$\Delta \Gamma/\Gamma$ and $B_s$ mixing at DØ

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Measurement Plan

• First measure $B_s$ lifetime using $D_s \mu X$ decays

  ➢ Flavor specific decay used for $\Delta \Gamma/\Gamma$ measurement

  ➢ Shows we understand systematics in $B_s \rightarrow D_s \mu X$ decays for the $\Delta m_s$ measurement
$B_s \rightarrow D_s^+ \mu^- \text{ Lifetime}$

“Right” sign combinations

Significance of pseudo-proper decay length $> 5$

$\chi^2$/dof = 1.33

Wrong sign combinations

$\chi^2$/dof = 0.98

Cannot apply lifetime biasing cuts so fairly large backgrounds.

5153 $D_s \mu$ candidates
Sample Composition

- **Signal:**
  - 25.4% $B_s \rightarrow D_s \mu X$
  - 67.7% $B_s \rightarrow D_s^* \mu X$
  - 2.4% $B_s \rightarrow D_{s0}^* \mu X$
  - 4.5% $B_s \rightarrow D_{s1}^* \mu X$
  - Background (branching rates)
    - 4.2% $B^0 \rightarrow D_s^- D^{**}$
    - 4.2% $B^+ \rightarrow D_s^- D^*$
    - 23% $B_s \rightarrow D_s^- D_s^{**}$
Lifetime Fit

\[
\begin{align*}
\tau &= L_{xy} \frac{m(B_s)}{P_T(D_s \mu)} \times K \\
L &= \prod_{i}^{N_s} \left[ f_{\text{sig}} F_{\text{sig}}^i + (1 - f_{\text{sig}}) F_{\text{bg}}^i \right] \prod_{j}^{N_{B}} F_{\text{bg}}^j \\
F_{\text{bg}}^j &= (1 - f_+ - f_{++} - f_-) G \\
&+ f_+ \frac{e^{-\lambda_j / \lambda^+}}{\lambda^+} \quad (\lambda_j \geq 0) \\
&+ f_{++} \frac{e^{-\lambda_j / \lambda^{++}}}{\lambda^{++}} \quad (\lambda_j \geq 0) \\
&+ f_- \frac{e^{-\lambda_j / \lambda^-}}{\lambda^-} \quad (\lambda_j < 0) \\
F_{\text{sig}}^i &= \int dK H(K) \left[ \frac{K}{c \tau} e^{-K \lambda_j / c \tau} \otimes G \right]
\end{align*}
\]
Fit and Results

$B_s \rightarrow D_s^+ \mu^-$

400 pb$^{-1}$

DØ Run II Preliminary

$\chi^2$/dof = 1.09

World Average: $1.461 \pm 0.057$ ps

$\tau = 1.420 \pm 0.043$ (stat) $\pm 0.057$ (syst) ps

Dominant systematic: Background estimate, should be reduced in future
Main measurement is lifetime difference in $B_s$ system.

We assume no CP violation in the $B_s$ system and measure two $B_s$ lifetimes, $\tau_L$ and $\tau_H$, (or $\Delta \Gamma/\Gamma$ and $\tau$) by simultaneously fitting the time evolution and angular distribution of untagged $B_s \rightarrow J/\psi \, \phi$ decays.

Exploring CP violation beyond SM.

We allow for a free CP violating angle $\delta \phi$, and use the relation between the measured $\Delta \Gamma/\Gamma$, and SM prediction, $\Delta \Gamma/\Gamma_{SM}$:

$$\Delta \Gamma/\Gamma = \Delta \Gamma/\Gamma_{SM} \cos^2(\delta \phi)$$

to extract $\delta \phi$.

