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VUV-SiPMs applied to BaF2 cross-luminescence detection for high-rate ultrafast timing applications

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Inorganic scintillators are widely used for fast timing applications in time-of-flight (TOF) positron emission tomography (PET), time tagging of soft and hard X-ray photons at advanced light sources and photon counting computed tomography (CT). As the best coincidence time resolution (CTR) achievable is proportional to the square root of the scintillation decay time it is worth studying fast cross-luminescence, for example in BaF2 which has an intrinsic yield of about 1400 photons/MeV. However, emission bands in BaF2 are located in the deep-UV at 195nm and 220nm, which sets severe constraints on the photodetector selection.

Recent developments in dark matter and neutrinoless double beta decay searches have led to silicon photomultipliers (SiPMs) with photon detection efficiencies of ˜20% at wavelengths of 200nm. We tested state-of-the-art devices from Fondazione Bruno Kessler and measured a best CTR of 51±5 ps FWHM when coupling 2x2x3mm^3 BaF2 crystals excited by 511keV electron–positron annihilation gammas. Using these vacuum ultraviolet SiPMs we recorded the scintillation kinetics of samples from Epic-crystal under 511keV excitation, confirming a fast decay time of 855ps with 12.2% relative light yield and 805ns with 84.0% abundance, together with a rise time of <4 ps, beyond the resolution of our setup. We further show that different dopants effectively can suppress this slow decay component, enabling GHz rate capabilities.

In addition, we revealed an ultra-fast component with sub-100 ps decay time and 3.7% light yield contribution, which is extremely interesting for advanced timing applications. Especially in the rising new field of time-of-flight CT, these almost prompt photons could imply a real breakthrough in thoroughly needed detector developments.

We will conclude this talk with exploratory Monte-Carlo simulations to fully investigate the timing benefits of cross-luminescence in TOF-CT, with the intention to give an action plan on future research focus.

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