Spin Structure of the Proton SANE experiment

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Outline

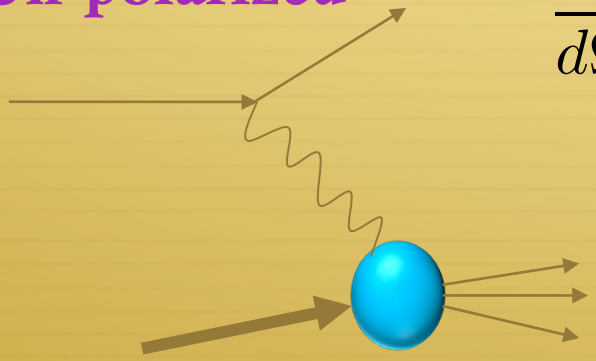
- Inclusive scattering
- Structure of the nucleus
- What do we know?
- Recent Experiment SANE
- Recent Results
- Summary

Inclusive Scattering

Un-polarized

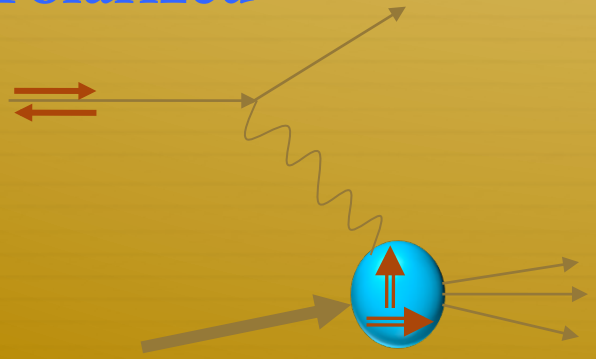
$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott} \cdot$$

$$[\frac{1}{\nu}F_2(x,Q^2) + \frac{2}{M_p}F_1(x,Q^2)\tan^2(\frac{\theta}{2})]$$



Polarized

$$+\gamma g_1(x,Q^2) + \delta g_2(x,Q^2)$$



Adding spin degrees of freedom

Structure Functions

- Structure Functions F_1,F_2 (un-polarized structure functions)
- Spin Structure Functions g_1 and g_2 (polarization observables)
  - In Quark-Parton Model

$$F_1(x) = \frac{1}{2}\sum_i e_i^2(q_i^+ + q_i^-) \qquad g_1(x) = \frac{1}{2}\sum_i e_i^2(q_i^+ - q_i^-)$$

Describe charge and spin distributions of the parton.

On the other hand $g_2 = g_2^{WW} + \bar{g}_2$

consists of twist-2 part g_2^{WW} (Wandzura-Wilczek) which is function of g_1 only

$\bar{g}_2$ which has part of twist-2 chiral odd transversity and twist-3 effect (responsible for quark-gluon correlations)

Proton Un-polarized SF

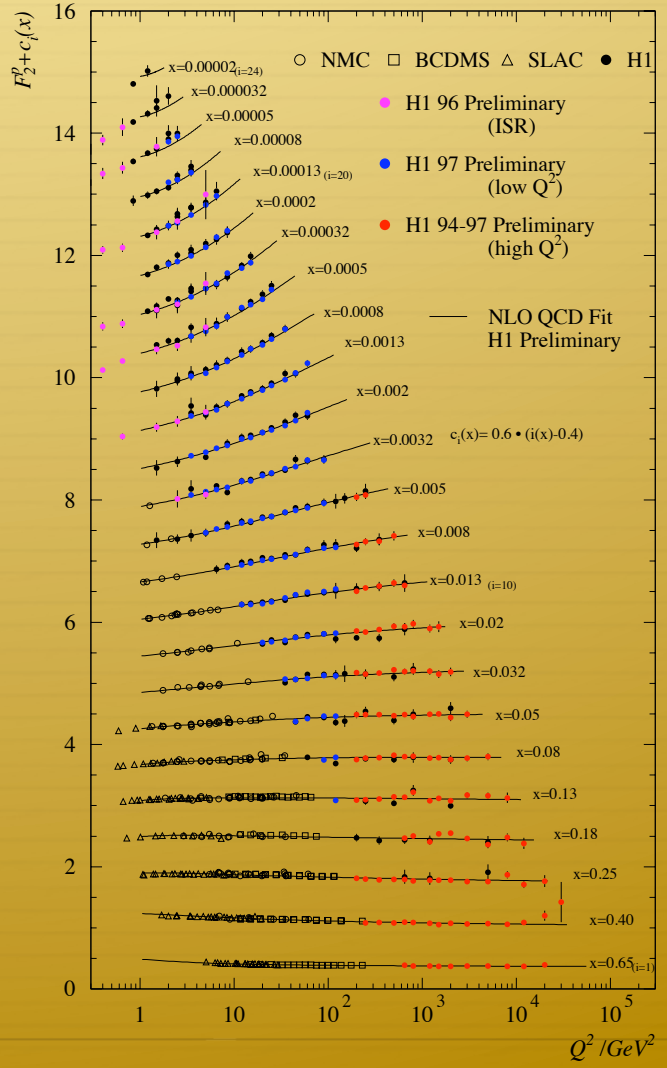
- Structure Functions F_1,F_2

(Investigated thoroughly)

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

Calan –Gross relation

$$F_2(x,Q^2) = 2xF_1(x,Q^2)$$



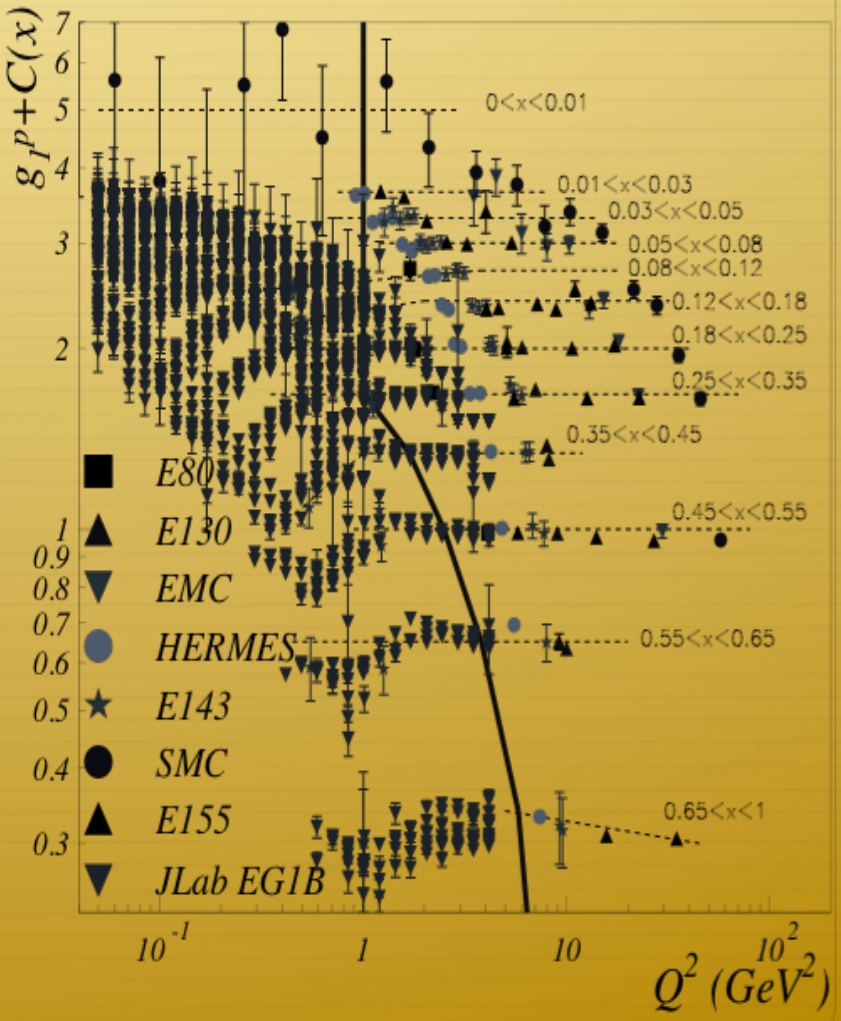
Proton Polarized SF g_1

- Structure Function g_1

(Investigated thoroughly)

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

Information obtained experimentally has un assumption that contribution of g_2 is negligible



