# Cooling Analysis of HVMAPS detector for Compton Polarimeter in Hall A of JLab

## 62nd Winter Nuclear & Particle Physics Conference, 2025

Shefali

Kristofer Isaak

Dr. Laheji Muhammad

Dr. Michael Gericke

Nafis Rafat Niloy

Dr. Wouter Deconinck

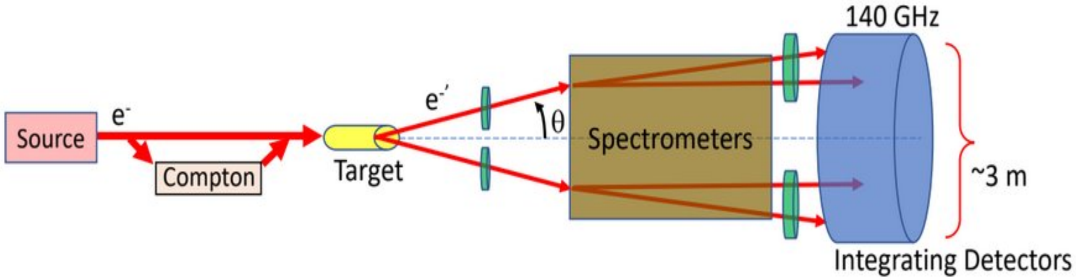
CINP ICPN Canadian Institute of Nuclear Physics
Institut canadien de physique nucléaire

MOLLER

University of Manitoba

# MOLLER (Measurement of Lepton-Lepton Electroweak Reaction) Experiment:

- MOLLER experiment will run at the Thomas Jefferson National Accelerator Facility, Virgina, USA.
- It will use high intensity high energy polarized electron beam.
- The experiment will be located in hall A.
- It is scheduled to commence in 2025-2026.
- MOLLER plans to take a longitudinal polarized beam of electrons, provided by JLab's Continous Electron Beam Accelerator Facility (CEBAF), scattering them off the unpolarised electrons in a liquid hydrogen target.

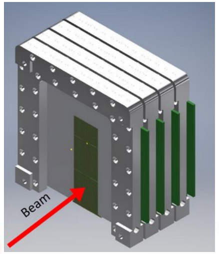


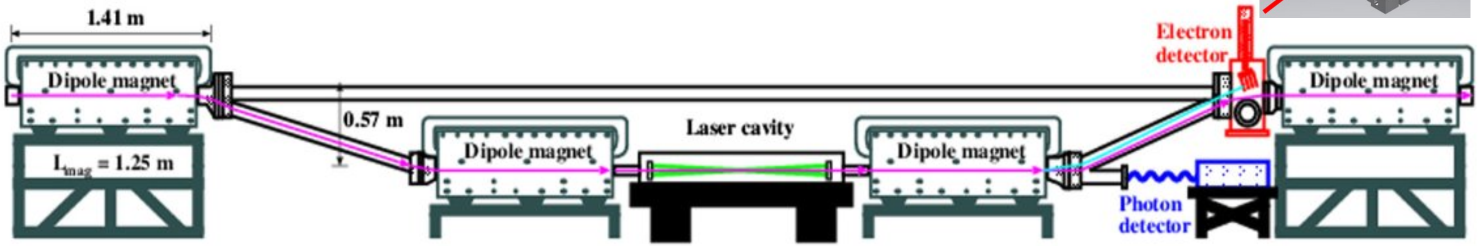

Experimental Setup


Thomas Jefferson National Accelerator Facility (JLab), Newport News, Virginia (USA).

# Compton Polarimeter:

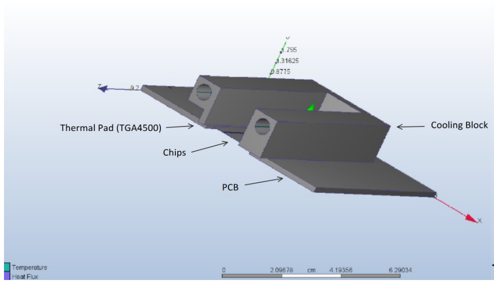
- The Compton Polarimeter is located in a chicane.
- It is about 15 m long.
- Chicane series consists of four dipole magnets.
- Momentum analyzation technique is used to separate the compton scattered electrons.
- The development of silicon pixel detectors on High Voltage Monolithic Active Pixel Sensors (HVMAPS) technology is underway for the electron detector.
- The design includes integration of four pixel detector planes with each plane accommodating 3 (2 X 2 $cm^2$) chips. Each chip operates at 1W and will contain 64,000 (80 X 80 $\mu$m^(2)) silicon pixel diodes (for the current experiment dummy chips have been used and heater is attached to them to deposit 3W of power over the chips).



