

γ angle from loop decays at LHCb

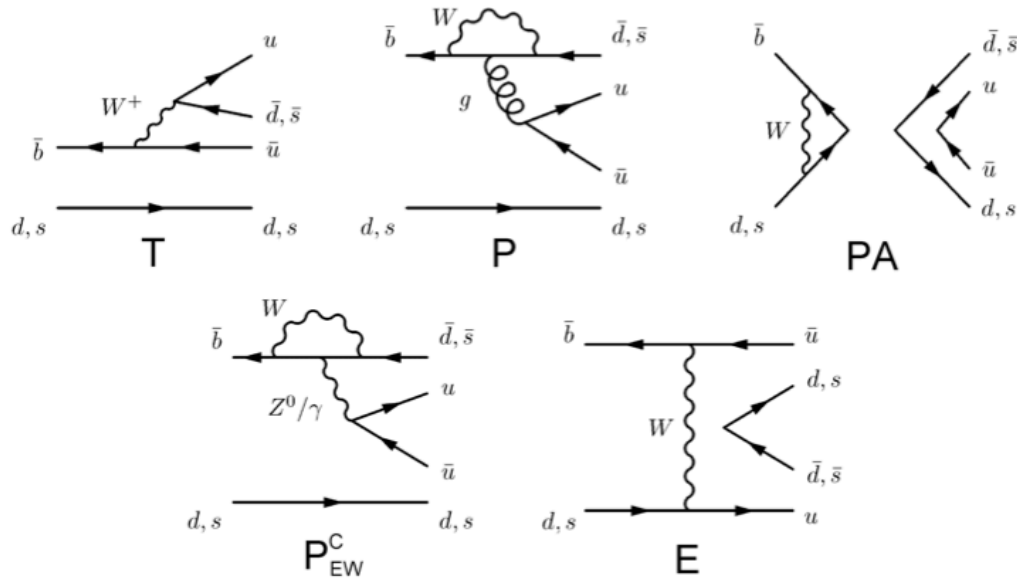
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For the LHCb Collaboration

- Recent LHCb results:
 - Charmless charged two-body B decays ($B \rightarrow h^+ h^-$) measurements:
 - Possibility to determine γ from decays receiving contributions from penguin diagrams
 - e.g. using U-spin, but with hadronic uncertainties
 - interplay between various $B \rightarrow h^+ h^-$ decays in order to constraint U-spin breaking effects
 - Results obtained with 0.35 fb^{-1} and $0.69 \text{ fb}^{-1} \rightarrow$ still rooms for improvements already with 2011 data
- Prospects from three-body charmless B decays

$B \rightarrow h^+ h^-$ measurements



- Several diagrams contribute to the decay amplitudes, notably including tree, strong and electroweak penguins, and certain annihilation and exchange topologies

- Important interplay amongst all the B → h⁺h⁻ channels
 - e.g. if U-spin is valid and annihilation diagrams are negligible one expects

Decay mode	Contributing diagrams
$B^0 \rightarrow \pi^+\pi^-$	T, P, PA, P_{EW}^C, E
$B^0 \rightarrow K^+\pi^-$	T, P, P_{EW}^C
$B_s^0 \rightarrow \pi^+K^-$	T, P, P_{EW}^C
$B_s^0 \rightarrow K^+K^-$	T, P, PA, P_{EW}^C, E
$B^0 \rightarrow K^+K^-$	PA, E
$B_s^0 \rightarrow \pi^+\pi^-$	PA, E

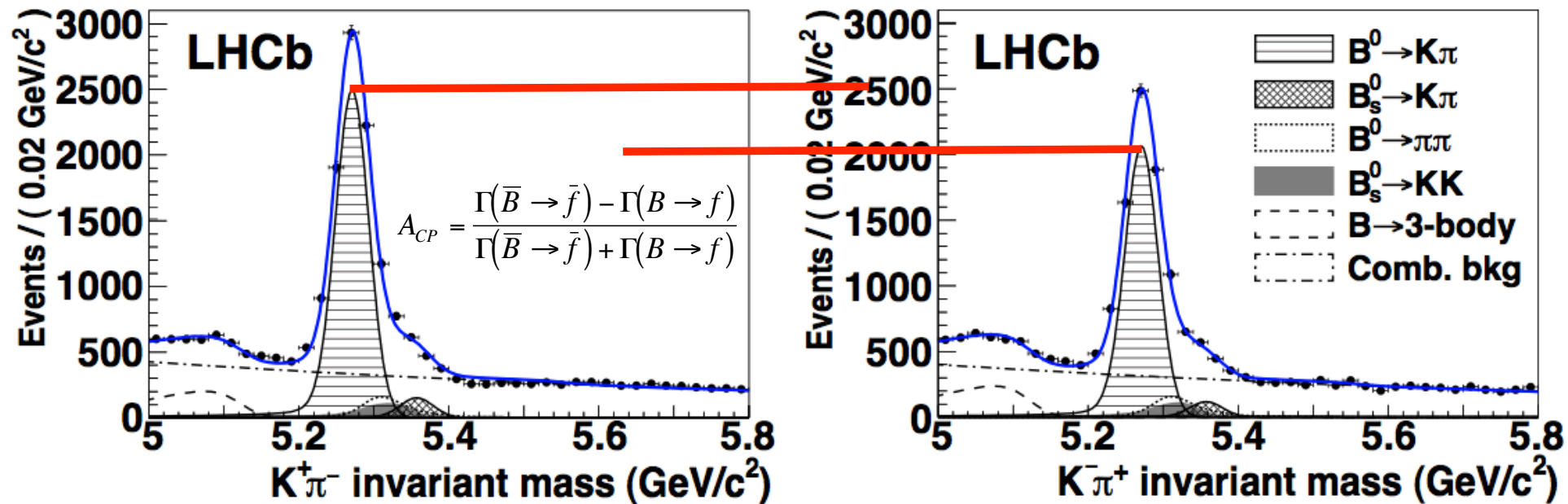
$$A_{\pi\pi}^{dir} \approx A_{CP}(B_s \rightarrow \pi K) \quad A_{KK}^{dir} \approx A_{CP}(B^0 \rightarrow K\pi)$$

