Photo/electro-production at an EIC

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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 $\sigma(\gamma p \rightarrow Vp)$
  - 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:
- $J/\psi \rightarrow e^+e^-$
- $\Upsilon(1S), \Upsilon(2S), \Upsilon(3S) \rightarrow e^+e^-$

Rapidity Beam Convention

$p/Au \rightarrow e^-$
Photoproduction of J/ψ ($Q^2 < 1 \text{ GeV}^2$)

\[ \text{J/ψ} \rightarrow e^+e^- \]

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

Outgoing electron deflection angle

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

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

p/Au → e^−

e+p higher Bjorken-x gluons

e+p at 100 GeV is like incoherent photoproduction in e+A
Electroproduction of $J/\psi$ ($Q^2 > 1$ 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
Bjorken-x for proton and Au targets \( J/\psi \ (0 < Q^2 < 10 \text{ GeV}^2) \)

Events generated with eSTARlight

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

Larger \( m_V \) corresponds to tighter rapidity range

Probe lower bjorken-x with heavier target
Bjorken-x for proton and Au targets

Detector Acceptance requirements

Electron (18 GeV) on Au (100 GeV)

J/ψ (0 < Q^2 < 10 GeV^2)

J/ψ → e^+e^−

Electron pair’s pseudorapidity important for detector acceptance
Bjorken-$x$ for proton and Au targets

$J/\psi$ and $\Upsilon(1S)$ ($0 < Q^2 < 10 \text{ GeV}^2$)

Events generated by eStarlight

Larger $m_\psi$ corresponds to tighter rapidity range
**eSTARlight with EICROOT**

Full Detector Simulation & Reconstruction

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**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

BeAST Detector
Electron $\eta < 4$

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

3 Tesla Field

All Silicon Detector
Electron $\eta < 4$

3 Tesla Field

1.5 Tesla Field

2 Particle Simulation ($e^+e^-$)
Bjorken-\(x\) for Reconstructed \(J/\psi\) \((0 < Q^2 < 10 \text{ GeV}^2)\)

- No background in reconstruction, only the daughter particles
- Select events within 3\(\sigma\) of \(J/\psi\) resolution
**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)

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**e+p**

\[ J/\psi \rightarrow e^+ e^- \]

2.6 pb$^{-1}$

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**e+A**

\[ J/\psi \rightarrow e^+ e^- \]

12 nb$^{-1}$
eSTARlight with EICROOT
Full Detector Simulation & Reconstruction

Resolution drops at backward rapidity
Resolution drops at backward rapidity
Bjorken-\(x\) Rapidity Distribution

\[ \text{eA} \mid Y(1S) \rightarrow e^+e^- \quad (0 < Q^2 < 10 \text{ GeV}^2) \]
Upsilon 1S,2S,3S Reconstructed in EICROOT All-Silicon Detector

Separating upsilon peaks should be a detector requirement

Upsilon peaks are still distinguishable with a lower B-Field
Conclusion & Future Work

**eSTARlight simulations for photoproduction & electroproduction at an EIC**

Vector Mesons:
- $J/\psi \rightarrow e^+e^-$
- $\Upsilon(1S), \Upsilon(2S), \Upsilon(3S) \rightarrow e^+e^-$
- Acceptance / Bjorken-x distributions of the $J/\psi$ and $\Upsilon(1S)$.

**Preliminary studies with eSTARlight in EICROOT (BeAST & LBNL All-Silicon Detectors)**
- Reconstruction efficiency
- Detector resolution for different field strengths and acceptance cuts

**OutLook:**
- Study $\phi \rightarrow K^+K^-$
- More extensive resolution studies:
  - Higher statistics
  - Resolution fits with Crystal Ball Function
  - Study resolution in $t$ (tagging outgoing electron)