$b \to (s, d)\mu\mu$ decays at LHCb

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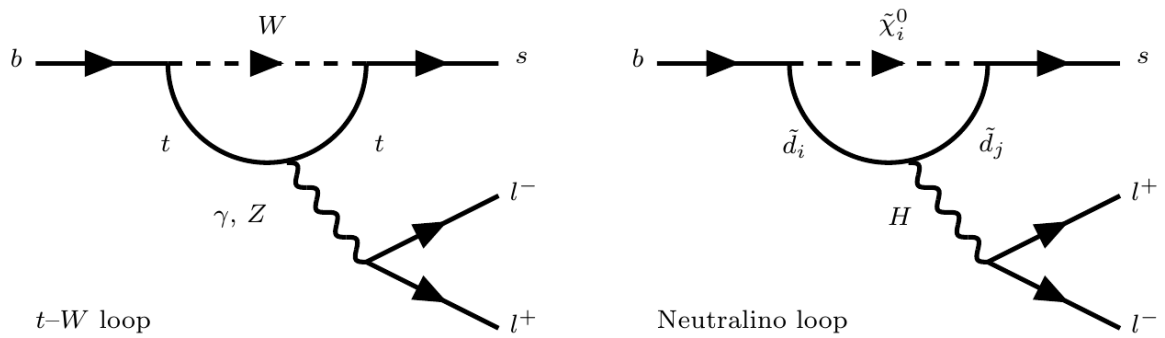
Introduction



- New particles, if they exist, enter into loop diagrams
- Their influence may measurably change observables:
  - Branching fraction (total or differential)
  - Angular distribution
  - CP asymmetry
- Look in processes which only occur at loop level in SM - Flavour Changing Neutral Current decays (FCNCs)

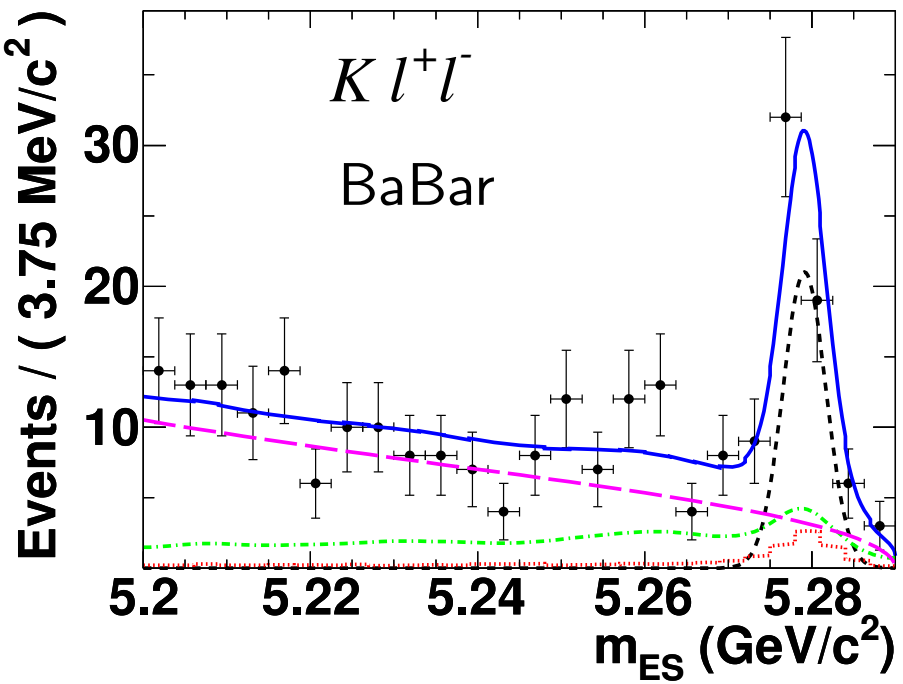
Minimal Flavour Violation

- If new physics is allowed to violate flavour generically, B and Kaon physics set a lower bound on the mass scale for new physics at $10^3 - 10^4\ \mathrm{TeV}$ (for O(1) couplings)
- Assume new physics only violates flavour in same pattern as SM
  - Only source of flavour violation in SM is CKM matrix
  - CKM matrix arises from Yukawa couplings
- Minimal Flavour Violation (MFV): hypothesis that the only sources of flavour violation are the Yukawa couplings
  - Common assumption in new physics models

