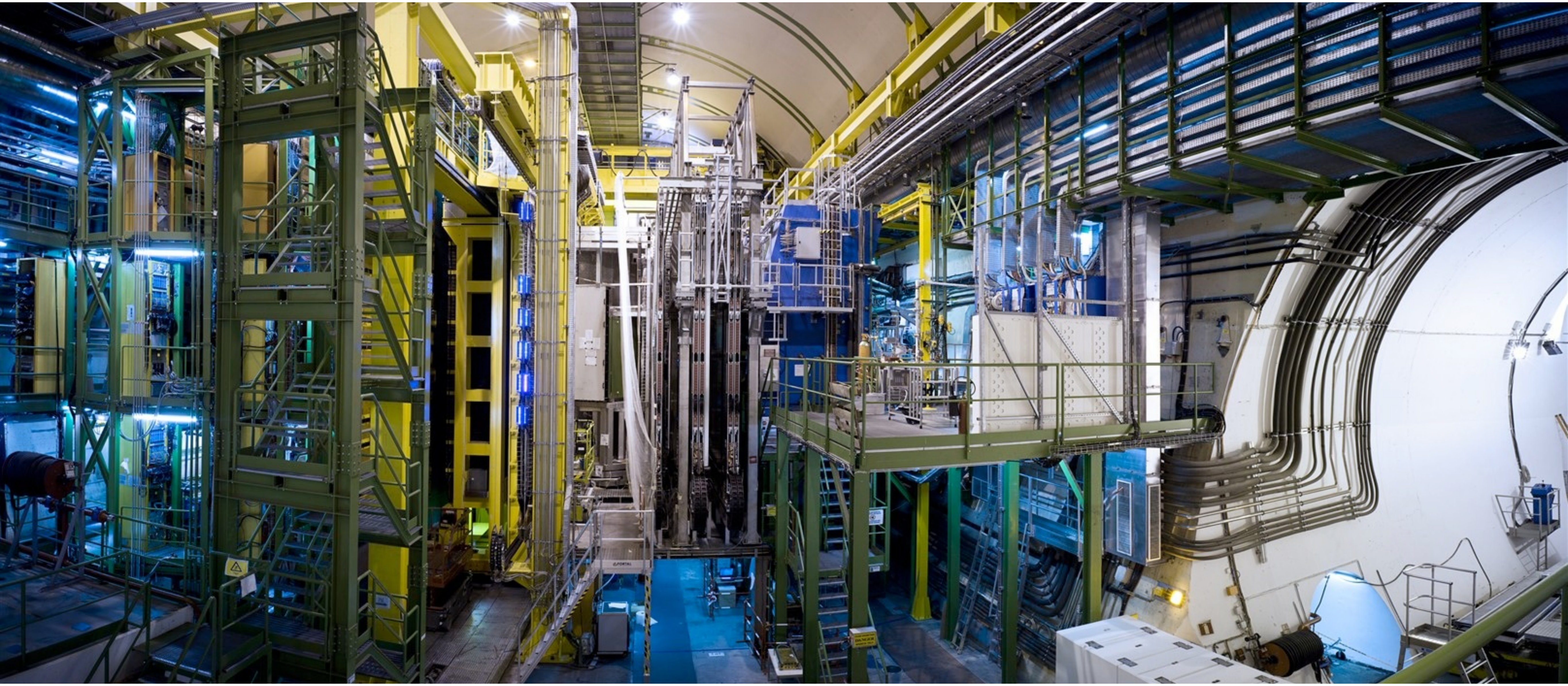


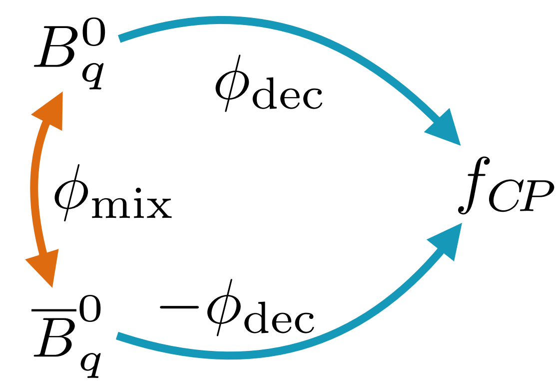
CP Violation in the $B_{(s)}$ meson system at LHCb

Julian Wishahi on behalf of the LHCb collaboration

50th Rencontres de Moriond, Electroweak Session, 20th of March 2015

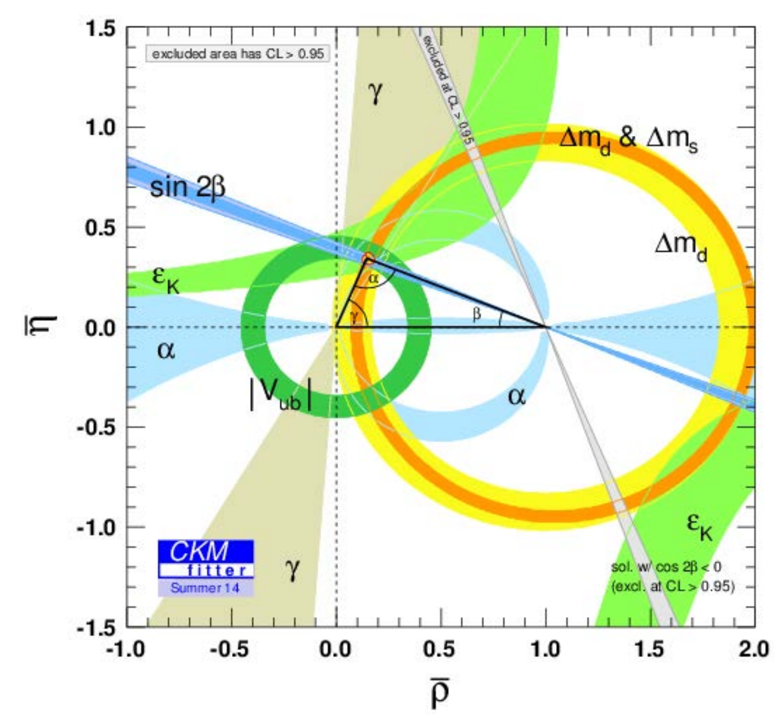
*CP*V in Interference of Mixing/Decay

- interference between direct decay and decay after oscillation
  - ➡ phase difference $\phi_q = \phi_{\text{mix}} - 2\,\phi_{\text{dec}}$



- phases related to CKM angles
  - "golden modes" (dominant $b\rightarrow c\bar{c}s$ tree decay)
    - $B_s \rightarrow J/\psi\, h^+h^-$ ($\phi_s = -2\beta_s$)
    - $B^0 \rightarrow J/\psi\, K_S$ ($\phi_d = 2\beta$)
  - precise constraints from other measurements
    - $\sin\phi_d = 0.771\ ^{+0.017}_{-0.041}$
    - $\sin\phi_s = -0.0365\ ^{+0.0013}_{-0.0012}$

J. Charles et al.
arXiv:1501.05013



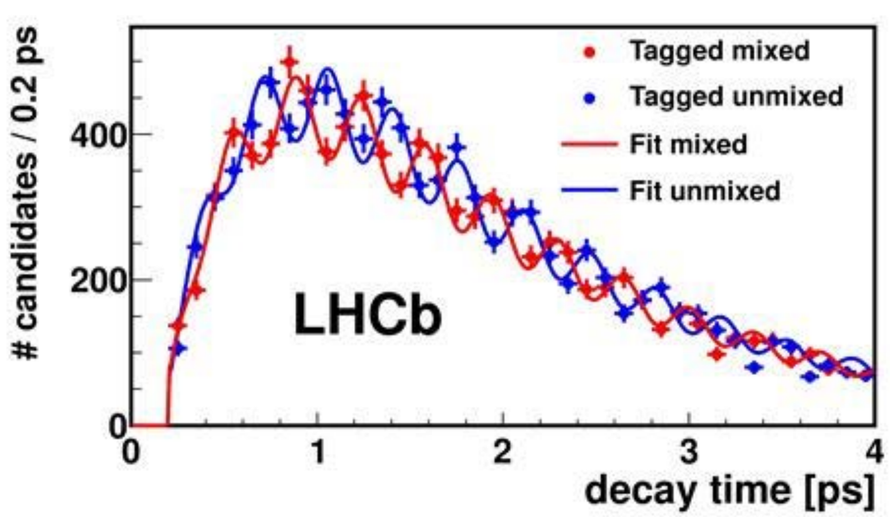
  - excellent probe for NP contributions

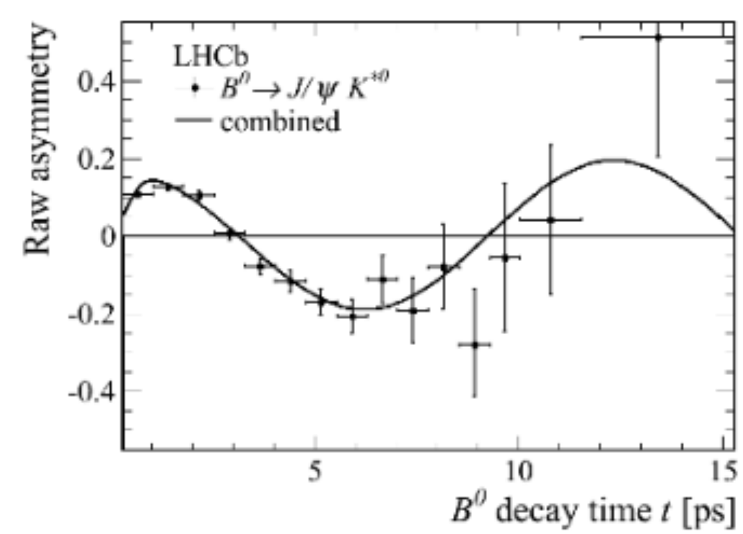
*CP*V in Interference of Mixing/Decay

- *CP*V leads to a decay-time dependent asymmetry

$$A_{CP}(t) = \frac{\Gamma(\bar{B}(t) \to f) - \Gamma(B(t) \to f)}{\Gamma(\bar{B}(t) \to f) + \Gamma(B(t) \to f)} = \frac{S\sin(\Delta m t) - C\cos(\Delta m t)}{\cosh\left(\frac{\Delta\Gamma t}{2}\right) + A_{\Delta\Gamma}\sinh\left(\frac{\Delta\Gamma t}{2}\right)}$$

- observables
  - *CP* observables $S, C, A_{\Delta\Gamma}$
  - mixing parameters $\Delta m = m_H - m_L$ and $\Delta\Gamma = \Gamma_H - \Gamma_L$





