MuIC: Kinematic Reach and Reconstruction

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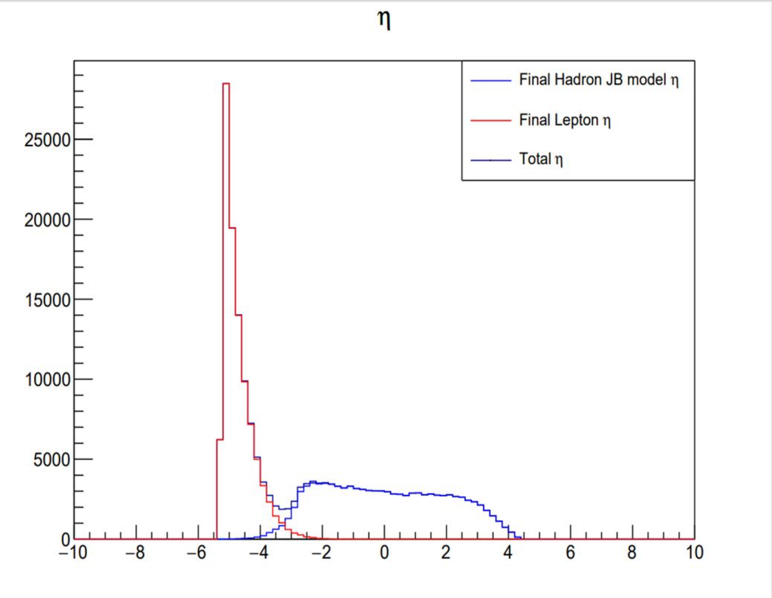
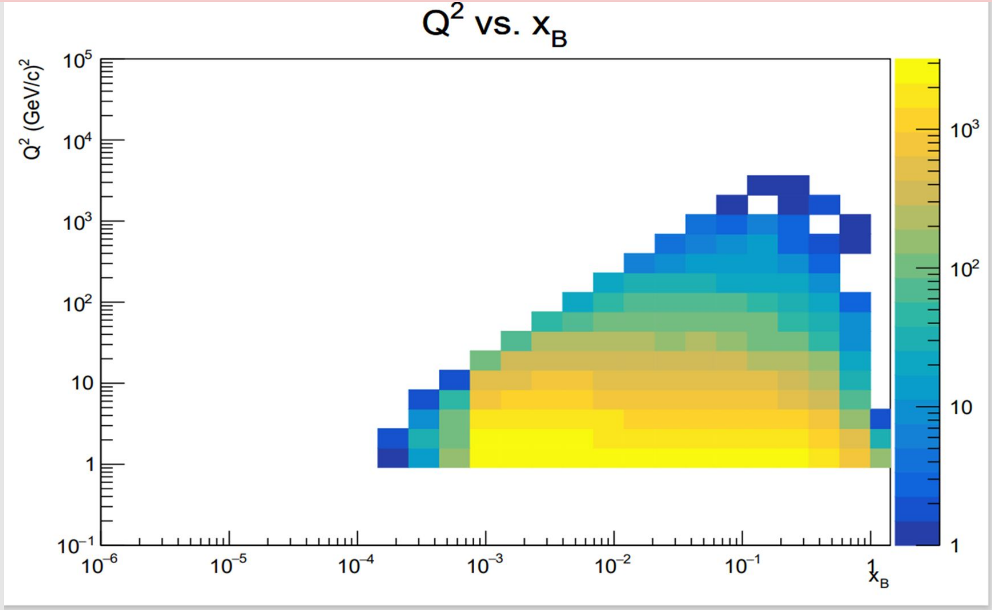
MuIC Concept

The high-energy physics community has shown significant interest in constructing a $\mu^+ \mu^-$ collider to probe a high center-of-mass energy regime. There are a number of high energy physicists interested in a muon collider generally as well. Once the physics program of the EIC has been completed, the existing infrastructure can be repurposed to host a future muon-ion collider (muon frontend).

This muIC can be used as a test facility to address key accelerator requirements for a future $\mu^+ \mu^-$collider, while also addressing several new physics on its own. In a small series of investigations at Brookhaven National Laboratory we showed the kinematic reach of the future muIC using some code that simulated elastic collisions between muons and protons (not significantly different than elastic proton and electron collisions), with several muon beam energies, ranging from 18 GeV to 200 GeV. The evolution of the Q2 and Bjorken x distributions, along with the pseudo rapidity distribution will be shown. As we vary energy, we see varying eta distributions and ratios of Q vs Bjorken x. Specifically, increases in muon energy led to decreases in representation in the high Q^2 region.

Previous Kinematic Reach Studies





Previous EIC Studies

In a previous paper we used methods of reconstruction, statistical background cuts, and more to do a feasibility study on the energies of the Electron Ion Collider (EIC) with respect to protons and electron elastic collisions. We use some of the methods and software of that paper for this presentation’s plots.

High Q^2 electron-proton elastic scattering at the future Electron-Ion Collider

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EIC Concepts

Definitions:

s = center of mass energy

$$
\begin{aligned}
y_e &= 1 - \frac{E'_e}{2E_e}(1-\cos\theta_e) \ , \\
Q^2_e &= 4E_eE'_e\cos^2(\theta_e/2) \ , \\
x_e &= \frac{Q^2_e}{sy_e} \ .
\end{aligned}
$$

$$
\begin{aligned}
y_{jb} &= \frac{E'_p - p_{z,p}}{2E_e} \ , \\
Q^2_{jb} &= \frac{p^2_{T,p}}{1-y_{jb}} \\
x_{jb} &= \frac{Q^2_{jb}}{sy_{jb}} \ .
\end{aligned}
$$

$$
\begin{aligned}
y_{da} &= \frac{\tan(\theta_p/2)}{\tan(\theta_e/2)+\tan(\theta_p/2)} \ , \\
Q^2_{da} &= 4E^2_e\frac{\cot(\theta_e/2)}{\tan(\theta_e/2)+\tan(\theta_p/2)} \ , \\
x_{da} &= \frac{Q^2_{da}}{sy_{da}} \ .
\end{aligned}
$$

