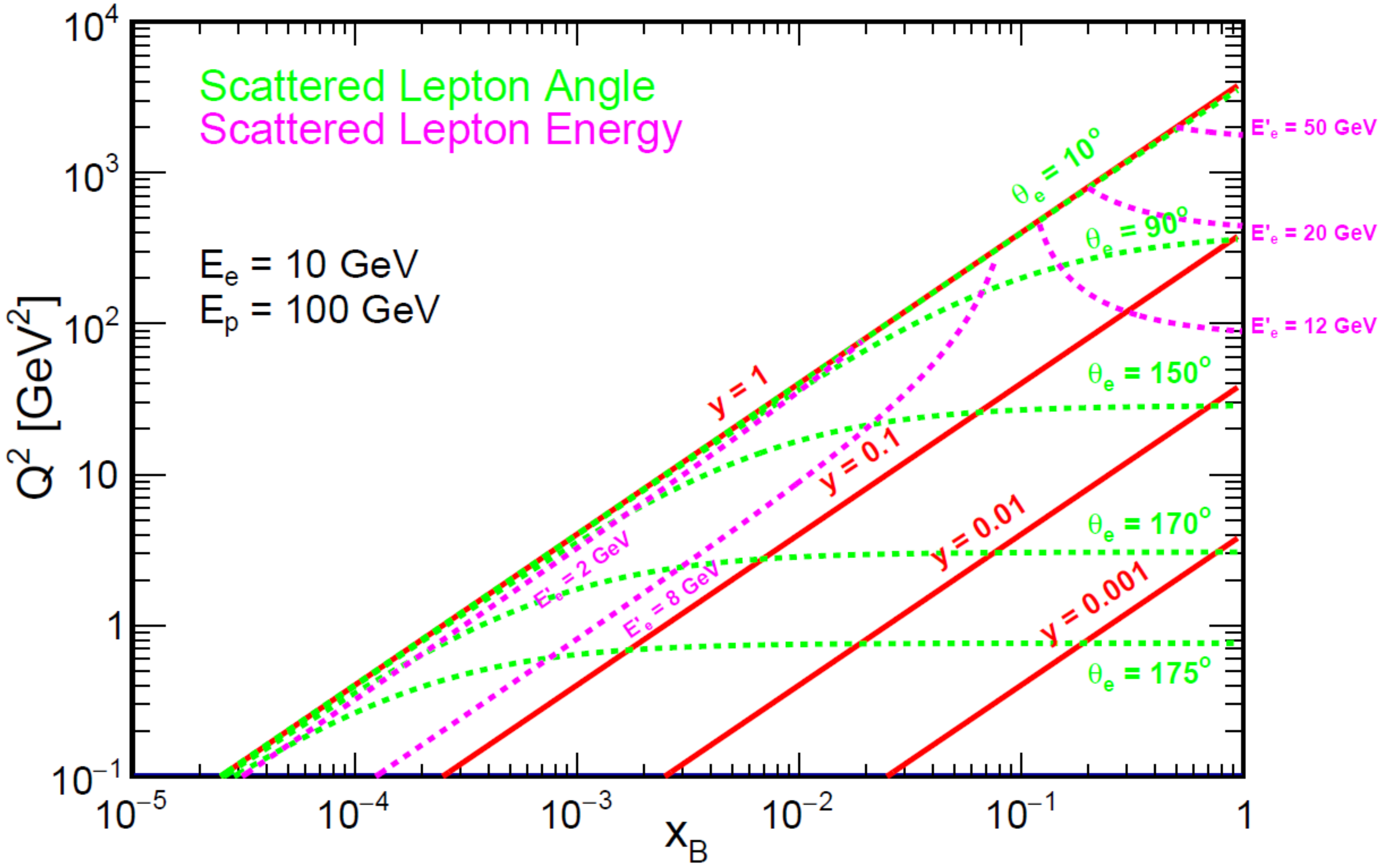
Neutral Current (NC) Inclusive Kinematic Maps and Unpolarized Cross Sections

Barak Schmookler
(for the Inclusive Reactions Group)

Outline

- One important item our group needs to provide to the detector group is the distribution of momentum and scattering angles for the final-state particles.
- We've created these kinematic maps using the both the *PYTHIA6* and the *Djangoh* event generators for electron-proton scattering for the 4 required yellow report beam energy combinations. (Thanks to Xiaoxuan Chu for providing the plotting template.)
- We are now working to recreate these maps assuming a non-zero beam crossing angle (i.e. 25 mRad and 50 mRad).
- We also will use the *BeAGLE* event generator to create similar kinematic maps for eA scattering

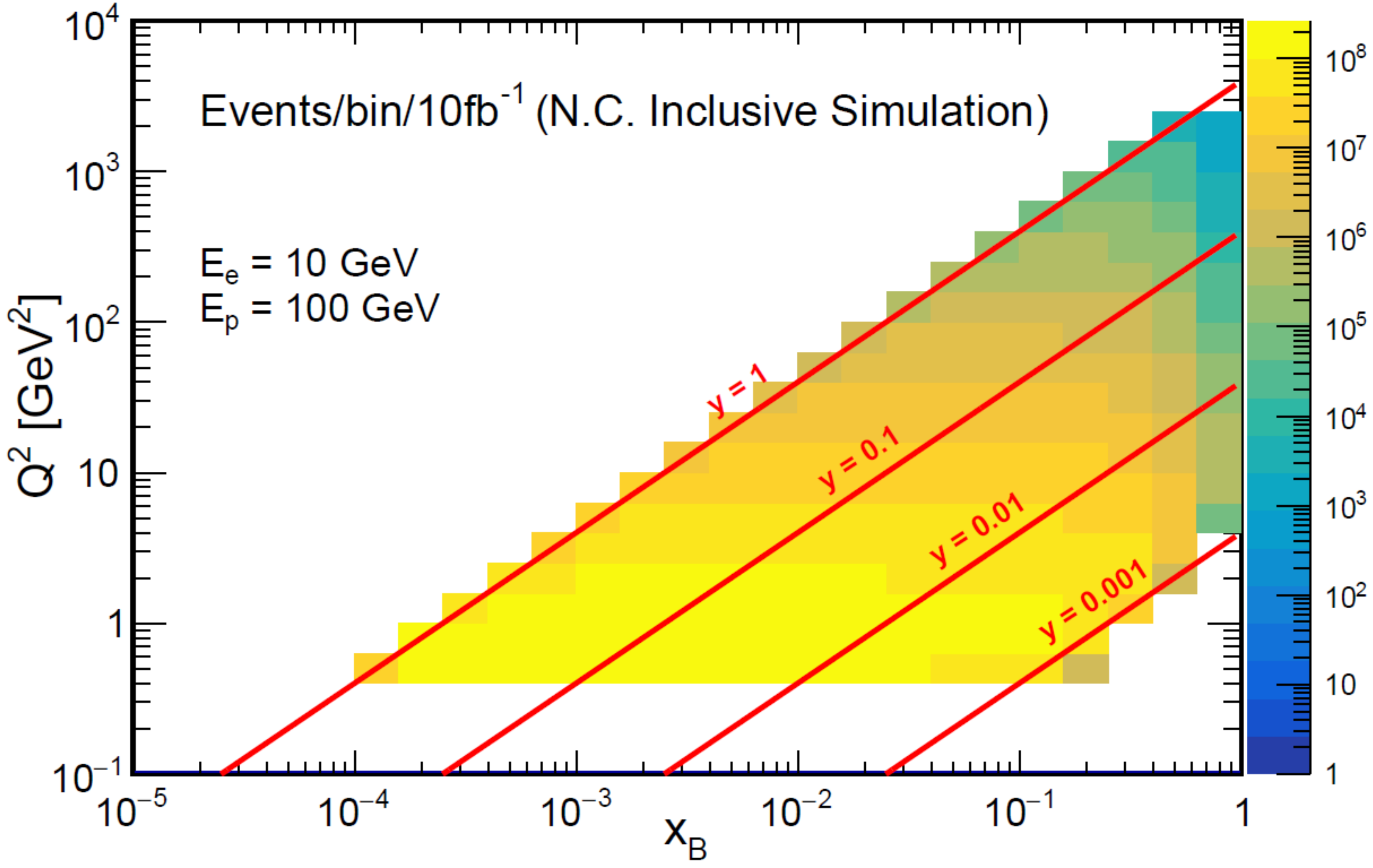
Kinematic Phase Space for 10 GeV x 100 GeV



