JOINT INSTITUTE FOR NUCLEAR RESEARCH

Veksler and Baldin Laboratory of High Energy Physics

FINAL REPORT ON THE INTEREST PROGRAMME

Heat Transfer Simulation of the Cooling System for NICA-MPD Platform Rack Cabinet

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Abstract

Simulations of equipment of a NICA-MPD rack cabinet were performed in order to asses heat transfer properties of the design. Simple 3D model and heat transfer simulations were prepared and air particles trajectory visualized.

1 Introduction

Nucleotron-based Ion Collider Facility - Multipurpose Detector (NICA-MPD) platform rack cabinet is a structure housing electronic equipment used in the process of obtaining data from the particle accelerator. It is therefore necessary to ensure proper conditions in order to achieve reliability of the whole system. Thus, two rack cabinets are cooled down by a separate air conditioning unit placed between them in a close loop setup. This design prevents outside particles to get inside the cabinet and contaminate the electronic equipment.

2 Methods

The 3D model was first prepared in Autodesk Inventor Professional 2019 software[1]. Simulated structure was simplified so that minor details that were not important for the simulation were omitted.

Using Autodesk CFD 2019, heat transfer simulations were conducted[2]. First, 3D model was placed in a volume of variable air. Then material properties were assigned to each part. Default materials were assigned to air and solid parts of the model. Specific parameters for default materials for heat sinks and heat exchangers were modified. In the next step the model was meshed with auto-sized parameter.

Boundary conditions were set to simulate ambient conditions. Outside temperature was set to be 25 °C. The simulation was then solved with account for gravitation and radiation.

3 Model equipment

For these simulations a simplified model of an 8U VME8100 crate was created[3]. Inside of this crate, 21 PCB boards were placed, each with 6 silicon chips and heat sinks. This system served as a source of heat in the simulation. Three fans were added below the set of PCB boards. Cases of the fans were made of polyether ether ketone (PEEK). In the simulation, air was permitted to flow from the bottom to the top of the crate through openings in aluminium chassis of the crate. Additionally, a hollow aluminium power supply was included at the back of the device with a single chip and heat sink.

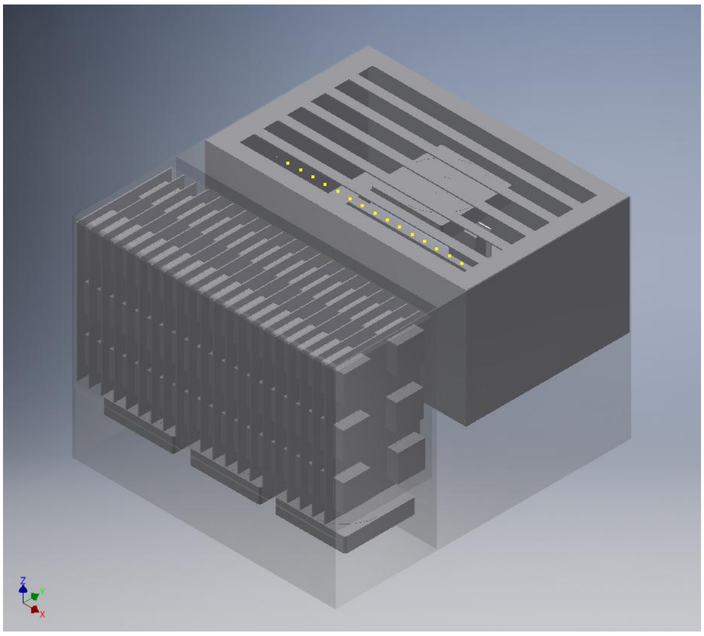
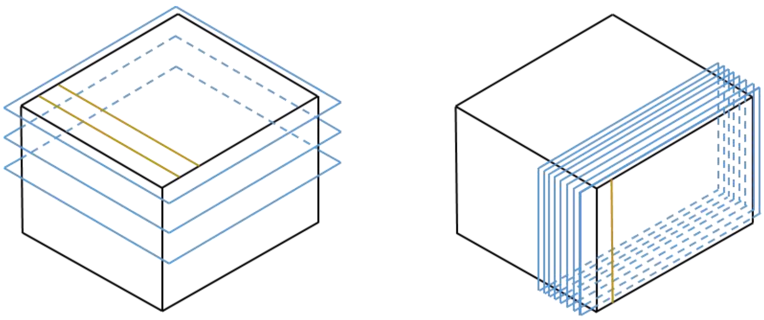