Asymmetry measurement

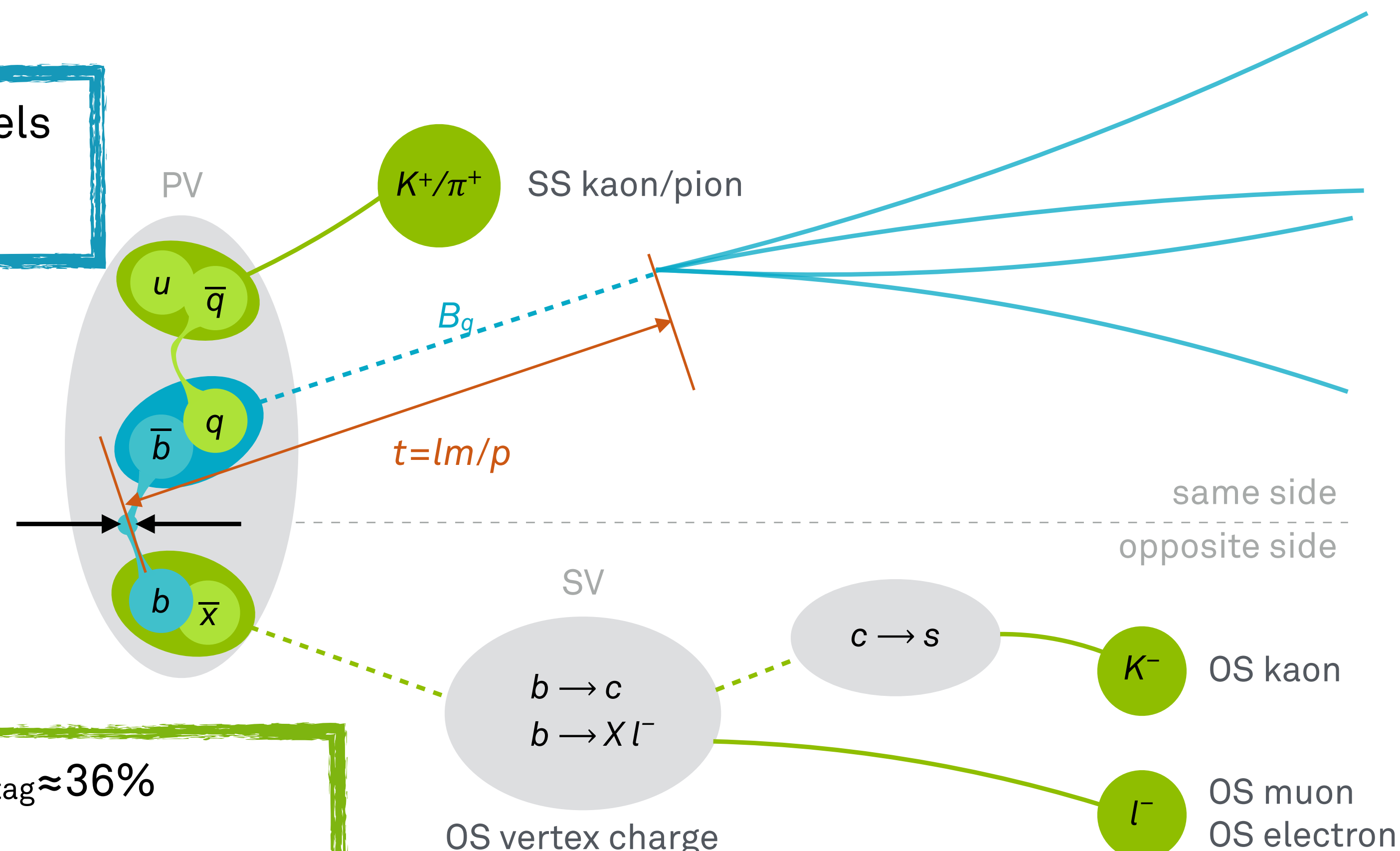
$$A_{\text{meas}}(t) = \frac{N_{\bar{B}_q^0}(t) - N_{B_q^0}(t)}{N_{\bar{B}_q^0}(t) + N_{B_q^0}(t)} \approx D \cdot A_{CP}(t) + A_{\text{exp}}$$

with $D \approx (1 - 2\omega)\, \mathrm{e}^{-\frac{\Delta m^2 \sigma_t^2}{2}}$

trigger efficiency ≈90% for $\mu\mu X$ channels

track reconstruction efficiency >96%

decay-time resolution ≈40–50 fs



determine initial B flavour, ε_{tag}≈36%

need to control rate of wrong tags (ω≈38%)

tagging power $\varepsilon_{\text{tag}}(1–2\omega)^2$≈3%

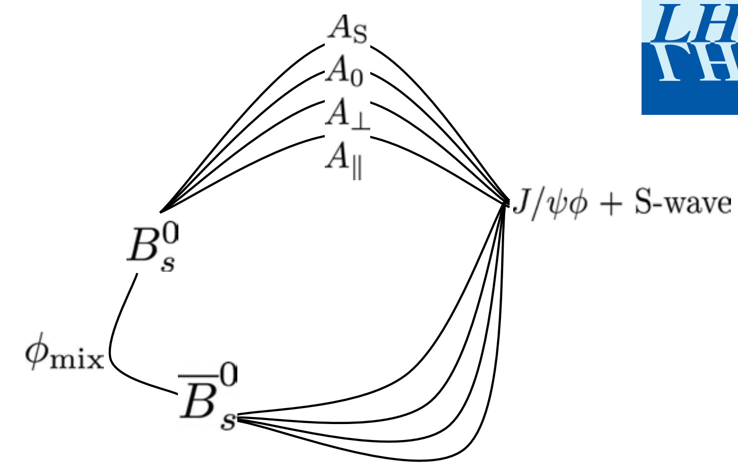
ϕ_s from $B_s \to J/\psi\, K^+K^-$

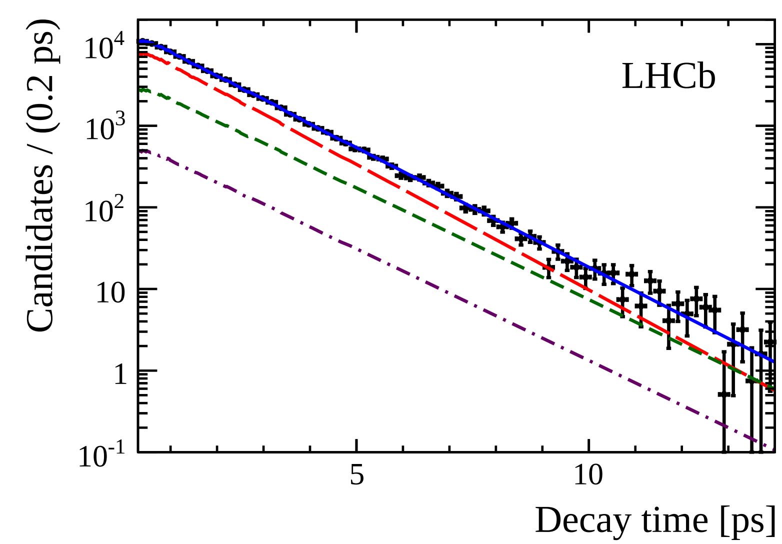
Phys. Rev. Lett. 114, 041801 (2015)

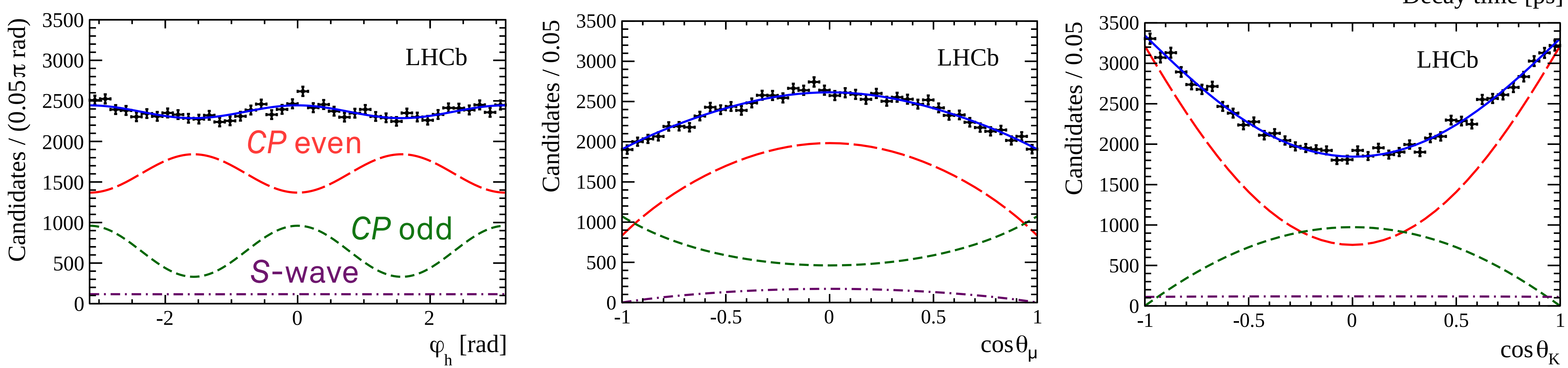
- ≈96000 signal candidates in 3 fb^{-1}
- analysis
  - decay-time dependent (resolution ≈46 fs)
  - flavour tagged (tagging power ≈3.7%)
  - angular analysis in 6 bins of m_{KK}
    - describe three P-wave and an S-wave state
    - disentangle *CP*-even and -odd P-wave contributions
- results (polarization-independent)

$$\phi_s = -0.058 \pm 0.049\,(\text{stat}) \pm 0.006\,(\text{syst})$$

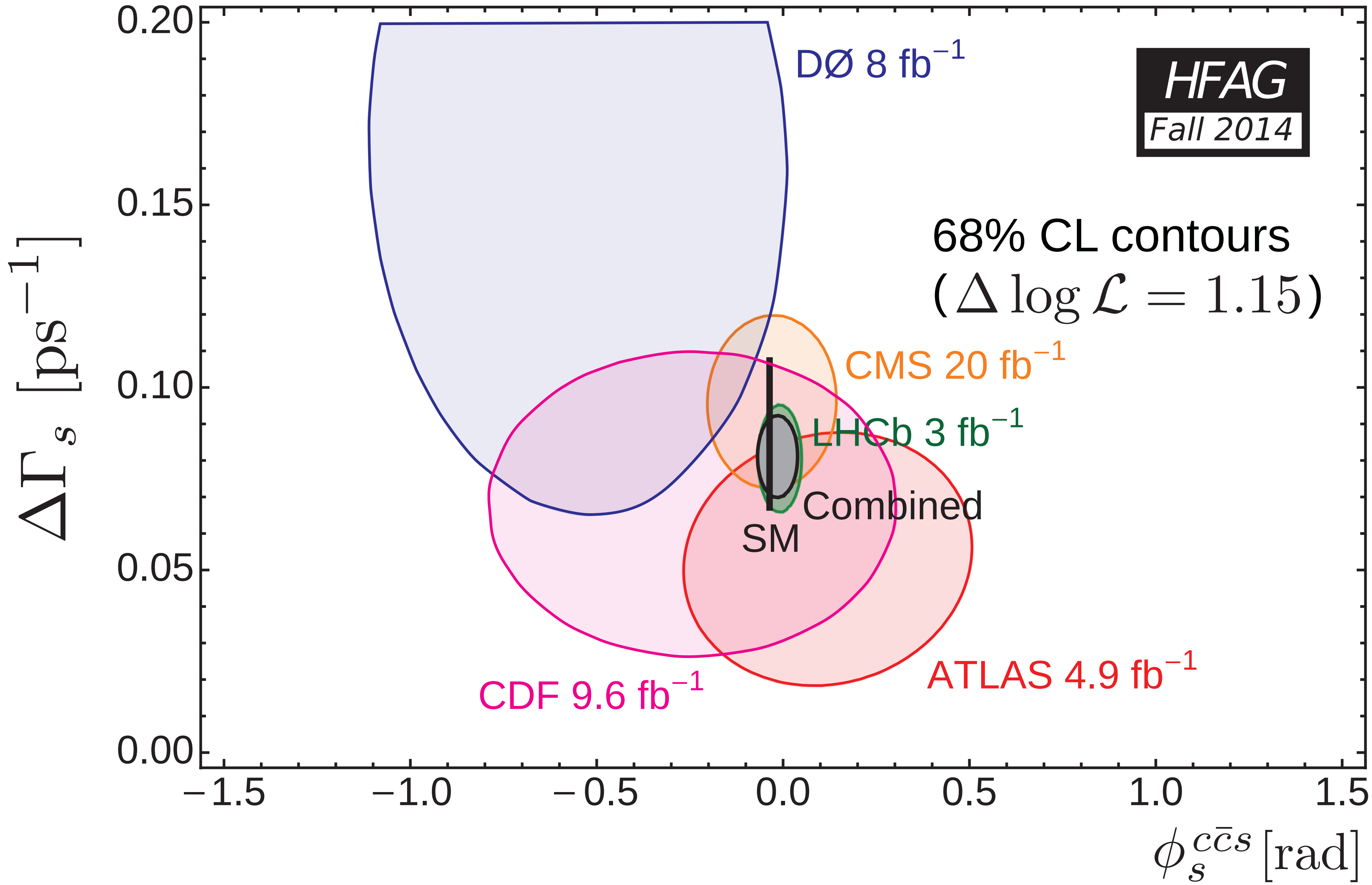
most precise!







