



HAL
open science

Rare Decays at LHCb

Jacopo Cerasoli

► **To cite this version:**

Jacopo Cerasoli. Rare Decays at LHCb. 20th Lomonosov Conference on Elementary Particle Physics, Aug 2021, Online, Russia. pp.189-190, 10.3103/S0027134922020230 . hal-03777958

HAL Id: hal-03777958

<https://hal.science/hal-03777958>

Submitted on 3 Apr 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Rare decays at LHCb

Jacopo Cerasoli*

Aix Marseille Univ, CNRS/IN2P3, CPPM, Marseille, France

(On behalf of the LHCb collaboration)

(Dated: February 20, 2023)

Abstract

The Standard Model (SM) of particle physics is the most advanced theory describing the behaviour and interactions of elementary particles. Despite passing an impressive amount of experimental tests, several deviations from the SM predictions have been observed in recent years in measurements of observables related to rare b -hadron decays, prompting great interest and motivating further investigations. A collection of selected recent results obtained by the LHCb collaboration [1] on the study of rare b -hadron decays is presented in these proceedings.

PACS numbers: 13.20.He, 13.30.Ce

Keywords: Rare decays, LHCb, Standard Model, lepton flavour universality, new physics.

* jacopo.cerasoli@cern.ch

I. INTRODUCTION

In the SM, $b \rightarrow sl^+l^-$ decays are flavour changing neutral current (FCNC) processes strongly suppressed and therefore sensitive to hypothetical new physics contributions which could manifest more prominently than the SM background. They can be described in a model-independent way by the effective Hamiltonian $H_{\text{eff}}^{b \rightarrow s} = \frac{G_F}{\sqrt{2}} \sum_i V_{ib} V_{is}^* C_i(\lambda) Q_i(\lambda)$, where the FCNC processes are encoded in Wilson coefficients $C_i(\lambda)$, the effect of the strong interaction is encoded in effective operators $Q_i(\lambda)$, G_F is the Fermi constant and $V_{ib} V_{is}^*$ is the relevant CKM factor [2]. The dominant SM contributions for rare b -hadron decays are encoded in the semileptonic (axial-)vector operator $Q_{9(10)}$ and the electromagnetic operator Q_7 .

II. RARE DECAYS AT LHCb

The R_K ratio, defined as $R_K = \frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)}$, is predicted to be $1 \pm \mathcal{O}(10^{-2})$ by the SM [3] because of Lepton Flavour Universality (LFU), a property of the SM which states that the three lepton families have the same electroweak coupling constant. The LHCb collaboration has performed the measurement of R_K in the di-lepton invariant mass squared (q^2) range $1.1 - 6.0 \text{ GeV}^2/c^4$, using data corresponding to an integrated luminosity of 9 fb^{-1} [4]. The ratio is measured to be $R_K = 0.846_{-0.039}^{+0.042} {}_{-0.012}^{+0.013}$, where the first uncertainty is statistical and the second systematic. The measurement exhibits a tension with respect to the SM prediction of 3.1 standard deviations (σ), providing evidence for LFU breaking in $B^+ \rightarrow K^+ l^+ l^-$ decays.

The measurement of the properties of $B_{(s)}^0 \rightarrow \mu^+ \mu^- (\gamma)$ decays has been performed using data corresponding to an integrated luminosity of 9 fb^{-1} [5]. In addition to the search for $B_{(s)}^0 \rightarrow \mu^+ \mu^-$ decays, the search for the initial state radiation process $B_s^0 \rightarrow \mu^+ \mu^- \gamma$ is performed for the first time, for values of the di-muon invariant mass $M_{\mu\mu} > 4.9 \text{ GeV}$. The $B_s^0 \rightarrow \mu^+ \mu^-$ decay is observed with a statistical significance of more than 10σ and its branching ratio is measured to be $\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-) = (3.09_{-0.43}^{+0.46} {}_{-0.11}^{+0.15}) \cdot 10^{-9}$, in agreement with the SM predictions [6, 7]. For the other two modes the measurements are compatible with the background-only hypothesis and upper limits of $\mathcal{B}(B^0 \rightarrow \mu^+ \mu^-) < 2.6 \cdot 10^{-10}$ and $\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^- \gamma) < 2.0 \cdot 10^{-9}$ are set at 95% confidence level. In addition, the value of

the $B_s^0 \rightarrow \mu^+ \mu^-$ effective lifetime is measured to be $\tau_{B_s^0 \rightarrow \mu^+ \mu^-} = (2.07 \pm 0.29 \pm 0.03)$ ps, in agreement with the SM predictions.

The branching ratio of the $B_s^0 \rightarrow \phi \mu^+ \mu^-$ decay has been measured using data corresponding to an integrated luminosity of 9 fb^{-1} [8]. The q^2 -integrated branching ratio is measured to be $\mathcal{B}(B_s^0 \rightarrow \phi \mu^+ \mu^-) = (8.14 \pm 0.21 \pm 0.16 \pm 0.03 \pm 0.39) \cdot 10^{-7}$, where the uncertainties are statistical, systematic, due to the extrapolation to the full q^2 range and due to the branching ratio of the $B_s^0 \rightarrow J/\psi \phi$ decay used as normalization channel. In the q^2 bin $1.1 - 6.0 \text{ GeV}^2/c^4$ the measurement shows a tension of 3.6σ with the SM prediction obtained combining Light Cone Sum Rule and Lattice QCD calculations. Moreover, the rare $B_s^0 \rightarrow f_2'(1525) \mu^+ \mu^-$ decay has been observed for the first time with a statistical significance of 9σ and its branching ratio has been measured to be $\mathcal{B}(B_s^0 \rightarrow f_2' \mu^+ \mu^-) = (1.57 \pm 0.19 \pm 0.06 \pm 0.06 \pm 0.08) \cdot 10^{-7}$.

