Quick Overview of Solenoid Reach for SIDIS

Jian-ping Chen, Jefferson Lab

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- Transversity and TMDs
  - Multi-dimension: high luminosity AND large acceptance needed
- Selonoid
  - DIS-PV, inclusive DIS (spin) and PV spin structure: 1-2 order
  - Kinemtic reach for SIDIS
  - SIDIS: Transversity and TMDs: 2-3 orders

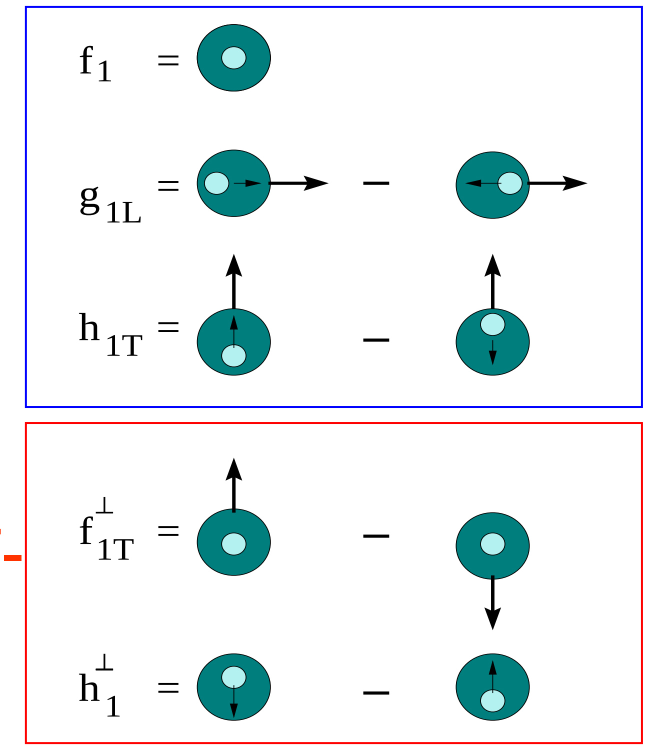
•***Acknowledgement: E. Chudakov, X. Qian, and many others***

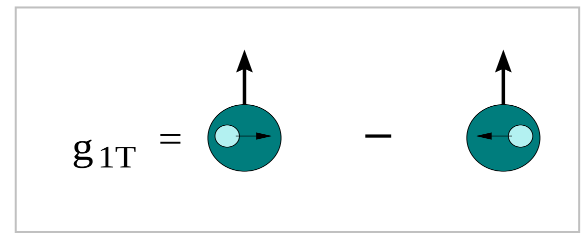
Leading-Twist Quark Distributions

(A total of eight distributions)

No $K_\perp$ dependence

$K_\perp$ - dependent, T-odd





$K_\perp$ - dependent, T-even

Transversity

- Three twist-2 quark distributions:
  - Momentum distributions: $q(x,Q^2) = q^{\uparrow}(x) + q^{\downarrow}(x)$
  - Longitudinal spin distributions: $\Delta q(x,Q^2) = q^{\uparrow}(x) - q^{\downarrow}(x)$
  - Transversity distributions: $\delta q(x,Q^2) = q^{\perp}(x) - q_{\top}(x)$
- It takes two chiral-odd objects to measure transversity
  - Semi-inclusive DIS

    Chiral-odd distributions function (transversity)

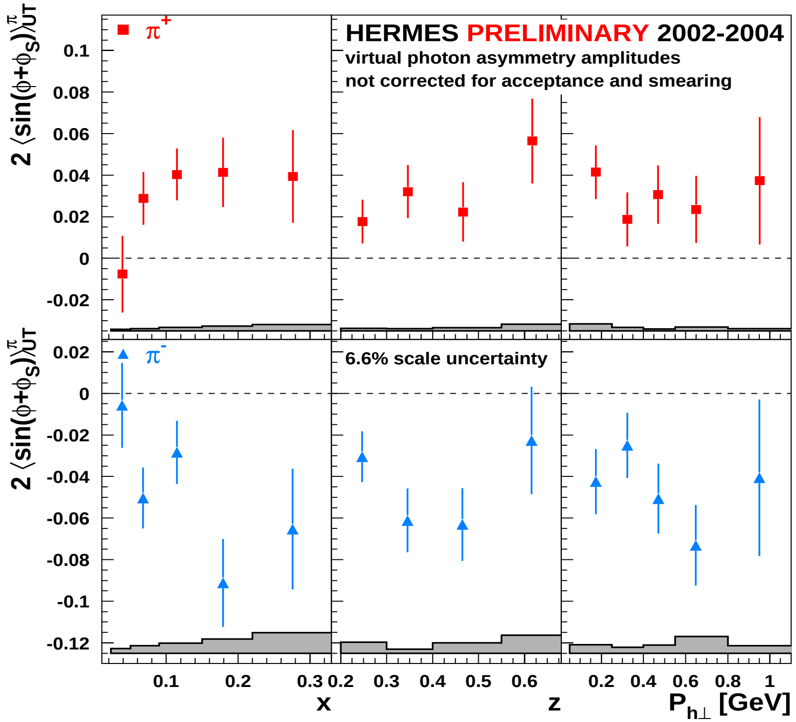
    Chiral-odd fragmentation function (Collins function)
- TMDs: (without integrating over P_T)
  - Distribution functions depends on x, $k_\perp$ and Q^2 : $\delta q,\ f_{1T}^{\perp}(x,k_\perp,Q^2),\ \ldots$
  - Fragmentation functions depends on z, $p_\perp$ and Q^2 : $D,\ H_1(x,p_\perp,Q^2)$
  - Measured asymmetries depends on x, z, $P_\perp$ and Q^2 : *Collins, Sivers, …*

