Mid- and long-term prospects of measurements of mixing and mixing-induced *CP* violation in the B system at LHCb

Veronika Chobanova
on behalf of the LHCb collaboration

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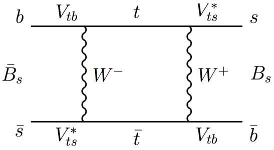
Mixing and mixing-induced *CP* violation



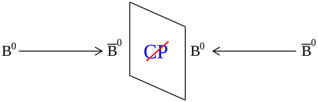
$$|B_{L,H}\rangle = p|B^0_q\rangle \pm q|\overline{B}^0_q\rangle$$

$$\lambda_f = \frac{q}{p}\frac{\bar{\mathcal{A}}_f}{\mathcal{A}_f}$$

Mixing of neutral B mesons can give rise to two types of *CP* violation

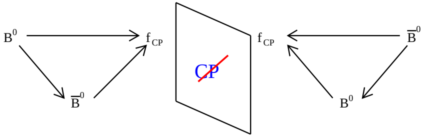
CPV in the mixing

Arises when $|q/p| \neq 1$ and thus $\mathcal{P}(B^0 \to \overline{B}^0) \neq \mathcal{P}(\overline{B}^0 \to B^0)$



Mixing-induced CPV

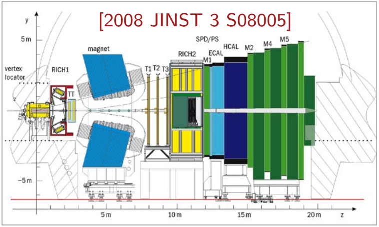
Arises in the interference between mixing and decay, when $\sin(-\arg(\lambda_f)) \neq 0$



LHCb prospects

Mixing-induced CPV access through time-dependent decay rates

- Excellent time resolution at LHCb, $\sigma(t) \approx 40\,\text{fs}$ ($B_s^0 \to J/\psi KK$)
- B flavour tagging efficiency $\approx 4\%$
- PID efficiencies $> 95\%$, fake rates $1 - 5\%$



[2008 JINST 3 S08005]

Period	Luminosity	CMS energy
Run 1 2010-2013	$3\,\text{fb}^{-1}$	$7 - 8$ TeV
Run 2 2015-2018	$8\,\text{fb}^{-1}$	13 TeV
Runs 3+4 2020-2030	$50\,\text{fb}^{-1}$	$13 - 14$ TeV
Run 5 (HL) from 2030 on	$300\,\text{fb}^{-1}$	$13 - 14$ TeV

[CERN-LHCC-2012-007]

← So far $5\,\text{fb}^{-1}$ of pp collisions

← Detector upgrade 2018-2020

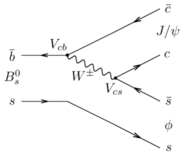
← Consider second upgrade for Run 5

← High-luminosity LHC, x10 current instantaneous luminosity ($300\,\text{fb}^{-1}$)

Outline

1. Mixing-induced CPV in b $\to$ c$\bar{c}$s and b $\to$ s$\bar{s}$s transitions of B_s^0 (ϕ_s)
2. Mixing-induced CPV in b $\to$ c$\bar{c}$s and b $\to$ $sq\bar{q}$ transitions of B^0 (β)
3. CPV in the mixing and B_s^0 and B^0 mixing parameters
4. Mixing-induced CPV in b $\to$ u$\bar{u}$d transitions of B^0 (α)
5. Mixing-induced CPV in b $\to$ u$\bar{c}$s transitions of B_s^0 ($\gamma - \phi_s$)

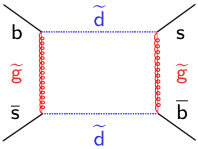
ϕ_s in $b \to c\bar{c}s$ transitions



- Interference between mixing and decay in B_s^0 decays via $b \to c\bar{c}s$ gives rise to *CP*-violating phase

  $$\phi_s \stackrel{\text{SM}}{=} -2\arg\left(\frac{V_{tb}V_{ts}^*}{V_{cb}V_{cs}^*}\right) \equiv -2\beta_s = -0.0376 \pm 0.0008\,\text{rad}$$

  neglecting penguin pollution [CKMFitter]



