Review of flavour anomalies

A. Mauri

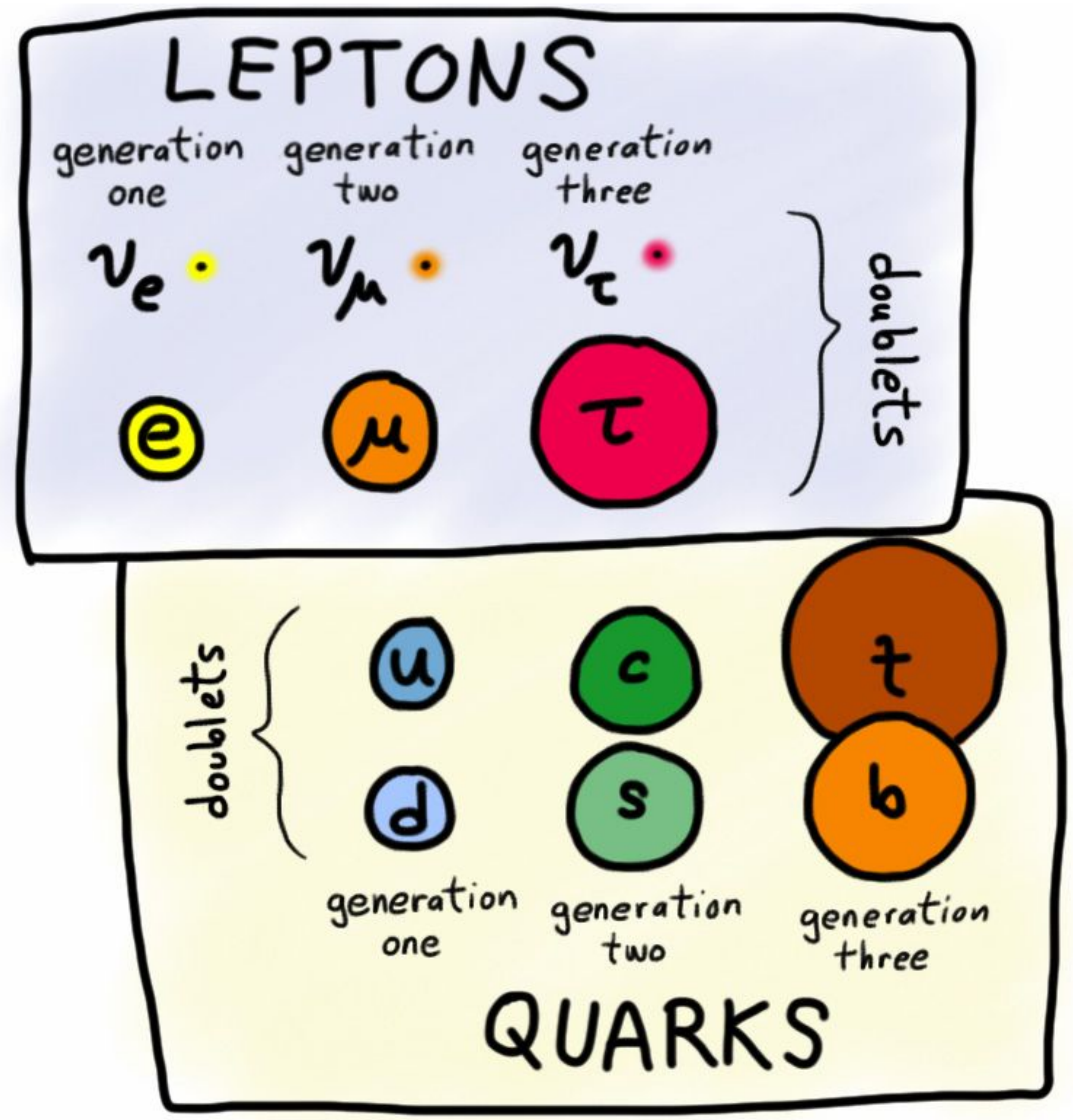
SPS & ÖPG Annual Meeting
27-31 Aug 2019, Zurich

What is flavour?

- **Flavour** is the property that distinguishes the various **fermions** of the Standard Model

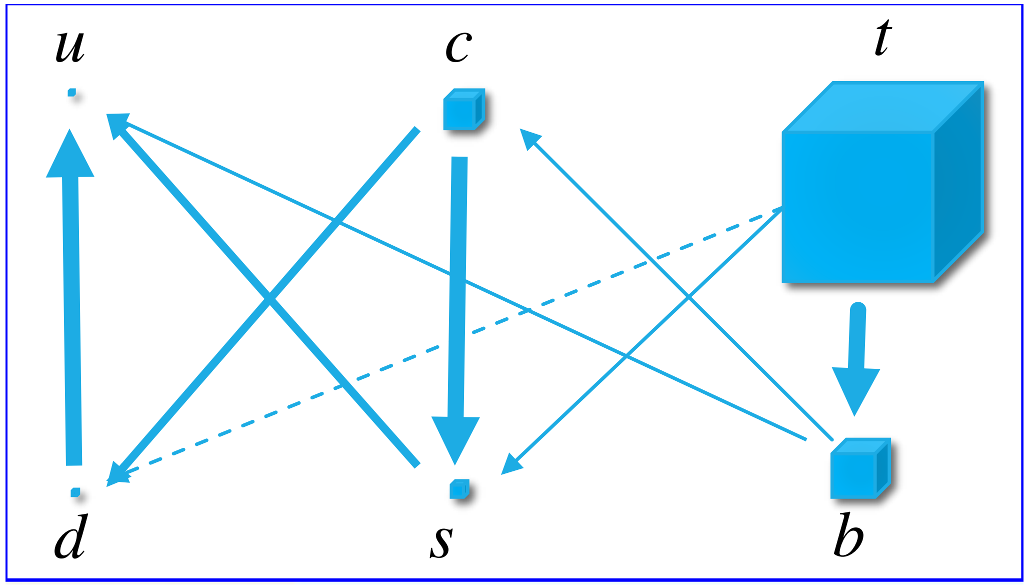
- In the SM, leptons and quarks naturally fit into **three generations** of doublets based on the way they interact with the **weak force**

- Flavour physics studies the **properties** and **interactions** of these particles



Why study flavour?

- ***Flavour puzzle***
  - 20 free parameters in the flavour sector
    - only 5 to characterize gauge interaction and boson masses
  - why 3 generations?
  - what is the origin of their mass hierarchy?
  - what is the origin of hierarchies in the quark mixing?
    - V_{CKM} hierarchical and nearly diagonal



Search for New Physics (NP)

DIRECT vs **INDIRECT**

Direct

- Look for direct production on new particles in high energy collisions (ATLAS, CMS, …)

✓ Unambiguous observation (of New Physics effects)

✗ Mass reach limited by the energy of the collision

Indirect

- Look for NP effects in well predicted flavour observables (LHCb, Belle, …)

✓ Possibility to reach much larger energy scales

✗ Require very clean theoretical predictions

Search for New Physics (NP)

DIRECT VS INDIRECT

- Look for direct production on new particle
(ATLAS

✓ Un
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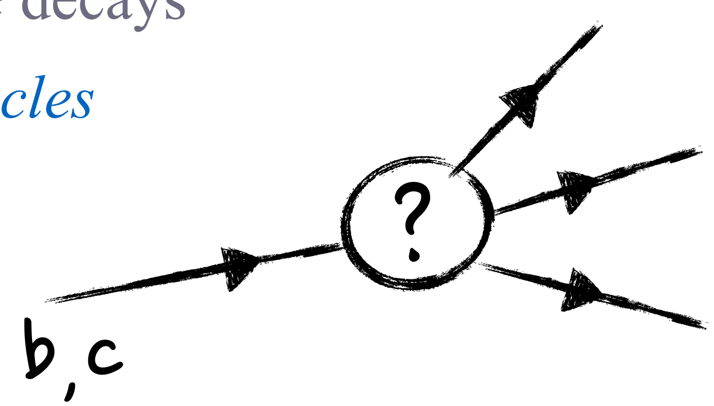
- Look for NP effects in well predicted
Cb, Belle, …)

much larger

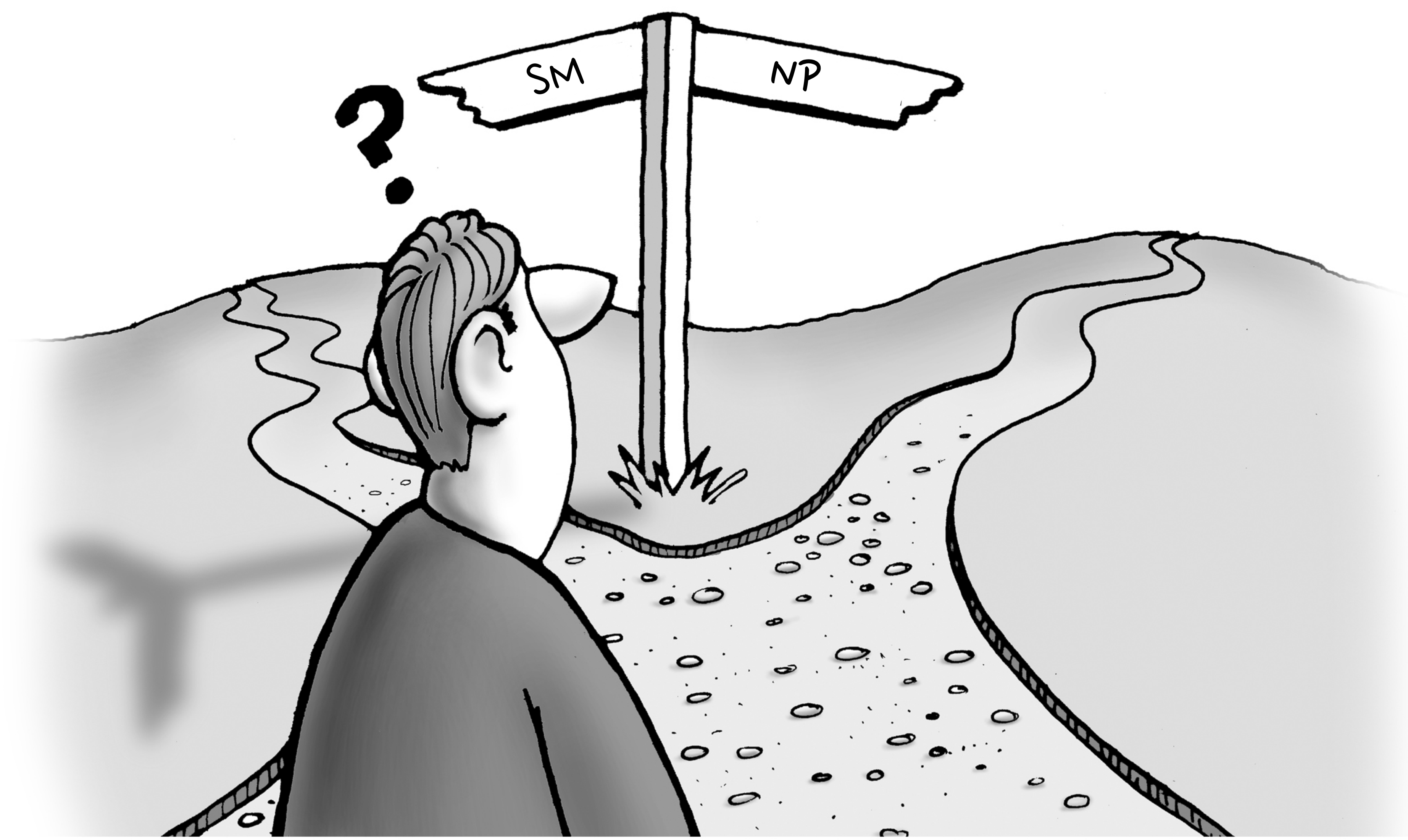
theoretical

Indirect searches in Flavour Physics

- precise measurements of ***b*, *c*** decays
- sensitive to *new virtual particles*



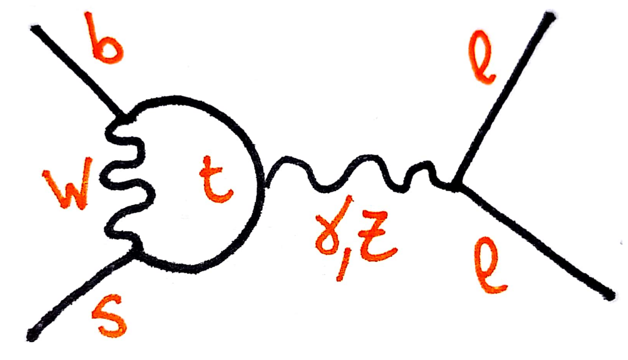
The flavour anomalies...



Flavour anomalies

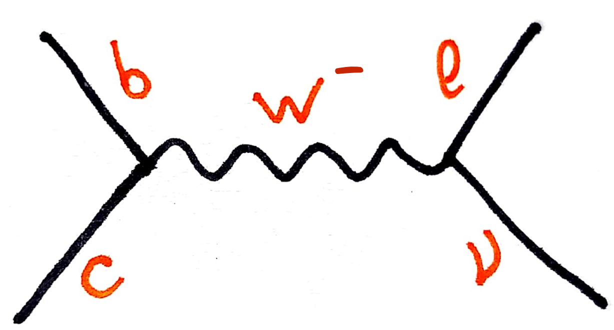
1. $b \to s\ell\ell$ processes
   - Rate and angular distributions of exclusive $b \to s\mu^+\mu^-$ decays
   - Relative rates of $b \to s\mu^+\mu^-$ and $b \to se^+e^-$ decays ($R_{K^{(*)}}$)

NEUTRAL CURRENT



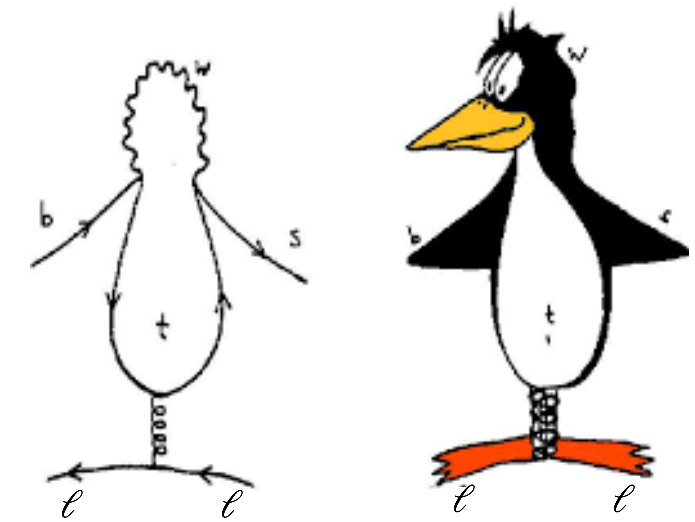
2. $b \to c\tau^-\bar{\nu}_\tau$ decays
   - Relative rates of $b \to c\tau^-\bar{\nu}_\tau$ versus decays with e/μ ($R_{D^{(*)}}$)

CHARGED CURRENT

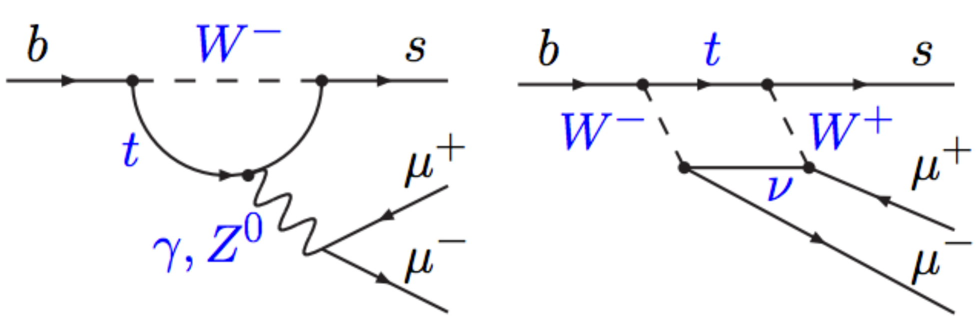


Why rare b decays?

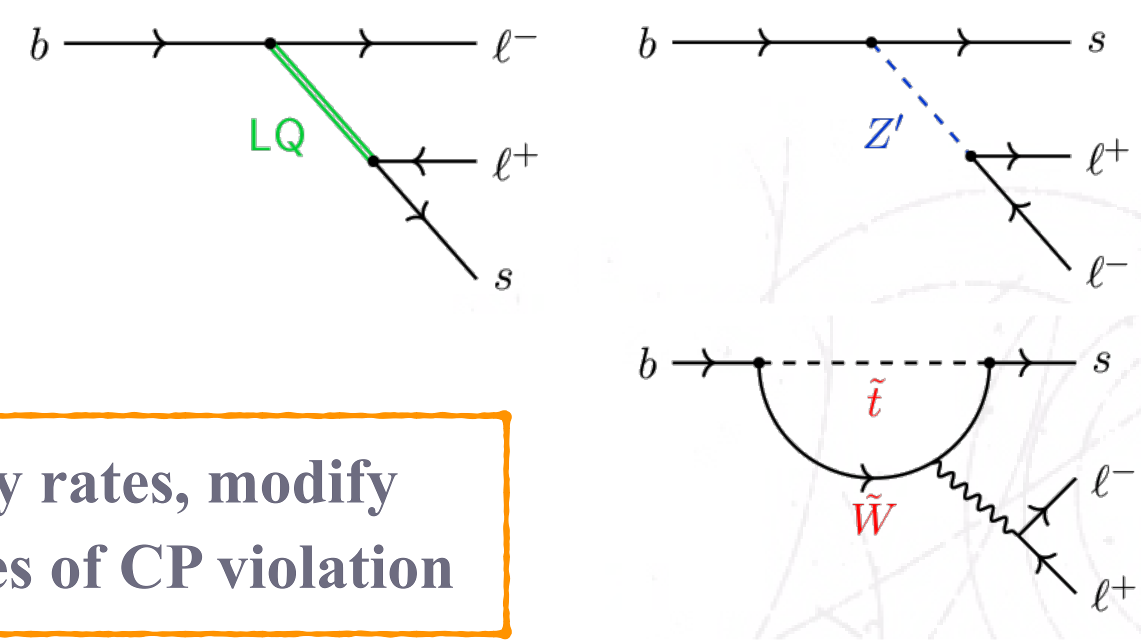
- $b \to s\ell\ell$ transitions are powerfull probes of New Physics
  - FCNC proceeding via loop diagrams only (“penguin" or box)
  - suppressed in the SM, more sensitive to New Physics



SM



NP



New particles could enhance/suppress decay rates, modify angular distributions, introduce new sources of CP violation

