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63U ATCA rack thermal performance and its integration in the underground areas

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Since for the High Luminosity LHC the instantaneous luminosity will be increased by a factor 3, an efficient trigger selection will be crucial. Therefore, the ATLAS hardware trigger and the calorimeter read-out will be upgraded for HL-LHC to base the trigger decision on much more fine-grained information. A custom designed 63U rack has been chosen as a house for the ATCA based systems allowing installation of 50% more shelves in the detector proximity. Higher power dissipation requires an assessment of the impact on the existing underground infrastructures and cooling capabilities verification in a test setup, which also became the cooling facility to qualify the detector boards prototypes.

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1. Introduction

In November 2014, the ATLAS technical coordination launched a project dedicated to the study of the ATCA (Advanced Telecommunications Computing Architecture) integration in the existing LHC rack infrastructure. In the beginning, the project focused on the standard 52U 19” rack equipped with two ATCA shelves cooling capabilities assessment [1]. But over the years, the goals of the test campaign were changing to adjust to the current needs of the detectors groups and to face encountered problems and restrictions such as high noise generated by the shelves and cooling capacity available only in the delta temperature of the water. At a certain stage of the project, it was clear that there will be a need for additional space for shelves in the detector proximity – due to the nature of the counting rooms the only possibility was to go to taller racks.

Therefore, a 63U 19” rack was designed, ordered and installed in a test facility together with three newly designed, adjusted for ATCA dimensions, 2U air/water heat exchangers and three ATCA shelves. Over the months, there were many requests for different tests layouts of which most were addressed. Among them are tests with different computing architectures mixed – ATCA and VME (Versa Module Europa), to evaluate if these two very different (in terms of power dissipation and cooling needs) architectures can be combined and work in one rack. Also verification of the cooling capacity of newly designed 2U heat exchangers and water flow optimization studies to provide maximum cooling efficiency for the rack equipped with 3 ATCA shelves were carried out.

The 63U ATCA rack, due to its large power dissipation, has a strong impact on the counting rooms existing infrastructures such as HVAC (Heating, Ventilation, Air Conditioning) and water cooling systems, this is why significant part of the test campaign was dedicated to address the unwanted heat release to the counting rooms, and consequently increasing the overall rack cooling efficiency [2]. For this reason different ATCA shelf types were tested to evaluate their cooling capabilities, also tests with 52U cooling doors were carried out to diminish the escaping heat.

One of the most important goals of this test campaign was to set the limit for the maximum power in front boards and on RTM (Rear Transition Module) that can be dissipated per slot to be able to stay within the 50°C temperature target. The results of a measurement campaign with different types of load boards will be presented.

2. Test setup

The test campaign took place in a laboratory using the following equipment:

- 63U 19” custom designed server rack
- 3x ATCA shelves – 2x CERN standard Schroff units + 1x ASIS
- 3 different sets of load blades (further called LB):
  - 14x ASIS LB, each equipped with 8 temperature sensors and able to dissipate up to 600W only in front board
  - 14x New type Comtel LB without temperature readout and each able to dissipate up to 800W only in front board
  - 14x Old type Comtel LB, each equipped with 6 temperature sensors and able to dissipate up to 300W in front board and 50W on RTM
- Dedicated water chiller with nominal cooling capacity of 25kW and 4.32m^3/h nominal flow [3]

- 3x ATCA optimized 2U heat exchangers with maximum cooling capacity of 7.9kW each

