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Towards a Cherenkov Based TOF-PET Scanner

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Positron emission tomography (PET) is a nuclear medicine modality enabling in-vivo imaging of a range of biological processes. The time-of-flight (TOF) measurement can be used to improve the signal-to-noise ratio of reconstructed images. In the last decade, the TOF resolution of PET scanners improved from about 500 ps FWHM to 200 ps FWHM with important consequences for the clinical capabilities. The most significant remaining contribution limiting the TOF resolution are the temporal properties of the light production in scintillators used for PET detectors. This limitation can be avoided by basing the TOF measurement on detection of Cherenkov photons, which are produced promptly. However, with energy of the annihilation gammas used in PET, only about 10 Cherenkov photons are produced, placing high performance requirements on the other main PET detector component, the photodetector. In this contribution, the Cherenkov based TOF-PET method and work exploring the performance of Cherenkov based detectors will be presented. Using lead fluoride (PbF_2), a pure Cherenkov radiator, instead of traditionally used scintillation crystals, a TOF resolution of 71 ps FWHM was experimentally demonstrated. With a module of 4×4 Cherenkov based detectors a gamma detection efficiency of up to 35% was measured. Simulations in GATE software show that a Cherenkov based TOF-PET scanner can achieve image quality comparable to current state-of-the-art. Also, lead fluoride is considerably less expensive than scintillator materials currently used, opening a possibility for lower cost PET detectors. This is of special interest for the emerging total-body PET scanners, which are pushing the length of the scanner to cover the whole human body.