Flavour Physics at LHCb

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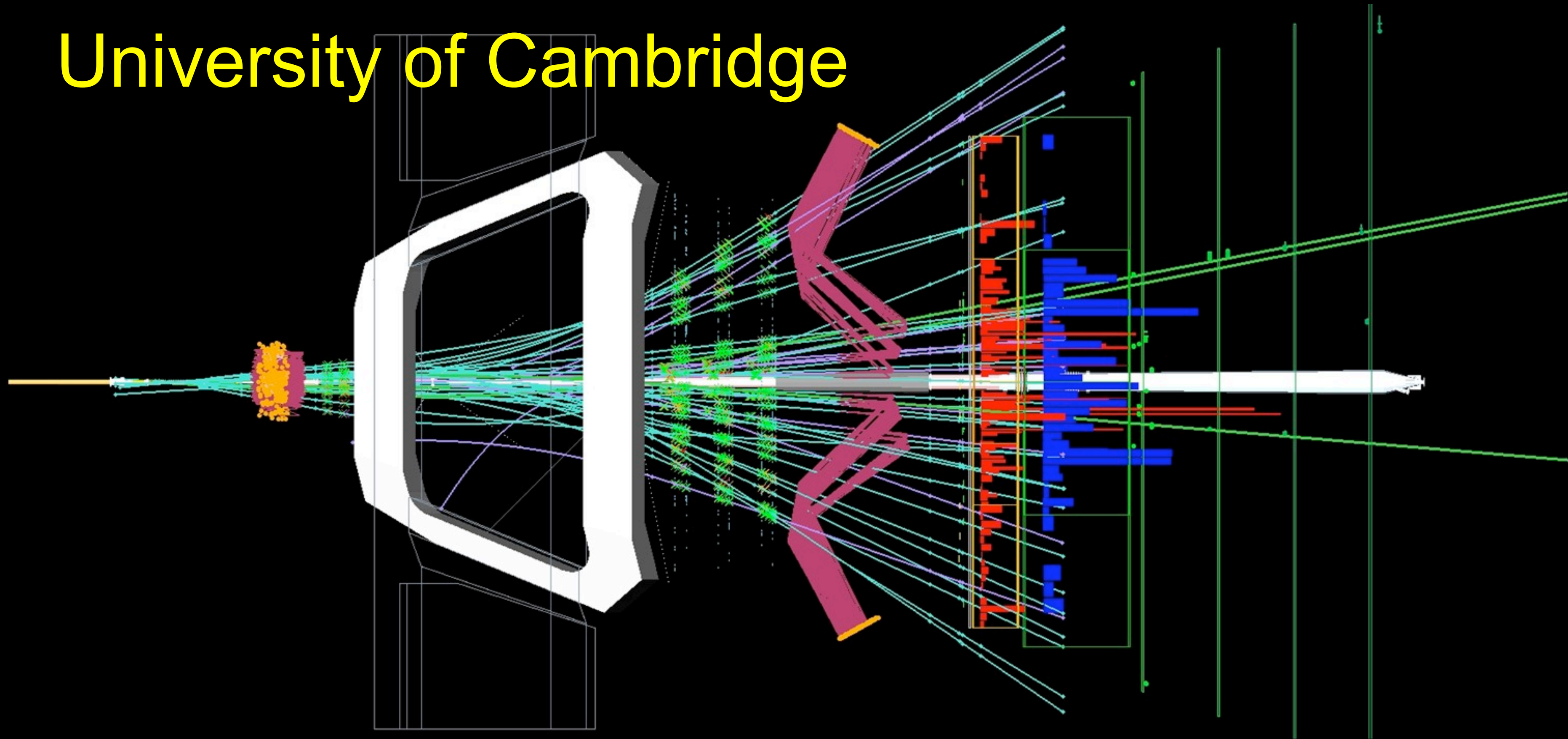
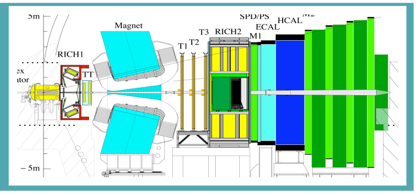


Collider Phenomenology 2011

Outline

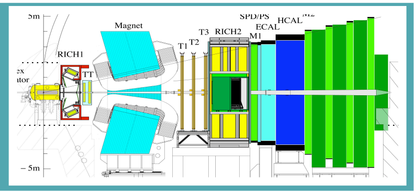


- Introduction
- The LHCb experiment
- Production Studies
- First observation of new B_s decays
- Search for new CP phases in B mixing
- Search for NP contributions to rare B decays
- Summary

All results very new!!

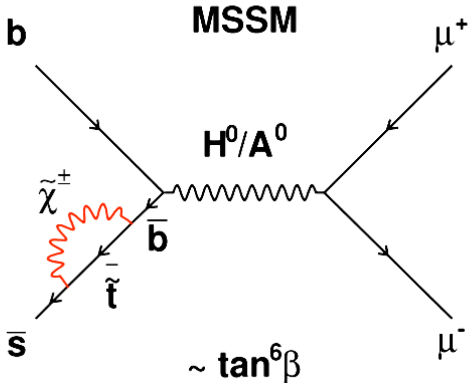
Moriond EW/QCD
Beauty 2011 and DIS

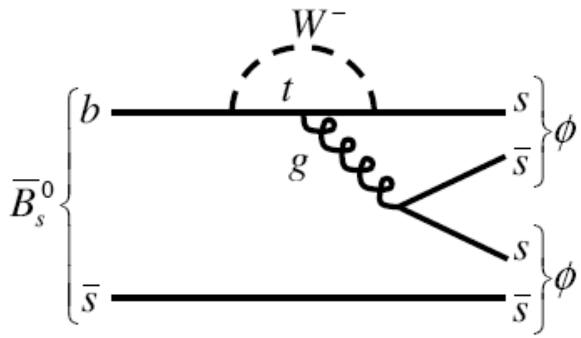
LHCb Physics Program

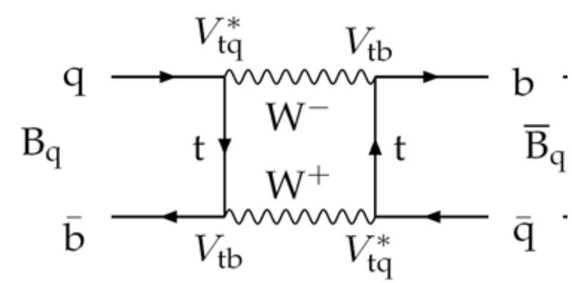


LHCb is designed to find evidence of New Physics through the indirect effect that the new degrees of freedom may have on heavy flavour (B and D) decays.

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



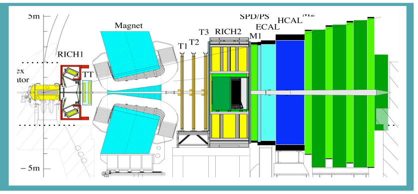




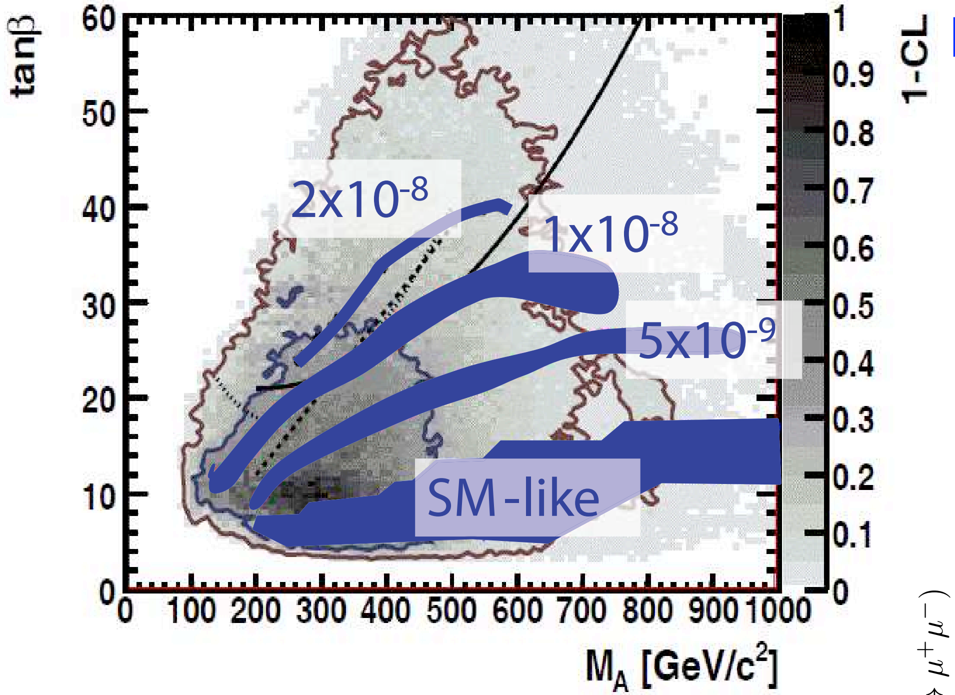
New Physics needs to have a special flavour structure

- to provide the suppression mechanism for FCNC processes already observed.
- It may be too “special”… Minimal Flavour Violation (MFV) models in which the flavour structure of the NP is governed by the CKM matrix.

New Physics in $B \to \mu^+\mu^-$



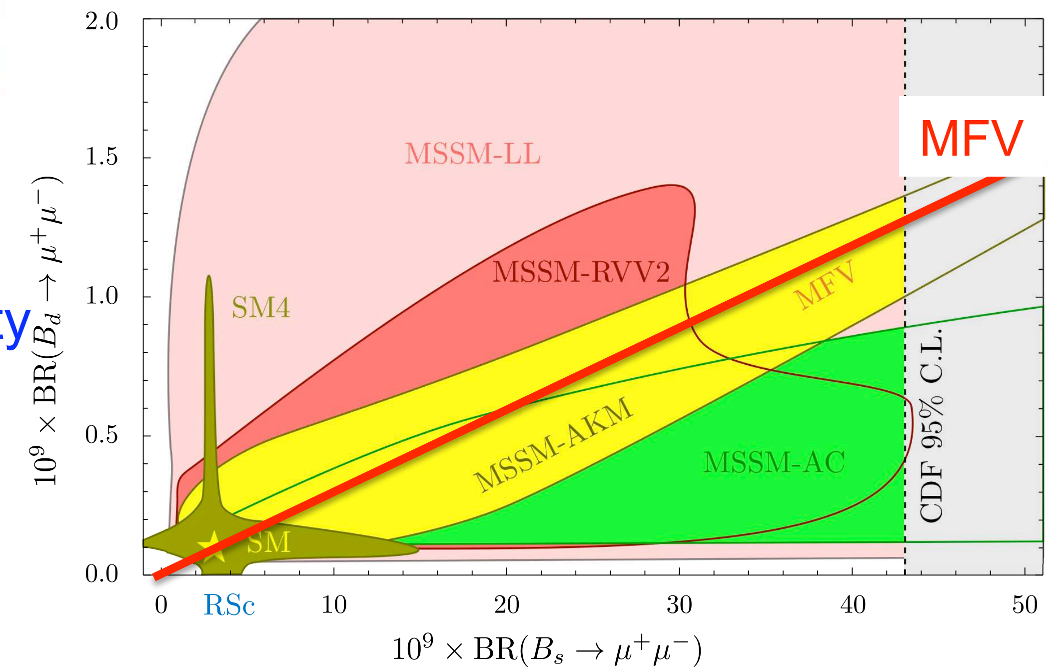
Example: the discovery power of the measurement of $B(B_{d,s} \to \mu^+\mu^-)$



Large $B(B_s \to \mu^+\mu^-)$ possible in NP models

CMS, 60 pb⁻¹
5σ contours

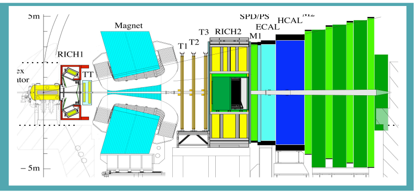
— $\tau^+\tau^-$ jets
---- jet + μ
···· jet + e



MFV would retain flavour universality

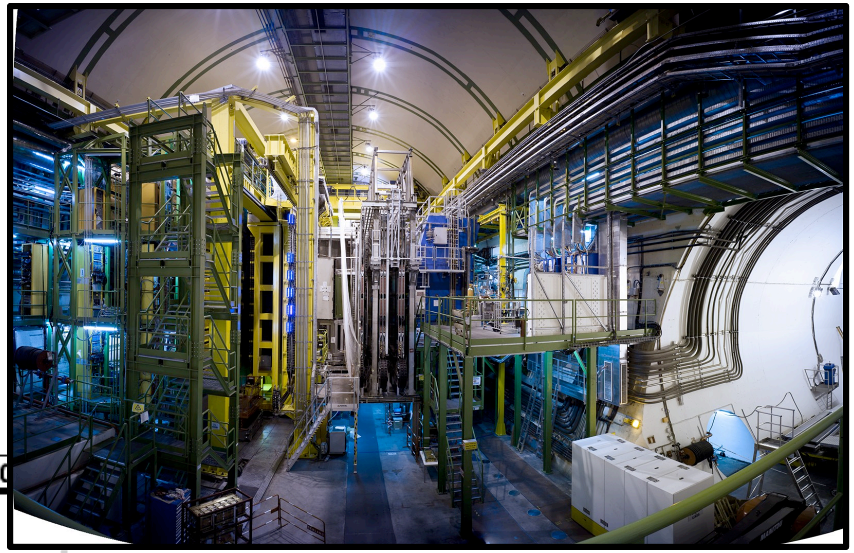
$$\frac{B(B_d \to \mu^+\mu^-)}{B(B_s \to \mu^+\mu^-)} = \left|\frac{V_{td}}{V_{ts}}\right|^2$$

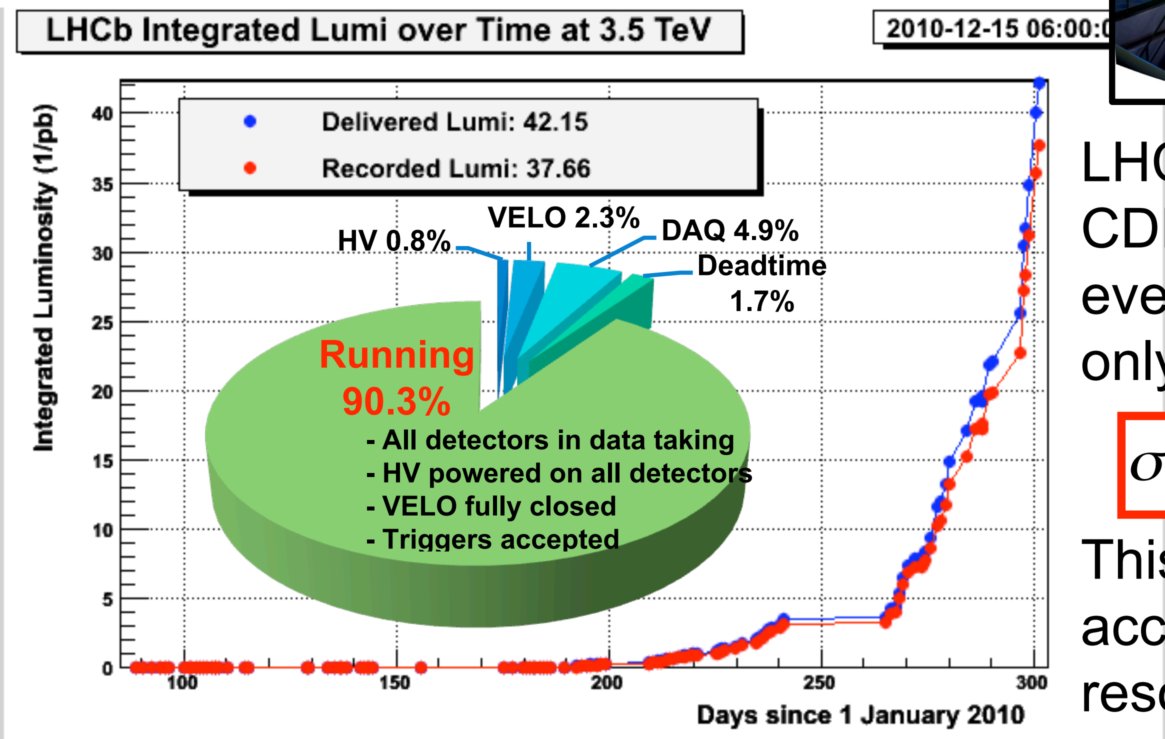
LHCb



LHCb recorded ~38 pb^{-1} in 2010 with ~90% efficiency and is running smoothly in 2011.

Expect ~200 pb^{-1} by summer conferences and ~1 fb^{-1} by end 2011.





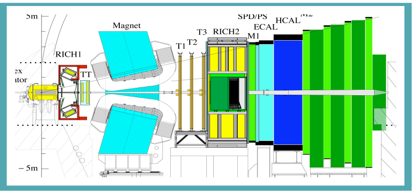
LHCb is already competitive with CDF/D0 who have 6000 pb^{-1} of data, even though the bb cross-section is only 3x higher…

$$\sigma\left(pp \to b\bar{b}\right) = \left(284 \pm 4 \pm 48\right)\ \mu b$$

This is possible due to the LHCb acceptance, trigger and detector resolution.

arXiv:1103.0423 (sub. EPJ C)

High multiplicity events

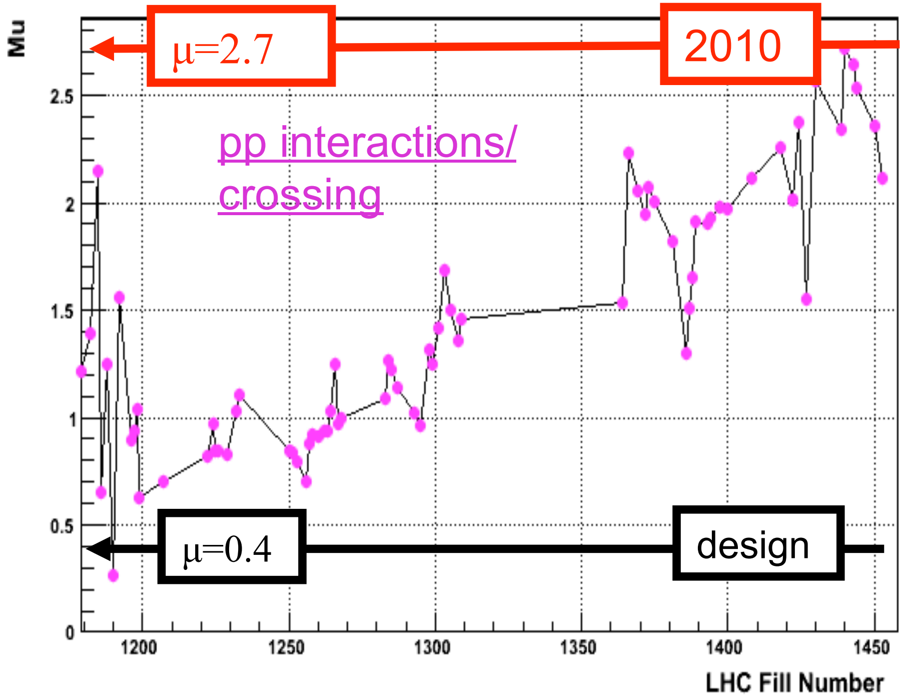


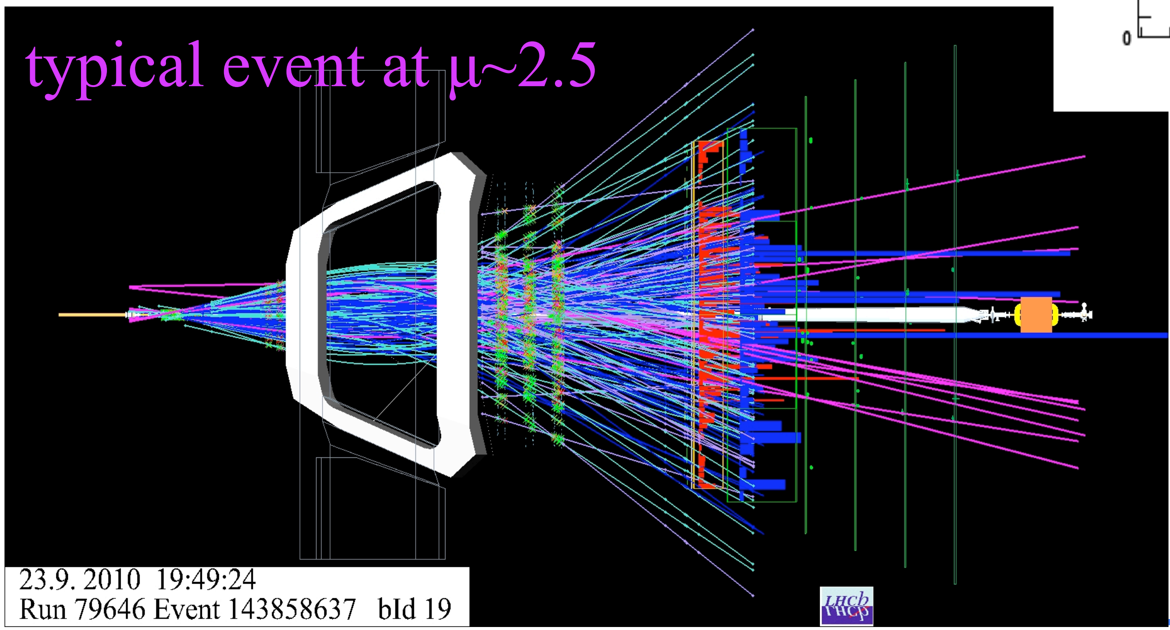
A big challenge for the detector operation, trigger, reconstruction and analysis.

High track multiplicity and many vertices.

Design : L=2x10^{32} cm^{-2} s^{-1},
n$_b$=2600, $<\mu>\sim0.4$

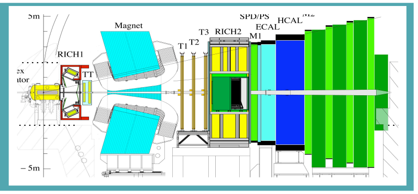
2010 : L=1.6x10^{32} cm^{-2} s^{-1},
n$_b$=344, μ_{max}=2.7 (6x expected!)





