LHCb/LNF 2015

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1 Research activity

In May 2015 the first observation of the $B_s^0 \to \mu^+\mu^-$ decay has been published on Nature by the LHCb and CMS collaborations [1)]. The statistical significance of the signal is 6.2σ, and it has been achieved through the combined analysis of LHCb and CMS data of LHC RUN I. The measured BR, $2.8^{+0.7}_{-0.6} \times 10^{-9}$, is in agreement with the SM prediction. The above result concludes a search that started more than three decades ago, and initiates a phase of precision measurements of the properties of this decay. The LNF team, which represented in 2012 and 2013 the driving force in the LHCb $B_s^0 \to \mu^+\mu^-$ analysis working group, contributed substantially to this achievement, partecipating in all the aspects of the combination.

With the same data, an excess for the $B^0 \to \mu^+\mu^-$ decay was observed, with a rate 2.2σ above the SM prediction. A departure of the B_d/B_s ratio from the SM prediction would falsify the Minimal Flavour Violation hypothesis, and this would unambiguously signal the presence of physics beyond the SM. For the above reason, the clarification of the experimental picture on the $B^0 \to \mu^+\mu^-$ decay rate is the main challenge during LHC RUN II, and this has been studied in detail during the past year by the Frascati analysis team. The leading role achieved in this field has been recognized by appointing Ricardo Vazquez Gomez, a postdoc of the LNF team, as convener of the working group on very rare decays.

Besides the actvity on rare dimuon decays, a new interesting study has been succesfully started on the semileptonic decays of B_s^0 with a τ lepton in the final state. This is particular important since significant departures from the SM predictions have been recently measured by the Babar, Belle and LHCb collaborations in the ratio of B^0 semileptonic decays to τ and μ leptons, respectively. The above apparent violation of lepton universality is also complemented by other puzzling results in the electroweak penguin decays of B meson with two muons or two electrons in the final

state, and are generating a lively theoretical debate on the possibility of interpreting them as signals of new physics beyond the SM.

In addition to a direct involvement in the physics analyses, a considerable effort has been spent by the LNF team on the particle identification performance assessment in view of RUN II. The unambiguous identification of kaons, pions, protons and muons is indeed a crucial task for LHCb to reach the physics goals in terms of background rejection for rare decay studies and of reconstruction capability of exclusive final states for CP studies. The work has been coordinated by B. Sciascia as LHCb PID convener, and is documented in Refs. [2] and [3]. As PID coordinator, B. Sciascia also acted as editor of the LHCb detector performance paper [4].

2 Preparation for the LHCb upgrade

Even though the physics harvest is now in full flow, and will continue certainly during the forthcoming LHC RUN II, the LHCb collaboration has been already approved for an upgrade of the experiment, intended to collect ~ 50 fb^{-1} starting in 2020, after the long shutdown 2 of LHC. This very large sample should allow to determine several SM variables in the flavor sector to a precision comparable with the ultimate theoretical uncertainty. In order to prepare the muon detector for the upgrade phase, several activities are ongoing at LNF.

The LNF electronic team (LNF-SEA), coordinated by P. Ciambrone, has the task of constructing the new readout board for the muon detector (nODE), which will operate at 40 MHz rate. The full project underwent the Engineering Design Review at CERN in november 2015, and was positively judged in that occasion by the international board of experts. Before switching to the production phase, the team is now facing the construction of the first prototype of the board, equipped with the final version of the chip (nSYNC).

Moreover, the LNF team is encharged of the production of 30 MWPC of large dimensions to use as spares for the muon detector in the next LHCb runs. Accepting this challenge was possible thanks to the support of LNF infrastructure, and to the local highly qualified expertise in this field. The construction consists of three distinct steps: the preparation of the panels equipped with PCB, fully completed, the chamber wiring and assembling, completed now at 50%, and the chamber test on a Cs-137 source. The latter phase has just started in a new facility prepared at the laboratory for testing detectors with radioactive sources, and which we have equipped with the specific tools needed to operate such test.

For the upgrade phase, one of the main challenges in operating the muon detector will be reaching the present high efficiency in identifying the muons, while maintaining the misidentification rate of hadrons at an acceptable level. If we cannot guarantee the above conditions, the increase in luminosity will not translate into an increase of sensitivity for many golden physics channels with muons in the final state. This is particular true since in the upgrade conditions the detector hardware efficiency will be limited by the intense flux of particles especially in the innermost

regions close to the beam pipe, which also tends to affect the hadron misidentification.

Detailed studies on the muon identification performances have been carried out in 2015 by the LNF team (with M. Palutan being the coordinator of LHCb muon identification working group), which consisted in integrating more information available from the detector in the muon identificatin algorithms, as documented in Ref. [5]. Background extrapolations to the upgrade conditions have been also computed, which allow to predict the same level of background we have now by introducing these optimized muon identification algorithms. These results triggered a lot of discussion and interesting developments in the collaboration, which have been summarized in a dedicated workshop on "Muon Identification at LHCb", hosted in Frascati in october.

3 List of Talks by LNF Authors in Year 2015

1. G. Lanfranchi, "Rare B decays at LHCb", Les Rencontres de Physique de la Vallee d'Aoste, La Thuile (Italia), March 1-7, 2015.

2. G. Lanfranchi, "Search for $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ decays at LHCb", Seminar and Lecture at the "Scuola Normale di Pisa", 14 May 2015.

3. G. Lanfranchi, co-convener of the session "Flavour Physics and Fundamental Symmetries", EPS Conference, Vienna (Austria), 22-29 July, 2015.

4. G. Lanfranchi, "Rare decays of Heavy mesons", Lepton Photon conference, Lubljana (Slovenia), 18-23 August, 2015.

5. M. Palutan, "Testing the Standard Model with rare decays at LHCb", invited seminar, Dortmund university, 16 Dec 2015.

6. M. Santimaria,"Studio del rivelatore GEM per l'upgrade dell'esperimento LHCb", Incontri di Fisica delle Alte Energie, Università di Roma Tor Vergata, 8-10 Apr 2015.

7. R. Vazquez Gomez,"Studio di decadimenti rari ad LHCb", Incontri di Fisica delle Alte Energie, Università di Roma Tor Vergata, 8-10 Apr 2015.

References

1. The CMS and LHCb Collaborations, "Observation of the rare $B_s^0 \to \mu^+\mu^-$ decay from the combined analysis of CMS and LHCb data", Nature 522 (2015) 68.

2. O. Lupton et al., "Calibration samples for particle identification at LHCb in Run 2", LHCb-PUB-2016-005.

3. R. Aaij et al., "Tesla: an application for real-time data analysis in High Energy Physics", to be submitted to Journal of Computational Physics.

4. The LHCb Collaboration, "LHCb detector performance", International Journal of Modern Physics A, Vol. 30, No. 7 (2015) 1530022.

5. A. Cardini et al., "New muon identification algorithms", LHCb-INT-2016-006.