CP Violation and CKM parameters
(and a few slides on Rare Decays)

- Heavy Flavour physics as a tool to search for New Physics
  - Strategy
  - Experimental observables and comments on their sensitivity to NP

- Current sensitivity to NP effects and prospects for the nearest future (2011-2012)
  - NP phases
  - Rare decays: rates and helicity structure
**Strategy:** find observables which test the penguin and box diagrams separately; make a test which involves quarks of all three generations $\rightarrow$ Explore both $B_{u,d}$ and $B_s$ sectors, and $b$-baryons

\[ \Delta_q \equiv \frac{M_{12}^q}{M_{12}^{q,SM}}, \quad \Delta_q \equiv |\Delta_q| e^{i\phi_q^q}. \]

**Plenty of room for NP !!!**
Masses and magnitude of the couplings of New Particles
Inclusive \( BR(b \rightarrow s\gamma) \) indirectly constrains the scale of NP masses \( \Lambda > 10^3 \text{ TeV} \) for generic coupling (flavour problem)

Look at specific cases with enhanced sensitivity to NP
\( B_{s,d} \rightarrow \mu\mu \), ...

Helicity structure of the couplings

Use the correlation between photon polarization and b flavour in \( b \rightarrow s\gamma \)

\[
b \rightarrow \gamma (L) + (m_s/m_b) \times \gamma (R)
\]

\( \phi \gamma \) produced in \( B_s \) and \( \bar{B}_s \) decays do not interfere
\( \Rightarrow \) corresponding CP asymmetry vanishes

Significantly non-zero \( A_{CP} \) indicates a presence of right-handed current in the penguin loop

Similar study in \( B \rightarrow K^*\mu^+\mu^- \) & \( K^*e^+e^- \)

**Observables:** CPV phases, rates of rare processes and helicity structure of involved amplitudes

- **Phases**
  CPV processes are the only measurements sensitive to the phases of New Physics e.g. measurements of \( \beta \), \( \beta_s \) & \( \gamma \)

- **Masses and magnitude of the couplings of New Particles**
  Inclusive \( BR(b \rightarrow s\gamma) \) indirectly constrains the scale of NP masses \( \Lambda > 10^3 \text{ TeV} \) for generic coupling (flavour problem)

  Exp. \( 3.55\pm0.26\times10^{-4} \)
  Theor. \( 3.15\pm0.23\times10^{-4} \)
Where are we now …

Current status and expectations for the next year(s)

Scan of the slide shown in late 80’s

Precision of UT elements improved dramatically!
The shape of UT, assumed intuitively >30 year ago, looks however as currently
State-of-art is given by UT:

- Accuracy of sides is currently limited by models:

  Extraction of $|V_{ub}|$

  Calculation of

  - Accuracy of angles ($\beta, \gamma$) is limited by experiment:

    $\sigma(\alpha) \sim 5^\circ$, $\sigma(\beta) = 0.8^\circ$, $\sigma(\gamma) \sim 20^\circ$

  Becomes almost a precision measurement thanks to large $BR(B^+ \rightarrow \rho^0 \rho^+)$ measured by BaBar

  Confirmation from BELLE is eagerly awaited!

Note:

UT geometry is such that the main constraint on NP comes from the comparison of the opposite elements i.e. angles vs sides
\( \beta \) vs \( |V_{ub}/V_{cb}| \) is largely limited by theory (~10% precision in \( |V_{ub}| \))

Note a discrepancy in \( |V_{ub}| \) determined in inclusive and exclusive measurements: \( |V_{ub}|^{\text{incl}} = (4.32 \pm 0.27) \times 10^{-3} \) and \( |V_{ub}|^{\pi \nu} = (3.51 \pm 0.47) \times 10^{-3} \)

( A. Lenz  FPCP2011)

B. Kowalewski
BEAUTY 2011

- Continued tension between inclusive and exclusive results
- Possible improvement ???
  - \( b \to u \nu \) measurements
  - combined data + theory fits to \( b \to c l \nu \) \( b \to \pi l \nu \)
New measurement of $\sin(2\beta)$ by BELLE

Good tag only, background subtracted.

