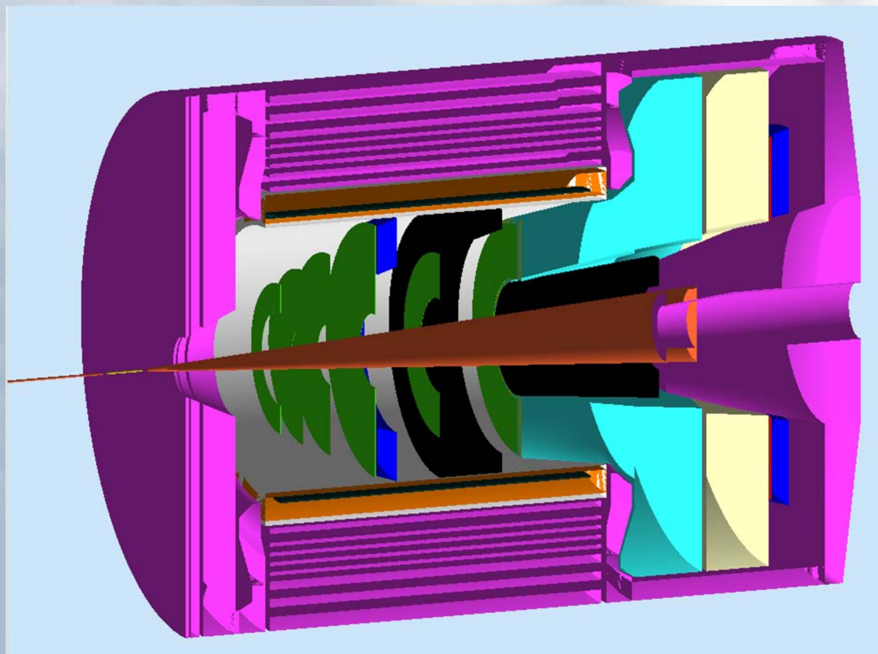
W.K.Kellogg

12 GeV Upgrade

Future Science at Jefferson Lab

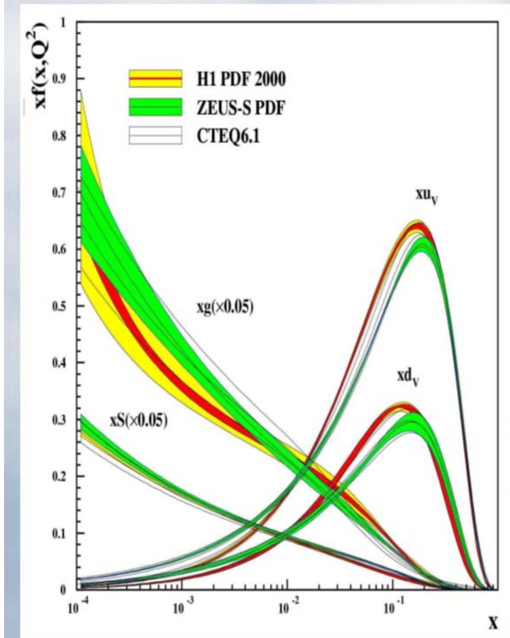
Overview of SIDIS



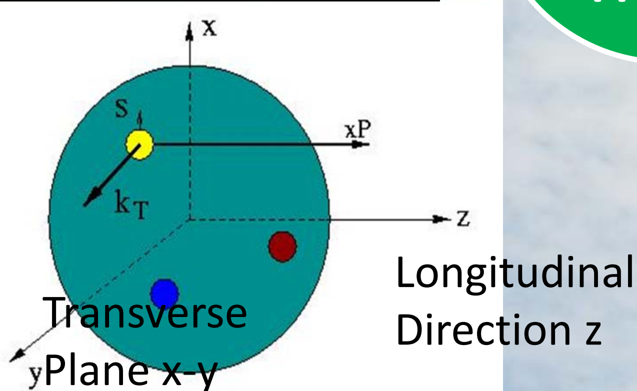
Xin Qian

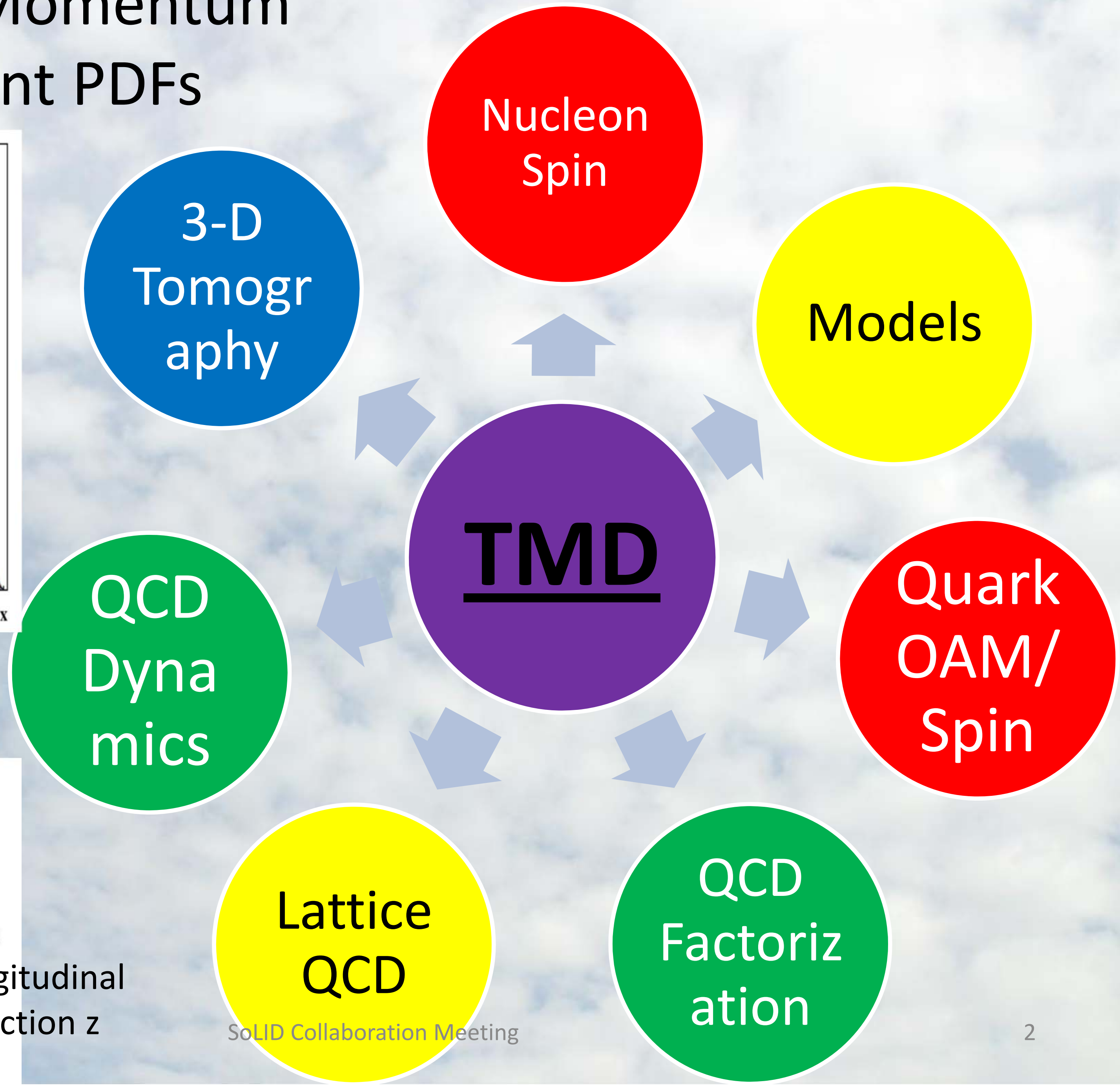
Caltech

Transverse Momentum Dependent PDFs



TMD $f_1^u(x,k_T)$

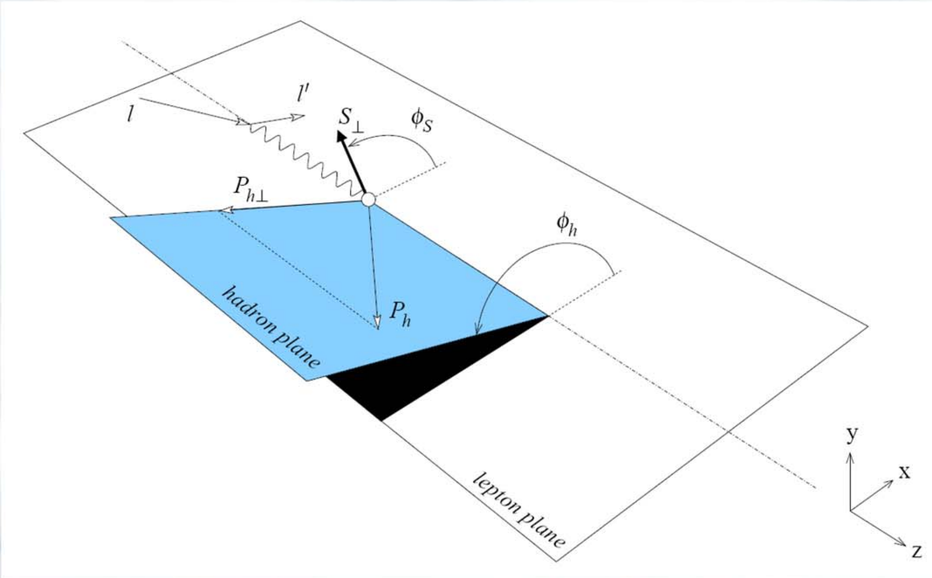


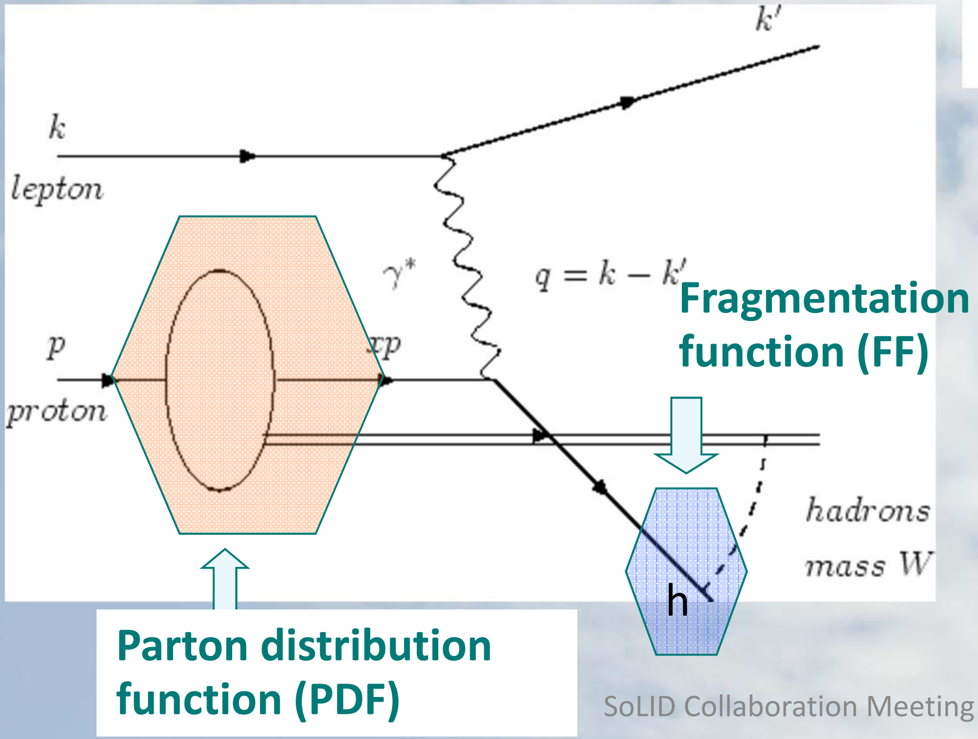


Golden Channel of TMD: **Semi-Inclusive DIS**

$$k + P \rightarrow k' + h + X$$

h tags struck quark's flavor, spin and transverse momentum





z: energy fraction of the leading hadron w.r.t virtual photon's energy

P_T: transverse momentum w.r.t. virtual photon's direction

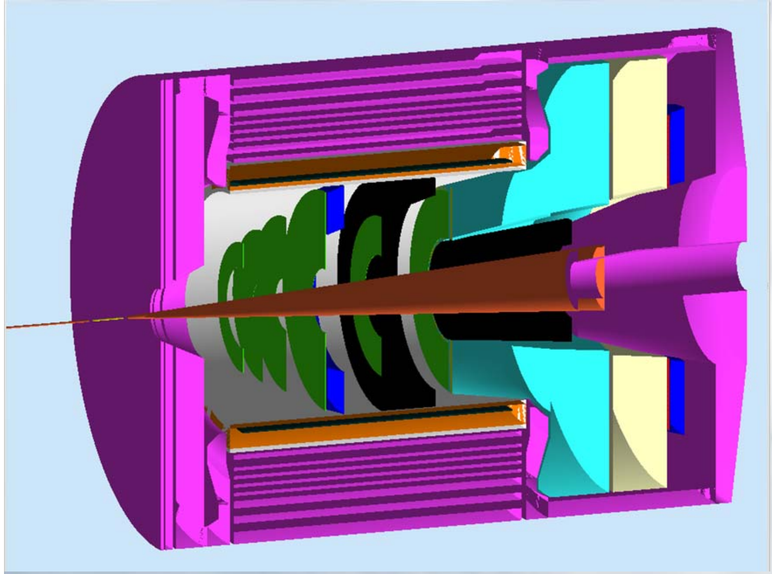
Leading-Twist TMD PDFs

Nucleon Spin
Quark Spin

		Quark polarization		
		Unpolarized (U)	**Longitudinally Polarized (L)**	**Transversely Polarized (T)**
Nucleon Polarization	U	f_1 = Very well known		$h_1^{\perp}$ = − Boer-Mulders
	L		Reasonably known g_1 = − Helicity	$h_{1L}^{\perp}$ = − Worm Gear (Kotzinian-Mulders)
