Publications and documentation

Pre-Run 1

- 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.

- Public Note LHCb-PUB-2010-002 "Calibration Strategy and Efficiency measurement of the Muon Identification procedure at LHCb": We present a strategy for calibrating with data the LHCb muon identification procedure and for extracting in-situ the performance.

- Public Note LHCb-PUB-2009-028 "Measurement of the time alignment between muon detector and calorimeters with the 2008 cosmic runs": This note presents some results concerning the time alignment between the LHCb Muon Detector and the Calorimeter system.

- Public Note LHCb-PUB-2009-019 "Study of the cross-talk between different gaps of the LHCb Muon chambers": During the tests before the installation phase of the Multi-Wire Proportional Chambers (MWPC) on the Muon Detector of LHCb an effect of cross talk between the different gas-gaps was found.

- Public Note LHCb-PUB-2009-018 "From noise to signal - a new approach to LHCb muon optimization": The detector lifetime prolongation 1.5-2 times can be achieved following the optimization of the LHCb muon system proposed in this note.

- Public Note LHCb-PUB-2009-017 "Studies of Efficiency of the LHCb Muon Detector Using Cosmic Rays": We study the efficiency of the muon detector using the cosmic ray events collected in the summer and autumn 2008.

- Public Note LHCb-PUB-2009-016 "Measurement of the time resolution of the installed muon chambers with the 2008 cosmic runs": In this note we focus on the measurement of the time resolution of the whole installed detector (M2-M5 stations) using the 2008 commissioning data.

- Public Note LHCb-PUB-2009-013 "The Muon Identification Procedure of the LHCb Experiment for the First Data": We present a refined muon identification algorithm for the LHCb experiment suitable for the first period of data taking.

- Public Note LHCb-2009-031 "Measurement of the logical pad cluster size of the installed muon chambers with the 2008 cosmic runs": This note deals with the measurement of the logical pad multiplicity, of shorts among channels and of unconnected channels of the installed muon chambers using cosmic rays from the 2008 runs. We present also a measurement of noise using a dedicated random trigger run.

- Public Note LHCb-2008-057 "Study of the performance of the LHCb MWPC with cosmic rays": In this note we report the results of measurements performed with cosmic rays on different LHCb Muon Chambers.

- Public Note LHCb-2006-042 "Test Facility for Full-Equipped Chambers for the LHCb Muon Detector": The test facility was used for studies and a quality control on the chambers before and during the final positioning on the detector. In this note an overview of the hardware setup and of the software will be given.
• Public Note LHCb-2007-145 "The Performance of the LHCb Muon Identification Procedure": This note describes the LHCb offline muon identification procedure and the algorithm parameters tuning using a Monte Carlo sample of $B \rightarrow J\psi K_s$ events.

• Public Note LHCb-2007-120 "A Laser Based Instrument for MWPC Wire Tension Measurement": fast and simple method for the measurement of the mechanical tension of wires of MWPCs is described. The system is based on commercial components and does not require any electrical connection to the wires or electric or magnetic field.

• Public Note LHCb-2007-115 "Results of the MWPC gas gain uniformity tests performed at CERN": We present the results of the gas gain uniformity tests performed as part of the quality control of the MWPCs produced at CERN.

• Public Note LHCb-2007-068 "Threshold calibration and threshold finding procedure in various LHCb muon MWPC"

• Public Note LHCb-2006-067 "On LHCb muon MWPC grounding"

• Public Note LHCb-2006-064 "Gas leakage and HV test procedure for the INFN Muon MWPCs"

• Public Note LHCb-2006-053 "Report on the quality of the LHCb-Muon four-gap MWPC produced at LNF"

• Public Note LHCb-2006-037 "A tool for the LHCb MWPC production monitoring: the LNF on-line database".

• Public Note LHCb-2006-011 "Cluster size measurements for the LHCb Muon System M5R4 MWPCs using cosmic rays": We present the preliminary results of cluster size measurements in the M5R4 wire-pad readout chambers.

• Public Note LHCb-2006-010 "Study of gas gain uniformity of the LHCb Muon System MWPCs using cosmic rays": We present here a measurement of the gas gain uniformity of the M2R3 and M5R4 chambers.

• Public Note LHCb-2005-079 "Study of the MWPC gas gain behaviour as a function of the gas pressure and temperature": The chamber gain depends on the gas density and therefore on the gas temperature and pressure. The impact of the environmental parameters on the MWPC gain has been studied in detail.

