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Advanced scintillators for fast-timing applications

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Fast scintillator detectors such as $LaBr_3$(Ce) are changing the landscape in several research fields including experimental nuclear physics and medical imaging systems. This is due to the combination of excellent time response, good energy resolution and high effective Z. Advanced instrumentation for radioactive ion beam experiments takes advantage of these novel scintillator crystals and enables fast-timing experiments that allow the measurement of nuclear state lifetimes down to tens of picoseconds. On the other hand faster scintillators allow replacing the present generation of LSO or LYSO-based PET scanners, and improving the achievable time resolution for TOF-PET. Moreover, short decays times will be able to sustain higher rates enhancing the sensitivity of modern preclinical scanners.

In this contribution we report on the experimental investigation of the time and energy response of detectors based on inorganic scintillators with strong potential for fast timing and imaging applications. The selected crystals are $LaBr_3$(Ce), $CeBr_3$ and co-doped $LaBr_3$(Ce+Sr) scintillators. An intercomparison of the energy resolution and time response of cylindrical 1-inch in height and 1-inch in diameter crystals coupled to optimized photomultiplier tubes, is provided. The performance of custom crystals, specially designed for timing measurements, is also described.

Secondly, alternative readouts based on Silicon Photomultipliers (SiPMs) are discussed. These photosensors exhibit high photon detection efficiency, are insensitive to magnetic fields, have a small size and are relatively easy to use with simple read-outs. They are also intrinsically fast. In this work we investigate the time and energy resolution achieved with the relatively large scintillator crystals coupled to suited SiPMs and compare them to those obtained with photomultiplier-tube readout.

Finally, we discuss digital signal processing for the fast signals from the scintillator detectors. Digital processing has become a standard in data acquisition for multi-parameter set-ups, since it provides good performance in terms of energy resolution, dead time and flexibility. Nevertheless digital methods able to recover the excellent intrinsic time resolution of fast scintillators are still not widely available. We present results of digital acquisition and processing strategies, and compare them to analogue electronics. We show that digital processing is a competitive technique for fast scintillators and holds a strong potential for its implementation in standard set-ups.

Primary authors: FRAILE, Luis Mario (Universidad Complutense (ES)); BENITO, Jaime (Universidad Complutense); GARCÍA DÍEZ, Miguel (Universidad Complutense (ES)); SANCHEZ-TEMBLEQUE, Víctor (Universidad Complutense (ES)); UDIAS MOINELO, Jose Manuel (Universidad Complutense de Madrid); VEDIA, Victoria (Universidad Complutense de Madrid (UCM))

Presenter: FRAILE, Luis Mario (Universidad Complutense (ES))

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