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Test of a two-phase CO2 Cooling System with a Micromegas Module

Deb Sankar Bhattacharya [*1,2], Paul Colas[1], David Attié[1]

The readout electronics with a Micromegas module consumes nearly 26 watts electric power. This gives rise to increase in temperature of the pad plane by few ten degrees. As a result, chances of damage of electronics is increased, precise measurement gets affected as well. To prevent this situation we introduced cooling pipes within the module and tested it with a cooling system called TRACI (purchased by KEK) in NIKHEF, Amsterdam. This report presents a documentation on the performance and promising future application of the cooling system.

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1. CEA Irfu,F-91191 Gif-Sur-Yvette, France
2. SINP, Salt Lake, Kolkata 700064, India

* dsb.physics@gmail.com

Requirement for cooling:

When the modules are set together on the end plate of the TPC for data taking they consume electric power and warm up. In present setup, integrated AFTER [1] electronics is used. It consists of 6 front-end cards (FECs) and one front-end mezzanine (FEM). The electronics runs at 5 Volts. We measured currents for different parts of the electronics. It is found that the FECs take 19 watts (out of which 12 watts is dissipated by the ASICs and rest of 7 watts is dissipated by the power regulators). The FEM takes 3.5 watts. Another 3.5 watts is taken by the FPGA. So each module is dissipating around 26 watts power. This power dissipation is good enough to increase temperature up to 60 to 65 degree centigrade. This may cause damage in electronics and mechanical system if heat is not removed for hours. Heating up of a module pad plane produces convection current in the TPC gas. Also inaccuracy in measurement may occur.

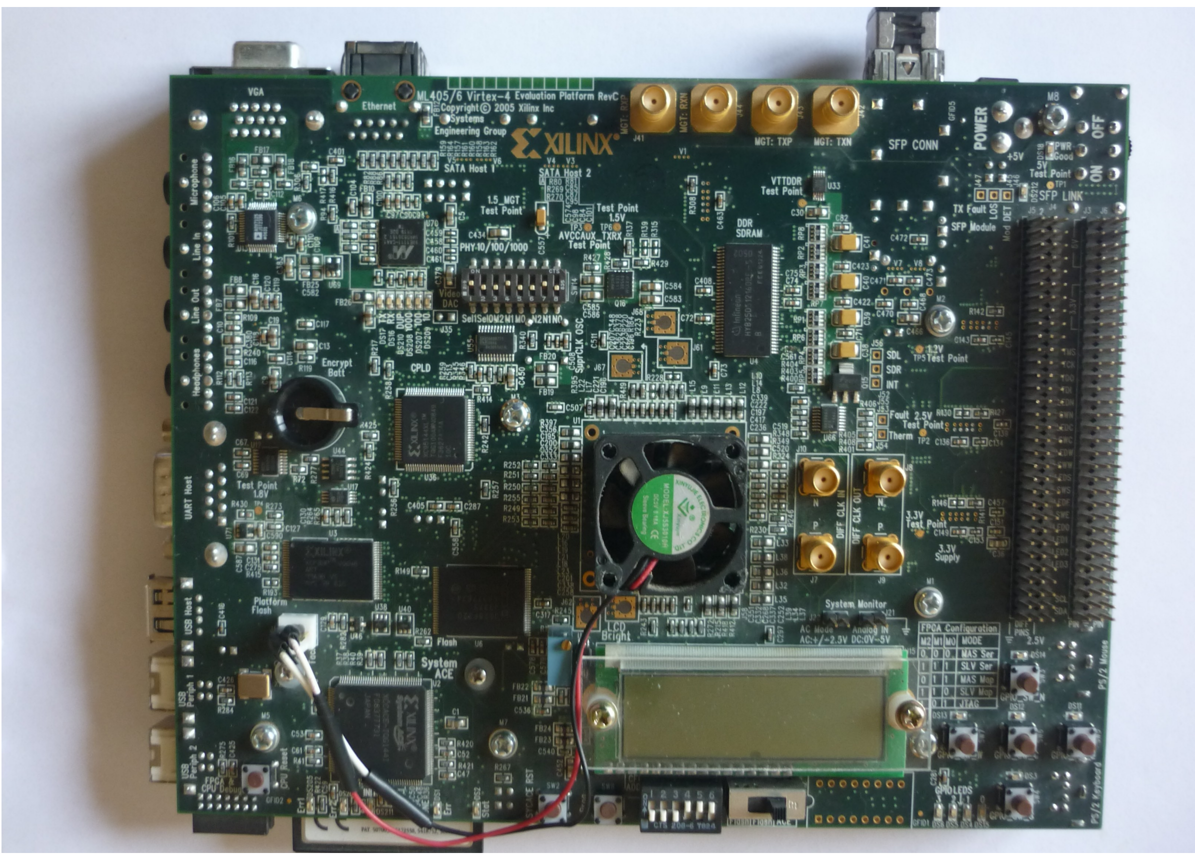
So for better performance it is essentially important to remove heat from the electronic boards of the modules.

