Transversity at Hall A

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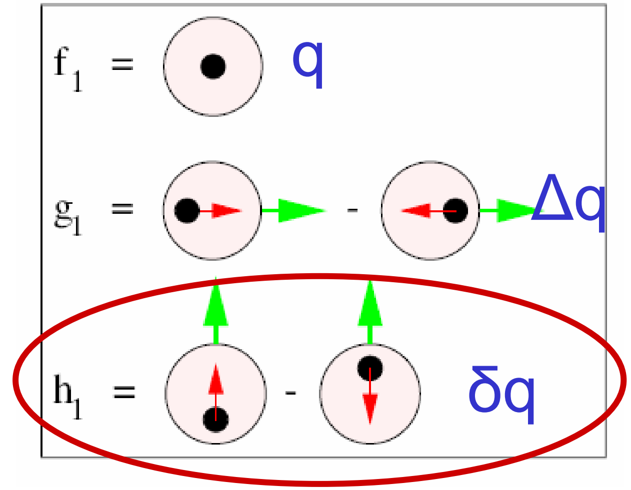
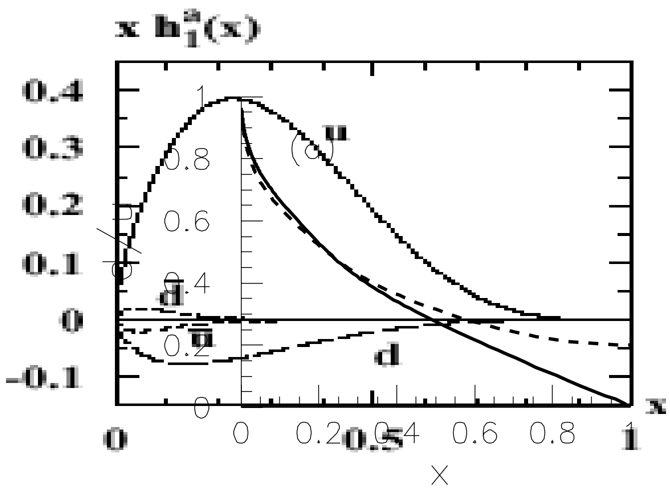
Transversity

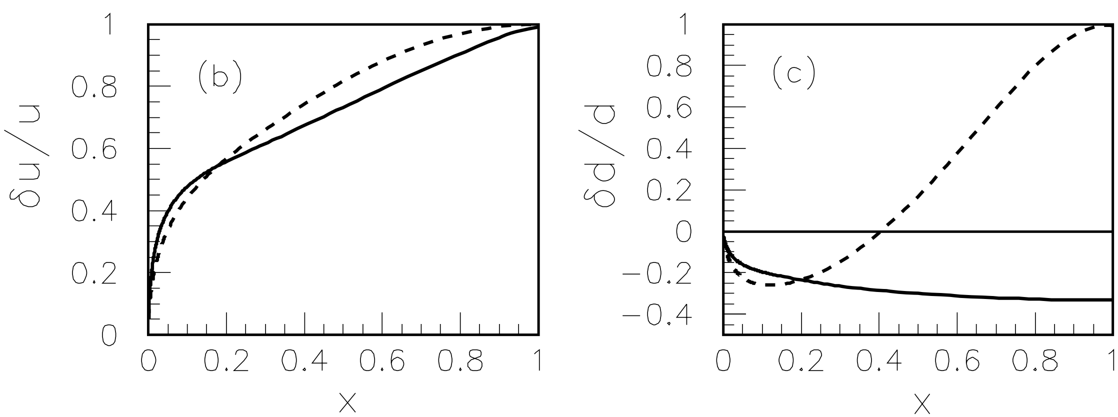


- δq(x) = Δq(x) for non-relativistic quarks
- δq and gluons do not mix
  → Q^2-evolution for δq and Δq are different
- Chiral-odd → not accessible in inclusive DIS

Chiral-quark soliton model



Quark – diquark model (solid) & pQCD-based model (dashed)



hep-ph/0101300

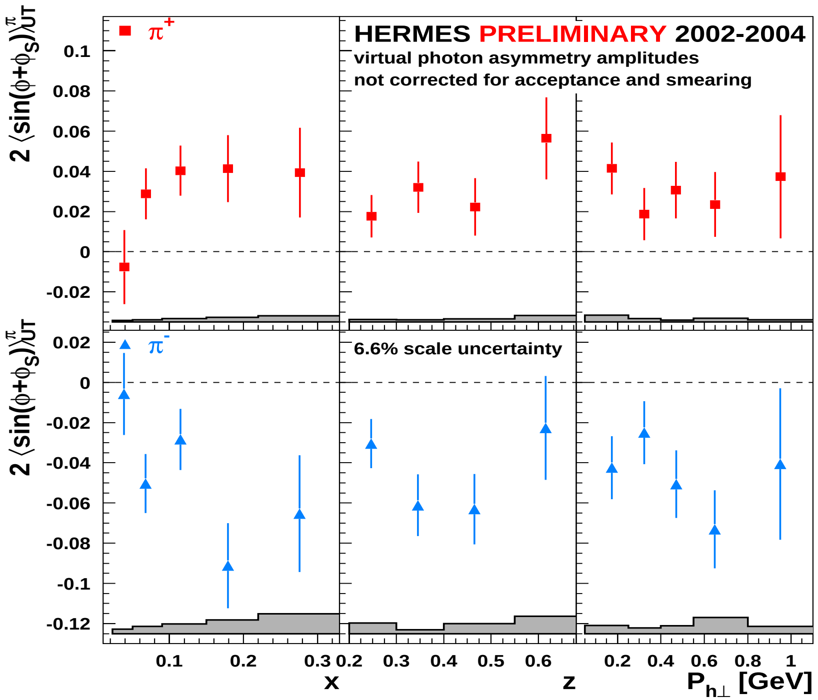
B. –Q. Ma, I. Schmidt and J. –J. Yang, PRD 65, 034010 (2002)

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

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

„Collins" moments

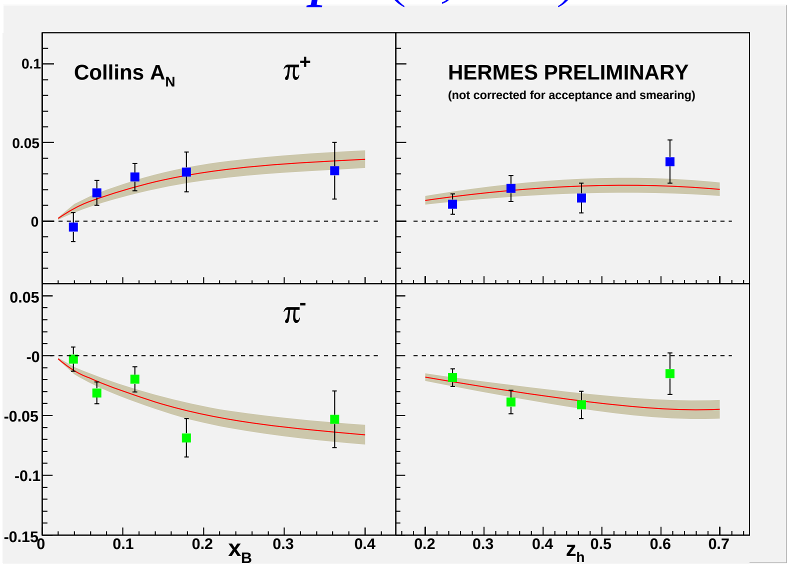
hep-ex/0507013



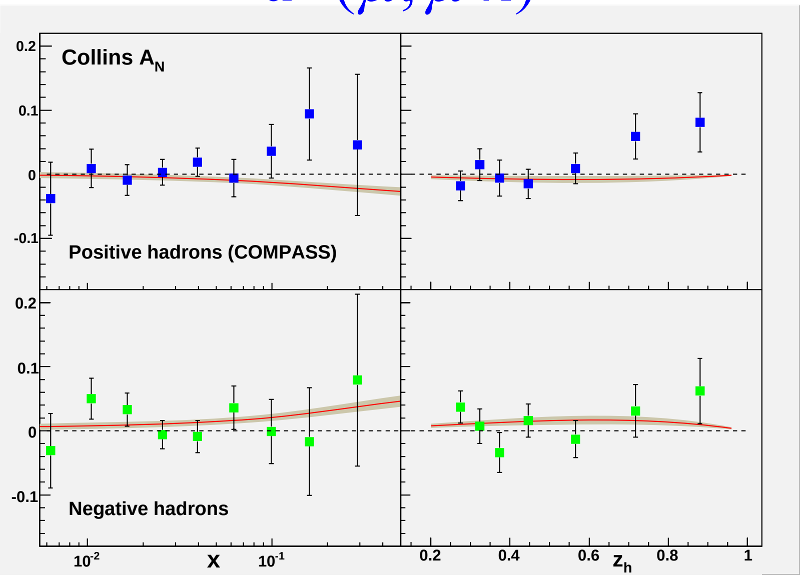
- Product of $\delta q(x) H_1^{\perp}(z)$ is non-zero
- A surprising flavor dependence : $H_1^{\perp,\, unfavored} / H_1^{\perp,\, favored} \approx -1$
- Extraction of $\delta q(x)$ requires an independent measurement of Collins function $H_1^{\perp}(z)$

