INTEREST JINR PROJECT

Wave 5

Simulation of the cooling system for the RACK cabinet

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Abstract

This report discusses and assesses the heat transfer simulations of the RACK cabinet. Simple 3D CAD models were made using Autodesk Inventor and Heat transfer simulations were performed on them to have a better understanding of the thermal properties of the materials to be used in the NICA-MPD facility. This project has two phases, - a heat transfer simulation performed on a PCB unit along with the designing of a simple CAD replica of the RACK cabinet of the NICA-MPD-Platform & Discussing the results of the simulation, conclusions & suggesting some recommendations.

Introduction

Nuclear energy and Nuclear science is one of the most, if not the most important source for energy in our world. Nuclear science is by far the greatest discovery of modern science. It has shaped the society into what it is today. Nuclear fusion, in which two atoms are collided to release a great amount of energy requires a nuclear collider. Nuclear collider is a research tool in which two opposing particle beams are accelerated so that they collide together. The analysis of the by-products of such collusion helps the scientists to study and understand more the structure of the subatomic world and the laws governing it.
The world's largest collider is the Large Hadron Collider built by CERN where over 10,000 scientists and hundreds of universities and laboratories from more than 100 countries are collaborating in it.
NICA stands for (**N**uclotron-based **I**on **C**ollider f**A**cility) which is built at Joint Institute for Nuclear Research (JINR) to study the properties of dense baryonic matter which will help the scientists to study more and understand the Quark-Gluon Plasma state on which our Universe stayed shortly after the Big-Bang.

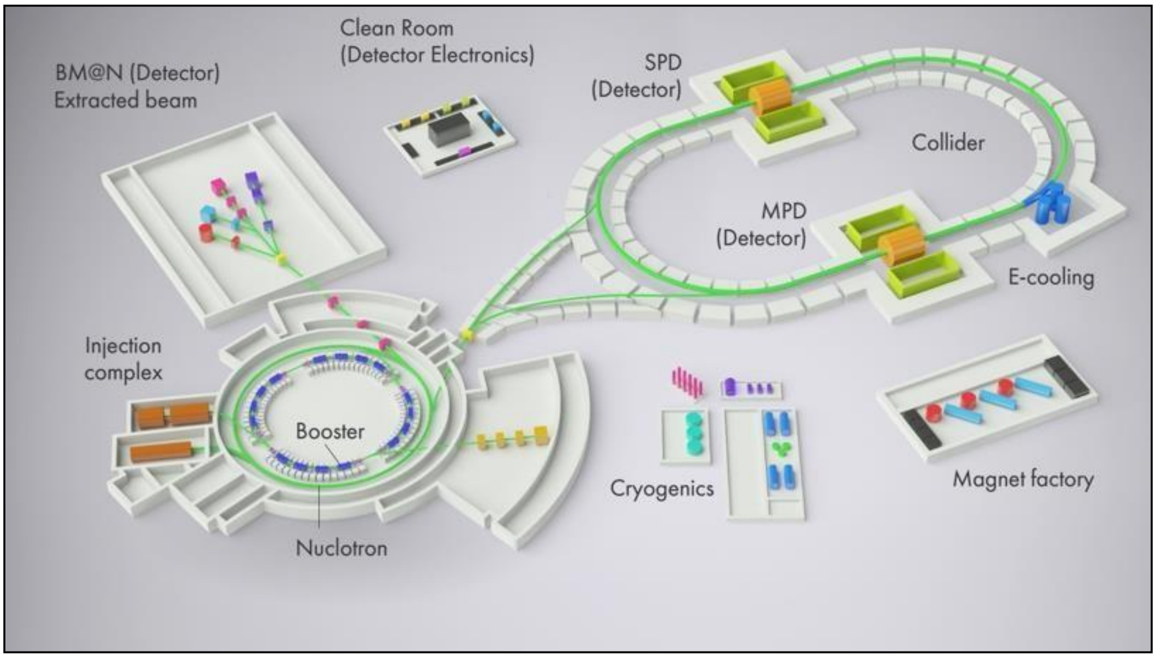

Figure 1 NICA Scheme

The Multipurpose Detector (NICA-MPD) platform's RACK cabinet is a structure housing highly sensitive electronic equipment whose main function is to analyse and interpret the data recorded by the particle accelerator.

