Mirco Dorigo  
(INFN and University of Trieste)  
On behalf of the CDF and DØ Collaborations  

Recent Heavy Flavor Results from the Tevatron
Flavor Matters

- Generic new couplings could introduce new sources of flavor/CP violation.
- If NP scale above LHC reach: flavor might be the only way to probe it…

Will focus on latest searches for NP through flavor at the **Tevatron**.

**All New results**
for Winter 2012

- ✓ CDF CPV in Charm w/ Full Run II Dataset
- ✓ CDF Search for $B \rightarrow \mu\mu$ w/ Full Run II Dataset
- ✓ CDF CPV in $B_s$ mixing w/ Full Run II Dataset
- ✓ DØ new State Decaying into $\Upsilon(1S)+\gamma$
CPV in Charm
Probe the up-quark sector.
Direct CPV >1% level suggestive of NP.

CDF 2011: trigger on displaced tracks - huge charm samples and unprecedented sensitivity in

\[
A_{\text{CP}}(D^0 \rightarrow K^+K^-) = (-0.24 \pm 0.22 \pm 0.10)\
A_{\text{CP}}(D^0 \rightarrow \pi^+\pi^-) = (+0.22 \pm 0.24 \pm 0.11)\%
\]

**PRD85, 012009 (2012)**

\[
\Delta A_{\text{CP}} = A_{\text{CP}}(D^0 \rightarrow K^+K^-) - A_{\text{CP}}(D^0 \rightarrow \pi^+\pi^-)
\]

maximally sensitive to NP.

Experimentally convenient: instrumental asymmetries cancel.

First evidence of CPV in charm from LHCb

\[
\Delta A_{\text{CP}} = (-0.82 \pm 0.21 \pm 0.11)\%, \ \text{3.5}\sigma \text{ from zero.}
\]

**arXiv1112.0938**

Independent confirmation crucial to establish it.
Optimize off-line selection for $\Delta A_{\text{CP}}$

✓ loosen selection requirements (no $D^0$ I.P. cut) w.r.t. 5.9 fb$^{-1}$ analysis:
  no need of $D^0 \rightarrow K\pi$.
✓ about double signal events.

$D^0$ flavor through $D^* \rightarrow D^0 \pi_s$

✓ soft pion induce $O(1\%)$ artificial asymmetries.

Cancel detector effects by differences of raw asymmetries:

$$\Delta A_{\text{CP}} = (A(K^+K^-) + \langle \delta(\pi_s) \rangle) - (A(\pi^+\pi^-) + \langle \delta(\pi_s) \rangle)$$

![Graph for $D^0$ and $\bar{D}^0$ distributions with mass bins and fit comparison](image-url)
$\Delta A_{CP} = (-0.62 \pm 0.21 \text{(stat)} \pm 0.10 \text{(syst)})\%$

CDF Note 10784

Confirm LHCb result $\Delta A_{CP} = (-0.82 \pm 0.21 \pm 0.11)\%$

When combining à la HFAG No CPV point is at $\sim 4\sigma$ from zero

$\Delta A_{CP}^{\text{dir}} = (-0.67 \pm 0.16)\%$

$A_{CP}^{\text{ind}} = (-0.02 \pm 0.22)\%$
SM rates well understood
\[ \text{BR}(B_s^0 \rightarrow \mu^+ \mu^-) = (3.2 \pm 0.2) \times 10^{-9}, \text{BR}(B^0 \rightarrow \mu^+ \mu^-) = (1.0 \pm 0.1) \times 10^{-10} \]

Important constraint for BSM building.

Long history of Tevatron searches brought down over orders of magnitude the upper limit to the $10^{-8}$ range.

Until last summer…

Interesting $\sim 2.5 \sigma$ deviation from bkg observed by CDF in 7 fb$^{-1}$.

Compatible with other experiments and SM.

CDF update the analysis with whole Run II sample (10 fb$^{-1}$, +30% data) while keeping the analysis unchanged.

No improvement with BDT.

August 2011
Clean signature
✓ Trigger on 2 muons with \( p_T > 1.5\text{-}2 \text{ GeV}/c \)

Challenge: reject \( 10^6 \) larger background while keeping the signal efficiency high.
✓ Optimized NN classifier separates S from B. Use of 14 discriminanting variables.

Combinatorial bkg predicted from mass sideband (dominant) and fake rates for \( B \rightarrow h^+h^- \). Checked on many control samples.