Also very useful to gauge LHCb upgrade performance

B Mass Measurements



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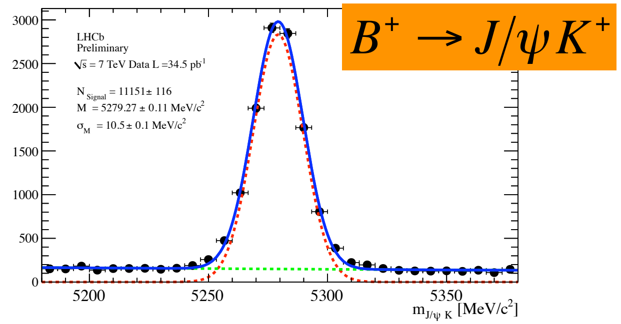
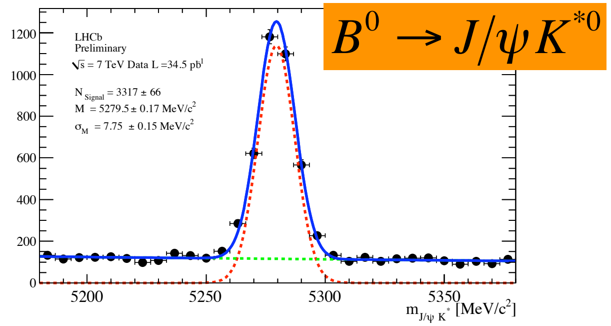
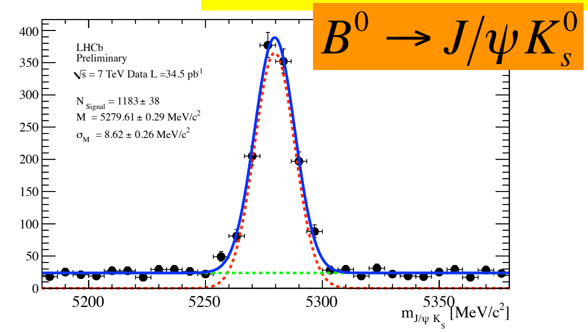




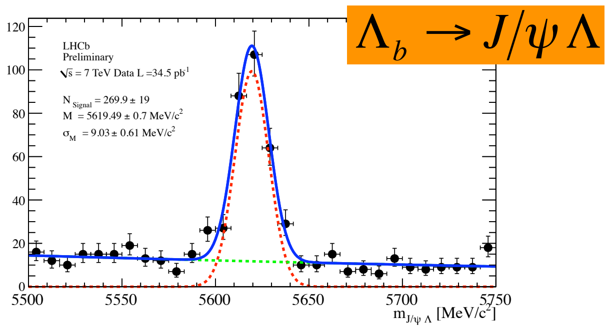


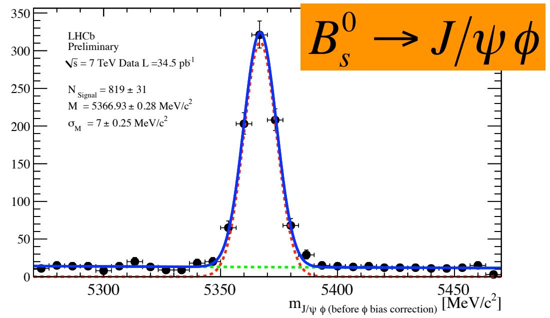
Channel	LHCb Mass, stat and sys (MeV/c²)	PDG (MeV/c²)
$B^+ \to J/\psi K^+$	5279.27 ± 0.11 ± 0.19	5279.17 ± 0.29
$B^0 \to J/\psi K^{*0}$ $B^0 \to J/\psi K_s$	5279.54 ± 0.15 ± 0.15 5279.61 ± 0.29 ± 0.20	5279.50 ± 0.30
$B_s \to J/\psi \phi$	5366.60 ± 0.28 ± 0.20	5366.3 ± 0.60
$\Lambda_b \to J/\psi \Lambda$	5619.48 ± 0.70 ± 0.19	5620.2 ± 1.6
$B_c \to J/\psi \pi^+$	6268.0 ± 4.0 ± 0.5	6277 ± 6

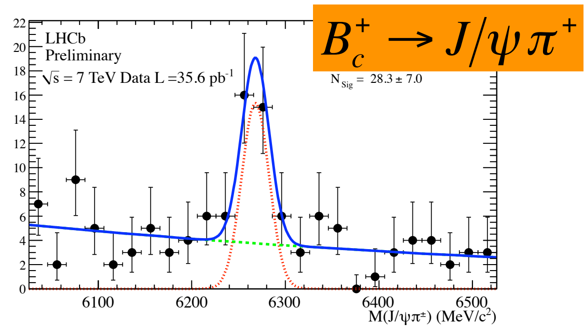
LHCb momentum scale known to ~0.1 per mille

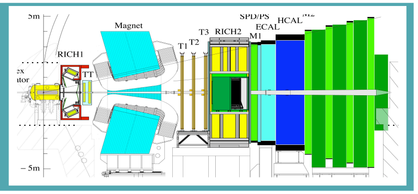
Excellent mass resolution (6-10 Mev/c²)

Worlds best B mass measurements! (except B_c)



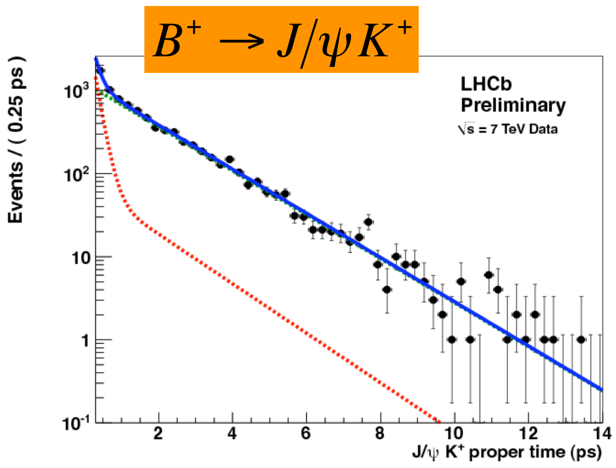


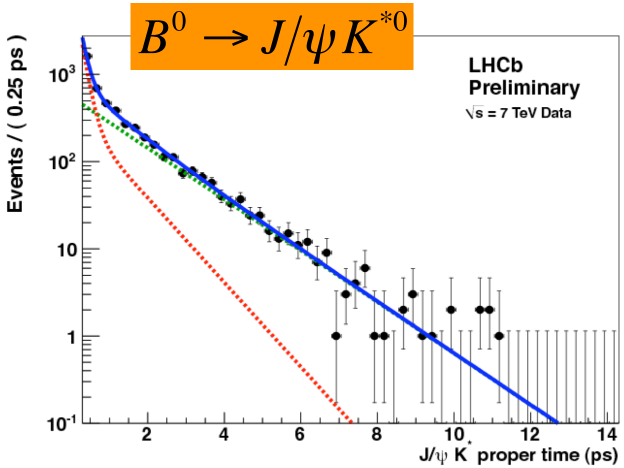


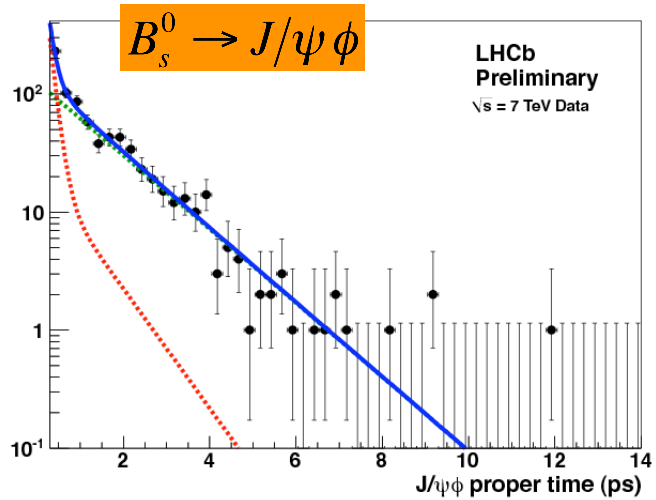


B Lifetime Measurements

LHCb-CONF-2011-001

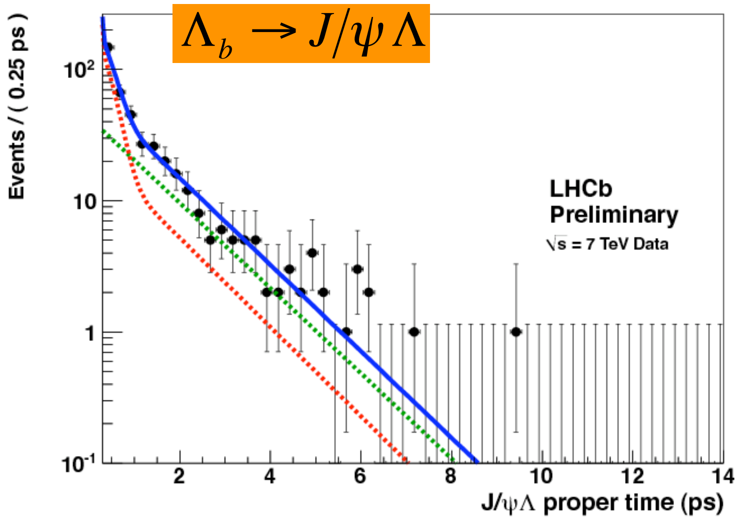






Channel	LHCb lifetime, stat and sys (ps)	PDG (ps)
$B^+ \to J//\psi K^+$	1.689 ± 0.022 ± 0.047	1.638 ± 0.011
$B^0 \to J//\psi K^{*0}$ $B^0 \to J//\psi K_s$	1.512 ± 0.032 ± 0.042 1.558 ± 0.056 ± 0.055	1.525 ± 0.009
$B_s \to J//\psi \phi$	1.447 ± 0.064 ± 0.056	1.477 ± 0.046
$\Lambda_b \to J//\psi \Lambda$	1.353 ± 0.108 ± 0.035	1.391 ± 0.038

Using lifetime unbiased trigger and t > 0.3 ps

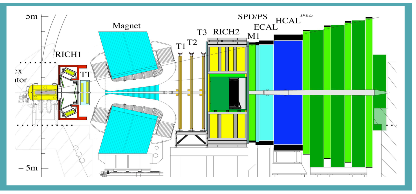


Excellent proper time resolution ~50 fs

Production Studies

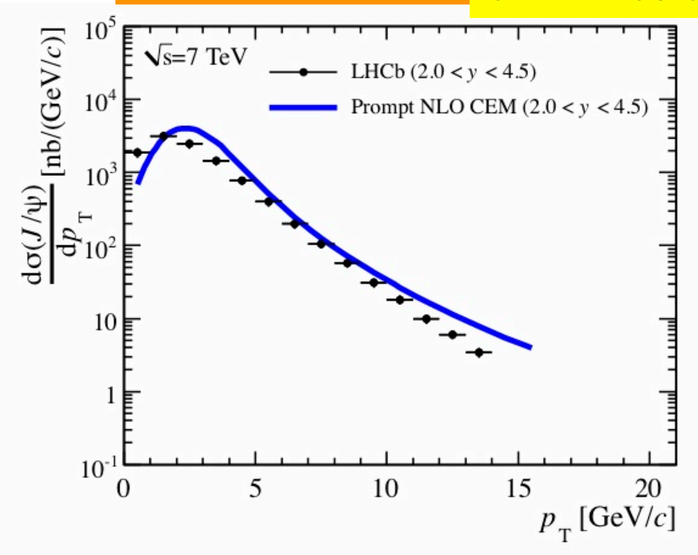
Onia (J/Ψ, Υ , χ_c)   X(3872) B_c B fractions

J/Ψ & ϒ



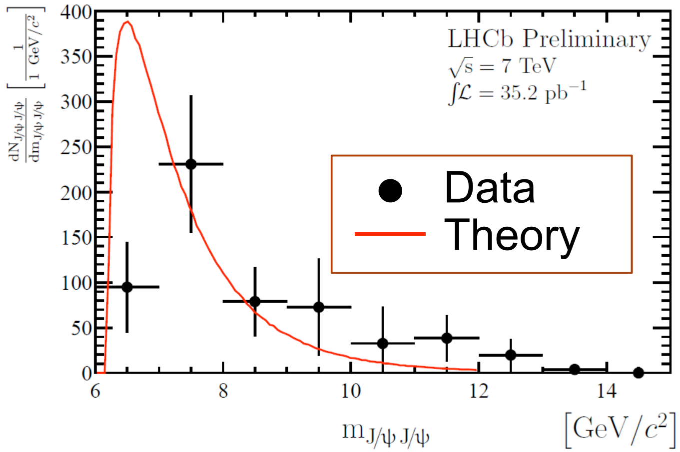
Inclusive J/ψ

arXiv:1103.0423 (sub. EPJ C)



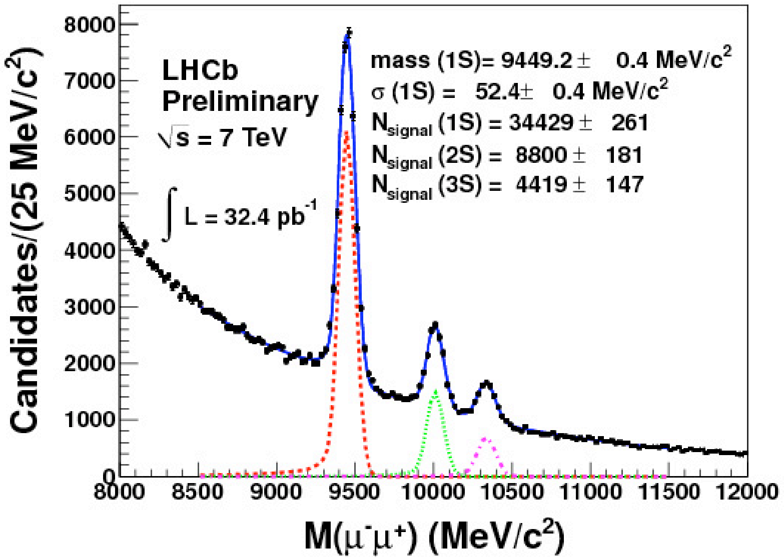
Double J/ψ

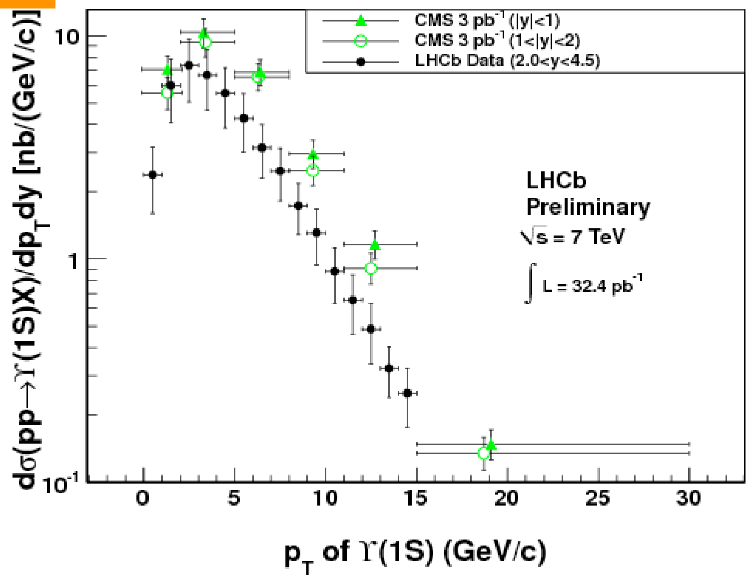
LHCb-CONF-2011-009



Inclusive ϒ

LHCb-CONF-2011-016



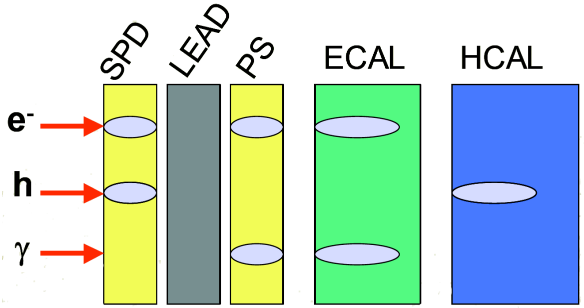


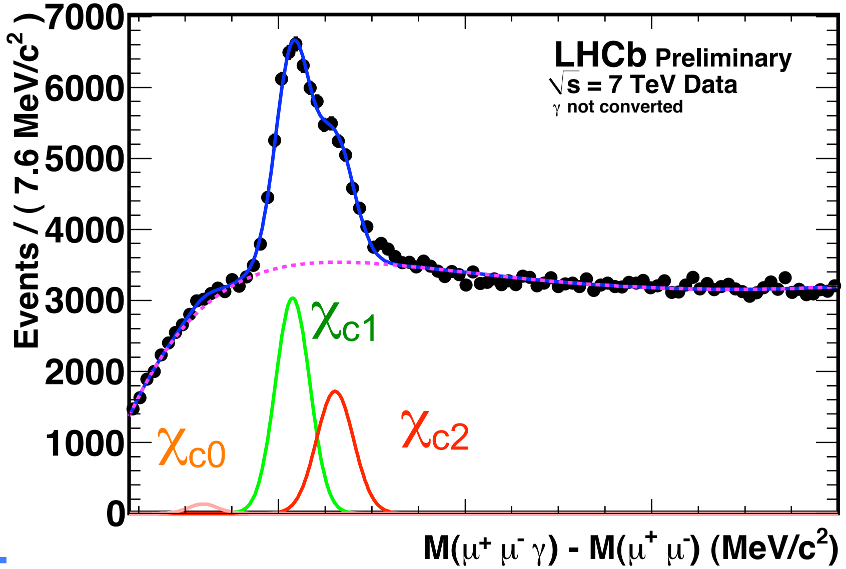
χ_c Production

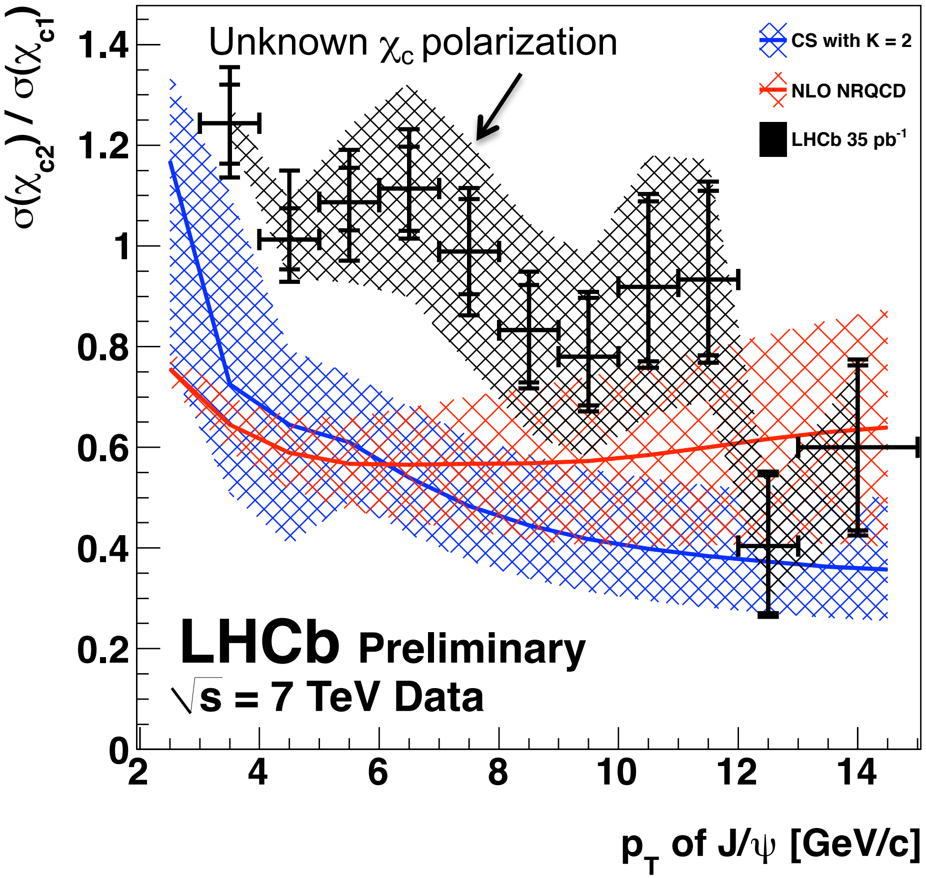
Inclusive prompt $\chi_c \to J/\psi\gamma$ production useful for testing NRQCD: colour singlet and octet mechanisms.

LHCb-CONF-2011-020

Photon identification based on calorimeter and tracking information





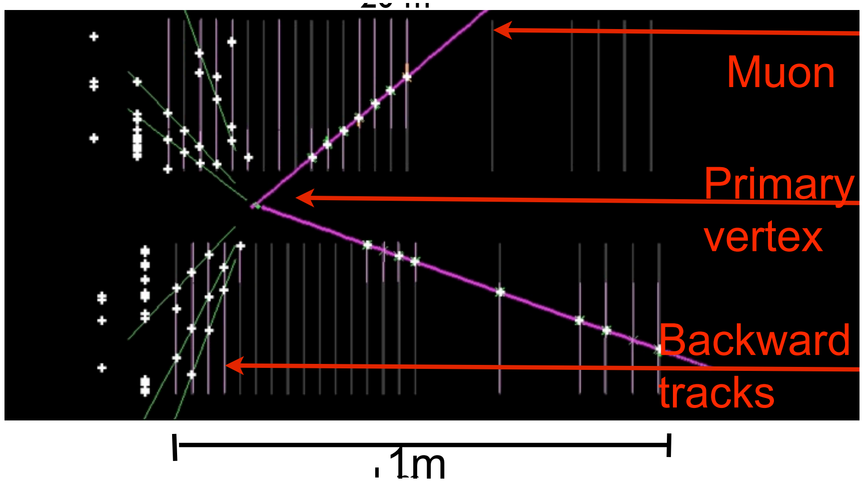


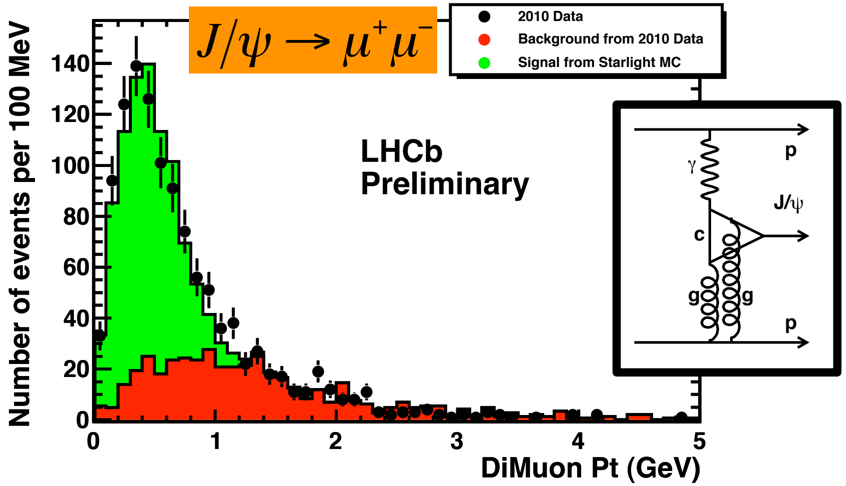
Theory predictions:
L.A.Harland-Lang and W.J.Stirling
Y.Ma, K.Wang, K.Chao, arXiv:1002.3987

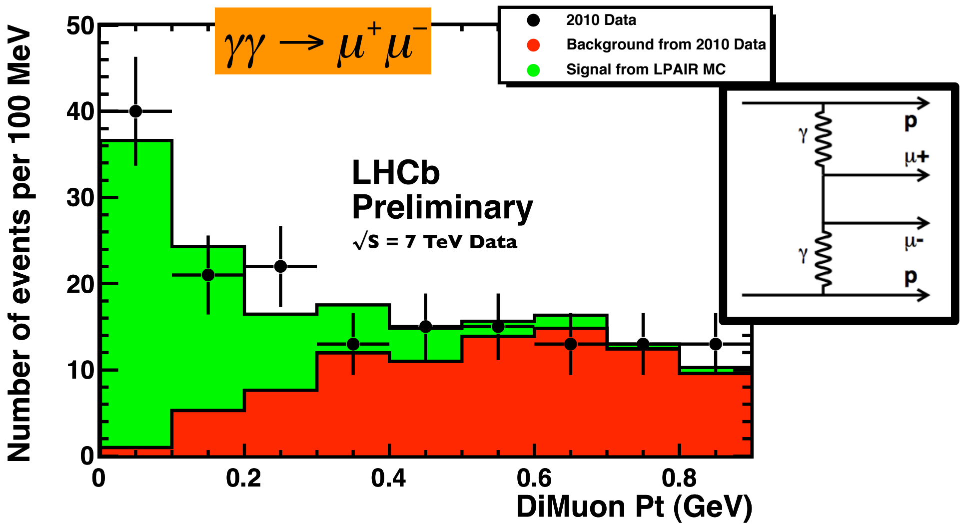
Central Exclusive Production

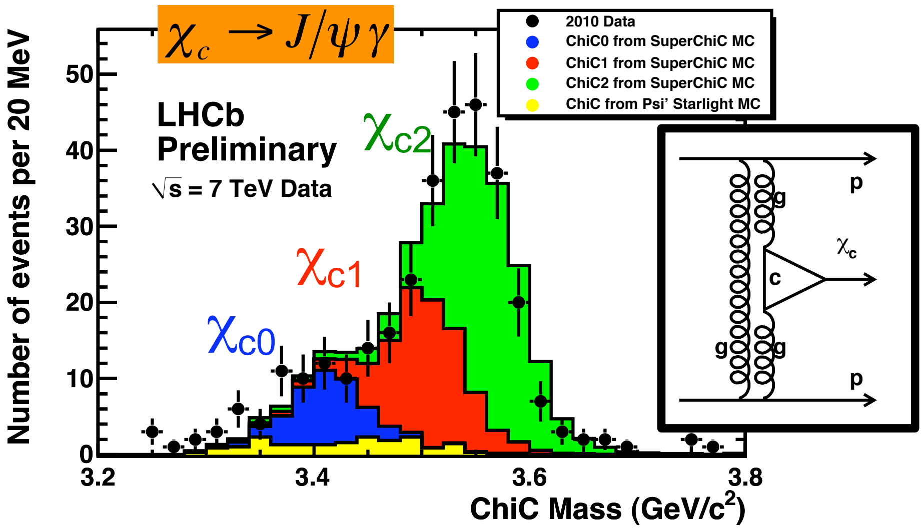
LHCb observes low-multiplicity events with large rapidity gaps.

Exclusive events have no backward tracks and only 2μ (+1γ) in forward region.









X(3872)

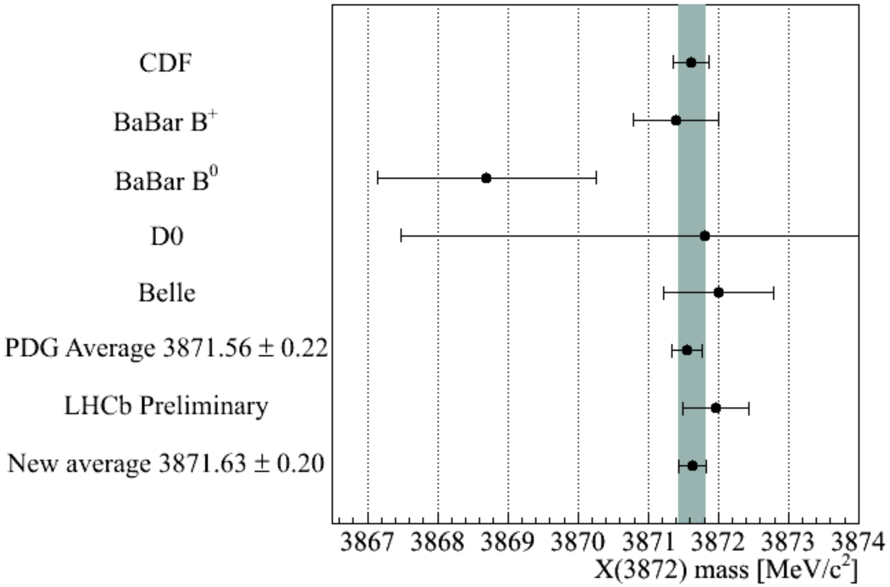
X(3872) discovered in 2003 by Belle in X(3872) →$J/\psi\pi^+\pi^-$ decays.

