

SANE

Spin Asymmetries on the Nucleon Experiment (TJNAF E03-109 / P07-003)

SANE Collaboration

U. Basel, Florida International U., Hampton U., Norfolk S. U., North Carolina A&T S. U.,
IHEP-Protvino, U. of Regina, Rensselaer Polytechnic I., Rutgers U., Seoul U., 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)
(E03-109 coauthor: G. Warren)

Hall C Users' Meeting
January 26, 2007
Jefferson Lab

SANE Physics

- Measure **proton** spin structure function $g_2(x, Q^2)$ and spin asymmetry $A_1(x, Q^2)$ at four-momentum transfer $2.5 \leq Q^2 \leq 6.5 \text{ GeV}^2$ and Bjorken x $0.3 \leq x \leq 0.8$

**REPORT TO THE
NUCLEAR SCIENCE ADVISORY
COMMITTEE**

**Submitted by the
SUBCOMMITTEE ON PERFORMANCE
MEASURES**

November 18, 2003

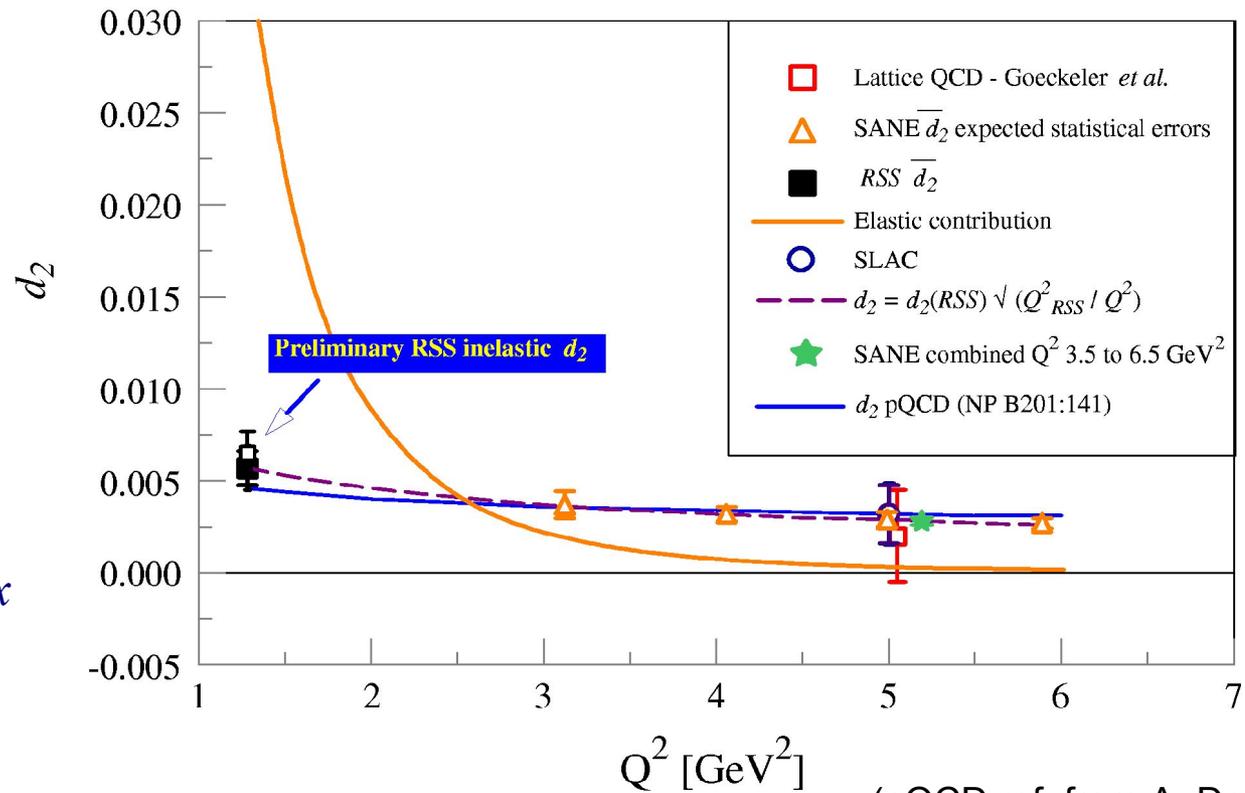
2011	<u>Measure the lowest moments of the unpolarized nucleon structure functions (both longitudinal and transverse) to 4 GeV^2 for the proton, and the neutron, and the deep inelastic scattering polarized structure functions $g_1(x, Q^2)$ and $g_2(x, Q^2)$ for $x=0.2-0.6$, and $1 < Q^2 < 5 \text{ GeV}^2$ for both protons and neutrons.</u>
------	--

- Meets or Exceeds DOE 2011 Milestone for Proton Spin Structure, IF
 - **SANE takes data no later than 2008**

SANE Physics (II)

- Goal is to learn all we can about proton SSF's from an inclusive double polarization measurement:
 - twist-3 effects from moments of g_2 and g_1 :
 - d_2 matrix element = $\int_0^1 x^2 (3 g_2 + 2 g_1) dx$
 - comparisons with Lattice QCD, QCD sum rules, bag models, chiral quarks
 - Study x dependence (test nucleon models) and Q^2 dependence (evolution)
 - Exploration of "high" x region: A_1 's approach to $x = 1$
 - Test polarized local duality for final state mass $W > 1.4$ 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**
- **JLAB is unique facility for measuring complete transverse spin structure**

SANE Expected Results



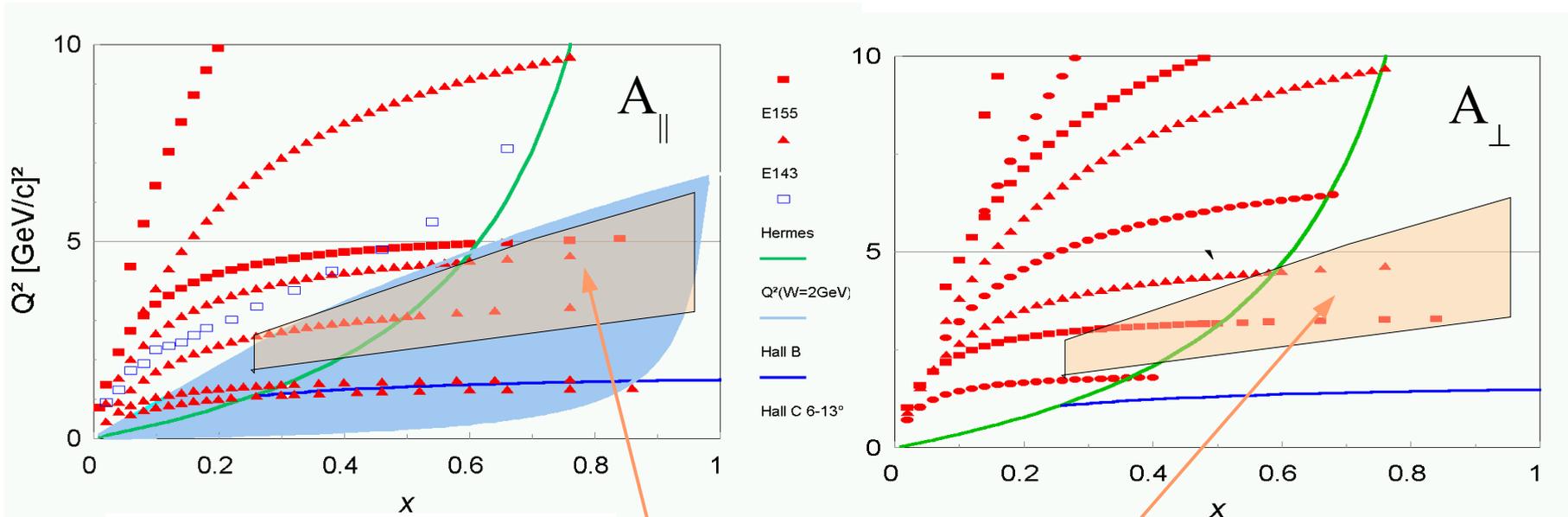
(pQCD ref. from A. Deur)