- $B^0 \rightarrow K^+K^-$ and $B_s \rightarrow \pi^+\pi^-$ decays occur only through annihilation diagrams

Direct CP asymmetry in $B^0 \rightarrow K\pi$

arXiv:1202.6251 (accepted by PRL)

$\int L dt = 0.35 \text{ fb}^{-1}$ ➔ $\sim 13\text{k } B^0 \rightarrow K\pi$



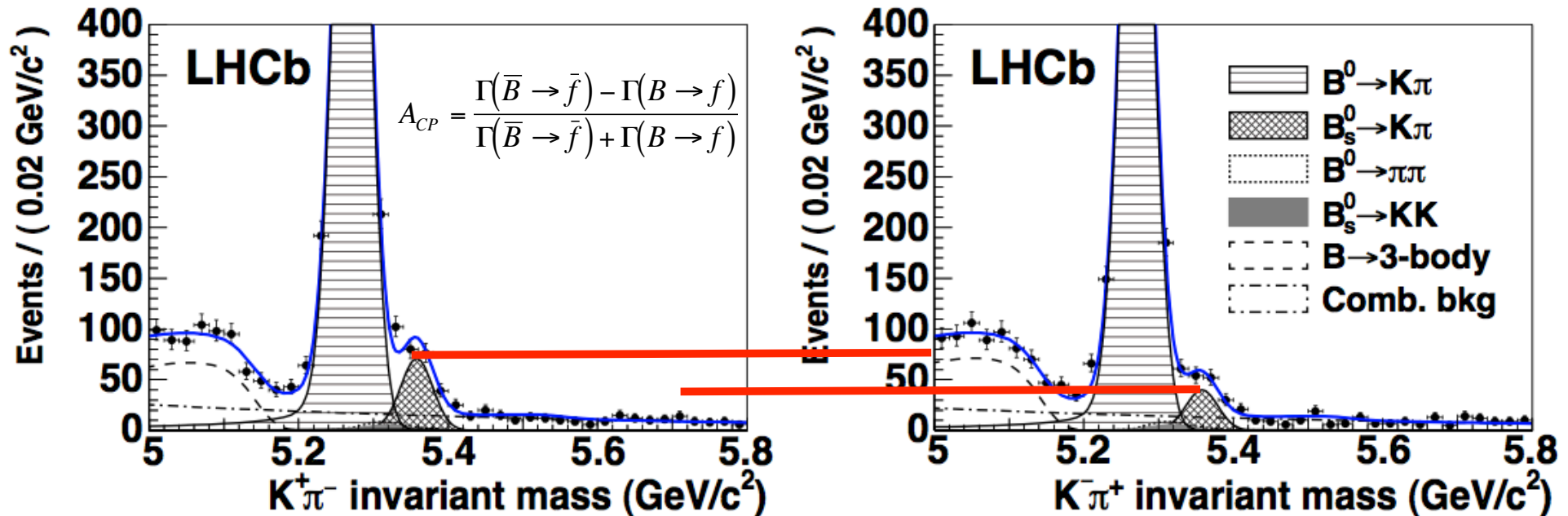
$$A_{CP}(B^0 \rightarrow K\pi) = -0.088 \pm 0.011 \text{ (stat)} \pm 0.008 \text{ (syst)}$$

World's best and first observation of CP violation at an hadron collider ($> 6\sigma$)

In agreement with HFAG world average: $A_{CP}^{HFAG}(B^0 \rightarrow K\pi) = -0.098^{+0.012}_{-0.011}$

Direct CP asymmetry in $B_s \rightarrow \pi K$

arXiv:1202.6251 (accepted by PRL) $\int Ldt = 0.35 \text{ fb}^{-1}$ \rightarrow $\sim 300 B_s \rightarrow \pi K$



