CDF – the party crashers

Capri 2010
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for the CDF Collaboration
Or “flavor problem”? 

Kaon physics and $B$ factories: SM picture of CP violation satisfactory at least at tree level in $B^0$ and $B^+$ decays. NP amplitudes < 10%, if any.

Success of the CKM picture rules out NP with a generic, natural flavor structure.

To keep the NP-scale in the TeV range, physics beyond the SM should have a highly fine-tuned flavor structure.

...the end of the story?
Why bother with CDF?

World’s largest samples of B and charm.

Challenge B factories (on charged final states)

Access strange bottom: new, uncharted territory of independent dynamics.

Access $b$-baryons and $B^+_c$.

40M $J/\psi$ (~20% from B)

6K $B^0_s \rightarrow J/\psi \phi$, 32K $B^0 \rightarrow J/\psi K^*$

50M $D^0 \rightarrow K^- \pi^+$, 12K $B^0 \rightarrow K^+ \pi^+$ ....
The program

So far 58 Run II papers published: 11 topcite50+ and 7 topcite100+

BSM

$A_{FB}(B \to K\mu\mu)$

$B \to \mu\mu$

$D \to \mu\mu$

CKM

$\sin 2\beta_s$

$B_s \to D_s D_s$

$A_{SL}$

$B \to h h$

$B \to D K$

Lifetimes

QCD

XYZ mesons

$D \to h h$

$B \to \phi\phi$

$B$-production

c-baryons

$b$-baryons

$\Psi$ & $Y$ production

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5/41
Gettin’ the basics straight
Vertexing - Lifetimes

45k \( B^+ \rightarrow J/\psi K^+ \), 17k \( B^0 \rightarrow J/\psi K^* \), 12k \( B^0 \rightarrow J/\psi K_s \), 1.7 \( \Lambda_b \rightarrow J/\psi \Lambda \) in 4.3 fb\(^{-1}\)

Use \( J/\psi \) vertex to measure \( ct \). Common to all modes, systematic uncertainties cancel in ratios – the ones HQE cares about.

Joint fit: mass, mass-uncertainty, decay time, and decay-time uncertainty.

Similar S/B for all modes
Resolution model from data sidebands
World leading measurements

No surprises from $B^0$ and $B^+$: further confidence in HQE.

Same expansion as for $\Gamma_{12}$ - crucial for interpretation of CPV in $B^0_s$ mixing

$\Lambda_b$ higher than theory predictions.

$\Lambda_b$ theory worse than for mesons: NLO not completed yet, non perturbative ME on lattice still at exploratory stage

CDF Public Note 10071
Momentum – $\Omega_b$ mass

Reconstruct complex $\Omega_b \rightarrow J/\psi \Omega$ (5 tracks, 3 vertices) using known $B^0 \rightarrow J/\psi K^*$, $J/\psi K_s$ as reference.

Joint mass, mass uncertainty and lifetime fit

$16^{+6}_{-4}$ $\Omega_b$ candidates 5.5$\sigma$

$M(\Omega_b) = 6054.4 \pm 6.8 \pm 0.9$ MeV/c$^2$

Inconsistent with D0 measurement (6105 ± 10 ± 13 MeV/c$^2$).

PRD 80, 072003 (2009)
New Physics in Penguins
$b \rightarrow s\mu^+\mu^-$ - analysis

Suppressed in SM. $\text{Br} \sim 10^{-6}$

NP in penguin or box modifies decay-kinematics

Pretty clean theoretically and experimentally.

- Need huge statistics (low-$p_T$ dimuon trigger collects 1.5-2 GeV/c muons at $|\eta|<1$)
- NN selection that uses PID on K.
- Use “resonant” channels as reference
Observation of $B^0_s \rightarrow \phi \mu^+ \mu^-$, the rarest $B^0_s$ decay observed.

$Br = [1.44 \pm 0.33 \text{ (stat)} \pm 0.46 \text{ (syst)}] \times 10^{-6}$

(consistent with predictions of $1.61 \times 10^{-6}$)
$b \rightarrow s \mu^+ \mu^- \ - A_{FB}$

Final state hadrons.

