

B physics anomalies and lepton flavour universality in $b \rightarrow sll$ transitions



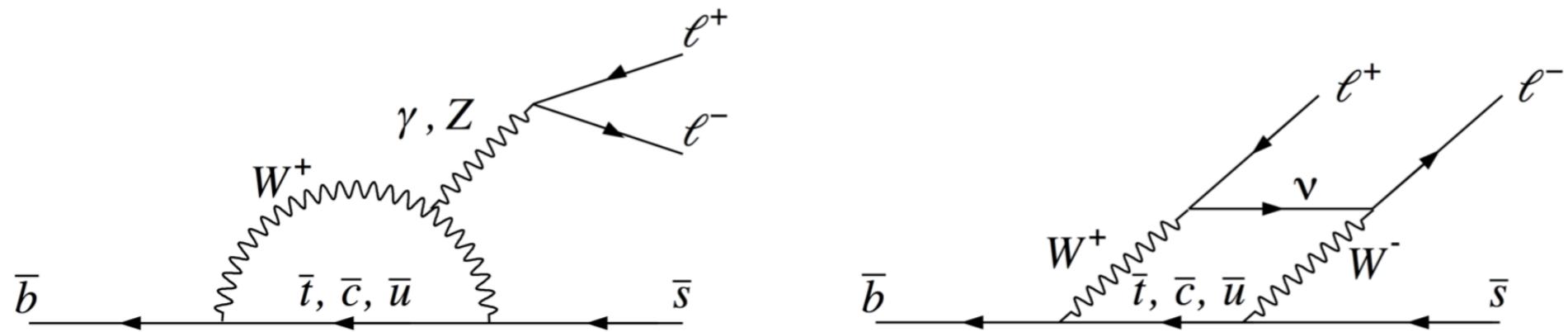
Violaine Bellée

on behalf of the LHCb collaboration
Lake Louise Winter Institute
23 February 2017

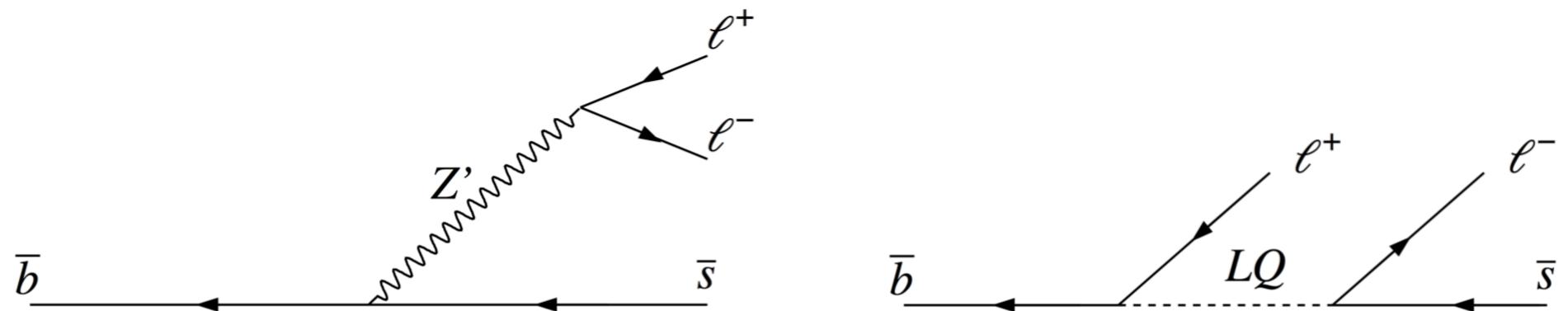
Why $b \rightarrow sll$ transitions?

- ❖ Flavour changing neutral currents

In the **Standard Model**: Forbidden at tree level, occur through loops



- ❖ New physics processes can contribute and change the branching ratios and angular distributions



Parametrising new physics

- ▶ Description of FCNC in term of an effective hamiltonian which is expanded in **operators** \mathcal{O}_i encoding short-distance physics and their **coupling strengths** C_i (the Wilson coefficients)

$$H_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i [\underbrace{C_i(\mu) \mathcal{O}_i(\mu)}_{\text{left-handed part}} + \underbrace{C'_i(\mu) \mathcal{O}'_i(\mu)}_{\text{right-handed part suppressed in SM}}]$$

$i=1, 2$	Tree
$i=3-6, 8$	Gluon penguin
$i=7$	Photon penguin
$i=9, 10$	Electroweak penguin
$i=S$	Higgs (scalar) penguin
$i=P$	Pseudoscalar penguin

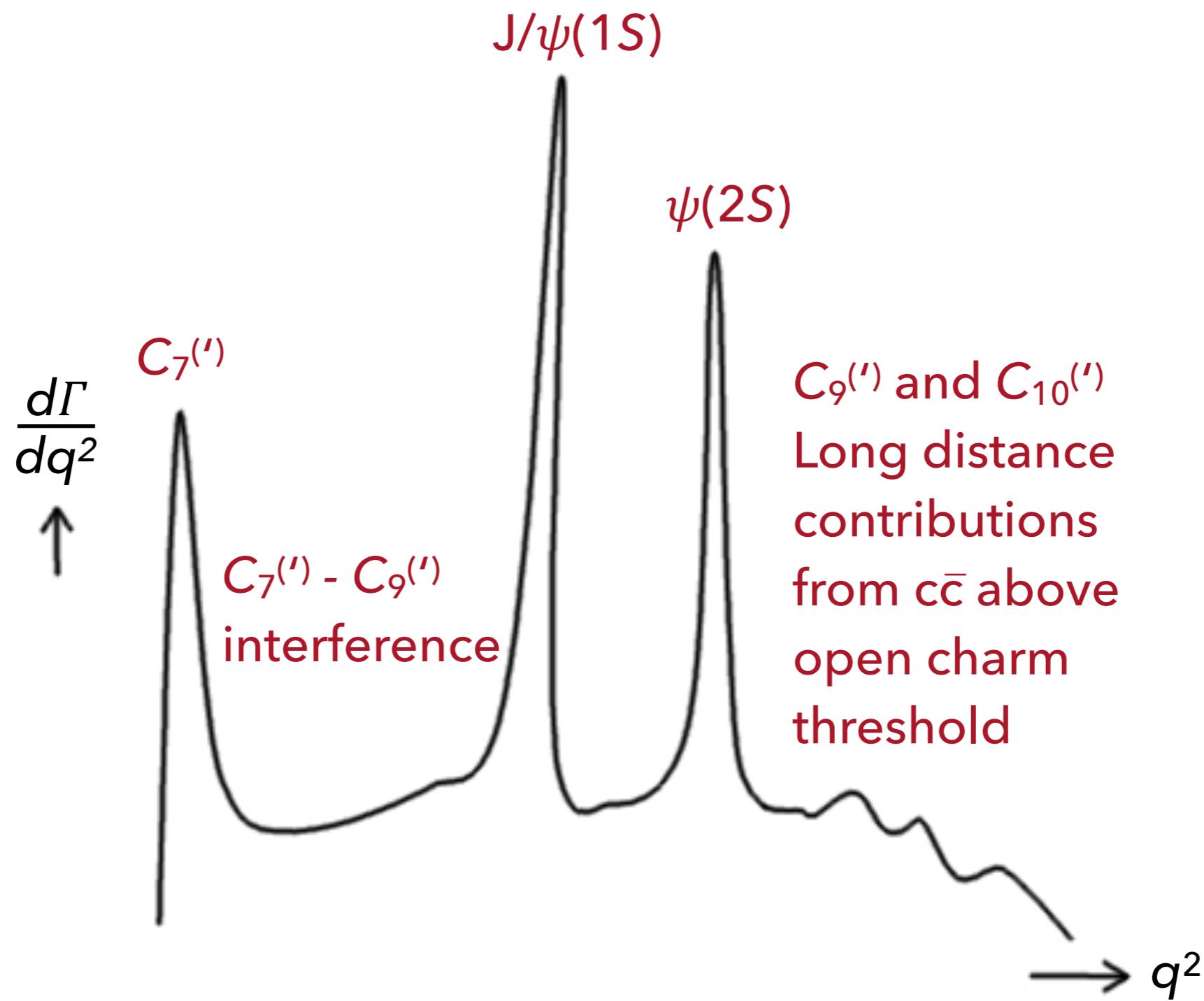
- ▶ Variables of interest:

$C_7^{(')}$: Strength of the couplings to **photons**

$C_9^{(')}$ and $C_{10}^{(')}$: Strength of the couplings to **leptons**

Different regions in di-lepton invariant mass q^2

4



What can we do? Which observables?

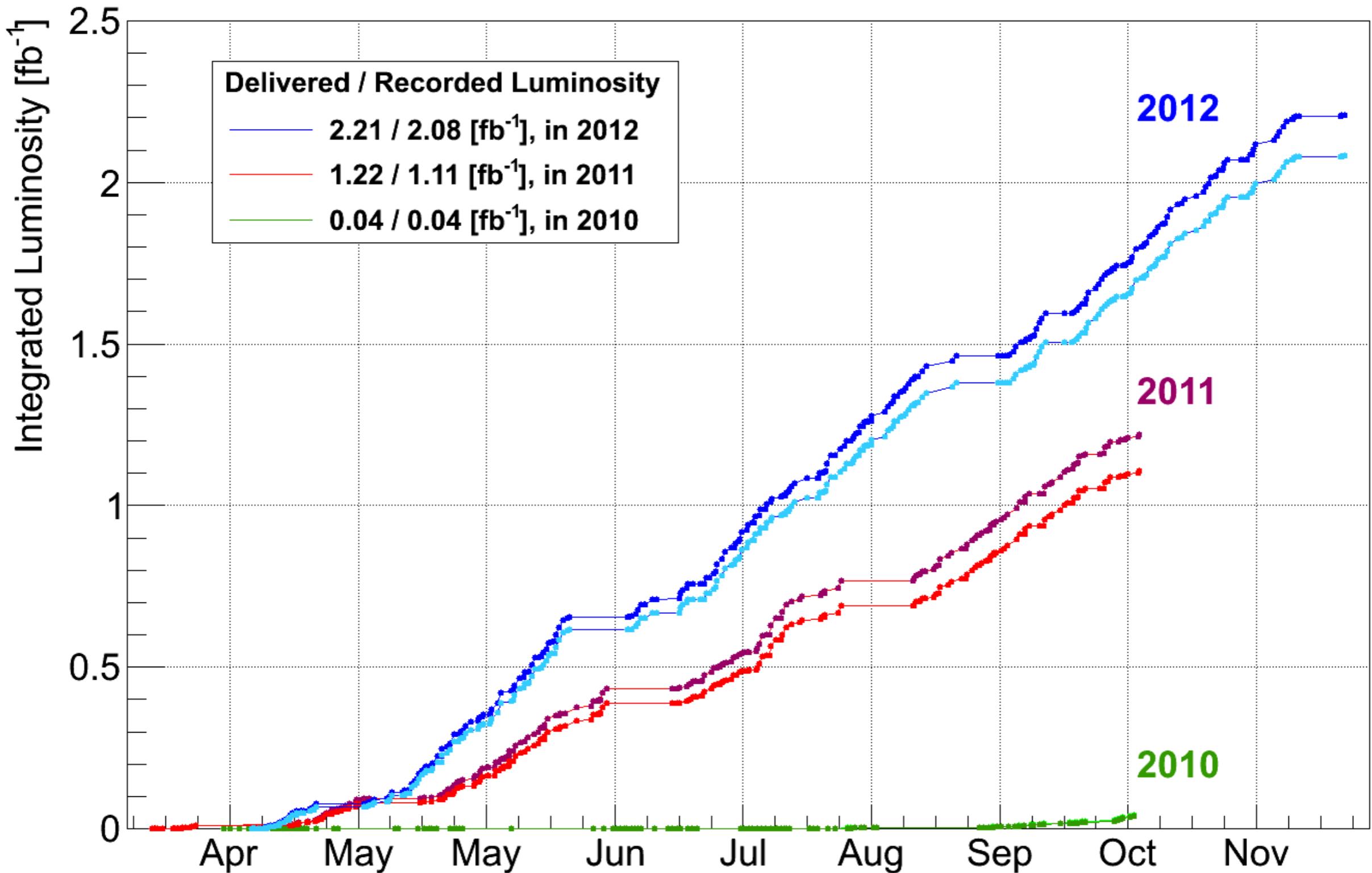
5

- Branching ratios** (but high hadronic uncertainties)
- Angular distributions**
- Lepton flavour universality tests**