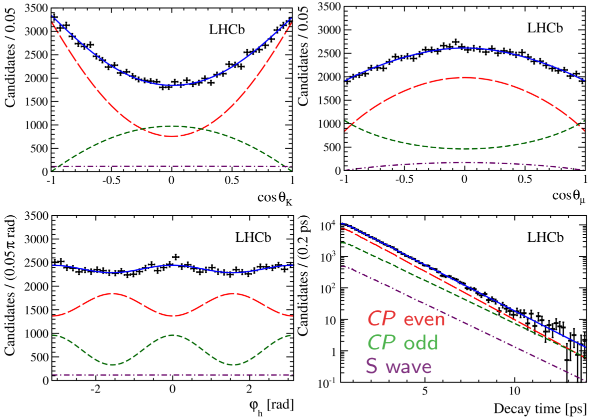
- ϕ_s precisely predicted by the SM, very sensitive to NP (box diagram), even at high scales

- $\phi_s^{c\bar{c}s}$ measured in a range of decays (see G. Cowan's talk on Tue, WG4):
  $B_s^0 \to J/\psi KK$, $B_s^0 \to J/\psi \pi\pi$, $B_s^0 \to \psi(2S)\phi$, $B_s^0 \to D_s^+ D_s^-$

- "Golden mode" for ϕ_s is $B_s^0 \to J/\psi[\mu\mu]KK$
- Access to ϕ_s, Δm_s, Γ_s, $\Delta\Gamma_s$, $|\lambda_f|$...

$B_s^0 \rightarrow J/\psi[\mu\mu]KK$ at LHCb with $3\,fb^{-1}$ [PRL 114, 041801 (2015)]

- Mainly $B_s^0 \rightarrow J/\psi\phi$ (three polarization states) but also S-wave contribution
- Use angular distribution to disentangle
  CP-even $(\mathcal{A}_0, \mathcal{A}_\parallel)$ and *CP*-odd $(\mathcal{A}_S, \mathcal{A}_\perp)$ components
  $\rightarrow$ Fit to three helicity angles and decay time in six M(KK) bins
- Individual ϕ_s^i for $i = 0, \perp, \parallel, S$ (possibly different penguin polution)

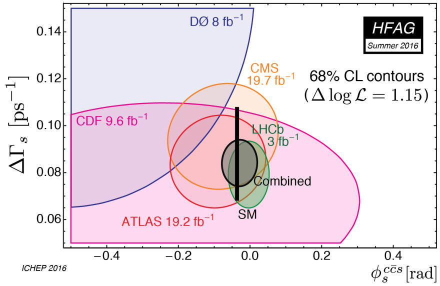


Parameter	Value
Γ_s [ps^{-1}]	$0.6603 \pm 0.0027 \pm 0.0015$
$\Delta\Gamma_s$ [ps^{-1}]	$0.0805 \pm 0.0091 \pm 0.0032$
$\lvert A_\perp \rvert^2$	$0.2504 \pm 0.0049 \pm 0.0036$
$\lvert A_0 \rvert^2$	$0.5241 \pm 0.0034 \pm 0.0067$
$\delta_\parallel$ [rad]	$3.26\ ^{+0.10}_{-0.17}\ ^{+0.06}_{-0.07}$
$\delta_\perp$ [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}]	$17.711\ ^{+0.055}_{-0.057} \pm 0.011$

ϕ_s in $b \to c\bar{c}s$ transitions

ϕ_s measured also at other experiments

Exp.	Mode	Lumi	ϕ_s [rad]	
LHCb	$J/\psi KK$	$3\,fb^{-1}$	$-0.058 \pm 0.049 \pm 0.006$	[PRL 114, 041801 (2015)]
	$J/\psi \pi\pi$	$3\,fb^{-1}$	$-0.070 \pm 0.068 \pm 0.008$	[PLB 736 (2014) 186]
	$\psi(2S)\phi$	$3\,fb^{-1}$	$+0.23^{+0.29}_{-0.28} \pm 0.02$	[PLB 762 (2016) 253]
	$D_s^+ D_s^-$	$3\,fb^{-1}$	$+0.02 \pm 0.17 \pm 0.02$	[PRL 113, 211801 (2014)]
ATLAS	$J/\psi \phi$	$19.2\,fb^{-1}$	$-0.098 \pm 0.084 \pm 0.040$	[JHEP 1608 (2016) 147]
CMS	$J/\psi \phi$	$19.7\,fb^{-1}$	$-0.075 \pm 0.097 \pm 0.031$	[PLB 757 (2016) 97]
Average	-	-	-0.033 ± 0.033	[HFAG]
Theory	-	-	-0.0376 ± 0.0008	[CKMFitter]



