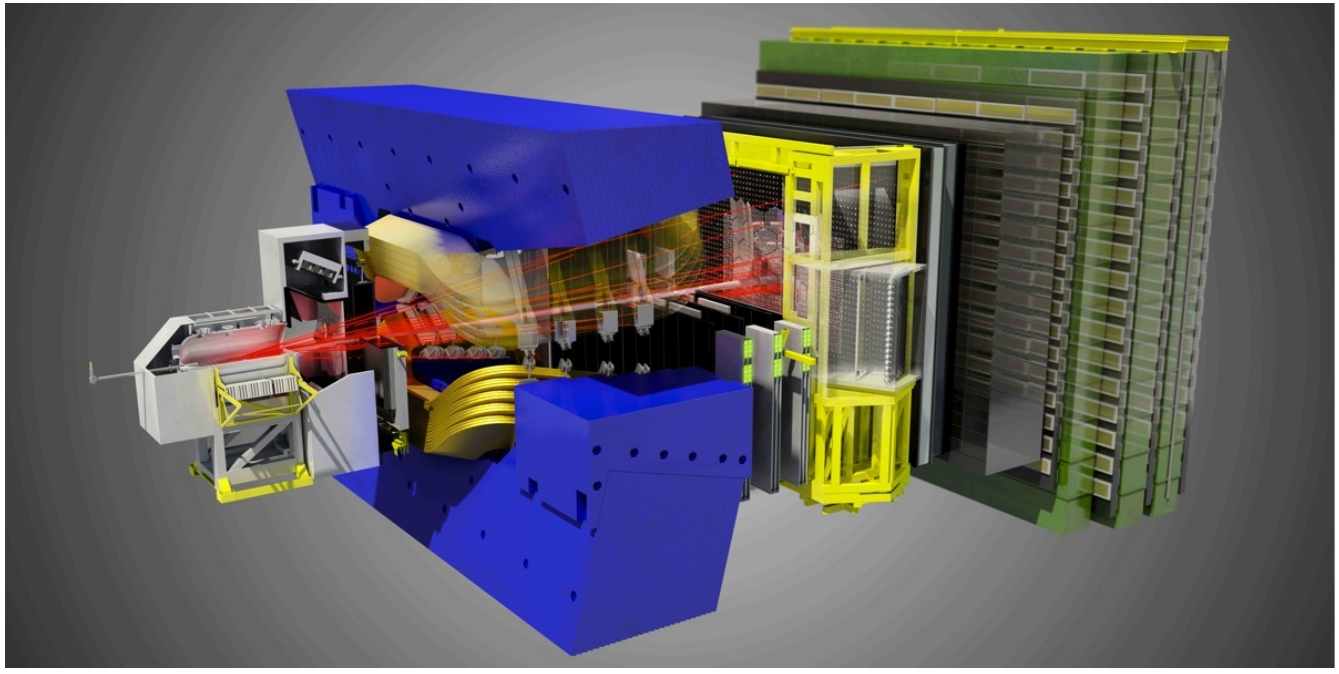
University of Zurich[UZH]

LHCb status report



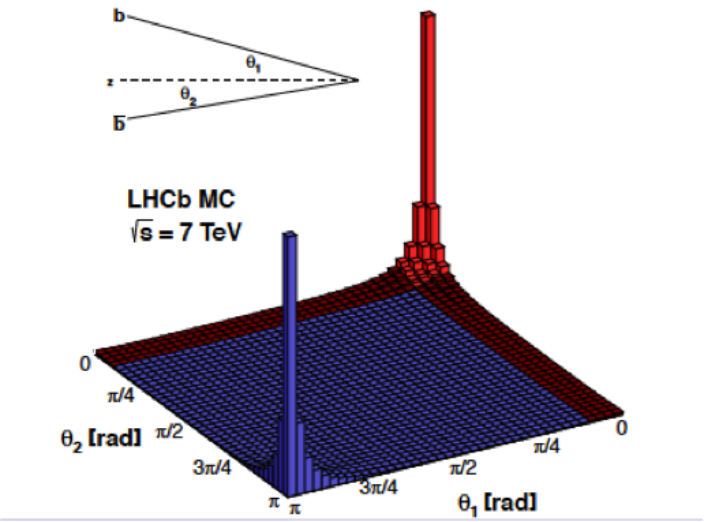
N. Serra on behalf of the LHCb Collaboration

LHCC Open session December 5th 2012

Overview

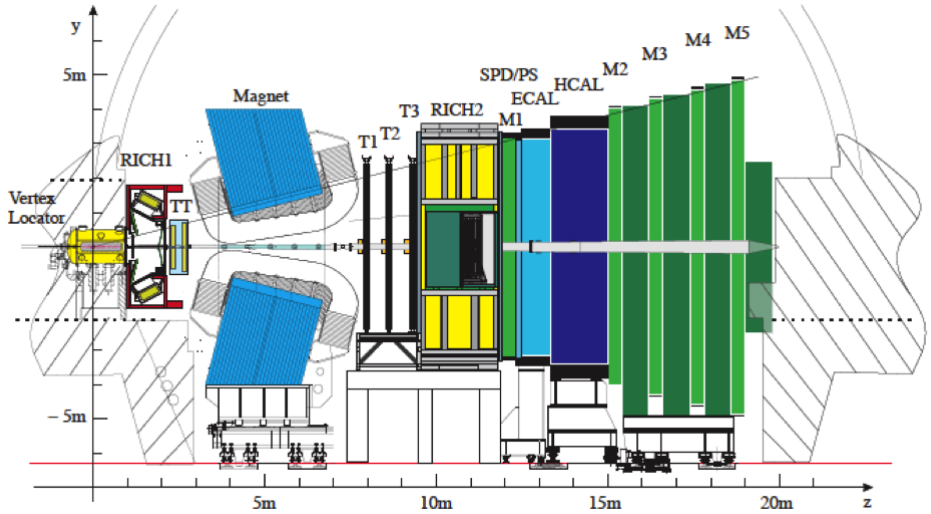
1. LHCb Experiment
2. Physics Results
   - D oscillations
   - γ measurement
   - $B_s \to \mu^+\mu^-$
   - Other Physics Results
   - Summary and Prospects
3. Upgrade
4. Conclusions

The LHC flavour factory



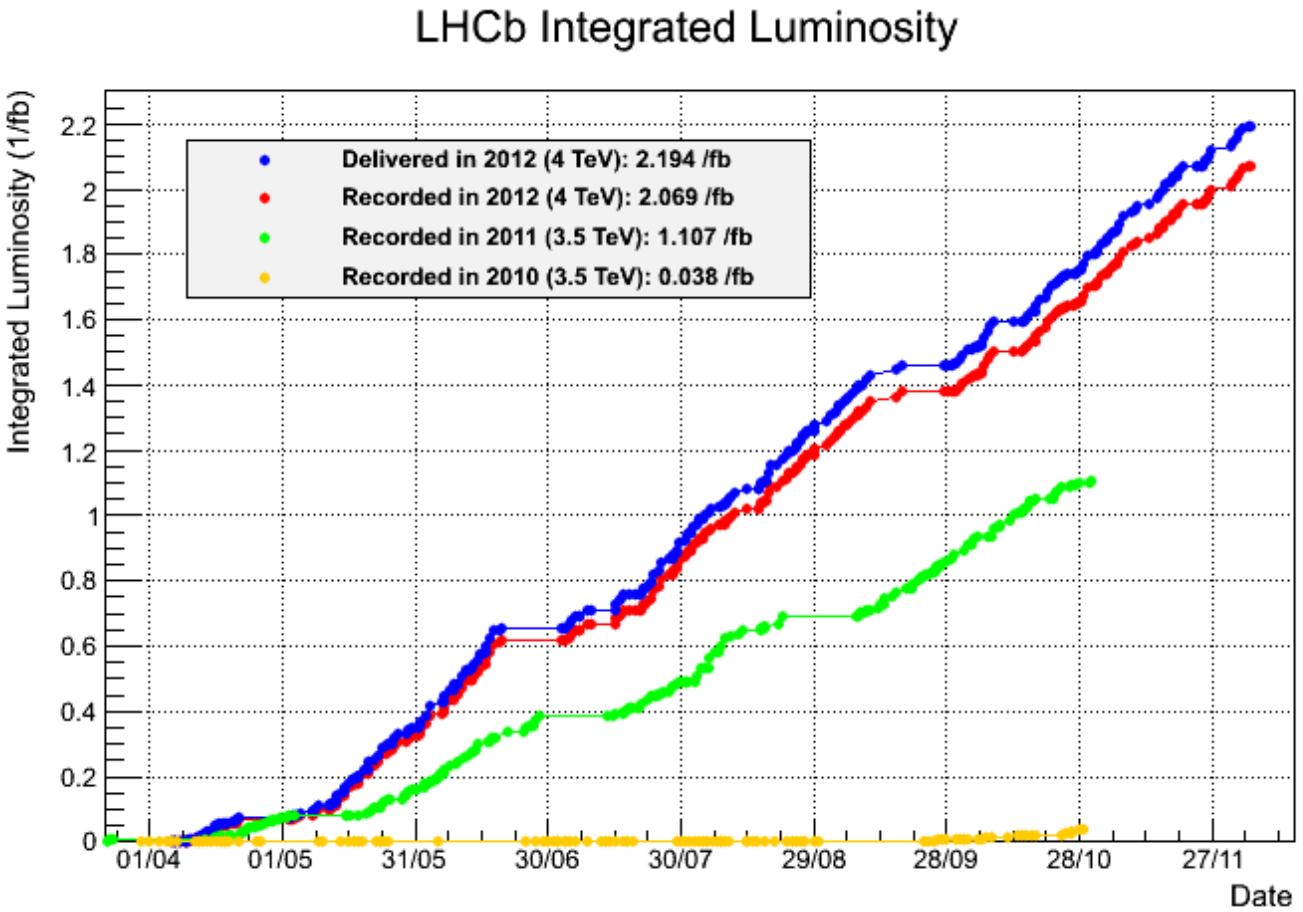
- LHCb is a flavour b and c factory
- $b\bar{b}$ and $c\bar{c}$ pairs are produce predominantly forward and backward
- Cross sections at $\sqrt{s} = 7$TeV:
  - $\sigma_{pp}^{incl} \sim 60$ mb (JINST 7 (2012) P01010)
  - $\sigma_{c\bar{c}}^{incl} \sim 6$ mb (LHCb-CONF-2010-013)
  - $\sigma_{c\bar{c}}^{LHCb} = 1419 \pm 12(stat) \pm 133(syst)\mu$b (LHCb-PAPER-2012-041)
  - $\sigma_{b\bar{b}}^{incl} \sim 0.3$ mb (PLB 694 (2010) 209)
- Yields increased by $\sim 20\%$ at $\sqrt{s} = 8$TeV

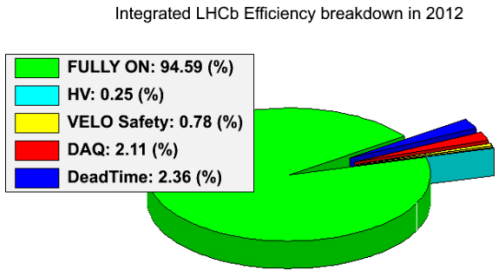
The LHCb detector



- Vertex Locator $\sigma_{PV}(x, y) \sim 10\mu m$, $\sigma_{PV}(z) \sim 60\mu$m
- Tracking $\Delta p/p = (0.4 - 0.6)\%$ in the range $5 - 100$GeV/c
- RICH Detectors $\epsilon(K) \sim 95\%$, mis-ID$(\pi \to K) \sim 5\%$
- Muon system $\epsilon(\mu) \sim 97\%$, mis-ID$(\pi \to \mu) 1 - 3\%$
- ECAL $\frac{\sigma_E}{E} \sim \frac{10\%}{\sqrt{E}} \bigoplus 1\%$ (E in GeV)
- HCAL $\frac{\sigma_E}{E} \sim \frac{70\%}{\sqrt{E}} \bigoplus 10\%$ (E in GeV)

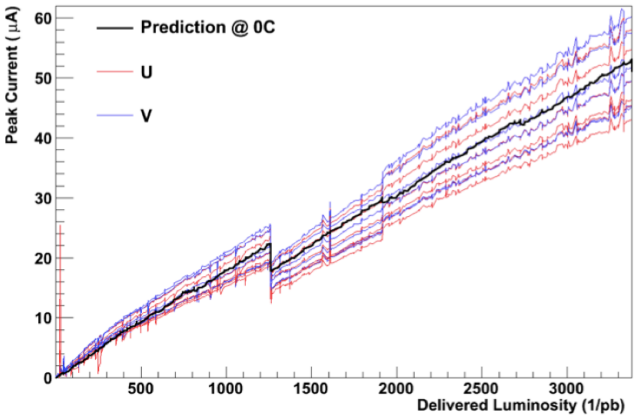
Recorded data

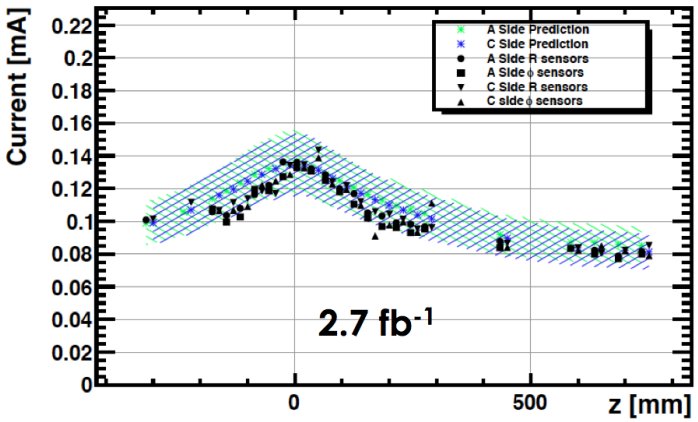


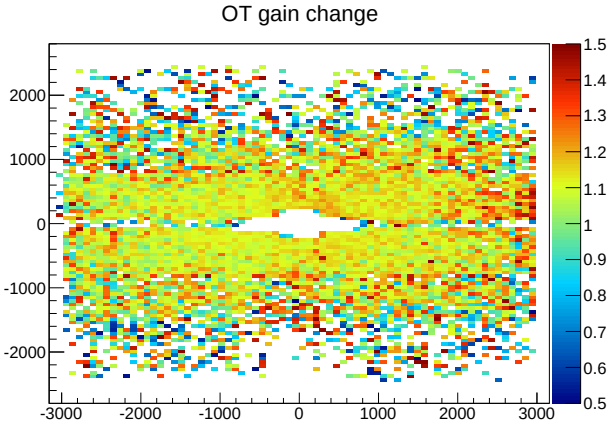


- Operational efficiency $\sim$ 94% in 2012 and $\sim$93% in 2010$-$2012
- Levelled luminosity
- Running at $\mathcal{L} = 4 \cdot 10^{32} \text{cm}^{-2}\text{s}^{-1}$

Detector Status (Tracking sub-systems)