Kinematic Phase Space for 10 GeV x 100 GeV

Yields calculated from *Pythia6*

'Constant Log' binning used for both x and Q^2



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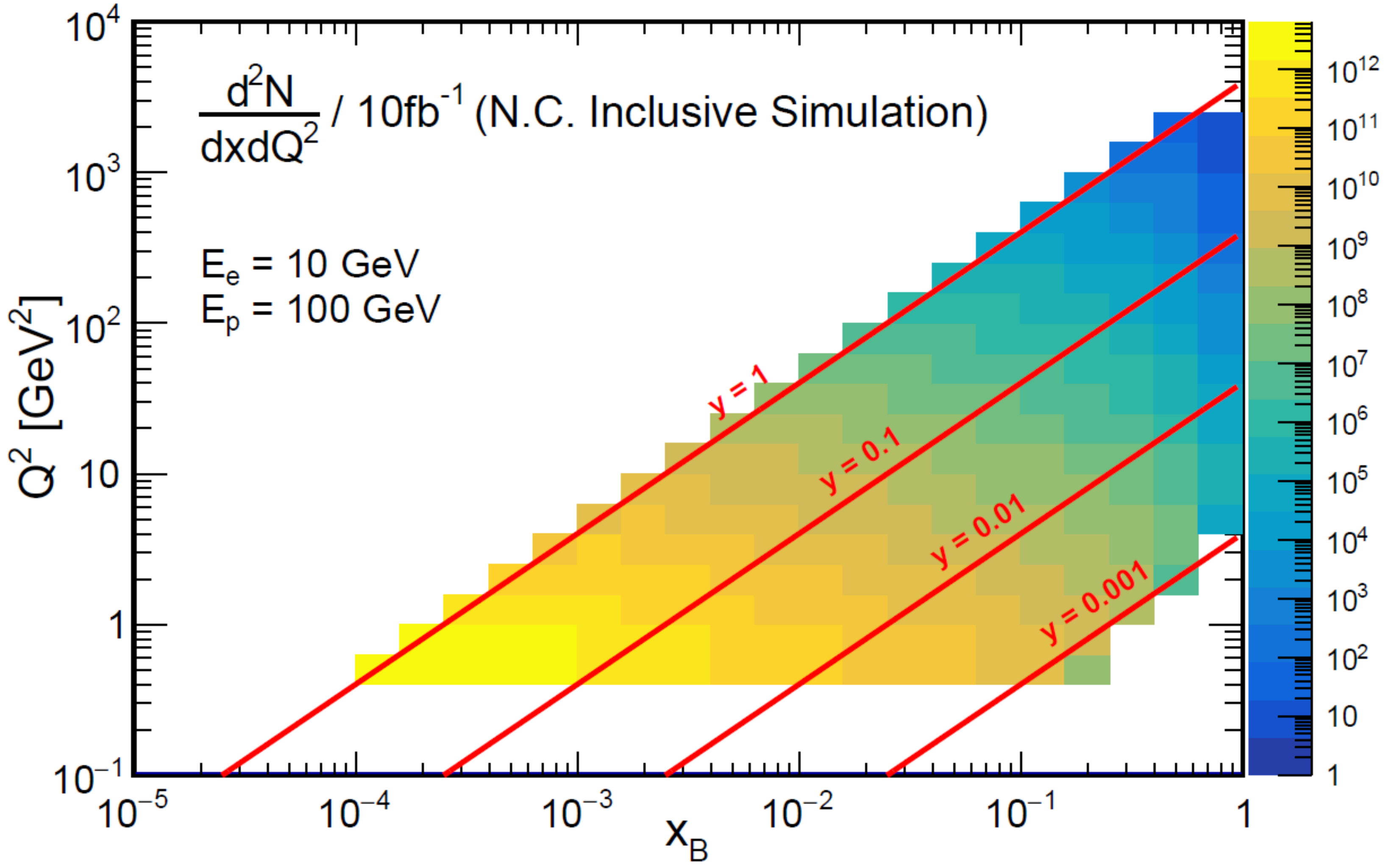
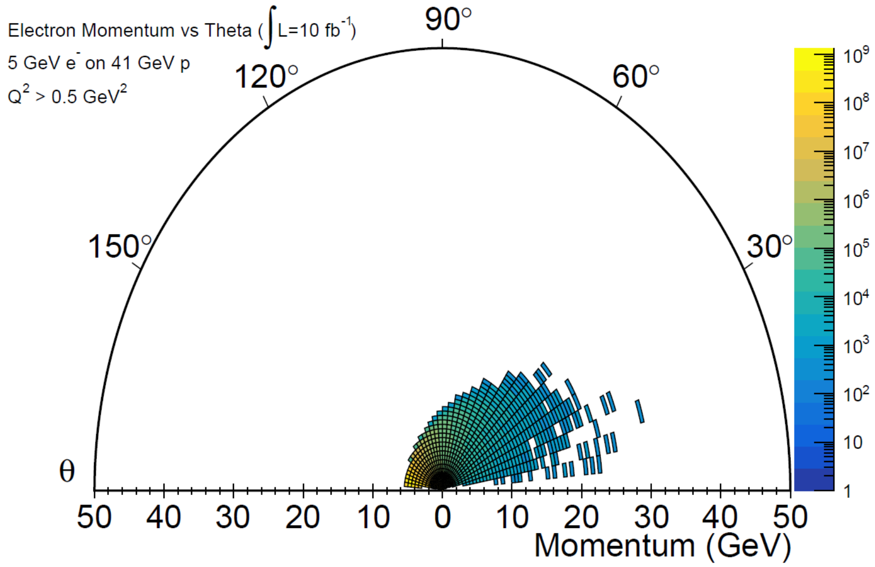
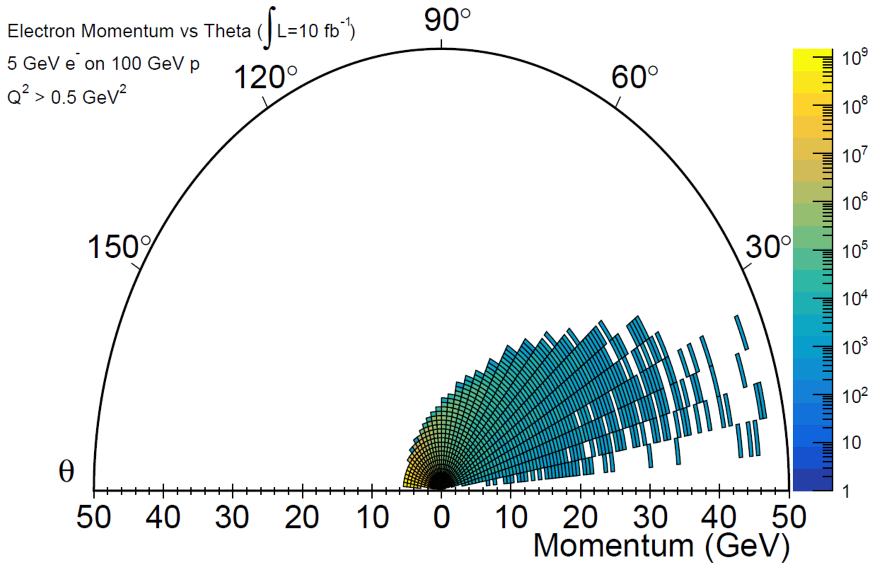
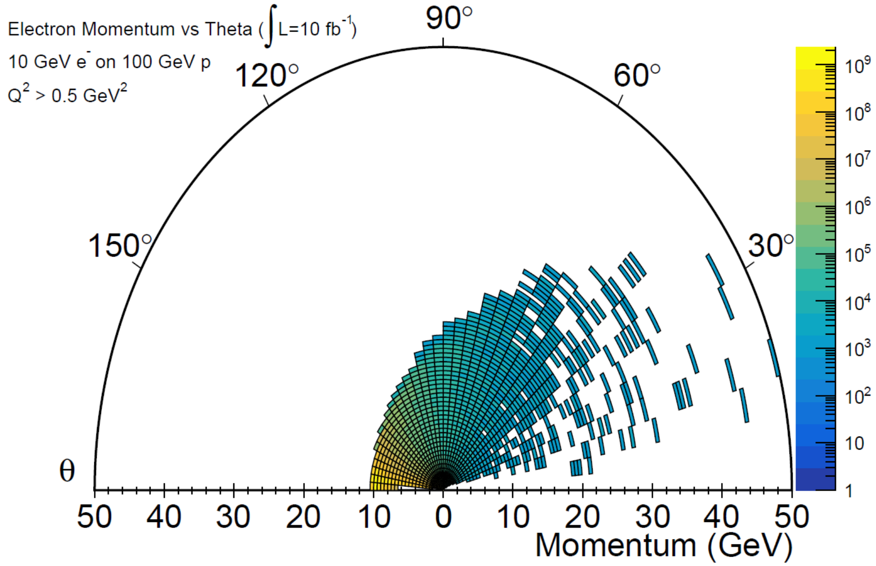
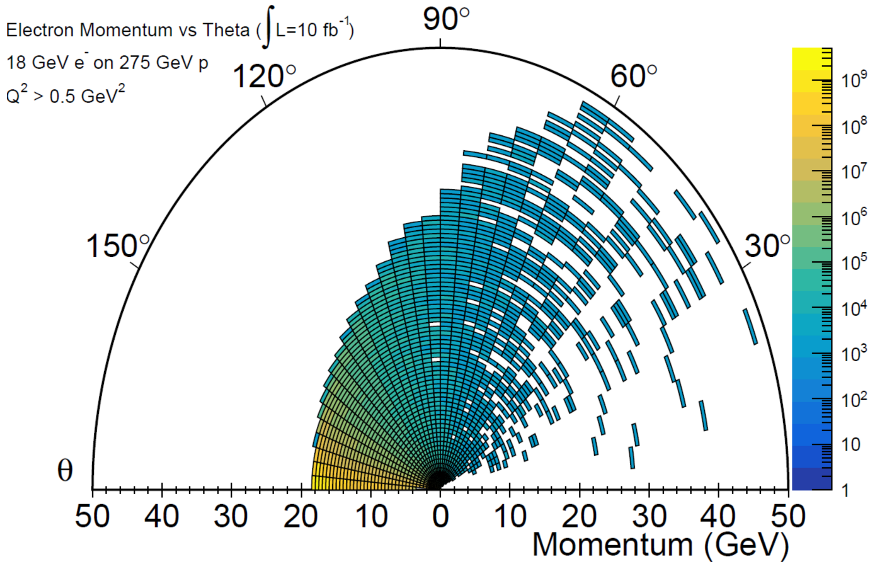