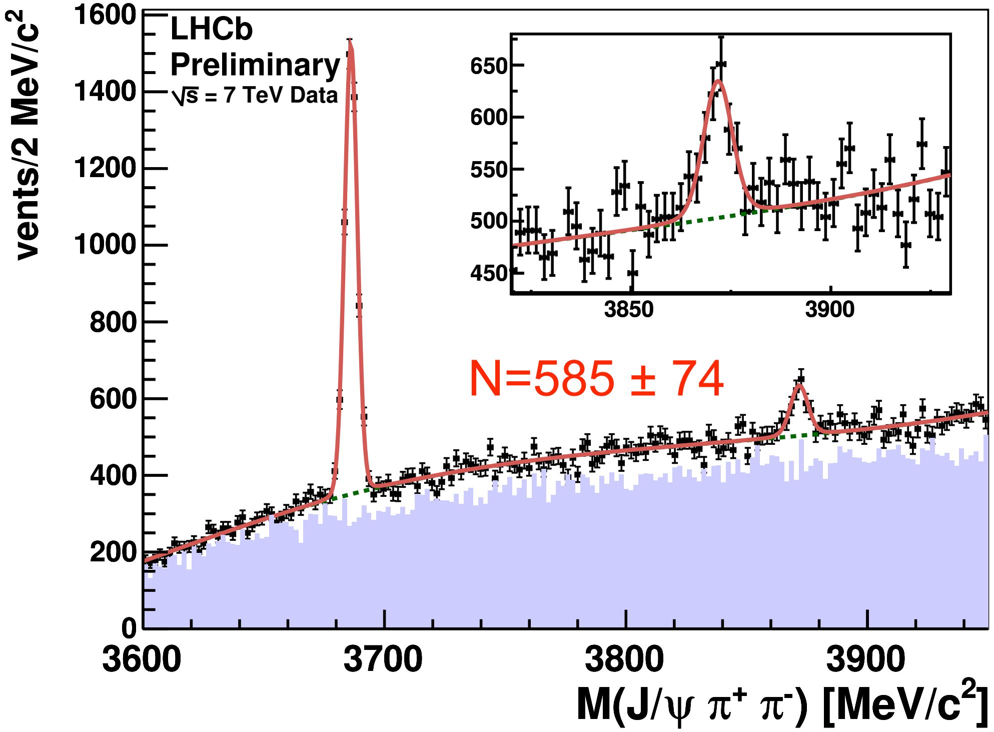
Since then observed in 4 experiments

LHCb-CONF-2011-030

Nature still unclear

- tetraquark ?
- Bound DD^* molecule?
- η_{c2}(1D) charmonium state?

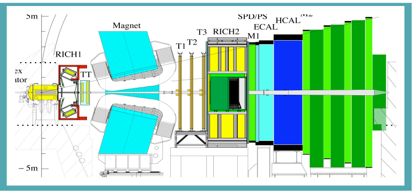




$$M_{X(3872)} = 3871.96 \pm 0.46\,(stat) \pm 0.10\,(syst)\ \text{MeV}/c^2$$

±0.14(stat) with 500 pb^{-1}

B_c Production



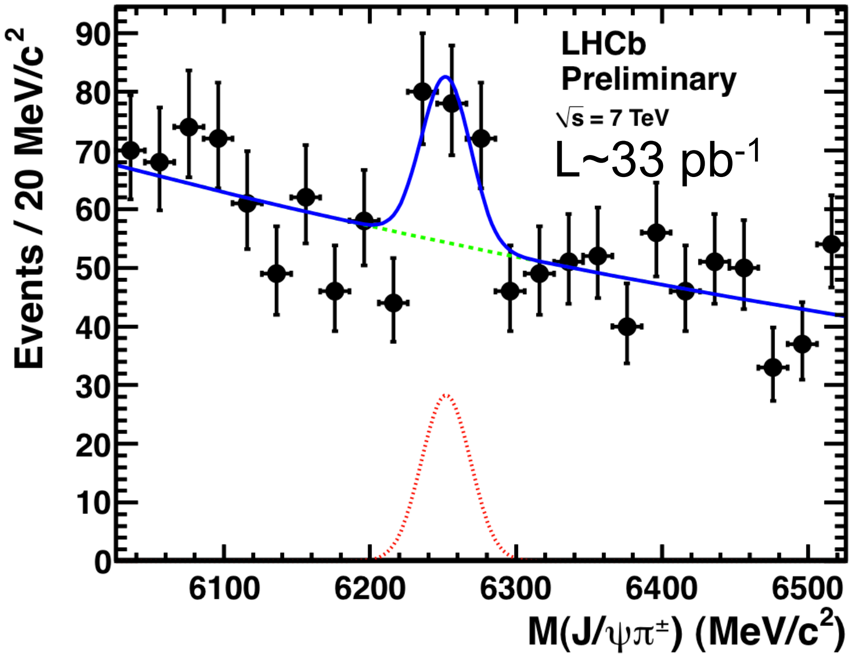
B_c^+ is the heaviest heavy quark meson ($c\bar{b}$) and is useful for constraining QCD.

First observation at CDF in 1998. Only been seen in 3 decay modes :

$B_c^+ \to J/\psi\pi^+$ (~100 cands.), $B_c^+ \to J/\psi\, \mu^+ \nu$ and $B_c^+ \to J/\psi\, e^+ \nu$ (~1k cands. each)

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

$$R_{c+} = \frac{\sigma(B_c^+) \times B(B_c^+ \to J/\psi\pi^+)}{\sigma(B^+) \times B(B^+ \to J/\psi K^+)} = (2.2 \pm 0.8 \pm 0.2)\%$$

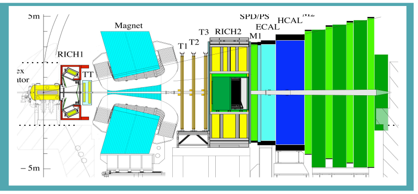


59±18 events observed.

4.1σ statistical significance

Looks great for the LHCb B_c physics program.

B fractions

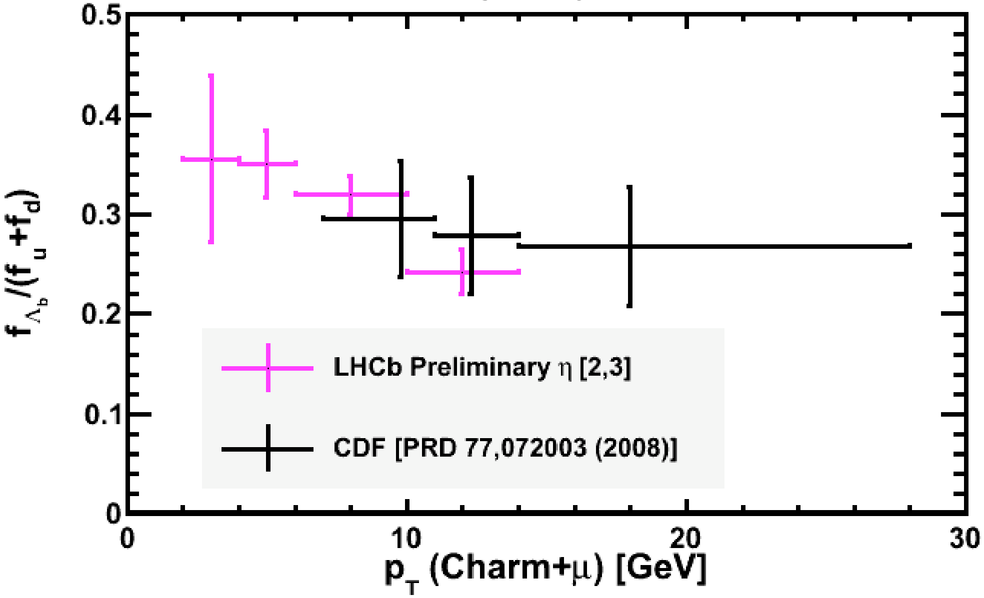


B fractions important input for all branching ratio measurements, in particular f_s/f_d for $B(B_{d,s} \to \mu^+\mu^-)$.

LHCb-CONF-2011-013

Semi-leptonic decays

$b \to (D^0/D^+/D_s^+/\Lambda_c^+) + X\mu\nu$

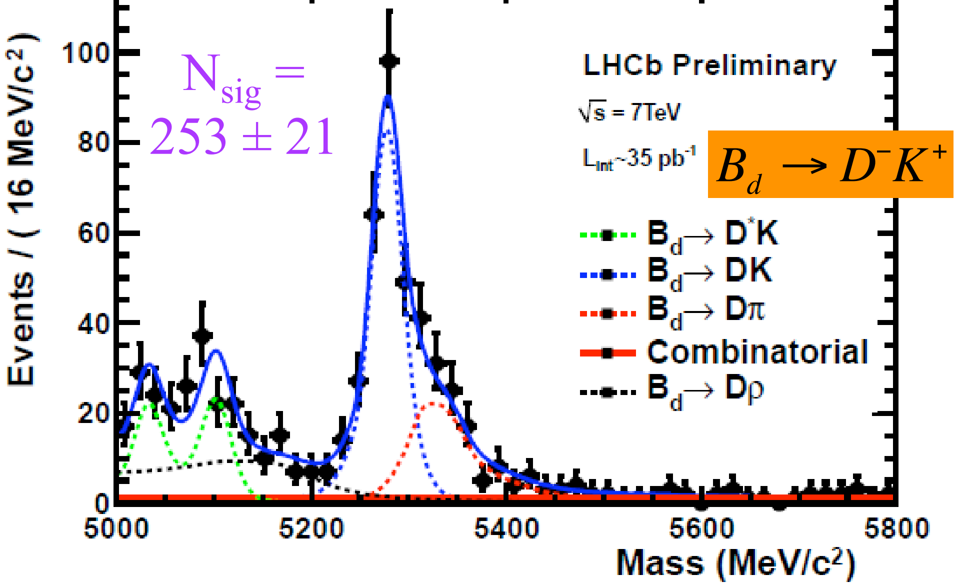


$$f_s/(f_u+f_d) = 0.136 \pm 0.004\,^{+0.012}_{-0.011}$$

$$f_{\Lambda_b}/(f_u+f_d) = 0.401 \pm 0.019 \pm 0.106 - (12 \pm 2.5 \pm 1.2)\times 10^{-3} \times p_T \;\; \mathrm{GeV}^{-1}$$

Hadronic decays

$B_d \to D^-K^+$, $B_s \to D_s^-\pi^+$, $B_s \to D_s^-\pi^+$



$$\frac{f_s}{f_d} = 0.245 \pm 0.017 \pm 0.018 \pm 0.018$$

theory error 6-10%

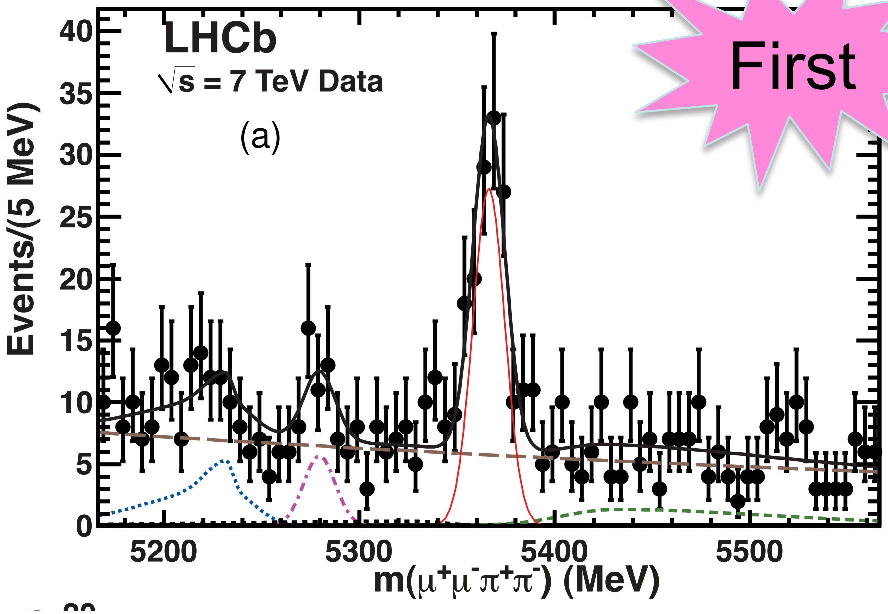
CDF (La Thuile): 0.269±0.03

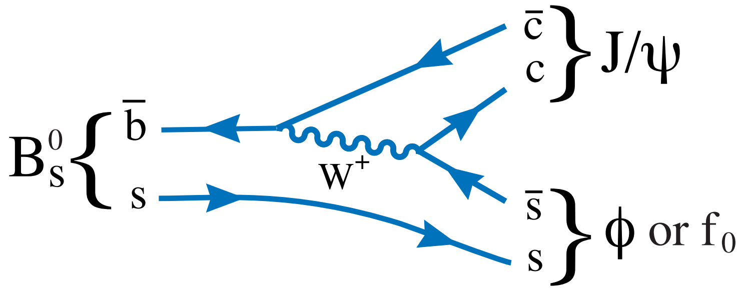
First Observation of new B_s decays

$B_s \to J/\psi f_0$ and $B_s \to \Psi'\phi$

PLB 698 (2011) 115

First

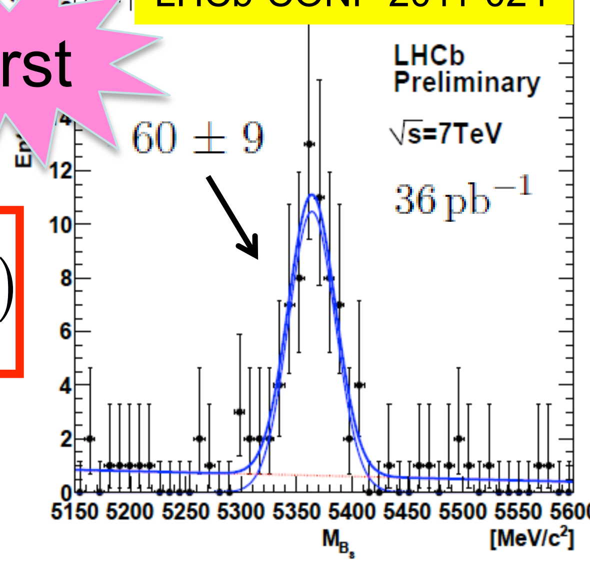




$$\frac{\Gamma\left(B_s \to J/\psi\, f_0,\, f_0 \to \pi^+\pi^-\right)}{\Gamma\left(B_s \to J/\psi\, \phi,\, \phi \to K^+K^-\right)} = 0.252^{+0.046+0.027}_{-0.032-0.033}$$

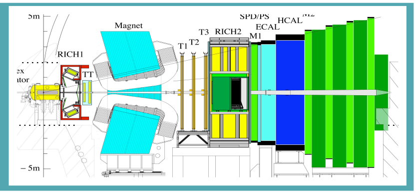
First

LHCb-CONF-2011-024



$$\frac{B\left(B_s \to \psi'\phi\right)}{B\left(B_s \to J/\psi\,\phi\right)} = 0.68 \pm 0.10\,(stat) \pm 0.09\,(syst.) \pm 0.07(B)$$

$B_s \to K^* K^*$ and $B_s \to J/\Psi K^*$



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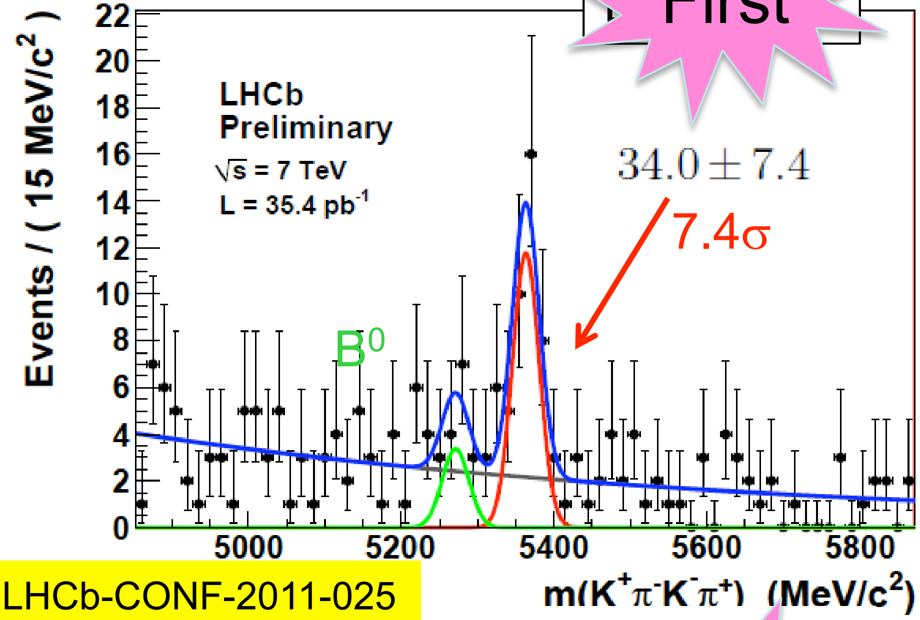
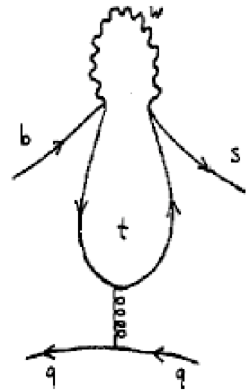
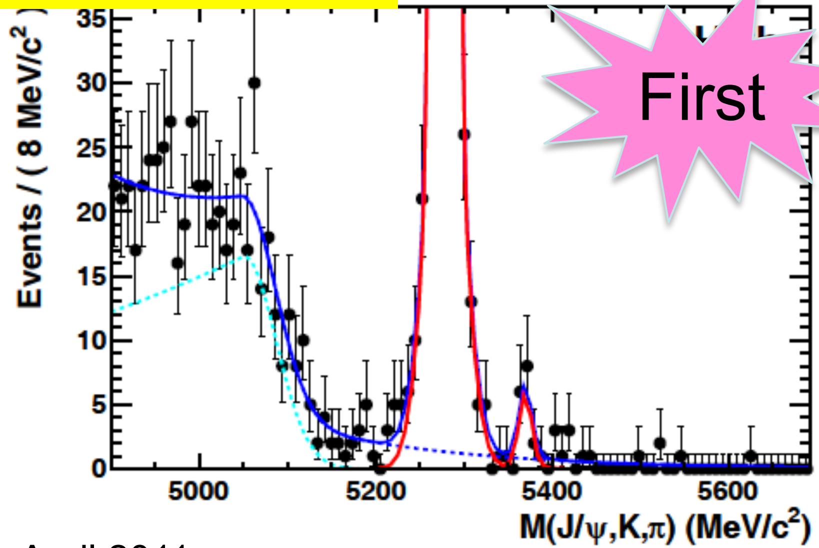


Penguin decay, similar to $B_s \to \phi\phi$



$$B\left(\overline{B_s} \to K^* \overline{K^*}\right) = \begin{pmatrix} 1.95 \pm 0.47\,(stat) \\ \pm 0.66\,(syst) \\ \pm 0.29\,(f_d/f_s) \end{pmatrix} \times 10^{-5}$$

LHCb-CONF-2011-025



$$B\left(B_s \to J/\psi\, \overline{K^*}\right) = \left(3.5^{+1.1}_{-1.0}\,(stat) \pm 0.9\,(syst)\right) \times 10^{-5}$$

Assuming that all events are $K^* \to K\pi$

Search for new CP phases in B_d and B_s mixing

CP angle γ

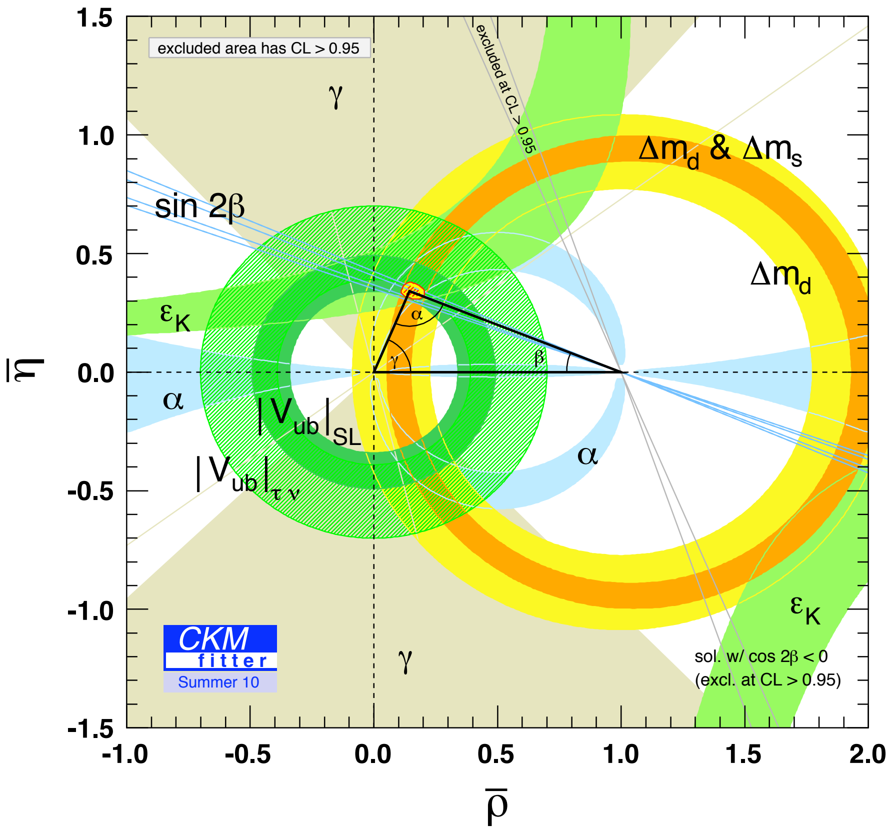
$B \rightarrow h^+h^-$

B_s CP phase, ϕ_s

The Golden Triangle

Fantastic achievement over the last decade to test the SM picture of quark couplings, especially CP Violation.