	T	$f_{1T}^{\perp}$ = − Sivers	g_{1T} = − Worm Gear	h_1 = − Transversity $h_{1T}^{\perp}$ = − Pretzelosity

Spin-orbital (trans. mom.) correlation is important!

SoLID-Spin: SIDIS on ^{3}He/Proton @ 11 GeV

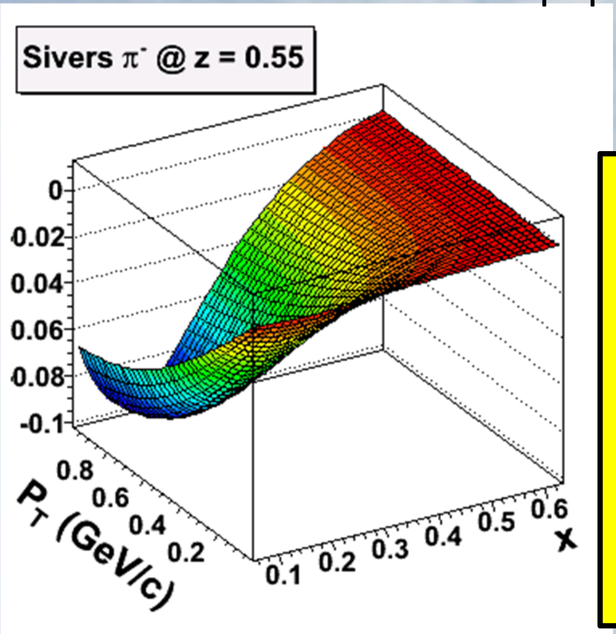


E12-10-006: Single Spin Asymmetry on Transverse ^{3}He @ 90 days

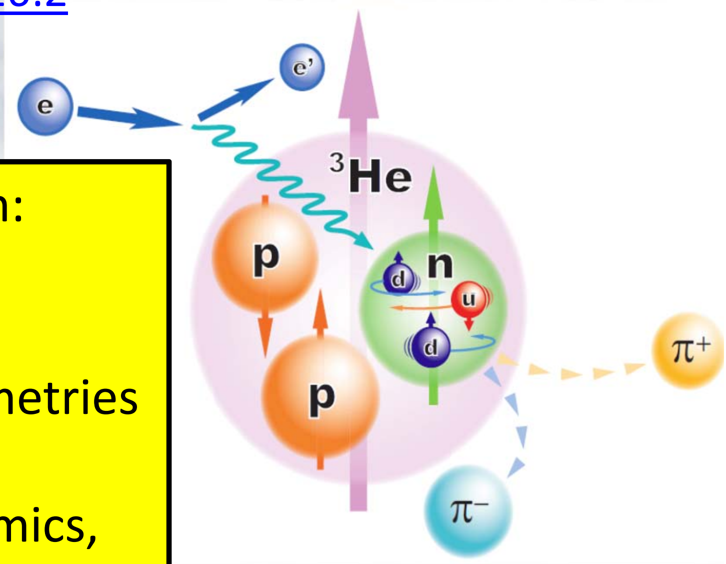
E12-11-007: Single and Double Spin Asymmetry on ^{3}He @ 35 days

PR12-11-108: Single and Double Spin Asymmetries on Transverse Proton (conditionally approved)

White paper: [Eur. Phys. J. Plus (2011) 126:2]



Key of SoLID-Spin program:
Large Acceptance
+ High Luminosity
→ **4-D** mapping of asymmetries
→ Tensor charge, TMDs …
→Lattice QCD, QCD Dynamics, Models.



Requirement of SIDIS

- Kinematics Coverage:
  - **0.05 ~ 0.6 in x (valence)**
  - **0.3 ~ 0.7 in z (factorization region)**
  - **P_T up to ~ 1 GeV (TMD Physics)**
  - **Fixed target → Q^2 coverage 1-8 GeV^2 (~ 2 GeV^2 in ΔQ^2 at fixed x)**
- Luminoisity:
  - **Unpolarized ~ 10^{37} N/cm^2/s**
- Polarized ^{3}He Target:
  - **~ 60% higher polarization**
  - **Fast spin flip (<20 mins)**
- Electron PID:
  - **<1% Pion contamination (asymmetry point of view)**
- Pion PID:
  - **<1% Kaons and Protons**
  - **<1% electron contamination**
- Optics of Reconstruction:
  - **< a few % in δP/P.**
  - **< 1 mr in polar angle.**
  - **< 10 mr in azimuthal angle**
  - **~ 1-2 cm vertex resolution**
  - **Similar precision required.**
  - **A factor of 2-3 better already achieved in MC.**
- DAQ:
  - **~ 3kHz Physics Coincidence**
  - ~ 200 kHz Single electron
  - ~ 50 kHz Coincidence
  - **Limits: 300 MB/s to tape.**

Special Considerations (I)

- SIDIS Trigger:
  - With the current rate estimation, we should work out a detailed trigger design.
  - Goal: running at 1e37 N/cm^2/s ~ 200 MB/s to tape.
  - Identify a clear list of risks and develop a detailed plan for the roadmap toward a full DAQ system.
- Target System:
  - Design Shielding and Correction Coil for SoLID Magnets
  - Lab tests/demonstration of design
  - Method to reduce target endcap thickness?

