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Study of Future 3D Calorimetry Based on LYSO or LaBrCe Crystals for High Energy Precision Physics

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In the field of charged lepton flavour violation (cLFV), one is investigating various decays, some of which contain photons in the final state. To discriminate between signal and background, detectors providing excellent resolutions in all particle variables are crucial.

The photons in muonic charged lepton flavour violating decays are expected to be on an energy scale in the range of 10 to 100 MeV. The state of the art technique to detect these is a calorimeter based on a scintillating material coupled to photosensors of various kind.

Two very promising materials for a future calorimeter are on the one hand LYSO and on the other hand Lanthanum Bromide. Recent progress in the crystal growing process makes it feasible to build a prototype in near future and to test its response to photons of the expected energy scale of future high precision experiments.

Coupling such a crystals to $\mathcal{O}(100)$ silicon photomultipliers results in a granular detection of the optical photons. This provides geometrical information about the distribution of the light amongst the photon sensors and hence allows for a three dimensional reconstruction of the position of the first interaction between the incident γ-photons and the scintillator.

The response of both, $LaBr_3$(Ce) and LYSO prototypes fired by gammas of an energy of 55 MeV have been studied and very promising results were obtained. The MC simulations are based on GEANT 4 and include customised codes for the whole electronics chain from the photosensors up to the data acquisition validated with measured data.The results presented here are based on the final reconstruction algorithm based on the full waveform analysis. The waveforms are digitised at a frequency of 2 GSamples/s.

For Lanthanum Bromide and LYSO crystals with a size of 10 Molière radii and 15 radiation lengths, these ultimate resolutions have been obtained for gammas of 55 MeV energy: an energy resolution significantly below 1 \percent with clearly better values for Lanthanum Bromide, a time resolution of $\mathcal{O}$(30 ps) and a position resolution of $\mathcal{O}$(5 mm).Such performances pose these future calorimeters at the technology forefront and makes them eligible candidates for upcoming cLFV experiments.

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