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Developments in the Use of Micro-structured Silicon devices for Thermal Management of HEP Detectors

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Microchannel cooling has been selected for the thermal management of the NA62 GTK detector. The baseline design is based on a 130 micron thick silicon microstructured plate spanning over the whole sensor surface. An alternative design, based on a "frame-like" geometry, is also under study. Experimental measurements detailing the performance of both configurations will be presented and compared.
Further applications in connection with two-phase evaporative flows are presently under developments for the upgrades of the ALICE ITS and LHCb Velo detectors. Preliminary results about these new cases will also be discussed.

Summary

First important developments related to the application of microchannel cooling to HEP Pixel detectors have been recently presented by the CERN PH/DT team and its collaborators. The concept relies on the integration into the detector module of thin micro-structured silicon plates for the thermal management of the sensor and its R/O electronics.
In December 2011 the NA62 collaboration has endorsed the selection of the microchannel-based design proposed for the local thermal management of the three stations of the GTK detector. The proposal is based on a silicon cooling plate locally thinned down to 130 microns in the sensitive area. Cold C6F14 in liquid phase is circulated through a series of 70x200 microns rectangular channels covering the whole detector module area. The selected configuration, optimized through accurate CFD simulations, provides the desired ±3 ℃ temperature uniformity on the surface of the GTK module. Also, a temperature difference between the coolant fluid and the warmest point on the surface of the sensor as low as 6 ℃ is ensured. Experimental results showing the on-design and off-design behavior obtained in realistic conditions with this baseline configuration will be presented.
In parallel, a study for an alternative design for the microchannel cooling plate of the NA62 GTK has been launched. The design is based on the expected difference of power density between the periphery of the chip, where all the digital components are concentrated, and its analog part underneath the sensor. A "frame-like" configuration has been designed, with micro-structured silicon only placed in contact with the thermally dissipative region of the digital portion of the chips, while all coling material is removed from the sensing area. The performance of this alternative configuration, as measured in the CERN PH/DT test set-up, will be discussed and compared with the one observed for the proposed baseline.
Further applications presently under study will also be presented, in connection with two-phase evaporative flows.
A first case-study is related to the ALICE ITS detector upgrade, for which a room temperature, low pressure evaporative cooling based on C4F10 is presently envisaged. Considering the narrow geometrical aspect ratio of the ITS module and its expected low power consumption in the central region, the proposed concept is similar to the alternative one proposed for the NA62 GTK: a "frame-like"geometry adding material for thermal management only at the periphery of the ITS stave.
A second case is the upgrade study for the LHCb Velo detector. For this application, the experiment considers as mandatory to preserve the present CO2-based cooling system, proved extremely successful and reliable in operation. A different design approach has been selected for this application. Taking advantage of the characteristic high pressure and low viscosity of CO2, very long microchannels spanning over the whole sensor area are envisaged. Preliminary calculations foresee low pressure drops and a very high thermal efficiency, including a temperature difference between the fluid and the sensor surface of just a few degrees.

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