“Overview of recent LHCb results”

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on behalf of the LHCb collaboration

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QCD@Work 2019 - Matera, June 25^{th}-28^{th} 2018

The LHCb experiment

The LHCb experiment: precision studies of b and c-hadron decays (CP violation, rare decays) $\rightarrow$ test SM/indirect evidence of NP

Requirements:

- High yield $\rightarrow$ efficient trigger and selection, large $\bar{b}b/\bar{c}c$ production cross section ($\sigma_{\bar{b}b}\sim$ 280μb, $\sigma_{\bar{c}c}\sim$ 6mb, @7 TeV)
- Low background $\rightarrow$ mass resolution, particle identification

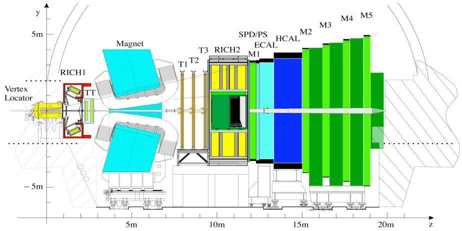
LHCb detector:

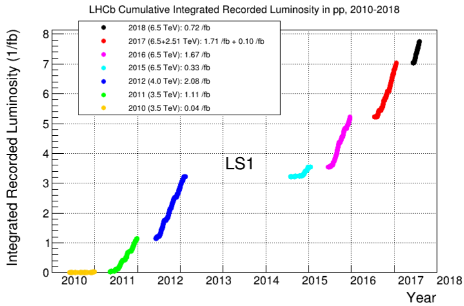
- Vertexing&Tracking: excellent resolutions
- Particle identification: $\pi/K/p$ (RICH), $\pi/e/\gamma$ (E/HCAL), μ (MUON)
- Trigger: L0 (hardware: highp_T e/γ/hadron/μ candidates), HLT1& HLT1 (software)
    - (since Run2) perform an almost Run-time detector alignment and calibration

Data Taking:

- operating at a levelled inst. lumi $\mathcal{L}\sim 4\times10^{32}\text{cm}^{-2}s^{-1}$
- Run1: $\int\mathcal{L} = 3$ fb^{-1} @7 and 8 TeV
- Run2: $\int\mathcal{L}\simeq 5$ ($\rightarrow$6) fb^{-1} @13 TeV (x2 $\sigma_{\bar{b}b}$ and increased trigger efficiency)

2008 JINST 3 S08005 , Int. J. Mod. Phys. A30 (2015) 1530022.





Outline

Selection of most recent/relevant/interesting LHCb measurements:

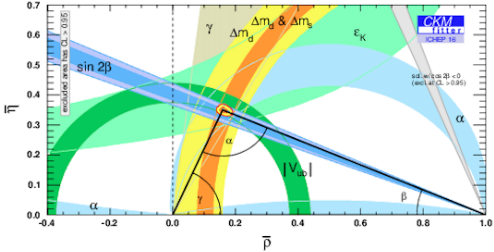
- **B physics**: measurement of the angle γ of UT (CKM)
- **Charm physics**: measurement of $D^0 - \bar{D}^0$ mixing
- **Tests of Lepton Flavour Universality** in semileptonic b-hadron decays:
  - in tree level $b \to c\ell\nu_\ell$ transitions
  - in loop level, FCNC, $b \to s\ell\ell$ transitions
- Not covered in this talk:
  - many interesting results in **hadron spectroscopy** $\to$ **see the talk by Antimo Palano on Wednesday**
  - Heavy Ion & fixed-target physics results
  - Electroweak measurements

see the LHCb public results web page for more information

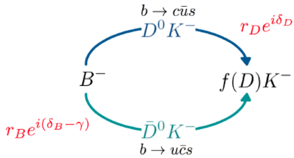
LHCb most relevant achievements: measurement of the CKM angle γ

- Angle $\gamma = arg(-\frac{V_{ub}^{*}V_{ud}}{V_{cb}^{*}V_{cd}})$ is the least well measured of the CKM UT angles.
  - Indirect $\gamma = (65.3^{+1.0}_{-2.5})^{\circ}$
  - Direct $\gamma = (72.1^{+5.4}_{-5.8})^{\circ}$

CKM fitter webpage



- Can be measured in tree-level B decays from the **interference** of $b \to c$ and $b \to u$ transitions
  - theoretically very clean ($\delta\gamma/\gamma \sim \mathcal{O}(10^{-7})$ from loops) JHEP 1401 (2014) 051 $\to$ SM benchmark
  - experimentally limited $\to$ typical $\mathcal{B}_{vis} \sim \mathcal{O}(10^{-7})$, size of interference $\mathcal{O}(10\%)$
- Several possible methods can be exploited:
  - GLW: D decays to a common CP eigenstate ($\pi\pi$ or KK)
  - ADS: interference between CF and DCS decays ($D \to K\pi$)
  - GGSZ: 3-body D decays ($D \to K_s\pi\pi$)
  - Dalitz: 3-body B decays ($B \to D^0(\bar{D}^0)K\pi$)
  - Time dependent: interference between B^0–$\bar{B}^0$ mixing and decay ($B_s^0 \to D_s^- K^+$)
- Best precision comes from a combination of measurements
  - need external inputs: $r = |\bar{\mathcal{A}}_f/\mathcal{A}_f|$, δ for each B (D) decay



