SANE

Spin Asymmetries on the Nucleon Experiment

(TJNAF E-03-109)

SANE Collaboration
U. Basel, Florida International U., Hampton U., Norfolk S. U., IHEP-Protvino,
U. of Regina, Rensselaer Polytechnic I., Temple U., TJNAF, U. of Virginia,
College of William & Mary, Yerevan Physics I.

Spokespersons: S. Choi (Seoul), Z-E. Meziani (Temple), O. A. Rondon (U. of Virginia)

Collaboration Meeting
April 21, 2005
Jefferson Lab

SANE Status - Organization

- Six previous collaboration meetings (11/03; 3/- 6/- 9/- 11/04; 1/05).
- Four new collaborator groups since PAC until 1/05:
  - Florida International U., Norfolk State U., U. of Regina and second U. of Virginia group
- New group from North Carolina A&T in attendance, welcome to SANE
- New groups from St. Norbert College, (WI) and Kent S. U.
- Two IHEP-Protvino collaborators working on BigCal, dedicated SANE work 4 mos. starting 5/05
- SANE poster for Hall C Open House
  - Brad Sawatzky and Florentin Butaru
- Hall C schedule update (R. Ent report - 9/04):
  - SANE tentatively to run in 2007, followed by Semi-SANE
- Time lines still showing adequate lead time for installation in Fall 2006.

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Potential Physics from SANE

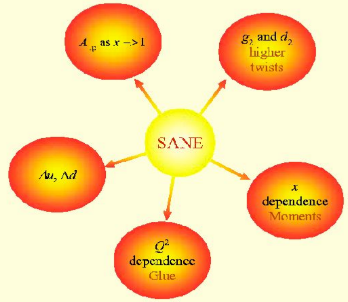
Electron scattering provides a powerful tool for studying the structure of the nucleus. The large x region (large transferred momentum) provides an window on proton structure in a regime where the sea quarks has been stripped away, potentially leading to insights into strong QCD and is essential for the determination of the nucleon spin structure functions (SSF).

The SSF's can be measured in inclusive inelastic scattering of polarized electrons on polarized nucleons. When the incident electron helicity is aligned with the target nucleon spin, the cross section is dominated by g_1, the *longitudinal* (||) SSF. When the target spin is perpendicular to the electron helicity, the cross section is dominated by g_2, the *transverse* ($\perp$) SSF. The conventional approach to extract g_1 and g_2 is to measure an *asymmetry* ($A=(\sigma_{\downarrow\uparrow}-\sigma_{\uparrow\downarrow})/(\sigma_{\uparrow\uparrow}+\sigma_{\uparrow\downarrow})$) for each of the above cases ($A_\perp$ and $A_\parallel$, respectively) instead of the cross section difference. Along with a set of kinematic factors *(a,b,c,d)*, the spin structure functions g_1 and g_2 are related to the asymmetries by:

$$A_1=a(A_\parallel-bA_\perp)=\frac{1}{F_1}(g_1-\gamma^2 g_2)$$

$$A_2=a(cA_\parallel-dA_\perp)=\frac{\gamma}{F_1}(g_1+g_2)$$

Our goal is to extract the proton A_1^p limited by systematic errors and a simultaneous statistics-limited measurement of g_2^p in the range $0.3<x<0.8$ at an average $Q^2=4.5$ (GeV/c)^2, in a model-independent fashion, from the measurement of the two asymmetries $A_\perp$ and $A_\parallel$ for two different orientations of the target magnetic field relative to the beam direction.



Why High x ? ($x=Q^2/2M\nu$)

- Understanding higher order moments to compare to Lattice QCD and QCD predictions.
- Higher twist effects become more significant at higher x.
- Examine predictions as $x\to 1$ of A_1^p of pQCD and SU(6) models:
  - SU(6) symmetric $A_1^p\to 5/9$.
  - SU(6) broken and pQCD predicts $A_1^p\to 1$, but different reasons.
- Region in which sea quarks play only minor role.
- Existing data at large x is limited compared to lower x region.
- Need better data to better understand extrapolation to $x\to 1$.

