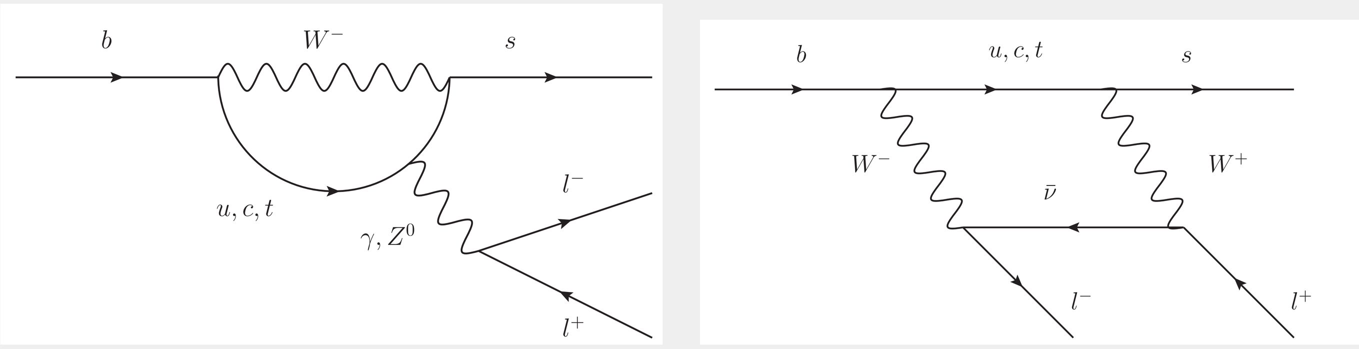
Universität Zürich[UZH]

Flavour Anomalies in Rare Semileptonic Transitions at LHCb

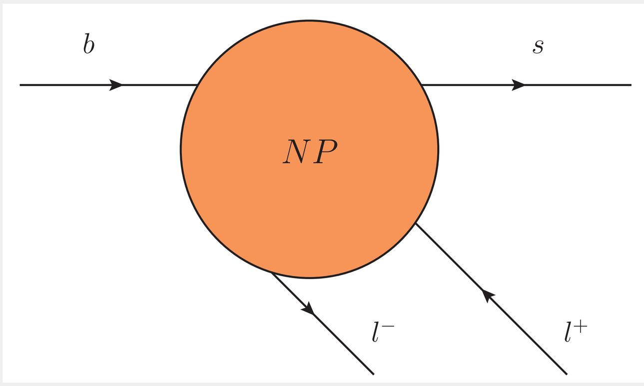
Davide Lancierini (davide.lancierini@uzh.ch)
M. Atzeni, R. S. Countinho, F. Lionetto, A. Mauri, A. Puig, N. Serra

1) Motivation

- In the Standard Model (SM), semi-leptonic $b \to s l^+ l^-$ transitions are only possible at loop level, and are independent of the lepton flavour, i.e. they are Lepton Flavour Universal (LFU)



- Rare decays are studied to search for NP particles which could distinguish between lepton flavours



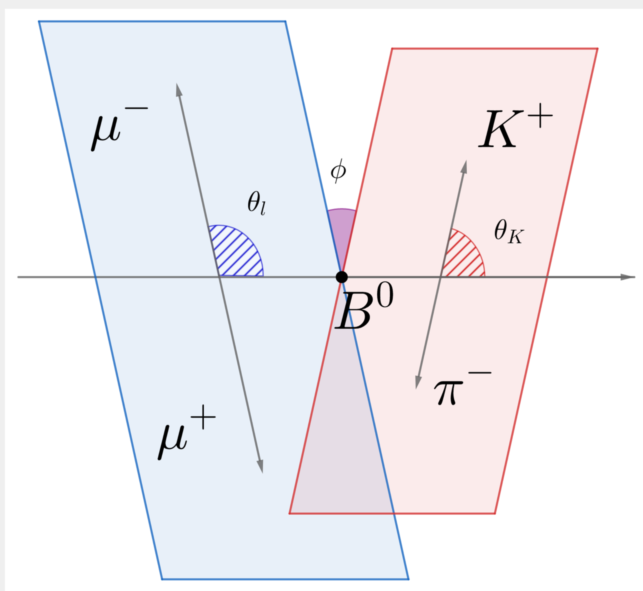
- Angular Observables and Ratios of Branching Fractions ($\mathcal{B}$) are indicative probes of NP

2) Angular Observables

- Model independent parametrization of NP

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \mathcal{C}_i \mathcal{O}_i$$

