$b \rightarrow s\ell^+\ell^-$ transitions at LHCb

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Outline

- LHCb detector
- Motivation
- $B^+ \rightarrow K^+ \mu^\pm e^{\mp}$
- $B^+ \rightarrow K^+ \ell^+ \ell^-$
- Summary
covers $2 < \eta < 5$ pseudorapidity range
- efficient particle identification
- calorimeters for measuring energy and position
- high-precision tracking system
- online event selection
Motivation

- SM is not complete (19 parameters, hierarchy problem, matter-antimatter asymmetry, etc.)
- Lepton flavour violation (LFV) in neutral sector, charged LFV negligible in SM
- Lepton universality (LU) tests in FCNC
- physics beyond the SM must exist
Flavour changing neutral currents in SM

$\bar{b} \rightarrow \bar{s} \ell^+ \ell^-$ transitions at LHCb
Flavour changing neutral currents - NP

$\bar{b} \rightarrow s \ell^+ \ell^-$ transitions at LHCb
Data sets recorded in 2011 and 2012 (pp collisions at 7 and 8 TeV)

Invariant-mass distributions of the
\[ B^+ \rightarrow K^+ \mu^- e^+ \] and \[ B^+ \rightarrow K^+ \mu^+ e^- \]

Signal model - sum of two Crystal Ball functions
Background - exponential function

Difference in $m(K^+ \ell^-)$ requirement.

Upper limits on the branching fractions of $B^+ \rightarrow K^+ \mu^- e^+$ and $B^+ \rightarrow K^+ \mu^+ e^-$

$$B(B^+ \rightarrow K^+ \mu^\pm e^\mp) = N(B^+ \rightarrow K^+ \mu^\pm e^\mp) \times \alpha$$ (1)

$$\alpha \equiv \frac{B(B^+ \rightarrow K^+ J/\psi(\rightarrow \mu^+ \mu^-))}{\epsilon(B^+ \rightarrow K^+ \mu^\pm e^\mp)} \times \frac{\epsilon(B^+ \rightarrow K^+ J/\psi(\rightarrow \mu^+ \mu^-))}{N(B^+ \rightarrow K^+ J/\psi(\rightarrow \mu^+ \mu^-))}$$ (2)

![Graphs showing CLs for $B(B^+ \rightarrow K^+ \mu^- e^+)$ and $B(B^+ \rightarrow K^+ \mu^+ e^-)$](image)

Data sets recorded in 2011 and 2012 (pp collisions at 7 and 8 TeV) and 2015-2016 (pp collisions at 13 TeV)

\[ q^2 \text{ range:} \]
\[ 1.1 < q^2 < 6.0 \text{ GeV}^2/c^4 \]

Double ratio of the branching fractions:

\[ R_K = \frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-) / \mathcal{B}(B^+ \rightarrow J/\psi(\rightarrow \mu^+ \mu^-)K^+)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-) / \mathcal{B}(B^+ \rightarrow J/\psi(\rightarrow e^+ e^-)K^+)} \quad (3) \]

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

Likelihood fits to the invariant mass distributions for electron and muon candidates for nonresonant and resonant decays.

Electron-mode signal mass shapes - sum of three distributions.
$R_K$ for $B^+ \rightarrow K^+ \mu^+ \mu^-$ and $B^+ \rightarrow K^+ e^+ e^-$

$$R_K = \frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow J/\psi(\rightarrow \mu^+ \mu^-)K^+)} / \frac{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}{\mathcal{B}(B^+ \rightarrow J/\psi(\rightarrow e^+ e^-)K^+)}$$

(4)

$$R_K = 0.846^{+0.060+0.016}_{-0.054-0.014}$$

Likelihood approx. Gaussian in $0.75 < R_K < 0.95$
Consistent with the SM expectation at 2.5 $\sigma$. 

Recent results of $b \to s \ell^+ \ell^-$ transitions have been shown:

\[ B^+ \to K^+ \mu^\pm e^\mp \]
- upper limits on the branching fractions were obtained
- results improve previous limits on the decays
- impose strong constraints on the extensions to the SM

\[ B^+ \to K^+ \ell^+ \ell^- \]
- $R_K$ ratio was measured in central $q^2$ range
- most precise measurements of $R_K$ to date
- compatible with the SM expectation at 2.5 $\sigma$

Big chance for more precise measurements with upgraded LHCb detector in near future.
Thank you for your attention