Setup preparation:

In order to get rid of this heating problem we, in CEA Saclay, trying to cool efficiently the electronics using two phase CO2 cooling. This worked quite well for single module and hopefully would be a promising solution for LPD [2].

We put one heat sensor for each FEC and one for the FEM. Before applying this cooling technique we first tested the modules just by letting the data acquisition electronic circuit working for 5 to 6 hours. This rises up temperature at 65 degree.

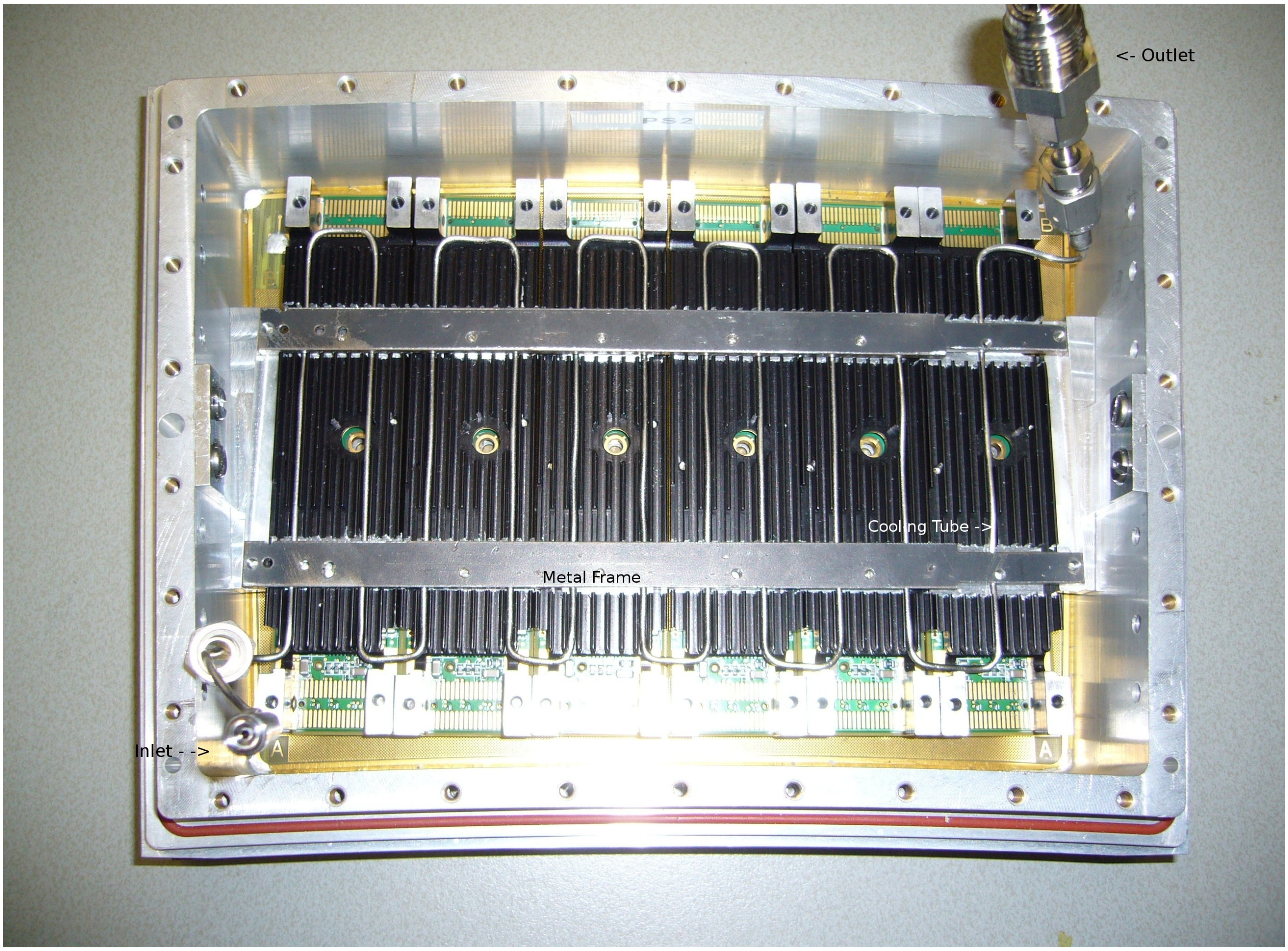
We are using back-end electronics based on ML-405 [3] to process signal. Signal from the heat sensors are also recorded and are then printed it in a file.



