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Exploring the limits of time resolution in Cherenkov detection of electron-positron annihilation events

High time resolution is becoming increasingly important for many applications in nuclear medicine (e.g., Time-of-Flight Positron Emission Tomography, TOF-PET) and high energy and nuclear physics applications (e.g., Positron Annihilation Spectroscopy, PALS). Present commercial TOF-PET systems based on inorganic scintillators provide coincidence resolving times (CRT) in the order of 325 ps –400 ps. Time resolutions at the level of 100 ps would drastically increase the signal-to-noise ratio of the reconstructed images. Ultimate time resolutions of 10 ps would allow direct image reconstruction.

We have performed experimental studies on employing the Cherenkov effect for bypassing the relatively slow scintillation processes and thus improving the CRT. The measurements show competitive results with state-of-the-art TOF-PET-scintillators approaching CRTs towards 100 ps, with the potential to be improved even further. Reduced energy information is inherent to this method. Possible solutions to this problem will be discussed as well.

The experiments were done using the Philips Digital Photon Counter (DPC), which provides excellent timing properties and single photon counting capability. For understanding the overall CRT, the intrinsic time resolution of the DPC and its individual single photon avalanche diodes were investigated using a femtosecond laser. The measurement results and their interpretation using Monte Carlo simulation will also be presented.

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