Photo/electro-production at an EIC

SAMUEL HEPPELMANN

UC DAVIS & LBNL

Photoproduction & electroproduction at an EIC

Overview of eSTARlight

Coherent photonuclear cross-sections are parameterizations of $\sigma(\gamma p)$ from HERA/fixed target data or theory

Convolution of photon flux from electron with $\sigma(\gamma p \to Vp)$

- Both depend on Q^2

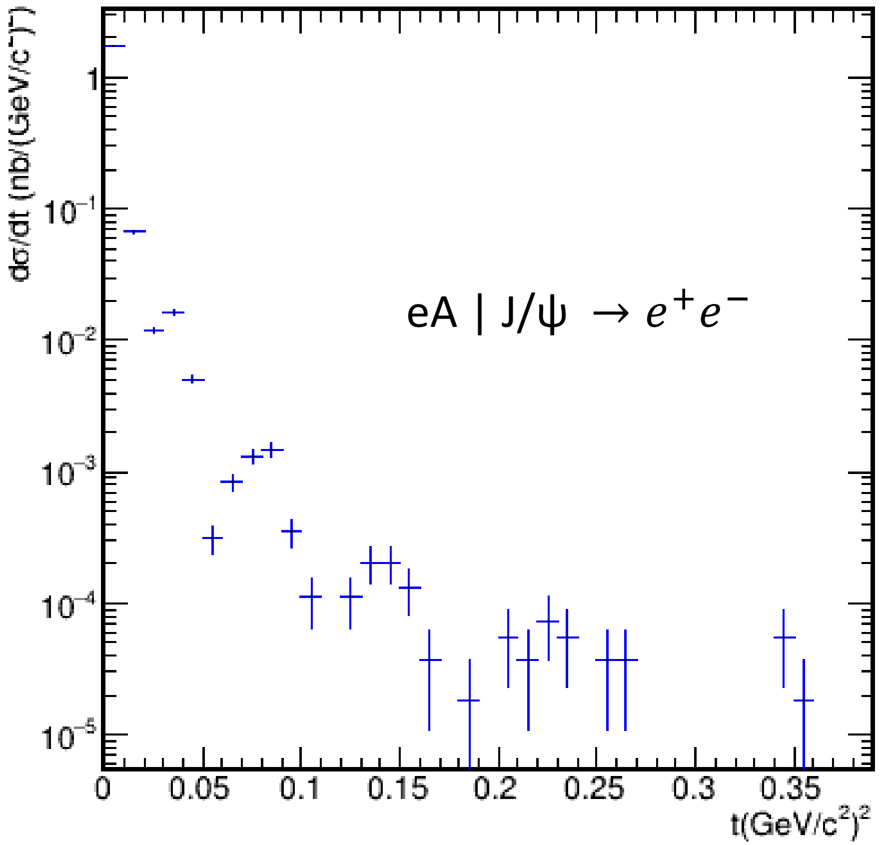
Weizsacker-Williams photon flux (with non-zero Q^2)

Nuclear targets included with a Glauber calculation

Vector mesons retain the photon spin

- For $Q^2 \sim 0$, transversely polarized
- As Q^2 rises, longitudinal polarization enters
- Spin-matrix elements quantified with HERA data

Embodied in eSTARlight code, available at:
http://estarlight.hepforge.org

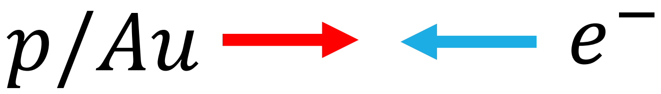


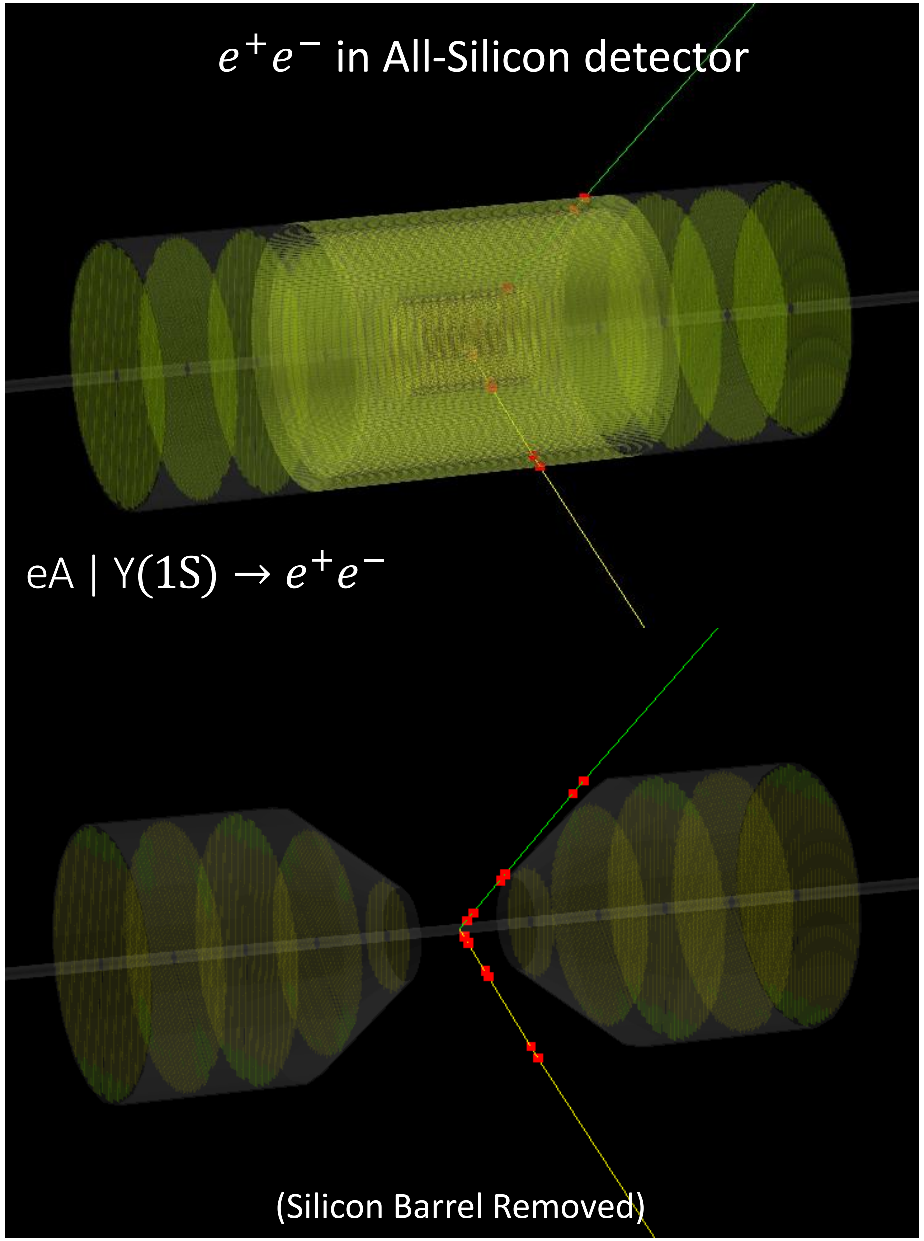
Coherent Vector Meson Production
eSTARlight

Systems studied:

- Collider configurations:
  - Electron (18 GeV) on Au (100 GeV) for and
  - Electron (18 GeV) on protons(250 GeV)
  - Electron (18 GeV) on protons(100 GeV)
- Vector Mesons:
  - J/ψ $\rightarrow e^+e^-$
  - Υ(1S), Υ(2S), Υ(3S) $\rightarrow e^+e^-$

Rapidity Beam Convention



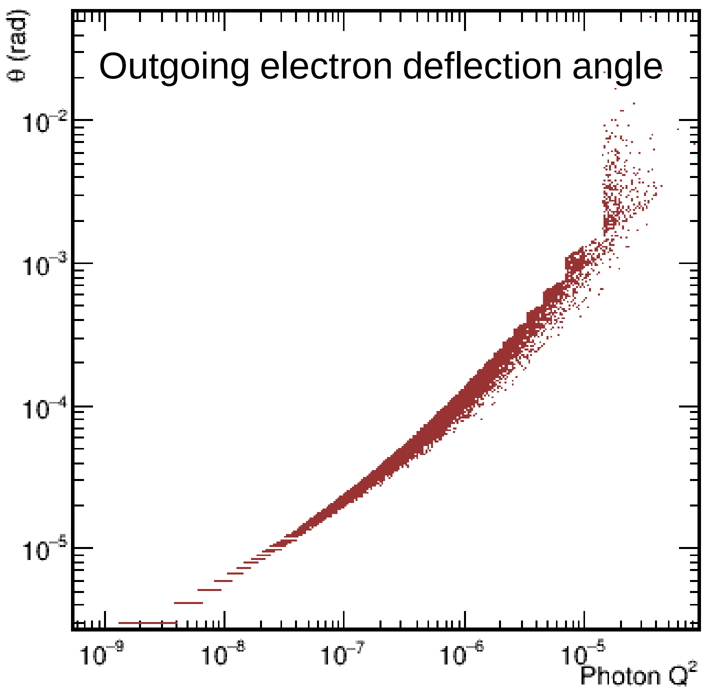


Photoproduction of J/ψ ($Q^2 < 1\ \mathrm{GeV}^2$)

