JRA2 SITRA Conductive Cooling System Prototype

A. Savoy Navarro[1], A. Galkin[2], V. Saveliev[2]

December 19, 2008

Abstract

A Conductive Cooling System Prototype (CCSP; deliverable JRA2-D13) was designed and built in cooperation of LPHNE and OSU. Technical calculations and description of the design are given in EUDET Memo 2007-52 [1].
For the current CCSP, new composite carbon fibre structures have been used to comply with the competing requirements of good thermal conductivity and low material budget.

1 LPNHE – Université Pierre et Marie Curie / IN2P3 – CNRS, France
2 Department of Applied Mathematics, Obninsk State University, Russia

Introduction

A cooling system is an essential part of a silicon tracking detector: it has to prevent the detectors from warming up and thus avoid increased noise while imposing as little cost in terms of added material budget.

The mechanics group at LPNHE, in cooperation with Obninsk State University (OSU) has been developing cooling systems for the SITRA prototypes, taking as starting point the now well-established main source of energy dissipation in these detectors, namely the on-detector electronics, which is also under development in the Paris Lab.

The goal was to develop mechanical prototypes of SiLC modules incorporating a cooling system, which would be sufficiently generic and scalable to reproduce realistic thermo-mechanical conditions of an ILC run in the lab. This gives the ILC community a useful tool to test the feasibility of proposed cooling solutions and an easily accessible benchmark for thermo-mechanical simulation studies.

Cooling system design

Because of the relatively low radiation levels at ILC, silicon modules can operate at ambient enclosure temperature, i.e. up to 30°C, and with a temperature gradient of 10°C (i.e.±5°C around 25°C). Thus the design goal for the cooling system is to maintain the Si tracking components within this temperature conditions by enclosing them in insulating box(es) and creating favourable conditions for air circulation inside the enclosure(s) to maintain the desired temperature conditions.

The silicon module prototypes will utilize custom designed front-end electronics fabricated using a 0.13 µm CMOS UMC process. The chain of front-end electronics includes a preamplifier/shaper chip, analog memory plus digitization ADC circuit, and the digital management of the overall system functioning.

The total power dissipation of the chip is foreseen to be less than 1 mW/channel, leading to a total heat load of 1.8 W per Si module made of 1,800 channels, without power cycling. It is intended to have the FE chips power-cycled, which would decrease power dissipation by a factor of 70 to 100 [1].

To have a universal prototype system, we designed the conduction cooling system so as not to interfere with convection cooling. The goal is to use conduction cooling for power-cycled operation, and engage convection cooling for operation without power cycling.

Materials

The selection of materials and basic technology processes have been done in co-operation and based on the development of the Research and Production Enterprise "Technologiya", State Research Centre of Russia [3].

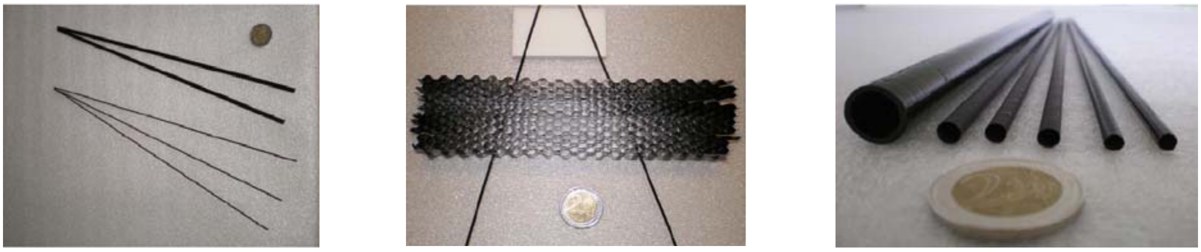
The main technological elements were selected and tested for the construction of the test setup box:

• The carbon fibre material used for building the cooling box is based on panels composed from two layers of honeycomb mechanical structural panels and a core of honeycomb polyimide structure {Fig. 1, top)

• The structural elements that support the cooling box, e.g. carbon rods and carbon strips {Fig. 1, bottom left and centre)

• Low material budget tubes from carbon composite material and polyimide tubes {Fig. 1, bottom right)

Fig. 1. Double-sided honeycomb carbon fibre structures used in the construction of the prototype components. These low-material budget structures posess favourable electrical, mechanical and thermal properties.



The Silicon Micro-Strip Module Prototype

The design of the module prototype was driven by the requirement of structural stability and cooling integration, but also by the requirements of module assembly technology.