Twist-3 matrix element:

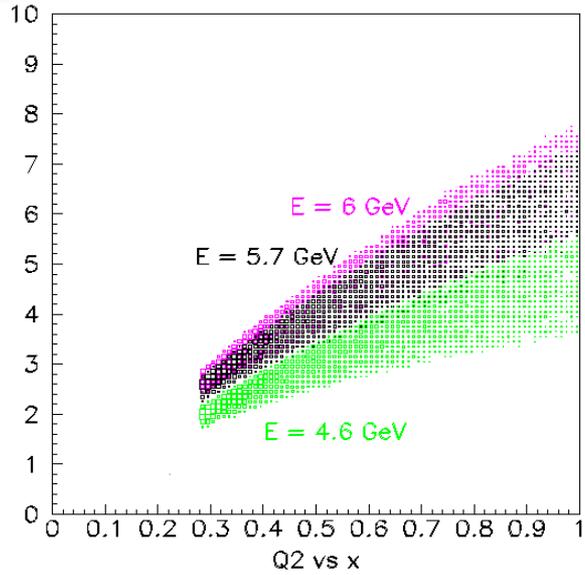
$$\overline{d}_2 = \int_{x_{\min}}^{x_{\max}} x^2 (2g_1 + 3g_2) dx$$

- SANE expected errors:
 - $\delta \overline{d}_2(Q^2 = 3 \text{ GeV}^2) = 7 \times 10^{-4}$ for $0.29 < x < 0.85$
 - $\delta \overline{d}_2(Q^2 = 3.5 \text{ to } 6.5 \text{ GeV}^2) = 2 \times 10^{-4}$ for $0.41 < x < 0.96$

World data on A_{\parallel} , A_{\perp} and SANE kinematics



SANE



- Two beam energies: **> 5.7 GeV, 4.6 GeV**
 - (small loss from **6 GeV**)
- Very good high x coverage with detector at 40°
 - (plot at left from GEANT simulation)

SANE Design

BETA at 40°

BigCal
w. Gain Monitor

Lucite Hodoscope

Gas Cherenkov

Forward
Hodoscope

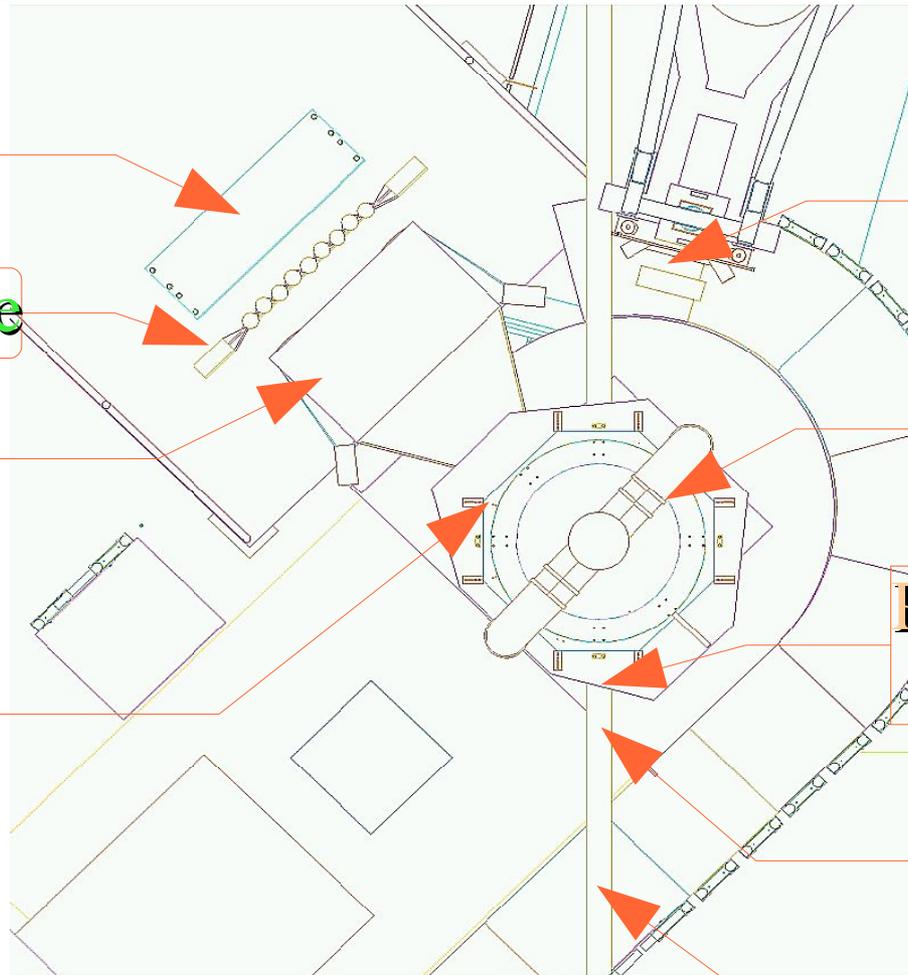
HMS ($13^\circ - 48^\circ$)

Polarized Target

Polarized Compton
radiator (~ 20 cm)

