b hadron lifetimes and mixing

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UK flavour workshop, Sept 6th 2013

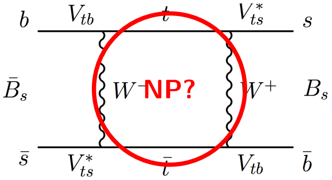
1. Measurements of $\Delta\Gamma_s, \phi_s$
2. Measurements of $\Delta m_{s,d}$
3. (Effective) lifetimes

Science & Technology Facilities Council

Brief introduction to $B^0_{s,d}$ meson mixing

$$i\frac{\partial}{\partial t}\begin{pmatrix} B^0_{s,d}(t) \\ \overline{B}^0_{s,d}(t) \end{pmatrix} = \left(\begin{bmatrix} M_{11} & M_{12} \\ M^*_{12} & M_{11} \end{bmatrix} - \frac{i}{2}\begin{bmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma^*_{12} & \Gamma_{11} \end{bmatrix} \right) \begin{pmatrix} B^0_{s,d}(0) \\ \overline{B}^0_{s,d}(0) \end{pmatrix}$$

$$\varphi_{12} = \arg\left(-\frac{M_{12}}{\Gamma_{12}}\right)$$



$$|B^0_L\rangle = p|B^0\rangle + q|\overline{B}^0\rangle$$
$$|B^0_H\rangle = p|B^0\rangle - q|\overline{B}^0\rangle$$

1. Large mass of b quark allows for reliable calculations.
2. Mixing is FCNC process $\rightarrow$ sensitive to new physics contributions.
3. Need **precision** measurements.

$B^0_{s,d}$ mixing observables

$$\mathrm{M_{B^0}} \equiv \frac{1}{2}(\mathrm{M_H} + \mathrm{M_L}) = \mathrm{M_{11}}, \qquad \Gamma \equiv \frac{1}{2}(\Gamma_\mathrm{L} + \Gamma_\mathrm{H}) = \Gamma_{11}$$

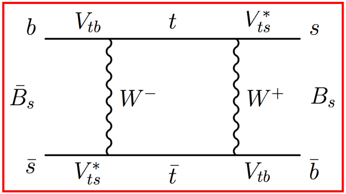
$$\Delta\mathrm{m} \equiv \mathrm{M_H} - \mathrm{M_L} \approx 2|\mathrm{M_{12}}|, \qquad \Delta\Gamma \equiv \Gamma_\mathrm{L} - \Gamma_\mathrm{H} \approx 2|\Gamma_{12}|\cos\varphi_{12}$$

	SM predictions (Lenz et al, 1102.4274, 1008.1593)	
	B^0	B^0_s
φ_{12} [rad]	-0.075 ± 0.024	0.004 ± 0.001
$\Delta\Gamma$ [ps^{-1}]	$(2.7 \pm 0.5) \cdot 10^{-3}$	0.087 ± 0.021
$\Delta\mathrm{m}$ [ps^{-1}]	0.555 ± 0.073	17.3 ± 2.6
$\mathrm{a_{fs}}$	$-(4.1 \pm 0.6) \cdot 10^{-4}$	$(1.9 \pm 0.3) \cdot 10^{-5}$
$\phi^{c\bar{c}s}$ [rad]	0.84 ± 0.05	-0.036 ± 0.002

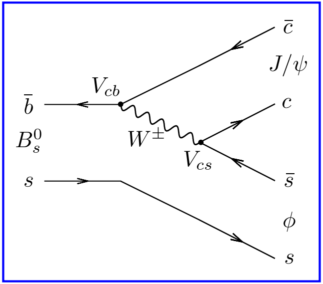
- Flavour specific final states, assuming no CP violation in decay:

$$\mathrm{a_{fs}} \equiv \frac{\Gamma_{\mathrm{B^0}\to\bar{\mathrm{f}}} - \Gamma_{\overline{\mathrm{B}}^0\to\mathrm{f}}}{\Gamma_{\mathrm{B^0}\to\bar{\mathrm{f}}} + \Gamma_{\overline{\mathrm{B}}^0\to\mathrm{f}}} \approx 1 - |\mathrm{q/p}|^2 \approx \frac{\Delta\Gamma}{\Delta\mathrm{m}}\tan\varphi_{12} \qquad \text{(Guennadi's talk)}$$

CP violation in $\mathrm{B_s^0}$ meson mixing/decay

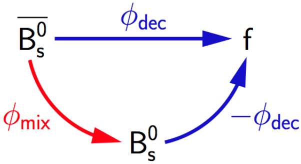


$$\phi_{mix} \equiv \arg(\mathrm{M_{12}}) = 2\arg(\mathrm{V_{ts}V_{tb}^*})$$



$$\phi_{dec} = \arg(\mathrm{V_{cs}V_{cb}^*})$$

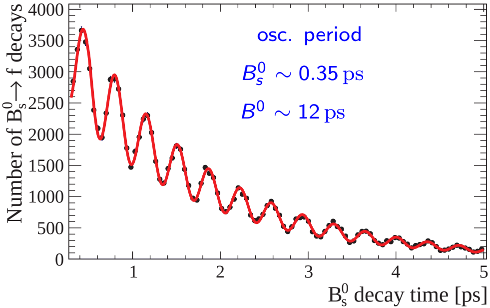
- Decay to CP-eigenstate f
  $\mathrm{A_f} \equiv \langle \mathrm{f}|\mathcal{H}|\mathrm{B^0}\rangle$, $\mathrm{\overline{A}_f} \equiv \langle \mathrm{f}|\mathcal{H}|\mathrm{\overline{B}^0}\rangle$
- **Use interference between mixing and decay to measure *CP*-violating phase**
  $\phi_s = \phi_{mix} - 2\phi_{dec}$
- Possible pollution from penguin decays.



