CERN/LHCC 2001-041
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Review of the LHCb Outer Tracker System Technical Design Report

1 Introduction

This document describes the process and conclusions of the review of the LHCb Outer Tracker system, designed to: (a) find charged particle tracks in the region between the vertex detector and the calorimeters and provide measurements of their momenta, (b) provide precise measurements of the directions of tracks segments in the two RICH counters, and (c) link measurements in the vertex detector with the calorimeters and the muon detector.

Reconstruction of the decays of neutral B meson to charged particles is the key to the LHCb programme of studying CP violation and searching for new physics via precision measurements of angles of the unitarity triangle. For example, $B_d^0 \to \pi^+\pi^-$ decays are sensitive to the angle $\beta+\gamma$, $B_d^0 \to J/\psi K_S^0$ decays are sensitive to the angle β, and $B_d^0 \to D^0 K^{*0}$ are sensitive to the angle γ. Separation of $B_d^0 \to \pi^+\pi^-$ from the much more abundant $B_d^0 \to K^+\pi^-$ decays requires excellent K/π separation in the RICH detectors, which can only be achieved with accurate measurements of tracks entering these detectors. Reconstruction of the electrons and muons to tag B flavors requires linking vertex detector measurements with calorimeter and muon system measurements, respectively. Therefore, precise and efficient track reconstruction is a fundamental requirement of the LHCb physics programme.

The TDR was received on 14 September 2001 (CERN/LHCC 2001-024). On 1 October, the referees discussed the document with the Collaboration. The open presentation was given to the LHCC session on 3 October. Following the LHCC meeting the LHCb Collaboration received a number of questions. The response to these questions and a discussion of milestones took place in the referees' meeting on 19 November. The referees were D. Cassel, F. Ferroni, Y. Karyotakis, and H. Schellman.

2 Detector Technology

The complete tracking system includes an Inner Tracker system located inside the Outer Tracker system in the high rate region near the beam pipe.

The LHCb Outer Tracker system consists of 8 stations located along the beam axis with horizontal acceptance of approximately ± 300 mrad and vertical acceptance of approximately ± 250 mrad from the beam line. Each station consists of straw tube

modules arranged in an XUVX pattern. The U and V stereo planes are at $\pm 5^\circ$ from the vertical. Each stand-alone module consists of two staggered layers of 64 straw tubes, making a total of 8 straw tube layers per station. The straw tubes have an inner diameter of 5.0 mm and a wall thickness of 75 μm, and they are installed in modules with a pitch of 5.25 mm.

The straw tubes consist of two spiral wound layers; the inner (cathode) layer is Kapton XC-160 foil and the outer layer is aluminum. The anodes are 25 μm diameter gold-plated tungsten wires and the gas is $Ar/CF_4/CO_2$ (75/15/10). The choice of this combination of straw tubes, gas, and anodes is based on extensive bench, beam, and radiation tests of prototype chambers. The anode wires are split in the midplane of the detector are are read out by electronics on the top and bottom of the stations.

Two preamplifier chips, the ASDBLR DMILL chip developed for ATLAS and the ASDQ chip developed for CDF match Outer Tracker requirements. The ASDQ chip is less expensive than the ASDBLR chip but is more sensitive to radiation. A dedicated TDC chip called OTIS is being developed in radiation hard 0.25 μm technology. This TDC could be mounted on the detector to minimize the amount of cabling. An alternative fall-back scheme based on the HPTDC chip has been developed, but this chip is not radiation hard. The Outer Tracker is not included in the current L0 and L1 triggers, but momentum information from a fast tracking algorithm in included in the L2 trigger decision.

Occupancies of Outer Tracker modules in all stations except T3 are expected to be below 12%, while the occupancy of T3 is expected to be below 18%. Monte Carlo studies indicate that $B_d^0 \to \pi^+\pi^-$ events can be reconstructed with a mass resolution of approximately 22 MeV/c^2.

3 Comments

The LHCC finds the detector technology and layout adopted for the Outer Tracker stations 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 LHCb Collaboration is studying the possibility of reducing the material budget in the experiment and this study could affect the Outer Tracker.
- The Outer Tracker is part of an integrated tracking system that includes an Inner Tracker, which will be described in a future TDR.
- The LHCb Collaboration intends to describe the integrated tracking system in a future TDR.

- The LHCC recommends that construction of production Outer Tracker modules and frames start with the stations labeled T7, T8, and T9 in the Outer Tracker 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.

Outer Tracker System Milestones

Straw Tube Modules	
Engineering design completed	Dec 2001
Begin module production	Jun 2002
10% of modules constructed	Jul 2003
50% of modules constructed	Jul 2004
Finish module construction	Apr 2005
Frames	
Engineering design completed	Jun 2002
Begin frame production	Mar 2003
10% of frames constructed	Sep 2003
50% of frames constructed	Feb 2004
Finish frame construction	Jun 2004
Station Assembly and Installation	
Start assembly of large stations in IP8	Jun 2004
Finish station installation	Jun 2005
Electronics	
TDC choice	May 2003
Start electronics production	Jun 2003
10% of electronics produced	Sep 2003
50% of electronics produced	Jul 2004
Finish electronics production and testing	Mar 2005
Outer Tracker Commissioning	
Finish Outer Tracker system commissioning	Mar 2006