SANE of Jefferson Lab: Spin Asymmetries on the Nucleon Experiment

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SANE Physics

- DIS: quark distribution in nucleon described by Spin Structure Functions:

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

$$g_2(x,Q^2) = g_2^{WW}(x,Q^2) + \overline{g_2}(x,Q^2)$$

$$= -g_1(x',Q^2) + \int_x^1 g_1(x',Q^2)\frac{dx'}{x'} - \int_x^1 \frac{\partial}{\partial x'}\left[\frac{m}{M}h_T(x',Q^2)x' + \xi(x',Q^2)\right]\frac{dx'}{x'}$$

- Spin Asymmetries A_1 and A_2

$$g_1 = \frac{F_1}{1+\gamma^2}\left(A_1 + \gamma A_2\right)$$

$$g_2 = \frac{F_1}{1+\gamma^2}\left(\frac{A_2}{\gamma} - A_1\right) \qquad \text{with } \gamma = \frac{2xM}{\sqrt{Q^2}}$$

SANE Physics

- SANE measures proton spin structure function $g_2(x,Q^2)$ and spin asymmetry $A_1(x,Q^2)$ at $2.5 < Q^2 < 6.5$ GeV^2 and $0.3 < x < 0.8$.

→ Measure inclusive asymmetries for 2 polarized target configurations

$$A_{\parallel} = A_{\perp} = \frac{1}{C_N f P_B P_T}\left(\frac{N^{\uparrow\downarrow} - N^{\downarrow\downarrow}}{N^{\uparrow\downarrow} + N^{\downarrow\downarrow}}\right) + A_{RC}$$

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

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

θ: target polarization angle 180^0 and 80^0

D': virtual photon depol., depends on kinematics and $R=\sigma_L/\sigma_T$

SANE goal

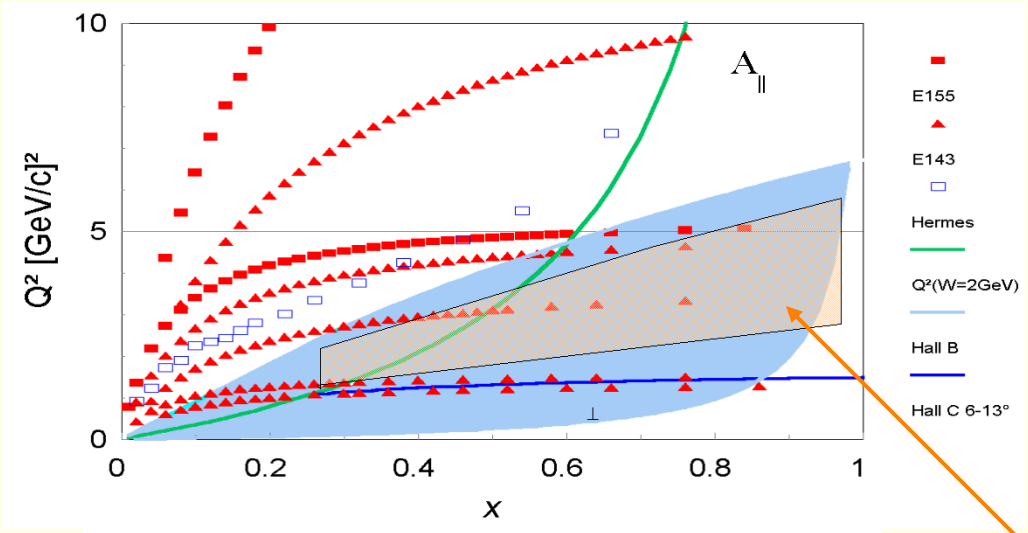
→ Learn about proton SSFs from an inclusive double polarization measurement

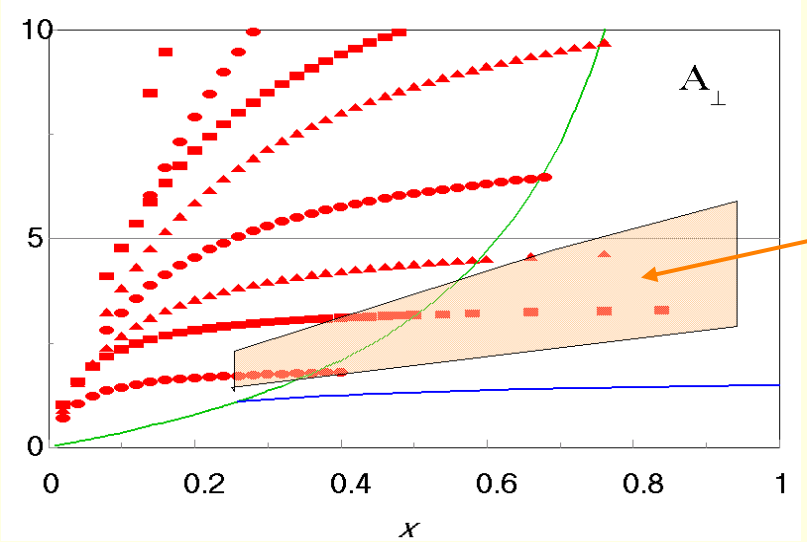
- measure A_1, g_2,
- Twist-3 effects from moments of g_1 & g_2:

Matrix element $$d_2 = \int_0^1 x^2 \left(3g_2 + 2g_1\right) dx$$

- Comparisons with Lattice QCD, QCD sum rules, bag models, chiral quarks.
- Study of x-dependence (test nucleon models) and Q^2-dependence
- Explore "high" x region: A_1 for x->1.

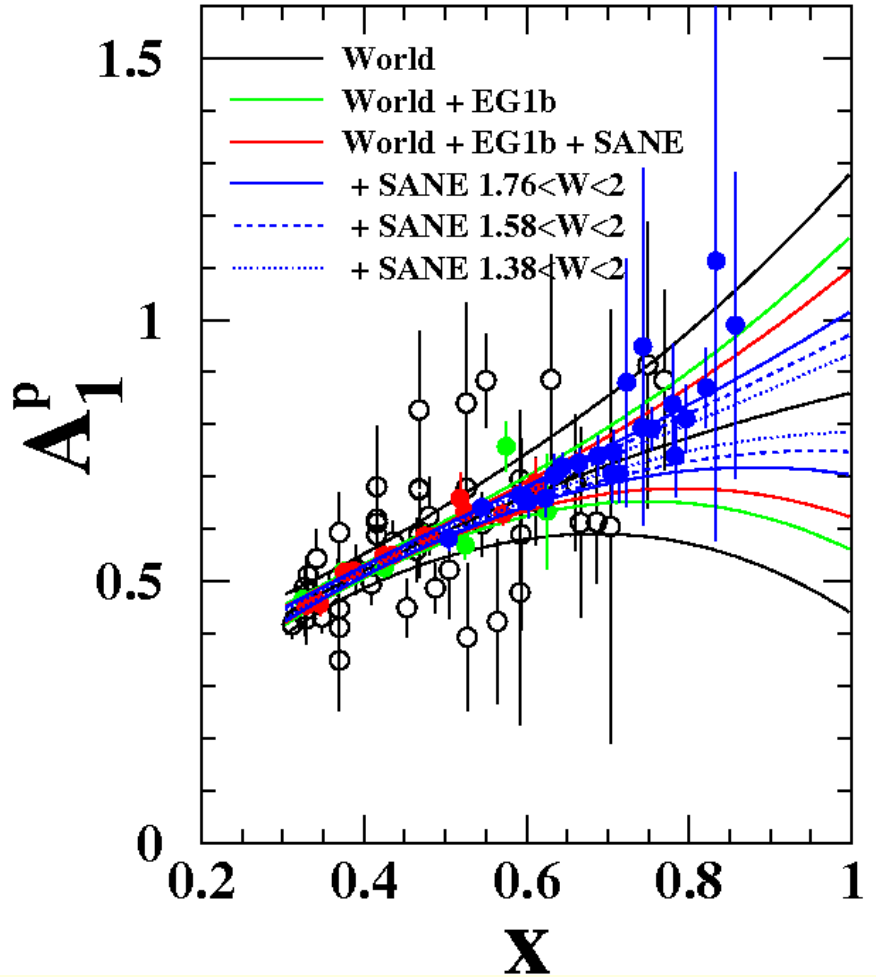
SANE kinematics coverage for $A_{//}$ and A_{perp}





