D^0 Reconstruction

A. Alikhanyan National Science Laboratory

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Artur Hoghmrtsyan, Aram Movsisyan, Hrachya Marukyan

Physics Goal and Strategy

Overall Objective

- Extract Gluon Sivers Asymmetry via charm production in DIS
- Use $D^0 \to K^-\pi^+$ as a clean probe of charm dynamics
- Access gluon transverse momentum distributions

Analysis Strategy

- Reconstruct D^0 candidates from kaon-pion pairs
- Select DIS events: $Q^2 > 1$ GeV^2, $W > 5$ GeV, $y < 0.95$
- Match Reco to MC particles to validate candidates
- Bin in azimuthal and kinematic variables for asymmetry extraction

File Source and Used Branches

DIS Dataset Location (minQ2=1)

`root://dtn-eic.jlab.org//volatile/eic/EPIC/RECO/25.03.1 /epic_craterlake/DIS/NC/18x275/minQ2=1/`

DIS Dataset Location (minQ2=10)

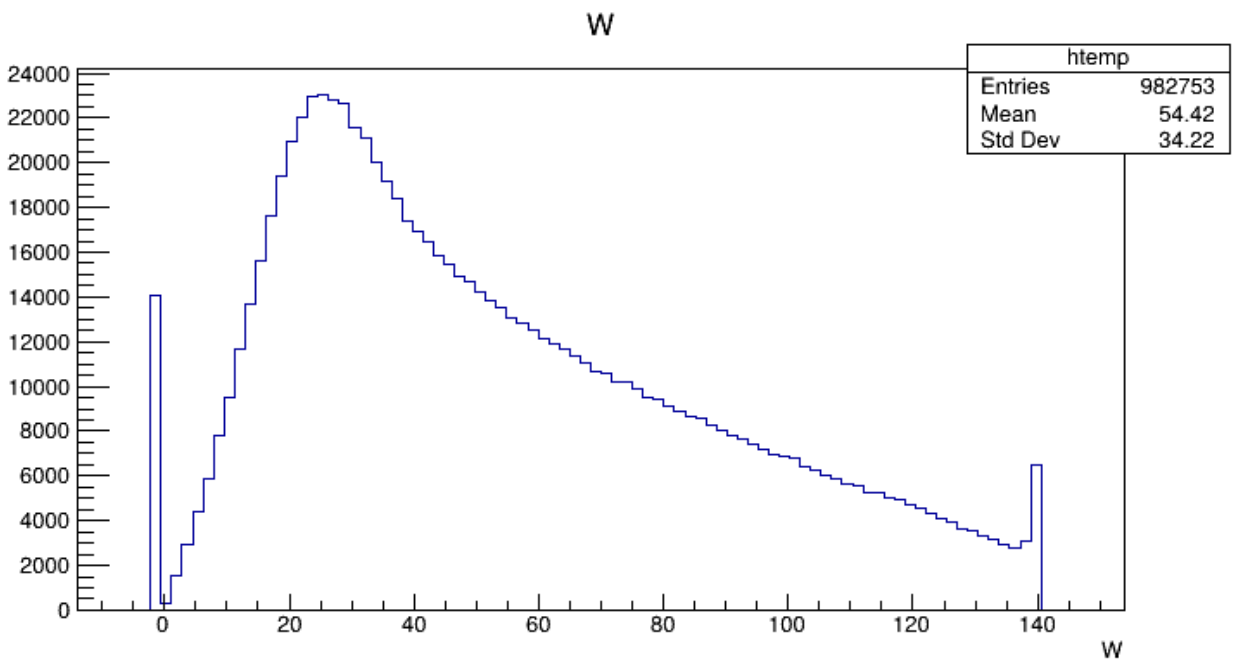
`root://dtn-eic.jlab.org//volatile/eic/EPIC/RECO/25.03.1 /epic_craterlake/DIS/NC/18x275/minQ2=10/`

Used Branches

- `MCParticles`
- `ReconstructedChargedParticles`
- `ReconstructedChargedParticleAssociations`
- `InclusiveKinematicsTruth` (previously Electron)

