OVERVIEW OF LHCb RESULTS

LHC Days in SPLIT
September 22, 2016

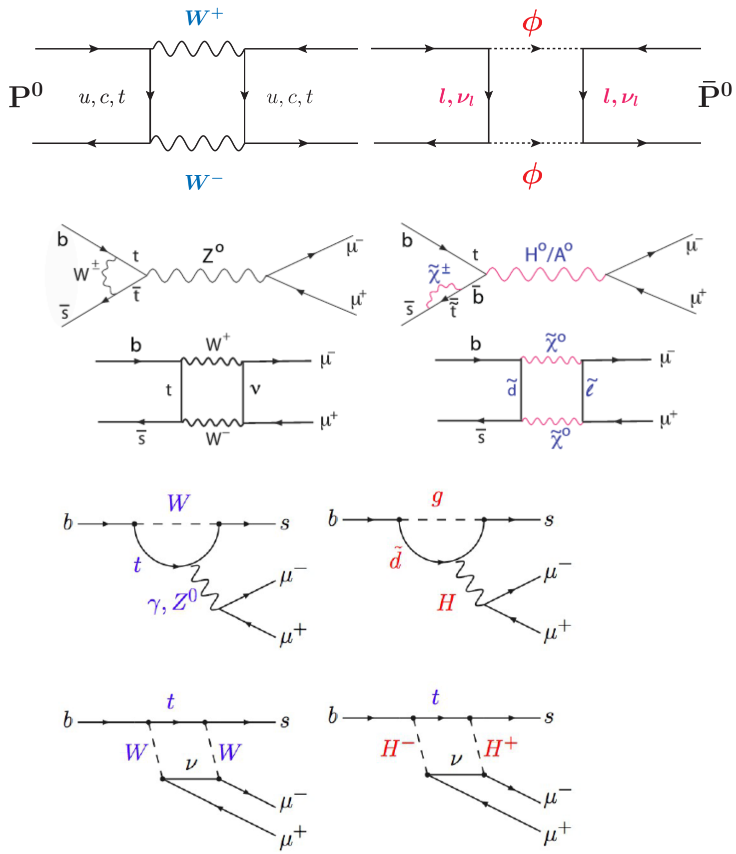
Bernardo Adeva, on behalf of the LHCb collaboration

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

WHY FLAVOUR PHYSICS

- The search for New Physics particles is not restricted to their mass-shell formation. Their effects can be seen in the vacuum, through quantum fluctuations
- A general SM amplitude will receive extra terms from new couplings (c_{NP}) and scales (Λ^2):

$$A = A_0 \left(c_{SM} \frac{1}{M_W^2} + c_{NP} \frac{1}{\Lambda^2} \right)$$



- When the SM contribution is large, NP effects may be hidden (→ rare processes)
- Need precision measurements on theoretically clean observables (→ CP-violation vis-à-vis CKM matrix as testing ground)
- Given the present picture of the flavour sector, there is still room for NP at 10-20% level

Need to identify new broken symmetries, and probe new mass scales through INDIRECT searches, beyond present-day accelerator energies

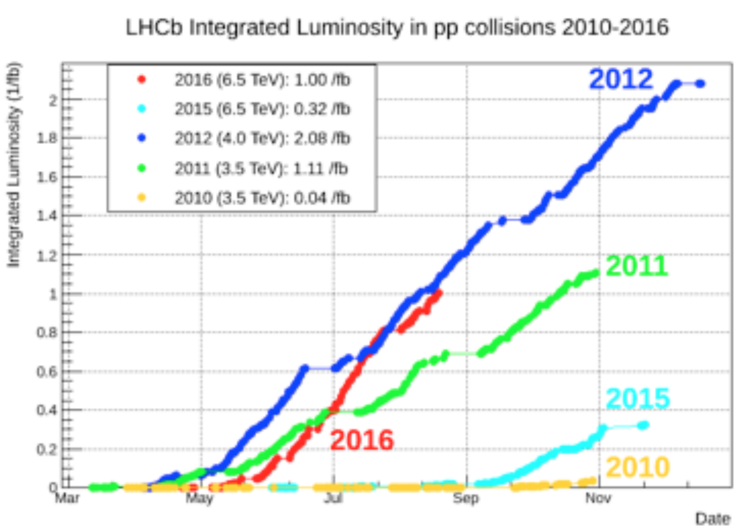
FLAVOUR PHYSICS AROUND THE WORLD

- Flavour physics has involved, over the last 15 years, different experiments at main accelerators:

Experiment	$\int \mathcal{L}dt\,[fb^{-1}]$	$\sigma_{beauty}[\mu b]$	End of life
BaBar	530 (total)	0.001 $[e^+e^- \text{at}\,\Upsilon(4s)]$	2008
Belle	1040 (total)	0.001 $[e^+e^- \text{at}\,\Upsilon(4s)]$	2010
CDF/D0	12 (total)	100 $[p\bar{p}\text{ at }2\,\text{TeV}]$	2011
ATLAS/CMS	55 (so far)	250-500 $[pp\text{ at }7-13\,\text{TeV}]$	> 2030
LHCb	4.2 (so far)	250-500 $[pp\text{ at }7-13\,\text{TeV}]$	> 2030

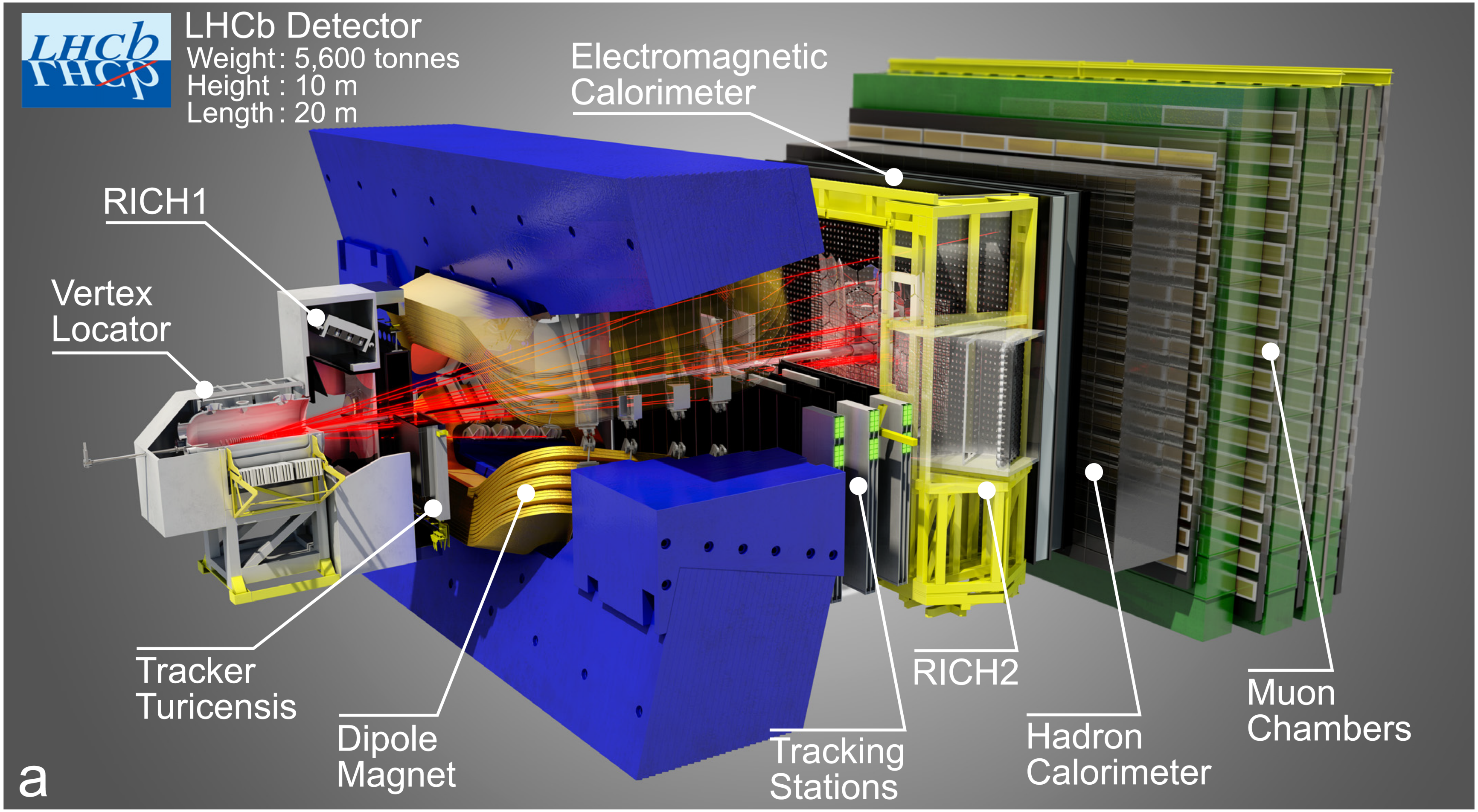
courtesy of V. Vagnoni
ICHEP 2016

- LHCb is a forward detector at the LHC, designed for beauty and charm physics, with levelled luminosity to limit pileup effects



Very deep forward VERTEX DETECTOR. EXCELLENT MASS resolution and K/π SEPARATION are achieved by a large conventional dipole and two RICH detectors. It provides very efficient μ TRIGGER AT LOW P_T

THE LHCb APPARATUS



proper time : $\Delta\tau \simeq 45 fs$ impact parameter : $\sigma_{IP} \simeq 35\,\mu m$ $\Delta p/p \simeq (5-7)\times 10^{-3}$

