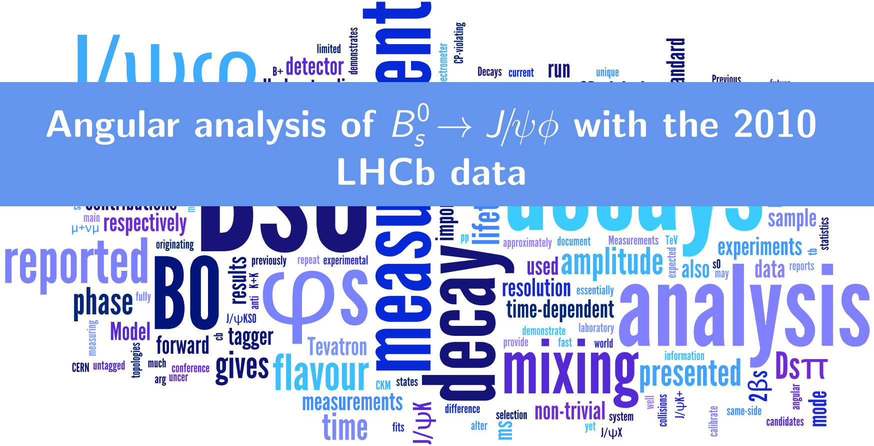


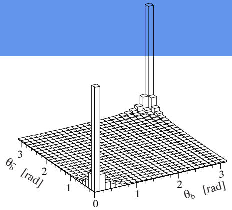
Angular analysis of $B_s^0 \to J/\psi\phi$ with the 2010 LHCb data

Greig Cowan (EPFL), Sara Furcas (Milano)

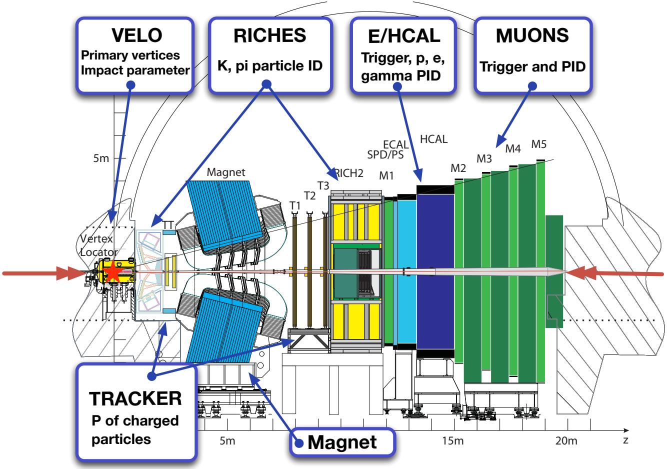
On behalf of LHCb. June 23, 2011, CCT

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

LHCb

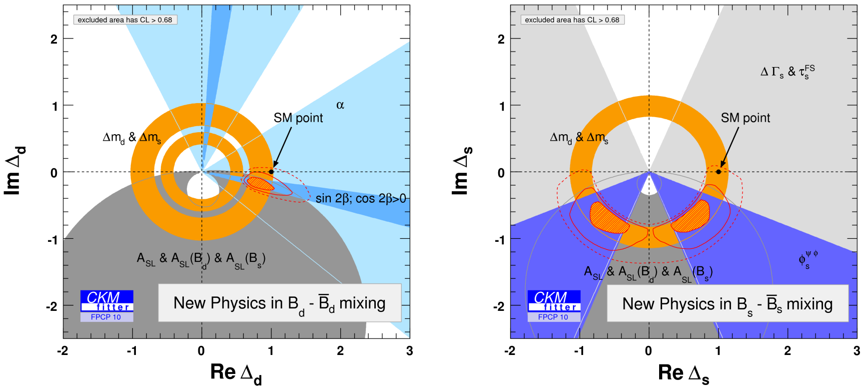


- Forward arm spectrometer. $b/\bar{b}$ production correlated in forward/backward direction. Access to $B_u, B_d, B_s, B_c, \Lambda_b$
- $\sigma_{b\bar{b}} \sim 290\mu b$ in pp collisions at $\sqrt{s} = 7$TeV.



- Low $p_{\rm T}$ trigger threshold $\Rightarrow$ efficient for leptonic and hadronic decays ($\epsilon_{trig} \sim 94\% - 60\%$).
- Excellent resolution for tracking and vertexing ($\sigma_{IPx} \approx 15\mu m$).
- Good particle identification:
  $K/p/\pi$ (RICH)
  $\pi/e/\gamma$ (ECAL)
  μ (MUON).

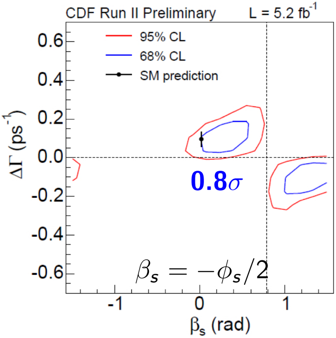
Space available for new physics



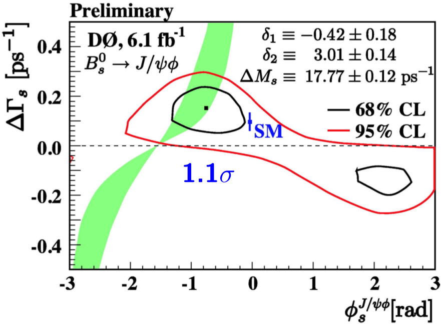
- $\mathrm{M}_{12}^{\mathrm{q}} = \mathrm{M}_{12}^{\mathrm{SM,q}} \cdot \Delta_{\mathrm{q}}, \qquad \Delta_{\mathrm{q}} = |\Delta_{\mathrm{q}}| e^{i\phi_s^{\Delta}}, \qquad \phi_s \rightarrow \phi_s + \phi_s^{\Delta}$