Target Beam
position monitor

Beam Line

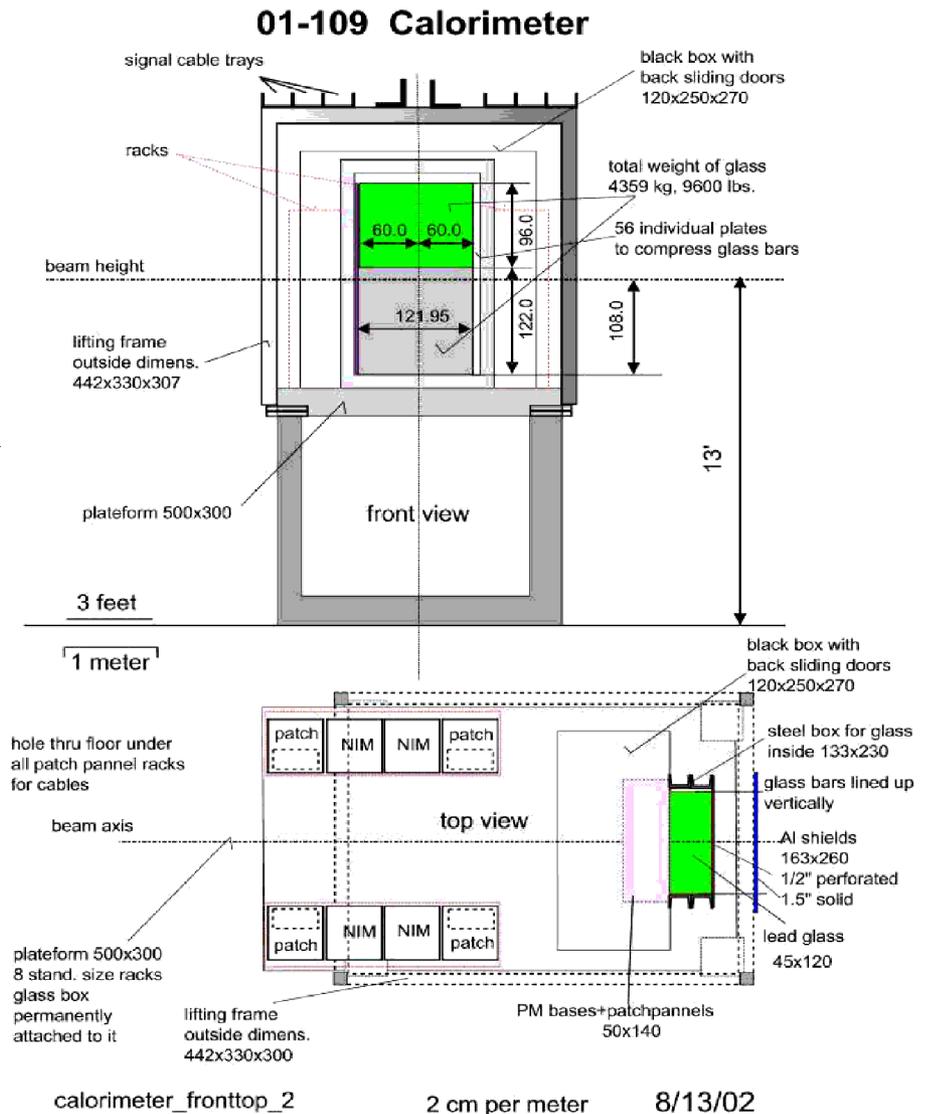


SANE Status - Subsystems

- BigCal
 - Operation: William & Mary, Protvino, Rensselaer, UVA, Hall C
 - Trigger: Rutgers U.
 - Gain Monitor: UVA
 - Calibration: U. Regina
- Gas Cherenkov: Temple U.
- Forward Tracking Hodoscope: Norfolk S.U., Hall C
- Lucite Hodoscope: North Carolina A&T S.U.
- Polarized Target: UVA, JLab
- Shielding design: Seoul U.
- HMS: Yerevan P. I.
- Target Beam Position Monitor: U. Basel, UVA
- Beam Line: Hall C, UVA

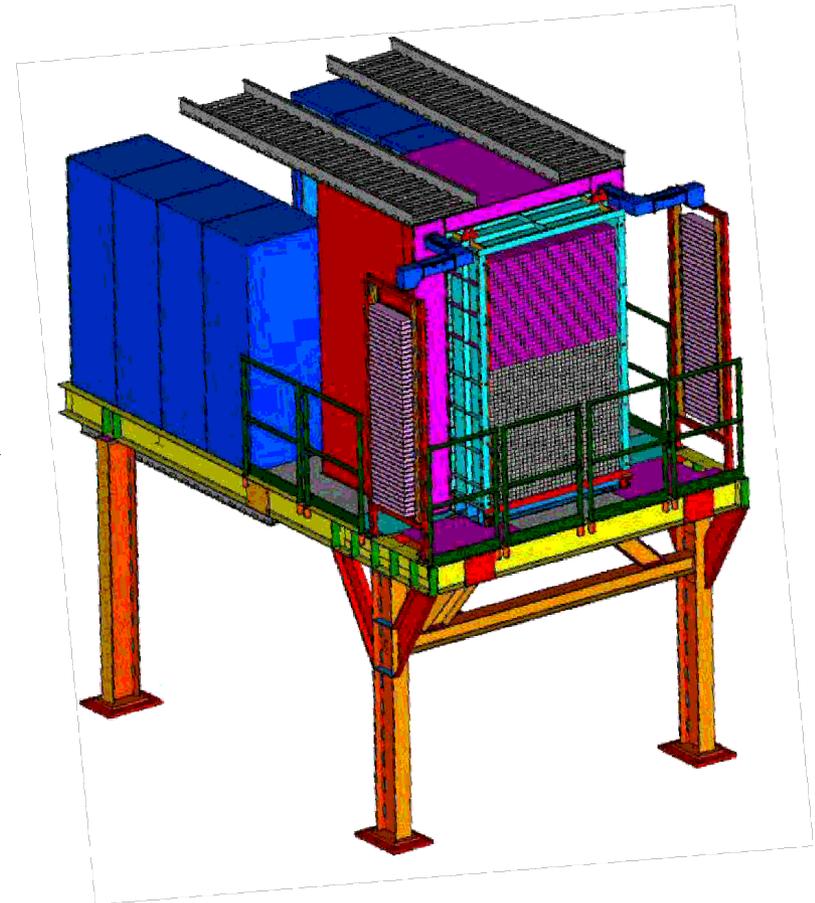
SANE Status - Subsystems(I)

- **BigCal Calorimeter** for *GEp-III*
- 1744 lead crystals, all PMT's and bases installed
- 3 platforms: Glass and mutiplexers, cables and floor electronics
- Replaced optical grease couplings between PMT and glass with silicone cookies.
- Added permanent perforated Al front plate with 1744 5mm holes
- Completed cosmic ray tests, cabling
- Ongoing: DAQ setup, tube response to cosmics vs gain monitor system, gain monitor final design/installation



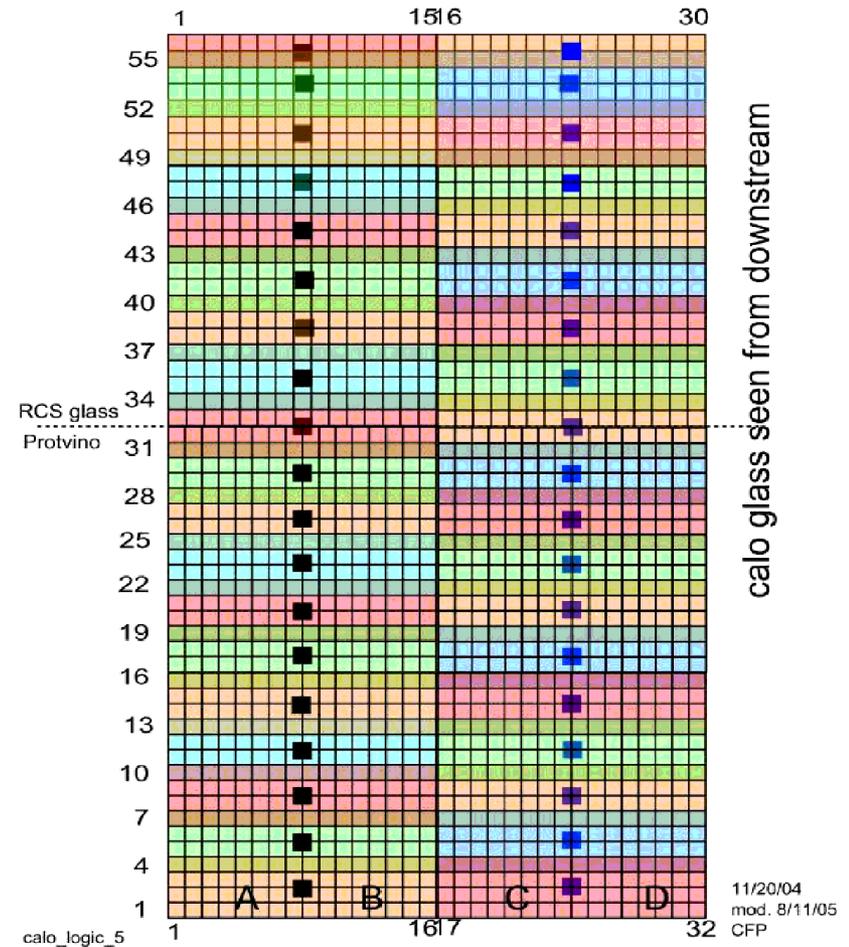
SANE Status - Subsystems(II)

