Elastic Electron-Proton and Electron-Deuteron Scattering at the EIC

Barak Schmookler

(+ Douglas Higinbotham

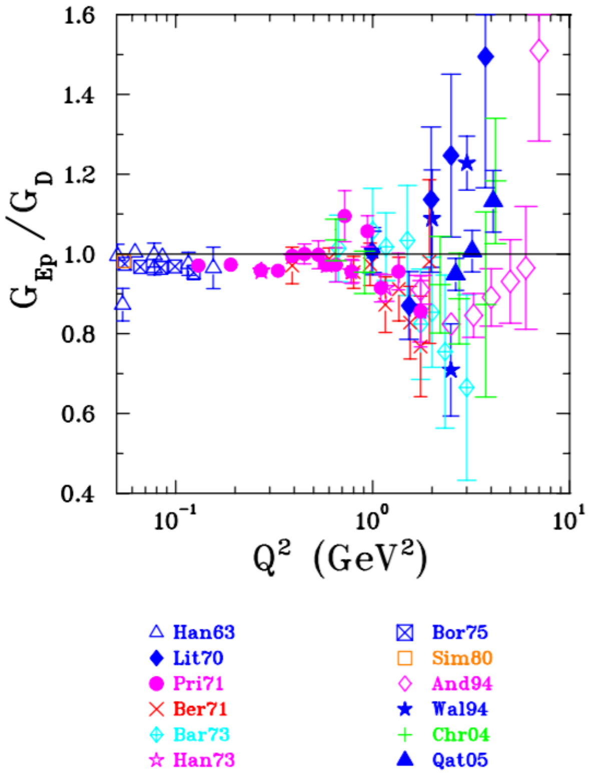
Andrew Puckett

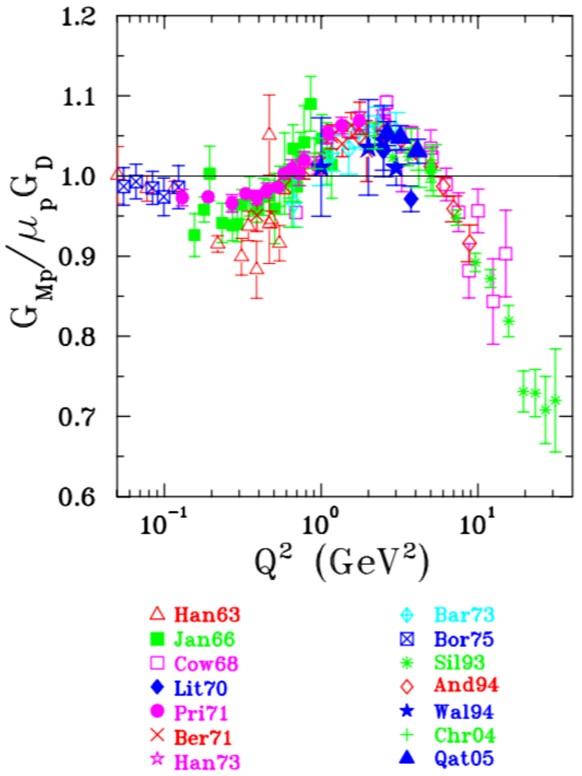
Elena Long)

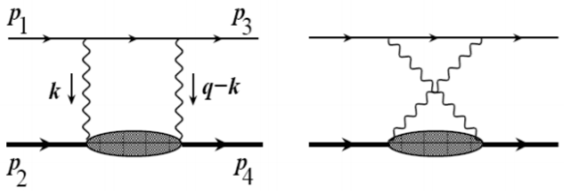
Elastic Electron-Proton Scattering at the EIC

Elastic electron-proton scattering at high Q^2 can be interesting in itself:

- Precision G_M required to study approach of QCD scaling in Dirac F_1 Form Factor
- Constraints on GPDs at high-x & high-t via sum rules
- Possible increased sensitivity to hard two-photon exchange effects

