Contribution ID: **25** Type: **Poster**

#9-25 First attempts at scalable readout electronics to efficiently exploit Cherenkov radiation in PET instrumentation

Tuesday, June 10, 2025 4:50 PM (5 minutes)

Positron Emission Tomography (PET) is established as the molecular imaging modality of choice for the study and diagnosis of different medical conditions such as cancer or neurodegenerative diseases. Current instrumentation research focuses on increasing the sensitivity of PET systems to provide faster imaging or/and a reduction of the dose administered to the patient. With this objective, it has been proposed to construct large axial coverage PET systems and/or boosting the signal-to-noise ratio (SNR) of the reconstructed PET images by including precise time-of-flight (TOF) information of the detected annihilation photons. Yet, implementing large coverage scanners presents, in addition to a huge investment (high cost), major mechanical challenges since they require large volumes of materials (big clinical facilities), a lot of electronical components and the ability to process massive amounts of data. Besides, enabling accurate TOF capabilities requires the development of fast and low-noise electronics in a scalable format.

Finding a compromise between the two-above mentioned solution will be the ideal scenario, and way to accomplish this is building large axial coverage PET systems using Bismuth Germanate Oxide (BGO) scintillators since they present high density, high photo-fraction, short attenuation length for 511 keV photons and a manufacturing price that can be a factor 2-3 times cheaper than the conventional lutetium-based scintillators. Moreover, the BGO's emission spectra has two main components, namely: i) scintillation light, which itself contains two components, the faster one having a decay time of 45 ns (8% of the scintillation emission) and a slower one having a decay time of 365 ns (92% of the scintillation emission), and ii) Cherenkov light, which represents ~0.2% of the scintillation emission, but has an ultrafast emission time in the range of picoseconds. These promptly-emitted photons (Cherenkov light, ~17 above BGO's absorption band) can be exploited to boost TOF performance since this type of light is generated much faster than the scintillator's main luminescence yield and thus can be used to derive faster timestamps for the photon arrival time to the detector.

However, detecting these Cherenkov photons is challenging and requires the implementation of specific readout electronics able to discriminate the events based on their dynamics (ultra-fast or fast), at a reasonable cost. The discrepancy regarding the dynamic characteristics of the events arises from the varying number of detected Cherenkov photons that affects the temporal behavior of the signals. Exploiting this low yield for timing measurements requires the implementation of novel detector electronics able to discriminate between these two emissions. Such electronic readout has to mitigate the influence of electronic noise on achievable timing performance, which is especially difficult and, to date, there are no scalable BGO-TOF detectors.

In this contribution we show our first steps towards designing and implementing a scalable readout solution for large coverage BGO-PET systems. Our custom-readout circuitry is based on a balun transformer to split the photodetector signals combined with a two-channel method for event discrimination. The discrimination is based on the estimation of the rising time of the signals which will be done by feeding the split signals into two ASIC channels with different threshold levels. We have already designed and fabricated the electronic board which provides identical split energy (x2) and timing (x2) signals. The output signals were fed the PETsys TOFPET2 ASIC for digitization.

For evaluation we used 3x3x5 mm3 BGO pixels with all lateral and entrance faces polished and covered with Enhanced Specular Reflector (ESR), to promote light collection. The exit face of the pixel was also polished but coupled to an FBK-HD-MT 3x3 mm2 Silicon Photomultiplier (SiPM) by means of optical grease which was also connected to the splitting boards. We assembled two of these detector elements and placed them inside a

light tightened environment with the temperature stabilized to 23℃. A 22Na source was placed in between the two BGO pixels and coincidence data was acquired. To determine optimal measurement conditions different SiPM values of Vbias = [42.0-44.5] V in steps of 0.5V and different PETsys thresholds (thE, th1-low, th1-high, th2) were tested. Note that thE and th2 were the same for both split signals while th1 was different (th1-low, th1-high) to allow for the rise time estimation.
Despite very preliminary, these results served us to understand the BGO signal behavior and compatibility with the TOFPET2 ASIC. So far, we have results for the energy channels which already reported < 850 ps CTR. We are currently calibrating the timing path signals, which will enable us to apply software-based corrections based on signal dynamics to improve CTR. Note that, we have validated this hypothesis by testing the boards with a high-frequency oscilloscope, the CTR results improve from 390 ps (energy signals) to 240 ps when using the timing signals. We target for ~350 ps CTR using our readout solution + ASIC, and after applying corrections based on the signal dynamics.

Primary author: Dr GONZALEZ-MONTORO, Andrea (Institute for Instrumentation in Molecular Imaging (i3M), CSIC-UPV)

Co-authors: Dr GONZALEZ, Antonio J. (Institute for Instrumentation in Molecular Imaging (i3M), CSIC-UPV); Dr SANCHEZ, David (Institute for Instrumentation in Molecular Imaging (i3M), CSIC-UPV); Dr LOIGNON-HOULE, Francis (Institute for Instrumentation in Molecular Imaging (i3M), CSIC-UPV); BARBERA, Julio (Oncovision S.A.); LATELLA, Riccardo (Institute for Instrumentation in Molecular Imaging (i3M), CSIC-UPV; Metacrystal S.A.)

Presenter: Dr GONZALEZ-MONTORO, Andrea (Institute for Instrumentation in Molecular Imaging (i3M), CSIC-UPV)

Session Classification: #09 - Environmental and Medical Sciences

Track Classification: 09 Environmental and Medical Sciences