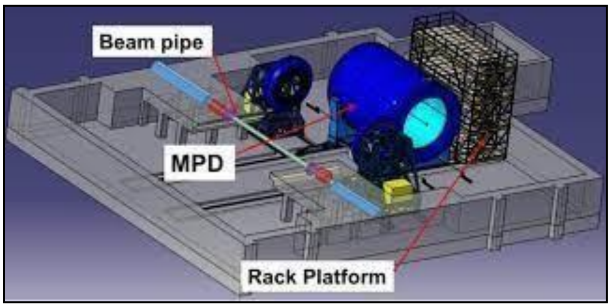

Figure 2 Scheme of MPD platform

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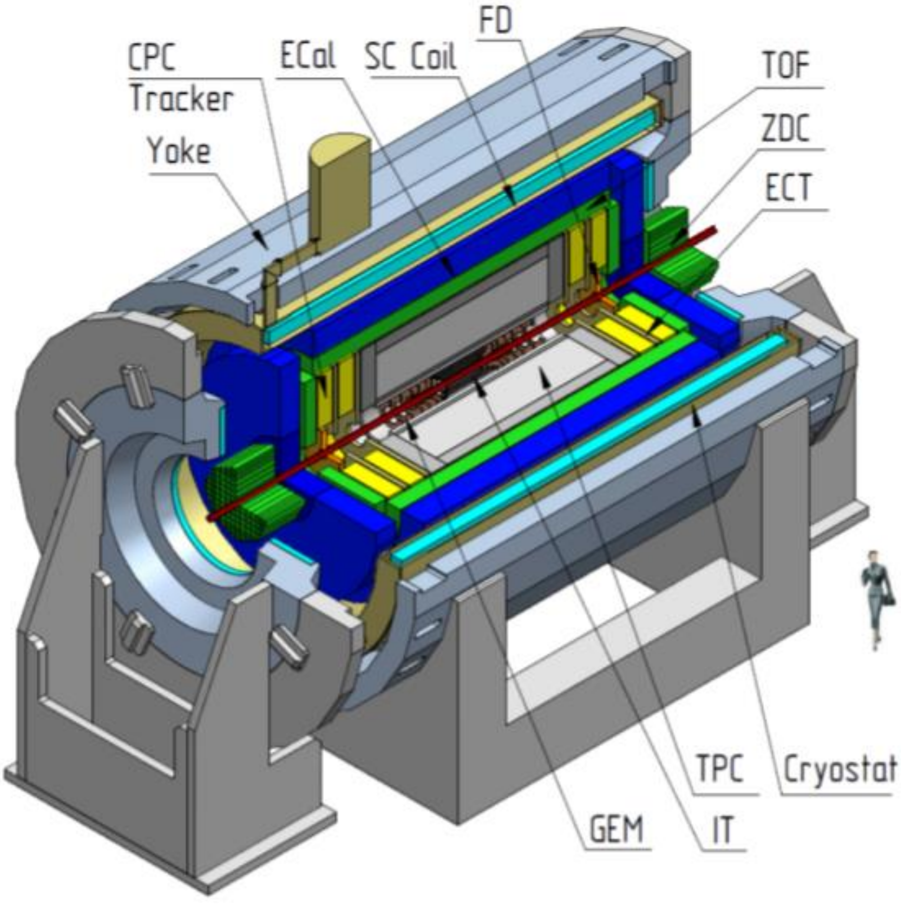


Figure of The multipurpose detector

Part 2 Design and Simulation Steps

CAD Design

To study the thermal behaviour around the PCB unit, first we need to draw a simple 3D module for it using Autodesk Inventor 2021, A CAD model was first prepared using the Autodesk Inventor Professional 2021 software using the technical documents (Appendix A). The model structure was simplified

PCB unit contents:

1. PCB with a Silicon Chip having a power output of 40W
2. MC20 Heatsink
3. ComairRotron Fan

Dimensions- ,PCB- Printed Circuit Board (100X50X3), Chip (25X25X4),Heat sink (29X29X42), Fan (50X15X50 + R22)