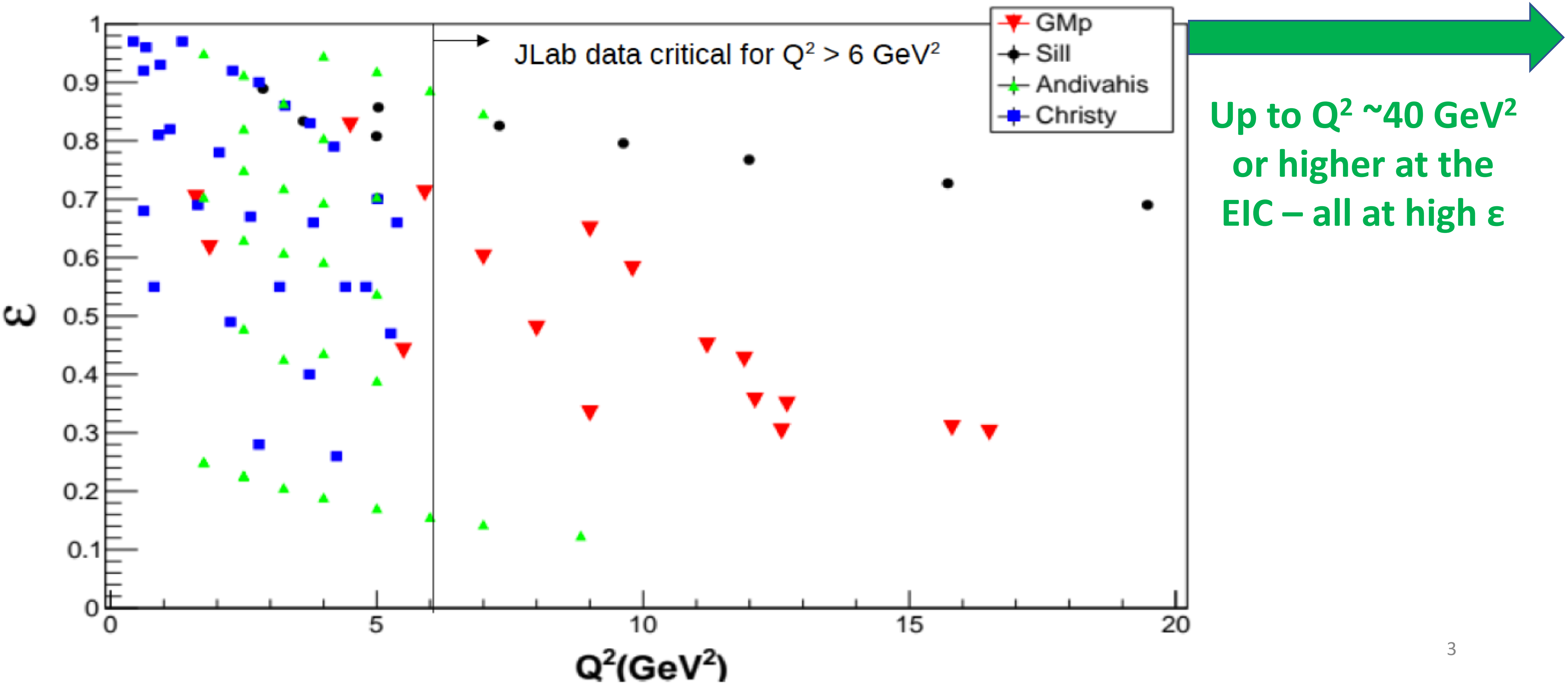






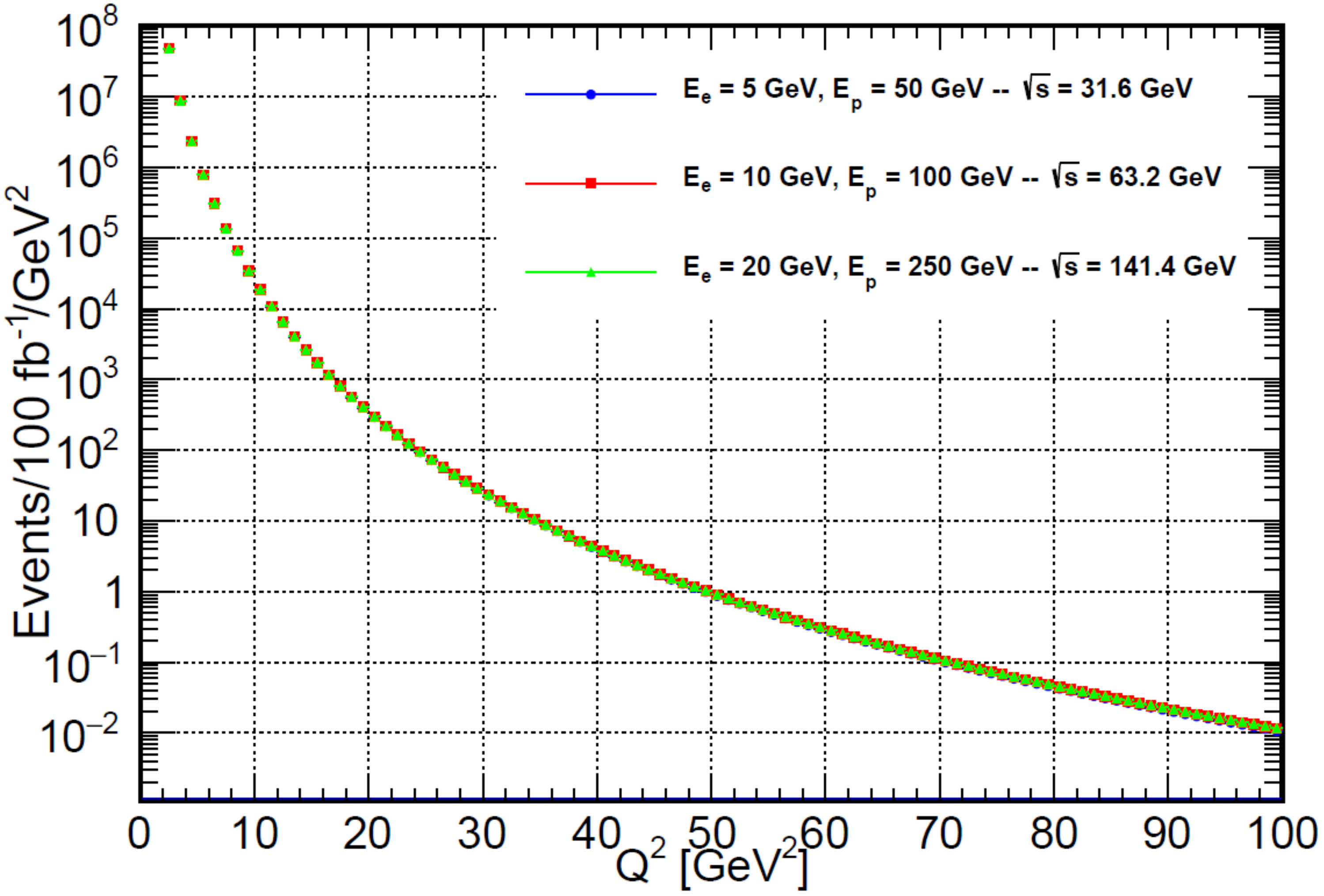
C.F Perdrisat, V. Punjabi, M. Vanderhaeghen, *Progress in Particle and Nuclear Physics 59 (2007) 694–764*

For ep elastic scattering, the *EIC* will allow us to probe the highest-ever values of Q^2

