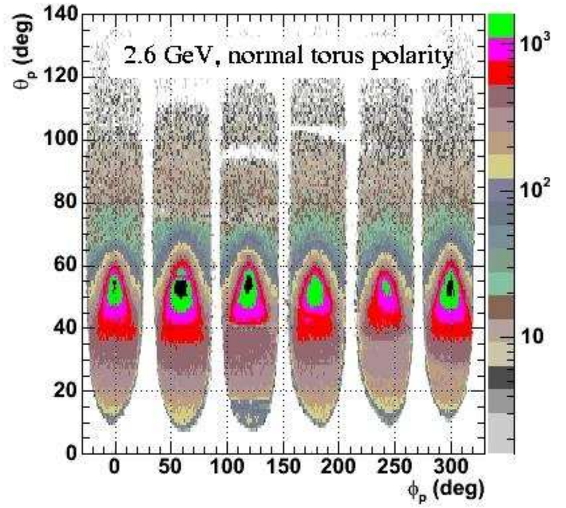
Event Selection and Corrections

- Select $e - p$ coincidences in quasi-elastic kinematics using a cut on the energy transfer so $\nu = \frac{Q^2}{2M_N} {}^{+0.03}_{-0.01}$ GeV.

- Use missing mass to select neutrons $0.84\,\mathrm{GeV}^2 \leq \mathrm{MM}^2 \leq 0.92\,\mathrm{GeV}^2$.



- Put fiducial cuts on electrons and protons.[a]



- Corrections: acceptance,[b] momentum, beam charge asymmetry.

[a]See Poster 3A.00030 by Kristen Greenholt in CEU session this afternoon.

[b]See Poster 3A.00012 by Rusty Burrell and Kuri Gill in CEU session this afternoon.

Method for Extracting A'_{LT}

To take full advantage of the nearly 4π coverage of CLAS we extract the ϕ_{pq}-dependent moments of the data in each each bin in p_m. Let

$$\langle \sin\phi_{pq}\rangle_{\pm} = \frac{\int_{-\pi}^{\pi} \sigma^{\pm} \sin\phi_{pq} d\phi_{pq}}{\int_{-\pi}^{\pi} \sigma^{\pm} d\phi_{pq}} = \pm \frac{\sigma'_{LT}}{2(\sigma_L + \sigma_T)} \approx \pm \frac{A'_{LT}}{2} \quad .$$

no σ_{TT} term

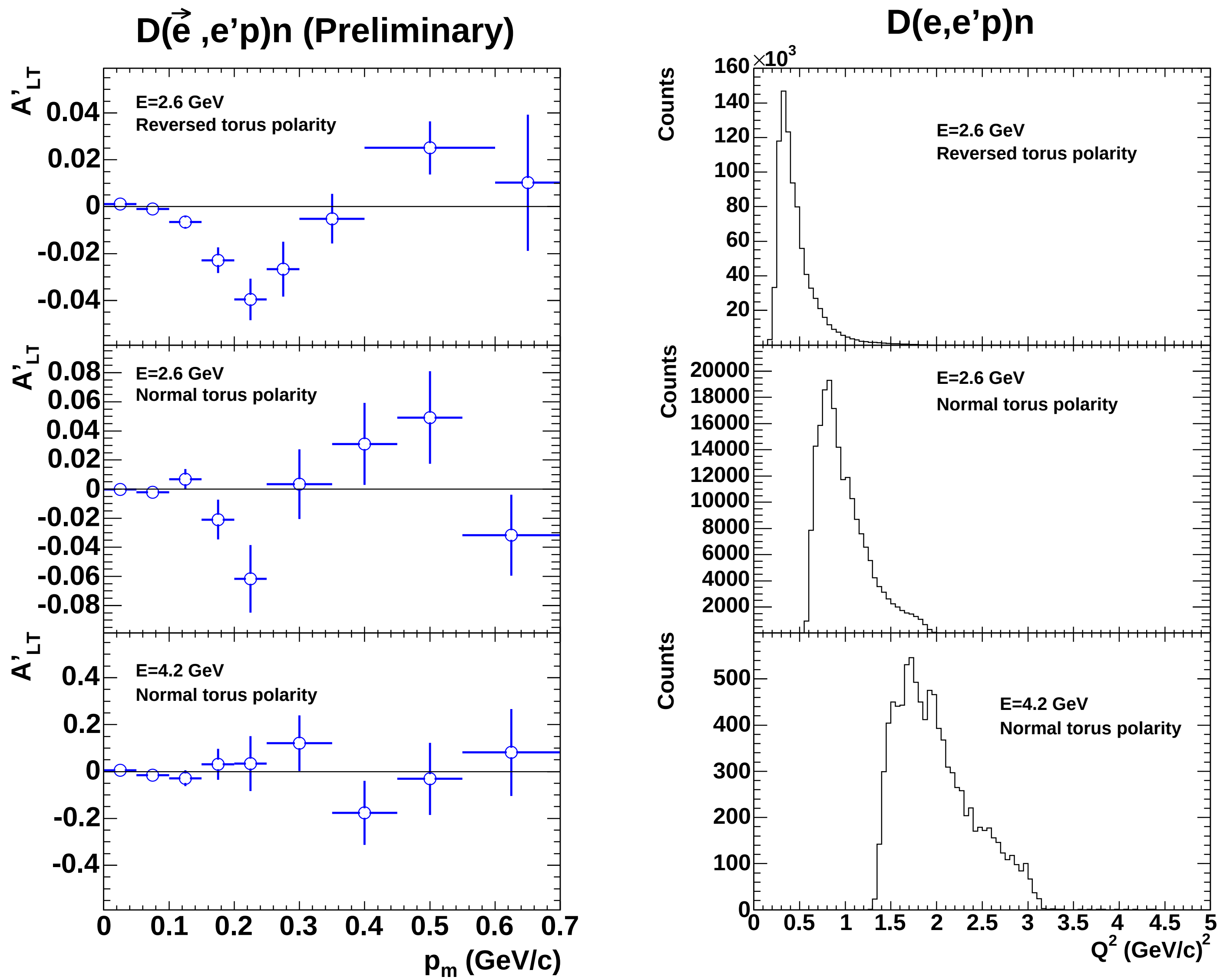
If there is a sinusoidally-varying component to the acceptance, then

