$B_s \to J/\psi\phi$, $B \to hh$ and $B \to hhh$ at LHCb

Vincenzo Vagnoni

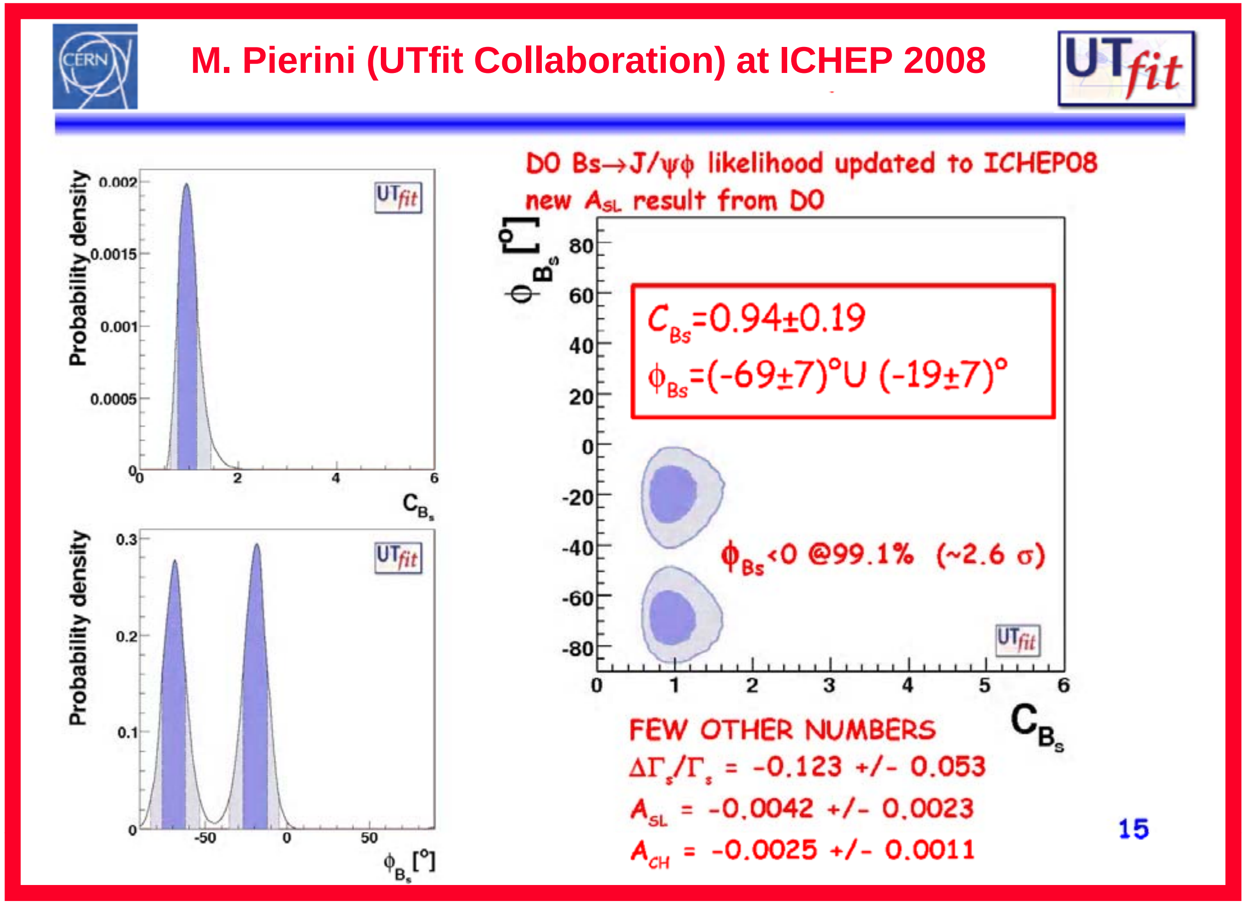
INFN Bologna

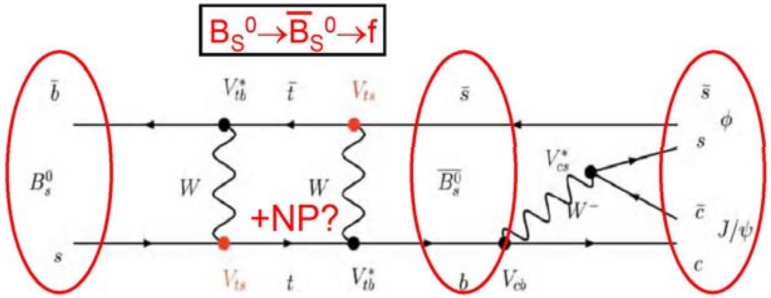
(on behalf of the LHCb Collaboration)

Beyond the 3SM generation at the LHC era
CERN, 5th September 2008

The mixing phase of the B_s meson

- The measurement of the mixing phase by CDF and D0 with $B_s \rightarrow J/\psi\phi$ have provided a significant discrepancy with the Standard Model