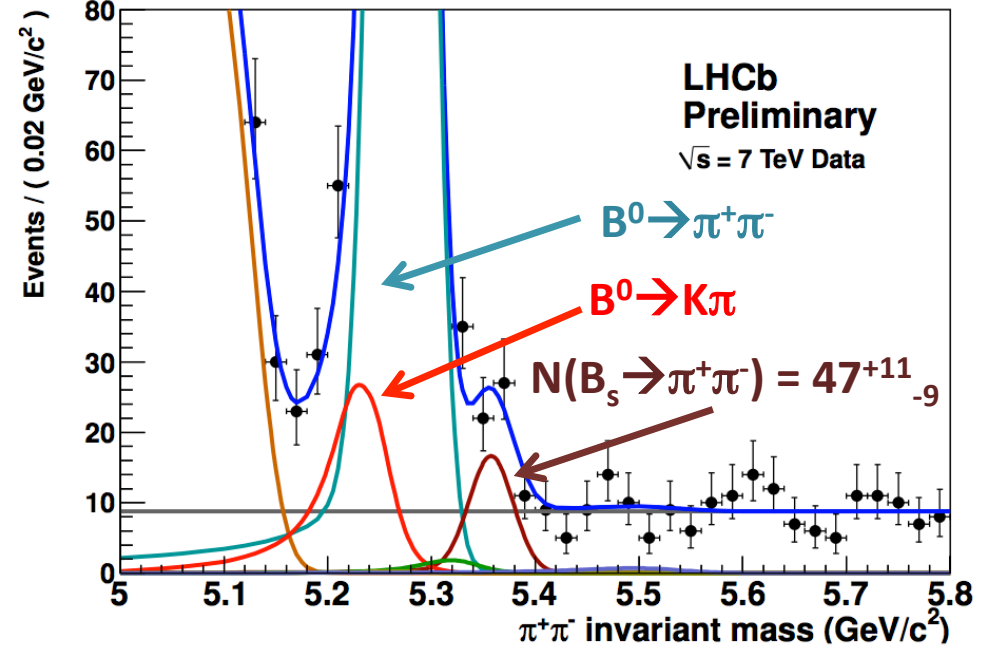
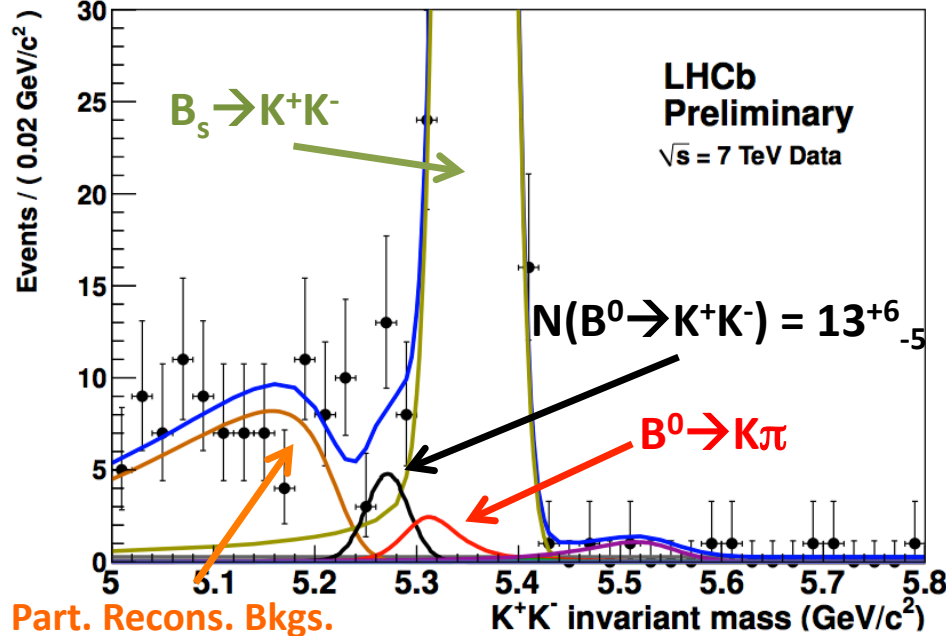
$$A_{CP}(B_s^0 \rightarrow K\pi) = 0.27 \pm 0.08 \text{ (stat)} \pm 0.02 \text{ (syst)}$$

First evidence of CP violation in B_s decays (3.3σ)

$$A_{CP}(B_s \rightarrow \pi K) = 0.39 \pm 0.15 \pm 0.08 \quad \text{CDF [Phys. Rev. Lett. 106 (2011) 181802]}$$

$$A_{CP}(B_s \rightarrow \pi K) \approx A_{dir}^{\pi\pi} = \begin{cases} 0.25 \pm 0.08 \pm 0.02 & \text{BaBar} \\ 0.55 \pm 0.08 \pm 0.05 & \text{Belle} \end{cases}$$