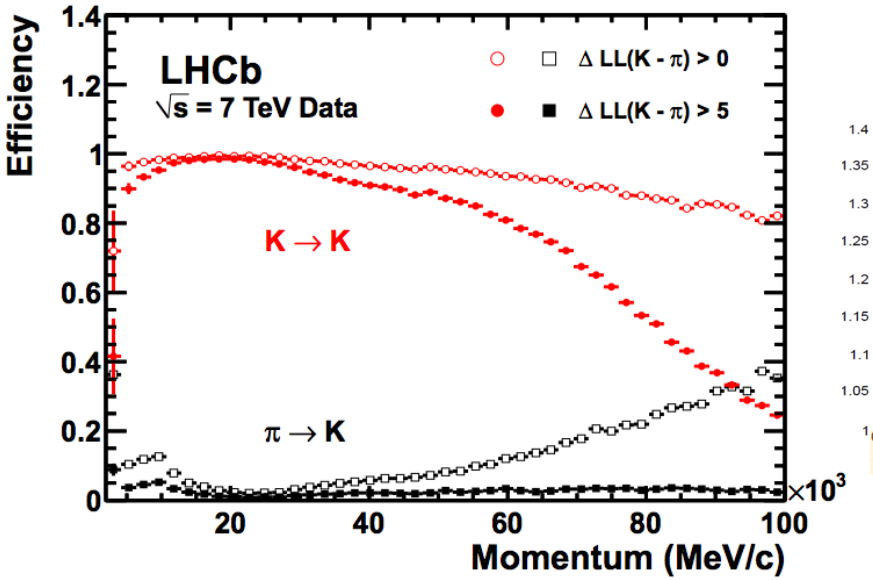


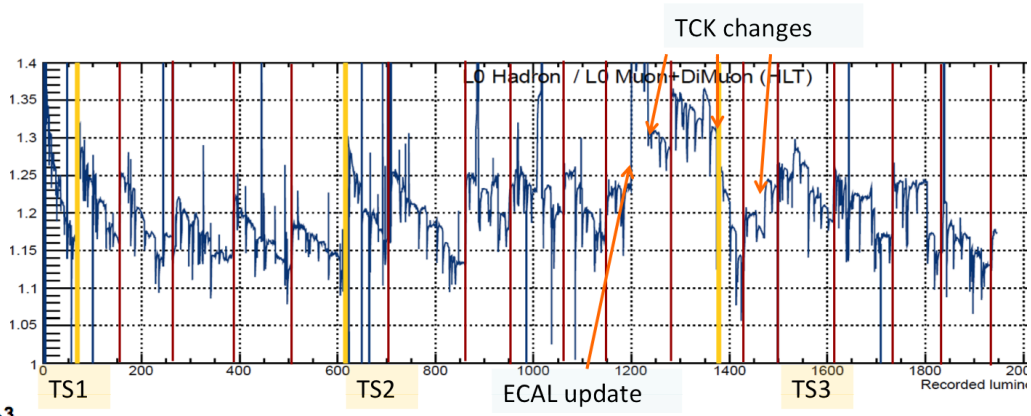




- Vertex Locator
  - Radiation Damage: Good agreement between data and predictions
- Silicon Tracker
  - $\sim 99\%$ working channels
  - Monitoring the radiation damage, good agreement with expectations
- Outer Tracker
  - No sign of ageing observed (NIM A695 (2012) 62-69)

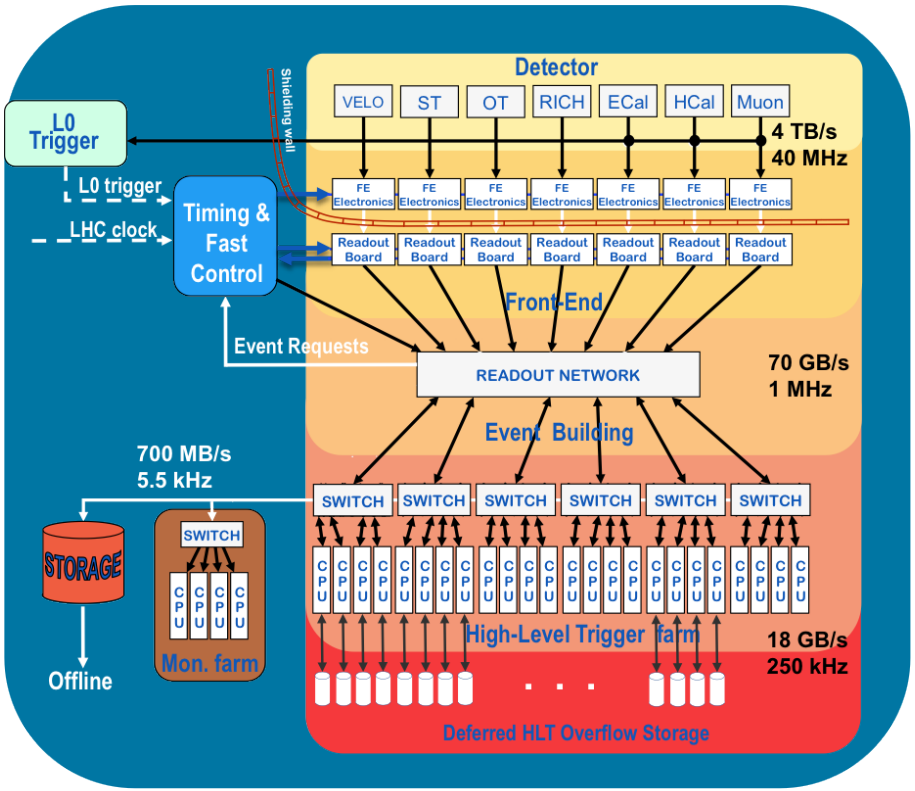
Detector Status (PID sub-systems)

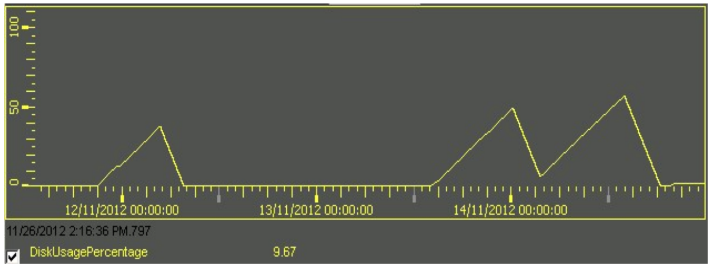




- RICH detectors, Calorimeters, Muon system
  - Good performances
  - RICH performance paper: arXiv:1211.6759
  - Monitoring ageing of ECAL and HCAL, needs regular adjusting
  - No observed ageing in the Muon system
  - Muon system performance paper: arXiv:1211.1346

Deferred Trigger

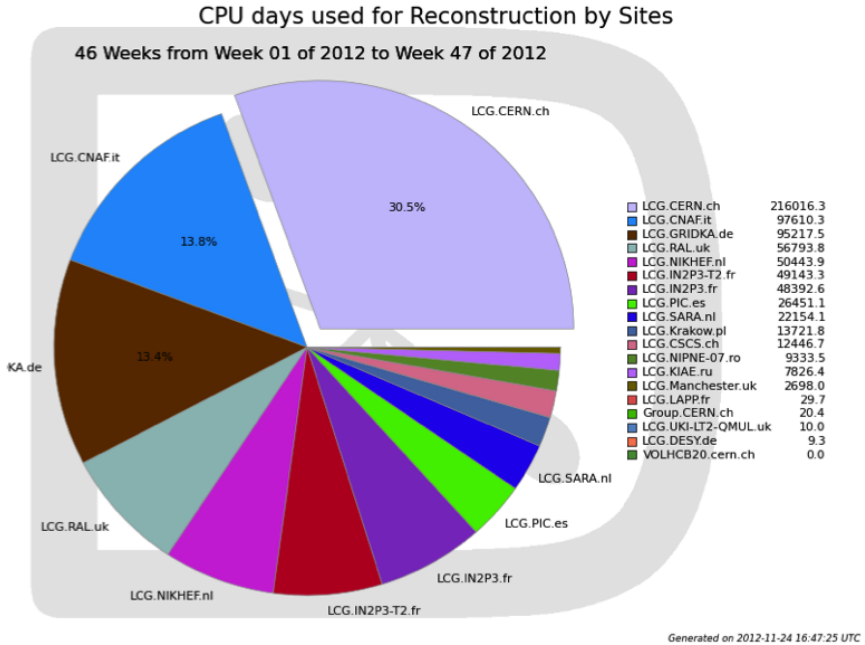




Trigger Performance paper
arXiv:1211.1346

- When the event builder detects that the HLT cannot process all the incoming events, they are written to the hard disk of the nodes in the EFF. Between fills, these events will be processed
- Equivalent 20% gain in CPU (but cheaper than buying 20% more CPUs)

Data Reprocessing



- Usually 100% raw data were prompt processed
- Since reprocessing started in September, we are giving priority to the reprocessing
- Only 30% of data will be prompt processed
- All 2012 data should be reprocessed for January 2013
- Pushing system to its limits (15K jobs running), very good stress test for post LS1 prompt processing

Papers submitted to journals since September

We now have 83 papers in total
New papers

- First evidence for the $B_s^0 \to \mu^+\mu^-$ decay
- First observation of the decay $B_{s2}^*(5840)^0 \to B^{*+}K^-$ and studies of excited B_s mesons
- First observation of the decays $\overline{B}_s \to D_s^+ K^-\pi^+\pi^-$ and $\overline{B}_s \to D_{s1}(2536)^+\pi^-$
- A study of the Z production cross-section in pp collisions at $\sqrt{s} = 7$ TeV using tau final states
- Measurement of the $B^0 - \overline{B}^0$ oscillation frequency Δm_d with the decays $B^0 \to D^-\pi^+$ and $B^0 \to J/\psi K^{*0}$
- Observation of $D^0 - \overline{D}^0$ oscillations
- First observation of the decay $B^+ \to \pi^+\mu^+\mu^-$
- Measurement of the CP asymmetry in $B^0 \to K^*\mu^+\mu^-$ decays
- A model-independent Dalitz plot analysis of $B^\pm \to DK^\pm$ with $D \to K_S^0 h^+h^-$ ($h = \pi, K$) decays and constraints on the CKM angle γ
- Measurement of the $D^\pm$ production asymmetry in 7 TeV pp collisions
- ....

- ....
- Evidence for the decay $B^0 \to J/\psi\omega$ and measurement of the relative branching fractions of B_s^0 meson decays to $J/\psi\eta$ and $J/\psi\eta'$
- First evidence for the annihilation decay mode $B^+ \to D_s^+\phi$
- Measurements of B_c^+ production and mass with the $B_c^+ \to J/\psi\pi^+$ decay
- Implications of LHCb measurements and future prospects
- First observation of the decay $B_{s2}^*(5840)^0 \to B^{*+}K^-$ and studies of excited B_s mesons
- Measurement of the time-dependent CP asymmetry in $B^0 \to J/\psi K_S^0$ decays

New conference notes

- Optimisation and calibration of the same-side kaon tagging algorithm using hadronic B_s^0 decays in 2011 data
- A measurement of γ from a combination of $B^\pm \to Dh^\pm$ analyses
- Studies of $\Lambda_b \to \Lambda J/\psi$ production in pp collisions at $\sqrt{s}$= 7 TeV
- First observation of the suppressed ADS modes $B^\pm \to [\pi^\pm K^\mp \pi^+\pi^-]_D K^\pm$ and $B^\pm \to [\pi^\pm K^\mp \pi^+\pi^-]_D \pi^\pm$
- Search for the lepton flavour violating and baryon number violating decays $\tau^- \to p^-\mu^+\mu^-$ and $\tau^- \to p\mu^-\mu^-$

D Oscillations

- Neutral mesons oscillates between matter and anti-matter

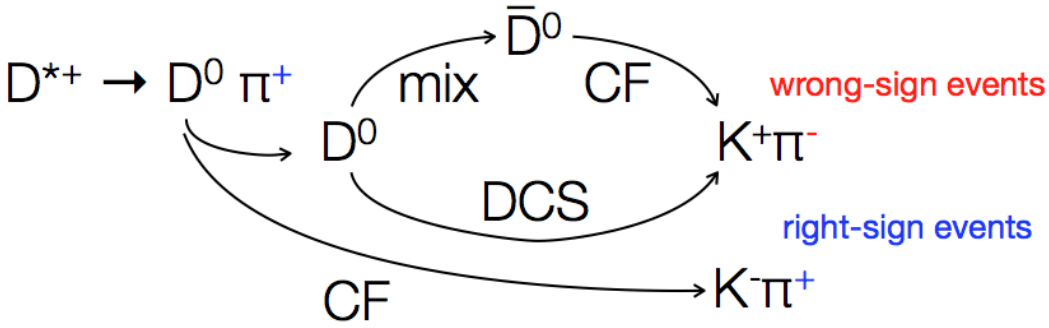
$$i\frac{d}{dt}\begin{bmatrix}|D^0\rangle \\ |\overline{D}^0\rangle\end{bmatrix} = \left(\begin{bmatrix}M_{11} & M_{12} \\ M_{12}^* & M_{22}\end{bmatrix} - \frac{i}{2}\begin{bmatrix}\Gamma_{11} & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma_{22}\end{bmatrix}\right)\begin{bmatrix}|D^0\rangle \\ |\overline{D}^0\rangle\end{bmatrix}$$

$$|D_{L,H}\rangle = p|D^0\rangle \pm q|\overline{D}^0\rangle \text{ where } \frac{q}{p} = \sqrt{\frac{M_{12}^* - \frac{i}{2}\Gamma_{12}^*}{M_{12} - \frac{i}{2}\Gamma_{12}}}$$

The charm mixing parameters are $x = \frac{\Delta m}{\Gamma}$ and $y = \frac{\Delta\Gamma}{2\Gamma}$

- Oscillations of neutral kaons and B-mesons are well established
- Charm mixing predicted to be small in the SM (x,$y \lesssim O(10^{-2})$)
- Sensitive to NP contributions
- Strong evidence of charm mixing only by combining the different experiments
- See also yesterday LHC Seminar by Angelo Di Canto

Strategy



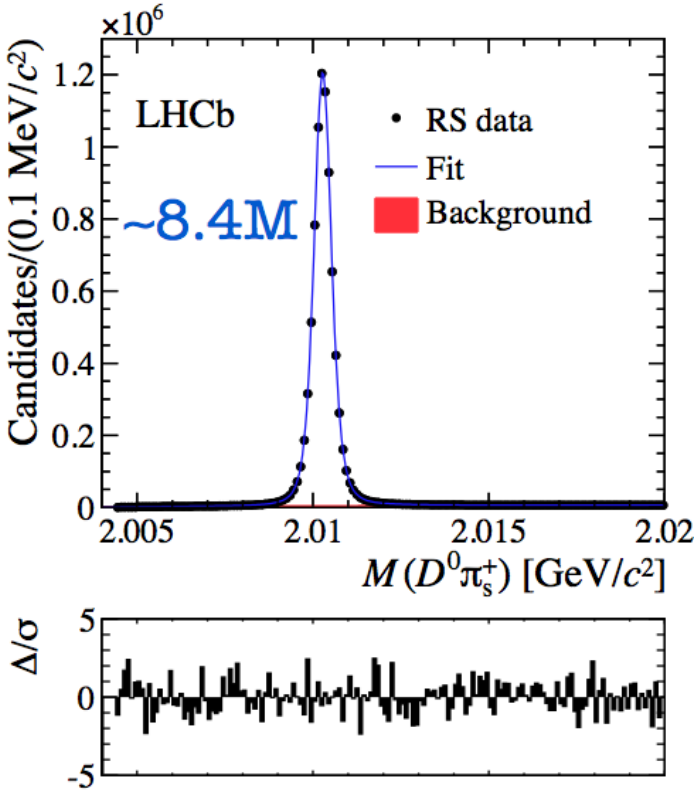
- Prompt $D^{*0} \to D^0\pi^+$ are used
- The wrong sign decays occurs either due to $D^0 - \overline{D}^0$ oscillations or via doubly-Cabibbo-suppressed decays