Theory uncertainties limited using relative quantities ($\mu$ distribution asymmetries) very sensitive to NP.
$b \rightarrow s \mu^+ \mu^-$ - status

Charmonium regions excluded

2.7σ

Cleaner predictions

PRL103, 171801 (2009)
$b \rightarrow s \mu^+ \mu^-$ - results

Not yet able to discriminate SM from non-SM
Consistent and competitive with best B-factories results.

CDF Public note 10047
**Upcoming**


**Compare Br*10^-6**

<table>
<thead>
<tr>
<th></th>
<th>BaBar (384M BB)</th>
<th>Belle (657M BB)</th>
<th>CDF (4.4fb^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K^0 µµ</td>
<td>1.35^{+0.40}_{-0.37} ± 0.10</td>
<td>1.06^{+0.19}_{-0.14} ± 0.07</td>
<td>1.06 ± 0.14 ± 0.09</td>
</tr>
<tr>
<td>K^*ll</td>
<td>1.11^{+0.19}_{-0.18} ± 0.07</td>
<td>1.07^{+0.11}_{-0.10} ± 0.09</td>
<td>same as above</td>
</tr>
</tbody>
</table>


**DØ weighing in (?)**

**LHCb**: 1200 events expected with 1 fb^-1 to exclude SM at 4σ and <1 GeV^2 precision on zero-crossing point.
$B^0_s \rightarrow \phi \phi$

Rich dynamics from three polarization amplitudes in PVV. First order SM hierarchy

$$|A_0|^2 \gg |A_\parallel|^2 \sim |A_\perp|^2$$

OK in $b \rightarrow d$ and $b \rightarrow u$. Violated in $b \rightarrow s$.

“Ad hoc” SM solutions are model dependent or inconclusive.

NP option still valid.

Further experimental info key to discriminate. $B^0_s \rightarrow \phi \phi +$ SU(3) checks for “penguin annihilation” EPJ C60 (2009)

$$BR(B^0_s \rightarrow \phi \phi) = [2.40 \pm 0.21 \text{ (stat)} \pm 0.27 \text{ (syst)} \pm 0.82(BR)] \cdot 10^{-5}$$
First measurement of $b \rightarrow s$: penguin polarization in $B^0_s$ sector.

Puzzling behavior confirmed

Measurement of CPV unrealistic at CDF. Statistics penalty from flavor tagging.
The deadliest NP killer around - $B^0_s \rightarrow \mu^+ \mu^-$
$B^0_s \rightarrow \mu^+ \mu^-$ - trivia

Gets all available suppressions in SM

All leptonic decay: robust SM prediction $\text{Br} = (3.6 \pm 0.3) \times 10^{-9}$.

NP can enhance rate up to 100x.

Sensitive to a broad class of NP models, complementary to many TeV/LEP direct searches.
**$B^0_s \rightarrow \mu^+ \mu^-$ - the measurement**

Latest result (summer 2009) uses 3.7 fb$^{-1}$ (half of current sample)

- Signal decays at 95%CL to be measured
- Trigger acceptance ratio from MC approx. 0.2-0.3
- Rec. efficiency ratio from MC/DATA approx 0.8
- $\mathcal{B}(B^0_s \rightarrow \mu^+ \mu^-) = \frac{N_s}{N_+} \cdot \frac{\alpha_+}{\alpha_s} \cdot \frac{\epsilon_+}{\epsilon_s} \cdot \frac{1}{\epsilon_N} \cdot \frac{f_u}{f_s} \cdot \mathcal{B}(B^+) \cdot \text{PDG}$
- $B^+ \rightarrow J/\psi K^+$ decays from data approx. 20K
- Efficiency of NN requirement from MC, approx 80-20% (cut-dependent)

The challenge: reject $10^6$ background while keeping signal efficiency high.
**$B^0_s \rightarrow \mu^+ \mu^-$ - selection**

Discriminants: mass, life, $p_T$ (obvious), B isolation and pointing to pp vertex

Combine discriminants into a NN. Validation of NN modeling and efficiency on $B^+$
$B^0_s \rightarrow \mu^+ \mu^-$ - backgrounds

✓ continuum $\mu^+ \mu^-$ from Drell-Yan
✓ sequential $b \rightarrow c \mu X \rightarrow \mu \mu s$ semilept.
✓ double semileptonic $b\bar{b} \rightarrow \mu^+ \mu^- + X$
✓ $b/c \rightarrow \mu + fake$
✓ fake + fake (peaking $B \rightarrow hh$)

Suppress fakes: calorimeter, dE/dx, muon-track matching.
All calibrated on $J/\psi \rightarrow \mu \mu$, $D^0 \rightarrow K\pi$, $\Lambda \rightarrow ph$ decays in data.

