Rare decays at LHCb

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Rare leptonic and semileptonic decays are studied using $1.0\,\mathrm{fb}^{-1}$ of pp collisions at a centre-of-mass energy of $\sqrt{s} = 7\,\mathrm{TeV}$ collected by the LHCb experiment [1] in 2011. Branching fractions measurements, angular distributions and isospin asymmetries are presented using this data sample.

1 Introduction

Rare decays are excellent tests to infer the presence of physics beyond the Standard Model (BSM), as they occur through processes prohibited at tree level in the SM. Any deviation from the SM prediction in branching fraction or angular distributions of such decays can lead to indications of new physics.

2 Branching fraction measurements of $B^0_{(s)} \to \mu^+\mu^-$

The SM predictions for the branching fractions of the decays $B^0_s \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ are small and have a low uncertainty: $\mathcal{B}(B^0_s \to \mu^+\mu^-)= (3.2 \pm 0.2) \times 10^{-9}$ and $\mathcal{B}(B^0_s \to \mu^+\mu^-)= (0.10 \pm 0.01) \times 10^{-9}$ [2]. Taking into account the oscillation of the B^0_s system, the time integrated branching fraction is evaluated to be [3]: $\mathcal{B}(B^0_s \to \mu^+\mu^-)= 3.4 \times 10^{-9}$. However, these values can be significantly enhanced within Minimal Supersymmetric extensions of the SM (MSSM) [4] due to contributions from new processes or new heavy particles. The LHCb results are the most constraining limits [5] on these branching fractions obtained with a single experiment to date at 95% C.L.: $\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-) < 4.5 \times 10^{-9}$ and $\mathcal{B}(B^0 \to \mu^+\mu^-) < 1.0 \times 10^{-10}$.

3 Branching fraction measurement of $D^0 \to \mu^+\mu^-$

The decay $D^0 \to \mu^+\mu^-$ is very rare in the SM: $10^{-13} < \mathcal{B}(D^0 \to \mu^+\mu^-) < 6\times10^{-11}$ [6]. In the context of MSSM scenarios with R parity violation, the predicted branching fractions can be largely enhanced [7]. The LHCb measurement of the branching fraction of this decay is [8] $\mathcal{B}(D^0 \to \mu^+\mu^-) < 1.3 \times 10^{-8}$ at 95% C.L., which is the world best limit to date.

4 Branching fraction measurement of $\tau^- \to \mu^-\mu^+\mu^-$

The branching fraction of the decay $\tau^- \to \mu^-\mu^+\mu^-$ is extremely suppressed in the SM. In New Physics models this branching fraction can be substantially enhanced. For instance, in the context of Little Higgs models $\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-) < 10^{-7}$ [9]. The LHCb measurement of this branching fraction ($\mathcal{B}(\tau^- \to \mu^-\mu^+\mu^-) < 7.8 \times 10^{-8}$ at 95% C.L.) [10] is comparable with the current best limits.

5 Angular analysis of $B^0 \to K^{*0}\mu^+\mu^-$

The angular distribution of the $B^0 \to K^{*0}\mu^+\mu^-$ decay can be described with several q^2-dependent parameters that are predicted in the SM [11] with high precision: $\mathrm{A_{FB}}$, $\mathrm{F_L}$, $\mathrm{S_3}$, and $\mathrm{A_{IM}}$. The LHCb measurements of these quantities [12] show no deviation from the SM predictions, and are the most precise measurements to date. Figure 1 shows the LHCb result for $\mathrm{A_{FB}}$ with the SM prediction superimposed.

The region where the forward-backward asymmetry changes sign, known as zero-crossing point (q_0^2), is predicted to lie in the range $[4.0 < q_0^2 < 4.3\,\mathrm{GeV^2/c^4}]$ [13]. LHCb has measured for the first time the zero-crossing point $q_0^2 = 4.9^{+1.1}_{-1.3}\,\mathrm{GeV^2/c^4}$, which agrees with the SM predictions (Figure 1).

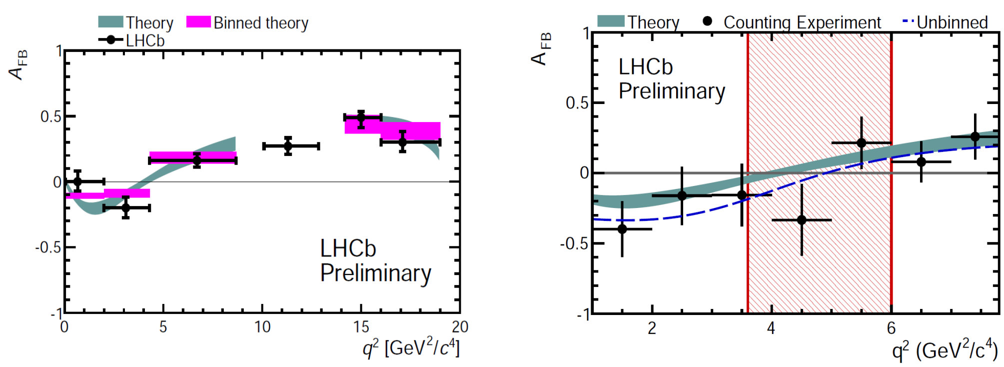

Figure 1: Forward-backward asymmetry of the di-muon pair (left) and zero-crossing point (right).