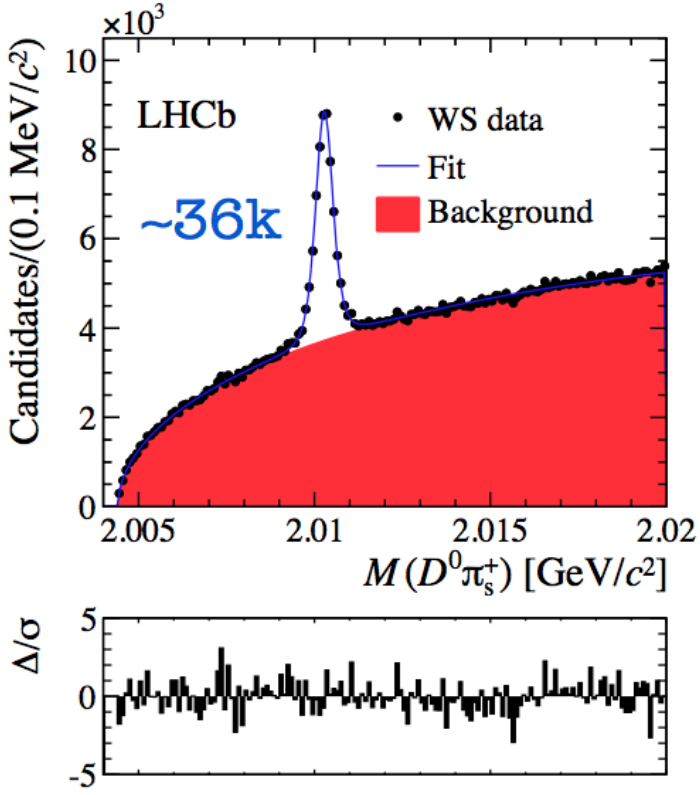
The time-dependent ratio between right-sign and wrong-sign is:

$$R(t) = \frac{N_{WS}(t)}{N_{RS}(t)} \approx R_D + \sqrt{R_D}y't + \frac{x'^2 + y'^2}{4}t^2$$

where $x' = x\cos\delta + y\sin\delta$ and $y' = y\cos\delta - x\sin\delta$

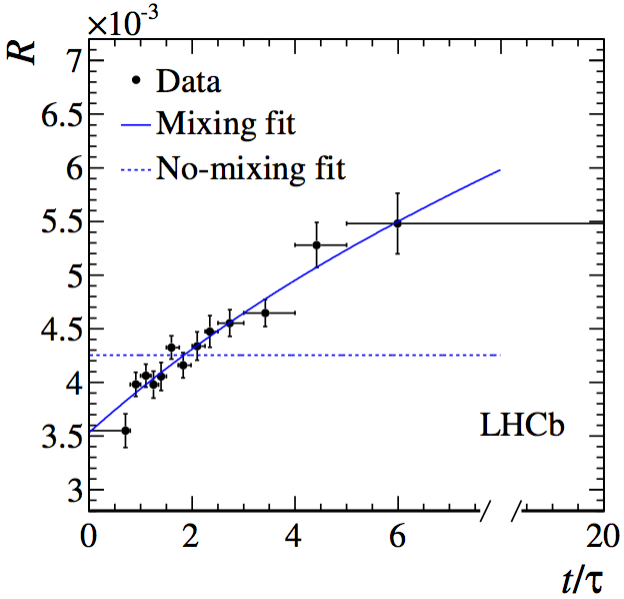
Signal Selection

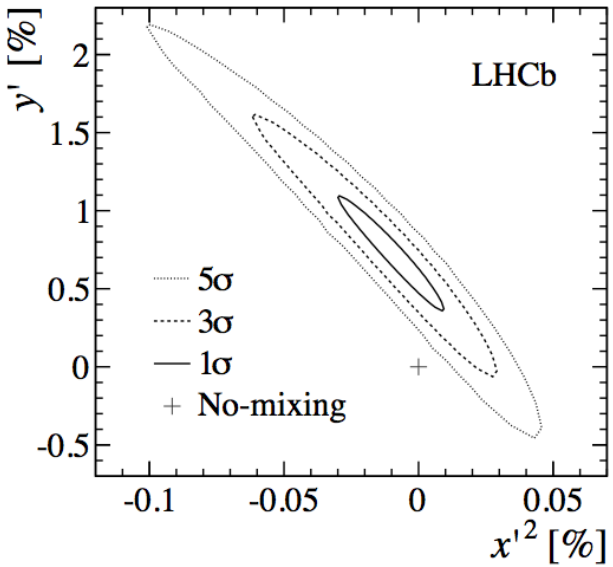




- Excellent resolution and PID important for this analysis
- Data are divided in into 13 decay-time bins
- $\frac{t}{\tau} = m_{D^0} \frac{L}{p\tau}$, where L is the distance $PV - SV$

Results



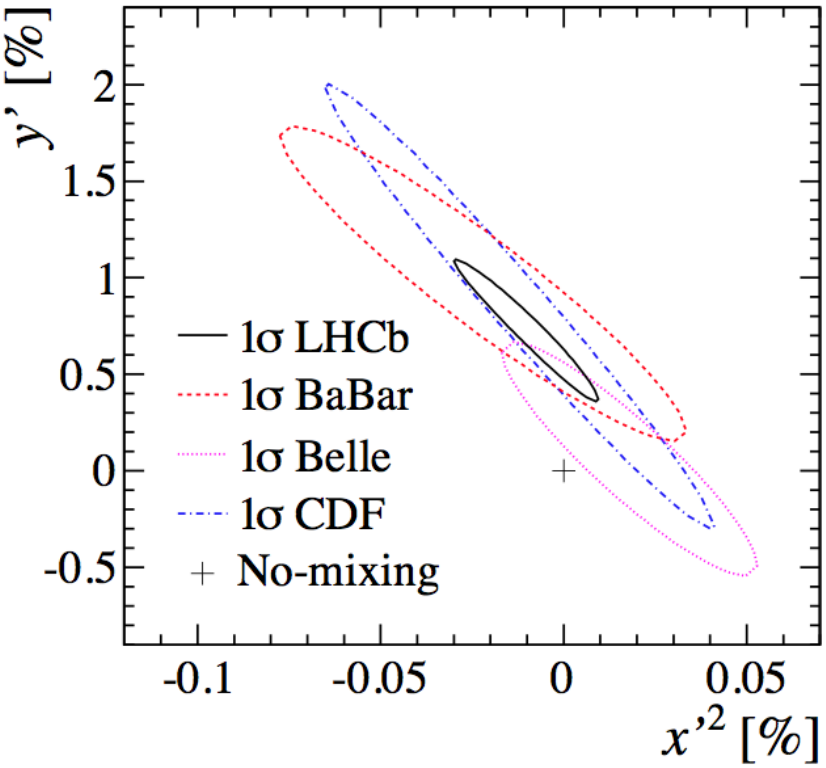


Fit type	Parameter	Result (10^{-3})
Mixing $\chi^2/nDoF = (9.5/10)$	R_D y' x'^2	3.52 ± 0.15 7.2 ± 2.4 -0.09 ± 0.13
No Mixing $\chi^2/nDoF = (98.1/12)$	R_D	4.25 ± 0.04

No-mixing hypothesis excluded at 9.1 standard deviations

First single experiment observation above 5 sigma!

Comparison with other experiments



BaBar: Phys. Rev. Lett. 98 (2007) 211802

Belle: Phys. Rev. Lett. 96 (2006) 151801

CDF: Phys. Rev. Lett. 100 (2008) 121802

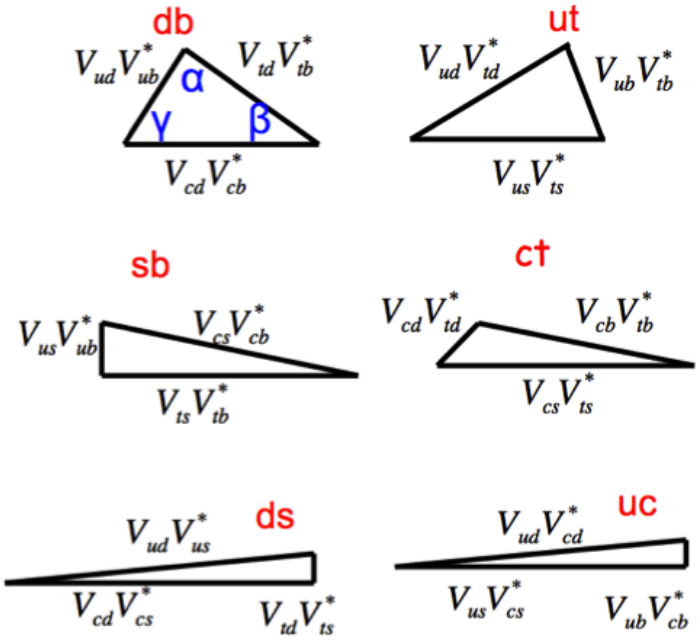
Experiment	R_D (10^{-3})	y' (10^{-3})	x'^2 (10^{-4})
LHCb	3.52 ± 0.15	7.2 ± 2.4	-0.9 ± 1.3
BaBar	3.03 ± 0.19	9.7 ± 5.4	-2.2 ± 3.7
Belle	3.64 ± 0.17	$0.6^{+4.0}_{-3.9}$	$1.8^{+2.1}_{-2.3}$
CDF	3.04 ± 0.55	8.5 ± 7.6	-1.2 ± 3.5

- Measured parameters nicely agree with other experiments
- Results dominated by statistical uncertainties

γ measurement

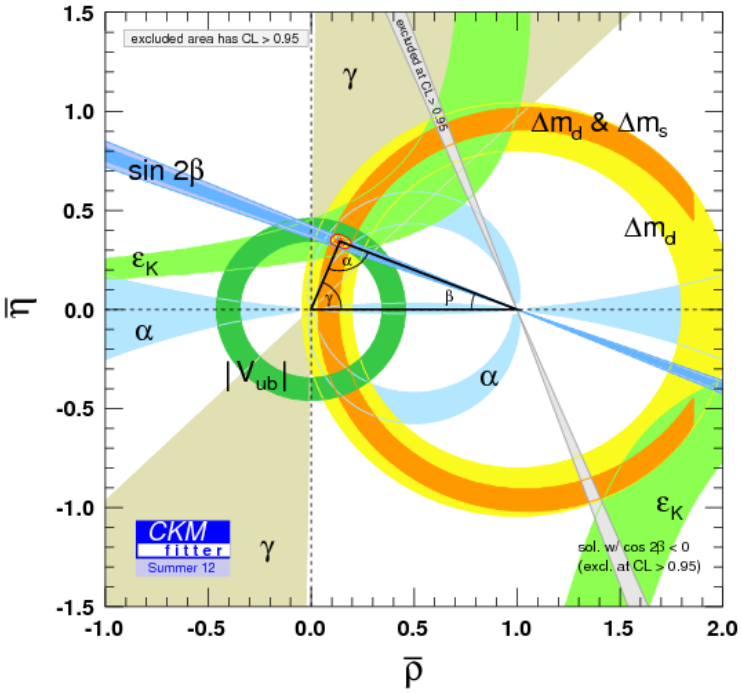
$$V^{CKM} = \text{CKM Matrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

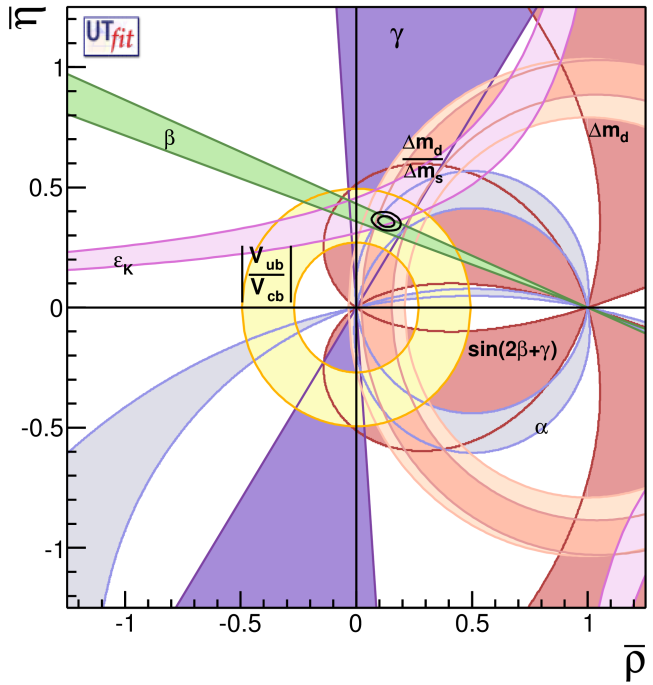
$$\text{where} \begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = V^{CKM} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$



- $\gamma = arg\left[-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right]$ is the least known of the angles of the UT
- γ can be extracted from Tree level (this talk) or penguin (JHEP 1210 (2012) 037, LHCb-CONF-2012-007) decays
- Difference between tree level and penguin would point to NP

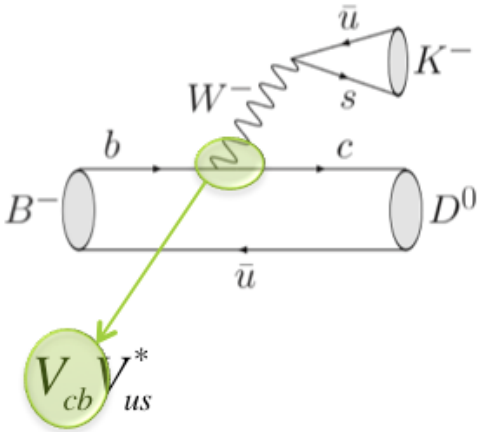
Present knowledge of γ



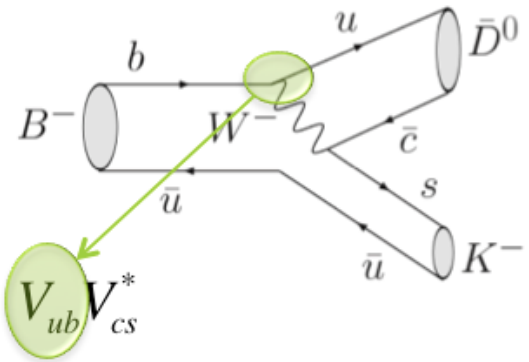


- The determination of γ is one of the goals of LHCb
- Over constraining the UT is a powerful test of the CKM paradigm
- CKM Fitter: $\gamma = (66 \pm 12)^\circ$, UTFit: $\gamma = (76 \pm 10)^\circ$

