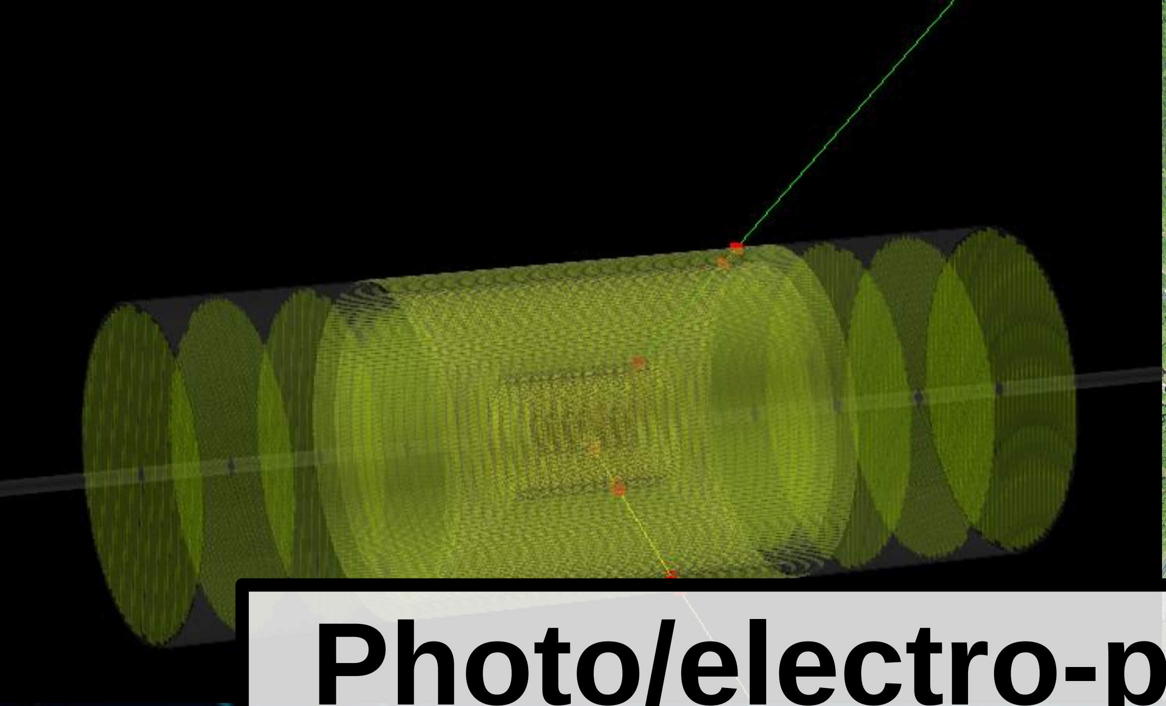
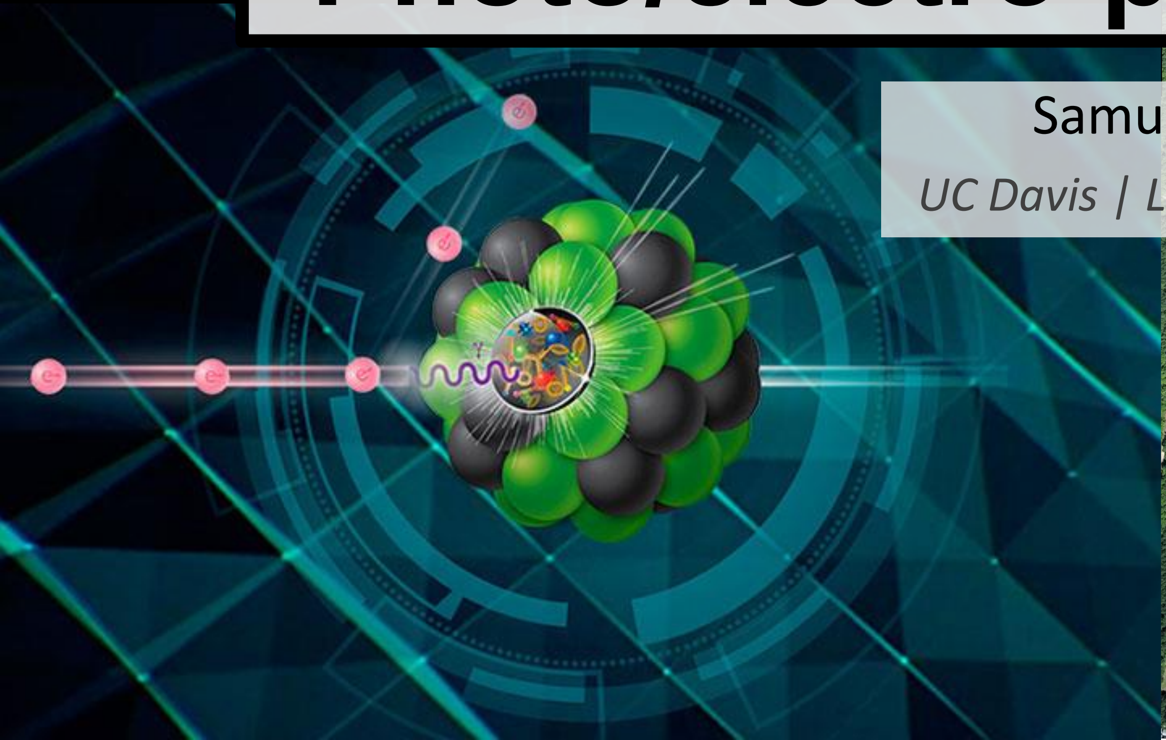
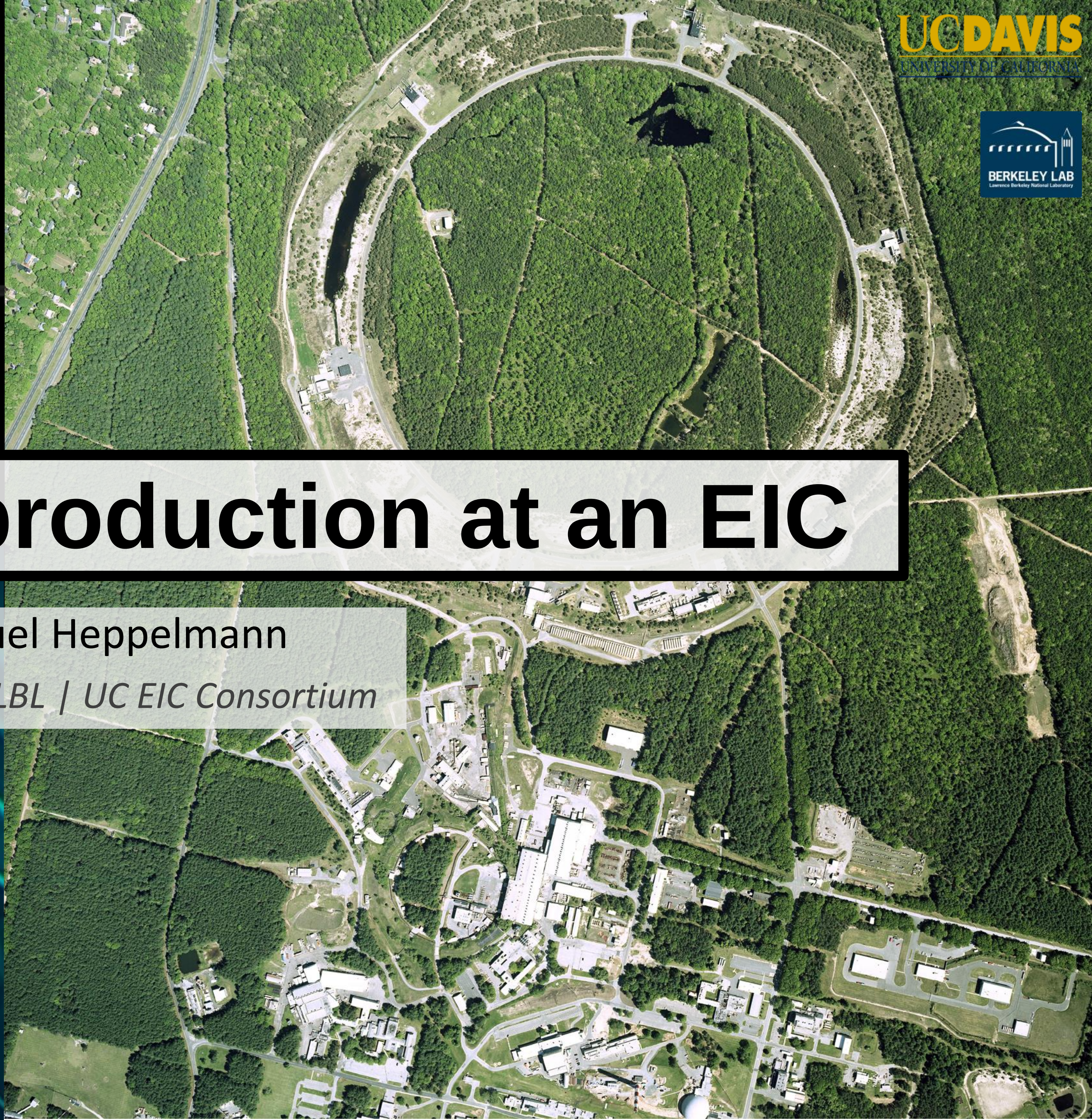






Photo/electro-production at an EIC

Samuel Heppelmann

UC Davis | LBL | UC EIC Consortium

Diffractive Physics in an EIC

In coherent Vector Meson production an incident photon fluctuates into a quark-anti quark dipole which scatters elastically off a target and emerges as a real Vector Meson

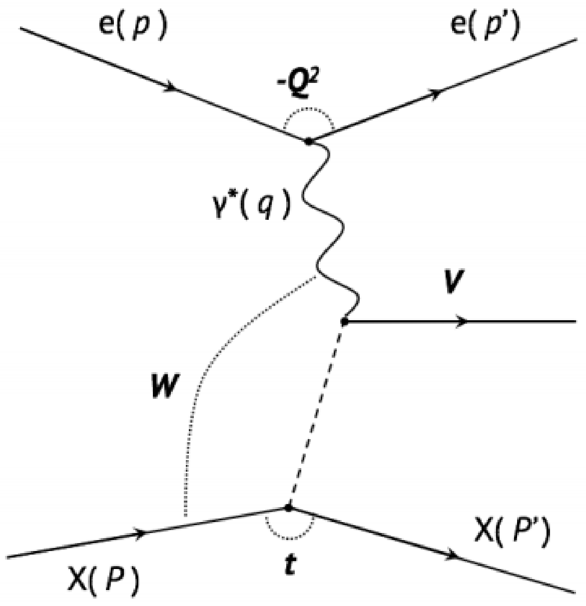
Photoproduction: Nearly real photon $(Q^2 \to 0)$

- Interaction involves elastic scattering
- (large cross section with increasing energy)
- Sensitive to parton saturation physics

Electroproduction: Virtual photon $(Q^2 > 0)$,

- Probe shorter distances and less sensitive to saturation effects
- By measuring the outgoing electron, we can fully determine the kinematics

To access lower Bjorken-x regions, in general, we look to forward regions (higher η) of our acceptance.