The state of the art is encapsulated in the Unitarity Triangle



CKMfitter group, PRD 83 036004 (2011)

$$V_{CKM} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

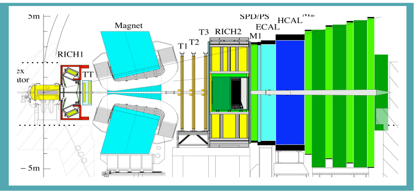
L.Wolfenstein PRL 51 (1983) 1945

$A = 0.815^{+0.011}_{-0.029}$ $\lambda = 0.22543^{+0.00077}_{-0.00077}$

$\bar{\rho} = 0.144^{+0.029}_{-0.018}$ $\bar{\eta} = 0.322^{+0.016}_{-0.016}$

$J_{CP} = \left(2.98^{+0.16}_{-0.18}\right) \times 10^{-5}$

The Golden Triangle



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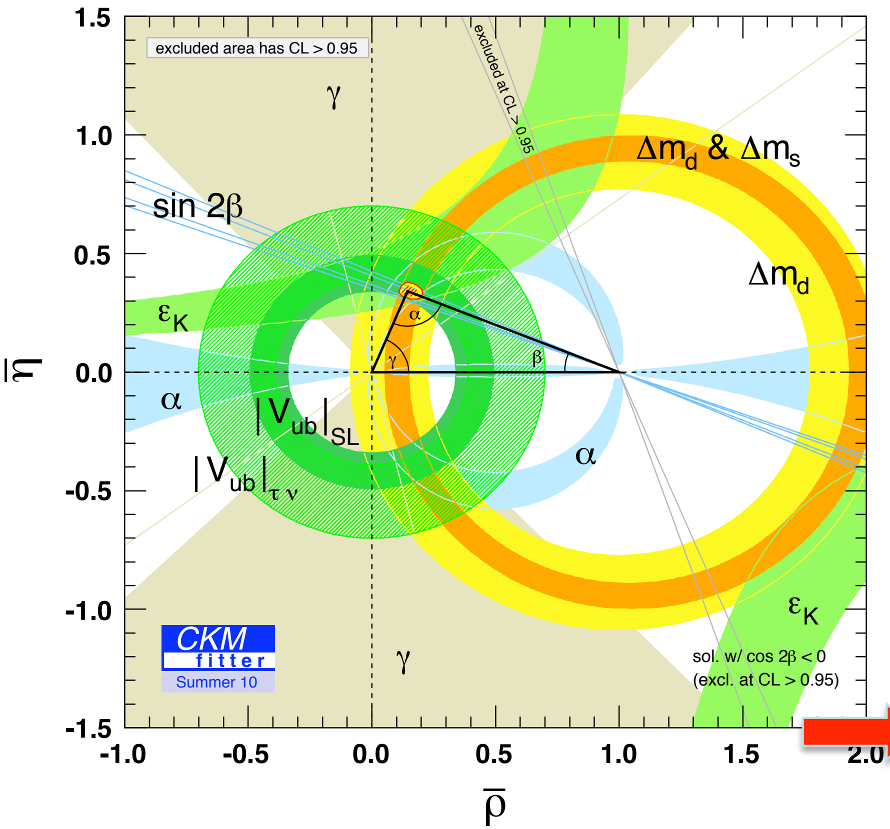

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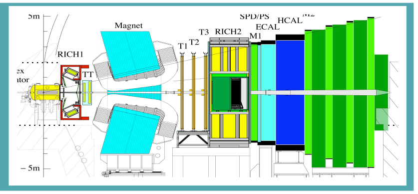

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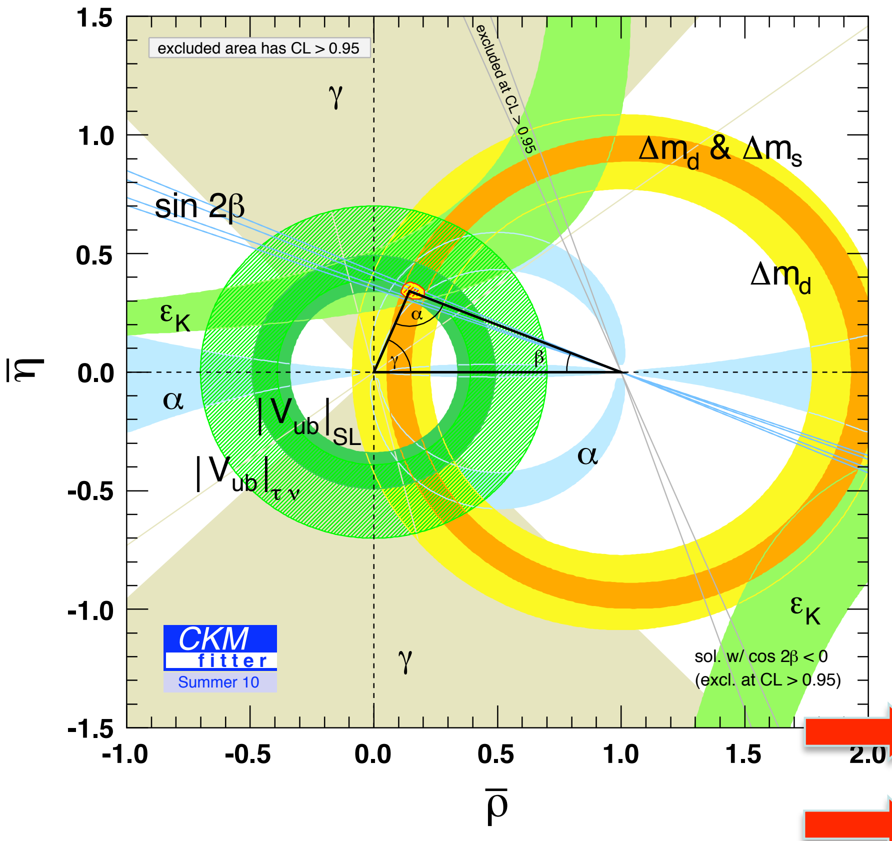

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Beautiful validation of CKM picture.

The Golden Triangle

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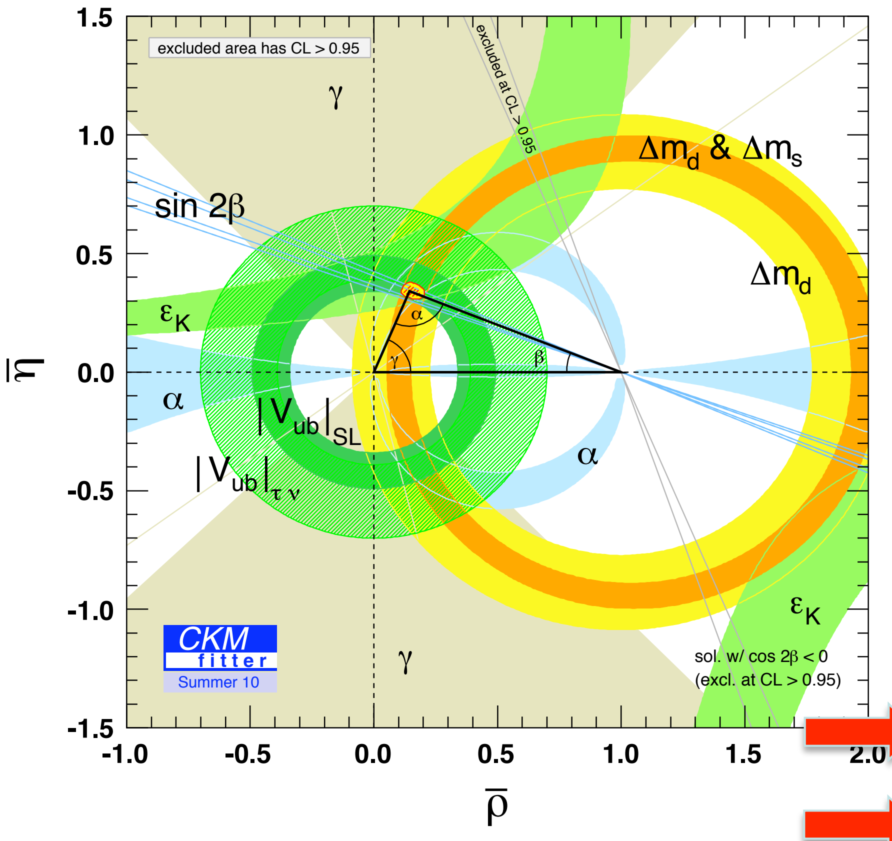

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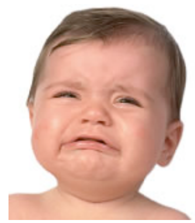
Amazing consistency !

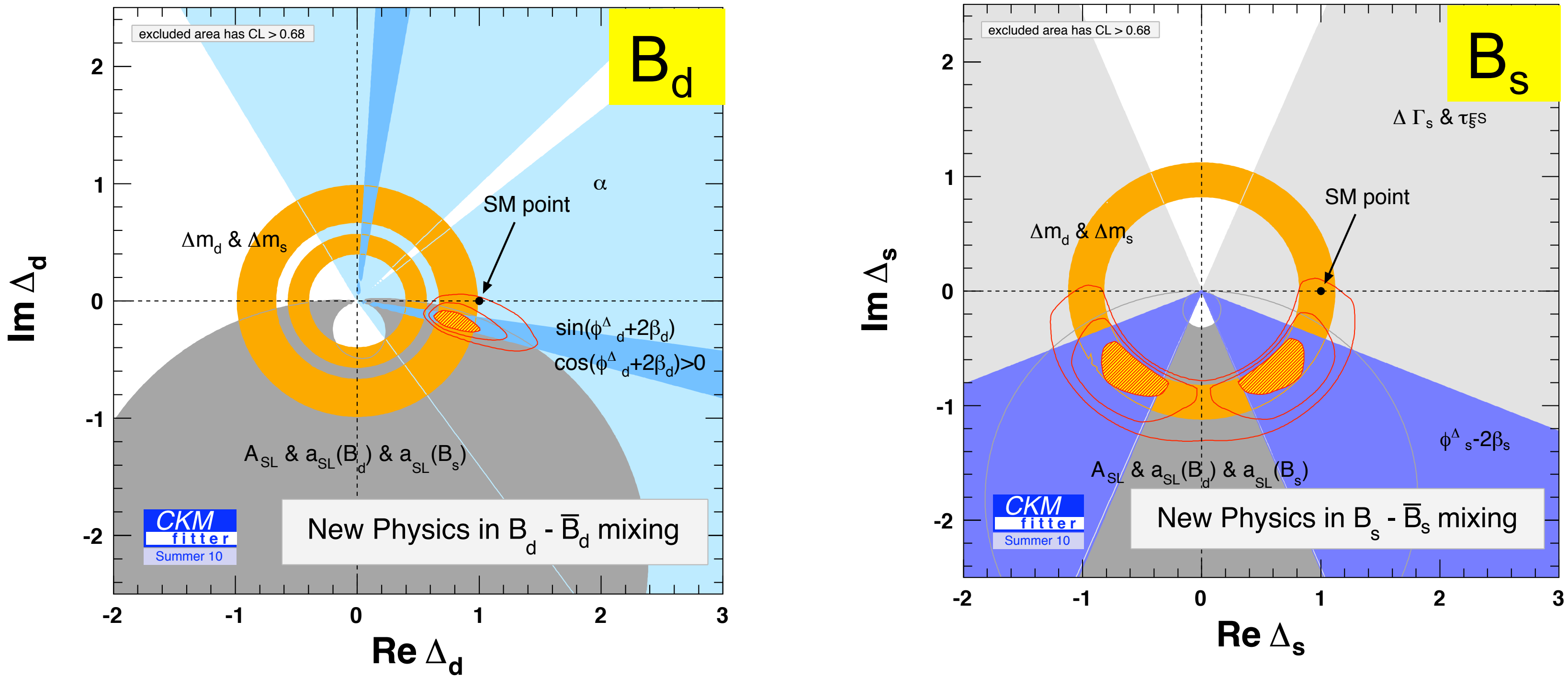
Any NP contributions are small.



Is there room for NP in B mixing?

$$\Delta_q \equiv \frac{M_{12}^q}{M_{12}^{q,SM}} \qquad \Delta_q = |\Delta_q| e^{i\phi_q^\Delta}$$

CKMfitter, PRD 83 036004 (2011)



Both B_d (due to the measurement of $B^+ \rightarrow \tau\nu$) and B_s (due to the measurement of ϕ_s) disfavour the SM at 2.7σ.

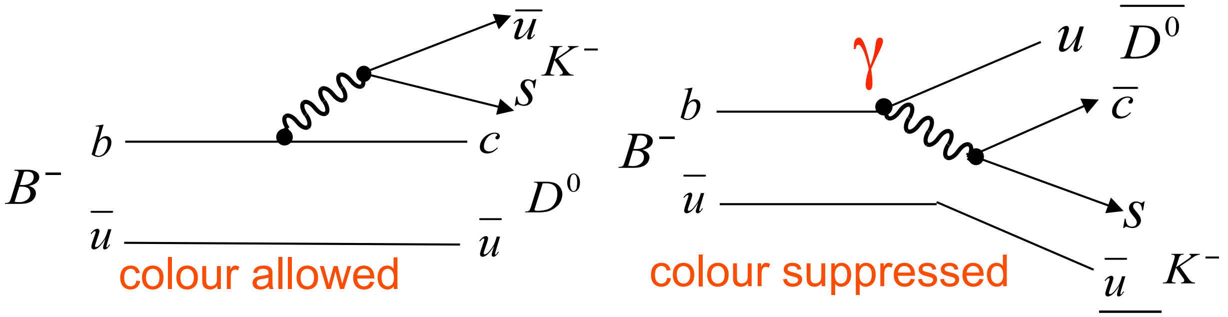
There is plenty of room for NP…..

LHCb goals : 1. Precise determination of γ at tree level $\quad \gamma = \left(71^{+21}_{-25}\right)$ deg.

2. Precise determination of ϕ_s

Prospects for γ from trees

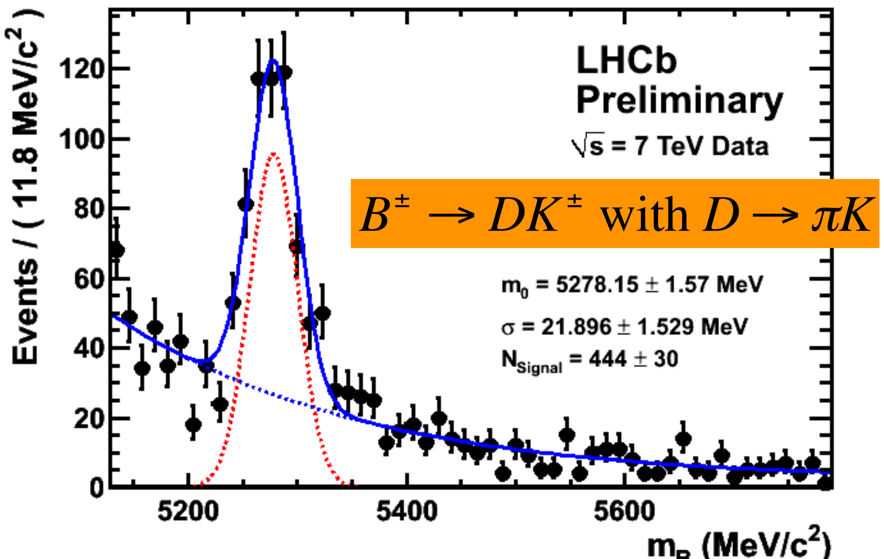
The theoretically cleanest method measures γ via the interference between $B \to D^0 K$ and $B \to \overline{D}^0 K$; only affected by possible NP in D^0 mixing.



Similar diagrams for B^0

Reconstruct D in final states accessible to both D^0 and $\overline{D}^0$

- Time integrated analysis
  requires no tagging,
  need to extract suppressed channels
  or Dalitz analysis of 3-body D^0 decays.
- Time dependent analysis
  $B^0 \to D^- \pi^+, \quad B_s \to D_s^- K^+$



Expect to measure γ with a combined precision of ~5° from 2011/2012 data.

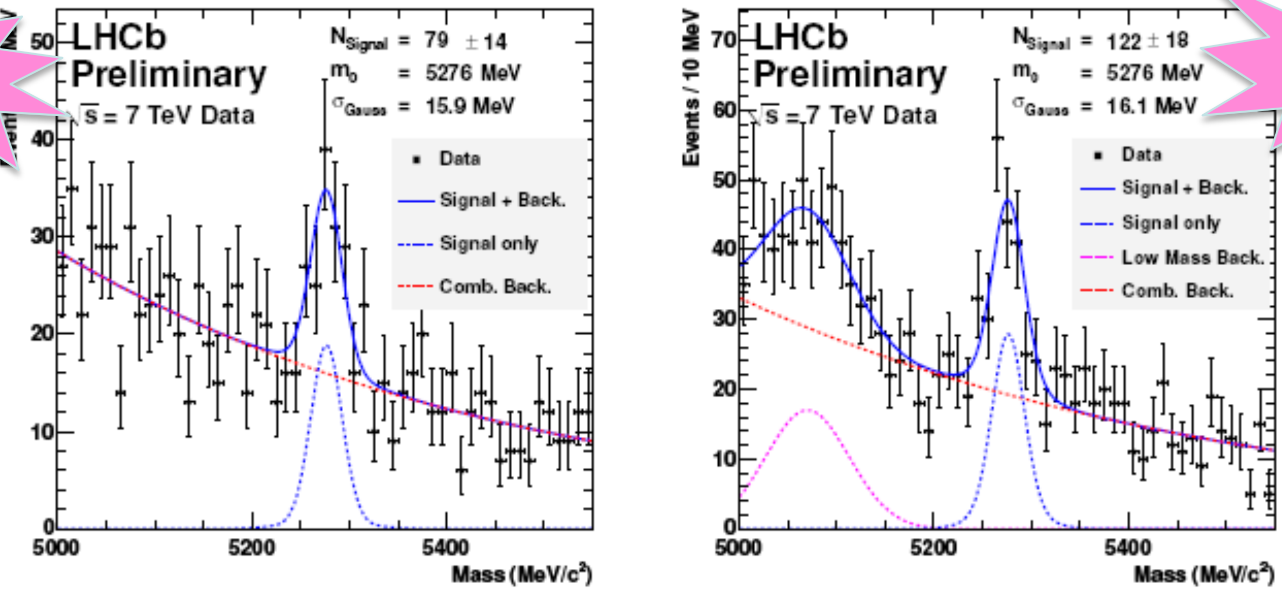
Prospects for γ from trees

In analogy to the decay $B^\pm \to D^0 K^\pm$, the decay $B^\pm \to D^0 K^\pm \pi^+ \pi^-$ can also be used to determine γ.

LHCb has measured the CF multi-body $B \to D\pi^\pm\pi^+\pi^-$ decays **LHCb-CONF-2011-007**

and for the first time observed the CS $B^\pm \to D^0 K^\pm \pi^+ \pi^-$ decays. **LHCb-CONF-2011-018**

First

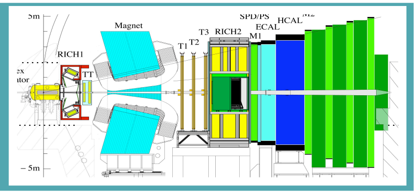


First

$$\frac{\mathcal{B}(\bar{B}^0 \to D^+ K^- \pi^+ \pi^-)}{\mathcal{B}(\bar{B}^0 \to D^+ \pi^- \pi^+ \pi^-)} = (5.2 \pm 0.9(\mathrm{stat}) \pm 0.5(\mathrm{syst})) \times 10^{-2}$$

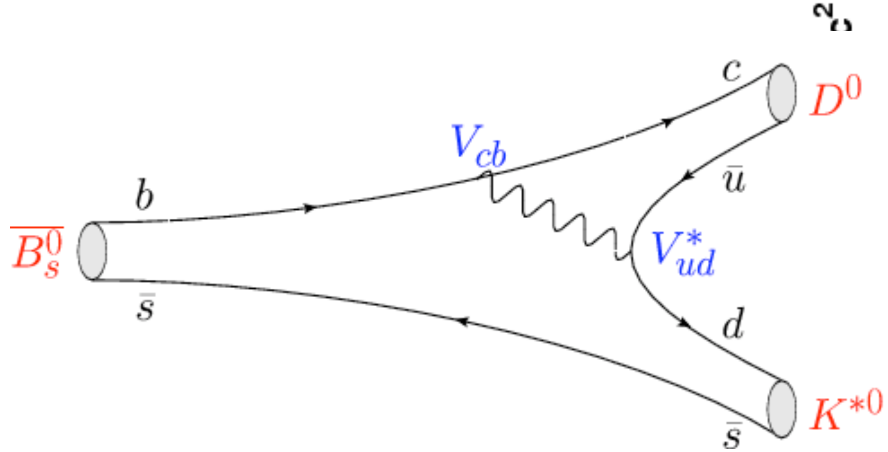
$$\frac{\mathcal{B}(B^- \to D^0 K^- \pi^+ \pi^-)}{\mathcal{B}(B^- \to D^0 \pi^- \pi^+ \pi^-)} = (9.6 \pm 1.5(\mathrm{stat}) \pm 0.8(\mathrm{syst})) \times 10^{-2}.$$

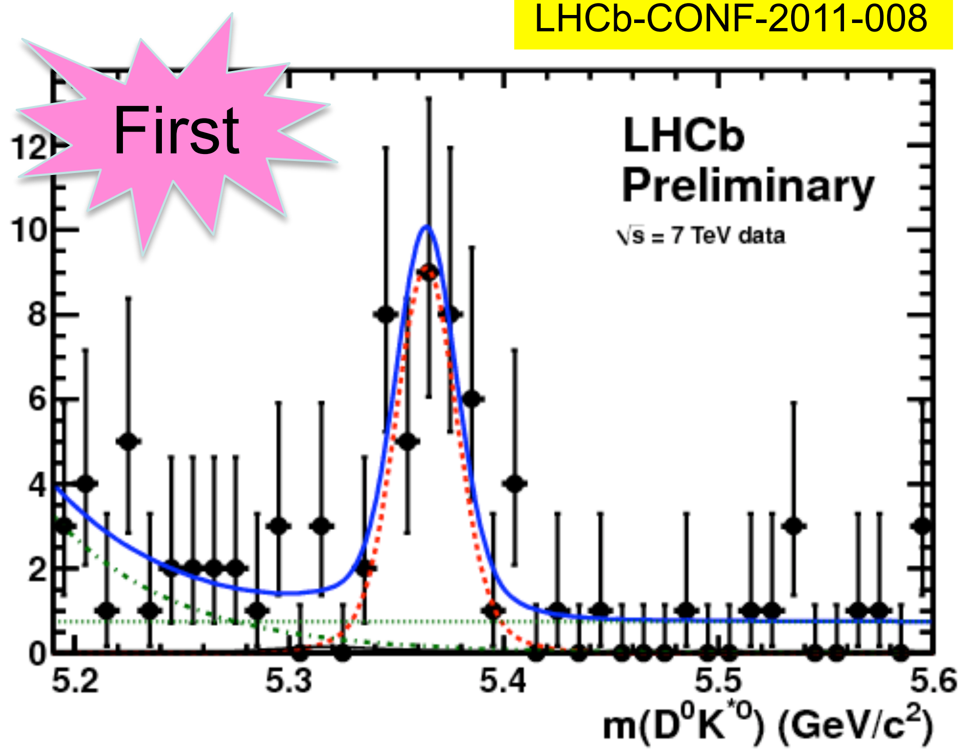
$\overline{B}_s \to D^0 K^*$



This decay may be a potentially dangerous background for the measurement of the CP angle γ

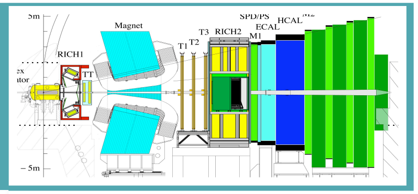
LHCb-CONF-2011-008



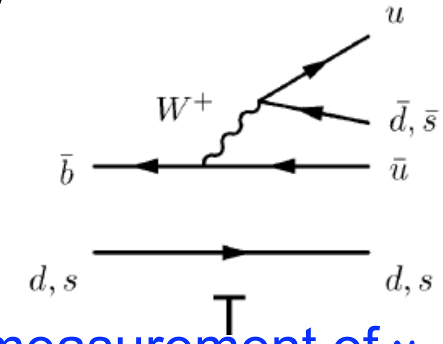


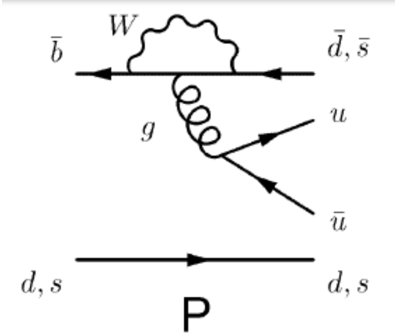
$$B\left(\overline{B}_s \to D^0 K^*\right) = \left(4.44 \pm 1.00\,(stat) \pm 0.55\,(syst) \pm 0.56\left(f_s/f_d\right) \pm 0.69\left(B_{\overline{B}^0 \to D^0 \rho^0}\right)\right) \times 10^{-4}$$

Prospects for γ from loops



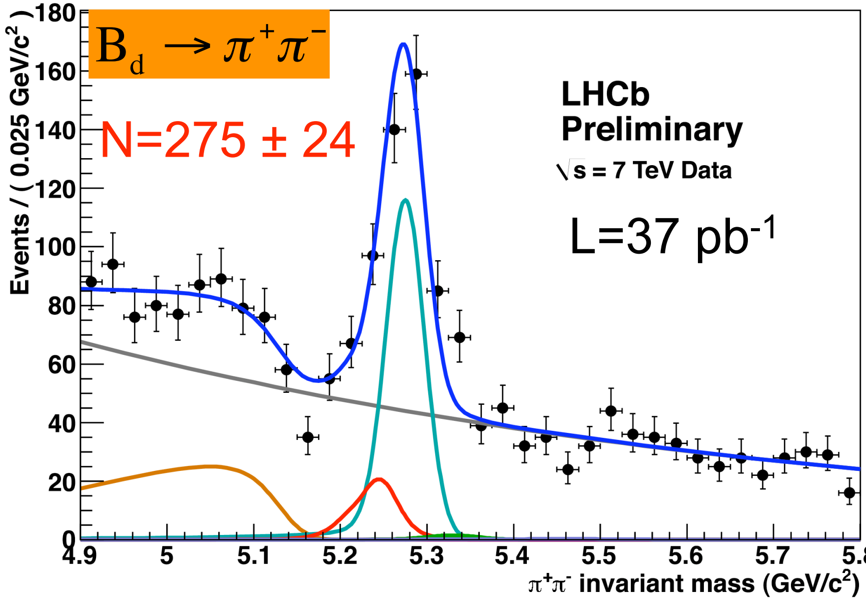
Large penguin contributions are expected for $B_s \to K^+K^-$ and $B_d \to \pi^+\pi^-$.