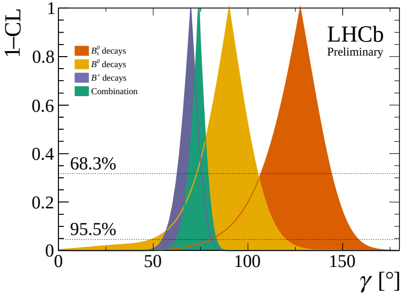
Hadronic terms determined experimentally
Measurement may require external charm input

CF: Cabibbo Favoured, DCS: Doubly Cabibbo Suppressed

LHCb most relevant achievements: measurement of the CKM angle γ

New combination of LHCb results performed including the following new results:

B decay	D decay	Method	Ref.	Dataset
$B^+ \to DK^+$	$D \to h^+h^-$	GLW	[14]	Run 1 & 2
$B^+ \to DK^+$	$D \to h^+h^-$	ADS	[15]	Run 1
$B^+ \to DK^+$	$D \to h^+\pi^-\pi^+\pi^-$	GLW/ADS	[15]	Run 1
$B^+ \to DK^+$	$D \to h^+h^-\pi^0$	GLW/ADS	[16]	Run 1
$B^+ \to DK^+$	$D \to K^0_S h^+h^-$	GGSZ	[17]	Run 1
$B^+ \to DK^+$	$D \to K^0_S h^+h^-$	GGSZ	[18]	Run 2
$B^+ \to DK^+$	$D \to K^0_S K^+\pi^-$	GLS	[19]	Run 1
$B^+ \to D^*K^+$	$D \to h^+h^-$	GLW	[14]	Run 1 & 2
$B^+ \to DK^{*+}$	$D \to h^+h^-$	GLW/ADS	[20]	Run 1 & 2
$B^+ \to DK^{*+}$	$D \to h^+\pi^-\pi^+\pi^-$	GLW/ADS	[20]	Run 1 & 2
$B^+ \to DK^+\pi^+\pi^-$	$D \to h^+h^-$	GLW/ADS	[21]	Run 1
$B^0 \to DK^{*0}$	$D \to K^+\pi^-$	ADS	[22]	Run 1
$B^0 \to DK^+\pi^-$	$D \to h^+h^-$	GLW-Dalitz	[23]	Run 1
$B^0 \to DK^{*0}$	$D \to K^0_S\pi^+\pi^-$	GGSZ	[24]	Run 1
$B^0_s \to D_s^{\mp}K^{\pm}$	$D_s^+ \to h^+h^-\pi^+$	TD	[25]	Run 1
$B^0 \to D^{\mp}\pi^{\pm}$	$D^+ \to K^+\pi^-\pi^+$	TD	[26]	Run 1



LHCb-CONF-2018-002

LHCb combination:

$$\gamma = (74.0^{+5.0}_{-5.8})^{\circ}$$
$$\gamma \in [68.2, 79.0]^{\circ} \quad @68.3\% \text{ CL}$$
$$\gamma \in [61.6, 83.7]^{\circ} \quad @95.5\% \text{ CL}$$

previous published LHCb combination
$\gamma = (72.2^{+6.8}_{-7.3})^{\circ}$ JHEP 12 (2016) 087

LHCb most relevant achievements: measurement $D^0 - \bar{D}^0$ mixing and CPV

Measure charm-mixing parameters from the fit to decay-time-dependent ratio of prompt D^0 decay rates to $K^+\pi^-$ (WS) and $K^-\pi^+$ (RS) (and its CC).[1]

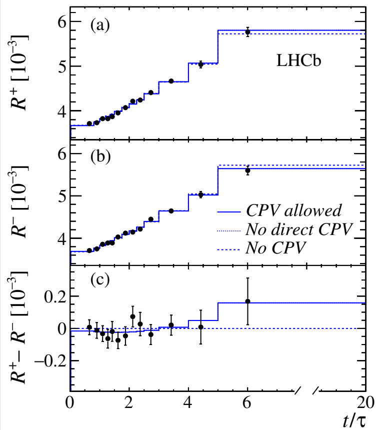
- RS: dominated by $D^0 \to K^-\pi^+$ (CF)
- WS: $D^0 \to K^+\pi^-$ (DCS) interfere with $D^0 \to \bar{D}^0(\to K^+\pi^-)$ (mixing & CF)

$$R^+(t) = \frac{WS(t)}{RS(t)} \times \frac{\epsilon_{\pi_s^+}\epsilon_{K^-\pi^+}}{\epsilon_{\pi_s^+}\epsilon_{K^+\pi^-}}$$

$$\approx R_D^+ + \sqrt{R_D^+}\, y'^+ \left(\frac{t}{\tau}\right) + \frac{x'^{+\,2} + y'^{+\,2}}{4}\left(\frac{t}{\tau}\right)^2$$