$B \to J/\psi K_S^0$  
$B \to J/\psi K_L^0$  
$B \to \psi(2S)K_S^0$  
$B \to \chi_{c1}K_S^0$

CPV is cleanly observed in all four modes

$\sin(2\beta) = \sin(2\phi_1)$

Belle preliminary

BELLE with $772 \times 10^6$ BB pairs:

$\sin(2\phi_1) = 0.668 \pm 0.023 \pm 0.013$

Current world's most precise measurement of $\Phi_1$

Indirect estimation: $\sin(2\phi_1) = 0.830^{+0.013}_{-0.034}$ (global fit, CKMfitter ICHEP10)
Tension in the current CKM fit:

- Several possible hints for NP ($A_{SL}$, $V_{ub}$ from $B \rightarrow \tau\nu$)
- Large contribution from NP not excluded
- **Precision measurement of $\gamma$ in trees is important !!!**

$\gamma$ vs $\Delta m_d/\Delta m_s$ is limited by experiment: $\gamma$ is poorly measured

From Lunghi and Soni, arXiv:1010.6069
(see also CKM fitter, UT fit, etc., etc.)

**Note:**

$\gamma = (74 \pm 11)^\circ$ used as input while CKM fitter gives $(71^{+21}_{-25})^\circ$

Direct measurement is less precise than SM prediction!
Tagged time-dependent analysis using $B_s \rightarrow D_s^{-}\pi^+$ and $B_s \rightarrow D_s^{-}3\pi^+$

$\Delta m_s = 17.63 \pm 0.11 \pm 0.04 \text{ ps}^{-1}$

CDF: $\Delta m_s = 17.67 \pm 0.10 \pm 0.07 \text{ ps}^{-1}$

Small systematic uncertainty due to LHCb excellent proper time resolution
Prospects for $\gamma$ measurements

Two strategies:

- **Time-independent CPV:** $B^+ \rightarrow D^0 K^+$, also $B^0 \rightarrow D^0 K^{*0}$

- **Time-dependent CPV:** $B_S \rightarrow D_S K^+$, also $B^0 \rightarrow D^- \pi^+$ (only possible @ hadron colliders)

### Time-independent analyses of BaBar/BELLE

#### BaBar

$(68^{+15}_{-14} \pm 4 \pm 3)^\circ \quad [B^\pm \rightarrow D^{(*)} K^{(*)}\pm]^\circ$ [model-dep. GGSZ]

#### BELLE

$(78^{+11}_{-12} \pm 4 \pm 9)^\circ \quad [B^\pm \rightarrow D^{(*)} K^{(*)}\pm]^\circ$ [model-dep. GGSZ]

\[
A_{\text{ADS}} = \frac{\Gamma(b \rightarrow D_{s\bar{s}} K^*) - \Gamma(b \rightarrow D_{s\bar{s}} K^{*0})}{\Gamma(b \rightarrow D_{s\bar{s}} K^*) + \Gamma(b \rightarrow D_{s\bar{s}} K^{*0})} = \frac{2 \xi_2 \xi_3 \sin(\delta_2 + \delta_3) \sin \gamma}{r_s^2 + r_s^2 + 2 \xi_2 \xi_3 \cos(\delta_2 + \delta_3) \cos \gamma}
\]

\[
R_{\text{ADS}} = \frac{\Gamma(b \rightarrow D_{s\bar{s}} K^*) + \Gamma(b \rightarrow D_{s\bar{s}} K^{*0})}{\Gamma(b \rightarrow D_{s\bar{s}} K^*) + \Gamma(b \rightarrow D_{s\bar{s}} K^{*0})} = \frac{r_s^2 + r_s^2 + 2 \xi_2 \xi_3 \cos(\delta_2 + \delta_3) \cos \gamma}{r_s^2}
\]

