IL NUOVO CIMENTO **40 C** (2017) 44
DOI 10.1393/ncc/i2017-17044-3

Colloquia: IFAE 2016

Novel Muon Identification Algorithms for the LHCb upgrade

V. Cogoni(1)(2)(3)

(1) *INFN, Sezione di Cagliari - Cagliari, Italy*
(2) *Dipartimento di Fisica, Università di Cagliari - Cagliari, Italy*
(3) *CERN, Organisation Européenne pour la Recherche Nucléaire - Geneva, Switzerland*

received 17 October 2016

Summary. — After the second Long Shutdown of the LHC scheduled for 2020, LHCb will operate at an istantaneous luminosity of $2 \cdot 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and at a centre-of-mass energy of 14 TeV. In this context, an overview of the possible new algorithms for the muon identification for the LHCb Upgrade is illustrated here. In particular, the performance on combinatorial background rejection is shown, together with the extrapolations to upgrade conditions.

1. – Introduction

The LHCb experiment is optimised to study the decays of hadrons containing b and c quarks in order to perform CPV measurement and to possibly reveal New Physics. In this regard, the study of decay channels with muons in the final state is crucial, therefore the current muon system has been designed to ensure high-momentum resolution and high efficiency at the present data-taking conditions. In the upgraded detector, the elevated particles flux could degrade the muon identification performances and lead to inefficienciess due to the dead time. For this reason it is mandatory to develop a new muon identification strategy in order to recover the muonID performances in view of the upgrade phase.

2. – The LHCb Muon System and its upgrade

The current Muon System consists of five stations: M1, located before the calorimeters; M2 to M5, placed behind the calorimeters and interleaved with iron walls. Each station is divided into four concentric regions, R1 to R4; they are equipped with Multi-Wire Proportional Chambers (MWPCs), except for M1R1 which hosts Gas Electron Multiplier (GEM) detectors. The foreseen interventions for the upgrade [1] include the installation of additional shielding behind HCAL to reduce the particle flux in the inner regions of M2, and new off-detector electronics in compliance with the 40 MHz readout.

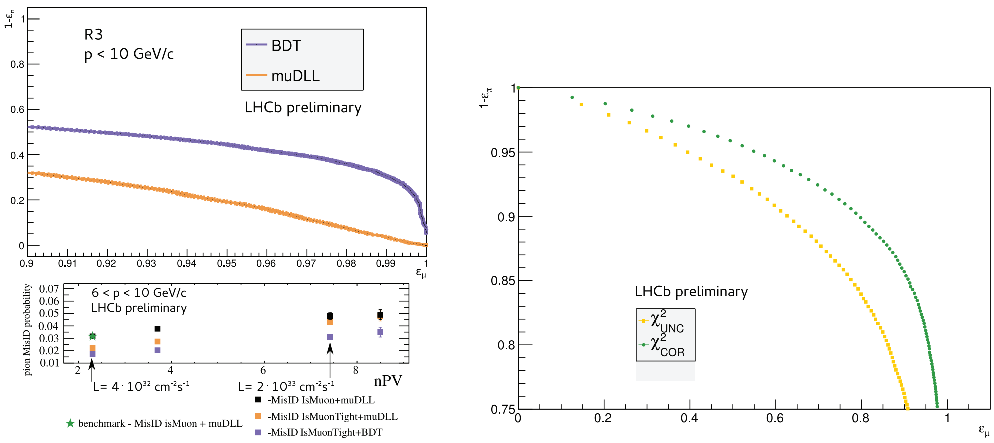

Fig. 1. – On the top left, the pion rejection as a function of the muon efficiency is shown for the BDT, trained using data calibration samples of muons ($J/\psi \to \mu\mu$) and pions ($D^0 \to K\pi$), and for the currently used muDLL, in the low-momentum region; the bottom one shows the pion misidentification probability as a function of the number of primary vertices (for a fixed muon ID efficiency of $\approx 91\%$) for the currently used algorithm (black), isMuonTight with muDLL (orange) and isMuonTight with the new BDT (purple). The situations corresponding to the current and the upgrade luminosity are indicated by arrows. The plot on the right shows the improvement introduced by the use of a discriminating variable which includes multiple scattering terms (χ^2_{COR}). This result has been obtained with a $J/\psi \to \mu\mu$ Monte Carlo sample for the upgrade. The subscript UNC stands for "uncorrelated" while COR stands for "correlated".

3. – The current Muon Identification procedure

The reconstructed tracks are identified (or rejected) as muons using the information from the Muon System through a two-step procedure [2]:

- isMuon, a Boolean decision based on the search of hits inside a Field of Interest (FoI) around the track extrapolation to each station;
- muDLL, the logarithm of the ratio between the muon and non-muon hypotheses, calculated starting from a discriminating variable, d^2, which depends on the distance between the position of the closest hit inside the FoI and the extrapolation of the track to each station weighted by the sub-detector's pad size.

The muon identification efficiency is measured as a function of a selection cut in the variable muDLL.

4. – Novel Muon Identification Algorithms

More information from the muon detector can be used to suppress combinatorial background more effectively.

4·1. *A BDT to identify muons.* – The first solution is a muon multivariate classifier applied to "isMuonTight" candidates (*i.e.* candidates that passed isMuon and have signals in both x and y readout channels), based on a Boosted Decision Tree (BDT) that combines the full information from muon detector variables (space residuals, multiple scattering errors, number of hits in FoI, ...). As can be seen in fig. 1 (left, top), the BDT improvement is evident with respect to the currently used muDLL. The extrapolations of misID at high luminosity show that using isMuonTight and the BDT guarantees for the upgrade conditions the same average π-misID we have today (fig. 1 (left, bottom)) without substantial losses of muon efficiency performance.

4·2. *A new discriminating variable:* χ^2_{COR}. – In parallel to BDT studies, a new variable has been developed that completes the d^2 including multiple scattering as a weight, which accounts for hit correlations. Figure 1 (right) shows that taking into account the correlations introduced by multiple scattering significantly helps muon identification.

5. – Conclusions

An overview of the possible new algorithms for the muon identification for the LHCb Upgrade is here presented. They foresee, for the upgrade, the same performances as today for pion rejection, ensuring at the same time high efficiency for muon identification. The methods are currently applied to extrapolations to upgrade conditions and their test on Run 1 data is in progress.

REFERENCES

[1] The LHCb Collaboration, *LHCb PID Upgrade Technical Design Report*, CERN-LHCC-2013-022. LHCB-TDR-014.
[2] Archilli F. *et al.*, *JINST*, **8** (2013) P10020, CERN-LHCB-DP-2013-001, LHCB-DP-2013-001.