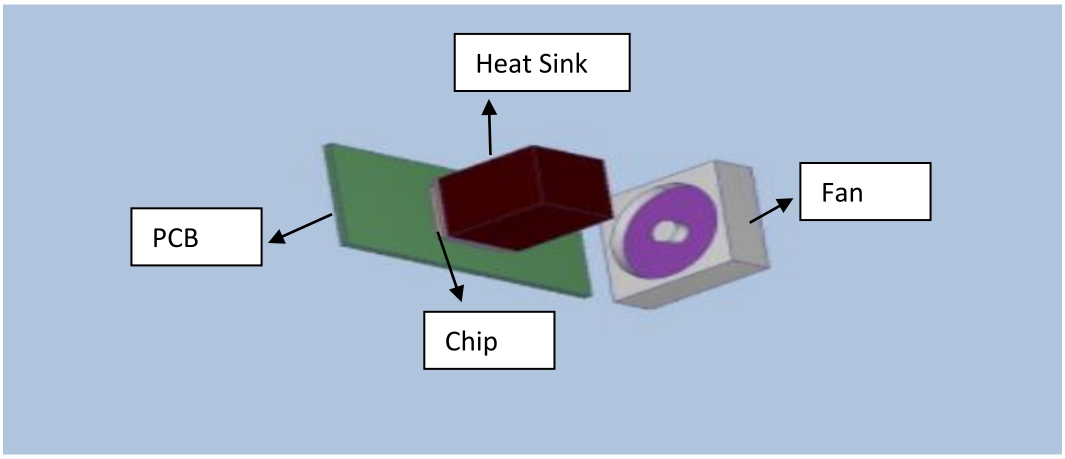
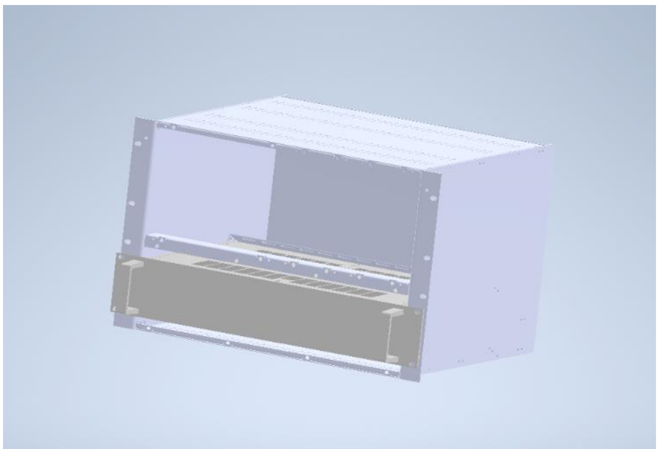


Figure 5 The 3D module of PCB unit

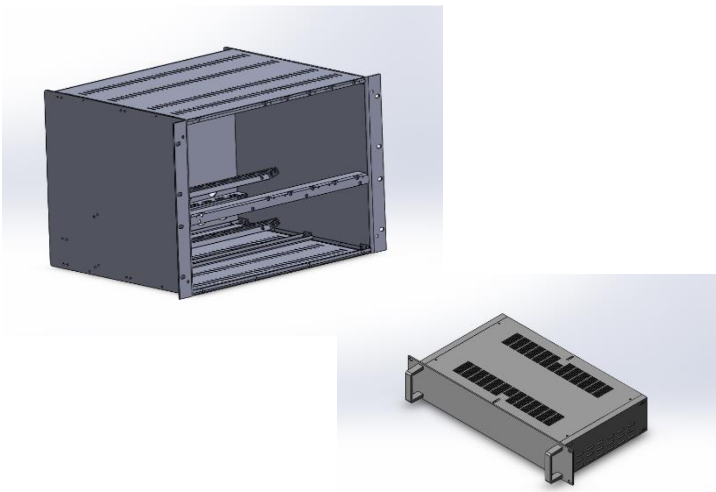
Modelling of EASY 3000Crate & Fan unit

<u>Main Parts of the Crate unit:</u>

1- Fan Box (NIM8304 fan unit)
2- EASY 300O CRATE



EASY3000 CREATE WITH FAN MODULE ASSEMBLED



EASY 3000 CRATE AND FAN MODULE SEPERATELY

CFD Analysis

To start the CFD analysis, we first need to specify the material for each part, Boundary conditions, and Mesh which will be discussed in this section.