Figure 1. 3D model of the VME crate. Chassis was made transparent to display PCB boards with chips and heat sinks placed inside the crate.

4 Results and conclusions

Results of the final simulation show that outlet temperatures at the top of the device reached over 31 °C. By analyzing temperatures along the x axis in three horizontal planes that cut through each row of chips and heat sinks (see Figure 1A), we can see that there were three peaks followed by sudden drops as can be seen in Figure 2. Every point in a row in Figure 2 corresponds to one chip with a heat sink in a particular plane. Differences between maximal and minimal temperatures for each of anterior rows were 4.01 °C, 4.69 °C and 5.12 °C (bottom to top row).



A **B**

Figure 2. Depiction of three horizontal planes (in blue) in **A** and eight vertical planes in **B**. Orange lines show where temperature was measured in each plane.

This is in accordance with velocity values observed in the same way as temperatures. Figure 3 shows observed velocities for each of anterior rows. By comparing velocity with temperature, a clear inverse relation arises. Three peaks in temperature across the x axis correspond to three drops in velocity.

This observation can be explained by an uneven distribution of airflow created by three fans placed below electronic equipment. Increased airflow right above the fan accelerates air to a higher speed.

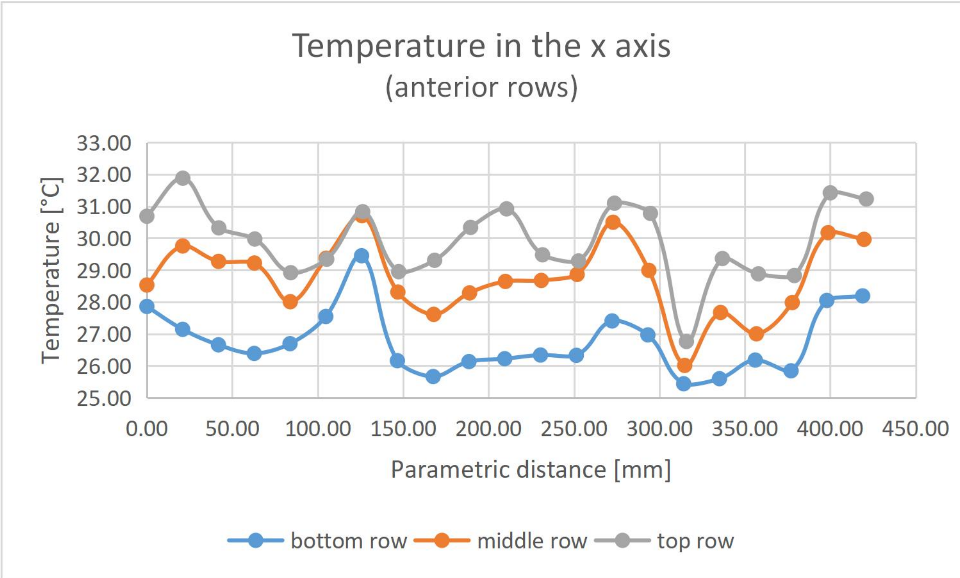


Figure 3. Temperature profiles in the x axis for anterior rows.

