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Time resolution studies for the future LHCb Electromagnetic Calorimeter

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During Runs 5 and 6, the LHCb experiment at CERN will operate at a luminosity up to 1.5×10^{34} cm^{-2}s^{-1}, requiring substantial upgrades to its Electromagnetic Calorimeter (ECAL) to handle high radiation doses and achieve time resolutions of few tens of picoseconds mitigating pile-up effects.

The detector under development is a Spaghetti Calorimeter (SpaCal) composed of scintillating fibres (polystyrene or garnet crystals) in a dense absorber (lead or tungsten). Ongoing investigations are focused on the photodetectors (PMTs) selection and their impact on the overall timing performance.

Simulation studies of a lead-polystyrene module show that fast PMTs result in worse time resolutions due to the longitudinal showers' fluctuations, which introduce a bias in the time stamps defined by the Constant Fraction Discriminator (CFD) algorithm. A correction procedure has been developed to remove such bias, improving the time resolution by few tens of picoseconds. Additionally, a correlation between signal rise time and shower depth has been observed.

Data from a test beam campaign conducted at the CERN SPS in June 2024 have been analysed to measure the timing resolution of two tungsten-polystyrene SpaCal prototypes, comparing four PMT models and two fibre types. By exploiting a rise-time-based correction procedure, time resolutions below 20 ps at high energies have been reached, with the fastest PMTs undergoing larger corrections, as expected from simulations.

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