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Study on Saturation of SiPM for Scintillator Calorimeter using UV Laser

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The saturation of SiPM can be an issue for scintillator calorimeter with SiPM readout. When a large number of particles hit a scintillator and a large number of photons are injected to a SiPM, the output of the SiPM can be saturated due to the limited number of pixels. In order to convert the output of the SiPM into the number of incident photons correctly, it is necessary to understand the behavior of the SiPM saturation.

The saturation curve is usually measured by directly injecting fast laser pulse (∼400 nm) to a SiPM. However, the time constant of the emission of scintillation light (a few ns) is not negligible compared to the recovery time of SiPM pixels (dozens ns), so the saturation is expected to be mitigated. We propose a new method to measure the SiPM saturation with scintillation light excited by UV laser. The measured saturation curve can directly be used for the saturation correction at the calorimeter since the effect of the scintillation emission time is correctly included.

For example, the Scintillator Electromagnetic CALorimeter (Sc-ECAL) is a high-granularity EM calorimeter based on scintillator strips readout by SiPMs for the International Linear Collider (ILC). It realizes the virtual segmentation of 5 mm $\times$ 5 mm with strips of 5 mm $\times$ 45 mm $\times$ 2 mm in x-y configuration. The saturation of SiPM and its correction can be an issue for the Sc-ECAL to measure the dense EM shower at the ILC.

The fast fs UV pulse laser with the a wavelengths of 190 nm is used. The 190 nm laser causes scintillation excitation and is invisible to the SiPM. The laser is injected to the standard scintillator strip (EJ-212) readout by SiPM which is the same configuration as used for the Sc-ECAL. Two types of SiPMs which are the candidates for the Sc-ECAL, S14160-1315PS and S12571-015P, are used. The laser light is split by a half mirror to measure the incident light intensity using the photodiode (S12689-02). SiPM signal is converted into number of photoelectrons (N_{pe}). The current of the photodiode is also converted into N_{pe} using the relation with N_{pe} of SiPM at small N_{pe} region where no saturation is anticipated.

The saturation curves are obtained for a wide range of N_{pe}, and over-saturations are observed for both SiPMs. The saturation curves are measured also by injecting 470 nm pulse laser which doesn't generate scintillation light. A significant difference in the saturation curves between 190 nm and 470 nm is observed. It is considered to be the effect of the time constant of the scintillation emission. It can be a big impact on the saturation correction for the Sc-ECAL.

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