    ($k_\perp$, $p_\perp$ and $P_\perp$ are related)

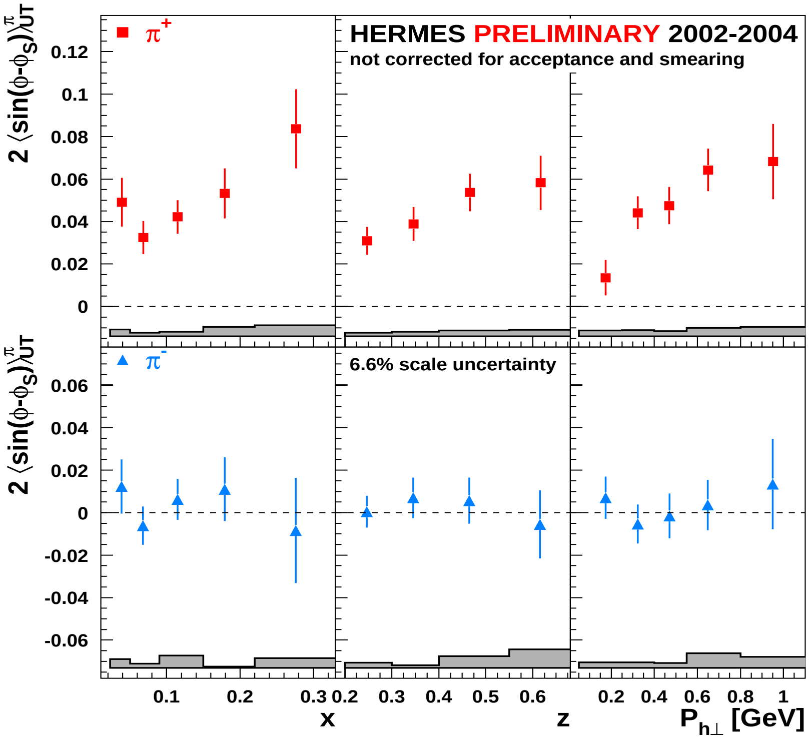
$A_{UT}^{\sin(\phi)}$ from transv. pol. H target

Simultaneous fit to $\sin(\phi + \phi_s)$ and $\sin(\phi - \phi_s)$

`Collins' moments



`Sivers' moments



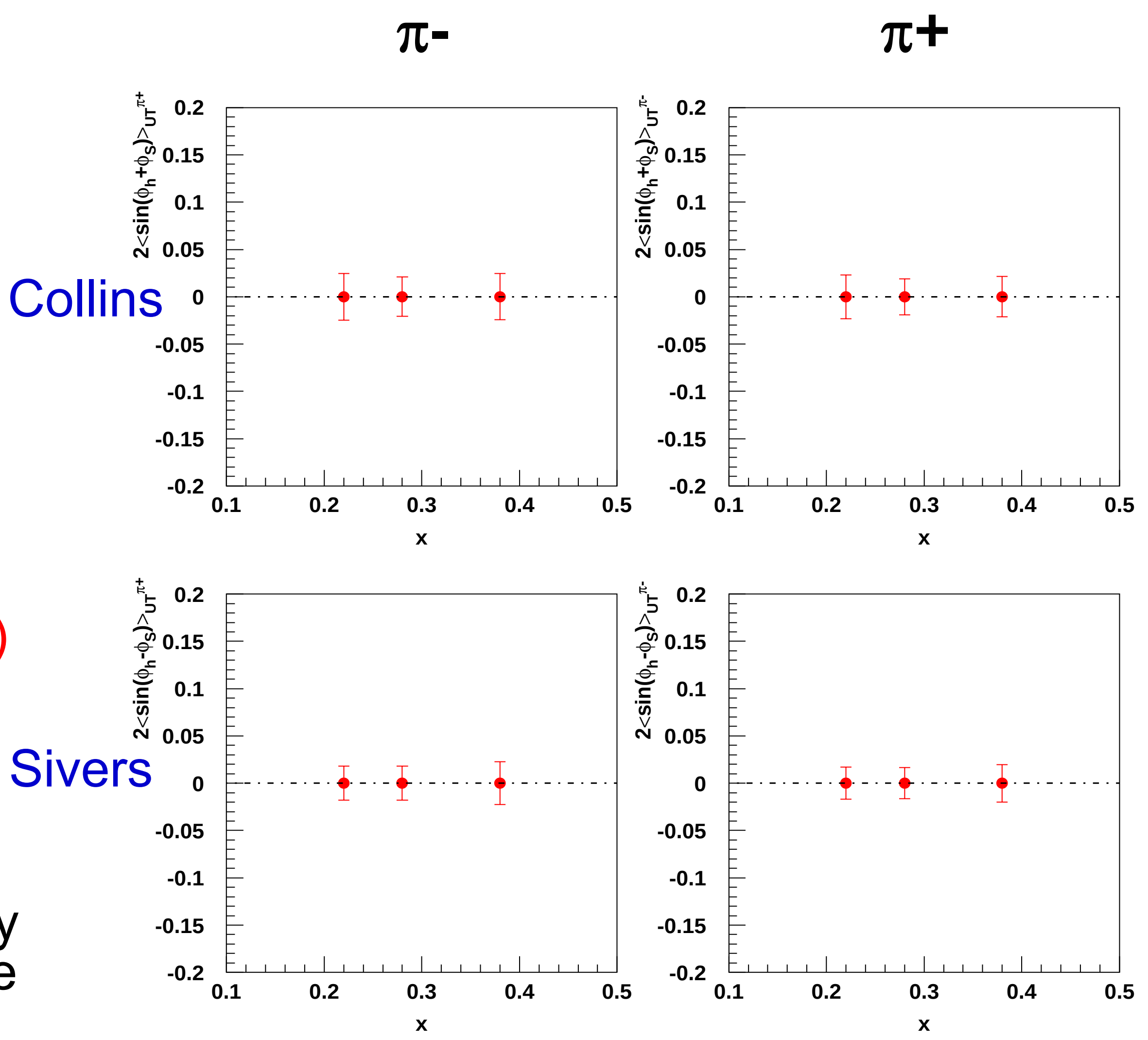
- Non-zero Collins asymmetry
- Assume $\delta q(x)$ from model, then

