UNIVERSITY OF BIRMINGHAM | SCHOOL OF PHYSICS AND ASTRONOMY

Kinematic Fitting Update

L. Gonella, P. G. Jones, S. Maple, P. R. Newman

Outline

- Performance as last shown
- Asymmetric Gaussian parametrisation of HFS
- More + Longer Markov Chains
- Extending to lower Q^2

Kinematic Fitting for DIS

- Only **need** 2 quantities to obtain **x, y, Q^2**

- Using measured quantities $\vec{D} = \{E_e, \theta_e, \delta_h, p_{t,h}\}$ a kinematic fit can extract additional information: $\vec{\lambda} = \{x, y, E_\gamma\}$

E_γ is energy of an ISR photon

- For kinematic fit, can use a **likelihood** function based on knowledge of the detector resolutions:

Likelihood

$$P(\vec{D}|\vec{\lambda}) \propto \frac{1}{\sqrt{2\pi}\sigma_E} e^{-\frac{(E_e - E_e^\lambda)^2}{2\sigma_E^2}} \frac{1}{\sqrt{2\pi}\sigma_\theta} e^{-\frac{(\theta_e - \theta_e^\lambda)^2}{2\sigma_\theta^2}} \frac{1}{\sqrt{2\pi}\sigma_{\delta_h}} e^{-\frac{(\delta_h - \delta_h^\lambda)^2}{2\sigma_{\delta_h}^2}} \frac{1}{\sqrt{2\pi}\sigma_{P_{T,h}}} e^{-\frac{(P_{T,h} - P_{T,h}^\lambda)^2}{2\sigma_{P_{T,h}}^2}}$$

- Note: above quantities taken to be uncorrelated → Correlations between E_e, θ_e and δ_h, $p_{t,h}$ will later need to be taken into account

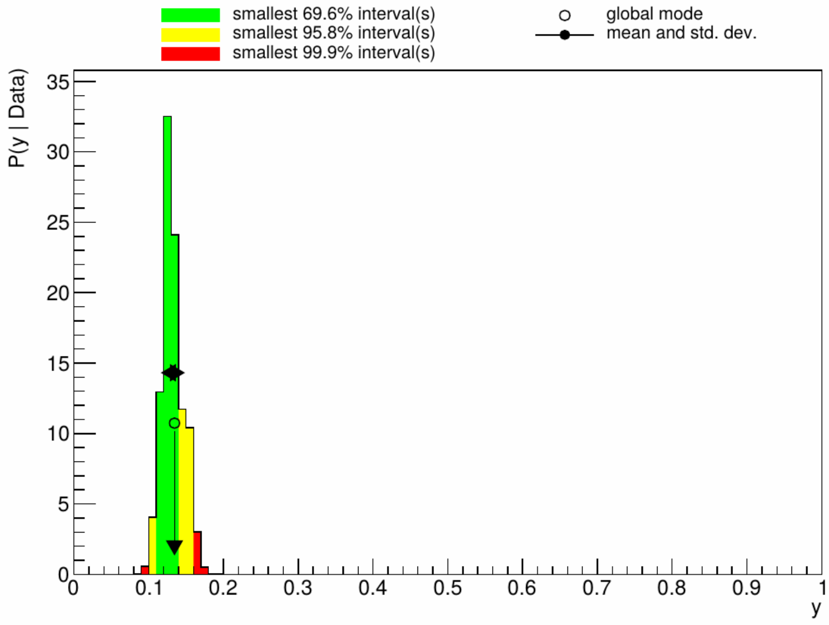
Kinematic Fitting for DIS – A Bayesian Approach

- A Bayesian method can be applied in which basic features of the DIS cross section are encoded as a **prior**:

Prior

$$P_o(\overrightarrow{\lambda}) = \frac{1+(1-y)^2}{x^3y^2}\frac{[1+(1-E_\gamma/A)^2]}{E_\gamma/A}$$

- Use "Bayesian analysis toolkit" to calculate most probable values of set $\vec{\boldsymbol{\lambda}}$ given measured quantities $\vec{\mathbf{D}}$
  - Metropolis algorithm MCMC used to find posterior distribution
  - Values for **x, y, E$_\gamma$** taken from global mode

