Time-dependent CP violation in the B system at LHCb

Sevda Esen
on behalf of the LHCb collaboration

EPS'2017

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

Time dependent CPV at LHCb

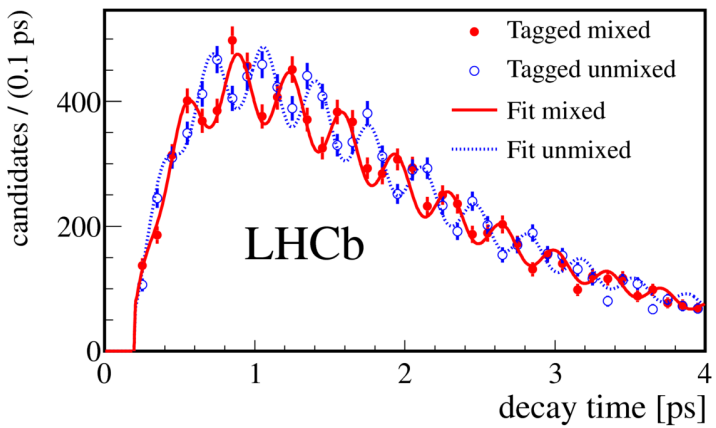
Time dependent asymmetry

$$\mathcal{A}_{CP} = \frac{\Gamma(\bar{B}(t) \to f) - \Gamma(B(t) \to f)}{\Gamma(\bar{B}(t) \to f) + \Gamma(B(t) \to f)} = \frac{S \sin(\Delta m t) - C \cos(\Delta m t)}{\cosh(\Delta\Gamma t/s) + \mathcal{A}_{\Delta\Gamma} \sinh(\Delta\Gamma t/s)}$$

Flavor tagging

- Sensitivity $\sigma_{stat} \propto \frac{1}{\sqrt{\epsilon(1-2w)N}}$
- LHCb taggers:
  - same side: π, K
  - opposite side: K, μ, e, vertex charge, charm

New J. Phys. 15 (2013) 053021



Acceptance

- Decay time: Trigger and reconstruction effects
- Angular: Detector acceptance region and reconstruction effects

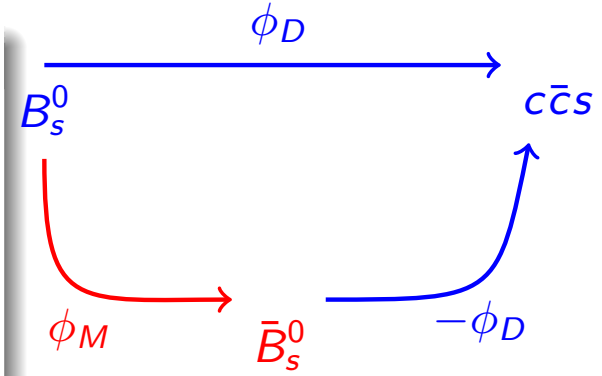
Resolution Int.J.Mod.Phys.A30, 1530022 (2015)

- Decay time: 40-50fs
- Angular: up to few mrad, negligible effect
- Mass: $\sigma_p/p \sim 0.5 - 1\%$

Measurement of $\phi_s^{c\bar{c}s} = -2\beta_s$

Interference between B_s mixing and decay

- $\phi_s^{SM} = -2arg(-\frac{V_{ts}V_{tb}^*}{V_{ts}V_{tb}^*}) = 0.0365^{+0.0013}_{-0.0012}$ [reference]
- Largest sensitivity from $B_s \to J/\psi\phi$ and $J/\psi f_0$
- Additional sensitivity from $D_s^+ D_s^-$ and $\psi(2S)\phi$



