Spin Asymmetries of the Nucleon Experiment

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Glen Warren

Jefferson Lab

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Outline

- Spin structure
- Why high *x?*
- How we will measure A_{1p} and g_2
- Projected Results
- Summary

Spin Structure

Deep Inelastic lepton scattering data has yielded wealth of knowledge of nucleon structure. Quark distributions inside nucleon are described by four structure functions

- Structure functions: F_1, F_2 - cross section
- Spin Structure Functions: g_1, g_2 - polarization observables

In Quark-Parton Model, we can write F_1 and g_1 in terms of helicity dependent quark distribution functions, $q_i^{\pm}\ x$:

$$F_1(x) = \frac{1}{2}\sum_i e_i^2 [q_i^+ + q_i^-]$$

$$g_1(x) = \frac{1}{2}\sum_i e_i^2 [q_i^+ - q_i^-]$$

Q^2 dependence follows QCD-based evolution of DGLAP.

g_2

$g_2(x,Q^2)$ does not have as simple an interpretation as g_1:

$$g_2 = g_2^{WW} + \bar{g}_2$$

g_2^{WW} depends only on g_1 (twist 2):

$$g_2^{WW} = -g_1 + \int_0^1 g_1(y,Q^2)/y\, dy$$

$\bar{g}_2$ vanishes when all twist-3 (d_n) matrix elements vanish in **O**perator **P**roduct **E**xpansion (OPE), e.g.

$$d_2 = 3\int_0^1 x^2 \bar{g}_2(x,Q^2)\, dx$$

$g_1, g_2 \leftrightarrow A_1, A_2$

The spin structure functions g_1 and g_2 are related to the asymmetries A_1 and A_2 by:

$$A_1 = \frac{\sigma_{1/2}^T - \sigma_{3/2}^T}{\sigma_{1/2}^T + \sigma_{3/2}^T} = \frac{1}{F_1}(g_1 - \gamma^2 g_2)$$

$$A_2 = \frac{2\sigma_{LT}}{\sigma_{1/2}^T + \sigma_{3/2}^T} = \frac{\gamma}{F_1}(g_1 + g_2)$$

$\gamma = 2Mx/Q$

Total photon nucleon helicity

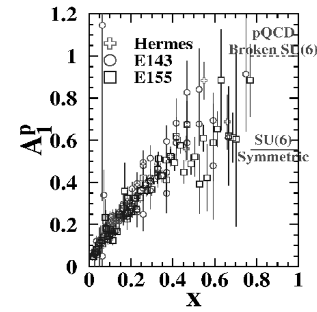
Thus the asymmetries have the added complication of F_1, which actually helps to reduce the Q^2 dependence of A_1 and A_2.

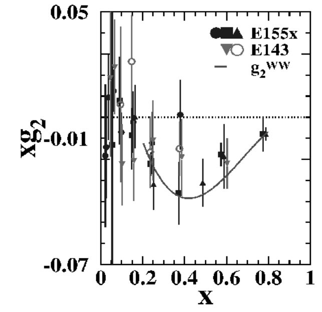
Why High x?

$$x = Q^2 / 2M\nu$$

- Understanding higher order moments to compare to LQCD and QCD predictions.
- Higher twist effects become more significant at higher x.
- Examine predictions of $x \rightarrow 1$ of A_{1p} of pQCD and SU(6) models:
  - SU(6) symmetric $A_{1p} \rightarrow 5/9$,
  - SU(6) broken and pQCD predicts $A_{1p} \rightarrow 1$, but different reasons.
- Region in which sea quarks play only minor role .
- Region not saturated with data.
- Need better data to better understand extrapolation to $x \rightarrow 1$.

World's Data at High x





- Dominated by NH_3 experiments.
- CLAS data under analysis.

- g_2^{WW} is twist 2 - from g_1.
- Significant uncertainty around x=0.4

Extraction

Measure inclusive beam-target asymmetries with polarized electron beam and polarized proton target.

For a target field orientation w.r.t. the beam θ_N the measured asymmetry is related to A_1 and A_2 by:

$$A_{meas}(\theta_N) = \alpha A_1[\cos(\theta_N) - \rho\sin(\theta_N)] + \beta A_2[\rho\cos(\theta_N) + \sin(\theta_N)]$$

$$\alpha = \alpha(E, E', \theta, R) \quad \beta = \beta(E, E', \theta, R) \quad \rho = \rho(E, E', \theta)$$

By measuring the beam-target asymmetry for two values of θ_N, we can extract A_1 and A_2.