Experimental Setup

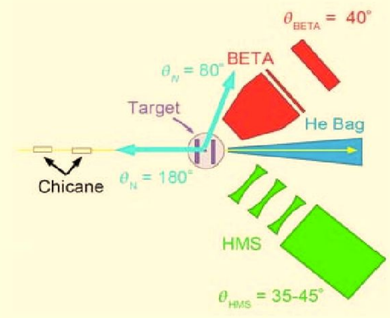
The experimental setup consists of the UVa polarized proton target, a total absorption electron telescope (BETA), the High Momentum Spectrometer (HMS), and the Hall C beam line with its now-standard augmentations to allow for 50-100 nA operations and several degrees of beam deflection by the target's magnetic field.

- The UVa target operates on the principle of Dynamic Nuclear Polarization, to enhance the low temperature (1K), high magnetic field (5T) polarization (up to 95%) in the NH_3 by microwave pumping. To minimize the source of systematic errors, its polarization direction is reversed after each anneal by adjusting the microwave frequency.

- BETA's low sensitivity to backgrounds, its high pixelization, low channel deadtime and large solid angle with adequate electron energy resolution make it ideal for large x measurements in DIS regime.

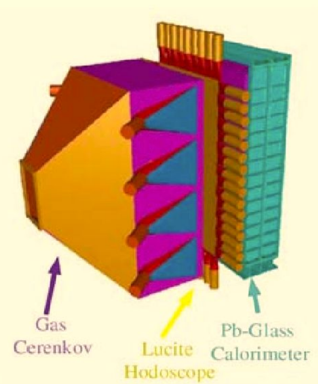
- While BETA can distinguish between charged and neutral particles, it is "blind" to the *sign* of the charge. Hence the measurement of charge-symmetric backgrounds will be carried out in parallel using the High Momentum Spectrometer (HMS).

- Two upstream chicane magnets are necessary to position the beam in the middle of the target for the non-parallel target field measurements.



Big Electron Telescope Array (BETA)

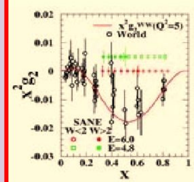
The BETA detector is based upon a 194 msr electromagnetic Calorimeter instrumented with Gas Cherenkov and Lucite Cherenkov (LC) detectors for clean electron identification, with a $\pi^\pm$ rejection of at least 1000:1. A drift space between the Lucite Cherenkov and the Calorimeter makes BETA a *telescope* with sufficient resolution to isolate events well within the scattering chamber.



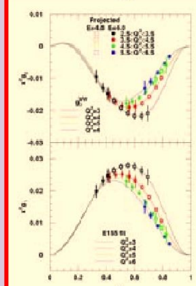
At a Glance:

- Energy resolution: $5\%/\sqrt{E(GeV)}$
- Assuming 3.6 cm (RMS) at LC:
  - Angular resolution: 2° (RMS)
  - Vertex resolution: 9.9 cm (RMS)
- d$\Omega\Delta$E of BETA > 100 times HMS for high x measurements
- Gas Cherenkov:
  - particle Identification (PID)
  - pions rejection
- Lucite Cherenkov:
  - redundant PID
  - tracking
- Pb-Glass Calorimeter:
  - hadron reduction

Expected Results



Projected results for g_2 compared to the world's data (black points), which are almost exclusively in the Deep Inelastic Scattering (DIS) region:
The red (green) points are the projected uncertainties from SANE for beam energy of 6.0 (4.8) GeV. The solid symbols denote SANE uncertainties in the DIS region, and the hollow ones are in the resonance region.



Statistical uncertainties in $x^2g_2^p$ and $x^2g_1^p$ in $\Delta Q^2=1(\mathrm{GeV/c})^2$ bins as a function of x:
We use the E155 fit to g_1/F_1 to calculate g_1 and g_2^{WW} for the solid lines. The projected uncertainties are shown as solid circles for 6.0 GeV and as hollow circles for 4.8 GeV.

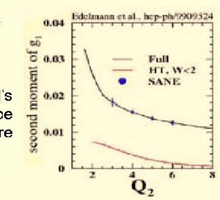
SANE enhancements:
- Smaller data uncertainties and x binning of points.
- Kinematic coverage is precisely where x^2g_2 is the largest (important in determining second moments).
- Data for all momenta are collected simultaneously for a given target field direction (point-to-point systematics of SANE are significantly reduced in this manner).

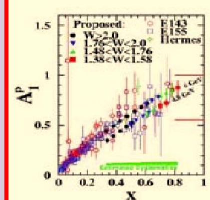
By measuring the *second moments* of g_1 and g_2 we can determine d_2 as:

$$d_2=\int_0^1 x^2(2g_1+3g_2)\,dx$$

When fitting the moments, we will include the world's data when it falls within the Q^2 bin. This will be particularly important in the low x region where SANE cannot provide data.

