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Noise Filter Studies for CMS Forward Hadron Calorimeter (HF) Between Old and New PMT's Using Data in 2012

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Abstract

During the data taking before 2012 some abnormal events which have higher signals than expected were observed. Most of these were due to muons. When a muon hits the PMT glass window it creates a huge signal. To eliminate this kind of events 24 old HF PMTs (Hamamatsu R7525) in HF Minus at iphi 43 (corresponds to one sector) were replaced with new multi anode PMTs (Hamamatsu multi anode R7600) which have thin glass windows. These new PMTs were installed and tested in H2 test beam area in 2009 [1]. To check whether these new PMTs perform better than the old ones data taken in 2012 were analyzed using various predefined noise filters. Noisy rechits percentage was found to be around 6-7 % for the new PMTs while it varies between 29-66 % for the old PMTs for various trigger selections and for HFLongShortFilter after an energy cut of 500GeV [2].

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1. Introduction

CMS experiment has various sub-systems and one of them is the Hadronic Calorimeter (HCAL). HCAL also has some sub-detectors and one of them is the Hadron Forward calorimeter (HF) which is located in the very forward region of the CMS detector and measures the energy of particles scattering at small angles with respect to the beam-line, corresponding to the high eta values of $3 < \eta < 5$. Front face of HF is located at 11.5 m away from the interaction point (IP). Two HF calorimeters are shown in 'pink' at the Plus and Minus sides of the CMS detector in Figure 1. It has a cylindrical geometry with an inner radius of 0.125 m and outer radius of 1.425 m with respect to the beam line and a depth of 1.65 m. HF is a sampling calorimeter which is made from steel as passive absorber and plastic-clad quartz fibers as the active component. To separate electromagnetic and hadronic showers, fibers of two different length were used: the long one is 1.65 m and the short one is 1.43 m long (in Figure 2 the long fiber is shown as red and the short one as blue). When relativistic particles pass through the fibers, they create Cherenkov light which is carried by the fibers to the air core light-guide and then to the PMTs. All PMTs of HF are located behind the absorber on the far away side of HF with respect to IP, roughly at 1.25 m vertically and 13.8 m horizontally from the IP. More detail information about HCAL could be seen in reference [3].

