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Review of recent LHCb measurements

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Université Blaise Pascal

Outline of the presentation

1. Introduction: flavour physics and CP violation.
2. The LHCb detector.
3. Operation and physics performance.
4. Production studies.
5. CP violation measurements.
6. Rare decays.
7. Summary.

1. Flavour Physics and CP violation

The LHCb experiment stands for beauty experiment at LHC. The core physics case of LHC is the understanding ElectroWeak Symmetry Breaking.

Within the Standard Model, after spontaneous symmetry breaking by the introduction of a scalar doublet and mass matrix diagonalisation:

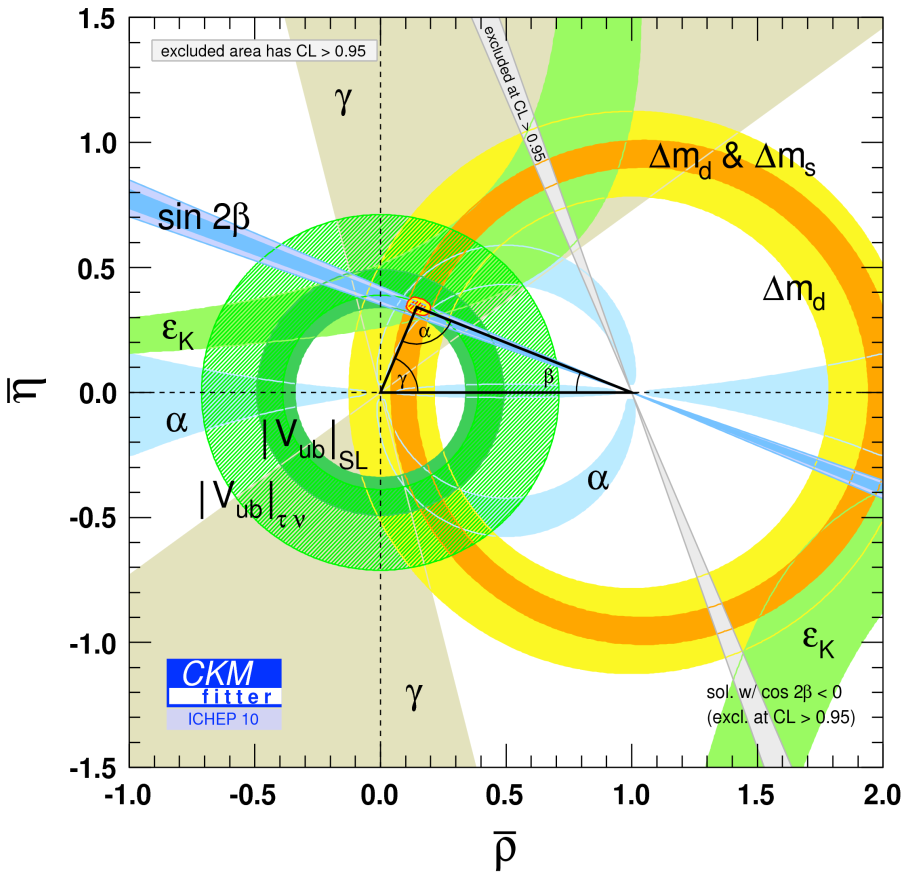
$$\mathcal{L}_{cc}^{\text{quarks}} = \frac{g}{2\sqrt{2}} W_\mu^\dagger [\sum_{ij} \bar{u}_i(q_2)\gamma^\mu(1-\gamma^5) V_{ij} d_j] + \text{h.c}$$

The CKM matrix elements relates the mass and the weak eigenstates and controls the strength of flavour changing charged currents between quark generations.

CKM matrix is described by four unknown parameters, one being a phase allowing for CP violation. Overconstraining these parameters makes possible a global consistency test of the SM hypothesis.

1.1 The global fit : CKM profile

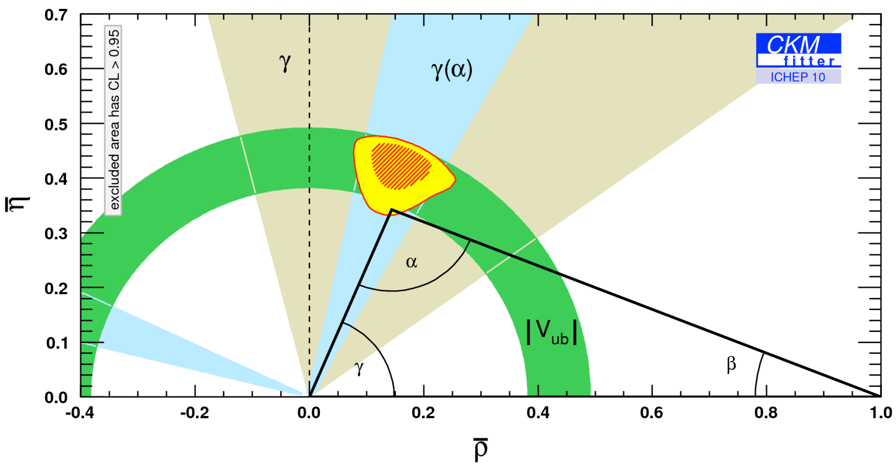
- This is a tremendous success of the Standard Model and especially the Kobayashi-Maskawa mechanism. This is simultaneously an outstanding experimental achievement by the B factories.
- CKM is at work in weak charged current.
- The KM phase IS the dominant source of CP violation in K and B system.
- The second pillar of the SM.

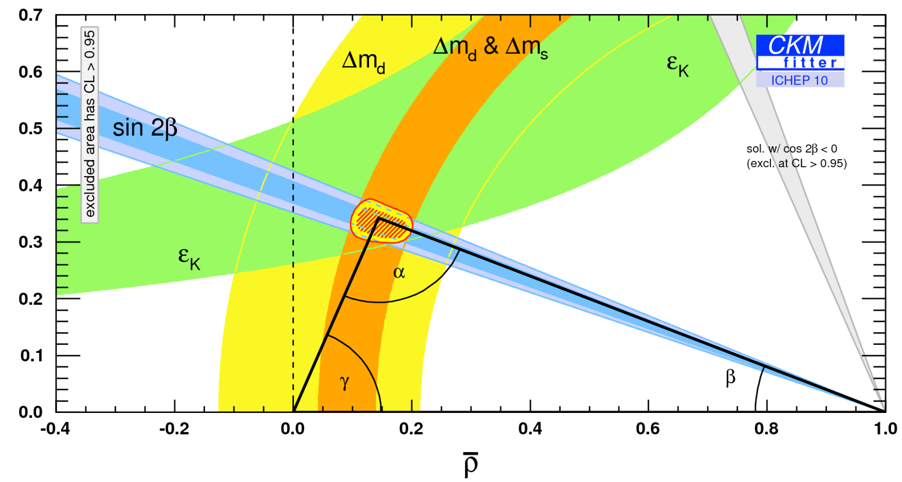


1.1 Introduction: the global fit in more details

- The global picture: comparison of observables constraints.

Trees against Loops.





- Tree-level processes are thought to be pure SM. Loops could new New Physics. Fair qualitative agreement.
- Still, there are tensions in the fit which are of interest for the LHCb physics case.

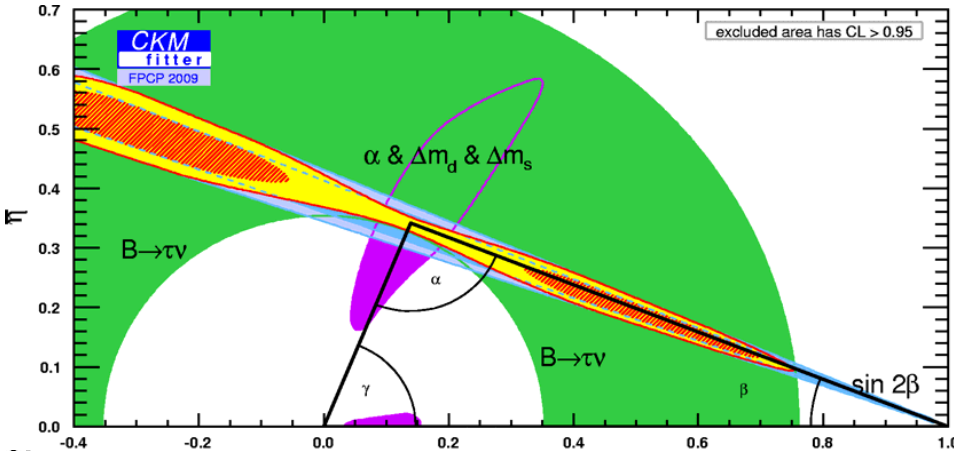
1.1 Introduction: the CKM tensions

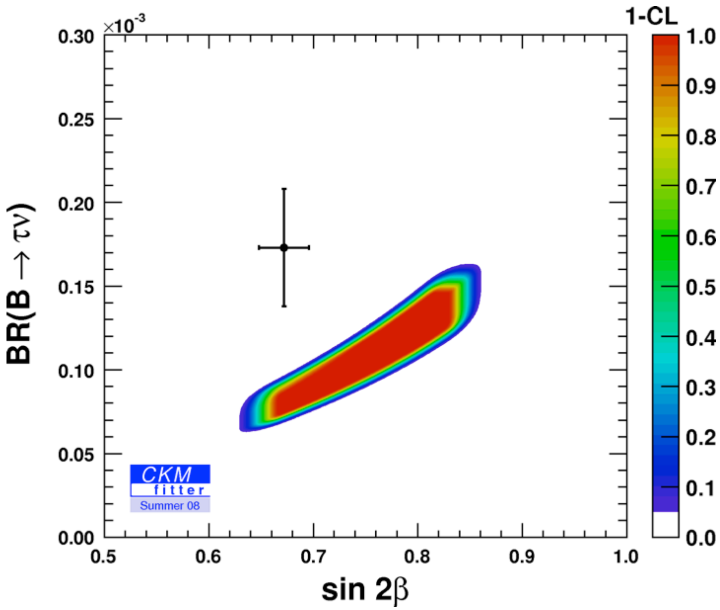
- There is one main tension in the global fit driven by two observables: sin 2β and B(B → τν) [and to a less extent inclusive determination of V_{ub}].

- The combination yields to 2 solutions which do not meet the preferred region from the rest of the observables.

- Of major interest for the LHCb physics case is the fact that this tension can be accommodated by new phases in both the Bd and Bs mixing.

- Tree observables (γ, V_{ub}, and B(B → τν) are fixing the apex of the reference triangle.





1.1 Introduction: NP in Bd mixing

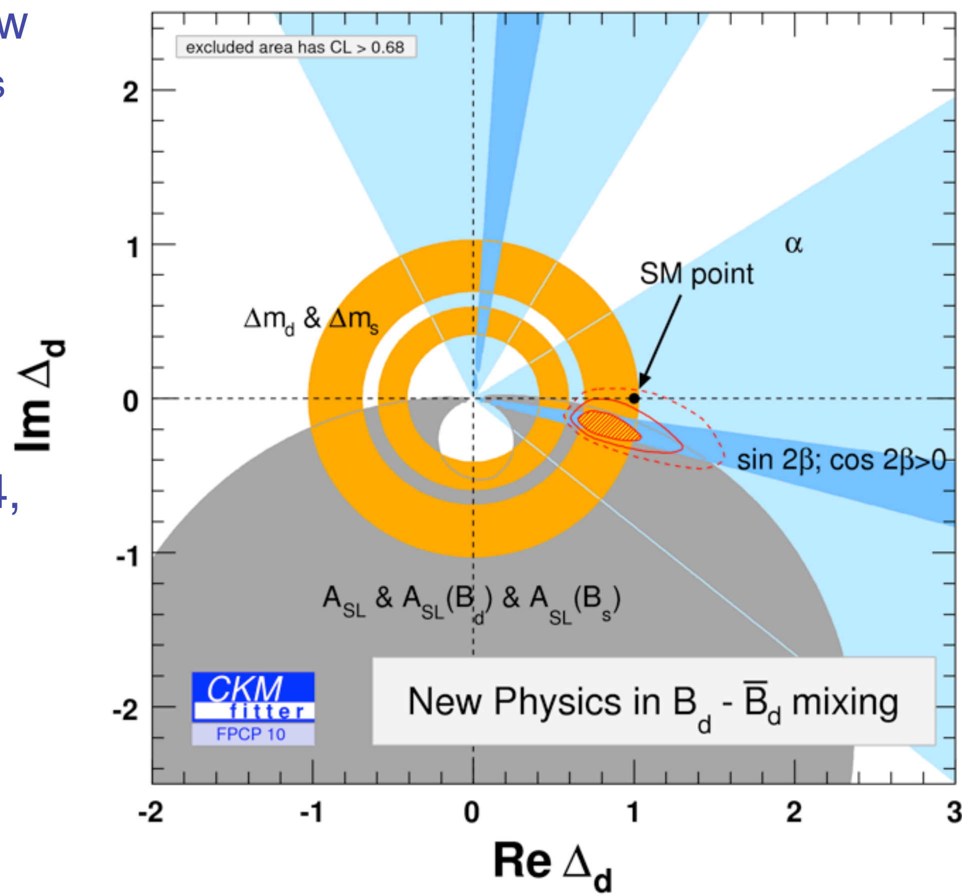
- NP can be accounted for by means of new phase and modulus (NP) both in Bd and Bs system, provided CKM unitarity preserved.

$$\langle B_q \,|\, \mathcal{H}^{\rm SM+NP}_{\Delta B=2} \,|\, \bar{B}_q \rangle \equiv \langle B_q \,|\, \mathcal{H}^{\rm SM}_{\Delta B=2} \,|\, \bar{B}_q \rangle \times (\mathrm{Re}(\Delta_q) + i\,\mathrm{Im}(\Delta_q))$$

$$\mathrm{Re}(\Delta_q) + i\mathrm{Im}(\Delta_q) = r_q^2 e^{i2\theta_q} = 1 + h_q e^{i\sigma_q}$$

- Lenz, Nierste & CKMfitter PRD83:036004, following exploratory work from:

Soares & Wolfenstein, PRD 47, 1021 (1993)
Deshpande, Dutta & Oh, PRL77, 4499 (1996)
Silva & Wolfenstein, PRD 55, 5331 (1997)
Cohen et al., PRL78, 2300 (1997)
Grossman, Nir & Worah, PLB 407, 307 (1997)
Goto et al., PRD 53, 6662 (1996)



- SM hypothesis (2D): 2.7 σ

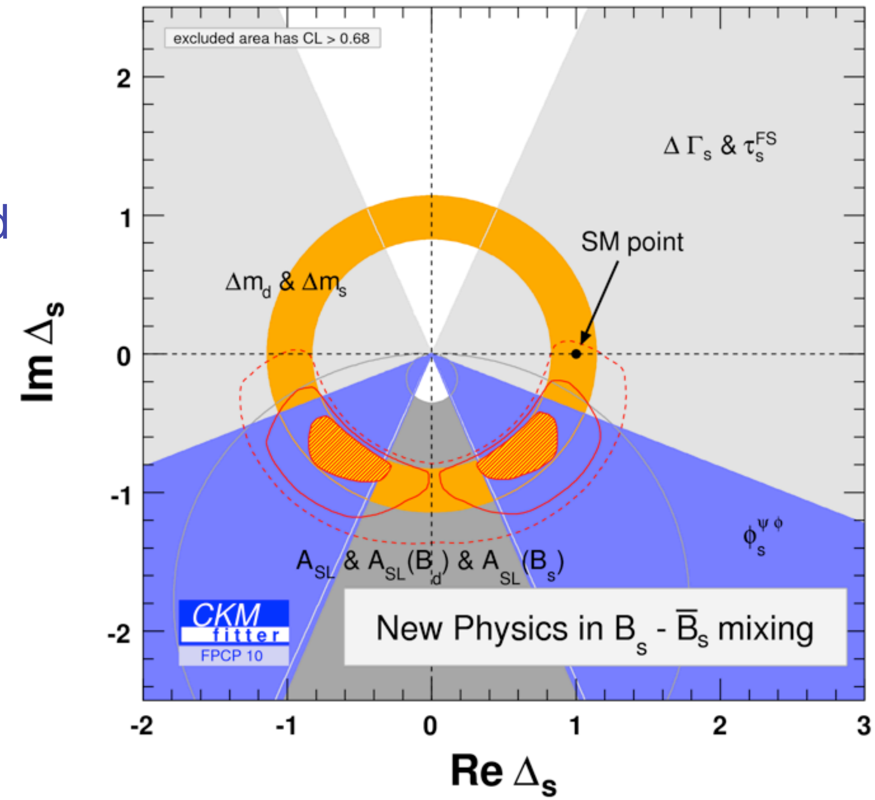
1.1 Introduction: NP in Bs mixing

- The Bs mixing is equally appealing, reenforced by recent measurements from Tevatron on the mixing phase β_s and the semileptonic charge asymmetry A_{SL} (both Bd and Bs).

- The two latter observables are both favouring the negative imaginary part.

- SM hypothesis (2D): 2.7σ

- Sizeable NP is allowed by current experimental in both Bd and Bs mixing.



LHCb can provide a decisive breakthrough by a complete characterization of the Bs mixing.

1. Flavour Physics and CP violation

• LHCb can provide a precise γ measurement which is a missing part of the global consistency check of the SM.

• In addition, γ angle measurement is required to fix the apex of universal unitarity triangle (tree-level driven) in order to quantify NP amplitude and phase in mixing processes. They can still be large in both B_d and B_s systems.