Ratios of branching fractions between channels with muons and with electrons as a null test of the SM (much less hadronic uncertainties because ratio)

Results of analyses using Run 1 data

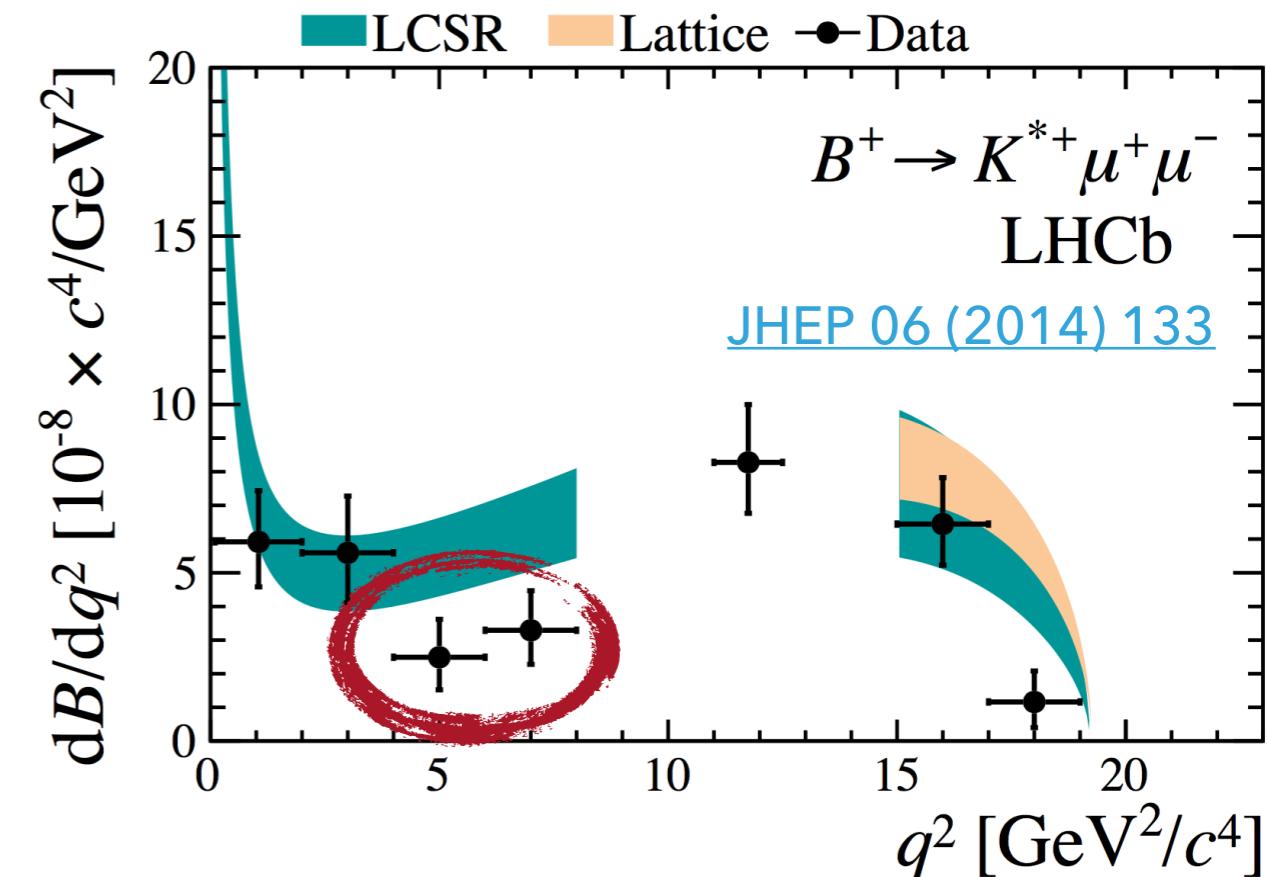
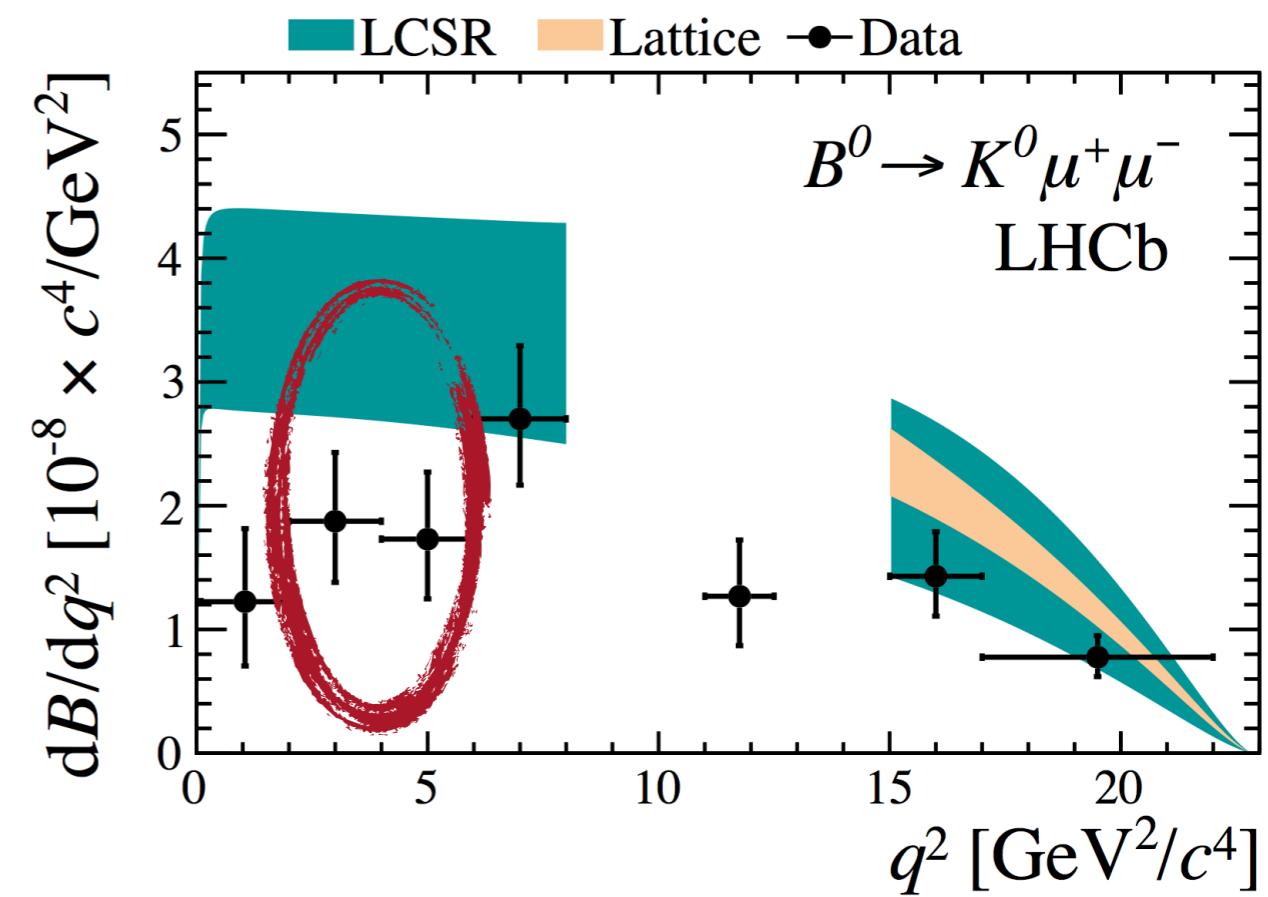
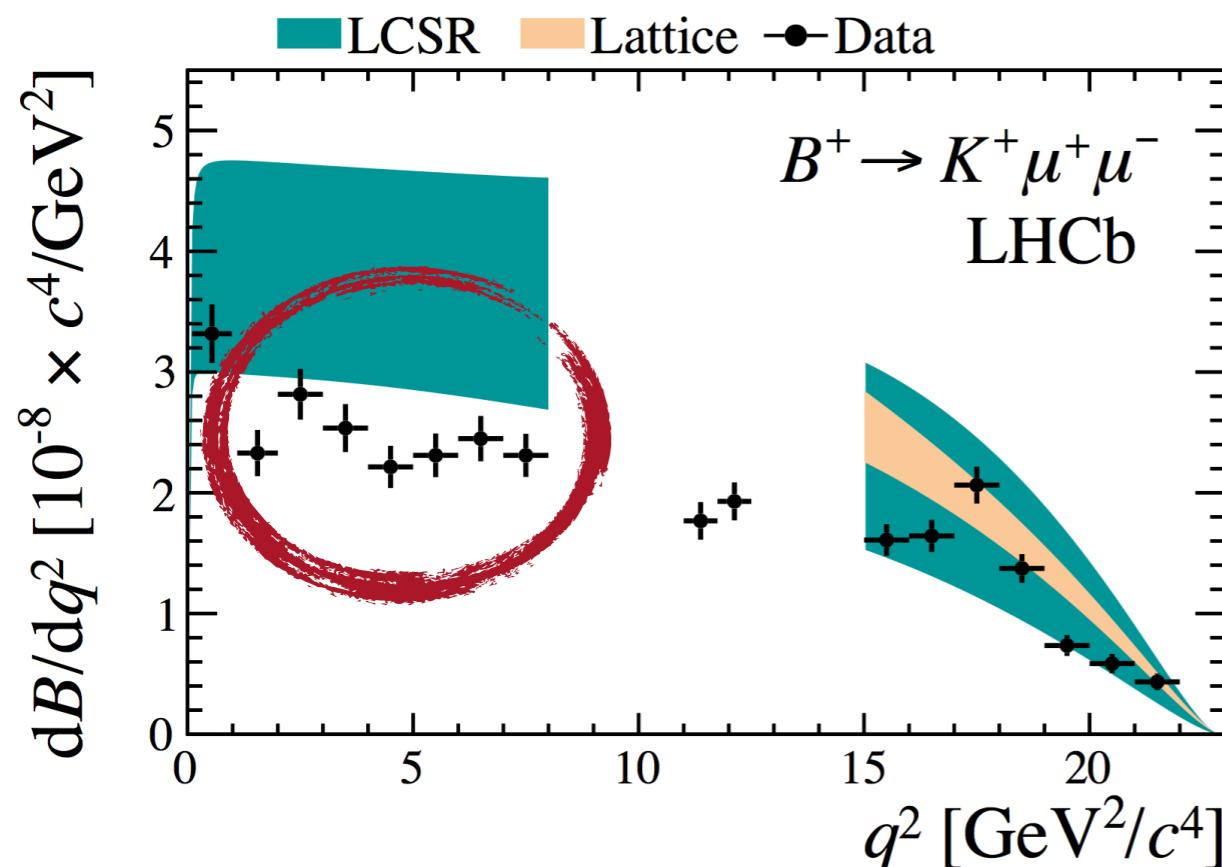
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Branching fraction measurements

