A New Expected Upper Limit on the Rare Decay $B_s \rightarrow \mu^+\mu^-$ with the DØ Experiment

Isabelle Ripp-Baudot

IPHC - CNRS/IN2P3 and Strasbourg University

on behalf of the DØ collaboration
FCNC processes have very low rate in SM:
\[ \mathcal{B}(B_s \rightarrow \mu^- \mu^+)_{\text{SM}} = (3.6 \pm 0.3) \times 10^{-9} \]

Whereas many Beyond SM theories predict enhancements → sensitivity to new physics.

Best current limit:  < 5.8 \times 10^{-8} \ (95\% \ CL) by CDF with 2 \ fb^{-1} \ PRL 100, 101802 (2008)

DØ-Run II previous limits on \( \mathcal{B}(B_s \rightarrow \mu^- \mu^+) \):
-  < 5.0 \times 10^{-7} \ (95\% \ CL) with 240 \ pb^{-1} \ PRL 94, 071802 (2005)
-  < 1.2 \times 10^{-7} \ (95\% \ CL) with 1.3 \ fb^{-1} \ PR D 76, 092001 (2007)
-  < 9.3 \times 10^{-8} \ (95\% \ CL) with 2 \ fb^{-1} \ preliminary
-  in this talk: preliminary with 5 \ fb^{-1}

Still room for new physics in this decay!
Run II (since 2001):
- $\sqrt{s} = 1.96$ TeV,
- inst. lumi $\approx 3.5 \times 10^{32}$ cm$^{-2}$s$^{-1}$,
- total lumi. > 6 fb$^{-1}$ recorded by DØ.

**Tevatron offers:**
- unique opportunity to study $B_s$,
- large $b\bar{b}$ production rate,
- high integrated luminosity.

**But also:**
- high track multiplicity environment.

- **good muon** identification with **wide acceptance** ($|\eta| < 2$) in DØ
  → highly **selective triggers**
Complete set of **di-μ triggers** in DØ Run II < Dec/2008, corresponding to 5 fb⁻¹ of integrated luminosity.

Data are divided in 3 independent sub-samples corresponding to different trigger lists:
- Run IIa: 1.3 fb⁻¹
- Run IIb-I: 1.9 fb⁻¹
- Run IIb-II: 1.6 fb⁻¹

→ underlying differences w.r.t. the instantaneous luminosity.

\[
\text{Isolation} = \frac{p_T(B)}{p_T(B) + \sum p_T(trk)}
\]
in cone \( \Delta R < 1 \)
**Normalized to** $B^+ \rightarrow J/\psi K^+ \rightarrow \mu\mu K^+$, with B.R. $\sim 10^{-5}$.

$$
\mathcal{B}(B_s^0 \rightarrow \mu\mu) = \frac{N(B_s \rightarrow \mu\mu)}{N(B^+ \rightarrow J/\psi K^+)} \times \frac{\varepsilon(B^+)}{\varepsilon(B_s^0)} \times f\left(\frac{b \rightarrow B^+}{b \rightarrow B_s^0}\right) \times \mathcal{B}(B^+ \rightarrow J/\psi K^+, J/\psi \rightarrow \mu\mu)
$$

- $B^0 \rightarrow \mu\mu$ suppressed by $|V_{td}/V_{ts}|^2$: neglected
- same reconstruction & selection than $B_s \rightarrow \mu\mu$: syst. cancellation.
- Observed
- 2006 PDG values used for consistency with CDF from MC
Bs→μμ selection

- preselection by sequential cuts: μ, q(μμ), p_T(μ), angle(μμ), IP(μ)/σ_{IP}, p_T(B), L(B)/σ_L, σ_L(B), χ^2(vtx).
- further background rejection: **Boosted Decision Tree** built with 5 discriminating variables: L_x/σ_{L_x}, IP/σ_{IP}, χ_{vtx}^2, Bs isolation, p_T(μμ).
- training: signal = MC, background = sideband data.
- one additional track for B^+ reconstruction.

Optimization:
- maximize the Punzi parameter \( P = \frac{S}{\alpha/2 + \sqrt{B}} \) with \( \alpha=2 \) for 95 % CL. physics/0308063

- **signal region blinded**, S taken from SM for optimization.
**Background $B$:** $B_s \rightarrow K^+ K^-$ and $B^0 \rightarrow K^+ \pi^-$ contributions + combinatorial background.

**$B_s \rightarrow \mu \mu$**

**$B^+ \rightarrow J/\psi K^+$**

Background: $B \rightarrow J/\psi K^+$ + $B^+ \rightarrow J/\psi \pi^+$ contributions + combinatorial background.
**$B_s\to\mu\mu$ expected limit**

- signal region remains **blind**, upper limit calculated assuming no signal in the blind region:
  
  \[
  \text{observed } N(B_s\to\mu\mu) = \text{estimated } N(\text{background})
  \]

- **expected 95% (90%) CL upper limits on $B_s\to\mu\mu$ with 5 fb$^{-1}$ of DØ data:**

  \[
  \begin{align*}
  \text{Run IIa:} & \quad < 9.4 \quad (7.6) \times 10^{-8} \\
  \text{Run IIb-I:} & \quad < 11.0 \quad (9.9) \times 10^{-8} \\
  \text{Run IIb-II:} & \quad < 13.0 \quad (10.0) \times 10^{-8}
  \end{align*}
  \]

  **combined upper limit: 5.3 (4.3) \times 10^{-8}**

- main syst.: $f_s/f_d$, observed $N(B^+)$, $p_T(B_s)$ spectrum.

- sensitivity with 2008 PDG values is about 10 % lower.

- improvements (in progress):
  - include single-$\mu$ triggers,
  - improve selection to reduce the background.

**and then... open the box!**
• DØ reports the current **world best sensitivity on** $B_s \rightarrow \mu \mu$, which is at the same level than CDF result.

• Tevatron limits are now a factor 10 above the SM:
  - still room for new physics ☺,
  - add data and combine DØ with CDF.

• Very good performance from the Tevatron:
  - 5 fb$^{-1}$ analysed in this measurement,
  - more than **6 fb$^{-1}$ already stored**, 
  - twice as much data expected at the end of Tevatron RunII.

→ **further significant reduction of theoretical parameter space can be expected as more data are included.**