- **BigCal Calorimeter** for *GEp-III*
- 1744 lead crystals, all PMT's and bases installed
- 3 platforms: Glass and mutiplexers, cables and floor electronics
- Replaced optical grease couplings between PMT and glass with silicone cookies.
- Added permanent perforated Al front plate with 1744 5mm holes
- Completed cosmic ray tests, cabling
- Ongoing: DAQ setup, tube response to cosmics vs gain monitor system, gain monitor final design/installation



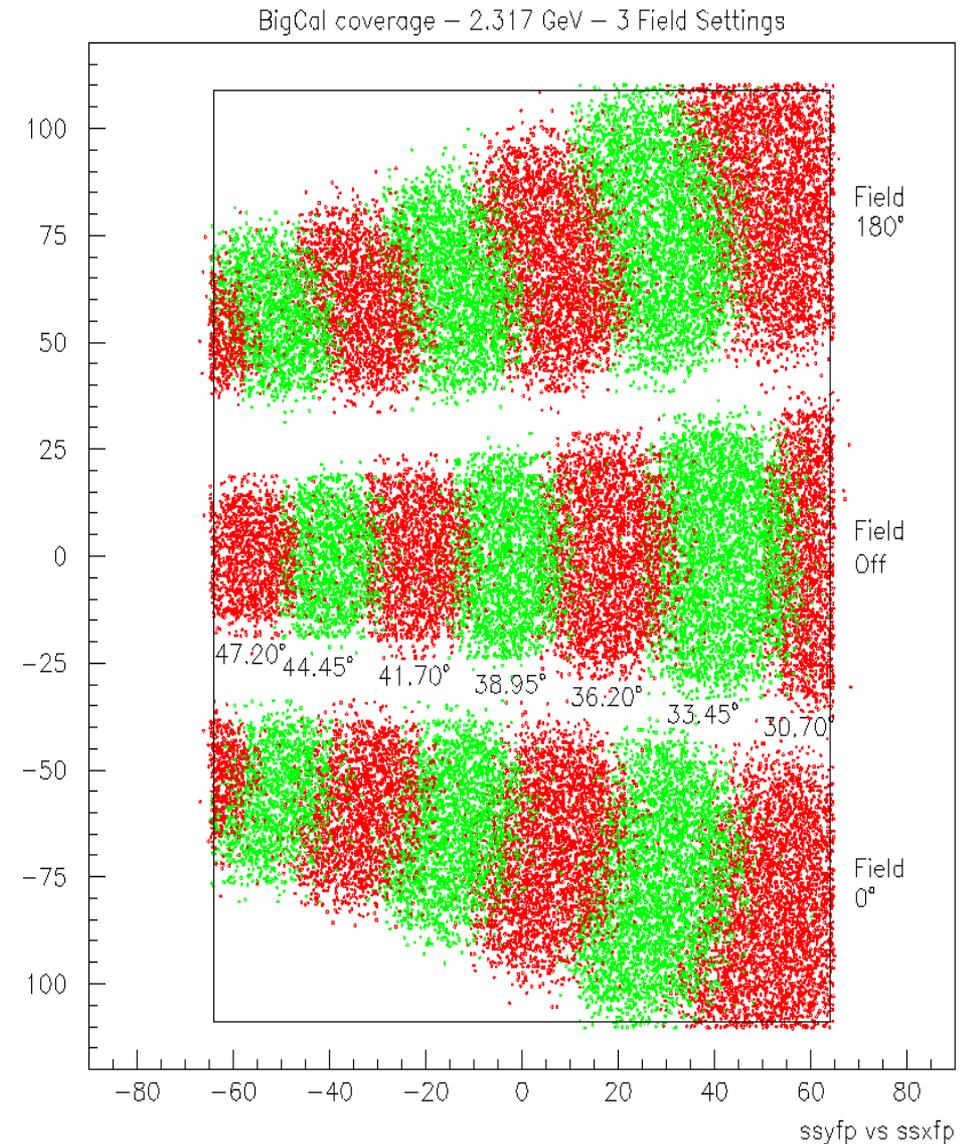
SANE Status - Subsystems(III)

- **BigCal Trigger** for *GEp-III*:
 - signals from every 8 crystals summed by 244 first summing modules
 - 5x signals to ADC's, 1x signals to second level
 - every 8 first modules added in 39 second summing modules.
 - every fourth row duplicated in second summing modules
- MC trigger simulations show good efficiency with overlapping groups
- For SANE (Seoul U.): integrate P. Degtiarenko particle generator for BETA with IHEP-A. Puckett BigCal code



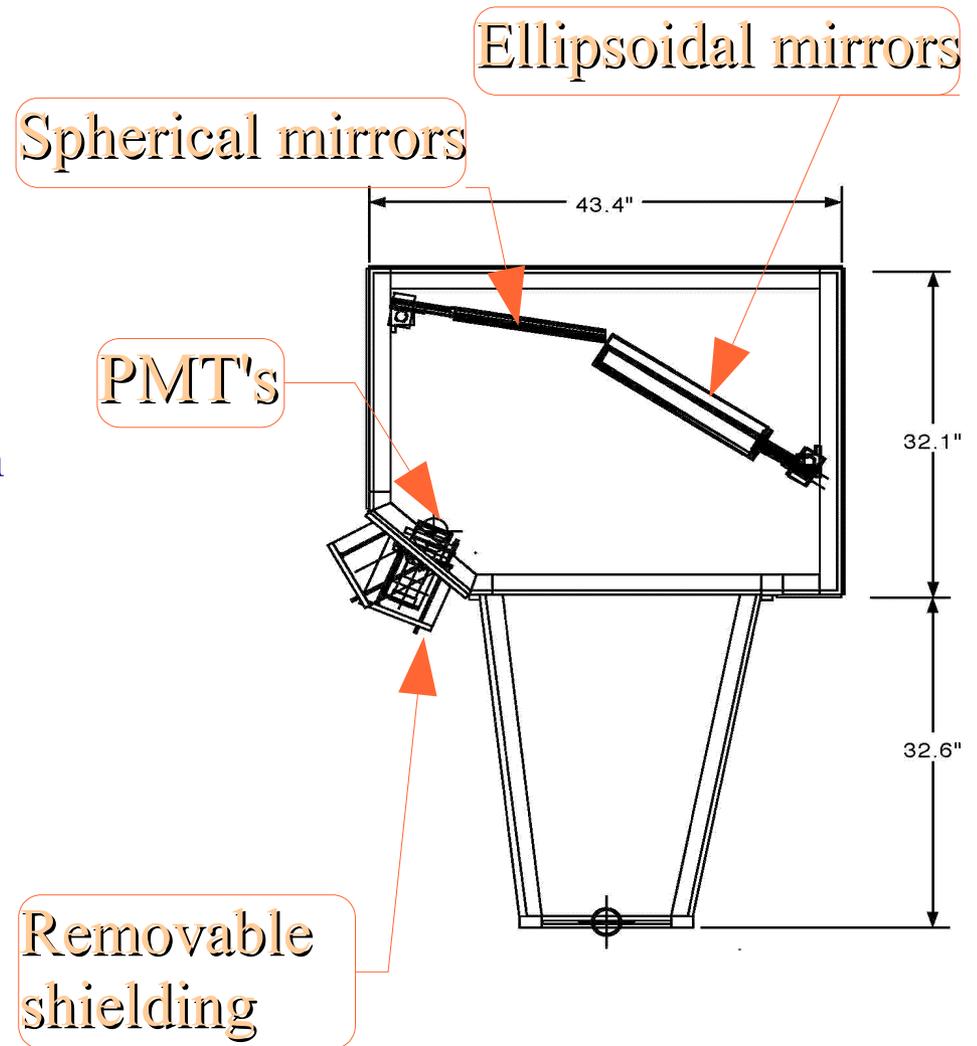
SANE Status - Subsystems(IV)

