Transversity with Solenoid

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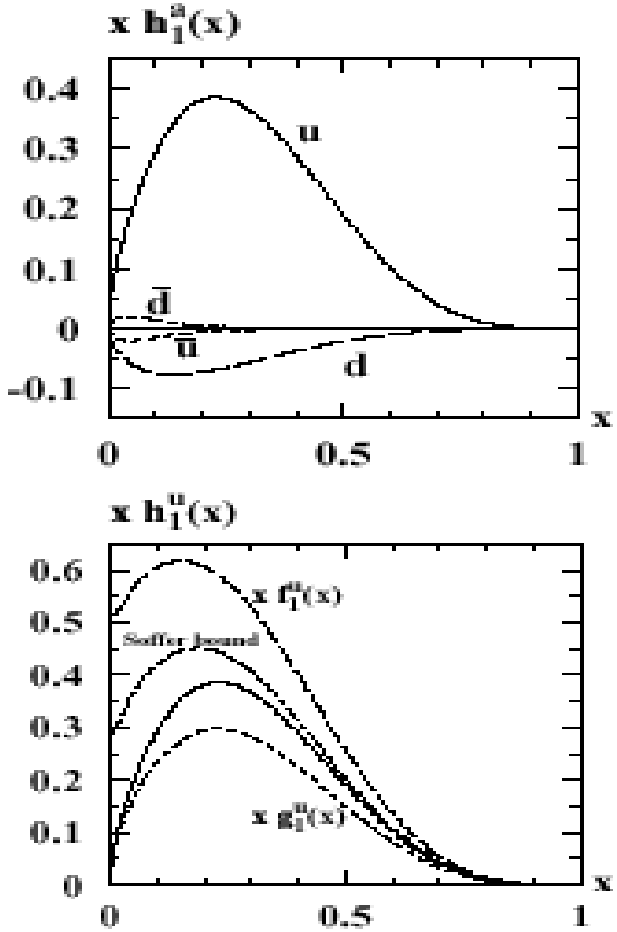
Outline

- Brief Introduction and existing data
- Proposed 6-GeV measurements
- Preliminary study with Solenoid and projections
- Summary

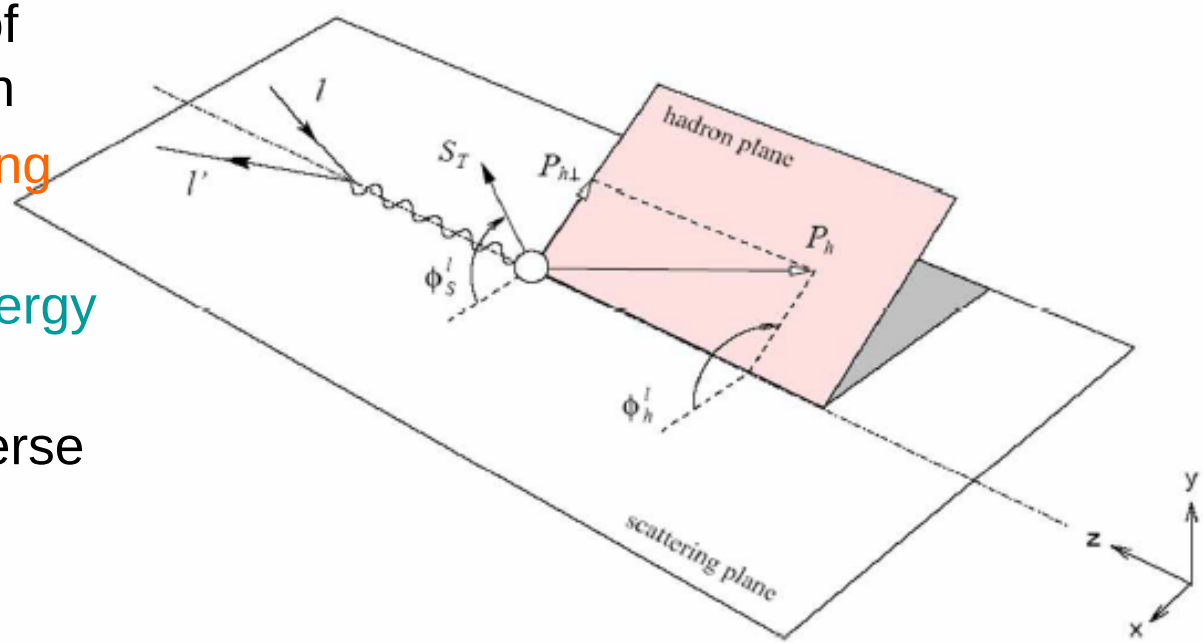
- It takes two Chiral-odd objects to measure transversity
  - Drell-Yan (Doubly transversely polarized p-p collision)
  - Semi-inclusive DIS
    - Chiral-odd distributions function (transversity)
    - Chiral-odd fragmentation function (Collins function)

Chiral-quark soliton model



The kinematics and coordinate

- E’ is the energy of scattered electron
- θ_e is the scattering angle
- ν =E-E’ is the energy transfer.
- k_γ: quark transverse momentum

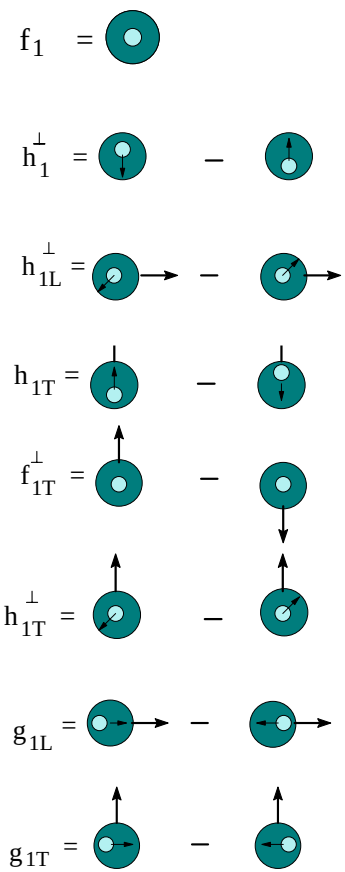


DIS: Q^2 and ν is large, but x is finite.

$$x = \frac{Q^2}{2P \cdot q}, \qquad y = \frac{P \cdot q}{P \cdot P_e}, \qquad z = \frac{P \cdot P_h}{P \cdot q}, \qquad s = (P+q)^2$$

All Eight Quark Distributions Are Probed in Semi-Inclusive DIS

$$d^6\sigma = \frac{4\pi\alpha^2 sx}{Q^4}\times$$



Transversity

Sivers

$$\{[1+(1-y)^2]\sum_{q,\bar{q}} e_q^2 f_1^q(x) D_1^q(z,P_{h\perp}^2)$$
$$+(1-y)\frac{P_{h\perp}^2}{4z^2 M_N M_h}\cos(2\phi_h^l)\sum_{q,\bar{q}} e_q^2 h_1^{\perp(1)q}(x) H_1^{\perp q}(z,P_{h\perp}^2)$$

Unpolarized

$$-|S_L|(1-y)\frac{P_{h\perp}^2}{4z^2 M_N M_h}\sin(2\phi_h^l)\sum_{q,\bar{q}} e_q^2 h_{1L}^{\perp(1)q}(x) H_1^{\perp q}(z,P_{h\perp}^2)$$
$$+|S_T|(1-y)\frac{P_{h\perp}}{zM_h}\sin(\phi_h^l+\phi_S^l)\sum_{q,\bar{q}} e_q^2 h_1^q(x) H_1^{\perp q}(z,P_{h\perp}^2)$$
$$+|S_T|(1-y+\frac{1}{2}y^2)\frac{P_{h\perp}}{zM_N}\sin(\phi_h^l-\phi_S^l)\sum_{q,\bar{q}} e_q^2 f_{1T}^{\perp(1)q}(x) D_1^q(z,P_{h\perp}^2)$$
$$+|S_T|(1-y)\frac{P_{h\perp}^3}{6z^3 M_N^2 M_h}\sin(3\phi_h^l-\phi_S^l)\sum_{q,\bar{q}} e_q^2 h_{1T}^{\perp(2)q}(x) H_1^{\perp q}(z,P_{h\perp}^2)$$

Polarized target

$$+\lambda_e|S_L|y(1-\frac{1}{2}y)\sum_{q,\bar{q}} e_q^2 g_1^q(x) D_1^q(z,P_{h\perp}^2)$$
$$+\lambda_e|S_T|y(1-\frac{1}{2}y)\frac{P_{h\perp}}{zM_N}\cos(\phi_h^l-\phi_S^l)\sum_{q,\bar{q}} e_q^2 g_{1T}^{(1)q}(x) D_1^q(z,P_{h\perp}^2)\}$$

Polarzied beam and target

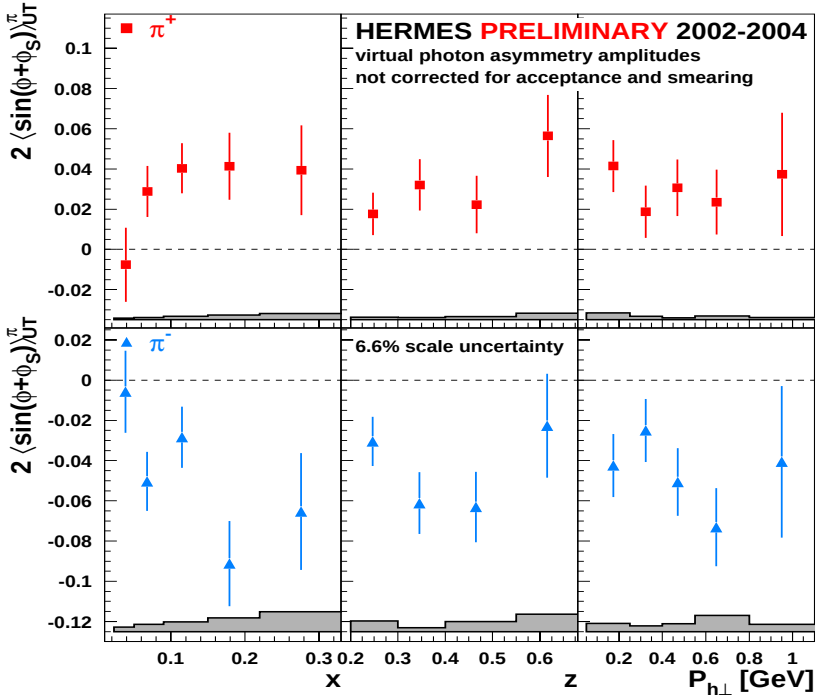
S_L and S_T: Target Polarizations; λe: Beam Polarization

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

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

„Collins" moments

hep-ex/0507013

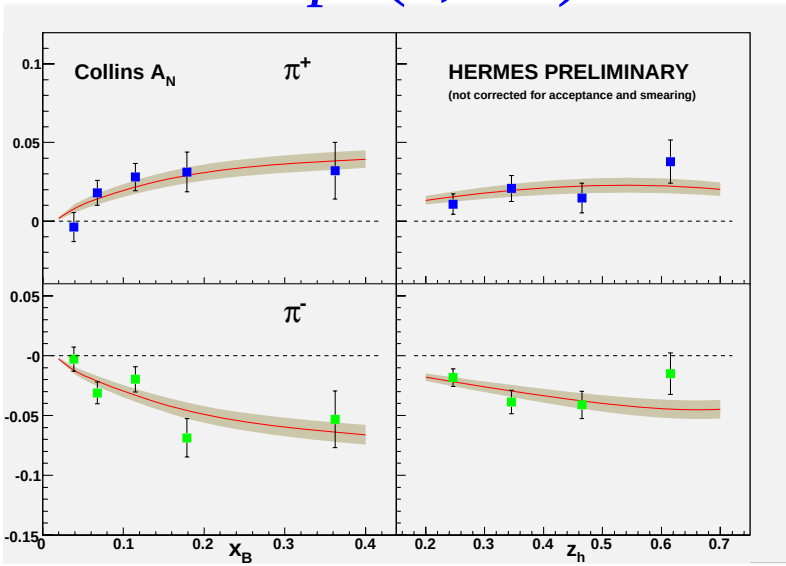


- Product of $\delta q(x) H_1^{\perp}(z)$ is non-zero
- A surprising flavor dependence : $H_1^{\perp,\,unfavored} / H_1^{\perp,\,favored} \approx -1$
- Extraction of $\delta q(x)$ requires an independent measurement of Collins function $H_1^{\perp}(z)$ (BELLE)

