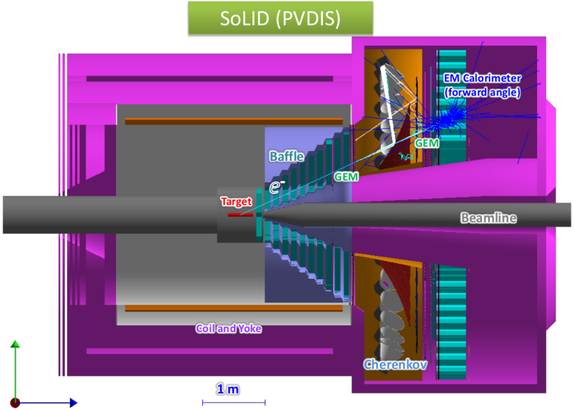
Tracking for SoLID experiment

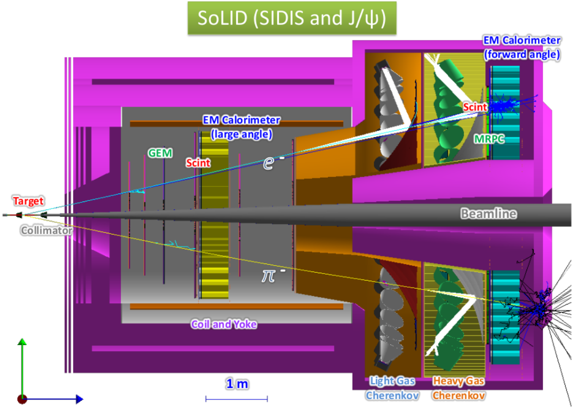
Zhongling Ji
in collaboration with
Zhiwen Zhao, Weizhi Xiong, Chao Peng, and Jian-Ping Chen
For the SoLID Collaboration Meeting 2025