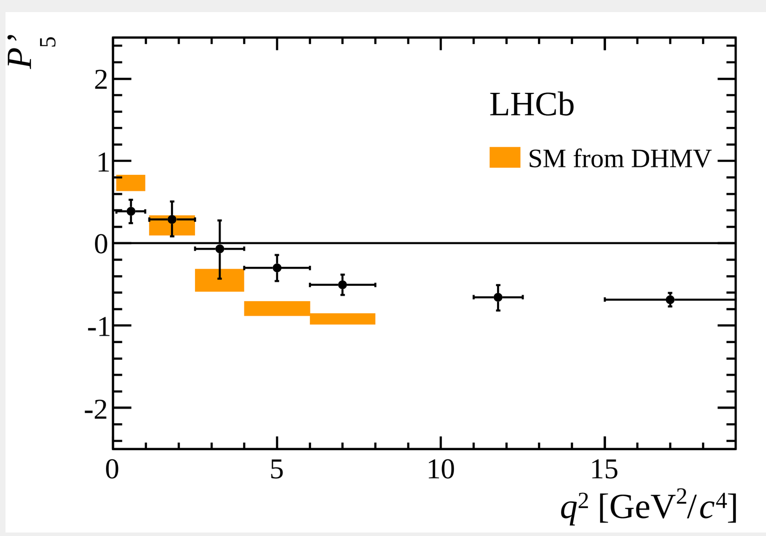
  - Wilson Coefficients $\mathcal{C}_i$ describe interactions at High Energy, possible source of NP
  - Operators $\mathcal{O}_i$ describe Low Energy effects



The $\frac{d\Gamma(B^0 \to K^* \mu\mu)}{d\cos\theta_l d\cos\theta_K d\phi}$ can be parametrized in terms of angular observables, one of those is P_5' which contains dependency on $\mathcal{C}_i$'s

3) The P_5' Anomaly

- P_5' LHCb measurement shows a 3.7 σ discrepancy [1] with the SM prediction [2], could be due to:
  - QCD contribution not reliably computed (charm-loop)
  - NP contribution in $\mathcal{C}_9$ (or $\mathcal{C}_9/\mathcal{C}_{10}$ simultaneously)



4) Ratios of Branching Fractions

Why study ratios of $\mathcal{B}$?

$$R_{K^{(*)}} \equiv \frac{\mathcal{B}(B \to K^{(*)}\mu^+\mu^-)}{\mathcal{B}(B \to K^{(*)}e^+e^-)}$$

- QCD uncertainties are reduced, no charm-loop effects
- they are Lepton Flavour Universality (LFU) probes $\to$ could point to NP

- the SM Predictions:
  - $R_K^{SM} = \mathbf{1.00023(63)}$ [3]
  - $R_{K^*}^{SM} = \mathbf{1.00(1)}$ [4]

