INTEREST JINR PROJECT

Wave 5

Simulation of the cooling system for the RACK cabinet

Supervisor:

Mr Maciej Czarnynoga

Veksler and Baldin Laboratory of High Energy Physics

czarnynoga@jinr.ru

Intern Researcher:

Diaaeldien Ahmed Behary

MSc. Power Plant Engineering, SPBPU

diaabehari@gmail.com

November 2021

Abstract

This report discusses a heat transfer simulation for the RACK cabinet. To perform such a study, we drew a 3D module for the PCB unit and the cooling unit of CAEN 3000 using Autodesk Inventor 2021 and the simulation using Autodesk CFD 2021. The report consists of three main parts; The 1st part contains an Introduction and information about the NICA-MPD-Platform project. The 2nd part shows the design and simulation steps. The 3rd part consists of the Results, conclusion, and further recommendations. Finally, we added a follow-up attachment containing some information about CAEN EASY3000 and the detailed drawing for the PCB.

Table of Contents

Introduction

Throughout history Man was trying to understand its surroundings and to find ways to use them for his comfort and progress. One of those new discoveries that he reached was the split of atoms in what is called Nuclear Fission and his benefit from the enormous amount of energy that released from it in peaceful ways as a source of Energy. Another way that he reached in his journey was the nuclear fusion, where 2 atoms are Impacted/ collided together to generate rather more energy than that released from the Fission, that's why he needed 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.[1]
The world's biggest and most famous 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 [2], however in many other different countries relatively smaller-scale colliders are also built for research purposes for example in NICA in Dubna, Russia.
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.

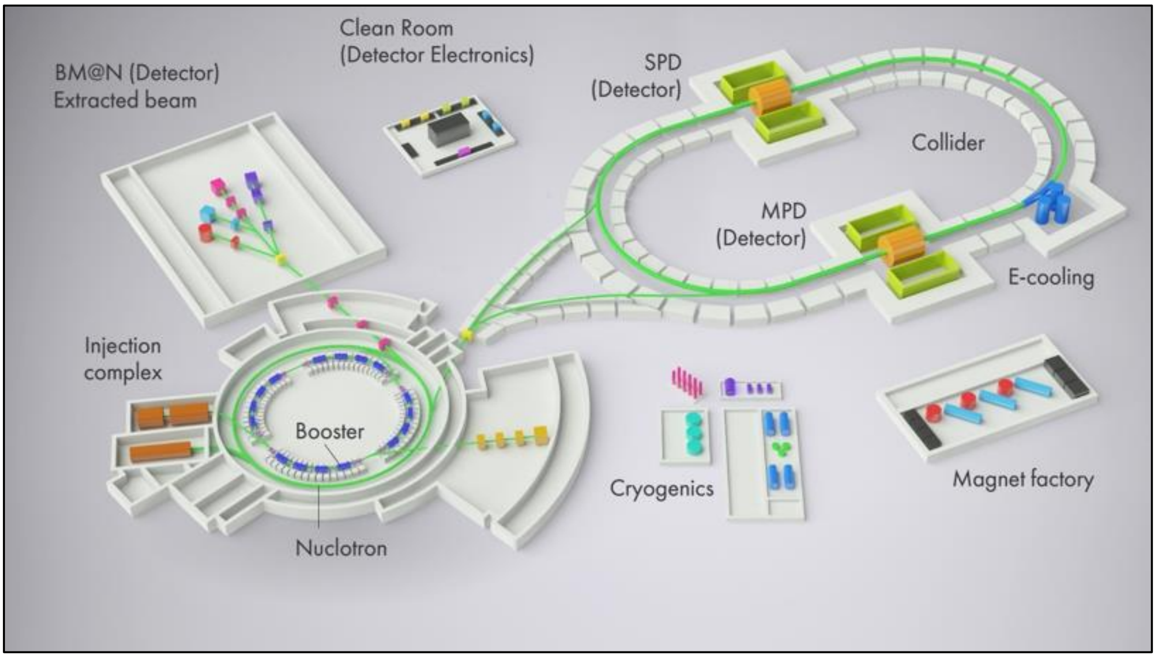


Figure 1 NICA Scheme

In this report we performed a simulation on the cooling unit of the RACK cabinet in the Multi-Purpose Detector (MPD) that can be found in Fig.1. Such simulation was made to study the temperature and flow behaviours around the PCB unit and to notice where the thermal instability issues appear. Also, the parts of Power supply CAEN EASY3000 were separated between the participants, and my task was to draw a simple 3D module for its Fan unit.