The back-end electronics

With the help of these arrangements we studied temperature profile of a module during cooling-heating phases. It is found that temperature goes up to 65 degree centigrade (for FECs) without cooling.

To devise the cooling circuit we make some room and insert 'Heat Absorbing' cooling tubes in side the module. They are hold tight with two metal frames (shown in the picture). These tubes are basically made up of stainless steal, which are essentially non-ferromagnetic to avoid any magnetic induction (this fact is taken into account to consider future plan to apply this setup for LPD). The tube has imperial inner and outer diameters of (1/32) inch and (1/16) inch respectively. One such 1.1 meter long tube is given a 11 fold shape. Then it is placed inside the heat radiators above the circuit board. Finally the inlet and outlet of the entire cooling tube are placed at the two diagonally opposite corners of the module.



Micromegas module

The above picture shows configuration of the cooling tubes.

Test setup:

The cooling test setup is tested at NIKHEF, Amsterdam [4]. We used 'TRACI' (Transportable Refrigeration Apparatus for CO2 Investigation) CO2 cooling system [5] for our module. The volume of the system 1.7 liter and the CO2 filling is 1 kg [6]. Using CO2 as cooling gas has several advantages. It works in two phase range which keeps the temperature constant, also, liquid CO_2 has large latent heat compared to other refrigerants [7].

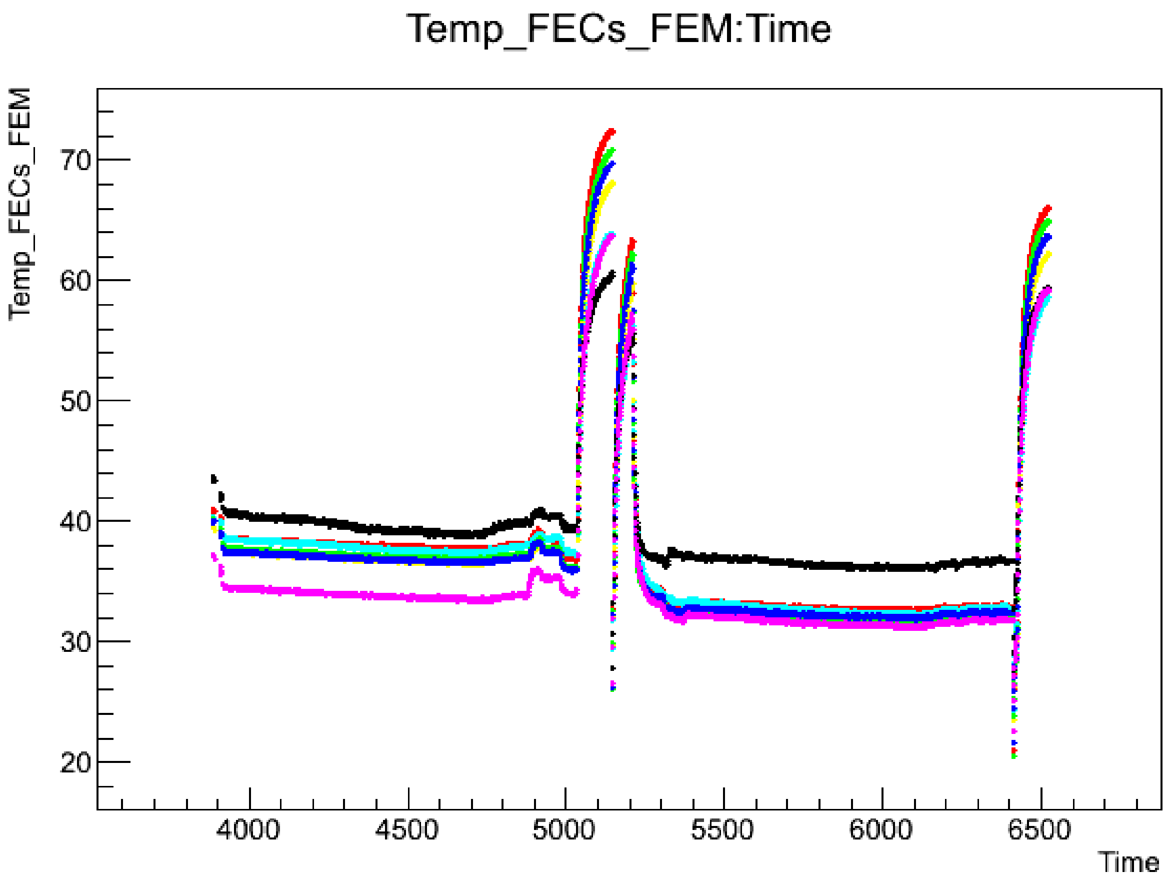
TRACI and other components of the system