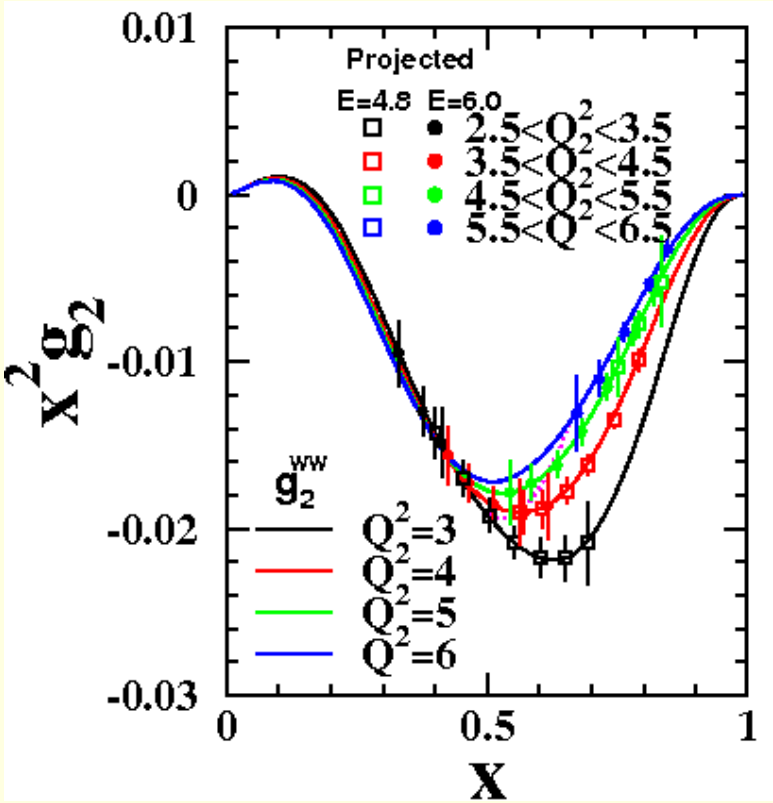
SANE

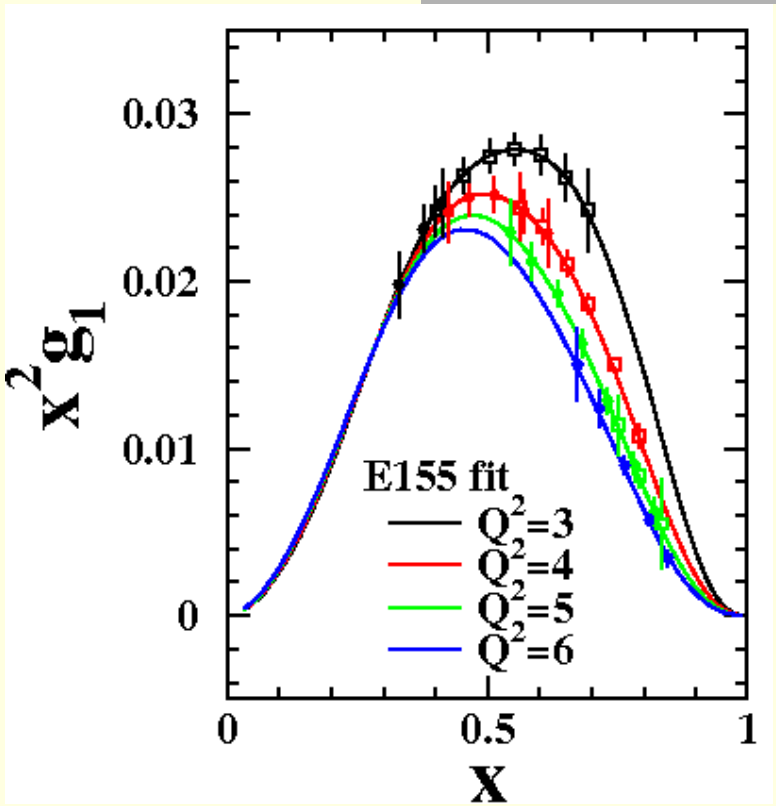
Expected Results A_1



- $A_{//}$ and A_{perp} → model free A_1 and A_2
- Constrain extrapolations of A_1 at large x
- SANE A_2 will help improve world's A_1 data set

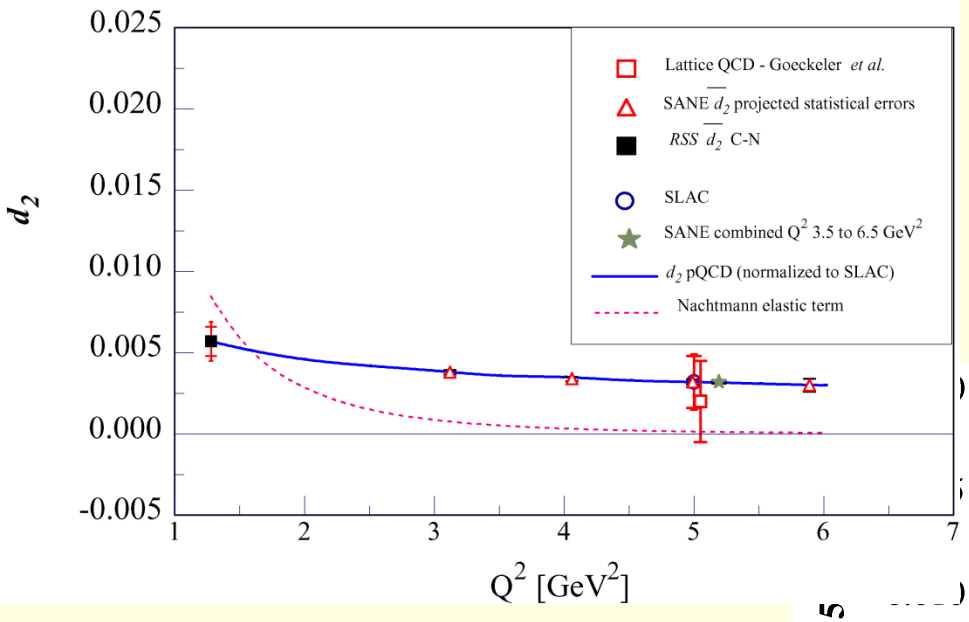
Expected Results g_1, g_2



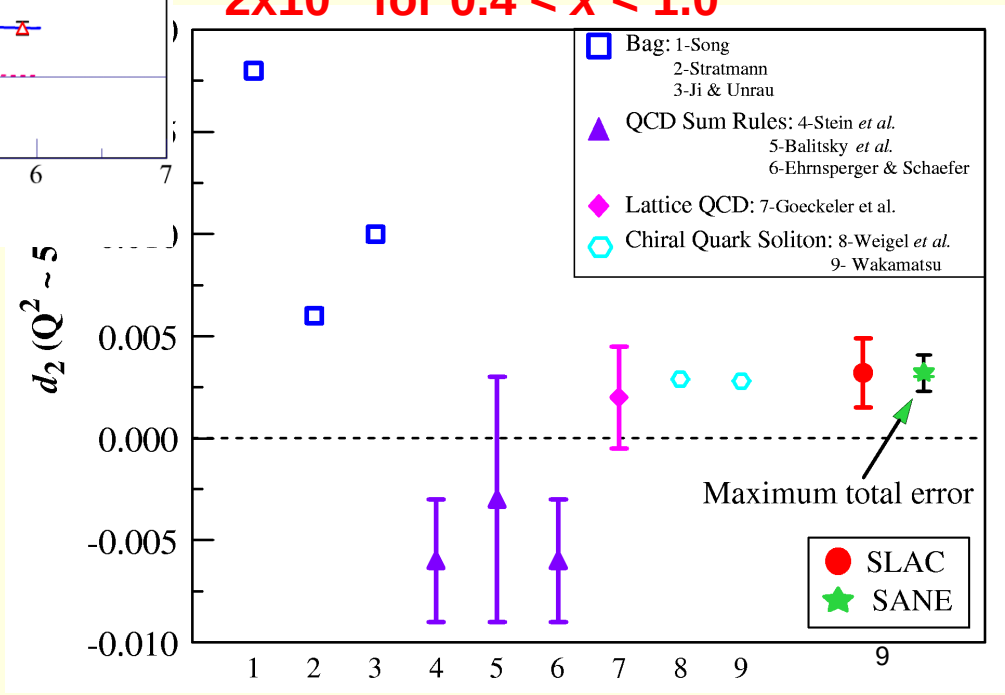


$x^2g_{1/2}(x,Q^2)$: data taken at most sensitive regions

Expected Results d_2



- **Expected errors for d_2:**
  - **$\Delta d_2(Q^2 = 3\text{GeV}^2) = 7\times10^{-4}$ for $0.3 < x < 0.8$**
  - **$\Delta d_2(3.5 < Q^2 < 6.5\text{GeV}^2) = 2\times10^{-4}$ for $0.4 < x < 1.0$**



