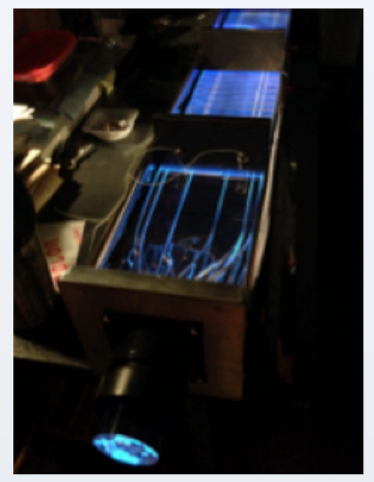
LED Pulser Array Characterization and Calibration

Larisa Thorne

Quark Interactions Group, Physics Department, Carnegie Mellon University

ABSTRACT

In order to study new physics in any experimental environment, it is necessary to understand how the detector interprets data that has been well studied.



In the case of Thomas Jefferson National Accelerator Facility's (JLAB) new Hadron Calorimeter (HCal-J), attaining the accurate position and time measurements required to track the motion of scattered particles necessitates some kind of calibration system.

In this calibration system, the photo-data of scattered particles will be mimicked by an array of bright, fast (<10ns) pulses, transmitted from LED board to PMT via optical fiber. Since the detector is very large, the array can be subdivided into modules, like the one being illuminated above.

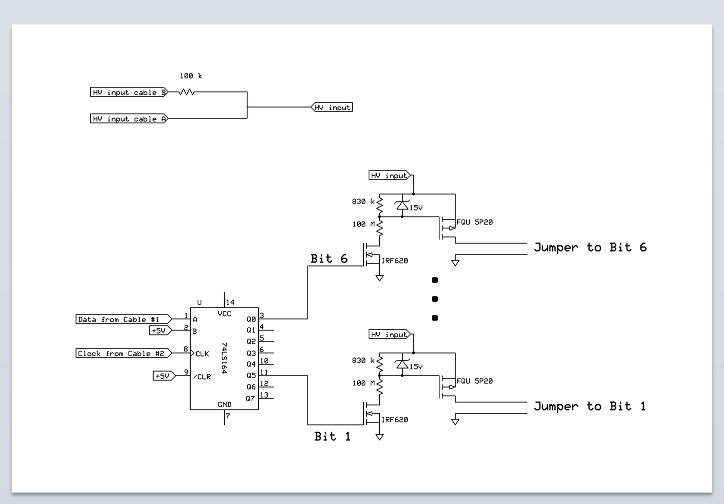
OBJECTIVES

Requirements of the LED array:

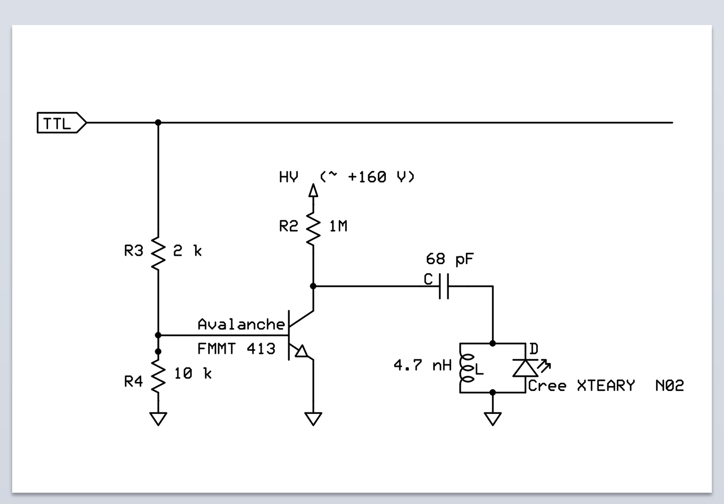
1. Ability to control 'on/off' state of each LED, individually.
2. No LED's signal should interfere with a neighboring LED's signal, at sufficiently far enough distance from the array (see "Cross-Talk")
3. LEDs have uniform brightness, allowing their total brightness to be tailored by combining individual signals from several LEDs.

ELECTRONICS

Satisfying requirement (1) involves designing a circuit board which depends on user input to determine timing of flashing of the LED(s) selected.

