Performance of an Automated Water Based Cooling System for CBM MuCh

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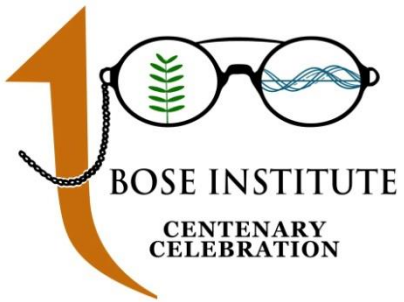


Outline

- Motivation
- Development of a water based cooling system for CBM MUCH.
- Future plan

Water based cooling system

- Front End Boards (FEBs) dissipate ~ 90 W of heat per MuCh sector (15 FEBs).

- The heat is to be continuously taken out to keep ambient temperature within working range (20 to 25°C).

- FEBs are connected using wire bonding technique, thus air cooling is not an option, **water cooling is preferred**.

- A controlled water based cooling system is designed for the CBM Muon Chamber (MUCH).

- Al-plate (8 – 10 mm thick) with water channels (5 – 6 mm dia) inside it works as both support structure for mounting detector and cooling plate.

- FEBs dissipate heat to the cooling plate which is taken out through controlled water flow.

FEB

Cooling Plate

Hardware Details

Basic design of the cooling system

- Two schemes are followed for mechanical design of the cooling plate:
  Scheme-I : 7 mm Grooves are made inside plate and then sealed with 3 mm Al plates.
  Scheme-II : Channels are made inside the plate and Al-pipe is inserted.

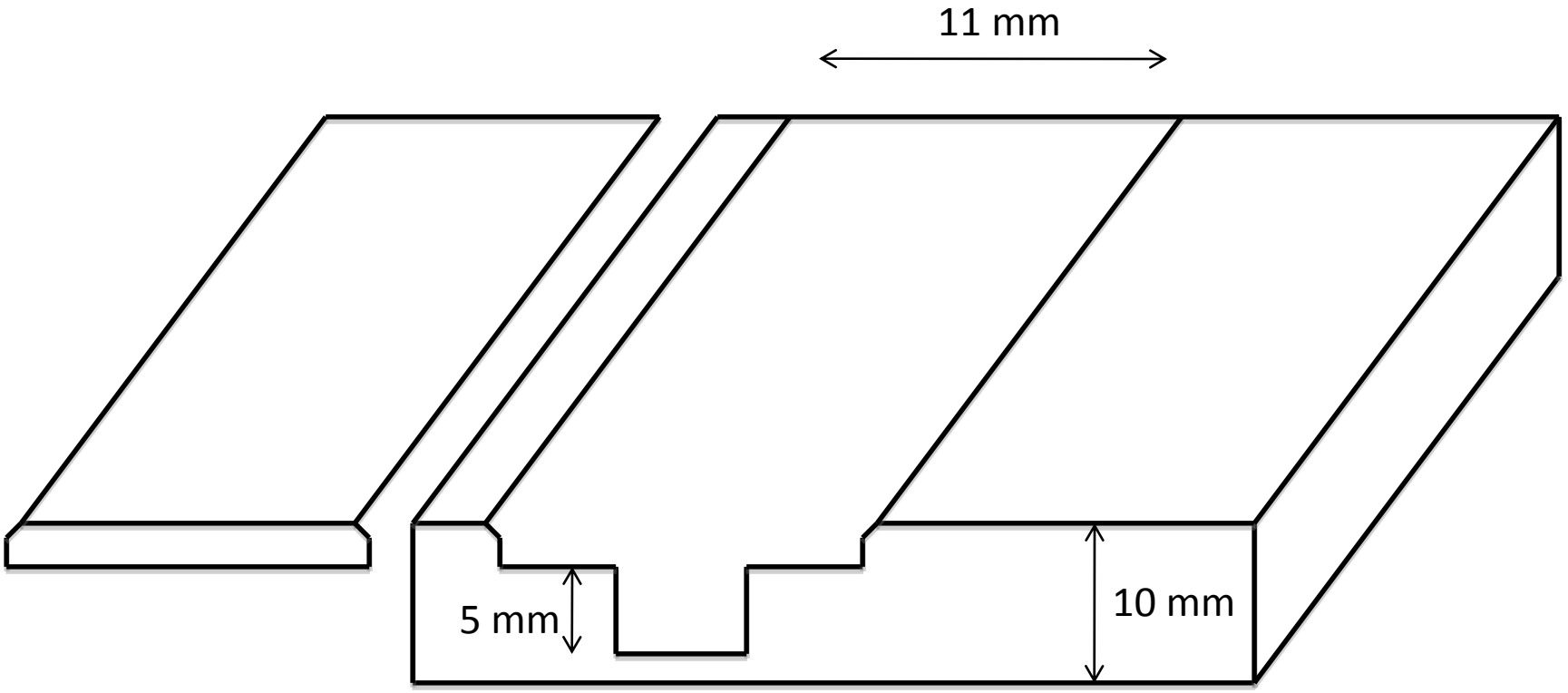
- Water channels are drawn closest to the FEBs to maximize the heat transfer.

- Temperature sensors are placed on top of cooling plate for monitoring and control.

- A micro-controller drives the submersible suction pump taking input from the temperature sensor as and when needed.