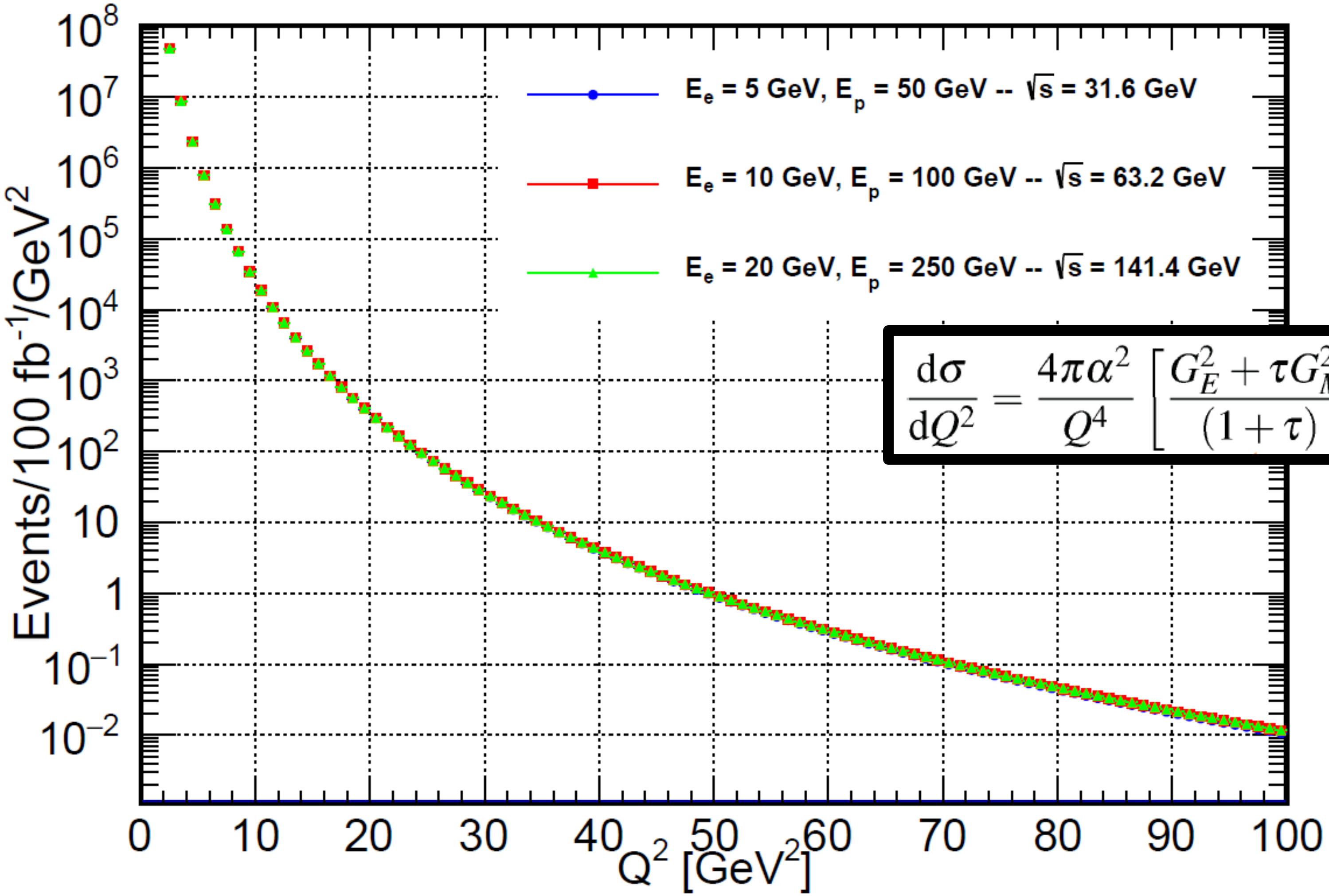


Up to Q^2 ~40 GeV^2 or higher at the EIC – all at high ε

Electron-Proton Elastic scattering expected yields



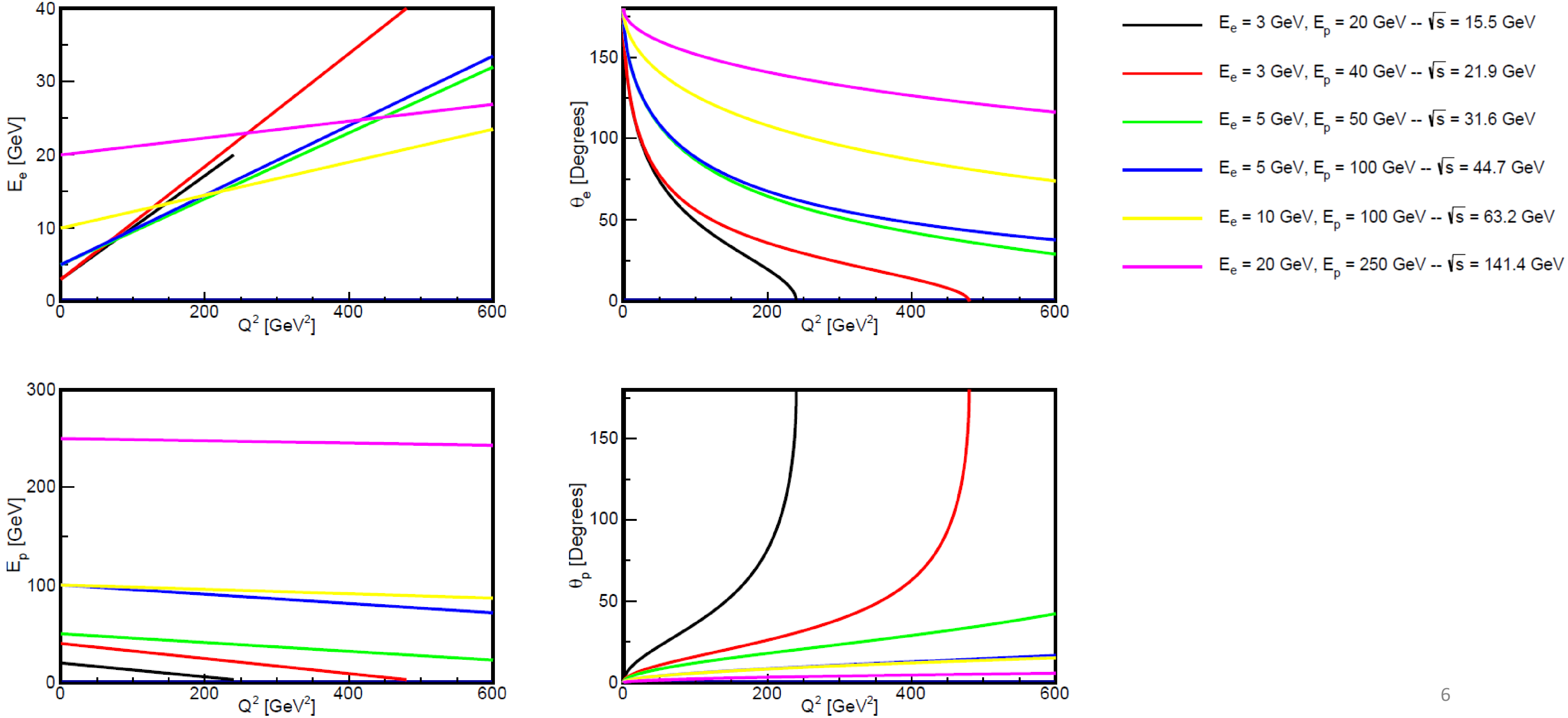
Electron-Proton Elastic scattering expected yields



$$\frac{d\sigma}{dQ^2} = \frac{4\pi\alpha^2}{Q^4}\left[\frac{G_E^2+\tau G_M^2}{(1+\tau)}\left(1-y-\frac{M^2y^2}{Q^2}\right)+\frac{1}{2}y^2G_M^2\right]$$

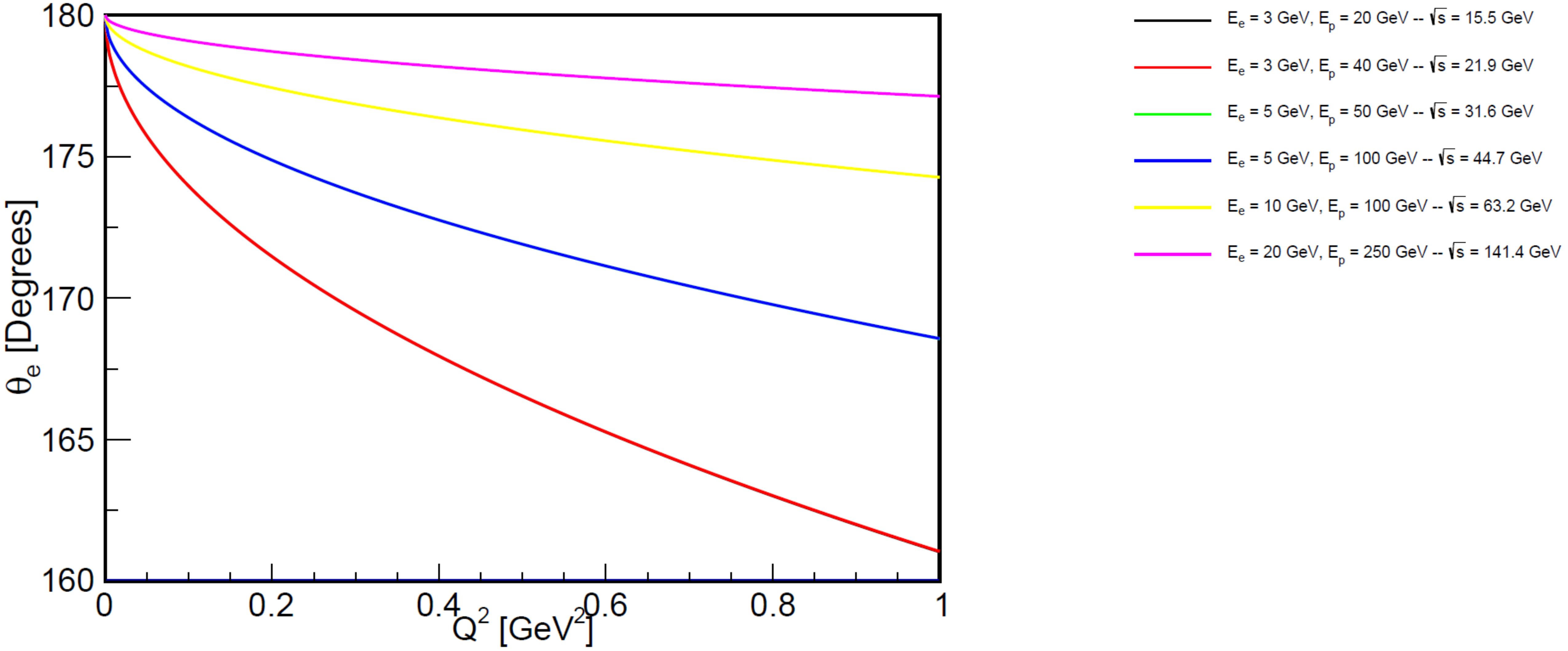
Lack of dependence on beam energy seen here is expected at the EIC since the data will all be at y~0 (ε~1). See the Lorentz-invariant cross section formula above