Special Consideration (II)

- GEM Chamber:
  - Common sets of GEM chamber +reconfiguration
  - Or different sets of GEM chamber
  - Pad readout to replace the thin scintillator plane.
- Gas Cerenkov:
  - How to reconfigure the mirror between PVDIS setup and SIDIS setup?
  - What is the risk of the background level ?
- Calorimeter:
  - Radiation Level: How will calorimeter survive SIDIS + PVDIS + additional experiments?
  - Additional layers of preshower?
  - R&D on cable layout (large angle + forward angle)
  - Improve energy resolution at high momentum?

Special Considerations (III)

- Risk in Backgrounds:
  - For Low energy backgrounds:
    - Is the additional shielding necessary (GEANT4)?
  - Roadmap towards background validation
- Calibration and Analysis:
  - Developing detailed optics calibration plan.
  - Plan to get a desired TOF calibration.
  - Test of online farm and fast tracking.

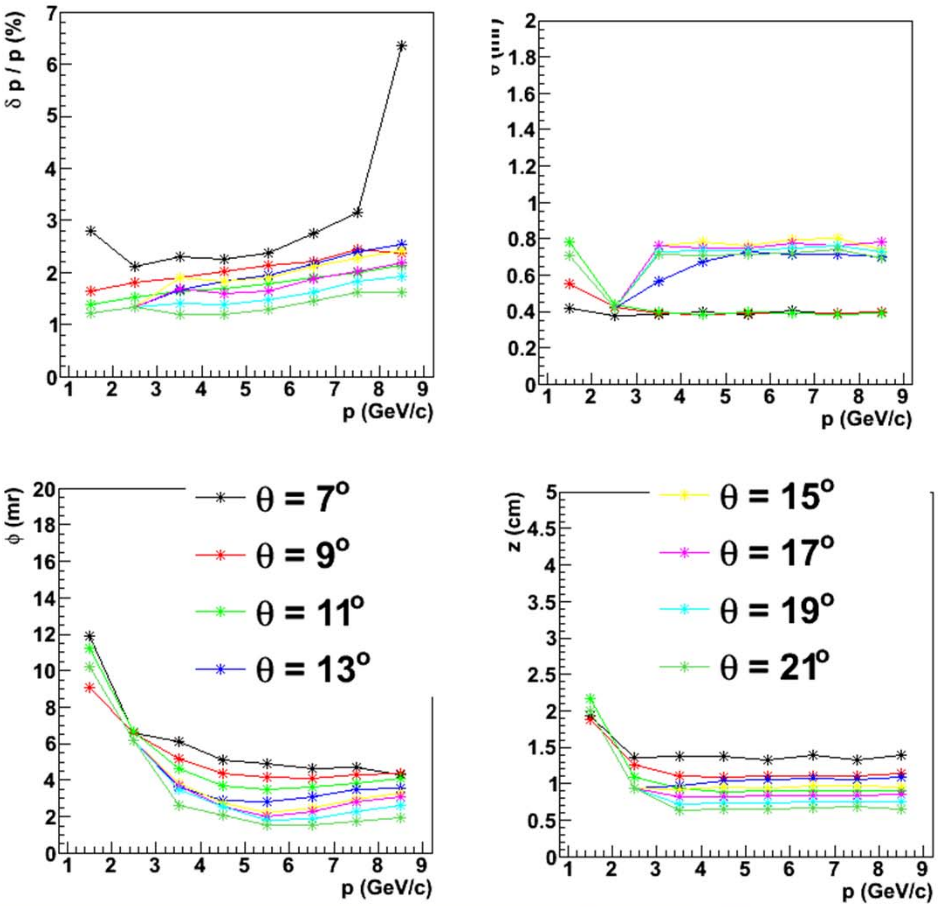
Update on Resolution

Summary of Table

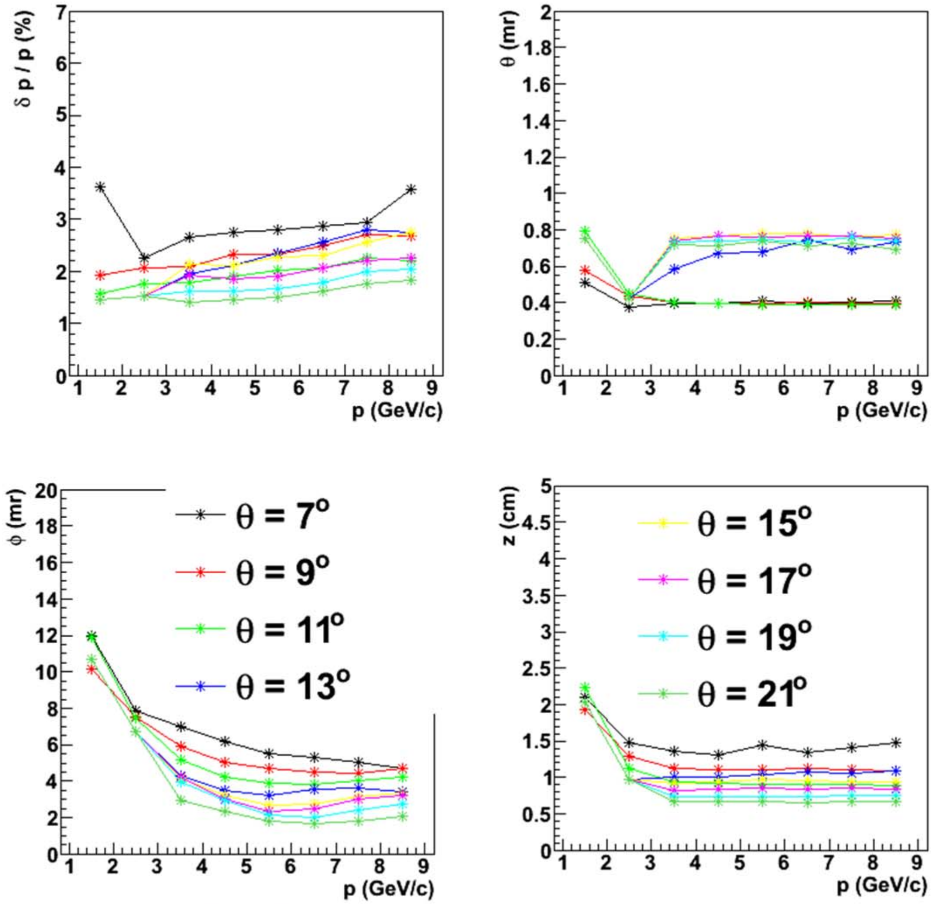
	Radiation Length	Polar Angle	Azimuthal Angle	Momentum
1 mm Cell Wall + 2 m Air before SoLID	3.7% @ 15 degrees	1.6 mr	6.2 mr	Resulting ~0.2% @ 4.4 GeV calibration
No GEM position resolution	N/A	0.1 mr	3 mr	0.5%
100 um + 10 degree readout	N/A	0.6 mr	6mr	1.8%
Additional Multiple scattering	0.76% per layer Equivalent to 170 um smearing	0.6 mr	6mr	2%