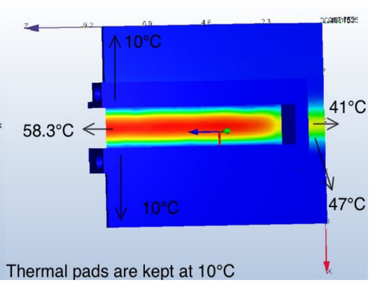



# Cooling Analyses for the models:

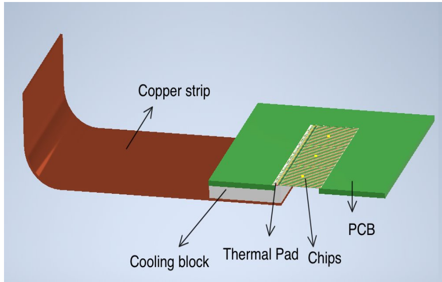
Chips: silicon, Thermal Pad: TG A4500, Cooling block: Aluminum (The CAD models have been modified by **Nafis Rafat Niloy**, PhD student, Department of Physics and Astronomy, the metal core PCB design was suggested and produced by **Dr. Jie Pan,** Postdoc in the MOLLER group.)



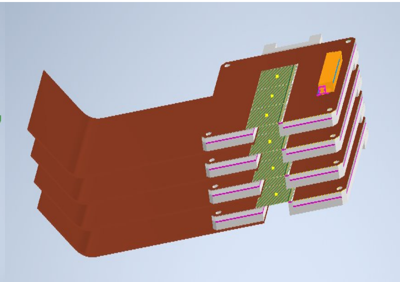

Model 1



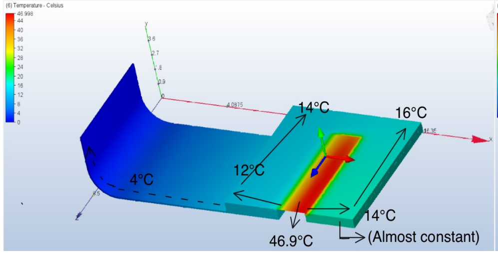

Simulation results from model 1



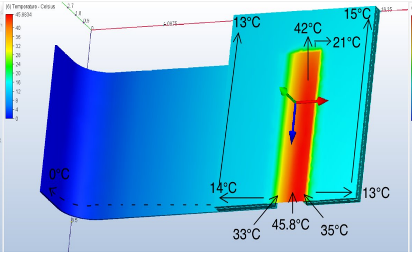

Model 2 with Cooling strip



Model 3 with metal core PCB

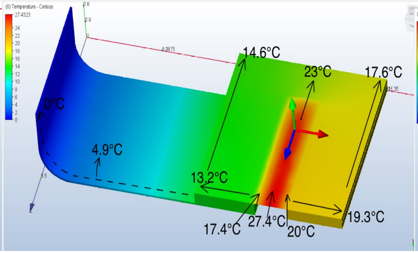



PCB: FR4
Cooling Block: Aluminum

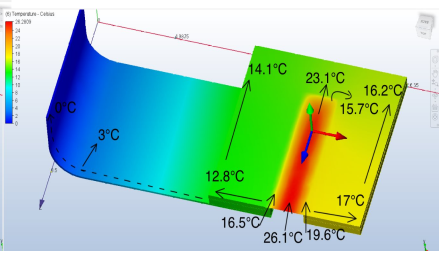



PCB: FR4
Cooling Block: Copper

Simulation results from model 2




PCB: Aluminum
Cooling Block: Aluminum



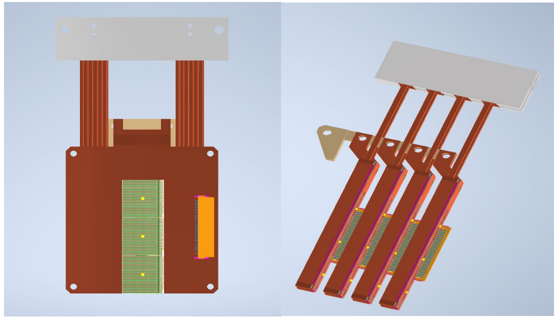

PCB: Aluminum
Cooling Block: Copper

Simulation results from model 3

# Cooling Analyses for the models:

- Cooling block: Copper
- Chips: Silicon
- Thermal Pad: TG A4500
- PCB: Metal Core
- Cooling strip: Copper.
- Thermal block : Aluminum

