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Search for the rare decay $B_s \to \mu^+\mu^-$ with ATLAS

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Summary. — An overview of the search for the rare decay $B_s \to \mu^+\mu^-$ with the ATLAS detector at Large Hadron Collider is presented. The analysis, based on $2.4\,\text{fb}^{-1}$ of integrated luminosity, has been performed by using a multivariate, multi-bin selection method. A 95% CL upper limit on the branching fraction of the process has been set at $BR\ (B_s \to \mu^+\mu^-) \leq 2.2\ 10^{-8}$.

PACS 11.30.Hv – Flavor symmetries.
PACS 12.15.Mm – Neutral currents.

1. – Introduction

The $B_s \to \mu^+\mu^-$ decay is a Flavor Changing Neutral Current process involving a $b \to s$ quark transition. It is highly suppressed in the Standard Model picture and occurs at the lowest order through one-loop diagrams, so that the theoretical estimation of the branching ratio is predicted to be extremely small: $(3.55 \pm 0.28) \times 10^{-9}$ [1, 2]. Contributions from New Physics can significantly increase this branching ratio. The search for this rare decay has been performed with the ATLAS detector [3] at the Large Hadron Collider (LHC). The analysis [4] is based on collision data collected at $\sqrt{s} = 7\,\text{TeV}$ in the first half of 2011 with stable LHC beams, corresponding to $2.4\,\text{fb}^{-1}$ of integrated luminosity.

2. – The $B_s \to \mu^+\mu^-$ analysis strategy

In order to minimize the systematic uncertainties the $B_s \to \mu^+\mu^-$ branching ratio is normalized to the branching ratio of the $B^\pm \to J/\psi K^\pm \to \mu^+\mu^- K^\pm$ decay, which is taken as a reference. In this view, the expression of the branching ratio can be written as

$$(1)\quad Br(B_s \to \mu^+\mu^-) = \frac{N_{\mu\mu}}{N_{B^\pm}} \times R_{\alpha\epsilon} \times \frac{\mathcal{L}_{ref}}{\mathcal{L}_{\mu\mu}} \times \frac{f_u}{f_s} \times Br(B^\pm \to J/\psi K^\pm \to \mu^+\mu^- K^\pm),$$

where $R_{\alpha\epsilon} = \frac{\epsilon_{B^\pm}\alpha_{B^\pm}}{\epsilon_{\mu\mu}\alpha_{\mu\mu}}$ and, for each decay mode: N is the number of observed events, ϵ and α are, respectively, the efficiencies and acceptances, $\mathcal{L}$ is the integrated luminosity and f_u/f_s is the relative p-p production rate of $B^\pm$ and B_s mesons. In eq. (1) the luminosity factors cancel out since the same integrated luminosity has been used; moreover, when setting $N_{\mu\mu} = 1$, the expression provides the so-called *Single Event Sensitivity* (SES). A blind search is performed, meaning that all the quantities entering the SES have been evaluated by excluding in the data sample the signal region, corresponding to a mass window of ± 300 MeV around the B_s mass, until the analysis was considered finalized and approved by the Collaboration. In particular, for each decay mode N is evaluated from data after background subtraction while the ratio $R_{\alpha\epsilon}$ is evaluated from Monte Carlo (MC); for the remaining quantities the values $\frac{f_u}{f_s} = 0.267 \pm 0.021$ [5, 6], and $Br(B^\pm \to J/\psi K^\pm \to \mu^+\mu^- K^\pm) = (6.01 \pm 0.21) \times 10^{-5}$ [7] are used. Data belonging to the sidebands of the signal region ($4766\,\text{MeV} < m_{\mu\mu} < 5066\,\text{MeV} \bigcup 5666\,\text{MeV} < m_{\mu\mu} < 5966\,\text{MeV}$) are used to model the main (*continuum*) background(1), while the irreducible background, which originates from neutral B meson two-body decays with charged hadrons in the final state, misidentified as prompt muons, has been evaluated using MC and accounted in the upper limit extraction. To improve the signal/background separation, the samples were split in three mass resolution categories ($\sigma_{m_{\mu\mu}} \sim 60/80/120$ MeV) depending on the maximum absolute value of the muons pseudorapidity in the di-muon candidate, η_{max}. A multivariate analysis has been used to combine the separation power of 14 different variables, selected according to their discriminating power and avoiding correlations. The chosen multivariate classifier was the Boosted Decision Tree (BDT) algorithm; the same BDT classification optimized on the $B_s \to \mu^+\mu^-$ signal has been used for the $B^\pm \to J/\psi K^\pm$ selection. For each mass resolution category, the selection has been optimized as a function of the width of the search window in mass Δm and of the lower cut on the BDT output. To obtain a limit at 95% CL, the estimator [8] $\mathcal{P} = \epsilon_S/(1 + \sqrt{N_{bkg}})$ is maximized, where ϵ_S is the signal efficiency and N_{bkg} is the number of background events.

3. – Conclusions

After the unblinding of the signal region, no excess of events has been found, therefore an upper limit is set. The observed limit, obtained by means of an implementation [9] of the CL_s method [10], is $BR\ (B_s \to \mu^+\mu^-) \leq 2.2(1.9) \times 10^{-8}$ at 95% (90%) CL.

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(1) To avoid biases, the sidebands data have been split in 2 equal populated parts: one was used in the optimization of the cuts, the other for the estimation of the background in the signal region after the optimization.