Input of LHCb γ combination



Color allowed



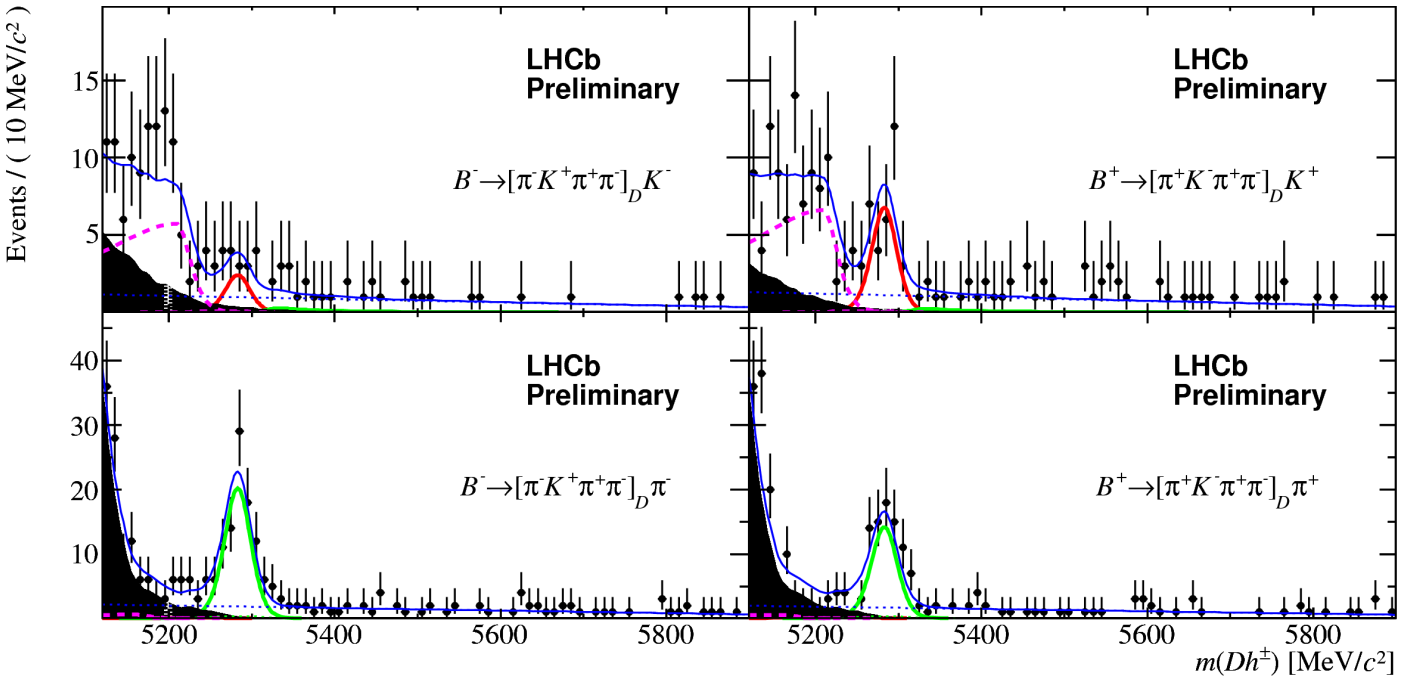
Color suppressed

GLW: $D^0 \to K^+K^-,\ \pi^+\pi^-$
ADS: $D^0 \to \pi^\pm K^\mp$
GGSZ: $D^0 \to K^0_S h^+h^-$

- $B^\pm \to [K\pi]_D h$ with $(h = \pi, K)$ (Phys. Lett. B 712 (2012) 203-212)
- $B^\pm \to DK^\pm$ with $D \to K^0_S h^+h^-$ $(h = \pi, K)$ (Phys. Lett. B 718 (2012) 43-55) *New from September*
- $B^\pm \to [K\pi\pi\pi]_D h$ with $(h = \pi, K)$ (LHCb-CONF-2012-030) *New from September*

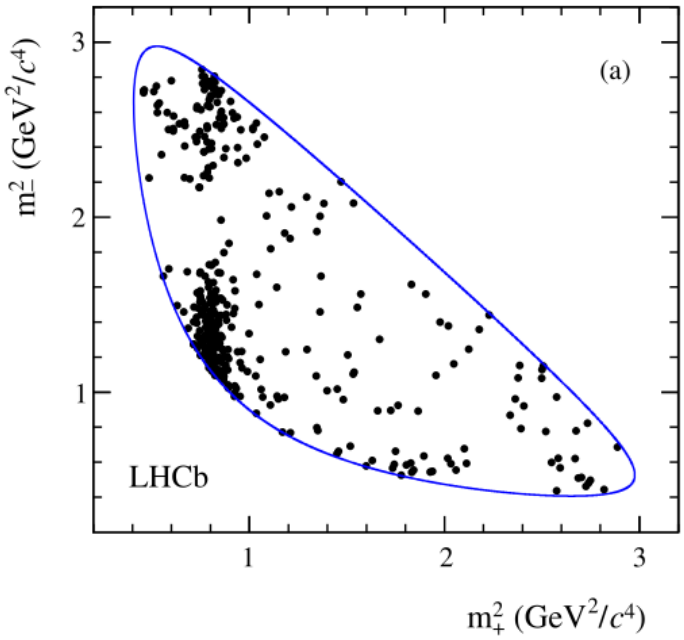
$B^{\pm} \to [K\pi\pi\pi]_D h$

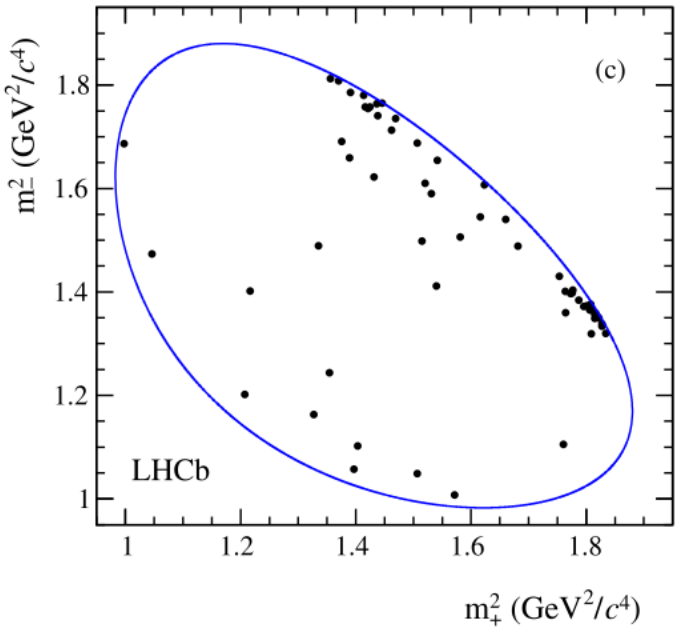
We have the first observation of the modes $B^{\pm} \to [\pi^{\pm}K^{\mp}\pi^{+}\pi^{-}]_D\pi^{\pm}$ ($\sim 10\sigma$) and $B^{\pm} \to [\pi^{\pm}K^{\mp}\pi^{+}\pi^{-}]_D K^{\pm}$ ($\sim 5\sigma$).



- $R_h^{\pm} = \frac{\Gamma(B^{\pm} \to [\pi^{\pm}K^{\mp}\pi^{+}\pi^{-}]_D h^{\pm})}{\Gamma(B^{\pm} \to [\pi^{\mp}K^{\pm}\pi^{+}\pi^{-}]_D h^{\pm})}$
- $R_K^{ADS} = \frac{(R_K^- + R_K^+)}{2} = 0.0124 \pm 0.0027,\ A_K^{ADS} = \frac{(R_K^- - R_K^+)}{(R_K^- + R_K^+)} = -0.417 \pm 0.222$
- $R_\pi^{ADS} = \frac{(R_\pi^- + R_\pi^+)}{2} = 0.00369 \pm 0.00036,\ A_\pi^{ADS} = \frac{(R_\pi^- - R_\pi^+)}{(R_\pi^- + R_\pi^+)} = 0.130 \pm 0.097$

GGSZ method

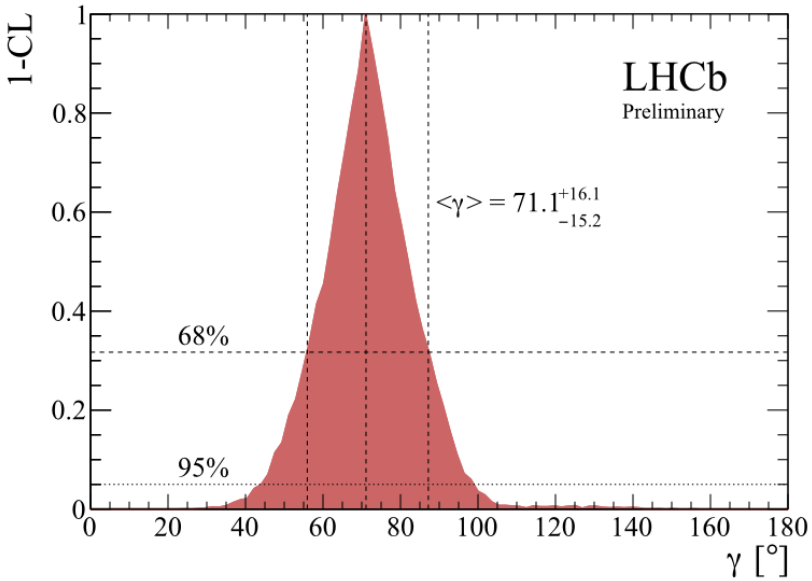




- Comparing the distribution of events in the $D^0 \to K^0_S h^+ h^-$ Dalitz plot for $B^+ \to DK^+$ and $B^- \to DK^-$ decays
- Necessary to know how the strong phase of the D decay varies over the Dalitz plot
- Use CLEO measurements for the D strong-phase
- Results: $\gamma = (44^{+43}_{-38})^\circ$, $\delta_B = (137^{+35}_{-46})^\circ$, $r_B = 0.07 \pm 0.04$

LHCb γ combination

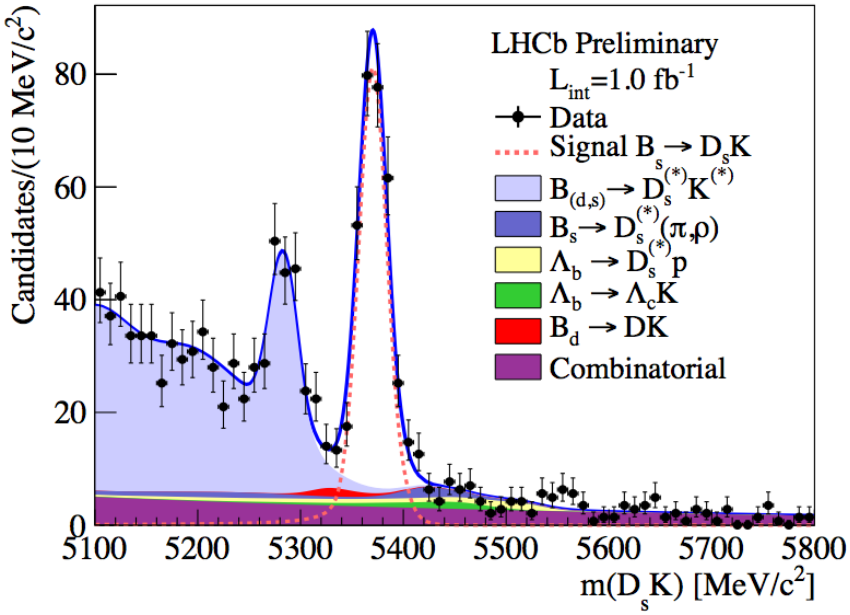
- Combination of $B^{\pm} \to DK^{\pm}$ analyses
- Parameters of Interest: $\vec{\alpha} = (\gamma,\ r_B\ ,\ \delta_B,\ ...)$
- The likelihood $\mathcal{L}(\vec{\alpha}) = \sum_i f_i(\vec{A}_{i\ obs}|\vec{A}_i(\vec{\alpha}_i))$ is used
- where $f_i \propto exp\left(-(\vec{A}_i(\vec{\alpha}_i) - \vec{A}_{i\ obs})V_i^{-1}(\vec{A}_i(\vec{\alpha}_i) - \vec{A}_{i\ obs})\right)$

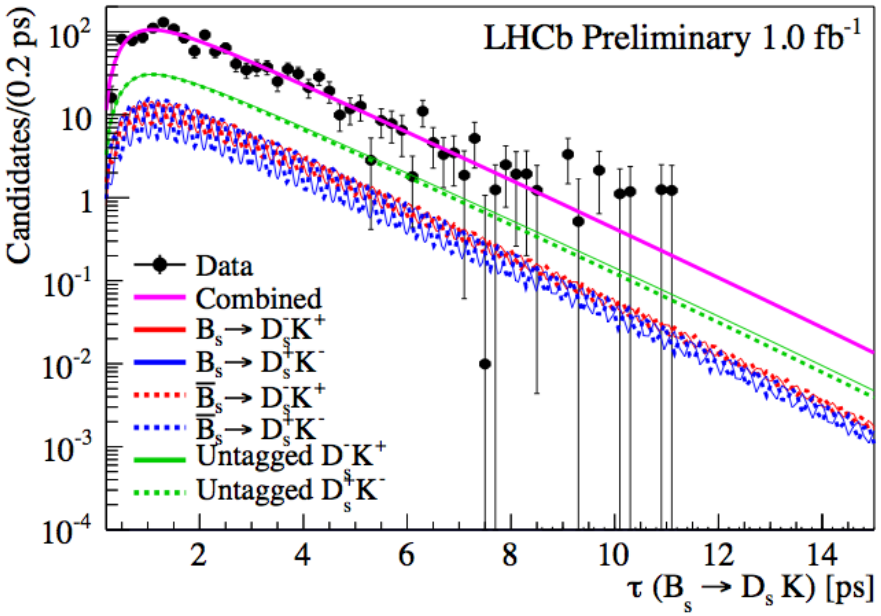


γ	71.1°
68%CL	[55.4, 87.7]
95%CL	[41.4, 101.3]

$B^- \to DK^-$ from LHCb
D-system from CLEO

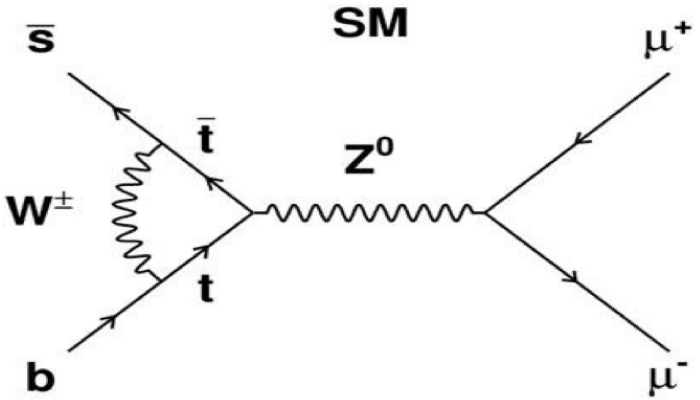
$B_s \to D_s K$





- Presented at CKM 2012 LHCb-CONF-2012-029
- Two possible decay paths:
  - Direct $b \to c$ decay
  - B_s mixing and $b \to u$ decay
- A time dependent analysis is required
- We do not have a γ extraction from this channel yet, more studies on systematics are required

$B_s \to \mu^+\mu^-$



Mode	SM prediction
$B_s \to \mu^+\mu^-$	$(3.54 \pm 0.30) \times 10^{-9}$
$B^0 \to \mu^+\mu^-$	$(0.11 \pm 0.01) \times 10^{-9}$