Comparison of No Multiple Scattering vs. Multiple Scattering

Without Multiple Scattering



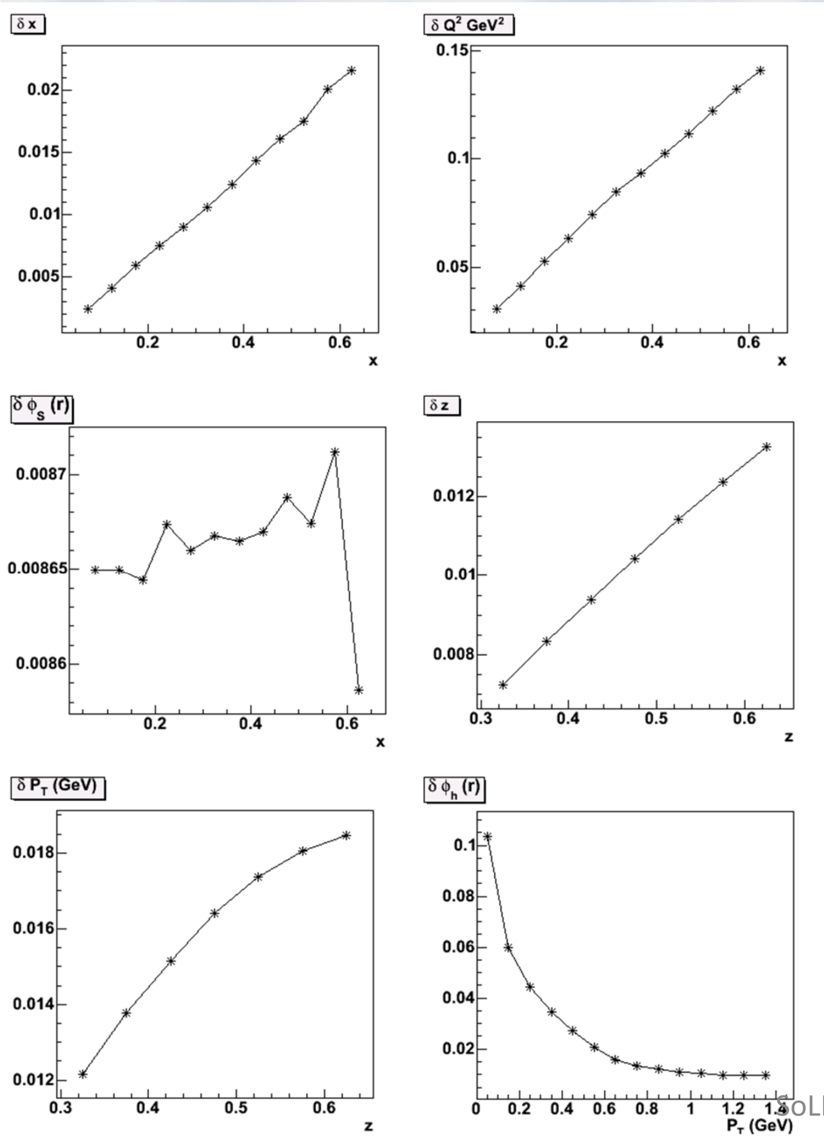
With Multiple Scattering



The effect due to multiple scattering is negligible.