Rate determined using \( B^+ \rightarrow J/\psi K^+ \) as reference.
Observed limit $< 4.6 \times 10^{-9}$ (Expected $4.2 \times 10^{-9}$). Consistent with SM. p-value for background-only hypothesis is 41%.

$B^0 \rightarrow \mu^+ \mu^-$ important analysis benchmark for $B_s^0 \rightarrow \mu^+ \mu^-$
\(0.8 \times 10^{-9} < \text{BR}(B_s \rightarrow \mu\mu) < 3.4 \times 10^{-8} \quad \text{at 95\% C.L.} \quad \left[ \text{BR} = (1.3^{+0.9}_{-0.7}) \times 10^{-8} \right]

Bkg+SM p-value 7.1\%. Bkg-only p-value 0.94\%

Summer deviation not reinforced by new data, but still >2\(\sigma\) for bkg-only hypothesis.
As of Last Week

Getting extremely interesting... nearing the sensitivity to see the first signal!
Search for NP in $B_s$ Mixing
Search for NP in $B_s$ Mixing

$B_s$ mixing phenomenology can be significantly altered by NP.

2011 DØ: $\sim 4\sigma$ deviation from SM in $B$ semileptonic asymmetry.

Independent cross-check is crucial.

Constrain BSM physics through

- CP-violating mixing phase largely suppressed in SM
- $B_s^{H} - B_s^{L}$ decay difference

Indeed: $a_{sl}^s \approx \left(\frac{\Delta \Gamma_s}{\Delta m_s}\right) \tan \phi_s$

CDF updates measurements with full Run II data.
Exploit interference between $B_s^0 \rightarrow J/\psi \phi$ decays w/ and w/o flavor oscillations.

- low $p_T$ dimuon trigger. Off-line optimized NN selection @CDF; BDT/square cuts @DØ.

- joint fit to mass, production flavor, decay-time, decay-angles

Look at other $B (\varepsilon D^2 \sim 1.4\%)$ +
Look at $K$ in fragmentation with $B_s (\varepsilon D^2 \sim 3\%)$

Disentangle CP-even/CP-odd final state
Include $J/\psi KK$ S-wave contribution

Trace the time-evolution and fast $B_s$ oscillations
Mixing Phase Bounds

Both experiments consistent with SM ($< 1 \sigma$).

CDF Run II Preliminary $L = 9.6 \text{ fb}^{-1}$

$\Delta \Gamma_s$ in $[-0.60, 0.12]$ rad @ 68% C.L.

CDF Note 10778

$\phi_s$ in $[-0.60, 0.12]$ rad @ 68% C.L.

$\phi_s = -0.55^{+0.38}_{-0.36}$ rad

Strong phases fitting range restricted based on $B^0 \rightarrow J/\psi K^*$
Decay Width Difference and Lifetime

Assuming SM CP-violation, new CDF measurement with full Run II dataset

$$\Delta \Gamma_s = 0.068 \pm 0.026 \pm 0.007 \text{ ps}^{-1}$$

$$\tau_s = 1.528 \pm 0.019 \pm 0.009 \text{ ps}$$

CDF Note 10778

**DØ:** $\Delta \Gamma_s = 0.163^{+0.065}_{-0.064} \text{ ps}^{-1}$

$$\tau_s = 1.443^{+0.038}_{-0.035} \text{ ps}$$

PRD 85, 032006 (2012)

Very interesting to constrain $A_{SL}$ (for instance, A. Lenz @Moriond EW 2012)
new State $\chi_b(3P)$
**new State Decaying into $Y(1S) + \gamma$**

While waiting for NP…

Confirm ATLAS observation ([arXiv:1112.5154](https://arxiv.org/abs/1112.5154)) of new state $\chi_b(3P) \rightarrow Y(1S) + \gamma$

$$M[\chi_b(3P)] = 10.551 \pm 0.014 \pm 0.017 \text{ GeV}$$
Conclusions
Tevatron keeps producing new, important results on the benchmark channels of heavy flavor physics with Full Run II dataset

**CPV in Charm sector**
CDF confirms LHCB’s evidence of CPV in charm with same precision

**Rare B decays**
Extension to full sample confirms summer result

**B_s mixing**
Closer to SM expectations. $A_{SL}$ needs independent check.

**Confirmation of $\chi_b(3P)$**

Pioneered and established role of hadron collisions in HF. Keep improving flagship measurements updated to full statistics.

Don't relax just yet – a few aces still up our sleeve!
And Many More...