Detector in the EIC

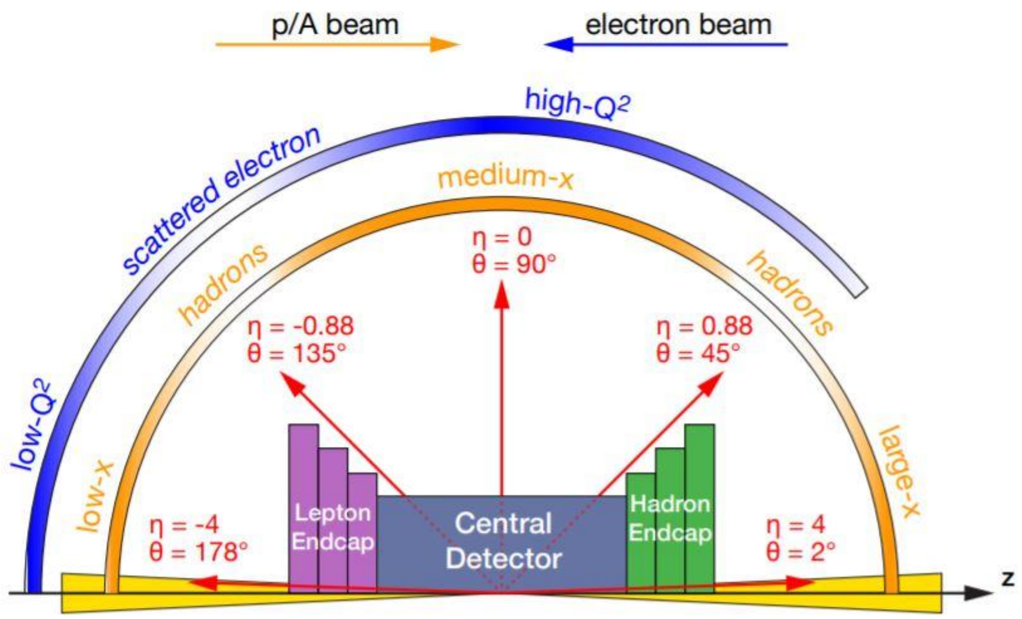


Figure 2.2: Schematic showing the distribution of the scattered lepton and hadrons for different $x - Q^2$ regions over the detector polar angle / pseudorapidity coverage.

Reconstruction

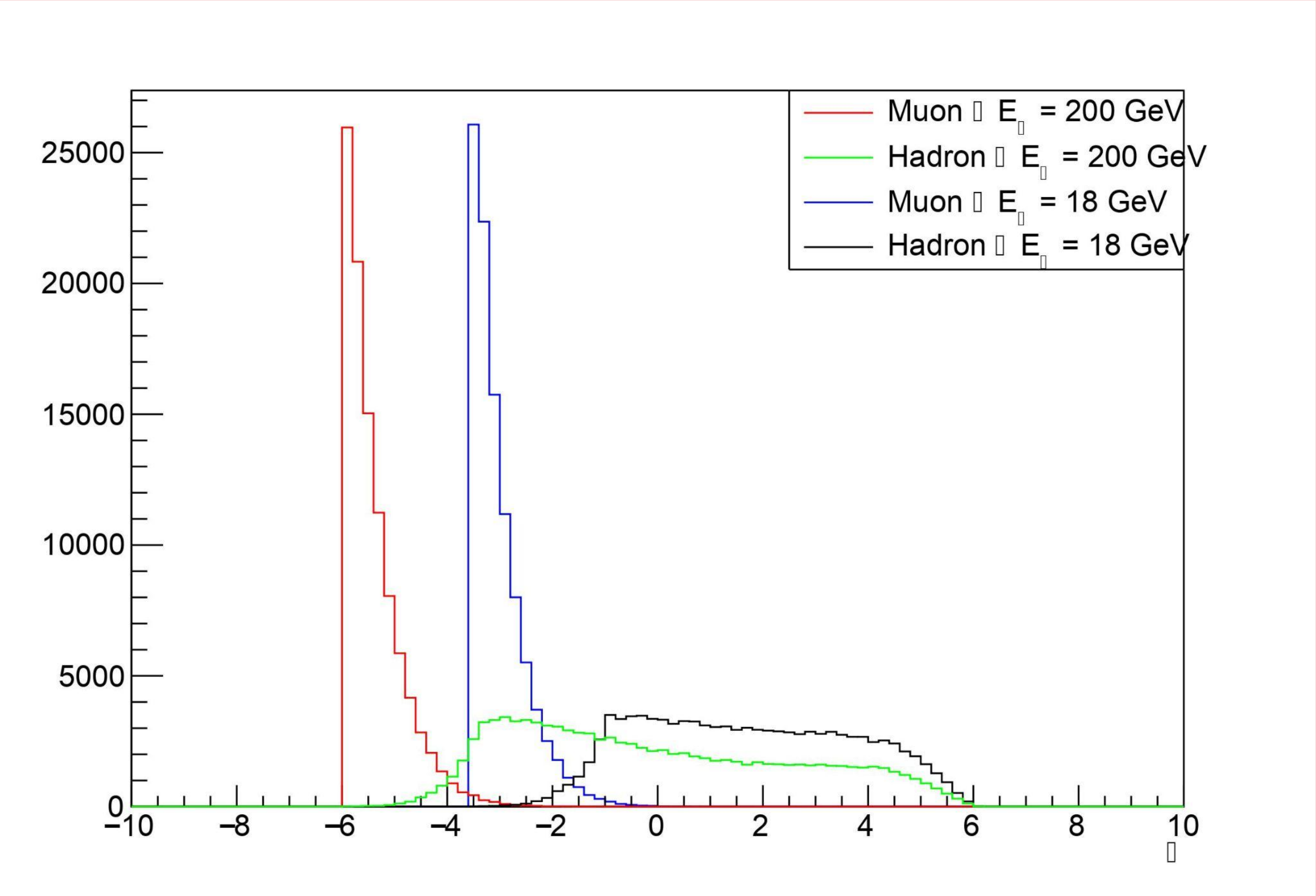
Several methods of reconstruction are needed because typically we rely on a scattered electron to be detected but at times they are not detected, there is no electron, or reconstruction is poor. Scattered electron method is the default method for reconstruction

