HERA-B

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Outline

- Latest news from commissioning:
  - Status of detector components.
  - Status of First Level Trigger.
- Analysis of 2000 data.
- Physics program for 2002.
- Summary.
HERA-B experiment.

**TRACKING**
- Vertex detector (VDS).
- Inner tracker (ITR).
- Outer tracker (OTR).

**PID**
- Cerenkov detector (RICH).
- Electromagnetic Calorimeter (ECAL).
- MUON detector.

**Target wires with**
- C, Al, Ti, Pd & W

**High p_t lepton**
- (µ & e) track trigger.

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### Status of detector components.

- **HERA-B detector** operational in 2000 run.
- Improvements during 2001 shutdown:
  - Noise reduction (improved grounding):
    - increased efficiency.
    - improved resolutions.
  - Dead detector modules repaired.

### Status & actions during 2001 shutdown

<table>
<thead>
<tr>
<th>Component</th>
<th>Status &amp; Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITR</td>
<td>Dead chambers repaired. Noise reduction (improved grounding). Installation of missing chambers.</td>
</tr>
<tr>
<td>OTR</td>
<td>Dead HV groups repaired. Noise reduction → Higher efficiency due to lower threshold cut.</td>
</tr>
<tr>
<td>RICH</td>
<td>Fully operational in 2000.</td>
</tr>
<tr>
<td>ECAL</td>
<td>Reduction of common noise (grounding improved) → better E resolution.</td>
</tr>
<tr>
<td>MUON</td>
<td>Dead channels repaired. Noise reduction → lower threshold, higher efficiency.</td>
</tr>
</tbody>
</table>
Status of First Level Trigger

The First Level trigger was not fully commissioned in 2000.
Low efficiency from detector and trigger performances.

Analysis of 2000 data finished:
- single track muon efficiency ~ 20%. (expected ~50% in 2002.)
- single track electron efficiency ~ 50%. (expected ~80% in 2002.)

Vector test successful: download MC event into the hardware for bit wise comparison between the hardware and simulation outputs. Independent confirmation of previous results.

Many improvements in hardware, algorithm, & simulation, ... implemented in 2001

Large improvement in performance expected for 2002.
Analysis of 2000 data.

- **Minimum Bias:** (No trigger)
  - $K_s^0$ & $\Lambda$ production cross section.
  - Inclusive particle productions.
  - $\Lambda$ polarisation.

- **$e^+ e^-$ pair** (ECAL $E_t$ trigger seed and tracking)

- **$\mu^+ \mu^-$ pair** (MUON track seed and tracking)
  - $\sigma_{bb}$ production cross section.
  - $J/\psi$ production cross section.
  - $x_f$ and $p_t$ inclusive $J/\psi$ distributions.
  - Fraction of $J/\psi$ from $\chi_c$.
  - $J/\psi$ suppression in different target materials.

- **Single lepton** (electron and muon trigger).
  - Open charm production cross-section.

- **Different trigger conditions.**

2000 ANALYSIS TOPICS
pA → bb cross section (σ_{bb})

Principle of the measurement

Look at the production chain: pA → b b → B → J/ψ X via detached J/ψ vertices.

Comparison of lepton impact parameter between Data and MC for prompt J/ψ.

and normalized to the inclusive J/ψ (prompt) cross section.
pA $\rightarrow$ bb cross section ($\sigma_{bb}$)

Event by event J/$\psi$ vtx. to primary vertex.

- **Background evaluation**
  - $\Delta z < -0.5$ cm

- **Upstream**
- **Background evaluation**
  - $\Delta z < -0.5$ cm

- **Downstream**
  - $\Delta z > 0.5$ cm

**Excess of J/$\psi$ downstream** → indication of B decays.

**Alternative method using the average target wire position** → reduced primary error

- **Upstream**
- **Background evaluation**
  - $\Delta z < -0.5$ cm

- **Downstream**
  - $\Delta z > 0.5$ cm

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pA → bb cross section ($\sigma_{bb}$)

$J/\Psi \rightarrow e^+ e^-$  
Method 1  $\sigma_{bb} = 60\pm19$ nb  
Method 2  $\sigma_{bb} = 55\pm22$ nb

$J/\Psi \rightarrow \mu^+ \mu^-$  
Similar analysis gives upper limit:  
$\sigma_{bb} < 98$ nb @ 90% C.L.

Published values (800 GeV):

E789:  $5.7 \pm 1.5 \pm 1.3$ nb  
E771:  $43^{+27}_{-17} \pm 7$ nb

HERA-B sees B mesons with low statistics.  
HERA-B will be able to measure $\sigma_{bb}$ in 2002:  
- expected error limited by $J/\psi$ direct cross section (20%).  
- possibility of measuring cross section vs. material nuclear mass (A)(NEW!).