For more NEW results since summer 2011:
CDF Heavy Flavor Group web page
DØ Heavy Flavor Group web page

- Measurement of $\text{BR}(B^0_s \rightarrow D^{(*)}_s + D^{(*)}_s)$
- Search for CP Violation in $D^0 \rightarrow K_S \pi^+ \pi^-$
- First 3-dimensional measurement of the $Y(nS)$ spin-alignment
- Fragmentation Study with $D^\pm_s/D^\pm K$ Correlations
- Measurement of the $B_c$ lifetime
- … … …
CDF and DØ demonstrated that cutting-edge HF physics is possible with hadron collisions in addition to high-\(p_T\) program

- **Tevatron**: \(10^{13} p\bar{p}\) collisions @ 2 TeV in 10 years: \(\approx 10 \text{ fb}^{-1}\) on tape per experiment. Shut down 30\(^{th}\) Sept. 2011.

- High-rate of all species of heavy flavors – \(B_d, B_c, B_s\), 5 new baryons (\(\Sigma_b^\pm, \Xi_b^{0-}, \Omega_b^-\)), copious D.

- Tracking: \(\sigma(p_T)/p_T^2=0.1\%\). Vertex known within 20 \(\mu\)m. Good muons. Some PID (1.5 \(\sigma\)).

- From 2001 silicon to trigger for tracks displaced from \(p\bar{p}\) vertex. Trigger with low-\(p_T\) leptons: both single and pairs.
More on $B_s$

$B_s \to D_s^{(*)+} D_s^{(*)-}$ Branching Ratio

Predominately CP-even. May give dominant contribution to $B_s$ width difference in SM.

6.8 fb$^{-1}$ collected by displaced track trigger

Simultaneous fit to signal $B_s^0 \to D_s^{(*)+} D_s^{(*)-}$ and normalization mode $B^0 \to D_s^{(*)+} D_s^{(*)-}$

$D_s^{(*)+} \to K^+ K^- \pi^+$ Dalitz structure for precise determination of acceptance.

Precise BR measurements

$$BR(B_s \to D_s^{(*)+} D_s^{(*)-}) = (0.49 \pm 0.06 \pm 0.05 \pm 0.08) \%,$$

$$BR(B_s \to D_s^{(*)+} D_s^{(*)-}) = (1.13 \pm 0.12 \pm 0.09 \pm 0.19) \%,$$

$$BR(B_s \to D_s^{(*)+} D_s^{(*)-}) = (1.75 \pm 0.19 \pm 0.17 \pm 0.29) \%,$$

$$BR(B_s \to D_s^{(*)+} D_s^{(*)-}) = (3.38 \pm 0.25 \pm 0.30 \pm 0.56) \%,$$

Under some theoretical assumptions, from BR possible to infer

$$\Delta \Gamma_s / \Gamma_s = (6.99 \pm 0.54 \pm 0.64 \pm 1.20)\%$$
Soft pion induce $O(1\%)$ artificial asymmetries. Cancel detector effects by differences of raw asymmetries:

$$\Delta A_{CP} = (A(K^+K^-) + \delta(\pi_s)) - (A(\pi^+\pi^-) + \delta(\pi_s))$$

Detector asymmetries are kinematic dependent, cancellation works if $\pi_s$ distributions are the same between KK and $\pi\pi$. Make them equal by reweighting.
Raw asymmetries:

\[ A(\pi\pi^*) = (-1.71 \pm 0.15)\%, \]
\[ A(KK^*) = (-2.33 \pm 0.14)\%. \]
<table>
<thead>
<tr>
<th>Source</th>
<th>$\Delta A_{CP}$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximations in the suppression of detector-induced effects</td>
<td>0.009</td>
</tr>
<tr>
<td>Shapes assumed in fits</td>
<td>0.020</td>
</tr>
<tr>
<td>Charge-dependent mass distributions</td>
<td>0.100</td>
</tr>
<tr>
<td>Asymmetries from residual backgrounds</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.103</strong></td>
</tr>
</tbody>
</table>
Another Charm Results

NEW At CDF full Dalitz analysis at Hadron Collider with $D^0 \rightarrow K_S \pi^+ \pi^-$

Big improvement w.r.t. CLEO results ([PRD70, 091101 (2004)](https://journals.aps.org/prd/abstract/10.1103/PhysRevD.70.091101))

$$A_{CP}(D^0 \rightarrow K_S \pi^+ \pi^-) = (-0.05 \pm 0.57 \pm 0.54)\%$$
$\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-) = \frac{N_s}{N_+} \cdot \frac{\alpha_+}{\alpha_s} \cdot \frac{\epsilon_+}{\epsilon_s} \cdot \frac{1}{\epsilon_N} \cdot \frac{f_u}{f_s} \cdot \mathcal{B}(B^+)$, PDG

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

$B^+ \rightarrow J/\psi K^+$ decays from data approx. 20K

Efficiency of NN requirement from MC, approx. 80-20% (cut-dependent)
Significance of 3\textsuperscript{rd} bin excess decreases with new data: support interpretation as statistical fluctuation.