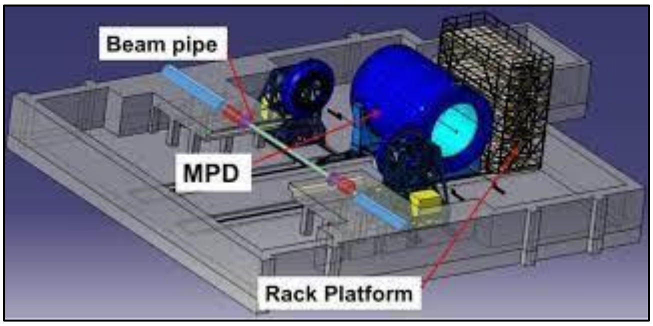


Figure 2 Scheme of MPD platform

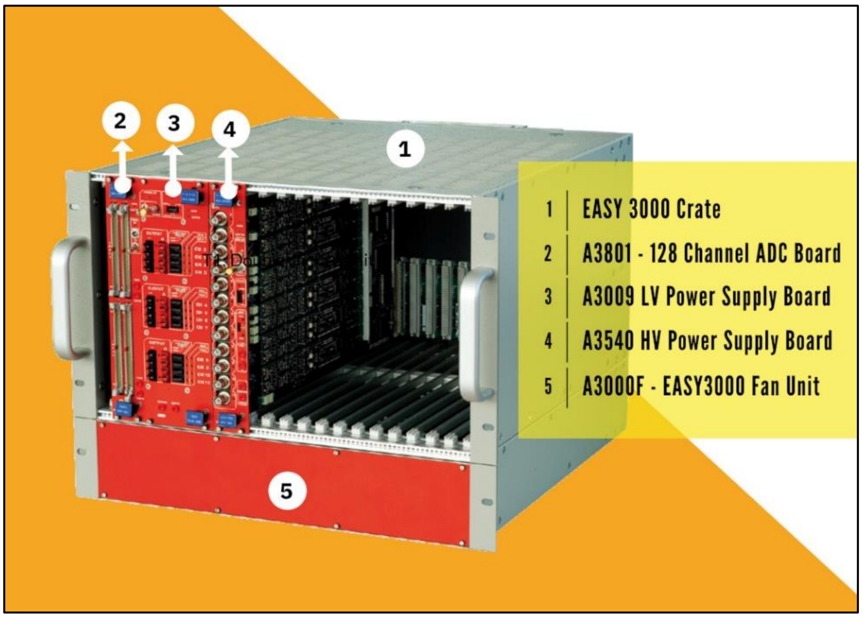


Figure 3 EASY 3000 Crate

Part 2 Design and Simulation Steps

2.1 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, the detailed dimension for each part can be found in the attachments.

2.1.1 Modelling of PCB unit

<u>Main parts of the PCB unit</u>

1- PCB- Printed Circuit Board (100X50X3)
2- Chip (25X25X4)
3- Heat sink (29X29X42)
4- Fan (50X15X50 + R22)

