CP-violation in the B system: overview of LHCb results

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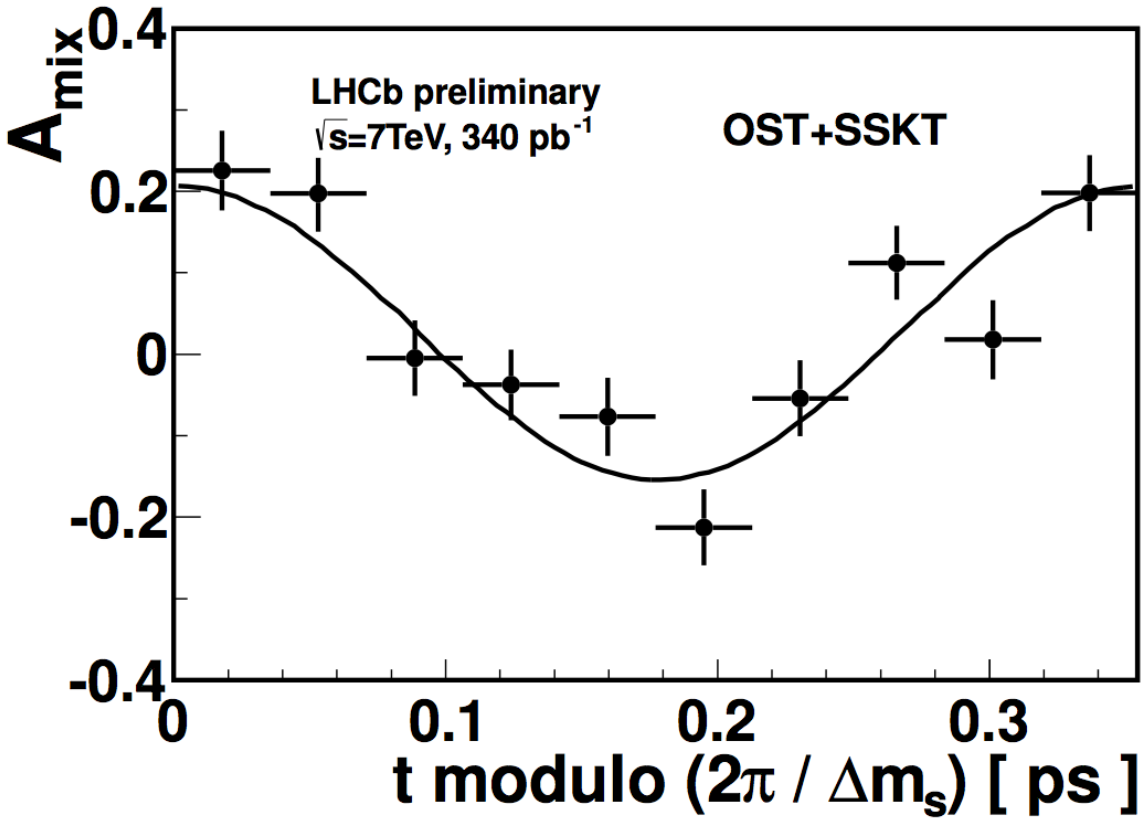
On behalf of LHCb

November 10, 2011

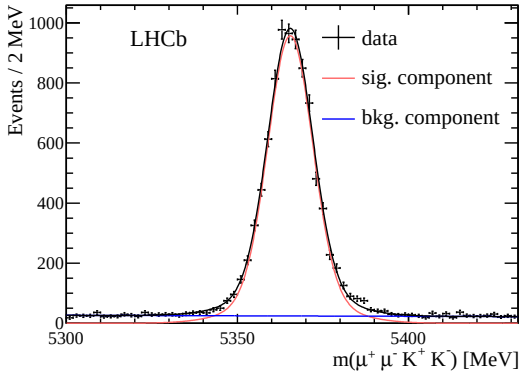
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

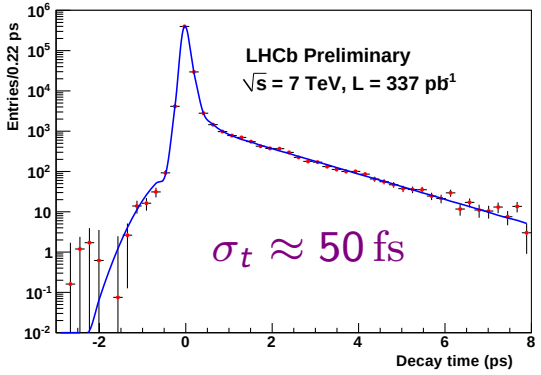
Δm_s from $B_s^0 \to D_s\pi$ using 340 pb^{-1}