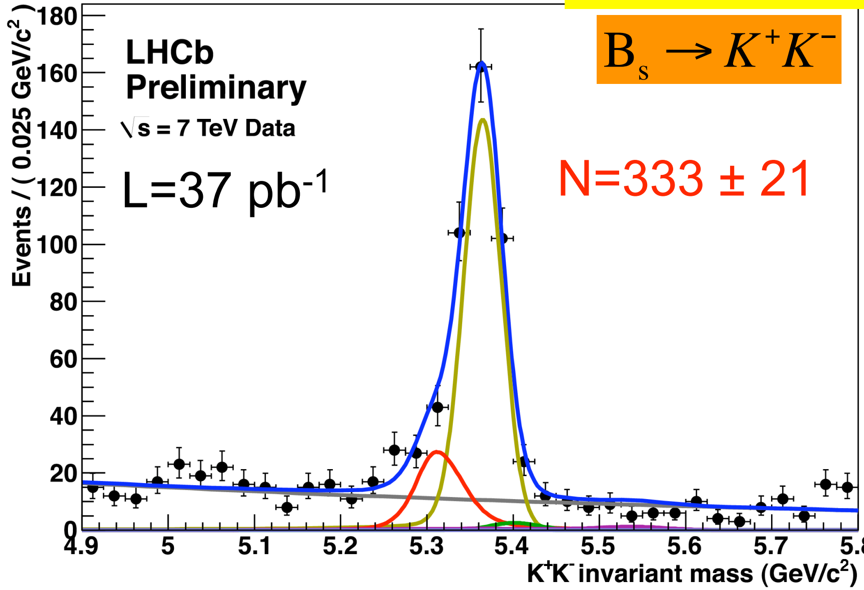




Assuming U-spin symmetry and using the known B_d mixing phase, the time-dependent CP asymmetry of these decays allows for a measurement of γ.

LHCb-CONF-2011-011





New measurement of the $B_s \to K^+K^-$ lifetime using two complimentary methods gives

$$\tau\left(B_s^0 \to K^+K^-\right) = (1.44 \pm 0.096 \pm 0.010) \text{ ps}$$

LHCb-CONF-2011-018

Observation of direct CP violation in B→Kπ

Direct CP asymmetry in $B_d \to K\pi$ is well-established, but not yet in $B_s \to \pi K$.

$$A_{CP}\left(B^0 \to K^+\pi^-\right) \approx A^{dir}_{K^+K^-}$$
$$A_{CP}\left(B^0_s \to \pi^+K^-\right) \approx A^{dir}_{\pi^+\pi^-}$$

Detector asymmetries: use D^* and $D^0 \to K\pi$ $\quad A_D = (-0.4 \pm 0.4)\%$

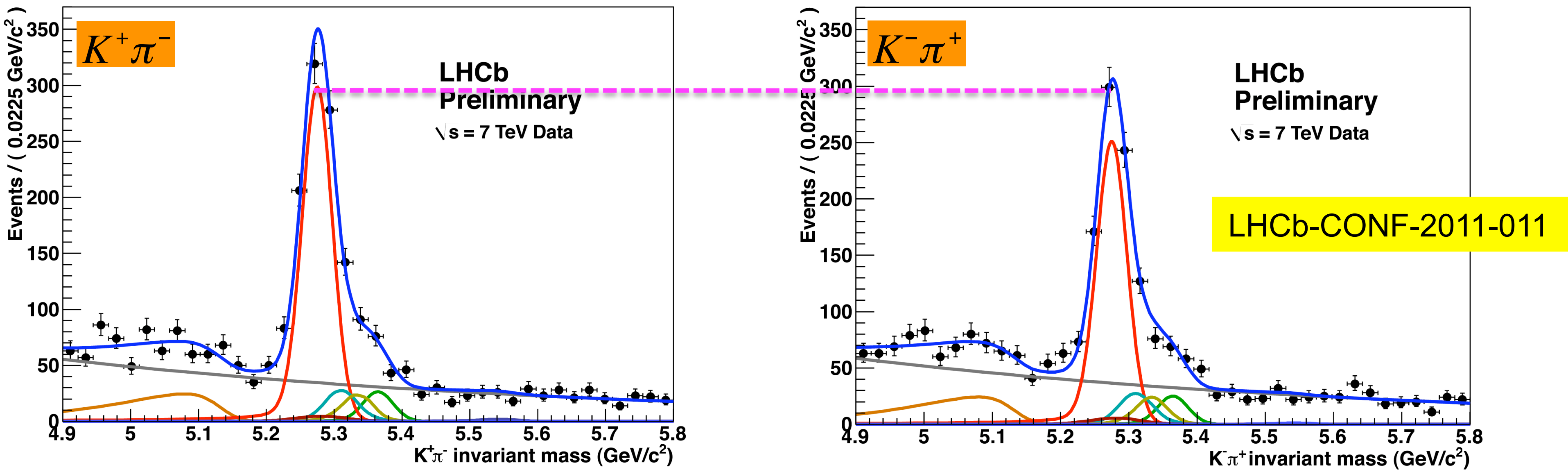
Production asymmetries: use $B^\pm \to J/\psi K^\pm$ $\quad A_P = (-2.4 \pm 1.7)\%$

Aside: D^0 production asymmetry $\quad A_P(D^0) = (-1.08 \pm 0.32 \pm 0.12)\%$

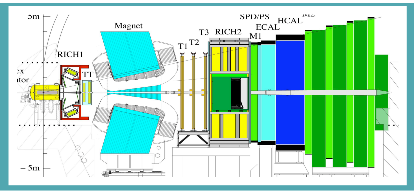
3σ

$$A_{CP}\left(B^0 \to K^+\pi^-\right) = -0.074 \pm 0.033 \pm 0.008$$
$$A_{CP}\left(B^0_s \to \pi^+K^-\right) = 0.15 \pm 0.19 \pm 0.02$$

$$A_{CP}\left(B^0 \to K^+\pi^-\right) = -0.098^{+0.012}_{-0.011}$$
$$A_{CP}\left(B^0_s \to \pi^+K^-\right) = 0.39 \pm 0.17$$

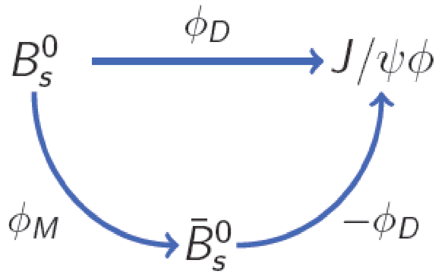


B_s CP Phase

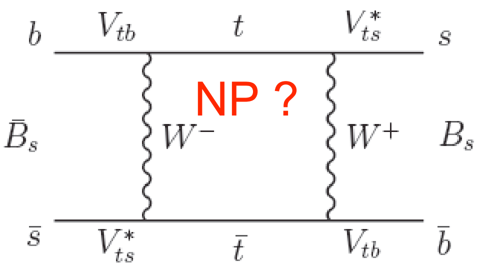


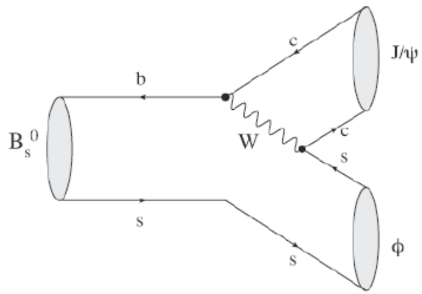
Interference of mixing and decay in $B_s \to J/\psi\phi$

$$\phi_s = \phi_M + 2\phi_D$$



Standard Model



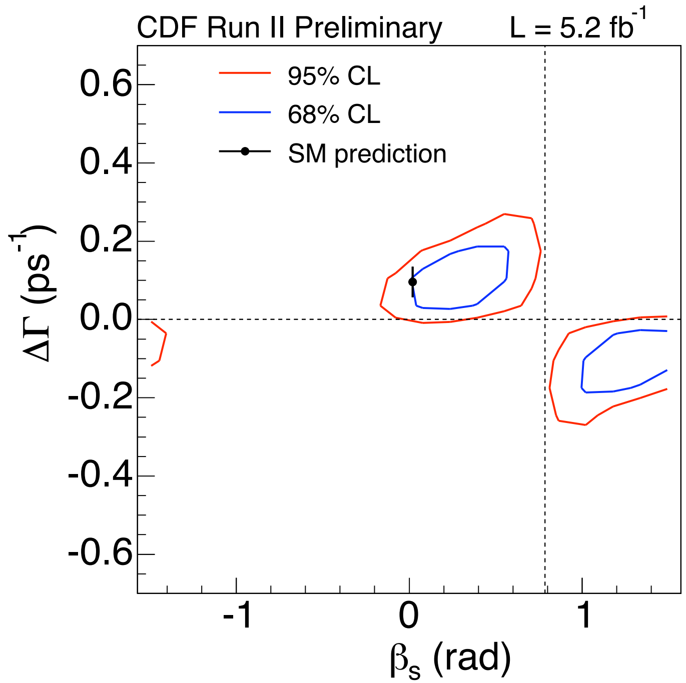


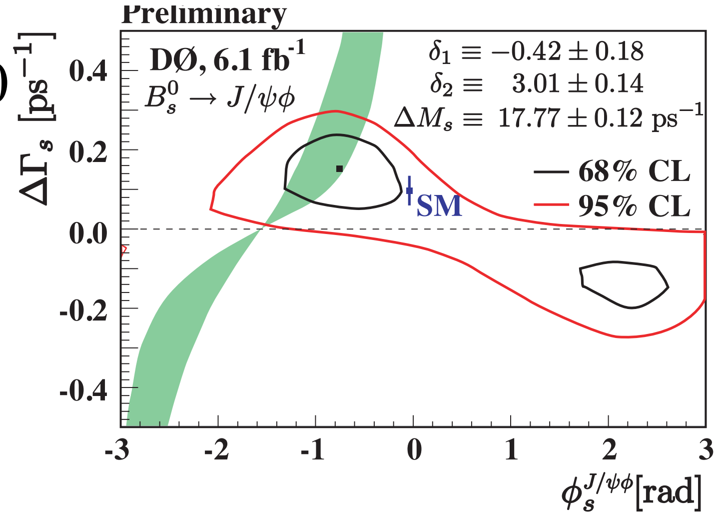
$$\phi_M^{SM} = -2\arg\left(V_{ts}V_{tb}^*\right) = -2\beta_s \qquad \phi_D^{SM} = -2\arg\left(V_{cs}V_{cb}^*\right) \approx 0$$

$$\phi_s^{SM} = -0.0363 \pm 0.0017 \text{ rad}$$

Possible NP

$$\phi_s = \phi_s^{SM} + \Delta\phi_s^{NP}$$





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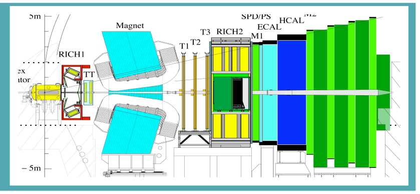
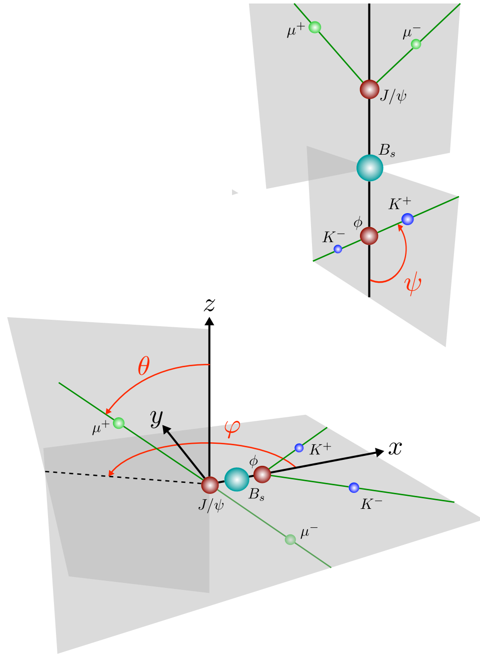


The measurement of ϕ_s is non-trivial.



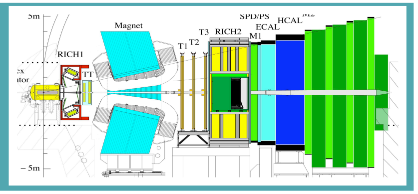
- $B_s \to J/\Psi\phi$ admixture of CP even/odd eigenstates
  - 3 polarization amplitudes $A_\perp$ $\quad CP\ odd\ \ell = 1$
    $A_0, A_\parallel$ $\quad CP\ even\ \ell = 0, 2$
  - 3 transversity angles $\Omega = \{\vartheta, \varphi, \psi\}$
- Signal event distribution

$$S(\lambda, t, \Omega) = \varepsilon(t, \Omega) \times \left[\frac{1 + qD}{2} \cdot s(\lambda, t, \Omega) + \frac{1 - qD}{2} \cdot \bar{s}(\lambda, t, \Omega)\right] \otimes R_t$$

Physics parameters $\lambda = \left(\Gamma_s, \Delta\Gamma_s, |A_0|^2, |A_\perp|^2, \delta_\parallel, \delta_\perp, \phi_s, \Delta m_s\right)$

Constraint $\Delta m_s = 17.77 \pm 0.12\ \text{ps}^{-1}$

B_s CP Phase



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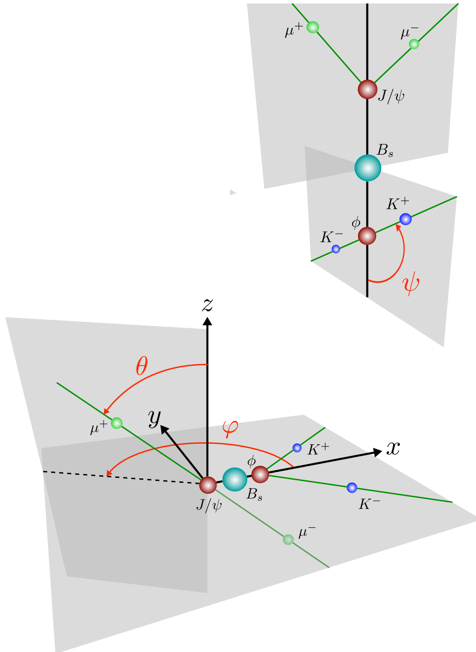

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Acceptance

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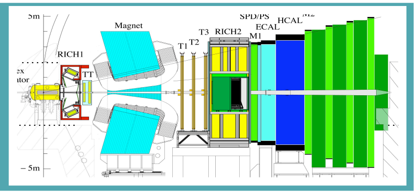

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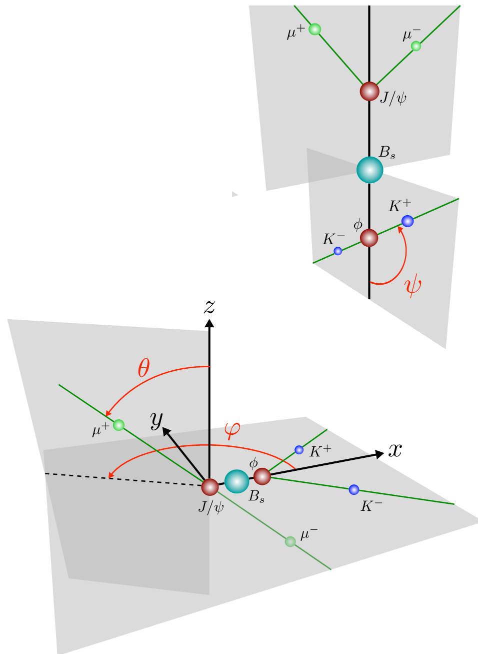

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Acceptance — Flavour tagging

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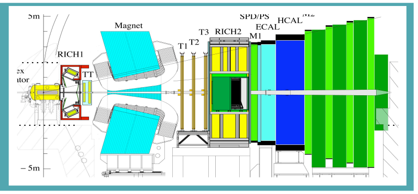

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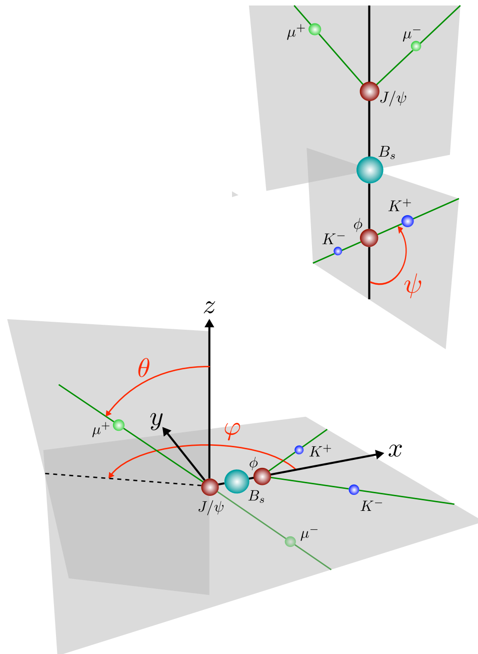

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Acceptance — Flavour tagging — Proper time resolution

$$S(\lambda, t, \Omega) = \varepsilon(t, \Omega) \times \left[\frac{1 + qD}{2} \cdot s(\lambda, t, \Omega) + \frac{1 - qD}{2} \cdot \bar{s}(\lambda, t, \Omega)\right] \otimes R_t$$

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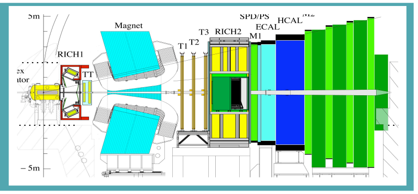
B_s CP Phase



The measurement of ϕ_s is core to the LHCb physics program

1. Select signal decay and cross-check channels
   - Determination of lifetimes (see slide 8)
   - $B_s \to J/\Psi\phi$, $B_d \to J/\Psi K^*$, $B^+ \to J/\Psi K^+$
   - $B_d \to J/\Psi K_{s,}$, $\Lambda_b \to J/\Psi\Lambda$

   LHCb-CONF-2011-001

2. Angular analysis & determination of $\Delta\Gamma_s$
   - Angular analysis of $B_d \to J/\Psi K^*$
   - Untagged angular analysis of $B_s \to J/\Psi\phi$

   LHCb-CONF-2011-002

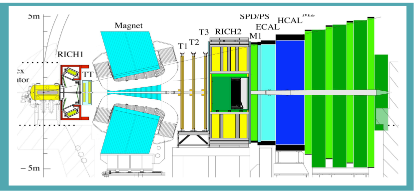
3. Determination of B production flavour
   - Determination of sin2β, Δm_d, Δm_s

   LHCb-CONF-2011-003
   LHCb-CONF-2011-004,010,0 05

4. Determination of ϕ_s
   - Tagged analysis of $B_s \to J/\Psi\phi$ decays

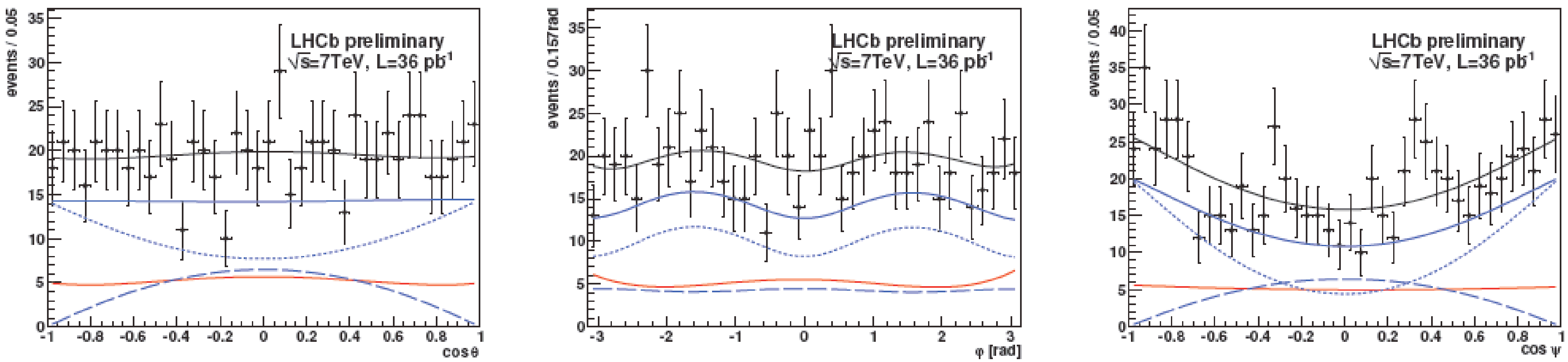
   LHCb-CONF-2011-006

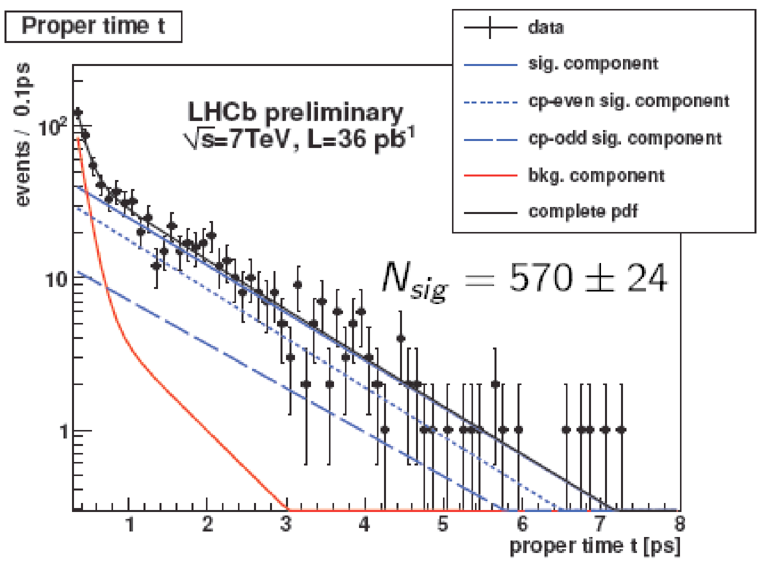
Untagged $B_s \to J/\Psi\phi$



ϕ_s fixed to zero

LHCb-CONF-2011-002



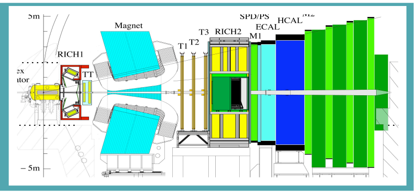


$N_{sig} = 570 \pm 24$

Parameter	Result ± stat. ± syst.
$\Gamma_s [\mathrm{ps}^{-1}]$	$0.679 \pm 0.036 \pm 0.027$
$\Delta\Gamma_s [\mathrm{ps}^{-1}]$	$0.077 \pm 0.119 \pm 0.021$
$\lvert A_0(0)\rvert^2$	$0.528 \pm 0.040 \pm 0.028$
$\lvert A_\perp(0)\rvert^2$	$0.263 \pm 0.056 \pm 0.014$

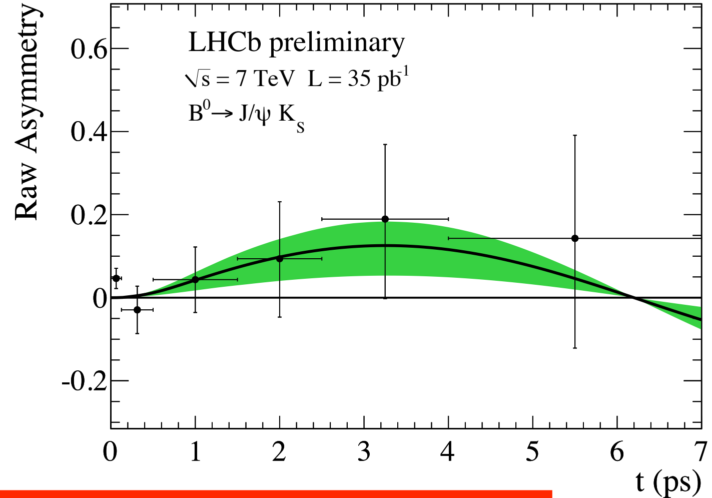
CDF note 10206, $L = 5.2\,\mathrm{fb}^{-1}$

