Development of a Cooling setup for Muon Chamber (MUCH) electronics for mini CBM experiment

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On behalf of

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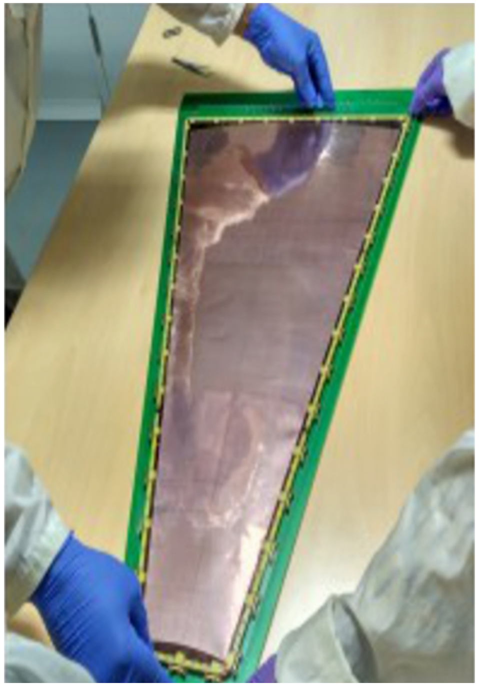
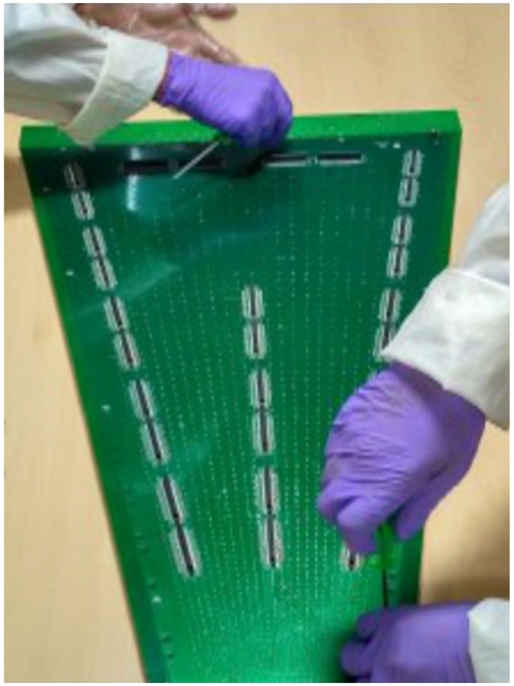
Outline:

- Requirement of Cooling in mini CBM and main CBM experiment.
- Development and demonstration of aluminum plate water cooling setup.
- Design of Air cooling setup for mCBM.
- Thermoelectric Peltier Cooling test.
- Rectangular Water Channel cooling for mini CBM.

Requirement of Cooling for mCBM MUCH FEB

- One Trapezoidal MUCH consists of 18 no of FEBs.
- Each FEB deposits 2.5 Watt heat.
- Total heat load for each sector= 2.5 X18 W= 45 Watt.
- We need to remove this heat continuously to keep all the FEBs below 25 °C


Basic design of the cooling plate

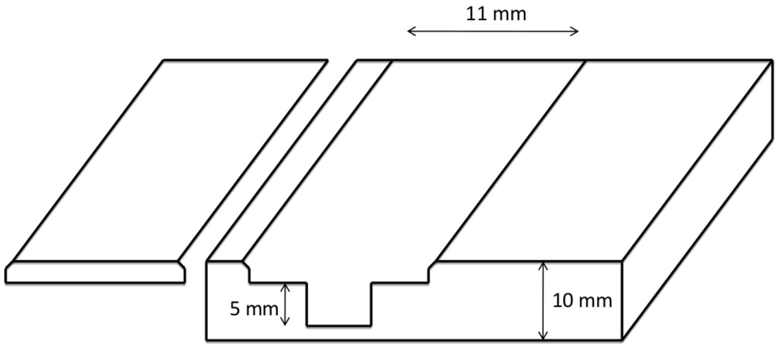
Two schemes are followed for mechanical design of the cooling plate:

Scheme-I : 7 mm Grooves are made inside plate and then welded with 3 mm Al plates.

Scheme-II : Channels are made inside the plate and Al-pipe is inserted.

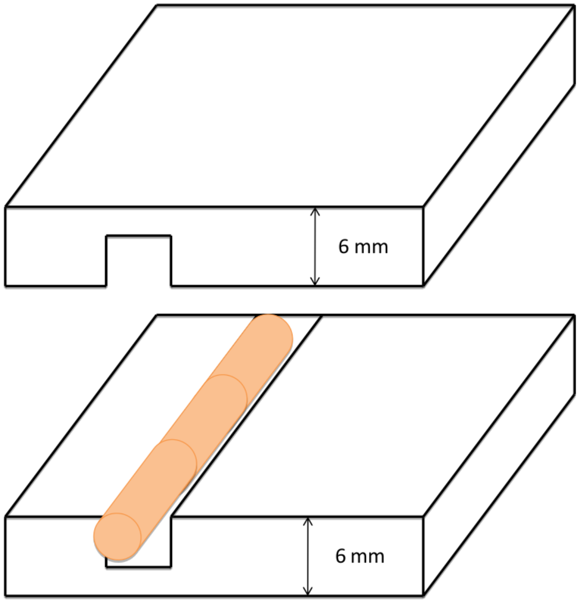
- Water channels are drawn closest to the FEBs to maximize the heat transfer.
- Temperature sensors are placed on top of cooling plate for temperature monitoring and control.
- A micro-controller drives the submersible suction pump taking input from the temperature sensor.
- Water chiller is used to provide chilled water at low temperature (10 – 15^0 C). The submersible pump is placed inside the water chiller.