The System consists of a refrigeration pump and a gas distribution box (Bypass Box, as shown in the picture). They are connected by a 3 meter long hose. The inlets and outlets are connected to the distribution box. Before flowing CO_2, the cooling system circuit is pumped out for few ten minutes. In the meantime we power on our module to get it warm. Then finally CO_2 flow is started. The embedded processor board started taking signals from the heat sensors and the temperature profile is being written in a file.

Rear side view

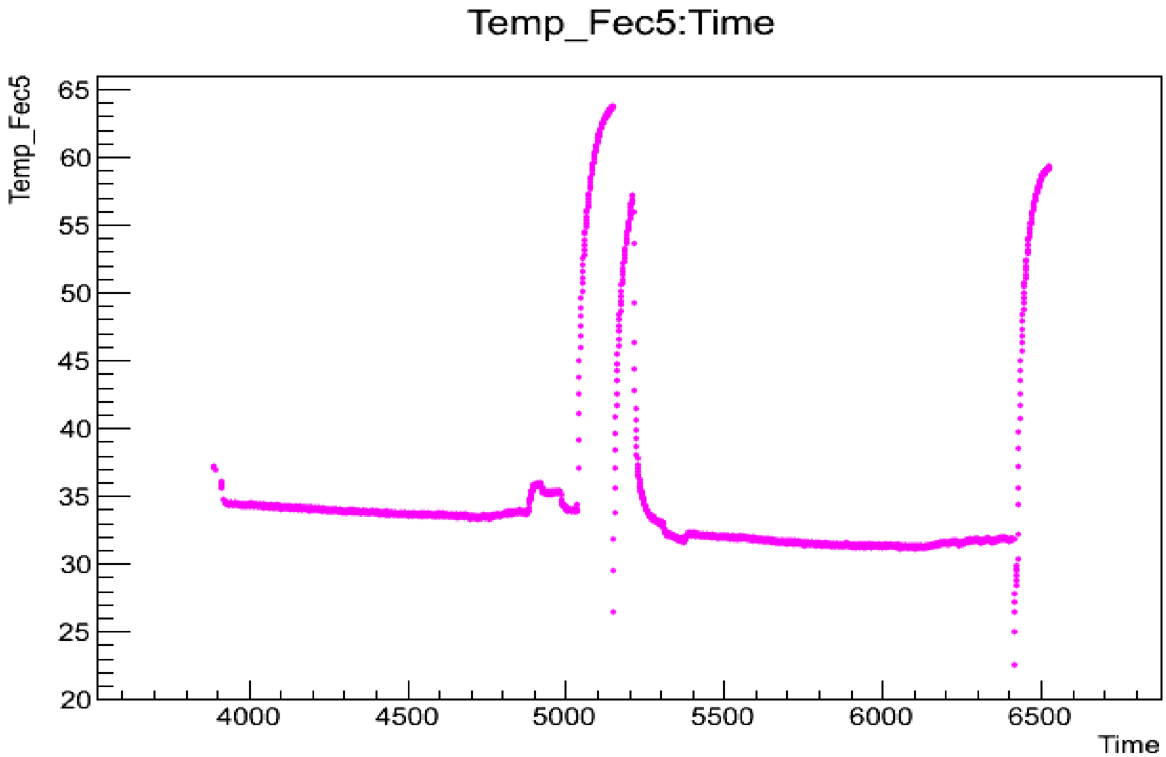
Test results:

The dramatic fall of temperature profile can be clearly seen in following graph. As soon as the CO2 flow is initiated the temperature started falling which clearly indicates the effective performance of the cooling system.