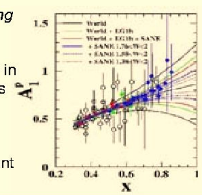
- Expected error on d_2 (Q^2 = 2.5 to 6 GeV^2) = 0.0009 (1/2 of the current world error).





Published world data for A_1^p for high x and SANE projected uncertainties for both beam energies:
- The E = 4.8 GeV points have been shifted down for clarity
- The two horizontal lines extending below x = 1 represent the *pQCD* (upper line) and *SU(6)* symmetric (bottom line) predictions for A_1^p at x = 1.
- The transverse target data from *SANE* would enable a model independent extraction of A_1 and g_1 from both *SANE* and *CLAS (EG1b)* data.

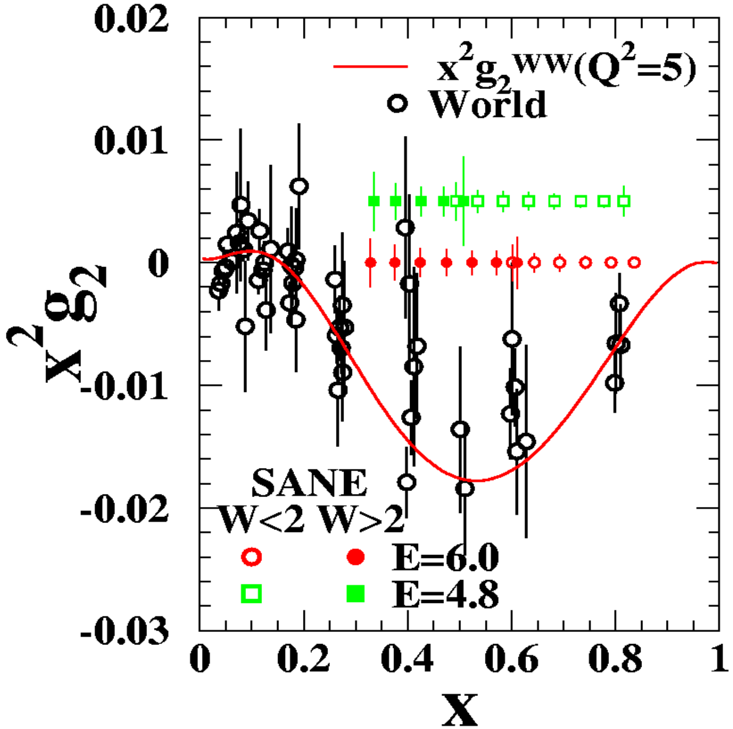
Potential impact of the SANE data on our understanding of A_1^p as $x\to 1$:
- *World's* published data, *EG1b* estimated data and *SANE* projected data together reduce the uncertainty in A_1^p as $x\to 1$ by 50% compared to the fit to the world's data alone.
- Further improvements in the SANE statistical uncertainties would not significantly reduce the uncertainty in A_1^p as $x\to 1$ due to the lack of significant statistics for x > 0.6 in the DIS region.