Theory formalism

- Low-energy processes (B decays) can be described by an **effective theory:**

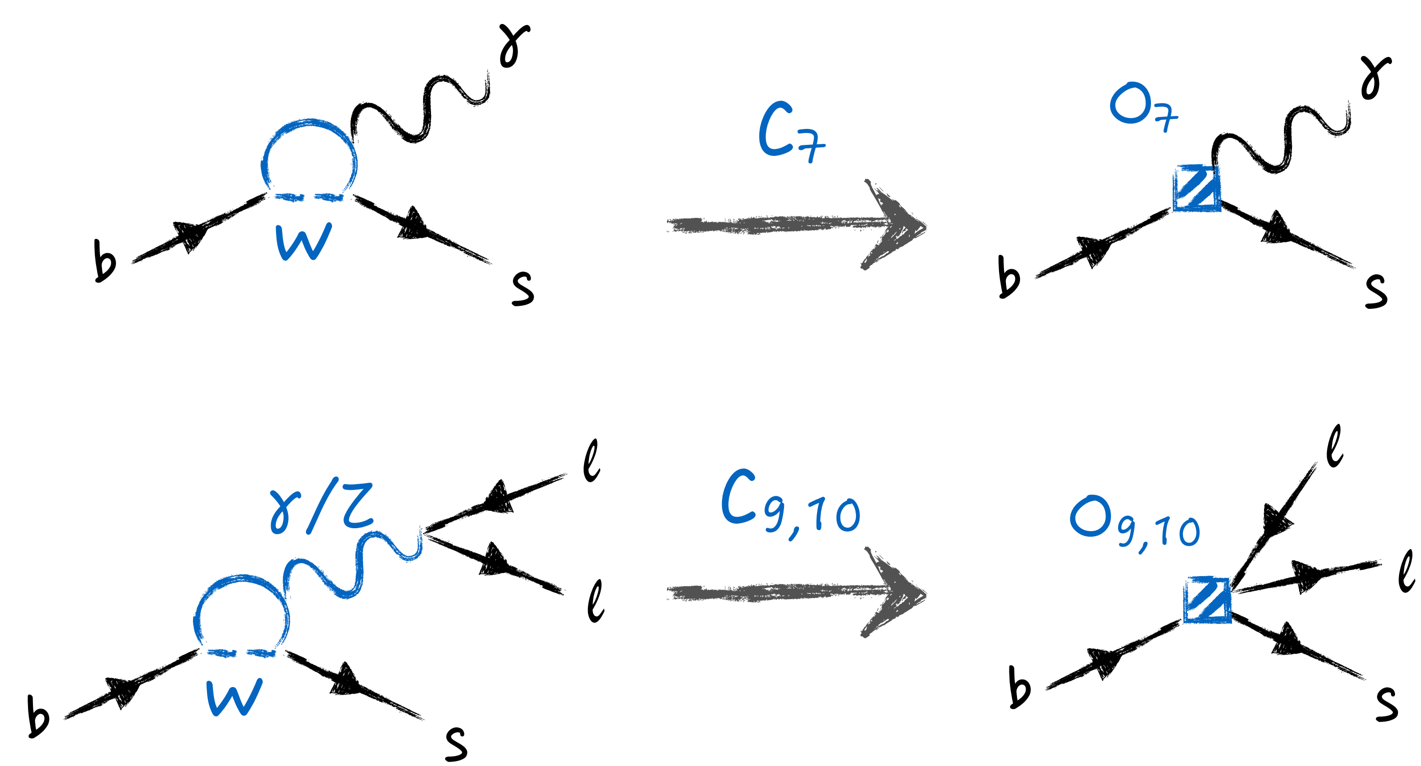
$$\mathcal{H}_{eff} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i \mathcal{C}_i \mathcal{O}_i$$

Wilson coefficients (*effective couplings*) → $\mathcal{C}_i$

Local operators → $\mathcal{O}_i$

- New Physics can contribute to different Wilson coefficients (or introduce new operators) depending on its Lorentz structure

$$\mathcal{C}_i = \mathcal{C}_i^{\mathrm{SM}} + \mathcal{C}_i^{\mathrm{NP}}$$



$B_{s,d} \to \mu^+\mu^-$ decays

- One of the golden channel to look for NP
  - helicity suppressed
  - $\mathcal{B}(B_s^0 \to \mu^+\mu^-) \propto |C_{10} - C'_{10}|^2$

- Precise SM prediction

  C. Bobeth et al. PRL 112, 101801 (2014)

  $$BR(B_s \to \mu^+\mu^-)_{SM} = (3.65 \pm 0.23) \times 10^{-9}$$

  $$BR(B^0 \to \mu^+\mu^-)_{SM} = (1.06 \pm 0.09) \times 10^{-10}$$

- Latest LHCb result uses Run1 + 1.4 fb^{-1} (Run2)

  $\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.0 \pm 0.6\,^{+0.3}_{-0.2}) \times 10^{-9}$ **7.8σ**

  $\mathcal{B}(B^0 \to \mu^+\mu^-) < 3.4 \times 10^{-10}$ at 90% CL **1.9σ**

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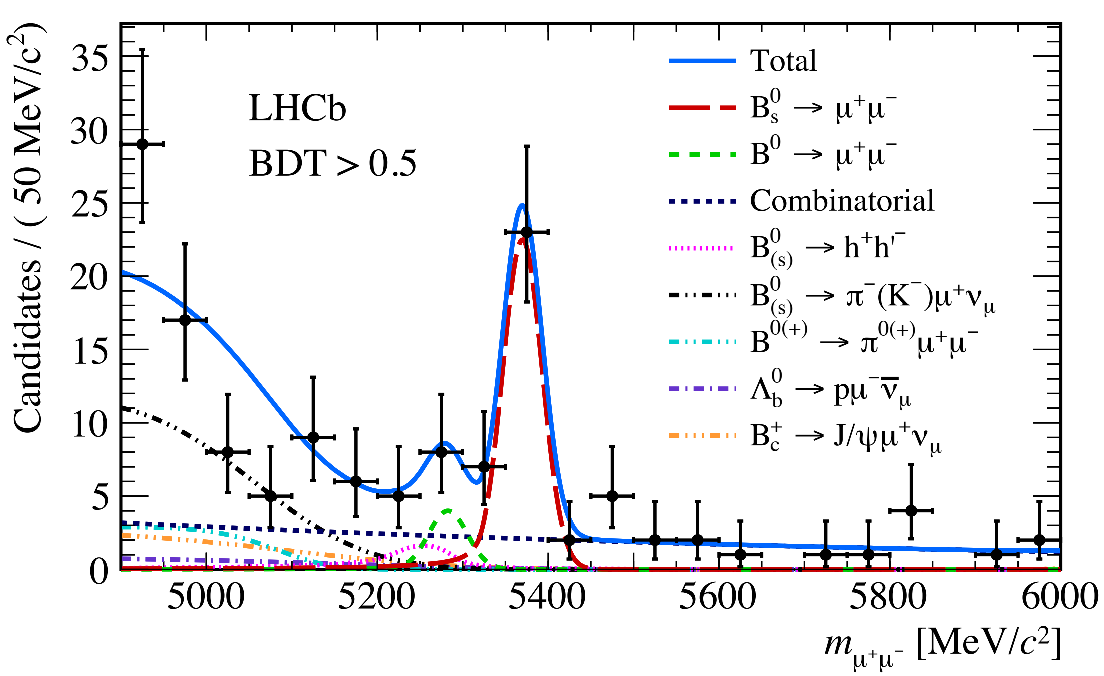
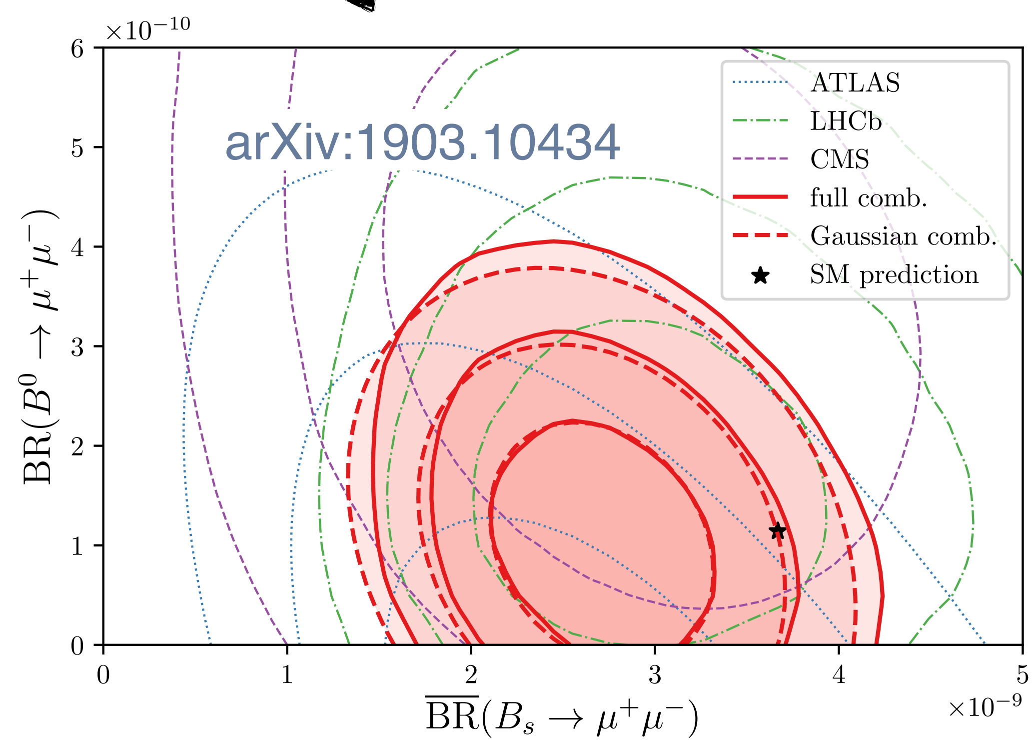
compatible with SM

PRL 118 (2017) 191801





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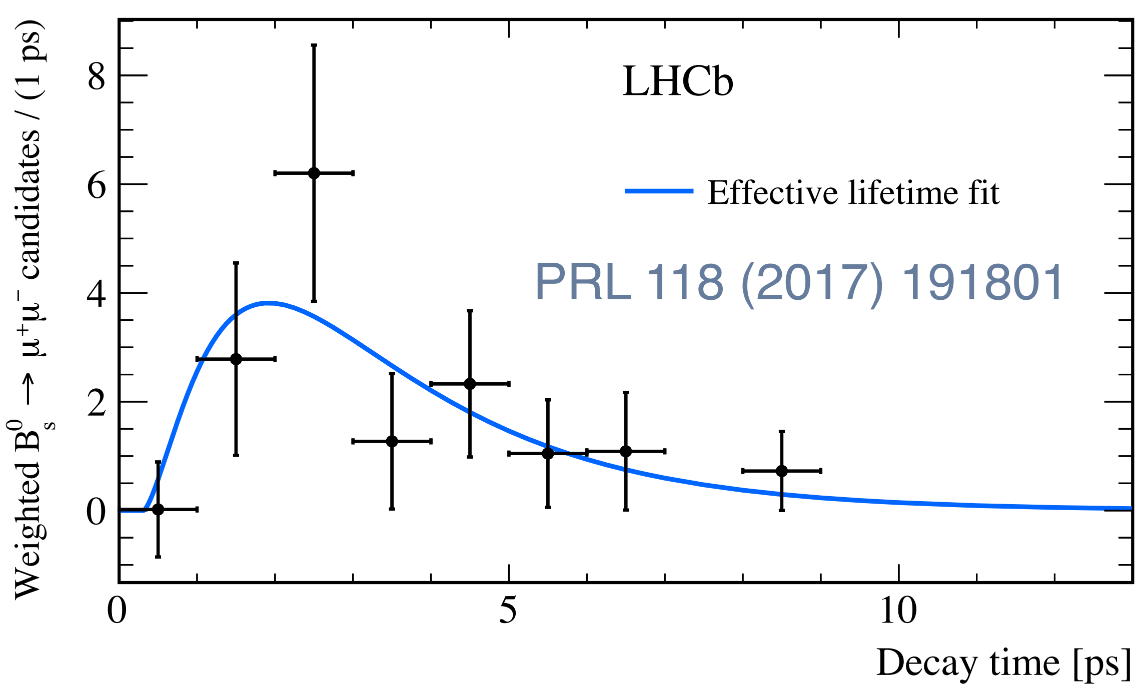
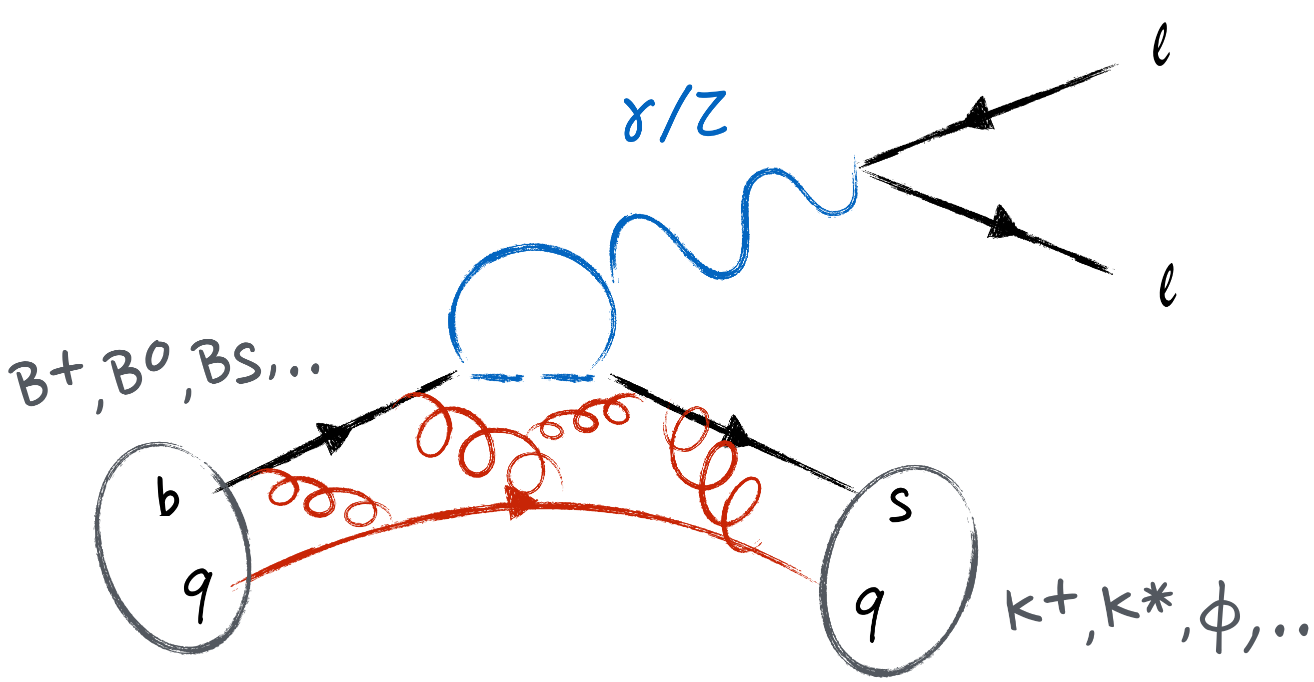
- First measurement of the effective lifetime
  - provides complementary constraints on NP models
  - $\tau_{eff}(B_s^0 \to \mu^+\mu^-) = (2.04 \pm 0.44 \pm 0.05)$ ps



$b \to s\ell^+\ell^-$ decays

- In experiments, we observe **hadronic decays**, not the quark-level transition



- Needs to compute hadronic matrix elements
  - Non-perturbative QCD, difficult to compute

Great variety of observables

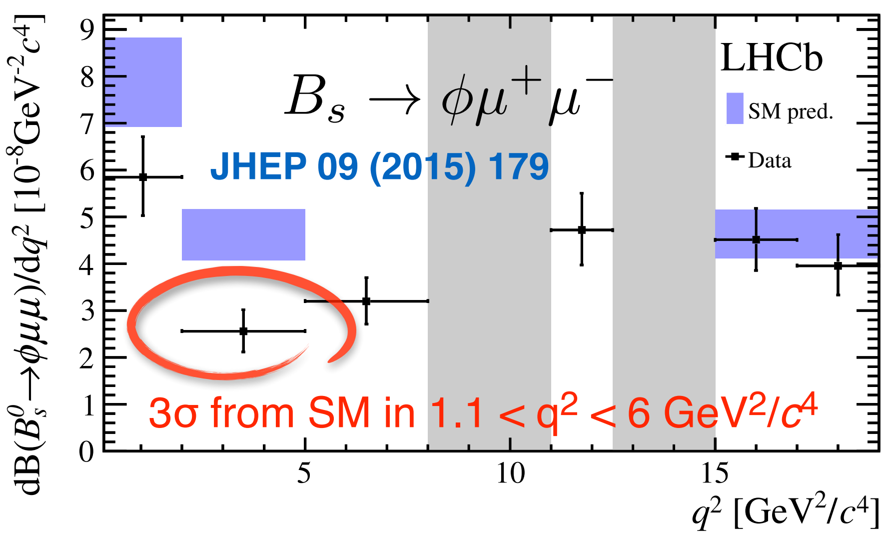
DIRTY

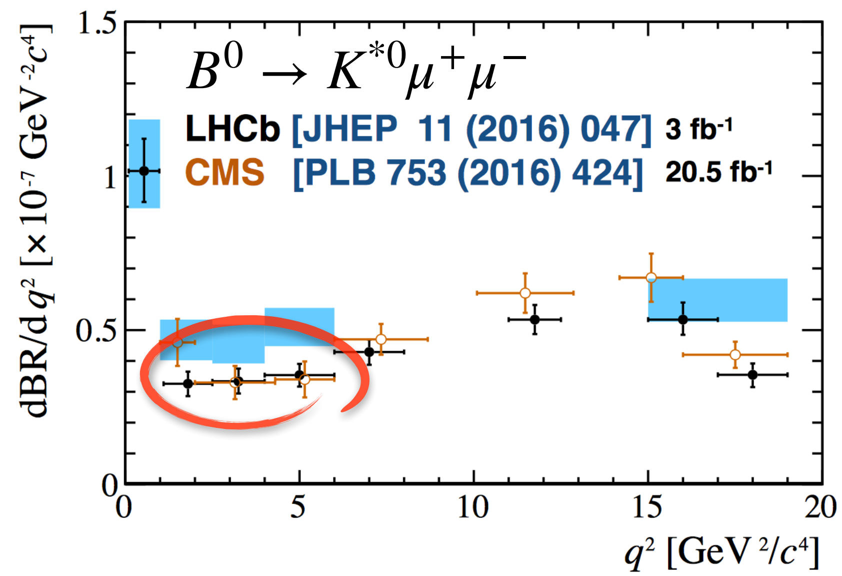
- Branching ratios: **large** theory uncertainties
- Angular observables: **reduced** theory uncertainties
- Lepton Flavour Universality tests (ratio of BR, etc.): **clean**, uncertainties cancels

CLEAN

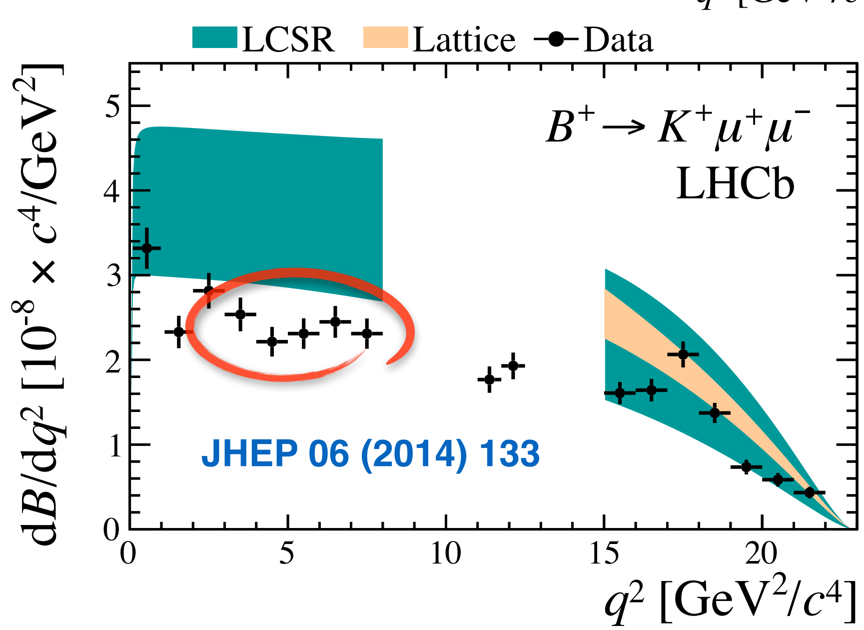
Branching fractions too low in $b \to s\mu^+\mu^-$?

