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Overview of large area triple-GEM detectors for the CMS forward muon upgrade

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ABSTRACT

In order to cope with the harsh environment expected from the high luminosity LHC, the CMS forward muon system requires an upgrade. The two main challenges expected in this environment are an increase in the trigger rate and increased background radiation leading to a potential degradation of the particle ID performance. Additionally, upgrades to other subdetectors of CMS allow for extended coverage for particle tracking, and adding muon system coverage to this region will further enhance the performance of CMS.

Following an extensive R&D program, CMS has identified triple-foil gas electron multiplier (GEM) detectors as a solution for the first muon station in the region $1.6 < |\eta| < 2.2$, while continuing R&D is ongoing for additional regions.

1. Introduction

One of the core components of the Compact Muon Solenoid (CMS) detector [1], the muon system (Fig. 1) has been designed to provide identification and tracking information on muons produced in pp collisions at the Large Hadron Collider (LHC). Muons feature in many signatures of new physics, and being able to trigger, identify, and obtain an accurate measurement of the muon momentum are critical features of the CMS experimental program.

During the first run of the LHC, the muon system was composed of alternating layers of resistive plate chambers (RPCs) and either drift tubes (DTs) in the barrel region ($0 < |\eta| < 0.9$), or cathode strip chambers (CSCs) in the endcap region ($0.9 < |\eta| < 2.4$). The RPC coverage extends only up to $|\eta| < 1.6$, resulting in a lack of redundancy in the forward muon system. One of the primary goals in upgrading the muon system is to recover this redundancy. In addition to this, due to the harsh environment in the forward region resulting from the increase in luminosity during the LHC Phase 2 to $L = 5 \times 10^{-34}$ cm^{-2} s^{-1}, a detector able to maintain the trigger and tracking performance is absolutely critical to the success of the CMS experimental program. Micro-pattern gaseous detectors (MPGDs) [2] are an excellent choice for these requirements and CMS has identified triple-foil gaseous electron multipliers (triple GEMs, Fig. 2) as a preferred solution [3,4].

Simulation studies have shown (Fig. 3) that coupling the trigger information from the CSCs and GEMs will allow CMS to maintain the muon trigger thresholds by keeping the rate low, compared to what would be the case with only the current system.

2. Overview of the CMS GEM upgrade

During the second LHC long shutdown (LS2) in 2018–2019, CMS will install 36 “superchambers”, two triple GEM detectors sandwiched together, in each GE1/1 endcap station (Fig. 1). The superchambers will cover the region $1.55 < |\eta| < 2.18$. Each detector is segmented into 3 sectors in ϕ, and 8 sectors in η, with each sector reading out 128 strips having a pitch of 0.5 mrad. The trapezoidal detectors measure roughly 1.2 m × 0.5 m.

The strips will be read out using a VFAT3 ASIC (Fig. 4) to convert the analog signal to a digital signal for fixed latency triggering as well as full granularity tracking information.

Signals from each VFAT3 are transmitted to the OptoHybrid, a concentrator card located on the detector, from where the tracking data will be sent off detector via optical links to the back-end electronics (Fig. 5). The trigger data will be additionally sent via optical links to the CSC optical trigger motherboard (OTMB) to be used to compute joint CSC–GEM trigger decisions.

Off detector, the system will use μTCA systems with custom built advanced mezzanine cards (AMCs) for communication with and slow controls of the front-ends as well as for collecting tracking data and building events to ship to the CMS data acquisition system (DAQ). The back-end will also receive trigger and clock from the CMS DAQ and distribute this information to the front-ends.

2.1. Slice test

In preparation for the full installation of the GE1/1 system during LS2, a slice will be installed during the extended year end shutdown in 2016–2017. Taking advantage of planned upgrades to the CMS pixel detector, four superchambers will be installed in the minus side CMS endcap, as shown in Fig. 6.

The primary purpose will be to begin the commissioning of the full electronics and readout system, integrated into the central CMS environment. The slice test readout system will differ slightly from the full installation, due to ongoing developments in the readout ASIC (VFAT2 vs. VFAT3) and the OptoHybrid, as well as a

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