LHCb Status Report
105th LHCC meeting

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On behalf of the LHCb Collaboration
1. **Introduction:**
   - What happened since the last LHCC meeting?
   - LHCb performance.
   - The LHCb physics program.

2. **Production Studies:**
   - Weak bosons production
   - $J/\Psi$, double $J/\Psi$ and $\Upsilon$ production
   - $B_c$ production
   - $b\bar{b}$ production.
   - Ratio of fragmentation functions: $f_d/f_s$

3. **Observation of new $B_s$ decays.**

4. **Search for new CP phases in $B_d$ and $B_s$ mixing.**
   - Towards a precise measurement of $\gamma$ at tree level.
   - Observation of CP violation in $B\rightarrow hh'$: towards a measurement of $\gamma$ from loops.
   - Status of the $B_s \rightarrow J/\Psi \Phi$ analysis: Acceptance, angular analysis, flavour tagging, $\Delta m_s$,

5. **Search for NP contributions in $B_{d,s}$ rare decays.**
   - Observation of $B_d \rightarrow K^*\mu^+\mu^-$. 
   - Search for $B_{d,s} \rightarrow \mu^+\mu^-$

6. **Outlook and Conclusions.**
I. Introduction
What happened since the last LHCC?

Last LHCC meeting was on November 17th, few days after end of LHCb data taking in 2010.

Other than the detector work performed during the technical stop, since then, the whole 2010 data sample has been re-processed with the latest alignment database and streamed for Data Analysis.

Large MC samples consistent with the 2010 data taking conditions, have been produced to support the LHCb analyses shown at the Winter Conferences (~20 Conference Notes). Big effort from the LHCb computing group.

Today, in 30 minutes, you can only expect a superficial overview of some of the physics results. More information can be obtained from the Conference Notes quoted.
Main Detector Activities:

**Silicon Tracker**: Exchange and repair of modules with broken bounds.

**RICH**: Replacement of ~7% HPDs.

**OT**: Repair FE, disconnect few broken channels.

**CALO**: Replace few PMTs.

**MUON**: Replace few non-fully operational chambers.

Overall very small changes to the detector. The biggest improvement is in the HLT farm:

**HLT**: Addition of 100 boxes (400 nodes), for a total of 50 subfarms x 27 nodes x (8 to 20) HLT tasks running = 24600 HLT tasks!

A lot of work also on *infrastructure maintenance and safety*
Data taking in 2010(11)

Recorded $\sim$38 pb$^{-1}$ in 2010 with $\sim$90% efficiency.

Most of it ($\sim\frac{3}{4}$) was collected in a single month (October 2010).

Efficiency (channels)

All sub-detectors working at $>99\%$ efficiency.

2011 data taking just started:

Initial 2011 fills (with 3 bunches) used to re-calibrate the detector. Some data taken with magnet off for alignment.

Fills with 32/64/136/200 bunches being taken as of today with $>90\%$ efficiency.
LHCb performance: momentum and vertex resolution

Evolution of \( J/\psi \rightarrow \mu^+\mu^- \) mass resolution with time (MC ~ 12 MeV/c\(^2\))

May: \( \sigma \sim 18 \text{ MeV/c}^2 \)
August: \( \sigma \sim 16 \text{ MeV/c}^2 \)
November: \( \sigma \sim 13 \text{ MeV/c}^2 \)

Fantastic job by a very hard-working group of people improving the alignment!

**PV resolution**: \( \sigma_x \sim \sigma_y \sim 16 \text{ \(\mu\text{m}\)} \) (MC: 11\(\mu\text{m}\)) , \( \sigma_z \sim 76 \text{ \(\mu\text{m}\)} \) (MC: 60 \(\mu\text{m}\)) as measured for events with 25 tracks/event.

**IP resolution**: \( \sigma(\text{IP}_x) \sim 15-20 \text{ \(\mu\text{m}\)} \) in the region of interest. Slope dominated by material interactions rather than misalignment.
LHCb performance: PID and Trigger

**RICH PID** working close to MC expectations.
Clean reconstruction of many hadronic decays.

**Trigger efficiencies** very close to expectations

<table>
<thead>
<tr>
<th></th>
<th>Muon trigger (J/ψ)</th>
<th>Hadron trigger (D⁰)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data</strong></td>
<td>94.9±0.2%</td>
<td>60±4%</td>
</tr>
<tr>
<td><strong>MC</strong></td>
<td>93.3±0.2%</td>
<td>66%</td>
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</table>
LHCb Physics Program

The main LHCb physics goal is to find evidence for New Physics, through the indirect effect that the new degrees of freedom may have on B and D decays.