Syracuse University

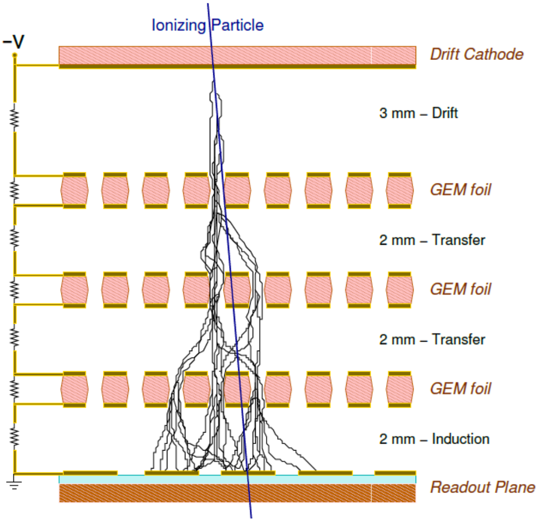
July 7, 2025

SoLID detector for PVDIS and SIDIS



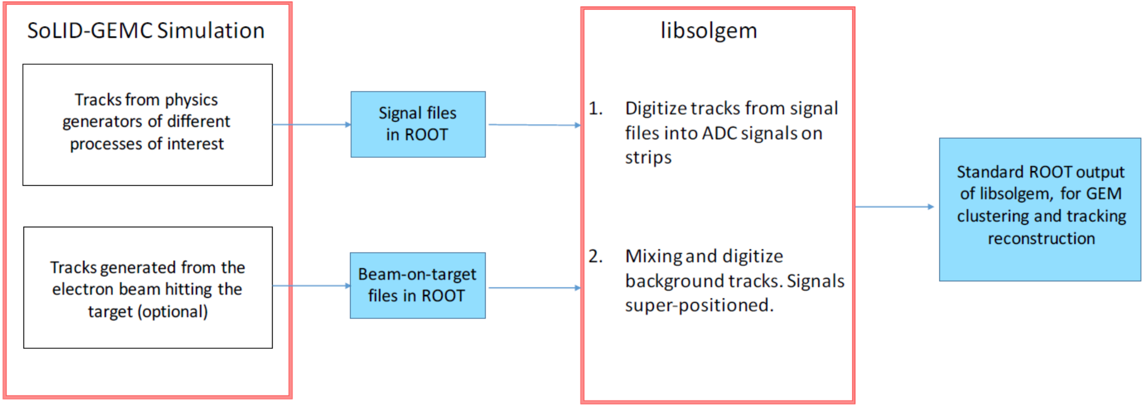


Principle of GEM detector

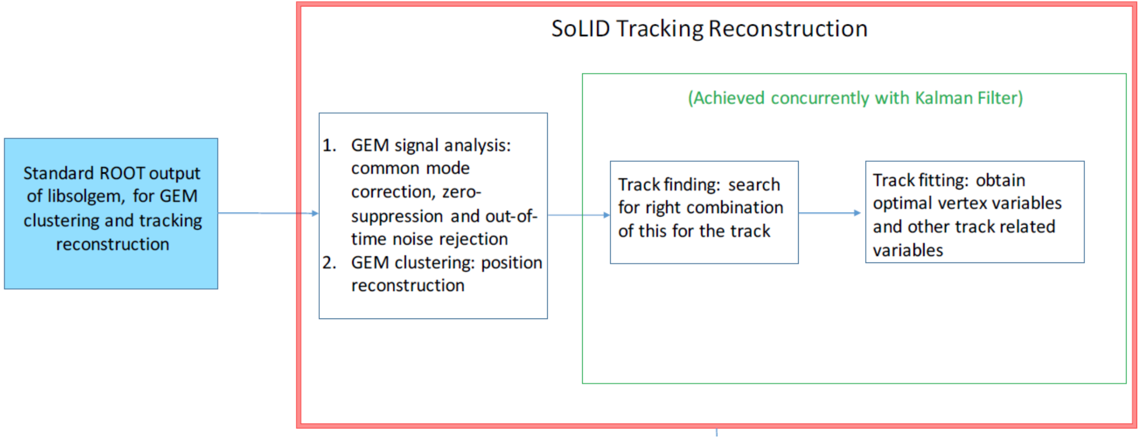


Standalone implementation

Mixing with background

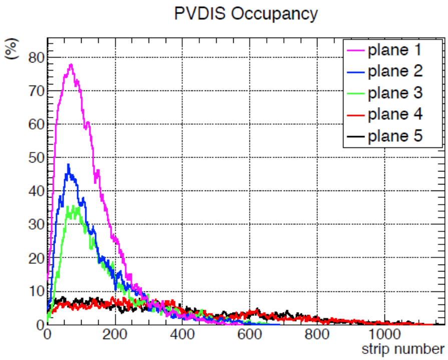


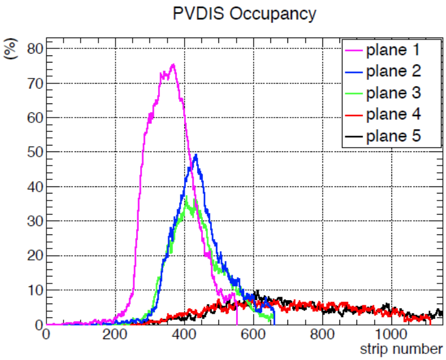
Data flow for tracking reconstruction



GEM occupancy

- 10^{37} $cm^{-2}s^{-1}$ for SIDIS-^{3}He and J/ψ.
- 10^{39} $cm^{-2}s^{-1}$ for PVDIS.
- Occupancy by strips in the PVDIS configuration:

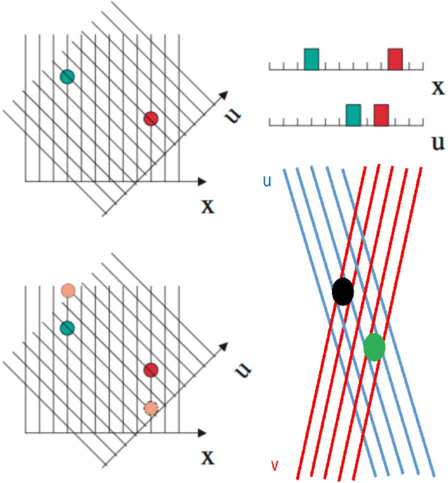




Hit multiplicity and false combinations

	GEM 1	GEM 2	GEM 3	GEM 4	GEM 5	GEM 6
Occupancy	2.5%	9.7%	4.1%	2.6%	2.0%	1.5%
Hit Multi.	420	5048	1860	1136	460	424