$$\langle \sin\phi_{pq}\rangle_{\pm} = \pm \frac{A'_{LT}}{2} + \alpha_{acc}$$

and we can get rid of that background by subtracting the results for the different helicities.

$$\langle \sin\phi_{pq}\rangle_{+} - \langle \sin\phi_{pq}\rangle_{-} = A'_{LT}$$

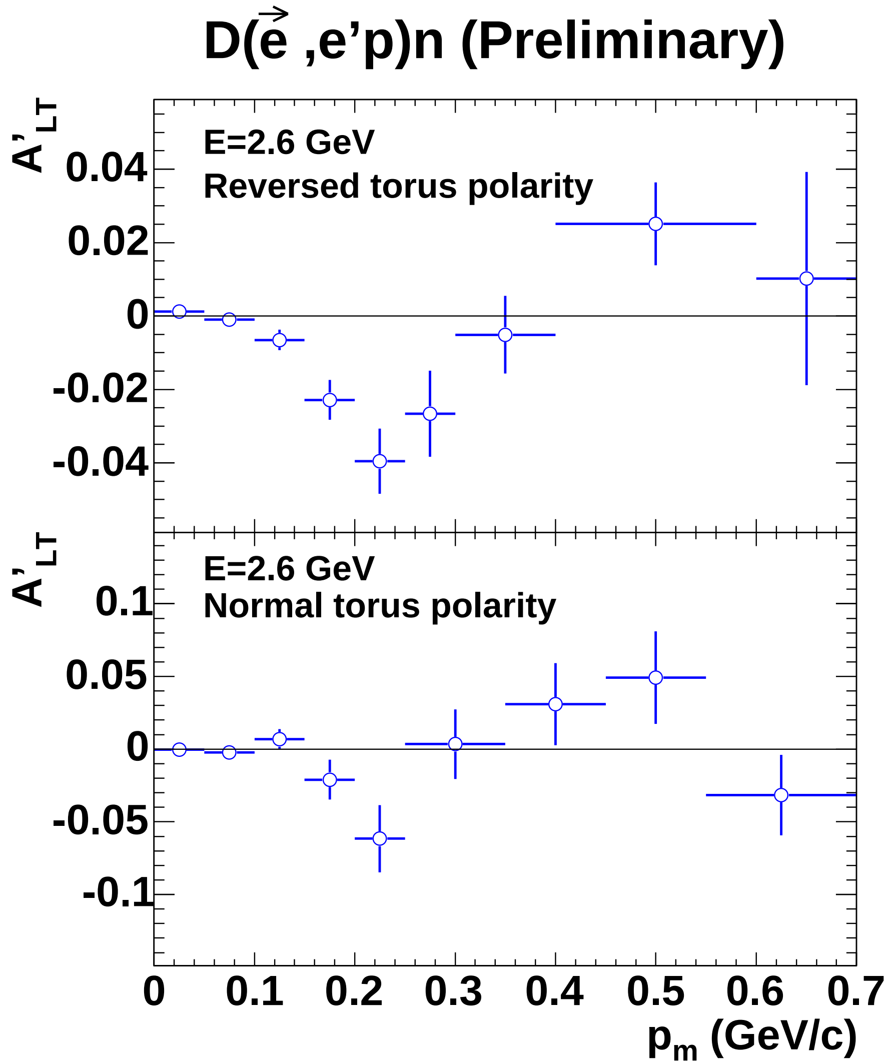
Preliminary A'_{LT} Results for $D(\vec{e}, e'p)n$



