γ from penguin decays at LHCb

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on behalf of the LHCb Collaboration

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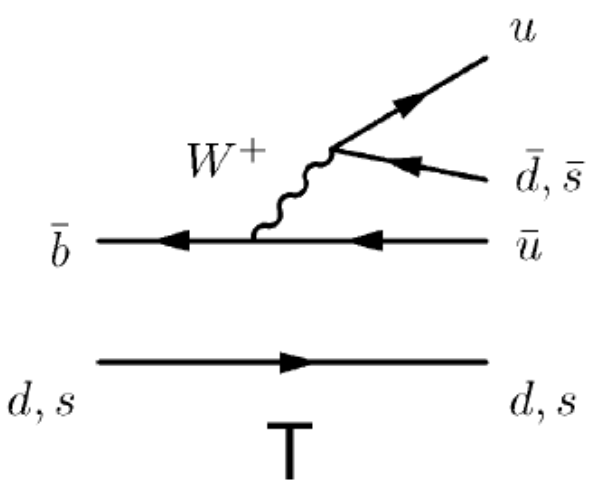
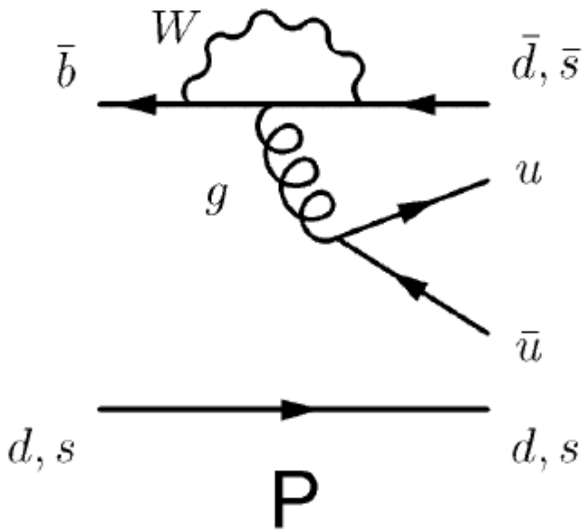
Physics motivation: γ from charmless B→hh

- B→hh decays comprise a rich set of channels and associated CP violation measurements
- b→u tree transitions allow access to the CKM phase γ
  - E.g. CP time-dependent measurements from $B \to \pi^+\pi^-$ and $B_s \to K^+K^-$ allow extraction of γ relying on U-spin [R. Fleischer, Phys. Lett. B 459 (306) 1999]
- New Physics may show up as virtual contributions of new particles inside the loops of penguin graphs





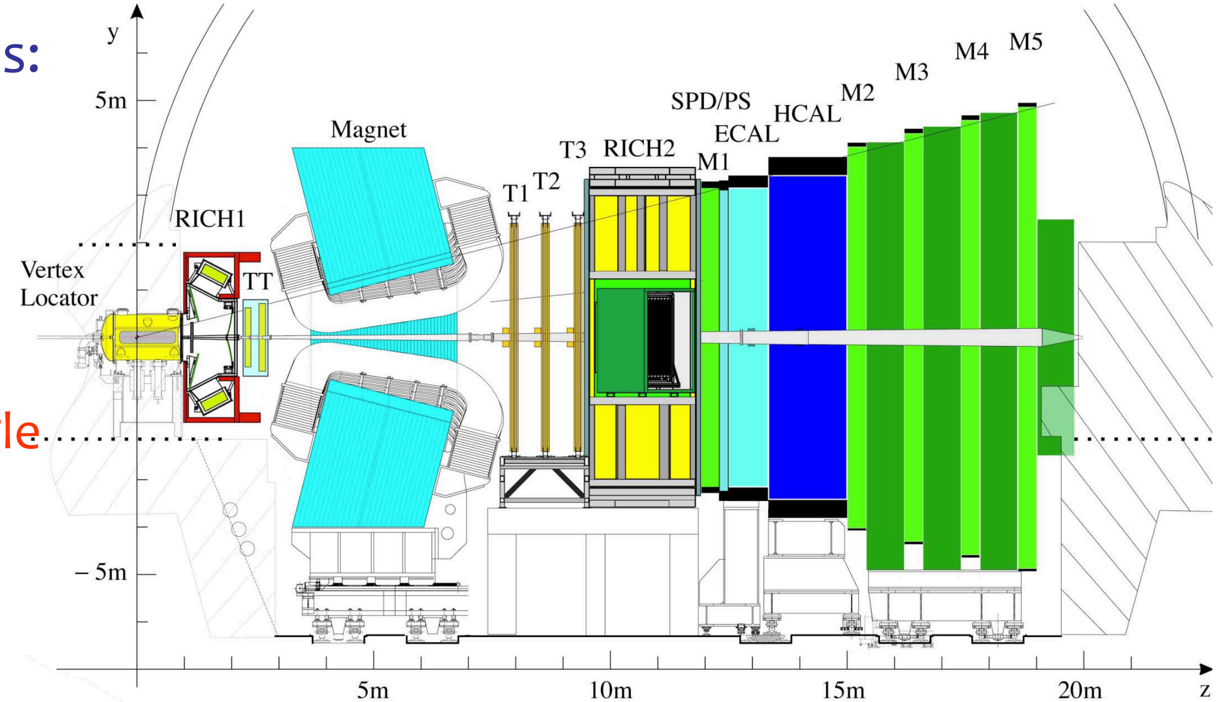
Physics motivation: γ from B→hhh

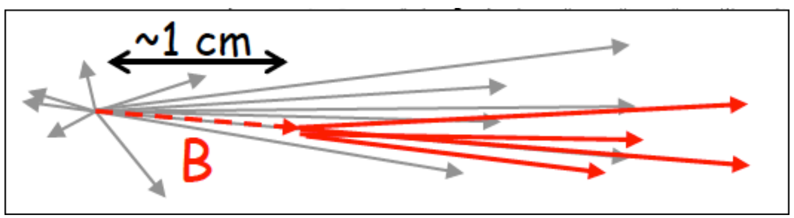
- I. Bediaga et al. in Ref. [Phys. Rev. D 76, 073011 (2007)] depict a method to extract γ by combining Dalitz plot amplitude analyses of $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$ and untagged B^0, $\overline{B}^0 \to K_s\pi^{+}\pi^{-}$
- The method also allows to measure the ratio and phase difference between the tree and penguin contributions from B^0 and $\overline{B}^0 \to K^{*\pm}\pi^{\mp}$ decays and the CP asymmetry between B^0 and $\overline{B}^0$