Consequences of MFV

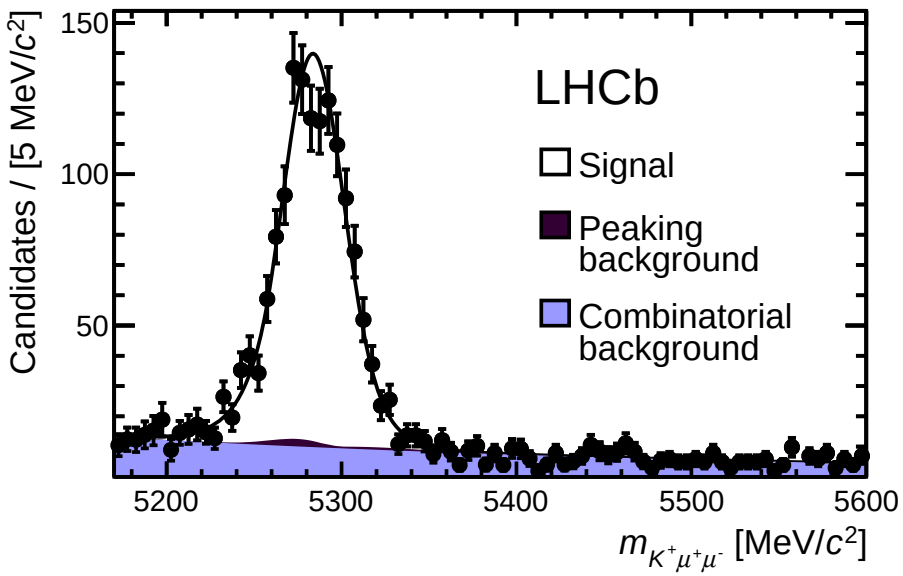
- MFV does not mean no deviations from SM possible in flavour physics
- Constrains ratios of observables
  - In SM & MFV, ratio of branching fractions for $b \to s\mu^+\mu^-$ and $b \to d\mu^+\mu^-$ is given by the CKM factor $|V_{td}|^2/|V_{ts}|^2$ ($\sim 1/25$)
  - Measuring a deviation from this would indicate new non-MFV physics
  - Can test this using exclusive modes $B^+ \to K^+\mu^+\mu^-$ and $B^+ \to \pi^+\mu^+\mu^-$

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



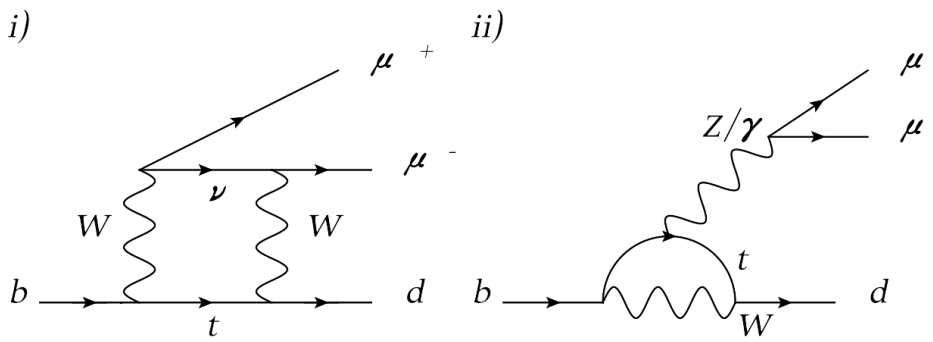
- $B^+ \to K^+\mu^+\mu^-$ previously measured by BaBar(shown), BELLE and CDF (rarest B decay seen before LHCb)
- Combined world sample: $\sim$ 250 signal candidates