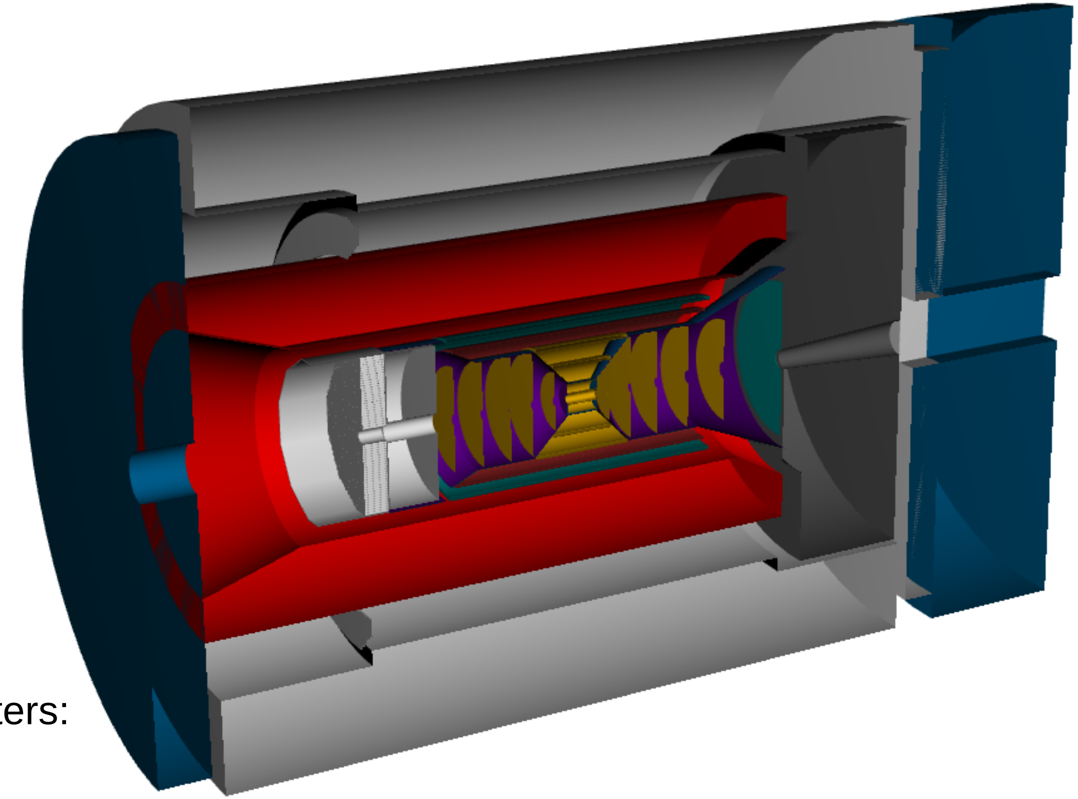


Marginalised **y** distribution for a single DIS event

ePIC Full Simulations

- Full simulation of Neutral Current DIS events in ePIC main detector
  - Pythia8 event generation
    - No QED corrections
    - 18x275 GeV^2 e on p
    - $Q^2 > 100\ GeV^2$
    - Beam effects included

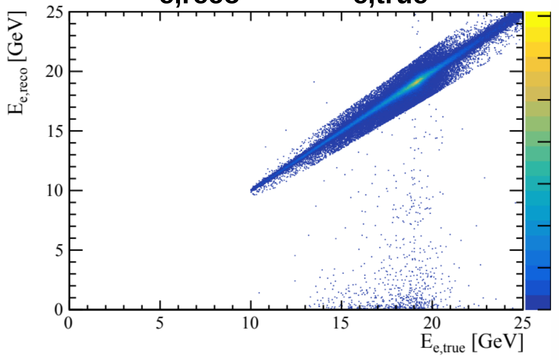
- Event reconstruction in Juggler
  - All charged particles taken from track measurements (ACTS)
  - Track projections matched to calorimeter clusters: → All clusters not associated with a track are added in as a neutral particle!



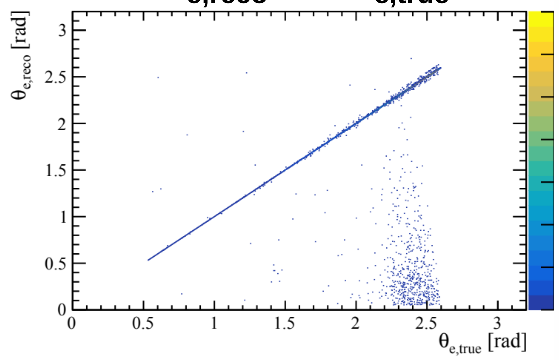
Kinematic Fitting

- Choose events to be processed:
  - Select events where scattered electron is found in barrel with p_T > 10 GeV (makes e^- finding easier)
  - Require y_{true} > 0.01: standard cut → also ensures HFS well measured in hadron endcap