The LHCb detector

Crucial for B →hh(h) physics:

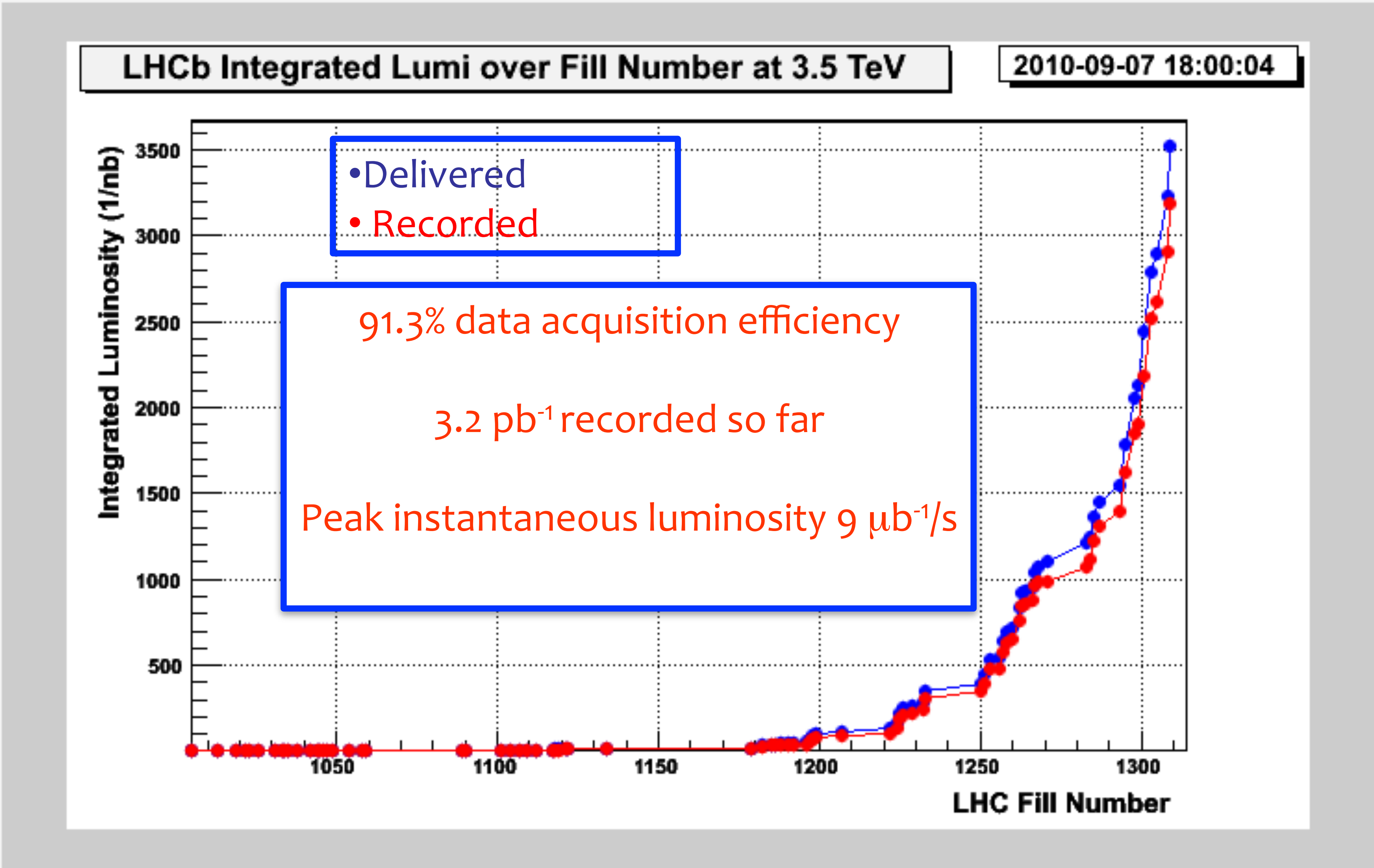
- Hadronic trigger
- excellent particle ID
  - Mass peaks overlap, p/K/π separation necessary to disentangle all the different modes
- excellent tracking/ vertexing
  - mass and proper time resolution





- •VELO: Vertex Locator (around IP)
- TT, T1, T2, T3: Tracking stations
- RICH 1-2: Ring Imaging Cherenkov (PID)
- M1–M5: Muon stations
- •ECAL, HCAL: Calorimeters