Combinatorial: extrapolate from sidebands into signal region

Extensive checks with background-enriched control samples: same-sign dimuons, dimuons with <0 decay-length, dimuons failing fake veto
World-leading.

\[ \text{Br}(B^0_s \rightarrow \mu^+\mu^-) < 4.3 \times 10^{-8} \ (95\% \ CL) \]

10*SM with 3.7 fb\(^{-1}\).

This result CDF Public Note 9892,

2 fb\(^{-1}\)  PRL100, 101802 (2008)  topcite100+

0.78 fb\(^{-1}\)  PRL93, 032001 (2008)  topcite50+

6 bckg expected, 7 evts observed
$B^0_s \rightarrow \mu^+\mu^- - a broad impact$

Lot of recent activity on implications for DM searches

$B^0_s \rightarrow \mu^+\mu^-$ rate and neutralino x-section depend on $\tan(\beta)$. Bounds on $\text{Br}(B^0_s \rightarrow \mu^+\mu)$ reduce allowed space of parameters for DM

Strongly constrains specific SUSY models, e.g. SO(10) Dermisek et al. JHEP 0509, 029 (2005)
**B^0_s → μ^+μ^- - year 2012**

Upper Limits on BR($B^0_s → μ^+μ^-$) at 95% C.L. at Tevatron

- SM value won’t be probed anytime soon, but eating-in last chunks of NP space.

Competition may be tight. ATLAS and CMS may join.

**@ 3.5 + 3.5 TeV**

- LHCb
  - CDF (3.7 fb\(^{-1}\))
  - CDF+DØ (8 fb\(^{-1}\))
  - 5σ Observation
  - 3σ Evidence

- SM prediction

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New Physics in $B^0_s$ mixing phase
 Why the phase?

\[
\frac{\langle M | H_{\text{full}}^{\text{eff}} | \bar{M} \rangle}{\langle M | H_{\text{SM}}^{\text{eff}} | \bar{M} \rangle} = C_M e^{2i\phi_M}
\]

Magnitude measured in 2006. It is SM within uncertainty that is now theory dominated.

Phase still largely unconstrained.

Large room for NP left unexplored.

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$B^0_s \rightarrow J/\psi \phi$ - the golden probe

Mixing phase sensitive to NP

Tree $b \rightarrow c\bar{c}s$ phase $\approx 0$

Time-evolution:

$$2\beta_s = -\arg[(V_{tb}V_{ts}^*)^2/(V_{cb}V_{cs}^*)^2]$$

CKM hierarchy predicts $2\beta_s$ tiny with error $<<$ current experimental sensitivity.

Any significant deviation is golden probe for new physics entering the box.
At a glance

Dimuon trigger

NN selection

Joint fit to mass, angles, decay-time and production flavor distributions

Mass to separate signal from bckg
Angles to separate CP-even/odd
Decay time to know time evolution
Flavor tagging to separate B from Bbar
Status

CDF Run II Prel. 2.8 fb$^{-1}$ + DØ 2.8 fb$^{-1}$

68% CL
95% CL
99% CL

SM

2.1σ

PRL101 161802 (2008) topcite100+
PRL101, 241801 (2008) topcite100+
http://tevbwg.fnal.gov/results/Summer2009_betals/
New update with 5.2 fb$^{-1}$
Selection optimized by minimizing the expected uncertainty on the phase as measured in pseudo-exp. 6500 signal decays. Compare with 3150 in 2.8 fb\(^{-1}\). Improvement better than \(\sim L\).
Calibrating production-flavor

SSKT fully recalibrated in data through new mixing analysis

$\Delta m_s = 17.79 \pm 0.07 \ p s^{-1}$ (stat. only)

$\epsilon A^2 D^2 \approx 3.2 \pm 1.4 \%$
Non-$\phi$ KK contributions

$B^0_s \to J/\psi KK$ decays (non resonant or $f^0$) can bias the phase measurement. Included their contribution in full fit.