Some Consistency Checks

Effect of Fiducial Cuts

$ep \rightarrow e'p\pi^0$ Comparison



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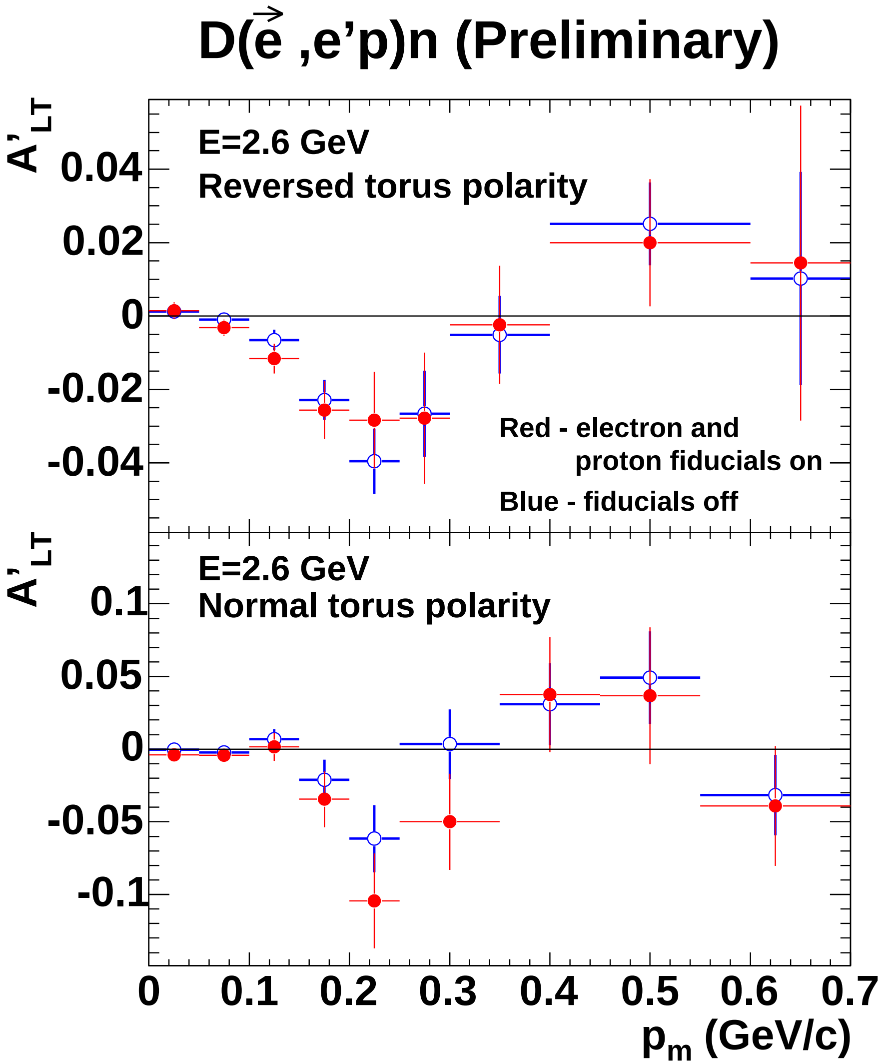

