CP violation in the B system at LHCb

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on behalf of the LHCb Collaboration

CRACOW EPIPHANY CONFERENCE
ON PRESENT AND FUTURE OF B-PHYSICS
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Outline

- Introduction
- CP violation in B→DX
- CP violation in Charmless B decays
- Measurements of Φ_s
- Conclusion

The LHCb experiment

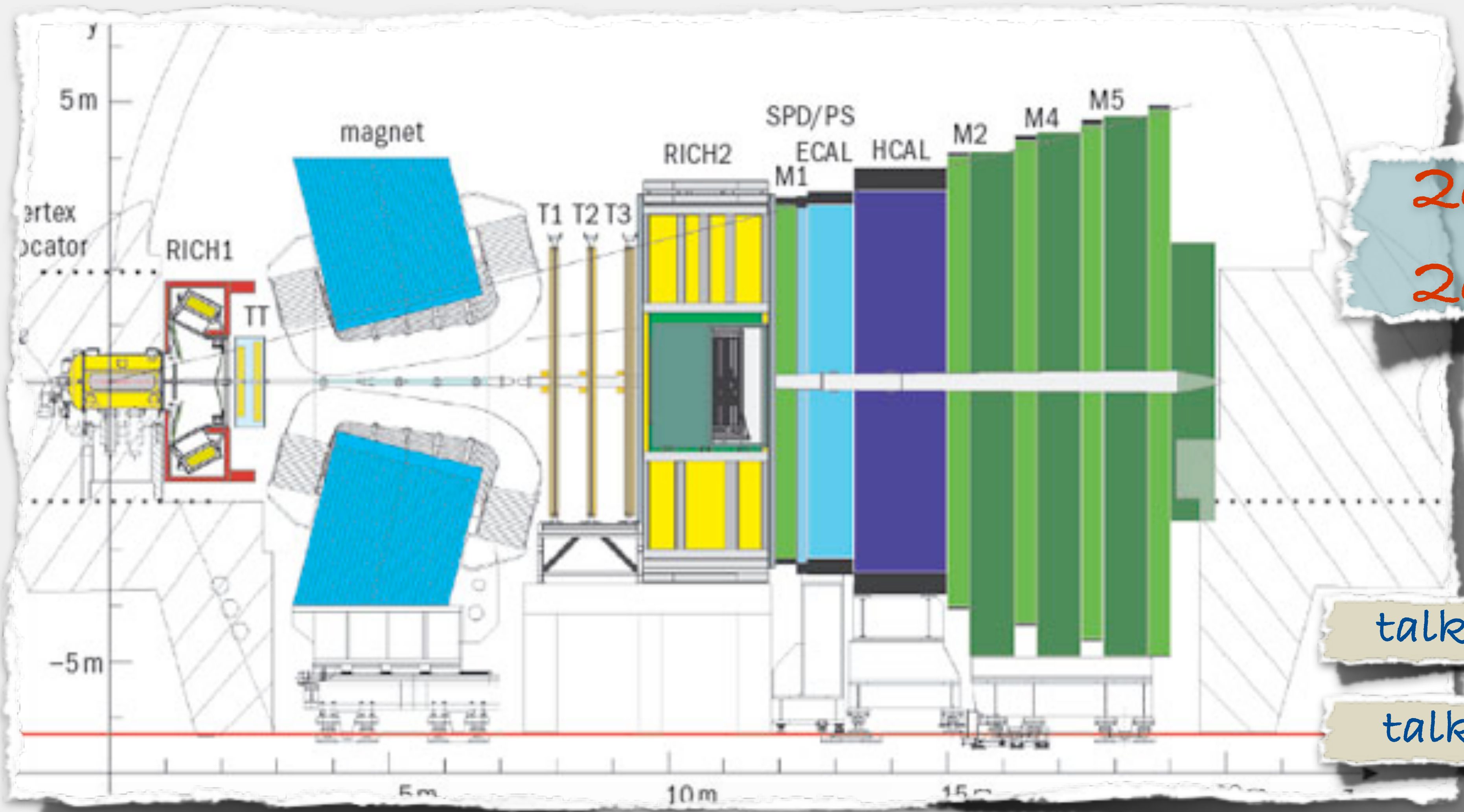
- Aims:
  - ➡ precise CPV measurements
    - B and D systems
  - ➡ rare decays
  - ➡ Spectroscopy
  - ➡ QCD/EW Physics

+talk by A. Ukleja

talk by F. Soomro

talk by A. A. Alves Jr.

- Required ingredients:
  - ➡ High trigger efficiency
  - ➡ Excellent Tracking system
    - Time, Impact parameter resolution
    - Mass resolution
  - ➡ Excellent Particle IDentification
    - Flavour tagging (PID at low momenta)



2010: $\int L = 36\,pb^{-1}$

2011: $\int L = 1.1\,fb^{-1}$

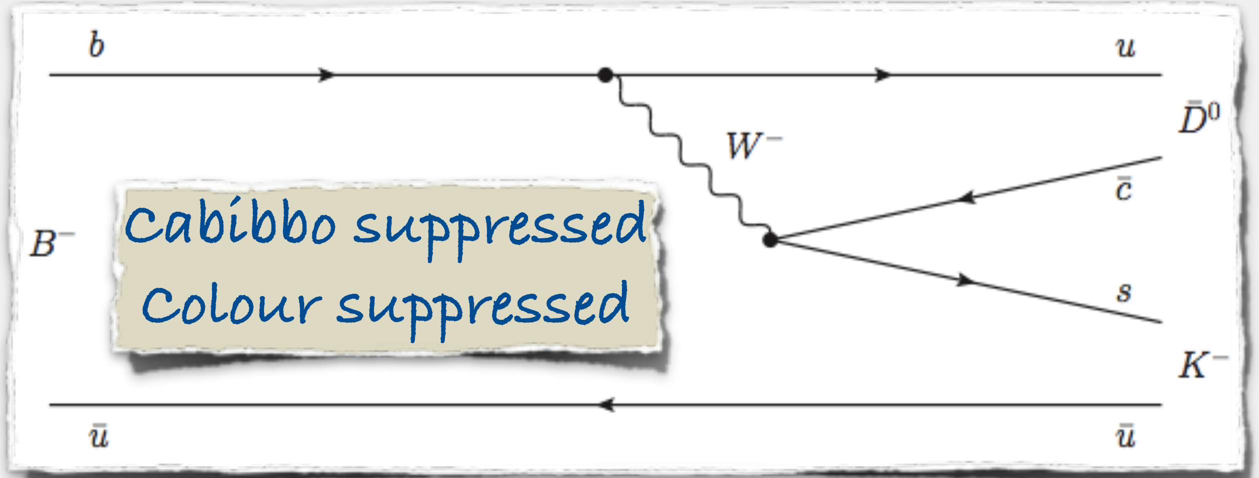
talk by F. Alessio

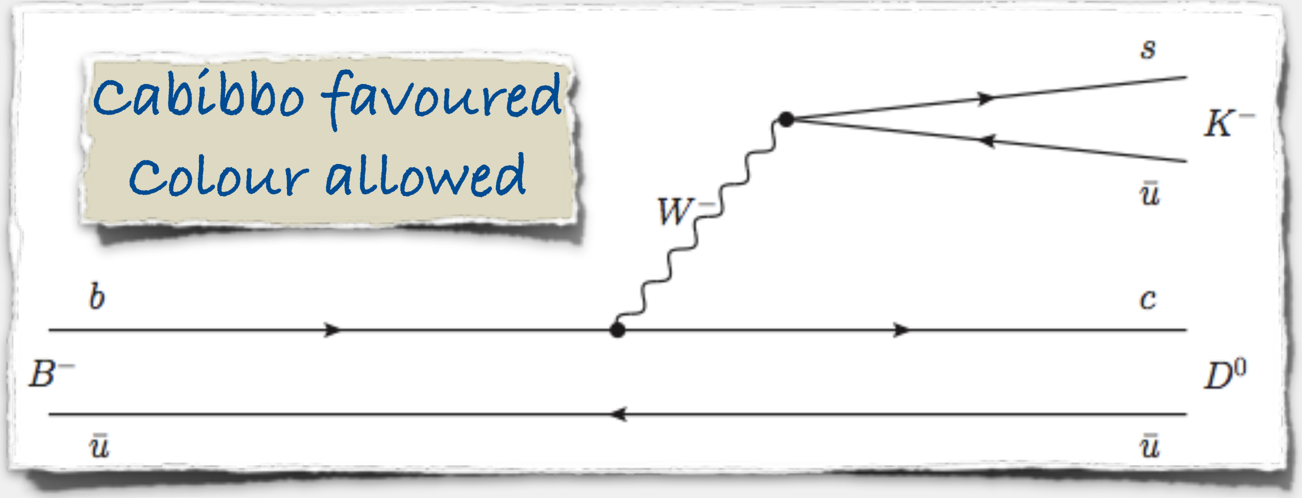
talk by C. Parks (upgrade)

CP violation in $B \to DX$

Idea of measurements in B→DX

- Aims at measuring $\gamma=\phi_3$ http://ckmfitter.in2p3.fr http://www.utfit.org
  - ➡ Direct measurements: $68^{\circ}{}^{+10^{\circ}}_{-11^{\circ}}$
  - ➡ Standard Model prediction: $67.1^{\circ}{}^{+4.6^{\circ}}_{-3.7^{\circ}}$
  - ➡ Sensitivity to γ from interference between b→u and b→c transitions





- D meson reconstructed in a common final state
  - ➡ CP eigenstate (K^+K^-, $\pi^+\pi^-$)
  - ➡ Quasi two body final state ($K^{\pm}\pi^{\mp}$, $K^{\pm}\pi^{\mp}\pi^+\pi^-$, $K^{\pm}\pi^{\mp}\pi^0$)
  - ➡ Multi-body final state ($K_S{}^0\pi^+\pi^-$, $K_S{}^0K^+K^-$, $K^+K^-\pi^+\pi^-$)
- Sensitivity driven by
  - ➡ size of interference term ($r_B \sim 0.1$)
  - ➡ branching fraction of the mode (typically $BR \sim 10^{-5}$-10^{-4})

$$A_{CP\pm} = \frac{\Gamma_{B^-\to D_{CP\pm}K^-} - \Gamma_{B^+\to D_{CP\pm}K^+}}{\Gamma_{B^-\to D_{CP\pm}K^-} + \Gamma_{B^+\to D_{CP\pm}K^+}}$$

$$R_{CP\pm} = \frac{\Gamma_{B^-\to D_{CP\pm}K^-} + \Gamma_{B^+\to D_{CP\pm}K^+}}{\Gamma_{B^-\to DK^-} + \Gamma_{B^+\to DK^+}}$$

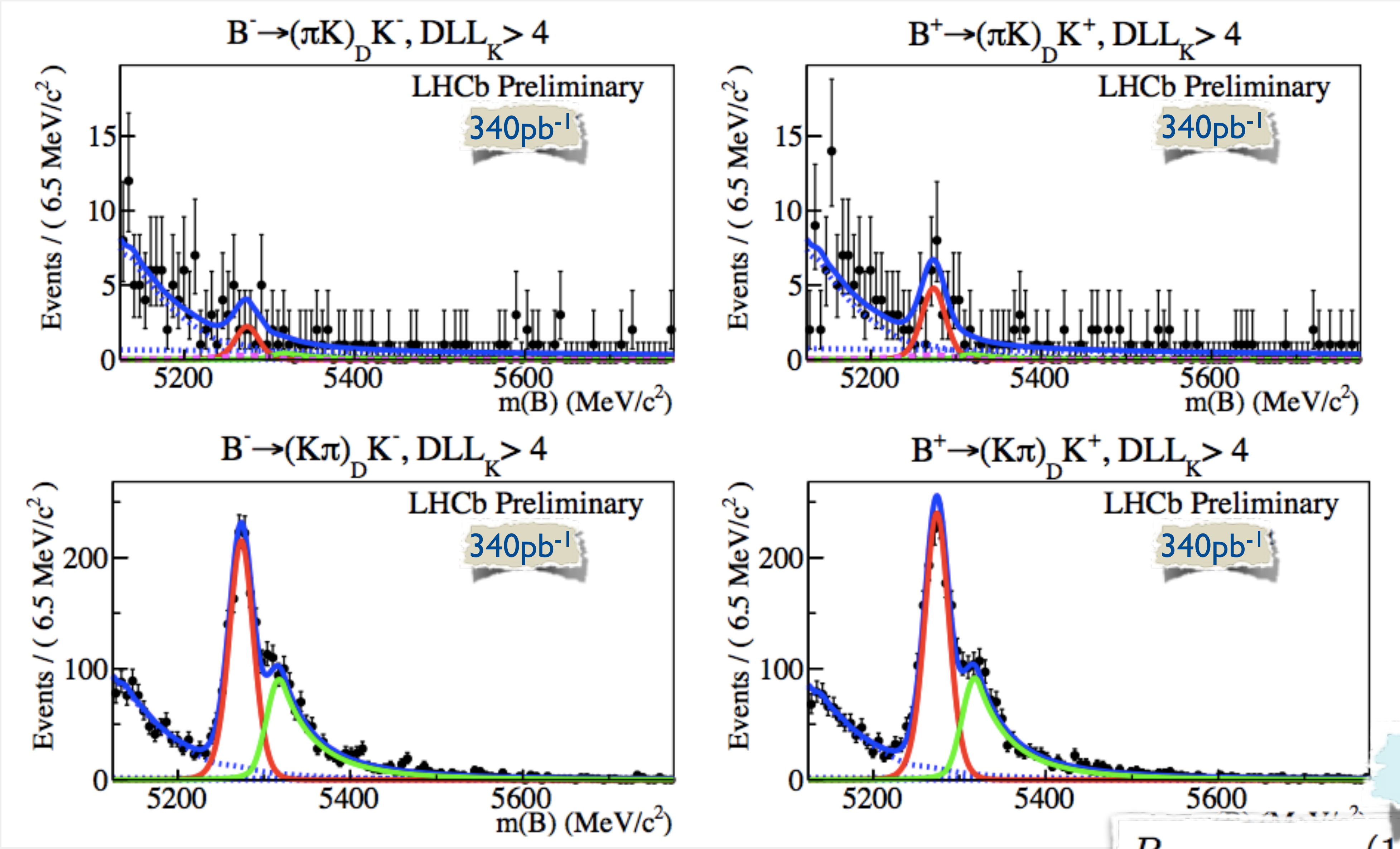
$$A_{ADS} = \frac{\Gamma_{B^-\to \bar{f}K^-} - \Gamma_{B^+\to fK^+}}{\Gamma_{B^-\to \bar{f}K^-} + \Gamma_{B^+\to fK^+}}$$

$$R_{ADS} = \frac{\Gamma_{B^-\to \bar{f}K^-} + \Gamma_{B^+\to fK^+}}{\Gamma_{B^-\to fK^-} + \Gamma_{B^+\to \bar{f}K^+}}$$

CPV in $B^{\pm} \to D^0 h^{\pm}$ ($h = K, \pi$)

LHCb-CONF-2011-044

- 4σ evidence (including systematic uncertainty) for the suppressed $B^{\pm} \to (K^{\mp}\pi^{\pm})_D K^{\pm}$ mode
- Measurement also performed for $B^{\pm} \to (K^{\mp}\pi^{\pm})_D \pi^{\pm}$

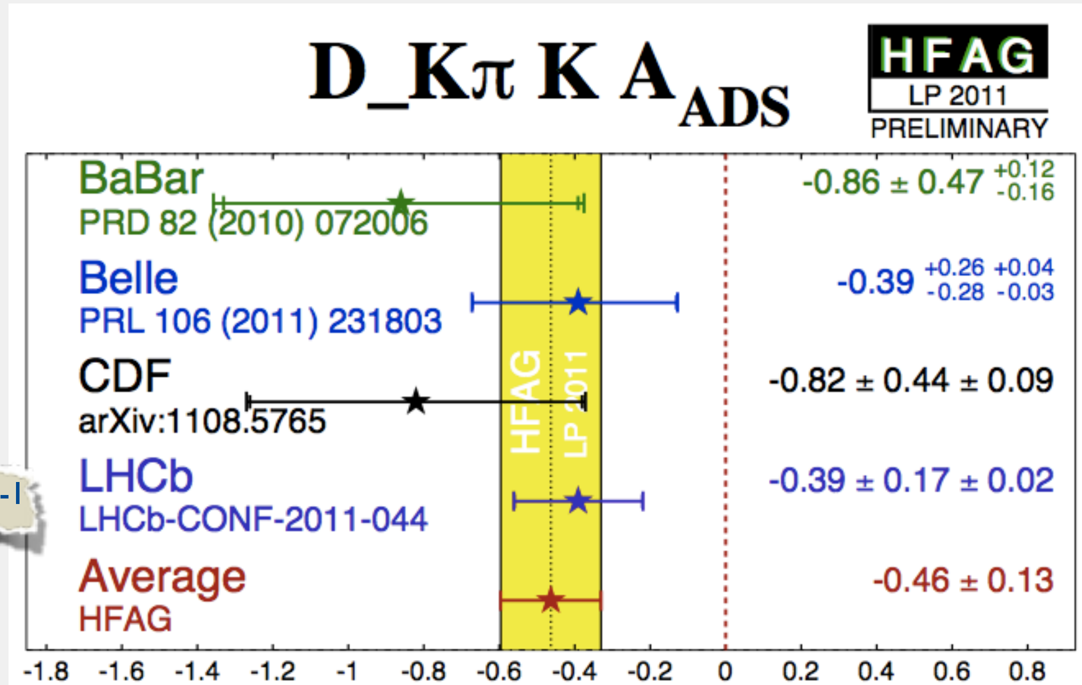


PRELIMINARY 340pb⁻¹

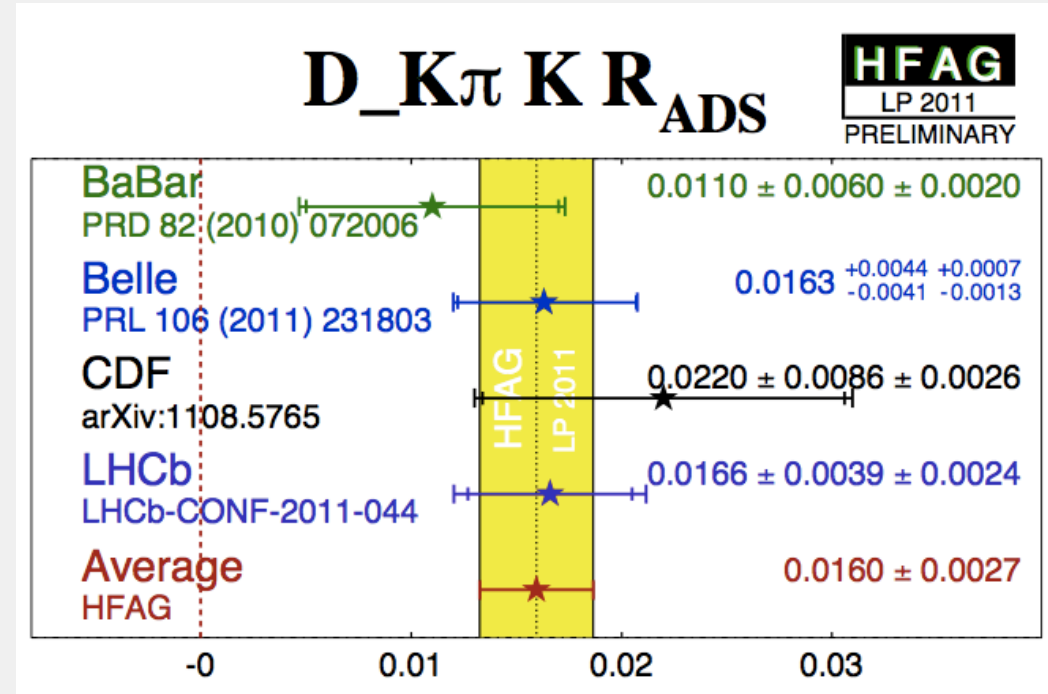
$$R_{ADS} = (1.66 \pm 0.39 \pm 0.24) \times 10^{-2}$$
$$A_{ADS} = -0.39 \pm 0.17 \pm 0.02$$
$$R_{ADS}^{D\pi} = (4.13 \pm 0.41 \pm 0.40) \times 10^{-3}$$
$$A_{ADS}^{D\pi} = 0.09 \pm 0.10 \pm 0.01.$$