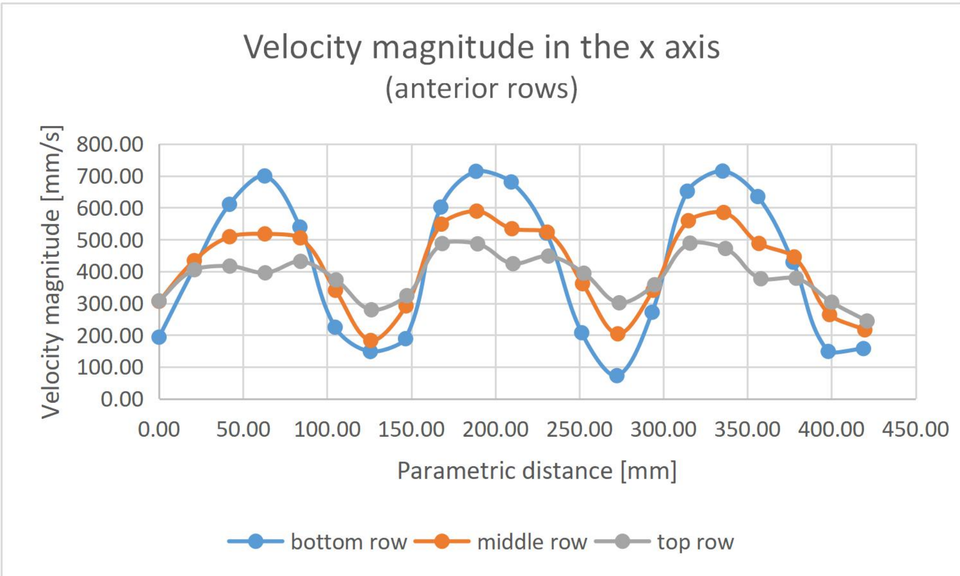


Figure 4. Velocity profiles in the x axis for anterior rows.

Analysis of temperatures and velocities in the same way for posterior rows shows similar results. The differences in temperatures were, however, less pronounced (see Figure 4). Differences between maximal and minimal temperatures for each row were 1.74 °C, 3.08 °C and 4.22 °C (bottom to top row). These values are noticeably lower from those for anterior rows.

Maximum velocity values here were on the other hand higher which could explain more stable temperature profiles shown in Figure 5. In addition, geometry of the 3D model used in the final simulation allows for airflow behind the electronic equipment due to simplifications made when creating this model. This means that the posterior rows are cooled down more efficiently than anterior rows. However, it is safe to assume that in a real device, this posterior flow would be minimized.

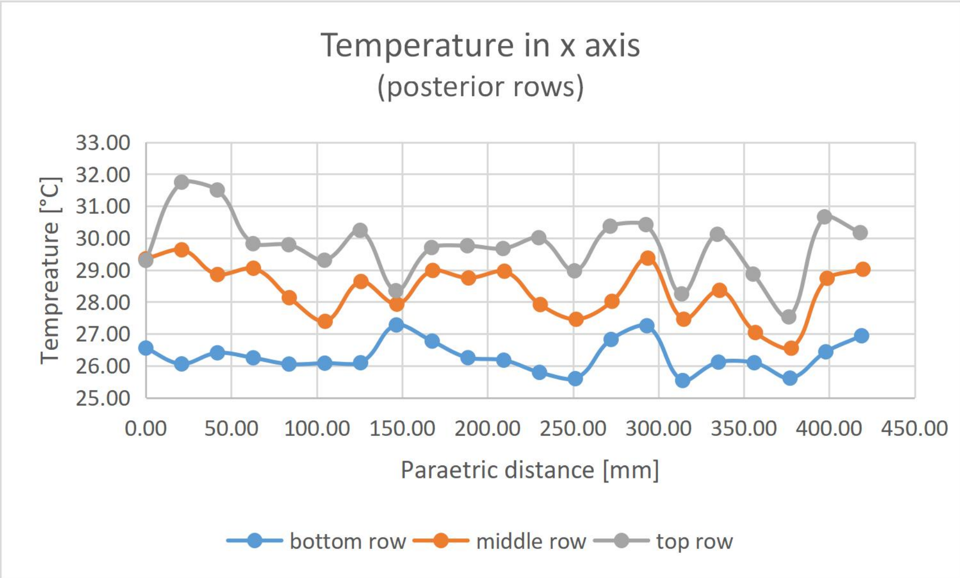


Figure 5. Temperature profiles in the x axis for posterior rows.