How to measure ϕ_s

$$\Gamma_{B^0\to f}(t) = |A_f|^2(1+|\lambda_f|^2)\frac{e^{-\Gamma t}}{2}\left[\cosh\left(\tfrac{1}{2}\Delta\Gamma t\right) + D_f \sinh\left(\tfrac{1}{2}\Delta\Gamma t\right) + C_f\cos(\Delta m\, t) - S_f \sin(\Delta m\, t)\right]$$

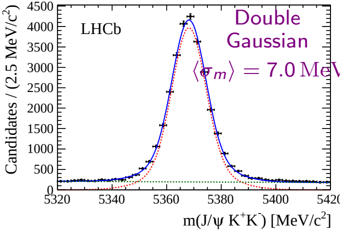
$$C_f \equiv \frac{1-|\lambda_f|^2}{1+|\lambda_f|^2}, \quad S_f \equiv \frac{2\Im(\lambda_f)}{1+|\lambda_f|^2}, \quad D_f \equiv -\frac{2\Re(\lambda_f)}{1+|\lambda_f|^2}, \quad \lambda_f \equiv \frac{q}{p}\frac{\bar{A}_f}{A_f}$$



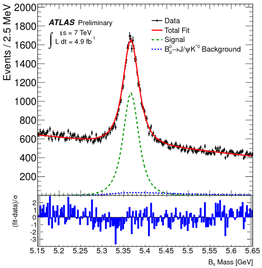
- Important to control:
  - Backgrounds
  - Decay time resolution ~ 45 fs
  - Tagging the flavour of the $B_s^0/\overline{B_s^0}$
  - Efficiencies

The GOLDEN mode: $B_s^0 \to J/\psi\phi$

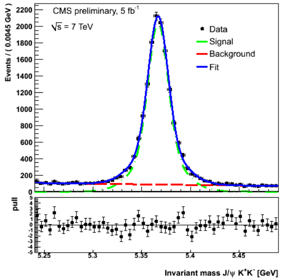
Phys. Rev. D 87, 112010 (2013)



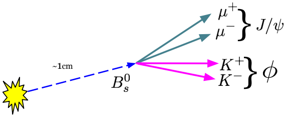
ATLAS-CONF-2013-039



CMS-PAS-BPH-11-006

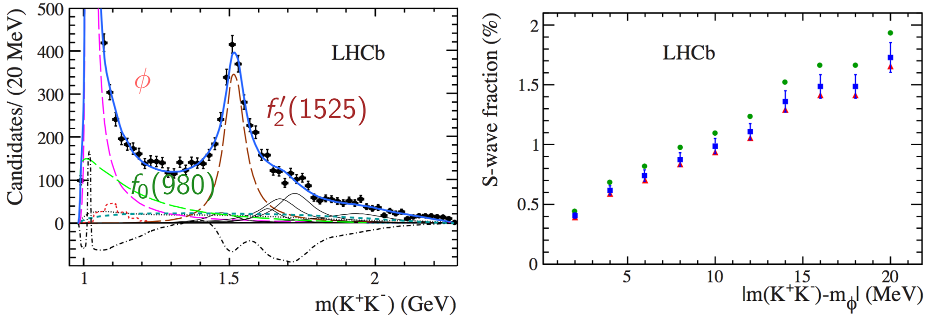


	LHCb	ATLAS	CMS
N_{sig}	27617	22690	19200
$\lvert m(K^+K^-) - m(\phi)\rvert$ [MeV/c^2]	± 30	± 10.5	± 10
$\langle\sigma_t\rangle$ [fs]	45	100	70
$\varepsilon_{tag}\mathcal{D}^2$	$\sim 3.0\%$	$\sim 1.5\%$	–



- Many of the results in this area rely on efficient triggering on dimuon events.
- LHCb has lower p_{T} thresholds than ATLAS/CMS (typically $\sim 4\,\mathrm{GeV}$).
- Important to understand efficiency of trigger as a function of B decay time.

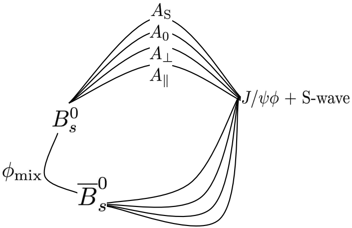
Closer look at the $\mathrm{K^+K^-}$ system in $\mathrm{B_s^0 \to J/\psi K^+K^-}$



- Modified Dalitz analysis of the $J/\psi\, K^+K^-$ system to understand higher order K^+K^- resonances.
- Possibility of using $\mathrm{B_s^0 \to J/\psi f_2'(1525)}$ for *CP* violation studies.[1]

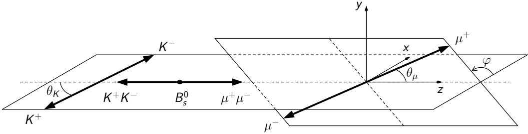
[1] Phys. Rev. D, Phys. Rev. Lett. 108 (2012) 151801, Phys. Rev. D86 (2012) 092011

Separating CP-odd and CP-even



- Spin-0 particle ($\mathrm{B_s^0}$) decaying to two spin-1 particles ($\mathrm{J}/\psi, \phi$).

$\Rightarrow$ Final state is ad-mixture of CP-odd and CP-even.