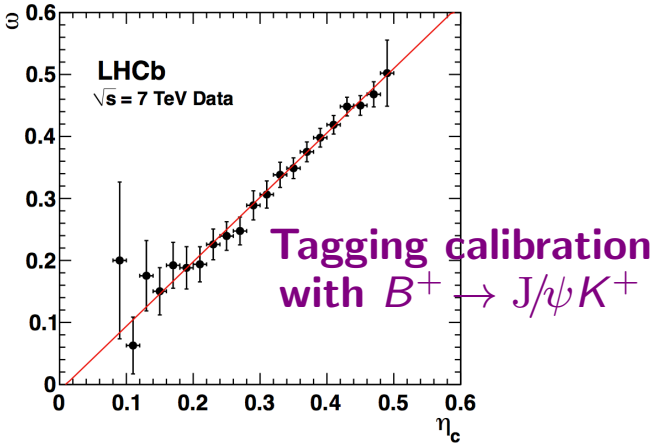


- $\Delta m_s = 17.725 \pm 0.041 \pm 0.026\,\mathrm{ps}^{-1}$.
- Same-side kaon tagger is working, further optimization ongoing.
- $\epsilon_{eff,SSK} = 1.3 \pm 0.4\%$, $\epsilon_{eff,OSK} = 2.1 \pm 0.2\%$.

ϕ_s from $B_s^0 \to J/\psi\phi$

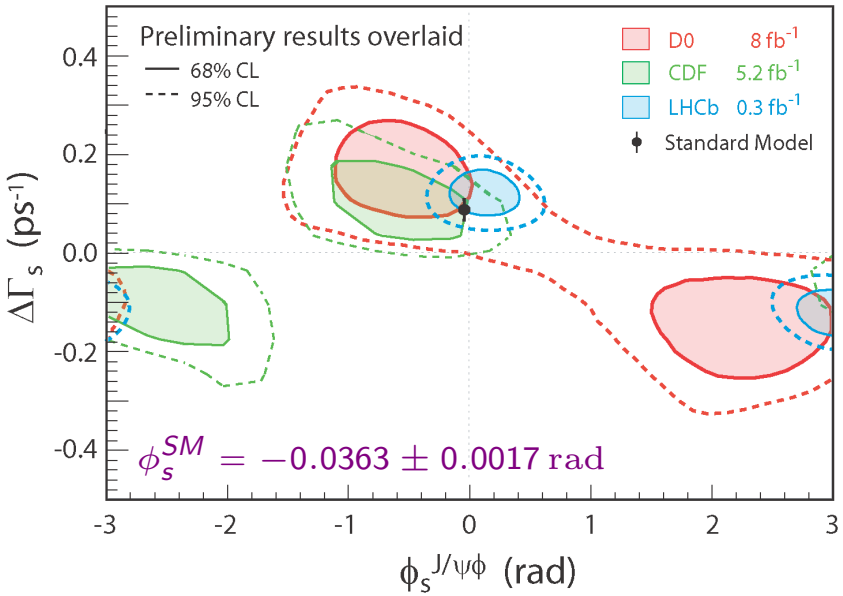






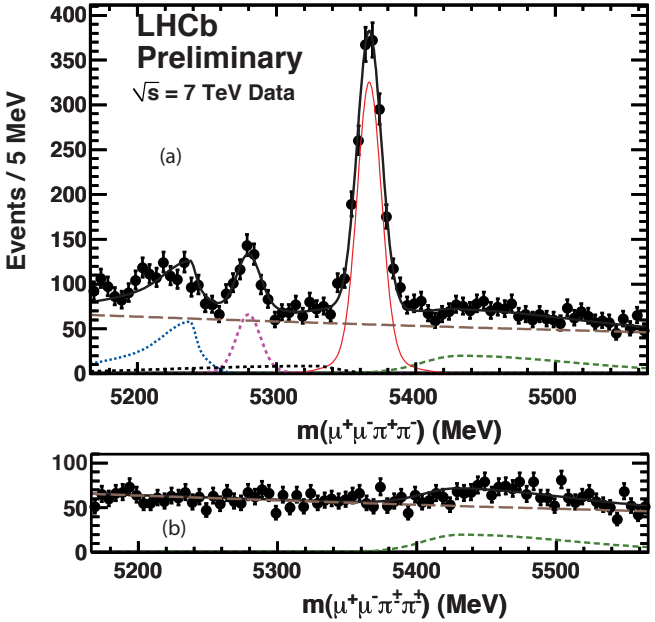
- 340 pb^{-1} has allowed us to make precision measurements of ϕ_s and $\Delta\Gamma_s$, $\bar{\Gamma}_s$.

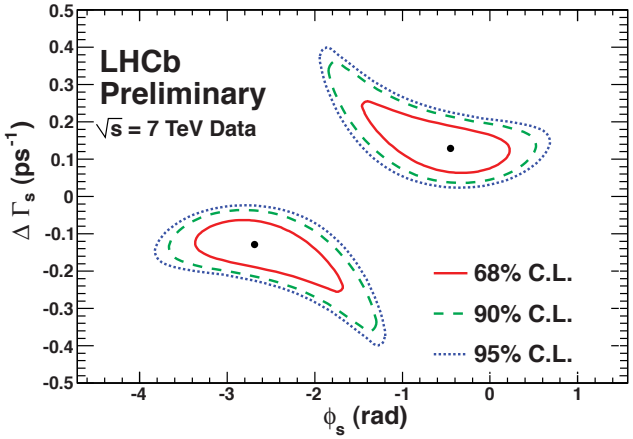
$$\begin{aligned} \phi_s &= 0.13 \pm 0.18 \pm 0.07\,\mathrm{rad} \\ \Delta\Gamma_s &= 0.123 \pm 0.029 \pm 0.008\,\mathrm{ps}^{-1} \\ \bar{\Gamma}_s &= 0.656 \pm 0.009 \pm 0.008\,\mathrm{ps}^{-1} \end{aligned}$$



- Now have $\sim \times 3$ more data on tape and...
- ...will include same-side kaon tagger for next round of analysis $\Rightarrow \sigma(\phi_s) \sim 0.10\,\mathrm{rad}$.