Extraction of Collins functions from the Collins asymmetry measurements

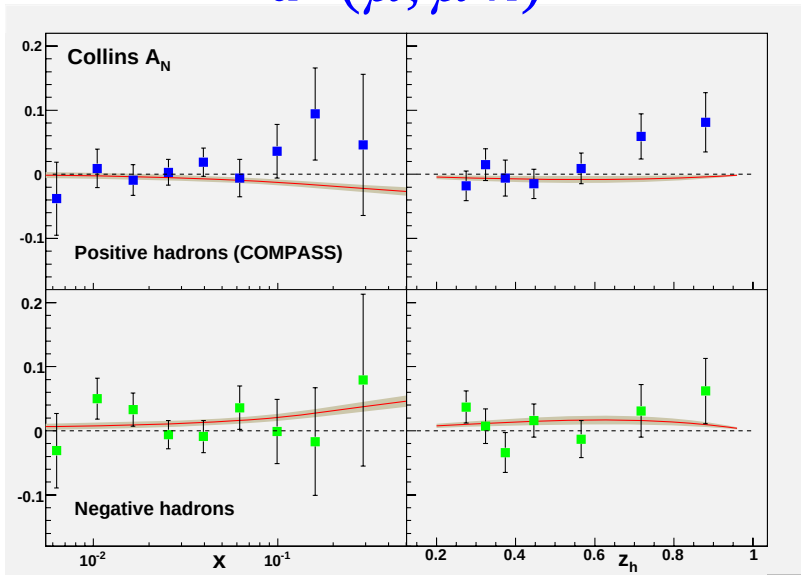
Fits to the Hermes data

$p^{\uparrow}(e,e'\pi)$



"Prediction" of the Compass data

$d^{\uparrow}(\mu,\mu'h)$



Assuming $H_1^{\perp,fav}(z) = C_{fav} z(1-z) D_1^{fav}(z)$; $H_1^{\perp,unfav}(z) = C_{unfav} z(1-z) D_1^{fav}(z)$

$C_{fav} = -0.29 \pm 0.04, \quad C_{unfav} = 0.33 \pm 0.04$

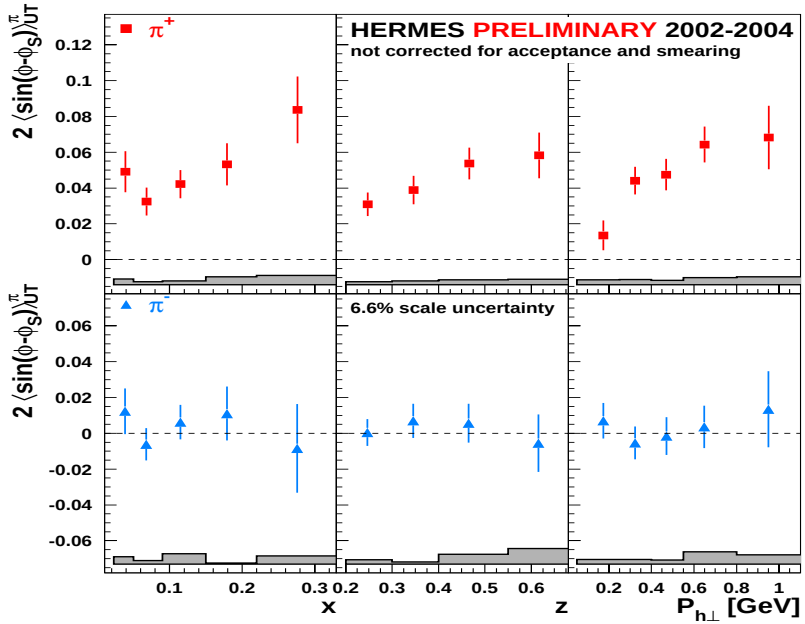
(Vogelsang and Yuan, hep-ph/0507266)

$$H_1^{\perp,unfavored} / H_1^{\perp,favored} \approx -1$$

Sivers moments from transversity experiments

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

"Sivers" moments



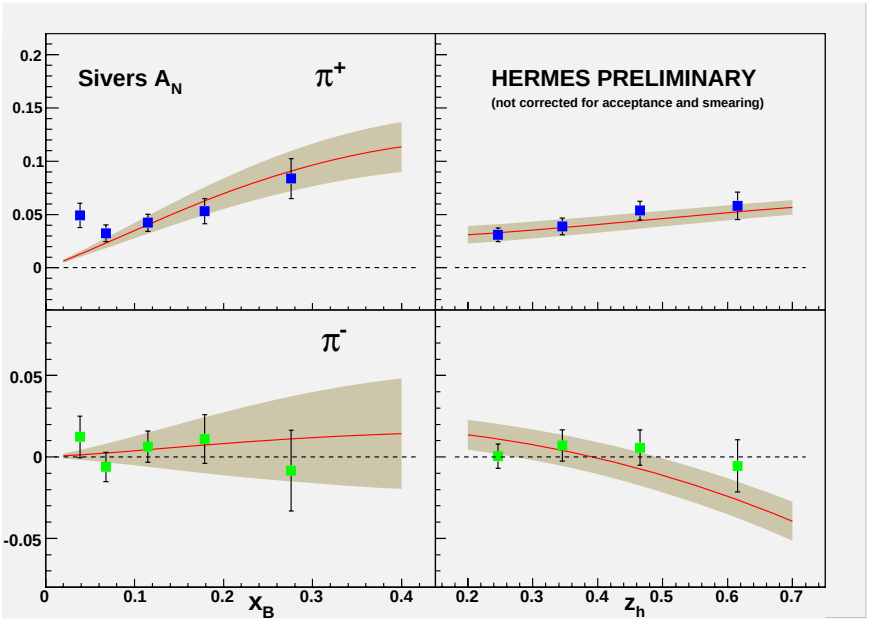
hep-ex/0507013

First measurement of Sivers asymmetry

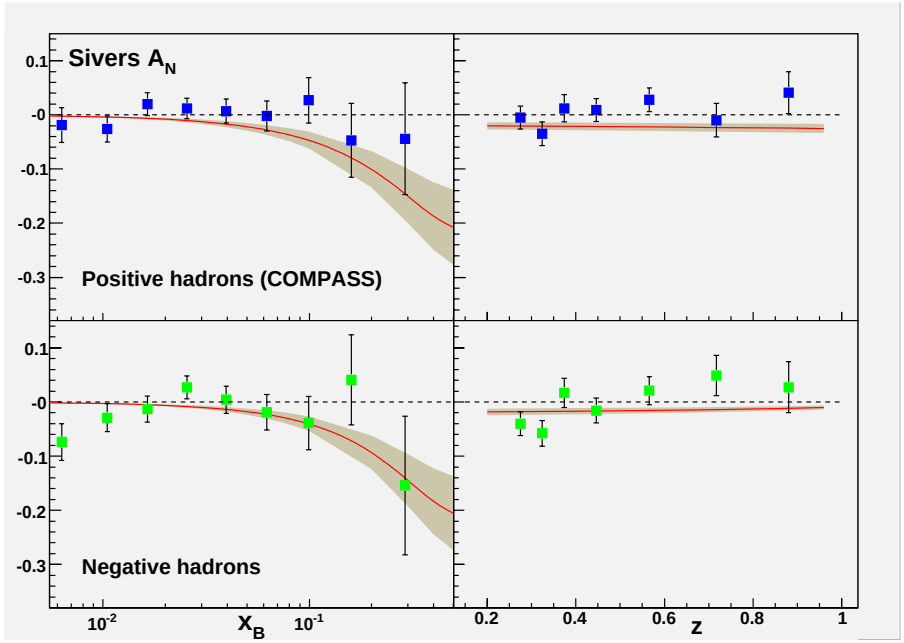
Sivers function nonzero $\rightarrow$ orbital angular momentum of quarks

Extraction of Sivers functions from the Sivers moment measurements

Fits to the Hermes data



"Prediction" of the Compass data



Assuming $f_{1T}^{\perp,u}(x) = S_u\, x(1-x)u(x); \quad f_{1T}^{\perp,d}(x) = S_d\, x(1-x)u(x)$

$S_u = -0.81 \pm 0.07, \quad S_d = 1.86 \pm 0.28$

(Vogelsang and Yuan, hep-ph/0507266)

Striking flavor dependence of the Sivers function

COMPASS leading hadron results

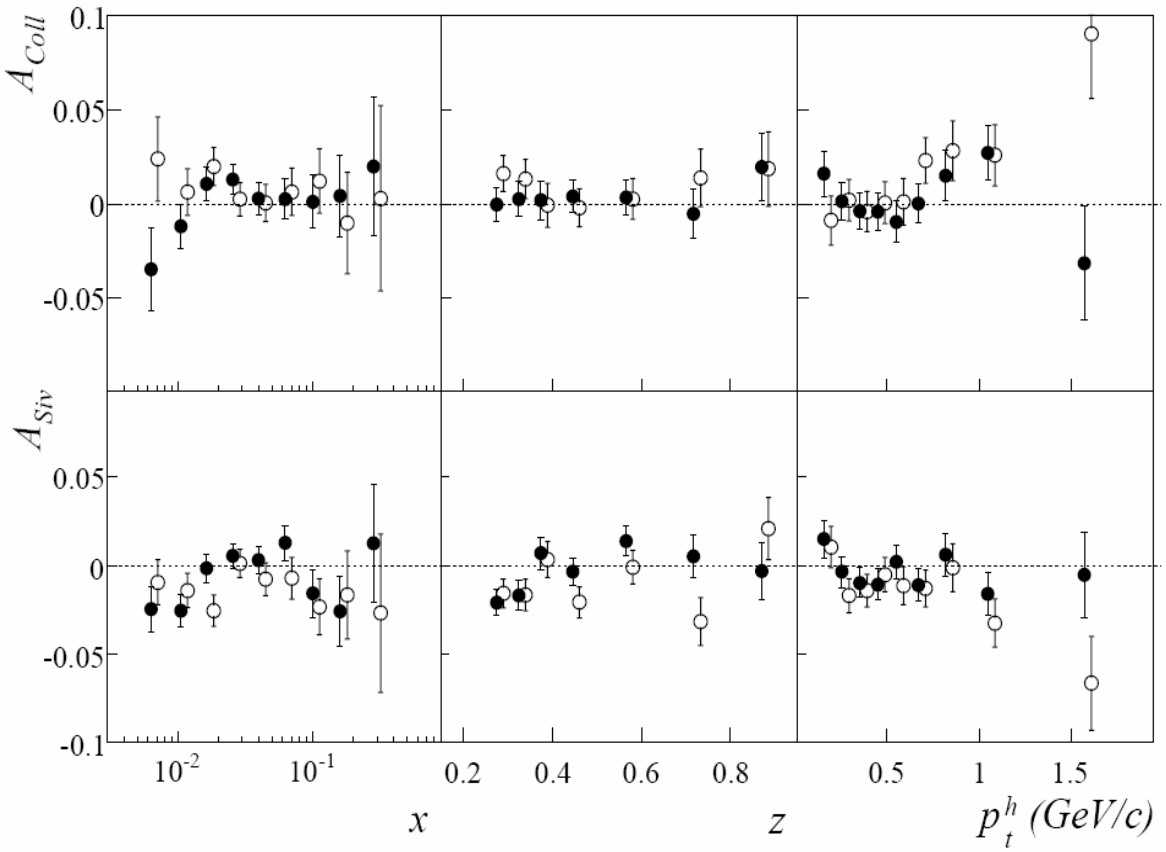


Figure 21: Overall results for Collins asymmetry (top) and Sivers asymmetry (bottom) against x, z and p_T^h for positive (full circles) and negative leading hadrons (open circles) from 2002, 2003, and 2004 data. Error bars are statistical only. In all the plots the open circles are slightly shifted horizontally with respect to the measured value.

