Search for the $B_s$ and $B^0$ decays to dimuons with the CMS experiment

Luca Martini (INFN Pisa & Uni Siena) for the CMS collaboration

Rencontres de Moriond on "Electroweak Interactions and Unified Theories"
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Motivation: search for new physics

In SM $B_s^0 \rightarrow \mu\mu$ and $B^0 \rightarrow \mu\mu$ have a highly suppressed rate:
1. **forbidden at tree level** and can only proceed through higher-order loop diagrams
2. **helicity suppressed** by factors of $(m_l/m_B)^2$, where $m_l$ and $m_B$ are the masses of the lepton and B meson
3. **require an internal quark annihilation** within the B meson

$\text{BF}(B_s^{0(\tau)} \rightarrow \mu\mu)$ are potentially sensitive probes for Physics Beyond SM:
- Sensitivity to extended Higgs boson sectors
- Constraints on SUSY parameter regions
- Small theoretical uncertainties

<table>
<thead>
<tr>
<th>Decay channel</th>
<th>BF SM predictions*</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_s^0 \rightarrow \mu^+\mu^-$</td>
<td>$(3.2 \pm 0.2) \times 10^{-9}$</td>
</tr>
<tr>
<td>$B^0 \rightarrow \mu^+\mu^-$</td>
<td>$(1.1 \pm 0.1) \times 10^{-10}$</td>
</tr>
</tbody>
</table>


![Graph showing upper limit (BR; 95% CL) for $B_s^0$ and $B^0$ decays to $\mu^+\mu^-$ over years from 1999 to 2014 with data points from various experiments: CLEO, Belle, BABAR, D0, CDF, CMS, LHCb, LHC comb.](image)
The CMS detector

- **Solenoid**
  - B = 3.8 T

- **ECAL**
  - Scintillating PbWO₄ Crystals

- **Calorimeters**
  - HCAL: Plastic scintillator
  - Brass

- **Tracker**
  - Pixels
  - Silicon Strips

- **Muon Barrel**
  - Drift Tubes (DT)

- **Muon Endcaps**
  - Cathode Strip Chambers (CSC)
  - Resistive Plate Chambers (RPC)

- **Weight:** 12500 t
- **Overall Diameter:** 15 m
- **Overall Length:** 21.6 m

*(JINST 3, S08004 (2008))***
Muon track reconstruction

- **Tracks**: Excellent $p_T$ resolution $\approx 1$
- **Tracking efficiency** $> 99\%$ for central muons
- **Excellent vertex reconstruction and impact parameter resolution** ($\approx 15 \, \mu m$)
- **Muon candidates**: Match between muon segments and a silicon track
- **Large pseudorapidity coverage**: $|\eta| < 2.4$

- **Muon and trigger efficiencies evaluated with**
  1. MC methods
  2. Data-driven methods: Tag & Probe
Analysis overview

- All the selections chosen with the signal regions **blinded**
- Backgrounds estimated from the sidebands and from MC
- **Normalization sample** $B^\pm \to J/\psi K^\pm \to (\mu^+\mu^-) K^\pm$ to avoid
  - uncertainties of the $b\bar{b}$ production cross section
  - luminosity measurement
  - mitigate the efficiency effects

\[
Br\left(B_s^0 \to \mu^+\mu^-\right) = \frac{N_S}{N_{obs}} \frac{f_u}{f_s} \frac{\varepsilon_{tot}^{B^+}}{\varepsilon_{tot}} Br\left(B^+\right)
\]

- **Control sample** $B_s^0 \to J/\psi \phi \to (\mu^+\mu^-)(K^+K^-)$ to compare and validate $B_s^0$ mesons in data and MC simulations

- **We do not need the luminosity absolute value anywhere**

- Divided the sample in:
  - **barrel** (both muons with $|\eta|<1.4$) $\to$ better sensitivity, mass resolution $\approx 40$ MeV
  - **endcap** (otherwise) $\to$ add statistics, mass resolution $\approx 60$ MeV

