Probing the Dynamics of Quarks in a Proton using CLAS at JLab

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Tallahassee, FL
July 2007

Motivation

"Proton Spin Crisis" -- EMC experiment at CERN

→ Only a small fraction of the spin of a proton comes from the constituent quarks.

$$\frac{1}{2} = \frac{1}{2}\Sigma + \Delta G + L_q + L_g$$

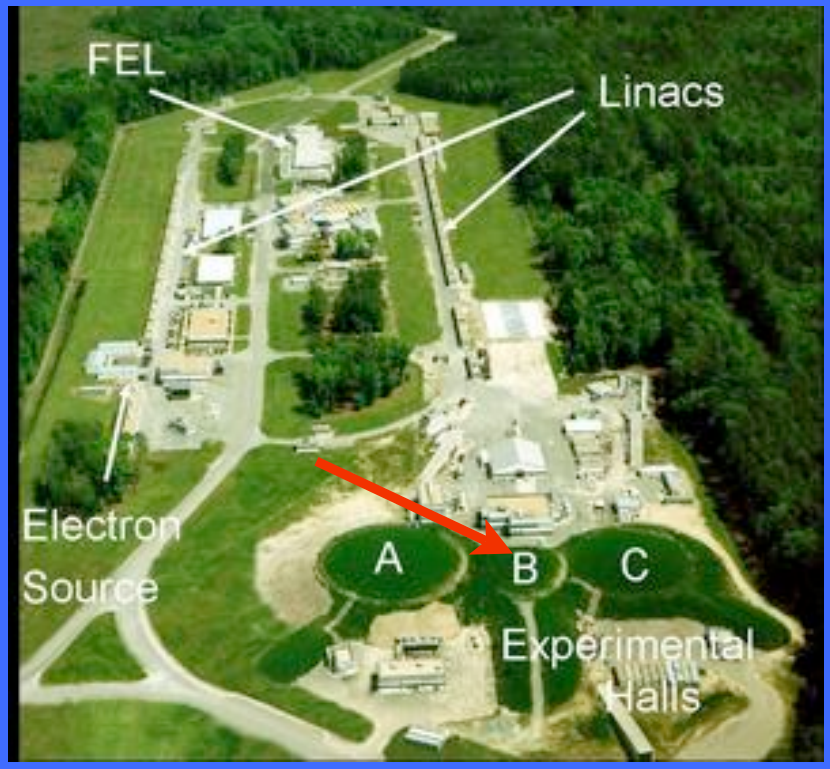
Possible sources of proton spin:

