Development of a controlled and monitored water cooling system for CBM-MUCH Detector

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Introduction

The CBM experiment at FAIR is being designed to explore the QCD phase diagram of high baryon density matter using high-energy fixed target nucleus-nucleus collisions. Muon Chamber (MUCH) is the detector to be used in CBM to detect low momentum muons, originating from the decay of low-mass vector mesons. The final design of the muon detector system consists of 6 hadron absorber layers and 18 Gaseous tracking chambers located in triplets behind each absorber slab. Fig.1 shows the first station GEM triplet.

VECC is in process of building and testing the Muon Chambers (MUCH) and related readout electronics for the first two stations [1]. MUCH uses Front End Electronics (FEE) board where the desired operating temperature range is 25-30 °C. Temperature going above this limit will drift the biasing scheme and further increase may lead to damage of FEE boards. We have developed a microcontroller based automated temperature controller system at VECC using multiple temperature sensors (DS18B20) on a One Wire Bus.

Required Cooling

In MUCH, for the first two stations (6 Layers) of GEM detectors total number of FEBs required are 1728. Each FEB dissipates power of 2.5 W so a total of 4.32 KW. We have designed an Aluminum Plate based water-cooling system to cool down the FEBs for smooth operation [2].

Real Size Plate Cooling Setup

We have used a 10 mm thick Aluminium plate on which a 7 mm groove is cut and then sealed with 3 mm Aluminum plate. Water channels are drawn closest to the FEB positions to maximize the heat transfer. Digital temperature sensors (DS18B20) are placed on the top of the plate to monitor the temperature of the plate online and as a control we have developed a microcontroller based setup.

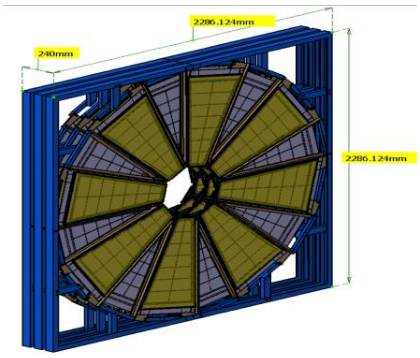

Fig. 1 First station of CBM

The generated heat by FEBs is being simulated using some heating resistors. Heat load of 4 W per resistor i.e. 72 W (18 FEB) per plate takes care of safety margin required. A water chiller unit for chilled water supply is used and a 12 V DC water pump is used to circulate the water through the grooved Aluminum plate, the outgoing hot water from the plate is looped back into the chiller, so water remains in closed loop (Fig.2).

Fig. 2 Test setup with real size Al plate

Control system

We used Arduino Uno SMD R3 single-board microcontroller to maintain the temperature of the Aluminum plate at initially set value. A micro-controller contains a CPU, clock circuitry, ROM, Ram and I/O circuitry on a single integrated circuit package. The temperature is measured by Dallas DS18B20 digital sensor, which communicates through a 1- Wire bus over a long distance. Each DS18B20 has a unique 64-bit serial code, so one can control many DS18B20s distributed over a large area by a single Arduino board. A code is written in Arduino IDE to display the temperature of various sensors in ^{0}C; according to the temperature readings the Arduino gives input to the base of a transistor (2N2222), thereby turning the cooling system on/off automatically depending upon the temperature (Fig.3).

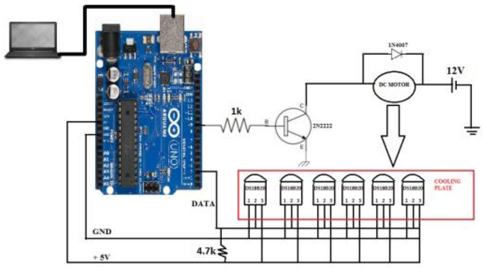

Fig. 3 Schematic Layout of control circuit

Experimental Results

The Aluminum plate was heated by 18 heating resistors with total power deposition of 72 W, 63 W and 54 W respectively. If no cooling is applied then the plate temperature reaches up to 45^{0} C. We set the plate temperature at 25^{0} C, so it remains between 25 ± 0.2^{0} C, which helps all FEBs to acquire data at constant temperature with least noise.

One of the data is shown in Fig.4 for 72 W power deposition and with temperature set point at 25^{0} C, the green line shows ambient, blue line chilled water, red and black line two sensors on different location of plate, orange line shows the average temperature of the two sensors. The data clearly shows that the average temperature of the Aluminum plate remains within ± 0.2^{0} C around the set value of 25^{0} C.

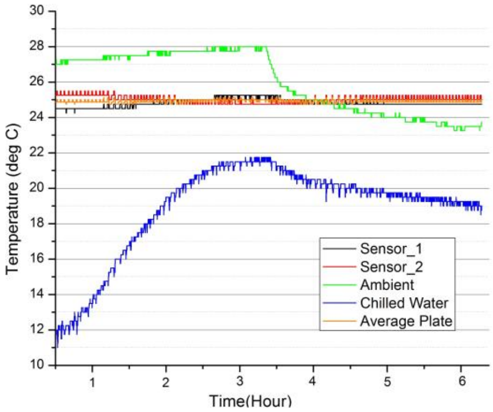

Fig. 4 Variation of temperature for 72W

CERN SPS H4 Test Beam

A 10 mm thick Aluminum plate was designed and fabricated in VECC Workshop and was used in CERN SPS H4 beam test during December 2016 for cooling of the electronics of our GEM detector (Fig.5). We are planning to test our GEM detector with particle beam of Pb+Pb collision in December 2017.

Fig. 5 CERN SPS H4 Test Beam

The proposed temperature sensors will be placed at appropriate places of detector area as shown in Fig.5. The in house designed temp controller will thus be implemented and tested.

References

[1] Anand Kumar Dubey et al, DAE Symp. on Nucl. Physics. 61 (2016)

[2] Vikas Jain et al, DAE Symp. on Nucl. Phys. 60 (2015).