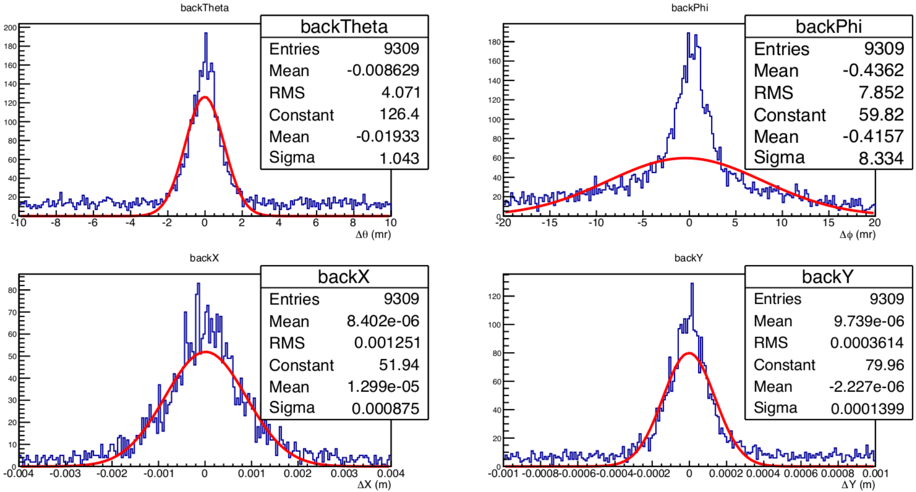
- Hit multiplicity for SIDIS:
  - High multiplicity after threshold cut.
  - Number will go up for 20 GEM sectors (currently 30).
  - Large amount of combinations $\sim 10^3$.
- Reject false combinations:
  - Out of physical intersection.
  - Charge asymmetry: $A = \frac{q_u - q_v}{q_u + q_v}$.



Track finding and fitting

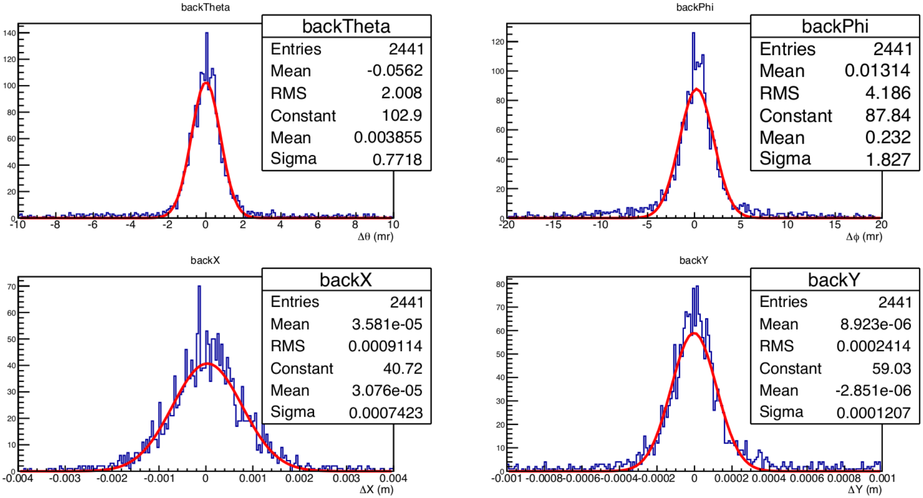
- Track finding:
  - Assume 100% beam-on-target background.
  - Use the calorimeter to start track finding.
  - Assume that there is only one high energy hit on the calorimeter.
  - Use hits on downstream detectors as the hit density there is much lower.
- Track fitting:
  - Use Kalman filter (KF) to look for hits along its way of propagation.
  - Allow only one missing hit.
  - Use a special hit from beam position monitor (BPM).
- Final selection rules:
  - Propagate to the calorimeter to check the agreement.
  - Compare with the energy measurement from the calorimeter.
  - For tracks that share a common hit, only the track with the largest number of hits are kept.

Resolutions of kinematic variables in PVDIS



Differences between reco and truth in PVDIS. No cut.