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<table>
<thead>
<tr>
<th>Region definitions</th>
<th>Invariant mass (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>overall window</td>
<td>$4.90 &lt; m_{\mu\mu} &lt; 5.90$</td>
</tr>
<tr>
<td>blinding window</td>
<td>$5.20 &lt; m_{\mu\mu} &lt; 5.45$</td>
</tr>
<tr>
<td>$B^0 \to \mu^+\mu^-$ window</td>
<td>$5.20 &lt; m_{\mu\mu} &lt; 5.30$</td>
</tr>
<tr>
<td>$B_s^0 \to \mu^+\mu^-$ window</td>
<td>$5.30 &lt; m_{\mu\mu} &lt; 5.45$</td>
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</tbody>
</table>

$f_s/f_u = 0.267 \pm 0.021$ [LHCb arxiv:1111.2357]

$Br(B^+)$ from the PDG
Signal versus Background

**Signal** $B_{(s)}^0 \rightarrow \mu^+ \mu^-$
- two reconstructed muons
- invariant mass around $m(B_{(s)}^0)$
- long lived $B$, with a well reconstructed secondary vertex and a momentum aligned with flight direction

**Backgrounds**
- two semileptonic $B$ decays
- one semileptonic $B$ decay and one misidentified hadron
- single $B$ decays
  - peaking ($B_s^0 \rightarrow K^- K^+$)
  - non peaking ($B_s^0 \rightarrow K^- \mu^+ \nu$)
Candidate selection
Signal selection: most discriminating variables

- Pointing angle $\alpha_{3D}$
- Flight length significance $l_{3D}/\sigma(l_{3D})$
- Impact parameter significance $\delta_{3D}/\sigma(\delta_{3D})$
- Selections optimized (random grid search) for best upper limit

Data side-bands vs signal MC:
Isolation

- **Isolation cone around the Primary vertex:**
  \[ I = \frac{p_{\perp}(B)}{p_{\perp}(B) + \sum_{n_k} |p_{\perp}|} \]
  - Tuned to minimize MC/data discrepancies and maximize bkg rejection

- **Isolation on the Secondary vertex:**
  - Distance of the closest track to SV \( (d_{ca}^0) \)
  - Number of close tracks in \( d_{ca} < 0.3 \text{ mm} \) and \( p_T > 0.5 \text{ GeV} \)

**Data side-bands vs signal MC:**

![Graphs showing isolation](image)
**Data - Simulation comparison**

- Needed to validate signal (through the control sample) and normalization samples
- Differences data – MC taken as systematics uncertainties:
  - $B^\pm \rightarrow J/\psi K^\pm$, max diff = 2.5% (isolation) tot = 4%
  - $B_s^0 \rightarrow J/\psi \phi$, max diff = 1.6% (secondary vertex $\chi^2$/ndof) tot = 3%
- Excellent MC – data comparison

**Side-bands subtracted data vs control MC:**

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**Graphs:**

1. **CMS, 4.9 fb$^{-1}$ Preliminary $\sqrt{s} = 7$ TeV**
   - Candidates / (2.0 GeV)
   - $p_T(B)$ [GeV]

2. **CMS, 4.9 fb$^{-1}$ Preliminary $\sqrt{s} = 7$ TeV**
   - Candidates
   - $l_{3D}/\sigma(l_{3D})$

3. **CMS, 4.9 fb$^{-1}$ Preliminary $\sqrt{s} = 7$ TeV**
   - Candidates
   - isolation

**Legend:**
- Data
- $B_s^0 \rightarrow J/\psi \phi$ (MC)
Pile-up

- in 2011: \( <N_{\text{PV}} > = 8 \), RMS(\( z \)) = 5.6 cm

- Selections have been tuned to be pile-up independent
  - e.g. isolation searches only for tracks coming from the same primary vertex or not associated to any

- Efficiencies of all selection criteria have been evaluated versus the number of reconstructed primary vertices

- All selections are compatible with a constant at least until 30 PV

The same conclusion is also obtained from MC simulations, looking at samples with low (<6) or high (>10) PU events
Normalization Channel: $B^\pm \rightarrow J/\psi \, K^\pm$