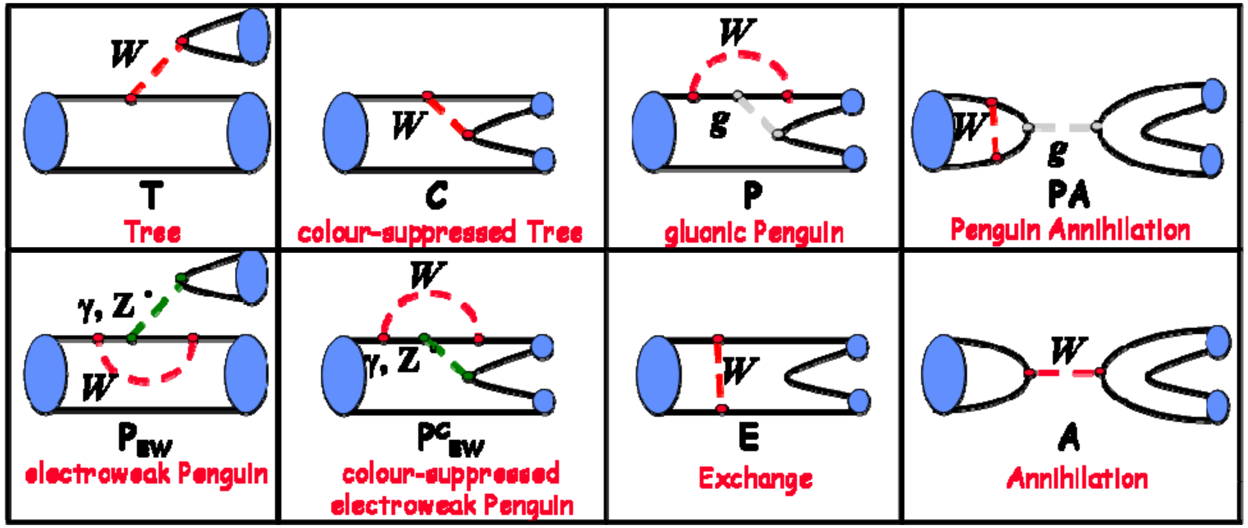


Is it real or just a weird statistical fluctuation?

Is it due to the presence of a fourth generation of other kind of New Physics?

- **This is most probably the most important measurement to be performed in the flavour sector at present**
- **LHCb has a unique opportunity to finally confirm whether the effect is real**