  H_1_unfav ~ -H_1_fav
- Need independent H_1 (BELLE)

- Sivers function nonzero (π^+)→ orbital angular momentum of quarks
- Regular flagmentation functions

Collins and Sivers Asymmetries

- Projections with MADII (1200 hours) for neutron by L. Zhu
- Summed over two other variables (z, P_T)
- Similar precision with SHMS/HMS
- Scheduled 6 GeV program also similar precision.
- Hall B 12GeV (p), better precision, still summed over



- Need much higher precision data to study 3-d (x, z and P_T) dependence
- High luminosity AND large acceptance
- 12 GeV baseline equipment

will have either high luminosity (Hall C/A) or large acceptance (Hall B)

DIS-PV: Requires Large Angle Large Acceptance

JLab Upgrade

- Need high rates at high x

- *CW 90 μA at 11 GeV*
- *40-60 cm liquid H_2 and D_2 targets*
- *Luminosity > $10^{38}/cm^2/s$*

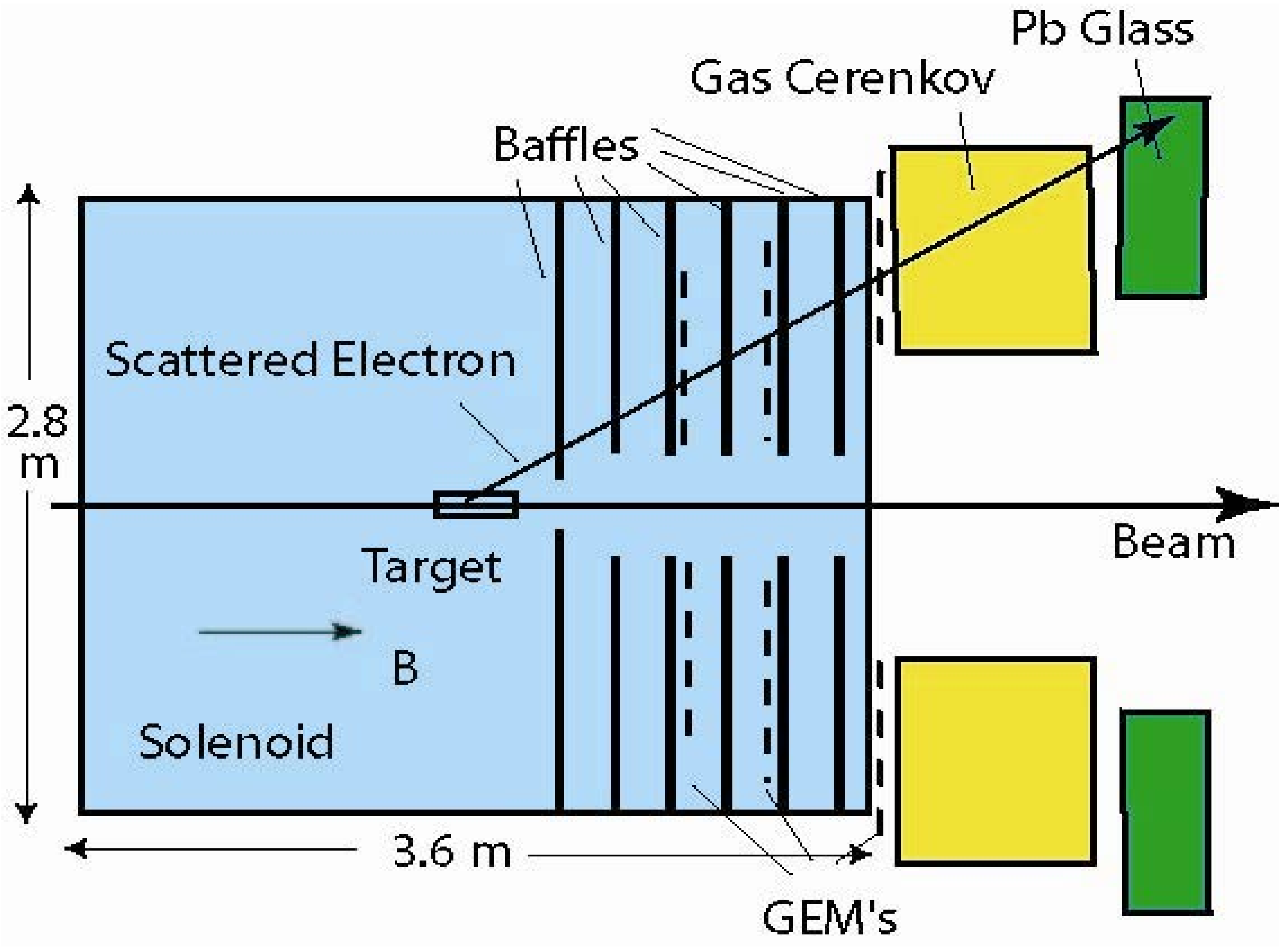
- For the first time: sufficient rates to make precision PV DIS measurements

- *solid angle > 200 msr*
- *Resolution<2%*
- *Count at 100 kHz*
- *online pion rejection of 10^2*

Need a magnet to block γ's and low energy π's

Plan View of the Spectrometer

BaBar
Solenoid?



