New Proposal: Proton Transversity Using SoLiD and Polarized NH_3 Target in Hall-A

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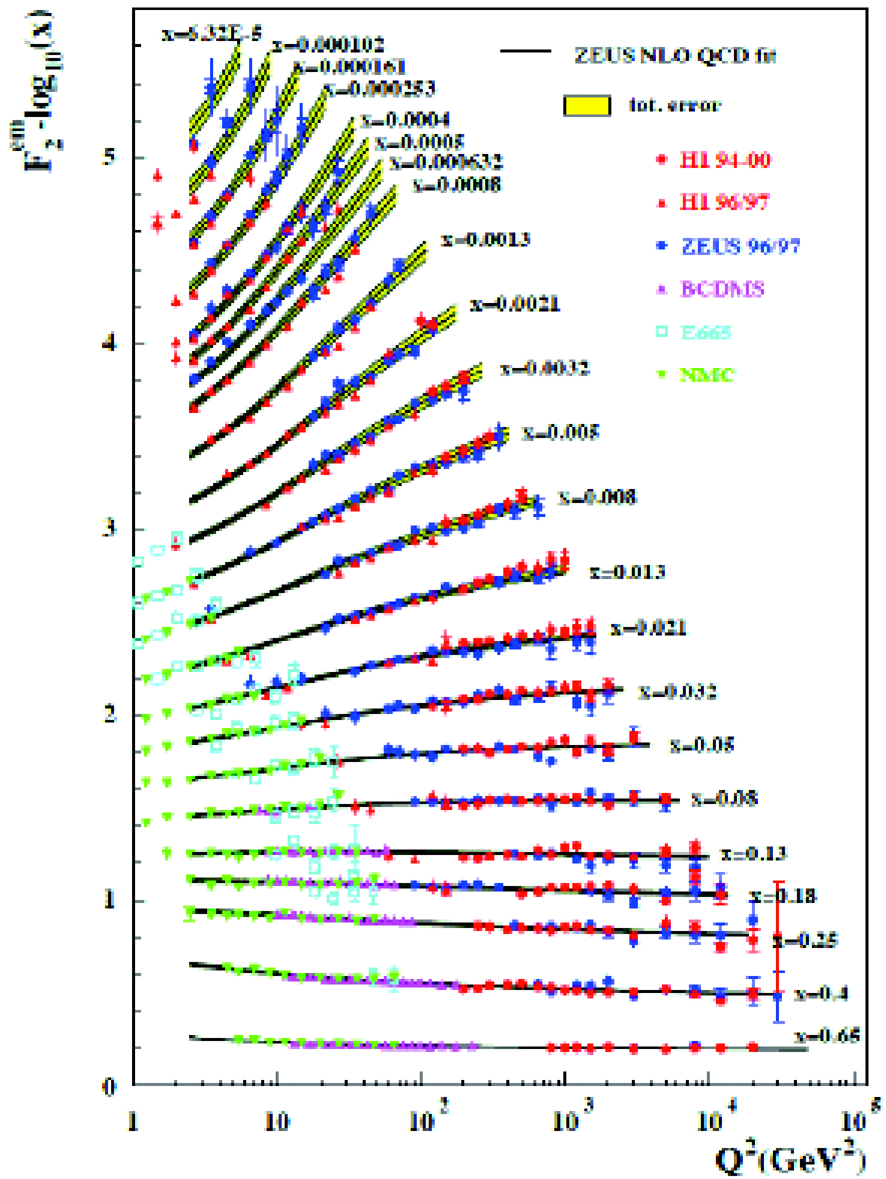
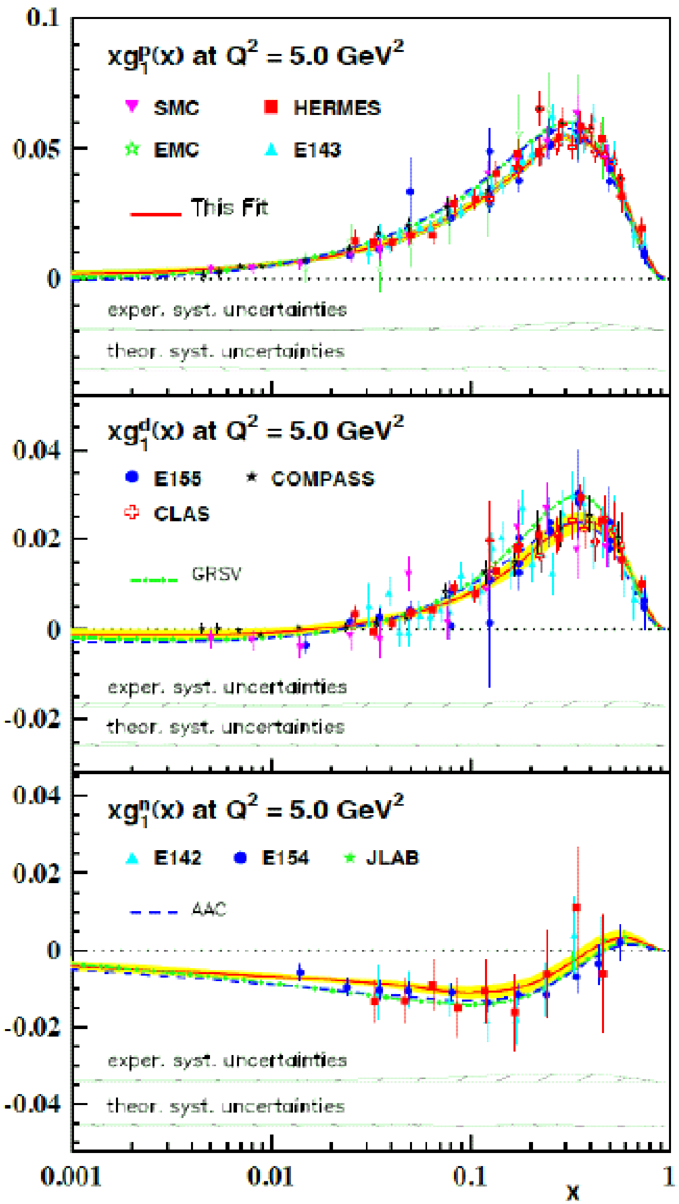
Hall-A Collaboration Meeting 10th June 2011

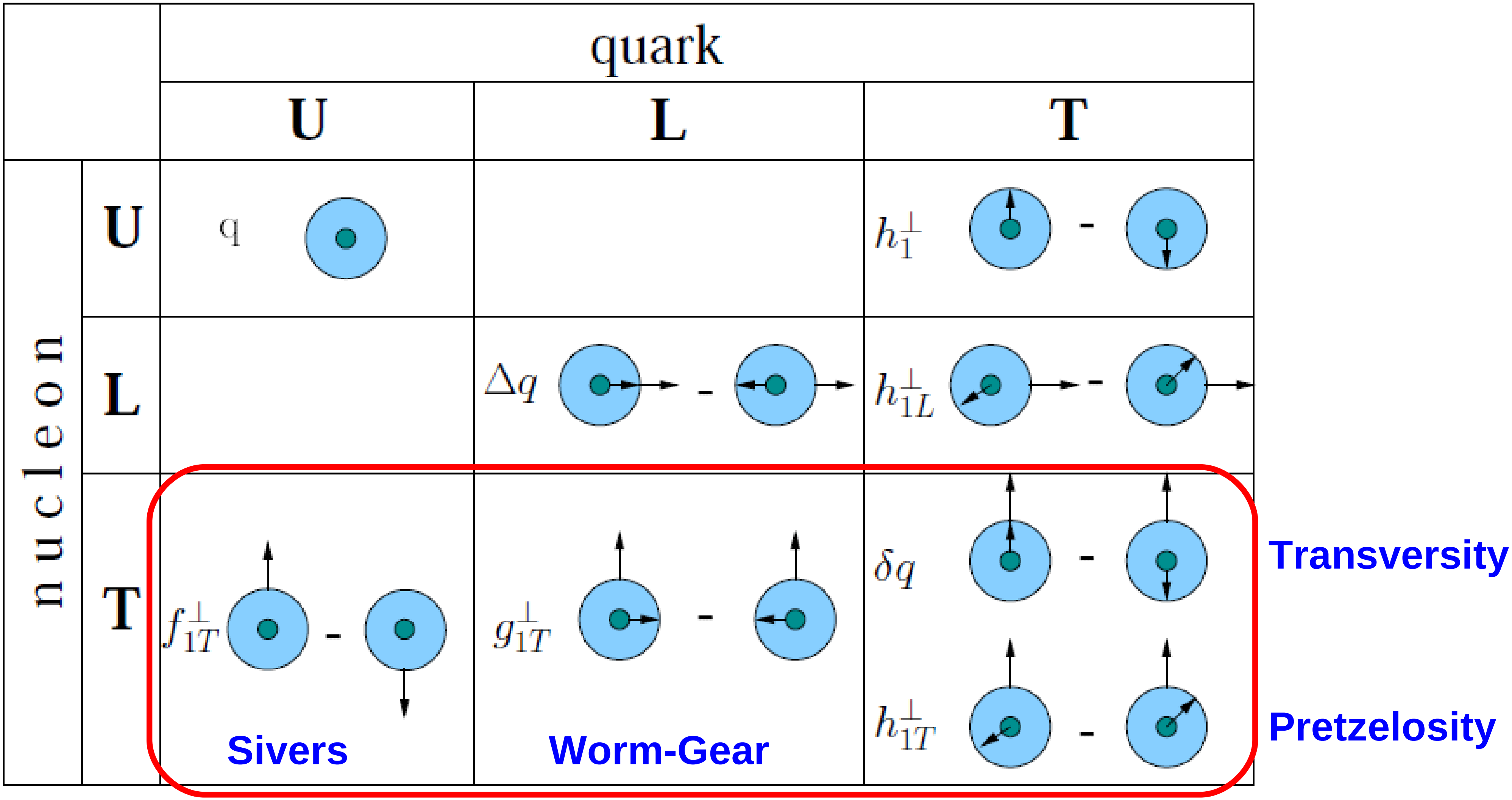
Jefferson Lab
Thomas Jefferson National Accelerator Facility