Unlikely to be peaking bckg. Only one is $B \to hh$. Is 10x larger in $B^0$ window where nothing is seen.

Unlikely to be syst. problem with combinatorial. Same procedure in $B^0$ where nothing is seen.

Unlikely to be NN-shape issue. Cross-check with $B^+$ looks good within <5%. And several crosscheck show no mass bias vs NN

We conclude this is a fluctuation. Not unlikely in one out of 80 bins. Using last 2 bins only:

$BR = (1.0^{+0.8}_{-0.6}) \times 10^{-8}$

$0.8 \times 10^{-9} < BR(B_s \to \mu\mu) < 2.5 \times 10^{-8}$ @ 95% C.L.

$BR(B_s \to \mu\mu) < 2.9 \times 10^{-8}$ @ 95% C.L.

No significant impact on result
### Table: $B_s^0 \rightarrow \mu^+\mu^-$: Expected vs Observed

<table>
<thead>
<tr>
<th>Mass Bin (GeV)</th>
<th>5.31-5.334</th>
<th>5.334-5.358</th>
<th>5.358-5.382</th>
<th>5.382-5.406</th>
<th>5.406-5.43</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC NN bin Exp Bkg</td>
<td>2.56±0.34</td>
<td>2.52±0.33</td>
<td>2.49±0.33</td>
<td>2.46±0.32</td>
<td>2.42±0.32</td>
<td>12.45</td>
</tr>
<tr>
<td>0.7-0.76 Obs</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>CC NN bin Exp Bkg</td>
<td>2.77±0.35</td>
<td>2.73±0.35</td>
<td>2.69±0.34</td>
<td>2.66±0.34</td>
<td>2.62±0.33</td>
<td>13.47</td>
</tr>
<tr>
<td>0.76-0.85 Obs</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>CC NN bin Exp Bkg</td>
<td>1.22±0.23</td>
<td>1.2±0.23</td>
<td>1.18±0.22</td>
<td>1.17±0.22</td>
<td>1.15±0.22</td>
<td>5.92</td>
</tr>
<tr>
<td>0.85-0.9 Obs</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>8</td>
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<tr>
<td>CC NN bin Exp Bkg</td>
<td>1.05±0.21</td>
<td>1.03±0.21</td>
<td>1.02±0.21</td>
<td>1.01±0.2</td>
<td>0.99±0.2</td>
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<tr>
<td>0.9-0.94 Obs</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>CC NN bin Exp Bkg</td>
<td>1.05±0.21</td>
<td>1.04±0.21</td>
<td>1.02±0.21</td>
<td>1.01±0.2</td>
<td>0.99±0.2</td>
<td>5.11</td>
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<tr>
<td>0.94-0.97 Obs</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>CC NN bin Exp Bkg</td>
<td>0.63±0.18</td>
<td>0.62±0.17</td>
<td>0.61±0.17</td>
<td>0.6±0.17</td>
<td>0.6±0.17</td>
<td>3.07</td>
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<tr>
<td>0.97-0.987 Obs</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>CC NN bin Exp Bkg</td>
<td>0.13±0.08</td>
<td>0.13±0.08</td>
<td>0.12±0.07</td>
<td>0.12±0.07</td>
<td>0.12±0.07</td>
<td>0.62</td>
</tr>
<tr>
<td>0.987-0.995 Obs</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>CC NN bin Exp Bkg</td>
<td>0.11±0.07</td>
<td>0.09±0.07</td>
<td>0.08±0.07</td>
<td>0.08±0.07</td>
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<tr>
<td>0.995-1 Obs</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