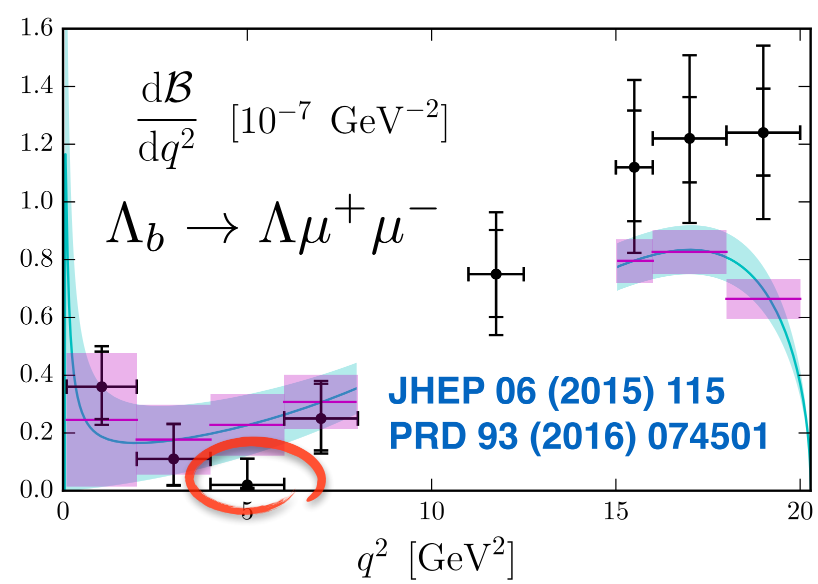
Measured BR are consistently lower than predicted in SM





q^2: squared di-lepton invariant mass

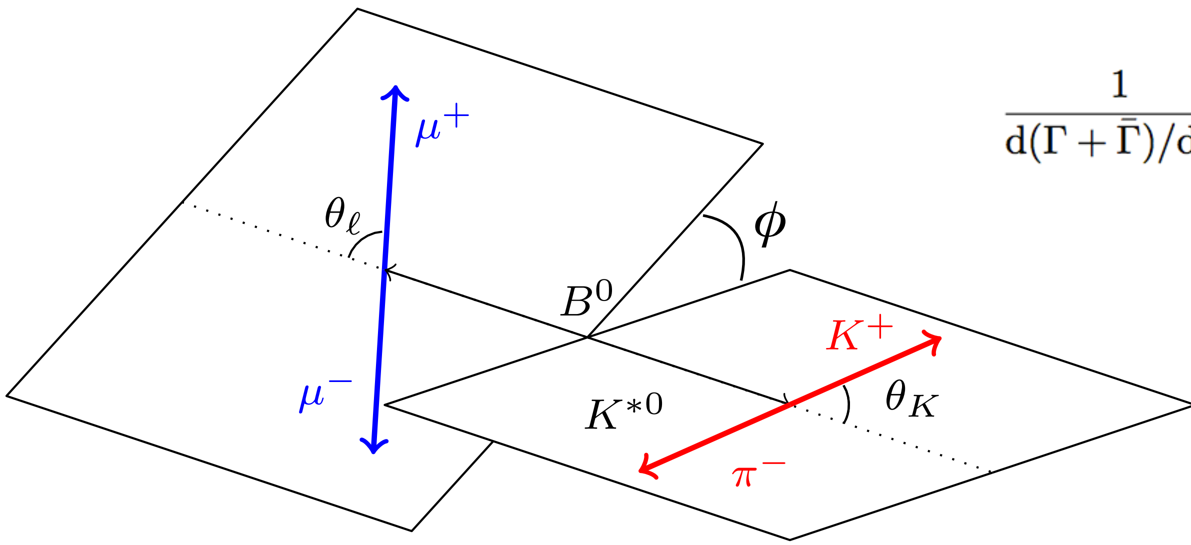




though SM suffers from large uncertainties…

$B \to K^* \mu\mu$ angular analysis

- Study the angular distribution of the 4 final state particles ($\cos\theta_\ell, \cos\theta_K, \phi$) in $B^0 \to K^{*0}\mu\mu$



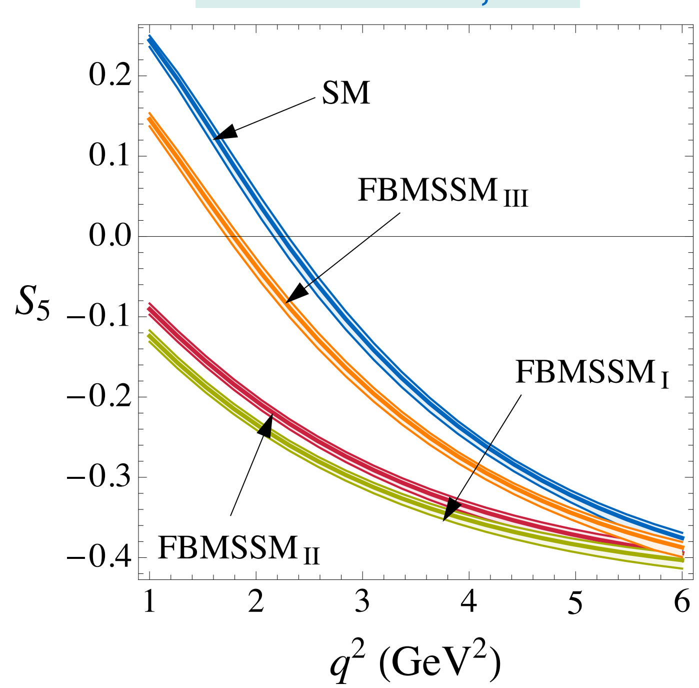
F_L: fraction of longitudinal polarization of the K*

$$\frac{1}{d(\Gamma+\bar{\Gamma})/dq^2}\frac{d^4(\Gamma+\bar{\Gamma})}{dq^2\, d\vec{\Omega}} = \frac{9}{32\pi}\Big[\frac{3}{4}(1-F_L)\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1}{4}(1-F_L)\sin^2\theta_K\cos 2\theta_l - F_L\cos^2\theta_K\cos 2\theta_l + S_3\sin^2\theta_K\sin^2\theta_l\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_l\cos\phi + S_5\sin 2\theta_K\sin\theta_l\cos\phi + \frac{4}{3}A_{FB}\sin^2\theta_K\cos\theta_l + S_7\sin 2\theta_K\sin\theta_l\sin\phi + S_8\sin 2\theta_K\sin 2\theta_l\sin\phi + S_9\sin^2\theta_K\sin^2\theta_l\sin 2\phi\Big]$$

A_{FB}: forward-backward asymmetry of the dilepton system

- A lot of information contained in the angular distributions

JHEP 0901:019,2009



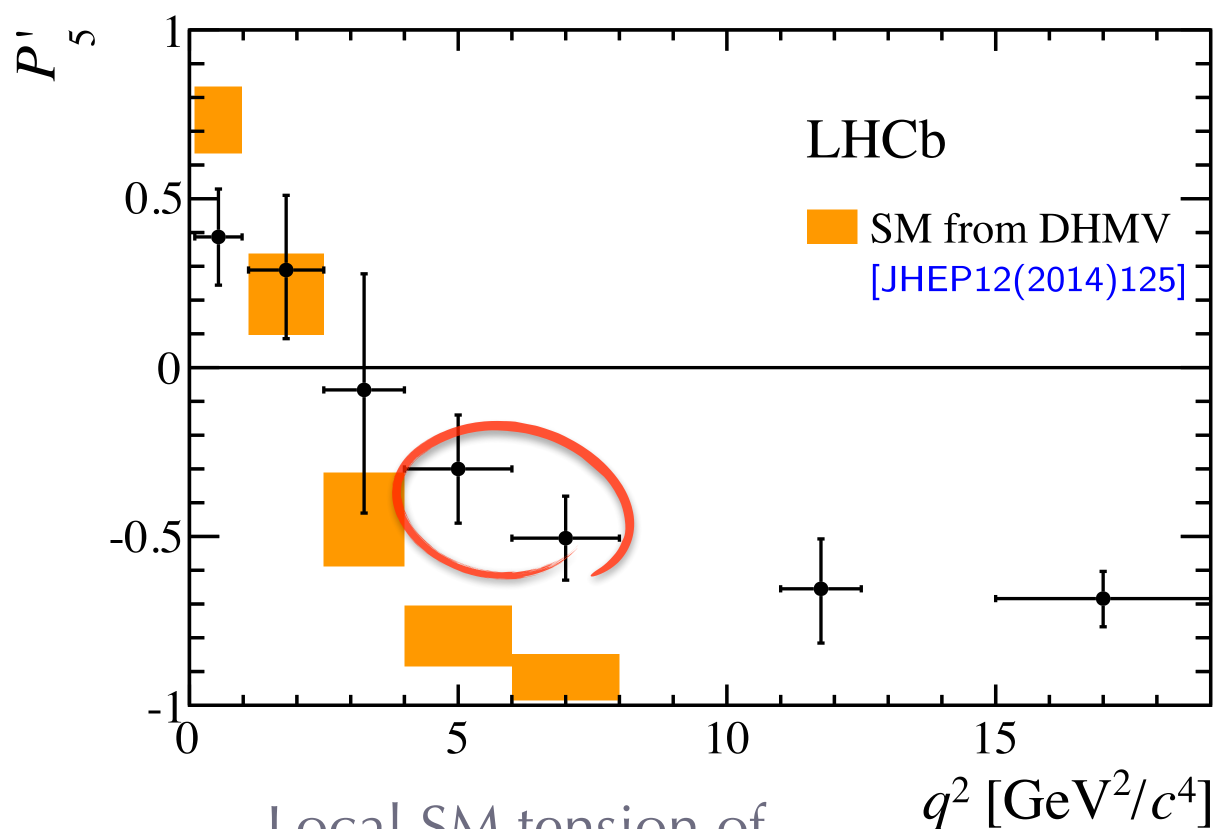
Form factor "free" observables

Optimized basis

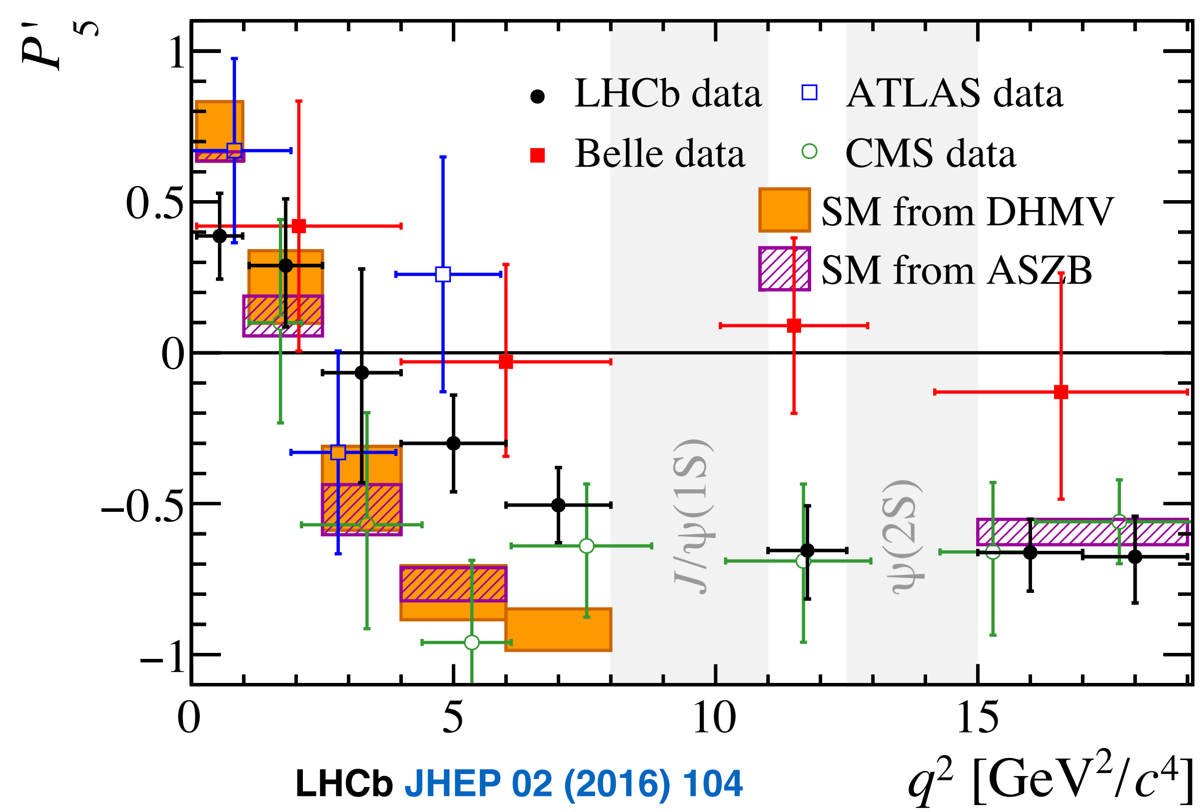
$$P_5' = \frac{S_5}{\sqrt{F_L(1-F_L)}}$$

→ reduced theoretical uncertainty

Descotes-Genon et al. [JHEP 04 (2012) 104]



Local SM tension of
2.8 and 3.0 σ
Global → 3.4 σ

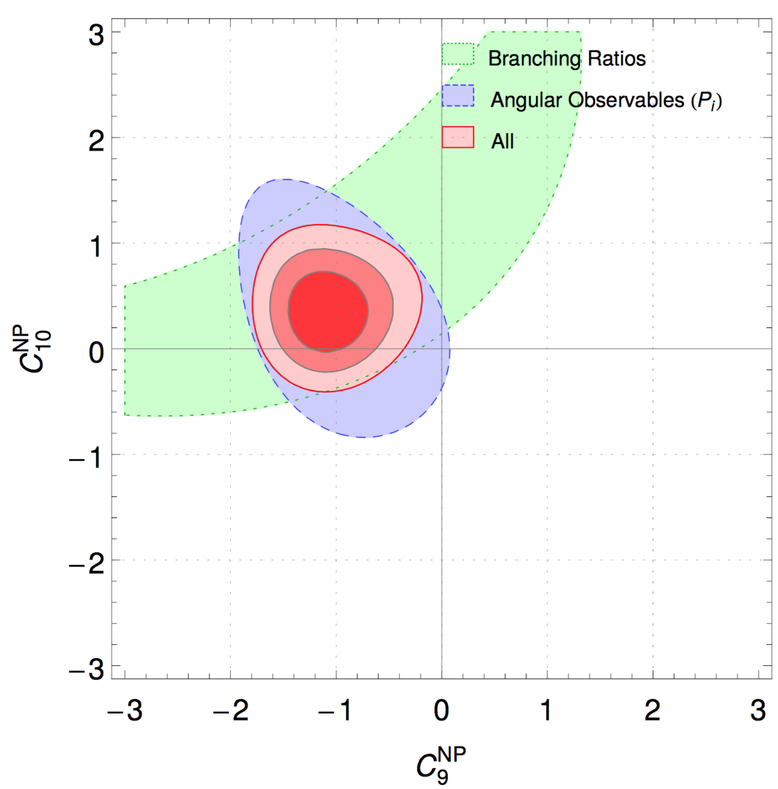


LHCb JHEP 02 (2016) 104
BELLE PRL 118 (2017)
ATLAS ATLAS-CONF-2017-023
CMS PLB 781 (2018) 517541

Theory uncertainty

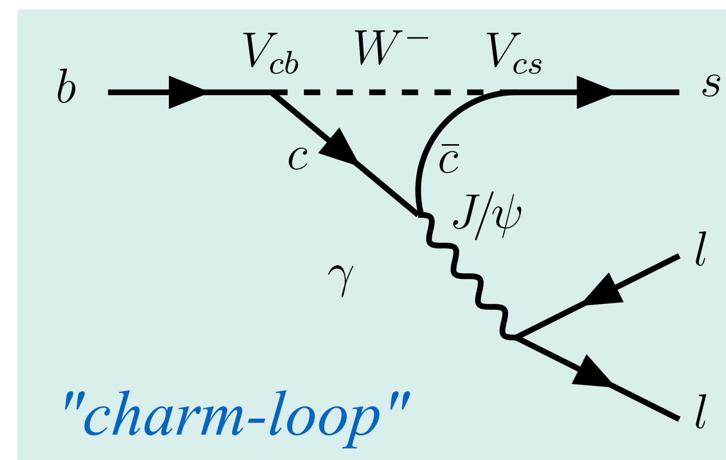
JHEP 05, 043 (2013)
PRD 93, 014028 (2016)
JHEP 06, 116 (2016)

- Both branching ratios and P_5' discrepancies can be explained with a shift in C_9 (or C_9 and C_{10})



[JHEP06 (2016) 092]

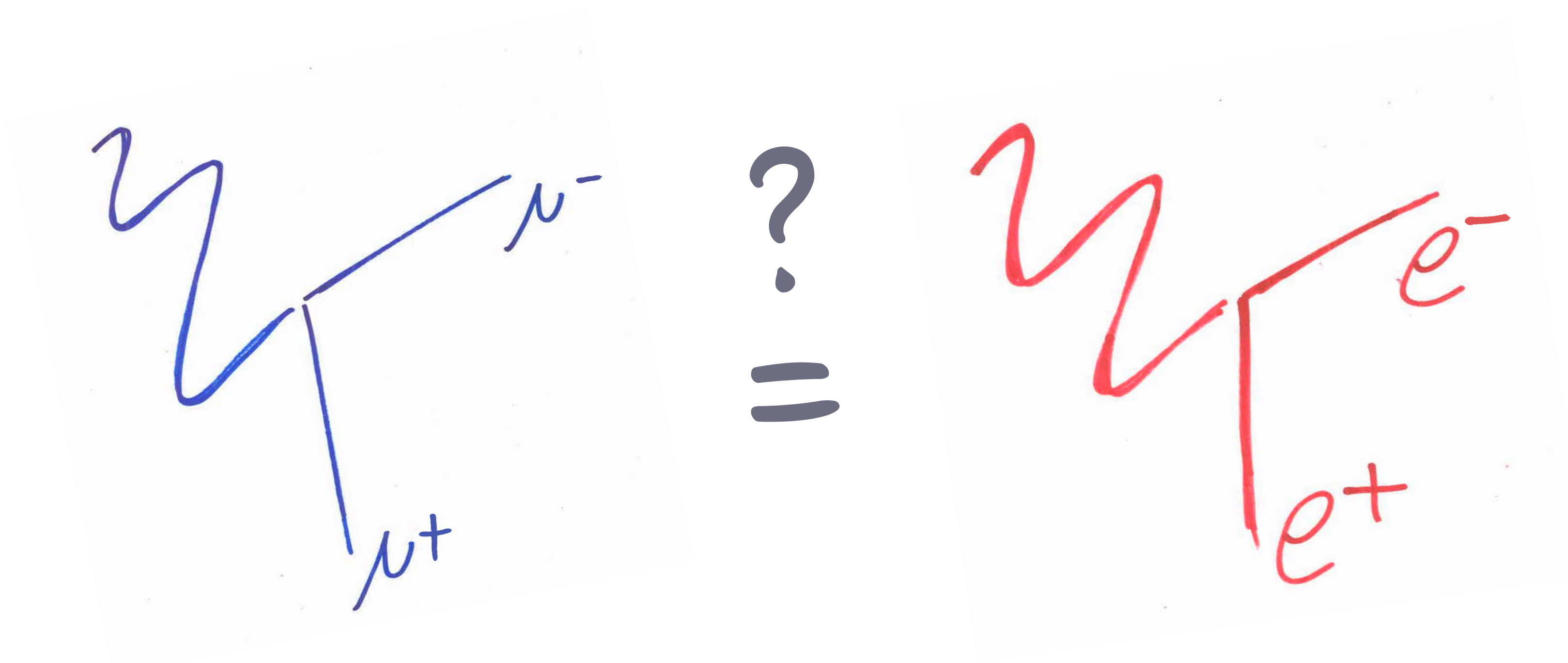
Be aware of <u>long-distance</u> effects