Scattered Electron Kinematic Maps

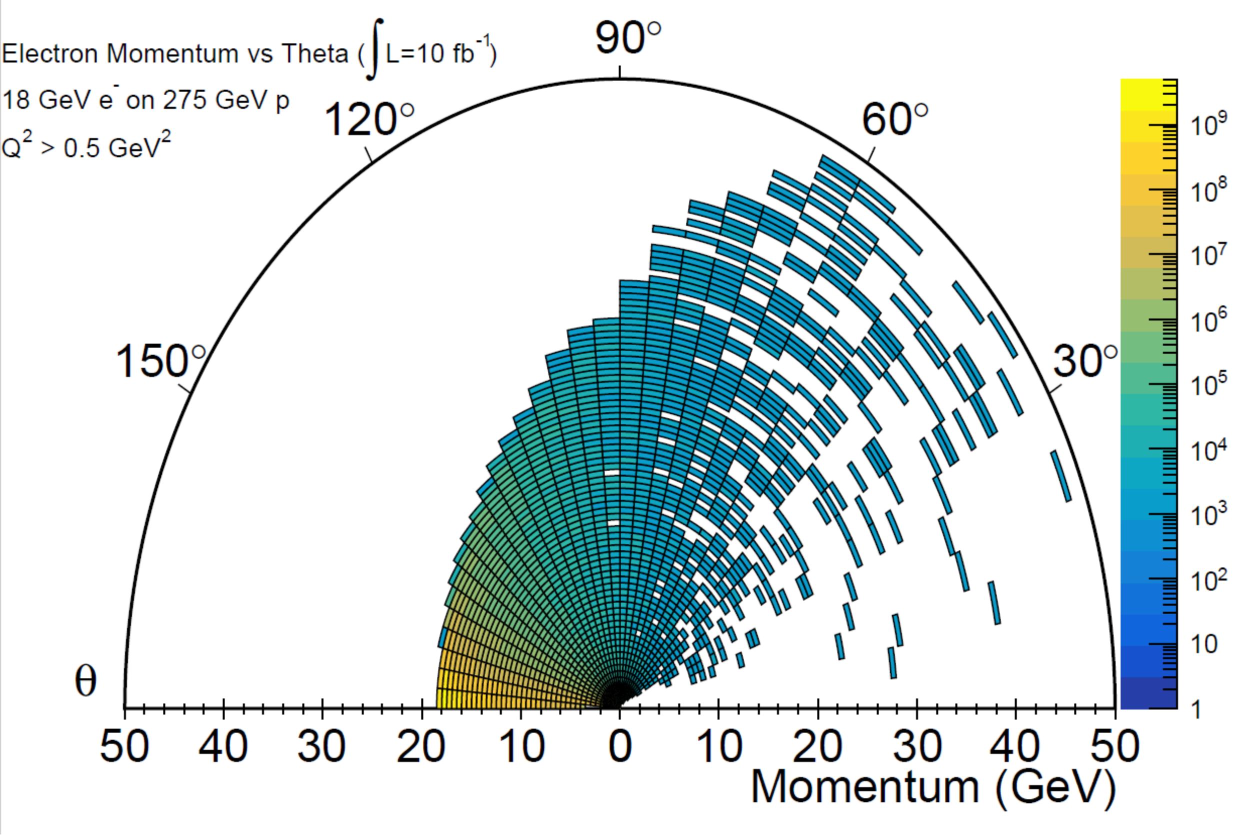


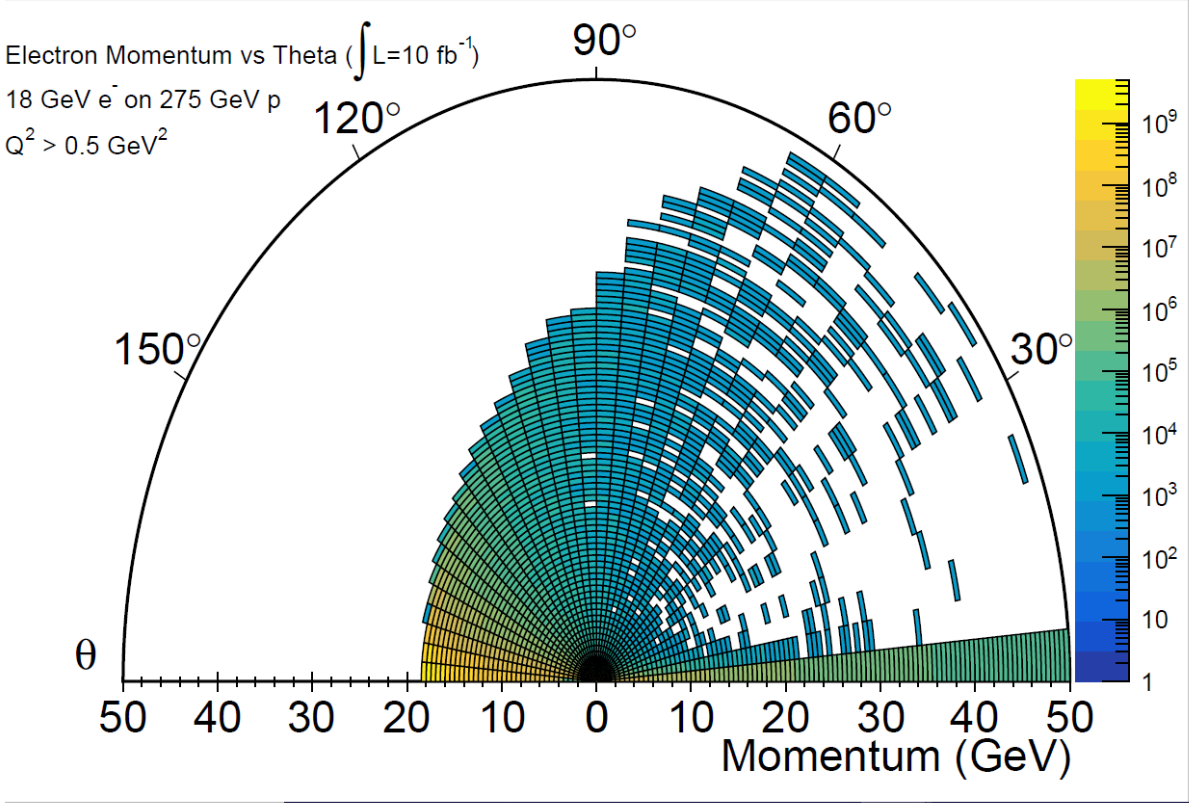






Scattered Electron vs. All Final-State Electrons





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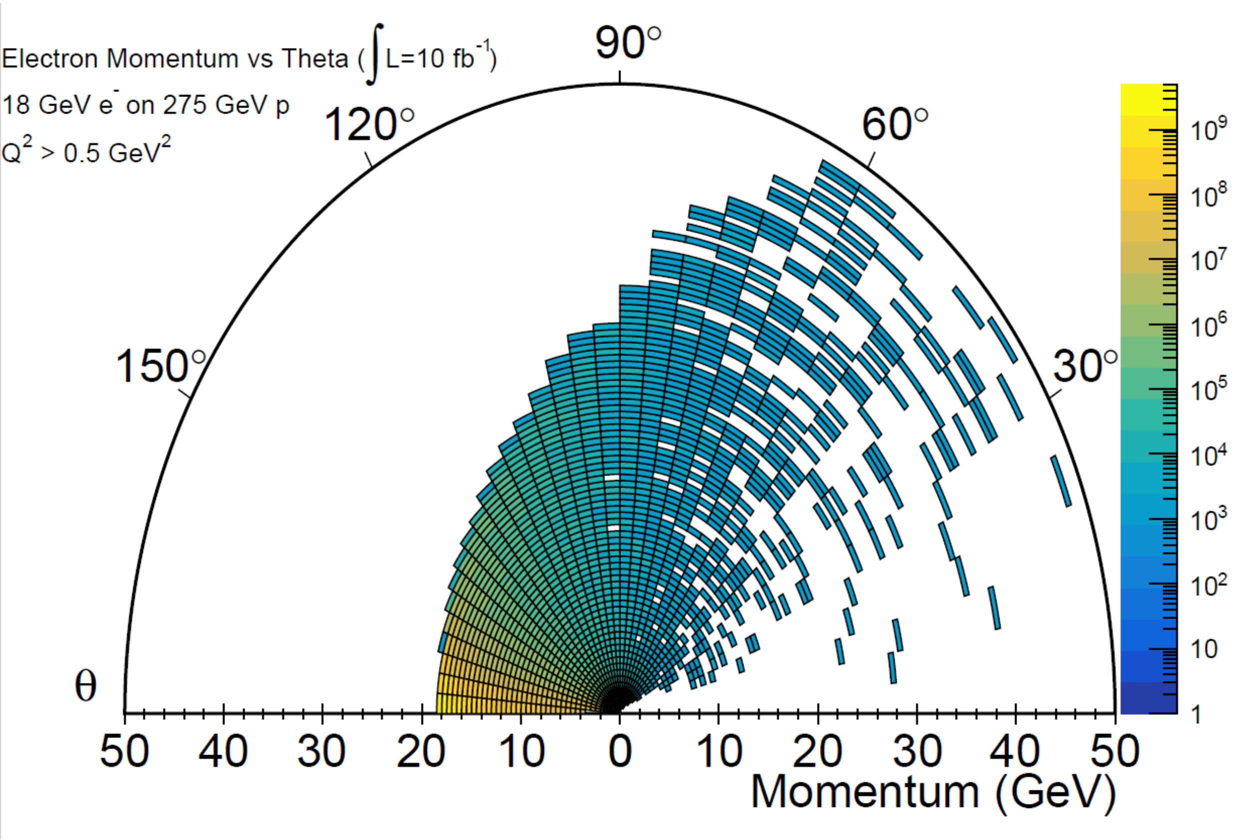
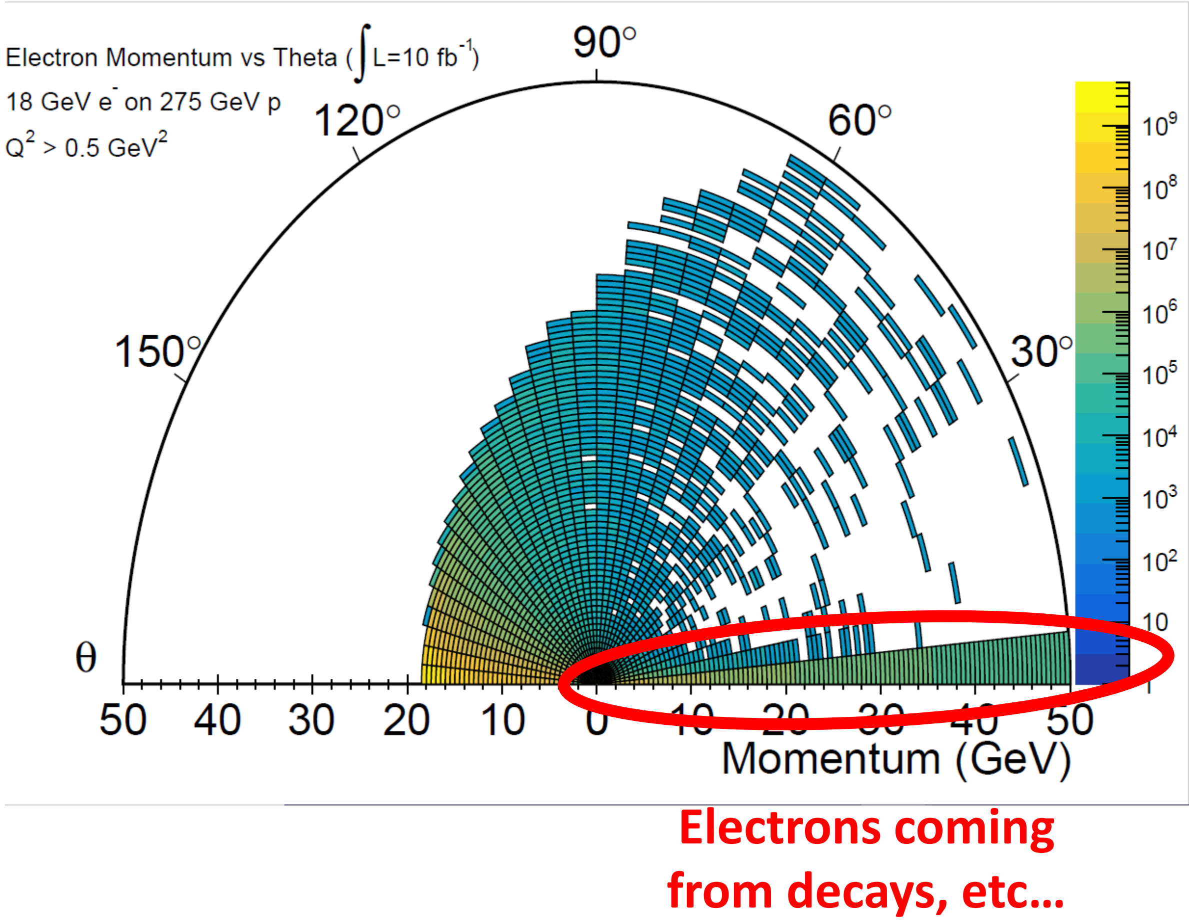
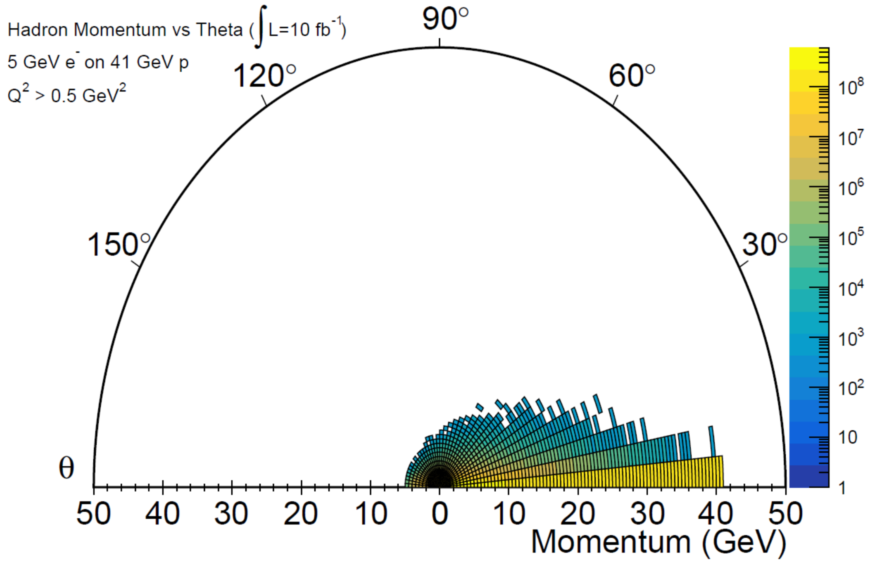
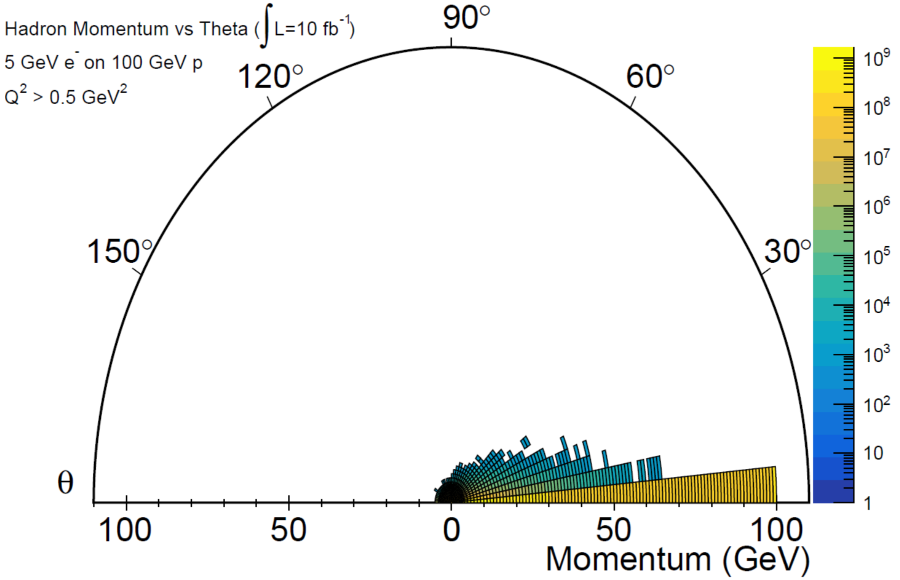
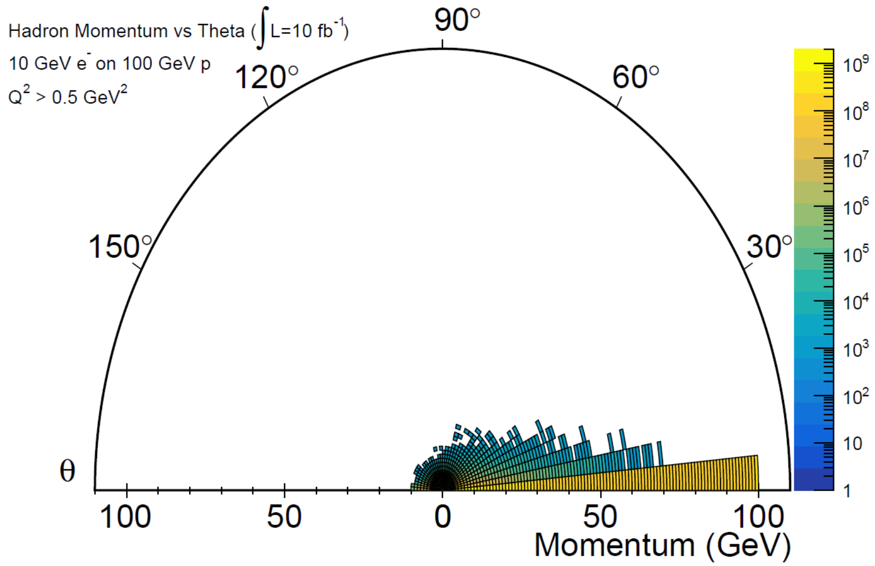


