New Proposal PR12-11-108:

SIDIS Using SoLID and Transversely Polarized Proton Target

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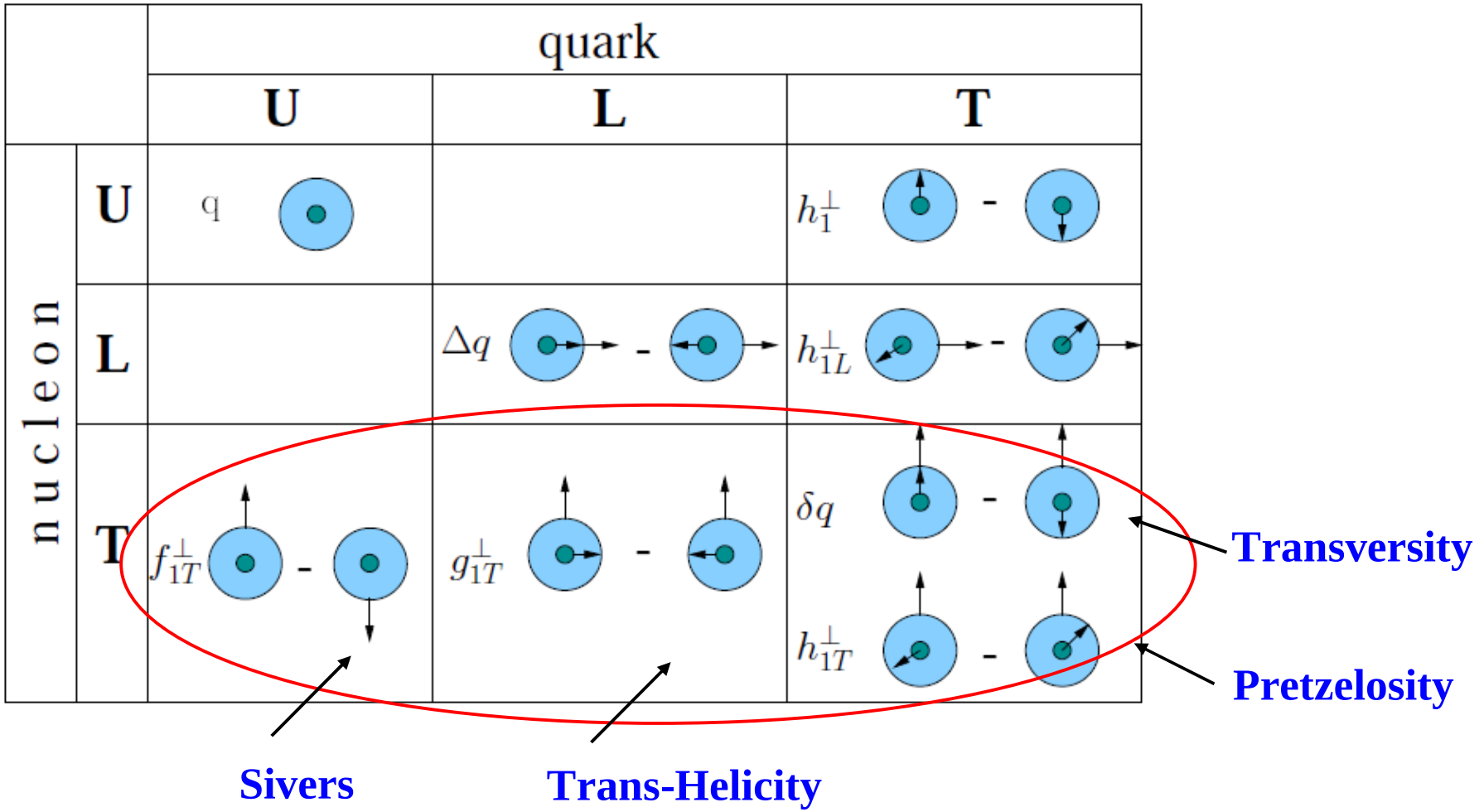
(Presented to PAC38 as a Hall-A and SoLID Collaboration proposal)

SoLID Collaboration Meeting, Newport News, Oct 14th 2011

Jefferson Lab
Thomas Jefferson National Accelerator Facility

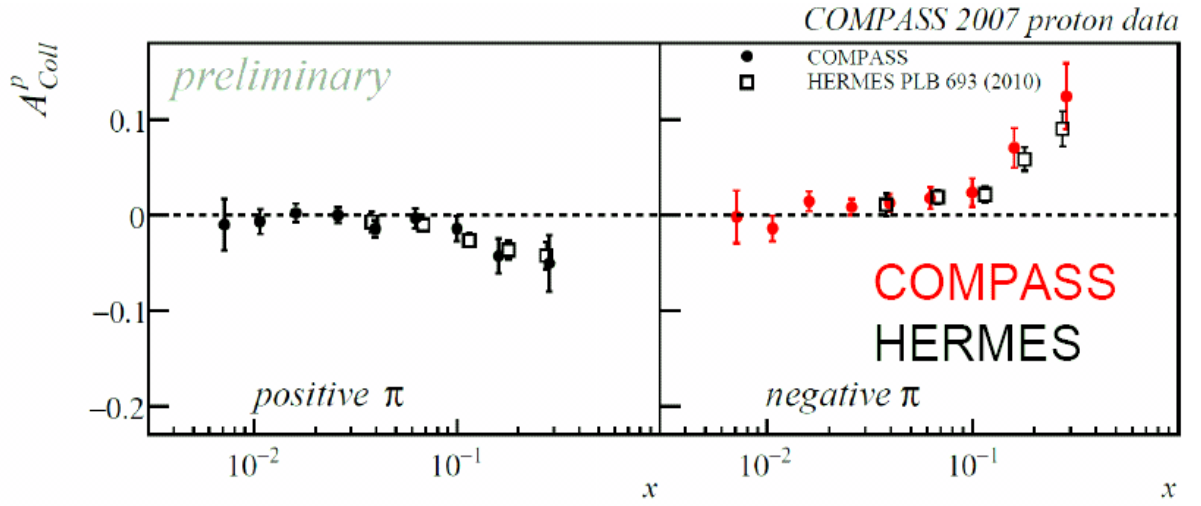
Leading Twist TMDs



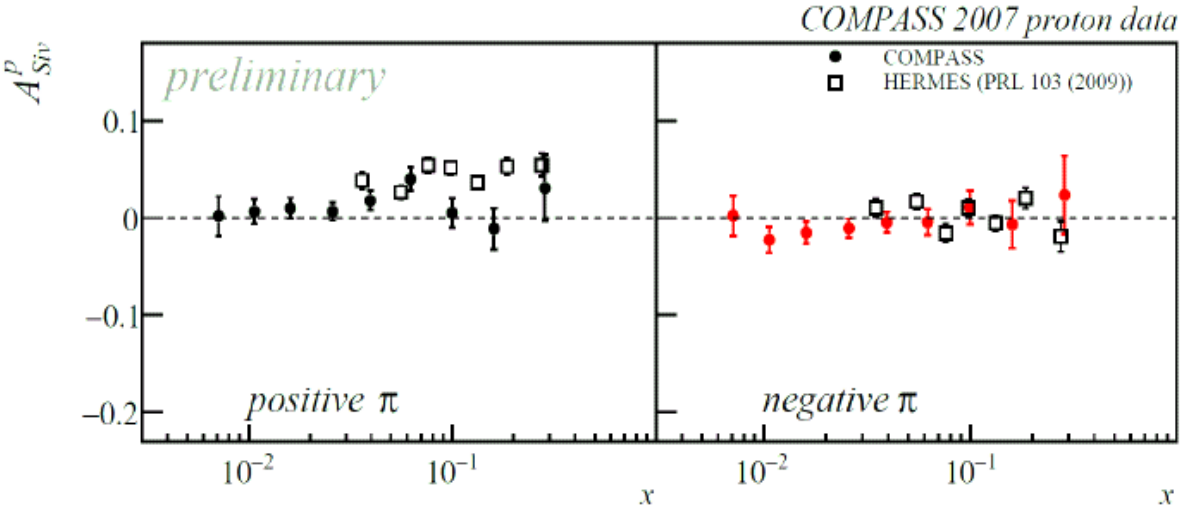
Distributions we can measure in this experiment

