COINCIDENCE TIME RESOLUTION OF FAST INORGANIC SCINTILLATION CRYSTALS: GAGG:Ce, LYSO:Ce AND BGO

Alexei Bondarev[1], Mikhail Korjik[1], Andrei Fedorov[1], Yauheni Talochka[1], Vitali Mechinski[1]

[1] Research Institute for Nuclear Problems, Belarusian State University, Belarus
alesonep@gmail.com

With the development of fundamental and applied physics, the demand for fast inorganic scintillation crystals as a working body of ionizing radiation detectors is growing. The latter are successfully used in positron emission tomography (PET) and detectors for experimental high energy physics. At present, an important property of scintillation crystals, in addition to light yield, luminescence decay time, radiation hardness, has become the ability to resolve signals in time or coincidence time resolution (CTR). Modern experiments in high-energy physics, such as CMS detector at LHC accelerator at CERN, require CTR value of dozens ps.

Scintillator time resolution measurements requires to use a special method called the coincidence method. It allows to determine the temporal relationship between correlating values. In this work CTR was measured by using SiPMs ASD-RGB4S-P with 4x4 mm^2 active area and PDE (photon detection efficiency) exceeding 33% at 550 nm. Crystals being wrapped with Teflon® tape. The experimental setup for the CTR measurements was composed of a pair of identical detection modules equidistantly placed on the opposite sides of a ^{22}Na source simultaneously emitting two 511 keV gamma-ray photons. Each detection module included of a SiPM and a transimpedance amplifier with dual output (amplitude output and timing output with PZ-shaper). The first amplifier output was used for selection of 511 keV photopeak events by measuring the energy of the detected gamma photons. A signal for CTR measurements takes from second output. The samples under study with dimensions 3x3x5 mm^3 for LYSO:Ce and 3x3x3 mm^3 for BGO.

We approximate our scintillation pulse entering a photo-receiver in a single detector by two exponents with rise and decay components τ_r , τ_d, respectively:

$$f(t,t_0) = \frac{\exp\left(-\frac{t-t_0}{\tau_d}\right) - \exp\left(-\frac{t-t_0}{\tau_r}\right)}{\tau_d - \tau_r}\theta(t-to) \tag{1}$$

where t_0 is the moment of energy deposit in a crystal, $\theta(t - t_0)$ is a Heaviside step function. Here and after, we will exploit the first approach for time resolution.exp

Using $f(t,t_0)$, we can obtain the distribution density $p_{CTR}(\Delta t)$ of the time delay Δt for registering the same annihilation event in two identical detectors (in a coincidence scheme):

$$p_s(t) = C_s Y^* f(t)\left(1 - \int_0^t f(\tau)\,d\tau\right)^{Y^*} \tag{2}$$

$$p_{CTR}(\Delta t) = \int_0^\infty p_s(t) p_s(t + |\Delta t|) dt \tag{3}$$

where Y^* − light yield, multiplied by the absorbed energy, C_s – normalizing constant.

The variance of the random value Δt is:

$$D[\Delta t] = \int_{-\infty}^{\infty} p_{CTR}(t)\,(t - M_{CTR}[\Delta t])^2 dt \tag{4}$$

where $M[\Delta t] = \int_{-\infty}^{\infty} p_{CTR}(t)\;t\;dt$.