ϕ_s from LHCb ($B_s \to J/\psi\, K^+K^- / \pi^+\pi^-$)



Phys. Rev. Lett. 114, 041801 (2015)
Phys. Lett. B736 (2014)

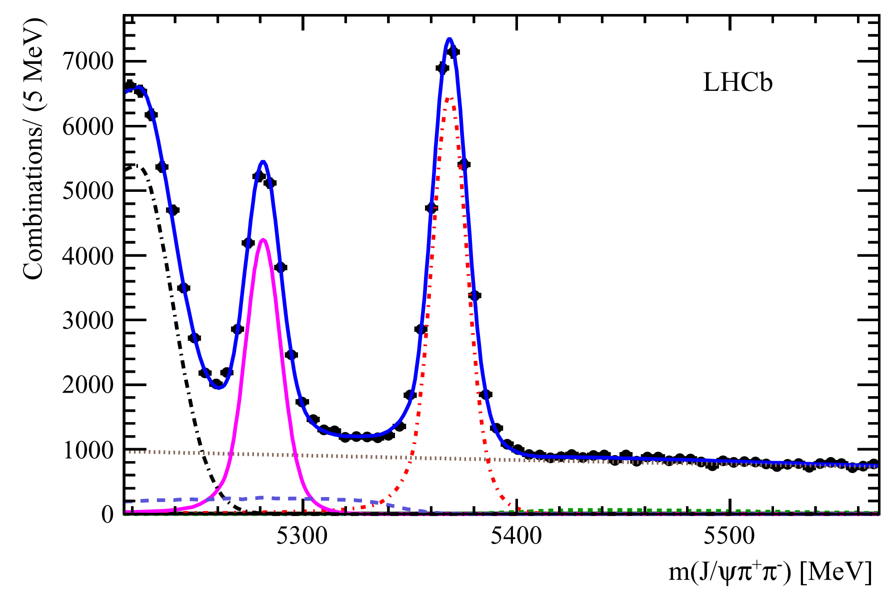
Penguin Control for ϕ_s

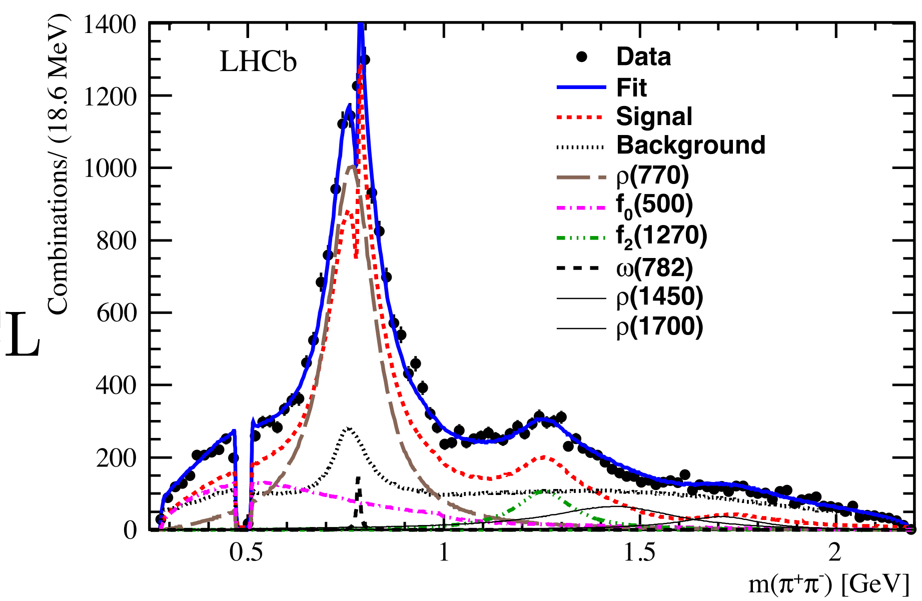
Phys. Lett. B 742 (2015), 38–49

- measure an effective phase $\phi_s = -2\beta_s + \phi^{\mathrm{NP}} + \Delta\phi_s$
  - separate higher-order SM contributions (penguins)
  - SU(3) flavour symmetry: constrain $\Delta\phi_s$ in $B^0 \to J/\psi\rho$
- $B^0 \to J/\psi\,\pi^+\pi^-$
  - 17500 candidates in dataset of 3 fb^{-1} (20 MeV around the B^0 mass)
  - angular + mass analysis to identify resonant $\pi^+\pi^-$ contributions

$$S = -0.66 \ \pm^{0.13}_{0.12}\ (\mathrm{stat}) \pm^{0.09}_{0.03}\ (\mathrm{syst})$$
$$C = -0.063 \pm 0.056\,(\mathrm{stat}) \pm^{0.019}_{0.014}\ (\mathrm{syst})$$

  - expected phase shift of $\Delta\phi_s = (0.05 \pm 0.56)^\circ = [-1.05^\circ, +1.18^\circ]$ at 95% CL
  - small compared to current exp. uncertainties $\phi_s^{\mathrm{exp}} = -0.015 \pm 0.035 = (-0.86 \pm 2.01)^\circ$

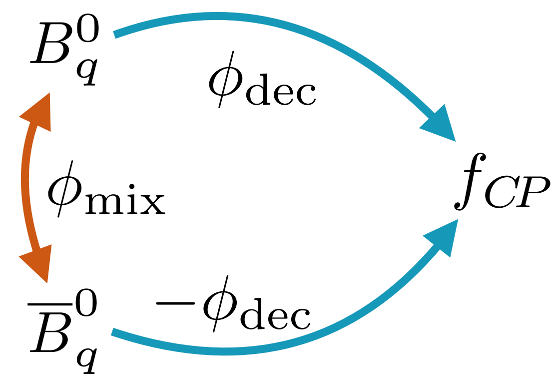




sin2β from $B^0 \to J/\psi\, K_S$

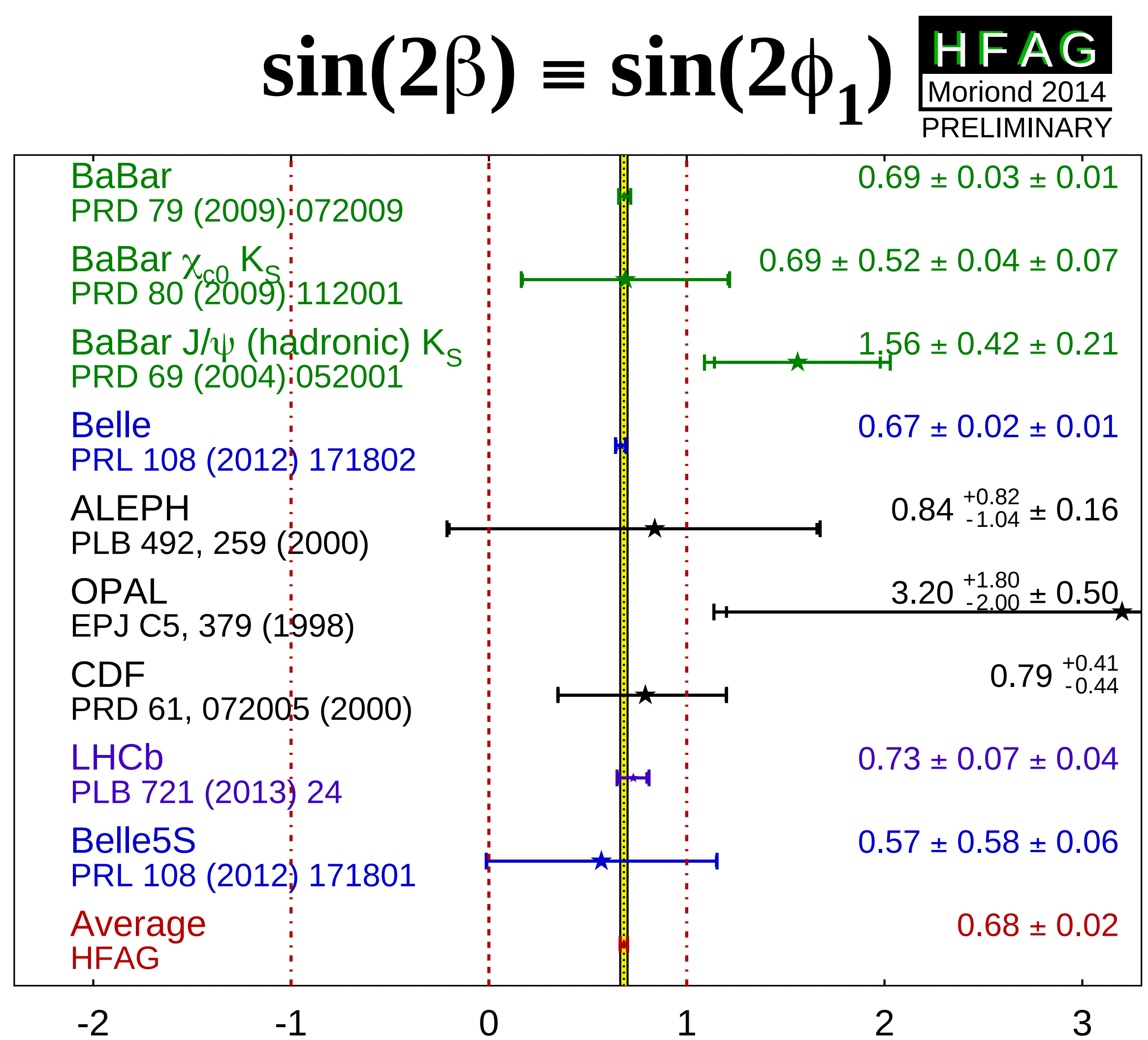
- time-dependent asymmetry ($\Delta\Gamma \approx 0$)

$$A_{J/\psi K^0_S}(t) = \frac{\Gamma(\overline{B}^0(t) \to J/\psi K^0_S) - \Gamma(B^0(t) \to J/\psi K^0_S)}{\Gamma(\overline{B}^0(t) \to J/\psi K^0_S) + \Gamma(B^0(t) \to J/\psi K^0_S)}$$
$$= S_{J/\psi K^0_S} \sin(\Delta m_d t) - C_{J/\psi K^0_S} \cos(\Delta m_d t)$$



- “golden channel”
  - *CPV* in the decay negligible
  - $C_{J/\psi K^0_S} \approx 0 \Rightarrow S_{J/\psi K^0_S} = \sin 2\beta$