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

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

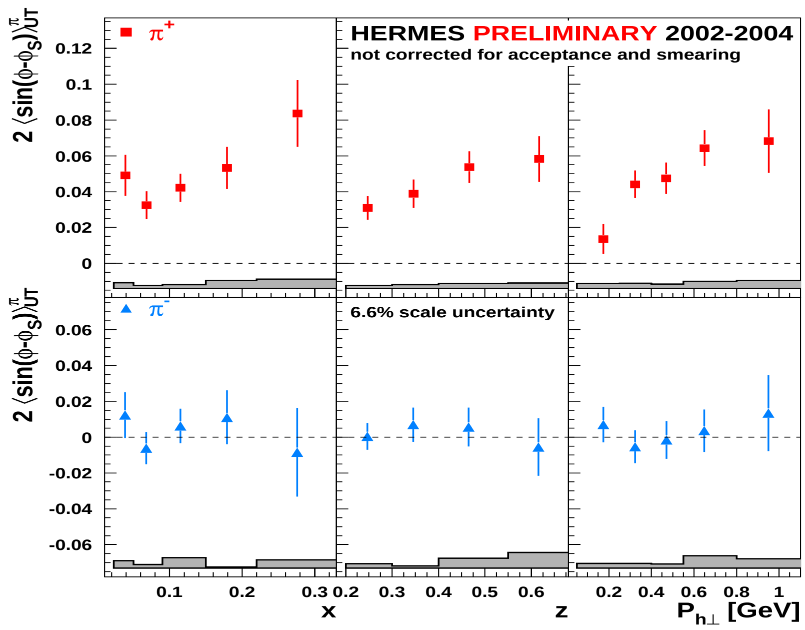
(Vogelsang and Yuan, hep-ph/0507266)

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

Sivers moments from transversity experiments

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

"Sivers" moments



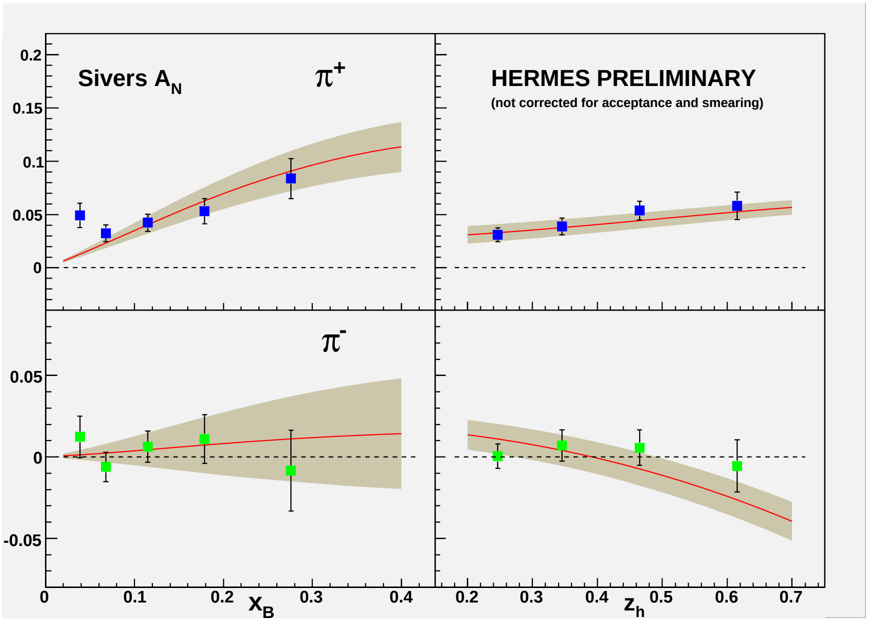
hep-ex/0507013

First measurement of Sivers asymmetry

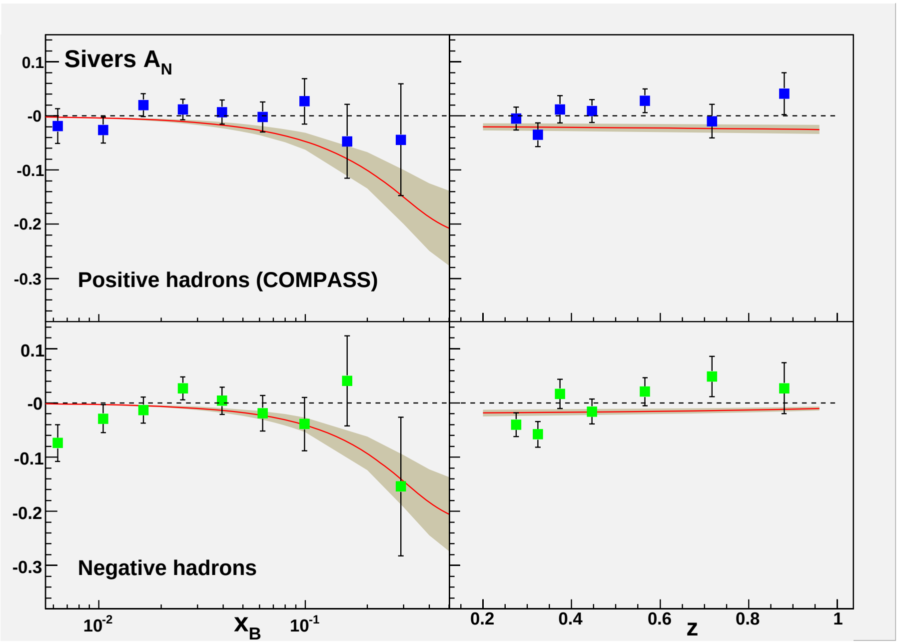
Sivers function nonzero $\rightarrow$ orbital angular momentum of quarks

Extraction of Sivers functions from the Sivers moment measurements

Fits to the Hermes data



"Prediction" of the Compass data



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

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

(Vogelsang and Yuan, hep-ph/0507266)

Striking flavor dependence of the Sivers function

Transversity Experiments at Hall A

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

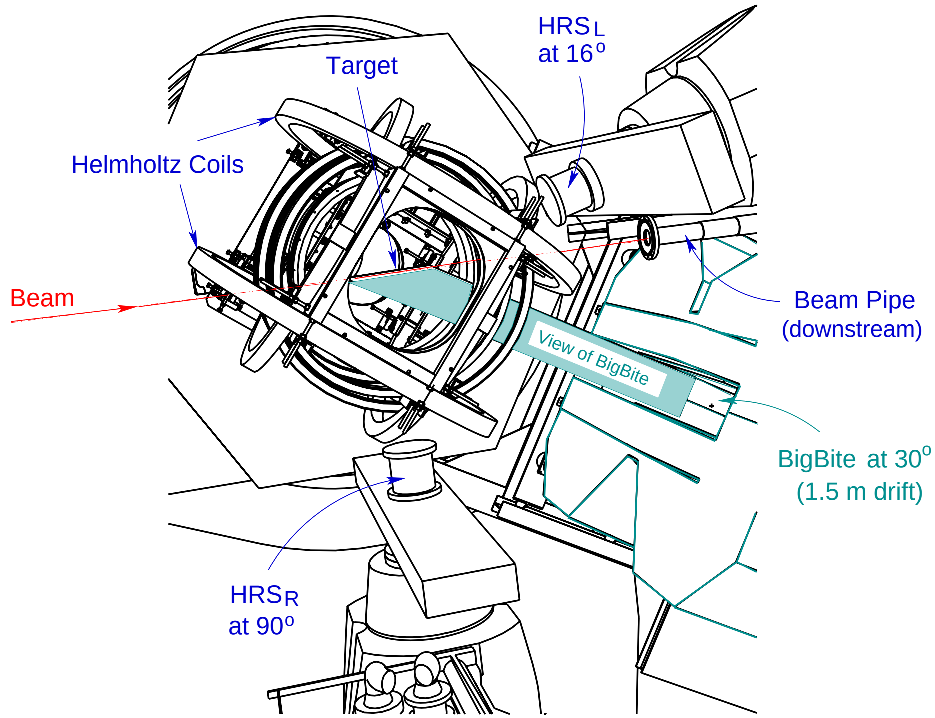
Single Target-Spin Asymmetry in Semi-Inclusive $n^{\uparrow}(e,e'\pi^{+/-})$ Reaction on a Transversely Polarized ^3He Target

Spokespersons:

Xiaodong Jiang (Rutgers, Contact Person)
Jian-ping Chen (JLab), Evaristo Cisbani (INFN-Rome)
Haiyan Gao (Duke),Jen-Chieh Peng (UIUC)