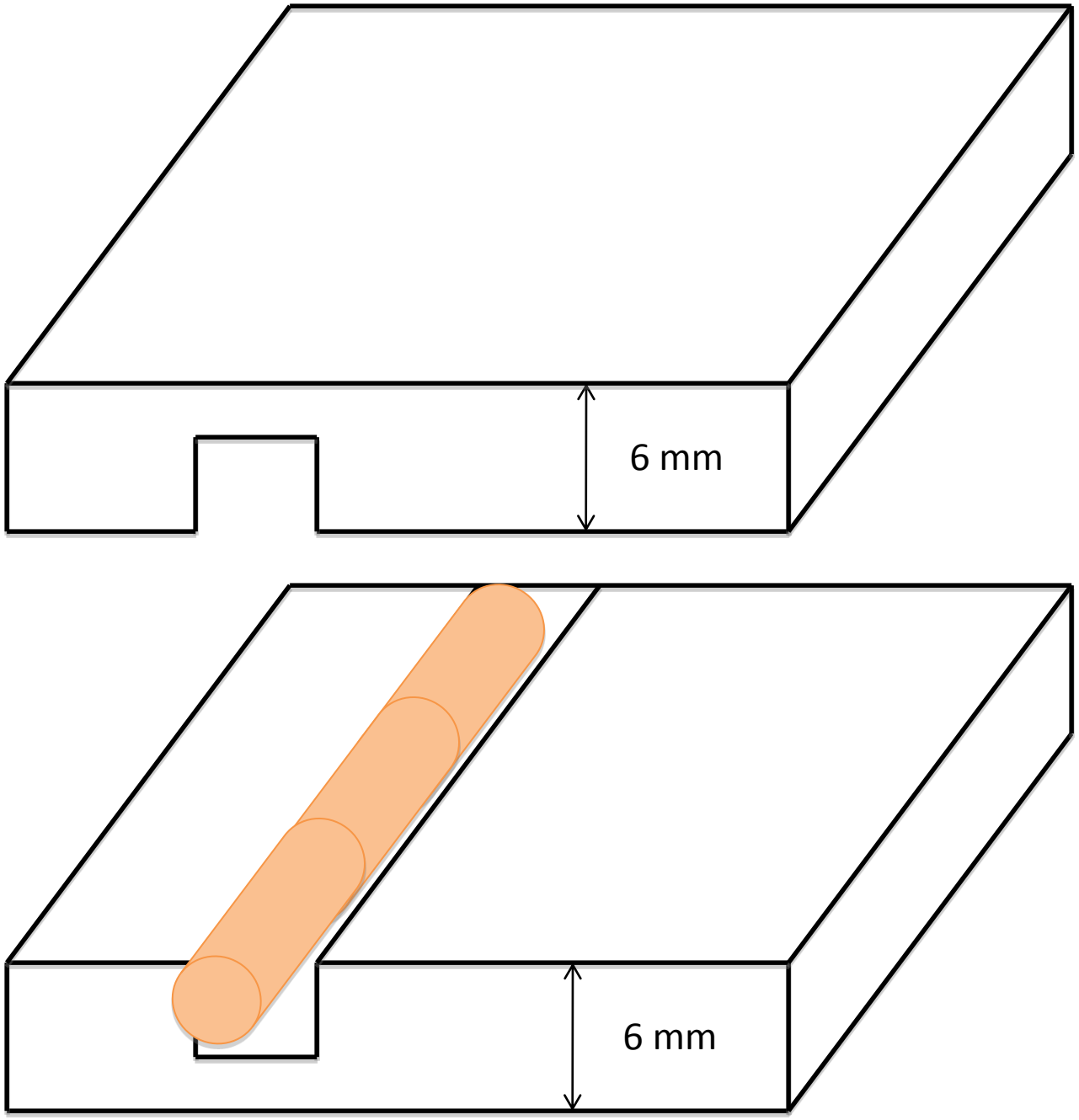
- Water cooler is used to provide chilled water at low temperature (10 – 15 ^{o}C). The submersible pump is placed inside the water cooler.

Scheme-I: in VECC workshop

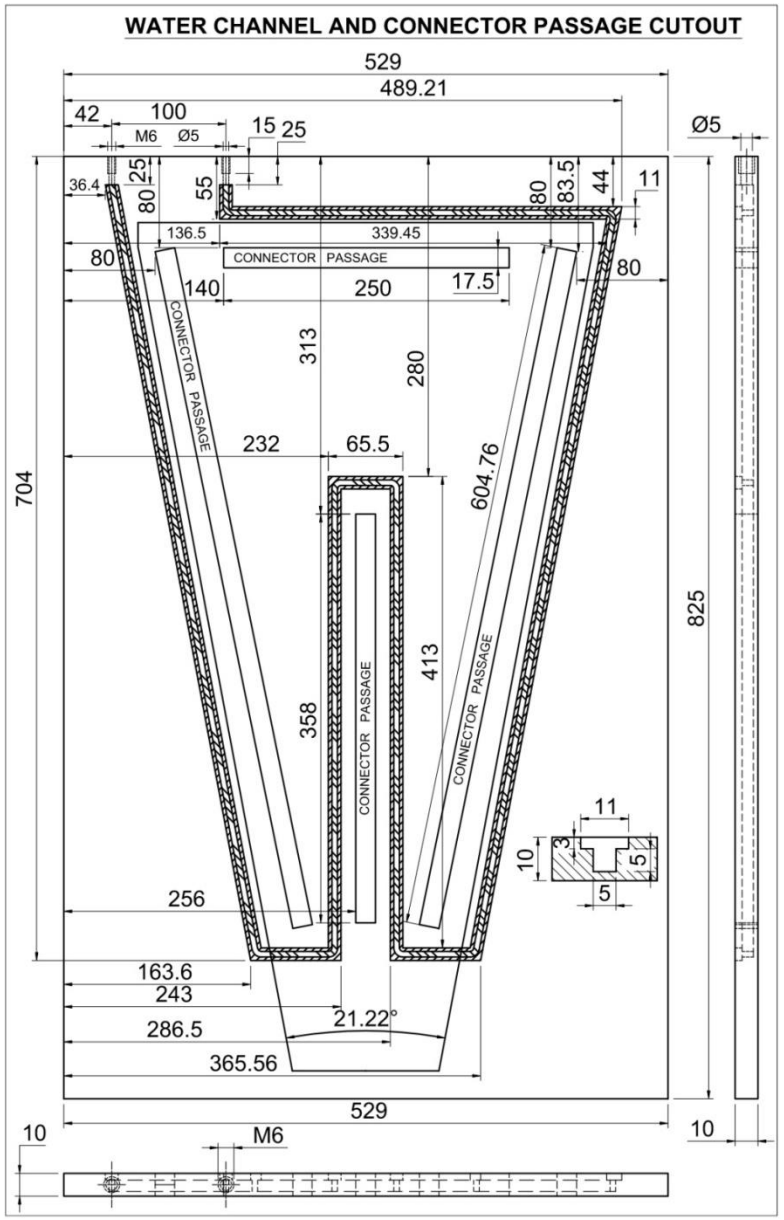


- ***A 10 mm thick Al sheet was taken, and T-shaped groove was drilled into the sheet.***
- ***The groove was covered with a 2mm thick Al strip, resulting in a water channel inside the sheet.***