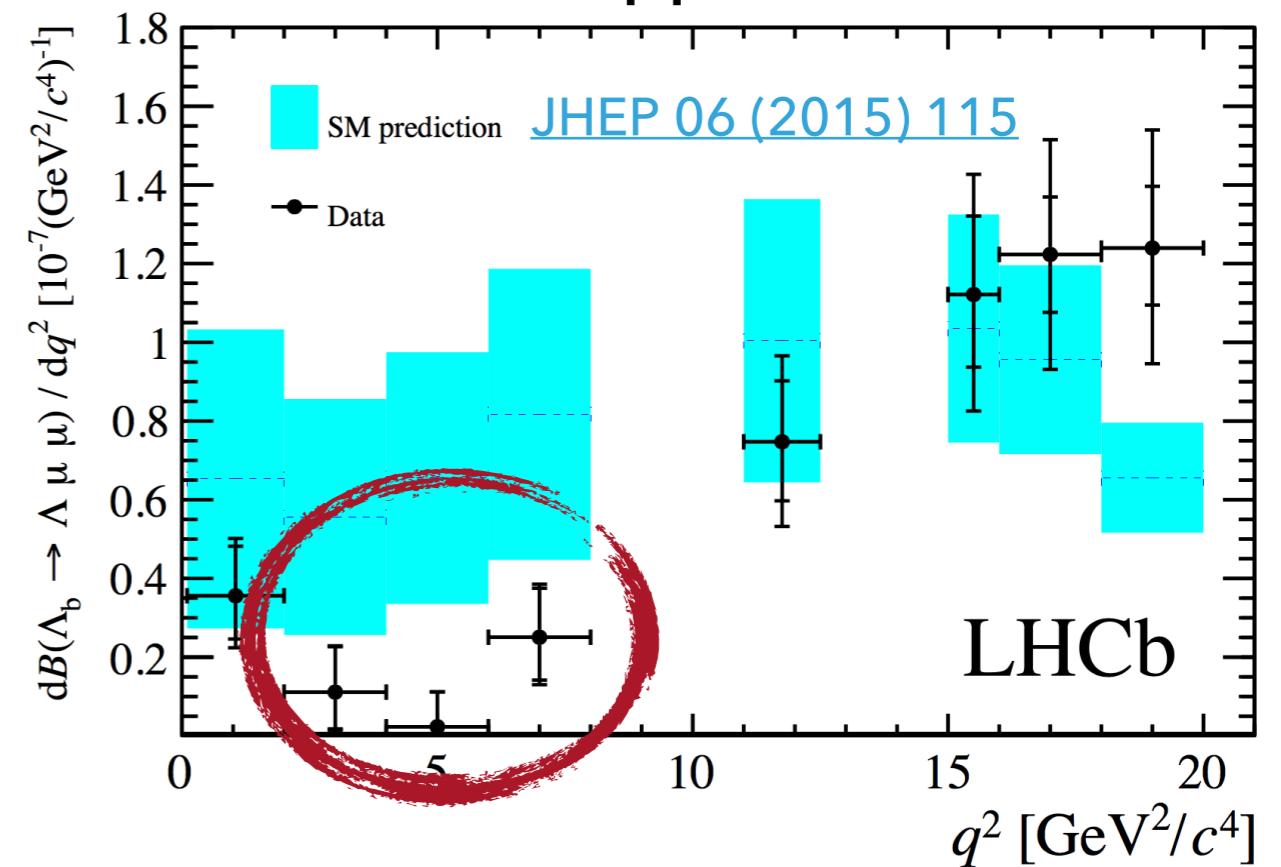
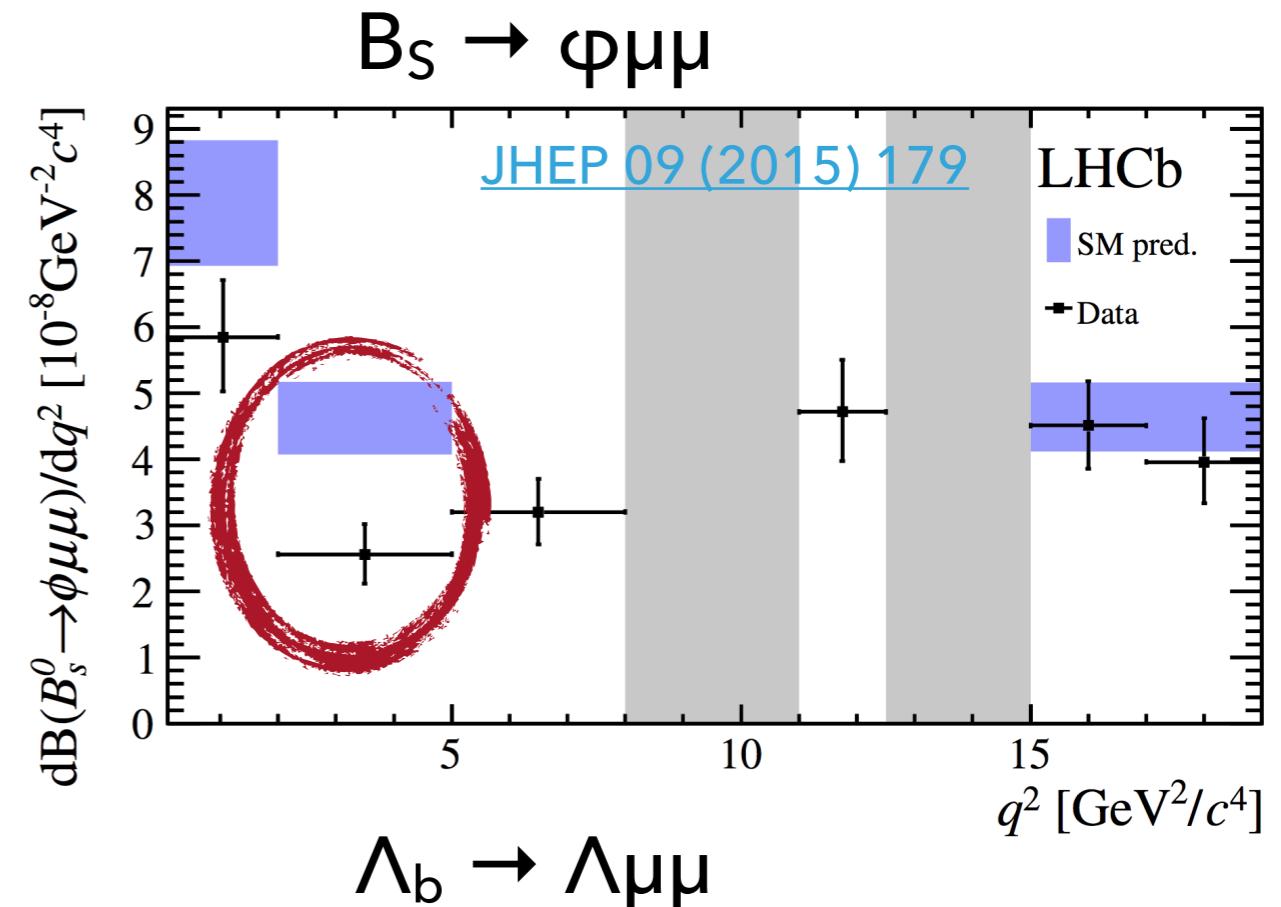
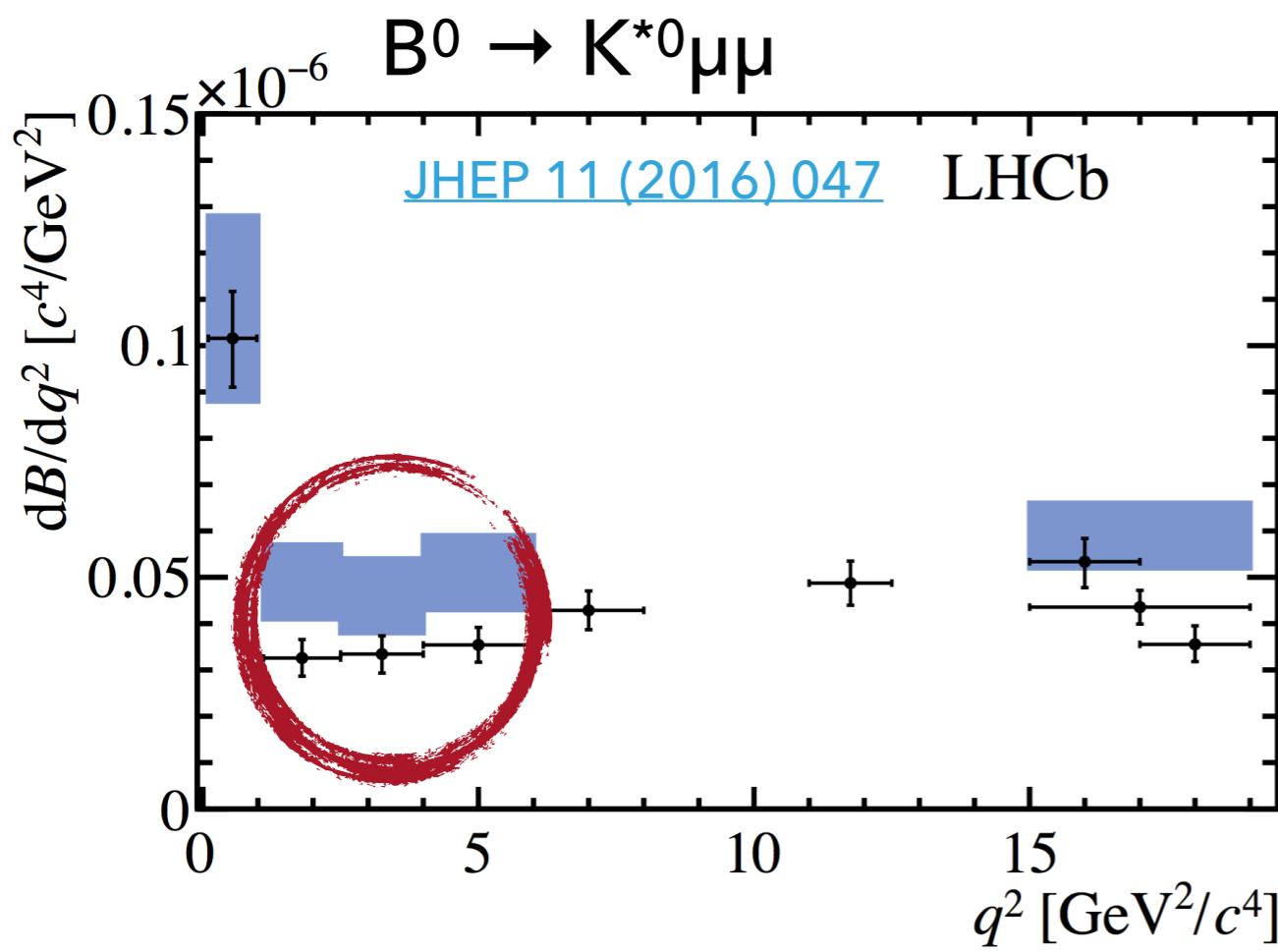
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- ▶ Results consistently lower than SM (but high hadronic uncertainties)