Large room for statistical improvement on CP asymmetries

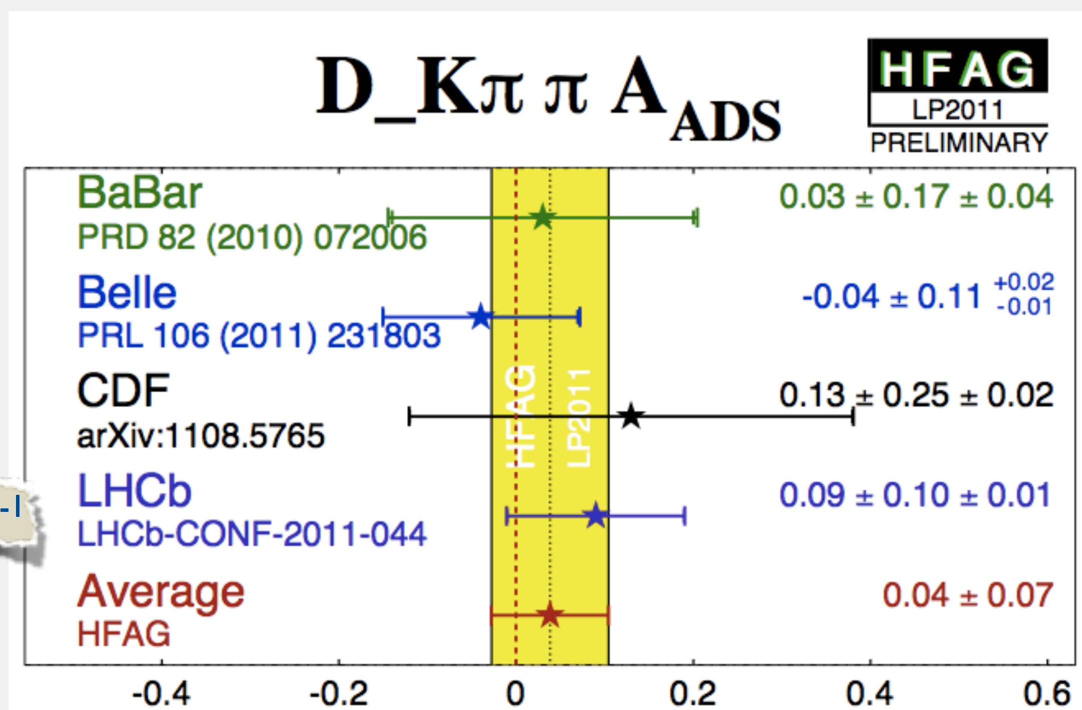
Impact of LHCb



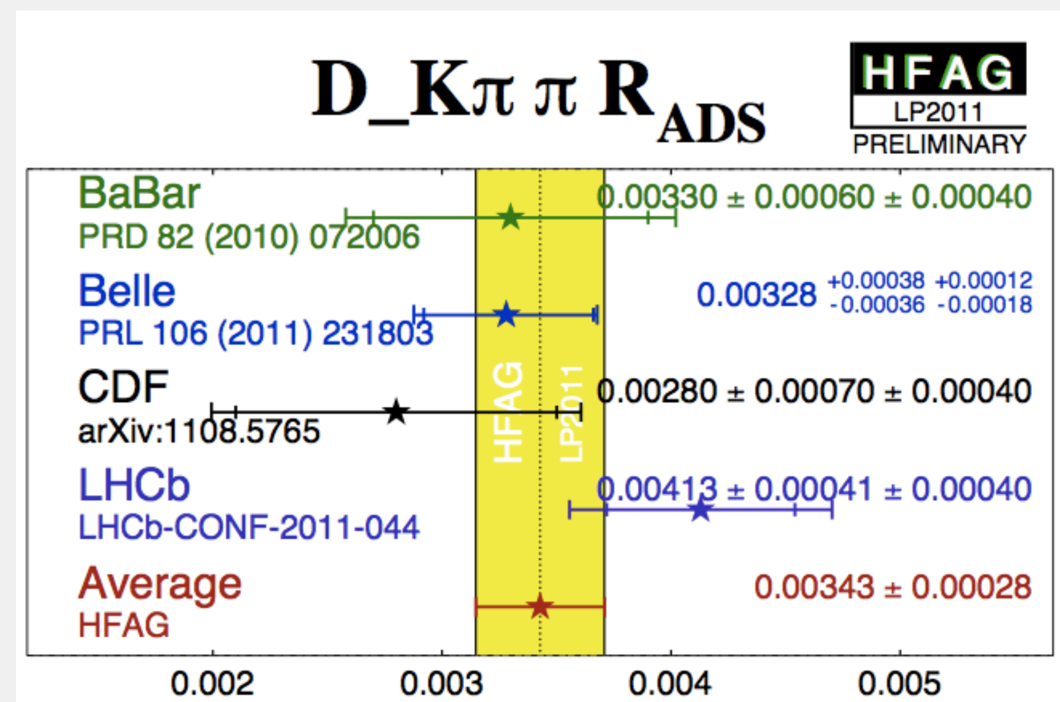
340pb^{-1}



340pb^{-1}



340pb^{-1}



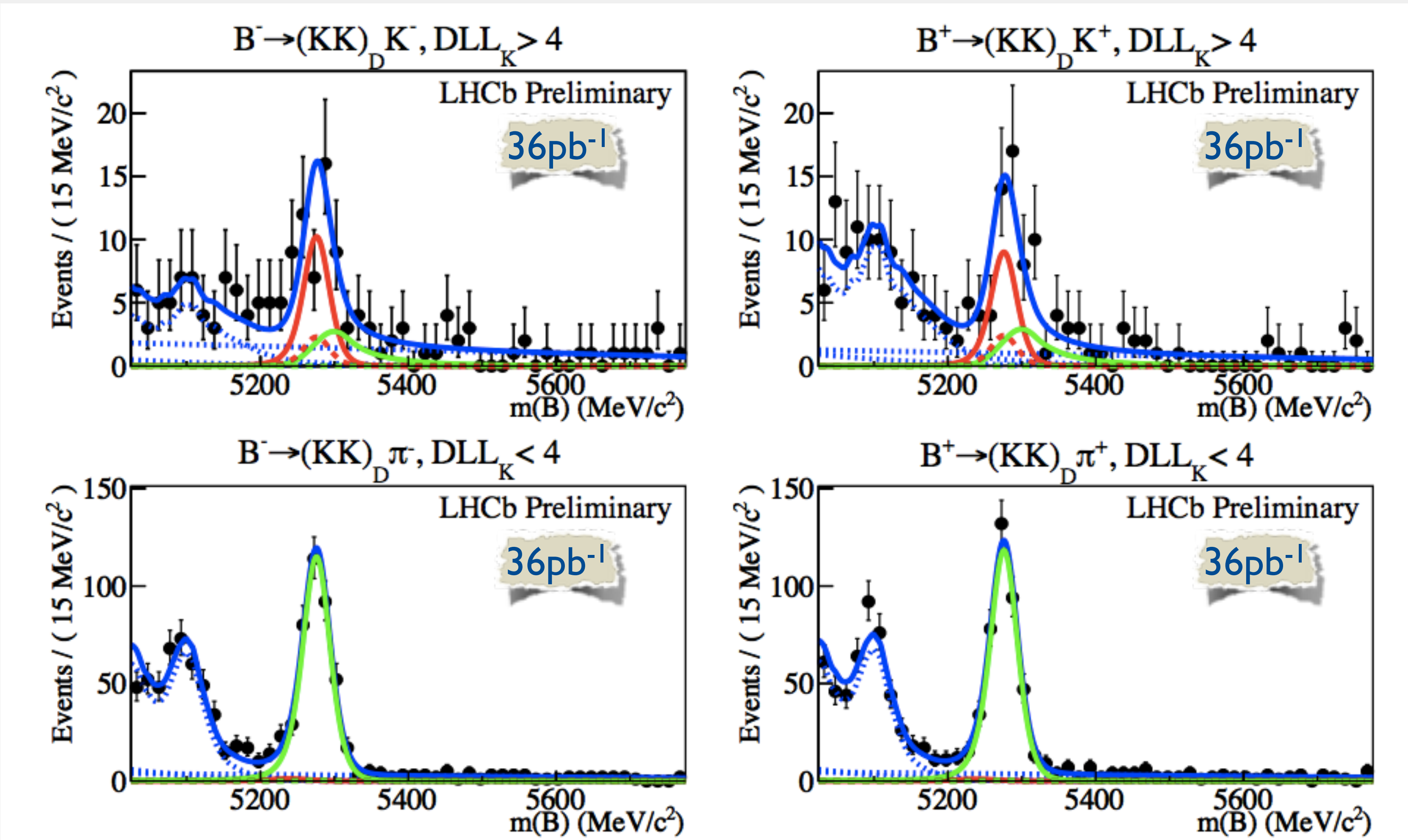
340pb^{-1}

- Good agreement with previous determinations
- LHCb already competitive with previous measurements
- Eagerly awaited 5σ observation of suppressed modes will arrive soon

CPV in $B^\pm \to D_{CP} h^\pm$ ($h = K, \pi$)

LHCb-CONF-2011-031

- Result obtained with 2010 data only, work ongoing to provide an update



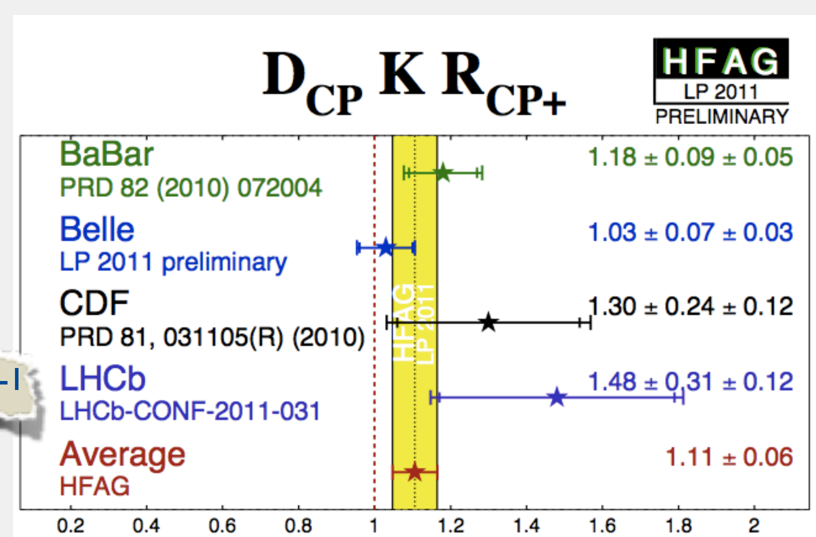
PRELIMINARY 36pb⁻¹

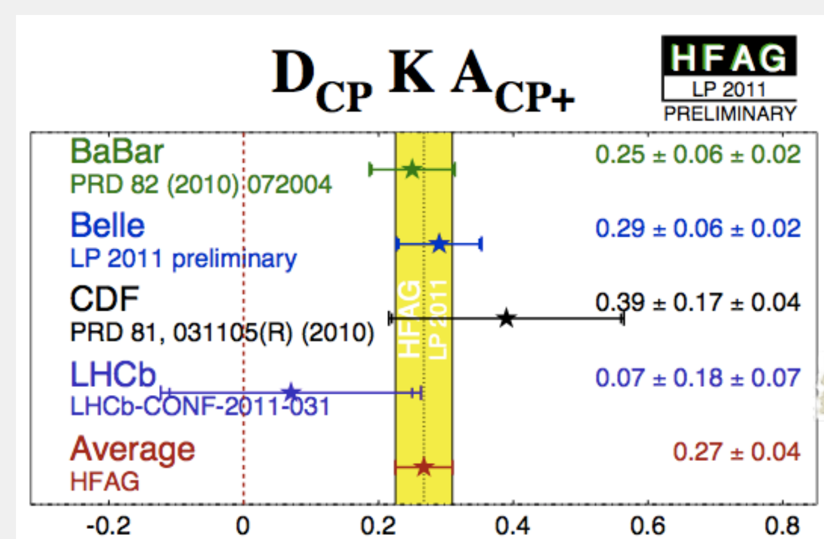
$$R_{CP+} = 1.48 \pm 0.31 \pm 0.12$$

$$\mathcal{A}^{DK}_{CF} = -0.08 \pm 0.06 \pm 0.02$$

$$\mathcal{A}^{DK}_{CP+} = 0.07 \pm 0.18 \pm 0.07$$

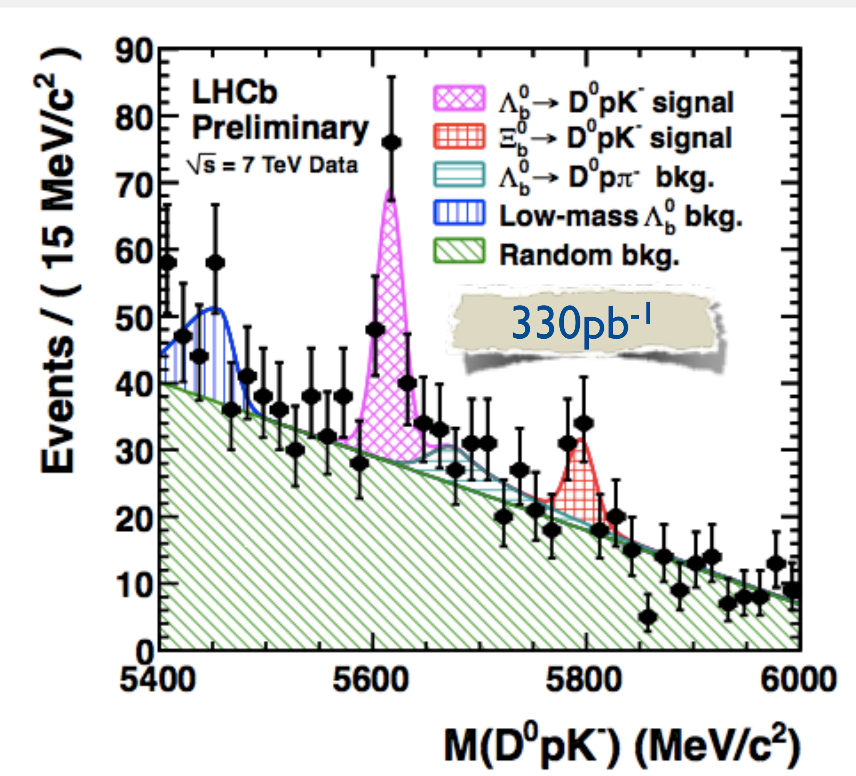
$$\mathcal{A}^{D\pi}_{CP+} = 0.01 \pm 0.04 \pm 0.01$$

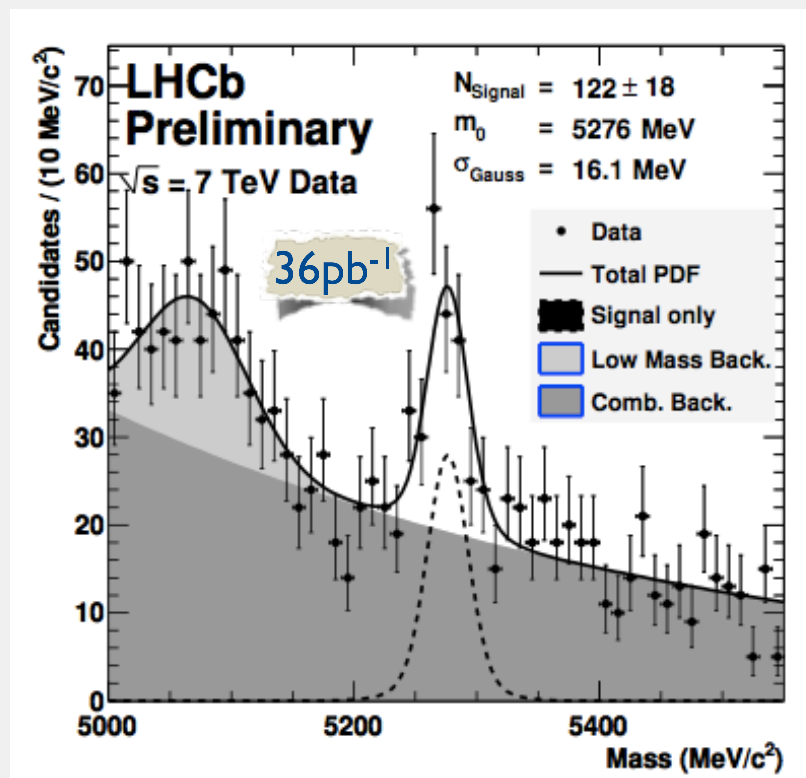


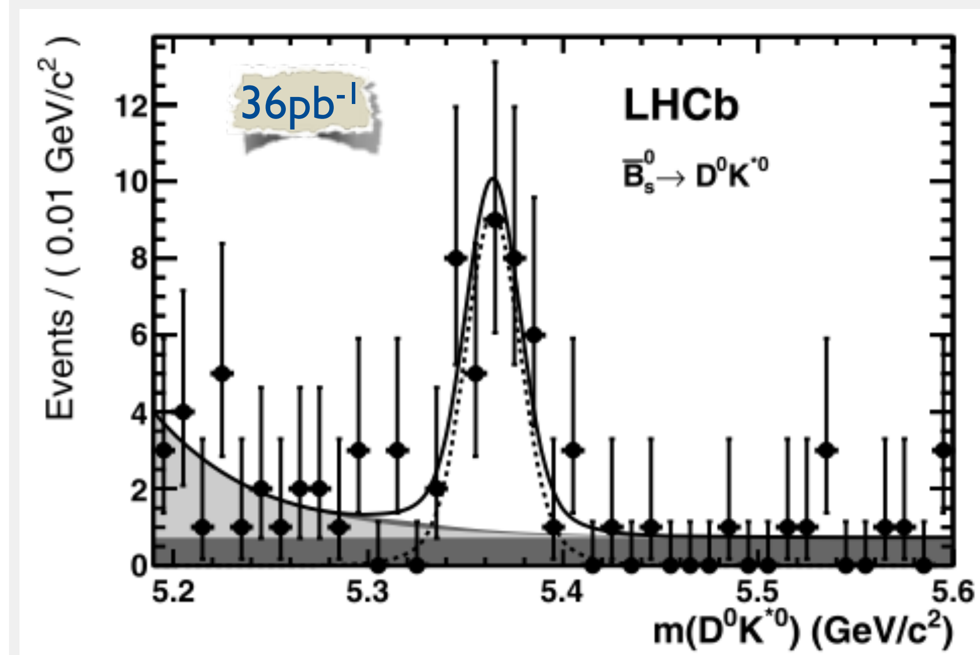


Prospects

- Many results on the road to γ for additional b-hadron decay modes
  - ➡ first observation of $B_s \to D^0K^{*0}$: background (not only) for $B_d \to D^0K^{*0}$ — Phys. Lett. B 706 (2011) 32-39
  - ➡ first observation of $B^\pm \to D^0K^\pm\pi^+\pi^-$: ~25% of the statistics in $B^\pm \to D^0K^\pm$ — LHCb-CONF-2011-024
  - ➡ first observation of $\Lambda_b \to D^0pK^-$: ~100 events in 330pb^{-1} — LHCb-CONF-2011-036







Many modes for γ measurements accessible at LHCb

Time dependent γ measurements

- Tree level $\gamma+\Phi_{mixing}$ measurement also accessible through $B_s \to D_s^{\mp} K^{\pm}$ and $B_d \to D^{\mp}\pi^{\pm}$
  - ➡ Large interference in the B_s case
  - ➡ Needs a time dependent analysis

- On the road to this measurement
  - ➡ determination of fs/fd using $B_s \to D_s^- \pi^+$, $B^0 \to D^- K^+$ and $B^0 \to D^- \pi^+$ 36pb^{-1}
    talk by P. Morawski
    Phys. Rev. Lett. 107 (2011) 211801
  - ➡ measurement of the branching fractions of $B_s \to D_s^{\mp} K^{\pm}$ and $B_s \to D_s^- \pi^+$ 340pb^{-1}
    talk by A. Dziurda
    LHCb-CONF-2011-057
  - ➡ competitive measurement of Δm_s using $B_s \to D_s^- \pi^+ (\pi^+\pi^-)$
    36pb^{-1} arXiv:1112.4311

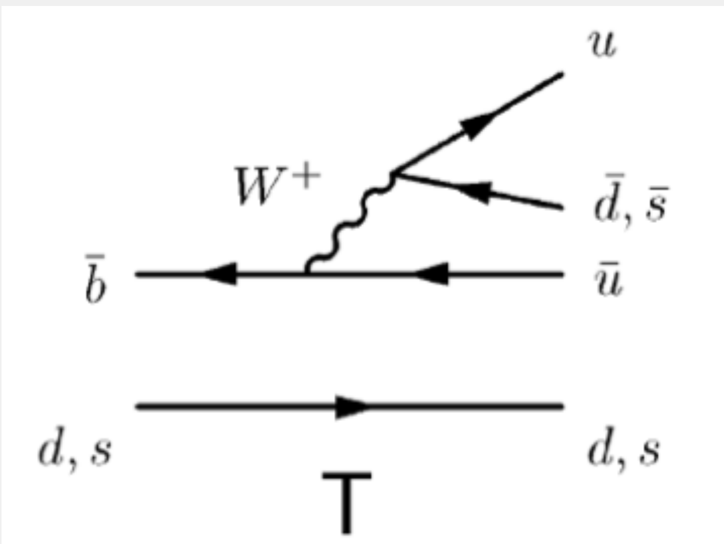
$$\Delta m_s = 17.63 \pm 0.11\ (\text{stat}) \pm 0.02\ (\text{syst})\ \text{ps}^{-1}.$$

  - ➡ first observation of additional similar modes $B^0 \to D^- K^+ \pi^+ \pi^-$ 36pb^{-1} LHCb-CONF-2011-024
    - Expect to observe $B_s \to D_s^{\mp} K^{\pm} \pi^+ \pi^-$ with 2011 data

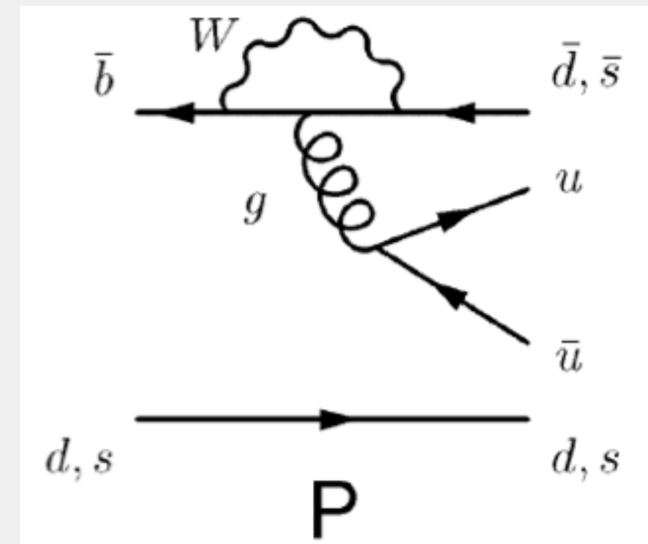
CP violation in Charmless B decays

General strategy in 2-body decays

- An other way to extract γ, but sensisible to potential new physics effects
- Two body B^0 decays easier to reconstruct and trigger than many