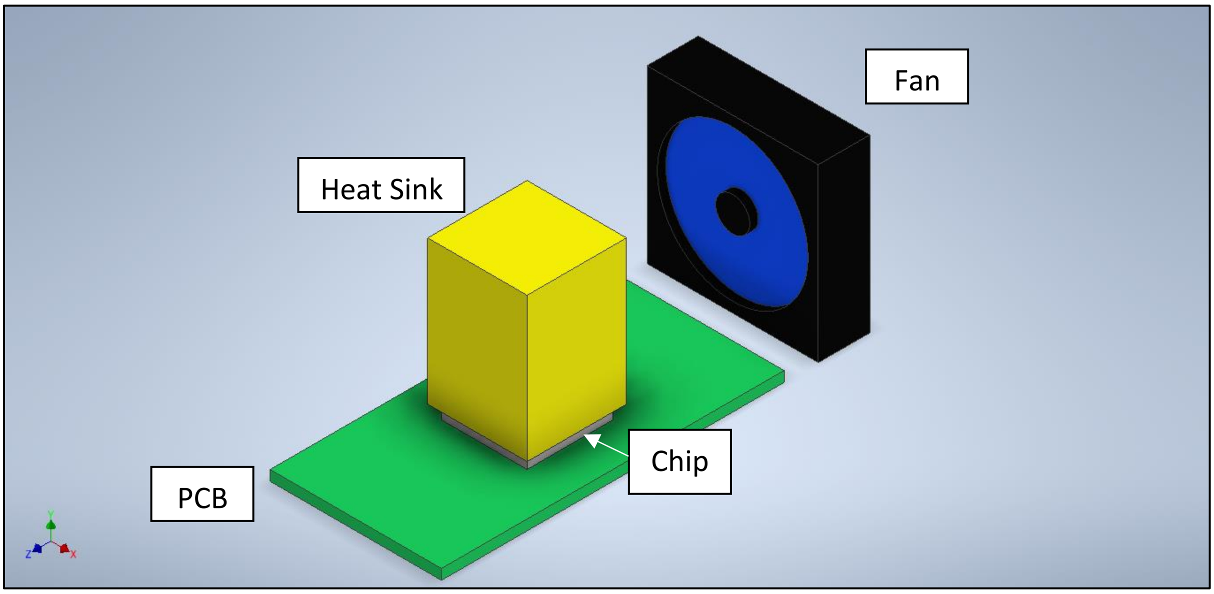


Figure 5 The 3D module of PCB unit

2.1.2 Modelling of EASY 3000 Fan unit

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

1- Fan base (240X150X30)
2- 6 Fans (50X50X15+R22)

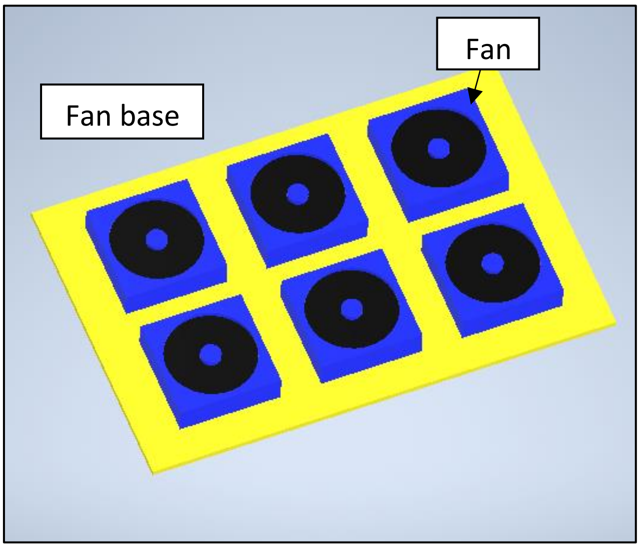


Figure 4 EASY 3000 Fan unit

2.2 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.

2.2.1 Materials

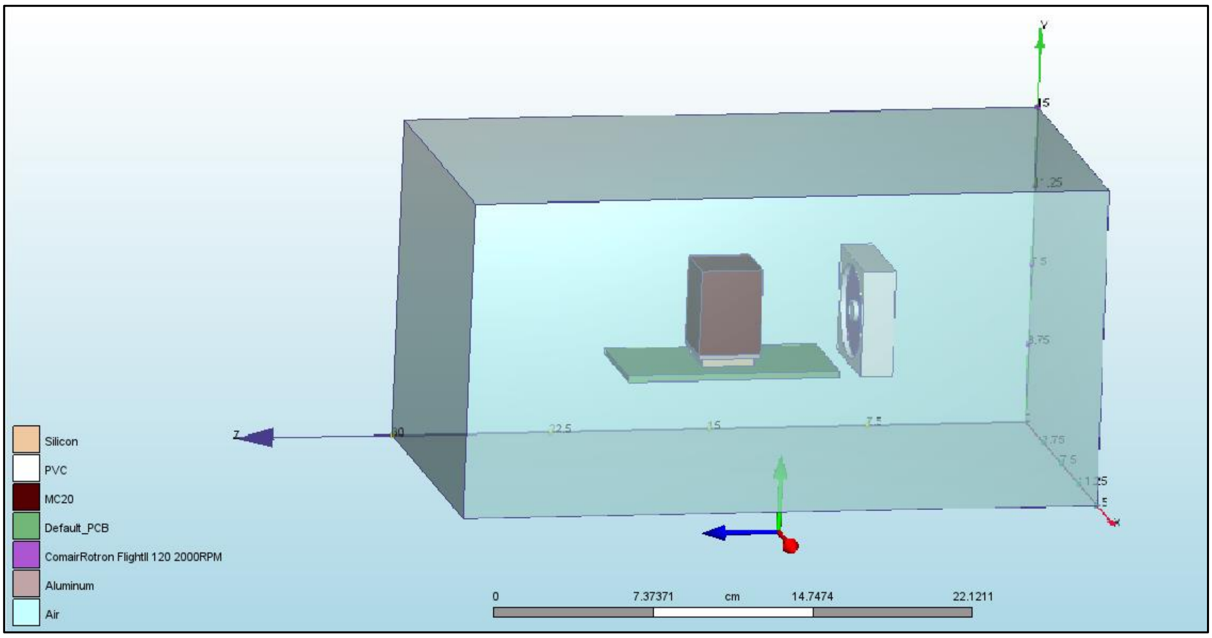


Figure 6 The PCB Unit inside the Control Volume

Different materials have been specified for each part (Fig.6) depending on its nature as follow:

1- *Control Volume*: Air
2- *Fan*: The Fan's case and hub were specified as PVC, while the fan blades were chosen as (Internal fan material) with Rotating speed= 2000RPM in Z-direction.
3- *Heat Sink*: Its material type was chosen as Heat sink material with Approach surface= 17 and Base surface= 16.
4- *Heat sink Base*: The 2 mm base was specified as Aluminium.
5- *Chip*: Silicon
6- *PCB*: Its material was chosen as Printed Circuit Boards.

2.2.2 Boundary Conditions

The boundary conditions are used to identify the surrounding conditions that our module will be working at, and they are of great importance since the results of the analysis will vary depending on their values. In our module, three main parameters are considered:

1- *Heat generation:* A steady state heat generation of 20 Watt was specified for the chip.
2- *Pressure*: A Zero Pa (P= 0 Pa) was specified for the front and back sides of the Control volume.
3- *Temperature:* A Zero °C (T= 0 °C) was specified to the four lateral sides beside the front side.

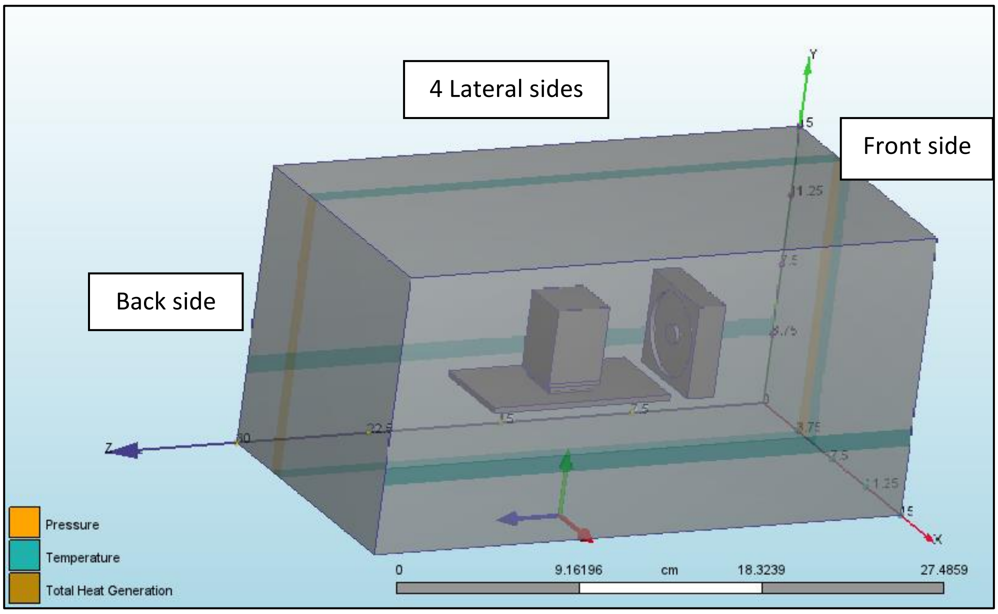


Figure 7 The Boundary conditions shown on the Control volume

2.2.3 Mesh

Thanks to Autodesk CFD software, the Mesh was auto-sized automatically without much effort in creating it manually.

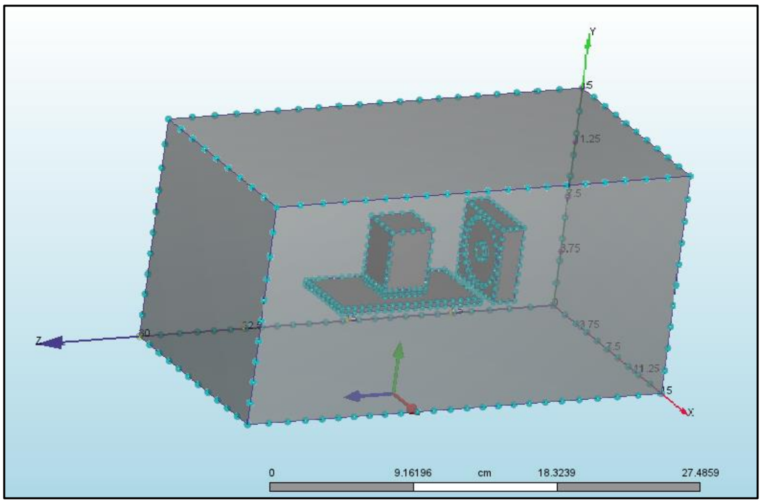


Figure 8 Auto-sized Mesh

Part 3 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.