Kinematics

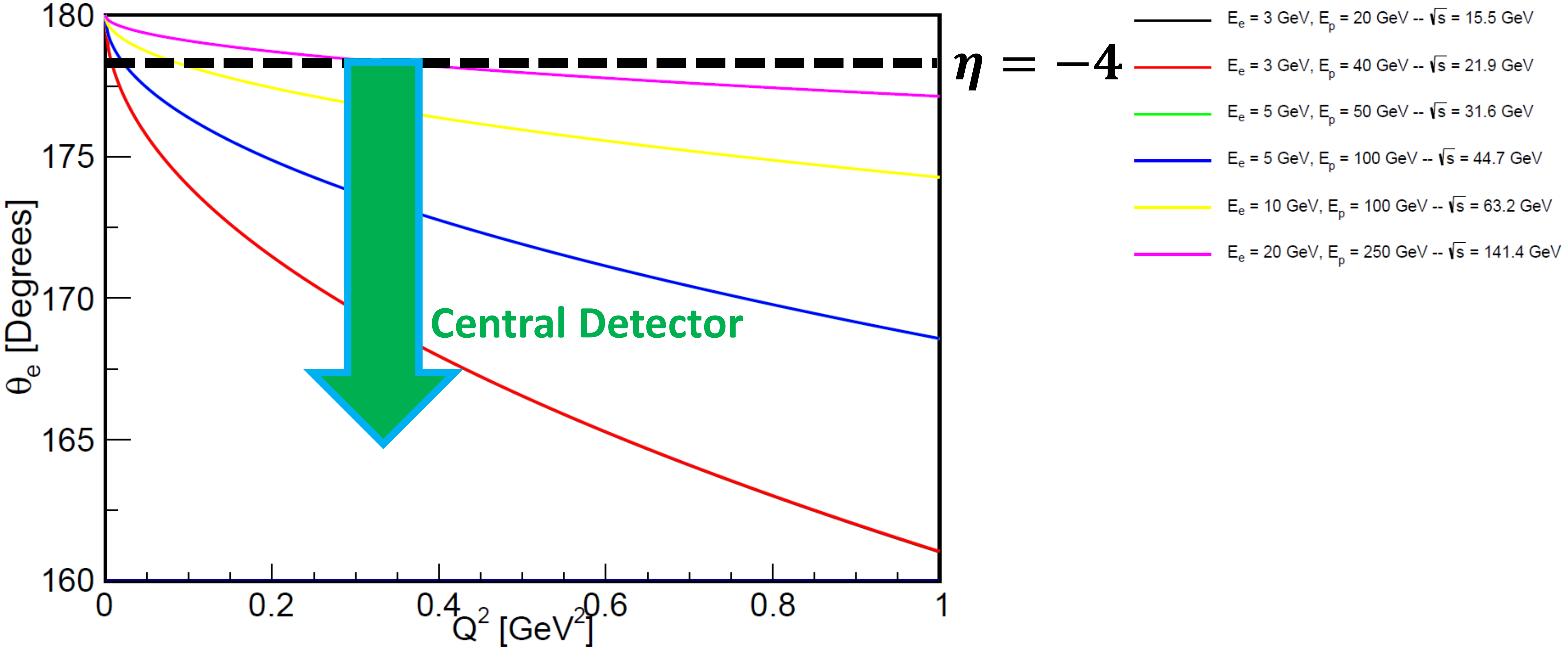


E_e [GeV]
θ_e [Degrees]
E_p [GeV]
θ_p [Degrees]
Q^2 [GeV^2]
E_e = 3 GeV, E_p = 20 GeV -- √s = 15.5 GeV
E_e = 3 GeV, E_p = 40 GeV -- √s = 21.9 GeV
E_e = 5 GeV, E_p = 50 GeV -- √s = 31.6 GeV
E_e = 5 GeV, E_p = 100 GeV -- √s = 44.7 GeV
E_e = 10 GeV, E_p = 100 GeV -- √s = 63.2 GeV
E_e = 20 GeV, E_p = 250 GeV -- √s = 141.4 GeV