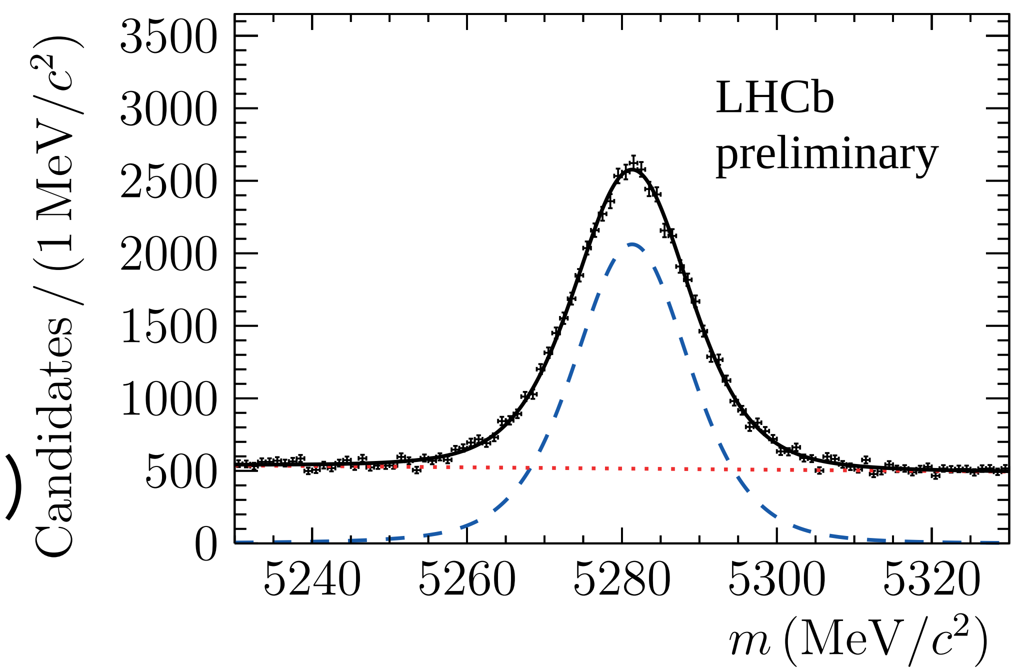
- precisely measured at *B* factories
  - ➡ benchmark for TD *CPV*
  - ➡ interesting prospects for LHCb

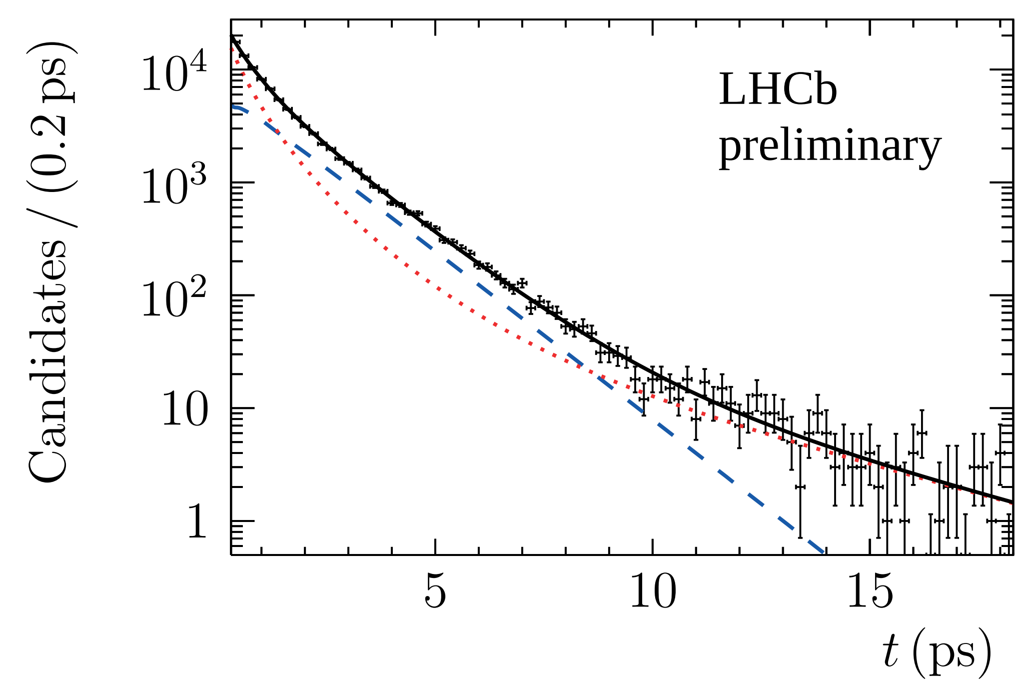


$\sin 2\beta$ from $B^0 \to J/\psi K_S$

LHCb-PAPER-2015-004, in preparation

- Run I dataset of 3 fb^{-1}
- $\approx$114000 $B^0 \to J/\psi K_S$ decays
- decay time resolution
  - negligible dilution (slow B^0 oscillation)
- improved flavour tagging
  - tagging power $(3.02 \pm 0.05)\%$
  - 41560 tagged decays
- analysis
  - account for production and tagging asymmetries
  - correct for K^0 effects



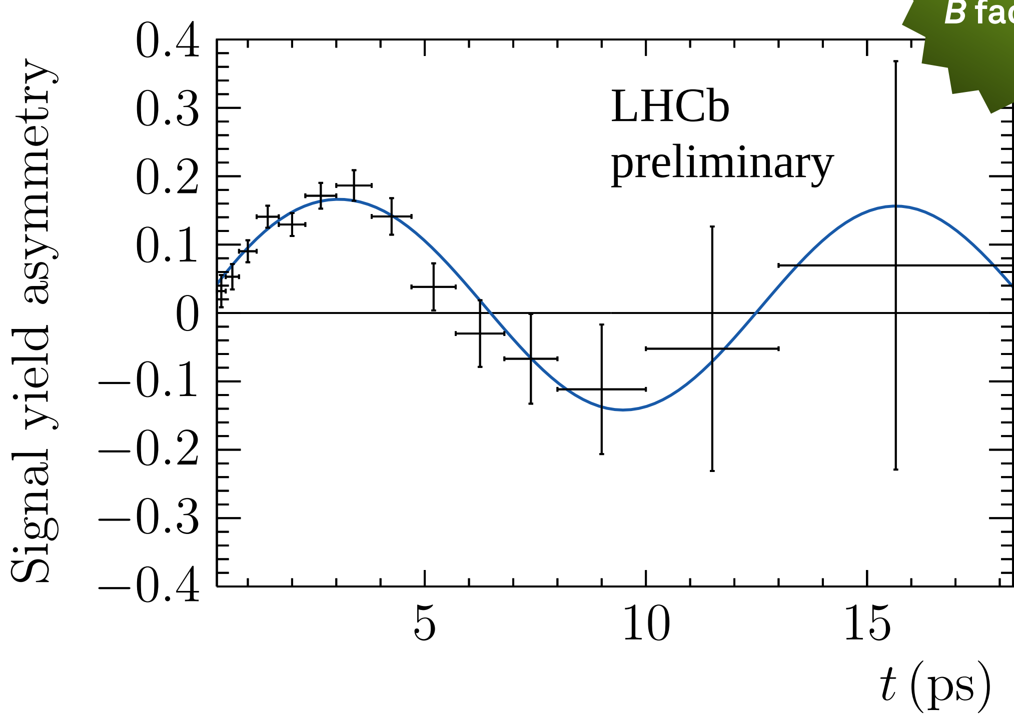


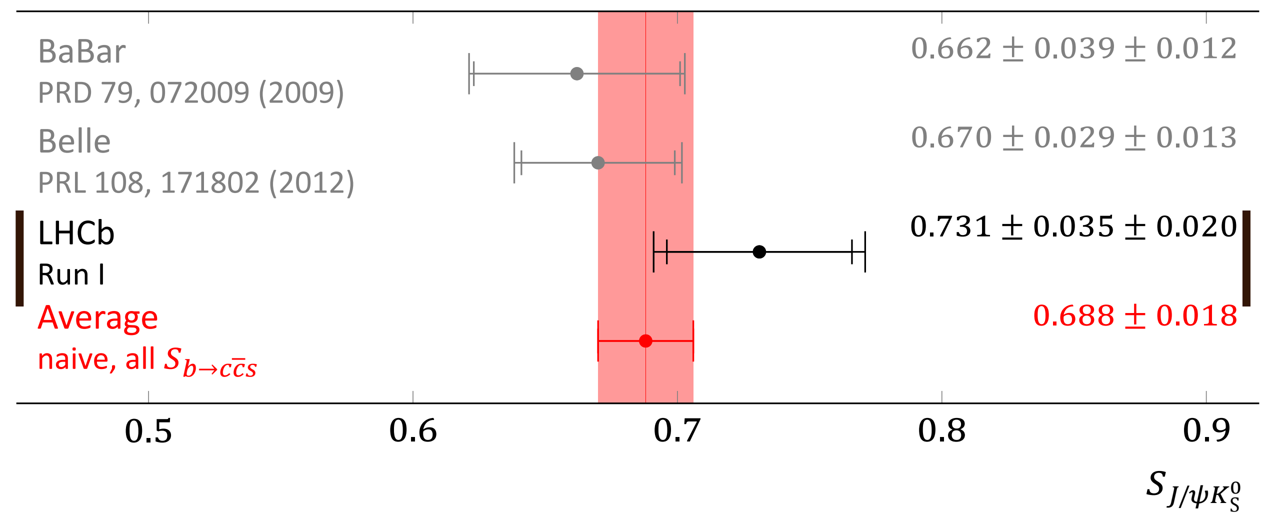
sin2β from $B^0 \to J/\psi\, K_S$ – Results

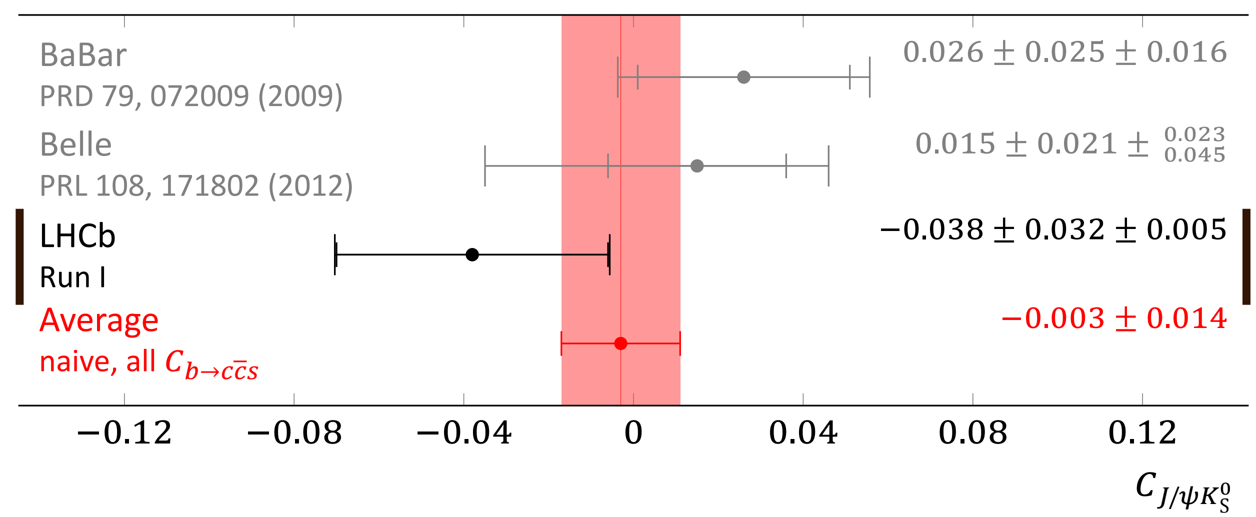
- preliminary results

$$S = 0.731 \pm 0.035\,(\text{stat}) \pm 0.020\,(\text{syst})$$
$$C = -0.038 \pm 0.032\,(\text{stat}) \pm 0.005\,(\text{syst})$$

precision similar to *B* factories!

