Test Results from Quality Control Measurements of Phototubes for the CMS-CASTOR Calorimeter

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On behalf of the CMS CASTOR Group

Abstract

The CMS CASTOR calorimeter will be equipped with 224 photomultiplier tubes (PMTs) in order to detect the Cherenkov light that is produced by the relativistic charged particles. Before the installation of these PMTs in the calorimeter they have to be verified to have sufficiently good performance during the operation of the detector. We constructed two different systems to make certain that PMTs have the required values to be used in the calorimeter. This paper details the CASTOR calorimeter, PMT testing systems and testing procedure. The measured operational parameters of the PMTs are also presented.

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1 Introduction

The Large Hadron Collider (LHC) has a wide range of physics accessibility. It will deliver the *pp* collisions and heavy ion collisions. The center of mass energy will be 14 TeV for *pp* collisions and 5.5 TeV per nucleon pair for heavy ion collisions (*Pb-Pb*). The very forward phase space of the *Pb-Pb* collisions at the LHC will generate a baryon rich environment that will provide an understanding of the Deconfined Quark Matter (DQM) states. The DQM states are supposed to exist in the core of the neutron stars. The Compact Muon Solenoid (CMS) [1] is one of the two general purpose experiments at the LHC. It is a long solenoid magnet with high magnetic field. The very forward region of the CMS will be completed by the ZDC (Zero Degree Calorimeter) and CASTOR (Centauro And STrange Object Research) calorimeters. They will locate after the Hadronic Forward calorimeter (HF) of the CMS and cover

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almost the whole angular region. The CASTOR calorimeter is dedicated to probe very forward rapidity range of the CMS ($5.6 \leq \eta \leq 7.2$). At the CASTOR particle-related measurements will be performed by using the Cherenkov effect. Cherenkov light from the quartz plates will be read by the PMTs. CASTOR will have 224 PMTs in total. Performance of these PMTs will be very important for the absolute operation of the calorimeter. So the various operational parameters of these PMTs have to verified to have the required values before installing them in the calorimeter. We have constructed two testing systems at our institute for this purpose. In this study we introduce our testing systems and present the gain, anode dark current, rise time, transit time and pulse width measurements of these PMTs. These results will provide us to have the best operating calorimeter.

2 The CMS-CASTOR Calorimeter

The CASTOR calorimeter [2] (see Fig.1) is currently under construction as a part of the CMS experiment. It will search the electromagnetic and hadronic contents of the interactions by measuring the energies of the particles. The main goal of the CASTOR is to study some anomalistic events so-called centauros and stranglets. Such events have been detected in the earlier cosmic ray experiments. It will also make possible to study the diffractive and low x physics through the pp and pA collisions [3].

CASTOR will locate at nearly $14m$ from the interaction point. It surrounds the beam pipe azimuthally and is divided into 16 sectors. Longitudinally it consists of 18 successive layers that are made of tungsten plates. Tungsten plates are followed by the quartz plates. Complete detector will be built in two steps. The first step deals with the full construction of the electromagnetic section and part of the hadronic section with a total of 160 reading channels. It will be convenient for the pp physics. In the second step the rest of the hadronic part that involves additional 64 channels will be completed.
Charged particles penetrating the CASTOR calorimeter will generate showers in the tungsten absorber plates. These particle showers are patterned by using the Cherenkov effect. Quartz plates are the active medium to generate the Cherenkov light. They are aligned in thin plates and inclined by 45° with respect to the beam axis in order to maximize the Cherenkov light. Cherenkov light generated by the shower charged particles carries the particle-related information. In the CASTOR calorimeter the R5380Q PMT series of Hamamatsu will be used to read out the Cherenkov light (see Table 1 for CASTOR PMT specifications). The Cherenkov light produced in the quartz plates will be transmitted to the PMTs by the mediation of the air filled light guides.

The stable operation of the calorimeter is closely related to the performance

Table 1
Specifications of CASTOR PMTs.

Parameter	**Value**
Size	25 mm
Spectral Response	300-650 nm
Peak Sensitivity	420 nm
Quantum Efficiency @ 420 nm	27 %
Active Diameter	22 mm
Supply Voltage	1800 V
Number of Dynodes	6
Cathode Luminous Sensitivity	125 μA / lm
Anode Luminous Sensitivity	0.75 A / lm

of these PMTs. We constructed two different systems for the verification of their quality. The first system was used for measuring the gains and anode dark currents of the PMTs whereas the second one was designed to measure the timing parameters. Both systems were organized in the light-tight boxes that were located in the dark room.