Example of interfering diagrams



Decays of interest, BR~$10^{-7} \rightarrow 10^{-5}$

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

U-spin

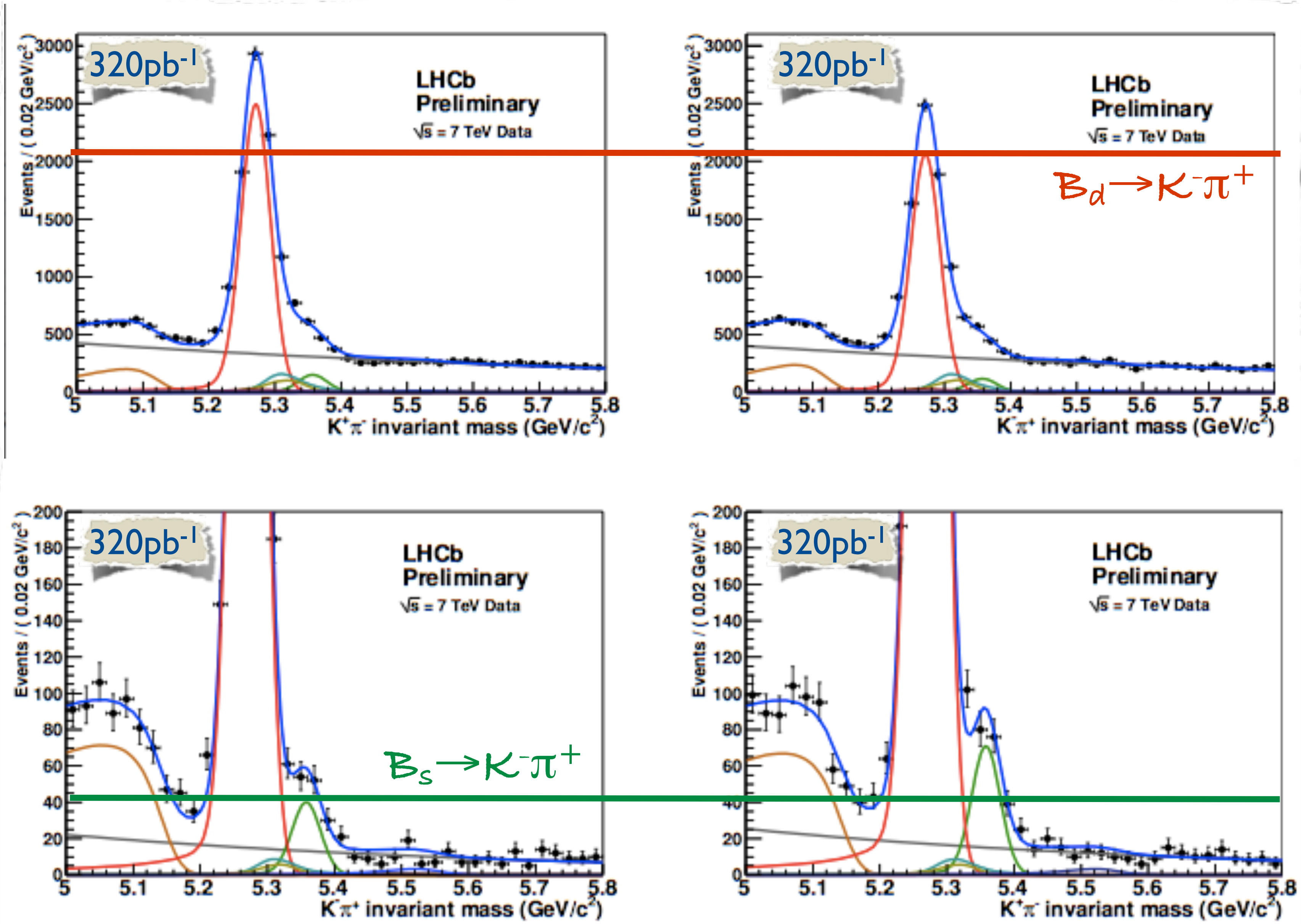
control U-spin for spectator quark

control size of polluting diagrams

CPV in $B_{(d,s)} \to K\pi$

LHCb-CONF-2011-042

$$\mathcal{A}_{CP} = \mathcal{A}_{Raw} - (\mathcal{A}_{Det.} + \kappa \mathcal{A}_{Prod.})$$



- Detector asymmetry:
  - ➡ determined from D's
  - ➡ reconstruction (0.2%)
    - ▸ suppressed by B field flip
  - ➡ interaction x-sec (1%)
- Production asymmetry:
  - ➡ diluted (30% in Bd):
    - ▸ mixing
    - ▸ proper time acceptance
  - ➡ use $B_d \to J/\psi K^{*0}$
  - ➡ $A_{prod} \sim 1\%$

CPV in $B_{(d,s)} \to K\pi$: result (prelim.)

LHCb-CONF-2011-042

$$A_{CP}(B_s^0 \to \pi K) = \frac{\Gamma(\bar{B}_s^0 \to \pi^- K^+) - \Gamma(B_s^0 \to \pi^+ K^-)}{\Gamma(\bar{B}_s^0 \to \pi^- K^+) + \Gamma(B_s^0 \to \pi^+ K^-)}.$$

$$A_{CP}(B^0 \to K\pi) = \frac{\Gamma(\bar{B}^0 \to K^- \pi^+) - \Gamma(B^0 \to K^+ \pi^-)}{\Gamma(\bar{B}^0 \to K^- \pi^+) + \Gamma(B^0 \to K^+ \pi^-)}$$

Recent CDF result : $0.39 \pm 0.15 \pm 0.08$

HFAG average : $-0.098^{+0.012}_{-0.011}$

$$A_{CP}(B_s^0 \to \pi K) = 0.27 \pm 0.08 \pm 0.02.$$

$320 pb^{-1}$

$$A_{\Delta}(B_s^0 \to \pi K) = 0.010 \pm 0.002.$$

PRELIMINARY

$$A_{CP}(B^0 \to K\pi) = -0.088 \pm 0.011 \pm 0.008$$

$320 pb^{-1}$

$$A_{\Delta}(B^0 \to K\pi) = -0.007 \pm 0.006.$$

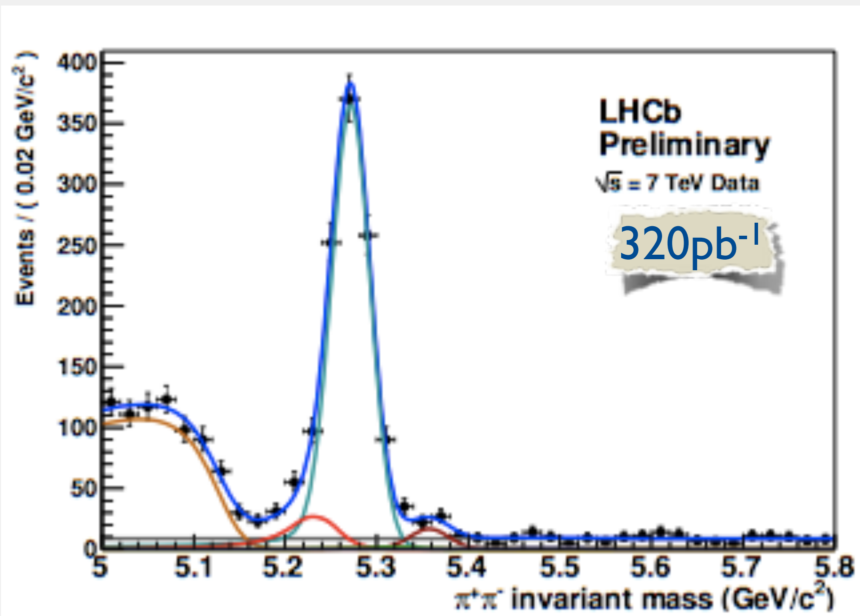
Systematics dominated by
the modeling of the B invariant mass (B_s case)
the correction of production and detector asymmetries (B_d case)

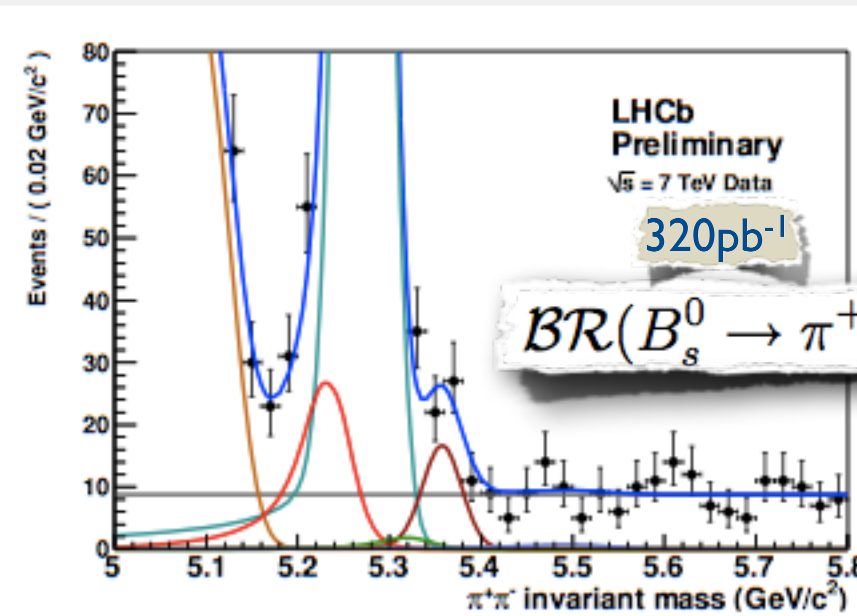
5σ observation for A_{CP} in B_d
First 3σ evidence for A_{CP} in B_s

Prospects: 2-body charmless decays

LHCb-CONF-2011-042

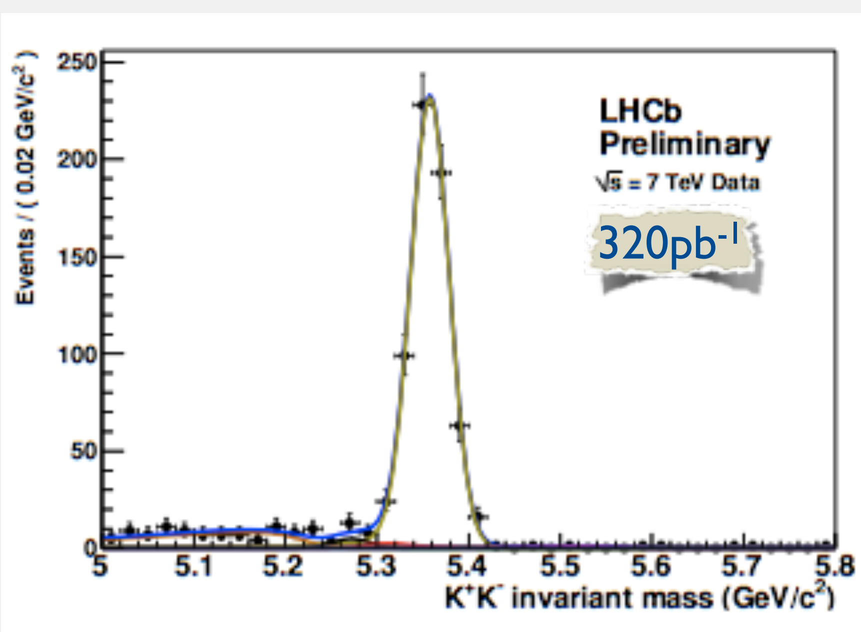
- On the road to constrain γ
  - ➡ measure the branching fractions of $B_d \to K^+K^-$ and $B_s \to \pi^+\pi^-$
  - ➡ time-dependent CPV analysis of $B_s \to K^+K^-$ and $B_d \to \pi^+\pi^-$ ongoing

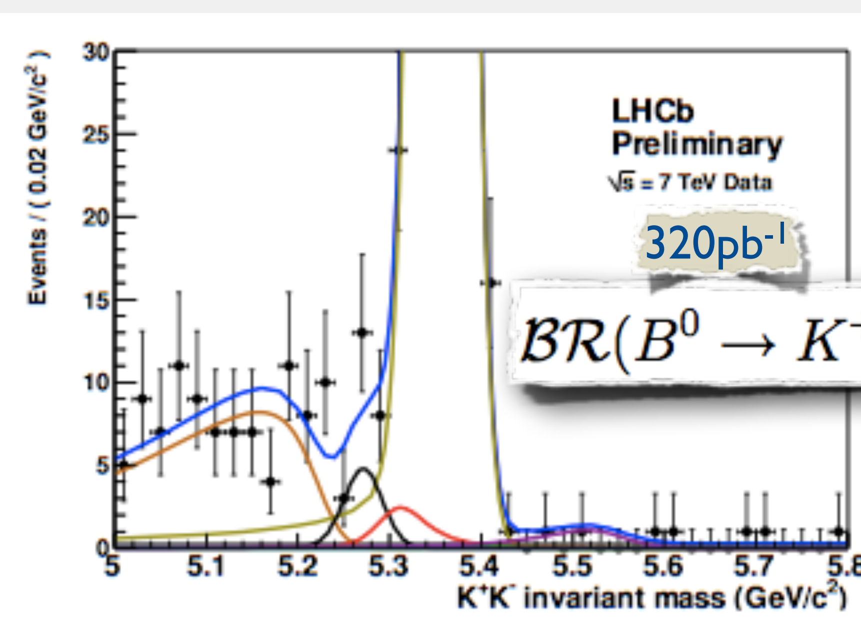




PRELIMINARY

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





PRELIMINARY

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

Prospects: 3 body charmless decays

- Recent competitive measurements of BR($B^{\pm} \to K^{\pm} h^{+} h^{-}$) ($h = K, \pi, p$)
  - ➡ next step: time-integrated CPV measurements
  - ➡ then: time-dependent measurements
    - require tagging (less powerful at pp collider than B factories)

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

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

PRELIMINARY

$36 pb^{-1}$

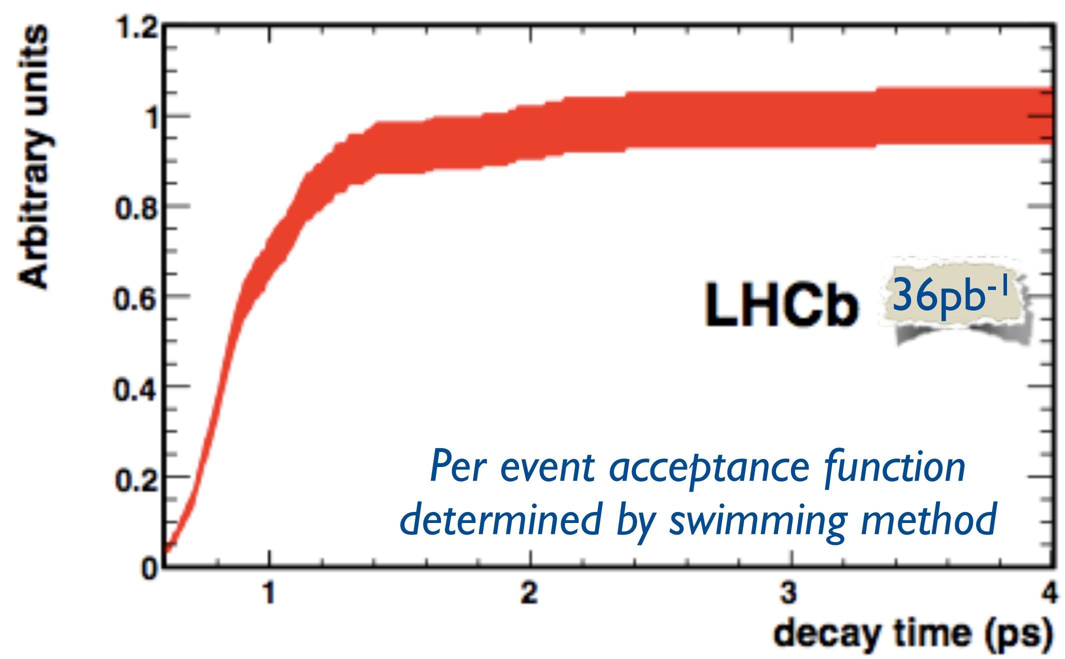
LHCb-CONF-2011-059

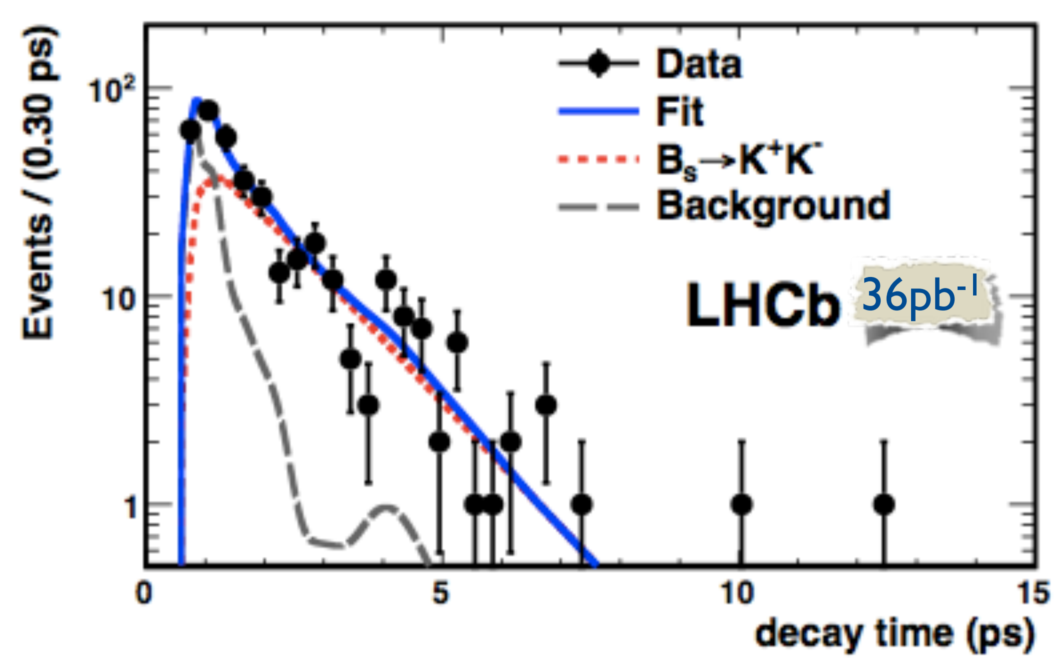
- Looking for $B_{(d,s)} \to K_S^{0} h^{+} h^{-}$ ($h = K, \pi$) with the full 2011 dataset

Effective Lifetime in $B_s \to KK$

arXiv:1111.0521

- Two analyses
  - ➡ Per event acceptance function absolute lifetime measurement
  - ➡ Relative lifetime to $B^0 \to K^+\pi^-$, $\tau_{K\pi} = \tau_{Bd}$ and similar acceptance functions





$$\tau_{KK} = \tau_{B_s^0}\left(1 + \mathcal{A}_{\Delta\Gamma_s} y_s + \mathcal{O}(y_s^2)\right) \text{ with } y_s = \Delta\Gamma_s/2\Gamma_s$$

$$\tau_{KK} = 1.440 \pm 0.096\ (\text{stat}) \pm 0.008\ (\text{syst}) \pm 0.003\ (\text{model})\ \text{ps}$$