| CF NN bin Exp Bkg | 1.74±0.28 | 1.72±0.27 | 1.69±0.27 | 1.67±0.27 | 1.64±0.26 | 8.46 |
| 0.7-0.76 Obs | 2 | 3 | 3 | 2 | 1 | 11 |
| CF NN bin Exp Bkg | 1.83±0.28 | 1.8±0.28 | 1.78±0.28 | 1.75±0.27 | 1.72±0.27 | 8.88 |
| 0.76-0.85 Obs | 1 | 5 | 2 | 2 | 0 | 10 |
| CF NN bin Exp Bkg | 1.23±0.23 | 1.21±0.23 | 1.2±0.23 | 1.18±0.22 | 1.16±0.22 | 5.99 |
| 0.85-0.9 Obs | 0 | 0 | 3 | 0 | 1 | 4 |
| CF NN bin Exp Bkg | 0.81±0.19 | 0.8±0.18 | 0.78±0.18 | 0.77±0.18 | 0.76±0.18 | 3.92 |
| 0.9-0.94 Obs | 2 | 1 | 2 | 2 | 1 | 8 |
| CF NN bin Exp Bkg | 0.68±0.17 | 0.67±0.17 | 0.66±0.17 | 0.65±0.16 | 0.64±0.16 | 3.3 |
| 0.94-0.97 Obs | 1 | 1 | 0 | 0 | 0 | 2 |
| CF NN bin Exp Bkg | 0.38±0.13 | 0.38±0.13 | 0.37±0.13 | 0.37±0.13 | 0.36±0.13 | 1.86 |
| 0.97-0.987 Obs | 0 | 2 | 0 | 0 | 1 | 3 |
| CF NN bin Exp Bkg | 0.17±0.09 | 0.17±0.09 | 0.17±0.09 | 0.16±0.09 | 0.16±0.09 | 0.83 |
| 0.987-0.995 Obs | 0 | 0 | 1 | 0 | 0 | 1 |
| CF NN bin Exp Bkg | 0.18±0.11 | 0.17±0.11 | 0.17±0.11 | 0.16±0.11 | 0.16±0.11 | 0.83 |
| 0.995-1 Obs | 0 | 0 | 0 | 0 | 0 | 0 |

Table: $B_s$ signal window for CC (top) and CF (bottom): Expected backgrounds including $B \rightarrow hh$, and number of observed events.

**Expected Limit is:** $BR < 1.3 \times 10^{-8}$ at 95% (90%) CL
### Table: $B^0 \rightarrow \mu^+ \mu^-$: Table

<table>
<thead>
<tr>
<th>Mass Bin (GeV)</th>
<th>CC NN bin</th>
<th>Exp Bkg</th>
<th>5.219-5.243</th>
<th>5.243-5.267</th>
<th>5.267-5.291</th>
<th>5.291-5.315</th>
<th>5.315-5.339</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7-0.76</td>
<td>Obs</td>
<td>2.69±0.35</td>
<td>2.65±0.35</td>
<td>2.62±0.34</td>
<td>2.58±0.34</td>
<td>2.55±0.34</td>
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<td>0.76-0.85</td>
<td>Obs</td>
<td>2.91±0.37</td>
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<td>0.85-0.9</td>
<td>Obs</td>
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<td>1.26±0.24</td>
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<td>0.9-0.94</td>
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<td>0.94-0.97</td>
<td>Obs</td>
<td>1.11±0.22</td>
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<td>Obs</td>
<td>0.16±0.08</td>
<td>0.15±0.08</td>
<td>0.15±0.08</td>
<td>0.14±0.08</td>
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<td>0.995-1</td>
<td>Obs</td>
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<td>0.12±0.07</td>
<td>0.1±0.07</td>
<td>0.72</td>
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</table>

<table>
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<td>0.7-0.76</td>
<td>Obs</td>
<td>1.84±0.29</td>
<td>1.81±0.29</td>
<td>1.79±0.28</td>
<td>1.76±0.28</td>
<td>1.74±0.28</td>
<td>8.93</td>
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<tr>
<td>0.76-0.85</td>
<td>Obs</td>
<td>1.93±0.3</td>
<td>1.9±0.3</td>
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<td>1.3±0.24</td>
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</tr>
<tr>
<td>0.9-0.94</td>
<td>Obs</td>
<td>0.85±0.2</td>
<td>0.84±0.19</td>
<td>0.83±0.19</td>
<td>0.82±0.19</td>
<td>0.81±0.19</td>
<td>4.15</td>
<td></td>
</tr>
<tr>
<td>0.94-0.97</td>
<td>Obs</td>
<td>0.72±0.18</td>
<td>0.71±0.18</td>
<td>0.7±0.18</td>
<td>0.69±0.17</td>
<td>0.68±0.17</td>
<td>3.49</td>
<td></td>
</tr>
<tr>
<td>0.97-0.987</td>
<td>Obs</td>
<td>0.41±0.14</td>
<td>0.4±0.14</td>
<td>0.4±0.14</td>
<td>0.39±0.14</td>
<td>0.38±0.13</td>
<td>1.98</td>
<td></td>
</tr>
<tr>
<td>0.987-0.995</td>
<td>Obs</td>
<td>0.18±0.1</td>
<td>0.18±0.09</td>
<td>0.18±0.09</td>
<td>0.17±0.09</td>
<td>0.17±0.09</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>0.995-1</td>
<td>Obs</td>
<td>0.2±0.12</td>
<td>0.2±0.12</td>
<td>0.19±0.12</td>
<td>0.18±0.11</td>
<td>0.17±0.11</td>
<td>0.94</td>
<td></td>
</tr>
</tbody>
</table>