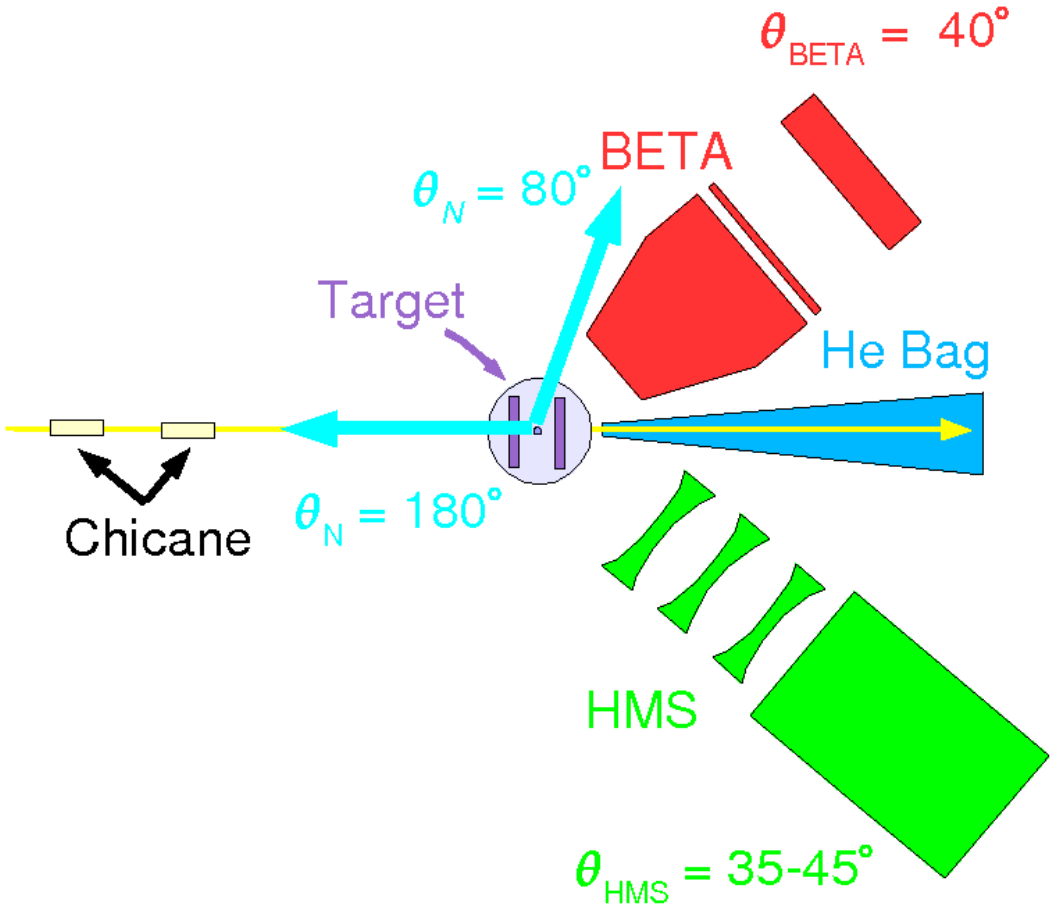
SANE Setup

Target:
- **UVa Polarized NH_3 target, 5T Field**

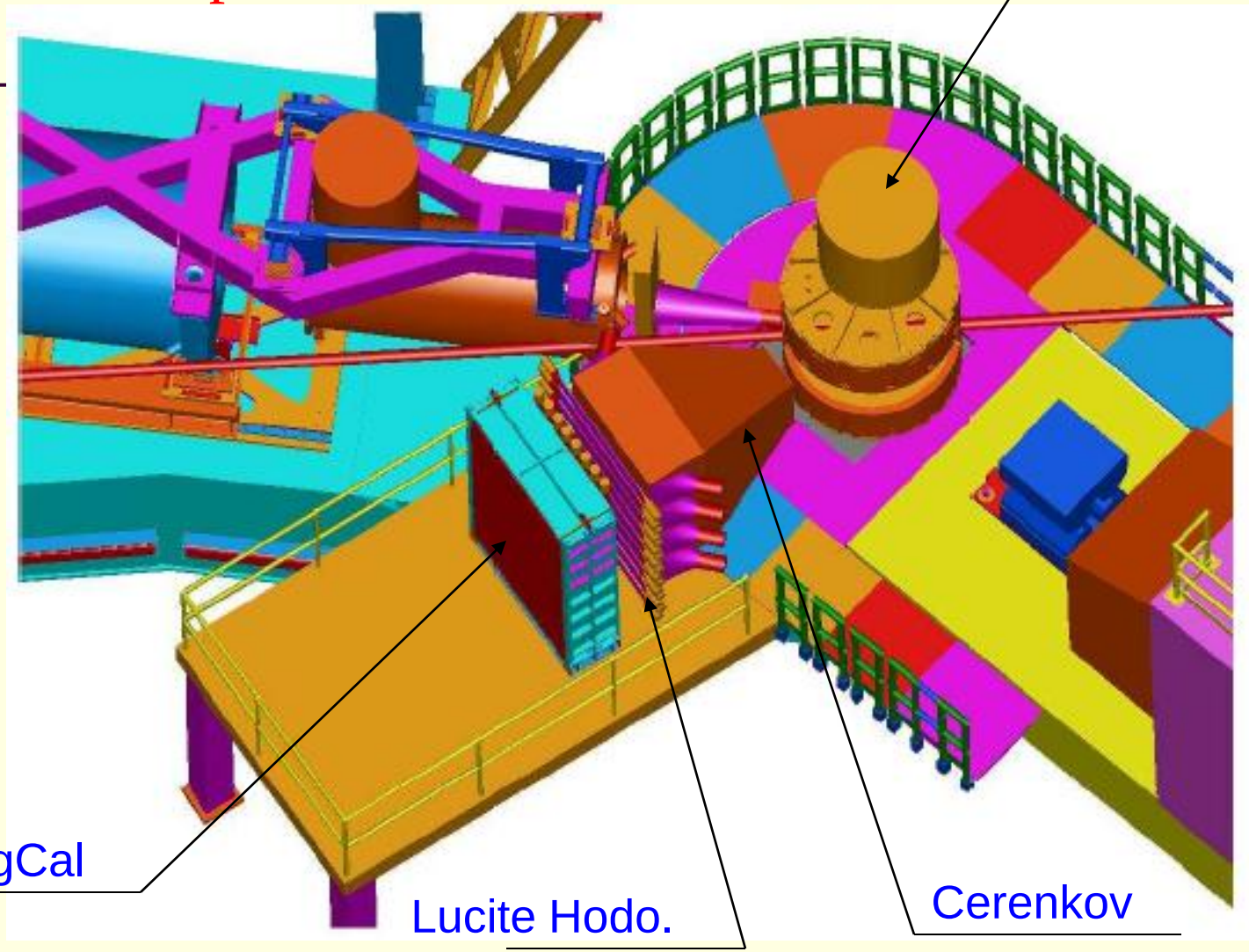
Beamline: 4.7, 5.9 GeV
- **Chicane**
- **He Bag**

Electron Arm: BETA
- **Tracker (tracking)**
- **Cerenkov (particle ID)**
- **Lucite (tracking, bkg reduct.)**
- **BigCal**

