Multidimensional Hadron Attenuation

Gevorg Karyan
(On behalf of the HERMES Collaboration)

A.I. Alikhanyan National Science Laboratory
Yerevan, Armenia
Overview

- Semi-Inclusive Deep-Inelastic Scattering (SIDIS)
- Nuclear Effects
- Experiment
- Results
- Summary
\[ Q^2 \equiv -q^2 = (k - k')^2 \]
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\[ z_h = \frac{E_h}{\nu} \]

\( p_t \): hadron momentum component transverse to \( \gamma^* \)
\[ \sigma^{eN \rightarrow eh} \propto \sum_f e_f^2 \cdot q_f(x_{Bj}, Q^2) \cdot \sigma^{eq \rightarrow eq} \cdot D_f^h(z_h, Q^2) \]

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Nuclear Effects
Nuclear Effects

Partonic Effects
Nuclear Effects

Partonic Effects

- Gluon Radiation
- Parton Rescattering
Nuclear Effects

Partonic Effects

- Gluon Radiation
- Parton Rescattering

Hadronic Effects
Nuclear Effects

Partonic Effects

- Gluon Radiation
- Parton Rescattering

Hadronic Effects

- Colorless Prehadron Interaction
- Hadronic Final State Interaction
Nuclear Effects

\[ \gamma^* \rightarrow q \bar{q} \rightarrow q \bar{q} \rightarrow h \]

0 \rightarrow t_p \rightarrow t_p + t_f
Nuclear Effects

Partonic Effects

Hadronic Effects
Nuclear Effects

Partonic Effects  Hadronic Effects

Nuclear Attenuation
Nuclear Effects

\[ R_A^h(\nu, Q^2, z, p_t^2, \phi) = \frac{N^h(\nu, Q^2, z, p_t^2, \phi)}{N_e(\nu, Q^2)} \frac{A}{D} \]

Partonic Effects

Hadronic Effects

Nuclear Attenuation
**Experiment**

- **e± beam of 27.6 GeV energy**
- **Nuclear Target** ($D$, $Ne$, $Kr$, $Xe$)
- **Good Momentum Resolution** ($\Delta p/p < 2\%$)
- **Excellent Particle Identification Capabilities**
- **Experiment**

- **e± beam of 27.6 GeV energy**
- **Nuclear Target** (D, Ne, Kr, Xe)
- **Good Momentum Resolution** (Δp/p < 2%)
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Results

Multidimensional representation of $R_A^h$
Results

Multidimensional representation of $R^h_A$

- $\nu$ for three $z$ slices
- $z$ for three $\nu$ slices
- $p_t^2$ for three $z$ slices
- $z$ for three $p_t^2$ slices
Multidimensional representation of $R_A^h$

- $\nu$ for three $z$ slices
- $z$ for three $\nu$ slices
- $p_t^2$ for three $z$ slices
- $z$ for three $p_t^2$ slices

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Results

\[ R_A \]

<table>
<thead>
<tr>
<th>Ne</th>
<th>Kr</th>
<th>Xe</th>
</tr>
</thead>
<tbody>
<tr>
<td>( z = 0.2-0.4 )</td>
<td>( z = 0.4-0.7 )</td>
<td>( z &gt; 0.7 )</td>
</tr>
</tbody>
</table>

\( p \) \( \pi^+ \) \( K^+ \)

\[ v \ [\text{GeV}] \]
Attenuation is larger for heavy nuclei.
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$R_{K^+}$ is different from $R_{\pi^+}$, $R_{\pi^-}$ and $R_{K^-}$. 

\[ \text{EINN 2015, Paphos, Cyprus} \]
Attenuation is larger for heavy nuclei. 
\( R_{\pi^+} \) is different from \( R_{\pi^-} \), \( R_{K^+} \) and \( R_{K^-} \).
Protons behave very differently from the other hadrons.
### Results

<table>
<thead>
<tr>
<th>$R_A$</th>
<th>Ne</th>
<th>Kr</th>
<th>Xe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- $\pi^+$
- $K^+$
- $p$

$\nu = 4-12$ GeV
$\nu = 12-17$ GeV
$\nu = 17-23.5$ GeV
$R_{A}^{K^{+}}$ is different from $R_{A}^{K^{-}}$ at small values of $z$. 
Results

\[ R_{A}^{K^+} \text{ is different from } R_{A}^{K^-} \text{ at small values of } z. \]

Strong dependence of \( R^p \) on heavy nuclei.
Results
Results

Reduction of $R_A^h$ with increasing of $z$. 

EINN 2015, Paphos, Cyprus
Reduction of $R_A^{h}$ with increasing of $z$.

Strong dependence of $R_A^{h}$ on $p_t^2$ at small values of $z$ for heavy nuclei.
Results

\[ \begin{array}{c|c|c|c}
R_A & Ne & Kr & Xe \\
\hline
0 & \text{\textcolor{red}{\textbullet}} \ z = 0.2-0.4 & \text{\textcolor{red}{\textdownarrow}} \ z = 0.4-0.7 & \text{\textcolor{red}{\textbullet}} \ z > 0.7 \\
2 & & & \\
1.5 & & & \\
1 & & & \\
0.5 & & & \\
1.5 & & & \\
1 & & & \\
0.5 & & & \\
0.5 & & & \\
\end{array} \]

\[ p_t^2 \text{[GeV}^2\text{]} \]
The Cronin effect is larger for protons.
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Multidimensional kinematic dependencies of $R_A^h$ for $\pi^+, \pi^-, K^+, K^-, p$ and $\bar{p}$ on Ne, Kr and Xe targets.
Summary

Multidimensional kinematic dependencies of $R_A^h$ for $\pi^+$, $\pi^-$, $K^+$, $K^-$, $p$ and $\bar{p}$ on Ne, Kr and Xe targets.

$R_A^h$ is similar for $\pi^+$ and $\pi^-$.
Summary

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- $R_A^h$ is similar for $\pi^+$ and $\pi^-$.

- Negatively charged kaons behave similarly to pions.
Multidimensional kinematic dependencies of $R^h_A$ for $\pi^+$, $\pi^-$, $K^+$, $K^-$, $p$ and $\bar{p}$ on Ne, Kr and Xe targets.

$R^h_A$ is similar for $\pi^+$ and $\pi^-$.

Negatively charged kaons behave similarly to pions.

$\nu$ dependence of $R^K_A$ for positively charged kaons is different from $R^{\pi^+}_A$, $R^{\pi^-}_A$ and $R^{K^-}_A$ in different $z$ slices.
Summary

- Multidimensional kinematic dependencies of $R_A^h$ for $\pi^+$, $\pi^-$, $K^+$, $K^-$, $p$ and $\bar{p}$ on Ne, Kr and Xe targets.

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- Negatively charged kaons behave similarly to pions.

- $\nu$ dependence of $R_A^{K^+}$ for positively charged kaons is different from $R_A^{\pi^+}$, $R_A^{\pi^-}$ and $R_A^{K^-}$ in different $z$ slices.

- $R_A^p$ for protons is very different compared with the other hadrons.