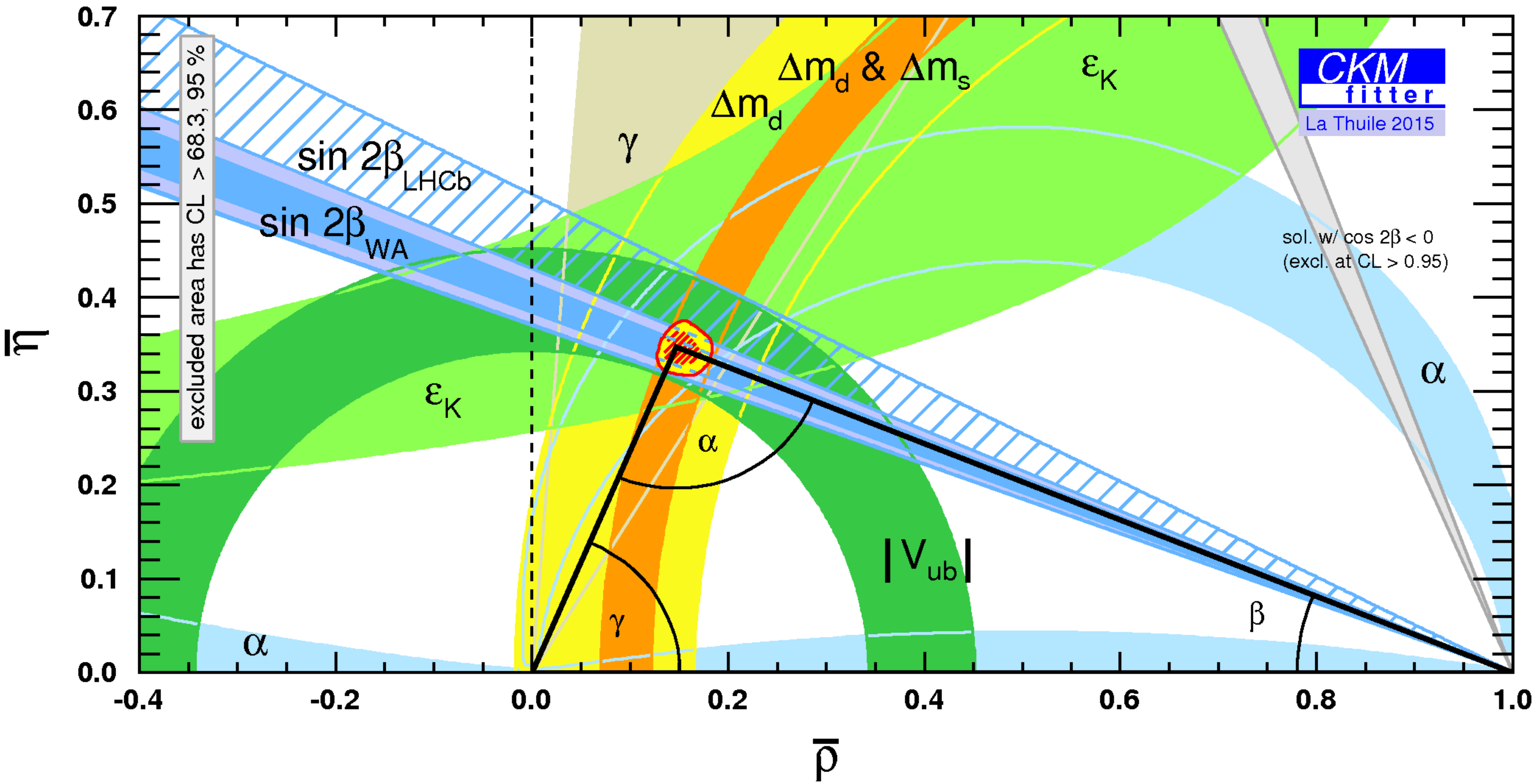




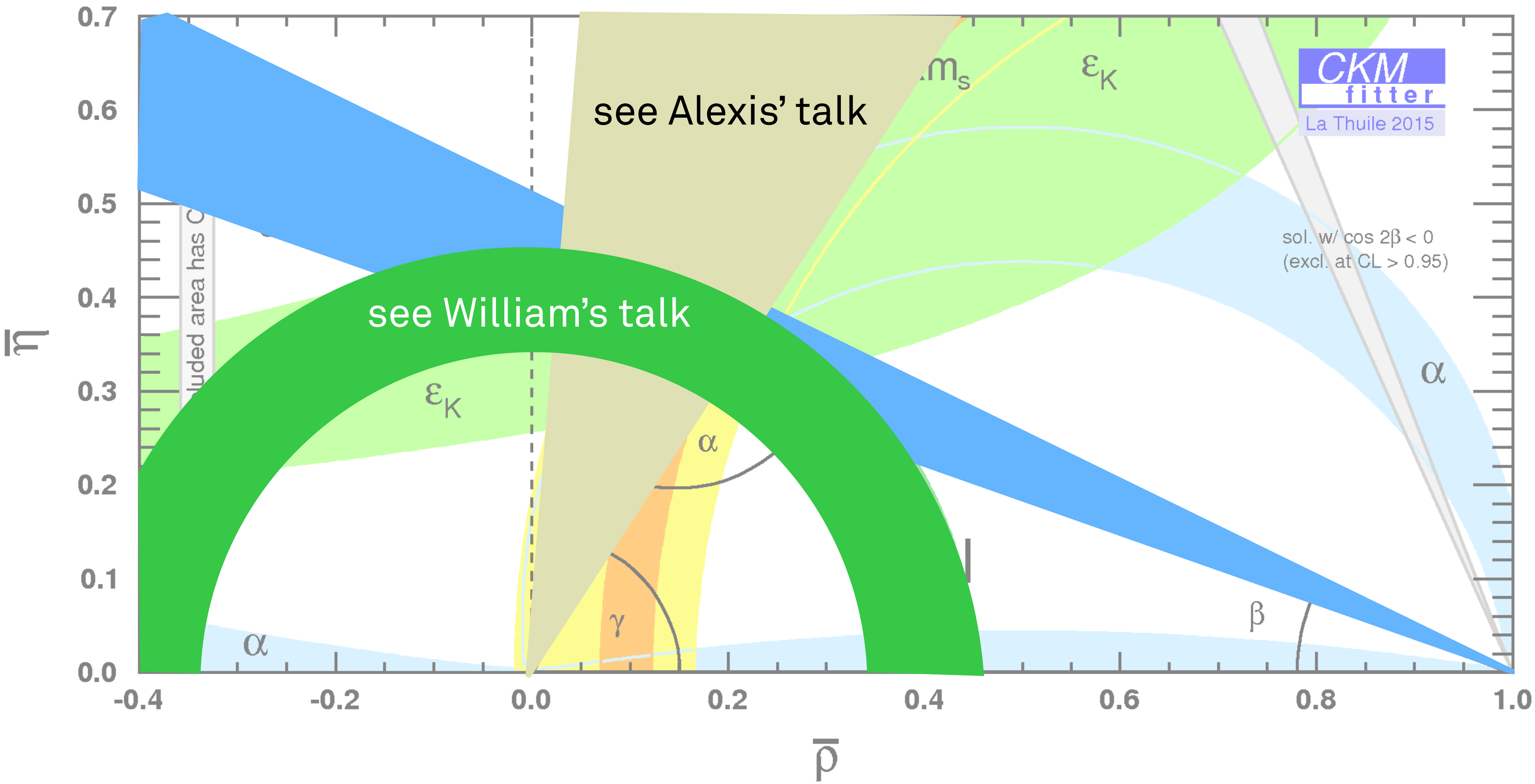


LHCb-PAPER-2015-004, in preparation

β from $B^0 \to J/\psi K_S$



β from $B^0 \to J/\psi\, K_S$

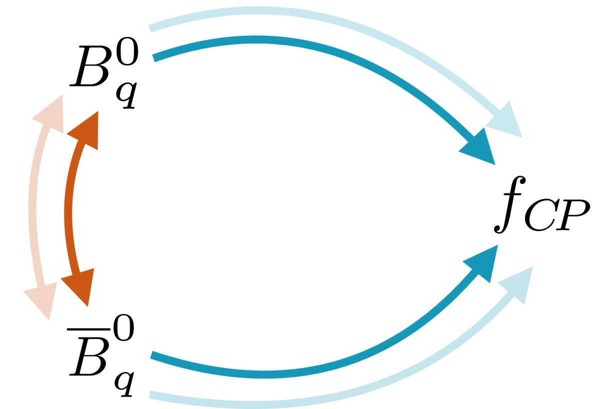


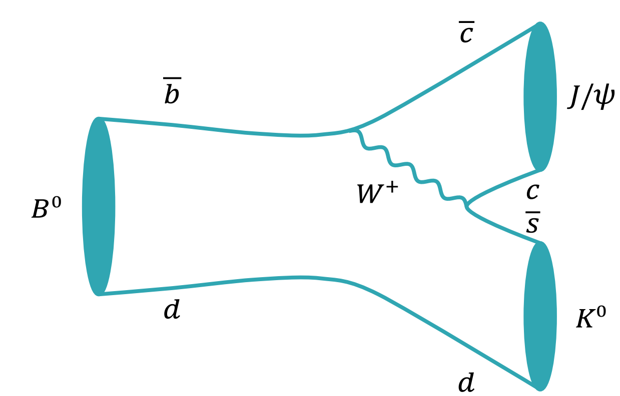
Penguin control for $B^0 \to J/\psi\, K_S$

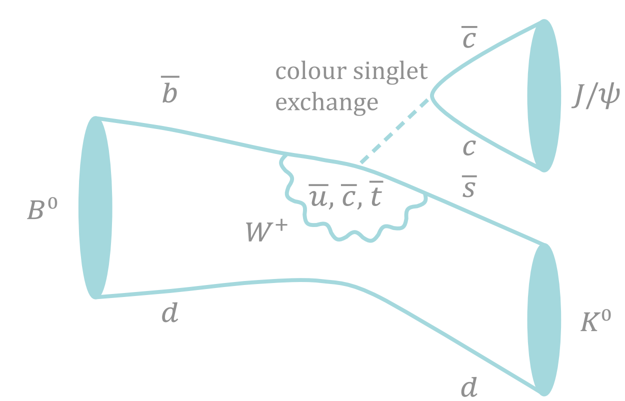
- measurement of β in $B^0 \to J/\psi\, K_S$
  - precision on β
    - current world avg. ≈0.8°
    - LHCb upgrade ≈0.2° (see LHCb-PUB-2012-006)
  - “penguin contributions negligible”?

$$\sin 2\beta_{B^0 \to J/\psi K^0_S} = \frac{S}{\sqrt{1-C^2}} = \sin(2\beta + \Delta\phi_d + \phi_d^{\mathrm{NP}})$$

- controlling SM penguins mandatory
  - U-spin symmetry: $B^0 \to J/\psi\, K_S \leftrightarrow B_s \to J/\psi\, K_S$
  - same decay topologies