Hep-ex/0610068: The COMPASS Collaboration

COMPASS all hadron results

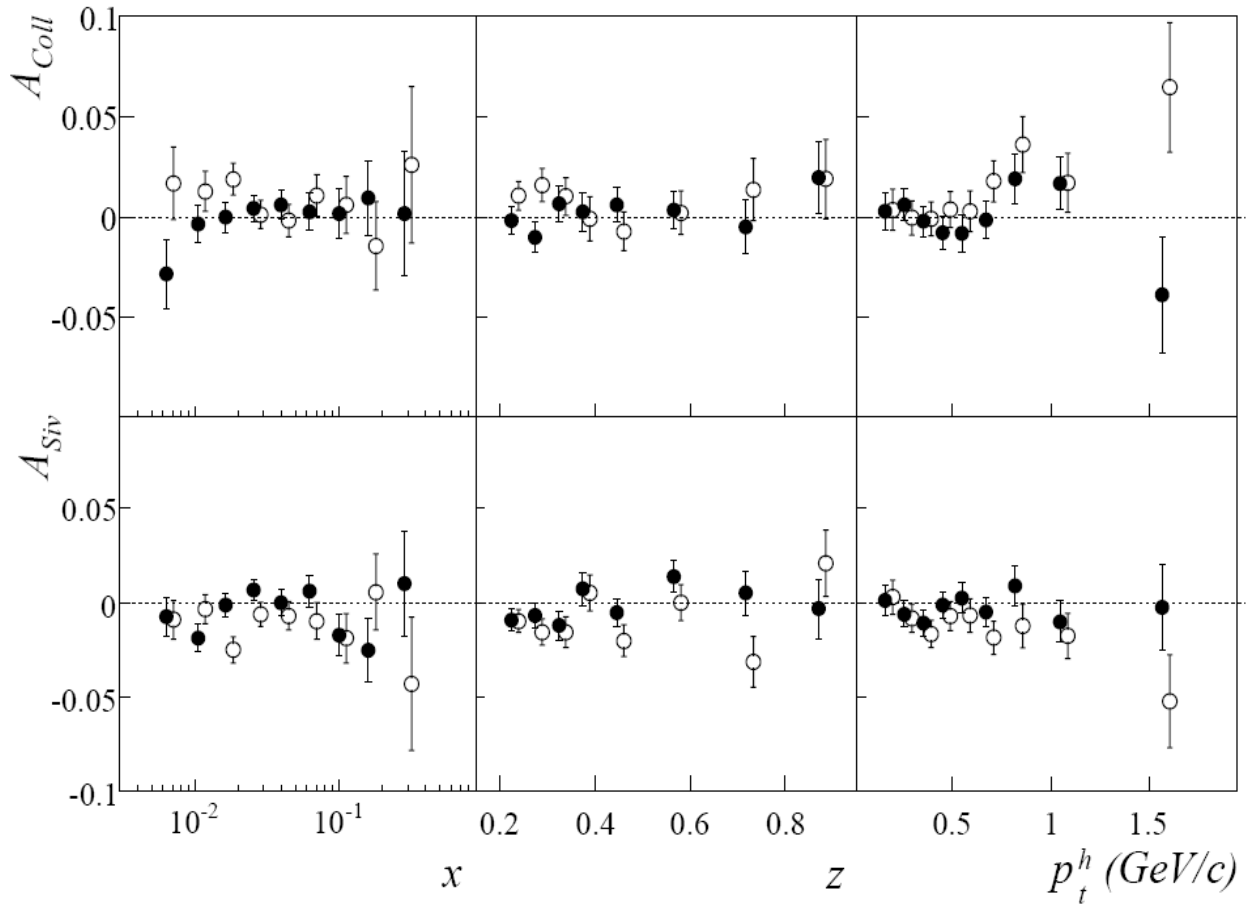


Figure 22: Overall results for Collins asymmetry (top) and Sivers asymmetry (bottom) against x, z and p_T^h for all positive (full circles) and all negative hadrons (open circles) from 2002, 2003, and 2004 data. Error bars are statistical only. In all the plots the open circles are slightly shifted horizontally with respect to the measured value.

Transversity Experiments at Hall A

E-06-010 (update of E-03-004) + E-06-011

Single Target-Spin Asymmetry in Semi-Inclusive $n^{\uparrow}(e,e'\pi^{+/-})$ Reaction on a Transversely Polarized ^{3}He Target

Spokespersons:

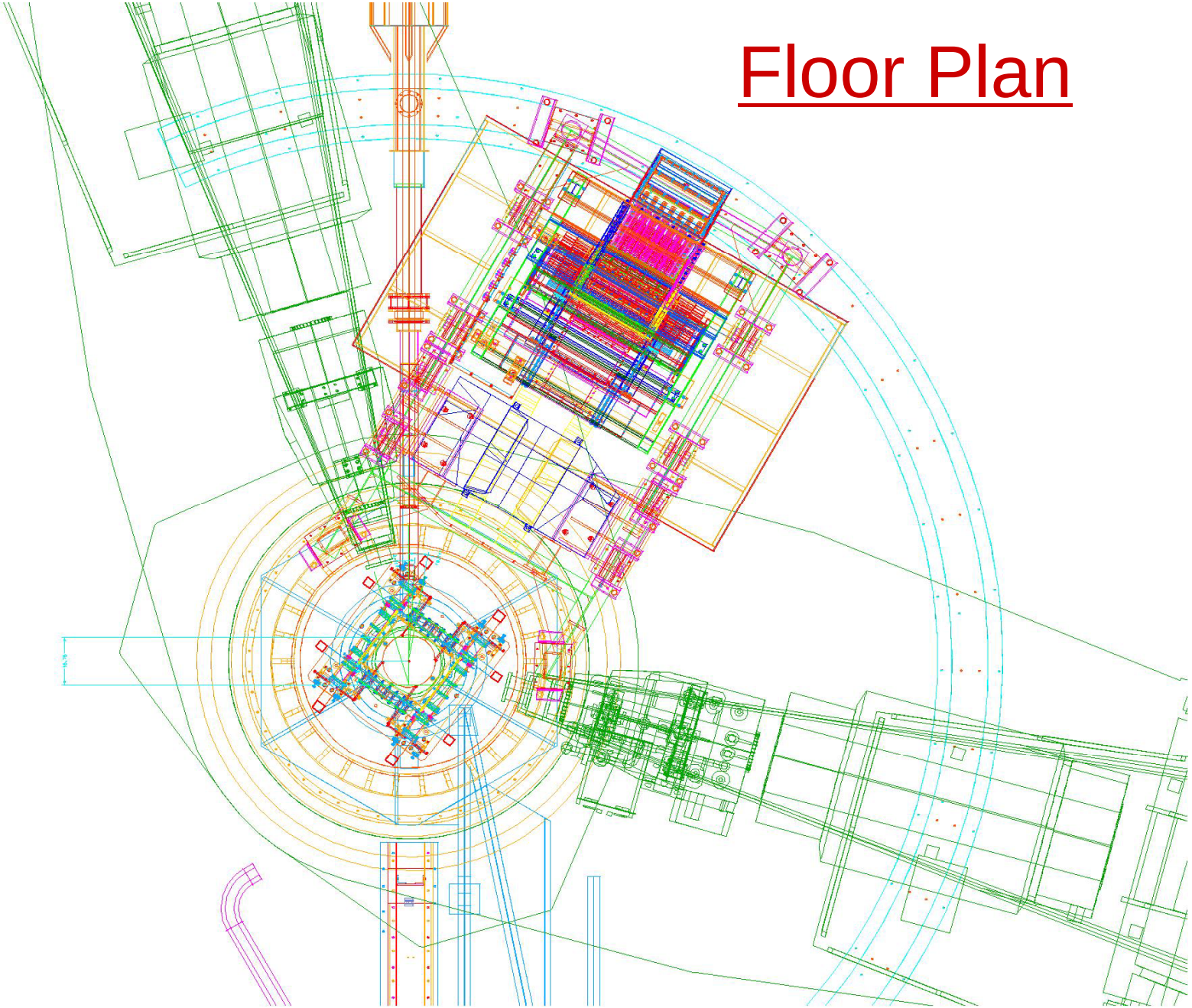
Xiaodong Jiang (Rutgers, Contact Person)

Jian-ping Chen (JLab), Evaristo Cisbani (INFN-Rome)

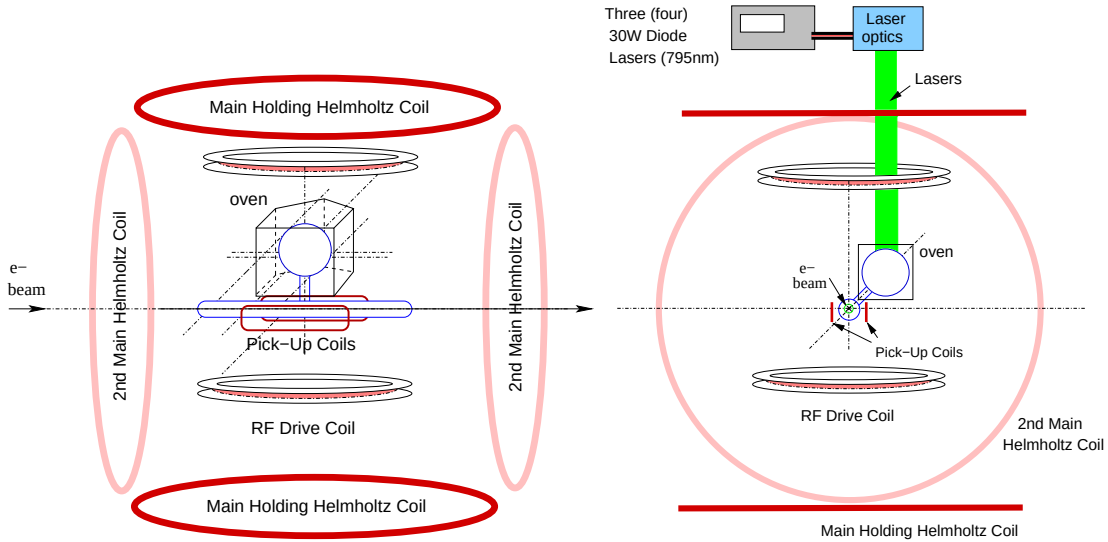
Haiyan Gao (Duke),Jen-Chieh Peng (UIUC)

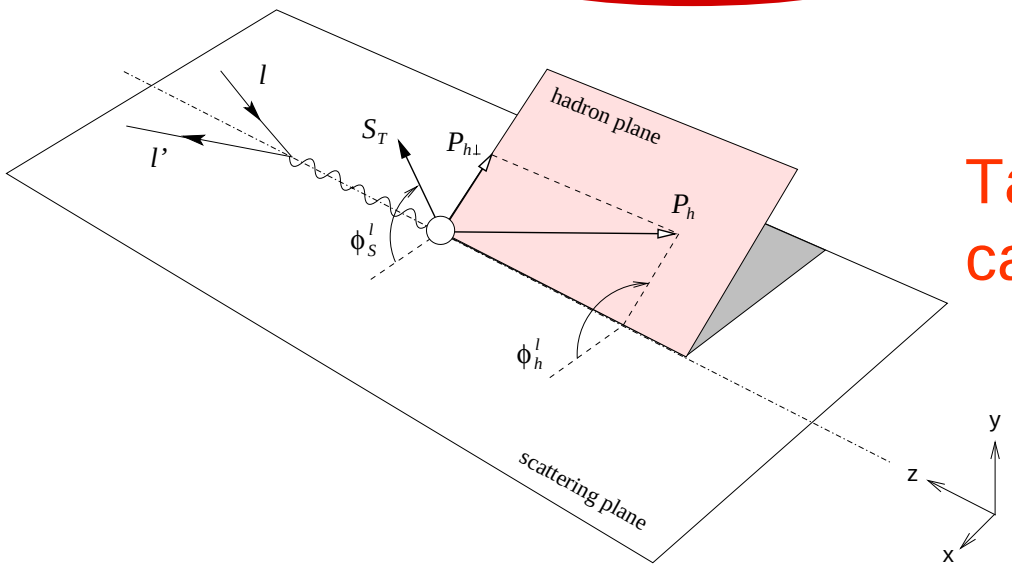
Approved with A rating, combined beam time of 29 days