LHCb-CONF-2011-042 $\int Ldt = 0.32 \text{ fb}^{-1}$



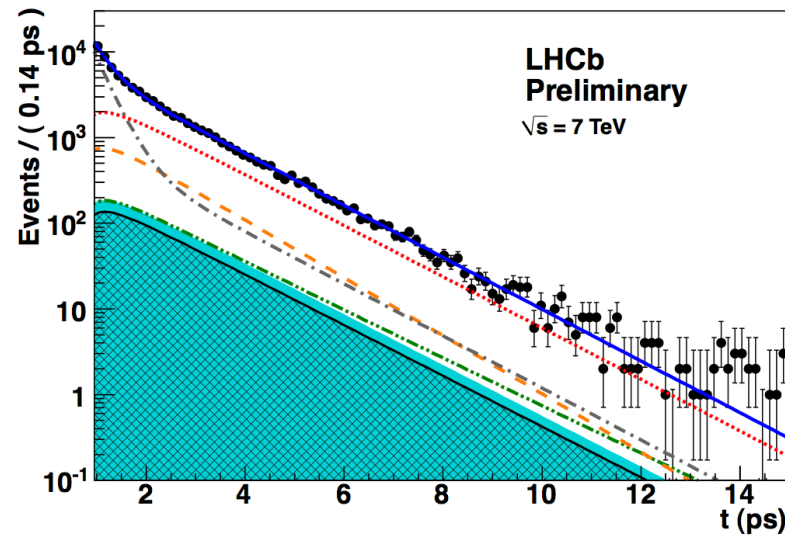
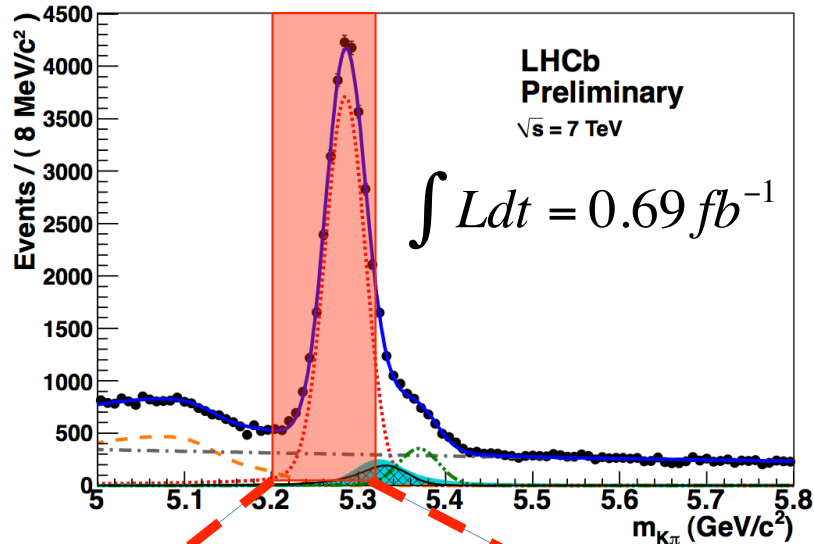
$$\mathcal{BR}(B^0 \rightarrow K^+K^-) = (0.13_{-0.05}^{+0.06} \pm 0.07) \times 10^{-6}$$

$$\mathcal{BR}(B_s^0 \rightarrow \pi^+\pi^-) = (0.98_{-0.19}^{+0.23} \pm 0.11) \times 10^{-6}$$

First observation of $B_s \rightarrow \pi^+\pi^-$ decay with a significance of 5.3σ

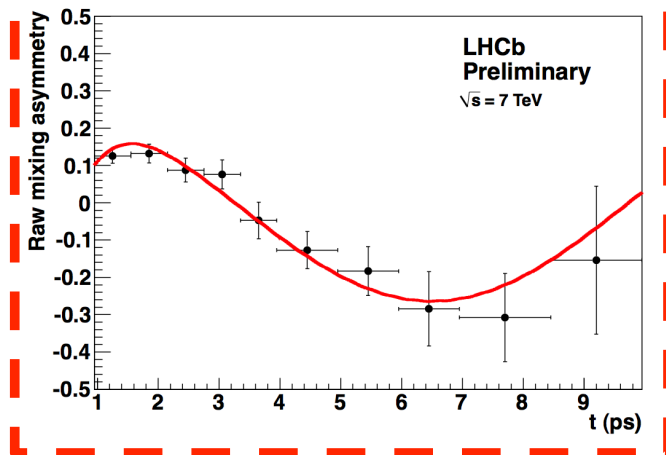
- $B_s \rightarrow \pi^+\pi^-$ is in a clean region of the invariant mass spectrum
- $B^0 \rightarrow K^+K^-$ is more challenging due to the presence of $B^0 \rightarrow K\pi$ cross-feed background and partially reconstructed backgrounds