- **BigCal Energy Calibration:**
 - $e+p$ elastic coincidences with p detected in HMS, NH_3 target, $1 \mu\text{A}$
 - one pass with target field off
 - two passes with full field on, pointing in opposite directions along beam, two passes with half field on
 - no beam deflection
 - 90% coverage of BigCal (5 passes; 75% with 3 passes)
 - 2.3 GeV beam, 47 h (5 passes, 100% efficiency) or 29 h (3 passes)
- Continuous π^0 mass reconstruction



SANE Status - Subsystems (V)

- Temple U.'s modular design of **gas Cherenkov**:
 - four spherical mirrors
 - four ellipsoidal mirrors
 - eight 3" PMT's on side far from beam
 - shielded for 50:1 magnetic field reduction
 - Mirror section decouples from upstream drift section
 - PMT positions adjustable in multiple ways
- Frame built by Alpha Tool (NJ) delivered
- Mirrors shipped to CERN for coating
- PMT's on hand



SANE Status - Subsystems (VI)

- Temple U.'s modular design of **gas Cherenkov**:
 - four spherical mirrors
 - four ellipsoidal mirrors
 - eight 3" PMT's on side far from beam
 - shielded for 50:1 magnetic field reduction
 - Mirror section decouples from upstream drift section
 - PMT positions adjustable in multiple ways
- Frame built by Alpha Tool (NJ) delivered
- Mirrors shipped to CERN for coating
- PMT's on hand



SANE Status - Subsystems (VII)

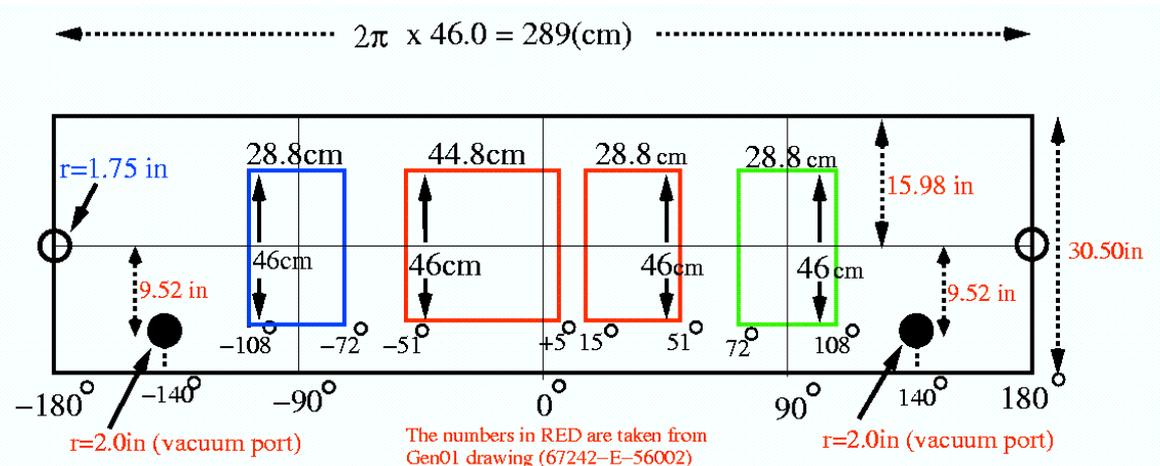
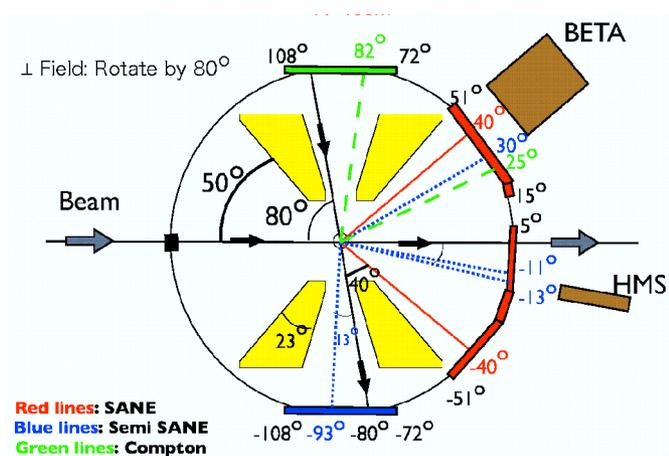
- **Forward tracking hodoscope**
 - Next to target OVC, much improved tracking resolution vs. reference design
 - covers full BETA solid angle with small device (40 cm x 22 cm)
 - charge sign separation for momenta < 1 GeV/c, background rate ~ 10 kHz/bar
 - Wavelength shifting fibers glued on scintillator
 - 73 400(L)x3(W)x3(T) mm³ vertical bars (x -coordinate)
 - 2 x133 220(L)x3(W)x3(T) mm³ horizontal bars (y -coordinate)
 - $\frac{1}{2}$ bar width overlap between y planes
 - resolution (sigma) ~ 0.9 mm
 - Readout by five 64-anode PMT's (Hamamatsu H7546B), on order
 - All 339 TDC channels available, 370 bars on hand, checking cables
 - Prototype tests Spring '07, full device tests Fall 2007.

SANE Status - Subsystems (VIII)

- **Lucite Hodoscope current design**
 - 28 80(L) x 6 (W) x 3.8 (T) cm³ horizontal bars
 - curved bars to maximize light collection and angular selection
 - angled ends to maximize light collection
 - 2" PMT's at both ends: horizontal position by mean time; 32/60 purchased
 - Improves reference design's vertex and angular resolution by better than factor of 2: 4 cm x by 8 cm y RMS vertex, 0.8° angular resolutions
 - Need 56 electronics channels (TDC, discriminator, ADC, HV, cables)
 - Need frame design, construction
 - Prototype tests in 04/2007, construction 07-08/2007, fully tested 12/2007
 - Single layer design and planned tests address TAC concerns

SANE Status - Subsystems (X)

- **Polarized target outer vacuum can (OVC) design completed**
 - S. Tajima (UVA) designed multi-use can (**SANE**, **Semi-SANE**, **Compton**)
 - Hall C has completed FE analysis of can
 - window thickness under design
- Nitrogen shield design completed
- OVC expected ready for bids by March 2007.
 - 4 months fabrication, followed by Lab tests, 6 weeks installation



SANE Status - Subsystems (XI)

- **BigCal Gain Monitor:** Lucite Plate excited by laser or LED light
 - UVA project (D. Počanić group; built similar one for Hall B's RadPhi)
 - successful tests of BigCal glass response to Lucite light done with prototype plate (L. Pentchev coordinated)
 - integration with BigCal planned for 2007
- **Target Beam Position Monitor** (Secondary Emission Monitor):
 - needed to determine beam raster position (1 cm radius spiral)
 - refurbished at U. Basel (used in *GEN01* and *RSS*)
 - electronics box will be moved away from above beam line
- **Downstream beam line:**
 - He gas bag plus short beam pipe section
 - minimal modification of E-01-006 (*RSS*) design