This search is complementary to direct searches, and provides information on the masses, couplings, spins and CP phases.

B$_s$ $\rightarrow$ $\mu^+\mu^-$ Higgs “Penguin”

LHCb is therefore using LHC as an “intensity frontier” machine, rather than “energy frontier”. But, if so, do we really expect to be competitive with $\sim$40 pb$^{-1}$ of data collected in 2010 compared with $>6000$ pb$^{-1}$ at CDF/D0, when the b b$\overline{b}$ xsection is only a factor three larger?

The answer is yes due to the LHCb acceptance, trigger and detector resolution. To be shown in the following slides...
2. Production Studies
The comparison of the $W^\pm$ asymmetries measured at LHCb with the different PDFs, provides constraints on the low $x$ quark content of the protons at high $q^2$.

$W$ selection: isolated $\mu$ with $P_T>$20 GeV/c and small recoil $P_T$. 

$LHCb$ preliminary $L = 16 \text{ pb}^{-1}$

$(NW^+ - NW^-)/(NW^+ + NW^-)$

Acceptance of GPDs 

- LHCb data 
- MCFM uncertainty
Prompt $J/\psi$ production

Comparison with theory

$\sigma(\text{prompt } J/\psi, P_t<14 \text{ GeV}/c, 2<y<4.5) = (10.52\pm0.04\pm1.40^{+1.64}_{-2.20}) \mu b$

Comparison with CMS

Double $J/\psi$ production observed in 35.2 pb$^{-1}$ in agreement with expectations

$L=5.2$ pb$^{-1}$

$\sigma(2J/\psi, P_t(J/\psi)<10 \text{ GeV}, 2<y(J/\psi)<4.5) = 5.6 \pm 1.1 \pm 1.2 \text{ nb}$

$LHCb$-CONF-2011-009

arXiv:1103.0423 (submitted to EPJ C)
\[ \sigma(Y(1S), \not P_t < 15 \text{ GeV}, 2<y<4.5) = 108.3 \pm 0.7 \pm 30.9 \pm 25.8 \text{ nb} \]
**B_c^+ production**

B_c^+ is an interesting object, (c bbar), to understand QCD.

First observation at CDF in 1998. Only seen in three decay modes:
B_c^+ → J/Ψ π^+ (~100 candidates), B_c^+ → J/Ψ μ^+ ν and B_c^+ → J/Ψ e^+ ν (~1k candidates each).

At LHCb we measure for p_T(B_c^+)>4 GeV/c:

\[
R_{c^+} = \frac{\sigma(B_c^+) \times \mathcal{B}(B_c^+ \rightarrow J/Ψ \pi^+)}{\sigma(B^+) \times \mathcal{B}(B^+ \rightarrow J/Ψ K^+)} = (2.2 \pm 0.8\text{(stat)} \pm 0.2\text{(syst)})\%
\]

**59±18** events observed, **4.1σ** statistical significance.

*Looks great for the LHCb B_c physics program*
b bbar production

Using J/ψ produced in B decays: $\sigma(J/\Psi \text{ from } b, 2<y<4.5)=1.14\pm0.01\pm0.16 \mu b$, which would correspond to $\sigma(pp\rightarrow b \ b\bar{b} \ X) = 288\pm4\pm48 \mu b$

In excellent agreement with LHCb measurement using $b \rightarrow D^0 \mu \nu X$: $\sigma(pp\rightarrow b \ b\bar{b} \ X) = 284\pm20\pm49 \mu b$

**Ratio of fragmentation functions**

### B\(_d\rightarrow\)DK / B\(_s\rightarrow\)D\(_s\)π:
- Same 4 particles in the final state
- At present theoretical error of order 7%

\[
\frac{f_d}{f_s} = 13.45 \times \frac{\tau_{B_s}}{\tau_{B_d}} \times \left[ N_{d} N_{F} c_{D_q \pi} N_{DK} \right]
\]

### B\(_d\rightarrow\)D π / B\(_s\rightarrow\)D\(_s\)π:
- Similar final state
- Theoretical error of order 9% (extra contribution from exchange diagram)

\[
\frac{f_d}{f_s} = 1.018 \times \frac{\tau_{B_s}}{\tau_{B_d}} \times \left[ \tilde{N}_{d} N_{F} N_{E} c_{D_q \pi} N_{D_s \pi} \right]
\]

fd/fs using semileptonic B\(_{(s)}\rightarrow\)D\(_{(s)}\)K\(\Lambda\mu\nu\) to be ready soon.

