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Implementation of an analytical model of SiPM in GATE

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The aim of this work is to implement a model of SiPM that can be used to simulate scintillator-based spectrometers implementing SiPM like with PMT in the GATE simulation platform.

GATE [1] is a monte carlo simulation tool built on top of GEANT4. It has been developed in order to ease the simulation of complete systems used in medical imaging and radiotherapy applications like Computed Tomography (CT) scanner, Positron Emission Tomography (PET), radiotherapy devices, etc. To fully simulate an acquisition, GATE can manage time-dependent phenomena. Movements are synchronized with the evolution of the source activities by subdividing the simulated run into acquisition time frames with frozen geometries.

The use of SiPM, instead of PMT in PET field has increased for several reasons: it is cheaper than PMT, insensitive to magnetic field and provides potentially better timings. Improvements in timing benefits directly to PET imaging by the reduction the uncertainties on the localization of the source of emission. With the inclusion of an analytical model of the pair scintillation crystal/SiPM, GATE users will be able to predict the impact of SiPM over PMT in a PET system.

The first step was to develop this model. For this, we have started by implementing an analytical model of SiPM from Marano et al. [2] which describes the electrical response of a SiPM to a photoelectron. In this model, SiPM is treated like an electrical circuit and its characteristic times (rising time, quenching time, recovery time) are combinations of the component specifications of this circuit (number of cells, internal resistances and capacitances, etc.). Theoretically, experimental determination of these electrical parameters can provide a complete response scheme to one photoelectron. With the inclusion in this model of crosstalk, afterpulse, dark count rate, we intend to develop a comprehensive simulation tool for scintillator-based spectrometer coupled with SiPM.

The second step is to exploit these results that will be cross-validated against experimental data to assess a more generic model, identifying what quantities are fundamental to simulate SiPM with the GATE digitizer and to describe a systematic method to measure these quantities.

[1] Jan S. et al., "GATE a simulation toolkit for PET and SPECT". Phys. Med. Biol., 2004, 49, 4543

[2] Marano, D. et al. "New Improved Model and Accurate Analytical Response of SiPMs Coupled to Read-Out Electronics"IEEE Sens. J. , 2016, 16, 19-21

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