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



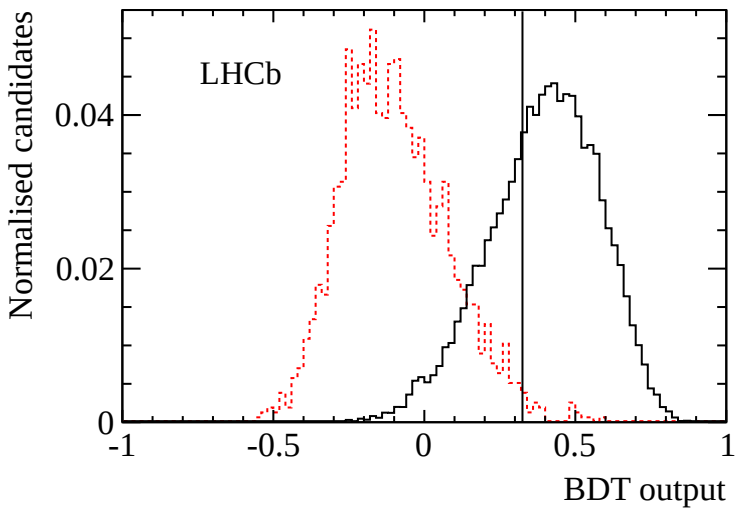
- $B^+ \to K^+\mu^+\mu^-$ now also measured by LHCb, using 2011 dataset (1 fb^{-1})
  - $\sim$ 1200 signal candidates
- $\mathcal{B}(B^+ \to K^+\mu^+\mu^-) = (4.36 \pm 0.15 \pm 0.18) \times 10^{-7}$
- Differential BR and angular observables also measured, all consistent with SM (LHCB-PAPER-2012-263)
- Is a background to $B^+ \to \pi^+\mu^+\mu^-$

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



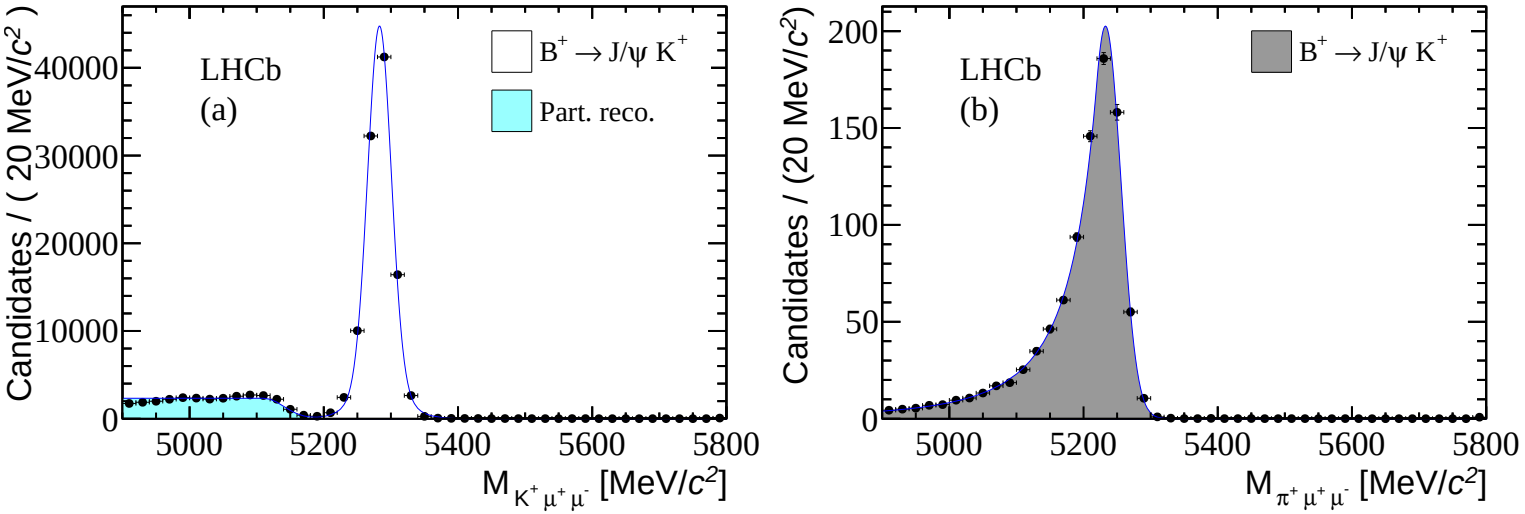
- Search for $B^+ \to \pi^+\mu^+\mu^-$ using 2011 dataset (LHCB-PAPER-2012-020)
- No $b \to d\mu^+\mu^-$ transition has previously been observed
- Previous best limit is $< 6.9\times10^{-8}$, from BELLE
- SM prediction $(1.96 \pm 0.21)\times10^{-8}$