Non-$\phi$ component < 7% at 95%CL
Results – SM fit

World-leading measurements of $B^0_s$ lifetime, decay-width difference and decay polarization amplitudes

$ct_s = 458.6 \pm 7.5 \text{ (stat.)} \pm 3.6 \text{ (syst.)} \mu \text{m}$

$\Delta \Gamma = 0.075 \pm 0.035 \text{ (stat.)} \pm 0.01 \text{ (syst.)} \text{ ps}^{-1}$

$|A_\parallel(0)|^2 = 0.231 \pm 0.014 \text{ (stat)} \pm 0.015 \text{ (syst.)}$

$|A_0(0)|^2 = 0.524 \pm 0.013 \text{ (stat)} \pm 0.015 \text{ (syst.)}$

$\phi_\perp = 2.95 \pm 0.64 \text{ (stat)} \pm 0.07 \text{ (syst.)}$

PDG 2009: $\tau_s = 1.472^{+0.024}_{-0.026} \text{ ps}$

$\Delta \Gamma = 0.062^{+0.034}_{-0.037} \text{ ps}^{-1}$

CDF Public Note 10206
Results -- CPV fit

Allowed region for phase greatly reduced

Two solutions clearly separated.

Unfortunately the contour moved toward SM…

CDF Public Note 10206

\[ \beta_s \text{ in } [0.0, 0.5] \cup [1.1, 1.5] \text{ at 68\% CL (one-dimensional)} \]

\[ \beta_s \text{ in } [-0.1, 0.7] \cup [0.9, \pi/2] \cup [-\pi/2, -1.5] \text{ at 95\% CL (one-dimensional)} \]

P-value = 44\% wrt SM
Comparison

Something old…  
Something new…

P-value = 15% wrt SM  
P-value = 44% wrt SM

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PRL101 161802 (2008) topcite100+
Getting hot

Tevatron 2012: discover or exclude NP in wide range of phases. LHCb competitive (if everything turns out as expected)
More than 10 fb⁻¹ of physics-quality data on tape by end of 2011 (and perhaps keep running beyond)
Concluding remarks

$B^0_s$: one of our last resorts to avoid the MVF suicide.

CDF leading experimental force. With D0, unique exploration of this physics. May disclose long-awaited first whimpers of NP at the TeV scale.

First hints promising. Next 2-3 years crucial to determine whether we see BSM or just Poisson fluctuations around SM.

In addition, largest $B$ and $D$ samples available, challenge $B$ factories (charged final states)

Today just a small selection of recent results. Many others not mentioned. Stay tuned for 4+ brand new results at ICHEP in 2 weeks.

CDF have a key role in HF now, will keep it for a while, hopefully challenged by LHCb soon
Detailed MC-data validation using control mode.

Need for isolation and momentum reweighing.

< 4% residual discrepancies

\[ B \rightarrow \mu^+\mu^- \] – NN validation
### $B \rightarrow \mu^+\mu^-$ - background control

**Predicted vs observed backgrounds in 4 control sample for 3 different NN cuts: 24 independent checks of bckg estimation method.**

<table>
<thead>
<tr>
<th>sample</th>
<th>$NN$ cut</th>
<th>CMU-CMU</th>
<th>CMU-CMX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>pred</td>
<td>obsv</td>
</tr>
<tr>
<td>OS-</td>
<td>$0.80 &lt; \nu_{NN} &lt; 0.95$</td>
<td>275±(9)</td>
<td>287</td>
</tr>
<tr>
<td></td>
<td>$0.95 &lt; \nu_{NN} &lt; 0.995$</td>
<td>122±(6)</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>$0.995 &lt; \nu_{NN} &lt; 1.0$</td>
<td>44±(4)</td>
<td>41</td>
</tr>
<tr>
<td>SS+</td>
<td>$0.80 &lt; \nu_{NN} &lt; 0.95$</td>
<td>2.7±(0.9)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>$0.95 &lt; \nu_{NN} &lt; 0.995$</td>
<td>1.2±(0.6)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$0.995 &lt; \nu_{NN} &lt; 1.0$</td>
<td>0.6±(0.4)</td>
<td>0</td>
</tr>
<tr>
<td>SS-</td>
<td>$0.80 &lt; \nu_{NN} &lt; 0.95$</td>
<td>8.7±(1.6)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>$0.95 &lt; \nu_{NN} &lt; 0.995$</td>
<td>3.0±(1.0)</td>
<td>4</td>
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<tr>
<td></td>
<td>$0.995 &lt; \nu_{NN} &lt; 1.0$</td>
<td>0.9±(0.5)</td>
<td>0</td>
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<tr>
<td>FM+</td>
<td>$0.80 &lt; \nu_{NN} &lt; 0.95$</td>
<td>169±(7)</td>
<td>169</td>
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<tr>
<td></td>
<td>$0.95 &lt; \nu_{NN} &lt; 0.995$</td>
<td>55±(4)</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>$0.995 &lt; \nu_{NN} &lt; 1.0$</td>
<td>20±(2)</td>
<td>20</td>
</tr>
</tbody>
</table>
$B \rightarrow \mu^+\mu^- - \text{background control}$

