LHCb Level-0 Trigger Detectors

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Abstract

The calorimeter and muon systems are essential components to provide a trigger for the LHCb experiment. The calorimeter system comprises a scintillating pad detector and pre-shower, followed by electromagnetic and hadronic calorimeters. The calorimeter system allows photons, electrons and hadrons to be identified, and their energy to be measured. The muon system consists of five measuring stations equipped with Multi-Wire Proportional Chambers (MWPCs) and triple-Gas Electron Multiplier (GEM) detectors, separated by iron filters. It allows the muons identification and transverse momentum measurement. The status of the two systems and their expected performance is presented.

Key words: LHCb, Calorimeter, MWPC, GEM, Level-0 Trigger
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1 Introduction

The LHCb experiment is dedicated to the study of the decays of beauty hadrons produced at the LHC. Precision measurements of CP violation and rare decays in the B meson systems, which are the main LHCb goals, can be achieved only with a very well designed and efficient trigger[1].
A key role in the trigger is played by the Level-0 (L0) hardware step that reduces the event rate from 40MHz to 1MHz using the input from the VELO[2] detector, the calorimeter system[3] and the muon system [4]. Design performances have been optimized in order to allow a fast reconstruction of high transverse energy (E_T, CALO system) or high transverse momentum (P_T, MUON system) candidates needed by the L0 decision unit (L0DU).

2 Calorimeter system

The CALO system[3] is made of a Scintillating Pad Detector (SPD), followed by a Pre-Shower (PS) in front of the Electromagnetic CALorimeter (ECAL) and the Hadronic CALorimeter (HCAL).

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The active elements are scintillating tiles, read out via wave-length shifting fibres to photo-multipliers. The scintillator is interleaved with lead for the electromagnetic calorimeter in a Shashlik construction, while for the hadronic calorimeter it is interleaved with steel tiles.
All these subdetectors are characterised by a pseudo-projective geometry achieved using a variable detector module granularity.

2.1 Scintillating pad detector and pre-shower

The SPD and PS detectors are used to distinguish electrons from pions and photons (SPD), photons from Minimum Ionizing Particles and to veto busy events with a very high charged multiplicity (SPD).
The SPD/PS system is made from a lead converter plate (14mm thick) that is sandwiched between two layers of scintillator pads (15mm thick). The light collected is read from a Multi-Anode PhotoMulTiplier (MAPMT) and sent to a Front-End card (VFE).

2.2 Electromagnetic calorimeter

The electromagnetic calorimeter is used to measure the electron, photon and pion E_T. It provides particle identification (PID) and reconstruction information for the particles used in offline analysis.
It consists of nearly 3k Shashlik modules, for a total of 6k detector cells,

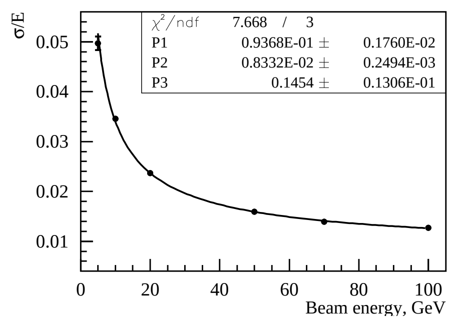

Fig. 1. ECAL module relative energy resolution, measured with a 50GeV electron beam.

that are read using WaveLenght Shifting (WLS) fibers from KURARAY. Each module is positioned on the ECAL wall with ±0.5mm (x, y) and ±2mm (z) precision.
In order to achieve the design relative energy resolution ($\sigma(E)/E = 10\%/\sqrt{E} \oplus 1.5\%$, with E in GeV), a sampling structure of 2mm lead sheets interspersed with 4mm thick scintillator plates has been used: test beam results, using 50GeV electrons, are shown in Fig.1 (the achieved $\sigma(E)/E$ is $(9.4\pm0.2)\%/\sqrt{E}\oplus(0.83\pm0.02)\% \oplus (0.145 \pm 0.013)/E$, with E in GeV).
Each module light yield is measured to be nearly 3000 ph.e./GeV. Cell dimensions are varying in the range $4\times4\text{cm}^2$ to $12\times12\text{cm}^2$. The ECAL depth accounts for 25 electromagnetic radiation lengths (X_0) and 1.1 hadronic interaction lengths (λ).

