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Calorimeters for precision timing measurements in high energy physics

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Current and future high energy physics particle colliders are capable to provide instantaneous luminosities of 1034 cm-2s-1 and above. The high center of mass energy, the large number of simultaneous collision of beam particles in the experiments and the very high repetition rates of the collision events pose huge challenges. They result in extremely high particle fluxes, causing very high occupancies in the particle physics detectors operating at these machines. To reconstruct the physics events, the detectors have to make as much information as possible available on the final state particles. We discuss how timing information with a precision of around 10 ps and below can aid the reconstruction of the physics events under such challenging conditions. High-energy photons play a crucial role in this context. About one third of the particle flux originating from high-energy hadron collisions is detected as photons, stemming from the decays of neutral mesons. In addition, many key physics signatures under study are identified by high-energy photons in the final state. They pose a particular challenge in that they can only be detected once they convert in the detector material. The particular challenge in measuring the time of arrival of a high-energy photon lies in the stochastic component of the distance to the initial conversion and the size of the electromagnetic shower. They extend spatially over distances with propagation times of the initial photon and the subsequent electromagnetic shower larger compared to the desired precision.

We present studies and measurements from test beams and a cosmic muon test stand for calorimeter based timing measurements to explore the ultimate timing precision achievable for high-energy photons of 10 GeV and above. We put particular focus on techniques to measure the timing with a precision of about 10 ps in association with the energy of the photon. For calorimeters utilizing scintillating materials and light guiding components, the propagation speed of the scintillation light in the calorimeter is important. We present studies and measurements of the propagation speed on a range of detector geometries. Finally, possible applications of precision timing in future high-energy physics experiments are discussed.

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