Beam Time Request

2003 Request

	Energy	θ_N	Time (h)	
Production	6.0	180	100	
	6.0	80	200	
	4.8	180	70	
	4.8	80	130	
	2.4	-	10	
Systematics	Packing Fraction		20	
	Mollers		21	
	Total beam time		551	(23 d)
Overhead	Anneals		62	
	Energy Change		48	
	Target Rotation		48	
	Stick Changes		48	
	Total Overhead		206	(9 d)
Requested Time		654	(27 d)	

2007 Request

	Energy	θ_N	Time (h)	
Calibration	2.3	off, 0, 180	47	
Production	4.6	180	70	
	4.6	80	130	rotate
	5.7	80	200	
	5.7	180	100	rotate
	Total beam time		588	(24.5 d)
Systematics	Packing Fraction		20	
	Mollers		21	
	Total beam time		588	(24.5 d)
Overhead	Anneals		62	
	Energy Change		48	
	Target Rotation		48	
	Stick Changes		48	
	Total Overhead		206	(9 d)
Requested Time		654	(27 d)	

Commissioning TAC recommended 14 calendar days

Updated Preliminary Run Plan

Start: 04/29/08
Finish: 06/22/08

SANE Run Gantt View: Gantt Table

?	Activity Name	Duration	Start	April 08					May 08					June 08				July		
				30	6	13	20	27	4	11	18	25	1	8	15	22	29			
1	SANE Run	54	04/29/08																	
2	Commission/Calibration	5	04/29/08																	
3	Energy change 2 pass => 4 pass	1	05/04/08																	
4	4.6 GeV parallel	4	05/05/08																	
5	Target rotation 180° - 80°	1	05/09/08																	
6	Chicane alignment	0	05/08/08																	
7	4.6 GeV 80 deg.	10	05/10/08																	
8	Energy change 4 pass => 5 pass	1	05/20/08																	
9	Chicane alignment (if needed)	0	05/19/08																	
10	5.7 GeV 80 deg.	21	05/21/08																	
11	Target rotation 80° - 180°	1	06/11/08																	
12	Chicane alignment	0	06/10/08																	
13	5.7 GeV parallel	10	06/12/08																	

SANE Membership - 1/07

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

L. Pentchev
College of William and Mary, Williamsburg, VA

W. Boeglin, S. Dhamija, P. Markowitz, J. Reinhold
Florida International University, Miami, FL

I. Albayrak, E. Christy, C. Keppel, V. Tvaskis
Hampton University, Hampton, VA

A. Vasiliev
Institute for High Energy Physics, Protvino, Moscow Region, Russia

M. Khandaker, F. Wesselmann
Norfolk State University, Norfolk, VA

A. Ahmidouch, S. Danagoulian
North Carolina A&M State University, Greensboro, NC

C. Butuceanu, G. Huber
University of Regina, Regina, SK

V. Kubarovsky
Rensselaer Polytechnic Institute, Troy, NY

R. Gilman, X. Jiang
Rutgers University, New Brunswick, NJ

S. Choi (cospokesperson), Ho-young Kang, Hyekoo Kang,
Byungwuek Lee, Yoomin Oh, Jeongseog Song
Seoul University, Seoul, Korea

Z.-E. Meziani (cospokesperson), B. Sawatzky
Temple University, Philadelphia, PA

P. Bosted, J.-P. Chen, V. Dharmawardarne, R. Ent, D. Gaskell, J. Gomez,
D. Higinbotham, M. Jones, D. Mack, J. Roche, G. Smith, B. Wojtsekhowski, S. Wood
Thomas Jefferson National Accelerator Facility, Newport News, VA

M. Bychkov, D. Crabb, M. Commisso, D. Day, E. Frlež, K. Kovacs, N. Liyanage,
J. Maxwell, D. Počanić, O. Rondon (cospokesperson), K. Slifer, L.C. Smith, S. Tajima
University of Virginia, Charlottesville, VA

A. Asaturyan, A. Mkrtchyan, H. Mkrtchyan, V. Tadevosyan
Yerevan Physics Institute, Yerevan, Armenia

SANE Status - 1/07

- Twelve collaboration meetings, most recent last Dec. 1st.
- Submitted Beam Request on 9/14/06
 - Not possible to be on schedule for 2007, because of Hall C constraints and available beam energy
 - Presenting jeopardy Update to PAC31
- Hall C schedule:
 - recent G0 extension shifts all dates by about a month
 - current: SANE tentatively to start in 5/2008 (?)
- Time lines show adequate lead time for 2008 run
- Readiness review in 2007

SUMMARY

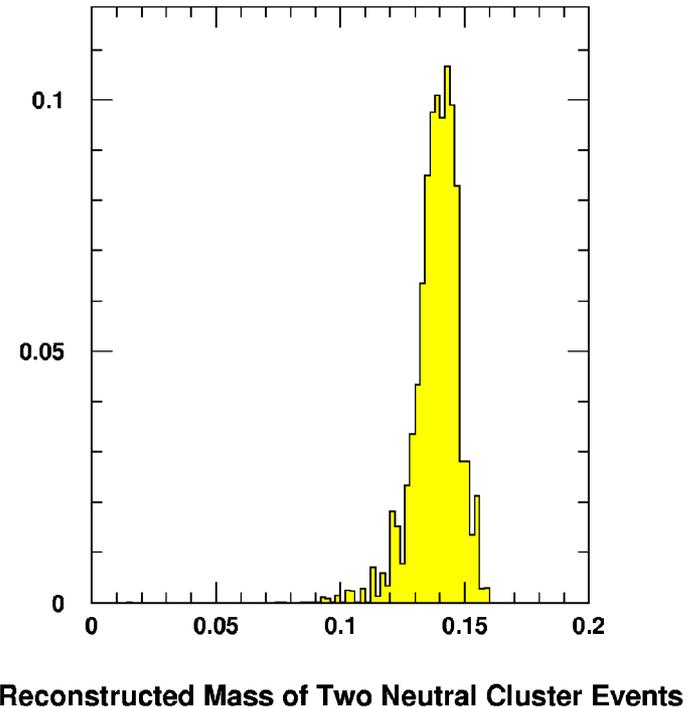
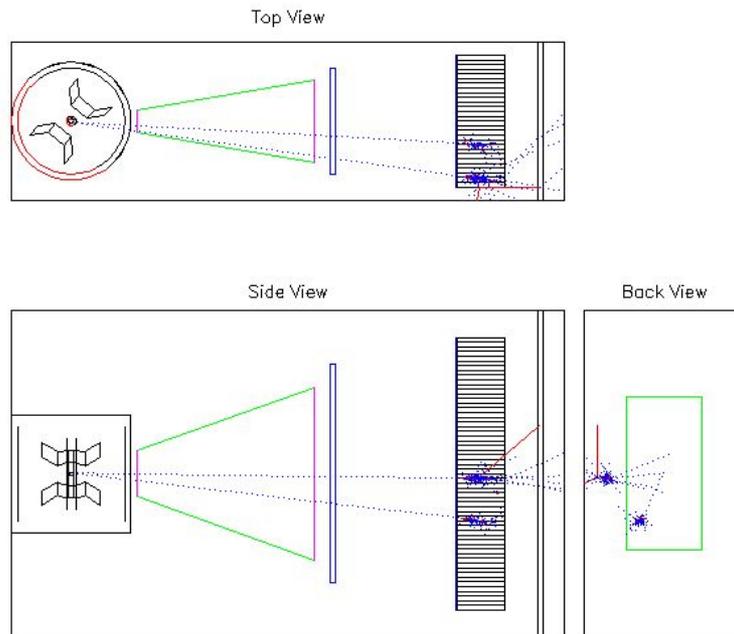
Steady progress over 3 years