• Public Note LHCb-2005-075 "Particle rates in the LHCb muon detector": In this note we update and summarize the estimated particle rates in the LHCb muon detector. The calculation is done with a dedicated Geant simulation using a detailed geometrical description of detector and cavern and low energy thresholds.

• Public Note LHCb-2005-071 "Muon identification in the LHCb High Level Trigger": In this note the muon identification algorithm used in the high level trigger is described and details on the obtained performance are given.

• Public Note LHCb-2005-003 "Test of a MWPC for the LHCb Muon System at the Gamma Irradiation Facility at CERN": We present the results of a test on a MWPC, of the region M3R3 of the LHCb Muon System, at the Gamma Irradiation Facility (GIF) at CERN.

• Public Note LHCb-2004-074 "Test of MWPC Prototypes for Region 3 of Station 3 of the LHCb Muon System": We present results on two full size MWPC prototypes for Region 3 of Station 3 of the LHCb Muon System.
LHCb Muon System. The measurements have been performed at T11 beam line at CERN PS with 3.6 GeV /c pions.

- Public Note LHCb-2004-063 "Muons system digitization": This note describes in detail the muon system digitization procedure. The readout scheme is illustrated, the physics and detector effects involved in the digitization are analysed and their implementation in the simulation is explained.

- Public Note LHCb-2004-029 "Extensive aging test of two prototypes of four-gap MWPC for the LHCb Muon System": We present the results of an aging test on two prototypes of four-gap MWPC designed for the LHCb Muon System. The test was carried out with a Co60 source, the Calliope gamma facility at ENEA-Casaccia Research Center.

- Public Note LHCb-2003-089 "Muon iD performance with the reoptimized LHCb detector"

- Public Note LHCb-2000-102 "Beam tests of WPC-7 prototype of iwire pad chambers for the LHCb muon system": A new prototype of the Wire Pad Chamber for the LHCb Muon System, WPC-7, has been constructed at PNPI and tested in the T11 beam at CERN.

- Public Note LHCb-99-036 "Particle fluxes in the LHCb muon system-comparison of GCALOR and MARS calculations": The main goal of the present study is to determine a possible divergence in the estimations of the background hit rates in the LHCb Muon System due to different methods of approximation of particle interactions with the matter of the detectors.

- Public Note LHCb-2001-024 "Results obtained with the first four gap MWPC prototype chamber": Results of measurements made with a full size four gap multi-wire proportional chamber prototype for the inner part of the LHCb muon system are presented.

- Public Note LHCb-2001-007 "Montecarlo samples and efficiency definitions for the muon system optimization"

- Public Note LHCb-2001-058 "Time resolution of the muon detector : consequences for trigger performance and detector synchronization"

- Public Note LHCb-2000-114 "Wire pad chambers and cathode pad chambers for the LHCb muon system": A proposal for Wire-Pad-Chambers and Cathode-Pad-Chambers for the LHCb Muon system is presented.

- Public Note LHCb-2001-009 "Muon identification in LHCb"

- Public Note LHCb-2001-060 "Simulation of chamber inefficiency and noise in the LHCb muon system and study of its effect on the L0 muon trigger performance": We describe the simulation of inefficiency and noise in the chambers of the LHCb muon system, and present results on their impact on the level-0 muon trigger.

- Public Note LHCb-2001-033 "LHCb muon chamber geometry simulation": A detailed model of the LHCb muon system chambers is presented.

- Public Note LHCb-2002-034 "Construction and test of the prototype chamber for region 1 of the LHCb muon station 2"

- Public Note LHCb-2001-084 "Multivariate Methods for Muon Identification at LHCb": A neural network method and two parametric statistical approaches (one Bayesian and one classical) were studied in the context of separating muons from other particles.
Public Note LHCb-98-059 "GCALOR studies of background in the LHCb muon chambers"

Public Note LHCb-2003-057 "A new calculation of the low energy background in the muon system": This note describes a completely new package to produce the muon system low energy background. New parametrizations have been generated using GCALOR.

Public Note LHCb-2001-026 "Design and construction of the wire chambers for the LHCb muon system": The electrical layout is discussed and finally the cost breakdown and the construction schedule is presented.

Public Note LHCb-2001-023 "Gas system proposal for the LHCb muon system": This document describes the gas system proposed for the LHCb Muon system, following the Gas Working Group mandate to ensure the uniform approach to gas technology and controls across the LHC detectors.

Public Note LHCb-2000-062 "Performance study of a MWPC prototype for the LHCb muon system with the ASDQ chip": We report results from a beam test evaluating the front-end electronics for Multi-Wire-Proportional-Chambers (MWPCs) for the LHCb Muon System.