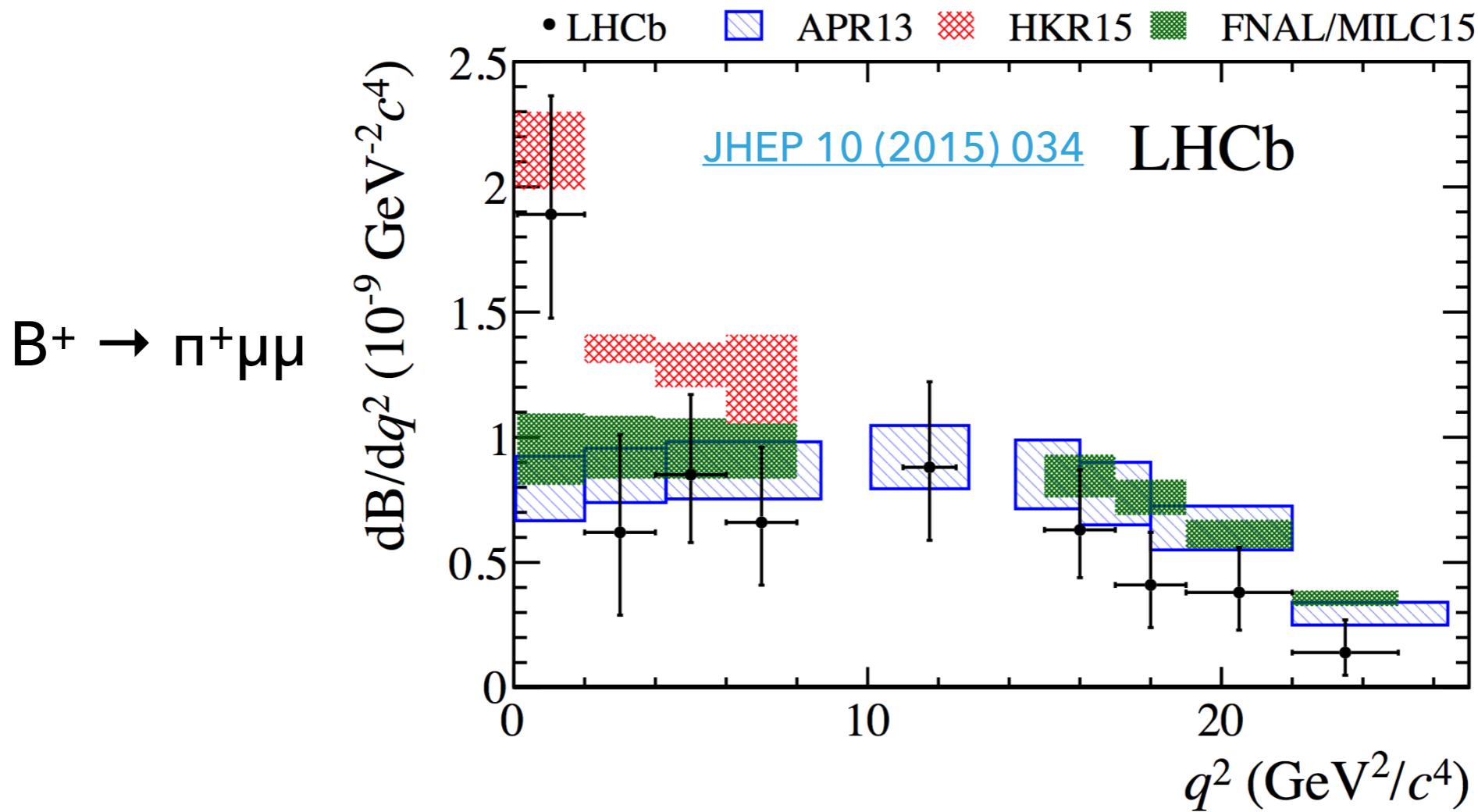
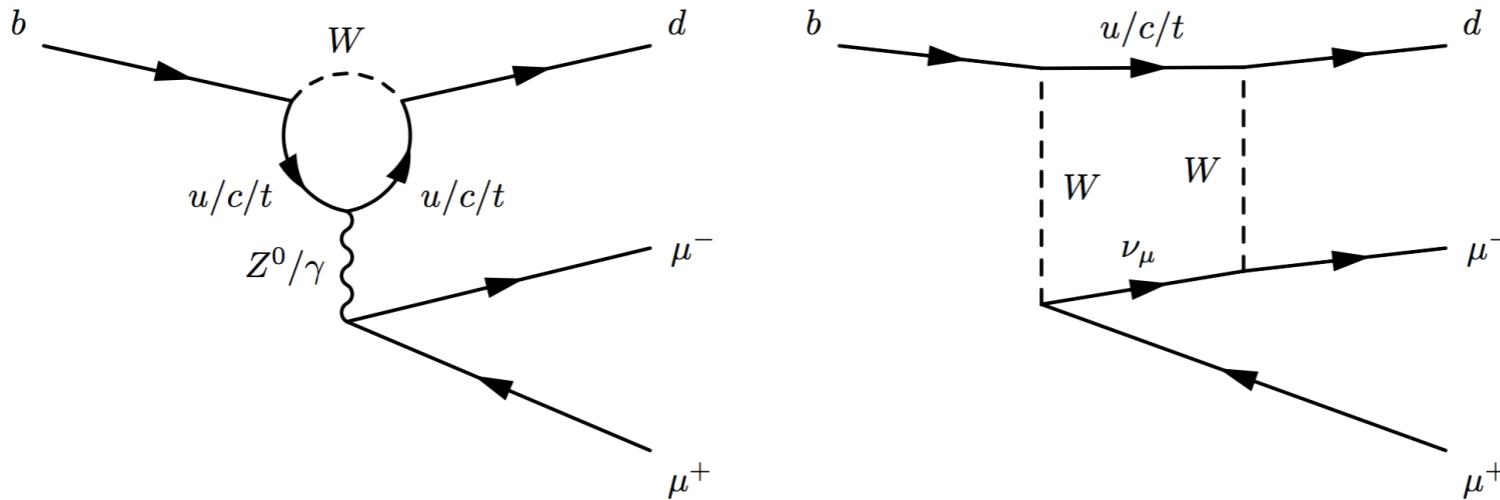
Branching fraction measurements

- ▶ Use all possible decays with a $b \rightarrow sll$ transition
- ▶ Same trend



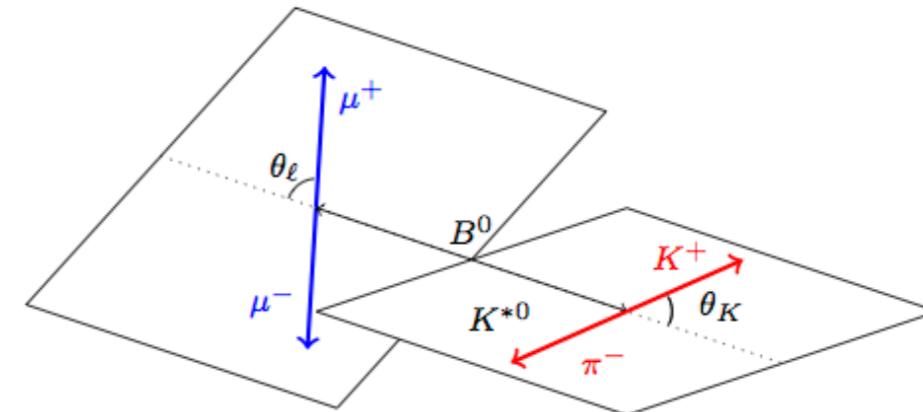
A $b \rightarrow d l \bar{l}$ transition

- ▶ FCNC but CKM suppressed

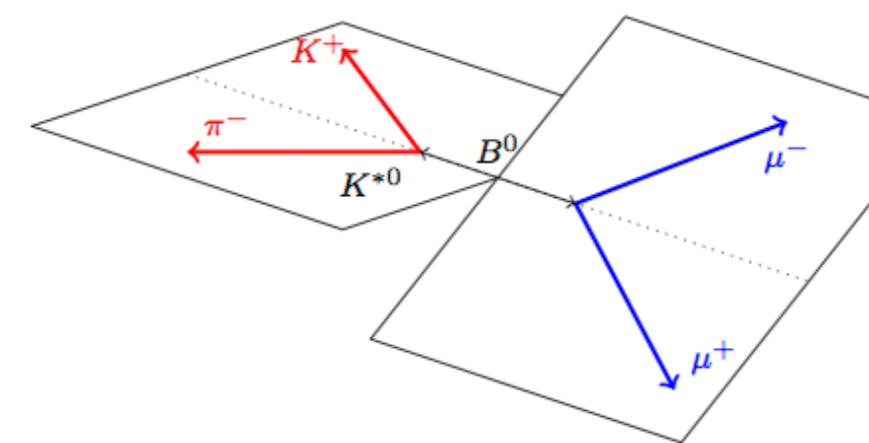


Angular analyses

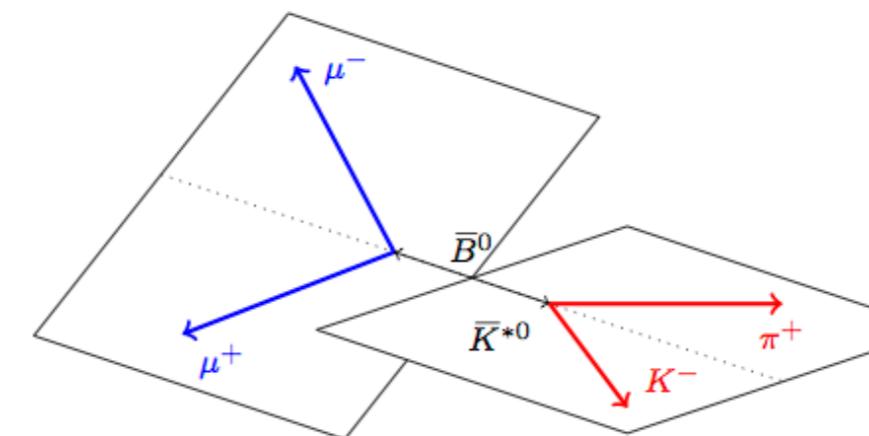
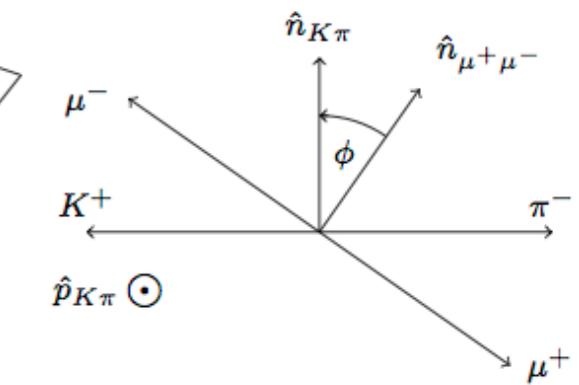
- ▶ 4 distributions using the 4-body final state
3 angles and the di-lepton invariant mass squared
- ▶ Give access to observables (such as A_{FB} , F_L , S_5) that depend on one or several **Wilson coefficients**
- ▶ But also depend on **hadronic matrix elements**



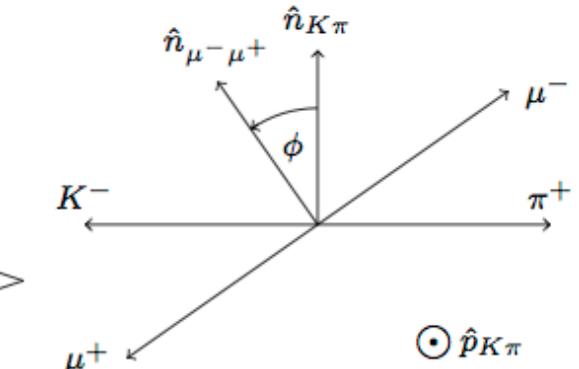
(a) θ_K and θ_ℓ definitions for the B^0 decay