The state of the art: Tevatron

CDF, FPCP'2010



DØ, ICHEP'2010



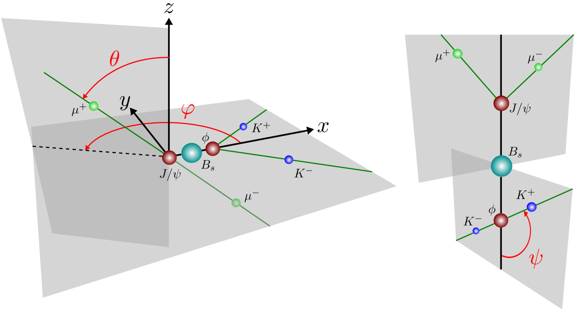
	Signal yield (lumi)	Ref.
CDF	6500 ($5.2\,\text{fb}^{-1}$)	CDF Note 10206
D0	3400 ($6.1\,\text{fb}^{-1}$)	D0 6098-CONF

Measuring ϕ_s using $B_s \to J/\psi(\mu\mu)\phi(KK)$

- $P \to VV$: final state is admixture of CP-odd ($\ell = 1$) and CP-even ($\ell = 0, 2$) with different lifetimes.

$$\mathrm{CP}|\,J/\psi\phi\rangle_\ell \;=\; \eta_f|\,J/\psi\phi\rangle_\ell \;=\; (-1)^\ell|\,J/\psi\phi\rangle_\ell$$

- **Angular analysis** using transversity angles $\Omega = (\theta,\ \varphi,\ \psi)$ to disentangle final state.



Differential decay rate

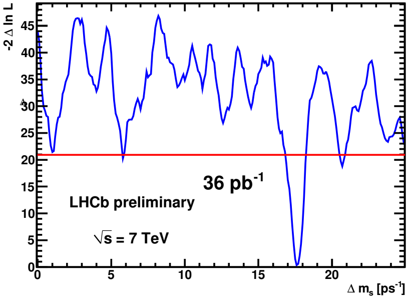
$$\frac{\mathrm{d}^4\Gamma(B_s^0 \to J/\psi\phi)}{\mathrm{d}t\ \mathrm{d}\cos\theta\ \mathrm{d}\varphi\ \mathrm{d}\cos\psi} \equiv \frac{\mathrm{d}^4\Gamma}{\mathrm{d}t\ \mathrm{d}\Omega} \propto \sum_{k=1}^{6} h_k(t) f_k(\Omega)\,. \tag{1}$$

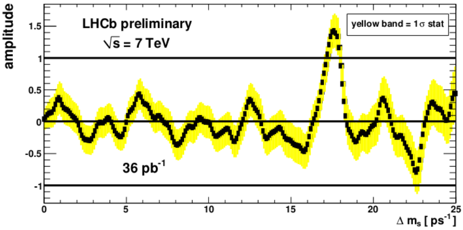
k	$h_k(t)$	$f_k(\theta,\psi,\varphi)$
1	$\lvert A_0(t)\rvert^2$	$2\cos^2\psi(1-\sin^2\theta\cos^2\varphi)$
2	$\lvert A_{\vert\vert}(t)\rvert^2$	$\sin^2\psi(1-\sin^2\theta\sin^2\varphi)$
3	$\lvert A_\perp(t)\rvert^2$	$\sin^2\psi\sin^2\theta$
4	$\Im\{A_{\vert\vert}^*(t)A_\perp(t)\}$	$-\sin^2\psi\sin 2\theta\sin\varphi$
5	$\Re\{A_0^*(t)A_{\vert\vert}(t)\}$	$\frac{1}{\sqrt{2}}\sin 2\psi\sin^2\theta\sin 2\varphi$
6	$\Im\{A_0^*(t)A_\perp(t)\}$	$\frac{1}{\sqrt{2}}\sin 2\psi\sin 2\theta\cos\varphi$

Time dependent decay amplitudes

$$
\begin{aligned}
|\bar{A}_0(t)|^2 &= |\bar{A}_0(0)|^2 e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) - \cos\phi_s \sinh\left(\frac{\Delta\Gamma_s t}{2}\right) - \sin\phi_s \sin(\Delta m_s t)\right] \\
|\bar{A}_\parallel(t)|^2 &= |\bar{A}_\parallel(0)|^2 e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) - \cos\phi_s \sinh\left(\frac{\Delta\Gamma_s t}{2}\right) - \sin\phi_s \sin(\Delta m_s t)\right] \\
|\bar{A}_\perp(t)|^2 &= |\bar{A}_\perp(0)|^2 e^{-\Gamma_s t}\left[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) + \cos\phi_s \sinh\left(\frac{\Delta\Gamma_s t}{2}\right) + \sin\phi_s \sin(\Delta m_s t)\right] \\
\Im\{\bar{A}_\parallel^*(t)\bar{A}_\perp(t)\} &= |\bar{A}_\parallel(0)||\bar{A}_\perp(0)| e^{-\Gamma_s t}\Big[-\cos(\delta_\perp - \delta_\parallel) \sin\phi_s \sinh\left(\frac{\Delta\Gamma_s t}{2}\right) \\
&\quad - \sin(\delta_\perp - \delta_\parallel)\cos(\Delta m_s t) + \cos(\delta_\perp - \delta_\parallel) \cos\phi_s \sin(\Delta m_s t)\Big] \\
\Re\{\bar{A}_0^*(t)\bar{A}_\parallel(t)\} &= |\bar{A}_0(0)||\bar{A}_\parallel(0)| e^{-\Gamma_s t}\cos\delta_\parallel\Big[\cosh\left(\frac{\Delta\Gamma_s t}{2}\right) - \cos\phi_s \sinh\left(\frac{\Delta\Gamma_s t}{2}\right) \\
&\quad - \sin\phi_s \sin(\Delta m_s t)\Big] \\
\Im\{\bar{A}_0^*(t)\bar{A}_\perp(t)\} &= |\bar{A}_0(0)||\bar{A}_\perp(0)| e^{-\Gamma_s t}\Big[-\cos\delta_\perp \sin\phi_s \sinh\left(\frac{\Delta\Gamma_s t}{2}\right) \\
&\quad - \sin\delta_\perp\cos(\Delta m_s t) + \cos\delta_\perp \cos\phi_s \sin(\Delta m_s t)\Big].
\end{aligned}
$$

