Testing lepton universality in $b \to sll$ decays

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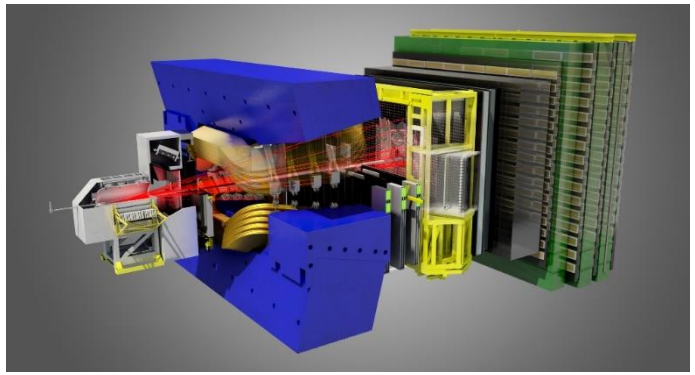
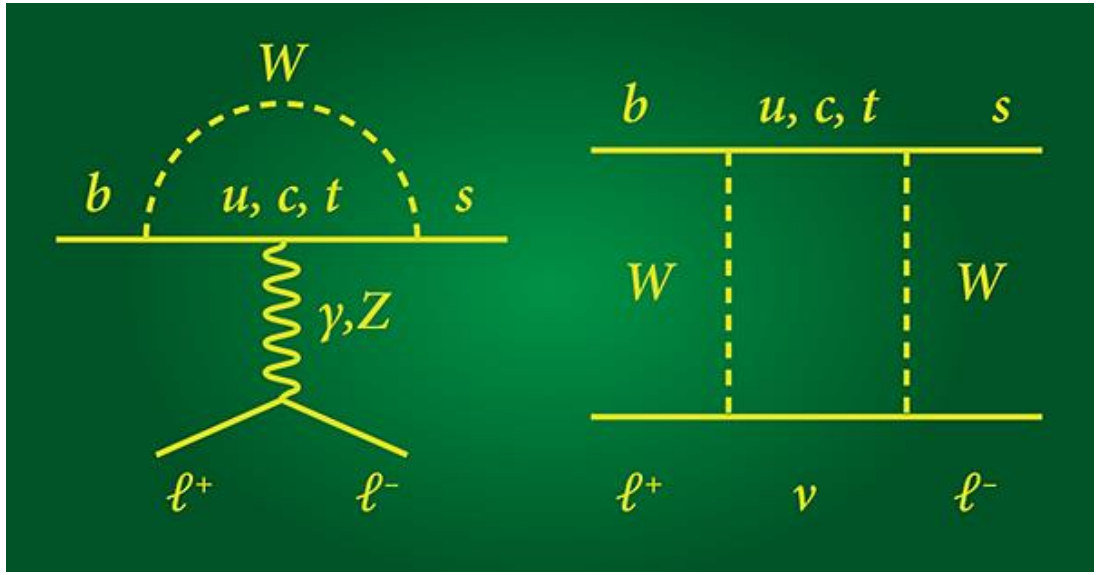
GDR Terascale @ Heidelberg invited talk



Physics beyond the Standard Model in the flavour sector

- Flavour-changing neutral currents are excellent places to search for physics beyond the standard model in the flavour sector.
- High suppression of standard model effects increase sensitivity to any new particles.
- The decay $b \to sll$ is ideal for this purpose!



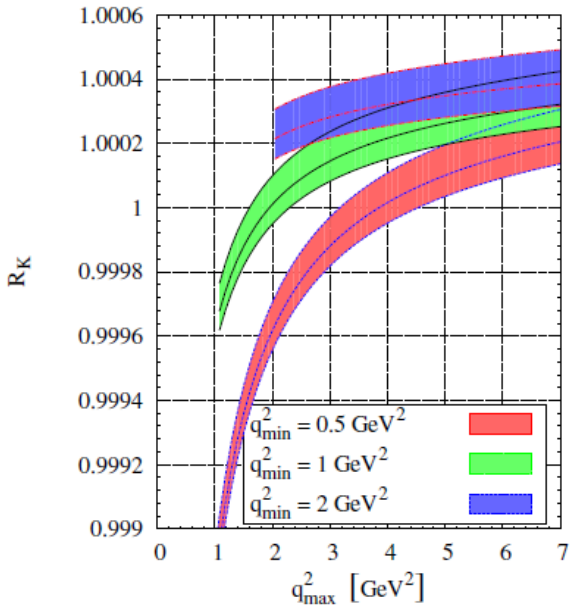
Exclusive decays:

$B^+ \to K^+ ee$, $B^0 \to K^{0^*} \mu\mu$, $B \to X_S \mu\mu$, $\Lambda_b \to \Lambda \mu\mu$