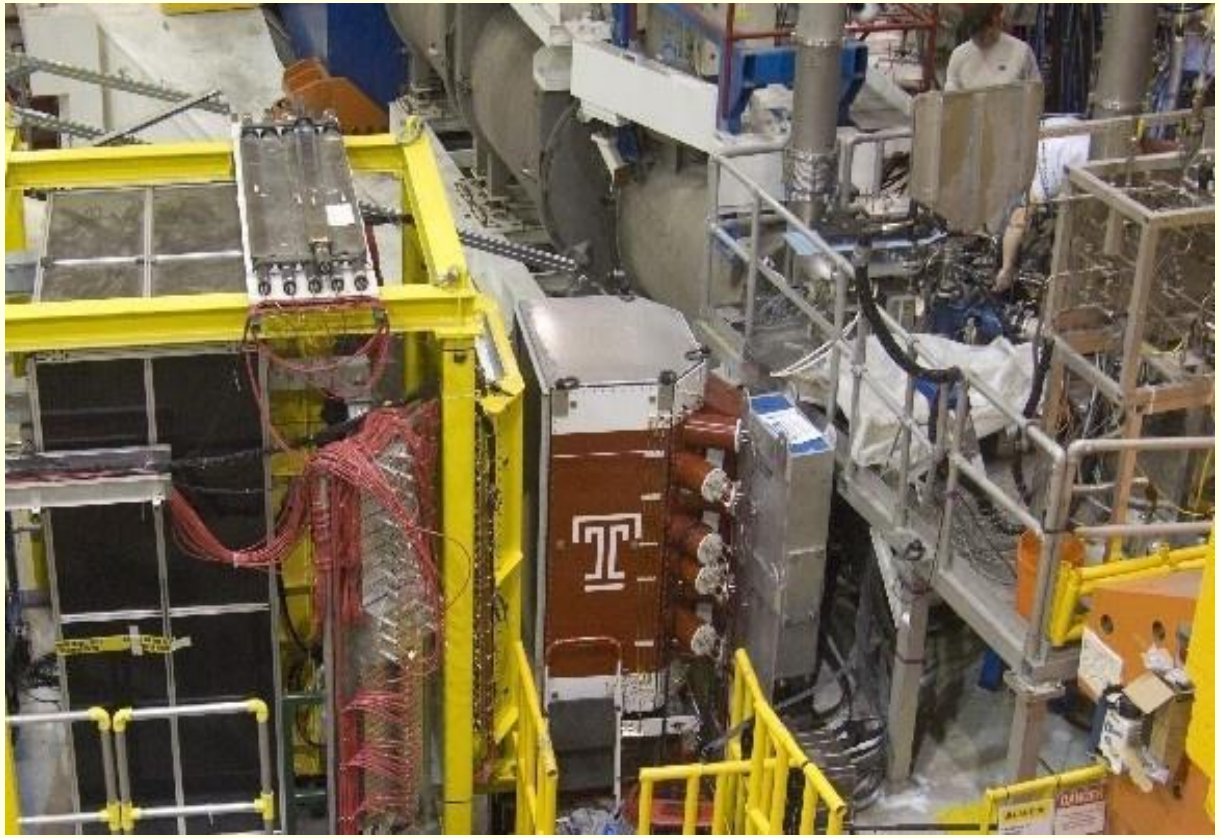
HMS:
- **Hall-C Spectrometer**
- **GepIII, Calibrations**



SANE Setup



SANE Setup



- UVa target:
  Frozen solid NH_3
- Superconducting magnet 5 T
- Dynamic nuclear polar. 28GHz
- Polar measured by NMR

BigCal calorimeter

- Big Electron Telescope Array (BETA) characteristics
  - →Effective solid angle = 0.194 sr
  - →Energy resolution 8%/sqrt *E(GeV)*
  - →1000:1 pion rejection
  - →vertex resolution ~ 5 mm
  - →angular resolution ~ 1 mr

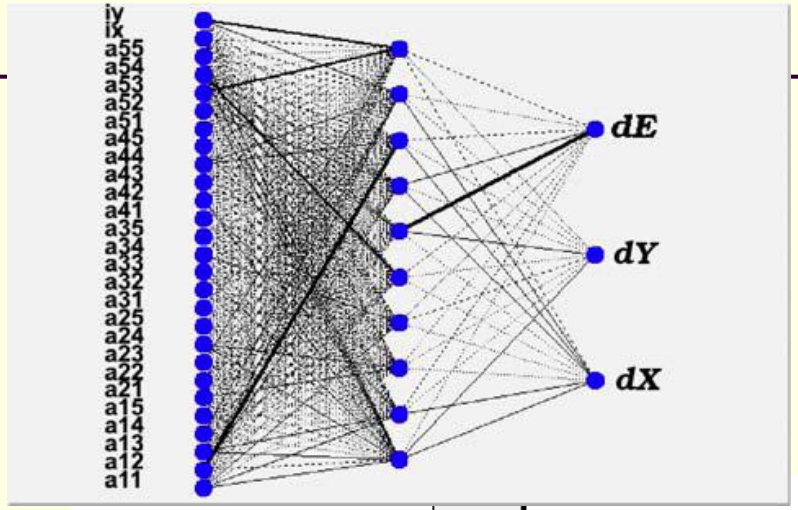
- Lead glass calorimeter

→1744 blocks aprox. 4cm x 4cm (Protvino), 3.8cm x 3.8cm (RCS)