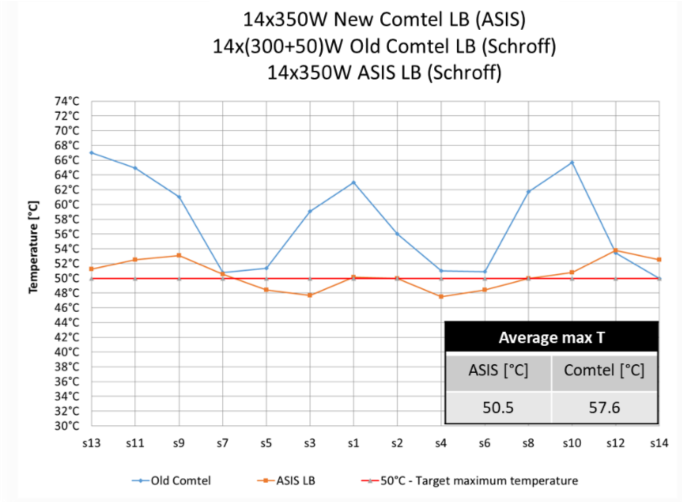
3. Boards cooling tests

During the test campaign the results showed that load blades with higher air resistance have better cooling efficiency (ASIS set) and more homogeneous temperature distribution across the shelf. At the same time, the less air resistive load blades (Old Comtel set) have high temperature peaks occurring on axis of the shelf fans – as indicated on figure 1 (s13 to s14 indicates slot number in the ATCA shelf).

Figure 1. ATCA crate – hot boards indication.

3.1 Maximum power dissipation tests

The tests show that in order to stay below the 50°C mark, the maximum power supplied to each blade has to stay within 350W in front board.



Total power in the rack 21.3 kW

Cooling water flow = 2.4 m^3/h

ΔT = 6.4°C

Q_r = 17.8kW

P = 84%

ΔT – Cooling water ($T_{out} - T_{in}$)
Q_r – heat removed from the rack by the cooling water
P – cooling efficiency Q_r/(Total power in the rack)

Figure 2. Cooling test results with 350W average per blade.

As can be seen on the graph, the ASIS LB (the set with higher air resistance) stay within the maximum target temperature, while the Old Comtel LB set exceeds it by over 7°C. The high temperature peaks over the axis of the fans are clearly visible on the graph as well.

3.2 RTM power influence tests

Since only one type of the load blades was equipped with RTM, additional tests were carried out to evaluate the impact of additional 50W dissipation on these modules on the overall board temperature. The test results showed that additional 50W dissipated on the RTM has no significant impact on the overall boards temperature (see fig. 3). The added energy is being removed from the rack and does not affect the boards temperature, therefore with proper board design, the blades can be kept in the target temperature of 50°C with power not exceeding 350W in the front, plus 50W on RTM.

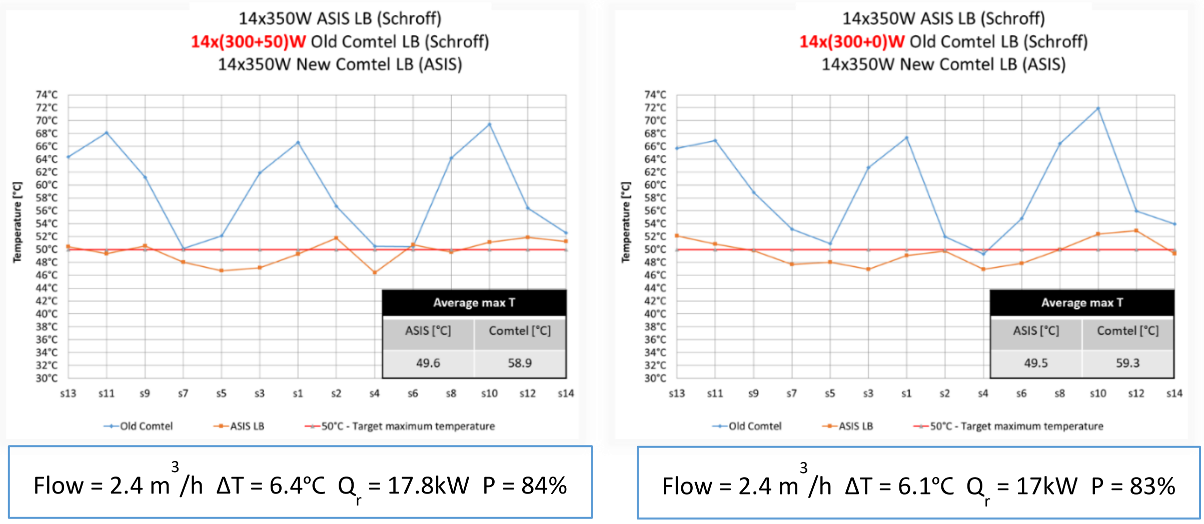


Figure 3. RTM power impact on the cooling efficienct test.