Proton Polarized SF g_2

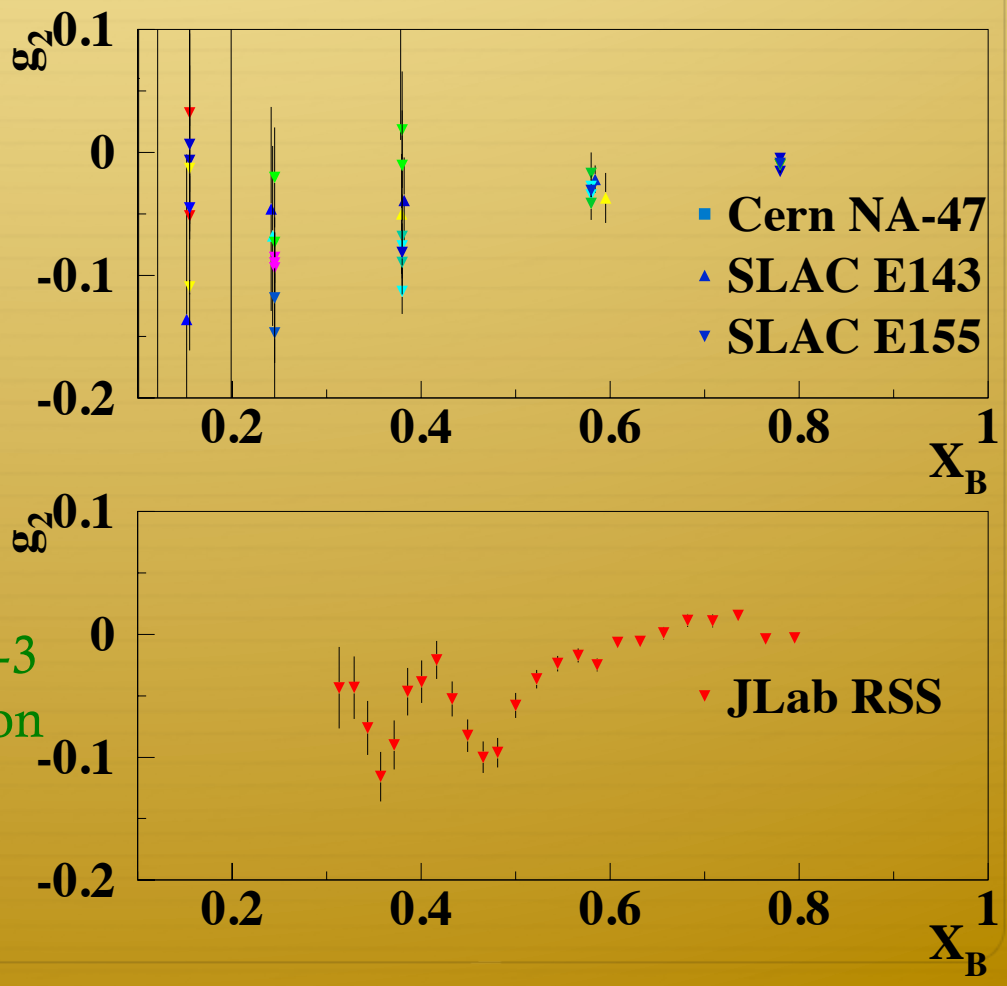
- Structure Function g_2

(known almost nothing)

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

consists of twist-2 part g_2^{WW} (Wandzura-Wilczek) which is function of g_1 only

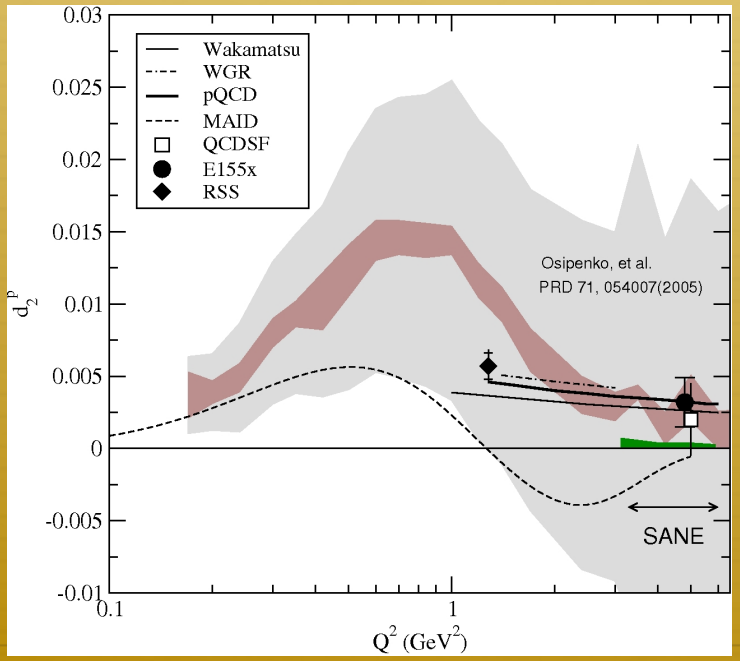
$\bar{g}_2$ which has part of twist-2 chiral odd transversity and twist-3 effect (responsible for quark-gluon correlations)



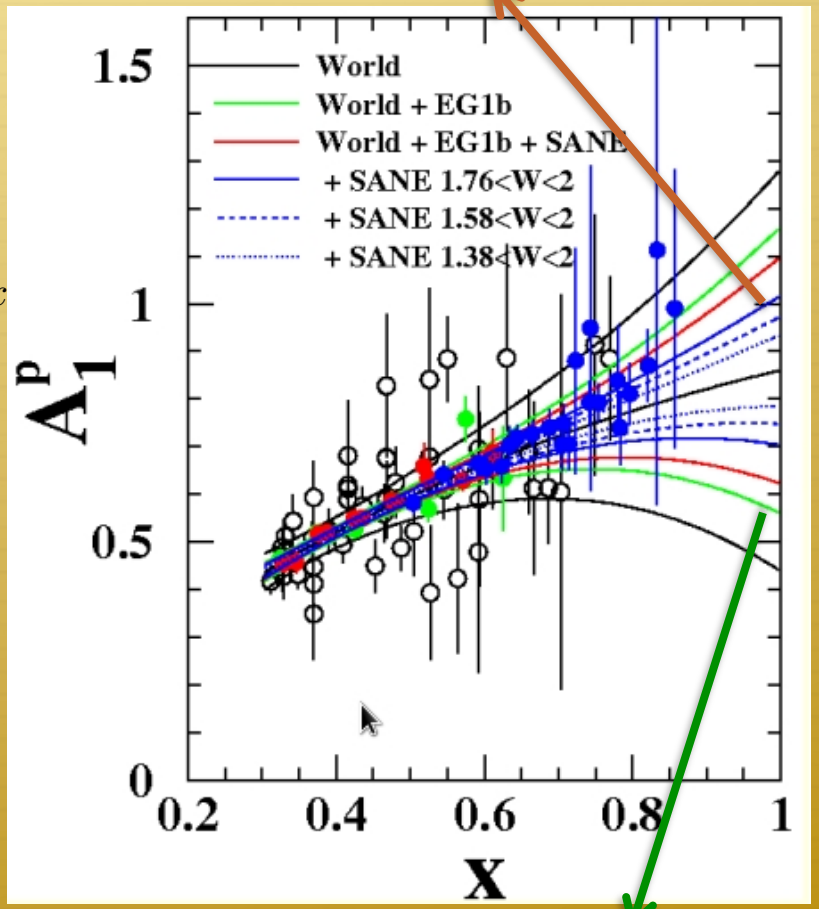
World Data of A_1^p and d_2^p

World Data (or lack of it)

- Little data on A_2^p
- A_1^p data (assumption)
- Only two points in regards to $d_2 = \int_0^1 x^2(2g_1 + 3g_2)\,dx$



pQCD



SU(6)