Trees, Penguins and some other graph in B→hh decays



We measure direct and mixing induced CP asymmetry coefficients

$$C_{\pi^+\pi^-} = f_1(d, \vartheta, \gamma)$$

$$S_{\pi^+\pi^-} = f_2(d, \vartheta, \gamma, \beta)$$

$$C_{K^+K^-} = f_3(d', \vartheta', \gamma)$$

$$S_{K^+K^-} = f_4(d', \vartheta', \gamma, \beta_s)$$

- $B_s \to \pi\pi$ and $B_s \to KK$ can be used to extract γ up to U-spin breaking corrections
  - Hadronic quantities d, θ entering the $B_d \to \pi\pi$ decay amplitude and d', θ' entering the $B_s \to KK$ decay amplitude are defined in ref. R. Fleischer, PLB 459 (1999) 306
- New Physics can show up inside the loops of the penguin diagrams and alter the measurement of g with respect to pure tree measurements
- Furthermore, $B_s \to KK$ is sensitive to New Physics in the B_s mixing
  - Two paths to New Physics, although the validity of the U-spin symmetry is a debated question from a theoretical point of view

$B \to hhh$ decays

- **hhh corresponds to several channels**
  - **$B^+ \to \pi^+\pi^+\pi^-$**
  - **$B^+ \to K^+\pi^+\pi^-$**
  - **$B^+ \to K^+K^-\pi^+$**
  - **$B^+ \to K^+K^+K^-$**
  - **$B^+ \to p\bar{p}\pi^+$**
  - **$B^+ \to p\bar{p}K^+$**
  - **but also e.g. $B_d \to K_S\pi^+\pi^-$**

Branching fractions in the range $10^{-5} - 10^{-6}$

- **They contain CKM V_{ub} transitions**
  - **Hence presence of CP violation**
  - **Possibility to measure $\gamma \to$ see e.g. I. Bediaga *et al.*, PRD 76, 073011 (2007)**
- **Also, it is possibile to look for the very rare decays**
  - **$B^+ \to K^-\pi^+\pi^+$**
  - **$B^+ \to K^+K^+\pi^-$**
- **3 body analysis**
  - **Measure resonant state magnitudes and phases $\to$ access to additional CP violation information**