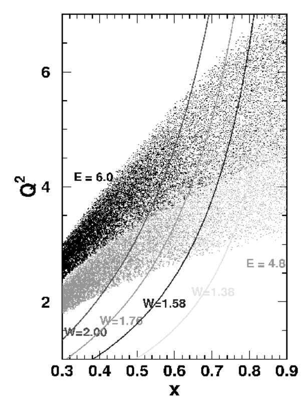
- Most sensitive to A_1 for $\theta_N = \theta_q$
- Most sensitive to A_2 for $\theta_N \approx 90^\circ$

Geometry of target magnet prevents 90˚ measurement, instead we will use 180˚ and 80˚.

Two Beam Energies

We propose to take measurements at 4.8 and 6.0 GeV beam energies because:

- Provides limited test of local duality for spin observables. If local duality can be demonstrated, then can significant extend maximum x.
- Study Q^2 dependence for constant x
- Study x dependence for constant Q^2



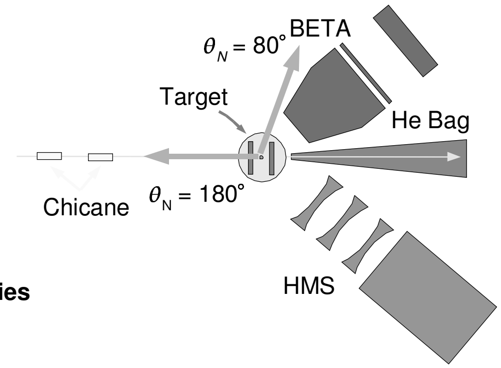
Experimental Setup

Target
- UVa NH3 target
- 5 T field

Beamline
- Chicanes
- SEM
- He Bag

Electron Arm
- BETA

Background Studies
- HMS

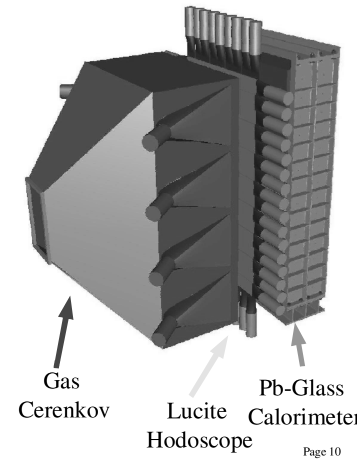


Big Electron Telescope Array (BETA)

Gas Cerenkov
- Particle Identification
- Minimal knock-on

Lucite Cerenkov
- Redundant PID
- Tracking

Pb-Glass Calorimeter
- Calorimetry
- Hadron reduction

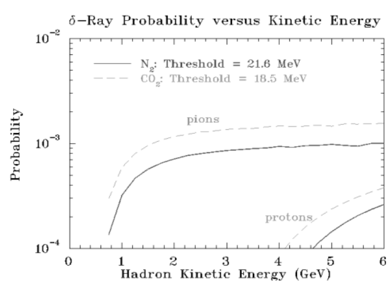


Gas Cerenkov

N_2 Gas
- Reduced knock-on's
- At STP, pion threshold is 5.8 GeV/c

Point-to-Point focusing
- Easy alignment of mirrors
- Further reduction of background

PMTs
- Baffled
- Apply tight electron cuts
- Expected 17-20 photoelectrons



Sytematics

Calorimeter Gains:
- Calibrated with proton elastics (using HMS in coincidence).
- Monitored through Lucite light system, cosmics and punch-through pions.

Background:
- Dominated by charge-symmetric processes, mostly $\pi^0 \to \gamma e^+ e^-$.
- Measured in HMS.
- Hadron backgrounds measured by ignoring Gas Cerenkov in trigger.

Estimated Systematics for 6 GeV

Radiative Corrections	1.5%
Dilution Factor	2.0%
Target Polarization	2.5%
Beam Polarization	1.0%
Nitrogen Correction	0.4%

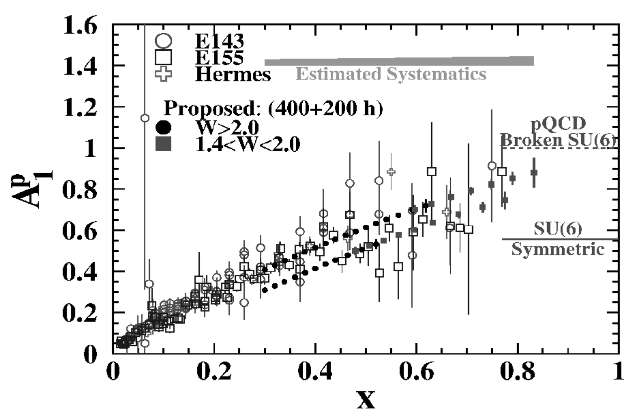
	A1p		g2	
	x=0.3	*x*=0.6	*x*=0.3	*x*=0.6
R	2.4%	1.8%	4.3%	2.5%
Kinematics	0.3%	0.3%	3.1%	3.6%
Background	5.7%	3.0%	5.7%	3.0%
Local	4.7%	3.2%	5.8%	4.3%
Global	5.5%	4.2%	6.4%	5.1%
Total	7.2%	5.1%	8.6%	6.5%