1. Quark Spin
2. Gluon Spin
3. Quark Orbital Angular Momentum

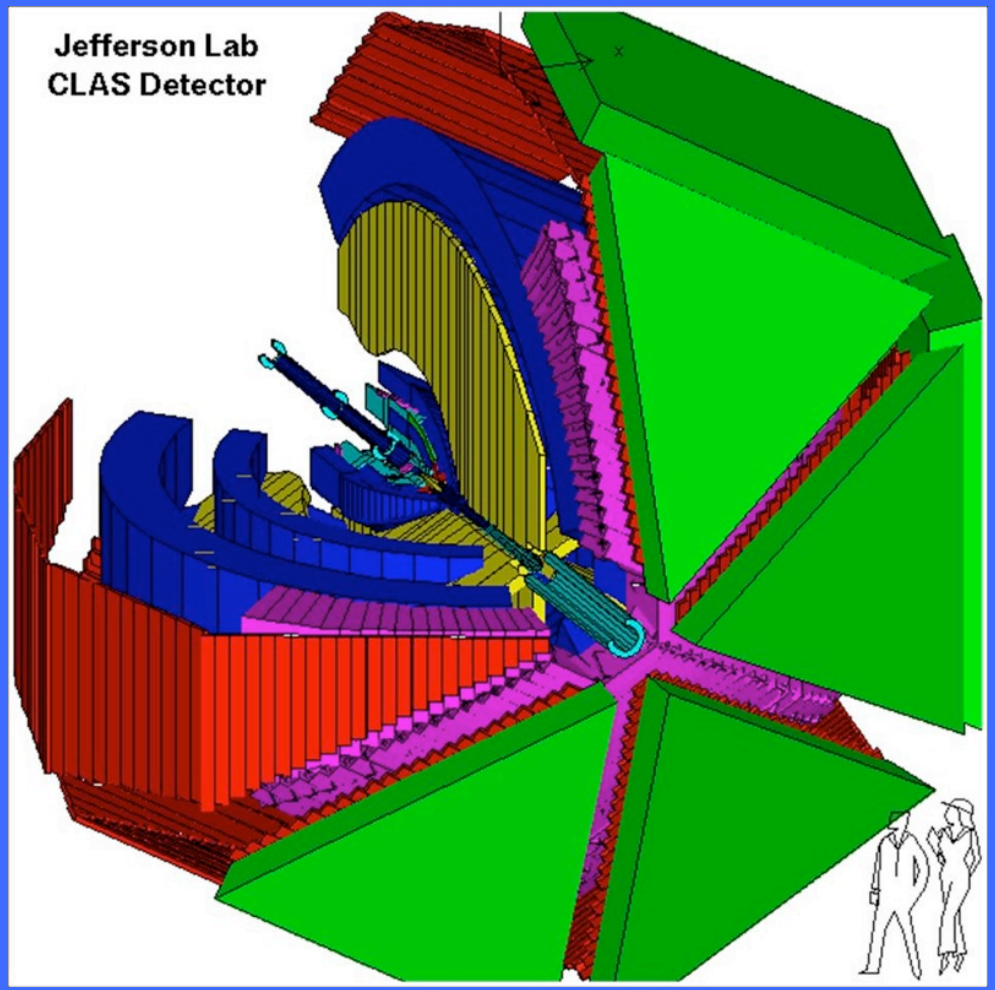
→ Quark orbital angular momentum related to transversity distribution: $\delta q(x)$

Jefferson Lab

- 6 GeV Polarized Electron Beam
- Three Experimental Halls
- CLAS is in Hall B



CLAS



B. Mecking et al.,Nucl. Instr. and Meth. A 376 (1996) 335

- Toroidal magnetic field produced by six superconducting coils
- 34 layer drift chambers provide tracking information
- Electron identification by electromagnetic calorimeter and Cerenkov counter
- Time-of-flight used to measure particle's mass