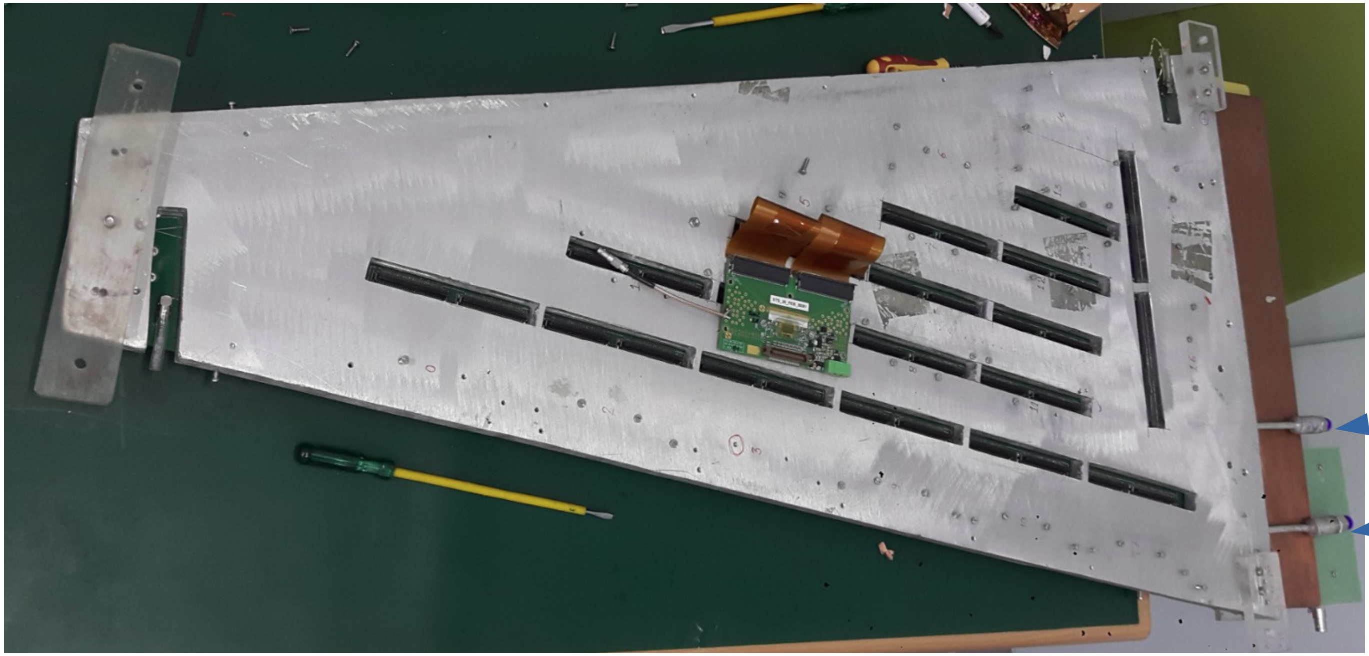
Scheme-I: in VECC workshop



➤*A 10 mm thick Al sheet was taken, and T-shaped groove was drilled into the sheet.*
➤*The groove was covered with a 2mm thick Al strip, resulting in a water channel inside the sheet.*