A. Buras et al., arXiv:1208.0934

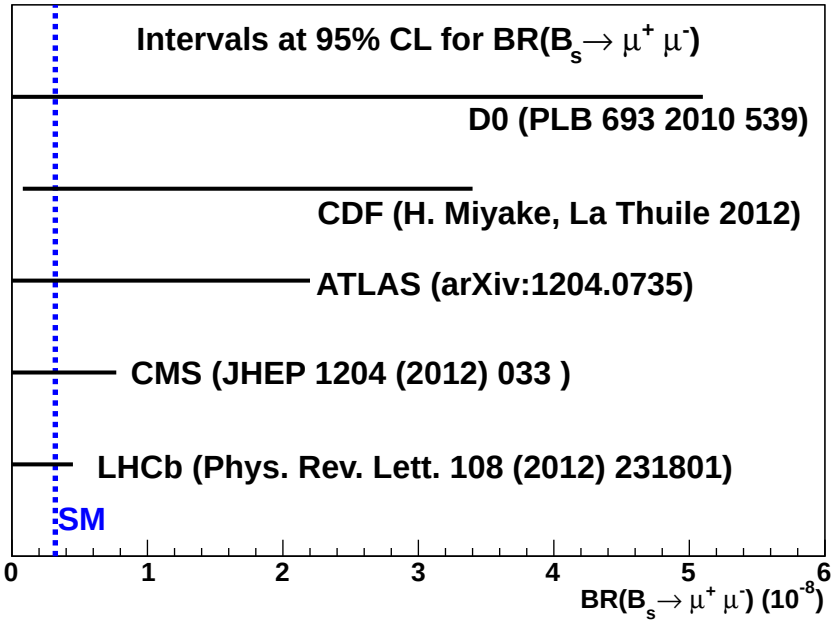
DeBruyn et al., arXiv:1204.1737

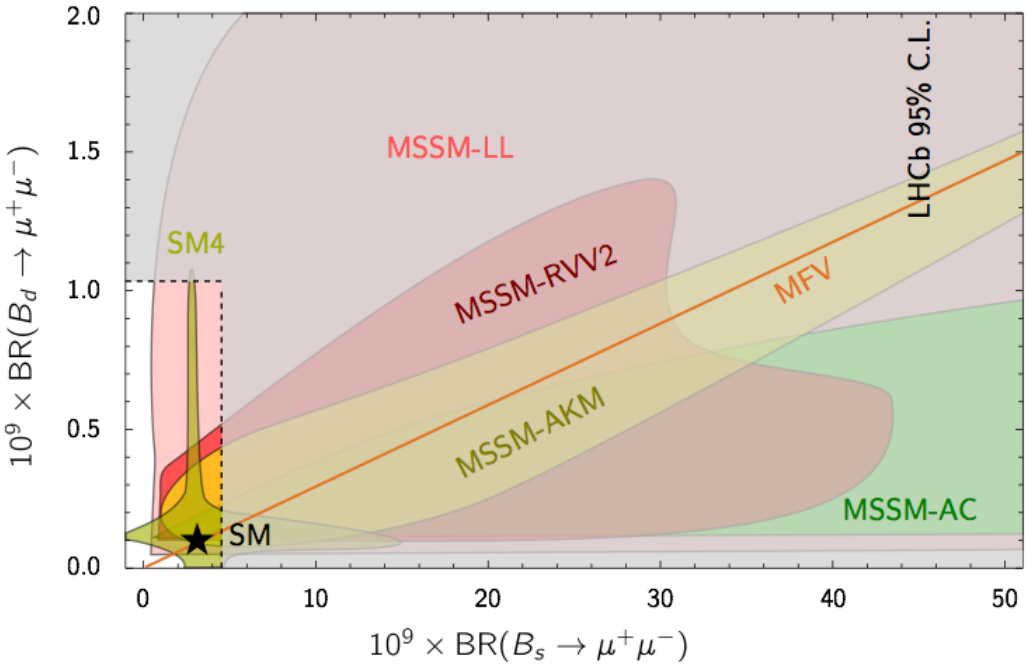
C. Davies, arXiv:1203.3862 (and ref. therein)

$$\mathcal{B}(B_s \to \mu^+\mu^-) \propto |\mathcal{C}_S - \mathcal{C}'_S|^2 \left(1 - \frac{4m_\mu^2}{m_{B_s}^2}\right) + \left|(\mathcal{C}_P - \mathcal{C}'_P) + \frac{2m_\mu}{m_{B_s}}(\mathcal{C}_{10} - \mathcal{C}'_{10})\right|^2$$

- Suppressed being a FCNC and also helicity suppressed
- Sensitive to "scalar" and "pseudo-scalar" contributions beyond the SM, e.g. MSSM with high $\tan\beta$

Present situation and new analysis



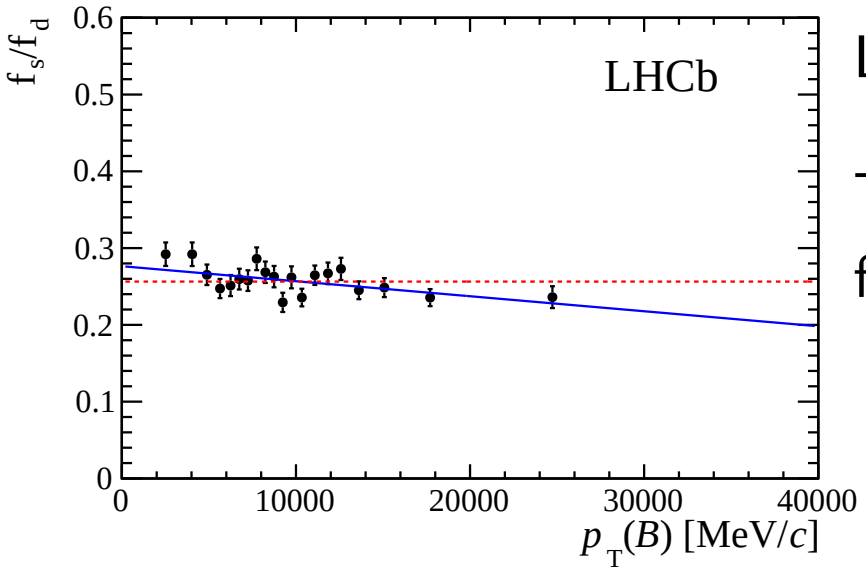


- LHC combination: $\mathcal{B}(B_s \to \mu^+\mu^-) < 4.2 \cdot 10^{-9}$ at 95% CL
- For the new analysis two datasets are combined
  - 1.0 fb^{-1} at $\sqrt{s} = 7$TeV (2011)
  - 1.1 fb^{-1} at $\sqrt{s} = 8$TeV (2012)
- The present analysis supersedes the previous 2011 publication

Analysis strategy

- The selection consist of a soft cut-based "pre-selection" to reduce the size of data followed by a BDT

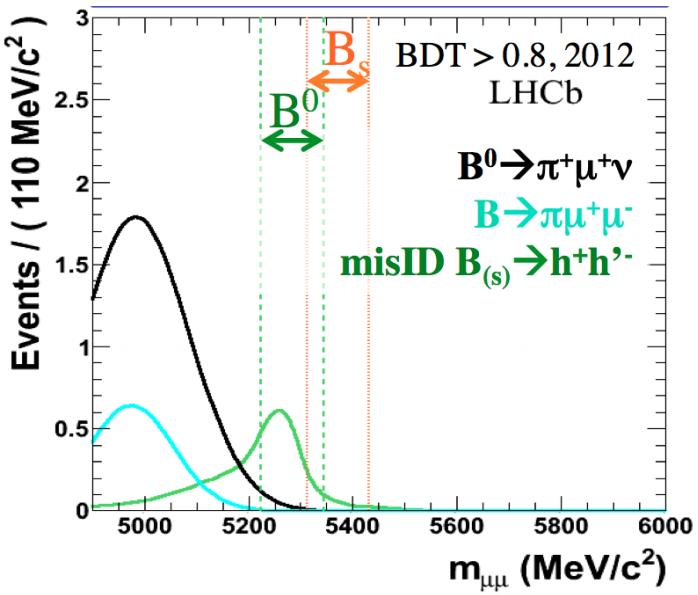
- The normalisation uses the decays $B^{\pm} \to J/\psi K^{\pm}$ and $B \to h^+ h'^-$
- $\frac{f_s}{f_d} = 0.256 \pm 0.020$ has been measured combining:
  - Ratio of $B_s \to D_s \mu X$ and $B \to D^+ \mu X$
  - Ratio of $B_s \to D_s \pi$ and $B^0 \to DK$

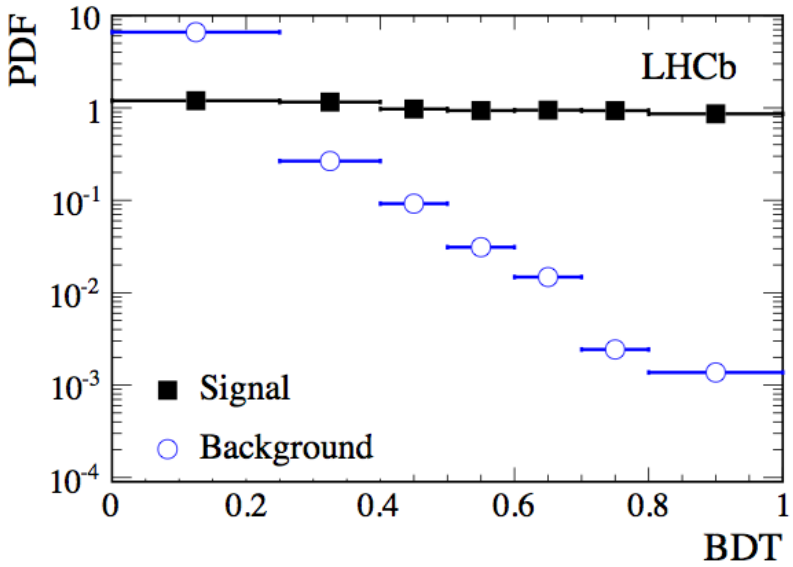


LHCb-Paper-2012-037, to appear shortly

The dependence of P_T is negligible for $B_s \to \mu^+\mu^-$ normalisation

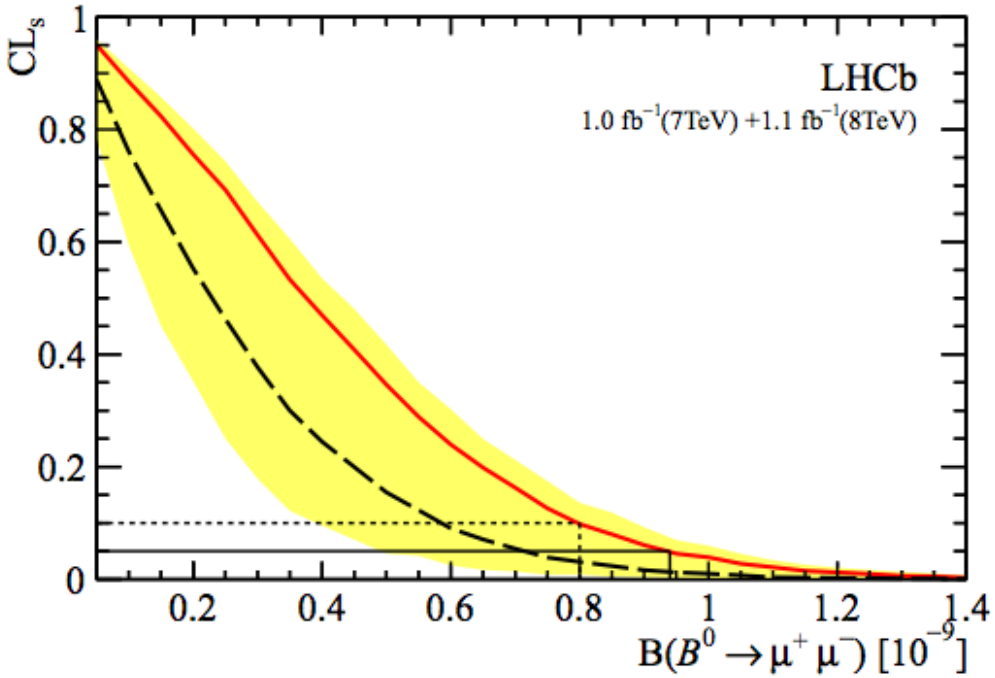
Analysis strategy II





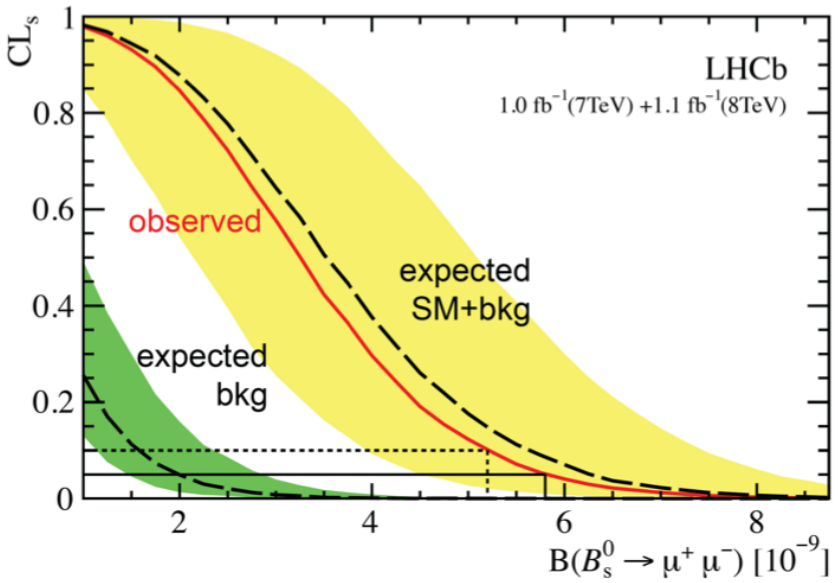
- The fit is performed in 8 (for 2011) + 7 (for 2012) BDT bins
- Combinatorial background modelled with an exponential
- Better treatment of exclusive backgrounds wrt previous analysis
  - $B^0 \to \pi^+\mu^-\nu$, $B_d \to \pi^0\mu^+\mu^-$
  - $B^+ \to \pi^+\mu^-\mu^+$
  - $B_{(s)} \to h^+h^{-\prime}$ with MisID

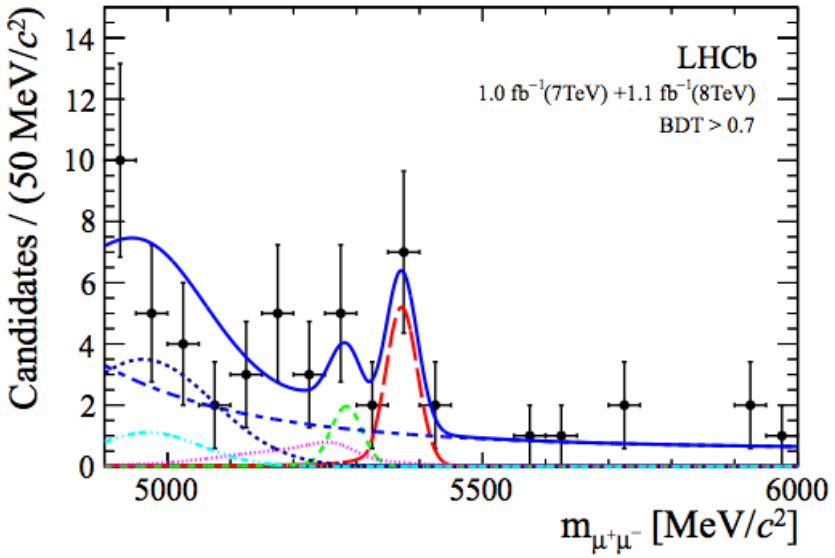
$B^0 \to \mu^+\mu^-$ Result



- Combining 2011 and 2012 dataset
- Background only p-value is 11%
- Upper limit $\mathcal{B}(B^0 \to \mu^+\mu^-) < 9.4 \times 10^{-10}$ at 95% CL
- World's best single experiment UL

$B_s \to \mu^+\mu^-$ Result





- Combining 2011+2012 data
- Bkg only hypothesis p-value is 5×10^{-4} corresponding to 3.5 σ
- $\mathcal{B}(B_s \to \mu^+\mu^-) = 3.2^{+1.4}_{-1.2}(stat)^{+0.5}_{-0.3}(syst) \times 10^{-9}$
- First evidence of the decay $B_s \to \mu^+\mu^-$
- Consistent with the SM!
- Submitted to PRL arXiv:1211.2674

