Status of DØ for $B$ Physics

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Why study $B$ physics at the Tevatron?

- **Large rate:**
  \[
  \sigma(p\bar{p} \rightarrow b\bar{b}) \approx 150 \mu b \text{ at 2 TeV} \\
  \sigma(e^+e^- \rightarrow b\bar{b}) \approx 7 \text{ nb at } Z^0 \\
  \sigma(e^+e^- \rightarrow B\bar{B}) \approx 1 \text{ nb at } \Upsilon(4S)
  \]

- **All species, including $B_s$, $B_c$, $\Lambda_b$ produced**
**DØ Run 2 B Physics Program**

- QCD tests
- cross sections
- correlations
- charmonium polarization

- CP Violation
- CKM angles
  - \( \sin(2\beta) \), \( B \rightarrow J/\psi K_s \)
  - \( \alpha, \gamma \), \( B \rightarrow \pi^+\pi^- \), \( B_s \rightarrow K^+K^- \)

- Non SM CP Violation
  - \( B_s \rightarrow J/\psi \phi \)

- \( B_s \) Mixing
  - \( B_s \rightarrow D_s n\pi \)
  - \( B_s \rightarrow D_s \ell \nu \)

- Spectroscopy & Lifetimes
  - \( B^0, B^+, B_s, B_c, \Lambda_b, \) double heavy baryons

- Rare decays
  - \( B \rightarrow \ell^+\ell^- X_s \)
  - \( B \rightarrow \ell^+\ell^- \)
- Retain excellent calorimetry, increase speed of readout
- Upgraded muon system for better muon identification and triggering (tagging $b$'s)

- Forward Mini-drift chambers
- Central Scintillator
- Forward Scintillator
- Shielding
- New Solenoid, Tracking System Si, SciFi, Preshowers
- Zooming in...
New tracker, preshower detectors

- Silicon Microvertex Tracker: 6 barrels (4 layers), single and double-sided interspersed double-sided disks
  800k channels $\rightarrow$ impact parameter resolution

- Central Fiber Tracker: 8 barrels of scintillating fiber doublets (half stereo), visible light photon detector readout, fast pick-off for track trigger
  77k channels $\rightarrow$ momentum resolution

- Solenoid: 2 T superconducting

- Central, Forward Preshower Detectors: scintillator strips, stereo, WLS fiber readout
  $\rightarrow$ non-isolated electron id for $b$ decays
What's different?

- Signal/background: $\sigma^\text{tot}_{\text{had}} \sim 75 \text{ mb} \quad \sigma_{bb} \sim 0.1 \text{ mb}$
  \[ \Rightarrow \text{triggering challenge: pipelined Level-3 trigger} \]
  \[ \Rightarrow \text{trigger on displaced tracks at Level 2 (STT)} \]
  \[ \Rightarrow \text{trigger on tracks at Level 1 (CTT)} \]

- Overlapping minimum bias events (e.g. <2.0> Run 2a)
• Good Momentum resolution:
  \[ \frac{d\rho_T}{\rho_T^2} = 0.002 \]  (Silicon + Fiber tracker)

• Tracking out to forward regions
  \[ |\eta| < 3 \]  (Silicon disks)

• Vertex Reconstruction:
  primary vertex:  \( \sigma_{\text{vertex}} = 15-30 \, \mu m \, (r-\phi) \)
  secondary vertex:  \( \sigma_{\text{vertex}} = 40 \, \mu m \, (r-\phi) \), 80 \, \mu m \, (r-z) \)

• Excellent lepton coverage trigger and ID efficiency:
  muons:  \( p_T > 1.5 \, \text{GeV}, \ |\eta| < 2 \)
  electrons:  \( p_T > 2.0 \, \text{GeV}, \ |\eta| < 2.5 \)

• Impact parameter trigger
  Silicon track trigger at Level 2 starting end Summer 2002

Status: What about now?
Run 2

- Increases energy from 1.8 TeV to 1.96 TeV
  \( (\bar{b}b\) cross section up by \(~30\%) \)

- Increases luminosity:

<table>
<thead>
<tr>
<th>Run 1</th>
<th>Run 2a</th>
<th>Run 2b</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 fb(^{-1})</td>
<td>2 fb(^{-1})</td>
<td>15 fb(^{-1})</td>
</tr>
</tbody>
</table>

DØ Run 2 Preliminary

- Delivered
- Utilized
- Recorded

(Physics Runs)

- Continue commiss.
- plus fiber tracker
- axial, stereo

- Commissioning
- silicon, timing,
- DAQ, Online

- Nov. shutdown,
- significant fraction of
- Fiber tracker AFE
- boards installed
Importance of tracking in $B$ physics – critical path item was late Analog Front End (AFE) boards essential for reading out central fiber tracker (CFT) and preshower detectors.

- Summer 2001: very restrictive slice in $\phi$ instrumented with CFT axial
- Nov. 2001 shutdown: large fraction of CFT axial AFE boards installed, commissioned over winter
- Many commissioning studies with silicon-only tracking!

Now CFT axial completely instrumented, and as of ~3 weeks ago, CFT stereo fully instrumented (i.e., full tracking only very recent...)