Scheme-II

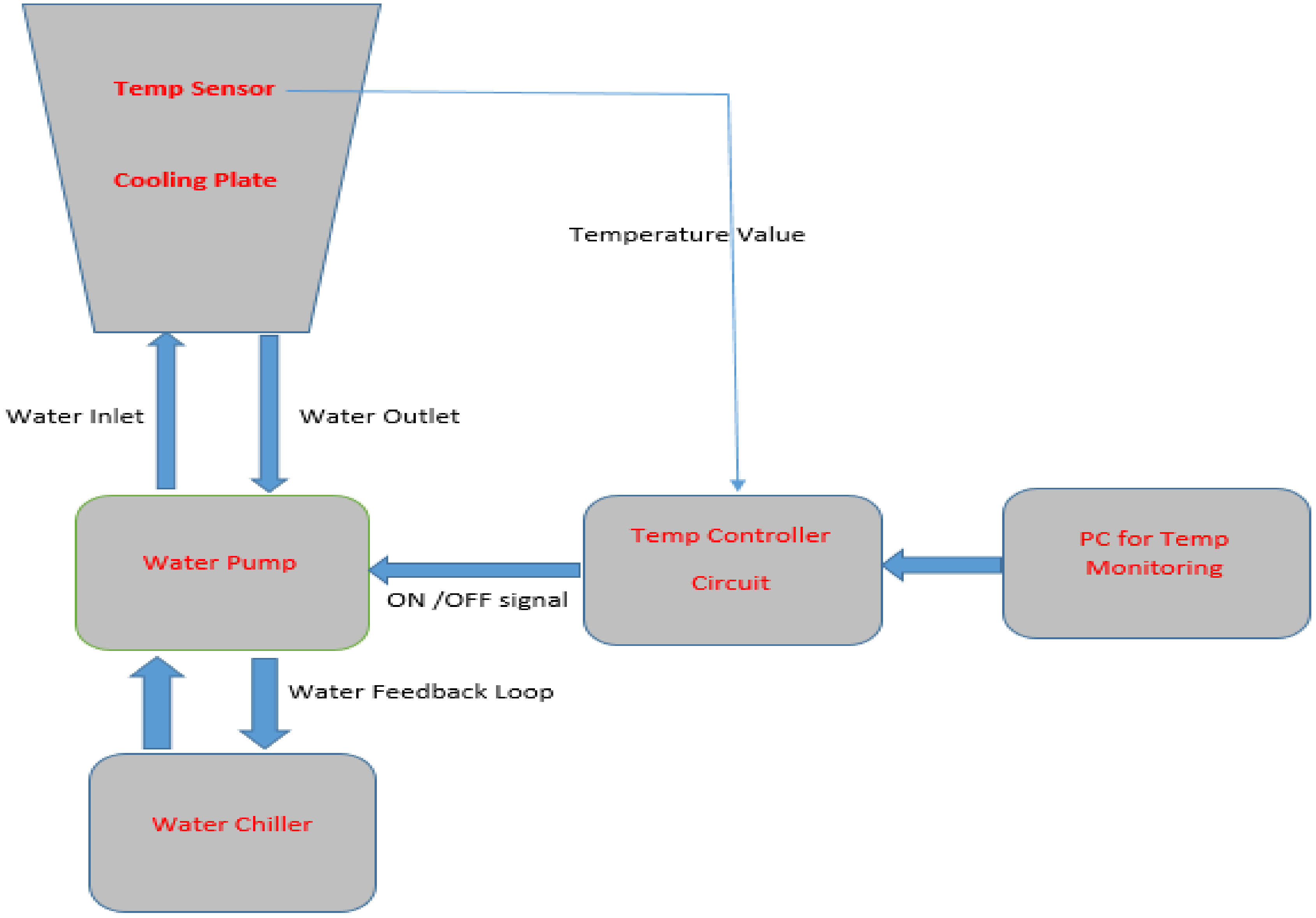




Real Size cooling plate

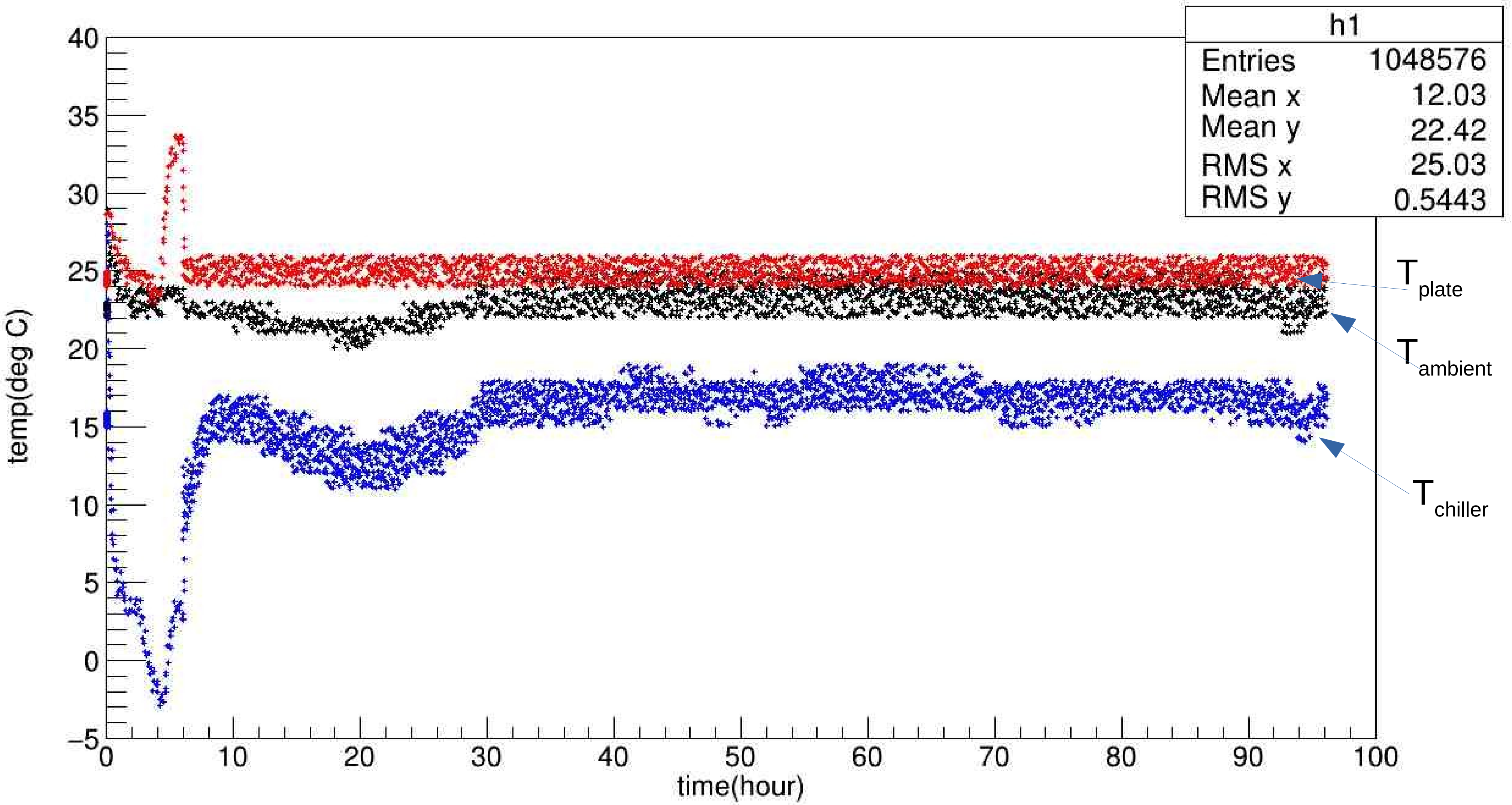
Water Cooling setup at VECC

Flow Chart of the water cooling Process:

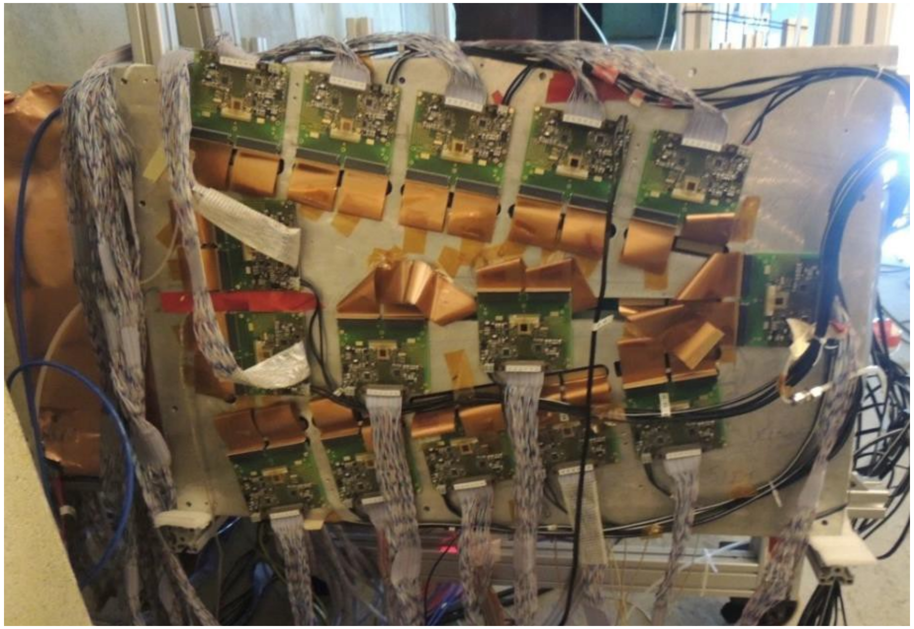


Aluminum plate Cooling results:

We tested the temperature stability with continous heating of 45 Watt using heating resistors. Tempearture was stable during 95 hours of continous operation at VECC, lab.



Cooling Plate arrangement at CERN SPS H4 Test Beam line



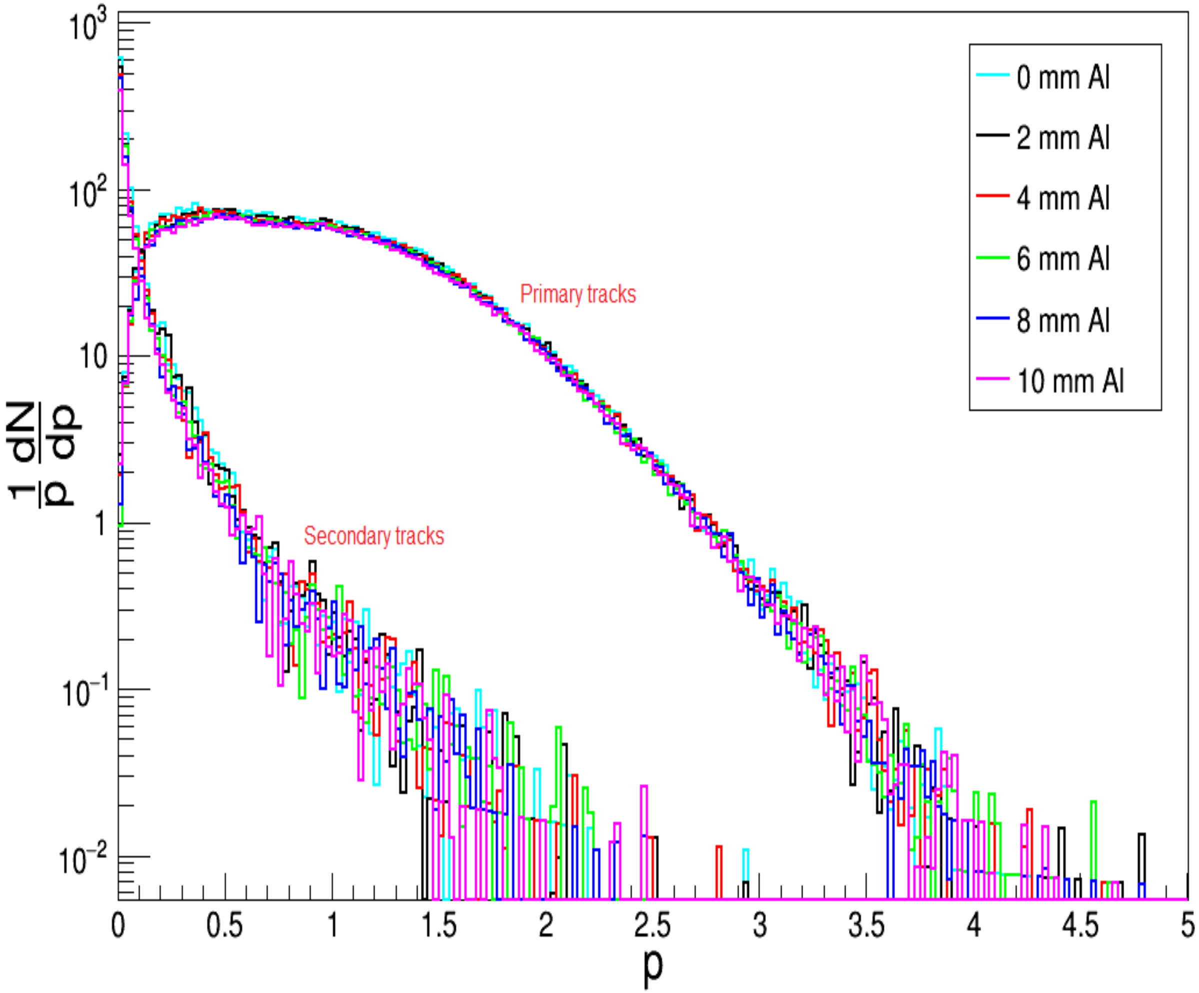
At CERN SPS H4 beam test during December 2016 two cooling plates were used