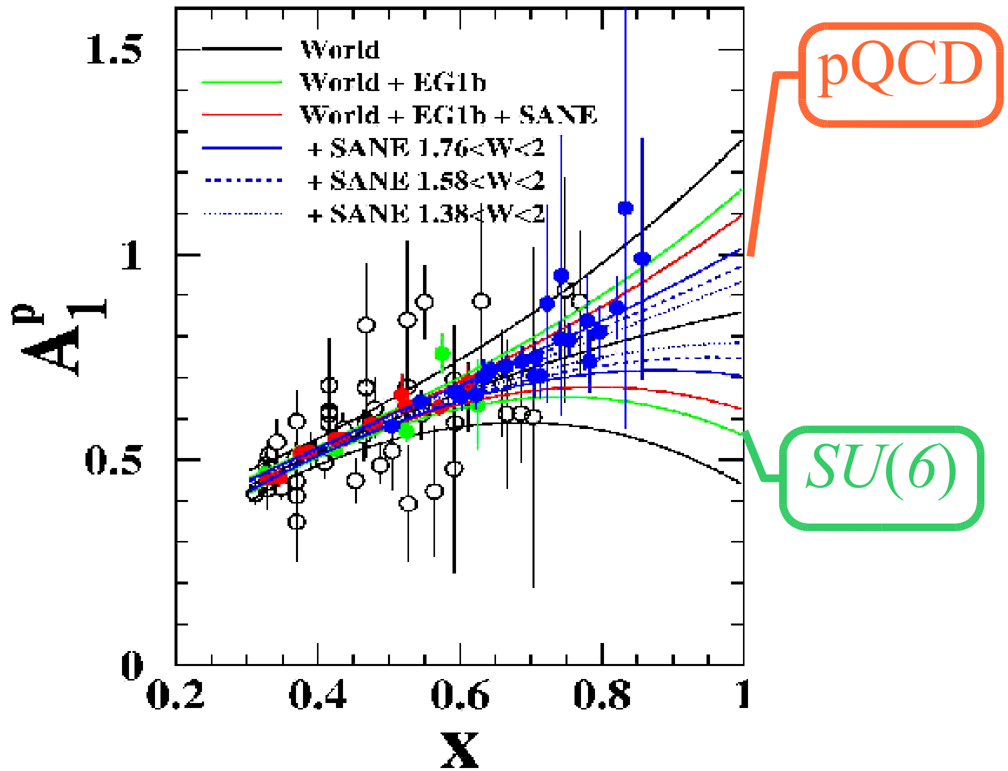


SANE Physics

- Measure proton spin structure function $\boldsymbol{g_2}(x, Q^2)$ and spin asymmetry $\mathbf{A_1}(x, Q^2)$ at four-momentum transfer $2.5 \leq \boldsymbol{Q^2} \leq 6.5$ GeV^2 and Bjorken $\boldsymbol{x}$ $0.3 \leq \boldsymbol{x} \leq 0.8$
- Goal is to learn all we can about proton SSF's from inclusive measurement:
  - Study x and Q^2 dependence
  - Twist-3 effects from moments of $\boldsymbol{g_2}$ and $\boldsymbol{g_1}$, comparison with Lattice QCD
  - Exploration of "high $\boldsymbol{x}$" region: $\mathbf{A_1}$ approach to $\boldsymbol{x} = 1$
  - Test polarized local duality for $W > 1.4$ GeV
- Method:
  - Measure inclusive spin asymmetries for two orientations of target spin relative to beam helicity (anti-parallel and near-perpendicular)
  - Detect electrons with large solid angle electron telescope **BETA**