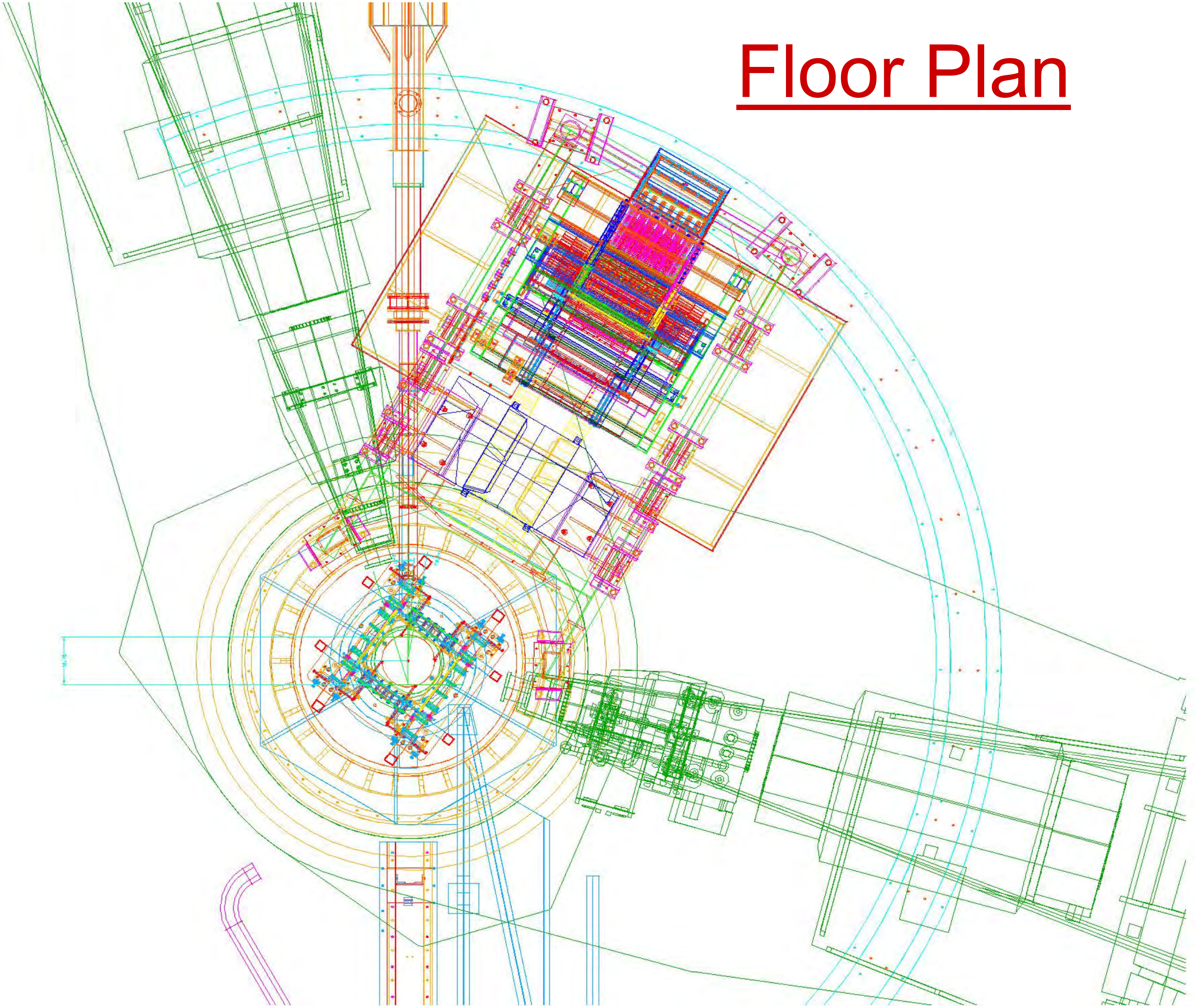
Approved with A rating, combined beam time of 29 days

$^3He^{\uparrow}(e,e'\pi^{+/-})x$ at Hall-A

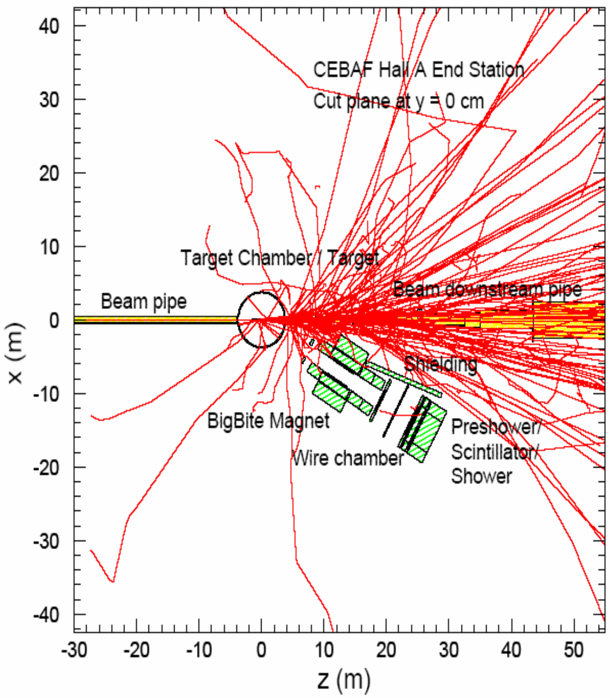


- **Beam**
  - **6 GeV, 15 μA e^- beam**
- **Target**
  - **Optically pumped Rb-K spin-exchange ^3He target, 50 mg/cm^2, ~42% polarization, transversely polarized with tunable direction**
- **Electron detection**
  - **BigBite spectrometer, Solid angle = 60 msr, $\theta_{Lab} = 30^0$**
- **Charged pion detection**
  - **HRS spectrometer, $\theta_{Lab} = -16^0$**

Floor Plan



BigBite Singles Rates



GENAT Simulation agrees with various of data within a factor of 2, ex.

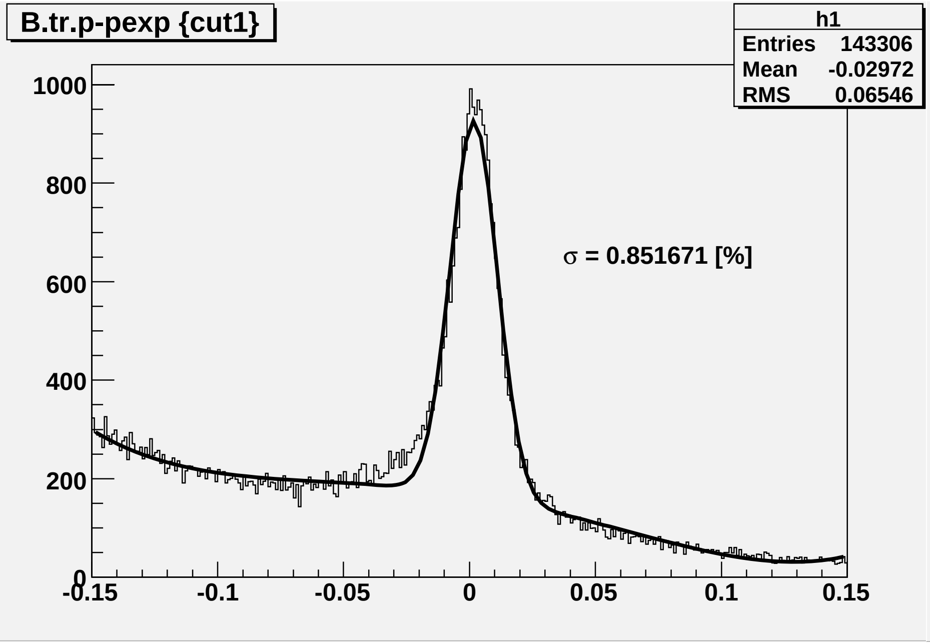
- Gen Setting 2, Run 2812 5.0 uA

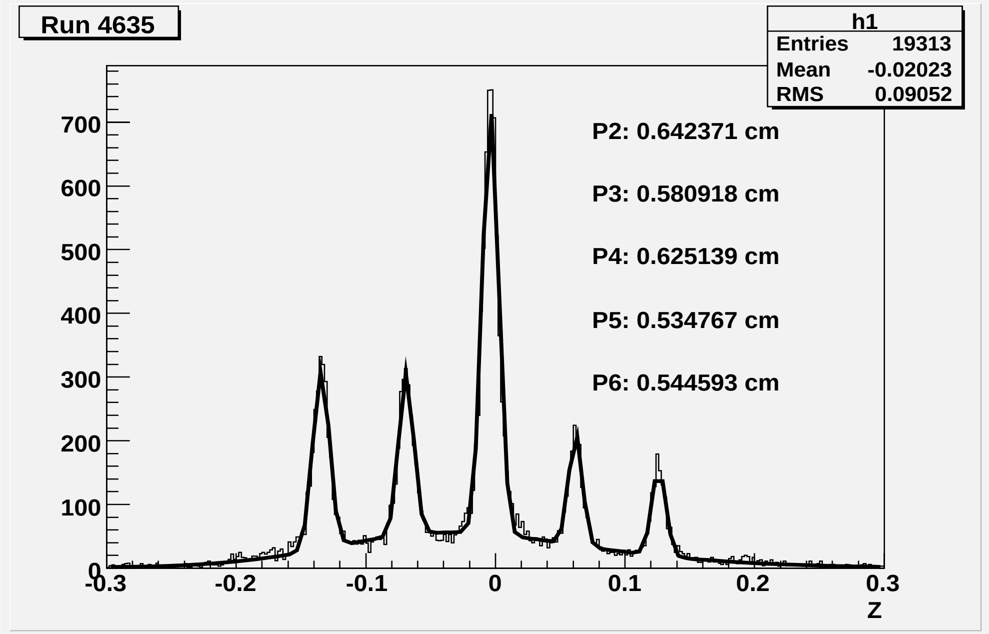
	WC1(MHz)	WC2(MHz)	WC3(MHz)
Data:	10.5	12.2	11.6
Simulation:	7.2	12.7	11.0

Wire chamber can at least survive 10 uA beam for transversity

From Xin Qian (Duke)