- LHCb dominates world average
- $B_s^0 \to J/\psi KK$ gives the lowest uncertainties
- Results consistent with SM prediction but still a lot of room for NP

ϕ_s in b $\to$ c$\bar{c}$s transitions

Ongoing measurements of ϕ_s with Run I data ($3\,\text{fb}^{-1}$)

- $B_s^0 \to J/\psi KK$ in the KK mass region above the ϕ resonance
- $B_s^0 \to J/\psi[ee]KK$

Possibility to add new modes in the future

- $B_s^0 \to J/\psi\eta[\gamma\gamma]$ [LHCb, arXiv:1607.06314]

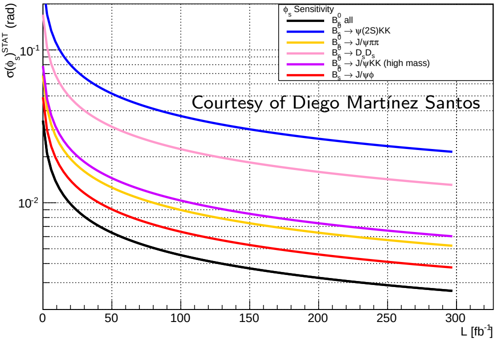
  Cons: Much less events and worse mass resolution

  Pro: $B_s^0 \to VP$, so no angular analysis needed
- $B_s^0 \to \eta_c\phi$ first observation, [LHCb-PAPER-2016-056, PRELIMINARY]

  $\mathcal{B}(B_s^0 \to \eta_c\phi) = [5.01 \pm 0.53(\text{stat}) \pm 0.27(\text{syst}) \pm 0.64(\text{norm})] \times 10^{-4}$

ϕ_s in $b \to c\bar{c}s$ transitions

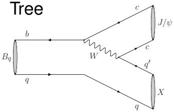
- $B_s^0 \to J/\psi KK$ currently statistics dominated, $\sigma_{syst} = 0.12\sigma_{stat}$
- Main systematics source is limited MC sample size to compute angular acceptance, can be improved easily
  $\Rightarrow$ possible to reduce total systematic uncertainty to $\sigma_{syst} = 2\,\text{mrad}$
- All projections in this talk use current results assuming
  $\to \sigma_{b\bar{b}}(14\,\text{TeV}) = 2 \times \sigma_{b\bar{b}}(7\,\text{TeV})$
  $\to$ same tagging efficiency as now



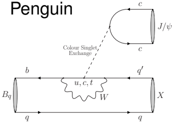
$\leftarrow$ ϕ_s combined precision to reach $< 5\,\text{mrad}$ at $300\,\text{fb}^{-1}$

ϕ_s in $b \to c\bar{c}s$ transitions

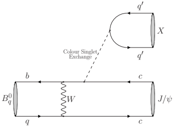
Tree



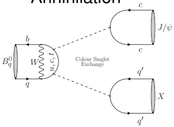
Penguin



Exchange



Penguin-Annihilation



- Measured ϕ_s in $B_s^0 \to J/\psi\phi$ contains penguin pollution!

$$\phi_s^{exp} = -2\beta_s + \Delta\phi_s^{peng} + \Delta\phi_s^{NP}$$

Crucial to control $\Delta\phi_s^{peng}$ to claim NP!

(More details on the following in S. Akar's talk on Tue, WG4)

Can be extracted using [arXiv:0810.4248]

- $B_s^0 \to J/\psi K^*$ (BF, a_{CP}) [LHCb, JHEP11(2015)082]

  No PA and E in $J/\psi K^*$, so need

  $B^0 \to J/\psi\rho$ [PLB742(2015)38-49] and

  $B^0 \to J/\psi\phi$ [PRD88,072005(2013)] and

  $B^0 \to J/\psi\omega$ (ongoing)

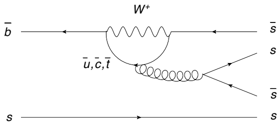
ϕ_s penguin contributions for $J/\psi\phi$ with 3 fb^{-1} ($J/\psi K^*$+$J/\psi\rho$) [JHEP11(2015)082,PLB742(2015)38-49]

$$\Delta\phi_s^0 = 0.000^{+0.011}_{-0.009}(\text{stat})^{+0.009}_{-0.004}(\text{syst})$$

$$\Delta\phi_s^{\parallel} = 0.001^{+0.010}_{-0.014}(\text{stat}) \pm 0.008(\text{syst})$$