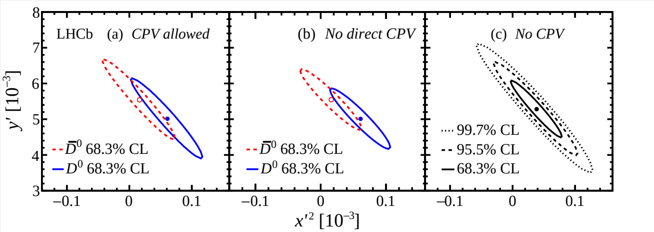
- tag D^0 using $D^{*+} \to D^0\pi_s^+$
- $D^{*\pm}$ production asymmetry and $\pi_s^\pm$ detection asymmetry cancel in the ratio.
- Fit $m(D^0\pi)$ in bins of decay time to extract the Yields of WS and RS (7×10^5 and 1.8×10^8 in total)
- Fit $R^+(t)$ and $R^-(t)$ with
  - two sets of independent parameters (CPV allowed)
  - $R_D^+ = R_D^-$ (No direct CPV)
  - same set of parameters (No CPV)

PRD 97 (2018) 031101 $\int\mathcal{L} = 5\ \mathrm{fb}^{-1}$



[1] $x \equiv \Delta m/\Gamma$, $y \equiv \Delta\Gamma/2\Gamma$, $x'^+ = x\cos\delta^+ + y\sin\delta^+$, $y'^+ = y\cos\delta^+ - x\sin\delta^+$, $R_D^+ = |\mathcal{A}_{CS}^+/\mathcal{A}_{CF}^+|^2$

PRD 97 (2018) 031101 $\int \mathcal{L} = 5\ \text{fb}^{-1}$



Results compatible with CP conservation

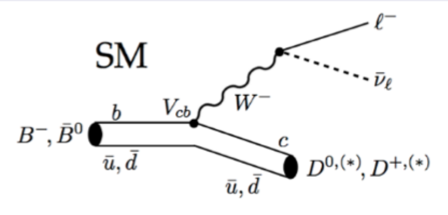
$$x'^2 = (3.9 \pm 2.7) \times 10^{-5},\ y' = (5.28 \pm 0.52) \times 10^{-3}$$
$$R_D = (3.454 \pm 0.031) \times 10^{-3}.$$

Most stringent bounds on D^0-$\bar{D}^0$ mixing parameters from a single-measurement

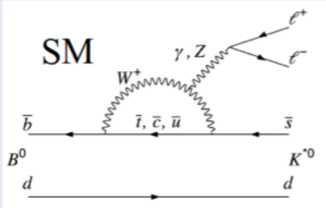
Test of Lepton Flavour Universality (LFU) using semileptonic *b*-hadron decays

Semileptonic *b*-hadron decays are excellent area to test the universality of the electroweak coupling to different lepton species (LFU) intrinsic in the SM.

$b \to c\ell\bar{\nu}_\ell$ charged current transitions

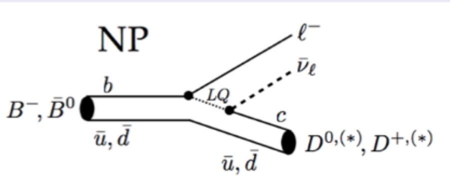


$b \to s\ell\ell$ neutral current transitions

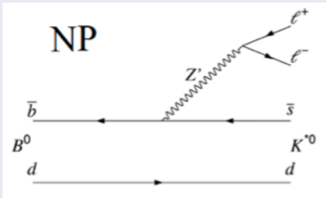


Experimental results on b-hadron decays show hints of deviations from the expectations of the SM that can be eventually addressed to NP contribution.

$b \to c\ell\bar{\nu}_\ell$ charged current transitions



$b \to s\ell\ell$ neutral current transitions



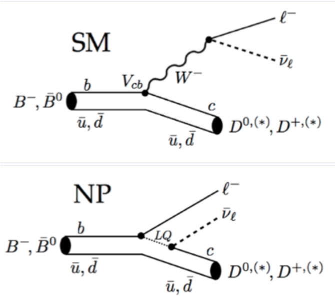
Test of Lepton Flavour Universality in tree level $b \to c\ell^- \bar{\nu}_\ell$ decays

Test of LFU by measuring the ratio:

$$\mathcal{R}(H_c) \equiv \frac{\mathcal{B}(B \to H_c \tau \nu_\tau)}{\mathcal{B}(B \to H_c \mu \nu_\mu)},$$

H_c = charmed hadron

convenient as most experimental and theoretical uncertainties cancel.



- SM prediction: $\neq$1 due to the different charged lepton masses
  - $\mathcal{R}(D) = 0.299 \pm 0.011$, PRD92 (2015) 034506
  - $\mathcal{R}(D^*) = 0.252 \pm 0.003$ PRD85 (2012) 094025
  - $\mathcal{R}(J/\psi) = 0.25 - 0.28$ (poorly constrained form factors)
    PLB 452 (1999)129, arXiv:hep-ph/0211021, PRD 73 (2006) 054024, PRDD85 (2012) 094025

LHCb test of Lepton Flavour Universality in tree level $b \to c\ell^-\bar{\nu}_\ell$ decays. $\mathcal{R}(D^*)$

Test of LFU by measuring the ratio:

$$\mathcal{R}(D^*) = \frac{\mathcal{B}(\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B}^0 \to D^{*+}\mu^-\bar{\nu}_\mu)}$$

Same visible final state for **signal** and **normalisation** modes using muonic tau decays: $\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$ $\mathcal{B} \sim 17\%$.

