Proposal: PR12-11-108

SIDIS Using SoLID and Transversely Polarized Proton Target

Kalyan Allada
Jefferson Lab

Spokespersons: K. Allada (JLab), J. P. Chen (JLab), Haiyan Gao (Duke), Xiaomei Li (CIAE), Z-E. Meziani (Temple)

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

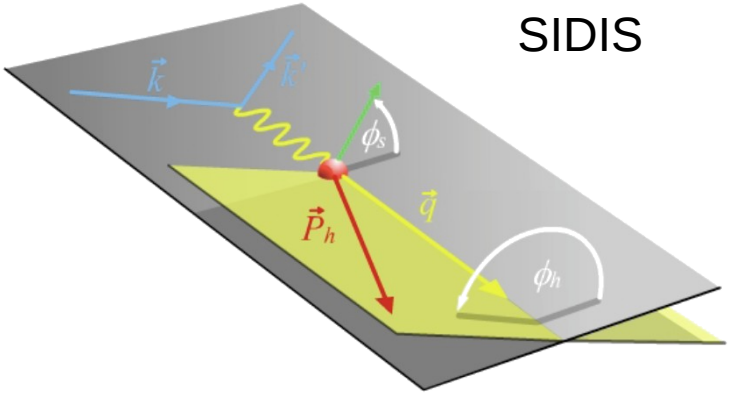
SoLID Collaboration Meeting, Newport News, Feb. 4th 2011

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Leading Twist TMDs

TMDs provide multi-dimensional information of the nucleon
(in this sense they are more fundamental than the integrated PDFs)

SIDIS



nucleon \ quark	U	L	T
U	q		$h_1^\perp$
L		Δq	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}^\perp$	δq, $h_{1T}^\perp$

Transversity

Pretzelosity

Sivers

Trans-Helicity

Distributions that can be 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)

- **Collins Moments:**

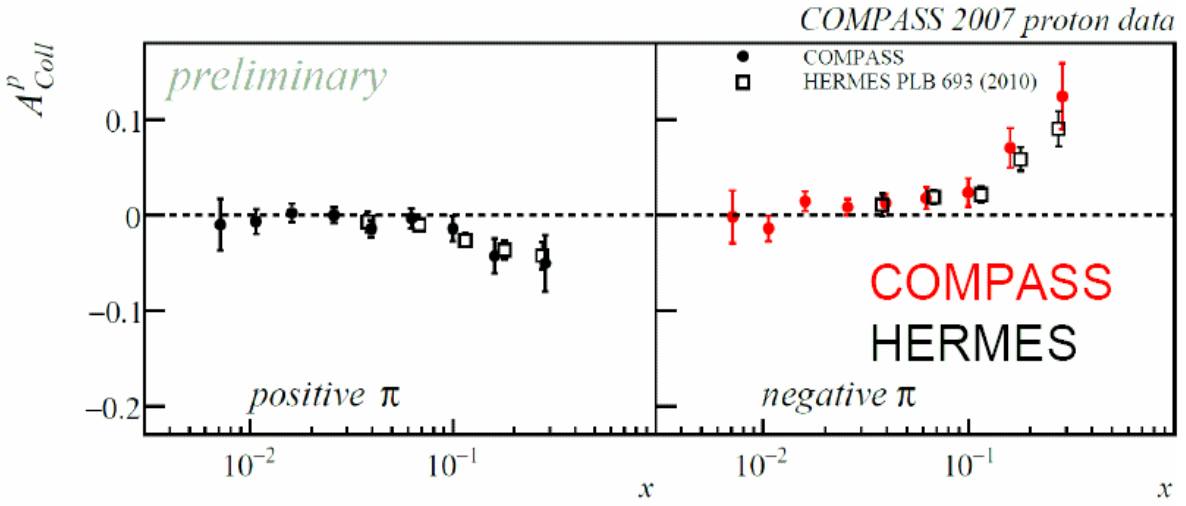
$$\sigma_{UT}^{SIDIS} \propto \sin(\phi_h + \phi_S)\; h_1 \otimes H_1^{\perp}$$

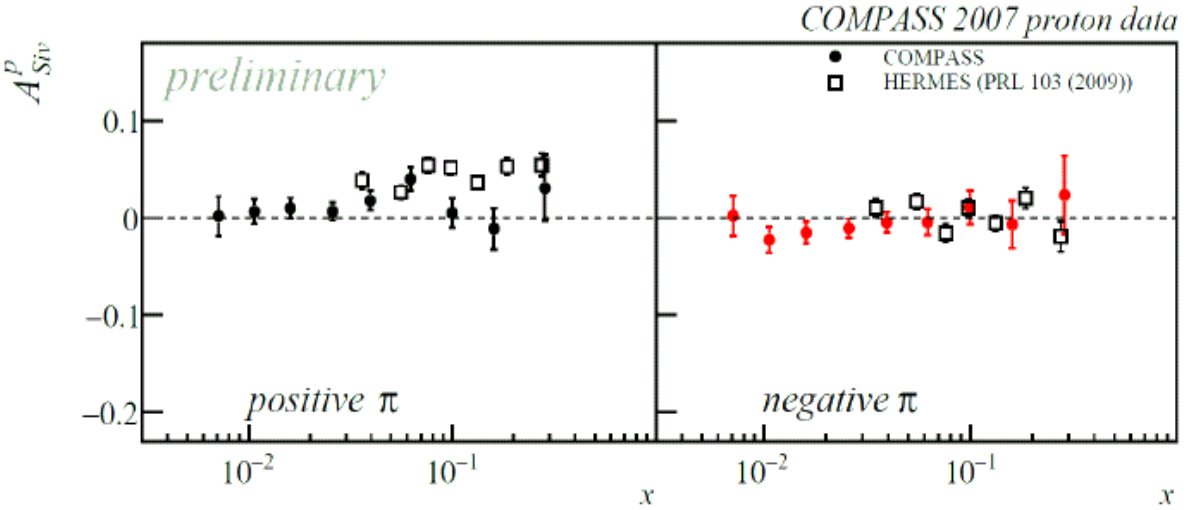
  - Transversity DF and extraction of nucleon tensor charge
  - Existing data only up to x~ 0.3
  - Need high precision and Multi-dimensional data to study p_T, and x dependence

- **Sivers Moments:**

$$\sigma_{UT}^{SIDIS} \propto \sin(\phi_h - \phi_S)\; f_{1T}^{\perp} \otimes D_1$$

  - Relation with Drell-Yan
  - Crucial to test sign change and hence the TMD factorization