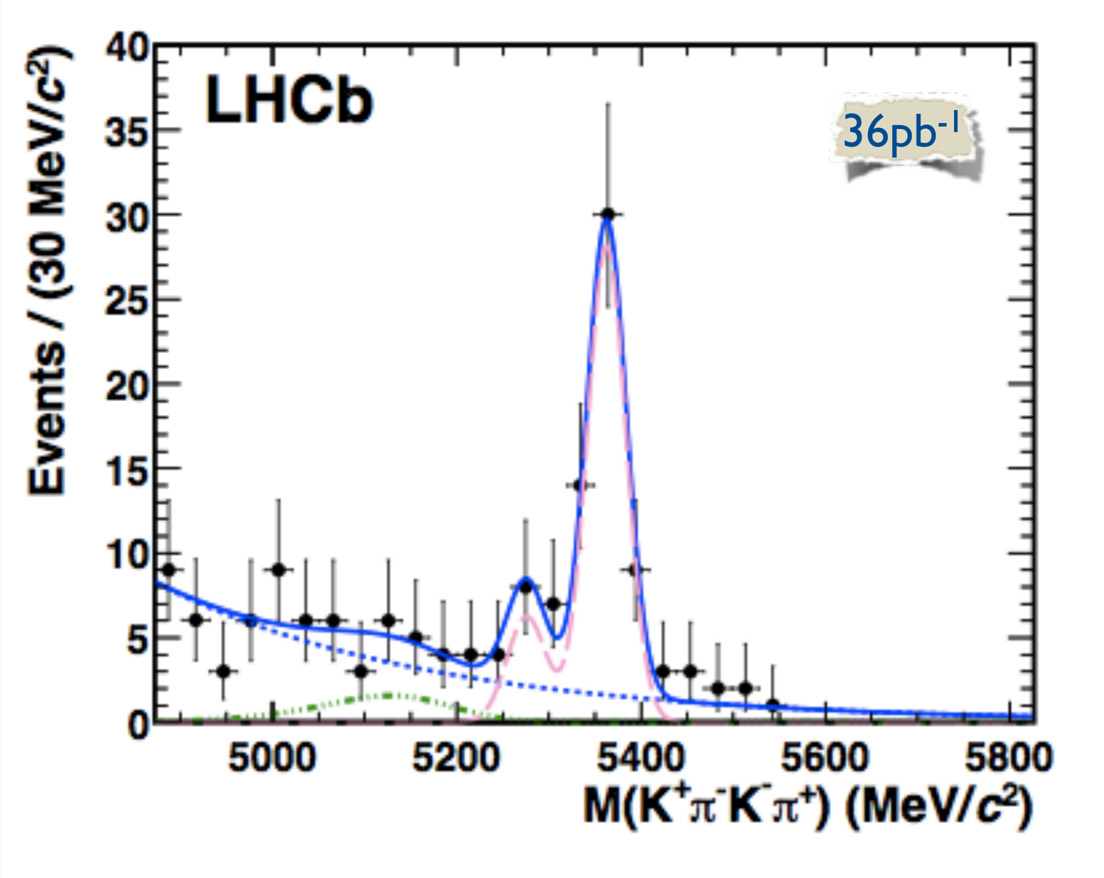
This result

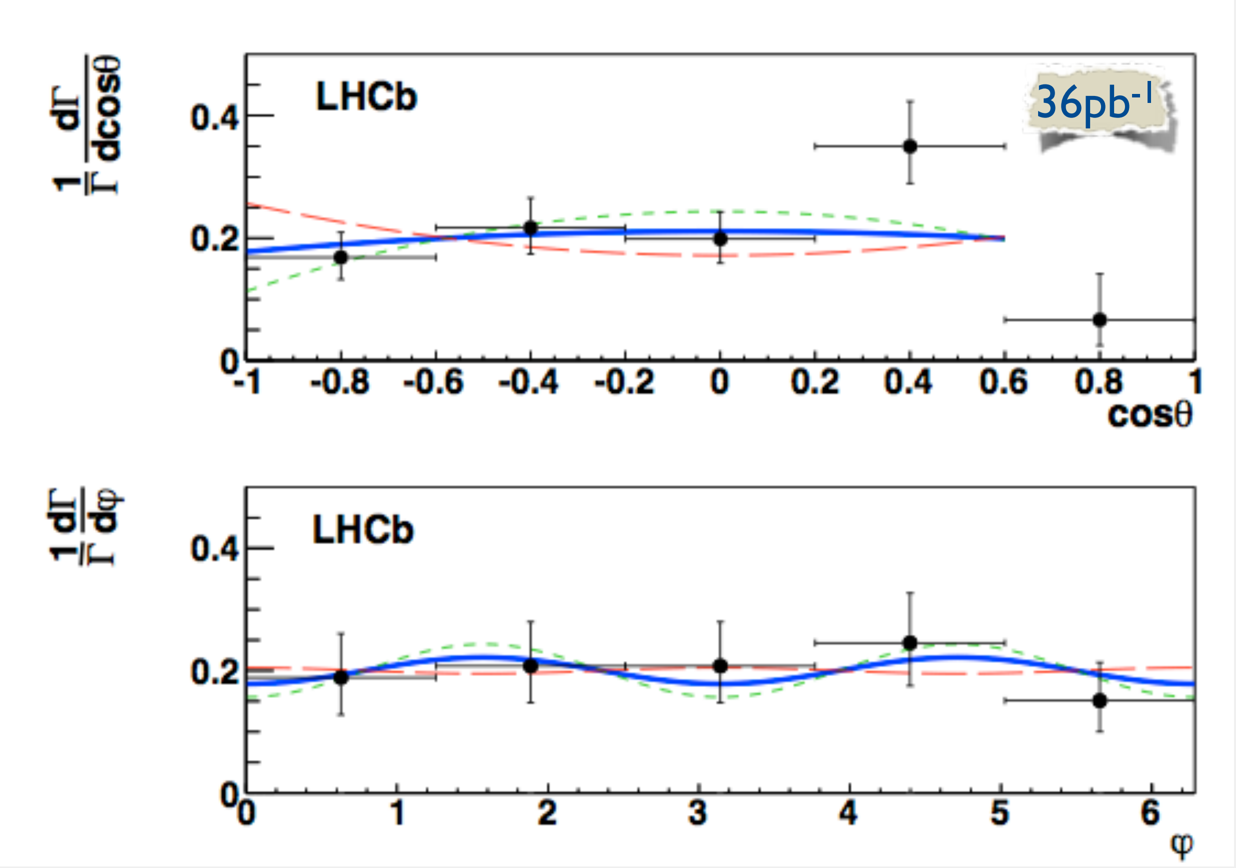
$$\tau_{KK} = 1.390 \pm 0.032\ \text{ps}$$

Standard Model prediction

$B_s \to K^{*0}K^{*0}$

- Charmless quasi 2-body decays can be used to extract weak phases
- First observation of $B_s \to K^{*0}K^{*0}$
- Measurement of the polarisation





$$\mathcal{B}(B_s^0 \to K^{*0}\overline{K}^{*0}) = (2.81 \pm 0.46\ (\text{stat.}) \pm 0.45\ (\text{syst.}) \pm 0.34\ (f_s/f_d)) \times 10^{-5}.$$

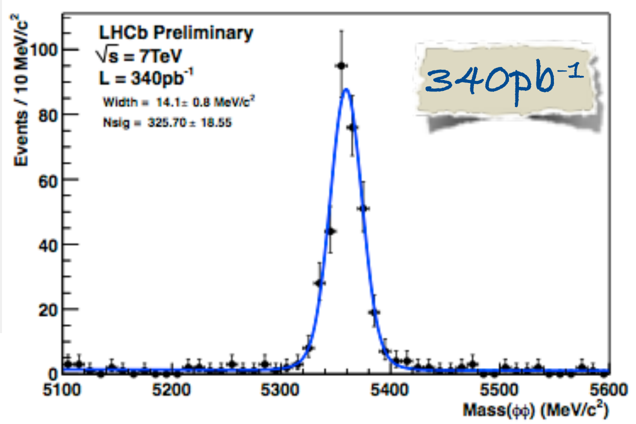
$$f_L = 0.31 \pm 0.12(\text{stat.}) \pm 0.04(\text{syst.})$$

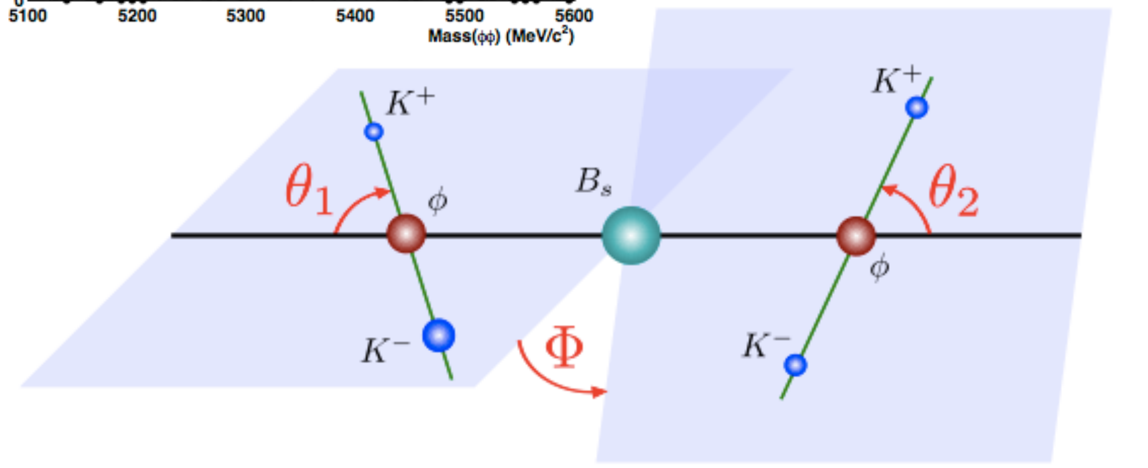
Measurement still statistically limited (36 pb^{-1} of 2010 data)

$B_s \to \Phi\Phi$

- Triple product asymmetries $A_U = \frac{N_{U<0} - N_{U>0}}{N_{U<0} + N_{U>0}}$
  ➡ CPV under CPT assumption

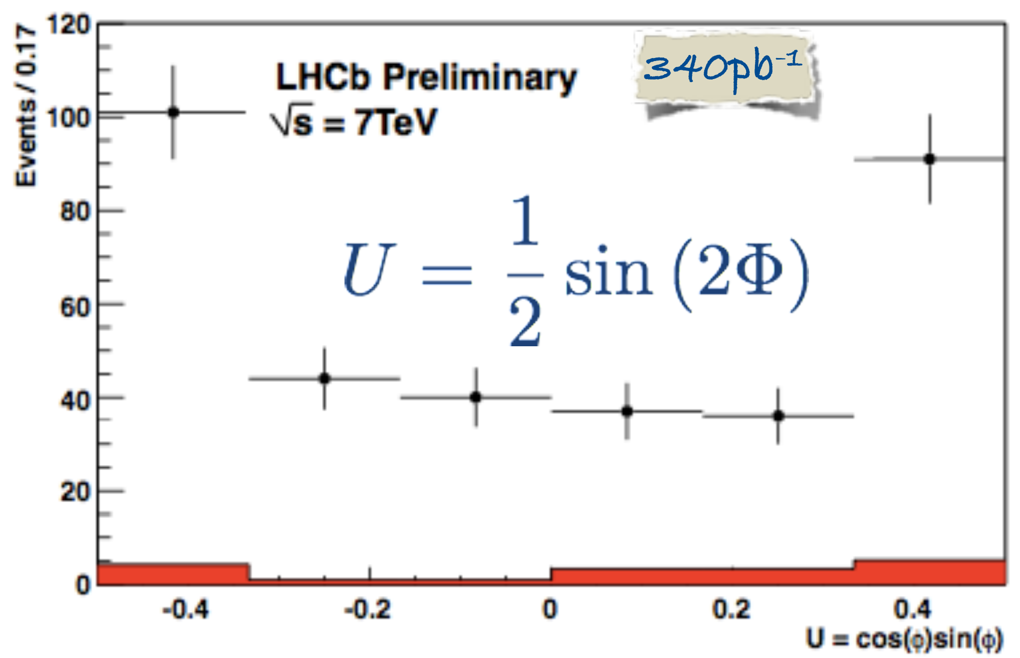
- Prospects:
  ➡ time-dependent analysis to measure Φ_s

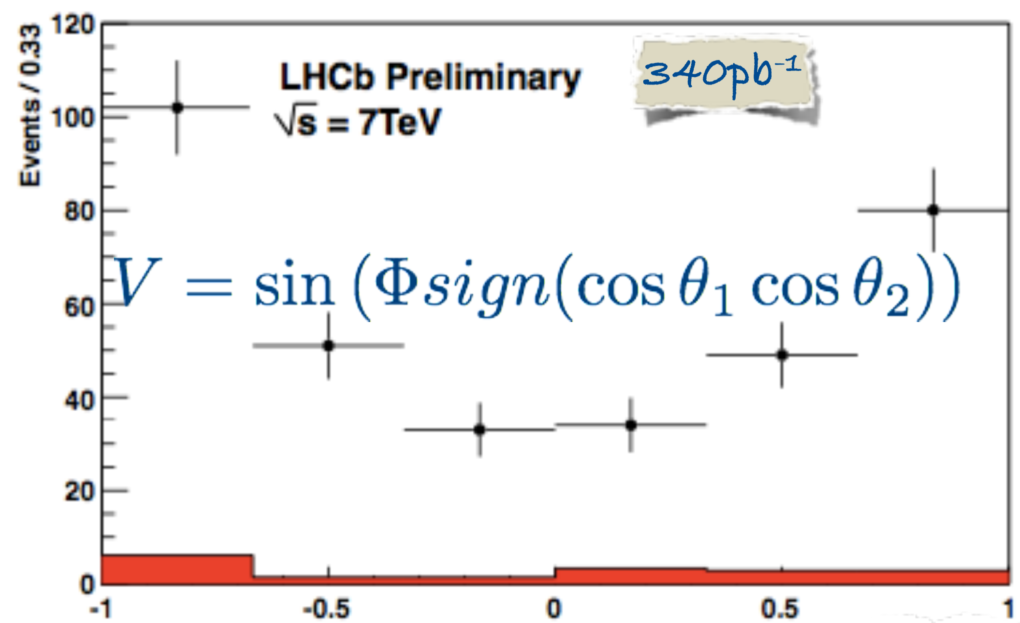




CDF

$$A_U = -0.007 \pm 0.064(stat) \pm 0.018(syst)$$
$$A_V = -0.120 \pm 0.064(stat) \pm 0.016(syst).$$





LHCb measurement in agreement with CDF

PRELIMINARY

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

340pb⁻¹

Measurements of Φ_s

Measurements of Φ_s

- CPV in the interference between mixing and decay

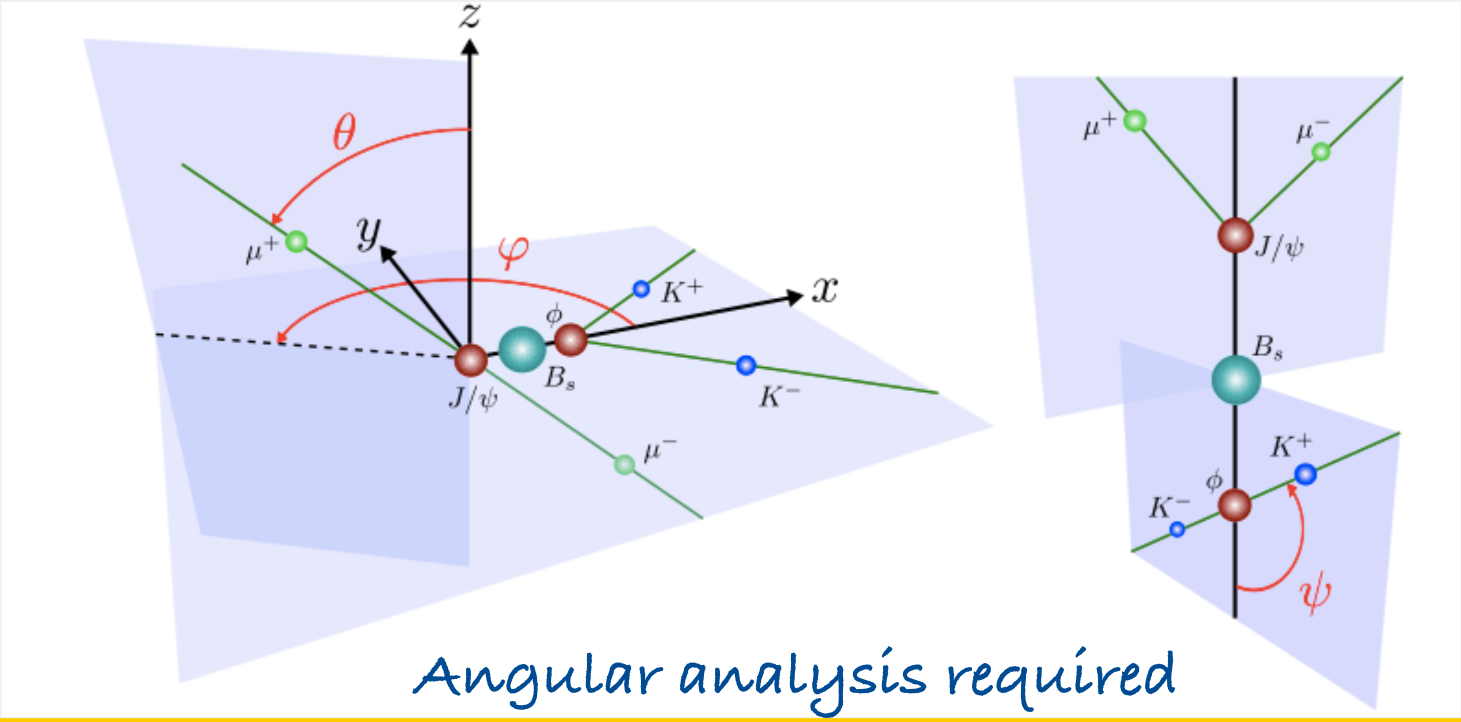
$$\Phi_s = \Phi_M - 2\Phi_D$$

- Precise SM prediction

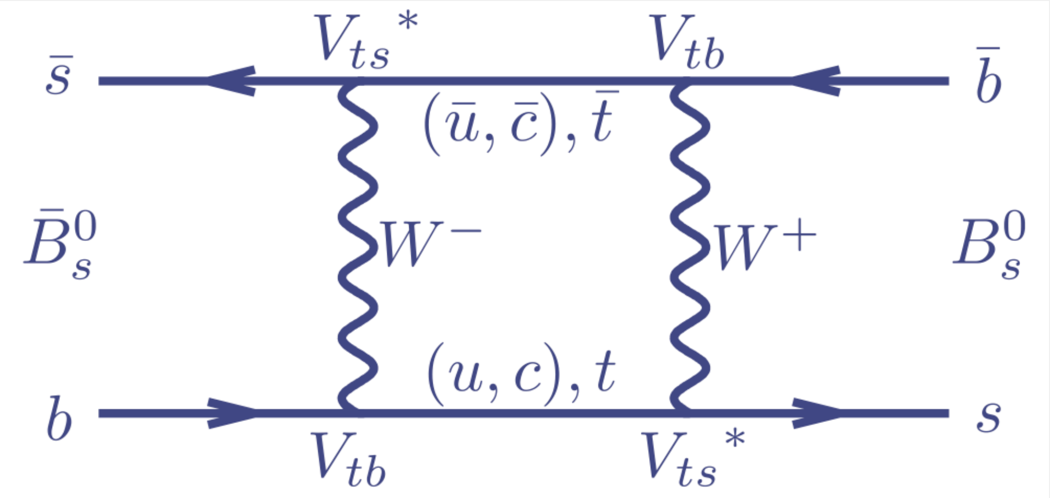
$$\Phi_s^{SM} = -2\beta_s = (-0.0363 \pm 0.0017)\ \text{rad}$$

- Decay dominated by tree level contributions
  ➡ decay phase robust again New Physics

- Mixing phase sensible to New Physics

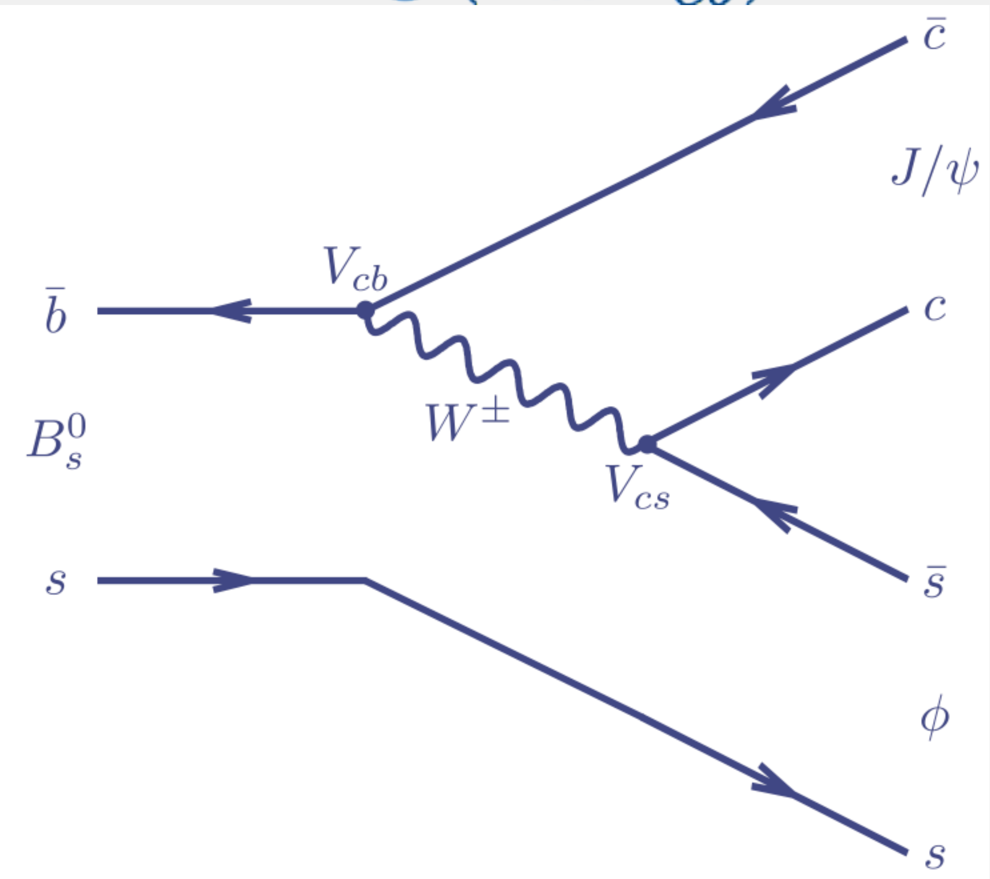


Angular analysis required



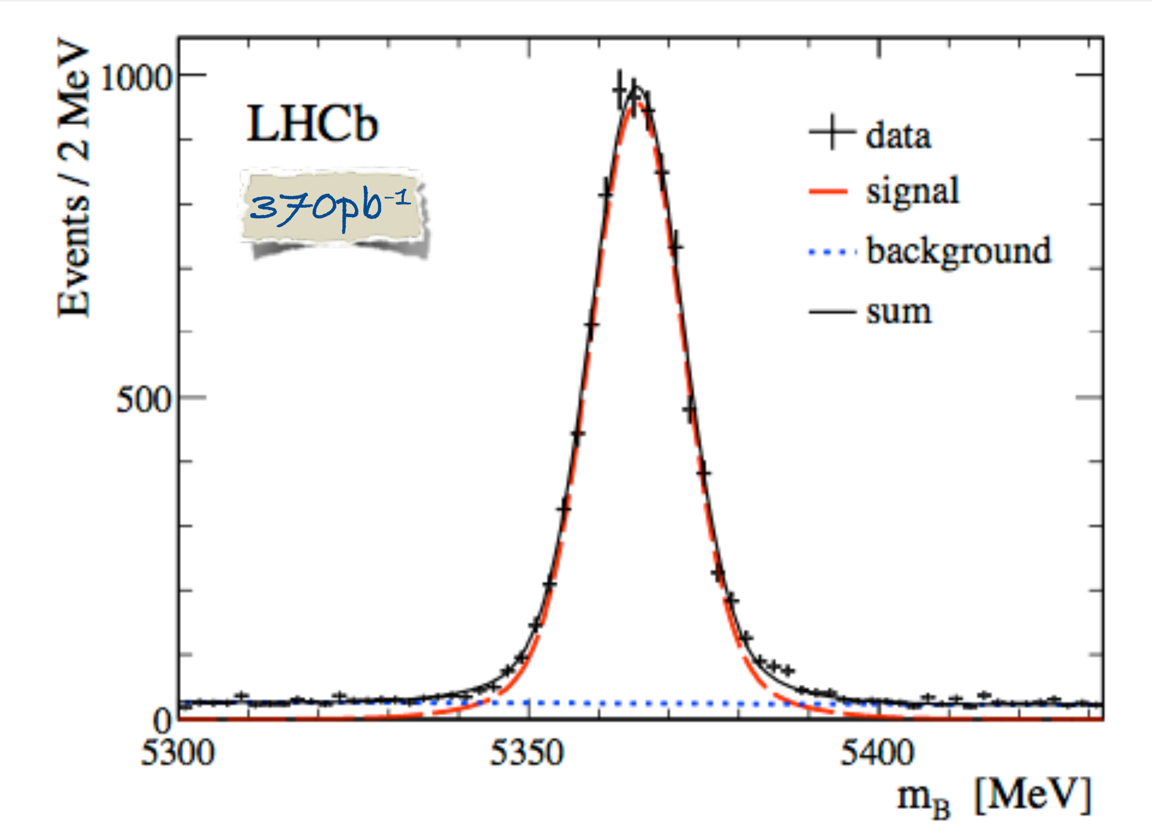
$$\Phi_M = 2\arg\left(V_{ts}V_{tb}^*\right) \simeq -2\beta_s$$