Spin Structure with the Solenoid at JLab 12 GeV

- Program on neutron spin structure with polarized ^{3}He and solenoid
  - **Polarized ^{3}He target**

    effective polarized neutron

    highest polarized luminosity: 10^{36}
  - **A solenoid with detector package (GEM, Shower counter+ gas Cherenkov**

    large acceptance: ~700 msr for polarized (without baffles)

  → high luminosity and large acceptance
  - **Inclusive DIS: improve by a factor of 10-100**

    A_1 at high-x: 200 hours, high precision

    d_2 at high Q^2: 100 hours, very high precision

    parity violating spin structure g_3/g_5 : first significant measurement
  - **SIDIS: improve by a factor of 100-1000**

    transversity and TMDs,

    spin-flavor decomposition (~2 orders improvement)
- Unpolarized luminosity: 5×10^{38} , acceptance ~ 300 msr (with baffles)
  - **Boer-Mulders function**

Semi-inclusive Deep Inelastic Scattering

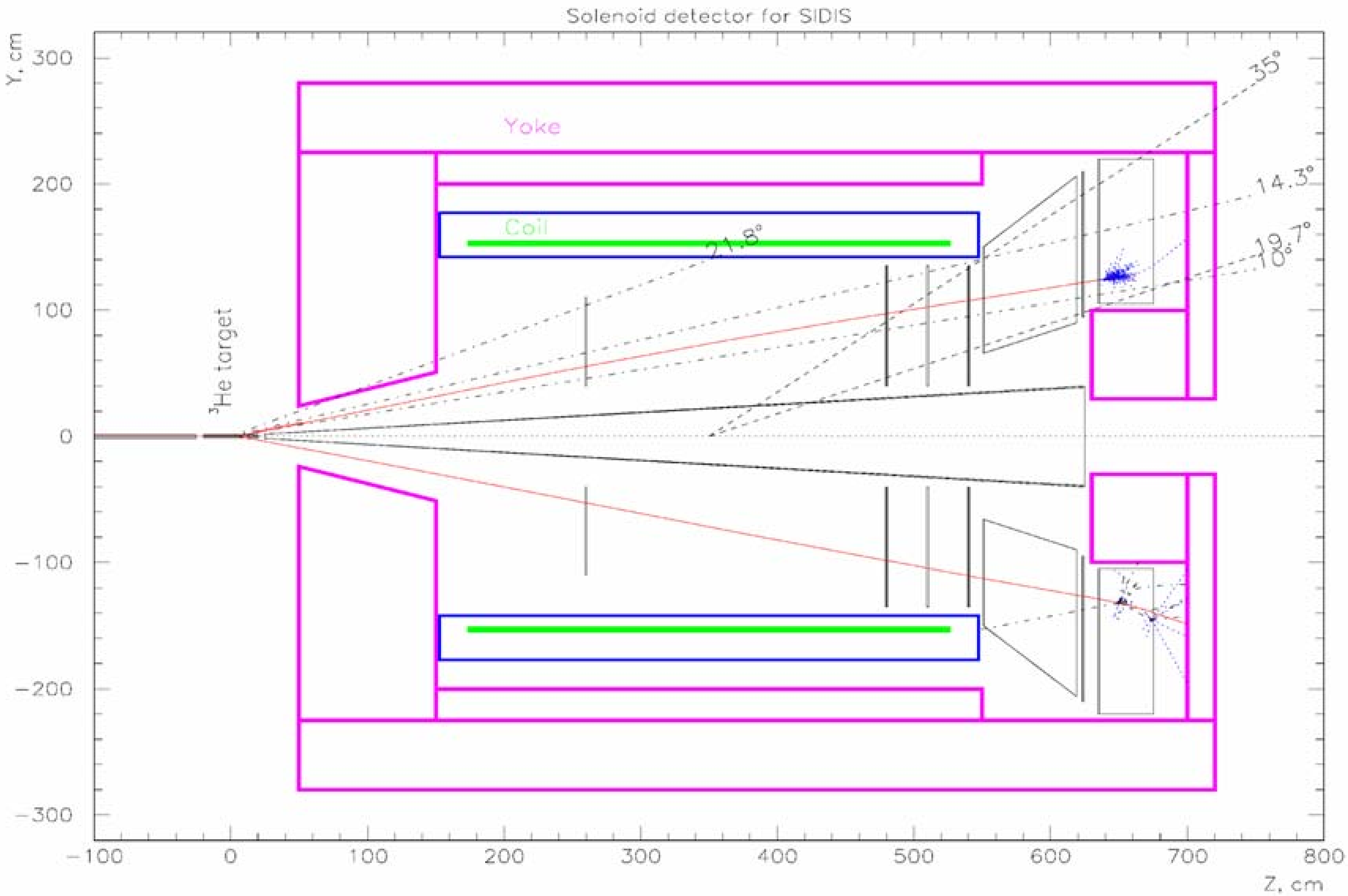