ϕ_s from $B_s^0 \to J/\psi f_0(980)$





$$\phi_s = -0.43 \pm 0.43 \pm 0.02\,\mathrm{rad}.$$

- $J/\psi f_0(980)$ is CP odd $\Rightarrow$ no need to perform complex angular analysis.

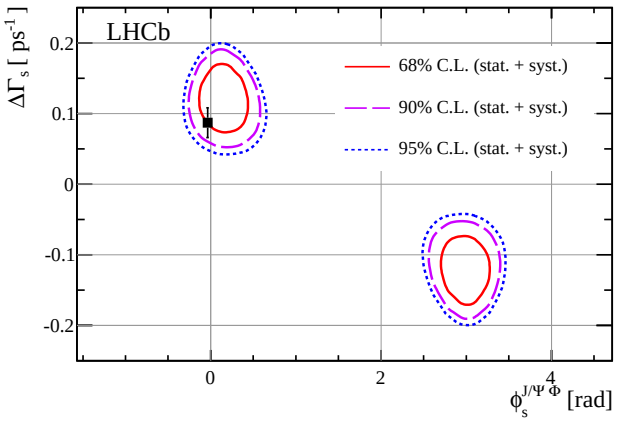
$$\boxed{\text{Combination } J/\psi\phi + J/\psi f_0(980) : \phi_s = 0.03 \pm 0.16 \pm 0.07\,\mathrm{rad}}$$

Plan to study other modes: $B_s^0 \to \psi(2S)\phi$, $D_s^{(*)}D_s^{(*)}$, $J/\psi\eta^{(\prime)}$, $\eta_c\phi$, $\chi_{c1}\phi$

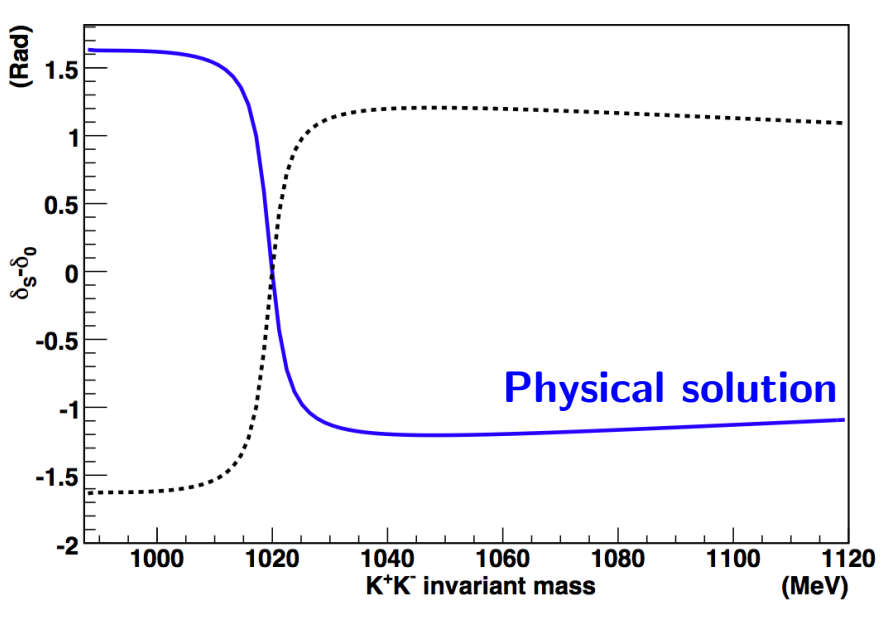
- $\psi(2S) \to \mu\mu$ mode will give $\sim 10\%$ of the statistics of $B_s^0 \to J/\psi\phi$.
- Should have $\sim 1.5k$ D_sD_s in 1/fb.
- Do we know the CP state of $D_s^*D_s^*$?

ϕ_s ambiguity removal

- Which solution is the correct one?
- 50% chance of finding New Physics! Need to remove the degeneracy.
- Use the *KK* *S*-wave, *P*-wave phase difference as function of KK mass.