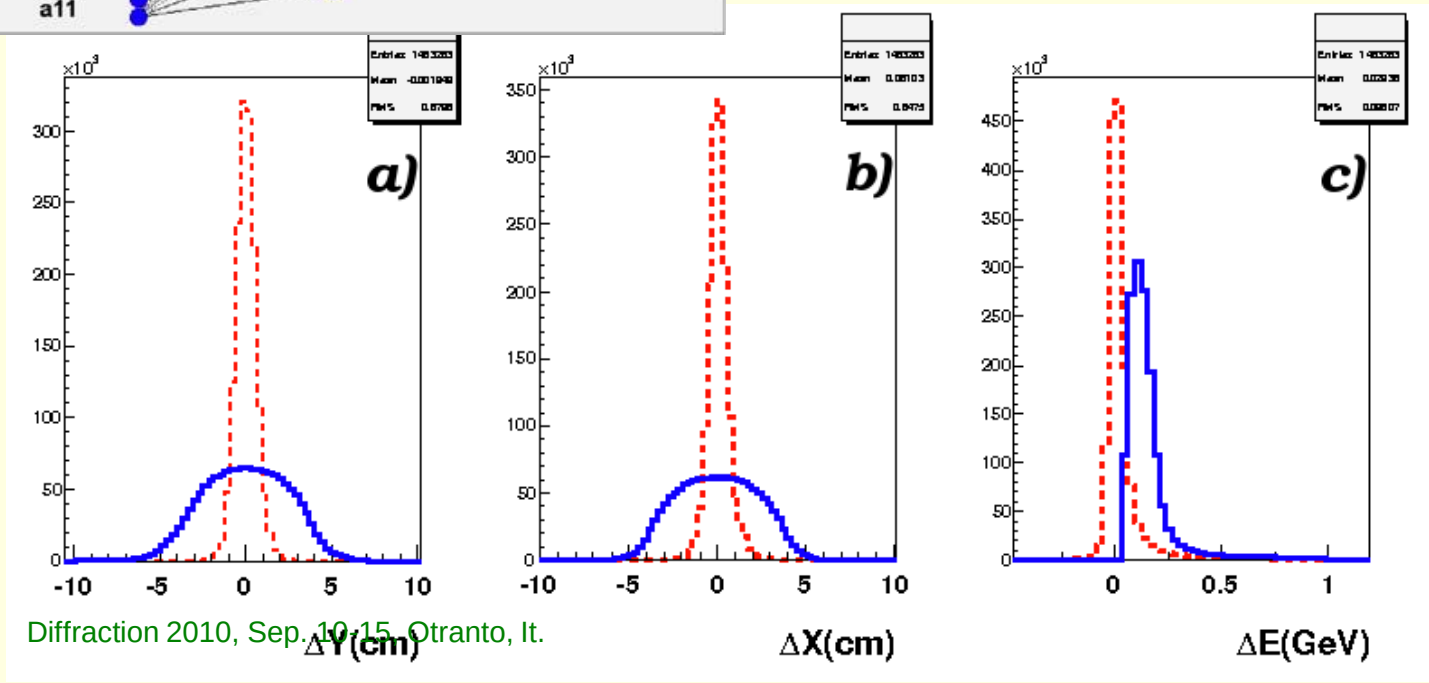
→ energy and position measurement

→ Calibrated by π^0

Artificial Neural Network

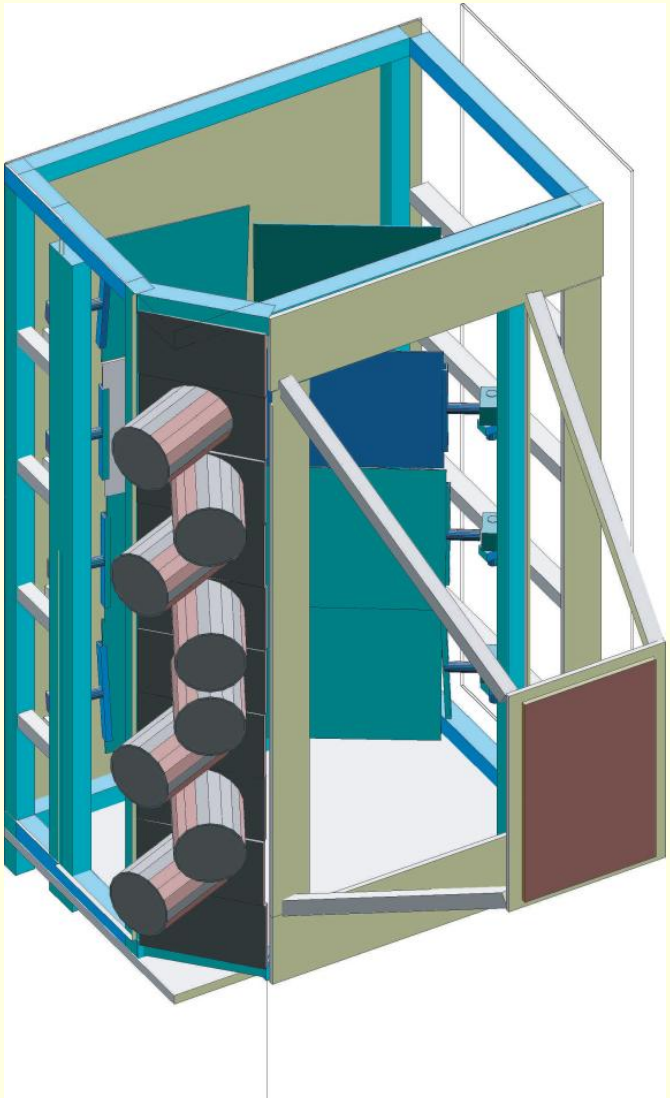


- ANN trained MC
- Energy cluster+ Cluster pattern → Coordinate and energy of a cluster

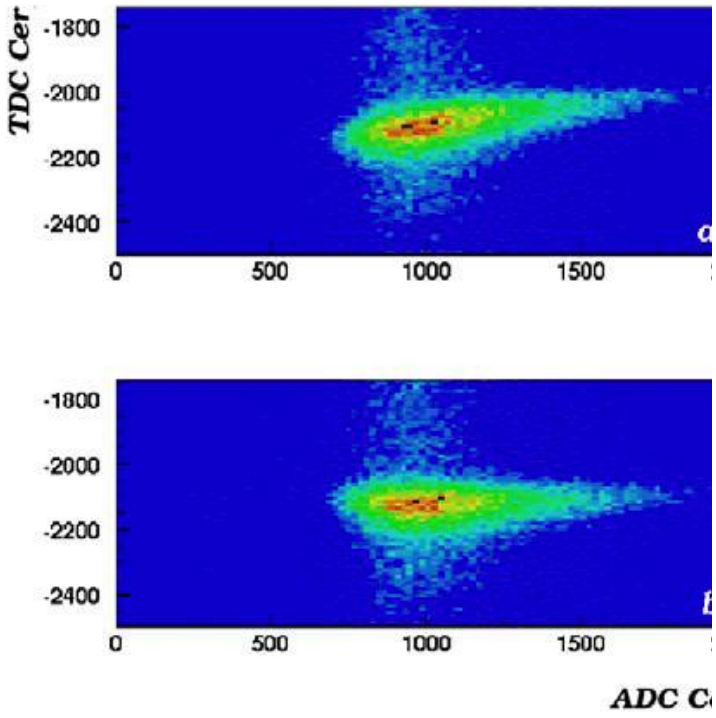


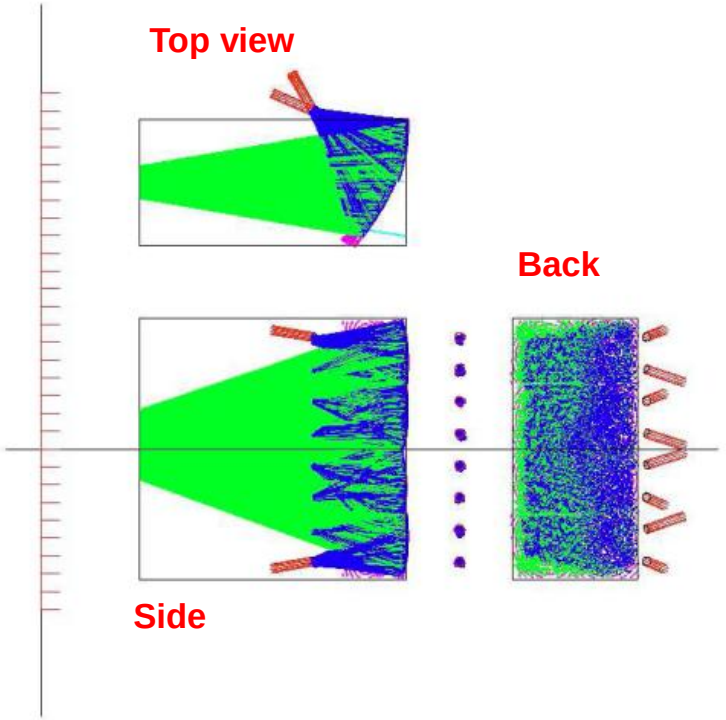
Threshold Cerenkov counter

- N_2 Cerenkov gas, n = 1.00279
- β = 0.999721, p_π=5.9 GeV/c
- 8 mirros (4 spherical + 4 elliptical)
- 8 3”-PMTs
- Pion rejection 1000:1
- Npe ~20

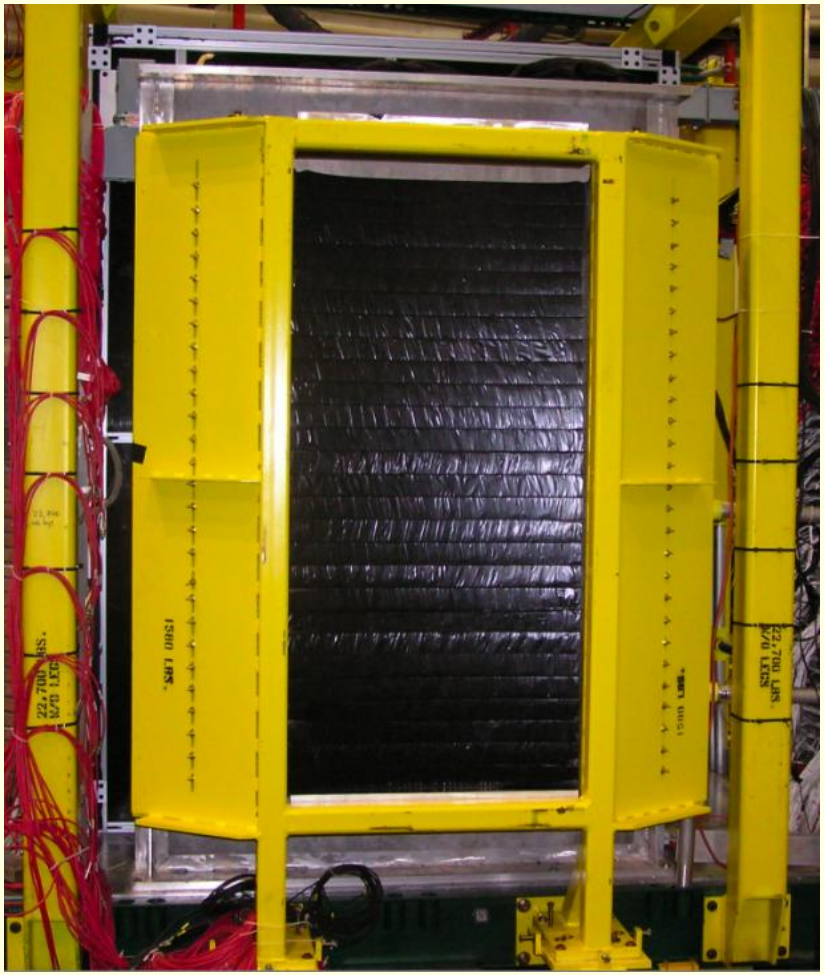


Cerenkov


TDC Cer
-1800
-2000
-2200
-2400
0
500
1000
1500
-1800
-2000
-2200
-2400
0
500
1000
1500
ADC C