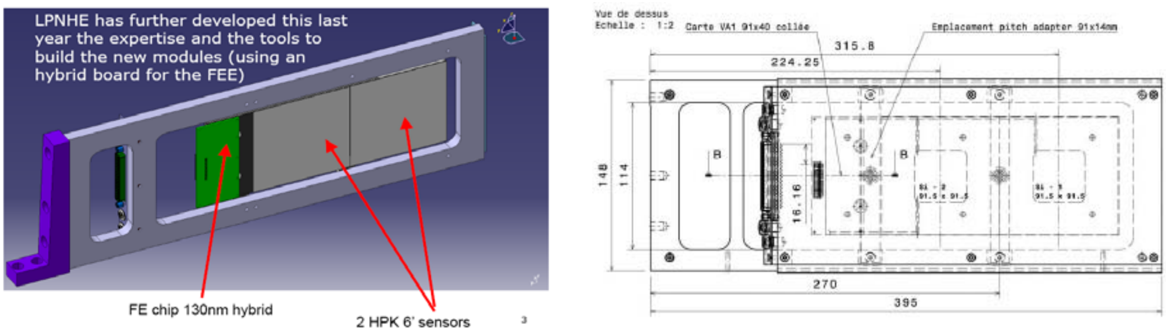


Fig. 2. The structure of a prototype SiLC module and its technical drawing

The Insulating Box

The insulating box serves several purposes. It is the main structural element supporting the modules, a Faraday cage, shielding the modules from ambient EM interference, a thermal insulation, separating the module setup from the environment, but also shaping thermal air flows to provide optimum heat dissipation to the environment.

In cooperation with OSU, an insulating cage meeting the above requirements has been developed. While being structurally stable, the cage is very modest in material budget and provides favourable conditions for conduction cooling of the module prototypes inside it.

An important feature of the cage and of the cooling system design is that it does not interfere with convection cooling, so that condution cooling can be tested in power-switched operation, while convection cooling is engaged for non-switched operation.

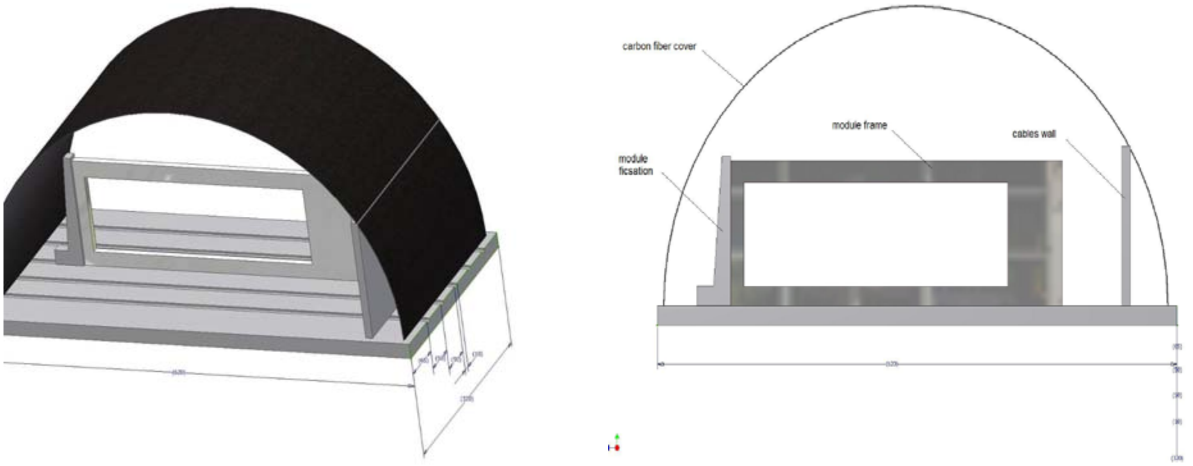


Fig. 3. The self-supporting domed structure of the insulating box provides for optimum air circulation in the enclosure, while being very modest in material budget.

Conclusions

The purpose of the prototype cooling system is threefold:

1. To provide the required thermal conditions for operating the prototype Si tracker system

2. To verify our calculations of thermal dissipation by the module electronics and the prototype cooling system design

3. To serve as an experimental benchmark for simulation studies of thermal regimes in ILC detector systems.

The R&D acitivities in this area, carried out from 2006 to 2008, can be summarized as follows:

- Simulation studies and tests of heat dissipation [1] have accompanied the design of detector electronics to set up design gaols for the prototype cooling system.

- These studies helped us adapt the design of modules and insulating box to meet the design goals for the conduction cooling system.

- The main components of the silicon tracker have been designed and were (modules) or will be (insulating box) tested at beam tests.

Acknowledgement

This work is supported by the Commission of the European Communities under the 6th Framework Programme “Structuring the European Research Area”, contract number RII3-026126.

References

1 A. Savoy Navarro, A. Galkin, V. Saveliev: Air Cooling of a Silicon Test Setup for a Linear Collider Experiment. EUDET Memo 2007-52, http://www.eudet.org/e26/e28/e182/e660/eudet-memo-2007-52.pdf

2 Proposal submitted to the ILCSC R&D Panel on Tracking at the BILCW'07 Workshop in Beijing (Feb. 2007) and answers to the Panel Questionary, by the SiLC R&D Collaboration. http://lpnhe-lc.in2p3.fr/DOCS/beijing.pdf

3 Research Center Technologia, http://www.technologiya.ru/tech/misc/maine.html