The detector

The muon detector of the LHCb experiment consists of four stations M2-M5, of rectangular shape, placed along the beam axis behind the hadronic calorimeter, and interleaved with 80 cm-thick iron absorbers to select penetrating muons. Until the end of Run 2, there was the M1 station placed in front of the calorimeters and used to improve the pT measurement in the trigger. Each muon station is subdivided into four regions, R1-R4, with different read-out schemes defining the x,y resolutions.

Publications and documentation

Since the start of the Muon Project, as defined in the TDR, six papers have been published containing relevant results obtained along the life of the detector and from its performance. These are:

- Paper LHCb-DP-2011-001 "Performance of the LHCb muon system with cosmic rays": the LHCb Muon system performance is presented using cosmic ray events collected in 2009. These events allowed to test and optimize the detector configuration before the LHC start.

- Paper LHCb-DP-2012-002 "Performance of the LHCb muon system": the performance of the LHCb Muon system and its stability across the full 2010 data taking with LHC running at $\sqrt{s} = 7$ TeV energy is studied. The optimization of the detector setting and the time calibration performed with the first collisions delivered by LHC is described.

- Paper LHCb-DP-2013-001 "Performance of the Muon Identification at LHCb": the performance of the muon identification in LHCb is extracted from Run 1 data using muons and hadrons produced in J/\psi -> \mu \mu, \Lambda -> p \pi and D^(*) -> \pi D(0)(K\pi) decays.

- Paper 2016 JINST 11 P04010 "Measurement of the front-end dead-time of the LHCb muon detector and evaluation of its contribution to the muon detection inefficiency": A method is described which allows to deduce the dead-time of the front-end electronics of the LHCb muon detector from a series of measurements performed at different luminosities at a bunch-crossing rate of 20 MHz. These results allow to estimate the performance of the muon detector at the future bunch-crossing rate of 40 MHz and at higher luminosity.

- Paper LHCb-DP-2020-003 "Long-term Operation of the Multi-Wire-Proportional-Chambers of the
LHCb Muon System": The muon detector of LHCb, which comprises 1368 multi-wire-proportional-chambers (MWPC) for a total area of 435 m², is the largest instrument of its kind exposed to such a high-radiation environment. In nine years of operation, from 2010 until 2018, we did not observe appreciable signs of ageing of the detector in terms of reduced performance.

- Paper LHCb-DP-2020-002 "Muon identification for LHCb Run 3": two new muon identification algorithms developed in view of the LHCb upgrade are presented, and their performance in terms of signal efficiency versus background reduction is shown.

- Muon Luminosity paper "A Method Based on Muon System to Monitor LHCb Luminosity": The present work describes a procedure based on hit counting in the muon detector for an on-line luminosity monitor. The performance and the precision achieved with this method in tests carried out on past data collected are presented, together with proposals for future upgrades.

All documents (the same papers, INT and PUB notes, as well as EDMS documents) describing the conception of the detector, the tests of the prototypes, the development of the electronics as well as its upgrade before Run 3, and the ongoing work towards the future LHCb Upgrades have been collected in the MuonPublications page. The documents have been organized in the following sub sections: Pre-Run 1, Run and Run 2, Upgrade 1, Upgrade 2, and EDMS links. There is also a direct link to talks and posters uploaded in CDS.

**Improved shielding of the LHCb Muon System at Upgrade 1**

- Engineering Design Review meeting, and EDMS document.

- Work Package Procedure WPP for the Installation of new HCAL/M2 Beam Plugs.

**Coordination and responsibilities**

PL: Barbara Sciascia

Deputies: Oleg Maev and Davide Pinci

Software: Patrizia De Simone

Future upgrades: Wander Baldini

U1 commissioning and run: Davide Brundu

Muon PLs and deputies since 1999 can be found here.

**Relevant meetings**

- Muon meetings on Indico (Parallel sessions at LHCb Weeks, ECS at Upgrade 1, Software, Upgrade 2, ...)

- Technical Board meetings on Indico

- 15-16 October 2015, Workshop on Muon Identification at LHCb
Muon system in Run 2

- See RUN2 Muon NEW Twiki pages

Links to Run 1 pages

- Main Muon web page
- OLD Muon online pages
- Muon System Performance

Muon Commissioning for Run 3

Planning of the work on 2018, by Matteo at the upgrade installation workshop in view of LS2.

Documentation on GitLab: documents and Wiki. Specific direct links are: RCM connections, TELL40 - data center, and Virtual Machines names.

Muon geography

All about chamber dressing, in particular numbering, nomenclature and connectors is collected here. The nODE boards placement is here.

Collection of useful links

Link to the online histogram db.

Link to the CERN Drawing Directory CDD, the web application which manages engineering drawings made either at CERN or in an external company. The aim of CDD is not to only store an electronic print of the graphical drawing itself, but also to store a reference with key information related to the drawing.

Monitoring

In the Online Twiki under Muon topic, some information relevant (and likely still useful) for monitoring can be found in the following pages: Monitoring for piquet, Monitoring for shifters, and Muon DAQ monitoring.

Under the Online topics, there is a guide for Monitoring Experts that may be useful.

Muon pages in the LHCb and Online Twiki

In the Online Twiki, the list of the topics under Muon can be found here. Direct links to pages documenting old (Run 1 - Run 2) electronics are: ELMB, ODE, Service Board (SB), and SYNC.

The following pages have been extracted with a search of the "muon" word through the WebIndex page of the LHCb Twiki (last update of the list: 22 May 2021).

The following ones may contain still useful information: MuonAlignment, MuonDAQ, MuonGeometry, MuonIDConferencePlots, MuonIDOffline (updated in 2019), MuonMC, MuonMonitoring, MuonReadOut, MuonSoftware, and PIDConferencePlots (this is the repository of all the PID-related approved performance
plots; so far only for Run 1 and Run 2)

While the following are typically very old and likely not useful: MuonCalibration (last update dates back to 2006), MuonCommissioning (last update dates back to 2008), MuonCommissioningHrdw (last update dates back to 2008), MuonCommissioningTest (last update dates back to 2008; to be check if there is something useful), MuonDaqAnalysis (last update dates back to 2008), MuonDaqMonitoring (last update dates back to 2008), MuonDaqPitFaq (last update dates back to 2008), MuonEventModel (last update dates back to 2006; to be check if there is something useful), MuonEventModelReviewComments (last update dates back to 2007; to be check if there is something useful), MuonKernel (last update dates back to 2006), MuonPID (last update dates back to 2006), MuonSystemPerformance (last update dates back to 2013), MuonTraining (last update dates back to 2008), MuonTrainingInfo (last update dates back to 2008; to be check if there is something useful), MuonUpgradeElectronics (last update dates back to 2012; to be check if there is something useful), MuonUpgradeElectronicsDocumentation (last update dates back to 2011; to be check if there is something useful), MuonUpgradeElectronicsInProgress (last update dates back to 2011), MuonUpgradeElectronicsMeetings (last update dates back to 2011), PIDActivities (last update dates back to 2018), ProtoParticleMUONFilter (last update dates back to 2007; to be check if there is something useful), ReRunningMuonIDInDaVinci (last update dates back to 2009; to be check if there is something useful), and UpgradeGPUMuonID (last update dates back to 2018)