Development of ultra-accelerated, radiation-hard GAGG for the upgrade phase II electromagnetic calorimeter of LHCb: PicoCal

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Future colliders aim to operate at high luminosity (HL), enabling the collection of larger datasets to study rare events. Picosecond timing is essential to cope with the high rate, by mitigating event pile-up, ensuring accurate particle identification, and preserving energy resolution. Additionally, hadron colliders entail severe radiation damage. This drives the need for scintillating materials combining fast scintillation, high light yield and strong radiation hardness.

Garnet-based scintillators, such as GAGG have emerged as promising candidates. Commercial GAGG has a slow tail in the scintillation which is prone to pile-up. However, it was demonstrated that the scintillation characteristics can be modified by tuning the composition. Significant R&D efforts are ongoing to optimize their performance for calorimeters, such as the upgrade II of the LHCb experiment (PicoCal) at the HL-LHC. The R&D effort program has been set up by Peking, Tsinghua Universities, and the SiPAT company in collaboration with the CERN's LHCb ECAL Upgrade II team. Our presentation will include comprehensive laboratory characterization of multiple ingots produced by SiPAT to assess the influence of growth conditions on light yield, timing performances and a systematic evaluation of radiation damage induced by protons and gamma rays. Spaghetti Calorimeter (SpaCal) prototypes with GAGG fibres have been assembled and testbeam measurements performed for performance studies focusing both on energy reconstruction and time resolution. Together, these measurements quantify the timing performance, optical and scintillation properties, and radiation tolerance of novel ultrafast garnet compositions.

The results demonstrate that GAGG's composition can be finely tuned to match application requirements, allowing the performance to be tailored between very high light yield, up to several tens of thousands of photons per MeV, and ultrafast scintillation down to a few ns. In this presentation, we will summarize the R&D process from small-sample characterization to ingot growth, and also report the latest results covering optical, timing, and radiation-tolerance measurements, ultimately defining the requirements for garnets for the PicoCal project.

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