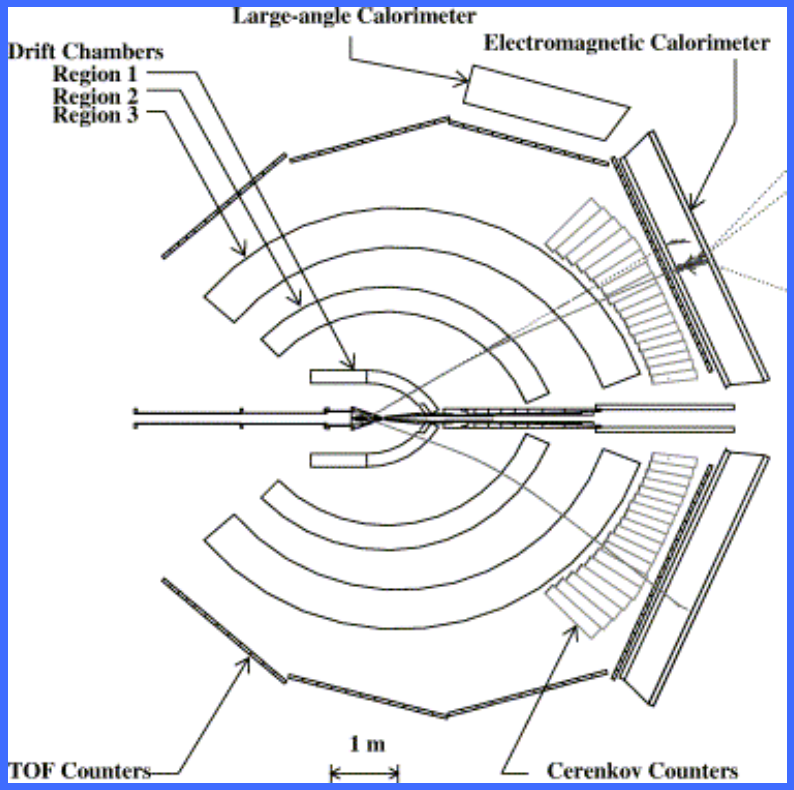
Experiment

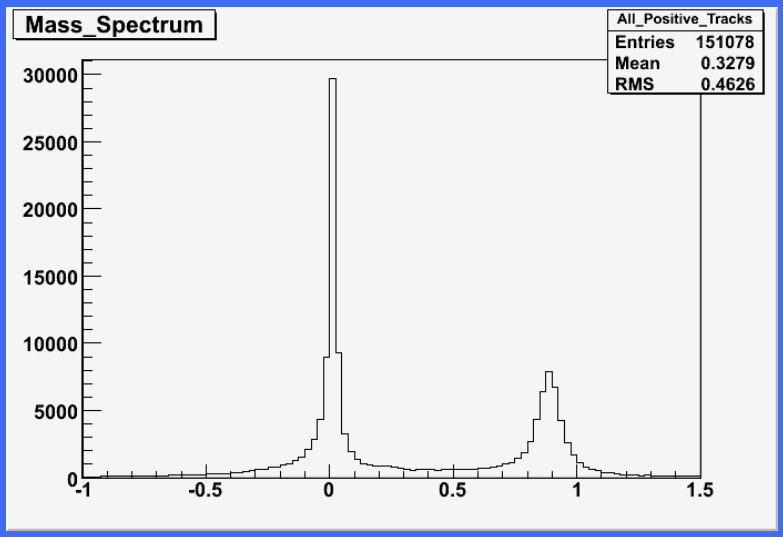
$$ep \longrightarrow e\pi^{\pm}X$$

- A 6 GeV polarized electron beam was collided upon an unpolarized liquid-hydrogen target.
- Will determine pion-production cross sections in semi-inclusive deep inelastic scattering

Finding Pions (+)

Positive particles are identified based on their direction of curvature in the magnetic field.

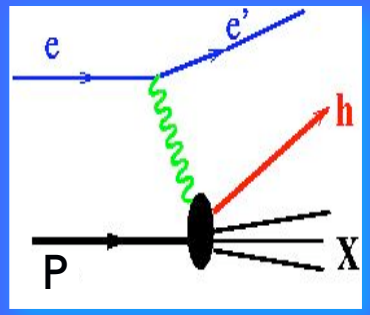




The above histogram was generated by selecting all positive tracks from a set of data and binning the particles by mass. The taller peak represents pions (0.1396 GeV).

Semi-Inclusive Deep Inelastic Scattering (SIDIS)

- Fragmentation Functions measured
- Quark flavors distinguished
- Orbital Angular Momentum of Quarks