Top view
Back
Side

Lucite hodoscope

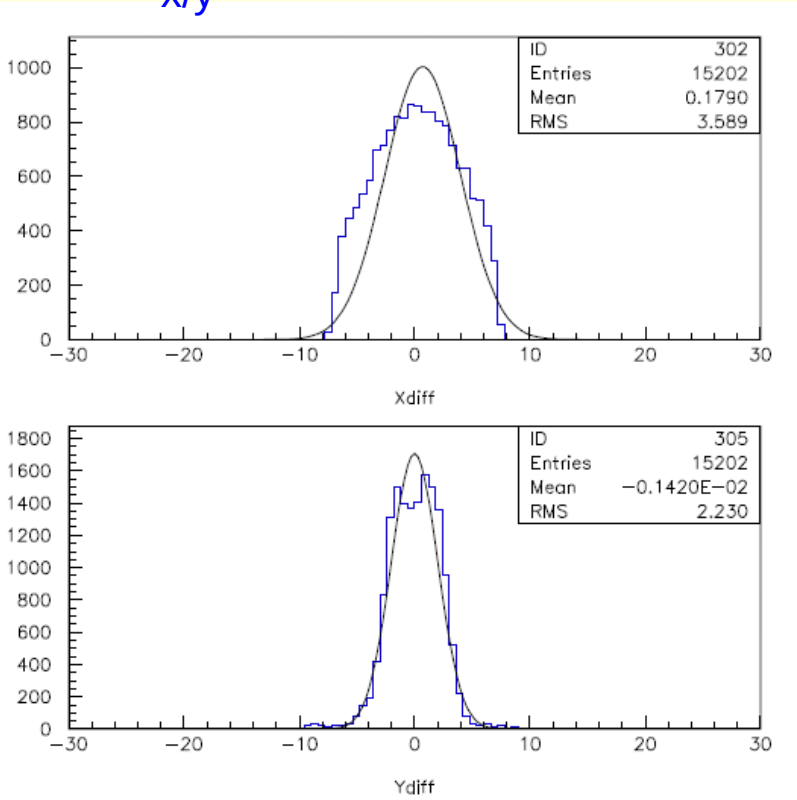


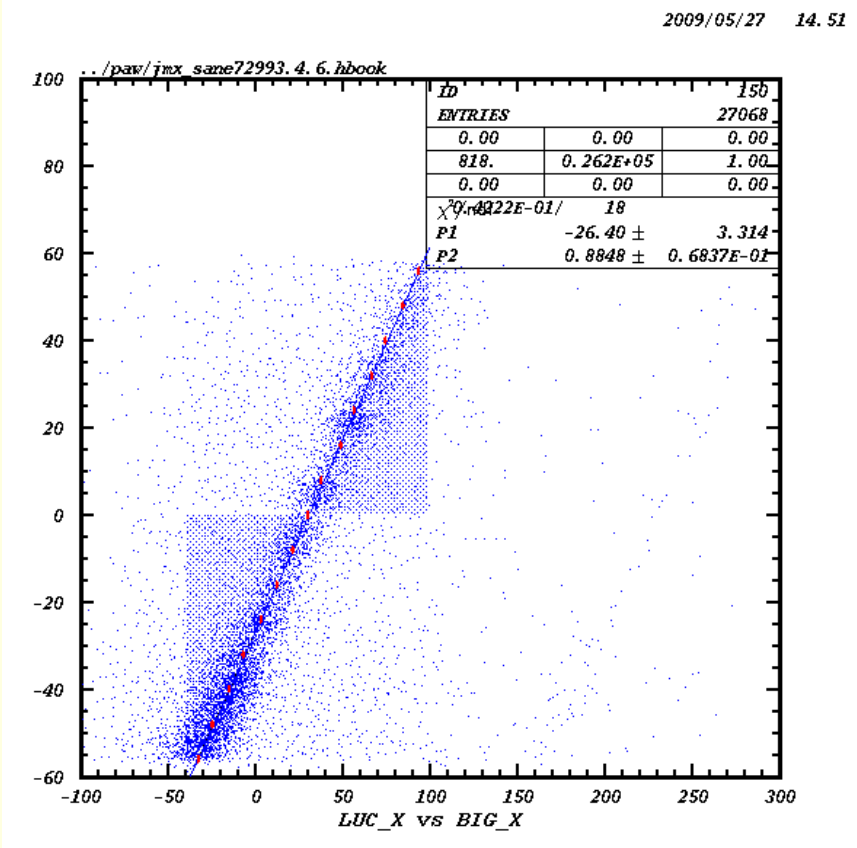
- 28 Lucite (3 x 6 cm^2) bars, n=1.49
- propagation of č-light by total Internal reflection.
- Curved with R=240 cm
- Edges cut at 45 deg (to avoid reflections)

Lucite hodoscope

- Position resolutions

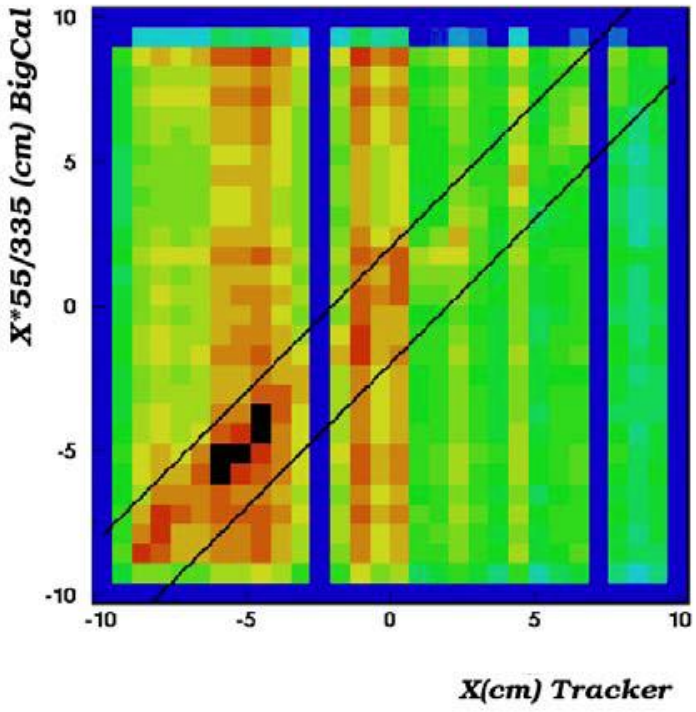
  $\sigma_{x/y}$ ~ 3.6 / 2.3 cm

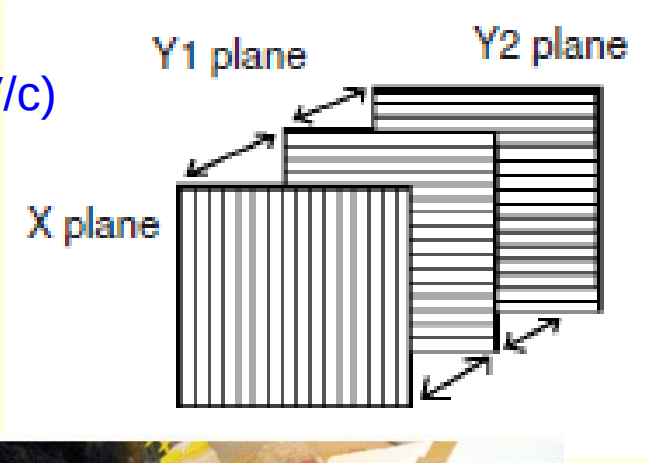




Forward tracking hodoscope

- 3 planes of plastic scintillators, 0.3 cm thick, glued to wave shifting fibers. Provide forward particle tracking + multianode PMTs.
- Target position resolution 0.5 cm
- Help reduce e^+ contamination (up to 1 GeV/c)