Integrated Luminosity

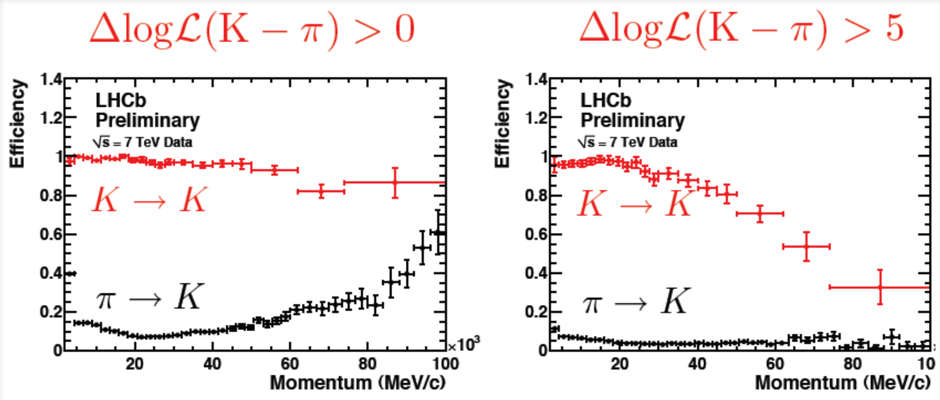


91.3% data acquisition efficiency

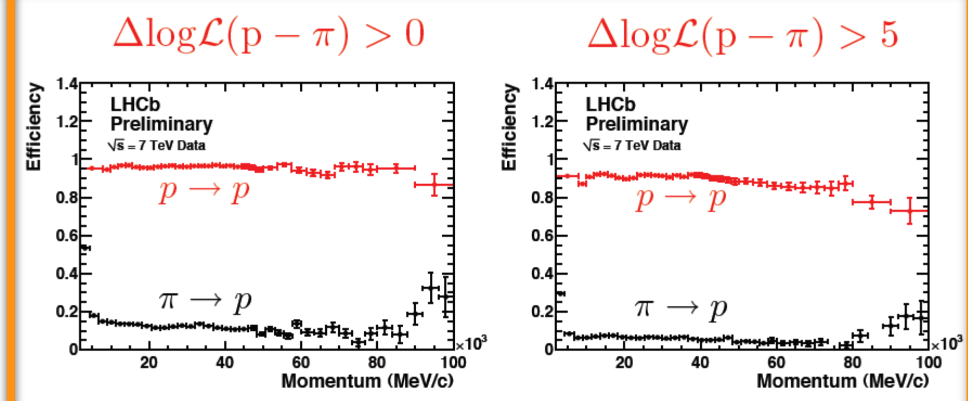
3.2 pb^{-1} recorded so far

Peak instantaneous luminosity 9 $\mu b^{-1}/s$

RICH performance p/K/π separation



K/π separation

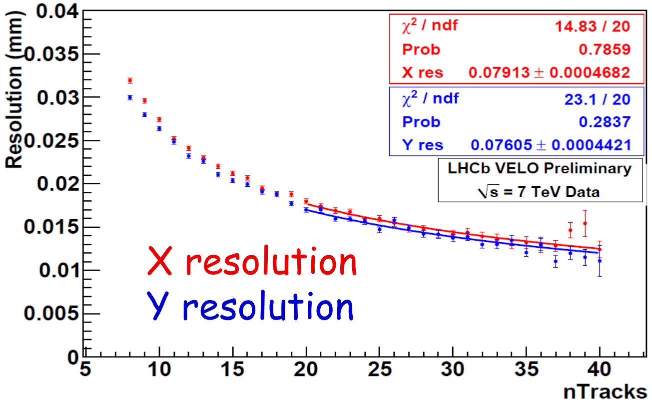


p/π separation

- To determine ID and mis-ID rates used samples from $K_s \rightarrow \pi\pi$, $\phi \rightarrow KK$ and $\Lambda \rightarrow p\pi$
- Good performance over expected B/D track momentum range
- …but a lot of work for improvement:
  - Precision tuning of radiator refractive index
  - Targeting designed Cherenkov angle resolutions

Tracking

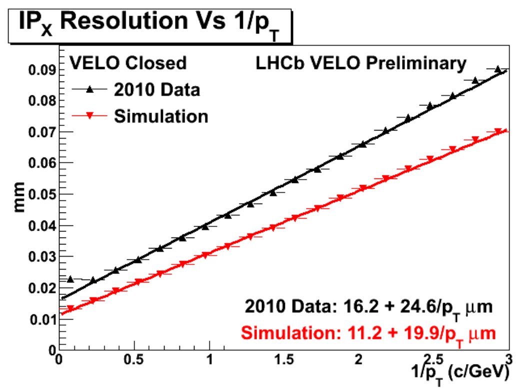
PV resolution

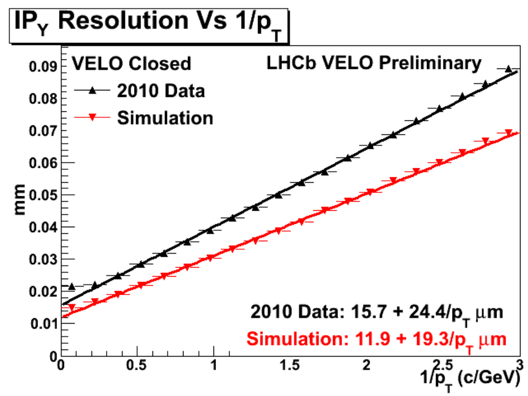


- With 25 tracks:
  - ~ 15 μm for **X** & **Y** and ~ 90 μm for Z
  - worse than MC: 11 μm for X & Y and 60 μm for Z