Primary vertex with silicon-only tracking

Operational
- Barrel 95%
- F-disks 96%
- H-disks 87%
Muons associated with jets

Consistent in shape with DØ Run 1 results in same kinematic region
**b's from Muons**

- Decay muon from heavier b quark gets transverse kick

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**DØ Run 2 Preliminary**

- Muons without charged particle match, current work with matched muons shows substantial improvement in separation
DØ Run 2 Preliminary

The plots show the distribution of $p_T^{\text{rel}}$ (GeV) for different events:

- **Data**
  - $p_T^{\text{rel}} = 1.25$ GeV
  - $p_T^{\text{rel}} = 1.01$ GeV

- **bb**
  - Green dots representing b quark events

- **cc (QCD)**
  - Red dots representing q̅q̅ (quark-antiquark) events

The plots are compared against a scintillator segment and PDT's (Preamplifier Digitizer Tracker's) in the DØ detector.
Lifetime signals from $B$'s

$N_{\text{tracks}} > 13$, $|z_{\text{vtx}}| < 20 \text{ cm}$

$\sigma_x = 46 \mu m$

$x$-width of Primary Vertex [cm]

$$\sigma = 62 \mu m$$

Global tracks with $p_T > 0.5 \text{ GeV}$

$\sigma(d_0), \mu m$

- DØ data (preliminary)
- DØ MC single muons

$p_T, \text{GeV}$

Entries/0.0025 cm
Positive dca

Negative dca

**Di-jet Sample**
- Track $p_T > 1.5$ GeV
- $> 10$ total hits (SMT+CFT)
- $|dca| < 1.0$ mm (reduces $K^0_S$, $\Lambda$)

**DØ Run 2 Preliminary**

**High-$p_T$,rel muon sample**

- $\mu$ associated w/ jet ($dR < 0.7$)
- $p_T^{rel} > 1.5$ GeV
- Same cuts

*Enhanced in b-jet Content*
Combine track probabilities of tracks in same jet into a jet probability.
**Vertexing and the "Benchmark"**

**$J/\psi K_s$ Reconstruction:**

- Measure decay length
- Tag flavour at production

**Opposite-Side tag:**
- lepton and jet charge

**Same-side tag:**
- pion charge

\[
A_{CP}(t) = \sin(2\beta)\sin(\Delta m_d t)
\]

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**DØ Run 2 Preliminary**

- Mean = $492.26 \pm 0.28$ MeV/c$^2$
- Sigma = $5.08 \pm 0.48$ MeV/c$^2$

**Silicon + CFT axial/s\textit{stereo} tracks**
Muons with central track match (no match, factor 3–4 more)

\[ J/\psi \rightarrow \mu^+\mu^- \]

Mass = \( 3.095 \pm 0.003 \) GeV
\[ \sigma = 118 \pm 3 \text{ MeV} \]
No. events in peak = 2250

For \( J/\psi \), if only take tracks with both silicon and CFT hits, mass resolution \(~70\) MeV, c.f. 50–60 MeV expected from Monte Carlo
Tagging Efficiency, \( \varepsilon = \frac{N_{\text{tag}}}{N_{\text{tot}}} \)

Dilution, \( D = \frac{N_R - N_W}{N_R + N_W} \)

Flavour Tag Quality \( = \varepsilon D^2 \)

<table>
<thead>
<tr>
<th>Tag</th>
<th>DØ Strength</th>
<th>DØ ( \varepsilon D^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same side</td>
<td>–</td>
<td>2.0</td>
</tr>
<tr>
<td>Soft lepton</td>
<td>( \mu, e ) ID coverage</td>
<td>3.1</td>
</tr>
<tr>
<td>Jet charge</td>
<td>forward tracking</td>
<td>4.7</td>
</tr>
<tr>
<td>Opp. side ( K )</td>
<td>no K ID</td>
<td>none</td>
</tr>
<tr>
<td>Combine</td>
<td></td>
<td>9.8</td>
</tr>
</tbody>
</table>

(+trigger on \( J/\psi \to e^+e^- \))

After Run 2a (2 fb\(^{-1}\)),
Expect 30-40k reconstructed events
\[ \Rightarrow \delta \sin 2\beta \sim 0.04 \]
**$B_s^0$ Mixing**

**Hadronic** (semileptonic also being studied)

$B_s^0 \rightarrow D_s^- \pi^+ (\pi^- \pi^+)$

$D_s^- \rightarrow \phi \pi^-$

$\phi \rightarrow K^+ K^-$

No missing $\nu$!

- trigger on opposite-side lepton
- lepton charge tags initial flavour
- final flavour tagged by charge of $D_s$
- expect 2000 events in 2 fb$^{-1}$
- reach estimates on $x_s$

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**Average Significance Estimates**

**Average Significance (S/B = 1/2)**

Sensitivity for $x_s$

Excluded

<table>
<thead>
<tr>
<th>Sensitivity for $x_s$</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_s$ (2000 evts, 0.075 ps)</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
</tr>
</tbody>
</table>

Preliminary

5 Sigma Observation
Future

- Finish detector commissioning
- Debugging, calibration, alignment
- Continue refining reconstruction algorithms
- Full tracking $\rightarrow$ secondary vertexing, electron id (and $J/\psi \rightarrow ee$) with road method and preshowers
- Complete triggers and improve DAQ
  - Level 2 trigger coming online
  - extend jet trigger beyond $|\eta| = 0.8 \rightarrow$ weeks
  - Level 1 central track trigger $\rightarrow$ Summer 2002
  - Level 2 silicon track trigger $\rightarrow$ End summer 2002
- Luminosity!!
  - ...but doesn't show last 3 weeks where turning up and record peak luminosity achieved!

![Graph showing integrated luminosity projections and actual values over time](image)