Belle with $772 \times 10^6 B\bar{B}$:

$\mathcal{R}_{DK} = (1.63_{-0.41}^{+0.44} \text{ (stat)} + 0.07_{-0.13}^{+0.07} \text{ (syst)}) \times 10^{-2}$

$A_{DK} = -0.39_{-0.28}^{+0.26} + 0.04_{-0.03}^{+0.04}$ (preliminary)

New ADS: Doubly Cabibbo-suppressed $D$ decays

GLW: CP-eigenstates (Cabibbo-suppressed)

GGSZ: Cabibbo-favoured multibody decays with Dalitz plane

Rencontres de Blois 2011
CDF: ADS analysis of $B^- \rightarrow D^0 K^-$ decays

Yield ($B \rightarrow D_{DCS} K$) = $34 \pm 14$ (5 fb$^{-1}$)
Yield ($B \rightarrow D_{DCS} \pi$) = $73 \pm 16$ (5 fb$^{-1}$)

$R_{ADS}(K) = r_d^2 + r_b^2 + 2 r_b r_d \cos(\delta_B + \delta_D) \cos \gamma$
$A_{ADS}(K) = 2 r_b r_d \sin(\delta_B + \delta_D) \sin \gamma / R_{ADS}(K)$

$R_{ADS}(\pi) = 0.0041 \pm 0.0008$(stat) $\pm 0.0004$(syst)
$A_{ADS}(\pi) = 0.22 \pm 0.18$(stat) $\pm 0.06$(syst)
$R_{ADS}(K) = 0.0225 \pm 0.0084$(stat) $\pm 0.0079$(syst)
$A_{ADS}(K) = -0.63 \pm 0.40$(stat) $\pm 0.23$(syst)

CDF results (with 5 fb$^{-1}$ data sample) competitive with B-factories

Significance for all DCS signals ($D_{DCS} \pi + D_{DCS} K$) $> 5 \sigma$
LHCb yields in $B^+ \rightarrow D\pi^+$ & $B^+ \rightarrow DK^+$

(LHCb takes shape!)

**LHCb yield:** $444 \pm 30 / 34 \text{ pb}^{-1}$

**CDF yield:** $516 \pm 37 / \text{ fb}^{-1}$

**LHCb yield:** $1035 \pm 54 / 34 \text{ pb}^{-1}$

**CDF yield:** $718 \pm 36 / \text{ fb}^{-1}$
**LHCb prospects for $\gamma$ measurement in $B_s \to D_s K$**

Large signals for $B_s \to D_s \pi$ useful for $\Delta m_s$ measurement

- $D_s K$ final state under study
- Expect world’s first time-dependent CPV analysis for $B_s \to D_s K$ analysis in 2011

**Combined estimated sensitivity for $\gamma$ in 2011/2012 Run is $\sim 5^\circ$**
LHCb measurement of $\gamma$ may hint to New Physics within next two years!

But I doubt that it will be conclusive with current theor. uncertainties. Higher accuracy in $\gamma$ ($\sim 1^\circ$) is definitely required here!
Box Diagrams ($B_s$ mixing phase)

$\phi_s^{J/\psi\phi} = -2\beta_s$ in SM is the $B_s$ meson counterpart of $2\beta$
penguin contribution $\leq 10^{-3}$

$\phi_s^{J/\psi\phi}$ is not really constrained so far

*Theoretical uncertainty is very small:* $-2\beta_s = -0.0368 \pm 0.0017$ (CKMfitter 2007)

**Results from TEVATRON**

- **CDF**: based on $5.2 \text{ fb}^{-1}$ with improved particle ID, NN, flavour tagging (SST) and contribution of S-wave included.
- **D0**: based on $6.1 \text{ fb}^{-1}$ with improved selection and no same side tagger anymore.

