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Energy Resolution and Timing Performance Studies of a W-CeF3 Sampling Calorimeter prototype with a Wavelength-Shifting Fiber Readout

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An electromagnetic sampling calorimeter prototype has been developed to satisfy the requirements for running at the CERN Large Hadron Collider after the planned High-Luminosity upgrade (HL-LHC).
An innovative design, with wavelength-shifting (WLS) fibers running along the chamfers of each calorimeter cell, minimizes the mechanical complexity. The resistance to radiation has been optimised by minimizing the light path, by adopting Cerium Fluoride crystals as active medium and by aiming at Cerium-doped quartz for the WLS fibers, as its luminescence excitation wavelength matches well the CeF3 emission.
At the Beam Test Facility in Frascati, Italy, electrons with an energy of up to 491 MeV have allowed us to obtain first performance results on a prototype channel of 24 mm x 24 mm transversal cross section, using Kuraray WLS fibers. At the SPS-H4 beam line at CERN, electrons with energies of up to 150 GeV have then been used for an in-depth study of the energy resolution and of the impact-point dependence of response, and agreement is found with detailed GEANT4 simulations. A further beam test, where Cerium-doped quartz fibers have been adopted for wavelength-shifting, gives an energy resolution matching expectations. First tests of the timing performance, an aspect which is crucial for pileup mitigation at the HL-LHC, yield a resolution better than 100 ps using SiPMs, when the fast Cherenkov component from the fibers is exploited.
A matrix of 5 x 3 channels has been built and has been exposed to high-energy electrons from the CERN SPS to study the impact angle dependence of energy resolution and response up to ˜15 deg. Its granularity and sampling fraction have been optimised for optimum pileup rejection. Transverse dimensions of 17 mm x 17 mm, 12 samplings of 6 mm Tungsten and 6 mm CeF3 for a total of 25 radiation lengths, and a readout using Avalanche Photodiodes have been adopted.

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