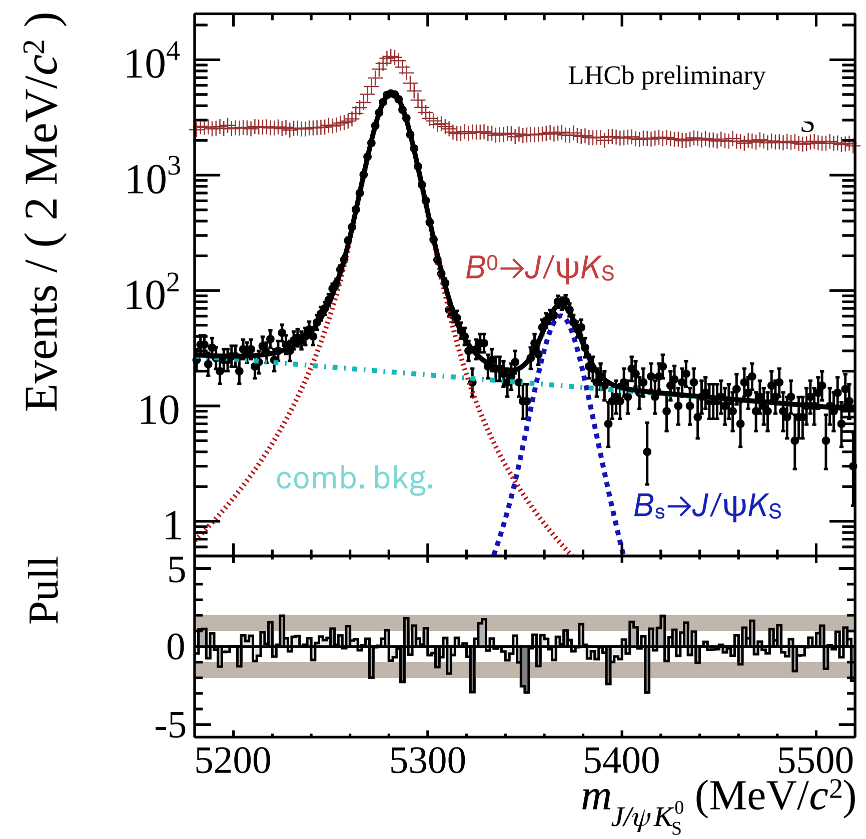


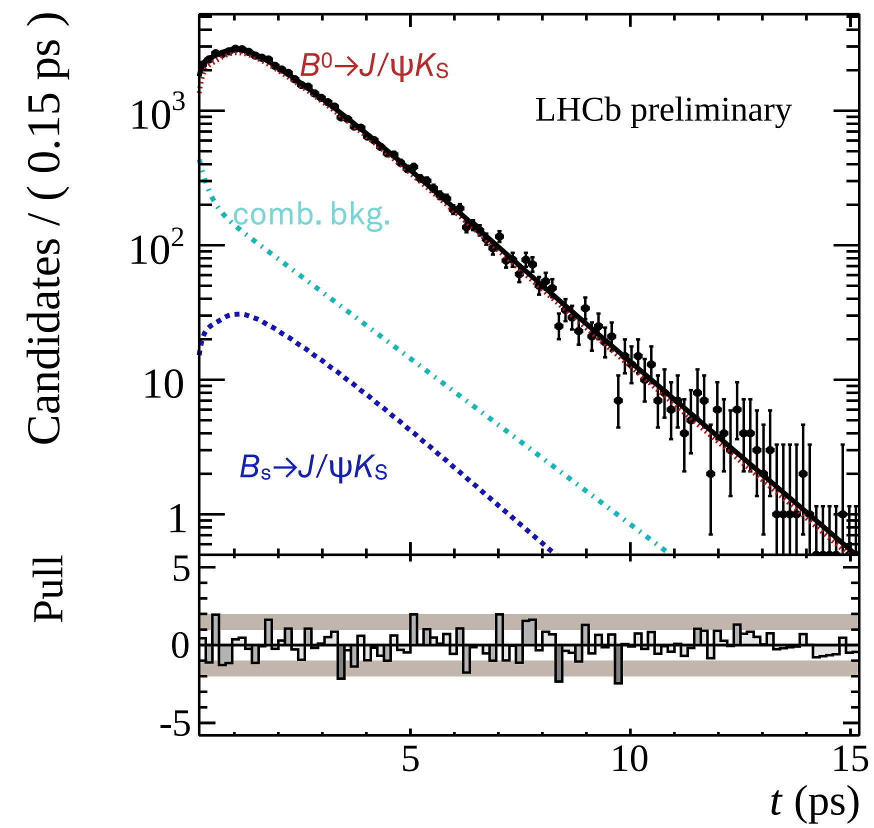




CPV in $B_s \to J/\psi\, K_S$

- analysis of 3 fb^{-1} dataset
  - 100x fewer B_s than B^0 decays
  - multivariate selection trained on B^0 proxy
  - ≈900 selected B_s decays (≈80k B^0)
- tagging
  - different treatment of B^0 and B_s comp.
  - tagging power in B_s 3.8% (2.6% in B^0)
- likelihood fit for B_s, B^0, comb. bkg.





LHCb-PAPER-2015-005, in preparation

CPV in $B_s \to J/\psi K_S$

LHCb-PAPER-2015-005, in preparation

- preliminary results

First measurement!

$$A_{\Delta\Gamma}\left(B_s^0 \to J/\psi K_S^0\right) = 0.49 \pm {}^{0.77}_{0.65}\,(\text{stat.}) \pm 0.06\,(\text{syst.})$$
$$C\left(B_s^0 \to J/\psi K_S^0\right) = -0.28 \pm 0.41\,(\text{stat.}) \pm 0.08\,(\text{syst.})$$
$$S\left(B_s^0 \to J/\psi K_S^0\right) = +0.08 \pm 0.40\,(\text{stat.}) \pm 0.08\,(\text{syst.})$$

- theory prediction (see arXiv:1412.6834)

$$A_{\Delta\Gamma}\left(B_s^0 \to J/\psi K_S^0\right) = 0.957 \pm 0.061$$
$$C\left(B_s^0 \to J/\psi K_S^0\right) = 0.003 \pm 0.021$$
$$S\left(B_s^0 \to J/\psi K_S^0\right) = -0.29 \pm 0.20$$

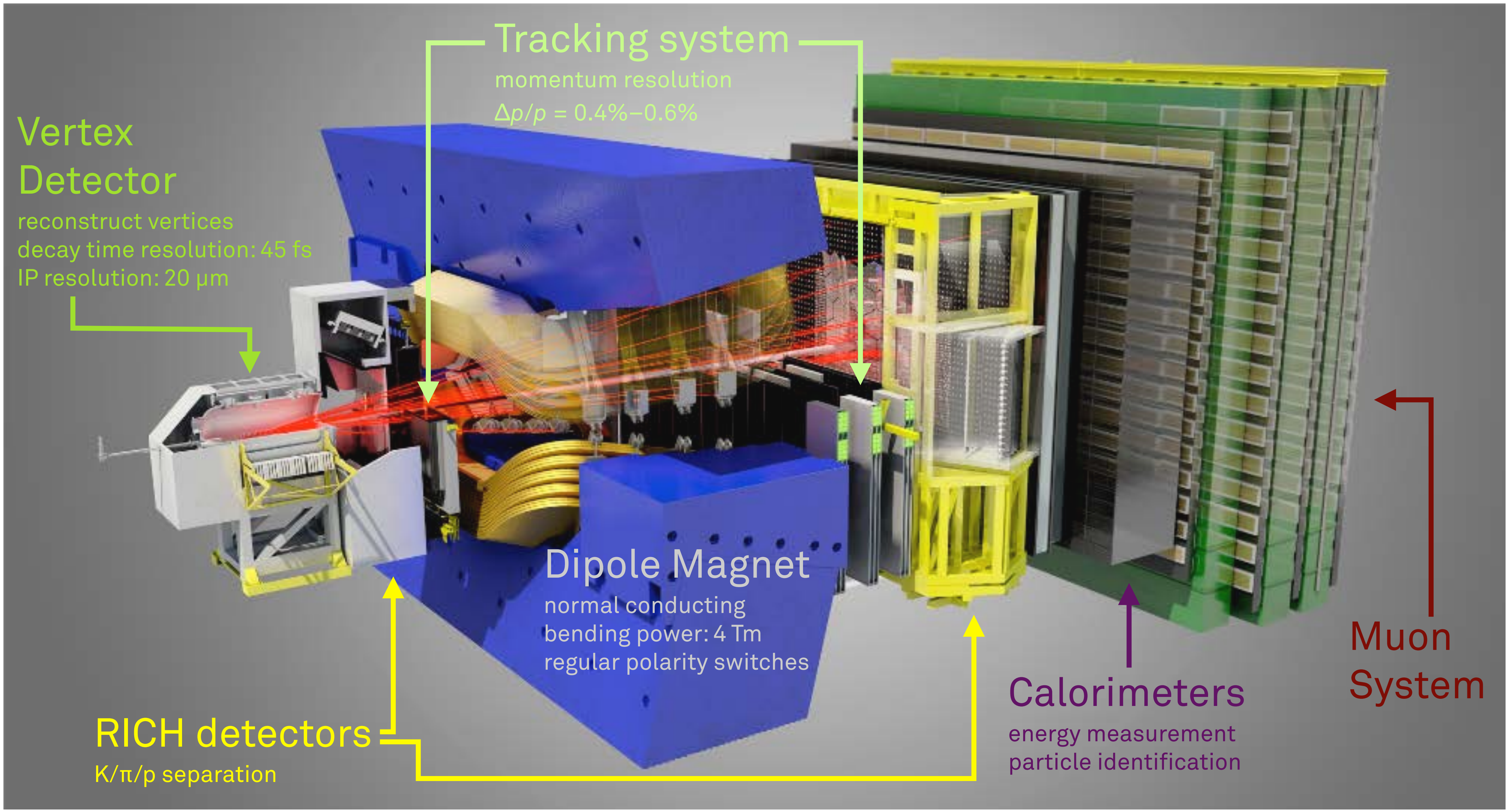
- successful proof of concept

Summary

- time-dependent, tagged *CP* analyses with Run I
  - precise measurements of *CPV* observables
  - unique access to the B_s meson system
  - starting to reach the precision of the *B* factories
- good agreement with the Standard Model, so far...
  - still large room for improvement in experimental sensitivity
  - further precision with more data and improved measurements
  - control of penguin contributions will become mandatory
- a lot of interesting prospects for Run II & the upgrade!

Backup

LHCb Detector



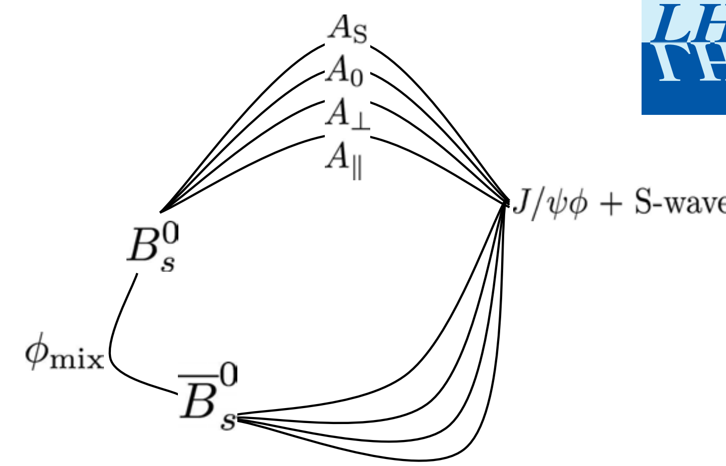
Prospects for Run II & Upgrade

LHCb-PUB-2012-006

Type	Observable	Current precision	LHCb 2018	**Upgrade** ($50\,\text{fb}^{-1}$)	Theory uncertainty
B_s^0 mixing	$2\beta_s\ (B_s^0 \to J/\psi\ \phi)$	0.10 [138]	0.025	0.008	~ 0.003
	$2\beta_s\ (B_s^0 \to J/\psi\ f_0(980))$	0.17 [214]	0.045	0.014	~ 0.01
	a_{sl}^s	6.4×10^{-3} [43]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguins	$2\beta_s^{\text{eff}}(B_s^0 \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{\text{eff}}(B_s^0 \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\text{eff}}(B^0 \to \phi K_S^0)$	0.17 [43]	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{\text{eff}}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\text{eff}}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguins	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,\text{GeV}^2/c^4)$	0.08 [67]	0.025	0.008	0.02
	$s_0\,A_{\text{FB}}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [67]	6 %	2 %	7 %
	$A_{\text{I}}(K\mu^+\mu^-; 1 < q^2 < 6\,\text{GeV}^2/c^4)$	0.25 [76]	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [85]	8 %	2.5 %	~ 10 %
Higgs penguins	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9} [13]	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	~ 10–$12°$ [244, 258]	4°	0.9°	negligible
	$\gamma\ (B_s^0 \to D_s K)$	–	11°	2.0°	negligible
	$\beta\ (B^0 \to J/\psi\ K_S^0)$	0.8° [43]	0.6°	0.2°	negligible
Charm *CP* violation	A_Γ	2.3×10^{-3} [43]	0.40×10^{-3}	0.07×10^{-3}	–
	$\Delta\mathcal{A}_{CP}$	2.1×10^{-3} [18]	0.65×10^{-3}	0.12×10^{-3}	–

