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WHAT'S NEW WITH THE CMS HADRON CALORIMETER

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Abstract

The CMS Hadron Calorimeter is designed to measure hadron jets, single hadrons and single μ 's. The Central Barrel and the two End Caps, made of brass and scintillators cover the $|\eta|$ range of 0.0 to 3.0. The two Forward Calorimeters made of iron and quartz fibers extend the $|\eta|$ range to 5.0. Scintillators are also placed outside of the magnet coil, within the muon system to measure the energy leakage from the Central Barrel. The construction of the calorimeter is about 50% complete. Several design changes were made to simplify the calorimeter and reduce the cost. The longitudinal segmentation of the central barrel and end caps was reduced by one unit. The quartz fiber diameter was doubled from 300 to 600 microns. Improvements were made to the Hybrid Photodetectors (HPD) and various other components. The special purpose ADC (QIE) and other electronics are in prototype stage.

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Figure 1: Hadron half-barrel calorimeter in CMS assembly hall

1 INTRODUCTION

The CMS is one of the major general purpose facilities for the CERN Large Hadron Collider (LHC). The Hadron Calorimeter [1] (HCAL) Central Barrel (HB) is 9 meters long, one meter thick and 6 meters in outer diameter. The HB is made of 36 wedges of brass and scintillator. The two End Caps (HE) are also made of brass and scintillator, with a diameter of 0.8 to 6.0 meters and a thickness of 1.8 meters. Both HB and HE are inside the 4-tesla solenoid coil. The $\eta - \phi$ segmentation of HB and HE is 0.087×0.087 , except near $|\eta| \approx 3.0$ where the size of the segmentation is doubled. The longitudinal segmentation for HB is one unit while for HE varies from one to three. The forward calorimeters (HF) are designed to measure forward jets. Since the HB is only 6.5 interaction lengths thick, the Outer Calorimeter (HO) (scintillators inside the muon barrel system, outside of the solenoid coil) measure the HB energy leakage. Monte Carlo studies and test beam results show that HO improves the energy resolution. To compensate for the radiation damage at $|\eta|$ above 2.0, HE has extra longitudinal segments to allow correction for signal loss. Various sections of the calorimeter have been tested using pion, proton, electron and muon beams [2]. For the test beam at CERN a large motion table has been constructed on which a 40° segment of the calorimeter can be placed. Besides the active and passive materials, the calorimeter has optical readout systems using 19 pixel Hybrid Photodiodes (HPD), 12 kV high voltage system, low voltage system, special design ADC (QIE), calibration systems using moving radioactive source, laser and LED and special purpose electronics. Details can be found in prior conference proceedings [3].

2 PROGRESS TO DATE

The Felguera factory in Spain constructed the barrel calorimeter wedges. The wedges were assembled in two barrels in the factory to make sure all the components fitted together and verify that the distortions were within acceptable limits. The wedges were then disassembled and shipped to CERN. In CERN the scintillator megatiles were inserted and the first half has been shipped to the CMS assembly hall and reassembled.

Figure 1 shows the first half-barrel comprising of 18 wedges. HB will be supported inside the magnet cryogenic housing. The first End Cap brass portion of calorimeter is completed and shipped to CERN, where the scintillator megatiles will be inserted. Figure 2 shows a HE End Cap on the MZOR factory floor in Russia. Prototypes of HO and HF have also been constructed and tested in the test beams. Various radiation tests are continuing to better understand the damage. Now that the major construction projects are well under way, the emphasis has shifted

Figure 2: Hadron half-barrel calorimeter in MZOR

Figure 3: QIE, multirange, nonlinear prototype

to the other parts of the calorimeter. This is where several changes were made recently for a variety of reasons, including simplification and lowering of the cost. HO is being constructed in India. HF construction is a joint project of many countries, including US, Russia, Hungary and Turkey. The major changes and improvements are discussed below.

2.1 HPD

The original design of the HPD's suffered a large amount of cross talk, where about half the signal in one pixel leaked into other pixels. Three sources of cross talk were identified. 1. Electrical cross talk between pixels. This cross talk was eliminated by creating a low impedance diode bias voltage electrode. 2. Optical cross talk due to internal reflection of the light signal. The optical cross talk has been almost eliminated by antireflection coating that produced destructive interference of the reflected light. 3. Back scattered electrons. The magnetic field of the CMS will spiral these electrons in tight circles. This solution requires that the HPD axis be well aligned with the magnetic field.

2.2 QIE

Figure 3 shows the four-range QIE prototype that almost meets all the specifications for the calorimeter. The QIE will measure charge from 1 fC to 10 pC. The next step is producing several production units that should be the final design and also be used in the test beam at CERN.

Figure 4: Fractional energy resolution vs. $(\text{energy})^{1/2}$ for 300, 600, 900 and 1,200 micron quartz fibers

2.3 Longitudinal Segmentation

Initially HPD's under consideration were the 19 and 73 pixel units, each 5 cm in diameter. The 73 pixel HPD required 66 QIE channels with 11 QIE cards. The width of the 73-pixel readout module became too large to be serviced in the very tight space available in CMS. The original proposed longitudinal segmentation for each tower was to read one layer immediately after the electromagnetic calorimeter and the remaining layers connected to single pixel. This arrangement required the 73 pixel HPD. Using test beam results and Monte Carlo studies, it was found out that the active first layer did not add substantially to the resolution. The passive addition of the first layer to the other layers, with a weight maximizing the resolution, gave almost the same results. Since physical space was tight and to reduce costs, the choice was made to reduce the longitudinal segmentation to one unit. For HE, the longitudinal segmentation was also reduced. These changes reduced the number of HPD's and QIE's by about 15% and 40% respectively.

2.4 Forward Calorimeter - HF

Two major changes were made in the design of the HF calorimeter. The HF is in a very high radiation area and the active material chosen for this sub-system is quartz fibers. The initial choice was 1% quartz fiber of 300-micron diameter. Monte Carlo studies were performed to study the resolution as a function of the quartz fiber diameter keeping the fraction of active material the same. Figure 4 shows a plot of the resolution as a function of the energy for four quartz fiber diameter-space of 2.5 mm (300 mic), 5.0 mm (600 mic), 7.5 mm (900 mic) and 10.0 mm (1,200 mic). The resolution deteriorated very little from 300 to 600 microns. Doubling the diameter reduces the number of fibers to be installed by a factor of four, thereby reducing the manpower. The second design change is replacing the quartz fiber with quartz clad with quartz fiber with plastic clad. This change reduces the cost of the fibers substantially. Test beam studies and radiation damage studies of quartz-quartz and quartz-plastic fiber have shown small difference in degradation due to radiation damage.

3 CONCLUSION

The CMS Hadron Calorimeter is about 50% constructed. Some critical improvements have been done that reduced the cost. Focus has now switched to electronics, assembly, installation and calibration. Front-end electronics is also progressing well. We expect to have a working hadron calorimeter on the first day of data taking.

ACKNOWLEDGEMENT

The CMS HCAL collaboration is composed of about 45 institutions from about a dozen countries. It is truly an international collaboration, with various nationalities taking lead responsibility of various sub-systems. This tremendous progress is due to the hard work of many members of these institutions, and I gratefully acknowledge the many scientists whose help was crucial for this report.

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