**CDF (assuming no CPV)**

$\tau_s = 1.53 \pm 0.025$ (stat.) $\pm 0.012$ (syst.) ps

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

**D0**

$\tau_s = 1.47 \pm 0.04$ (stat.) $\pm 0.01$ (syst.) ps

$\Delta\Gamma_s = 0.15 \pm 0.06$ (stat.) $\pm 0.01$ (syst.) ps$^{-1}$

$\phi_s = -0.76 \pm 0.37$ (stat.) $\pm 0.02$ (syst.)

In both analyses a contribution from S-wave ($B_s \rightarrow J/\psi\phi^0$) found to be non-significant
**TEVATRON: $\phi_s$ from $B \to J/\psi\phi$**

- $\phi_s = -2\beta_s$
- $\beta_s$ (rad)
- $\Delta \Gamma_s$ [ps$^{-1}$]

**CDF Run II Preliminary**

- $L = 5.2$ fb$^{-1}$
- 95% CL
- 68% CL
- SM prediction

**DØ, 6.1 fb$^{-1}$**

- $\delta_1 = -0.42 \pm 0.18$
- $\delta_2 = 3.01 \pm 0.14$
- $\Delta M_s = 17.77 \pm 0.12$ ps$^{-1}$

**Preliminary**

- 68% CL
- 95% CL

- $\phi_s \in [-\pi, -1.78] \cup [-1.36, 0.26] \cup [2.88, \pi]$ @ 95% C.L.
- 0.8σ deviation from SM central point

- $\phi_s \in [-1.65, 0.24]$, $\Delta \Gamma_s \in [0.014, 0.263]$ ps$^{-1}$
  - and $\phi_s \in [1.14, 2.93]$, $\Delta \Gamma_s \in [-0.235, -0.040]$ ps$^{-1}$ @ 95% C.L.
  - 1.1σ deviation from SM central point

Rencontres de Blois 2011
**LHCb: $\phi_s$ from $B \rightarrow J/\psi \phi$**

*SS tagging will significantly improve sensitivity
Exciting prospects for the nearest future
Expect $\sigma(\phi_s) \sim 0.1$ with about 1 fb$^{-1}$*

<table>
<thead>
<tr>
<th>LHCb 36 pb$^{-1}$</th>
<th>CDF 5.2 fb$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_s \rightarrow J/\psi \phi$</td>
<td>836</td>
</tr>
<tr>
<td>Proper time resolution</td>
<td>50 fs</td>
</tr>
<tr>
<td>OS tagging power</td>
<td>2.2 ± 0.5%</td>
</tr>
<tr>
<td>SS tagging power</td>
<td>work ongoing</td>
</tr>
</tbody>
</table>

$\phi_s \in [-2.7, -0.5]$ rad at 68% CL
$\phi_s \in [-3.5, 0.2]$ rad at 95% CL
**Summary of Tevatron results on \( A_{SL} \)**

- **CDF analysis (using muon IP cut) is underway**
  Expected stat. accuracy for 6 fb\(^{-1}\) is 70% worse than in D0 (no IP cut)

\[
\overline{\chi}_b = \frac{\Gamma(B^0 \to \bar{B}^0 \to \ell^+X)}{\Gamma(B \to \ell^\pm X)} = f_d \chi_d + f_s \chi_s \text{ is important cross-check towards } A_{SL}
\]

New CDF result: \( \overline{\chi} = 0.126 \pm 0.008 \) is entirely consistent with LEP: \( \overline{\chi} = 0.1259 \pm 0.0042 \)
(probable cause of the previous discrepancy – “ghost” muons not properly accounted in MC)

- **D0 analysis**

\[
A_{sl}^b = (-0.957 \pm 0.251 \text{ (stat)} \pm 0.146 \text{ (syst)}) \%
\]

\[
A_{sl}^b (SM) = (-2.3^{+0.5}_{-0.6}) \times 10^{-4}
\]