BigBite Resolution

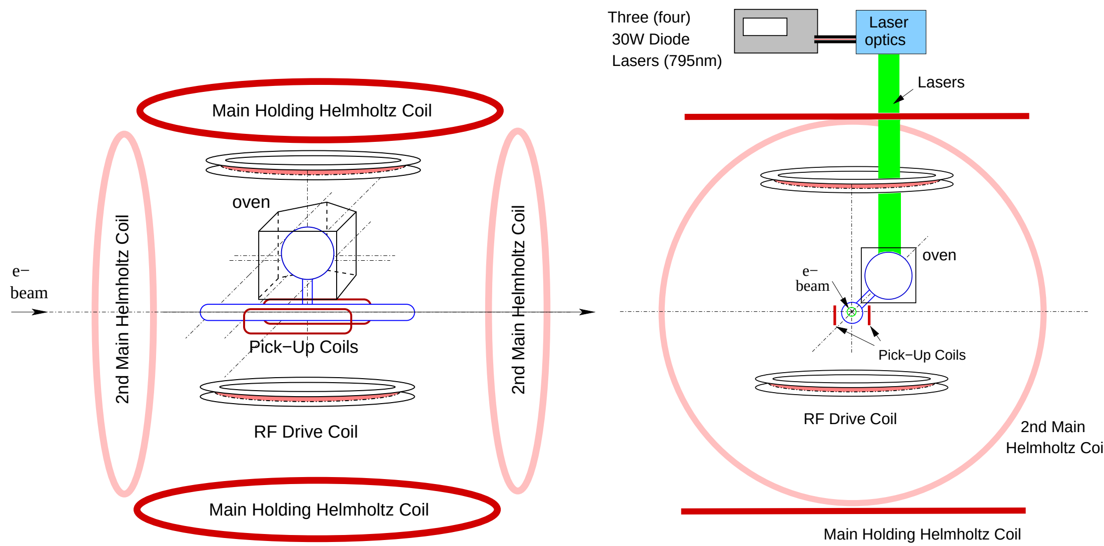


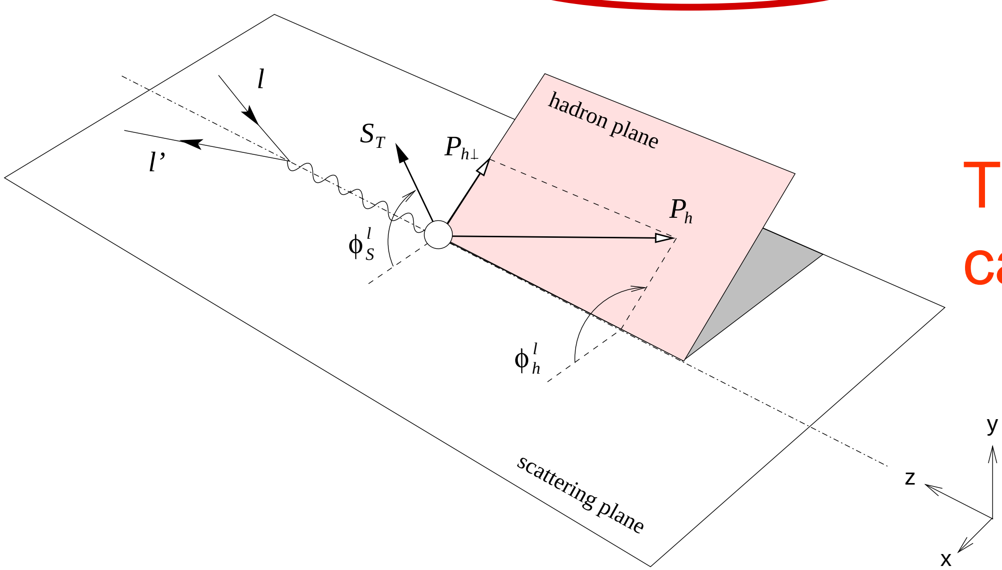


Momentum: <1%   React z: ~0.6cm → In-plane-angle: ~1.8mr

From Xin Qian (Duke)