p/Au → ← e^-

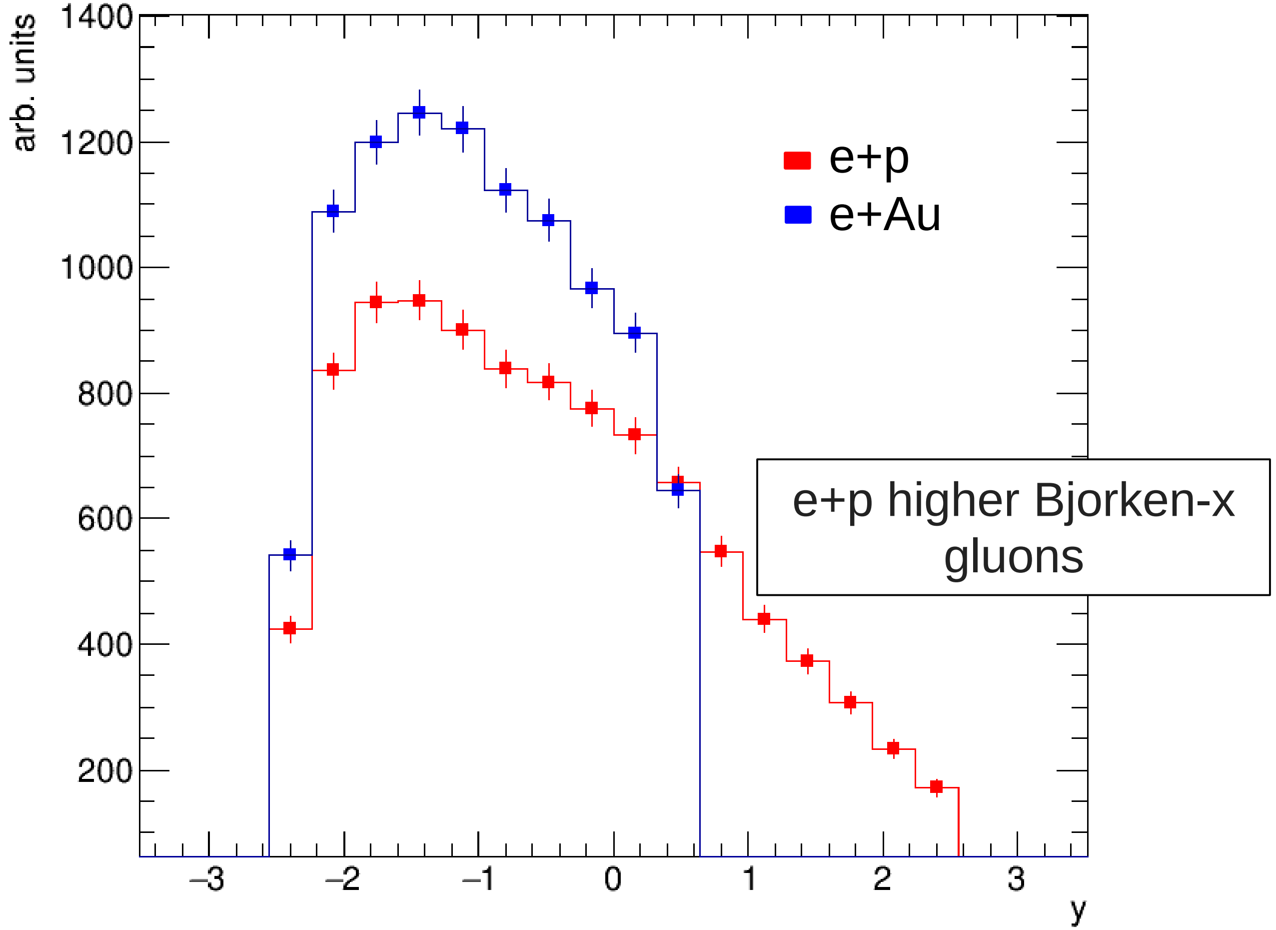
$J/\psi \rightarrow e^+e^-$

Electron (18 GeV) on Au (100 GeV)
Electron (18 GeV) on protons(100 GeV)



At low Q^2, the scattered electron is less than 1 radian

For VM Production, a larger target has narrower rapidity range.

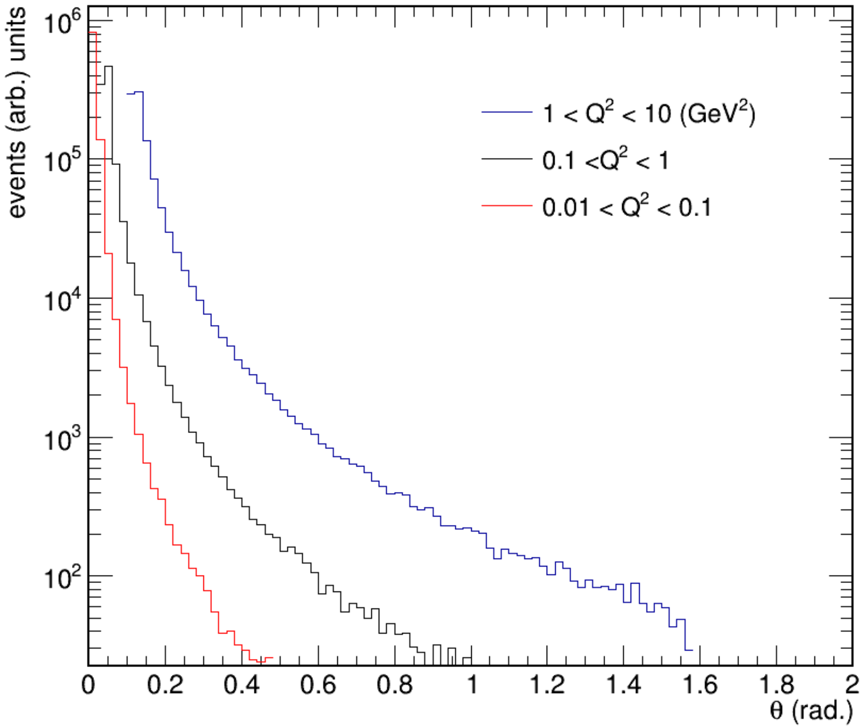


e+p at 100 GeV is like incoherent photoproduction in e+A

Electroproduction of J/ψ ($Q^2 > 1$ GeV^2)

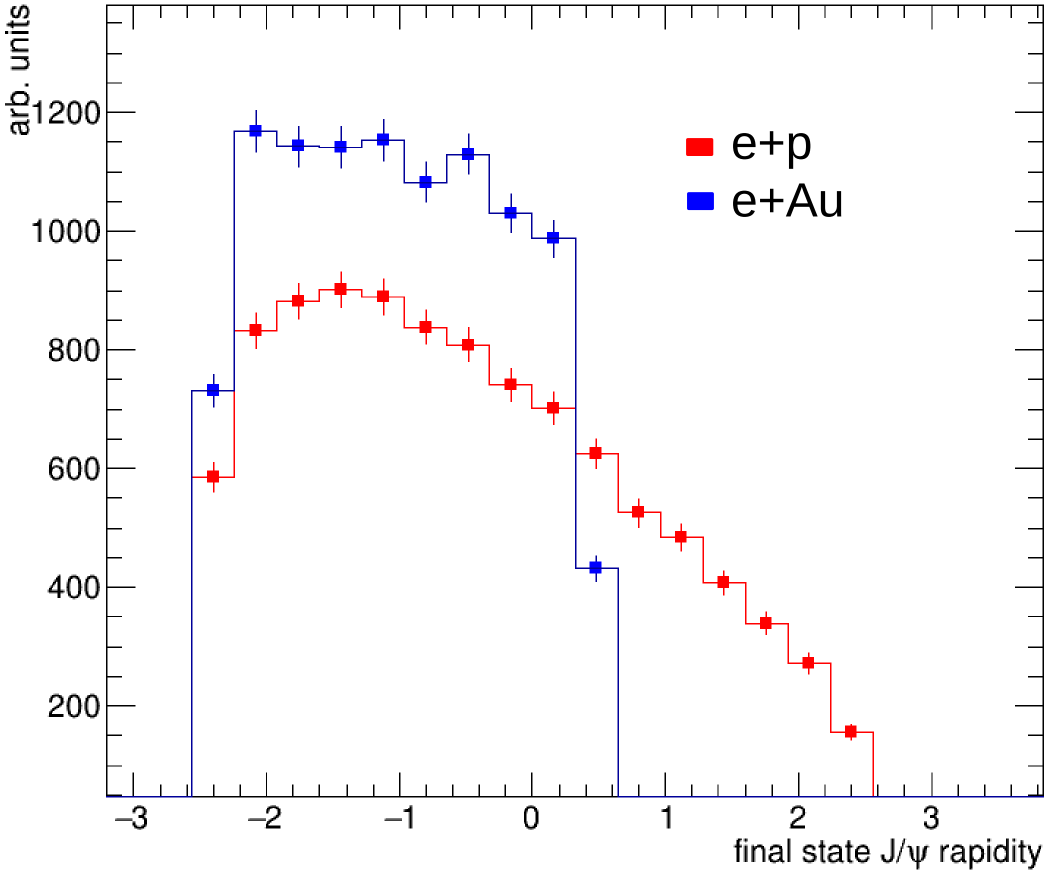
$J/\psi \rightarrow e^+e^-$

Electron (18 GeV) on Au (100 GeV)
Electron (18 GeV) on protons(100 GeV)