Time-dependent $B \rightarrow K\pi$ fit



LHCb-CONF-2012-007

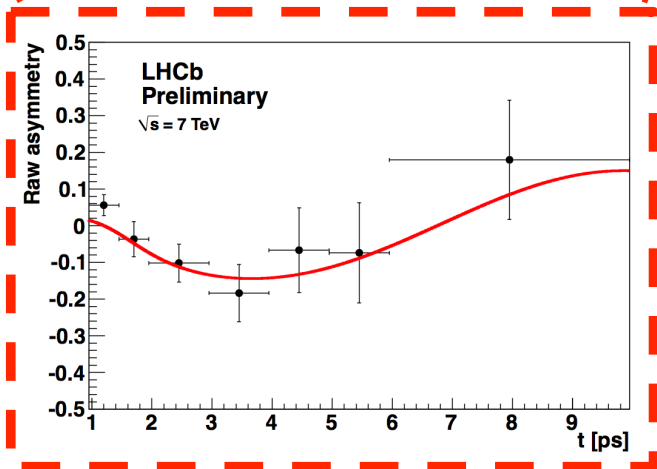
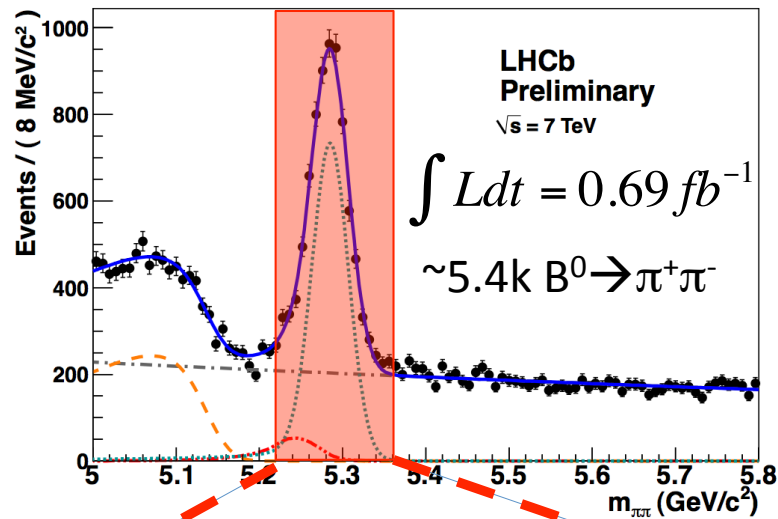
Note that the time-dependent fit allows to extract the production asymmetries



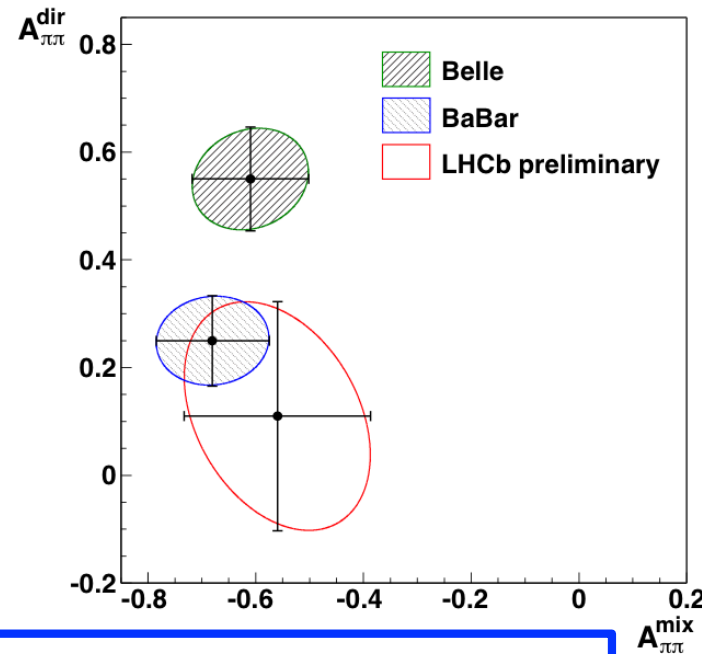
Production asymmetries:
 $A_p(B^0) = -0.015 \pm 0.013$
 $A_p(B_s) = -0.03 \pm 0.06$
 Tagging power:
 $eD^2 = 2.3 \pm 0.1 \%$

Values propagated as
 Gaussian terms into the
 $\pi\pi$ and KK likelihood
 functions

- Used to calibrate Opposite side flavour tagging
- Still need to introduce into the analysis same side- π and same side-K tags



First time-dependent CP asymmetry plot of $B^0 \rightarrow \pi^+\pi^-$ decay at an hadron collider