Materials

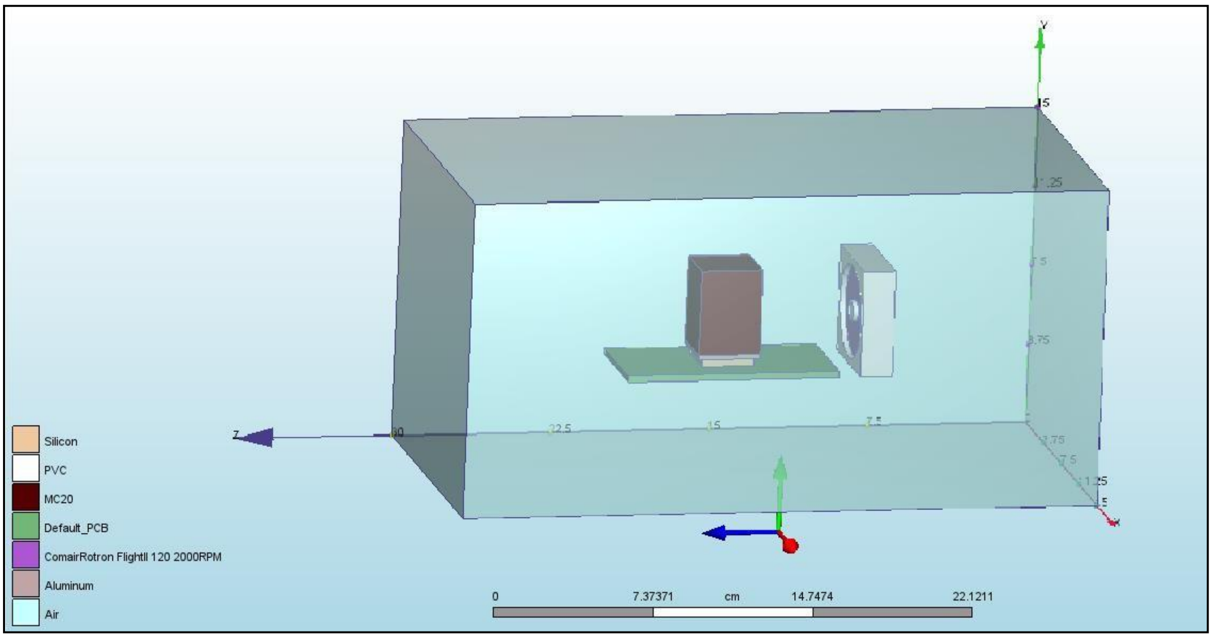


Figure 6 The PCB Unit inside the Control Volume

Different materials have been specified for each part depending on its nature as follows:

COMPONENT	*MATERIAL ASSIGNED*
1. Control Volume	Air.
2. ComairRotron cooling Fan	The fan's case and hub are assigned as PVC, whereas the fan blades are assigned default Internal cooling fan material with a rotating speed of 2000 RPM in Z-direction (0,0,1).
3. MC20 Heat Sink	Default Heat sink material with; Approach surface = 16 and Base surface = 8.
4. Heat sink Base	Aluminium.
5. Chip	Silicon.
6. PCB	Default Printed Circuit Board material.

Table 1

Boundary Conditions

The boundary conditions are used to identify the surrounding conditions that our module will be working at. In our module, three main parameters are considered:

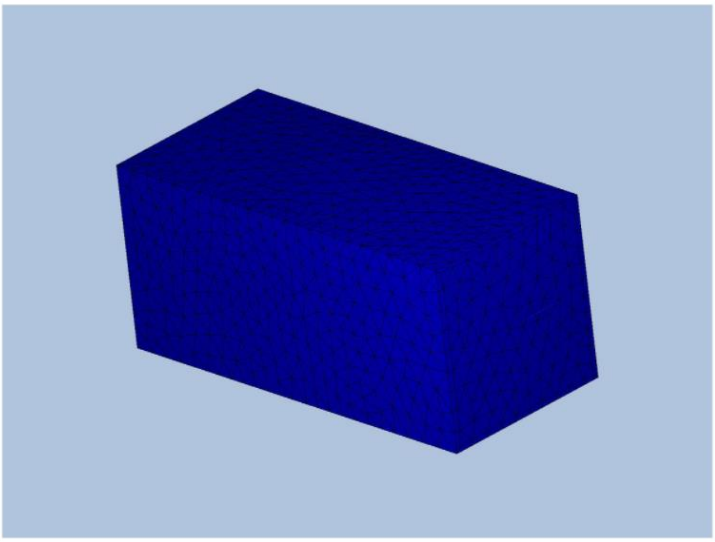
Condition	*Assigned To*
1. Total Heat Generation	A steady state heat generation of 40 W was assigned for the chip
2. Pressure	A pressure of 0 Pa (P= 0 Pa) was assigned to the front and back sides of the Control volume.
3. Temperature	A temperature of 20°C (T= 20 °C) was assigned to the other four lateral sides of the Control volume.

Table 2

MESH

Thanks to Autodesk CFD software, the mesh was sized automatically without much effort

