CERN/LHCC 2001-029
4 October 2001

Review of the LHCb Muon System Technical Design Report

1 Introduction

This document describes the process and conclusions of the review of the LHCb Muon system, designed to provide a high p_T early muon trigger (Level-0) and off-line muon reconstruction and identification in the LHCb detector.

Muons are present in many CP-sensitive B decays, *e.g.*: $B_d^0 \to J/\psi(\mu^+\mu^-)K_S$, or $B_s^0 \to J/\psi(\mu^+\mu^-)\phi$ measuring the angles β and γ, of the unitarity triangle. Flavor tagging of the accompanying B, necessary to provide a tag of the initial B flavour and measure the CP asymmetry, is also performed using muons from semi-leptonic b decays. The study of rare B decays such as $B_s^0 \to \mu^+\mu^-$ can potentially reveal new physics. Therefore, muon triggering and off-line reconstruction and identification are fundamental requirements of the LHCb experiment.

The TDR was received on 28 May 2001 (CERN/LHCC 2001-010). On 13 June, the referees discussed the document with the collaboration. The open presentation was given to the LHCC session on 2 July. Following the LHCC meeting the LHCb group received a number of questions. The response to these questions and a discussion of the milestones took place in the referees' meeting on 1 October. The referees were D. Cassel, Y. Karyotakis, and H. Schellman.

2 Detector Technology

The LHCb muon system consists of 5 muon stations located along the beam axis covering the angular region of 20 to 306(258) mrad horizontal(vertical); corresponding to a geometrical acceptance of about 20% for muons from b-hadron decays. Station 1 is placed immediately behind RICH-2 while Stations 2 to 5 lie behind the hadronic calorimeter and are interspersed with a shielding wall, totalling 20 nuclear interaction lengths. Hits on all 5 stations are required to trigger, corresponding to a minimum muon momentum of 5 GeV/c. Each station is subdivided radially into 4 regions each one having a different granularity, to cope with different particle rates per unit area. Regions 3 and 4 of Stations 4 and 5 are instrumented with Resistive Plate Chambers (RPCs), while for all the other regions but Region 1 of Station 1, MWPCs are adopted. For the inner part of Station 1 the technology is not yet selected.

For the MWPC the anode to cathode distance is 2.5 mm while the anode-wire spacing is 1.5 mm. The anodes are 30 μm gold-plated tungsten wires. Each chamber contains 4 sensitive gaps, grouped by 2 to the front end electronics, providing redundancy and high efficiency. The chambers have to survive up to 0.5 C/cm accumulated charge on the wires and 1.7 C/cm^2 on the cathode.

RPCs consist of a thin gap, formed by 2 bakelite parallel plates, filled with gas and placed between 2 resistive electrodes. Strips with a width of 6 cm and a strip to strip distance of 2 mm are used for the readout. The chambers are operated in avalanche mode to increase the rate capability. The RPCs are grouped by two in an 'or' so losses of trigger efficiency are less than losses of RPC efficiency. Ageing problems associated with the linseed oil used as coating for the bakelite planes are a serious concern for these chambers. In response, the LHCb collaboration has chosen oil-less RPCs as the baseline design, and is studying both oiled and oil-less chambers.

3 Comments

The LHCC finds the detector technology adopted for the Muon chambers adequate to achieve the physics goals stated in the Technical Proposal, and **congratulates** the LHCb collaboration for the quality of work presented in the TDR.

Although there are no major concerns, the LHCC notes that:

- The collaboration should perform realistic and extensive ageing tests of RPC chambers before making a final decision on whether or not to use oil.
- The RPC construction procedure and quality control must be reviewed in detail with the producer.
- The technology choice for Region 1 of Station 1 should be justified in an addendum to this TDR.

The LHCC recommends that LHCb follows the established practice of conducting independent reviews of the engineering designs.

A list of agreed milestones to monitor and regulate the progress of the project is appended.

Muon System Milestones

MWPC detectors	
Engineering design completed	Jan 2002
Begin chamber construction and tests	Jan 2003
10% of chamber construction done	Jun 2003
50% of chamber construction done	Mar 2004
Chamber construction completed	Dec 2004
RPC detectors	
Decision on use of linseed oil	Dec 2001
RPC engineering design completed	Jan 2002
Begin RPC assembly and tests	May 2003
10% of chamber construction done	Sep 2003
50% of chamber construction done	Jun 2004
Chamber construction completed	Dec 2004
Chambers for the inner part of M1	
Technology choice	Jan 2003
Chamber construction completed	Dec 2004
Electronics	
CARIOCA design and test completed	Mar 2002
DIALOG design and test completed	Mar 2002
SYNC design and test completed	Jun 2002
Full chain electronics test completed	Oct 2002
Begin FE-board production	Jan 2003
10% of FE-board production done	Jun 2003
50% of FE-board production done	Feb 2004
Begin IM- SB and ODE-board production	Oct 2003
10% of IM- SB- and ODE-production done	Jan 2004
50% of IM- SB- and ODE-production done	Jul 2004
Electronics assembly and test completed	Dec 2004
Muon filter and support structures	
Iron filter installation completed	Dec 2003
Chamber support structures installed	Jun 2004
Muon System commissioning completed	Jul 2005