Studies of Silicon Photomultiplier Detector Performance

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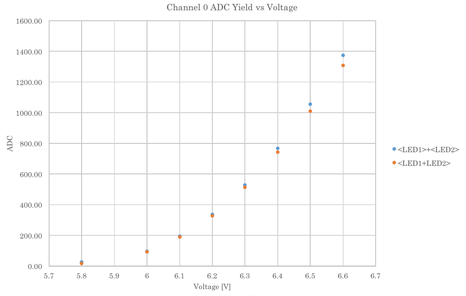
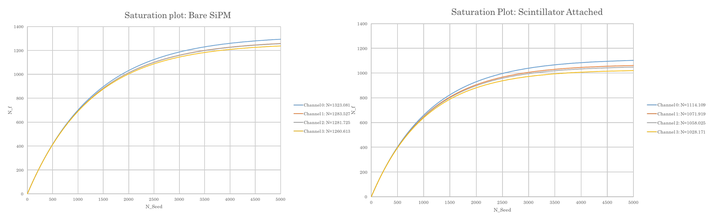
Introduction

As part of prototype testing for the Mu2e cosmic ray veto shield, the impact of silicon photomultiplier (SiPM) performance was studied over a range of experimental conditions. SiPMs were exposed to LED light pulses to determine response linearity as a function of exposed light intensity. Using the same light source, double peak data was recreated in effort to mimic stray neutrons and cosmic muons.

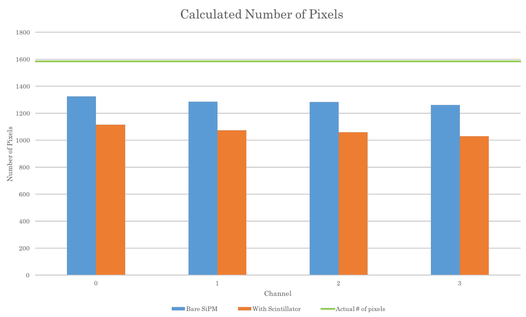
Saturation Effects



Above: ADC yield from running both LEDs simultaneously and from sum of each individual LED



Above: Channel-by-channel comparison of number of fired pixels as a function of total photon count times photon detection efficiency



Above: Comparison of measurements made with and without scintillator attached

Possible reasons

-Pixels hit by two photons cannot fire twice at the same time

-High amount of light emitted from two LEDs

-Optical fiber has preferred angles to emit light

-Area of optical fiber is smaller than area of SiPM

-Electronic noise and dark current being double counted when adding ADC yield from individual LEDs

$$N_f = N\left(1 - e^{\frac{N_{Seed}}{N}}\right)$$

N_f = Number of fired pixels in SiPM N = Total number of pixels

N_γ = Total number of photons PDE = Photon Detection Efficiency

$N_{seed} = N_\gamma * PDE$

$$N = \frac{N_f^1 * N_f^2}{N_f^1 + N_f^2 - N_f^{12}}$$

N_f^1 = Pixels fired from LED 1 N_f^2 = Pixels fired from LED 2

N_f^{12} = Pixels fired from both LED 1 and LED 2

Used the relation between number of fired total pixels to convert ADC values to # of photons

-Recorded maximum ADC values, used root macro to calibrate ADC to PE conversion

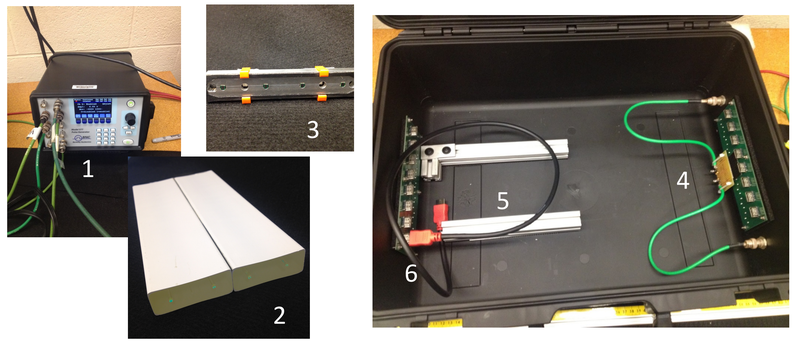
-Increased attenuation and used resulting data to scale ADC to PE conversion at higher attenuation

Acknowledgements

Thank you to:

Professor Craig Group, Dr. Yuri Oksuzian, Professor E. Craig Dukes, and Tyler Lam of the University of Virginia, Paul Rubinov of Fermilab.

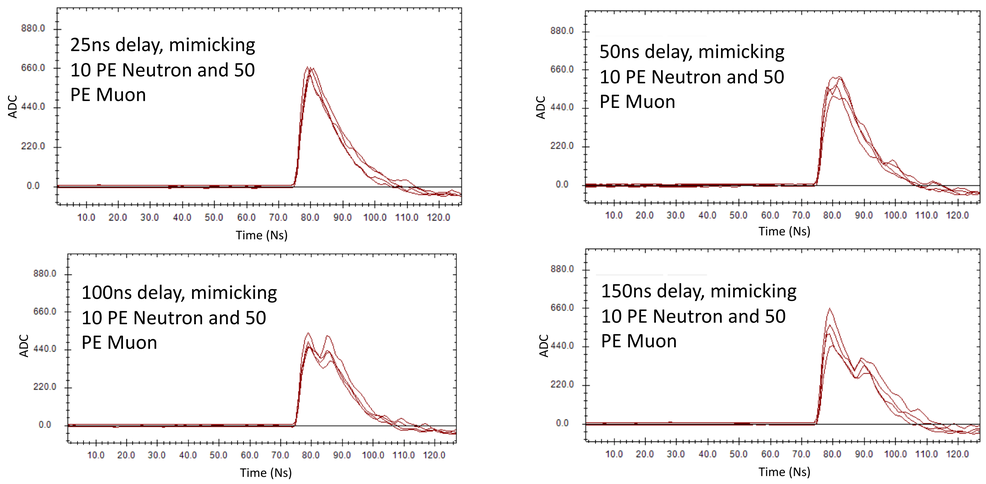
Experimental Setup



1. Pulse Generator with outputs to FEB and LED connectors
2. Example of bare scintillator
3. SiPM housed in CMB and casing
4. LED and breadboard
5. 80/20 Dicounter frame
6. HDMI Connector to FEB

Double Peak Resolution

Below: Double peak resolution data is reproduced by altering settings on pulse generator. Double peaks are observed experimentally when two pixels fire simultaneously, and affect data collection and fitting



Further Studies

-Further tests to determine the silicon photomultiplier dynamic range, and the relationship between optical power and SiPM photocurrent linearity

-In depth investigation of the optimal operating bias voltage

-Determine relationship between SiPM performance and radiation exposure

-Determine the relationship between photodetector resolution of bare fibers versus dicounters in response to ultraviolet light radiation

high frequency pulsar and laser diode