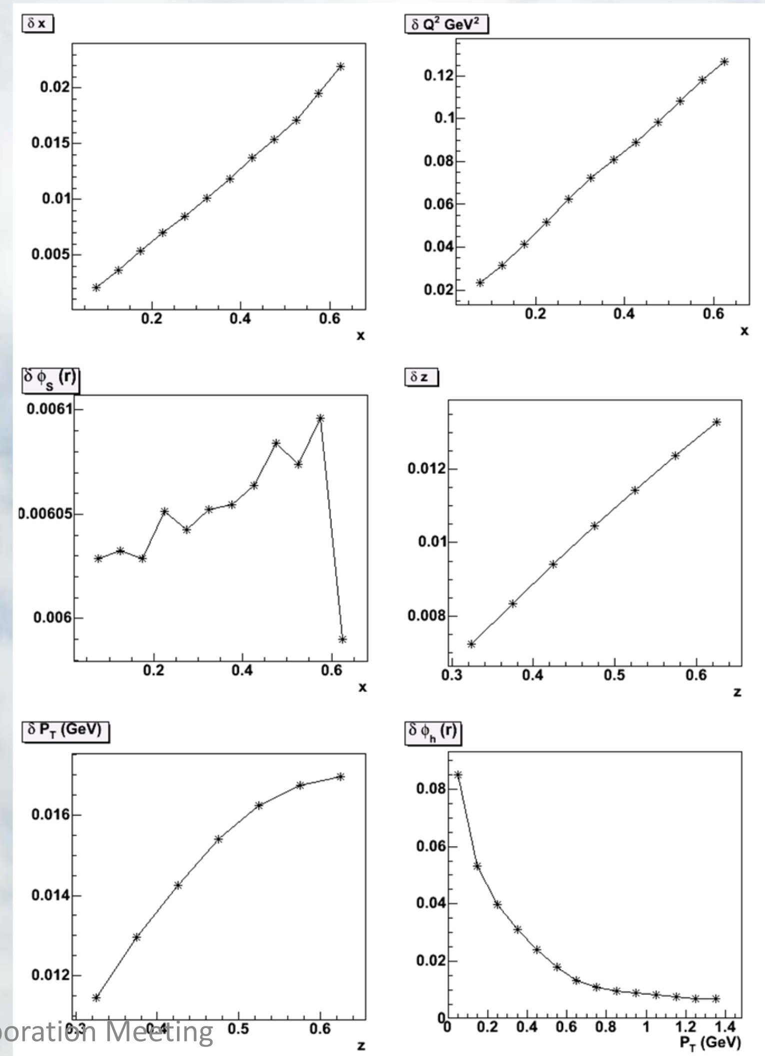
Impact on High Level Variables

With Target In



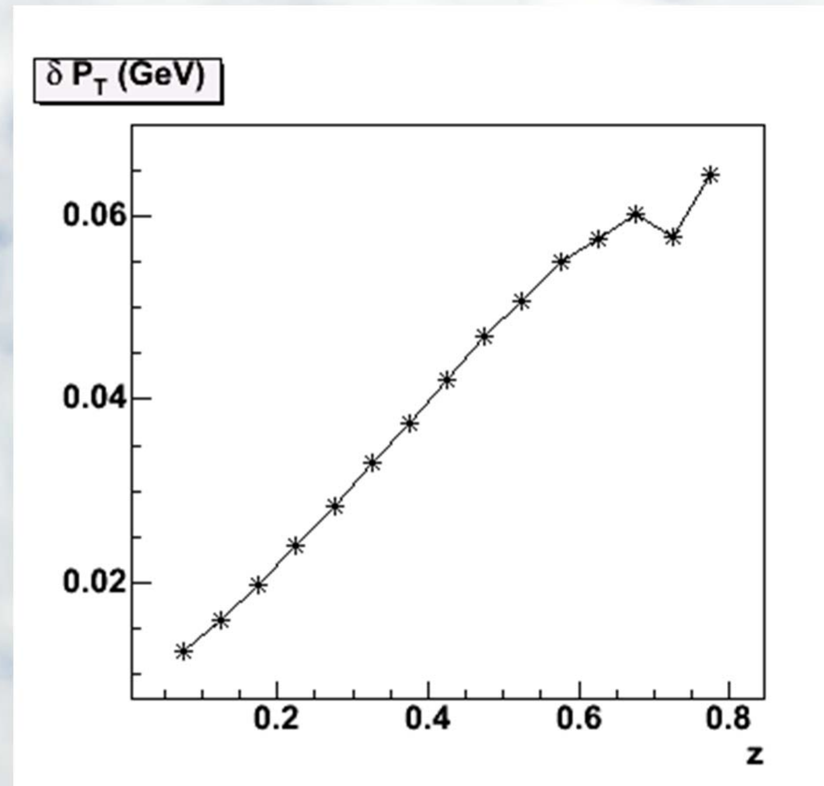
Impact are acceptable.

Intrinsic resolution from SoLID



Issue I: About P_T resolution

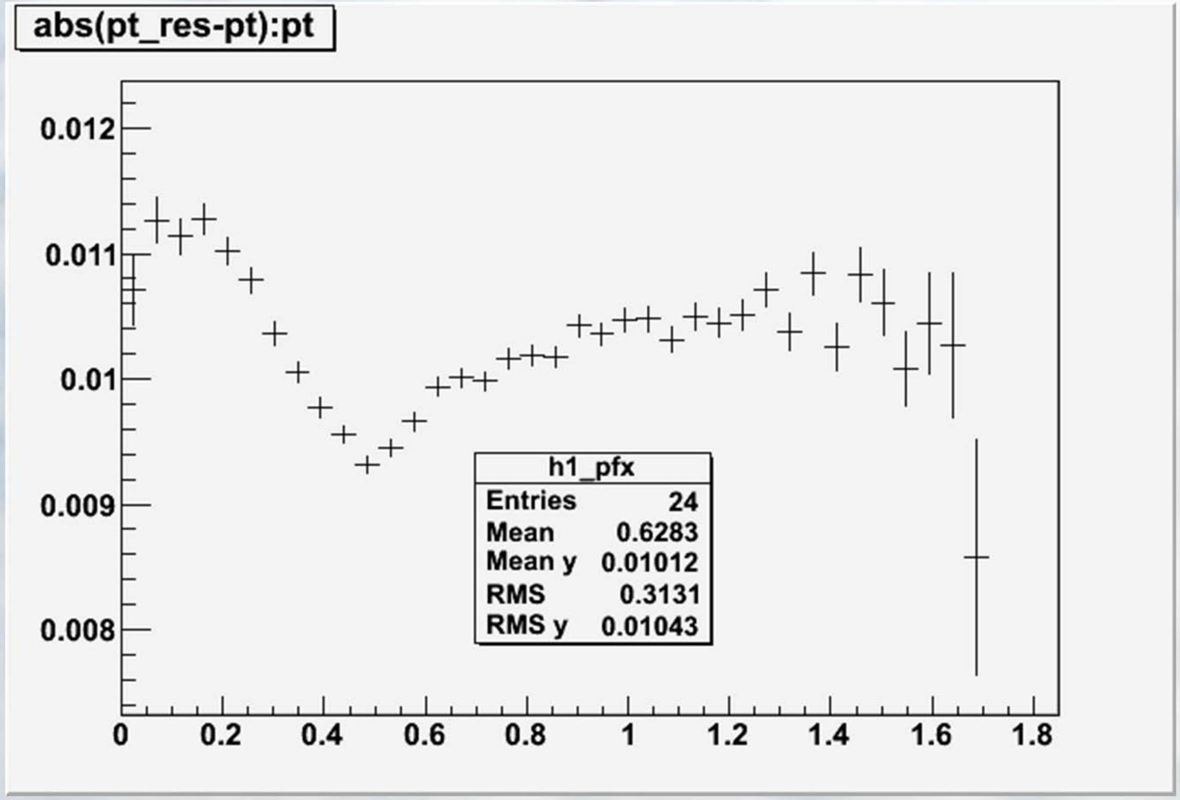
- The cross section falls as $\exp(-bP_T^2)$
- The Asymmetry expect to increase as P_T (for Collins and Sivers)
- PT resolution increase vs. z (shown right)
- What about PT resolution vs. PT? What about PT2?



PT res. Vs. PT

As shown in the right plot, resolution in PT does not have strong dependence with PT.