Lepton universality in $b \to sll$ decays

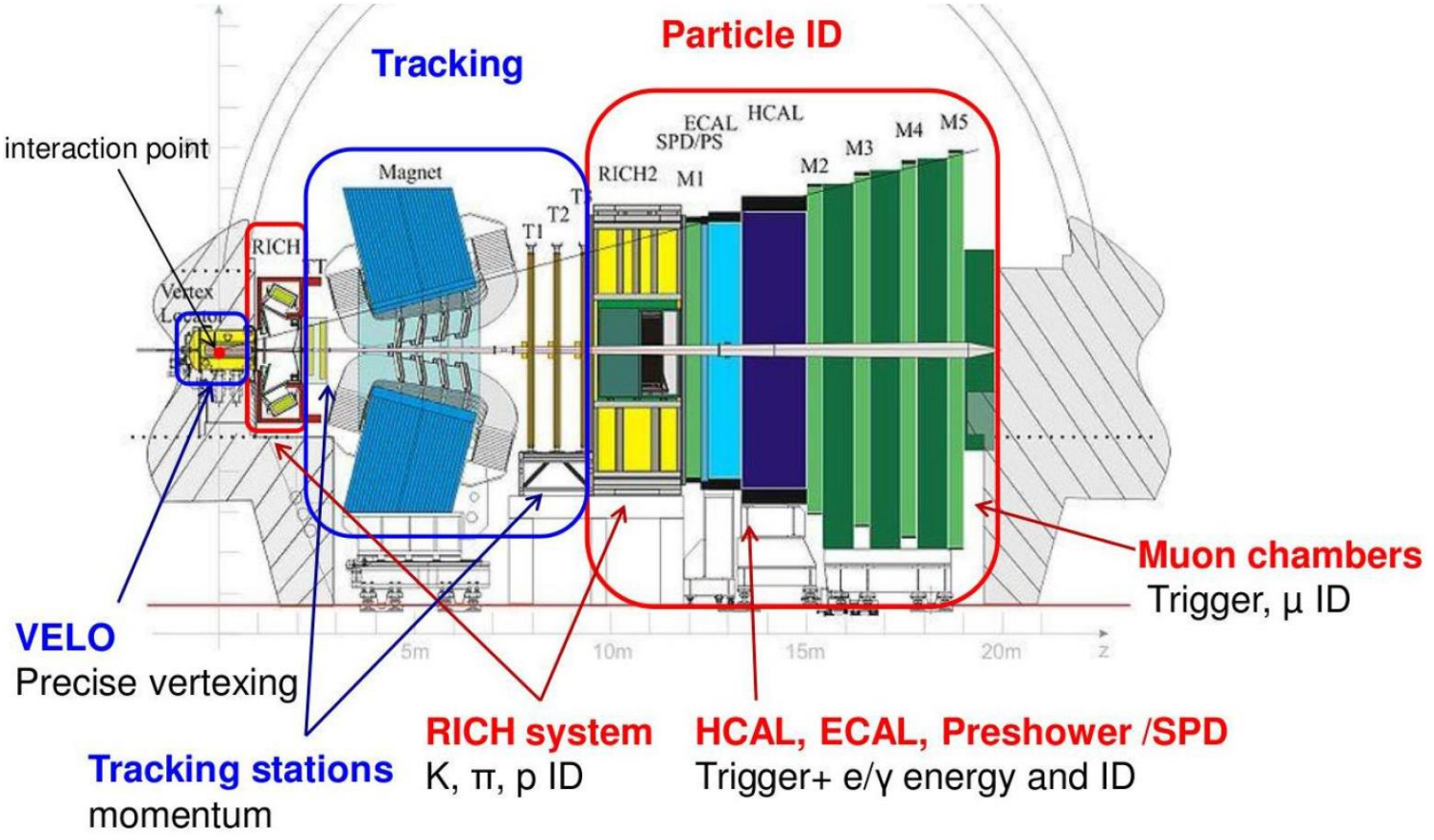
- Leptonic final states allow for tests of lepton universality
- Ratio of $B^+ \to K^+\mu\mu$ to $B^+ \to K^+ee$, R_K, proposed (Hiller, 2007)
- Contributions from electroweak penguin, scalar and pseudoscalar operators
- However, deviations are only possible from lepton non-universal effects in the loop (i.e. NP!)