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Absolute $J/\psi$ cross section

HERA-B is able to measure an absolute cross-section comparable to previous experiments.

Trigger efficiency & Luminosity determination (from reference minimum bias) can be controlled.
$J/\Psi$ $P_t$ and $x_f$ spectra.

$$\frac{dN}{dx_f} = A(1 - |x_f|)^c$$

Phenomenological dependency.

$J/\Psi \rightarrow \mu^+ \mu^-$

Samples for C and Ti.

$P_t$

$$\frac{dN}{dp_t^2} = A(1 + (p_t/p_0)^2)^{-6}$$

Phenomenological dependency.

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J/ψ $P_t$ and $x_f$ spectra.

HERA-B will be able to measure the $p_t$ and $x_f$ spectra in 2002 with comparable precision to the existing data.

It will extend for the first time data to the negative Feynman $x$.

Errors will be limited by the modelling of trigger and detector acceptance.
HERA-B spectrometer allows to look at more than the dileptons.  
HERA-B will be able to reconstruct a large sample of $\chi_c$ in 2002:  
- first measurement of suppression in nuclear matter.  
- study of production ratios between $J/\psi$, $\chi_c$ and $\Psi^\ast$.  

$\chi_c \rightarrow J/\psi \gamma$ (sum of $ee\gamma$ and $\mu\mu\gamma$)
Physics program for 2002

- Next year HERA-B will run a dilepton trigger (μ & e).
- Expected number of events:

<table>
<thead>
<tr>
<th>Event Type</th>
<th>2002</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>J/ψ (μ channel)</td>
<td>~2 \times 10^6</td>
<td>~4 \times 10^3</td>
</tr>
<tr>
<td>χ_c → J/ψ γ</td>
<td>~2 \times 10^5</td>
<td>~1 \times 10^2</td>
</tr>
<tr>
<td>Ψ'</td>
<td>~3 \times 10^4</td>
<td>~2 \times 10^1</td>
</tr>
</tbody>
</table>

Distributed over different target materials: C, Ti and W. (possibly Al & Pd)

With a large acceptance into the negative Feynman x [-0.4,0.3].

Acceptance from MC

![Graph showing acceptance from MC](image-url)
Physics program for 2002

Study of charmonium suppression

$X_f$ measures the distance the ccg state travels before charmonium formation.

<table>
<thead>
<tr>
<th>$X_f$</th>
<th>Dist.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>15fm</td>
</tr>
<tr>
<td>0.0</td>
<td>5fm</td>
</tr>
<tr>
<td>-0.2</td>
<td>1.5fm</td>
</tr>
</tbody>
</table>

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

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

$\Delta t \approx 0.5 \text{ fm} \times \gamma$ (dependent on state)

Nuclear radius:
- $C \sim 3$ fm.
- $W \sim 8$ fm.

$e^+ / \mu^+$
$e^- / \mu^-$

Positive $x_f \rightarrow$ ccg abandons the nucleus before it forms a bound state.

Negative $x_f \rightarrow$ charmonium is formed before leaving the nucleus.

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Physics program for 2002

The charmonium cross section versus nuclear mass:

\[ \sigma = \sigma_0 A^{\alpha(x_f)} \]

\( \alpha(x_f) \) measures the charmonium suppression in nuclear matter. (\( \alpha=1 \rightarrow \) no suppression)

- E-866 has measured the suppression in nuclear matter for positive \( x_f \).
- HERA-B will measure the charmonium suppression in the negative \( x_f \) region.
- HERA-B explores the charmonium-N cross-section for \( J/\psi \) and \( \Psi' \).
- HERA-B will measure the suppression of \( \chi_c \) in nuclear matter for the first time.

Expected precision similar to existing data in the common \( x_f \) range.
Summary

• **First analysis of 2000 data** shows the capabilities of the detector to provide interesting physics.

• **Improved performance** of the HERA-B spectrometer for 2002.

• HERA-B will cover an unexplored area of proton-nucleus collisions with $x_f<0$.

• **Large statistics of charmonium states** expected for year 2002. (factor of ~60 increase of production rate)
Summary (physics program)

Base line physics program for 2002

- Charmonium suppression.
- bb production cross section.

Possible extensions

- Drell-Yan (e.g. angular distribution).
- Direct photon production at high $p_t$.
- Limit on $\text{Br}(D^0 \rightarrow \mu+\mu^-)$.
- Open charm production.
- Minimum bias (e.g. Inclusive particle production).
Summary

HERA-B is anxiously waiting for the new data to come.