- One developed at Bose Institute*
- Other one developed at VECC Workshop

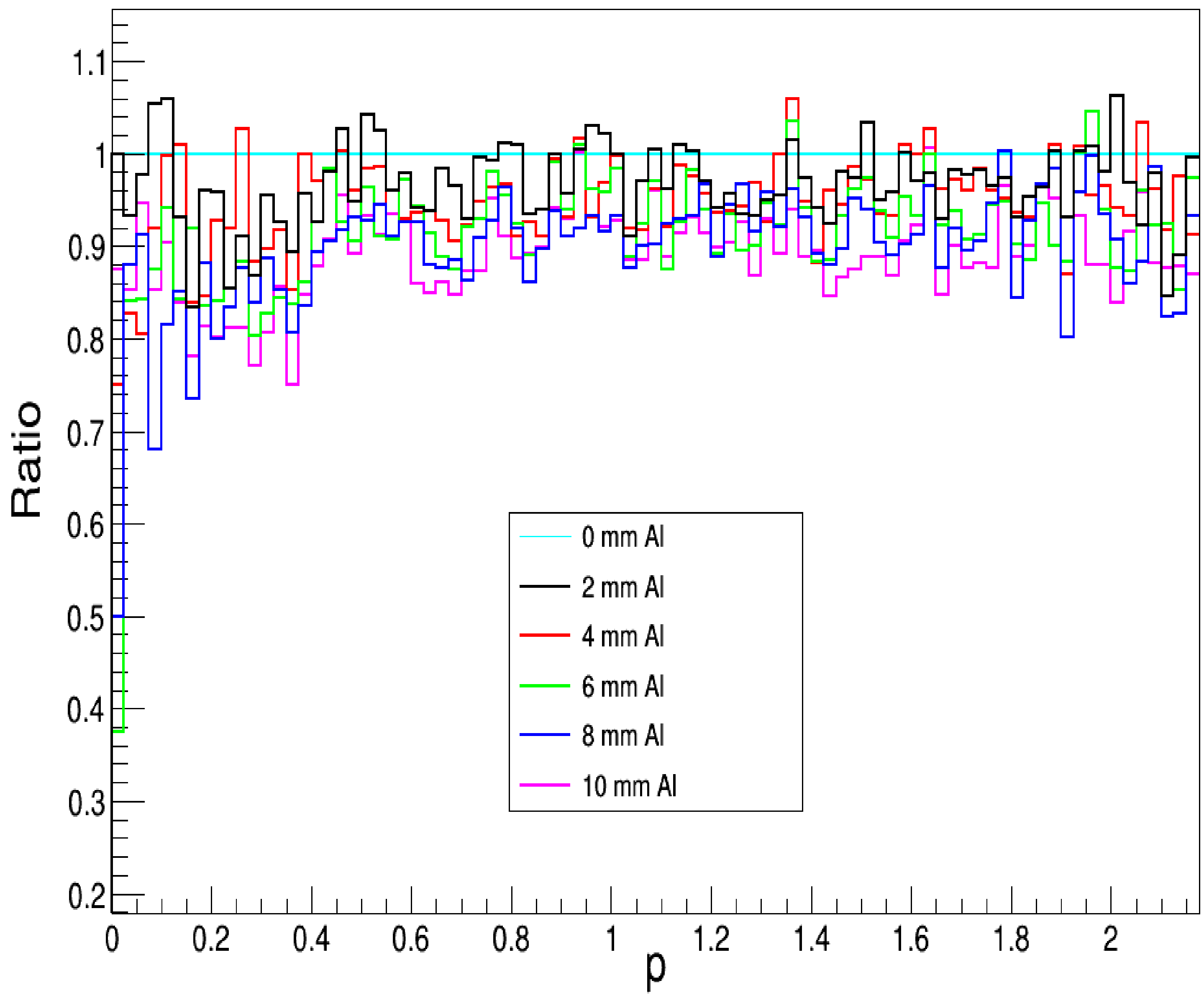
Both performed well to maintain the FEB temps below 25°C

**D. Nag et al, DAE Symp. on Nucl. Phys. 76 (2016).*

Effect of Aluminium plate on momentum of primary and secondary particles at TOF :



*Plot courtesy: Omveer Singh, AMU



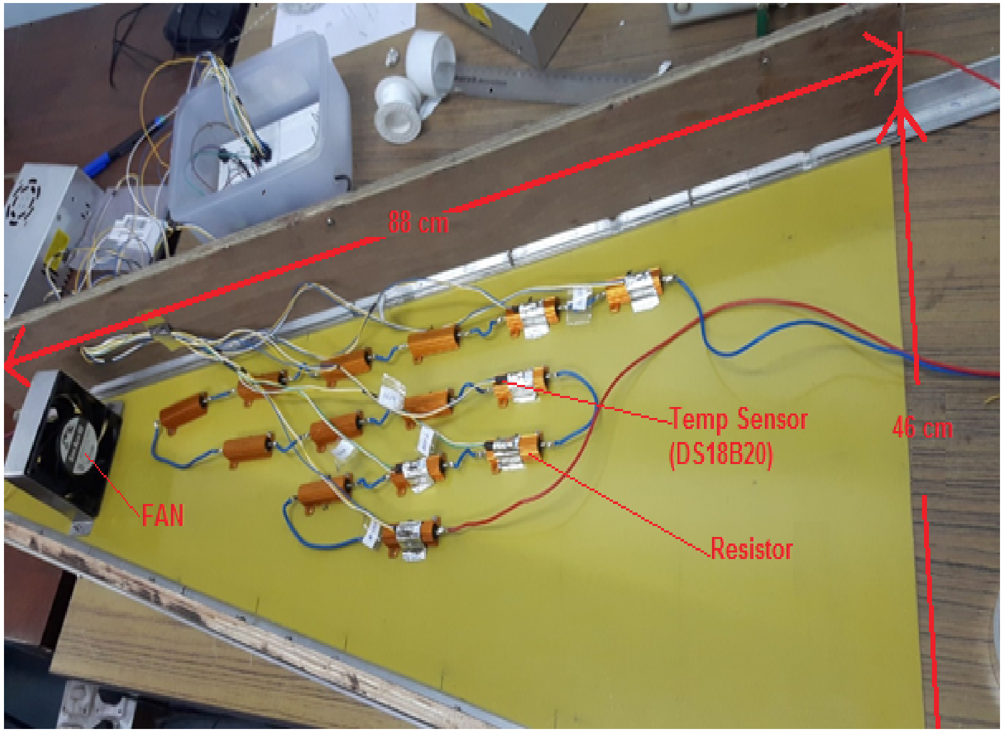
Need to use minimum amount of Aluminium in MUCH coverage