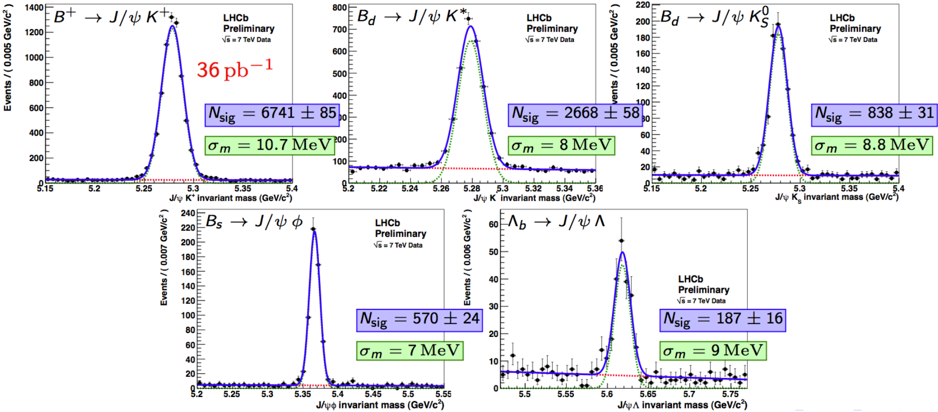
B_s^0 oscillations in $B_s^0 \to D_s^+(3)\pi$ (LHCb-CONF-2011-005)





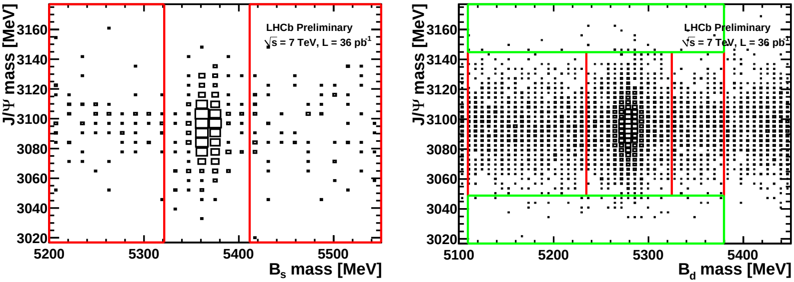
$$\Delta m_s = 17.63 \pm 0.11(stat) \pm 0.04(syst)\ ps^{-1}$$

Common selection for b-hadron $\to J/\psi X$ (LHCb-CONF-2011-001)



- Cut at $t > 0.3\,\mathrm{ps}$ to suppress prompt background.

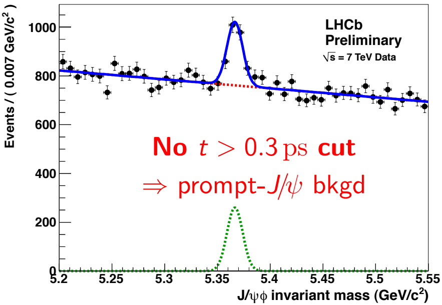
Background model

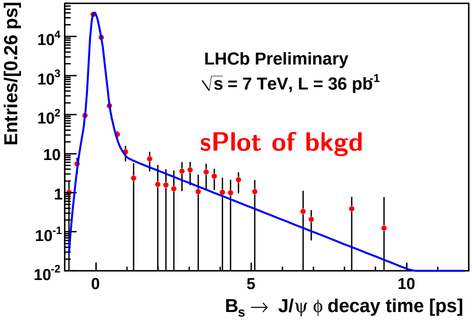


- Low background in $B_s^0 \to J/\psi\phi$ with the $t > 0.3$ps cut.

Proper time resolution

(LHCb-CONF-2011-001)



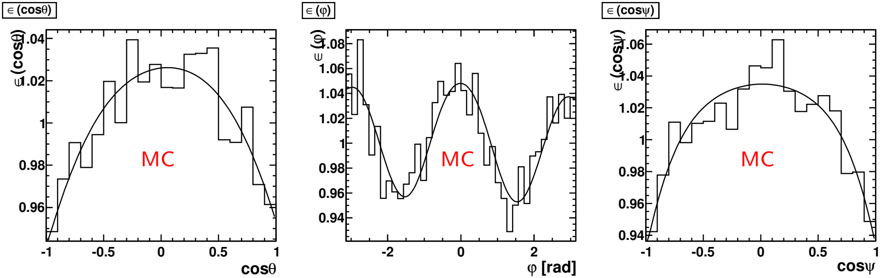


- Use a triple Gaussian resolution model.
- Extract parameters from a fit to the prompt J/ψ peak in data.
- $\langle \sigma_t \rangle \approx 50\,\text{fs}$.