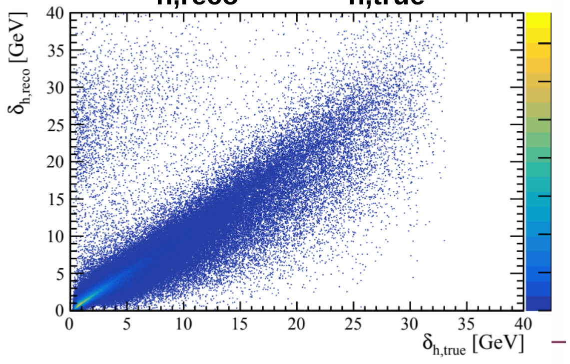
$E_{e,reco}$ vs $E_{e,true}$



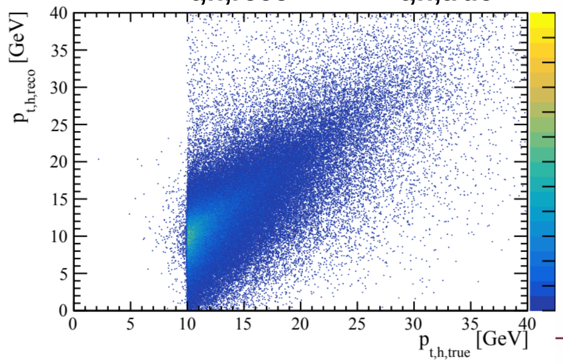
$\theta_{e,reco}$ vs $\theta_{e,true}$



$\delta_{h,reco}$ vs $\delta_{h,true}$



$p_{t,h,reco}$ vs $p_{t,h,true}$



Parametrisation

$\sigma(E_e)/E_e = 0.02E_e \oplus 1.1\%$

$\sigma(\theta_e) = 1.1/E_e \oplus 0.05$

$\sigma(\delta_h) / \delta_h = 25\%$

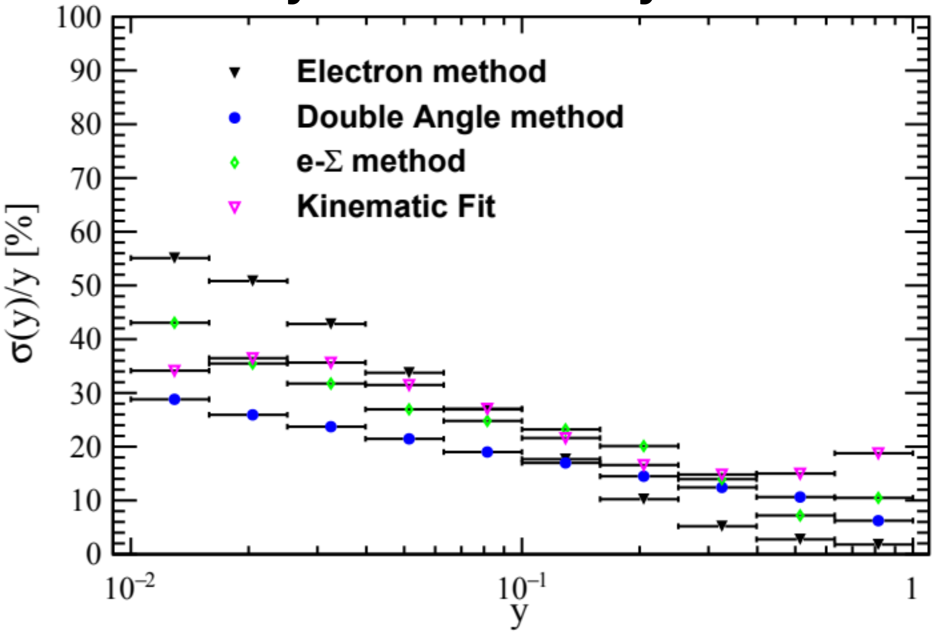
$\sigma(p_{t,h}) / p_{t,h} = 25\%$

Note: Distributions from full simulation are complicated
→ **Detailed studies needed**

