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# Review of the LHCb Trigger System Technical Design Report

## 1 Introduction

This document describes the process and conclusions of the review of the LHCb Trigger System Technical Design Report. The LHCb experiment is designed to exploit the large number of $b\bar{b}$-pairs produced at the LHC in order to make precise studies of CP asymmetries and rare decays in b-hadron systems. The single arm spectrometer consists of the Vertex Locator (VELO), including the Pile-Up System, the Trigger Tracker (TT), the dipole magnet, two Ring Imaging Cherenkov detectors (RICH1 & RICH2), three tracking stations T1-T3, the Calorimeter system, including the Scintillating Pad Detector (SPD) and the Preshower (PS) in addition to the electromagnetic and hadronic calorimeter (ECAL & HCAL) and the Muon system, containing five stations (M1-M5). The 10 MHz frequency of interactions visible by the spectrometer has to be reduced by the trigger to a few hundred Hz. The requirement for the trigger is to achieve the highest efficiency for offline selected events, which show a large variety of final states. The trigger should allow overlapping and pre-scaled triggers. It should be possible to emulate the trigger from the data written to storage, which will give an additional handle on trigger efficiencies and possible systematics.

The first draft of the Trigger System TDR was received by the LHC referees and the external referee on 4 August 2003. A number of questions were raised and the answers discussed in a meeting on 1 September 2003. The TDR was received by the LHCC on 9 September 2003 (CERN/LHCC 2003-031). The open presentations to the separate Trigger System components were given to the LHCC session in September 2003. Following the LHCC meeting the LHCb group received a few more questions. The response to these questions and the discussion of milestones took place during the 67th LHCC meeting in November 2003. The external referee was M. Medinnis and the LHCC referees were K.Borras, F.Ferroni and Y.Karyotakis.

## 2 Trigger Concept and Technology

The reduction of event rate is achieved in three different trigger levels: Level-0 (L0), Level-1 (L1) and the Higher Level Trigger (HLT).

The Level-0 trigger reduces the LHC beam crossing rate of 40 MHz, from which about 10 MHz are visible in the spectrometer, down to about 1 MHz. With the number of interactions per crossing from the Pile-Up System, data from the Calorimeter Trigger on the highest $E_T$ clusters from hadron, electron, photon and $\pi^0$, the multiplicity in the SPD and the two highest $p_T$ muons from the Muon Trigger the L0 Decision Unit defines the L0 trigger. This decision is passed to the Readout Supervisor, which transmits it to the Front End Electronic, and to the next trigger level L1.

The L1 algorithm reconstructs tracks in the VELO and matches these tracks to L0 muons of calorimeter clusters to identify them and measure their momenta. Events are selected based on tracks with a large $p_T$ and significant impact parameter to the primary vertex. The maximum L1 output rate has been fixed to 40 kHz. The implementation is easily scalable to allow the inclusion of stations T1-T3 or M2-M5.

The HLT has access to all data and starts with reconstructing the VELO tracks and the primary vertex. A fast pattern recognition program links the velo tracks to the tracking stations T1-T3. The final selection of interesting events is a combination of confirming the L1 decision with better resolution and selection cuts dedicated to specific final states. The output rate of the HLT is kept flexible envisaging about 200 Hz.

L0 is implemented in custom electronics, while L1 and the HLT are executed on a farm of standard PC processors. Both L1 and HLT run concurrently on the same CPU nodes, with L1 taking priority due to its limited latency budget.

## 3 Comments

The LHCC finds the architecture adopted for the Trigger System 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 major design decisions have been taken. Nevertheless considerable design work is still needed for L0, which should be completed end of 2005. Furthermore the HLT algorithm, which supplies most of the rate suppression, has not yet been presented.

- Some simplifications of the L0 design appear possible, particularly in the area of rejection of multi-event interactions and by reducing redundancy in the ECAL-based triggers. The LHCC suggests that these possibilities be investigated.

The LHCC recommends that LHCb follows the established practice of conducting independent reviews of the engineering designs. In addition to these general reviews, a common understanding of the concept of rigorous pre-installation test programs with adequate quality assurance criteria for all electronic boards of the Trigger System should be established by the LHCb management to avoid possible delays due to failures in the performance of these boards. A list of agreed milestones to monitor and regulate the progress of the project is appended.

The LHCC **recommends** general approval of the LHCb Trigger System Technical Design Report.

## Trigger System Milestones

| **Milestone** | Date |
|---|---|
| **Calorimeter Triggers** | |
| Start of board production | 9/2004 |
| 50% of boards produced | 10/2005 |
| 100% of boards produced and tested | 6/2006 |
| **Muon Trigger** | |
| Start of board production | 8/2005 |
| 25% of boards produced | 2/2006 |
| 100% of boards produced and tested | 8/2006 |
| **Pile-Up System** | |
| Detector produced | 1/2006 |
| Trigger boards produced and tested | 5/2006 |
| **L0 Decision Unit** | |
| Boards produced and tested | 6/2006 |
| **Level-1** & **HLT** | |
| Sorter Implementation Decision | 05/2004 |
| Event Builder Switch specification | 12/2004 |
| Subfarm Controller specification | 01/2005 |
| 10(5)% of network(farm) ready | 07/2005 |
| 100% of network ready | 10/2006 |
| Full farm installed | 3/2007 |
| **Trigger installed** | **9/2006** |