Could install by year's end if beam schedule allowed

SANE Status – Other Items

- Backgrounds and their reduction: from beam line
 - detailed simulation and shielding design:
 - P. Degtiarenko provided us with latest version of .MCWORKS code
 - Seoul U. integrating with BETA
- Update of SANE and BETA's GEANT
 - UVA dissertation student J. Maxwell working on G. Warren's legacy
- Backgrounds from target: pion and positron rejection/identification
 - V. Dharmawardane reviewed reference estimates, >20% rate for $E' < 1.1$ GeV, reduce background with software cut
 - P. Bosted: precision π^0 asymmetry possible with 0.7 GeV threshold; can be used to make pair symmetric asymmetry systematics negligible
- Target material: $^{14}\text{NH}_3$. UVA working on better freezing method. Irradiation in 2007.
- Target platform design, integration with BETA stands in the works with Hall C engineering and design group, Temple, UVA and Hall C physics providing input

BigCal's neutral pion mass reconstruction



- Use π^0 mass reconstruction to: continuously calibrate BigCal,
 - calibrate blocks not covered in $e+p$ elastic procedure ($\sim 10\%$)
 - measure asymmetry with >0.7 GeV/c threshold to control the pair symmetric background
 - GEANT simulated π^0 events in BETA: $\sigma \sim 10$ MeV

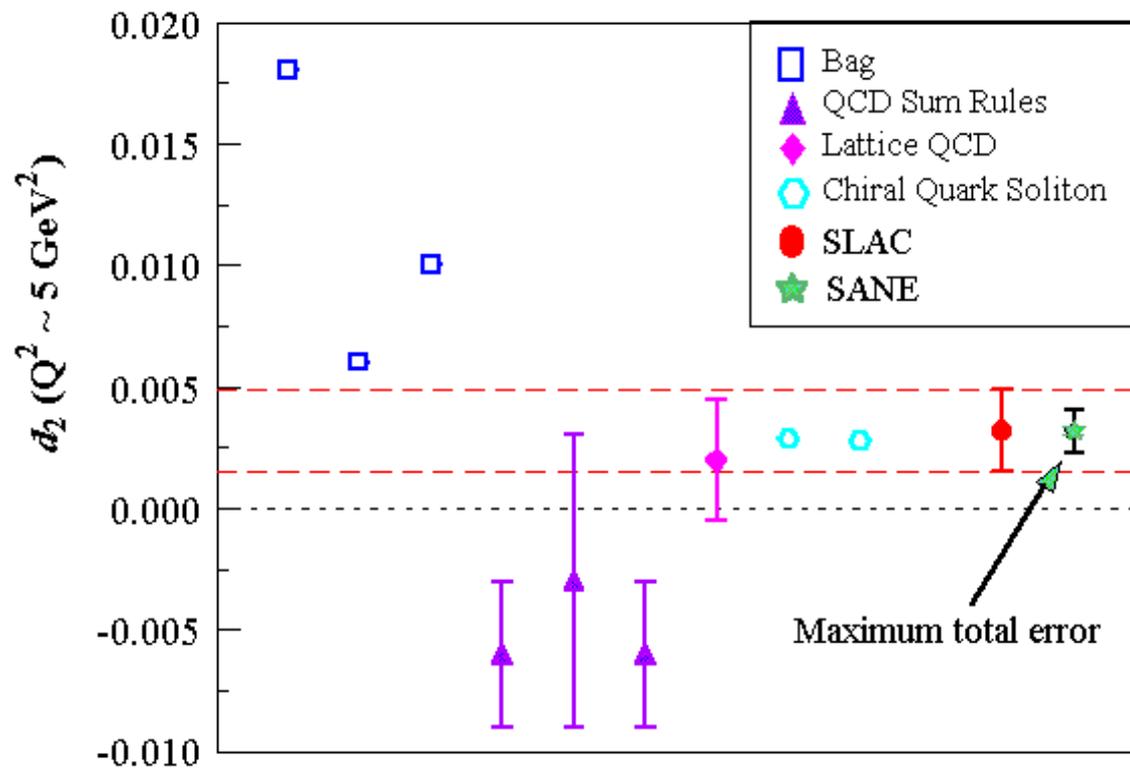
Systematics

Radiative Corrections	1.50%
Dilution Factor	2.00%
Target Polarization	2.50%
Beam Polarization	1.00%
Nitrogen Correction	0.40%

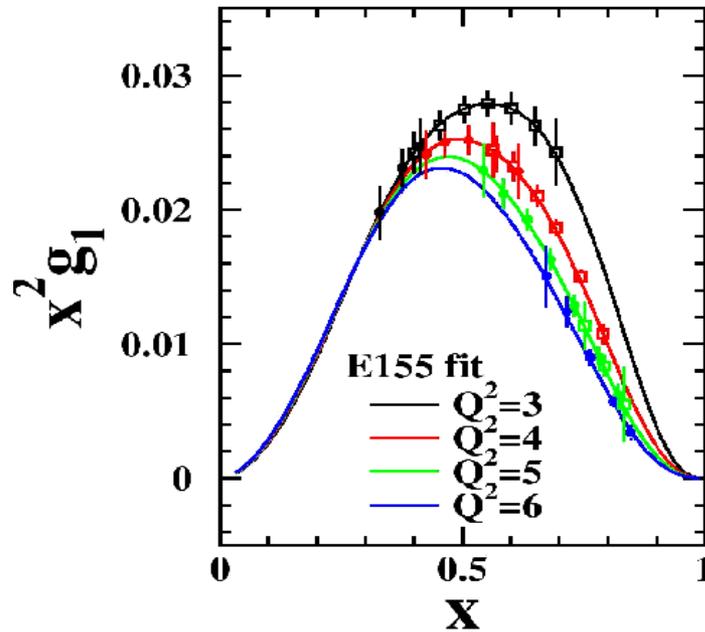
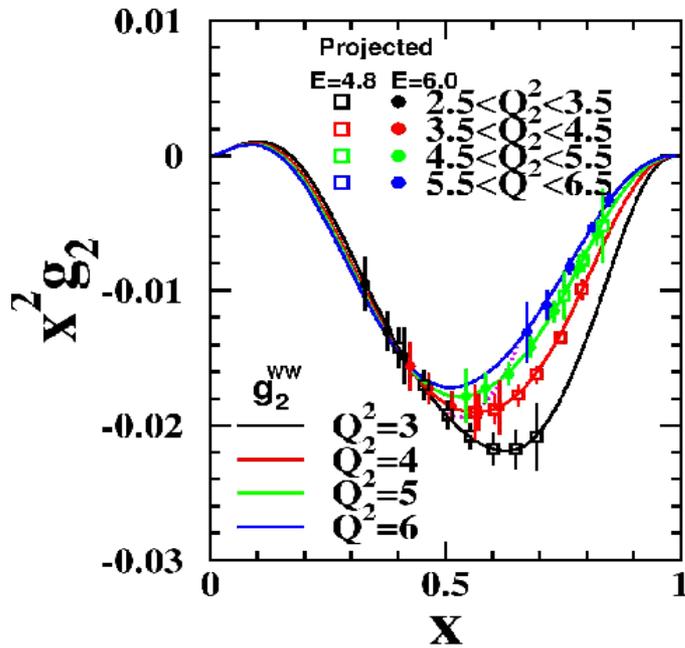
	A1p		g2	
	x=0.3	x=0.6	x=0.3	x=0.6
<i>R</i>	0.80%	1.20%	1.50%	1.30%
Kinematics	0.40%	0.50%	2.70%	4.50%
Background	1.00%	1.00%	3.70%	1.80%
Local	2.10%	2.30%	4.00%	4.10%
Global	3.30%	3.30%	4.60%	4.70%
Total	4.20%	4.00%	6.80%	6.70%