Scheme-II



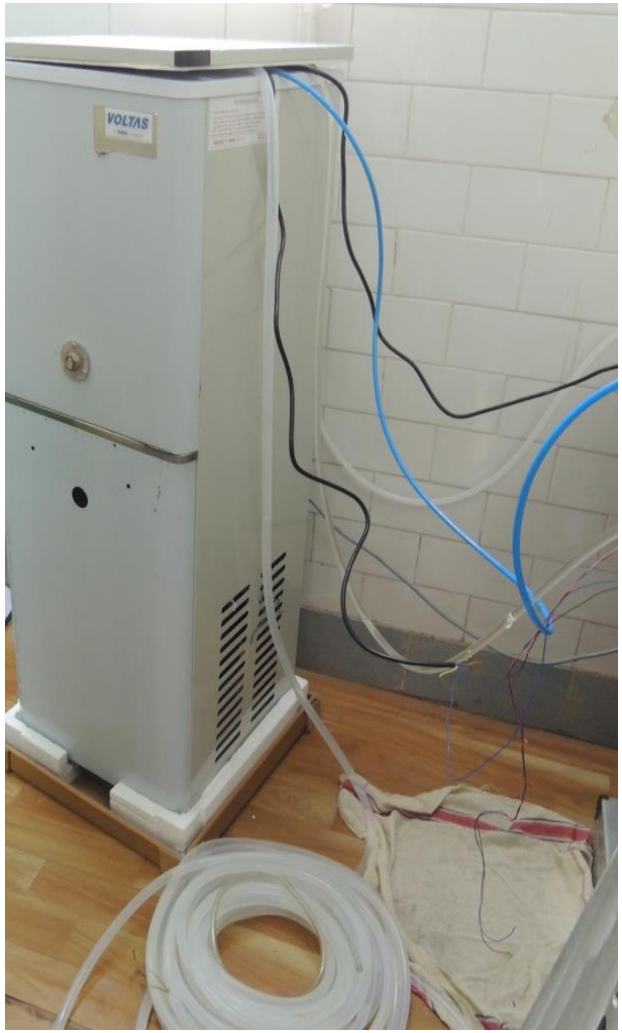
Mechanical design



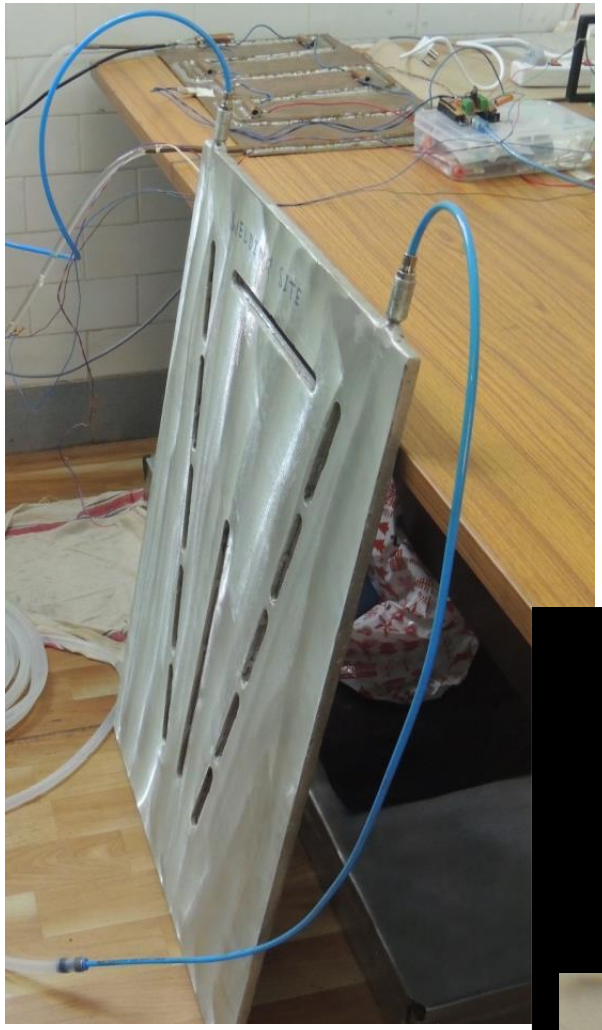
Prepared by Jayant Kumar, VECC

Designing the Cooling plates

Setup in the lab at Bose Institute



Water Chiller (sink)



Al Plate

Inlet

Software and electronics

The Control Mechanism:

➢ A closed loop ***negative feedback PID system*** is used for the flow control mechanism.

The Algorithm is based on the formula

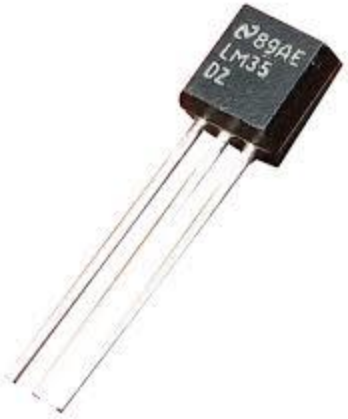
$$OUTPUT = k_p * e(t) + k_i \int e(t)\,dt + k_d * de(t)/dt,$$

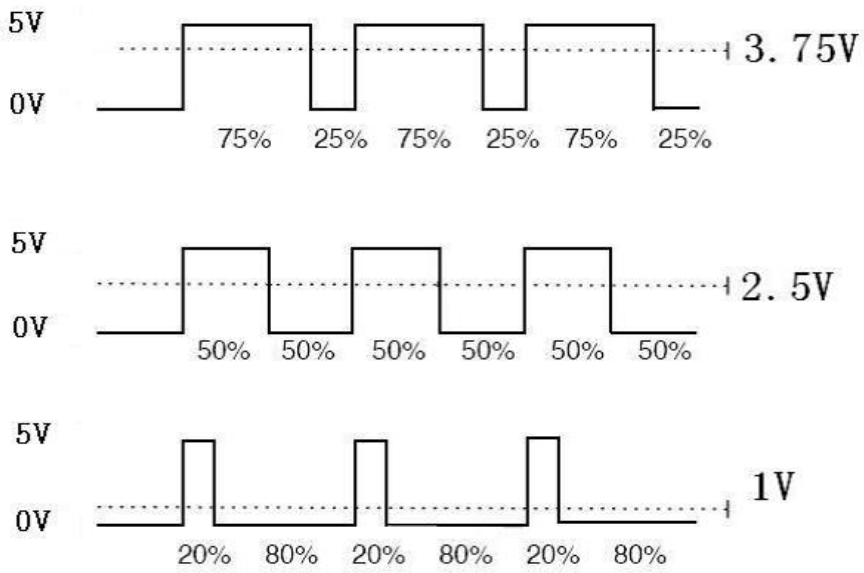
where $\mathbf{k_p}$, $\mathbf{k_d}$, $\mathbf{k_i}$ = constants
e(t) = *(Desired temperature-Actual temperature)*

➢ The Controller is programmed to take the measured temperature as input and control the motor as output.

➢ Output from controller is 8 bit PWM signal

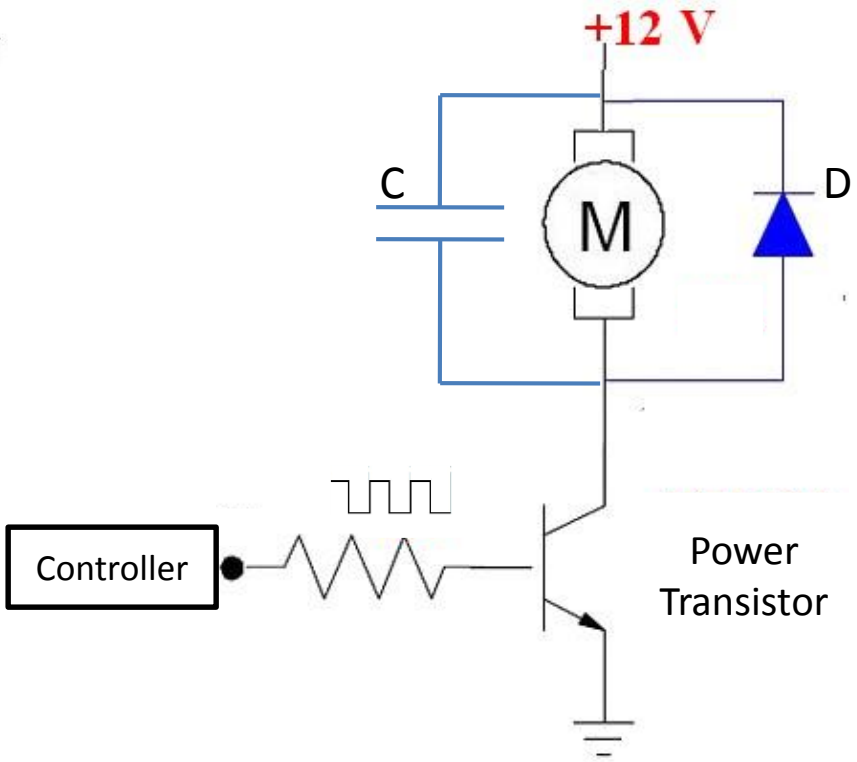
➢ Motor is controlled via Power Transistor