Additional cross-check:

\( A_{SL} \) as a function of \( M(\mu\mu) \)

**Note:** D0 \( M(\mu\mu) > 2.8 \text{ GeV/c}^2 \)

CDF \( M(\mu\mu) > 5 \text{ GeV/c}^2 \)

---

Presented at BEAUTY 2011

Rencontres de Blois 2011
Future prospects on $A_{SL}$

- **CDF measurement**
- **D0 update (with 9 fb$^{-1}$)**
  IP cut and improved data selection
- **LHCb measurement (with 1 fb$^{-1}$)**

![Graph showing measurements and results]

**NB:** This is MC, scaled to real data.
CPV in charm

\[ A_{CP}(D^0 \rightarrow h^+h^-) = \frac{\Gamma(D^0 \rightarrow h^+h^-) - \Gamma(\bar{D}^0 \rightarrow h^+h^-)}{\Gamma(D^0 \rightarrow h^+h^-) + \Gamma(\bar{D}^0 \rightarrow h^+h^-)} \]

CDF world's most precise measurement:

\[ A_{CP}(D^0 \rightarrow \pi^+\pi^-) = (+0.22\pm0.24\pm0.11)\% \]
\[ A_{CP}(D^0 \rightarrow K^+K^-) = (-0.24\pm0.22\pm0.10)\% \]

\[ \sim 476'000 \ D^* \text{-tagged} \ D^0 \rightarrow KK \]
Excellent prospects for CPV studies: Expect about a few millions tagged $D^0 \rightarrow KK$ with $L \sim 1$ fb$^{-1}$

Sample sizes in low multiplicity decay modes with low mis-tag rate already similar to those of B-factories!

$A_\Gamma$ is well in progress!

$A_\Gamma = \frac{\tau(D^0 \rightarrow K^{-}K^{+}) - \tau(D^0 \rightarrow K^{-}K^{+})}{\tau(D^0 \rightarrow K^{-}K^{+}) + \tau(D^0 \rightarrow K^{-}K^{+})}$

$A_\Gamma = (-2 \pm 4) \times 10^{-3}$

Control channel: ($A_\Gamma$ in $D \rightarrow K\pi$)

$A_\Gamma = \frac{A_M}{2}\gamma \cos \phi - x \sin \phi$

$407.6 \pm 2.4$ fs

$409.2 \pm 2.4$ fs
Penguin Diagrams: $B_{d,s}$

In $B_d$ sector:

from $B \to J/\psi K^0$ (tree)

$$\sin(2\beta) = 0.655 \pm 0.024$$

from $B \to \phi K_S$ (penguin)

$$\sin(2\beta) = 0.56^{+0.16}_{-0.18}$$

For most of the final states theory predicts larger value of $\sin(2\beta)$ in SM
In $B_s$ sector:

- CPV study in $B_s \rightarrow \phi \phi$ requires very large data samples (~50 fb$^{-1}$ at LHC)
- Use other similar decays → First observation of $B_s \rightarrow K^*K^*$ by LHCb

$$BR(B_s \rightarrow K^*K^*) = (1.95 \pm 0.47 \pm 0.66 \pm 0.29) \times 10^{-5}$$

on the upper side of expectations
(compare to $B_d \rightarrow K^*K^*$ observed by BELLE)
Meanwhile make a test with $B \rightarrow \pi\pi$ and $B_s \rightarrow KK$

Large penguin contribution in both $B_s \rightarrow KK$ & $B_d \rightarrow \pi\pi$

→ Sensitive to NP effects in time-dependent CP asymmetries (exploit U-spin symmetry)


• LHCb yields: $275 \pm 24 \ B_d \rightarrow \pi^+\pi^- \ & \ 333 \pm 21 \ B_s \rightarrow K^+K^- \ in \ 37 \ pb^{-1}$
  c.f. CDF in 1 fb$^{-1}$ $1121 \pm 63 \ B_d \rightarrow \pi^+\pi^-$ and $1307 \pm 64 \ B_s \rightarrow K^+K^-$

• Expect first time-dependent measurements in 2011/2012
  (including measurement of $B_s$ lifetime in CP-even $K^+K^-$ final state)

Rencontres de Blois 2011
CDF: First search for CPV in $B_s \rightarrow \phi \phi$

Look for asymmetry in the distributions of CP-odd variables (triple-products) → Ingenious way to measure CPV with low stat. samples before any tagged analysis!