Transversity and TMDs

Current Status

- Collins Asymmetries
  - sizable for proton (HERMES)
    large at high x, large for π^-
    π^- and $\pi+$ has opposite sign
    unfavored Collins fragmentation as large as favored (opposite sign)?
  - consistent with 0 for deuteron (COMPASS)
- Sivers Asymmetries
  - non-zero for π^+ from proton
  - consistent with zero for π^- from proton and for all channels from deuteron
  - large for K^+
- Very active theoretical and experimental study
  RHIC-spin (PHENIX, STAR, BRAHMS), JLab (Hall A 6 GeV, CLAS12)
  KEK (Belle), GSI FAIR (PAX)
- Fits/models by Anselmino *et al.*, *Yuan et al.* and other groups
- Solenoid with polarized ^{3}He at JLab 12 GeV
  Unprecedented precision with high luminosity and large acceptance

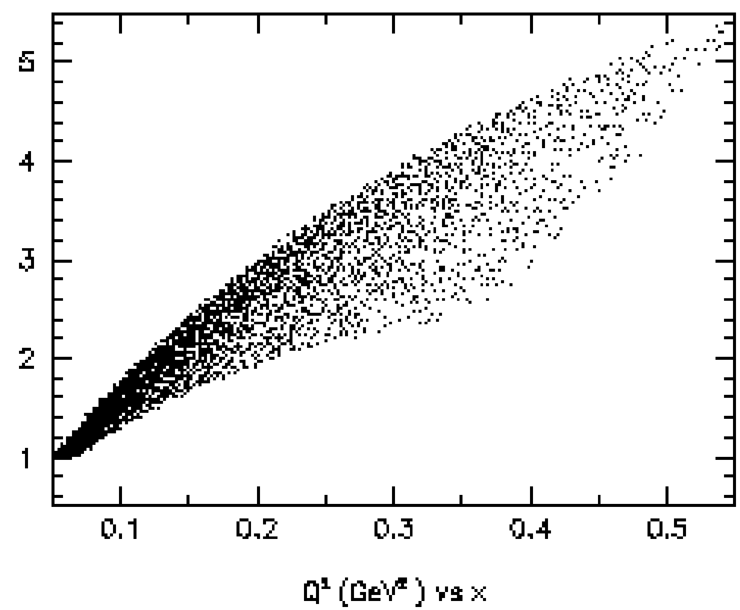
Solenoid for SIDIS

E. Chudakov's talk

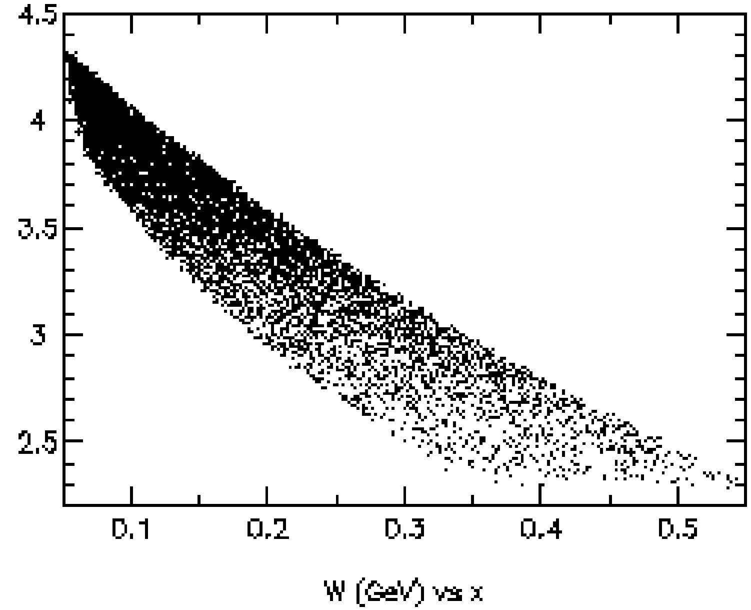


SIDIS Kinematical with the Solenoid (10º-17º)