In our studies here, there are muons, not electrons. There will be a reconstruction with just lepton information (muon post collision)

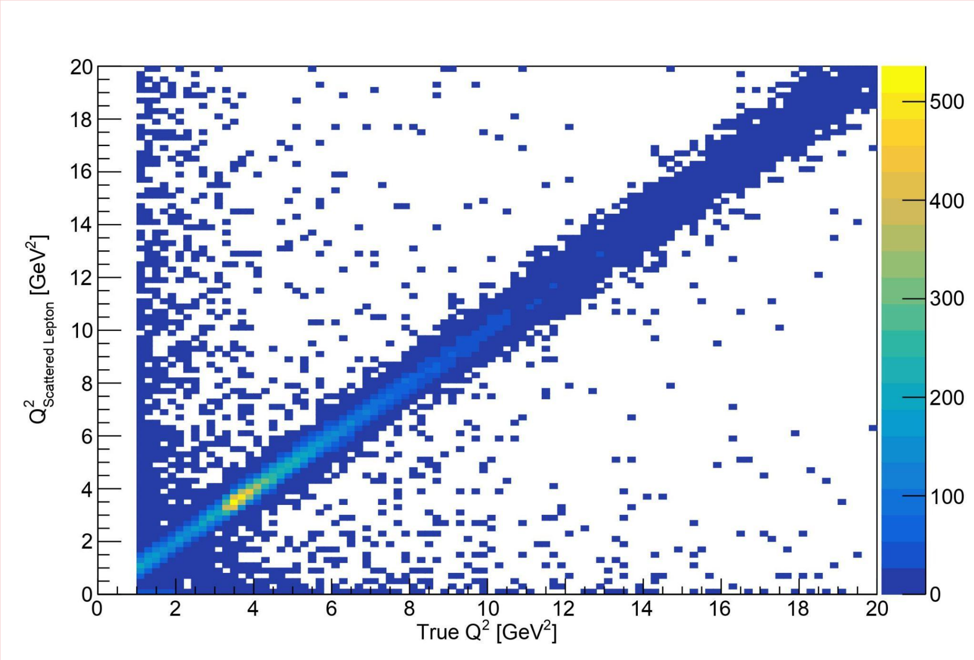
Jacquet Blondel method only consider hadronic information (proton in this case)