Selection: minimal cuts on D^* and μ and no extra tracks from B or PV (MVA: isolation)

Multidimensional (3D) fit to distributions of:

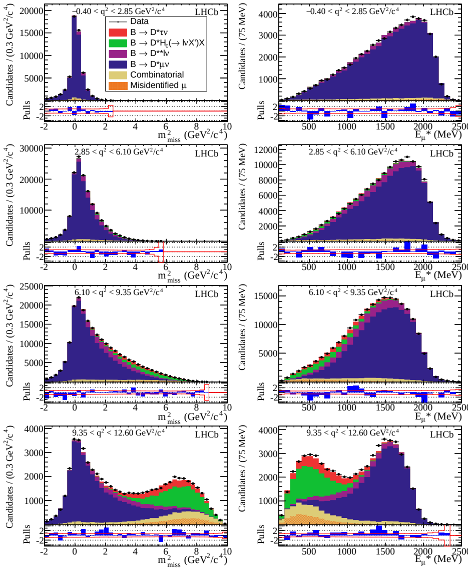
- E^*_μ (muon energy in the B rest frame)
- $m^2_{miss} = (p_B - p_{D^*} - p_\mu)^2$
- $q^2 = (p_B - p_{D^*})^2$

Approximation: p_B momenta computed using the B direction and visible momenta $p_{D^*\mu}$: $p_{z,\,B} = (m_B/m_{D^*\mu})p_{z,\,D^*\mu}$

using templates to model different components taken from simulation (FF HQET) and control samples.

PRL 115 (2015) 111803

$\int \mathcal{L} = 3$ fb^{-1}



LHCb test of Lepton Flavour Universality in tree level $b \to c\ell^- \bar{\nu}_\ell$ decays. $\mathcal{R}(D^*)$

PRL 115 (2015) 111803 $\int \mathcal{L} = 3\ \text{fb}^{-1}$

Yields of Signal: 363000±16000
Signal/Normalization: $(4.54 \pm 0.46) \times 10^{-2}$

Result:

$\mathcal{R}(D^*) = 0.336 \pm 0.027 \pm 0.030$

in agreement with BaBar and Belle results and 2.1 σ above the SM prediction

Model uncertainties	**Absolute size ($\times 10^{-2}$)**
Simulated sample size	**2.0**
Misidentified μ template shape	1.6
$\bar{B}^0 \to D^{*+}(\tau^-/\mu^-)\bar{\nu}$ form factors	0.6 (*)
$\bar{B} \to D^{*+}H_c(\to \mu\nu X')X$ shape corrections	0.5
$\mathcal{B}(\bar{B} \to D^{**}\tau^-\bar{\nu}_\tau)/\mathcal{B}(\bar{B} \to D^{**}\mu^-\bar{\nu}_\mu)$	0.5
$\bar{B} \to D^{**}(\to D^*\pi\pi)\mu\nu$ shape corrections	0.4
Corrections to simulation	0.4
Combinatorial background shape	0.3
$\bar{B} \to D^{**}(\to D^{*+}\pi)\mu^-\bar{\nu}_\mu$ form factors	0.3 (*)
$\bar{B} \to D^{*+}(D_s \to \tau\nu)X$ fraction	0.1
Total model uncertainty	2.8
Normalization uncertainties	**Absolute size ($\times 10^{-2}$)**
Simulated sample size	0.6
Hardware trigger efficiency	0.6
Particle identification efficiencies	0.3
Form-factors	0.2
$\mathcal{B}(\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau)$	< 0.1
Total normalisation uncertainty	0.9
Total systematic uncertainty	**3.0**

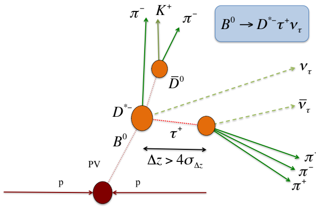
theoretical, external source of systematic uncertainty

LHCb test of Lepton Flavour Universality in tree level $b \to c\ell^- \bar{\nu}_\ell$ decays. $\mathcal{R}(D^*)$

An independent measurement using three-prong tau decay $\tau^- \to \pi^-\pi^-\pi^+(\pi^0)\nu_\tau$ ($\mathcal{B} \sim 15\%$) for the **signal** and $\bar{B}^0 \to D^{*-}\pi^+\pi^+\pi^-$ for the **normalisation** modes.