- Needed for the extraction of the branching fraction
- Same selections as for signal, plus
  - $3.0 < m(\mu\mu) < 3.2$ GeV
  - $pT(\mu\mu) > 7$ GeV
  - $pT(K) > 0.5$ GeV
  - all tracks used in vertexing
- Fit pdf:
  - signal: double Gaussian
  - bkg: exponential + error function at 5.145 GeV for
    - $B^0 \rightarrow J/\psi \, K^* \rightarrow \mu^+\mu^- K (\pi^+)$ decays
- estimated sys error on the event yield: 5%
  - varying bkg, signal pdf
  - mass-constraining dimuons to $J/\psi$

<table>
<thead>
<tr>
<th></th>
<th>Barrel</th>
<th>Endcap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance</td>
<td>$0.162 \pm 0.006$</td>
<td>$0.111 \pm 0.006$</td>
</tr>
<tr>
<td>$\varepsilon_{\text{tot}}$</td>
<td>$0.00110 \pm 0.00009$</td>
<td>$0.00032 \pm 0.00004$</td>
</tr>
<tr>
<td>$N_{\text{obs}}$</td>
<td>$82712 \pm 4146$</td>
<td>$23809 \pm 1203$</td>
</tr>
</tbody>
</table>
Rare Backgrounds

- CKM-suppressed semileptonic decays
  - e.g. $B_s^0 \rightarrow K \mu^+ \nu$, with one fake muon (continuous shape)

- Peaking hadronic decays
  - e.g. $B_s^0 \rightarrow K K^+$, with two fake muons (shifted to left due to muon mass assignment)

- Each channel normalized to $B^\pm$ in data:
  \[ N(X) = \frac{Br(Y \rightarrow X) \cdot f_Y \cdot \varepsilon_{\text{tot}}(X)}{Br(B^\pm \rightarrow J / \psi K^\pm) \cdot f_u \cdot \varepsilon_{\text{tot}}(B^\pm)} \cdot N_{\text{obs}}(B^\pm) \]

- weighted with muon-misid evaluated from data:  
  $D^*+ \rightarrow D^0 \pi^+ \rightarrow K \pi^+ \pi^+$, $\Lambda \rightarrow p \pi$
  - $r \leq 0.10 \%$ both for pions and kaons
  - $r \leq 0.05 \%$ for protons

- sys errors: branching fractions and $f_s/f_u$

- Expected events:

<table>
<thead>
<tr>
<th>Channel</th>
<th>low sideband</th>
<th>$B^0$ window</th>
<th>$B_s^0$ window</th>
<th>high sideband</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrel</td>
<td>3.01 ± 0.63</td>
<td>0.332 ± 0.070</td>
<td>0.182 ± 0.057</td>
<td>0.02 ± 0.00</td>
</tr>
<tr>
<td>Endcap</td>
<td>1.26 ± 0.24</td>
<td>0.149 ± 0.028</td>
<td>0.082 ± 0.023</td>
<td>0.02 ± 0.00</td>
</tr>
</tbody>
</table>
Systematics & cross-checks

<table>
<thead>
<tr>
<th>Category</th>
<th>Uncertainty</th>
<th>Barrel</th>
<th>Endcap</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_s/f_u$</td>
<td>production ratio of $u$ and $s$ quarks</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>acceptance</td>
<td>production processes</td>
<td>3.5</td>
<td>5.0</td>
</tr>
<tr>
<td>$P_{ij}^B$</td>
<td>mass scale and resolution</td>
<td>3.0</td>
<td>3.0</td>
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<tr>
<td>efficiency (signal)</td>
<td>discrepancies data/MC simulation</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>efficiency (normalization)</td>
<td>discrepancies data/MC simulation</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>efficiency (normalization)*</td>
<td>kaon track efficiency</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>efficiency</td>
<td>trigger</td>
<td>3.0</td>
<td>6.0</td>
</tr>
<tr>
<td>efficiency</td>
<td>muon identification</td>
<td>4.0</td>
<td>8.0</td>
</tr>
<tr>
<td>normalization</td>
<td>fit pdf</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>background</td>
<td>shape of combinatorial background</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>background</td>
<td>rare decays</td>
<td>20.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Cross Checks:

- **Background estimate with inverted isolation** ($I<0.7$, not blinded)
- **Branching fraction of $B^0_s \rightarrow J/\psi\phi$**
  - cross-check for consistency
- **Stability of the event yield ratios during 2011**
Results
Before unblinding...

