Search for the lepton flavour violating decay $B^0_{s,d} \to e^\pm\mu^\mp$ in the LHCb experiment at CERN

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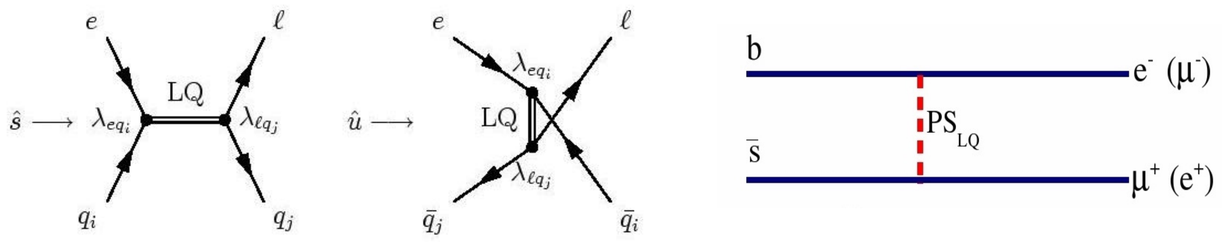
Theoretical motivation

The $B^0_{s,d} \to e^\pm\mu^\mp$decay is a Lepton Flavour Violating (**LFV**) process, thus strongly suppressed within the Standard Model (SM) of particle physics.
In various **scenarios beyond SM**, however, this decay would be allowed.

An example is the Pati-Salam model, predicting the existence of **Lepto-Quarks** (figure) carrying both leptonic and baryonc quantum numbers[5] (figure). Lepto-Quarks can couple to a quark and a lepton at the same time, and could explain the similarity between quark and lepton sector.



Other examples are models with heavy singlet Dirac neutrinos [4] and supersymmetric models [2]

Experimental status

This analysis is currently in progress. The interest for such a study mainly arises from:

- First analysis with 1.02 fb^{-1} published in 2013[1] established new upper limits at 90% (95%) C.L. :

$$\mathcal{B}(B^0_s \to e^\pm\mu^\mp) = \mathbf{1.1(1.4)} \times \mathbf{10^{-8}}$$
$$\mathcal{B}(B^0_d \to e^\pm\mu^\mp) = \mathbf{2.8(3.7)} \times \mathbf{10^{-9}}$$

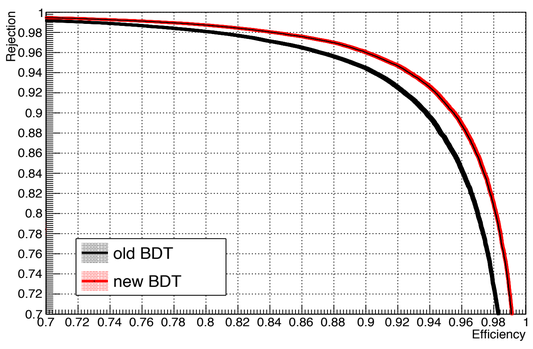
  ($\sim$ **20** times lower than the previous bounds from CDF)
- Recently renewed interest for LFV after LHCb measurement of

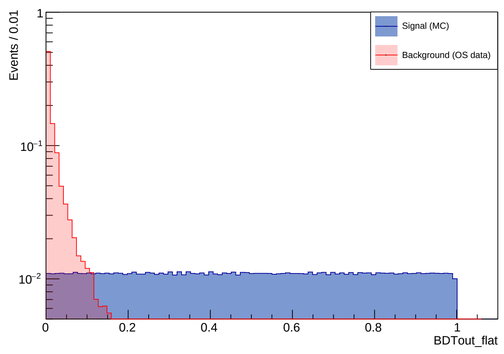
$$R_K = \frac{\mathcal{B}(B^+ \to K^+\mu^+\mu^-)}{\mathcal{B}(B^+ \to K^+e^+e^-)} = \mathbf{0.745^{+0.090}_{-0.074}(\mathrm{stat}) \pm 0.036(\mathrm{syst})}$$

  which hints for Lepton Flavour Non-Universality. This might imply the existence of LFV at accessible branching ratios [3]

Multivariate Selection

A **Boosted Decision Tree** (BDT) is used to separate signal from background events.
It is trained on a signal simulated sample and $B^0_{s,d} \to e^\pm\mu^\pm$ for background, using 9 kinematic variables, mainly related to tracks' direction, the isolation and the distance from the primary decay vertex.





The analysis is then performed binning in 8 BDT bins. Having a flat output for the signal allows to expect the same number of signal events in each BDT bin.

The flat shape is then validated using a $B \to hh'$ data sample, where $h, h' = K, \pi$, as a proxy of the signal.

References

[1] L. Collaboration.
Search for the lepton-flavor violating decays $B^0_s \to e^\pm\mu^\mp$ and $B^0_d \to e^\pm\mu^\mp$.
Phys. Rev. Lett. 111, 2013.