---

**B\(_d\)→D π : 4109 ± 75**

**B\(_s\)→D\(_s\) π : 670 ± 34**

**B\(_d\)→D K : 253 ± 21**

---

\[
\frac{f_s}{f_d} = 0.249 \pm 0.013^{\text{stat}} \pm 0.020^{\text{syst}} \pm 0.025^{\text{theor}}
\]

\[
\frac{f_s}{f_d} = 0.242 \pm 0.024^{\text{stat}} \pm 0.018^{\text{syst}} \pm 0.016^{\text{theor}},
\]

To be compared with HFAG average: \(f_s/f_d = 0.270\pm0.034\)

- LEP: 0.256±0.026
- CDF: 0.327±0.039
- new CDF(La Thuile): 0.269±0.03
3. Observation of new $B_s$ Decays
First observation of $B_s \rightarrow J/\Psi f_0(980)$ decays

PLB 698 (2011) 115.

Final state is CP-eigenstate → no need for angular analysis
BR is $\sim \frac{1}{4}$ of $B_s \rightarrow J/\Psi \phi$ → looks promising for $\beta_s$
First observation of $B_s \rightarrow K^*K^*$ decay

The use of decays like $B_s \rightarrow \phi\phi$ and $B_s \rightarrow K^*K^*$ allows to disentangle NP contributions to the as yet unexplored penguins in the $B_s$ system.

$LHCb$-CONF-2011-019

$LHCb$ measures BR($B_s \rightarrow K^*K^*$) to be:

\[
\frac{\mathcal{B}(B_s^0 \rightarrow K^{*0} \overline{K}^{*0})}{\mathcal{B}(B_s^0 \rightarrow J/\psi \overline{K}^{*0})} = 0.37 \pm 0.09 \pm 0.14
\]

\[
\mathcal{B}(B_s^0 \rightarrow K^{*0} \overline{K}^{*0}) = (1.95 \pm 0.47 \pm 0.72) \times 10^{-5}
\]

on the upper side of expectations.

$LHCb$ Preliminary

$\sqrt{s} = 7$ TeV

$L = 35.4$ pb$^{-1}$

$NB_s = 34.5 \pm 7.4$

$NB_d = 9.9 \pm 4.8$

$B_d \rightarrow K^*K^*$ observed at BELLE with ~29 events.
First observation of $B_s \to D^0K^*$ decay

This decay may be a potentially dangerous background for the measurement of $\gamma$ using the ADS method in $B_d \to D^0K^*$ decays.

With $\sim 36$ pb$^{-1}$ the expected yield of $B_d \to D^0K^*$ is negligible.

LHCb measures $\text{BR}(B_s \to D^0K^*)$ to be:

$$\frac{\mathcal{B}(\bar{B}_s^0 \to D^0K^*)}{\mathcal{B}(\bar{B}_s^0 \to D^0\rho^0)} = 1.39 \pm 0.31 \pm 0.25$$

$$\mathcal{B}(\bar{B}_s^0 \to D^0K^*) = (4.44 \pm 1.00 \pm 0.79) \times 10^{-4}$$

N = 34.5 ± 6.9
4. Search for new CP phases in $B_d$ and $B_s$ mixing
Is there room for NP in $B_{d,s}$ mixing?

$$\Delta q \equiv \frac{M_{q_{12}}^q}{M_{q_{12}}^{q_{SM}}}, \quad \Delta q \equiv |\Delta q|e^{i\phi_{\Delta q}}.$$  

Both, $B_d$ (due to the measurement of $B^+ \rightarrow \tau \nu$) and $B_s$ (due to the measurement of $\beta_s$) disfavor the SM at $2.7\sigma$.