Floor Plan



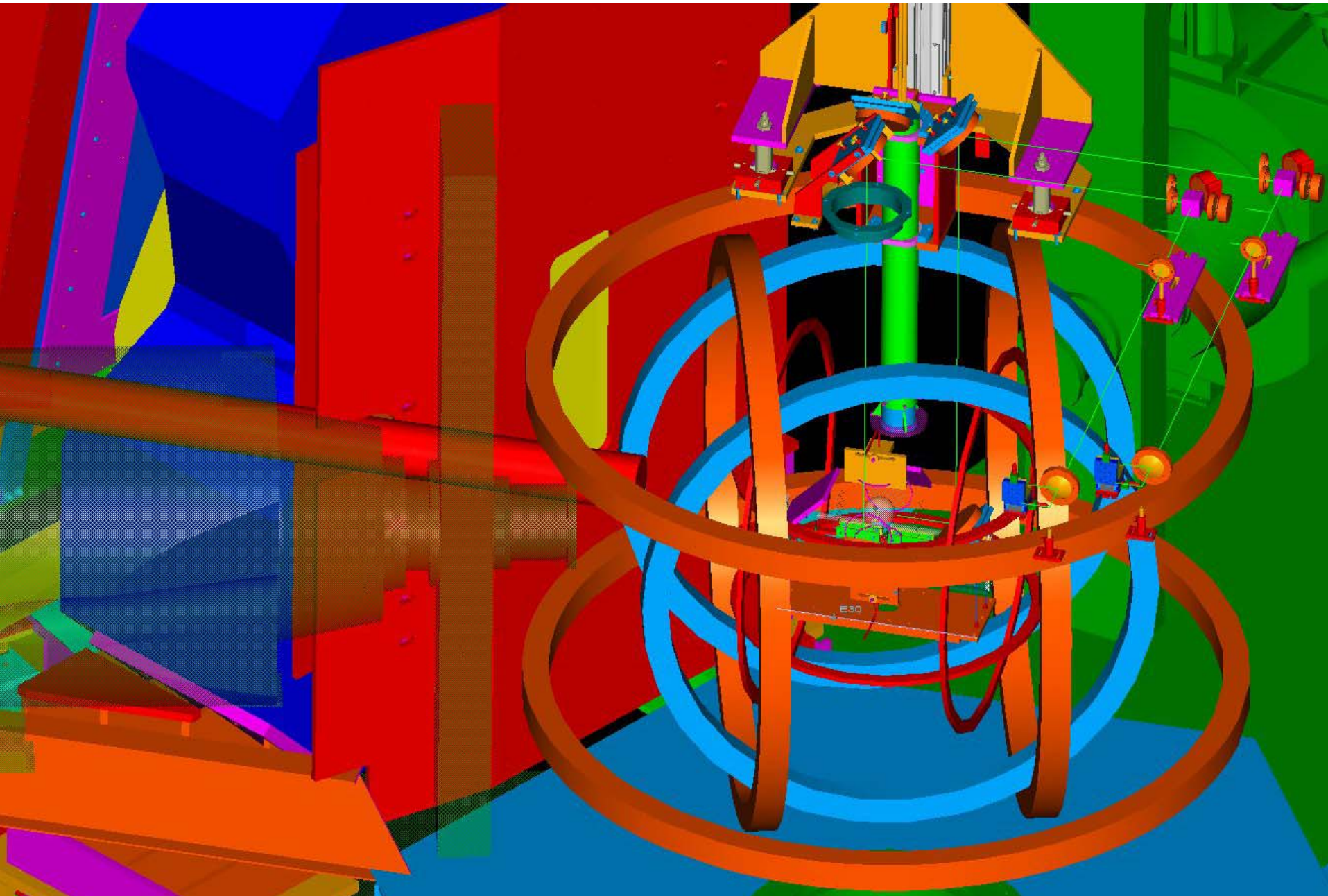
Transversely polarzied ^{3}He target



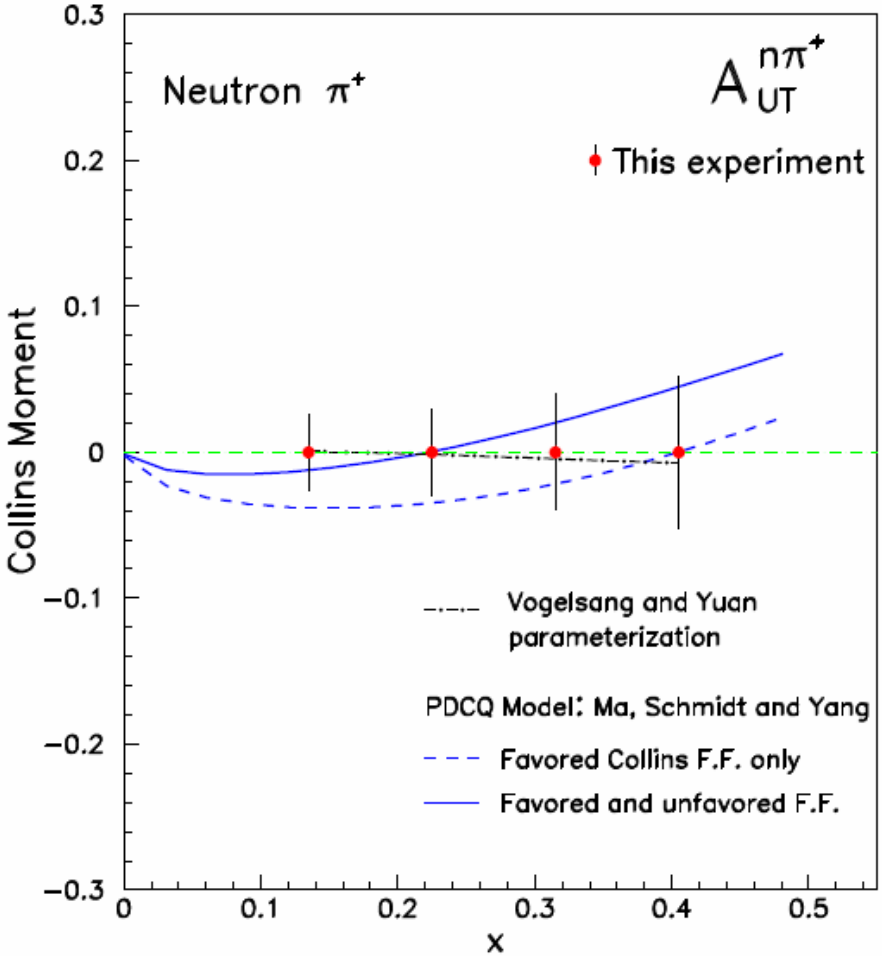


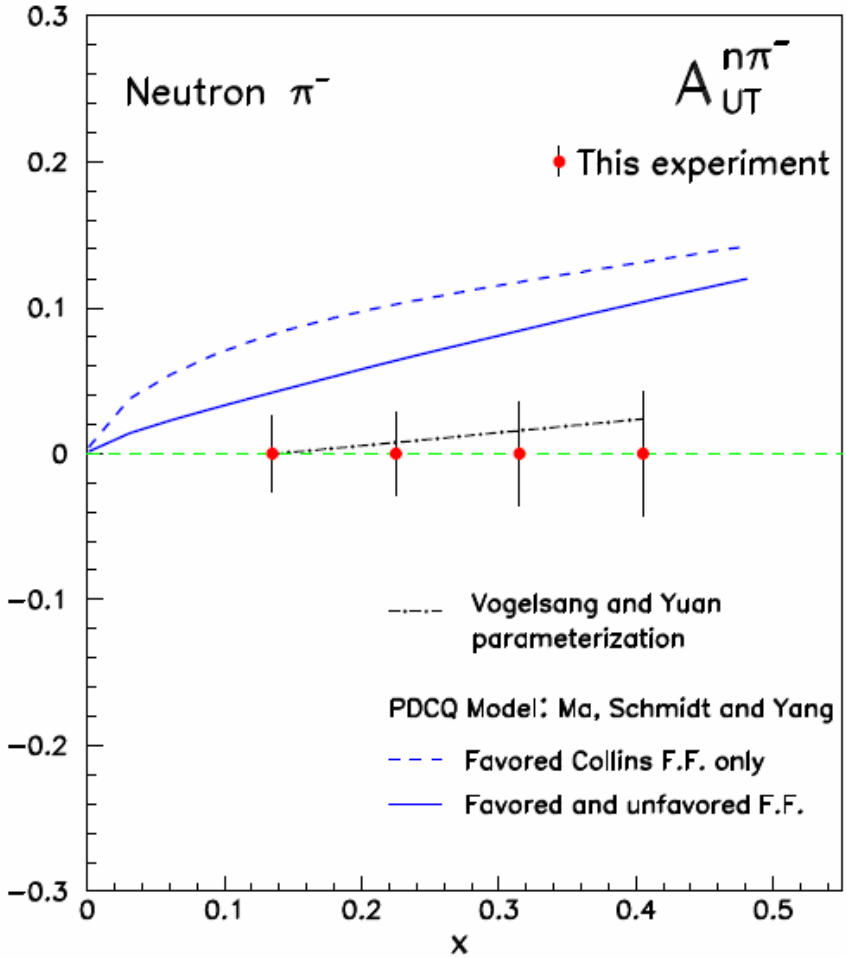
Target polarization orientation can be rotated to increase the coverage in Φ_S^l

Vertical Coil Design



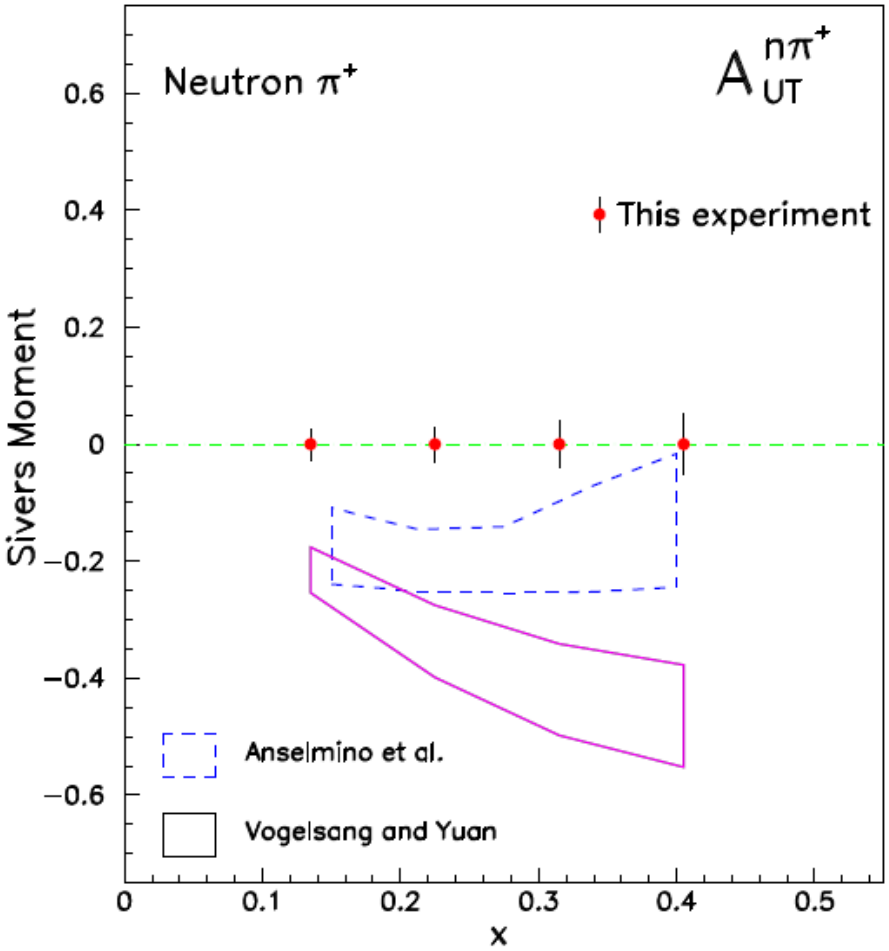
Predictions of Collins asymmetry on neutron