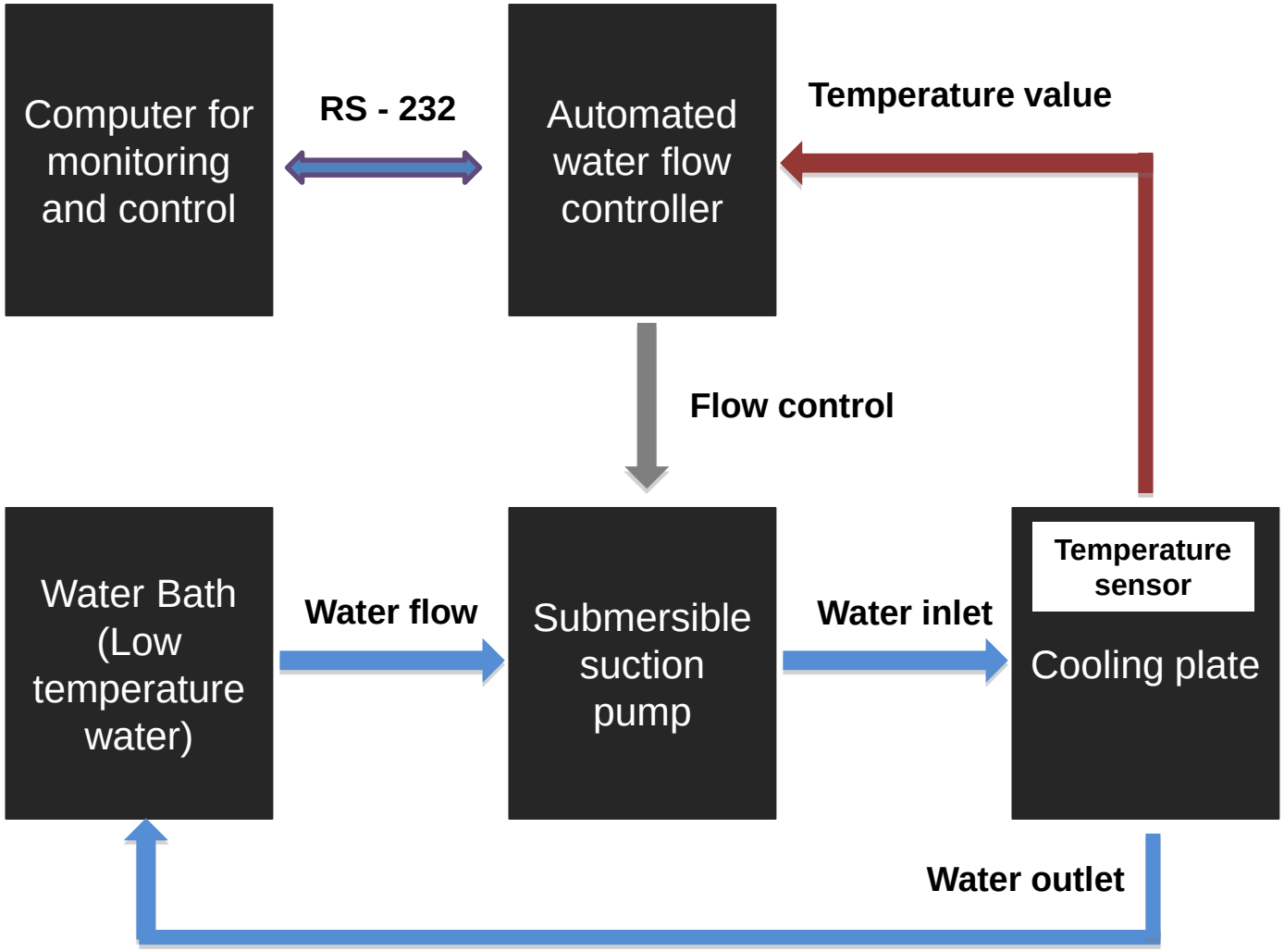


PWM pulses depicting various Duty Cycles

Basic control circuitry



Block diagram of the process

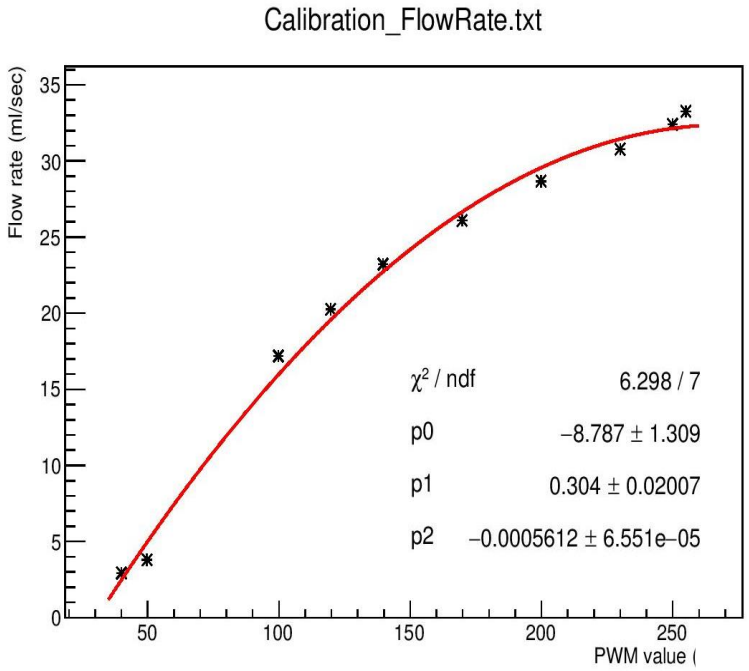


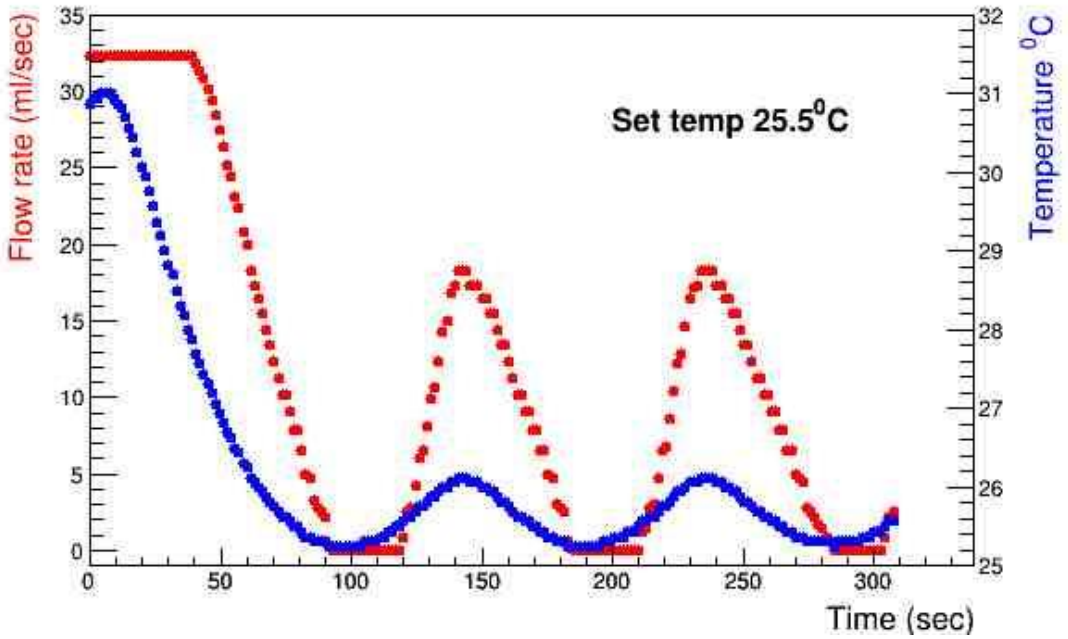
Preliminary tests:

- Preliminary tests were done using copper plate of thickness 2 mm, with copper tubes of diameter 6mm welded on the plate.
- Heat load was simulated using seven heating elements, each of 4W dissipative power.
- Several set-points were set and the corresponding data was recorded.
- Temperature was recorded using DS18B20 sensor, which was later replaced with an analogue sensor LM35.

Preliminary test results

- Water volume flowing against various PWM values were recorded.
- The data was fitted, and the fit parameters were obtained.

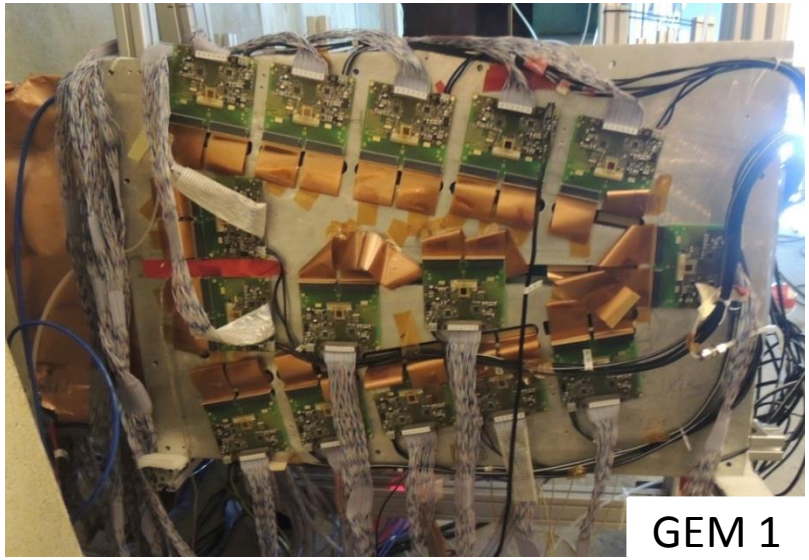


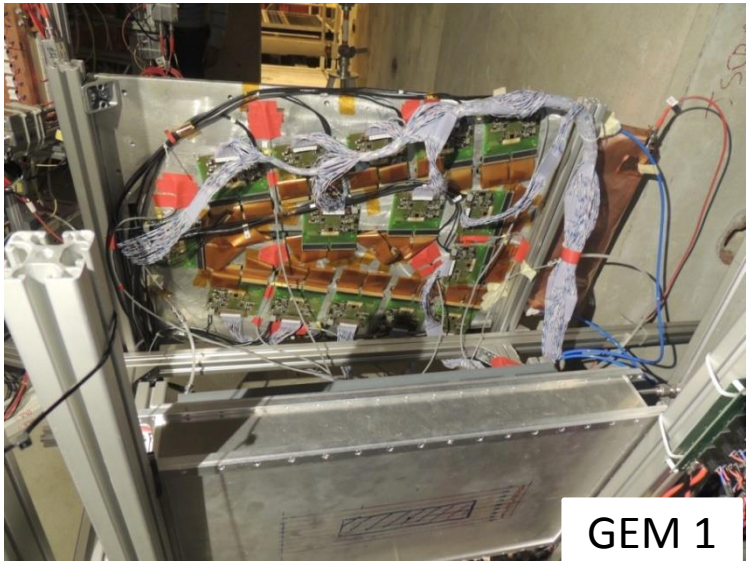


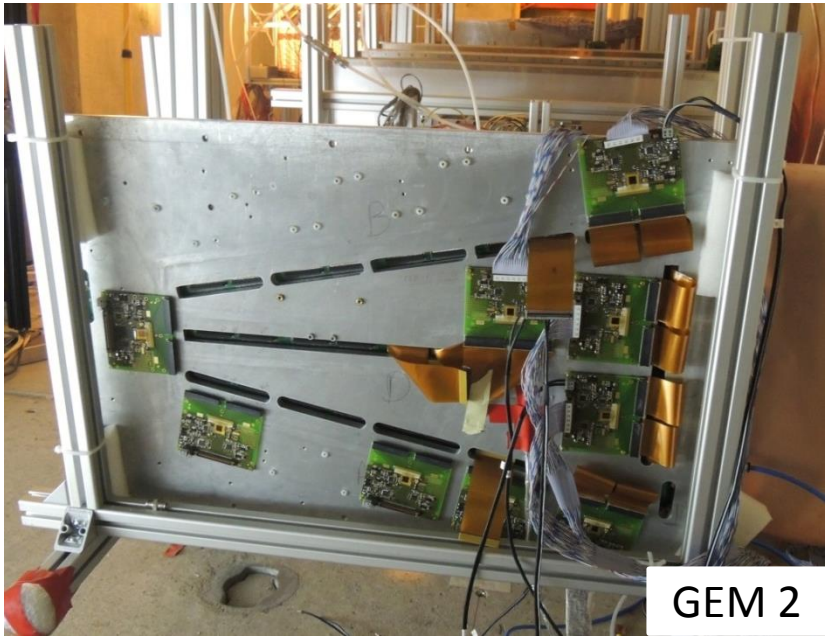
Testing at CERN SPS H4 Test Beam line

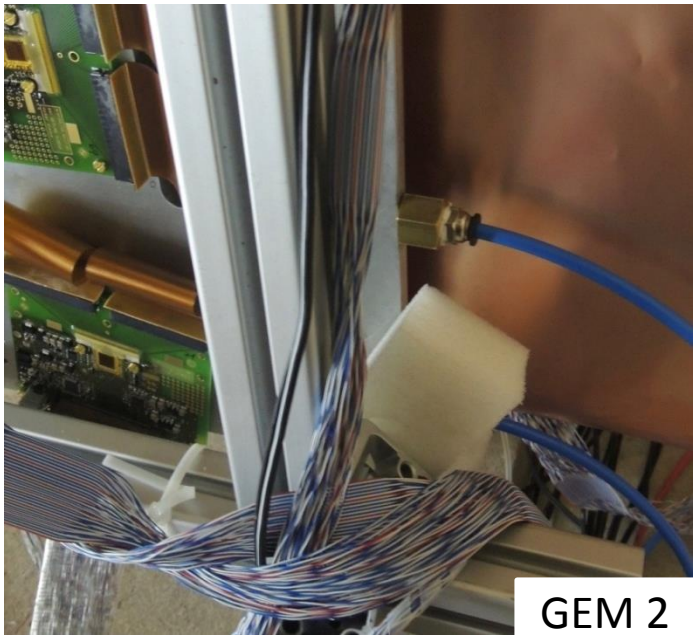
- Both the mechanical designs were tested at CERN SPS test beam.
- Two different Full sized GEM foils were used, one equipped with complete number of FEB's and the other partially equipped with FEB's.