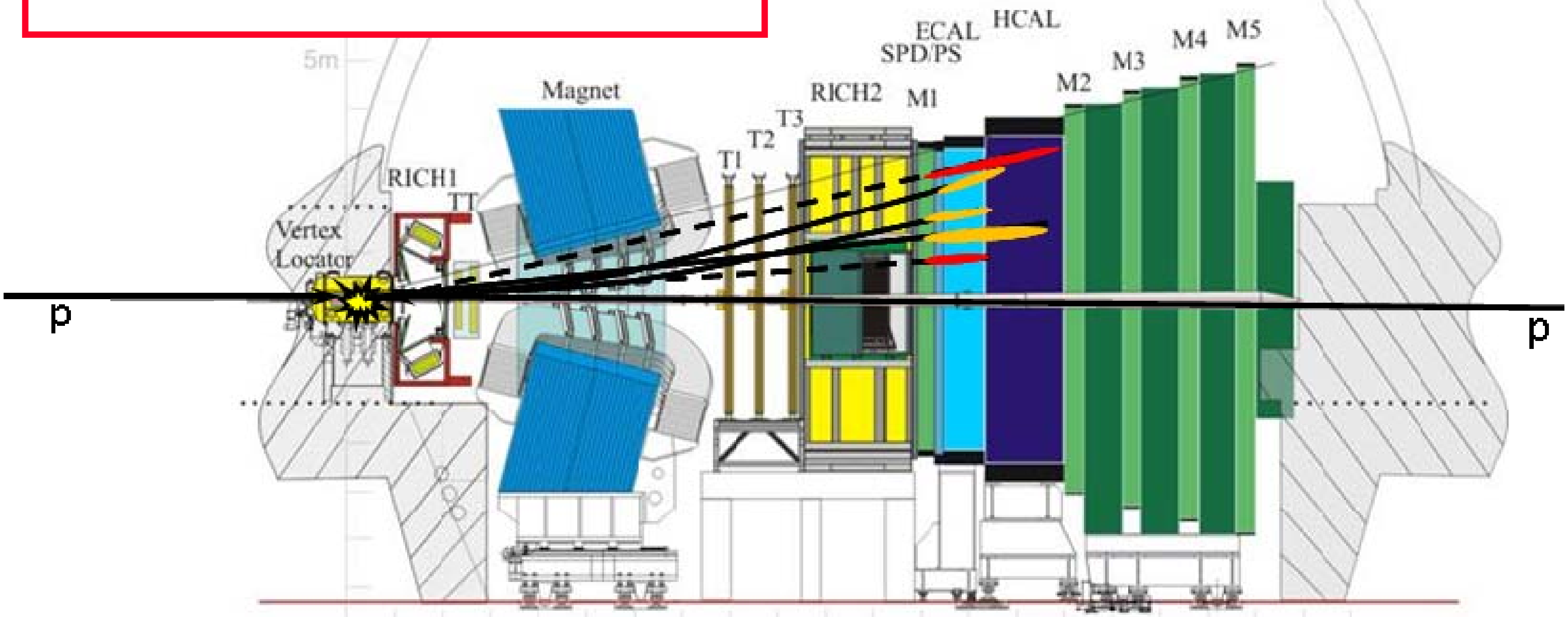
LHCb detector in one slide

Forward spectrometer operating in the range: $1.8 < h < 4.9$

Working luminosity at the LHCb IP: 2-5 x 10^{32} cm^{-2} s^{-1}
(# bb pairs / $2fb^{-1}$: 1-2.5 x 10^{12})

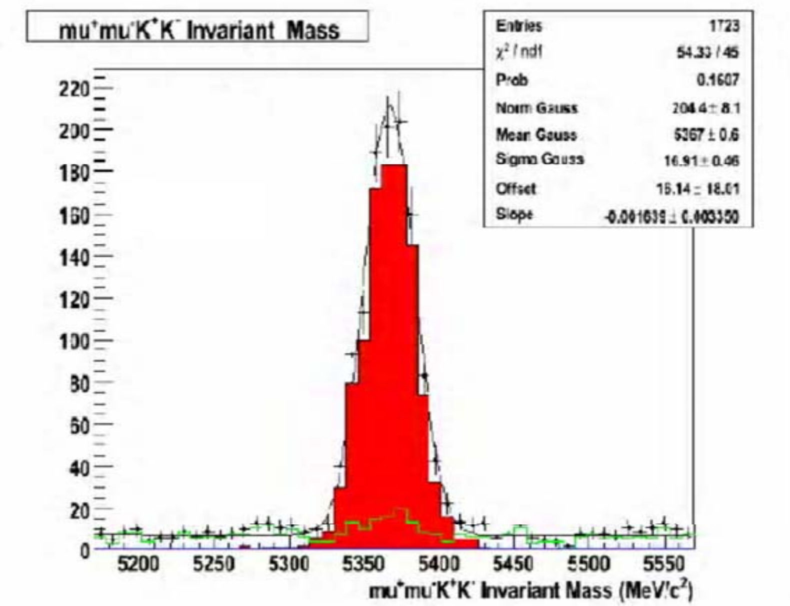
Trigger

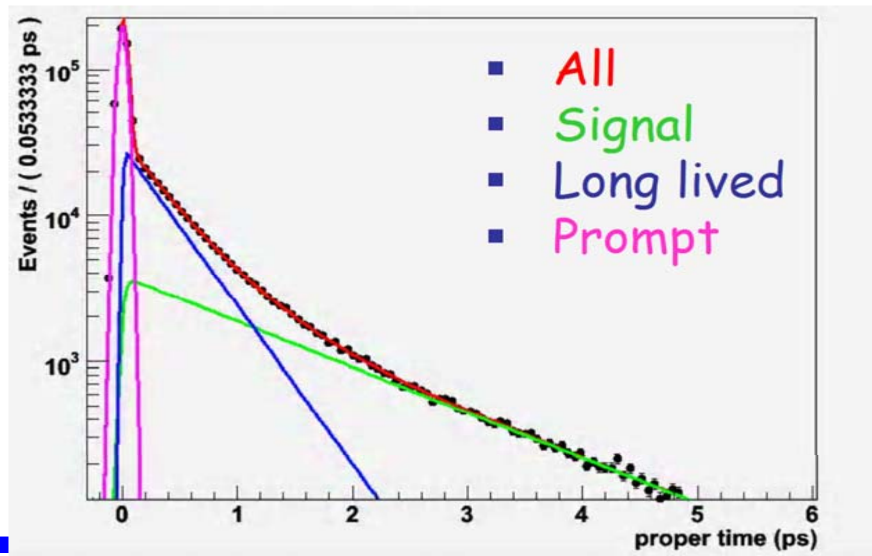
L0 (hardware trigger): 40 MHz → 1 MHz
HLT (software trigger): 1 MHz → 2 kHz



