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LHCb VELO Microchannel cooling and Module Construction

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The upgrade of the LHCb experiment, currently being installed for the LHC Run 3, will transform the experiment to a trigger-less system reading out the full detector at 40 MHz event rate. All data reduction algorithms will be executed in a high-level software farm with access to the complete event information. This will enable the detector to run at luminosities of 2 x 1033 /cm2/s and probe physics beyond the Standard Model in the heavy flavour sector with unprecedented precision.

The Vertex Locator (VELO) surrounding the interaction region is used to reconstruct the collision points (primary vertices) and decay vertices of long-lived particles (secondary vertices). The upgraded VELO will be composed of 52 modules placed along the beam axis divided into two retractable halves. The modules will each be equipped with 4 silicon hybrid pixel tiles, each readout by 3 VeloPix ASICs. The detector assemblies are operated cooled to -30degC, while consuming around 3W each.

The VELO upgrade modules are composed of the detector assemblies and electronics hybrid circuits GLUED onto a cooling substrate, which is composed of thin silicon plates with embedded micro-channels that allow the circulation of liquid CO2. This technique was selected due to the excellent thermal efficiency, the absence of thermal expansion mismatch with silicon ASICs and sensors, radiation hardness of CO2, and very low contribution to the material budget. The front-end hybrid hosts the VeloPix ASICs and a GBTx ASIC for control and communication. The design and construction techniques of the VELO upgrade Modules will be presented with the results from the latest R&D.

The material budget of the pixel modules is minimised by the use of evaporative CO2 coolant circulating in microchannels within 400 μm thick silicon substrates. Microchannel cooling brings many advantages: very efficient heat transfer with almost no temperature gradients across the module, no CTE mismatch with silicon components, and low material contribution. This is a breakthrough technology developed for LHCb; the microchannel plates will be inaccessible once the run begins and must be capable of operation in vacuum and to reliably withstand up to 200 bar pressure. The development has been carried out hand in hand with industry and has required many specialised quality control techniques, as well as a novel fluxless soldering technique to attach the connectors to the microchannel plates to allow the delivery of the coolant. The production of the first complete set of 52 microchannel plates will be described, highlighting the way in which the perfection of the cooling channels, bonding and surface quality has been maintained over the large area plates, how the construction is achieved, and the performance of the microchannel plates when fully loaded with heat dissipating electronics.

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