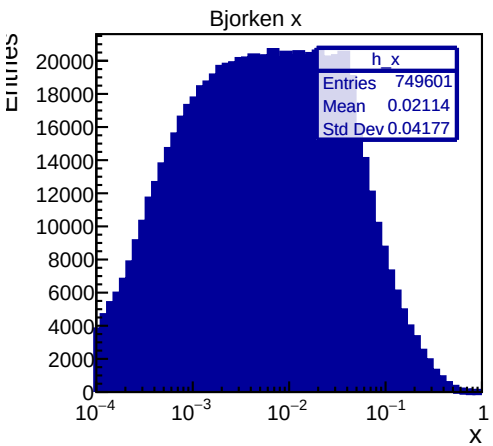
D^0 Event Statistics Summary

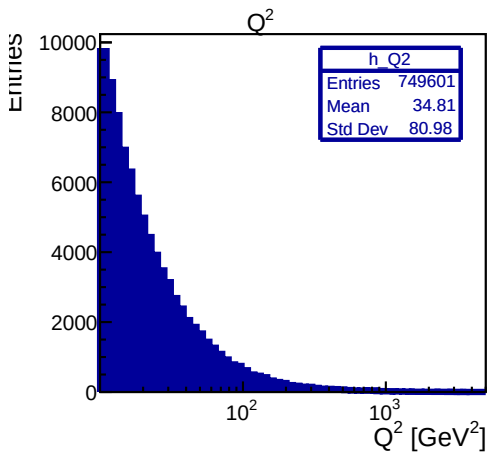
Decay Channel	DIS Events after Cuts	$\pi^- K^+$ Pairs	Generated D^0
Electron Branch (minQ2=10)	858,182	637,474	15,378
Truth Branch (minQ2=10)	948,165	671,671	16,015
Truth Branch (minQ2=1)	749,601	298,185	4,110

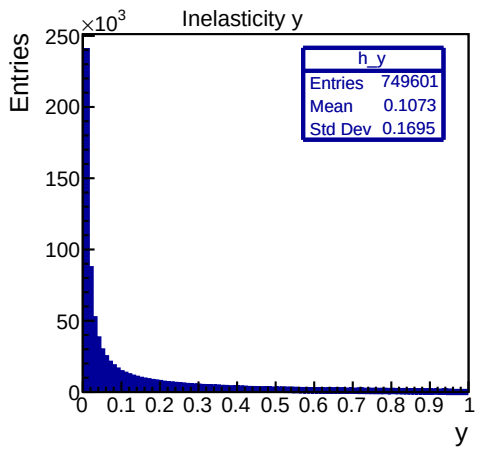


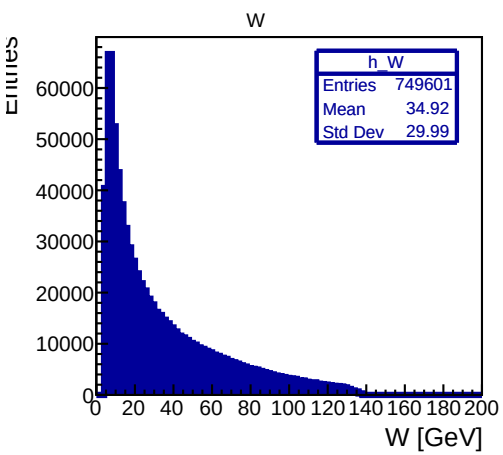
W distribution with `InclusiveKinematicsElectron` branch.

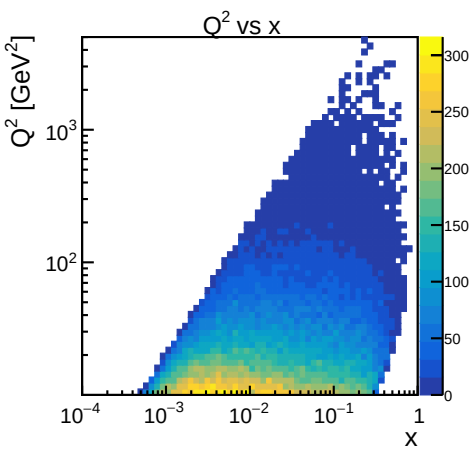
SIDIS Kinematics (minQ2=1)



