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High voltage system for the CMS forward calorimeter

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Abstract

The power supply system developed for the photomultipliers (PMTs) of the forward calorimeter (HF) of the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider is described. The 1728 PMTs of the HF are divided into 24 clusters of 72 with similar gain value. All of the PMTs within each cluster are powered by the same three high voltage (HV) power supplies, making a total of only 72 power supplies in the entire system. In this so-called parallel dynode voltage distribution, the three HV power supplies can be adjusted from 0 to −2000, −800, and −400 V, respectively. All output voltages are floating to facilitate a single-point ground configuration. The system is computer controlled and integrated into the CMS detector slow control facility.

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Keywords: Calorimeter; Photomultiplier; Power supply system

1. Introduction

The Compact Muon Solenoid (CMS) is one of two general-purpose detectors for precision detection of gammas, leptons, hadrons and jets at the Large Hadron Collider (LHC) at CERN [1]. The hadronic calorimeters for the CMS experiment [2] consist of three systems: Hadronic Barrel (HB), Hadronic Endcap (HE) and Hadronic Forward (HF), as shown in Fig. 1. The HF system consists of two identical forward calorimeters (HF+ and HF−) located at ±11 m from the interaction point. Their absorber structure is composed of 5-mm-thick stacked grooved iron plates and the active medium consists of fused-silica core optical fibers inserted into these grooves. The signal is generated when charged shower particles above the Cherenkov threshold ($E \geqslant$ 190 keV for electrons) generate Cherenkov light, thereby rendering the calorimeter mostly sensitive to the electromagnetic component of hadronic showers. The absorber structure of each calorimeter is azimuthally subdivided into eighteen 20° modular wedges (Fig. 2). The fibers run parallel to the beam line and are bundled to form towers with a size of $\Delta\eta \times \Delta\varphi = 0.175 \times 0.175$, where η is the pseudorapidity and φ is the azimuthal angle. Each calorimeter is functionally subdivided into two longitudinal depth segments: half of the fibers run over the full depth of the absorber (165 cm) while the other half starts at a depth of 22 cm from the front of the detector. These two sets of fibers are read out separately by Hamamatsu R7527 photomultipliers (PMTs). This arrangement makes it possible to distinguish showers generated by electrons and photons, which mostly deposit a large fraction of their energy in the first 22 cm, from those generated by hadrons, which produce signals in both segments.

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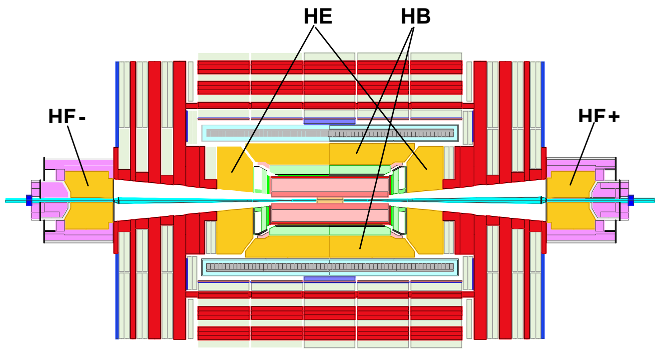

Fig. 1. Three subdetectors make up the hadronic calorimeter system in CMS—Hadronic Barrel (HB), Hadronic Endcap (HE) and Hadronic Forward (HF).

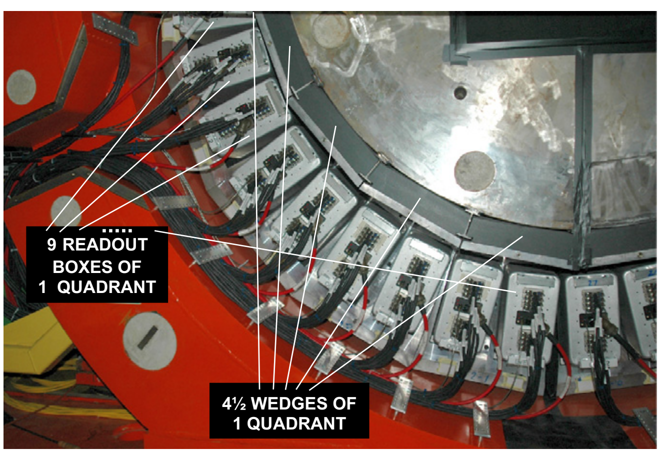

Fig. 2. Back view of one quadrant (a 90° section) of the calorimeter with its $4\frac{1}{2}$ wedges and nine readout boxes.