Untagged $B_s$ Rate in Time, Decay Angles

\[
\frac{d^3\Gamma \rightarrow J/\psi (\rightarrow \mu^+\mu^-) \phi (\rightarrow K^+K^-)}{d\cos\theta \, d\phi \, d\cos\psi \, dt} \propto \frac{9}{16\pi} \left[ 2|A_0(0)|^2 \, e^{-\Gamma t} \cos^2\psi (1 - \sin^2\theta \cos^2\phi) \\
+ \sin^2\psi \left( |A_{\parallel}(0)|^2 \, e^{-\Gamma t} \left( 1 - \sin^2\theta \sin^2\phi \right) + |A_{\perp}(0)|^2 \, e^{-\Gamma t} \sin^2\theta \right) \right] \\
+ \frac{1}{\sqrt{2}} \sin 2\psi \left\{ |A_0(0)||A_{\perp}(0)| \cos(\delta_2 - \delta_4) e^{-\Gamma t} \sin^2\theta \sin^2\phi \right\} \\
+ \left\{ \frac{1}{\sqrt{2}} |A_0(0)||A_{\perp}(0)| \cos\delta_2 \sin 2\psi \sin 2\theta \cos\phi \right\} \frac{1}{2} \left\{ e^{-\Gamma_1 t} - e^{-\Gamma_2 t} \right\} \delta_\phi \\
- \left\{ \frac{1}{\sqrt{2}} |A_{\parallel}(0)||A_{\perp}(0)| \cos\delta_1 \sin 2\psi \sin 2\theta \sin\phi \right\} \frac{1}{2} \left\{ e^{-\Gamma_1 t} - e^{-\Gamma_2 t} \right\} \delta_\phi \right] H(\cos\psi) F(\phi) G(\cos\theta)
\]

$\theta = \text{transversity}$
3 Angles $\rightarrow$ 1 Angle

Inserting $H(\cos \psi) = 1$, and $F(\phi) = 1 + J \cos(2\phi) + K \cos^2(2\phi)$, and integrating over $\cos \psi$ and $\phi$, we obtain a 1-angle time evolution:

$$\frac{d^3 \Gamma}{d \cos \theta \, dt} \rightarrow J/\psi \, (\rightarrow l^+_l \, l^-_l \, \phi \rightarrow K^+_K \, K^-_K) = N \pi \left[ (|A_0(0)|^2 + |A_{\parallel}(0)|^2)e^{-T_\perp t} (1 + \cos^2 \theta) \right.$$

$$+ \frac{K}{2} \left\{ (|A_0(0)|^2 + |A_{\parallel}(0)|^2) e^{-T_\perp t} (1 + \cos^2 \theta) + 2 |A_{\perp}(0)|^2 e^{-T_\parallel t} \sin^2 \theta \right\}$$

$$- \frac{J}{2} (|A_0(0)|^2 - |A_{\parallel}(0)|^2) e^{-T_\perp t} \sin^2 \theta + 2 |A_{\perp}(0)|^2 e^{-T_\parallel t} \sin^2 \theta \left. \right\} G(\cos \theta)$$

$$= 0.355 \pm 0.066 \text{ (from CDF)}$$

$$|A_0(0)|^2 + |A_{\parallel}(0)|^2 + |A_{\perp}(0)|^2 = 1$$

defining, $R_\perp = |A_{\perp}(0)|^2$
Detector Acceptance (MC)

\[ F(\phi) = 1 + J \cos(2\phi) + K \cos^2(2\phi) \]

\[ G(\cos \theta) = 1 + B \cos^2\theta + C \cos^4\theta \]

\[ H(\cos \psi) \text{ flat distribution} \]
$B_s \rightarrow J/\psi \phi$ mass

450 pb$^{-1}$

Fit prob: 19.8%

Fit prob: 11.2%

Lifetime significance > 5
Maximum Likelihood Fit

Simultaneous fit to mass, proper decay length and transversity using an unbinned maximum log-likelihood method

\[
\mathcal{L} = \prod_{i=1}^{N} \left[ f_{\text{sig}} F_{\text{sig}}^i + (1 - f_{\text{sig}}) F_{\text{bck}}^i \right]
\]

- \( f_{\text{sig}} \): signal fraction
- \( c_\tau = \frac{c}{\bar{\Gamma}} \), \( \bar{\Gamma} = (\Gamma_L + \Gamma_H)/2 \)
- \( R_\perp \): CP-odd fraction at t=0
- \( \Delta \Gamma / \bar{\Gamma} \)

Other free parameters
- \( m_{\text{signal}}, m_{\text{background}} \) slope (1 prompt, 1 long-lived)
- \( \sigma(c_\tau) \) scale
- \( 6 \): bkg c_\tau shape
- \( 4 \): bkg transversity (2 prompt +2 long-lived)

---

19 total
Results

\[ \tau \text{ (in ps)} = 1.39^{+0.13}_{-0.14} \text{(stat)} \]

\[ R_\perp = 0.17 \pm 0.10 \]

\[ \tau_L \text{ (in ps)} = 1.23^{+0.14}_{-0.11} \text{(stat)} \]

\[ \Delta \Gamma / \Gamma = 0.21^{+0.27}_{-0.40} \text{(stat)} \]

\[ \tau_H \text{ (in ps)} = 1.52^{+0.39}_{-0.43} \text{(stat)} \]
Add in World Average based on semileptonic decays

Flavor specific final states (e.g. $B^0_s \rightarrow l\nu D_s$) provide:

$$c\tau = c\tau(\text{f.s.}) \frac{1 - \left( \frac{\Delta\Gamma}{2\Gamma} \right)^2}{1 + \left( \frac{\Delta\Gamma}{2\Gamma} \right)^2}$$
New Physics?