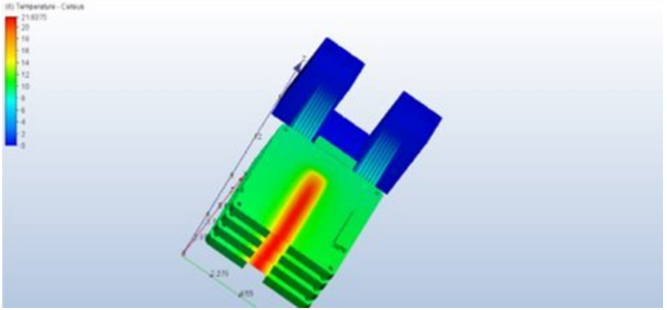
Model 4 with Heat Exchanger



Front View

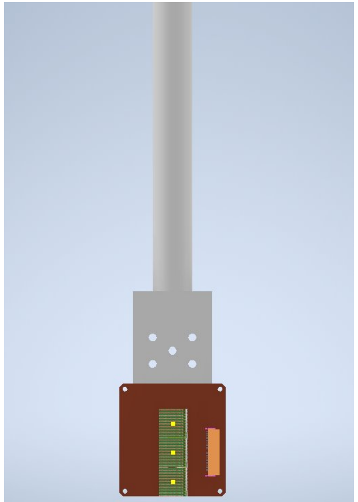
Side View

Simulation Results for Model 4



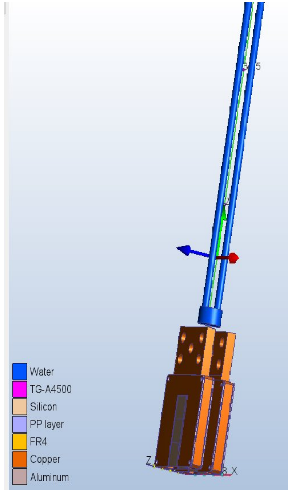
# Cooling solution with new HVMAPS mounting and cooling structure:

Model 5

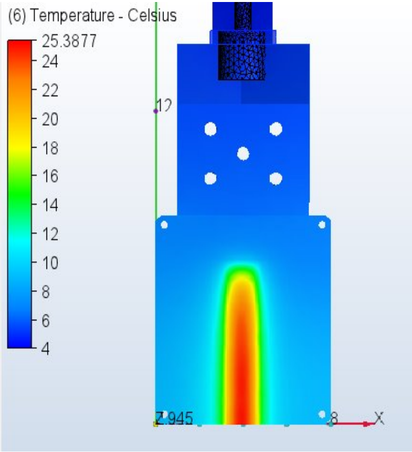


Model 6

Model 6



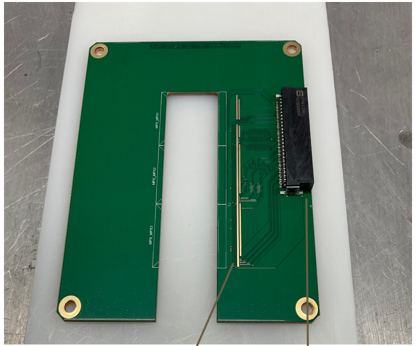

Coolant flow




Simulated Results for Model 6

# PCB, Dummy Chips and other machined parts:

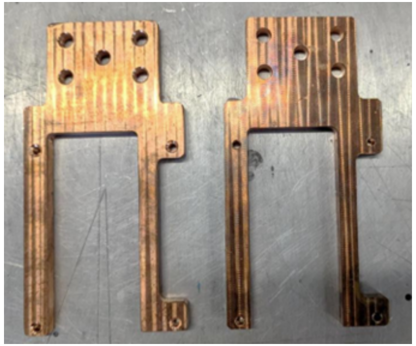
(The parts are machined at the University of Manitoba by an engineer in the MOLLER Group.)