  $\leftarrow$ are LFU in SM, SM Gauge Bosons do not distinguish flavour

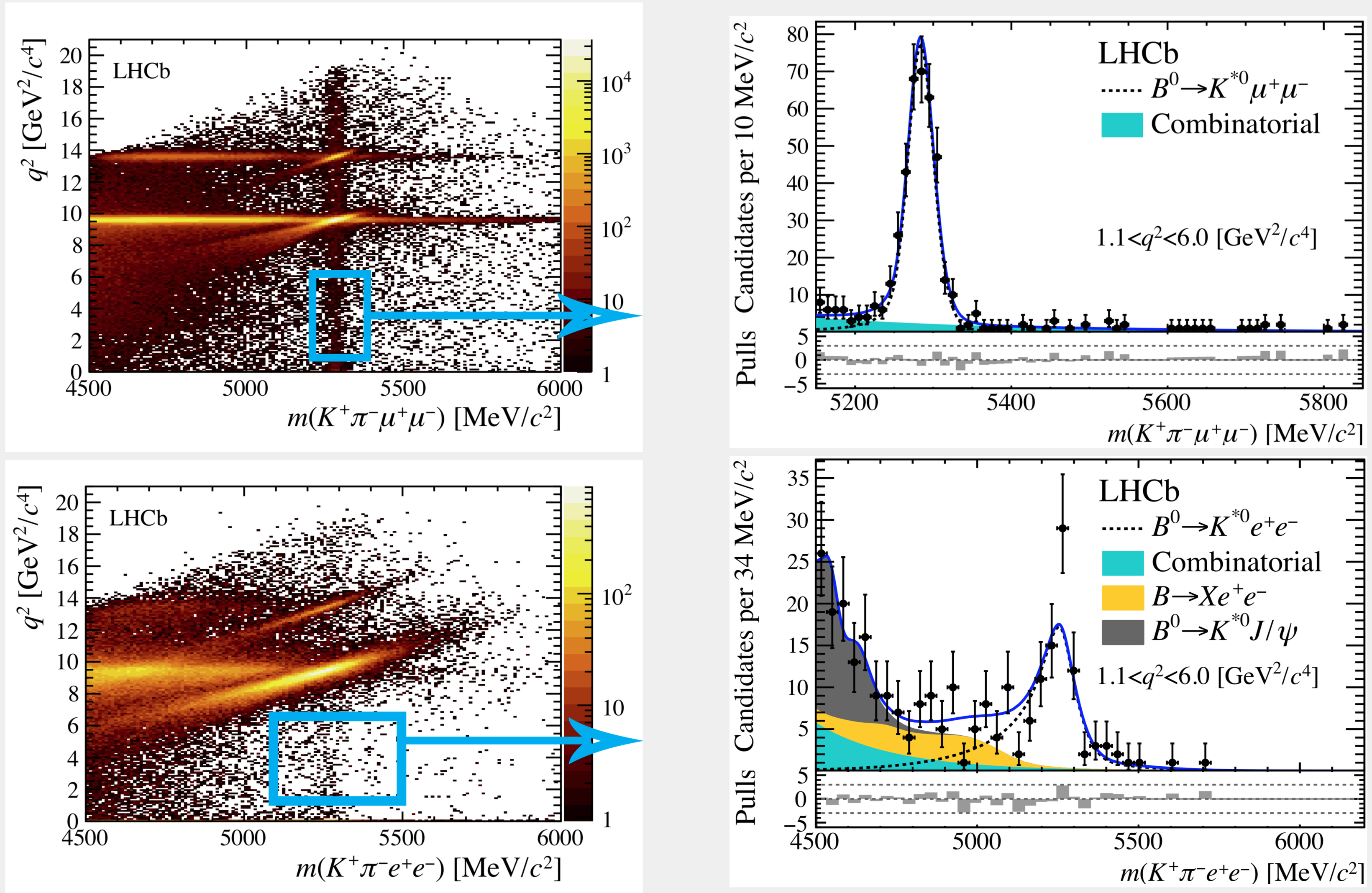
- Experimental strategy: Double Ratio

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

  - Cancel potential sources of systematic uncertainties and $\mathcal{B}(B \to K^{(*)}J/\psi)$ is known precisely [5]
  - $R_{J/\psi}$ is assumed LFU [5]

5) Branching Fractions Measurements at LHCb

Number of candidates for $B^0 \to K^{*0} l^+ l^-$ final states with (up) muons and (down) electrons as a function of the dilepton invariant mass squared, and the four-body invariant mass of the B^0 [7].



- In $e^{\pm}$ channel:
  - Difficult Bremsstrahlung recovery affects invariant mass resolution
  - Lower trigger efficiency, harder reconstruction and Particle Identification

6) Comparison with the SM

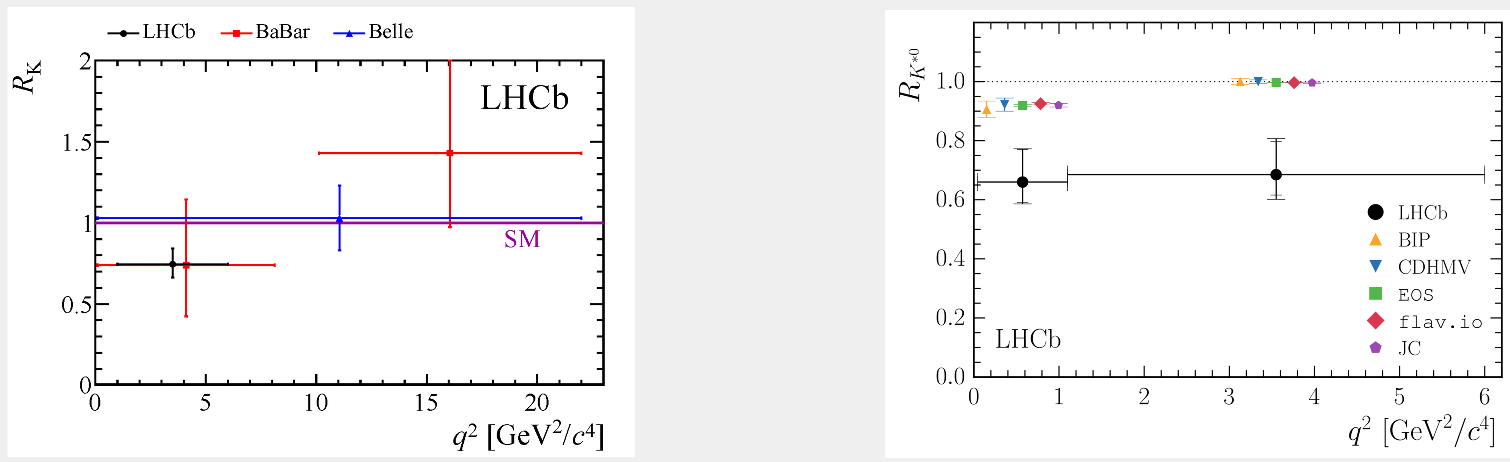
Comparing the results on $R_{K^{(*)}}$ with the predicted SM values