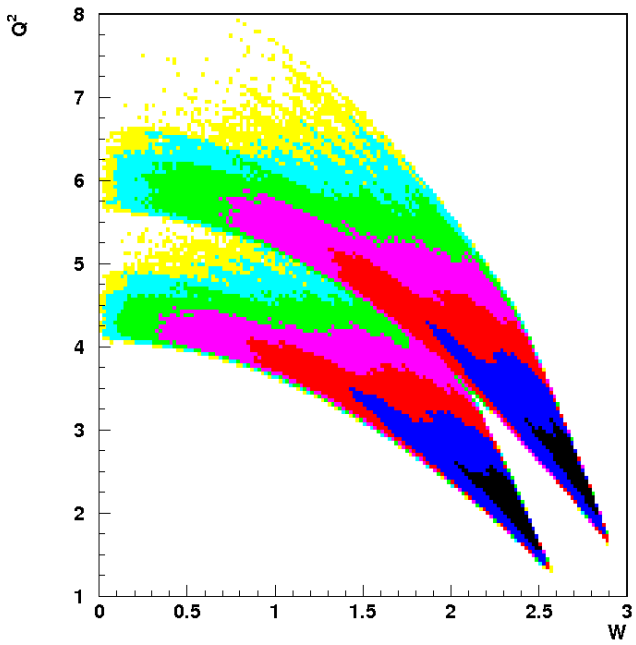
Run info:

- Experiment run Feb-Mar 2008

- Energy/field $\langle P_{Beam} \rangle^{*}$ Proposed/FOM**

Energy/field	$\langle P_{Beam} \rangle^{*}$	Proposed/FOM**
4.7GeV Parallel	~66%	~36%
5.9GeV Parallel	~88%	~33%
4.7GeV Perp	~85%	~56%
5.9GeV Perp	~71%	~56%

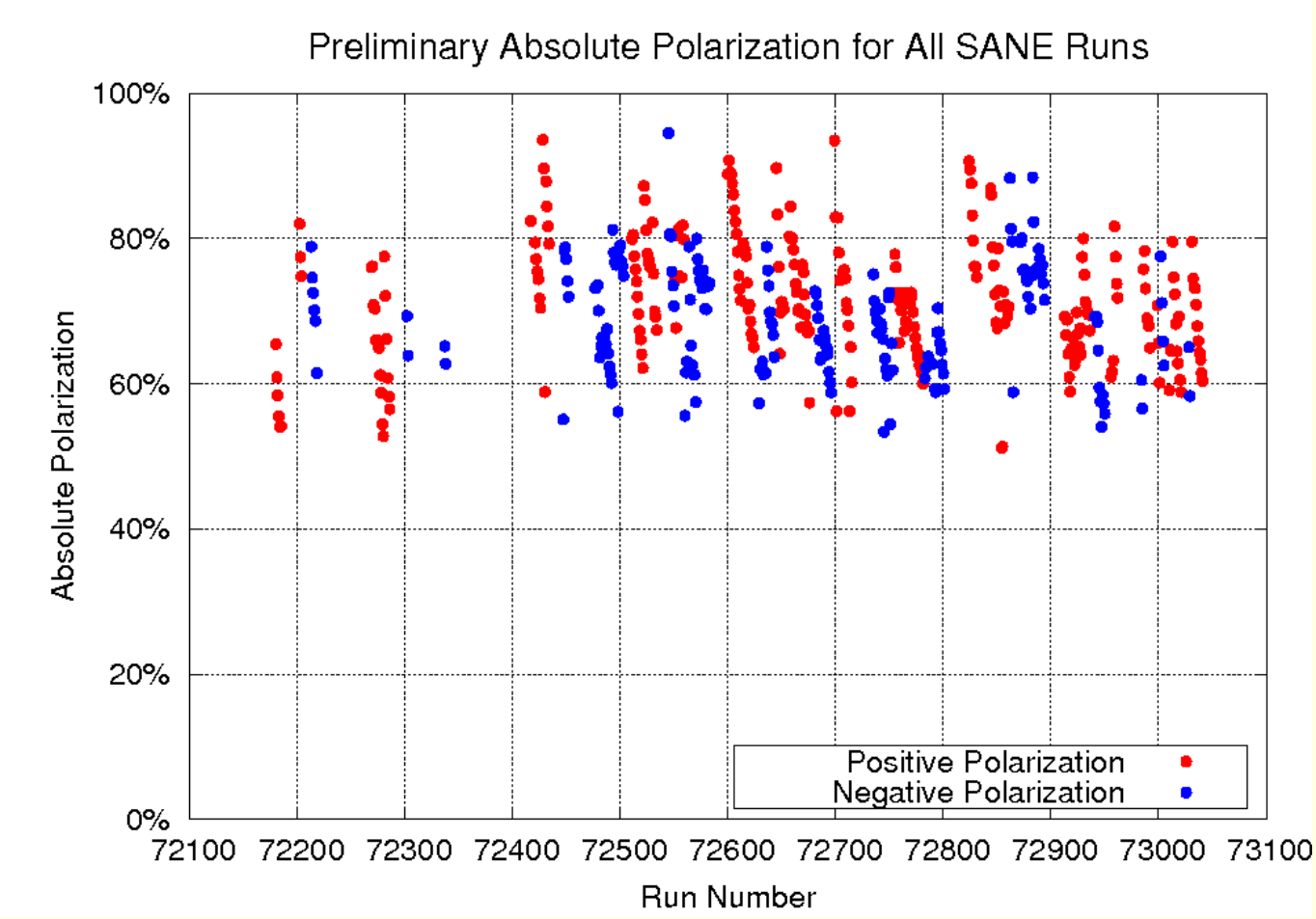
- Target:
  $\langle P_{Targ} \rangle$~71%