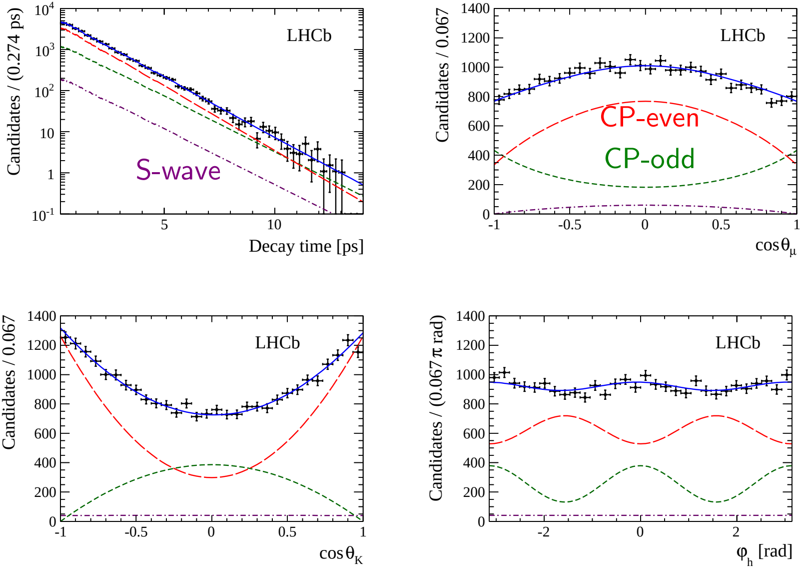


$$h_k(t) = N_k e^{-\Gamma_s t}\left[a_k \cosh\left(\tfrac{1}{2}\Delta\Gamma_s t\right) + b_k \sinh\left(\tfrac{1}{2}\Delta\Gamma_s t\right) + c_k \cos(\Delta m_s t) + d_k \sin(\Delta m_s t)\right]$$

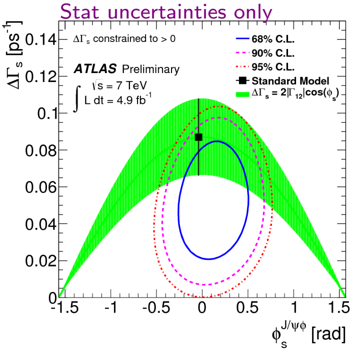
k	$f_k(\theta_\mu, \theta_K, \varphi_h)$	N_k	a_k	b_k	c_k	d_k
1	$2\cos^2\theta_K \sin^2\theta_\mu$	$\lvert A_0\rvert^2$	1	D	C	$-S$
2	$\sin^2\theta_K\left(1-\sin^2\theta_\mu\cos^2\varphi_h\right)$	$\lvert A_\parallel\rvert^2$	1	D	C	$-S$
3	$\sin^2\theta_K\left(1-\sin^2\theta_\mu\sin^2\varphi_h\right)$	$\lvert A_\perp\rvert^2$	1	$-D$	C	S
4	$\sin^2\theta_K\sin^2\theta_\mu\sin 2\varphi_h$	$\lvert A_\parallel A_\perp\rvert$	$C\sin(\delta_\perp-\delta_\parallel)$	$S\cos(\delta_\perp-\delta_\parallel)$	$\sin(\delta_\perp-\delta_\parallel)$	$D\cos(\delta_\perp-\delta_\parallel)$
5	$\frac{1}{2}\sqrt{2}\sin 2\theta_K\sin 2\theta_\mu\cos\varphi_h$	$\lvert A_0 A_\parallel\rvert$	$\cos(\delta_\parallel-\delta_0)$	$D\cos(\delta_\parallel-\delta_0)$	$C\cos(\delta_\parallel-\delta_0)$	$-S\cos(\delta_\parallel-\delta_0)$
6	$-\frac{1}{2}\sqrt{2}\sin 2\theta_K\sin 2\theta_\mu\sin\varphi_h$	$\lvert A_0 A_\perp\rvert$	$C\sin(\delta_\perp-\delta_0)$	$S\cos(\delta_\perp-\delta_0)$	$\sin(\delta_\perp-\delta_0)$	$D\cos(\delta_\perp-\delta_0)$
7	$\frac{2}{3}\sin^2\theta_\mu$	$\lvert A_S\rvert^2$	1	$-D$	C	S
8	$\frac{1}{3}\sqrt{6}\sin\theta_K\sin 2\theta_\mu\cos\varphi_h$	$\lvert A_S A_\parallel\rvert$	$C\cos(\delta_\parallel-\delta_S)$	$S\sin(\delta_\parallel-\delta_S)$	$\cos(\delta_\parallel-\delta_S)$	$D\sin(\delta_\parallel-\delta_S)$
9	$-\frac{1}{3}\sqrt{6}\sin\theta_K\sin 2\theta_\mu\sin\varphi_h$	$\lvert A_S A_\perp\rvert$	$\sin(\delta_\perp-\delta_S)$	$-D\sin(\delta_\perp-\delta_S)$	$C\sin(\delta_\perp-\delta_S)$	$S\sin(\delta_\perp-\delta_S)$
10	$\frac{4}{3}\sqrt{3}\cos\theta_K\sin^2\theta_\mu$	$\lvert A_S A_0\rvert$	$C\cos(\delta_0-\delta_S)$	$S\sin(\delta_0-\delta_S)$	$\cos(\delta_0-\delta_S)$	$D\sin(\delta_0-\delta_S)$

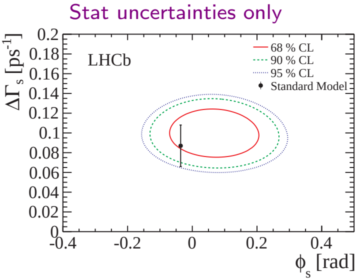
Projection of time-dependent angular fit

- 4D, background subtracted fit using sWeights.
- Angular acceptance extracted from simulation.



$\Delta\Gamma_s - \phi_s$ contours





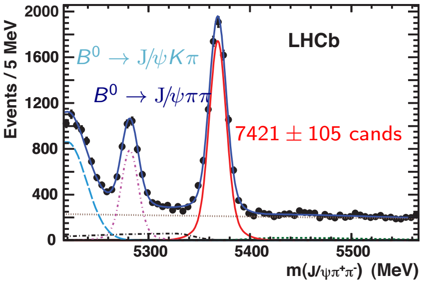
	LHCb	ATLAS	CMS
$\phi_s[\,\mathrm{rad}\,]$	$0.07 \pm 0.09 \pm 0.01$	$0.12 \pm 0.25 \pm 0.11$	–
$\Gamma_s[\,\mathrm{ps}^{-1}\,]$	$0.663 \pm 0.005 \pm 0.006$	$0.677 \pm 0.007 \pm 0.003$	$0.655 \pm 0.008 \pm 0.003$
$\Delta\Gamma_s[\,\mathrm{ps}^{-1}\,]$	$0.100 \pm 0.016 \pm 0.003$	$0.053 \pm 0.021 \pm 0.009$	$0.048 \pm 0.024 \pm 0.003$

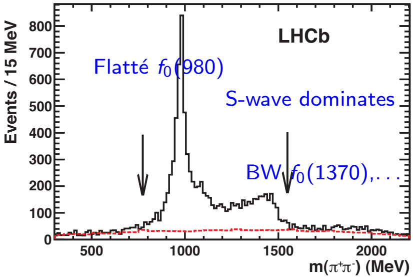
- Main systematic comes from the tagging, decay time acceptance and knowledge of the background.