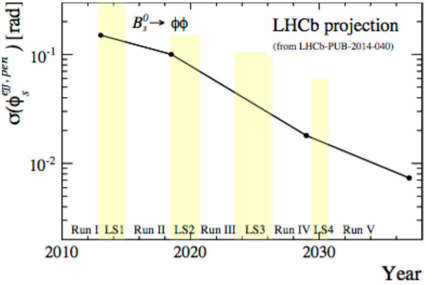
$$\Delta\phi_s^{\perp} = 0.003^{+0.010}_{-0.014}(\text{stat}) \pm 0.008(\text{syst})$$

ϕ_s in b $\to$ s$\bar{s}$s transitions



- $\phi_s^{s\bar{s}s}$ measured in loop-dominated B_s^0 decays, sensitive to NP
- SM: $|\phi_s^{s\bar{s}s}| < 0.02$ [arXiv:8010.0249], [NP B774 (2007)64], [PRD 80 (2009) 114026]

- $B_s^0 \to \phi\phi$ at LHCb with 3 fb^{-1} [PRD 90 052011 (2014)]: $\phi_s = -0.17 \pm 0.15 \pm 0.03$, consistent with SM
- Analysis started with Run 2 data, should reach precision $\mathcal{O}(0.1\,\text{rad})$ by the end of the run [LHCb-PUB-2014-040]
- Can reach precision below $\mathcal{O}(0.01\,\text{rad})$ at 300 fb^{-1}



ϕ_s in b $\to$ s$\bar{s}$s transitions

ϕ_s in other penguin modes to be studied in the future

- $B_s^0 \to K^{*0}\overline{K}^{*0}$ (see J. García's talk on Thu, WG4)
  $\to$ Update with $3\,fb^{-1}$ ongoing, $\sigma_{stat} < 0.2$ [LHCb PRELIMINARY]
  $\to$ Can reach precision of $\Delta\phi_s \approx \mathcal{O}(0.01\,\text{rad})$ at $300\,fb^{-1}$

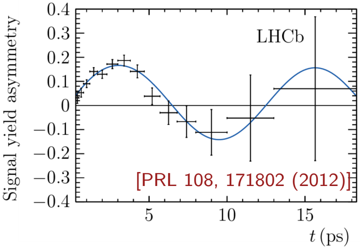
- $B_s^0 \to \phi\pi^+\pi^-$
  $\to$ First observation by LHCb [arXiv:1610.05187, PRELIMINARY]
  $\mathcal{B}(B_s^0 \to \phi\pi^+\pi^-) = [3.48 \pm 0.23(\text{stat}) \pm 0.17(\text{syst}) \pm 0.35(\phi\phi)] \times 10^{-6}$

Outline

1. Mixing-induced CPV in b $\to$ c$\bar{c}$s and b $\to$ s$\bar{s}$s transitions of B_s^0 (ϕ_s)
2. Mixing-induced CPV in b $\to$ c$\bar{c}$s and b $\to$ s$q\bar{q}$ transitions of B^0 (β)
3. CPV in the mixing and B_s^0 and B^0 mixing parameters
4. Mixing-induced CPV in b $\to$ u$\bar{u}$d transitions of B^0 (α)
5. Mixing-induced CPV in b $\to$ u$\bar{c}$s transitions of B_s^0 ($\gamma - \phi_s$)

β from b $\to$ c$\bar{c}$s transitions

- β is the most precisely measured angle of the unitarity triangle
- Current average: $\beta = (22.6 \pm 0.4)^\circ$ [CKMfitter]

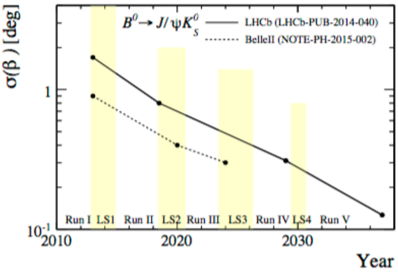


- Access through mixing-induced CPV parameter $\mathcal{S}_{CP} = \sin 2\beta$ in B^0 decays via b $\to$ c$\bar{c}$s
- Golden channel is $B \to J/\psi K^0_S$; measured with $3\,\text{fb}^{-1}$ [PRL 115 031601 (2015)]