Elastic VM electroproduction $\sigma(eX \to eVX)$

The Bjorken-x depends on the photon energy where $x = (M_v c^2)^2/W^2$, W^2 *is the photon-nucleon center of mass*

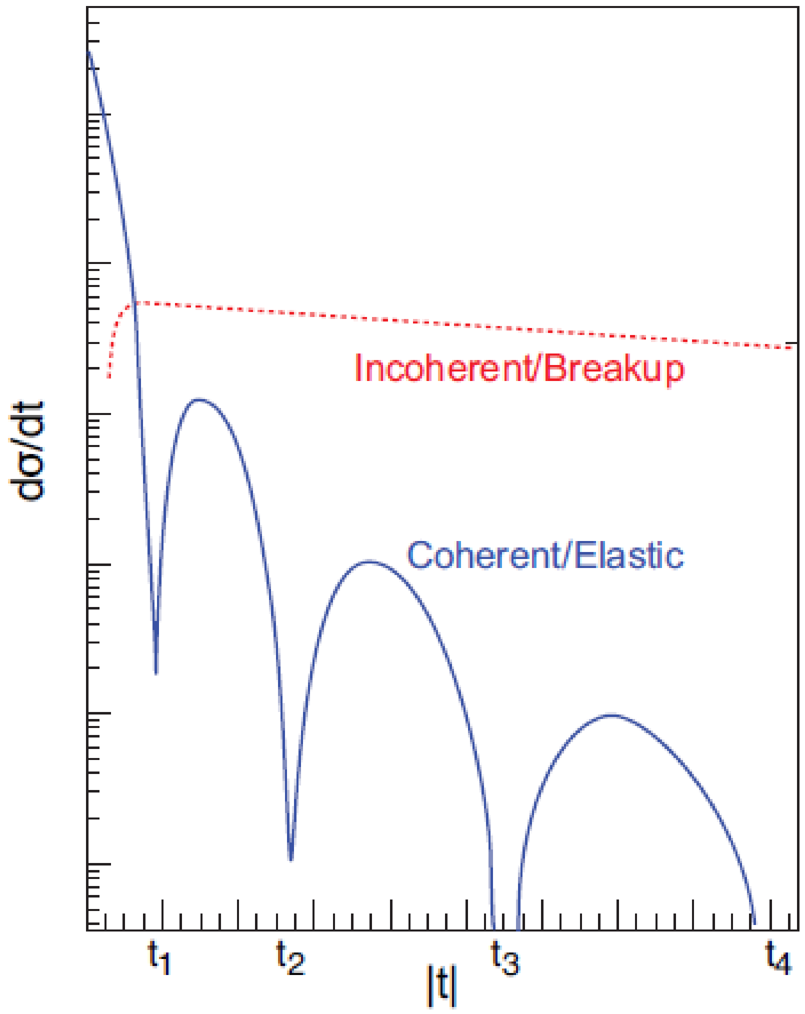
EIC White Paper, arXiv:1212.1701

Coherent photoproduction

- Sensitive to average gluon distributions
- Access to the transverse distribution for interactions
  (similar to Generalized Parton Distributions for nuclei)

Incoherent production *(Nuclear Breakup)*

- sensitive to event-by-event fluctuations, including gluonic hotspots (fluctuations of nucleon position and substructure)
- Experimentally, events are characterized by the empty detector (rapidity gap)



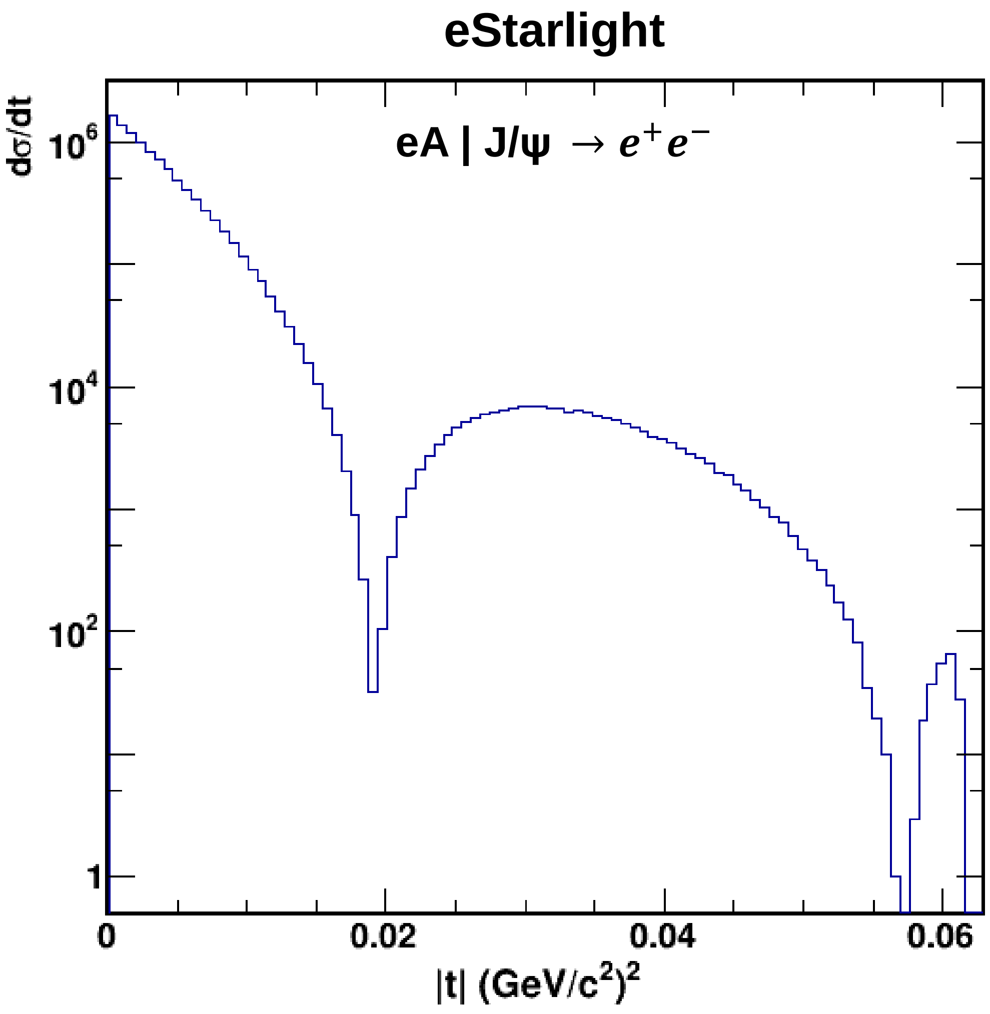
Overview of eSTARlight

Coherent photonuclear cross-sections are parameterizations of σ(γp) from HERA/fixed target data or theory

Convolution of photon flux from electron with σ(γp->Vp)
- Both depend on Q^2

Nuclear targets included with a Glauber calculation

Vector mesons retain the photon spin
- For Q^2 ~ 0, transversely polarized
- As Q^2 rises, longitudinal polarization enters
- Spin-matrix elements quantified with HERA data



Systems studied:

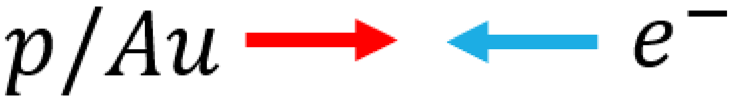
Collider configurations:

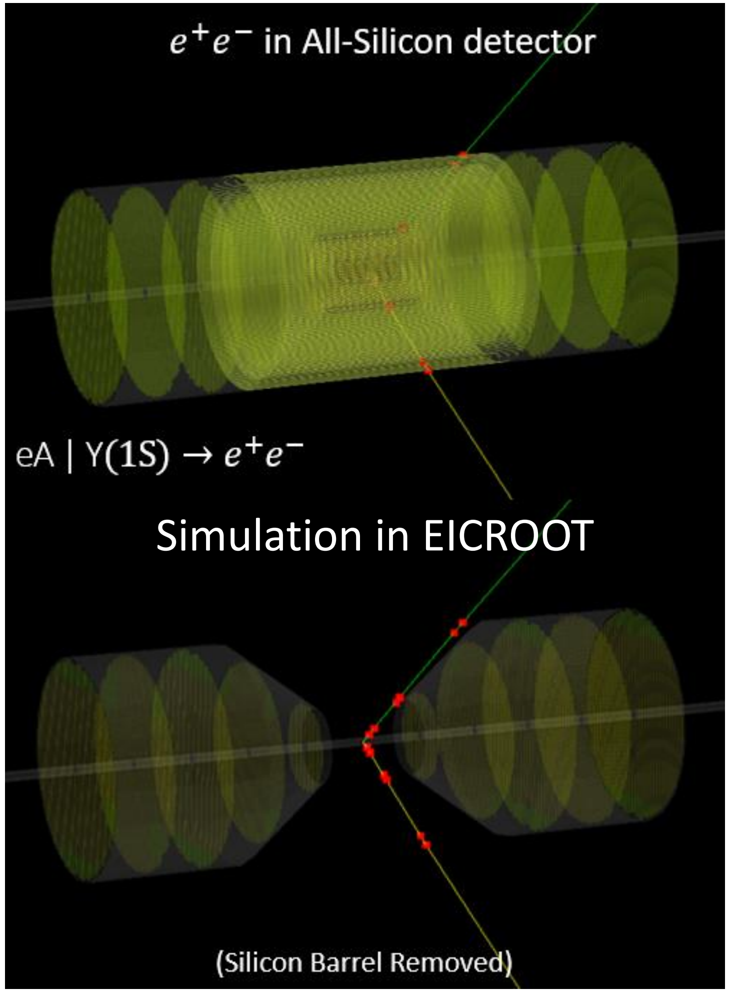
Electron (18 GeV) on Au (100 GeV) for and
Electron (18 GeV) on protons(250 GeV)
Electron (18 GeV) on protons(100 GeV)

Vector Mesons:

J/ψ $\rightarrow e^+e^-$
ϒ(1S), ϒ(2S), ϒ(3S) $\rightarrow e^+e^-$
$\rho \rightarrow \pi^+\pi^-$
$\omega \rightarrow \pi^+\pi^-$
ϕ $\rightarrow K^+K^-$