✓ removed by mass cuts
✗ interferes elsewhere
✗ difficult to access reliably

- Long debate in the community if these effect can be interpreted as NP or must be attributed to charm loop

Lepton Flavour Universality (LFU)
test in rare decays



LFU in rare decays

- SM implies ***Lepton Flavour Universality***
  - Different lepton generations **couple identically** to SM processes
  - Only difference mass $\longrightarrow$ phase space
- Ratios of the form

$$R_{K^{(*)}} = \frac{\mathcal{B}(B \to K^{(*)}\mu^+\mu^-)}{\mathcal{B}(B \to K^{(*)}e^+e^-)} \overset{\text{SM}}{=} 1 \pm \mathcal{O}(10^{-2})$$

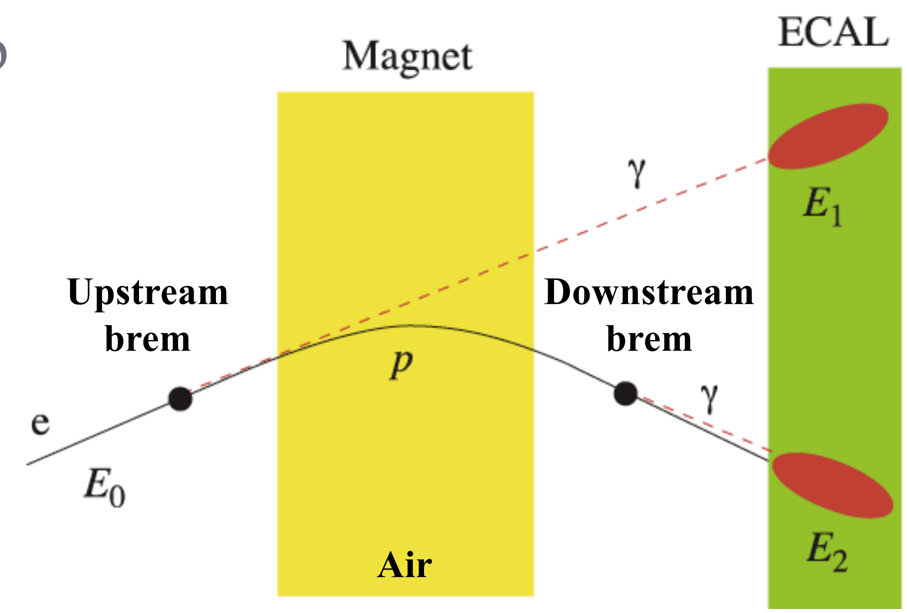
EPJ C76 (2016) 8 440

$\longrightarrow$ Free from QCD uncertainties

Lepton non-universality would be a clear sign of NP

Experimental double ratio

- Electrons and muons behave very differently in LHCb due to large bremsstrahlung radiation for electrons:
  - worse B mass and q^2 resolution
  - low reconstruction efficiency
  - selected in 3 different trigger categories (electron, hadron, TIS)



- LFU experimentally measured as double ratio:

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

most of the systematics cancel out

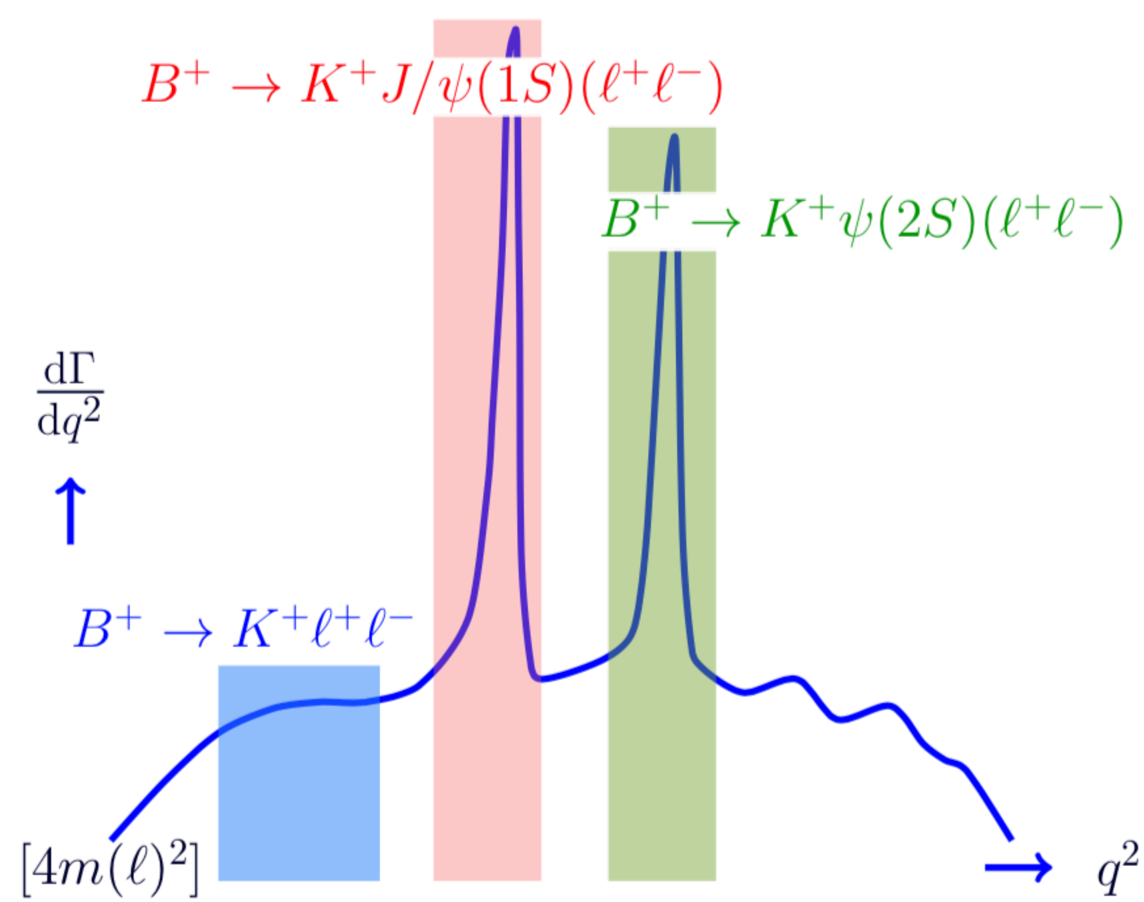
- Status LHCb Run1:
  - $R_K = 0.745^{+0.090}_{-0.074}\,(\mathrm{stat}) \pm 0.036\,(\mathrm{syst})$
  - $R_{K^{*0}} = \begin{cases} 0.66^{+0.11}_{-0.07} \pm 0.03 & \text{for } 0.045 < q^2 < 1.1 \ \mathrm{GeV}^2 \\ 0.69^{+0.11}_{-0.07} \pm 0.05 & \text{for } 1.1 < q^2 < 6.0 \ \mathrm{GeV}^2 \end{cases}$

This year updated with 2015 & 2016 datasets (roughly double the statistics)

Efficiency calibration

- Key ingredients:
  - Yields determined from a fit to the invariant mass
  - Efficiency computed with MC simulation calibrated on control channels in data

- Efficiency calibration makes extensive use of $B^+ \to K^+ J/\psi(\ell^+\ell^-)$ and $B^+ \to K^+ \psi(2S)(\ell^+\ell^-)$ decays
  - resonant and non-resonant modes are separated in q^2
  - however, good overlap in the variables relevant for detector response



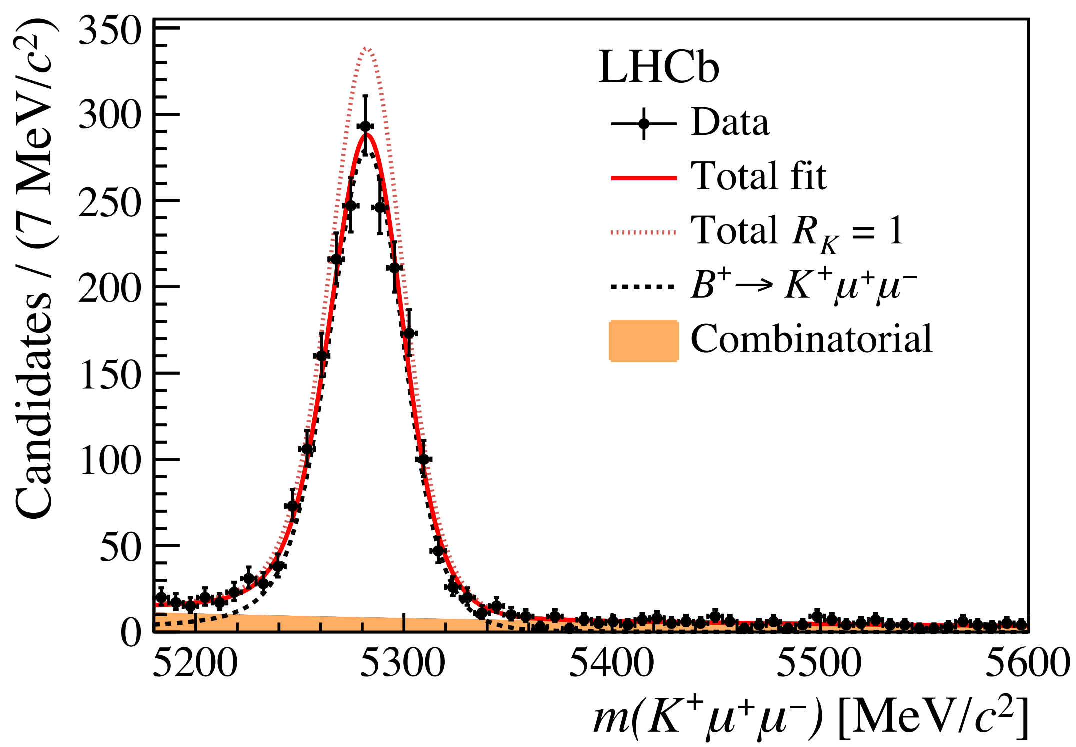
R_K measurement

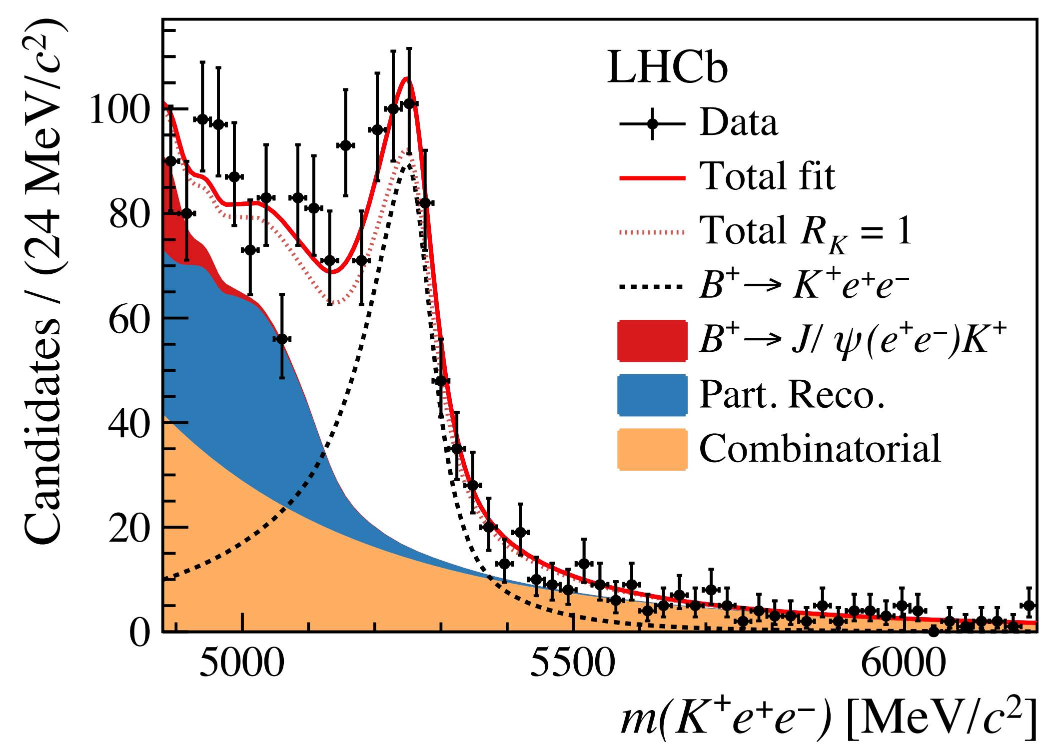
- Simultaneous fit to m($K\mu\mu$) and m(Kee) to extract R_K

Phys. Rev. Lett. 122, 191801 (2019)

$B^+ \to K^+\mu^+\mu^-$ ($N_{sig} \sim 1940$)

$B^+ \to K^+e^+e^-$ ($N_{sig} \sim 760$)

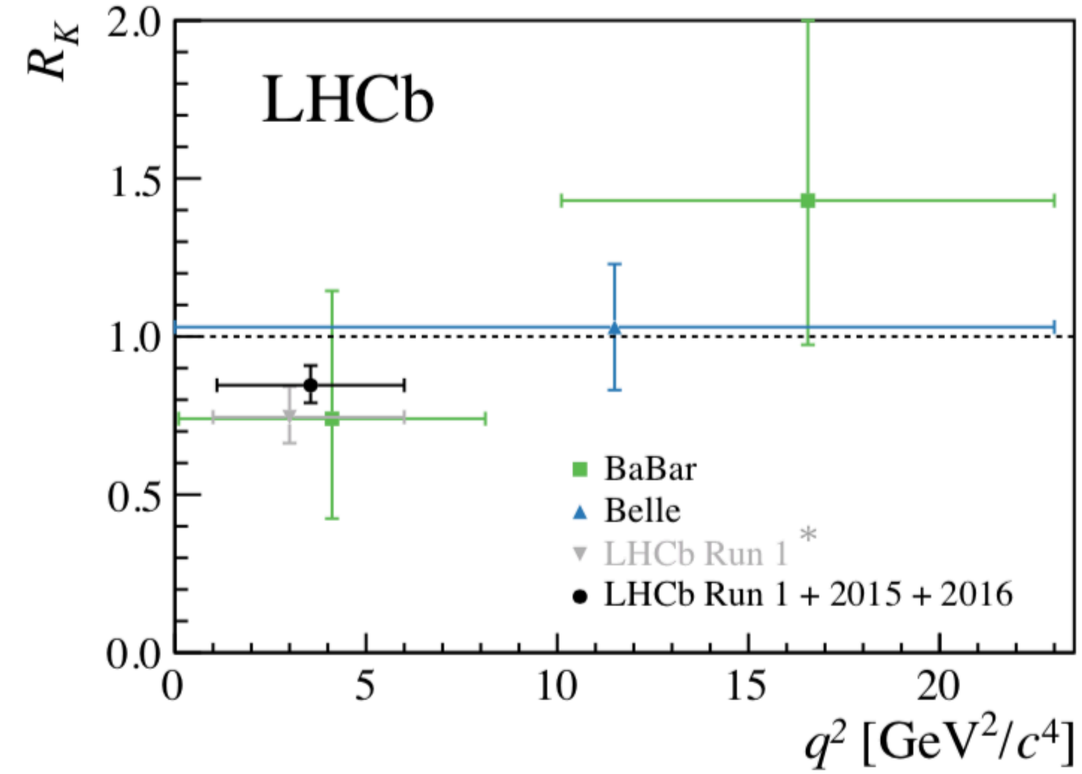




$$R_K = 0.846\,^{+0.060}_{-0.054}\,(\text{stat})\,^{+0.014}_{-0.016}\,(\text{syst})$$

R_K measurement: overview

- LHCb updated R_K measurement
  - re-analysing 2011-2012 data
  - adding 2015-2016 data



$$R_{K\ \mathrm{Run1}}^{\mathrm{new}} = 0.717\ ^{+0.083}_{-0.071}\,(\mathrm{stat})\ ^{+0.017}_{-0.016}\,(\mathrm{syst})$$

$$R_{K\ \mathrm{Run2}} = 0.928\ ^{+0.089}_{-0.076}\,(\mathrm{stat})\ ^{+0.020}_{-0.017}\,(\mathrm{syst})$$

$$\longrightarrow\quad R_K = 0.846\ ^{+0.060}_{-0.054}\,(\mathrm{stat})\ ^{+0.014}_{-0.016}\,(\mathrm{syst})$$

1.9 sigma compatibility between Run1 and Run2

Combined 2.5 sigma from SM prediction

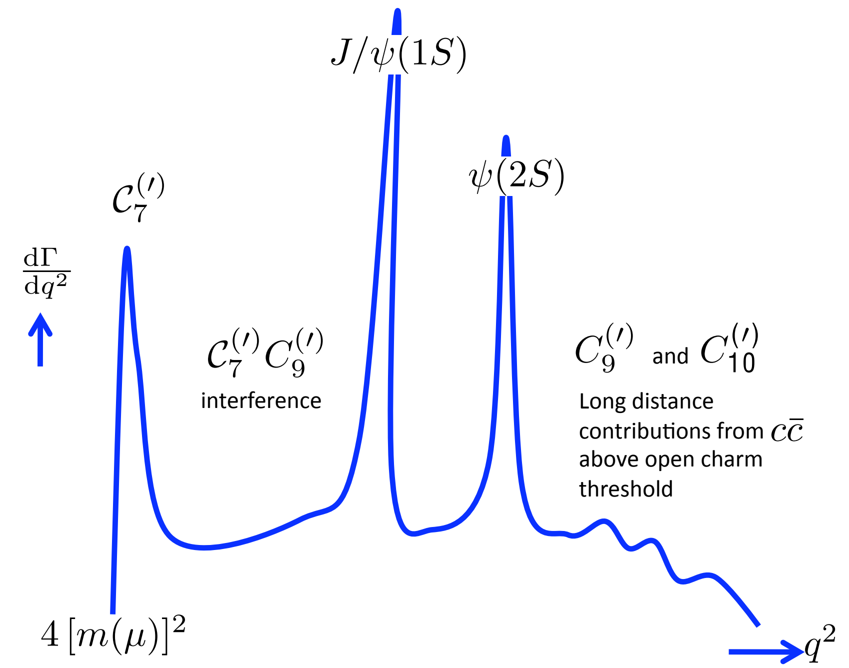
- $\mathcal{B}(B^+ \to K^+ e^+ e^-)$ compatible with SM for all years