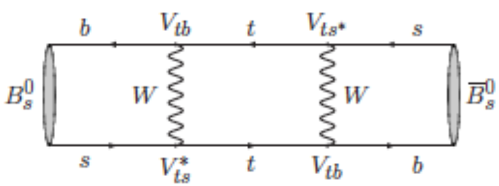
The LHCb detector at the LHC, JINST 3 (2008) S08005

β_s PHASE: A MILESTONE IN KM THEORY

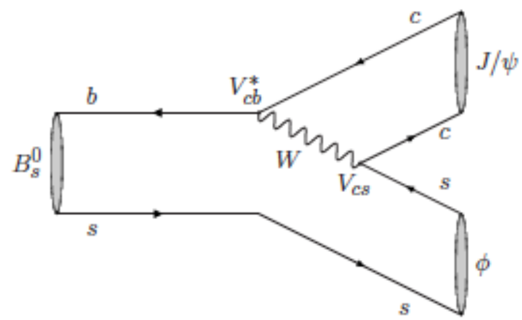
- An important test of the Kobayashi-Maskawa theory is assessing the UT with a very small side:

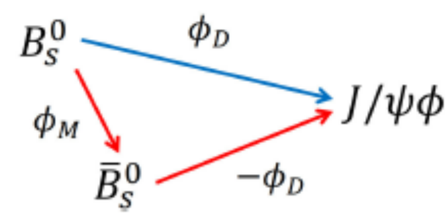
$$\beta_s \equiv \arg\left(\frac{V_{cb}V_{cs}^*}{V_{tb}V_{ts}^*}\right) \qquad \overset{\lambda\cdot\lambda^3}{V_{us}V_{ub}^*} + \overset{1\cdot\lambda^2}{V_{cs}V_{cb}^*} + \overset{\lambda^2\cdot 1}{V_{ts}V_{tb}^*} = 0$$

- Measured through interference between the B_s mixing and the $b \to c\bar{c}s$ decay tree below. New Physics still possible in the mixing.



Mixing: $\phi_M = 2\arg(V_{tb}V_{ts}^*)$

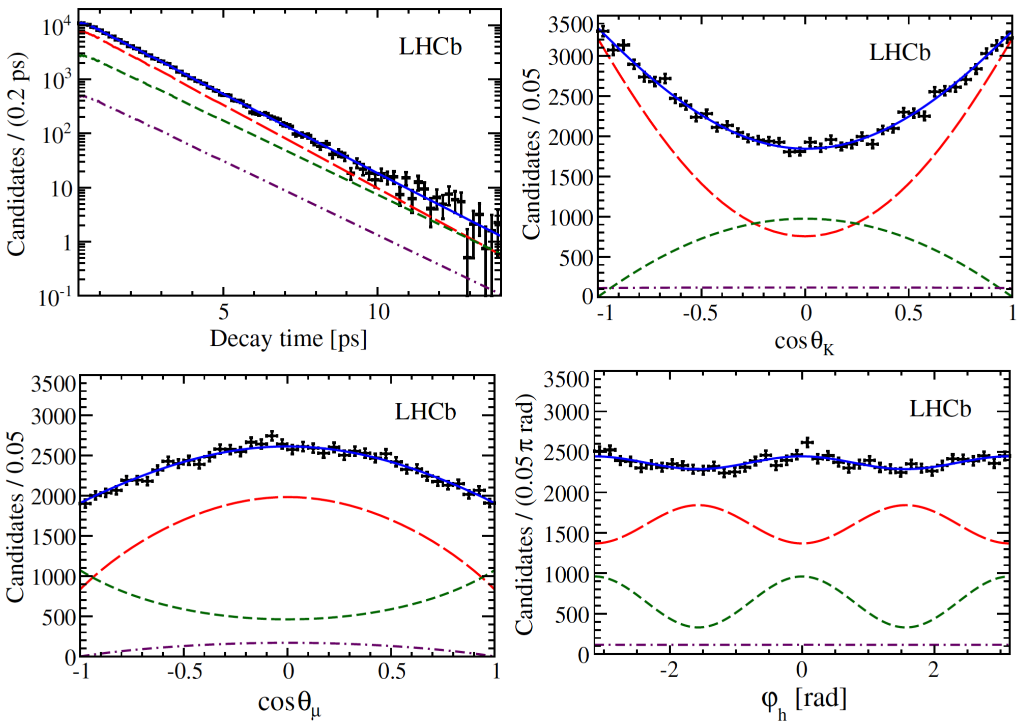


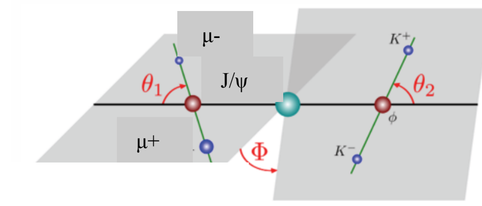


- $B_s^0 \to J/\psi\phi(K^+K^-)$ is considered as golden channel, with the SM prediction: $\phi_s^{c\bar{c}s} = -37.4 \pm 0.7\,\mathrm{mrad}$ $\quad \phi_s^{c\bar{c}s} \simeq -2\beta_s \;\; \mathcal{O}(\lambda^4)$
- The lifetime difference between B^0_s mass eigenstates is also predicted by the SM: $\Delta\Gamma_s = 88 \pm 20\ \mathrm{ns}^{-1}$ A. Lenz, U. Nierste JHEP 06 (2007) 072.

β_s measurement by LHCb

LHCb collaboration, R. Aaij et al. PRL 114 (2015) 041801





$$\phi_s = -0.058 \pm 0.049 \pm 0.006 \text{ rad}$$

$$\Delta m_s = 17.711\, ^{+0.055}_{-0.057} \pm 0.011 \text{ ps}^{-1}$$

$$\Gamma_s = 0.6603 \pm 0.0027 \pm 0.0015 \text{ ps}^{-1}$$

$$\Delta\Gamma_s = 0.0805 \pm 0.0091 \pm 0.0032 \text{ ps}^{-1}$$

$$|\lambda| = 0.964 \pm 0.019 \pm 0.007$$

CP – even
CP – odd
S – wave($K\pi$)

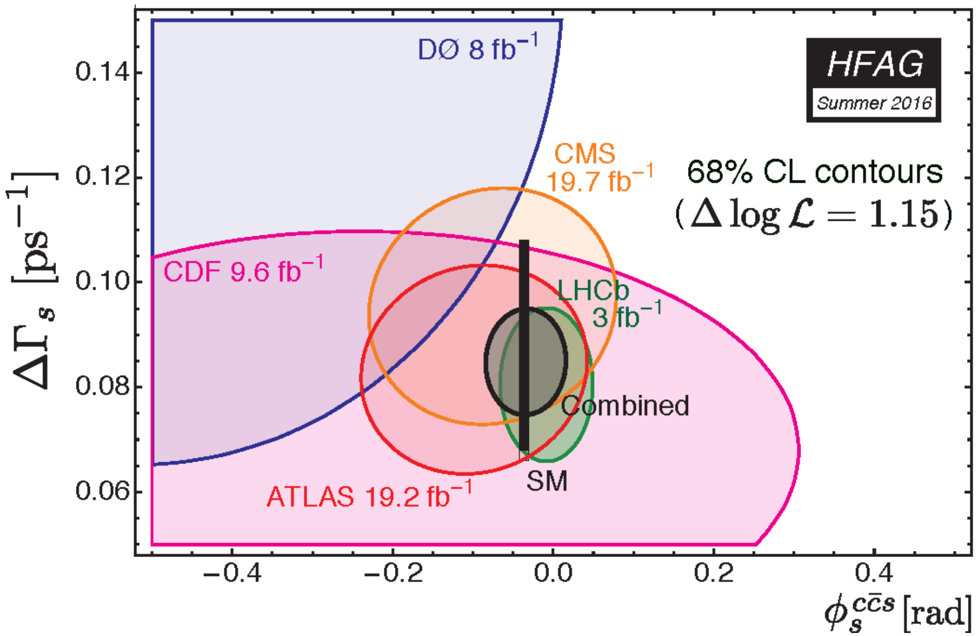
- Fit to decay time and helicity angles, result *consistent with SM* (no direct CPV $|\lambda|=1$)
- Most precise $\phi_s^{c\bar{c}s}$ to date. Additional measurement from $B_s^0 \to J/\psi \pi^+\pi^-$ gives: $\phi_s^{c\bar{c}s} = 50 \pm 69 \pm 8$ mrad , combination: $\phi_s^{c\bar{c}s} = -10 \pm 39$ mrad

ϕ_s FROM $B^0_s \rightarrow J/\psi\ \Phi(K^+K^-)$

- Several measurements at the Tevatron and the LHC. World averages:

$$-\phi_s^{c\bar{c}s} = -30 \pm 33\,\mathrm{mrad}$$

$$\Delta\Gamma_s = 83 \pm 6\ \mathrm{ns}^{-1}$$



Compatible with the SM at the current level of precision. Further improvement will require assessment of higher order corrections from penguins