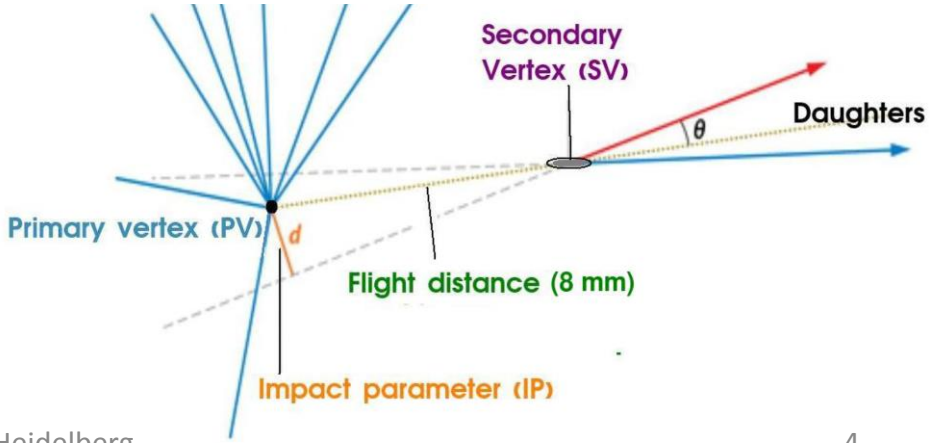
$$R_K = \frac{\int_{q^2_{\rm min}}^{q^2_{\rm max}} \frac{{\rm d}\Gamma[B^+ \to K^+\mu^+\mu^-]}{{\rm d}q^2}{\rm d}q^2}{\int_{q^2_{\rm min}}^{q^2_{\rm max}} \frac{{\rm d}\Gamma[B^+ \to K^+e^+e^-]}{{\rm d}q^2}{\rm d}q^2} ,$$



LHCb

- Forward spectrometer at the LHC.
- Designed for B physics.
- VELO: $\sigma_{IP}^{trk} \sim 20\mu m$ for pT > 2 GeV
- Tracking: $\delta p/p = 0.4 - 0.6\ \%$
- RICH: ϵ_K^{id} = 95% for 5% mis-ID
- Muon: ϵ_μ^{id} = 98% for 1% mis-ID