Yes, indeed, there is **plenty of room for NP** and it does not look like CMSSM. LHCb main goals:

1. precise determination of $\gamma$ at tree level (disentangle NP contribution to $\sin 2\beta$)
2. precise determination of $\beta_s$
Prospects for a measurement of $\gamma$ using $B^+ \to D^0 K^+$, $B^0 \to D^0 K^*$ and $B_s \to D_s K$

Similar diagrams for $B^0$. No penguin pollution, only affected by possible NP in $D^0$ mixing.

$B^0$ and $D^0$ decays self tagging.

No need to do a time dependent analysis. Only the ratio of the different decay modes is needed → Challenge is to extract the suppressed modes.

**B$^\pm \to DK^\pm$ with D → $\pi K$**

![LHCb yield: 444 ± 30 / 34 pb$^{-1}$
CDF yield: 516 ± 37 / fb$^{-1}$](image)

Alternatively, use **time dependent CP asymmetry from $B_s \to D_s K$.**

Expect to measure $\gamma$ with a combined precision of ~5° from 2011/2012 data
Prospects for a measurement of \( \gamma \) using multi-body \( B_d \) decays.

In analogy to the decay \( B^\pm \rightarrow D^0 K^\pm \), the decay \( B^\pm \rightarrow D^0 K^\pm \pi^+ \pi^- \) can be used to determine \( \gamma \) if the intermediate resonances can be properly modelled.

As proof of principle LHCb has measured:

\[
\frac{B(\bar{B}^0 \rightarrow D^+ \pi^- \pi^+ \pi^-)}{B(B^0 \rightarrow D^+ \pi^-)} = 2.35 \pm 0.11 \text{(stat)} \pm 0.24 \text{(syst)}
\]

\[
\frac{B(B^- \rightarrow D^0 \pi^- \pi^+ \pi^-)}{B(B^- \rightarrow D^0 \pi^-)} = 1.26 \pm 0.07 \text{(stat)} \pm 0.12 \text{(syst)}
\]

\[
\frac{B(\bar{B}^0_s \rightarrow D^+_s \pi^- \pi^+ \pi^-)}{B(B^0_s \rightarrow D^+_s \pi^-)} = 2.22 \pm 0.41 \text{(stat)} \pm 0.25 \text{(syst)}
\]

\[
\frac{B(\Lambda^0_b \rightarrow \Lambda_c^+ \pi^- \pi^+ \pi^-)}{B(\Lambda^0_b \rightarrow \Lambda_c^+ \pi^-)} = 1.32 \pm 0.15 \text{(stat)} \pm 0.14 \text{(syst)}
\]

Up to six tracks in the final state!

With better precision than current PDG, and yields larger than the single bachelor equivalent. The decays \( X_b \rightarrow X_c \pi \pi \pi \) are dominated by a single resonance \( a_1(1260)^+ \).

Looks interesting for an improved measurement of \( \gamma \)
Prospects for a measurement of $\gamma$ from loops using $B_s \rightarrow K^+K^-$ and $B_d \rightarrow \pi^+\pi^-$. 

Large Penguin contributions are expected for $B_s \rightarrow K^+K^-$ and $B_d \rightarrow \pi^+\pi^-$. Assuming U-spin and the measured $\beta$ ($B_d$ mixing phase), the time dependent CP asymmetry of these decays allows for a measurement of $\gamma$ and $\beta_s$. 

![Graphs showing distribution of invariant masses for $B_s \rightarrow K^+K^-$ and $B_d \rightarrow \pi^+\pi^-$ decays.](image)
**Observation of direct CP violation in $B_{d,s} \rightarrow K\pi$**

**Direct CP asymmetry** in $B_d \rightarrow K\pi$ is well established ($\sim 9\sigma$) but not yet convincing in $B_s \rightarrow \pi K$.

*Detector asymmetries* controlled using $D^*$ and $D^0 \rightarrow K\pi$ decays taken with both magnet polarities ($A_D = -0.004 \pm 0.004$).