As we push to higher Q^2, easier to measure the scattered electron

Similar Rapidity distribution for higher Q^2



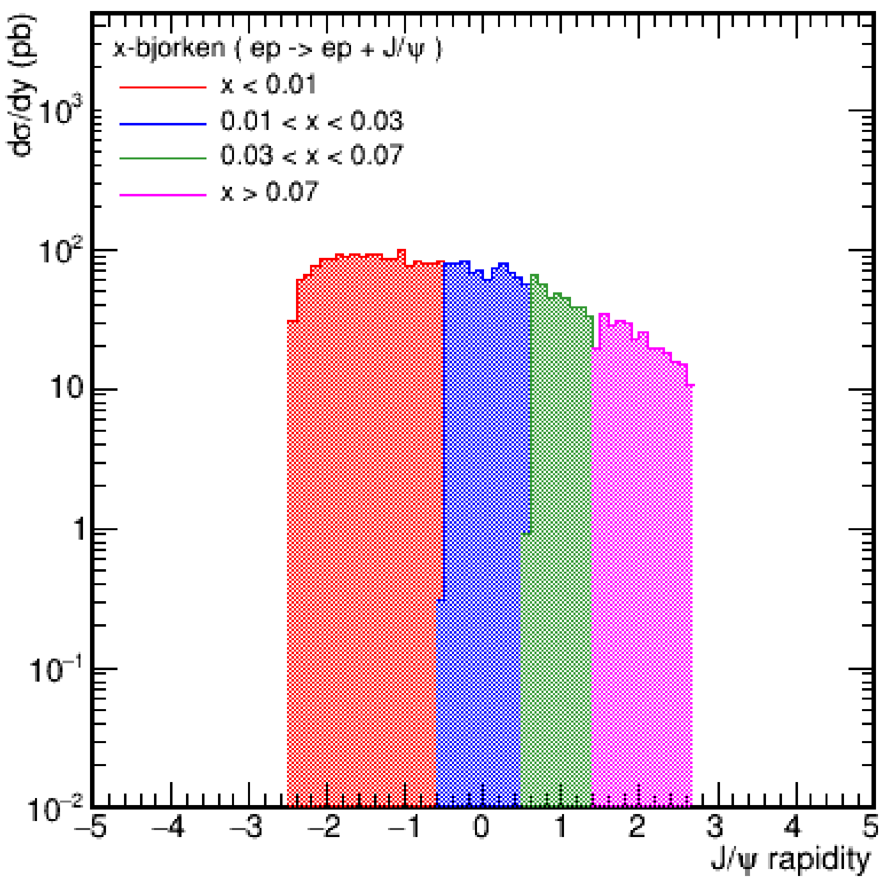
Bjorken-x for proton and Au targets $J/\psi\ (0 < Q^2 < 10\ \mathrm{GeV}^2)$

Events generated with eSTARlight

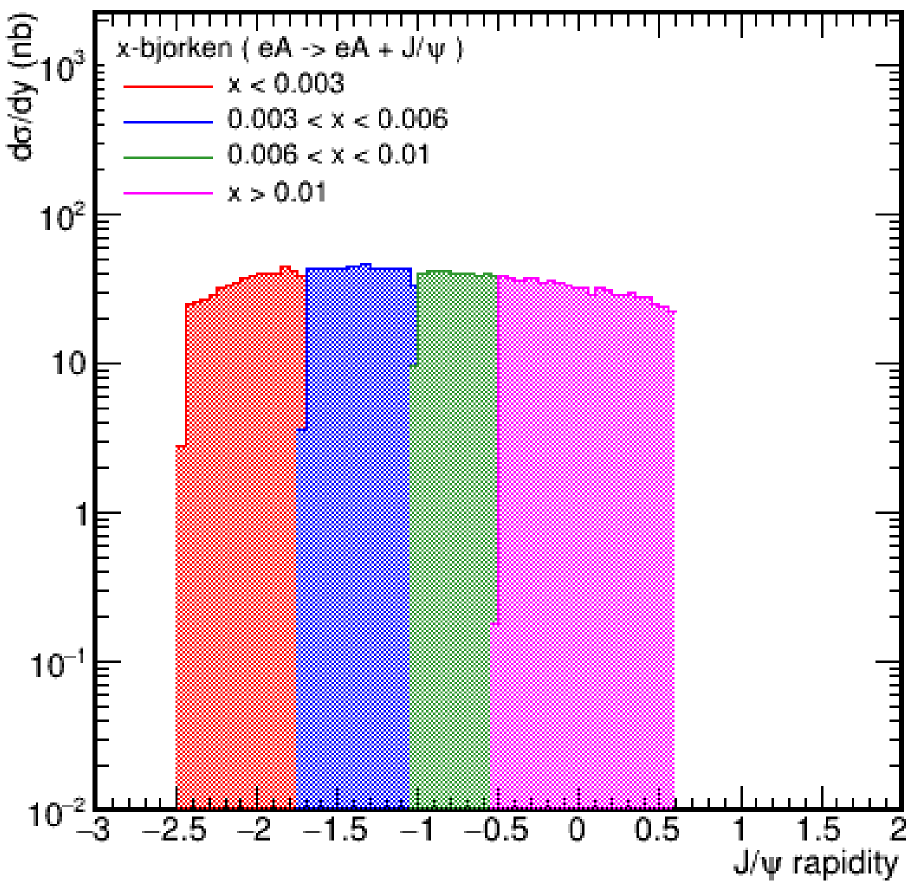
Narrow range of rapidity (Bjorken-x) for coherent vector meson production

Larger m_V corresponds to tighter rapidity range

Electron (18 GeV) on Proton (100 GeV)



Electron (18 GeV) on Au (100 GeV)



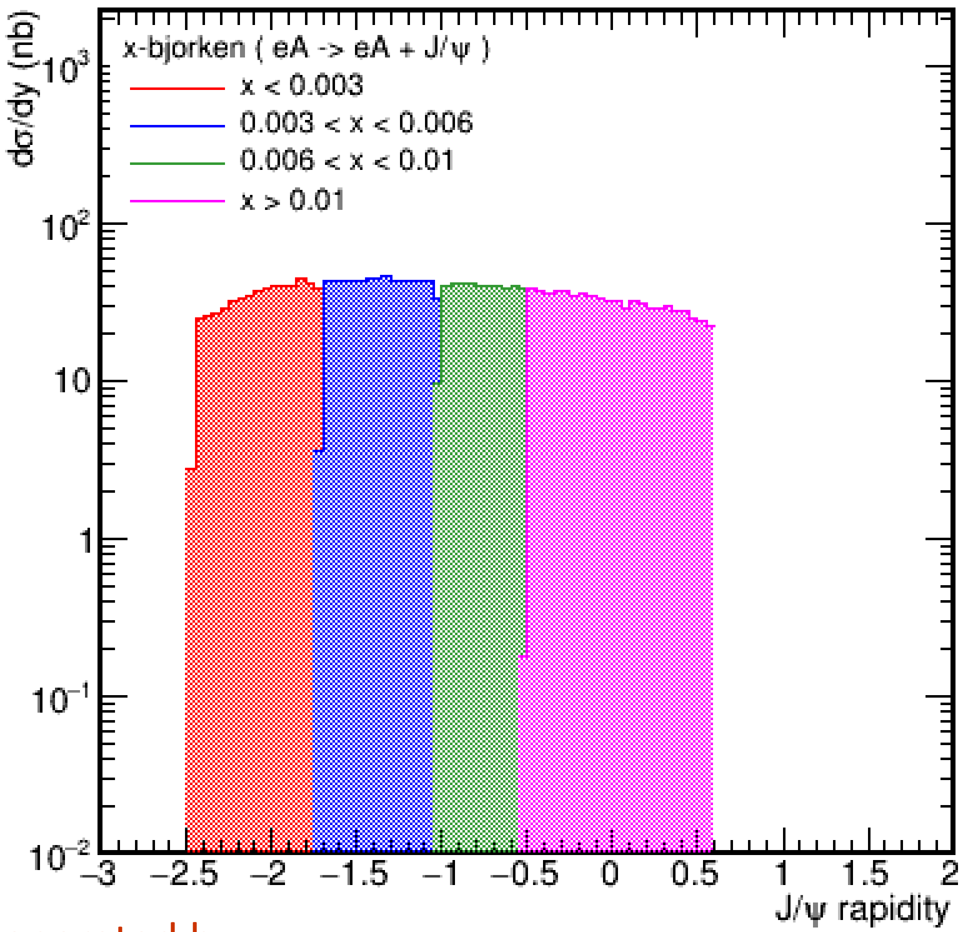
Probe lower bjorken-x with heavier target

Bjorken-x for proton and Au targets

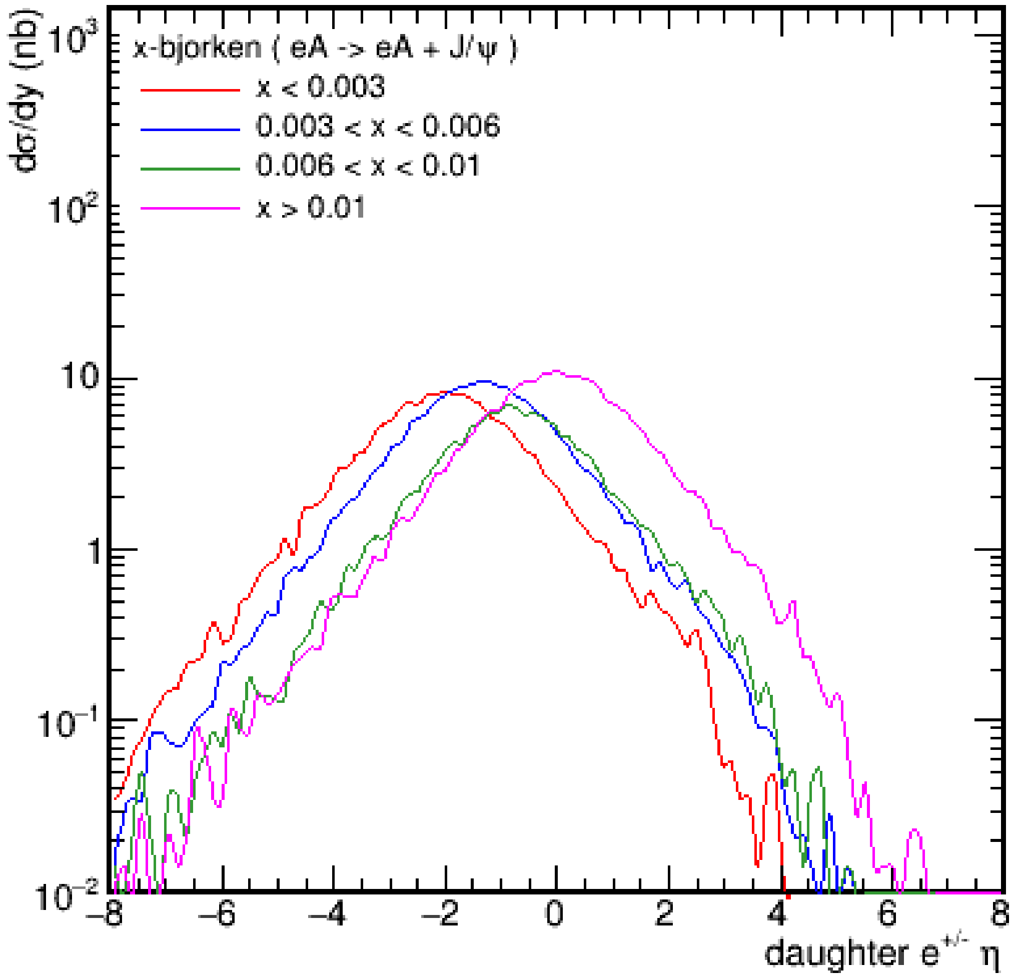
$J/\psi \ (0 < Q^2 < 10 \ \mathrm{GeV}^2)$