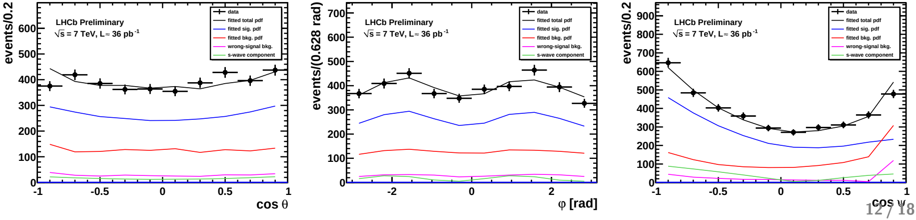
Angular acceptance

(LHCb-CONF-2011-002)

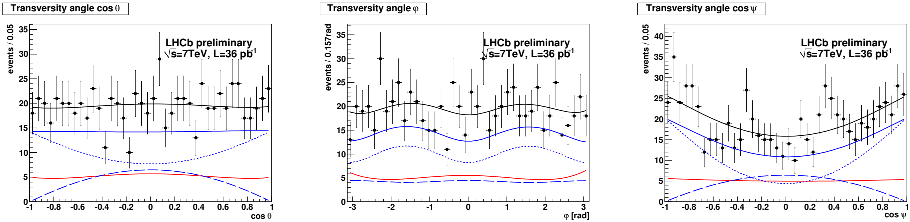
- Take angular acceptance from MC, i.e., for $B_s^0 \to J/\psi\phi$:

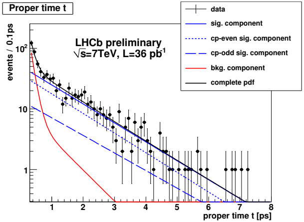


- Cross check procedure on $B^0 \to J/\psi K^{*0}$ data:



Untagged analysis of $B_s^0 \to J/\psi\phi$ (LHCb-CONF-2011-002)

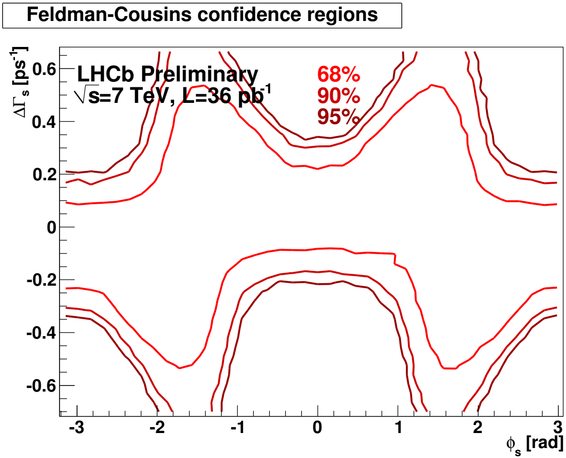




Parameter	LHCb prelim. ($\phi_s = 0$)
Γ_s (ps^{-1})	$0.680 \pm 0.034_{stat.} \pm 0.027_{syst.}$
$\Delta\Gamma_s$ (ps^{-1})	$0.084 \pm 0.112_{stat.} \pm 0.021_{syst.}$
$\lvert A_\perp(0)\rvert^2$	$0.279 \pm 0.057_{stat.} \pm 0.014_{syst.}$
$\lvert A_0(0)\rvert^2$	$0.532 \pm 0.040_{stat.} \pm 0.028_{syst.}$

- CDF note 10206, $\mathcal{L} = 5.2\,\mathrm{fb}^{-1}$: $\Delta\Gamma_s = 0.077 \pm 0.035_{stat.} \pm 0.010_{syst.}$ (ps^{-1})

Untagged analysis of $B_s^0 \to J/\psi\phi$ (LHCb-CONF-2011-002)



- No ϕ_s sensitivity from untagged sample.
- Tagging reduces 4-fold $\to$ 2-fold ambuiguity

Tagging performance

(LHCb-CONF-2011-003)

- The sensitivity of the measured asymmetry is directly related to the effective tagging efficiency $\varepsilon_{\rm eff} = \varepsilon_{\rm tag} D^2 = \varepsilon_{\rm tag}(1-2\omega)^2$.

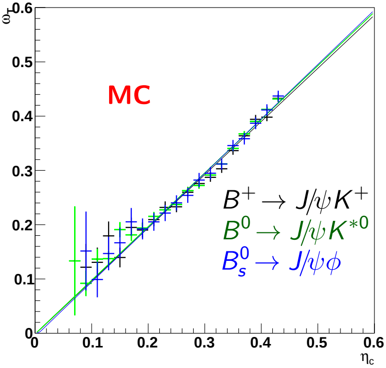
$$\varepsilon_{\rm tag} = \frac{R+W}{R+W+U} \qquad \omega = \frac{W}{R+W}$$