*Production asymmetry* constrained using $B^{\pm} \rightarrow J/\psi K^{\pm}$ ($A_P = -0.024 \pm 0.016$).

\[
\begin{align*}
A_{CP}(B_0 \rightarrow K^+\pi^-) &\approx A_{\pi^{+}\pi^{-}}^{\text{dir}} \\
A_{CP}(B_0 \rightarrow K^-\pi^+) &\approx A_{K^{+}K^-}^{\text{dir}} \\
A_{CP}(B_0 \rightarrow K^+\pi^-) &= -0.077 \pm 0.033 \pm 0.007 \\
A_{CP}(B_s^0 \rightarrow \pi^+K^-) &= 0.15 \pm 0.19 \pm 0.02 \\
A_{CP}(B_s^0 \rightarrow K^+\pi^-) &= 0.39 \pm 0.17 \\
A_{CP}(B_0 \rightarrow K^+\pi^-) &= -0.098_{-0.011}^{+0.012} \\
\end{align*}
\]

LHCb preliminary:  
HFAG average:
Towards a measurement of the $B_s$ mixing phase: Strategy

1. **Trigger & select $B_s^0 \rightarrow J/\psi\phi$ events**
   - Together with control channels, $B^+ \rightarrow J/\psi K^+$, $B^0 \rightarrow J/\psi K^{*0}$, ...

2. **Measure proper time**
   - *Proof of principle*: measure $B \rightarrow J/\psi X$ lifetimes

3. **Measure decay angles**
   - $P \rightarrow VV$ decay: $J/\psi\phi$ is a mixture of CP odd and CP even states
   - Angular analysis to disentangle statistically the 3 amplitudes
   - *Proof of principle*: measure transversity amplitudes in $B^0 \rightarrow J/\psi K^{*0}$ and $B_s^0 \rightarrow J/\psi\phi$ and $\Delta \Gamma_s$

4. **Tag initial flavour**
   - Calibration using control channels:
     - $B^0 \rightarrow J/\psi K^{*0}$, $B^+ \rightarrow J/\psi K^+$, $B^0 \rightarrow D^{*-} \mu^+ \nu_\mu$, $B_s^0 \rightarrow D_s^- \pi^+$, ...
   - *Proof of principle*: measure $\Delta m_d$ and $\Delta m_s$

5. **Fit differential decay rates (for $B_s^0$ and $\overline{B_s^0}$)**
   
   \[
   \frac{d^4 \Gamma(B_s^0 \rightarrow J/\psi\phi)}{dt \, d \cos \theta \, d \phi \, d \cos \psi} = f(\phi_s, \Gamma_s, \Delta \Gamma_s, \Delta m_s, M_{B_s^0}, |A_\perp|, |A_\parallel|, \delta_\perp, \delta_\parallel)
   \]
   
   depends on 9 physics parameters and > 15 detector parameters
Towards a measurement of the $B_s$ mixing phase: Acceptance

$\sigma_m = 10.7$ MeV/$c^2$

B$^+ \rightarrow J/\psi K^+$
L=36 pb$^{-1}$

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

LHCb Preliminary
$\sqrt{s} = 7$ TeV Data

$\sigma_m = 7$ MeV/$c^2$

B$^0 \rightarrow J/\psi \phi$
L=36 pb$^{-1}$

B$^0 \rightarrow J/\psi \phi$

LHCb Preliminary
$\sqrt{s} = 7$ TeV Data

Clean signals, very low bkg!

Measurements of lifetimes in agreement with PDG, confirms understanding of the proper time distributions.
Systematic uncertainties probably conservative at this very preliminary stage.

Proper time resolution $\sim$ 50 fs!

<table>
<thead>
<tr>
<th>Channel</th>
<th>LHCb yield</th>
<th>LHCb “lifetime”(*) stat. and sys. (ps)</th>
<th>PDG (ps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B$^+ \rightarrow J/\psi K^+$</td>
<td>6741 ± 85</td>
<td>1.689 ± 0.022 ± 0.047</td>
<td>1.638 ± 0.011</td>
</tr>
<tr>
<td>B$^0 \rightarrow J/\psi K^{*0}$</td>
<td>2668 ± 58</td>
<td>1.512 ± 0.032 ± 0.042</td>
<td>1.525 ± 0.009</td>
</tr>
<tr>
<td>B$^0 \rightarrow J/\psi K^0_S$</td>
<td>838 ± 31</td>
<td>1.558 ± 0.056 ± 0.022</td>
<td>1.525 ± 0.009</td>
</tr>
<tr>
<td>B$^0_s \rightarrow J/\psi \phi$</td>
<td>570 ± 24</td>
<td>1.447 ± 0.064 ± 0.056</td>
<td>1.477 ± 0.046</td>
</tr>
<tr>
<td>$\Lambda_b \rightarrow J/\psi \Lambda$</td>
<td>187 ± 16</td>
<td>1.353 ± 0.108 ± 0.035</td>
<td>1.391$^{+0.038}_{-0.037}$</td>
</tr>
</tbody>
</table>