X-axis: PT
Y-axis: mean of abs(pt_smeared – pt_true)



PT2 resolution vs. PT

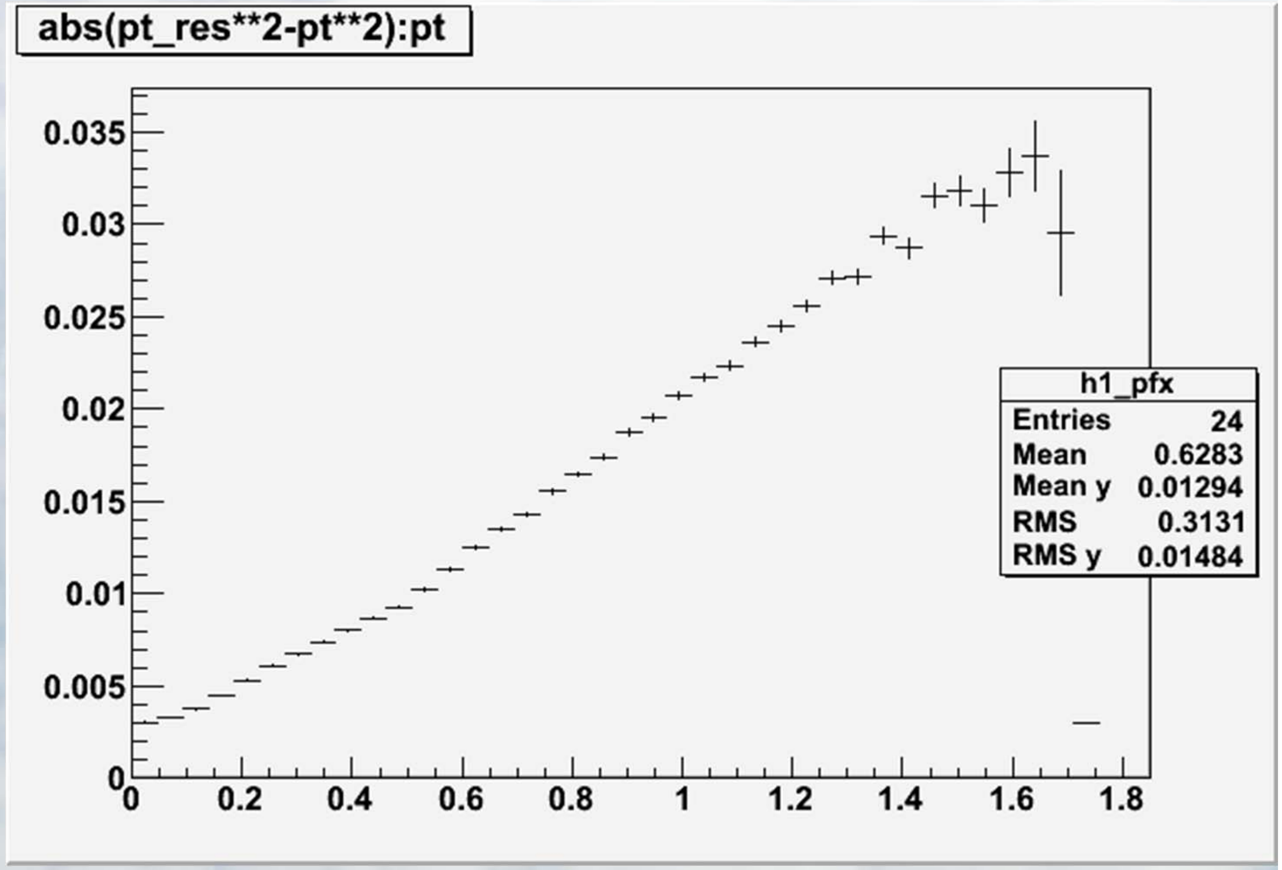
Resolution in PT2 does have strong dependence with PT, because

$$\delta P_T^2 = 2 P_T \delta P_T$$

The resolution is suppressed at small PT for PT^2.

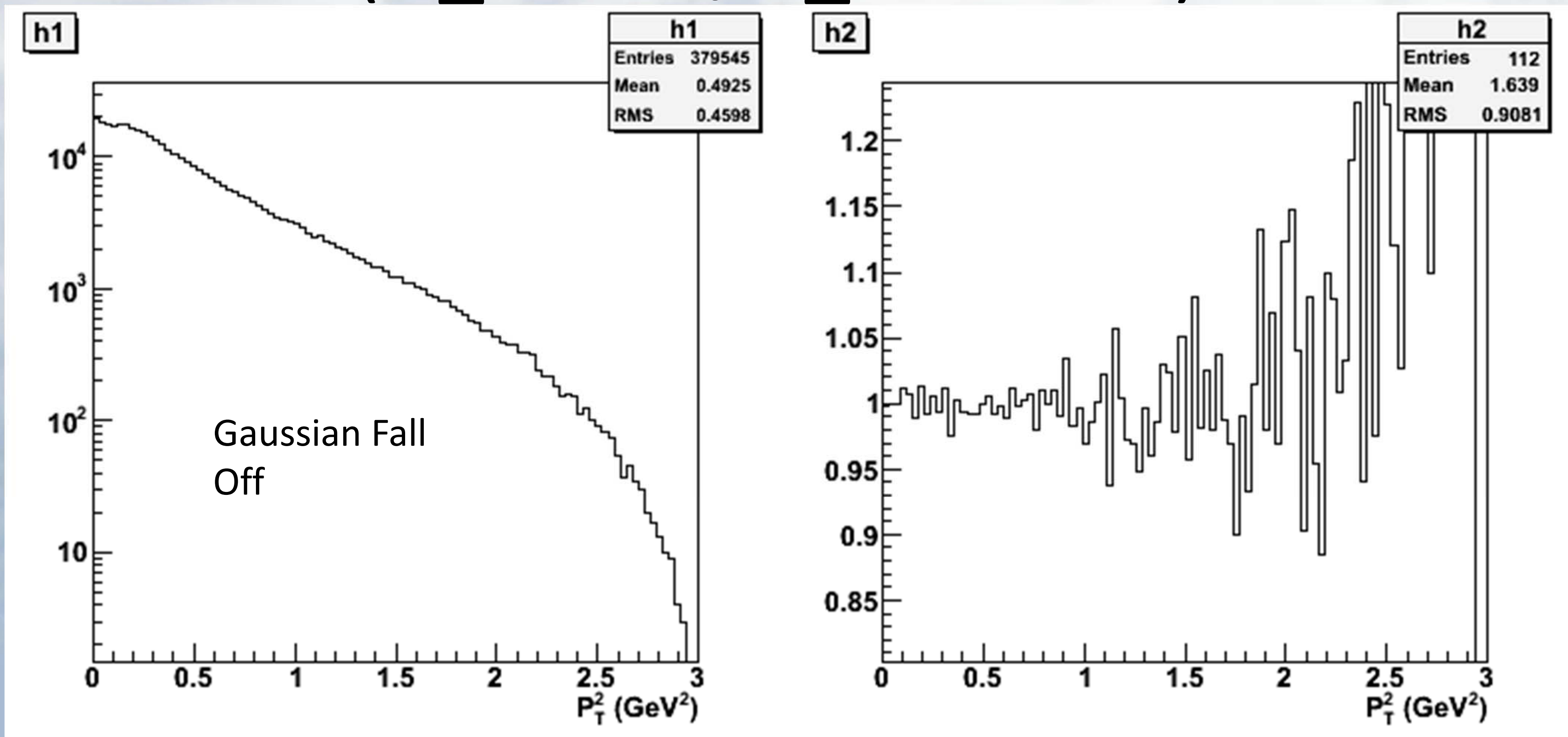
Therefore, although the cross section drops fast at small PT, the effect of PT resolution is still small.