Rapidity Beam Convention





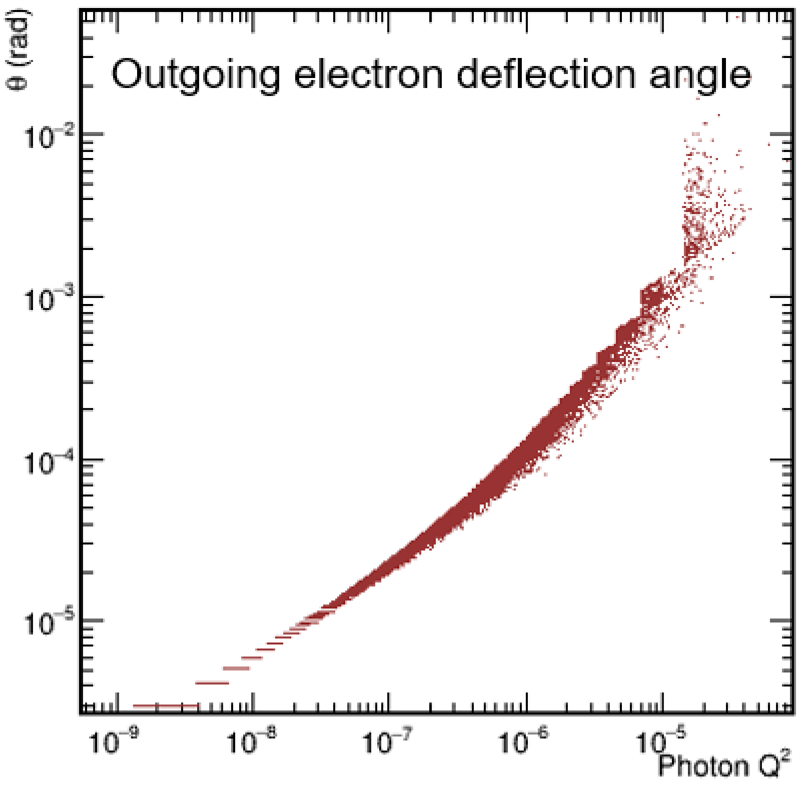
LBNL All-Silicon Detector

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

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

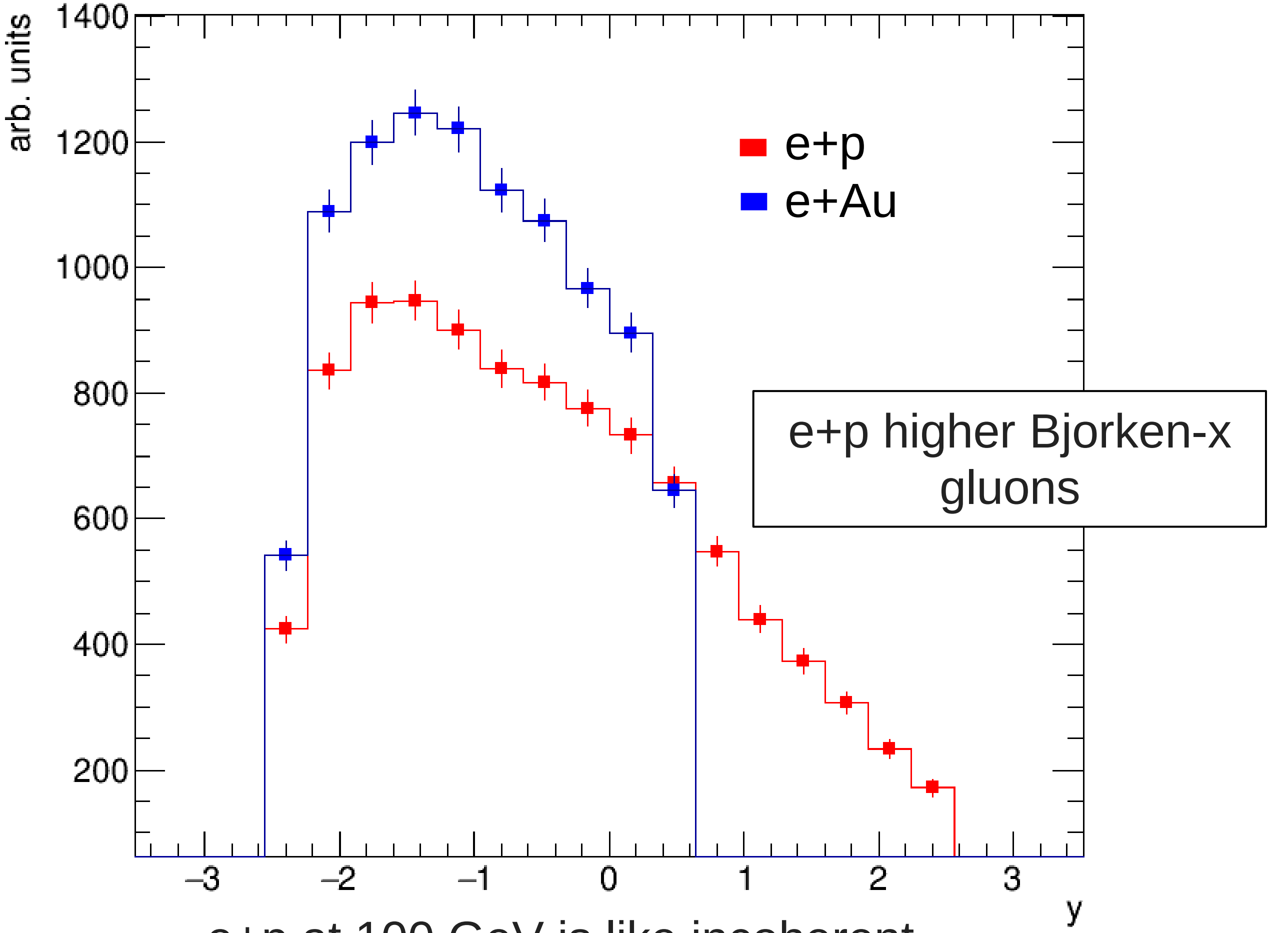
$J/\psi \rightarrow e^+e^-$

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.

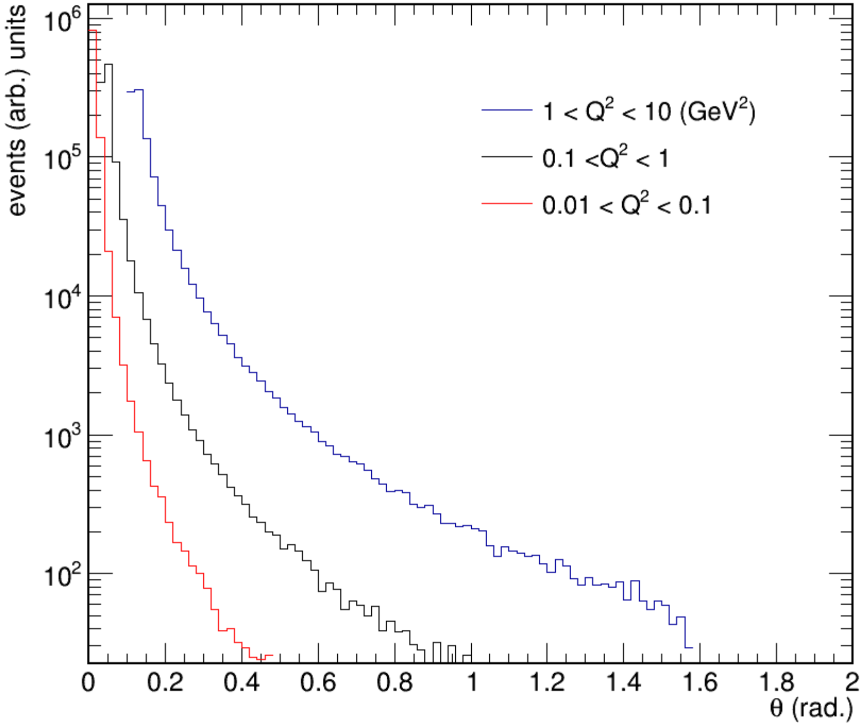


e+p at 100 GeV is like incoherent photoproduction in e+A

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

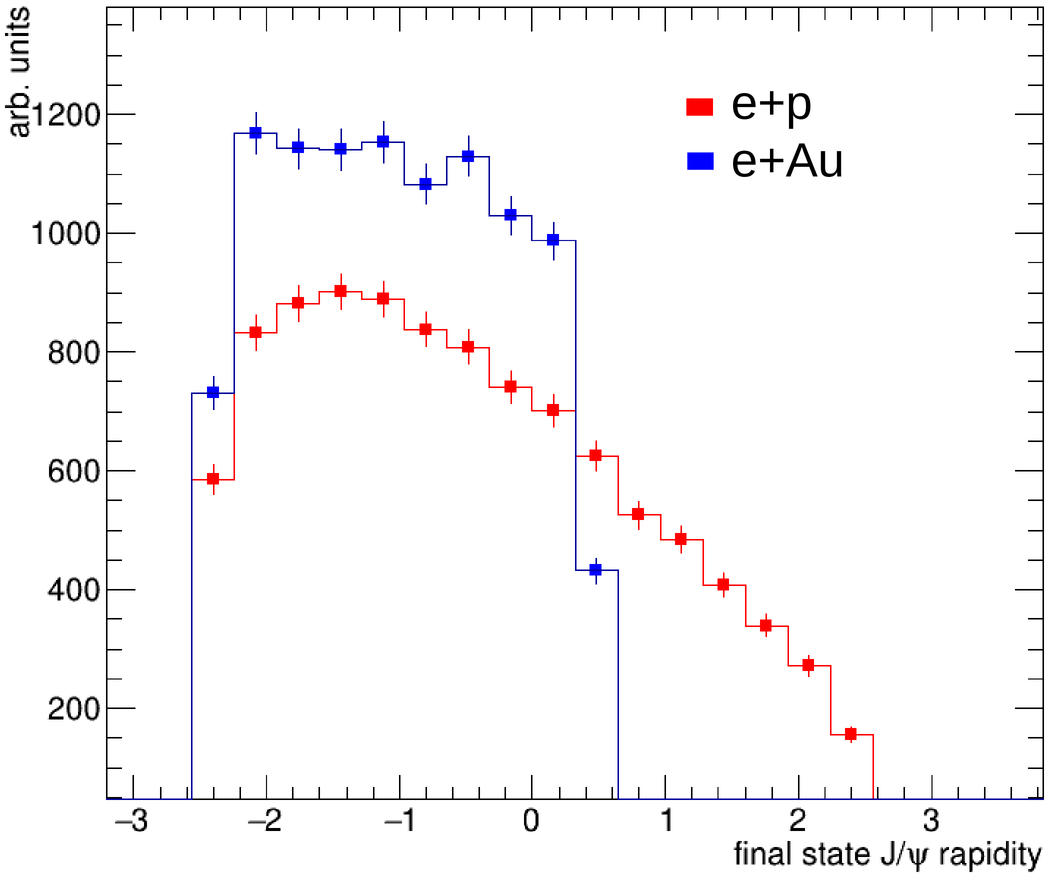
$J/\psi \rightarrow e^+e^-$

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

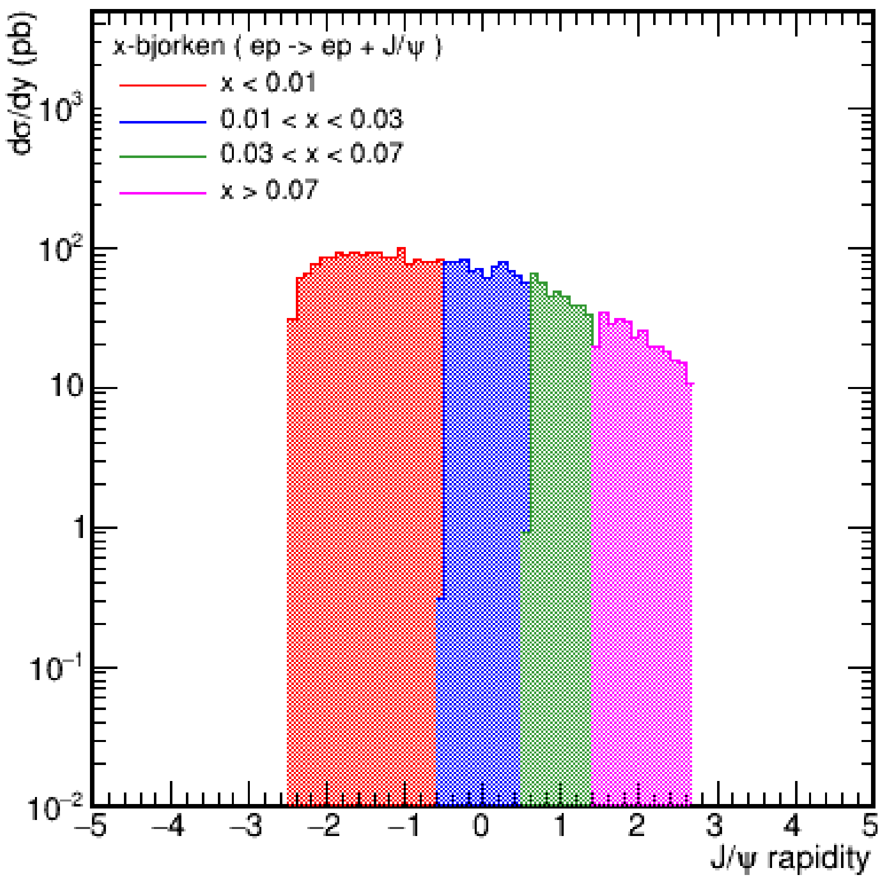
Similar Rapidity distribution for higher Q^2



