Status of the HERA-B Analysis
58th PRC Open session, May 26, 2005

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• Data samples
• Physics topics
• Selected topics:
  • $J/\psi$ cross section
  • $\psi(2S)$ production
  • A-dependence of $J/\psi$ production
  • $\chi_c$ production
• Summary
Data samples


- 150 M di-lepton trigger events
- 210 M minimum bias events
- 35 M hard photon trigger events
- 60 M “glueball” trigger events

⇒ 300 000 J/ψ: e⁺e⁻ + μ⁺μ⁻

Different target wires, mainly C, Ti, W

proton-nucleon CM energy: √s = 41.6 GeV
Analysis Topics

- $bb$ production cross section
- $\Upsilon$ production cross section
- Production of $\phi$ and K* mesons
- $J/\psi$ production cross section
- $D^+/D^0$ production ratio
- Production ratio $\psi(2S) / J/\psi$
- $J/\psi$ differential distributions
- Charmonium production A-dependence
- $\chi_c$ production, A dependence
- high-$p_t$ photons
- $\Lambda$ polarization
- $V^0$ differential and total cross section
- Hyperon production
- Deuteron/anti-deuteron production
- Bose-Einstein correlations
- Jet production

Published (2002/03 only)

Draft stage

Analysis note in preparation

Preliminary results available

Needs more work

Needs $J/\psi$ ref. cross section

Analysis note in preparation

Preliminary results available

Needs more work
**J/ψ Cross Section from Min. Bias Data**

relatively low statistics, but no trigger uncertainty

\[
\sigma^A_{J/\psi} = \frac{N_{J/\psi}}{\varepsilon_{J/\psi} \cdot BR(J/\psi \rightarrow \mu^+\mu^-) \cdot L^A}
\]

A lot of work for lumi studies; publication in preparation

\[\sigma_{J/\psi} = (605 \pm 67 \pm 43) \text{ nb/nucleon}\] (prelim.)

HERA-B \(\sim 1.7 \times\) higher than E771 / 789 extrapolated to this energy region (!?)

Important for cross section normalization of di-lepton triggered data
**Study of J/ψ Cross Section Parametrisations**

Fit of cross section data currently studied with F. Maltoni using NRQCD model

Fits rather stable w.r.t. changes in model input (PDF’s, ME’s, ..)

**Biggest problem:** inconsistent exp. data

Our new reference cross section : $\sigma_{J/\psi} = (514 \pm 50) \text{ nb/nucleon}$

(previously from E771 and E789: $(357 \pm 8 \pm 27) \text{ nb/nucleon}$)

$\times 1.44$
Results for Beauty Cross Sections
have to be scaled by new \(J/\psi\) reference cross section

\[
\frac{\sigma_{b\bar{b}}}{\sigma_{J/\psi}} = 0.033 \pm 0.005 \pm 0.004
\]

(prelim.)

Plots still normalized to \(\sigma_{J/\psi}\) from E771 and E789 will change by \(\sim \times 1.4\)

\[
B(l^+l^-) \cdot \frac{d\sigma_{\Upsilon}}{dy} \bigg|_{y=0} = (10.0 \pm 2.1) \cdot 10^{-6}
\]

(prelim.)
Study of Charmonium Suppression
as input for QGP searches in heavy ion collisions

Kinematical distributions \( (x_F, p_T, \text{polarization}) \) derived from:
- NRQCD for nucleon-nucleon reactions
- models for nuclear effects in pA reactions

Initial state effects:
- Shadowing
- Parton energy loss
- Intrinsic charm

\( x_F \) measures the formation length of the ccg state:

\[ L_f \approx 0.3 \, \text{fm} \cdot \gamma_\psi \]

\begin{tabular}{|c|c|}
\hline
\( x_F \) & \( L_f \, \text{[fm]} \) \\
\hline
0.2 & 20 \\
0.0 & 7 \\
-0.2 & 2 \\
\hline
\end{tabular}

Nuclear radius:
\( C \approx 3 \, \text{fm} \)
\( W \approx 8 \, \text{fm} \)

Formation state effects:
- Nuclear Absorption
- Comover Absorption
- Energy loss/multiple soft scattering

\( \sigma_{cc} = \sigma_0 \cdot A^\alpha \)
\( \alpha \neq 1 \implies \text{“suppression”} \)

\( x_F > 0 \): ccg forms a bound state outside the nucleus
\( x_F < 0 \): ccg forms a bound state inside the nucleus
A dependence of $J/\psi$ Production: $\alpha(x_F), \alpha(p_T)$

$$\sigma_{pA} = \sigma_{pN} \cdot A^\alpha; \quad \sigma = N/(\varepsilon \cdot L)$$

$$\alpha \equiv \frac{1}{\ln(A_w/A_c)} \cdot \ln \left( \frac{N_W}{N_C} \frac{L_W}{L_C} \frac{\varepsilon_C}{\varepsilon_W} \right)$$

Dominant syst.: “wire sharing”; ~2% decrease to ~1% (?)

