Status update of analysis note on "Hadronization studies via pi0 electroproduction"

Taisiya Mineeva

Universidad Técnica Federico Santa María

CLAS collaboration meeting 13-15 June
Status update on the analysis note

https://www.jlab.org/Hall-B/secure/eg2/taya/review.html

Neutral pion electroproduction ratios off C, Fe, and Pb to D

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CLAS Analysis Note

Review committee: Yordanka Ilieva, Larry Weinstein and Michael Wood

The original analysis note submitted to the committee can be found here.
The review was requested on March 25, 2014 and received on July 3, 2014

Questions

- The committee response to original note is here
- Larry W. supplementary comments are here

Answers

- Current form of corrected analysis note is here
- Response to committee's questions is here

Meeting discussions

- Multiplicities presentation
- Acceptance correction presentation
- Systematics due to DC fiducial cuts presentation
- Systematics due to fit to the invariant mass presentation
- Systematics due to model dependence of acceptance presentation
- 1D multiplicity, acceptance and RC corrected: presentation

My wiki page

Last update June 13, 2017
Hadronization
Hadronization: vacuum

Hadronization is the process by which energetic $q$ and $g$ evolve into hadrons

- **Quark propagation:** in hard hadronic processes, energetic partons can be temporarily liberated from hadrons; distribution of the color charge over an extended volume.

- **Hadron formation:** color charge is neutralized into color singlet hadrons.
Hadronization: in-medium

Nuclear medium of variable size acts as a ruler that provides space-time information on hadronization process

- partonic multiple scattering
- medium-stimulated gluon emission
- additional prehadron interaction
Observables
Kinematic variables of SIDIS

\[ Q^2 = -q^2 \text{ four-momentum transferred by the electron;} \]

\[ \nu = E-E' \text{ (lab) energy transferred by the electron;} \]

\[ z = E_h/\nu \text{ fraction of initial quark energy carried by hadron;} \]

\[ P_T \text{ hadron momentum transverse to } \gamma^* \text{ direction;} \]

\[ \phi \text{ angle between leptonic and hadronic planes} \]
Reaction of interest: SIDIS $\pi^0$

DIS regime: $Q^2 > 1\, (\text{GeV/c})^2$ and $W > 2\, \text{GeV/c}$

$$e\ D \rightarrow e'\ \pi^0\ X$$

$$e\ A \rightarrow e'\ \pi^0\ X$$
Observables

Transverse momentum broadening

$$\Delta p_T^2 = \langle p_T^2 \rangle_A - \langle p_T^2 \rangle_D$$

Connects to partonic phase
- in-medium scattering
- quark energy loss
- access to production time $\tau_p$
Observables

Hadronic multiplicity ratio

Connects to hadronic phase
hadron formation space-time mechanisms
Analysis note

- Particle identification
  - electron ID
  - photon ID
  - $\pi^0$ reconstruction
  - binning

- Corrections
  - electron vertex
  - photon energy
  - $e^-$ and $\pi^0$ acceptance
  - radiative corrections

- Systematic studies
  - DC fiducial cuts
  - radiative corrections
Phase-space of the analysis was expanded

Before

\[ p_{T^2} = 0, 0.1, 0.25, 0.4, 0.55, 0.75, 0.9 \]
\[ z = 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 \]

Now

\[ p_{T^2} = 0, 0.1, 0.25, 0.4, 0.55, 0.75, 1.5 \]
\[ z = 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 1.0 \]

Entire analysis is binned in 2 sets of 3D bins: \((\nu, z, p_{T^2})\) and \((Q^2, \nu, z)\)
Purity-based bin exclusion in \((\nu, z, pT^2)\)

Exclude bins for which \(\text{Purity} < (1\sigma)^3\)
which amounts to Purity below 30%

\[
Purity = \frac{N_{\text{gen}}}{N_{\text{rec}}}
\]

Purity in \((Q^2, \nu, z)\) set of bins exceeds 30% for all the bins
Multiplicity ratios in \((\nu, z, pT^2)\)

Results are corrected for acceptance and radiative effects. Statistical uncertainties only.
Multiplicity ratios in \((Q^2, \nu, z)\)

Results are corrected for acceptance and radiative effects. Statistical uncertainties only.
Systematic uncertainties for C, Fe and Pb multiplicities in (Q^2, ν, z).