(b) ϕ definition for the B^0 decay



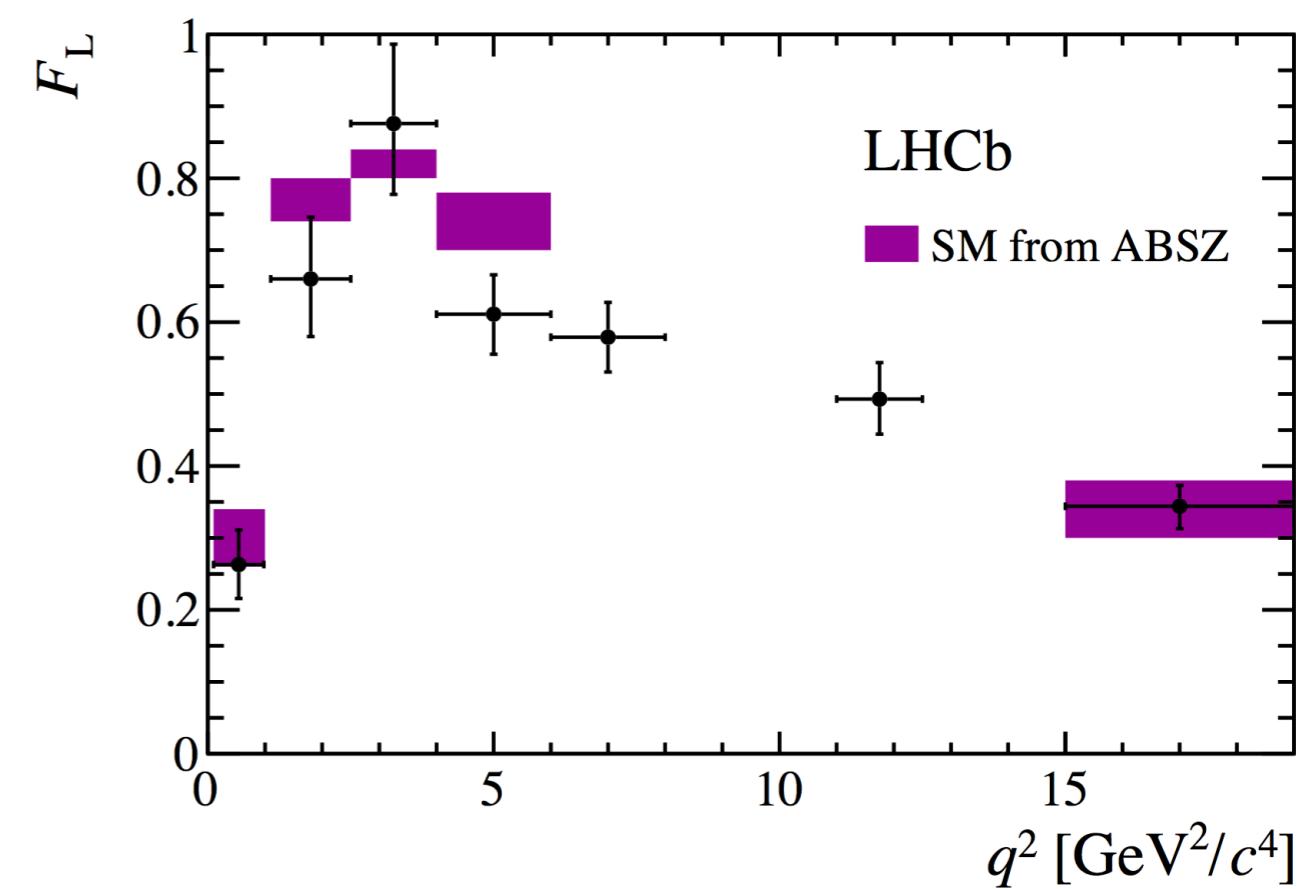
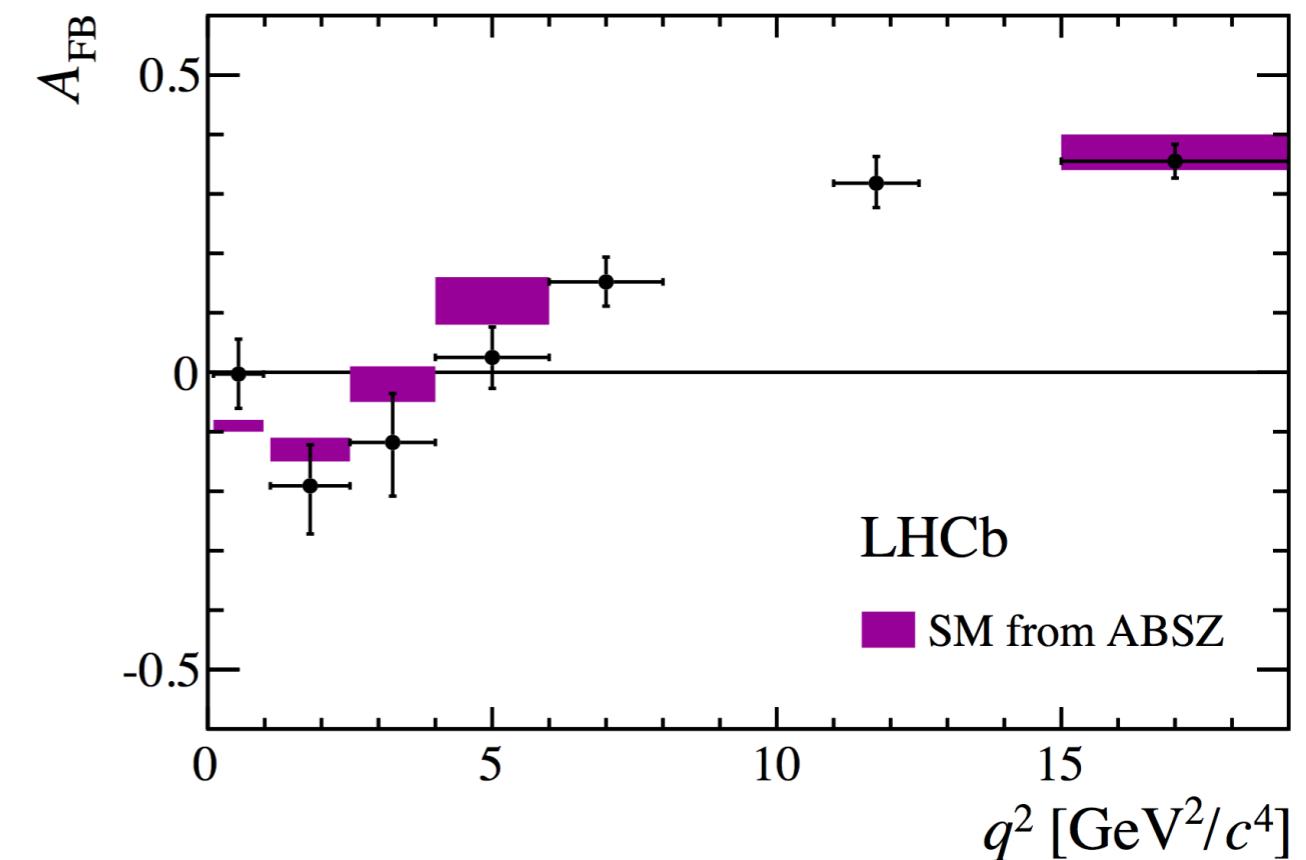
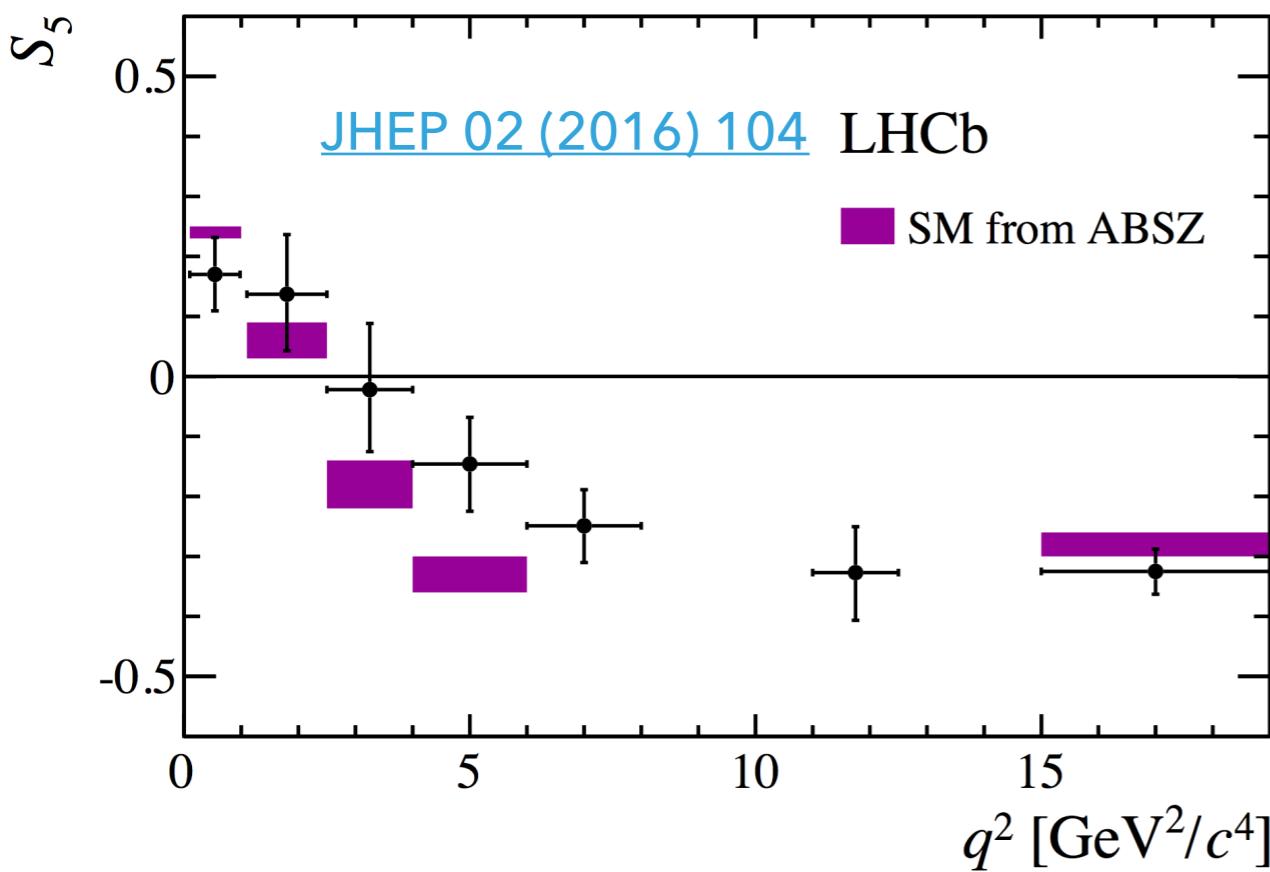
(c) ϕ definition for the \bar{B}^0 decay



Angular analyses

11

- ▶ Full angular analysis of $B^0 \rightarrow K^{*0} \mu\mu$
- ▶ CP averaged angular observables 3σ away from SM