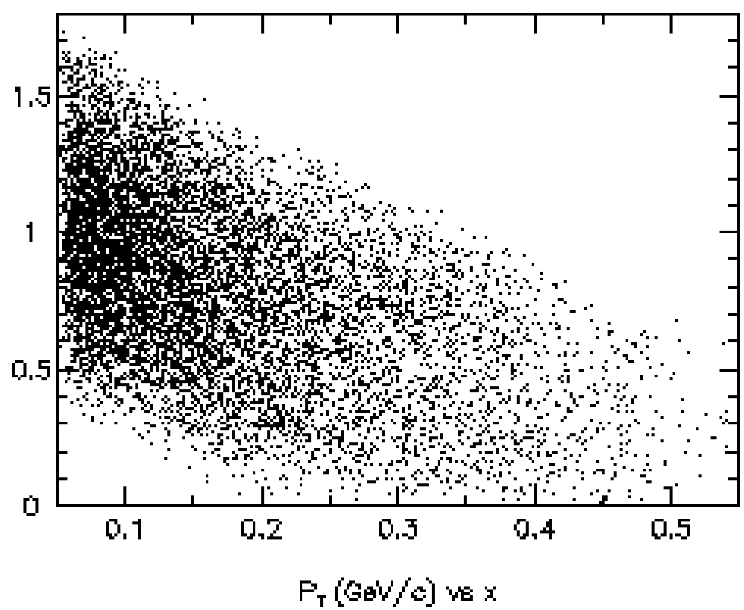
Q^2 vs x



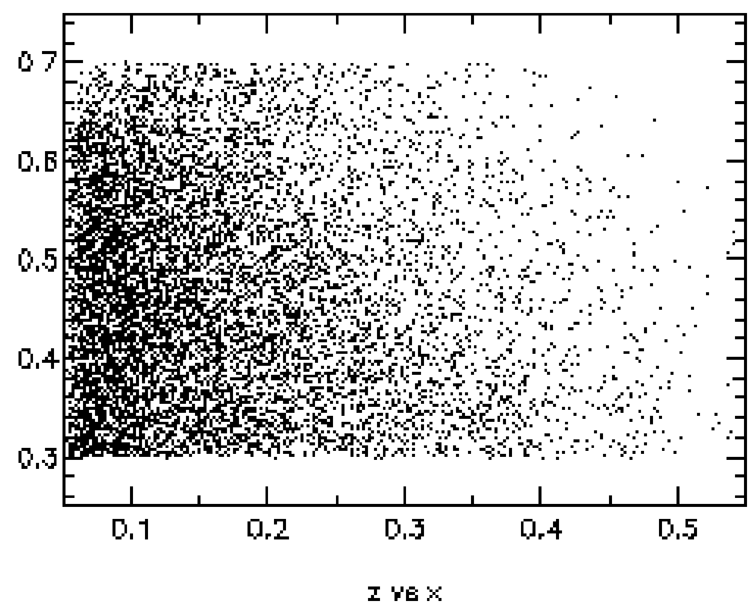
W vs x



P_T vs x



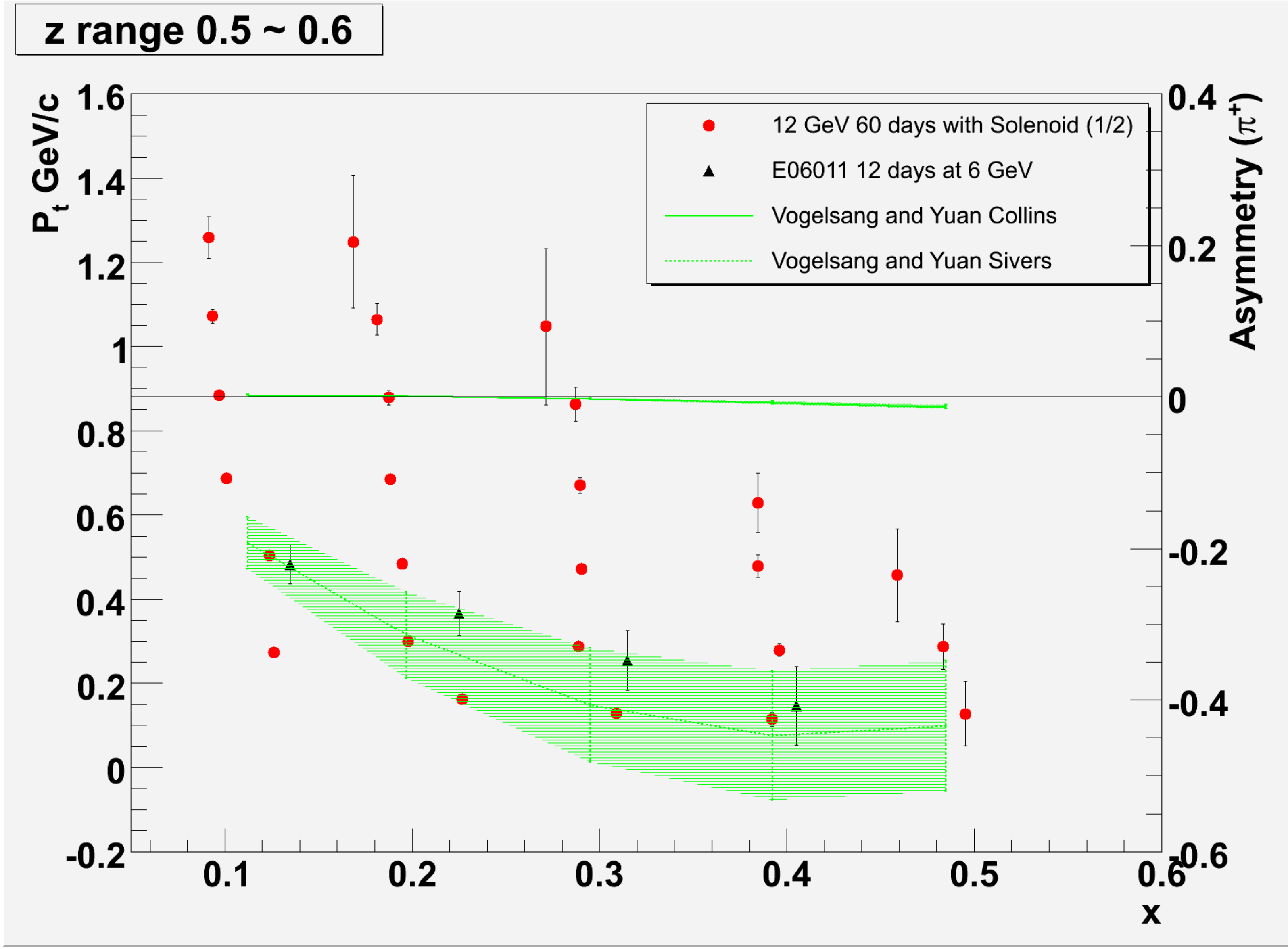
z vs x



Projection vs P_T and x for π+ (60 days)