LFU test in $B^0 \to K^*\ell^+\ell^-$ decays

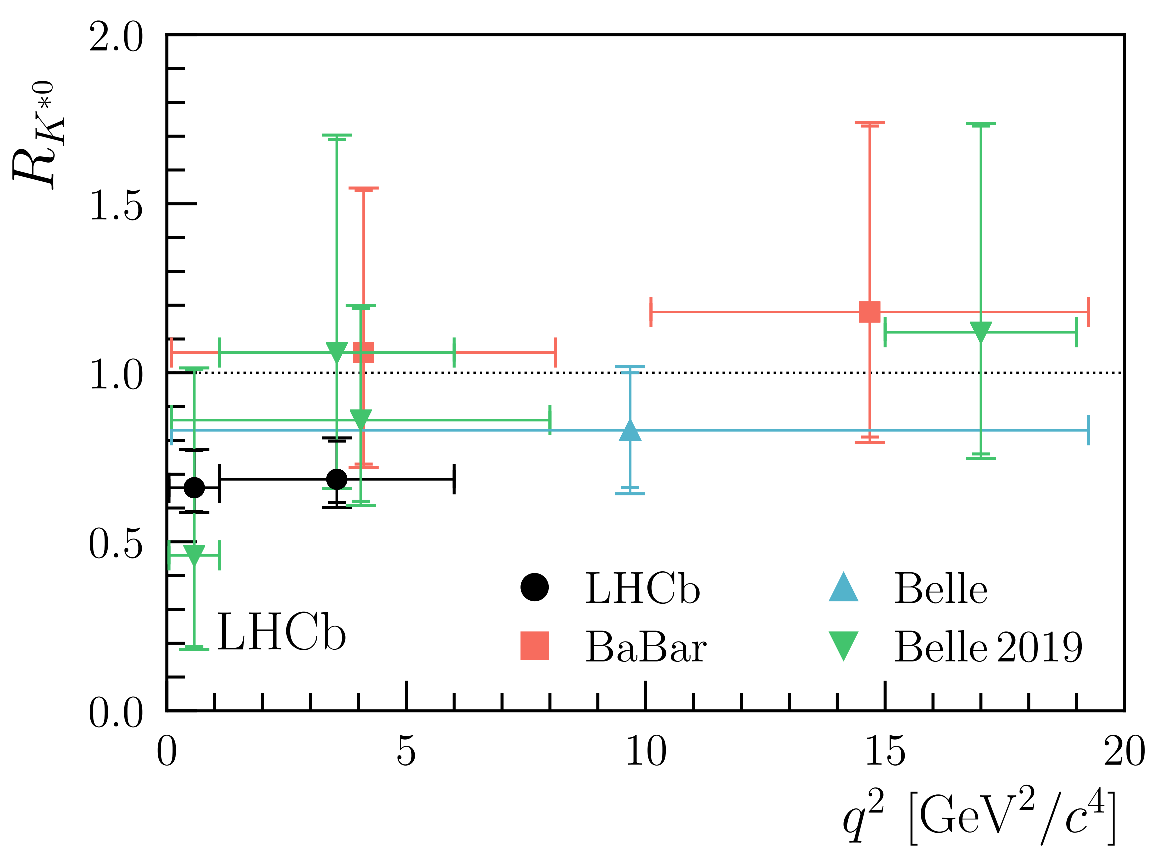
- LHCb Run 1: [JHEP 08 (2017) 055]

$$R_{K^{*0}} = \begin{cases} 0.66^{+0.11}_{-0.07} \pm 0.03 & \text{for } 0.045 < q^2 < 1.1 \ \text{GeV}^2 \\ 0.69^{+0.11}_{-0.07} \pm 0.05 & \text{for } 1.1 \quad < q^2 < 6.0 \ \text{GeV}^2 \end{cases}$$

- 2.1 (2.4) σ tension with the SM

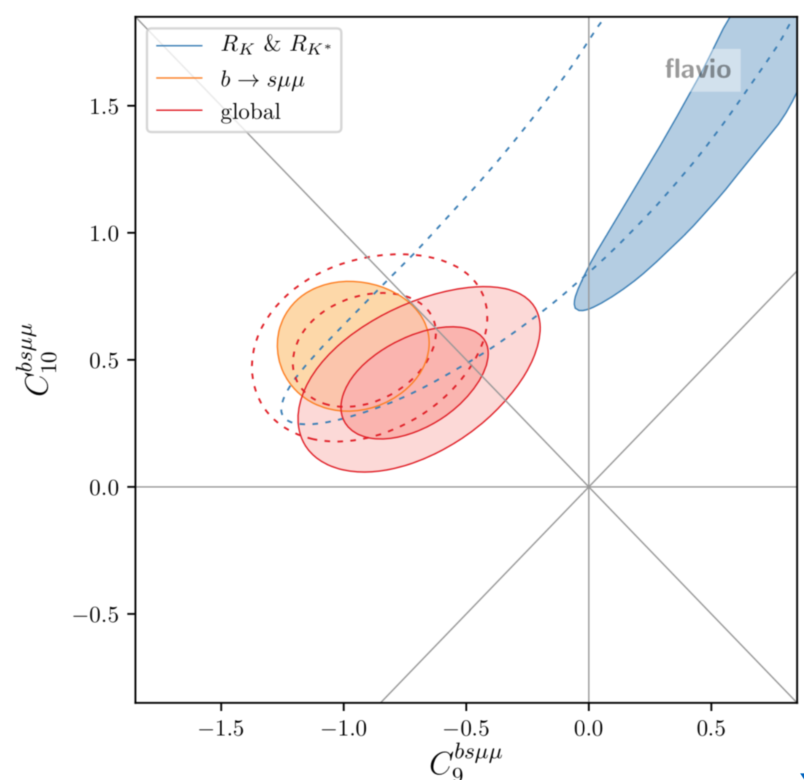


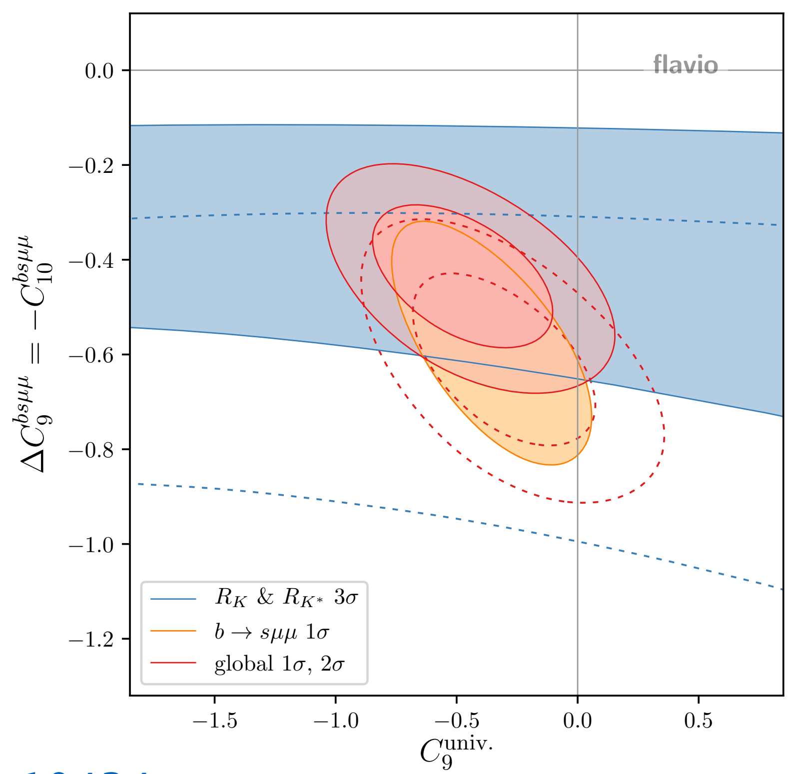
- Belle recently updated measurement of R_{K^*}
  [arXiv:1904.02440]



Impact on global fits

- After R_K update LFU measurements slightly moved away from common solution with $b \to sll$ anomalies
  - NP universal contribution to C_9…?

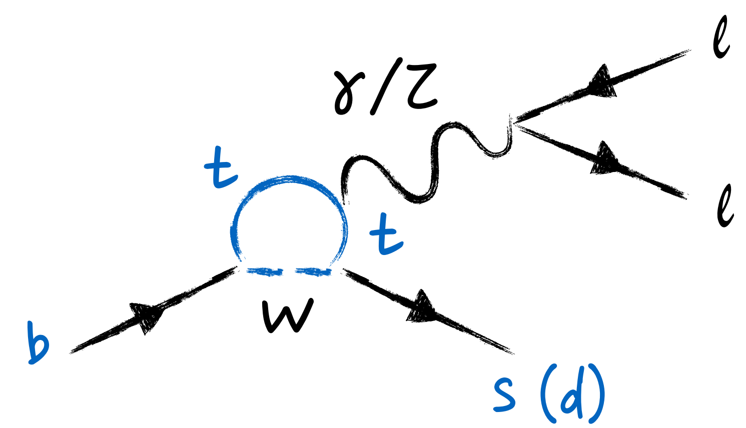




arXiv:1903.10434

What about $b \to dll$ transitions?

- $b \to dll$ is **Cabibbo suppressed** respect to $b \to sll$ (~25 times smaller)
- Similar but **complementary** information
  - allow V_{td} / V_{ts} measurement
  - test Minimal Flavour Violation hypothesis
- **Very rare processes**, on the brink of observation

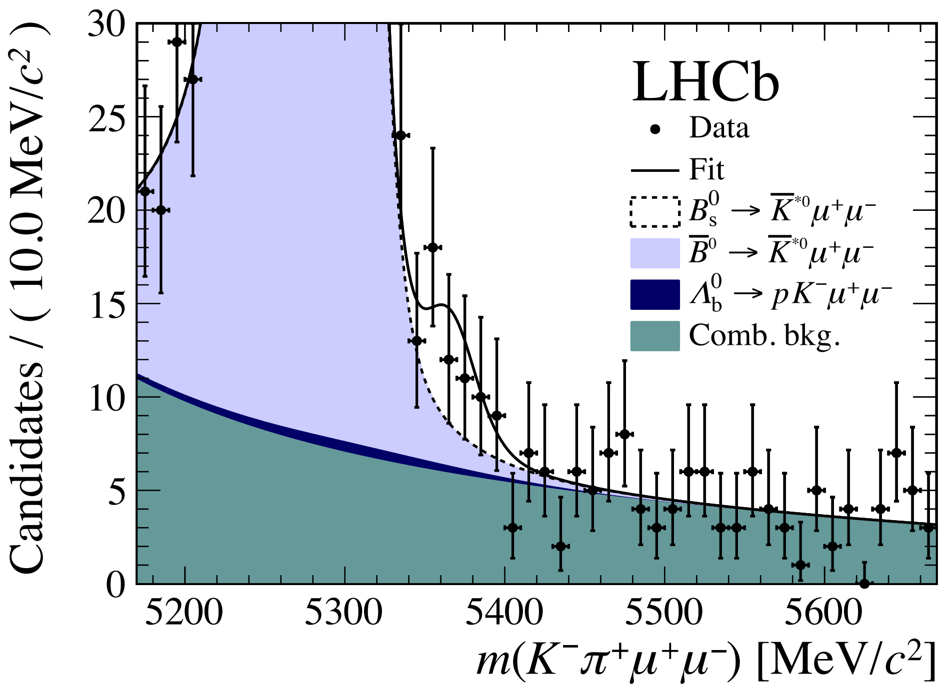


Evidence for the decay $B_s^0 \to \overline{K}^{*0} \mu^+ \mu^-$

- equivalent to $B^0 \to K^* \mu^+ \mu^-$
- **First evidence: 3.4σ with 4.6 fb^{-1}**
  - 38 ± 12 candidates (4200 $B^0 \to K^* \mu^+ \mu^-$)
- $\mathcal{B} = (2.9 \pm 1.0 \pm 0.2 \pm 0.3) \times 10^{-8}$

Too little data to say anything about q^2 or angular distributions

JHEP07(2018)020



Near future for rare decays

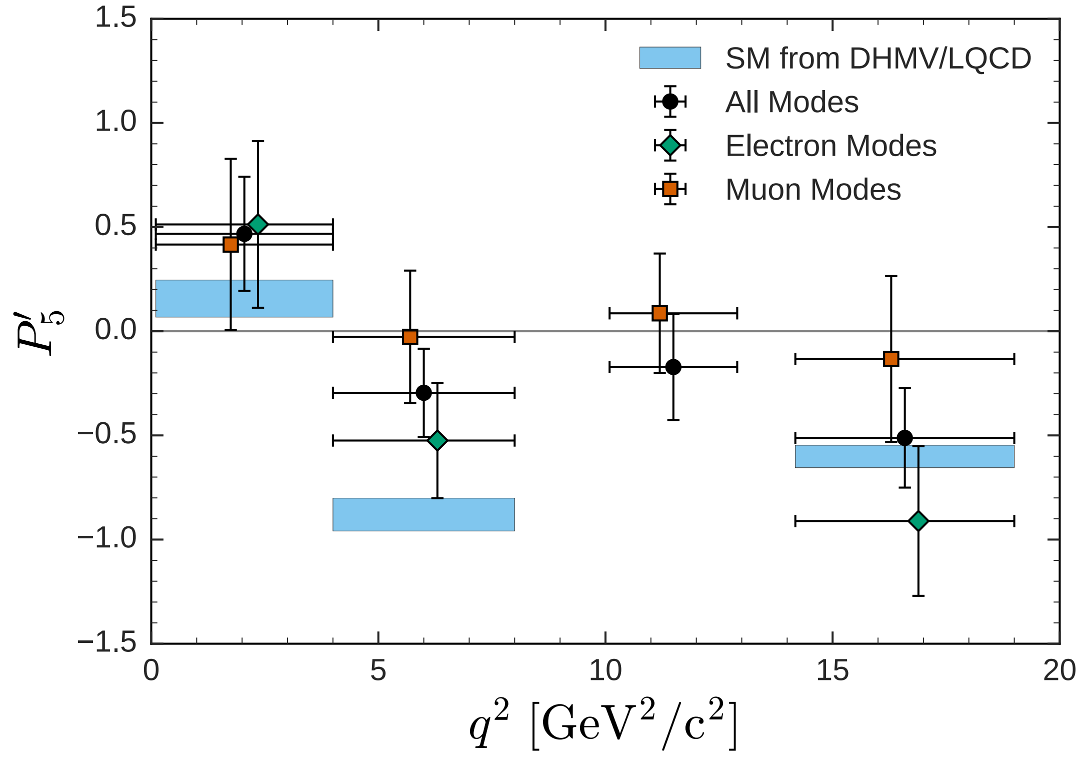
Updates of:

- R_{K^*} (+ Run2)
- R_K (+ 2017 & 2018)
- $B^0 \rightarrow K^*\mu^+\mu^-$ angular analysis

New measurements:

- New ratios: $R_{(K\pi\pi)}$, R_φ, etc.
- $B^0 \rightarrow K^*e^+e^-$ angular analysis
  - non-LFU angular asymmetries $\Delta P'_i$
- Direct measurements of Wilson coefficients (C_9 & C_{10}) from data
  - via amplitude analysis of $B^0 \rightarrow K^*\mu^+\mu^-$

Belle - PRL 118 (2017) 11 111801



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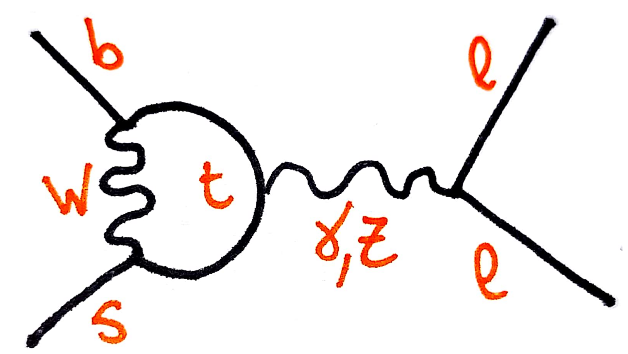
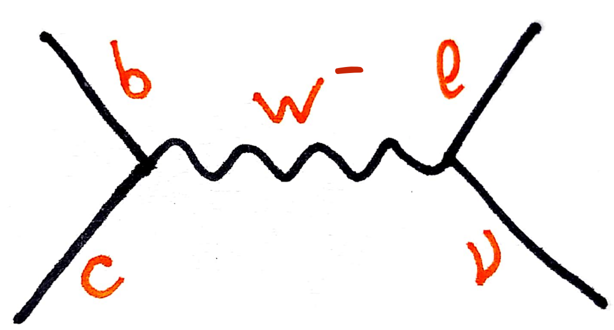
1. $b \to s\ell\ell$ processes
   - Rate and angular distributions of exclusive $b \to s\mu^+\mu^-$ decays
   - Relative rates of $b \to s\mu^+\mu^-$ and $b \to se^+e^-$ decays ($R_{K(*)}$)

NEUTRAL CURRENT



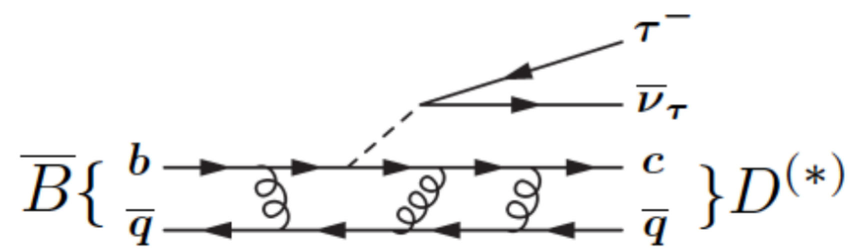
2. $b \to c\tau^-\bar{\nu}_\tau$ decays
   - Relative rates of $b \to c\tau^-\bar{\nu}_\tau$ versus decays with μ ($R_{D(*)}$)

CHARGED CURRENT



Lepton universality in $b \to cl\nu$ decays

- $b \to c\ell\nu$ are **tree level** decays
  - abundant at LHC and B factories
    - B-factories have **cleaner** events
    - LHCb **more statistics**
- Complicated experimentally by **missing energy** in the final-state from multiple **missing neutrinos**



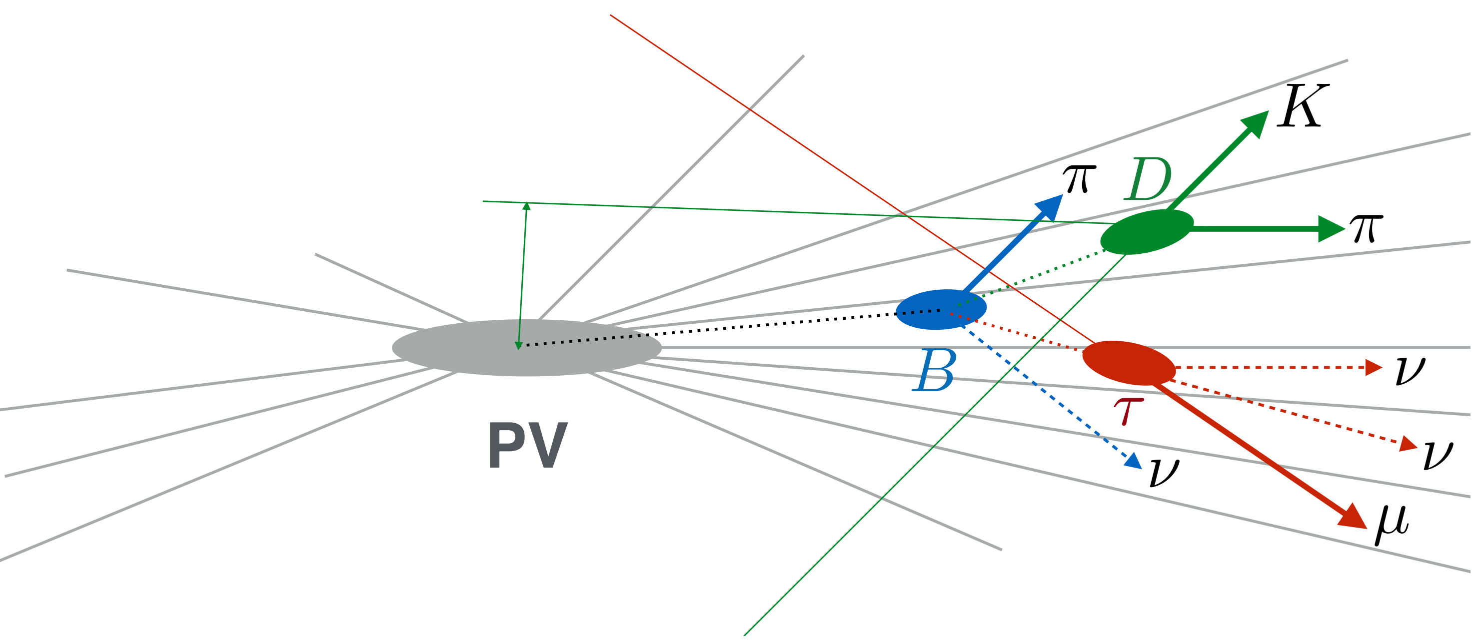
LFU ratio

$$R_{D^{(*)}} = \frac{\mathcal{B}(B \to D^{(*)}\tau\nu)}{\mathcal{B}(B \to D^{(*)}\mu\nu)}$$

Theoretically clean (hadronic uncertainties and |Vcb| cancel)

- $R_D^{SM} = 0.299 \pm 0.03$
- $R_{D^*}^{SM} = 0.258 \pm 0.05$

PRD 94 (2016) 094008, PRD 85 (2012) 094025

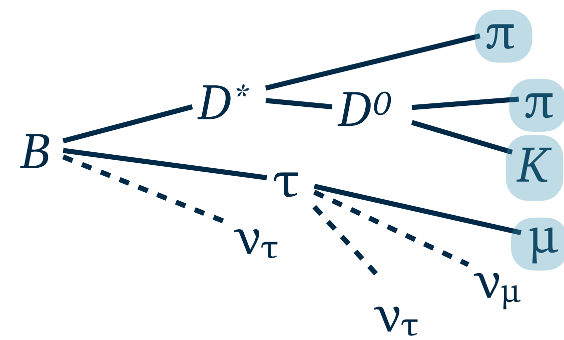


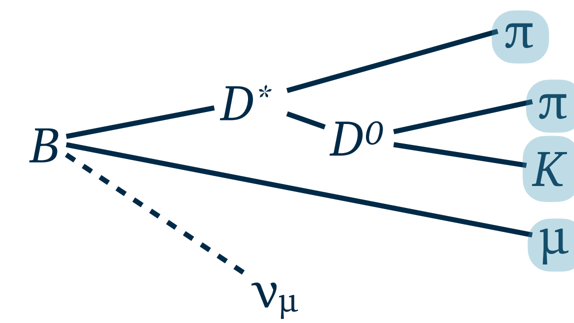
τ reconstruction

- **Leptonic**: Br ~17 %
  - $\tau \to \mu\, \nu_\mu\, \nu_\tau$
  - $\tau \to e\, \nu_e\, \nu_\tau$ → only at *B* factories

Signal and normalization have the same visible final state

→ Part of the systematic cancels in the ratio!