3.1 Results

3.1.1 Convergence Plot

From fig.9 we can see the convergence plot of the Temperature. Temperature mainly appears around the PCB, Chip, and heat sink, since they are sources of heat in our module and as specified in the boundary conditions, the heat is generated by 20 watts from the chip which appears in the high error value in the beginning and after a while when the temperature starts to dissipate gradually the errors decreases and the convergence increases till it reaches a value of 0.7646 at the 300th iterations.

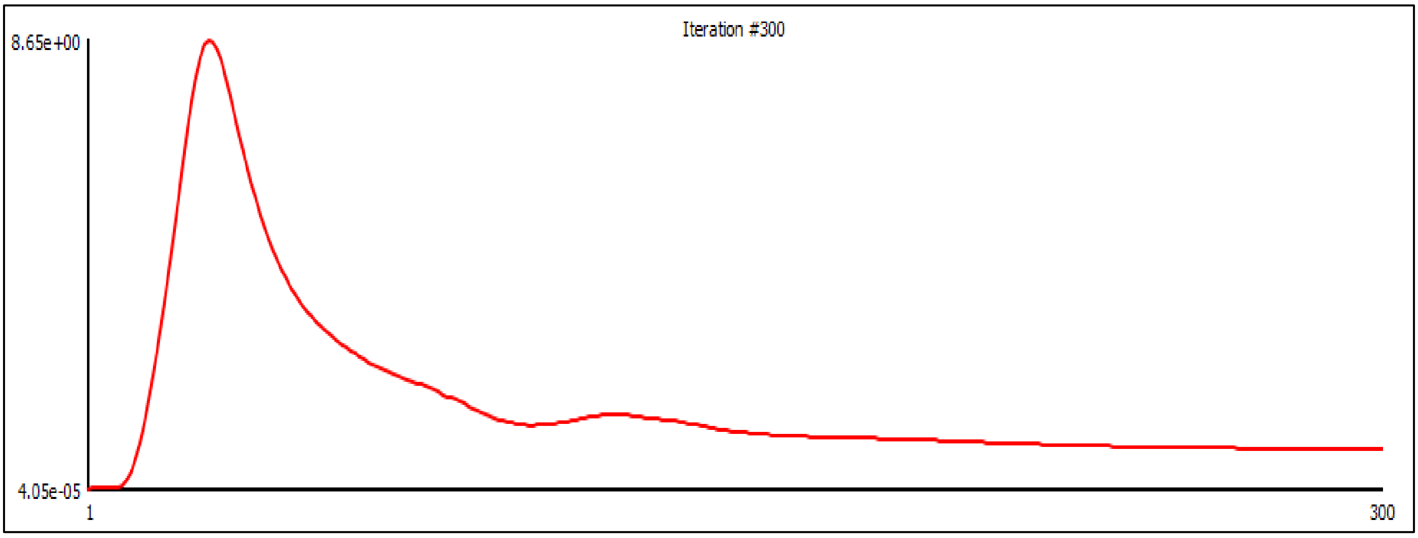


Figure 9 Convergence plot with 300 iterations

3.1.2 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 colours bar. In Fig.10 ,11 and 12, we can see a higher temperature value on the Chip and the PCB since they are sources for heat generation, also in the front of the heat sink (fig.11) there is no increase in temperature since this area is well cooled by the fan, while we can see a relative increase in the temperature on its rear side since air flow cannot reach this area probably. Additionally, similar behaviour can be notices on the PCB, where the side facing the cooling fan has a relative lower temperature than the other side which is a bit far from the fan behind the heat sink.