2-wire runs (C, W), $\mu^+\mu^-$ data:

HERA-B now absolutely normalized

Extending the range of measurements to $x_F = -0.35$

• Systematic studies ongoing
• Electron channel being finalized
$\psi(2S)$ Production: $\sigma(\psi(2S)) / \sigma(J/\psi)$

$\mu^+\mu^-$ data:

$B(\psi(2S) \rightarrow l^+l^-) \cdot \sigma_{\psi(2S)} = \frac{N_{\psi(2S)}}{N_{J/\psi}} \cdot \frac{\varepsilon_{J/\psi}}{\varepsilon_{\psi(2S)}}$
\( x_F \) distributions

- C: \( J/\psi(\mu\mu) \), \( n = 5.7 \pm 0.1 \)
- W: \( J/\psi(\mu\mu) \), \( n = 6.2 \pm 0.2 \)
- \( \psi'(\mu\mu) \), \( n = 6.9 \pm 1.3 \)
- \( \psi'(\mu\mu) \), \( n = 5.8 \pm 1.7 \)

**Ratio:**
- In agreement with NRQCD
- Almost constant vs \( x_F \)

Ratio fitted by \( a + b \cdot |x_F| \)
Dependence on $p_T$

**Power-law is suitable for the fitting**

$$\frac{d\sigma}{dp_T^2} = A \left[ 1 + \left( \frac{p_T}{p_0} \right)^2 \right]^{-n}$$

$J/\psi$

- $p_0 = 3.49 \pm 0.06$
- $n = 7.76 \pm 0.19$

$\psi'$(2S)

- $p_0 = 2.90 \pm 0.45$
- $n = 5.33 \pm 1.14$

$\psi$ appears to have a wider $p_T$ distribution

⇒ nuclear effects different for radial excitation?
A- and s-Dependence of $\sigma(\psi'(2S)) / \sigma(J/\psi)$

Agrees with E866 value:
$\alpha(\psi(2S)) - \alpha(J/\psi) = -0.026 \pm 0.005$

Results from $\mu^+\mu^-$ data:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>(1.667 +/- 0.069) %</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>(1.596 +/- 0.114) %</td>
<td></td>
</tr>
<tr>
<td>Ti</td>
<td>(1.979 +/- 0.293) %</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>(1.659 +/- 0.058) %</td>
<td></td>
</tr>
</tbody>
</table>

Similar results from $e^+e^-$ data
The production ratio of $\chi_c$ to $J/\psi$ particles is observed in radiative decay as $\chi_c \rightarrow J/\psi \gamma \rightarrow l^+l^-\gamma$.

The decay rate is given by:

$$R_{\chi_c} = \frac{\sum_{i=1}^{2} \sigma_{\chi_i} \cdot BR(\chi_i \rightarrow J/\psi\gamma)}{\sigma_{J/\psi}} = \frac{N_{\chi_c}}{N_{J/\psi}} \cdot \frac{\epsilon_{J/\psi}}{\epsilon_{\chi_c}}$$

where $\sigma_{\chi_i}$ is the cross section for the decay $\chi_i \rightarrow J/\psi\gamma$, $BR$ is the branching ratio, $N_{\chi_c}$ and $N_{J/\psi}$ are the counts of $\chi_c$ and $J/\psi$ respectively, and $\epsilon_{\chi_c}$ and $\epsilon_{J/\psi}$ are the efficiencies of the detectors.

The mass difference $\Delta m = m(l^+\gamma) - m(l^+l^-)$ is calculated and compared for different targets such as carbon and tungsten.

May 26, 2005  H.Kolanoski - Status report HERA-B - PRC59  13
$\chi_c$ production: results

Systematic studies ongoing

- background determination
- $\gamma$ efficiency
- electron channel (similar results)
- dependence on polarization

$R(\chi_c) = 0.21 \pm 0.05$ (prel.) from only 10% of 2002/03 data

The efficiencies for all possible polarization states have been calculated and differ by less than 10%.
Conclusion

- HERA-B has a considerable list of interesting topics under study which should be published.

- The number of active collaboration members is decreasing as expected but the main analysis topics should be reasonably covered.

- The goal is to produce draft publications by end of this year for most of the topics ($O(10)$, for sure 4 publications this summer)