$\Delta\Gamma_s = (0.075 \pm 0.035 \pm 0.010)\,\mathrm{ps}^{-1}$



sin2β, Δm_d, Δm_s

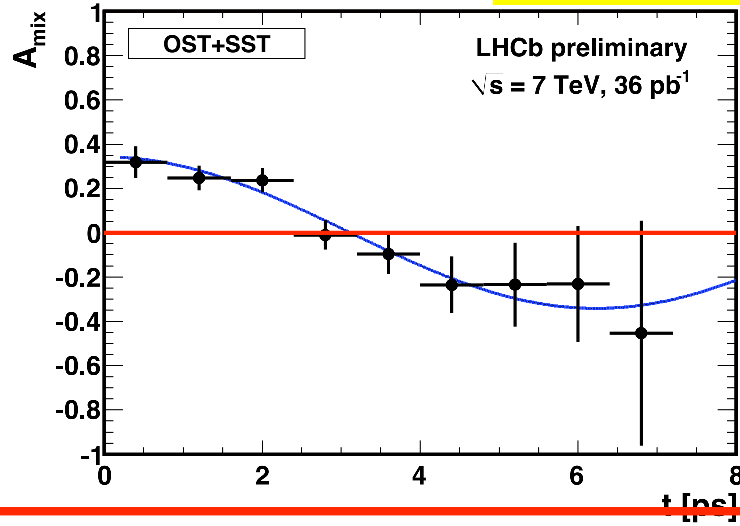
LHCb-CONF-2011-004



$$\sin 2\beta = 0.53^{+0.28}_{-0.29} \pm 0.02$$

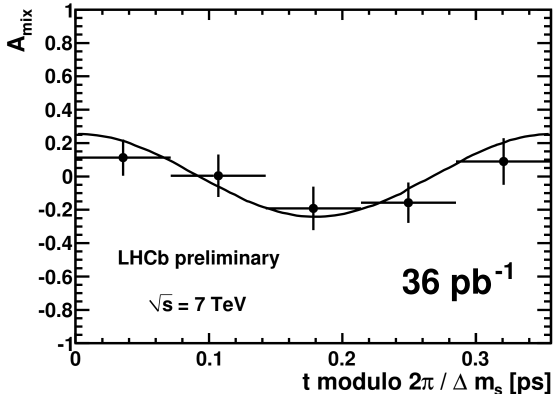
World average sin2β=0.672±0.023

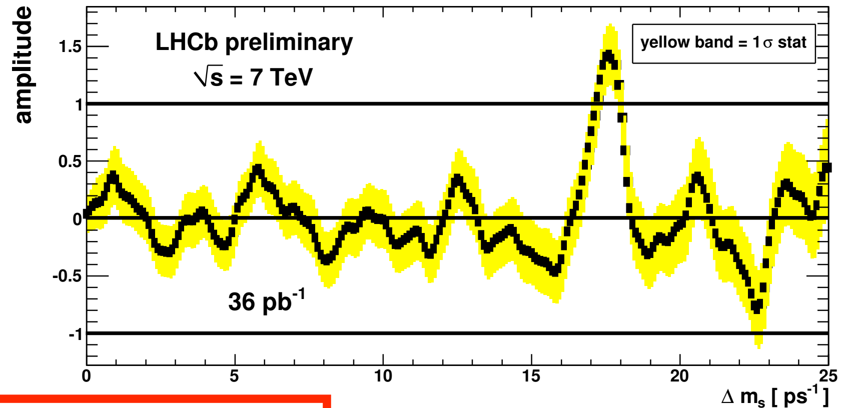
LHCb-CONF-2011-010



$$\Delta m_d = 0.499 \pm 0.032 \pm 0.003 \quad ps^{-1}$$

World average Δm_d=0.507±0.005 ps^{-1}



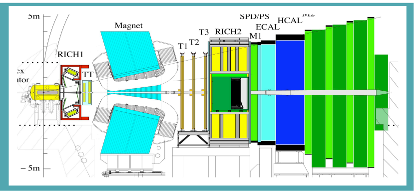


LHCb-CONF-2011-005

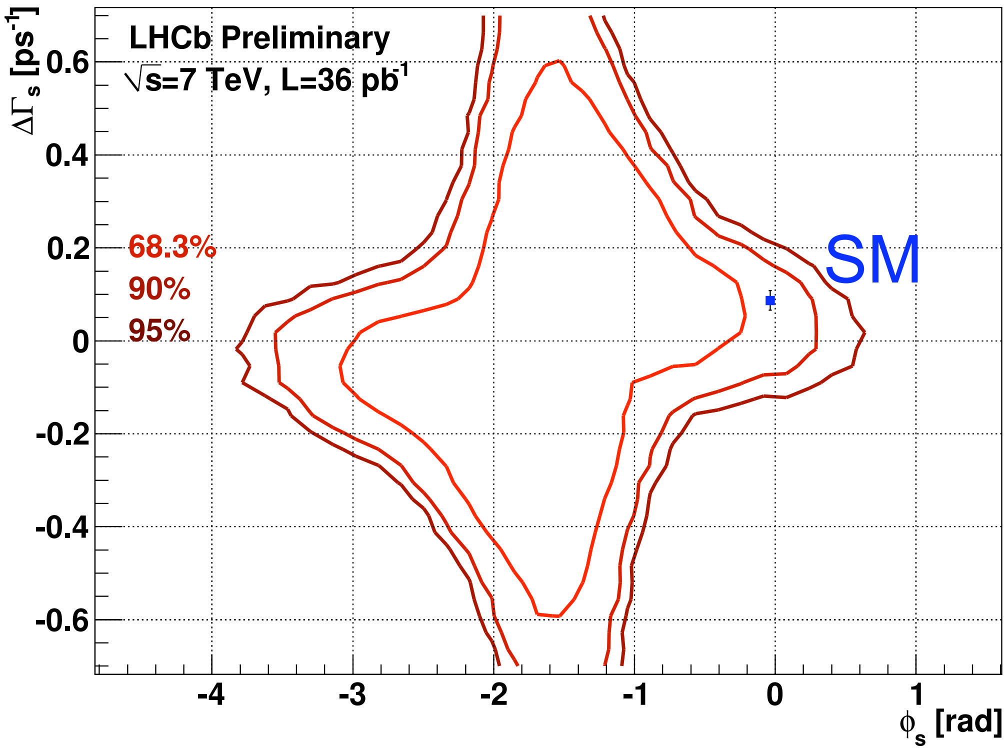
$$\Delta m_s = 17.63 \pm 0.11 \pm 0.04 \quad ps^{-1}$$

World average Δm_s=17.77±0.10±0.07 ps^{-1}

Constraints on ϕ_s



LHCb-CONF-2011-006



$$\phi_s \in [-2.7, -0.5] \text{ rad } @68\% \text{ c.l.}$$
$$\phi_s \in [-3.5, 0.2] \text{ rad } @95\% \text{ c.l.}$$

- No meaningful point estimate
  - Confidence contours using Feldman-Cousins method
- Statistical errors only: accounts for systematic uncertainty of tagging
- All systematic errors negligible compared with statistics

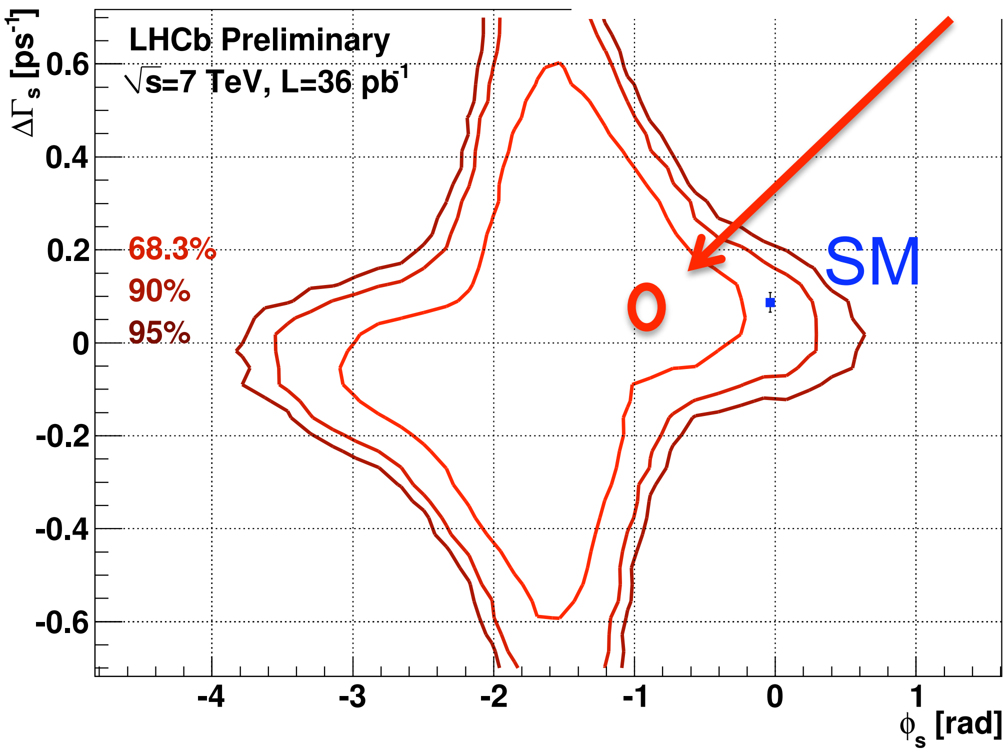
- SM p-value = 22% (1.2σ)

Standard Model:
$\Delta\Gamma_s = 0.087 \pm 0.021$ ps-1
(A.Lenz, U.Nierste. arXiv:1102.4274)
$\phi_s = -0.0363 \pm 0.0017$ rad (CKMfitter)

Constraints on ϕ_s

LHCb 2011
0.13 rad sensitivity with 1 fb^{-1}

LHCb-CONF-2011-006



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ϕ_s = -0.0363 ± 0.0017 rad (CKMfitter)

Search for NP contributions in $B_{d,s}$ rare decays

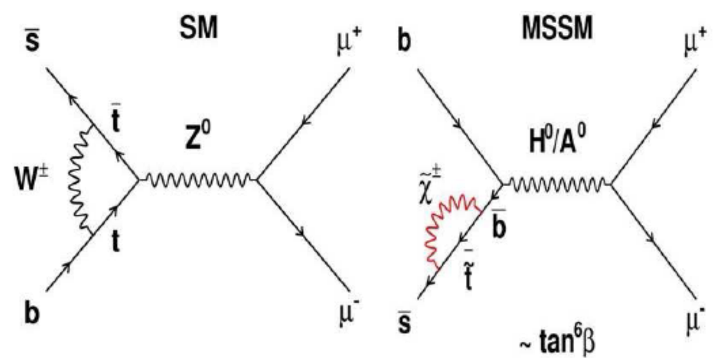
Search for $B_{d,s} \rightarrow \mu^+\mu^-$

Search for $B \rightarrow \mu^+\mu^-$

Very rare and golden FCNC $b \rightarrow d,s$ transition

Mode	SM
$B_s \rightarrow \mu^+\mu^-$	$3.2 \pm 0.2\ 10^{-9}$
$B^0 \rightarrow \mu^+\mu^-$	$0.10 \pm 0.01\ 10^{-9}$

A.J.Buras: arXiv:1012.1447
E. Gamiz et al: Phys.Rev.D 80 (2009) 014503



Strong enhancements in MSSM :

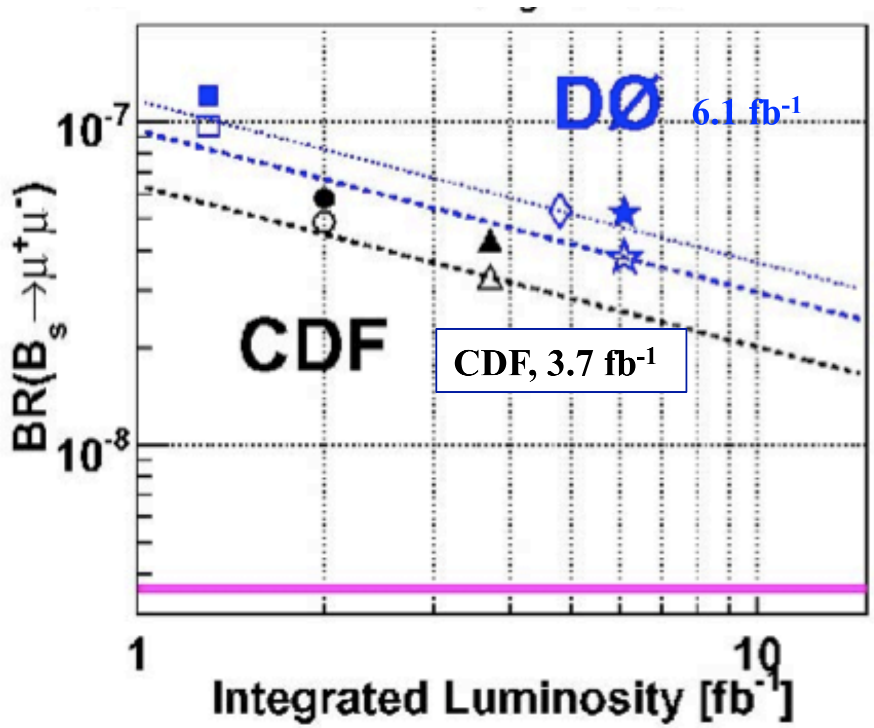
$$B\left(B_s \rightarrow \mu^+\mu^-\right) \propto \frac{\tan^6\beta}{M_A^4}$$

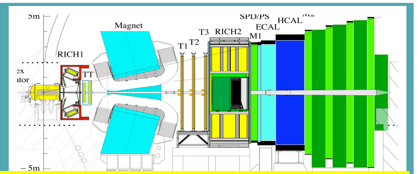
Limits from the Tevatron @95% c.l.

CDF (~3.7 fb^{-1})

$$\begin{cases} B\left(B_s \rightarrow \mu^+\mu^-\right) < 43 \times 10^{-9} \\ B\left(B_d \rightarrow \mu^+\mu^-\right) < 7.6 \times 10^{-9} \end{cases}$$

D0 (~6.1 fb^{-1}) $\quad B\left(B_s \rightarrow \mu^+\mu^-\right) < 51 \times 10^{-9}$

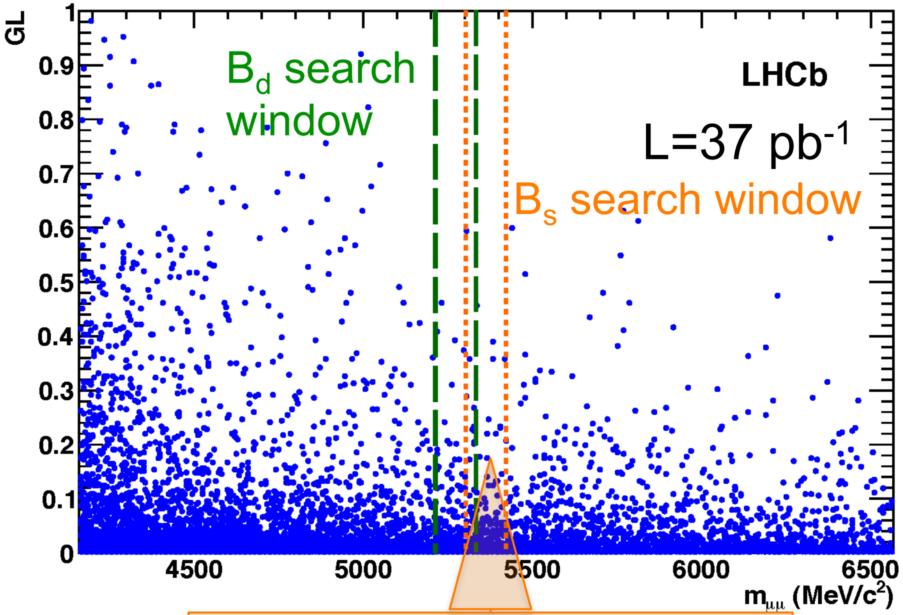


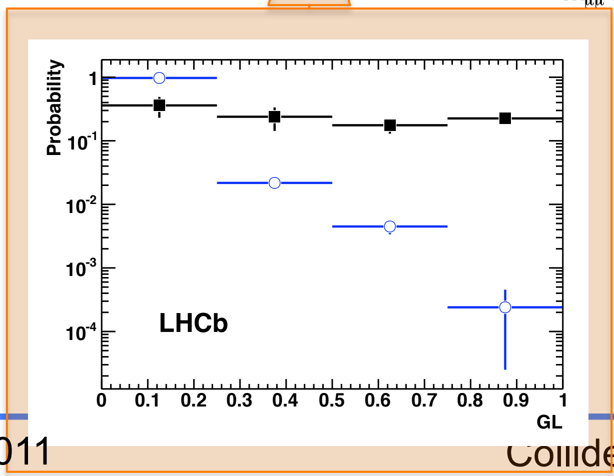


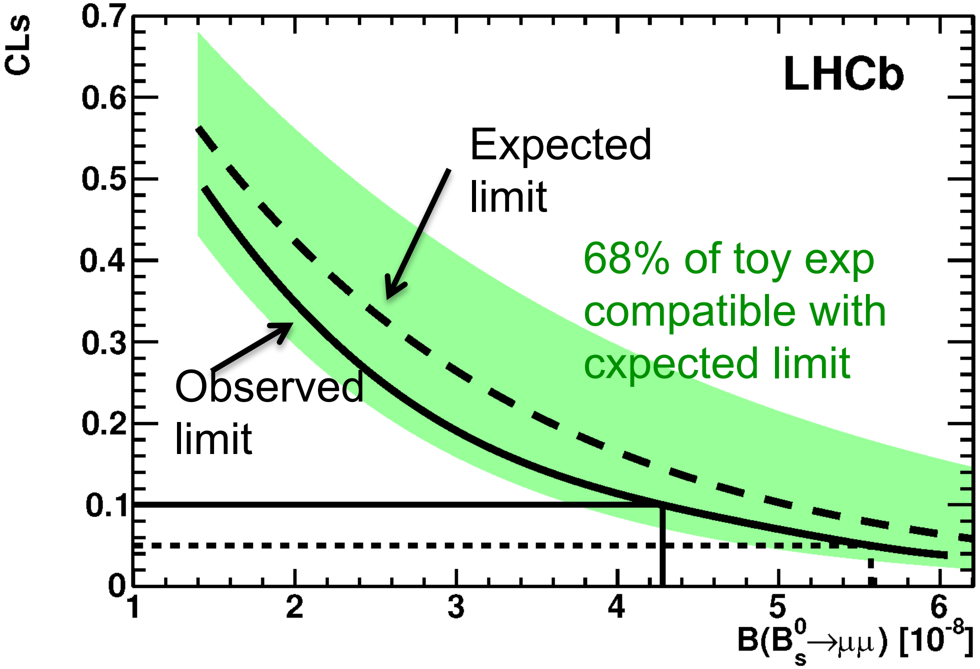
Search for $B \to \mu^+\mu^-$

arXiv:1103.2465 (acc PLB)

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





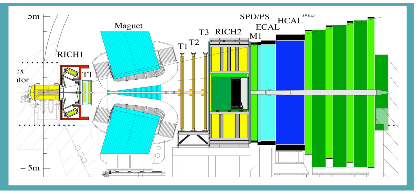


LHCb results @90(95)% c.l.

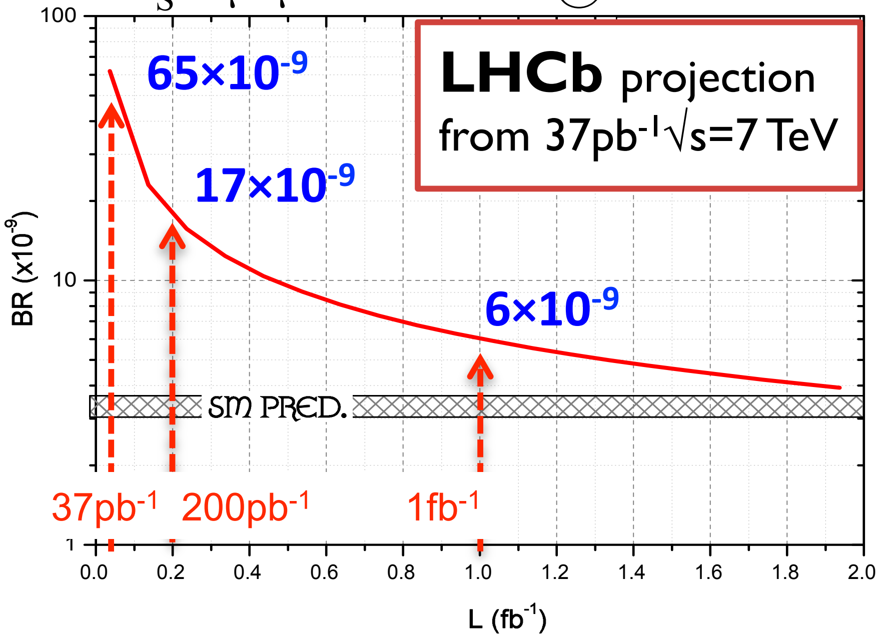
$$B(B_s \to \mu^+\mu^-) < 4.3(5.6) \times 10^{-8}$$

$$B(B_d \to \mu^+\mu^-) < 1.2(1.5) \times 10^{-8}$$

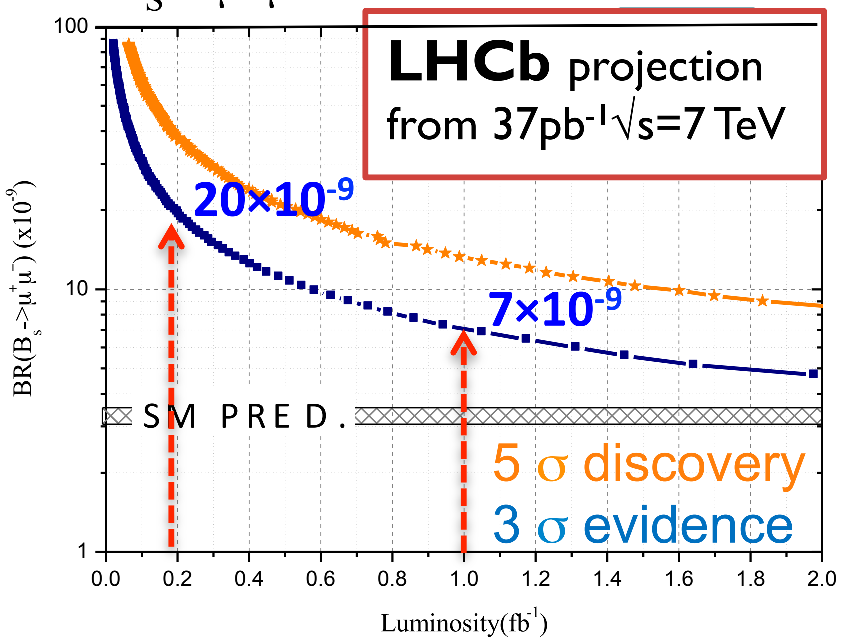
Prospects for B→μ⁺μ⁻ 2010/2011

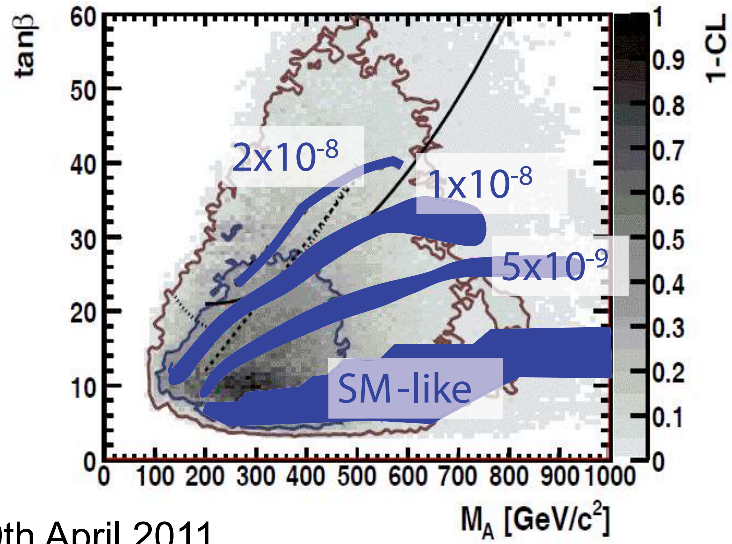


$B_S \rightarrow \mu^+\mu^-$ exclusion @ 95% CL



$B_S \rightarrow \mu^+\mu^-$ observation

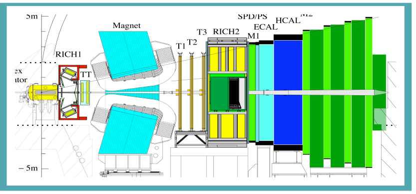




LHCb will either **find signs of NP** or **exclude most of the tanβ vs M_A** plane with the 2010/2011 data.

Strong impact on viable SUSY scenarios

Summary



- LHCb is producing world-class measurements in flavour physics

$$e.g.\quad \Delta m_s,\quad \phi_s,\quad B\left(B_{d,s}\rightarrow \mu^+\mu^-\right)\quad \ldots$$

- New avenues are being explored to search for NP in the B_s system with many new decay modes observed

$$e.g.\quad B_s\rightarrow J/\psi\, f_0,\quad B_s\rightarrow K^*K^*$$

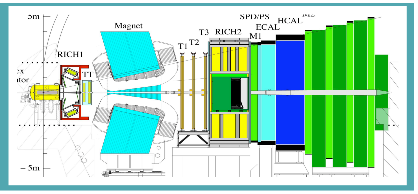
- Many results not mentioned here and still in the pipeline for the 2010 data

e.g. W/Z production, D^0 mixing

- LHCb is running very well in 2011 and expects to collect >200 pb^{-1} by ~June and 1 fb^{-1} by end of 2011

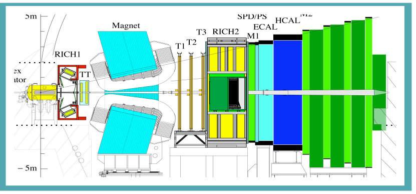
LHCb is now at the forefront of a new era of discoveries (?) and precision measurements in flavour physics ! Exciting times ahead !

Thank you !
Happy LHC Experimentalists !



Questions?