Double Angle method uses both leptonic and hadronic information

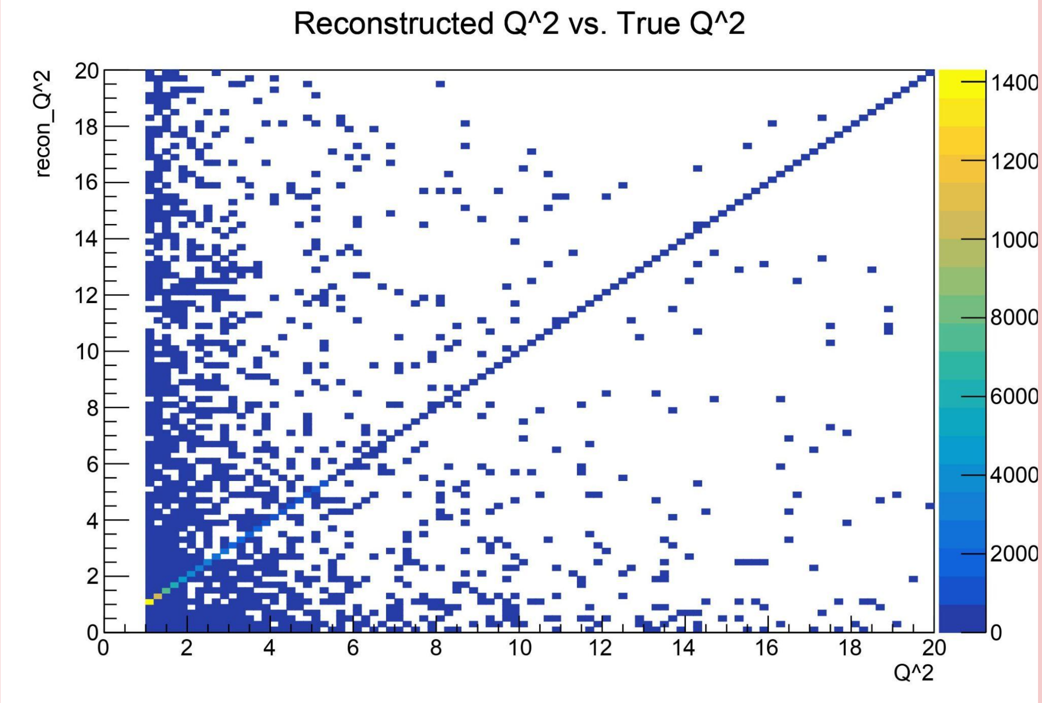
Count vs Eta Range



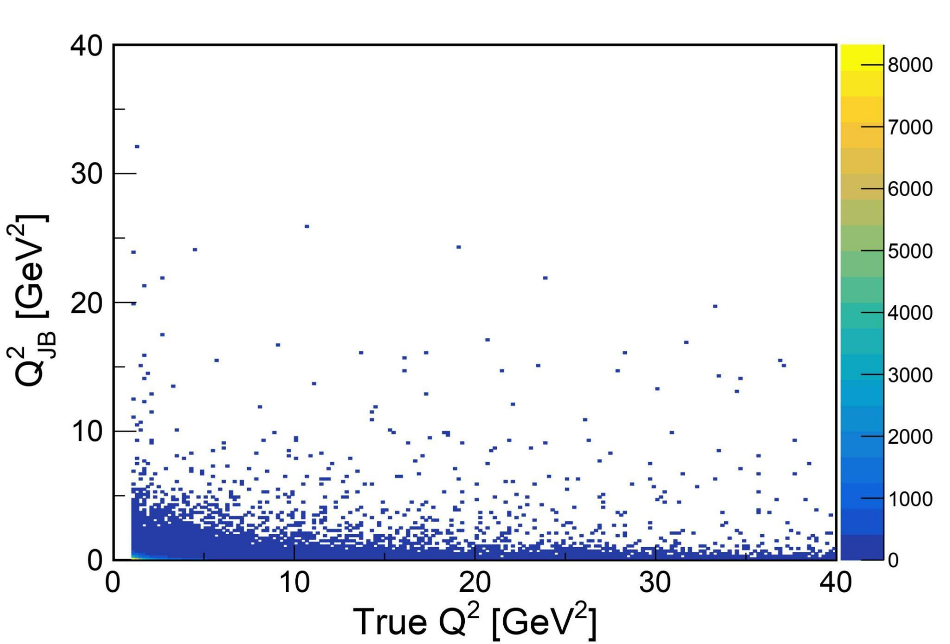
Reconstruction Q^2, EIC detector (scattered lepton method)



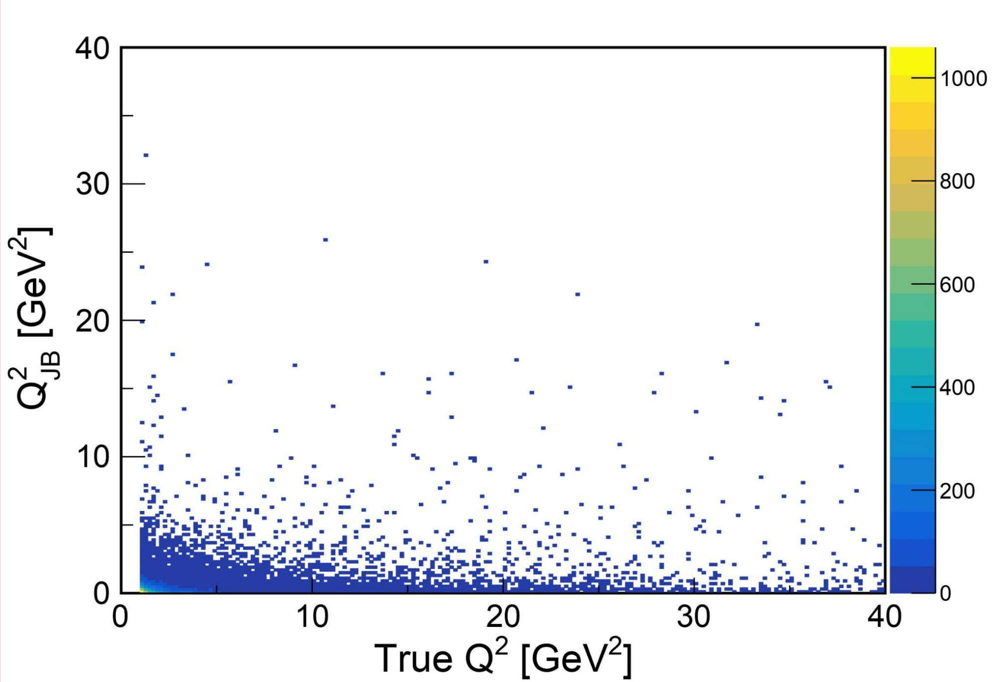
Reconstructed Q^2, Perfect Detector (scattered lepton method)



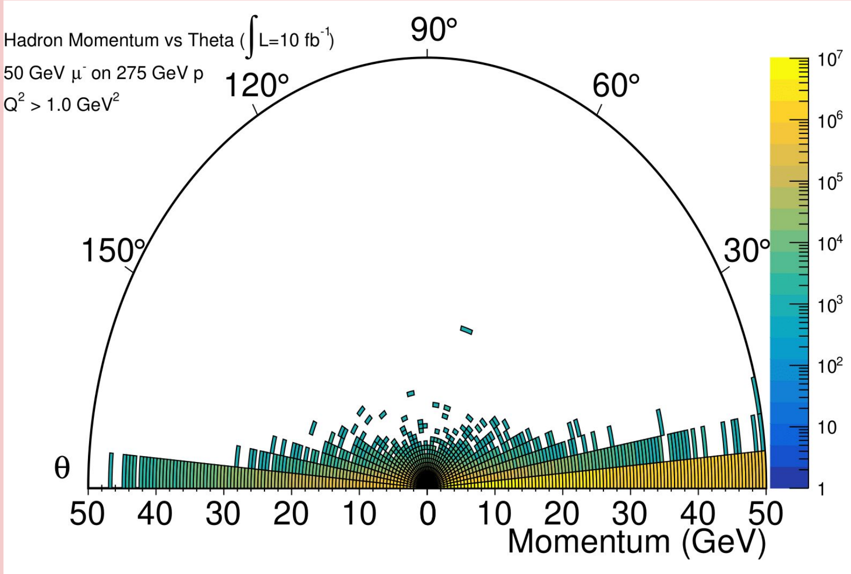
Reconstruction Q^2, perfect detector (Jacquet Blondel method)