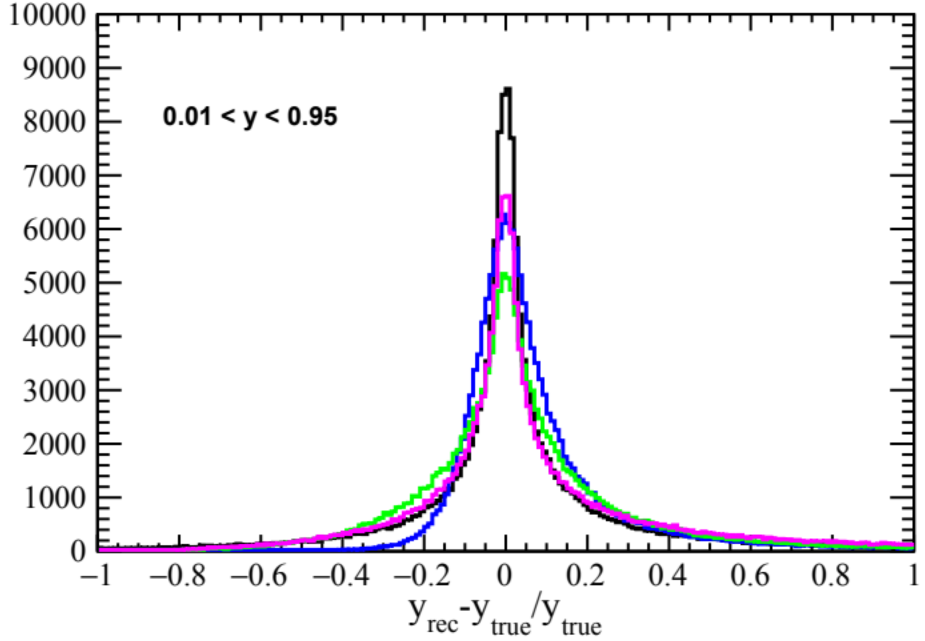
Full Simulations: Fit Results

- Kinematic Fit of fully simulated data gives "okay" performance, at same level as conventional methods, but doesn't win as expected
  - Possible causes: a) Inaccurate parametrisation of detector performance, or b) maximum likelihood value not being properly found… or both

y resolution vs y



y_{rec}-y_{true}/y_{true} for 0.01 < y < 0.95



Asymmetric HFS parametrisation

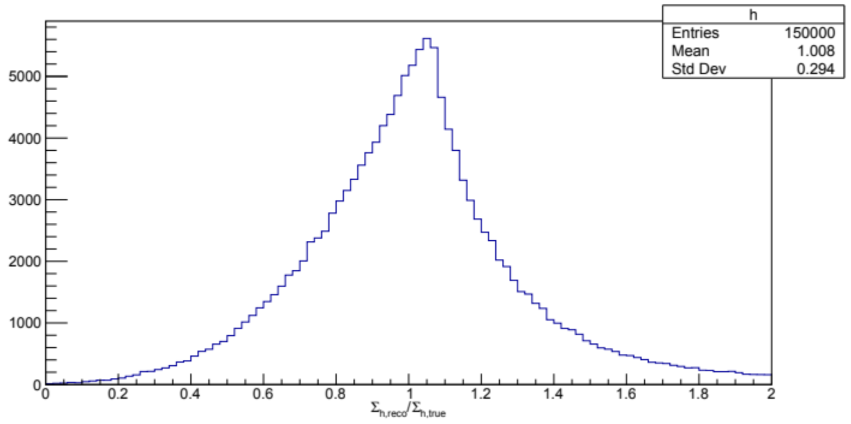
- Reconstructed/True distribution is clearly not a standard gaussian as assumed when calculating likelihood:

$$\frac{1}{\sqrt{2\pi}\sigma_{\delta_h}} e^{-\frac{(\delta_h - \delta_h^{\lambda})^2}{2\sigma^2_{\delta_h}}} \frac{1}{\sqrt{2\pi}\sigma_{P_{T,h}}} e^{-\frac{(P_{T,h} - P^{\lambda}_{T,h})^2}{2\sigma^2_{P_{T,h}}}}$$

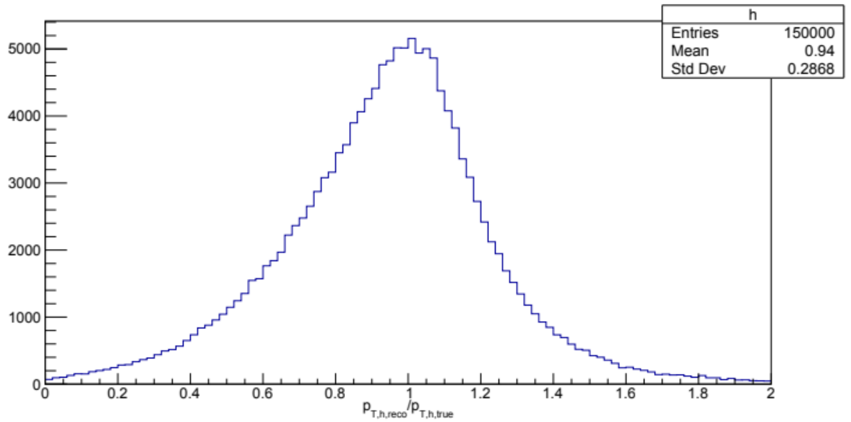
- Use split gaussian fit to calculate likelihood

$\sigma(\delta_h)$ / δ_h = 35% (below) or 25% (above)
$\sigma(p_{t,h})$ / $p_{t,h}$ = 35% (below) or 25% (above)