Flavour Physics



Flavour physics is highly successful. It has led the way to

- The 3 generation Standard Model
- The CKM picture of flavour
- CP Violation

Flavour physics is a proven tool of discovery

$Br(K^0_L \rightarrow \mu\mu)$ & GIM → prediction of charm
CP violation → need for a 3rd generation
B mixing → top quark is very heavy

Many open questions found in the flavour sector

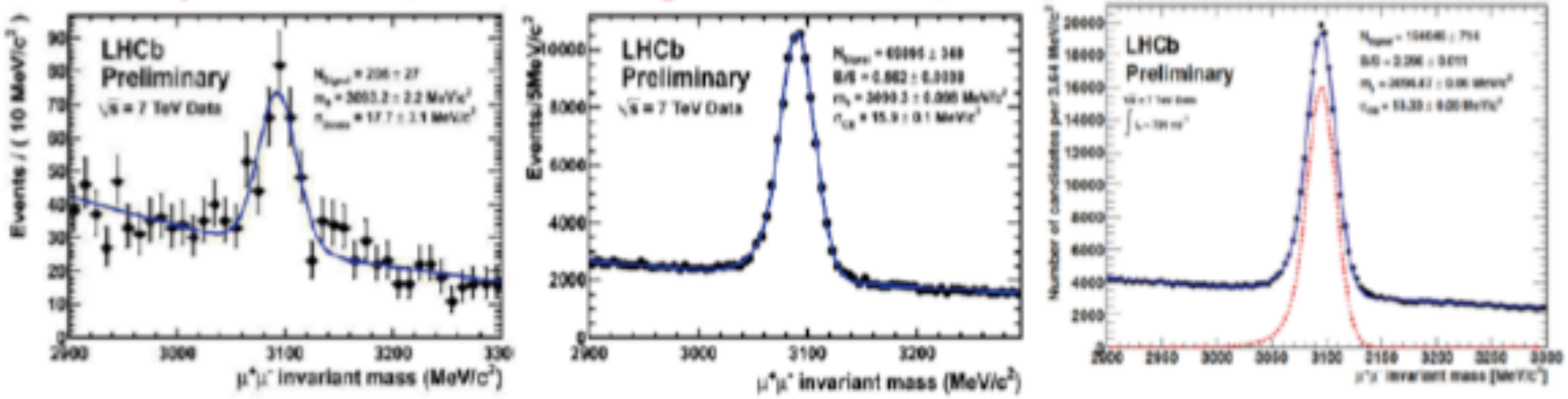
- Why are there 3 generations ?
- What determines the hierarchy of fermion masses ?
- What determines the elements of the CKM matrix ?
- What is the relationship between the CKM matrix and the ν mixing matrix ?
- What is the origin of CP Violation ?

Flavour physics also helps to understand open questions in cosmology
e.g. SM CPV insufficient to explain matter/antimatter asymmetry

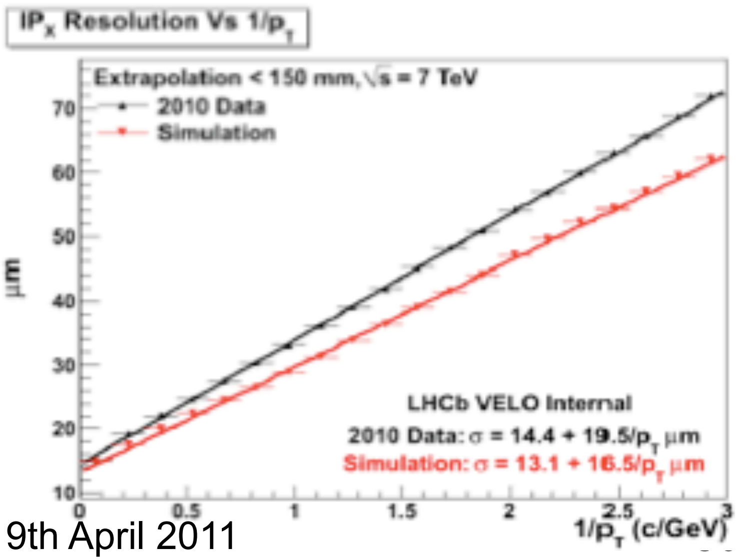
LHCb performance: momentum and vertex resolution

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

May: σ ~ 18 MeV/c^2 August: σ ~ 16 MeV/c^2 November: σ ~ 13 MeV/c^2



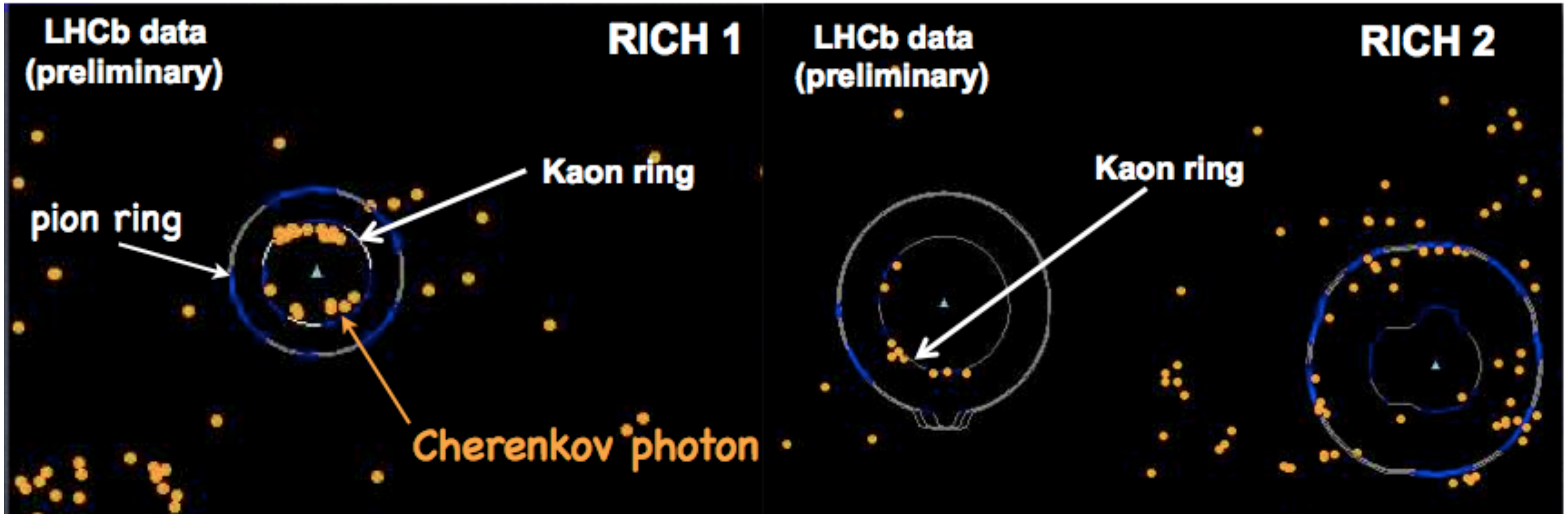
Fantastic job by a very hard-working group of people improving the alignment!

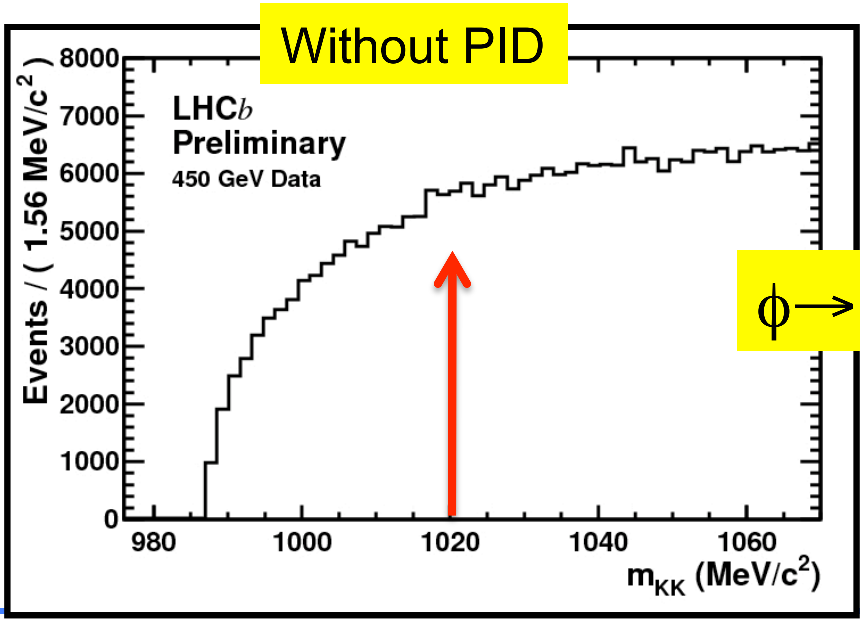


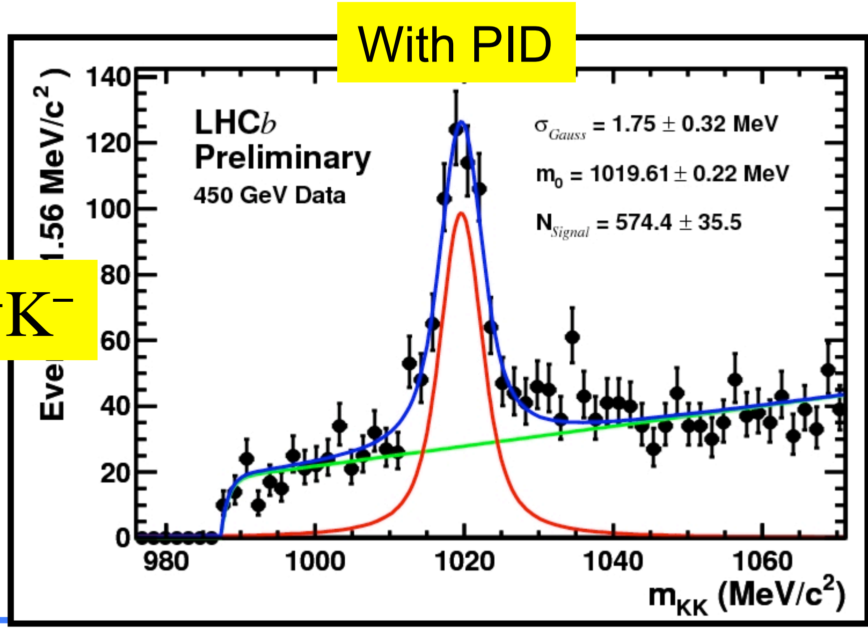
PV resolution: σ_x~σ_y~16 µm (MC:11µm) , σ_z~76 µm (MC:60 µm) as measured for events with 25 tracks/ event.

IP resolution: σ(IPx)~15-20 µm in the region of interest. Slope dominated by material interactions rather than misalignment.

LHCb Particle Identification



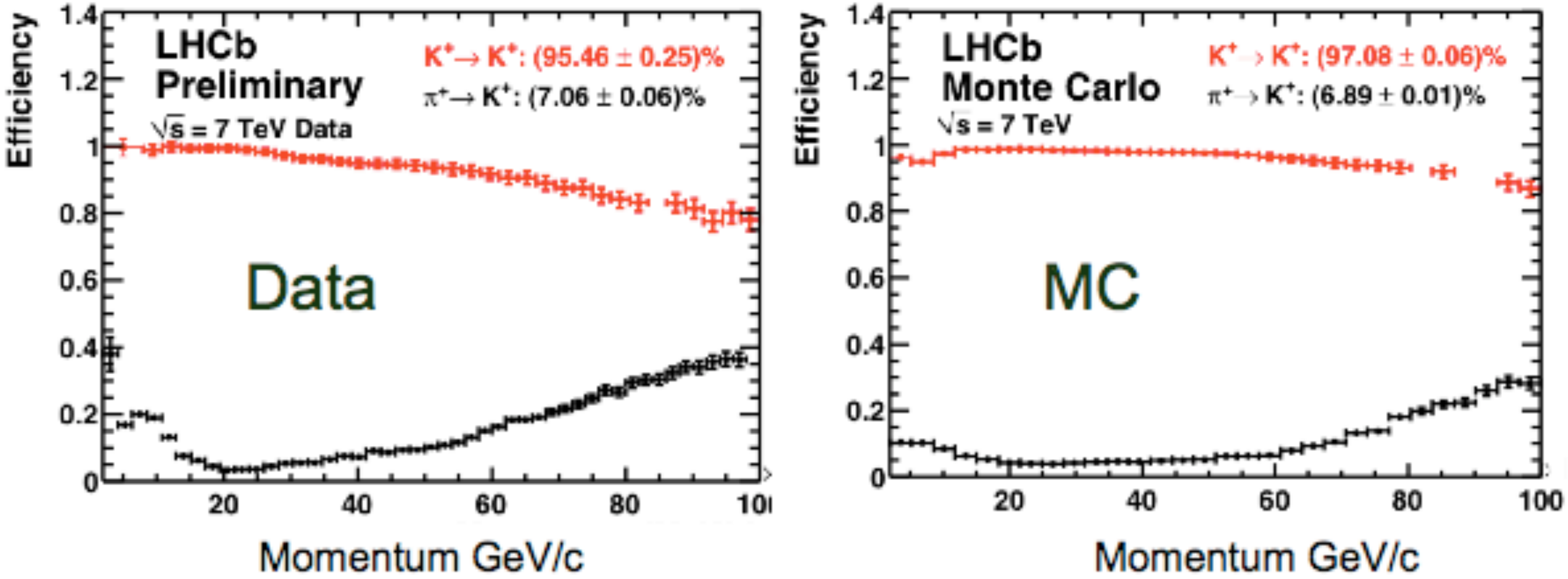




$\phi \rightarrow K^+K^-$

LHCb performance: PID and Trigger

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

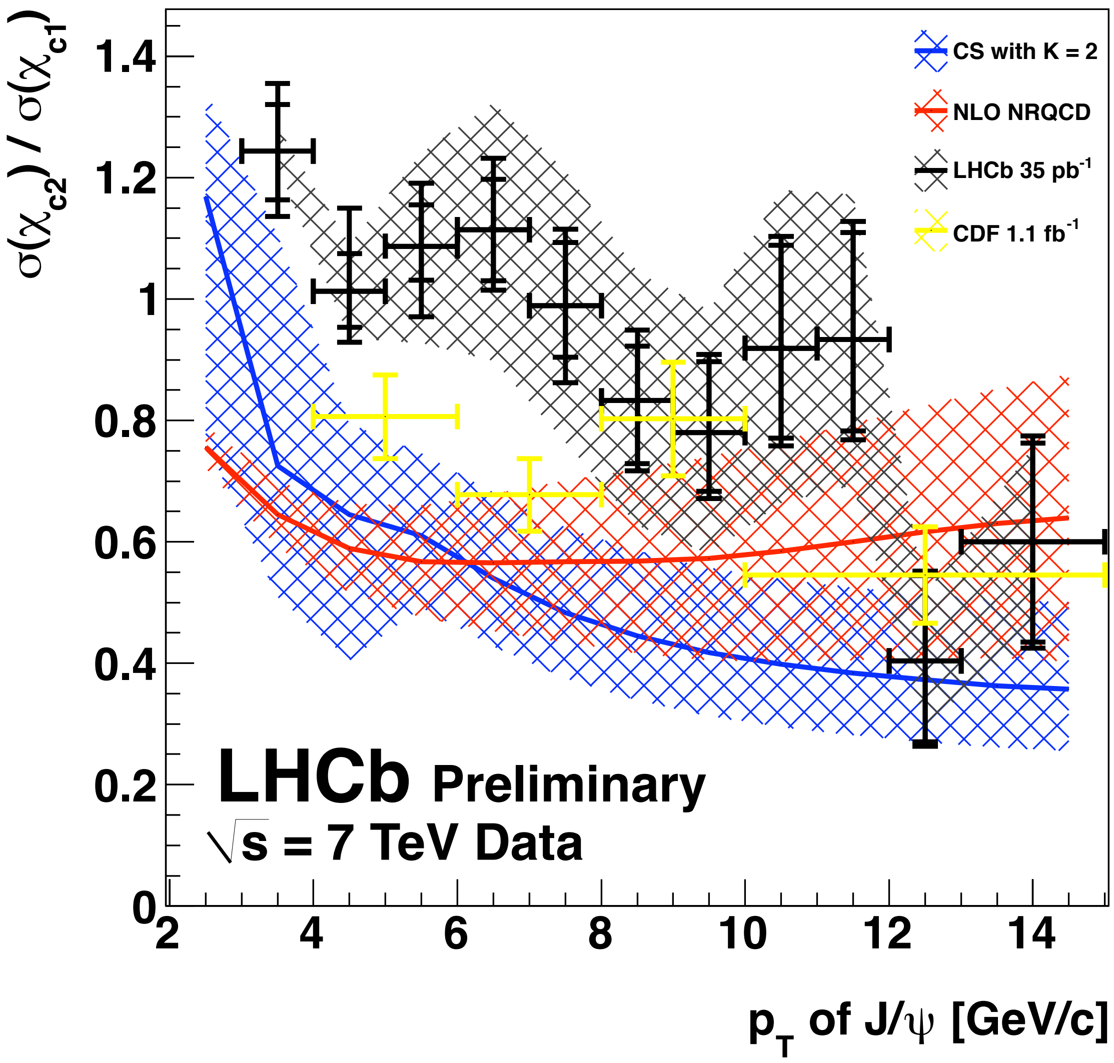


Trigger efficiencies very close to expectations

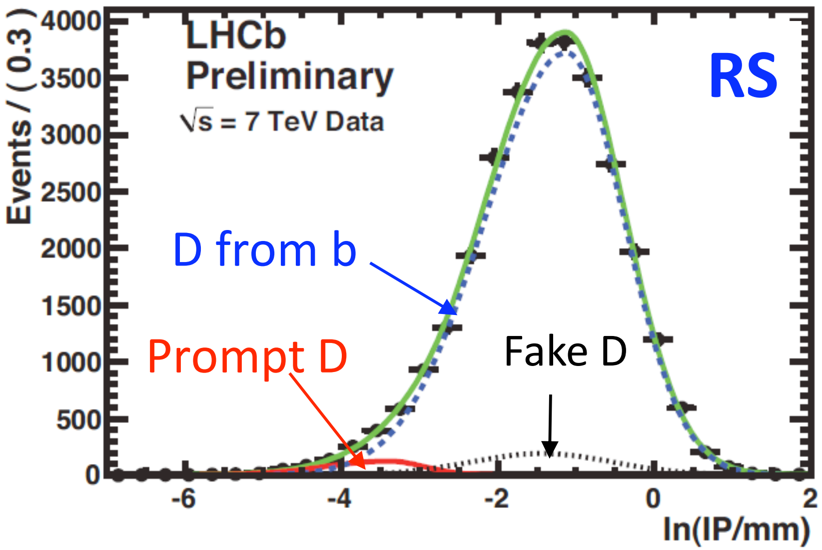
Trigger efficiencies L0xHLT1 determined on data using the tag-and-probe methods:

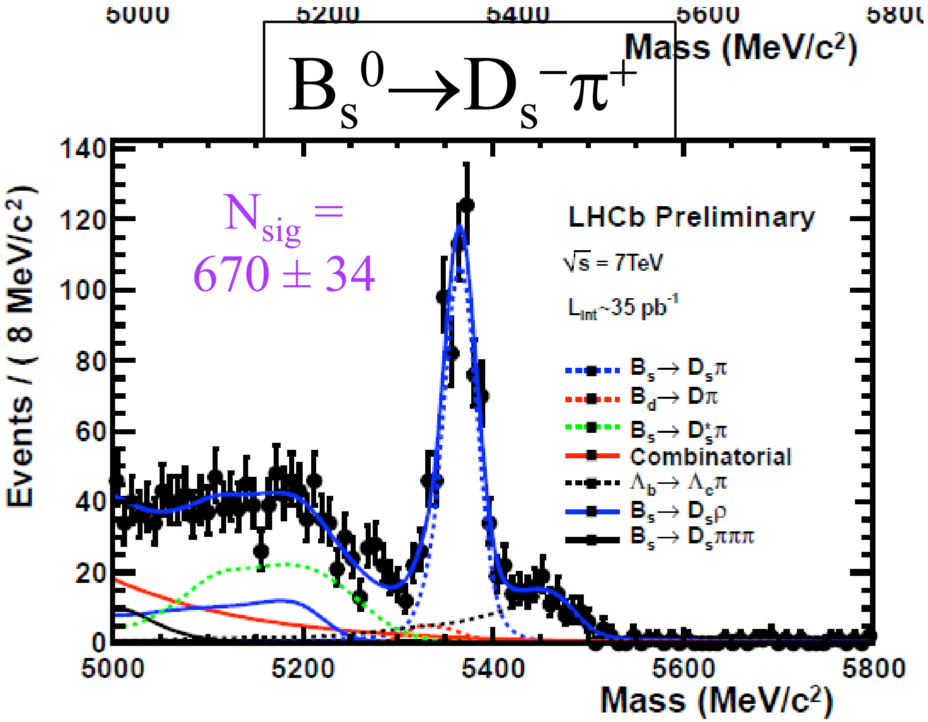
	Muon trigger (J/ψ)	Hadron trigger (D^0)
Data	94.9±0.2%	60±4%
MC	93.3±0.2%	66%

χ_c production



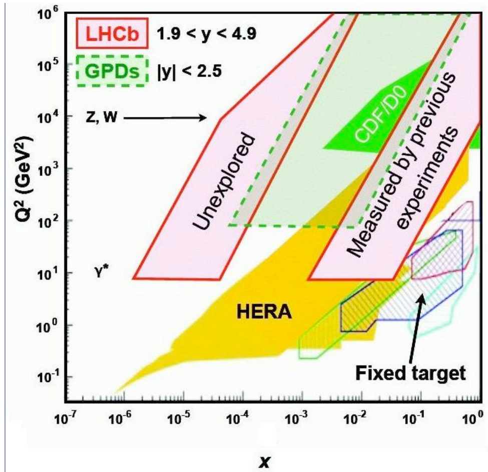
B fractions

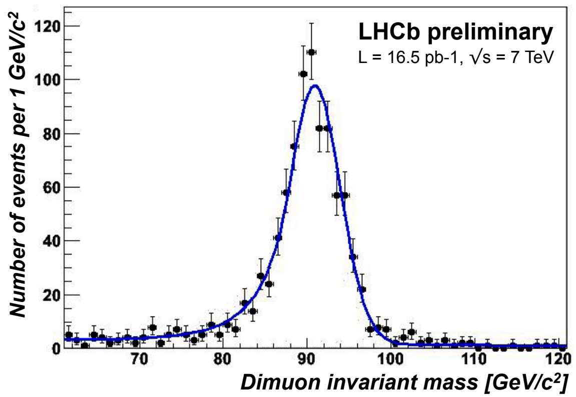

LHCb
Preliminary
√s = 7 TeV Data
RS
D from b
Prompt D
Fake D
Events / (0.3)
ln(IP/mm)

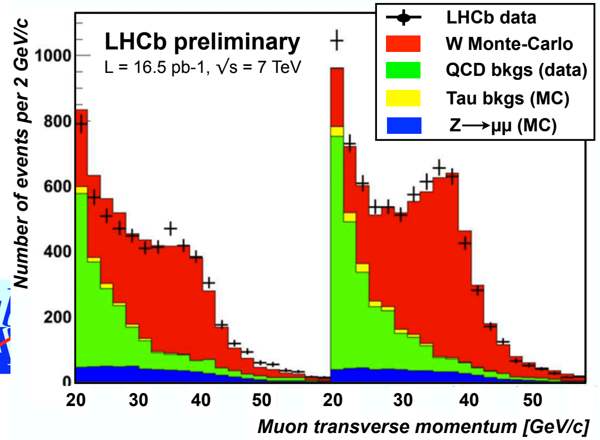

$B_s^0 \to D_s^- \pi^+$
N_{sig} =
670 ± 34
LHCb Preliminary
√s = 7TeV
L_{int}~35 pb^{-1}
$B_s \to D_s\pi$
$B_d \to D\pi$
$B_s \to D_s^*\pi$
Combinatorial
$\Lambda_b \to \Lambda_c\pi$
$B_s \to D_s\rho$
$B_s \to D_s\pi\pi\pi$
Events / (8 MeV/c²)
Mass (MeV/c²)

W & Z Production

LHCb sensitive to unexplored regions of phase space (W&Z, low mass Drell-Yan).

