Projected Performance of CMS Cathode Strip Chambers at HL-LHC

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On behalf of CMS Muon Group

Abstract

Cathode Strip Chambers (CSCs) are a crucial component of the CMS Endcap Muon System which will operate throughout the lifetime of the LHC and beyond, during the HL-LHC running. We present an analysis of the expected CSC performance in a HL-LHC-like environment.

Introduction

HL-LHC is expected to deliver luminosity as high as 7.5×10^{34} cm^{-2}s^{-1}. The Cathode Strip Chambers (CSCs) are supposed to operate throughout HL-LHC era. A study was conducted to assess stability of the efficiency of CSC L1 trigger primitives. The results shown here come from the analysis of the response of two CSCs which are presently being tested at the Gamma Irradiation Facility (GIF++).

The CMS Muon System

The Muon system is a key component of the CMS detector with three primary objectives: muon triggering, identification and momentum measurement. It consists of ionization gas detectors: Drift Tubes (DTs), Resistive Plate Chambers (RPCs), Cathode Strip Chambers (CSCs). The DTs cover the barrel region whereas the CSCs cover the endcap region, and RPCs cover both.

Cathode Strip Chambers (CSCs)

The CSCs are trapezoid-shaped Multi Wire Proportional Chambers (MPWC) chambers with six planes. The strips run along the radial direction to measure ϕ coordinate whereas the wires, which measure r coordinate, run orthogonal to the strips (figure 1). The gas gaps are filled with a mixture of Ar (40%),CO_2(50%) and CF_4(10%) gas. A muon passing through the gas gap causes ionization of gas molecules which result in an avalanche of electrons around the wire and an induced change on the cathode strips.

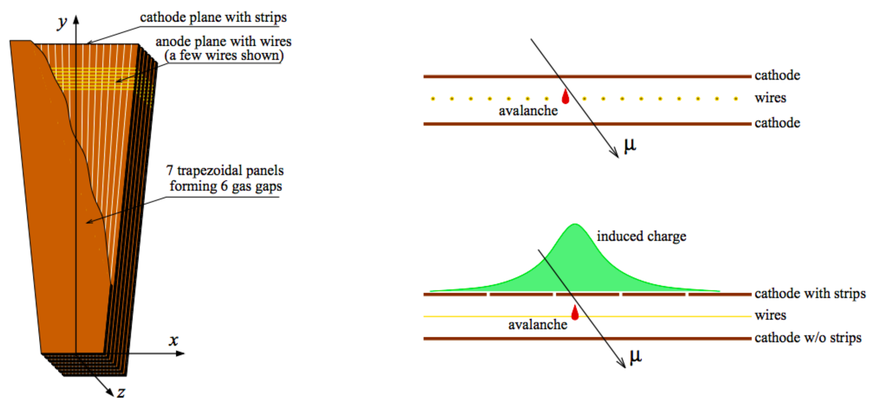

Figure 1: A schematic view of a CSC (left). An illustration of working principle of CSCs (right).

CSC L1 Trigger Primitives

The Anode Local Charge Track (ALCT) board looks for valid anode wire hit patterns 6 layers every bunch crossing (25 ns). A valid pattern is requires hits across at-least 4 out of 6 layers. Similarly, a Cathode Local Charge Track (CLCT) is found using the strip hits. A comparator logic in CFEB determines the position of the hits with half-strip accuracy. Further, the information from ALCT(s) and CLCT(s) is combined to define a 2D LCT(s).

CSC Readout Electronics

Upon arrival of a Level-1 (L1) trigger matching the ALCT/CLCT generated by the chamber, data from all Front End Boards (FEBs) in the corresponding sampling time window is digitized and read-out.

Procedure

At GIF++, the two CSC chambers are placed at a distance of 1 m and 3 m respectively, from the irradiation source, along a muon beam line (figure 2). This offers an opportunity to measure the efficiency of one CSC using the other as reference. At GIF++, the L1 trigger is generated by the coincidence of signals from the three external scintillators resulted from passage of incoming muons. The following criteria is used for selecting 'clean' muon events:

- The events must have exactly 1 ALCT, 1 CLCT and 1 LCT in the 'fiducial' volume of the 'reference' chamber (events that contain single muons)
- The events can have at-most 20 'in-time' hits in comparators and wires in the fiducial volume of the reference chamber (filter out events with muons accompanied by showers(10%).)