LHCb results with full run 1 data

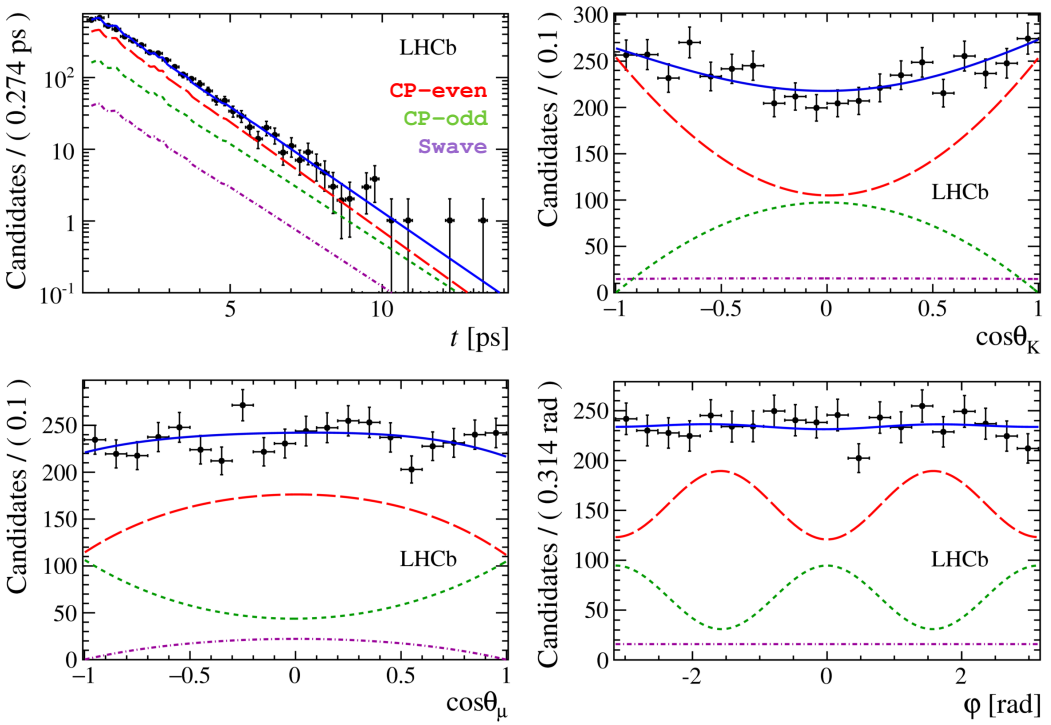
Decay	result	
$J/\psi\phi$	$-0.058 \pm 0.049 \pm 0.006$	PRL114, 041802 (2015)
$J/\psi\pi^+\pi^-$	$+0.070 \pm 0.068 \pm 0.008$	PLB B736, 186 (2014)
D_sD_s	$+0.02 \pm 0.17 \pm 0.02$	PRL113, 211801 (2014)
$\psi(2S)\phi$	$+0.23^{+0.29}_{-0.28} \pm 0.02$	PLB B762, 252-262 (2016)
$J/\psi K^+K^-$ above ϕ	$+0.119 \pm 0.107 \pm 0.034$	arxiv:1704.08217 (2107)
$J/\psi(e^+e^-)\phi$	ongoing	

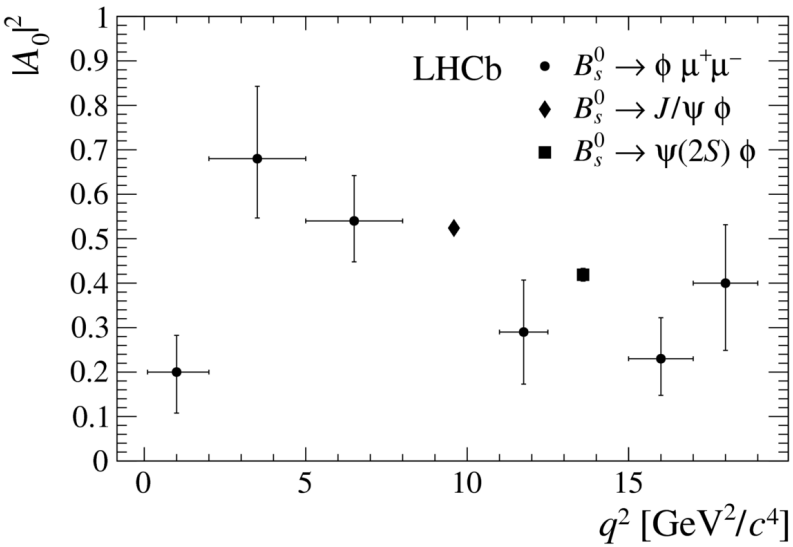
$B_s^0 \to \psi(2S)\phi$

PLB 762 (2016) 253–262

Analysis

- Similar to $B_s \to J/\psi\phi$ analysis
- Comparable time resolution and tagging power
- $B^0 \to \psi(2S)K^{*0}$ as control channel
- 4695 ± 71 signal events