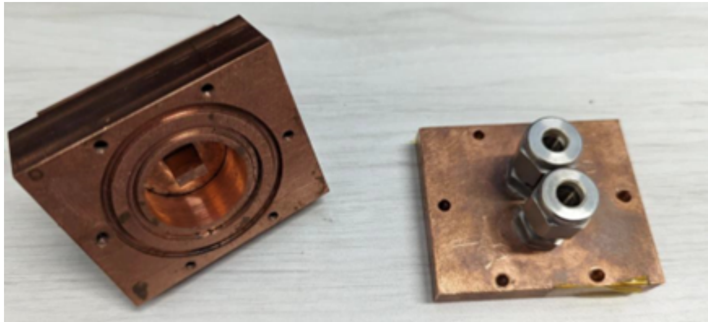
PCB

Readout side of PCB

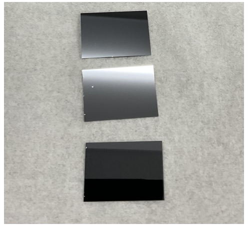
J1 Connector



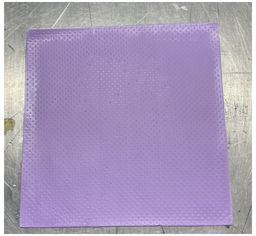
Cooling blocks



Heat Exchanger and coolant feed through system

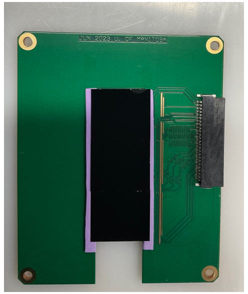


Silicon wafer dummy chips



Thermal Pad

Integrating the parts together

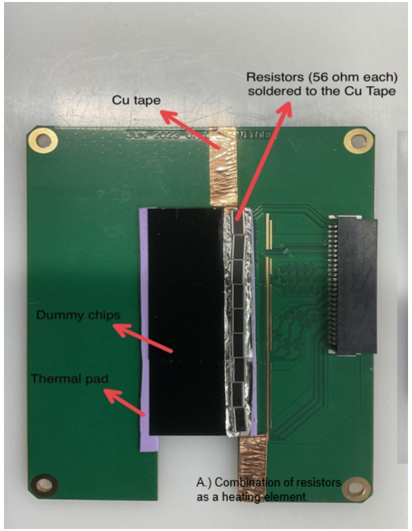


Assembling of chips over PCB

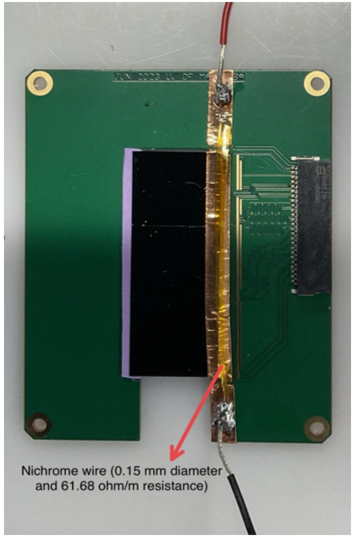
# Dummy HVMAPS assembly with Nichrome wire vs Resistor:

We tried making heating element with two possibilities:

| A.)Combination of resistors as heating element | B.)Nichrome wire as a heating element |
|---|---|
| **Advantages of using Resistors:**<br>a) Properly soldered, so no worry of loose connection.<br>b) Usually have a longer operational life as compared to Nichrome wire<br>(In our short-term setup it would not matter much). | **Advantages of using Nichrome wire:**<br>a) Simple to use(due to its flexibility) and easy to solder.<br>b) Has high electrical resistance, so can dissipate a significant amount of power as heat.<br>c) Fast response time. |
| **Limitations of using Resistors:**<br>a) It is difficult to make a copper trace using tape and stick it onto the chips as one need to lay down copper tape on the delicate chips as traces for the resistors to be soldered on, while this was not required for the nichrome wire.<br>b) The copper tape may have poor adhesion and thermal contact. | **Disadvantages of using Nichrome wire:**<br>a) Secure connection of the wire to the chip is crucial,otherwise it would be difficult to fix once the assembly goes into the vacuum. Thermal epoxy was used to ensure proper heat conduction. |