Public Note LHCb-2000-003 "Wire pad chamber for LHCb muon system": Wire pad chambers (WPC) have been proposed for the outer Region 4 of the LHCb Muon System. These are double gap MWPCs with small wire spacing allowing to obtain 99% detection efficiency in a 20 ns time window.

Public Note LHCb-2002-025 "Test results of a full size prototype of the muon chambers for region M2/R4 of the LHCb muon system": A full size prototype M2R4-01 of the Wire Pad Chambers for region M2/R4 of the LHCb Muon System has been constructed at PNPI and tested in the T11 beam at CERN.

Public Note LHCb-2001-025 "Beam tests of WPC-8 and WPC-9 prototypes of the wire pad chambers for the LHCb muon system": Two new prototypes, WPC-8 and WPC-9, of the Wire Pad Chambers have been constructed at PNPI. The prototypes have been tested in the T11 beam at CERN, and this report presents the results of the tests.

Public Note LHCb-2000-061 "Crosstalk, cathode structure and electrical parameters of the MWPCs for the LHCb muon system": This note discusses the electrical characteristics of the MWPCs for the LHCb muon system that were originally developed at PNPI. Optimized layouts for cathode structure and readout traces together with the expected crosstalk numbers are presented.

Public Note LHCb-2000-060 "Detector physics and performance : simulations of the MWPCs for the LHCb muon system": This note discusses some basic detector physics and performance parameters of the MWPCs for LHCb that were developed at PNPI.

Internal Note LHCb-INT-2009-026 "Studies of Efficiency of the LHCb Muon Detector Using Cosmic Rays": We study the efficiency of the muon detector using the cosmic ray events collected in the summer and autumn 2008. We find that the efficiencies in all stations are consistent with 100% for cosmic tracks coming from the LHCb interaction point, in a large time window.

Internal Note LHCb-INT-2009-010 "Pre-installation tests of the inner-most LHCb Muon Multi-Wire Proportional Chambers"

Internal Note LHCb-2008-056 "Study of the performance of the LHCb MWPC with cosmic rays": The main characteristics of the MWPC have been investigated as a function of the high voltage value in order to achieve a better comprehension of the detector performance both for optimizing the chamber working conditions on the experimental apparatus and for providing useful information for the Monte Carlo simulation.
Internal Note LHCb-2007-133 "Construction and Tests of an M2R3 MWPC for the LHCb Muon System": In this note are presented the most significant results of the test beam made at the CERN T11 beam area on an official MWPC built for the region 3 of the station 2 (M2R3) of the LHCb muon system.

Internal Note LHCb-2007-012 "Dependence of the efficiency from gain and threshold for the LHCb MWPC"

Internal Note LHCb-2006-059 "Remarks on MWPC pre-installation tests": The first pre-installation tests of the M5R4 chambers are presented. Recommendations for the testing procedure are issued, in particular for the software.

Internal Note LHCb-2005-099 "Update on the Muon ID performance for the DC04 Monte Carlo data"

Internal Note LHCb-2005-098 "Study of the MuonID performance for OffLine algorithm"

Internal Note LHCb-2005-096 "MWPC conditioning technique"

Internal Note LHCb-2005-011 "Characterization of the MWPC test station for the production sites": We present the apparatus of the test station proposed for gas gain uniformity tests of the chambers produced at CERN.

Internal Note LHCb-2004-048 "The simulation of the muon detector response": This note describes in detail the muon system digitization procedure. The readout scheme is illustrated, the physics and detector effects involved in the digitization are analysed and their implementation in the simulation is explained.

Internal Note LHCb-2003-167 "Quadri gap Cathode Pad Chamber (CPC) prototype for the innermost region R1 of station M4 of the LHCb muon system"

Internal Note LHCb-2003-163 "Muon System Part Numbering and Labeling: Draft Proposal"

Internal Note LHCb-2003-113 "TGC chambers for the LHCb muon detector": This note refers to work on Thin Gap Chambers concluded in February 2000. The technology of Thin Gap Chambers offers flexible and safe solutions for the LHCb muon detector. These chambers have already been extensively studied and tested (see ATLAS muon TDR) operating with a highly quenching and relatively high gain gas mixture.

Internal Note LHCb-2002-023 "A wire tension measurement device for the multi-wire chambers of the LHCb muon system": A system for measuring the wire tension of multi-wire proportional chambers is described. The method is based on the Fast Fourier Transform analysis of a pulse induced on a wire in a magnetic field.