Further improvement is expected with better Alignment
→ lot of work in progress

Impact parameter resolution

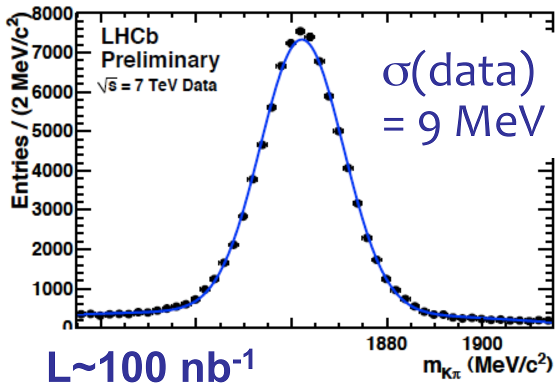




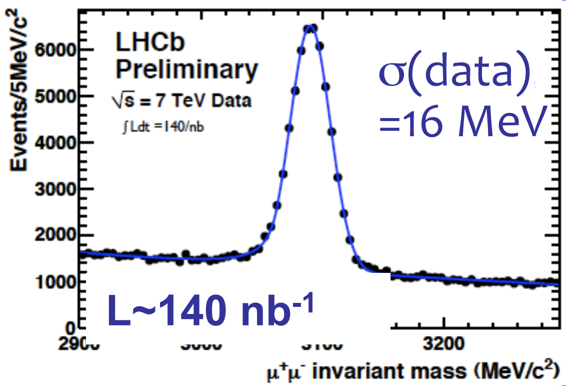
IP resolution ~20 μm for the highest P_T bins

Invariant mass resolution

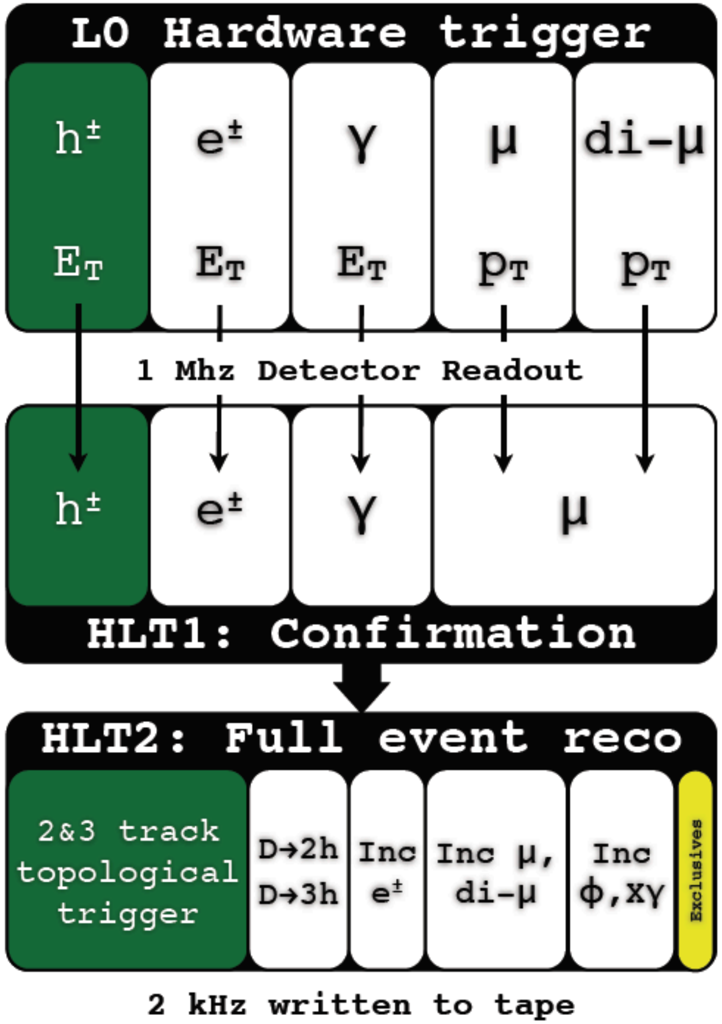
$D \rightarrow K\pi$ [σ(MC)= 7MeV]



$J/\psi \rightarrow \mu\mu$ [σ(MC)=11 MeV]



LHCb trigger



Triggering on B→hh

L0 hadron → cut on highest E_T measured by the hadronic calorimeter

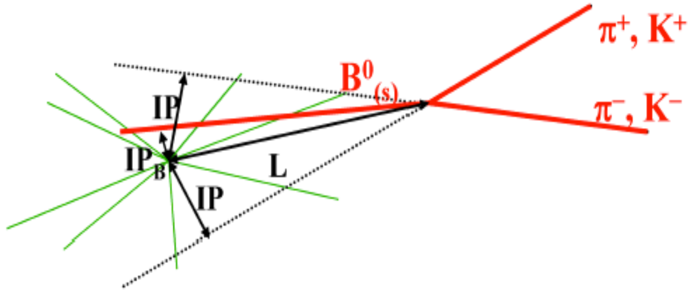
Hadron alley → confirm L0 decision using tracking system , cut on IP, p_T

Exclusive selection → unique selection algorithm based on full detector information (except PID) for all B→hh modes

Total efficiency with nominal trigger on B→hh ~40%

Selecting B→hh at LHCb

- Measured bbar cross section at 7 TeV: $\sigma_{b\bar{b}}$ =292±15±43 μb (Preliminary)
- Branching ratios are of the order 10^{-5} - 10^{-6}
- Selection criteria must reject a huge amount of background
- Two main sources of background expected from Monte Carlo studies:
  - Combinatorial: mainly due to tracks coming from other B decays
  - Physical: partially reconstructed B→3-body decays



