\( \Upsilon(1S) \) Production at DØ

Daniela Bauer

Indiana University

2004 Phenomenology Symposium, Madison, Wisconsin
April 26-28, 2004
Why measure $\Upsilon(1S)$ at DØ?

• Measuring the $\Upsilon(1S)$ production cross-section provides an ideal testing ground for our understanding of the production mechanisms of heavy quarks.

• The $\Upsilon(1S)$ cross-section had been measured at the Tevatron (Run I measurement by CDF) up to a rapidity of 0.4. DØ aims to measure this cross-section up to a rapidity of 1.8.

• The color octet model predicts an increase in transverse polarization with increasing $p_t$. Measurements so far have been inconclusive.
Where do the $\Upsilon(1S)$ come from?

- All Bottomonium States are produced directly.
- ~50% of $\Upsilon(1S)$ are produced directly.
- The rest are the result of higher mass states decaying.
The upgraded DØ Detector

- Forward Mini-drift chambers
- Central Scintillator
- Forward Scintillator
- Shielding
- New Solenoid, Tracking System Si, SciFi, Preshowers
- New Electronics, Trig, DAQ
The DØ trigger system

Detector

L1 Trigger

6kHz

L2 Trigger

1kHz

L3 Trigger

50Hz 250kB/ev

SVXII chip Digitization Rate

Reconstruction Farm

7.5MHz (132ns/decision)

Calorimeter Digitization Rate
Data sample used in $\gamma$ analysis

$\sim 159 \text{ pb}^{-1}$
The Analysis

Goal:
Measuring the $\gamma(1S)$ cross-section in the channel $\gamma(1S) \rightarrow \mu^+\mu^-$ as a function of $p_t$ in three rapidity ranges:
$0 < |y^\gamma| < 0.6$, $0.6 < |y^\gamma| < 1.2$ and $1.2 < |y^\gamma| < 1.8$

Sample selection:

- Opposite sign muons
- Muon have hits in all three layers of the muon system
- Muons are matched to a track in the central tracking system
- $p_t(\mu) > 3$ GeV and $|\eta(\mu)| < 2.2$
- At least one isolated muon
- Track from central tracking system must have at least one hit in the Silicon Tracker
The signal

**Signal:** 3 Gaussians: $\Upsilon(1S), \Upsilon(2S), \Upsilon(3S)$

**Background:** 3rd order polynomial

$$m(\Upsilon(2/3S)) = m(\Upsilon(1S)) + \Delta m_{\text{PDG}}(\Upsilon(2/3S)-\Upsilon(1S))$$

$$\sigma(\Upsilon(2/3S)) = \sigma(\Upsilon(1S)) + m\Upsilon(2/3S)/m(\Upsilon(1S)) \times \sigma(\Upsilon(1S))$$

$\rightarrow$ 5 free parameters in signal fit: $m(\Upsilon(1S)), \sigma(\Upsilon(1S)), c(\Upsilon(1S)), c(\Upsilon(2S)), c(\Upsilon(3S))$

Fitting a single Gaussian recovers $\sim 95\%$ of the signal.

All plots: $3 \, \text{GeV} < p_t(\Upsilon) < 4 \, \text{GeV}$

PDG: $m(\Upsilon(1S)) = 9.46 \, \text{GeV}$

$m(\Upsilon) = 9.423 \pm 0.008 \, \text{GeV}$

$m(\Upsilon) = 9.415 \pm 0.009 \, \text{GeV}$

$m(\Upsilon) = 9.403 \pm 0.013 \, \text{GeV}$
Width from fit for $\Upsilon(1S)$ with $|y^\Upsilon| < 0.6$

- Data
- MC

$\sim 43000 \ \Upsilon(1S)$ candidates
\[d^2\sigma(\Upsilon(1S)) = \frac{N(\Upsilon)}{dp_t \times dy} = \frac{L \times \Delta p_t \times \Delta y \times \varepsilon_{\text{kinem}} \times \varepsilon_{\text{acc}} \times \varepsilon_{\text{trig}} \times \varepsilon_{\text{muid}} \times \varepsilon_{\text{trk}} \times \varepsilon_{\text{fit}} \times \varepsilon_{\text{iso-smt}}}{\text{luminosity } L}\]

Rapidity \( y = \frac{1}{2} \ln \left( \frac{(E+p_z)}{(E-p_z)} \right) \)

**\( \varepsilon_{\text{kinem}} \)**

Muons that will not reach the muon system are removed after the generator stage \((p_t(\mu) > 1.8 \text{ GeV} \text{ and } |y(\mu)| < 2.2)\).

Determined from Monte Carlo without trigger condition.