Unpolarized and Longitudinally Polarized Structure Functions





Leading Twist Transverse Momentum Dependent PDFs



Semi-Inclusive DIS

$$\frac{d\sigma}{dx\,dy\,d\phi_S\,dz\,d\phi_h\,dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\cdot$$

$$\{F_{UU,T} + \ldots$$
$$+\,\varepsilon\cos(2\phi_h)\cdot F_{UU}^{\cos(2\phi_h)} + \ldots$$

Unpolarized

$$+\,S_L[\varepsilon\sin(2\phi_h)\cdot F_{UL}^{\sin(2\phi_h)} + \ldots]$$
$$+\,S_T[\varepsilon\sin(\phi_h+\phi_S)\cdot F_{UT}^{\sin(\phi_h+\phi_S)}$$
$$+\sin(\phi_h-\phi_S)\cdot(F_{UL}^{\sin(\phi_h-\phi_S)} + \ldots)$$
$$+\,\varepsilon\sin(3\phi_h-\phi_S)\cdot F_{UT}^{\sin(3\phi_h-\phi_S)} + \ldots]$$

Polarized Target

$$+\,S_L\lambda_e[\sqrt{1-\varepsilon^2}\cdot F_{LL} + \ldots]$$
$$+\,S_T\lambda_e[\sqrt{1-\varepsilon^2}\cos(\phi_h-\phi_S)\cdot F_{LT}^{\cos(\phi_h-\phi_S)} + \ldots]\}$$