- For one z bin (0.5-0.6)
- Will obtain 4 z bins (0.3-0.7)
- Also π- at same time
- With upgraded PID for K+ and K-

Haiyan Gao's talk



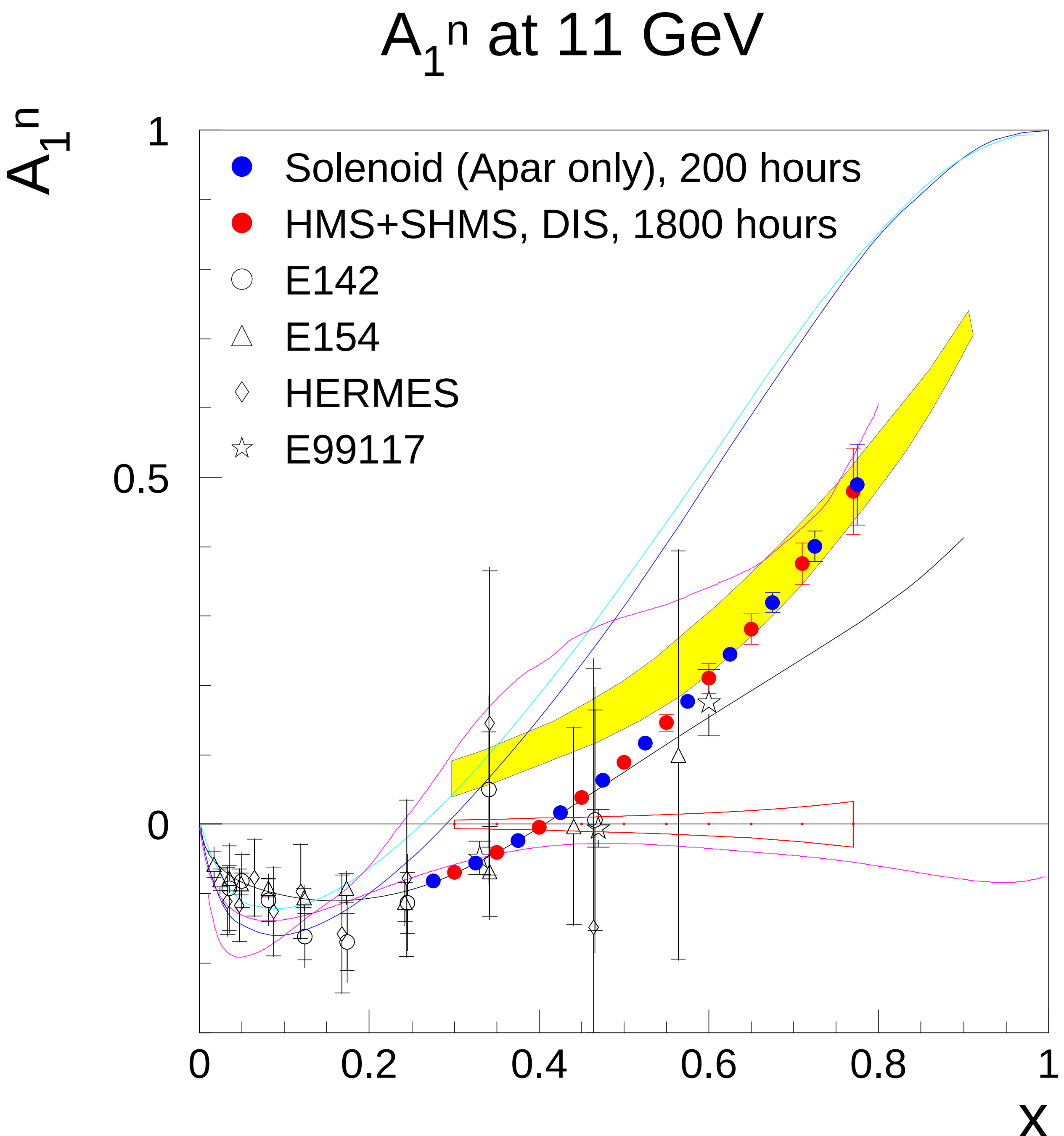
Summary

- A large acceptance solenoid with high luminosity
  - 700 msr, 10^{36} polarized (n); 300 msr, 5 x 10^{38} unpolarized
- A powerful tool for inclusive DIS spin study
  - Improvement of a factor of 10-100 in acceptance*luminosity
  - A_1^n at high-x, d_2^n , *parity violating spin structure*
- Even more powerful for semi-inclusive DIS spin
  - 2-3 orders of magnitude improvement
  - *Flavor-decompostion*
  - *Transversity, TMDs*
  - Entering a new era of precision study of SIDIS:

    3-dimentional “mapping” (x, P_T and z)