ϕ_s from $B_s \to J/\psi\, K^+K^-$

Phys. Rev. Lett. 114, 041801 (2015)



- analysis
  - decay-time dependent (resolution ≈46 fs)
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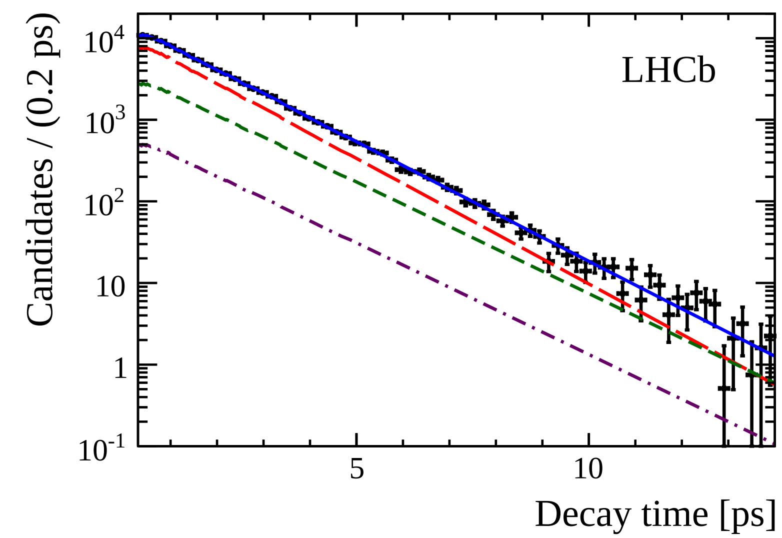
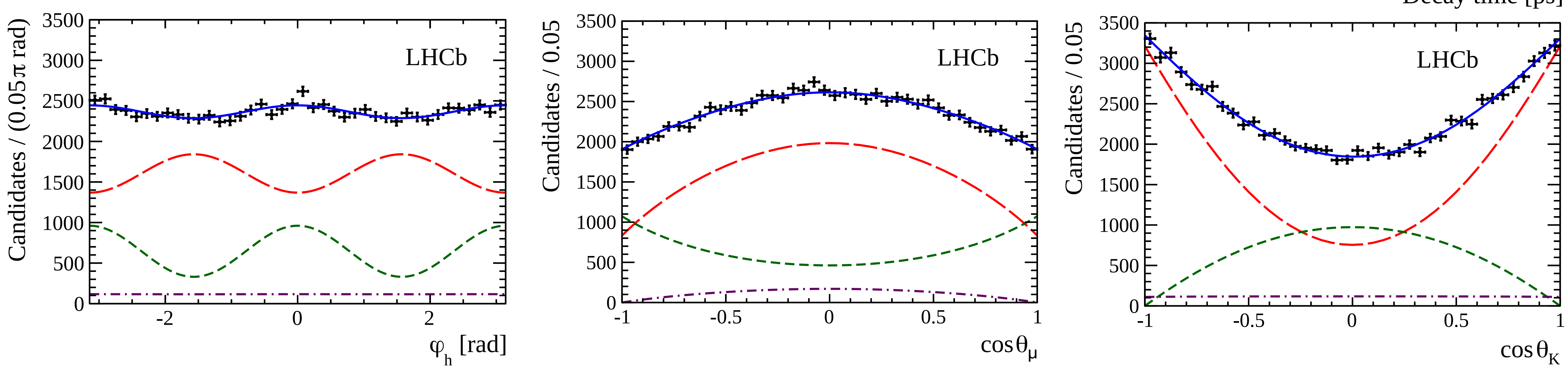
most precise!

$$\phi_s = -0.058 \pm 0.049\,(\text{stat}) \pm 0.006\,(\text{syst})$$

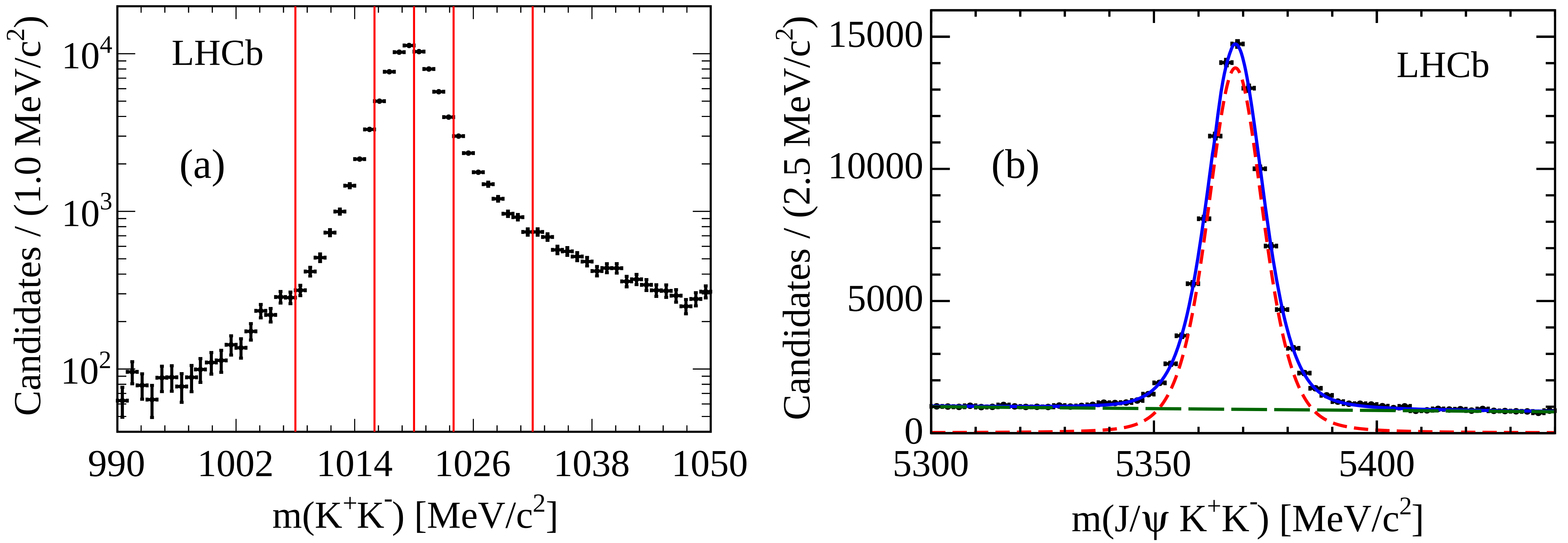




ϕ_s from $B_s \to J/\psi\, K^+K^-$

Phys. Rev. Lett. 114, 041801 (2015)

- select ≈96000 signal candidates in 3 fb^{-1}



ϕ_s from $B_s \to J/\psi\, K^+K^-$

- polarisation-independent results

Parameter	Value
Γ_s (ps^{-1})	$0.6603 \pm 0.0027 \pm 0.0015$
$\Delta\Gamma_s$ (ps^{-1})	$0.0805 \pm 0.0091 \pm 0.0032$
$\lvert A_\perp \rvert^2$	$0.2504 \pm 0.0049 \pm 0.0036$
$\lvert A_0 \rvert^2$	$0.5241 \pm 0.0034 \pm 0.0067$
$\delta_\parallel$ (rad)	$3.26^{+0.10}_{-0.17}{}^{+0.06}_{-0.07}$
$\delta_\perp$ (rad)	$3.08^{+0.14}_{-0.15} \pm 0.06$
ϕ_s (rad)	$-0.058 \pm 0.049 \pm 0.006$
$\lvert\lambda\rvert$	$0.964 \pm 0.019 \pm 0.007$
Δm_s (ps^{-1})	$17.711^{+0.055}_{-0.057} + 0.011$

Phys. Rev. Lett. 114, 041801 (2015)

ϕ_s from $B_s \to J/\psi K^+K^-$

Phys. Rev. Lett. 114, 041801 (2015)

- syst. uncertainties (polarisation-independent)

Source	Γ_s (ps^{-1})	$\Delta\Gamma_s$ (ps^{-1})	$\lvert A_\perp\rvert^2$	$\lvert A_0\rvert^2$	$\delta_\parallel$ (rad)	$\delta_\perp$ (rad)	ϕ_s (rad)	$\lvert\lambda\rvert$	Δm_s (ps^{-1})
Total statistical uncertainty	0.0027	0.0091	0.0049	0.0034	$^{+0.10}_{-0.17}$	$^{+0.14}_{-0.15}$	0.049	0.019	$^{+0.055}_{-0.057}$
Mass factorization	...	0.0007	0.0031	0.0064	0.05	0.05	0.002	0.001	0.004
Signal weights (statistical)	0.0001	0.0001	...	0.0001	...	...	...	...	...
b-hadron background	0.0001	0.0004	0.0004	0.0002	0.02	0.02	0.002	0.003	0.001
B_c^+ feed down	0.0005	...	...	...	...	...	...	...	...
Angular resolution bias	...	...	0.0006	0.0001	$^{+0.02}_{-0.03}$	0.01	...	...	...
Angular efficiency (reweighting)	0.0001	...	0.0011	0.0020	0.01	...	0.001	0.005	0.002
Angular efficiency (statistical)	0.0001	0.0002	0.0011	0.0004	0.02	0.01	0.004	0.002	0.001
Decay-time resolution	...	...	...	...	...	0.01	0.002	0.001	0.005
Trigger efficiency (statistical)	0.0011	0.0009	...	...	...	...	...	...	...
Track reconstruction (simulation)	0.0007	0.0029	0.0005	0.0006	$^{+0.01}_{-0.02}$	0.002	0.001	0.001	0.006
Track reconstruction (statistical)	0.0005	0.0002	...	...	...	...	...	...	0.001
Length and momentum scales	0.0002	...	...	...	...	...	...	...	0.005
S-P coupling factors	...	...	...	...	0.01	0.01	...	0.001	0.002
Fit bias	...	...	0.0005	...	...	0.01	...	0.001	...
Quadratic sum of systematics	0.0015	0.0032	0.0036	0.0067	$^{+0.06}_{-0.07}$	0.06	0.006	0.007	0.011

ϕ_s from $B_s \to J/\psi\, K^+K^-$

- polarisation-dependent results

Parameter	Value
$\lvert\lambda^0\rvert$	$1.012 \pm 0.058 \pm 0.013$
$\lvert\lambda^{\parallel}/\lambda^0\rvert$	$1.02 \pm 0.12 \pm 0.05$
$\lvert\lambda^{\perp}/\lambda^0\rvert$	$0.97 \pm 0.16 \pm 0.01$
$\lvert\lambda^{\mathrm{S}}/\lambda^0\rvert$	$0.86 \pm 0.12 \pm 0.04$
${\phi_s}^0$ (rad)	$-0.045 \pm 0.053 \pm 0.007$
${\phi_s}^{\parallel} - {\phi_s}^0$ (rad)	$-0.018 \pm 0.043 \pm 0.009$
${\phi_s}^{\perp} - {\phi_s}^0$ (rad)	$-0.014 \pm 0.035 \pm 0.006$
$\phi_s^{\mathrm{S}} - \phi_s^0$ (rad)	$0.015 \pm 0.061 \pm 0.021$

Phys. Rev. Lett. 114, 041801 (2015)

ϕ_s from $B_s \to J/\psi\, K^+K^-$

- syst. uncertainties (polarisation-dependent)

TABLE IV. Statistical and systematic uncertainties for the polarization-dependent result.