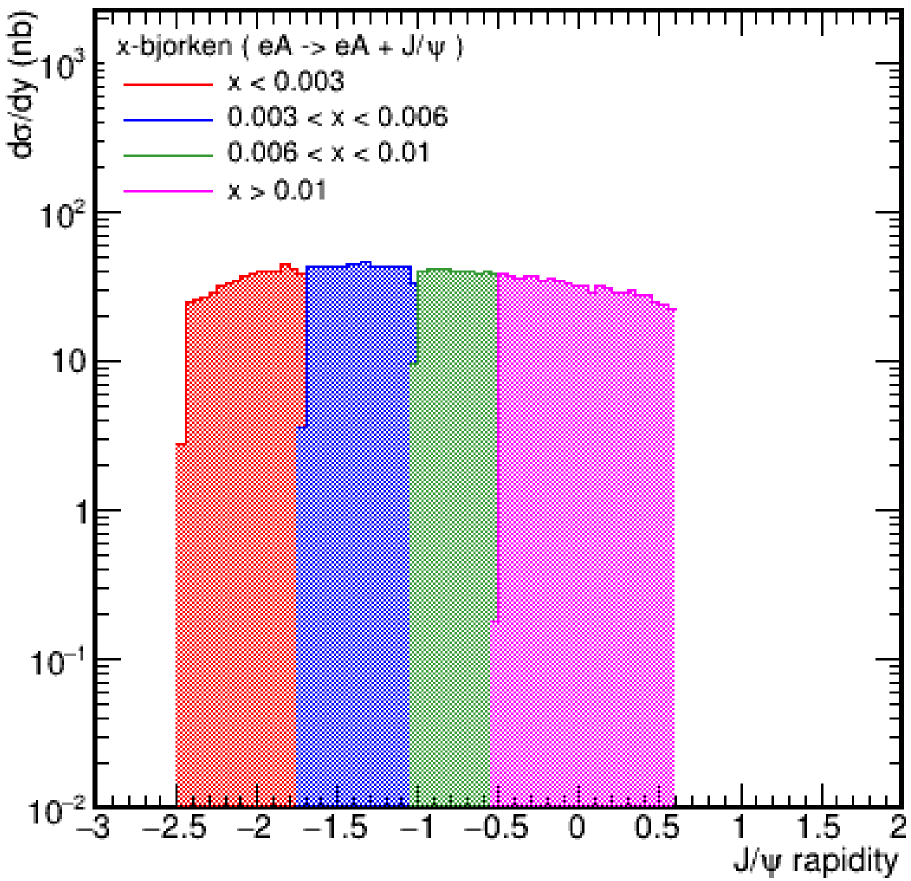
Events generated with eSTARlight

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

Electron (18 GeV) on Proton (100 GeV)



Electron (18 GeV) on Au (100 GeV)



Larger m_V corresponds to tighter rapidity range

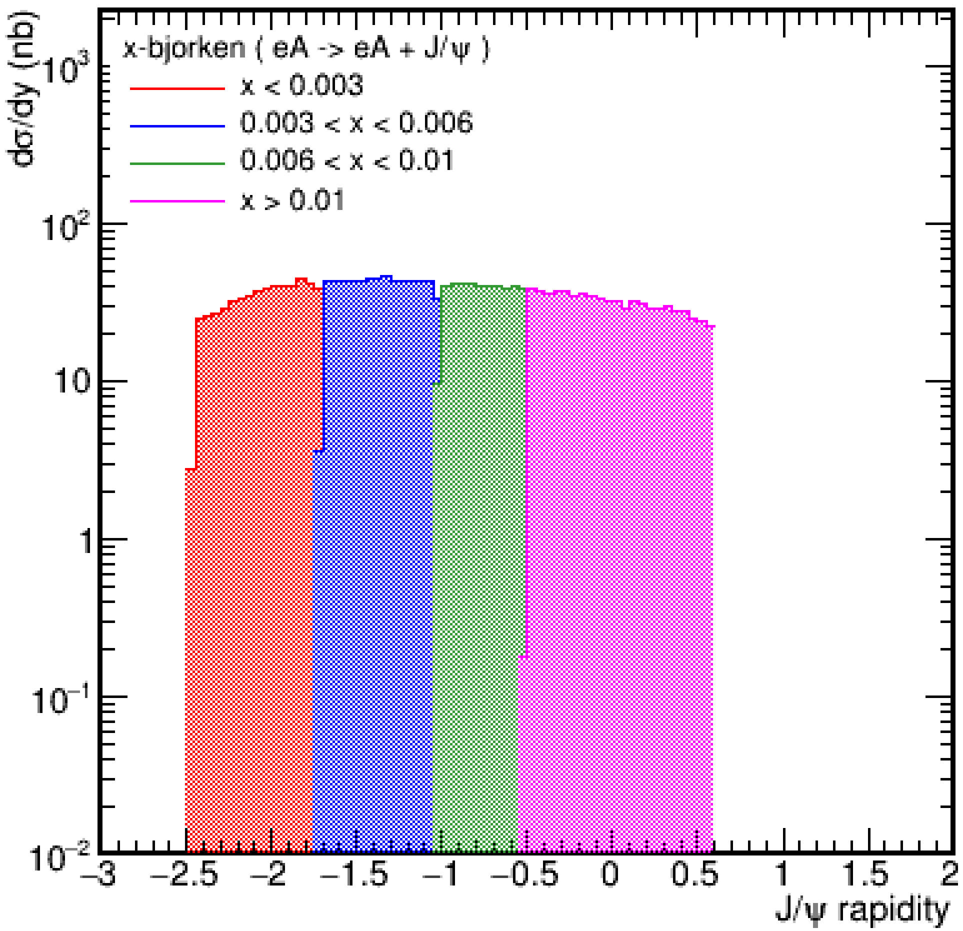
Bjorken-x for proton and Au targets   J/ψ ($0 < Q^2 < 10\ GeV^2$)