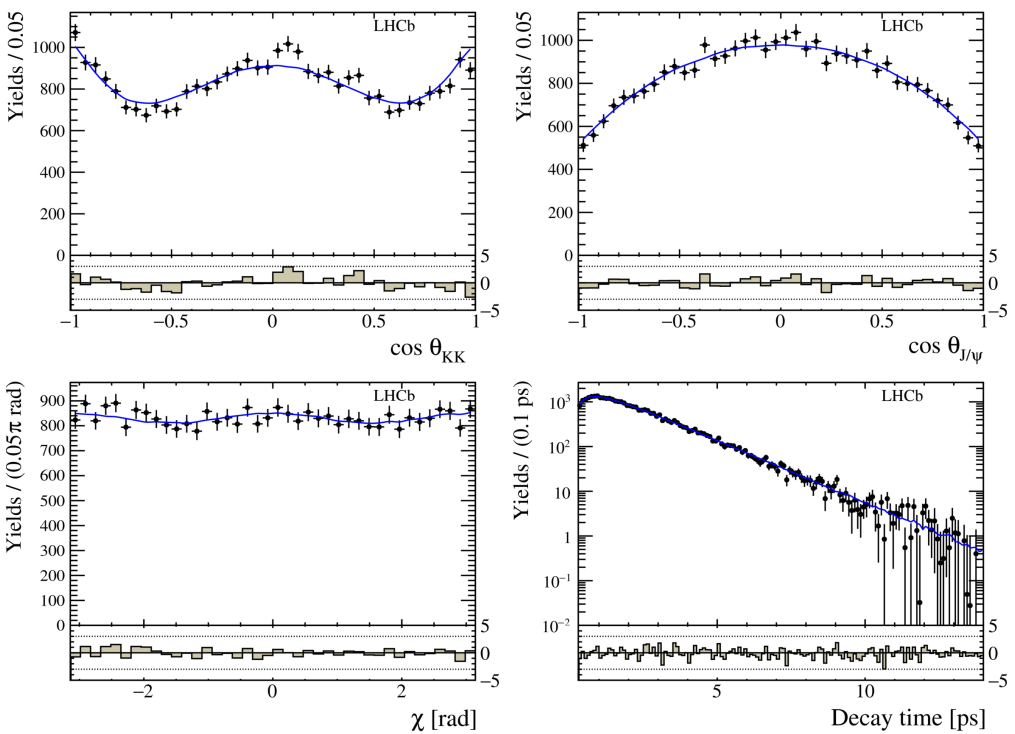


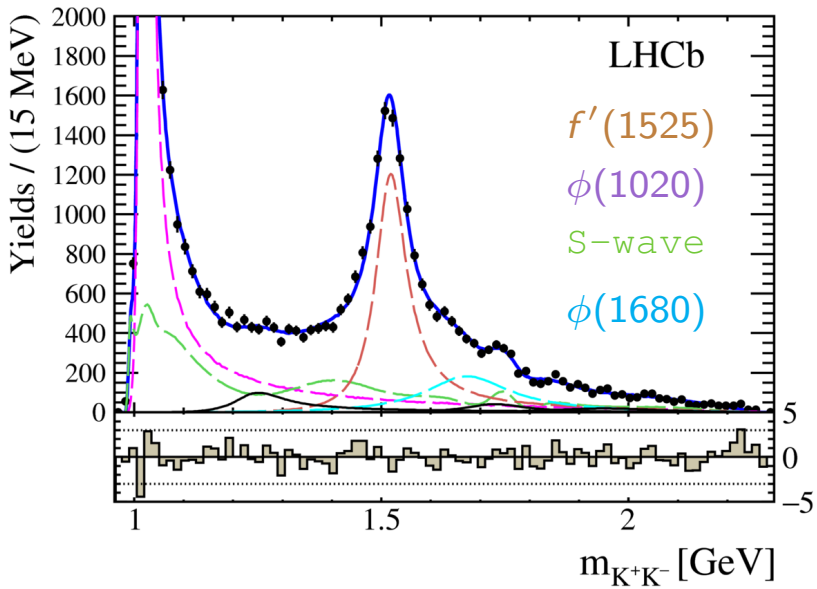
Parameter	Value
Γ_s [ps^{-1}]	$0.668 \pm 0.011 \pm 0.006$
$\Delta\Gamma_s$ [ps^{-1}]	$0.066^{+0.041}_{-0.044} \pm 0.007$
$\lvert A_\perp \rvert^2$	$0.264^{+0.024}_{-0.023} \pm 0.002$
$\lvert A_0 \rvert^2$	$0.422 \pm 0.014 \pm 0.003$
ϕ_s [rad]	$0.23^{+0.29}_{-0.28} \pm 0.02$
$\lvert\lambda\rvert$	$1.045^{+0.069}_{-0.050} \pm 0.007$