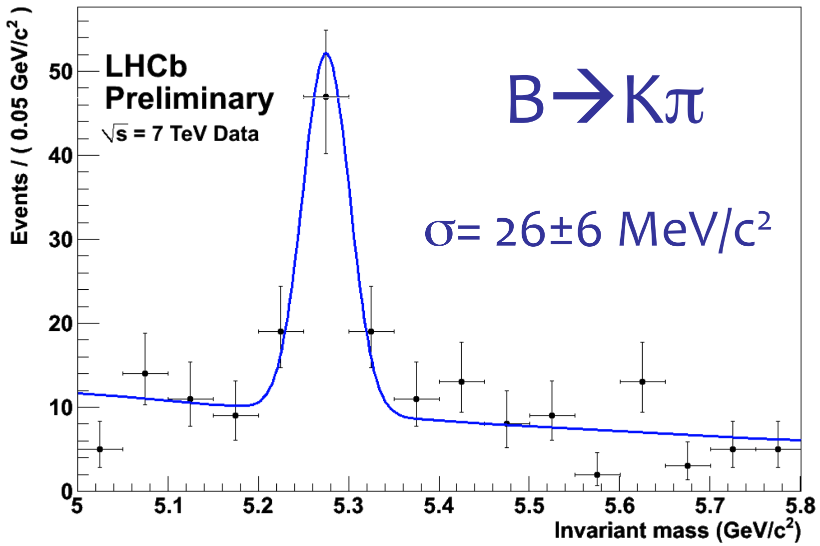
For each pair of charged Tracks the cuts are applied on

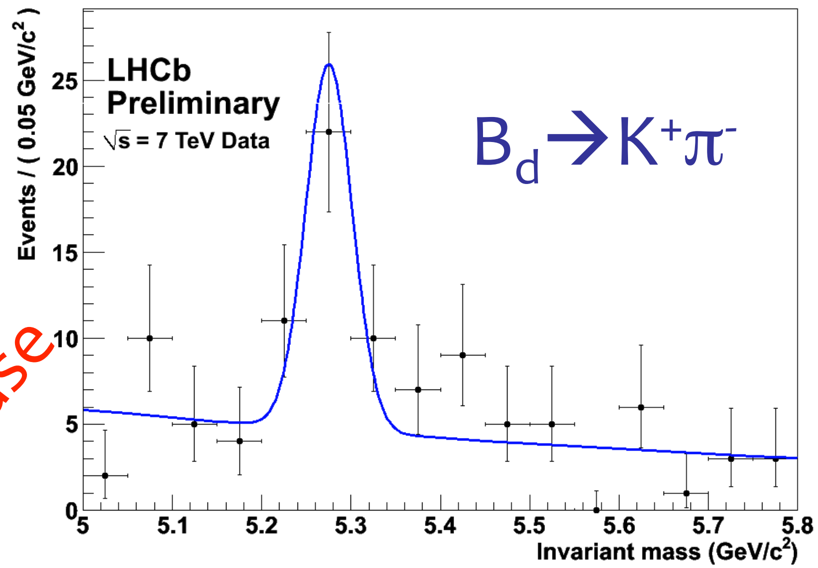
- Transverse momentum
- Impact parameter
- χ^2 of common vertex

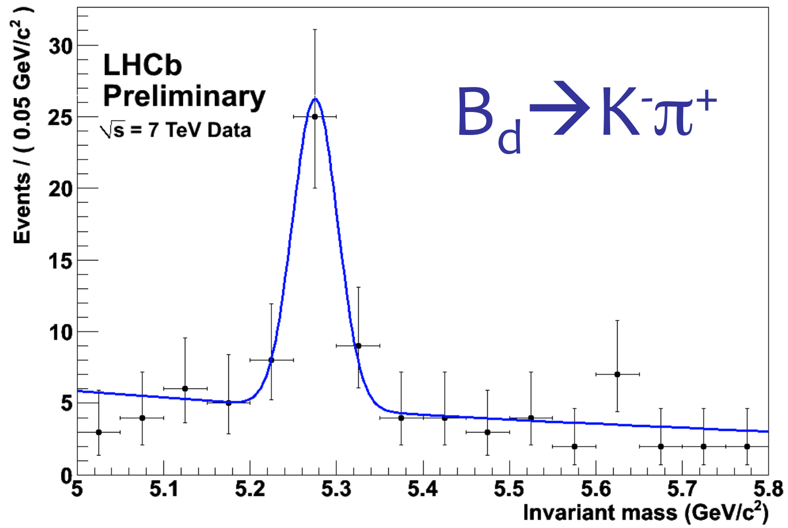
Then, the B candidate is selected with cuts on:

- Transverse mometum
- Impact parameter
- Distance of flight

B→hh working in progress with L= 0.9 pb^{-1}







RICH PID in use

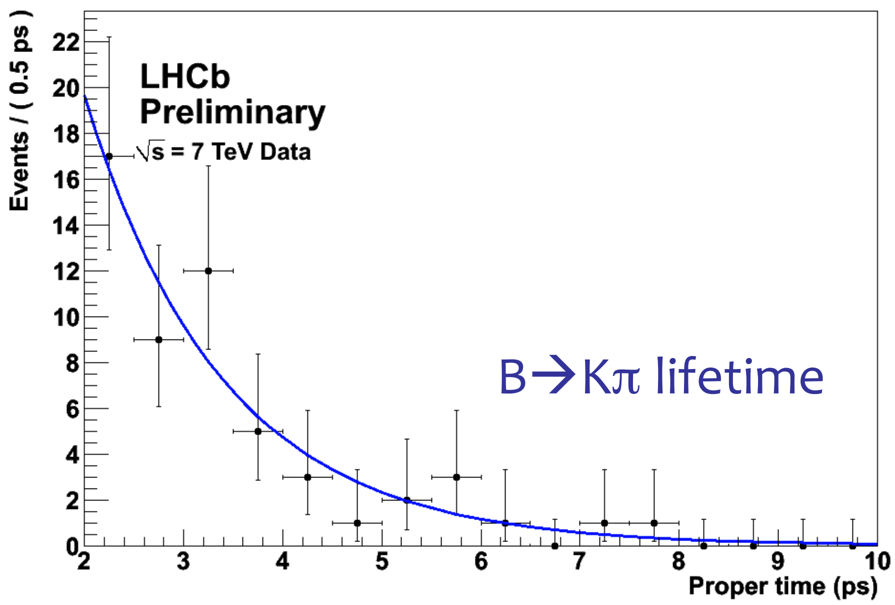
Yield: 56±10

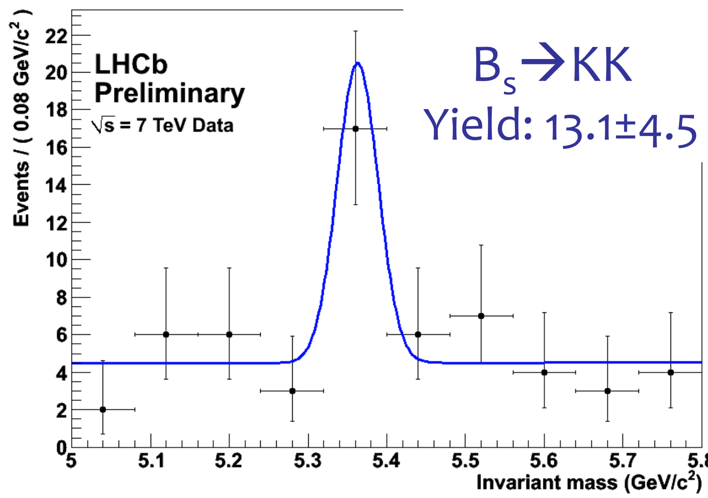
$$\frac{N_{\pi+K-} - N_{K+\pi-}}{N_{\pi+K-} + N_{K+\pi-}} = 0.01 \pm 0.16 \text{ (stat)}$$

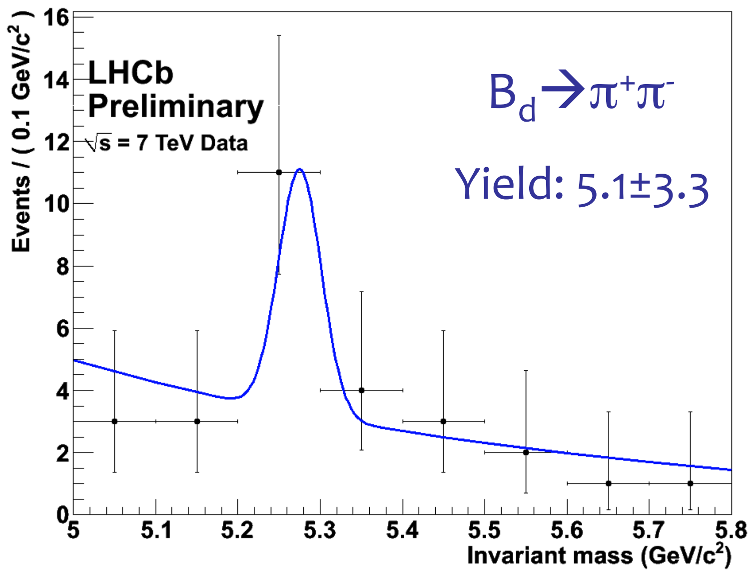
(HFAG: -0.098 ± 0.012)

Yield statistically consistent with Monte Carlo expectation

B→hh working in progress with L= 0.9 pb^{-1}







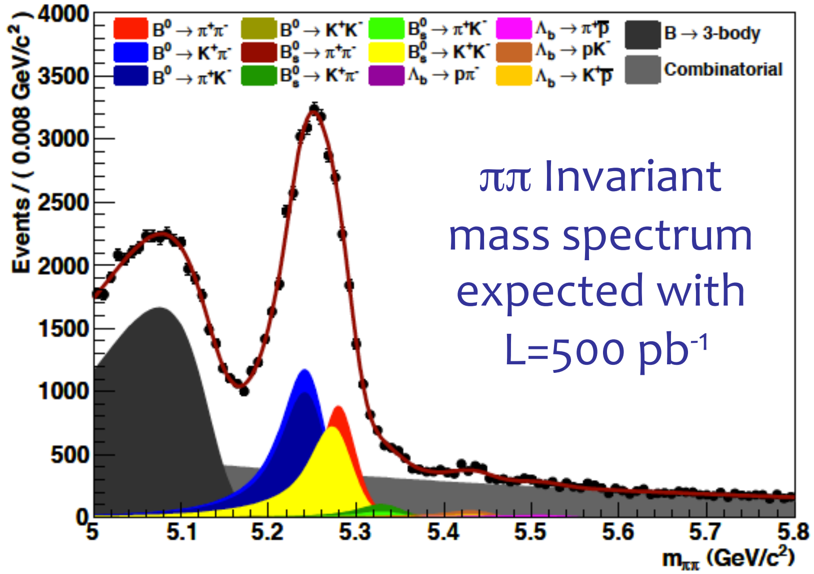
- lifetime fit on early B→Kπ data sample using a cut t>2 ps in order to select a region of flat proper time acceptance

τ_d = (1.5 1± 0.28) ps

Prospects: yields for B→hh

- Detailed studies available in "LHCb Roadmap document" [arXiv:0912.4179]
  - Studies made there for 14 TeV, here yields rescaled to 7 TeV according to the measured cross section

Decay mode	$\mathcal{BR} \times 10^6$	L= 500pb^{-1}
$B^0 \to \pi^+\pi^-$	5.16 ± 0.22	8.5k
$B^0 \to K^+\pi^-$	19.4 ± 0.06	31k
$B_s^0 \to \pi^+K^-$	5.27 ± 1.17	2.3k
$B_s^0 \to K^+K^-$	25.8 ± 4.2	10.2k
$\Lambda_b \to p\pi^-$	3.1 ± 0.9	1k
$\Lambda_b \to pK^-$	5.0 ± 1.2	1.6k