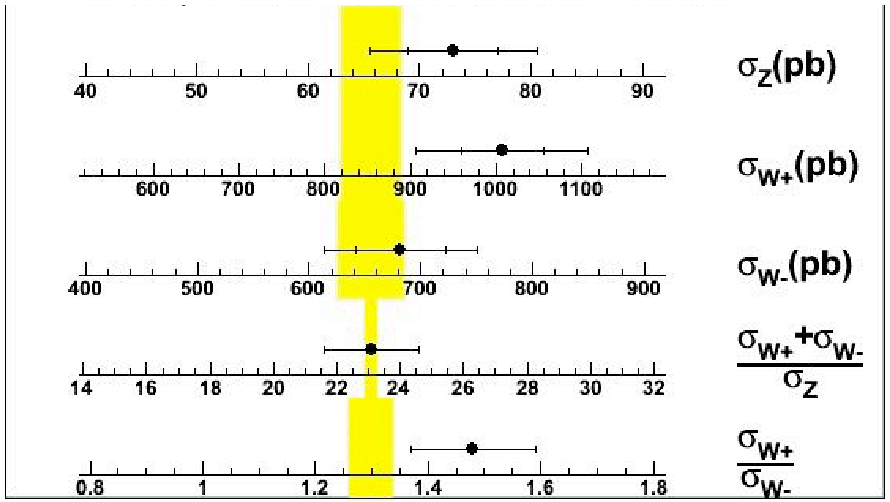


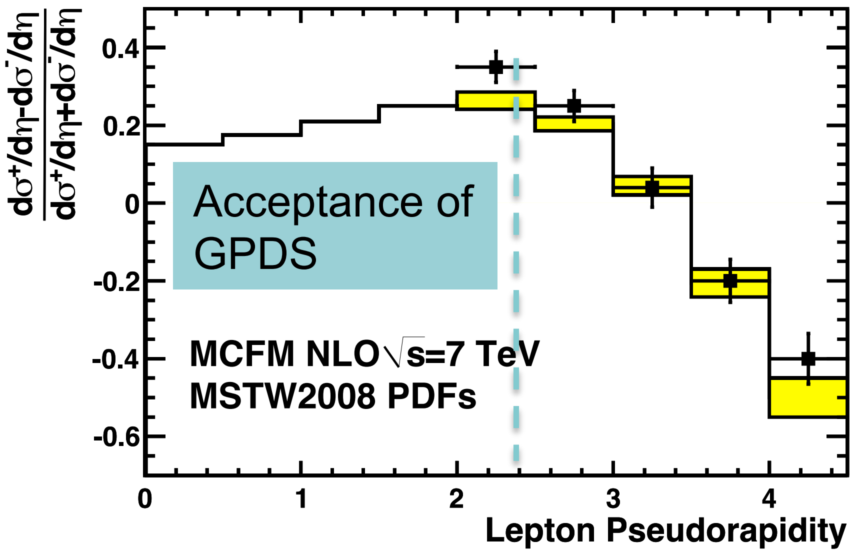




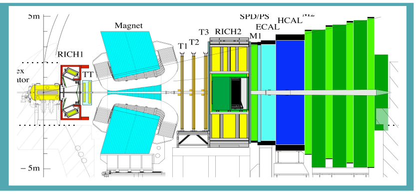
LHCb-CONF-2011-012

W charge asymmetry also sensitive to PDFs.





Prospects for ϕ_s



Current performance

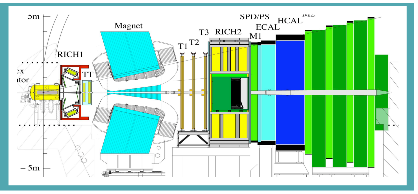
	LHCb 36 pb^{-1}	CDF 5.2 fb^{-1}
$B_s \to J/\psi\,\phi$	836	6500
Proper time resolution	50 fs	100 fs
OS tagging power	$2.2 \pm 0.5\%$	$1.2 \pm 0.2\%$
SS tagging power	work ongoing	$3.5 \pm 1.4\%$

With current performance, using only OS tagger, expected ϕ_s sensitvity for 1 fb^{-1} at 7 TeV is 0.13 rad

- SS tagger will improve sensitivity significantly
- Decay modes with final states which are CP eigenstates

Expect world's best measurement with 2011 data

Charge asymmetry A_{SL}



D0 : evidence for an anomalous like-sign dimuon charge asymmetry

D0 Collaboration, arXiv:1005.2757v1

Evidence for an anomalous like-sign dimuon charge asymmetry

V.M. Abazov,[36] B. Abbott,[74] M. Abolins,[63] B.S. Acharya,[29] M. Adams,[49] T. Adams,[47] E. Aguilo,[6] G.D. Alexeev,[36] G. Alkhazov,[40] A. Alton[a],[62] G. Alverson,[61] G.A. Alves,[2] L.S. Ancu,[35] M. Aoki,[48] Y. Arnoud,[14] M. Arov,[58] A. Askew,[47] B. Åsman,[41] O. Atramentov,[66] C. Avila,[8] J. BackusMayes,[81] F. Badaud,[13] L. Bagby,[48] B. Baldin,[48] D.V. Bandurin,[47] S. Banerjee,[29] E. Barberis,[61] A.-F. Barfuss,[15] P. Baringer,[56] J. Barreto,[2] J.F. Bartlett,[48] U. Bassler,[18] S. Beale,[6] A. Bean,[56] M. Begalli,[3] M. Begel,[72] C. Belanger-Champagne,[41] L. Bellantoni,[48] J.A. Benitez,[63] S.B. Beri,[27] G. Bernardi,[17] R. Bernhard,[22] I. Bertram,[42] M. Besançon,[18] R. Be

...

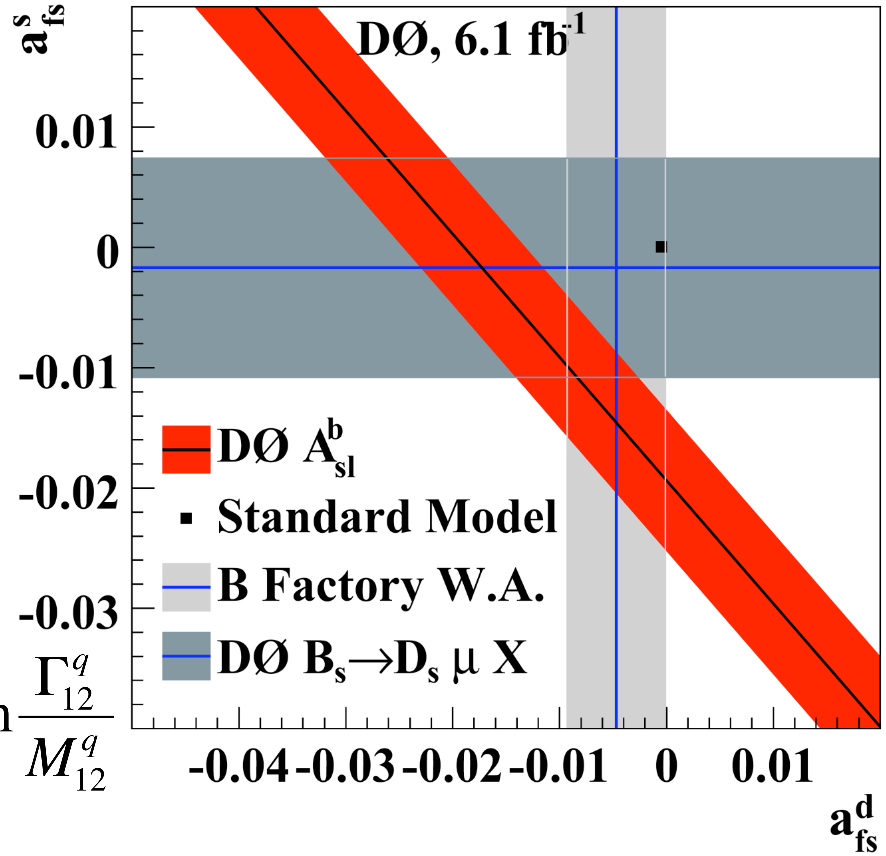
We measure the charge asymmetry A of like-sign dimuon events in 6.1 fb^{-1} of $p\bar{p}$ collisions with the D0 detector at a center-of-mass energy $\sqrt{s} = 1.96$ TeV at the Fermilab Tevatron From A, we extract the like-sign dimuon charge asymmetry in semileptonic b-hadron deca -0.00957 ± 0.00251 (stat) ± 0.00146 (syst). This result differs by 3.2 standard deviations standard model prediction $A^b_{sl}(SM) = (-2.3^{+0.5}_{-0.6}) \times 10^{-4}$ and provides first evidence of a CP-violation in the mixing of neutral B mesons.

$$A_{sl} = -0.00957 \pm 0.00251 \pm 0.00146$$

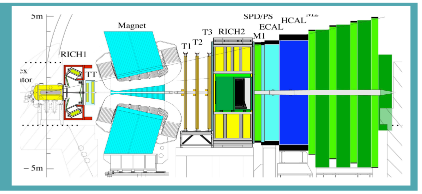
$$A_{sl}^{SM} = \left(-2.3^{+0.5}_{-0.6}\right) \times 10^{-4}$$

3.2σ

D0 measure $A_{sl}^{SM} \approx \dfrac{a_{fs}^s + a_{fs}^d}{2}$ where $a_{fs}^q = \mathrm{Im}\dfrac{\Gamma_{12}^q}{M_{12}^q}$

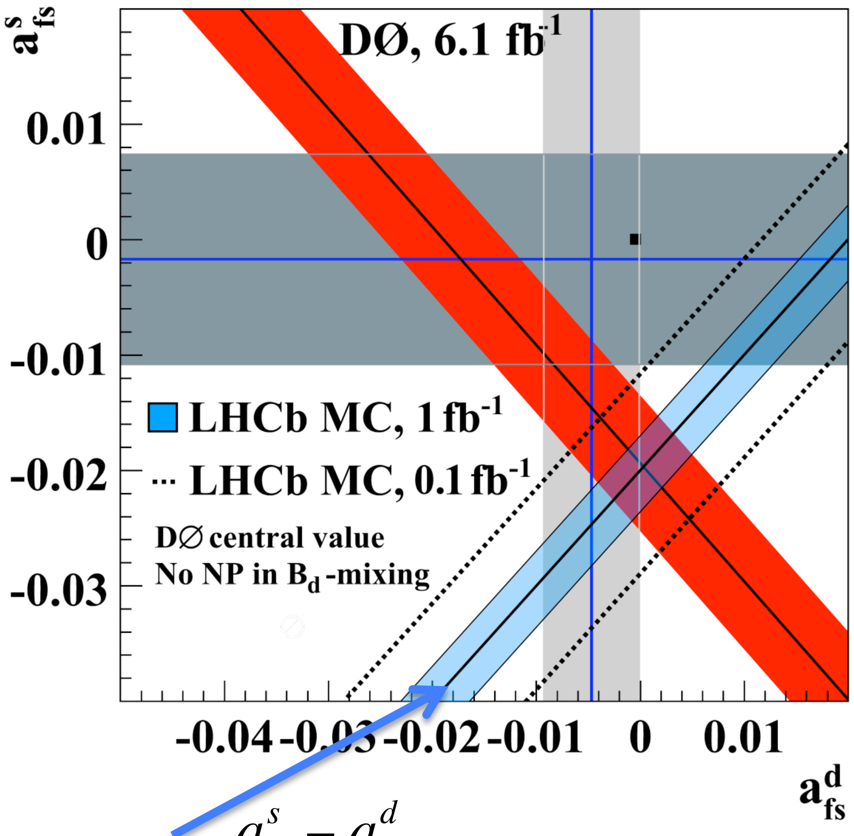


Charge asymmetry A_{SL}

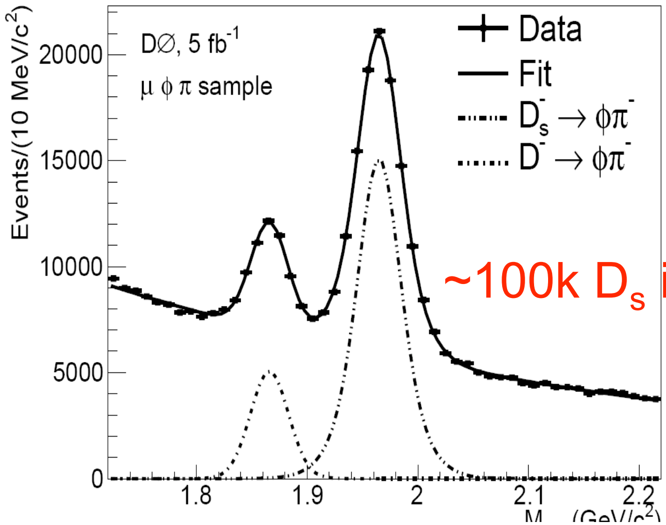


LHCb is catching up with D0 very quickly.

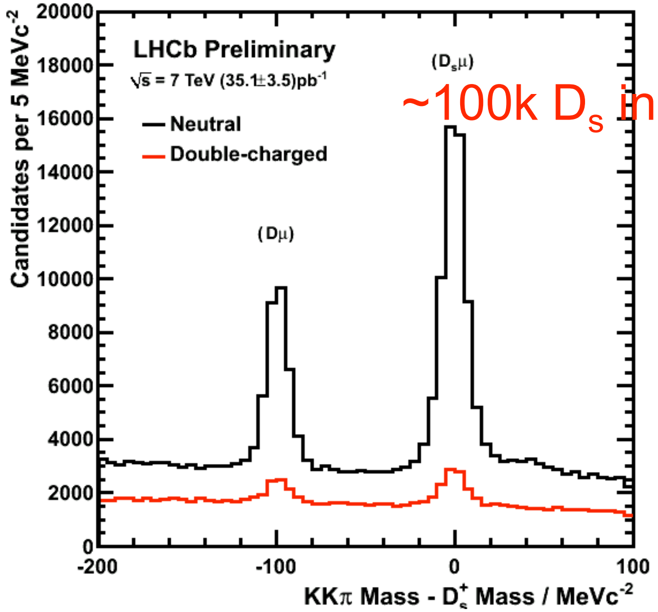
Reconstruct $B_d \to D^{\pm}\mu^{\mp}\nu$ and $B_s \to D_s^{\pm}\mu^{\mp}\nu$



$$\Delta A_{sl} \approx \frac{a_{fs}^{s} - a_{fs}^{d}}{2} = (2.1 \pm 0.3) \times 10^{-4} \quad (\mathrm{SM})$$

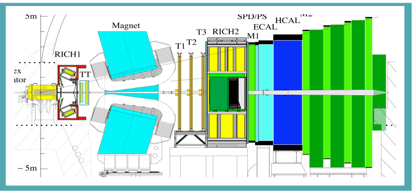


~100k D_s in 5 fb^{-1}



~100k D_s in 0.2 fb^{-1}

B →K*μμ

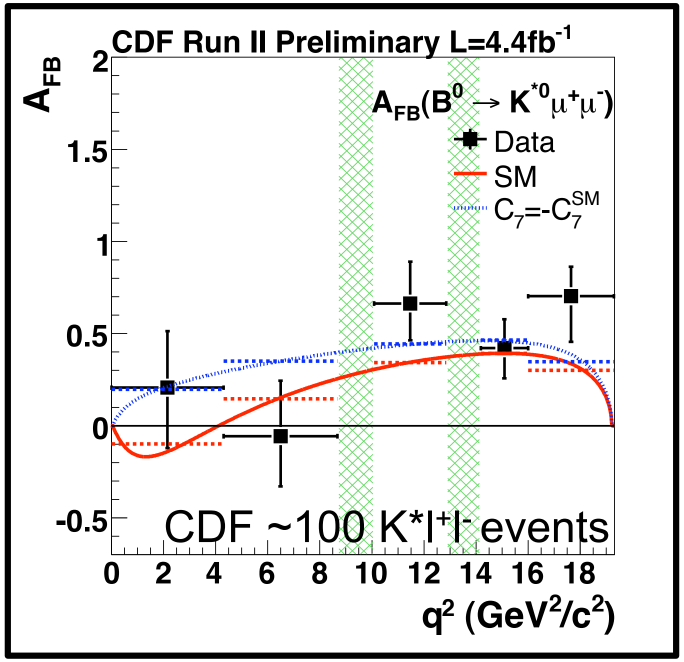


FCNC b→s transition, very sensitive to NP
The forward-backward asymmetry arises from the interference between γ and Z⁰ contributions

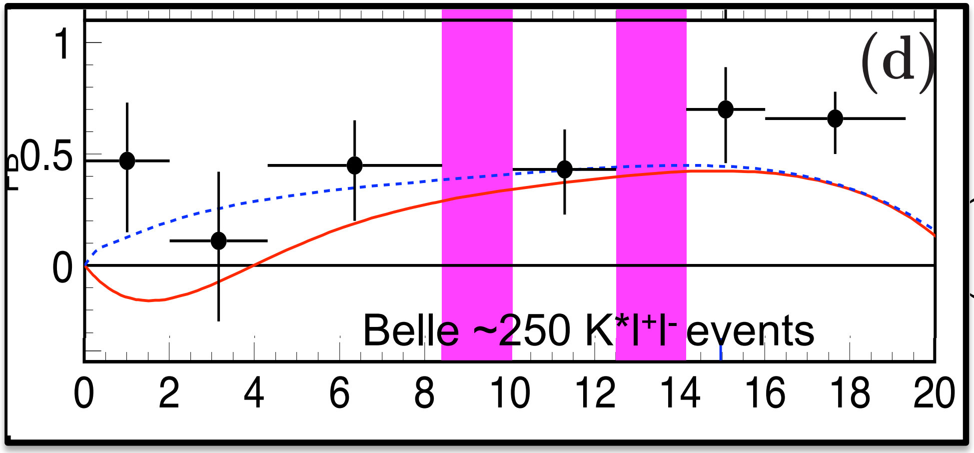
$$A_{FB}\left(q^2 = m_{\mu\mu}^2\right) = -C_{10}\,\xi(s)\left[\mathrm{Re}(C_9)F_1 + \frac{1}{q^2}C_7F_2\right]$$

Most reliable predictions are at low q^2 (1-6 GeV^2)

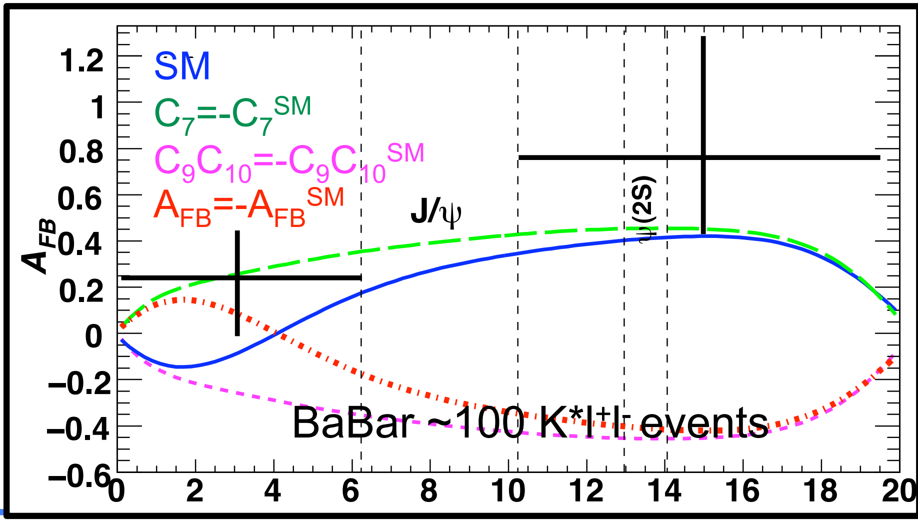
Early results are showing intriguing hints.



CDF Public Note 10047



Belle PRL 103 (2009) 171801



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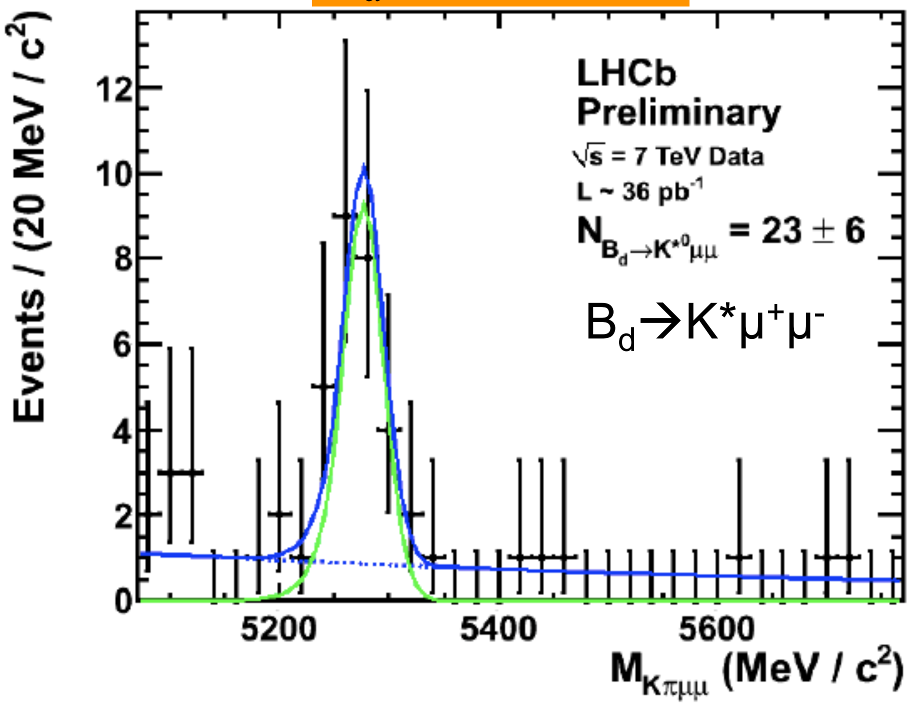
Observation of $B_d \to K^* \mu^+ \mu^-$

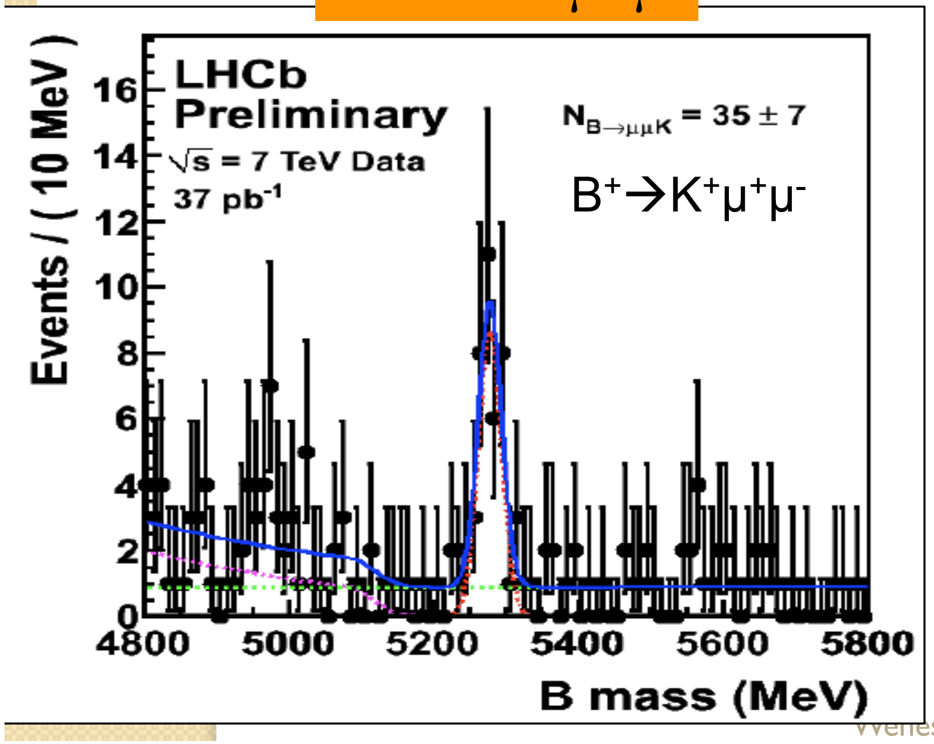
Clean observation of $B_d \to K^* \mu^+ \mu^-$ (23±6) events close to expectations.

Also, observation of the rarest B decay at LHCb so far: $B^+ \to K^+ \mu^+ \mu^-$ (35±7) events (Br~5x10^{-7}).

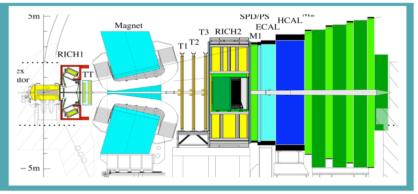
$B_d \to K^* \mu^+ \mu^-$



$B^+ \to K^+ \mu^+ \mu^-$



LHCb sensitivities



Type	Observable	Current precision	LHCb (5 fb^{-1})	Upgrade (50 fb^{-1})	Theory uncertainty
Gluonic penguin	$S(B_s \to \phi\phi)$	-	0.08	0.02	0.02
	$S(B_s \to K^{*0}\bar{K}^{*0})$	-	0.07	0.02	< 0.02
	$S(B^0 \to \phi K_S^0)$	0.17	0.15	0.03	0.02
B_s mixing	$2\beta_s\ (B_s \to J/\psi\phi)$	0.35	0.019	0.006	~ 0.003
Right-handed currents	$S(B_s \to \phi\gamma)$	-	0.07	0.02	< 0.01
	$\mathcal{A}^{\Delta\Gamma_s}(B_s \to \phi\gamma)$	-	0.14	0.03	0.02
E/W penguin	$A_T^{(2)}(B^0 \to K^{*0}\mu^+\mu^-)$	-	0.14	0.04	0.05
	$s_0\ A_{\text{FB}}(B^0 \to K^{*0}\mu^+\mu^-)$	-	4%	1%	7%
Higgs penguin	$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	30%	8%	$< 10\%$
	$\frac{\mathcal{B}(B^0 \to \mu^+\mu^-)}{\mathcal{B}(B_s \to \mu^+\mu^-)}$	-	-	$\sim 35\%$	$\sim 5\%$
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	$\sim 20^\circ$	$\sim 4^\circ$	0.9°	negligible
	$\gamma\ (B_s \to D_s K)$	-	$\sim 7^\circ$	1.5°	negligible
	$\beta\ (B^0 \to J/\psi\, K^0)$	1°	0.5°	0.2°	negligible
Charm CPV	A_Γ	2.5×10^{-3}	2×10^{-4}	4×10^{-5}	-
	$A_{CP}^{dir}(KK) - A_{CP}^{dir}(\pi\pi)$	4.3×10^{-3}	4×10^{-4}	8×10^{-5}	-