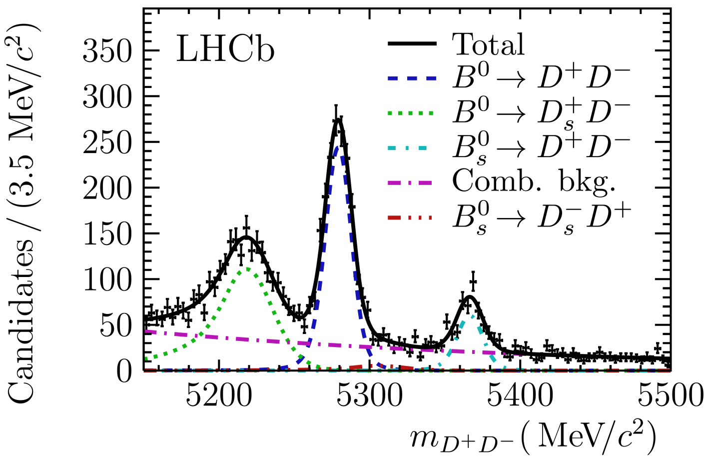
latest LHCb result on $B^0_s \rightarrow J/\psi\ (2s)\phi$: LHCb-PAPER-2016-027 in preparation

$\sin(2\beta)$ $B^0 \rightarrow D^+D^-$ AND PENGUINS

R. Aaij et al. arXiv:1608.06620 (2016), submitted to PRL

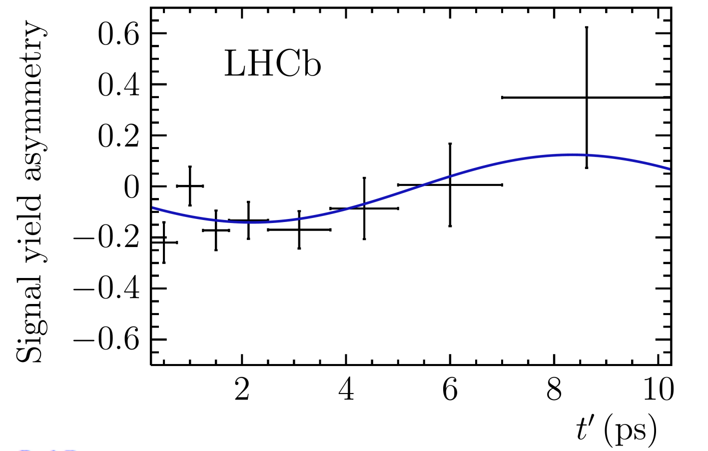
- $\sin(2\beta)$ can also be measured from the time analysis of $B^0 \rightarrow D^+D^-$ (CP = +1):

$$\frac{d\Gamma(t,\pm)}{dt} = e^{-t/\tau}\Big(1 \mp S\sin(\Delta m t) \pm C\cos(\Delta m t)\Big)$$



- (S, C) are sensitive to an additional decay amplitude beyond the tree-level:

$$S/\sqrt{1-C^2} = -\sin(2\beta + \Delta\phi)$$



- Belle and BaBar measurements show room for large $\Delta\phi$: M. Rohrken et al. Phys. Rev D85 (2012) 091106

$$S = 0.98 \pm 0.17 \quad C = -0.31 \pm 0.14$$

However LHCb results are compatible with $C=0$ and $B^0 \to D^+D^-$ being tree-level dominated:

$$S = -0.54\,^{+0.17}_{-0.16}\,(\text{stat}) \pm 0.05\,(\text{syst}) \quad C = 0.26\,^{+0.18}_{-0.17}\,(\text{stat}) \pm 0.02\,(\text{syst})$$

CP VIOLATION IN B^0 / B^0_s MIXING

- CP violation in the mixing matrix : $\mathcal{P}\left(B_q \to \bar{B}_q\right) \neq \mathcal{P}\left(\bar{B}_q \to B_q\right)$ $q = d, s$ is very small in the SM :

$a^s_{sl} = (2.22 \pm 0.27) \times 10^{-5}$ $\quad a^d_{sl} = (-4.7 \pm 0.6) \times 10^{-4}$ Artuso, Borisov, Lenz arXiv: 1511.09466

- A non-zero a_{sl} was reported in 2010 by D0 experiment from the asymmetry of like-sign dimuons, difficult to reproduce at the LHC ($pp/p\bar{p}$ collisions).

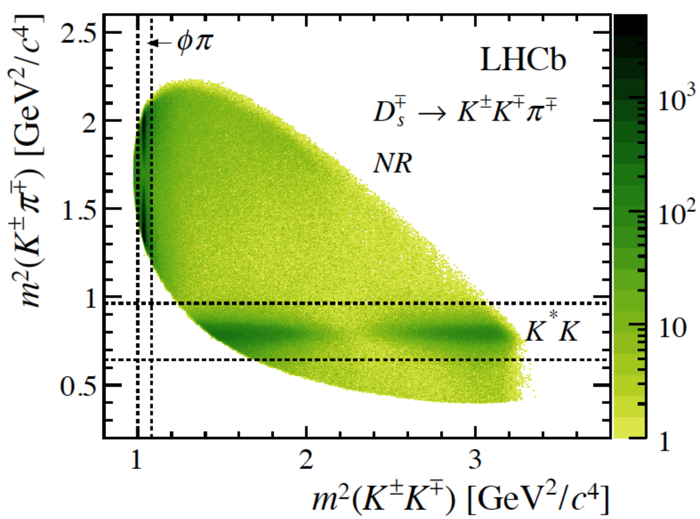
D0 collaboration, V. M. Abazov et al., PRD 89 (2014) 012002

- LHCb has separated the components related to B^0_s (q=s) and B^0 (q=d) mesons, using *semileptonic* decays in the modes:

$$B^0_s \to D^-_s \mu^+ \nu_\mu X \quad D^-_s \to K^+ K^- \pi^-$$
$$B^0 \to D^- \mu^+ \nu_\mu X \quad D^- \to K^+ \pi^- \pi^-$$
$$B^0 \to D^{*-} \mu^+ \nu_\mu X \quad D^{*-} \to \bar{D}^0(K^+\pi^-)\pi^-$$

LHCb collaboration, PRL 114 (2015) 041601

LHCb collaboration, PRL 117 (2016) 061803



- The high oscillation frequency Δm_s reduces the effect of production asymmetry by factor 10^{-3}.

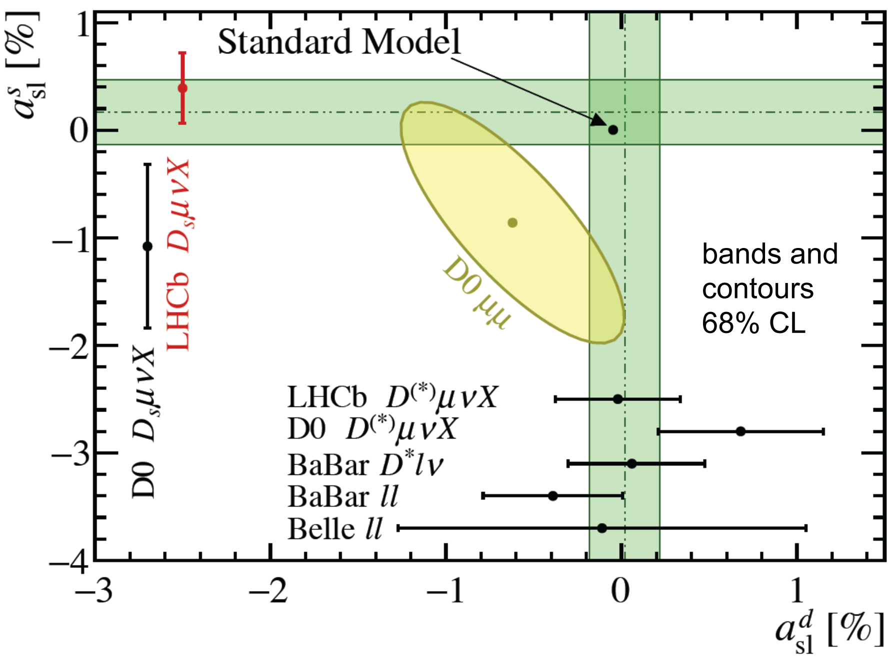
SUMMARY CPV IN B^0 / B^0_s MIXING

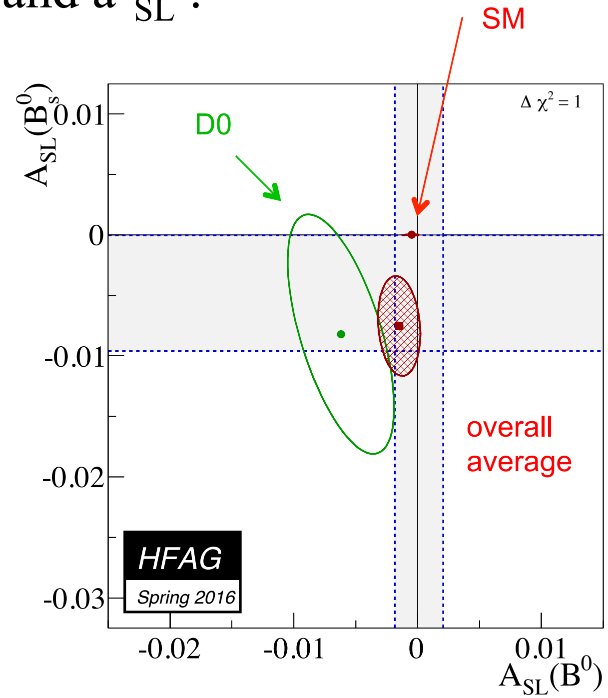
- Final LHCb values are the most precise to date, compatible with other measurements:

a^s_{SL} = (0.39 ± 0.26 (stat) ± 0.20 (syst)) % LHCb collaboration, PRL 117 061803 (2016)

a^d_{SL} = (-0.02 ± 0.19 (stat) ± 0.30 (syst))% LHCb collaboration, PRL 114 041601 (2015)