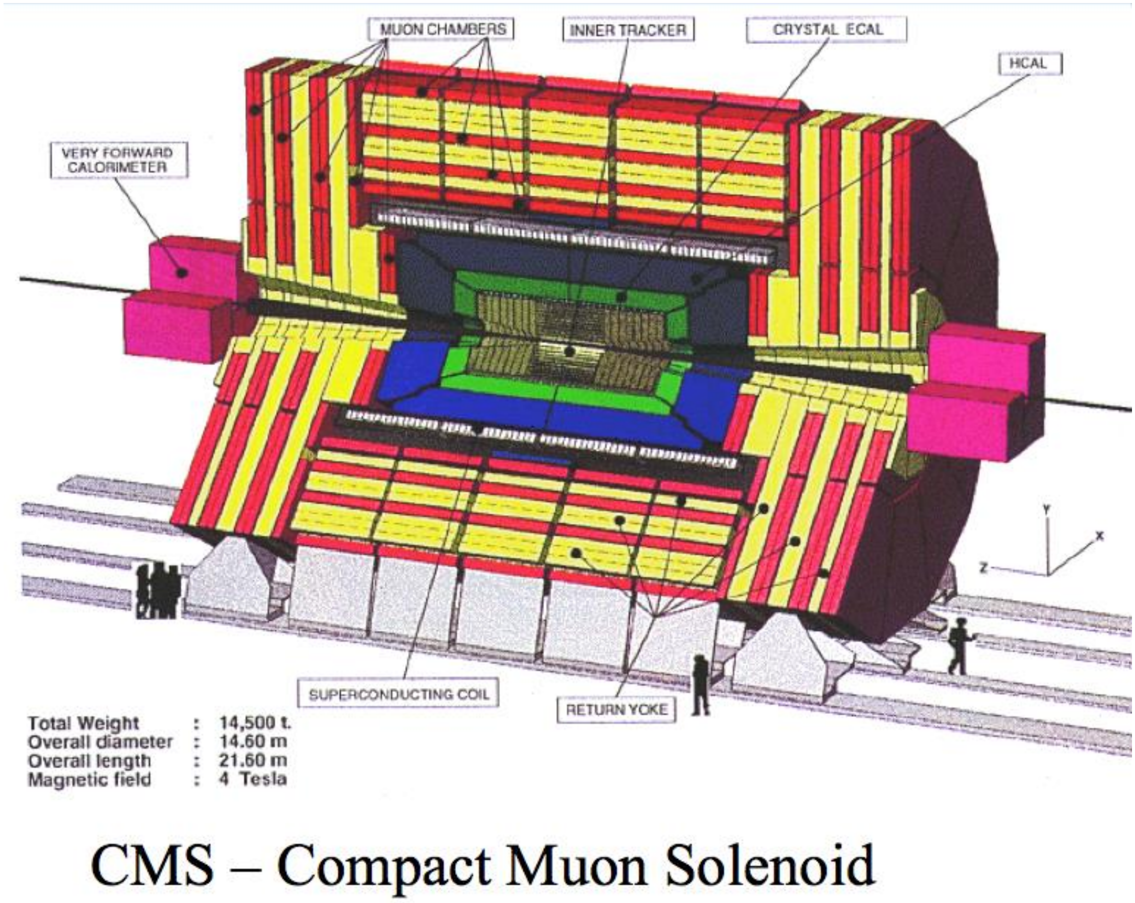

Figure 1: CMS Detector at LHC. Hadron Forward Calorimeter is shown in pink (labeled as 'Very Forward' Calorimeter).

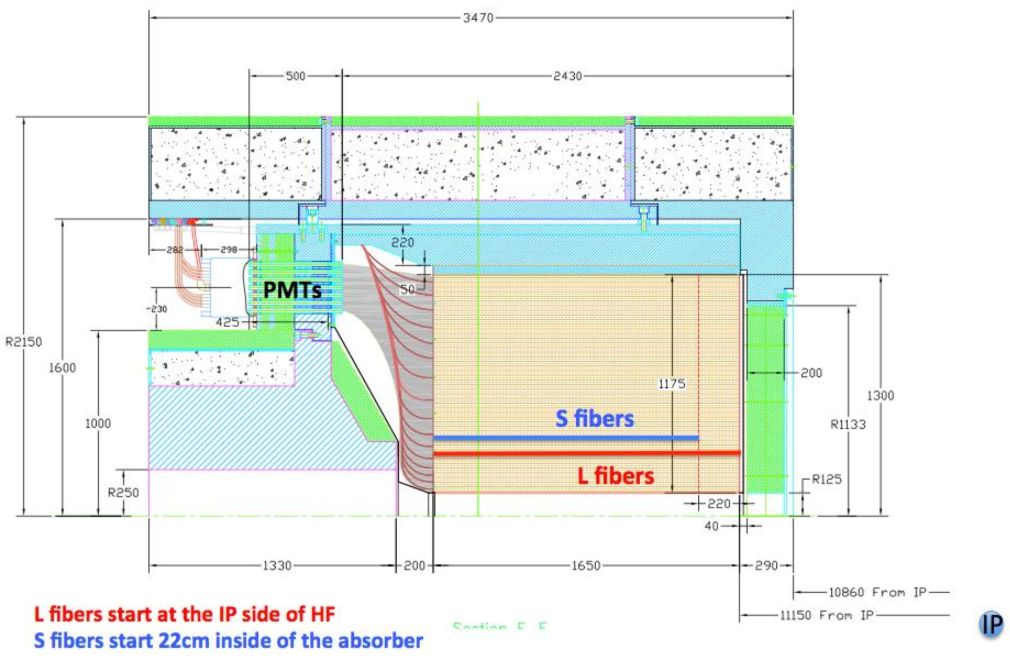

Figure 2: Schematic drawing of Hadron Forward (HF) Calorimeter.

2. Problems

When a muon traverses the HF without interacting much and hits the glass window of PMTs, it creates a much large Cherenkov signal then expected. This kind of abnormal signals should be eliminated to prevent their negative contribution to the physics analysis. Abnormal signals have larger amplitudes and arrive to the readout unit earlier than the usual signal. Knowing some features of the abnormal signals, gives us some opportunity to eliminate them using software algorithms (filters). But somehow all algorithms are not working perfectly.