SANE Experiment

Hall-C –TJNAF

UVA NH_3 Polarized target

80 and 180 degree

Electron arm BETA detector

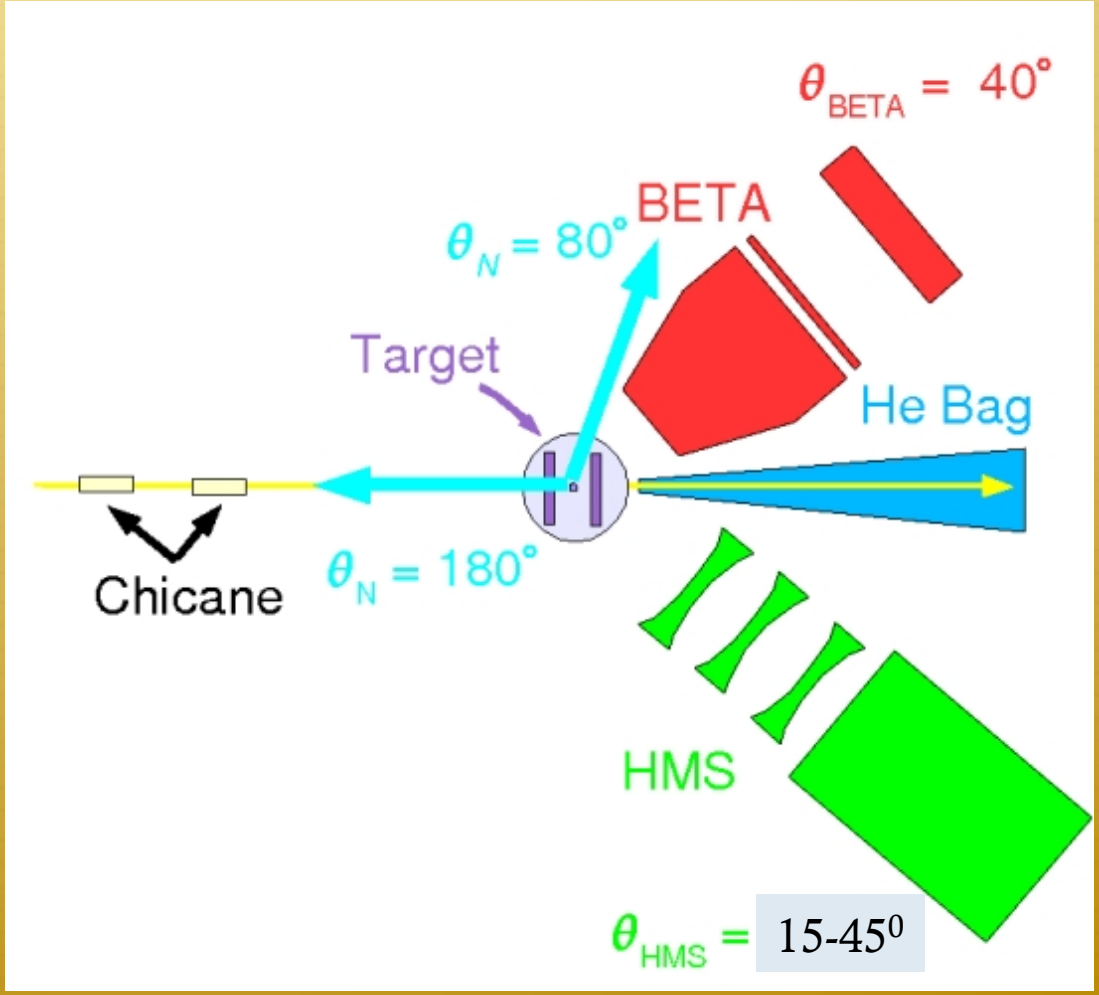
Tracker (Regina, NSU)
Cerenkov (T)
Lucite (N.Carolina A&T)
BigCal

HMS arm

15-45^o

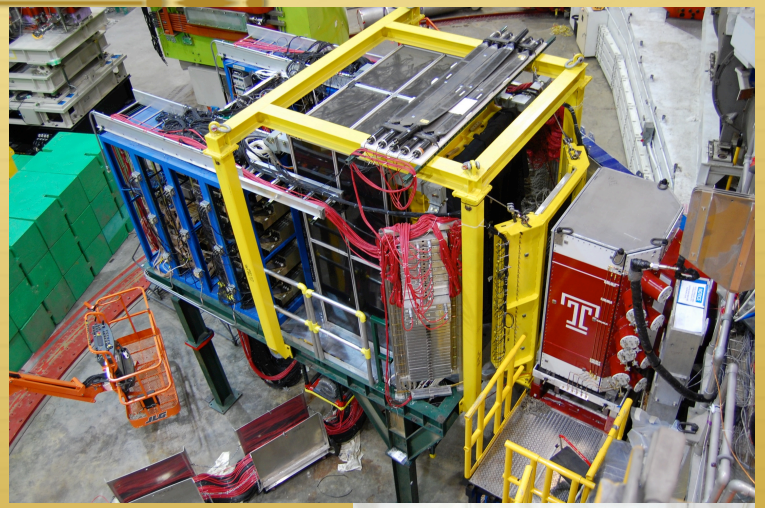
BEAM

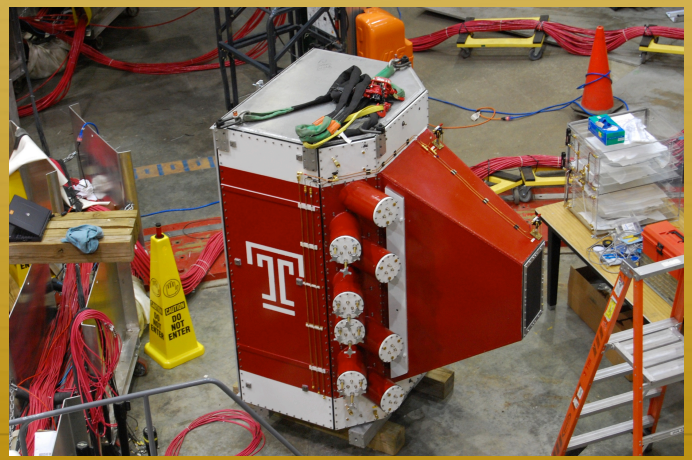
80-100nA current
Chicane
He bag



Detectors

- Tracker
  - 3 planes X(64),Y1(128),Y2(128) 3mm
- Cerenkov
  - 8 Mirrors (4 spherical, elliptical)
- Lucite
  - 28 Lucite bars
- BigCal
  - 32x32(3.82cm)+24x30(4cm) lead glass





Run Info

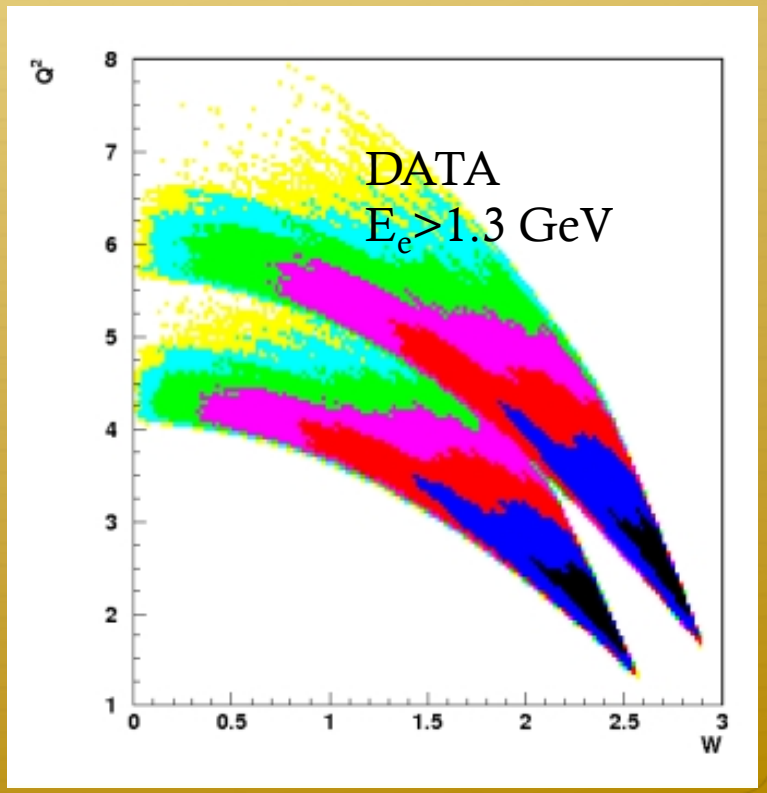
- **Experiment ran Feb – Mar 2009**
- **Energy/field Beam Pol* Proposed /FOM****

4.7 GeV Parallel	66%	39%
5.9 GeV Parallel	88%	35%
4.7 GeV Perp	85%	58%
5.9 GeV Perp	71%	62%

Target Pol 69%

(*) Measured by Moller polarimeter

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



Goal of the experiment

- Measure A_{80} and $A_{||}$ on polarized protons in frozen ammonia with polarized electron beam
- Extract A_1^p and A_2^p
- Extract g_1^p and g_2^p (Spin Structure Functions)
- Calculate Twist-3 matrix element $d_2 = \int_0^1 x^2(2g_1 + 3g_2)\,\mathrm{d}x$

(Quantifying quark – gluon interactions)