Theory

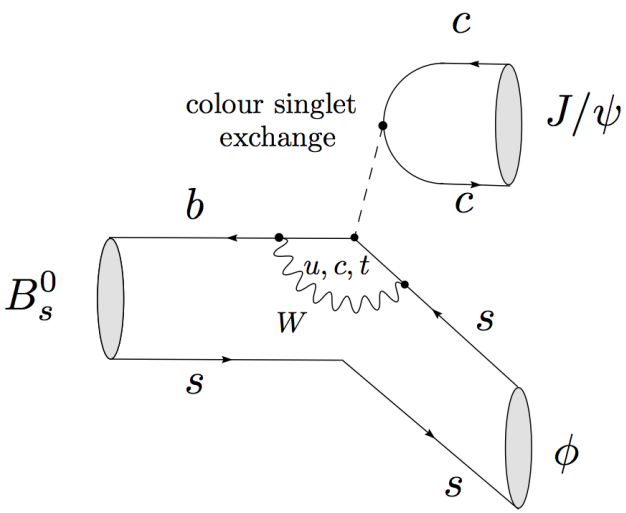


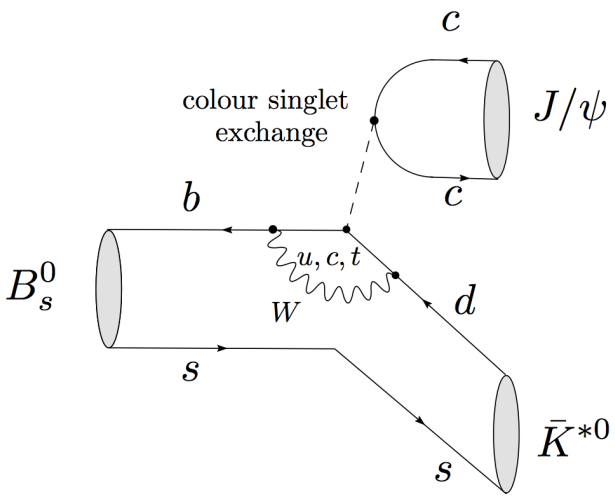
LHCb 2011

Expect result soon!

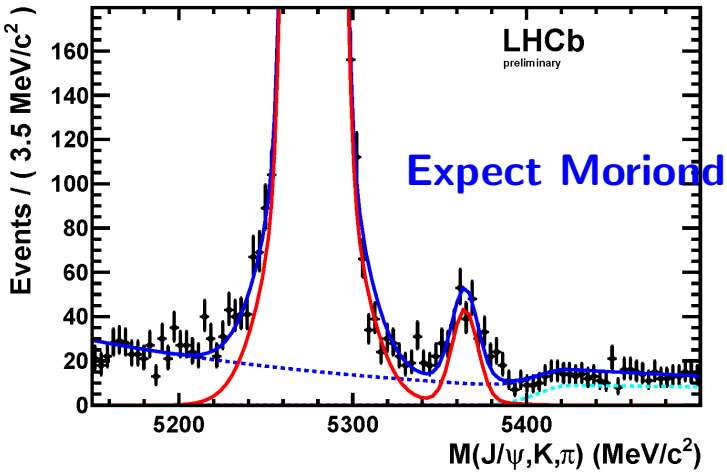
Penguin pollutions

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





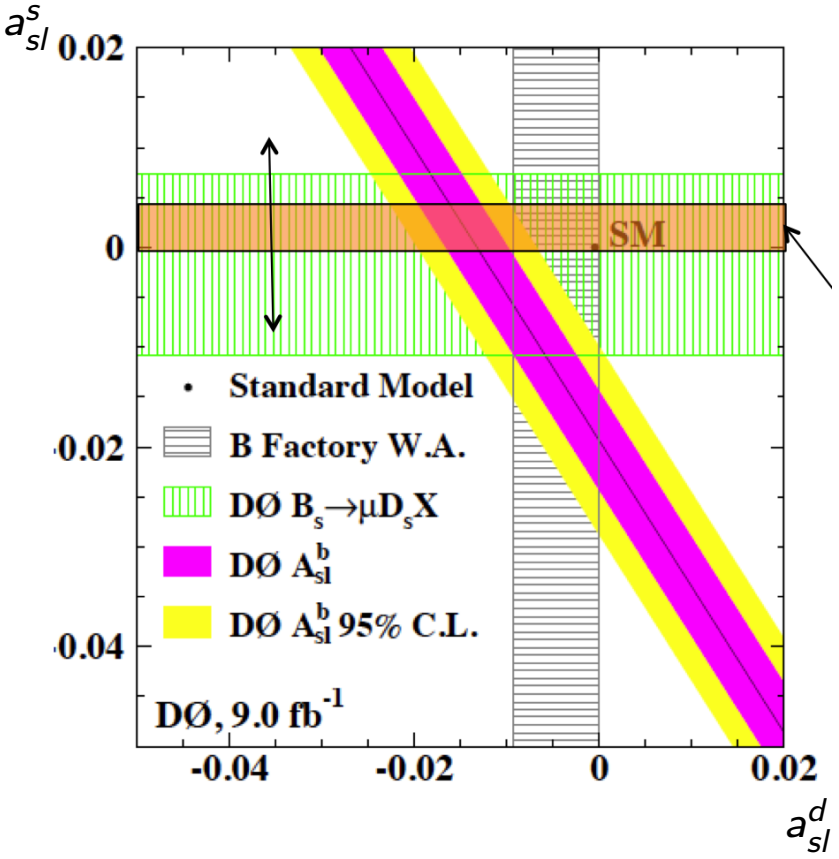
Should hear about this from R. Fleischer today.