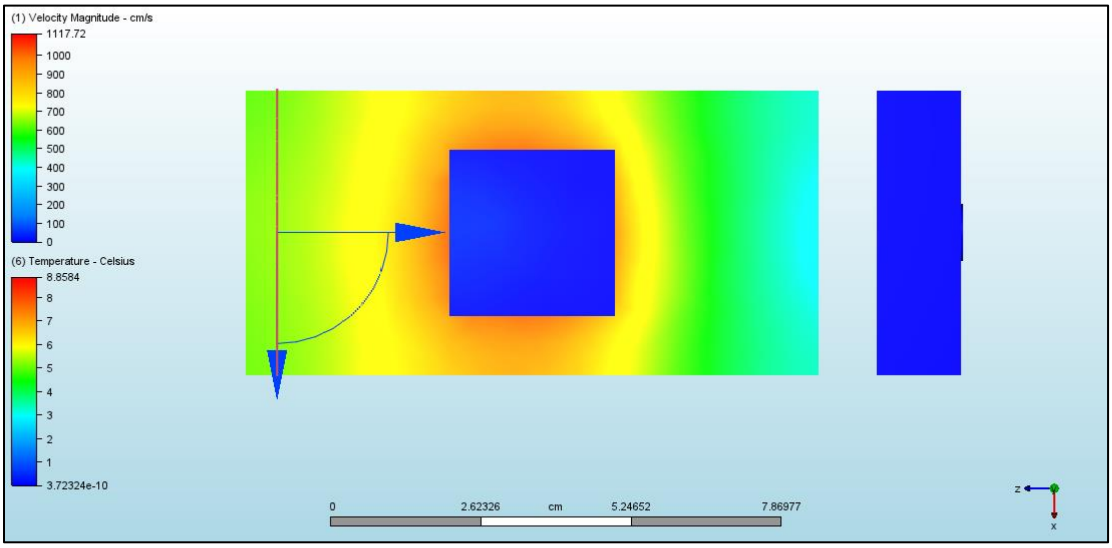


Figure 10 Temperature magnitude (Plane view)

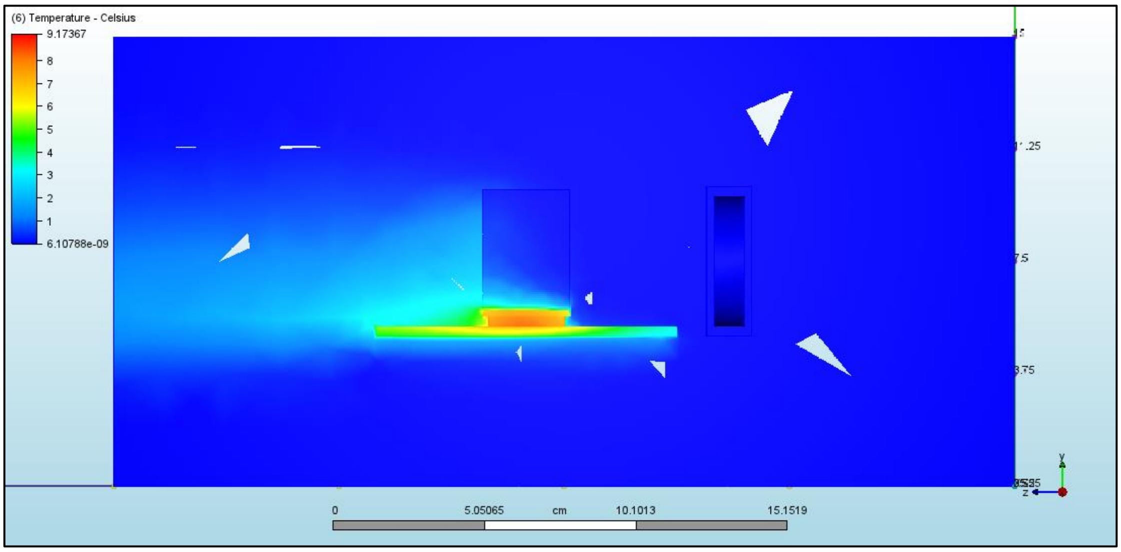


Figure 11 Temperature magnitude (Side view)