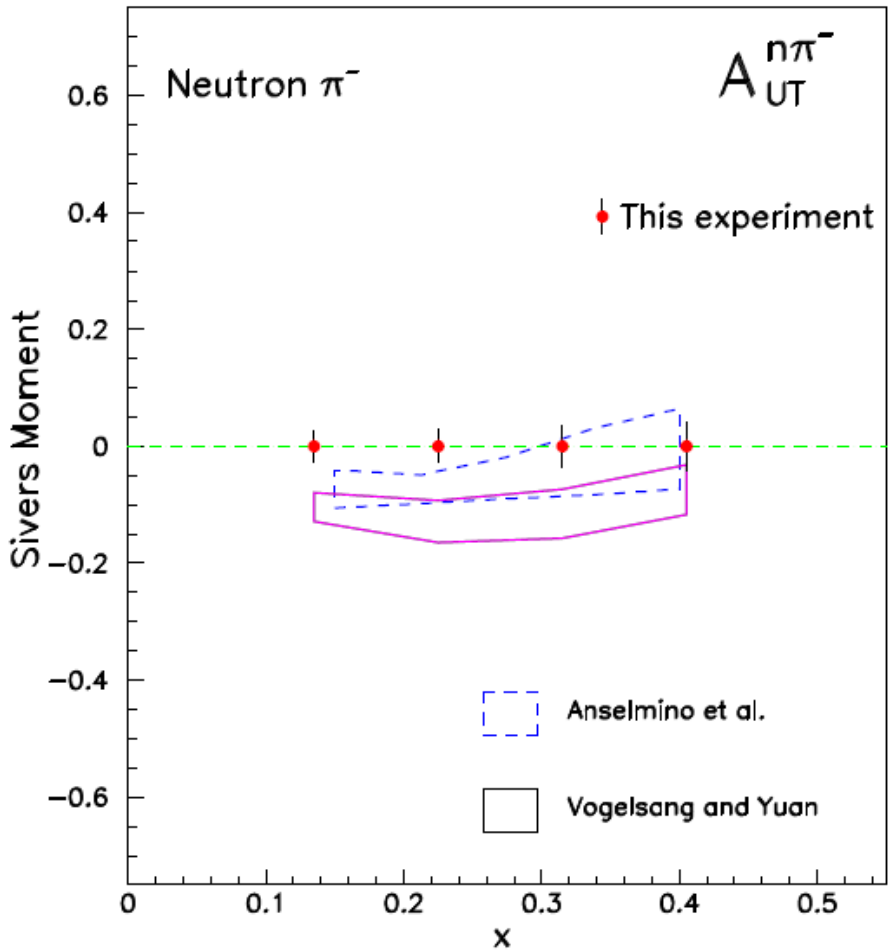




The errors with approved beam time will be 33% higher.

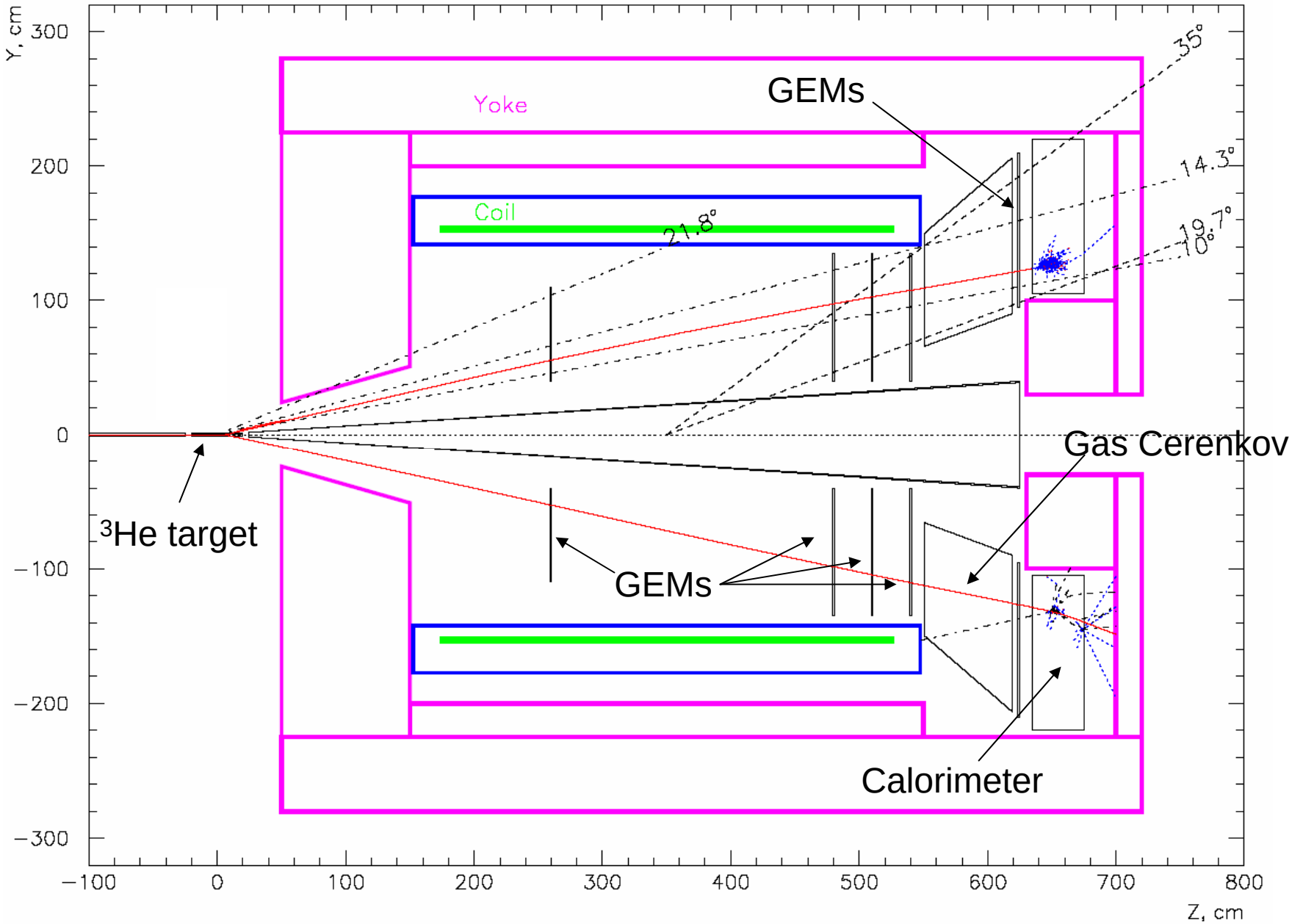
Predictions of Sivers asymmetry on neutron





The errors with approved beam time will be 33% higher.

Solenoid detector for SIDIS



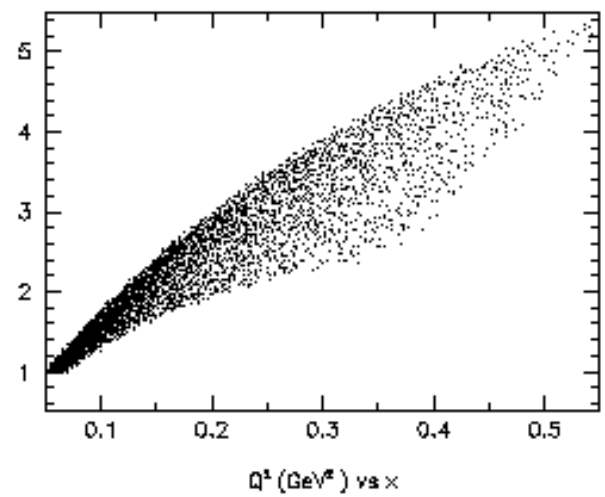
Simulation

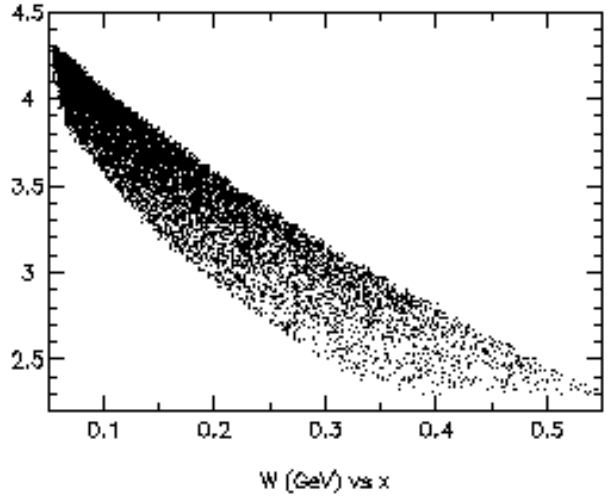
- Geant3 simulation: COMGEANT
  - From Eugene Chudakov.
- Event generator (SIDIS):
  - Modified from cross-section calculation code (Xiaodong Jiang, Lingyan Zhu and Xin Qian)
    - Using CTEQ6.
    - Using AKK fragmentation function parameterization.
- Detector Geometry:
  - Assume 17 degrees as the maximum angle
  - 14.3 degree (newest number)

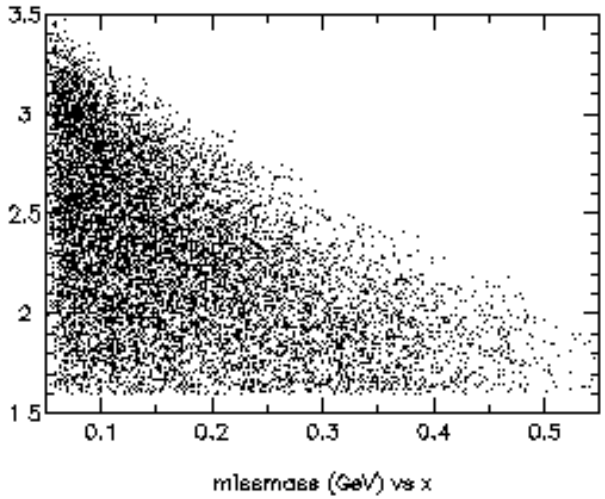
- 40 cm transversely polarized ^{3}He target. (45% polarization with spin flip technique)