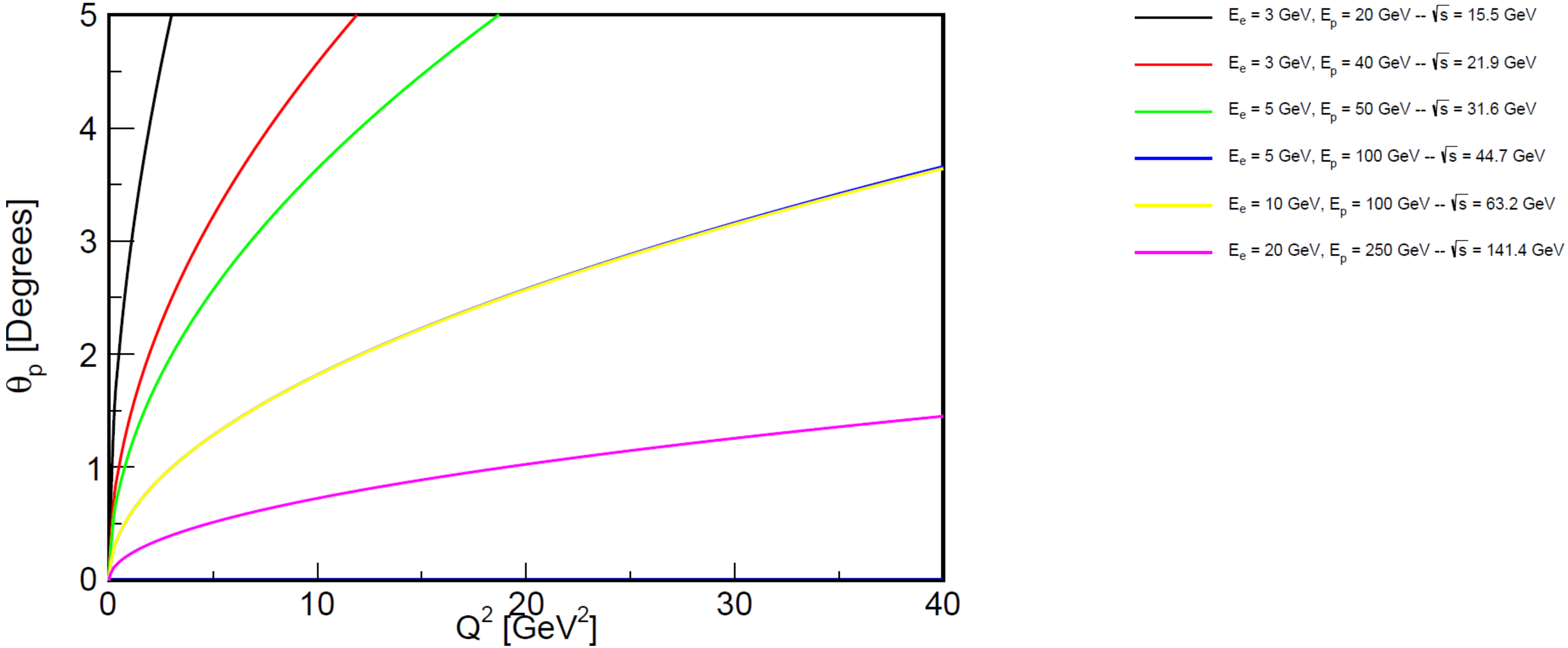
Kinematics: Low Q^2 Electron Angle



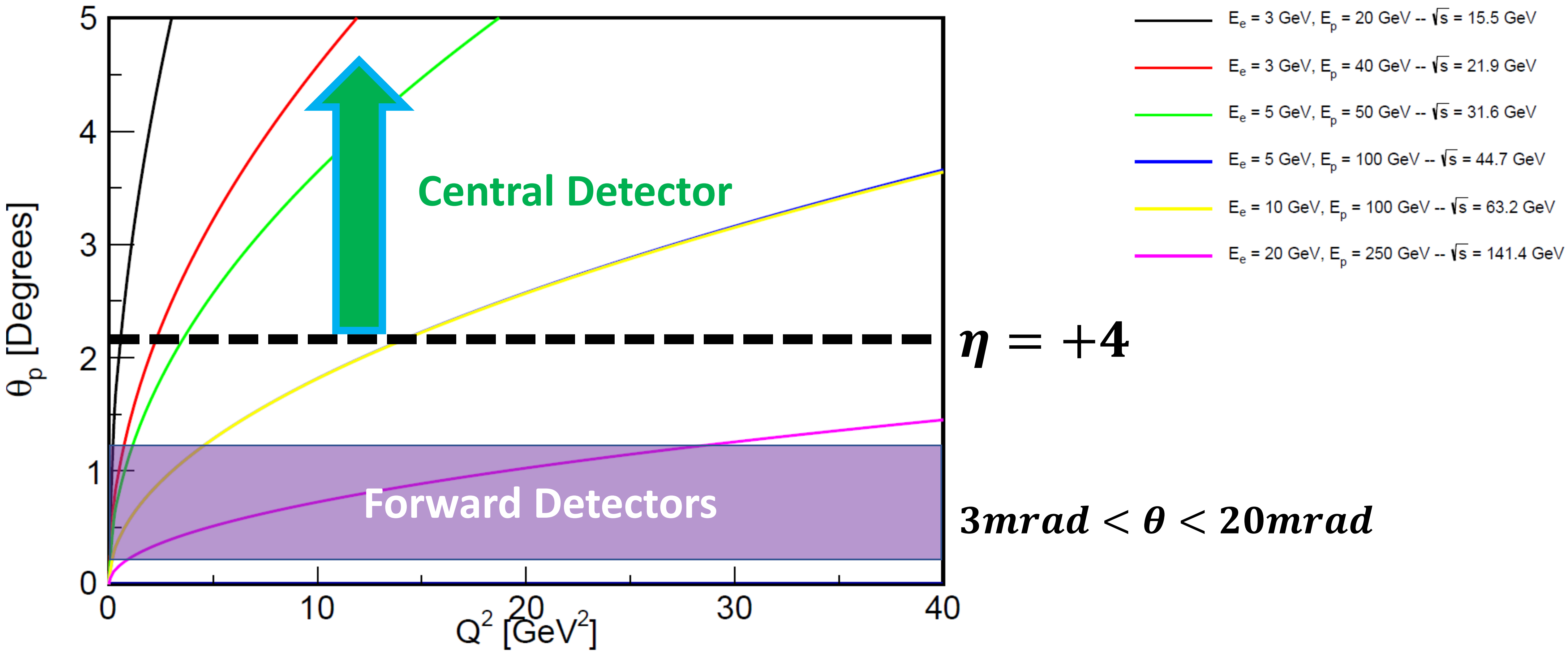
Kinematics: Low Q^2 Electron Angle



Kinematics: Proton Angle

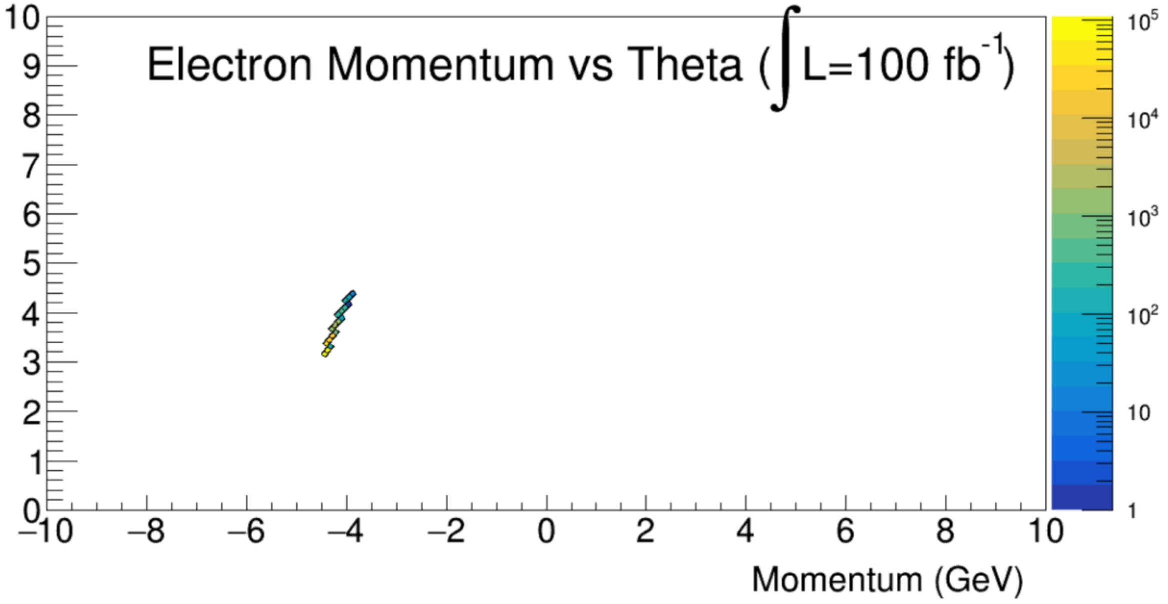


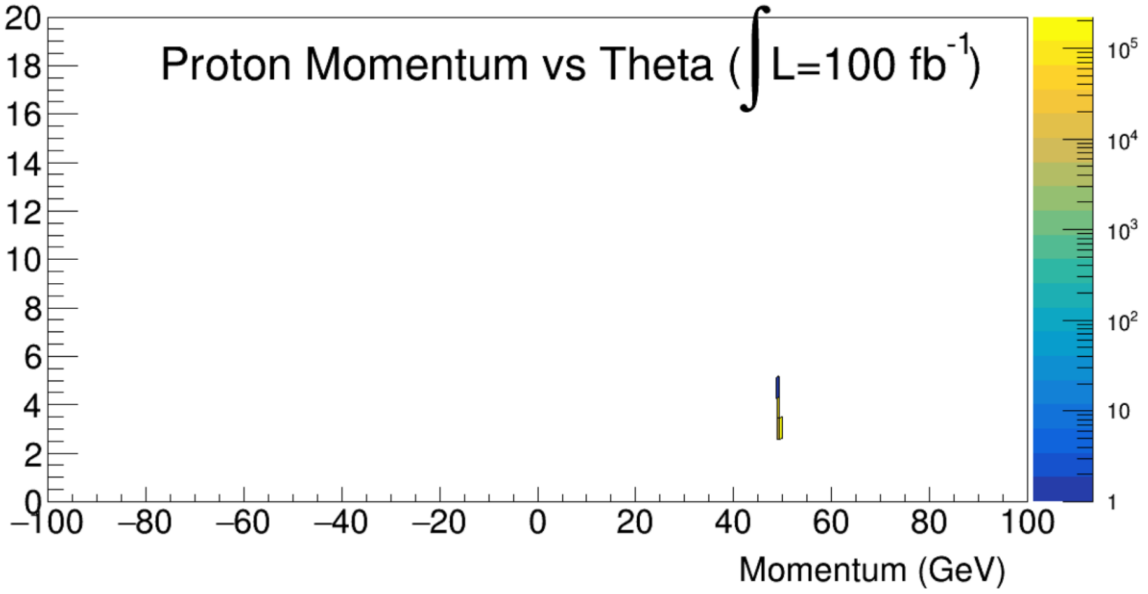
Kinematics: Proton Angle



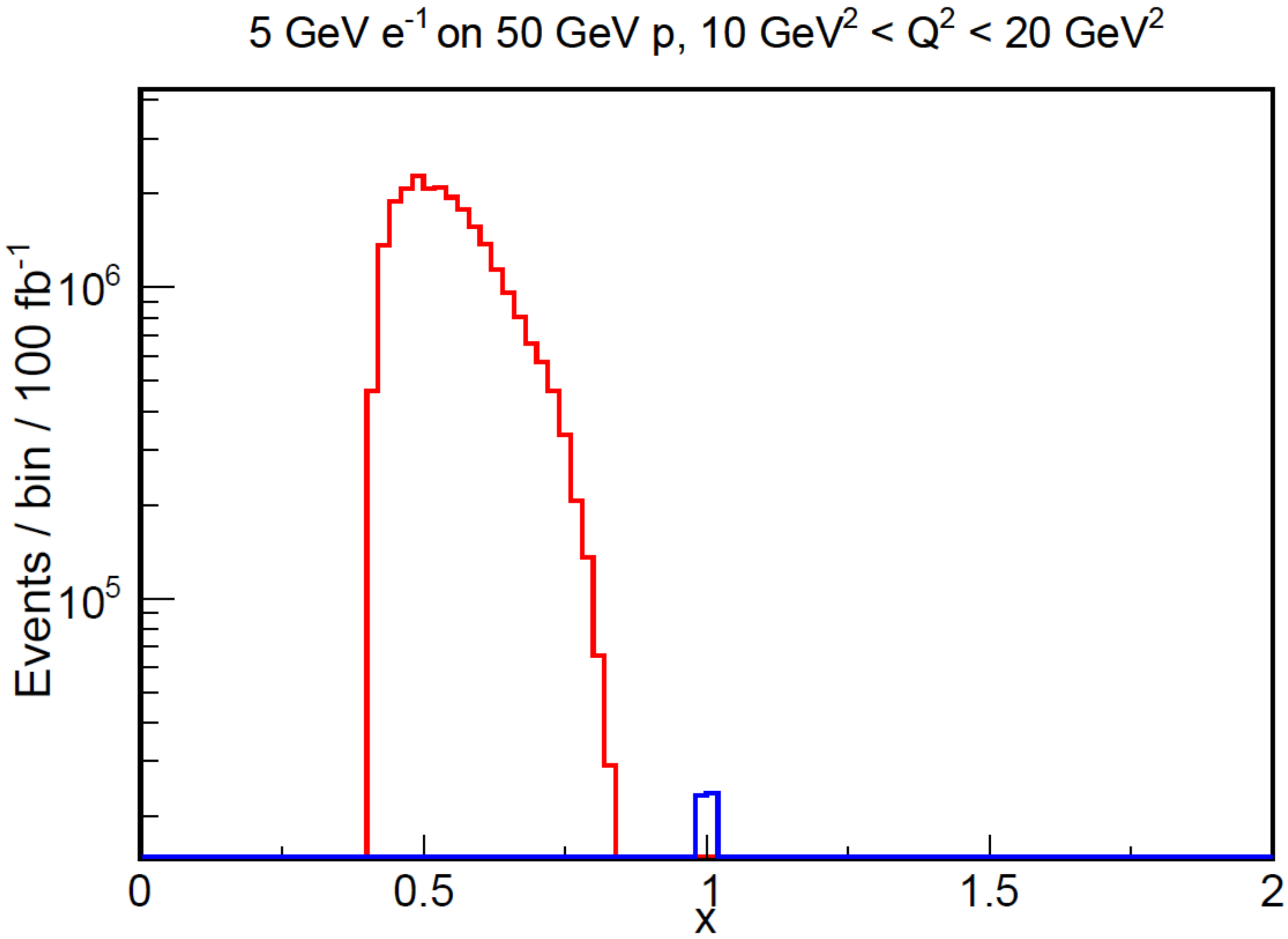
Kinematics: Momentum vs. Angle

5 GeV electron on 50 GeV proton
10 $GeV^2 < Q^2 <$ 20 GeV^2





Mix With *Pythia6* Events – Generator Level



PYTHIA6 Events

Elastic Events

Polarized Electron-Proton Elastic Scattering Asymmetry Measurements

$$
\begin{aligned}
A_{eN} &= -\frac{P_{beam}P_{target}}{1+\frac{\epsilon}{\tau}r^2}\left[\left(\sqrt{\frac{2\epsilon(1-\epsilon)}{\tau}}\sin\theta^*\cos\phi^*\right)r+\sqrt{1-\epsilon^2}\cos\theta^*\right] \\
&\equiv P_{target}\left[A_t\sin\theta^*\cos\phi^*+A_\ell\cos\theta^*\right]
\end{aligned}
$$