Another problem was about the degradation of the gain of the old PMTs of HF which was observed at the end of 2011 LHC proton-proton collisions run [4].

3. Solution

To solve this problem it was decided to replace the regular HF Hamamatsu R7525 PMTs with R7600U-200-M4 of Hamamatsu PMTs. Just before LS1 and during the 2012 year-end technical stop 24 old PMTs were replaced with new PMTs at $i\varphi$=43. Filters were implemented both for old and new PMTs [5].

3.1. HF PMT Hits

In order to tag PMT hit events, the information from HF topology and time response are very important. Essentially this information is useful to separate real hits which are produced by the passage of particles through detector, from PMT hits which are mainly produced by the passage of muons through PMTs. To discriminate these events various types of filters were defined. These filters can be classified into two categories as topological filters and time based filters.

3.1.1 Topological Filters

PMT hit events typically have large energy in either the long (or the short) sections with no significant energy in the corresponding short (long sections). The topological filters are HFLongShort Filter, HFPET Filter and HFS8S1 Filter. Detailed definition can be found in [5][6].

3.1.2 Filters Using Timing or Pulse Shape

PMT hit events produce pulses that arrive earlier than the Cherenkov light produced in the fibers. This property could be used to discriminate regular signals from the PMT hits. The timing or pulse shape filters are HFDigiTime Filter and HFInTime Window. Detailed definition can be found in [5][6].

4. Results

In Figure 4 energy measured from the short fibers versus energy measured from the long fibers are plotted before (left plot) and after applying all filters (right plot) which are mentioned in the above sections. Long and short fiber energies should be correlated. Scattered points in Figure 4 are mostly due to PMT hits and most of them were eliminated after applying the filters. The data which were collected from new and old PMTs, are compared in terms of reconstruction energy and efficiency of the noise filters (Figure 5). As shown in the Figure 5 new PMTs show fewer high energy hits than the old ones. Five different noise filters which are mentioned above were applied for eliminating these high energy hits. Noise filters flag according to their definitions. Individual rechits' energy distributions and effects of applying noise filters can be seen in Figure 5 for PMTs at three different iphi groups (PMTs at iphi 43 are new). Also number of rechits flagged as PMT hits by each filter are given in Table 1 for each iphi. Also various energy cuts were applied to see the energy dependency of HF PMT hits. After applying the energy cut of 500 GeV, percentage of noisy hits are given in Table 1 for each iphi [2].

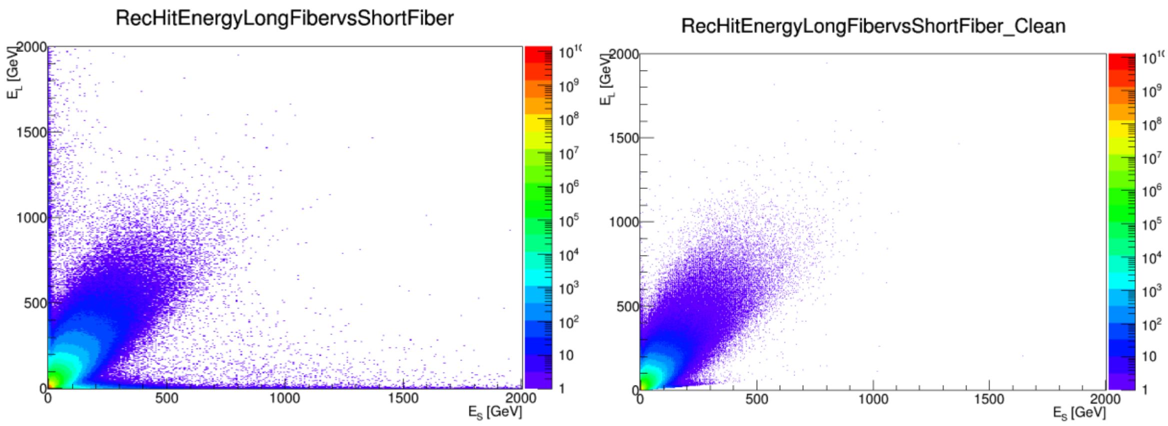

Figure 4: Long fiber RecHit energy vs. short fiber RecHit energy from the same HF tower for 8 TeV collision data before the noise filters (left) and after the noise filters (right). High energy entries close to either of the two axes (left plot) are due to the HF PMT window hits [2][7].