Systematics for 4.8 GeV are very similar

SANE Expected Results (Ia)

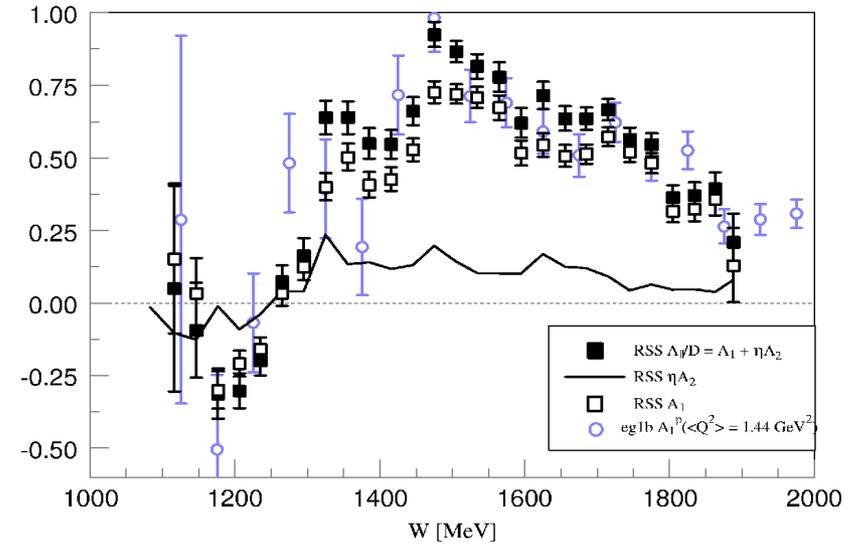
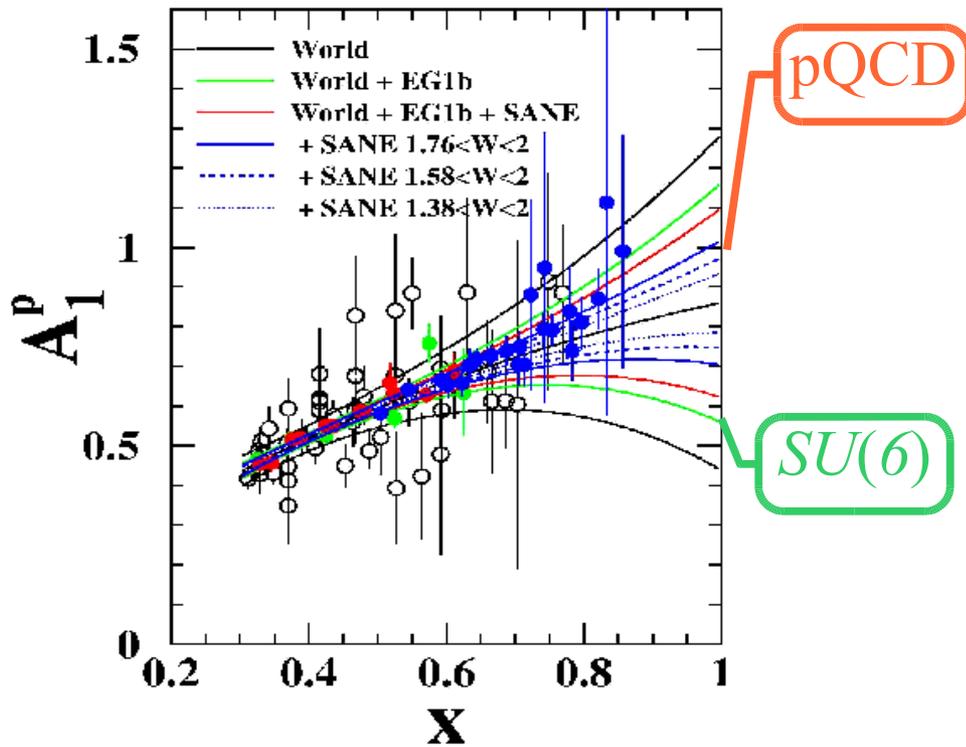


SANE Expected Results (II)



- x dependence at constant Q^2 and Q^2 dependence at fixed x (illustrative binning)
- data are concentrated in the region most sensitive to $x^2 g_{2,1}$

SANE Expected Results (III)

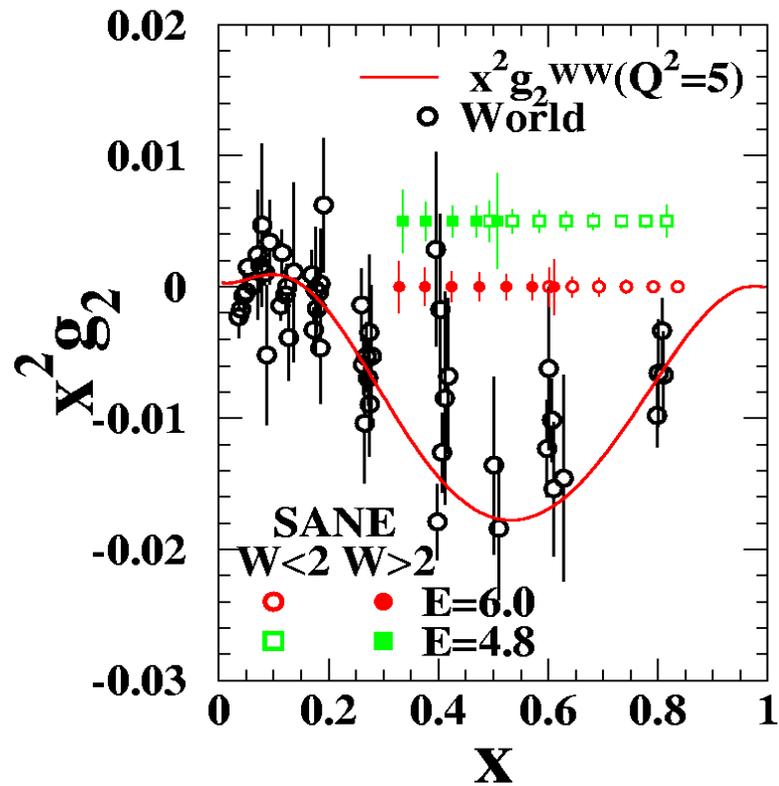


$$A_1 = \frac{1}{(E + E')D'} \left((E - E' \cos \theta) A_{\parallel} - \frac{E' \sin \theta}{\cos \phi} A_{\perp} \right)$$

$$A_2 = \frac{\sqrt{Q^2}}{2ED'} \left(A_{\parallel} + \frac{E - E' \cos \theta}{E' \sin \theta \cos \phi} A_{\perp} \right)$$

- Constrain extrapolations of A_1^p to $x = 1$ within ± 0.1 (using duality)
- Observed $A_2 > 0$ requires both A_{\parallel} and A_{\perp} to get accurate, model-free A_1

SANE Expected Results (IV)



- DIS data for x up to 0.6 (with 6 GeV)