Meshed Model



Number of Nodes	14931
Number of Elements	70892

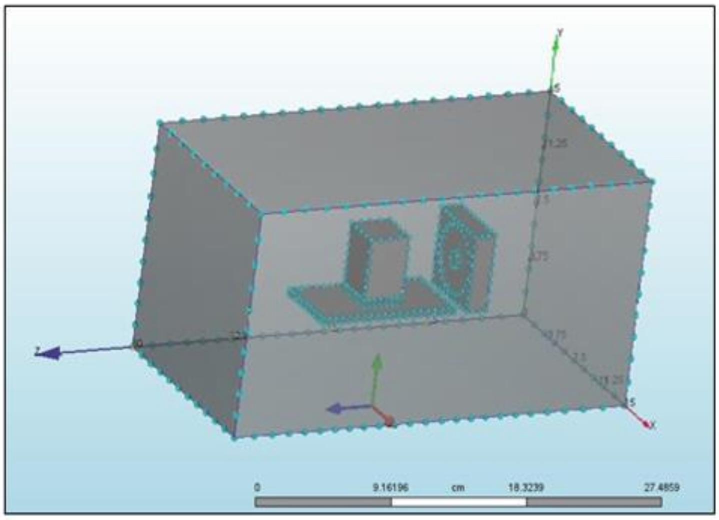


Figure 8 Auto-sized Mesh

Automatic Meshing Settings

Surface refinement	0
Gap refinement	1
Resolution factor	1.0
Edge growth rate	1.1
Minimum points on edge	2
Points on longest edge	10
Surface limiting aspect ratio	20
Refinement length	0.19615045245933033
Fluid gap elements	1.0
Thin solid elements	0.2

Results, Conclusion, and Recommendations

An analysis for the incompressible steady state flow with heat transfer factor was conducted using 300 iterations. In our case, we will focus more on the temperature since our task is to study the instability issues appearing in the module.

Results

Convergence Plot

We can see the convergence plot of the Temperature. The heat is generated by 20 watts from the chip which appears in the high error value in the beginning and after a while gradually decreases to value of 0.762 at the 300th iterations. There is a gradient in temperature which corresponds with the colour bar. In the given heat maps, we can see a higher temperature value on the Chip and the PCB since they are sources for heat generation. Additionally, similar behaviour can be noticed on the PCB, where the side facing the fan has a relative lower temperature than the other side which is a bit far from the fan behind the heat sink

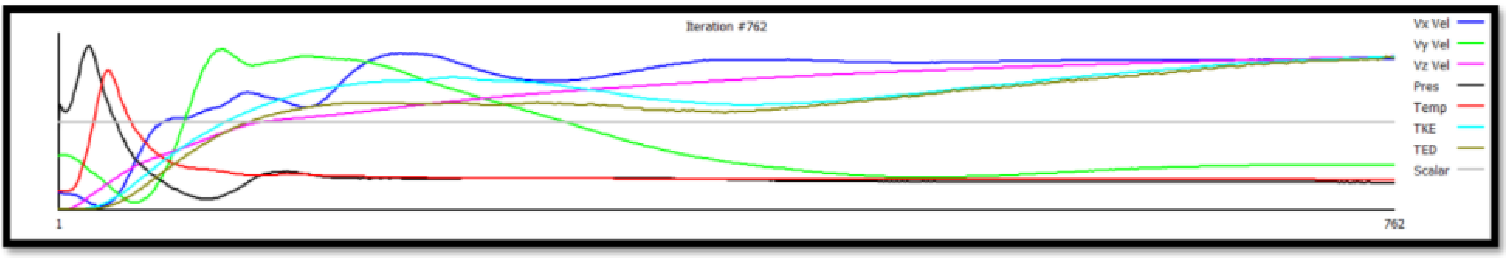


Figure 9 Convergence plot with 300 iterations

Temperature magnitudes

Different shots for the temperature are illustrated in this section to see the temperature effect on the module. As shown, there is a gradient in temperature which correlates with the colors bar. In Fig.10 ,11 and 12, a higher temperature value on the Chip and the PCB is noticed since they are sources for heat generation, also in the front of the heat sink (fig.11) there is no increase in temperature due to well cooling, while we can see a relative increase in the temperature on its rear side.

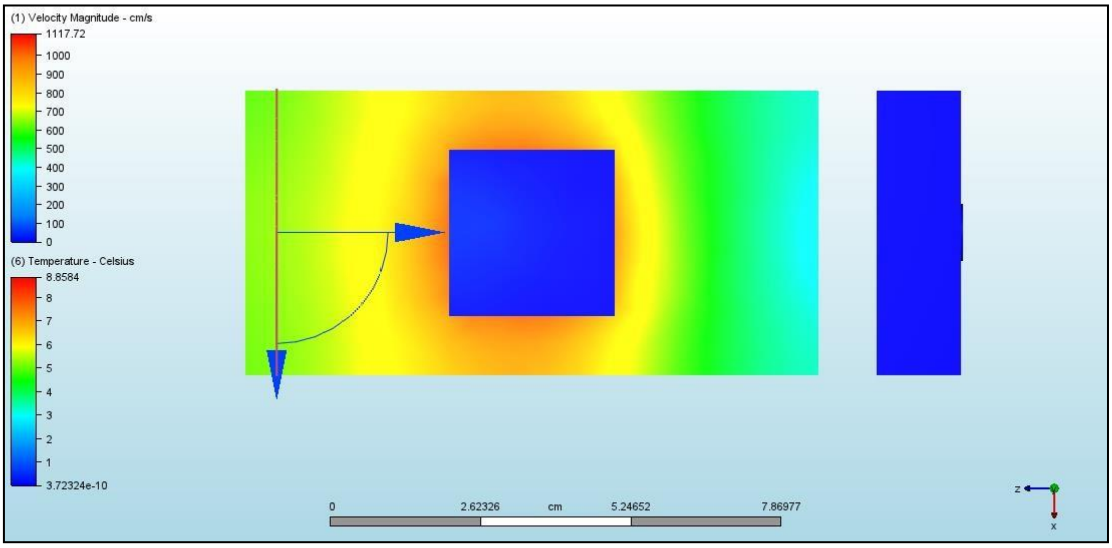


Figure 10 Temperature magnitude (Plane view)