- Summary of existing measurements of a^s_{SL} and a^d_{SL} :



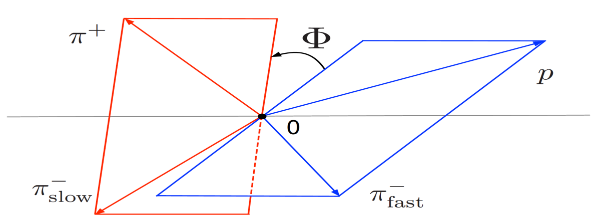


D0 μμ included in average

LHCb precise measurements of the semileptonic asymmetries do not confirm the anomaly

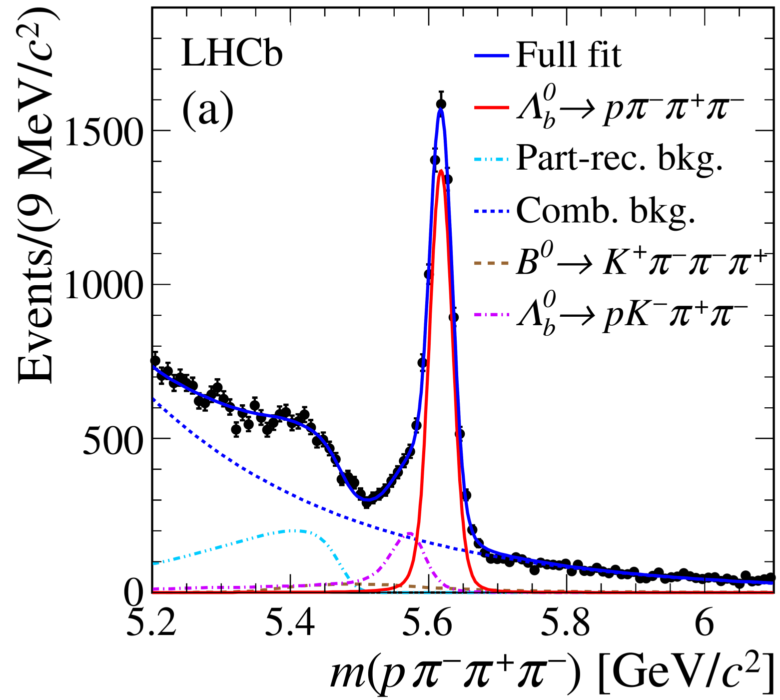
CPV BARYON DECAYS: $\Lambda_b \to p\pi^-\pi^+\pi^-$

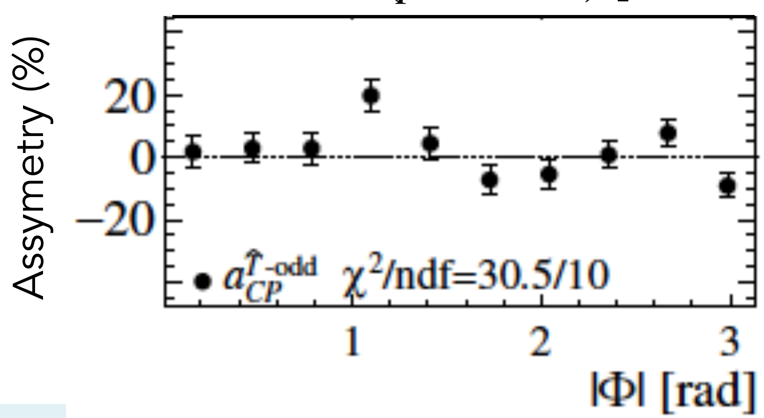
- CP violation has never been observed in the decays of any baryon
- Triple products $C = \vec{p}_p \cdot \left(\vec{p}_{h_1^-} \times \vec{p}_{h_2^+}\right)$ have been searched for in $\Lambda_b \to p\pi^- h_1^+ h_2^-$ final states
- CP violation was studied *locally* in the four-body phase-space, in particular as function of the azimuth Φ (angle between the pπ and ππ decay planes)



- Evidence for CPV is 3.3σ (stat. and syst.)
- This is the first evidence for CP- and T-non-invariance in the baryon sector

LHCb-PAPER-2016-030 in preparation



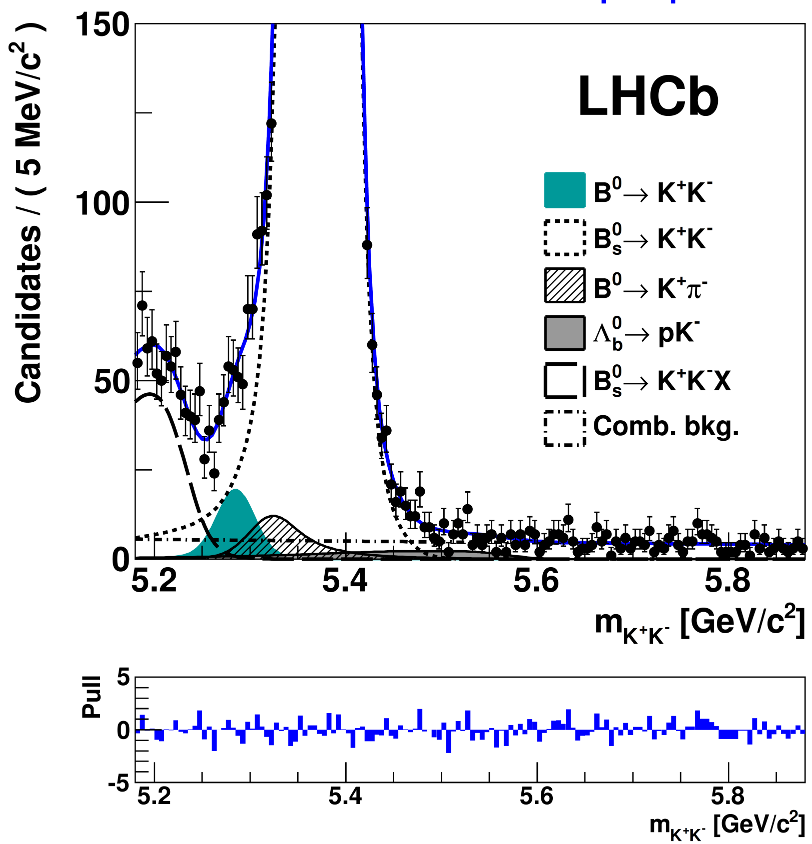


EVIDENCE FOR $B^0 \rightarrow K^+K^-$

- $B^0 \rightarrow K^+K^-$ signal had escaped detection so far, despite endeavours by BaBar, CDF, Belle and LHCb
- Decay proceeds through penguin and W-exchange. A challenging hadron decay, that improves our understanding of QCD.
- The significance is 5.8σ, including systematic uncertainty. The rarest B-meson decay into a fully hadronic final state ever observed.
- Reasonable agreement (factor 2) with pQCD within uncertainties.

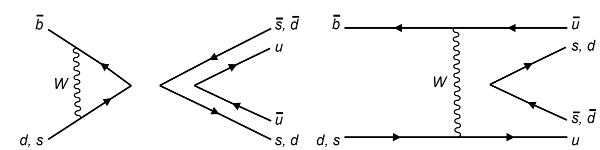
Z. Xiao, W. Fang, and Y. Fan PR D85 (2012) 094003

LHCb-PAPER-2016-036 in preparation



$$\mathcal{B}(B^0 \rightarrow K^+K^-) = (7.80 \pm 1.27 \pm 0.81 \pm 0.21(K\pi)) \times 10^{-8}$$

$$\mathcal{B}(B^0_s \rightarrow \pi^+\pi^-) = (6.91 \pm 0.54 \pm 0.63 \pm 0.19(K\pi) \pm 0.40(f_s/f_d)) \times 10^{-8}$$



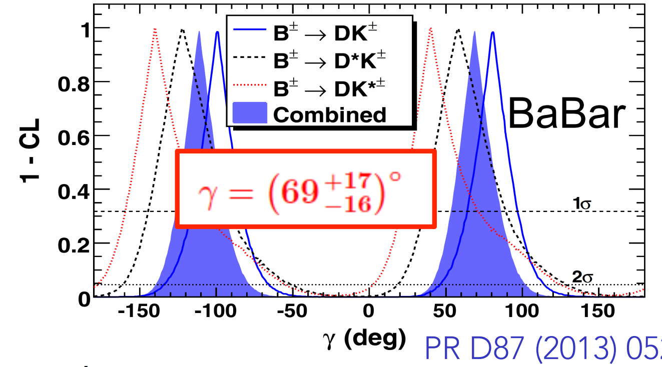
Constraints on recent suggestion of light Z' contribution can be derived Y. Li et al. Eur. Phys. J. C75 (2015)

TREE-LEVEL γ STATUS

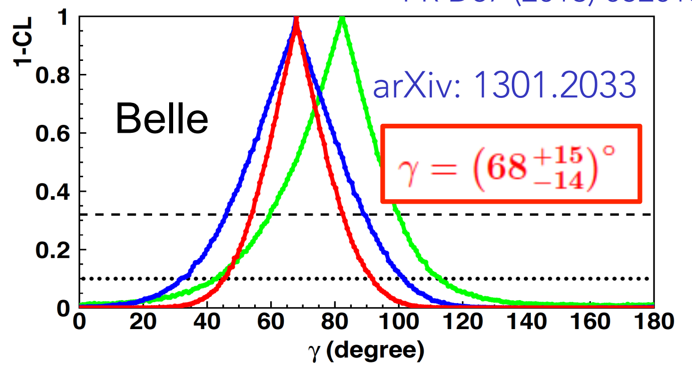
- The only phase of CKM matrix that can be determined at tree-level in the SM, it provides essential model-building constraints for any new physics contribution $\gamma \equiv \arg\left(-V_{ud}V_{ub}^{*}/V_{cd}V_{cb}^{*}\right)$
- LHCb has accumulated all Run-1 information from interference between favoured $b \to cW\,(V_{cb})$ and suppressed $b \to uW\,(V_{ub})$ amplitudes in B→ DK-like decays:

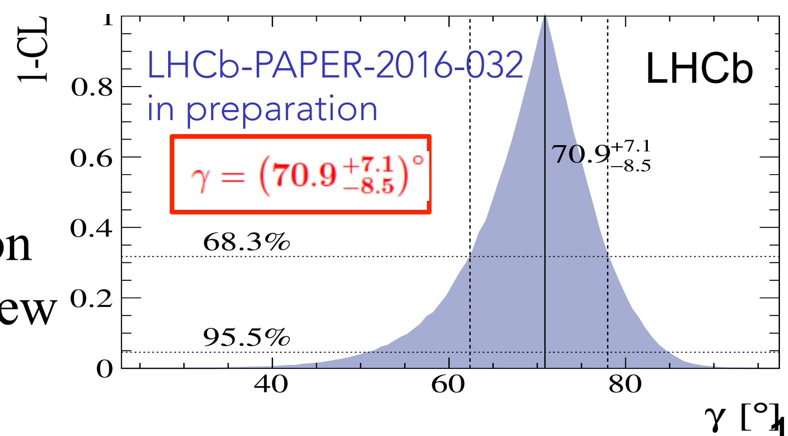
B decay	D decay	Method
$B^+ \to Dh^+$	$D \to h^+h^-$	GLW/ADS
$B^+ \to Dh^+$	$D \to h^+\pi^-\pi^+\pi^-$	GLW/ADS
$B^+ \to Dh^+$	$D \to h^+h^-\pi^0$	GLW/ADS
$B^+ \to DK^+$	$D \to K^0_S h^+h^-$	GGSZ
$B^+ \to DK^+$	$D \to K^0_S K^+\pi^-$	GLS
$B^+ \to Dh^+\pi^-\pi^+$	$D \to h^+h^-$	GLW/ADS
$B^0 \to DK^{*0}$	$D \to K^+\pi^-$	ADS
$B^0 \to DK^+\pi^-$	$D \to h^+h^-$	GLW-Dalitz
$B^0 \to DK^{*0}$	$D \to K^0_S\pi^+\pi^-$	GGSZ
$B^0_s \to D^{\mp}_s K^{\pm}$	$D^+_s \to h^+h^-\pi^+$	TD

- Results consistent (≈ 1σ high) with expectation from CMFV for sin 2β = 0.691 ± 0.017 and new lattice results on hadronic amplitudes UUT: Blanke-Buras arXiv: 1602.04020



PR D87 (2013) 052015





CP VIOLATION IN CHARM

The time evolution of the CP asymmetry under the *slow* D^0-$\bar{D}^0$ mixing:

$$A_{CP}(t) = \frac{\Gamma\left(D^0(t) \to f\right) - \Gamma\left(\bar{D}^0(t) \to f\right)}{\Gamma\left(D^0(t) \to f\right) + \Gamma\left(\bar{D}^0(t) \to f\right)} \simeq a_{CP}^{dir} - A_\Gamma \frac{t}{\tau_D} \quad \mathcal{O}(10^{-4})$$

$$A_\Gamma = \frac{\Gamma - \bar{\Gamma}}{\Gamma - \bar{\Gamma}} \simeq a_{CP}^{dir}\, y\cos\phi + a_{CP}^{ind}$$

effective lifetimes

$$a_{CP}^{dir} = -\frac{1}{2}(A_m + A_d) \qquad \left|\frac{q}{p}\right|^{\pm 2} \approx 1 \pm A_m \qquad \left|\frac{\bar{A}_f}{A_f}\right|^{\pm 2} \approx 1 \pm A_d$$

$$a_{CP}^{ind} = x\sin\phi \qquad |D_{1,2}\rangle = p|D^0\rangle \pm q|\bar{D}^0 \qquad \phi \equiv \text{Phase}\left(\frac{q}{p}, \frac{\bar{A}_f}{A_f}\right)$$

$$x \equiv (m_1 - m_2)/\Gamma \quad y \equiv (\Gamma_1 - \Gamma_2)/2\Gamma \quad \Gamma \equiv (\Gamma_1 + \Gamma_2)/2 \quad \tau_D \equiv 1/\Gamma$$

LHCb has performed, with the full Run-1 data (3 fb^{-1}) :

- A TIME INTEGRATED analysis of $A_{CP}(t)$ for $D^0 \to K^+K^-, \pi^+\pi^-$ by taking the difference:

mean decay time in the sample

$$\Delta A_{CP} \equiv A_{CP}\left(K^+K^-\right) - A_{CP}\left(\pi^+\pi^-\right) \approx \Delta a_{CP}^{dir}\left(1 + \frac{\overline{\langle t\rangle}}{\tau_D}\, y\cos\phi\right) + \frac{\Delta\langle t\rangle}{\tau_D} a_{CP}^{ind}$$

mainly sensitive to *direct* CP violation in mixing and decay (2^{nd} term suppressed)

LHCb collaboration, R. Aaij et al. PRL 116, 191601 (2016) $\quad \mathbf{\Delta A_{CP} = (-0.10 \pm 0.08 \pm 0.03)\%}$

- A TIME DEPENDENT analysis of the linear term in $A_{CP}(t)$ to determine A_Γ, more sensitive to *indirect* CP violation (from the interference)

LHCb collaboration, R. Aaij et al. LHCb-CONF-009 / LHCb-CONF-010 CHARM 2016

TIME-DEPENDENT $D^0 \rightarrow K^+K^-/\pi^+\pi^-$

R. Aaij et al. LHCb-CONF-010 /CHARM 2016

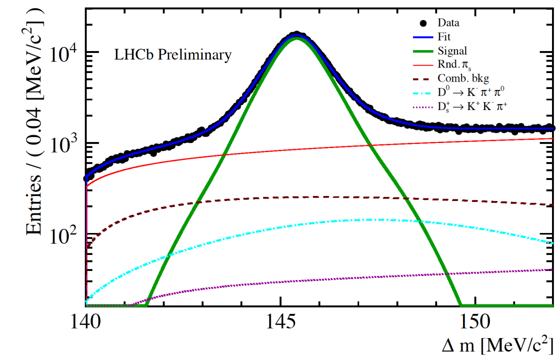
- Flavour tagging by the soft pion charge in the prompt decay $D^{*+} \rightarrow D^0\pi^+$
  with $\Delta m = m\left(D^{*+}\right) - m\left(D^0\right) < 152\ MeV/c^2$
  6.7M (K^+K^-) and 2.2M ($\pi^+\pi^-$) signal evts.
- Main background is long-lived b-hadrons, flight distance of D^0 candidates have large (χ^2-difference χ^2_{IP} of primary vertex w and w/o a track)
- The asymmetry between D^0 and $\bar{D}^0$ decay-time distributions is measured (overlaid by fit results):

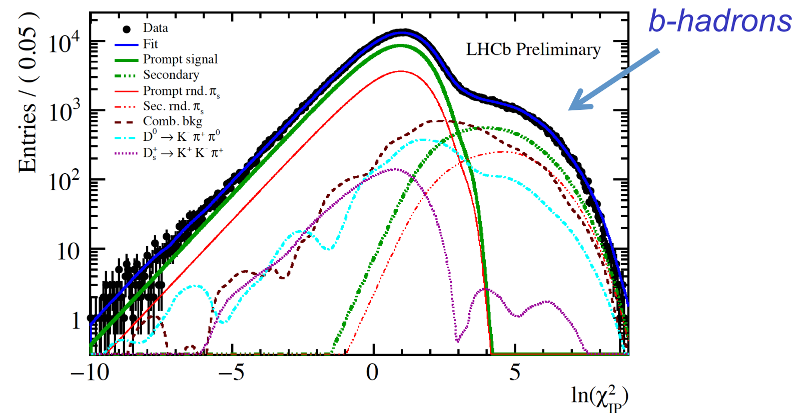
$$\mathbf{A_\Gamma(D^0 \rightarrow K^+K^-) = (-0.14 \pm 0.37 \pm 0.10) \times 10^{-3}}$$
$$\mathbf{A_\Gamma(D^0 \rightarrow \pi^+\pi^-) = (0.14 \pm 0.63 \pm 0.15) \times 10^{-3}}$$

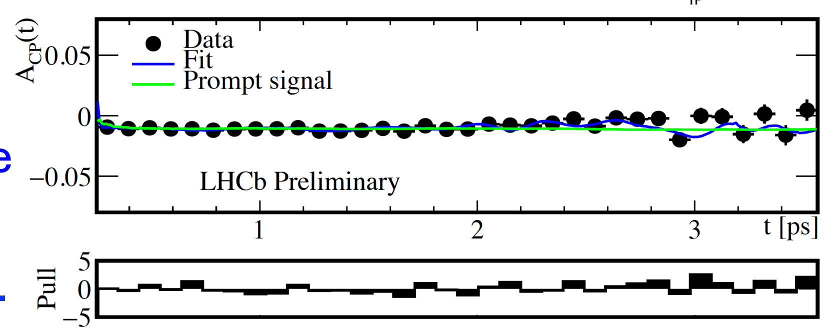
If averaged, as from universal mixing:

$$\mathbf{A_\Gamma = (-0.07 \pm 0.32 \pm 0.11) \times 10^{-3}}$$

Consistent with no CP violation. Most precise measurement to date on these observables. It confirms the smallness of CPV in c decays.