- **Background = combinatorial** (constant shape) + **rare** (MC shape)
- **Combinatorial events in signal windows:**
  - subtract rare events from sidebands
  - scale remaining events to the different widths of the regions
...Unblinded

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B^0\rightarrow\mu\mu$ Barrel</th>
<th>$B_s^0\rightarrow\mu\mu$ Barrel</th>
<th>$B^0\rightarrow\mu\mu$ Endcap</th>
<th>$B_s^0\rightarrow\mu\mu$ Endcap</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\epsilon_{\text{tot}}$</td>
<td>$0.0029 \pm 0.0002$</td>
<td>$0.0029 \pm 0.0002$</td>
<td>$0.0016 \pm 0.0002$</td>
<td>$0.0016 \pm 0.0002$</td>
</tr>
<tr>
<td>$N_{\text{signal}}^{\text{exp}}$</td>
<td>$0.24 \pm 0.02$</td>
<td>$2.70 \pm 0.41$</td>
<td>$0.10 \pm 0.01$</td>
<td>$1.23 \pm 0.18$</td>
</tr>
<tr>
<td>$N_{\text{comb}}^{\text{exp}}$</td>
<td>$0.40 \pm 0.34$</td>
<td>$0.59 \pm 0.50$</td>
<td>$0.76 \pm 0.35$</td>
<td>$1.14 \pm 0.53$</td>
</tr>
<tr>
<td>$N_{\text{peak}}^{\text{exp}}$</td>
<td>$0.33 \pm 0.07$</td>
<td>$0.18 \pm 0.06$</td>
<td>$0.15 \pm 0.03$</td>
<td>$0.08 \pm 0.02$</td>
</tr>
<tr>
<td>$N_{\text{total}}^{\text{exp}}$</td>
<td>$0.97 \pm 0.35$</td>
<td>$3.47 \pm 0.65$</td>
<td>$1.01 \pm 0.35$</td>
<td>$2.45 \pm 0.56$</td>
</tr>
<tr>
<td>$N_{\text{obs}}$</td>
<td>$2$</td>
<td>$2$</td>
<td>$0$</td>
<td>$4$</td>
</tr>
</tbody>
</table>

CMS, 4.9 fb$^{-1}$ Preliminary $\sqrt{s} = 7$ TeV

Barrel

Endcap

Candidates / 0.025 GeV

$B_s^0$ signal window

$B^0$ signal window
Results on the upper limits

With CLs at 95%CL:

<table>
<thead>
<tr>
<th></th>
<th>observed</th>
<th>median expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{BR}(B_s^0 \rightarrow \mu\mu)$</td>
<td>$7.7 \times 10^{-9}$</td>
<td>$8.4 \times 10^{-9}$</td>
</tr>
<tr>
<td>$\text{BR}(B^0 \rightarrow \mu\mu)$</td>
<td>$1.8 \times 10^{-9}$</td>
<td>$1.6 \times 10^{-9}$</td>
</tr>
</tbody>
</table>

Bkg only hypothesis

Bkg + SM hypothesis
Conclusions

- A blind analysis searching for the rare decays $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ has been performed by CMS in pp collisions at $\sqrt{s} = 7$ TeV.

- The data sample corresponds to the integrated luminosity of all 2011 run (4.9 fb$^{-1}$).

- This result supersedes our previous measurement ($\text{BR}(B_s^0 \to \mu^+\mu^-) < 19 \times 10^{-9}$)
  - Stricter selection requirements are applied resulting in a better sensitivity and a higher signal to background ratio.

