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Fiber-based Calorimeters for High Energy Physics

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Future high energy physics experiments will require major improvements in the performances of hadron and jet calorimetry. Because of the challenging conditions in which they will be operated, unprecedented levels of energy and timing resolutions, as well as efficient particle identification are required. An approach based on heavy inorganic crystal fibers to form a fully homogeneous calorimeter was proposed earlier. Designs based on assemblies of small elements of undoped and doped materials have to potential to combine excellent energy resolution and particle identification abilities with its dual readout and vertexing/tracking capabilities. Shaping the scintillators in elongated (fiber-like) geometries becomes a challenge when criteria on their performances are set so high.

The initial focus was set on LuAG since this garnet structure has enough density to allow for homogeneous designs. A careful analysis of the fiber geometries and the growth parameters led to an enhanced optical quality and light propagation. First demonstrators were then assembled and tested during multiple test beam campaigns, demonstrating the potential of crystal fibers in a set of calorimeter geometries (homogeneous and sampling both in pointing and transverse configurations). Because of cost considerations, more emphasize is being given to sampling geometries. As a consequence, prototypes with crystals of lower density (YAG) were later also assembled into calorimeter units and thoroughly tested. The flexibility of this innovative type of calorimetry was demonstrated and results were obtained with modules either with very fine granularity or rather loose sampling fraction. Based on Geant4 simulations, we also studied the best way to find a good compromise between cost and performances by smartly sacrificing the homogeneity of the calorimeters in specific regions.

Another line of work was directed to the improvement of the timing properties and of the radiation hardness of the fibers. Studies performed on both bulk and shaped materials demonstrated the crucial role of the raw material and impurities. Codopants were also used to balance compositions as an attempt to meet all the requirements. Because of the large quantities of fibers to be considered for the construction of a full calorimeter, extra care was taken to ensure the reproducibility of the growth processes. On this later point, as an alternative to crystal fibers, silica-based fibers were also considered. Their lower density is counterbalanced by growth processes more easily scalable to mass production.

This contribution will review the collective R&D effort which is on-going both on the bulk material, the fiber growth and the assembly of prototypes.

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