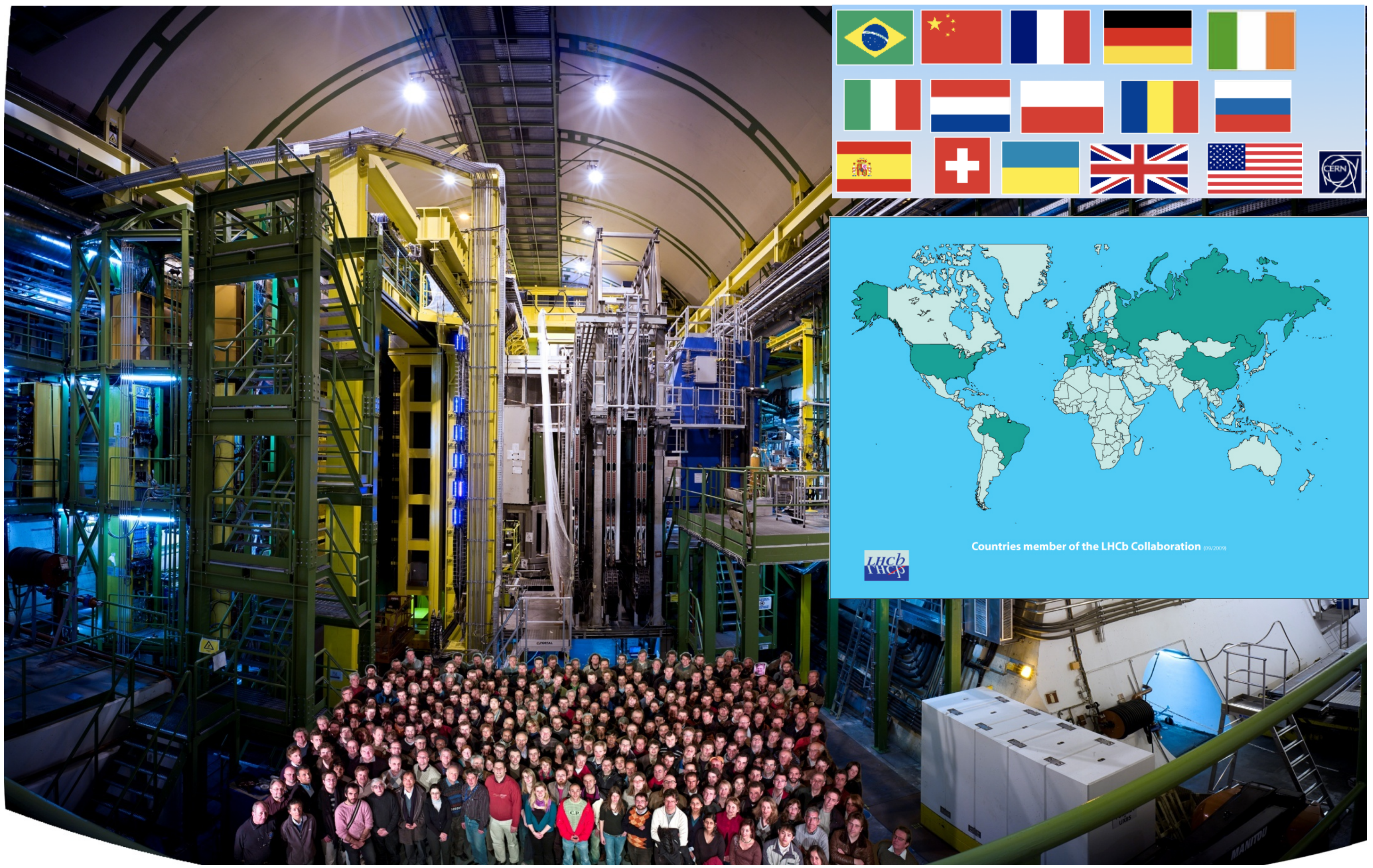
• In the latter scope, LHCb can fully characterize the B_s mixing.

• Last but not least, rare decays in LHCb will provide null test of the SM hypothesis and constraints on NP scenarii and parameters space.

• On the way to this program, many flavour physics and QCD results are / can be obtained.

2.1 LHCb collaboration.

- ~700 members, from 54 institutes in 15 countries



2.2 LHCb experiment: design

• bb-pairs produced with high cross-section at LHC energy (10^{12} bb produced in 2 years at $L=2 \cdot 10^{32}\ cm^{-2}s^{-1}$).

• bb-pair production is strongly correlated and sharply peaked forward-backward: detector with forward geometry (unique $2 < \eta < 5$ coverage).

• all species of particles containing a b-quark are produced (B_u^+, B_u^-, B_d^0, B_d^0, B_c^+, B_c^-, B_s^0, B_s^0, Λ_b , etc.): efficient PID required.

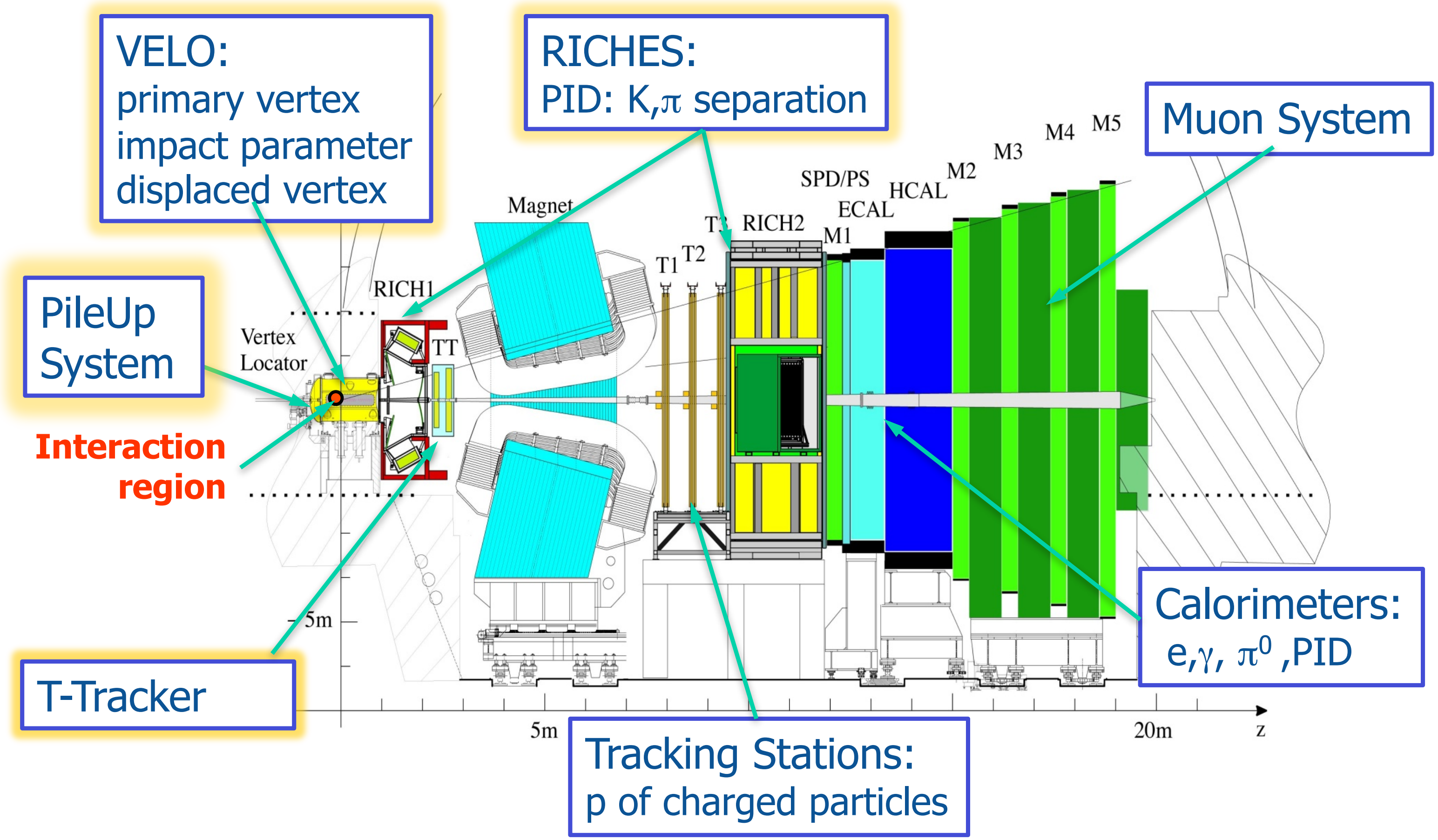
• b-hadron decays have long flight-distance ~1 cm: powerful decay vertex locator (important for b-hadron decays selection and essential for time-dependent CP violation measurements).

• <u>Big challenge to select events of interest</u>: σ_{bb} is less than 1% of total inelastic cross section, b-hadron decays of interest typically have $BR < 10^{-5}$.

• Requires high statistics and high selectivity: robust and flexible trigger.

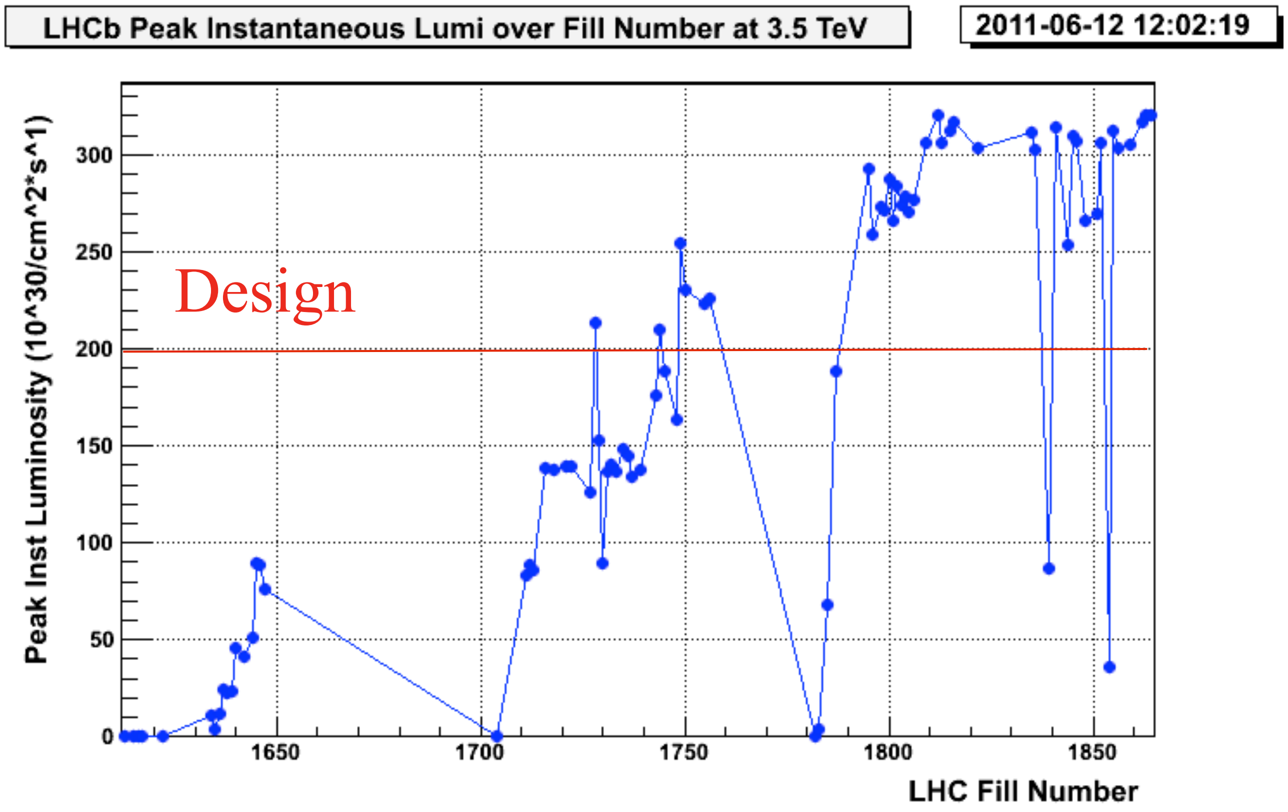
2.2 LHCb experiment: the detector.

- Unique PID Riches, VELO movable up to 7 mm to the interaction point.



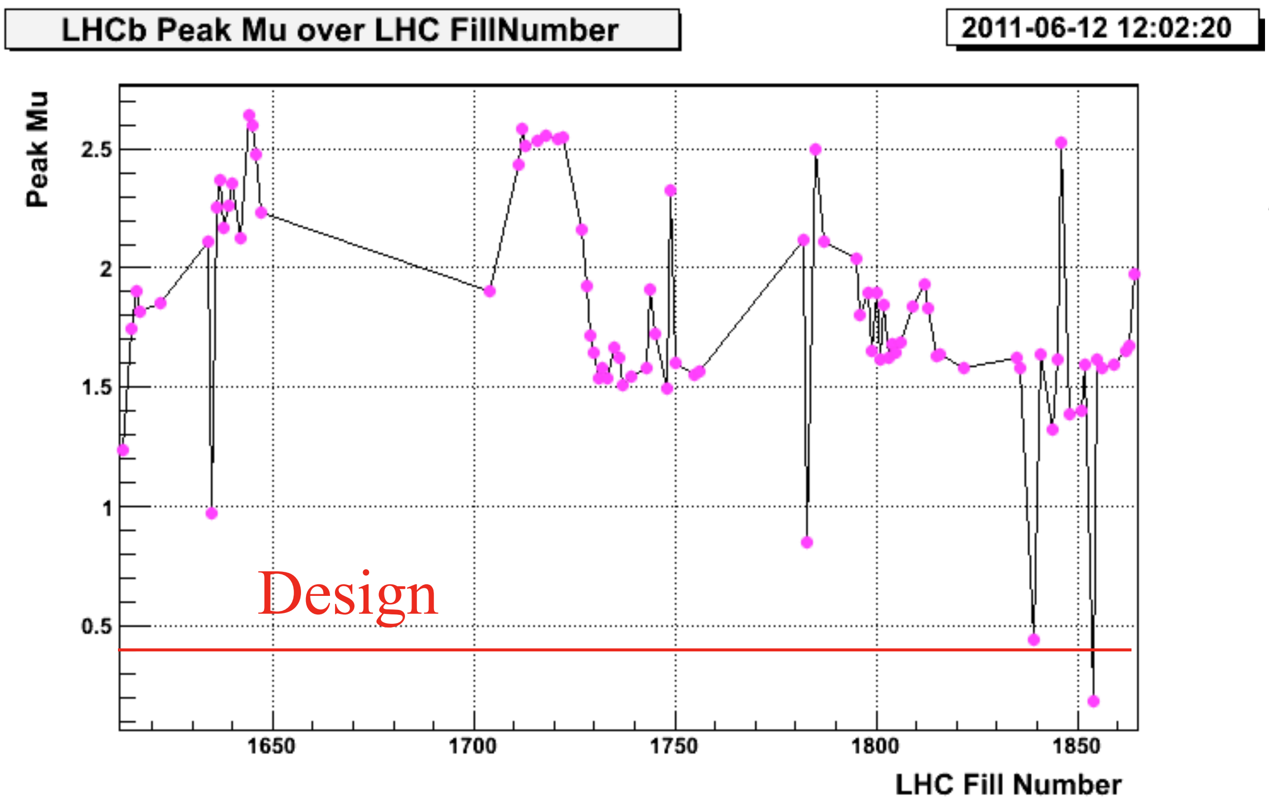
2.3 LHCb experiment: operation in 2011

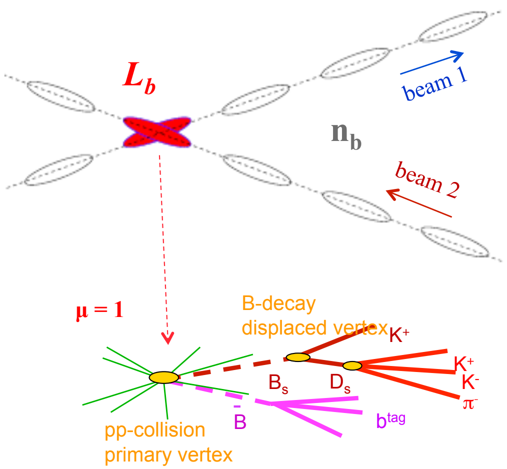
- Outstanding performance of the LHC machine and physicists.
- Luminosity levelling in LHCb to keep acceptable L.
- Peak luminosity in 2011 above the design value of $2{\cdot}10^{32}$ $cm^{-2}s^{-1}$:



2.3 LHCb experiment: operation in 2011

- Number of visible interactions per collision is also above the design value of $2 \cdot 10^{32}$ $cm^{-2}s^{-1}$:

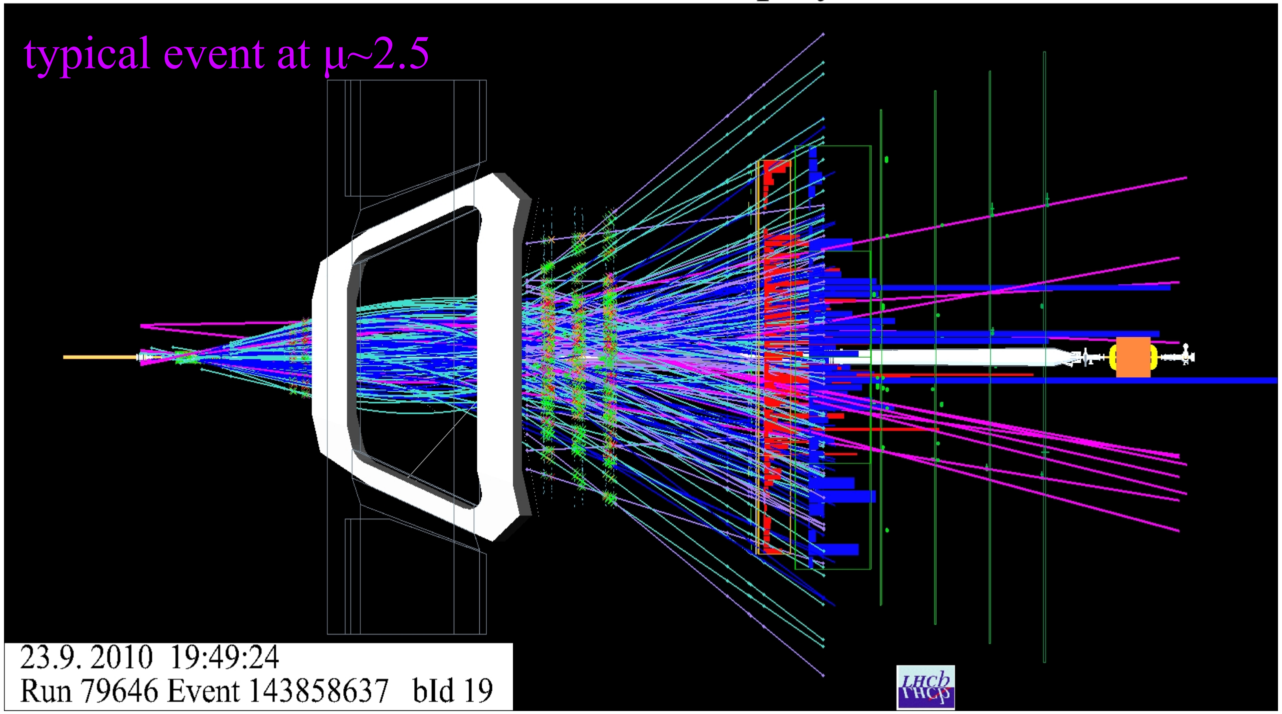




2.3 LHCb experiment: operation in 2011

- Number of visible interactions per collision is also above the design value of $2 \cdot 10^{32}$ cm^{-2}s^{-1}:

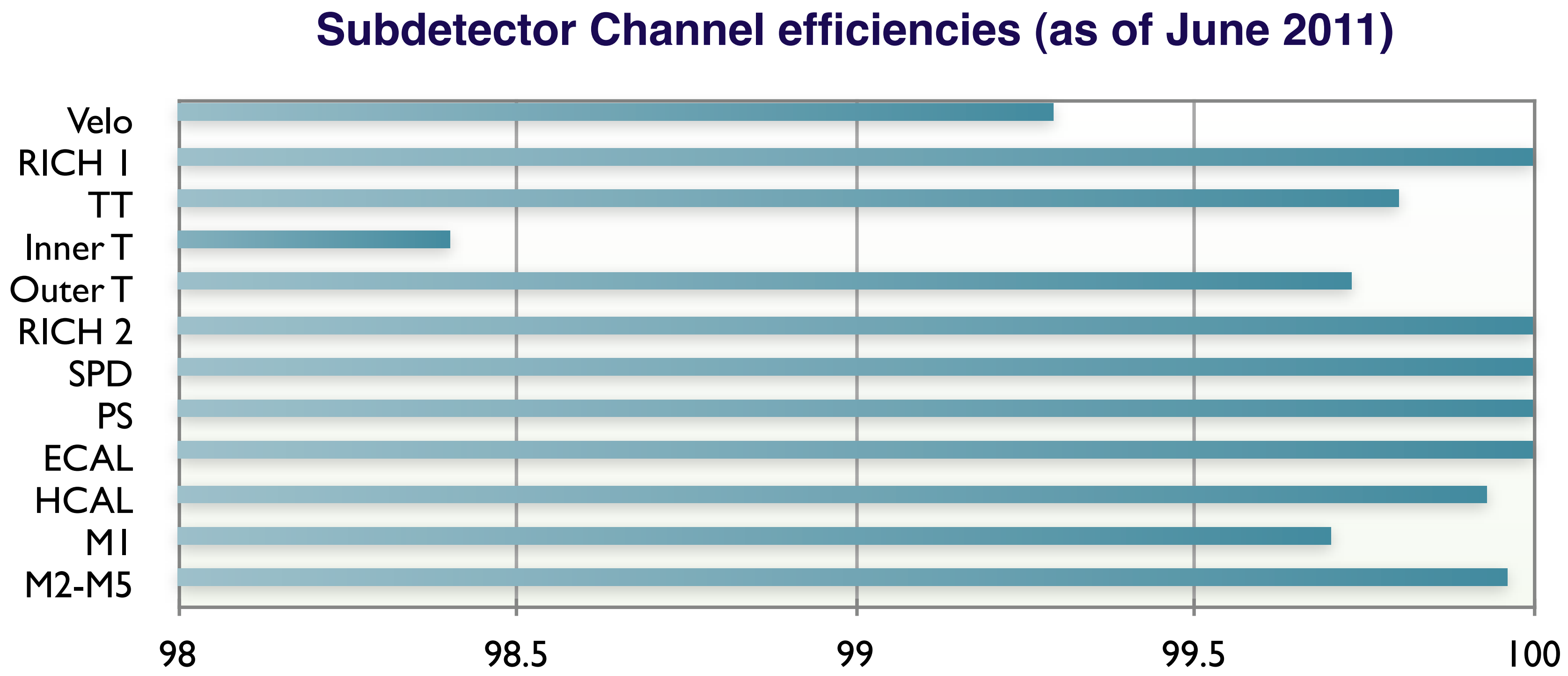
LHCb Event Display



- Very high detector occupancy: a challenge for trigger and DAQ. Met successfully so far.

2.3 LHCb experiment: operation in 2011

- Sub-detectors efficiencies (channels):



- Excellent overall performance.

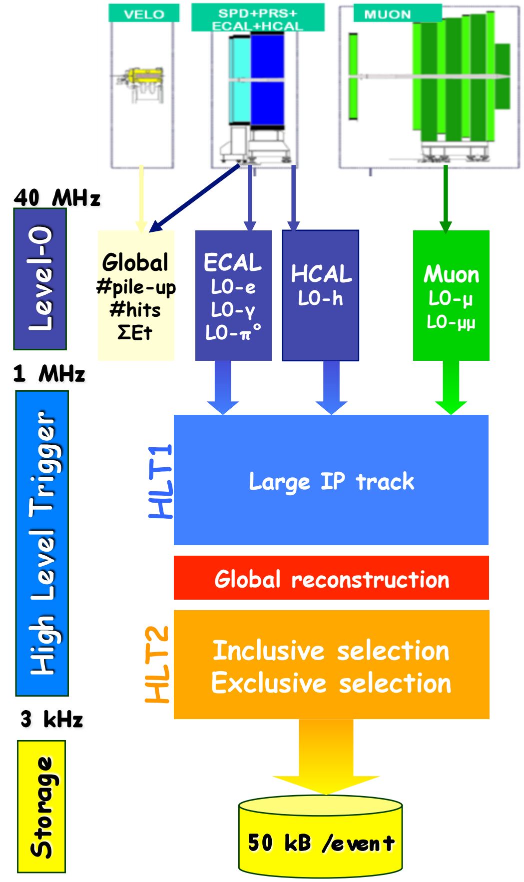
2.4 LHCb experiment: operation in 2011 - trigger

- Customized Hardware Level Trigger (L0)
  - random trigger
  - high-p_t μ, e, γ and hadron candidates

  typical threshold : μ ~ 1 GeV/c - h, e, γ, π^0 ~ 3-4 GeV/c

- Software High Level Trigger (HLT1&HLT2) Farm with O(2000) multi-core processors.
  - HLT1:
    - add info from tracking, Vertex Locator
    - c & b physics: search for tracks with high impact parameter and lifetime cuts.
  - HLT2:
    - global event reconstruction
    - inclusive and exclusive selections

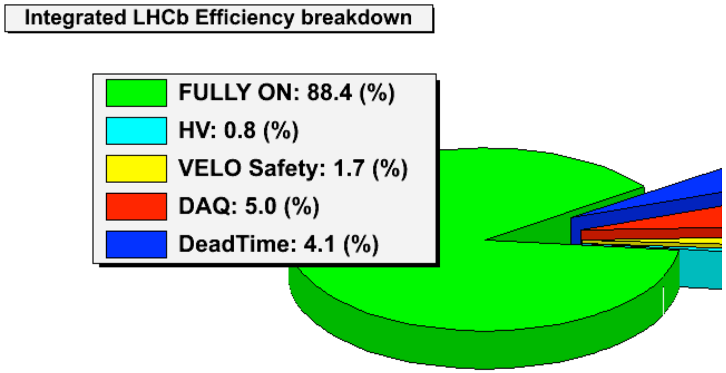
- In order to deal with higher occupancy than foreseen in design, L0 p_t threshold are increased and global event cut imposed. Acceptable efficiencies yet.

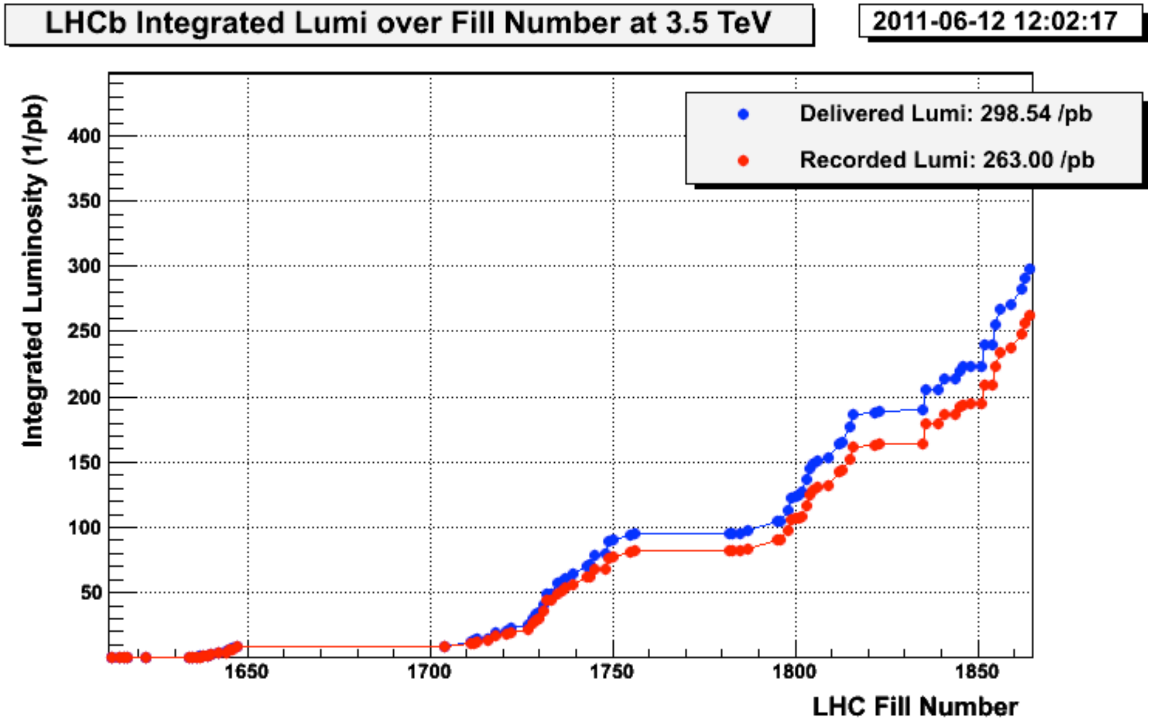


	Muon trigger (J/ψ)	Hadron trigger (D^0)
Data	94.9±0.2%	60±4%
MC	93.3±0.2%	66%

2.3 LHCb experiment: operation in 2011

- Recorded data:



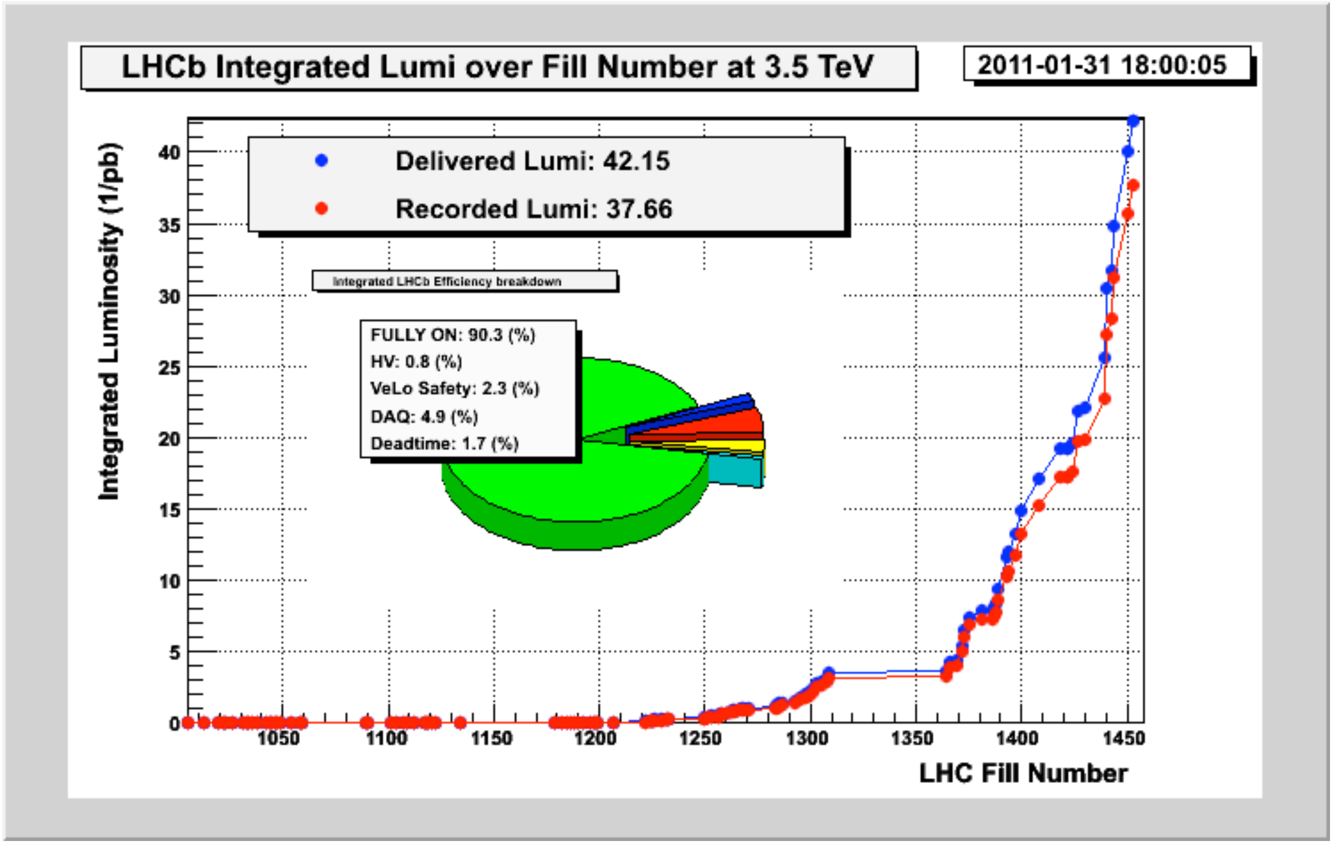


- Very satisfactory overall operation performance. 263 /pb recorded so far.

- Most of the results presented in this talk will rely on 2010, yet.

2.3 LHCb experiment: operation in 2010

- Recorded data:

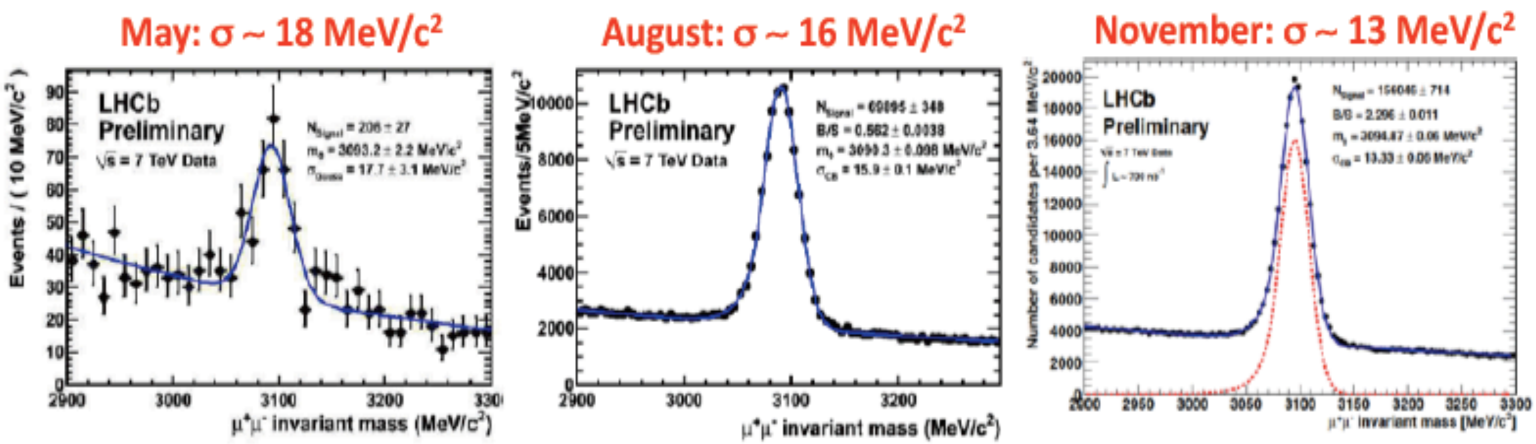


- Satisfactory overall operation perfomance. 37 /pb recorded in 2010.

2.4 LHCb experiment: selected performance

- Following the LHCb physics case, one aims at excellent performance in tracking, vertexing, proper time resolution, particle identification an tagging.