Collins and Sivers Moments

- Currently available data in SIDIS :
  - HERMES proton (2002-2005)
  - COMPASS proton (2007) and (2010-11)
  - COMPASS deuteron (2004-2006)
  - Hall-A E06010 neutron (2009)



- HERMES and COMPASS proton:
  - Large and opposite signals for π^+ and π^- Collins moments
  - Large signal in π^+ Sivers moments
- COMPASS deuteron:
  - Small (near zero) signals on both Collins and Sivers moments



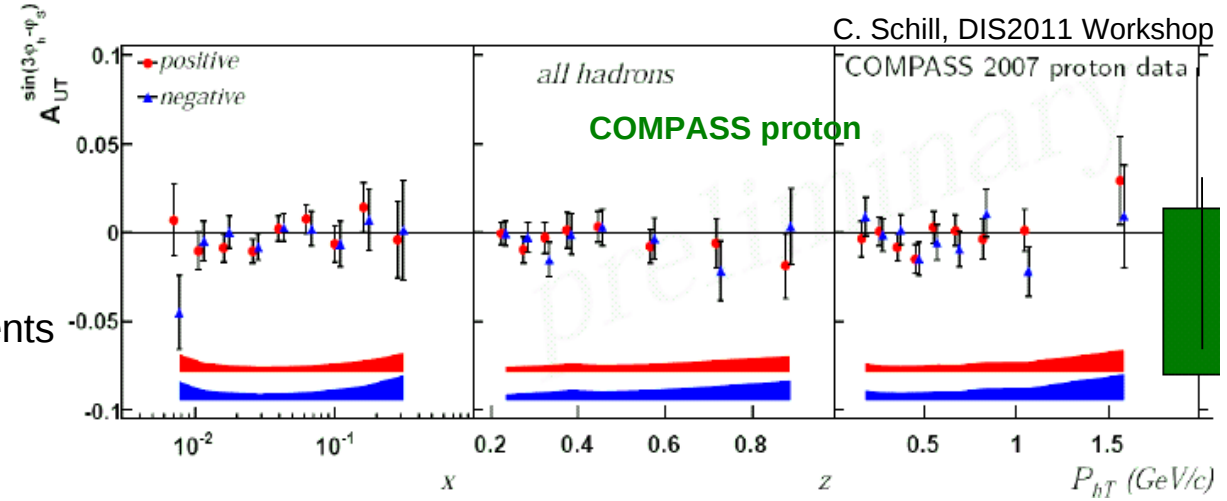
C. Schill, DIS2011 Workshop

Pretzelosity and g_{1T}

Pretzelosity

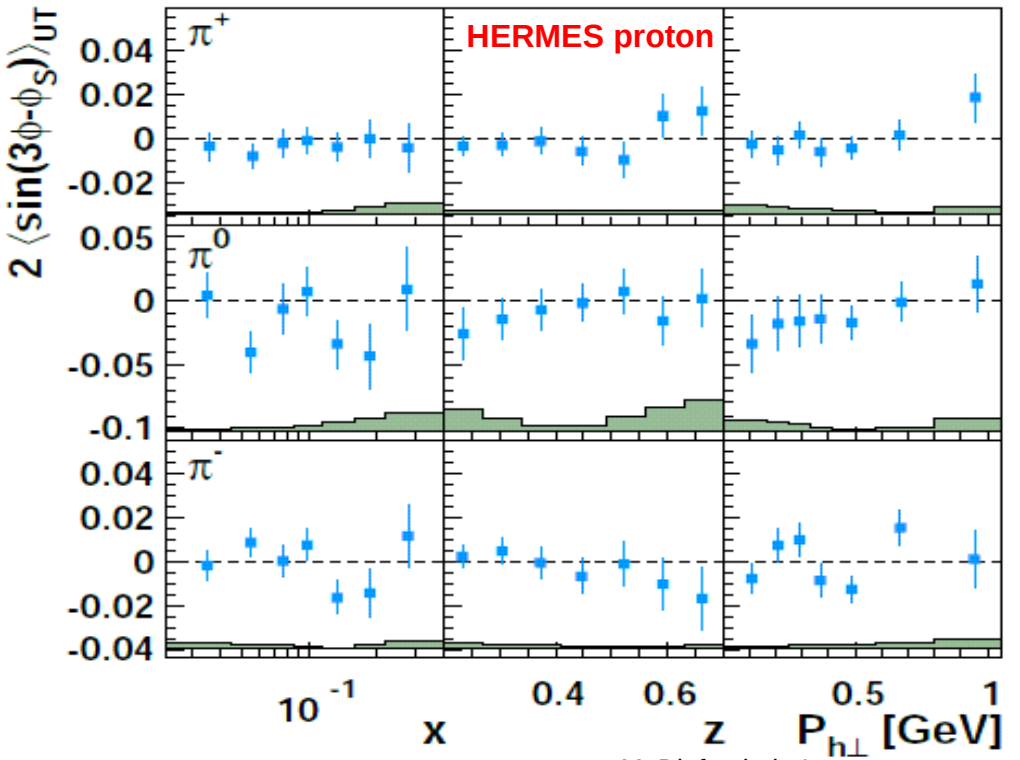
- HERMES and COMPASS proton:
  - No clear signal seen on $sin(3\phi_h-\phi_s)$ moments

C. Schill, DIS2011 Workshop



g_{1T} (trans-helicity)

- Measure A_{LT} using Double Spin Asymmetry
- Existing A_{LT} data:
  - HERMES (proton)
  - COMPASS (proton)
  - Hall-A (neutron)
- This measurement will cover large x region

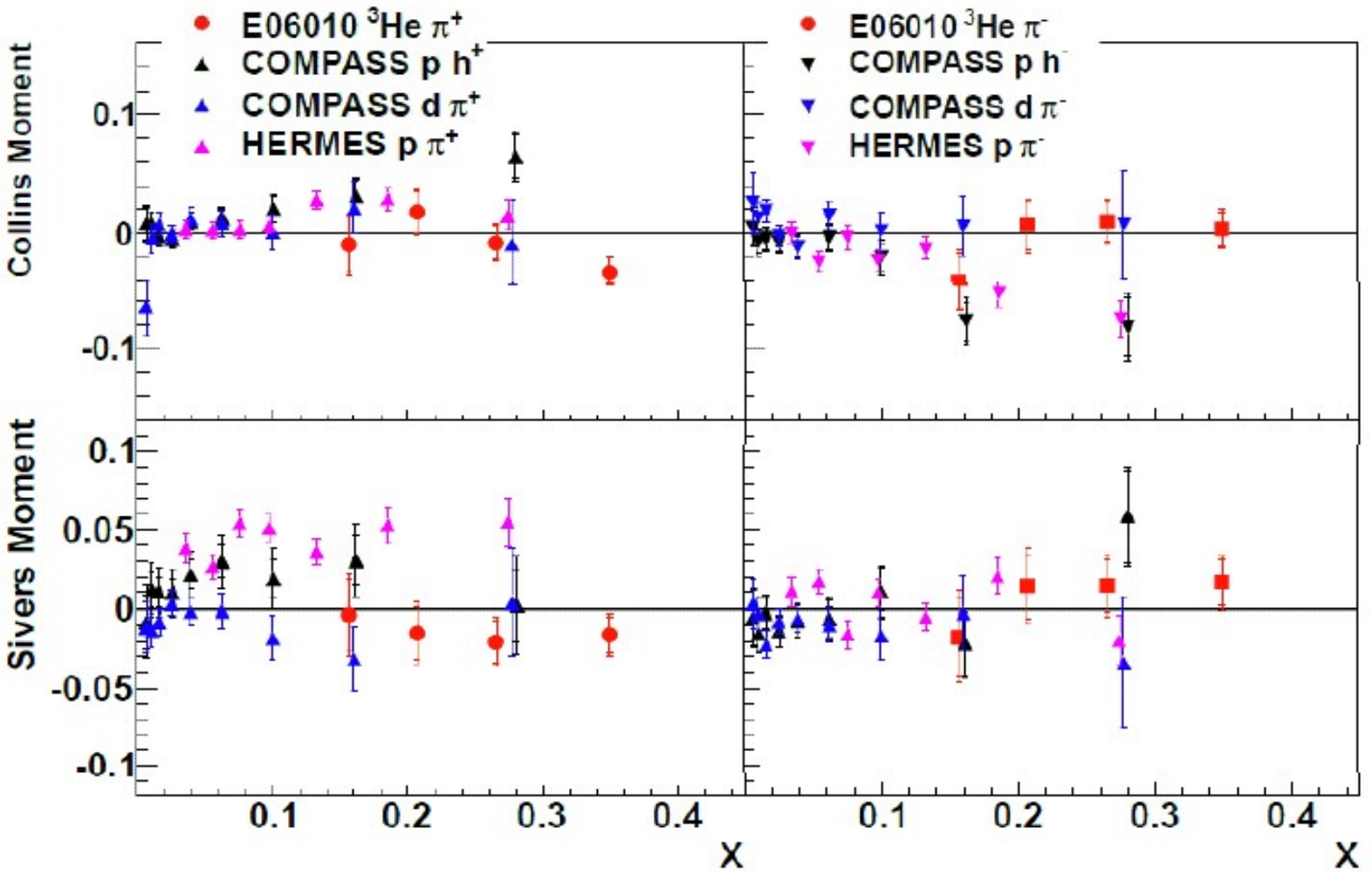


M. Diefenthaler's Dissertation (HERMES)

World Data on Collins and Sivers: (p, d, ^{3}He)

