Neutral Current Inclusive measurement in unpolarized ep collisions

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2\textsuperscript{nd} EIC YR workshop
Outline

1. Measurement of reduced cross section at HERA energy, reproducing HERA data by EIC simulation.
2. EIC NC data at highest energy can reduce Proton PDFs uncertainty band.
3. Lepton Identification study.
4. Smear effect on outgoing electron.
Reproduce HERA data by Djangoh

HERA data
EIC Djangoh
Reduced cross sections at EIC

ep NC events with DJANGOH for 18 GeV x 275 GeV
Impact of NC@EIC on PDFs: very preliminary

5 GeV x 100 GeV   10 GeV x 100 GeV   18 GeV x 275 GeV

\[ \sigma_{r,NC} = F_2(x, Q^2) - \frac{y^2}{[1+(1-y)^2]} \cdot F_L(x, Q^2) \]

First full fit results from EIC NC in combination with HERA data.

To separate the structure function \( F_L \) and \( F_2 \) for a given \( x \) and \( Q^2 \), one needs to measure cross section for different \( y \) and hence different collision energies.
Lepton PID (1)

5 × 50 GeV
Hadron
Photon
Electron
Lepton PID (2)

-5<\eta<-4

-4<\eta<-3

-3<\eta<-2

-2<\eta<-1

-1<\eta<0

0<\eta<1

1<\eta<2

20 \times 250 \text{ GeV}

Hadron
Photon
Electron

• Lepton PID: hadron and photon suppression are required to ensure good lepton identification.
Kinematics reconstruction

\[ Q^2 = -q^2 = -(k_\mu - k'_\mu)^2 \]

\[ Q^2 = 2E_e E'_e (1 - \cos \Theta'_e) \]

\[ y = \frac{pq}{pk} = 1 - \frac{E'_e}{E_e} \cos^2 \left( \frac{\theta'_e}{2} \right) \]

\[ x = \frac{Q^2}{2pq} = \frac{Q^2}{sy} \]

- NC kinematics reconstruction: focus on energy and theta of the outgoing electrons.
- Resolution diverges when y is close to 0.

\[
\frac{\delta x_e}{x_e} = \frac{1}{y_e} \frac{\delta E'_e}{E'_e} \oplus \frac{x_e}{E_e / E_p} - 1 \tan \frac{\theta'_e}{2} \delta \theta'_e
\]

\[
\frac{\delta y_e}{y_e} = \left( 1 - \frac{1}{y_e} \right) \frac{\delta E'_e}{E'_e} \oplus \frac{1}{y_e} - 1 \cot \frac{\theta'_e}{2} \delta \theta'_e
\]

\[
\delta Q^2_e = \delta E'_e \oplus \tan \frac{\theta'_e}{2} \delta \theta'_e
\]

diverges for \( y_e \to 0 \) depends on \( E'_e \)

\[
\delta Q_e^2 = \delta E'_e \oplus \tan \frac{\theta'_e}{2} \delta \theta'_e
\]

diverges for \( \theta'_e \to 180^\circ \) depends on \( E'_e \) and \( \theta'_e \)
Inelasticity requirement

Outgoing electron hit map

- Small $y$: electron energy is large and the outgoing direction is backward.
- Minimum $y$ cut is required to ensure high resolution.

$y$ distribution map on electron
Total coverage of the handbook for emcal:

-4.5 < \eta < 4.5

Smear::Device SmearThetaEmcal(Smear::kTheta, "0.001");

EMcal:

\eta = -4.5 — -2: \sigma_E \sim \sqrt{\text{pow}(0.01*E,2) + \text{pow}(0.01,2)*E}
\eta = -2 — -1: \sigma_E \sim \sqrt{\text{pow}(0.02*E,2) + \text{pow}(0.08,2)*E}
\eta = -1 — 4.5: \sigma_E \sim \sqrt{\text{pow}(0.02*E,2) + \text{pow}(0.12,2)*E}
The current parameter set up in EIC smear handbook is very preliminary.
Smeared kinematics: Smeared Vs true level

Needs to be compared with true level phase space.
Summary

Neutral current channel: final state electrons

1. EIC NC data at true level can improve PDFs constraint.
2. Low inelasticity events affect resolution, $y>0.01$.
3. Lepton PID is critical: the lepton needs to be identified with high purity from the hadron and photon samples.
4. EIC-smear study is on-going.
Backup: Reproduce HERA data by Djangoh (2)

\begin{align*}
\frac{d\sigma}{dx dQ^2} &= 200 \text{ GeV}^2 \\
\frac{d\sigma}{dx dQ^2} &= 250 \text{ GeV}^2 \\
\frac{d\sigma}{dx dQ^2} &= 300 \text{ GeV}^2 \\
\frac{d\sigma}{dx dQ^2} &= 400 \text{ GeV}^2 \\
\frac{d\sigma}{dx dQ^2} &= 600 \text{ GeV}^2 \\
\frac{d\sigma}{dx dQ^2} &= 1000 \text{ GeV}^2
\end{align*}

\(Q^2 = 200 \text{ GeV}^2\)

\(Q^2 = 250 \text{ GeV}^2\)

\(Q^2 = 300 \text{ GeV}^2\)

\(Q^2 = 400 \text{ GeV}^2\)

\(Q^2 = 600 \text{ GeV}^2\)

\(Q^2 = 1000 \text{ GeV}^2\)