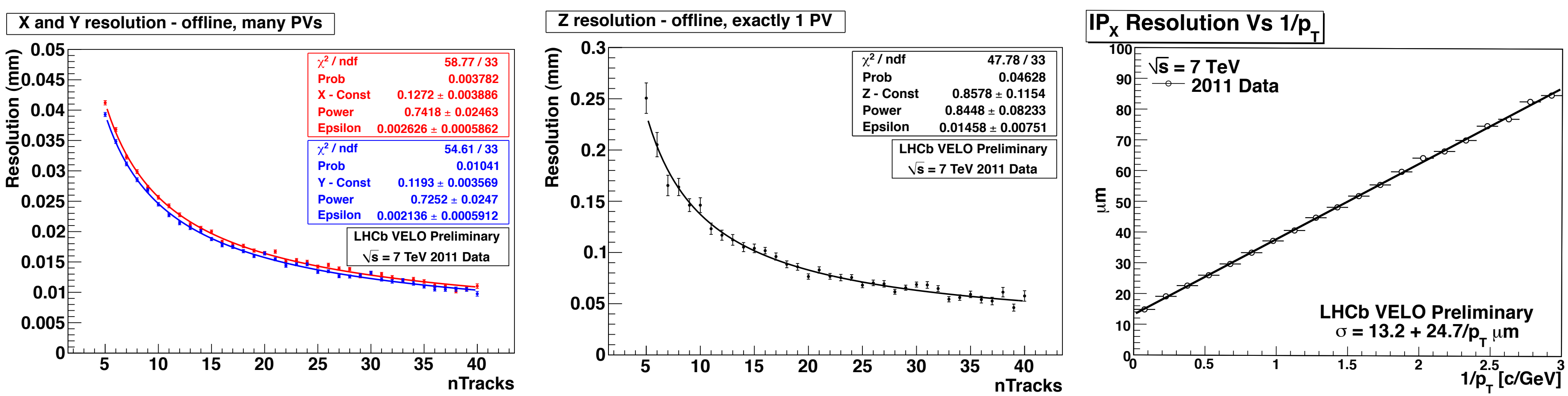
- Let's review these canonical performance as measured on the 2010 data, starting with momentum resolution:



- MC expectation is 12 MeV/c². Main issue there is tracking alignment by mastering the B field map.

2.4 LHCb experiment: selected performance

- Vertexing and impact parameter resolutions:



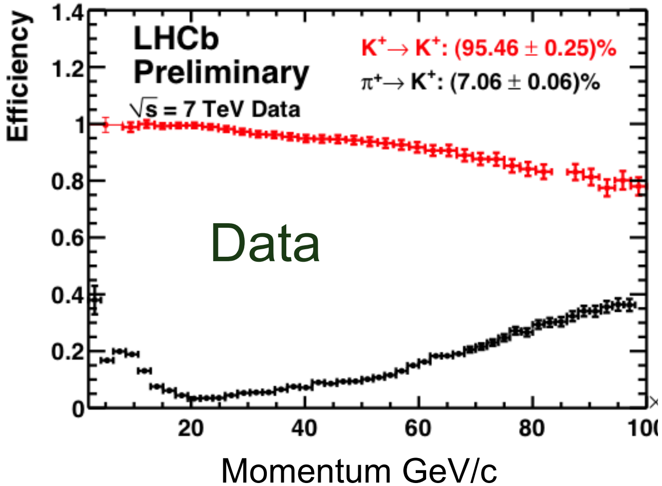
- results in a typical proper time resolution of 50 ps.

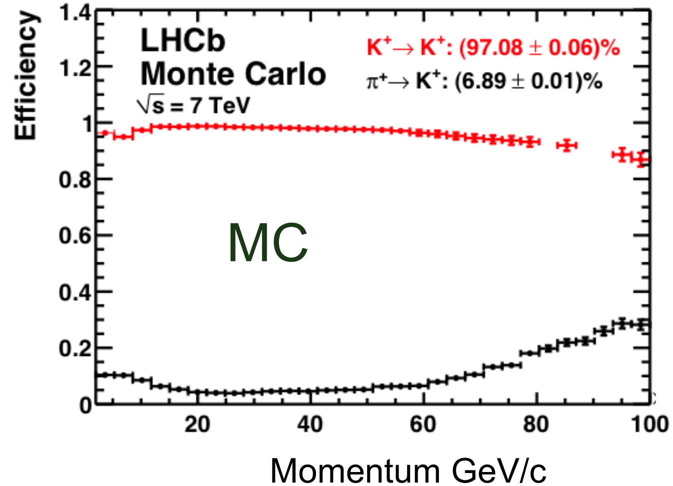
- Overall performance remains satisfactory in presence of many PVs.

- For 25 tracks in the event, typical resotutions in 2011 are $\left\{ \begin{array}{ll} \sigma_x & = 14\ \mu\mathrm{m}, \\ \sigma_y & = 13\ \mu\mathrm{m}, \\ \sigma_z & = 70\ \mu\mathrm{m}. \end{array} \right.$

2.4 LHCb experiment: selected performance

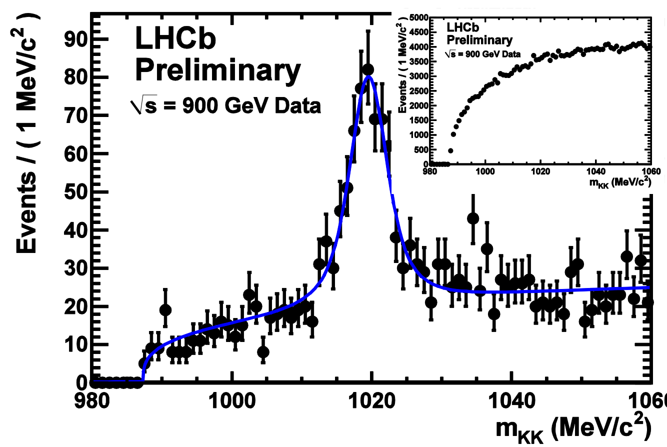
- Particle Identification with RICHes are close to the MC expectations in the full momentum range.





- A good laboratory for PID application is Φ reconstruction →

- Excellent muon identification.



2.4 LHCb experiment: selected performance

LHCb-CONF-2011-003
LHCb-CONF-2011-010

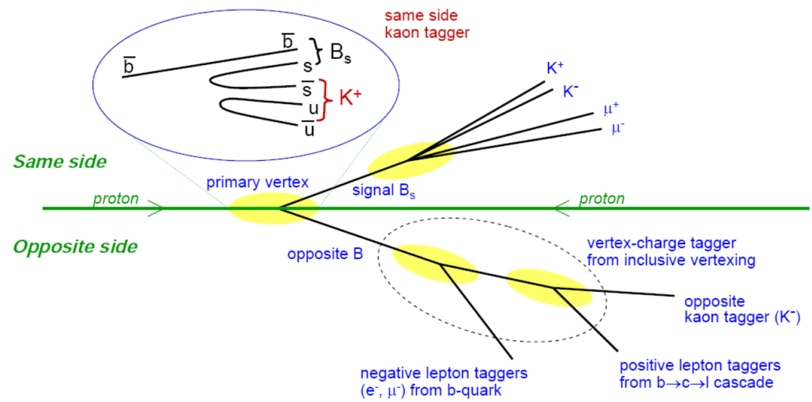
- Flavour tagging performance:

- NN based tagging algorithms calibrated from real data, using self-tagging modes.

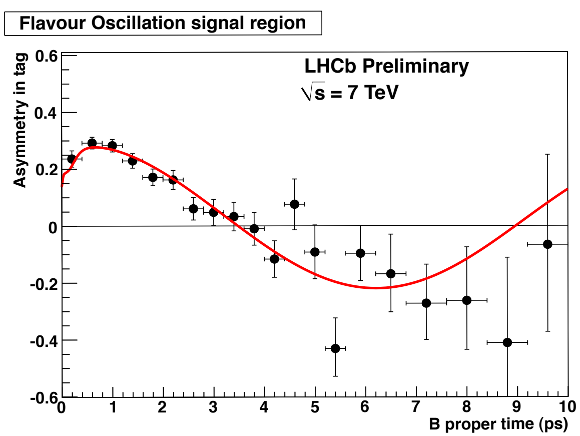
- Accuracy still limited by statistics.

- Tagging power evaluated event-by-event.

- Proof of principle: Bd oscillation frequency with either semileptonic or (Dπ) final states.



OS+SS-π	$\varepsilon_{tag}(\%)$	$\omega(\%)$	$\varepsilon_{eff}(\%)$
$B^0 \to D^{*-}\mu^+\nu_\mu$	28.9 ± 0.2	34.2 ± 0.8	2.87 ± 0.32
$B^+ \to J/\psi K^+$	23.0 ± 0.5	33.9 ± 1.1	2.38 ± 0.33
$B^0 \to J/\psi K^{*0}$	26.1 ± 0.9	33.6 ± 5.1	2.82 ± 0.87



← Semileptonic - (Dπ) with D in (Kππ) ↓

$$\Delta m_d \text{ (LHCb 35/pb)} = 0.499 \pm 0.032 \text{ (stat)} \pm 0.003 \text{ (syst) ps}^{-1}$$

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

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1. Introduction: flavour physics and CP violation.
2. The LHCb detector.
3. Operation and physics performance.
4. Production studies.
5. CP violation measurements.
6. Rare decays.
7. Summary.

4. Production studies

- Will be covered in this talk:
  - W/Z production.
  - bb pairs production cross-section.
  - b-quark hadronization fraction.
  - Onia production (J/ Ψ, Υ, χ_c). Also X(3872).
  - Exclusive measurements.
  - Flavour physics.
  - See V. Coco's talk in parallel session for the details of the analyses.

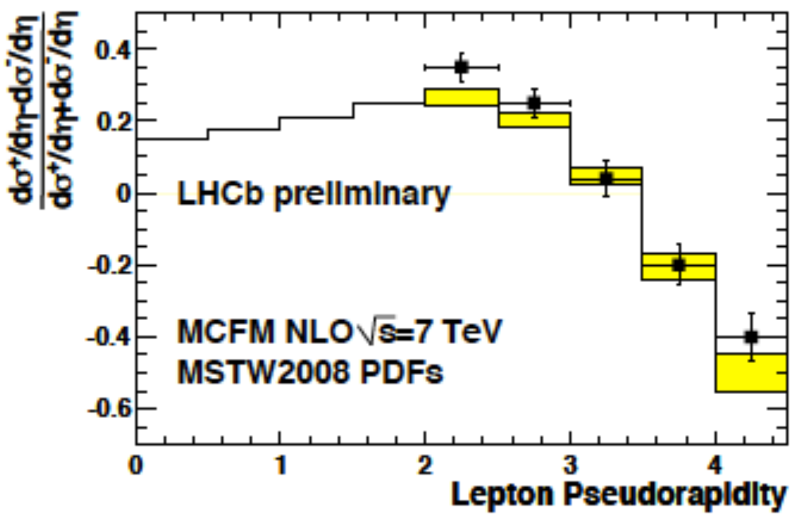
4.1 Production studies: W/Z production.

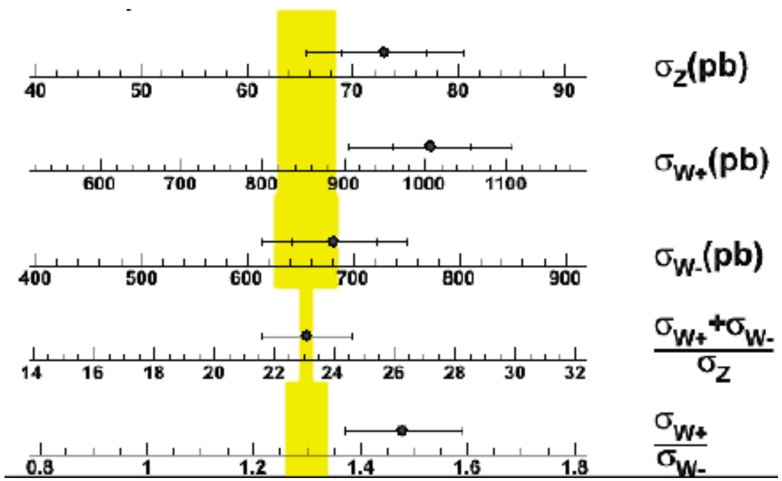
LHCb-CONF-2011-012

- Physics: EW probe of the parton density functions in a unique rapidity range.

- Of particular interest is the charge production asymmetry for W bosons. Its sign is changing in LHCb sensitive region.

- Yields to constraints on the low x quark content of the protons at high q^2.





- Fair agreement with the theoretical expectation. Models are under control.

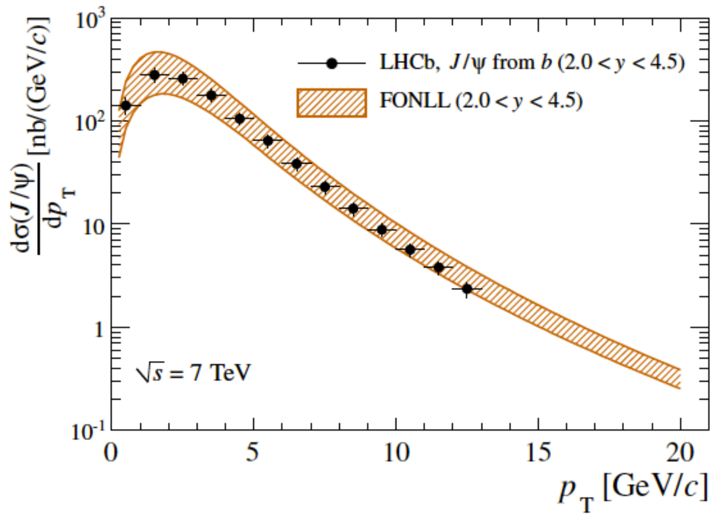
4.2 Production studies: bb & cc cross sections

LHCb-CONF-2011-013
PLB 694 (2010) 209

- Physics: test of models and input to branching ratios estimates.
- Two distinct measurements of the bb cross-section have been performed in LHCb [5.2 pb^{-1}, 12 nb^{-1}, resp.]

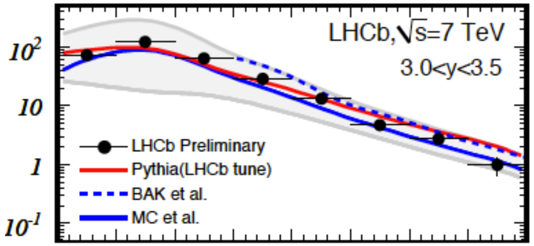
$$\sigma(pp \to b\bar{b}) = 288 \pm 4 \pm 48\ \mu\text{b}\ (b \to J/\Psi)$$

$$\sigma(pp \to b\bar{b}) = 284 \pm 20 \pm 49\ \mu\text{b}\ (b \to D^0 \mu\nu X)$$



- Open charm cross-sections have been also measured with the very first nb:

$$\sigma(pp \to c\bar{c}X) = (6.10 \pm 0.93)\ \text{mb}$$



- Fair agreement with the theoretical expectations. Models under control.

4.3 Production studies: exclusive di-muons

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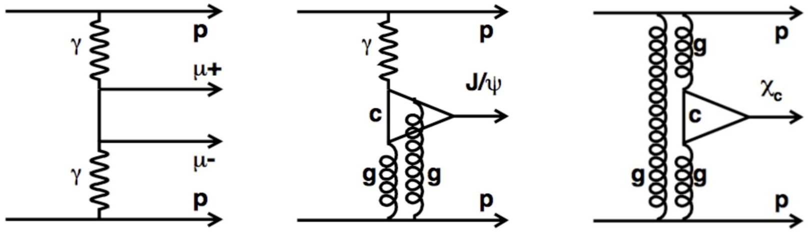
- Dimuon final states in diffractive events.

- Physics: colourless object mediation γ/ Pomeron



From left to right, non-resonant di-muon production (LPAIR), resonant pomeron-photon fusion (STARLIGHT) and resonant pomeron-pomeron fusion (SUPERCHIC).

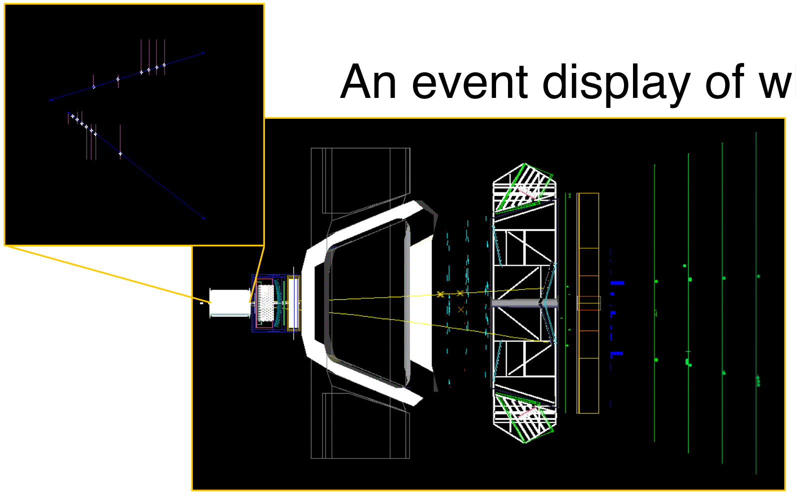
- Yielding only 2 muon tracks with a smaller p_t than when proton dissociation occurs.

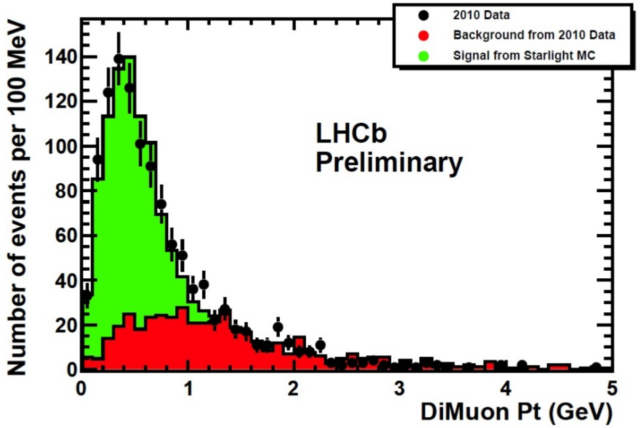
- LHC b is very well-suited for such diffractive studies:
  - High rapidities unique to LHCb ($2.5 < \eta < 5.0$)
  - Ability to trigger on low momentum μ: - $p > 3$ GeV & $p_t > 0.4$ GeV.

