SIDIS kinematic reconstruction with ML

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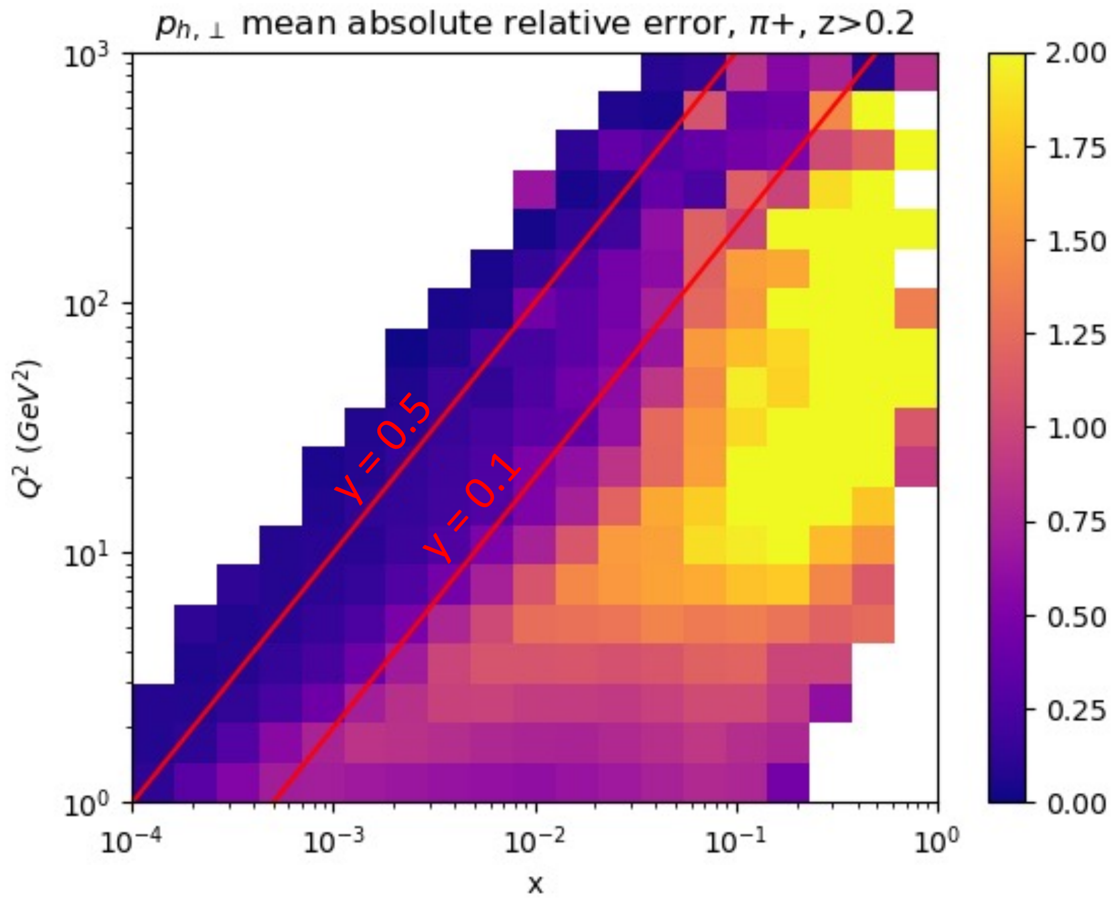
SIDIS kinematic reconstruction at EIC/Introduction

- SIDIS reconstruction centered around reconstruction of virtual photon four-momentum, q
  - Past fixed target/HERA analyses: from scattered lepton, $q = l - l'$
- Studies for YR, ATHENA/ECCE, etc. show electron performs very poorly at low-y
- Anselm introduced method reconstructing q using hadronic final state (HFS) in the YR
- I previously presented results of ML SIDIS kinematic reconstruction on ATHENA full sim. (DIS proceedings, https://inspirehep.net/literature/2158328)
- We are now hoping to publish these two methods demonstrated on the ePIC full simulation