ϕ_s from $B_s^0 \to J/\psi\pi^+\pi^-$

arXiv:1204.5675v3, PLB

- $B_s^0 \to J/\psi\pi^+\pi^-$ is another $\bar{b} \to \bar{c}c\bar{s}$ transition.
- $\pi^+\pi^-$ is $> 97.7\%$ CP-odd @ 95% Conf. Level.

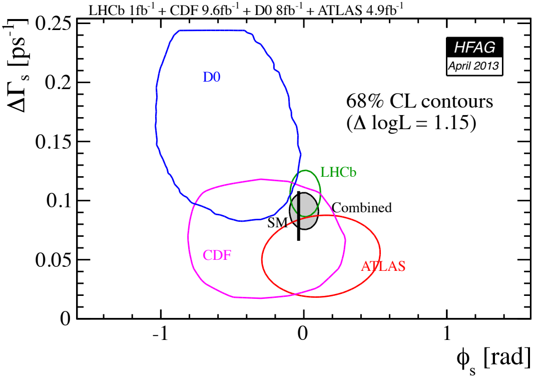




k	$f_k(\theta_\mu, \theta_K, \varphi_h)$	N_k	a_k	b_k	c_k	d_k
7	$\frac{2}{3}\sin^2\theta_\mu$	$\lvert A_S\rvert^2$	1	$-D$	C	S

$$\phi_s = -0.014^{+0.17}_{-0.16} \pm 0.01\,\text{rad}$$

Precision measurement of ϕ_s



- Only now are we reaching precision that is required to look for small deviations from the SM.
- With LHCb upgrade ($50\,\mathrm{fb}^{-1}$) expect precision on ϕ_s of $0.007\,\mathrm{rad}$.

$$
\begin{aligned}
\phi_s &= 0.01 \pm 0.07\ (\text{stat}) \pm 0.01\ (\text{syst})\ \text{rad},\\
\Gamma_s \equiv (\Gamma_\mathrm{L} + \Gamma_\mathrm{H})/2 &= 0.661 \pm 0.004\ (\text{stat}) \pm 0.006\ (\text{syst})\ \mathrm{ps}^{-1},\\
\Delta\Gamma_s \equiv \Gamma_\mathrm{L} - \Gamma_\mathrm{H} &= 0.106 \pm 0.011\ (\text{stat}) \pm 0.007\ (\text{syst})\ \mathrm{ps}^{-1},
\end{aligned}
$$

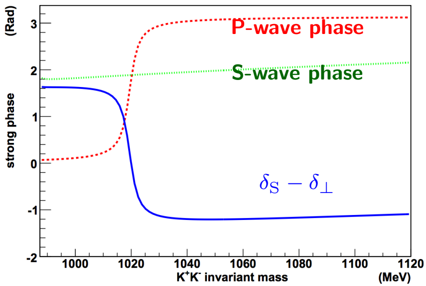
Resolving the ambiguity

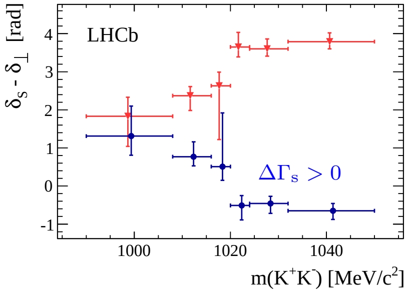
Phys. Rev. D 87, 112010 (2013)

- Expressions are invariant under the transformation, giving rise to a two-fold ambiguity.

$$(\phi_s, \Delta\Gamma_s, \delta_0, \delta_\parallel, \delta_\perp, \delta_S) \longmapsto (\pi - \phi_s, -\Delta\Gamma_s, -\delta_0, -\delta_\parallel, \pi - \delta_\perp, -\delta_S)$$

- Physical solution: $\Delta\Gamma_s > 0$
$\Rightarrow$ the heavy B_s^0 eigenstate lives longer than the light one!

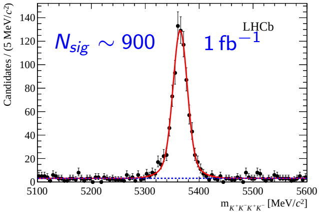


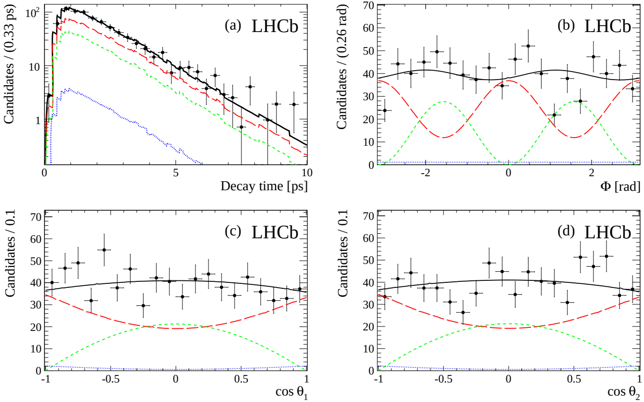


ϕ_s from $B_s^0 \to \phi\phi$

Phys. Rev. Lett. 110, 241802 (2013)

- First measurement using $b \to s\bar{s}s$ transition.
- Expect cancellation between (small) phase in the mixing and decay.
  - Measuring $\phi_s \neq 0$ would be null test of SM.