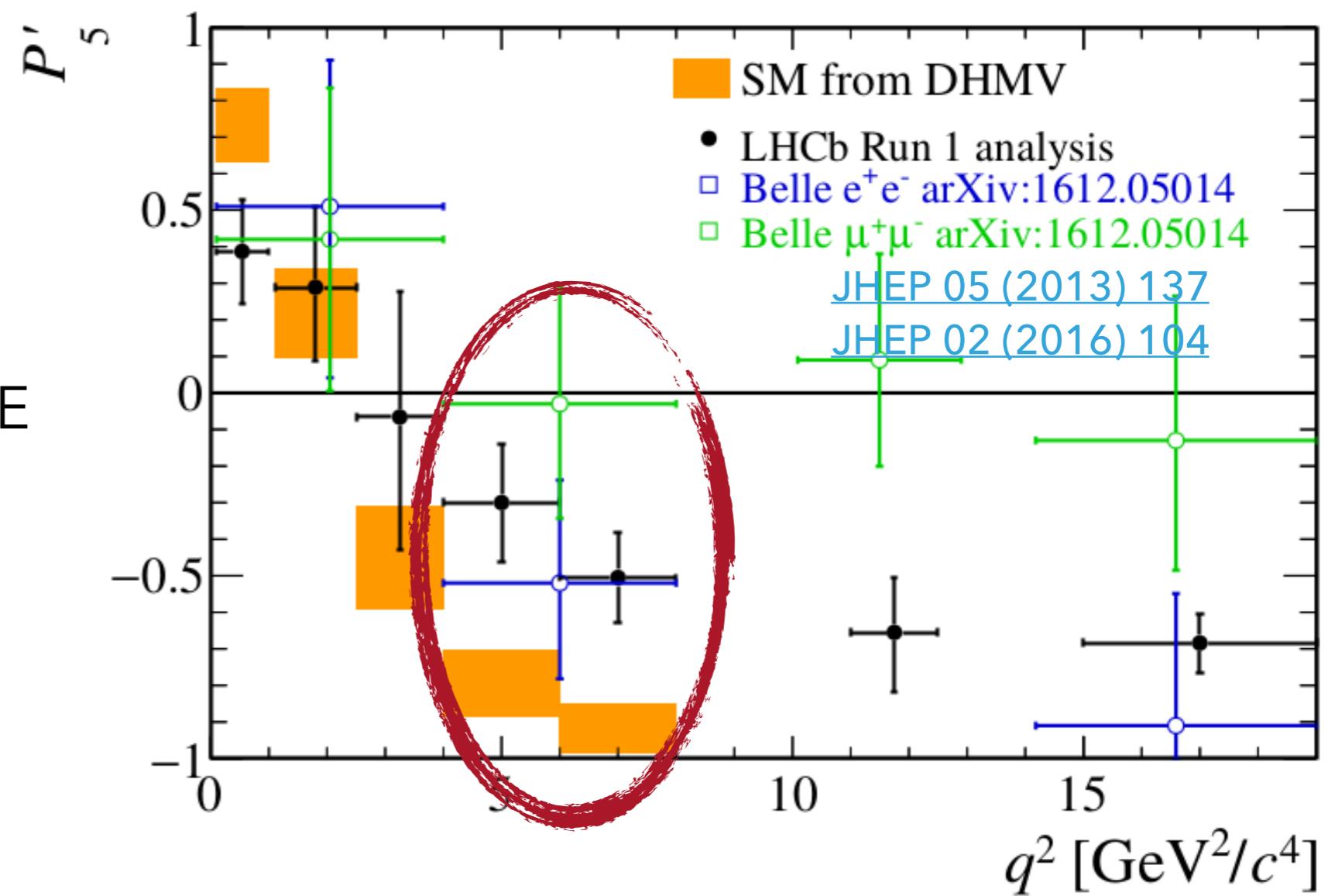
Angular analyses

12

- Less form-factor dependent observable: P'_5

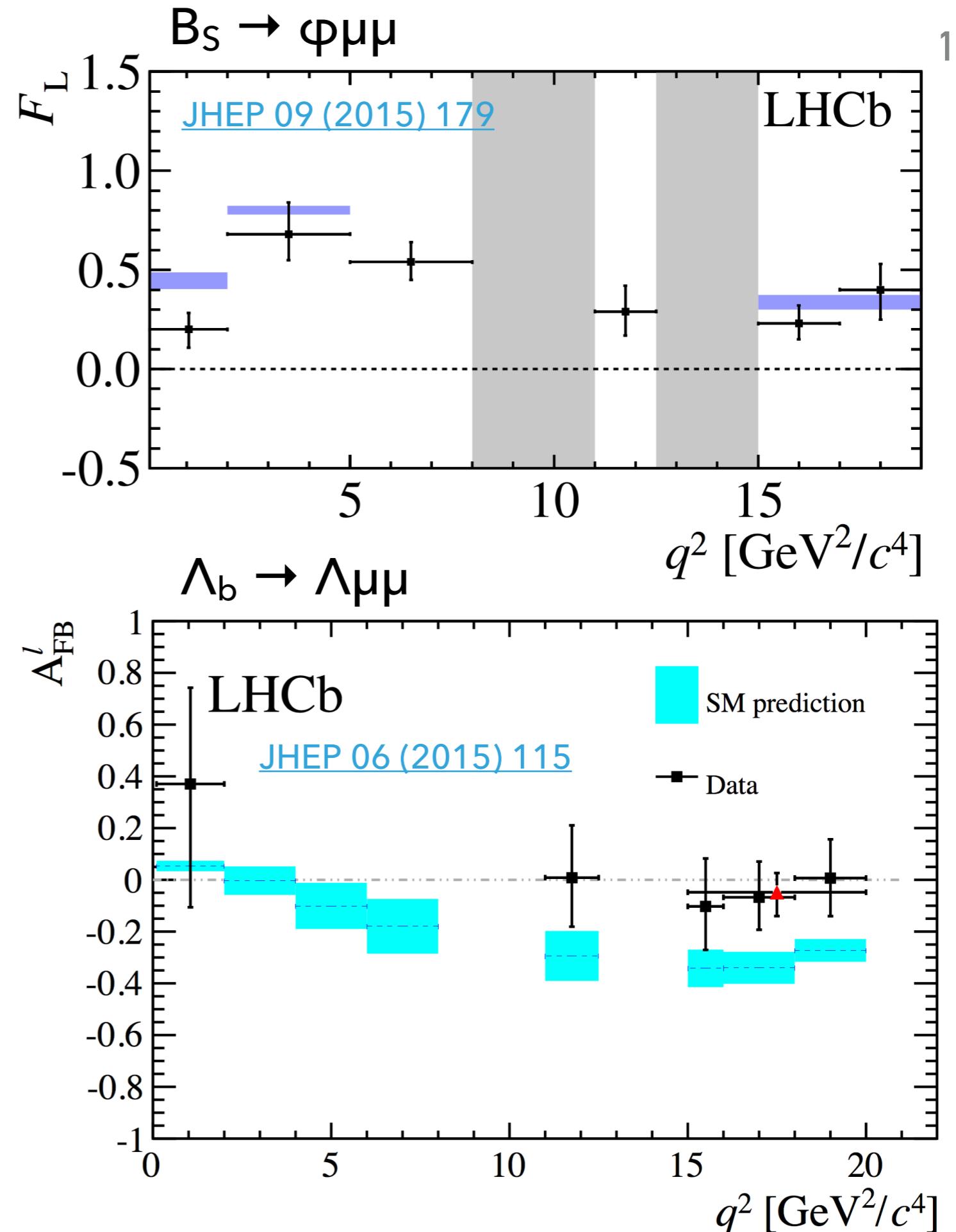
$$P'_5 = \frac{S_5}{\sqrt{F_L(1 - F_L)}}$$

- Still slightly away from SM (2.8σ and 3.0σ)
- Compatible with BELLE in the low q^2 region



Angular analyses

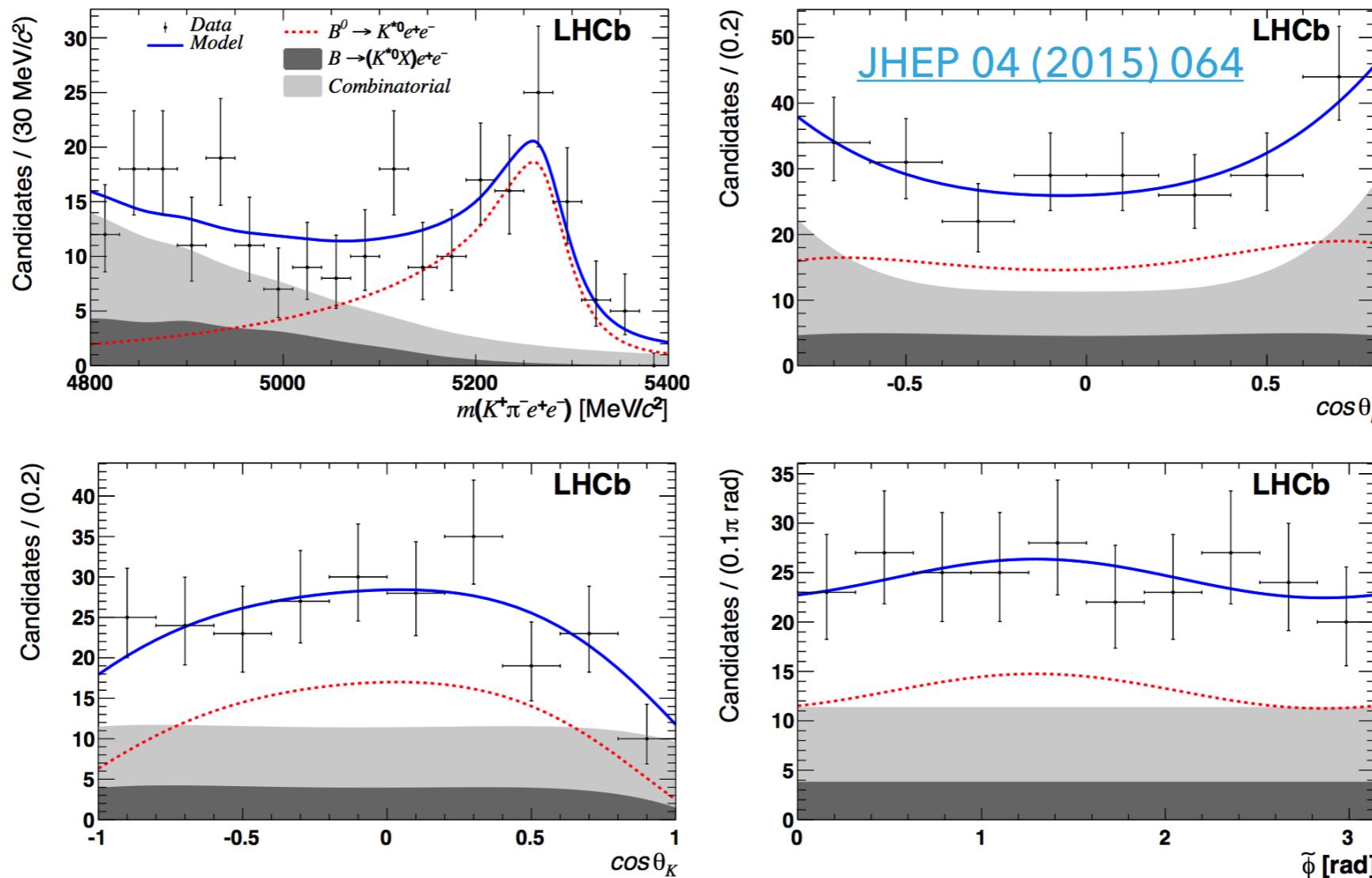
- ▶ Repeated with several $b \rightarrow sll$ transitions
- ▶ Λ_b decays give access to **different combinations** of Wilson coefficients



Angular analyses

- ▶ Full angular analysis of $B^0 \rightarrow K^{*0}ee$ at **very low q^2** in the [0.002 - 1.120] GeV^2/c^4 range
- ▶ Challenging due to Bremsstrahlung
- ▶ Sensitive to C_7 and C_7' (which are found to be **consistent with SM**)

F_L	$=$	$0.16 \pm 0.06 \pm 0.03$
$A_T^{(2)}$	$=$	$-0.23 \pm 0.23 \pm 0.05$
A_T^{Im}	$=$	$+0.14 \pm 0.22 \pm 0.05$
A_T^{Re}	$=$	$+0.10 \pm 0.18 \pm 0.05$