- LHCb precision in $B \to J/\psi K^0_S$ getting close to B factories

Experiment	Lumi	$\sin 2\beta$	
BaBar	$0.4\,\text{ab}^{-1}$	$0.687 \pm 0.028(\text{stat}) \pm 0.012(\text{syst})$	[PRD 79 072009 (2009)]
Belle	$0.7\,\text{ab}^{-1}$	$0.667 \pm 0.023(\text{stat}) \pm 0.012(\text{syst})$	[PRL 108 171802 (2012)]
LHCb	$3\,\text{fb}^{-1}$	$0.731 \pm 0.035(\text{stat}) \pm 0.020(\text{syst})$	[PRL 115 031601 (2015)]
SM (no peng.)		$0.748^{+0.030}_{-0.032}$	[CKMfitter]
Average		0.710 ± 0.011	[CKMfitter]

β from b → c$\bar{c}$s transitions

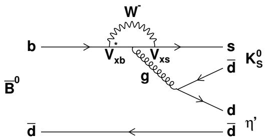


- $B^0 \to J/\psi K^0_S$ currently statistics dominated, $\sigma_{syst} \approx 0.6\sigma_{stat}$
- $\sin 2\beta$ to reach precision of $\mathcal{O}(0.01)$ at 300 fb^{-1}
  → penguin pollution of the same order, needs control
  (see U. Nierste's talk, Tue WG4)

- Can use $B^0_s \to J/\psi K^0_S$ (U-spin related channel) [JHEP06(2015)131]
  → $\mathcal{S}(B^0_s \to J/\psi K^0_S) = -0.08 \pm 0.40(\text{stat}) \pm 0.08(\text{syst})$ with 3 fb^{-1}

- Or $B^0 \to J/\psi \pi^0$ (ongoing at LHCb, Belle II to provide crosscheck)
  However, contains EW penguin and penguin annihilation
  (none in $B_{(s)} \to J/\psi K^0_S$)
  To understand completely, would need $B^0_s \to J/\psi \pi^0$

β from b $\to$ $sq\bar{q}$ transitions



- β accessible also in b $\to$ $sq\bar{q}$ transitions, sensitive to NP
- Due to tree pollution (CKM suppressed) measure β^{eff}

- Future data will allow time-dependent analysis of $\mathrm{B}^0 \to \mathrm{K}^0_\mathrm{S} hh'$ ($h = \mathrm{K}, \pi$)

  $\to$ Can extract $\sin 2\beta^{eff}$ in two-body approximation or study Dalitz plot and extract β^{eff} directly

- e.g. $\mathrm{B}^0 \to \phi \mathrm{K}^0$, where $\Delta S = \sin 2\beta^{eff} - \sin 2\beta^{c\bar{c}s} = 0.022^{+0.004}_{-0.002}$ (precise prediction) [QCDf, PRD 80 114008 (2009)]

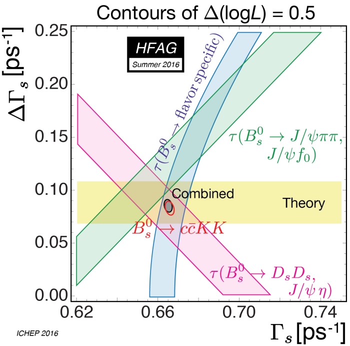
  $\to$ Expected to reach $\sigma(\Delta S) = 0.06(0.02)$ at 50(300)fb^{-1} [LHCb-PUB-2014-040]

Outline

Γ_s and $\Delta\Gamma_s$

- Precise knowledge of mixing parameters important for
  - $\to$ time-dependent analysis (systematics)
  - $\to$ search and constraint of NP

(More details in G. Cowan's talk on Tue, WG4)



- Already $\sigma_{exp} < \sigma_{theo}$,in agreement [arXiv:1511.09466]

$$\Delta\Gamma_s^{exp} = 0.0827 \pm 0.006\,\text{ps}^{-1}$$
$$\Gamma_s^{exp} = 0.6643 \pm 0.0020\,\text{ps}^{-1}$$

- Precision dominated by $B_s^0 \to J/\psi K^+K^-$ [PRL 114, 041801 (2015)]

$$\Delta\Gamma_s = [0.0805 \pm 0.0091 \pm 0.0032]\text{ps}^{-1}$$
$$\Gamma_s = [0.6603 \pm 0.0027 \pm 0.0015]\text{ps}^{-1}$$

$\to$ Currently $\sigma_{stat} > \sigma_{syst}$ for both Γ_s and $\Delta\Gamma_s$ but expected to be systematics dominated in the future (track reconstruction)