Experimentally accessed by asymmetry of distribution of two angular functions

$$u = \cos \Phi \sin \Phi \quad \rightarrow \quad A_\parallel A_\perp$$

$$v = \begin{cases} \sin \Phi & \text{if } \cos \vartheta_1 \cos \vartheta_2 > 0 \\ \sin(-\Phi) & \text{if } \cos \vartheta_1 \cos \vartheta_2 < 0 \end{cases} \quad \rightarrow \quad A_0 A_\perp$$

$$A_u = (-0.8 \pm 6.4\text{(stat.)} \pm 1.8\text{(syst.)})\%$$

$$A_v = (-12.0 \pm 6.4\text{(stat.)} \pm 1.6\text{(syst.)})\%$$

$$\propto \sin \varphi_{\text{weak}} \cos \delta_{\text{strong}} \approx 0 \text{ in SM}$$

No CPV within 7%
Penguin Diagrams: direct CP violation in $B_{d,s}$

Direct $A_{CP}$ in 2-body $B$ decays have been measured by the $B$-factories and CDF
- CP violation is well established in $B^0 \rightarrow K^{+}\pi^{-}$
  (Average $A_{CP} = -0.098^{+0.012}_{-0.011}$)
- $A_{CP}(B_s \rightarrow \pi^{+}K^{-}) = 0.39 \pm 0.15 \pm 0.08$ (CDF with 1 fb$^{-1}$)

As seen by LHCb:

LHCb preliminary:

$A_{CP}(B^0 \rightarrow K^{+}\pi^{-}) = -0.074 \pm 0.033 \pm 0.008$

$A_{CP}(B^0_s \rightarrow \pi^{+}K^{-}) = 0.15 \pm 0.19 \pm 0.02$

Raw CP asymmetry in $B^0 \rightarrow K\pi$ decays: $-0.086 \pm 0.033$

Raw CP asymmetry in $B_s \rightarrow \pi K$ decays: $0.15 \pm 0.19$
Penguin Diagrams (prospects with charm): LHCb

- Time integrated CPV asymmetries in $D \rightarrow hh'$ decays:
  $$A_{CP}(f) = \frac{\Gamma(D^0 \rightarrow f) - \Gamma(D^0 \rightarrow \bar{f})}{\Gamma(D^0 \rightarrow f) + \Gamma(D^0 \rightarrow \bar{f})}$$

Expect mixing induced CPV to cancel out in the difference as well as many other systematics (e.g. production and tracking asymmetries):

$$A_{CP}(KK) - A_{CP}(\pi\pi) = A_{CP}^{RAW}(KK)^* - A_{CP}^{RAW}(\pi\pi)^* \text{ (very clean measurement !)}$$

**Sensitivity to penguins is retained !**

Measure raw asymmetries in flavour tagged samples

$$A_{CP}^{RAW}(f)^* = \frac{N(D^{*-} \rightarrow D^0(f)\pi^-) - N(D^{*-} \rightarrow \bar{D}^0(\bar{f})\pi^-)}{N(D^{*-} \rightarrow D^0(f)\pi^+) + N(D^{*-} \rightarrow \bar{D}^0(\bar{f})\pi^-)}$$

$$A_{CP}(KK) - A_{CP}(\pi\pi) = -0.275 \pm 0.701 \pm 0.250\%$$

Expect a factor 5 better sensitivity with 2011 data
Current status: Rare Decays and their helicity structure