Detector Acceptance requirements

Electron (18 GeV) on Au (100 GeV)



$J/\psi \rightarrow e^+e^-$

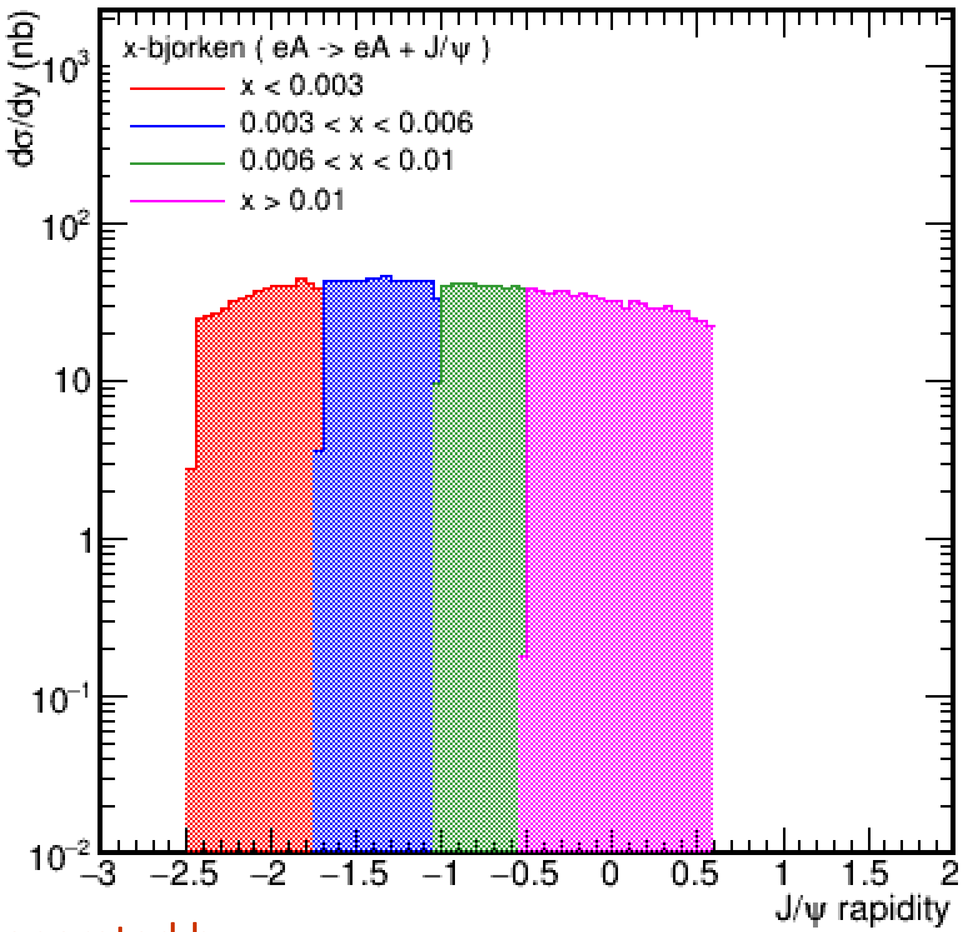


Events generated by eStarlight

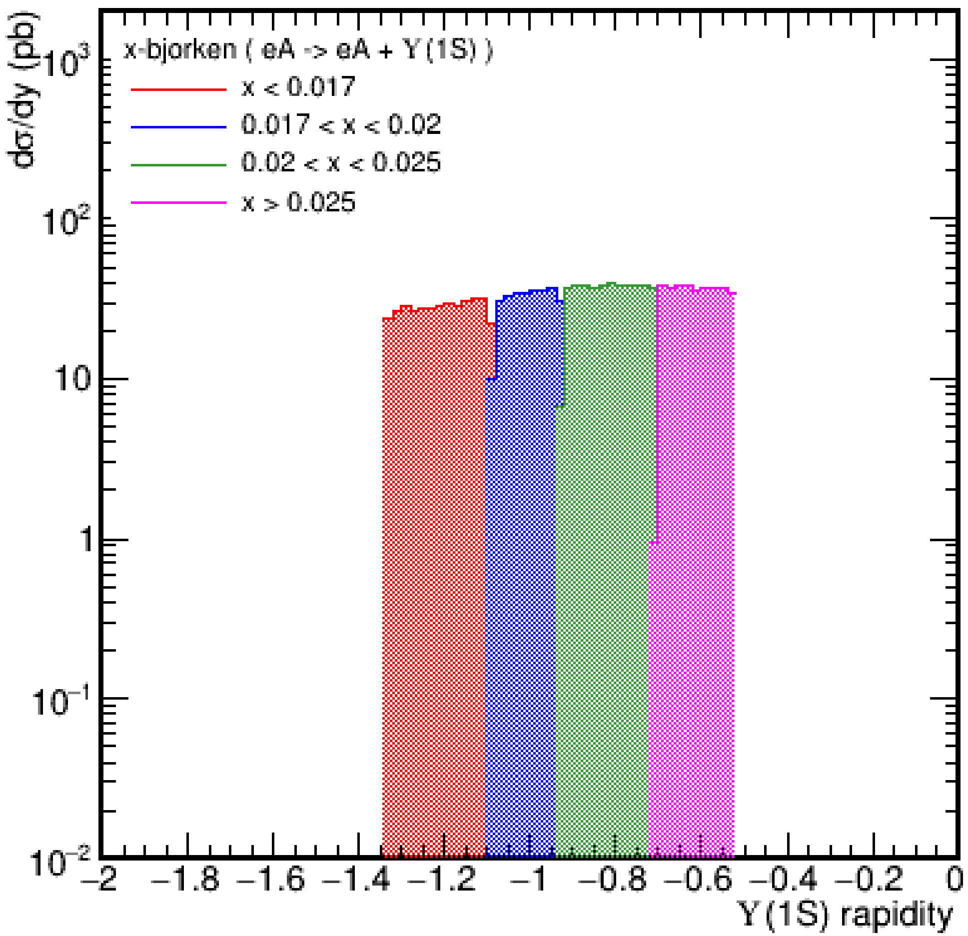
Electron pair's pseudorapidity important for detector acceptance

Bjorken-x for proton and Au targets   J/ψ and Υ(1S) ($0 < Q^2 < 10\ \mathrm{GeV}^2$)

Electron (18 GeV) on Au (100 GeV)



Electron (18 GeV) on Au (100 GeV)

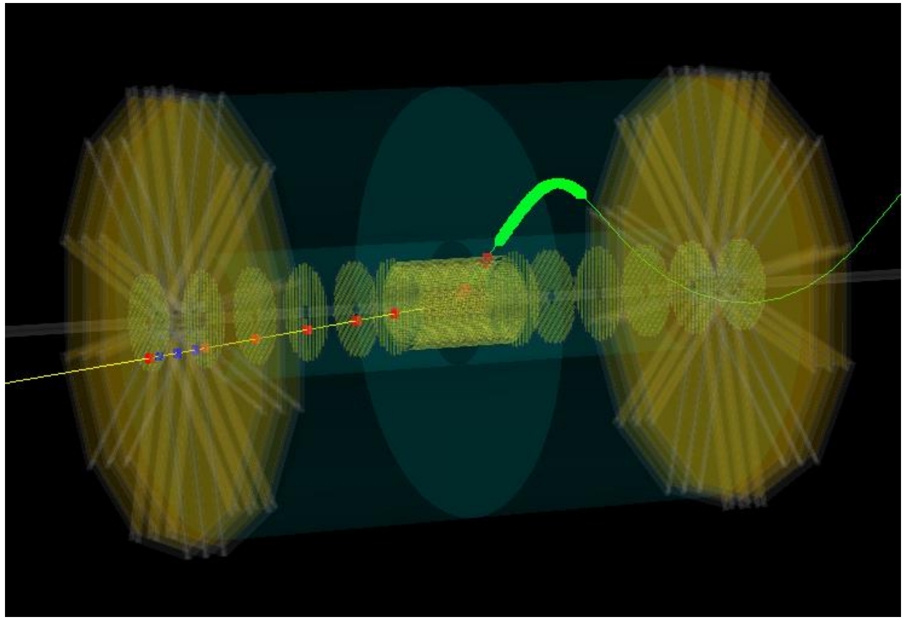


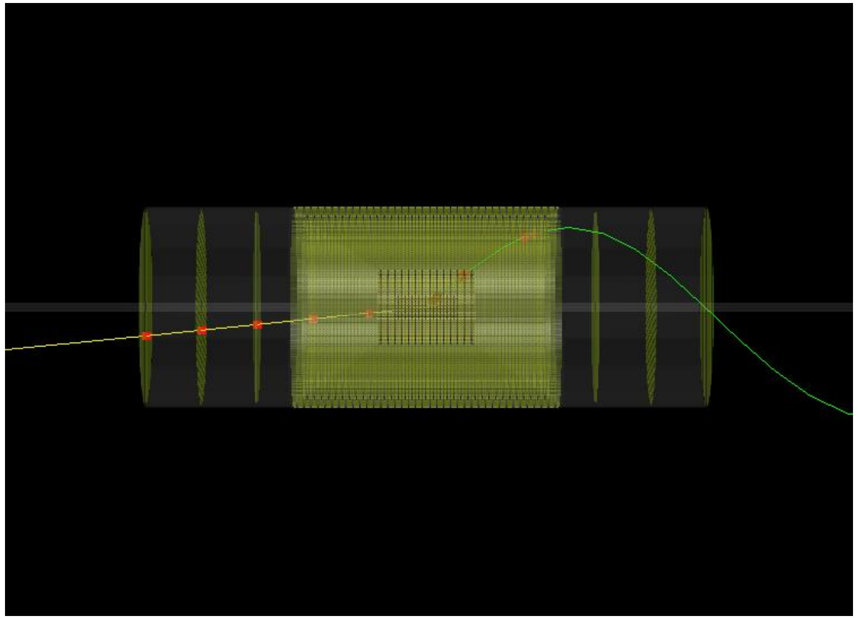
Events generated by eStarlight

Larger m_V corresponds to tighter rapidity range

eSTARlight with EICROOT

Full Detector Simulation & Reconstruction





BeAST Detector (Brookhaven eA Solenoidal Tracker)

