Probing the Intrinsic Charm
in the nucleon at EIC

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Outline

- Motivation
- Extraction of Intrinsic charm component from D meson electroproduction
- Pythia simulation
- Projection
- Conclusion
Motivation

- A complete map out of the proton structure in terms of its quark constituents.

- Charm mesons lepto-production is one of the main sources of information on the nucleon’s gluon distribution


First evidence of intrinsic charm was observed in the di-muons production EMC experiment at CERN

- IC can be generated \(gg \rightarrow c\bar{c}\) fluctuation inside the proton where the gluons are coupled to the valence quarks.

- Existence of IC component provides an evidence for a five-quark state \(|uudc\bar{c}\rangle\) contribution to the nucleon wave function.

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Intrinsic strangeness

HERMES data shows a clear evidence for the existence of intrinsic strangeness component in the proton

W.C. Chang and J.-C. Peng Arxiv:1105.2381

\[ S(x, Q^2) = S_{int}(x, Q^2) + S_{ext}(x, Q^2) \]

Access the five-quark state \(|uuds\bar{s}\rangle\) contribution to the proton wave function
# Measurement of IC and EC

Lepto-production of charm mesons from SIDIS off deuteron provides access to
- charm mesons multiplicities $\rightarrow$ fragmentation functions
- Access the charm distribution in the nucleon

Particle data group

<table>
<thead>
<tr>
<th>D meson</th>
<th>Mass (GeV)</th>
<th>Hadronic decay mode</th>
<th>BR</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D^0$</td>
<td>1.864</td>
<td>$K^-\pi^+$</td>
<td>3.9%</td>
</tr>
<tr>
<td>$D^+$</td>
<td>1.869</td>
<td>$K^-\pi^+\pi^+$</td>
<td>9.4%</td>
</tr>
<tr>
<td>$D^-$</td>
<td>1.869</td>
<td>$K^+\pi^-\pi^-$</td>
<td>9.4%</td>
</tr>
<tr>
<td>$D^{*0}$</td>
<td>2.007</td>
<td>$D^0\pi^0 \rightarrow K^-\pi^+\gamma\gamma$</td>
<td>62%</td>
</tr>
</tbody>
</table>
| $D^{*+}$| 2.010      | $D^0\pi^+ \rightarrow K^-\pi^+\pi^+$  
              |          | $D^+\pi^0 \rightarrow K^-\pi^+\pi^+\gamma\gamma$ | 67.7% |
| $D^{*-}$| 2.010      | $D^0\pi^- \rightarrow K^-\pi^+\pi^-$  
              |          | $D^-\pi^0 \rightarrow K^+\pi^-\pi^-\gamma\gamma$ | 67.7% |
Formalism

\[
\frac{dN^h(x, Q^2, z)}{dN^{DIS}(x, Q^2)} \approx \frac{d\sigma^h(x, Q^2, z)}{d\sigma^{DIS}(x, Q^2)} \frac{dx \, dQ^2 \, dz}{dx \, dQ^2} = \frac{\sum_q e_q^2 \, q(x, Q^2) \, D_q^h(z, Q^2)}{\sum_q e_q^2 \, q(x, Q^2)}
\]

Integrating over \( z \) for a deuteron target, \( h = D^{*+} + D^{*-} \equiv D^* \)

\[
\frac{Q(x, Q^2) \int D_{NS}^{D^*}(z, Q^2) \, dz + S(x, Q^2) \int D_{S}^{D^*}(z, Q^2) \, dz + C(x, Q^2) \int D_{C}^{D^*}(z, Q^2) \, dz}{5Q(x, Q^2) + 2S(x, Q^2) + 8C(x, Q^2)}
\]

\( Q(x, Q^2) = u(x, Q^2) + \bar{u}(x, Q^2) + \bar{d}(x, Q^2) + \bar{d}(x, Q^2) \)

\( S(x, Q^2) = s(x, Q^2) + \bar{s}(x, Q^2) \quad C = c(x, Q^2) + \bar{c}(x, Q^2) \)

\[
c(x, Q^2) = \frac{Q \int D_{NS}^{D^*}(z, Q^2) \, dz + S \int D_{S}^{D^*}(z, Q^2) \, dz - M(x, Q^2)[5Q + 2S]}{8M(x, Q^2) - \int D_{C}^{D^*}(z, Q^2) \, dz}
\]

\( M(x, Q^2) \) is the measured multiplicity

PDF input:
- \( S, Q \) pdf from CTEQ6 parametrization

FF input:
- FF from KKKS08 parameterization
KKKS08 parametrization:

- Fit to experimental data from BELLE, CLEO, ALEPH and OPAL are used to determine fragmentation function for $D^0$, $D^+$ and $D^*$


$10^{-4} < z < 1$, $2.25$ GeV$^2 < Q^2 < 10^6$ GeV$^2$
Pythia event generator is used to determine the $D^{*\pm}$ multiplicities

- $e$- beam energy 11 GeV
- $p$ beam energy 50, 250 GeV
- pdf: cteq65 + BHPS model to include the intrinsic charm component
- Change Active flavor number to 4

Background Processes

PGF

QCDC

Resolved photons processes

Leading
kinematics

\[ Q^2 = -(k - k')^2 \]

\[ W^2 = (P + q)^2 \]

\[ x = \frac{Q^2}{2 (Pq)} \]

\[ s = (P + k)^2 \]
$Q^2$ versus $x$

$\sqrt{s} = 45\text{ GeV}$

$\sqrt{s} = 105\text{ GeV}$

large $x$ coverage

low $x$ coverage
Angular distribution of scattered electron

\[ \sqrt{s} = 45 \text{ GeV} \]

\[ \sqrt{s} = 105 \text{ GeV} \]
Angular and momentun distributions of D**+ meson

$$\sqrt{s} = 45 \text{ GeV}$$

$$\sqrt{s} = 105 \text{ GeV}$$
Angular and mometun distributions of D*- meson

$$\sqrt{s} = 45 \text{ GeV}$$

$$\sqrt{s} = 105 \text{ GeV}$$
Projection

- Two years of running at luminosity $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- Overall 90% detection efficiency is assumed
Conclusion

- Electroproduction of $D^{*\pm}$ mesons at EIC offers an opportunity to access the extrinsic and intrinsic charm density in the nucleon.
- Extraction of $D^{*\pm}$ meson multiplicities will provide an input to the fragmentation function database.
- Systematic uncertainties related to parton distribution function and fragmentation function are under study.
- Multi binning analysis to determine charm pdf as function of $x$ and $Q^2$.