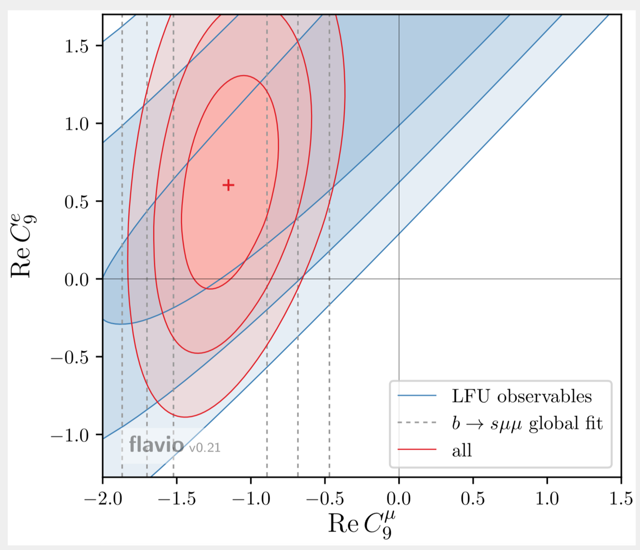
$R_K[1-6\text{GeV}^2] = \mathbf{0.745}^{+0.090}_{-0.074}(\text{stat}) \pm \mathbf{0.036}(\text{syst})$ [6]

2.6 σ from the SM Prediction

$R_{K^*} = \begin{cases} \mathbf{0.66}^{0.11}_{-0.07}\text{stat} \pm \mathbf{0.03}\text{syst}\ [\mathbf{0.045-1.1}\text{GeV}^2] \\ \mathbf{0.69}^{0.11}_{-0.05}\text{stat} \pm \mathbf{0.03}\text{syst}\ [\mathbf{1.1-6.0}\text{GeV}^2] \end{cases}$ [7]

2.2-2.4 and 2.4-2.5 σ from the SM Prediction





- Ratios of $\mathcal{B}$ and Angular Observables allow to exclude regions in the $\mathcal{C}^{NP}_{i,\mu,e}$ planes
- Both classes of observables allow compatible regions [8]
- Possible interpretation in terms of coherent NP pattern

7) Future Prospects

- Determining the charm loop in $b \to s l^+ l^-$ by measuring angular observables in $B^0 \to K^{*0} l^+ l^-$
- Measuring other ratios of $\mathcal{B}$ in addition to updating $R_{K^{(*)}}$ with data from the second run of LHC
- Test LFU in angular observables in decays $B^0 \to K^{*0} l^+ l^-$

References

[1] R. Aaij et al., JHEP05(2014)082
[2] S. Descotes-Genon, L. Hofer, J. Matias, J. Virto, JHEP12(2014)125
[3] C. Bouchard, G. P. Lepage, C. Monahan, H. Na, J. Shigemitsu, Phys Rev Lett.111.162002
[4] M. Bordone, G. Isidori, A. Pattori, Eur. Phys. J. C (2016) 76: 440
[5] C. Patrignani et al., Chin. Phys. C, 40, 100001 (2016) and 2017 update
[6] R. Aaij et al., Phys. Rev. Lett. 113.151601
[7] R. Aaij et al., JHEP08(2017)055
[8] W. Altmannshofer, P. Stangl, D. M. Straub, Phys. Rev. D. 96.055008