LHCb performance with $B_s \rightarrow J/\psi\phi$

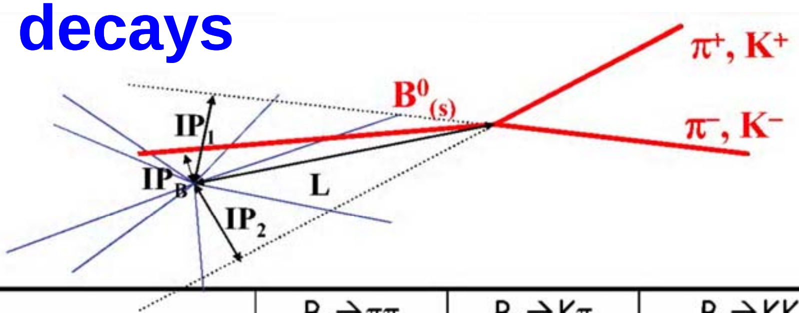
- **LHCb will collect about 114k events in 2 fb^{-1} of integrated luminosity (one nominal year of data taking) with very high purity**
  - **The statistical precision so achievable on $2\beta_s$ for L=2/fb is estimated to be 0.03 rad**
  - **Largely able to pinpoint the mixing phase if the Tevatron hints are real**





Performance for B→hh

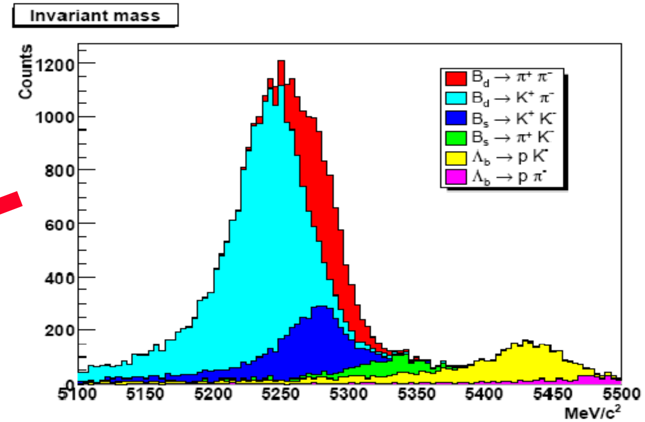
- LHCb will collect an unprecedented number of B→hh decays



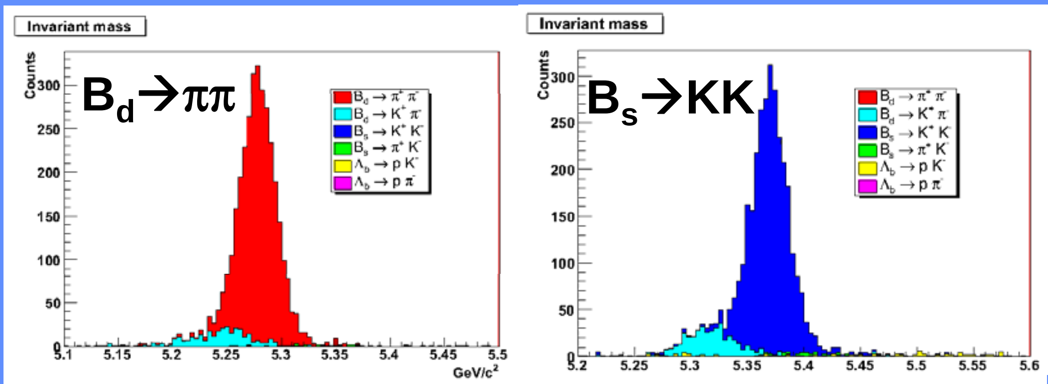
	$B_d \to \pi\pi$	$B_d \to K\pi$	$B_s \to KK$	$B_s \to \pi K$
L=0.01 fb^{-1}	0.18k	0.69k	0.18k	0.05k
L=0.5 fb^{-1}	9k	34.5k	9k	2.5k
L=2 fb^{-1}	36k	138k	36k	10k
B/S	0.5	<0.06	0.15	1.9

