Contribution ID: **27** Type: **not specified**

Low Power Implementations of High Performance Electronic Readout to Advance TOF-PET Detector Module Performance

Sunday 5 June 2022 11:30 (15 minutes)

State-of-the-art (SoA) electronic readout for silicon photomultiplier (SiPM)-based scintillation detectors that demonstrate experimental limits in achievable coincidence time resolution (CTR) leverage low noise, high frequency signal processing to facilitate a single photon time response that is near the limit of the SiPM's architecture. This readout strategy can optimally exploit fast luminescence and prompt photon populations, and promising measurements show detector concepts employing this readout can greatly advance PET detector CTR, relative to SoA in clinical systems (~200 ps FWHM). However, the technique employs power hungry components which make the electronics chain impractical for channel-dense TOF-PET detectors. We are developing readout circuits which are performant at low power and have small footprints, making them feasible for integration into TOF-PET detector prototypes. An implementation integrated with 3x3 mm2 Broadcom SiPMs exhibits sub-100 ps single photon time resolution (SPTR) at 10 mW/channel, with a minor performance degradation to 120±2 ps FWHM at 5 mW/channel. CTR measurements with 3x3x20 mm3 LYSO and fast LGSO scintillators demonstrated 127±3 ps and 113±2 ps FWHM at nominal power dissipation and 133±2 ps and 121±3 ps CTR at 5 mW/channel. 3x3x20 mm3 BGO crystals show 271±5 ps FWHM CTR at nominal power dissipation and 289±8 ps at 5 mW/channel. The compact and low power readout topologies that achieve this performance thereby offer a platform for TOF-PET to greatly advance system CTR, exploring novel detector concepts to push system CTR ≤100 ps, and also opportunities to provide high performance TOF-PET at greatly reduced material cost. We will present our readout developments for single pixel measurements and scintillation detectors comprising arrays of SiPMs with electronic multiplexing. We will also outline how this readout strategy can be employed in a novel photon counting detector concept that can facilitate ≤100 ps PET.

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Session Classification: Technologies for ≤100ps TOFPET resolution: Electronics

Track Classification: Technologies: Electronics