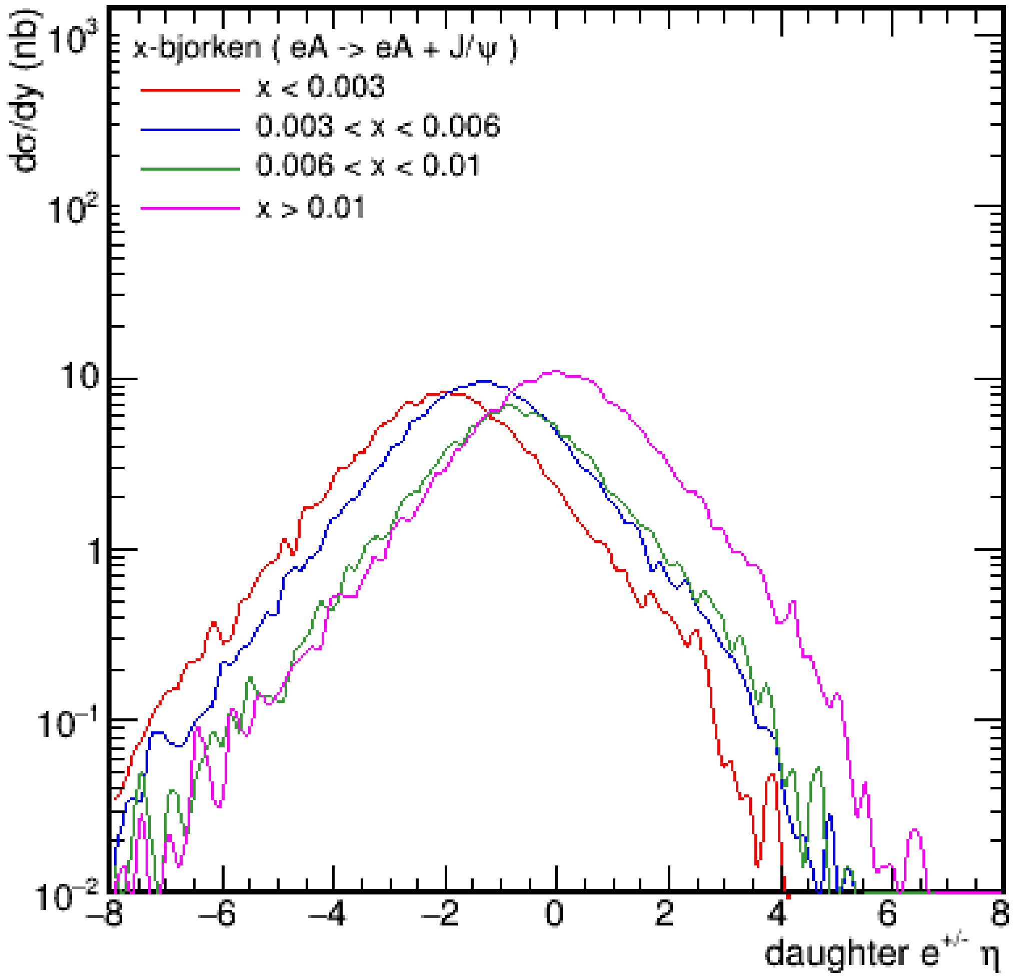
UC DAVIS UNIVERSITY OF CALIFORNIA   BERKELEY LAB

Events generated with eSTARlight

Detector Acceptance requirements

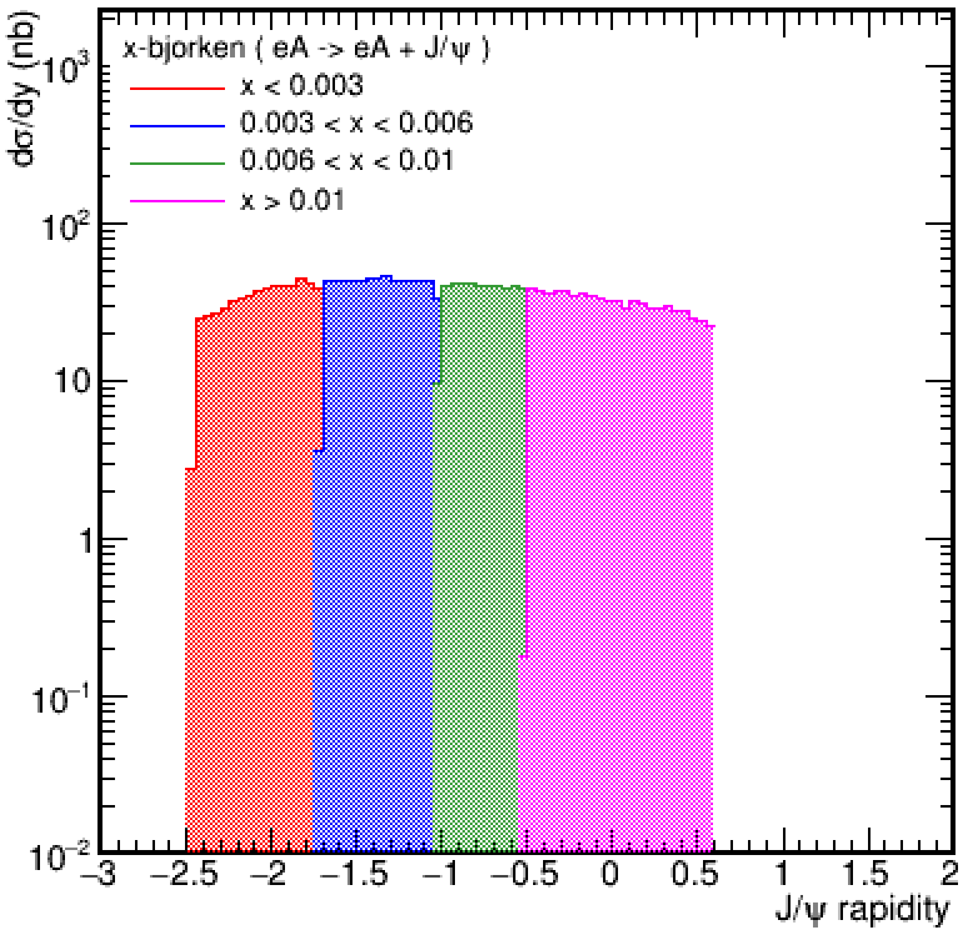
J/ψ $\rightarrow e^+e^-$

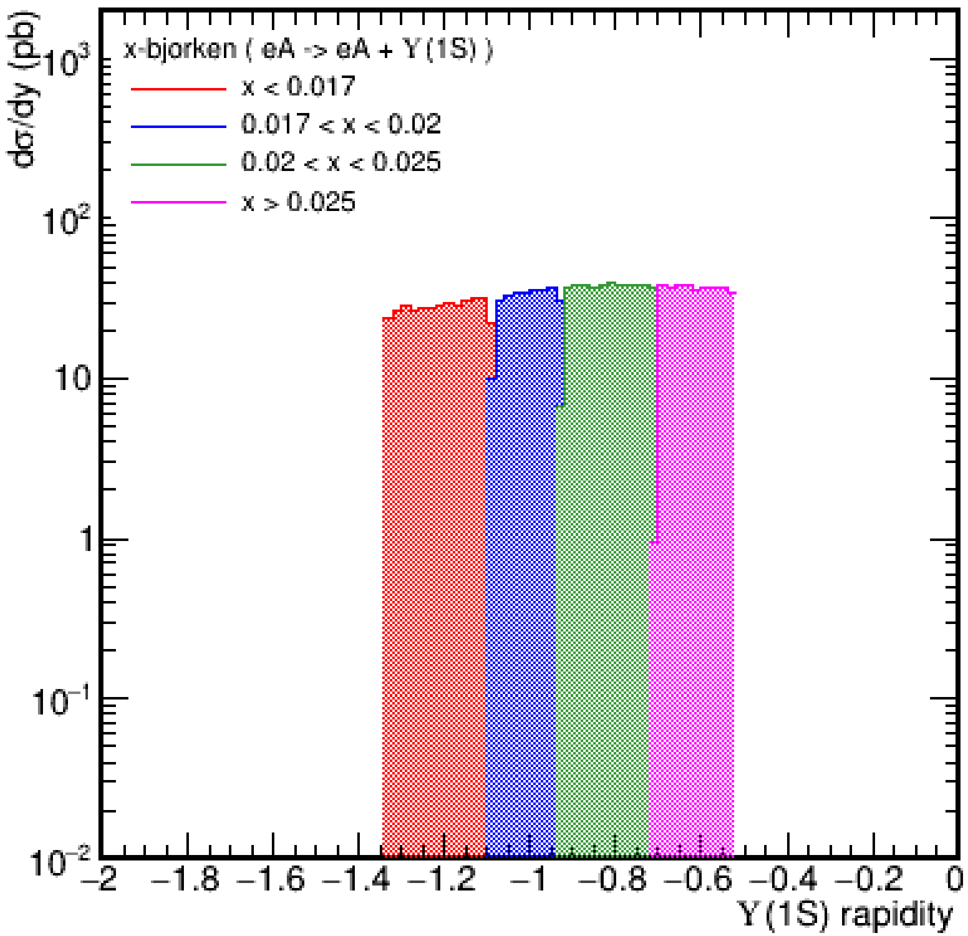




Electron pair's pseudorapidity important for detector acceptance

Events generated with eSTARlight

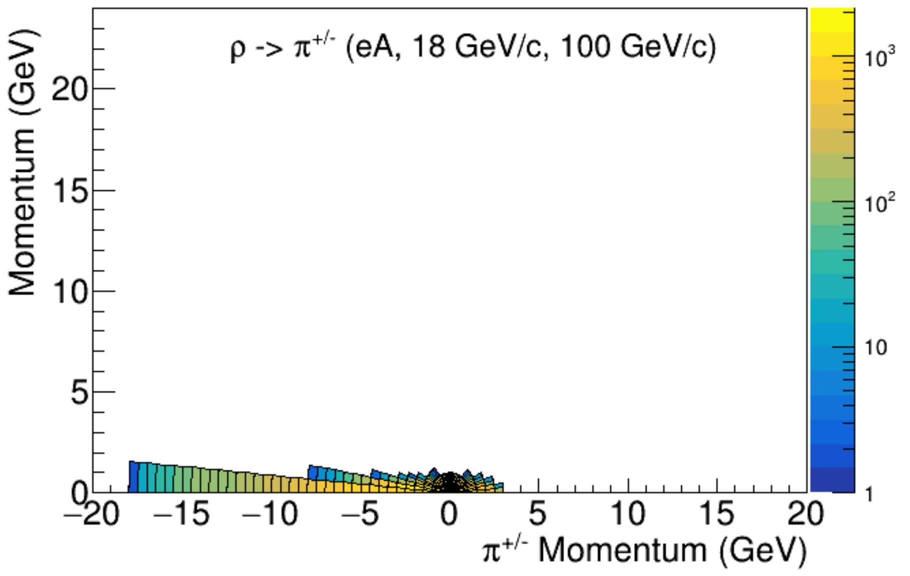


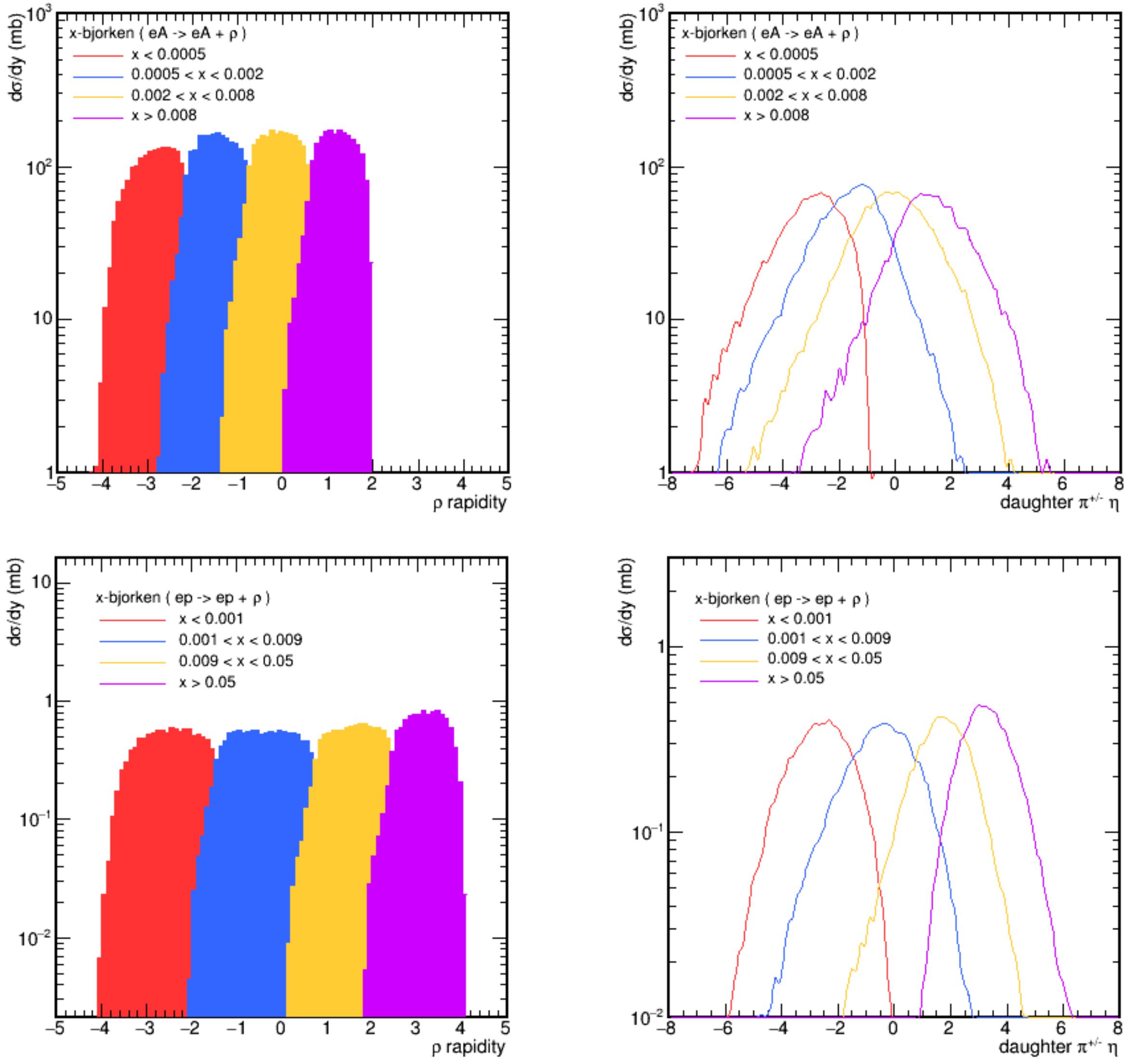


Larger m_V corresponds to tighter rapidity range

ρ production

(ep and eA, 18 GeV, 100 GeV)