Target SSA on transversely polarized targets

Moments integrated over other dimensions (z, P_T)



Proposed Experimental Goals

- Provide ultimate precision 4d(x, z, P_T, Q^2) mapping of target SSA in the valence quark region for proton
- Flavor decomposition of Transversity, Sivers and Pretzelosity (when combined with neutron data)
- Extract tensor charge of both u and d-quark to better than 10% accuracy
- Extract leading-twist TMD, $g_{1T,}$ using DSA

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

Dominated by u-quark

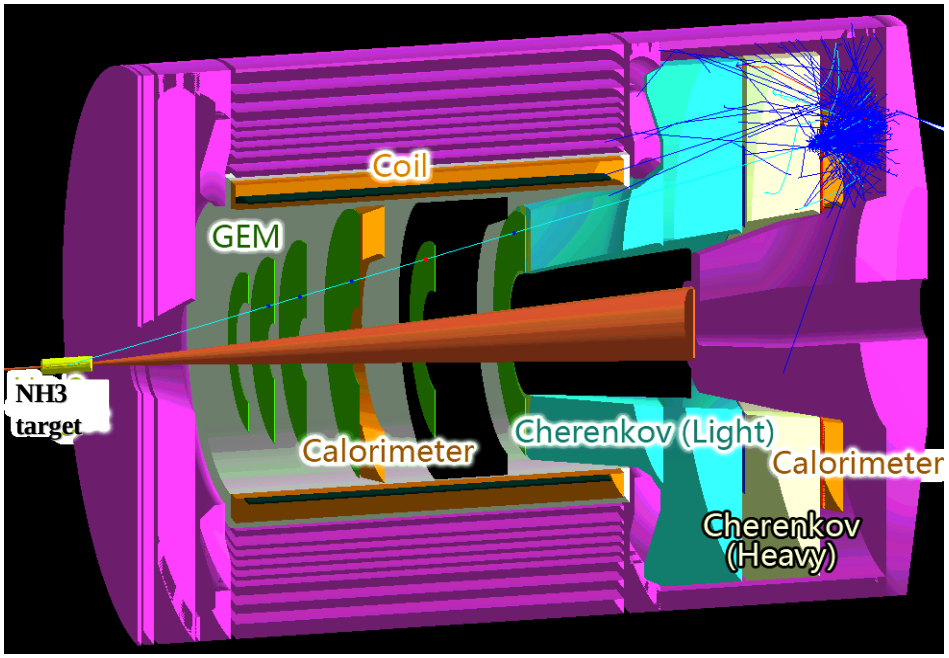
$$N = u_n(\frac{4}{9}) \oplus d_n(\frac{1}{9}) \oplus d_n(\frac{1}{9}) \overset{C.S.}{=} d_p(\frac{4}{9}) \oplus u_p(\frac{2}{9})$$

Sensitive to d-quark

Experiment Overview

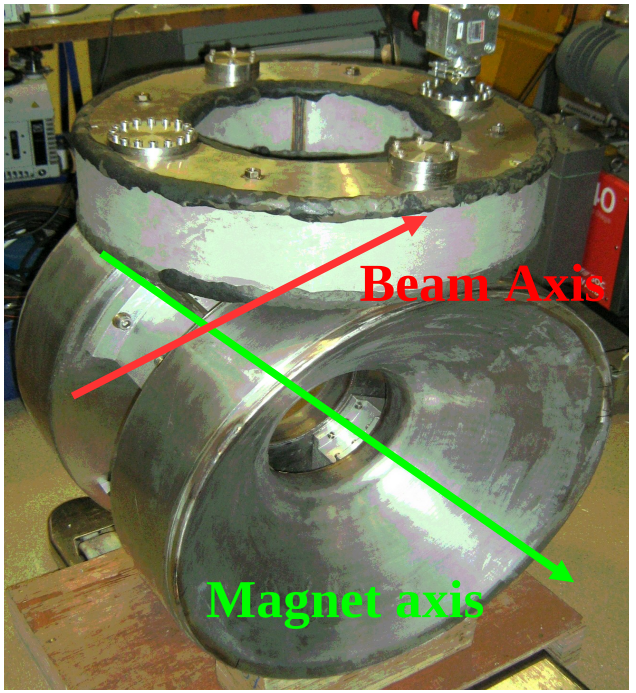
$$e + p^{\uparrow} \longrightarrow e' + \pi^{+/-} + X$$

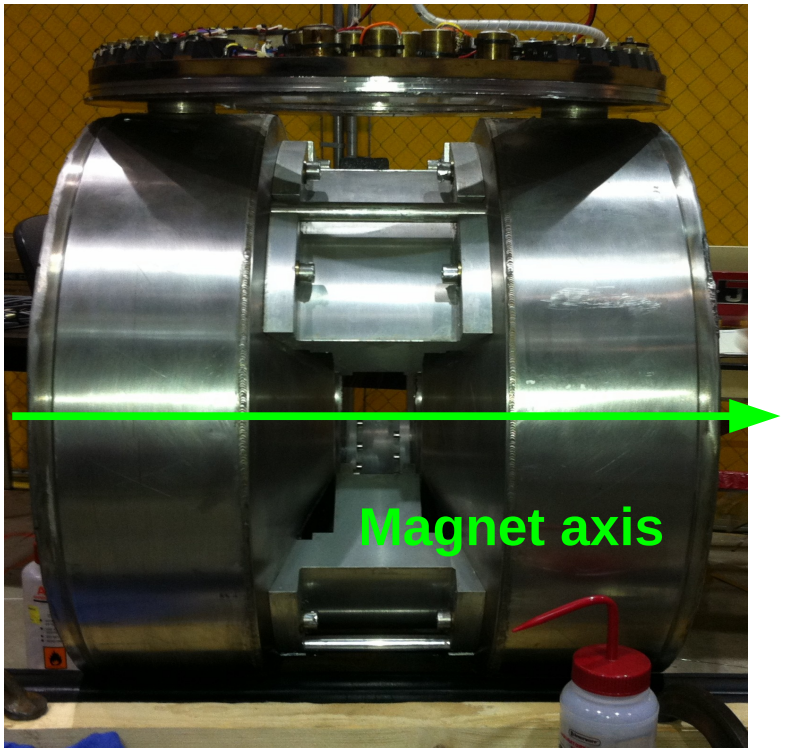
- Similar detector setup as that of two approved ^{3}He SoLID expts.
- JLab/UVa polarized NH_3 target with upgraded design of the magnet
- Target spin-flip every two hours with average in-beam polarization of 70%
- Two Beam energies: 11 GeV and 8.8 GeV
- Polarized luminosity with 100nA current: 10^{35} $cm^{-2}s^{-1}$
- Beamline chicane to transport beam through 5T target magnetic field (already designed for g2p expt.)