Γ_d and $\Delta\Gamma_d$

(More details in S. Vecchi's talk on Wed, WG 4)

- $\Delta\Gamma_d/\Gamma_d$ much smaller in B^0 system, access through effective lifetime

$$\tau^{eff}_{B_q\to f} = \frac{1}{\Gamma_q}\frac{1}{1-y_d^2}\left[\frac{1+2A^f_{\Delta\Gamma}y_d + y_d^2}{1+A^f_{\Delta\Gamma}}\right],$$

where $y_q = \Delta\Gamma_q/(2\Gamma_q)$ and $A^f_{\Delta\Gamma}$ depends on the final state, e.g. $A^f_{\Delta\Gamma} = 0$ for flavour-specific decays

- Measure in various decays, e.g. $B^0 \to J/\psi K^0_S$ and $B^0 \to J/\psi K^*$

LHCb analysis with $1\,\text{fb}^{-1}$ [JHEP 04 (2014) 114]:

$$\Gamma_d = 0.656 \pm 0.003 \pm 0.002\,\text{ps}^{-1}$$
$$\Delta\Gamma_d = -0.029 \pm 0.016 \pm 0.007\,\text{ps}^{-1}$$

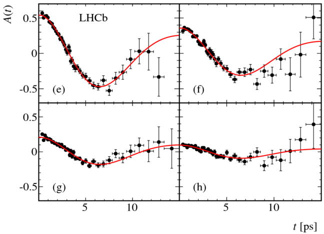
	$\Delta\Gamma_d/\Gamma_d$ $[\times 10^{-2}]$	
LHCb	$-4.4 \pm 2.5 \pm 1.1$	[JHEP04(2014)114]
ATLAS	$-0.1 \pm 1.1 \pm 0.9$	[JHEP06(2016)081]
World average	-0.2 ± 1.0	[HFAG]
SM	0.397 ± 0.090	[arXiv:1511.09466]

- Reduce σ_{stat} by an order of magnitude for $\Delta\Gamma_d$ and Γ_d at $300\,\text{fb}^{-1}$
- Some main systematic uncertainties reducible (e.g. MC sample size)

Δm_d and Δm_s

Experimental results on Δm_d and Δm_s already much more precise than theory

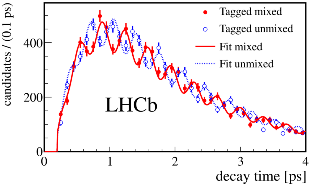
Δm_d world's best result, LHCb with $3\,\mathrm{fb}^{-1}$ in $B^0 \to D^{(*)-}\mu^+\nu_\mu$ [EPJ C (2016) 76]



	Δm_d [ns^{-1}]	
LHCb	$505.5 \pm 2.1 \pm 1.0$	[EPJ C (2016) 76]
Average	506.4 ± 1.9	[HFAG]
SM	528 ± 78	[arXiv:1511.09466]

- Systematics due to background BF, fit, k-factor $\Rightarrow$ only slight improvement in the future

Δm_s world's best result, LHCb with $1\,\mathrm{fb}^{-1}$ in $B^0_s \to D^-_s\pi^+$ [NJP15(2013)053021]



	Δm_s [ps^{-1}]	
LHCb	$17.768 \pm 0.023 \pm 0.006$	[NJP15(2013)053021]
Average	17.757 ± 0.021	[HFAG]
SM	18.3 ± 2.7	[arXiv:1511.09466]

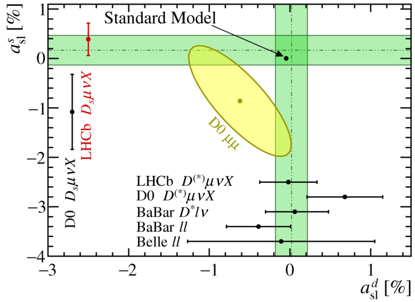
- Systematics dominant in the future; mainly due to limited knowledge of $\tau(B^0_s)$, should improve