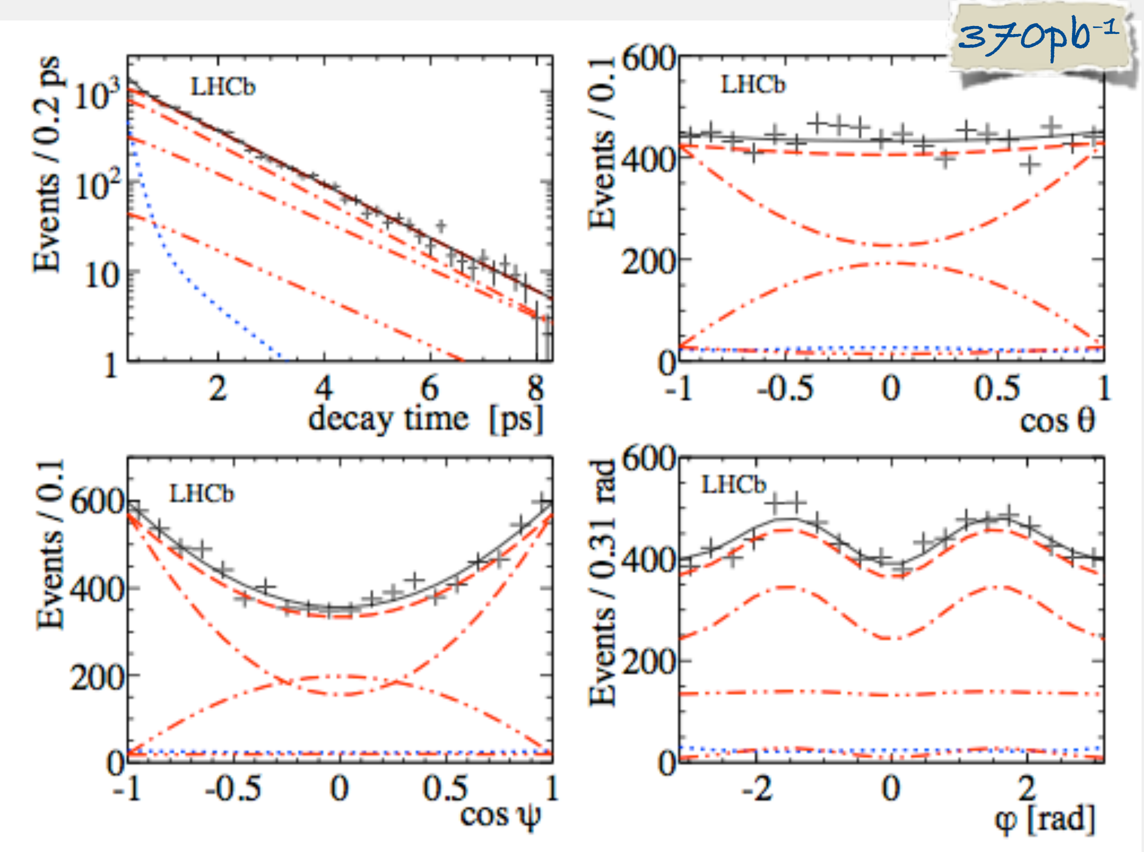
$$\Phi_D = \arg\left(V_{cs}V_{cb}^*\right) \simeq 0$$



Φs in $B_s \to J/\psi\Phi$

- Projections of the angular time-dependent fit





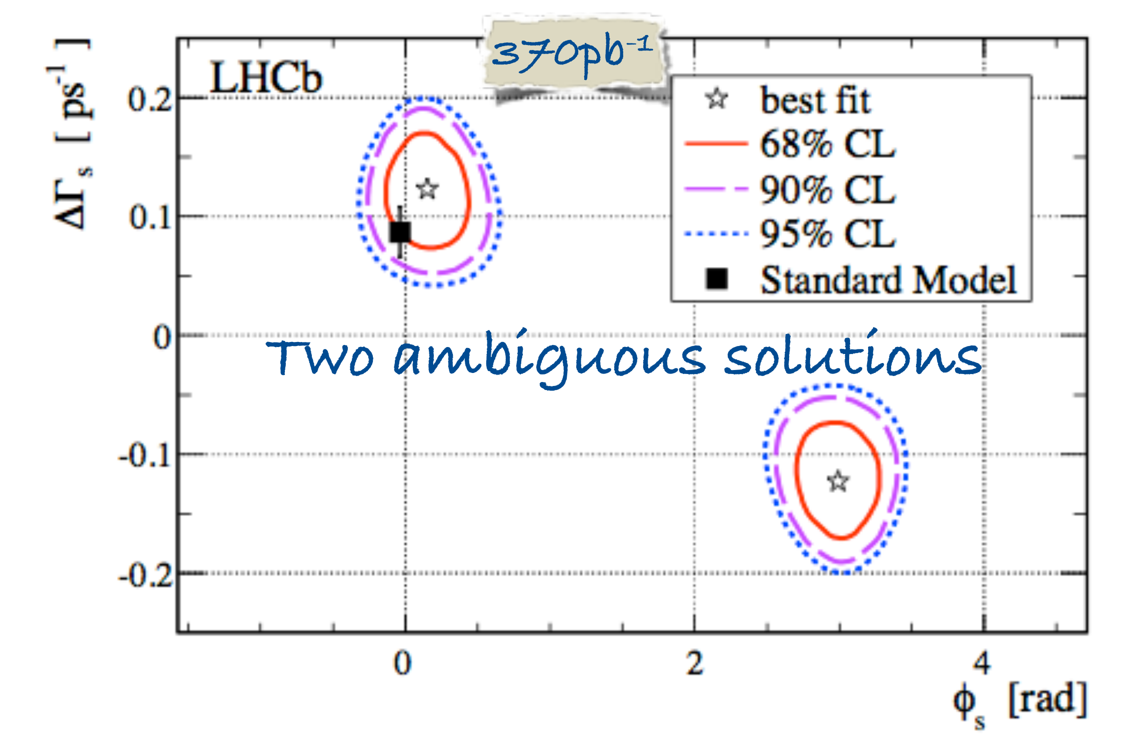
$$\phi_s = 0.15 \pm 0.18 \text{ (stat)} \pm 0.06 \text{ (syst) rad},$$
$$\Gamma_s = 0.657 \pm 0.009 \text{ (stat)} \pm 0.008 \text{ (syst) } ps^{-1},$$
$$\Delta\Gamma_s = 0.123 \pm 0.029 \text{ (stat)} \pm 0.011 \text{ (syst) } ps^{-1},$$

370pb⁻¹

One of the solutions very compatible with SM

Evidence for non zero $\Delta\Gamma_s$

$$\Delta\Gamma_s^{SM} = 0.082 \pm 0.021 ps^{-1}$$



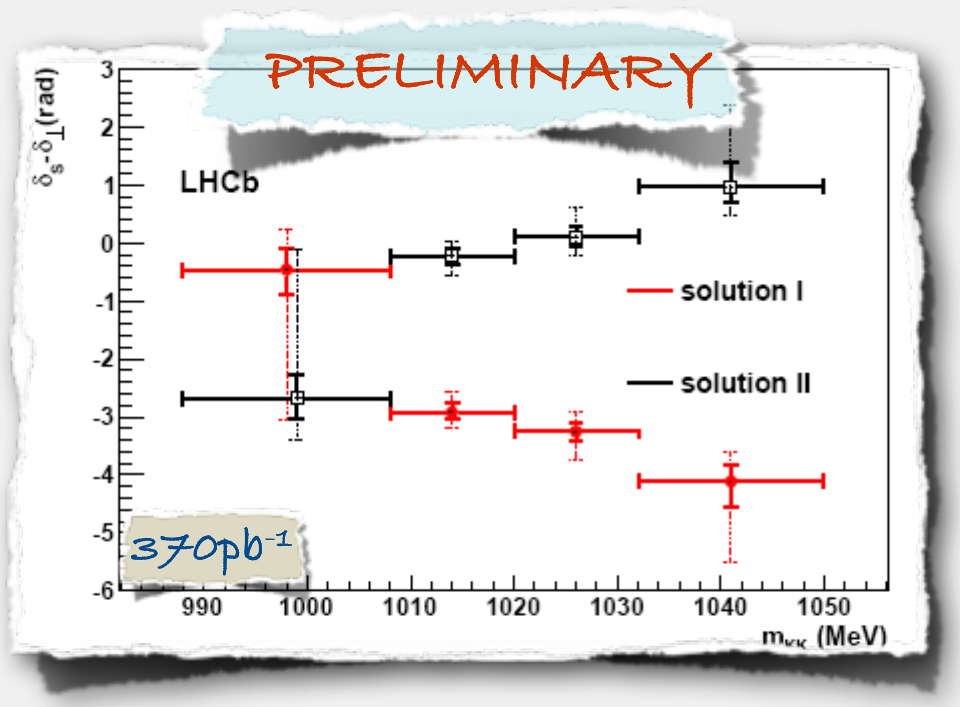
Ambiguity resolution of Φs

Paper in preparation

- Differential decay rate invariant under

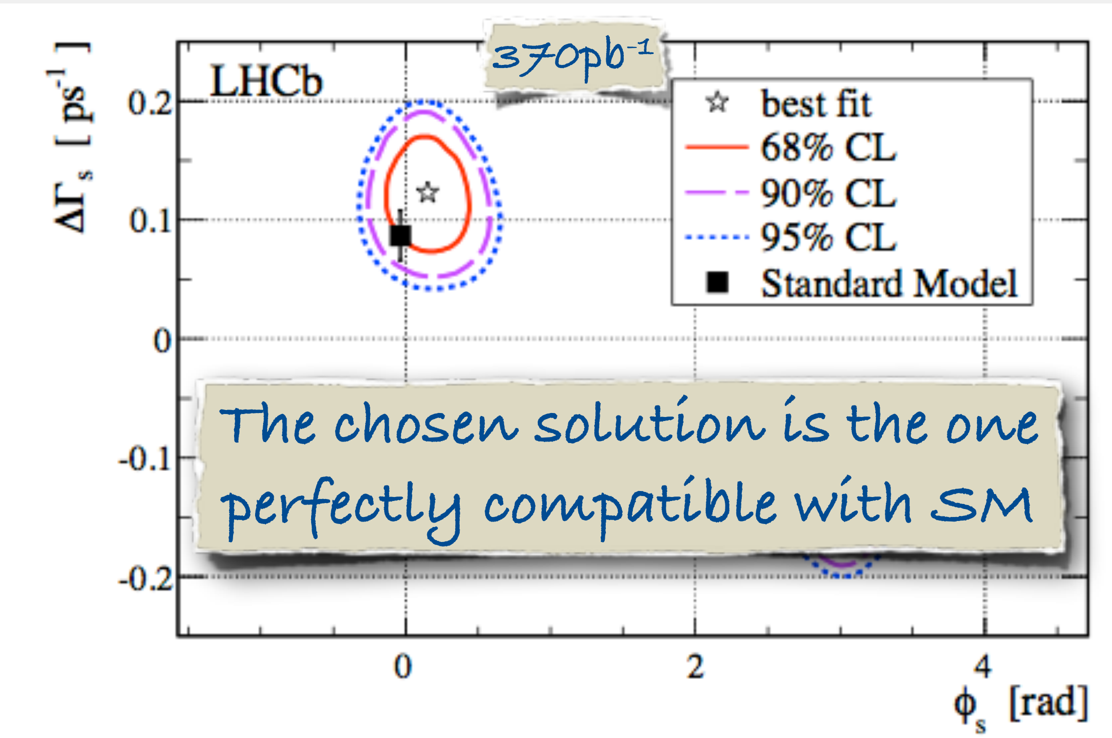
$$(\phi_s, \Delta\Gamma_s, \delta_\parallel - \delta_0, \delta_\perp - \delta_0, \delta_s - \delta_0) \longleftrightarrow (\pi - \phi_s, -\Delta\Gamma_s, \delta_0 - \delta_\parallel, \pi + \delta_0 - \delta_\perp, \delta_0 - \delta_s)$$

- δ_S-δ_P is expected to decrease as a function of m_{KK}
  - ➡ P-wave Breit-Wigner (Φ) phase δ_P increases rapidly as a function of m_{KK}
  - ➡ S-wave Flaté (non-Φ) phase δ_S vary slowly



370pb-1

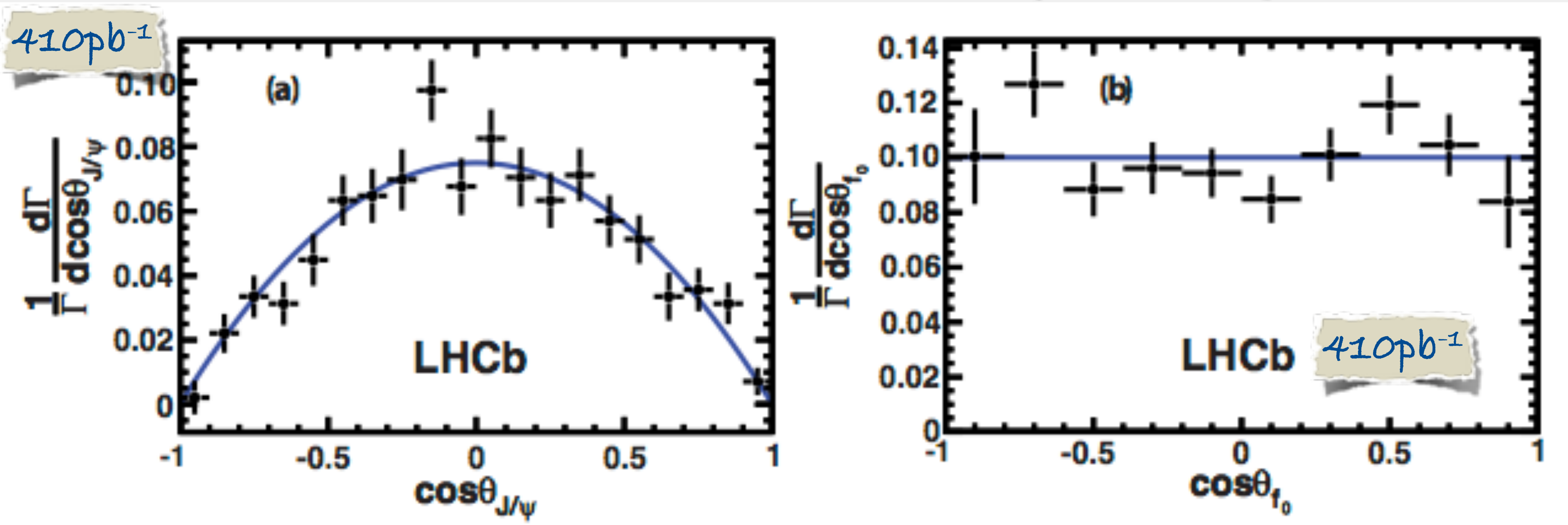
$$\phi_s = 0.15 \pm 0.18 \text{ (stat)} \pm 0.06 \text{ (syst) rad},$$
$$\Gamma_s = 0.657 \pm 0.009 \text{ (stat)} \pm 0.008 \text{ (syst) ps}^{-1},$$
$$\Delta\Gamma_s = 0.123 \pm 0.029 \text{ (stat)} \pm 0.011 \text{ (syst) ps}^{-1},$$

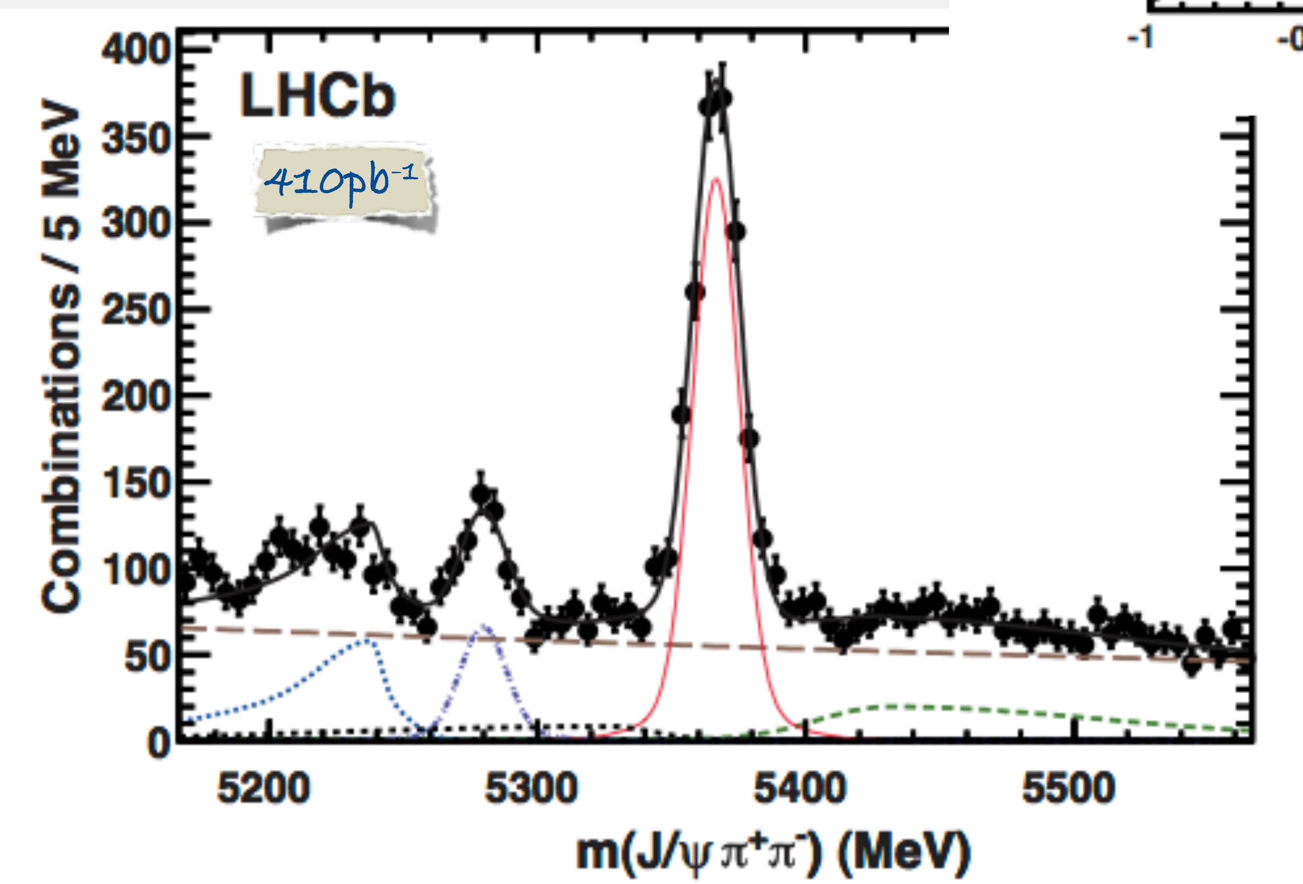


Φ_s in $B_s \to J/\psi f_0$

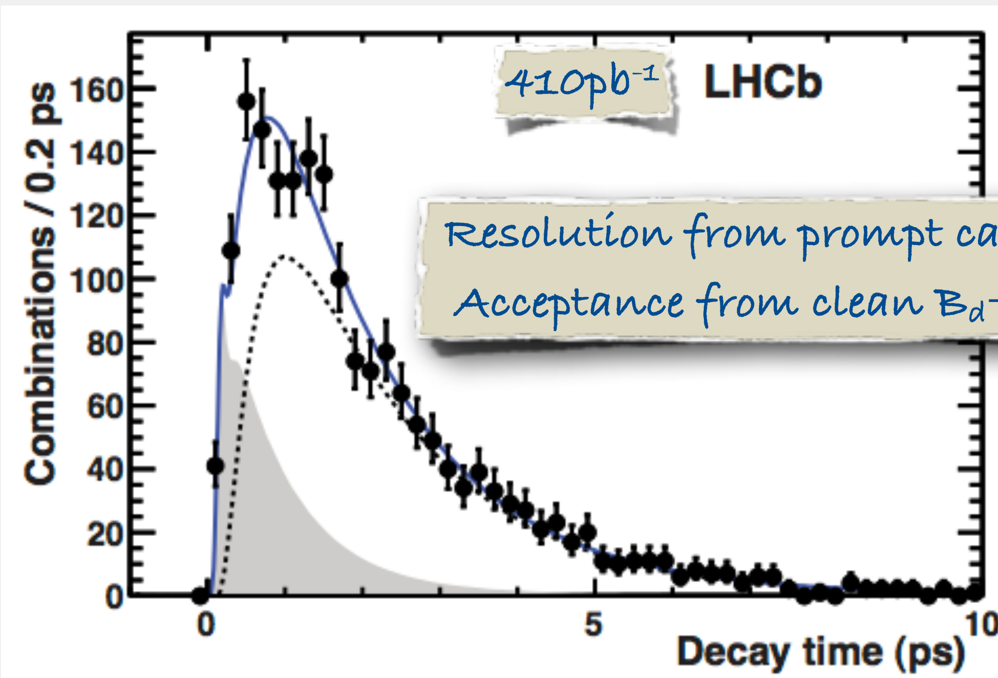
arXiv:1112.3056

- f_0 is a spin-0 resonance
  ➡ not an angular analysis
- Constrain $\Delta\Gamma_s$ and Γ_s
  ➡ use previous measurement