- Thanks to its unique RICH system, the different B→hh samples will be perfectly isolated

If not using RICH info



Using RICH information

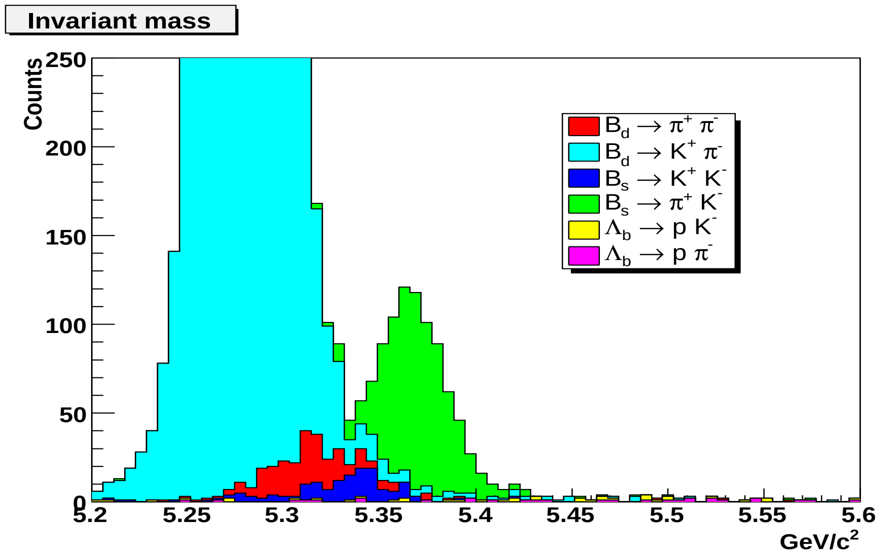


CP measurements with flavour specific modes

- **Amongst the first measurements LHCb can do**
  - **No tagging nor proper time required**