Olivier's invariance at work

$B_s \to \mu^+\mu^-$

Slide shown to the CERN Scientific Policy Committee in December 2007

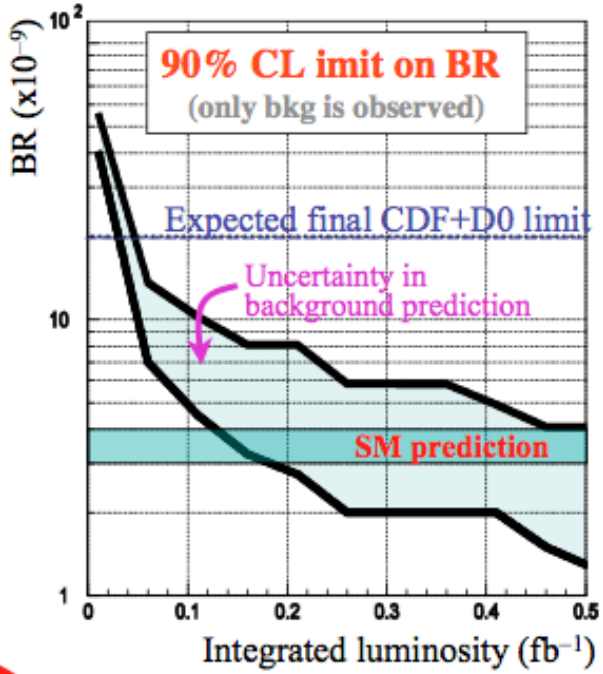
select

s

- specific background dominated by $B_c \to J/\psi(\mu\mu)\mu\nu$

— Exploit good detector performance:

- muon ID
- vertexing (topology)
- mass resolution (18 MeV/c^2)

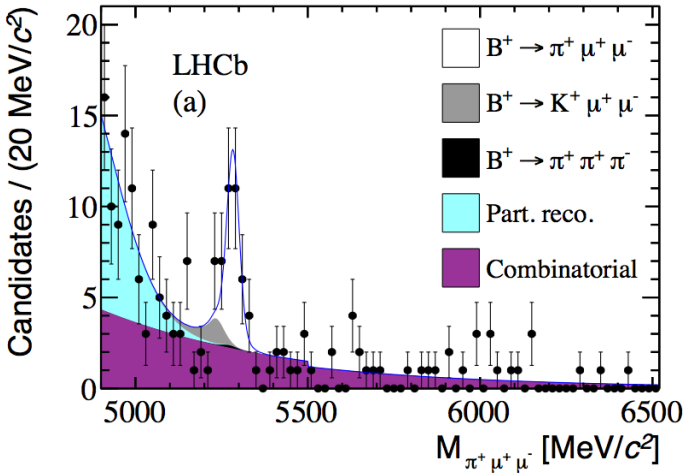


0.05 fb^{-1} ⇒ overtake CDF+D0
0.5 fb^{-1} ⇒ exclude BR values down to SM
2 fb^{-1} ⇒ 3σ evidence of SM signal
6 fb^{-1} ⇒ 5σ observation of SM signal

LHCb's best NP discovery potential with the very early data !

SPC meeting — O. Schneider, Dec 10, 2007 — 16

Other rare decays

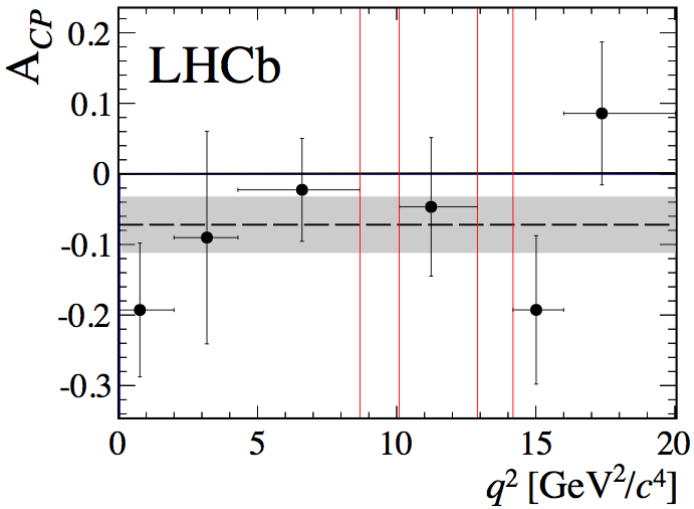


The rarest B-decay ever observed (before $B_s \to \mu^+\mu^-$)

$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-) = (2.3 \pm 0.6(stat) \pm 0.1(syst)) \times 10^{-8}$

Good agreement with SM predictions

arXiv:1210.2645



Direct CP asymmetry in $B_d \to K^*\mu^+\mu^-$

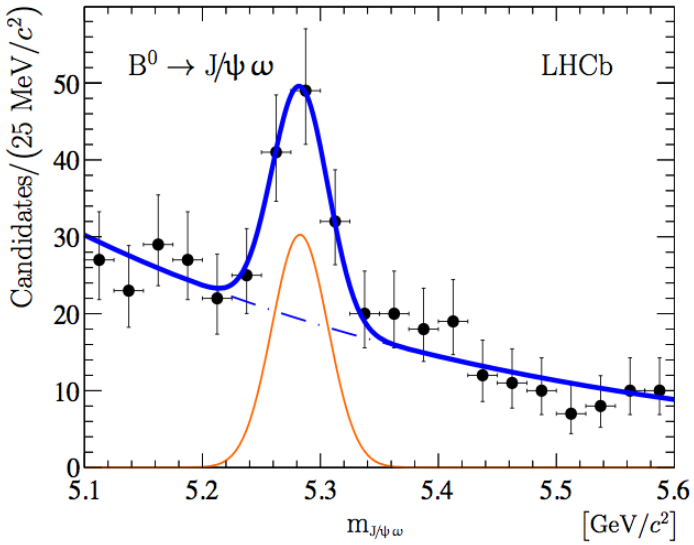
$\mathcal{A}_{CP}(B_d \to K^*\mu^+\mu^-) = (-7.2 \pm 4.0(stat) \pm 0.5(syst))\%$

World's best measurement of this observable

Good agreement with Belle and BaBar measurements

arXiv:1210.4492

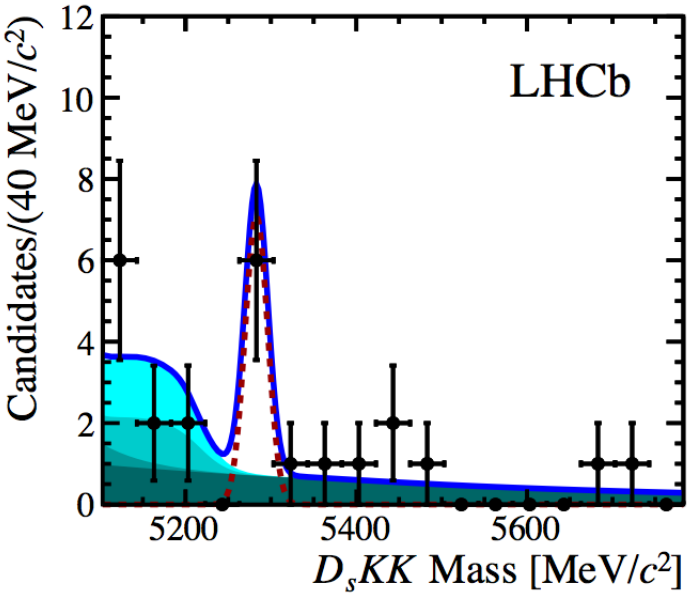
First observation/evidence of ...



First observation of $B^0 \to J/\psi\omega$

$\frac{B^0 \to J/\psi\omega}{B^0 \to J/\psi\rho} = 0.89 \pm 0.19(stat)^{+0.07}_{-0.13}(syst)$

arXiv:1210.2631



First evidence of the $B^+ \to D_s^+\phi$ decay

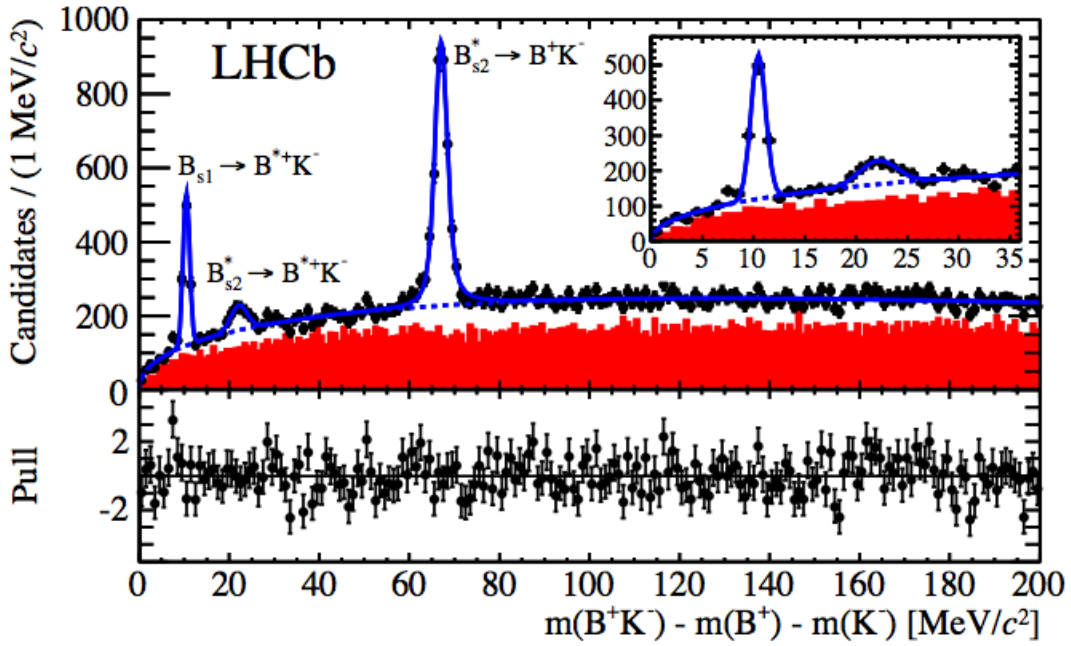
$\mathcal{B}(B^+ \to D_s^+\phi) = (1.87^{+1.25}_{-0.73}(stat) \pm 0.37(syst)) \times 10^{-6}$

Also measurement of $\mathcal{A}_{CP}$

$\mathcal{A}_{CP} = -0.01 \pm 0.41(stat) \pm 0.03(syst)$

arXiv:1210.1089

First observation/evidence of ...

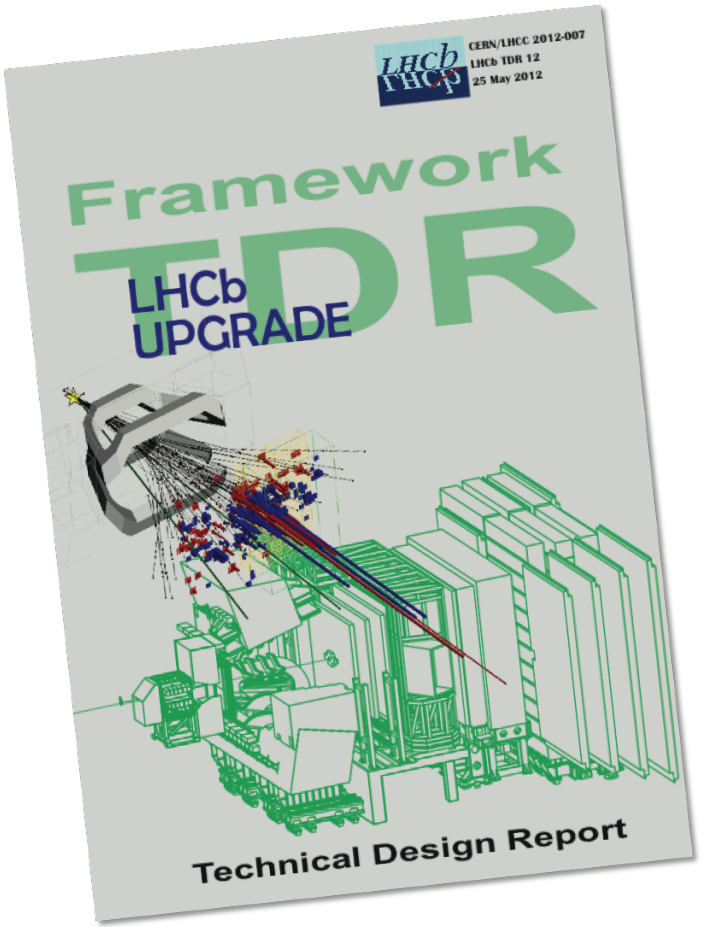


- First observation of the decay $B_{s2}^*(5840)^0 \to B^{*+}K^-$
- World's best measurement of the $B^* - B$ mass difference
- Important for the understanding of Z_b^+ (observed by Belle), which may be a $B - B^*$ molecule
- favours $B_{s2}^*(5840)^0 J^P = 2^+$
- arXiv:1211.5994 submitted to PRL

Physics Summary and Prospects

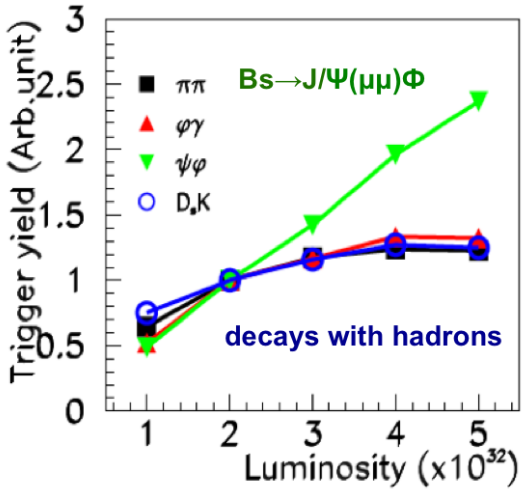
- γ measurement:
  - We have the first γ combination from LHCb
  - Results for γ competitive with B-factories
  - More data to analyse and more modes to be added!
- Charm physics
  - Performing well in charm physics
  - First single observation of $D^0 - \overline{D}^0$ mixing ($\sim 9\sigma$)
  - I also remind you the evidence of CP violation in charm PRL 108, 111602 (2012)
  - More CPV measurements in the charm will come
- $B_{s,d} \to \mu^+\mu^-$
  - First evidence of the decay $B_s \to \mu^+\mu^-$
  - Now we will hunt for $B_d \to \mu^+\mu^-$
  - Very important a precise measurement of the ratio $\frac{B_s \to \mu^+\mu^-}{B_d \to \mu^+\mu^-}$
- So far measurements are consistent with the SM
- Much more statistics after LS1 (till 2018), with increased cross section

Upgrade


CERN/LHCC 2012-007
LHCb TDR 12
25 May 2012
Framework
TDR
LHCb
UPGRADE
Technical Design Report