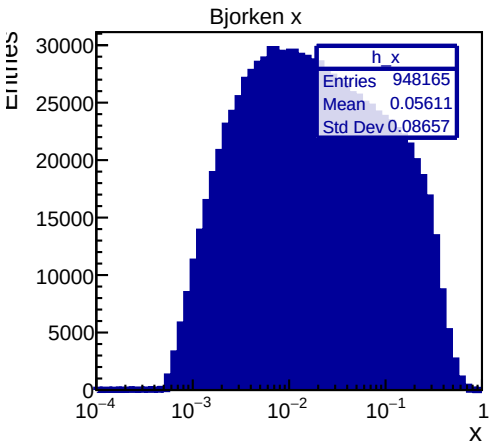


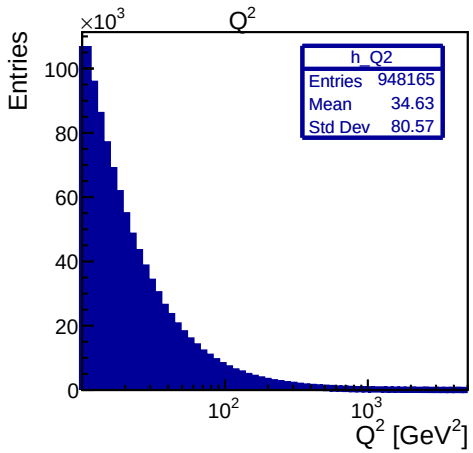


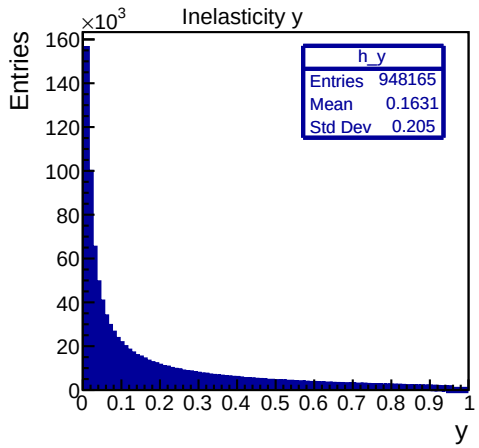


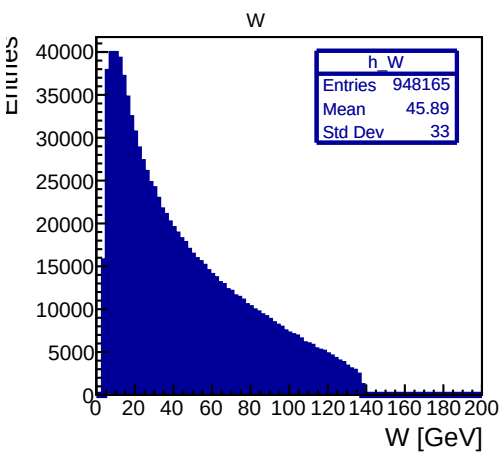


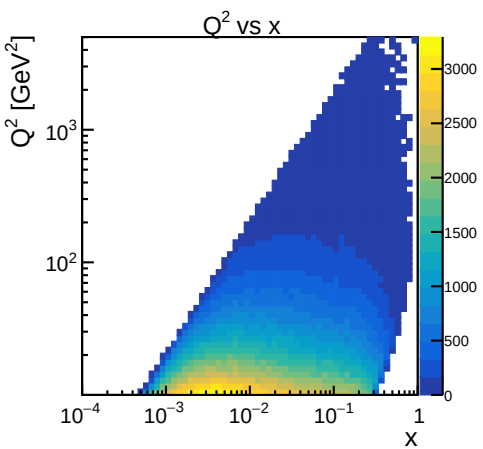
SIDIS Kinematics (minQ2=10)











Injecting Asymmetries via Spin-Dependent Weights

Procedure for Toy Model Asymmetry

- Assign random spin state (up or down) to each event
- Apply spin-dependent weight:

$$\text{Spin Up:} \quad w = 1 + A \cdot \cos(\phi_{\text{true}})$$
$$\text{Spin Down:} \quad w = 1 + A \cdot \cos(\phi_{\text{true}} + \pi)$$

- Fill histograms of reconstructed azimuthal angle ϕ_{rec} with these weights
- Extract asymmetry as:

$$A_{\text{rec}}(\phi) = \frac{N_{\uparrow}(\phi) - N_{\downarrow}(\phi)}{N_{\uparrow}(\phi) + N_{\downarrow}(\phi)}$$

- Fit the result with a cosine to check reconstruction performance

Which ϕ do we use?