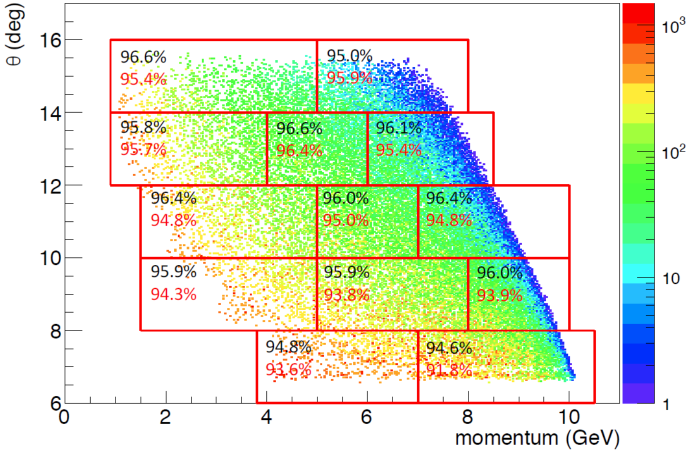
Resolutions of kinematic variables in PVDIS



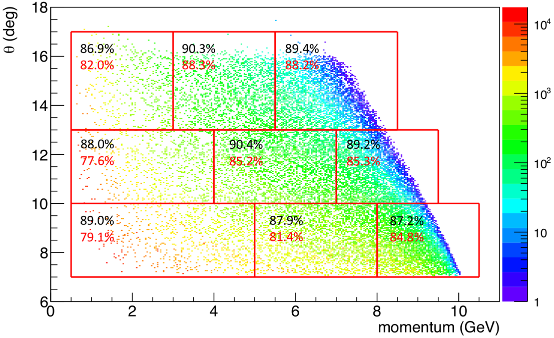
Require hit on every GEM tracker and $\chi^2/\text{ndf} < 8$.

Tracking efficiency and accuracy in SIDIS-^{3}He

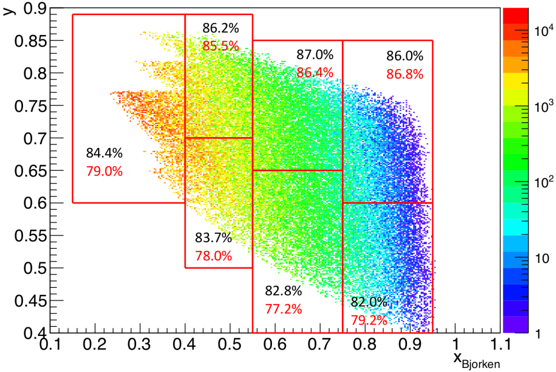
- Hits of an accurate track are all from hits of the MC particle.
- Track finding efficiency (black numbers) and accuracy (red numbers) for SIDIS-^{3}He.