- Measured E-p_z divided by true

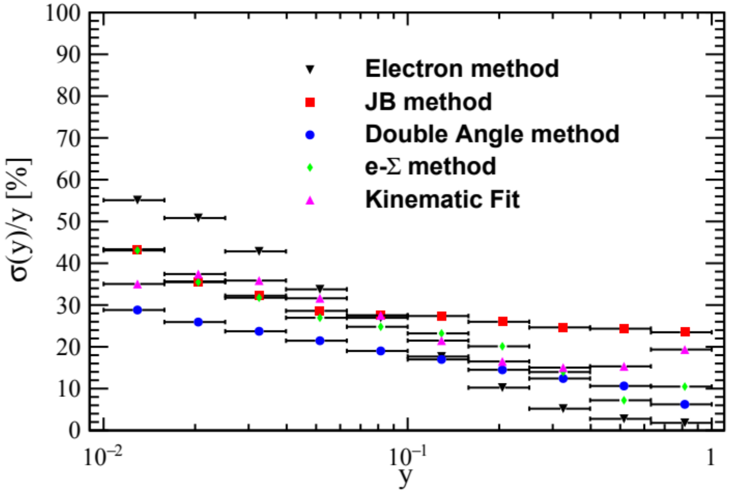


- P_t predicted by fit divided by true



Asymmetric HFS parametrisation

RMS(y) vs y with split gaussian HFS parametrisation

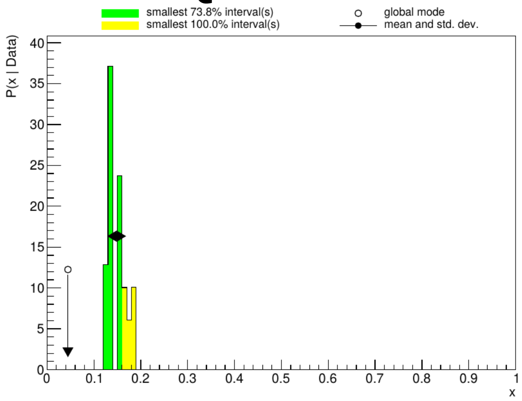


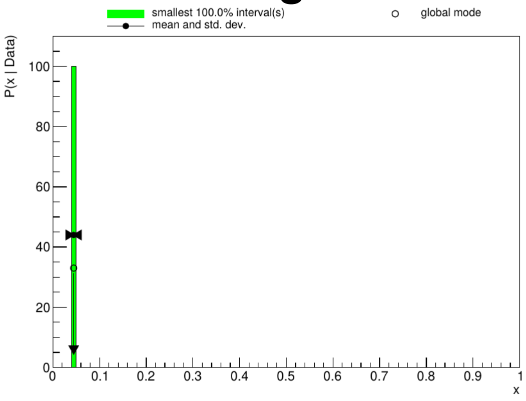
- Performance is essentially the same as before → pursue avenue b) (that the maximum likelihood value isn’t being properly found)

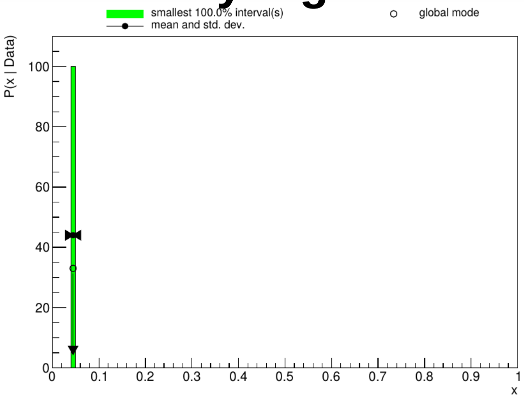
(Marginalised) Posterior distributions vs precision

```
root [3] event_var->Scan("x_true:y_true")
************************************
*    Row   *     x_true *     y_true *
************************************
*        0 * 0.0441935 * 0.5189875 *
************************************
```