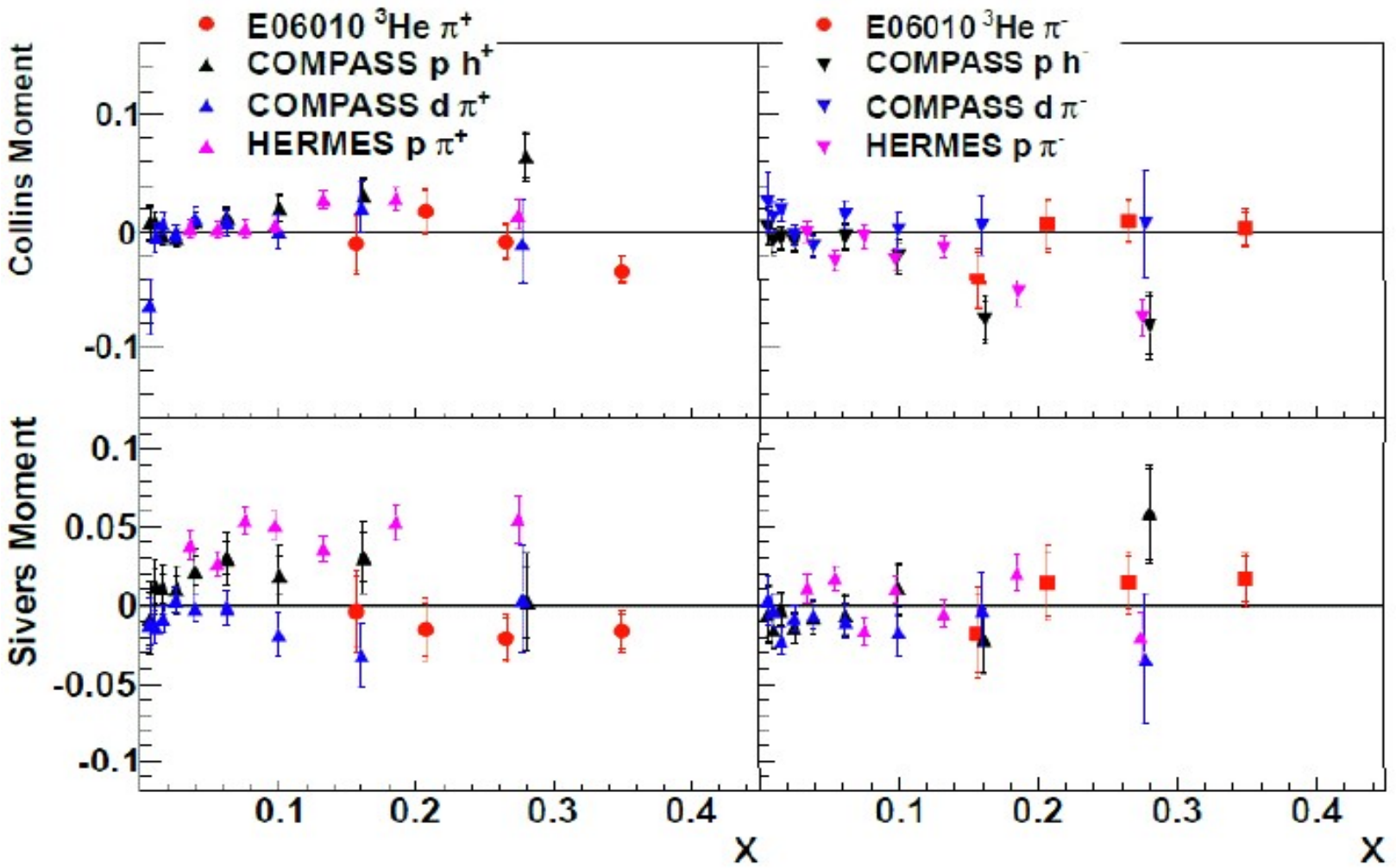




C. Schill, DIS2011 Workshop

Existing Data on Collins and Sivers

(Targets: p, d, ^{3}He)



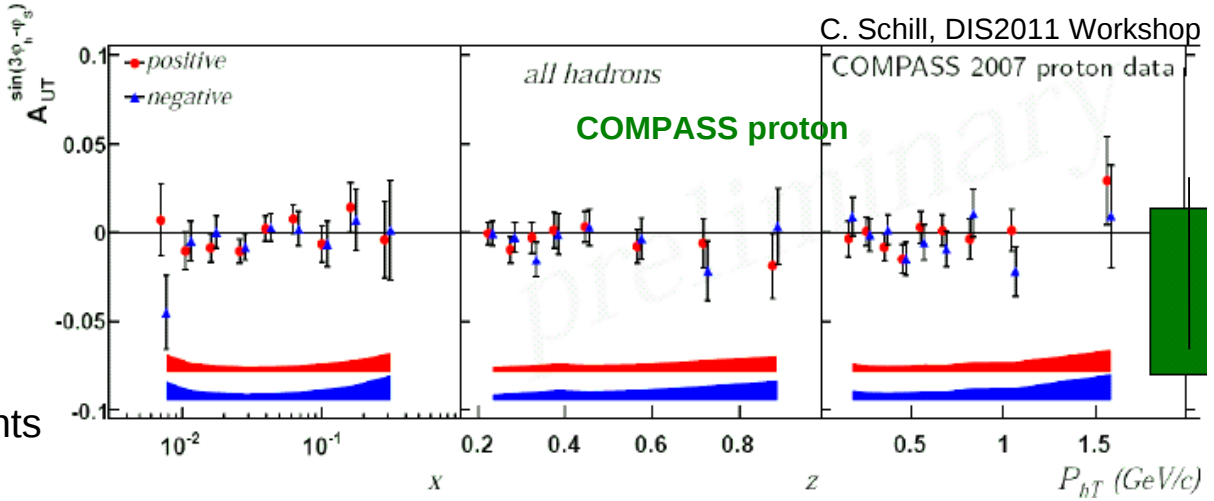
Moments integrated
over other dimensions (z, Q^2, P_T)

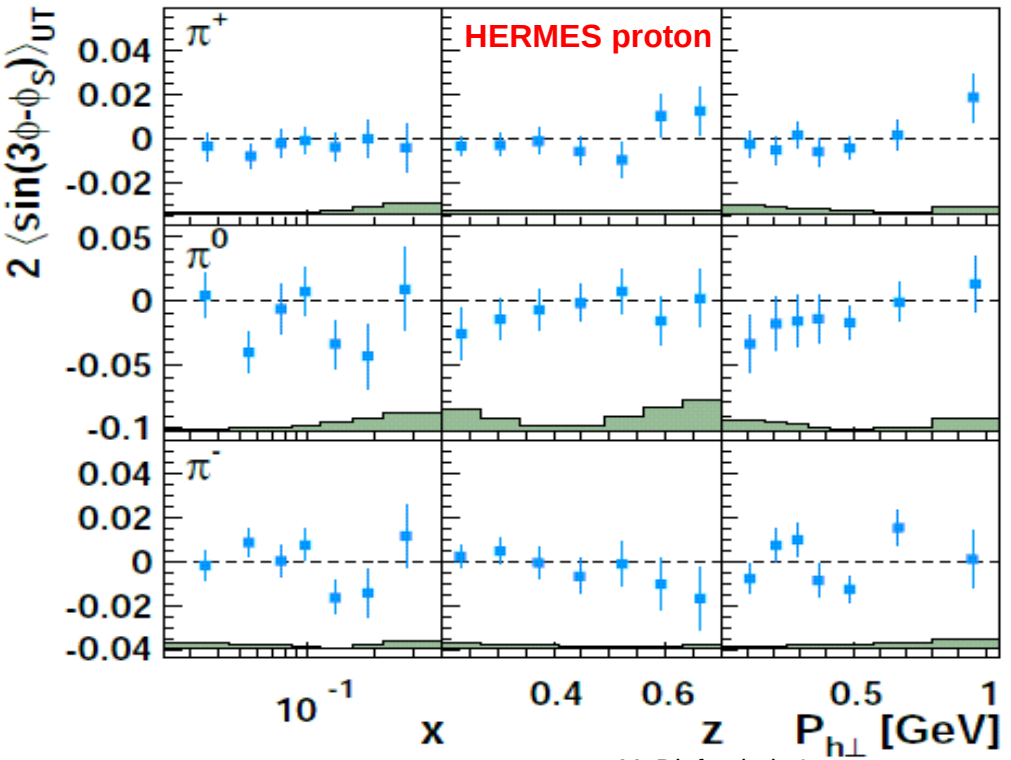
Pretzelosity and g_{1T}

Pretzelosity

- Related to the non-spherical shape of the nucleon
- First data from HERMES and COMPASS
  - No clear signal seen on $sin(3\phi_h-\phi_S)$ moments
  - Not enough precision
  - Basically pretzelosity DF is unknown

C. Schill, DIS2011 Workshop





M. Diefenthaler's Dissertation (HERMES)

g_{1T} (trans-helicity)