2.1 Gain Test System

Gain test system (see Fig.2) is designed to measure the PMT gains and dark currents. In this system we used a halogen tungsten lamp as the light source. We have opened a patch panel on one side of the light-tight box. The light was sent to the PMTs through a Neutral Density Filter (NDF, factor=2) followed by a blue filter (transmission % 65). Both filters were used during the anode and cathode current measurements. These currents were read by a picoammeter and light intensity inside the box was monitored by a spectrometer. For all the measurements the high voltage was set to ramp up from 500 V to 1600 V with 50 V steps. Gain measurement process was automated by using a LabView code and collected data were stored in a computer.

2.2 Test System for Timing Parameters

In the testing system for timing parameters (see Fig.3) we used a 337 nm pulsed laser source. A LeCroy oscilloscope was used for reading the values of the timing parameters. The laser light was directed to a NDF followed by a beam-splitter. The reflected light was oriented to a PIN diode and the transmitted light sent to the PMT after passing through few more NDFs. The PIN diode was powered by 7 V and used to trigger the oscilloscope. Then the rise time, pulse width and transit time values of each PMT were read with the oscilloscope.

3 PMT Test Results

Each tube has been tested for the gain, dark current and timing parameters, separately. Through the 224 in total, 34 of PMTs were tested for the first step. Results of these measurements will clarify whether they will be used or not in the calorimeter. We first measured the dark currents of the PMTs and then measured their anode and cathode currents one by one. The operational requirements of the PMTs in the calorimeter is listed in Table 2.

Table 2
Required values for timing parameters.

Operational Parameter	**Preferred Value**
Anode Dark Current	$< 10nA$
Anode Pulse Rise Time	$< 5ns$
Electron Transit Time	$< 25ns$
Pulse Width	$< 15nsFWHM$
Average Anode Current	$< 100\mu A$

3.1 Gain and Dark Current Measurements

The PMT gain is given as the ratio of anode current to the cathode current. We made two different resistive bases for measuring the anode and cathode currents. We obtained a gain value at 1100 V around 5800 for the tubes. For all PMTs the gain measurements as the function of the ramping voltage from 500 to 1600 V were done more than three times. The testing conditions like same light intensity and same position for each PMT was also kept during the measurements. Only a few PMTs were out of the acceptable gain range required by the CASTOR Group. Apart from two tubes all the dark current measurements of the tubes were under the required value. We plot the collective behavior of the gain measurements (see Fig.4) and anode dark currents versus high voltage (see Fig.5).

3.2 Results of the Timing Parameters

Having the well determined timing characteristics for the PMTs will be crucial during the operation of the CASTOR. The characteristic parameters to be measured are the transit time, rise time and pulse width. Transit time is the time difference between the PIN diode and the PMT signal when they both reach % 50 of their peak values, consecutively [4]. The rise time is the time interval when the signals access from % 10 of the peak value to % 90. Pulse width is the FWHM of the PMT signal. These measurement were done by an oscilloscope which has an operating system on itself and has an opportunity for tuning the above definitions of timing parameters. newline The measurements of the timing parameters on each tube were performed three times. The transit time (see Fig. 6) and rise time distributions (see Fig. 7) show the measured values approximately $12ns$ and $2ns$ at 1100 V, respectively. These values are very good for the operation of the calorimeter. Pulse width distribution is around $3ns$ at 1100 V which is also less than the required value during the operation of the CASTOR.

4 Conclusion

The testing systems we built in our university operated smoothly in the testing of the PMTs. We have tested 34 PMTs for the CASTOR calorimeter. All of the tested tubes have an average gain about 5830 at applied 1100 V. Their timing characteristics were evaluated in a wide voltage range, from 500 V to 1600 V. They showed similar timing measurement results that are less than the operational criteria. Among the 34 of PMTs only two had dark currents around $12nA$. Apart from having high dark currents these two PMTs still had acceptable timing values. We report the results of the measurements to the CASTOR group and PMTs were confirmed to have good performance. The experience we gained in the testing of the PMTs will help us to test the remaining 200 PMTs in a short time for the planned operation date of the CASTOR calorimeter.

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6 Figure captions

Fig. 1: The forward region of the CMS experiment and schematic view of the CASTOR calorimeter [2].

Fig. 2: Schematic view of the gain setup.

Fig. 3: Schematic view of the timing setup.

Fig. 4: Collective behavior of gain measurements.

Fig. 5: Anode dark current measurements of 32 tubes.

Fig. 6: Transit time distribution for 34 tubes.

Fig. 7: Rise time distribution for 34 tubes.

Fig. 8: Pulse width distribution of 34 tubes at 1100 V.

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