**Table:** $B_d$ signal window for CC (top) and CF (bottom): Expected backgrounds including $B \rightarrow hh$, and number of observed events.

**Expected Limit is:** $BR < 4.2\, (3.4) \times 10^{-9}$ at 95% (90%) CL
$B_s^0 \rightarrow \mu^+ \mu^-$ Result

CDF II Preliminary 9.7 fb$^{-1}$

$\Delta \chi^2$

SM

95% Bound

90% Bound

68% Bound

$\times 10^{-9}$

$BR(B_s \rightarrow \mu^+ \mu^-)$
\[ \Delta \Gamma_s : \text{Systematics} \]

| Source of systematic effect          | \( c\tau(B_s^0) [\mu \text{ m}] \) | \( \Delta \Gamma \ [\text{ps}^{-1}] \) | \( |A_{||}(0)|^2 \) | \( |A_0(0)|^2 \) | \( \delta_{\perp} \) |
|-------------------------------------|-------------------------------------|-------------------------------------|----------------|----------------|----------------|
| Signal Angular Efficiency           | 0.29                                | 0.0014                             | 0.0134         | 0.0162         | 0.076          |
| Mass Signal Model                   | 0.17                                | 0.0007                             | 0.0006         | 0.0020         | 0.018          |
| Mass Bkg Model                      | 0.14                                | 0.0006                             | 0.0003         | 0.0002         | 0.034          |
| ct Resolution                       | 0.52                                | 0.0010                             | 0.0004         | 0.0002         | 0.066          |
| ct Bkg                              | 1.31                                | 0.0057                             | 0.0006         | 0.0012         | 0.064          |
| Angular Bkg                         | 0.46                                | 0.0037                             | 0.0011         | 0.0022         | 0.009          |
| Sigma mass                          | 0.85                                | 0.0006                             | 0.0003         | 0.0002         | 0.036          |
| Sigma ct                            | 0.63                                | 0.0006                             | 0.0003         | 0.0002         | 0.038          |
| \( B_d \rightarrow J/\psi K^* \) cross-feed | 0.18                                | 0.0018                             | 0.0002         | 0.0015         | 0.034          |
| SVX alignment                       | 2.0                                 | 0.0004                             | 0.0002         | 0.0001         | 0.034          |
| Pull bias                           | 0.2                                 | 0.0012                             | 0.0021         | 0.0008         | 0.02           |
| **TOT**                             | **2.7**                             | **0.007**                          | **0.014**      | **0.017**      | **0.15**       |
two samples: 2 billion single $\mu$ and 6 million di-$\mu$ in 9 fb$^{-1}$. $p_T > 1.5-4.2$ GeV/c

Measure +/- asymmetry in both samples

Asymmetry washed by muons from non-oscillating sources (from MC)

Asymmetry biased by background asymmetries from instrumental effects

Kaon contribution measured in data, pions extrapolated from MC.

Combine asymmetries from single-$\mu$ and di-$\mu$ samples to subtract common backgrounds
\[ A_{SL}: \text{Muons from } B? \]

Reduce the contamination of background of non-B decays cutting on IP of the muons.

Perform test on two subsamples with IP less/greater than 120 micron. Reduce statistical resolution, but results consistent with default analysis.

IP > 120 micron more \( B^0 \)-like \( \mu \)
IP < 120 micron more \( B_s \)-like \( \mu \)

\[
\begin{align*}
A_{sl}^d &= (-0.12 \pm 0.52)\% \\
A_{sl}^s &= (-1.81 \pm 1.06)\%
\end{align*}
\]

Highly correlated \( \rho_{ds} = -0.799 \).