What can we learn from comparing different leptonic final states in $b \to sll$?

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Flavour of New Physics in $b \to s$ transitions,
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Introduction

- Measurements of different dilepton final states in $b \to sll$ can test the lepton and flavour couplings simultaneously.
- Part of spectrum of precision tests of $b \to sll$ decays to map out the coefficients.
- Consider the ratio of decay rates for $B^+ \to K^+\mu^+\mu^-$ and $B^+ \to K^+e^+e^-$.

$$R_H \equiv \frac{\int_{4m_\mu^2}^{q^2_{\max}} dq^2 \frac{d\Gamma(B \to H\mu^+\mu^-)}{dq^2}}{\int_{4m_\mu^2}^{q^2_{\max}} dq^2 \frac{d\Gamma(B \to He^+e^-)}{dq^2}}, \quad H = X_s, K^{(*)},$$

[Hiller, Kruger 2003]

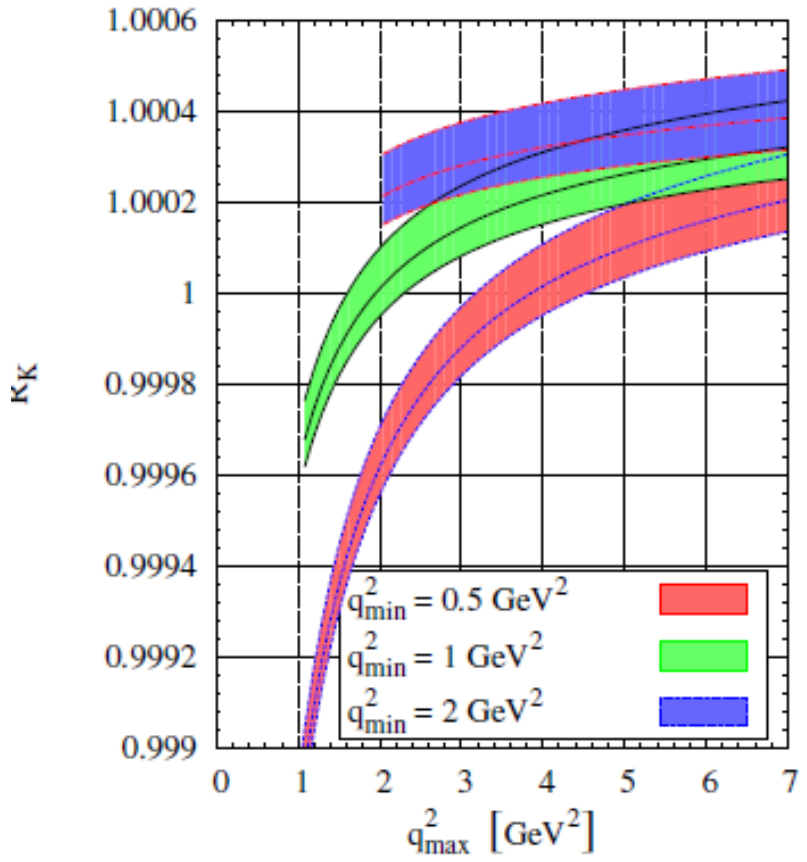
- Enable more precise predictions than the O(30%) theoretical error in the *BR*!

Theoretical background

[Hiller, Kruger: 0310219]
[Bobeth, Hiller et al: 0709.4174]
[Bobeth, Hiller et al: 1111.2558]

- Standard model: $R_H^{\mathrm{SM}} = 1 + O(m_\mu^2/m_b^2),$

- Equality of coupling is concept of *lepton-universality.*
- Enhancement possible from either muon or electron modes.
- Contributions from scalars and pseudo-scalars could have sizeable effects.
- Anything which breaks lepton universality, for example R-parity violating models.



SM prediction!

Observables for leptonic final states

- Basic observable is the ratio of branching fractions:

- Angular expansion: $$\frac{d^2\Gamma_l}{dq^2\, d\cos\theta} = a_l(q^2) + b_l(q^2)\cos\theta + c_l(q^2)\cos^2\theta,$$