Selection



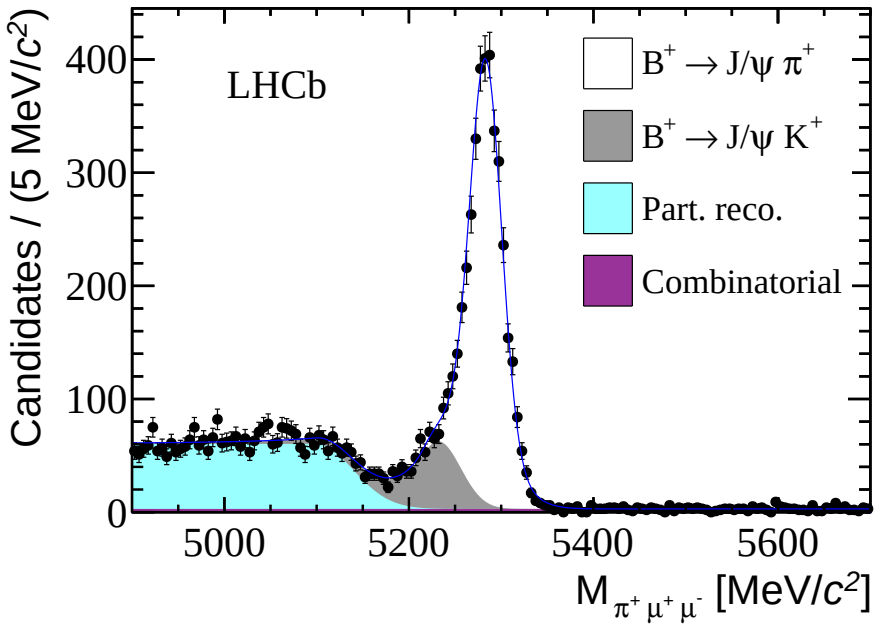
- Use a Boosted Decision Tree (BDT) to seperate signal (black) from combinatorial background (red)
- Use simulated $B^+ \to \pi^+\mu^+\mu^-$ events for signal sample, portion of mass sidebands in data for background sample
  - Background sample used is excluded from remainder of analysis
- Hadron particle identification requirements suppress $B^+ \to K^+\mu^+\mu^-$ by a factor ~ 100

Fit strategy



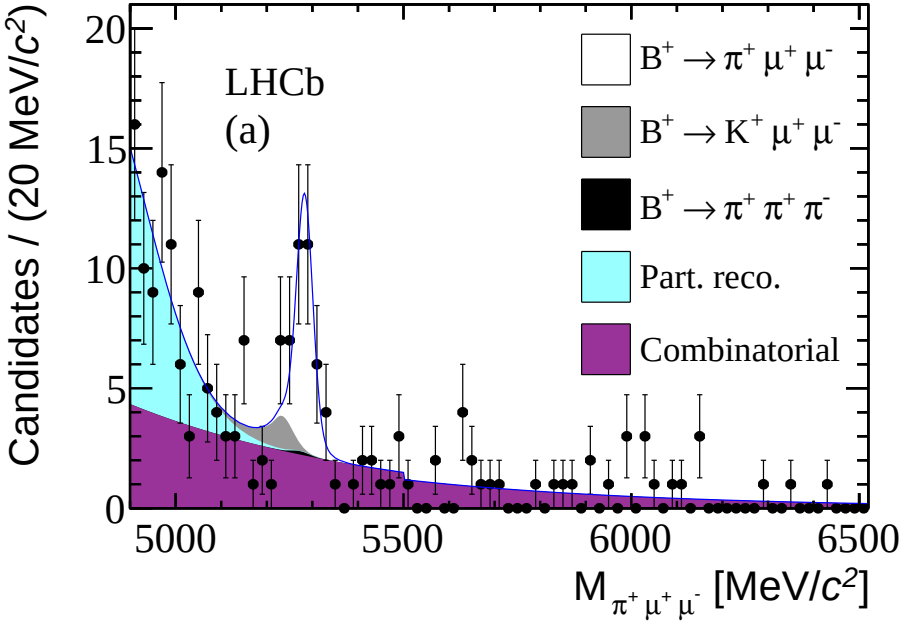
- Signal and misidentified background mass shapes both taken from data:
- Signal taken from $B^+ \to J/\psi K^+$ under the correct ($M_{K\mu\mu}$) mass hypothesis (left)
- Misidentified $B^+ \to K^+\mu^+\mu^-$ taken from $B^+ \to J/\psi K^+$ under the ($M_{\pi\mu\mu}$) mass hypothesis (left)