Setup at CERN SPS test beam

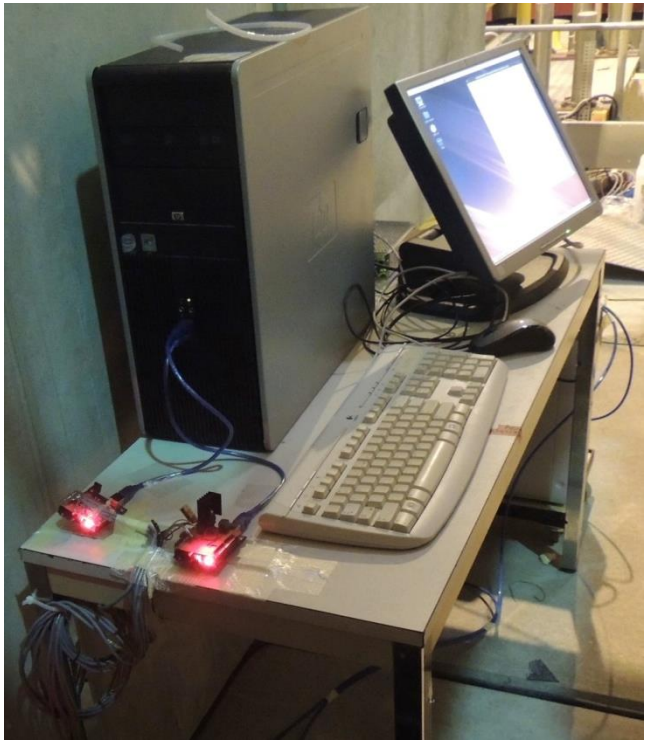

GEM 1


GEM 1

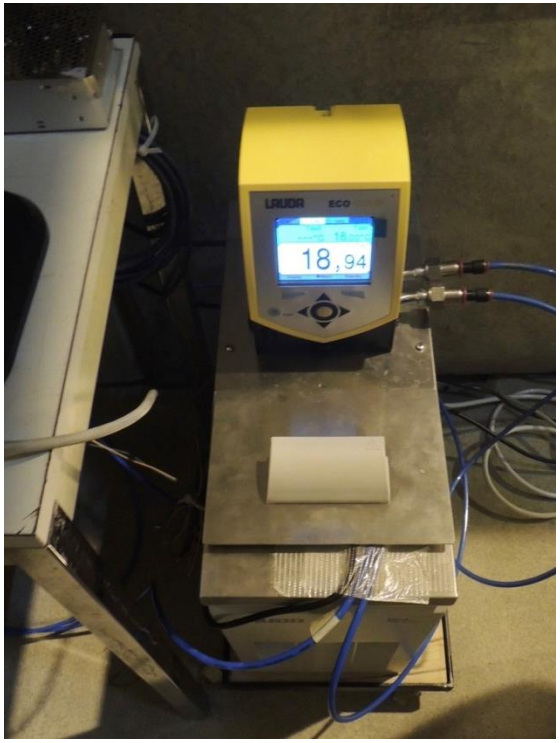

GEM 2


GEM 2

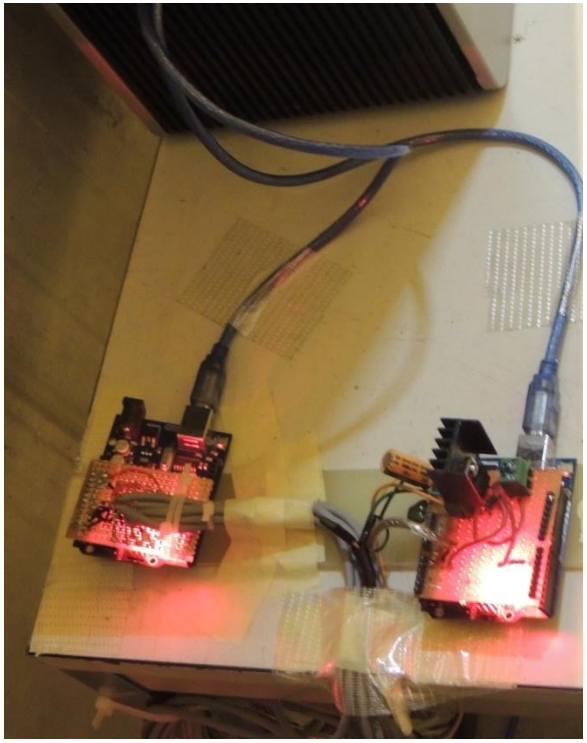
Setup at CERN SPS test beam



Controller with PC

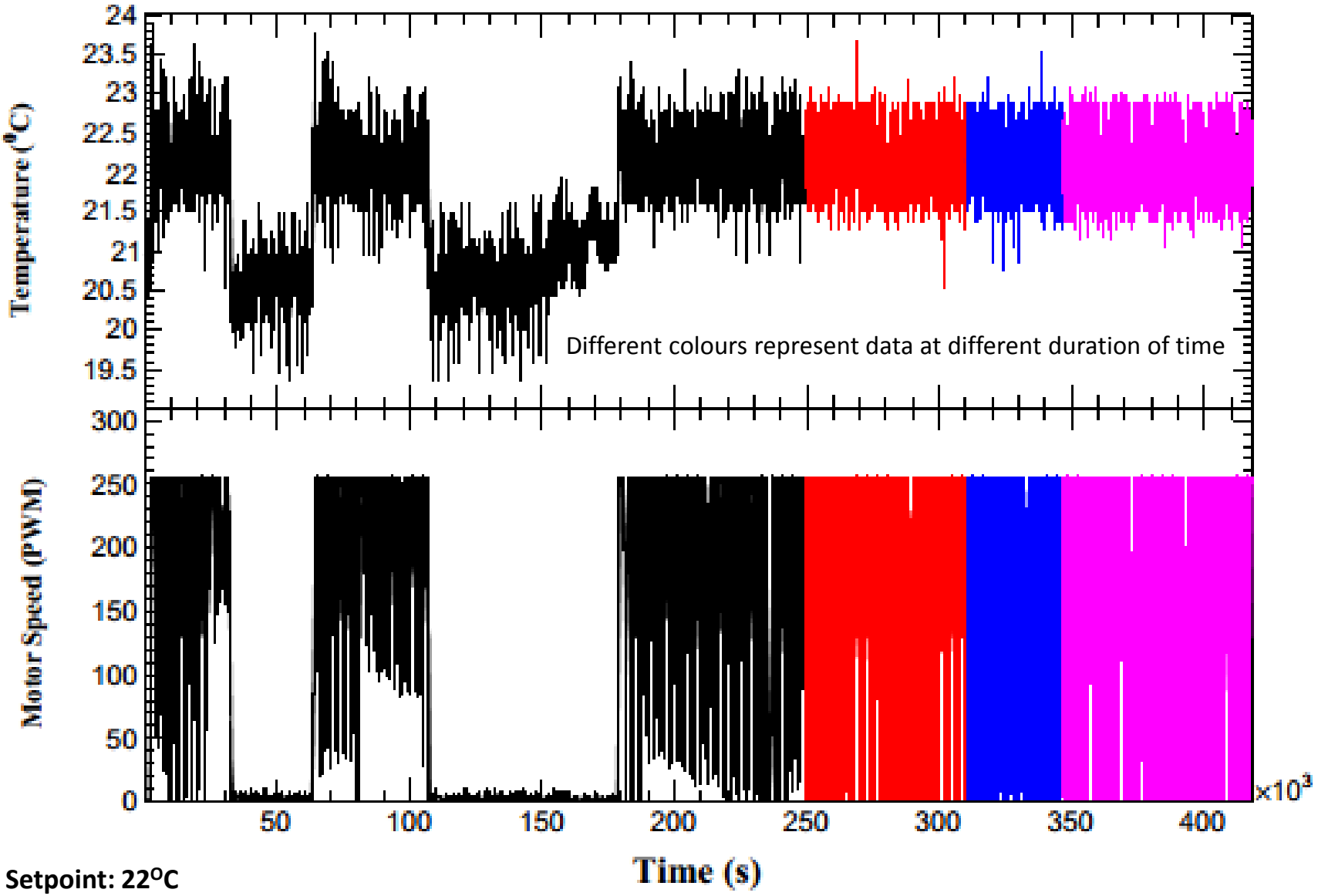


Chiller module



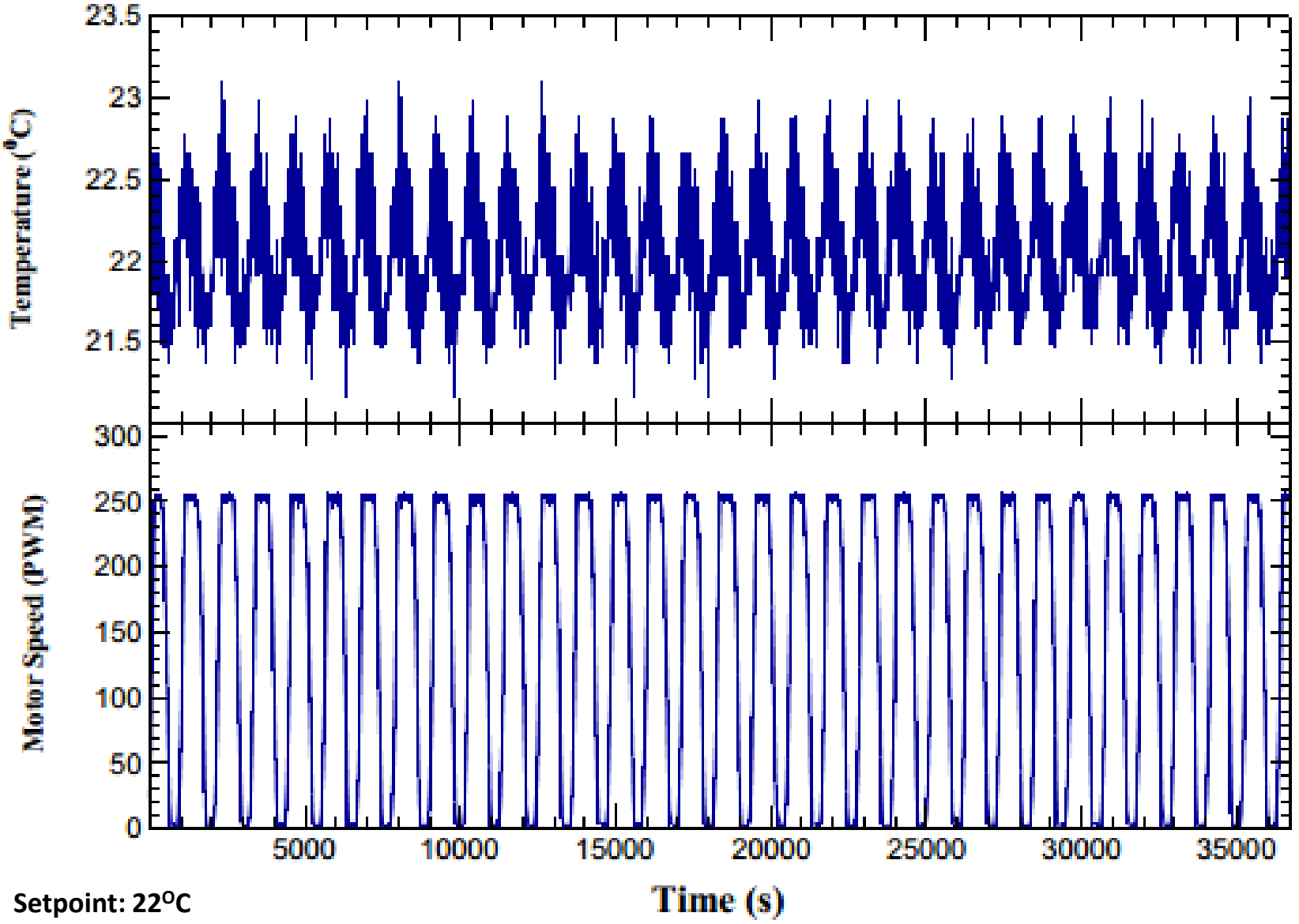
Controllers

Data from SPS Test Beam