CP violation in the mixing: a_{sl}

CPV in the mixing can be accessed in $B_{(s)} \to D^{\pm}{}_{(s)}\mu^{\mp}\nu X$ decays through

$$a_{sl}^{q} = \frac{\Gamma(B \to f) - \Gamma(\overline{B} \to \bar{f})}{\Gamma(B \to f) + \Gamma(\overline{B} \to \bar{f})} \simeq \frac{\Delta M}{\Delta \Gamma} \tan\phi_{12}, \quad \phi_{12} \equiv \arg\left(-\frac{M_{12}}{\Gamma_{12}}\right)$$

	a_{sl}^{d}	a_{sl}^{s}	
LHCb 3 fb^{-1}	$(-2 \pm 19 \pm 30) \times 10^{-4}$	$(3.9 \pm 2.6 \pm 2.0) \times 10^{-3}$	[PRL 114 041601 (2015)]
(world's best)			[PRL 117 061803 (2016)]
SM	$(-4.7 \pm 0.6) \times 10^{-4}$	$(2.22 \pm 0.27) \times 10^{-5}$	[arXiv:1511.09466]



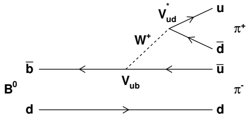
- Latest results consistent with SM
- Main systematics: detection asymmetry (statistics of the calibration samples)

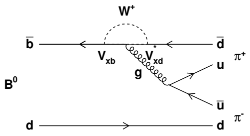
  $\to$ Reducible with more data
- $\sigma_{tot} = 2 - 3 \times 10^{-4}$ at 300 fb^{-1} [LHCb-PUB-2014-040]

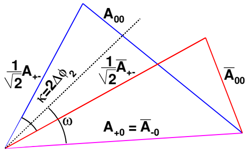
Outline

1. Mixing-induced CPV in b $\to$ c$\bar{c}$s and b $\to$ s$\bar{s}$s transitions of B_s^0 (ϕ_s)
2. Mixing-induced CPV in b $\to$ c$\bar{c}$s and b $\to$ $sq\bar{q}$ transitions of B^0 (β)
3. CPV in the mixing and B_s^0 and B^0 mixing parameters
4. Mixing-induced CPV in b $\to$ u$\bar{u}$d transitions of B^0 (α)
5. Mixing-induced CPV in b $\to$ u$\bar{c}$s transitions of B_s^0 ($\gamma - \phi_s$)

α from b $\to u\bar{u}d$







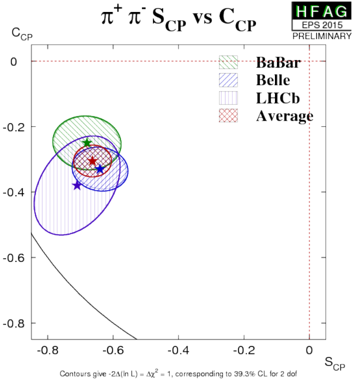
- $\pi - \beta - \gamma$ (corresponds to α assuming a closing unitarity triangle) accessed in B decays via b $\to u\bar{u}d$ (tree), e.g. B $\to \pi\pi$
- Penguin pollution removed in an SU(2) isospin analysis [PRL 65 3381 (1990)]: $\mathcal{B}(\pi^+\pi^-)$, $\mathcal{C}_{CP}(\pi^+\pi^-)$, $\mathcal{S}_{CP}(\pi^+\pi^-)$, $\mathcal{B}(\pi^+\pi^0)$, $\mathcal{B}(\pi^0\pi^0)$, $\mathcal{C}_{CP}(\pi^0\pi^0)$

α from b $\to u\bar{u}d$

- LHCb 3 fb^{-1}
  [PRELIMINARY, LHCb-CONF-2016-018]
  (see S. Perazzini's talk, Thu WG4)

$$\mathcal{C}_{CP}(\pi^+\pi^-) = ??.?? \pm 0.07 \pm 0.01$$
$$\mathcal{S}_{CP}(\pi^+\pi^-) = ??.?? \pm 0.06 \pm 0.01$$

- $\sigma_{stat} < 0.01$ for $\mathcal{C}_{CP}(\pi^+\pi^-)$ and $\mathcal{S}_{CP}(\pi^+\pi^-)$ at 300 fb^{-1}



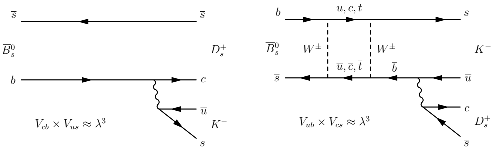
- Analogous procedure for B $\to \rho\rho$, using longitudinal amplitude
  $\to$ Need to extract f_L
- BF and f_L already measured by LHCb with 3 fb^{-1} [PLB 747 468-478 (2015)], to add time-dependent parameters with more data