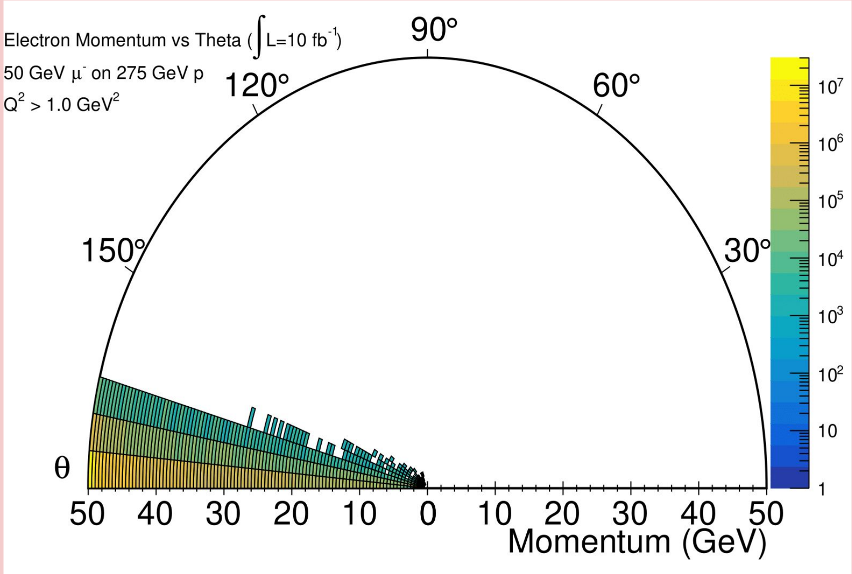


Reconstruction Q^2, EIC detector (Jacquet Blondel Method)