$B_s^0 \to J/\psi K^+K^-$

Analysis

- Amplitude analysis of K^+K^- spectrum
- Simultaneous fit to low and high m(K^+K^-) regions
  - $m_{KK} < 1020$ MeV $= 53440 \pm 240$ events
  - $m_{KK} > 1020$ MeV $= 33200 \pm 240$ events



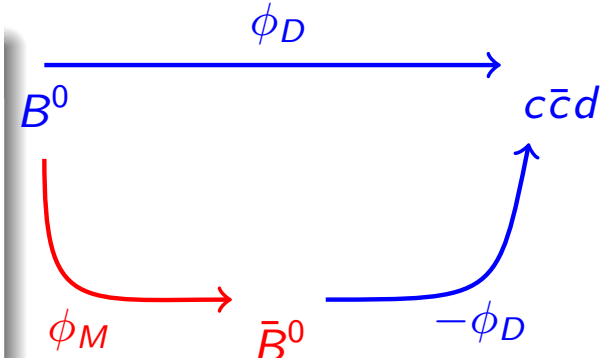


Parameter	Value
Γ_s [ps^{-1}]	$0.650 \pm 0.006 \pm 0.004$
$\Delta\Gamma_s$ [ps^{-1}]	$0.066 \pm 0.018 \pm 0.010$
ϕ_s [mrad]	$119 \pm 107 \pm 34$
$\lvert\lambda\rvert$	$0.994 \pm 0.018 \pm 0.006$

Measurement of $\phi_d^{c\bar{c}s} = -2\beta$

Interference between B^0 mixing and decay

- $\phi_d^{SM} = -2arg(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}) \Rightarrow \sin 2\beta = 0.771^{+0.017}_{-0.041}$
- Largest sensitivity from $B^0 \to J/\psi K_S$
- Small $\Delta\Gamma_d$ simplifies the analysis
- More from $\psi(2S)K_S$ and $J/\psi(e^+e^-)K_S$

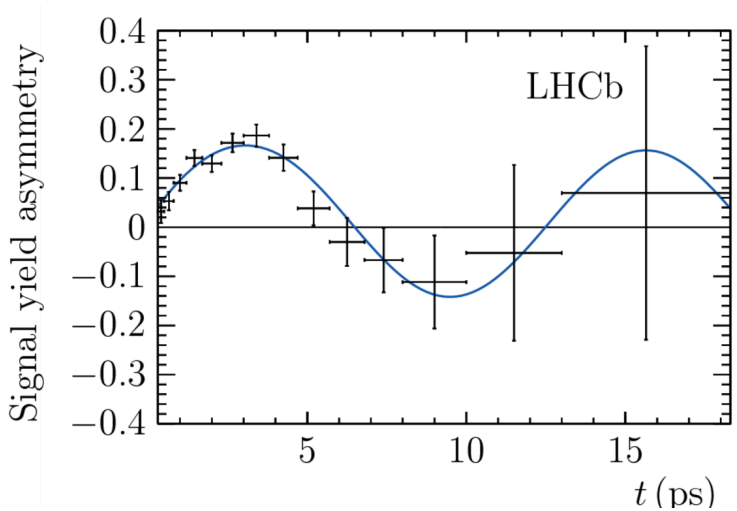


$B^0 \to J/\psi K_S$ analysis in run I

PRL 115, 031601 (2015)

- 41560 ± 270 signal events
- Tagging power: 3.02%
- Measured:
  - $S = 0.731 \pm 0.035(stat) \pm 0.020(syst)$
  - $C = -0.038 \pm 0.032(stat) \pm 0.005(syst)$