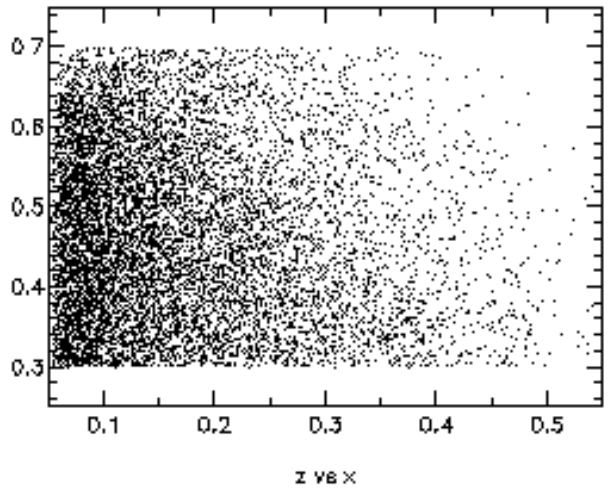
Phase space I

- After DIS selection:
  - W>2.3 GeV
  - W'>1.6 GeV
  - Q2 > 1.0 GeV^2
  - 0.3<z<0.7



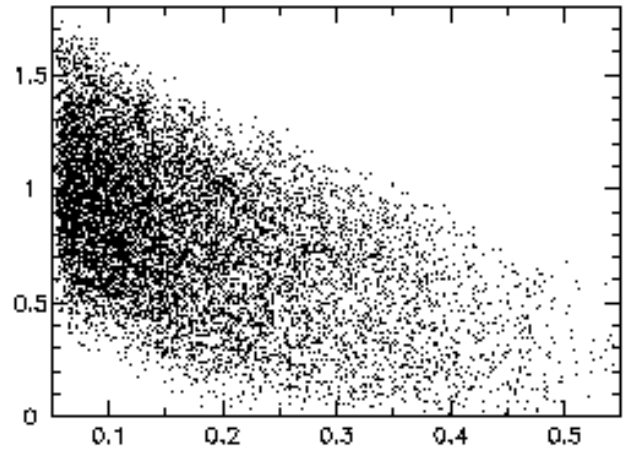


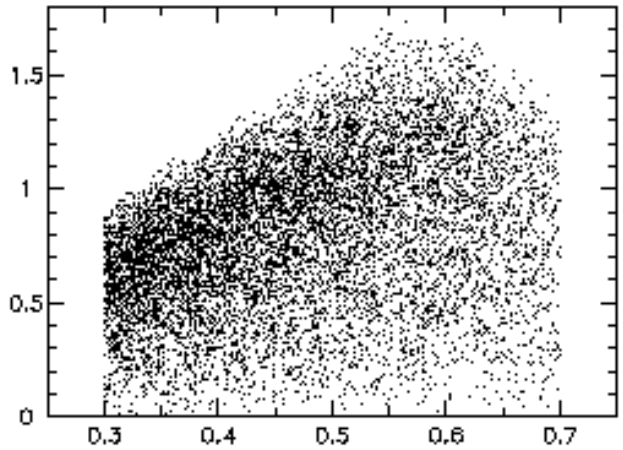




Phase space II

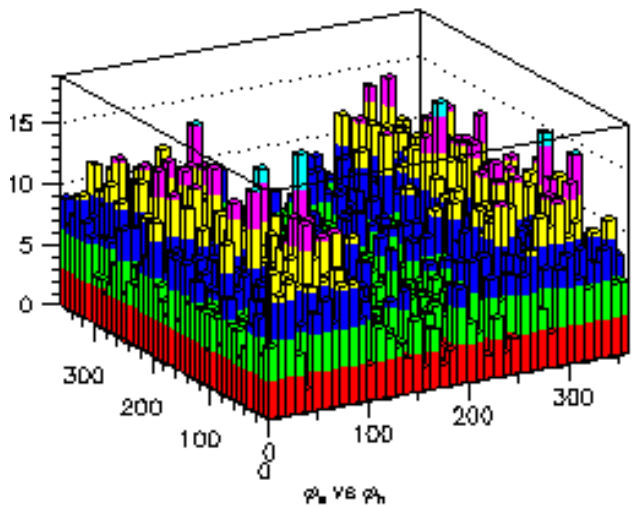
- Full coverage of azimuthal angle.
- Large P_T coverage.

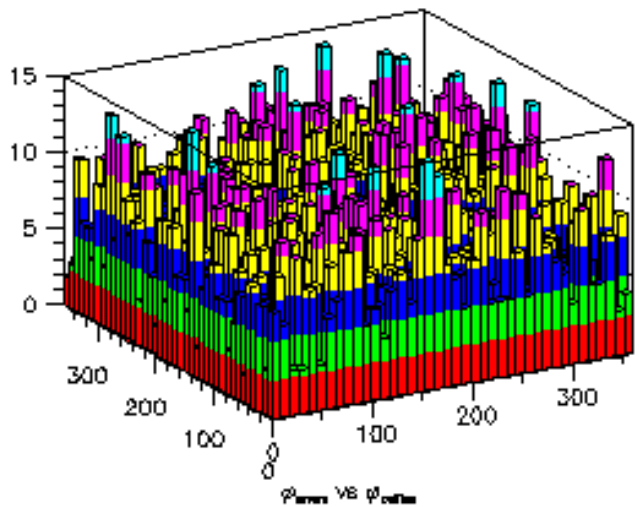




P_T (GeV/c) vs x

P_T (GeV/c) vs z

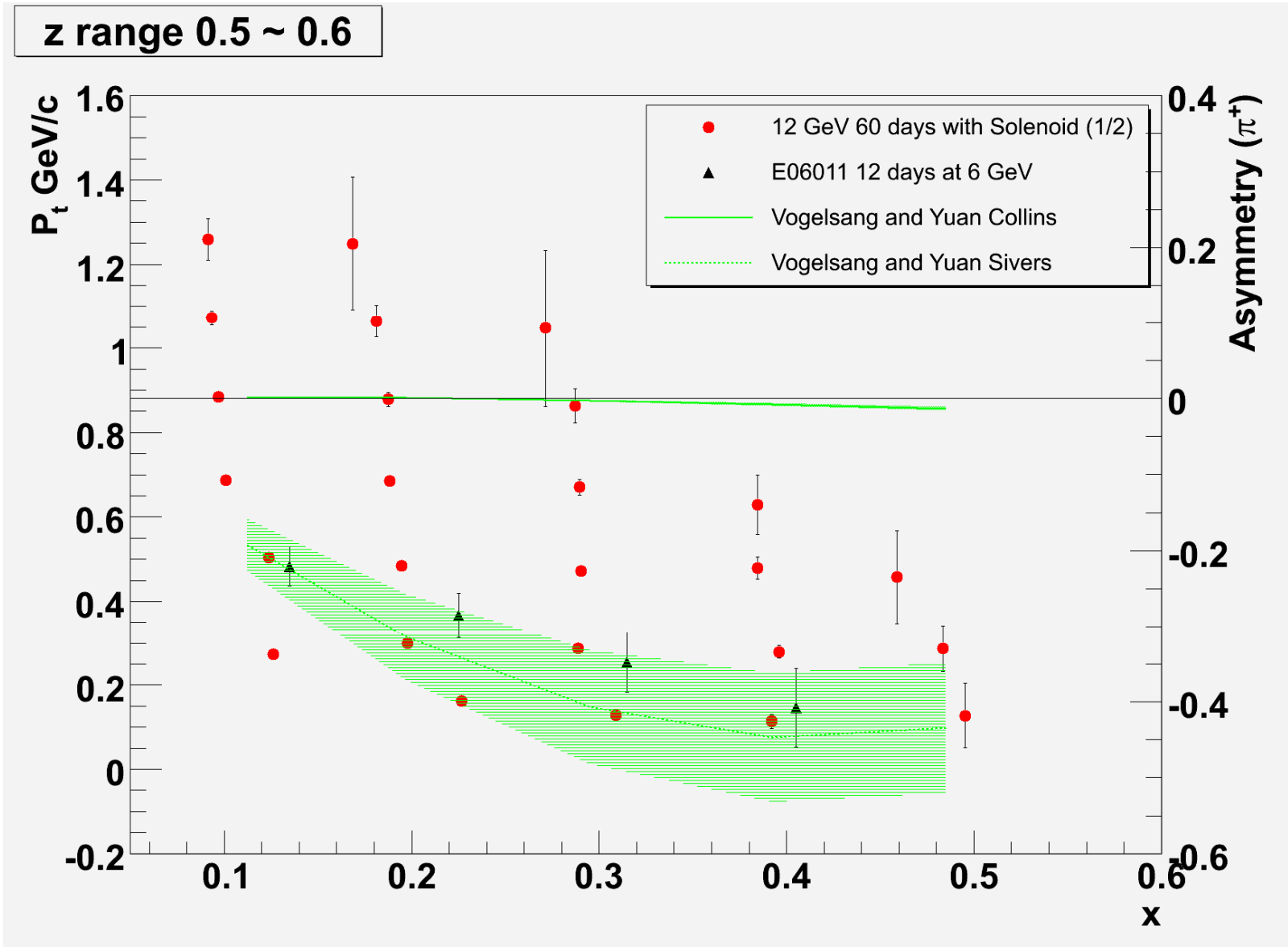




Projections

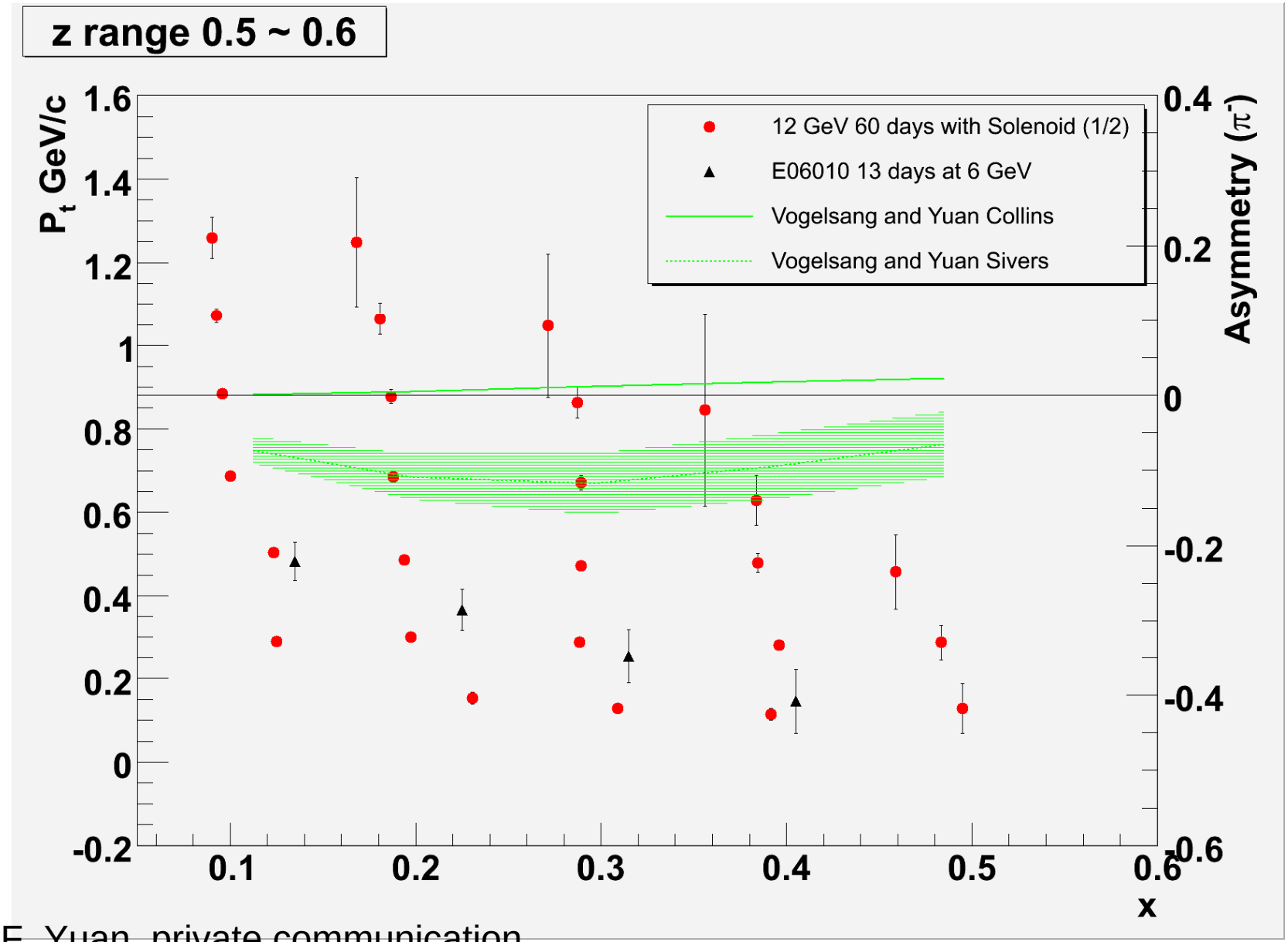
- 3-dimention:
  - Bin in x, z and $P_{T.}$
- 60 days running
- Negative charged particle can be collected at the same time.
- With a new kaon PID detector, can provide nice kaon data.