We measure $\Delta \Gamma / \Gamma = \Delta \Gamma / \Gamma_{SM} \cos^2(\delta \phi)$, where $\Delta \Gamma / \Gamma_{SM} = 0.12 \pm 0.05$ (Lenz)

SM predicts $\cos(\delta \phi) \sim 1$

Fit for $\cos^2(\delta \phi)$ gives:

$$| \cos(\delta \phi) | = 1.46^{+0.73}_{-0.69}$$

Consistent with SM
Future for $\Delta \Gamma / \Gamma$

- Currently a *statistics* dominated measurement
- Systematics are small (~0.02)
- Precision of *semileptonic lifetime* is very important
- Biggest issue for high luminosity running is triggering. (can require a single PV)
Bs mixing

- Currently only using a single semileptonic decay of the Bs
- \( B_s \rightarrow D_s \mu X (D_s \rightarrow \phi \pi) (\phi \rightarrow K^+K^-) \)
- Using \( \mu + SV \) vertex tag (Opposite side tag so independent of reconstructed side)
- Goal was to develop tools and to allow a baseline to build on for the future
Event Sample

Very Large sample

\[ \text{Events/(0.01 MeV/c}^2) \]

![Graph showing mass distribution for D_s sample](image)

DØ Run II Preliminary
After applying flavor tag using muon and SV information

D_{s} signal

DØ Run II Preliminary

376 ± 31 events
Since our cuts bias the lifetime, we fit the data in bins of VPDL and fit the asymmetry.

Separate data in 7 bins of 100 µm.

\[ VPDL = \left( \vec{L}_t \cdot \vec{P}_{t}^{\mu D_s} \right) / \left( P_{t}^{\mu D_s} \right)^2 \cdot M_{B_s} \]

\[ A = \frac{N_{\text{non-osc}} - N_{\text{osc}}}{N_{\text{non-osc}} + N_{\text{osc}}} \]
## Sample composition

<table>
<thead>
<tr>
<th>Decay</th>
<th>Sample composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_s \rightarrow D_s \mu \nu$</td>
<td>20.6%</td>
</tr>
<tr>
<td>$B_s \rightarrow D^*_s \mu \nu$</td>
<td>57.2%</td>
</tr>
<tr>
<td>$B_s \rightarrow D^*_{0s} \mu \nu$</td>
<td>1.4%</td>
</tr>
<tr>
<td>$B_s \rightarrow D^*_{1s} \mu \nu$</td>
<td>2.9%</td>
</tr>
<tr>
<td>$B_s \rightarrow D_s D_s X$</td>
<td>11.3%</td>
</tr>
<tr>
<td>$B^0 \rightarrow D_s D X$</td>
<td>3.2%</td>
</tr>
<tr>
<td>$B^- \rightarrow D_s D X$</td>
<td>3.4%</td>
</tr>
</tbody>
</table>

$\bar{c}c$ estimated at $\sim 3.5 \pm 2.5 \%$
Efficiency of selection cuts

Efficiency vs. VPDL (cm) for $B_s \rightarrow D_s \mu X$

DØ Run II Preliminary
Measure Dilution using $B_d$ and $B^+$ samples

Mistag rate: $27.6 \pm 2.1\%$

Mistag rate: $26.6 \pm 1.5\%$

$\epsilon D^2 \sim 1.2\%$
Result

DØ Run II Preliminary

Amplitude

95% CL limit: 5.0 ps⁻¹
sensitivity: 4.6 ps⁻¹

5.2 ps⁻¹ (stat. only)
5.1 ps⁻¹ (stat. only)
• Main contributions to the systematic error are from