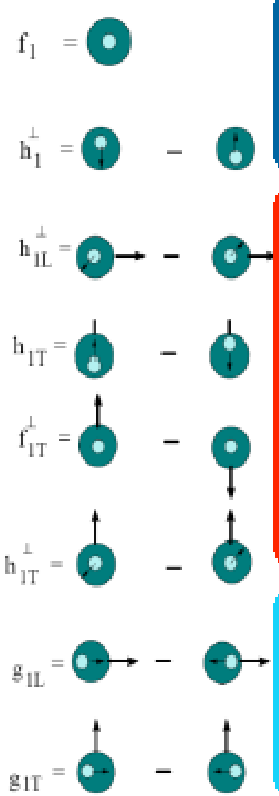
Polarized Beam and Target

Boer-Mulder

Transversity/ Collins

Sivers

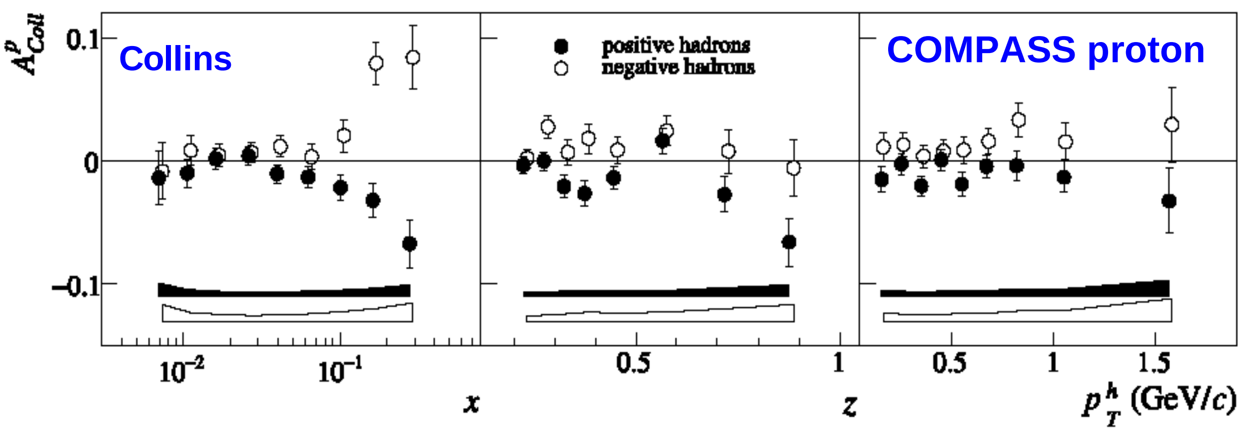
Pretzelosity

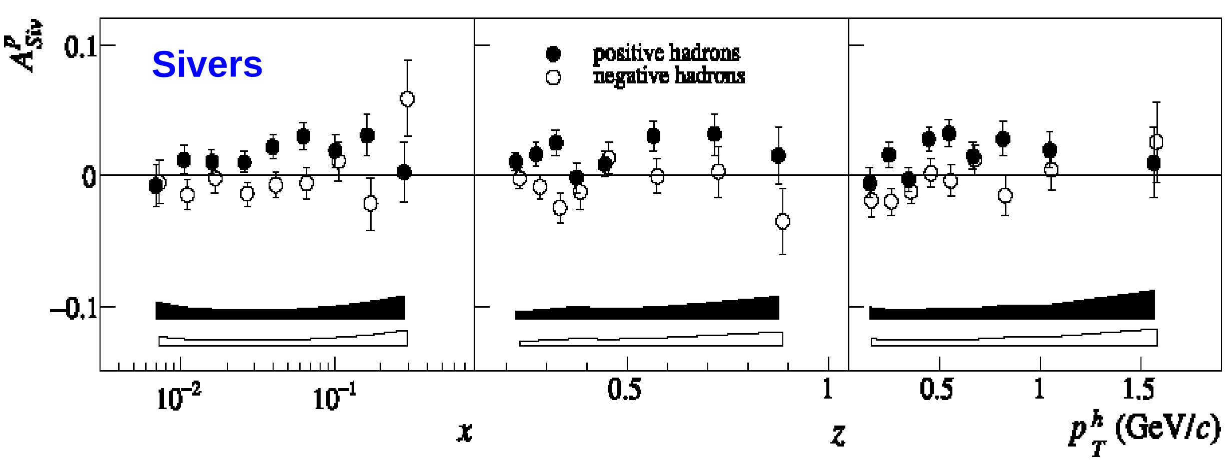


S_L, S_T: Target Polarization; λ_e: Beam Polarization

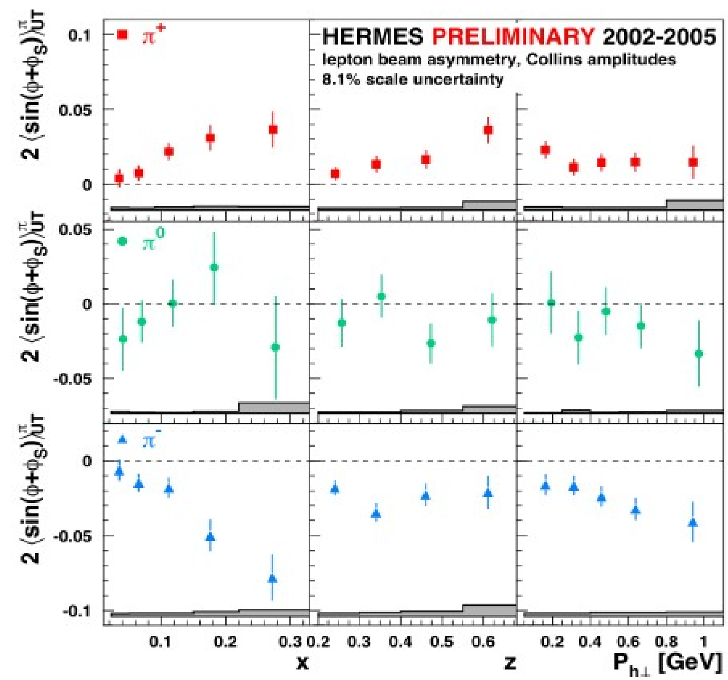
Currently Available SIDIS Data on A_{UT}

- Currently available SIDIS data :
  - HERMES proton (2002-2005)
  - COMPASS proton (2007) and (2010-11)
  - COMPASS deuteron (2004-2006)
    (all deuteron asymmetries consistent with zero)
  - JLab Hall-A E06-010 3He (2008-2009)

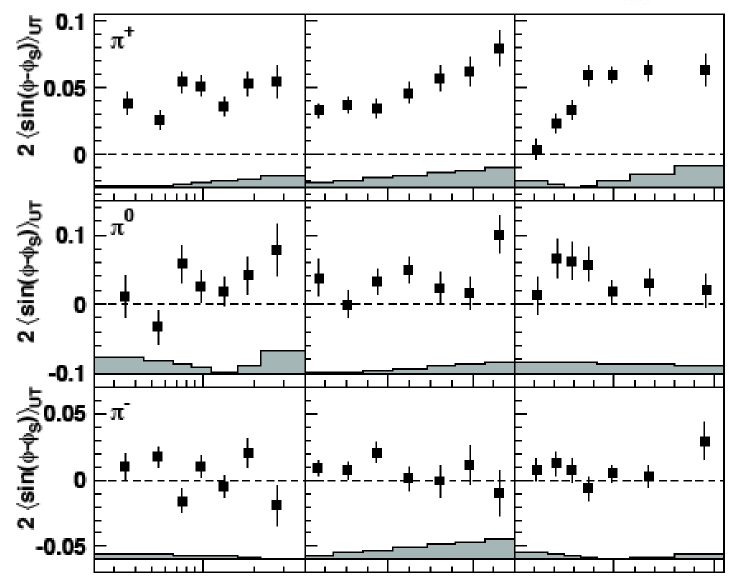




Collins

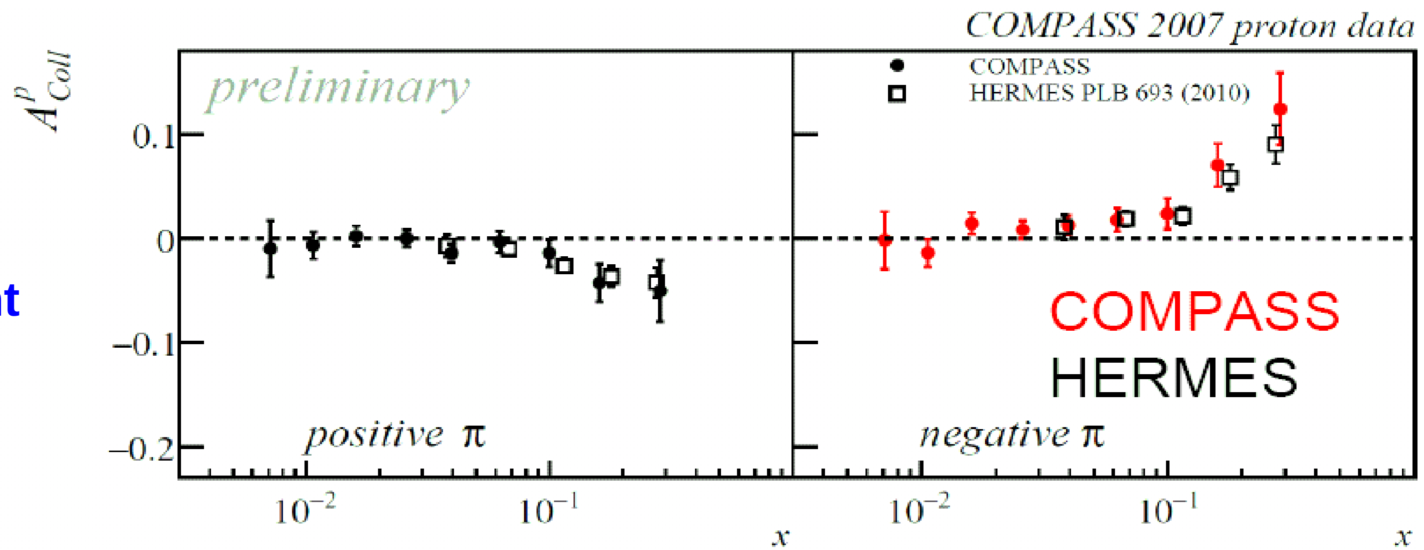


Sivers

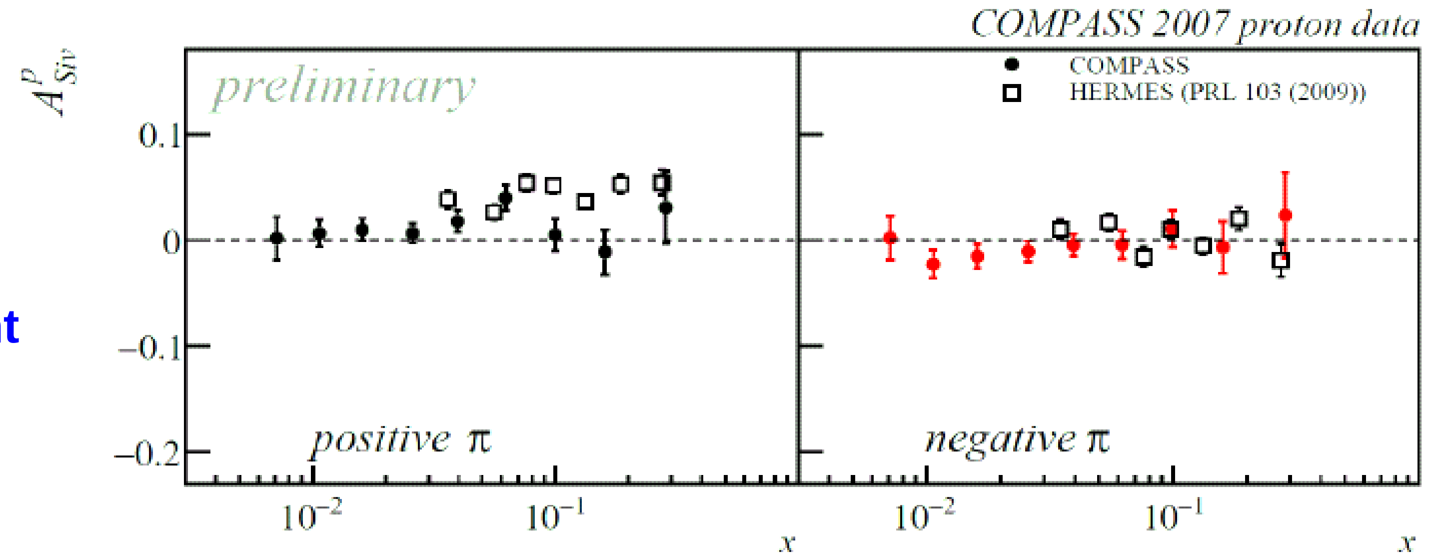


Comparison: HERMES vs COMPASS (Proton)