		ϵ_{tag}(%)	ω (%)	ϵ_{eff}(%)
combined OS	$B^0 \to D^{*-}\mu^+\nu$	18.3 ± 0.2	33.6 ± 0.8	1.97 ± 0.18
	$B^+ \to J/\psi K^+$	15.4 ± 0.3	32.2 ± 1.2	1.97 ± 0.31
	$B^0 \to J/\psi K^{*0}$	15.8 ± 0.7	30.0 ± 6.6	2.52 ± 0.82
combined OS + SSπ	$B^0 \to D^{*-}\mu^+\nu$	28.9 ± 0.2	34.2 ± 0.8	2.87 ± 0.32
	$B^+ \to J/\psi K^+$	23.0 ± 0.5	33.9 ± 1.1	2.38 ± 0.33
	$B^0 \to J/\psi K^{*0}$	26.1 ± 0.9	33.6 ± 5.1	2.82 ± 0.87

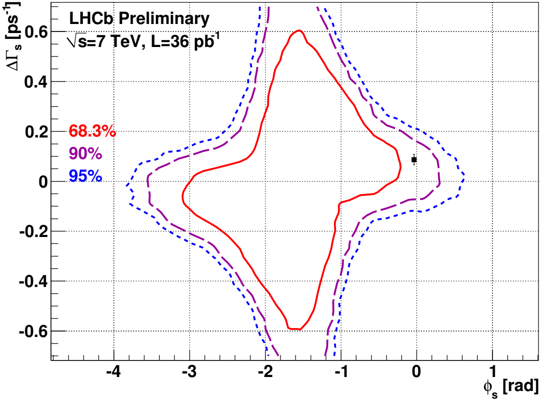
- Combined OS for $B_s^0 \to J/\psi\phi = 2.2 \pm 0.5\%$

Exporting the tagging to $B_s^0 \to J/\psi\phi$

- Use MC to look at the calibrated neural net mistag compared to the true mistag.

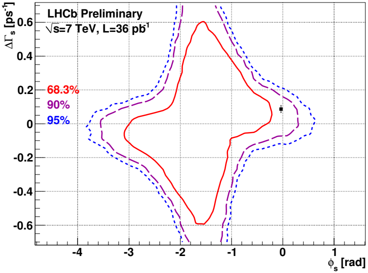


Tagged analysis of $B_s^0 \to J/\psi\phi$ (LHCb-CONF-2011-006)



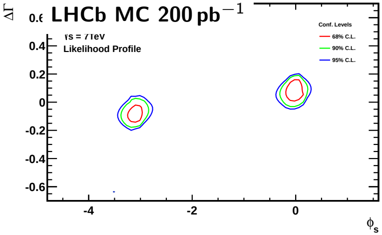
$$\phi_s^{SM} \in [-2.7, -0.5] \text{ rad @ 68\% CL}$$

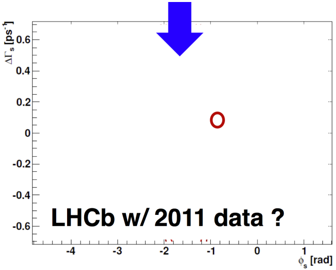
ϕ_s prospects in 2011



	LHCb 36 pb^{-1}	CDF 5.2 fb^{-1}
$B_s^0 \to J/\psi\phi$ cands[3]	836 $\pm$ 60	6500
Proper time res.	50 fs	100 fs
OS tagging power	2.2 $\pm$ 0.5%	1.2 $\pm$ 0.2%
SS tagging power	work ongoing	3.5 $\pm$ 1.4%

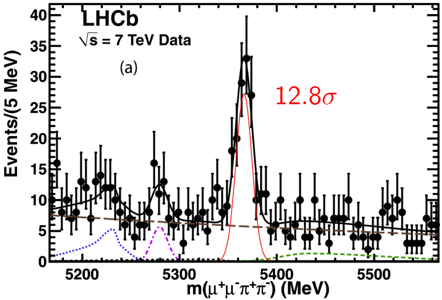
- With current performance and only OS tagger the expected ϕ_s sensitivity for 1 fb^{-1} at 7TeV is 0.13 rad.
- SS tagger will help improve sensitivity significantly.
- **Expect world's best measurement this year.**

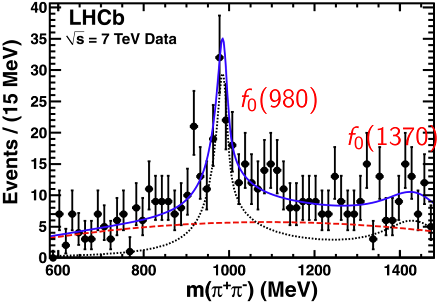




[1] No $t > 0.3$ ps cut

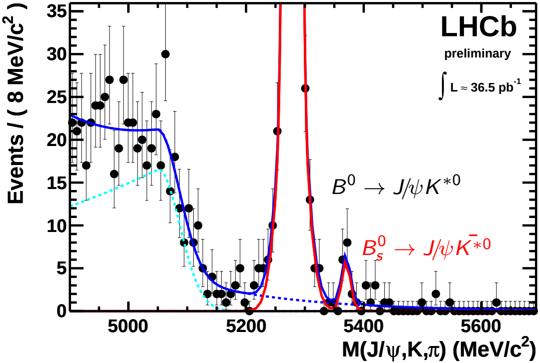
First observation of $B_s^0 \to J/\psi f_0(\pi\pi)$ (Phys. Lett. B 698 (2011) 115.)





$$R_{f_0/\phi} = \frac{\Gamma(B_s^0 \to J/\psi f_0, f_0 \to \pi^+\pi^-)}{\Gamma(B_s^0 \to J/\psi \phi, \phi \to K^+K^-)} = 0.252^{+0.046+0.027}_{-0.032-0.033}$$

Controlling penguins with $B_s^0 \to J/\psi \bar{K}^{*0}$ (LHCb-CONF-2011-025)



- $\mathrm{A}(\bar{\mathrm{b}} \to \bar{\mathrm{c}}\mathrm{c}\bar{\mathrm{d}})$ penguin contribution not suppressed ⇒ use to control δP for ϕ_s.[2]
- $\mathcal{B}(B_s^0 \to J/\psi \bar{K}^{*0}) = 3.5^{+1.1}_{-1.0}(stat.) \pm 0.9(syst.) \times 10^{-5}$

[2] R. Fleischer, Nucl. Phys. B 659 (2003) 321 among others

BACKUP

What is ϕ_s?