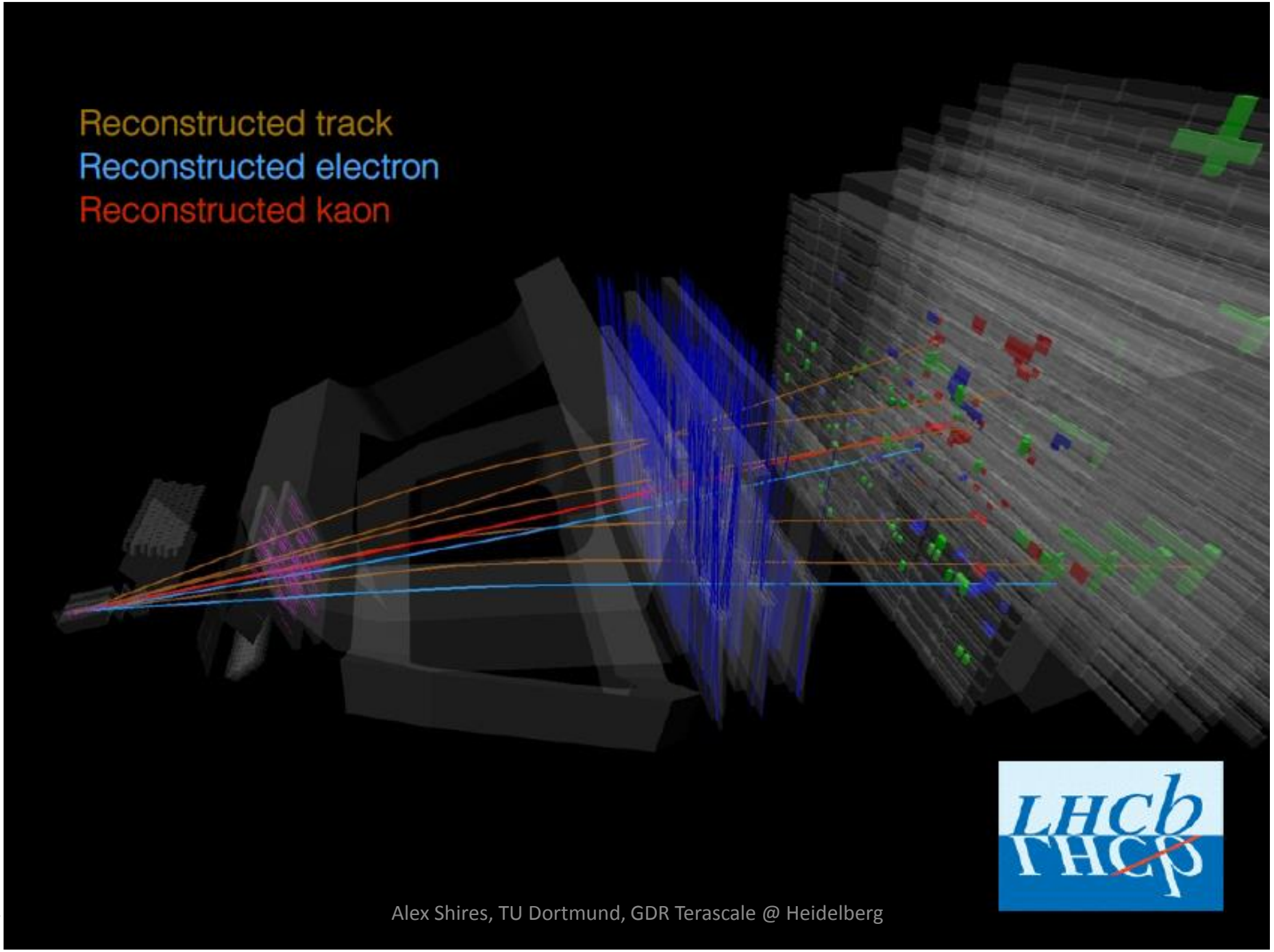




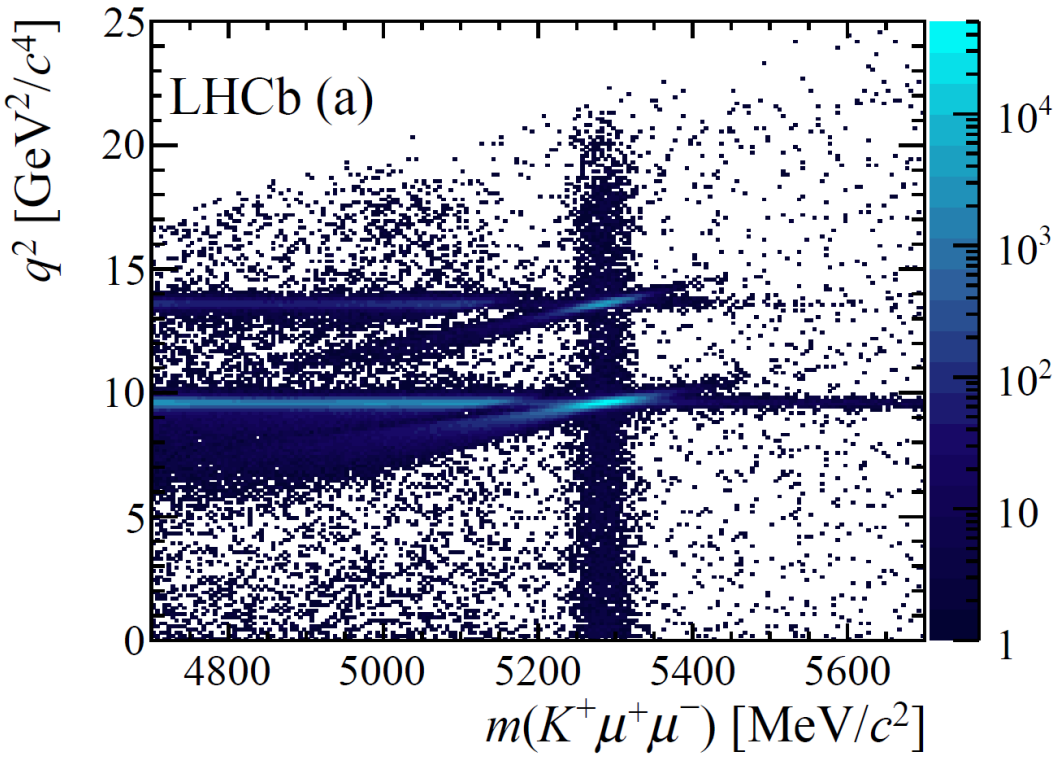
Event selection

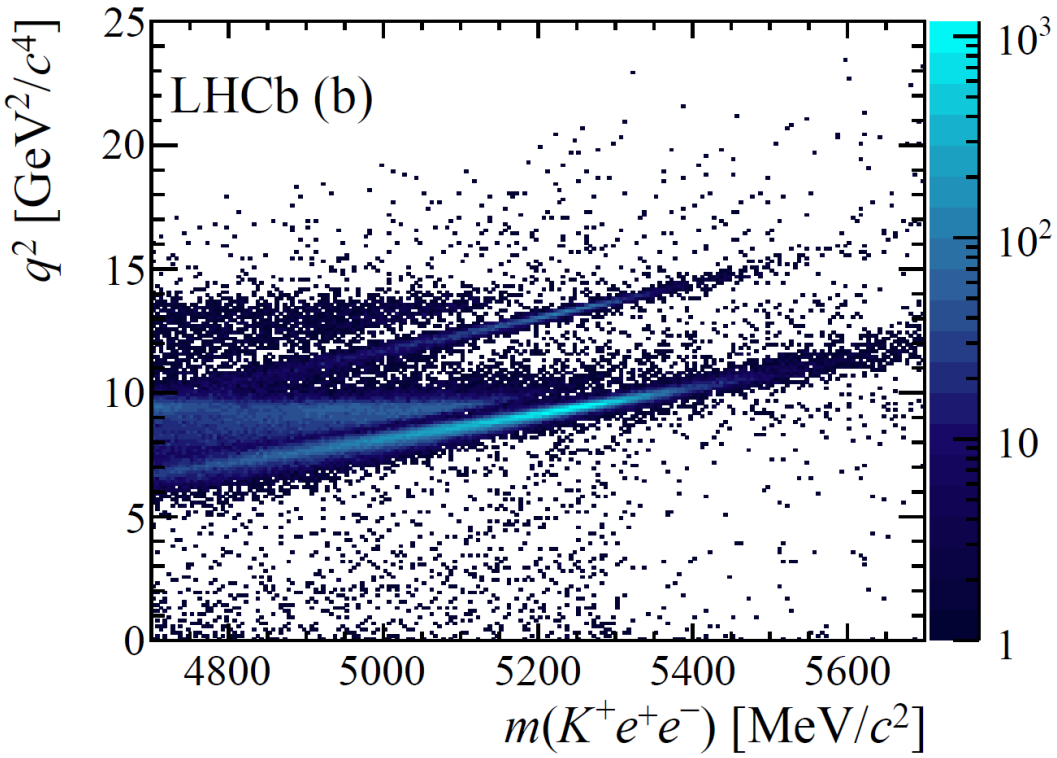
- Combination of events triggered using:
  - High pT electron.
  - High pT hadron.
  - High pT track from the other *b quark.*
- Separation of signal from background:
  - kinematic and candidate quality cuts.
  - multivariate classifier to separate combinatorial background
- Select q^2 region from 1 to 6

- Efficiency to select events calculated using combination of data-corrected simulation and data driven methods
- Efficiency calculated for each trigger category independently.
- Normalised such that the measured efficiency corrected yield of $B^+ \to J/\Psi(\mu\mu)K^+$ to $B^+ \to J/\Psi(ee)K^+$ is consistent with the PDG.