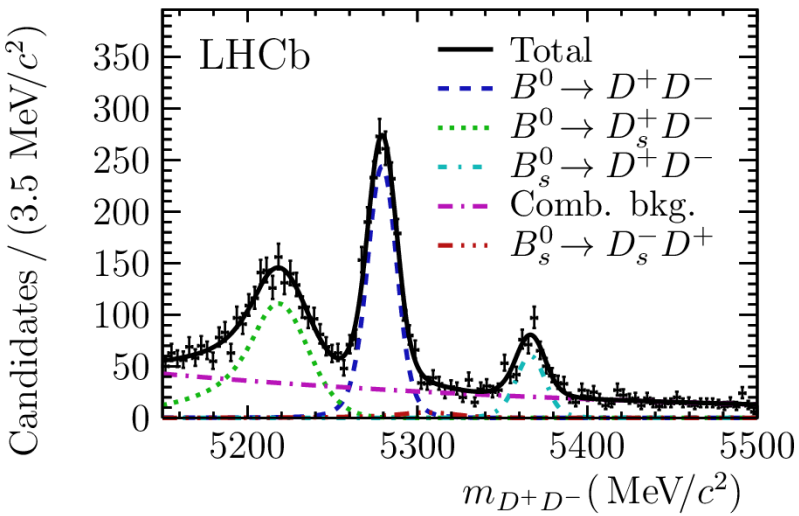
with $\rho(S, C) = 0.483$

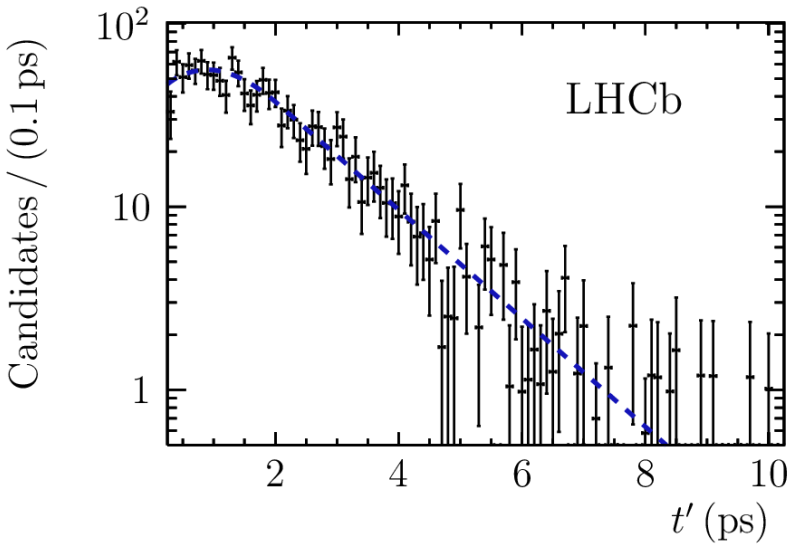


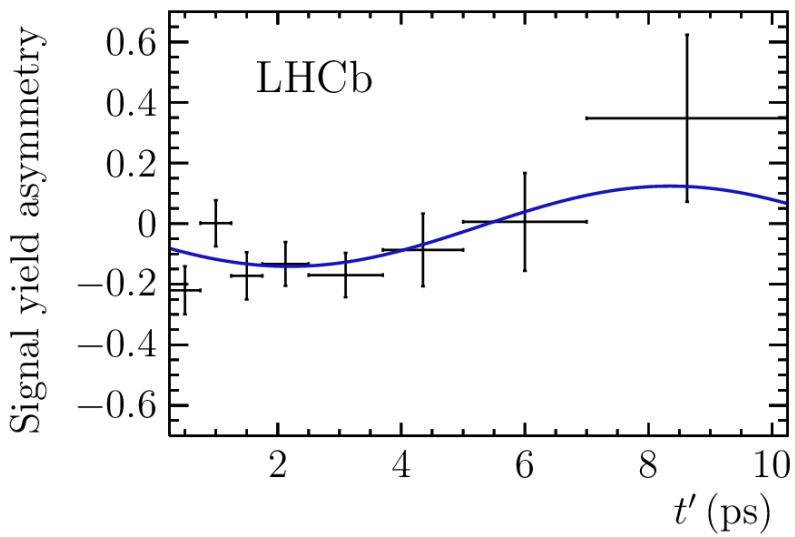
$B^0 \to D^+D^-$

Analysis

- CP even final state
- Enhanced penguin contribution compare to $B^0 \to J/\psi K_S$
- Shift in ϕ_d: $\Delta\phi = S/(\sqrt{1-C^2})$
- $D^+ \to K^-\pi^+\pi^+$ and $K^-K^+\pi^+$
- 1610 ± 50 signal events
- Tagging power: $(8.1 \pm 0.6)\%$