Tracking efficiency and accuracy in J/ψ and PVDIS

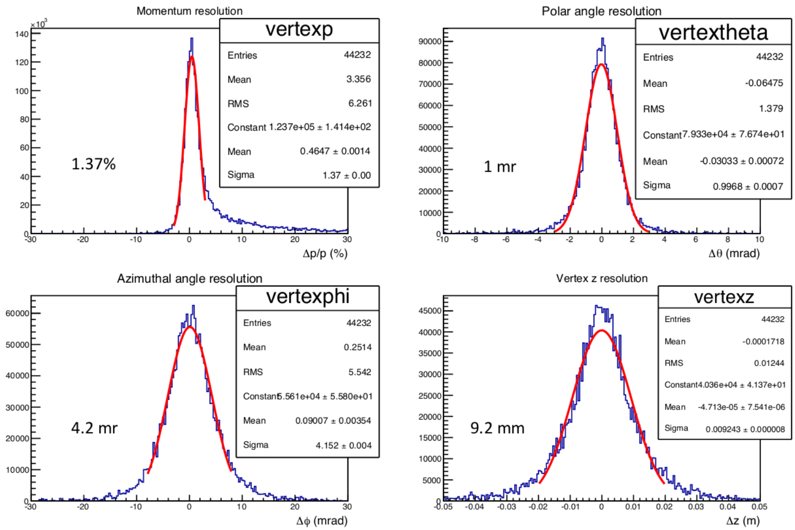


SIDIS-J/ψ



PVDIS

Resolutions in SIDIS at forward angle



ACTS implementation

Purposes and procedures

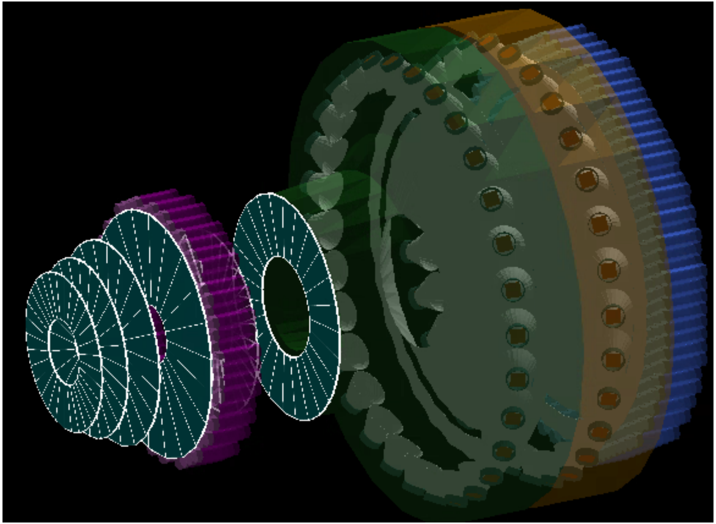
- Purposes:
  - ✔ Signal level ACTS tracking (single electron with SIDIS configuration) and comparison with the standalone results
  - ✖ Realistic ACTS tracking (signal + background for SIDIS/PVDIS configuration) and comparison with the standalone results
- Procedures:
  - ✔ Verify the geometries for SIDIS tracking
  - ✔ Implement the ACTS tracking geometry in the solid_dd4hep repository and run single electron simulations
    - Use the existing algorithms in EICrecon for digitization (add resolution smearing and efficiency) and track seeding/finding/fitting

GEM geometry

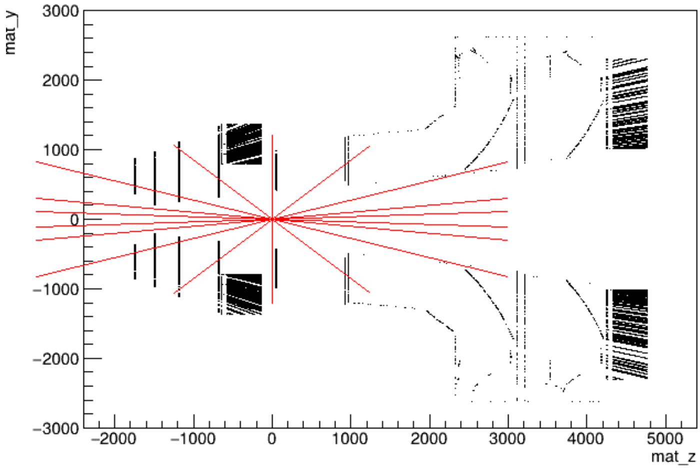
- Use trapezoidal structure to create the GEM disks.
- Build the material map for each tracking layer.

Location	Z (cm)	R^{needed}_{min} (cm)	R^{needed}_{max} (cm)
1	-175	36	87
2	-150	21	98
3	-119	25	112
4	-68	32	135
5	5	42	100
6	92	55	123

DD4hep implementation in SIDIS



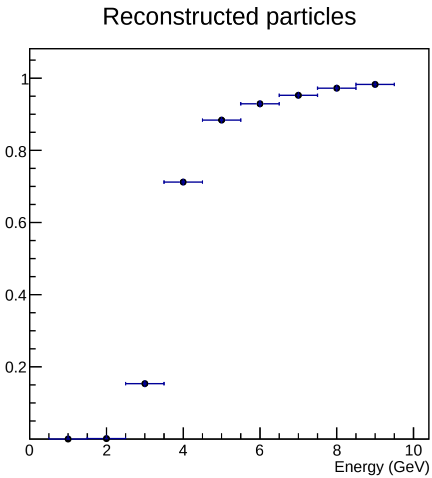
Material map in SIDIS

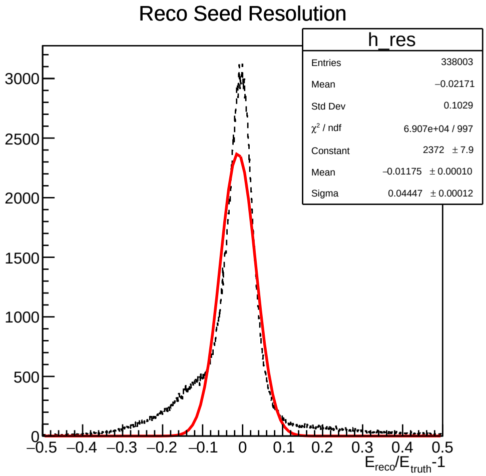


Tracking performance

- Only use the GEM detector, not use ECal.
- Use a uniform magnetic field for seeding, but a non-uniform field in DD4hep.
- Tracks need to have 3 hits in GEM to be considered.
- Compare reconstructed or truth seeds.