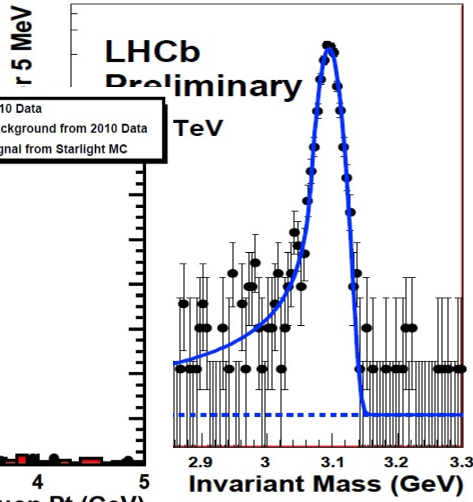
- Events are specially triggered at L0 by 1 or 2 muons and a small activity in Scintillating Plane Detector. No backward tracks offline.

4.3 Production studies: exclusive di-muons

- An event display of what we're looking for:

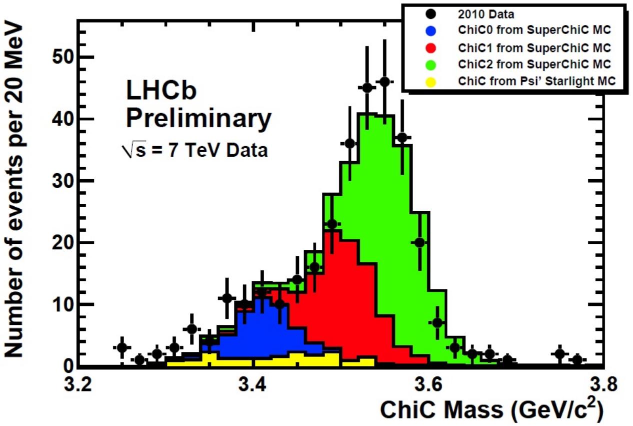






- Cross-sections in fair agreement with theoretical expectations. Exclusive Φ and Y on their way.

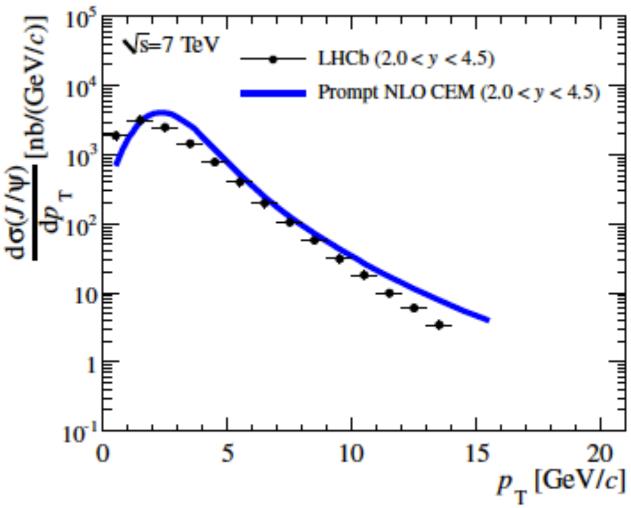
- Since non resonant dimuon production is well controlled, could be used for a precision luminosity measurement.

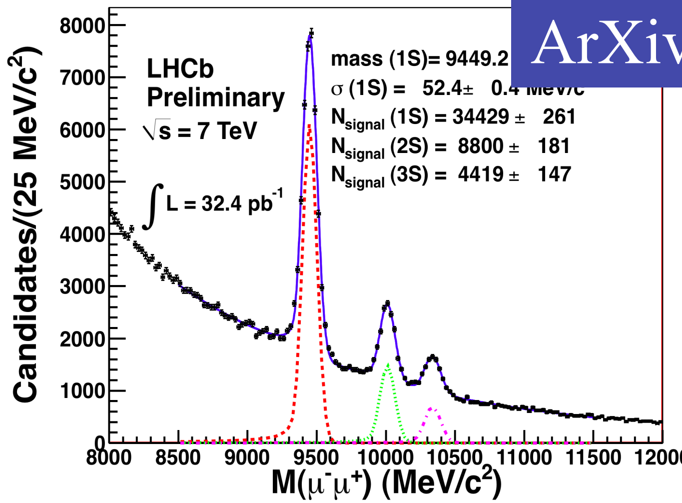


4.4 Production studies: Onia, X(3872) ...

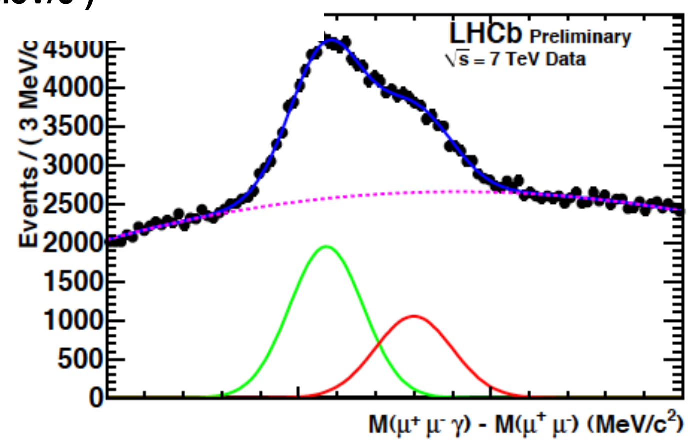
LHCb-CONF-2011-009
LHCb-CONF-2011-016
LHCb-CONF-2011-017
ArXiv:1103.0423

- LHCb spectroscopic capacities and test of QCD production model thanks to prompt J/ Ψ, Υ, X_c





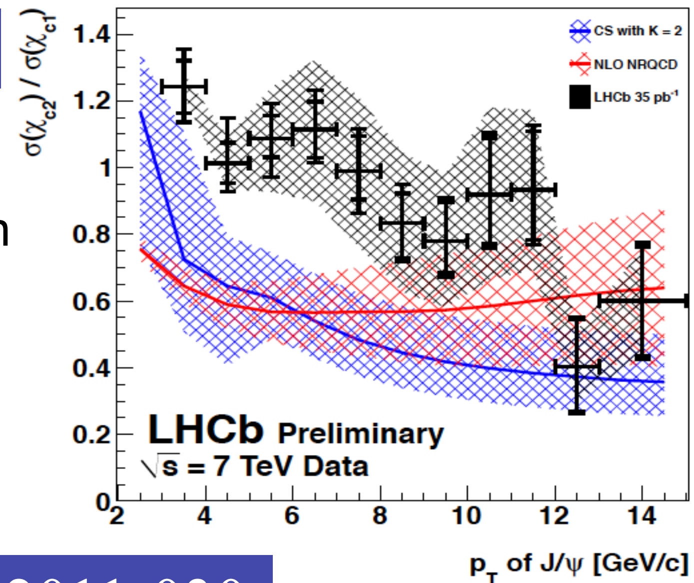
- Search for P-wave X_c → J/ Ψγ
  LHCb capability to reconstruct low p_t photons in high multiplicity events. X_{c1} and X_{c2} are resolved.



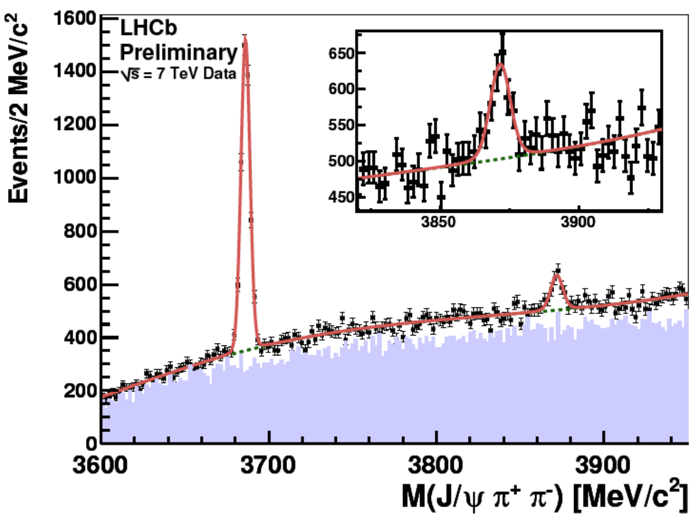
4.4 Production studies: Onia, X(3872) ...

- $\chi_c \rightarrow J/\Psi\gamma$ (cont'd) **LHCb-CONF-2011-020**

  Measure the relative production of χ_{c2} to χ_{c1} in order to test colour singlet/colour octet production models. Indications of discrepancies.



- X(3872): disc. by Belle. Its nature is unclear.



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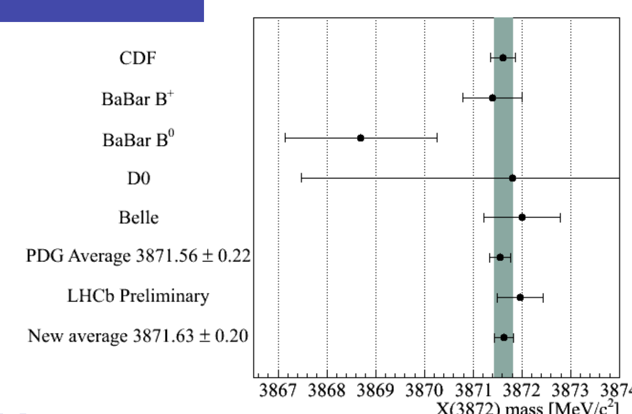


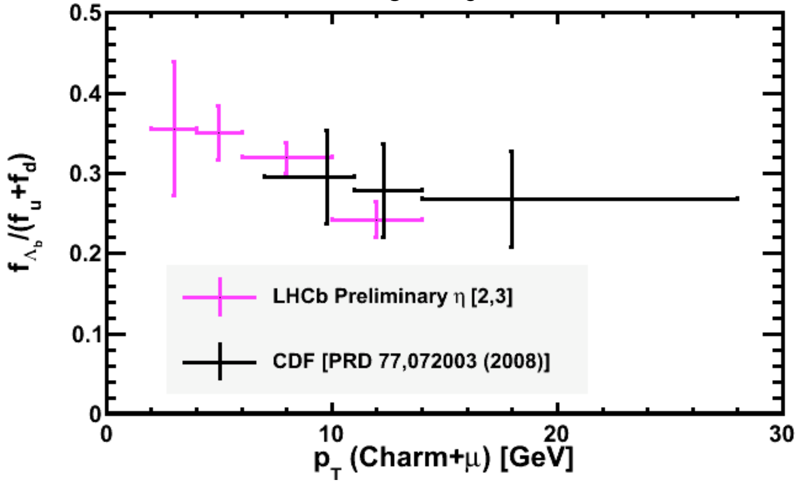
- Momentum calibration using J/Ψ. Cross-check Υ, D^0, K_s

4.5 Production studies: hadronization fractions

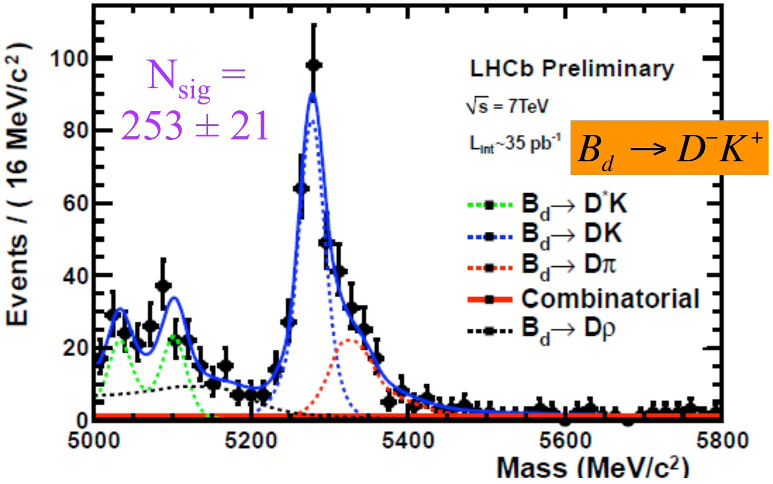
LHCb-CONF-2011-013

- b quark hadronization fractions are important for any relative branching ratios mesurement relating two species (*e.g.* $B_s \to \mu\mu$)
- Measured in semileptonic decay modes and fully hadronic decay chain.

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



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



- Good agreement with LEP and Tevatron measurements as far as fs/fd is concerned.
- Discrepant with LEP for Λb.

$$f_s/(f_u+f_d) = 0.136 \pm 0.004^{+0.012}_{-0.011}\ (\mathrm{semi-lept}),$$
$$f_s/f_d = 0.245 \pm 0.017 \pm 0.018 \pm 0.018\ (\mathrm{hadronic}),$$
$$f_{\Lambda_b}/(f_u+f_d) = 0.401 \pm 0.019 \pm 0.106 - (12 \pm 2.5 \pm 1.2)10^{-3} p_t/\mathrm{GeV}.$$

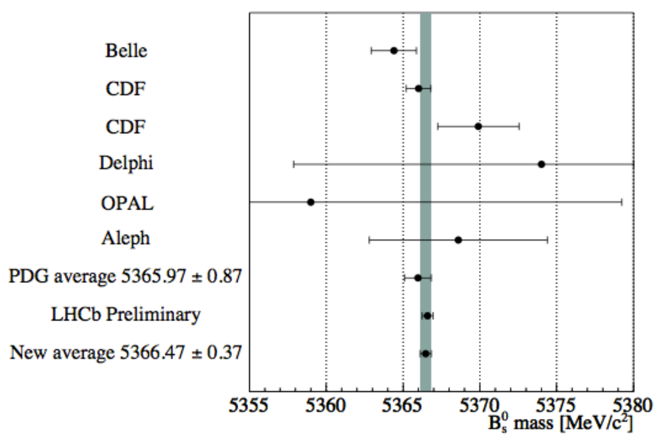
4.6 Flavour Physics: b-hadron masses

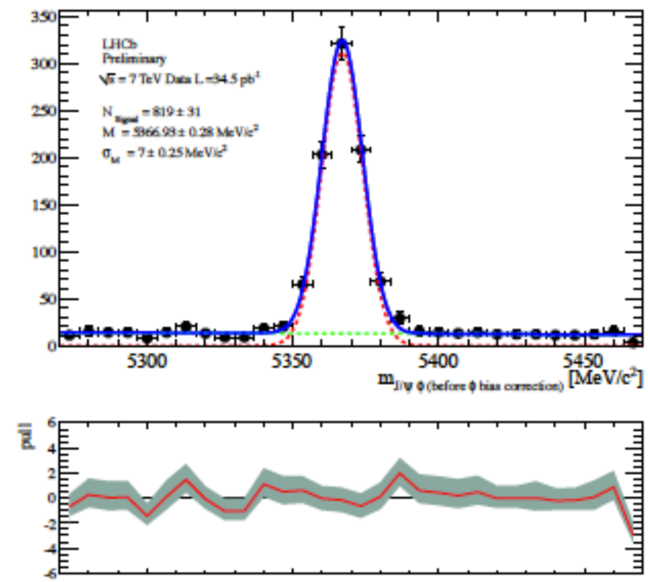
LHCb-CONF-2011-027

- Thanks to its excellent momentum resolution and mastering of tracking alignment, LHCb produces world class measurements of masses:

$B^+ \to J/\psi K$	$5279.27 \pm 0.11\,(\text{stat}) \pm 0.19\,(\text{syst})\ \text{MeV}/c^2$
$B^0 \to J/\psi K^{*0}$	$5279.54 \pm 0.15\,(\text{stat}) \pm 0.15\,(\text{syst})\ \text{MeV}/c^2$
$B^0 \to J/\psi K^0_S$	$5279.61 \pm 0.29\,(\text{stat}) \pm 0.20\,(\text{syst})\ \text{MeV}/c^2$
$B^0_s \to J/\psi \phi$	$5366.60 \pm 0.28\,(\text{stat}) \pm 0.21\,(\text{syst})\ \text{MeV}/c^2$
$\Lambda_b \to J/\psi \Lambda$	$5619.48 \pm 0.70\,(\text{stat}) \pm 0.19\,(\text{syst})\ \text{MeV}/c^2$
$B^+_c \to J/\psi \pi^+$	$6268.0 \pm 4.1\,(\text{stat}) \pm 0.5\,(\text{syst})\ \text{MeV}/c^2$

- As an illustration, Bs meson mass receives an uncertainty better by a factor 3 from previous WA.