$\int \mathcal{L} = 3\ \text{fb}^{-1}$

PRD 97 (2018) 072013 PRL 120 (2018) 171802

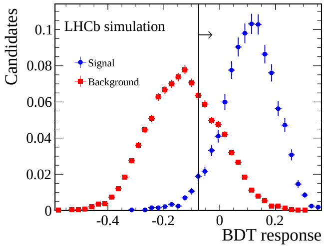


Test of LFU by measuring the ratio:

$$\mathcal{R}(D^*) = \frac{\mathcal{B}(B^0 \to D^* \tau\nu_\tau)}{\mathcal{B}(B^0 \to D^* 3\pi)} \times \left[\frac{\mathcal{B}(B^0 \to D^* 3\pi)}{\mathcal{B}(B^0 \to D^* \mu\nu_\mu)}\right]_{ext}$$

Selection (signal only):

- 3π decay vertex downstream the B vertex (suppress $B \to D^{*-}3\pi X$)
- BDT (suppress $B \to D^* D_{(s)} X$)
  - no extra tracks compatible with B or τ vertices (isolation)
  - no neutrals in a cone containing the τ (calorimeters)
  - exploit different $\tau/D_{(s)}$ 3-prong decay dynamics



BDT validated using control samples

LHCb test of Lepton Flavour Universality in tree level $b \to c\ell^-\bar{\nu}_\ell$ decays. $\mathcal{R}(D^*)$

Kinematics of $\bar{B}^0 \to D^{*+}\tau^-(\to 2\pi^-\pi^+\nu_\tau)\,\bar{\nu}_\tau$: the τ and B momenta known using flight direction and mass up to a 2-fold ambiguity $\to$ take the average value

- $q^2 = (p_B - p_{D^*})^2$ is unbiased and has enough resolution (18% FWHM)

Yield of the signal mode: multidimensional fit to distributions of

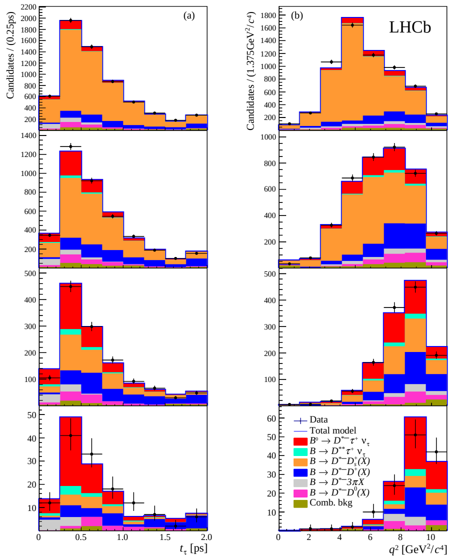
- τ decay time
- $q^2 = (p_B - p_{D^*})^2$
- BDT

using templates to model different components taken from simulation.
Extensive validation of inputs from simulation using control samples of data ($B \to D^* D$)
Note: D_s decay dynamics determined from $B \to D^* D_s$ data (low BDT).

$N_{sig} = 1296 \pm 86$

$\int \mathcal{L} = 3\ \text{fb}^{-1}$

PRD 97 (2018) 072013 PRL 120 (2018) 171802



LHCb test of Lepton Flavour Universality in tree level $b \to c\ell^- \bar{\nu}_\ell$ decays. $\mathcal{R}(D^*)$

Signal mode: $N_{sig} = 1296 \pm 86$

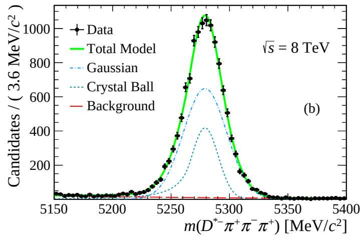
Normalisation mode $\bar{B}^0 \to D^{*+}(\to D^0\pi^+)\,2\pi^-\pi^+$:

- Selection: D^0 vertex downstream the 3π. Exclusive reconstruction.
- Yields from a fit to $m(D^{*-}3\pi)$ distribution.

$N_{norm} = 17660 \pm 158$ (w/o 151 ± 22 $B \to D^* D_s$)

$\int \mathcal{L} = 3\ \mathrm{fb}^{-1}$

PRD 97 (2018) 072013 PRL 120 (2018) 171802



Result:

$$\mathcal{K}(D^*) = \frac{\mathcal{B}(B^0 \to D^* \tau \nu_\tau)}{\mathcal{B}(B^0 \to D^* 3\pi)} = 1.97 \pm 0.13 \pm 0.18$$

$$\mathcal{R}(D^*) = 0.291 \pm 0.019 \pm 0.026 \pm 0.013(\mathcal{B})$$

in agreement with previous results and 1.1 σ above the SM prediction

Systematic uncertainties

Source	$\delta\mathcal{R}/\mathcal{R}$ [%]
Simulated sample size	**4.7**
Empty bins in templates	1.3
Signal decay model	1.8
$D^{**}\tau\nu$ and $D_s^{**}\tau\nu$ feeddowns	2.7
$D_s^+ \to 3\pi X$ decay model	2.5
$B \to D^{*-} D_{(s)}^{+,0} X$ backgrounds	3.9
Combinatorial background	0.7
$B \to D^{*-} 3\pi X$ background	2.8
Efficiency ratio	**3.9**
Normalisation channel efficiency (modelling of $B^0 \to D^{*-}3\pi$)	2.0
Total uncertainty	**9.1**

theoretical, external source of systematic uncertainty

LHCb test of Lepton Flavour Universality in tree level $b \to c\ell^- \bar{\nu}_\ell$ decays. $\mathcal{R}(J/\psi)$

PRL 120 (2018) 121801 $\int \mathcal{L} = 3\ \text{fb}^{-1}$

Add more decay channels: exploit B_c^- decays produced at LHC:

Test of LFU by measuring the ratio:

$$\mathcal{R}(J/\psi) \equiv \frac{\mathcal{B}(B_c^- \to J/\psi \tau^- \bar{\nu}_\tau)}{\mathcal{B}(B_c^- \to J/\psi \mu^- \bar{\nu}_\mu)}$$

Same visible final state for **signal** and **normalisation** modes using muonic tau decays: $\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$.