Internal Note LHCb-2001-150 "Construction and test of the prototype chamber for region 1 of the LHCb muon station 2"

Internal Note LHCb-2001-120 "Test of a double gap MWPC for the region 3 of the LHCb muon system": We present the first results obtained with a double gap prototype of MPWC with cathode readout for the region 3 of the LHCb muon system.

Internal Note LHCb-2001-008 "Test results of Chempir Core panels for the MWPC of the LHCb muon system": A new material (Chempir Core 75) is proposed to the Collaboration for substituting honeycomb in the panels of MWPC of the muon system.
• Internal Note LHCb-2000-089 "LHCb muon system by numbers": This note summarises, mainly in the form of tables, the present configuration of the muon system. It is meant as a working document of the muon group and will be updated as the project progresses.

• Internal Note LHCb-2001-061 "Update on Muon Identification Performance"

• Internal Note LHCb-2002-047 "A Test Station for Muon MWPC's"

• Internal Note LHCb-2003-040 "Aging test of a prototype of quadrigap MWPC for the region 3 of the LHCb muon system": The test was carried out with the Co60 source of the Calliope gamma facility at ENEA-Casaccia Research Center

• Internal Note LHCb-99-039 "Electronics noise and time resolution of the multiwire proportional chamber": It is shown in the paper that electronic noise doesn't make time resolution of the multi-wires proportional chamber worse. The noise level defines the threshold of the signal registration only.

• Internal Note LHCb-2001-030 "Muon Detector Front-end Architecture: an update": This document summarizes the changes realized in the architecture of the muon detector electronics since the LHCb technical note 2000-017. They concern especially the generation of logical channels, which has been moved on detector as much as possible. Costs have been reduced at the expenses of some degree of redundancy. A new baseline architecture has been thus conceived.

• Internal Note LHCb-2000-004 "X-ray tests of multi-wire micro-gap chamber": A special design of multi–wire proportional chamber is proposed with the wire plane in close vicinity to one of the cathode plane. A 200 µm gap between these planes is provided by nylon threads stretched over the cathode plane perpendicular to the wire direction.

• Internal Note LHCb-2001-032 "LHCb Muon Detector Mechanical Support Structure": The design of the mechanical support structure for the five stations of the LHCb Muon Detector is driven by different factors such as: chambers positioning, total amount of material, access for maintenance, support for electronics, cabling, piping, installation operations. Time schedule and cost estimate are presented as well as technical details.

• Internal Note LHCb-2003-001 "Asymmetric Single Cathode Read Out and Symmetric Double Cathode Read Out MWPCs for the LHCb muon system"

• Internal Note LHCb-2003-011 "Sandwich panels for the MWPC of the LHCb muon system: mechanical properties before and after irradiation.": A polyurethane foam (ESADUR 120) was proposed to the Collaboration for substituting honeycomb in the panels of the MWPC of the LHCb muon system.

• Internal Note LHCb-2001-087 "Cross talk simulation in the Muon system": A short summary of the cross talk situation in the LHCb Muon system. The effects of cross talk induced by multiple chamber layers and non-zero track crossing angle and the simulation of particle trajectories as well as the electrical cross talk between detector channels and studied.

• Internal Note LHCb-2000-011 "Muon system parameterised background-algorithm and implementation": The procedure of a fast parameterised simulation of the background in the LHCb Muon system is described.

• Internal Note LHCb-2003-138 "Methods of cross-talk reduction in the cathode pad chambers (CPC) of the LHCb muon system"
Public Note LHCb-2007-150 "Production of the front-end boards of the LHCb muon system": This note describes the production of the front end boards CARDIAC, for the 1368 MWPC, and CARDIAC-GEM, for the 12 triple-GEM chambers

Public Note LHCb-2007-132 "Test with cosmic rays of the GEM chambers for the LHCb muon system produced in Cagliari": The seven GEM chambers produced in Cagliari were studied for several days each using cosmic rays.

Public Note LHCb-2001-051 "A triple-GEM detector with pad readout for the inner region of the first LHCb muon station"

Internal Note LHCb-2008-078 "Performance analysis and remarks on Triple-GEM detector of the LHCb muon system": As can be seen from presented characteristics of the GEM detector, there are some unsolved problems: systematically observed missing efficiency and strange hit multiplicity distributed in time after the first hit. Both imperfections are analyzed in this note with possible explanations of the reason. Detectors made with blocking capacitors for suppression of the signals induced on the last GEM-electrode and without capacitors are considered.