Quick	High	Very high

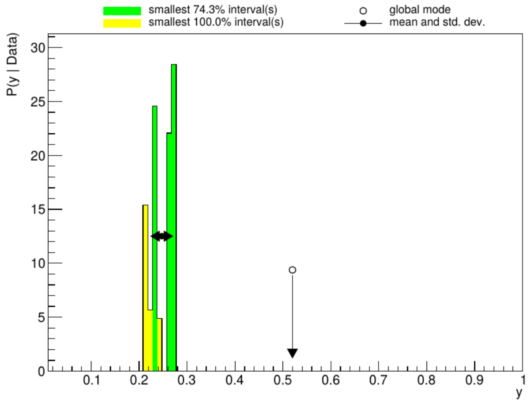


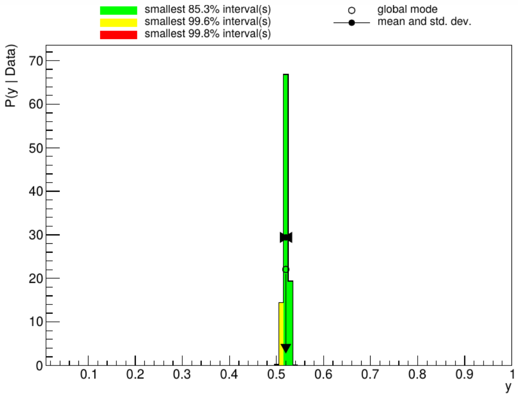


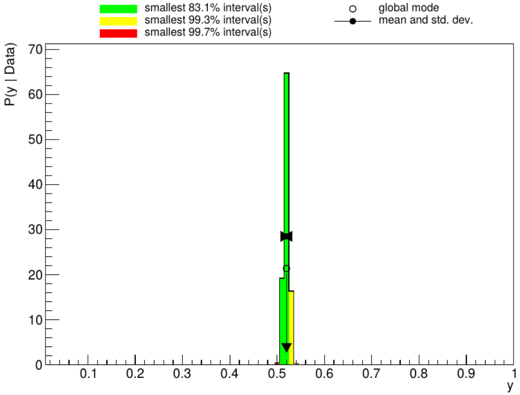


Previous results used Quick setting

High and Very High usually converge







Very High setting runs slowly → High precision is a happy middle ground

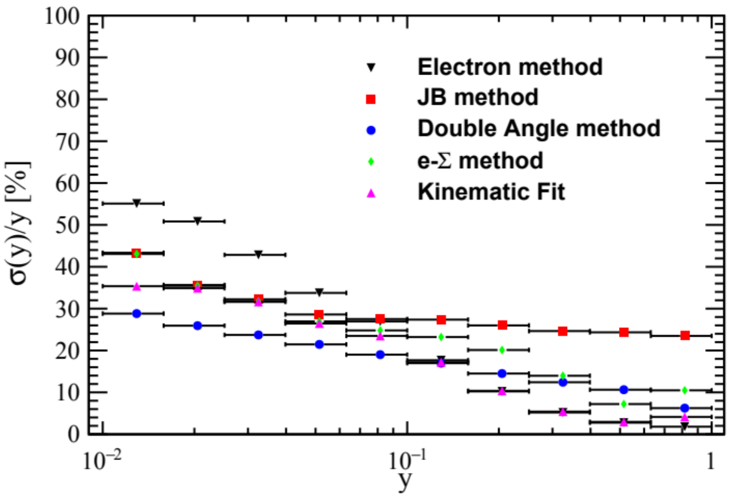
2 Chains, 10k iterations

8 Chains, 1M iterations

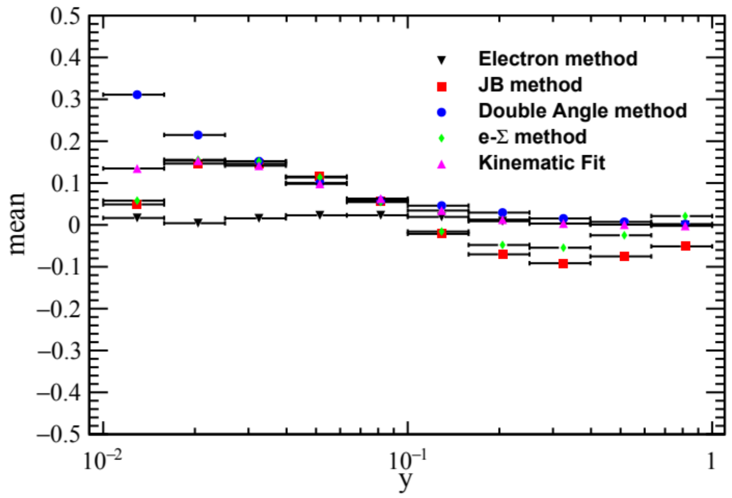
8 Chains, 10M iterations

Fitting same events with "High precision"