- Measure A_{LT} using Double Spin Asymmetry
- Related to quark OAM
- Existing A_{LT} data:
  - HERMES (proton)
  - COMPASS (proton)
  - Hall-A (neutron)
- Not enough precision for the existing data

Proposed Experimental Goals

- Provide a high 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

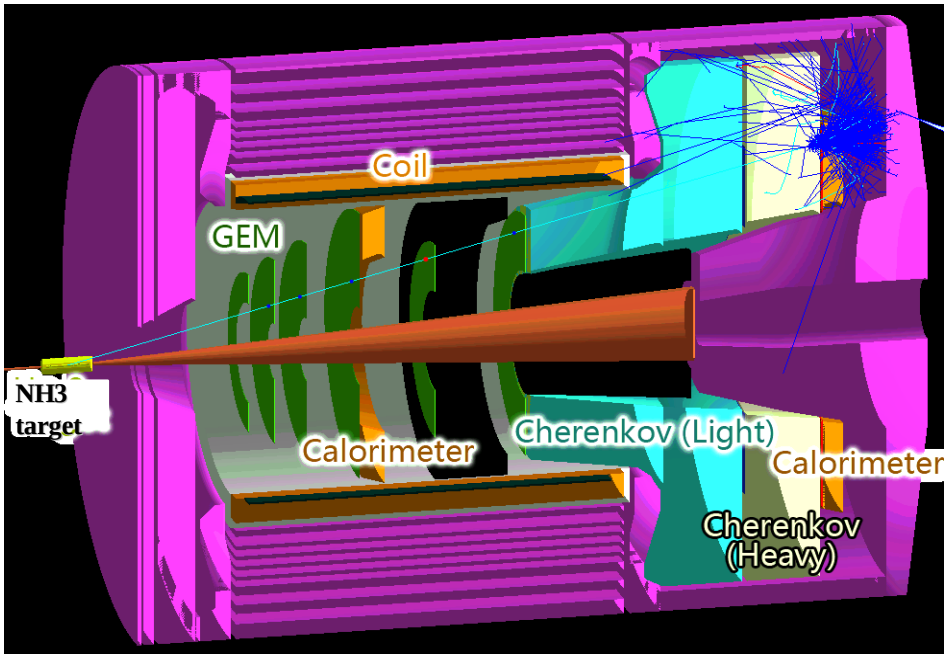
$$N = u_n(\frac{4}{9}) \oplus d_n(\frac{1}{9}) \oplus d_n(\frac{1}{9}) \overset{C.S.}{=} d_p(\frac{4}{9}) \oplus u_p(\frac{2}{9})$$

Sensitive to d-quark

Experiment Overview

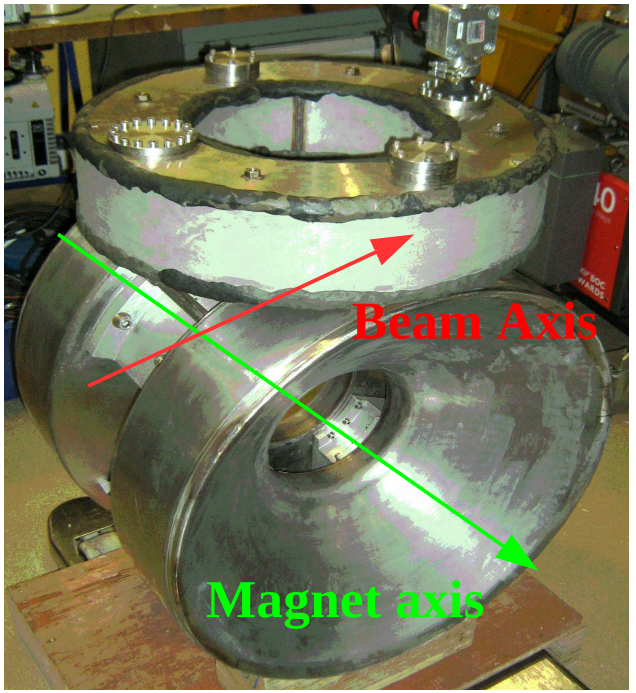
$$e + p^{\uparrow} \longrightarrow e' + \pi^{+/-} + X$$

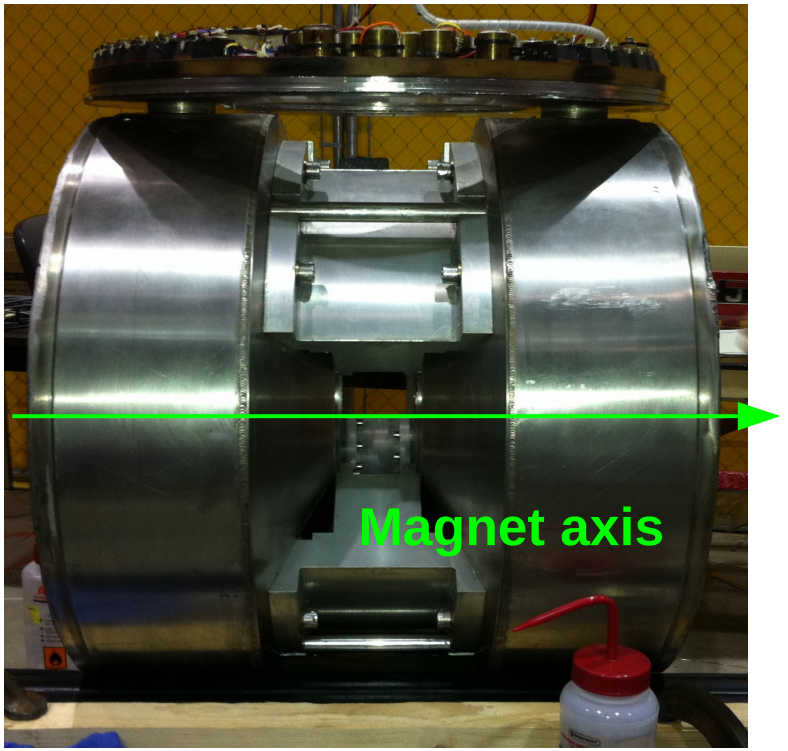
- Similar detector setup as that of two approved ^{3}He SoLID expts.
- JLab/UVa polarized NH_3 target with upgraded design of the magnet
- Target spin-flip every two hours with average in-beam polarization of 70%
- Two Beam energies: 11 GeV and 8.8 GeV
- Polarized luminosity with 100nA current: 10^{35} $cm^{-2}s^{-1}$
- 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_3, 5 Tesla superconducting magnet
  - 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)





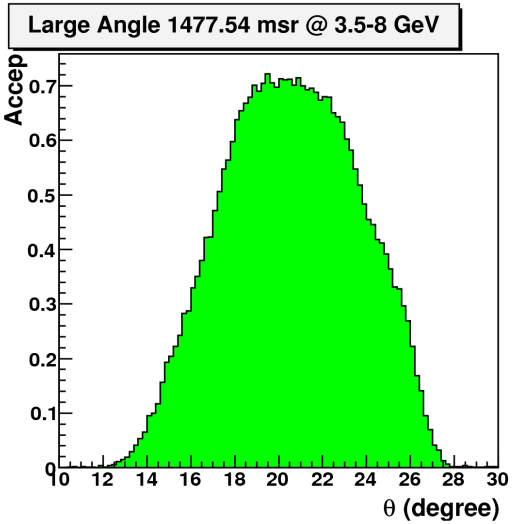
Issues and Updates

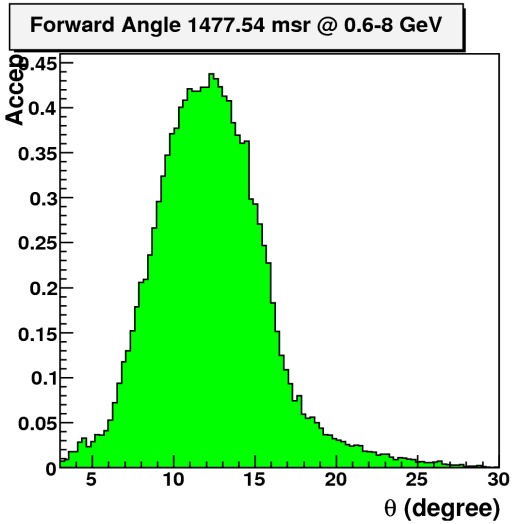
(To be addressed before next PAC)