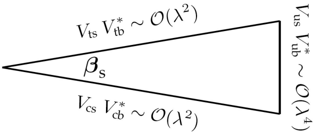
$$A(b \to \bar{c}c\bar{s}) = V_{cs}V_{cb}^*(A_T + P_c) + V_{us}V_{ub}^*P_u + V_{ts}V_{tb}^*P_t$$
$$= V_{cs}V_{cb}^*(A_T + P_c - P_t) + V_{us}V_{ub}^*(P_u - P_t).$$
$$V_{ts}V_{tb}^* = -V_{us}V_{ub} - V_{cs}V_{cb}.$$

- Penguin contribution $(P_u - P_t)$ suppressed by factor $\lambda^2 \sim 0.05$ wrt $(A_T + P_c - P_t)$.
- So assume decays dominated by single weak phase $\Phi_D = arg(V_{cs}V_{cb}^*)$.
- B_s^0 mixing phase, $\Phi_M = 2arg(V_{ts}V_{tb}^*)$.
- $\phi_s^{J/\psi\phi} = \Phi_M - 2\Phi_D = 2arg(V_{ts}V_{tb}^*) - 2arg(V_{cs}V_{cb}^*) + \delta P$
- CKM triangle:

$$V_{us}V_{ub}^* + V_{cs}V_{cb}^* + V_{ts}V_{tb}^* = 0 \quad \Rightarrow \quad \beta_s = arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right) = \eta\lambda^2 + O(\lambda^4)$$

- SM prediction, $\delta P = 0$:

$$\phi_s^{J/\psi\phi} = -2\beta_s = -0.0363 \pm 0.0017$$

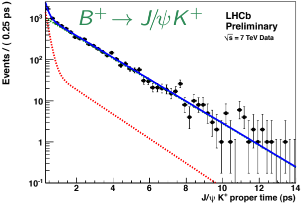


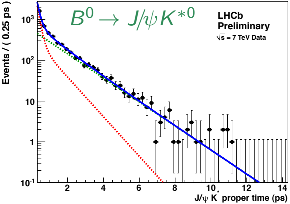
New physics in ϕ_s

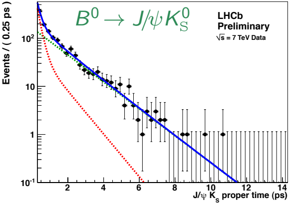
- ϕ_s^Δ is the same NP phase modifying other quantities, e.g.,

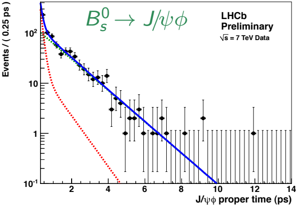
$$
\begin{aligned}
\Delta\Gamma_s &= 2|\Gamma_{12}^{SM}|\cos(\phi_{s,SM}^{M/\Gamma} + \phi_s^\Delta) \\
\phi_{s,SM}^{M/\Gamma} &= arg\left(-\frac{M_{12}^{SM}}{\Gamma_{12}^{SM}}\right) \sim 0.0034 \neq \phi_s^{J/\psi\phi}
\end{aligned}
$$

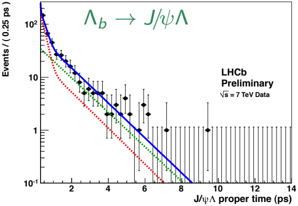
$b \to J/\psi X$ lifetimes using unbiased trigger (LHCb-CONF-2011-001)









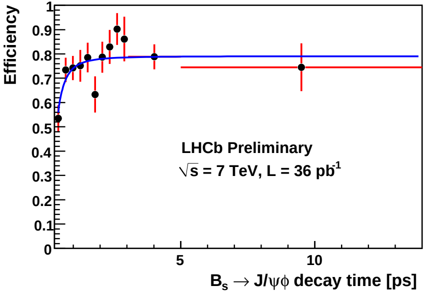


- Fit signal using a single exponential
- Syst. dominated by lifetime acceptance

Channel	LHCb prelim. (ps)	Yield	PDG lifetime (ps)
$B^+ \to J/\psi K^+$	$1.689 \pm 0.022_{stat.} \pm 0.047_{syst.}$	6741 ± 85	1.638 ± 0.011
$B^0 \to J/\psi K^{*0}$	$1.512 \pm 0.032_{stat.} \pm 0.042_{syst.}$	2668 ± 58	1.525 ± 0.009
$B^0 \to J/\psi K^0_S$	$1.558 \pm 0.056_{stat.} \pm 0.022_{syst.}$	838 ± 31	1.525 ± 0.009
$B^0_s \to J/\psi \phi$	$1.447 \pm 0.064_{stat.} \pm 0.056_{syst.}$	570 ± 24	1.477 ± 0.046
$\Lambda_b \to J/\psi \Lambda$	$1.353 \pm 0.108_{stat.} \pm 0.035_{syst.}$	187 ± 16	$1.391^{+0.038}_{-0.037}$