<table>
<thead>
<tr>
<th>Channel</th>
<th>CMS new upper limits (95%CL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR($B_s^0 \to \mu\mu$)</td>
<td>$7.7 \times 10^{-9}$</td>
</tr>
<tr>
<td>BR($B^0 \to \mu\mu$)</td>
<td>$1.8 \times 10^{-9}$</td>
</tr>
</tbody>
</table>
Backup
A new and improved analysis

- The data analyzed here includes the data set used to obtain the earlier result
  - 1.14 fb$^{-1}$ have been “reblinded”

- Significant analysis improvements
  - Muon identification algorithm moved to a tighter selection
    - decreases the muon misidentification rate by 3x
  - Isolation variables:
    - primary vertex isolation modified
    - distance of closest track modified
    - track counting added
  - Added 3D impact parameter
  - non-monotonous changes

- Analysis improved with
  - higher sensitivity
  - pile-up insensitive up to ~30 primary vertexes
  - larger S/B
Trigger

- Trigger requirements tightened during the 2011 data-taking, following the increasing instantaneous luminosity.

- Signal (eff 74-84%)
  - dimuon $p_T > 3.9 \, \text{GeV}$ (5.9 GeV in the endcap)
  - muon $p_T > 4 \, \text{GeV}$,
  - invariant mass $4.8 < m_{\mu\mu} < 6.0 \, \text{GeV}$,
  - distance of closest approach to each other < 5 mm
  - dimuon vertex fit $\chi^2/dof > 0.5\%$

- Normalization and control samples (eff 77-60%)
  - dimuon $p_T > 6.9 \, \text{GeV}$
  - muon $p_T > 4 \, \text{GeV}$, $|\eta| < 2.2$
  - invariant mass $2.9 < m_{\mu\mu} < 3.3 \, \text{GeV}$
  - distance of closest approach to each other < 5 mm
  - dimuon vertex fit $\chi^2/dof > 15\%$
  - “displacement”:
    - pointing angle $\cos \alpha_{xy} > 0.9$
    - flight distance significance $l_{xy}/\sigma(l_{xy}) > 3$

Trigger efficiencies evaluated vs $p_T$ and $\eta$ with
1. MC methods
2. Data-driven methods: Tag & Probe
The defining regions

For the signal:  \( \text{B Mass} = 5.28 \text{ GeV, B}_s \text{ Mass} = 5.37 \text{ GeV} \)

<table>
<thead>
<tr>
<th>Region definitions</th>
<th>Invariant mass (GeV)</th>
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<th>Invariant mass (GeV)</th>
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</thead>
<tbody>
<tr>
<td>overall window</td>
<td>( 4.90 &lt; m_{\mu_1\mu_2} &lt; 5.90 )</td>
<td>( B^0 \to \mu^+\mu^- ) window</td>
<td>( 5.20 &lt; m_{\mu_1\mu_2} &lt; 5.30 )</td>
</tr>
<tr>
<td>blinding window</td>
<td>( 5.20 &lt; m_{\mu_1\mu_2} &lt; 5.45 )</td>
<td>( B^0_s \to \mu^+\mu^- ) window</td>
<td>( 5.30 &lt; m_{\mu_1\mu_2} &lt; 5.45 )</td>
</tr>
</tbody>
</table>

For the normalization: (Jpsi mass in [3.0, 3.2])

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<th>Invariant mass (GeV)</th>
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</thead>
<tbody>
<tr>
<td>overall window</td>
<td>( 4.90 &lt; m_{\mu_1\mu_2k} &lt; 5.90 )</td>
<td>signal region</td>
<td>( 5.20 &lt; m_{\mu_1\mu_2k} &lt; 5.35 )</td>
</tr>
<tr>
<td>low sideband</td>
<td>( 5.05 &lt; m_{\mu_1\mu_2k} &lt; 5.15 )</td>
<td>high sideband</td>
<td>( 5.40 &lt; m_{\mu_1\mu_2k} &lt; 5.50 )</td>
</tr>
</tbody>
</table>