Internal Note LHCb-2007-110 "Test with cosmics of the GEM chambers for the LHCb muon system produced in Cagliari"

CERN-THESIS-2008 "The GEM detectors for the innermost region of the forward muon station of the LHCb experiment"

CERN-THESIS-2013-296 "Study of the GEM detector for the LHCb experiment upgrade"

CERN-THESIS-2006-070 "A triple GEM detector for the muon system of the LHCb experiment"

CERN-THESIS-2006-013 "Triple-GEM detectors for the innermost region of the muon apparatus at the LHCb experiment"

Public Note LHCb-2008-052 "Procedure for determination and setting of thresholds implemented in the LHCb Muon system": When dealing with individual channels of the Muon system, the variations of the specific properties of each CARIOCA channel should be properly taken into account in order to fine tune the thresholds.

Public Note LHCb-2004-055 "Detailed Specification of the ODE-Muon Trigger interface": This note specifies the electronics interface implemented on the ODE boards to transmit data to the muon trigger processing boards.

Public Note LHCb-2000-093 "CARIOCA - a fast binary front-end implemented in 0.25 µm CMOS using a Novel current-mode technique for the LHCb muon detector"

Public Note LHCb-2003-009 "The CARIOCA Front End Chip for the LHCb muon chambers": This note describes the specifications, overall functionality and building blocks of the chip.

Public Note LHCb-98-003 "LHCb muon detector front end electronics"

Public Note LHCb-2003-026 "Front-End Electronics Test System Status Information (After ASDQ++ boards TEST at CERN)"
• Internal Note LHCb-INT-2009-018 "A software tool for noise analysis in the LHCb Muon System": NOEMI (NOise EMbedded Inspector) is a software tool developed to quickly analyse noise in the muon chambers of LHCb. The information about the noise is acquired by the threshold scan analysis and needs to be analysed for optimization and debugging purposes. This note illustrates how to use NOEMI to enforce this kind of analysis and how to link one own script to NOEMI to enforce new analysis accessing the chamber database and the interactive user interface of NOEMI. Analysis functions are also briefly described.

• Internal Note LHCb-2005-065 "LHCb muon off-detector electronics power supplies": In the following we give the specifications for crates and power supply required to instrument the off-detector electronics of the LHCb muon sub-detector.

• Internal Note LHCb-2004-006 "The LVPS requirements for the LHCb muon detector on-chamber FEE": The document describes the Low Voltage Power Supply (LVPS) requirements for the on-chamber LHCb muon detector FE. Two solutions using commercially available devices will be presented. Finally, the experience on the use of switching power supply for the KLOE drift chamber front-end electronics is reported.

• Internal Note LHCb-2004-004 "The muon chamber mapping for the IB system": The logical channels size for the muon detector is defined by the muon trigger requirements. Due to the occupancy and noise, anyway, front end outputs can not match trigger requirements for most of the detector. Then a further stage defined as Intermediate Boards (IB’s) system has been introduced to build up the logical channels by arranging several front-end outputs in a single channel. In the document the numbering scheme adopted to map the front-end outputs to the IB system together with the data frame sent to the trigger is described.

• Internal Note LHCb-2002-013 "Method for test and diagnostics of the on-detector front-end electronics for the LHCb muon system": A universal method is proposed for the LHCb Muon system as a 'diagnostic tool' for each channel of the on-detector front-end electronics (FEE). The method shows correct operation of the FEE without charge injection and under high voltage on the chambers and can provide an alarm signal, if a parameter is out of specifications. It can easily be implemented.

• Internal Note LHCb-2003-023 "Muon Off-Detector electronics: The IB system"

• Internal Note LHCb-2000-016 "Optimization of the muon system logical layout"

• Internal Note LHCb-2003-016 "DIALOG-beta data sheet"

• Internal Note LHCb-2001-002 "Simulation of detector response of LHCb muon system and study of its effects on level 0 muon trigger"

• Internal Note LHCb-2000-017 "Muon detector front-end architecture": This document describes the present envisaging of the front-end electronics of the LHCb muon detector, considering the whole system from the Amplifier-Shaper-Discriminator (ASD) outputs, up to the trigger and DAQ interfaces.

• Internal Note LHCb-2002-014 "ASDQ++ front-end board for the MWPC readout of the LHCb muon system": Schematics of both the 16-channel Spark Protection Board (SPB) and the 16-channel Amplifier Chip Board (ACB) based on the ASDQ chip are presented.

• Internal Note LHCb-2002-040 "One universal LHCb muon amplifier chip versus two": At present two versions of the front-end chip (CARIOCA negative and CARIOCA positive) are developed for the LHCb Muon System. As shown in this note, the development of only one ASIC should be considered using the same 'building blocks' in 0.25?m CMOS technology as used in the CARIOCA
chip.