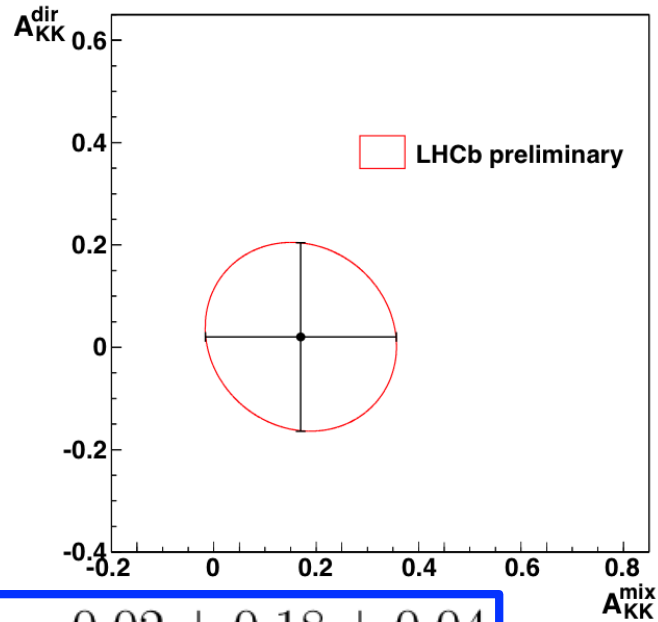
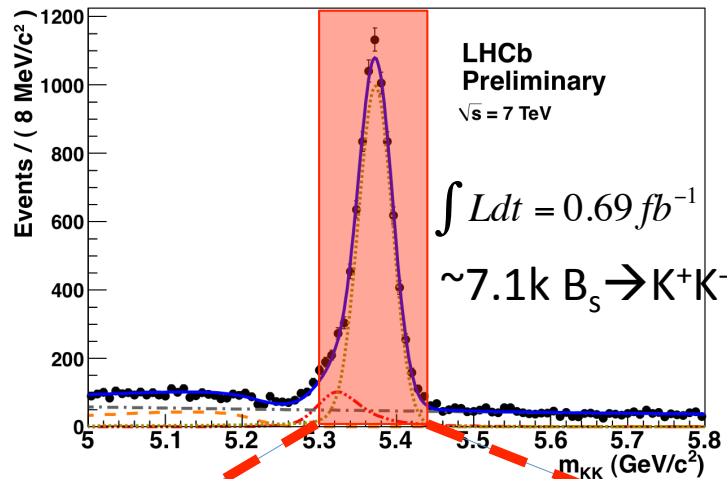
$$A_{\pi\pi}^{\text{dir}} = 0.11 \pm 0.21 \pm 0.03$$

$$A_{\pi\pi}^{\text{mix}} = -0.56 \pm 0.17 \pm 0.03$$

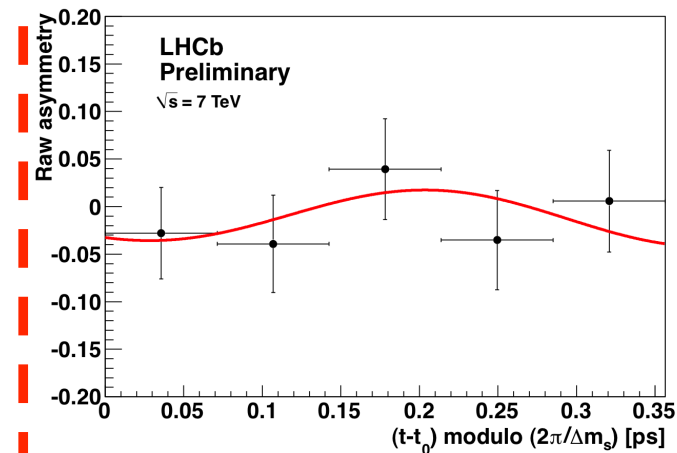
$$\rho(A_{\pi\pi}^{\text{dir}}, A_{\pi\pi}^{\text{mix}}) = -0.34.$$

- LHCb results are compatible with previous measurements
- A_{mix} is the first evidence of mixing-induced CP violation at an hadron collider (3.2σ)