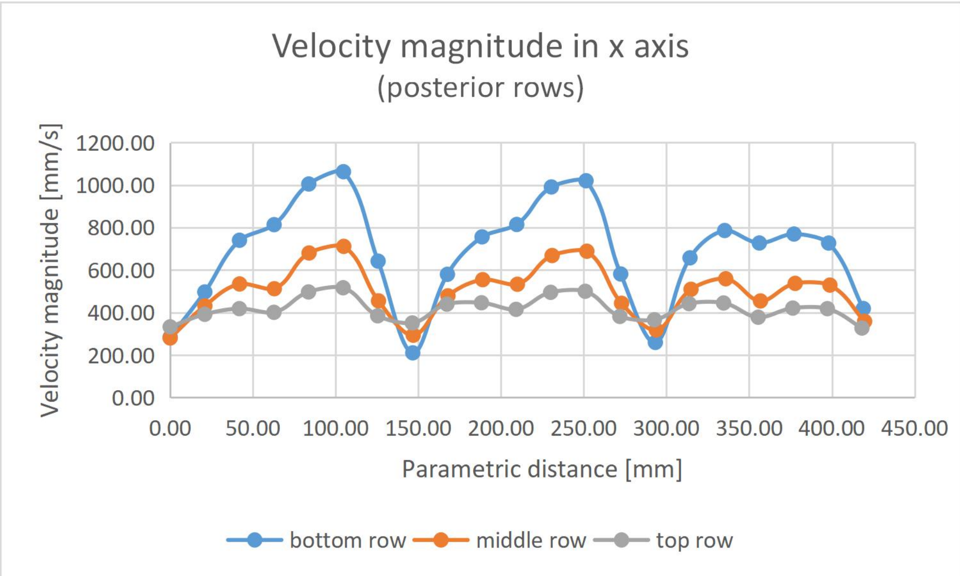


Figure 6. Velocity profiles in the x axis for posterior rows.

These results suggest that the output temperature at the top of the whole device greatly depends on the air velocity distribution. This can be demonstrated by looking at output temperatures above a fan in a sequence of planes (see Figure 1B). Values obtained this way are shown in Figure 6. It is clear that temperatures aren’t uniform but change significantly with a position over the fan. Third through sixth planes are positioned directly above simulated blades of the fan and therefore reach the lowest temperatures. On the contrary, the first two as well as the last two planes are positioned over casing of the fan. Comparable results could be visualized for the two remaining fans as well.