- **Silicon Tracker**
  - 4 layers with 0.3% X_0 each
- **TPC**
  - 2 m long, Gas: Argon:Freon:Isobutane(95:3:2)
- **Silicon Endcap Disks**
  - 6 disks

LBNL All-Silicon Detector

(Developed by LBNL's eRD16 generic EIC detector project)

- **Silicon Tracker**
  - 6 layers
- **Silicon Endcap Disks**
  - 5 disks

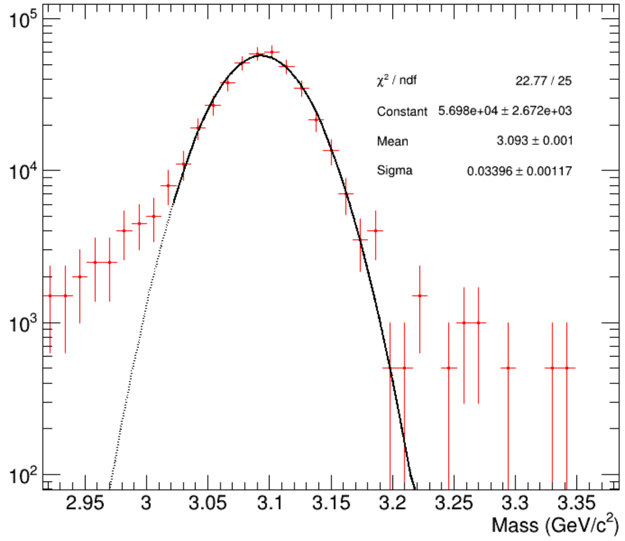
Detector Reconstruction Comparison

2 Particle Simulation (e^+e^-)

BeAST Detector
Electron η < 4

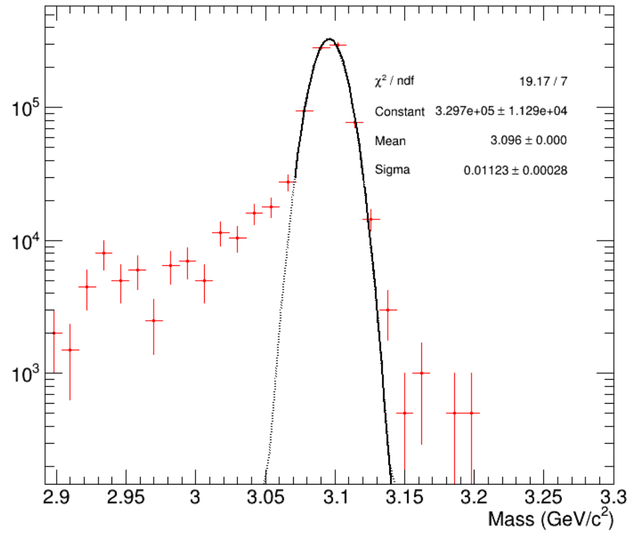
All Events normalized to $10\ fb^{-1}/179$