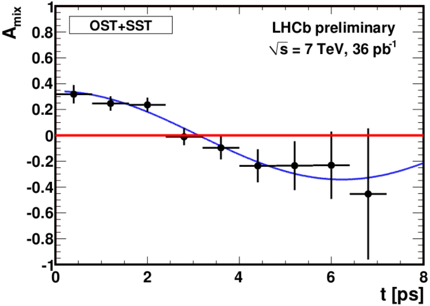
Including the biased triggered events (LHCb-CONF-2011-006)

- To maximise sensitivity to ϕ_s, we need as many events as possible.
  - $\Rightarrow$ Add in the events coming through the **biased trigger** lines to gain $\sim 30\%$ in statistics.
- Perform simultaneous NLL fit to independent datasets (unbiased + biased).



- Take acceptance from overlap between the unbiased and biased triggered events.
- Acceptance also applied to background.

B^0 oscillations in $B^0 \to D^- \pi^+$ (LHCb-CONF-2011-010)

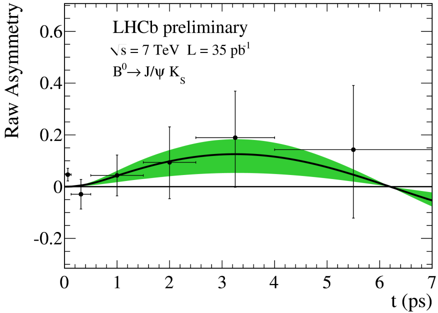


$$A_{mix}(t) = \frac{N(tagged\ as\ unmixed)(t) - N(tagged\ as\ mixed)(t)}{N(tagged\ as\ unmixed)(t) - N(tagged\ as\ mixed)(t)},$$

$$\Delta m_d = 0.499 \pm 0.032(stat) \pm 0.003(syst)\ ps^{-1}$$

CP violation in $B^0 \to J/\psi K^0_S$

(LHCb-CONF-2011-004)



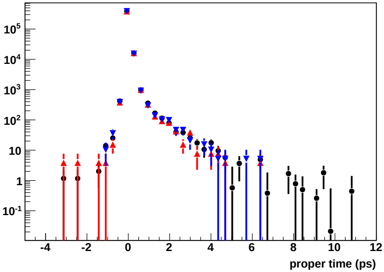
$$\mathcal{A}_{J/\psi K^0_S}(t) \equiv \frac{\Gamma(\overline{B}^0(t) \to J/\psi K^0_S) - \Gamma(B^0(t) \to J/\psi K^0_S)}{\Gamma(\overline{B}^0(t) \to J/\psi K^0_S) + \Gamma(B^0(t) \to J/\psi K^0_S)}$$

$$= S_{J/\psi K^0_S} \sin(\Delta m_d t) - C_{J/\psi K^0_S} \cos(\Delta m_d t) \; ,$$

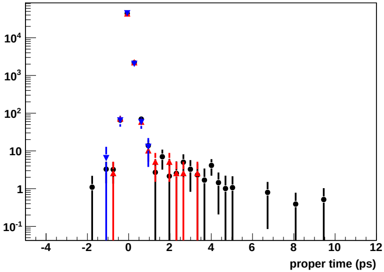
$$S_{J/\psi K^0_S} = 0.53^{+0.28}_{-0.29}, \; C_{J/\psi K^0_S} = 0$$

Proper time background model

$B^0 \rightarrow J/\psi K^{*0}$



$B_s^0 \rightarrow J/\psi \phi$

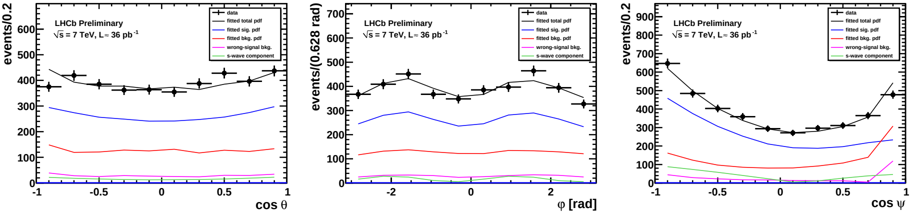


- Proper time distributions obtained in the low mass sideband [5150, 5200] MeV/c^2 (red), in the high mass sideband [5350, 5400] MeV/c^2 (blue) and background sPlot in the range [5200, 5400] MeV/c^2 (black), normalized to the same area.

⇒ Use same proper time background model across entire B mass.

$$\mathcal{P}_{\mathrm{bkg}}(\mathrm{t}) = \mathrm{f}_{\mathrm{LL},1}\mathrm{e}^{-\mathrm{t}/\tau_{\mathrm{LL},1}} + \mathrm{f}_{\mathrm{LL},2}\mathrm{e}^{-\mathrm{t}/\tau_{\mathrm{LL},2}} + (1 - \mathrm{f}_{\mathrm{LL},1} - \mathrm{f}_{\mathrm{LL},2})\delta(0) \qquad (2)$$

Polarization amplitudes from $B^0 \to J/\psi K^{*0}$ (LHCb-CONF-2011-002)