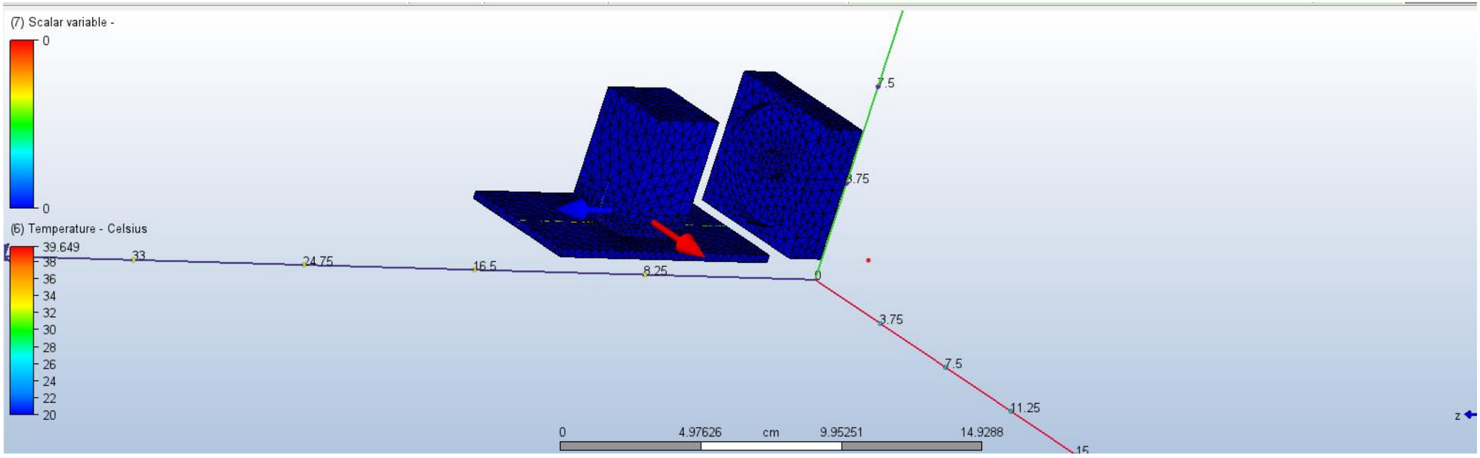
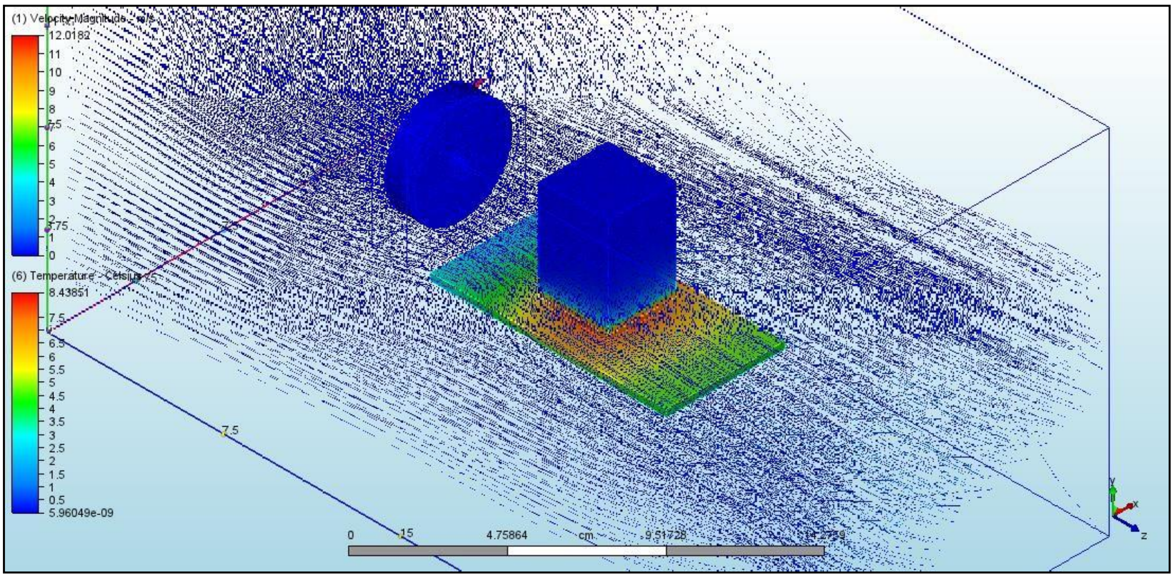
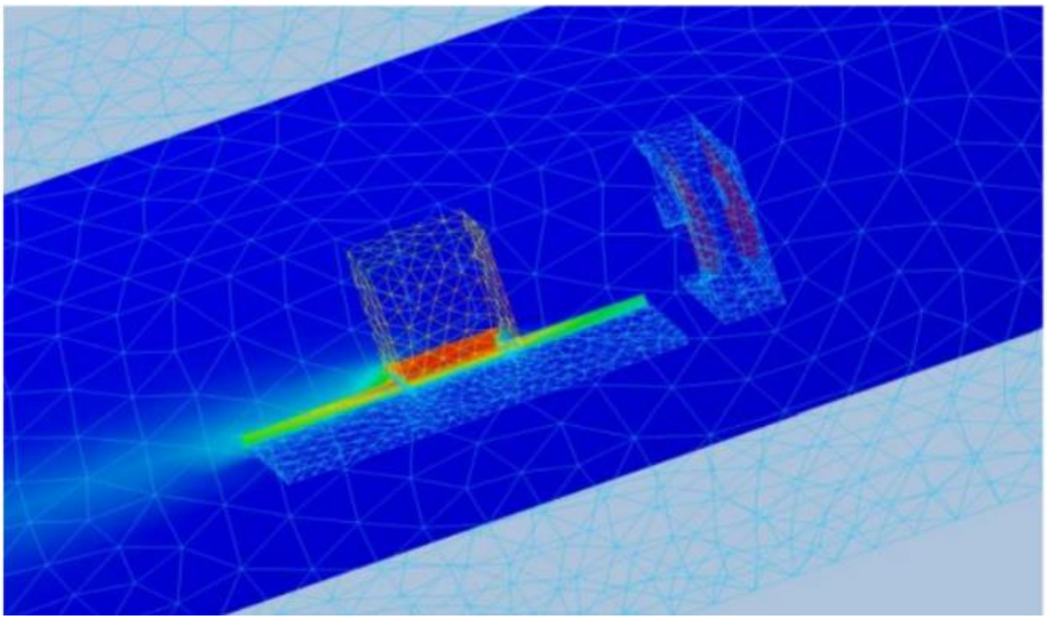


