Feasibility study of water distribution for the CBM MuCh cooling system

Sumit Kumar Kundu[1],* Susnata Seth[2], Saikat Biswas[2], Sanjay Kumar Ghosh[2], Supriya Das[2], and Sidharth Kumar Prasad[2]
[1]*Department of Physics, IIT Indore, Khandwa Road, Indore-453552, Madhya Pradesh, India and*
[2]*Bose Institute, EN-80, Sector V, Bidhannagar, Kolkata-700091, West Bengal, India*

Introduction

The Compressed Baryonic Matter (CBM) experiment is under construction at the Facility for Antiproton and Ion Research (FAIR) at Darmstadt, Germany. The Muon Chamber (MuCh) detector, a part of the CBM experiment, will be used to detect the muons coming from the decay of low mass vector mesons (such as ρ, ω, ϕ) and J/ψ in high energy heavy-ion collisions for the range of energy from 4 to 40A GeV/c. The Muon Chamber consists of hadron absorbers and gaseous detectors (Gas Electron Multiplier (GEM) and Resistive Plate Chamber (RPC)) based tracking stations. The first two tracking stations consist of three layers each. In the first and second tracking stations, each layer comprises of 16 and 20 modules respectively. Eighteen Front-End Electronic Boards (FEBs) are to be mounted on the single module to collect signal from detectors. Each FEB while in operation is expected to produce around 3-4 W of heat reasulting in about 7 kW of total heat for the first two tracking stations of Muon Chamber. The performance of FEBs are sensitive to the ambient temperature for their optimal performance. It is necessary to remove generated heat from the cave and to maintain the temperature in the range from 20° to 25°C. A demineralized water based cooling system made up of 10 mm thick aluminum plate with water channels inside is developed at Bose institute, Kolkata [1, 2]. Its performance were tested at CERN SPS test beam facility and mCBM experiment at GSI [3, 4] for a configuration with each module connected to the water source and sink saperately.

In the final configuration, more than one modules will be connected together to water source and sink either in parallel or series connection which is to be determined. In this work, we have studied the possible configurations of more than one cooling modules connected together and their performances.

Test setup

A test setup is reconstructed at Bose Institute, Kolkata, using aluminum extrusion and plywoods of configuration 244 cm x 244 cm as shown in figure 1. Three different types of modules 1, 2, and 3, are used, which are of thickness 6 mm, 12 mm, and 10 mm respectively and of area 2883 cm^2, 4233 cm^2 and 4233 cm^2 respectively.

In the absence of a FEB, the 10 Ω resistors are used as heating elements to produce uniform heat over the whole aluminum module. In each module, eighteen such resistors are embedded. The flat surface of each resistor is attached to the plate using thermal tape to efficiently transfer the heat to the modules. A water chiller is used to provide chilled distilled water, which is re-circulated through the internal water channels of modules by using a submersible suction pump. The room is kept at 25°C temperature utilizing an air conditioning facility. LM35 temperature sensors connected with Arduino boards measure the temperature on the module surface. Pneumatic push-in connectors and tubes are used to connect the inlet and outlet of each module with the water source and sink.

*Electronic address: phd1701151005@iiti.ac.in

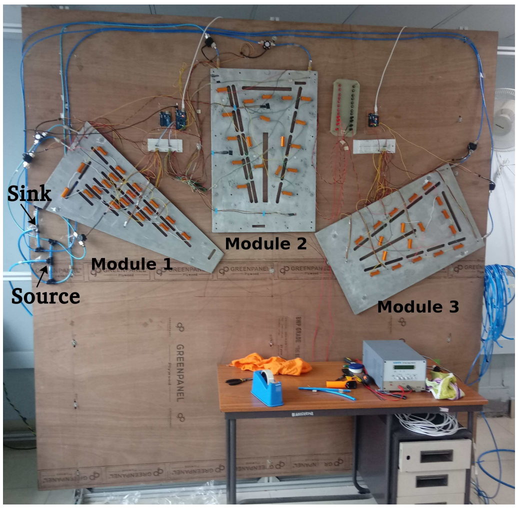

FIG. 1: *Test setup of three cooling plates build at Bose Institute.*

Results

First of all, every module allows reaching up to the maximum temperature due to the heating elements. Then the flow of water starts to stabilize the temperature of the modules. Two different configurations are used to study the cooling performance:

1) In the first (series) configuration, the inlet of the first module connects directly to the source, and the outlet of the first module connects to the inlet of the second module, and so on. Finally, the outlet of the third module connects to the sink.

2) In the second (parallel) configuration, the inlet of every module gets water directly from the source, and the outlet of every module is directly connected to the sink. A combination of 10 mm and 6 mm diameter pneumatic polyurethane (PPU) tubes are used to make it possible.

A comparision of the results from these two configurations are shown in table 1 and 2.

It is observed that both the configurations are able to keep the modules temperature in the required range of 20°–25°C. In series configuration, a systematic increase in temperature is observed while going from module 1 to 3. While in the parallel configuration, the temperature of three modules found to be more uniform.

Module	Heat produced(W)	Temp. attained	
		after heating (°C)	after cooling (°C)
1	72.5	30	21
2	78.2	30	24
3	82.2	35	26

TABLE I: *Performance of modules when connected in series.*

Module	Heat produced(W)	Temp. attained	
		after heating (°C)	after cooling (°C)
1	72.5	31	21
2	78.2	30	24
3	82.2	35	22

TABLE II: *Performance of modules when connected in parallel.*

Based on these studies, it is suggested to use a parallel configuration of water distribution of modules in final experiment.

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