- **Hadronic**

Decay	$\mathcal{B}$ (%)
$\tau^- \to \pi^-\pi^0\, \nu_\tau$	25.49 ± 0.09
$\tau^- \to \pi^-\, \nu_\tau$	10.82 ± 0.05
$\tau^- \to \pi^-\pi^+\pi^-\, \nu_\tau$	9.02 ± 0.05
$\tau^- \to \pi^-\pi^+\pi^-\pi^0\, \nu_\tau$	4.49 ± 0.05

(first two rows) 1-prong decays, only at *B* factories

(last two rows) 3-prong decays, only at LHCb

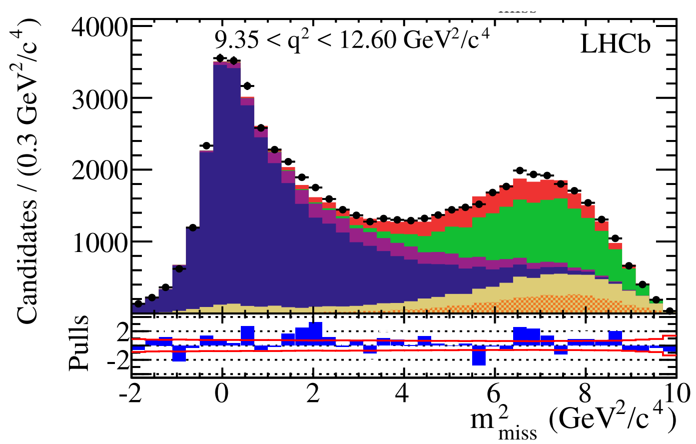
  - requires an other decay channel with similar final state, e.g. $B \to D^*\pi\pi\pi$

Run I data

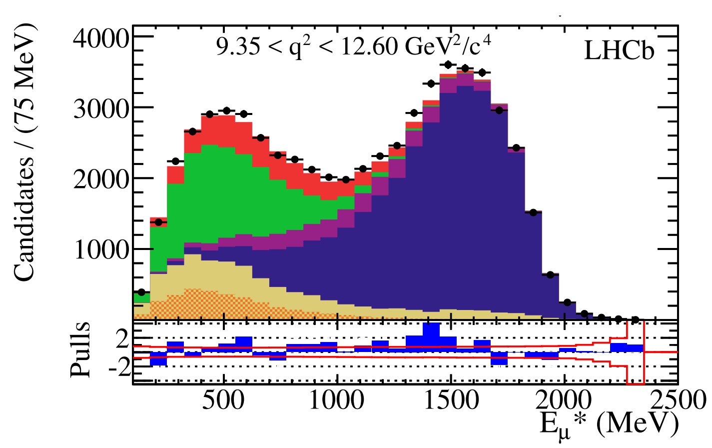
“Muonic” VS “hadronic” R_{D^*}

muonic

Set of variables
- E_μ
- q^2
- m^2_{miss}



Projection in one of the four q^2 bins



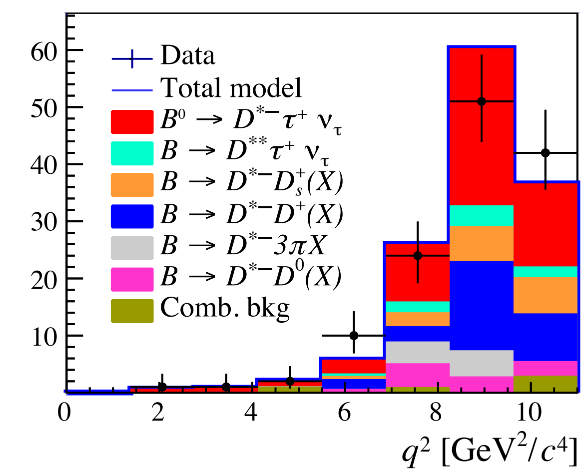
PRL 115 (2015) 111803

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

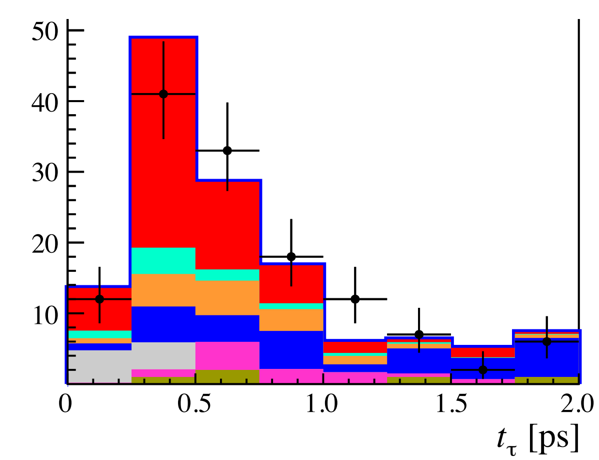
2.1σ greater than SM

hadronic

Set of variables
- t_τ
- q^2
- BDT output



Projection in one bin of BDT response



PRD 97 (2018) 072013

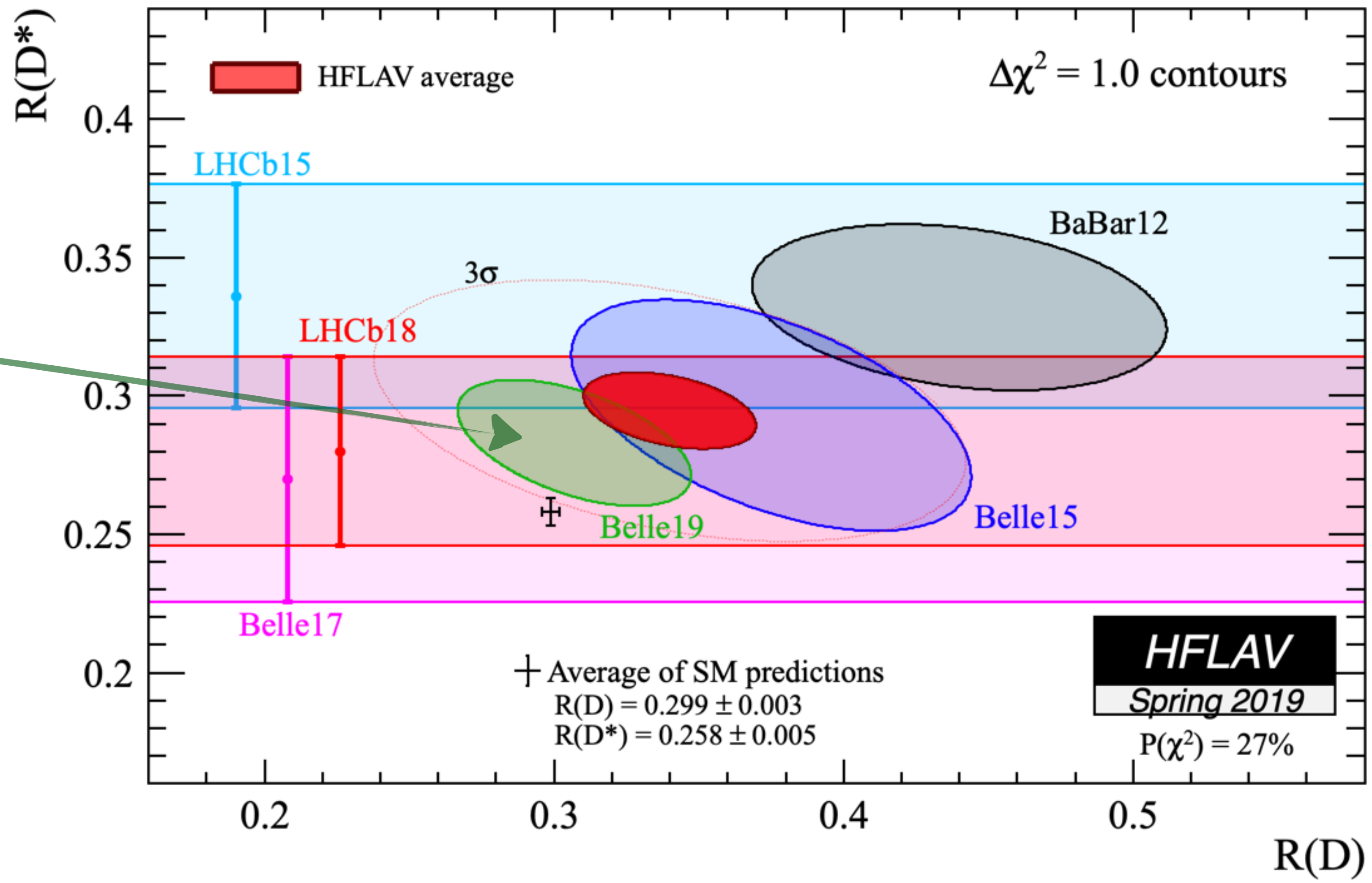
$$\mathcal{R}(D^*) = 0.291 \pm 0.019 \pm 0.026 \pm 0.013$$

~1σ above the SM

$R_{D^{(*)}}$ combination

- After Moriond 2019 tension with SM is reduced from 3.8 to 3.1 σ

New measurement from Belle!



More measurements …

- What about B_c decays?
  - test of LFU in $b \to c\ell\nu$ decays with different spectator quark

$$R_{J/\psi} = \frac{\mathcal{B}(B_c \to J/\psi\tau\nu)}{\mathcal{B}(B_c \to J/\psi\mu\nu)} \stackrel{\text{SM}}{=} [0.25, 0.28]$$

Large interval due to form factor uncertainties

$$R_{J/\psi}^{\text{LHCb}} = 0.71 \pm 0.17 \pm 0.18$$

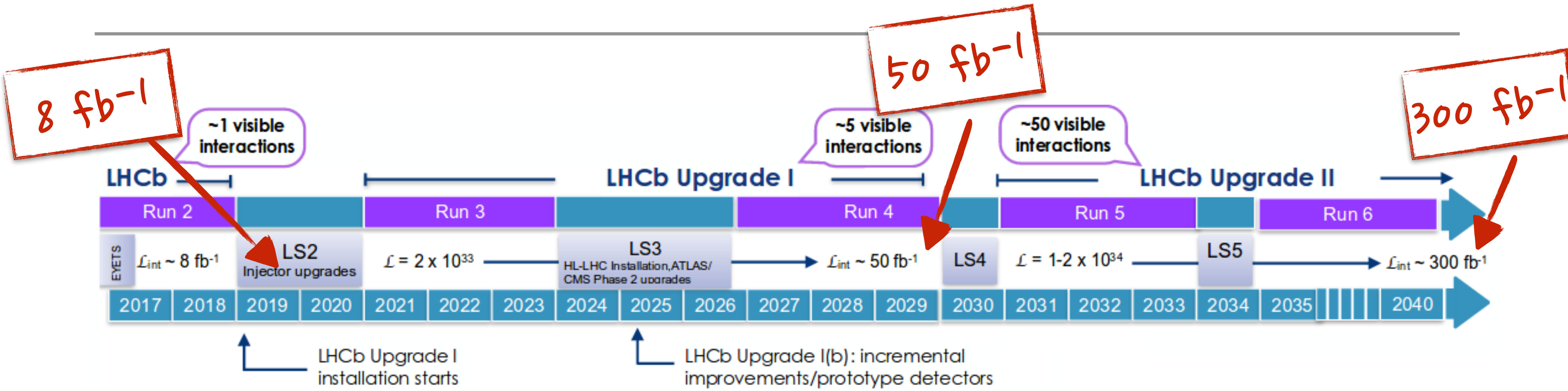
PRD 120 (2018) 121801

2σ above the SM

Near future → several measurement in the pipeline:

- Simultaneous measurements of R(D*) & R(D^0) and R(D*) & R(D^+)
- New measurement of R(Λ_c), R(D_s), etc.
- Updates with Run2

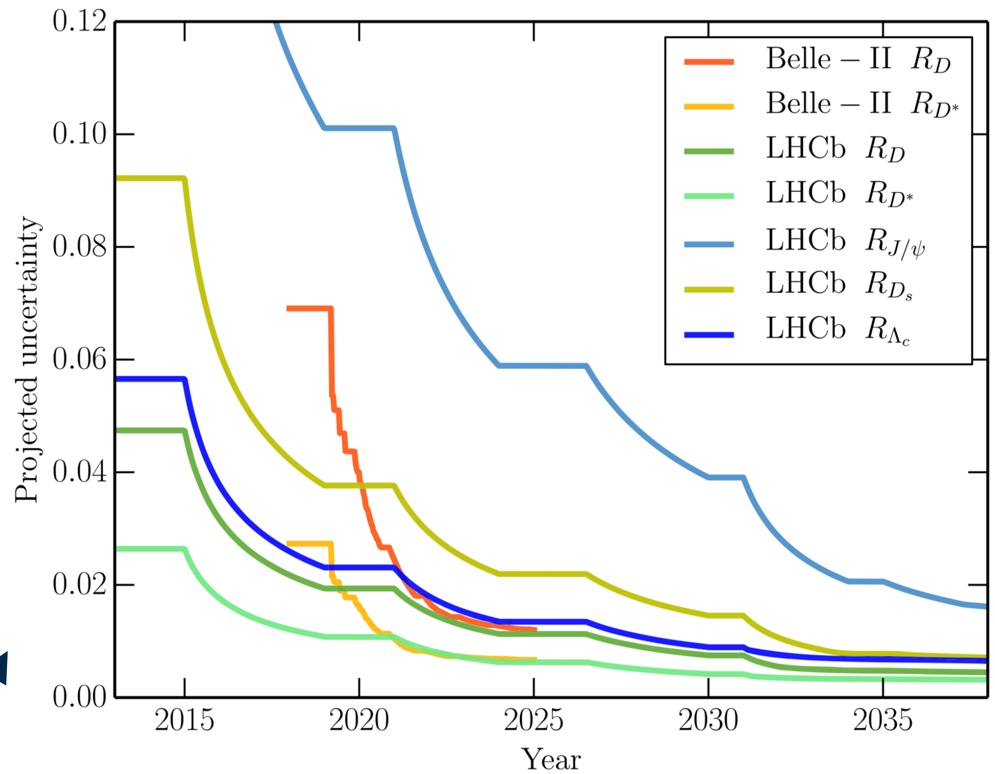
LHCb Upgrades = new era of precision measurements



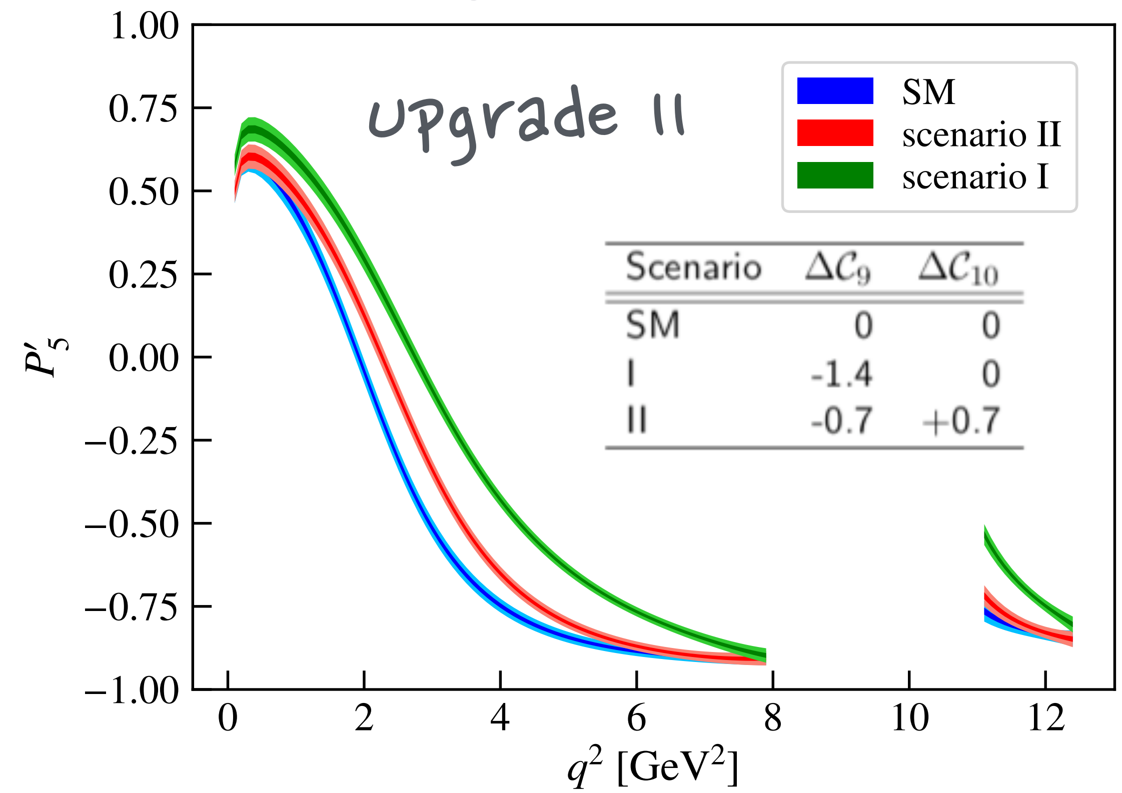
- Projected sensitivity for LHCb future upgrades

Physics of the HL-LHC, WG4 Flavour [arXiv:1812.07638]

LFU ratios



Angular observables



Conclusion

Intriguing pattern of anomalies in neutral and charged currents transitions

- measurements by LHCb, Babar and Belle
- still need larger statistics to understand if these anomalies are genuine sign of physics beyond the SM
- more results will come from LHCb Run2 analyses

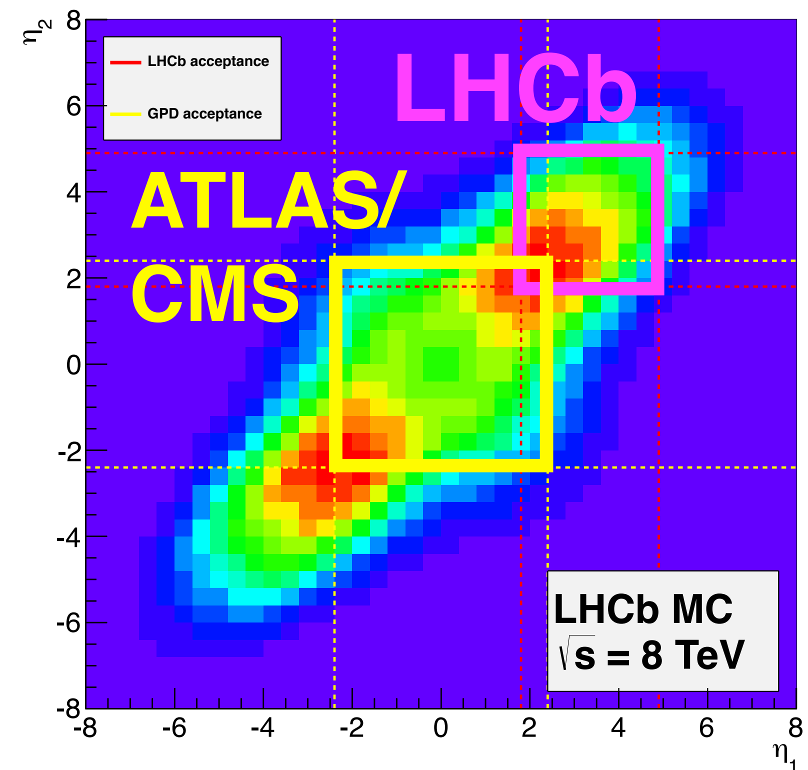
Thank you!

