B Physics at the DØ Experiment

Harald Fox, Northwestern University,
for the DØ Collaboration

Content:
Improved Tracking Performance
B Cross section
B Lifetimes
B Flavor Tagging Performance
Since low $P_T$ tracks are very important for B physics, tracking algorithm has been improved.

Improved performance for low $P_T$ tracks and tracks with large impact parameter ($K_s, \Lambda$).
Results with new Tracking

$K_S \rightarrow \pi \pi$

$\Lambda \rightarrow p\pi$

$\Omega \rightarrow \Lambda K$

$\Xi \rightarrow \Lambda \pi$
According to CDF Run I measurement:
fraction of $J/\psi$ from $\chi_c$:

$(27.4 \pm 1.6 \pm 5.2)$ %

$\varepsilon_\gamma \approx 0.4\%$ with $p_{T\gamma} > 1$ GeV

Expect ~ 80 events

Fit with fixed $M_{\chi_{c1}} - M_{\chi_{c2}} = 46$ MeV
but float relative contributions

Cuts:
1. Track $p_T > 2.0$ GeV on tracks from $J/\psi$
2. $p_{T\gamma} > 1.0$ GeV
B Jet Cross Section

Measured in Run I: 2-3 times higher in the central region than predictions

Strategy:
Measure μ+jet cross-section
Extract b-content using $P_T^{\text{Rel}}$

Data selection & kinematic cuts:
- $p_T^\mu > 6$ GeV/c, $|\eta^\mu| < 0.8$
  (Muon $P_T$ measured in muon system only)
- 0.5 cone jet
- $|\eta^{\text{jet}}| < 0.6$
- $E_T^{\text{corr}} > 20$ GeV
- $\delta R(\text{jet}, \mu) < 0.7$

Data:
02/28/02-05/10/02: (3.4 pb$^{-1}$)
Obtain B jet cross section from $\mu +$jets cross section:
Fit data to $P_T^{\text{rel}}$ distribution of b-jets and background in bins of $E_T$ (cannot distinguish $c \rightarrow \mu X$ and decays in flight so only fit b, non-b).

Example: $P_T^{\text{rel}}$ for jets with $20 \text{ GeV} < E_T < 25 \text{ GeV}$

**DØ Run 2 Preliminary**

B fraction as a function of Jet $E_T$: **DØ Run 2 Preliminary**
Deconvolution of jet energy resolution.

Jet Energy Scale is the dominant error.

Uncertainty:
- b quark mass
- Renormalization / factorization scale
- pdf’s
- Fragmentation function (NLO + Pythia)

Consistent with Run I result
Data Sample

For now focusing on $J/\psi \rightarrow \mu^+\mu^-$ sample

- Useful for calibration
- Easy trigger and provides lots of B’s

\[
\begin{align*}
\mu^+\mu^- \text{ Invariant Mass} & \\
\text{DØ Run 2 Preliminary} & \\
J/\psi \text{ Signal} = 75013 \text{ events} & \\
\text{Mean} = 3.0719 \pm 0.0003 \text{ GeV/c}^2 & \\
\text{Sigma} = 0.0713 \pm 0.0003 & \\
\psi' \text{ Signal} = 1746 \text{ events} & \\
\text{Mean} = 3.669 \pm 0.004 \text{ GeV/c}^2 & \\
\text{Sigma} = 0.057 \pm 0.004 \text{ GeV/c}^2 & \\
\end{align*}
\]

L\sim 40 \text{ pb}^{-1}

75,000 \times 0.17

\sim 13,000 \text{ b’s}
Inclusive B Lifetime

\[ J/\psi \text{ Sources} \begin{cases} \text{(cc) states (prompt)} \\ B \rightarrow J/\psi \ X \end{cases} \]

\[ \text{Difference} \begin{cases} \text{Prompt} \sim PV \\ J/\psi(B) \sim SV \end{cases} \]

\[ F(P_T) = A e^{B P_T} + C \]

\[ \lambda_B \text{ through } \lambda_{\psi} : \quad \lambda_B = L_{xy} \frac{M_{\psi}}{P_T \left< F(P_T) \right>} \]

Correction factor

B\rightarrow\psi \text{ from MC}
Inclusive B Lifetime

Fit the $\lambda_B$ distribution in sideband windows to extract the background shape ($g+g+e+c$).