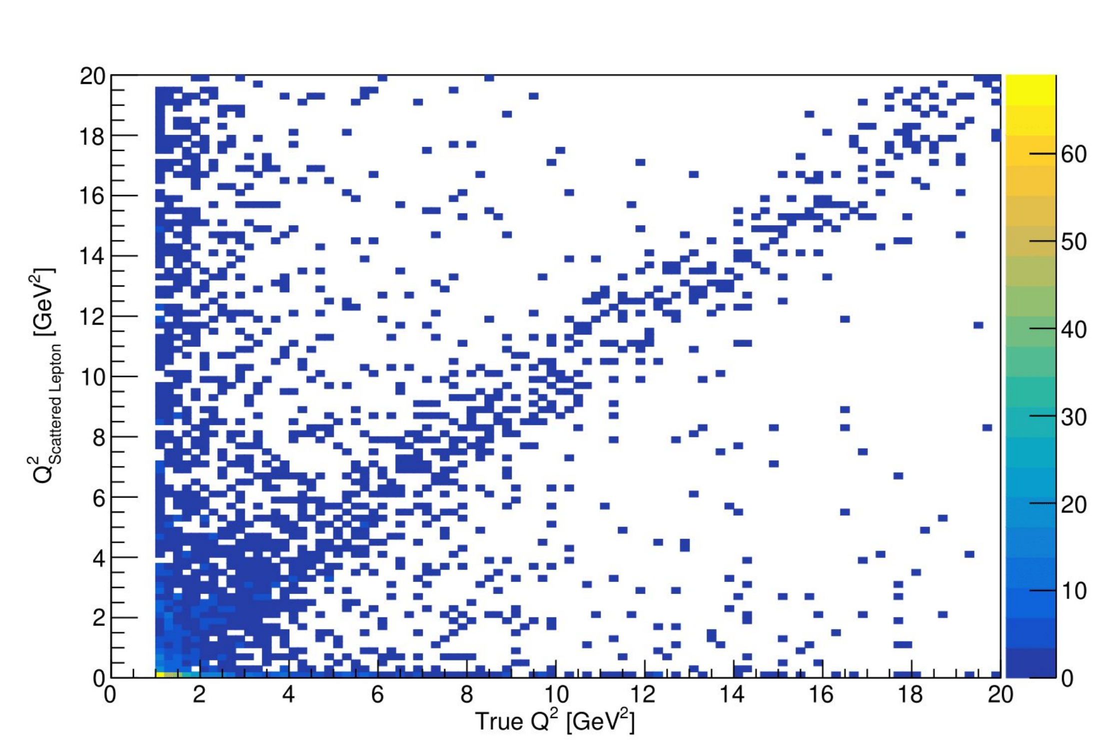


50 GeV muon vs 275 GeV proton

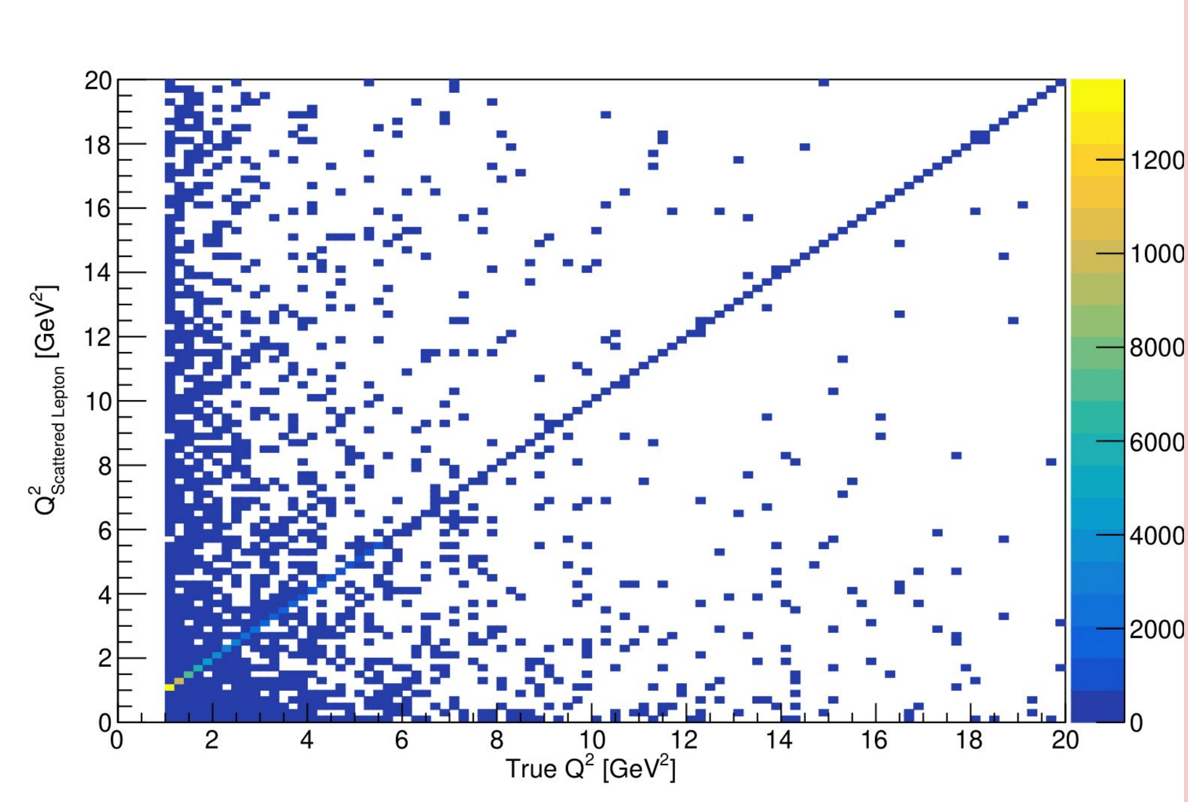




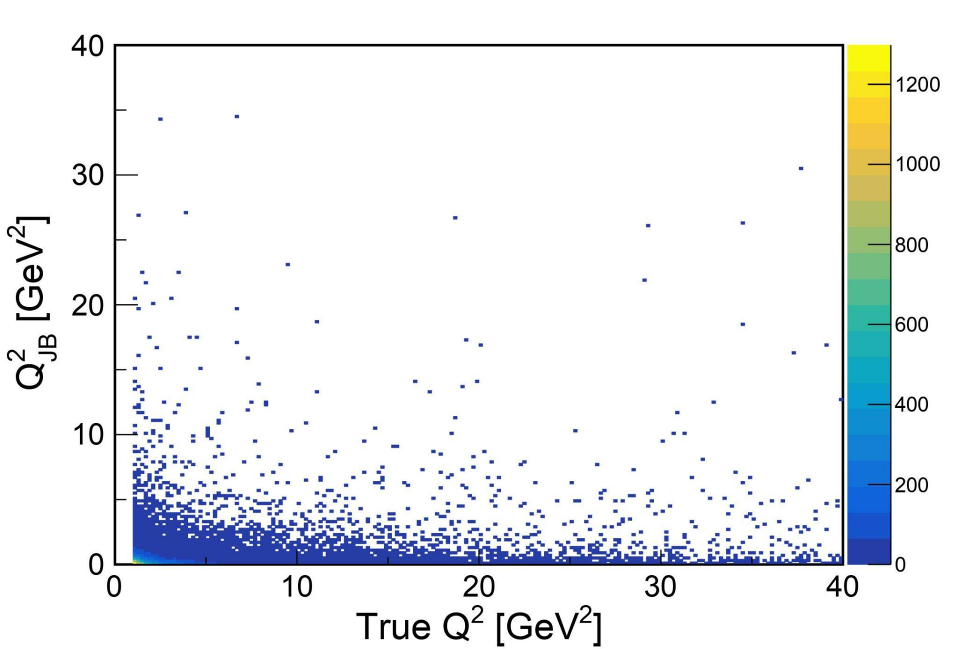
Reconstruction Q^2, EIC detector (scattered lepton method), 200 GeV muon vs 275 GeV proton



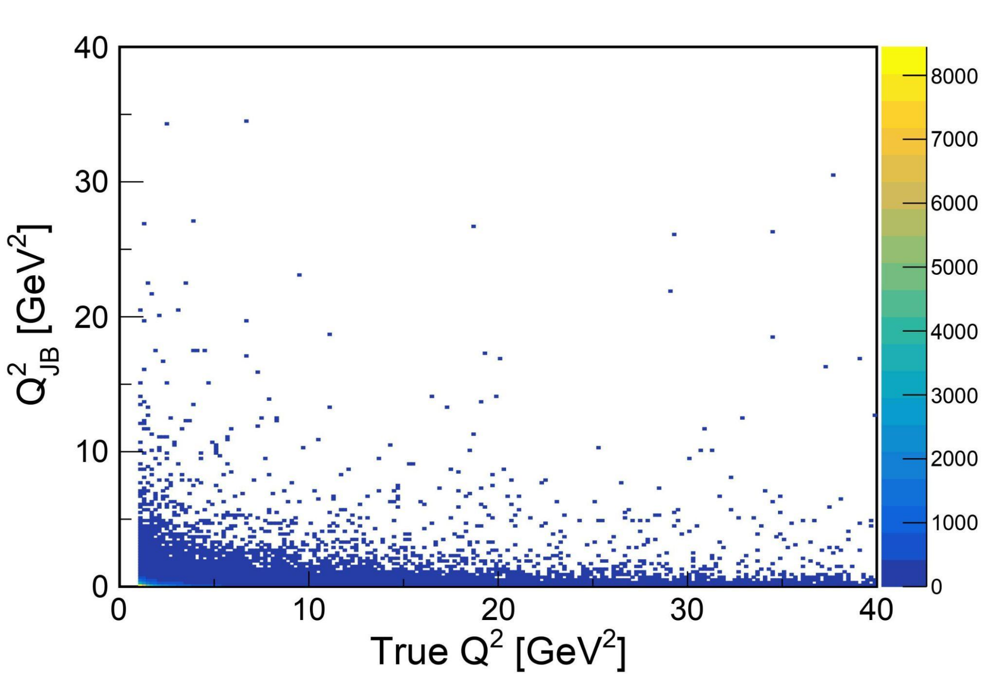
Reconstruction Q^2, perfect detector (scattered lepton method), 200 GeV muon vs 275 GeV proton



