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The $B_d \to K^* \mu^+ \mu^-$ decay: A study in the Standard Model

M. CIUCHINI(1), M. FEDELE(2)(3), E. FRANCO(2), S. MISHIMA(4), A. PAUL(2), L. SILVESTRINI(2) and M. VALLI(5)(6)

(1) *INFN, Sezione di Roma Tre - I-00146 Rome, Italy*
(2) *INFN, Sezione di Roma - I-00185 Rome, Italy*
(3) *Dipartimento di Fisica, Università di Roma - I-00185 Rome, Italy*
(4) *High Energy Accelerator Research Organization (KEK) Ibaraki, Tsukuba 305-0801, Japan*
(5) *INFN, Sezione di Trieste - I-34127 Trieste, Italy*
(6) *SISSA - I-34136 Trieste, Italy*

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Summary. — The rare semileptonic $B_d \to K^* \mu^+ \mu^-$ decay has been extensively studied within the Standard Model and beyond. Recently, data provided by the LHCb experiment suggested the presence of new physics given the discrepancy found between the theoretical and the experimental value of a certain observable (P_5') at low q^2. This requires a careful re-examination of the Standard Model estimates so that a discrimination between the latter and any model of new physics can be made. We present in this work a Bayesian analysis of the decay in the full range of q^2, in which we perform a full fit from available data. We also make well-motivated arguments about the size of the hadronic uncertainties and ultimately study the compatibility of the currently available experimental data with the Standard Model predictions.

1. – Introduction

Flavour-Changing Neutral Current (FCNC) processes are very sensitive probes of New Physics (NP). Within the Standard Model (SM) they can only arise at the loop level, and they are further suppressed by the GIM cancellation mechanism, so that even very heavy new particles can give rise to sizable contributions, especially if they carry new sources of flavour violation. In particular, the semileptonic decays $B \to K^* \ell^+ \ell^-$ have been advocated to be among the cleanest FCNC processes.

Experimentally, a full angular analysis of this decay has been recently performed allowing for the extraction of twelve angular coefficients in several q^2 bins [1, 2]. For these observables, very precise predictions can be found in the literature, showing some deviations in one of the measured observables, namely P_5' [3, 4].

In these proceedings we argue that no deviation is present once all the theoretical uncertainties are taken into account. While the effect of power corrections and non-perturbative contributions cannot presently be computed from first principles, allowing them to vary in a range compatible with the theoretical arguments outlined in [5] is mandatory to obtain a reliable estimate of the uncertainty in the SM predictions for $B \to K^*\ell^+\ell^-$ observables. This is the main goal of the present analysis.

2. – Weak effective hamiltonian

The $\bar{B} \to \bar{K}^*\ell^+\ell^-$ decay can be described by means of the $\Delta B = 1$ weak effective Hamiltonian

$$\mathcal{H}_{\text{eff}}^{\Delta B=1} = \mathcal{H}_{\text{eff}}^{\text{had}} + \mathcal{H}_{\text{eff}}^{\text{sl}}, \tag{1}$$

where the first term is the hadronic contribution

$$\mathcal{H}_{\text{eff}}^{\text{had}} = \frac{4G_F}{\sqrt{2}} \sum_{p=u,c} \lambda_p \Big(C_1 Q_1^p + C_2 Q_2^p + \sum_{i=3}^{6} C_i P_i + C_8 Q_{8g} \Big), \tag{2}$$

involving current-current, QCD penguin and chromomagnetic dipole operators [6], while the second one, given by

$$\mathcal{H}_{\text{eff}}^{\text{sl}} = -\frac{4G_F}{\sqrt{2}} \lambda_t \Big(C_7 Q_{7\gamma} + C_9 Q_{9V} + C_{10} Q_{10A} \Big), \tag{3}$$

includes the electromagnetic penguin plus the semileptonic operators [7]. The contribution of $\mathcal{H}_{\text{eff}}^{\text{sl}}$ in eq. (3) clearly factorizes into the product of hadronic form factors and leptonic tensors. On the other hand, the matrix elements of $\mathcal{H}_{\text{eff}}^{\text{had}}$ in eq. (2) factorize only in the infinite m_b mass limit and below the charm threshold [8, 9]. In our analysis, we parametrize this term following the notation of ref. [7] and writing the nonperturbative hadronic contribution as follows:

$$h_\lambda(q^2) = \frac{\epsilon_\mu^*(\lambda)}{m_B^2} \int \mathrm{d}^4x e^{iqx} \langle \bar{K}^* | T\{ j^\mu_{\text{em}}(x) \mathcal{H}_{\text{eff}}^{\text{had}}(0)\} | \bar{B} \rangle = h_\lambda^{(0)} + q^2 h_\lambda^{(1)} + q^4 h_\lambda^{(2)}, \tag{4}$$

where $\lambda = +, -, 0$ represents the helicity.

3. – Analysis

Our analyses was perfromed using a Markov Chain Monte Carlo framework called `SM@HEPfit`([1]), based on BAT [10]. Three ingredients are necessary for this computation: all Wilson coefficients were computed at NNLO running them from the scale $\mu_0 = M_W$ to $\mu = 4.8$ GeV; we use the form factors from [11]; we use the results from [5] as a flat prior at 1 GeV^2 for the hadronic contributions parametrized by eq. (4).

([1]) `https://github.com/silvest/HEPfit`

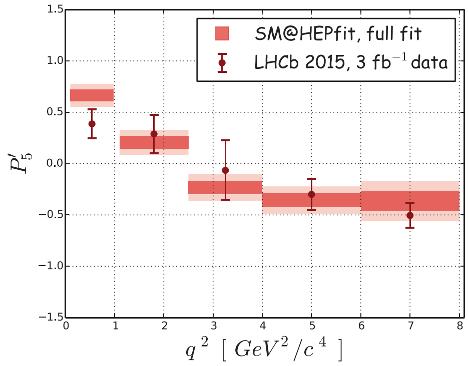

Fig. 1. – Full fit results for observable P_5.

4. – Results

The results concerning the observable P'_5 obtained from our full fit are shown in fig. 1. The deviation found in previous studies is no longer present, once all the theoretical uncertainties have been properly taken into account. We therefore claim that at present there is no anomaly.

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