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Recent developments of the SDHCAL prototype

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After the construction and the successful operation of the first technological prototype of The Semi-Digital Hadronic CALorimeter (SDHCAL), developed within the CALICE collaboration, new R&D efforts to fully validate the SDHCAL option for future experiments such as those that could equip the ILC and CEPC colliders have been initiated.
The SDHCAL is a sampling hadronic calorimeter using large GRPC as active medium with embedded readout electronics. The GRPC prototype size is 1 m² while future detectors will require GRPC detectors with a scalable length up to 3m long. The readout Printed Circuit Board (PCB) consists of 1 cm² copper pads on one side and 64-channel HARDROC readout chips on the other side, each chip processing the signal arriving on a 64 cm² square.
The design of such large size scalable detectors has been addressed and has required rethinking the gas flow in the GRPC in order to maintain detection efficiency and spatial response homogeneity. The readout PCB was also redesigned and now uses the latest version of the HARDROC readout chips series.
Unlike the previous design, this new PCB design is scalable in length and more tolerant of ASIC readout failures. The PCB clock distribution, slow control and fast control have been redesigned to speed up communication over long chains of ASICs and PCBs. The clock is distributed via the TTC protocol while the slow and fast control use I2C protocol.
The lack of PCB manufacturer, able to produce PCBs larger than 1 m² with 8-layers, necessitated the development of an ingenious scheme with several PCBs connected to each other by tiny, flexible connectors.
A new DAQ interface board is currently under development. This new DAQ interface board has an optimized geometry to fit the requirements of the ILD detector.
It can handle up to 432 HARDROC3 chips, covering a PCB area of 2.76 m², which is sufficient to cope with the maximum size of the GRPC in ILD (0.9x3 m²).
Communication with the external environment is via an ethernet connector using the TCP/IP protocol to ensure coherence in data transmission.
A new cassette, as part of the calorimeter absorber, is being designed. The main challenge is to ensure the rigidity and uniform contact between the GRPC and its PCB. For the ILC detector, the ASICs are power-pulsed using the specific time structure of the linear collider beam. This keeps the ASIC power consumption low enough to avoid cooling the PCB. For the CEPC, the continuous operation of the accelerator implies adding cooling capacity to the designed cassette structures.
Finally, the mechanical structure to support 3m long GRPC requires improved flatness of the steel plates used in the structure. Furthermore, to maintain this flatness, usual screw and bolt assembly is not sufficient. A sophisticated method of joining the plates using the electron beam welding technique has been developped.
In addition, new developpements to replace single gap GRPC by multigap GRPC coupled with fast timing electronics are being pursued. A time resolution better than 50 ps is achievable. This will allow to follow the temporal evolution of the hadronic showers developing in the calorimeter.
The first prototypes of the PCB with HARDROC3 chips, the mechanical structure and the DAQ interface board have been manufactured. An improved version of the DAQ interface board and the design of the holding cassettes are being finalized. Tools to handle such large detectors are also being designed. A first fully assembled prototype of 2 m² with 4 layers is expected to be ready in year 2022.
In parallel, the first SDHCAL prototype has been extensively tested in beam test facilities. Refined analysis techniques are being developed to improve the energy and shower reconstruction of the SDHCAL prototype.

The latest analysis developments cover techniques to improve the spatial uniformity of the response and a better treatment of the particle incidence angle in the energy reconstruction.

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