Outline

1. Mixing-induced CPV in b $\to$ c$\bar{c}$s and b $\to$ s$\bar{s}$s transitions of B_s^0 (ϕ_s)
2. Mixing-induced CPV in b $\to$ c$\bar{c}$s and b $\to$ $sq\bar{q}$ transitions of B^0 (β)
3. CPV in the mixing and B_s^0 and B^0 mixing parameters
4. Mixing-induced CPV in b $\to$ u$\bar{u}$d transitions of B^0 (α)
5. **Mixing-induced CPV in b $\to$ u$\bar{c}$s transitions of B_s^0 ($\gamma - \phi_s$)**

$\gamma - \phi_s$ from b $\to cs\bar{u}$ in $B_s^0 \to D_s^{\mp}K^{\pm}$

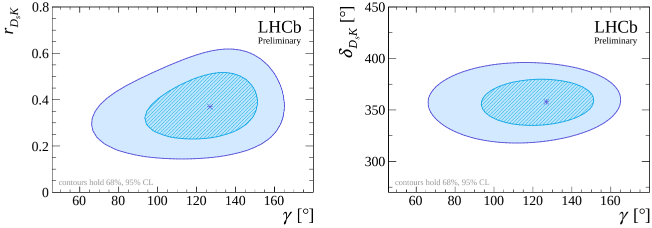
(Details in A. Dziurda's talk on Thu, WG5)



- $B_s^0 \to D_s^{\mp}K^{\pm}$ proceeds through two transitions of similar size

$$\mathcal{S}_{f/\bar{f}} \propto \sin(\delta \mp (\gamma - \phi_s))$$
$$\mathcal{A}^{\Delta\Gamma}_{f/\bar{f}} \propto \cos(\delta \mp (\gamma - \phi_s))$$

- Measurement with $3\,\mathrm{fb}^{-1}$ $\gamma = (???^{+17}_{-22})^\circ$ [PRELIMINARY, LHCb-CONF-2016-015]



- Can reach precision of $\sigma(\gamma) < 2^\circ$ with $300\,\mathrm{fb}^{-1}$

Conclusion

ϕ_s

- Highly sensitive to NP, precisely predicted by the SM, $\sigma(\phi_s) = 0.8\,\text{mrad}$
- Adding new modes to increase precision, $\sigma(\phi_s) < 5\,\text{mrad}$ at $300\,\text{fb}^{-1}$
- Penguin pollution starts to get relevant, already have a roadmap for it
- ϕ_s in $b \to s\bar{s}s$: $\sigma_{exp} \approx \sigma_{theo}$ at $50\,\text{fb}^{-1}$

$\sin 2\beta$

- Precision already close to B factories, need to control penguins
- Getting close to theory limit

$B - \overline{B}$ mixing

- $\Delta\Gamma_s$, Δm_s, Δm_d: $\sigma_{exp} \ll \sigma_{theo}$, still interesting to increase precision
- $\Delta\Gamma_d$: Future measurements to improve result significantly
- $a_{sl}^{s,d}$: Keep improving precision

α

- $B^0 \to \pi^+\pi^-$ studied with $3\,\text{fb}^{-1}$; to add more modes

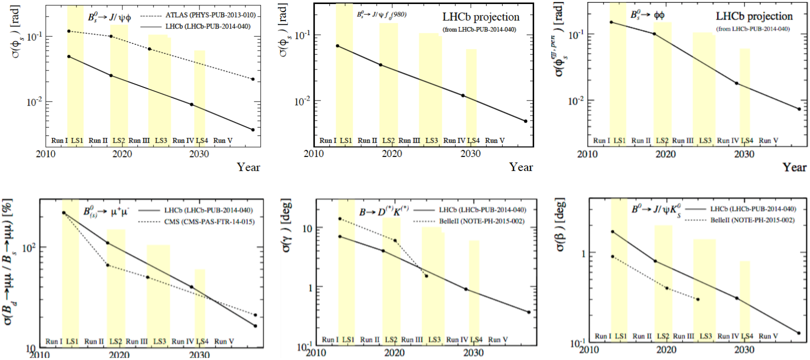
γ

- Can reach precision of $\sigma(\gamma) < 2^\circ$ with $300\,\text{fb}^{-1}$ in $B_s^0 \to D_s^{\mp}K^{\pm}$

Thank you for your attention!

BACKUP

Projections on some key observables



Assuming Run 5 upgrade luminosity of $2 \times 10^{34}\text{cm}^{-1}\,\text{s}^{-1}$