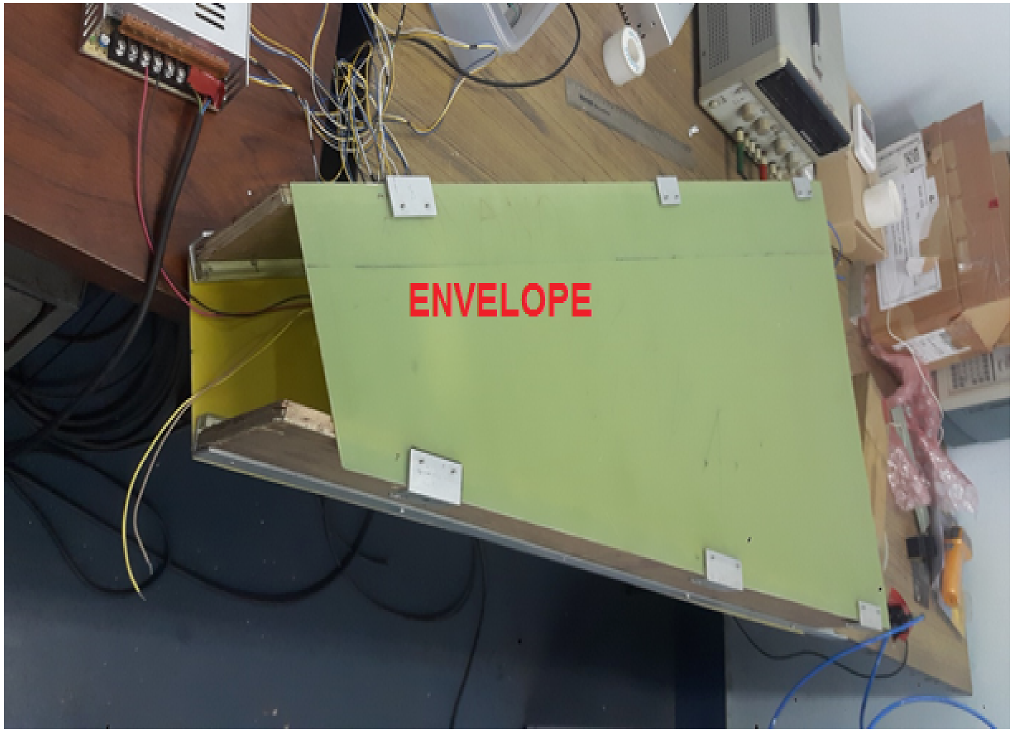
*Plot courtesy: Omveer Singh, AMU

Air Cooling setup version-1

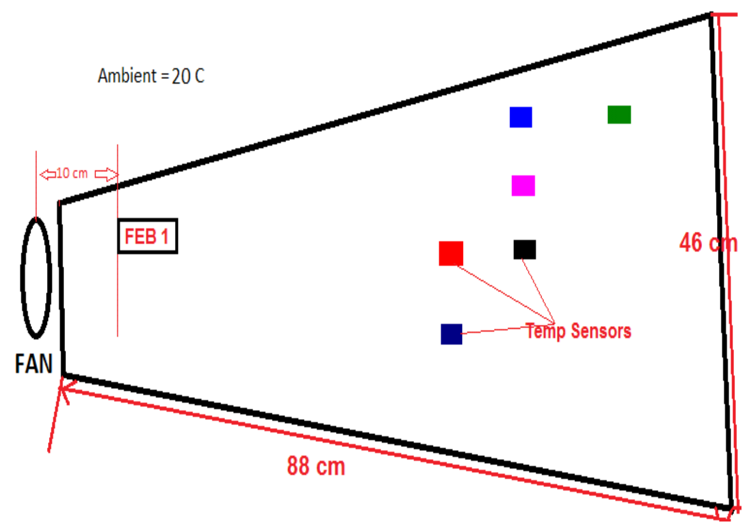
Component details:
No of Heating elements= 14
Resistance value= 10 Ohm
Heat deposited by each= 2.5 Watt
Temp sensor= DS18B20

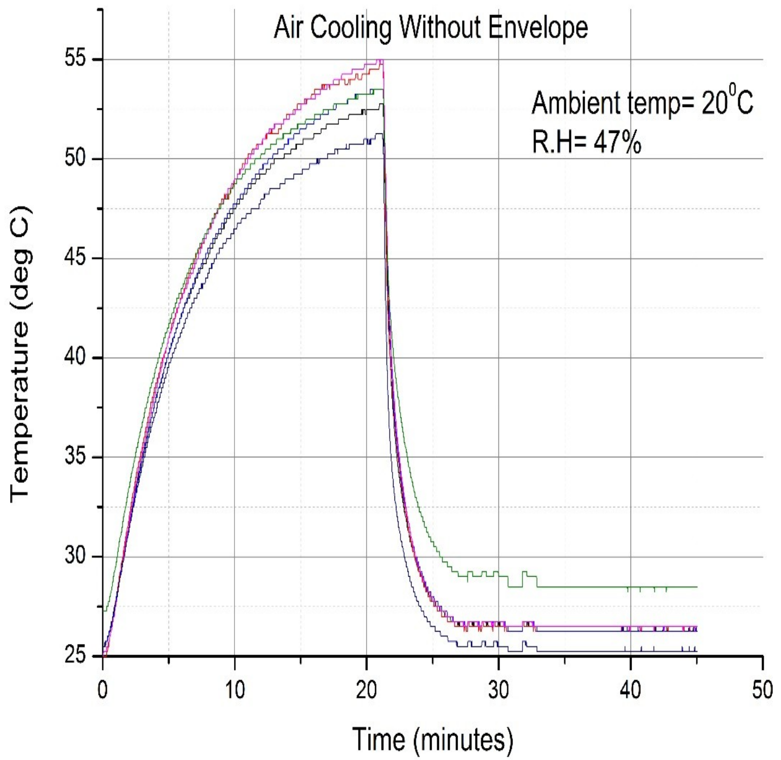
FAN Details:
Operating Voltage: 12.6 Volt
Airflow : 5.1 m^3 /minute
Rated Speed: 14900 rpm
Lifetime: 70,000 hours continuous working