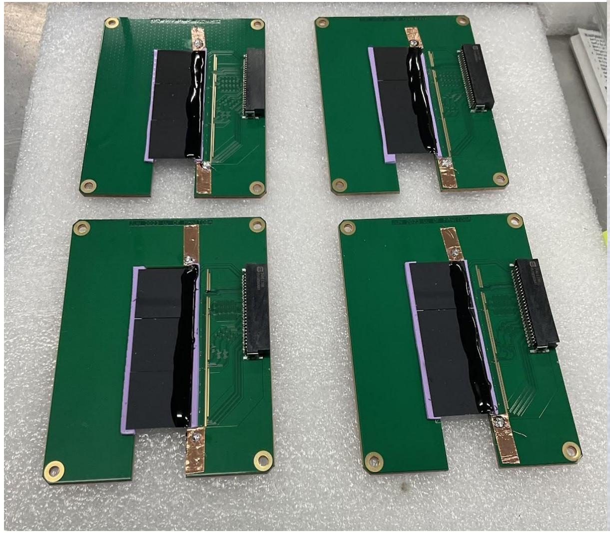


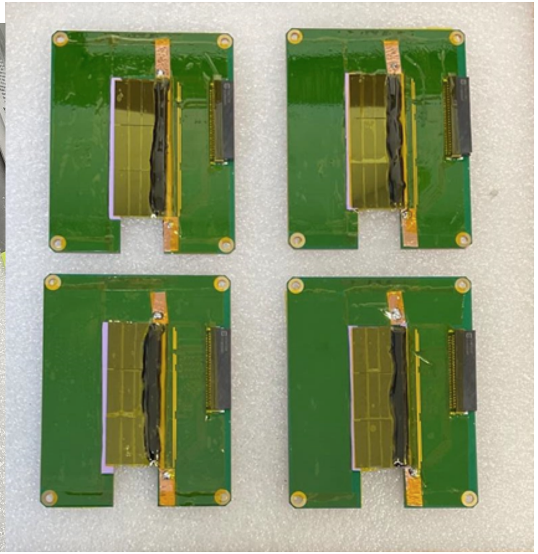

A.) Combination of resistors as a heating element



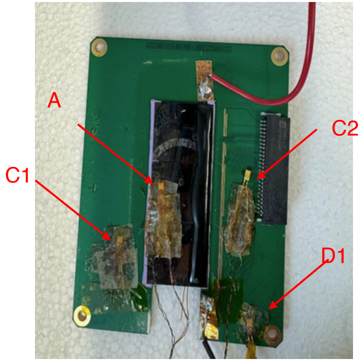

B.) Nichrome wire as a heating element

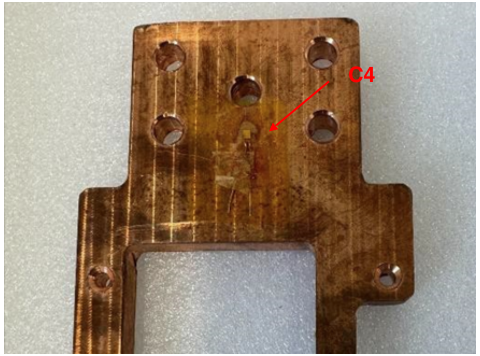
# Nichrome wire final heater assemblies:

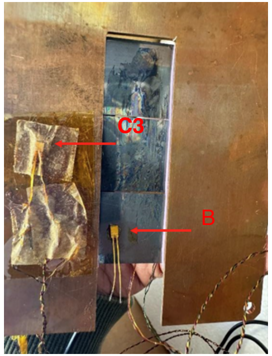


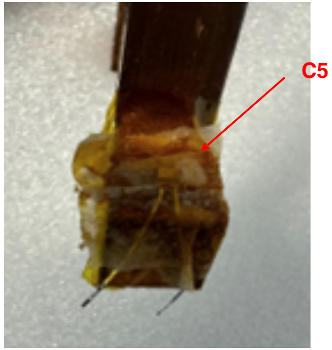


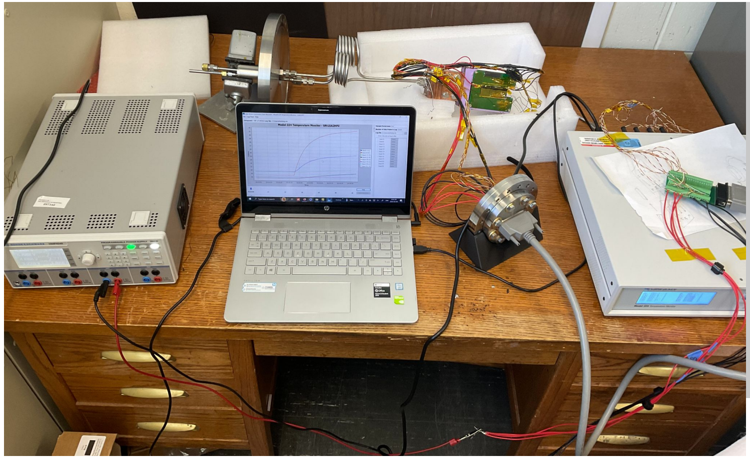
# Temperature measurement with the complete assembly:

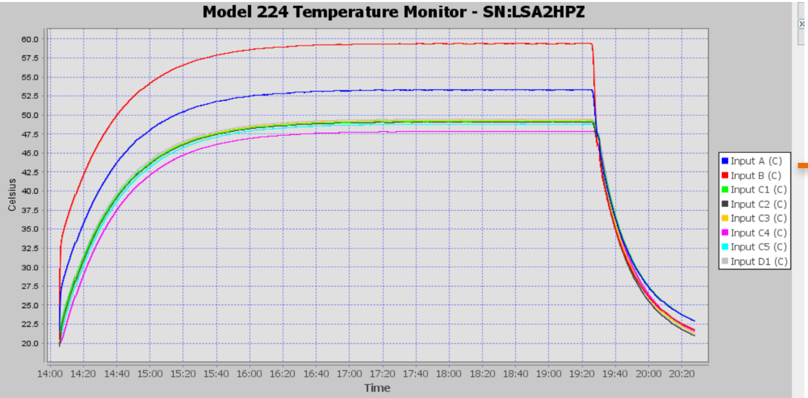




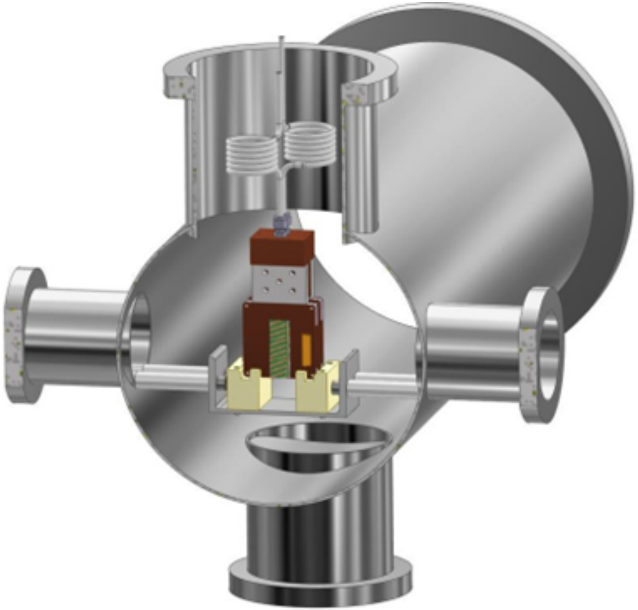

→ With complete intended power supply.

The placement of the sensors/inputs is mentioned in above pictures.

# Vacuum Chamber Assembly

We assembled four e-detector planes using this dummy chip and heater configuration, and place them in the vacuum chamber to assess the heating.

Vacuum chamber existing in UoM, Winnipeg.