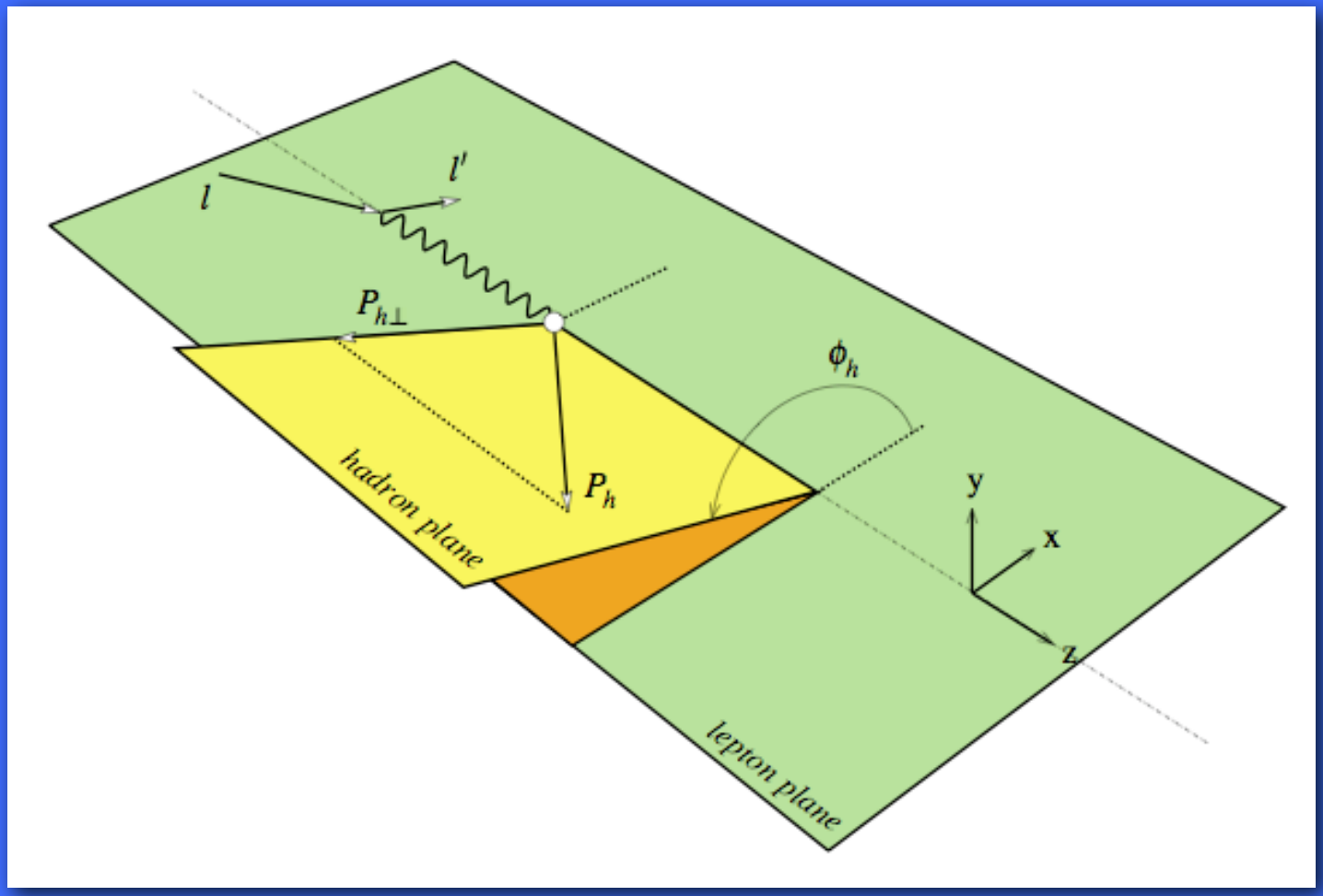


Distribution Functions	Even Chirality	Odd Chirality
twist 2: { U, L, T }	$\{q,\ \Delta q,\ f_{1T}^{\perp}\}$	$\{h_1^{\perp}, h_{1L}^{\perp}, \delta q\}$
twist 3: { U, L, T }	$\{f^{\perp}, g_L^{\perp}, g_T^{\perp}\}$	$\{e, h_L, h_T\}$

Distribution functions that can be accessed via SIDIS

Requires W > 2 GeV

Kinematics



Cross sections are measured in terms of phi, the angle between the leptonic and hadronic planes

Cross Sections

Expanding cross section in terms of phi:

$$\sigma = \sigma_0 + \sigma_1 \cos\phi + \sigma_2 \cos 2\phi + \lambda_e \sigma_3 \sin\phi$$

Separating the beam spin-independent part and the helicity dependent part and writing in terms of structure functions:

$$\frac{d\sigma_{UU}}{dx_B dy dz d^2P_\perp} = \frac{4\pi\alpha^2 s}{Q^4} x_B \{(1 - y + \frac{y^2}{2} + \frac{\gamma^2}{4}) H_T + (1 - y - \frac{\gamma^2}{4}) H_L$$
$$- (2 - y)\sqrt{1 - y - \gamma^2/4}\cos\phi H_{LT} + (1 - y - \gamma^2/4)\cos 2\phi H_{TT}\}$$

$$\frac{d\sigma_{LU}}{dx_B dy dz d^2P_\perp} = \lambda_e \frac{4\pi\alpha^2 s}{Q^4} x_B \sqrt{y^2 + \gamma^2}\sqrt{1 - y - \gamma^2/4}\sin\phi H'_{LT}$$

Where: $\gamma^2 = \frac{4M^2 x_B^2}{Q^2}$ $x_B = \frac{Q^2}{2P_1 \cdot q}$ $y = \frac{P_1 q}{P_1 \cdot k_1}$