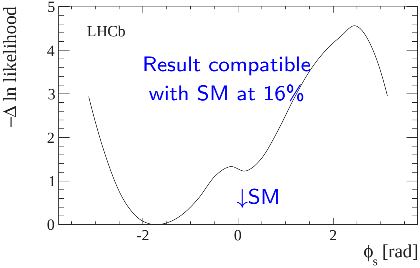




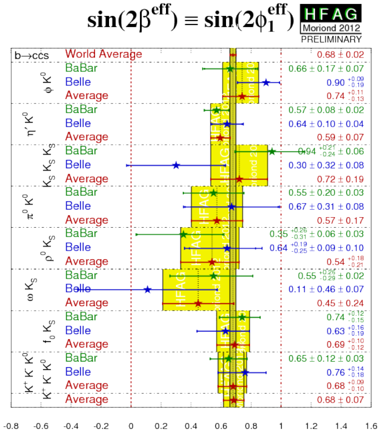
ϕ_s from $B_s^0 \to \phi\phi$

Phys. Rev. Lett. 110, 241802 (2013)

$\phi_s \in [-2.46, -0.76]$ rad at 68% CL



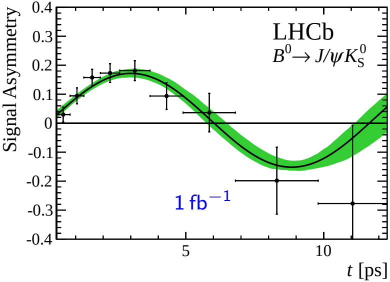
Hopefully help to resolve the $\sin 2\beta^{eff}$ situation.

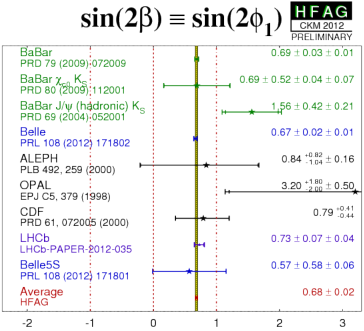


$\sin 2\beta$ using $B^0 \to J/\psi K^0_S$

Phys. Lett. B 721 (2013) 24-31

- $\sin 2\beta$ well measured at the B-factories, but we should continue.
- LHCb recently made most precise measurement at hadron collider.
- Update with $3\,\text{fb}^{-1}$ is ongoing, possibility of precision of 0.01 is possible with LHCb upgrade and Belle-II.





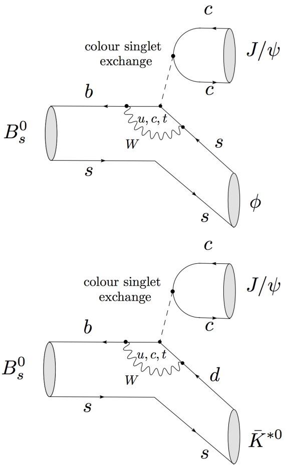
$$S_{J/\psi K^0_S} = 0.73 \pm 0.07 \pm 0.04$$
$$C_{J/\psi K^0_S} = 0.03 \pm 0.09 \pm 0.01$$

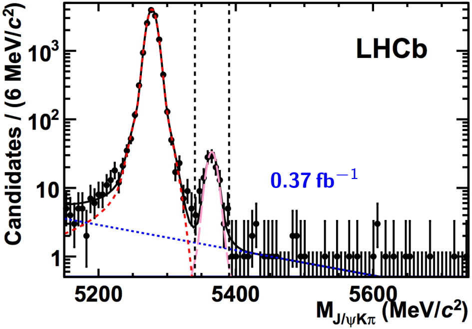
$$A_{CP}(t) \equiv \frac{\Gamma_{B^0\to f} - \Gamma_{\overline{B}^0\to f}}{\Gamma_{B^0\to f} + \Gamma_{\overline{B}^0\to f}} = S_{J/\psi K^0_S} \sin(\Delta m\, t) + C_{J/\psi K^0_S} \cos(\Delta m\, t)$$

Penguin pollutions

Phys. Rev. D 86 (2012) 071102

- Penguin contributions to ϕ_s are expected to be small. How can we control them?
- Possible to use $B_s^0 \to J/\psi \bar{K}^{*0}(892)$ ($\bar{b} \to \bar{c}c\bar{d}$) via U-spin symmetry.
  - Angular and time dependent analysis.
  - Direct CP asymmetries.



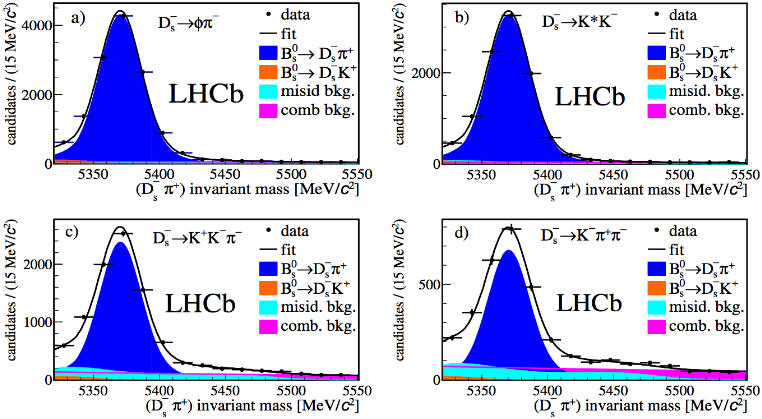


Δm_s using $B_s^0 \to D_s^- \pi^+$

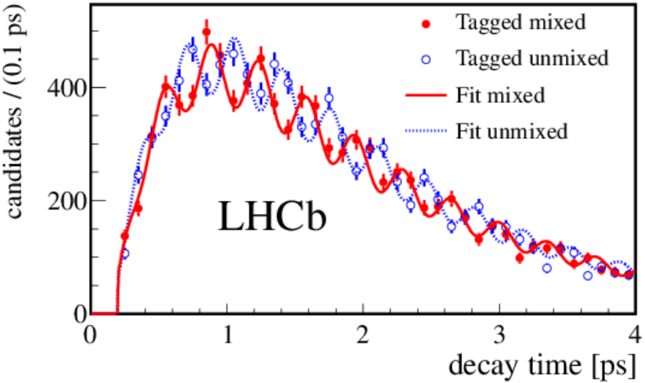
New J. Phys. 15 (2013) 053021

$$A_{mix}(t) = \frac{N(\text{unmixed}) - N(\text{mixed})}{N(\text{unmixed}) + N(\text{mixed})} \propto \frac{\cos(\Delta m t)}{\cosh(\Delta\Gamma t/2)}$$