- Probe the Approach of A_1 to x=1 at constant Q^2 to test quark models and pQCD

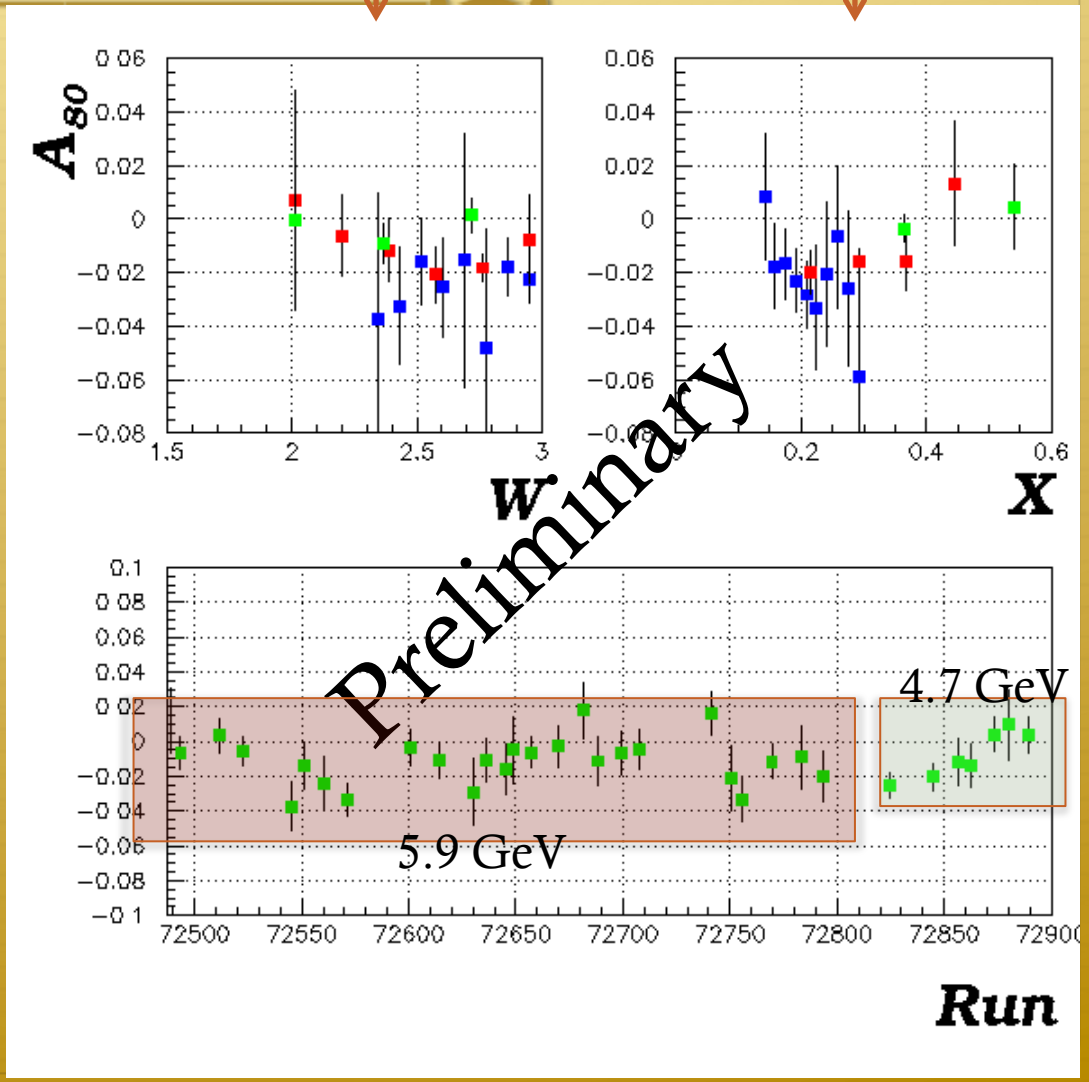
80^0 Field Orientation

- Q^2 1.7 GeV^2
- Q^2 2.5 GeV^2
- Q^2 3.5 GeV^2

- Starting from A_{180} and A_{80}
- Only constant dilution factor applied
- Large energy range (>0.8)

What else should be done for Asymmetry extraction

- Kinematics dependent dilution factors
- RAD corrections
- Pair symmetric background contribution



Extraction

$$A_\alpha \sim [(\cos(\theta_0)\cos(\alpha) + \sin(\alpha)\sin(\theta_0)\cos(\phi))E' + \cos(\alpha)E]M_p G_1 + 2[\cos(\theta_0)\cos(\alpha) - \cos(\alpha) + \sin(\alpha)\sin(\theta_0)\cos(\phi)]E'EG_2$$

$$A_{180} \sim ((\cos(\theta_0)E' + E)M_p G_1 - Q^2 G_2)$$

Solve for $\frac{M_p \cdot G_1}{W_1}, \frac{G_2}{W_1}$ which can be used to extract A_1 and A_2

$$A_1 = \nu \cdot \frac{M_p \cdot G_1}{W_1} - Q^2 \cdot \frac{G_2}{W_1} \qquad g_1 = \nu M_p^2 G_1$$

$$A_2 = \sqrt{Q^2}\left(\frac{M_p \cdot G_1}{W_1} + \nu \cdot \frac{G_2}{W_1}\right) \qquad g_2 = \nu^2 M_p G_2$$

A_1 and A_2 are obtained in model independent way using experimental asymmetries only