**\( \varepsilon_{\text{acc}} \)**

Fraction of \( \Upsilon \) that pass the kinematic cuts and are reconstructed.

Determined from Monte Carlo.

**\( \varepsilon_{\text{trig}} \)**

Trigger efficiency (Level1 and Level2).

From data and Monte Carlo.
Correction to account for differences between data and MC in the local (i.e. muon system only) muon reconstruction.

Correction to account for differences between data and MC in the efficiency to match local tracks in the muon system to tracks in the central tracking system. This includes the tracking efficiency for muons in the central tracking system.

Correction to account for differences between data and MC regarding track isolation and Silicon hit requirement.

To account for losses due to a single Gaussian fit to model the $\Upsilon(1S)$ mass resolution.
Efficiencies from Monte Carlo

\[ 0.6 < |y(\gamma)| < 1.2 \]

- **MC**
- **Data**

*9.0 GeV < m(\mu\mu) < 9.8 GeV

| \( |y(\gamma)| \) | \( \varepsilon_{\text{kinem}} \) | \( \varepsilon_{\text{acc}} \) |
|----------------|----------------|----------------|
| 0.0 – 0.6      | 0.8 – 0.9      | 0.25 – 0.4     |
| 0.6 – 1.2      | 0.8 – 0.9      | 0.25 – 0.4     |
| 1.2 – 1.8      | 0.7 – 0.75     | 0.25 – 0.4     |
Level 1: di-muon trigger, scintillator only
Level 2: one medium muon (early runs)
    two muons, at least one medium, separated in eta and phi (later runs)
Both triggers at Level 2 are $\sim 97\%$ efficient wrt Level 1 condition.

**Trigger efficiency for fully reconstructed di-muon events:**
central region: 65 %
forward region: 80 %

![Graph showing trigger efficiency vs. pT(\gamma) for |y(\gamma)| < 0.6]
Method:
Reconstruct $J/\psi$ using *global* (i.e. muons matched to a track in the central tracking system) and *local* (i.e. muons that are only reconstructed in the muon system and not matched to a central track) muons.

* i.e. the local momentum of the test muon is used, whether is was matched or not.
Corrections: Tracking Efficiency

Efficiency = \frac{N_{J/\psi}^{\text{global & global}}}{N_{J/\psi}^{\text{global & local}} + N_{J/\psi}^{\text{global & global}}}

\begin{align*}
\text{Corrections: Tracking Efficiency} \\
\text{Efficiency} & = \frac{N_{J/\psi}^{\text{global & global}}}{N_{J/\psi}^{\text{global & local}} + N_{J/\psi}^{\text{global & global}}} \\
\end{align*}
Corrections: Local muon reconstruction efficiency

- reconstruct $J/\psi$: muon & muon and muon & track
- $\epsilon = \text{muon} \& \text{muon} / \text{muon} \& \text{track}$
From data – Monte Carlo predicts isolation requirement to be 100% efficient.
Normalized Cross-section for $\Upsilon(1S)$

$\frac{d^2\sigma}{dp_t dy}/\sigma_{\text{tot}}$

- DZero Run2 Preliminary Results
- Statistical errors only

$\Upsilon(1S) p_t$ in GeV
Normalized Cross-section

\[ \frac{d^2 \sigma}{dp_t dy} / \sigma_{\text{TOT}} \]

- preliminary
- DZERO Run2 Results (|y|<1.8)
- CDF Run1 Results (|y|<0.4)

Y(1S) p_t in GeV
Systematic Errors – very preliminary

<table>
<thead>
<tr>
<th>Source</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>local muon ID</td>
<td>6-10 %</td>
</tr>
<tr>
<td>trigger</td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>MC modeling of kinematics</td>
<td>2-4 %</td>
</tr>
<tr>
<td>fitting procedure</td>
<td>3-5 %</td>
</tr>
<tr>
<td>central track matching</td>
<td>2 %</td>
</tr>
<tr>
<td>primary vertex requirement</td>
<td>1 %</td>
</tr>
<tr>
<td>momentum resolution</td>
<td>1 %</td>
</tr>
<tr>
<td>isolation and Silicon hit requirement</td>
<td>1-3 %</td>
</tr>
<tr>
<td><strong>Luminosity</strong></td>
<td><strong>6.5 %</strong></td>
</tr>
<tr>
<td><strong>Polarization</strong></td>
<td><strong>~20 %</strong></td>
</tr>
</tbody>
</table>

**Total (not including polarization): 14-16 %**
Conclusions

• $\Upsilon(1S)$ Cross-section measurement extended to $y = 1.8$

• Normalized cross-sections show very little dependence on rapidity.

• Normalized cross-section is in good agreement with published results.

• Absolute cross-section measurement is nearly ready.

• Next step: Polarization measurement.