For the control: (Jpsi mass in [3.0, 3.2], Phi mass in [0.995, 1.045] and \( \Delta R_{kk} < 0.25 \))

<table>
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<th>Invariant mass (GeV)</th>
<th>Region definitions</th>
<th>Invariant mass (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>overall window</td>
<td>( 4.90 &lt; m_{\mu_1\mu_2kk} &lt; 5.90 )</td>
<td>signal region</td>
<td>( 5.27 &lt; m_{\mu_1\mu_2kk} &lt; 5.47 )</td>
</tr>
<tr>
<td>low sideband</td>
<td>( 5.10 &lt; m_{\mu_1\mu_2kk} &lt; 5.20 )</td>
<td>high sideband</td>
<td>( 5.50 &lt; m_{\mu_1\mu_2kk} &lt; 5.60 )</td>
</tr>
</tbody>
</table>
Candidate Selection: optimization

- Optimization of the selections made with a random grid search with $1.4 \times 10^6$ runs
- Uses Bkg side-band and signal MC
- figure of merit: best upper limit

<table>
<thead>
<tr>
<th>Variable</th>
<th>Barrel</th>
<th>Endcap</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_T_{\mu,1} &gt;$</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>$p_T_{\mu,2} &gt;$</td>
<td>4.0</td>
<td>4.2</td>
</tr>
<tr>
<td>$p_T_B &gt;$</td>
<td>6.5</td>
<td>8.5</td>
</tr>
<tr>
<td>$\delta_{3D} &lt;$</td>
<td>0.008</td>
<td>0.008</td>
</tr>
<tr>
<td>$\delta_{3D} / \sigma(\delta_{3D}) &lt;$</td>
<td>2.000</td>
<td>2.000</td>
</tr>
<tr>
<td>$\alpha &lt;$</td>
<td>0.050</td>
<td>0.030</td>
</tr>
<tr>
<td>$\chi^2 / dof &lt;$</td>
<td>2.2</td>
<td>1.8</td>
</tr>
<tr>
<td>$\ell_{3d} / \sigma(\ell_{3d}) &gt;$</td>
<td>13.0</td>
<td>15.0</td>
</tr>
<tr>
<td>$I &gt;$</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>$d_{ca}^0 &gt;$</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>$N_{trk}^{\text{close}} &lt;$</td>
<td>2</td>
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<tr>
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<td>GeV</td>
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<td></td>
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<td>rad</td>
</tr>
<tr>
<td></td>
<td>tracks</td>
<td></td>
</tr>
</tbody>
</table>
Combinatorial bkg evaluation

- Dimuon background = rare + combinatorial background
- The combinatorial bkg is assumed to have a constant shape
  - checked with inverted isolation sample (syst 4%)
  - The rare bkg is subtracted from the sidebands
  - scale the remaining event counts proportionally $\tau$:

  $$\tau_{s,d} = \frac{\Delta m_{s,d}}{5.9 - 4.9 - 0.25}$$

  - width of the signal window
  - width of the side-bands
Upper limit extraction

\[ N_s^B \sim \text{Pois}(\tau_s^B \nu_b^B + \nu_{s, \text{rare}}^B + P_{ss}^B \mu_s^B + P_{sd}^B \mu_d^B) \]
\[ N_d^B \sim \text{Pois}(\tau_d^B \nu_b^B + \nu_{d, \text{rare}}^B + P_{ds}^B \mu_s^B + P_{dd}^B \mu_d^B) \]

with \( i = s, d \)

\[ \tau_i^B \] Ratio of \( (B_i^0 \to \mu\mu) \)-signal window size to size of background window
\[ \nu_i^B \] Expected number of rare background in \( (B_i^0 \to \mu\mu) \)-signal window.
\[ \nu_{i, \text{rare}}^B \] Expected number of reconstructed \( (B_i^0 \to \mu\mu) \) decays in barrel region assuming the SM
\[ P_{ij}^B \] Probability for a reconstructed \( B_j^0 \to \mu\mu \) decay to be in \( (B_i^0 \to \mu\mu) \)-signal window.
\[ \mu_i \] Signal strength of \( B_i^0 \to \mu\mu \), that is the ratio of true branching ratio to SM branching ratio.