No contribution from spin-2 resonance



Resolution from prompt candidates
Acceptance from clean $B_d \to J/\psi K^{*0}$

$$\phi_s = -0.44 \pm 0.44 \pm 0.02 \text{ rad},$$

PRELIMINARY

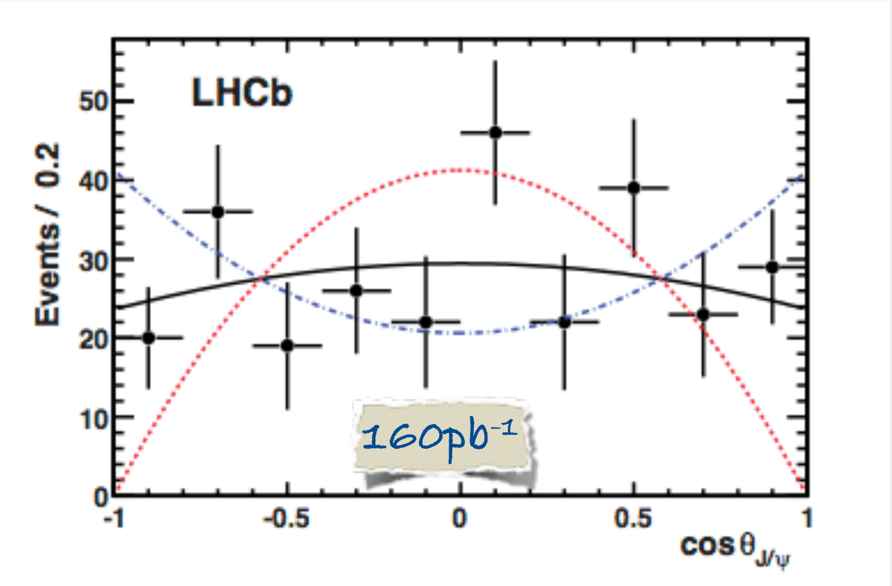
LHCb-CONF-2011-056

Combination using a simultaneous fit:

$$\phi_s = 0.03 \pm 0.16 \text{ (stat)} \pm 0.07 \text{ (sys) rad},$$

Prospects on Φs

- First observation of $B_s \to J/\psi f'_2$ arXiv:1112.4695
  - ➡ 15% of the statistics collected in $B_s \to J/\psi \Phi$
  - ➡ Ratio of BR measured to be 19.4±1.8±1.0 %
  - ➡ More complicated than $B_s \to J/\psi \Phi$ (spin-2)

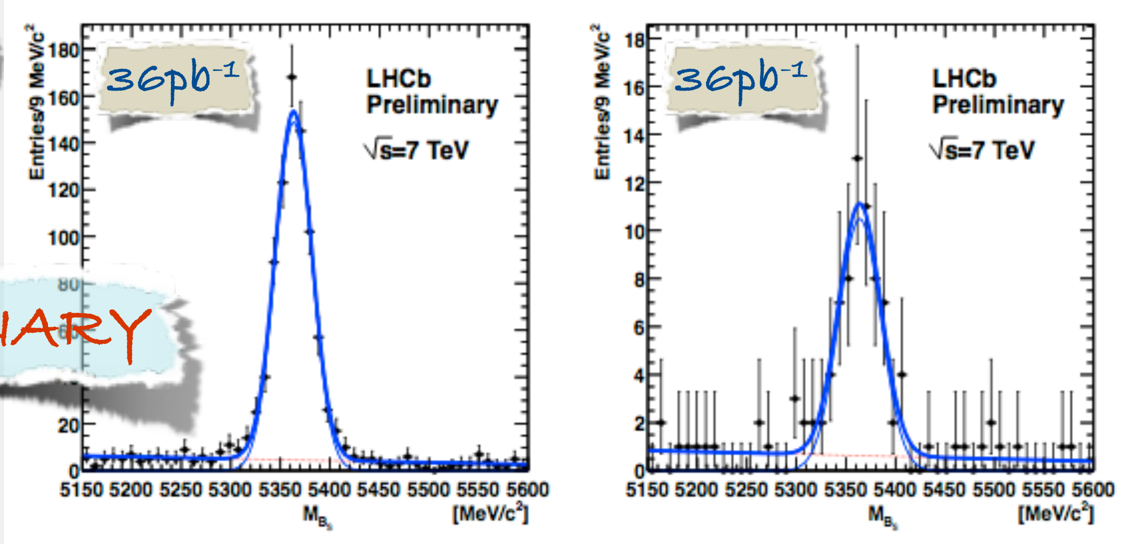


- Measurement of $B_s \to \psi(2S)\Phi$ LHCb-CONF-2011-014

36pb⁻¹

$$\frac{\mathcal{B}(B_s^0 \to \psi(2S)\phi)}{\mathcal{B}(B_s^0 \to J/\psi\phi)} = 0.68 \pm 0.10(\mathrm{stat}) \pm 0.09(\mathrm{syst}) \pm 0.07(\mathcal{B})$$

PRELIMINARY

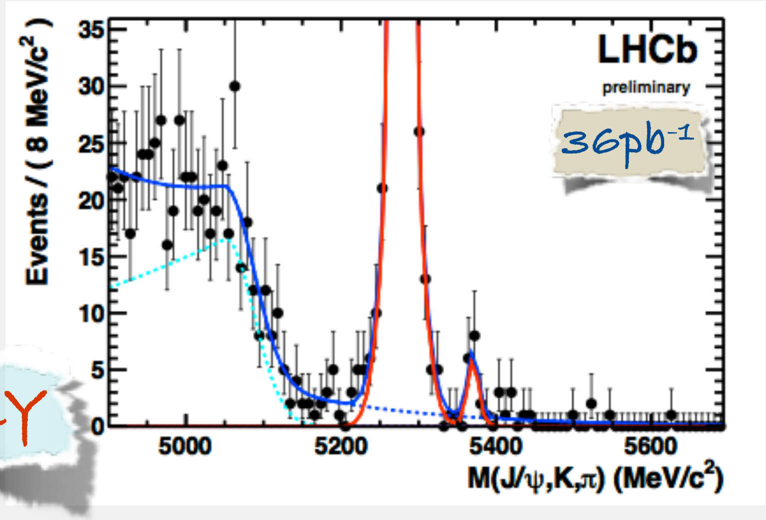


- Evidence for $B_s \to J/\psi K^{*0}$ LHCb-CONF-2011-025
  - ➡ allows to control penguin effects in $B_s \to J/\psi \Phi$

36pb⁻¹

$$\mathcal{B}(B_s^0 \to J/\psi \overline{K}^{*0}) = (3.5^{+1.1}_{-1.0}(stat.) \pm 0.9(syst.)) \times 10^{-5}$$

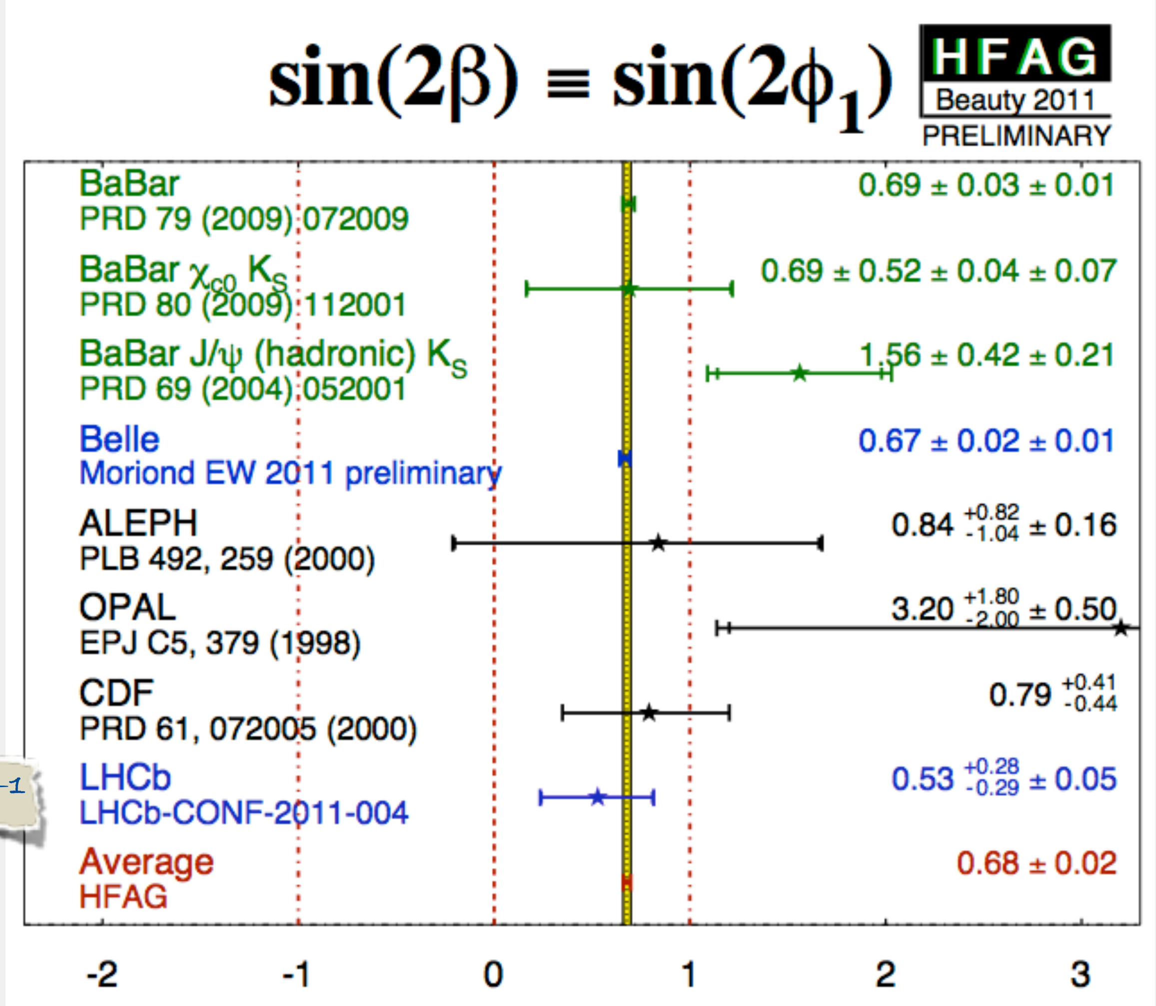
PRELIMINARY



use of $B_{d,s} \to J/\psi K_S$

- CPV in $B_d \to J/\psi K_S$
  - ➡ Result obtained with 2010 data only
  - ➡ work ongoing to update the measurement

36pb^{-1}



- Measurement of $BR(B_s \to J/\psi K_S)$
  - ➡ constrain amplitude and phase of penguin contribution in $B_d \to J/\psi K_S$ under SU(3)

PRELIMINARY

380pb^{-1}

$$\frac{\mathcal{B}(B_s^0 \to J/\psi K_S^0)}{\mathcal{B}(B^0 \to J/\psi K_S^0)} = 0.0378 \pm 0.0058\,(\text{stat}) \pm 0.0020\,(\text{syst}) \pm 0.0030\,(\frac{f_s}{f_d}).$$

LHCb-CONF-2011-048

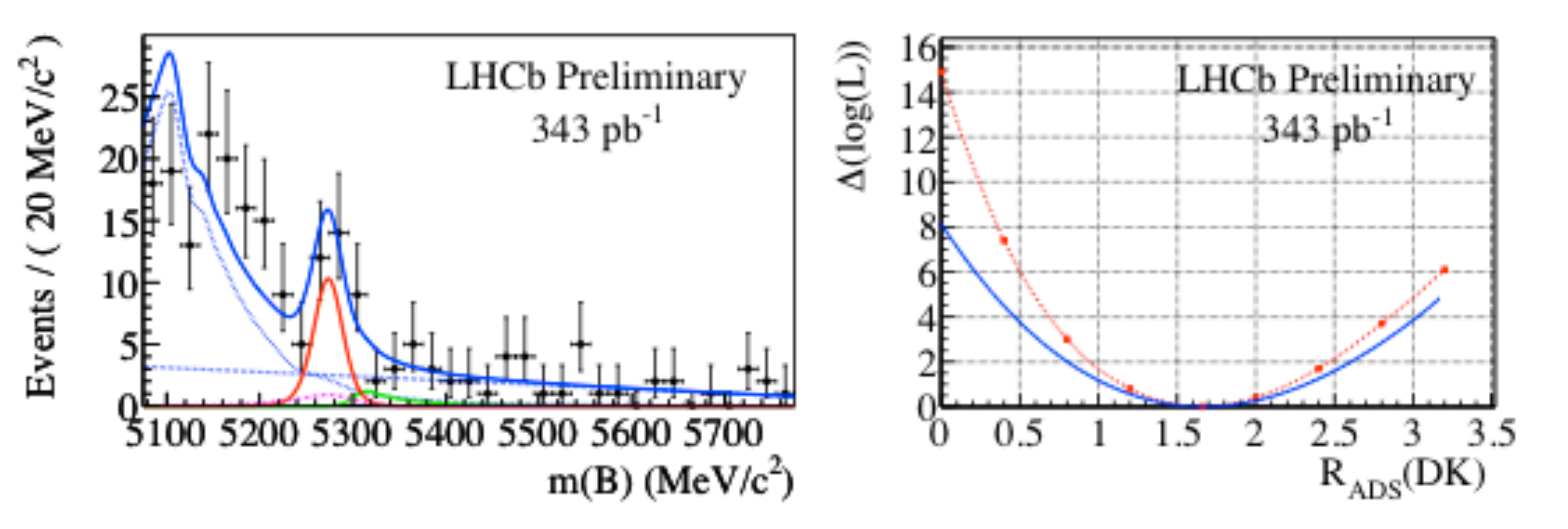
Conclusion

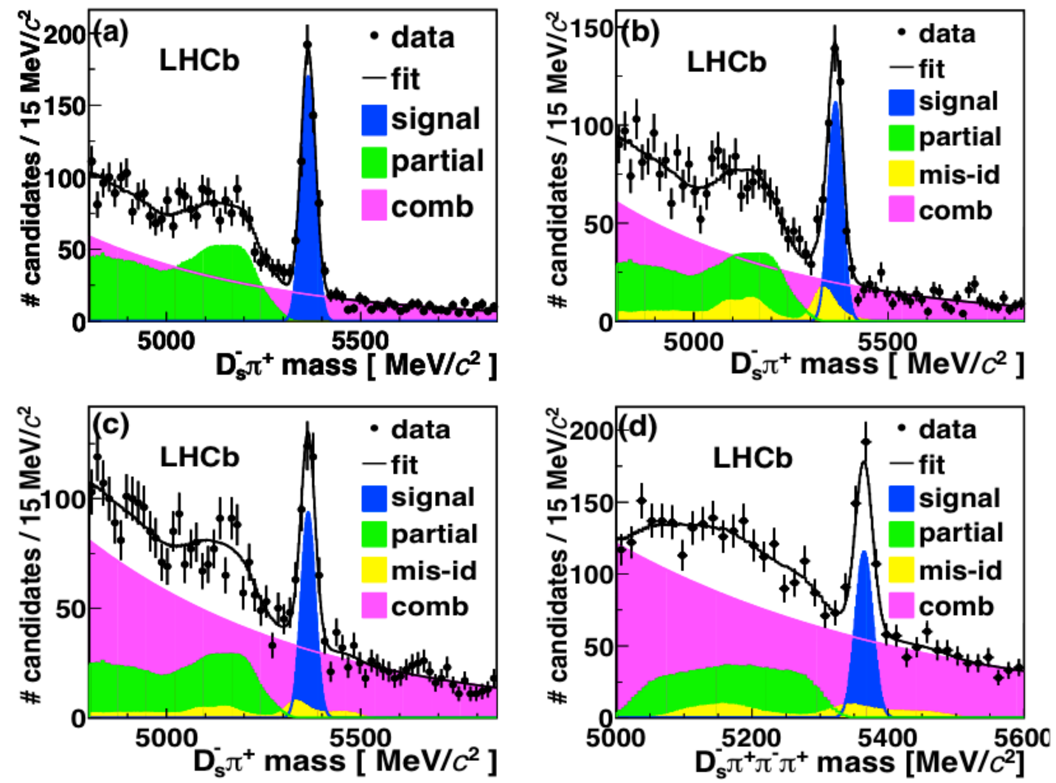
- A long year of excellent physics results
- Selected highlights:
  - ➡ tree level γ measurements starts to compete with B-factories
    - many modes in the pipeline
  - ➡ CP asymmetries in $B \rightarrow h^+h^-$ are the most precise single measurements
    - evidence for $B_s \rightarrow \pi^+\pi^-$
  - ➡ Φ_s measurement forbids large mixing phase
    - combine two channels
    - ambiguity resolved
- All of this is very promising at the dawn of the winter 2012 conferences

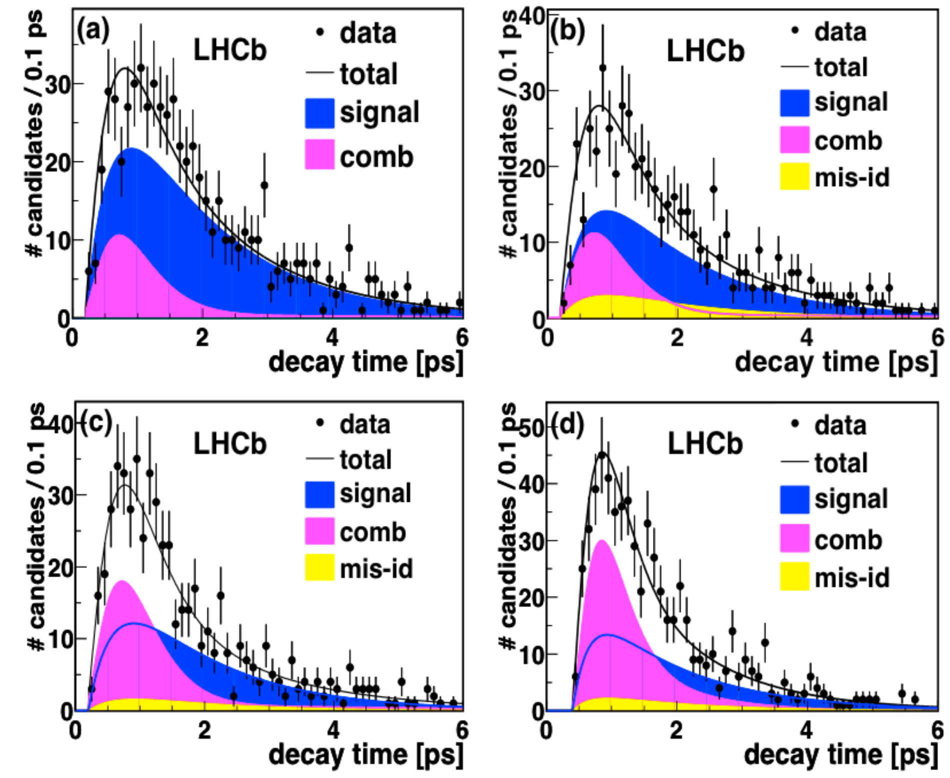
BACKUP

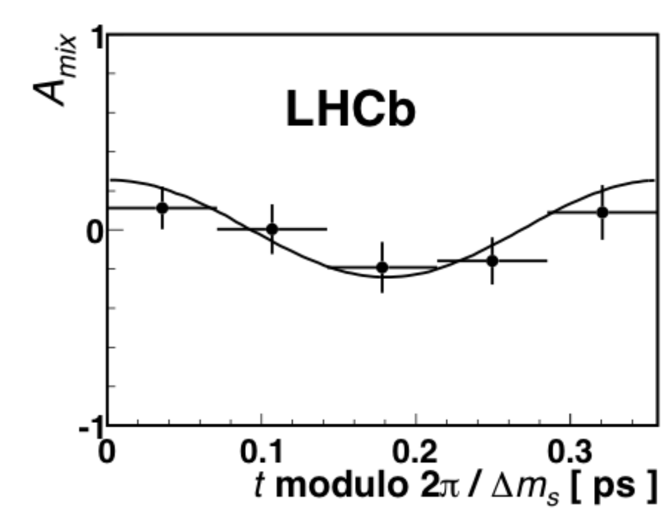
more on the ADS measurement

	A_{ADS}	$A_{ADS}^{D\pi}$	R_{ADS} $(\times 10^{-2})$	$R_{ADS}^{D\pi}(\times 10^{-3})$
Constrained $B \to DK$ shape	0.001	0.000	0.01	0.00
PID efficiency determination	0.006	0.002	0.08	0.08
Validity of the low-mass PDF	0.012	0.005	0.11	0.04
Charmless branching fractions	0.002	0.001	0.02	0.00
Kaon interaction asymmetry	0.004	0.007	-	-
Charmless bkgd. asymmetry	0.006	0.000	-	-
PID cuts on D-daughters	0.014	0.001	0.20	0.40
Total (summed in quadrature)	0.020	0.010	0.24	0.40









$$A_{\rm mix}(t) = \frac{N^+(t) - N^-(t)}{N^+(t) + N^-(t)}$$

$$\mathcal{P}_t(t|\sigma_t) \propto [\Gamma_s e^{-\Gamma_s t} \cosh(\frac{\Delta\Gamma_s}{2} t)\, \theta(t)] \otimes G(t, \sigma_t)\, \epsilon(t).$$