Figure 11 Temperature magnitude (Side view)





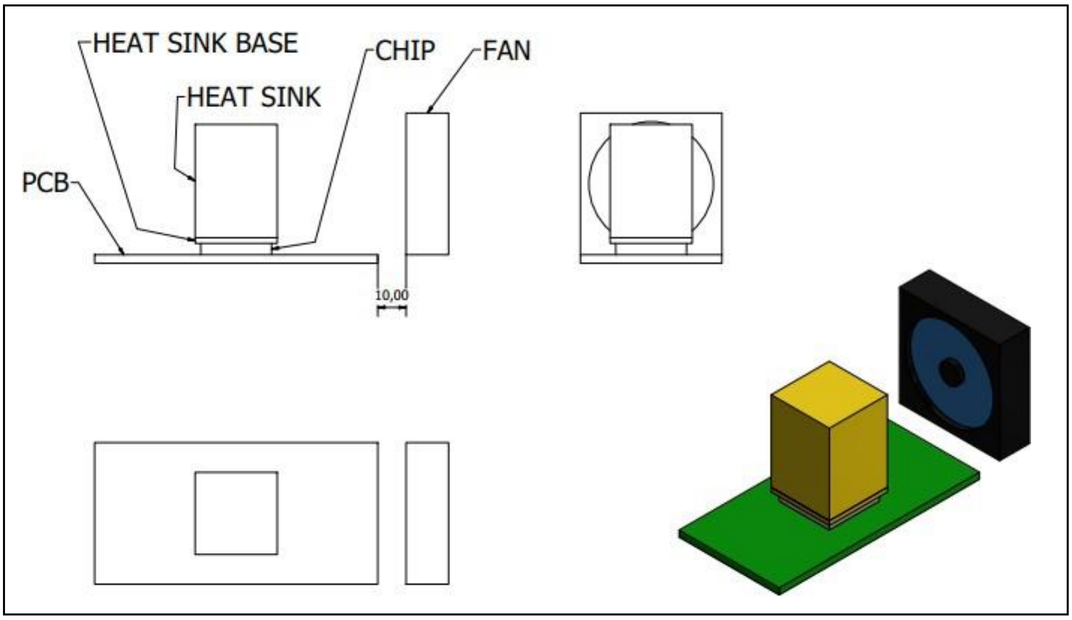
Conclusion

From the previous analysis we notice that the major instability issues of temperature appear mainly from the chip, and the PCB especially the rear side behind the heat sink. The instabilities increase in the middle of the PCB where heat generation from it meet with the heat generated from the Chip. So, these sections need a better circulation for the air flow for better cooling.