The expected number of reconstructed decays assuming SM is

\[ \nu_i = \frac{B_{i}^{\text{SM}}(B_i^0 \to \mu\mu)}{B(B^\pm \to J/\psi K^\pm)} \frac{f_s}{f_u} \frac{A_{B_s^0}}{A_{B_u^\pm}} \frac{\varepsilon_{\text{trig}}^{B_s^0}}{\varepsilon_{\mu}^{B_u^\pm}} \frac{\varepsilon_{\text{analysis}}^{B_s^0}}{\varepsilon_{\text{analysis}}^{B_u^\pm}} N_{\text{obs}}(B^\pm \to J/\psi K^\pm) \]

in each “channel” \( (B_s, B_d \text{ in barrel, endcap}) \)

The total model is 6 poissonian observables \( (N_s^E, N_s^B, N_d^E, N_d^B, N_b^E, N_b^B) \), 2 nuisance parameters for background \( (\nu_b^E, \nu_b^B) \) and additional nuisance parameters for systematic uncertainties.
Results on the upper limits: p-values

- With CLs at 95%CL

<table>
<thead>
<tr>
<th></th>
<th>observed</th>
<th>median expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{BR}(B_s^0 \rightarrow \mu\mu)$</td>
<td>$7.7 \times 10^{-9}$</td>
<td>$8.4 \times 10^{-9}$</td>
</tr>
<tr>
<td>$\text{BR}(B^0 \rightarrow \mu\mu)$</td>
<td>$1.8 \times 10^{-9}$</td>
<td>$1.6 \times 10^{-9}$</td>
</tr>
</tbody>
</table>

- p-values for SM + bkg

<table>
<thead>
<tr>
<th></th>
<th>w/o cross feed</th>
<th>w/ SM cross feed</th>
<th>floating cross feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{BR}(B_s^0 \rightarrow \mu\mu)$</td>
<td>0.06 (1.5σ)</td>
<td>0.07 (1.5σ)</td>
<td>0.11 (1.2σ)</td>
</tr>
<tr>
<td>$\text{BR}(B^0 \rightarrow \mu\mu)$</td>
<td>0.11 (1.2σ)</td>
<td>0.29 (0.6σ)</td>
<td>0.24 (0.7σ)</td>
</tr>
</tbody>
</table>

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![Graph showing CLs for Bkg only and Bkg+SM signals.](attachment:graph.png)

**Graph Legends:**
- **Observed CLs**
- **Expected CLs - Median**
- **Expected CLs ± 1σ**
- **Expected CLs ± 2σ**

**SM expectation bands:**
- **Observed CLs+b**
- **Expected CLs+b - Median**
- **Expected CLs+b ± 1σ**
- **Expected CLs+b ± 2σ**

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**CMS Preliminary = 7 TeV s**
Few interpretation examples, IsaJet calculations

White regions due to previous upper limit results

Biggest impact for high tan(β)
Best fit for CMSSM
With summer 2011 result

With this new result

CMSSM

NUHM1
In the process of precision determination of the luminosity collected by CMS in 2011, a slight time-dependent calibration drift was found in the calorimeter used as a luminometer.

To remedy this, we developed an independent luminosity determination using stable and precise pixel tracker.

Preliminary result presented at the LHC Luminosity Days suggests an upward change in the estimated luminosity for 2011 by ~6%, i.e. slightly outside the 1σ-band of our original estimate of the luminosity uncertainty.

The corresponding change for the low-luminosity part of the run (2011A), which is the basis of our new and published precision measurements, is ~3.5%, well within the quoted systematics.

We are finalizing determination of the new luminosity measurement, with significantly better precision.

The anticipated change has a very minor effect on our preliminary results and no visible change in published limits.

Instability does not affect the 2010 luminosity determination, as it only affects high-luminosity running.