Selection: minimal requirements on J/ψ and μ, require no extra tracks from the B_c (BDT).

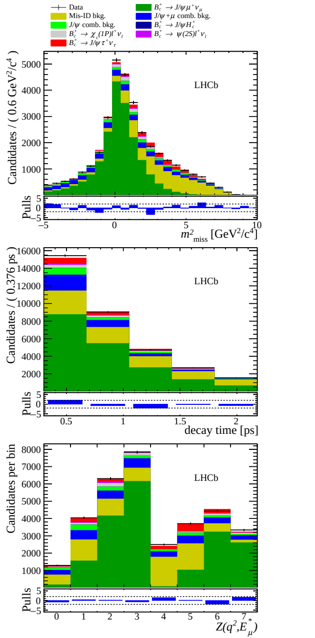
Multidimensional (3D) template fit to distributions of:

- B_c-candidate decay time, t
- $m^2_{miss} = (p_{B_c} - p_{J/\psi} - p_\mu)^2$
- Z define ranges of (q^2, E^*_μ)

same approximation as for muonic $\mathcal{R}(D^*)$ to compute p_{B_c}

Limited knowledge of signal and normalisation **form factors** affects template shapes $\to$ **determined using data** (norm. mode $B_c \to J/\psi \mu \nu_\mu$).

lattice calculation on the way



LHCb test of Lepton Flavour Universality in tree level $b \to c\ell^- \bar{\nu}_\ell$ decays. $\mathcal{R}(J/\psi)$

Signal mode: $N_{sig} = 1400 \pm 300$ (significance 3σ)
Normalisation mode: $N_{norm} = 19140 \pm 340$

Result:

$\mathcal{R}(J/\psi) = 0.71 \pm 0.17 \pm 0.18$

(*) correcting for a bias due to empty bins in the templates

above the range of SM predictions $(0.25 - 0.28)$ and compatible within $2\ \sigma$.

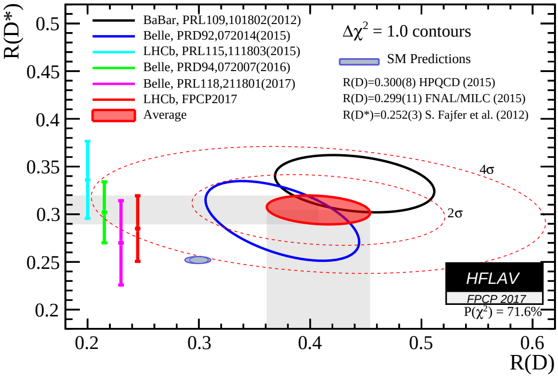
PRL 120 (2018) 121801 $\int \mathcal{L} = 3\ \text{fb}^{-1}$

Source of uncertainty	Size ($\times 10^{-2}$)
Limited size of simulation samples	**8.0**
$B_c^+ \to J/\psi$ form factors (currently data driven)	**12.1**
$B_c^+ \to \psi(2S)$ form factors	3.2
Fit bias correction (*)	5.4
Z binning strategy	5.6
Misidentification background strategy	5.6
Combinatorial background cocktail	4.5
Combinatorial J/ψ sideband scaling	0.9
$B_c^+ \to J/\psi H_c X$ contribution	3.6
Semitauonic $\psi(2S)$ and χ_c feed-down	0.9
Weighting of simulation samples	1.6
Efficiency ratio	0.6
$\mathcal{B}(\tau^+ \to \mu^+ \nu_\mu \overline{\nu}_\tau)$	0.2
Total systematic uncertainty	**17.7**

theoretical, external source of systematic uncertainty

Summary: anomalies in tree level $b \to c\ell^-\bar{\nu}_\ell$ decays. $\mathcal{R}(D^*)$, $\mathcal{R}(D)$ and $\mathcal{R}(J/\psi)$

HFLAV



- $\mathcal{R}(D)$ and $\mathcal{R}(D^*)$ are **systematically larger than theoretical expectations**. Compatibility with the SM: 4.1σ (Global) and 3.5σ ($\mathcal{R}(D^*)$)
- First measurement of $\mathcal{R}(J/\psi)$ ever! Result compatible within 2σ the ranges of SM predictions (poor precision), though on the high-side.
- more to come: $\mathcal{R}(\Lambda_c^{(*)})$ (testing LFU in Λ_b decays, with a different spin structure) and $\mathcal{R}(D_s)$ (using B_s^0 decays)

Test of Lepton Flavour Universality in loop-mediated $b \to s\ell^+\ell^-$ decays