Combinatorics from linear fit to sidebands. Use exp for systematics.
### B$\rightarrow \mu^+\mu^-$ - results

<table>
<thead>
<tr>
<th>Mass Bin (GeV)</th>
<th>5.310-5.334</th>
<th>5.334-5.358</th>
<th>5.358-5.382</th>
<th>5.382-5.406</th>
<th>5.406-5.430</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>UU NN bin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.80-0.95</td>
<td>Exp Bkg</td>
<td>9.66 ± 0.47</td>
<td>9.46 ± 0.46</td>
<td>9.27 ± 0.46</td>
<td>9.08 ± 0.46</td>
<td>8.88 ± 0.45</td>
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<tr>
<td></td>
<td>Obs</td>
<td>7</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>UU NN bin</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.95-0.995</td>
<td>Exp Bkg</td>
<td>3.42 ± 0.27</td>
<td>3.33 ± 0.27</td>
<td>3.25 ± 0.27</td>
<td>3.17 ± 0.26</td>
<td>3.09 ± 0.26</td>
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<tr>
<td></td>
<td>Obs</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>UU NN bin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.995-1.0</td>
<td>Exp Bkg</td>
<td>0.869 ± 0.17</td>
<td>0.821 ± 0.18</td>
<td>0.783 ± 0.19</td>
<td>0.75 ± 0.19</td>
<td>0.717 ± 0.21</td>
</tr>
<tr>
<td></td>
<td>Obs</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UX NN bin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.80-0.95</td>
<td>Exp Bkg</td>
<td>9.94 ± 0.48</td>
<td>9.8 ± 0.48</td>
<td>9.66 ± 0.48</td>
<td>9.51 ± 0.47</td>
<td>9.37 ± 0.47</td>
</tr>
<tr>
<td></td>
<td>Obs</td>
<td>12</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>UX NN bin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.95-0.995</td>
<td>Exp Bkg</td>
<td>3.5 ± 0.29</td>
<td>3.47 ± 0.29</td>
<td>3.43 ± 0.29</td>
<td>3.39 ± 0.29</td>
<td>3.36 ± 0.29</td>
</tr>
<tr>
<td></td>
<td>Obs</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>UX NN bin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.995-1.0</td>
<td>Exp Bkg</td>
<td>0.467 ± 0.14</td>
<td>0.438 ± 0.15</td>
<td>0.412 ± 0.15</td>
<td>0.387 ± 0.16</td>
<td>0.362 ± 0.16</td>
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<tr>
<td></td>
<td>Obs</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 10: $B_s$ signal window for CMU-CMU(top) and CMU-CMX(bottom): Expected backgrounds, including $B \rightarrow hh$, and number of observed events.
Checks
Checks

CDF Run II Preliminary

$L = 5.2 \text{ fb}^{-1}$

- S-wave not included
- S-wave included

$\Delta \Gamma (\text{ps}^{-1})$

$\beta_s \text{ (rad)}$

5.99
2.30
Mixing phase - *Enforcing coverage*

Remap observed $2\Delta\log L$ distribution in terms of actual CL from toys. E.g. to get the 95.5% CL, $2\Delta\log L \sim 9$ units (as opposed to 5.99 asymptotic)

Include systematics: vary nuisance parameters within 5\(\sigma\) of their estimates on data. Use worst case.