Then, the efficiency for a given trigger primitive **TP**(ALCT, CLCT, LCT) can be defined as

$$\epsilon_{\mathbf{TP}} = \frac{\mathbf{n}}{\mathbf{N}},$$

where **N** is the number of 'clean' events and **n** be the number of events in which there is at-least 1 **TP** in the 'fiducial' volume of the 'test' chamber.

The source intensity can be varied using different filter attenuations. Measurement of current in wires planes at GIF++ allows us to compare a particular filter attenuation with LHC luminosity (figure 4).

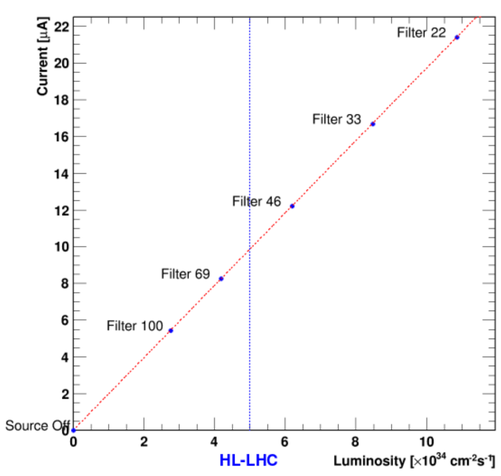

Figure 4: A figure illustrating an estimated relation between luminosity and the current measured in ME1/1 chamber.

GIF++ Setup

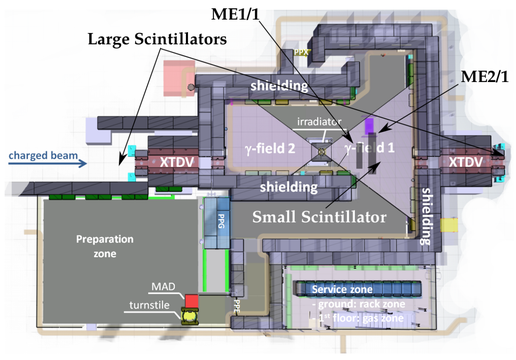

Figure 2: A top view of GIF++ bunker.

The facility uses 14 TBq source of ^{137}Cs for irradiation purposes. The source emits 662 KeV photons. A Muon beam with energy as high as 100 GeV is provided by the SPS. There are two large scintillator (40 cm × 30 cm) placed at the two ends outside the bunker, whereas a small scintillator (10 cm × 10 cm) is placed inside, near ME21.

Event Displays

Below are examples of 'efficient' events as seen in the 'test' chamber. Here, the ALCT and CLCT are correctly identified in the 'fiducial' volume.

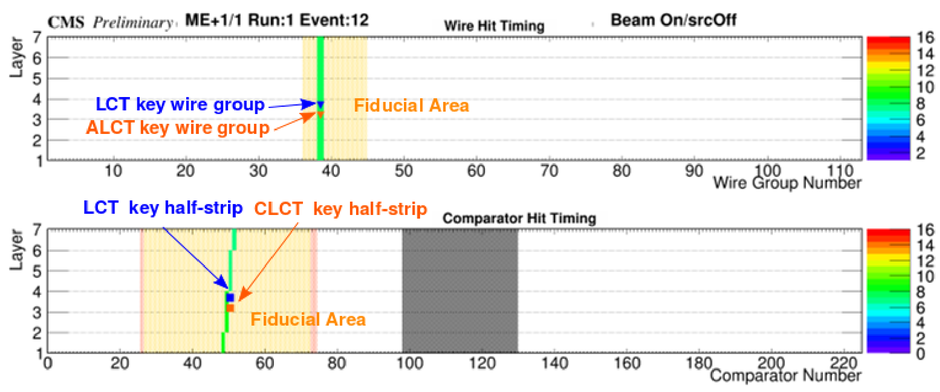

Figure 3(a): 'Clean' event in absence of background radiations.