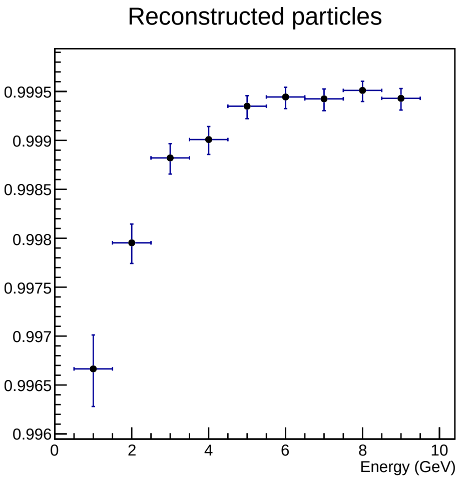
Tracking performance: reconstructed seed

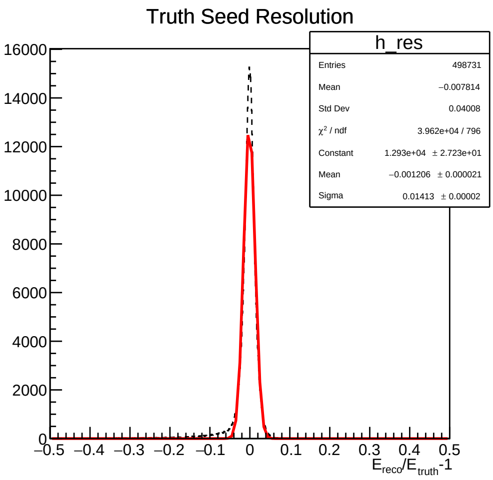




Reco seeding does not perform well.

Tracking performance: truth seed





Truth seeding gives good performance. Track fitting works well.

Future plans

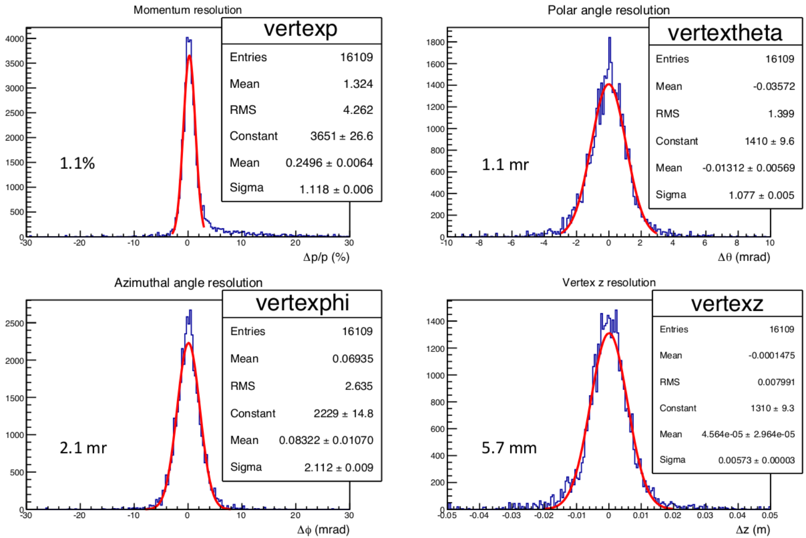
- Use ECal for seeding.
- Use a non-uniform magnetic field in seeding.
- Add background particles.
- Add PVDIS configuration in DD4hep and solid_recon.
- Use machine learning to improve efficiency.