Physics Asymmetries

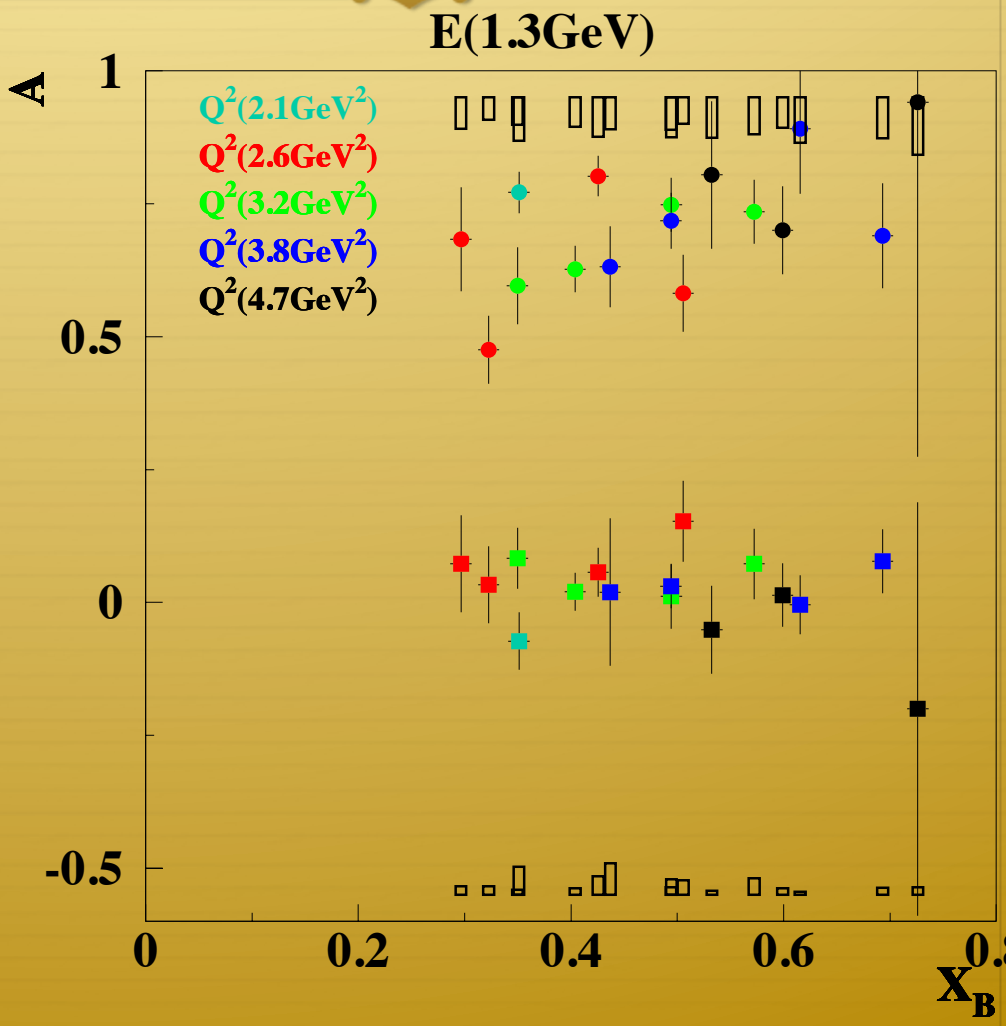
We observe A_1 dependence on Q^2

A_1 decreases with Q^2

A_1 slop decreases with Q^2

A_2 is non 0 at low and high x_B

A_2 has Q^2 dependence



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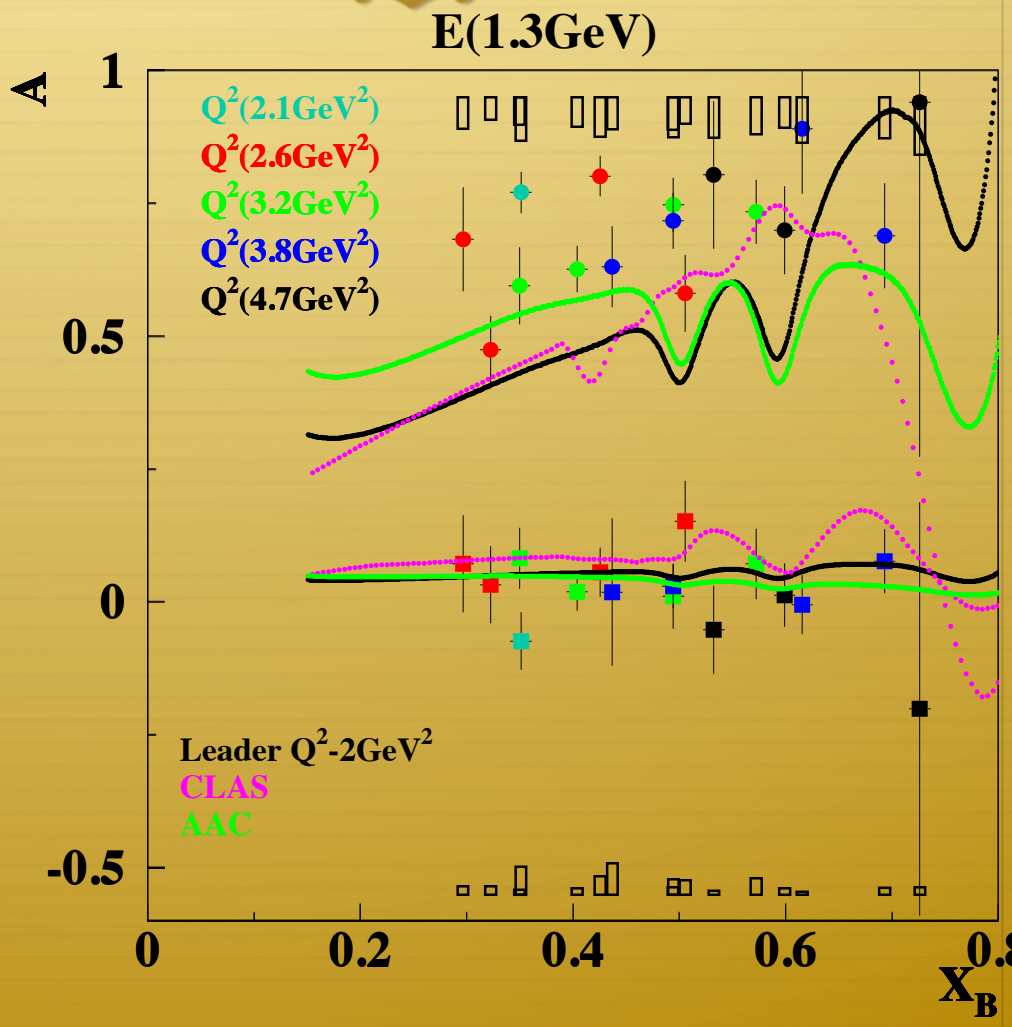


Physics Asymmetries

We observe A_1 dependence on Q^2

A_1 decreases with Q^2

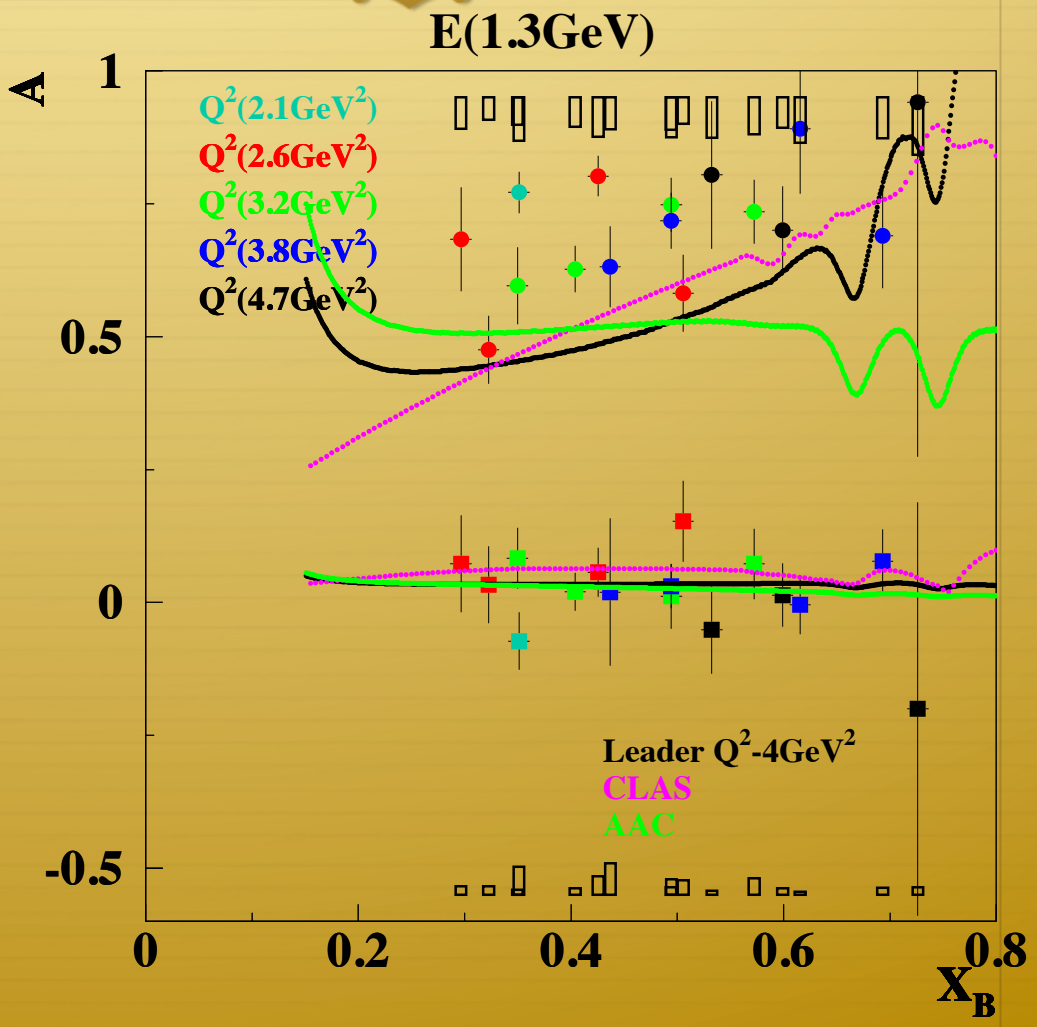
A_1 slop decreases with Q^2

Models for A_1 are missing the data

A_2 is non 0 at low and high x_B

A_2 has Q^2 dependence

Models for A_2 within the errors



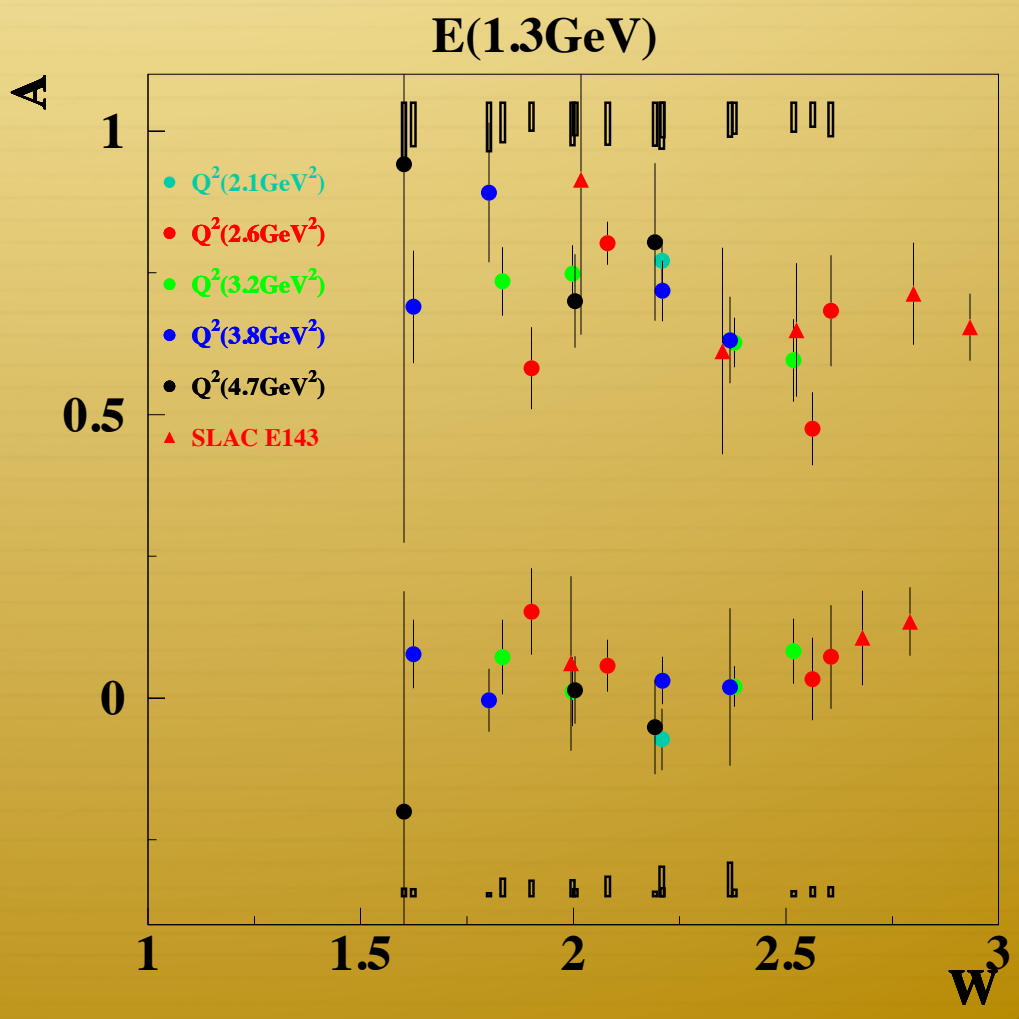
Maybe W instead of X

In DIS region almost no Q^2 (besides Q^2 dependence of W)