\[ -2\log L \]

\[ \text{parameter} \]

\[ \begin{array}{c}
\text{Standard likelihood ratio method fails} \\
\end{array} \]

\[ -2\log L \]

\[ \begin{array}{c}
\text{parameter} \\
\end{array} \]

\[ \begin{array}{c}
\text{Gaussian} \\
\text{reality} \\
\end{array} \]

\[ \begin{array}{c}
\text{non-Gaussian} \\
\text{Gaussian} \\
\text{68\% CL} \\
\text{95\% CL} \\
\end{array} \]

\[ \text{arXiv:0810.3229} \]
Fit mass and helicity angles of final state kaons.

\[ B^0_s \rightarrow \phi\phi - \text{angular analysis} \]
How large correction?

CDF Run II Preliminary $L = 5.2 \text{ fb}^{-1}$

- Red: 5.99
- Blue: 2.30
- Black: SM prediction

Just out of the fit

Adjusted for non-Gaussian tails

Adjusted for non-Gaussian tails and systematics
# Systematics

| Systematic                                         | $\Delta \Gamma$ | $c\tau_s$ | $|A_{||}(0)|^2$ | $|A_0(0)|^2$ | $\phi_\perp$ |
|---------------------------------------------------|-----------------|-----------|----------------|----------------|--------------|
| Signal efficiency:                                 |                 |           |                |                |              |
| Parameterisation                                   | 0.0024          | 0.96      | 0.0076         | 0.008          | 0.016        |
| MC reweighting                                     | 0.0008          | 0.94      | 0.0129         | 0.0129         | 0.022        |
| Signal mass model                                  | 0.0013          | 0.26      | 0.0009         | 0.0011         | 0.009        |
| Background mass model                              | 0.0009          | 1.4       | 0.0004         | 0.0005         | 0.004        |
| Resolution model                                   | 0.0004          | 0.69      | 0.0002         | 0.0003         | 0.022        |
| Background lifetime model                          | 0.0036          | 2.0       | 0.0007         | 0.0011         | 0.058        |
| Background angular distribution:                   |                 |           |                |                |              |
| Parameterisation                                   | 0.0002          | 0.02      | 0.0001         | 0.0001         | 0.001        |
| $\sigma(c\tau)$ correlation                       | 0.0002          | 0.14      | 0.0007         | 0.0007         | 0.006        |
| Non-factorisation                                  | 0.0001          | 0.06      | 0.0004         | 0.0004         | 0.003        |
| $B^0 \rightarrow J_\psi K^*$ crossfeed            | 0.0014          | 0.24      | 0.0007         | 0.0010         | 0.006        |
| SVX alignment                                      | 0.0006          | 2.0       | 0.0001         | 0.0002         | 0.002        |
| Mass error                                         | 0.0001          | 0.58      | 0.0004         | 0.0004         | 0.002        |
| $c\tau$ error                                      | 0.0012          | 0.17      | 0.0005         | 0.0007         | 0.013        |
| Pull bias                                          | 0.0028          |           | 0.0013         | 0.0021         |              |
| **Totals**                                         | **0.01**        | **3.6**   | **0.015**      | **0.015**      | **0.07**     |
Detector sculpting

Angular sculpting from simulation.

Validated comparing with combinatorial background and measuring polarization of $B^0 \rightarrow J/\psi K^*$ decays consistent with B-factories.

CDF Run II Preliminary 5.2 fb$^{-1}$

Distribution of combinatorial background (sidebands data)

Angular sculpting from simulation
Efficiency = 94%. Dilution = 11% (correct tag probability ~56%)

Total tagging power = 1.2%
Nasty likelihood

Each plot is the result of the measurement from a single pseudo-experiment.
All experiments generated with same true values. Results vary wildly.
For starters – SM fit

Determination of $B^0_s$ polarization amplitudes by imposing $\beta_s=0$
The CDF approach

Data-driven. 1.6 fb⁻¹

Use superior impact parameter resolution (45 µm) to unfold dimuons from $b$, $c$, and prompt sources

Nailing down sample composition ensures your dimuons come from B.

But impact parameter requires silicon tracking, which reduces statistics

If repeated on current sample a factor of ~2 worse resolution than DØ.

Would be non-informative

$A_{SL} = (0.8 \pm 0.9 \pm 0.7) \%$