Fit validation



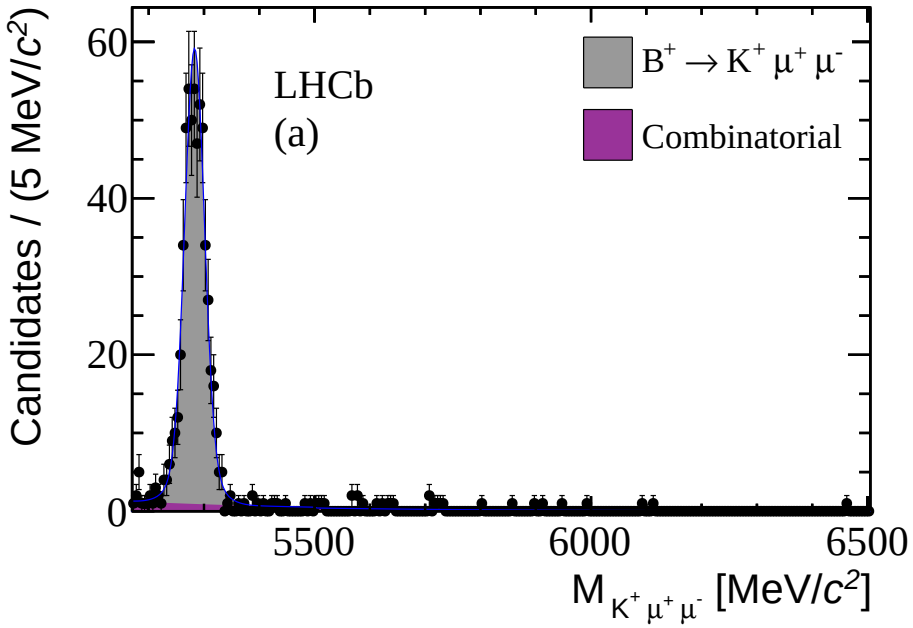
- Fit strategy validated on $B^+ \to J/\psi\,\pi^+$ in data
- Observed $B^+ \to J/\psi\,K^+$ yield (1024 ± 61) consistent with expectation (958 ± 31)

Result



- $25.3\ ^{+6.7}_{-6.4}$ $B^+ \to \pi^+ \mu^+ \mu^-$ candidates, corresponding to a significance of 5.2 σ
- $\mathcal{B}(B^+ \to \pi^+ \mu^+ \mu^-) = (2.3 \pm 0.6\ (\text{stat}) \pm 0.1\ (\text{syst})) \times 10^{-8}$
- Consistent with SM prediction of $(1.96 \pm 0.21) \times 10^{-8}$

$|V_{td}|/|V_{ts}|$



- Measure ratio between $B^+ \to \pi^+\mu^+\mu^-$ and $B^+ \to K^+\mu^+\mu^-$ directly
- Determine $|V_{td}|/|V_{ts}| = 0.266 \pm 0.035\ (\mathrm{stat}) \pm 0.003\ (\mathrm{syst})$
  - Theory uncertainty not yet available
- Consistent with previous determinations

Conclusion

- $B^+ \to \pi^+\mu^+\mu^-$ observed at 5.2 σ
  - First observation
  - First $b \to d\mu^+\mu^-$ transition observed
- $\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-) = (2.3 \pm 0.6\ (\text{stat}) \pm 0.1\ (\text{syst})) \times 10^{-8}$
  - Rarest B decay observed
  - Agrees with SM prediction
- Ratio of $\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)$ and $\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$ used to extract $|V_{td}|/|V_{ts}| = 0.266 \pm 0.035\ (\mathrm{stat}) \pm 0.003\ (\mathrm{syst})$
  - Agrees with previous determinations
- No evidence for non-MFV physics
- SM wins again