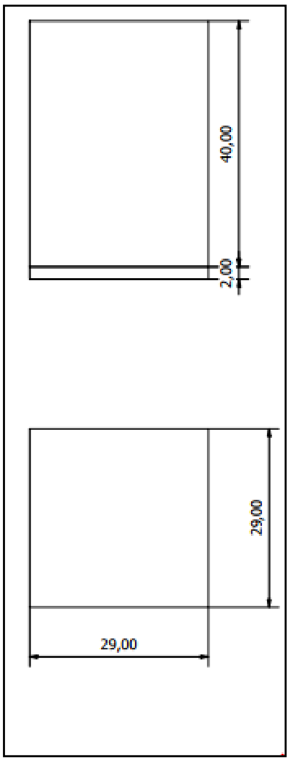
(III)Further recommendations

My further recommendation is to use a different of two fans of the same/smaller size on the opposite side for cross ventilation.

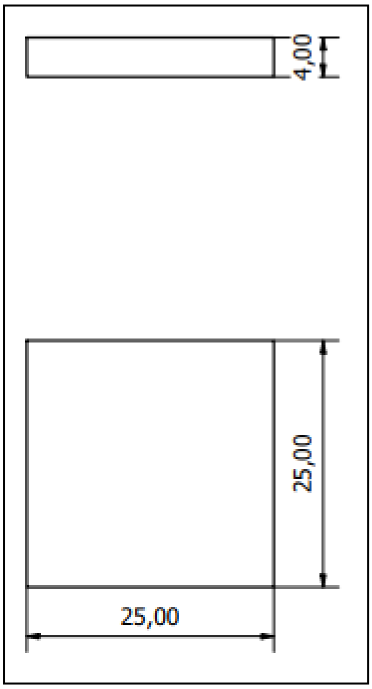
Appendix



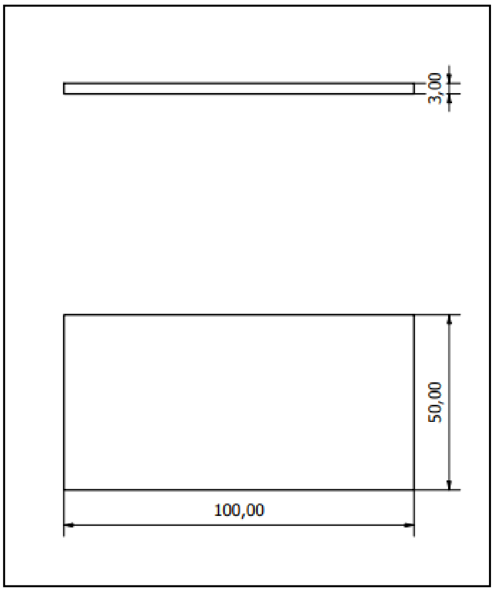
3D Module



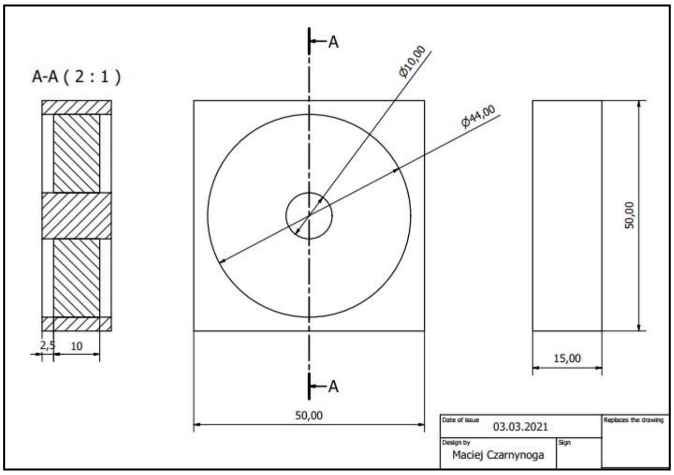
Heat Sink



Chip



PCB



Fan unit

References

- [1]: https://en.wikipedia.org/wiki/Collider
- [2]: https://en.wikipedia.org/wiki/Large_Hadron_Collider
- [3]: https://nica.jinr.ru/