Polarized Target

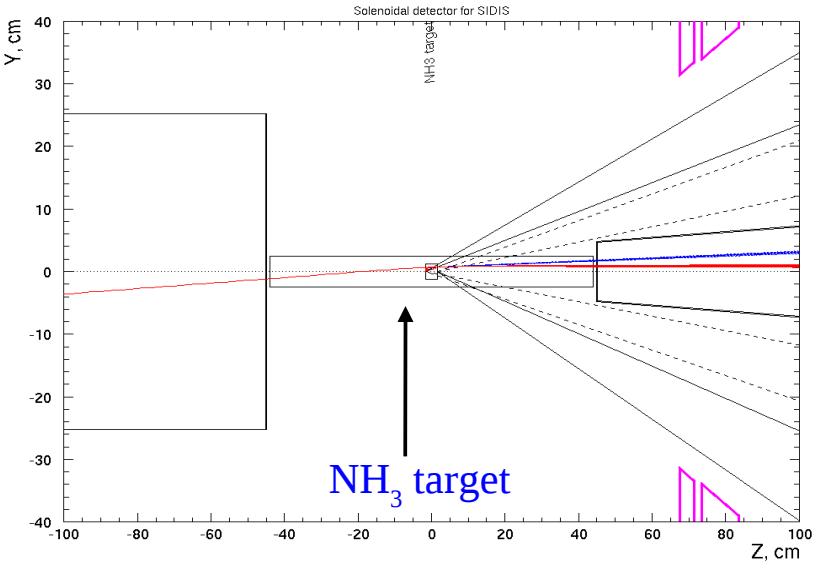
- JLab/UVa/SLAC polarized target, used in many different experiment (SANE, RSS etc..)
  - 3cm long NH_3target
  - 5 Tesla superconducting magnet
  - Dynamic Nuclear Polarization(DNP) using microwave pumping
  - Target magnet optimized for longitudinal setting
    - Opening of +/- 45^{O} in long. direction
    - Opening of +/- 17^{O} in transverse direction
- Need new magnet to cover entire phase space (proposed)
    - Nominal opening of +/- 28^{O} in transverse direction
- Spin-flip using Adiabatic Fast Passage(AFP) technique
- Plans to improved packing fraction (using target disks instead of beads)

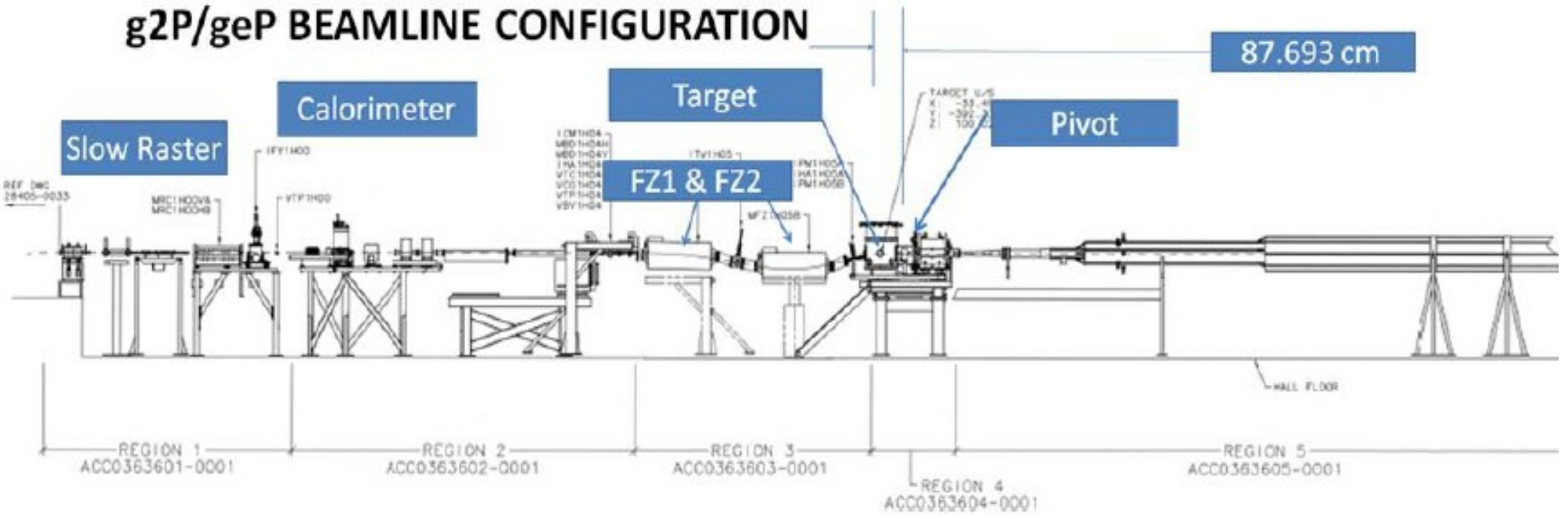




Beamline Instrumentation

- Beam Chicane:
  - Two chicane magnets to steer beam through target magnetic field
- Beam Diagnostics:
  - BPM, BCM, slow raster will run at low current (100nA) in Hall-A
  - These upgrades are being done for g2p/GEp running for Fall 2011 run
- We will gain experience from g2p/GEp running in Dec, 2011

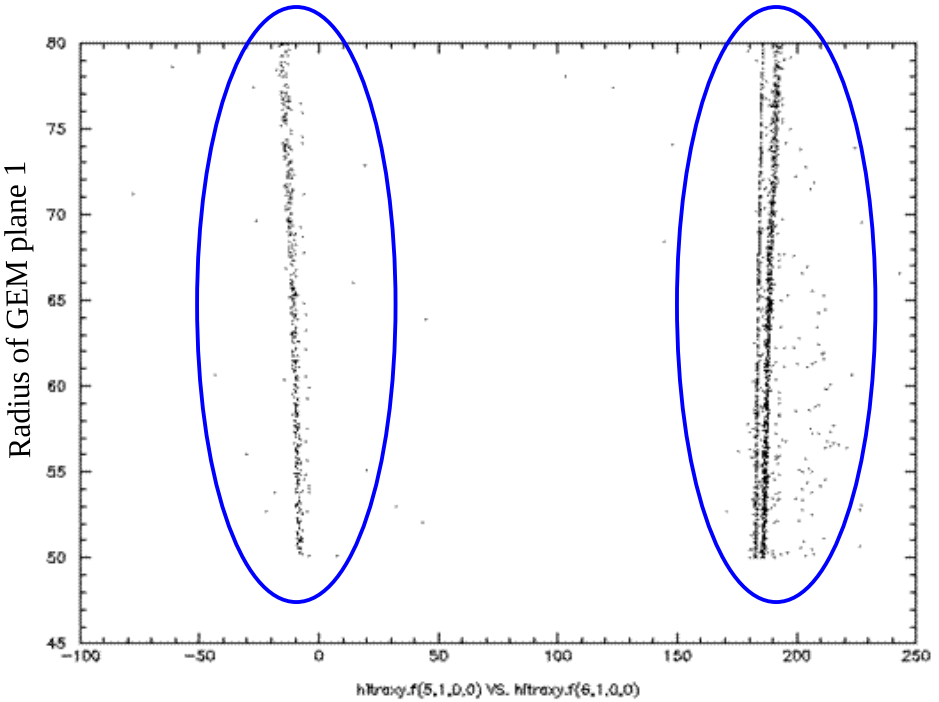




Backgrounds

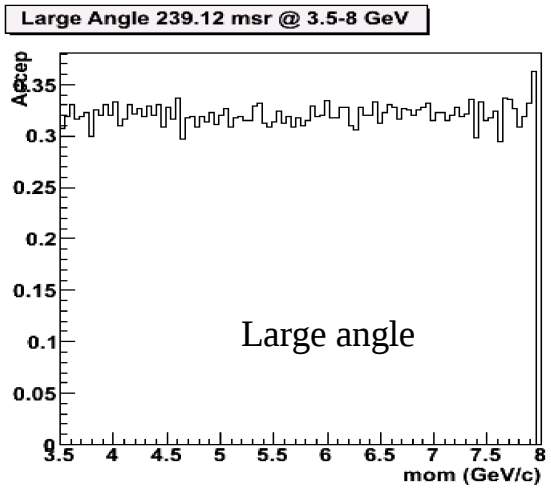
- GEANT3 simulation was performed
- *"Sheet of flame"* background: High rates in localized area of acceptance (due to high target magnetic field)
- Turn off/remove relevant areas of the detectors
- Low momentum particles will be swept away by the target field
  - First GEM plane is about 1.7m away from the target
- Rates on GEMs < 1 kHz/mm^2