Prospects: CP and BR measurements in B→hh

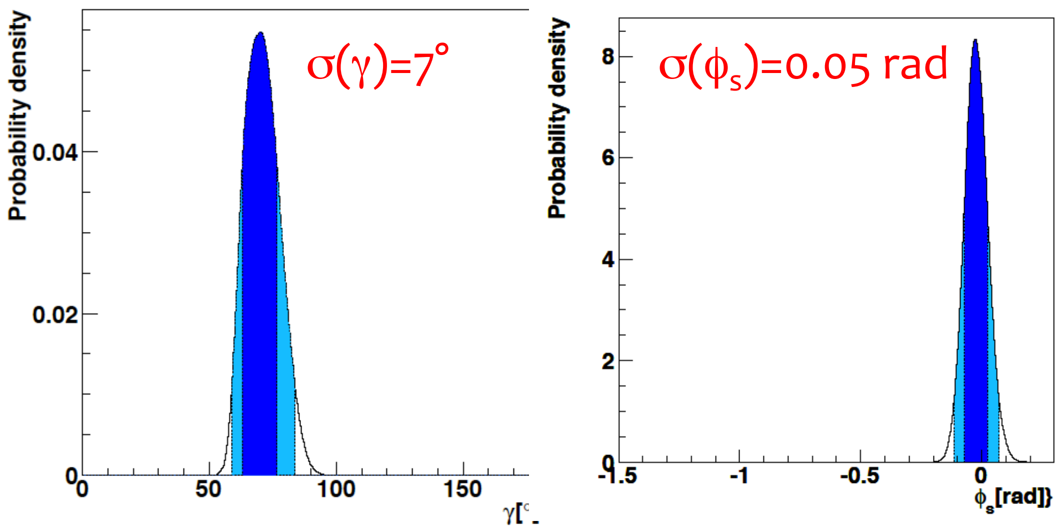
- Competitive measurements already possible with $L=200\ pb^{-1}$
  - E.g. $B_s \to K\pi$ charge asymmetry, relative BR's, …
  - $B_s \to KK$ Lifetime
- With $500\ pb^{-1}$ we will largely overcome the current world statistics and measurements of time dependent CP asymmetries will be possible
  - (Maybe, unless CDF) first measurement of $B_s \to KK$ time dependent CP violation
- Observation/strong bounds on very rare decay $B_d \to K^+K^-$ and $B_s \to \pi^+\pi^-$

	Current knowledge	LHCb stat.
$\mathcal{A}^{CP}_{K^+\pi^-}$	$-0.098^{+0.012}_{-0.011}$	0.008
$\mathcal{A}^{CP}_{\pi^+K^-}$	$0.39 \pm 0.15 \pm 0.08$	0.05
$\mathcal{A}^{CP}_{p\pi^-}$	$0.03 \pm 0.17 \pm 0.05$	0.05
$\mathcal{A}^{CP}_{pK^-}$	$0.37 \pm 0.17 \pm 0.03$	0.03
$\mathcal{A}^{dir}_{\pi^+\pi^-}$	0.38 ± 0.06	0.13
$\mathcal{A}^{mix}_{\pi^+\pi^-}$	-0.65 ± 0.07	0.13
$\mathrm{Corr}(\mathcal{A}^{dir}_{\pi^+\pi^-}, \mathcal{A}^{mix}_{\pi^+\pi^-})$	0.08	-0.03
$\mathcal{A}^{dir}_{K^+K^-}$	Unmeasured	0.15
$\mathcal{A}^{mix}_{K^+K^-}$		0.11
$\mathrm{Corr}(\mathcal{A}^{dir}_{K^+K^-}, \mathcal{A}^{mix}_{K^+K^-})$		0.02
$\frac{\mathcal{BR}(B^0\to\pi^+\pi^-)}{\mathcal{BR}(B^0\to K^+\pi^-)}$	0.264 ± 0.011	0.006
$\frac{\mathcal{BR}(B^0\to K^+K^-)}{\mathcal{BR}(B^0\to K^+\pi^-)}$	$0.020 \pm 0.008 \pm 0.006$	0.005
$\frac{f_s\,\mathcal{BR}(B^0_s\to K^+K^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	$0.347 \pm 0.020 \pm 0.021$	0.006
$\frac{f_s\,\mathcal{BR}(B^0_s\to \pi^+K^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	$0.071 \pm 0.010 \pm 0.007$	0.004
$\frac{f_s\,\mathcal{BR}(B^0_s\to \pi^+\pi^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	$0.007 \pm 0.004 \pm 0.005$	0.002
$\frac{f_{\Lambda_b}\,\mathcal{BR}(\Lambda_b\to p\pi^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	$0.0415 \pm 0.0074 \pm 0.0058$	0.0016
$\frac{f_{\Lambda_b}\,\mathcal{BR}(\Lambda_b\to pK^-)}{f_d\,\mathcal{BR}(B^0\to K^+\pi^-)}$	$0.0663 \pm 0.0089 \pm 0.0084$	0.0018

LHCb stat. sensitivity with $L=500\ pb^{-1}$

Prospects: γ from B→hh (for L=2 fb^{-1} at 14 TeV)

- Direct and mixing induced CP asymmetries in $B_d \rightarrow \pi^+\pi^-$ and $B_s \rightarrow K^+K^-$ measured using tagged, time-dependent analysis allow to extract γ up to U-Spin breaking corrections [R. Fleischer, PLB 459 (306) 1999]
- Extraction of unknown parameters still possible even allowing U-spin breaking to a certain extent
- Not only γ, but also the B_s mixing phase can be probed