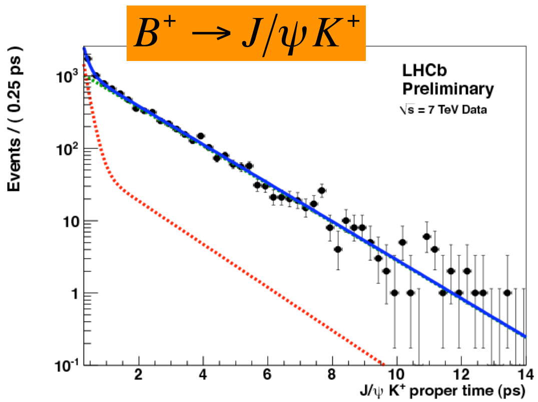


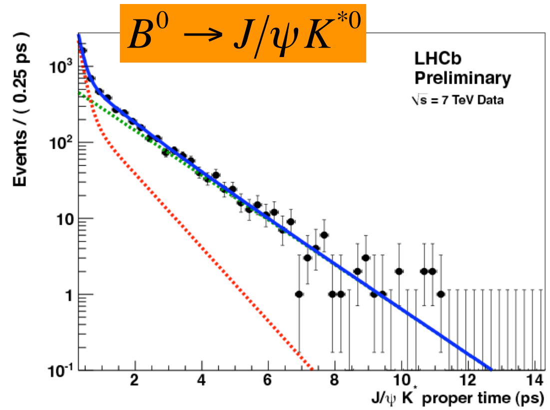


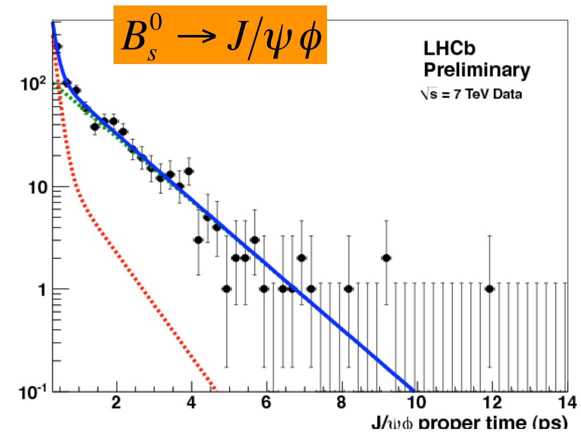
4.7 Flavour Physics: b-hadron lifetimes

LHCb-CONF-2011-001

- Thanks to its excellent momentum resolution and proper time measurement, measurement of lifetimes of b-hadrons is a necessary path towards time-dependent CP asymmetries measurements

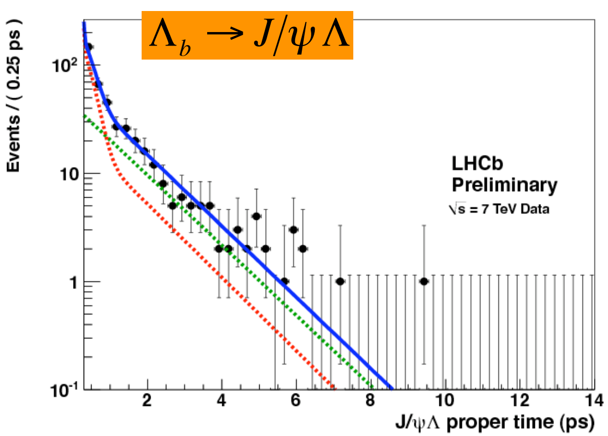






Channel	LHCb lifetime, stat and sys (ps)	PDG (ps)
$B^+ \to J/\psi K^+$	1.689 ± 0.022 ± 0.047	1.638 ± 0.011
$B^0 \to J/\psi K^{*0}$ $B^0 \to J/\psi K_s$	1.512 ± 0.032 ± 0.042 1.558 ± 0.056 ± 0.055	1.525 ± 0.009
$B_s \to J/\psi \phi$	1.447 ± 0.064 ± 0.056	1.477 ± 0.046
$\Lambda_b \to J/\psi \Lambda$	1.353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

Using lifetime unbiased trigger and t > 0.3 ps

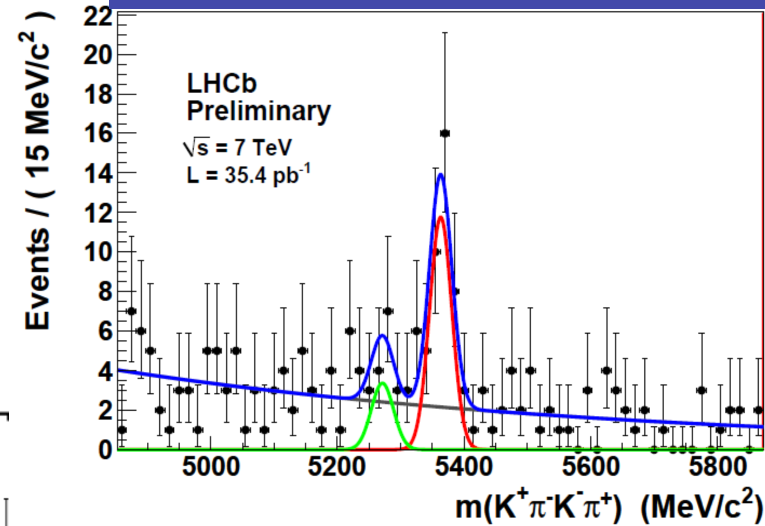


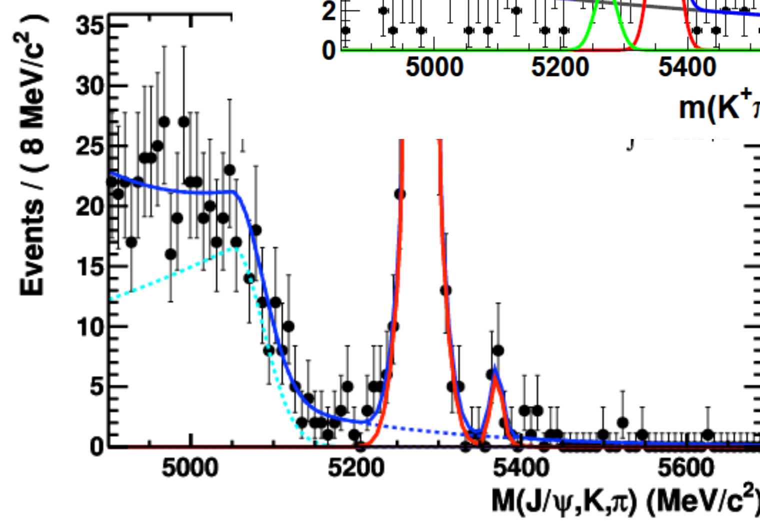
- Systematic uncertainties are conservative.

4.8 Flavour Physics: new Bs decay modes.

LHCb-CONF-2011-008
LHCb-CONF-2011-019
PLB 698 (2011)-14/115

- Observations of:
  - A new CP eigenstate for β_s: $B_s \rightarrow \Psi f^0(980)$.
  - Charmless penguin analogous to $B_s \rightarrow \Phi\Phi$: $B_s \rightarrow K^*K^*$.
  - A background for γ angle with tree: $B_s \rightarrow D^0K^*$.
  - Studying semi-leptonic spectra: $B_s \rightarrow D_{s2}^* X \mu \nu$.
  - A new: $B_s \rightarrow J/\Psi K^{*0}$.





Outline of the presentation

1. Introduction: flavour physics and CP violation.

2. The LHCb detector.

3. Operation and physics performance.

4. Production studies.

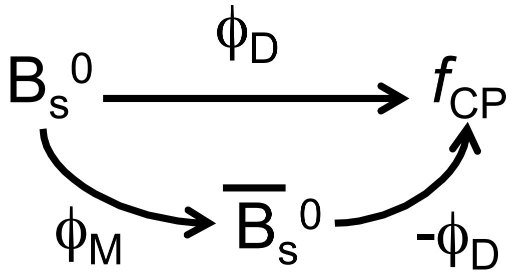
5. CPV measurements. [Details of the analyses will be given in J. Wishahi's talk]

6. Rare decays.

7. Summary.

5.1 CP violation in Bs mixing decays

- Study the CP violation in interference between decay and mixing in B_s decays in $B_s^0 \to J/\psi\ (\mu^+\mu^-)\ \phi\ (K^+K^-)$ decays: CP violating phase $\phi_S = \phi_M - 2\phi_D$



- In the Standard Model, ϕ_S is well determined: $\phi_S = -2\beta_S = -0.0363 \pm 0.0017$ rad, up to penguin diagram phase contributions (10^{-4}–10^{-3}).

- The mixing phase, $\phi_M \approx 0$ in Standard Model can be modified by New Physics and enhance the measured ϕ_S.

- Since the decay is P → VV, the final state is superposition of states with different CP value: the measurement requires a tagged, time-dependent angular analysis.

5.1 CP violation in Bs mixing - Tagging

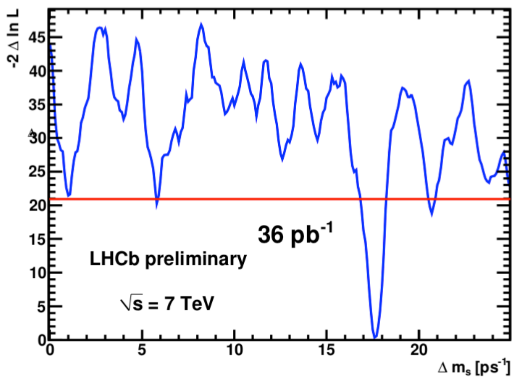
LHCb-CONF-2011-005

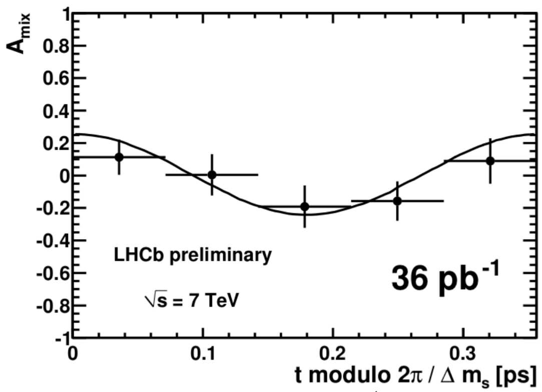
- We discussed tagging performance in the part 3.

- Flavour of the Bs meson at production is tagged by opposite side algorithms (sign of μ, e, K and charge of tracks from secondary vertex). The same side algorithm (sign of K) not yet used.

- Performance: $\varepsilon_{tag} = (17.6\pm1.4)\%$, $\omega = (32\pm2)\%$, $\varepsilon_{tag}(1-2\omega)^2 = (2.2\pm0.5)\%$

- Δm_s measured using $B_s^0 \to D_s^- \pi^+$ and $B_s^0 \to D_s^- \pi^+\pi^-\pi^+$ (1300 events) [Proof of principle and input to the analysis].





$$\Delta m_s \text{ (LHCb 35/pb)} = 17.63 \pm 0.11 \text{ (stat)} \pm 0.04 \text{ (syst) ps}^{-1}$$

$$\Delta m_s \text{ (CDF 2.8/fb)} = 17.77 \pm 0.10 \text{ (stat)} \pm 0.07 \text{ (syst) ps}^{-1}$$

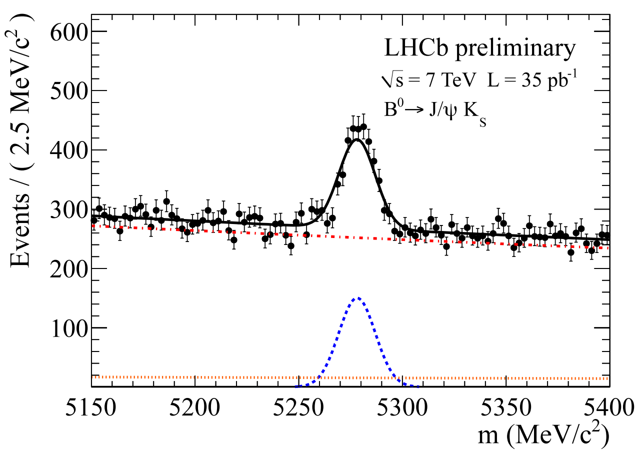
5.1 CP violation in Bs decays - Time dependence

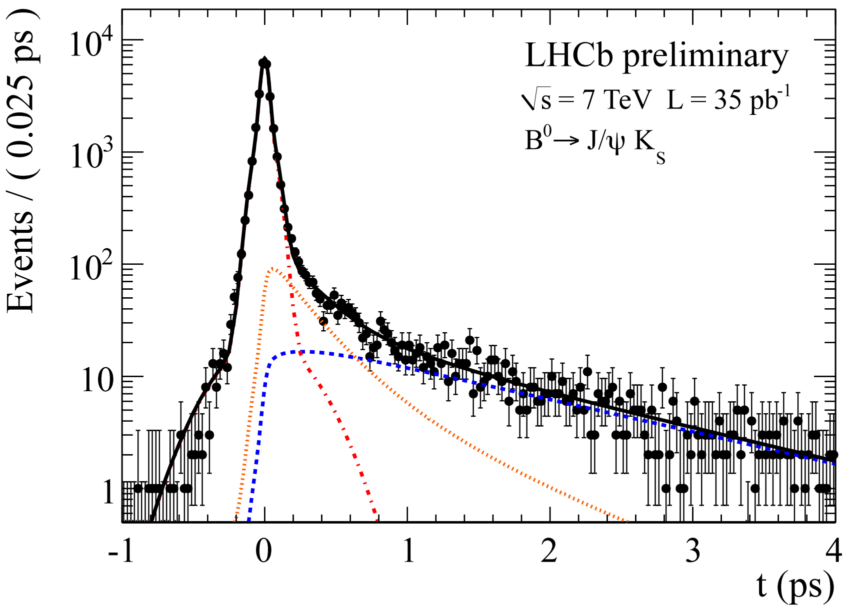
LHCb-CONF-2011-004

- sin2β measurement as a proof of principle for time-dependent measurement at LCHb.

- Using 1330 events reconstructed in $B^0 \rightarrow J/\psi\ K_S^0$, recorded with lifetime unbiased and biased triggers and a tagging with opposite and same sign: $\varepsilon(1-2\omega)^2 \approx 2.8\%$

- Proper time resolution: ≈50 fs



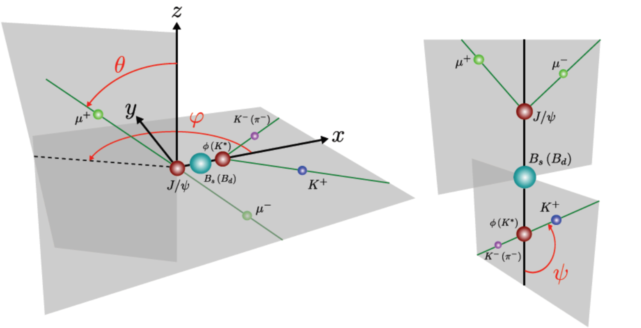


- Obviously far from the competition with B factories *now*, but validate time dependent measurements in LHCb.

5.1 CP violation in Bs decays - Angular analysis

LHCb-CONF-2011-002

- Proof of principle with $B^0 \to J/\psi\ K^{*0}$ polarization amplitudes measurements

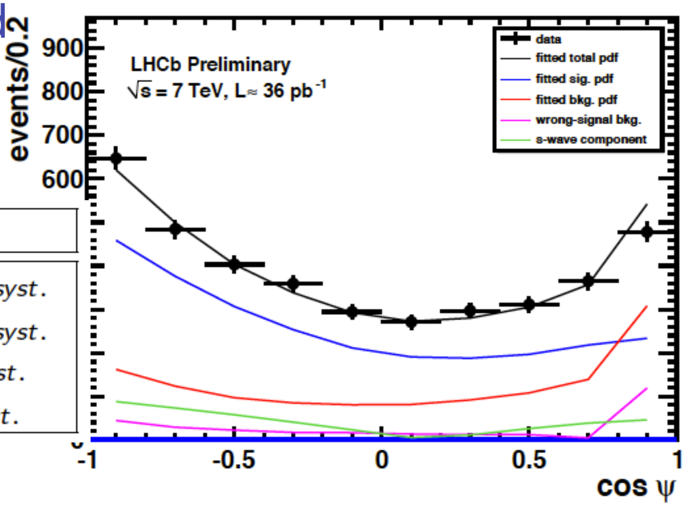


- It requires a simultaneous fit to m, t, ϕ, ψ, θ.

- Corrective factors (~5%) for non flat acceptance as a function of the decay angles taken from full Monte Carlo.

- Results, obtained with 2600 signal events, are found in good agreement with BaBar measurements.

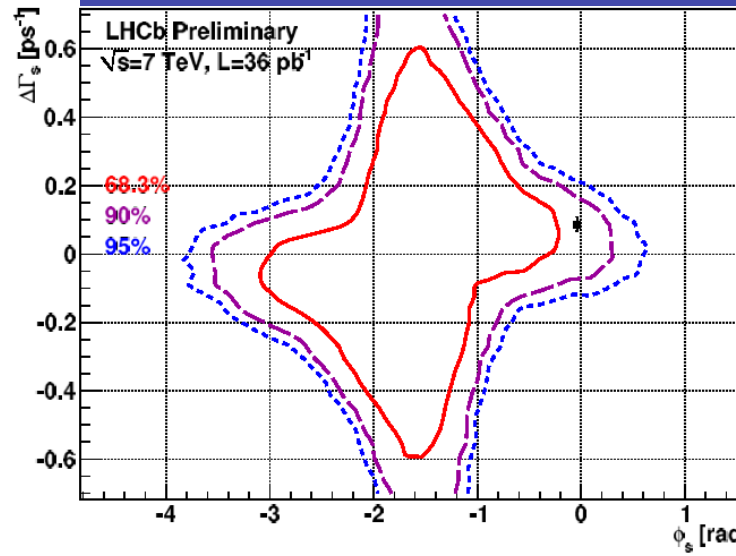
Parameter	LHCb prelim.	BaBar PRD 76, 031002
$\lvert A_{\parallel}(0)\rvert^2$	$0.252 \pm 0.020_{stat.} \pm 0.016_{syst.}$	$0.211 \pm 0.010_{stat.} \pm 0.006_{syst.}$
$\lvert A_{\perp}(0)\rvert^2$	$0.178 \pm 0.022_{stat.} \pm 0.017_{syst.}$	$0.233 \pm 0.010_{stat.} \pm 0.005_{syst.}$
$\delta_{\parallel}$	$-2.87 \pm 0.11_{stat.} \pm 0.10_{syst.}$	$-2.93 \pm 0.08_{stat.} \pm 0.04_{syst.}$
$\delta_{\perp}$	$3.02 \pm 0.10_{stat.} \pm 0.07_{syst.}$	$2.91 \pm 0.05_{stat.} \pm 0.03_{syst.}$

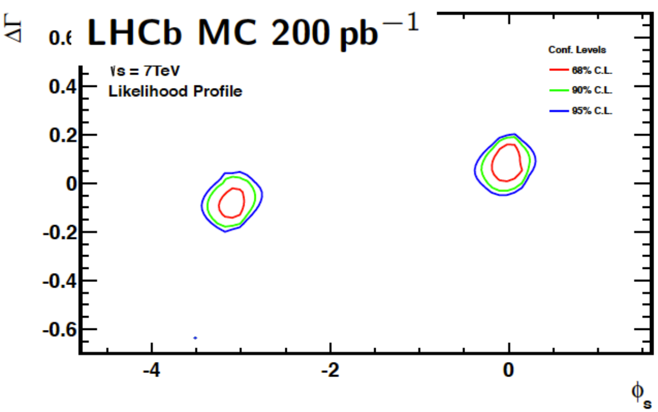


5.1 CP violation in Bs decays - Results.

LHCb-CONF-2011-006

- 757 ± 28 signal events retained.
- FC Confidence Level contours in ($\phi_s - \Delta\Gamma_s$) space plane. Statistical errors only.
- Standard Model p-value: 22%



