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Physics and Experimental Studies of SiPM Nonlinearity and Saturation

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Silicon Photomultiplier (SiPM) is often considered at the basic level as an array of Geiger mode APD cells which are connected in parallel, operate independently, and produce a sum of binary signals equal to number of fired cells. However, many specific effects make SiPM much more complicated device than just a collection of independent GM APDs.

Namely, during Geiger discharge and recovery of the SiPM cell a p-n junction potential drops down and turns back to its initial value resulting in non-binary response of the cell with loss of responsibility due to lower probability of avalanche triggering and lower gain in case of triggering. recovering. Correlated effects (crosstalk and afterpulsing) result in loss of independency of cell operations due to a random number of false events - fired cells. These effects are also sensitive to effective value of the cell potential thus being dependent on a state of the recovery process.

These simple factors are very important in considerations of SiPM nonlinearity and saturation as they lead to a quite complicated dependence of an output SiPM signal on input photons (SiPM response curve), especially for an arbitrary light pulse shape.

Generally, the response curve has three different parts determined by a number of impinging photons (photoelectrons) per cell. One can assume that the linear operating regime is characterized by the low number of photoelectrons per cell $N_{pe} \ll 1$, the oversaturation appears at $N_{pe} \gg 1$, and the nonlinear or saturated regime is between them.

It is obvious that the cell recovery process plays a key role in a behavior of the response curve for the saturated second and third regime in their dependence on light intensity. To understand it in detail, one should start from single cell studies and then takes into account all these effects in their interactions and complications associated with multi-cell operations of the SiPM.

Physics and experimental studies of the single-cell SiPMs and different types of SiPMs related to the nonlinearity and saturation will be presented.

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