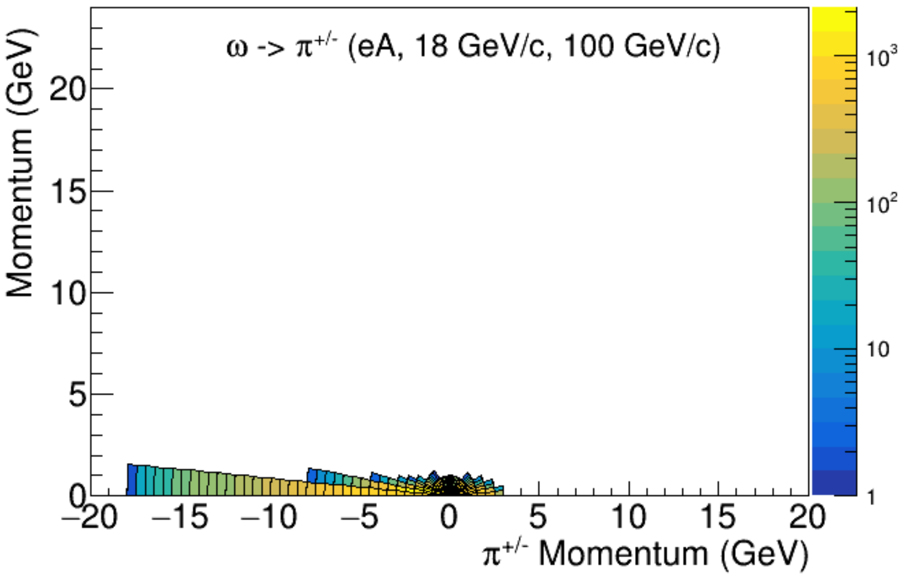


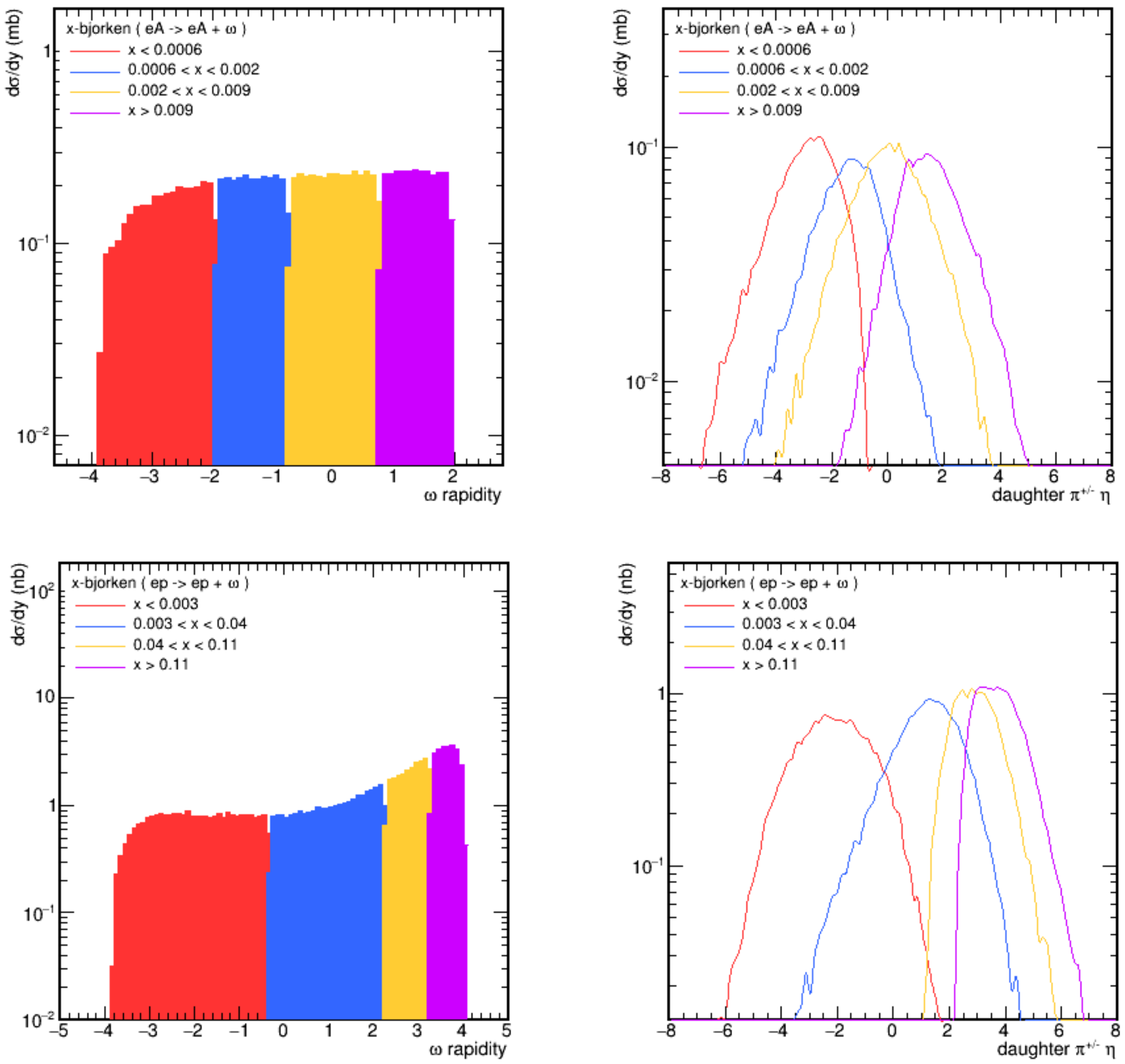
The $\boldsymbol{\rho}$ production at mid-rapidity, is primarily low momentum $\pi^{+/-}$

To reconstruct $\boldsymbol{\rho}$ requires forward reconstruction

ω production

(ep and eA, 18 GeV, 100 GeV)

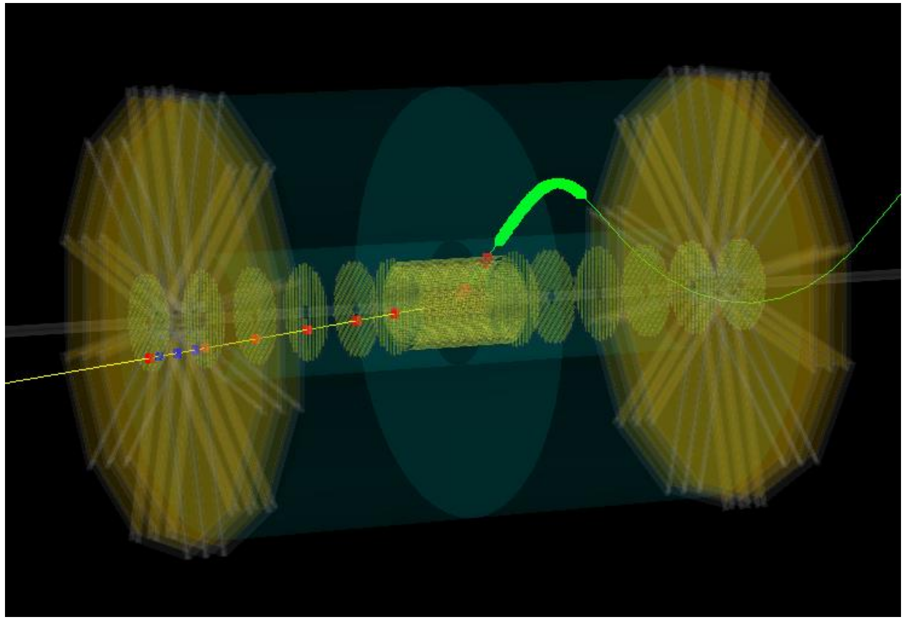


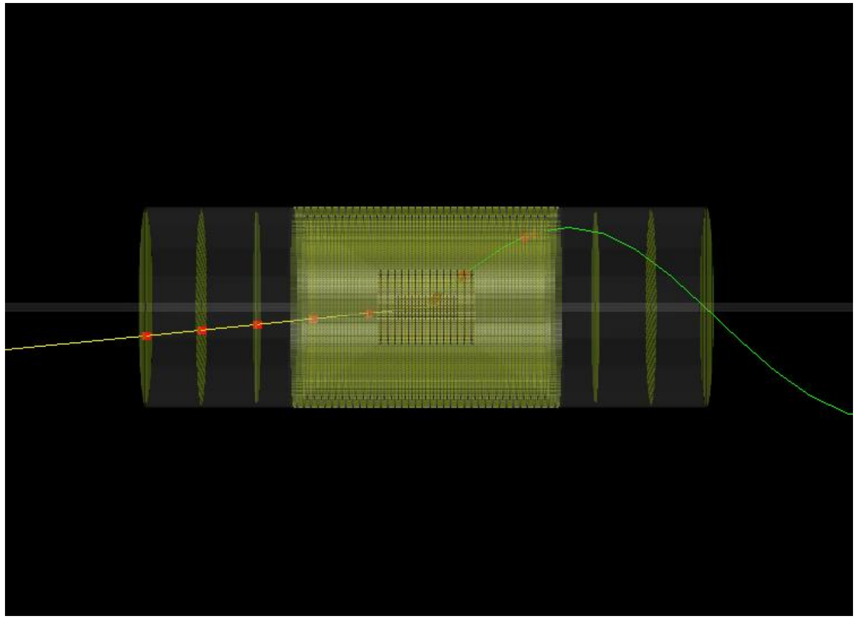


The $\boldsymbol{\omega}$ production at mid-rapidity has similar acceptance to the $\boldsymbol{\rho}$

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 (each side)

LBNL All-Silicon Detector

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

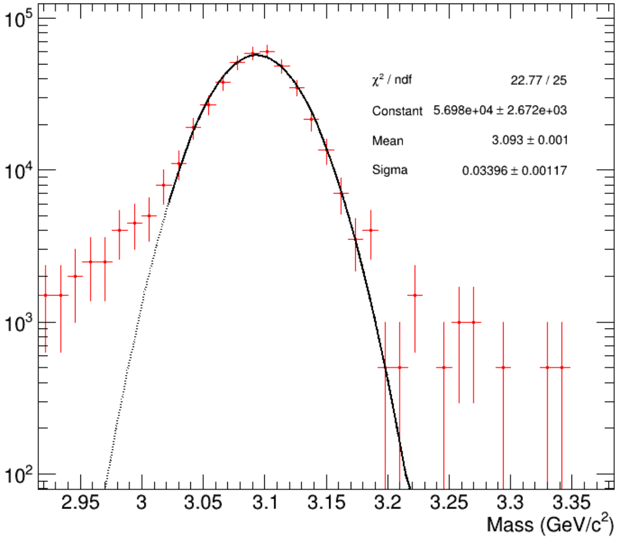
- **Silicon Tracker**
  - 6 layers
- **Silicon Endcap Disks**
  - 5 disks (each side)

Detector Comparison in EICROOT

BeAST Detector
Electron η < 4

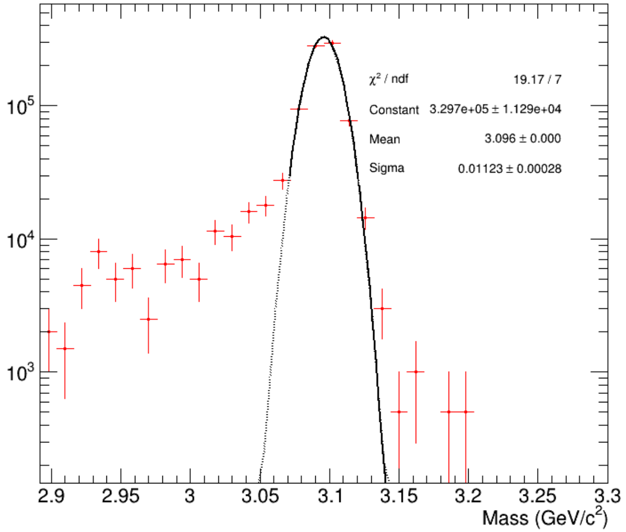
All Events normalized to $10\,fb^{-1}/179$