SANE Expected Results

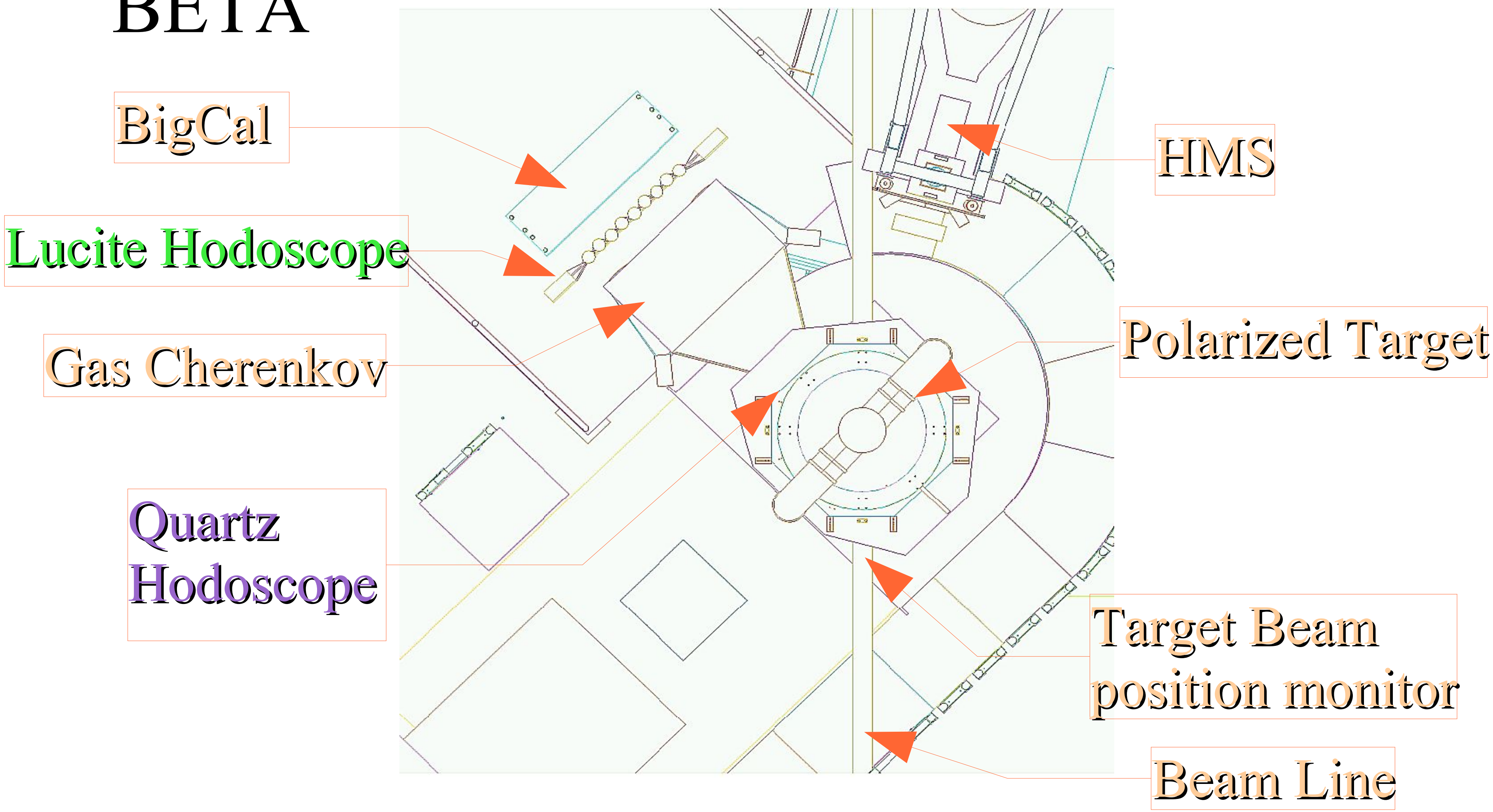




- DIS data for ***x*** up to 0.6 (with 6 GeV)
- Constrain extrapolations of A1p to $x = 1$ within +/- 0.1 (using duality)

SANE Current Design (4/05)

BETA



SANE Status - Subsystems

- BigCal review by M. Jones
- Gas Cherenkov update by B. Sawatzky
- Forward tracking hodoscope
  - Next to target OVC, much improved tracking resolution vs. reference design
  - Quartz as Cherenkov material
    - SaintGobain, Quartz Scientific and Specialty Glass to be tested.
  - SiPM light detectors
    - UVA purchased Channel PM with response in UV, quartz window
  - Mahbub Khandaker (NSU) leads project
  - North Carolina A&T also participating

SANE Status - Subsystems (II)

- Lucite Hodoscope
  - Michael Olson, St. Norbert College (WI) is interested in building it
    - work at JLab in Summer 2006
    - Kent S. U. graduate students (M. Petratos) will help
    - need to define new design
- Polarized target outer vacuum can (OVC) design under way
  - S. Tajima and UVA polarized target group, JLab engineers.
- Gain Monitor: Lucite Plate excited by laser light
  - integration with BigCal in 2005
    - E. Frlez (UVA) and IHEP-Protvino will work on gain monitor, other BigCal tasks in summer.

SANE Status - Open Issues on 1/05

- Backgrounds and their reduction:
  - from beam line: detailed simulation and shielding design
  - from target: pion and positron rejection/identification
    - V. Dharmawardane
- BigCal absolute energy calibration
  - *e-p* elastic scattering with HMS: kinematics and running time optimization
    - G. Huber
  - π° reconstruction: simulation and on-line code
    - P. Bosted
- Target material: $^{14}NH_3$ or ^{7}LiH?
- Optimization of pair-symmetric asymmetry measurement with HMS

Big Electron Telescope Array - BETA

- Three subsystems:
  - BigCal lead glass calorimeter: main detector, being built for ***GEp-III.***
  - Gas Cherenkov (N): additional pion rejection
  - Tracking hodoscope (Cherenkov)
- Target field sweeps low *E* background
- Characteristics of *BETA*
  - Effective solid angle (with cuts) = 0.194 sr
  - Energy resolution $5\%/\sqrt{E}$(GeV)
  - angular resolution = 2°
  - 1000:1 pion rejection