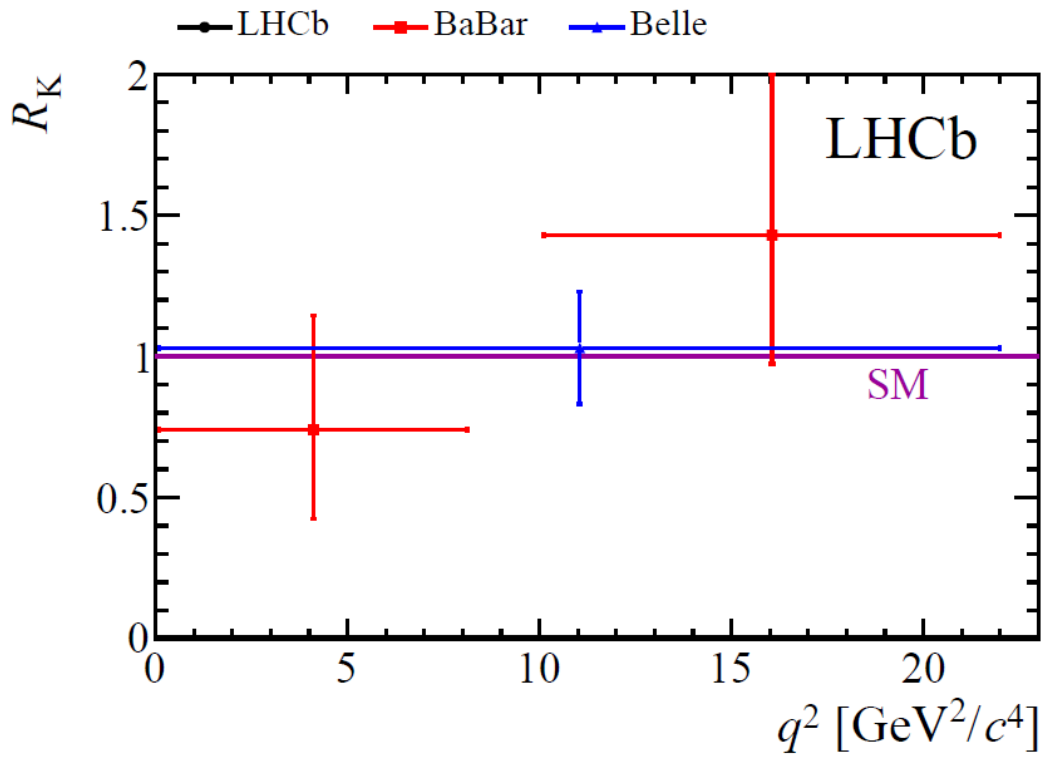
- With observables: $$\frac{1}{\Gamma_l}\frac{d\Gamma_l}{d\cos\theta} = \frac{3}{4}(1 - F_H^l)(1 - \cos^2\theta) + \frac{1}{2}F_H^l + A_{\mathrm{FB}}^l \cos\theta,$$

- $R_K = \frac{\Gamma_\mu}{\Gamma_e}$, $R_{A_{FB}} = \frac{A_{FB}^\mu}{A_{FB}^e}$, $R_{F_L} = \frac{F_H^\mu}{F_H^e}$

Experimental status

Babar, arXiv: 1204.3933
Belle, arXiV: 0904.0770

- Babar: (0.1-8.12)
- $0.74^{+0.31}_{-0.40}(stat.)^{+0.06}_{-0.06}(syst.)$
- Belle: (0.1-22)
- $1.03^{+0.19}_{-0.19}(stat.)^{+0.06}_{-0.06}(syst.)$
- Measurements from Babar, Belle are compatible with unity with a 20% error!
- Present an measurement using the LHCb dataset from Run 1 of the LHC



Event selection

- Combination of events triggered using
  - High pT electron
  - High pT hadron
  - High pT track from the other *b*
- Separation of signal and combinatorial background achieved using kinematic and candidate quality cuts in addition to an multivariate classifier