2.3 Hadronic calorimeter

The hadronic calorimeter is an iron-scintillator tile calorimeter, composed of 52 modules (1468 detector cells) with variable granularity: the cell dimensions vary from $13\times13\text{cm}^2$

to 26×26cm^2.
It is used to measure the E_T of hadrons, and to provide them to the offline analysis. The HCAL depth accounts for 5.6 λ: each module is read using WLS fibers and PMTs.
HCAL modules have been tested with a 30GeV electron beam: the signal pulse is well contained in the 25ns bunch-crossing window. The energy resolution achieved matches the design value ($\sigma(E)/E = 80\%/\sqrt{E} \oplus 10\%$, with E in GeV) while the achieved tile-to-tile spread is less than 5%.
The HCAL wall has been assembled achieving a module-positioning precision of the order of 0.5mm (x, y plane and y coordinate) and 1.5mm (y, z lateral plane).

3 Muon system

The LHCb muon system [4] is composed of five tracking stations, each subdivided in four concentric regions, which comprise 1368 MWPCs and 24 triple GEM detectors. The muon detector is required to have a high detection efficiency and a good spatial and time resolution.
The geometry is projective: the layout has been optimized by choosing an x, y granularity that added a contribution to the P_T resolution nearly equal to that from the multiple scattering. The final layout is composed of 20 different pad sizes (from 6.3×31mm to 250×310mm) resulting in 120k logical channels.

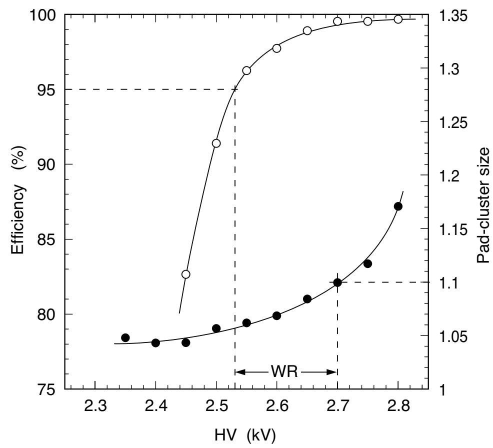

Fig. 2. Efficiency (left scale and open circles) and pad-cluster size (right scale and solid circles) of a double-gap MWPC as a function of the high voltage (HV). The working region (WR) is shown. Curves are drawn to guide the eye.

3.1 Triple GEM detectors

Triple GEM detectors[5] are going to be used only in the innermost region of the first station, where the particle rate is expected to be the highest.
Those chambers are characterised by a high rate capability, a high station efficiency (greater than 96% in 20ns time window) and a low cluster size (less than 1.2). The achieved time resolution is 3ns when using an $Ar/CO_2/CF_4$ gas mixture of 45%/15%/40%.

3.2 MWPC

The MWPCs used in the muon system are composed of double gas gaps that are further logically OR-ed: this will ensure a high hit detection efficiency and enhance the detector robustness.

In order to meet the performance required for triggering and for physics analysis, each double-gap should have an efficiency $\geq$ 95%, within a 20ns time window, a cluster size $\leq$ 1.1, as well as good ageing properties. These performances were measured, using a MIP test beam, as a function of the high voltage (HV) applied to the wires, using an $Ar/CO_2/CF_4$ gas mixture of 40%/50%/10%. The results reported in Fig.2 show that the above conditions are satisfied for $2530 \leq HV \leq 2700V$.
MWPCs are read out with a custom radiation hard chip (named CARIOCA) that works as an amplifier, shaper and discriminator characterised by a 10ns peak time. Chambers installation is currently starting: the expected positioning precision is $\pm$1mm.

4 L0 trigger

The L0 hardware trigger[1] is fully synchronous, it has a fixed latency (4μs) and reduces the 40MHz interaction rate to 1MHz. The L0 Decision Unit (L0DU) takes as input: (from the CALO) the highest E_T candidate for each type (e, γ, π^0), the total measured energy, the charged multiplicity and (from the MUON) the two highest P_T candidates per quadrant. An efficiency of 30-50% is achieved for the hadronic channels (accounting for about 700kHz bandwidth) while the muon channels are selected with 90% efficiency.

5 Conclusion

The LHCb CALO and MUON systems are currently under installation and are going to be ready for the data taking start in July 2007. The calorimeter construction is now almost completed, and more than half of the required muon chambers have been produced. The muon filters are already in place while the support wall is being built. Test beam data showed that the design values have been achieved: detectors timing and resolution performances are very good. The L0 hardware trigger design has been finalized: the obtained efficiencies for hadronic, muonic and radiative channels are expected to be 30–50%, 90% and 70% respectively.

References

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