- PAC38 conditionally approved this proposal pending new magnet design
- Magnet Design:
  - Complete design (transverse opening, field uniformity etc..) and a cost estimations was requested
  - Calculation of magnetic forces between target and SoLID, and impact on mechanical changes
- Background rates
  - Detailed simulation of background rates and its impact on detectors/tracking
- **Updates:**
  - Magnet design is currently being pursued with two different companies (details in Jian-ping's target talk)
  - Intend to do TOSCA calculations to know the magnetic forces between target and SoLID (will need Hall-A engineer's help)
  - Original simulation for the proposal was done using GEANT3
  - Converting to SoLID GMC simulation is in progress. Mostly done by Chao Peng from Duke until now

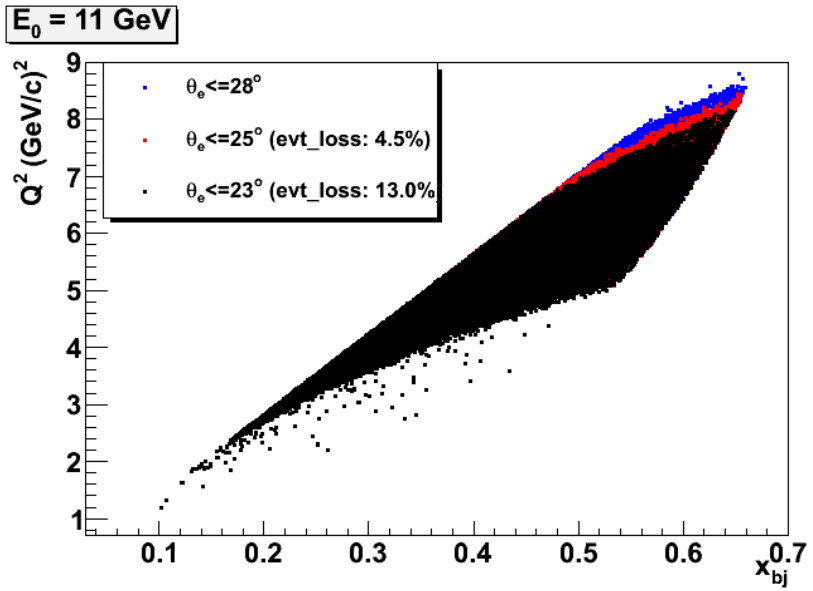
Acceptance

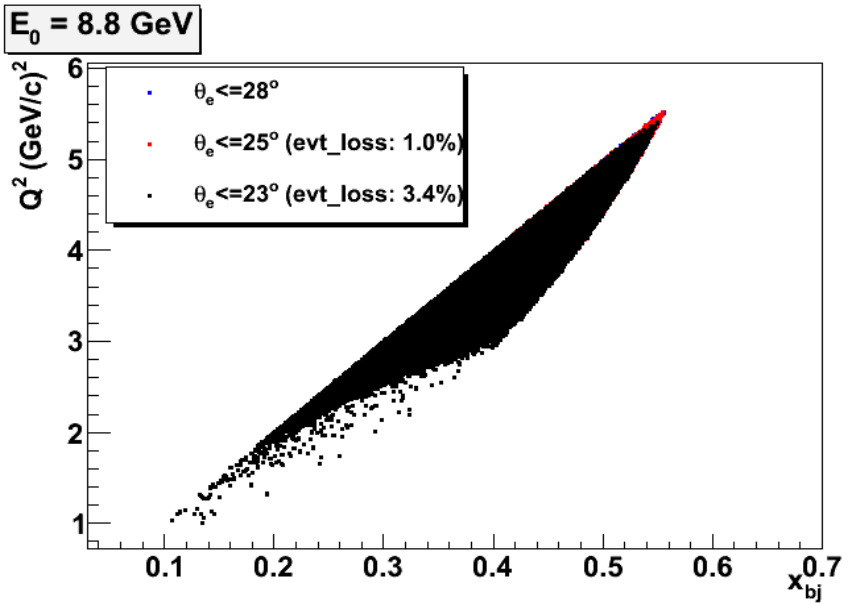
- In the proposal the target magnet opening transverse direction was 28°
- With an opening of 25° we can still cover almost all the phase space without losing lot of statistics
- Currently a preliminary design study is underway with 25° opening