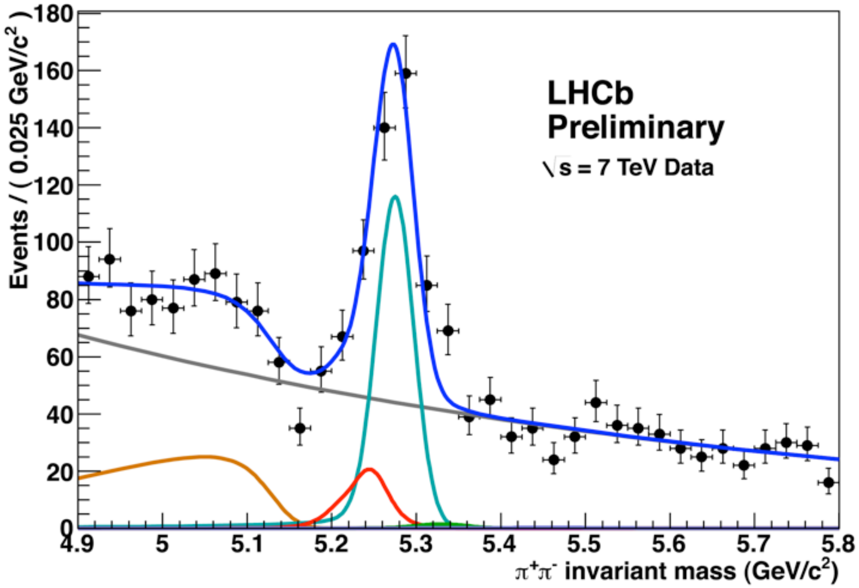


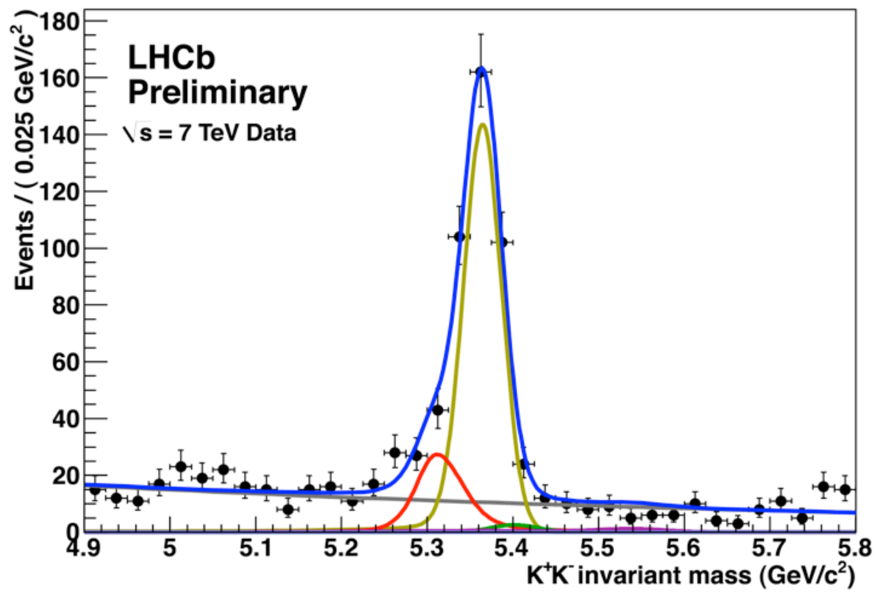
- Prospects with 1 fb^{-1} : precision of 0.13 rad on ϕ_s.
- Improvements expected in 2011 by introducing the same side tagging.
- LHCb will shed an indirect light on the CKM global fit tension in 2011.

5.2 γ angle with loops

LHCb-CONF-2011-012

- Assuming U-spin symmetry and Bd mixing phase β, the joint study of time-dependent CP asymmetry in Bd → ππ and Bs → KK decay modes gives access to of γ.





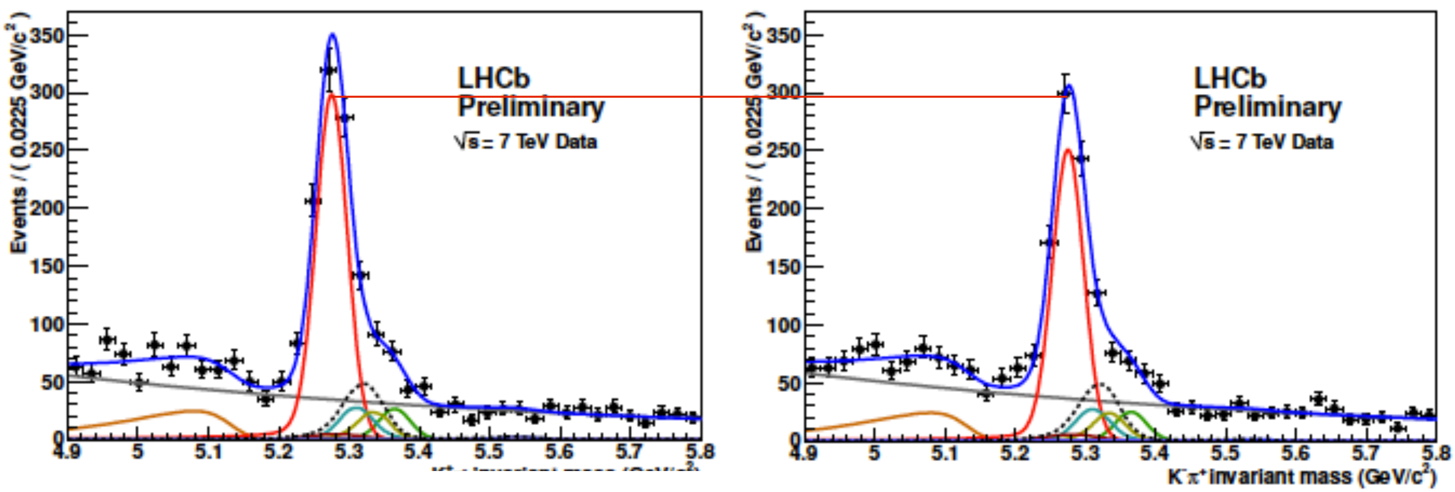
- Lifetime of the decay mostly Bs → KK (mostly short-lived Bs component) has been measured. $\tau(B_s \to K^+K^-) = 1.440 \pm 0.096 \pm 0.010\ \mathrm{ps}^{-1}$.

LHCb-CONF-2011-018

5.3 Direct CP violation in Bs → πK.

LHCb-CONF-2011-012

- The direct CP asymmetry well-established in $B_d \to K\pi$. Look at $B_s \to \pi K$.
- Production asymmetry controlled from $B^+ \to J/\psi\, K^+$ (A_P=-0.024±0.016)
- Detector asymmetry controlled with magnet up/down data with D* and $D^0 \to K\pi$ (A_D=-0.004±0.004)



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

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

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

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

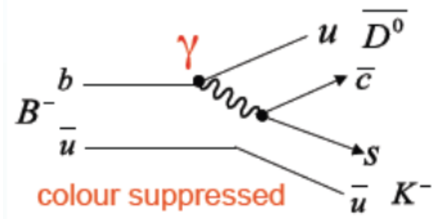
5.4 Prospects for γ angle with trees.

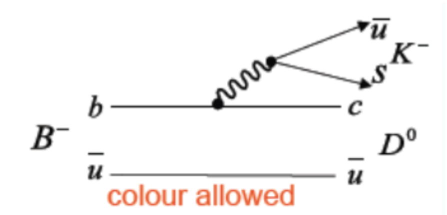
LHCb-CONF-2011-012

- γ is the less well-known Unitarity Triangle angle.
  Its experimental uncertainty is by far larger than the CKM prediction.

- It can be measured in interferences between B^+ and B^- decays to a final state (D^0 K)cc where the kaon tags the B flavour and the D^0 and $\bar{D}^0$ share the same decay:

  - $D^0 \to K^+K^-$, $\pi^+\pi^-$ [GLW]
  - $D^0 \to K^-\pi^+$, $D^0 \to K^+\pi^-$ [ADS]
  - $D^0 \to K_s^0\pi^+\pi^-$, $K_s^0K^+K^-$ [GGSZ]





- It will also be measured in the Bs decay [$B_s \to D_sK$] through a time-dependent analysis.

- LHCb prospect is a measurement with a combined precision of 5 degrees at the horizon of 1/fb. Meanwhile, observe the suppressed modes and understand their backgound !

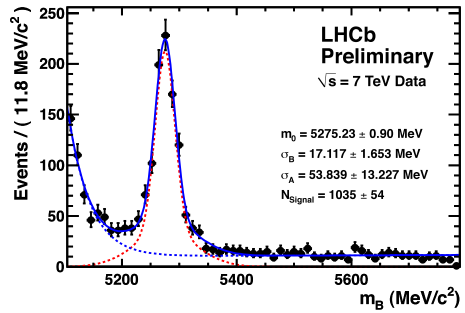
5.4 Prospects for γ angle with trees.

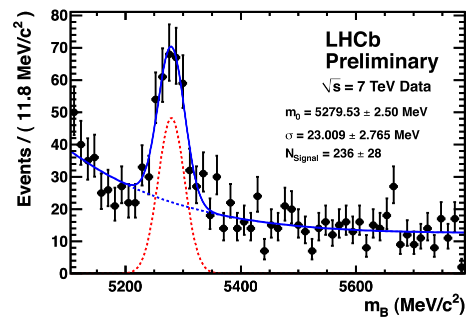
LHCb-CONF-2011-004
LHCb-CONF-2011-007
LHCb-CONF-2011-018

- γ is the less well-known Unitarity Triangle angle. Its experimental uncertainty is by far larger than the CKM prediction.

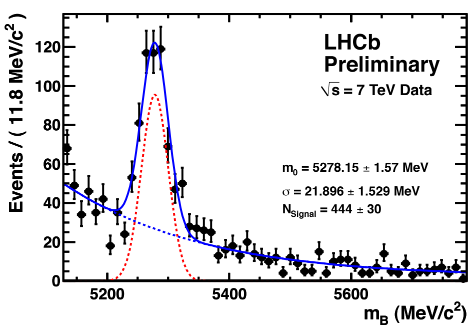
- Not enough statistics for γ measurement, but first signals of the interesting decay modes have been reconstructed with $35 pb^{-1}$.

- GLW: CP (KK and ππ):

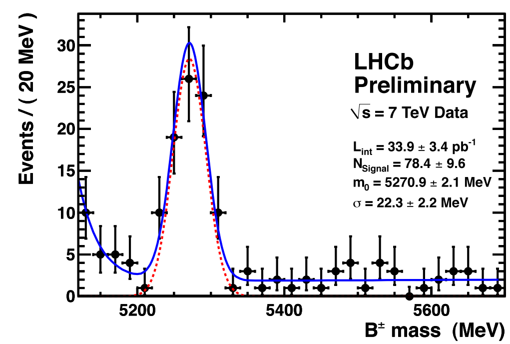




- ADS [$B^+ \rightarrow D^0(K^-\pi^+)K^+$]:



- GGSZ [$B^+ \rightarrow D^0(K_s^0 K^+ K^-)\pi^+$]:

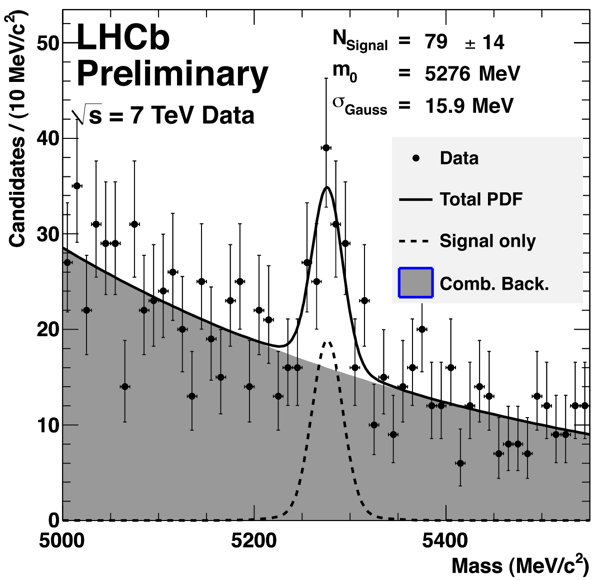


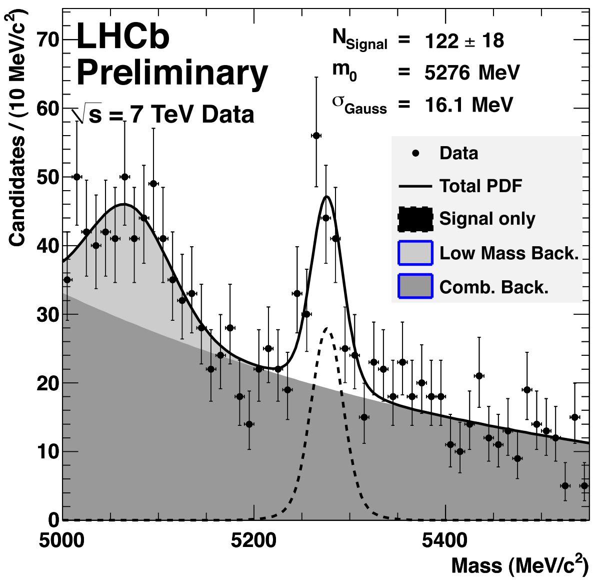
5.4 Prospects for γ angle with trees.

LHCb-CONF-2011-024

- γ is the less well-known Unitarity Triangle angle. Its experimental uncertainty is by far larger than the CKM prediction.

- Not enough statistics for γ measurement, but one can also consider high multiplicity decays such that:





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

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

Outline of the presentation

1. Introduction: flavour physics and CP violation.

2. The LHCb detector.

3. Operation and physics performance.

4. Production studies.

5. CP violation measurements.

6. Rare decays [Details of the analyses are to be found in Francesco Dettori's talk].

7. Summary.

6.1 Rare Decays

- Rare decays are a privileged laboratories to probe NP by making null test of the SM hypothesis in suppressed SM processes. Conversely, they are difficult to tackle experimentally.

  - Search for $B_{d,s} \rightarrow \mu\mu$: highly suppressed mode (Z-penguin and box diagram) predicted with a good precision within SM ($\sim 3.10^{-9}$) . EW-penguin process sensitive to scalar mediation potentially enhancing the branching fraction.

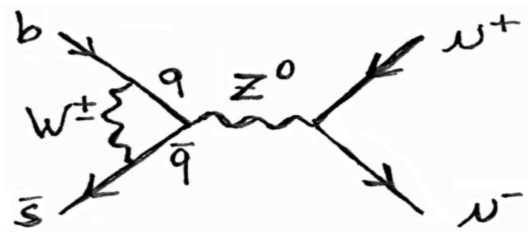
  - Search for $B_d \rightarrow K^*\mu\mu$: rare process ($\sim 10^{-7}$) suppressed. Probing NP through the dynamics of the decay.

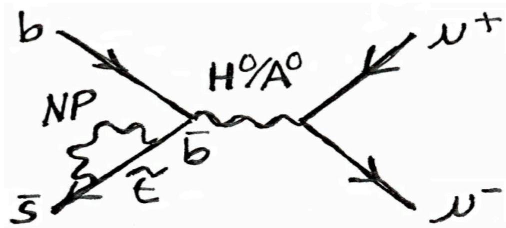
  - Radiative decays $B_d \rightarrow K^*\gamma$ and $B_s \rightarrow \phi\gamma$: not so rare ($\sim 10^{-5}$). The photon polarization is basically left-handed in SM. Probing NP through time-dependent measurements.

  - Details of the analyses will be given in Francesco Dettori's talk.

6.1 Rare Decays: Bd,s → μμ

- Physics: FCNC box annihilation and Z-penguin diagram. The latter decay process is especially appealing since it can receive scalar mediation (e.g. enhancing SM BR by a factor $\tan^6\beta/m_H^4$ in MSSM):





- State of the art: predictions and experimental reach.

  - Prediction (NLO): Buchalla&Buras hep-ph/9901288 B(Bs → μμ) ~ 3.2 10^{-9}.
  - (3.64^{+0.17}_{-0.31})\cdot 10^{-9}\

  - Experimentally:

$B(B_s \to \mu^+\mu^-) < 51\times10^{-9}$ (D0) *[PLB 693 539 (2010)]*

$B(B_s \to \mu^+\mu^-) < 43\times10^{-9}$ (CDF) *[CDF note 9892 (2009)]*

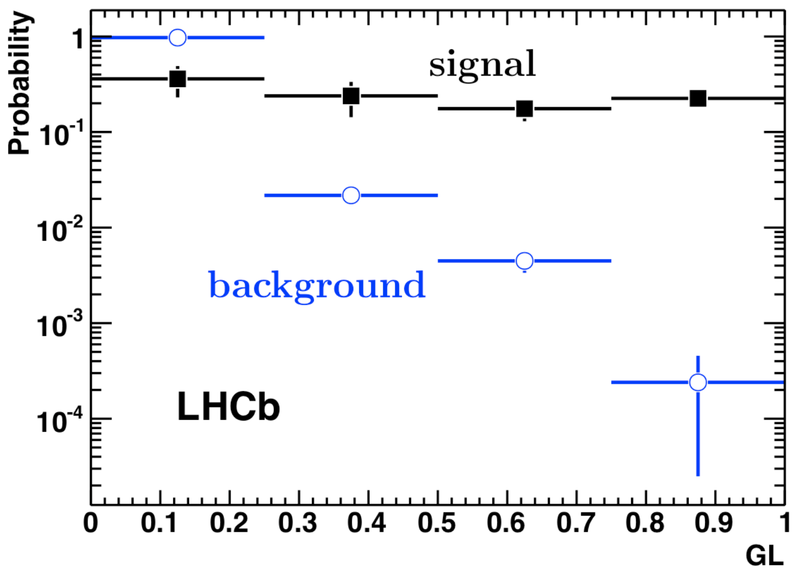
$B(B_d \to \mu^+\mu^-) < 7.6\times10^{-9}$ (CDF)

6.1 Rare Decays: Bd,s → μμ

- Analysis strategy:

PLB 699 (2011) 330-340

- Event selection based on 2D Likelihood: geometrical & kinematical Likelihood (GL) based on Impact Parameter, B vertex, Isolation+Invariant mass Likelihood modelled with a Crystal Ball.