Collins Moment

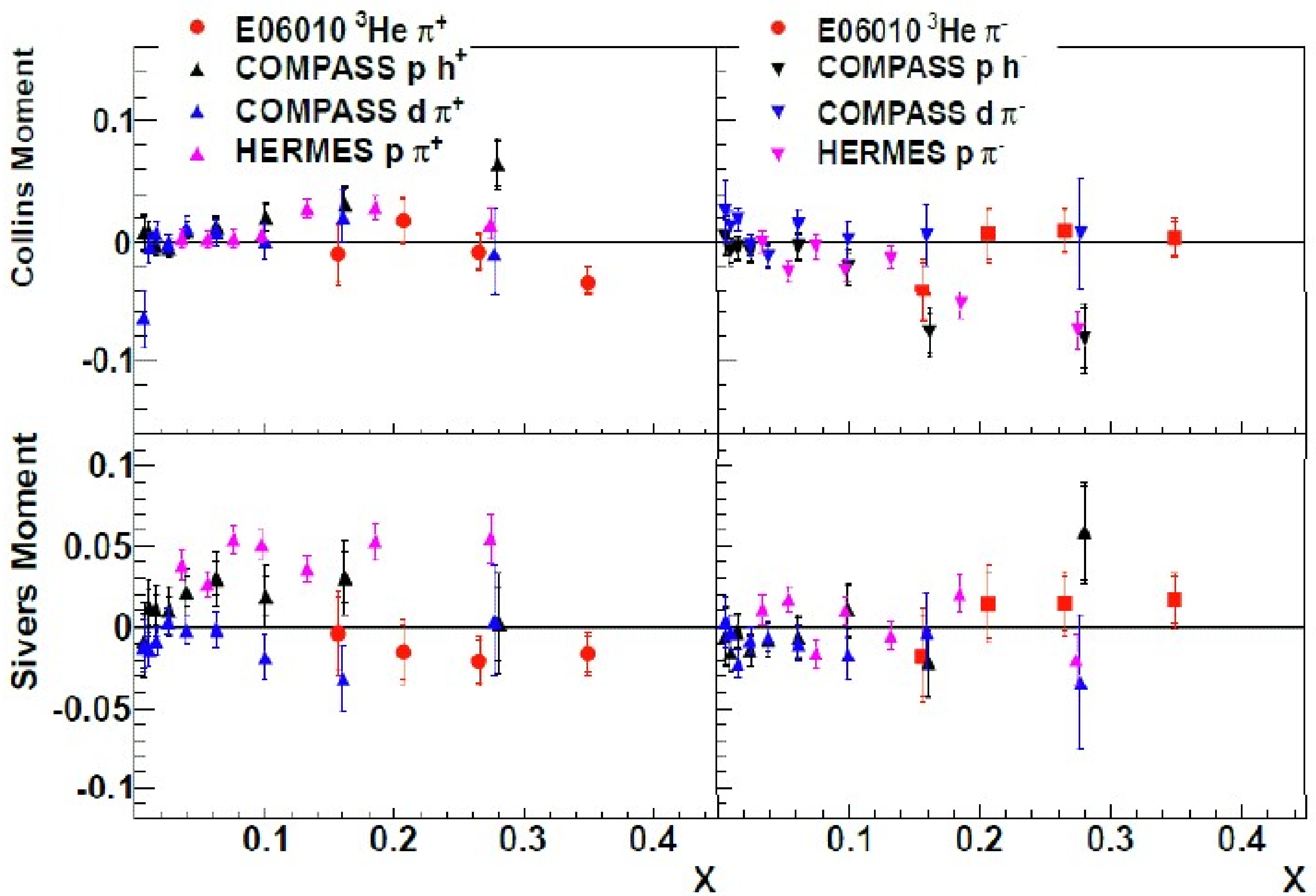


Sivers Moment



Plots from Christian Schill's talk in DIS 2011

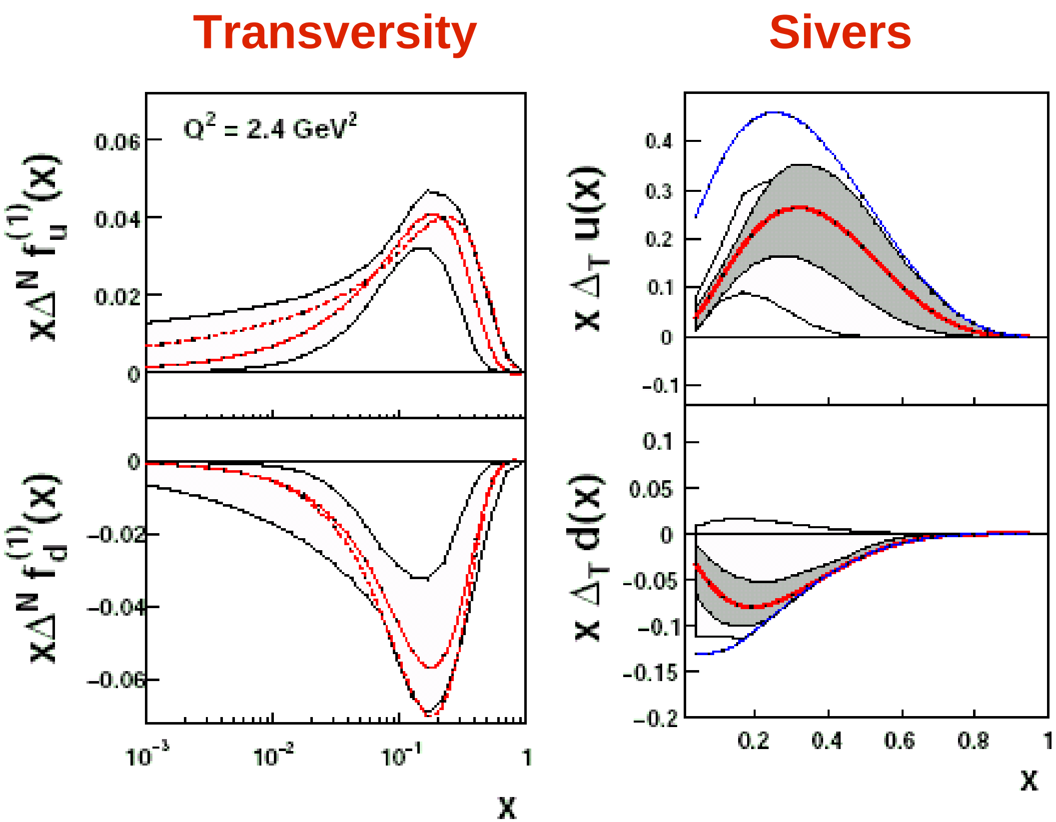
Hall-A E06-010 vs World Data : (p, d, ^{3}He)



Hall-A SoLiD Spectrometer

Moving from exploratory measurements to precision measurements (in multi-dimensions)

- Precision 4-d mapping of TMDs in x, z, P_T and Q^2 to study parton dynamics
- Ultimate kinematical coverage in 4-d
- Need both proton and neutron data at same level of precision
- Flavor decomposition of transversity and Sivers DFs
- Extract tensor charge of nucleon to 10% accuracy



$$P = u_p(\frac{4}{9}) \oplus u_p(\frac{4}{9}) \oplus d_p(\frac{1}{9}) = u_p(\frac{8}{9}) \oplus d_p(\frac{1}{9})$$