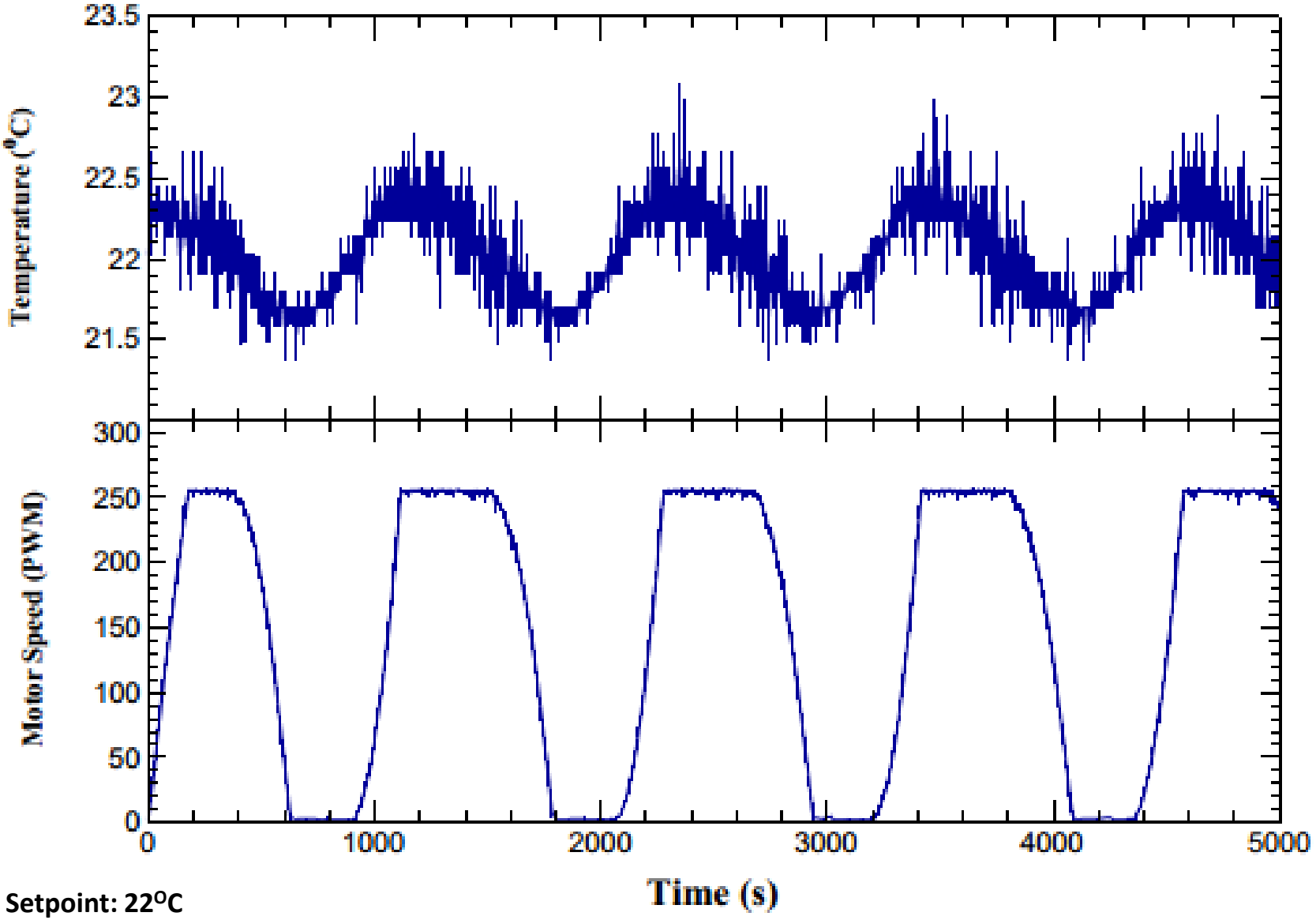
Setpoint: 22°C
Sink Temperature: 12°C

Data from SPS Test Beam



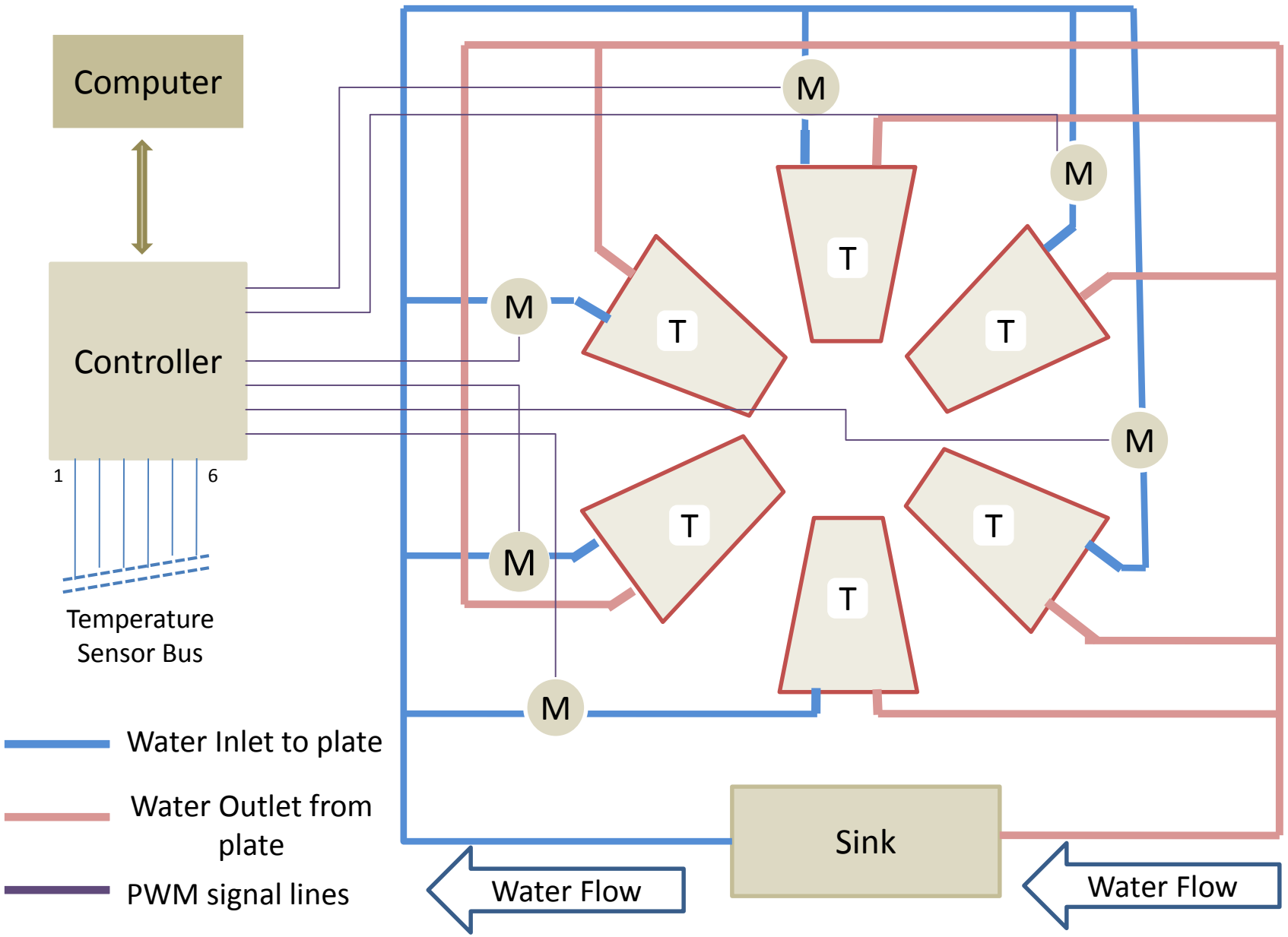
Setpoint: 22^{O}C
Sink Temperature: 12^{O}C

Data from SPS Test Beam - zoomed view



Setpoint: 22°C
Sink Temperature: 12°C

Complete layout for a single sector



Summary

- One micro-controller based Cooling system has been developed.
- The cooling system is successfully used in the test-beam of CBM GEM chamber at CERN-SPS.

Future plan

- To conduct more rigorous tests.
- To equip the system with a leak detection mechanism.
- To develop the system for the real experimental need and to tune the program for less fluctuations.

Acknowledgement

- G. N. S. Murthy (ECIL)
- VECC workshop

Backup slides