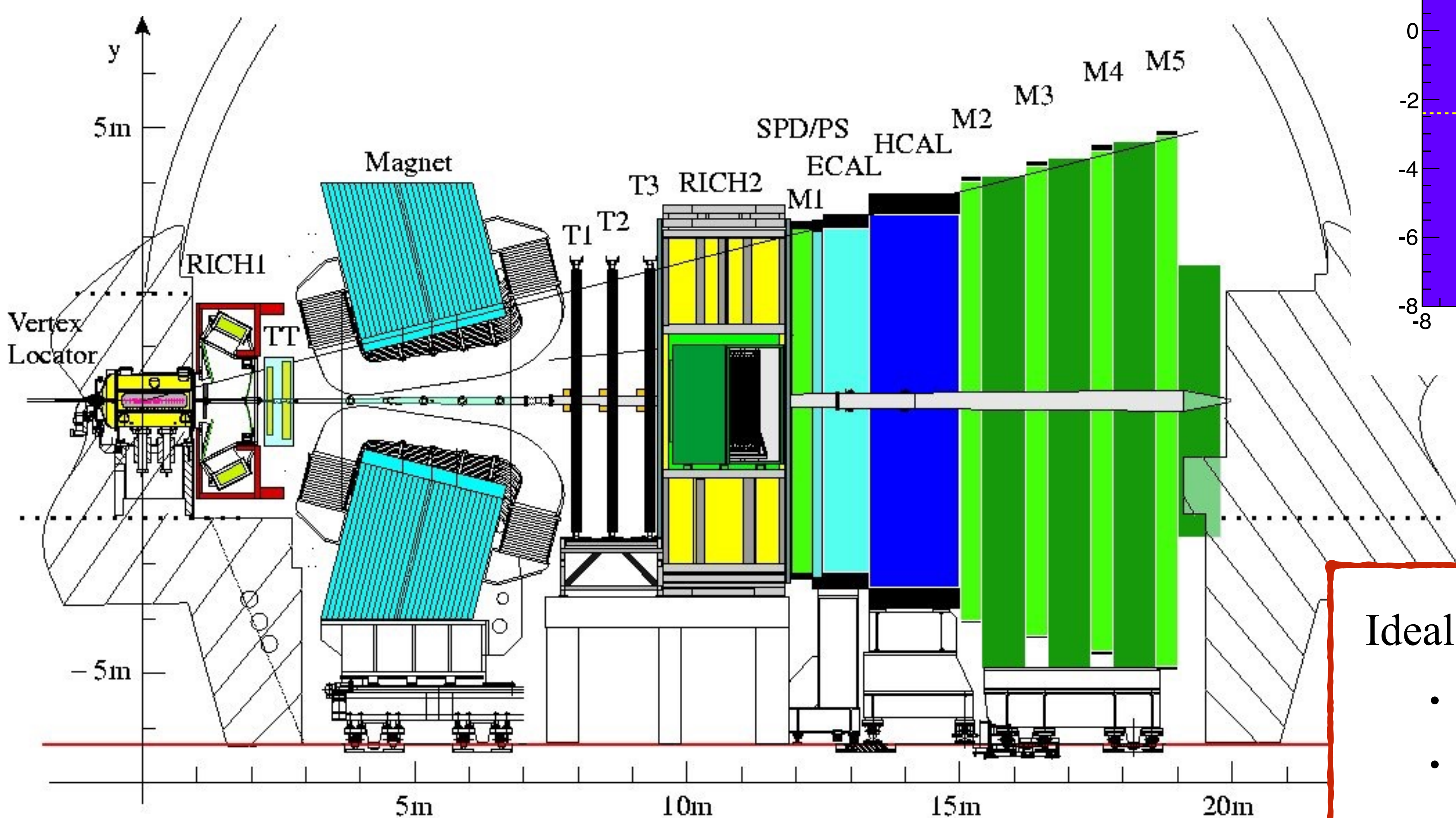
The LHCb detector

LHCb is a forward spectrometer placed at LHC

- Pseudorapidity range: $2 < \eta < 5$
- focused on the study of *b* and *c* decays
  - $O(10^5)$ $b\bar{b}$ pairs produced every second
  - $\sigma(pp \to H_b X) = 144 \pm 1 \pm 21\,\mu b$ in acceptance

$pp \to b\bar{b}$ cross section



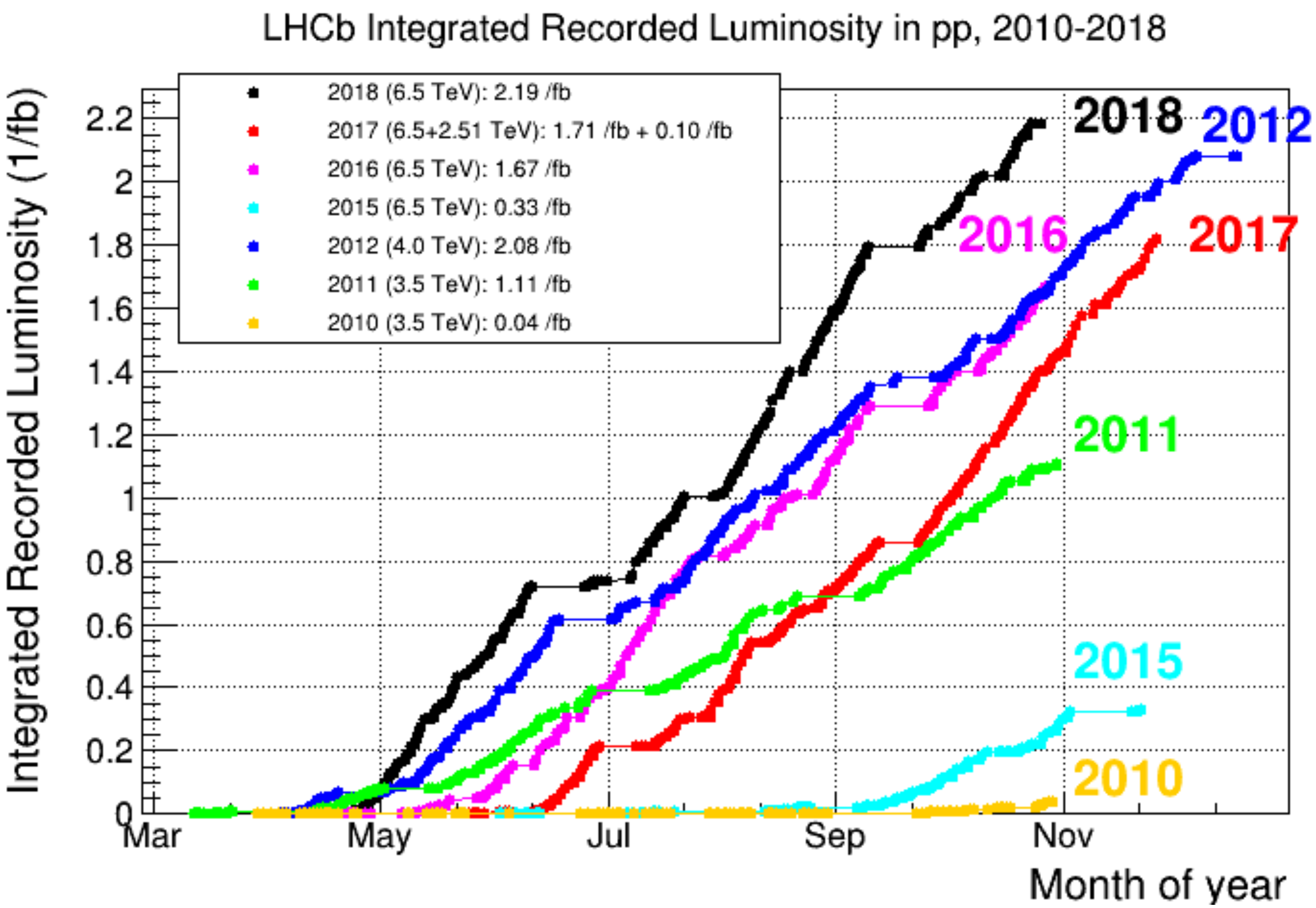


Ideal place for studying b and c decays:

- excellent vertex resolution
- excellent momentum resolution
- excellent particle identification

JINST 3 (2008) S08005 IJMPA 30 (2015) 1530022

Collected datasets

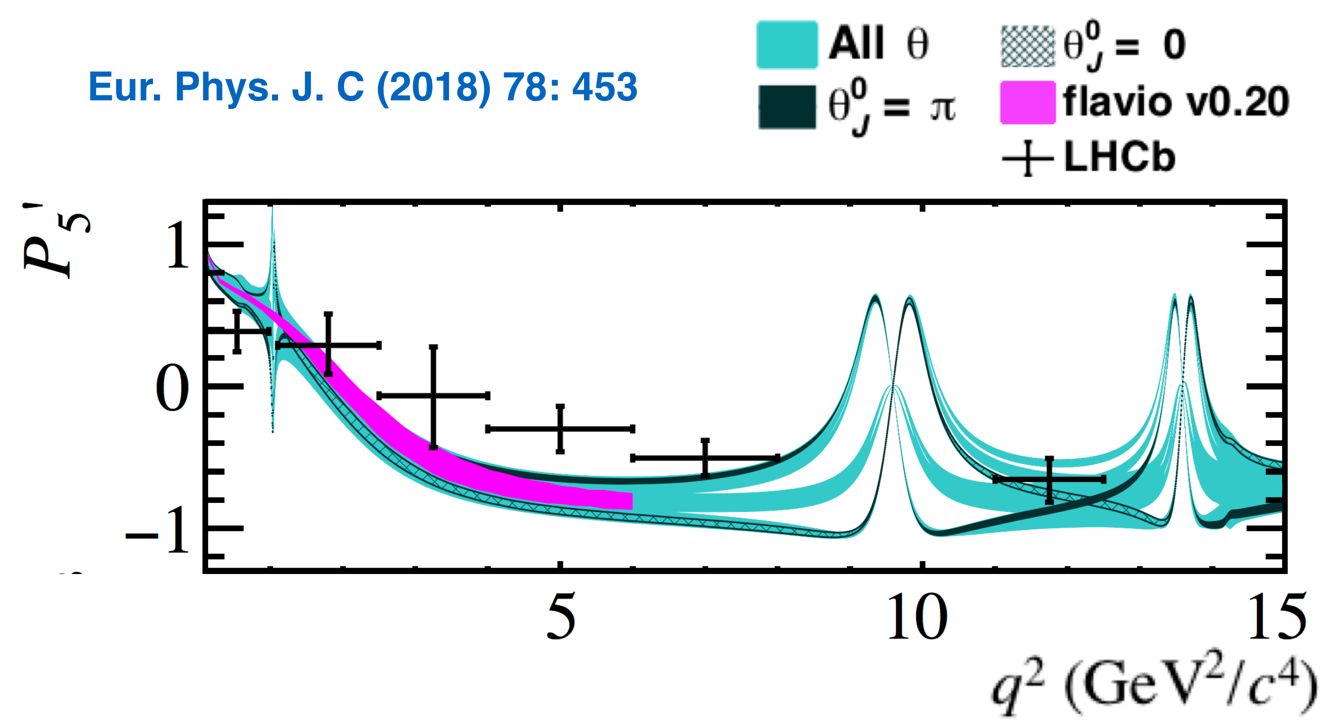


- **Run1** LHCb collected **1+2 fb^{-1}** of data in **2011+2012**
- **Run2** LHCb collected **6 fb^{-1}** of data between **2015** and **2018** (roughly twice b-meson per fb-1 due to **increased √s**)

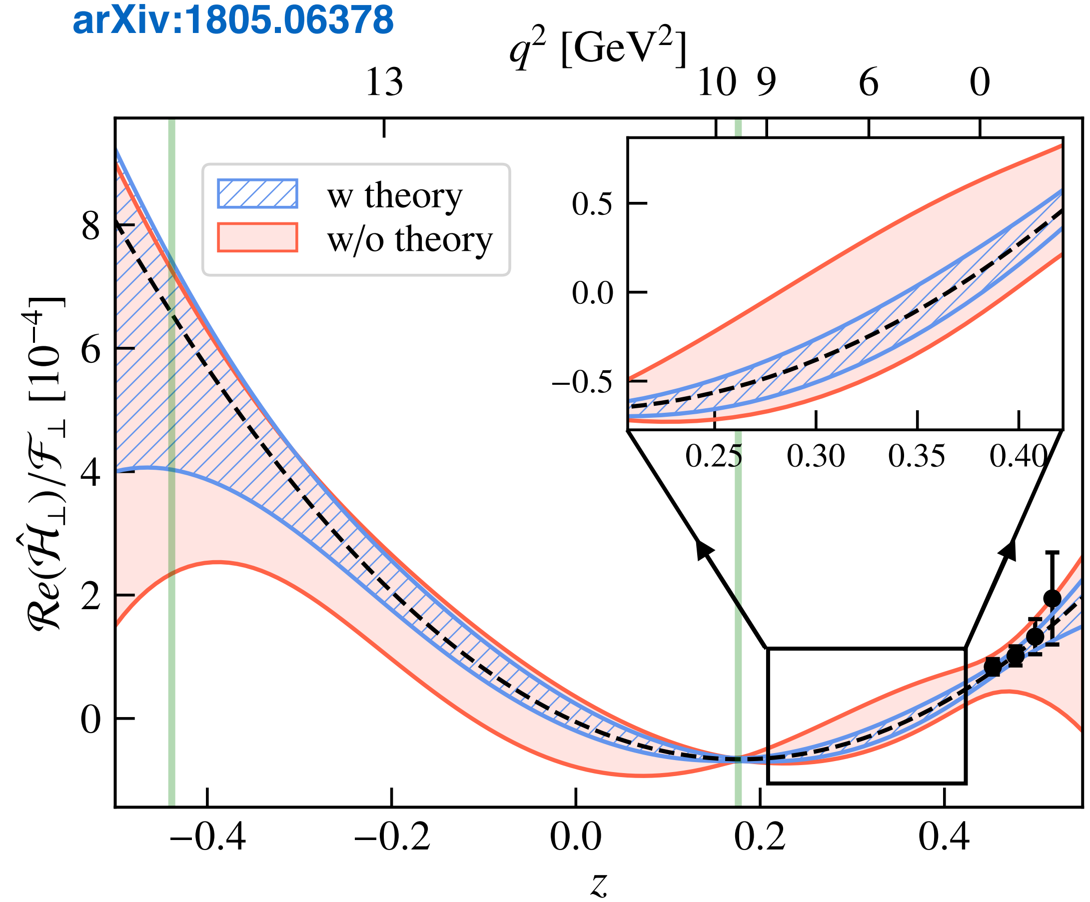
Fighting the charm loop at experimental level

- Several attempts to disentangle short-distance (WCs) from long-distance (cham loop) contributions
  - Parametrizing charmonia resonances as sum of Breit-Wigner
    - including tails away from resonances, each with magnitude and phases
  - Parametrizing charmonia resonances as polynomials

Eur. Phys. J. C (2018) 78: 453

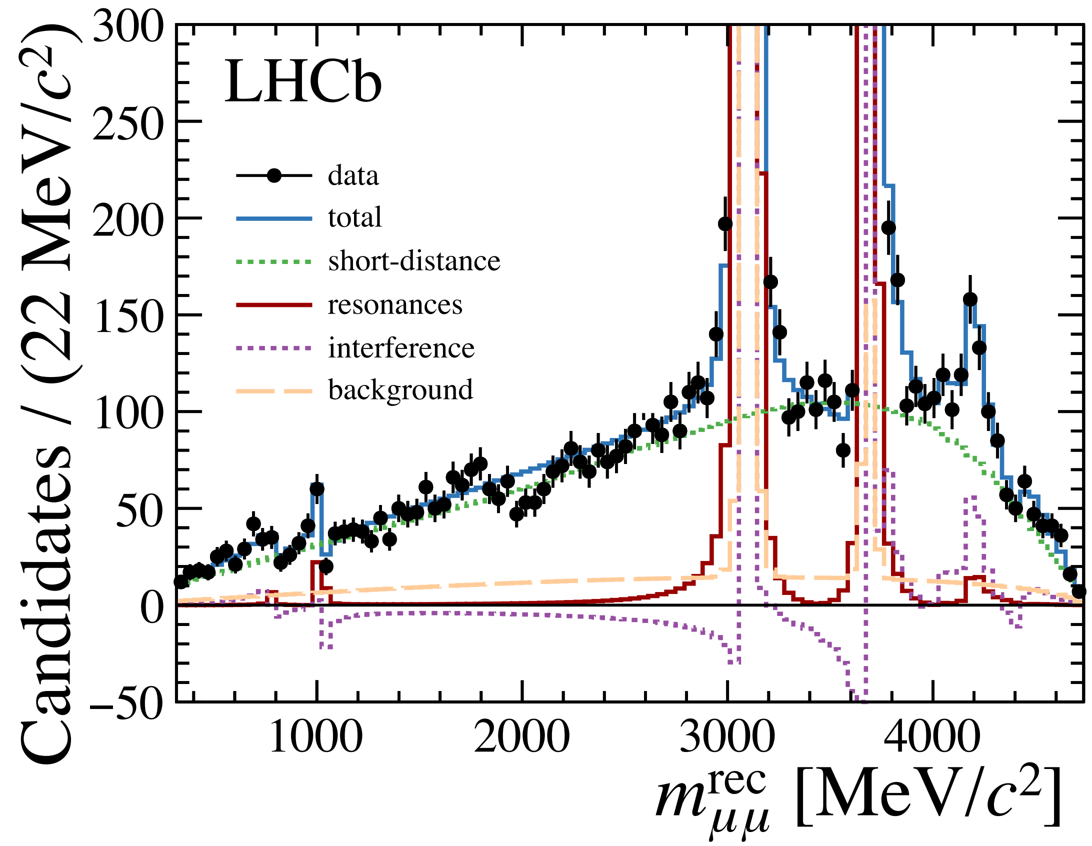


arXiv:1805.06378



Phases in $B^+ \to K^+\mu\mu$

- $B^+ \to K^+\mu\mu$ decays present simpler phenomenology compared to $B^0 \to K^{*0}\mu\mu$ (K^+ is a scalar)
- Fit to m($\mu\mu$) to determine the interference between "rare mode" and resonances
- 4 solutions equally compatible with data
  - J/ψ-"rare mode" phase difference compatible with ±π/2
  - interference far from the pole mass is small