Projections for Collins and Sivers Asymmetry (π^+)



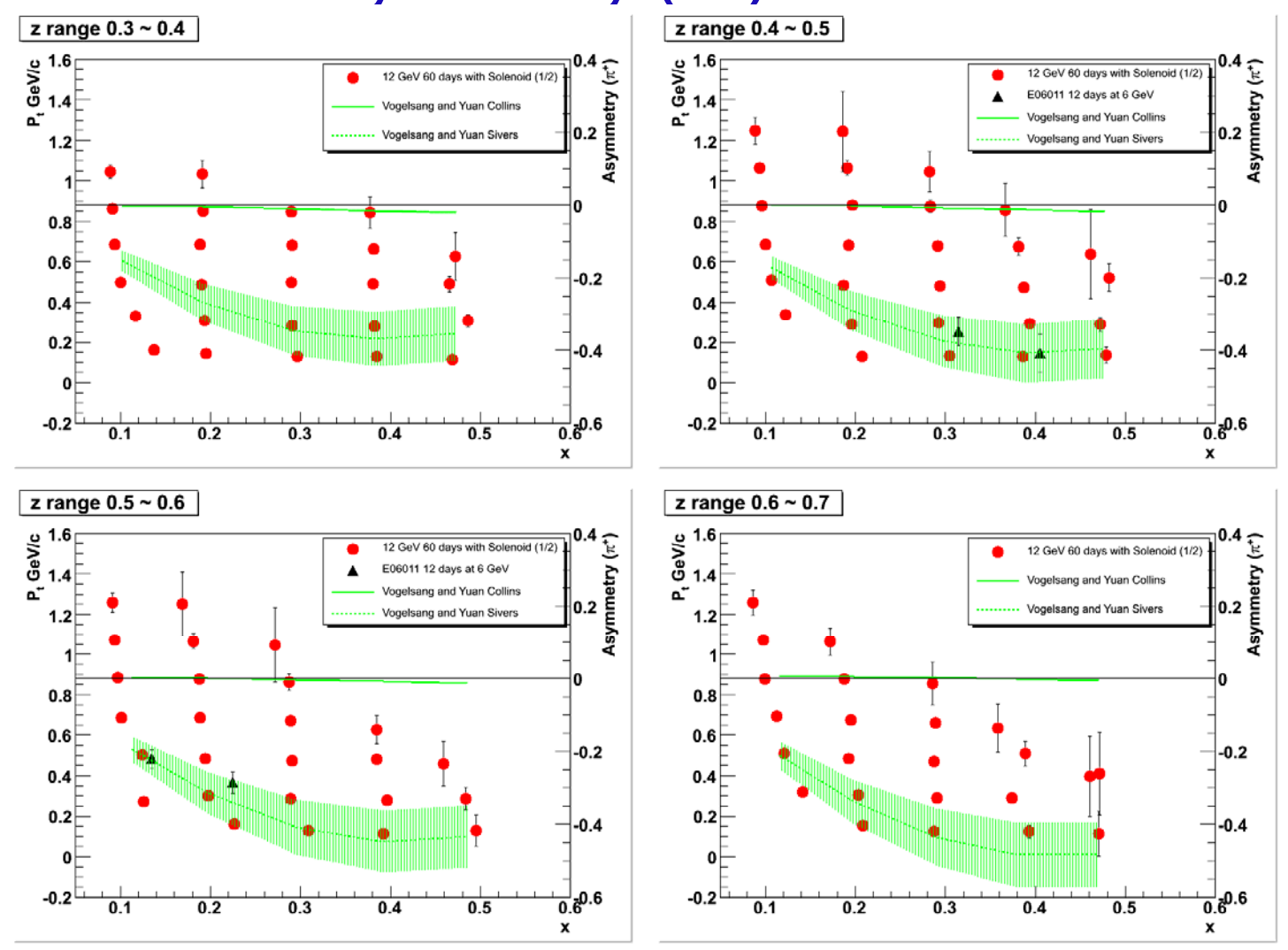
F. Yuan, private communication

Projections for Collins and Sivers Asymmetry (π^-)



F. Yuan, private communication

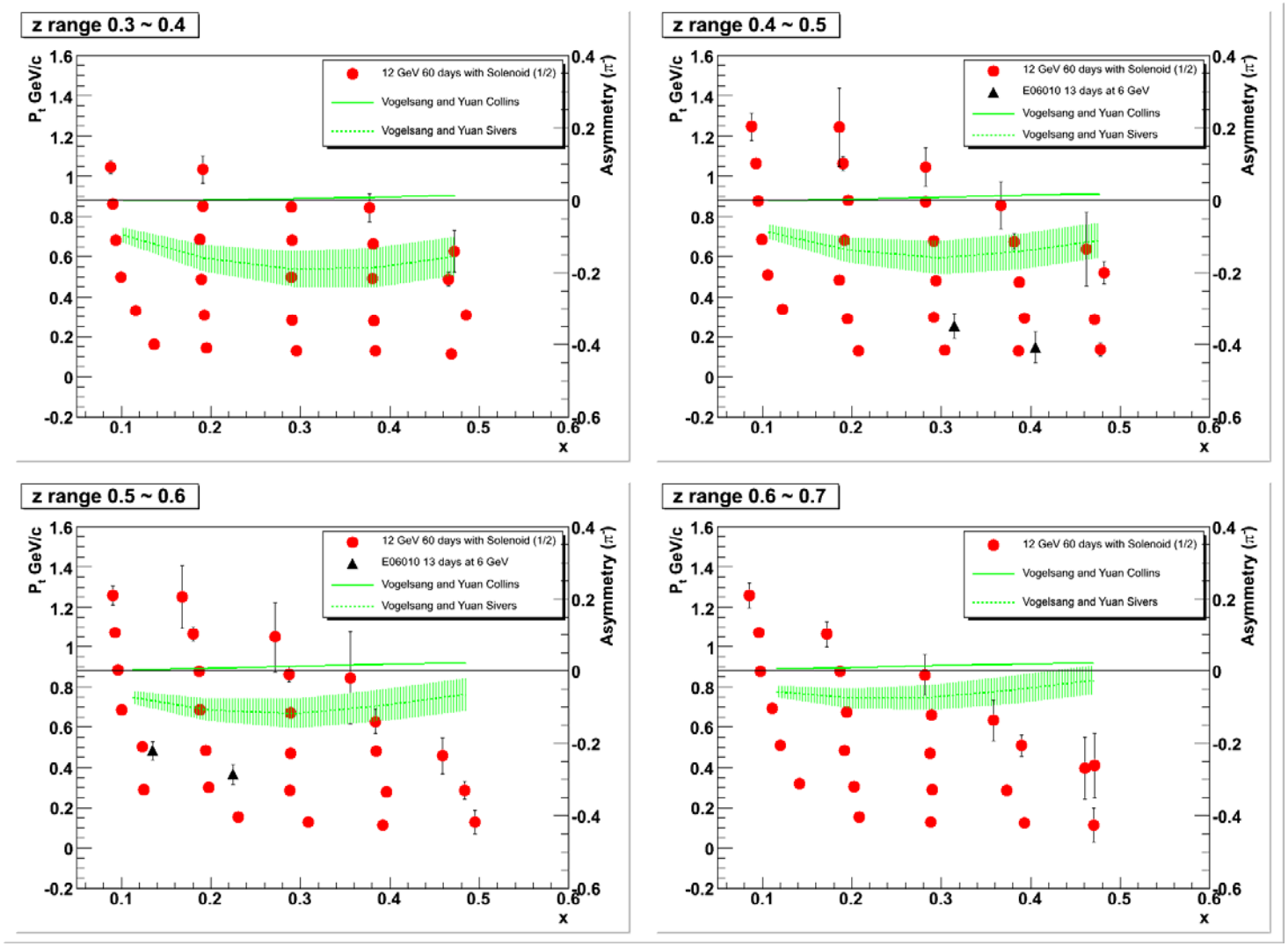
3-D Projections for Collins and Sivers Asymmetry (π^+)



F. Yuan, private communication

Anselmino's talk

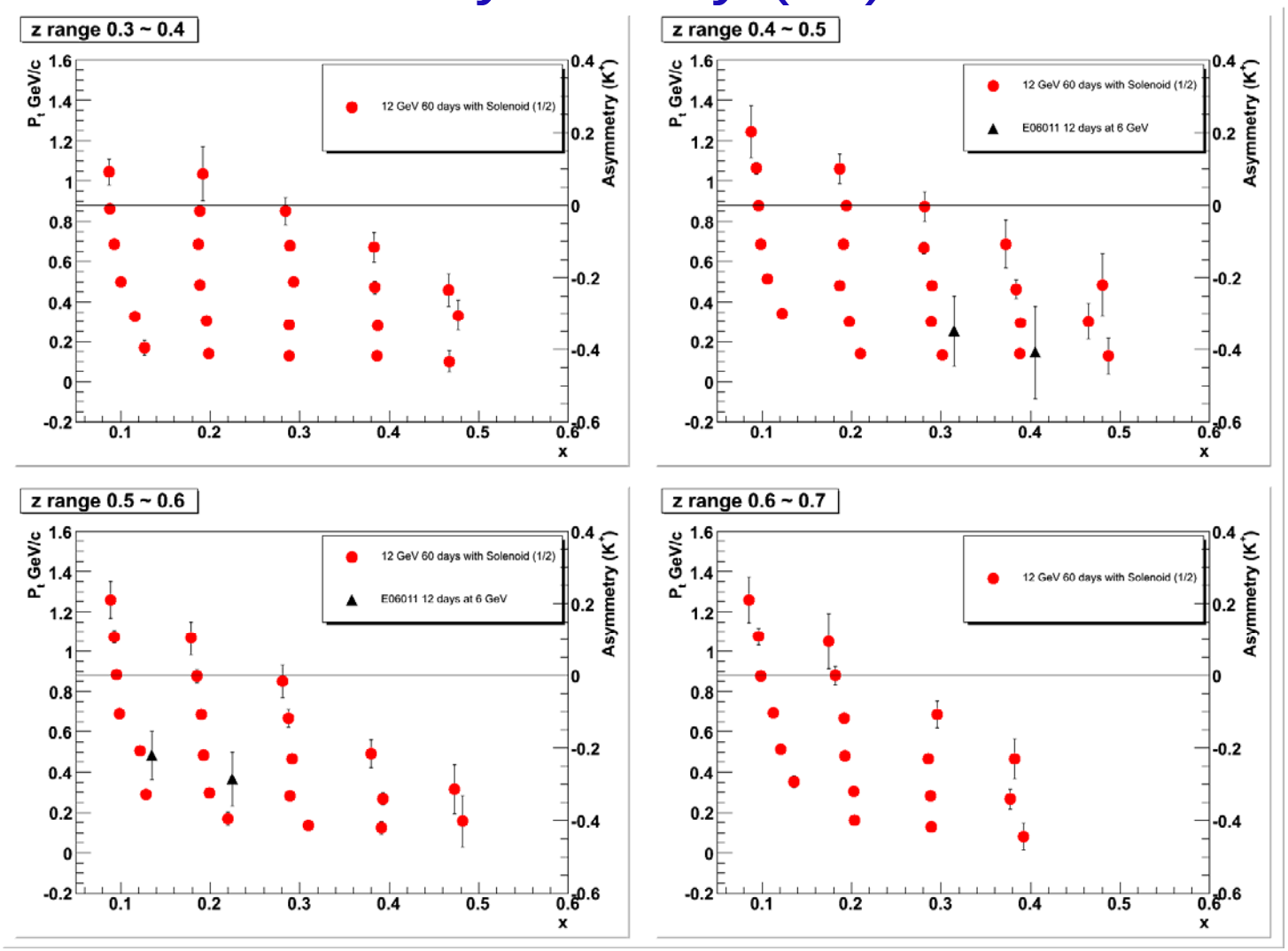
3-D Projections for Collins and Sivers Asymmetry (π^-)