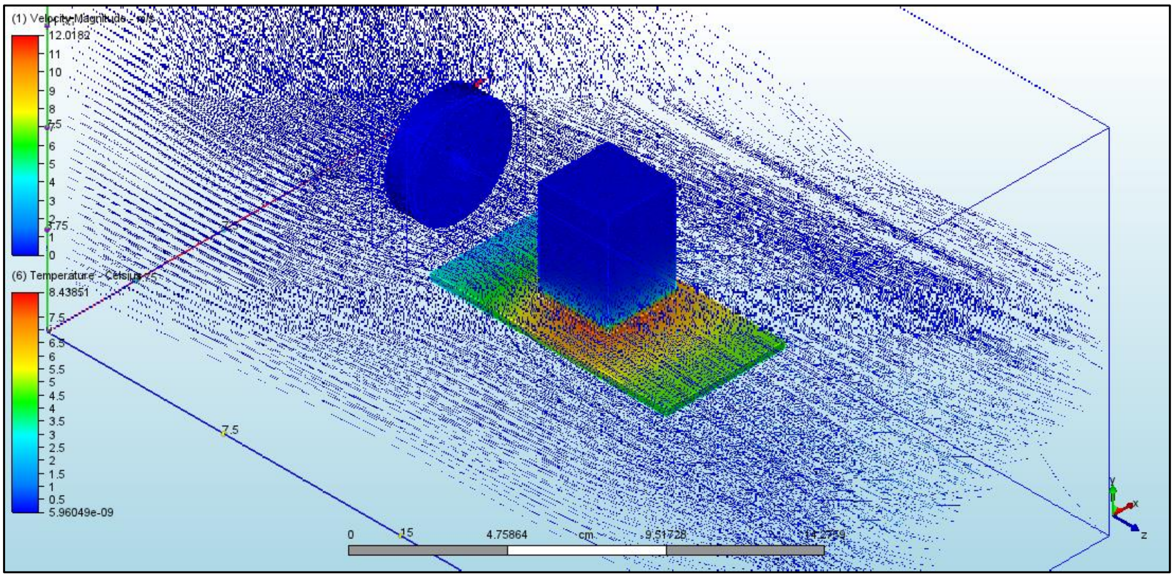


Figure 12 Temperature effect with the air traces

3.2 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 suggestion is to use two smaller/ same-sized fans on of the lateral sides of the PCB unit, by this the PCB and the chip will be cooled horizontally instead of vertically and wider area will be covered with the air flow, and we will have a better circulation for the air and cooling around the heat sink and on the PCB as shown in fig 13 compared to fig. 10, and by this we will decrease the temperature instability of the module.

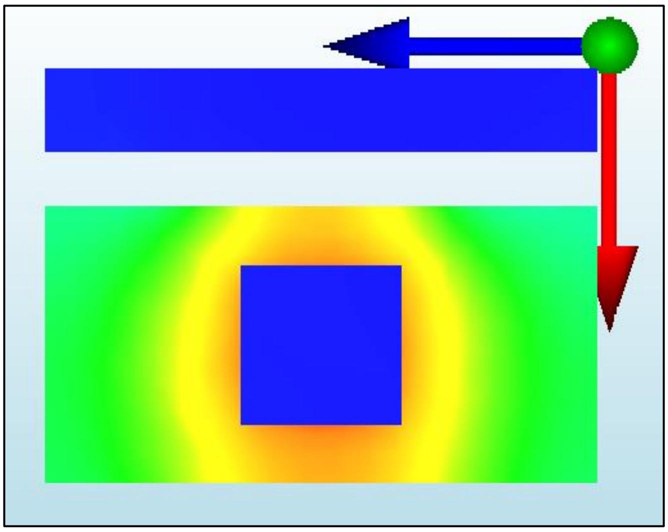
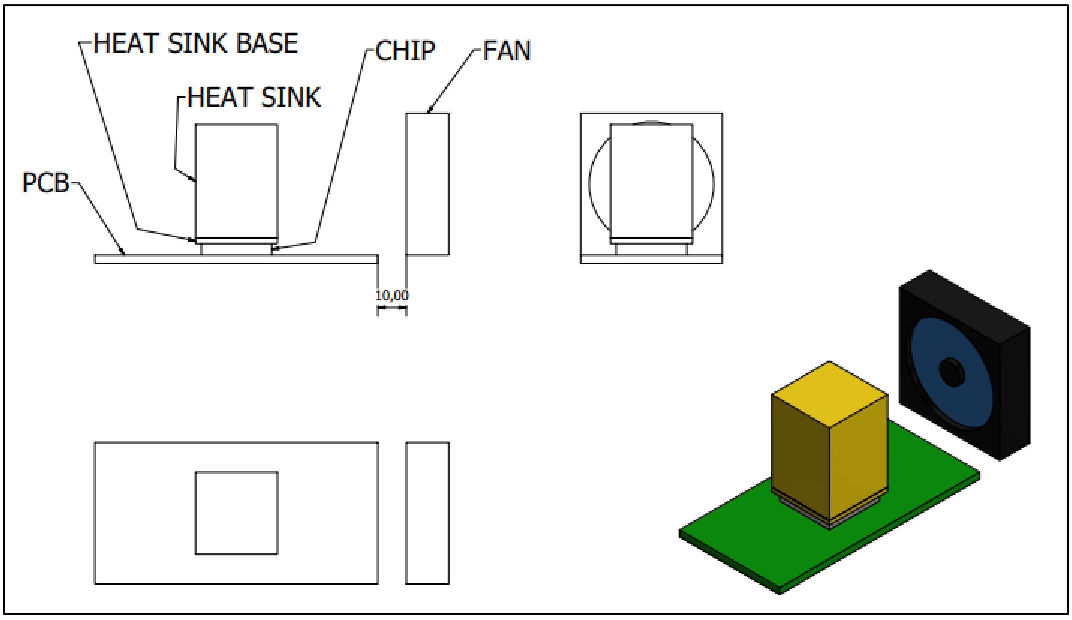
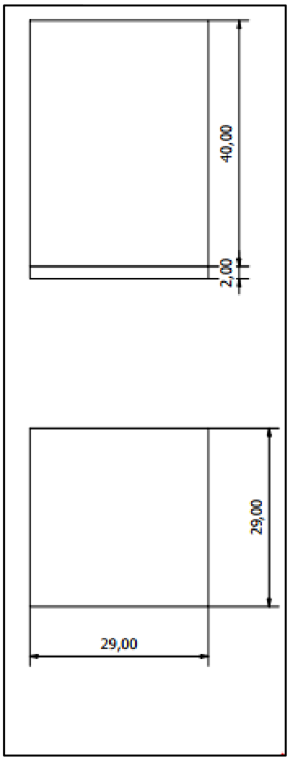