Systematics for 4.8 GeV are very similar

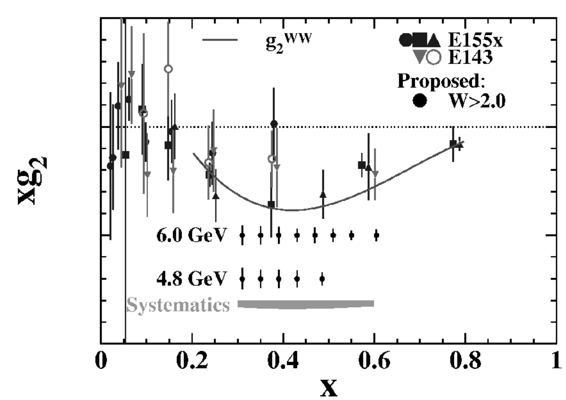
Beam Time request

	Energy	θ_N	Time (h)	
Production	6.0	180	325	
	6.0	80	75	
	4.8	180	170	
	4.8	80	30	
	2.4	-	50	
Systematics	Packing Fraction		20	
	Mollers		25	
	Total beam time		695	(29 d)
Overhead	Anneals		75	
	Energy Change		48	
	Target Rotation		48	
	Stick Changes		48	
	Total Overhead		219	(9 d)

A_1^p



g_2

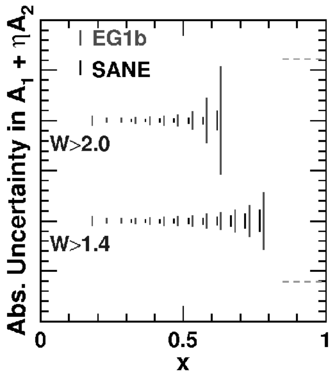


EG1b and SANE - $A_{\parallel}$

Projected statistics for SANE vs *estimated* statistics for EG1b.

For DIS at high x, need large angles; acceptance time luminosity much better for highest x bins than EG1b.

For resonance region, wider scattering angle acceptance improves EG1b to SANE comparison: SANE has FOM of only 4 times larger than EG1b for highest x bin.

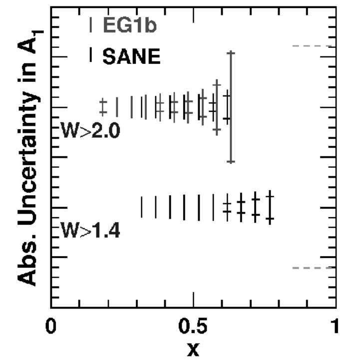


EG1b vs SANE - A_1

Add point-to-point systematic errors to statistics to estimate uncertainties in A_1 for local fits to data.

For EG1b:

- Assume same systematics as SANE.
- Include 3% uncertainty for A_2 subtraction.
- Only quality data for A_2 in resonance region is from E01-006 (RSS) at Q^2=1.3.



Collaboration

J.-P. Chen, R. Ent, D. Gaskell, J. Gomez, D. Higinbotham, M. Jones, D. Mack, J. Roche, G. Smith, G. Warren, B. Wojtsekhowski, S. Wood
Jefferson Lab

D. Day, N. Liyanage, P. McKee, O. Rondon, F. Wesselmann, H. Zhu
University of Virginia

E. Christy, C. Keppel
Hamption University

T. Averett
College of William and Mary

V. Kubarovsky, A. Vasiliev
Institute for High Energy Physics, Protvino

T.A. Forest
Louisiana Tech University

S. Choi, Z.-E. Meziani
Temple University

J. Jourdan, M. Kotulla, D. Rohe
University of Basel, Switzerland

A. Agalaryan, R. Asaturyan, H. Mkrtchyan, S. Stepanyan, V. Tadevosyan
Yerevan Physics Institute, Armenia

Summary

SANE : Spin Asymmetries of the Nucleon Experiment

Physics:

- Significant improvement in A_{1p} and g_2 in DIS at high *x*.
- Expansive study of *x* and Q^2 dependence.
- Limited test of local duality.
- Simultaneously collect data in resonance region.
- Proposed next logical step in proton spin structure at high *x*.

BETA

- Designed to handle high rates of low energy background.
- Provides proof of principle for Son Of BETA (SOB) calorimeter system for 12 GeV upgrade.
- As commented in TAC, BETA could open the possibility to other exclusive and semi-inclusive measurements.