using only lifetime unbiased trigger and $t \in [0.3, 14]$ ps

(*) $B^0_s \rightarrow J/\psi \phi$ proper time fitted by a single exponential!
Towards a measurement of the $B_s$ mixing phase: Angular analysis.

Untagged $B_s \rightarrow J/\Psi\phi$ analysis ($\Phi_s$ fixed to zero)

The measurements of the transversity amplitudes in both untagged $B_d \rightarrow J/\Psi K^*$ and $B_s \rightarrow J/\Psi\phi$ are compatible with world average $\Rightarrow$ fitting model validated
Towards a measurement of the $B_s$ mixing phase: Flavour tagging

- Tagging algorithm optimized and calibrated on real data with $B^0 \to D^*-\mu^+\nu_\mu$, $B^+ \to J/\psi K^+$ and $B^0 \to J/\psi K^{*0}$

- Proof of principle that flavour tagging is working: measure $\Delta m_d$ in $B^0 \to D^- (K^+\pi^-\pi^-)\pi^+$:

  $\Delta m_d = 0.499 \pm 0.032 \text{(stat)} \pm 0.003 \text{(sys)} \text{ps}^{-1}$

  (World average: $\Delta m_d = 0.507 \pm 0.005 \text{ps}^{-1}$)

Wednesday, March 23, 2011  Frederic Teubert
Towards a measurement of the $B_s$ mixing phase: $\Delta m_s$

<table>
<thead>
<tr>
<th>Decay mode</th>
<th># signal candidates</th>
</tr>
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<tbody>
<tr>
<td>$B_s \rightarrow D_s(\phi \pi)\pi$</td>
<td>515 ± 25</td>
</tr>
<tr>
<td>$B_s \rightarrow D_s(K^* K)\pi$</td>
<td>338 ± 27</td>
</tr>
<tr>
<td>$B_s \rightarrow D_s \pi$ non-resonant</td>
<td>283 ± 27</td>
</tr>
<tr>
<td>$B_s \rightarrow D_s 3\pi$</td>
<td>245 ± 46</td>
</tr>
</tbody>
</table>

Use:

- per event proper time uncertainties, $\langle \sigma_I \rangle = 36 - 44$ fs
- per event mistag rate, $\varepsilon_{\text{eff}} = 3.8 \pm 2.1\%$ (OS only)

\[ \Delta m_s = 17.63 \pm 0.11(\text{stat}) \pm 0.04(\text{sys}) \text{ ps}^{-1} \] (4.6$\sigma$ stat. significance)

CDF: $\Delta m_s = 17.77 \pm 0.10$ (stat) $\pm 0.07$ (sys) ps$^{-1}$

Expect world best sensitivity on the $B_s$ mixing phase very soon (Beauty 2011?)

LHCb-CONF-2011-05
5. Search for NP contributions in $B_{d,s}$ decays
Search for new Lorentz structure: Observation of $B_d \rightarrow K^* \mu^+ \mu^-$ decay

Forward-backward asymmetry

Measurements at BaBar, BELLE and CDF (O(100) events) are consistent, with a slight preference for non-SM contributions to $C_7$.

Clean observation at LHCb of $B_d \rightarrow K^* \mu^+ \mu^-$ (23±6) events close to expectations. Also observation of the rarest B decay at LHCb so far: $B^+ \rightarrow K^+ \mu^+ \mu^-$ (BR~5×10$^{-7}$).
Search for non SM Higgs contributions: $B_{d,s} \rightarrow \mu^+ \mu^-$ decays

arXiv:1103.2465 (submitted to PLB)

$$BR(B_q \rightarrow l^+ l^-) \approx \frac{G_F^2 \alpha^2 M_{B_q}^3 f_{B_q}^2 \tau_{B_q}}{64 \pi^3 \sin^4 \theta_W} |V_{tb} V_{tq}^*|^2 \sqrt{1 - \frac{4m_l^2}{M_{B_q}^2}} \left\{ M_{B_q}^2 \left( 1 - \frac{4m_l^2}{M_{B_q}^2} \right) c_S^2 + \left[ M_{B_q} c_P + \frac{2m_l}{M_{B_q}} (c_A - c_A') \right]^2 \right\}.$$

This decay is very sensitive to **new scalar and/or pseudoscalar** interactions. In the MSSM the BR is proportional to $\tan^6 \beta / M_A^4$.