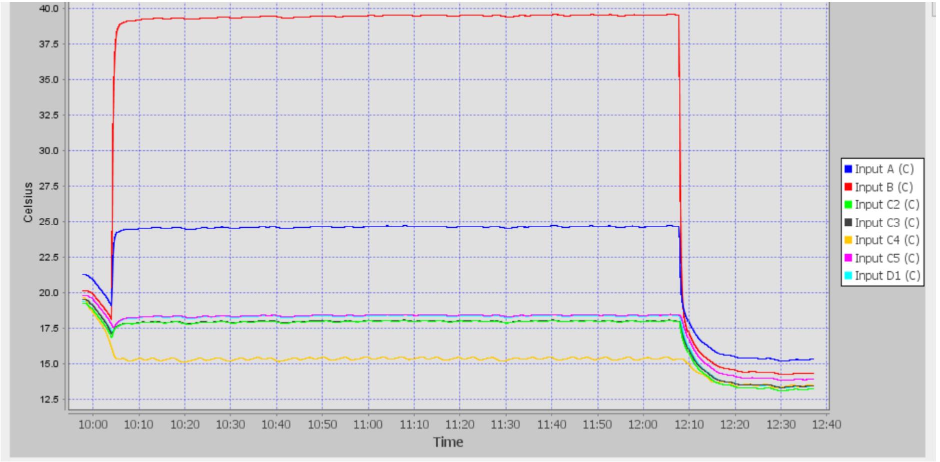


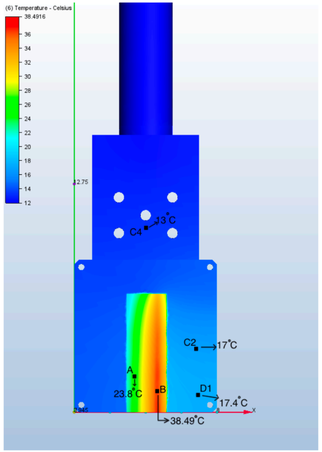
CAD of the vacuum chamber with prototype of e-detector setup placed inside it.

# Comparison of the Lab Measurements with the CFD Simulations:

Our aim is to compare the temperature gradient at various positions of the prototype functioning inside the vacuum with the computationally modeled thermal simulations of the same model.

Power: 12 W , Temperature of the Coolant: 12 degrees Celsius.



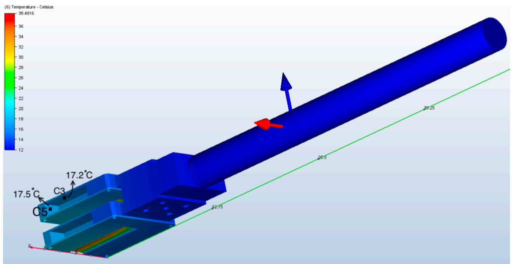




Table 4.3: Comparison of Temperature Results at diffrent Sensors Locations for both the CFD Analysis and Experimental Setup, for this specific Case: Coolant Temperature: 12 °C, Flow Rate: 7.5 L/min, Power per Plane: 3 W.

| Sensor Location | Experimental Results [°C] | CFD Results [°C] |
|---|---|---|
| B | 39 | 38.5 |
| A | 24.5 | 23.8 |
| C2 | 17.5 | 17 |
| C3 | 18 | 17.2 |
| C5 | 18.5 | 17.5 |
| D1 | 18 | 17.4 |
| C4 | 15.3 | 13 |

## Comparison of the Lab Measurements with the CFD Simulations:

| Power(W) | Temp. of the Coolant (°C) | Experimental Results (°C) | CFD Simulation Results (°C) | Difference(ºC) |
|---|---|---|---|---|
| 6 | 4 | 20.8 | 17.3 | 2.8 |
| 6 | 8 | 24.1 | 21.3 | 2.8 |
| 6 | 12 | 27.7 | 25.2 | 2.4 |
| 6 | 16 | 33 | 29.2 | 3.7 |
| 12 | 4 | 33.5 | 30.5 | 3 |
| 12 | 8 | 36 | 34.4 | 1.6 |
| 12 | 12 | 39 | 38.4 | 0.5 |
| 12 | 16 | 47 | 42.5 | 5 |
| 15 | 4 | 43 | 37.1 | 5.9 |
| 15 | 8 | 46 | 41.1 | 4.8 |
| 15 | 12 | 49 | 45.1 | 3.8 |
| 15 | 16 | 55 | 49.1 | 5.9 |

The difference is always less than 6 Degrees Celsius.

All the tests were performed under the supervision of **Laheji Mohammad**, Postdoc in the MOLLER group.

# Conclusion and next steps:

- HV-MAPS are required to perform the measurement with more precision as it provides better spacial resolution and less noise to signal ratio.

- Cooling is necessary for in vacuum operation of these detectors.

- The simulated results performed on CFD are in close to the data collected during Lab tests.

- The next steps are to bond the real HVMAPS chips to the PCB and run the similar tests.

- There is an upcoming POS paper supporting the suitability of this detector design for Hall A of JLab. The proceeding would be available in few weeks.

# Thank You for Listening!

**I am in the process of concluding my Master's at the University of Manitoba, I'm open to future opportunities. Contact: prabhak2@myumanitoba.ca**