CO2 cooling for particle detectors

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The ATLAS Inner Tracker for the phase-II upgrade

For the High-Lumi LHC the ATLAS detector has to be able to operate after exposure to large particle fluences due to the increase in the integrated luminosity. Therefore an upgrade is required to guarantee a working detector in these conditions. The current tracking detector will be completely replaced in order to deal with the unprecedentedly high levels of radiation and pile-up of the collider. The Inner Tracker (ITk) will be made of all-silicon detector pixel and strip sensors cover the inner and outer radii respectively. The ITk is divided in a central region called Barrel and two lateral wheels, the Endcaps.

The ATLAS ITk Strip Petal and its components

The Petal, as well as the Stave, is a support structure loaded with silicon modules on both sides. It is constructed with three main objects:

- Silicon modules: the readout and power/control electronics is directly glued on the sensor, wire-bonds are needed to bias the sensor, power the readout chips and transmit the data collected by the strips.
- The Core: a carbon-fiber structure with an embedded titanium pipe form the mechanical support for modules. All electrical connections are incorporated in a multi-layered polymer structure.
- The End of substructure card (EoS): electrical interface between Petal and off-detector, this board provides power to modules, sends commands and collects data from them through the optical fiber.

Quality control tests on cores and petals

The petal core, after the assembly, has to go through several tests to be accepted. The tests involve a thermal analysis to establish the quality of the object, making use of the infra-red picture at 100 thermal cycles between +40°C and -40°C are expected over full detector lifetime.

Thermal investigation on the petal core

A qualitative evaluation of the infra-red thermograms was performed on two cores produced at DESY (core #7 and #8). The analysis is done looking at:

- The temperature distribution along the cooling pipe
- The temperature distribution over the module area
- Possible degradation after thermal cycling

Thermal investigation on the electrical petal

The same technique of investigation used for the core is repeated on the electrical petal. In this case the cooling pipe is barely visible in the thermogram due to the presence of modules. The IR pictures show the petal in three different CO2 set points: +18°C, 0°C and -34°C when the modules are powered. The electronics (especially the powerboard) generates most of the heat which is dissipated by the CO2. The temperature of each module is evaluated from the thermography using polygonal markers and plotted for every CO2 temperature.

The Strip Barrel has a cylindrical geometry, made of four concentric layers, the main unit is called Stave which hosts 14 identical rectangular Modules on each side. The Strip Endcap is built with six disks with 32 Petals each. Due to the trapezoidal geometry, the modules are wedge-shaped and six different geometries are needed. To cover the sensitive area.

Conclusions

The thermal analysis on the core making usage of the thermography is a powerful instrument to detect possible internal defects during the building process of a petal core. The tests are performed using a CO2 cooling machine which allows to work in a range between room temperature and -35°C. The delamination, observed in core #8, breaks the heat dissipation flow from the core to the CO2 due to a weak contact area between materials and glue. This discovery demonstrates the feasibility of infrared thermography as a powerful diagnostics tool for the local supports Quality Control.