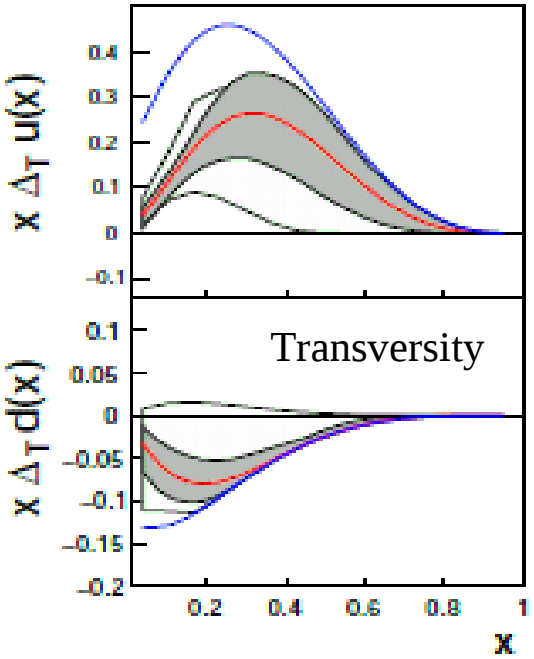


Loss in phase space with different opening angle in transverse direction



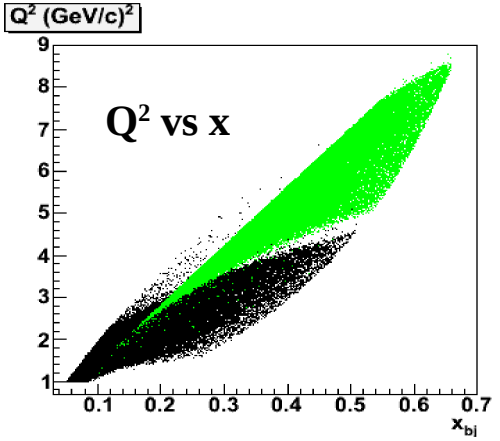


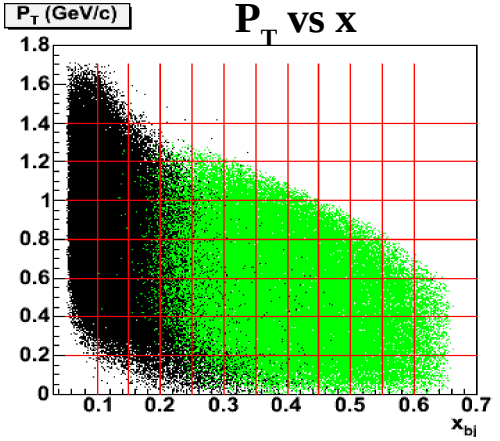
Kinematics Coverage

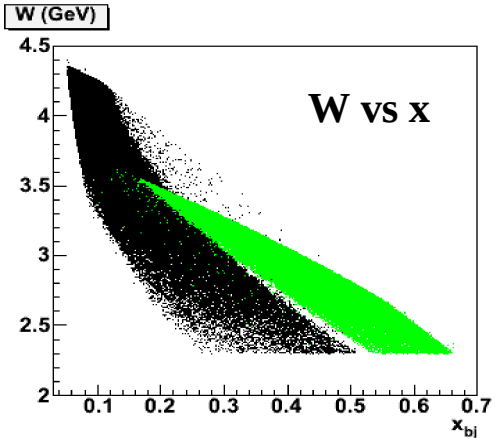


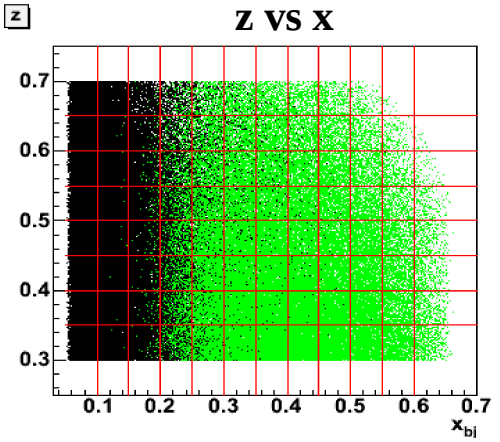
Coverage with 11 GeV beam
(both **forward** and **large angle**)

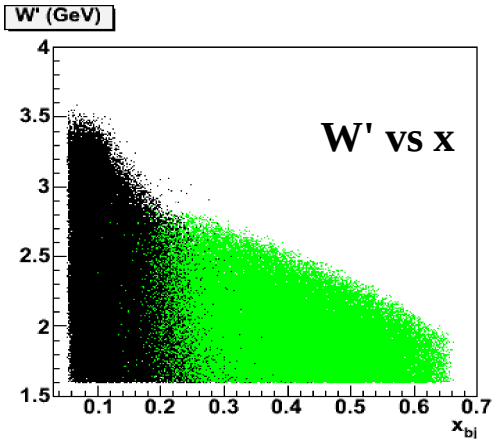
- x_B = 0.05 – 0.68
- Q^2 = 1.0 – 9.0 $(GeV/c)^2$
- P_T = 0 – 1.8 GeV/c
- z = 0.3 – 0.7
- W > 2.3 GeV