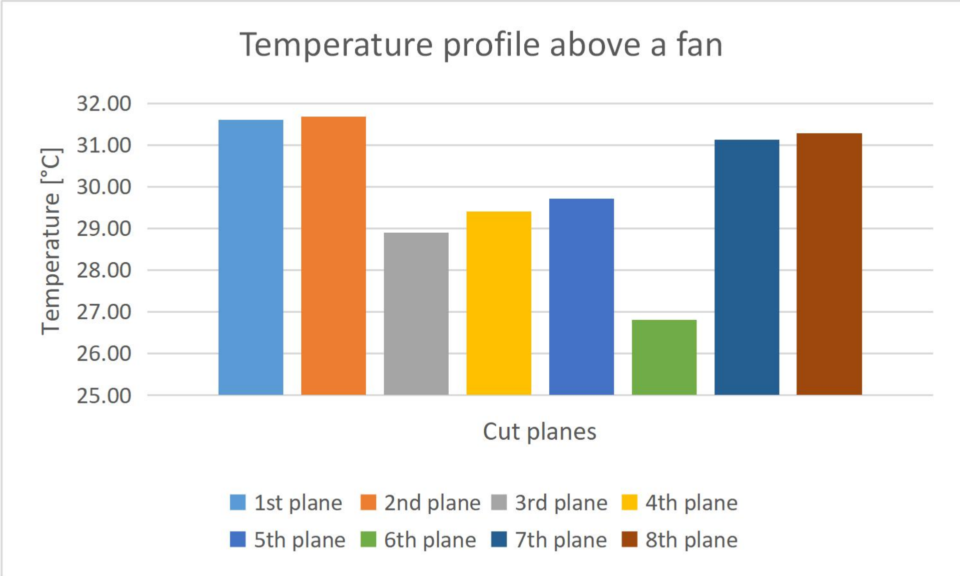


Figure 7. Temperature profile above a fan.

By looking at Figures 7 and 8, we can see that the highest temperatures are reached at the top of the device despite all chips generating same amount of heat. Heated air then leaves the devices in two separate columns that merge together at a certain distance above the device. Temperature differences described above are thus assumed to be minimized with increasing distance from the device. A relative temperature instability inside and directly above the device is therefore not a major concern to us at this point.

Next step in the simulations was replacing the electronic equipment with a set of heat exchangers. This was done to further simplify the model and speed up the simulations. Heat output of these heat exchangers was calculated from the previous simulation.

Results of this simulation showed a much more stable temperature profile at the top of the device with temperatures in a range between 26 and 27 °C. Such uniformity was expected because airflow through the heat exchangers is constant.

Achieved temperatures most likely correspond to highest rates of airflow directly over the fans. This is also supported by temperatures measured over the fans in the previous simulation which are comparable to temperatures from simulation with heat exchangers.

Final step would be to simulate a close loop cooling system of two rack cabinets connected to the air conditioner where several devices would be placed above each other in rack cabinets to asses how much heat would be generated by such a system and also cooling effects of a cooling unit. Unfortunately, due to time reasons further simulations weren't conducted as part of this internship.