Source	$\lvert\lambda^0\rvert$	$\lvert\lambda^{\parallel}/\lambda^0\rvert$	$\lvert\lambda^{\perp}/\lambda^0\rvert$	$\lvert\lambda^{S}/\lambda^0\rvert$	ϕ_s^0 (rad)	$\phi_s^{\parallel} - \phi_s^0$ (rad)	$\phi_s^{\perp} - \phi_s^0$ (rad)	$\phi_s^{S} - \phi_s^0$ (rad)
Total statistical uncertainty	0.058	0.12	0.16	0.12	0.053	0.043	0.035	0.061
Mass factorization	0.010	0.04	0.01	0.03	0.003	0.005	0.003	0.016
b-hadron background	0.002	0.01	⋯	0.01	0.003	0.001	0.001	0.009
Angular efficiency (reweighting)	⋯	⋯	⋯	0.02	0.001	0.002	0.001	0.007
Angular efficiency (statistical)	0.004	0.02	0.01	0.01	0.004	0.007	0.005	0.004
Decay-time resolution	0.006	0.01	⋯	0.01	0.003	0.002	0.001	0.002
S-P coupling factors	⋯	⋯	⋯	⋯	⋯	⋯	⋯	0.006
Quadratic sum of systematics	0.013	0.05	0.01	0.04	0.007	0.009	0.006	0.021

Phys. Rev. Lett. 114, 041801 (2015)

$B^0 \to J/\psi\, \pi^+ \pi^-$

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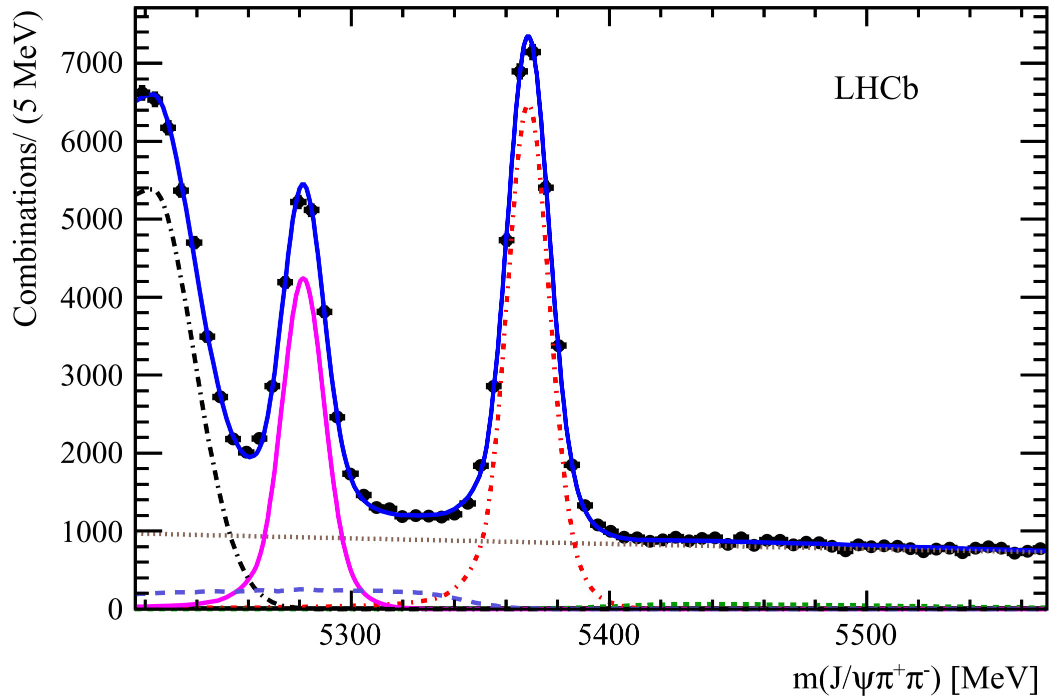
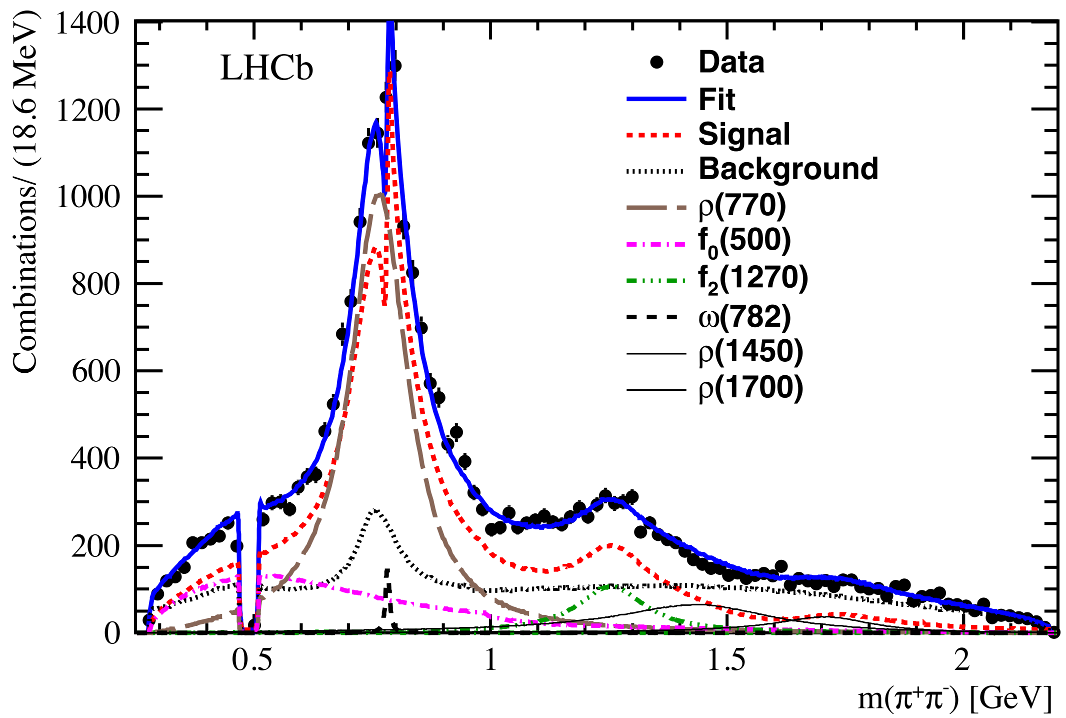
- 17500 candidates in dataset of 3 fb^{-1}
  (20 MeV around the B^0 mass)
- angular + Dalitz analysis to identify resonant contributions

Component	Fit fraction (%)
$\rho(770)$	65.6 ± 1.9
$f_0(500)$	20.1 ± 0.7
$f_2(1270)$	7.8 ± 0.6
$\omega(782)$	$0.64^{+0.19}_{-0.13}$
$\rho(1450)$	9.0 ± 1.8
$\rho(1700)$	3.1 ± 0.7





$B^0 \to J/\psi\, \pi^+ \pi^-$

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- *CP* observables

$$S = -0.66 \;\pm^{0.13}_{0.12}\,(\text{stat}) \pm^{0.09}_{0.03}\,(\text{syst})$$
$$C = -0.063 \pm 0.056\,(\text{stat}) \pm^{0.019}_{0.014}\,(\text{syst})$$

First measure ment!

- *CP* phase

$$\phi_d^{\text{eff}}(B^0 \to J/\psi\rho^0) = (41.7 \pm 9.6\,(\text{stat})^{+2.8}_{-6.3}\,(\text{syst}))^\circ$$

- constraint on penguin shift

$$\Delta\phi_s = (0.05 \pm 0.56)^\circ = [-1.05^\circ, +1.18^\circ] \text{ at } 95\% \text{ CL}$$

- small compared with exp. uncertainty on world average

$$\phi_s^{\text{exp}} = -0.015 \pm 0.035 = (-0.86 \pm 2.01)^\circ$$

$B^0 \to J/\psi\, \pi^+ \pi^-$

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- systematic uncertainties

Systematic uncertainties on *CP*-violating phases $2\beta_i^{\rm eff}$ (°). Statistical uncertainties are also shown.

Fit Sources	Fit 1			Fit 2		
	ρ	other $-\ \rho$	ρ_0	$\rho_\parallel - \rho_0$	$\rho_\perp - \rho_0$	other $-\ \rho_0$
Resonance model	$^{+1.85}_{-5.94}$	$^{+0.51}_{-0.33}$	$^{+1.99}_{-6.56}$	$^{+1.35}_{-0.05}$	$^{+1.50}_{-0.59}$	$^{+0.68}_{-0.52}$
Resonance parameters	±1.21	±0.43	±1.35	±0.68	±0.57	±0.60
Mass and angular acceptance	±0.27	±0.05	±0.28	±0.21	±0.16	±0.05
Angular acc. correlation	±0.22	±0.03	±0.22	±0.21	±0.08	±0.03
Decay time acceptance	±0.05	±0.02	±0.06	±0.04	±0.04	±0.03
Bkg. mass and angular PDF	±0.43	±0.09	±0.47	±0.22	±0.26	±0.11
Bkg. decay time PDF	±0.14	±0.05	±0.12	±0.06	±0.08	±0.07
Bkg. model	±0.49	±0.23	±0.15	±0.97	±0.38	±0.13
Flavor Tagging	±1.46	±0.03	±1.66	±0.44	±0.86	±0.01
Production asymmetry	±0.17	±0.50	±0.28	±0.09	±0.49	±0.42
Total systematic uncertainty	$^{+2.8}_{-6.3}$	$^{+0.9}_{-0.8}$	$^{+3.0}_{-6.9}$	$^{+1.9}_{-1.3}$	$^{+2.0}_{-1.4}$	$^{+1.0}_{-0.9}$
Statistical uncertainty	±9.6	±3.6	±10.2	±6.5	±7.2	±3.9

sin2β from $B^0 \to J/\psi K_S$

LHCb-PAPER-2015-004, in preparation

- systematic uncertainties

Origin	σ_S	σ_C
Background tagging asymmetry	0.0179 (2.5 %)	0.0015 (4.5 %)
Tagging calibration	0.0062 (0.9 %)	0.0024 (7.2 %)
$\Delta\Gamma$	0.0047 (0.6 %)	—
Fraction of wrong PV component	0.0021 (0.3 %)	0.0011 (3.3 %)
z-scale	0.0012 (0.2 %)	0.0023 (7.0 %)
Δm	—	0.0034 (10.3 %)
Upper decay time acceptance	—	0.0012 (3.6 %)
Correlation between mass and decay time	—	—
Decay time resolution calibration	—	—
Decay time resolution offset	—	—
Low decay time acceptance	—	—
Production asymmetry	—	—
Sum	0.020 (2.7 %)	0.005 (15.2 %)

CPV in $B_s \to J/\psi K_S$

- systematic uncertainties

Source	$\mathcal{A}_{\Delta\Gamma}$	C_{dir}	S_{mix}	Long $R \times 10^5$	Downstream $R \times 10^5$
Mass modelling	0.045	0.009	0.009	15.5	17.2
Decay-time resolution	0.038	0.066	0.070	0.6	0.3
Decay-time acceptance	0.022	0.004	0.004	0.6	0.5
Tagging calibration	0.002	0.021	0.023	0.1	0.2
Mass resolution	0.010	0.005	0.006	12.6	8.0
Mass–time correlation	0.003	0.037	0.036	0.2	0.1
Total	0.064	0.079	0.083	20.0	19.0

LHCb-PAPER-2015-005, in preparation