RMS(y) vs y

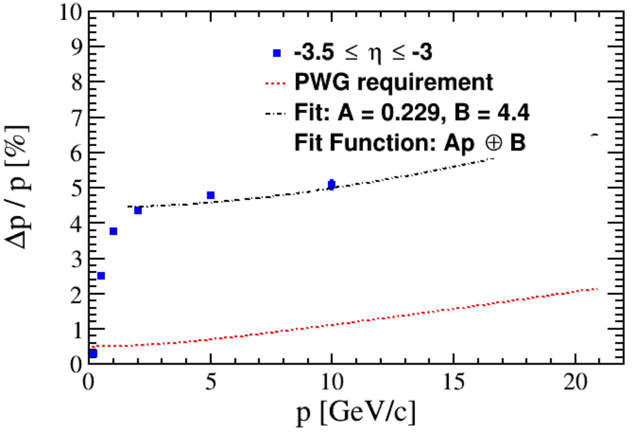


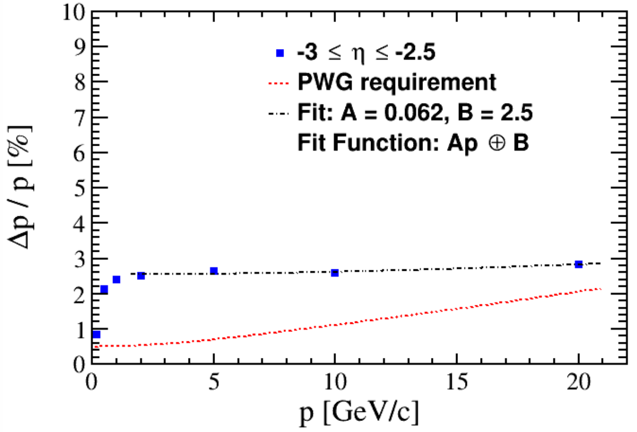
Mean y vs y

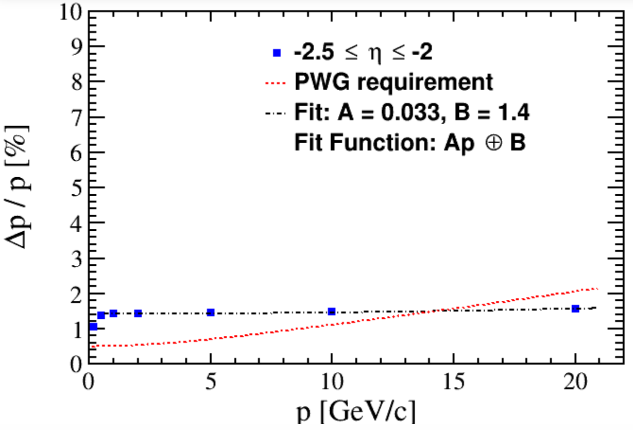


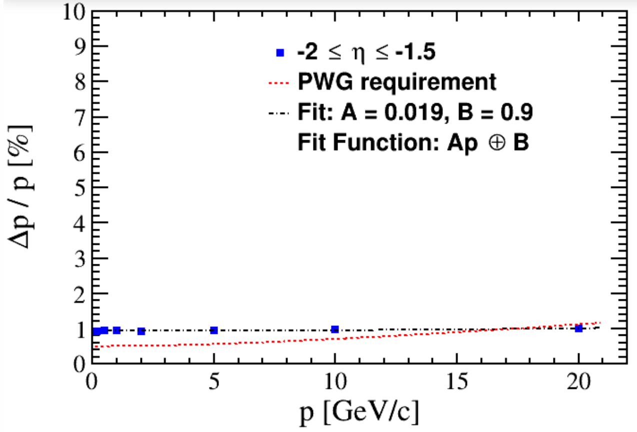
- Significant improvement to KF resolution!
- Generally matches or beats resolution of methods other than DA, which has better resolution at lower y (but larger mean offset)