Parameter	LHCb prelim.	BaBar PRD 76, 031002
$\lvert A_{\parallel}(0)\rvert^2$	$0.252 \pm 0.020_{stat.} \pm 0.016_{syst.}$	$0.211 \pm 0.010_{stat.} \pm 0.006_{syst.}$
$\lvert A_{\perp}(0)\rvert^2$	$0.178 \pm 0.022_{stat.} \pm 0.017_{syst.}$	$0.233 \pm 0.010_{stat.} \pm 0.005_{syst.}$
$\delta_{\parallel}$	$-2.87 \pm 0.11_{stat.} \pm 0.10_{syst.}$	$-2.93 \pm 0.08_{stat.} \pm 0.04_{syst.}$
$\delta_{\perp}$	$3.02 \pm 0.10_{stat.} \pm 0.07_{syst.}$	$2.91 \pm 0.05_{stat.} \pm 0.03_{syst.}$

- $P \to VV$ decay, so angular analysis required.
- Add non-resonant $K\pi$ (S-wave) to signal PDF (5±2%).
- Main systematics come from S-wave, background modelling and angular acceptance.

S-wave contribution to $B_s^0 \to J/\psi KK$

- $B_s^0 \to J/\psi\phi$ decay rate only includes $\phi \to KK$ (P-wave) in the KK mass region.

$$\frac{d\Gamma}{d\Omega} = \left[g(\Omega, \mathbf{A}) + |A_S|^2 f_7(\Omega) + \left[f_8(\Omega)\Re(A_\parallel A_S^*) \pm f_9(\Omega)\Im(A_\perp A_S^*) + f_{10}\Re(A_0 A_S^*)\right]\right], \quad (3)$$

The additional angular functions $f_{7\ldots10}$ of the transversity angles Ω are defined as:

$$f_7(\Omega) = \frac{3}{32\pi} 2\left[1 - \sin^2\theta\cos^2\phi\right], \quad (4)$$

$$f_8(\Omega) = \frac{3}{32\pi}\sqrt{6}\sin\psi\sin^2\theta\sin 2\phi, \quad (5)$$

$$f_9(\Omega) = \frac{3}{32\pi}\sqrt{6}\sin\psi\sin 2\theta\cos\phi, \quad (6)$$

$$f_{10}(\Omega) = \frac{3}{32\pi} 4\sqrt{3}\cos\psi\left[1 - \sin^2\theta\cos^2\phi\right] \quad (7)$$

$$(8)$$

Lifetime systematics

	$B^+ \to J/\psi K^+$	$B^0 \to J/\psi K^{*0}$	$B_s^0 \to J/\psi \phi$	$B^0 \to J/\psi K_S^0$	$\Lambda_b \to J/\psi \Lambda$
signal mass model	0.002	0.002	0.010	0.014	0.012
signal time acceptance	0.043	0.038	0.040	0.015	0.022
bkg. mass model	0.009	0.020	0.005	0.008	0.023
bkg. time model	0.003	0.006	0.003	0.006	0.006
time resol. model	0.005	0.005	0.005	0.005	0.005
momentum scale	0.001	0.001	0.001	0.001	0.001
decay length scale	0.001	0.001	0.001	0.001	0.001
quadratic sum	0.047	0.042	0.056	0.022	0.035

- Signal time acceptance correction determined from MC.
- Systematic assigned by ignoring this effect.

$B^0 \to J/\psi K^{*0}$ systematics

Systematic effect	$\lvert A_{\parallel}\rvert^2$	$\lvert A_{\perp}\rvert^2$	$\delta_{\parallel}$	$\delta_{\perp}$
proper time acceptance	-	-	-	-
data/MC differences	0.008	0.006	0.07	0.05
statistical error of acceptance	0.002	0.001	-	0.01
wrong-signal fraction	0.004	0.001	-	0.01
background treatment	0.002	0.008	0.04	0.01
statistical error of background	0.008	0.005	0.02	0.01
mass model	0.010	0.002	0.01	0.01
s-wave treatment	0.001	0.013	0.05	0.05
total (quadratic sum)	0.016	0.017	0.10	0.07

- Sideband subtracted data shows disagreement with MC.
- The MC is reweighted in several distributions.
- Fit is repeated with acceptance corrections determined from reweighted MC.

Untagged $B_s^0 \to J/\psi\phi$ systematics

Systematic effect	Γ_s $[\mathrm{ps}^{-1}]$	$\Delta\Gamma_s$ $[\mathrm{ps}^{-1}]$	$\vert A_\perp(0)\vert^2$	$\vert A_\parallel(0)\vert^2$
Proper time resolution	0.0001	-	-	-
Angular acceptance	-	-	-	0.0007
Acceptance parametrisation	0.0002	0.001	0.0017	0.0013
Proper time acceptance	0.0272	0.001	0.0003	0.0002
S-wave treatment	0.003	0.003	0.013	0.028
Background treatment	0.0002	0.02	0.0016	0.0012
Mass model	0.0004	0.004	0.0032	0.0006
Total (quadratic sum)	0.0274	0.0206	0.0136	0.0281

- Including S-wave in fit leads to instabilities with current event yields.
  - Ignoring it leads to $\sim 10\%$ bias on ϕ_s.
  - Need to include it to resolve 2-fold ambiguity.
- Neglection of 6.7% S-wave determined from toy MC.
- For the angular background, a flat background is used instead of the analytic parameterisation.

LHCb in 2010

- Forward arm spectrometer. $b/\bar{b}$ production correlated in forward/backward direction. Access to $B_u, B_d, B_s, B_c, \Lambda_b$
- $\sigma_{b\bar{b}} \sim 290\mu b$ in pp collisions at $\sqrt{s} = 7$TeV.