Search for the lepton-flavour-violating decays $B^+ \rightarrow K^+ e^\pm \mu^\mp$

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**Introduction**

**Charged lepton flavour violation**

Motivated by lepton flavour violations in neutrino oscillations and hints of lepton flavour non-universality in $K_{33}(10)$.

**Standard model and New Physics models**

$B(B^+ \rightarrow K^+ e^\pm \mu^\mp) \sim 10^{-9}$ in extended SM, NP models with leptoquarks or $Z^0$ bosons within experimental reach of $B \sim 10^{-8}$.[2]

**Current limit**

- Best limit from BaBar with 90% CL.[4]
  - $B(B^+ \rightarrow K^+ e^\pm \mu^\mp) < 9.1 \times 10^{-8}$
  - $B(B^+ \rightarrow K^+ e^\pm \mu^\mp) < 13 \times 10^{-8}$

**Dataset and analysis strategy**

Data taken by the LHCb experiment during Run 1 corresponding to an integrated luminosity of $1.0^{+0.3}_{-0.2}$ at $7$ TeV and $2.0^{+1.5}_{-1.0}$ at $8$ TeV.

- Loose selection and trigger requirements
- MC-corrections in kinematic and particle identification variables
- Selection with two multivariate classifiers
- Tight particle identification requirements
- Upper limit relative to $B^+ \rightarrow K^+ J/\psi \rightarrow \mu^\pm e^\mp$ with CLs method.[5] using GammaCombo framework.[6]

**Suppress peaking backgrounds**

- Veto $m_{e\mu}$ for charmonium resonances, where $e \leftrightarrow \mu$ and $K \leftrightarrow J/\psi$ misidentification is considered
- Veto decays including $D^+$ with $m_{e\mu} > 1885$ MeV/c$^2$
- Veto misidentified backgrounds with particle identification requirements

With and without charm resonance veto in $B^+ \rightarrow K^+ J/\psi \rightarrow \mu^\pm e^\mp$ and $B^+ \rightarrow e^\pm \mu^\mp D^+ \rightarrow \pi^- K^+$

**Data-MC corrections**

Correction of the simulation to reproduce kinematics and PDG variables accurately

- Kinematic reweighting
  - Iterative calculation of weights in bins of track multiplicity
  - R transverse momentum
  - B meson vertex quality

Resampling of particle identification variables

- Correction of simulated particle identification variables with calibration datasets

**Bremssstrahlung**

- Energy loss due to bremsstrahlung radiation by electrons $\rightarrow$ momentum corrections
- Describe the mass distribution in two categories, whether bremsstrahlung corrections are applied or not

**HOP variable**

- $P_t(X_e), P_t(Y_e)$: transverse momentum wrt. B meson flight direction of the electron, all other particles
- $P_t(X_\mu), P_t(Y_\mu)$: for perfect reconstruction
- $P_t(X_\mu) = P_t(Y_\mu) \neq 1$ for partial reconstructed decays
- Helpful to reduce partially reconstructed backgrounds

**Selection**

**BDT**

- BDT with GradientBoost algorithm.[7]
- $k$-folding with $k = 10$
- Signal: reweighted simulation of $B^+ \rightarrow K^+ e^\pm \mu^\mp$
- Background: upper mass sideband from data of $B^+ \rightarrow K^+ e^\pm \mu^\mp$
- Features: kinematic, vertex quality and track isolation variables
- Greatly reduces combinatorial background

**BDT HOP**

- 2nd BDT after applying 1st BDT requirements
- The same technique as 1st BDT
- Signal: reweighted simulation of $B^+ \rightarrow K^+ e^\pm \mu^\mp$
- Different background sample: lower mass sideband from data
- Add $m_{e\mu}$ to feature set
- Strongly reduces partial reconstructed backgrounds

**Optimisation of selection cuts**

- Based on expected upper limit with the CLs method
- Split samples in $B^+ \rightarrow K^+ e^\pm \mu^\mp$ and $B^+ \rightarrow K^+ \mu^\pm e^\mp$ to find optimal cut unbiased

**Analysis status and outlook**

The physical background found to be negligible. The expected background yield in the signal region is

$$N_{\text{Bkg.}} < O(1), \quad N_{\text{Bkg.}} < O(10).$$

This analysis is still blind but in review. The expected upper limit is $O(10^{-9})$.

**References**