Each calorimeter is housed in a hermetic radiation shield consisting of layers of 40 cm thick steel, 40 cm of concrete, and 5 cm of polyethylene. A large plug structure in the back of the detector provides additional shielding.

In this paper, we describe our design for supplying high voltage (HV) to the 1728 PMTs, maintaining economy and ease of use without sacrificing performance. In Section 2, we elaborate on the design considerations. In Sections 3 and 4, we concentrate on the design of the power supply and HV units. The description of the controller and monitoring is in Section 5. The software system is discussed in the next section, Section 6. After a brief presentation of critical system parameters in Section 7, we draw conclusions in Section 8.

2. Design considerations

2.1. Parallel dynode HV distribution

The principle of a parallel dynode HV system is to use a common resistive divider on a single printed circuit board (PCB) to supply the dynodes of a set of PMTs that are nearly identical in gain. This approach reduces the number of HV channels, the dissipated power in the dividers and the cost of the overall system. Individual PMT gain adjustments are not possible, but this is easily addressed by selecting PMTs with similar gains.[1]

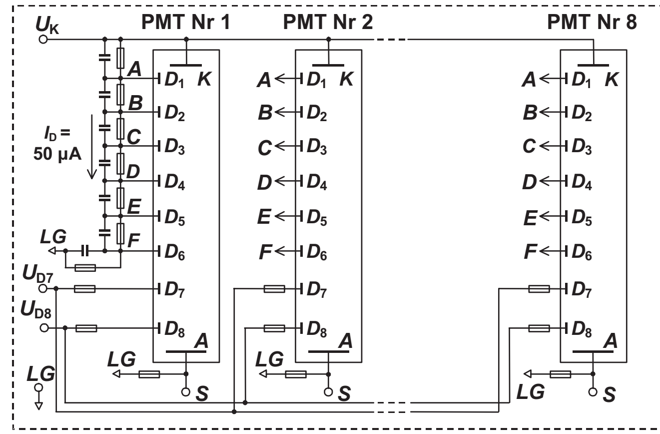

Fig. 3. Electrical diagram of the PMT parallel voltage distribution showing that there are three voltages provided to PMTs in a group of eight—the photocathode is set at U_K and the last two dynodes are set at U_{D_7} and U_{D_8}, respectively.

We chose to bias eight PMTs with one PCB as depicted in Fig. 3. The first six dynodes are supplied from one HV channel (U_K) by means of a common resistive divider chain since there is relatively low current through the first six dynodes. Two separate HV channels (U_{D_7} and U_{D_8}) are used to supply dynodes D_7 and D_8 directly. This arrangement makes it possible to provide the highest dynode currents directly from the corresponding HV channels, ensuring high D_7 and D_8 voltage stability and drastically decreasing the power losses in the intermediary resistors. To decrease the total number of HV channels, the cluster of three HV channels required per PCB is designed to supply nine PCBs that service PMTs with similar gain (see Section 2.2).

2.2. PMT PCBs distribution

One of the concerns in a calorimeter system of this kind is the PMT lifetime at high luminosity. The criterion is that the gain degradation should not exceed 20% over 10 years of LHC operation. We estimate that the PMT gain will degrade by this amount after 1 kC of accumulated charge. In order to remain under this value, the PMT gain must be about 5×10^4 for the region nearest to the beam (high rapidity), 1.5×10^5 for the middle region, and 5×10^5 for the outer region (low rapidity).

The 24 PMTs are mounted in a readout box and two readout boxes are needed per wedge (see Fig. 2). In order to provide three groups of eight PMTs with different gains,

[1] Overall gain correction in each channel can be done by controlling the charge-to-digital conversion ratio. More information about the HF uniformity is given in Ref. [3].