Expect Moriond update

a_{sl} at LHCb

- Compare $\bar{B}_s^0 \to D_s^+(\phi\pi)\mu\nu X$ and $B_s^0 \to D_s^-(\phi\pi)\mu\nu X$ using a time integrated method.
- Time-dependent analysis also being pursued ("subtraction method").

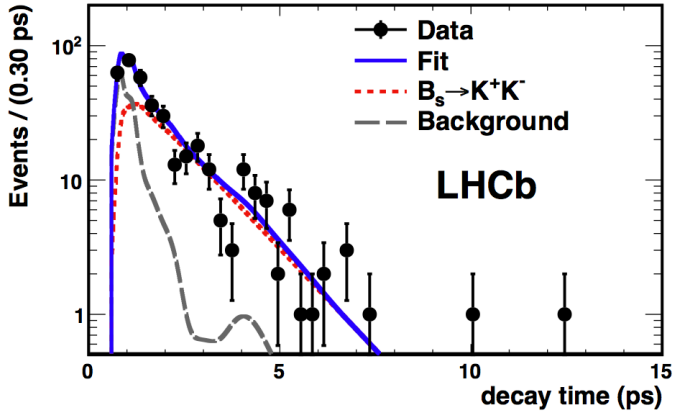


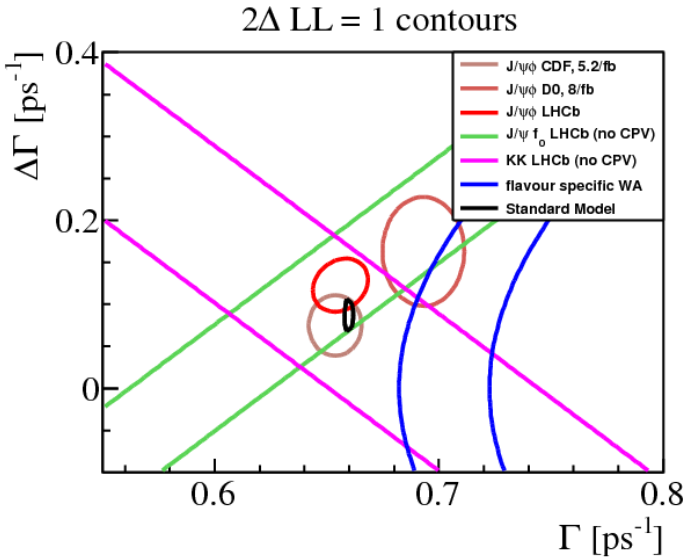
Projected statistical uncertainty $\sim 0.25\%$ with 1.1/fb (for Moriond)

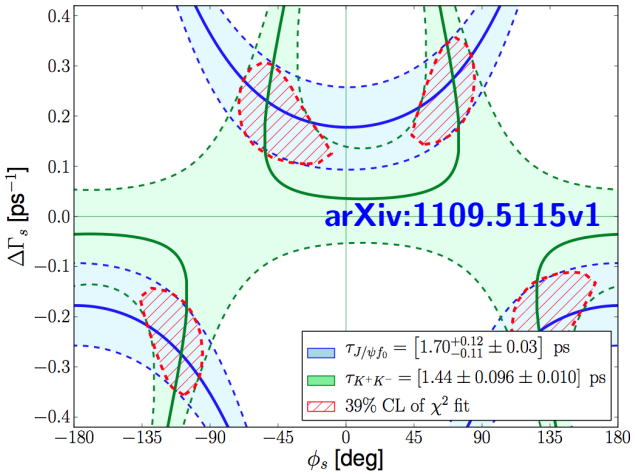
Can we reconcile SM value of ϕ_s and large a_{sl} from D0?

Measuring Γ_s and $\Delta\Gamma_s$

- $\Delta\Gamma_s$ from $B_s^0 \to J/\psi\phi$ is world's best direct measurement (4σ from zero).
- B_s^0 effective lifetime measurements can be used to constrain new physics.
- $\tau_{B_s^0 \to KK} = 1.440 \pm 0.096(stat) \pm 0.008(syst) \pm 0.003(model)$ ps.







Future plans

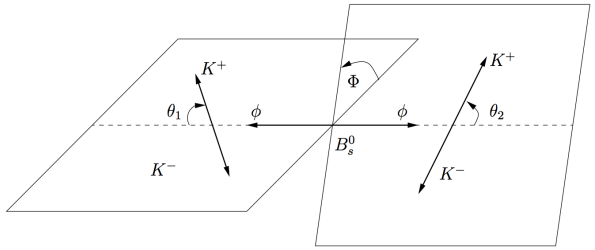
- Measurement of flavor specific B_s^0 lifetime with 2011 data.
- Combine $B_s^0 \to J/\psi\phi$ with (e.g) $B_s^0 \to D_s\pi$ and/or $J/\psi f_0(980)$ to reduce $\rho(\Gamma_s, \Delta\Gamma_s)$.
  - Experimentally, different triggers/acceptances must be understood.