Fit the data in the $J/\psi$ signal window to background + prompt production ($g+g$) + exponential with fixed resolution.

$<\tau> = 1.561 \pm 0.024 \text{ (stat) } \pm 0.074 \text{ (sys) ps}$

$<\tau> = 1.564 \pm 0.014 \text{ ps (PDG)}$

B fraction: $17.3 \pm 0.5 \%$

$\lambda_B = 468 \pm 7\text{(stat)} \pm 22\text{(syst) } \mu\text{m}$

Dominant Uncertainty:

<table>
<thead>
<tr>
<th>Correction factor</th>
<th>16 $\mu$m</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.053 ps</td>
<td></td>
</tr>
<tr>
<td>Fitting Bias (MC)</td>
<td>13 $\mu$m</td>
</tr>
<tr>
<td>0.043 ps</td>
<td></td>
</tr>
</tbody>
</table>
Charged B Lifetime

Fully reconstructed B so no need for a correction factor:

\[ \lambda = \frac{L_{xy} M(B)}{P_T(B)} \]

The background shape is extracted from the high mass sideband. The data is fitted to background + prompt production \((g+g)\) + exponential with fixed resolution + 12% residual B contamination.

\(<\tau> = 1.76 \pm 0.24\) (stat) ps

\(<\tau> = 1.674 \pm 0.018\) ps (PDG)
Flavor Tagging

Use charged B sample to determine the flavor tagging performance.

**Soft Muon Tag:**
- Muon $\Delta R > 2.0$ from $B^+$
- Muon $p_T > 1.9$ GeV/c
- Charge of $\mu$ with highest $p_T \Rightarrow B$-tag

**Jet Charge Tag:**
- Choose tracks opposite of the reconstructed $B^+$ close (2cm) to the primary vertex
- Only events with $|Q| > 0.2$ are used as tags

$$Q = \frac{\sum p_{T,i}^* q_i}{\sum p_{T,i}}$$
Significance of a mixing measurement: proportional to $\varepsilon D^2$

$\varepsilon$: Efficiency = \[ \frac{N_{\text{correct}} + N_{\text{wrong}}}{N_{\text{correct}} + N_{\text{wrong}} + N_{\text{notag}}} \]

$D$: Dilution = \[ \frac{N_{\text{correct}} - N_{\text{wrong}}}{N_{\text{correct}} + N_{\text{wrong}}} \]

### Jet Charge Tag
- $N_{\text{right}} = 66$
- $N_{\text{wrong}} = 48$
- $\varepsilon = 55.0 \pm 4.1\%$
- $D = 21.1 \pm 10.6\%$
- $\varepsilon D^2 = 2.4 \pm 1.7\%$

### Soft Muon Tag
- $N_{\text{right}} = 13$
- $N_{\text{wrong}} = 5$
- $\varepsilon = 8.2 \pm 2.2\%$
- $D = 63.9 \pm 30.1\%$
- $\varepsilon D^2 = 3.3 \pm 1.8\%$

raw numbers

corrected for background
Towards $\sin(2\beta)$

Combine $J/\Psi$ with $K_S$, $\Phi$ or $\Lambda$ and require decay length significance $> 3.0$

$B_d \rightarrow J/\Psi K^*$

$B_d \rightarrow J/\Psi K_S$

$B_S \rightarrow J/\Psi \Phi$

$\Lambda_b \rightarrow J/\Psi \Lambda$

Northwestern University

Harald Fox, Photon 2003
Conclusion

DO has made significant progress in tracking and understanding of the data.

We have good results on basic quantities such as masses, lifetimes, cross sections.

We start to understand flavor tagging.

More interesting things to come:

- $B_s$ mixing
- $CP$ violation in $B_d$
- $CP$ violation in $B_s$
Charged B

$B^{+} \rightarrow J/\psi K^{+}$

Cuts ($J/\psi$):
1. Muons with opp. charge
2. $p_T(\mu) > 2.0$ GeV
3. SMT hits $\geq 1$
4. $\chi^2$ on $J/\psi$ vertex $< 10$
5. $2.8 < m(J/\psi) < 3.3$

Cuts (Charged B):
1. $\chi^2$ for $K < 10$
2. Total $\chi^2 < 20$
3. Kaon hits $\geq 3$
4. $p_T(K) > 2.0$ GeV
5. Collinearity $> 0.9$
6. $B$ decay length $> 0.3$ mm