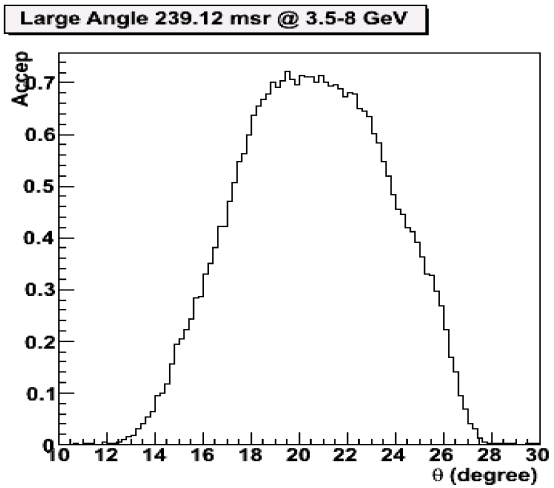
  (GEMs can handle very high rates - COMPASS expt.: 30kHz/mm^2)
- Tracking is not an issue at these rates (as demonstrated in ^{3}He SoLID proposal)
  - Rates and multiplicities are much smaller outside the *"sheet of flame" (*compared to ^{3}He SoLID proposal) due to lower luminosity

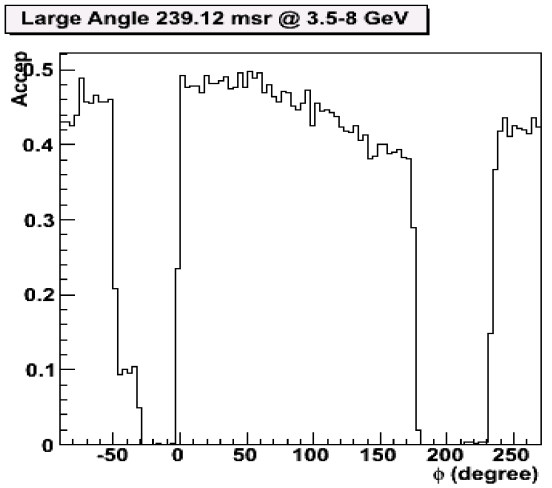


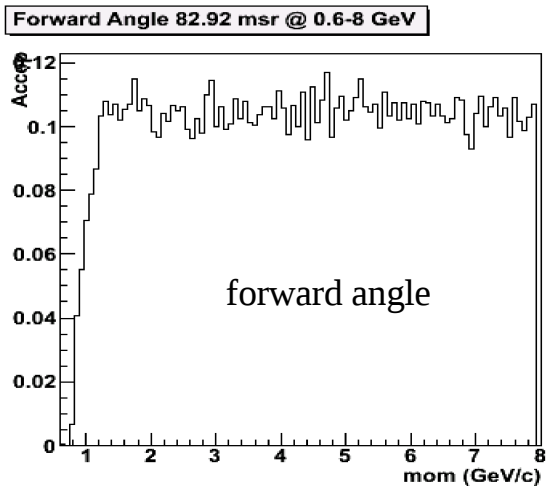
Acceptance (electron)

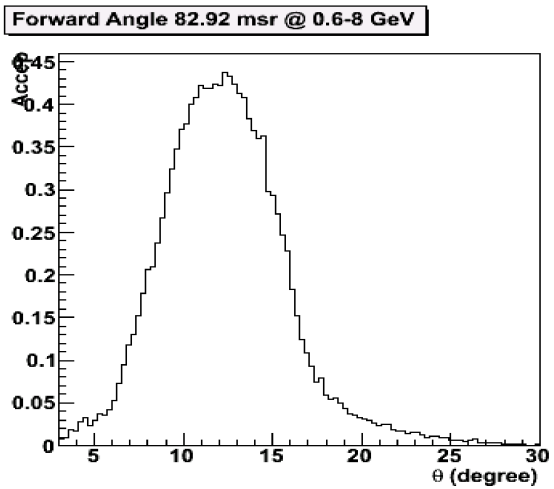
- Acceptance studies done with GEANT3 model including realistic target fields
- Acceptance of theta extend to lower and higher angles compared to the no target field situation

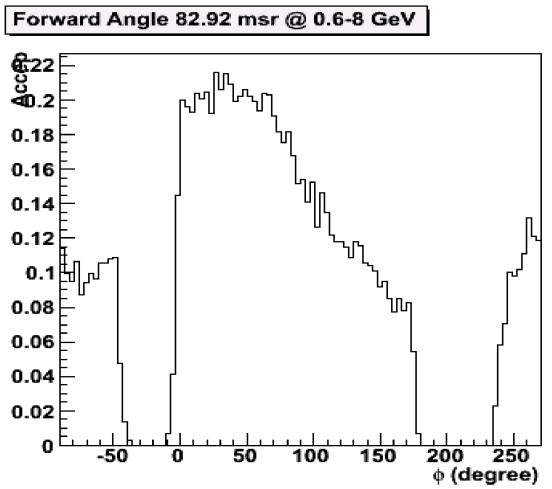




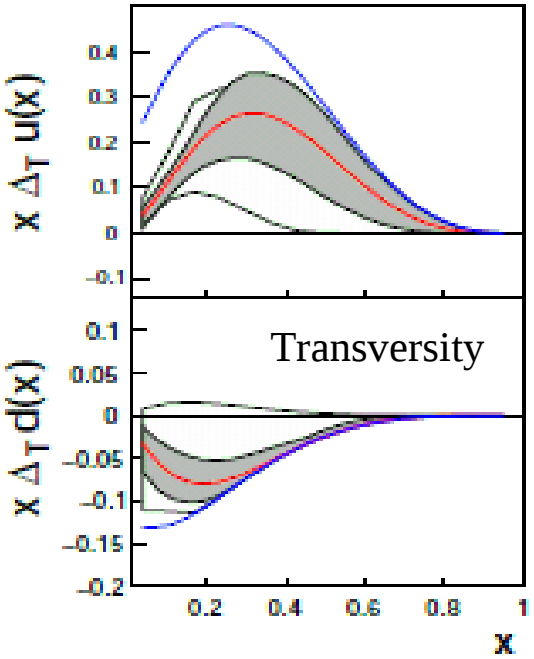






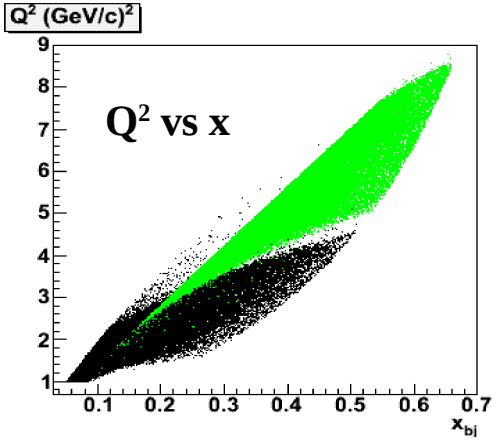


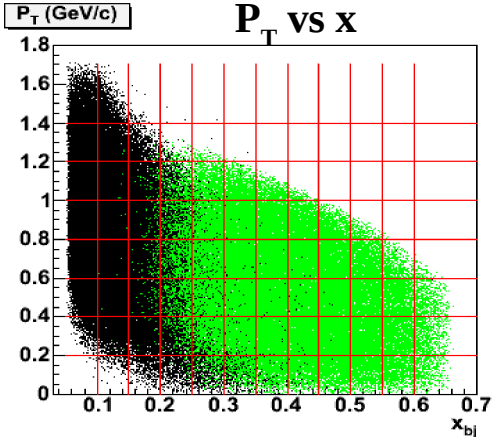
Kinematics Coverage

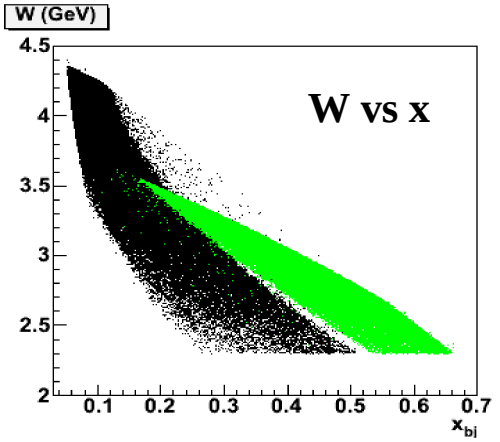


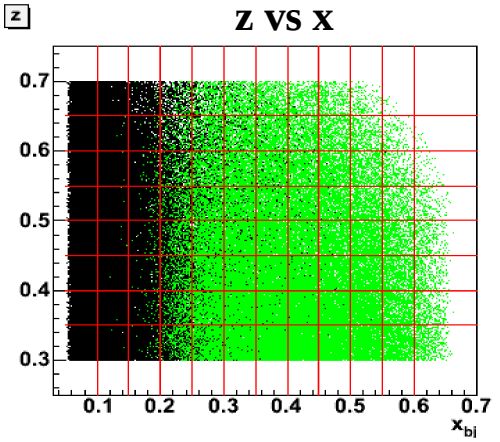
Coverage with 11 GeV beam
(both **forward** and **large angle**)