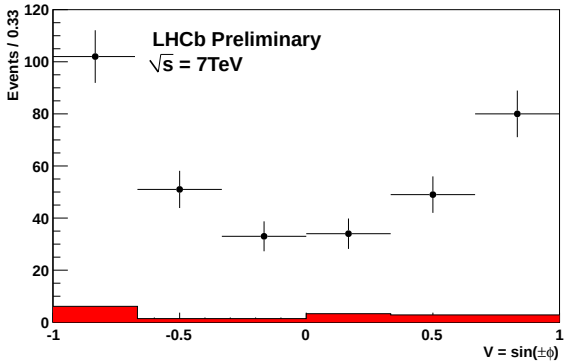
CPV in $b \to s$ penguins

- $B_s^0 \to \phi\phi$ is FCNC in the SM; $\phi_s^{SM} = 0$.
- First step: measure triple product asymmetries ($U = \sin 2\Phi,\ V = \sin(\pm\Phi)$):

$$A_U = -0.064 \pm 0.057(stat) \pm 0.014(syst)$$
$$A_V = -0.070 \pm 0.057(stat) \pm 0.014(syst)$$

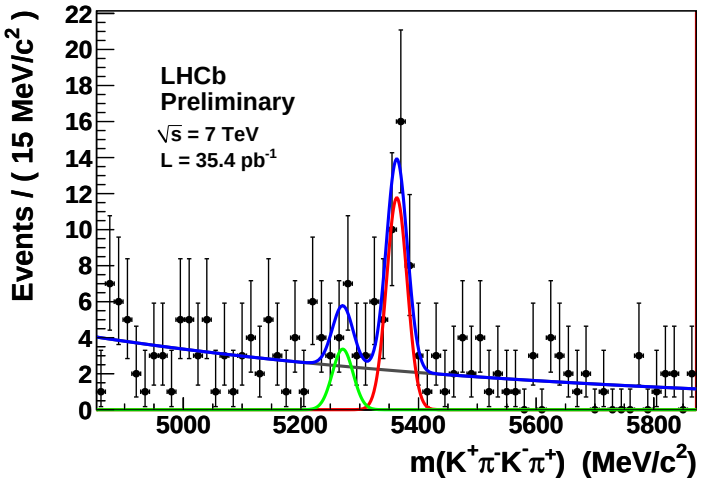
- Future: full angular analysis of final state.





How sensitive are A_U, A_V to NP?

Can SM prediction of ϕ_s in the time-dependent analysis be improved?

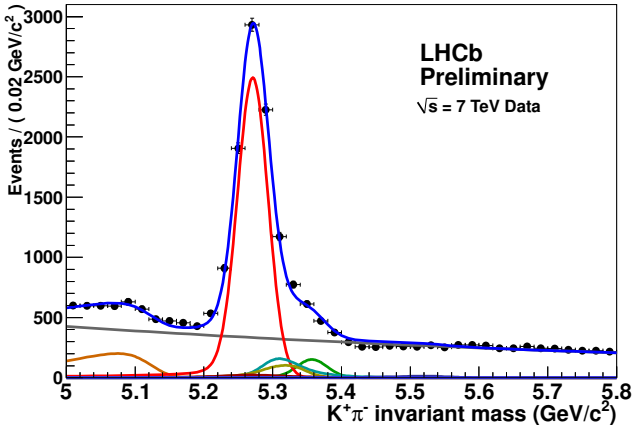


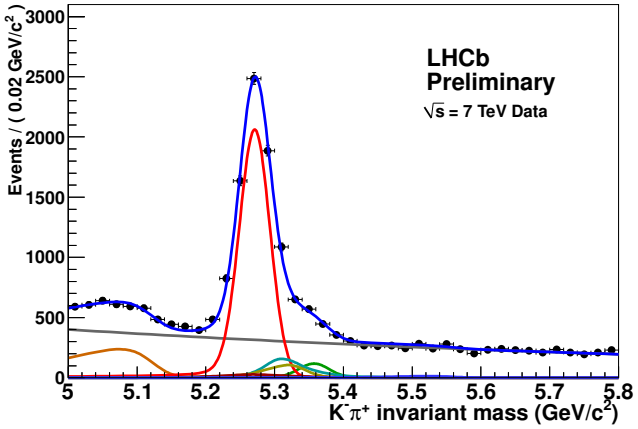
- First observation of $B_s^0 \to K^{*0}\bar{K}^{*0}$ with $35\,\mathrm{pb}^{-1}$.
  - $\mathcal{BR} = 1.95 \pm 0.47(stat) \pm 0.51(syst) \pm 0.29(f_d/f_s)$.
- Can be used to extract ϕ_s and γ.