Lepton flavour universality tests

15

- ▶ Use **ratio of branching fractions** to cancel theoretical uncertainties

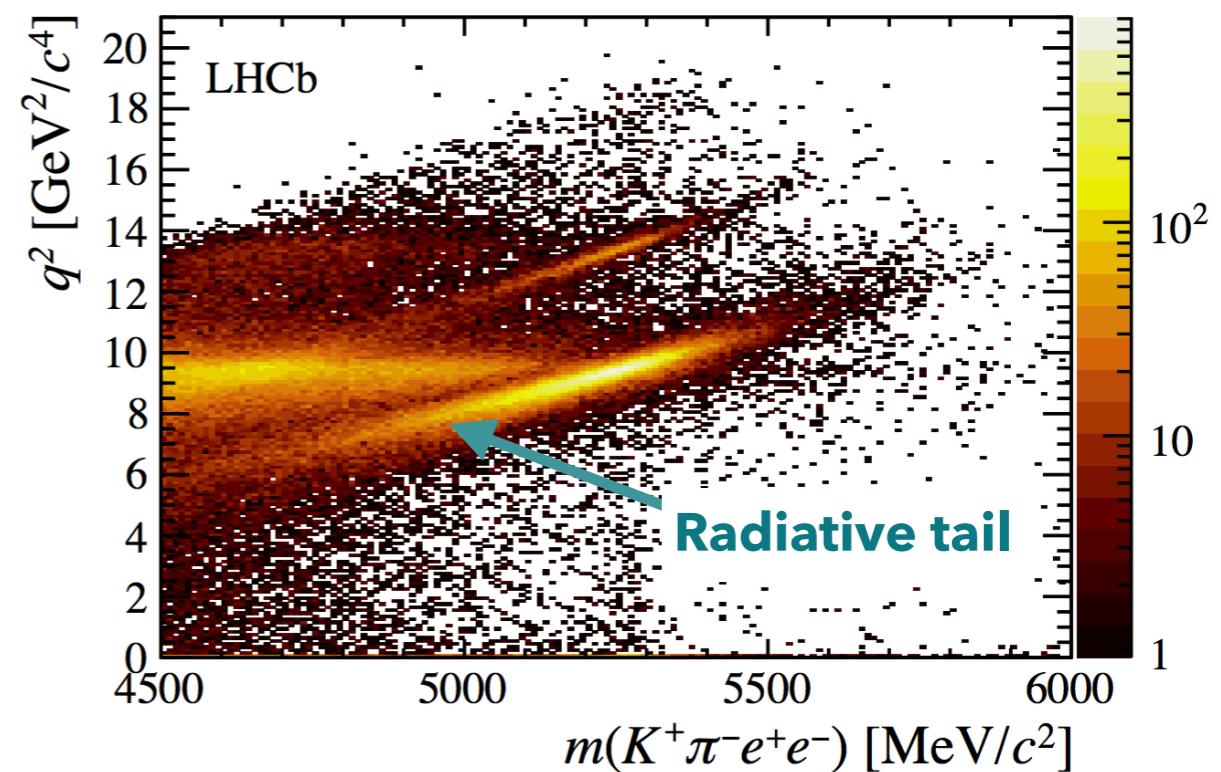
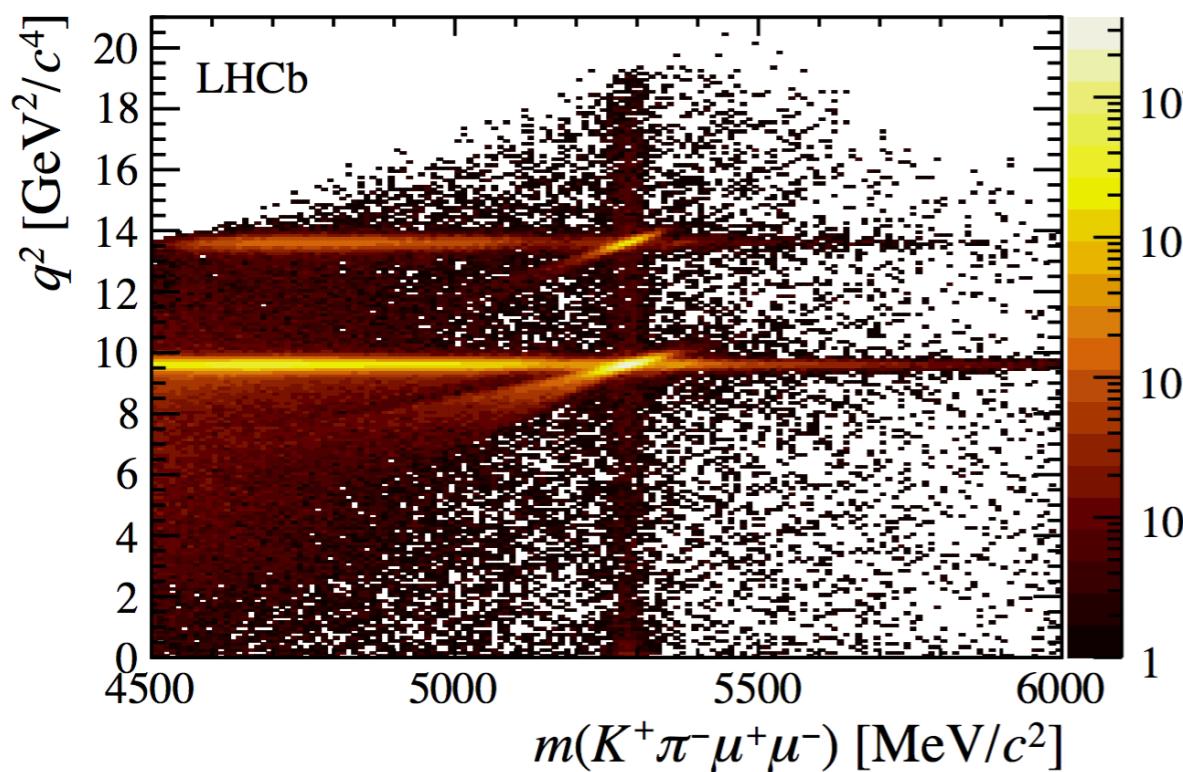
$$R_H = \frac{\int \frac{d\Gamma(B \rightarrow H \mu^+ \mu^-)}{dq^2} dq^2}{\int \frac{d\Gamma(B \rightarrow H e^+ e^-)}{dq^2} dq^2}$$

- ▶ In SM, $R_H = 1$

(up to phase-space corrections and Higgs contributions at the % level: [arXiv:1605.07633](https://arxiv.org/abs/1605.07633))

Deviation from 1 would be clear sign of NP

- ▶ Difficult because of **Bremsstrahlung**



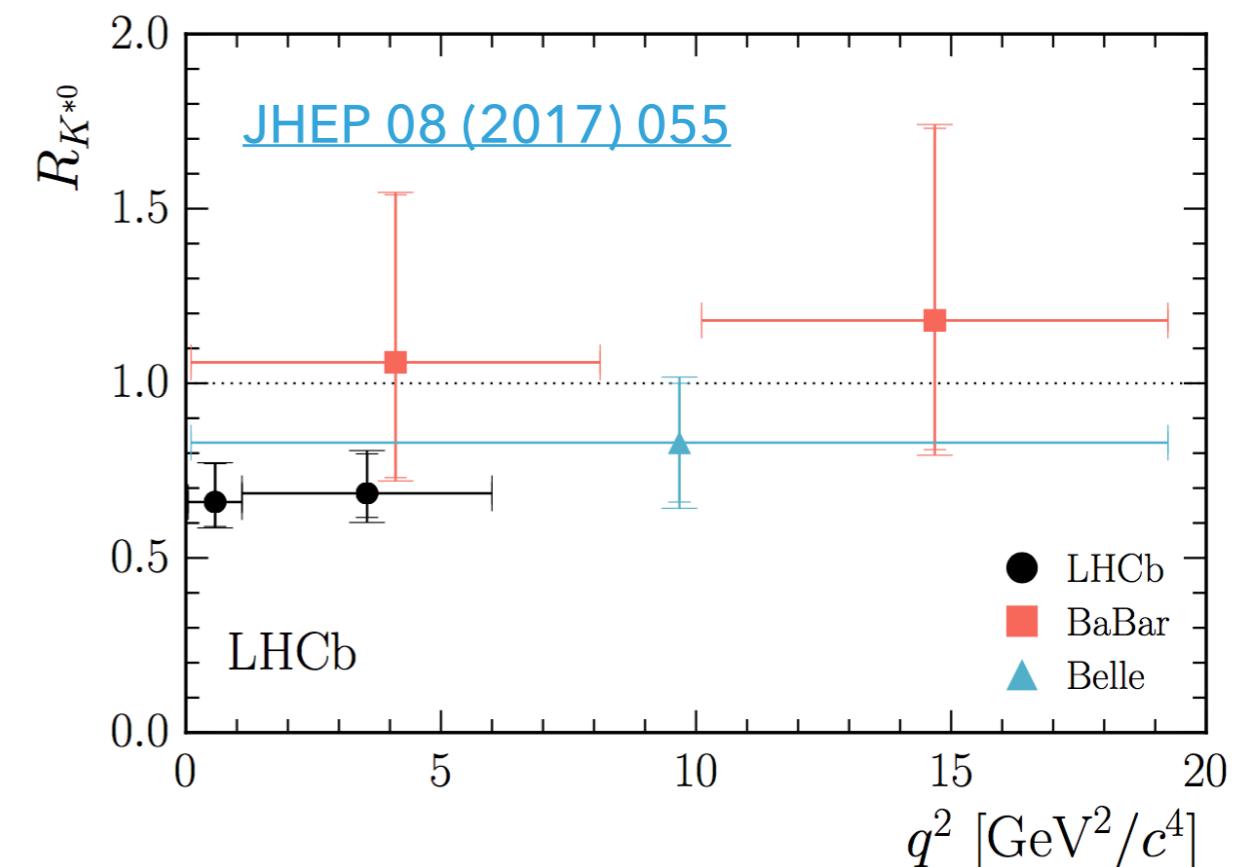
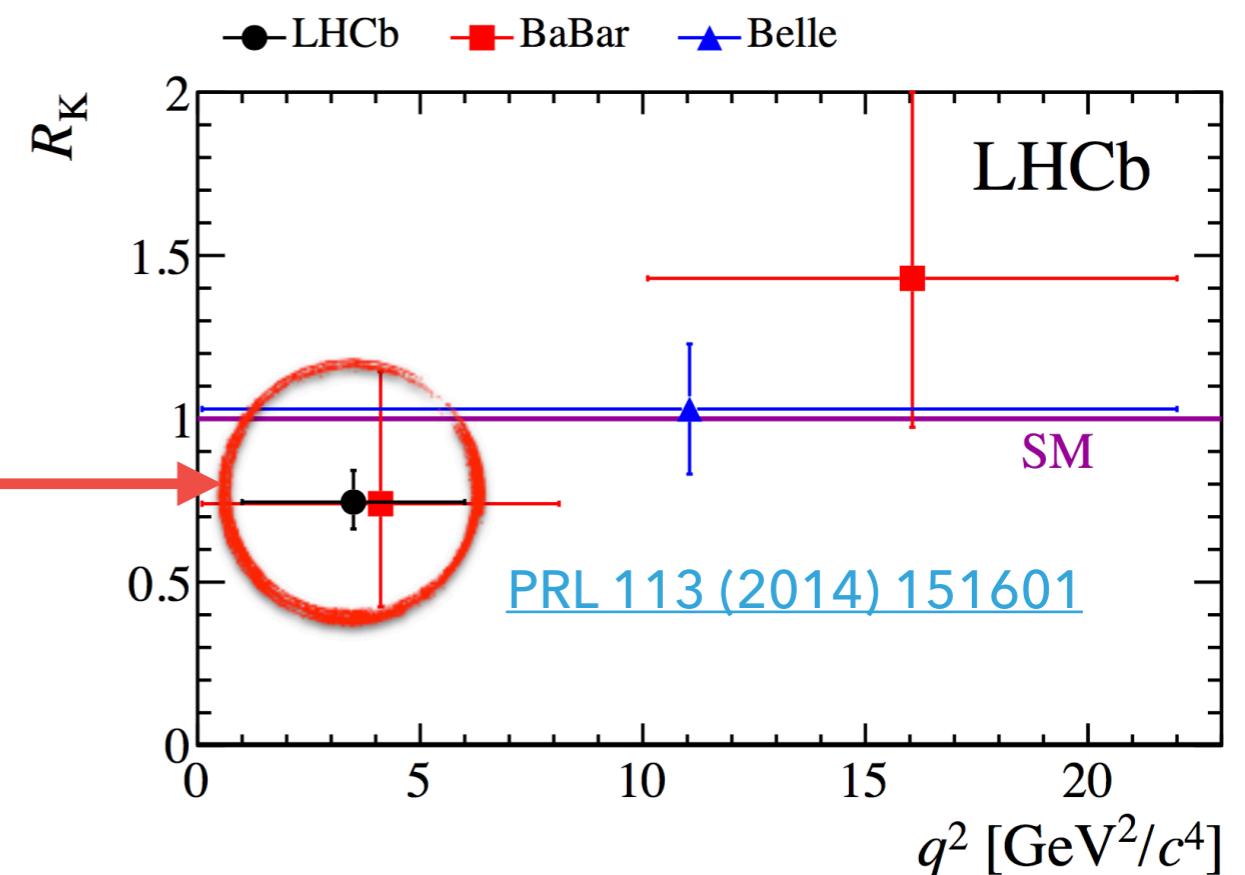
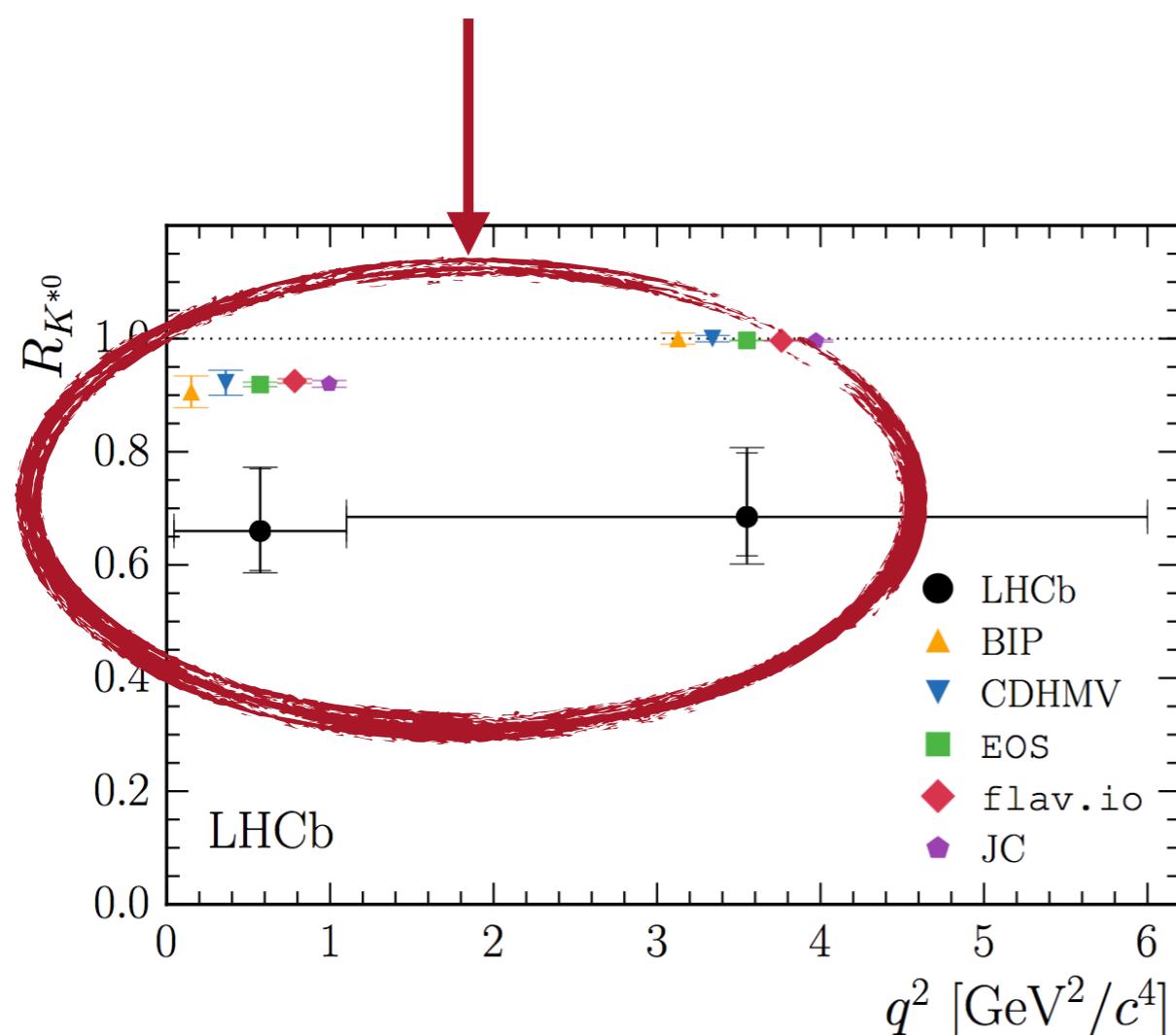
Lepton flavour universality tests - Results