4. Cooling performance and heat release

4.1 Load blades design study

The measured cooling efficiency of the rack oscillated around 80-85%, meaning that around 3kW of heat was being released to the environment. Throughout the tests the dissipation of the heat on the surface of the rack has been analysed with a thermal camera FLUKE TiS10 [4]. During the thermal scan, a difference of 10°C between top and bottom crates was noticed with equal power distribution through the rack. Since the difference in heat dissipation was significant, the analysis of the blades design begun. The findings show that the set of blades with lower frontal heat release had their whole radiating part insulated and separated from the front of the board by specially shaped cover. Additionally due to their special design, the air is driven mostly through the dissipating part which resulted in better heat pickup.

4.2 Tests with a 52U cooling door

In order to improve heat removal from the rack a 52U cooling door was installed, and the remaining 10U gap was closed with an insulated plexi-glass panel (see fig. 4). The aim of the cooling door was to remove the heated air from the back of the rack and create an air corridor while the front door was closed. The tests performed with this configuration showed, that overall cooling efficiency could be sustained above 90%.

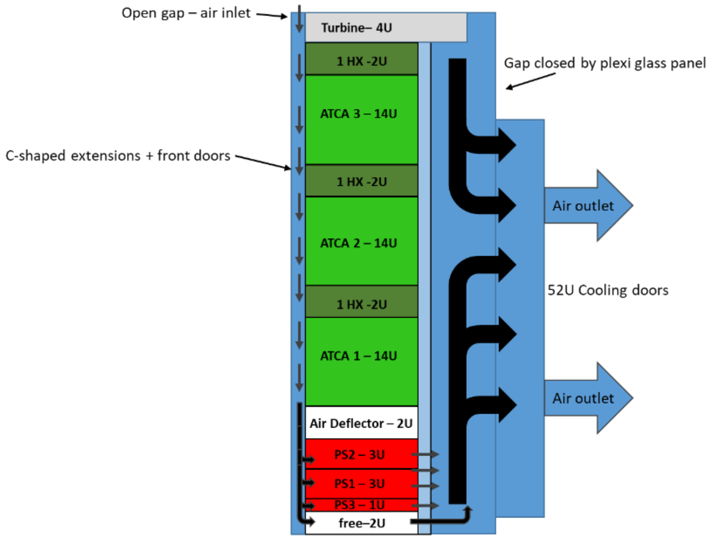


Figure 4. Side view of the 63U ATCA rack with cooling door.

5. Conclusions

After many tests in different configurations, the test campaign allows to conclude that for the future boards development the maximum power that can be dissipated per board and still allow it to stay under 50°C is 350W in front boards + 50W on the RTM. It is important to remember that board's heat sinks design play one of the key roles in the cooling efficiency. That is why it is mandatory to test prototypes of the boards which are foreseen to dissipate power close to the 350W+50W at the ATLAS SR1 test facility.

To reduce the heat radiated to the room by the front of the boards it is advised to design air corridors on the board which will drive the air mostly through the heat dissipating part which will also increase the overall board cooling efficiency.

It is important to remember that each of the load blades sets that were tested consists of 14 identical pieces with the heat dissipation spread equally on the whole surface – there are no hot spots on the blades which may not be the case for the real boards.

While operating in proper conditions the cooling efficiency of the rack can be kept above 90%, reducing the heat released to the counting rooms.

Although not presented, the measurements have shown that the VME crate has negligible impact on the overall rack airflow and cooling efficiency – yet this solution must be treated as an exception.

References

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[3] EWAQ025CAWH water chiller: https://www.daikin.pt/pt_pt/products/EWAQ-CWH.table.html

[4] Fluke TiS10 thermal camera: https://www.fluke.com/en-us/product/thermal-cameras/tis10

PoS(TWEPP2019)068