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Hadron Calorimetry Test Bench

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Today particle physics experiments conducted at the energy and intensity frontiers demand more and more sophisticated detectors. The scale of the detectors increases, and that translates into ever increasing costs. This naturally affects calorimetry R&D activities which are conducted by larger groups, often within multi-institutional and multi-national collaborations. And usually it takes years to finalize the design of the new calorimeter while very few alternative design options are considered. "Clustering"of R&D within larger collaborations results in fewer groups doing generic calorimetry studies.

Calorimetry community needs tools and methods which allow diversified, yet inexpensive, R&D studies. Such tools and methods would lead to better optimization of the final detector design, meanwhile reducing costs. At the same time, inexpensive calorimetry tools allow smaller groups to organize and conduct small and mid-scale experiments over short periods of time.

Sampling calorimetry test benches are among such tools. Using the test bench, one can carry extensive systematic R&D studies with the objective to tune the test bench calorimeter stack to the optimal constant or varying sampling fraction for the energies of interest. Compensation, metrological, and mechanical engineering limits can be optimized with the test bench, as well. Reconfigurable test benches allow wealth of studies before one progresses to building a prototype detector.

We designed and fabricated a reconfigurable test bench for hadron calorimetry studies. The test bench includes: 1) a box-case made of sheet steel, the length of the box-case is about 2 m, 2) 380 antimony lead plates with antimony content of ~10%, the dimensions of each plate are 350 mm x 350 mm x 2 mm, 3) 210 polystyrene scintillator tiles, the dimensions of each tile are 350 mm x 350 mm x 4 mm, 4) fourteen polystyrene scintillator tiles, the dimensions of each tile are 350 mm x 350 mm x 5 mm, 5) 232 polystyrene non-scintillator tiles, the dimensions of each tile are 350 mm x 350 mm x 2 mm, 7) five steel plates with thicknesses of 40 mm or less, the lateral dimensions of each plate are 350 mm x 350 mm, 7) six 36-fiber bundles, 8) two 12-fiber bundles, 9) four 4-fiber bundles, 10) two 2-fiber bundles. Clear-wave guides are in the fiber bundles.

Thin lead plates allow making absorber layers of various thicknesses, such as 2 mm, 4 mm, 6 mm, ⋯, 12 mm, ⋯, 24 mm, ⋯, 36 mm, ⋯, and so on. Lead-scintillator configurations can be chosen with uniform or variable thicknesses of the absorber layers through the depth of the test bench.

The box-case is assembled from steel components. A support is made of 30 mm thick steel sheet welded to one I-beam and twelve C-beams. Two frames made of sheets with milled windows are attached to the support' s front and rear ends. Two side walls are attached to the support C-beams and to the front and rear frames. Each side wall has milled slots that run with a step of 120 mm along the length of the wall. The slots in opposing walls allow fixing the stack of absorbers and scintillators inside the box-case for a certain chosen total thickness of the stack.

Kuraray Y-11 wavelength shifting fiber (diameter = 1.2 mm) is glued with optical cement in grooves made in the scintillator tiles. Fibers are glued in the scintillator tiles in such a way that the light is read out from two fiber ends that exit the tile. Upon exiting the tile, the wavelength-shifting fibers are coupled through optical silicone to clear-wave guides that transmit the light to Phillips XP2262/H04 photomultipliers. Each photomultiplier serves a bundle of clear-wave guides that bring the light from several scintillator tiles. Depending on chosen thicknesses of absorber layers, one or several photomultipliers read out the data with help of CAMAC-based data acquisition system.
Non-scintillator thin plastic tiles can be used to research mechanical design options for the real hadron calorimeters. Such non-scintillator tiles can be placed between scintillator tiles and absorbers to see how the energy resolution and compensation are affected from such placement. Fourteen 5 mm thick scintillator tiles can be attached to the side walls of the box-case to study lateral shower leaks.

Performance of the test bench was preliminarily studied at T9 beam line of CERN Proton Synchrotron with beam momenta ranging from 1 GeV/c to 10 GeV/c. Energy responses of the test bench to hadron, electron and muon beams were measured with absorber thicknesses of 16 mm, 24 mm, and 48 mm.

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