SIDIS kinematics at ePIC

- Known problem since yellow report studies: electron method performance drops off significantly at low-y
  - Low-y : small electron energy loss
- Tail of very poorly reconstructed events cut off here (require absolute error of pT < 1000%)

ePIC 23.07.1, 18x275
Electron method



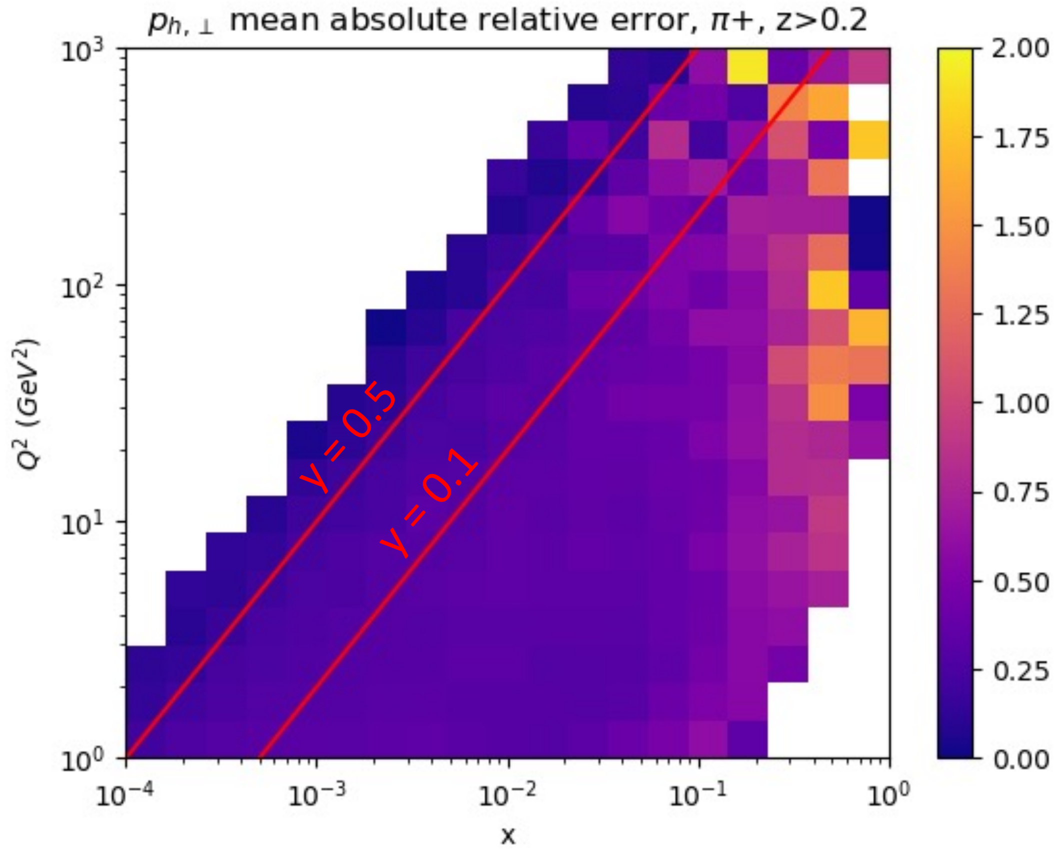
First hadronic final state method

- Introduced in YR by Anselm: extending HERA kinematic reconstruction methods for (x,Q2,y) to constraining q

$$\left.\begin{array}{l} (q_x, q_y) = \text{HFS } \vec{p_T} \parallel \text{electron } \vec{p_T}, \\ Q^2 = -q^2, \\ y = \frac{P.q}{P.k} \end{array}\right\} (q_x, q_y, q_z, q_t)$$

- Q2, y taken from HFS or hybrid reconstruction method (double-angle, Jacquet-Blondel, etc.)
- Transverse recoil from electron or HFS
- Quadratic formula to solve for remaining two components of q

ePIC 23.07.1, 18x275
Quadratic method, DA + electron recoil



Machine learning approach

- Utilizing Particle Flow Networks (PFN, arXiv:1810.05165)
  - Deep sets architecture: operate on unordered, permutation invariant set
  - First demonstrated on jet tagging tasks at LHC
- Training PFN to directly reconstruct q
  - Unordered set: All HFS particles
  - Also utilize electron information
  - First shown on ATHENA full simulation (DIS 2022: https://inspirehep.net/literature/2158328, and AI4EIC 2022)