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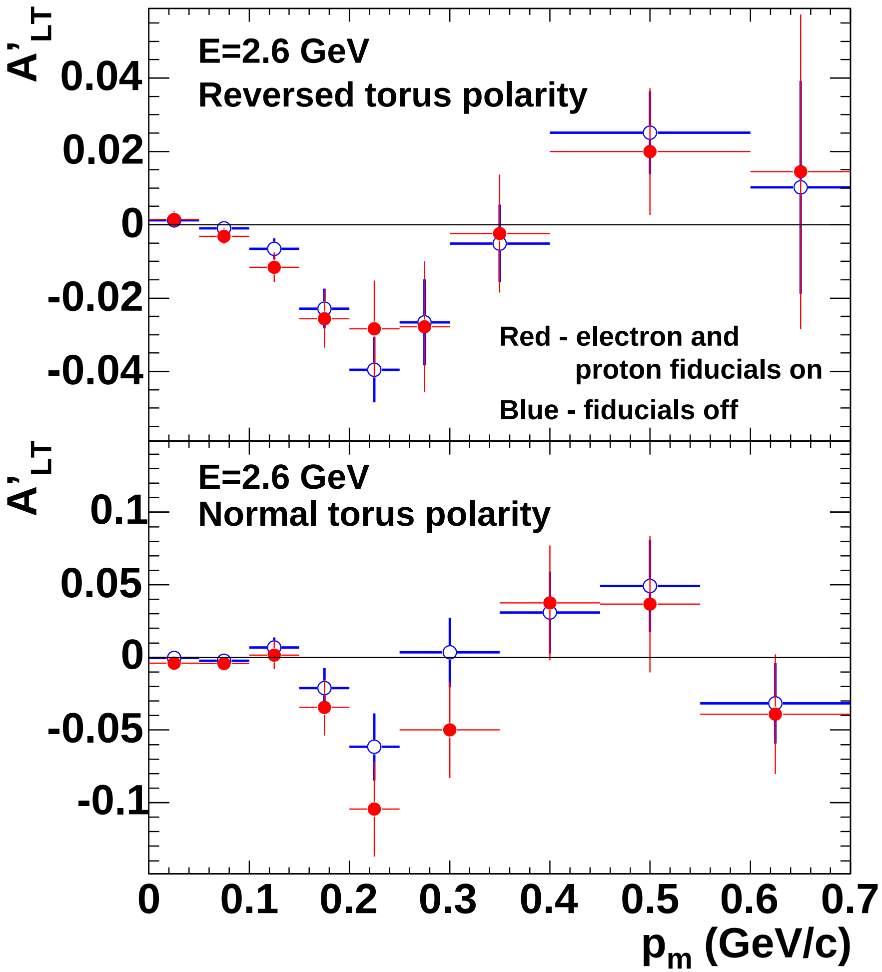
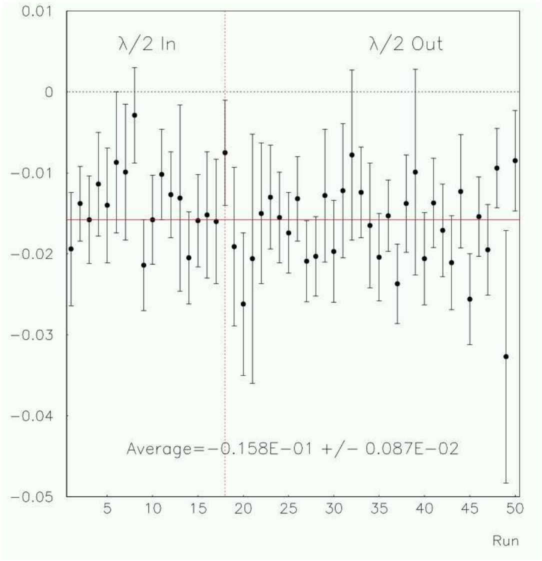
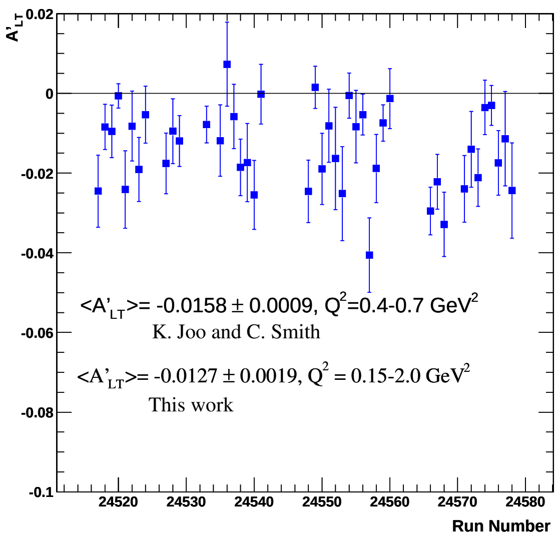
$D(\vec{e},e'p)n$ (Preliminary)



$ep \to e'p\pi^0$ Comparison



K.Joo and C.Smith, CLAS Analysis Note 2001-008.