What `D0.Phi()` is (Used now)

- `TLorentzVector::Phi()` $\Rightarrow$ **lab-frame azimuth** around the beam axis
- Good for basic checks, but **not** the SIDIS/TMD azimuth used in asymmetry formulas

Asymmetry uses a plane–plane angle (Next step)

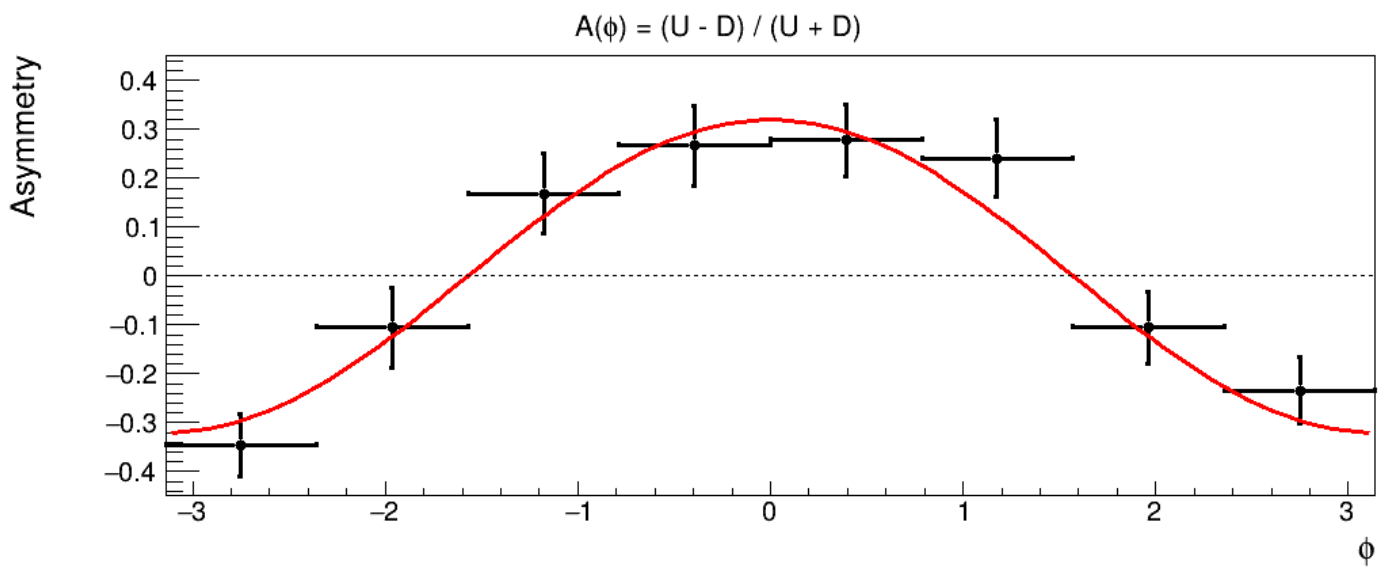
- Define the virtual photon: $\vec{q} = \vec{\ell} - \vec{\ell'}$ (incoming e minus scattered e)
- **Lepton plane**: spanned by $(\vec{\ell}, \vec{q})$ **Hadron plane**: spanned by $(\vec{q}, \vec{P}_{D^0})$
- The SIDIS azimuth ϕ is the signed angle between these planes, measured **around** $\vec{q}$

$$\phi = \operatorname{atan2}\left(\hat{q} \cdot (\vec{n}_\ell \times \vec{n}_h),\ \vec{n}_\ell \cdot \vec{n}_h\right), \quad \vec{n}_\ell = \frac{\vec{\ell} \times \vec{q}}{|\vec{\ell} \times \vec{q}|}, \quad \vec{n}_h = \frac{\vec{q} \times \vec{P}_{D^0}}{|\vec{q} \times \vec{P}_{D^0}|}$$