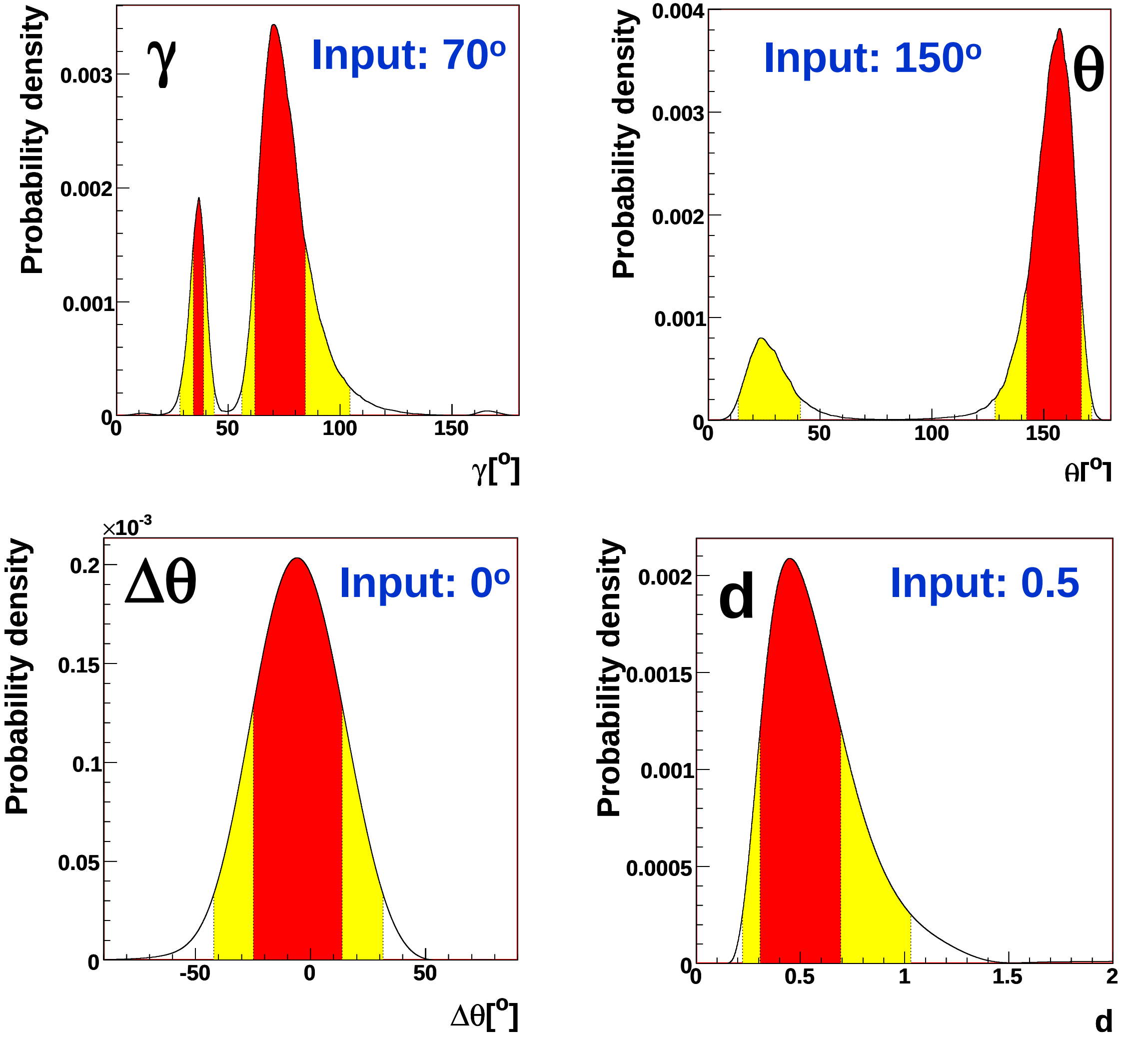
- **$B_d \to K^+\pi^-$ dominating due to f_d and BR**
  - **PID important to clean up the sample from $B_d \to \pi^+\pi^-$ and $B_s \to K^+K^-$**
  - **$\sigma_{stat}(A_{K\pi}) \cong 0.006$ already with L=0.5/fb**

- **$B_s \to \pi^+K^-$ more difficult due to lower f_s and BR**
  - **16 times less abundant and same signature as $B_d \to K^+\pi^-$**
  - **$\sigma_{stat}(A_{\pi K}) \cong 0.04$ with L=0.5/fb**