Dominated by u-quark

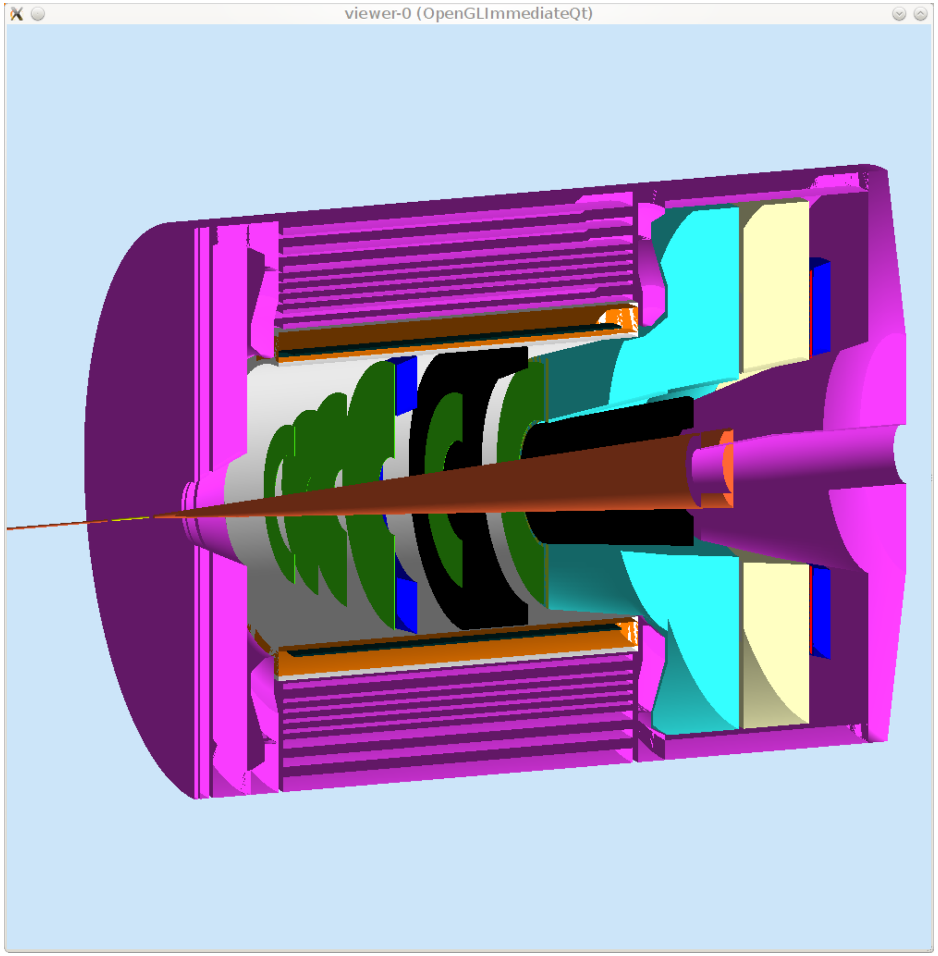
$$N = u_n(\frac{4}{9}) \oplus d_n(\frac{1}{9}) \oplus d_n(\frac{1}{9}) \overset{C.S.}{=} d_p(\frac{4}{9}) \oplus u_p(\frac{2}{9})$$

Sensitive to d-quark

Hall-A SoLiD Spectrometer

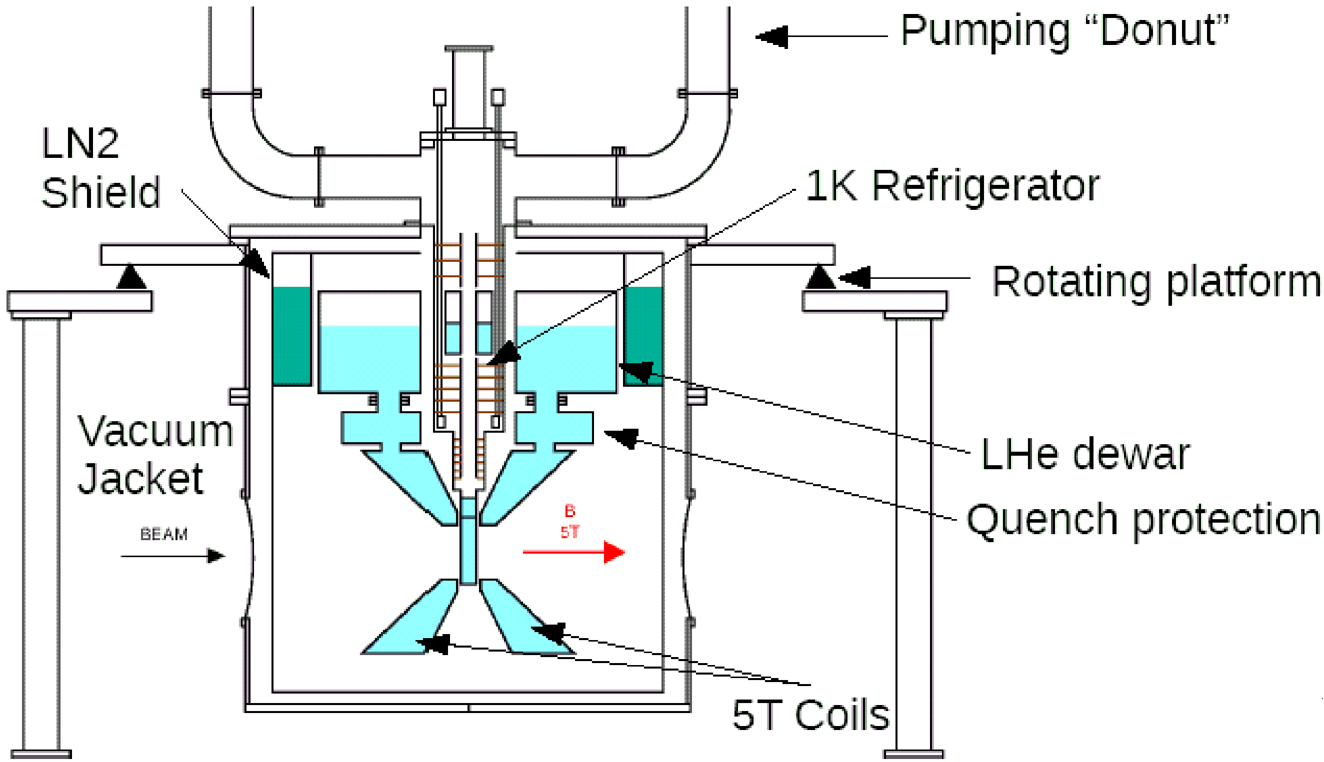
- Approved SIDIS Experiments:
  - E12-10-006 (PAC35): Transversely pol. 3He, Collins, Sivers, Pretzelosity
  - E12-11-007 (PAC37): Longitudinally pol. 3He, Worm-gear TMDs
- New Proposal: Proton Transversity
  - Measure SSA on transversely polarized proton target
  - Use same detector setup as that of two approved ^{3}He expts.
  - Use JLab/UVa polarized NH_3 target
  - Two Beam energies: 11 GeV and 8.8 GeV
  - Luminosity with 100nA current: 10^{35} $cm^{-2}s^{-1}$

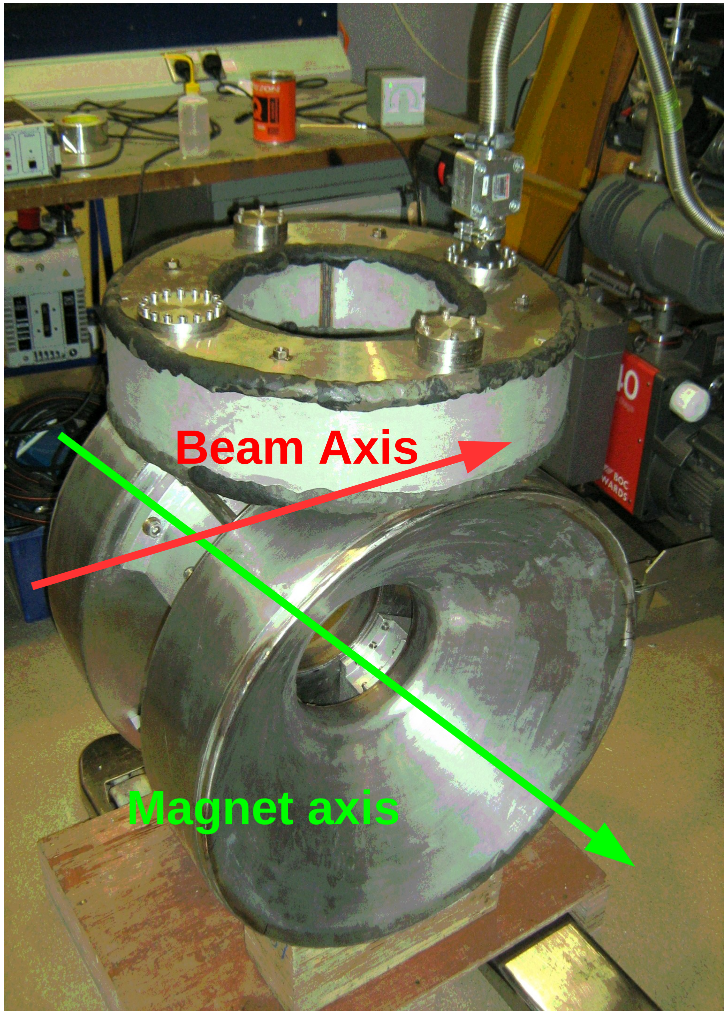
    (order of magnitude smaller than ^{3}He proposal)
  - Beamline modifications due to the 5T target magnetic field