A_1 decreases with W

A_2 is linearly increasing with W

A_2 has Q^2 dependence in non DIS region



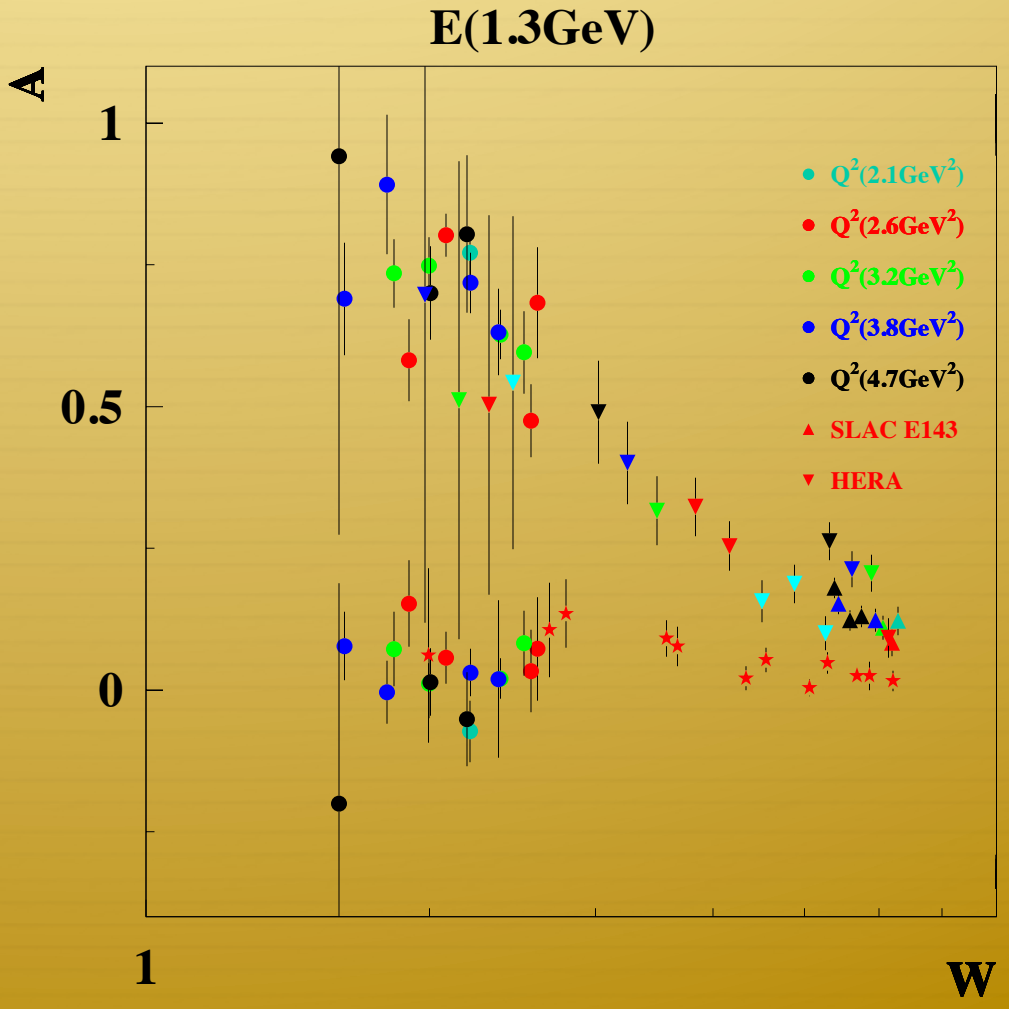
Maybe W instead of X

Slop of world data is in agreement with data ???

A_1 decreases with W ????

A_2 is in agreement with previously measured ?????

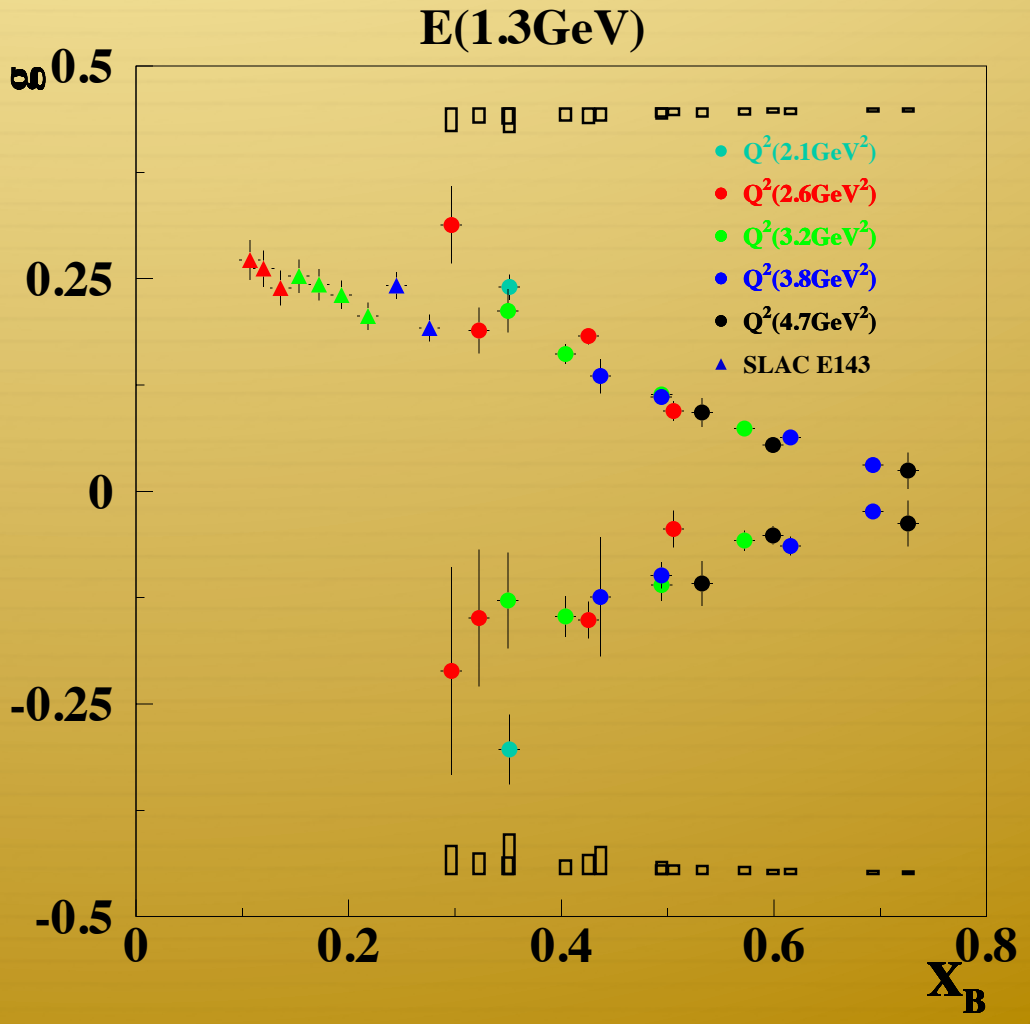
A_2 has Q^2 dependence in non DIS region???



