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R&D for a colder future in HEP

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CO2 cooling has been the ideal cooling technology for detectors since its introduction for the LHCb-VELO cooling in the beginning of the millennium. The target operational temperatures for silicon detectors have been lowered over the years stretching the CO2 cooling technology to its limits. Detector cooling typically having small tubes need a high pressure evaporative fluid to be able to remove the detector heat in an efficient way. CO2 cooling has proven to work efficiently at high pressure close to the critical point and is reducing its favorable properties by going colder. The current targets for CO2 cooling is below -40'C. CO2 cooling performs still well compared to other cooling fluids, but is loosing efficiency fast. CO2 cooling is also hitting a real hard boundary which is the tripple point, where the liquid CO2 freezes to dry-ice at -56'C.

Some future detectors are considering colder cooling temperatures. If efficient cooling with small tubes is required a different fluid is needed with a lower critical point than CO2. R&D on the heat transfer behaviour of other fluids either sub or super critical is needed. Systems with lower critical points also need a different way of operating than the current operation of the CO2 systems. A super critical cool down is needed to cool down the detector in a gentle way. This new system approach and new fluid applications needs R&D to explore the possible cooling technology for the colder future.
Beside investigating the use of fluid (or mixture of fluids) with lower critical point, the other obvious way to cope with requests for lower temperature of the sensors is to work on thermal management design approaches minimizing the temperature difference between the sensor and the cooling fluid. The most effective solutions in this sense come from the integration of micro-structured cold plates in the detector supports, where tremendous progresses have been recently made. However, today the most developed approach relies on the application of MEMS-derived processes to the micro-fabrication of silicon devices, which prove to be extremely effective, but very expensive and difficult to integrate.
Promising developments with high potential come from the extension of additive manufacturing techniques to ceramic materials and from the introduction of innovative processes for silicon microstructuring. These subjects certainly call for active R&D.

Authors: VERLAAT, Bart (CERN); PETAGNA, Paolo (CERN)

Presenters: VERLAAT, Bart (CERN); PETAGNA, Paolo (CERN)

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