Results here obtained allowing for 20% of U-spin breaking for these channels

Sensitivities still good up to 50% of U-spin breaking, see LHCb Roadmap [arXiv: 0912.4179] for details

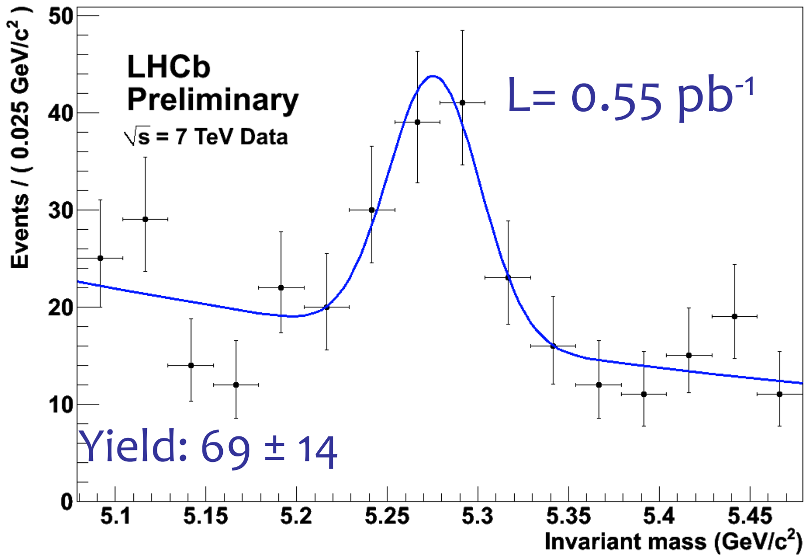
Prospects: yields for $B^{\pm} \rightarrow hhh$

- Expected events from MC studies with $L=1fb^{-1}$ @ 7 TeV

	BR x 10^5	Yield
$B \rightarrow K\pi\pi$	5.50±0.70	162k
$B \rightarrow \pi\pi\pi$	1.62±0.15	48k
$B \rightarrow KK\pi$	0.50±0.07	15k
$B \rightarrow KKK$	3.37±0.22	99k
$B \rightarrow pp\pi$	0.16±0.02	5k
$B \rightarrow ppK$	0.59±0.05	17k

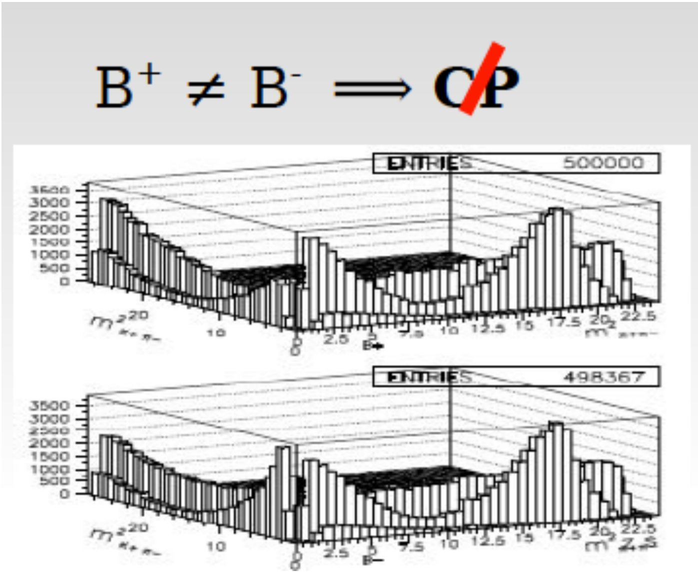
More than one order of magnitude than current world statistics

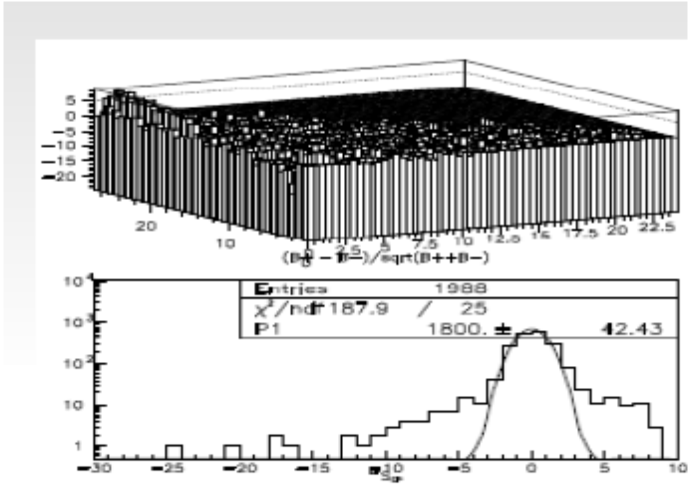
$B \rightarrow K\pi\pi$ signal with current data



CP violation in $B^{\pm} \rightarrow hhh$ modes

- Possibility of probing regions of the Dalitz plot looking at interference with CP violation → Mirandazing method





$$^{DP}S_{CP}(i) = \frac{N^{+}(i) - N^{-}(i)}{\sqrt{N^{+}(i) + N^{-}(i)}}$$

- Method: subtract B^{+} and B^{-} Dalitz surface and write the significance of each bin
- If not gaussian → presence of CP violation

I. Bediaga et al., Phys. Rev. D 80, 096006 (2009)

Summary

- Analysis of first inverse pb of data very encouraging
  - First B→hh and B→hhh signals established
  - Observed yields confirm Monte Carlo expectations
    - detector and trigger in good shape
      - Trigger will have to cope soon with larger instantaneous luminosity
    - lot of work in progress on alignment and PID
- Depending on LHC ramp up in luminosity, we expect to be competitive with and even overcome current world statistics at some point in 2011
- Stay tuned!