  – $B_s \rightarrow D_s D_s$ branching ratio uncertainty

  – background parameterization

  – Uncertainty in the $D_s$ width : $\sigma_{D_s}$

  – Uncertainty in the $D^-$ mass : $M_{D^-}$
Summary

\[ \Delta m_s > 5.0 \text{ ps}^{-1} \text{ at 95\% CL} \]

- Still statistically limited
- Improvements (near term)
- Event-Event unbinned fitting procedure
- Optimization of tagging, addition of other taggers
- Use of other decay modes
- Use of hadronic decays

- Hope to have 95\% CL about 10-12 \text{ ps}^{-1} by summer 2005
Future improvements to semileptonic $\Delta m_s$ measurement

- $x \sim 2$: additional channels, $K^*K$, $3\pi$, $K^0\bar{K}$
- $x \sim 2.4$: electron flavor tagging
- $x \sim 1.7$: selection, improved S/N

Further improvement, unbinned likelihood:
- $x \sim 2$: flavor tag probability event-by-event
- $x \sim 1.3$: resolution event-by-event
Future (longer term)

• Increase bandwidth for B triggers to allow us to lower prescales on triggers
  – 50 Hz additional bandwidth for B physics

• L0 Silicon to improve vertex resolution
Semileptonic Mode, $B_s \rightarrow D_s \mu \nu X$

Current Resolution

+ 50 Hz Upgrade

From global fits (hep-ph/0406184)
Hadronic Mode, $B_s \rightarrow D_s \pi$

Integrated Lumi for Observation at $3\sigma$ [pb$^{-1}$] + 50 Hz Upgrade

From global fits (hep-ph/0406184)
Backup Slides
Cuts for lifetime analysis

- Muon has hit in all 3 layers of muon system
- Kaon $P_T > 1$ GeV
- Pion $P_T > 0.7$ GeV
- $1.008 < M(\phi) < 1.032$
- $\chi^2$ prob ($D_s$) > 0.1%
- $\chi^2$ prob($B_s$) > 0.01%
- $1.6 < M(D_s) < 2.3$ GeV
- $3.0 < M(B_s) < 5.0$ GeV
- Helicity (D) > 0.4
- $P_T (\mu \text{ w.r.t D}) > 2$
- $P_T (D) > 3.5$ GeV
- $L_{xy} (D) \cdot P_T (D) > 0$
- All tracks within same jet
Cuts for Bs mixing analysis

- Muon has hit in at least 2 layers of muon system, $P_T > 1.5$ GeV, $|η| < 2$ and $P > 3$ GeV
- Kaon $P_T > 0.7$ GeV
- Pion $P_T > 0.7$ GeV
- $1.006 < M(φ) < 1.030$
- $χ^2 (D_s) < 16$
- $χ^2 (B_s) < 9$
- $1.5 < M(B_s) < 5.5$ GeV
- $\cos(\alpha) > .9$
- Significance of Ds vertex >4
- All tracks within same jet
- Impact parameter significance of pion >2 and at least 1 kaon with impact significance > 4
## Cuts for $\Delta \Gamma/\Gamma$ analysis ~450 pb$^{-1}$

<table>
<thead>
<tr>
<th>Bs candidate mass</th>
<th>5.0 $&lt;$M($J/\psi,\phi$) $&lt;$5.8 GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$J/\psi$ candidate mass</td>
<td>2.9 $&lt;$M($\mu^+,\mu^-$) $&lt;$3.25 GeV</td>
</tr>
<tr>
<td>Non-$J/\psi$ meson mass</td>
<td>1.01 $&lt;$M($K^+,K^-$) $&lt;$1.03 GeV</td>
</tr>
<tr>
<td>$B_s$ p$_T$</td>
<td>$&gt;$ 6.0 GeV</td>
</tr>
<tr>
<td>$J/\psi$ p$_T$</td>
<td>$&gt;$ 4.0 GeV if</td>
</tr>
<tr>
<td>$\phi$ p$_T$</td>
<td>$&gt;$1.5 GeV</td>
</tr>
<tr>
<td>$\phi$ $\chi^2$</td>
<td>$&lt;$15.0</td>
</tr>
<tr>
<td>$K^\pm$ p$_T$</td>
<td>$&gt;$0.7 GeV</td>
</tr>
<tr>
<td>SMT hits on track</td>
<td>$&gt;$0</td>
</tr>
<tr>
<td>CFT hits on track</td>
<td>$&gt;$0</td>
</tr>
<tr>
<td>$J/\psi$ decay length error</td>
<td>$&lt;$ 0.02 cm</td>
</tr>
<tr>
<td>$B$ candidate decay length error</td>
<td>$&lt;$ 0.006 cm</td>
</tr>
<tr>
<td>Absolute decay length difference between $B_s$ candidate and $J/\psi$</td>
<td>$&lt;$0.02 cm</td>
</tr>
</tbody>
</table>