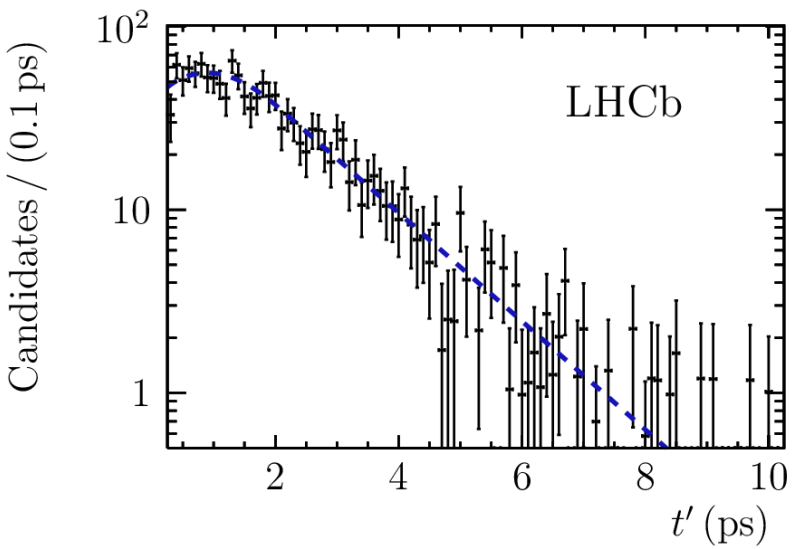


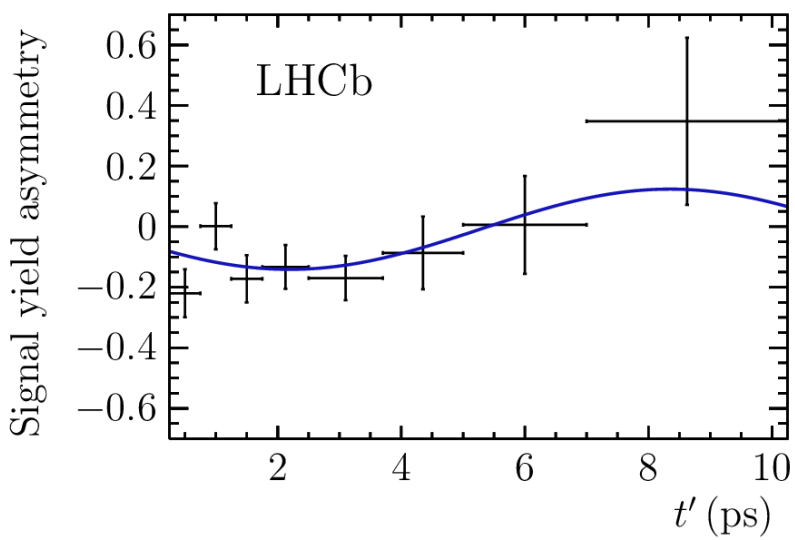
$B^0 \to D^+ D^-$

Analysis

- CP even final state
- Enhanced penguin contribution compare to $B^0 \to J/\psi K_S$
- Shift in ϕ_d: $\Delta\phi = S/(\sqrt{1-C^2})$
- $D^+ \to K^-\pi^+\pi^+$ and $K^-K^+\pi^+$
- 1610 ± 50 signal events
- Tagging power: $(8.1 \pm 0.6)\%$

Parameter	Value
S	$-0.54^{+0.17}_{-0.16} \pm 0.05$
C	$+0.26^{+0.18}_{-0.17} \pm 0.02$
$\Delta\phi$ [rad]	$-0.16^{+0.19}_{-0.21}$