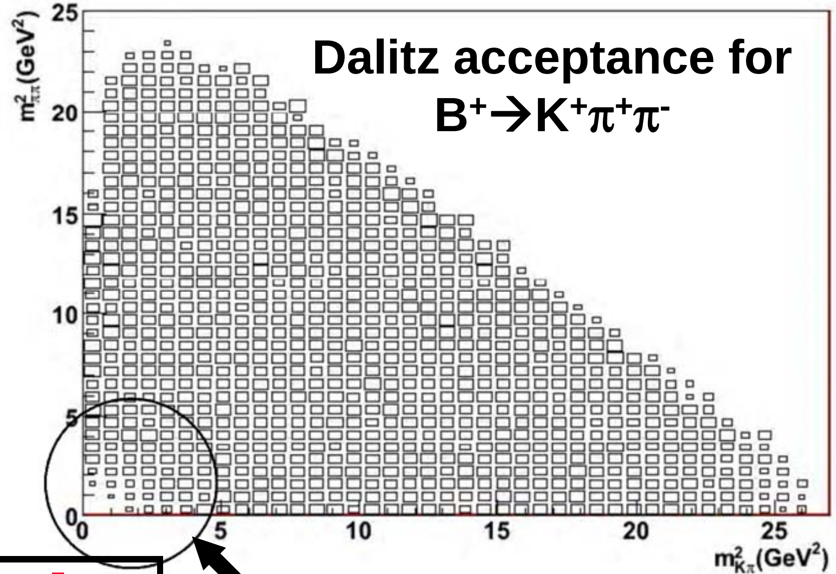
γ measurement with CP eigenstates $B_d \rightarrow \pi\pi$ and $B_s \rightarrow KK$ ($L=2fb^{-1}$)

- **Minimal use of U-spin symmetry assumptions**
  - The strong phases θ and θ' of the $B_d \rightarrow \pi\pi$ and $B_s \rightarrow KK$ amplitudes are left free to be fitted independently
    - i.e. no U-spin assumption at all
  - For the strong magnitudes d and d' instead, they are assumed to be identical, but up to a 20% U-spin breaking
    - as to say d = d' ± 20%
- **Sensitivities**
  - $\sigma(\gamma) = 10^{\circ}$
  - $\sigma(\theta) = 9^{\circ}$
  - $\sigma(\Delta\theta) = 17^{\circ}$
  - $\sigma(d) = 0.18$



LHCb performance for B→hhh

- **Very large event yields expected**
  - **About 2 orders of magnitude more than B factories**
  - **Good purity**
  - **Rich potential for nice physics results!**



Lower efficiency due to transverse momentum cut

	Yield (2/fb)	S/B	BR (times 10^5)
$B^+ \to \pi^+\pi^+\pi^-$	142k	1.4	1.6
$B^+ \to K^+\pi^+\pi^-$	494k	3.1	5.6
$B^+ \to K^+K^-\pi^+$	39k	0.3	0.5
$B^+ \to K^+K^+K^-$	236k	21	3.0
$B^+ \to p\bar{p}\pi^+$	22k	0.2	0.3
$B^+ \to p\bar{p}K^+$	39k	1.5	0.6

γ measurement from $B \rightarrow hhh$

- **Possibility to extract γ by combining $B^+ \rightarrow K^+\pi^+\pi^-$ and $B_d \rightarrow K_S\,\pi^+\pi^-$**
  - **I. Bediaga *et al.*, PRD 76, 073011 (2007)**
- **Event yield of $B_d \rightarrow K_S\pi^+\pi^-$ significantly smaller due to the presence of the K_S**
  - **50% of the K_S can fly and decay after the vertex detector → lower precision of tracks**
  - **or even worse 25% can decay after the TT tracking chambers behind the magnet → no momentum measured → tracks are definitively lost**
  - **Nevertheless, 90k of $B_d \rightarrow K_S\pi^+\pi^-$ can be collected with an integrated luminosity of 2/fb**
    - **To be compared with 494k for $B^+ \rightarrow K^+\pi^+\pi^-$**
- **Ideal toy MC studies indicate that we can reach a sensitivity as good as 5° with L=2/fb with this method**

Conclusions

- **LHCb will play a crucial role in establishing the existence of New Physics in the B_s mixing**
  - **If the central value measured at the Tevatron is real, LHCb should be able to confirm it already in 2009**
    - **assuming that LHC will deliver to IP8 a few hundreds of pb^{-1}**
- **Other interesting possibilities for spotting out New Physics come from decays involving penguin graphs**
  - **LHCb will enlarge the available statistics of charmless two and three body decays by orders of magnitude**
- **Looking forward for the first collisions…**