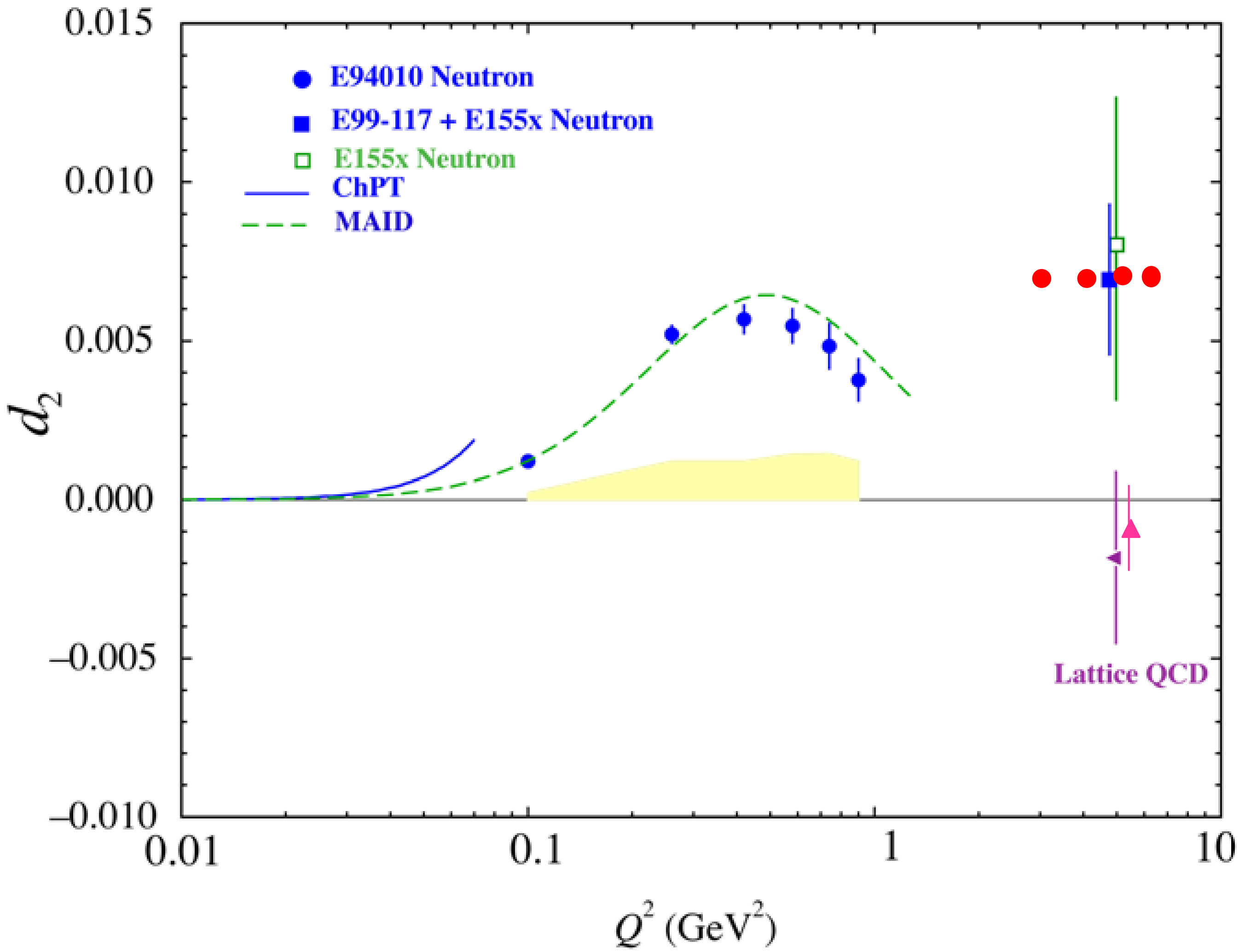
- Solenoid,
  200 hours

- HMS+SHMS,
  1800 hours
  (X. Zheng)



d_2^n with JLab 12 GeV

- Projection with Solenoid, Statistical only, will be systematic limited?
- Improved Lattice Calculation (QCDSF, hep-lat/0506017)



*L*ongitudinal Target Single Spin Asymmetry

- unpolarized beam on longitudinally polarized target

  keep γZ interference terms, neglect Z^2 terms

$$\frac{d^2\sigma^{\Rightarrow}}{dxdy} - \frac{d\sigma^{\Leftarrow}}{dxdy} \approx 16\pi ME \tfrac{\alpha^2}{Q^4} \eta^{\gamma Z}$$

$$\{g_V[(1-y)(g_3^{\gamma Z} - g_4^{\gamma Z}) + xy^2 g_5^{\gamma Z}] + g_A xy(2-y) g_1^{\gamma Z}\}$$

$g_1^{\gamma Z}$ term can be eliminated by using positron beam

PV-SSF in Naïve Parton Model

- Naïve Parton Model:

$$g_1^{\gamma Z} = \sum_q e_q (g_V)_q (\Delta q + \Delta \bar{q})$$

$$g_3^{\gamma Z} = 2x \sum_q e_q (g_A)_q (\Delta q - \Delta \bar{q}) = 2x g_5^{\gamma Z}$$

$$g_4^{\gamma Z} = 0$$

Put back into the general formula, we get

$$\frac{d^2\sigma^{\Rightarrow}}{dxdy} - \frac{d\sigma^{\Leftarrow}}{dxdy} \propto g_V (1 - y + \frac{1}{2} y^2) g_3^{\gamma Z} + g_A xy(2-y) g_1^{\gamma Z}$$

Measure PV-TSSA with the Selonoid

- At $x=0.2$, $Q^2=2.4$, $y=0.58$, $A \sim 10^{-5}-10^{-4}$
- Need high luminosity and large acceptance
- Rate estimation with the Solenoid detector:

→ 1000 hours beam, statistical precision for asymmetry will be a few x 10^{-5}.

A significant first measurement (~ a few σ?)

Flavor Decomposition with SIDIS

Projection with MAD
2000 hours (X. Jiang)
compared with HERMES

- Solenoid would improve by 2 orders of magnitude.