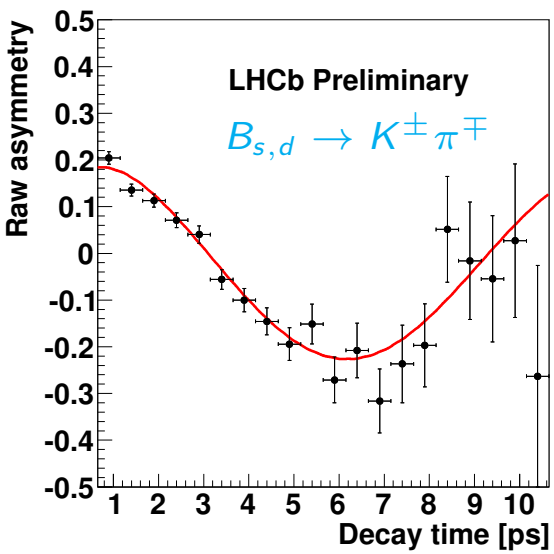


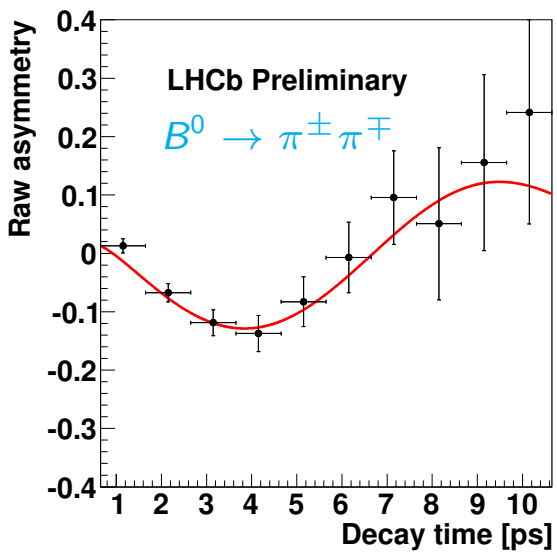


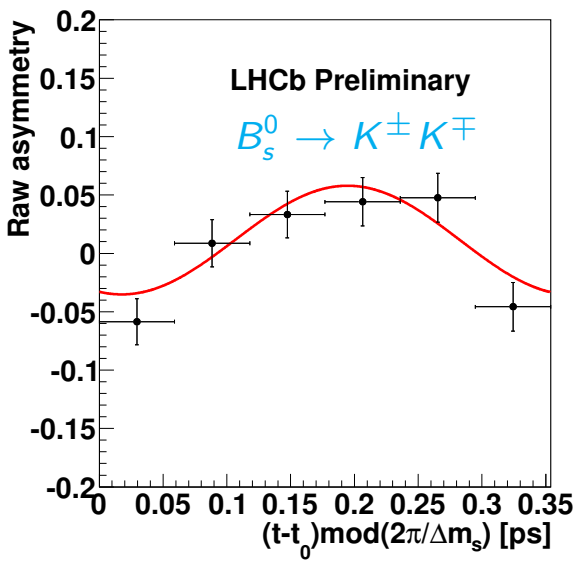
Analysis

- U-spin symmetry $\Rightarrow \gamma$ or $2\beta_s$
- Simultaneous fit to 4 channels
  - $B_s \to K^+K^-$ 36840 ± 222 events
  - $B_s \to K^-\pi^+$ 7032 ± 119 events
  - $B^0 \to \pi^+\pi^-$ 28652 ± 226 events
  - $B^0 \to K^+\pi^-$ 94220 ± 339 events
- $\Delta\Gamma_{s,d}$, $\Delta m_{s,d}$ and $\Gamma_{s,d}$ fixed

Parameter	Value
$C_{\pi\pi}$	-0.243 ± 0.069
$S_{\pi\pi}$	-0.681 ± 0.060
C_{KK}	$+0.236 \pm 0.062$
S_{KK}	$+0.216 \pm 0.062$
$A_{KK}^{\Delta\Gamma}$	-751 ± 0.075







Summary

- Many CPV results from B decays
- Measurements of ϕ_s and $\sin 2\beta$
  - statistically dominated
  - far from reaching theory sensitivity
  - no sign of NP but there is still room for it in B mixing