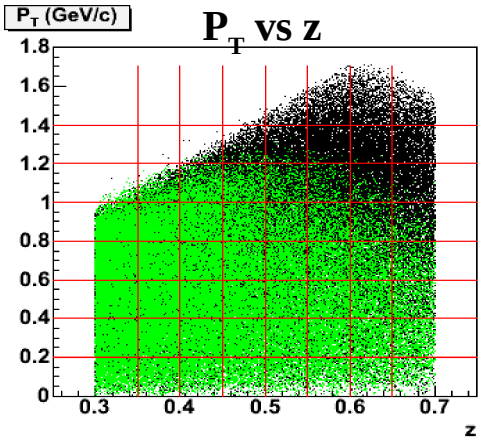






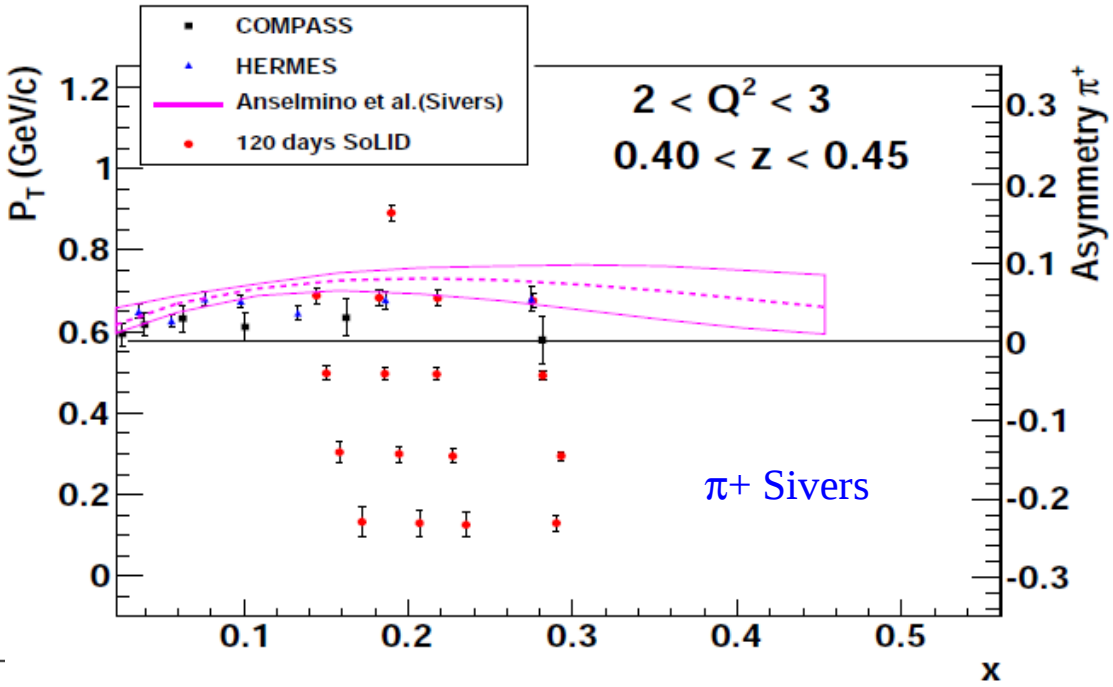


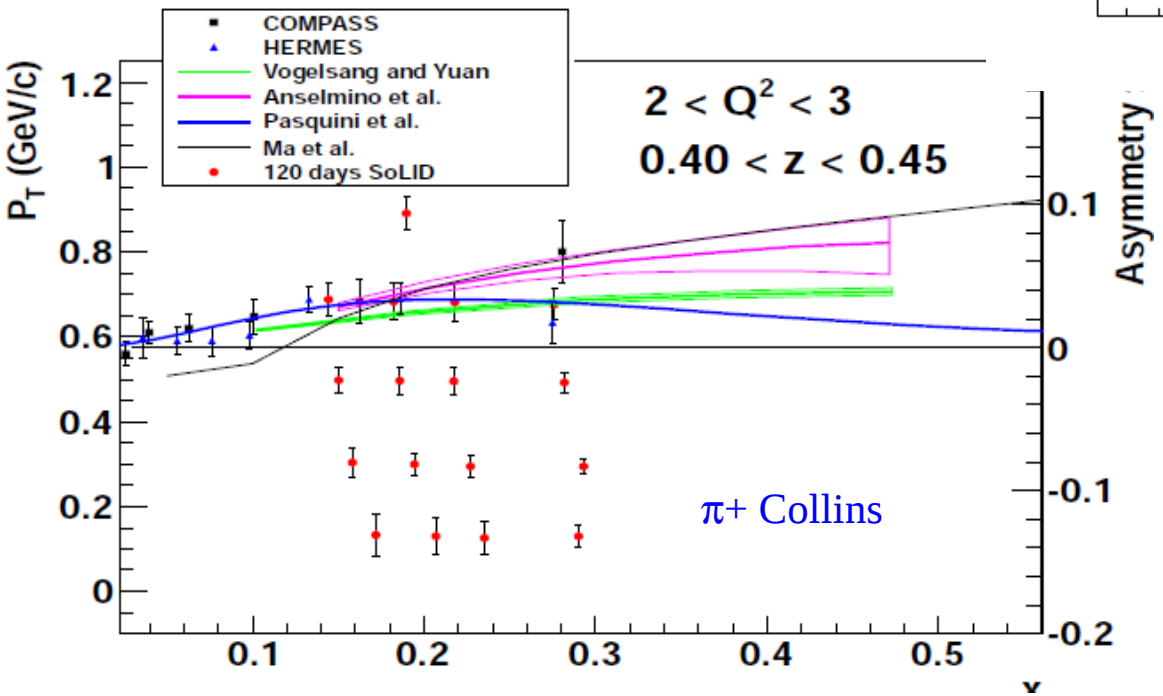




A_{UT} Projections

- 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



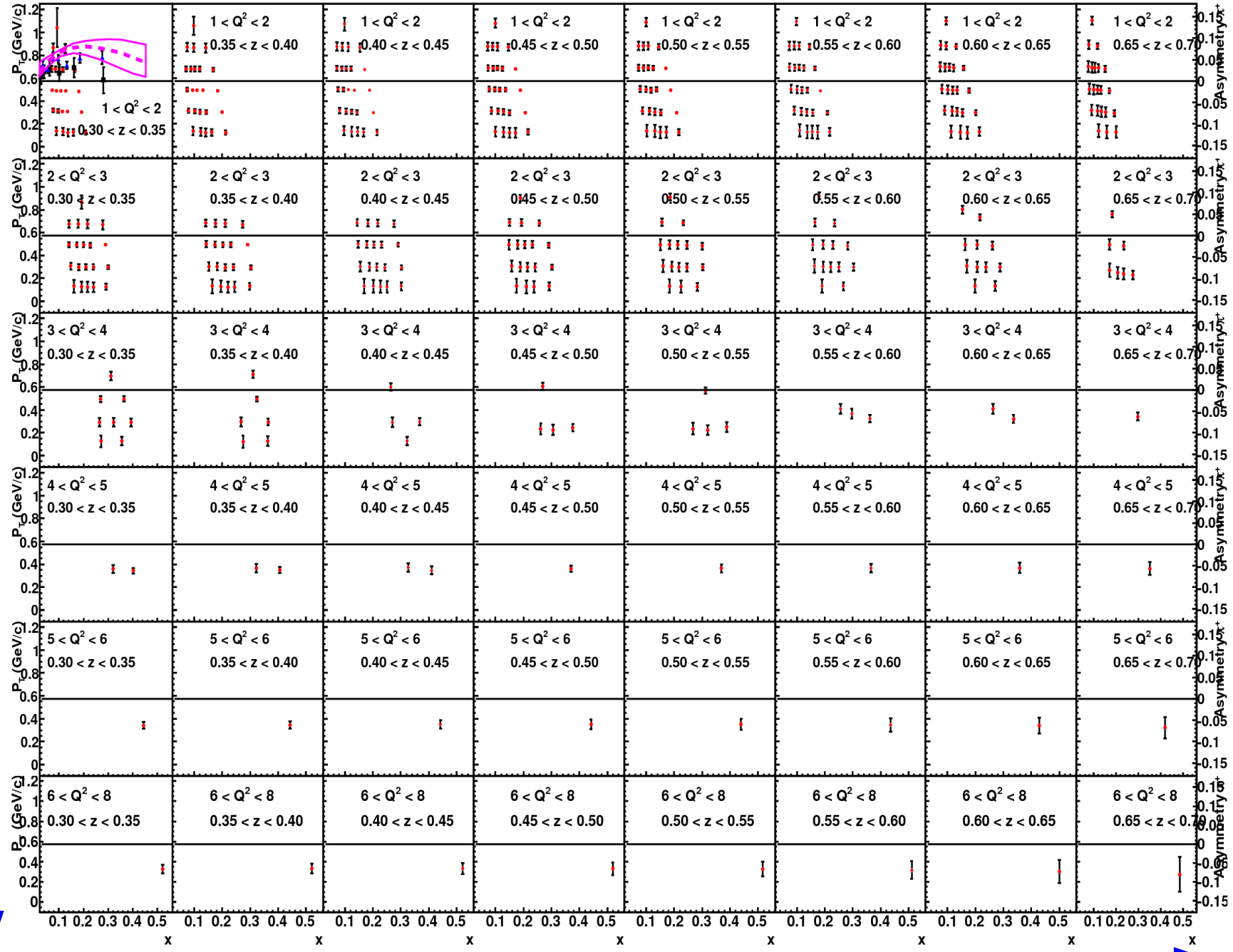


A_{UT} Projections (π^+ Sivers)

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

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

(674 bins in total)



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

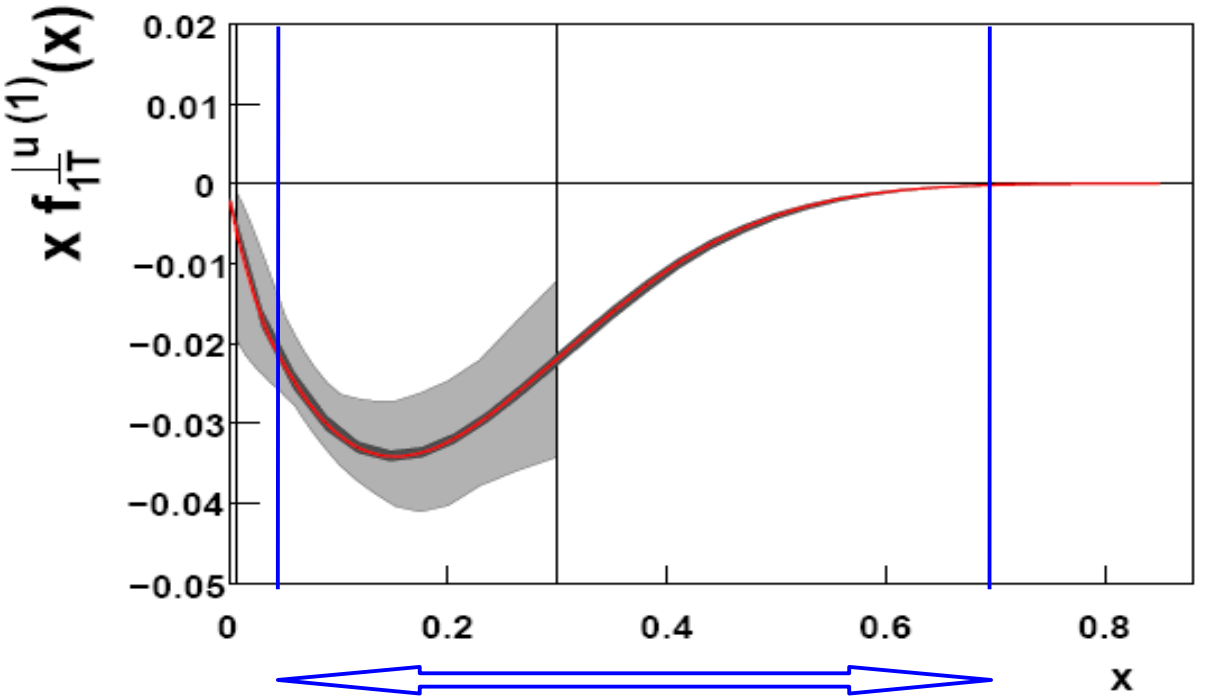
z = 0.3 → z = 0.7

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



Region covered

A. Prokudin

A high precision SIDIS SSA data on proton is extremely important to test the QCD prediction of Sivers function sign change