Summary

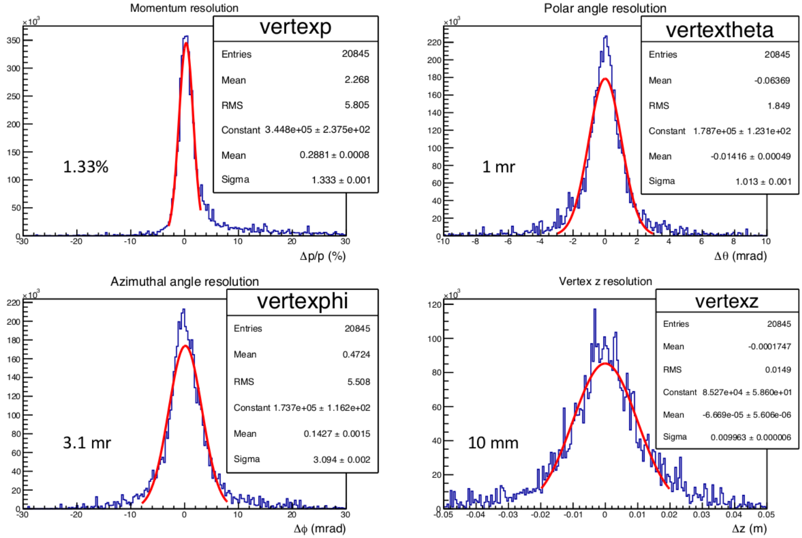
- High occupancy in GEM tracker brings difficulty in track reconstructions.
- Large multiplicity leads a lot of false combinations in UV hits.
- How to use ACTS to help on
    - Denoising at high background?
    - Finding missing planes?
    - Implementing AI/ML for tracking finding and fitting?

Backup

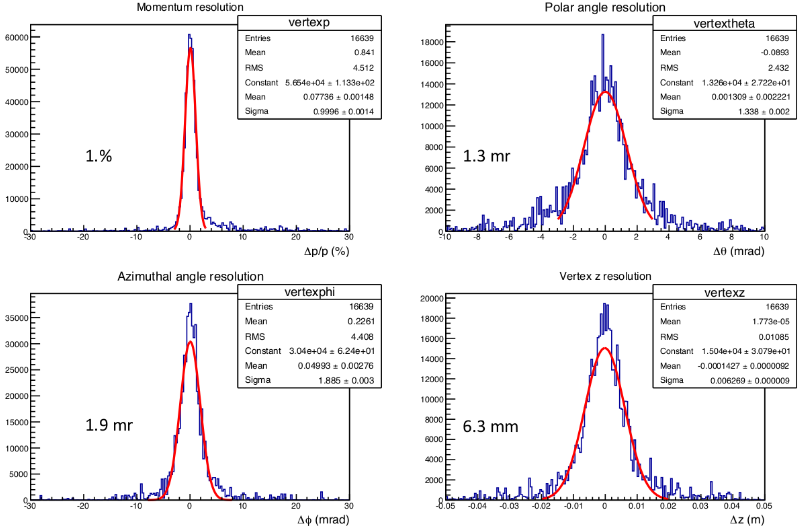
Resolutions in SIDIS at large angle



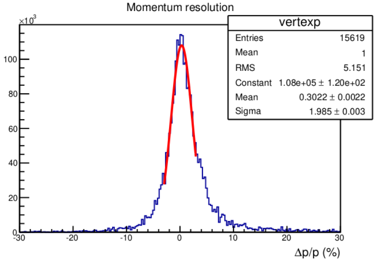
Resolutions in J/ψ at forward angle

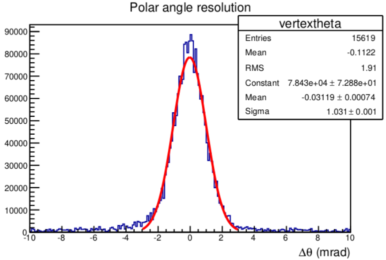


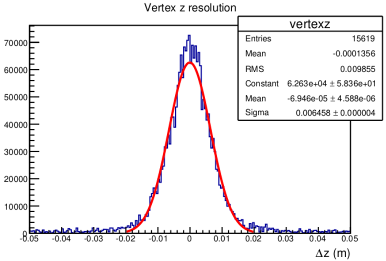
Resolutions in J/ψ at large angle



Resolutions in PVDIS







Benchmark for KF propagation in PVDIS

- x position between prediction and measurement in KF propagation.
- Blue arrows indicate the direction of track finding.
- Large propagation distance leads to large error in Δx_2.