LHCb-CONF-2012-007



LHCb-CONF-2012-007



$$A_{KK}^{\text{dir}} = 0.02 \pm 0.18 \pm 0.04$$

$$A_{KK}^{\text{mix}} = 0.17 \pm 0.18 \pm 0.05$$

$$\rho(A_{KK}^{\text{dir}}, A_{KK}^{\text{mix}}) = -0.10.$$

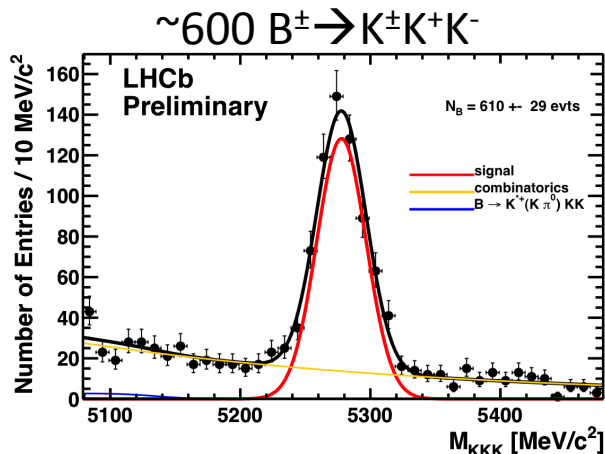
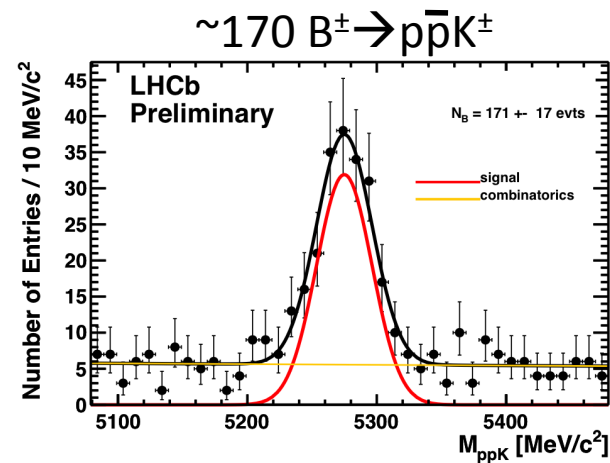
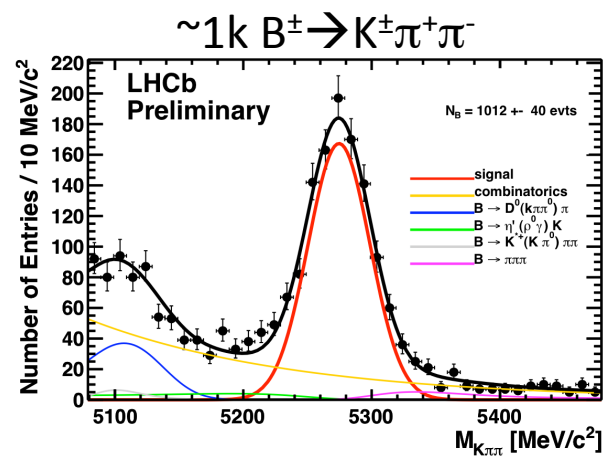
First time-dependent CP asymmetry plot of $B_s \rightarrow K^+K^-$ decay ever

- First measurement ever of time-dependent CP asymmetries of the $B_s \rightarrow K^+K^-$ decay
 - Statistical errors are still large
 - Will benefit from the introduction of SSK tagging

Prospects from charmless three-body B decays

- At the moment only branching ratio measurements of charmless $B \rightarrow hhh$ decays have been made public by LHCb
- Precise measurements of CP asymmetries are expected soon

LHCb-CONF-2011-059



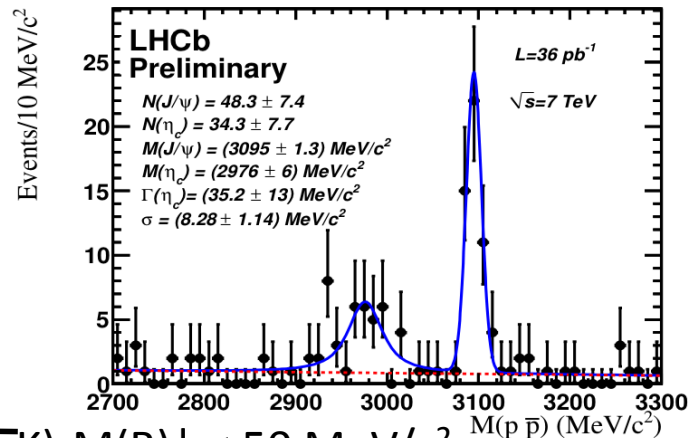
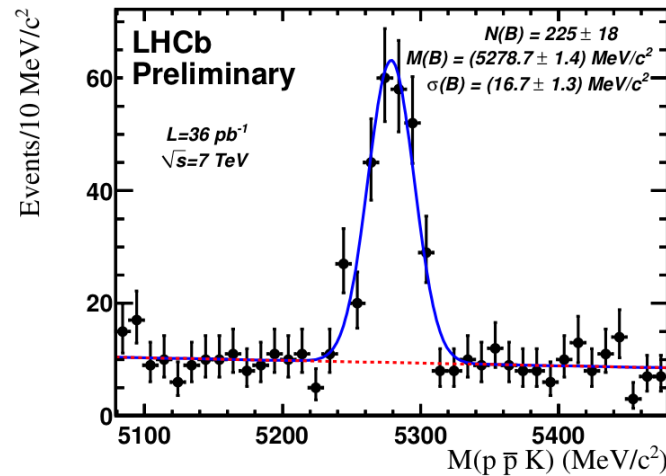
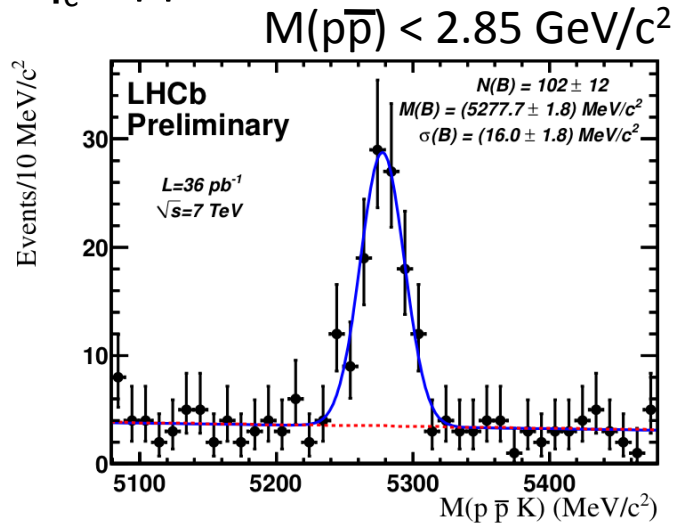
$$\frac{\mathcal{B}(B^\pm \rightarrow K^\pm K^+ K^-)}{\mathcal{B}(B^\pm \rightarrow K^\pm \pi^+ \pi^-)} = 0.52 \pm 0.03(\text{stat}) \pm 0.01(\text{syst}),$$