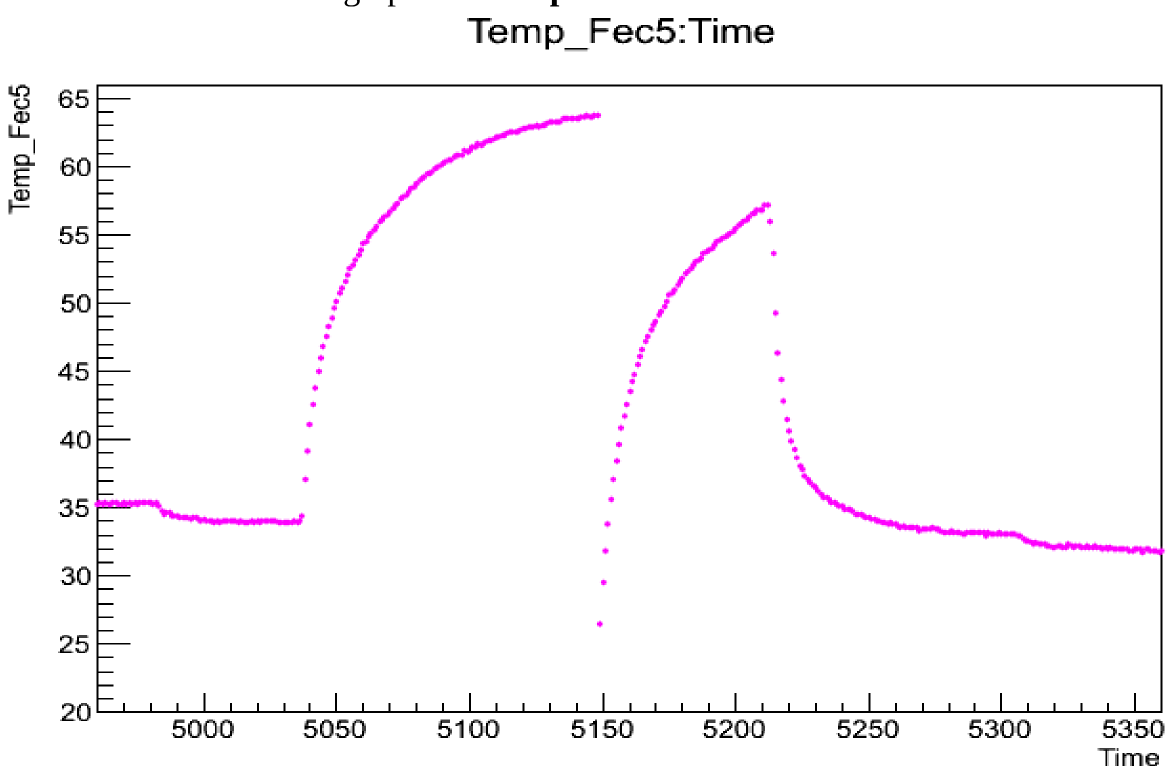


graph-1 **Temperature profile for all FECs and FEM**

It takes 20 to 25 minutes to get a stabilized thermal state of the module. As can be seen the stabilized temperature is about 35 degrees centigrade in the current case. Interestingly we had the provision to change this thermal state to a lower or upper value. By changing the pressure we can change the vapor point of liquid CO_2 and hence we can change the final thermal state of the module. (The pressure regulator is shown in the rare side view of 'TRACI'.) There are flats and peaks in the graph. The top most curve corresponds to the FEM which is supposed to be at higher temperature than the all other six FECs due to our present configuration. The flats are the state of thermal equilibrium which lasts during entire period of night. The first one is done during 2nd December night. Then another heating up is done on 3rd December. Electronics was shut down for few minutes which shows a discontinuity of the curve near at 5500 minute. Then another heat up can be seen next to it. Temperature falls in same rate for all FECs and FEM when cooling is started. The next flat is taken during over night run on 3rd December. And lastly cooling is stopped around 6400 minute.
In the second flat region the curves for all FECs are seen to be more close. This is done by making good and equal thermal contact for each them.