Spin Structure Functions

Black bars are showing systematic errors

Largest contribution to systematic error comes from positron contamination at lower energies

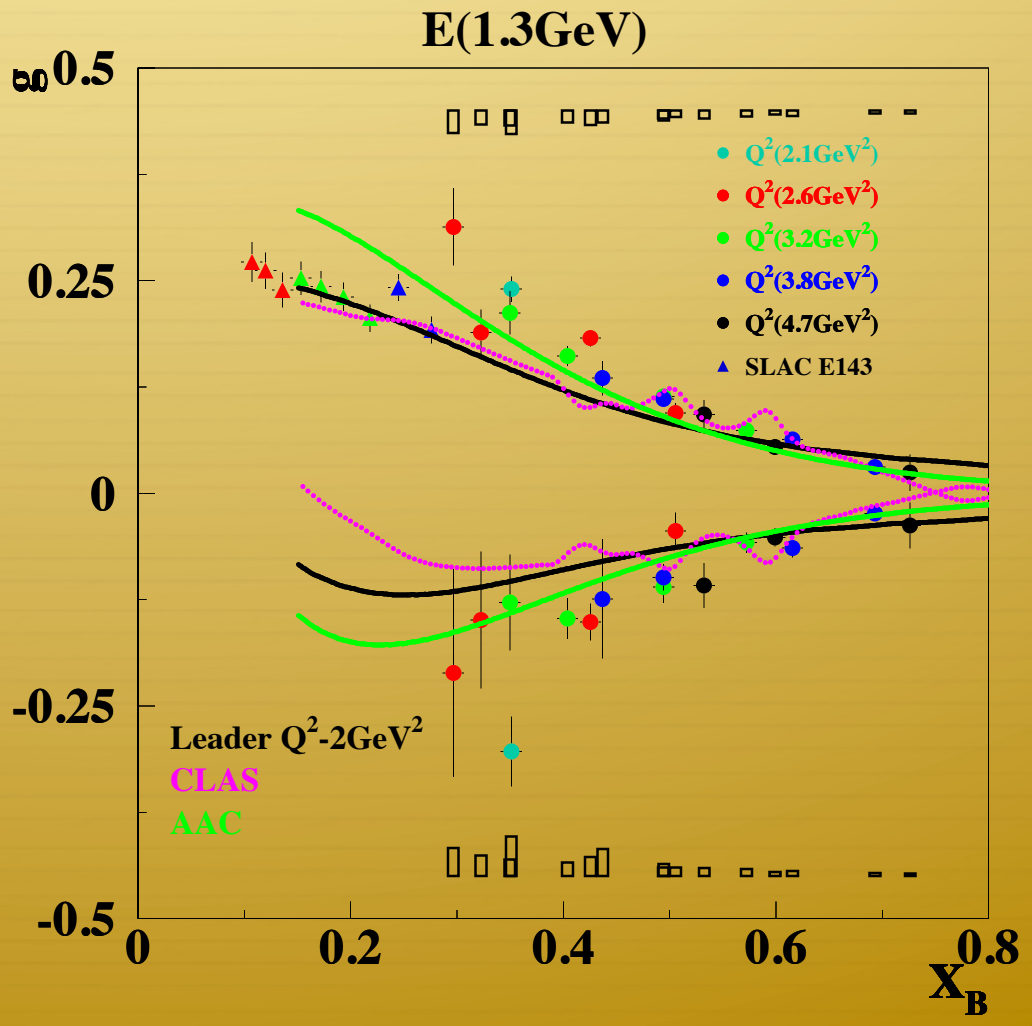


Spin Structure Functions

Black bars are showing systematic errors

Largest contribution to systematic error comes from positron contamination at lower energies

Q^2~2 GeV x_B >0.3 are within errors

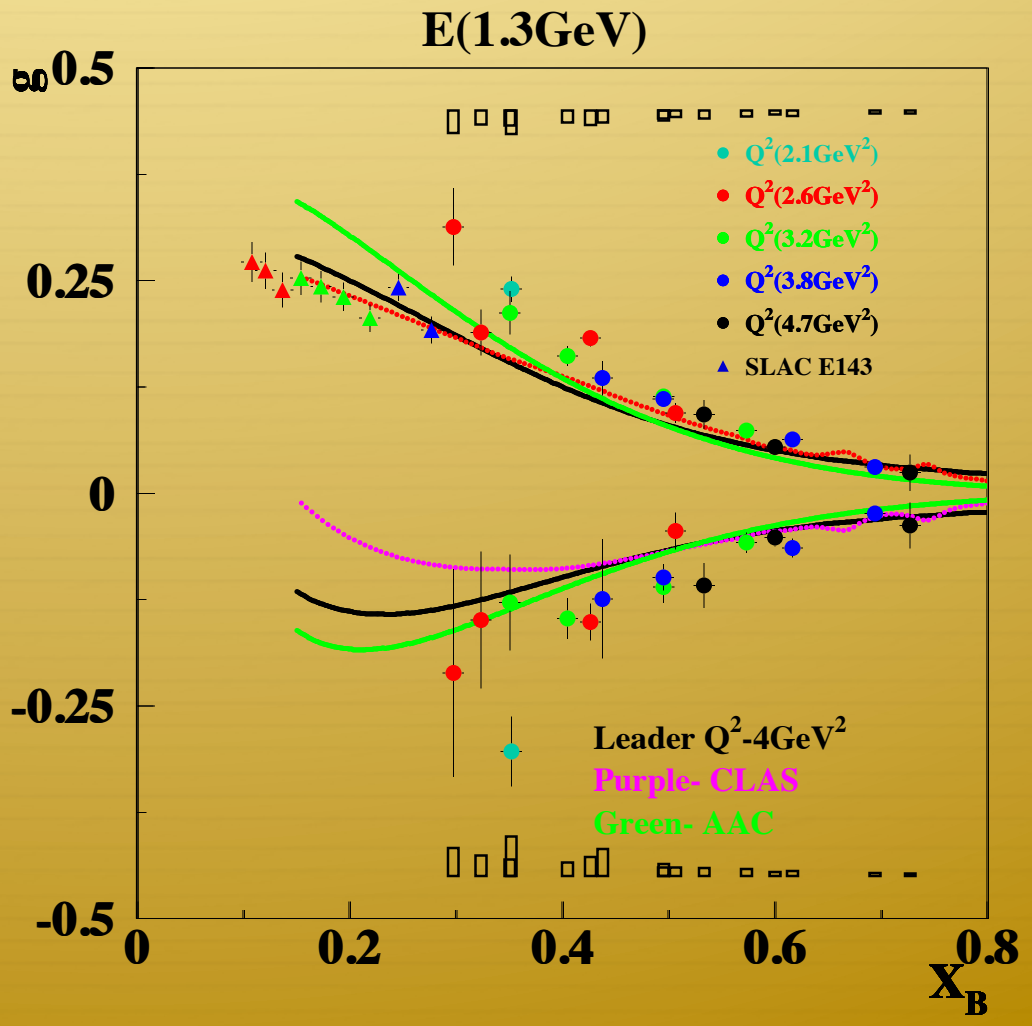


Spin Structure Functions

Black bars are showing systematic errors

Largest contribution to systematic error comes from positron contamination at lower energies

Q2~4 GeV x_B >0.3 are within errors



Summary

- TO BE DONE

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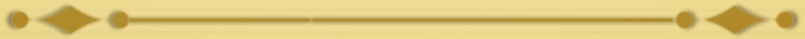
Backup slides



Experiment Challenge

- BigCal Calibration

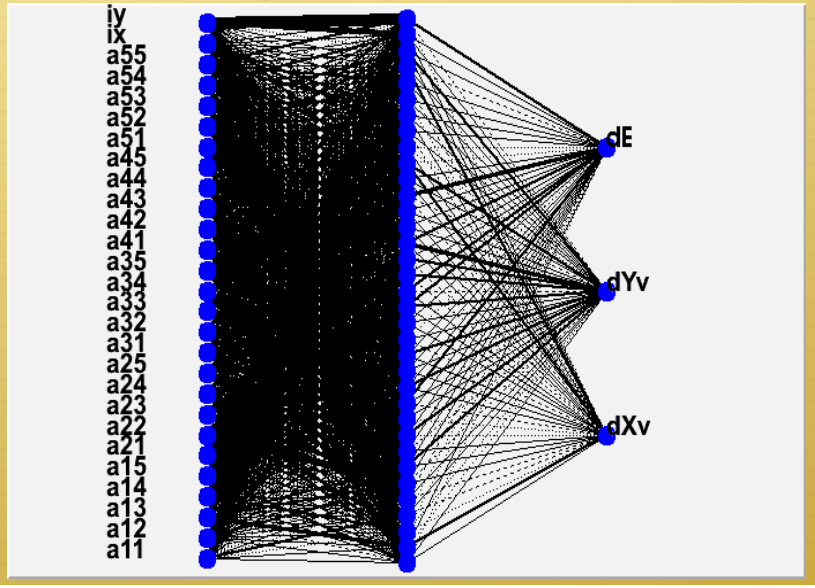
No time for detector calibration using elastic events

