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CO₂ cooling through microchannels

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The LHCb Vertex Detector (VELO) is currently being upgraded to a lightweight, pixel detector capable of 40 MHz readout and operation in very close proximity to the LHC beams. The thermal management of the system will be provided by evaporative CO₂ circulating in micro channels embedded within 500 micron thin silicon plates. This solution has been selected due to the excellent thermal efficiency, the absence of thermal expansion mismatch with silicon ASIC's and sensors, the radiation hardness of CO₂, and very low contribution to the material budget.

Although micro channel cooling is gaining considerable attention for applications related to microelectronics, it is still a novel technology for particle physics experiments, in particular when combined with evaporative CO₂ cooling. The LHCb design focusses on an efficient layout of the channels together with a delivery system composed of stainless steel pipes and an invar manifold. The assembled silicon plate and connector system must be capable of withstanding pressures in the order of 200 bars. Even distribution of the coolant is ensured by means of the use of 50 x 50 micron restrictions implemented before the entrance to a race-track layout of the main cooling channels.

The cooling plates are produced by etching microchannels in a multi-step process, to account for the different channel depths, in a base silicon wafer, followed by bonding a cover wafer, and finally thinning the assembly. The microchannel production is a complex process involving quality control of production and dicing steps at the manufacturer, followed by a careful assembly technique of the cooling plates to the connectors and pipes, via a flux free soldering process which is performed partially in vacuum and uses formic acid. The quality control includes assessment of surface quality, a cyclic stress test in pressure and temperature, high pressure tests, and helium leak tests. The microchannel production is now underway and the status will be described along with future R&D improvements that could be envisaged.

Submission declaration

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