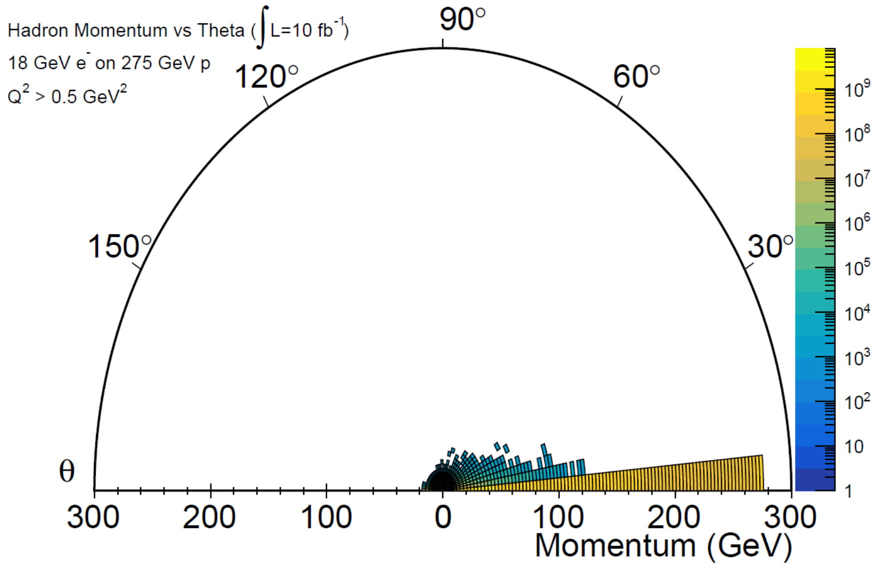


Final-State Hadrons Kinematic Maps

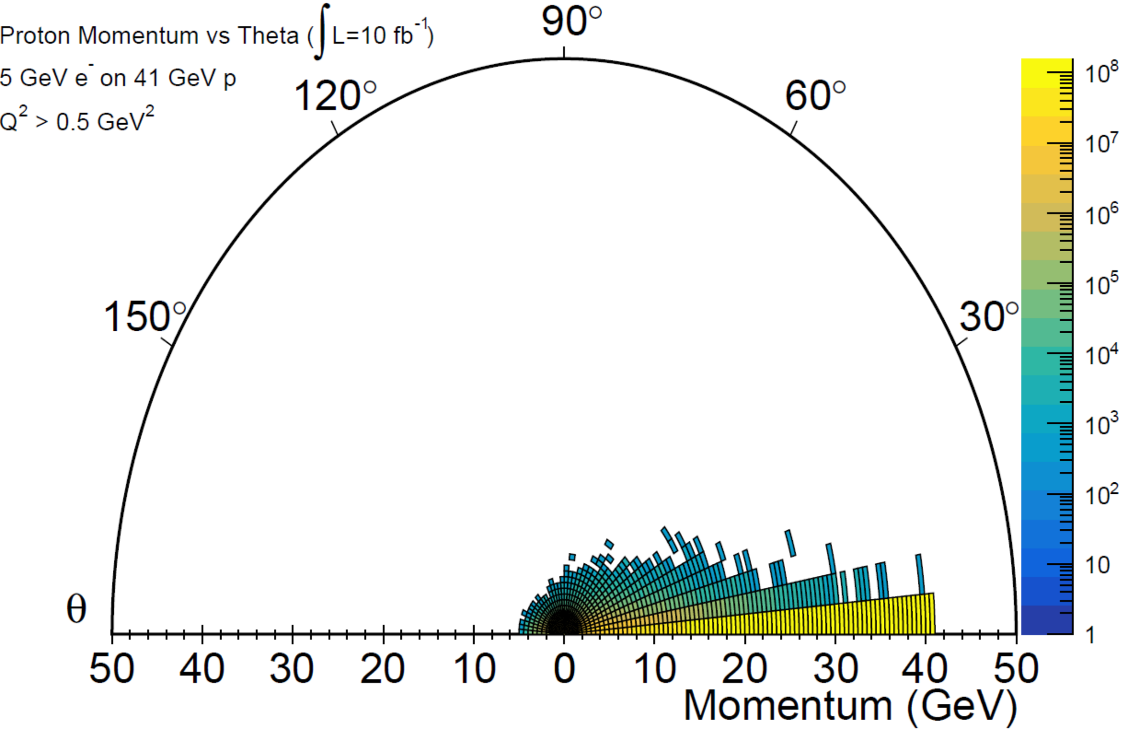


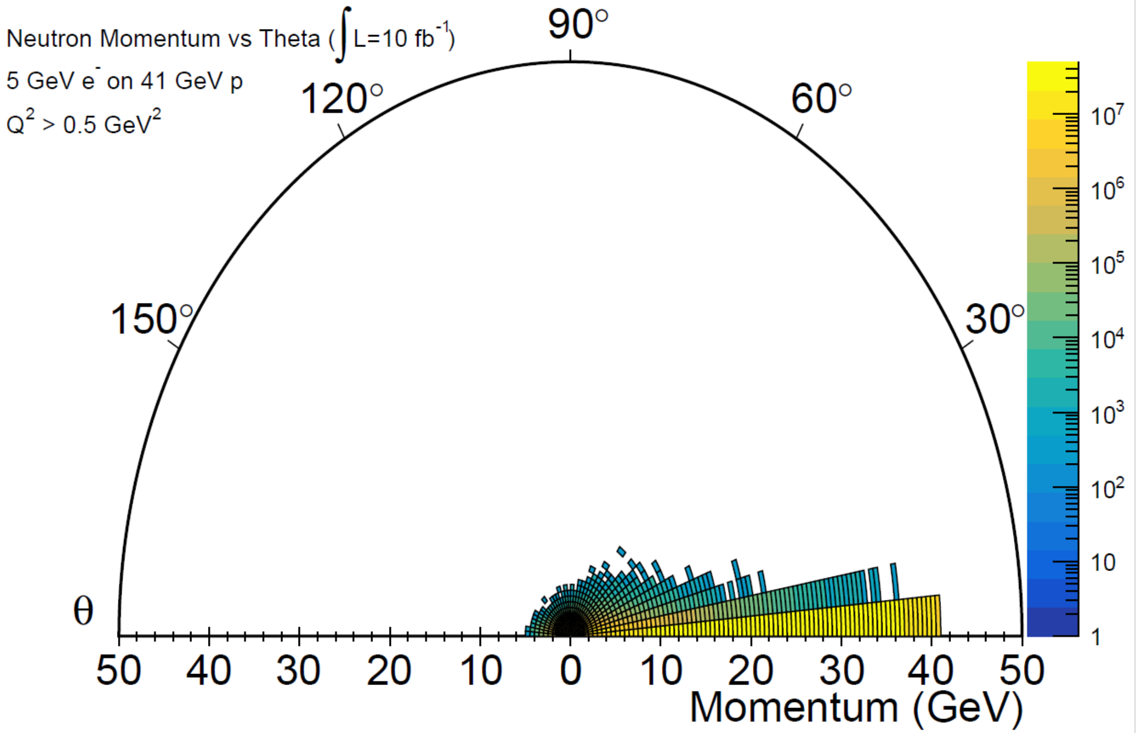




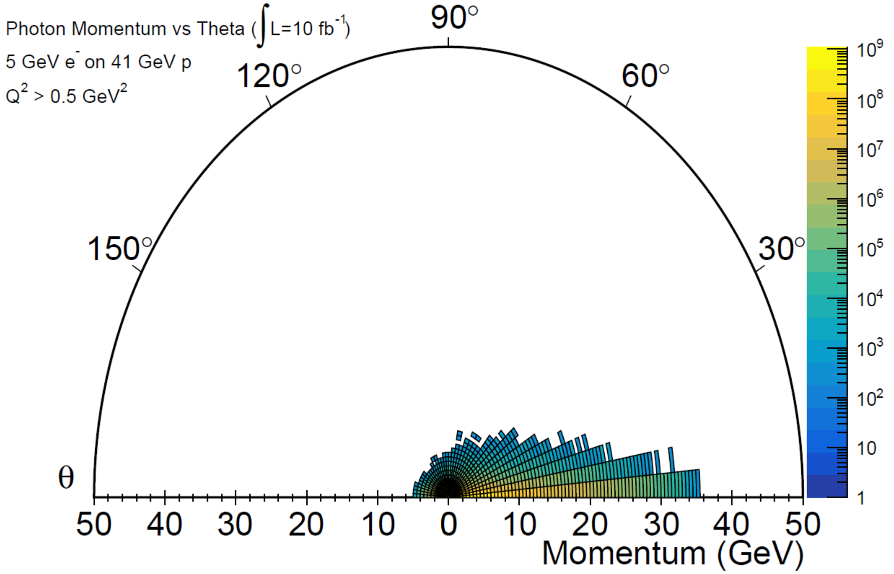


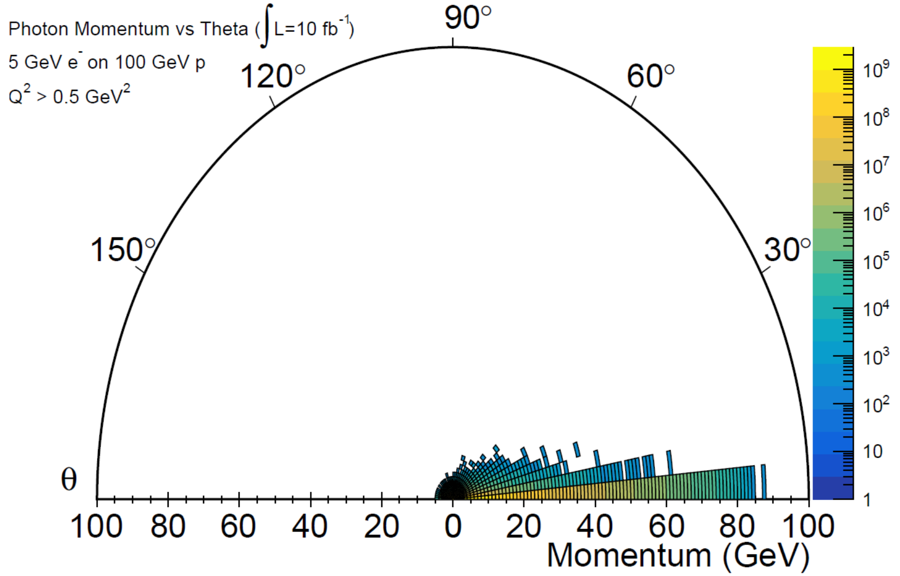
We also display the Protons and Neutrons separately