Preliminary Comparison With Theory

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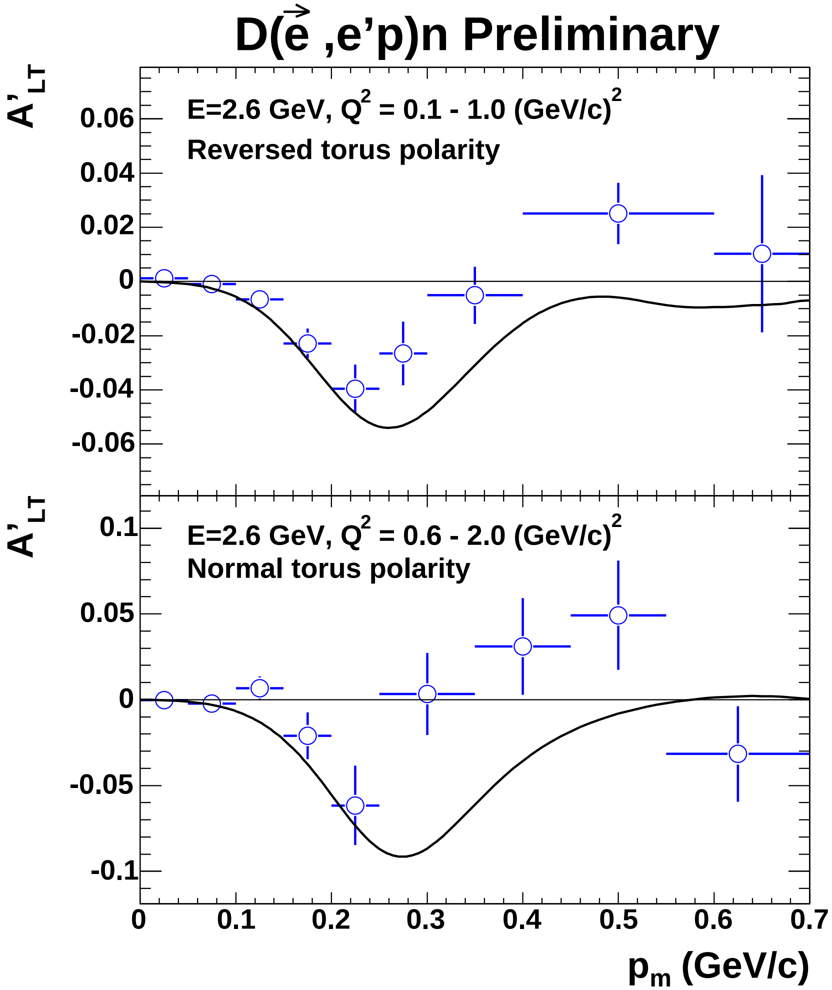

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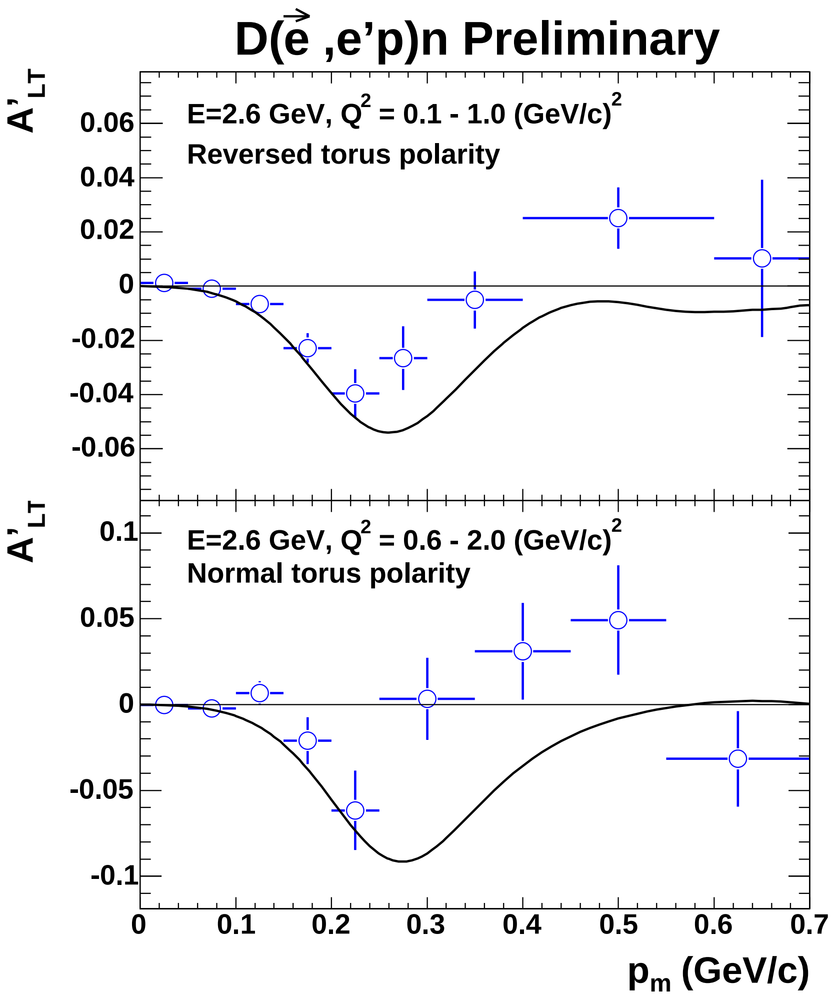