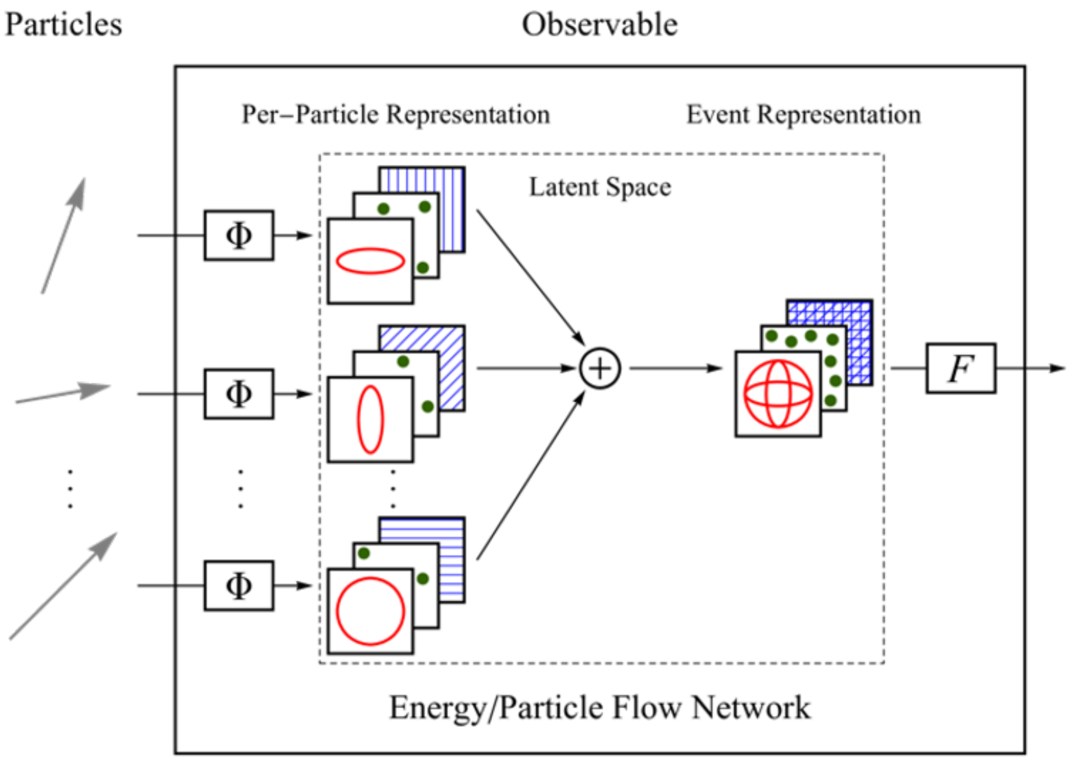
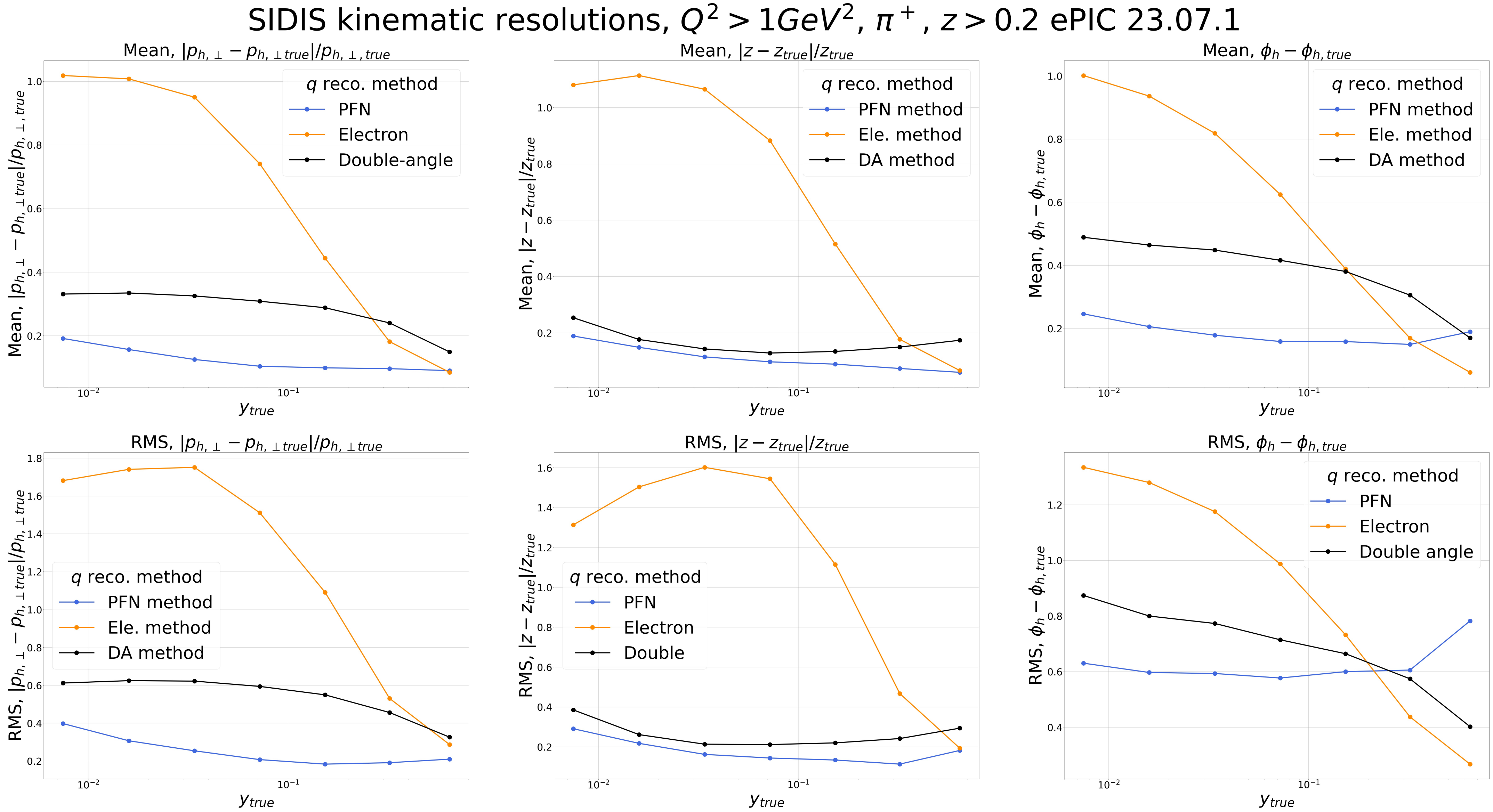


Diagram of Particle Flow Network, from arXiv:1810.05165

Training details

- Utilized 2.6 million events from ePIC 23.07.1 campaign (Q^2 > 1 GeV^2 sample)
  - 1.6 million used for training, remaining 1 million used for validation
  - Using MC truth matching to get scattered electron (what is currently done in epic-analysis)
  - Using tracks only for charged particles and calorimeter for neutrals
- HFS particle information input to first layers: p_x, p_y, p_z, E
- Electron information input in latent space: $q_{x,ele}$, $q_{y,ele}$, $q_{z,ele}$, $q_{E,ele}$
- Inclusive DIS information input to latent space: -log10(x), log10(Q2) from DA, Σ, electron methods
- Two networks trained: one reconstructing (q_x, q_y), and one reconstructing (q_z, q_E)

Results, ePIC full simulation 23.07.1



Conclusions

- Constraining (q_z,q_t) using (y,Q^2) from hybrid HFS-electron methods significantly improves reconstruction at low-y
- Training Particle Flow Networks to reconstruct virtual photon four momentum using scattered electron and all HFS particles outperforms other method across all y
- We would like to submit a write-up of these methods and results on ePIC 23.07.1 for publication (JINST or similar)