<table>
<thead>
<tr>
<th>Mode</th>
<th>SM</th>
</tr>
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<tbody>
<tr>
<td>$B_s \rightarrow \mu^+ \mu^-$</td>
<td>$3.2 \pm 0.2 \times 10^{-9}$</td>
</tr>
<tr>
<td>$B^0 \rightarrow \mu^+ \mu^-$</td>
<td>$0.10 \pm 0.01 \times 10^{-9}$</td>
</tr>
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</table>

Search for the rare decays $B_{d,s} \to \mu^+ \mu^-$. 

Signal and background candidates are discriminated by a 2D likelihood: multivariate discriminant variable (GL) and invariant mass, both obtained from data.

Three complementary normalization channels: $B^+ \to J/\psi K^+$, $B_s \to J\psi \phi$ and $B_d \to K^+ \pi^-$. 

LHCb results with 37 pb$^{-1}$:

- $\text{BR}(B_S \to \mu^+ \mu^-) < 5.6 \times 10^{-8}$ @ 95% CL (expected $6.5 \times 10^{-8}$)
- $\text{BR}(B^0 \to \mu^+ \mu^-) < 1.5 \times 10^{-8}$ @ 95% CL (expected $1.8 \times 10^{-8}$)

Already very close to best limits from CDF using 3.7 fb$^{-1}$:

- $\text{BR}(B_S \to \mu^+ \mu^-) < 4.3 \times 10^{-8}$ @ 95% CL
- $\text{BR}(B^0 \to \mu^+ \mu^-) < 0.76 \times 10^{-8}$ @ 95% CL
Search for $B_{d,s} \to \mu^+ \mu^-$ decays: 2010/2011 prospects

LHCb will either find signs of NP or exclude most of the tan$\beta$ vs $M_A$ plane with the 2010/2011 data.

Strong impact on viable SUSY scenarios

Very exciting indeed!
6. Outlook and conclusions
Outlook and conclusions

Thanks to the superb work at the CERN accelerator departments, LHCb was able to collect \(~38\ \text{pb}^{-1}\) of pp collisions. This was good enough to provide world class measurements at this winter conferences:

\[
\begin{align*}
\Delta m_s &= 17.63\pm 0.11\text{(stat)} \pm 0.04\text{(syst)} \text{ ps}^{-1} \\
\text{BR}(B_s \rightarrow \mu^+\mu^-) &< 5.6\times10^{-8} \text{ @ 95\% CL} \\
\text{BR}(B^0 \rightarrow \mu^+\mu^-) &< 1.5\times10^{-8} \text{ @ 95\% CL}
\end{align*}
\]

and open new paths to look for NP in the barely explored $B_s$ system with several new decay modes observed.

Many new results are in the pipeline still with 2010 data: $\beta_s$, $D^0$ mixing…

LHCb is performing very well and the results obtained already guarantee we will start exploring “terra incognita” in 2011 provided we get enough luminosity.

LHCb would like to run in 2011 with a visible pp-collisions/bunch crossing up to $\mu=2$ (2.5 at start-up). Prefer to maximize the number of bunches to minimize $\mu$. Luminosity leveling will be crucial and we will run with almost flat luminosity ($3\times10^{32} \text{ cm}^{-2} \text{ s}^{-1}$) throughout the year.

We would like to get $\geq 200\ \text{pb}^{-1}$ by end of June and $\sim 1\ \text{fb}^{-1}$ by the end of 2011.
Backup
γ measurement

- All measurements together determine (indirectly) the CKM angle $\gamma = (68 \pm 4)^\circ$
- However, as processes involve loops, may be affected by new physics:
  \[
  \sin (2\beta + \phi_{bd}^{NP})
  \]
  → should be compared with measurement of $\gamma$ from tree process:
  $B \to DK$, unaffected by new physics
  Currently only poorly constrained: $\gamma = (70 \pm 14 \pm 21)^\circ$ (direct measurement)

A precise measurement of $\gamma$ from tree processes and improved precision in $V_{ub}$ will show if there are new phases involved in $B_d$ mixing processes.