(*) Measured by Moller polarimeter

(**) FOM = $(P_{Targ} * P_{Beam})^2 * I_{Beam}$

Target performance

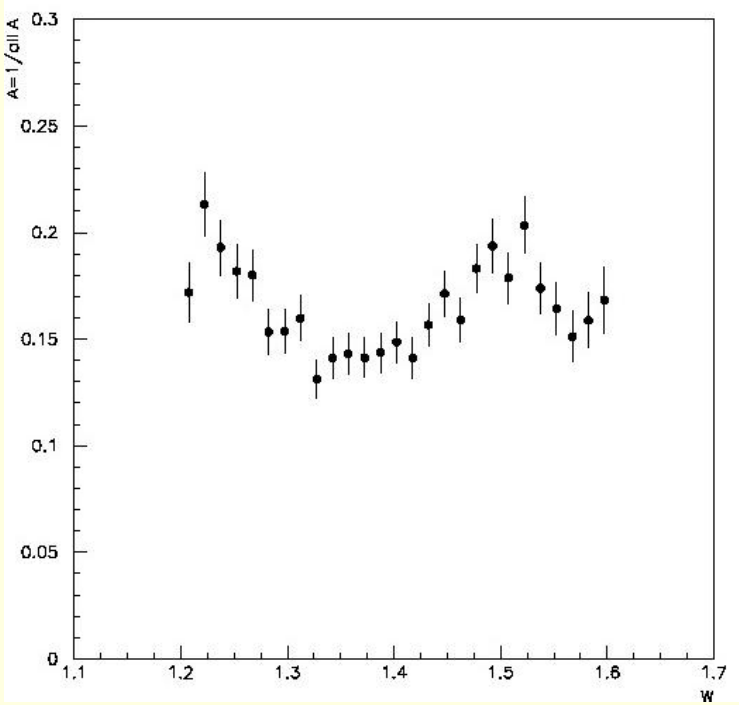


$\langle P_{Targ} \rangle \sim 71\%$

Dilution and packing factor

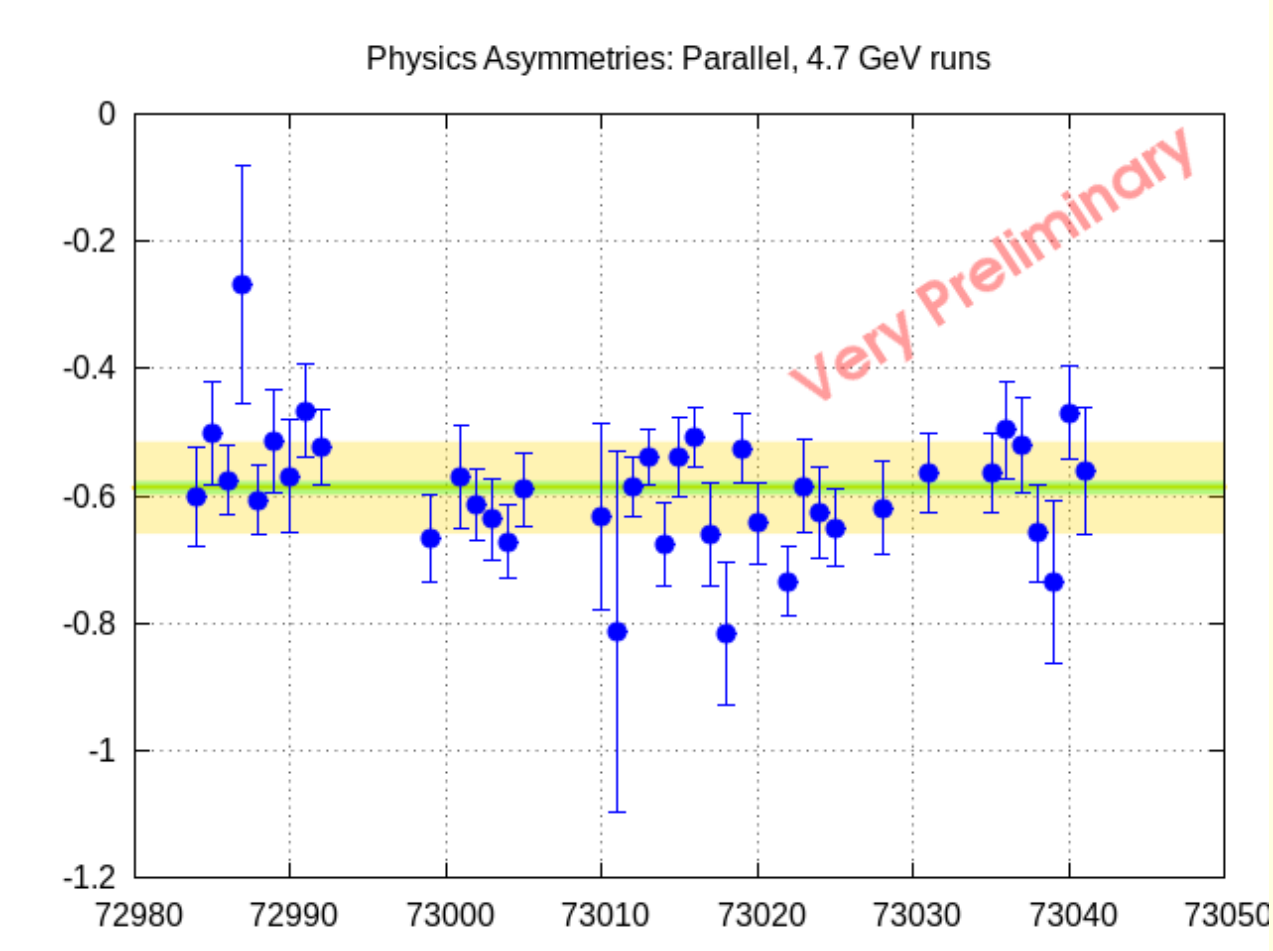
- **Packing factor**

- **Dilution Factor (*f*) ratio of rates of free polarizable nucleons (proton) to all nucleons composing the target sample (nitrogen, NMR coils, …). kinematics dependant.**

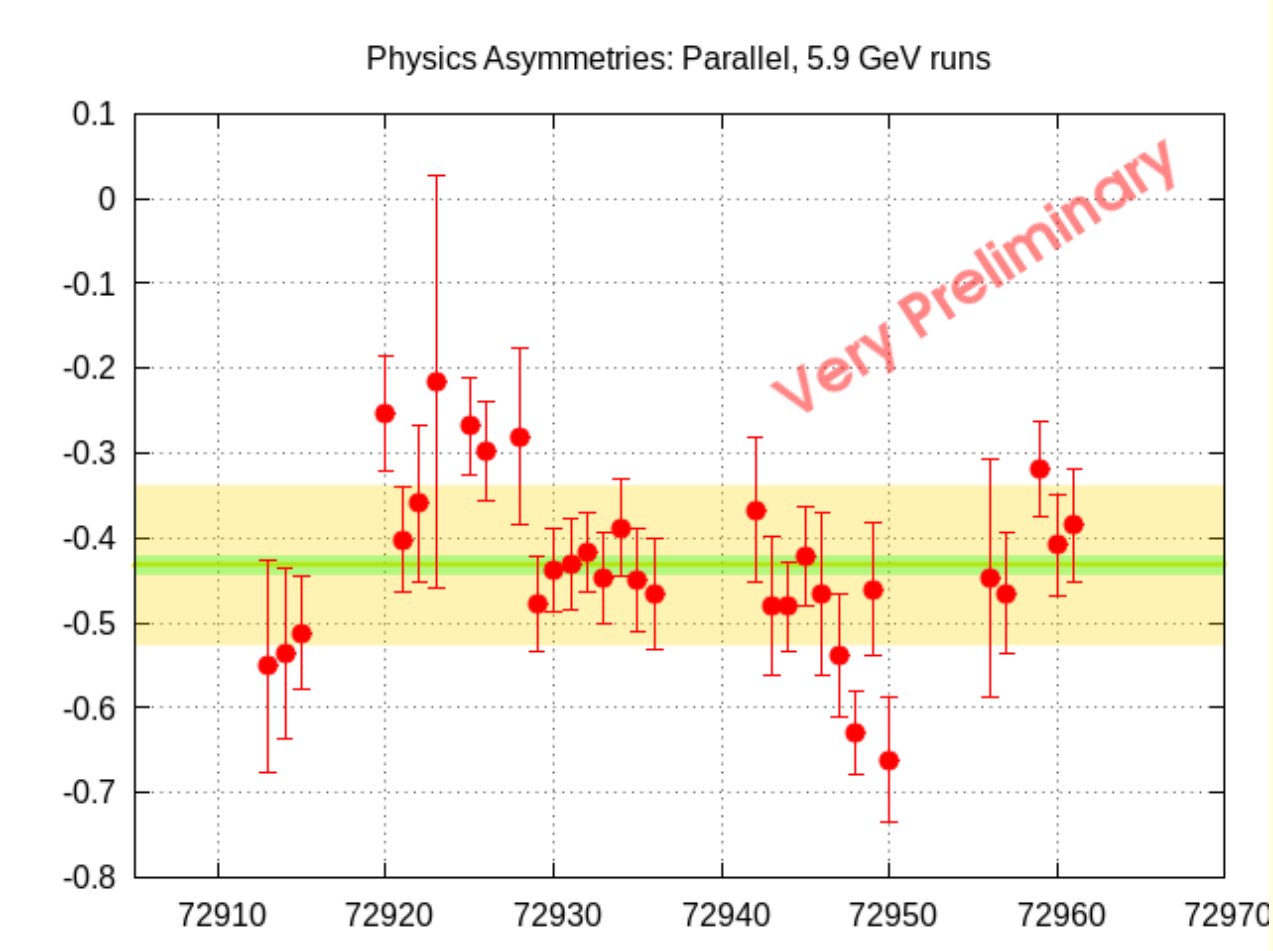


$$f(Q^2,W)=\frac{N_1\sigma_1(Q^2,W)}{N_{14}\sigma_{14}(Q^2,W)+N_1\sigma_1(Q^2,W)+\sum N_A\sigma_A(Q^2,W)}$$

Preliminary results, A//, E = 4.7 GeV



Preliminary results, $A_{//}$, E = 5.9 GeV



Summary

- SANE performed inclusive double polarization scattering → A_1, g_2, d_2
- Sane run Feb thru Mar 2008, polarized beam of 4.7 and 5.9 GeV, polarized target in // and near-perp polarizations
- Novel and large acceptance detector package BETA, performed very well
- Results:

  $A_{//}$ preliminary,

  A_{perp} in progress

Acknowledgment

- The project was supported in part by US National Science Foundation, award no. PHY-0758095 to the NC A&T State University Nuclear Physics group