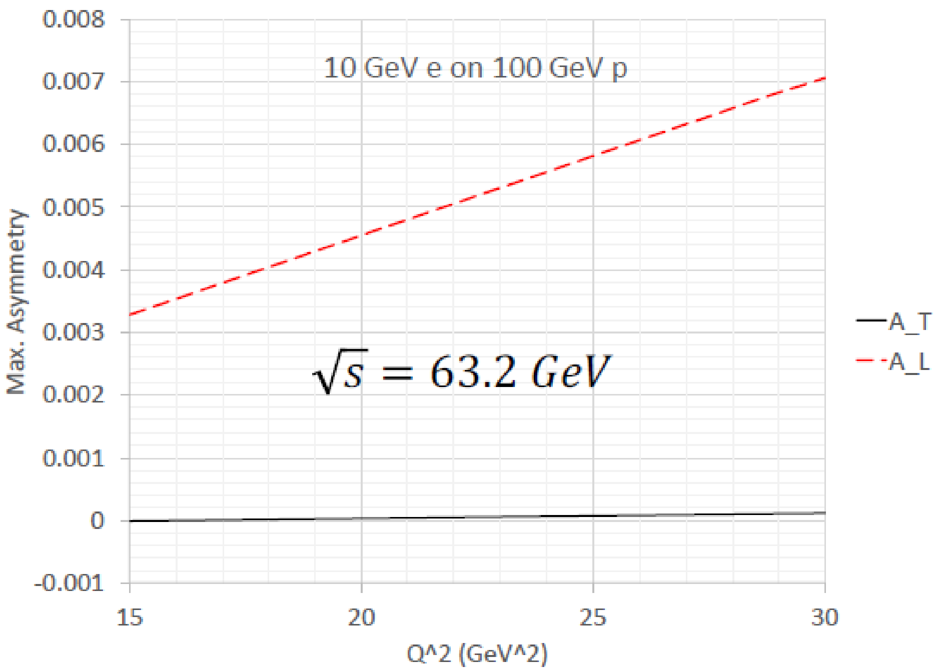
$$
r \equiv \frac{G_E}{G_M}
$$

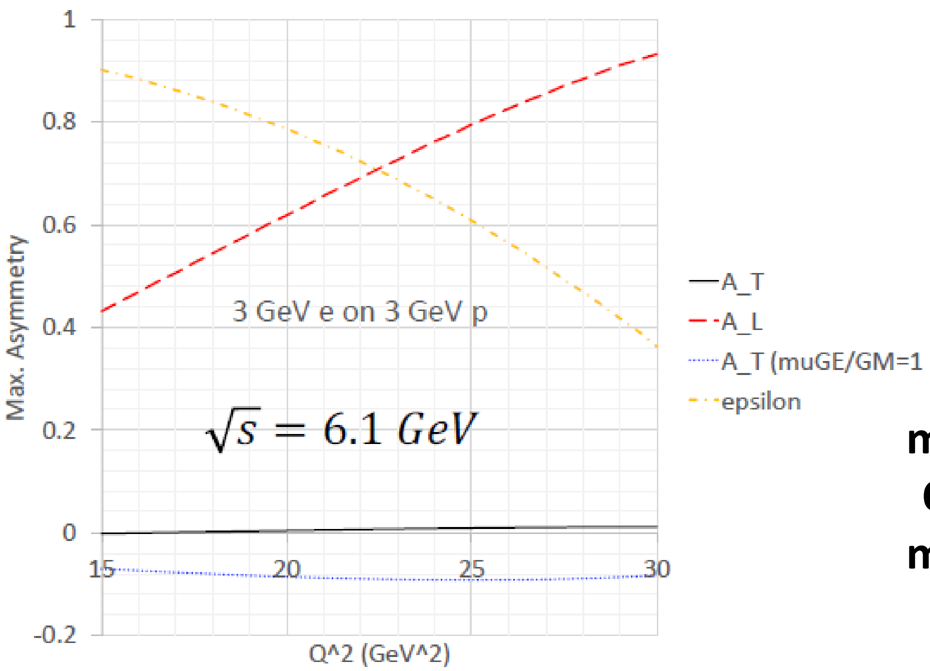
Polarized Electron-Proton Elastic Scattering Asymmetry Measurements

$$A_{eN} = -\frac{P_{beam}P_{target}}{1+\frac{\epsilon}{\tau}r^2}\left[\left(\sqrt{\frac{2\epsilon(1-\epsilon)}{\tau}}\sin\theta^*\cos\phi^*\right)r+\sqrt{1-\epsilon^2}\cos\theta^*\right]$$

$$\equiv P_{target}\left[A_t\sin\theta^*\cos\phi^*+A_\ell\cos\theta^*\right]$$

$$r \equiv \frac{G_E}{G_M}$$





To make reasonable measurements in this higher Q^2 range, we would need a much lower energy than will be provided by the *EIC*

Summary

- For unpolarized electron-proton scattering, we see the possibility of making high Q^2 measurements. We are working to determine how easily elastic events can be separated from high-x inelastic events.
- We will most likely be unable to make useful beam-target double-spin asymmetry measurements at high Q^2 using the *EIC*.
- We are beginning to conduct simulation studies on elastic electron-deuteron scattering for both form factor measurements and tensor polarization determination.

BACKUP

Description of rest-frame Elastic generator with anti-parallel beams

1. Boost from lab frame to proton's rest frame
2. Generate events according to Born cross section below
3. Form factor parameterization comes from *Kelly (*PHYSICAL REVIEW C **70**, 068202 2004, Phys. Rev. C **96**, 055203).
4. We choose to generate 100 fb^{-1} worth of simulation data

$$\frac{d\sigma}{d\Omega_e} = \left(\frac{d\sigma}{d\Omega_e}\right)_{Mott} \frac{\epsilon G_E^2 + \tau G_M^2}{\epsilon(1+\tau)}$$

$$\left(\frac{d\sigma}{d\Omega_e}\right)_{Mott} = \frac{\alpha^2 \cos^2\left(\frac{\theta_e}{2}\right)}{4E_e^2 \sin^4\left(\frac{\theta_e}{2}\right)} \frac{E'_e}{E_e}$$

$$\sigma_R = \epsilon G_E^2 + \tau G_M^2$$

$$\tau \equiv \frac{Q^2}{4M_p^2}$$

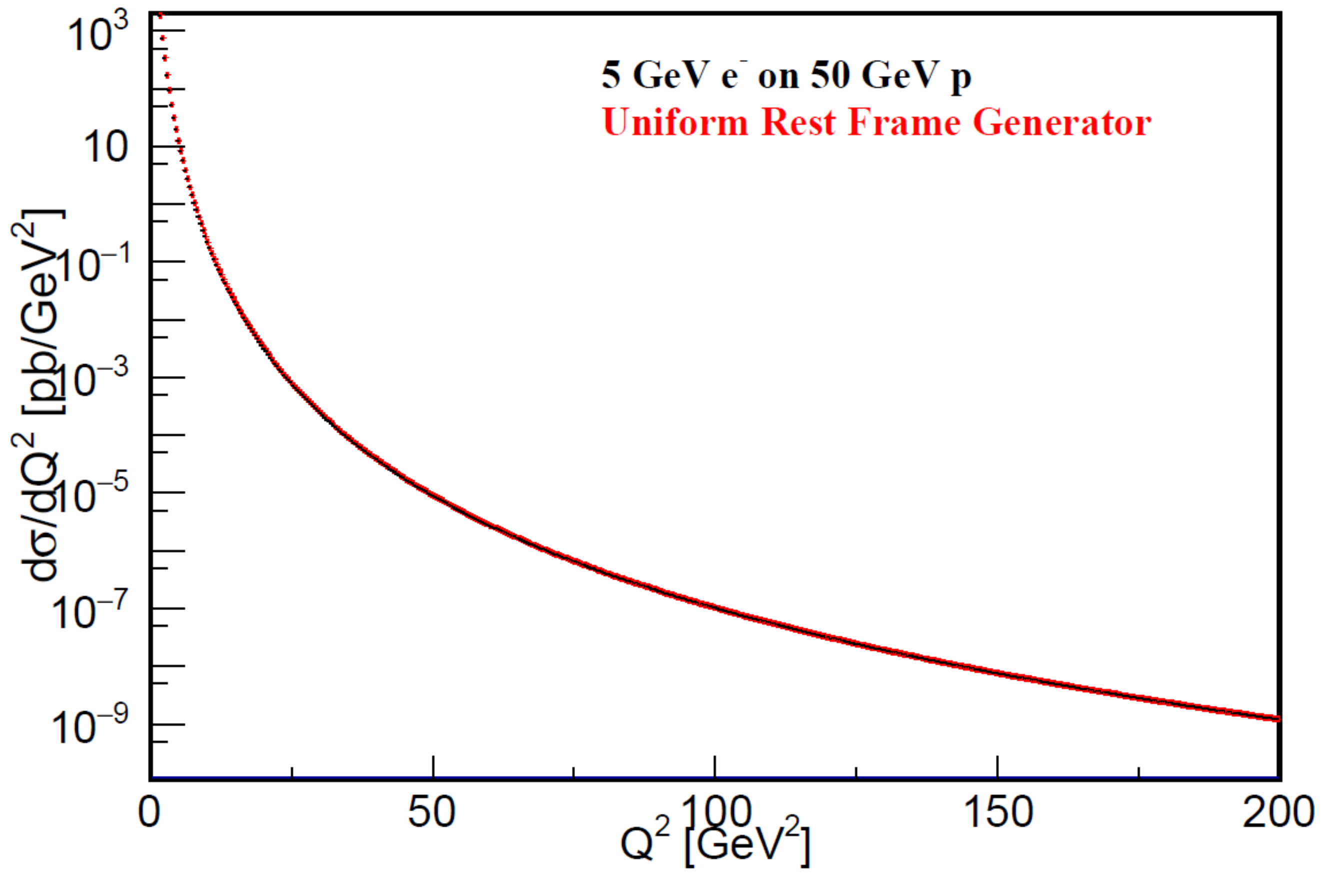
$$\epsilon \equiv \left[1 + 2(1+\tau)\tan^2\left(\frac{\theta_e}{2}\right)\right]^{-1}$$