- 5 different D_s decay modes: $D_s \to (K^+K^-)\pi^-, D_s \to (K^-\pi^+)\pi^-, D_s \to \pi^+\pi^-\pi^-$
- 2, 3, 4 track displaced vertex trigger. $\to$ **34k events**
- 1 large IP track, $p_T > 1.7\,\text{GeV}/c$.

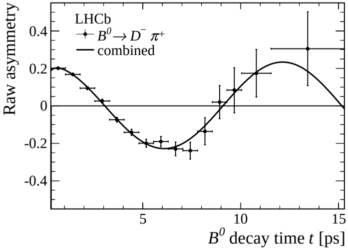


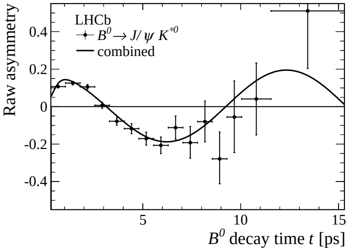
$$\Delta m_s^{SM} = 17.3 \pm 2.6\,\mathrm{ps}^{-1}$$
$$\Delta m_s = 17.768 \pm 0.023 \pm 0.006\,\mathrm{ps}^{-1}$$



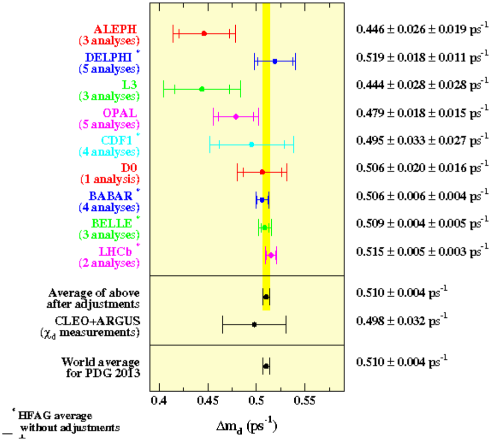
- Magnet polarity reversed periodically to cancel detector asymmetries.
- Main systematic from length and momentum scales.

Δm_d using $B^0 \to D\pi$, $B^0 \to J/\psi K^{*0}$ Phys. Lett. B 719 (2013) 318-325



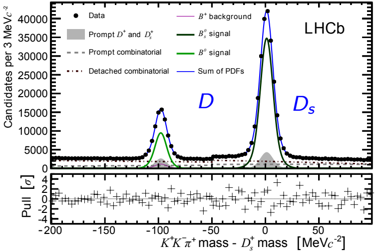


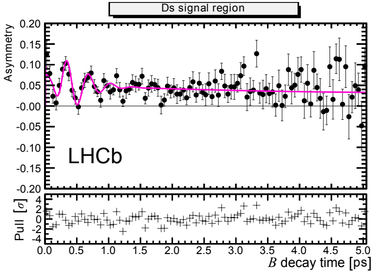
$$A_{mix}(t) = \frac{N(\text{unmixed}) - N(\text{mixed})}{N(\text{unmixed}) + N(\text{mixed})} \propto \frac{\cos(\Delta m_d t)}{\cosh(\Delta\Gamma_d t/2)}$$

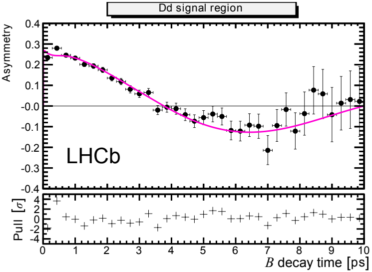


$$\Delta m_d^{SM} = 0.555 \pm 0.073\,\text{ps}^{-1}$$
$$\Delta m_d = 0.515 \pm 0.005 \pm 0.003\,\text{ps}^{-1}$$

- Select 1.8×10^6 $B^0_{(s)} \to D^-_{(s)} \mu^+$ (+ anything) events.
- Time resolution is $\sim 1\,\mathrm{ps}$, dominated by correction to momentum from missing ν.
- First observation of B^0_s mixing with only semileptonic decays.







$\Delta m_s = 17.93 \pm 0.22 \pm 0.15\,\mathrm{ps}^{-1}$

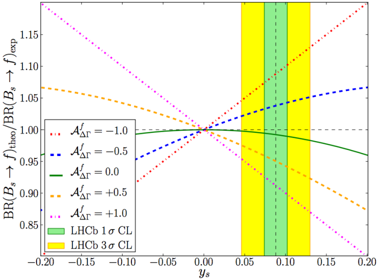
$\Delta m_d = 0.503 \pm 0.011 \pm 0.013\,\mathrm{ps}^{-1}$

Consequence of $\Delta\Gamma_s > 0$

Phys. Rev. D 86, 014027 (2012)

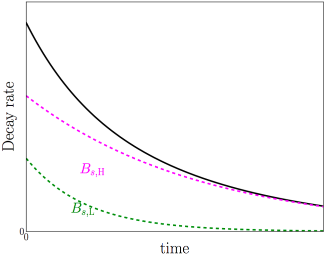
- Leads to different value for BR compared to theoretical ones.
- Biases of $\sim 10\%$, depending on decay mode.

$$\mathrm{BR}^{\mathrm{exp}}(B_s^0 \to f) = \mathrm{BR}^{\mathrm{theo}}(B_s^0 \to f)\left[\frac{1 + y_s A_f}{1 - y_s^2}\right]$$