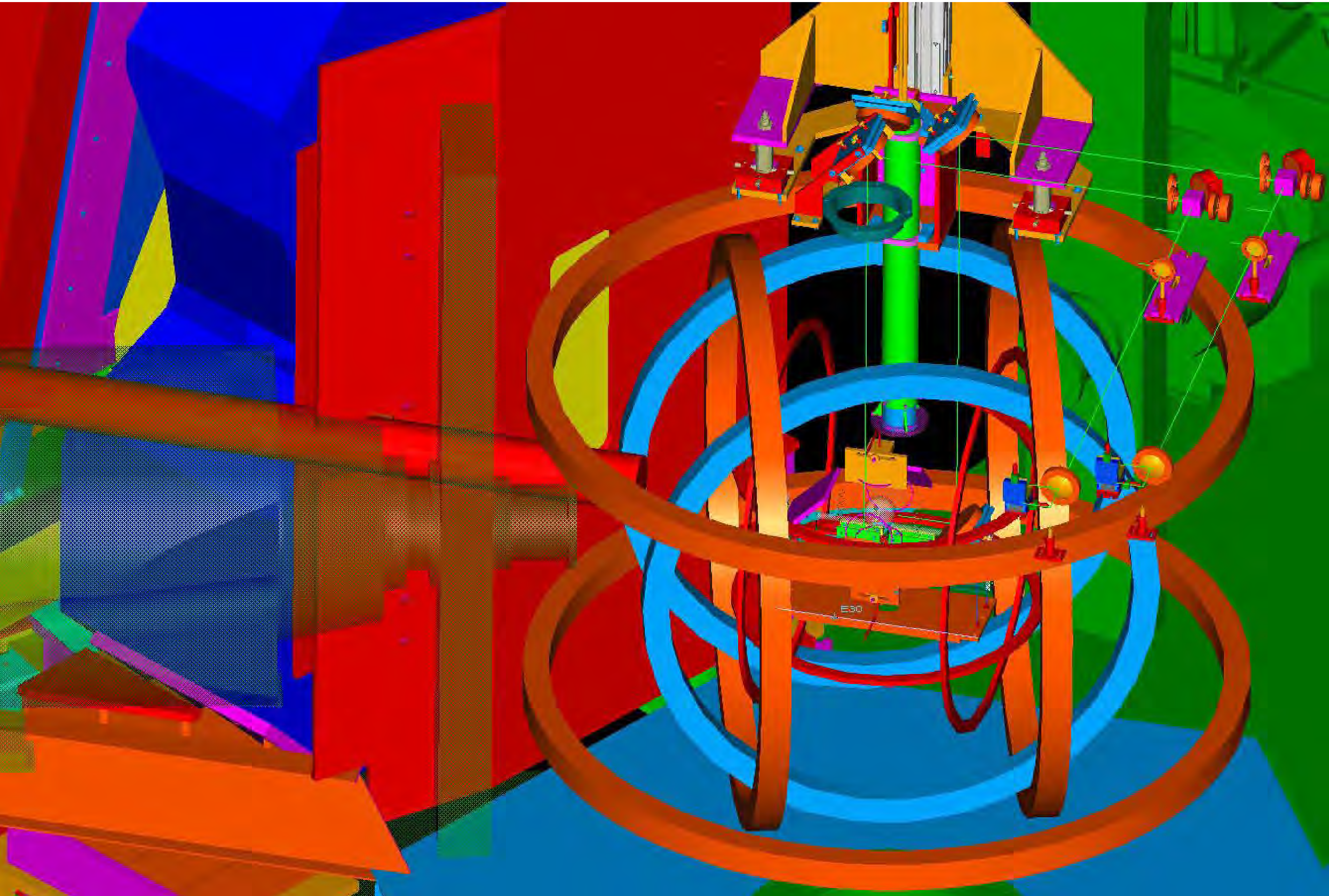
Transversely polarzied ^{3}He target



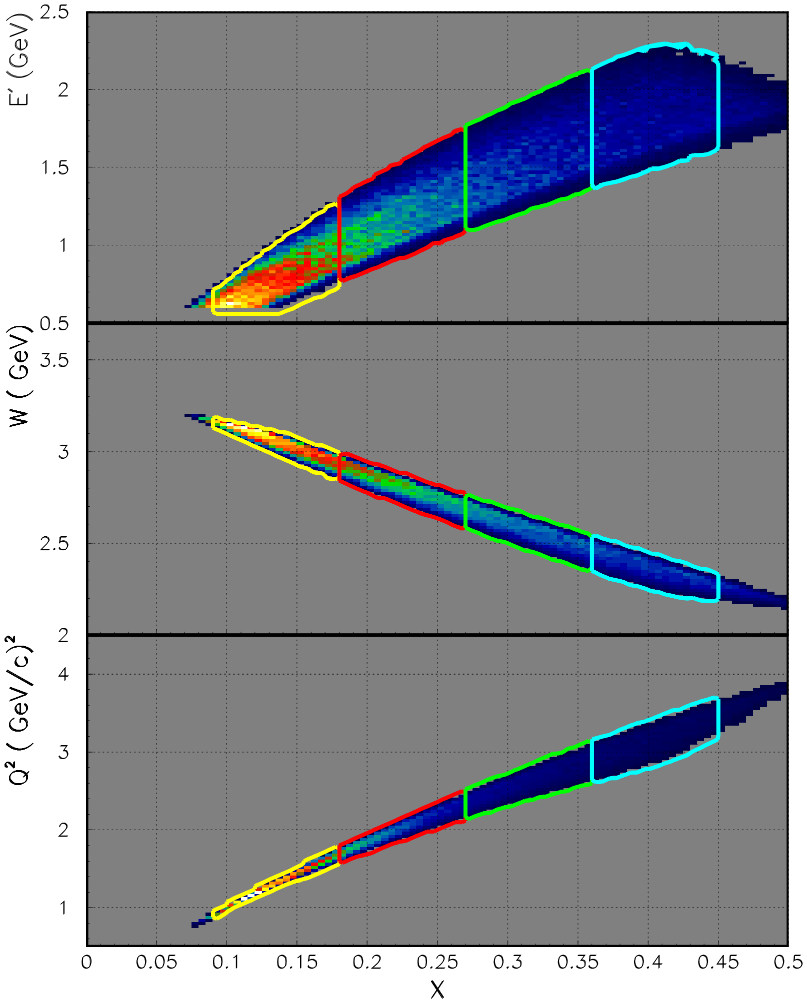


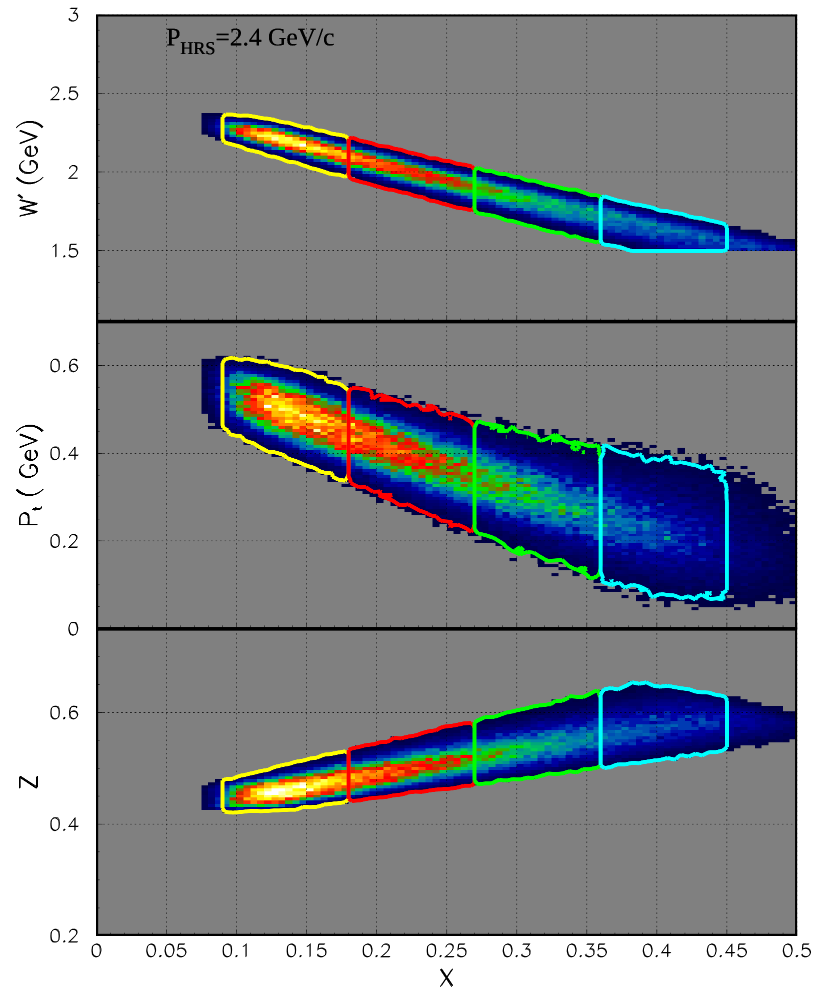
Target polarization orientation can be rotated to increase the coverage in Φ_S^l

Vertical Coil Design



Kinematic Coverage





<x>=0.135,0.225,0.315,0.405

<z>=0.473,0.515,0.558,0.601

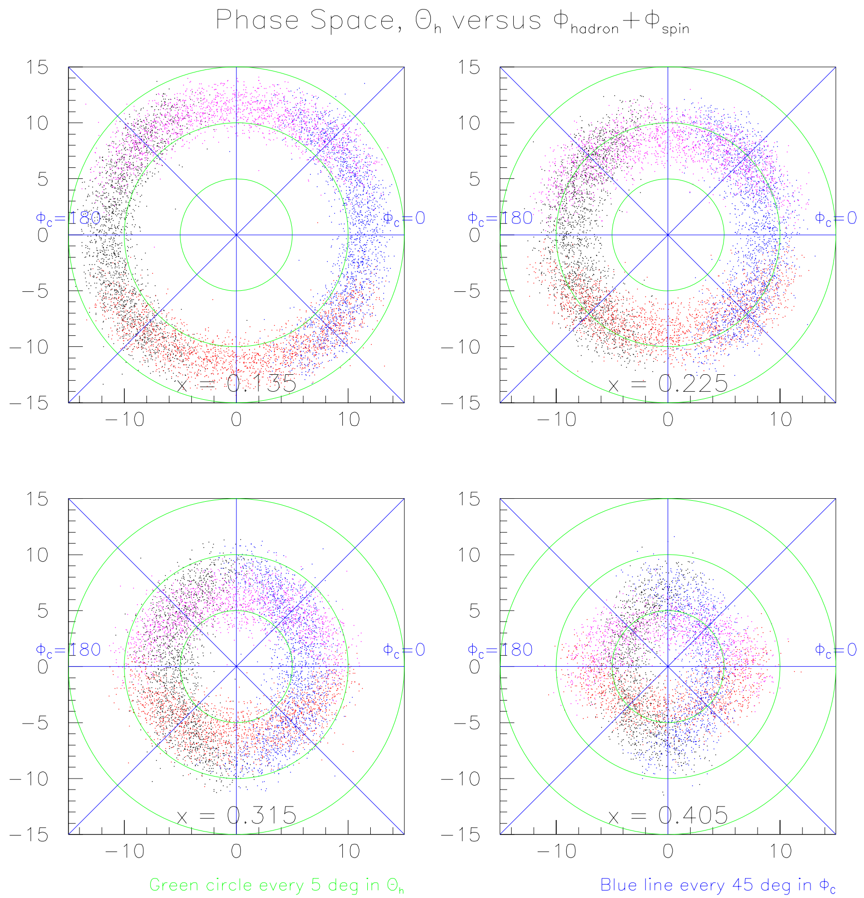
Coverage of the Collins angle

$$\phi_{Collins} = \phi_h^l + \phi_S^l$$

$\phi_S^l = 0^\circ$ (black), $\phi_S^l = 90^\circ$ (red), $\phi_S^l = 180^\circ$ (blue), $\phi_S^l = 270^\circ$ (purple)

<x>=0.135 <x>=0.225

<x>=0.315 <x>=0.405



Coverage of the Sivers angle

$$\phi_{Sivers} = \phi_h^l - \phi_S^l$$

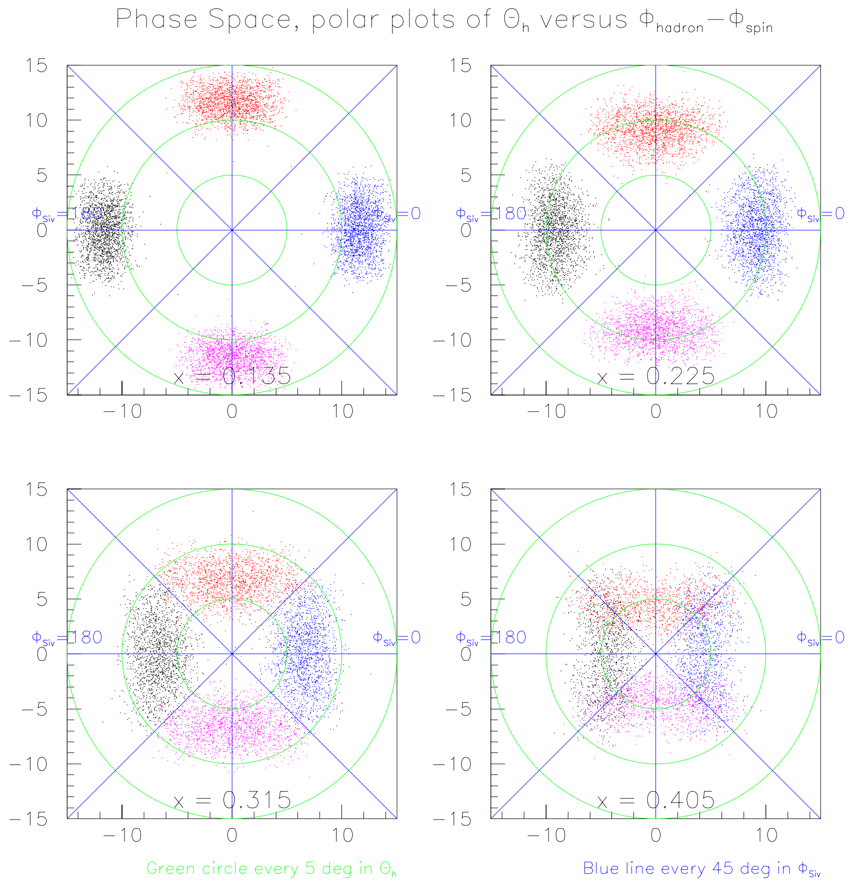
$\phi_S^l = 0^\circ$ (black), $\phi_S^l = 90^\circ$ (red), $\phi_S^l = 180^\circ$ (blue), $\phi_S^l = 270^\circ$ (purple)