Total number of candidates: 9699
## Systematic Errors for $\Delta \Gamma / \Gamma$

<table>
<thead>
<tr>
<th>Source</th>
<th>$c\tau$ (in $\mu$m)</th>
<th>$R_\perp$</th>
<th>$\Delta \Gamma / \Gamma$</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal $\varepsilon$ vs $\cos \theta$</td>
<td>$\pm 0.6$</td>
<td>$\pm 0.005$</td>
<td>$\pm 0.001$</td>
<td>MC</td>
</tr>
<tr>
<td>Signal $\varepsilon$ vs $\phi$, $\psi$ angles including: (</td>
<td>$A_0</td>
<td>^2 -</td>
<td>A_1</td>
<td>^2$)</td>
</tr>
<tr>
<td>Signal mass model</td>
<td>$\pm 0.4$</td>
<td>$\pm 0.006$</td>
<td>$\pm 0.016$</td>
<td>data</td>
</tr>
<tr>
<td>Procedure bias</td>
<td>$\pm 2$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.025$</td>
<td>MC</td>
</tr>
<tr>
<td>Detector alignment</td>
<td>$\pm 2$</td>
<td>--</td>
<td>--</td>
<td>data</td>
</tr>
<tr>
<td>Bkg lifetime model</td>
<td>0.5</td>
<td>0.005</td>
<td>0.016</td>
<td>data</td>
</tr>
</tbody>
</table>
Summary of $\Delta \Gamma/\Gamma$

From $B_s \rightarrow J/\psi (\rightarrow \mu^+ \mu^-) \phi (\rightarrow K^+ K^-)$ we find:

\[
\Delta \Gamma/\Gamma \equiv (\Gamma_L - \Gamma_H)/\Gamma = 0.21^{+0.33}_{-0.45}, \quad \tau = 1.39^{+0.15}_{-0.19} \text{ ps}
\]

With constraint from the W.A. $c\tau$ from semileptonic decays

\[
\tau(\text{f.s.}) = 1.43 \pm 0.05 \text{ ps}
\]

we obtain:

\[
\Delta \Gamma/\Gamma = 0.23^{+0.16}_{-0.17}, \quad \tau = 1.39^{+0.05}_{-0.06} \text{ ps}
\]

Allowing for a free CP violating angle, using SM constraint $\Delta \Gamma/\Gamma_{\text{SM}} = 0.12 \pm 0.05$, we obtain:

\[
| \cos(\delta \phi) | = 1.46^{+0.73}_{-0.69}
\]
Table 1: Systematic uncertainties on the amplitude. The shifts of both the measured amplitude, $\Delta A$, and its statistical uncertainty, $\Delta \sigma$, are listed.