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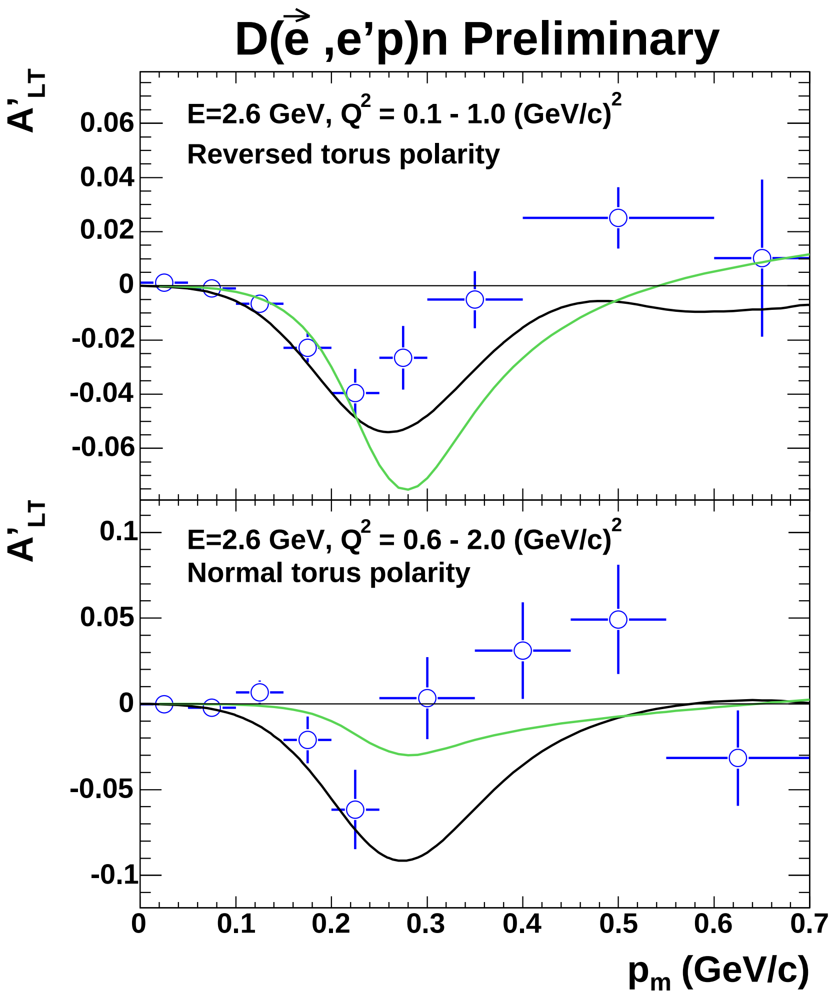