Extending to lower Q^2







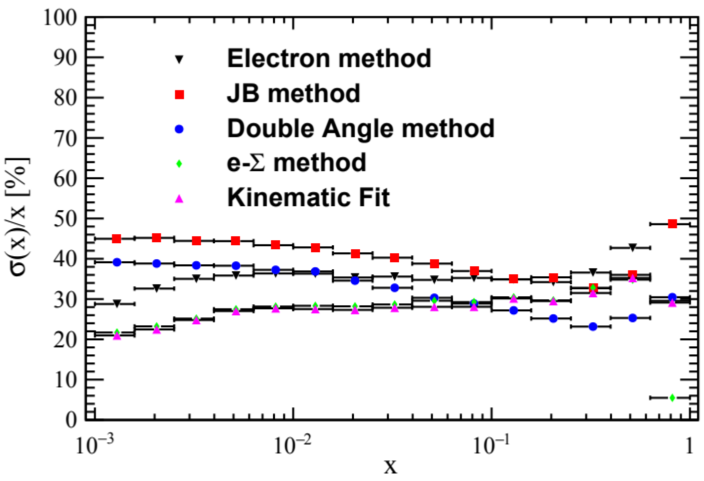


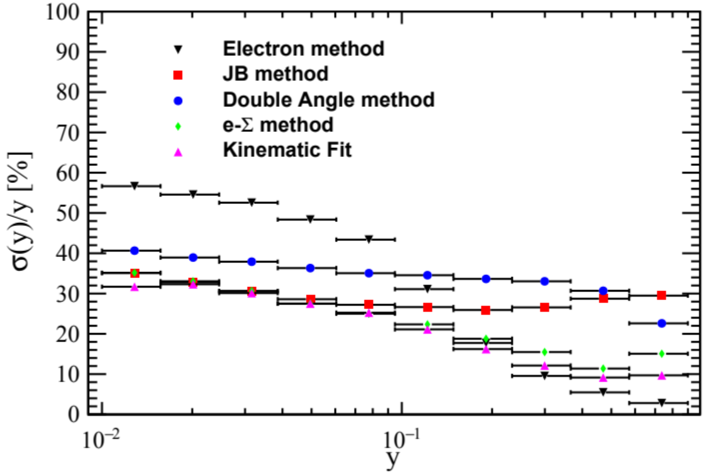
- Previously restricted events to high Q^2 events with electrons scattered into barrel
  - Extended to events with Q^2>1GeV^2 → Requires parametrisation of dE/E and dθ in pseudorapidity bins

<u>A couple of caveats:</u>

- At low p_T an issue with truth track seeding in simulations at the time results sees dp/p improve at low p → unphysical ("fixed" in eicrecon)
- Electron "finding" wasn't changed in my recon → bad approximation at high y

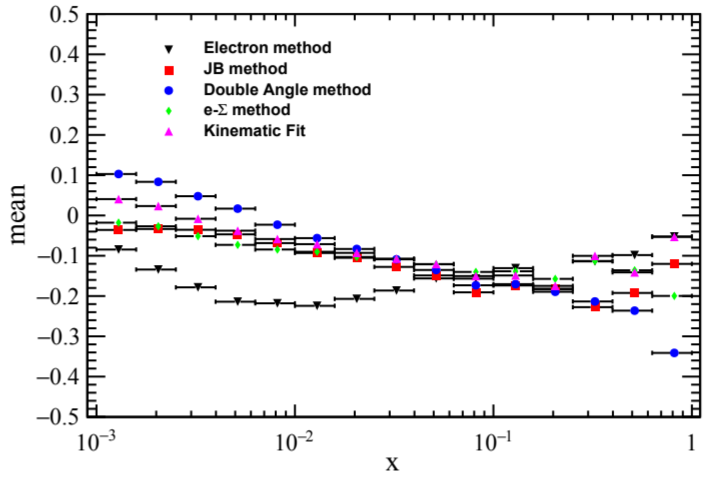
Resolutions (Juggler $Q^2>1GeV^2$)

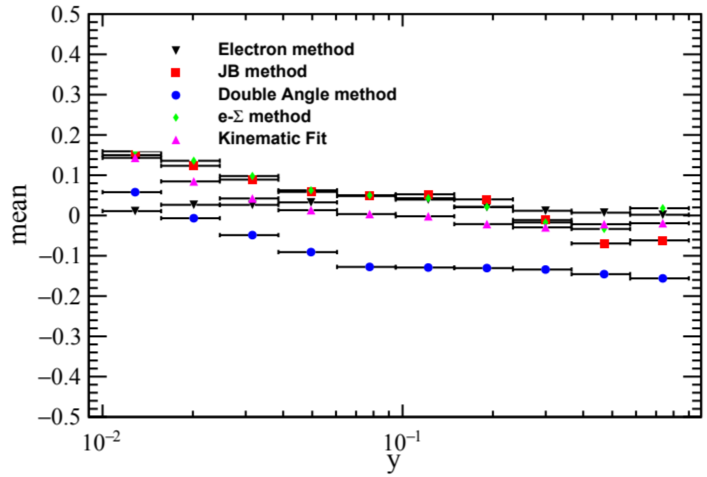




Resolution

- KF matches or beats conventional recon methods except e-method at high y (poorly described due to previously mentioned problems)





Mean

- KF shows low level of bias compared to conventional recon methods

Future Plans

- EIC Simulation and Reconstruction software are being (rapidly) developed, but there is still much work to be done for complete realism
  - I now have an H1 computing account (thanks H1 folks!) → plan to use this to test KF with mature MC, and at some point with real H1 data
- Thanks to Barak and Kolja we now have Djangoh files successfully passing through afterburner, which should tested with full sim (I tried a while ago but simulation crashed for me) → can hopefully figure this out and have some full sim events with QED=on to test with KF to show full power of the method
- Should eventually look at correlations between measured quantities e.g. p_T and Σ_h and include these in KF