<table>
<thead>
<tr>
<th>Osc. frequency</th>
<th>$\Delta A$</th>
<th>1 ps$^{-1}$</th>
<th>2 ps$^{-1}$</th>
<th>3 ps$^{-1}$</th>
<th>4 ps$^{-1}$</th>
<th>5 ps$^{-1}$</th>
<th>6 ps$^{-1}$</th>
<th>7 ps$^{-1}$</th>
<th>8 ps$^{-1}$</th>
<th>9 ps$^{-1}$</th>
<th>10 ps$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_{\text{stat}}$</td>
<td>0.349</td>
<td>0.366</td>
<td>0.457</td>
<td>0.479</td>
<td>0.572</td>
<td>0.860</td>
<td>1.043</td>
<td>1.189</td>
<td>1.466</td>
<td>2.065</td>
</tr>
<tr>
<td>$\eta_\beta = 0.719$</td>
<td>$\Delta \sigma$</td>
<td>+0.024</td>
<td>+0.026</td>
<td>+0.031</td>
<td>+0.033</td>
<td>+0.039</td>
<td>+0.059</td>
<td>+0.071</td>
<td>+0.081</td>
<td>+0.113</td>
<td>+0.169</td>
</tr>
<tr>
<td>$e\bar{e}$ : 6%</td>
<td>$\Delta \sigma$</td>
<td>+0.044</td>
<td>+0.042</td>
<td>+0.058</td>
<td>+0.012</td>
<td>+0.004</td>
<td>-0.018</td>
<td>+0.013</td>
<td>+0.114</td>
<td>+0.175</td>
<td>+0.471</td>
</tr>
<tr>
<td>$D_s D_s : 21.6%$</td>
<td>$\Delta \sigma$</td>
<td>+0.034</td>
<td>+0.022</td>
<td>+0.026</td>
<td>+0.027</td>
<td>+0.033</td>
<td>+0.068</td>
<td>+0.086</td>
<td>+0.097</td>
<td>+0.124</td>
<td>+0.270</td>
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<tr>
<td>$e_{\tau_{\beta}} = 455\mu m$</td>
<td>$\Delta \sigma$</td>
<td>+0.004</td>
<td>-0.004</td>
<td>-0.005</td>
<td>+0.001</td>
<td>+0.001</td>
<td>+0.000</td>
<td>+0.005</td>
<td>+0.014</td>
<td>+0.016</td>
<td>+0.0408</td>
</tr>
<tr>
<td>same eff. dependence</td>
<td>$\Delta \sigma$</td>
<td>+0.003</td>
<td>+0.002</td>
<td>+0.003</td>
<td>+0.002</td>
<td>+0.003</td>
<td>+0.007</td>
<td>+0.006</td>
<td>+0.008</td>
<td>+0.023</td>
<td>+0.034</td>
</tr>
<tr>
<td>for signal and bkg</td>
<td>$\Delta \sigma$</td>
<td>+0.004</td>
<td>+0.004</td>
<td>+0.005</td>
<td>+0.005</td>
<td>+0.006</td>
<td>+0.011</td>
<td>+0.011</td>
<td>+0.013</td>
<td>+0.028</td>
<td>+0.028</td>
</tr>
<tr>
<td>Resolution S.F. = 2</td>
<td>$\Delta \sigma$</td>
<td>-0.01</td>
<td>-0.002</td>
<td>-0.003</td>
<td>-0.003</td>
<td>-0.004</td>
<td>-0.006</td>
<td>-0.125</td>
<td>-0.019</td>
<td>+0.000</td>
<td>-0.011</td>
</tr>
<tr>
<td>for background</td>
<td>$\Delta \sigma$</td>
<td>+0.006</td>
<td>+0.006</td>
<td>+0.005</td>
<td>+0.013</td>
<td>+0.017</td>
<td>-0.006</td>
<td>+0.000</td>
<td>+0.034</td>
<td>+0.053</td>
<td>+0.053</td>
</tr>
<tr>
<td>$D_s$ mass changed to 1.9601 + 0.0007</td>
<td>$\Delta \sigma$</td>
<td>-0.041</td>
<td>-0.034</td>
<td>-0.006</td>
<td>+0.010</td>
<td>+0.136</td>
<td>+0.186</td>
<td>-0.075</td>
<td>-0.114</td>
<td>+0.002</td>
<td>-0.009</td>
</tr>
<tr>
<td>$D_s$ sigma changed to 0.02336 - 0.0007</td>
<td>$\Delta \sigma$</td>
<td>+0.014</td>
<td>+0.015</td>
<td>+0.010</td>
<td>+0.048</td>
<td>+0.025</td>
<td>+0.031</td>
<td>-0.002</td>
<td>+0.057</td>
<td>+0.101</td>
<td>+0.119</td>
</tr>
<tr>
<td>$D^+ \text{ mass changed to 1.8641 - 0.0016}$</td>
<td>$\Delta \sigma$</td>
<td>-0.018</td>
<td>-0.006</td>
<td>+0.023</td>
<td>+0.040</td>
<td>+0.062</td>
<td>+0.065</td>
<td>-0.015</td>
<td>-0.046</td>
<td>-0.063</td>
<td>-0.162</td>
</tr>
<tr>
<td>Bkg. from wrong sign combination</td>
<td>$\Delta \sigma$</td>
<td>+0.006</td>
<td>+0.001</td>
<td>+0.007</td>
<td>+0.019</td>
<td>+0.021</td>
<td>+0.002</td>
<td>+0.002</td>
<td>+0.035</td>
<td>+0.067</td>
<td>+0.071</td>
</tr>
<tr>
<td>Bkg. parametrized by straight line</td>
<td>$\Delta \sigma$</td>
<td>-0.103</td>
<td>+0.008</td>
<td>+0.035</td>
<td>-0.020</td>
<td>-0.002</td>
<td>+0.066</td>
<td>-0.016</td>
<td>-0.227</td>
<td>-0.412</td>
<td>-0.756</td>
</tr>
<tr>
<td>mass bin smaller by 50%</td>
<td>$\Delta \sigma$</td>
<td>-0.029</td>
<td>-0.010</td>
<td>-0.031</td>
<td>-0.030</td>
<td>-0.021</td>
<td>-0.120</td>
<td>-0.123</td>
<td>-0.116</td>
<td>-0.124</td>
<td>-0.194</td>
</tr>
<tr>
<td>$\Delta \Gamma / \Gamma = 0.2$</td>
<td>$\Delta \sigma$</td>
<td>-0.000</td>
<td>-0.001</td>
<td>-0.001</td>
<td>-0.001</td>
<td>-0.001</td>
<td>+0.001</td>
<td>+0.002</td>
<td>+0.002</td>
<td>+0.002</td>
<td>+0.002</td>
</tr>
<tr>
<td>Resolution S.F. = 1.115</td>
<td>$\Delta \sigma$</td>
<td>+0.006</td>
<td>-0.003</td>
<td>-0.021</td>
<td>-0.011</td>
<td>+0.002</td>
<td>+0.001</td>
<td>+0.038</td>
<td>+0.154</td>
<td>+0.247</td>
<td>+0.233</td>
</tr>
<tr>
<td>K-factor variation 2%</td>
<td>$\Delta \sigma$</td>
<td>+0.009</td>
<td>+0.012</td>
<td>-0.000</td>
<td>-0.035</td>
<td>-0.011</td>
<td>-0.027</td>
<td>-0.095</td>
<td>-0.134</td>
<td>-0.096</td>
<td>-0.264</td>
</tr>
<tr>
<td>Total</td>
<td>$\sigma_{\text{tot}}$</td>
<td>0.427</td>
<td>0.424</td>
<td>0.490</td>
<td>0.541</td>
<td>0.655</td>
<td>0.951</td>
<td>1.084</td>
<td>1.254</td>
<td>1.577</td>
<td>2.636</td>
</tr>
</tbody>
</table>
Events