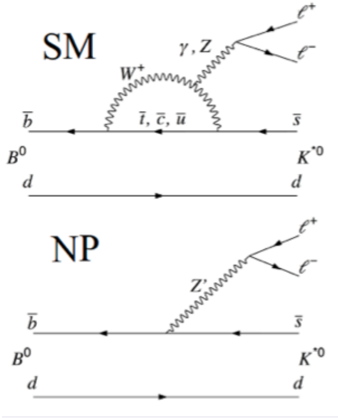
Test of LFU by measuring the ratio:

$$\mathcal{R}(H_s) \equiv \frac{\mathcal{B}(H_b \to H_s \mu^+ \mu^-)}{\mathcal{B}(H_b \to H_s e^+ e^-)} \quad H_b,\ H_s = \text{beauty/strange hadron}$$

Complementary test of LFU:

- in 2^{nd} and 1^{st} generation of leptons
- in neutral current transitions that are mediated by loops in the SM
- more information from q^2-dependent measurements

SM prediction of $\mathcal{R}(K^{(*)}) = 1 + \mathcal{O}(\%)$ EPJ C76 (2016) 8 440
with ‰ precision as most hadronic uncertainty cancel



LHCb test of Lepton Flavour Universality in loop-mediated $b \to s\ell^+\ell^-$ decays $\mathcal{R}(K^*)$

JHEP 08 (2017) 055 $\int \mathcal{L} = 3$ fb^{-1}

Test of LFU by measuring the double ratio:

$$\mathcal{R}(K^*) = \frac{\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-)}{\mathcal{B}(B^0 \to K^{*0}e^+e^-)} \times \frac{\mathcal{B}(B^0 \to K^{*0}J/\psi(\to e^+e^-))}{\mathcal{B}(B^0 \to K^{*0}J/\psi(\to \mu^+\mu^-))}$$

in two bins of $q^2 \equiv (p_{\ell^+} + p_{\ell^-})^2$

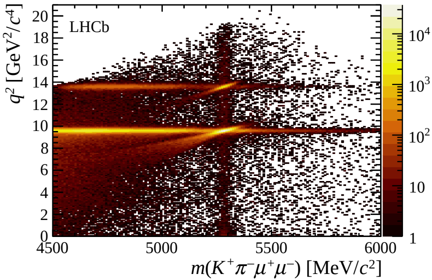
Double ratio to reduce systematic uncertainties due to the different experimental efficiencies of the $\mu\mu$ and ee modes.

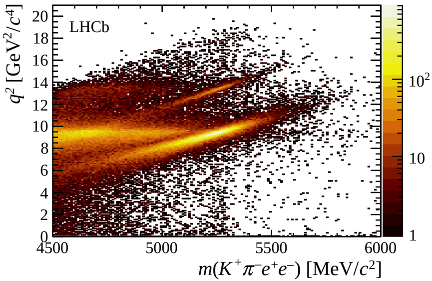
Reconstruction:

- Bremsstrahlung recovery is crucial to measure $p_{e^\pm}$ in ee mode (>50% of events). Still $\boldsymbol{\sigma_m^{ee} >> \sigma_m^{\mu\mu}}$
- $\varepsilon^{ee}_{\mathbf{trig}} < \varepsilon^{\mu\mu}_{\mathbf{trig}}$ due to higher trigger cuts (large occupancy in the calorimeter) $\to$ statistics limitations.

Background suppression:

- NNet for combinatorial background
- Vetoes for mis-ID or partially reconstructed exclusive b-hadron decays



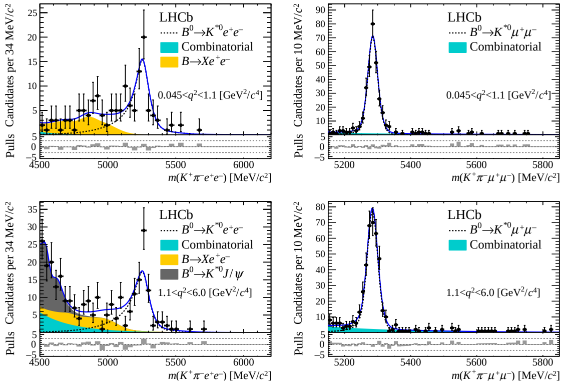


LHCb test of Lepton Flavour Universality in loop-mediated $b \to s\ell^+\ell^-$ decays $\mathcal{R}(K^*)$

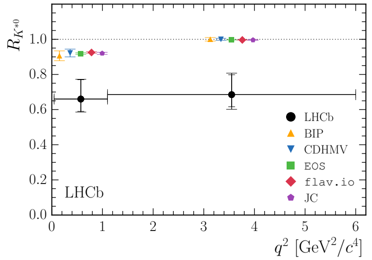
JHEP 08 (2017) 055 $\int \mathcal{L} = 3\ \text{fb}^{-1}$

Fit to the $m(K^+\pi^-\ell^+\ell^-)$ in 2 bins of q^2 ($+J/\psi$ region for normalization).

Different treatment of $\mu\mu$ and ee modes due to differences in reconstruction.