X-axis: PT
Y-axis: mean of difference in smeared pt2 and true pt2.



Note: this is the simulated PT2 and smeared PT2 (smearing the individual momentum and angles for electrons and pions.

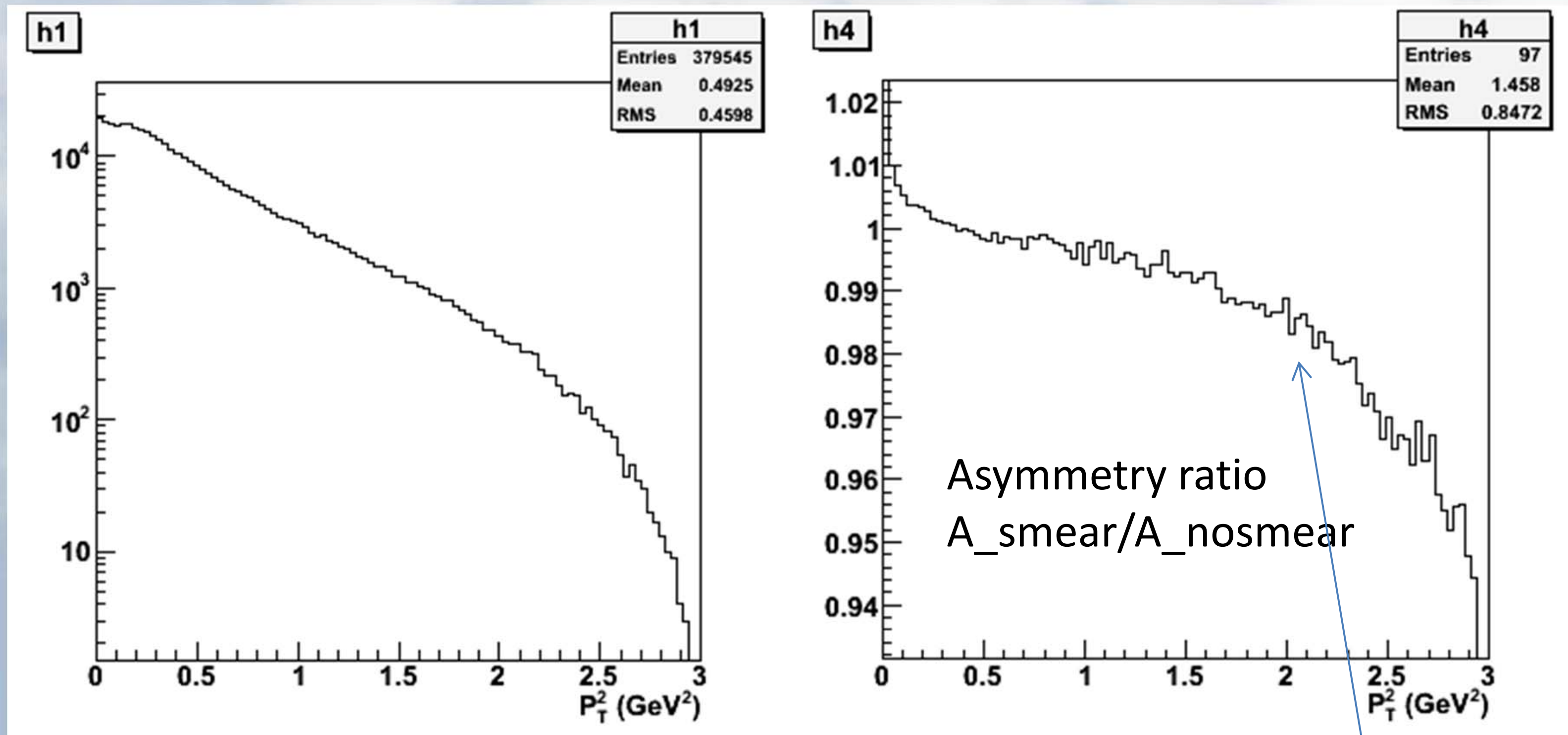
Simulation Results of (N_smear/N_nosmear)



Here are the real full simulation with smearing on angles and momentum at GEM configuration of 175 um, 12 degrees readout. Same results as the toy model that we had before. A small visible effect is shown on the right.

Estimate of Impact

- Assume asymmetry is proportional to PT, then we can calculate the asymmetry ratio of two cases, (with smearing and without smearing).



As shown, the effect in asymmetry is smaller than 1% in the region of interests,

PV Pion Asymmetry

Neutral Current

- The Asymmetry for PVDIS electron is about 100 ppm * Q^2 ~ Q^2/Mz^2
- So one also expected that for the single pion production, the asymmetry is about Q^2/Mz^2
- Then the central question is to calculate the average Q^2 for the eletro-pion production.

For Electro-Pion Production

- One can use equivalent photon flux

$$\frac{d\sigma}{d\Omega_e dP_e} = \Gamma \sigma(\gamma N)$$

$$\Gamma \sim \frac{\alpha}{2\pi^2} \frac{E_e^{'}}{E_e} \frac{\nu}{Q^2}$$

- The average Q2 can be obtained as

$$< Q^2 >= \frac{\int Q^2 \Gamma d\Omega_e dP_e}{\int \Gamma d\Omega_e dP_e}$$

- Here, we assume the same photon-N scattering total cross section.

Simulation

- Uniform sample electron momentum and solid angle.
- Make sure the kinematics permit a pion to reach the desired kinematics:
  - 12.9 degrees @ 3.66 GeV
- Weighted by Gamma Flux and calculate average Q2.
  - Obtained <Q2> ~ 0.264 ~ 32 ppm
  - Assuming a 120 pm in PVDIS electron for Q2 @ 1 GeV^2.

Additional Contribution for Real Photon Production

- The internal radiation has already been taken into account in previous formula.
- The external radiation is 0.5 * 15 / 866 ~0.87%
  – Comparing to ~2% effective radiation length, we will have additional dilution of 32 ppm * 2 / (2+0.87) ~ 22 ppm
- For 40 cm long target, the external radiation length is about 2.3%, so the dilution is about 0.5.
- Same method can be used to estimate the asymmetry of PV Pion for SoLID-PVDIS.