CP ASYMMETRY IN $D^0 \to K^+K^-$

- A further measurement of the *individual* time-integrated asymmetry $A_{CP}(K^+K^-)$ has been achieved, after accounting for c-production and detection asymmetries:

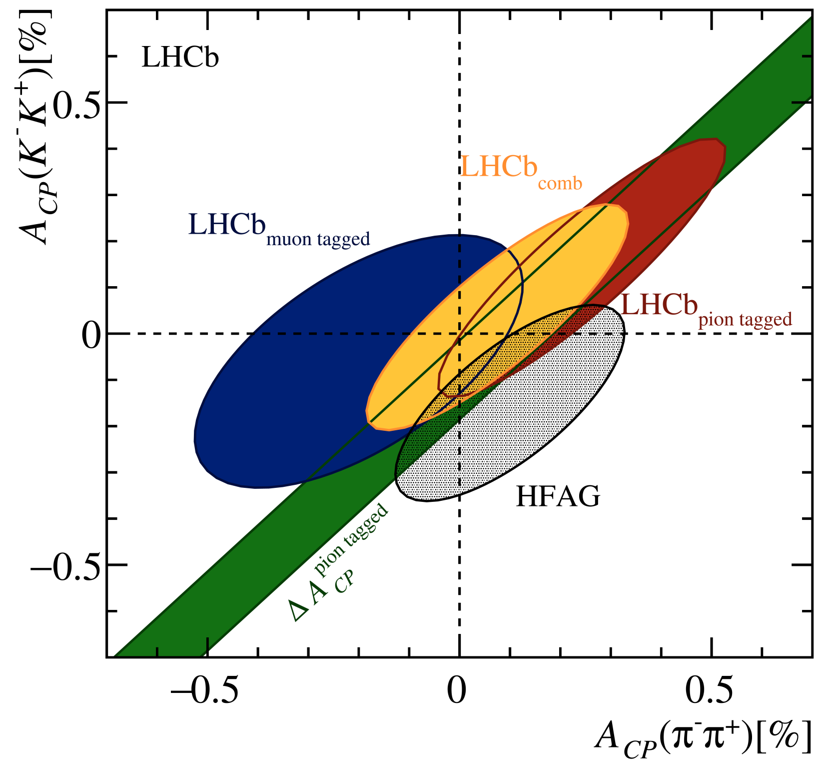
$$A_{CP}(K^+K^-) = A_{raw}(K^+K^-) - A_P(D^{*+}) - A_D(\pi_s^+)$$

by a remarkable reduction of charged → neutral asymmetries

$$\mathbf{A_{CP}(K^+K^-) = (0.14 \pm 0.15(stat) \pm 0.10(syst))\%}$$

- When combined with the previous measurement of **ΔA_{CP}** , and with LHCb results using **μ-tag** , a final result is obtained, assuming negligible CPV in D^0-mixing:

LHCb-PAPER-2016-035, in preparation



$$\mathbf{A_{CP}(K^+K^-) = (0.04 \pm 0.12(stat) \pm 0.10(syst))\%}$$

$$\mathbf{A_{CP}(\pi^+\pi^-) = (0.07 \pm 0.14(stat) \pm 0.11(syst))\%}$$

most precise measurements of a time-integrated CPA in charm from a single experiment

ANOMALIES IN LEPTON UNIVERSALITY

- In the SM all flavor-dependent interactions originate from Yukawa couplings to the Higgs boson, the smallness of neutrino masses making lepton interactions universal (e, μ, τ). The only theoretical uncertainty in ratios of semileptonic decays comes from different lepton masses.
- The ratios below are particularly sensitive to physics beyond the SM, and have shown anomalies in various experiments:

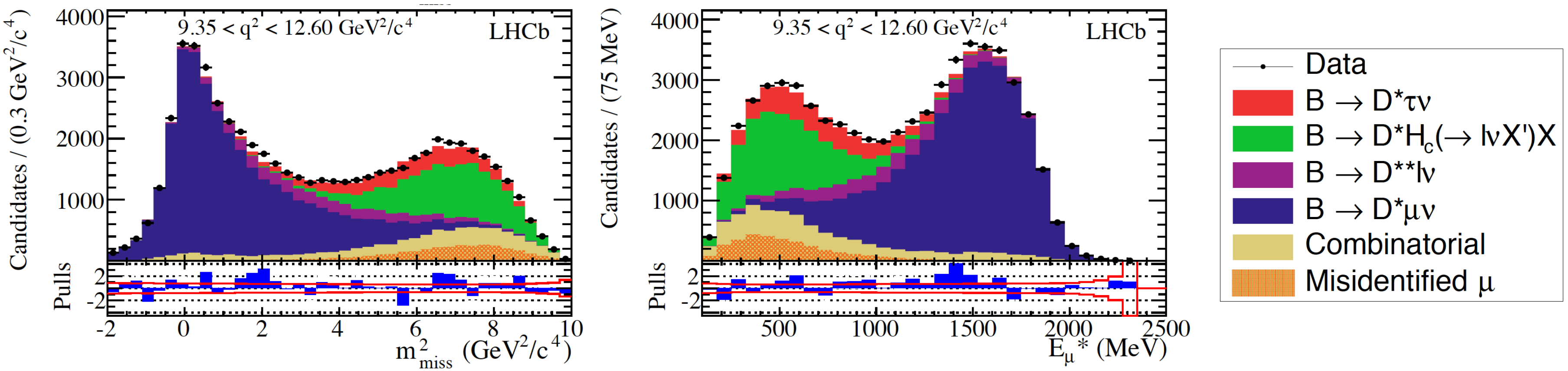
$$R_{D(*)} = \frac{\Gamma\left(B \to D^{(*)}\tau\nu_\tau\right)}{\Gamma\left(B \to D^{(*)}\mu\nu_\mu\right)} \qquad R_K = \frac{\int_{q^2_{min}}^{q^2_{max}} \left[d\Gamma\left(B^+ \to K^+\mu^+\mu^-\right)/dq^2\right]\ dq^2}{\int_{q^2_{min}}^{q^2_{max}} \left[d\Gamma\left(B^+ \to K^+e^+e^-\right)/dq^2\right]\ dq^2}$$

- *R(D)* and *R(D*)* may receive contributions from new Higgs bosons, showing discriminating power to different 2HDM's. BaBar experiment reported *anomalous* values of both (>3σ), excluding 2HDMs of the so-called type II (minimal SUSY), in the full $\tan\beta$-$m_{H\pm}$ plane.

J. P. Lees et al, PR D88 (2013) 072012, also PRL 109 101802.

B → D*τν AT LHCb

- First b → τ reconstruction at a hadron collider: $R(D^*) = \frac{\Gamma(\bar{B}^0 \to D^{*+}\tau^-(\mu^-\bar{\nu}_\mu\nu_\tau)\bar{\nu}_\tau)}{\Gamma(\bar{B}^0 \to D^{*+}\mu^-\bar{\nu}_\mu)}$. Challenging at the LHC, since both decays produce identical final-state topologies, with no kinematic constraint: $D^{*+} \to D^0(K^-\pi^+)\pi^+$



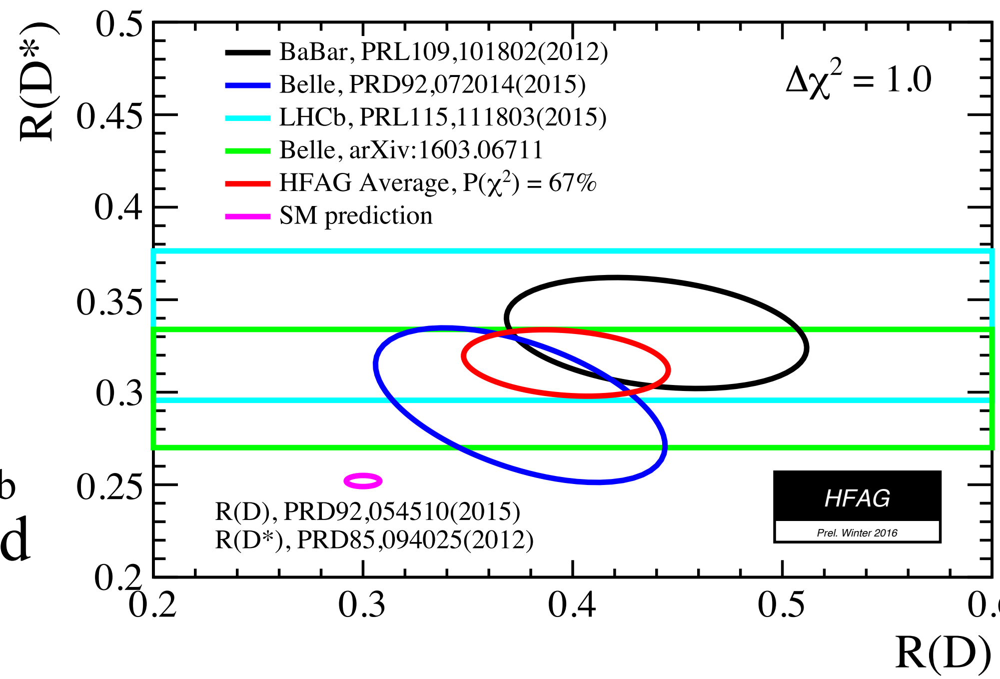
R(D*) = 0.336 ± 0.027± 0.030

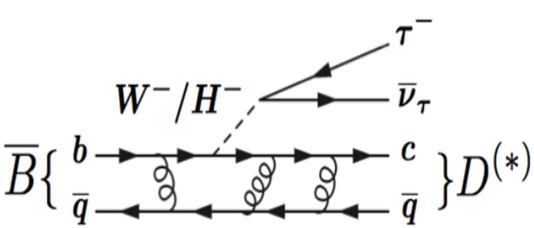
R. Aaij et al. PRL 115, 111803 (2015)