Polarized NH_3 Target

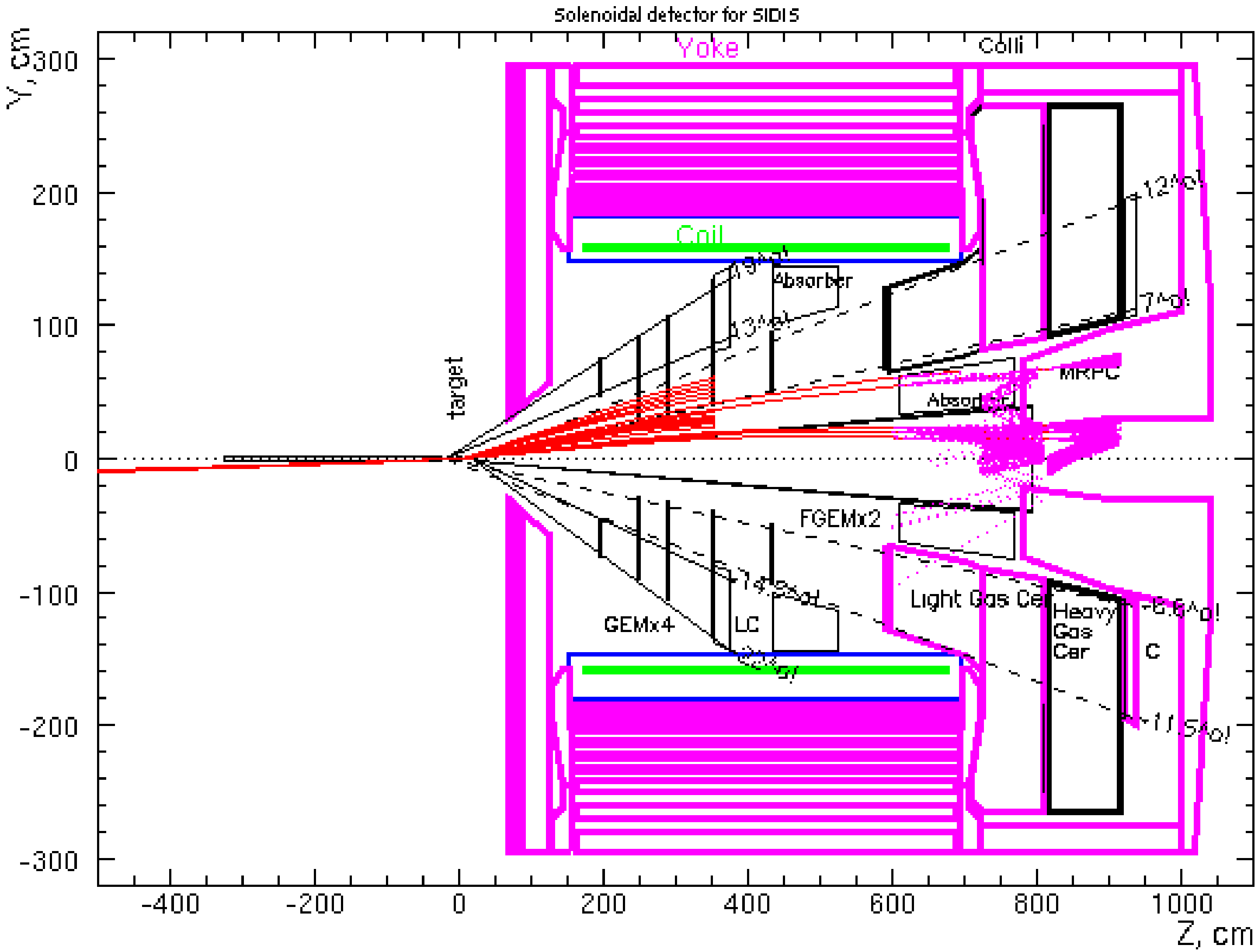
- 3cm long NH_3/ND_3 targets
- 5 Tesla superconducting magnet
- 1K high cooling power 4He evaporation fridge
- NMR system for polarization measurement
- Spin-flip is possible using microwaves (Important: NOT to change holding magnetic field direction)
- Possibility of new magnet with a large opening in the transverse directions??





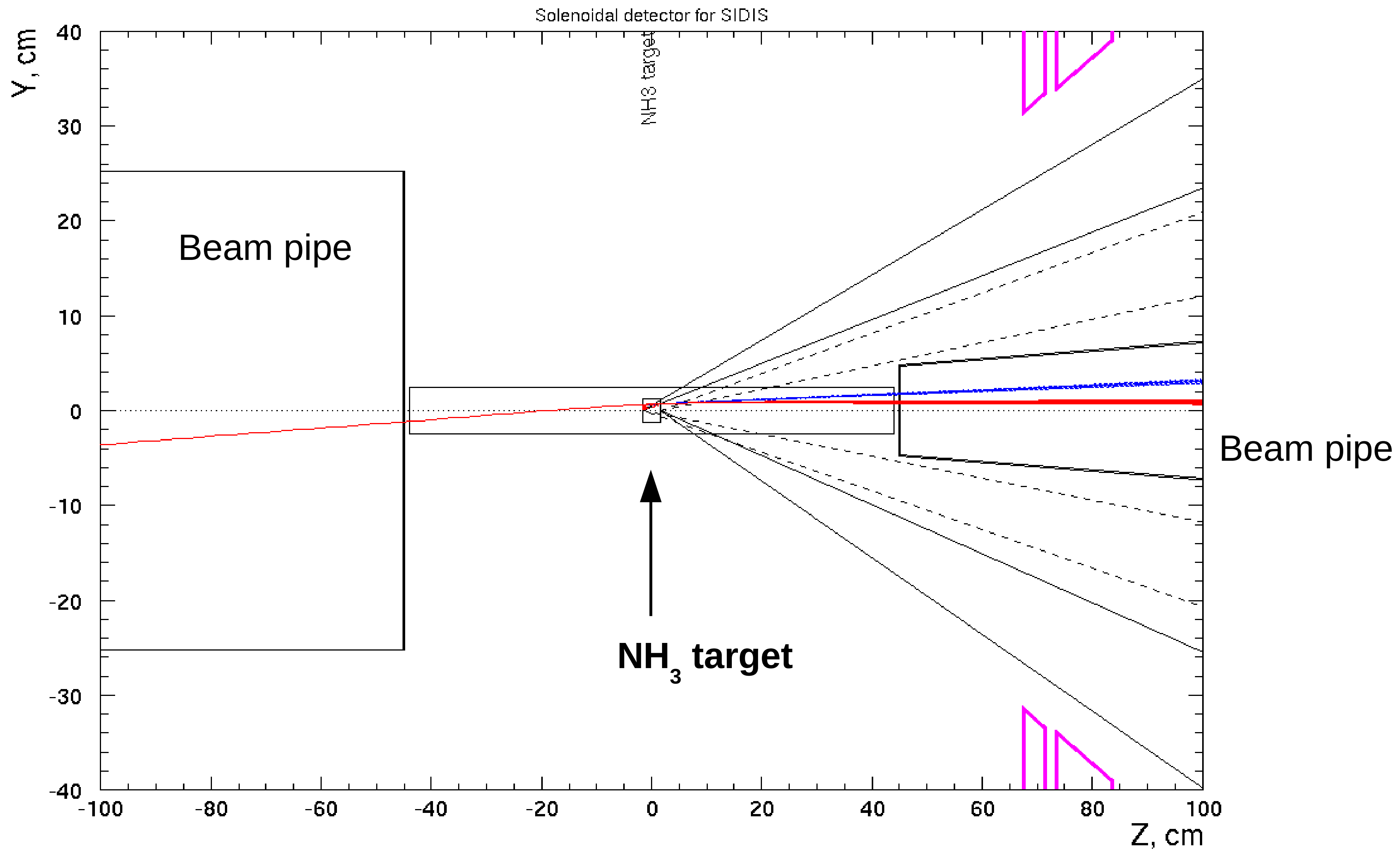
(picture courtesy: C. Keith)