F. Yuan, private communication

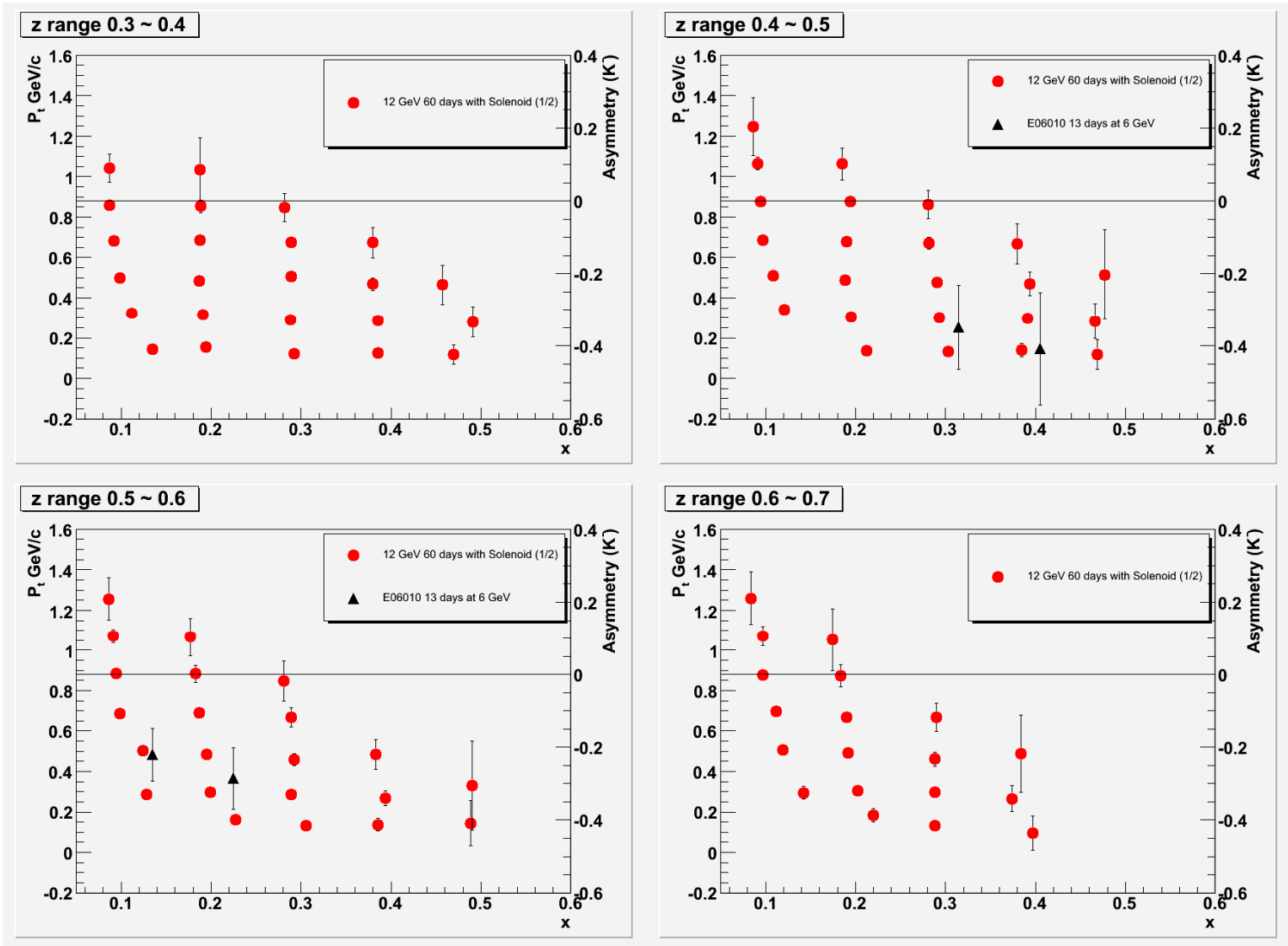
Anselmino's talk

3-D Projections for Collins and Sivers Asymmetry (K^+)



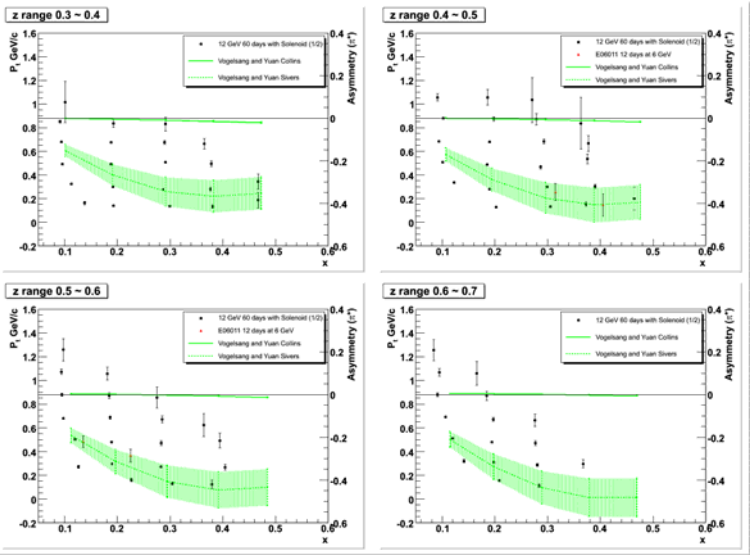
Anselmino's talk

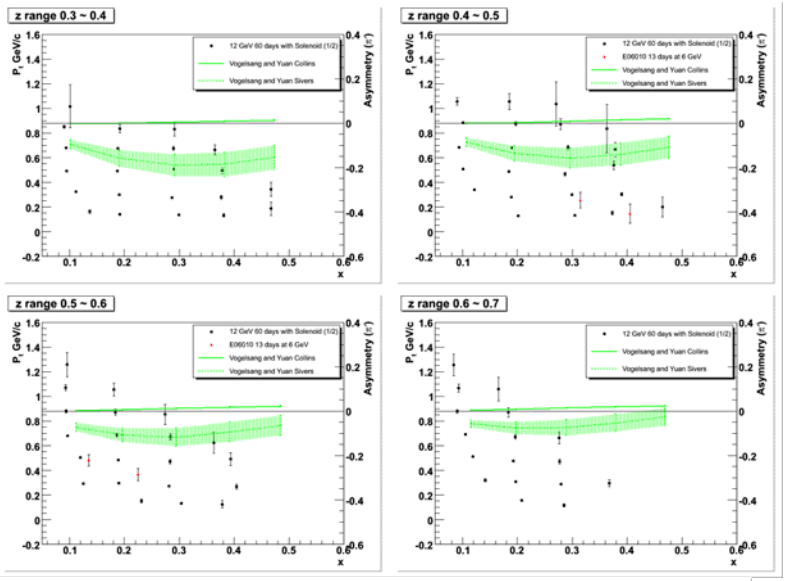
3-D Projections for Collins and Sivers Asymmetry (K^-)



Anselmino's talk

14.3 degree


z range 0.3 ~ 0.4
z range 0.4 ~ 0.5
z range 0.5 ~ 0.6
z range 0.6 ~ 0.7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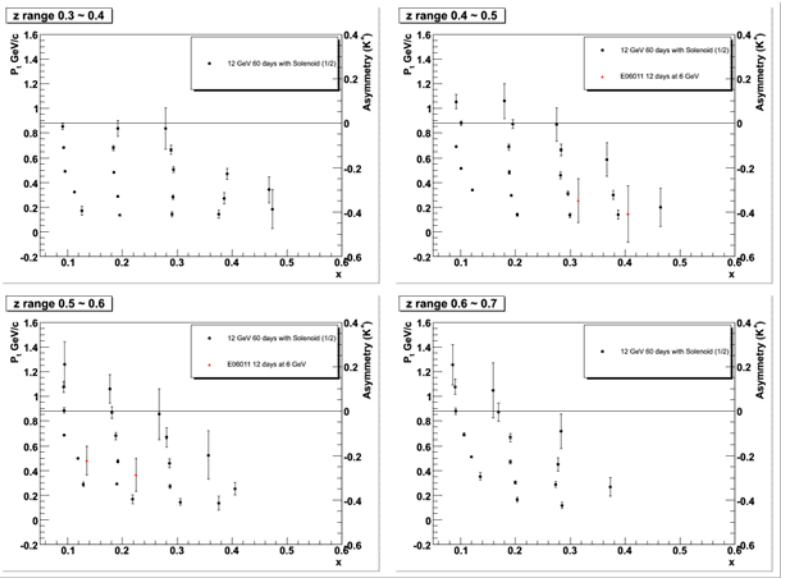
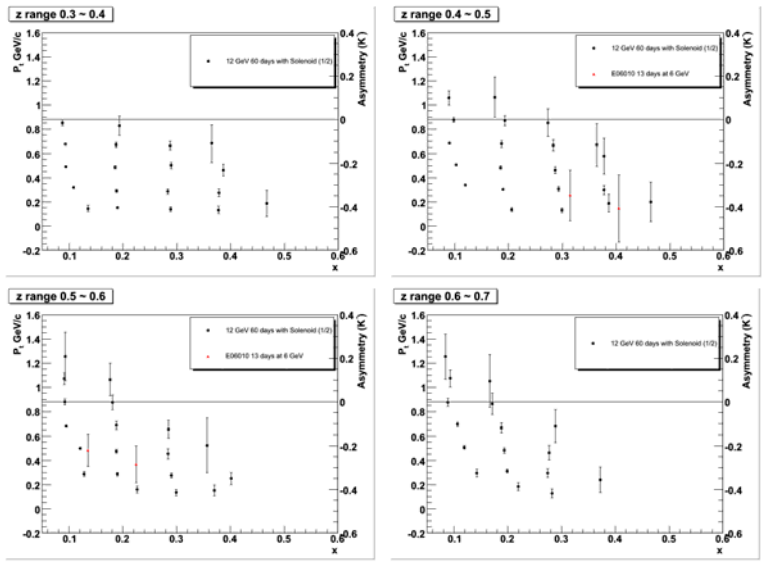
z range 0.4 ~ 0.5
z range 0.5 ~ 0.6
z range 0.6 ~ 0.7


z range 0.3 ~ 0.4
z range 0.4 ~ 0.5
z range 0.5 ~ 0.6
z range 0.6 ~ 0.7


z range 0.3 ~ 0.4
z range 0.4 ~ 0.5
z range 0.5 ~ 0.6
z range 0.6 ~ 0.7

Summary

- The study of k_T-dependent quark distribution (transversity, Sivers function …) and fragmentation functions (Collins function …) is an exciting frontier in nuclear physics. Surprising flavor dependence has been observed in Collins and Sivers function.

- The 6 GeV transversity experiments with polarized ^{3}He target is underway in Hall A to measure the pion SIDIS target single-spin asymmetry on ``neutron'' (kaon data as the by-product).

- 11 GeV prospect for transversity with Solenoid is extremely bright. These experiments will contribute greatly to the worldwide effort on the study of the transversity.