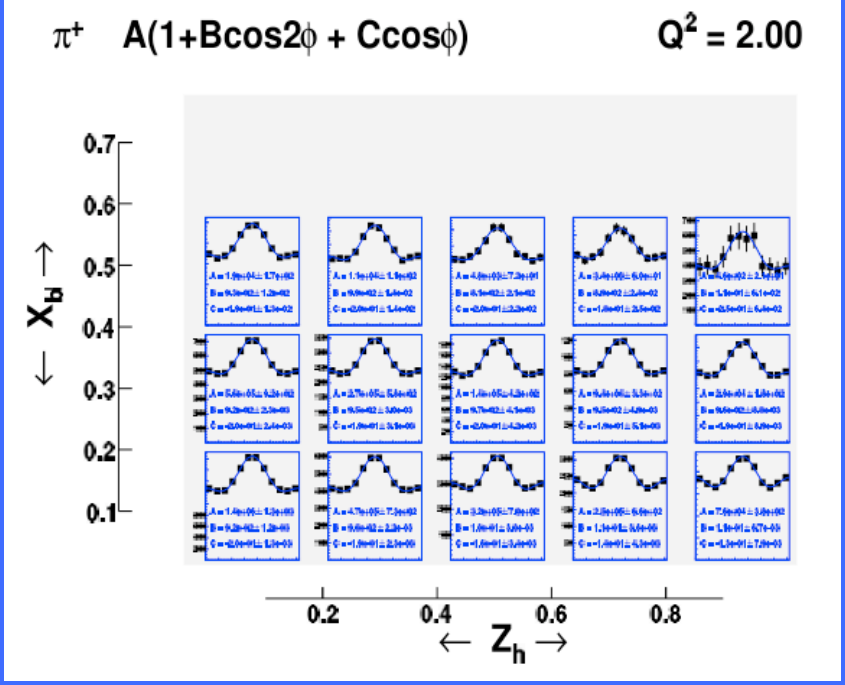
$z = \frac{P_1 \cdot P}{P_1 \cdot q}$ $Q^2 = -q^2$ $q = k_1 - k_2$

Asymmetry

$$Asym. = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\sigma_3 \sin\phi}{\sigma_0 + \sigma_1 \cos\phi + \sigma_2 \cos 2\phi}$$

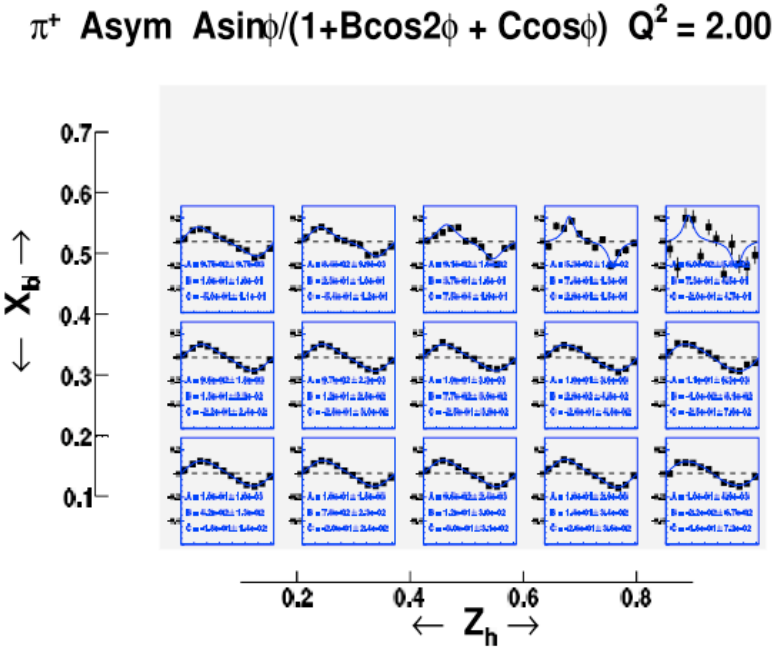
- Extraction of fragmentation functions provide access to additional distribution functions which describe quark structure at leading twist.
- Low sensitivity to acceptance (good for systematic errors)

Simulated Cross Sections



The data will be compared to Monte Carlo simulations in order to extract the relevant physical information.

Simulated Asymmetries



Concluding Remarks

- Pion production will be studied in SIDIS at 6 GeV to learn about the quark dynamics in the proton.
- Cross-section coefficients will be measured to provide information about the proton's structure.
- Asymmetry measurements will give insight into the transversity distribution of quarks inside the proton.