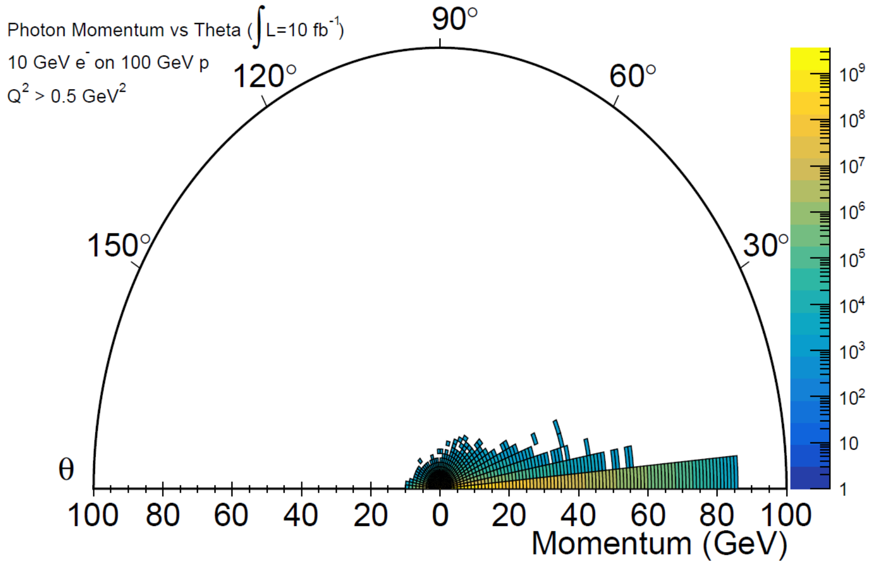


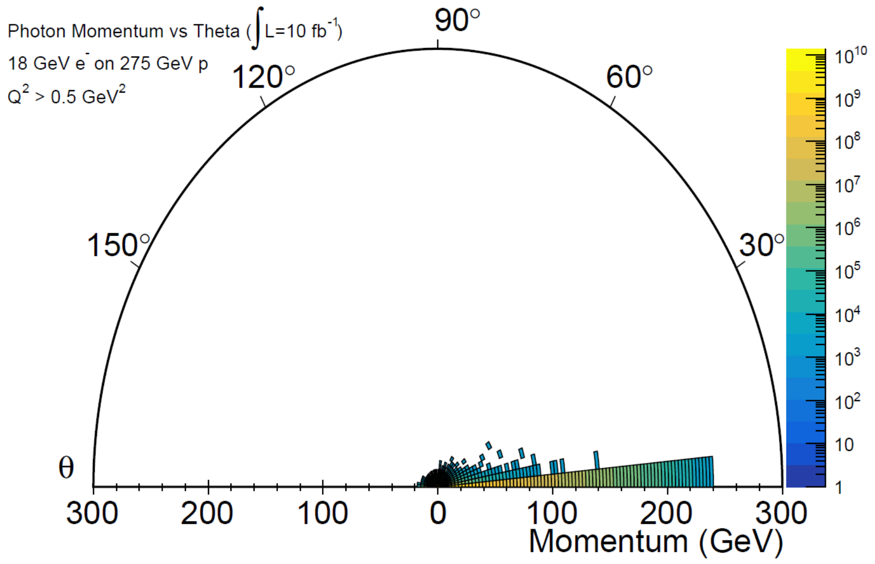


Photon Kinematic Maps

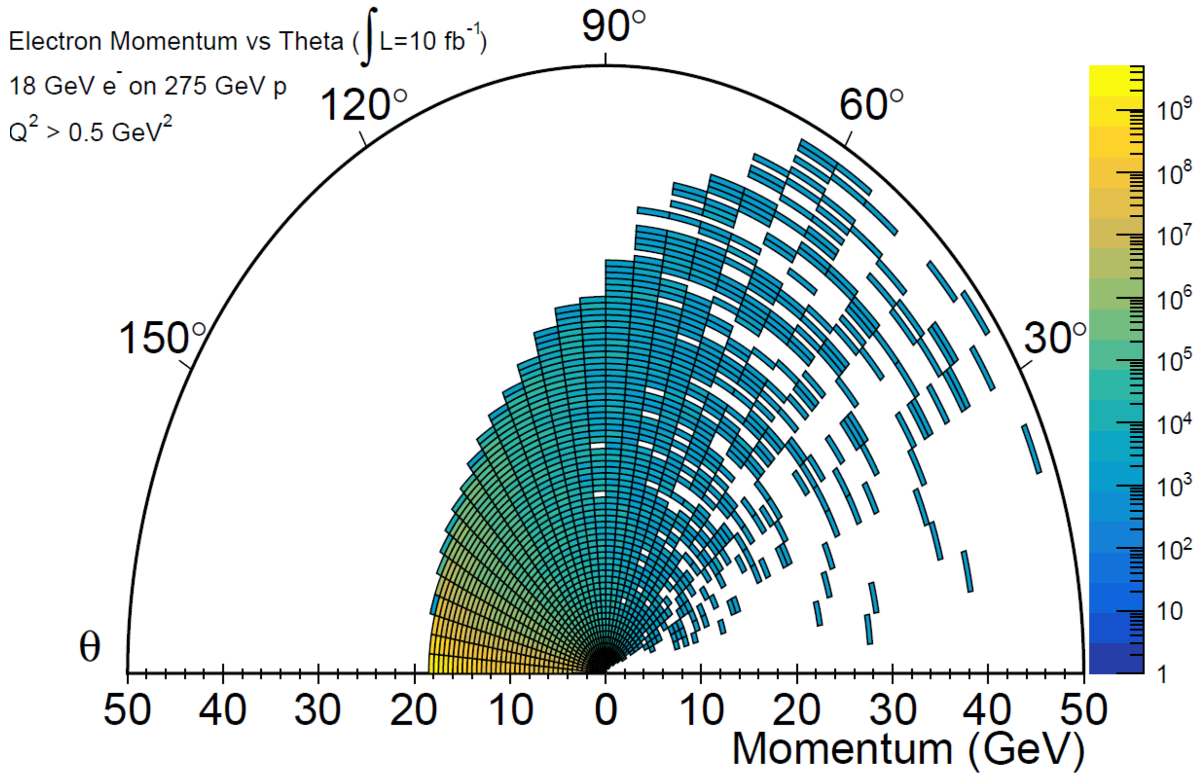


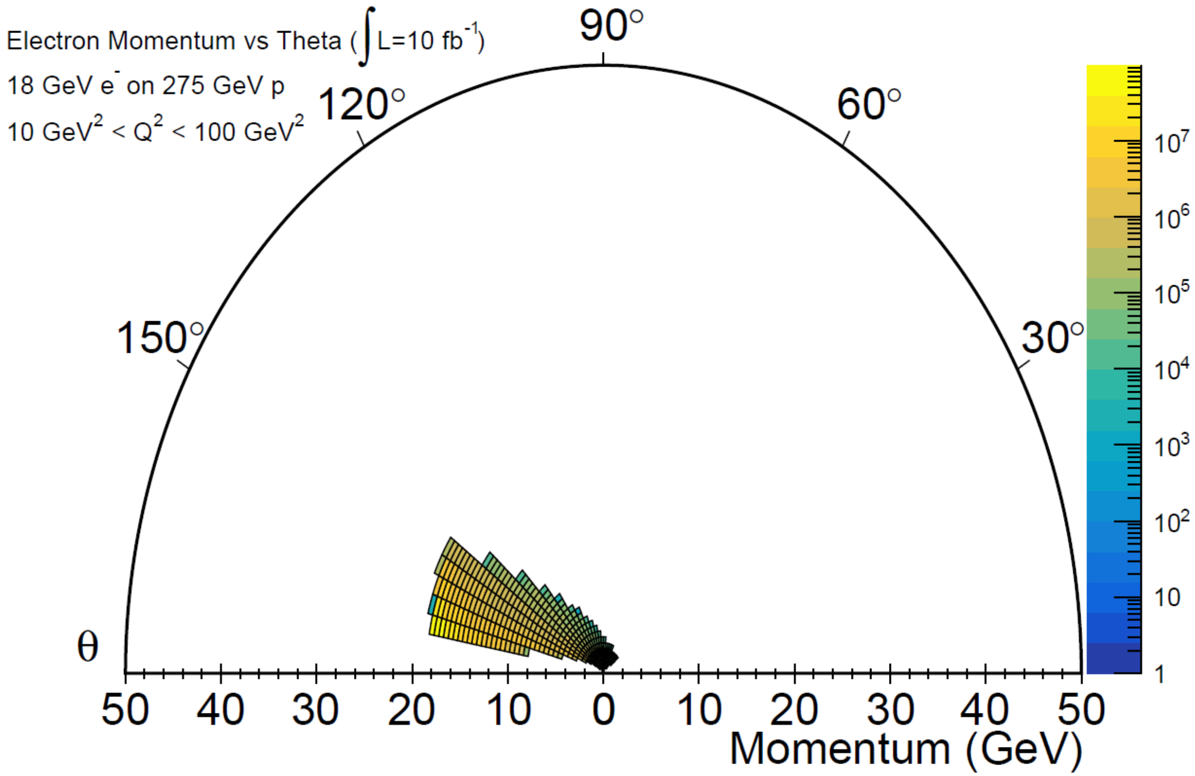




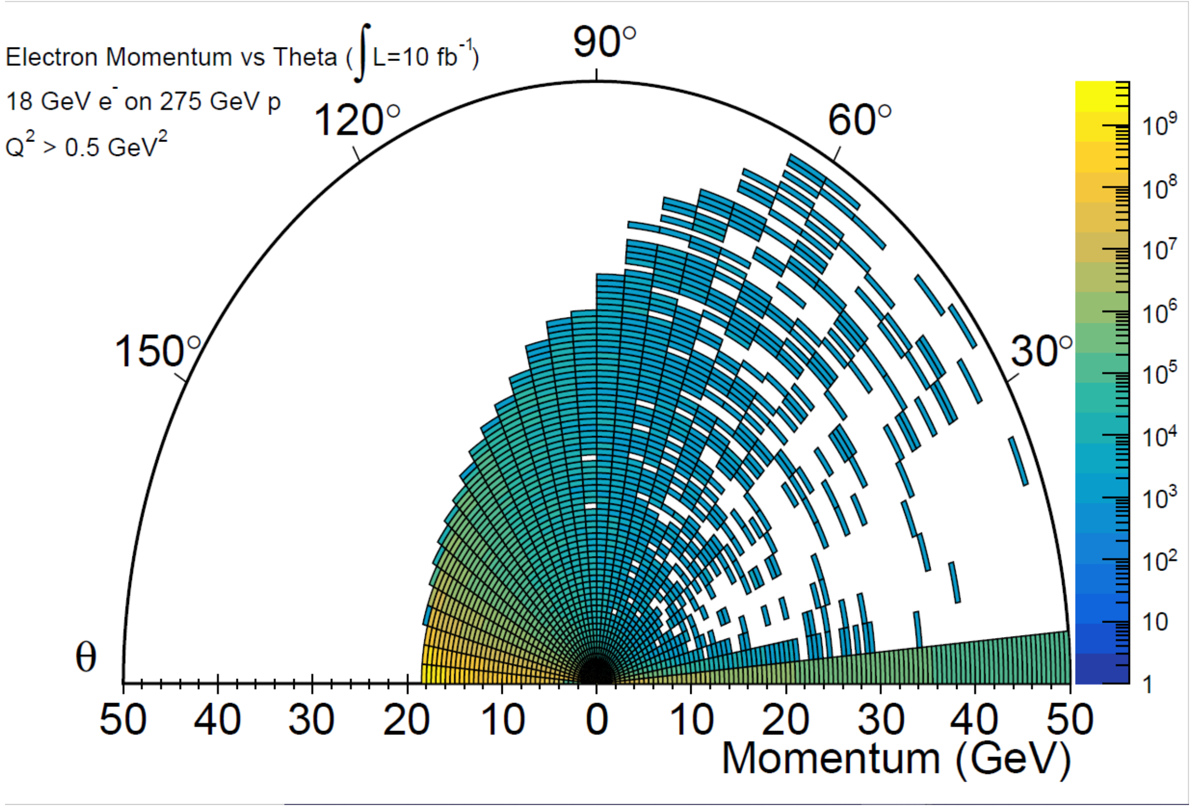


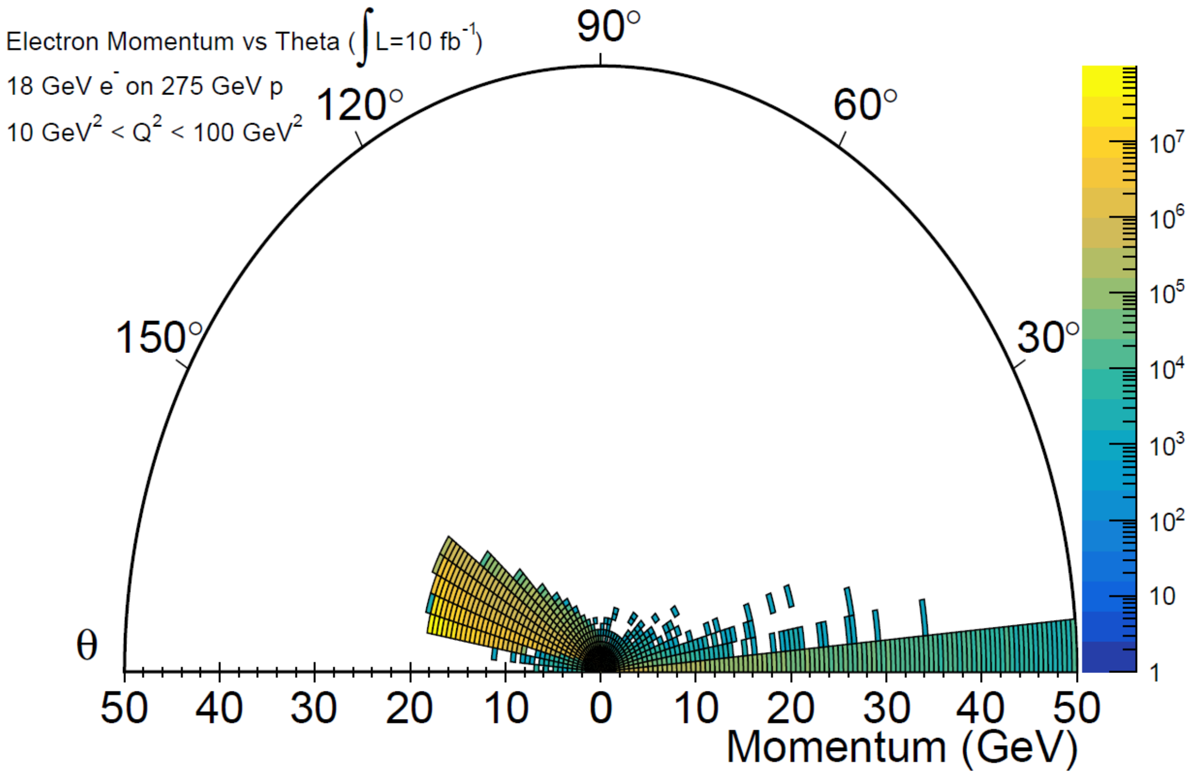
Angular Acceptance and Q^2: Scattered Electron