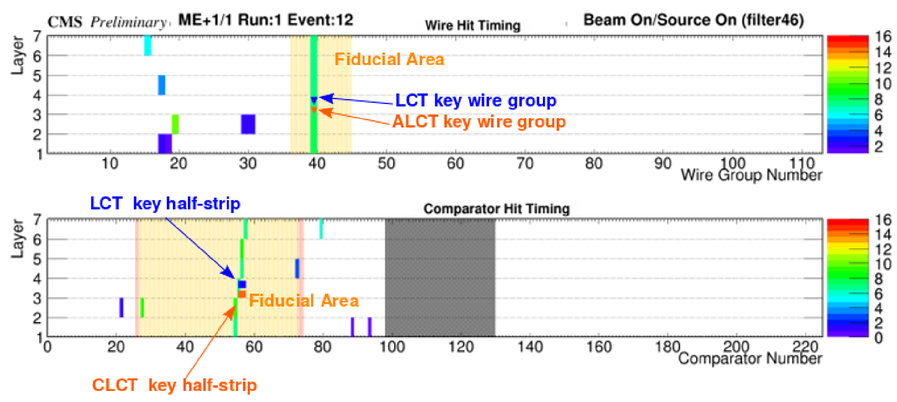

Figure 3(b): 'Clean' event in presence of background radiations, as evidenced by the random hits on wires and comparators. The filter attenuations correspond to HL-LHC environment.

Conclusions

- The estimated LCT efficiency at HL-LHC-like environment is 99.4% for ME1/1 and 98.0% for ME2/1
- CLCT signals are the main source of LCT inefficiency as compared to ALCT signals (firmware that finds CLCT is being updated to improve the CLCT efficiency)
- The marginal losses in the Trigger Primitive efficiencies at lower source attenuations are caused due to the increased background hits in the chambers

Results

The following graphs show Trigger Primitive efficiencies for ME1/1. The efficiency increases with increasing gas gain and reaches a plateau (figure 5), and decreases with increasing source intensity (figure 6) due to increasing background rates.

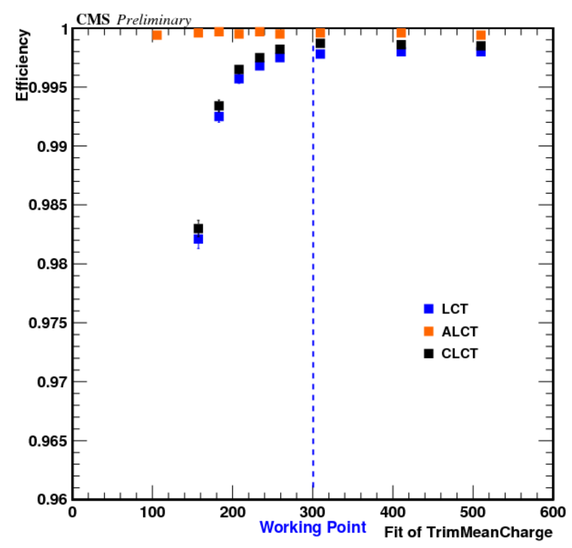

Figure 5: ME1/1 efficiency vs gain. The horizontal axis represents "TrimMean" charge which is used as proxy for gas gain. The 'nominal' working point is indicated by the vertical line (blue).

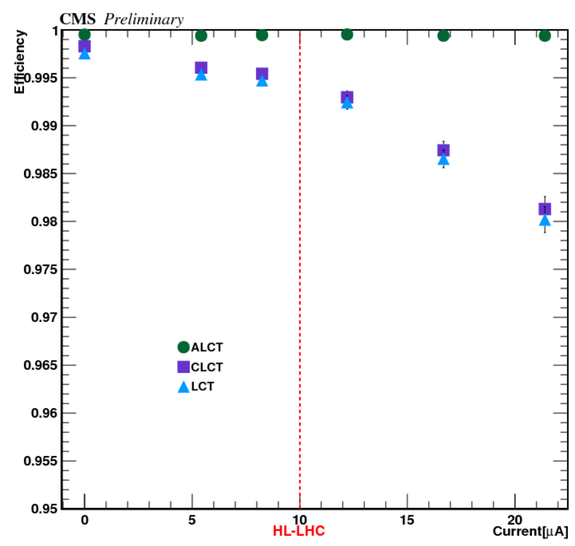

Figure 6: ME1/1 efficiency vs current. The vertical line (red) indicates the wire currents corresponding to HL-LHC luminosity.

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