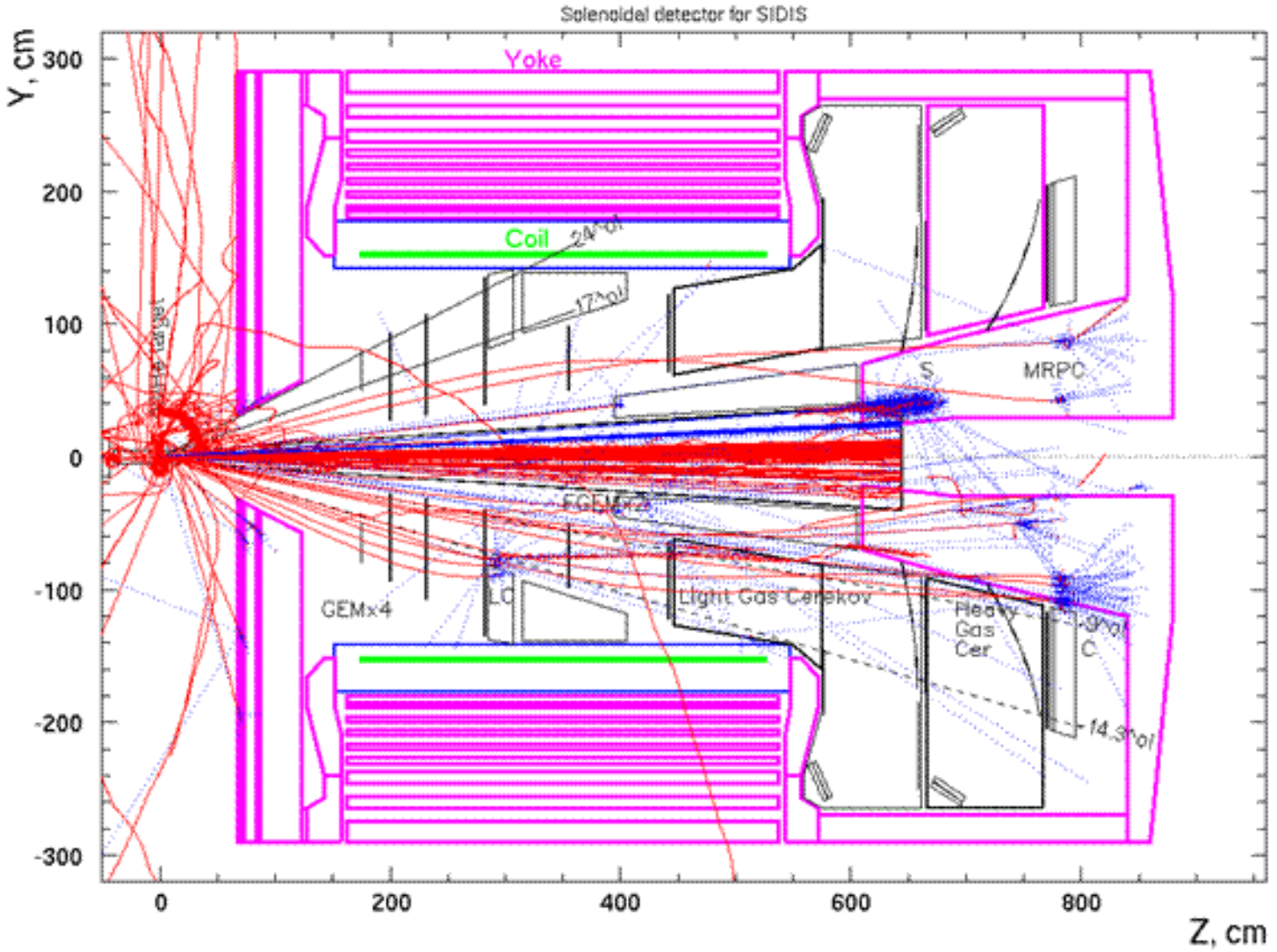
$$f_{1T}^{\perp q}\,|_{SIDIS} = -f_{1T}^{\perp q}\,|_{DY}$$

Summary

- A new proposal to measure SSA in SIDIS using SoLID and transversely polarized proton was submitted to PAC38
  - Conditionally approved (target magnet design in progress)
- 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 $(GeV/c)^2$
- GEANT4 simulations work in progress to address all the issues for next PAC
- With plans for precision Drell-Yan measurements in near future at Fermilab and elsewhere, there is an urgent need to provide very precise SSA data using SIDIS

Backup Slides

Event Display



Systematic Uncertainties

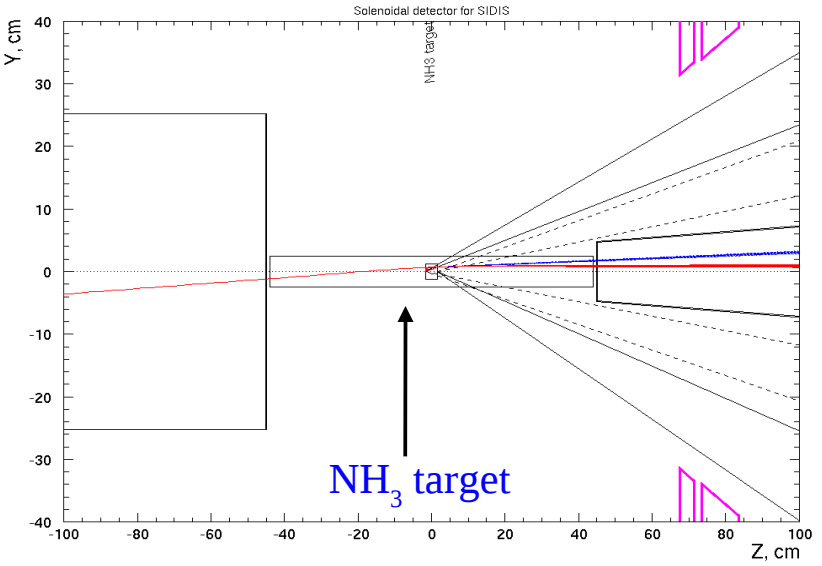
Sources	Type	Collins(π+)	Collins(π-)	Sivers(π+)	Sivers(π-)
Raw asymmetry	absolute	6.5E-3	6.5E-3	6.5E-3	6.5E-3
Dilution factor	relative	5%	5%	5%	5%
Diffractive vector meson	relative	3%	2%	3%	2%
Radiative correction	relative	2%	2%	2%	2%
Target polarization	relative	3%	3%	3%	3%

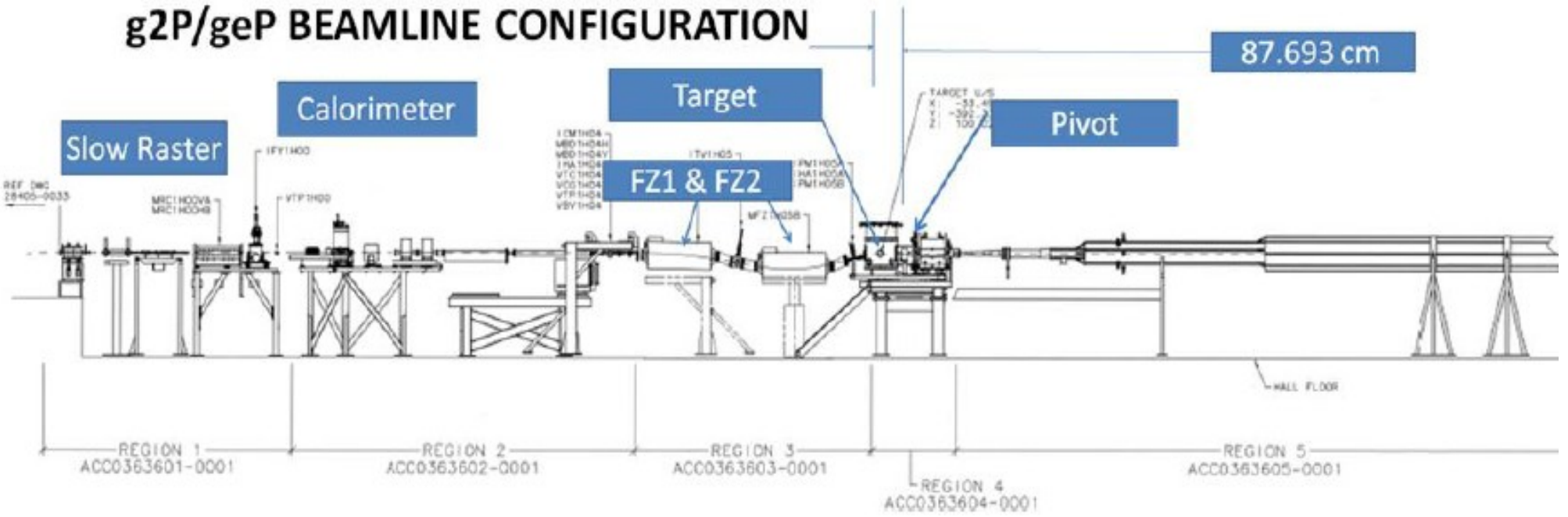
- Other systematics:
  - Detector efficiency/acceptance/luminosity : < 2 % in each spin-pair
  - Target polarization direction, random background: negligible
  - For contributions from A_{UL} , we will take dedicated data