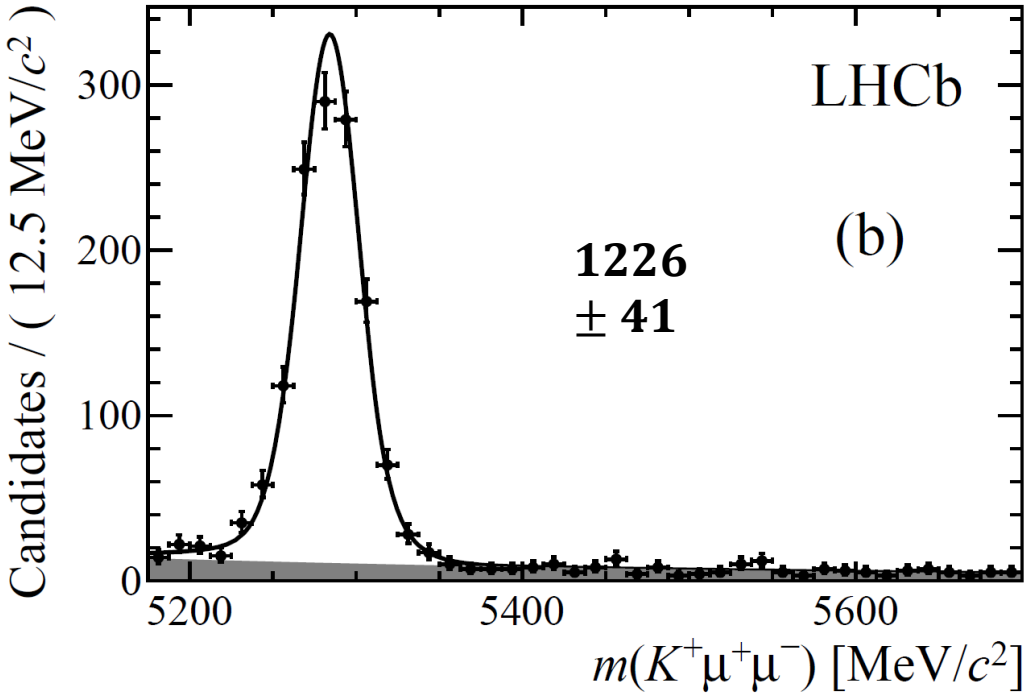
- Efficiency to select events calculated using combination of data-corrected simulation and data driven methods
- Select q^2 region from 1 to 6
- Theoretically favoured
- Below radiative tail from $B^+ \rightarrow J/\Psi(ee)K^+$
- Avoids contamination from $c\bar{c}$ in the low recoil region