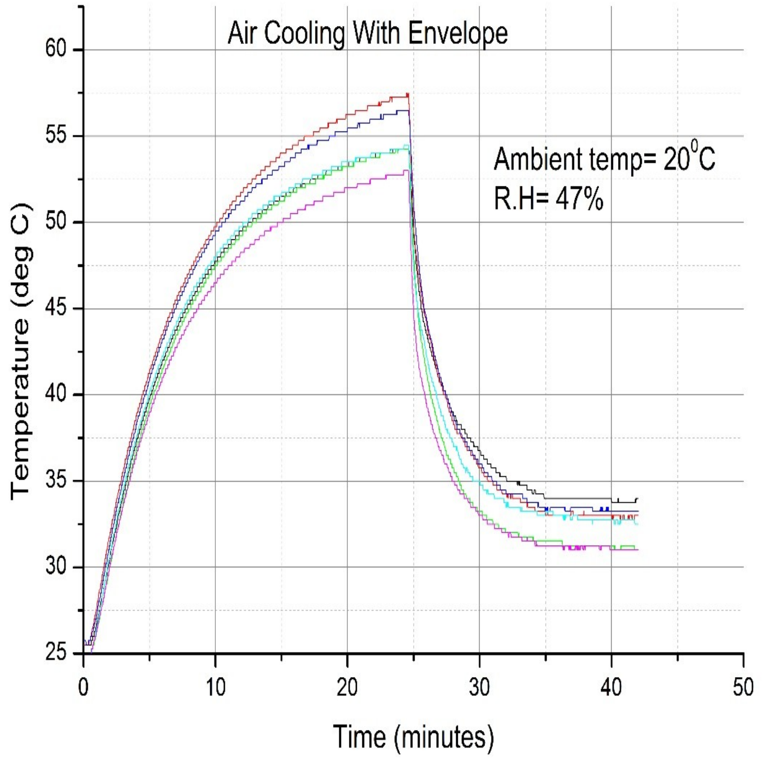




Results of Air cooling setup with and without envelope



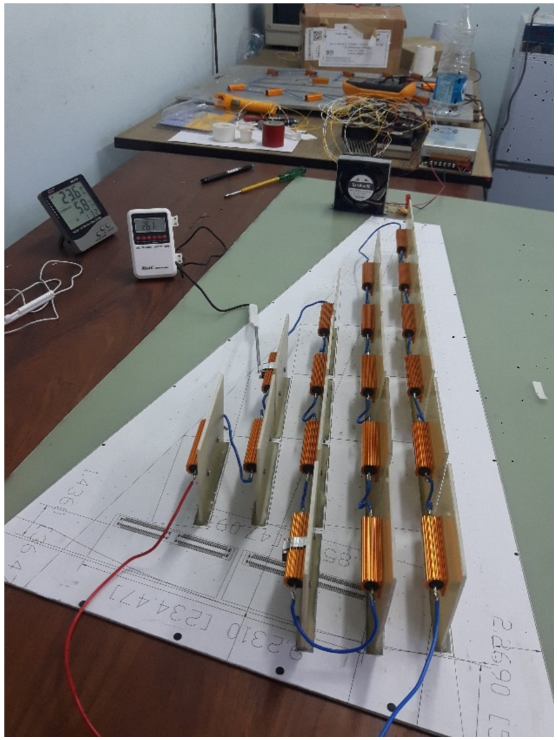




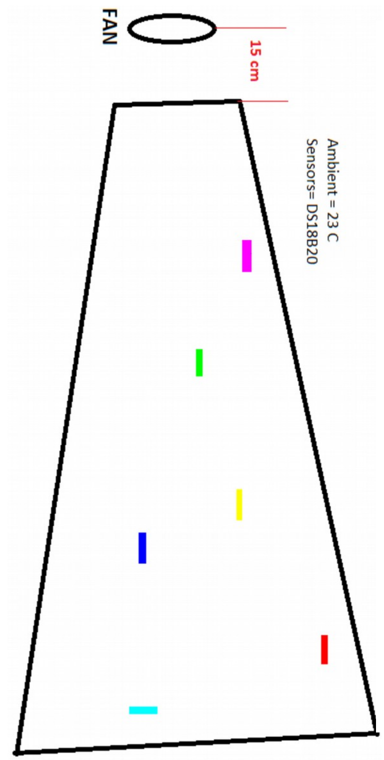
Results:

1. Without envelope case: within 5 mins the temp value comes within 25°C to 28°C.
2. With envelope case: within 10 mins temp value comes within 31°C to 34°C.
3. If we can make some proper airflow duct then cooling efficiency may get improved.

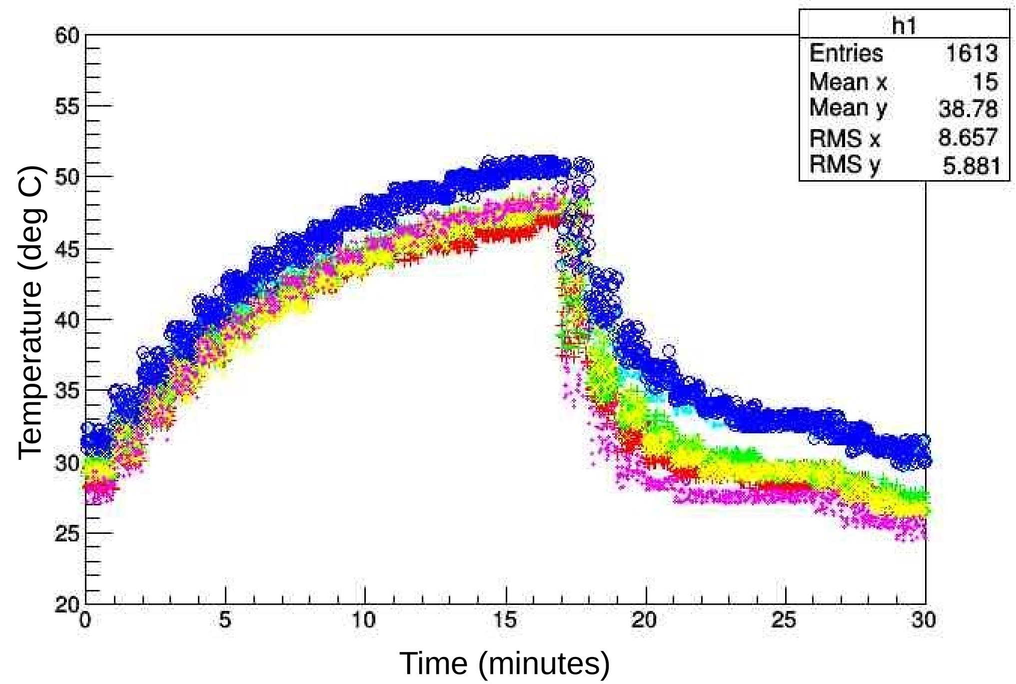
Air cooling setup version-2



Dummy of real size detector
With FEE boards mounted



Colors show different
Position of the temp
sensors



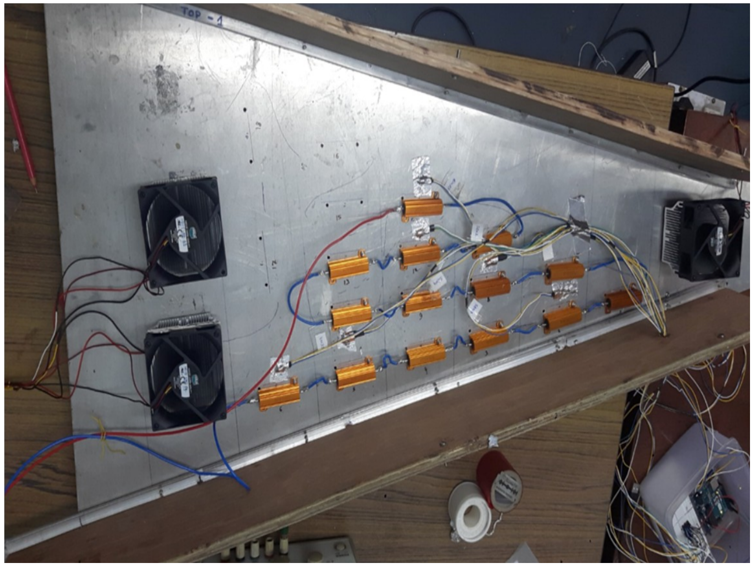
Variation of temperature at different position with time

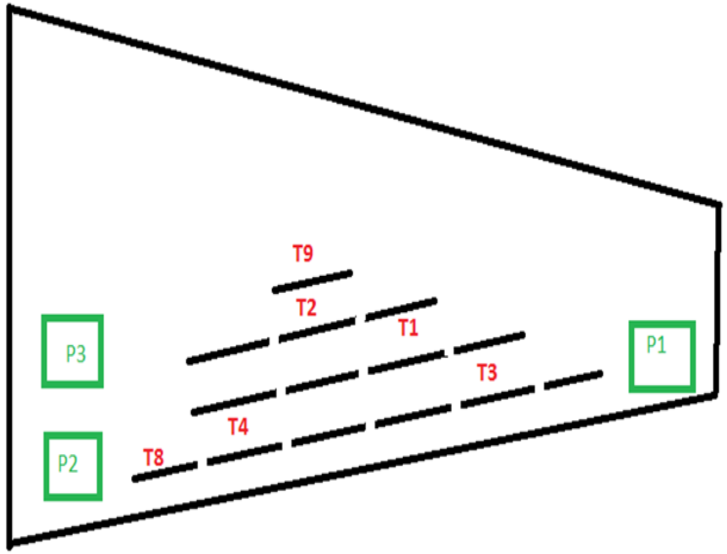
Observations:

1. From the temperature profile it can be seen that if no cooling is applied then the heating element temp rises up to 50°C.
2. From the plots we can infer that after cooling the final temp value lies between **25°C to 31°C**.