- Internal Note LHCb-2001-064 "Measurement Results of the First CARIOCA Front-end Version for the Cathode Readout"

- Internal Note LHCb-2001-062 "DIALOG: a chip for the muon detector front-end and logic": This document gives the specifications of an ASIC, names DIALOG (Diagnostics, time Adjustment and Logics), being presently designed to equip the front-end boards of the LHCb muon system.

- Internal Note LHCb-2001-063 "The SYNC chip in the Off-Detector Electronics of the LHCb muon system": We give the specifications of a basic component in the Off-Detector Electronics in the LHCb Muon system.

- SYNC data sheet, version 1

- DIALOG data sheet, version 1

- LHCB Technical Note 2010 "Muon Off Detector Electronics Board": The major features of muon L0front-end electronics board (ODE) are described and its performances are analysed. The ODE board architecture and design criteria are discussed and the Trigger, DAQ and the ECS interface are described.

- CERN-THESIS-2006-010 "Instruments for calibration and monitoring of the LHCb Muon Detector"

- CERN-THESIS-2002-021 "CARIOCA A New Front-end Electronic for the LHCb Muon Detector"

- CERN-THESIS-2005-022 "Muon Detector Synchronization in LHCb experiment"

**Pre-Run 1, RPC**

- Public Note LHCb-99-050 "Performance of a multigap RPC prototype for the LHCb muon system"

- Public Note LHCb-2002-069 "A model for RPC detectors operating at high rate"

- Public Note LHCb-99-049 "Performance of low resistivity single and dual-gap RPCs for LHCb"

- Public Note LHCb-2001-027 "Design and construction of the RPC detector for the LHCb muon system":

- Public Note LHCb-2000-053 "Proposal for the RPC muon detector of LHCb"

- Public Note LHCb-2000-112 "RPC simulations": This note discusses simulation results of several important RPC performance characteristics. We discuss single gap RPCs with 2mm gap that are used in ATLAS and LHCb.

- Public Note LHCb-2003-013 "First results from an aging test of a prototype RPC for the LHCb Muon System": Recent results of an aging test performed at the CERN Gamma Irradiation Facility on a single-gap RPC prototype developed for the LHCb Muon System are presented. The results are based on an accumulated charge of about 0.45 C/cm2, corresponding to about 4 years of LHCb running at the highest background rate.

- Internal Note LHCb-2001-131 "Study of full-size RPC gaps": We have studied the I vs. V behaviours of 6 full-size gaps (2 oiled and 4 non-oiled). Washing the non-oiled gaps results in a sizeable decrease of dark current.
Run 1 and Run 2

- 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 $J/\psi \rightarrow \mu \mu$, $\Lambda \rightarrow p \pi$ and $D^\star \rightarrow \pi D_0 (K\pi)$ decays.

- 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.

- Public Note LHCb-PUB-2017-007 "Optimization of the muon reconstruction algorithms for LHCb Run 2": The muon identification algorithm in the LHCb HLT software trigger and offline reconstruction has been revisited in view of the LHC Run 2.

- Public Note LHCb-PUB-2017-021 "Quality of the spare triple-GEM detectors": The spares of Triple-GEM chambers have been assembled at LNF. This note summarizes the results of the quality tests performed at the end of the production procedure.

- Public Note LHCb-PUB-2015-023 "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 luminosity.

- Public Note LHCb-PUB-2015-013 "Study of the performance of the MWPC single gap": In this note we report the results of measurements performed with cosmic rays on single gaps of different LHCb Muon Chambers.

- Public Note LHCb-PUB-2013-005 "Performance of the Muon MWPC in high luminosity runs": In order to study the possibility of increasing the luminosity of operation several tests were performed. This paper reports detailed studies on the performance of the LHCb Muon System in runs with a luminosity between $4 \times 10^{32}$ cm$^{-2}$s$^{-1}$ and $10^{33}$ cm$^{-2}$s$^{-1}$.

- Public Note LHCb-PUB-2011-027 "Study of the LHCb Muon Detector performance using 2010 beam data": this note describes the improvements on timing calibration and the resulting time resolution, and an accurate measurement of the chamber efficiency.

- Internal Note LHCb-INT-2017-003 "Optimization of the Muon Identification software for LHCb Run 2": The muon identification code in the LHCb HLT software trigger and offline reconstruction has been revisited in view of the LHC Run 2.

- Internal Note LHCb-INT-2016-028 "The PIDCalib package": The PIDCalib package is a tool, widely used within the LHCb Collaboration, providing access to the calibration samples of electrons, muons, pions, kaons and protons.