LHCb
UPGRADE
Letter of Intent

Why Upgrade

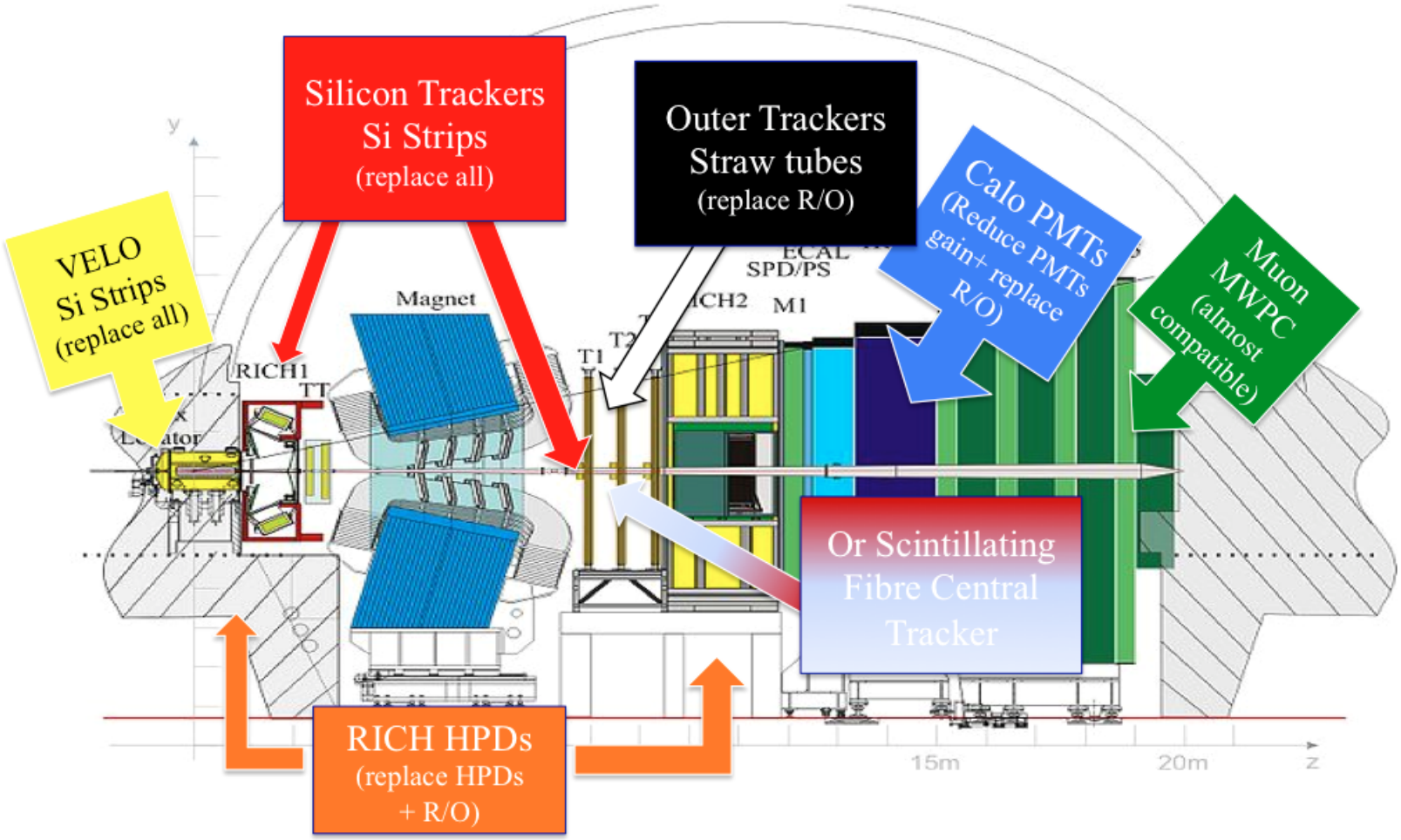


- Limitations of current detector
  - Rate for hadrons saturate at luminosities above $\sim 4 \cdot 10^{32} cm^{-2} s^{-1}$
  - P_T cuts must be raised to stay within 1MHz R/O limit
- Baseline for LHCb upgrade
  - increase luminosity up to $\mathcal{L} \sim 2 \cdot 10^{33} cm^{-2} s^{-1}$
  - Upgrade readout electronics to 40MHz
  - Upgrade DAQ architecture to full software trigger
  - Increase annual signal yield, compared 2011 by a factor ~ 10 for muonic and ~ 20 for hadronic decays
- Collect 50fb^{-1} (over ~ 10 years) with much increased efficiency for hadronic final states

Upgrade Physics

Type	Observable	Current precision	LHCb 2018	**Upgrade** ($50\,\text{fb}^{-1}$)	Theory uncertainty
B_s^0 mixing	$2\beta_s\ (B_s^0 \to J/\psi\,\phi)$	0.10 [9]	0.025	0.008	~ 0.003
	$2\beta_s\ (B_s^0 \to J/\psi\,f_0(980))$	0.17 [10]	0.045	0.014	~ 0.01
	$A_{\text{fs}}(B_s^0)$	6.4×10^{-3} [18]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguin	$2\beta_s^{\text{eff}}(B_s^0 \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{\text{eff}}(B_s^0 \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\text{eff}}(B^0 \to \phi K_S^0)$	0.17 [18]	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{\text{eff}}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\text{eff}}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,\text{GeV}^2/c^4)$	0.08 [14]	0.025	0.008	0.02
	$s_0\,A_{\text{FB}}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [14]	6 %	2 %	7 %
	$A_{\text{I}}(K\mu^+\mu^-; 1 < q^2 < 6\,\text{GeV}^2/c^4)$	0.25 [15]	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [16]	8 %	2.5 %	~ 10 %
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9} [2]	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	~ 10–12° [19, 20]	4°	0.9°	negligible
	$\gamma\ (B_s^0 \to D_s K)$	–	11°	2.0°	negligible
	$\beta\ (B^0 \to J/\psi\,K_S^0)$	0.8° [18]	0.6°	0.2°	negligible
Charm *CP* violation	A_Γ	2.3×10^{-3} [18]	0.40×10^{-3}	0.07×10^{-3}	–
	ΔA_{CP}	2.1×10^{-3} [5]	0.65×10^{-3}	0.12×10^{-3}	–

Implications of LHCb measurements and future prospects:
arXiv:1208.3355


Silicon Trackers
Si Strips
(replace all)
Outer Trackers
Straw tubes
(replace R/O)
Calo PMTs
(Reduce PMTs gain+ replace R/O)
Muon
MWPC
(almost compatible)
VELO
Si Strips
(replace all)
Magnet
RICH1
TT
T1
T2
ECAL
SPD/PS
M1
Or Scintillating
Fibre Central
Tracker
RICH HPDs
(replace HPDs
+ R/O)
15m
20m
z
y

Roadmap for the LHCb Upgrade

- Submitted "*Upgrade LOI*" in March 2011 CERN-LHCC-2011-001
  - physics case fully *endorsed*, 40 MHz architecture reviewed
  - *recommendation* in June 2011 to proceed to "*Framework TDR*" and detectors TDRs
- Submitted "*Framework TDR*" in May 2012 CERN-LHCC-2012-007
  - "*Framework TDR*" fully endorsed in September 2012
- Now proceeding to sub-system TDRs according to schedule given in FTDR
  - all detector TDRs at the end of 2013, online TDR early 2016
  - 40MHz detector ready for installation in 2018 during LS2
- Preparing addenda to MoU for Upgrade
  - Addendum for Common Projects has been submitted to RRB in October 2012
  - sub-system addendum will be submitted following approval of individual TDRs

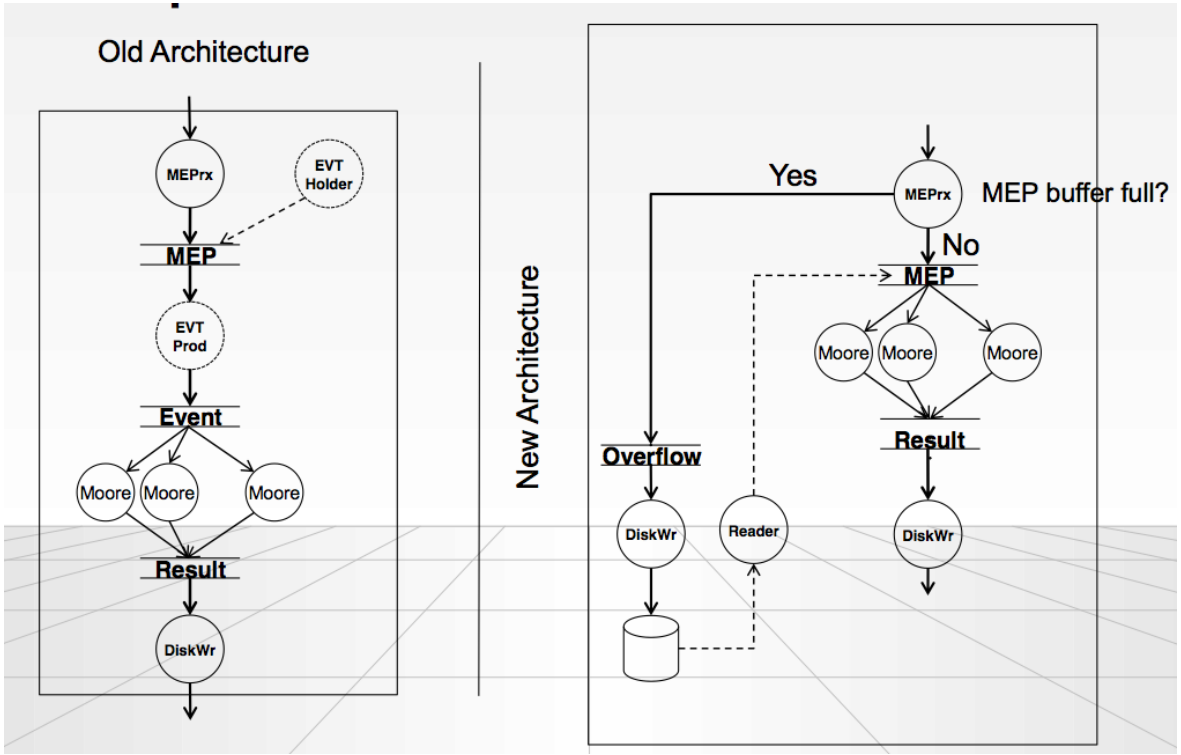
Conclusions

- Our detector is running smoothly and is very healthy
- Important steps in B-physics:
  - γ measurement
  - $B_s \to \mu^+\mu^-$
  - ... and more
- Doing well in charm physics
- All consistent with the SM, with only two "tensions":
  - Evidence of CPV in charm PRL 108, 111602 (2012)
  - Isospin asymmetry in $B \to K\mu^+\mu^-$ JHEP 07 (2012) 133
- We are almost everywhere limited by statistical error
- The LHCb upgrade will allow several measurements to get an error of the order of the theory error
- Next year will be the year of the TDRs for upgrade

We would like to express our gratitude to our colleagues in the CERN accelerator departments for the excellent performance of the LHC.

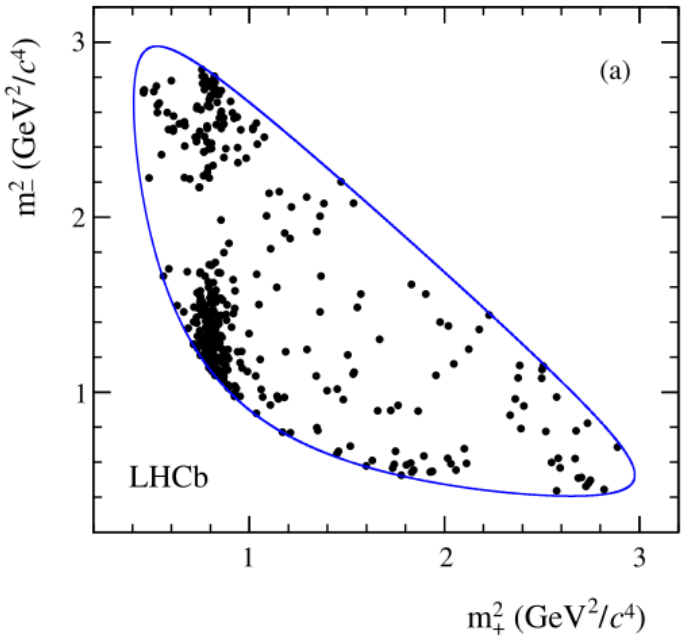
Backup Slides

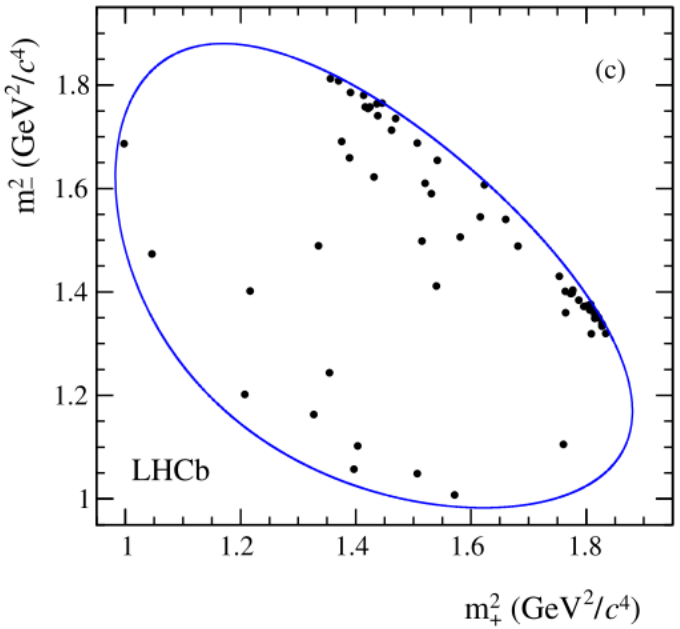
Deferred Trigger



- When the event builder detects that the HLT cannot process all the incoming events, they are written to the hard disk of the nodes in the EFF. Between fills, these events will be processed
- Equivalent 20% gain in CPU (but cheaper than buying 20% more CPUs)

GGSZ method

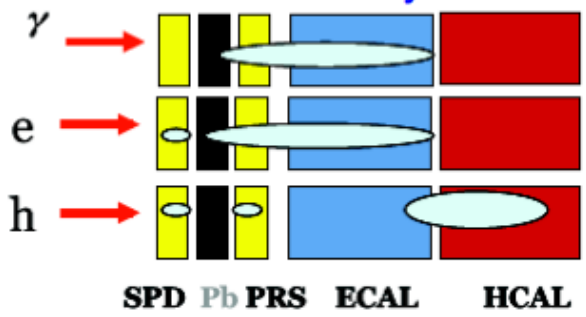




- Comparing the distribution of events in the $D^0 \to K^0_S h^+ h^-$ Dalitz plot for $B^+ \to DK^+$ and $B^- \to DK^-$ decays
- Determine the yield of B^+ and B^- in each bins of the Dalitz plot
- $N^+_{+i} = n_{B^+}\left(K_{-i} + (x^2_+ + y^2_+)K_{+i} + 2\sqrt{K_{+i}K_{-i}}(x_+ c_{+i} - y_+ s_{+i})\right)$
  $x_\pm = r_B \cos(\delta_B \pm \gamma)$, $y_\pm = r_B \sin(\delta_B \pm \gamma)$
- K_i flavour tagged yield in bin i, c_i,s_i - CLEO inputs

Calorimeter system

PID with Calo system



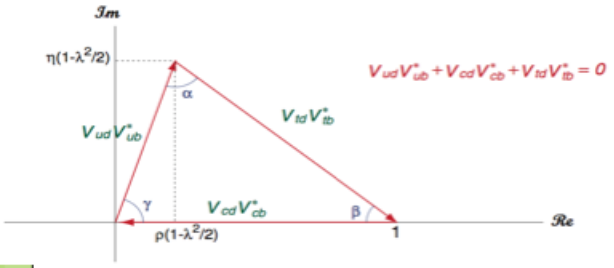
Scitillating Pad Detector and Preshower detector
~6000 plastic scintillator pads 15 mm thick
interlayed with 2.5 X_0 lead converter;

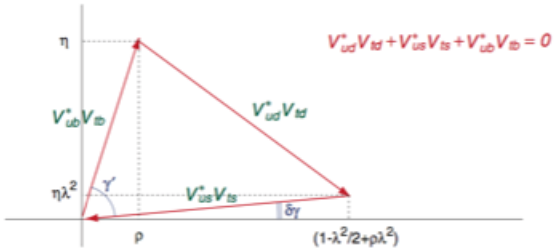
Electromagnetic calorimeter (ECAL)
Shashlik sampling technology
Alternating scintillator (4 mm)/lead (2mm) tiles
42mm thick = $25X_0$