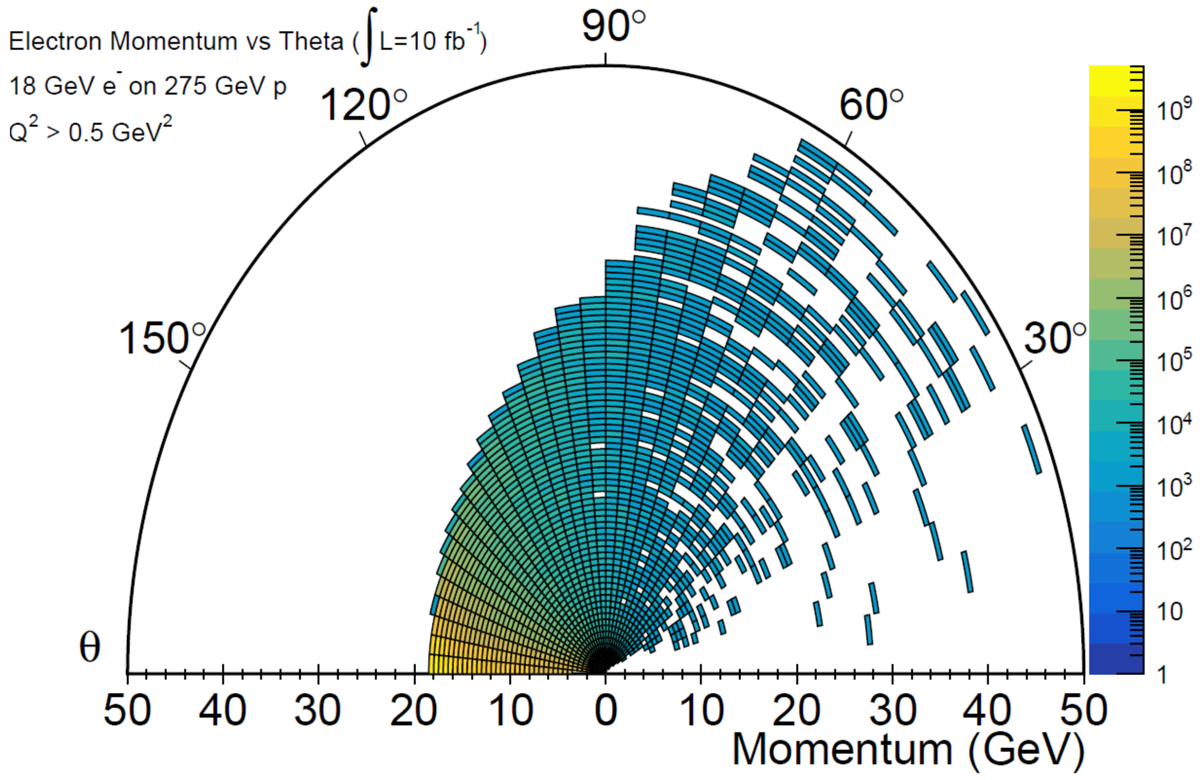


Angular Acceptance and Q^2: All Electrons

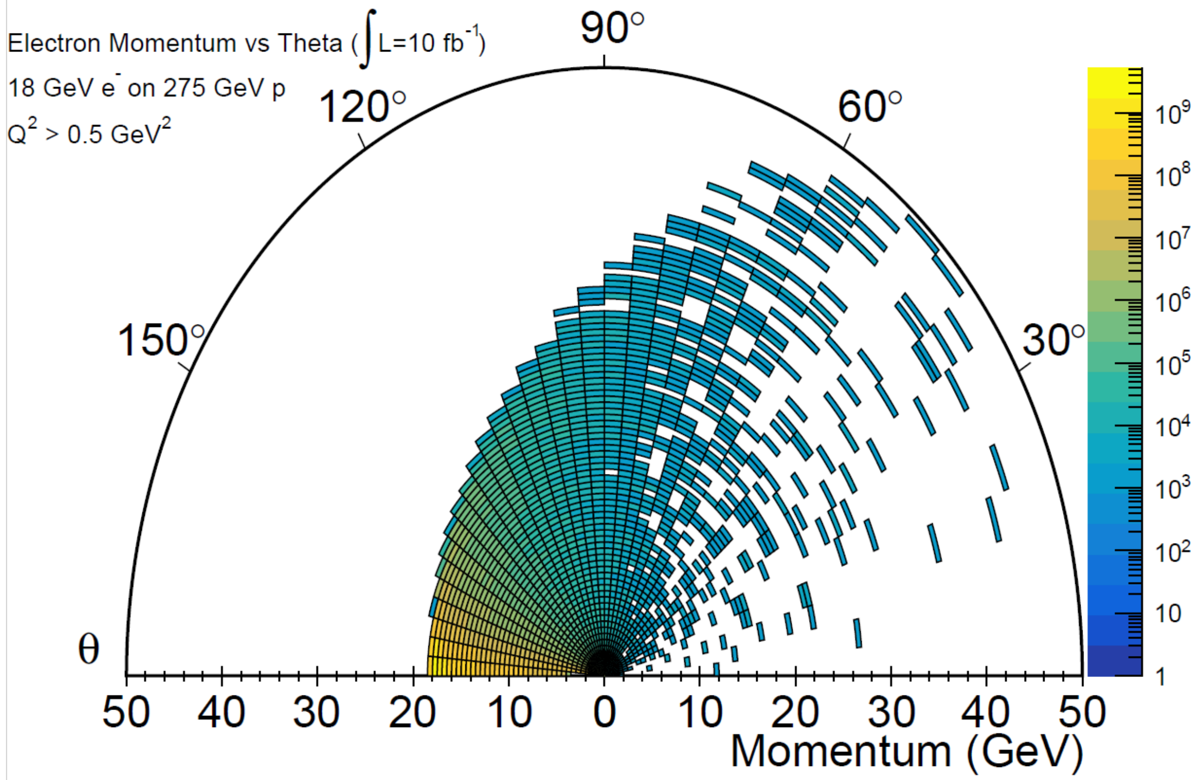




Comparison between *Pythia6* and *Djangoh* event generators: Scattered Electron

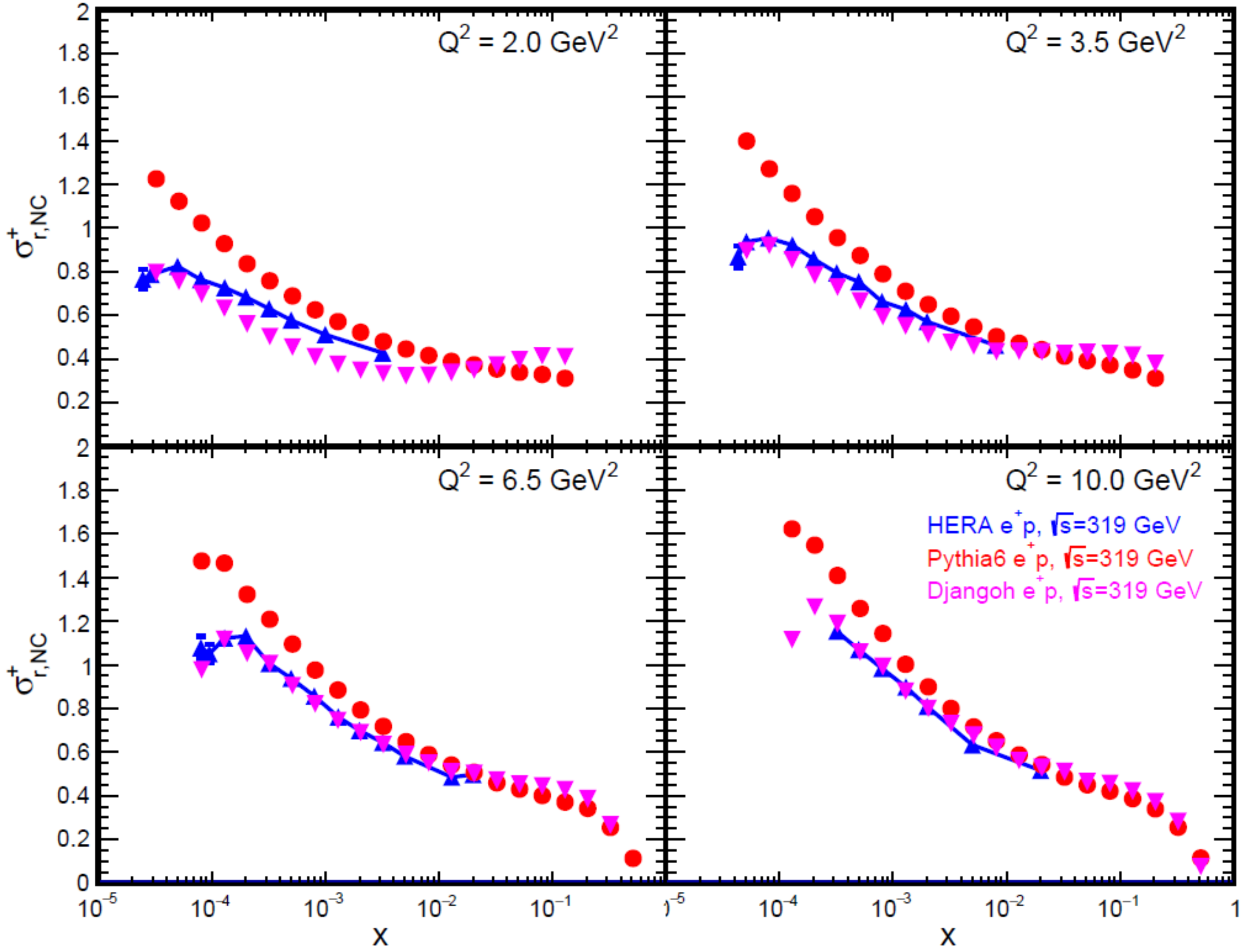


Pythia6



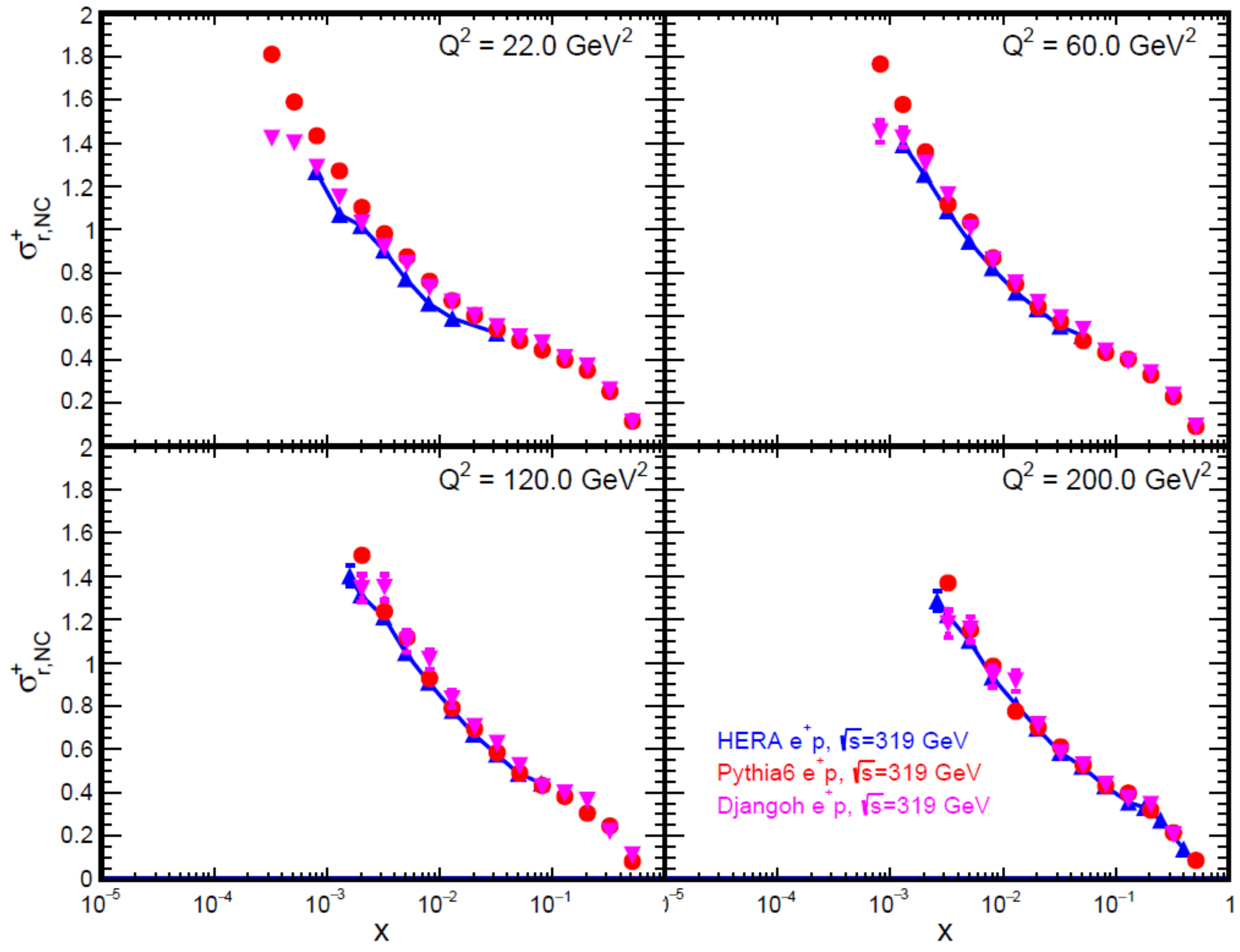
Djangoh

Why we wanted to remake these Kinematic Maps using *DJANGOH*



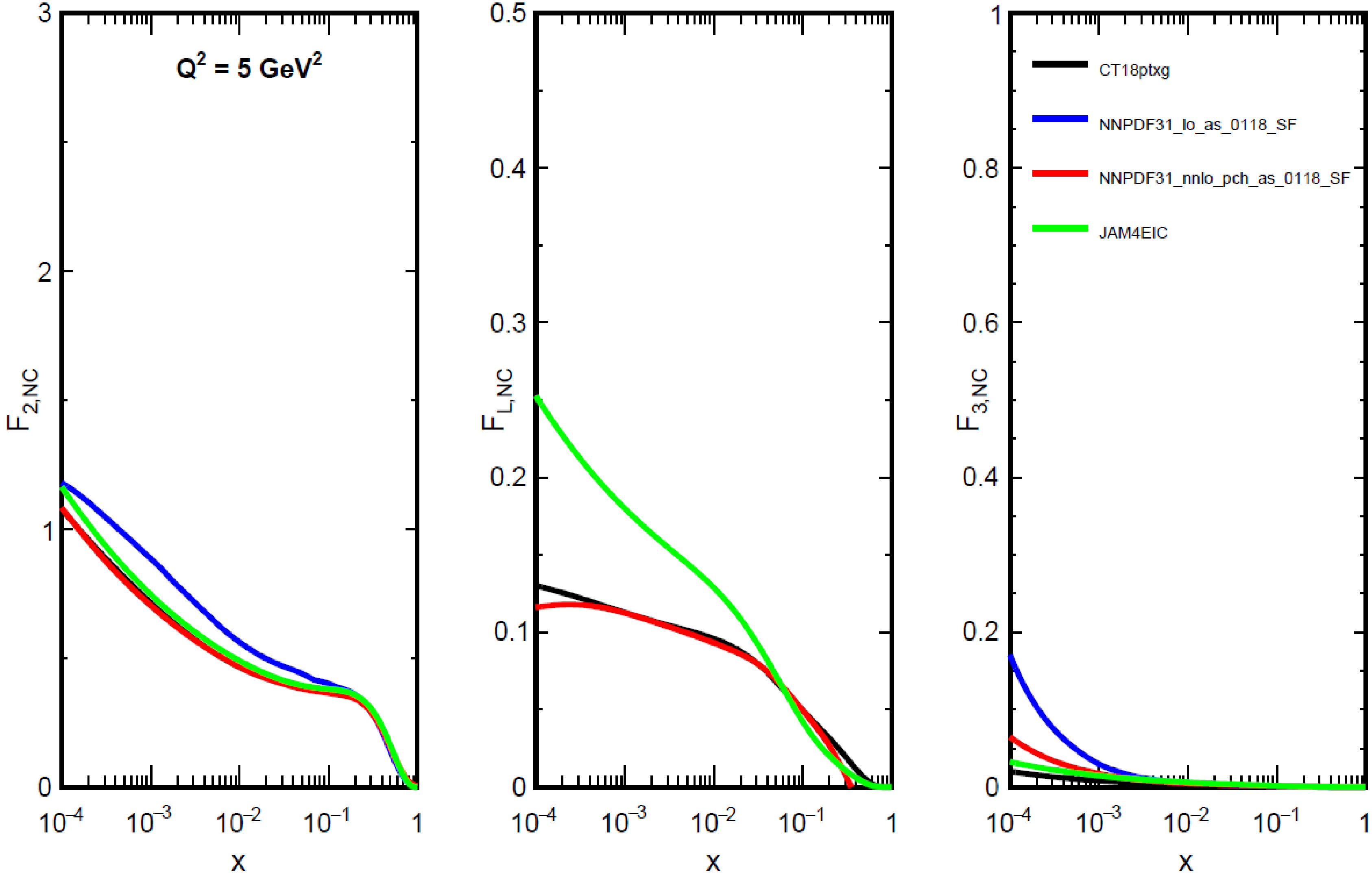