Asymmetry Fit with 8 ϕ Bins

Configuration

- Number of azimuthal bins: **8** (tested 16; some bins underpopulated)



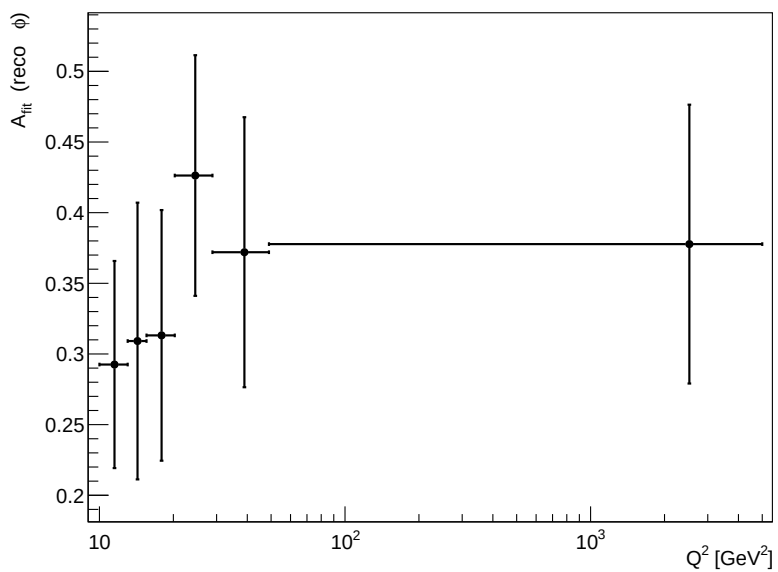
Example: asymmetry vs. ϕ (8 bins) with cosine fit overlay.

Fit result: $A = 0.320021 \pm 0.0360831$

Asymmetry vs. Q^2 (Binning & Fits)

Q^2-bin edges (analysis)

```
Q2Edges = { 10, 13, 15, 20, 28, 49, 5000 }
```



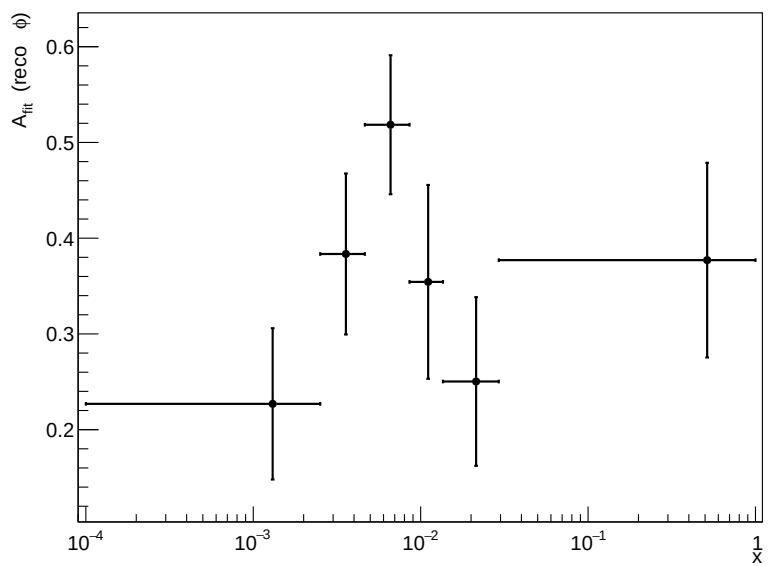
Extracted amplitude vs. Q^2.

Notes: Constant injected amplitude $\mathbf{A = 0.3}$. Binning shown is *not final* and will be **finalized**.

Asymmetry vs. x (Binning & Fits)

x-bin edges (analysis)

```
xEdges = { 0.0001, 0.0025, 0.0046, 0.0085, 0.0135, 0.0292, 1.0 }
```



Extracted amplitude vs. x.

Notes: Constant injected amplitude $\mathbf{A = 0.3}$. Binning shown is *not final* and will be **finalized**.