Reconstructed track
Reconstructed electron
Reconstructed kaon
LHCb

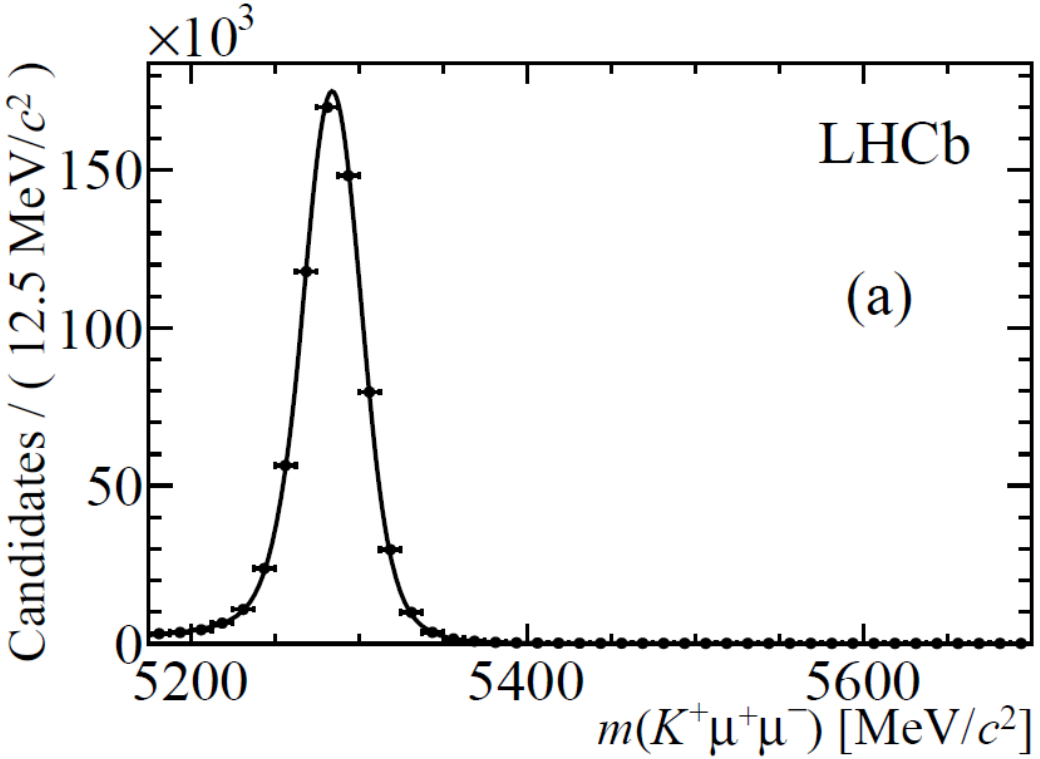
B candidate mass distributions



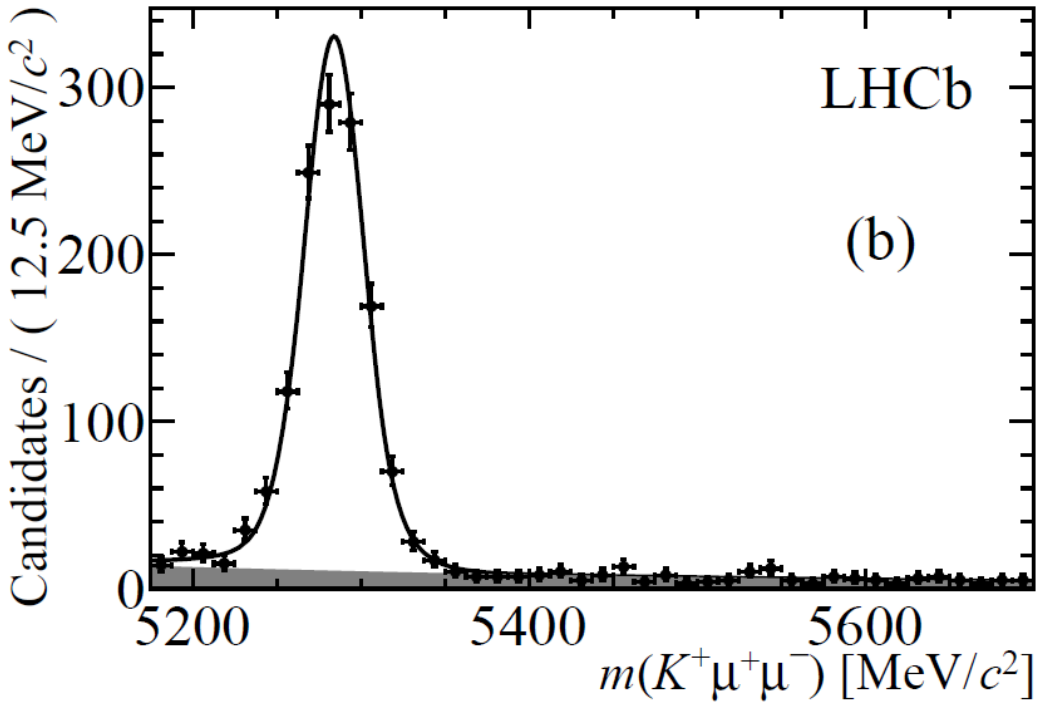


Event yields: muon decays

$B^+ \to J/\Psi(\mu\mu)K^+$: 600k events



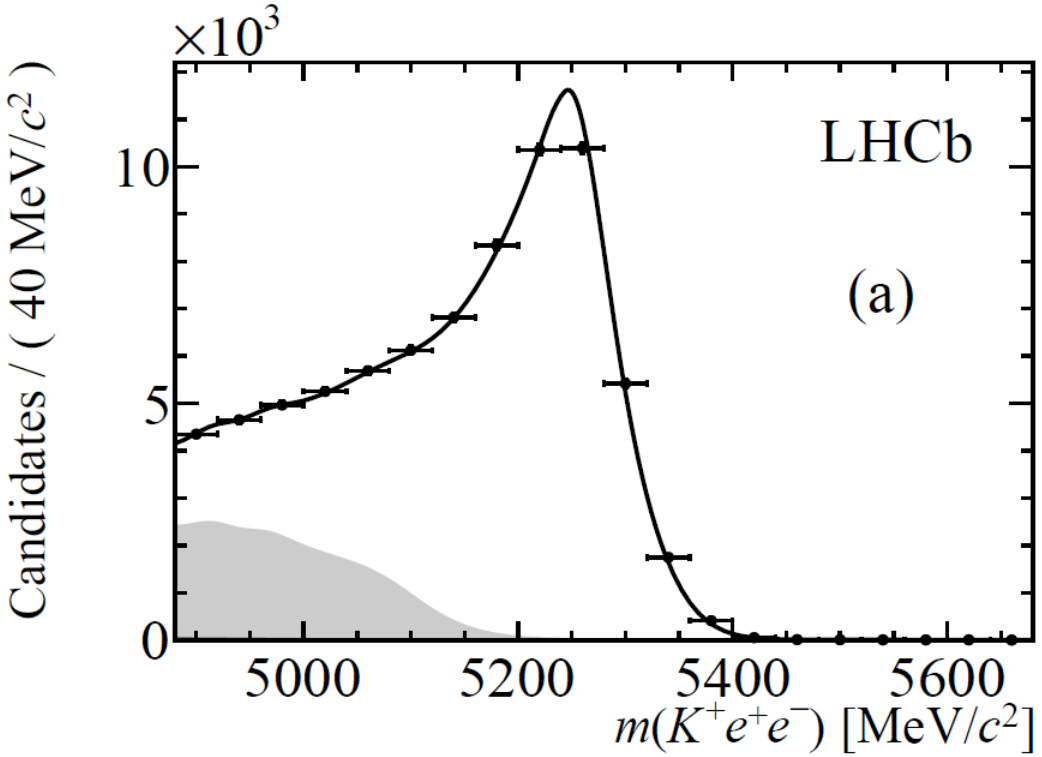
$B^+ \to K^+\mu\mu$: 1226 ± 41 events



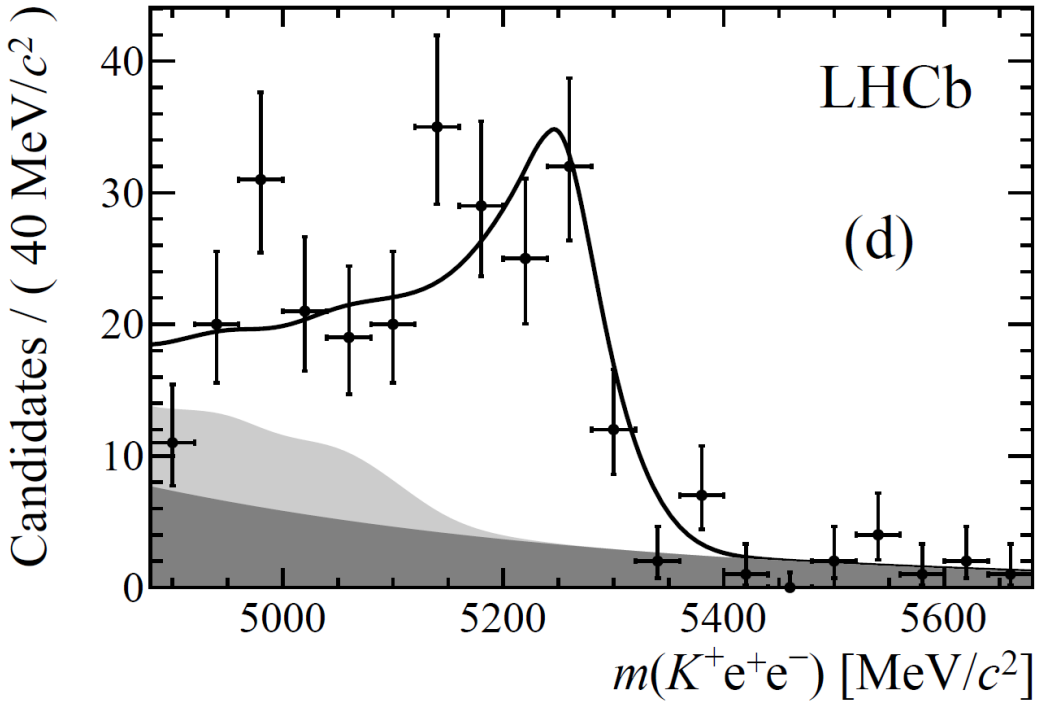
Event yields: electron decays

Triggered on an electron

$B^+ \to J/\Psi(ee)K^+$: 62,324 ± 318 events



$B^+ \to K^+\mathrm{ee} : 172^{+20}_{-19}$ events



Results

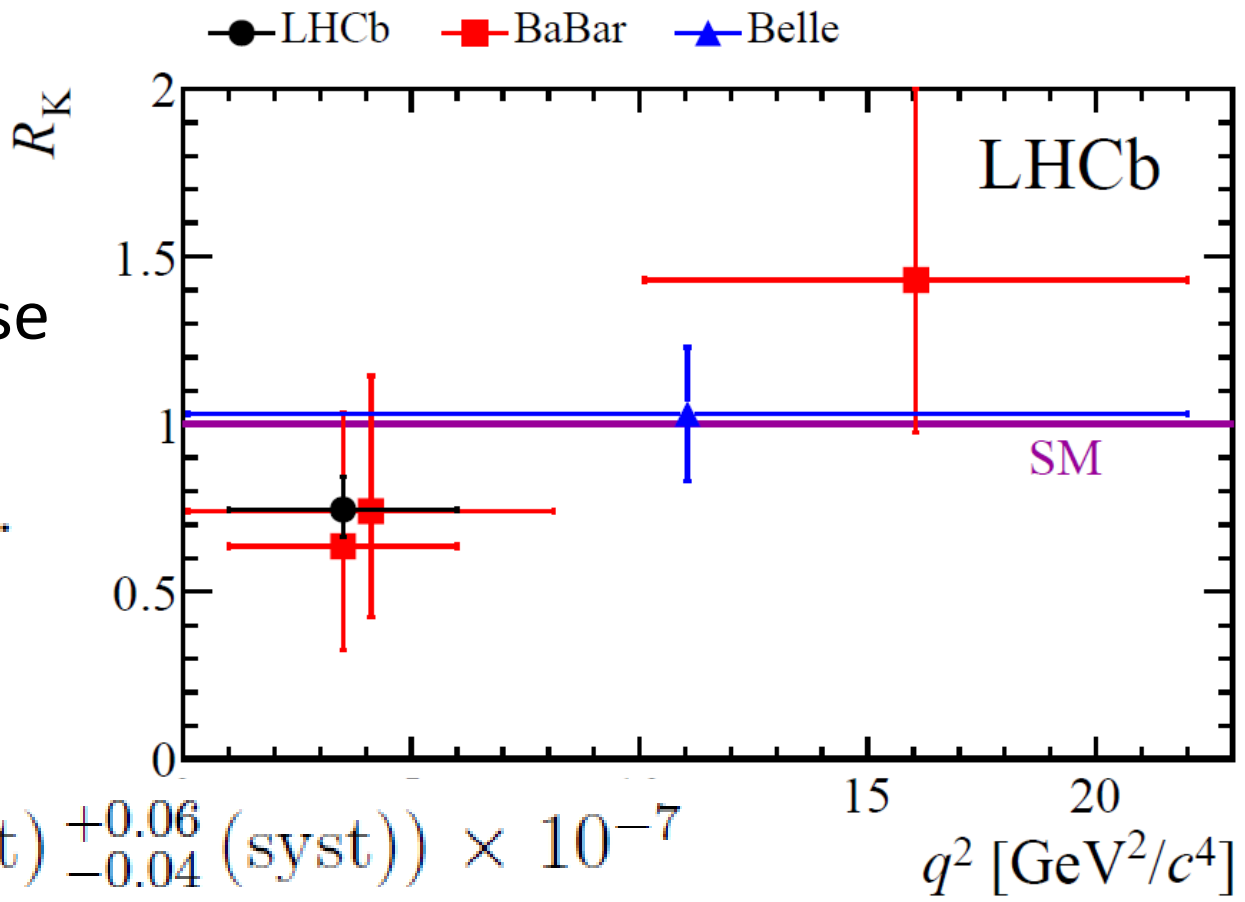
- Bin: $1 < q^2 < 6\ GeV^2/c^4$
- Value of RK, combined across all these trigger categories:

$$R_K = 0.745^{+0.090}_{-0.074}\,(\text{stat}) \pm 0.036\,(\text{syst}).$$