3 Tesla Field

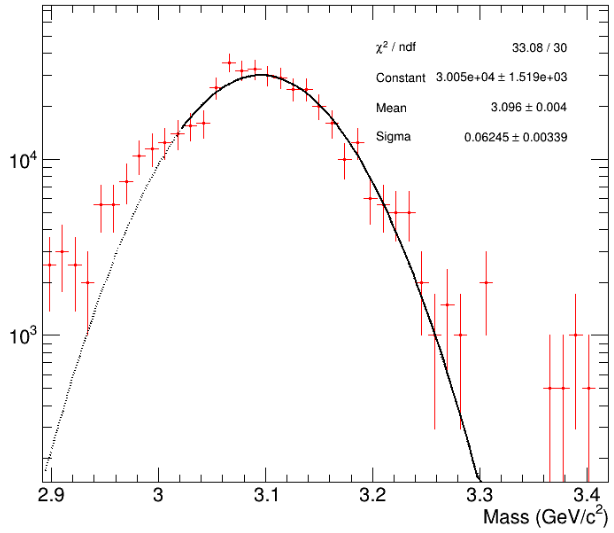


All Silicon Detector
Electron η < 4

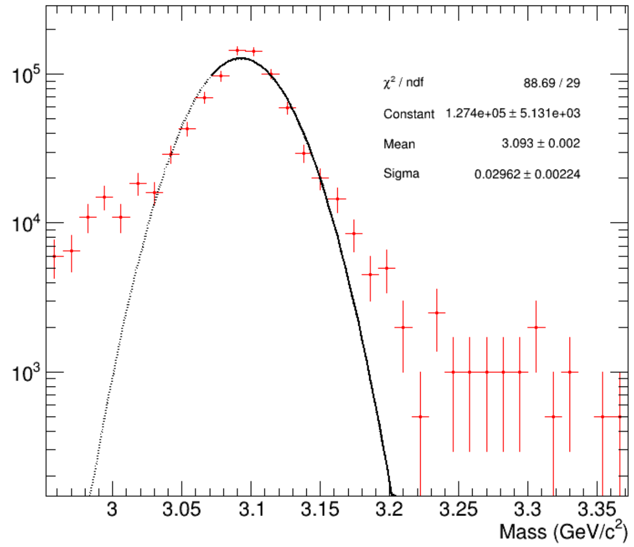
3 Tesla Field



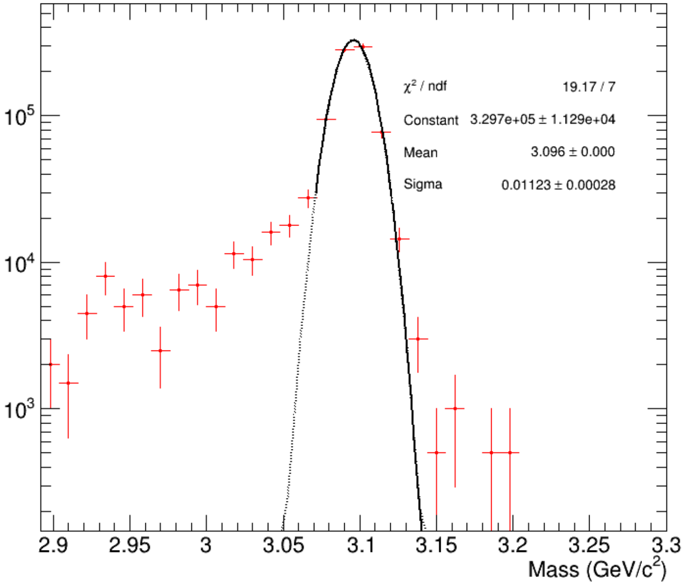
1.5 Tesla Field



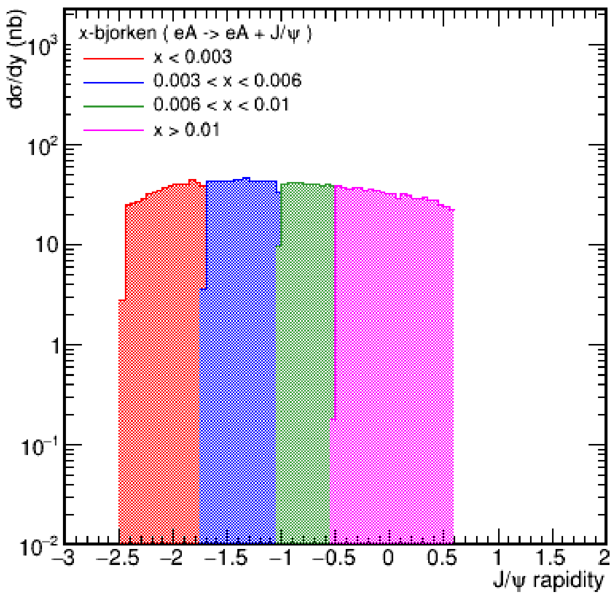
1.5 Tesla Field



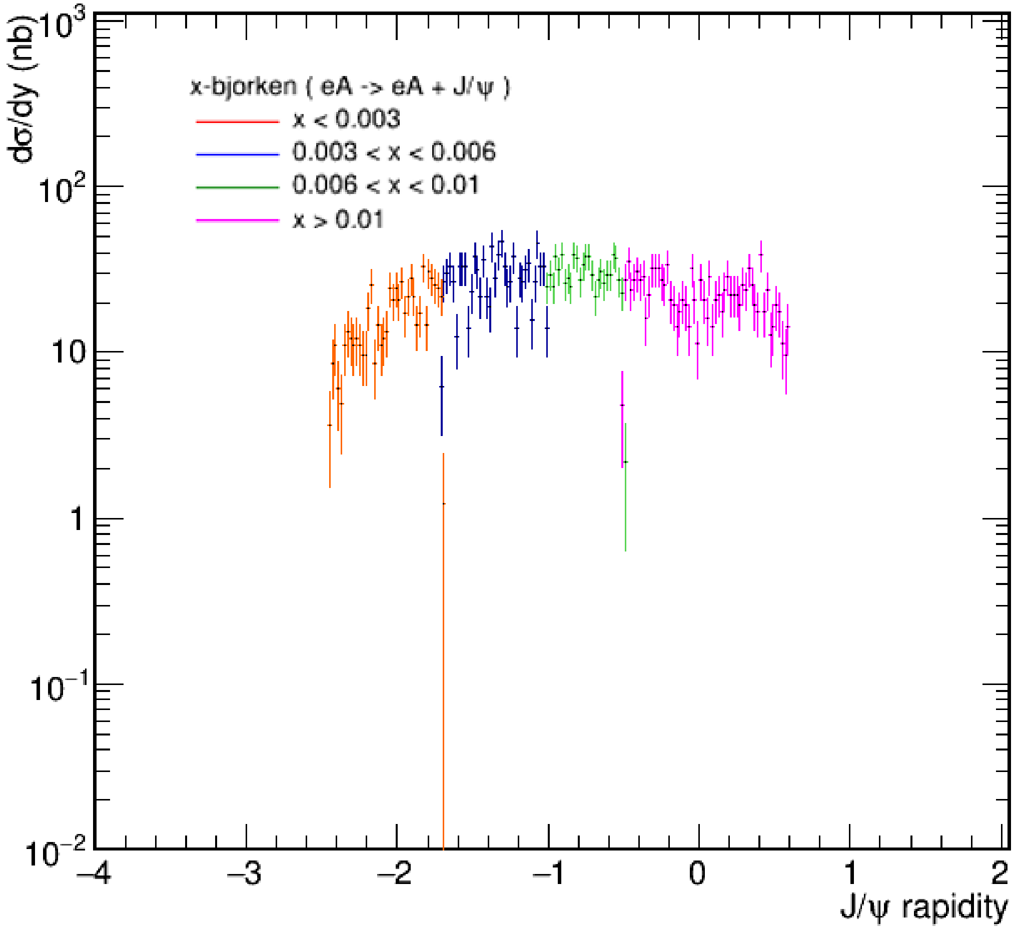
Bjorken-x for Reconstructed J/ψ $(0 < Q^2 < 10 \text{ GeV}^2)$



eSTARlight



eSTARlight & All-Silicon Detector



Reconstructed J/ψ

- No background in reconstruction, only the daughter particles
- Select events within 3σ of J/ψ resolution

eSTARlight with EICROOT

Full Detector Simulation & Reconstruction

$$J/\psi \rightarrow e^{+}e^{-}$$

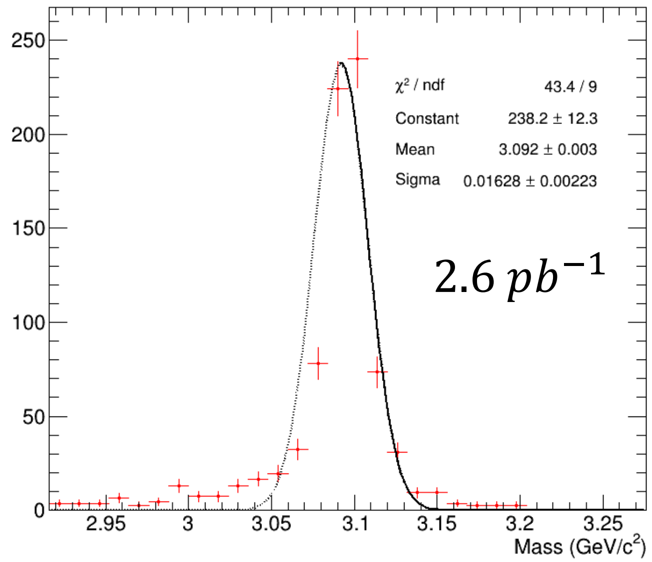
Comparison of rapidity distributions for different Q^2 regions

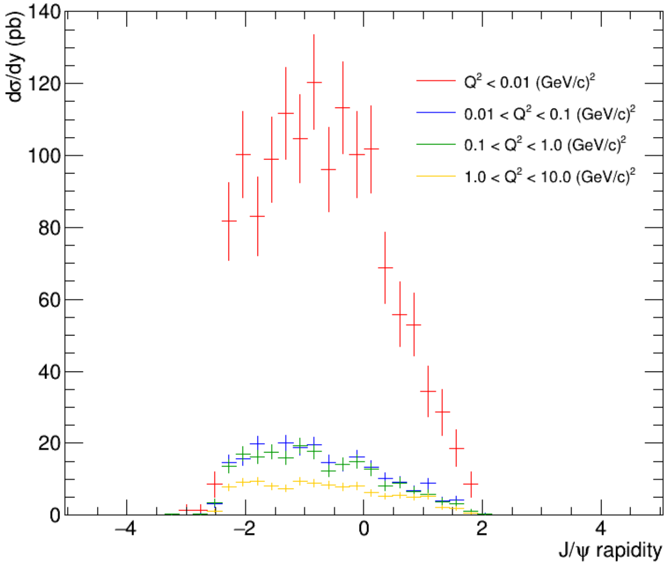
for:

e + p (18 GeV on 250 GeV)

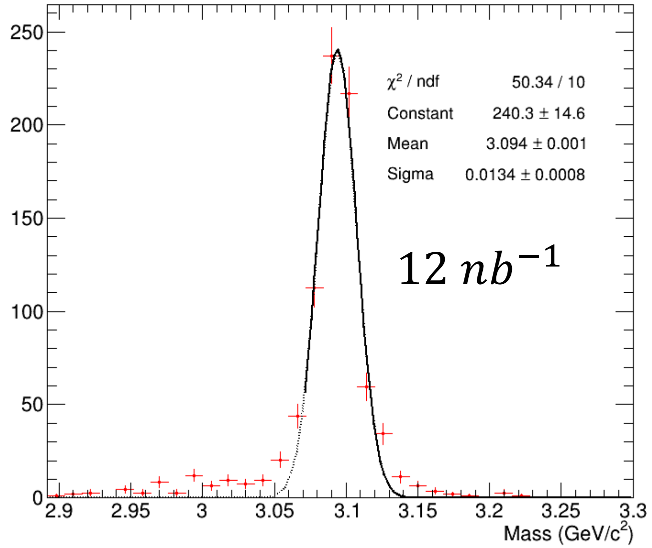
e + A (18 GeV on 100 GeV Au)