By far not fully representative list of topics:

To measure accurately the rates and perform a search:

- $B \rightarrow \tau\nu, K^{*}\nu\nu$, etc. ($e^+e^-$ factories are unique to study such decays)

- $b \rightarrow s\gamma$ ($e^+e^-$-factories)

- Search for FCNC at the tree level

- Search for $B_{s,d} \rightarrow \mu\mu$ (hadron colliders)

To measure helicity structure of the amplitudes

- $B_d \rightarrow K^{*}\mu\mu, B_s \rightarrow \phi\mu\mu$ (possibility of the CPV analysis with larger data sample)

- $B_s \rightarrow \phi\gamma, B \rightarrow K^{*}e^+e^-, B_d \rightarrow K^{*}(K_s\pi^0)\mu\mu$

\[ BR(B_s \rightarrow \phi\mu\mu) = [1.44\pm0.33\text{(stat)}\pm0.46\text{(syst)}] \times 10^{-6} \]
Forward backward asymmetry, $A_{FB}$, is extremely powerful observable for testing SM vs NP

Intriguing hint is emerging !!!

- BELLE, BaBar and CDF consistent with each other and SM
- Flipped $C_7$ scenario looks however more favoured from $A_{FB}$ data

- With $1 \text{ fb}^{-1}$ LHCb expects $\sim 1400$ events, and should clarify existing situation. Expected accuracy in $A_{FB}$ zero crossing point is $\sim 0.8 \text{ GeV}^2$ in $1 \text{ fb}^{-1}$
$B_s \to \mu\mu$

Current status and prospects

**BR($B_s \to \mu\mu$) @ 95% CL**

- $< 4.3 \times 10^{-8}$ (3.7 fb$^{-1}$)
  
  CDF public note 9892

- $< 5.1 \times 10^{-8}$ (6.1 fb$^{-1}$)
  
  PLB 693 539 (2010)

- $< 5.6 \times 10^{-8}$ (0.036 fb$^{-1}$)
  
  arXiv:1103.2465v1
- Twice larger data sample $\sim 7$ fb$^{-1}$
- Increased muon acceptance
- New Neural Network with improved signal efficiency
- Better background prediction

**New improved CDF analysis**
LHCb current limit is based on zero events in the most sensitive GL bins: $BR(B_s \rightarrow \mu\mu) < 5.6 \times 10^{-8}$ at 95% CL (37 pb$^{-1}$ of 2010 data)

**Observed distribution of events**

<table>
<thead>
<tr>
<th>GL bin</th>
<th>[0, 0.25]</th>
<th>[0.25, 0.5]</th>
<th>[0.5, 0.75]</th>
<th>[0.75, 1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$[-60, -40]$</td>
<td>39</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$[-40, -20]$</td>
<td>55</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$[-20, 0]$</td>
<td>73</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$[0, +20]$</td>
<td>60</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$[+20, +40]$</td>
<td>53</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$[+40, +60]$</td>
<td>55</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>sum</strong></td>
<td>335</td>
<td>7</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>bkg exp.</strong></td>
<td>329</td>
<td>7.36</td>
<td>1.51</td>
<td>0.081</td>
</tr>
</tbody>
</table>

LHCb prospects for the 2011/2012 LHC Run

ATLAS and CMS in particular should be very competitive !!!

Very exciting sensitivity expected !
Conclusions

- Thanks to the excellent performance of the LHC machine and detectors there are exciting prospects in the nearest future!
  - Increase of LHC data by a factor of ~ 30 / 100 for LHCb / ATLAS & CMS in 2011
- Also significant updates are expected from CDF / D0 & BELLE / BaBar
- Very interesting sensitivity reach is guaranteed!
  - $B_s \rightarrow \mu\mu$
  - $\phi_s$ in $B_s \rightarrow J/\psi\phi$
  - $A_{FB}$ in $B_d \rightarrow K^*\mu\mu$