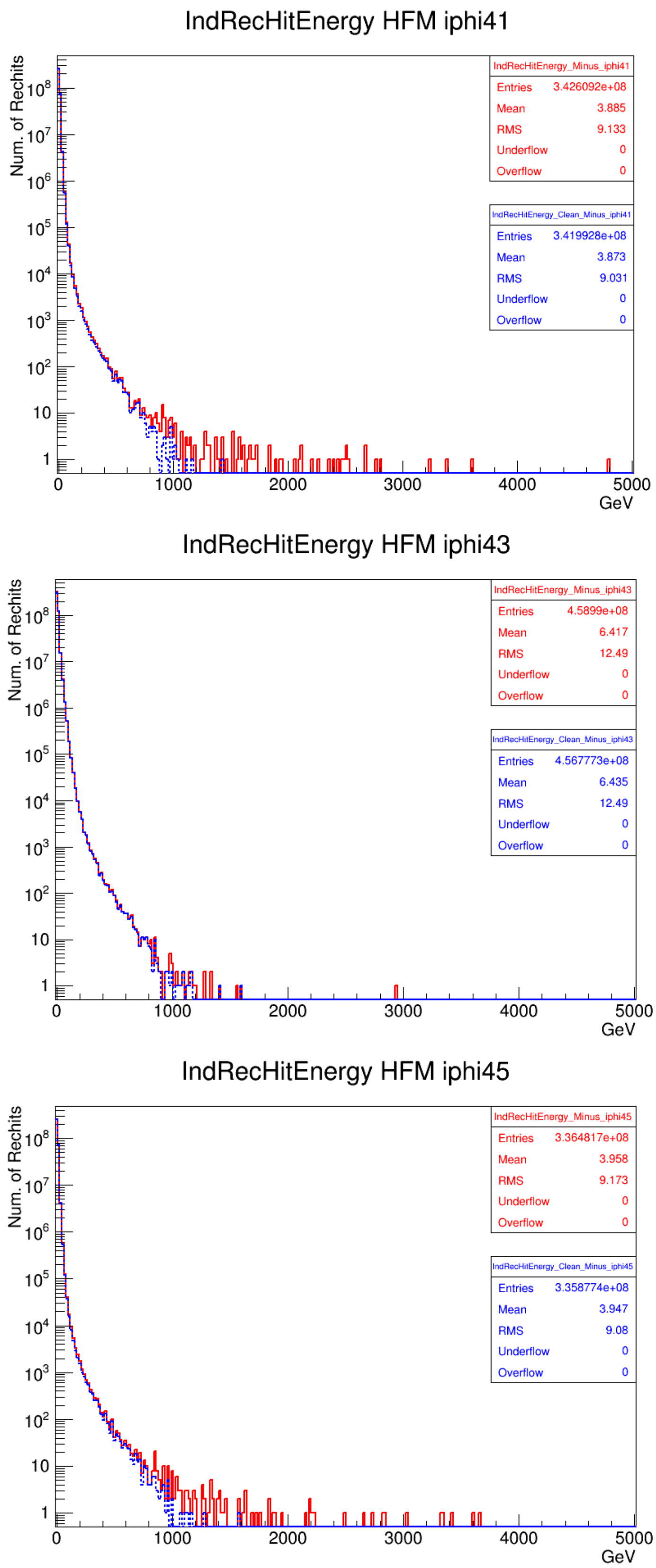

Figure 5: Rechit energy before the noise filters (red Line) and after the noise filters (blue Line). Middle distribution is given for new PMTs at iphi 43 and other two distributions are given for the old PMTs at iphi41 and iphi45 [2][7].

Table 1: Percentage of eliminated rechits for each iphi after applying an energy cut of 500 GeV and each filter [2][7].

iPhi	HFLongShort	HFS8S1Ratio	HFPET	HFDigiTime	HFInTimeWindow	Total
41	33,1	24,3	23,3	10,6	0,34	33,4
43	6,8	4,3	4,7	3,1	0,18	7,9
45	32,6	24,1	23,1	9,3	1,1	32,9

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