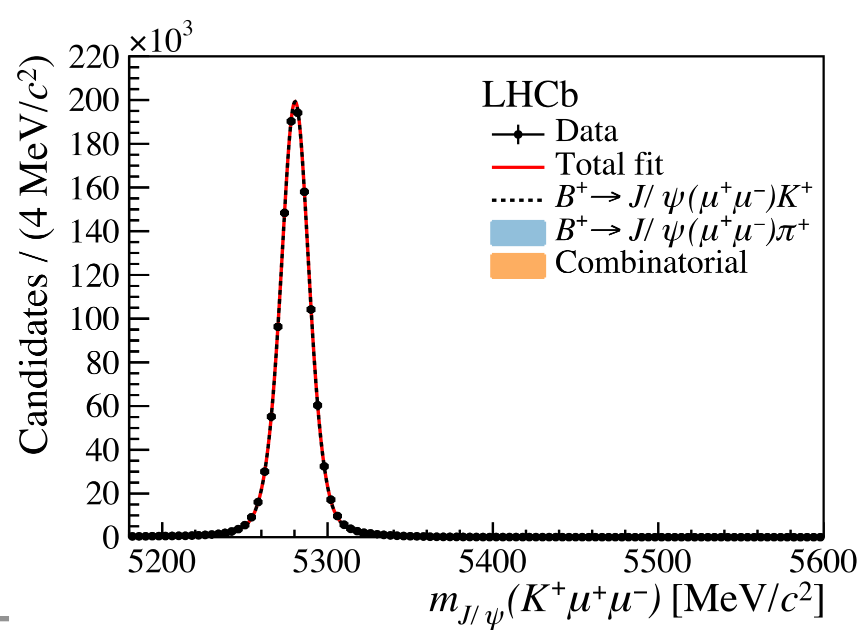
Cross-check #1: $r_{J/\psi}$

- To ensure efficiencies are under control, check $r_{J/\psi} = \dfrac{\mathcal{B}(B^+ \to K^+ J/\psi(\mu^+\mu^-))}{\mathcal{B}(B^+ \to K^+ J/\psi(e^+e^-))} = 1$
  - Very stringent check:
    - Single ratio ⟶ direct control of efficiencies

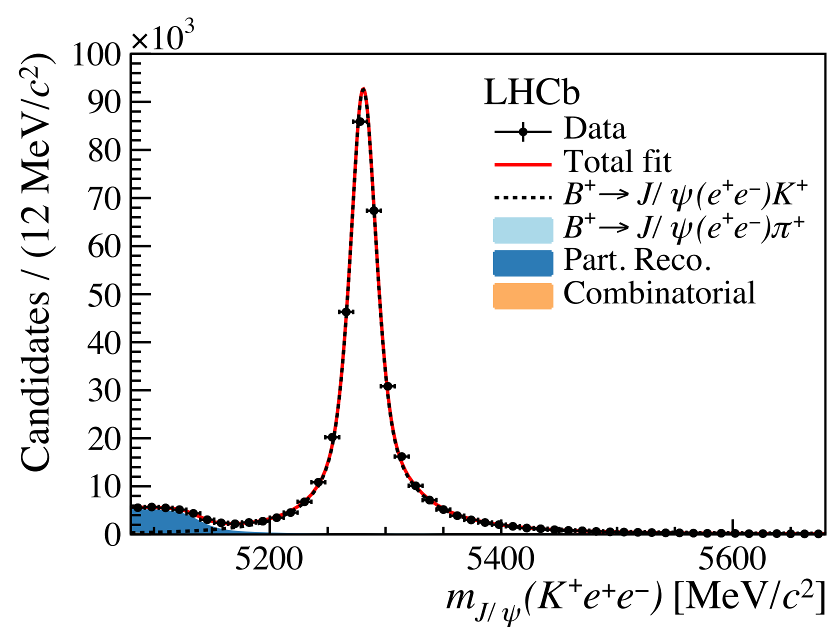
$$r_{J/\psi} = 1.014 \pm 0.035 \;\; \text{(stat+syst)}$$

Checked compatibility of $r_{J/\psi}$=1 for both Run1 and Run2, and in all trigger category

$B^+ \to K^+ J/\psi(\to \mu^+\mu^-)$



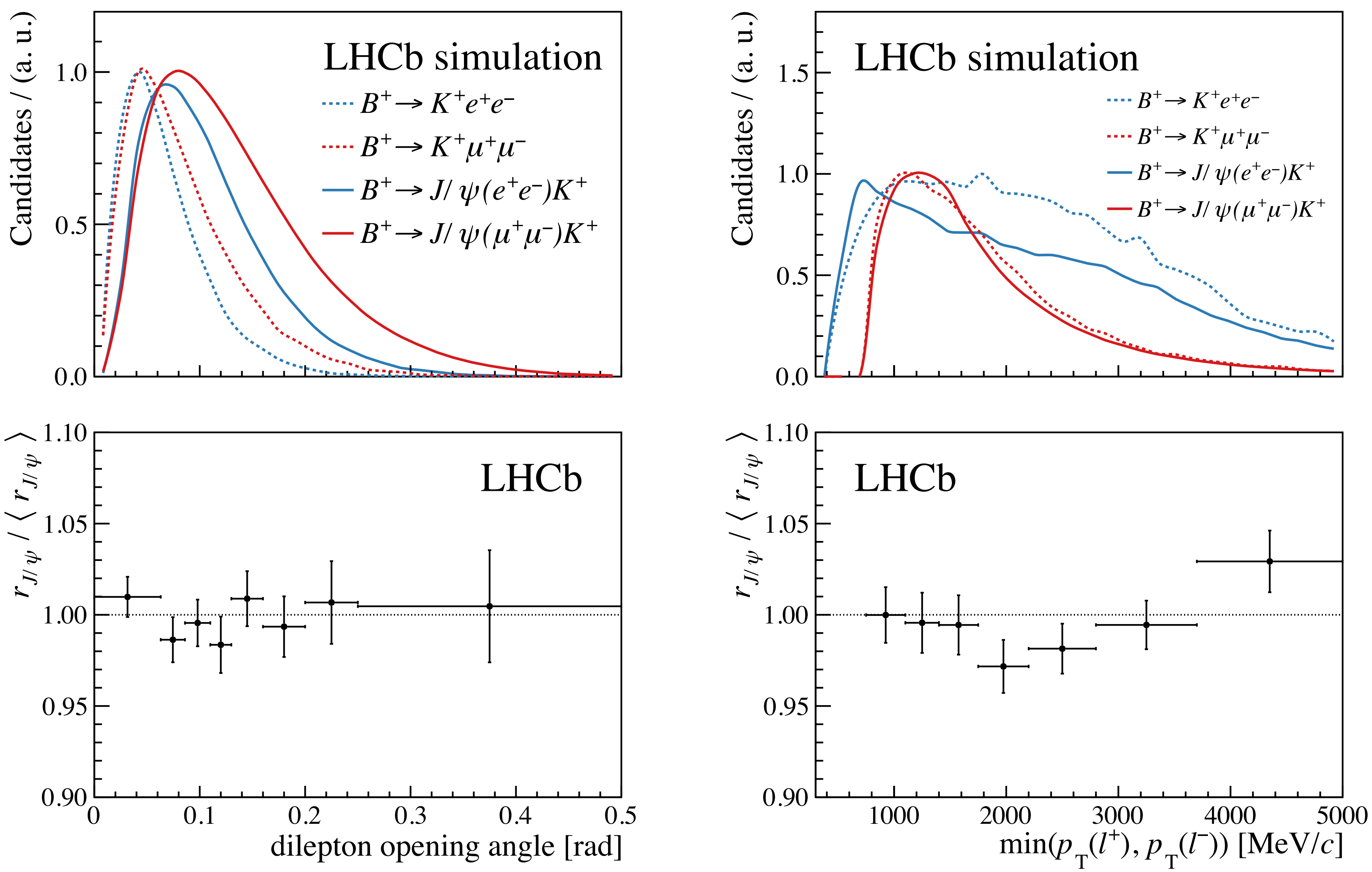
$B^+ \to K^+ J/\psi(\to e^+e^-)$



Phys. Rev. Lett. 122, 191801 (2019)

Cross-check #2: differential $r_{J/\psi}$

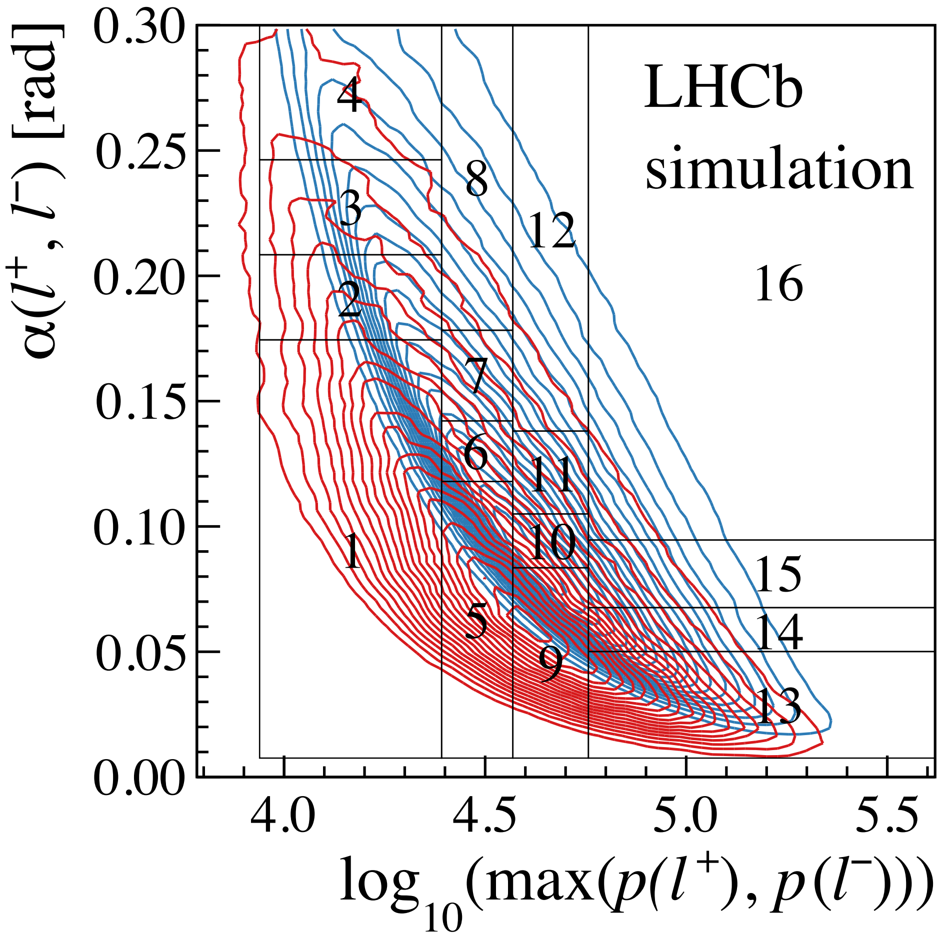
- Cross-check efficiency is well understood in all kinematic region
  - Ensure $r_{J/\psi}$ is flat for all variables examined



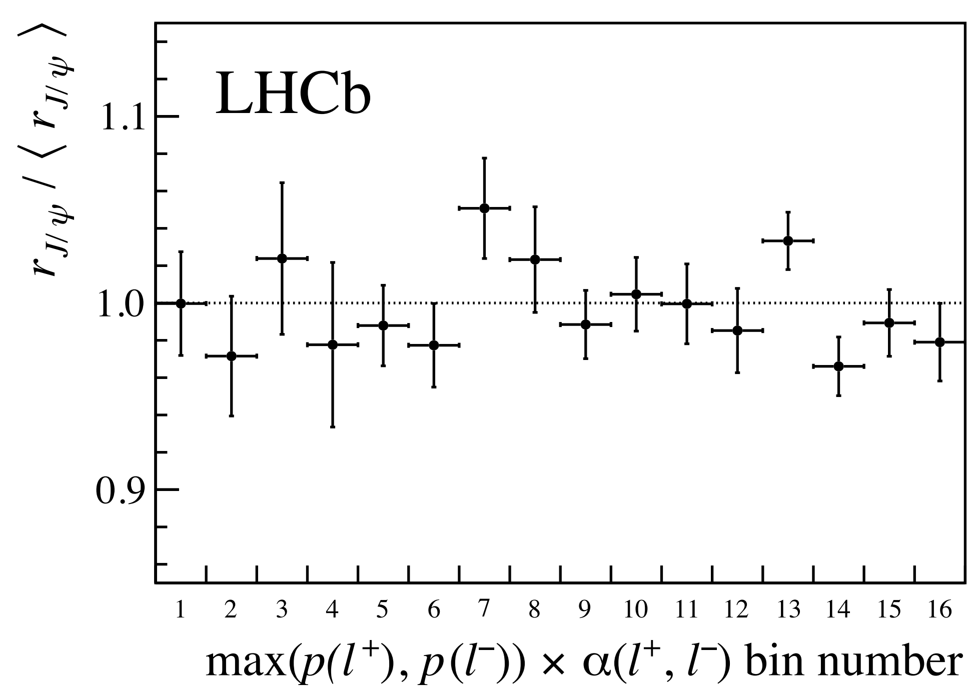
Phys. Rev. Lett. 122, 191801 (2019)

Cross-check #2(b): 2D-differential $r_{J/\psi}$

- Cross-check for possible correlated effects in kinematic variables



Phys. Rev. Lett. 122, 191801 (2019)



Flatness gives confidence that efficiencies are understood in the entire phase space!

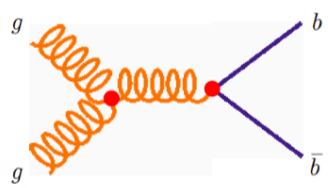
Cross-check #3: $R_{\psi(2S)}$

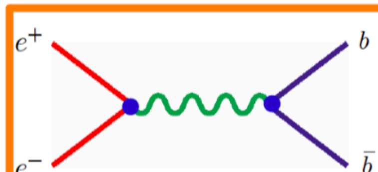
- Test double ratio cancellation on $B^+ \to K^+\psi(2S)(\ell^+\ell^-)$ decays

Phys. Rev. Lett. 122, 191801 (2019)

$$R_{\psi(2S)} = \frac{\mathcal{B}(B^+ \to K^+\psi(2S)(\mu^+\mu^-))}{\mathcal{B}(B^+ \to K^+J/\psi(\mu^+\mu^-))} \Bigg/ \frac{\mathcal{B}(B^+ \to K^+\psi(2S)(e^+e^-))}{\mathcal{B}(B^+ \to K^+J/\psi(e^+e^-))} = 0.986 \pm 0.013\ (\mathrm{stat} + \mathrm{syst})$$

Belle II and LHCb Upgrades





- Time dependent B_s physics
  - CPV in $B_s \to J/\psi\,\phi$, $B_s \to \phi\phi$
- $B_s \to \mu^+\mu^-$
- CKM angle γ
- CPV in B_d
- $B \to X_s\,\ell^+\ell^-$ (exclusive) → **LFU**
- $B \to X_s\,\gamma$ (exclusive)
- Charm physics
- Semileptonic B decays
- $B \to D\,\tau^-\,\nu$, $B \to D^*\,\tau^-\,\nu$
- Dark matter
- τ – physics: LFV
- $B \to \tau^-\,\nu$, $B \to \mu^-\,\nu$
- $B \to K^*\,\nu\nu$, $B \to \nu\nu$
- $B \to X_s\,\ell^+\ell^-$ (inclusive)
- $B \to X_s\,\gamma$ (inclusive)

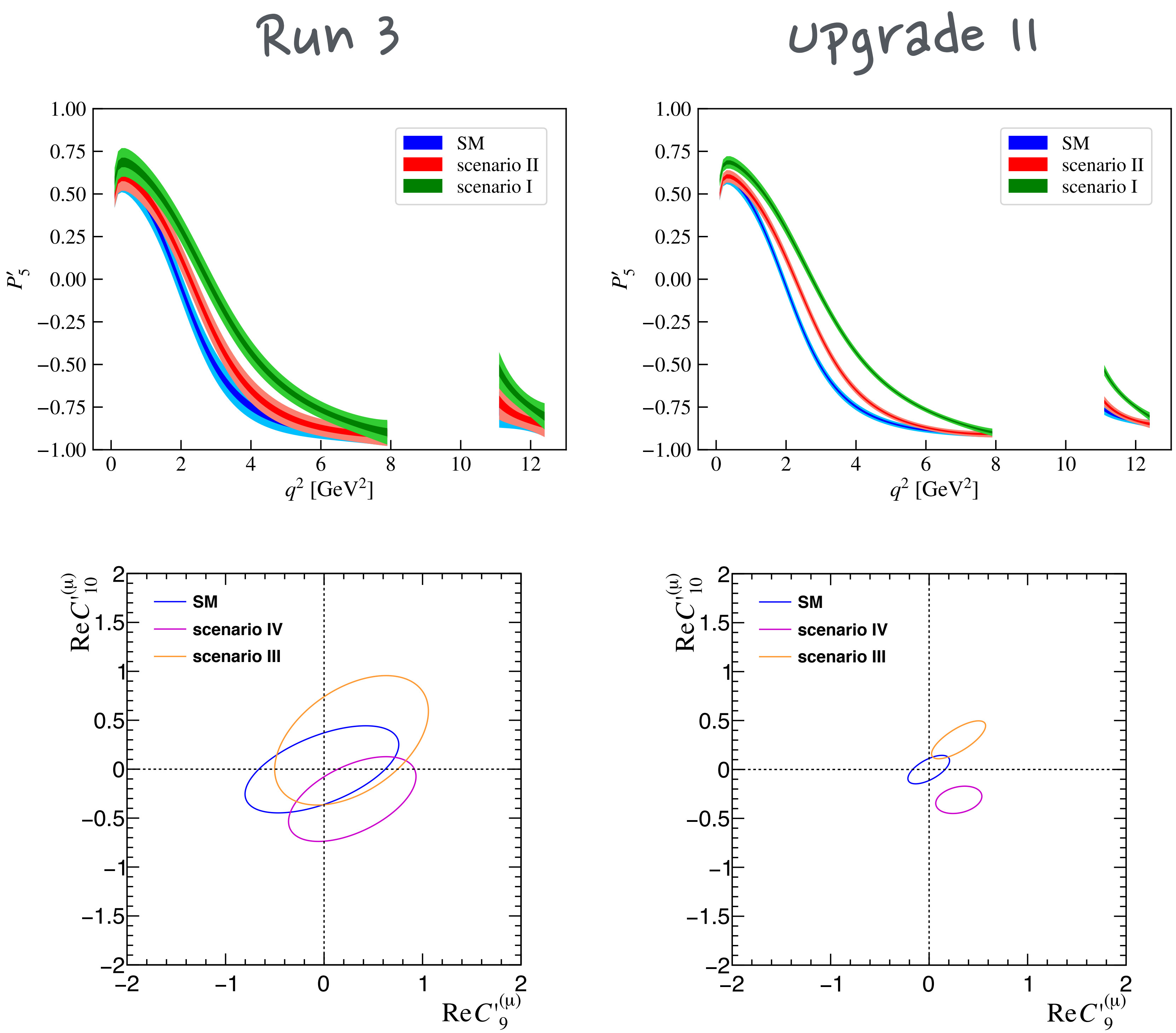
"B_s & charged tracks"

Important overlap: sporty competition!

"inclusive & neutrals "

J. Albrecht Portoroz 2019

New era of precision measurements



Precise (unbinned) determination of angular observables

Scenario	$\Delta\mathcal{C}_9$	$\Delta\mathcal{C}_{10}$
SM	0	0
I	-1.4	0
II	-0.7	+0.7

Right-handed Wilson coefficients

Scenario	$\mathcal{C}'_9$	$\mathcal{C}'_{10}$
SM	0	0
III	+0.3	+0.3
IV	+0.3	-0.3

Physics of the HL-LHC, WG4 Flavour [arXiv:1812.07638]