Contribution ID: **106** Type: **not specified**

Is sub-100 picosecond time resolution feasible in realistic TOF PET systems?

Saturday, 6 September 2014 15:30 (20 minutes)

The use of time-of-flight (TOF) information in positron emission tomography (PET) significantly improves image quality. Commercially available TOF-PET systems currently have a coincidence resolving time (CRT) of ~500 ps FWHM. The TOF benefit is inversely proportional to the CRT. In recent years, several groups have achieved experimental CRTs of about ~100 ps FWHM at the bench-top level, using small (~mm) scintillation crystals in combination with PMTs or SiPMs. An intriguing question is whether sub-100 picosecond CRT' s will be feasible in clinical PET systems. In 2012 we have shown how the statistical lower bound on the time resolution of a scintillation detector can be calculated as a function of the pertinent scintillator and photosensor properties. It seems reasonable to expect that future photosensors with low single-photon timing resolution (SPTR) and high photodetection efficiency (PDE) will enable CRTs « 100 ps FWHM in small scintillators. It is less obvious whether sub-100 ps CRT's can be achieved in large (~cm) crystals that are typically used in clinical PET systems. One important bottleneck is the variation of the optical path lengths of scintillation photons within the crystal, which is a function of the varying position of interaction of the annihilation photons. Furthermore, improvement of the CRT only makes sense if it can be achieved without sacrificing other important performance parameters, such as spatial resolution, energy resolution, and system sensitivity. These topics will be discussed from a theoretical as well as a practical point of view, including examples of recent experimental approaches towards sub-100 ps PET.

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Session Classification: Technology session I