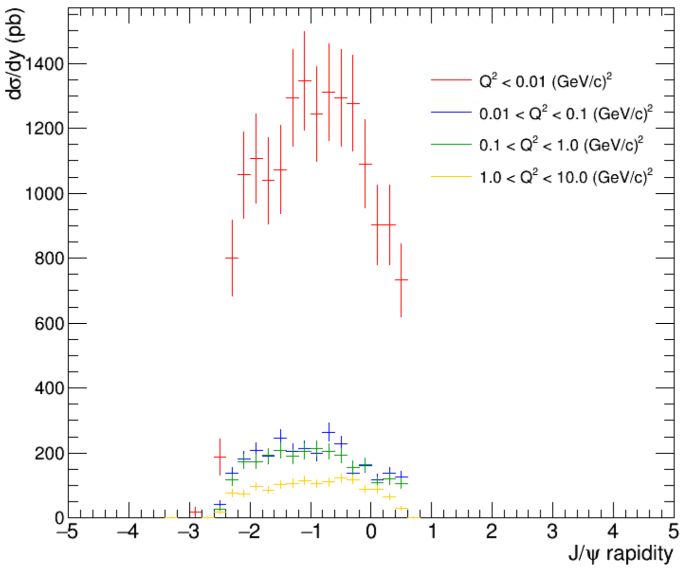
e+p





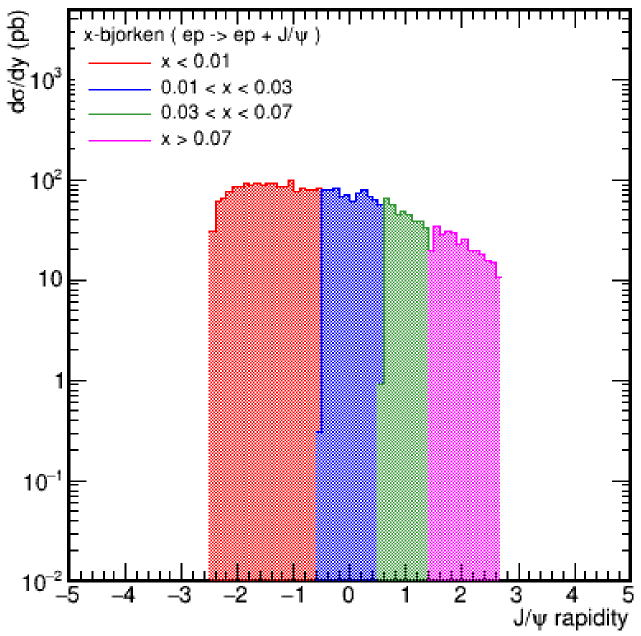
e+A





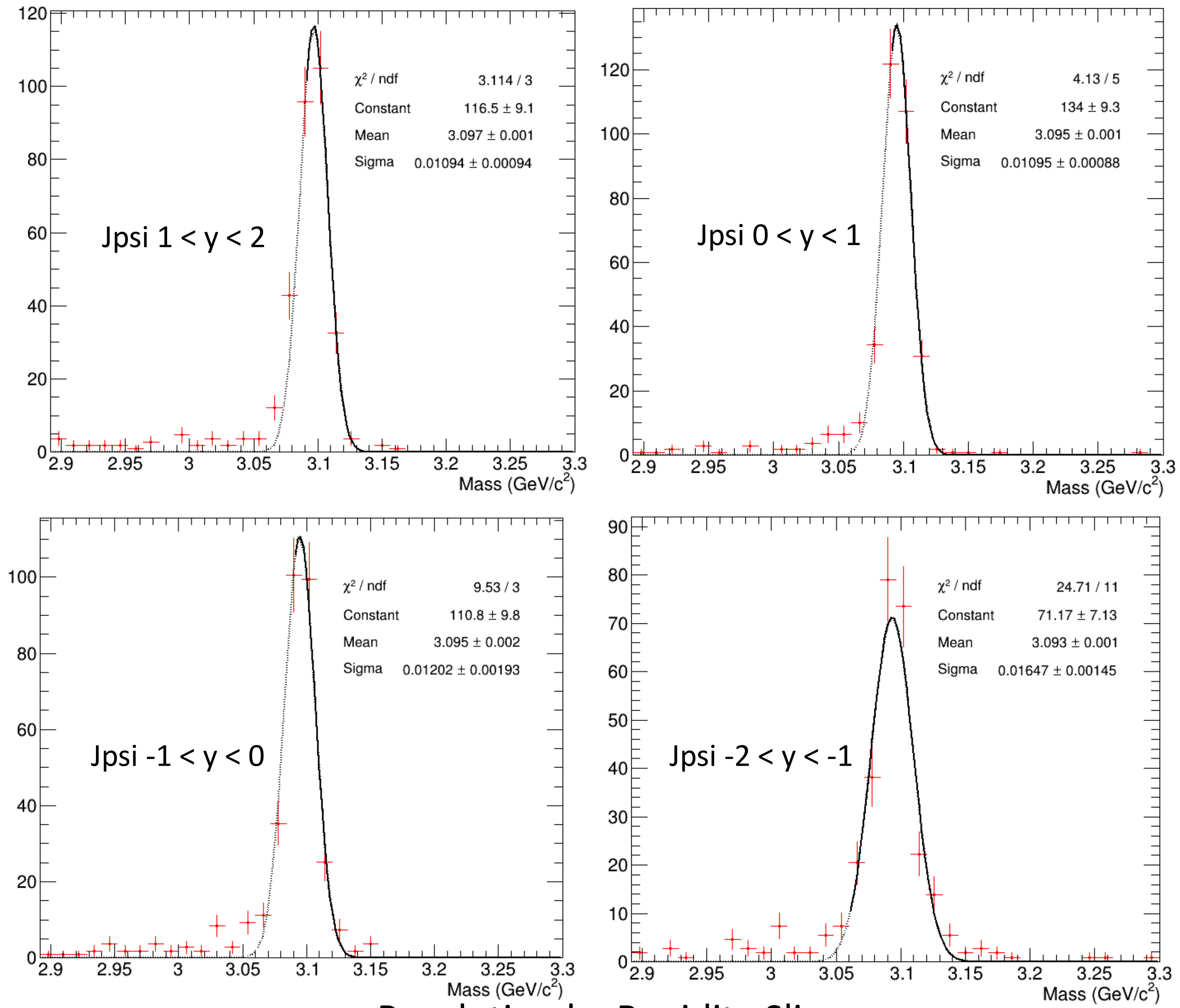
eSTARlight with EICROOT

Full Detector Simulation & Reconstruction



Resolution drops at backward rapidity

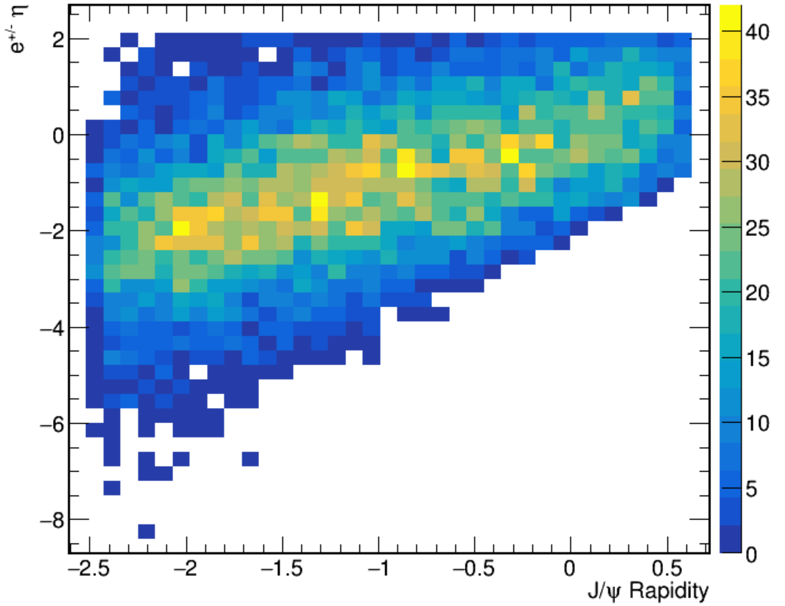
ep | J/ψ $\rightarrow e^+e^-$



Resolution by Rapidity Slice

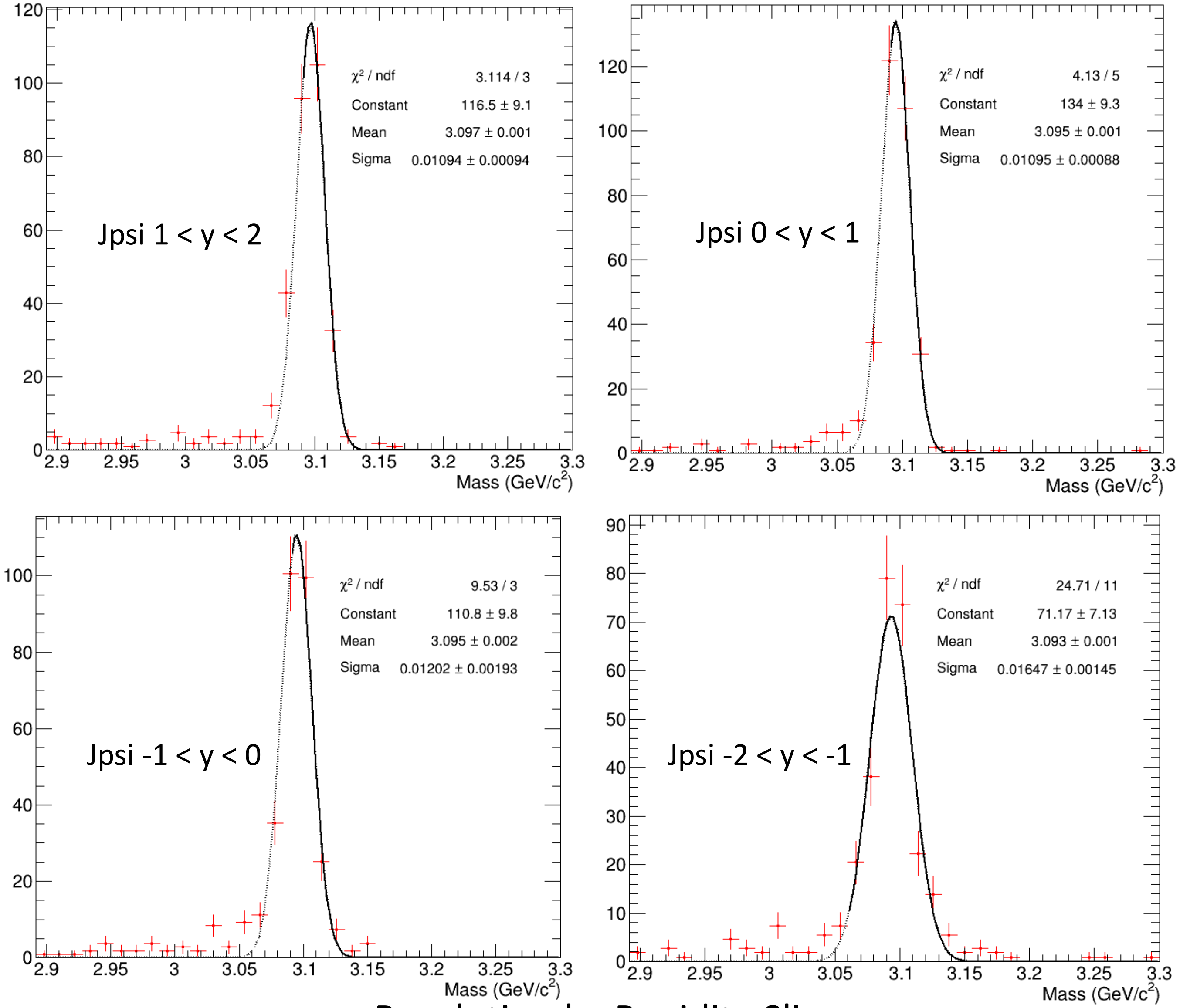
eSTARlight with EICROOT

Full Detector Simulation & Reconstruction



Resolution drops at backward rapidity

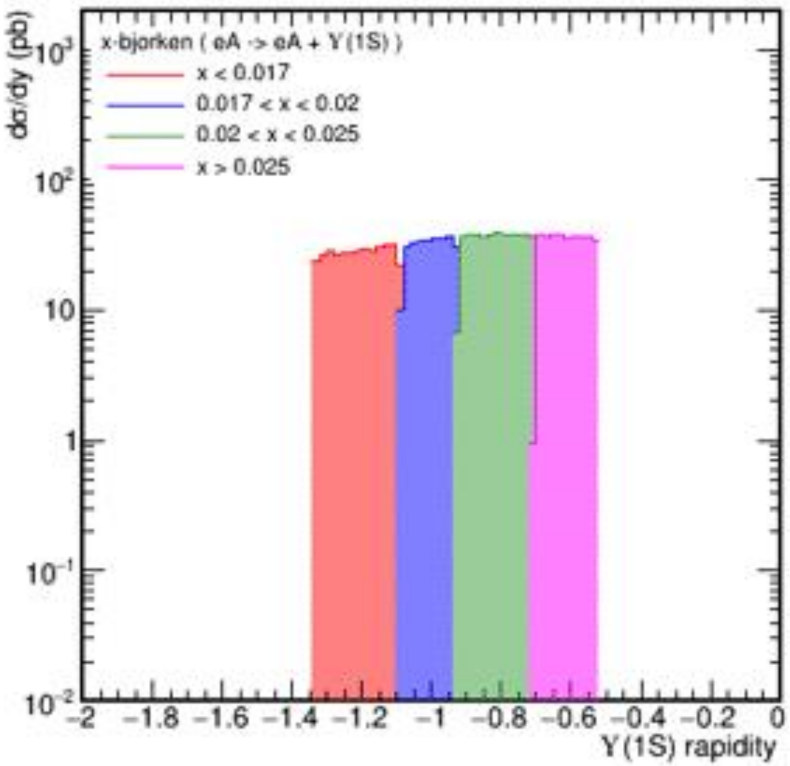
ep | J/ψ $\rightarrow e^+e^-$



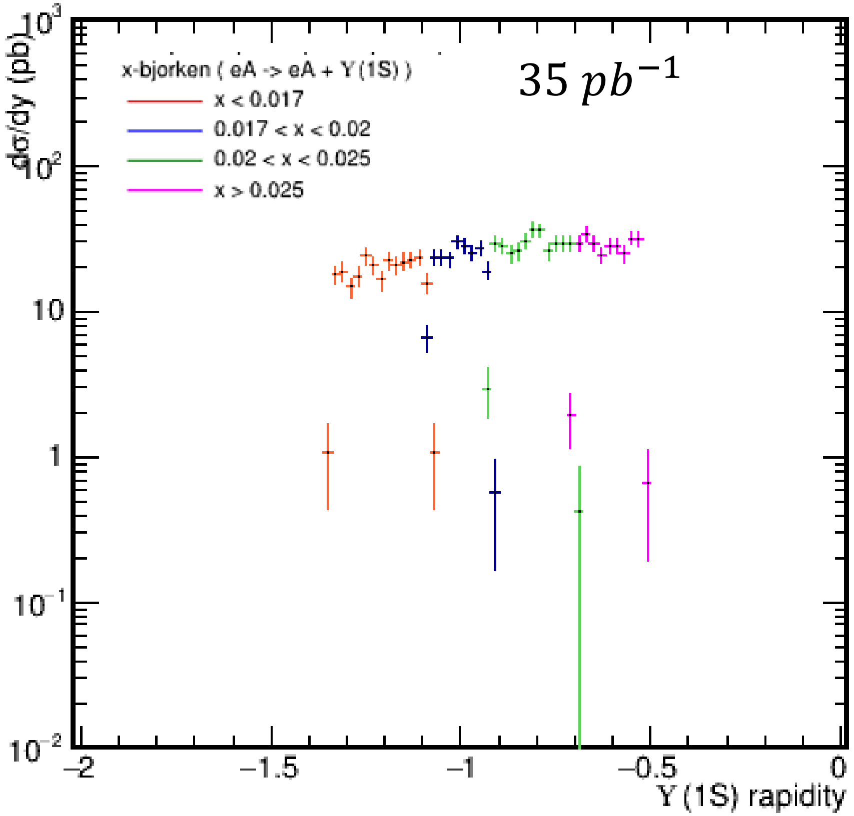
Resolution by Rapidity Slice

Bjorken-x Rapidity Distribution $\text{eA} \mid \Upsilon(1S) \rightarrow e^+e^- \quad (0 < Q^2 < 10\ \text{GeV}^2)$

eSTARlight Simulation (no detector)



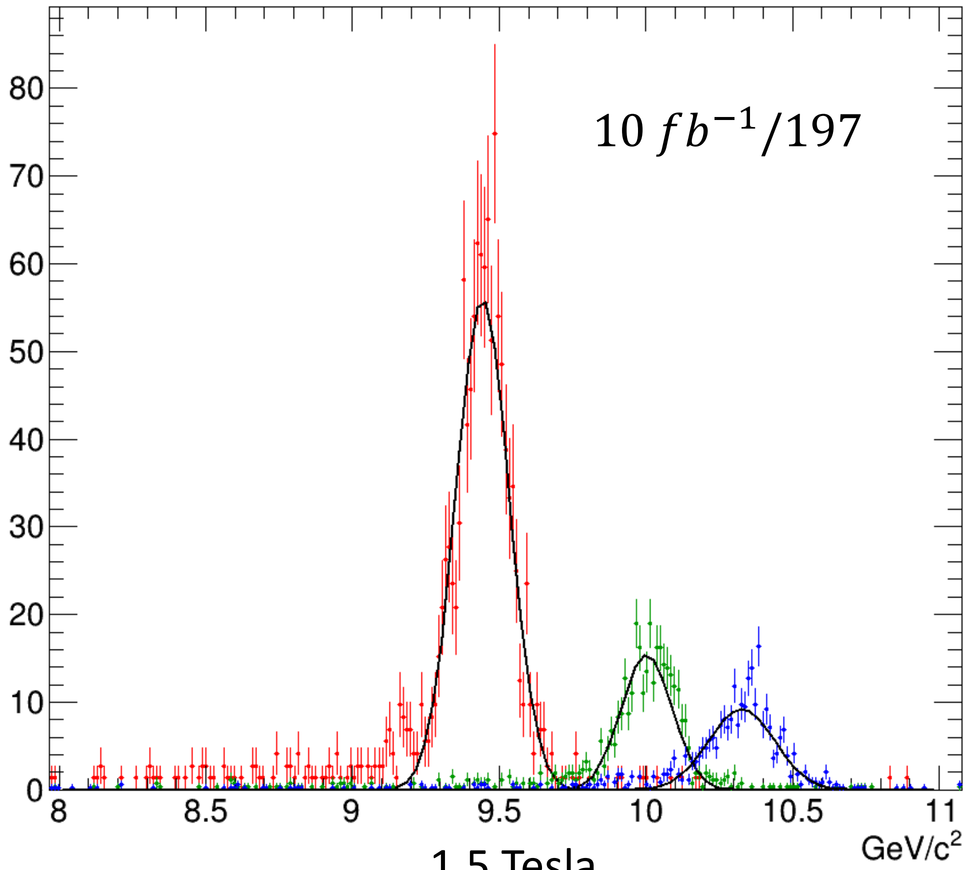
eSTARlight & All-Silicon Detector



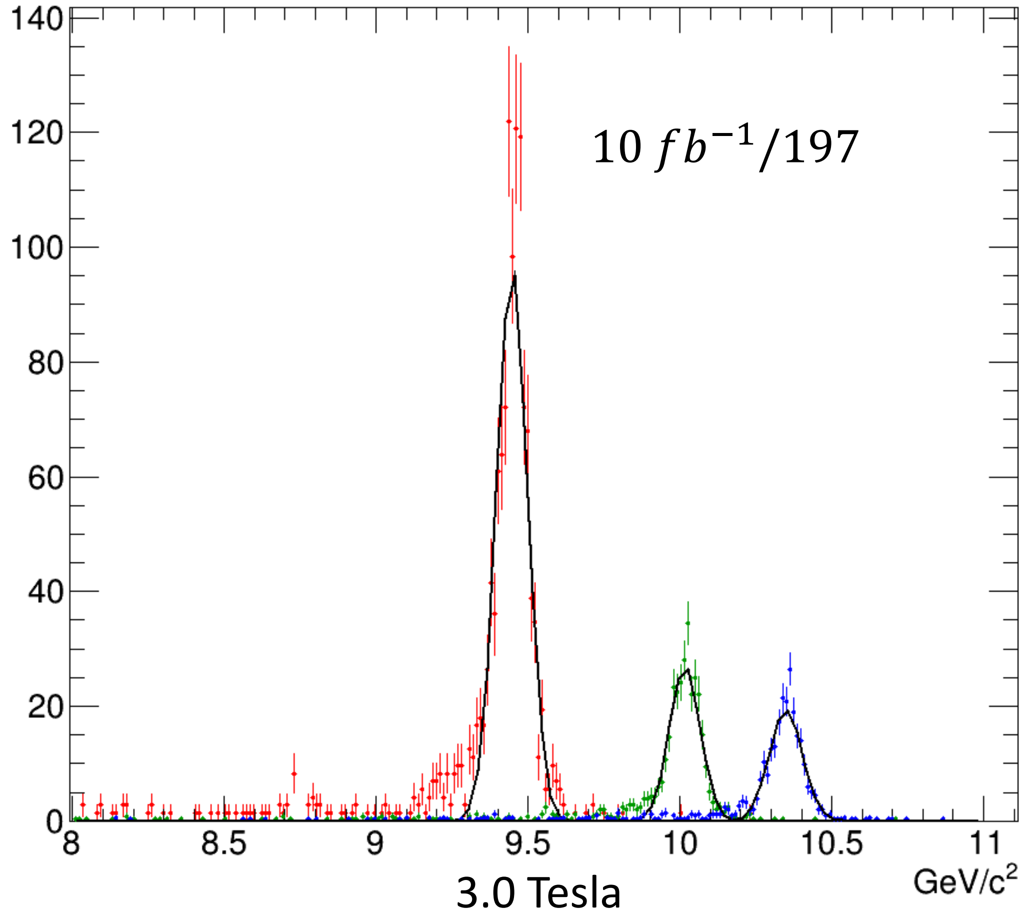
Reconstructed Upsilons
3 Sigma Mass Cut

Upsilon 1S,2S,3S Reconstructed in EICROOT All-Silicon Detector

Separating upsilon peaks should be a detector requirement



1.5 Tesla



3.0 Tesla

Upsilon peaks are still distinguishable with a lower B-Field

Conclusion & Future Work

eSTARlight simulations for photoproduction & electroproduction at an EIC

Vector Mesons:

- J/ψ $\rightarrow e^{+}e^{-}$
- ϒ(1S), ϒ(2S), ϒ(3S) $\rightarrow e^{+}e^{-}$
- Acceptance /Bjorken-x distributions of the J/ψ and ϒ(1S).

Preliminary studies with eSTARlight in EICROOT (BeAST & LBNL All-Silicon Detectors)

- Reconstruction efficiency
- Detector resolution for different field strengths and acceptance cuts

OutLook:

Study ϕ $\rightarrow K^{+}K^{-}$

More extensive resolution studies:

- Higher statistics
- Resolution fits with Crystal Ball Function
- Study resolution in t (tagging outgoing electron)