- Internal Note LHCb-INT-2014-030 "A measurement of high-pT muon reconstruction efficiencies in 2011 and 2012 data": the efficiency for triggering, reconstructing and identifying high-pT muons is determined for data collected by LHCb in 2011 and 2012 using a data-driven tag-and-probe method on $Z \rightarrow \mu \mu$ events.

- Internal Note LHCb-INT-2012-034 "Additional shielding behind the LHCb muon detector": This note presents studies on the effect of backsplash hits in the last station of the LHCb muon detector (M5) and the results of Monte Carlo simulations of various additional shielding behind M5.
Internal Note LHCb-INT-2012-016 "Performance of the Muon Identification in LHCb with 2011 data": The performance of the LHCb muon identification is extracted from the 2011 data using \( J/\psi \rightarrow \mu^+\mu^- \), \( p^- \) and \( D^0(K^+) \) decays.

Internal Note LHCb-INT-2011-048 "Muon Identification performance at LHCb with the 2010 data": We present the performance of the muon identification procedure in the LHCb experiment based on the first 37 pb\(^{-1}\) of integrated luminosity in the 2010 run, both in terms of muon efficiency and non-muon misidentification rates.

Internal Note LHCb-INT-2011-045 "Results on Muon identification efficiency with 2011 data at LHCb": We present the results on muon identification efficiency measured on a sample of about 300 pb\(^{-1}\) acquired in the first months of 2011 data taking.

Internal Note LHCb-INT-2011-001 "Measurements of muon identification efficiencies for Z\( \rightarrow \mu\mu \) and \( W \rightarrow \mu\mu \) decays": Estimations for muon identification efficiencies for the Z\( \rightarrow \mu\mu \) and W\( \rightarrow \mu\mu \) channels in \( 16.5\text{nb}^{-1} 7 \text{TeV} \) data taken from the "Reco06-Stripping10".

Internal Note LHCb-INT-2010-052 "A Muon Identification procedure for LHCb with Kalman Filter": This method introduces the possibility of fitting the hits in the muon chambers to LHCb tracks with a Kalman Filter and use the \( \chi^2 \) obtained as discrimination variable.

Internal Note LHCb-INT-2010-051 "Preliminary results for MuonID with Kalman Filter with 2010 data":

Internal Note LHCb-INT-2010-036 "Study of the efficiency of the LHCb Muon Detector chambers using 2009 beam data": This note describes a method for the determination of the efficiency of the LHCb Muon Detector chambers. Results are given for data collected during the 450GeV p-p collisions run of the LHC in 2009.

Internal Note LHCb-INT-2010-023 "Equivalent Noise Charge (ENC) in the LHCb muon system measured at 100 meters under ground": This study is devoted to comparison the Equivalent Noise Charge (ENC) in the LHCb muon system measured in pit and calculated. It has been found, that ENC in pit is lower with respect to one measured in laboratory.

CERN-THESIS-2020-188 "Machine Learning for particle identification in the LHCb detector"

CERN-THESIS-2015-181 "Optimisation of the software-based muon identification at the LHCb experiment"

CERN-THESIS-2010-054 "Development of the Experiment Control System and Performance Study of the Muon Chambers for the LHCb Experiment"

CERN-THESIS-2010-051 "Misura dell' efficienza e dell' allineamento spaziale del rivelatore di muoni dell' esperimento LHCb"

CERN-THESIS-2010-044 "The spatial alignment of the Muon Detector for the LHCb experiment"

CERN-THESIS-2010-037 "Optimization of the operating parameters of the LHCb muon system"

**Upgrade 1**

- FTDR CERN-LHCC-2012-007 "Framework TDR for the LHCb Upgrade : Technical Design Report"
• PID TDR CERN-LHCC-2013-022 "LHCb PID Upgrade Technical Design Report"

• 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.

• 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.

• 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.

• Public Note LHCb-PUB-2018-007 "An X-Ray facility to perform irradiation tests and TID studies on electronics and detectors": The X-Ray irradiation system of the LHCb group, installed in Cagliari, is presented; with a particular focus on the setup configuration and dose rate calibration. It was already used to test the nSYNC chip, an ASIC for the readout of the LHCb upgraded muon system.

• Public Note LHCb-PUB-2015-014 "Analysis of the performance of GEM chambers for the upgrade of the LHCb muon system": In this note, the study of the GEM efficiency and time performance is presented. Two gas mixtures are used for the measurements: Ar/CO2/CF4 40:55:5 and 45:15:40.

• Public Note LHCb-PUB-2013-022 "Additional shielding in front of M2": This note presents studies on possibilities to improve the shielding in front of M2 in order to reduce occupancy of the hottest areas of the Muon System and to mitigate the dead-time problem.