- LHCb result *has confirmed* the excess to the SM value 0.252±0.003. Fit also extracts form factor parameters, which appear to agree with world averages.
  - B^0 rest-frame variables (m_{miss}^2, E_μ^*, $q^2 = (p_B - p_D)^2$) are measured with (15-20)% resolution thanks to $\vec{p}_B$ stimation with charged particles
  - Control samples of the different backgrounds allow precise corrections

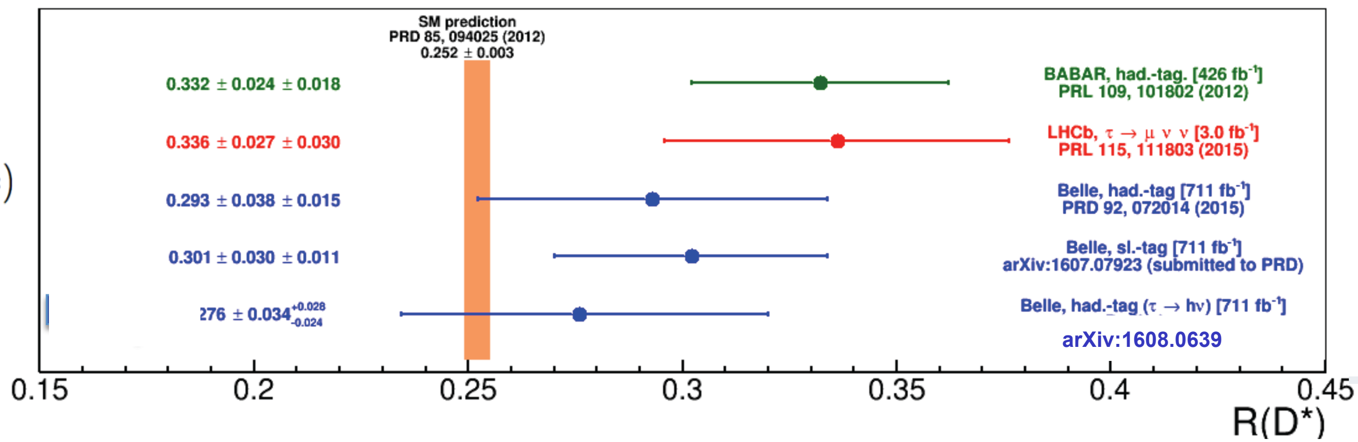
$B \to D^{(*)}\tau\nu$ CURRENT STATUS

- Overall average shows a 4σ discrepancy from the SM
- LHCb can perform further measurements with other b-hadrons, such as B_s, B_c and Λ_b that will help better understand the picture → stay tuned!





V. Vagnoni, ICHEP 2016

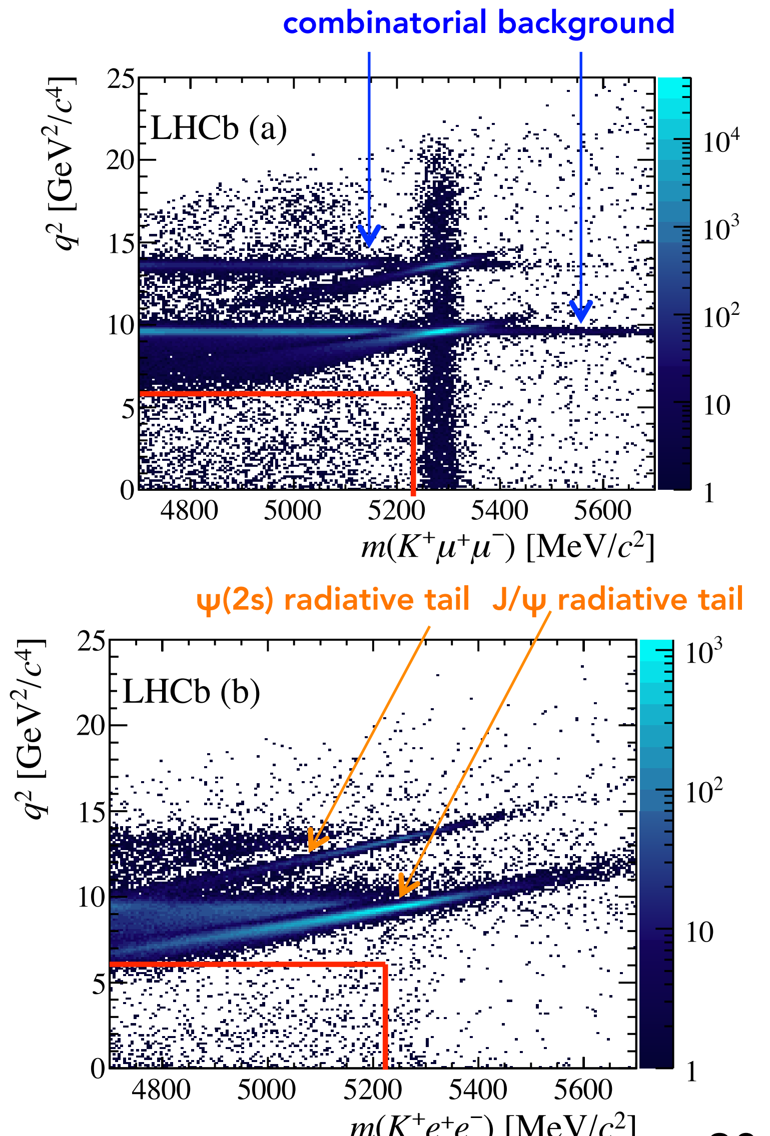


SM: S. Fajfer, J. F. Kamenik, and I. Nisandzic, PR D85 (2012) 094025

OTHER FLAVOUR ANOMALIES: R_K

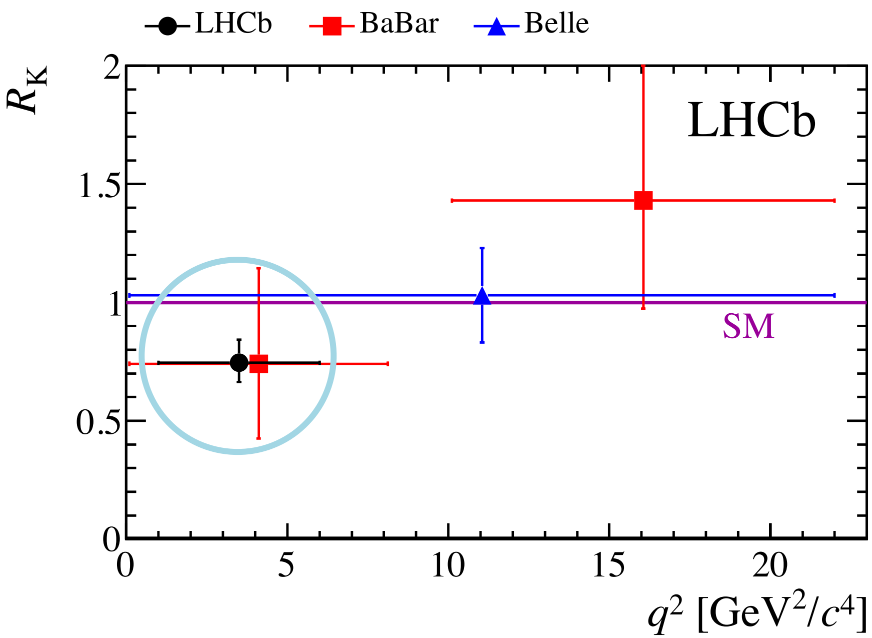
$$R_K = \frac{\int_{q^2_{min}}^{q^2_{max}} \left[d\Gamma \left(B^+ \to K^+ \mu^+ \mu^- \right) / dq^2 \right] \, dq^2}{\int_{q^2_{min}}^{q^2_{max}} \left[d\Gamma \left(B^+ \to K^+ e^+ e^- \right) / dq^2 \right] \, dq^2}$$

LHCb collaboration, PRL 113 (2014) 151601



- Ratio free of all hadronic uncertainties, notably form factors
- $1 < q^2 < 6$ GeV^2 excludes J/ψ and region above ψ(2s) affected by broad charmonium resonances
- Strong advantage is taken from the copious control channel $B^+ \to J/\psi\,(l^+l^-)\,K^+$ to cancel potencial sources of systematics (assuming universality in $J/\psi \to l^+l^-$)

SUMMARY R_K RESULTS



LHCb : PRL 113 (2014) 151601
BaBar : PRD 86 (2012) 032012
Belle : PRL 103 (2009) 171801

$$R_K = 0.745\,^{+0.090}_{-0.074}\,(\text{stat}) \pm 0.036\,(\text{syst})$$

- R_K is expected to be unity in the SM with high precision. Observation of LFU violation would be a clear sign of New Physics
- LHCb observed a 2.6 σ deviation from SM in the low q^2 region. A muon deficit is consistently seen by LHCb also in other $b \to s\,\mu^+\mu^-$ channels
- New measurements are expected soon, e.g. R_{K*}