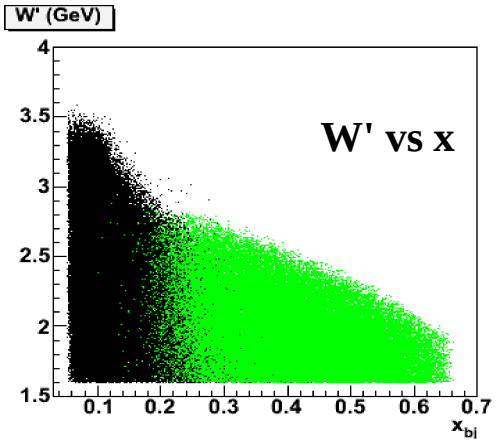
- x_B = 0.05 – 0.68
- Q^2 = 1.0 – 9.0 $(GeV/c)^2$
- P_T = 0 – 1.8 GeV/c
- z = 0.3 – 0.7
- W > 2.3 GeV

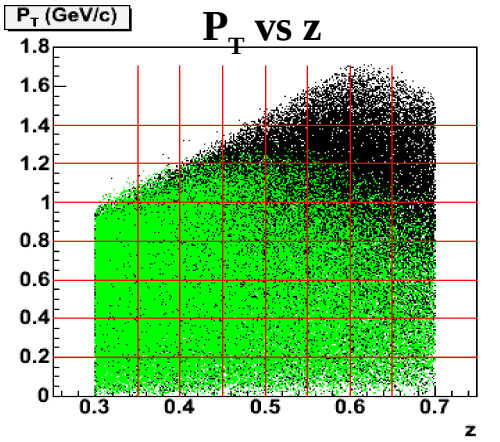






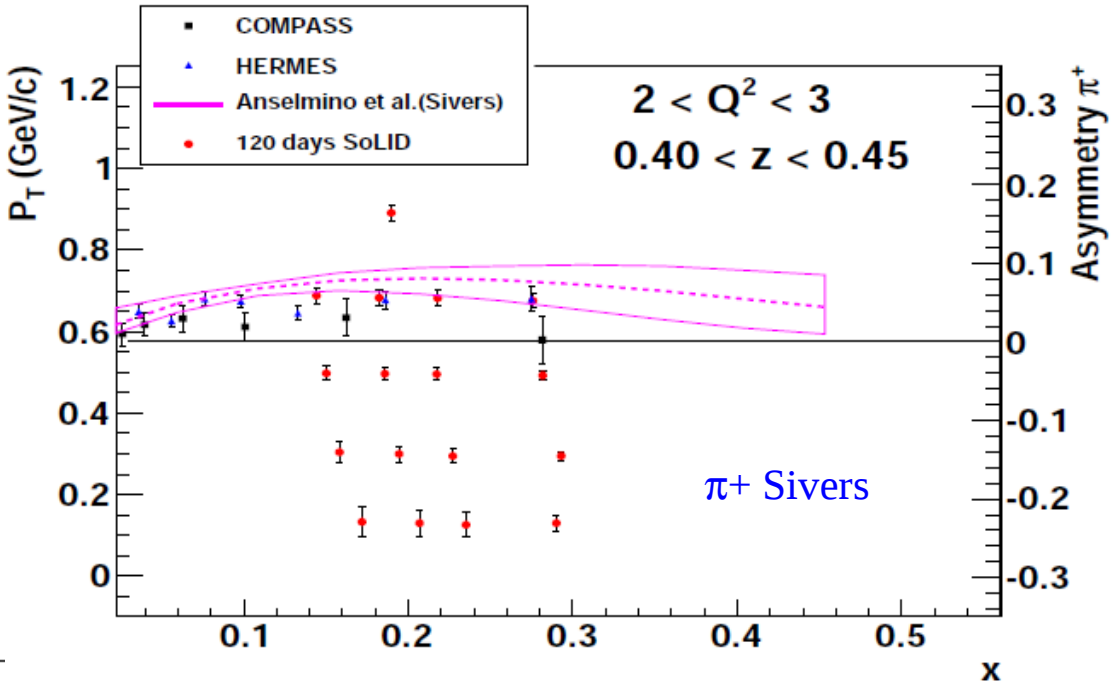


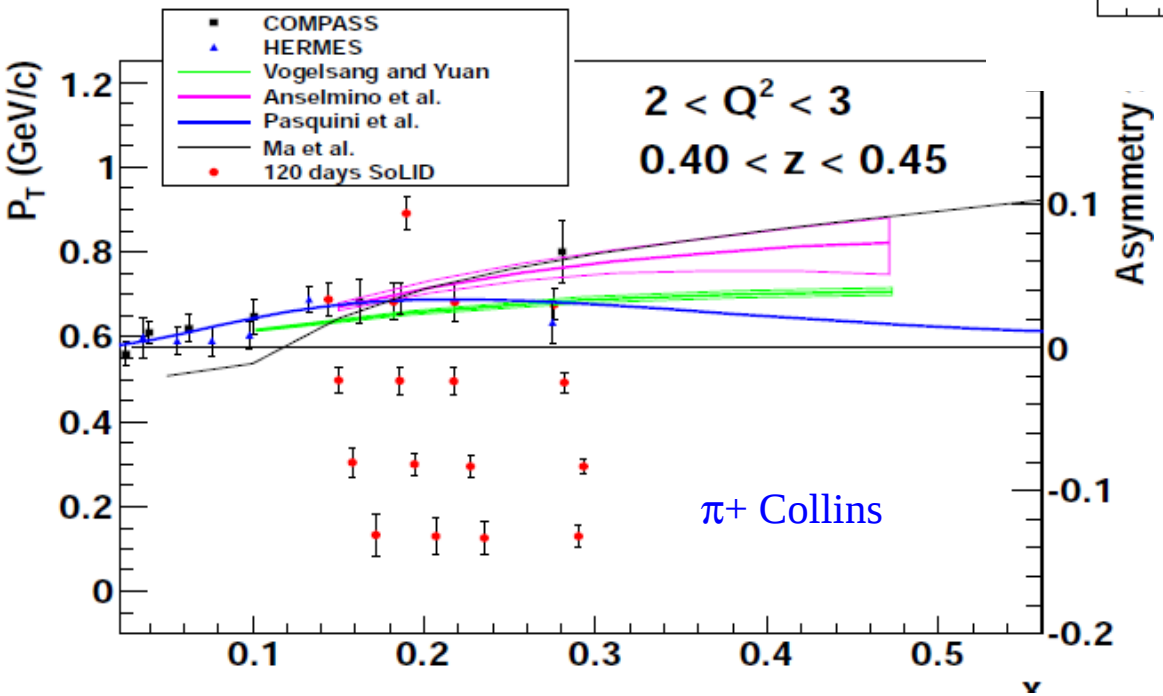




A_{UT} Projections

- Projections for one out of 48 panels in Q^2 and z
- Partial loss of azimuthal coverage due to "*sheet of flame*" background taken into account
- Dilution and packing fraction included
- 120 days of running