SoLiD Setup

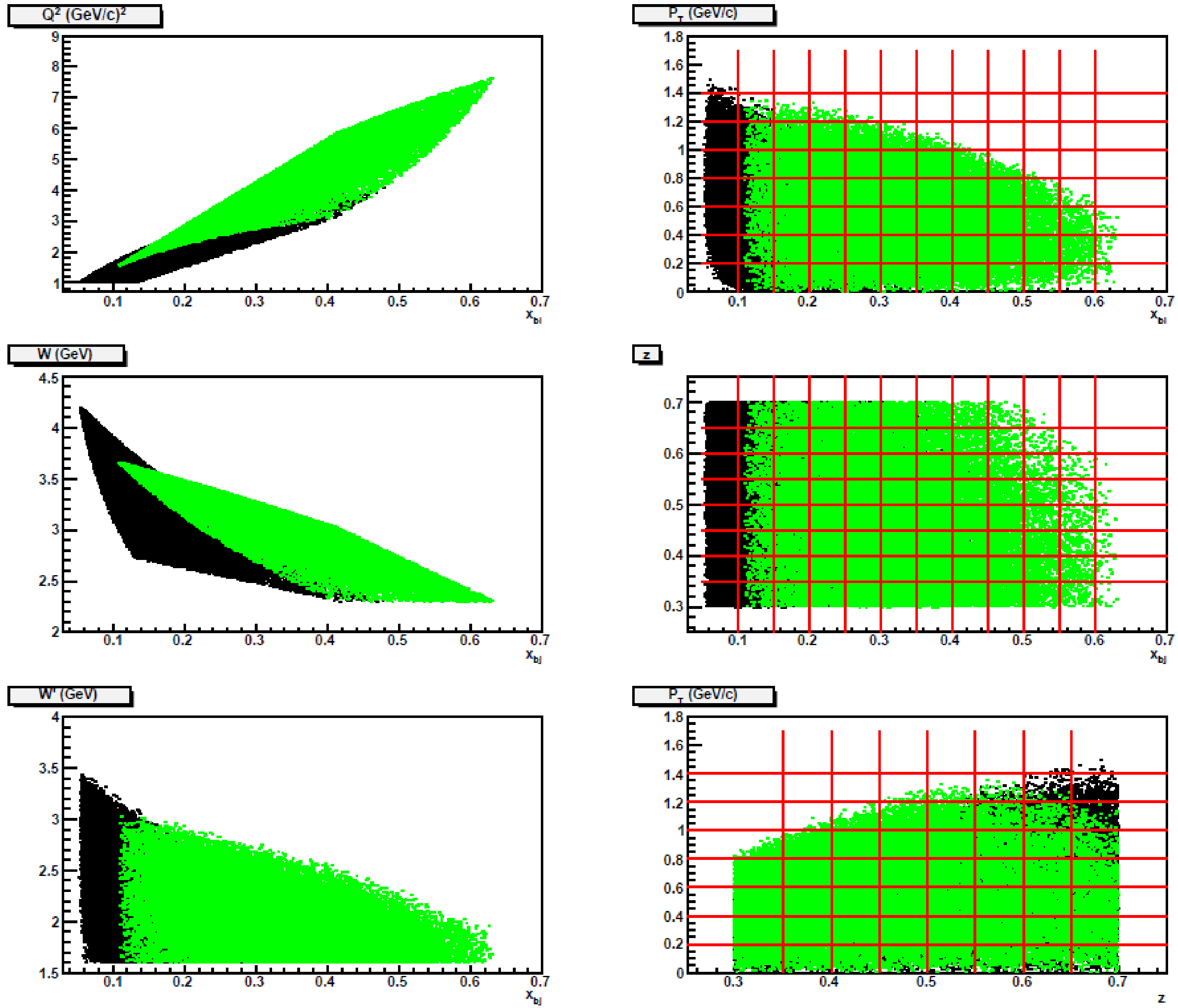


Solenoidal detector for SIDIS
Y, cm
Z, cm
Yoke
Colli
Coil
Absorber
MRPC
target
FGEMx2
Light Gas Cer
Heavy Gas Cer
GEMx4
LC
C

Beam Direction



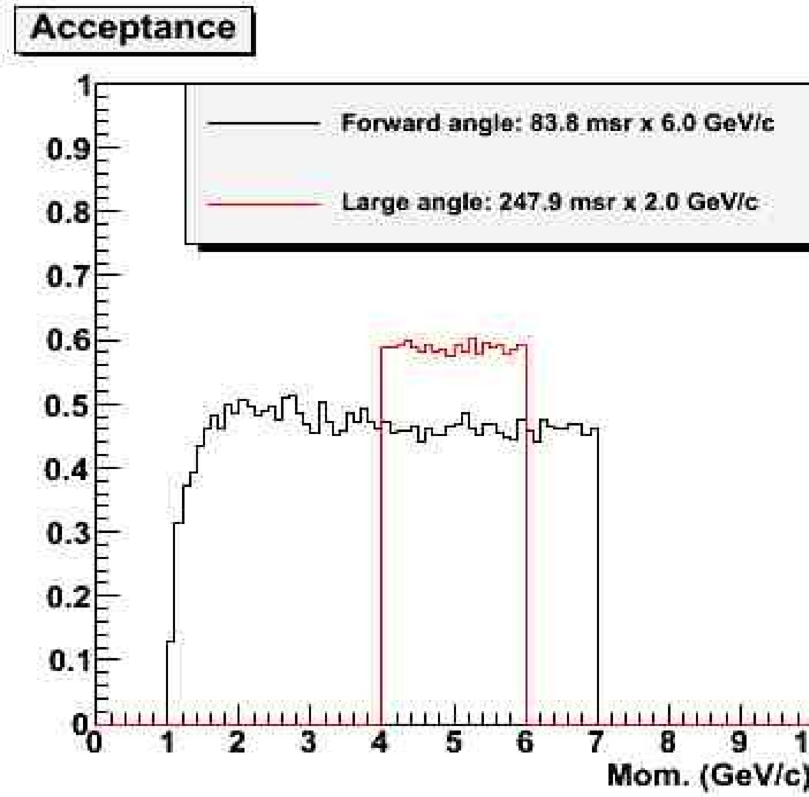
Kinematics Coverage

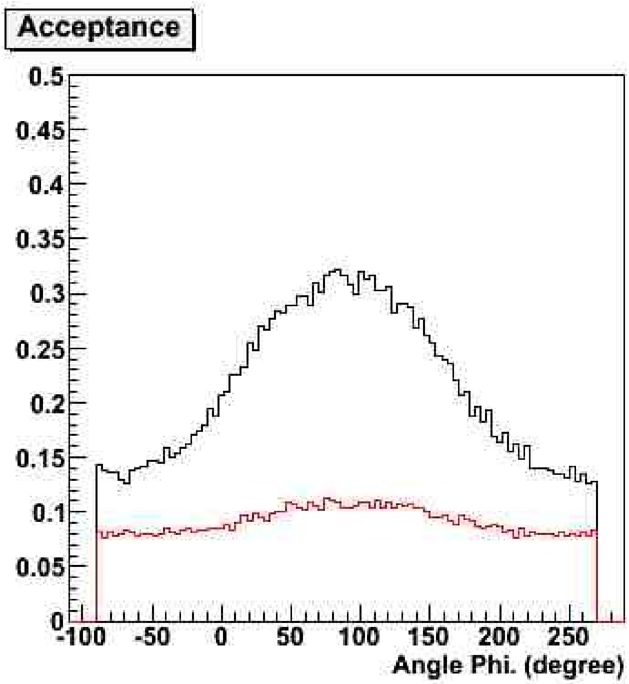


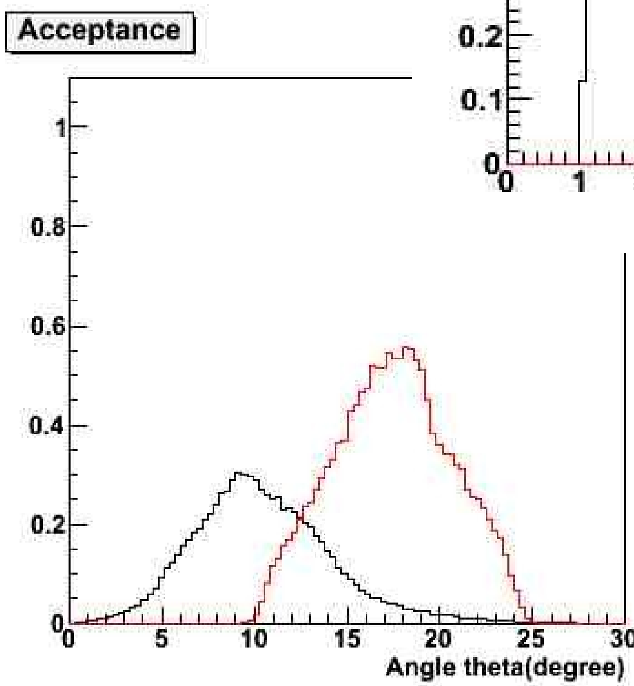
Plots from Chao Peng/Qiujian Ye (Duke)