It's a nice observation that almost all the heating element temp goes down below **28°C,** the blue element shows relatively higher temp as it is slightly out of the air flow path.

Thermoelectric Peltier cooling using 2mm Aluminium plate



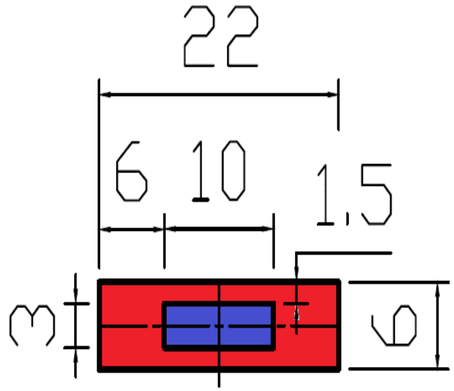


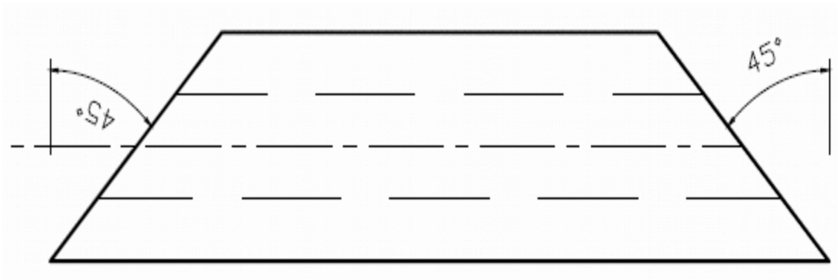
Thermoelectric cooling resulted in uneven cooling of the aluminum plate surface

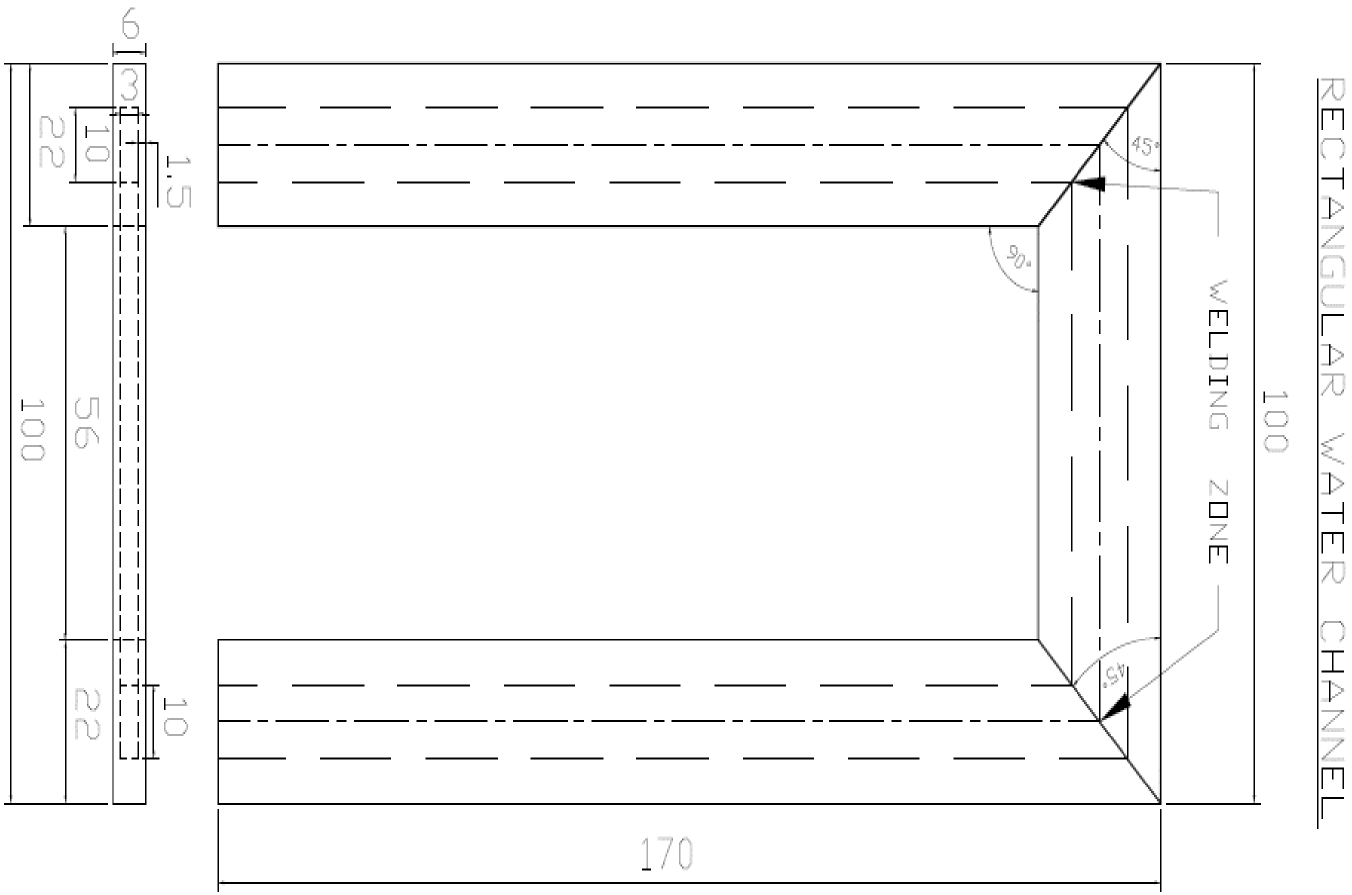
DATA SET 1 (R.T=23.5°C, R.H= 46%)

SENSOR No.	Before cooling stable temp(° C)	After peltier cooling stable temp(° C)	ΔT (°C)
T3	35.50	30.50	5
T8	31.75	24.00	7.75
T4	34.50	29.00	5.5
T1	36.50	32.00	4.5
T2	35.00	31.25	3.75
T9	33.75	30.00	3.75