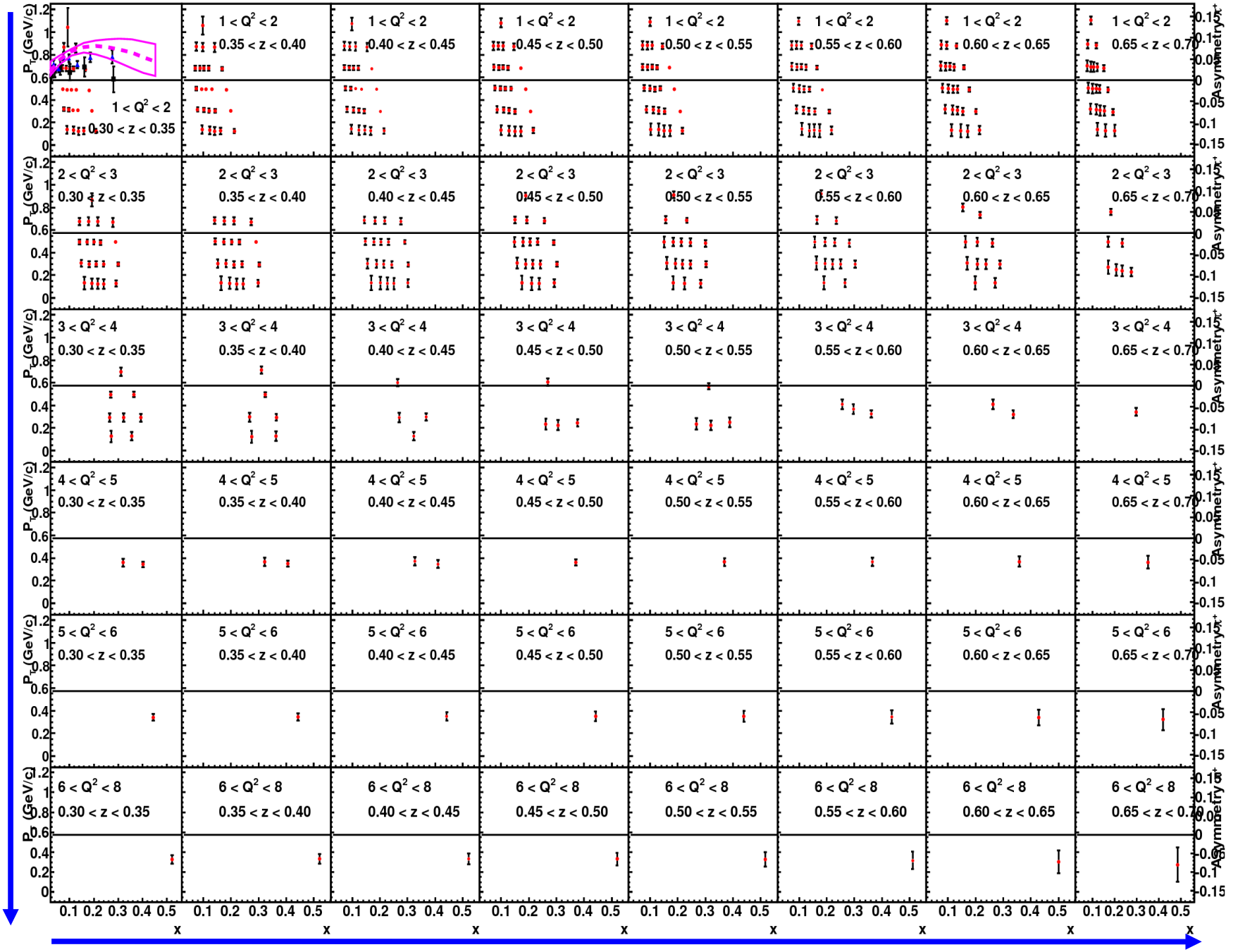


A_{UT} Projections (π^+ Sivers)

$Q^2 = 1.0$ (GeV/c)^2

Multi-dimensional binning in x, Q^2, p_T, z

(674 bins in total)



$Q^2 = 8$ (GeV/c)^2

z = 0.3

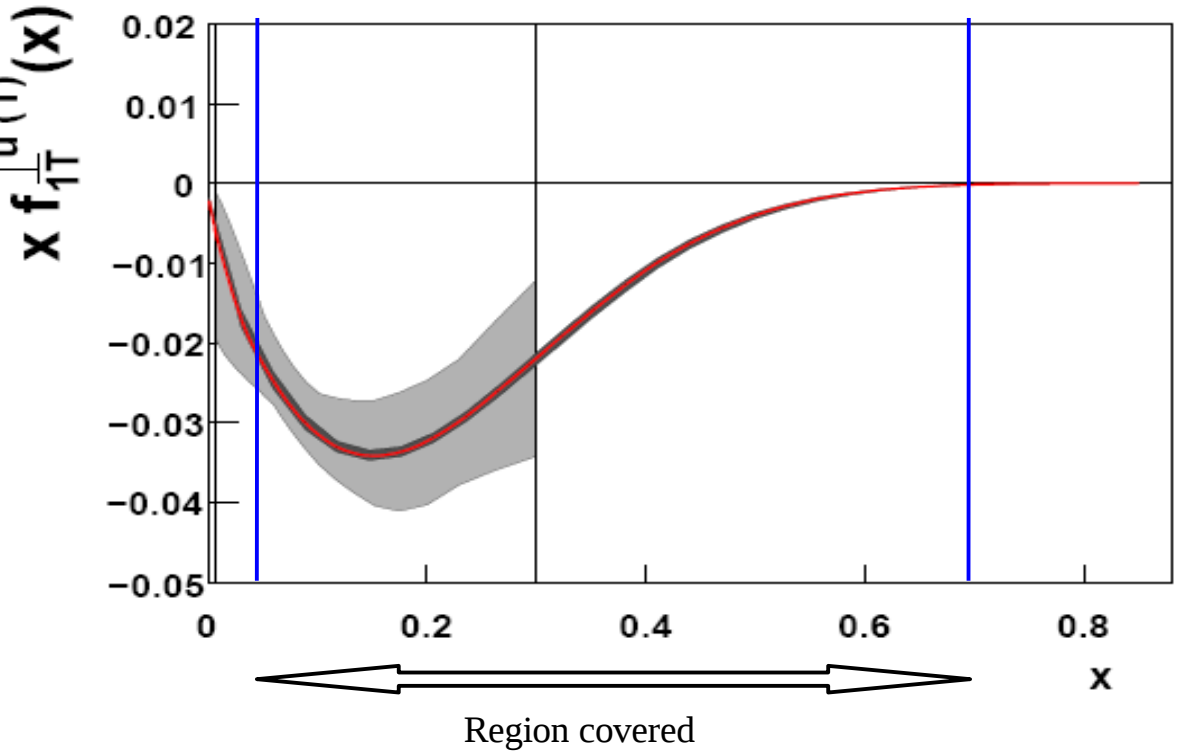
z = 0.7

Impact

Impact of this measurement on u-quark Sivers distribution function

- Current uncertainties shown in light grey band
- Projected uncertainties shown in dark grey band

u-quark Sivers distribution function



A. Prokudin

Updates and Issues

(To be addressed before next PAC)