Result:



$\mathcal{R}(K^*) = 0.66\ ^{+\ 0.11}_{-\ 0.07} \pm 0.03$ (low-q^2)

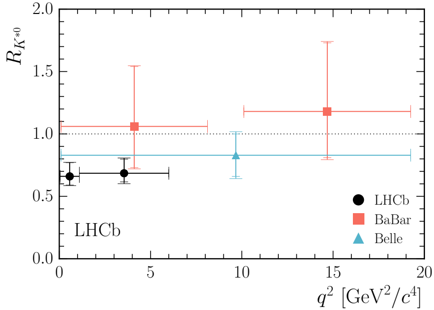
$0.69\ ^{+\ 0.11}_{-\ 0.07} \pm 0.05$ (central-q^2)

Summary: anomalies in loop-mediated $b \to s\ell^+\ell^-$ decays $\mathcal{R}(K^*), \mathcal{R}(K)$

$\mathcal{R}(K^{*0})$

JHEP 08 (2017) 055 $\int \mathcal{L} = 3$ fb^{-1}

transverse and longitudinal decay amplitude

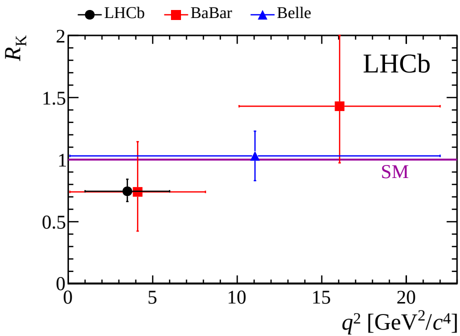


compatibility of LHCb measurement with SM: 2.1-2.3σ (2.4-2.5σ) for the low (central) q^2 bin.

$\mathcal{R}(K^+)$

PRL 113, 151601 (2014) $\int \mathcal{L} = 3$ fb^{-1}

longitudinal decay amplitude only



LHCb: $\mathcal{R}(K^+) = 0.745^{+0.090}_{-0.074} \pm 0.036$

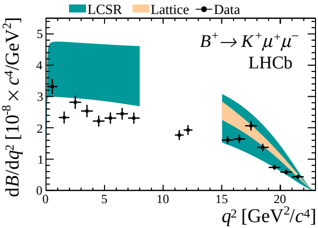
compatibility with SM: 2.6σ.

More to come: updated measurements of $\mathcal{R}(K^+)$ using Run1+2 statistics, new measurement of $\mathcal{R}(K^*)$ using Run2, consider other H_s mesons: K_s, K^{*+}, ϕ ... (also considering $\Lambda_b \to pK\ell\ell$)

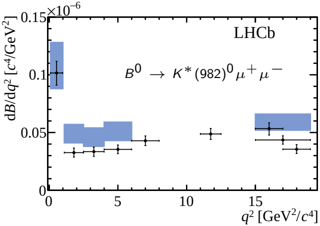
More LHCb anomalies in loop-mediated $b \to s\ell^+\ell^-$ decays

differential Branching ratios of several B^0, B^+ and Λ_b decays

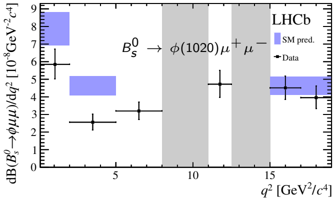
JHEP 06 (2014) 133



JHEP 11 (2016) 047



JHEP09(2015)179



angular analysis of B^0, B^+ and Λ_b decays

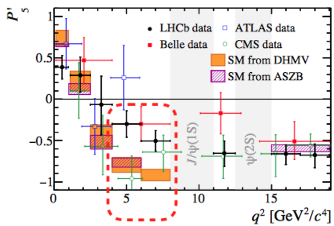
Angular analysis determine P_i' coefficients (ratios of angular coefficients, less sensitive to FF) $\to$ better to compare with theory

Compatibility of LHCb results with SM of 2.8 and 3.0 σ (Local) and 3.4 σ (Global)

Angular analysis of $B_s^0 \to \phi\mu\mu$ JHEP09(2015)179

Angular moments in decays:
$B^0 \to K_{0,2}^*(1430)^0\mu\mu$ JHEP 12 (2016) 065
$\Lambda_b \to \Lambda\mu\mu$ (in progress)

$B^0 \to K^*(982)^0\mu^+\mu^-$



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PRL 118 (2017) 111801

Summary

LHCb has performed several interesting measurements on heavy flavour

- reached a precision on γ of $5-6^{\circ}$ from a combination of measurements using Run1 (+Run2) data
- provide most stringent bounds on $D^0 - \bar{D}^0$ mixing parameters form a single measurement

Superseded any expectations in its capability to test LFU using semileptonic decays $b \to c\ell\nu_\ell$ transitions.

- measurement of $R(D^*)$ in using two τ decay modes (Run1)
- measurement of $R(J/\psi)$ using B_c decays (Run1)

Performed precise measurements of $b \to s\ell\ell$ transitions,

- for tests of LFU – $R(K^*)$ and $R(K)$ (Run1)
- for searches of deviations from the SM – $d\mathcal{B}/dq^2$ and angular analyses

The experimental picture is clearly interesting (hints of anomalies seen) and will soon evolve:

- many analyses are being updated with Run2 statistics
- new decay channels are under study

The evolution will also continue in the future