Tagging power combined for all modes

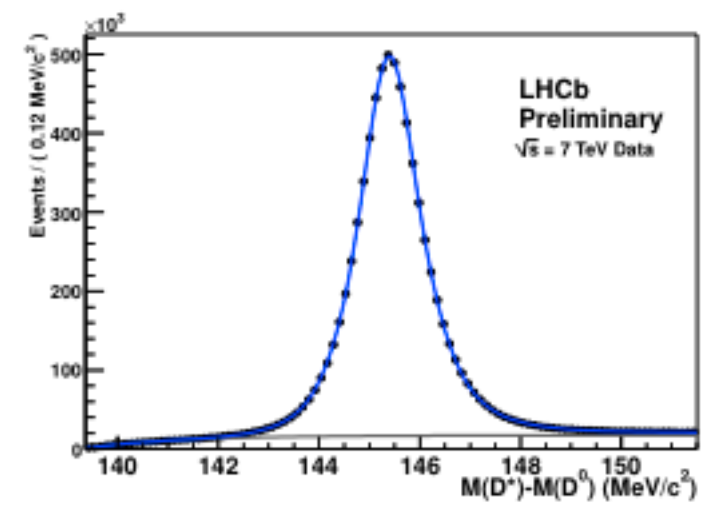
$$\epsilon_{\rm s} = (23.6 \pm 1.3)\,\% \text{ and } \epsilon_{\rm s} = (17.6 \pm 3.2)\,\%$$

$$\epsilon_{\rm eff} = (3.8 \pm 2.1)\,\%.$$

Source	Uncertainty [ps^{-1}]
Momentum scale	0.004
z scale	0.018
Comb. background mass shape	0.010
Decay time resolution	0.006
Total systematic uncertainty	0.022

more on $B_{(d,s)} \to K\pi$

$$A_\Delta(B_s^0 \to \pi K) = -A_D(K\pi) + \kappa(B_s^0 \to \pi K) A_P(B_s^0).$$



$$A_D(K\pi) = A_I(K\pi) + \alpha(H_b \to h^+h'^-) A_R(K\pi),$$

$$\alpha(H_b \to h^+h'^-) = \frac{N(B^0 \to K\pi)^\uparrow - N(B^0 \to K\pi)^\downarrow}{N(B^0 \to K\pi)^\uparrow + N(B^0 \to K\pi)^\downarrow} \simeq -0.2.$$

Asymmetries	Values
$A_I(K\pi)$	-0.010 ± 0.002
$A_R(K\pi)$	-0.0018 ± 0.0002

$$\kappa(B_s^0 \to \pi K) = \frac{\int \left(e^{-\Gamma_s t} \cos \Delta m_s t\right) \varepsilon_{B_s^0 \to \pi K}(t) dt}{\int \left(e^{-\Gamma_s t} \cosh \frac{\Delta\Gamma_s}{2} t\right) \varepsilon_{B_s^0 \to \pi K}(t) dt} \simeq -0.03,$$

$$\begin{aligned} A_{CP}^{RAW}(B^0 \to J/\psi K^{*0}) &= A_{CP}(B^0 \to J/\psi K^{*0}) + A_I(K\pi) + \\ &+ \alpha(B^0 \to J/\psi K^{*0}) A_R(K\pi) + \kappa(B^0 \to J/\psi K^{*0}) A_P(B^0). \end{aligned} \quad (13)$$

$$\alpha(B^0 \to J/\psi K^{*0}) = \frac{N(B^0 \to J/\psi K^{*0})^\uparrow - N(B^0 \to J/\psi K^{*0})^\downarrow}{B^0 \to J/\psi K^{*0})^\uparrow + N(B^0 \to J/\psi K^{*0})^\downarrow} \simeq -0.22.$$

$$\kappa(B^0 \to J/\psi K^{*0}) = \frac{\int \left(e^{-\Gamma_d t} \cos \Delta m_d t\right) \varepsilon_{B^0 \to J/\psi K^{*0}}(t) dt}{\int \left(e^{-\Gamma_d t} \cosh \frac{\Delta\Gamma_d}{2} t\right) \varepsilon_{B^0 \to J/\psi K^{*0}}(t) dt} \simeq 0.46,$$

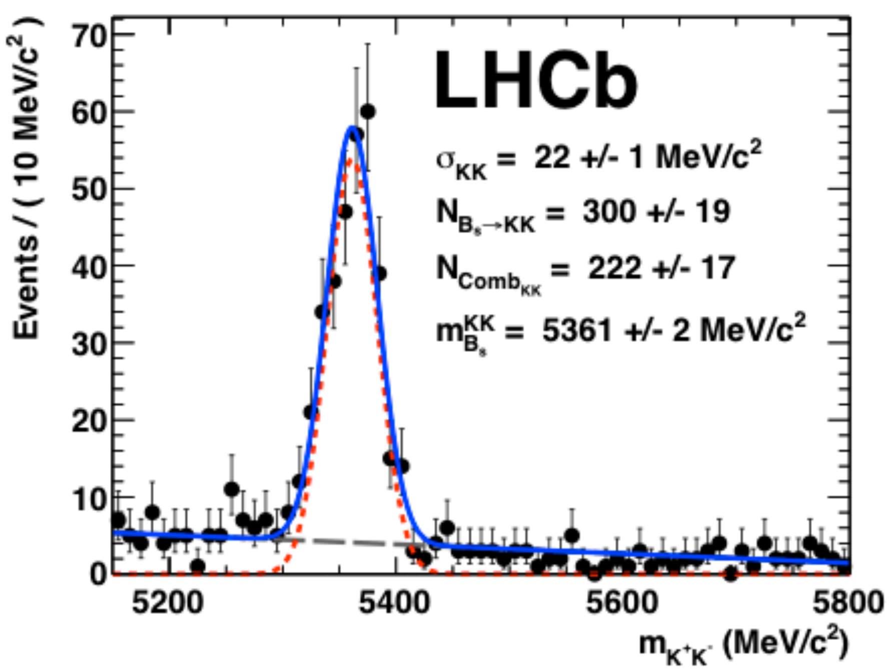
$$A_{CP}^{RAW}(B^0 \to J/\psi K^{*0}) = -0.005 \pm 0.006.$$

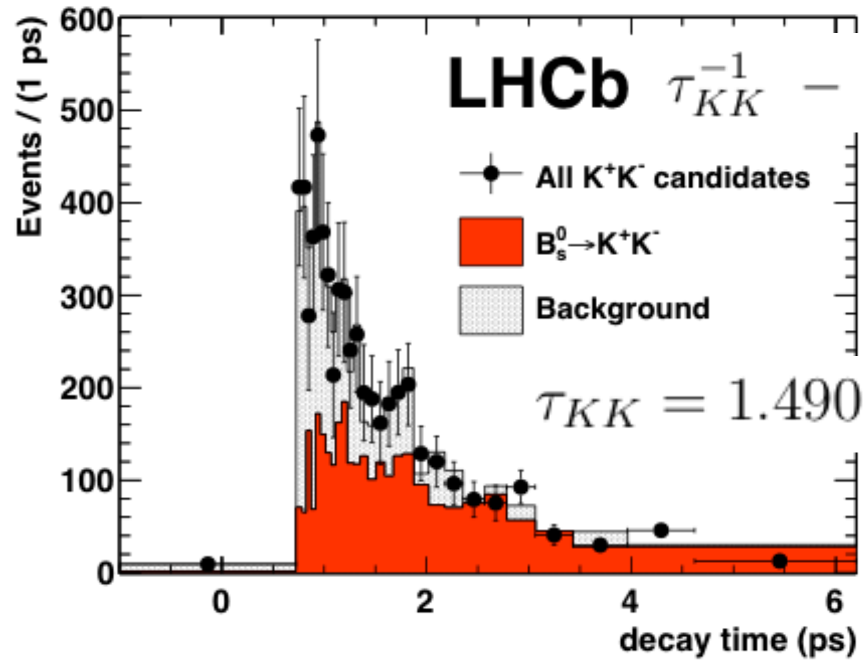
$$\begin{aligned} A_P(B^0) &= \frac{1}{\kappa(B^0 \to J/\psi K^{*0})}[A_{CP}^{RAW}(B^0 \to J/\psi K^{*0}) + \\ &- A_I(K\pi) - \alpha(B^0 \to J/\psi K^{*0}) A_R(K\pi)] = 0.010 \pm 0.013, \end{aligned}$$

more on $B_s \to KK$

$$\Gamma(t) \propto (1 - \mathcal{A}_{\Delta\Gamma_s})\, e^{-\Gamma_L t} + (1 + \mathcal{A}_{\Delta\Gamma_s})\, e^{-\Gamma_H t}$$

$$\mathcal{A}_{\Delta\Gamma_s} = -2\mathrm{Re}(\lambda)/(1+|\lambda|^2) \text{ where } \lambda = (q/p)(\overline{A}/A)$$

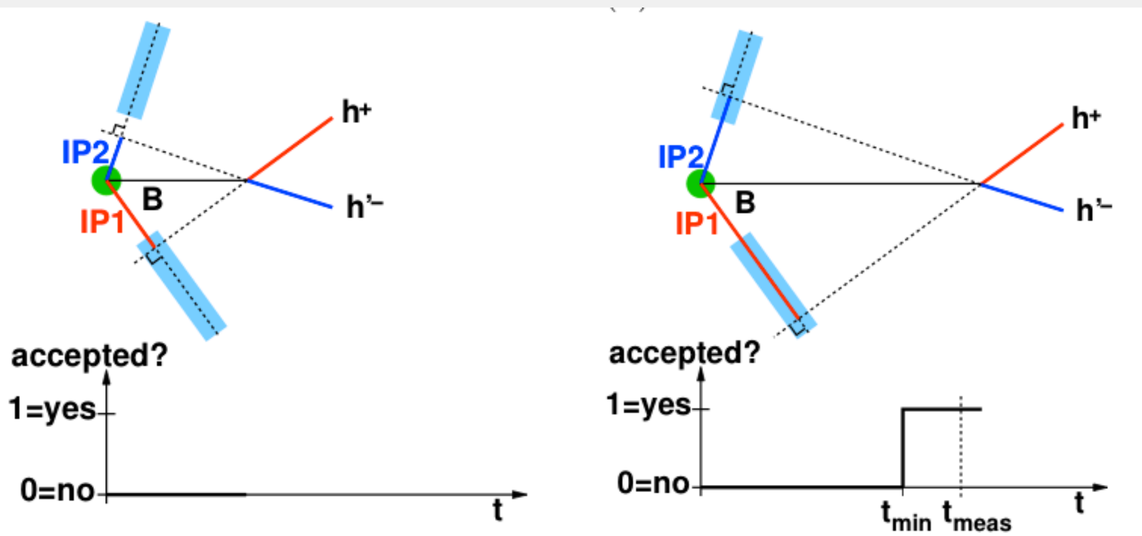




$$\tau_{KK}^{-1} - \tau_{K\pi}^{-1} = 0.013 \pm 0.045 \text{ (stat) ps}^{-1}.$$

$$R(t) = R(0)e^{-t(\tau_{KK}^{-1} - \tau_{K\pi}^{-1})}.$$

$$\tau_{KK} = 1.490 \pm 0.100 \text{ (stat)} \pm 0.007 \text{ (input) ps}$$

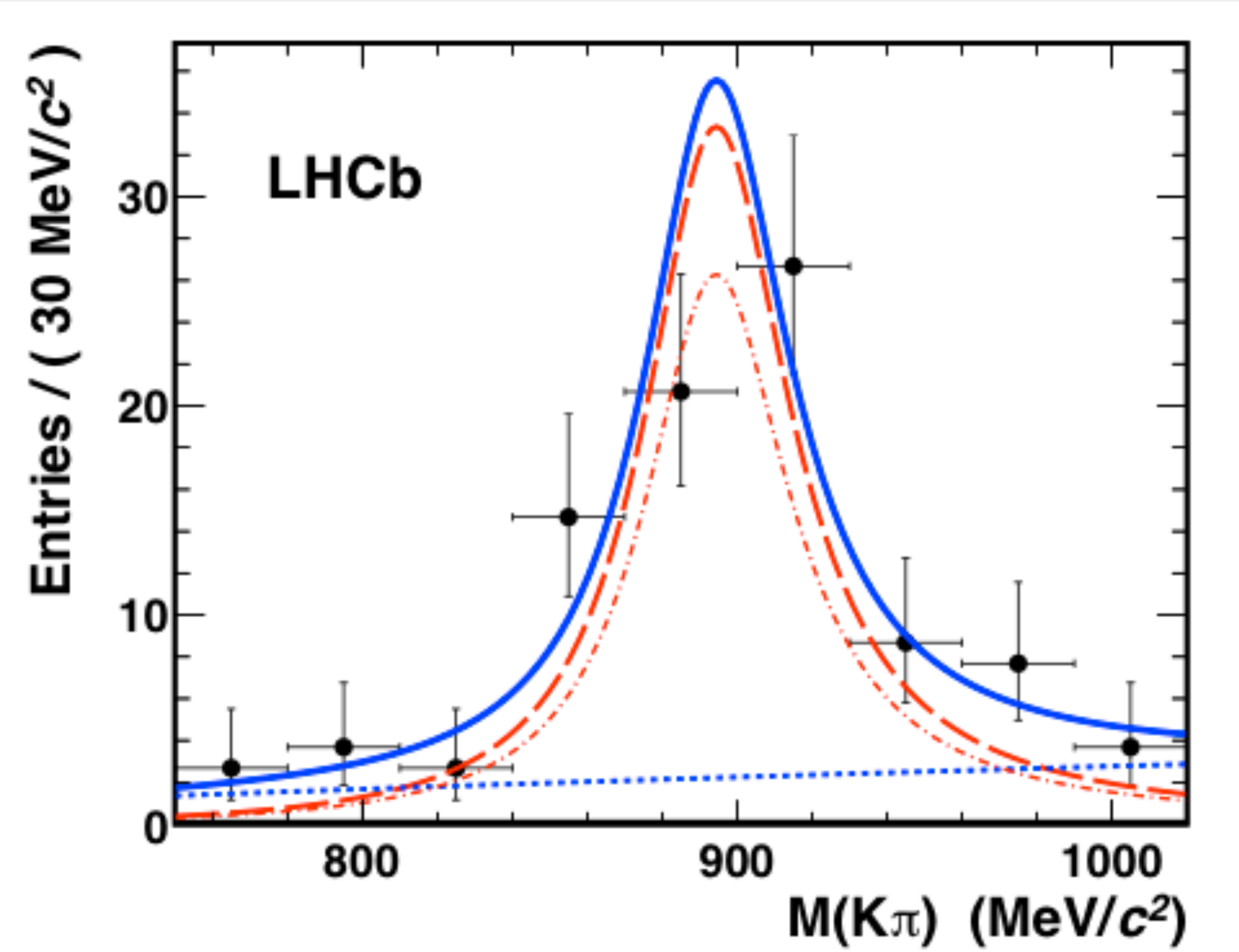


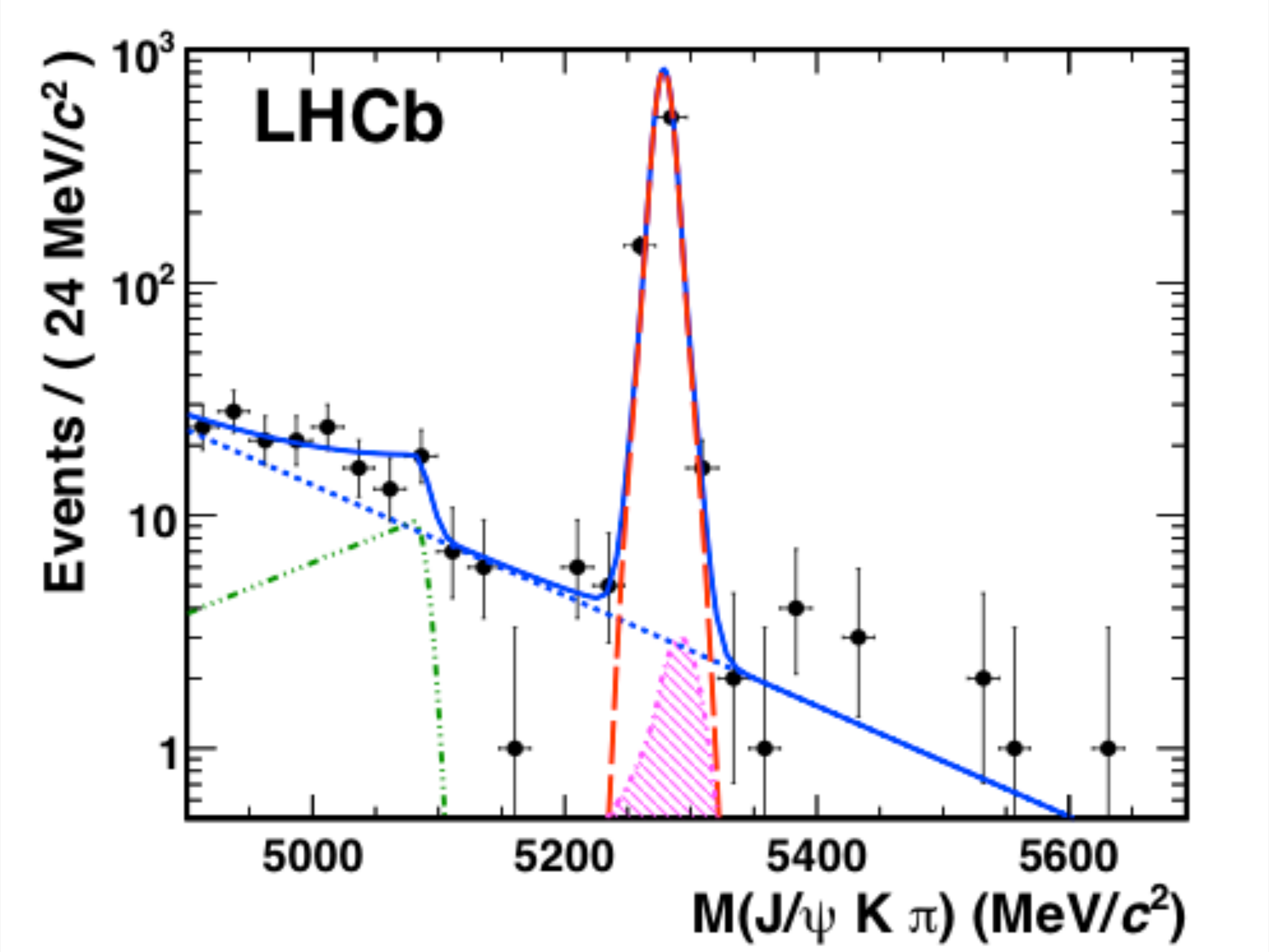
Source of uncertainty	Uncertainty on τ_{KK} (fs)	Uncertainty on $\tau_{KK}^{-1} - \tau_{K\pi}^{-1}$ (ns^{-1})
Fit method	3.2	} 0.5
Acceptance correction	6.3	
Mass model	1.9	
$B \to h^+h'^-$ background	1.9	1.4
Partially reconstructed background	1.9	1.1
Combinatorial background	1.5	1.6
Primary vertex association	1.2	0.5
Detector length scale	1.5	0.7
Production asymmetry	1.4	0.6
Minimum accepted lifetime	1.1	N/A
Total (added in quadrature)	8.4	2.7
Effective lifetime interpretation	2.8	1.1

- systemtaics from the vairation of the result in different phase space regions

$$I(\theta_1,\theta_2,\varphi) = \frac{d^3\Gamma}{d\cos\theta_1\, d\cos\theta_2\, d\varphi} = \left(\frac{1}{\Gamma_L}|\mathcal{A}_L|^2\cos^2\theta_1\cos^2\theta_2 + \frac{1}{\Gamma_L}|\mathcal{A}_\parallel|^2\frac{1}{2}\sin^2\theta_1\sin^2\theta_2\cos^2\varphi + \frac{1}{\Gamma_H}|\mathcal{A}_\perp|^2\frac{1}{2}\sin^2\theta_1\sin^2\theta_2\sin^2\varphi + \frac{1}{\Gamma_L}|\mathcal{A}_L|\,|\mathcal{A}_\parallel|\cos\delta_\parallel\frac{1}{2\sqrt{2}}\sin 2\theta_1\sin 2\theta_2\cos\varphi\right)$$