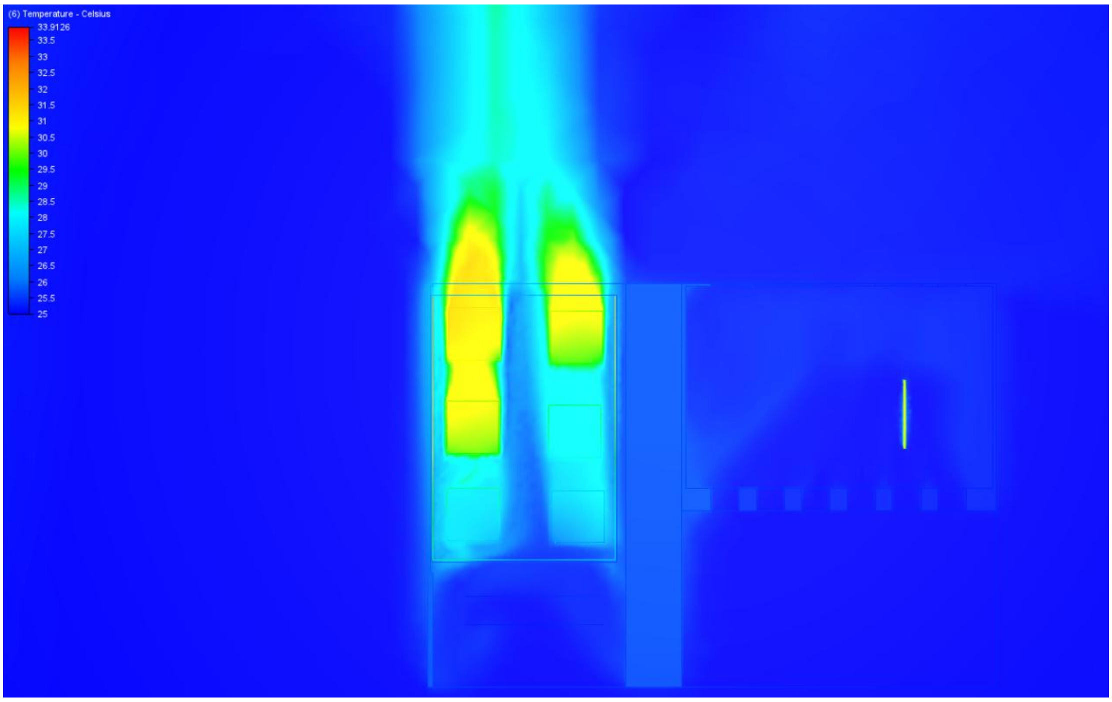


Figure 8. Temperature in the ZY axis (right side) of the VME crate.

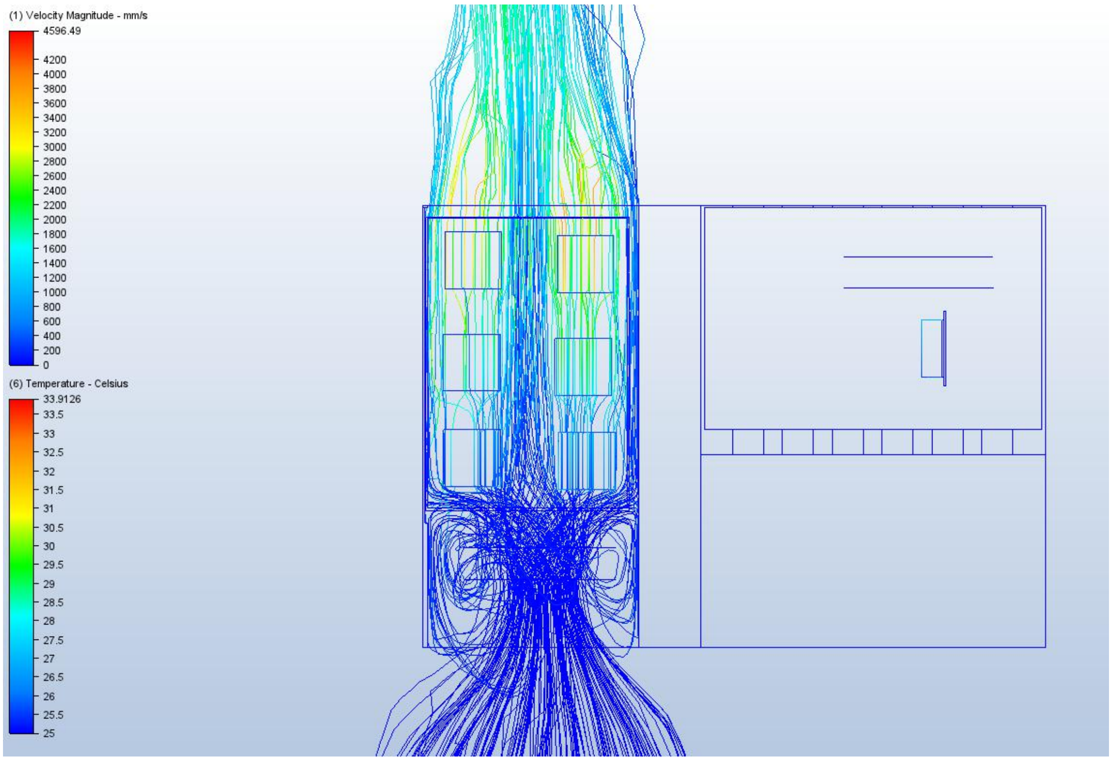


Figure 9. Particle trajectory through fans with heat map.

5 References

[1] Autodesk. Autodesk Inventor. Version 19.1. San Rafael, CA: Autodesk; 2019.

[2] CFD: Explore learn resources
https://knowledge.autodesk.com/support/cfd/learn?sort=score

[3] VME8100:
https://www.caen.it/products/vme8100/