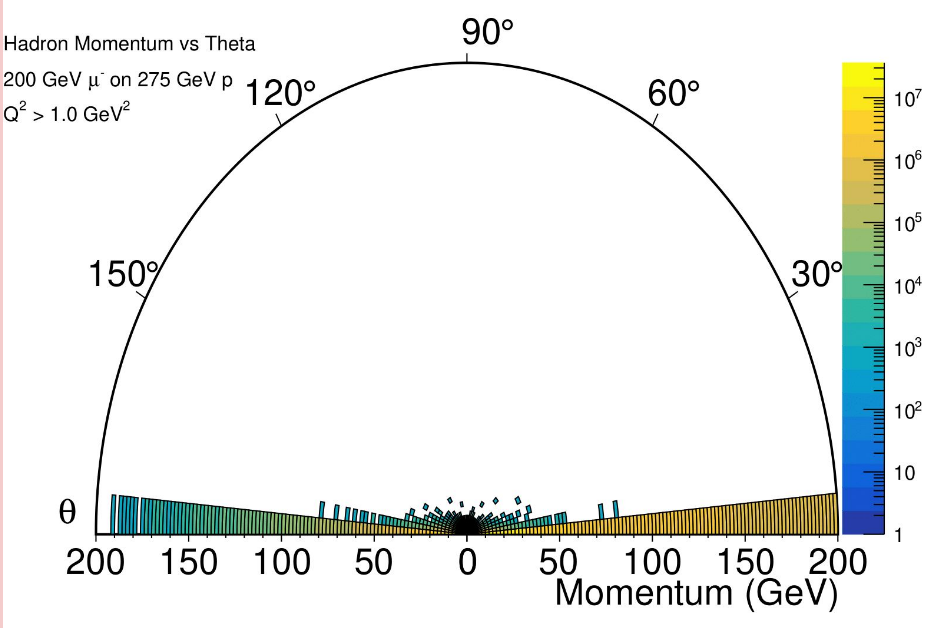
Reconstruction EIC Jacquet Blondel 200 GeV muon vs 275 GeV proton

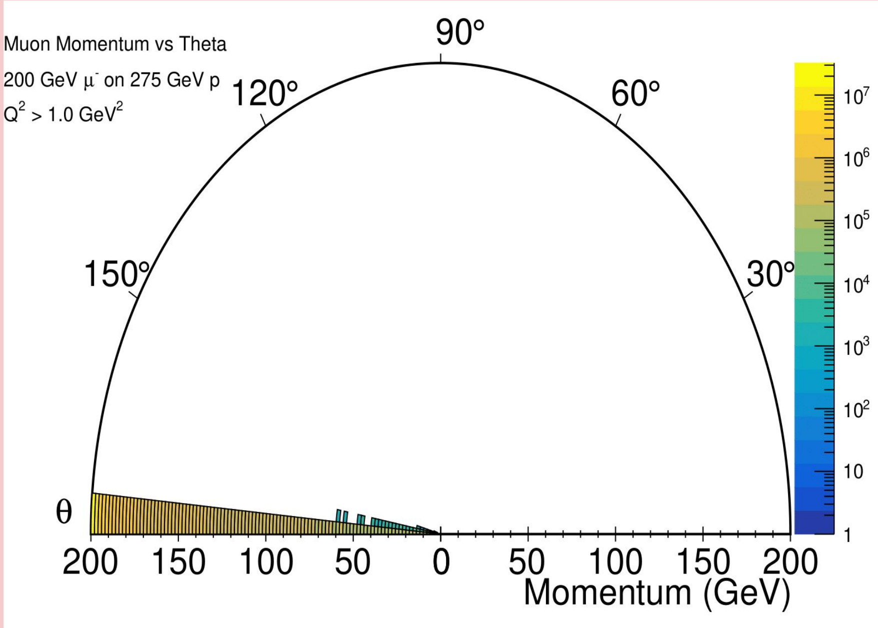


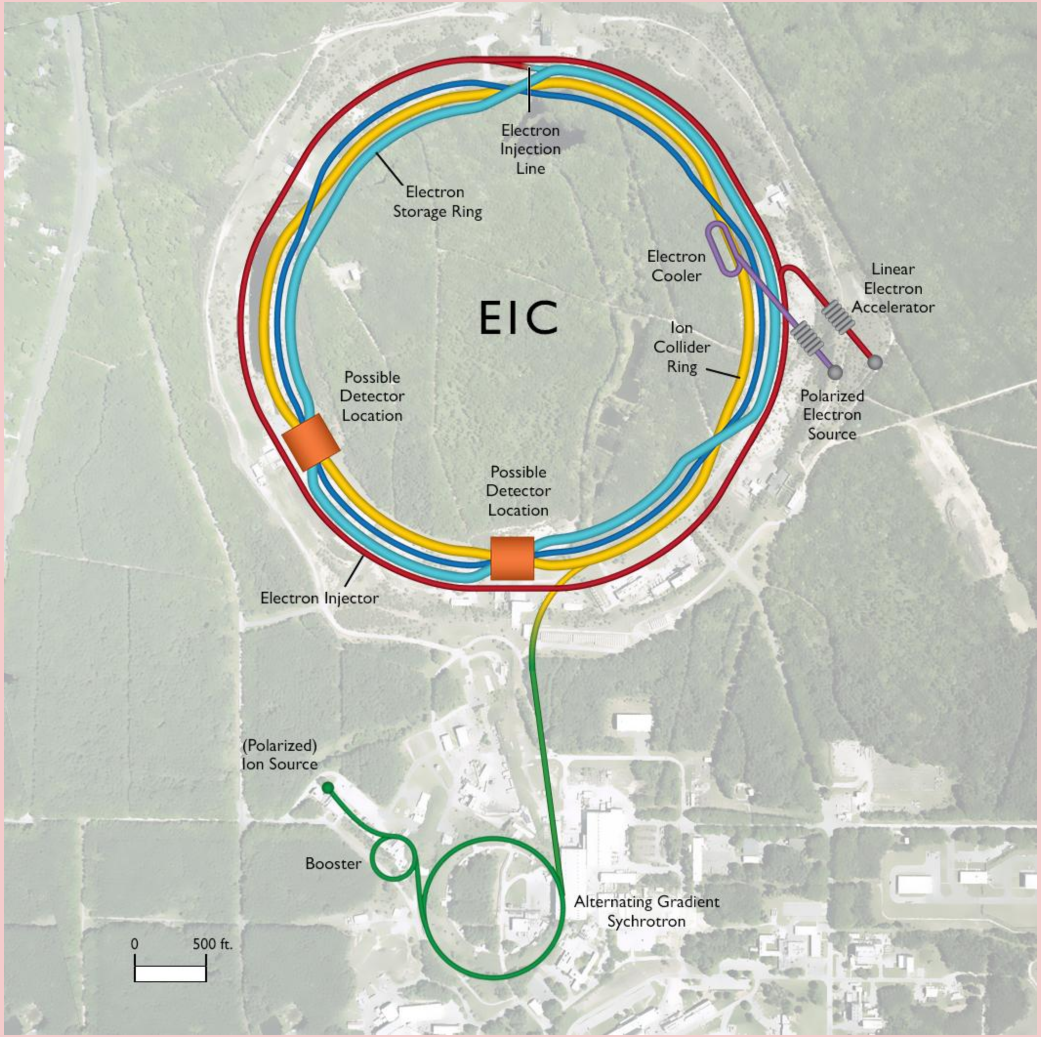
Reconstruction perfect Jacquet Blondel 200 GeV muon vs 275 GeV proton