Event yields

PRELIMINARY, THIS IS A SNEAK PREVIEW
FIRST OFFICIAL ANNOUNCEMENT at LHCP TOMORROW

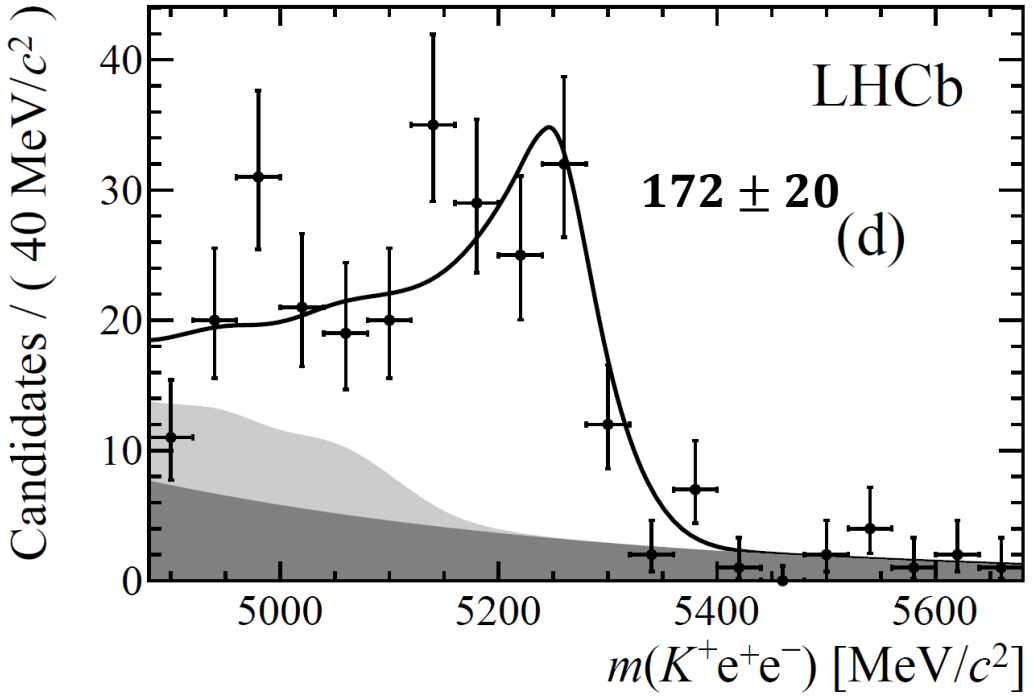
$B^+ \to K^+\mu^+\mu^-$

all events



$B^+ \to K^+e^+e^-$

events with a high pT electron



Results

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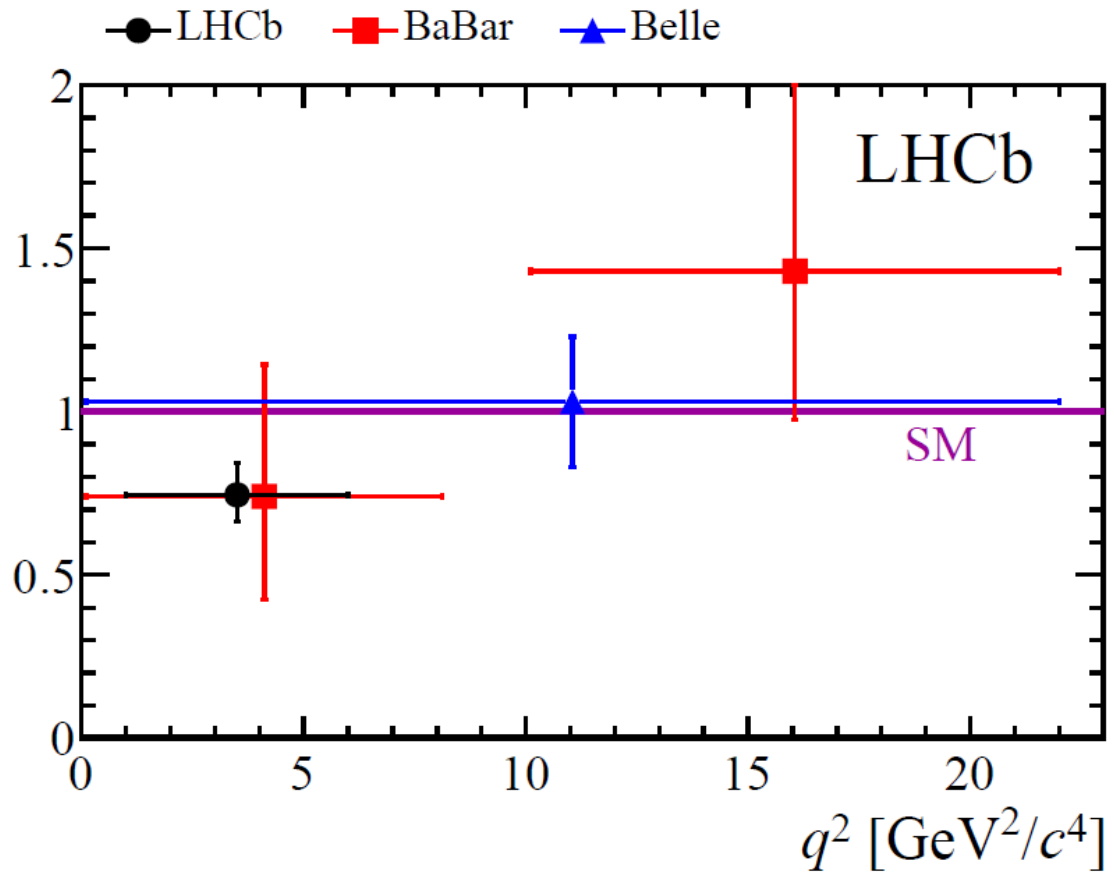
- Bin: $1 < q^2 < 6\ GeV^2/c^4$
- Value of RK, combined across all these trigger categories:
- $R_K = 0.745^{+0.090}_{-0.074}(stat) \pm 0.036(syst)$
- 2.6σ from unity!
- Differential branching fraction
- $B(B^+ \to K^+e^+e^-) =$
- $1.56^{+0.19}_{-0.15}(stat)^{+0.06}_{-0.04}(syst) \times 10^{-7}$



Summary

- Measuring $b \to sll$ decays with different leptonic final states extends search for physics beyond the standard model to test *lepton universality*.
- R_K is the ratio of $B^+ \to K^+\mu^+\mu^-$ to $B^+ \to K^+e^+e^-$.
- LHCb measurement [PRELIMINARY] $R_{\mathrm{K}} = 0.745^{+0.090}_{-0.074}\,(\mathrm{stat})\,^{+0.036}_{-0.036}\,(\mathrm{syst}),$
- Most precise measurement of RK and differential branching fraction in the world.
- Exciting times ahead, many extensions possible: R_{K^*}, $R_{A_{FB}}$, R_{F_L}

Back up

Introduction

- The flavour changing neutral current $b \to sll$ is sensitive to effects from physics beyond the standard model
- The OPE provides a model-independent way to investigate the effects of any new couplings to the flavour sector.
- The equality of the electroweak couplings to electrons, muons and taus is called '*lepton universality*'

Future prospects

- Electron final states are becoming more interesting!
- Where does this fit in with the current constraints?
- Measurements of $B_s \to ee$, $B_d \to K^* ee$?
- Taus?
- Possibility to measure more ratios with muon modes:
- Proposed observables $\mathrm{F}_{\mathrm{H}}^{\mathrm{l}}$, A_{FB}^{l} for the decay $B \to Kll$
- High dilepton invariant mass?
- B factories?