<x>=0.135

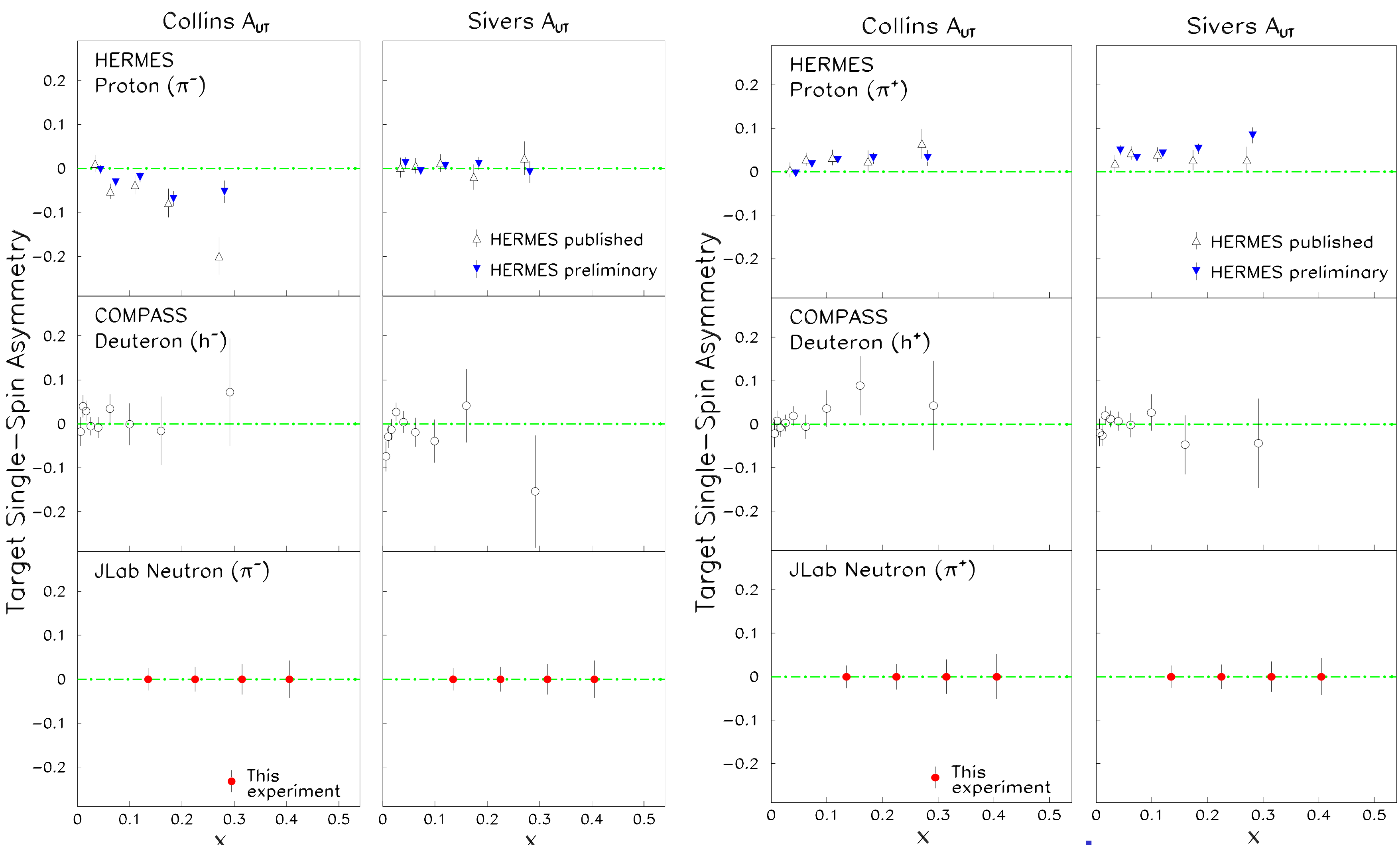
<x>=0.225

<x>=0.315

<x>=0.405



Projected Target Single-Spin Asymmetries

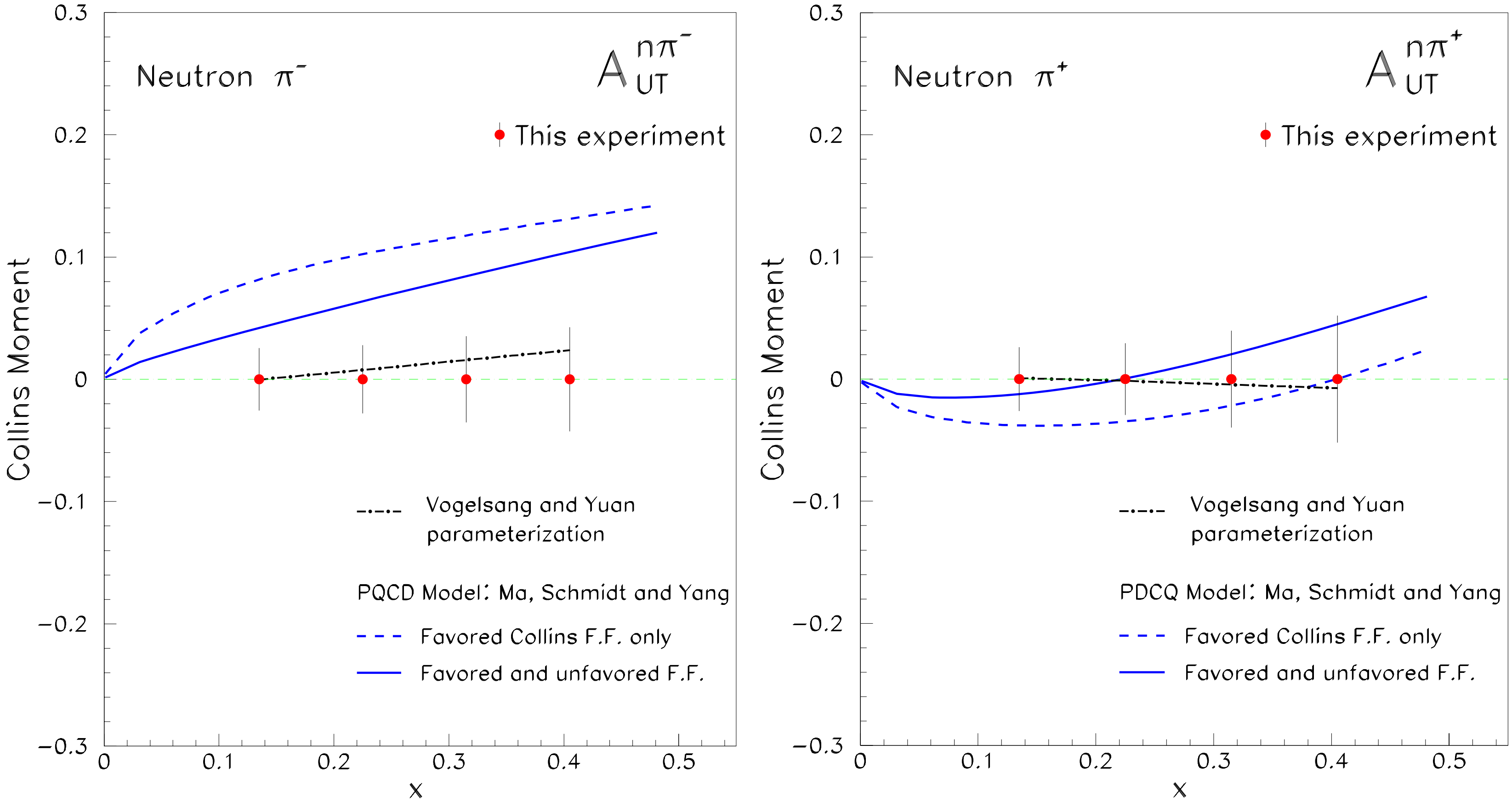


π-

π+

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

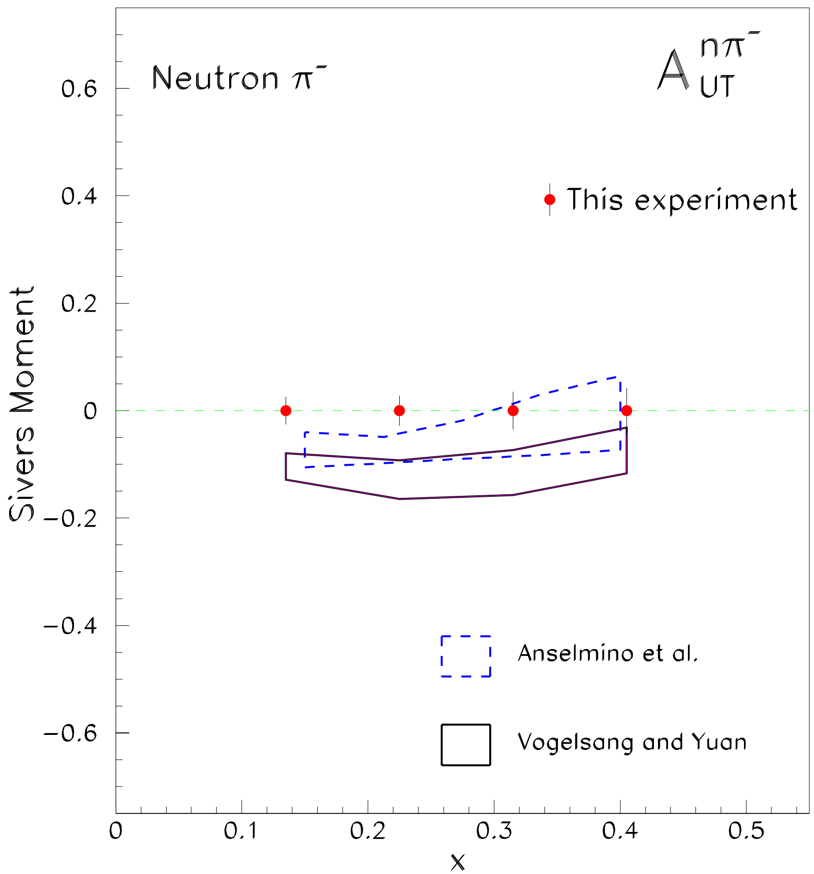
Predictions of Collins asymmetry on neutron