- 2.6σ from unity!
- Differential branching fraction

$$\mathcal{B}(B^+ \to K^+ e^+ e^-) = (1.56\,^{+0.19}_{-0.15}\,(\text{stat})\,^{+0.06}_{-0.04}\,(\text{syst})) \times 10^{-7}$$

- Hints at an effect in the muon modes – C9!



Summary

- The flavour changing neutral current $b \to sll$ is a good candidate to search for physics beyond the standard model in a model-independent way.
- Searching for non-lepton universal effects from new particles.
- LHCb has measured the ratio of branching fractions of
  - $B(B^+ \to K^+ e^+ e^-)$ and $B(B^+ \to K^+ \mu^+ \mu^-)$.
- This result is compatible with the SM at 2.6σ.
- Many extensions of these tests are possible, such as different leptonic and hadronic final states and ratios of angular observables.
- The $b \to sll$ question just got more interesting!

Backup

Lessons from history

- *c*-quark inferred from measurement showing suppression of $K^0 \to \mu\mu$ rate compared to $K^0 \to \mu\nu$ (GIM 1970)
  - Discovery of the J/Ψ (SLAC, BNL)
- *t*, *b* quarks inferred from CP violation in the *K* sector (CKM 1979)
- Limit on *t*-quark mass from B^0 mixing (ARGUS 1987)
  - Discovery of the *t*-quark (D0, CDF 1995)
- Weak neutral current inferred from neutrino scattering (1973)
  - Discovery of the Z boson (UA1,2 1983)
- <*insert particle*> inferred from $b \to sll$ measurements at LHCb (<*insert theorist*> 20XX)
  - Discovery of <*insert particle*> by HEP experiment in 20XX

Thanks to Kostas!