16

Tensions with SM predictions:

2.6σ level in R_K

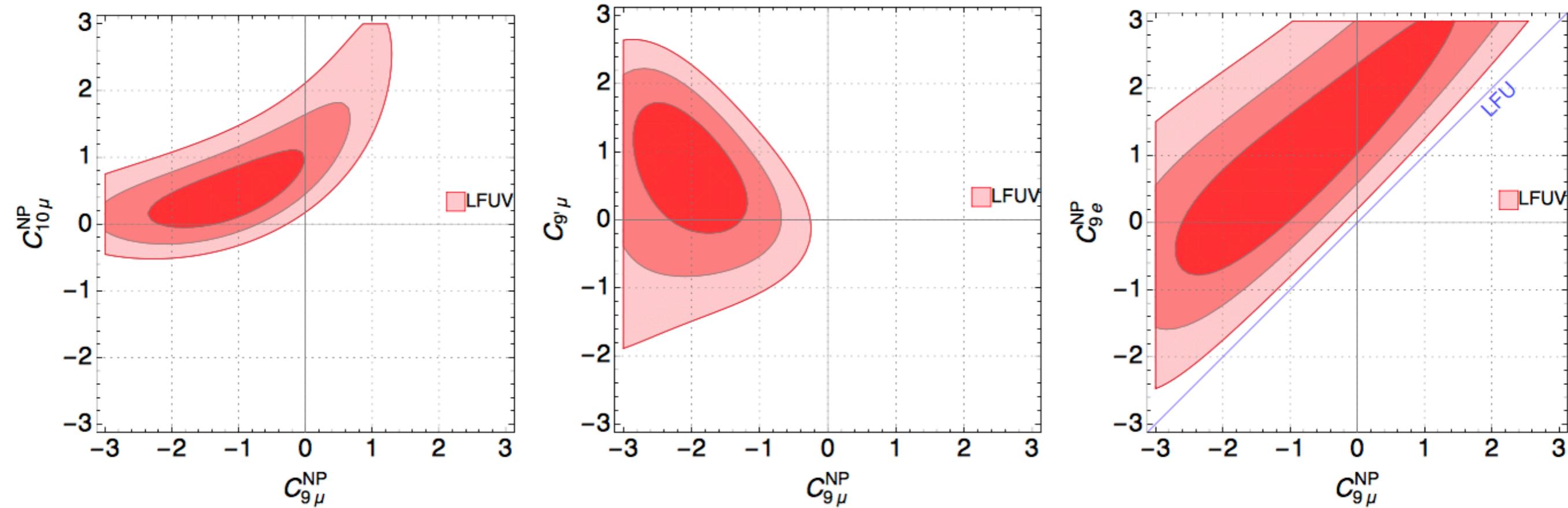
$2.2-2.5\sigma$ level in R_{K^*}



Combinations using lepton-flavour unitarity tests

17

[Capdevila et al. \(arXiv:1704.05340\)](#)

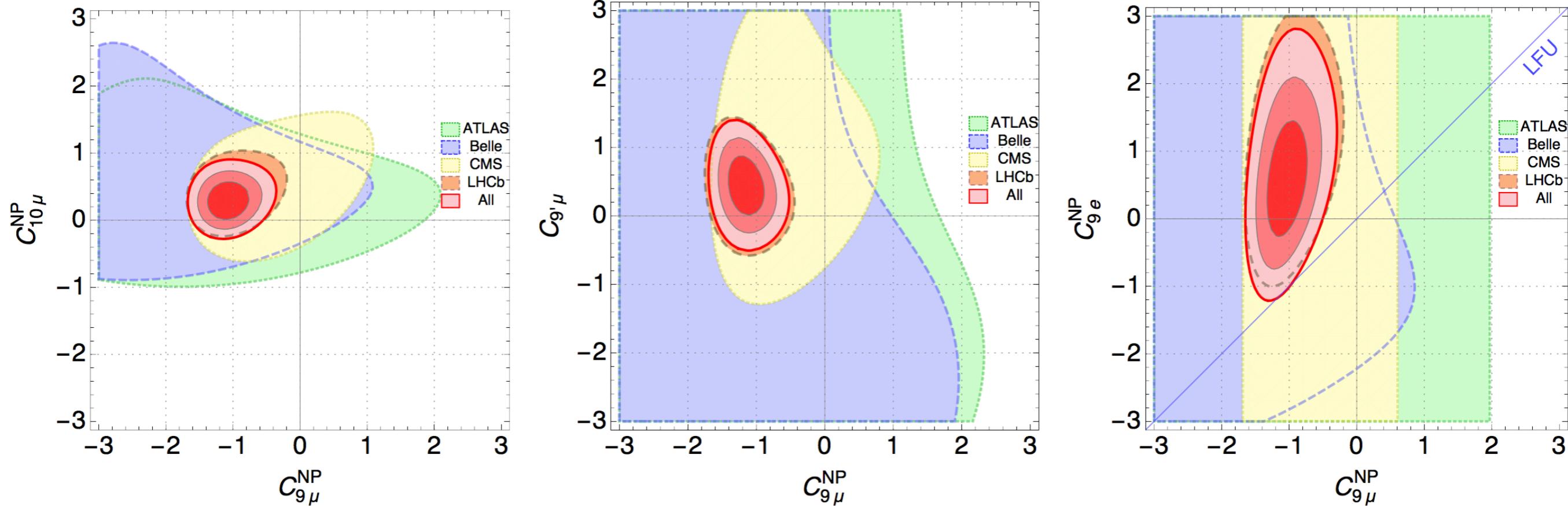


- Hadronic uncertainties would not affect LFU
- With only LFU (and $b \rightarrow s\gamma$) results, discrepancy of more than 3σ with SM

Combinations of branching ratios, angular analyses and lepton-flavour unitarity tests

18

[Capdevila et al. \(arXiv:1704.05340\)](https://arxiv.org/abs/1704.05340)



- ▶ Use **all available data** plus constraints from $b \rightarrow s\gamma$ transitions and $B_s \rightarrow \mu\mu$ to obtain **more information on the Wilson coefficients**
- ▶ Reaches more than 4σ discrepancy from SM
- ▶ In favour of new physics in C_9 and C_{10} (that would couple more to muons from LFU tests)

This is just an example...

Many others here:

[arXiv:1704.05438v1](https://arxiv.org/abs/1704.05438v1), [arXiv:1704.05444v1](https://arxiv.org/abs/1704.05444v1)
[arXiv:1704.05446v1](https://arxiv.org/abs/1704.05446v1), [arXiv:1704.05447v1](https://arxiv.org/abs/1704.05447v1)
[arXiv:1704.05672v1](https://arxiv.org/abs/1704.05672v1), [arXiv:1704.05835v1](https://arxiv.org/abs/1704.05835v1)
[arXiv:1704.05849v1](https://arxiv.org/abs/1704.05849v1), [arXiv:1704.06005v1](https://arxiv.org/abs/1704.06005v1)
[arXiv:1704.06188v1](https://arxiv.org/abs/1704.06188v1), [arXiv:1704.06200v1](https://arxiv.org/abs/1704.06200v1)
[arXiv:1704.06240v1](https://arxiv.org/abs/1704.06240v1), [arXiv:1704.06659v1](https://arxiv.org/abs/1704.06659v1)
[arXiv:1704.07347v1](https://arxiv.org/abs/1704.07347v1)

Conclusion

19

- Many analyses exploiting $b \rightarrow s\ell\ell$ transitions have been performed using LHCb Run 1 data
- Even though there is no evidence of new physics from any single analysis, global fits show a **clear tension** with the SM



Traces-Kačka a Ondra

The way to go

- ❑ Effort ongoing to try to control hadronic uncertainties
- ❑ Update all analyses with Run 2 data ($\sim 5 \text{ fb}^{-1}$ expected)
- ❑ New measurements
 - R_φ (suppressed by f_s/f_d but narrow mass window)
 - R_{pK}
 - $R_{K\pi\pi}$
- ❑ Studies of lepton flavour violation
 - $B_{(S)} \rightarrow e\mu$ ([arXiv:1710.04111](https://arxiv.org/abs/1710.04111))
 - $B \rightarrow K e\mu$



Mountaineers-ashokboghani



Thanks for your attention!