3 Tesla Field

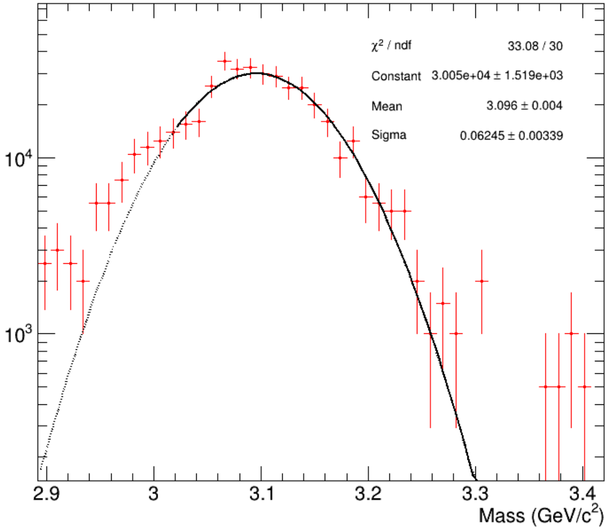


All Silicon Detector
Electron η < 4

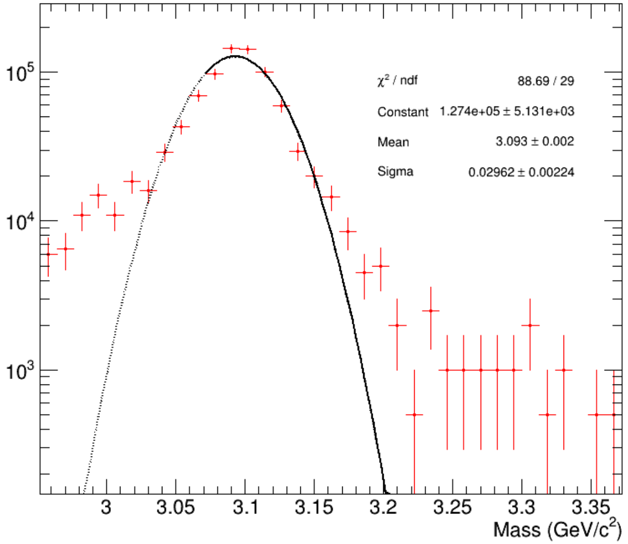
3 Tesla Field



1.5 Tesla Field

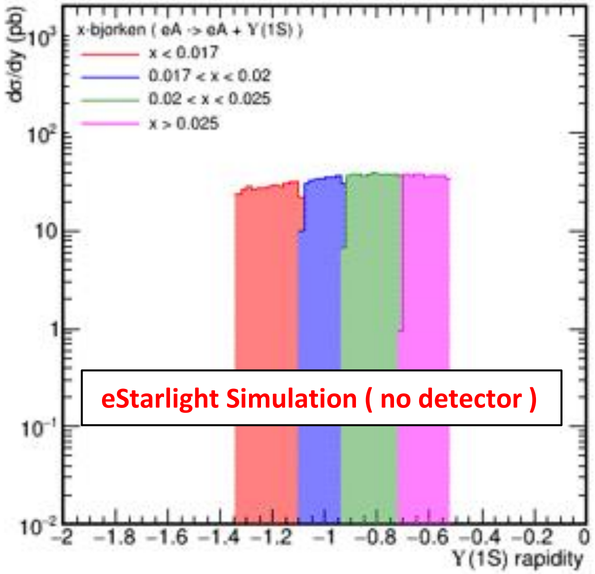


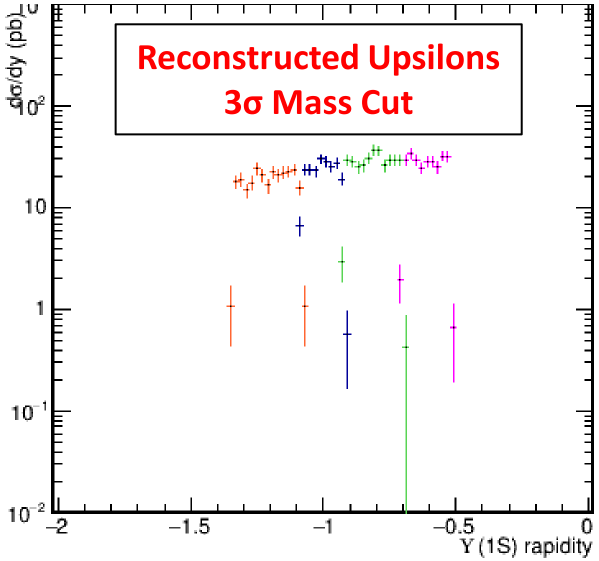
1.5 Tesla Field



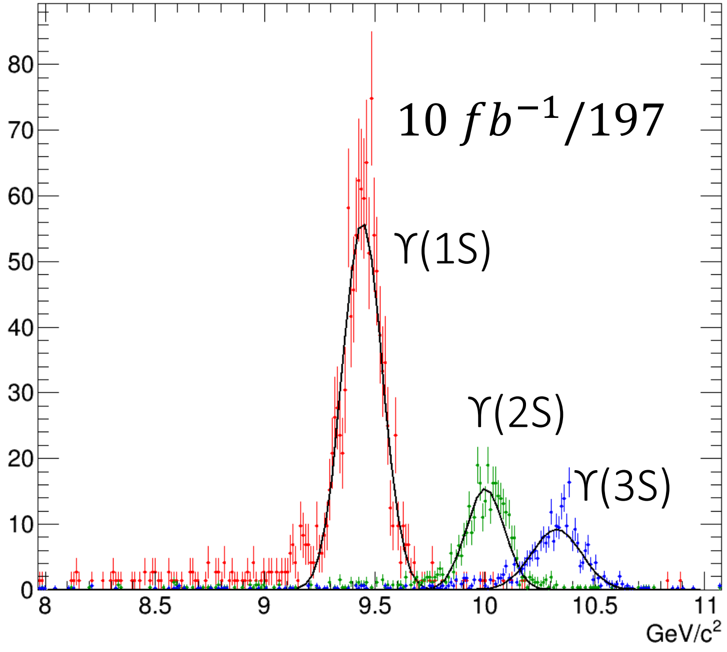
Upsilon 1S,2S,3S Reconstructed in EICROOT All-Silicon Detector

eSTARlight & All-Silicon Detector

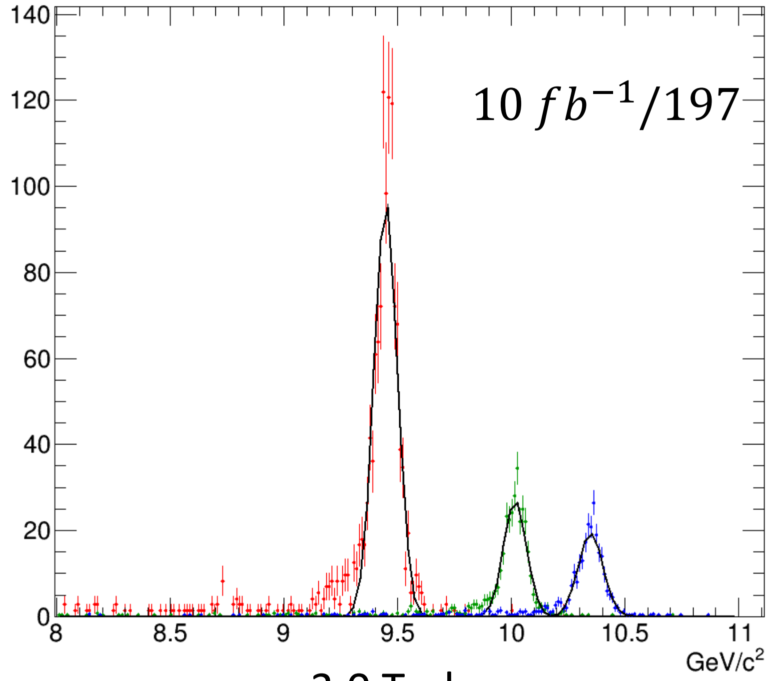




Separating upsilon peaks should be a detector requirement



1.5 Tesla

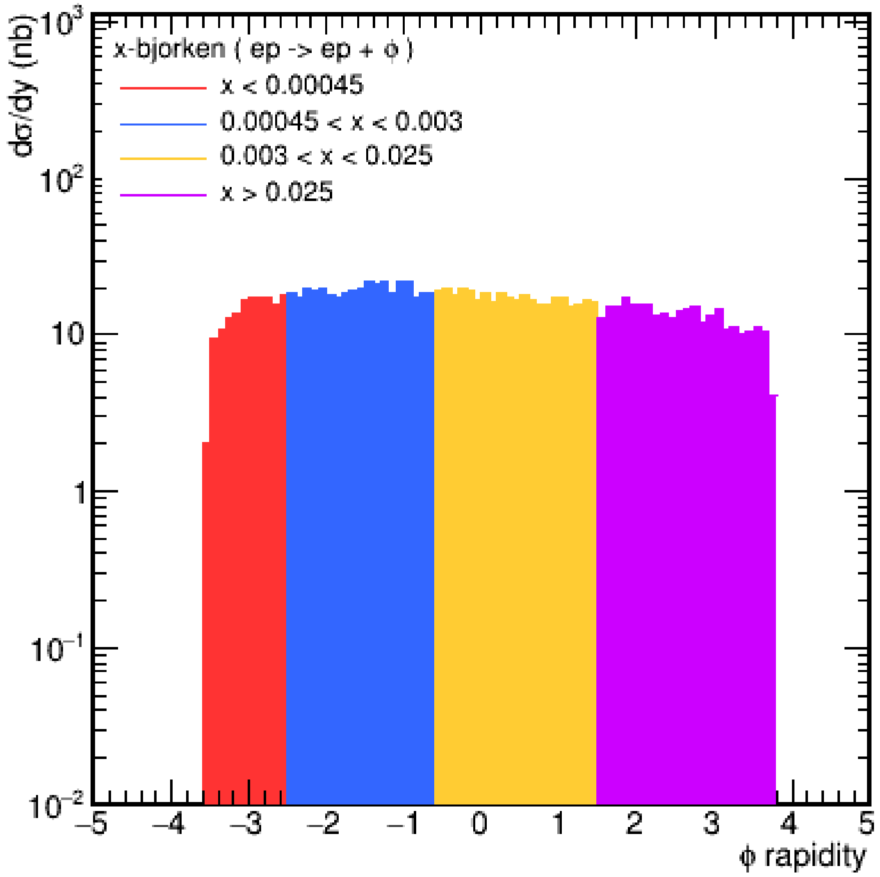


3.0 Tesla

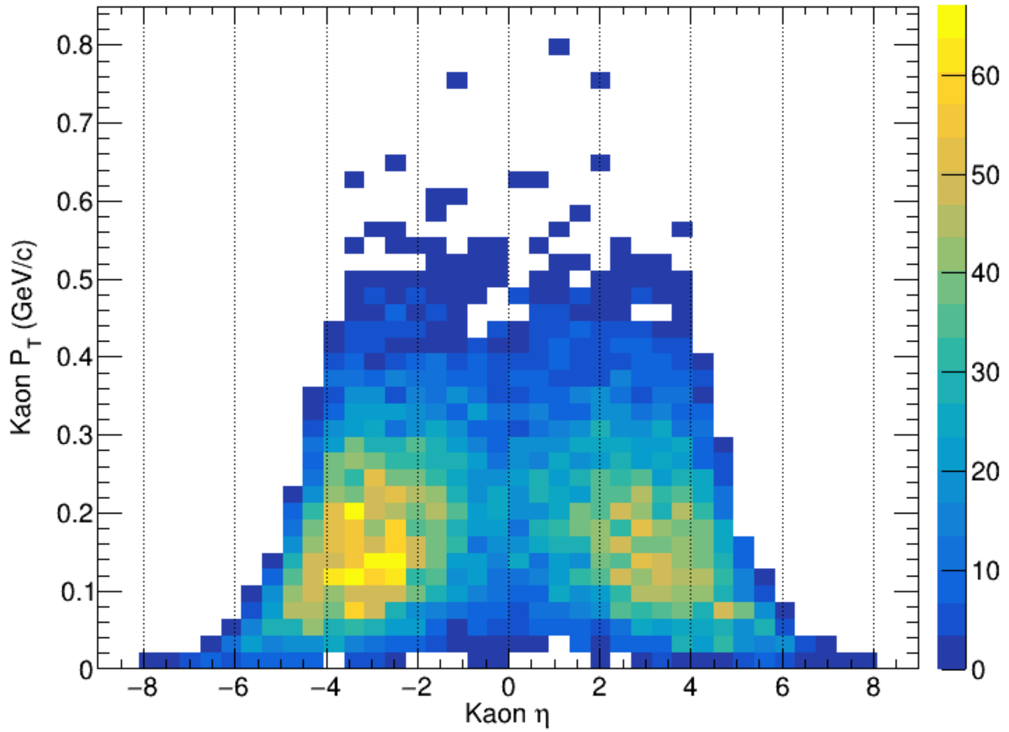
The All-Silicon detector provides enough energy resolution to distinguish the three upsilon states with either a 1.5 or 3 Tesla field