Wednesday, March 23, 2011  Frederic Teubert
What about the flavour specific asymmetry measured at D0?

\[ a_{fs}^q \propto A_{fs}^q(t) = \frac{\Gamma(B_q^0 \text{ or } \bar{B}_q^0 \rightarrow f) - \Gamma(B_q^0 \text{ or } \bar{B}_q^0 \rightarrow \bar{f})}{\Gamma(B_q^0 \text{ or } \bar{B}_q^0 \rightarrow \bar{f}) + \Gamma(B_q^0 \text{ or } \bar{B}_q^0 \rightarrow f)} \]

Inclusive method using \( bb \rightarrow \mu\mu X \) events:

\[ A^b = \frac{N^{++} - N^{-}}{N^{++} + N^{-}} = (0.494)a_{fs}^s + (0.506)a_{fs}^d \]

More promising looks fitting simultaneously the production asymmetry using the exclusive method either with \( B_s \rightarrow D_s \pi \) decays, or using the \( B_s \) and \( B_d \) semileptonic decays and subtracting them, such that the detector asymmetry cancels and we are left with:

\[ \Delta A_{fs}^{s,d} \approx \frac{a_{fs}^s - a_{fs}^d}{2} \]

<table>
<thead>
<tr>
<th>Stat. Error</th>
<th>100 pb(^{-1})</th>
<th>1 fb(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_{fs}^s (D_s \pi) )</td>
<td>( 2 \times 10^{-2} )</td>
<td>( 6.8 \times 10^{-3} )</td>
</tr>
<tr>
<td>( \Delta A_{fs} (D_q \mu\nu) )</td>
<td>( 2 \times 10^{-3} )</td>
<td>( 6.3 \times 10^{-4} )</td>
</tr>
</tbody>
</table>
Towards a measurement of the $B_s$ mixing phase: Angular analysis.

- LHCb forward geometry $\rightarrow$ small distortions of angular acceptance $\rightarrow$ corrected with MC

Validity of MC-angular acceptance corrections tested measuring known values of polarization amplitude in $B^0 \rightarrow J/\psi K^{*0}$
Towards a measurement of the $B_s$ mixing phase: Angular analysis.

Untagged angular analysis of $B^0 \rightarrow J/\psi K^{*0}$

5D unbinned likelihood fit ($m, t, \cos \theta, \varphi, \cos \psi$)

Projection on transversity angles:

![Graphs showing 5D unbinned likelihood fits for $m, t, \cos \theta, \varphi, \cos \psi$.]

$$|A_\parallel|^2 = 0.252 \pm 0.020\text{(stat)} \pm 0.016\text{(sys)}$$

$$|A_\perp|^2 = 0.178 \pm 0.022\text{(stat)} \pm 0.017\text{(sys)}$$

$$\delta_\parallel (\text{rad}) = -2.87 \pm 0.11\text{(stat)} \pm 0.10\text{(sys)}$$

$$\delta_\perp (\text{rad}) = 3.02 \pm 0.10\text{(stat)} \pm 0.07\text{(sys)}$$

Compatible with world best measurements

Will be competitive in 2011

BaBar, Phys. Rev. D76, 031102 (2007),

$$|A_\parallel|^2 = 0.211 \pm 0.010 \pm 0.006$$

$$|A_\perp|^2 = 0.233 \pm 0.010 \pm 0.005$$

$$\delta_\parallel (\text{rad}) = -2.93 \pm 0.08 \pm 0.04$$

$$\delta_\perp (\text{rad}) = 2.91 \pm 0.05 \pm 0.03$$
Towards a measurement of the $B_s$ mixing phase: Angular analysis.

Coverage-adjusted two-dimensional profile likelihood of $\Delta \Gamma_s - \phi_s$

- As expected, $\sim$no constraint on $\phi_s$. However, can still limit $\Delta \Gamma_s$
- 4-fold ambiguity
  → use flavour tagging to discard two solutions