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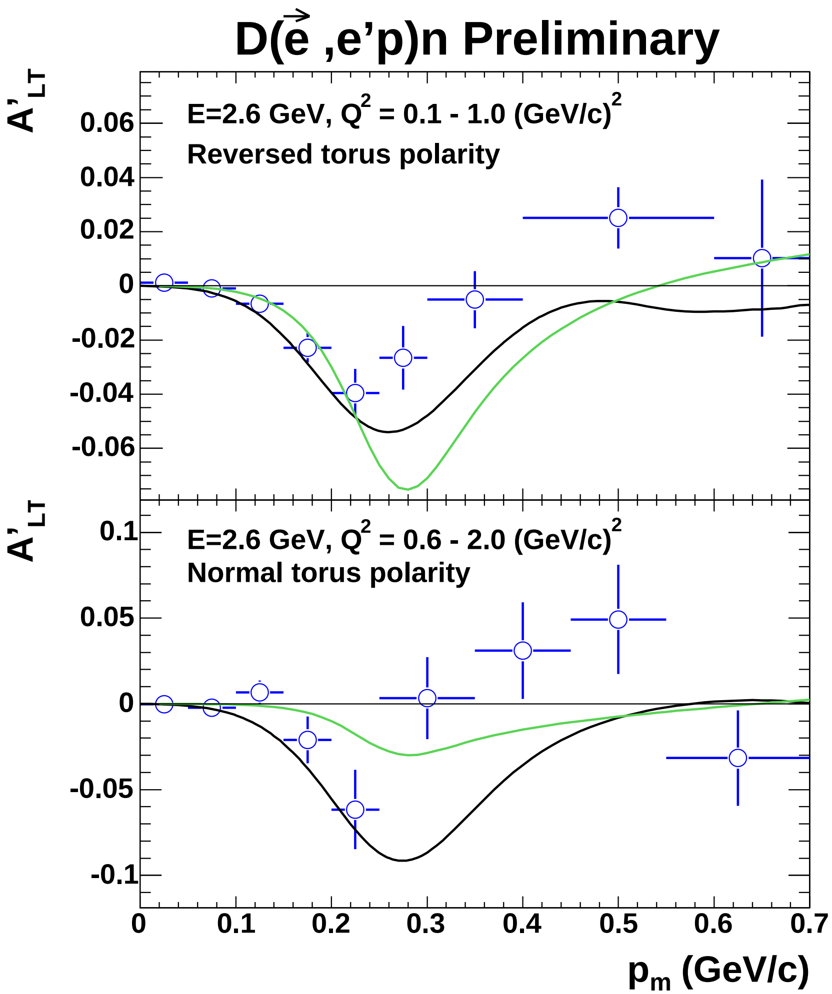

See Sabine's talk!

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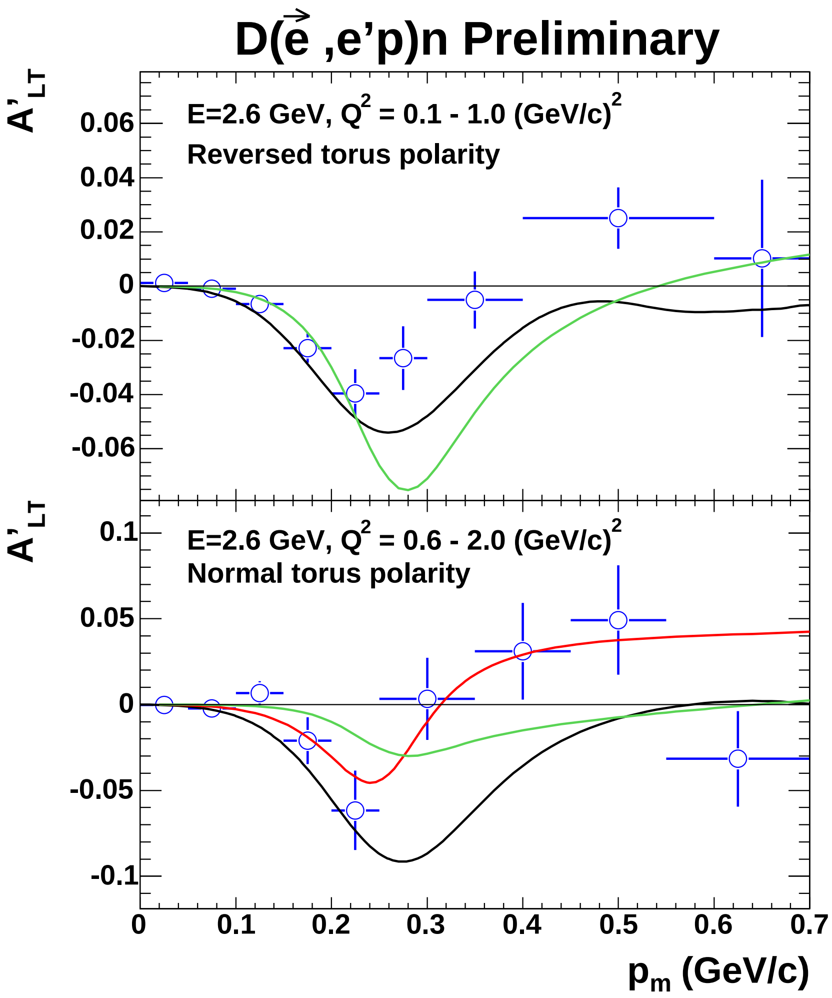