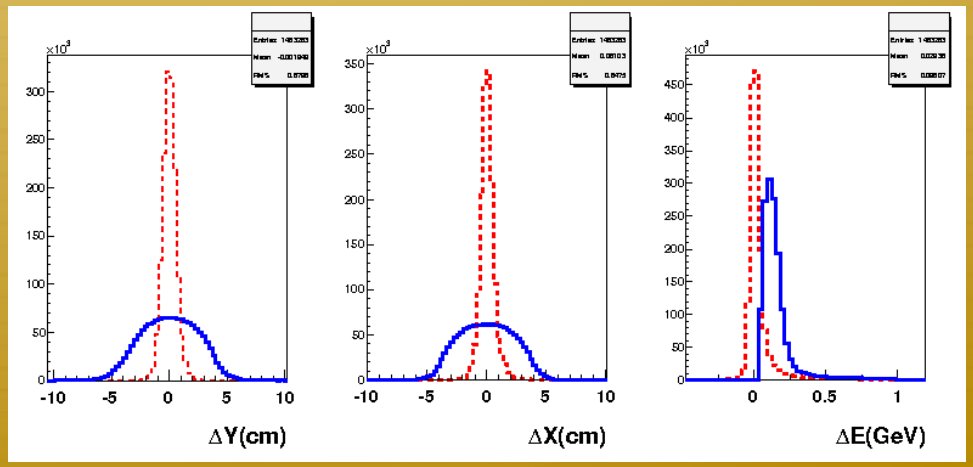
SOLUTION :

Neural Network (uses information from 25 blocks and position of central block)

Calibration using neutral pions

Better than 10% cluster energy resolution

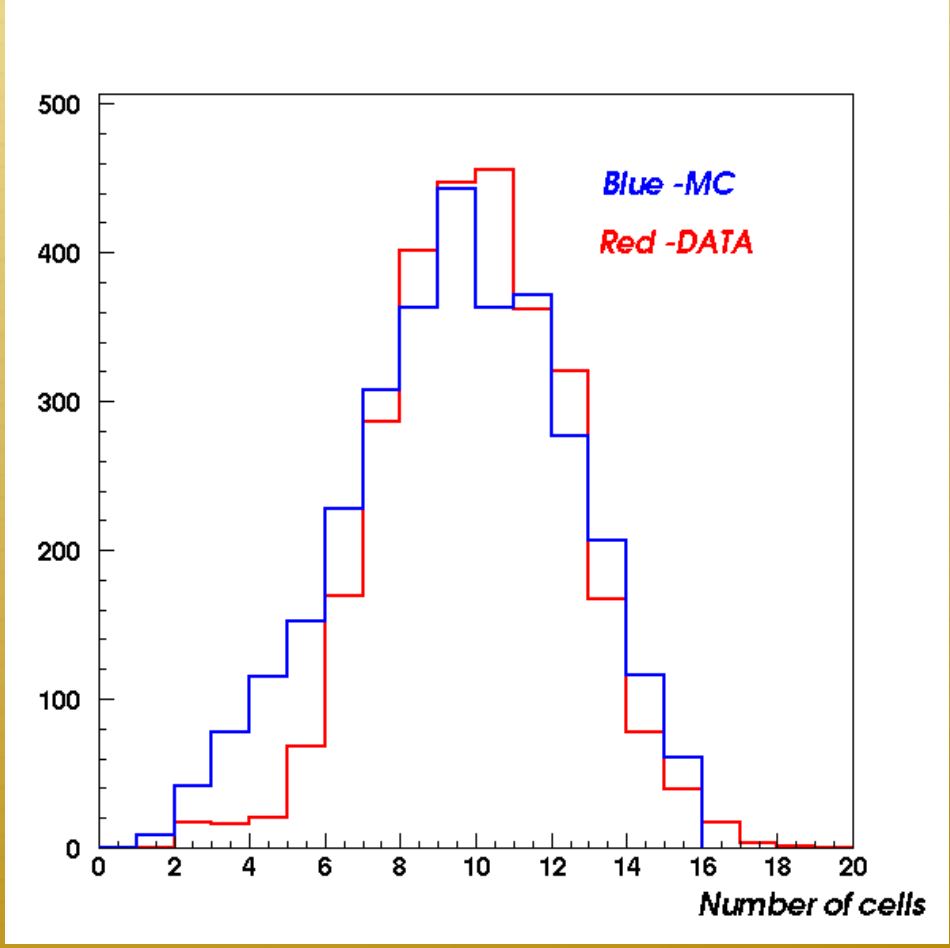




Pileup

Average cluster size with E>0.8 GeV

- **Generated cluster size is similar to Data cluster size**
- **Block energy cut >10 MeV**
- **Most energetic block cut >150 MeV**
- **No Pile-up observer**



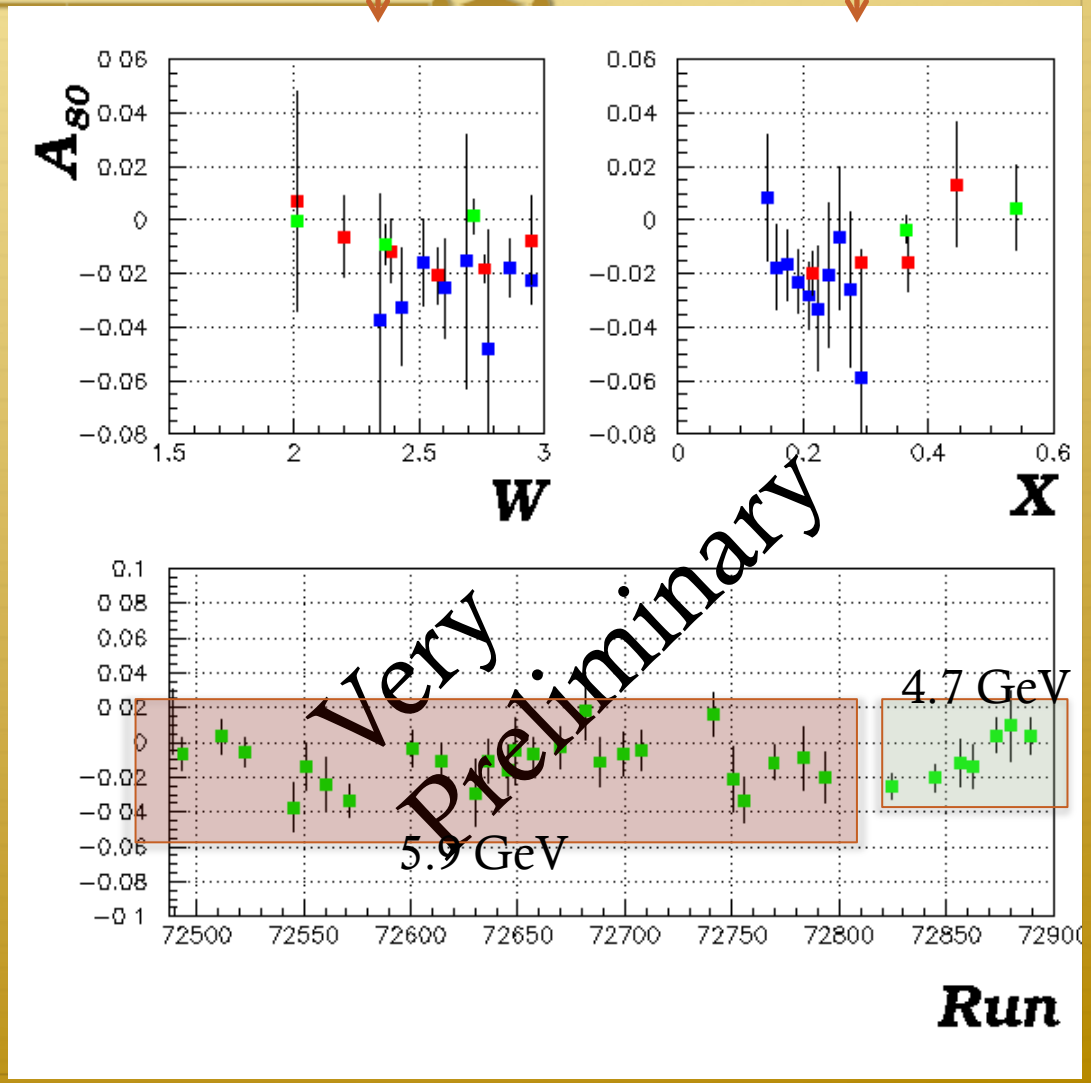
80^0 Field Orientation

- Q^2 1.7 GeV^2
- Q^2 2.5 GeV^2
- Q^2 3.5 GeV^2

- Non-zero Asymmetry (2%)
- In some kinematics ranges A_{80} is about 20% of A_{180}

What else needs to be done

- Only shows about 50% of data taken
- Kinematics dependent dilution factors
- RAD corrections
- Better binning



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What about slope

Red triangles are E143

Slop of our data corresponds to slop of E143 data

Data are consistent with each other in the region of interest