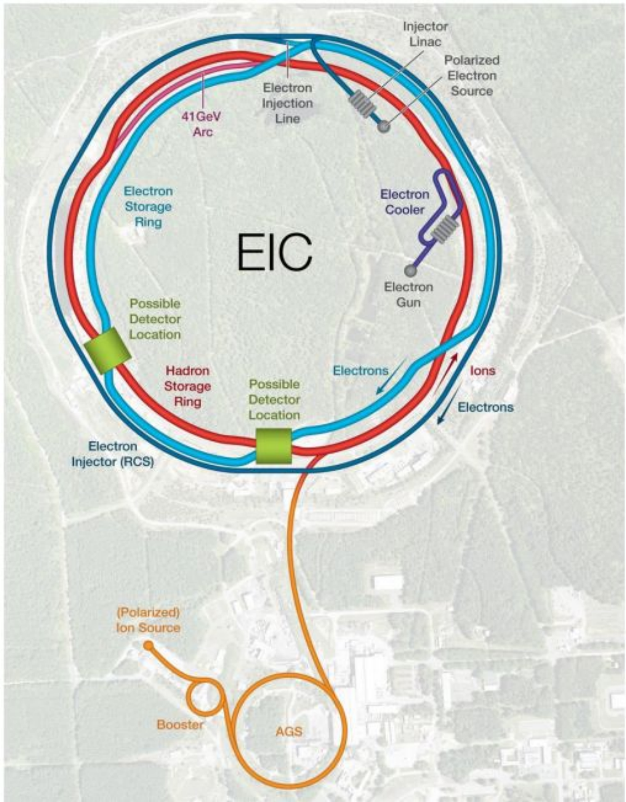
200 GeV muon vs 275 GeV proton



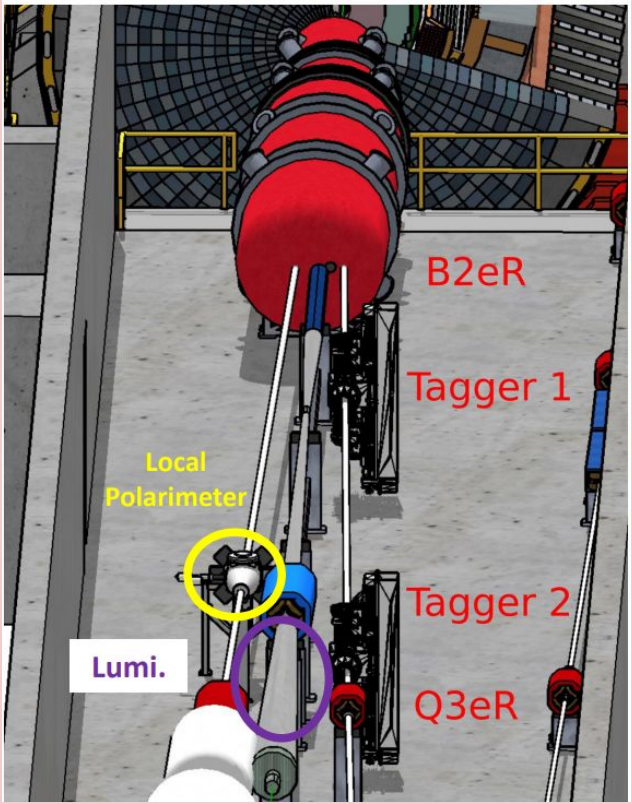



EIC
Electron Injection Line
Electron Storage Ring
Electron Cooler
Linear Electron Accelerator
Ion Collider Ring
Polarized Electron Source
Possible Detector Location
Possible Detector Location
Electron Injector
(Polarized) Ion Source
Booster
Alternating Gradient Sychrotron
0
500 ft.

ePIC detector backward region



There is not ample space for a muon spectrometer downstream of the electron beam. A MuIC detector could be put in the detector locations of the EIC (either first or second). Beamline will be rebuilt in this area anyway so it is worth studying.



Future of the MuIC

The muon ion collider also has promise in achieving higher total center of mass energy $\sqrt{s}$ and Q^2, and could further the electron ion collider's experimental capabilities by doing similar measurements but with polarized and unpolarized muons and proton scattering.

There should be more studies done on the muon ion collider's potential with respect to detector acceptances but also a lot of detector R&D would have to come onto the scene to make the MuIC project a serious endeavor.

Close studying and collaboration with the EIC experiment and its hurdles should be considered imperative for the development of a future MuIC