***DJANGOH* agrees better with low Q^2 (low x) *HERA* data than the *PYTHIA6* tune we are using**

Why we wanted to remake these Kinematic Maps using *DJANGOH*



Both simulation programs do well at higher Q^2 (higher x)

At *EIC* energies, we will need to compare to theory



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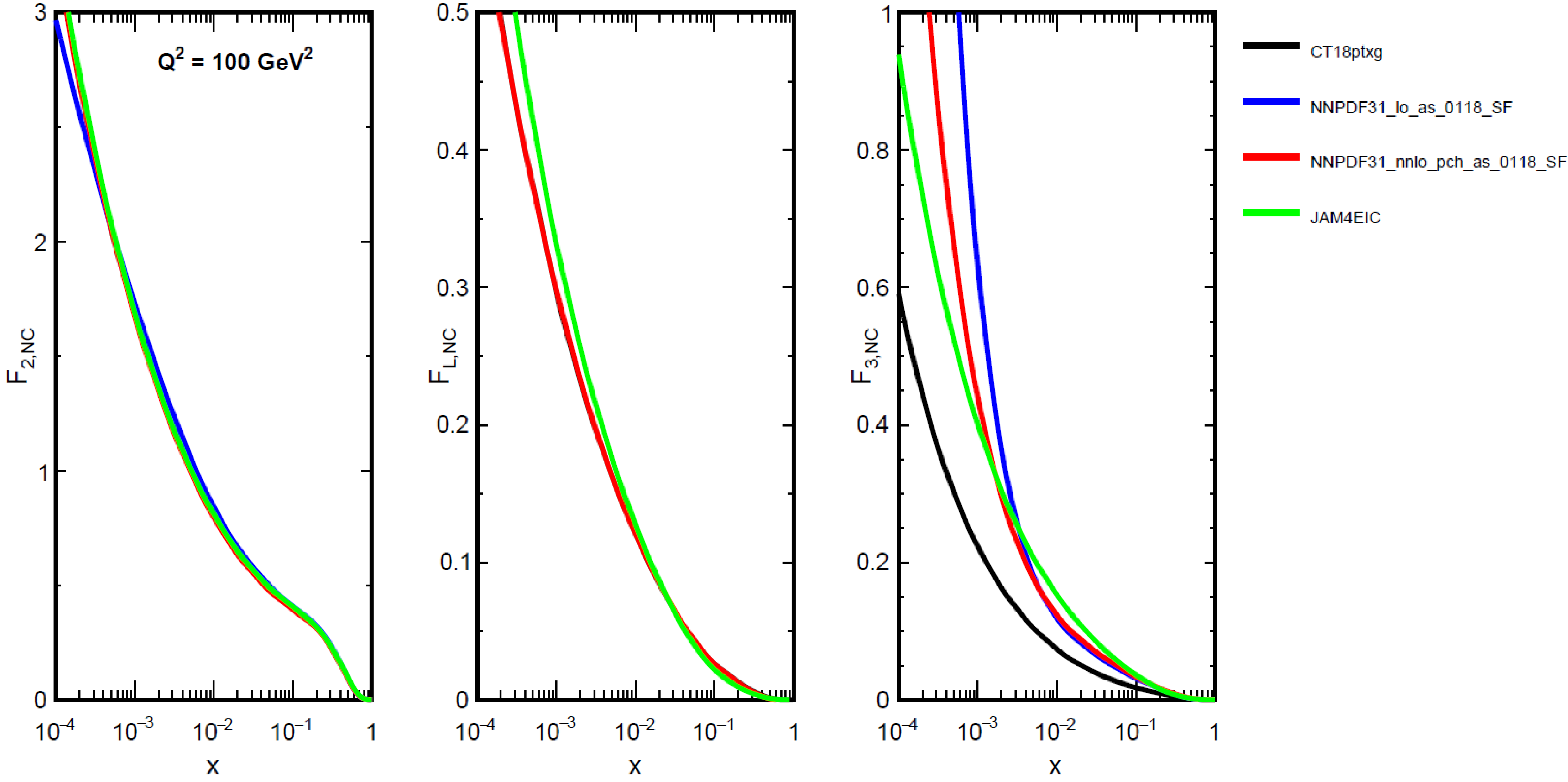
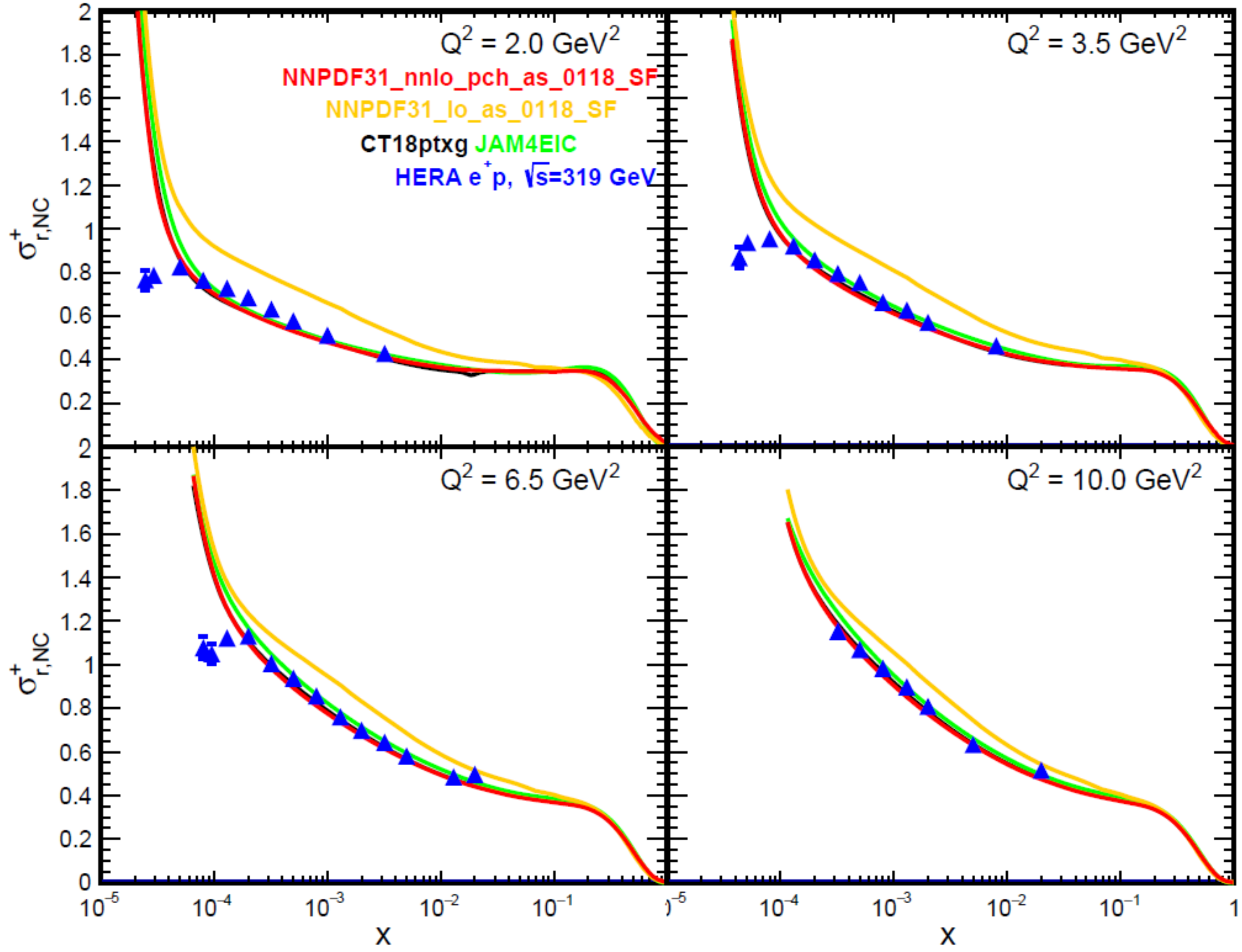
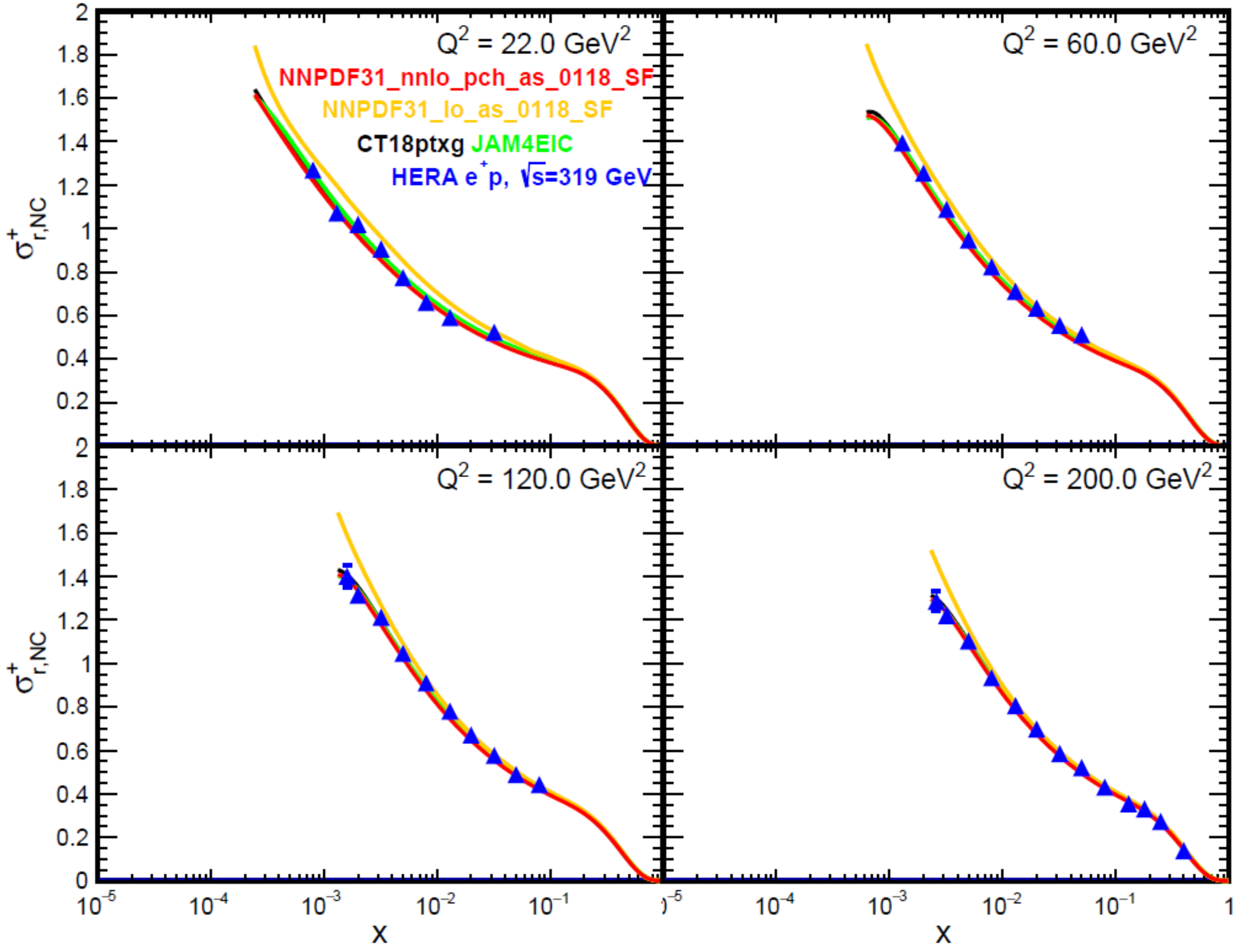