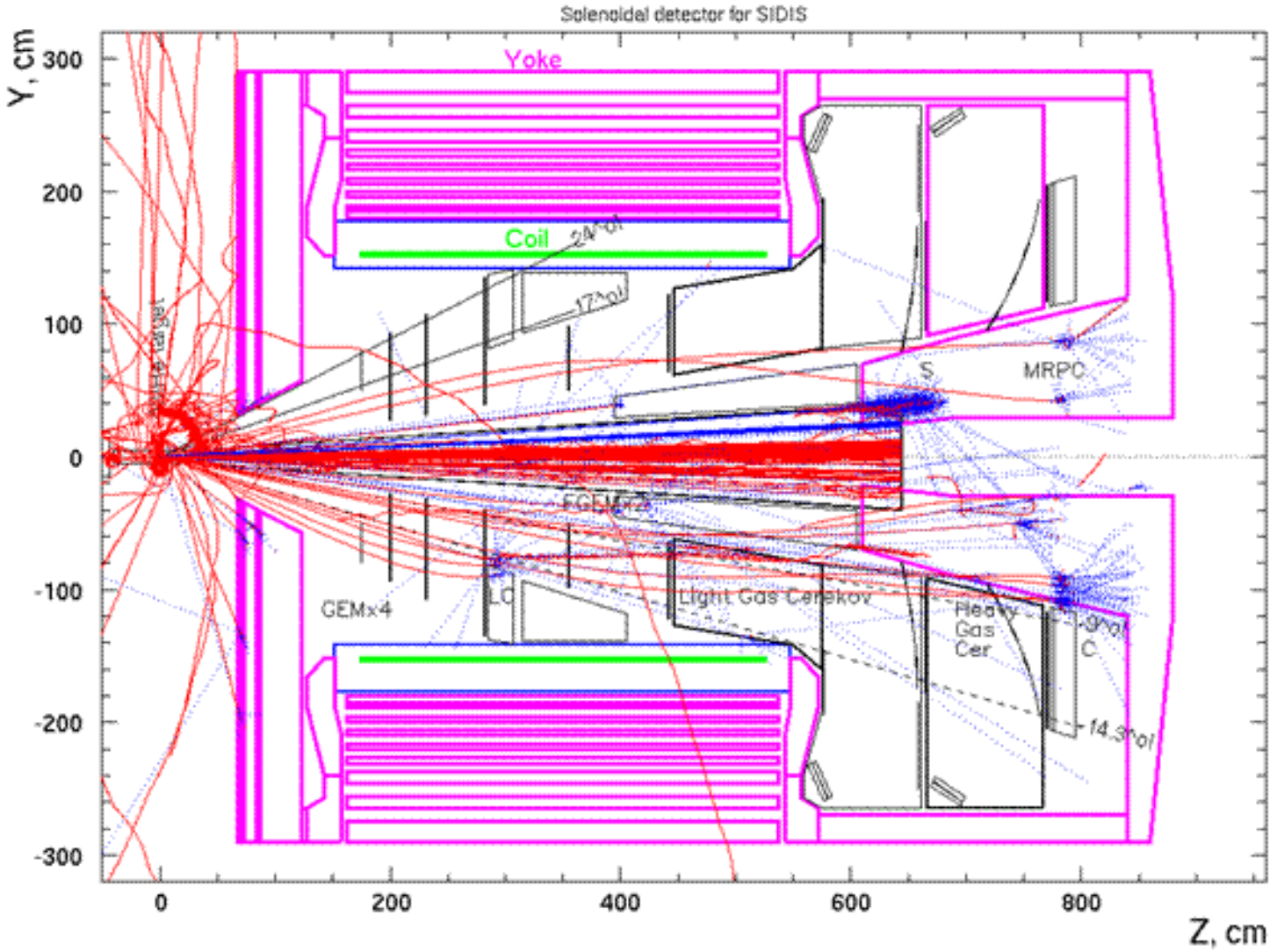
- PAC38 conditionally approved this proposal pending new magnet design
- Magnet Design: optimize transverse/longitudinal opening and get a design done from Oxford and/or Scientific Instruments
- Simulation: Migrate from GEANT3 to GEANT4 (Chao Peng from Duke is working on it)
- GEANT4 simulation: (To do)
  - Reproduce GEANT3 results (signal and background rates, phase space etc..)
  - Change from BABAR to CLEO magnet
  - Add target geometry (coils, scattering chamber, windows etc.)
  - Background shielding study
  - Tracking and reconstruction
  - Study the effect of synchrotron radiation due to upstream chicane and target magnets
- TOSCA calculations to study the forces between SoLID and target magnet (Hall-A design engineer support?)

Summary

- A new proposal to measure SSA in SIDIS using SoLID and transversely polarized proton was submitted to PAC38
  - It was conditionally approved
- Will provide most precise SSA/DSA data on proton in the kinematic region:
  - $0.05 < x < 0.68$
  - $0.3 < z < 0.7$
  - P_T up to 1.8 GeV/c
  - Q^2 up to 9 $(GeV/c)^2$
- Get the GEANT4 simulation working and address all the issues for next PAC

Backup Slides

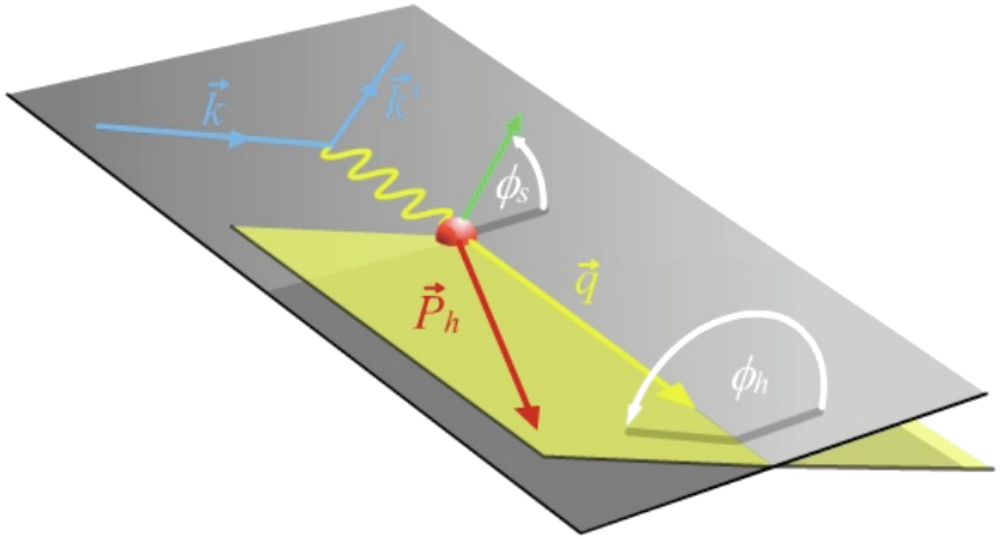
Event Display



Asymmetry

$$A_{UT}^{h}(\phi_h, \phi_S) = \frac{1}{(p_T)} \cdot \frac{N_1(\phi_h, \phi_S) - N_2(\phi_h, \phi_S + \pi)}{N_1(\phi_h, \phi_S) + N_2(\phi_h, \phi_S + \pi)}$$

- Asymmetry formed using luminosity normalized yields
- Asymmetry extraction
  - 2D(ϕ_h,ϕ_s) fitting
  - Maximum Likelihood Estimation (MLE)
- Well established analysis methods in 6GeV E06-010 experiment
- Systematics reduced with spin-flip



Systematic Uncertainties

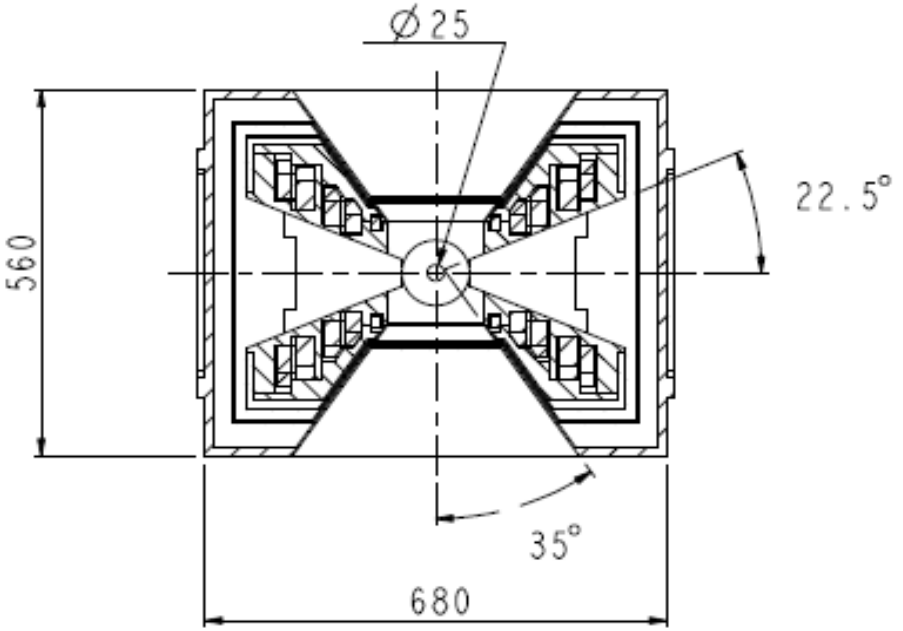
Sources	Type	Collins(π+)	Collins(π-)	Sivers(π+)	Sivers(π-)
Raw asymmetry	absolute	6.5E-3	6.5E-3	6.5E-3	6.5E-3
Dilution factor	relative	5%	5%	5%	5%
Diffractive vector meson	relative	3%	2%	3%	2%
Radiative correction	relative	2%	2%	2%	2%
Target polarization	relative	3%	3%	3%	3%

- Other systematics:
  - Detector efficiency/acceptance/luminosity : < 2 % in each spin-pair
  - Target polarization direction, random background: negligible
  - For contributions from A_{UL} , we will take dedicated data

- Systematics < statistical precision

Target Split-Coil Design

- A preliminary magnet design with transverse opening of 22.5^0 was performed for CLAS
- We are proposing a new design with +/- 28^0 opening in transverse direction
- D. Crabb (UVa) is in the process of discussing the design with two companies (Oxford and Scientific Magnets)



Preliminary design done for CLAS