LUMINOSITY PROSPECTS FOR LHCb

	LHC era			HL-LHC era	
	Run 1 (2010-12)	Run 2 (2015-18)	Run 3 (2021-24)	Run 4 (2027-30)	Run 5+ (2031+)
ATLAS, CMS	25 fb^{-1}	100 fb^{-1}	300 fb^{-1}	⟶	3000 fb^{-1}
LHCb	3 fb^{-1}	8 fb^{-1}	25 fb^{-1}	50 fb^{-1}	*300 fb^{-1}

* assumes a future LHCb upgrade to raise the instantaneous luminosity to 2×10^{34} $cm^{-2}s^{-1}$

- Note the LHCb upgrade comes already at Run-2, whereas the HL (phase-2) ATLAS and CMS upgrades come after Run-3
- The LHCb upgraded detector after Run-2 will handle ×5 instantaneous luminosity, from 4×10^{32} $cm^{-2}s^{-1}$ to 2×10^{33} $cm^{-2}s^{-1}$.
- The hardware trigger stage will be eliminated, and trigger become fully software based. RICH photodetectors will be replaced, as well as tracking detectors
- LHCb is starting to consider a phase-2 upgrade for Run-5+

In the meantime, very exciting prospects exist from the SuperKEKB machine (x100 luminosity) and the new Belle II detector, expected to rump up in 2019

We are gladly anticipating further highlighting results !

SUMMARY LHCb OVERVIEW

- Flavour physics in the quark sector keeps florishing over the last years, with a large number of precision tests of the Standard Model of particle physics.
- LHC experiments have been very succesful in flavour physics. In electroweak physics, LHCb has made significant and complementary contributions to ATLAS and CMS (see F. Betti's talk)
- Sensitivity to very rare channels, such as $B \rightarrow \mu^+\mu^-$, has reached the 10^{-10} level and will continue to improve (see ensuing talks by M. McCann and T. Tekampe)
- No evidence of new physics has been found in the first precision measurements of the CKM phases β_s and γ, providing further support for the Kobayashi-Maskawa theory of CP violation.
- A few interesting "tensions" with the SM to follow up very closely:
  - hints on lepton non-universality in R_K, $R(D^*)$ and $R(D)$
  - observables in $B \rightarrow K^{*0} \mu\mu$ (will be discussed by M. McCann)

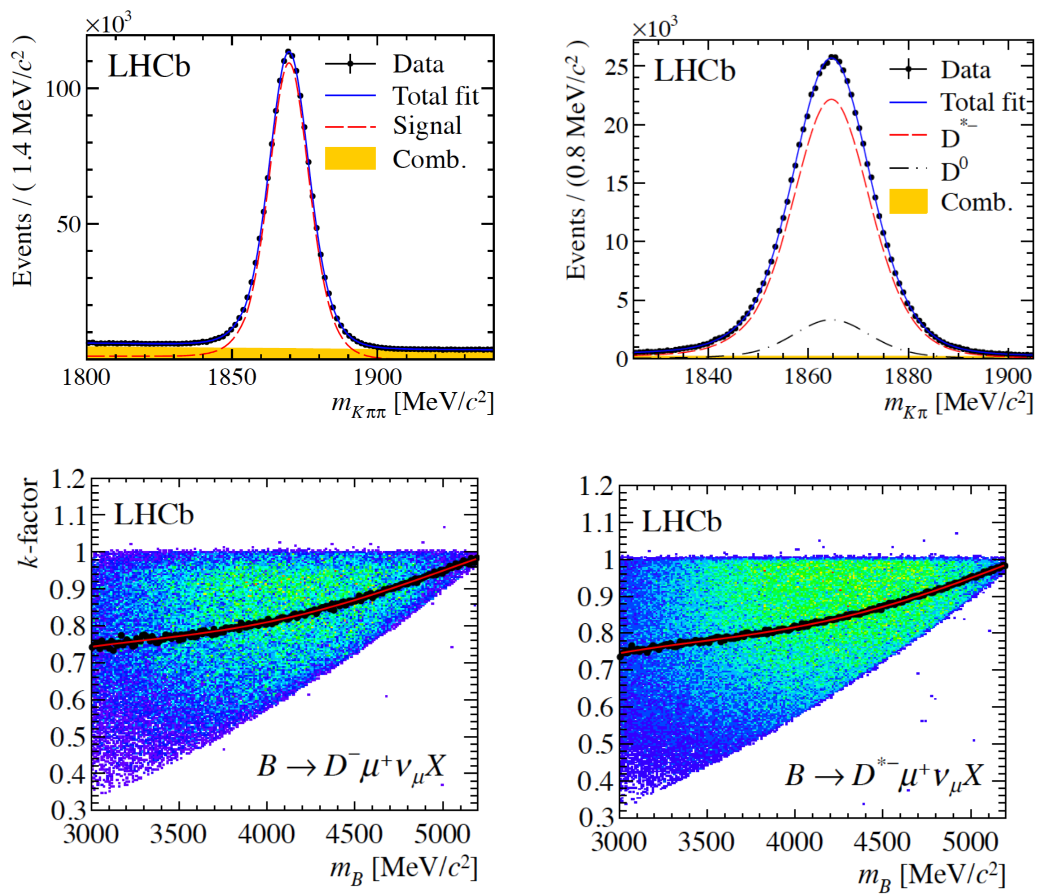
THANK YOU

Δm_d MEASUREMENT

- The decays $B^0 \to D^-\mu^+\nu_\mu X \quad D^- \to K^+\pi^-\pi^-$ and $B^0 \to D^{*-}\mu^+\nu_\mu X \quad D^{*-} \to \bar{D}^0(K^+\pi^-)\pi^-$ are chosen at LHCb for their large branching fraction (b → c) and efficient μ-ID

LHCb collaboration, R. Aaij et al. arXiv:1604.03475 (2016)

- Huge samples ($\sim 2 \times 10^6$ D^0) were collected with 3 fb^{-1}, with excellent mass resolution
- The proper decay time of the B^0 meson is calculated from the visible momentum
- Missing neutrino accurately described by the simulation. It degrades the time resolution only slightly (75 fs)



Δm_d FROM SEMILEPTONIC DECAYS

- The flavor (B^0 or $\bar{B}^0$) is identified both at production time (t = 0) and at decay time (self-tagging modes) :

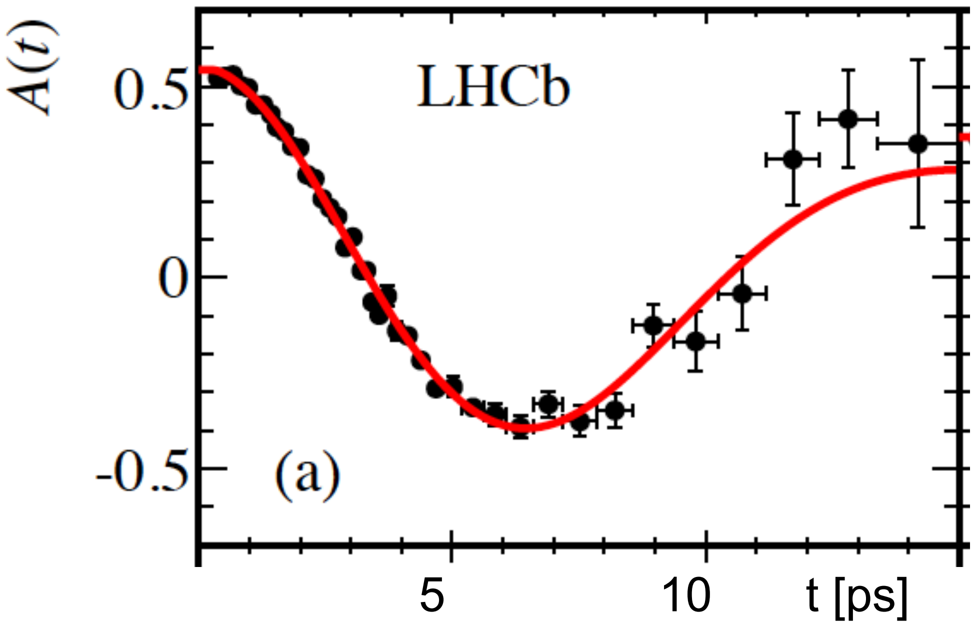
LHCb collaboration, R. Aaij et al. arXiv:1604.03475 (2016)

$$N^{\rm unmix}(t) = N\left(B^0 \to D^{(*)-}\mu^+\nu_\mu X\right)(t) \propto e^{-\Gamma_d t}\left[1+\cos(\Delta m_d t)\right]$$

$$N^{\rm mix}(t) = N\left(B^0 \to \bar{B}^0 \to D^{(*)+}\mu^-\bar{\nu}_\mu X\right)(t) \propto e^{-\Gamma_d t}\left[1+\cos(\Delta m_d t)\right]$$

$$A(t) = \frac{N^{\rm unmix} - N^{\rm mix}}{N^{\rm unmix} + N^{\rm mix}} = \cos(\Delta m_d t)$$

mistag : 0 < η < 0.25



- World's most precise, in agreement with previous measurements, and very constraining for NP models

$$\Delta m_d = (0.5050 \pm 0.0021 \pm 0.0010)\ {\rm ps}^{-1}$$