- Systematics < statistical precision

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

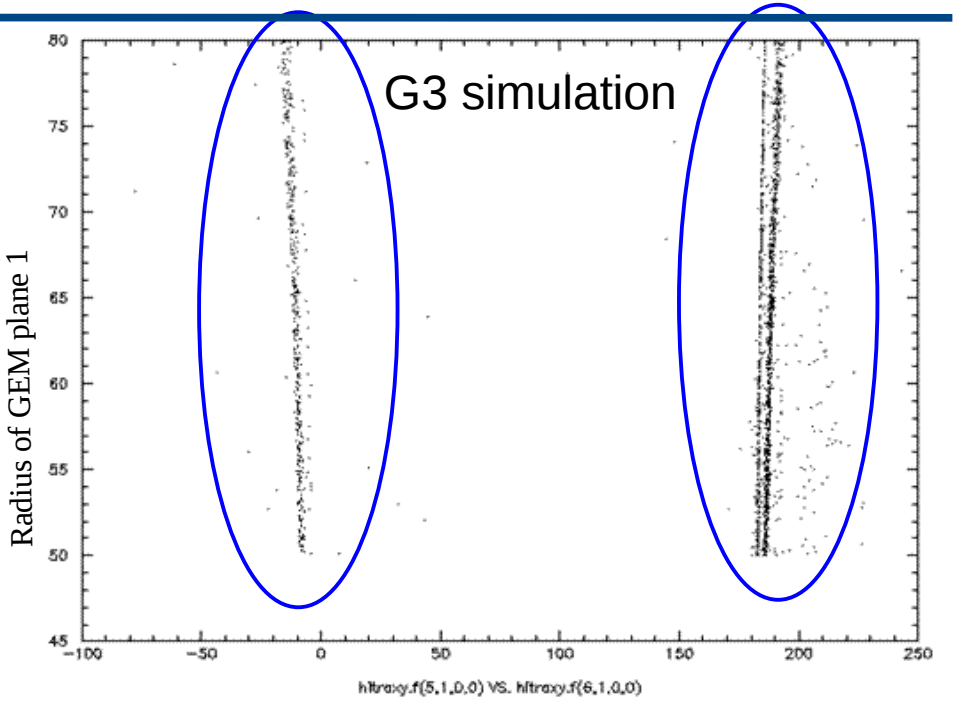


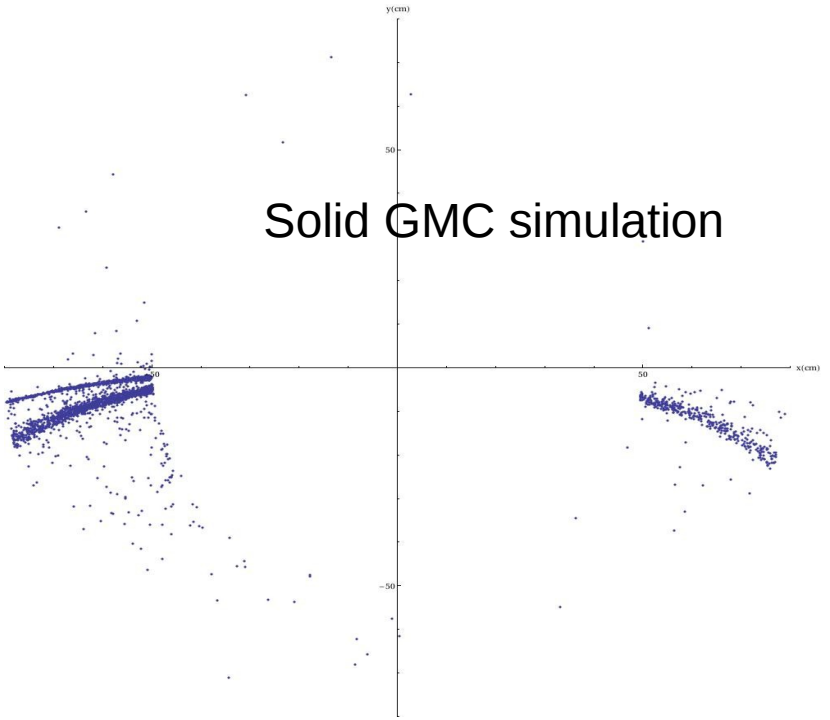


Backgrounds

- 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

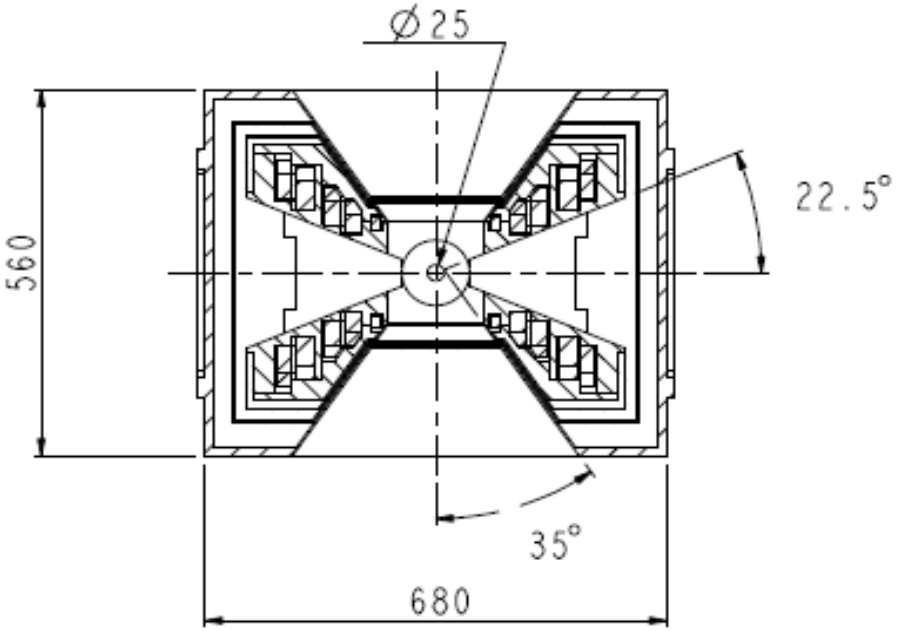
  (GEMs can handle very high rates - COMPASS expt.: 30kHz/mm^2)
- Tracking is not an issue at these rates (as demonstrated in ^{3}He SoLID proposal)
  - Rates and multiplicities are much smaller outside the *"sheet of flame" (*compared to ^{3}He SoLID proposal) due to lower luminosity





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