$$\frac{\mathcal{B}(B^\pm \rightarrow p\bar{p}K^\pm)}{\mathcal{B}(B^\pm \rightarrow K^\pm \pi^+ \pi^-)} = 0.19 \pm 0.02(\text{stat}) \pm 0.02(\text{syst}),$$

- Results based on 34 pb⁻¹
- ~ 30 times more statistics already in 2011 data

- From $B^\pm \rightarrow p\bar{p}K^\pm$ decays:
 - Branching ratio of non resonant decay
 - Relative contributions of the decays through charmonium states $J/\psi \rightarrow p\bar{p}$ and $\eta_c \rightarrow p\bar{p}$

LHCb-CONF-2011-058



$|M(p\bar{p}K) - M(B)| < 50 \text{ MeV}/c^2$

$$\frac{\mathcal{B}(B^\pm \rightarrow \eta_c K^\pm) \times \mathcal{B}(\eta_c \rightarrow p\bar{p})}{\mathcal{B}(B^\pm \rightarrow J/\psi K^\pm) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})} = 0.71 \pm 0.20_{\text{stat}} \pm 0.07_{\text{syst}}$$

$$\frac{\mathcal{B}(B^\pm \rightarrow p\bar{p}K^\pm)_{M_{p\bar{p}} < 2.85 \text{ GeV}/c^2}}{\mathcal{B}(B^\pm \rightarrow J/\psi K^\pm) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})} = 2.21 \pm 0.41_{\text{stat}} \pm 0.24_{\text{syst}}$$

$$\frac{\mathcal{B}(B^\pm \rightarrow p\bar{p}K^\pm)_{\text{all}}}{\mathcal{B}(B^\pm \rightarrow J/\psi K^\pm) \times \mathcal{B}(J/\psi \rightarrow p\bar{p})} = 4.6 \pm 0.6_{\text{stat}} \pm 0.5_{\text{syst}}$$

- Results based on 36 pb^{-1}

- $B \rightarrow h^+ h^-$ measurements:
 - Using 0.35 fb^{-1} LHCb obtained (arXiv:1202.6251, accepted by PRL):
 - World's best measurement of direct CP asymmetry of $B^0 \rightarrow K^+ \pi^-$
 - First evidence of direct CP asymmetry in B_s sector
 - Using 0.32 fb^{-1} LHCb measured the branching ratios of $B^0 \rightarrow K^+ K^-$ and $B_s \rightarrow \pi^+ \pi^-$ (LHCb-CONF-2011-042, paper in preparation)
 - First observation of rare mode $B_s \rightarrow \pi^+ \pi^-$: 5.3σ
 - Using 0.69 fb^{-1} LHCb obtained (LHCb-CONF-2012-007):
 - Measurement of time-dependent CP asymmetries in $B^0 \rightarrow \pi^+ \pi^-$ and $B_s \rightarrow K^+ K^-$ decays
 - Time-dependent CP asymmetry of $B_s \rightarrow K^+ K^-$ is measured for the first time

- $B \rightarrow h^+ h^-$ short term prospects:
 - Adding full 2011 statistics (1 fb^{-1})
 - Further constrain $A_{\text{CP}}(B^0 \rightarrow K^+ \pi^-)$ and $A_{\text{CP}}(B_s \rightarrow \pi^+ K^-)$
 - Update branching ratios of $B^0 \rightarrow K^+ K^-$ and $B_s \rightarrow \pi^+ \pi^-$ decays
 - Adding full 2011 statistics and same side tagging
 - Update of time-dependent asymmetries in $B^0 \rightarrow \pi^+ \pi^-$ and $B_s \rightarrow K^+ K^-$

- Results from $B \rightarrow hhh$
 - Measurement of relative BR's available with 2010 statistics: $\sim 35 \text{ pb}^{-1}$
 - Relative BR's of $B^\pm \rightarrow K^\pm K^+ K^-$ and $B^\pm \rightarrow p \bar{p} K^\pm$ with respect to $B^\pm \rightarrow K^\pm \pi^+ \pi^-$
 - Relative contribution of $B^\pm \rightarrow p \bar{p} K^\pm$ through charmonium states $J/\psi \rightarrow p \bar{p}$ and $\eta_c \rightarrow p \bar{p}$
 - A factor 30 of more statistics available with 2011 data
 - Work ongoing on CP asymmetry measurements