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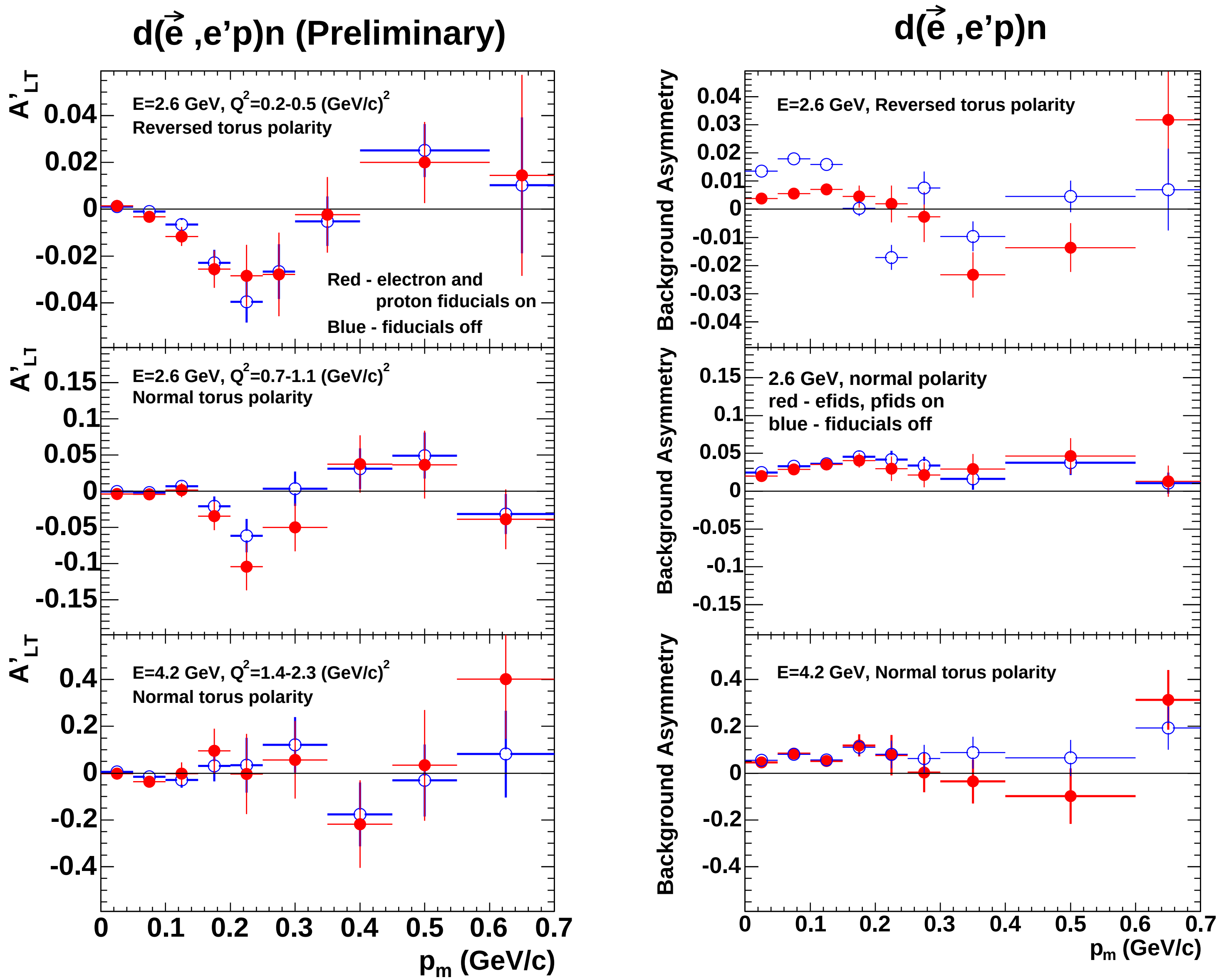
Conclusions

- We observe a 4% dip in A'_{LT} at $p_m \approx 220\ MeV/c$ in the low Q^2 data set and a 6% dip in A'_{LT} at the same p_m in the middle Q^2 range. The high-Q^2 data has poor statistics for A'_{LT}.
- The calculation by Jeschonnek reproduces the data in the middle Q^2 range!
- At low p_m, the calculations by Arenhövel reproduce the data, but diverge (they're too negative) above $p_m = 250\ MeV/c$.
- At low p_m, the Laget calculations reproduce the low-Q^2 data, but are too small in magnitude in the middle Q^2 range.
- The $\langle \sin\phi_{pq} \rangle$ technique works well including the subtraction of the two different beam helicities to eliminate sinusoidal components of the acceptance.

Asymmetry Background Results



W dependence of A'_{LT} at the Quasi-elastic Peak