[2] R. A. Diaz and al.
Improving bounds on flavor changing vertices in the two higgs doublet model from $B^0 - \overline{B^0}$ mixing.
Eur. Phys. J C41, 2005.

[3] S. L. Glashow, D. Guadagnoli, and K. Lane.
Charged-lepton mixing and lepton flavor violation.
PHYS. REV. LETT. 114, 2015.

[4] A. Ilakovic.
Lepton flavor violation in the standard model extended by heavy singlet dirac neutrinos.
Phys. Rev. D 62, 2000.

[5] J. C. Pati and A. Salam.
Lepton number as the fourth color.
Phys. Rev. D 10, 1974.

Improvements with respect to the 2013 analysis

Improvements are obtained mainly from:

- Increase of statistics: 3 times from full RUN I + 300 pb^{-1} of 2015 data;
- improvements in handling of radiative losses;
- new multivariate classifier, specifically designed;
- introduction of new normalisation channel: $B^\pm \to J/\psi K^\pm$ along with $B^0 \to K^\pm\pi^\mp$.

Normalization

To estimate the branching fractions, the number of observed signal events is normalized to that of $B^\pm \to J/\psi K^\pm$ and $B^0 \to K^\pm\pi^\mp$, whose branching fractions are well known.

$$\mathcal{B} = \mathcal{B}_{cal} \times \frac{\epsilon^{GEN}_{cal}\epsilon^{SEL\&REC|GEN}_{cal}\epsilon^{TRIG|SEL}_{cal}}{\epsilon^{GEN}_{sig}\epsilon^{SEL\&REC|GEN}_{sig}\epsilon^{TRIG|SEL}_{sig}} \times \frac{f_{cal}}{f_{B^0_q}} \times \frac{N_{B^0_q \to e\mu}}{N_{cal}}$$

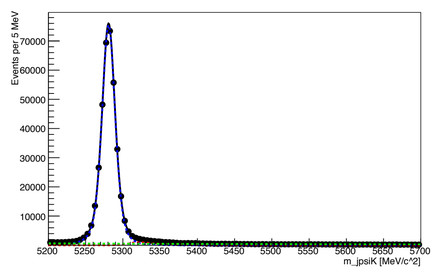


Figure: Mass fit to $B^\pm \to J/\psi K^\pm$ data.

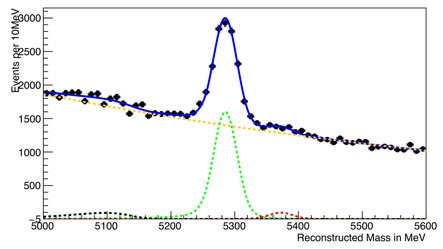


Figure: Mass fit to $B^0 \to K^\pm\pi^\mp$ data.

Upper limits (from 2013 analysis)

Merely considering the increase of statistics, the new upper limits on the $B^0_{s,d} \to e^\pm\mu^\mp$ branching fracton are expected to be at least a factor $\sim \sqrt{\mathbf{3.6}}$ **lower than those from the 2013 analysis**.

Mode	Limit	90 % C.L.	95 % C.L.
$B^0_s \to e^\pm\mu^\mp$	Expected	1.5×10^{-8}	1.8×10^{-8}
	Observed	1.1×10^{-8}	1.4×10^{-8}
$B^0 \to e^\pm\mu^\mp$	Expected	3.8×10^{-9}	4.8×10^{-9}
	Observed	2.8×10^{-9}	3.7×10^{-9}

Figure: Limits on $\mathcal{B}(B^0_{s,d} \to e^\pm\mu^\mp)$ as obtained from 2013 analysis.

Focusing on the Pati-Salam model, these limits can be translated in **upper bounds on the mass of the Lepto-Quark**.

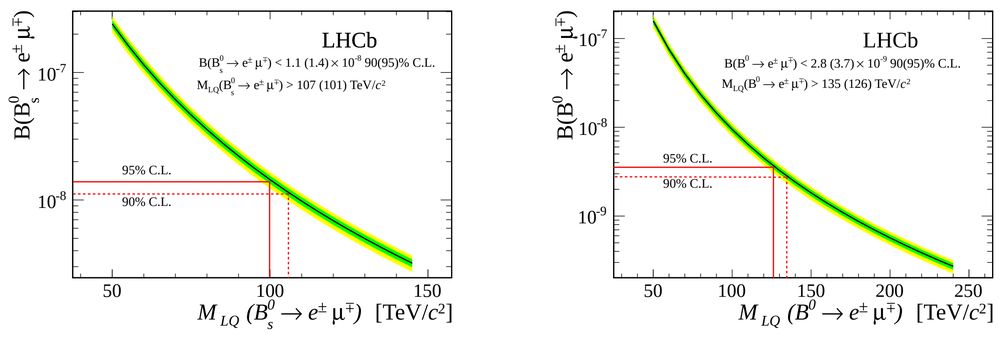


Figure: Limits on Pati-Salam Lepto-Quark mass as obtained from 2013 analysis.