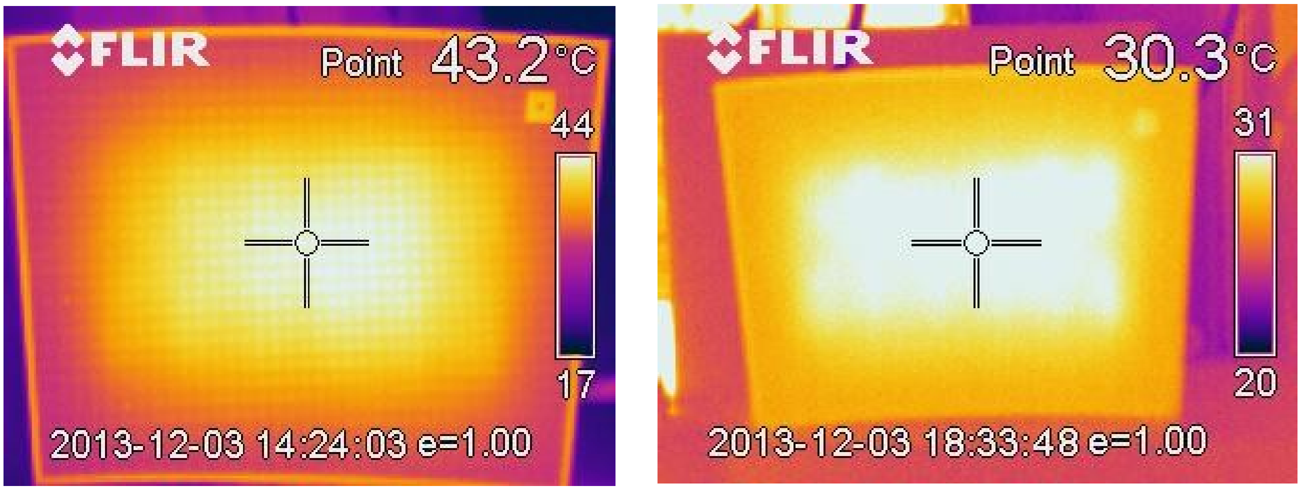
graph-2 **Temperature Profile for FEC 5**



graph-3 **Closer view of temperature fall**

Some fluctuations near 4900 and 5400 minutes may be noticed in the curves (graph-1). This this due to the changes in pressure on liquid CO2 which in turn proportionally change boiling temperature of liquid CO2. This is how we can change the stable temperature.

The sudden fall of temperature near to the heating-up peaks is most probably due to adiabatic expansion of CO2 inside the tube. This occurred when we start to evacuate the tube to stop cooling (or in other words to start heating).



Temperature difference on the pad plane in IR camera

Limitations:

We can not lower the temperature below dew point of water because it may start water condensation along the side-walls of the inlet tube. This may put the whole set up in a risk of short circuit.
Best thermal contact is needed to build up. Then we can lower the temperature even more.

Preparation for the 7 modules in Large Prototype:

It may be noticed from the cooling graphs that the cooling system worked quite well. We plan to use this system applicable for all the seven modules simultaneously and use this for next data taking in Feb 2014. Seven similar circuits are planned to be connected in parallel. For that 3.5 gm/sec (7 times 0.5 gm/sec) flow rate would be required. The manifolds would be connected to a distribution box. The outer diameter and inner diameter of the tube would be (1/16) and (1/32) of an inch respectively. Length of the cooling tubes for each module will be changed to 80 cm.

Conclusion:

We can comfortably cool the 7 modules with 0.5 gm/sec flow rate in parallel at nearly 10 degrees down to 38 degrees.

Acknowledgement:

We express our sincere gratitude to KEK, Japan for building this cooling system. We also thank Jan Timmermans and Bart Verlaat, NIKHEF for their helps during the test.

References:

[1] D. Attié et al., “The readout electronics of the Micromegas-based large time projection chamber prototype for the international linear collider” Real Time Conference (RT), 2012 18th IEEE-NPSS

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[5] *traci*, amultipurpose co 2 *cooling system* for r&d – Nikhef
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