DØ Run II Preliminary

$B_s \rightarrow D_s \mu \nu$, $\langle k \rangle = 0.878$

$B_s \rightarrow D_s^* \mu \nu$, $\langle k \rangle = 0.857$

$B_s \rightarrow D_s^{**} \mu \nu$, $\langle k \rangle = 0.821$
Semileptonic Mode: Proper Decay Length Resolution, Current

- $\sigma_1 = 27 \, \mu m \ (38\%)$
- $\sigma_2 = 55 \, \mu m \ (48\%)$
- $\sigma_3 = 138 \, \mu m \ (14\%)$

+ K-factor smearing due to missing particles, including neutrino
Hadronic Mode Proper Decay Length
Resolution with Layer 0 Silicon

\[\sigma_1 = 19 \, \mu m \ (51\%)\]
\[\sigma_2 = 26 \, \mu m \ (49\%)\]
The table shows the following entries:

<table>
<thead>
<tr>
<th>Entries</th>
<th>36751</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.0001737</td>
</tr>
<tr>
<td>RMS</td>
<td>0.007375</td>
</tr>
<tr>
<td>$\chi^2$/ndf</td>
<td>19.28/25</td>
</tr>
<tr>
<td>Prob</td>
<td>0.7837</td>
</tr>
</tbody>
</table>

The parameters $p_i$ and $p_j$ are given with uncertainties:

- $p_0 = 0.00001 \pm 0.00198$
- $p_1 = 1.031 \times 10^{-4} \pm -3.147 \times 10^{-5}$
- $p_2 = 0.000000 \pm 0.002497$
- $p_3 = 0.0000 \pm 0.1982$
- $p_4 = 7.951 \times 10^{-5} \pm -7.593 \times 10^{-5}$
- $p_5 = 0.000000 \pm 0.004718$
- $p_6 = 0.0000 \pm 0.5051$
- $p_7 = 0.0001485 \pm -0.0004733$
- $p_8 = 0.0000 \pm 0.01134$

$SF = 0.006 \pm 1.095$ (cm)

The graph compares the distributions before and after tuning for $VPDL_{rec} - VPDL_{gen}$ (cm).