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Microchannel CO2 cooling for silicon detectors

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The LHCb Vertex Detector (VELO) will be upgraded for the LHC run-III to a pixel detector capable of 40 MHz full event readout and operation in very close proximity to the LHC beams. The thermal management of the system is provided by evaporative CO_2 circulating in micro-channels embedded within thin silicon plates. The VELO modules host 12 VeloPix ASICs with a total power consumption of up to 30 W. The implementation of an efficient and radiation hard cooling system is mandatory to remove the heat produced by the ASICs and keep the sensors below -20o.C and mitigate the radiation damage. The solution created is to use a cooling substrate composed of thin silicon plates with embedded micro-channels that allow the circulation of boiling CO_2. The direct advantages of this technique is the low and uniform material contribution, same thermal expansion coefficient that of the sensor-ASIC tiles, the radiation hardness of CO_2 and high heat transfer capacity. The fluidic connector to the substrate should be leak tight in order to withstand the operational pressures and be placed in vacuum. A flux-free connector soldering solution was developed which respects the planarity and the correct positioning required for the subsequent construction of a precise tracking system. The solder joint was tested for long term effects of creep and fatigue. Alternative solutions were pursued in parallel to the development of the micro-channels, based on 3D printed titanium tubes or on steel capillaries inside a ceramic substrate. However, the micro-channel evaporative cooling provides a better physics performance, due to the low material and no CTE mismatch. This talk will cover the key points of the micro-channels R&D which includes design optimisation, fabrication, robustness tests, cooling performance and the comparison with the backup options.

Collaboration

LHCb

Primary authors: AKIBA, Kazu (Nikhef); COLLINS, paula (cern)

Presenter: DE AGUIAR FRANCISCO, Oscar Augusto (The University of Manchester)

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