- B_s^0 has two lifetimes, can define "effective lifetime".

$$\tau_{\mathrm{eff}} = \frac{1}{\Gamma_s}\left[\frac{1 + 2y_s A_f + y_s^2}{(1 - y_s^2)(1 + y_s A_f)}\right]$$



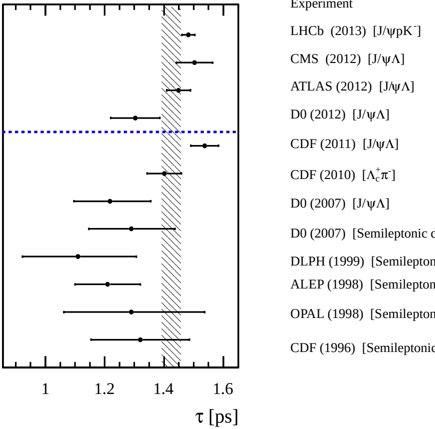
$$A_f = D_f \qquad y_s = \frac{\Delta\Gamma_s}{2\Gamma_s}$$

b hadron lifetimes

- b hadron decay dominated by the decay of the b quark.
- $\tau_{B^0} \sim \tau_{B^+} \sim \tau_{B_s^0} \sim \tau_{\Lambda_b}$
- Heavy quark expansion is very useful theoretical tool for making predictions.

$$
\begin{aligned}
\tau_{B^+}/\tau_{B^0} &= 1 + \mathcal{O}(1/m_b^3) \\
\tau_{B_s^0}/\tau_{B^0} &= (1.00 \pm 0.01) + \mathcal{O}(1/m_b^3) \\
\tau_{\Lambda_b}/\tau_{B^0} &= 0.98 + \mathcal{O}(1/m_b^3) \\
\tau_{\Omega_b^-}/\tau_{B^0} &= ??
\end{aligned}
$$

Λ_b lifetime arXiv:1307.2476

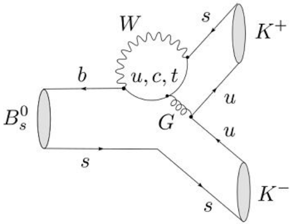


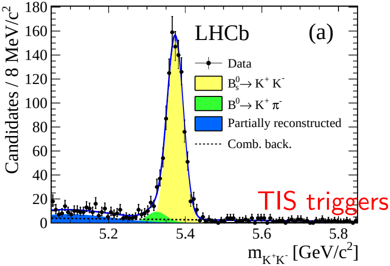
See talk from Roger Jones' yesterday.
See talk from Alex Lenz's later.

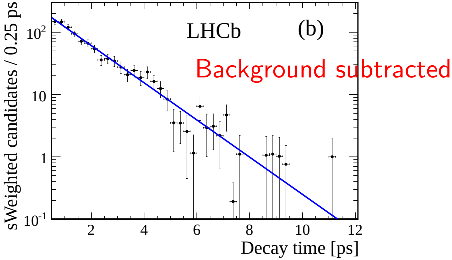
$B_s^0 \to K^+K^-$ effective lifetime

Phys. Lett. B 716 (2012) 393-400

- Penguin dominated decay $\Rightarrow$ sensitive to NP at loop level.
- K^+K^- final state is CP-even eigenstate $\Rightarrow$ decay is produced by light B_s^0 mass eigenstate.
  - Assuming no CP-violation: $\tau_{B_s^0 \to KK} = 1/\Gamma_L$.







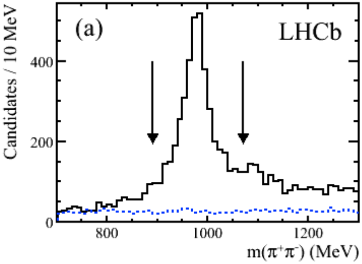
$$\tau^{SM}_{Bs \to KK} = 1.40 \pm 0.02\,\mathrm{ps}^2 \qquad \tau_{KK} = 1.455 \pm 0.046 \pm 0.006\,\mathrm{ps}$$

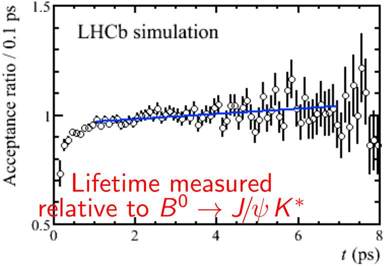
[2] (Eur. Phys. J C71, 1532)

$B_s^0 \to J/\psi\, f_0(980)$ effective lifetime

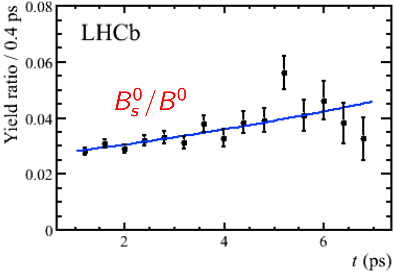
Phys. Rev. Lett. 109 (2012) 152002

- $J/\psi\, f_0(980)$ final state is CP-odd eigenstate $\Rightarrow$ decay is produced by heavy B_s^0 mass eigenstate.
  - Assuming no CP-violation: $\tau_{Bs\to KK} = \tau_H$.
- Main systematic related to acceptance from MC.