$\phi \rightarrow K^+ K^-$ in eSTARlight

18 GeV Electron
100 GeV Proton



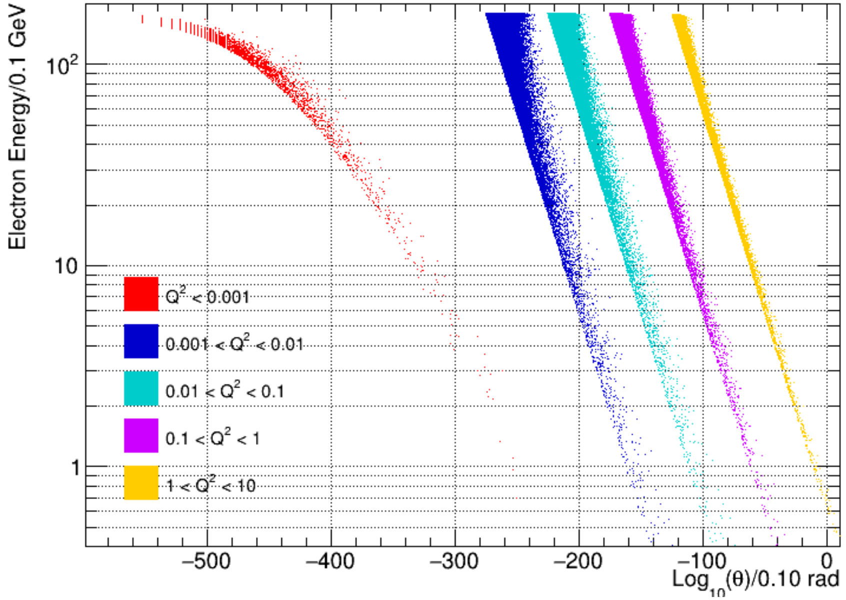
Electron (18 GeV) on Proton (100 GeV)
$(0 < Q^2 < 100\ \text{GeV}^2)$

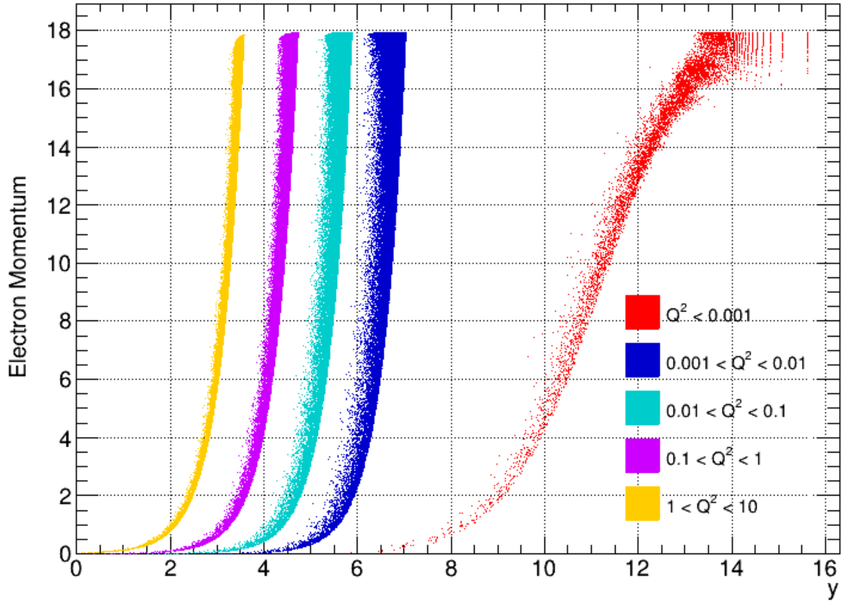


Forward/backward decay of the Kaons

$\phi \rightarrow K$^+ K^− in eSTARlight Scattered Electron

18 GeV Electron
100 GeV Au





Plots from Jaroslav Adam

Figure: Tagger 1

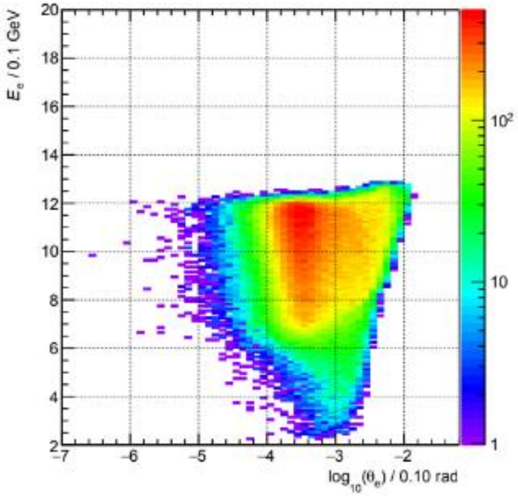


Figure: Tagger 2

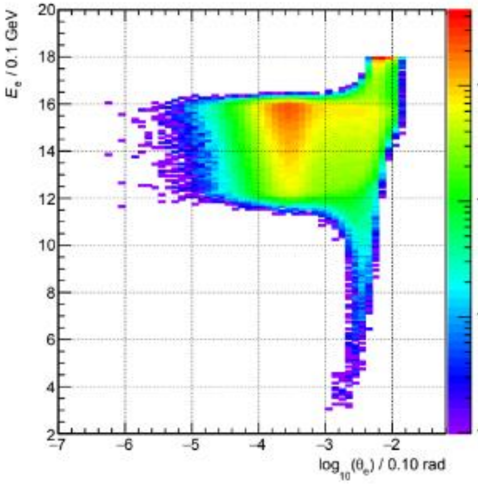
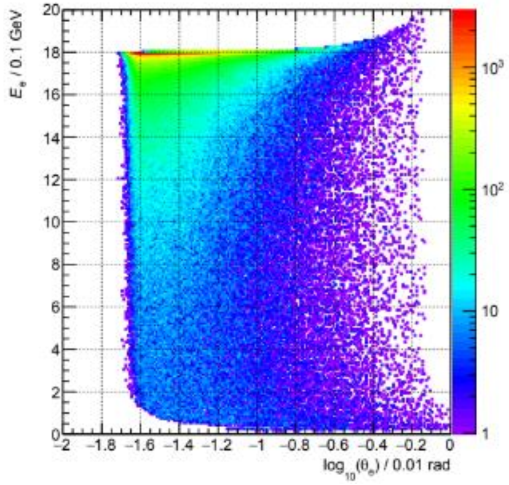


Figure: ECAL

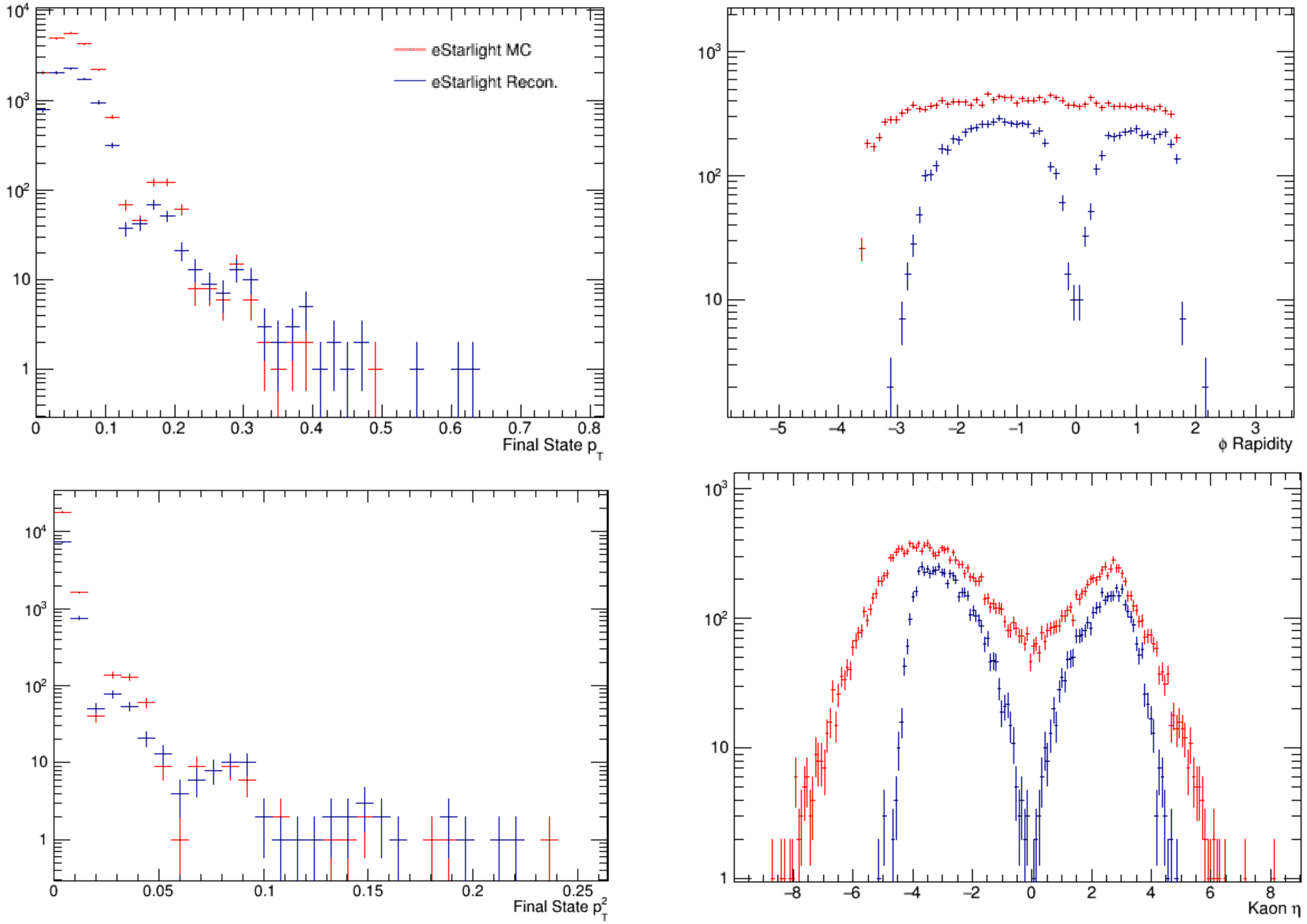


$\phi \rightarrow K^+ K^-$ in eSTARlight and EICRoot

18 GeV Electron
100 GeV Au

$(\mathbf{Q^2 < 1\ GeV^2})$

40% Efficiency



Two peak structure causes drop in acceptance at η=0

Structure arises from linear photon polarization and Clebsch-Gordon coefficients

Scanning beam energies will shift rapidity acceptance, allowing full probe of low $\mathbf{Q^2}$

Software Updates

eStarlight now supports HEPMC3 and is integrated into the EIC software hub.
https://github.com/eic/estarlight

HEPMC3 integration allows compatibility with EIC-Smear and Fun4All

Future projects:

- Comparisons of Fun4All and EICROOT performance
- Include backward production of vector meson production

Summary

eSTARlight simulations for photoproduction & electroproduction

Systems studied:

Collider configurations:

Electron (18 GeV) on Au (100 GeV) for and

Electron (18 GeV) on protons(100 GeV)

Vector Mesons:

$\phi \rightarrow K^+ K^-$

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).

Studies with eStarlight in EICROOT (BeAST & LBNL All-Silicon Detectors)

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

OutLook

- eStarlight recently integrated with the EIC software framework and HEPMC3
- Future studies with eic-smear and Fun4All
- Forward/Backward production of baryons