Figure 123 Two lateral fan module

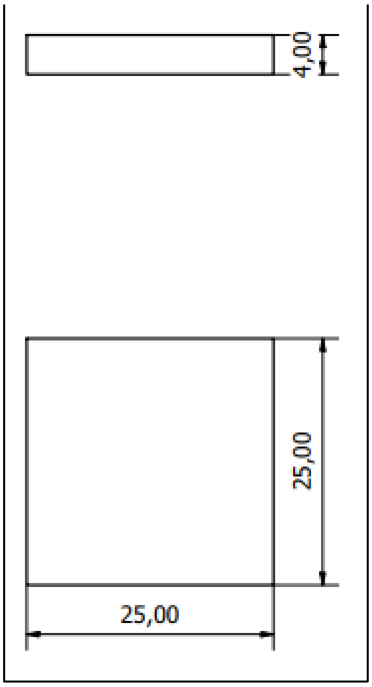
Appendix



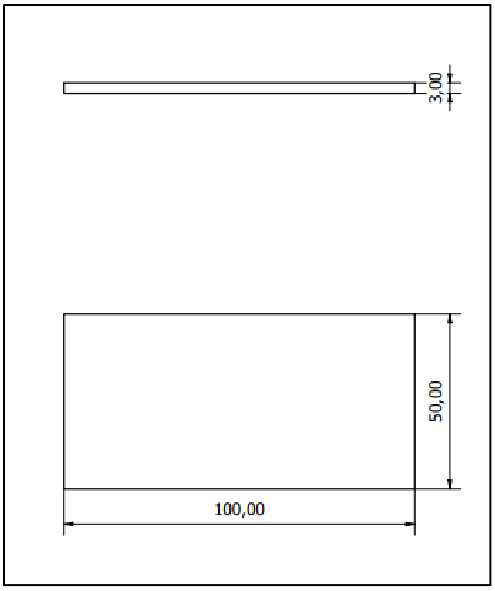
3D Module



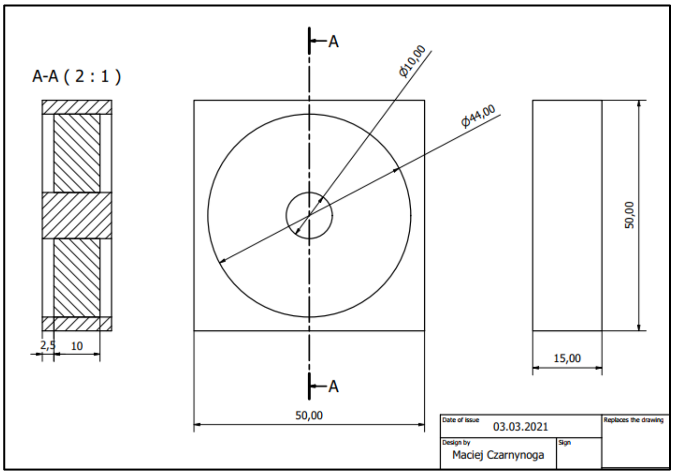
Heat Sink



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/