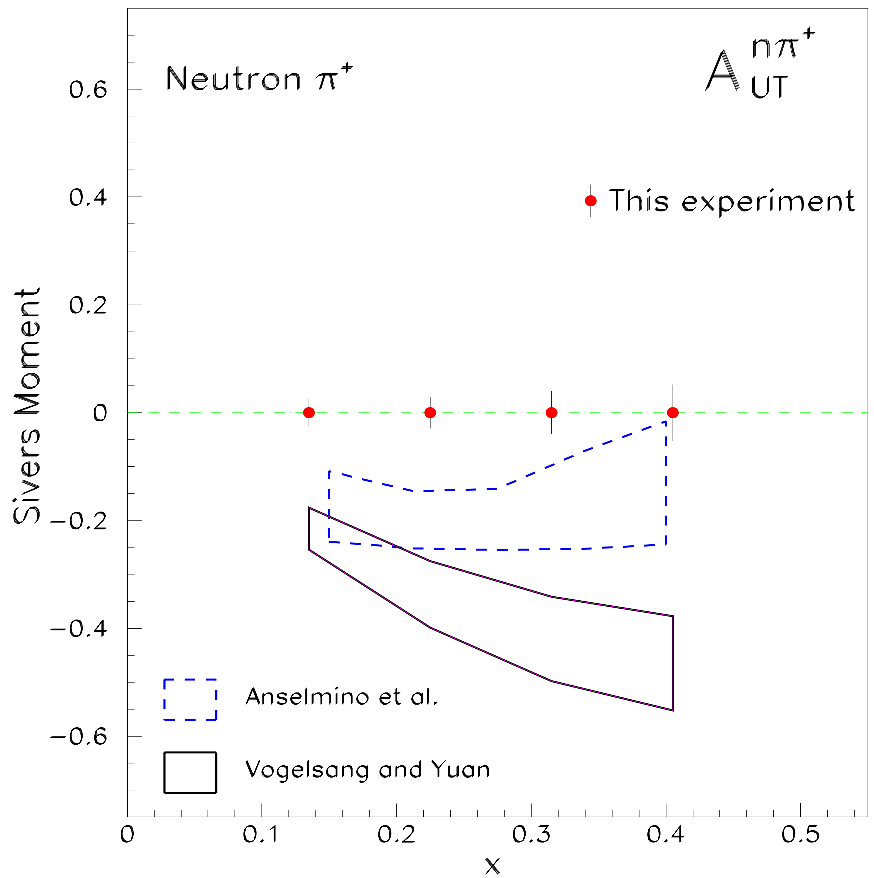
π- π+

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

Predictions of Sivers asymmetry on neutron



π-



π+

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

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 Hall A transversity experiments with polarized ^{3}He target was approved with A rating to measure the pion SIDIS target single-spin asymmetry on neutron, with kaon data as the by-product.

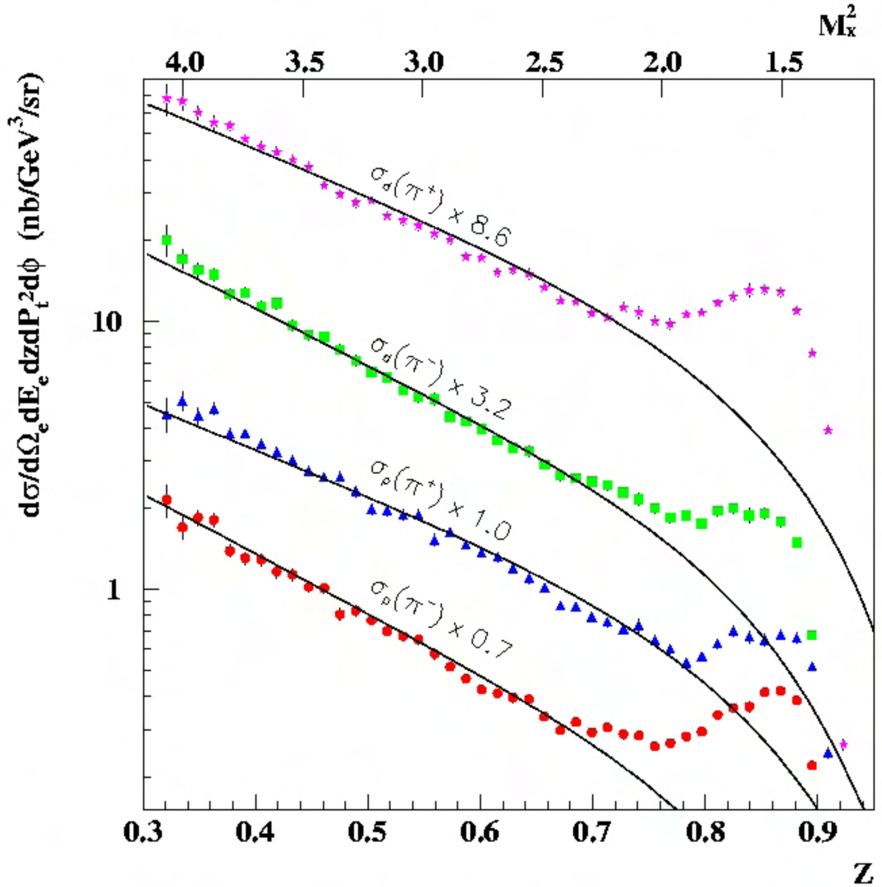
- The Hall A transversity experiment will be a great contribution to the world transversity measurements and can constrain different theoretical calculations. It can provide very useful information by combining the π^- and π^+ data alone.

Backup Slides

Is SIDIS applicable at 6 GeV?

Preliminary results from Hall-C E00-108

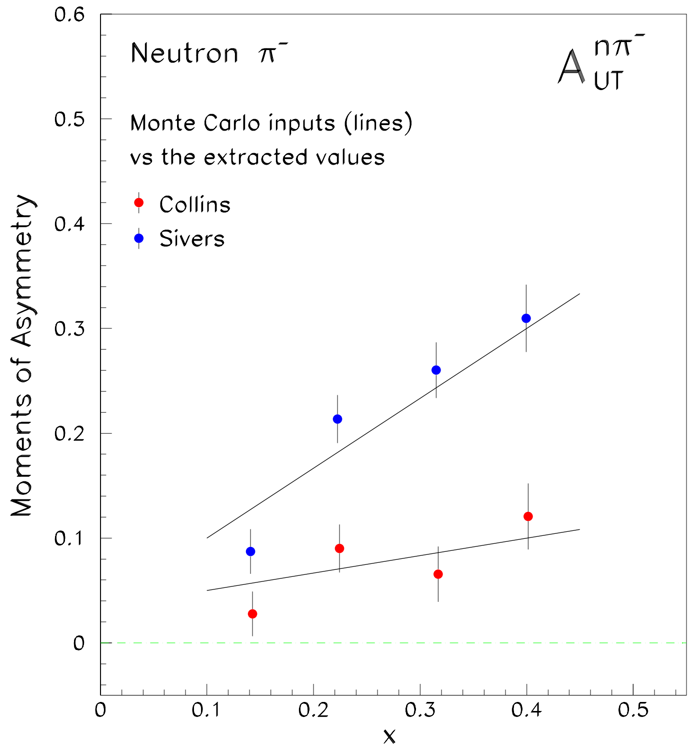
$p(e,e'\pi^{\pm})$ and $d(e,e'\pi^{\pm})$ at $x=0.3$

