Contribution ID: **28** Type: **Talk**

Statistics and Models of SiPM Nonlinearity and Saturation

Thursday, 14 June 2018 16:10 (20 minutes)

SiPM is an inherently nonlinear detector. Nonlinearity and saturation effects are originated from excess random losses of photon detection events due to a limited number of SiPM cells and non-instant recovery of the cells. From a statistical point of view, SiPM nonlinearity and saturation could be completely characterized by a probability distribution of a SiPM response in a required range of incident light signals. Partial characterization could be provided by a mean and variance of the response distribution, and it is the most important practical case for SiPM calibration and evaluation of the SiPM energy resolution beyond a linear operating range.
Known analytical models of the SiPM probability distribution could not simultaneously combine key factors affecting SiPM nonlinearity and saturation, namely, a limited number of cells, recovery process, crosstalk, and afterpulsing. Therefore, corresponding approximate expressions for the mean and sometimes also for the variance are proposed and used for the calibration. However, such combined expressions could hardly be associated with solid probabilistic grounds.
The report presents an overview of the state-of-art and modern developments in statistics and models of the SiPM nonlinearity and saturation as well as some practical recommendations on their applicability for calibration and energy resolution related applications of the SiPM.

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Session Classification: Nonlinearity and Saturation

Track Classification: Nonlinearity and Saturation