Theory predictions compared to *HERA* data



Theory predictions compared to *HERA* data



Ongoing Studies related to Kinematic Distributions

1. Kinematic Distributions for eA scattering using *BeAGLE*
2. Formal study with non-zero crossing angles
3. Study of hadronic reconstruction methods for NC events

Conclusions

- We've created NC kinematic maps using the *PYTHIA6* and *DJANGOH* generators for electron-proton scattering for the 4 required yellow report beam energy combinations.
- We are now working to recreate these maps assuming a non-zero beam crossing angle (i.e. 25 mRad and 50 mRad).
- We also will use the *BeAGLE* event generator to create similar kinematic maps for eA scattering
- The work shown here is documented here: https://wiki.bnl.gov/eicug/index.php/Yellow_Report_Physics_Inclusive_Reactions

BACKUP

Formal Studies with non-zero crossing angles

For 18GeV electrons on 275 GeV protons with 50 mRad crossing angle:

```
Initial Lorentz Vectors: (Electron, Proton, Center-Of-Mass):
(x,y,z,t)=(0.899625,0.000000,-17.977505,18.000000) (P,eta,phi,E)=(18.000000,-3.688671,0.000000,18.000000)
(x,y,z,t)=(0.000000,0.000000,274.998399,275.000000) (P,eta,phi,E)=(274.998399,10000000000.000000,0.000000,275.000000)
(x,y,z,t)=(0.899625,0.000000,257.020895,293.000000) (P,eta,phi,E)=(257.022469,6.348085,0.000000,293.000000)

Boost to COM frame and rotate so Proton (after Boost) is still along +z
```

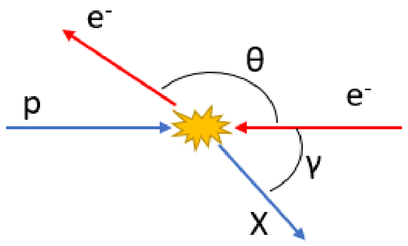
Event generation in the COM frame

```
Lorentz Vectors in COM Frame: (Electron, Proton, Center-Of-Mass):
(x,y,z,t)=(0.000000,0.000000,-70.332584,70.332584) (P,eta,phi,E)=(70.332584,-10000000000.000000,0.000000,70.332584)
(x,y,z,t)=(0.000000,0.000000,70.332584,70.338843) (P,eta,phi,E)=(70.332584,10000000000.000000,0.000000,70.338843)
(x,y,z,t)=(0.000000,0.000000,-0.000000,140.671427) (P,eta,phi,E)=(0.000000,-5.545193,0.000000,140.671427)

Boost back to original frame from COM frame

Lorentz Vectors in Original Frame: (Electron, Proton, Center-Of-Mass):
```

Particles are then boosted to the lab frame

```
(x,y,z,t)=(0.899625,0.000000,-17.977505,18.000000) (P,eta,phi,E)=(18.000000,-3.688671,0.000000,18.000000)
(x,y,z,t)=(0.000000,0.000000,274.998399,275.000000) (P,eta,phi,E)=(274.998399,10000000000.000000,0.000000,275.000000)
(x,y,z,t)=(0.899625,0.000000,257.020895,293.000000) (P,eta,phi,E)=(257.022469,6.348085,0.000000,293.000000)
```

Additional Reconstruction Methods



Jacquet-Blondel Method

$$P_e = (E_e, 0, 0, -\overset{E_e}{\cancel{P_e}})$$

$$P_p = (E_p, 0, 0, \overset{E_p}{\cancel{P_p}})$$

$$\cancel{P_{e'} = (E_{e'}, P_{e'} \sin\theta \cos\varphi, P_{e'} \sin\theta \sin\varphi, P_{e'} \cos\theta)}$$

$$P_X = (\cancel{E_X}, \cancel{P_X \sin\gamma \cos(\varphi+\pi)}, \cancel{P_X \sin\gamma \sin(\varphi+\pi)}, \cancel{P_X \cos\gamma})$$

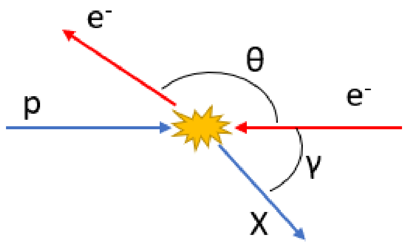
$$\sum_i E_i \qquad \sum_i p_{x,i} \qquad \sum_i p_{y,i} \qquad \sum_i p_{z,i}$$

F. Jacquet, A. Blondel, DESY 79-048 (1979) 377

Kinematic Invariants:

$$y_h = \frac{P_p \cdot q}{P_p \cdot P_e} = \frac{\Sigma_h}{2E_e}$$

$$\Sigma_h = \sum_i (E_i - p_{z,i}) = \sum_i E_i - \sum_i p_{z,i}$$



Additional Reconstruction Methods

E_e

$P_e = (E_e, 0, 0, -P_e)$

E_p

$P_p = \left(E_p, 0, 0, P_p\right)$

$E_{e'}$ $E_{e'}$ $E_{e'}$

$P_{e'} = (E_{e'}, P_{e'} \sin\theta\cos\varphi\,, P_{e'} \sin\theta\sin\varphi\,, P_{e'} \cos\theta)$

$P_X = (E_X, P_X \sin\gamma\cos(\varphi+\pi)\,, P_X \sin\gamma\sin(\varphi+\pi)\,, P_X \cos\gamma)$

$\sum_i E_i$ $\sum_i p_{x,i}$ $\sum_i p_{y,i}$ $\sum_i p_{z,i}$

F. Jacquet, A. Blondel, DESY 79-048 (1979) 377

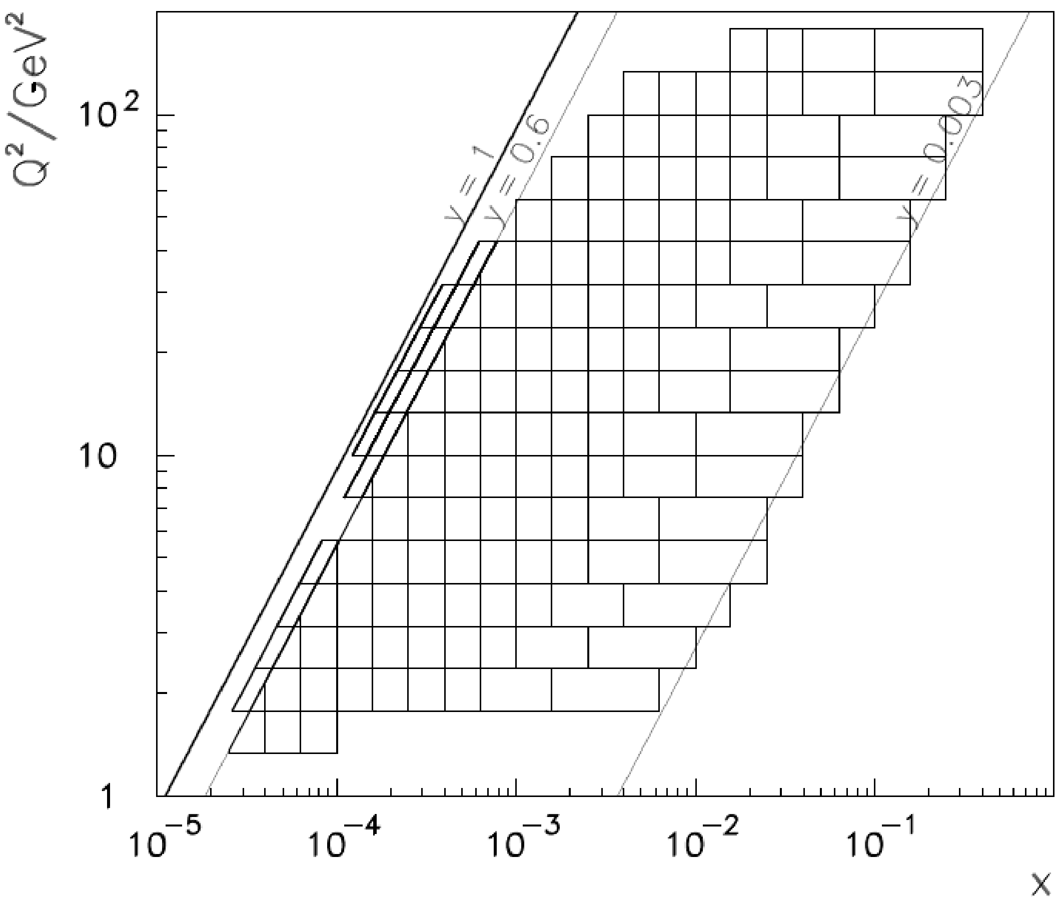
Double-Angle Method

Kinematic Invariants:

$$y_{DA} = \frac{\tan\gamma/2}{\tan\theta/2 + \tan\gamma/2}$$

$$Q^2_{DA} = 4E_e^2 \frac{\cot\theta/2}{\tan\theta/2 + \tan\gamma/2}$$

Approximate binning used for *HERA* data



We used approximately the same Q^2 binning for the simulation/*HERA* comparison plots shown in the above slides