- Data driven calibration:
  - GL calibrated on data using $B_{s,d} \to hh$ for signal and mass side-bands for background.
  - Invariant mass Likelihood: from $B_{s,d} \to K^+\pi^-$ (K^+K^-) and resolution from interpolation of the di-muon resonances (J/ψ, $\psi(2S)$, Υ's) and inclusive $b \to hh'$

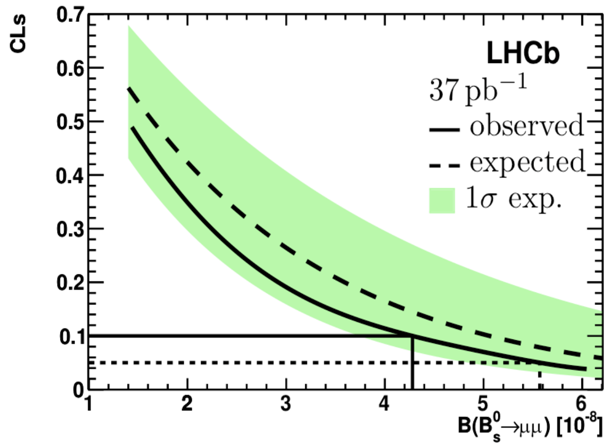
- Branching ratio normalization:

- Use 3 complementary channels (known Br) $J/\psi(\mu^+\mu^-)K^+$, $B_s \to J/\psi(\mu^+\mu^-)\Phi(K^+K^-)$, $B_d \to K^+\pi^-$ (yielding consistent results - hence weighted average)

$$B(B_{s,d} \to \mu^+\mu^-) = \left(\frac{B_{norm}}{N_{norm}} \cdot \frac{\varepsilon_{sig}^{rec,sel,trig}}{\varepsilon_{norm}^{rec,sel,trig}} \cdot \frac{f_{q_{norm}}}{f_{s,d}}\right) \cdot N_{B_{s,d} \to \mu\mu} = \alpha_{s,d} \cdot N_{B_{s,d} \to \mu\mu}$$

6.1 Rare Decays: Bd,s → μμ

- Results 2010 data:



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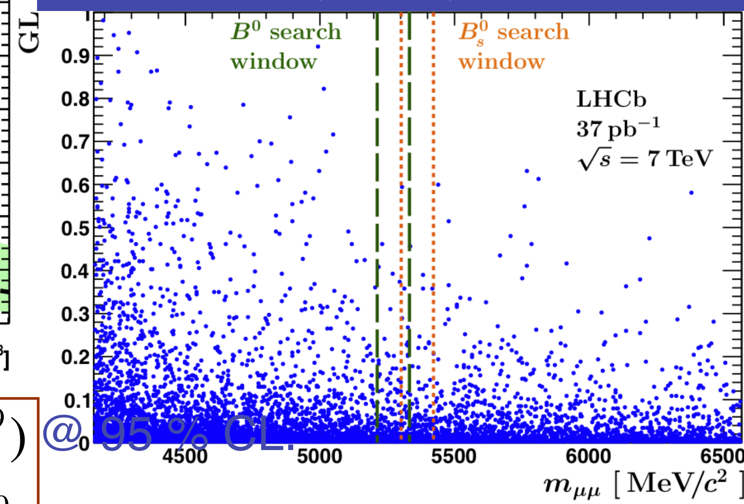
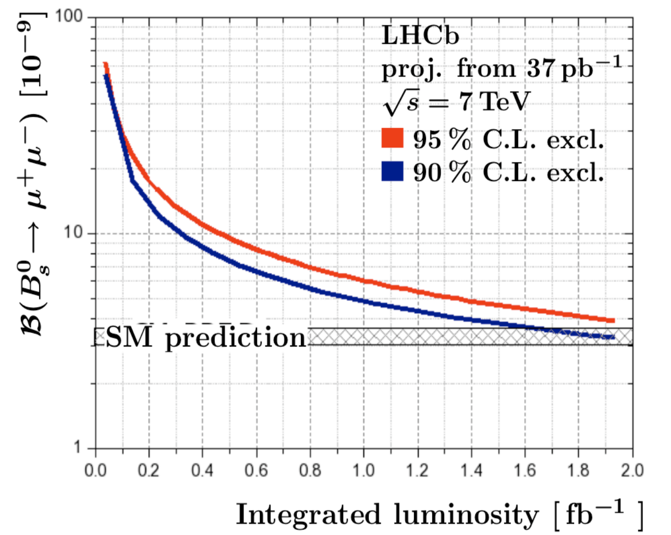


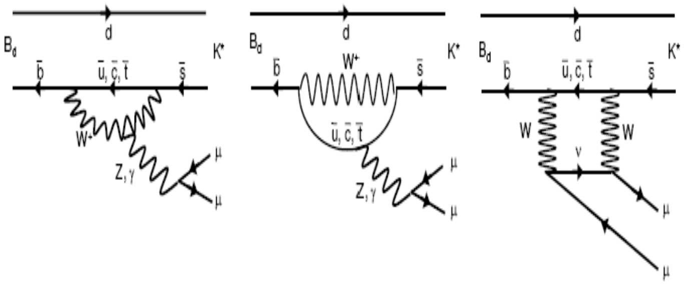
- $B(B_s \to \mu^+\mu^-) < 56\times10^{-9}$ (exp. limit : 65×10^{-9}) @ 95 % CL.
  $B(B_d \to \mu^+\mu^-) < 15\times10^{-9}$ (exp. limit : 18×10^{-9})



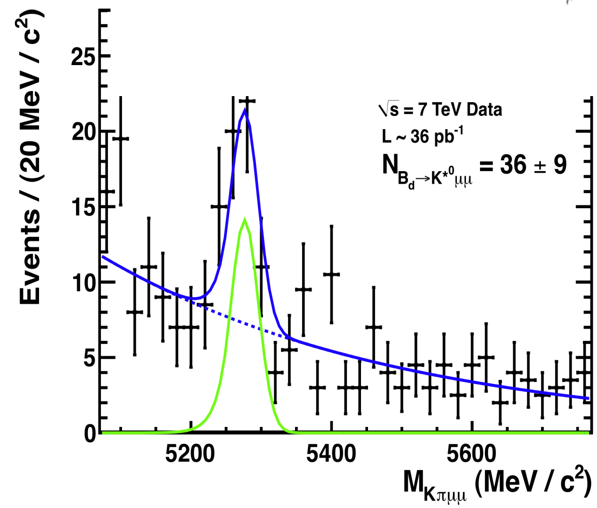
- Excellent prospects: LHCb will explore the interesting region in 2011-2012.

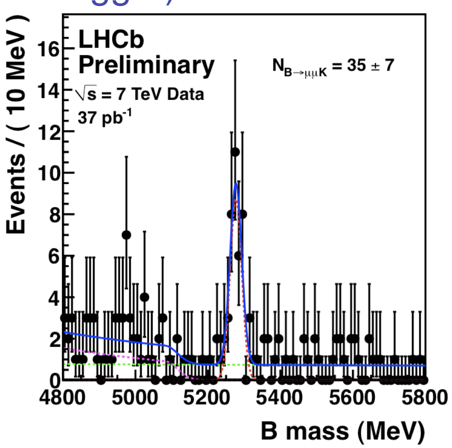
6.2 Rare Decays: Bd → K*μμ

- Physics: mode suppressed FCNC in b→s EW-penguin transition BR ~ 10^{-6}. Lepton angular distribution potentially affected by NP.



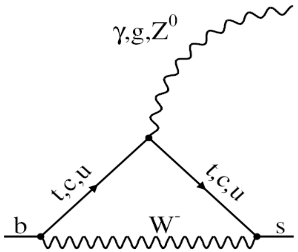
- LHCb prospects are very promising:
  - Clean observation of 36±9 events in 36 pb^{-1} (2010 data)close to expectation.
  - With 300 pb^{-1} (summer conference), LHCb expects to be competitive with existing measurements. Good MC/data agreement (acceptance, selection, trigger) for the control channel $B_s \rightarrow J/\psi(\mu^+\mu^-)K^*$.





- Rarest mode so far observed in LHCb: Bd → Kμμ $B(B^+ \rightarrow K^+\mu^+\mu^-) \sim (4.3 \pm 0.5) \times 10^{-7}$ (HFAG2010).

6.3 Radiative decays: Bd → K*ɣ and Bs → ϕɣ.

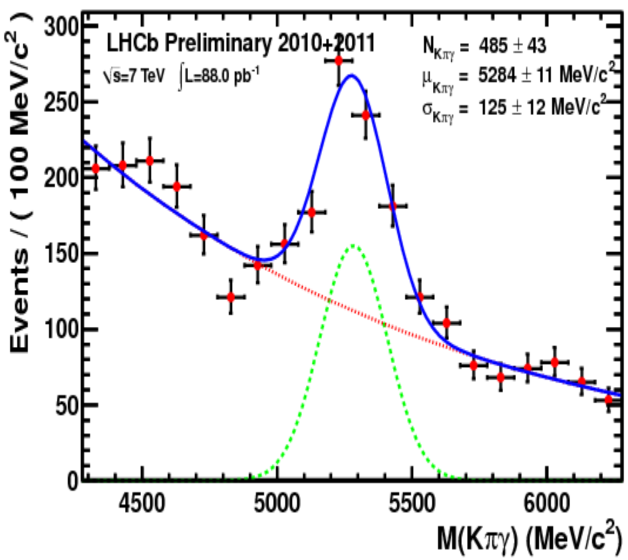


- Physics: Radiative b→qγ FCNC penguin (q=d,s)

- Ratios of BR of exclusive mode provides a direct constraint on UT.

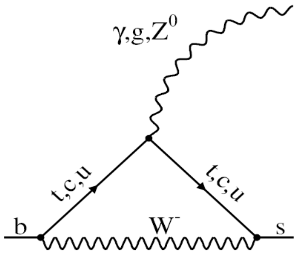
- Right-handed photon is suppressed by (m_q/m_b) within SM. Search for an anomalous polarization in Bs → ϕɣ indirectly through the time-dependent decay rate ($A^\Delta \sim \sin(2\Psi)$), Ψ measuring the ratio of right-handed and left-handed amplitudes:

$$\Gamma(\overset{(-)}{B}_q \to f^{CP}\gamma) = |A|^2 e^{-\Gamma_q \tau}\left[\cosh(\Delta\Gamma_q \tau/2) + A_q^\Delta \sinh(\Delta\Gamma_q \tau/2) \pm C_q \cos(\Delta m_q \tau) \mp S_q \sin(\Delta m_q \tau)\right]$$

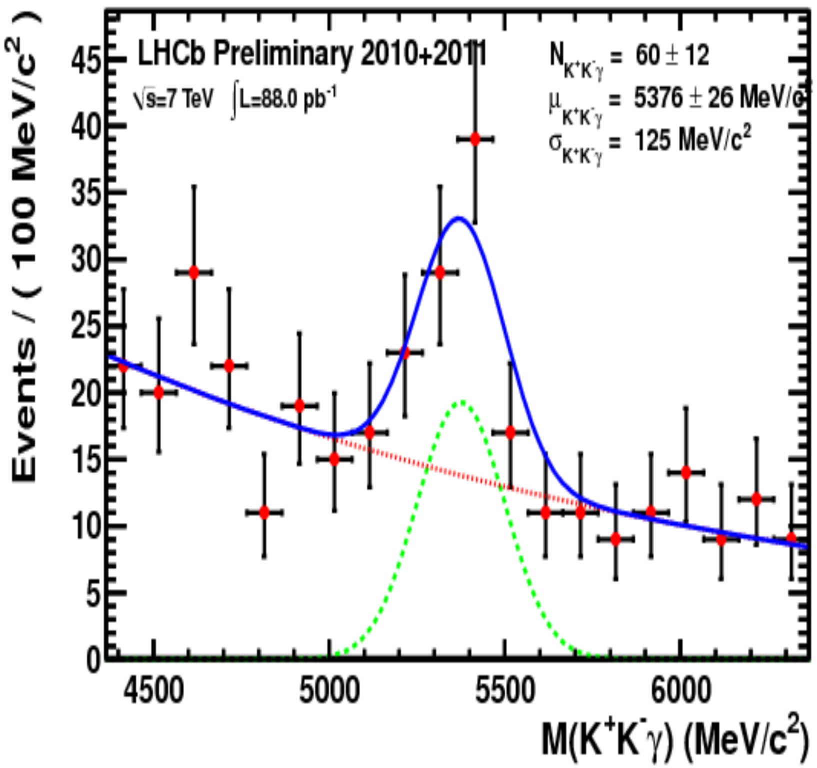


- LHCb prospects:
- Bd → K*ɣ reference channel for other radiative decays trigger)
- Production rate in LHCb -> expect O(6k) the end of 2011.
- Measurement of the direct CP asymmetry by the end of year [$A_{CP}(K^*\gamma)$ predicted less than 1% in SM and measured at B factories as $A_{CP}(K^*\gamma)$=(-1.6 ± 2.3)%]

6.3 Radiative decays: Bd → K*γ and Bs → φγ.

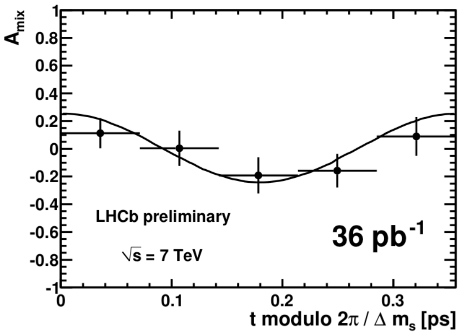


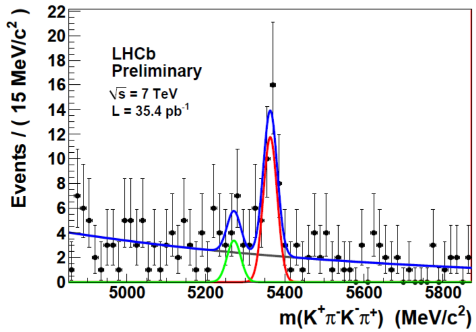
- Physics: Radiative b→qγ FCNC penguin (q=d,s)
- Evidence for B_s→Φ(KK)γ in LHCb
- LHCb production rate : O(700)B→γ by the end of 2011
- Measurement of the Branching Fraction $B(B_s \rightarrow \Phi\gamma)/B(B^0 \rightarrow K^*\gamma)$ expected by this summer.

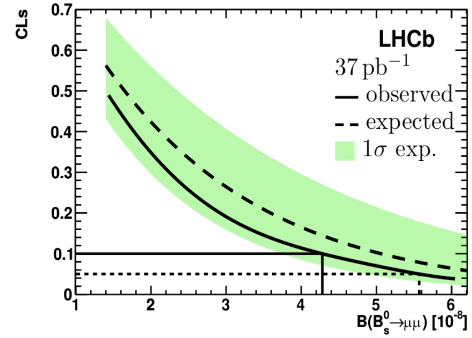


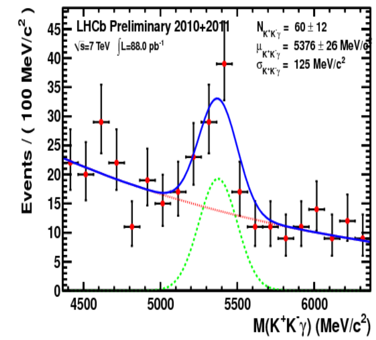
7. Summary.

- Great achievements so far:

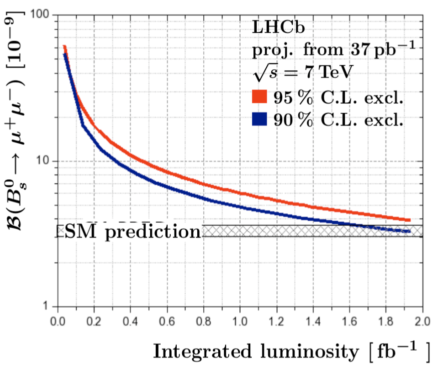


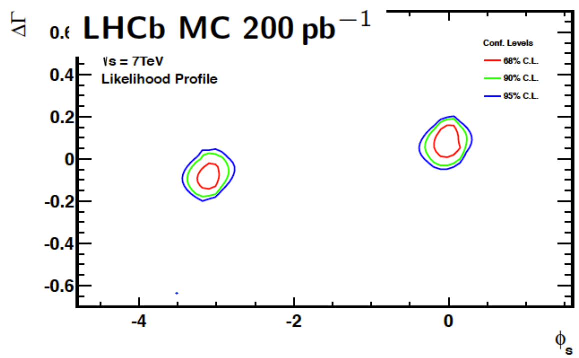


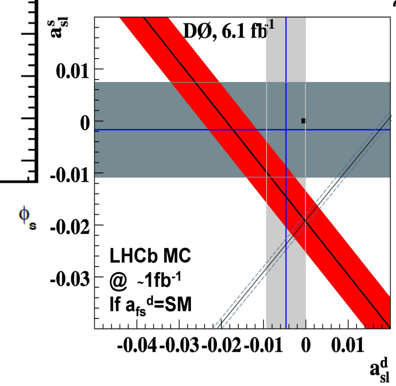


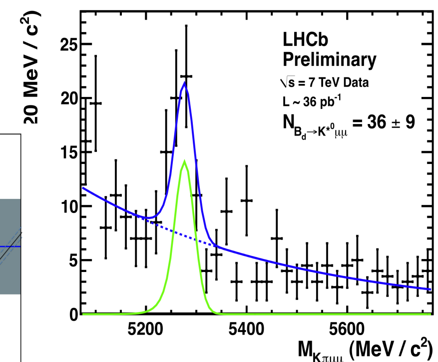


- Promises to keep:









- Explore the core physics case now.