Acceptance

- Acceptance studies done with GEANT3 SoLiD model and realistic target fields
- Acceptance of theta extend to lower and higher angles compared to the no target field situation
- The effect on total acceptance due to target field is small





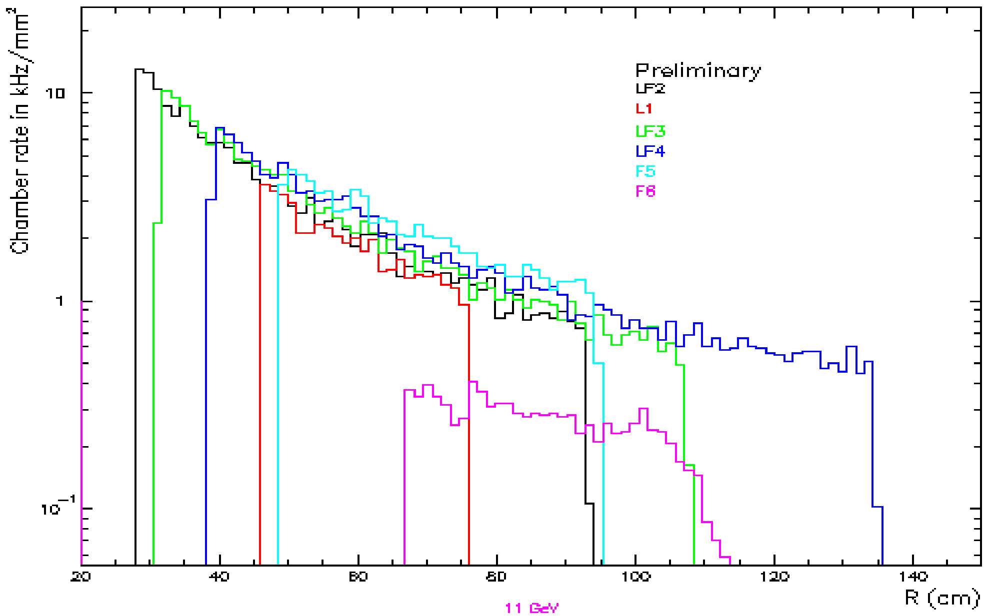


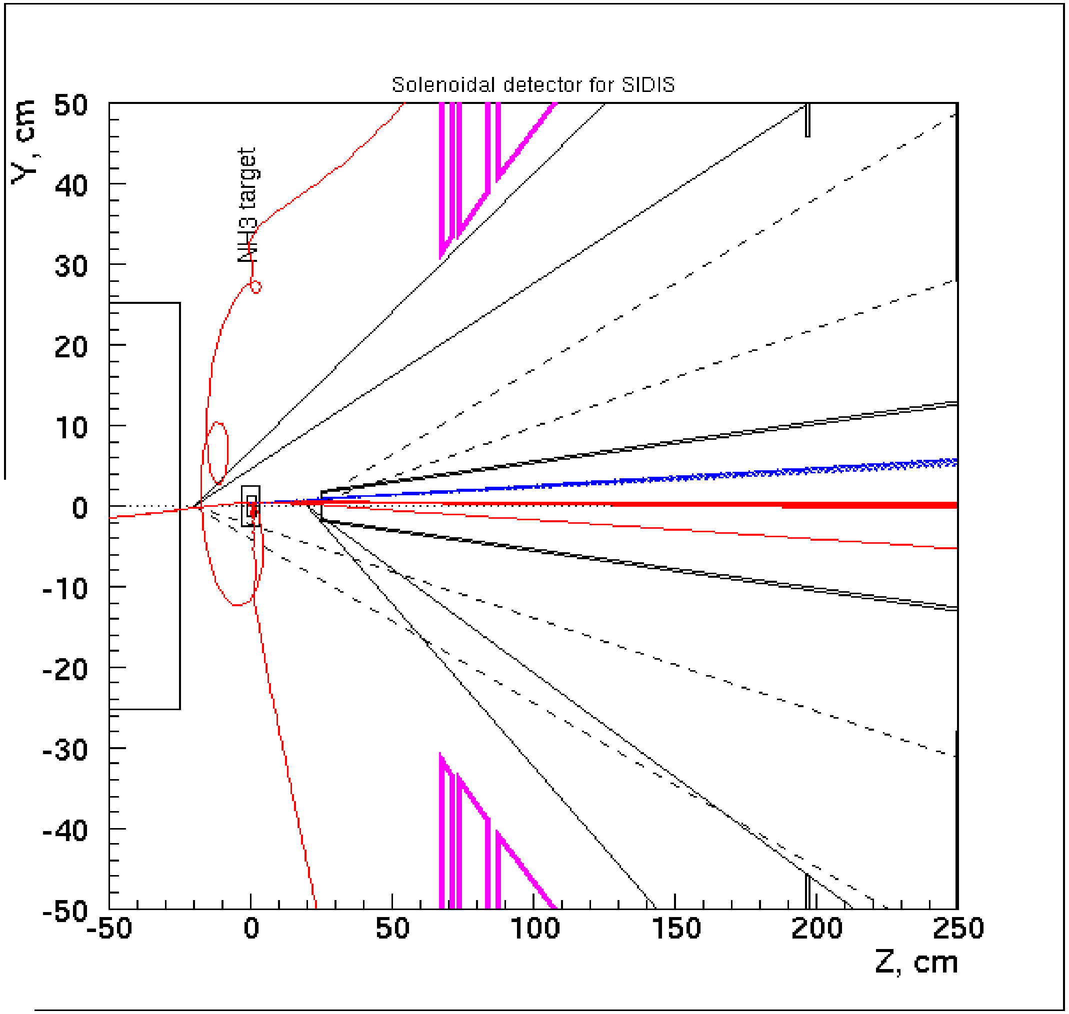
Plots from Chao Peng/Qiujian Ye (Duke)

Background Rates

- A preliminary study shows background rates are not very high
- Low momentum (up to few hundred MeV) particles will be swept away by the target field
- GEMs can handle very high rates (COMPASS expt.: 30KHz/mm^2)

Very preliminary
(need more optimizations to the setup)





Work In Progress...

- We have identified all the issues and trying to address each one of them
- For example:
  - Target spin-flip cannot be done very frequently (every few hours)
  - Target magnetic field can create an asymmetric angular acceptance
    - Need good tracking scheme to reconstruct azimuthal angles
    - A global fit such as Maximum Likelihood Estimation(MLE) to extract the single spin asymmetries
    - Control over systematic uncertainties
- Currently working on experimental projections, background rates (low energy, singles etc..) estimations.
- Work with theorists to estimate the impact of this measurement on the global extraction of transversity DF and TMDs

Summary

- Hall-A is in very good position to carry out precision 4-d mapping measurements of TMDs using polarized NH_3(p), ^{3}He(n) and deuteron targets
- SoLID is an ideal device to carry out such precision measurements:
  - High luminosity, large acceptance and full azimuthal coverage
  - Will provide precise SSA/DSA data at high-x (valence), low Q^2 region, which is crucial input to global analysis
  - Test SIDIS factorization, P_T dependence at JLab12 (complementary to SIDIS programs in Hall B/C)
- We are working hard to meet both PAC and Hall-A deadlines for the proposal!