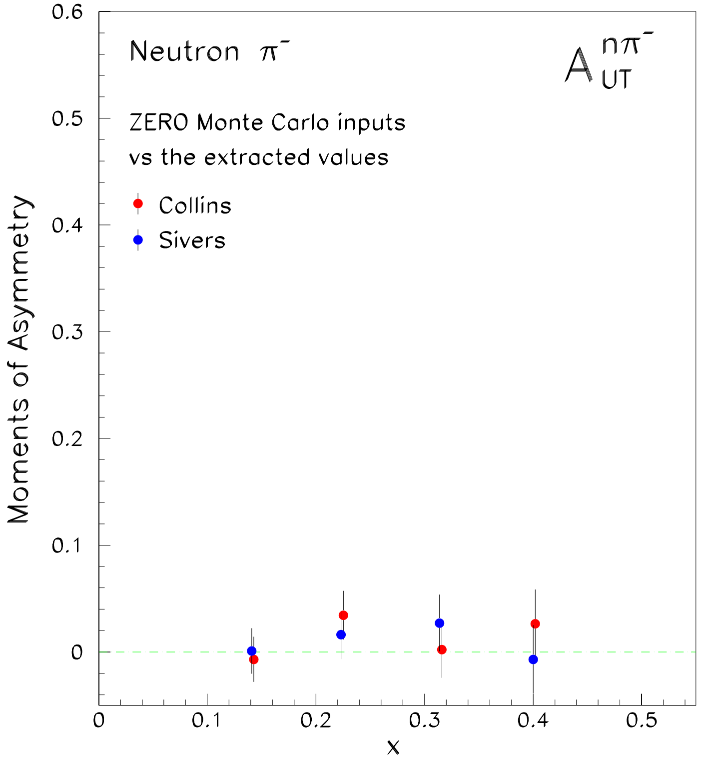


Data are well described by SIDIS calculations for 0.4 < z < 0.7

Disentangling Collins from Sivers asymmetries

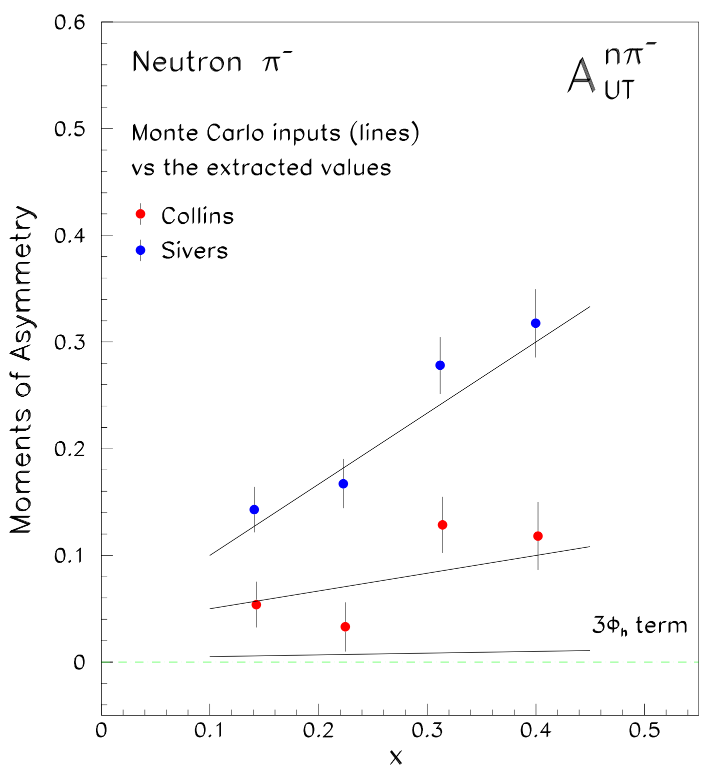
simulation taking into account of the finite acceptance of the spectrometer

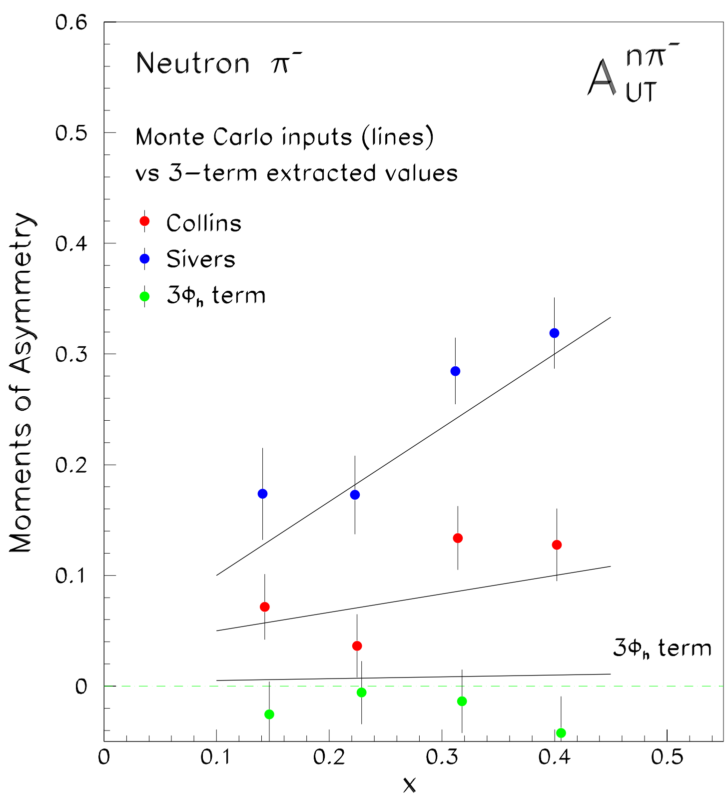




Disentangling Collins from Sivers asymmetries

simulation taking into account of the finite acceptance of the spectrometer, and the $3\Phi_h$-Φ_s term





Systematic errors

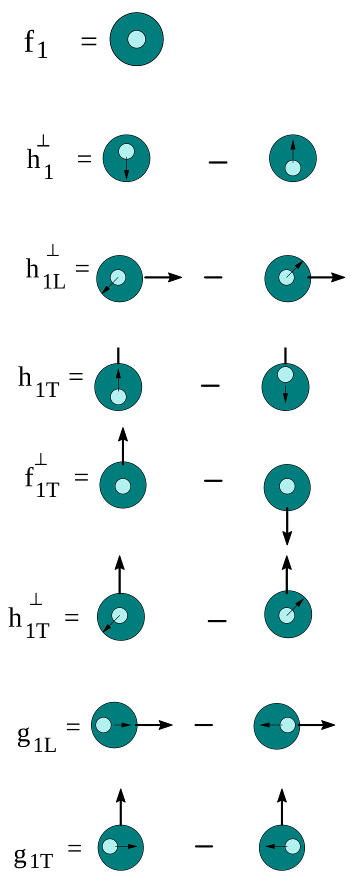
- Nuclear effects in ^{3}He
  - Proton carries ~ 2.8 % of the polarization and can be well corrected for, using the asymmetry data from HERMES
- Target polarization drift
  - Only contributes to the relative uncertainty of the measured A_{UT} at a level of 4 %
- Decays from exclusive ρ-meson production
  - Negligible at z=0.5, based on the simulation of Hall-C E00-108
- Other terms in SSA
  - Monte-Carlo simulations indicate very small effect

π^- versus π^+, which do we prefer?

- If both π^- and π^+ data are obtained, one can make an independent extraction of the Sivers functions based on Jlab data alone (and compare them with Hermes data).
- π^- and π^+ data will provide two independent tests of the current results on Sivers and Collins function obtained at Hermes and Compass.
- If only one charged pion data will be measured, then one can make a single test of the results on Sivers and Collins function. In this case, there is no difference which charged state one selects.
- Under severe beam-time constraints, a measurement for both pions with somewhat reduced statistics might be considered.

All Eight Quark Distributions Are Probed in Semi-Inclusive DIS

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



Unpolarized

$$\{[1+(1-y)^2]\sum_{q,\bar{q}} e_q^2 f_1^q(x) D_1^q(z, P_{h\perp}^2)$$

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

Polarized target

$$-|S_L|(1-y)\frac{P_{h\perp}^2}{4z^2 M_N M_h}\sin(2\phi_h^l)\sum_{q,\bar{q}} e_q^2 h_{1L}^{\perp(1)q}(x) H_1^{\perp q}(z, P_{h\perp}^2)$$

$$+|S_T|(1-y)\frac{P_{h\perp}}{zM_h}\sin(\phi_h^l+\phi_S^l)\sum_{q,\bar{q}} e_q^2 h_1^q(x) H_1^{\perp q}(z, P_{h\perp}^2)$$

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

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

Polarized beam and target

$$+\lambda_e|S_L|y(1-\frac{1}{2}y)\sum_{q,\bar{q}} e_q^2 g_1^q(x) D_1^q(z, P_{h\perp}^2)$$

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

S_L and S_T: Target Polarizations; λe: Beam Polarization

Hall A Collaboration Experiment

The Institutions

California State Univ., Duke Univ., Florida International. Univ., Univ. Illinois, JLab, Univ. Kentucky, Univ. Maryland, Univ. Massachusetts, MIT, Old Dominion Univ., Rutgers Univ., Temple Univ., Penn State Univ., Univ. Virginia, College of William & Mary, Univ. Sciences & Tech, China Inst. Of Atomic Energy, Beijing Univ., Seoul National Univ., Univ. Glasgow, INFN Roma and Univ. Bari, Univ. of Ljubljana, St. Mary's Univ., Tel Aviv Univ.

Collaboration members (103 members)

A. Afanasev, K. Allada, J. Annand, T. Averett, F. Benmokhtar, W. Bertozzi, F. Butaru, G. Cates, C. Chang, J.-P. Chen (Co-SP), W. Chen, S. Choi, C. Chudakov, E. Cisbani, E. Cusanno, R. De Leo, A. Deur, C. Dutta, D. Dutta, R. Feuerbach, S. Frullani, L. Gamberg, H. Gao, F. Garibaldi, S. Gilad, R. Gilman, C. Glashausser, J. Gomez, M. Grosse-Perdekamp, D. Higinbotham, T. Holmstrom, D. Howell, M. Iodice, D. Ireland, J. Jansen, C. de Jager, X. Jiang (Co-SP), Y. Jiang, M. Jones, R. Kaiser, A. Kalyan, A. Kelleher, J. Kellie, J. Kelly, A. Kolarkar, W. Korsch, K. Kramer, E. Kuchina, G. Kumbartzki, L. Lagamba, J. LeRose, R. Lindgren, K. Livingston, N. Liyanage, H. Lu, B. Ma, M. Magliozzi, N. Makins, P. Markowitz, Y. Mao, S. Marrone, W. Melnitchouk, Z.-E. Meziani, R. Michaels, P. Monaghan, S. Nanda, E. Nappi, A. Nathan, V. Nelyubin, B. Norum, K. Paschke, J. C. Peng (Co-SP), E. Piasetzky, M. Potokar, D. Protopopescu, X. Qian, Y. Qiang, B. Reitz, R. Ransome, G. Rosner, A. Saha, A. Sarty, B. Sawatzky, E. Schulte, S. Sirca, K. Slifer, P. Solvignon, V. Sulkosky, P. Ulmer, G. Urciuoli, K. Wang, D. Watts, L. Weinstein, B. Wojtsekhowski, H. Yao, H. Ye, Q. Ye, Y. Ye, J. Yuan, X. Zhan, X. Zheng, S. Zhou, X. Zong,