• Public Note LHCb-PUB-2013-021 "Additional shielding behind the LHCb muon detector": This note presents studies on the effect of backslash hits in the last station of the LHCb muon detector (M5) and the results of Monte Carlo simulations of various additional shielding behind M5.

• Internal Note LHCb-INT-2019-020 "New muon identification operators": In this document we present some of the new muon identification algorithms developed in view of the LHCb upgrade. Their performance in terms of signal efficiency versus background reduction is shown, as well as the minimum bias rate reduction in the upgrade scenario should they be inserted at the first stage of the software trigger. From the latter study, a cut for the muonic trigger for each operator is suggested.

• Internal Note LHCb-INT-2018-009 "Pad chambers for the consolidation of muon detector": At the luminosity foreseen after the LS2 upgrade, the dead time of the muon chambers will induce order of 10% inefficiency on relevant dimuon channels. Moreover, localised spots with inefficiency as high as 25% will appear in the innermost region of station M2. To mitigate this problem during LHC Run 3 and Run 4, the installation of MWPC chambers with PAD readout may be considered on region 1 of stations M2 and M3, and region 2 of station M2.

• Internal Note LHCb-INT-2017-028 "Status of spare chambers for the LHCb MUON detector": In view of the next eight years of data taking up to the end of RUN4, the status of the spare MWPCs of the MUON detector is revised.

• Internal Note LHCb-INT-2017-019 "Considerations on muon detector granularity at upgrade": In this document we present some recent calculations on the deadtime induced losses on benchmark physics channels extrapolated at the LS2 upgrade conditions. These calculations are based on the
deadtime maps prepared for the PID-TDR, convoluted with MC events after stripping and selection.

- Internal Note LHCb-INT-2017-017 "An X-Ray facility to perform irradiation tests and TID studies on electronics and detectors":

- Public Note LHCb-PUB-2011-011 "Electronics Architecture of the LHCb Upgrade": The electronics architecture of the upgraded LHCb experiment is defined. This covers all data processing from the detectors up to the input of the data acquisition system. Building blocks for implementation are also described.

- Internal Note LHCb-INT-2014-036 "Muon reconstruction efficiencies in events containing jets": This note details measurements of the muon tracking, trigger and reconstruction efficiencies in events containing jets.

- CERN-THESIS-2020-324 "Radiation hardness of the upgraded LHCb muon detector electronics and prospects for a full angular analysis in multi-body rare charm decays": (...) For this reason the readout electronics has been completely replaced by a new optimised version. Several tests have been performed on the new readout electronics that will be here discussed, and that have allowed a comprehensive radiation hardness characterization of the UMC 130 nm technology, used to develop the main electronics device of the muon system readout electronics, the nSYNC chip. (...)

**Upgrade 2**

- Public Note LHCb-PUB-2013-019 "The Phase 2 Upgrade of the LHCb Muon System"

- Internal Note LHCb-INT-2020-007 "Considerations on Muon detector upgrade II": In this document we present a preliminary discussion about the muon upgrade II, which includes options on detector technology, electronics and readout, and very first cost estimates.

- Internal Note LHCb-INT-2019-008 "Considerations on additional shielding for the muon detector phase 2 upgrade": preliminary study about an additional shielding wall for phase 2 upgrade of the muon detector to be installed in place of the present HCAL detector. A couple of options are discussed, consisting of a wall 1.7 m thick made fully of iron, and a mixed configuration with an iron core and the surrounding part made of concrete. This last design seems very attractive in terms of performances versus complexity and cost.

**Repositories for pubblication Twikis**

* Documentation describing the LuMUONmeter method to measure the luminosity can be found in the LuminosityPaper page.

**Talks**

Clik here to access the list of all the talks in CDS under LHCb and with the "muon" word in the title.

**Posters**

Clik here to access the list of all the posters in CDS under LHCb and with the "muon" word in the title.
EDMS useful links

- Link to LHCb (0001)

- Direct link to Muon system (0221) (Run 1 and Run 2) expanded tree in EDMS. (Also the direct link to the Muon system (0167) under the LHCb baseline detector (0109) but all here seems empty)

- Direct link to Muon system (0576) (Run 3) expanded tree in EDM under the LHCb Experiment Upgrade (0564)

Obsolete links:

- Link to LHCb

- Direct link to Muon system (Run 1 and Run 2) expanded tree in EDMS.

- Direct link to Muon system (Run 3) expanded tree in EDMS.

-- BarbaraSciascia - 2022-04-21