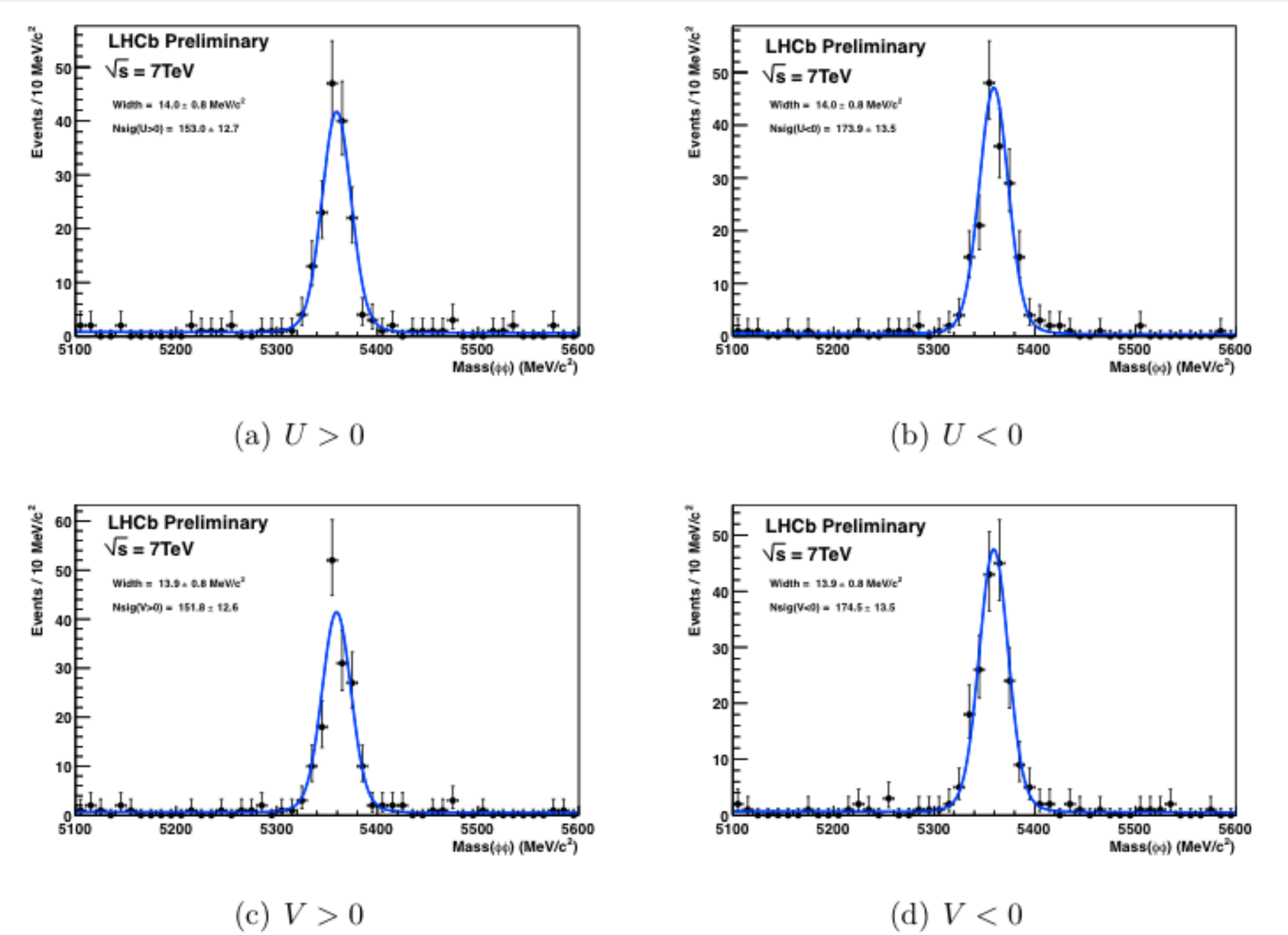
$$F(\theta_1,\theta_2,\varphi) = (1-\alpha)\epsilon_\theta(\theta_1)\epsilon_\theta(\theta_2)I(\theta_1,\theta_2,\varphi) + \alpha(1+\beta\cos\theta_1)(1+\beta\cos\theta_2)\epsilon_\theta(\theta_1)\epsilon_\theta(\theta_2).$$



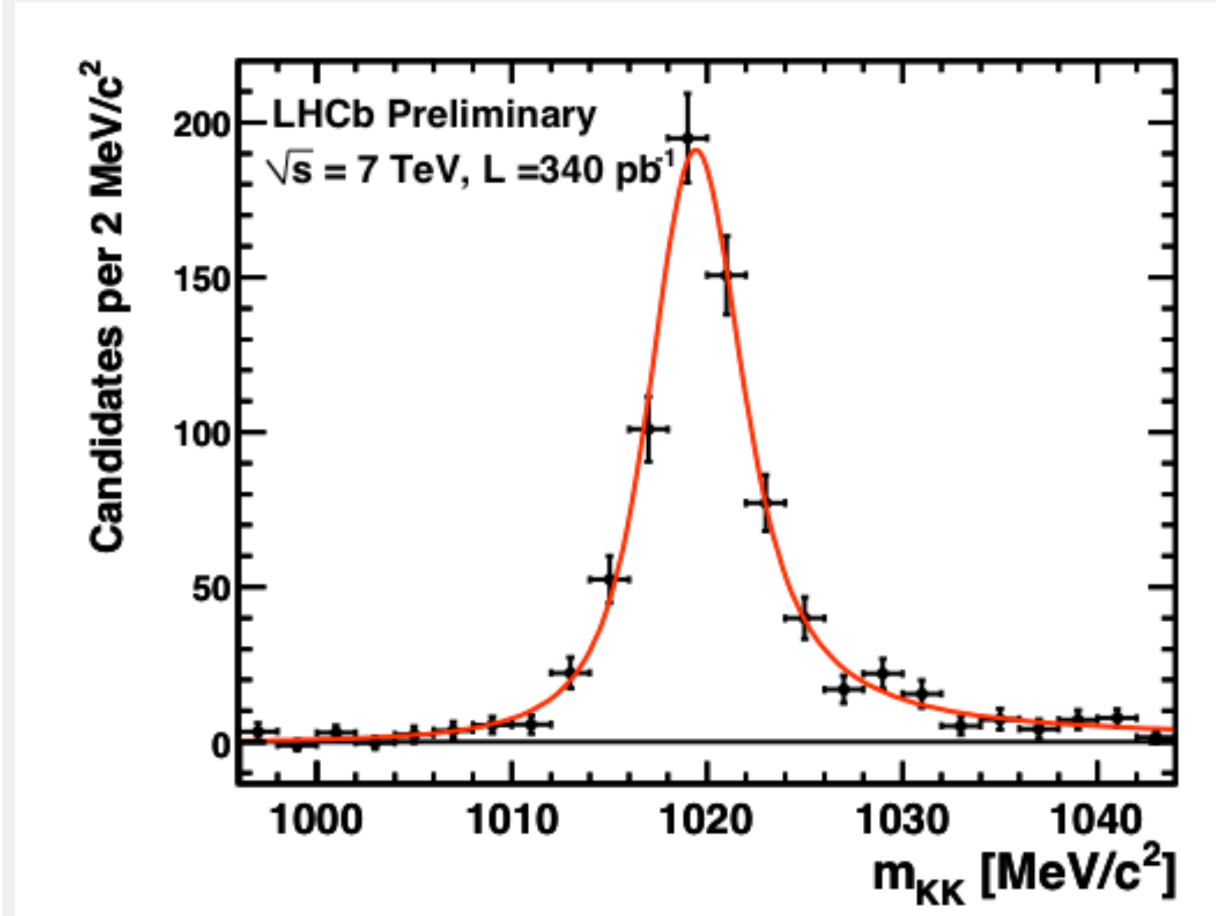


more on $B_s \to \Phi\Phi$

- Simultaneous fit, assume flat acceptance (ok on MC)



(a) $U > 0$ (b) $U < 0$ (c) $V > 0$ (d) $V < 0$



Splot
P-wave only (fit)
x-check : 1+-1% S-wave

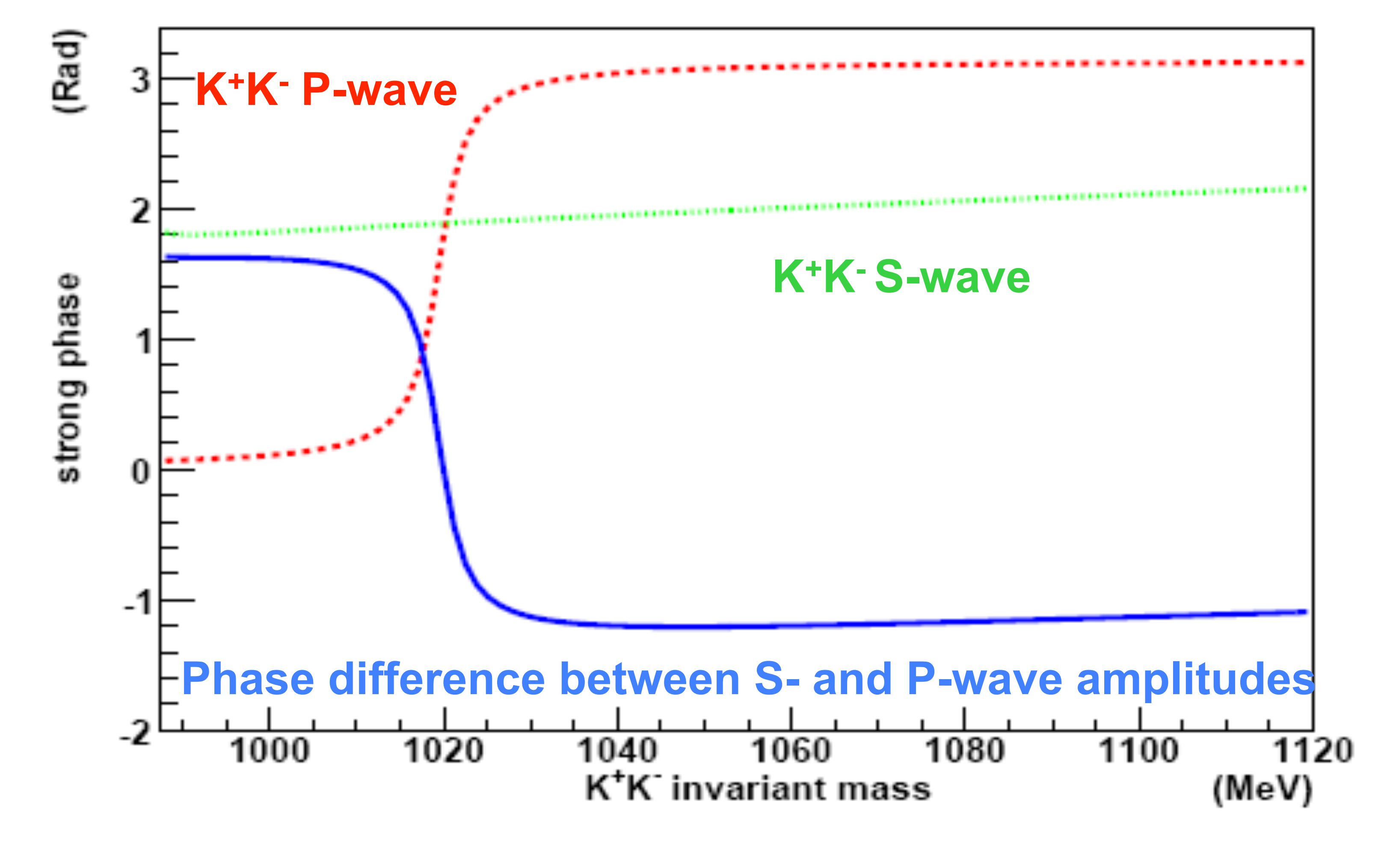
Source	A_U	A_V	Chosen uncertainty
Acceptance	0.0100	0.0020	0.010
Mass model for Signal and Background	0.0040	0.0004	0.004
Impact parameter cuts	0.0030	0.0100	0.010
Total systematic uncertainty	0.014		

more on Φ_s in $B_s \to J/\psi\Phi$

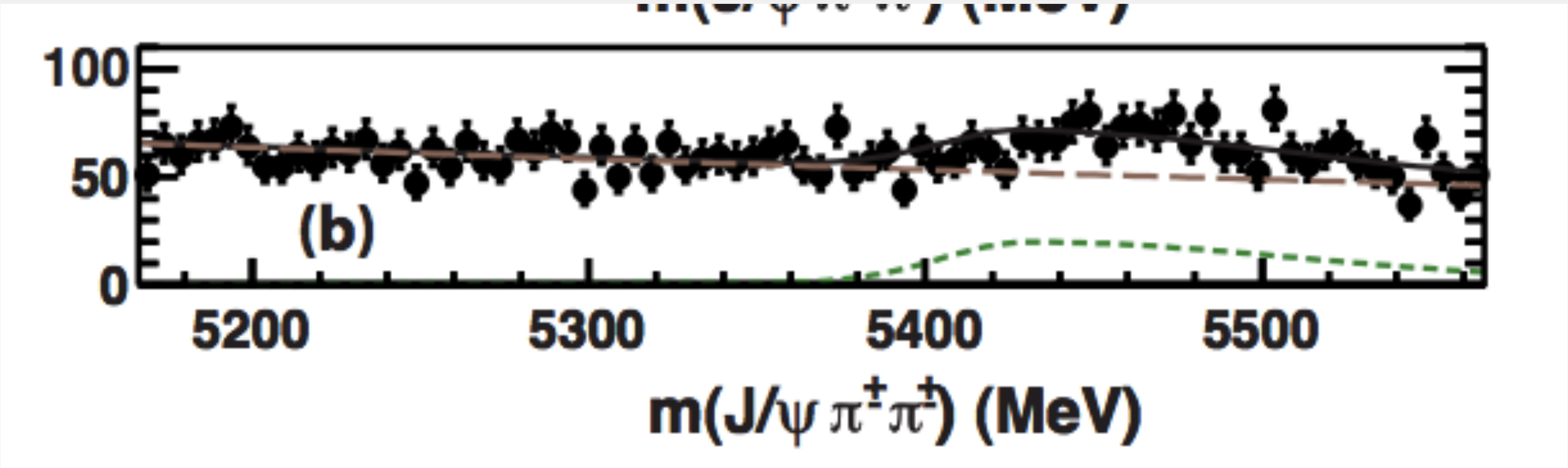
- [Y. Xie et al., JHEP 0909:074, 2009]
  - ➡ Similar to Babar measurement of sign of cos(2β), PRD 71, 032005 (2007)

- Same selection as in Φ_s paper
  - ➡ except m_{KK}

PRELIMINARY



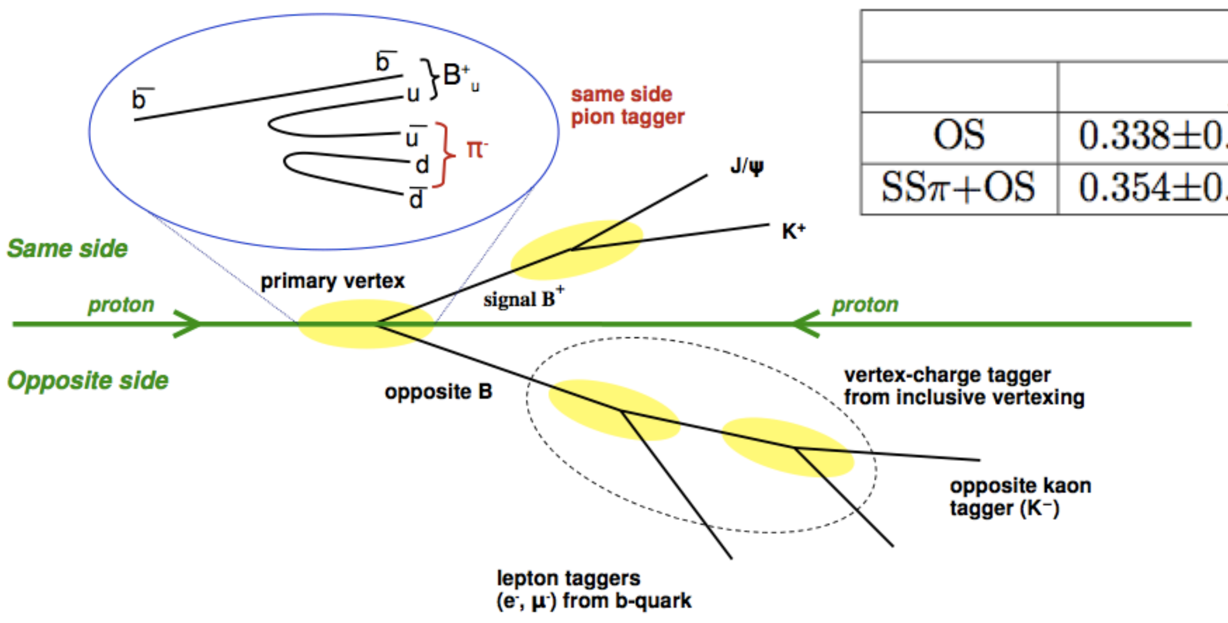
more on Φs in $B_s \to J/\psi f_0$



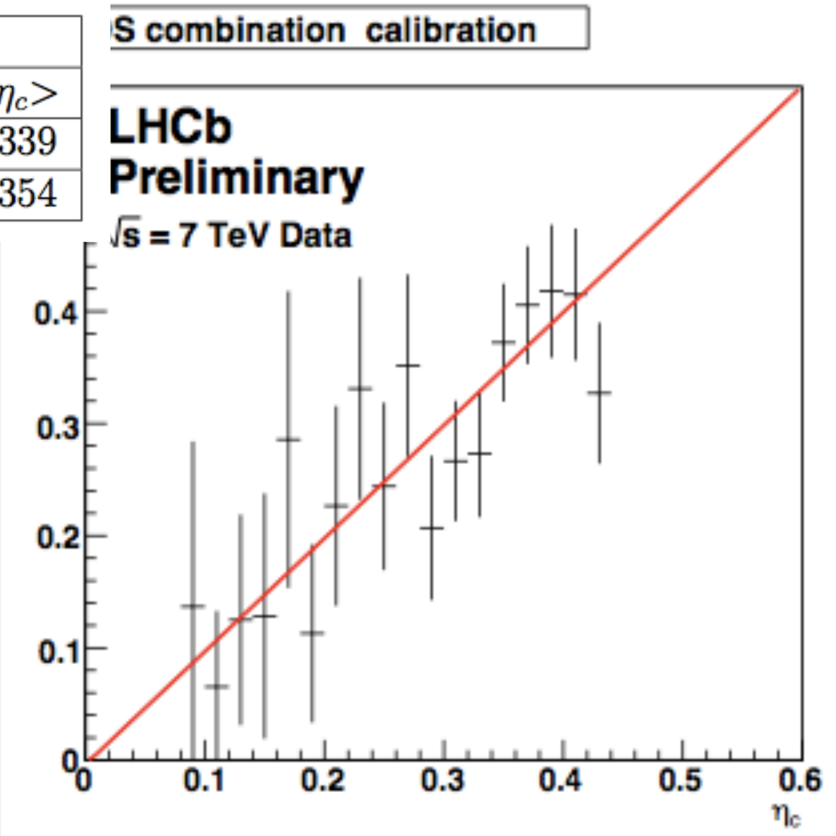
$$\frac{|A_{20}|^2}{|A_{00}|^2} = (0.1^{+2.6}_{-0.1})\%,$$

$$\frac{|A_{21}|^2 + |A_{2-1}|^2}{|A_{00}|^2} = (0.0^{+1.7}_{-0.0})\%,$$

more on tagging



$B^+ \to J/\psi K^+$			
	p_0	p_1	$<\eta_c>$
OS	0.338±0.012±0.004	1.01±0.12±0.01	0.339
SSπ+OS	0.354±0.010±0.004	1.00±0.11±0.01	0.354



PRELIMINARY

	$\varepsilon_{tag}(\%)$	$\omega(\%)$	$\varepsilon_{eff}(\%)$
$B^0 \to D^{*-}\mu^+\nu_\mu$			
average OS	18.2±0.2	34.3±0.8	1.79±0.18
combined OS	18.3±0.2	33.6±0.8	1.97±0.18
average SSπ+OS	29.1±0.2	35.8±0.8	2.36±0.26
combined SSπ+OS	28.9±0.2	34.2±0.8	2.87± 0.32
$B^+ \to J/\psi K^+$			
average OS	15.4±0.4	33.3±1.2	1.71±0.29
combined OS	15.4±0.3	32.2±1.2	1.97±0.31
average SSπ+OS	22.7±0.4	35.5±1.0	1.92±0.30
combined SSπ+OS	23.0±0.5	33.9±1.1	2.38±0.33
$B^0 \to J/\psi K^{*0}$			
average OS	15.7 ± 0.6	33.1 ± 3.0	1.79 ± 0.71
combined OS	15.8 ± 0.7	30.0 ± 6.6	2.52 ± 0.82
average SSπ+OS	25.9 ± 0.8	37.0 ± 2.4	1.75 ± 0.70
combined SSπ+OS	26.1 ± 0.9	33.6 ± 5.1	2.82 ± 0.87