Hadron calorimeter (HCAL)
Iron plates interspaced with scintillating tiles
5.6 λ_I thick

11

Unitarity Triangle





Sides:

V_{ud}	β-decay	$(A,Z) \to (A,Z+1) + e^- + \bar{\nu}_e$	$\cos\vartheta_C$
V_{us}	K-decay	$K^+ \to \pi^0 + \ell^+ + \nu_\ell$	$\sin\vartheta_C$
		$K^0 \to \pi^- + \ell^+ + \nu_\ell$	
V_{cd}	ν-production of c's	$\nu_\ell + d \to \ell^- + c$	$\cos\vartheta_C$
V_{cs}		$D^\pm \to K^0 + \ell^\pm + \nu_\ell$	$\sin\vartheta_C$
V_{ub}	B-decay	$b \to u + \ell^- + \bar{\nu}_\ell$	
V_{cb}		$b \to c + \ell^- + \bar{\nu}_\ell$	
V_{td}	Δm in B^0-$\bar{B}^0$		

Measurement of the angles:

$$\alpha \Rightarrow \begin{array}{l} B \to \pi\pi \\ B \to \rho\rho \\ B \to \rho\pi \end{array}$$

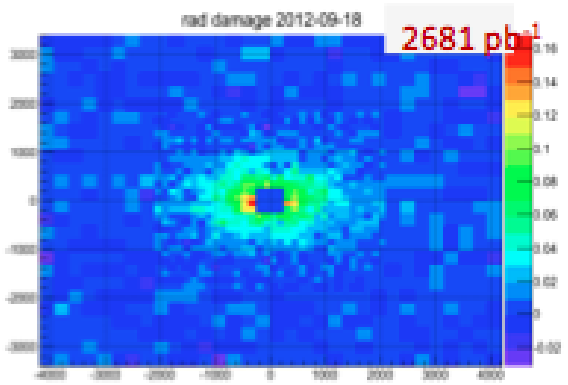
$$\beta \Rightarrow \begin{array}{l} B \to J/\psi K_s \\ B \to \phi K_s \\ B \to D^{(*)}D^{(*)} \end{array}$$

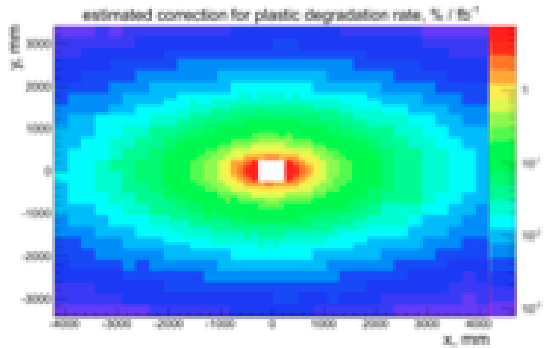
$$\gamma \Rightarrow \begin{array}{l} B \to D^{(*)}\pi \\ B \to DK \end{array}$$

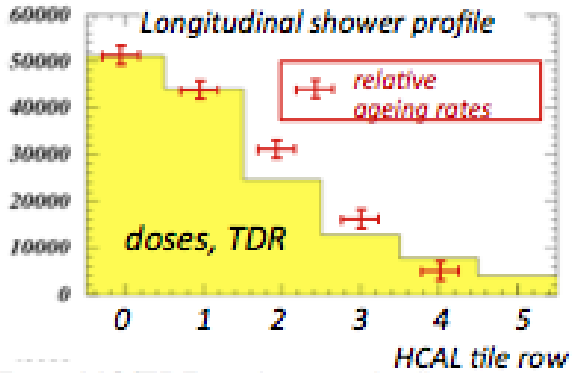
HCAL calibration

PMT aging from LED system

Radiation damage measured by Cs source





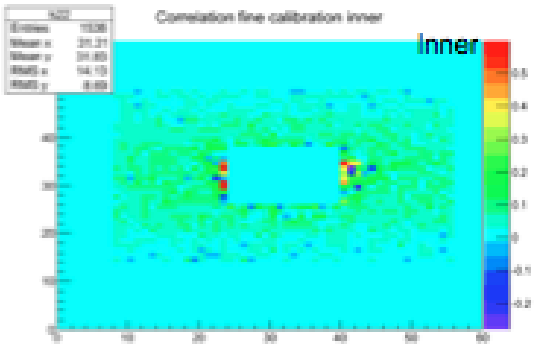


From MC/TDR aging rate in tiles rows are weighted according to longitudinal profile

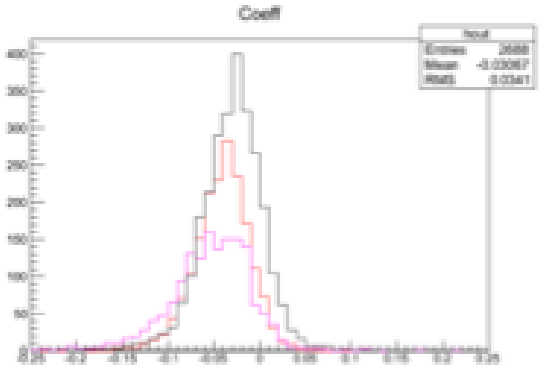
Naive model ~7%/fb at center
Probably overestimated
On top of LED correction

ECAL ageing

8 Fine calibration



Up to 50% ageing ..

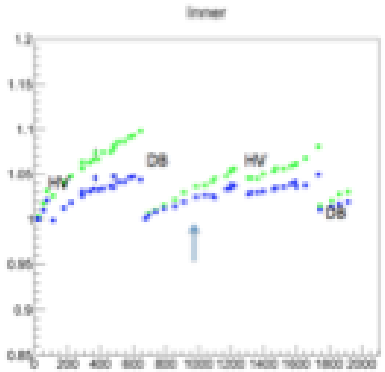


Ageing correction May-Mid-september

Dasha
M.Noelle

Outer 3%
Middle 4.1%
Inner 5.3%

Electron E/p trending



DB corrections

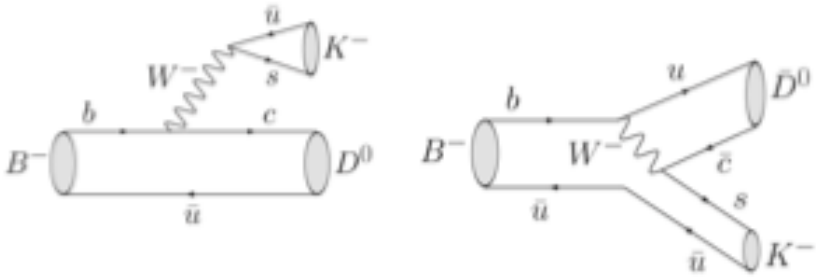
LHCb Calorimeters

27/11/2012

LHCb week M.N Minard

11

Gamma with Trees



$A(B^- \to D^0 K^-) = A_c e^{i\delta_c}$, $A(B^- \to \overline{D}^0 K^-) = A_u e^{i(\delta_u - \gamma)}$

$A(D^0 \to f) = A_f e^{i\delta_f}$ and $A(\overline{D}^0 \to f) = A_{\bar{f}} e^{i\delta_{\bar{f}}}$ f being a generic final state of D-meson.

The δs are strong phases and γ is the week phase, while A are real and positive

$$A(B^- \to (f)_D K^-) = A_C A_f e^{i(\delta_c + \delta_f)} + A_u A_{\bar{f}} e^{i(\delta_u + \delta_{\bar{f}} - \gamma)}$$

$$\Gamma(B^- \to (f)_D K^-) = A_C^2 A_{\bar{f}}^2 \left({A_f^2}/{A_{\bar{f}}^2} + r_B^2 + 2 r_B \, {A_f}/{A_{\bar{f}}} \, \mathrm{Re}(e^{i(\delta_B + \delta_D - \gamma)}) \right)$$

where $r_B = {A_u}/{A_C}$, $\delta_B = \delta_u - \delta_C$, $\delta_D = \delta_{\bar{f}} - \delta_f$

GLW method

In the GLW method the D meson is reconstructed when it decays into a CP eigenstate (e.g. K K), therefore the $A_f / A_{\bar{f}} = 1$, $\delta_D = 0, \pi$ and CP=+1,-1 $\Rightarrow$

$$\Rightarrow \quad \Gamma(B^- \to [f_{CP\pm}]_D K^-) = A_C^2 A_{f_{CP\pm}}^2 (1 + r_B^2 \pm 2 r_B \cos(\delta_B - \gamma))$$

We have:

$$A_{CP\pm} = \frac{\Gamma(B^- \to D^0_{CP\pm} K^-) - \Gamma(B^+ \to D^0_{CP\pm} K^+)}{\Gamma(B^- \to D^0_{CP\pm} K^-) + \Gamma(B^+ \to D^0_{CP\pm} K^+)} = \frac{\pm 2 r_B \sin\delta_B \sin\gamma}{1 + r_B^2 \pm 2 r_B \cos\delta_B \cos\gamma}$$

$$R_{CP\pm} = \frac{\Gamma(B^- \to D^0_{CP\pm} K^-) + \Gamma(B^+ \to D^0_{CP\pm} K^+)}{2\Gamma(B^- \to D^0 K^-)} = 1 + r_B^2 \pm 2 r_B \cos\delta_B \cos\gamma$$

ADS method

In the ADS method it used the interference of

$B^- \to D^0 K^-$ followed by doubly Cabibbo-suppressed $D^0 \to K^+\pi^-$

and the suppressed $B^- \to \overline{D}^0 K^-$ followed by the Cabibbo-allowed $\overline{D}^0 \to K^+\pi^-$.

$$r_D = A/A = \frac{\left\| A(D^0 \to K^+\pi^-) \right\|}{\left\| A(D^0 \to K^-\pi^+) \right\|}$$

Since $r_D \sim 5\%$ and $r \sim 10\%$ the interference can be quite large!

$$R_{ADS} = \frac{\Gamma(B^- \to [K^+\pi^-]_D K^-) + \Gamma(B^+ \to [K^-\pi^+]_D K^+)}{\Gamma(B^- \to [K^-\pi^+]_D K^-) + \Gamma(B^+ \to [K^+\pi^-]_D K^+)} = r_B^2 + r_D^2 + 2 r_B r_D \cos\gamma \cos(\delta_B + \delta_D)$$

$$A_{ADS} = \frac{\Gamma(B^- \to [K^+\pi^-]_D K^-) - \Gamma(B^+ \to [K^-\pi^+]_D K^+)}{\Gamma(B^- \to [K^+\pi^-]_D K^-) + \Gamma(B^+ \to [K^-\pi^+]_D K^+)} = 2 r_B r_D \sin\gamma \sin(\delta_B + \delta_D) / R_{ADS}$$

Other ways of extracting γ

GGSZ:

In this method the D^0 is reconstructed when it decays in 3bodies (e.g. $K_s^0 \pi \pi$).

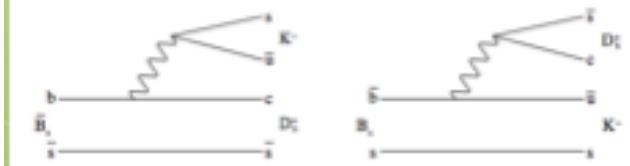
$$A_f e^{i\delta_f} = f(m_-^2, m_+^2)$$

$$A_{\bar{f}} e^{i\delta_{\bar{f}}} = f(m_+^2, m_-^2)$$

$$\Gamma(B^{\mp} \to [K_s^0 \pi\pi]_D K^{\mp}) \propto \left| f(m_{\mp}^2, m_{\pm}^2) \right|^2 + r_B^2 \left| f(m_{\pm}^2, m_{\mp}^2) \right|^2 + 2 r_B \left| f(m_{\mp}^2, m_{\pm}^2) \right| \left| f(m_{\pm}^2, m_{\mp}^2) \right| \cos(\delta_B + \delta_D(m_{\mp}^2, m_{\pm}^2) \mp \gamma)$$

Bs→DsK (Time dependent CP asymmetry):

The interference between the direct decay and the decay after mixing allows to access γ. The non-zero $\Delta\Gamma_s$ allows to include non tagged events in the analysis.



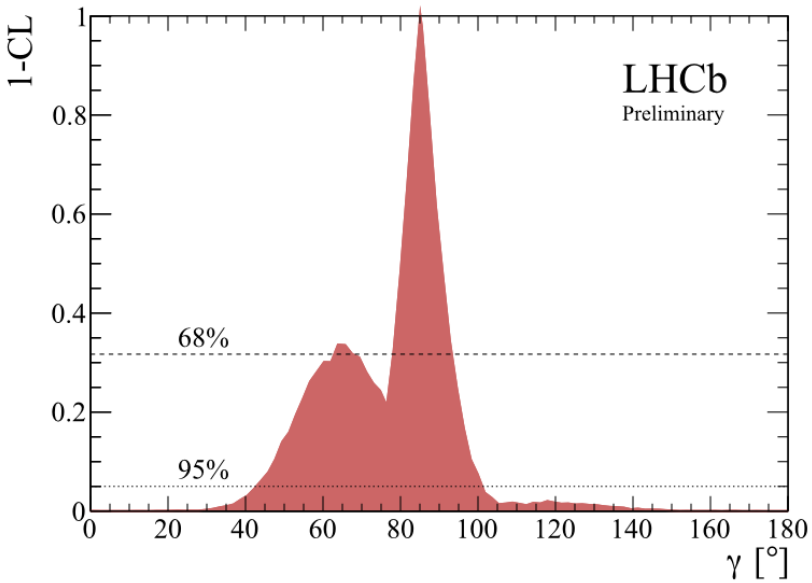
$$\Gamma_{B_s^0/B_s^0 \to f}(t) = 2 \cdot |A_f|^2 (1 + |\lambda_f|^2) \frac{e^{-\Gamma_s t}}{2} \cdot \left(\cosh \frac{\Delta\Gamma_s t}{2} + D_f \sinh \frac{\Delta\Gamma_s t}{2} \right)$$

$$\Gamma_{B_s^0/B_s^0 \to \bar{f}}(t) = 2 \cdot |\bar{A}_f|^2 (1 + |\bar{\lambda}_f|^2) \frac{e^{-\Gamma_s t}}{2} \cdot \left(\cosh \frac{\Delta\Gamma_s t}{2} + D_f \sinh \frac{\Delta\Gamma_s t}{2} \right)$$

$$\gamma + \phi_s = \frac{1}{2}[arg(\bar{\lambda}_{\bar{f}}) - arg(\lambda_f)]$$

LHCb γ combination

- Combination of $B^{\pm} \to Dh^{\pm}$ analyses
- Parameters of Interest: $\vec{\alpha} = (\gamma,\, r_B\ ,\, \delta_B,\, ...)$
- The likelihood $\mathcal{L}(\vec{\alpha}) = \sum_i f_i(\vec{A}_{i\ obs}|\vec{A}_i(\vec{\alpha}_i))$ is used
- where $f_i \propto exp\left(-(\vec{A}_i(\vec{\alpha}_i) - \vec{A}_{i\ obs})V_i^{-1}(\vec{A}_i(\vec{\alpha}_i) - \vec{A}_{i\ obs})\right)$



γ	$63.7°$	$85.1°$
68%CL	$[61.8, 67.8]°$	$[77.9, 92.4]°$
95%CL		$[43.8, 101.5]°$

$B^- \to DK^- + B^- \to D\pi^-$ from LHCb
D-system from CLEO