6 Isospin asymmetry of $B \to K^{(*)}\mu^+\mu^-$

The isospin asymmetry of the decays $B \to K\mu^+\mu^-$ and $B \to K^*\mu^+\mu^-$ is defined as:

$$A_I \equiv \frac{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) - \frac{\tau_0}{\tau_\pm}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}{\mathcal{B}(B^0 \to K^{(*)0}\mu^+\mu^-) + \frac{\tau_0}{\tau_\pm}\mathcal{B}(B^\pm \to K^{(*)\pm}\mu^+\mu^-)}, \quad (1)$$

where $\frac{\tau_0}{\tau_\pm}$ is the ratio of lifetimes of the B^0 and $B^\pm$ mesons. For the $B \to K^*\mu^+\mu^-$ case, the SM predicts A_I of $\mathcal{O}(-1\%)$ at low q^2 and $\mathcal{O}(1\%)$ at $q^2 \to 0$ [14], while there is no precise prediction of A_I for the $B \to K\mu^+\mu^-$ case. Figure 2 shows the LHCb results on the isospin asymmetries [15]. Theoretical prediction and experimental measurement are in agreement for the $B \to K^*\mu^+\mu^-$ case, while a precise SM prediction for the $B \to K\mu^+\mu^-$ case is foreseen in order to reveal whether the measured $4.4\,\sigma$ statistical significance deviation from zero can be accommodated in the SM or is a New Physics effect.

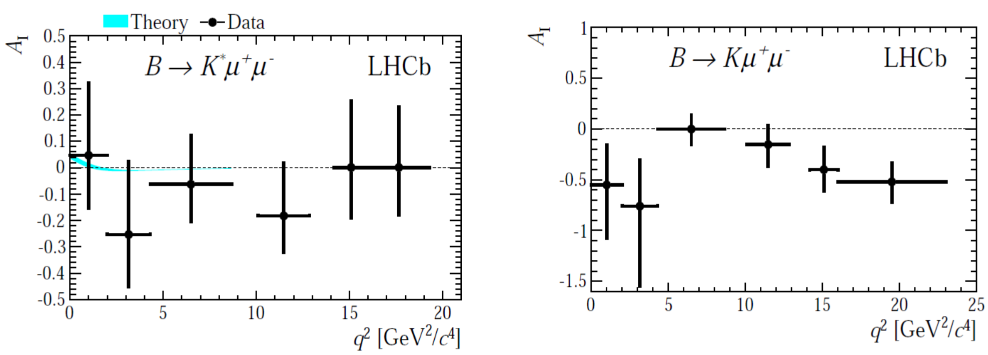

Figure 2: Isospin asymmetry as a function of q^2 in the $B \to K^*\mu^+\mu^-$ (left) and $B \to K\mu^+\mu^-$ systems (right). The blue line corresponds to theoretical predictions.

7 Branching fraction measurement of $B^+ \to \pi^+\mu^+\mu^-$

$B^+ \to \pi^+\mu^+\mu^-$ decays are processes mediated by $b \to d\, l^+l^-$ transitions never observed before. In the SM, such transitions are suppressed by a factor $|V_{td}/V_{ts}|$ that does not necessarily appear in New Physics models. The LHCb measurement [17], $\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)= (2.4 \pm 0.6_{(stat)} \pm 0.2_{(syst)}) \times 10^{-8}$, is in agreement with the SM prediction of $\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)= (1.91 \pm 0.21) \times 10^{-8}$ [16]. $B^+ \to \pi^+\mu^+\mu^-$ is the rarest B decay ever observed.

8 Conclusions

The LHCb Collaboration has presented measurements of branching fractions of beauty, charm, and tau decays, as well as of angular distribution of $B^0 \to K^{*0}\mu^+\mu^-$ and of the isospin asymmetry of the $B \to K^{(*)}\mu^+\mu^-$ system. All these measurements are of an unprecedented accuracy and are consistent with the SM predictions. The measured isospin asymmetry of the $B \to K\mu^+\mu^-$ system shows a $4.4\,\sigma$ deviation from zero.

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