The angular analysis of the $B_s^0 \rightarrow \phi \mu^+ \mu^-$ decay has been performed using data corresponding to an integrated luminosity of 8.4 fb^{-1} [9]. A four-dimensional fit to the B_s^0 invariant mass and three helicity angles is performed to determine the values of four CP averages (F_L and $S_{3,4,7}$) and four CP asymmetries (A_{FB}^{CP} and $A_{5,8,9}$) [10]. The results are in overall agreement with the SM predictions, despite a mild tension in F_L at low q^2 values. A fit to the CP averages varying the value of the real part of the Wilson coefficient C_9 shows a tension with respect to the SM predictions of 1.9σ .

A measurement of the photon polarization (α_γ) in $\Lambda_b \rightarrow \Lambda \gamma$ decays has been performed using data corresponding to an integrated luminosity of 6 fb^{-1} [11]. Photons from $b \rightarrow s \gamma$ decays are predominantly left-handed in the SM, and therefore the angular distribution of the $\Lambda_b \rightarrow \Lambda(\rightarrow p \pi^-) \gamma$ decay is sensitive to right-handed new physics contributions encoded in the Wilson coefficient C_7' . The measured value of the photon polarization is $\alpha_\gamma = 0.82_{-0.26}^{+0.17+0.04}_{-0.13}$, in agreement with the SM expectation. This represents the first measurement of the photon polarization in b -baryon decays.

III. CONCLUSIONS

Rare b -hadron decays are powerful probes for new physics beyond the SM. Despite several deviations with respect to the SM predictions have been observed, none of them is statistically significant enough to claim a discovery. More measurements are therefore necessary in order to shed light on the nature of the flavour anomalies.

REFERENCES

- [1] R. Aaij *et al.* (LHCb), LHCb Detector Performance, *Int. J. Mod. Phys. A* **30**, 1530022 (2015), arXiv:1412.6352 [hep-ex].
- [2] T. Blake, G. Lanfranchi, and D. M. Straub, Rare B Decays as Tests of the Standard Model, *Prog. Part. Nucl. Phys.* **92**, 50 (2017), arXiv:1606.00916 [hep-ph].
- [3] M. Bordone, G. Isidori, and A. Pattori, On the Standard Model predictions for R_K and R_{K^*} , *Eur. Phys. J. C* **76**, 440 (2016), arXiv:1605.07633 [hep-ph].
- [4] R. Aaij *et al.* (LHCb), Test of lepton universality in beauty-quark decays, (2021), arXiv:2103.11769 [hep-ex].
- [5] R. Aaij *et al.* (LHCb), Measurement of the $B_s^0 \rightarrow \mu^+\mu^-$ decay properties and search for the $B^0 \rightarrow \mu^+\mu^-$ and $B_s^0 \rightarrow \mu^+\mu^-\gamma$ decays, (2021), arXiv:2108.09283 [hep-ex].
- [6] M. Beneke, C. Bobeth, and R. Szafron, Power-enhanced leading-logarithmic QED corrections to $B_q \rightarrow \mu^+\mu^-$, *JHEP* **10**, 232, arXiv:1908.07011 [hep-ph].
- [7] D. Guadagnoli, M. Reboud, and R. Zwicky, $B_s^0 \rightarrow \ell^+ \ell^- \gamma$ as a test of lepton flavor universality, *JHEP* **11**, 184, arXiv:1708.02649 [hep-ph].
- [8] R. Aaij *et al.* (LHCb), Branching Fraction Measurements of the Rare $B_s^0 \rightarrow \phi\mu^+\mu^-$ and $B_s^0 \rightarrow f_2'(1525)\mu^+\mu^-$ Decays, *Phys. Rev. Lett.* **127**, 151801 (2021), arXiv:2105.14007 [hep-ex].
- [9] R. Aaij *et al.* (LHCb), Angular analysis of the rare decay $B_s^0 \rightarrow \phi\mu^+\mu^-$, *JHEP* **11**, 043, arXiv:2107.13428 [hep-ex].
- [10] C. Bobeth, G. Hiller, and G. Piranishvili, CP Asymmetries in $\bar{B} \rightarrow \bar{K}^*(\rightarrow \bar{K}\pi)\bar{\ell}\ell$ and Untagged $\bar{B}_s, B_s \rightarrow \phi(\rightarrow K^+K^-)\bar{\ell}\ell$ Decays at NLO, *JHEP* **07**, 106, arXiv:0805.2525 [hep-ph].
- [11] R. Aaij *et al.* (LHCb), Measurement of the photon polarization in $\Lambda_b^0 \rightarrow \Lambda \gamma$ decays, (2021), arXiv:2111.10194 [hep-ex].