<table>
<thead>
<tr>
<th>Systematic uncertainty</th>
<th>ΔC_RMS (%)</th>
<th>ΔFe_RMS (%)</th>
<th>ΔPb_RMS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalization type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target vertex cut</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Target leakage</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Sampling fraction cut</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Photon energy cutoff</td>
<td>1.2</td>
<td>1.2</td>
<td>2.7</td>
</tr>
<tr>
<td>EC time (beta) cut</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>DC fiducial cuts</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Radiative corrections</td>
<td></td>
<td></td>
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Bin-by-bin basis

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</thead>
<tbody>
<tr>
<td>Background shape</td>
<td>0.6</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Signal shape</td>
<td>3.1</td>
<td>1.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Acceptance in finite bin width</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Total in (Q^2, ν, z)</td>
<td>3.9</td>
<td>3.1</td>
<td>6.3</td>
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</table>

Systematic uncertainties for C, Fe and Pb multiplicities in (ν, z, p_T^2) bins.

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<td>0.5</td>
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<tr>
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<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Sampling fraction cut</td>
<td>0.4</td>
<td>0.4</td>
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<tr>
<td>Photon energy cutoff</td>
<td>2.1</td>
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<td>2.2</td>
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<td>EC time (beta) cut</td>
<td>0.6</td>
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<td>Signal shape</td>
<td>2.1</td>
<td>2.1</td>
<td>4.5</td>
</tr>
<tr>
<td>Acceptance in finite bin width</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Total in (ν, z, p_T^2)</td>
<td>4.0</td>
<td>4.0</td>
<td>5.7</td>
</tr>
</tbody>
</table>

Work in progress: estimation of systematic uncertainties for the radiative corrections.
People @ UTFSM

**EG2 group at UTFSM**

Will Brooks (Director)
Ahmed El Alaoui
Hayk Hakobyan
Taisiya Mineeva
Sebastián Moran
Jose Peña
Antonio Radic
Orlando Soto

**Theory support**

Boris Kopeliovich
Benjamin Guiot
Independent cross checks of analysis: $\pi^0$ multiplicities
Independent cross checks of analysis: $\pi^+$ multiplicities

Sebastián Moran
Independent cross checks of analysis: $\pi^+$ acceptance

Discrepancy between the results ($\%$), Acc, 4D and 5D

Sebastián Moran
Summary

- The phase space of the analysis was expanded up to $z=1$ and $p_{T^2}=1.5 \text{ GeV}^2$. Multiplicity ratios in two sets of bins, acceptance corrections, radiative effects and systematic uncertainties were reevaluated correspondingly.

- The systematic uncertainties on the multiplicity ratio, w/o uncertainty on radiative corrections, are 3 - 6 % depending on the bin set and target type.

- What remains: systematics on radiative corrections.

- We plan to submit answers to the review committee within the next several months.
7th International Conference on High Energy Physics in the LHC era

8-12 January 2018
Universidad Técnica Federico Santa María
Valparaíso, Chile

Topics

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Astroparticle Physics    Hadron Spectroscopy
Neutrino Physics    High Energy QCD    Non Perturbative QCD
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Ads/CFT Phenomenology

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Edson Carquín    Jonathan Miller
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Ahmed El Alaoui    Iván Schmidt
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https://indico.cern.ch/e/hec2018
Backup slides
Missing mass curves as a function of ($p_T^2, z$)

$|W-2.5| < 0.1 \text{ GeV}, |Q^2-1.5| < 0.1 \text{ GeV}^2$

$W_x = M_p$

$W_x = 1.2 \text{ GeV}$

$W_x = 1.5 \text{ GeV}$

$W_x = 2.0 \text{ GeV}$

Entries 492637
Mean $\times$ 0.2876
Mean $\gamma$ 0.1195

$10^3$

$10^2$

$10$

$1$
Radiative Corrections in \((Q^2, \nu, z)\): SIDIS

SIDIS contribution to RC factors for D, Fe and Fe/D ratio in set of \((Q^2, \nu, z)\)
Radiative Corrections in $(Q^2, \nu, z)$: SIDIS + Exclusive

SIDIS + Exclusive contribution to RC factors for D, Fe and Fe/D ratio in set of $(Q^2, \nu, z)$
Radiative Corrections in ($\nu$, $z$, $pT^2$): SIDIS
Radiative corrections $C$ in $(\nu, z, pT^2)$: SIDIS + Exclusive
Multiplicity ratios
Multiplicity ratios in \((v, z, pT^2)\)

*Corrected for ACCEPTANCE ONLY*

P.S. low purity bins not excluded
Multiplicity ratios in $(\nu, z, pT^2)$

Corrected for ACCEPTANCE + Radiative corrections
Multiplicity ratios in \((Q^2, \nu, z)\)

Corrected for ACCEPTANCE ONLY
Multiplicity ratios in \((Q^2, \nu, z)\)

*Corrected for ACCEPTANCE + Radiative Corrections*