Elastic Generator normalization for uniform generator

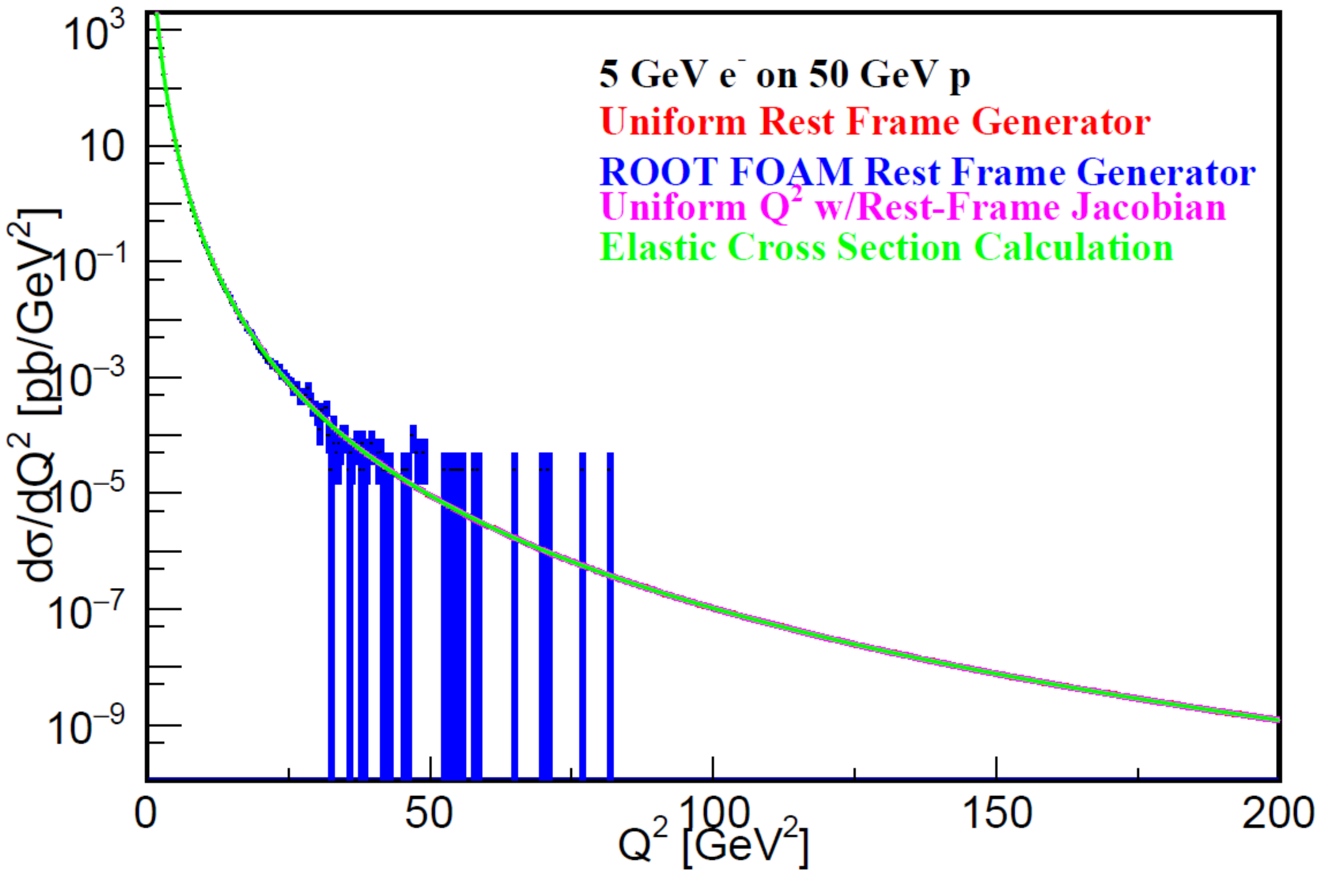
For Uniform Generator, to get expected yield (in bins of Q^2, for example), weight each event by:

$$\frac{\frac{d\sigma}{d\Omega_i}\ (\Omega_{tot})}{N_{tot}\ \Delta Q_i^2} \times luminosity$$

Generator agrees with cross section calculation



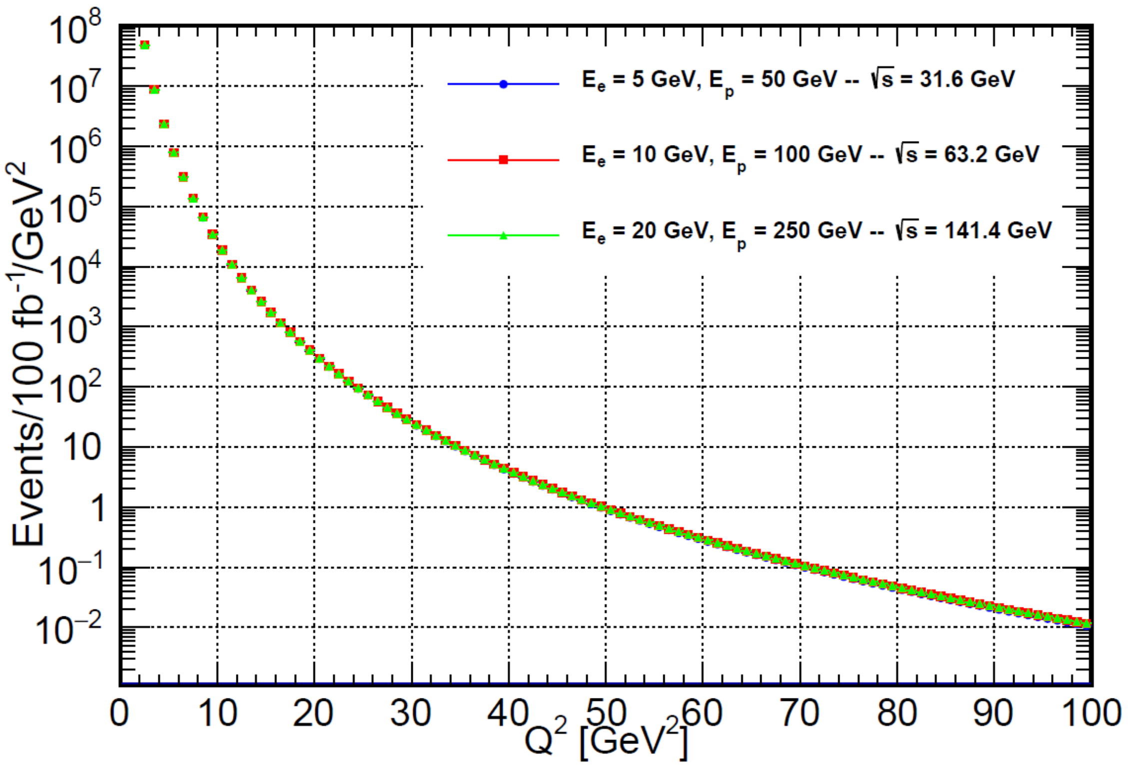
Generator agrees with cross section calculation



$$\frac{d\sigma}{dQ^2} = \frac{4\pi\alpha^2}{Q^4}\left[\frac{G_E^2+\tau G_M^2}{(1+\tau)}\left(1-y-\frac{M^2y^2}{Q^2}\right)+\frac{1}{2}y^2G_M^2\right]$$

Generating in the proton rest frame and the lab frame also gives consistent results

Rest Frame Generator



Lab Frame Generator