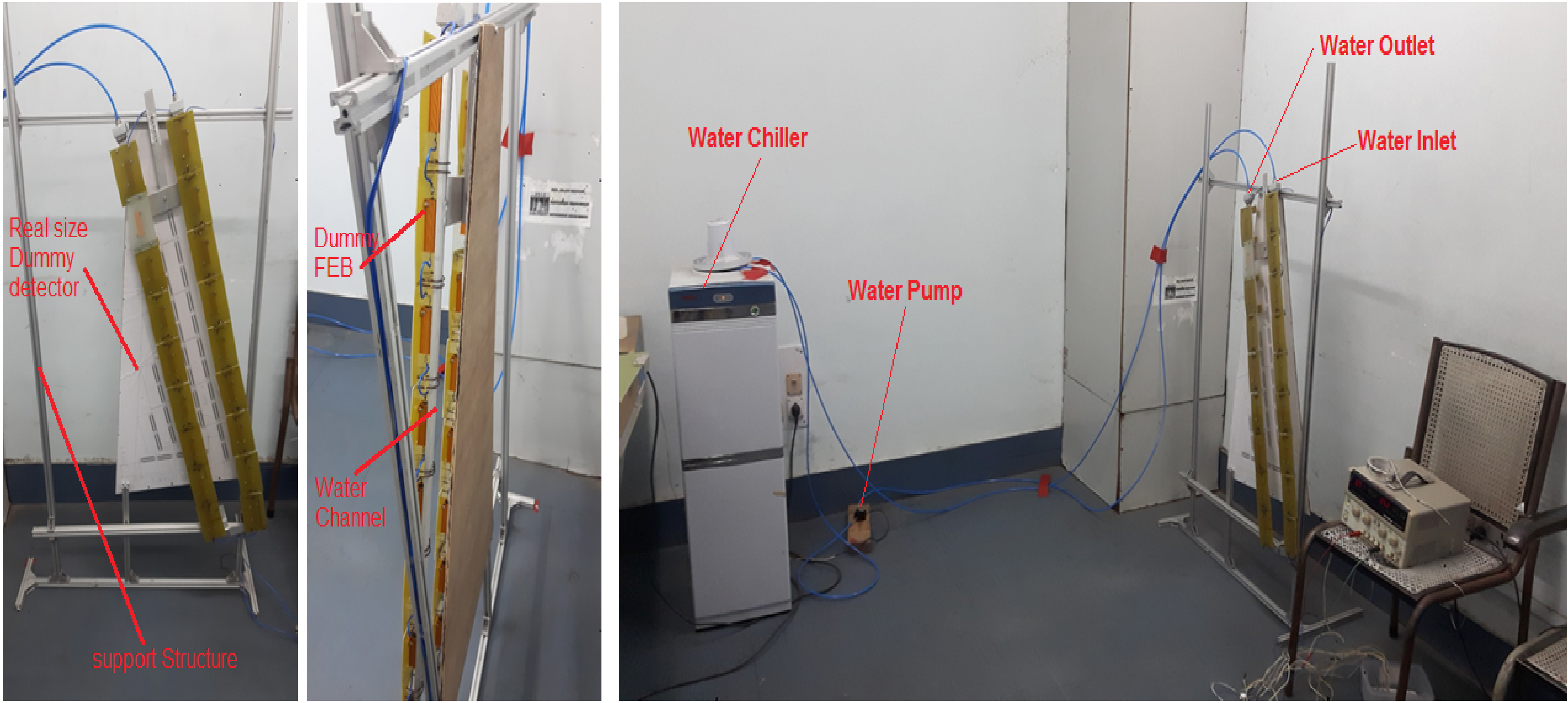
Rectangular Water Channel Cooling for mCBM







Water Channel Cooling setup in VECC



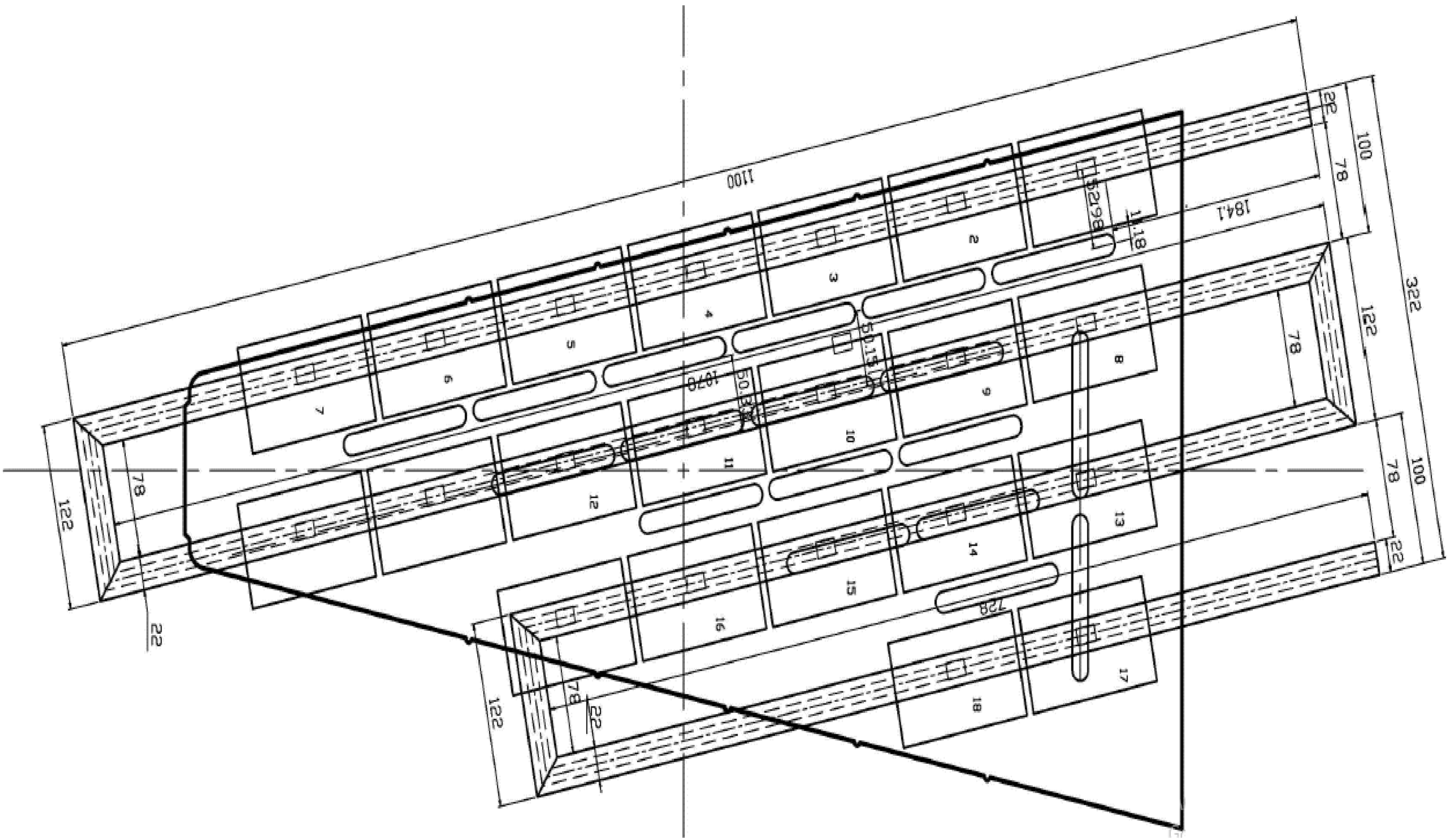
Component details:
No of Heating elements= 18
Heating applied= 2.5W X 18 = 45Watt
Water Flow rate= 14 Lit/Hour
Tin= 19˚ C
Tout=22.75˚ C

Results:

- All the dummy FEBs were placed on the channel
- Temp of all FEBs were well maintained around 20°C
- Flexible cable length from FEB to PCB connector increases more than 10 cm

➡ **Water Channel design modified**

New Layout for rectangular water channel



Layout prepared in AutoCAD by Jayant kumar

Modified water channel prepared at VECC Workshop

All the FEBs can be positioned on the Water channel using Flexi cable of length 10 cm

Component details:

No of Heating elements= 18

Heating applied= 2.5W X 18 = 45Watt

Water Flow rate= 14 Lit/Hour

Tin= 19˚ C

Tout=22˚ C

Results:

- All the dummy FEBs were placed on the channel
- Temp of all FEBs were well maintained around 20°C

Conclusion:

- Two type of aluminum cooling plate for MUCH electronics cooling has been fabricated and tested.
- Few iterations of Air cooling setup has been demonstrated.
- Peltier cooling setup was developed → No satisfactory result. Heat extraction issue from hot side and uneven cooling of the aluminum plate.
- Rectangular water channel cooling setup is developed at VECC Workshop this accounts the low material budget criteria in the detector coverage.
- The design of entire water cooling setup structure for main CBM experiment is under process.

Thank You