Lifetime measured relative to $B^0 \to J/\psi\, K^*$

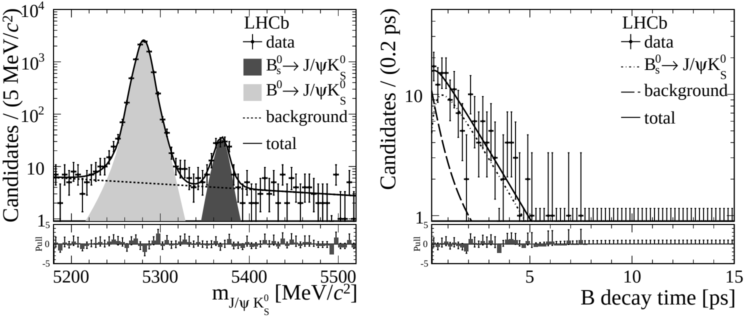


$\tau_{J/\psi\, f_0} = 1.700 \pm 0.040 \pm 0.026\,\mathrm{ps}$ $\qquad \Gamma_H = (0.588 \pm 0.014 \pm 0.009\,\mathrm{ps}^{-1})^3$

$B_s^0 \to J/\psi\, K^0_{\rm S}$ effective lifetime

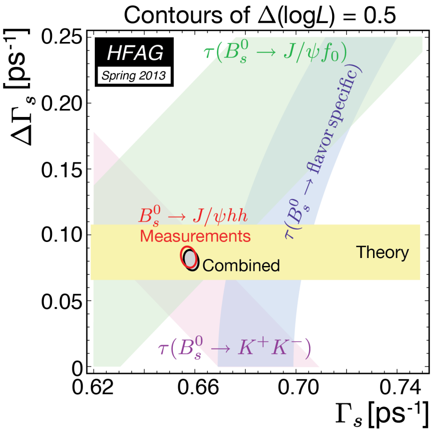
Nucl. Phys. B 873 (2013) 275-292

- $J/\psi\, K^0_{\rm S}$ final state is another CP-odd eigenstate.
- Split sample of events depending on $K^0_{\rm S}$ reconstruction (LL, DD).
- Determine decay time acceptance using large sample of $B^0 \to J/\psi\, K^0_{\rm S}$.
- Main systematic comes from background parameterisation.
- Future: use to control penguin pollution in $\sin 2\beta$ from $B^0 \to J/\psi\, K^0_{\rm S}$.



$$\tau^{SM}_{J/\psi\, K^0_{\rm S}} = 1.639 \pm 0.022\,\text{ps} \qquad \tau_{J/\psi\, K^0_{\rm S}} = 1.75 \pm 0.12 \pm 0.07\,\text{ps}$$

B_s^0 lifetime combination



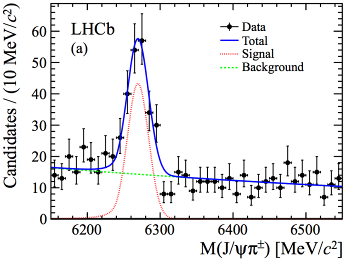
$$\begin{aligned} \Delta\Gamma_s &= 0.081 \pm 0.008 \\ \Gamma_s &= 0.659 \pm 0.003 \\ \rho(\Gamma_s, \Delta\Gamma_s) &= -0.19 \end{aligned}$$

- All results (including preliminary) shown up until Beauty.
- Need new measurement of the flavour specific lifetime ($B_s^0 \to D_s\pi$).

B_c^+ lifetime

Experiment	τ_{B_c} (ps)			Mode	Reference
CDF	0.46	$^{+0.18}_{-0.16}(stat)$	$\pm 0.03(syst)$	$J/\psi\ \ell^+\ \nu$	[6]
CDF II	0.463	$^{+0.073}_{-0.065}(stat)$	$\pm 0.036(syst)$	$J/\psi\ e^+\ \nu_e$	[7]
D0	0.448	$^{+0.038}_{-0.036}(stat)$	$\pm 0.032(syst)$	$J/\psi\ \mu^+\ \nu_\mu$	[8]
CDF II	0.452	$\pm 0.048(stat)$	$\pm 0.027(syst)$	$J/\psi\ \pi^+$	[10]
PDG 2012	0.453	± 0.041			[12]

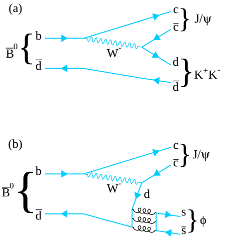
Table 1: Measured values of the B_c lifetime. The PDG 2012 average does not include t[h]
result of reference [10].

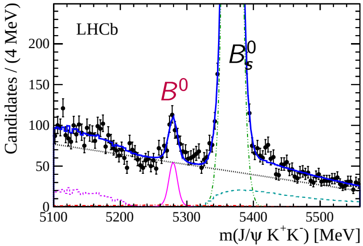


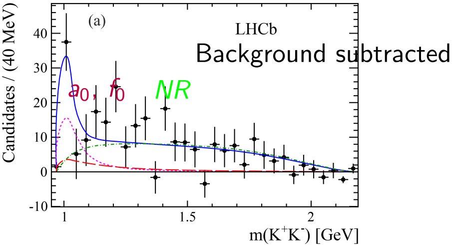
- Meson which is a combination of two heavy quarks.
- Treat in a non-relativistic way $\rightarrow$ test QCD and weak interaction.
- Improved lifetime measurements $\Rightarrow$ reduced BR measurements.
- With LHCb upgrade ($50\,\text{fb}^{-1}$) expect $\sigma(\tau_{B_c}) \sim 0.004\,\text{ps}$.

Amplitude analysis of $B^0 \to J/\psi K^+ K^-$ arXiv:1308.5916

- First observation of $B^0 \to J/\psi K^+ K^-$.
- Amplitude analysis $\to 3.9\sigma$ evidence for $B^0 \to J/\psi a_0(980)$, $a_0(980) \to K^+ K^-$.
- No evidence of $B^0 \to J/\psi \phi$.
- NR contribution dominates.







$$\mathcal{B}(B^0 \to J/\psi\, a_0(980), a_0(980) \to K^+K^-) = (4.70 \pm 3.31 \pm 0.72) \times 10^{-7}$$

Summary

- Many results of B meson mixing and lifetime parameters.
- LHC experiments are leading the way.
- Everything consistent with expectations (see Alex Lenz's talk for details).
- Much more to come!
  - Better precision – full datasets (LHCb $3\,\mathrm{fb}^{-1}$, ATLAS/CMS $25\,\mathrm{fb}^{-1}$) to be analysed.
  - $\Delta\Gamma_d$ (null test of SM).
  - Lifetime ratios.
  - B_c^+ meson lifetime.
  - B-baryon lifetimes.
  - ...