CPV in $B \to hh$

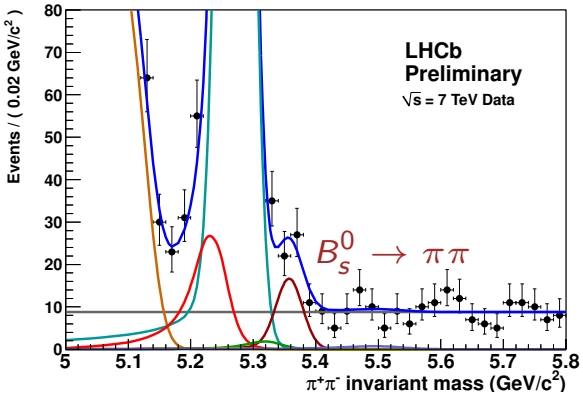
- Excellent PID at LHCb to separate hadronic final states.
- With 320/pb, measured the direct CP asymmetries:

$$A_{CP}(B^0 \to K\pi) = -0.088 \pm 0.011(stat) \pm 0.008(syst).$$
$$A_{CP}(B_s^0 \to K\pi) = 0.27 \pm 0.08(stat) \pm 0.02(syst).$$





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

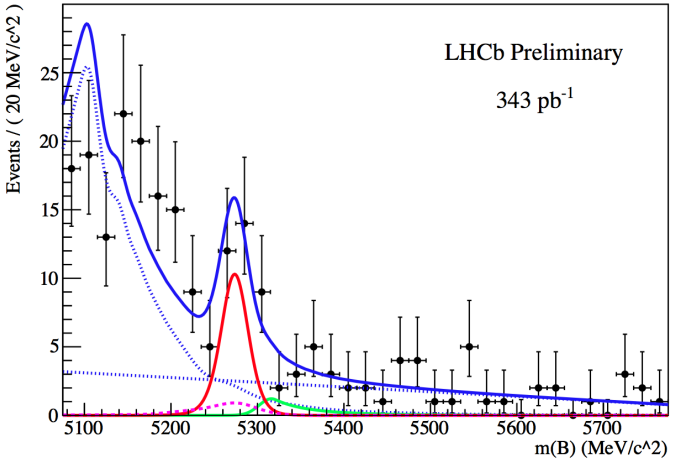


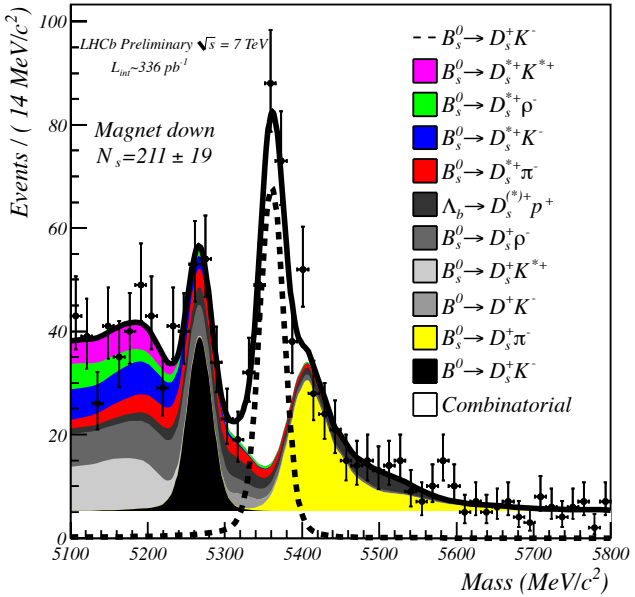
- Theoretical uncertainties in some diagrams.

Future plans

- Time-dependent measurements from $B_s^0 \to KK, B^0 \to \pi\pi$.
  $\sigma(A_{CP}^{dir}(B_s^0 \to KK), A_{CP}^{mix}(B_s^0 \to KK)) \sim 0.15$ with $1\,\text{fb}^{-1}$, with room for improvement.
- γ extraction possible, subject to theoretical uncertainties (Fleischer *et al*).

γ from $B \to DX$





- Above shows sum of the ADS modes $B^+ \to (K^-\pi^+)_D K^+$ and $B^- \to (K^+\pi^-)_D K^-$. 4.0σ significance.
- With 343/pb, we measured:

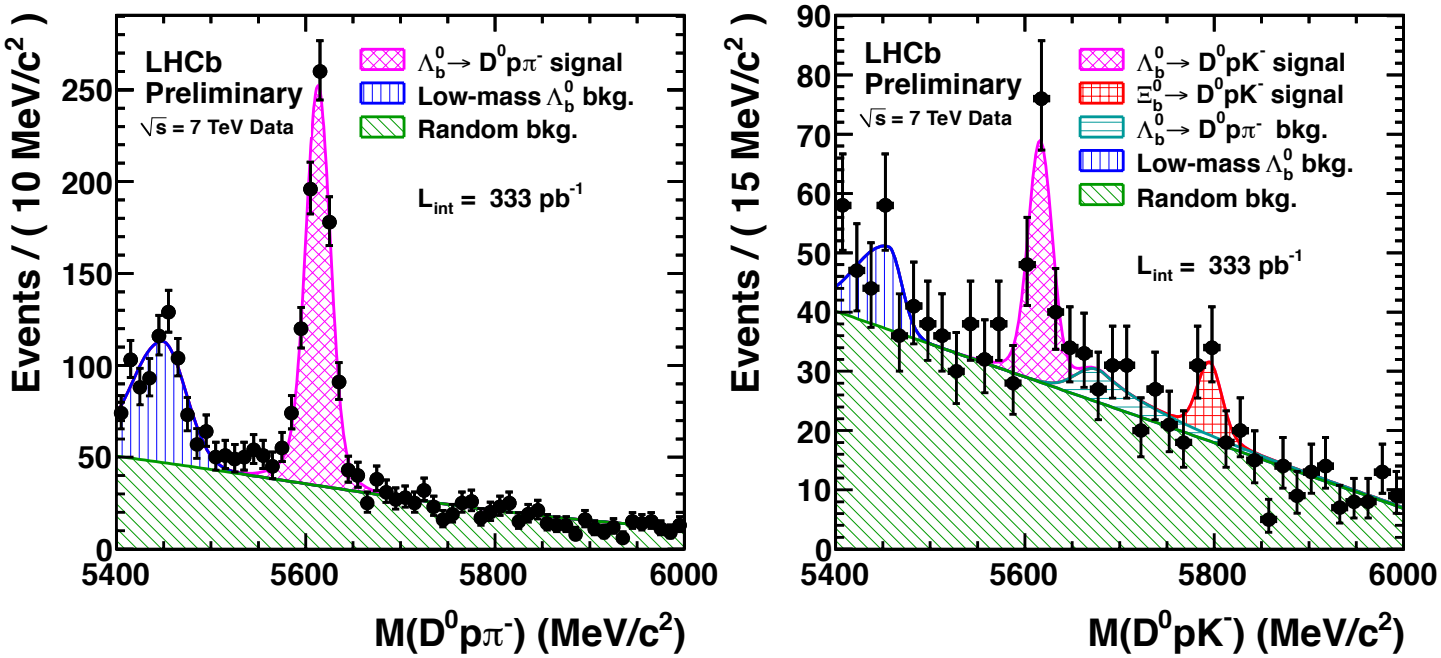
$$R_{ADS} = (1.66 \pm 0.39 \pm 0.24) \times 10^{-2}$$
$$A_{ADS} = -0.39 \pm 0.17 \pm 0.02$$

- Observation of $B_s^0 \to D_s^{\mp} K^{\pm}$ at LHCb.
- With 336/pb, we measured:

$$\mathcal{BR}(B_s^0 \to D_s^{\mp} K^{\pm}) =$$
$$(1.97 \pm 0.18(stat)\ ^{+0.19}_{-0.20}(syst)\ ^{+0.11}_{-0.11}(f_d/f_s)) \times 10^{-3}$$

- Expect time dependent measurement for Moriond.

b-baryons



- First observation of the Cabibbo-suppressed decay $\Lambda_b^0 \to D^0 pK^-$ that can be used to measure the angle CKM angle γ.

$$\mathcal{BR}(\Lambda_b^0 \to D^0 pK^-)/\mathcal{BR}(\Lambda_b^0 \to D^0 p\pi^-) = 0.112 \pm 0.019^{+0.011}_{-0.014}$$

- 2011+2012 data set: CPV search in b-baryons using amplitude analysis of $\Lambda_b^0 \to D^0 pK^-, D \to KK, \pi\pi$.

- Λ_b lifetime measurement with 1/fb. $\sigma(\tau_{\Lambda_b}) \sim 0.008\,\mathrm{ps}$ $(stat)$.

Summary

- Many excellent measurements have already been made at LHCb.
- Many more to come with 1/fb of 2011 data.
- We welcome new ideas which we can apply to our 2012 analyses.

14:00	**Overview of LHCb results on CPV in the B sector and future prospects**	*COWAN, Greig*	
	Filtration Plant, CERN	14:00 - 14:15	
	Impacts of recent LHCb results on NP models	*ISIDORI, Gino*	
	Filtration Plant, CERN	14:15 - 14:45	
15:00	**Penguin pollution in phi_s and effective B_s lifetime measurements**	*FLEISCHER, Robert*	
	Filtration Plant, CERN	14:45 - 15:15	
	Coffee		
	Filtration Plant, CERN	15:15 - 15:45	
16:00	**What we can learn from b->s penguins?**	*JAEGER, Sebastian*	
	Filtration Plant, CERN	15:45 - 16:15	
	New method for measuring phi_s	*VIRTO, Javier*	
	Filtration Plant, CERN	16:15 - 16:30	
17:00	**Discussion**		
	Filtration Plant, CERN	16:30 - 17:30	
18:00	**Social drink**		
	Glassbox Restaurant 1, CERN	18:00 - 19:00	

References

Some selected references (many of which will soon be published):

ϕ_s, $\Gamma_s, \Delta\Gamma_s$	LHCb-CONF-2011-049, LHCb-CONF-2011-051, LHCb-CONF-2011-025, LHCb-CONF-2011-056
Lifetimes	LHCb-PAPER-2011-014
$b \to s$ **penguins**	LHCb-CONF-2011-052, LHCb-CONF-2011-019
$B \to hh$	LHCb-CONF-2011-042
$B \to DK$	LHCb-CONF-2011-044, LHCb-CONF-2011-057, LHCb-PAPER-2011-008
b-baryons	LHCb-CONF-2011-036