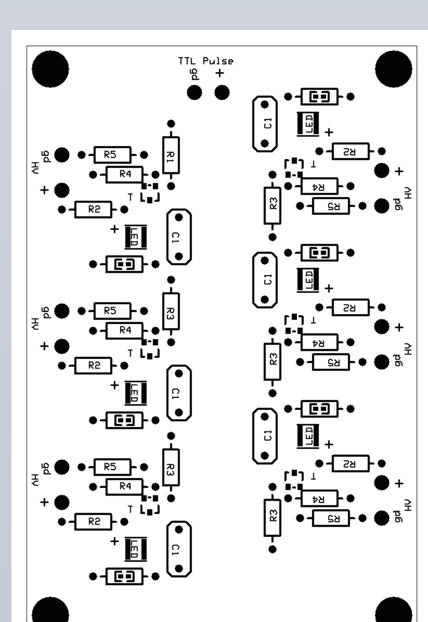


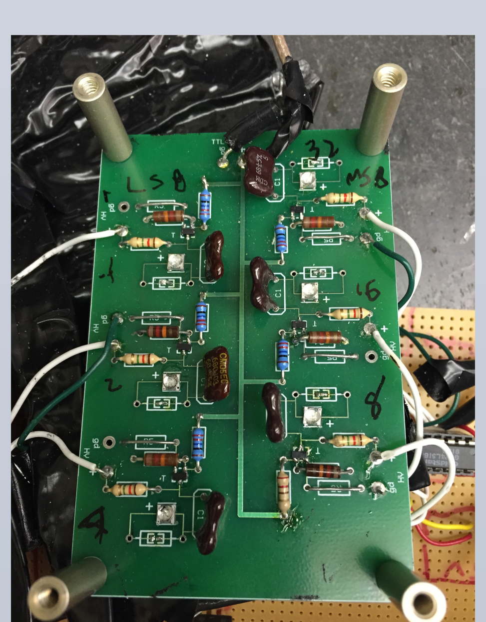
High voltage control schematic



LED pulser circuit

Implemented onto PCB, this design controls a sub-array of 6 LEDs. Pictured below are the layout (left) and actual (right) board.





THEORY

In scattering, the main mode of tracking scattered particle trajectories is via their interaction with surrounding media. In the context of this experiment, particles inelastically collide with HCal; yielding position, time, and energy information.

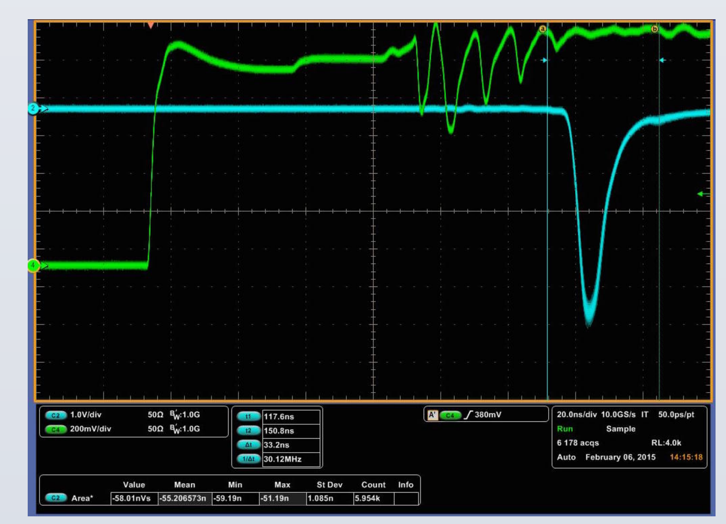
Since photoelectron distributions are governed by Poisson statistics, we can relate the number (N) of photoelectrons ("PE") to the mean and standard deviation of the acquired pulse integral:

$$N = \left(\frac{\mu}{\sigma}\right)^2$$

CROSS TALK

"Cross-talk" quantifies the effect of having other LEDs flashing during measurements on a single LED. This is usually done in the context of 'brightness' (=PE count), where relative difference shows how many extra PE are captured by the PMT as a result of simultaneously having LED3 and some combination of other LEDs on.

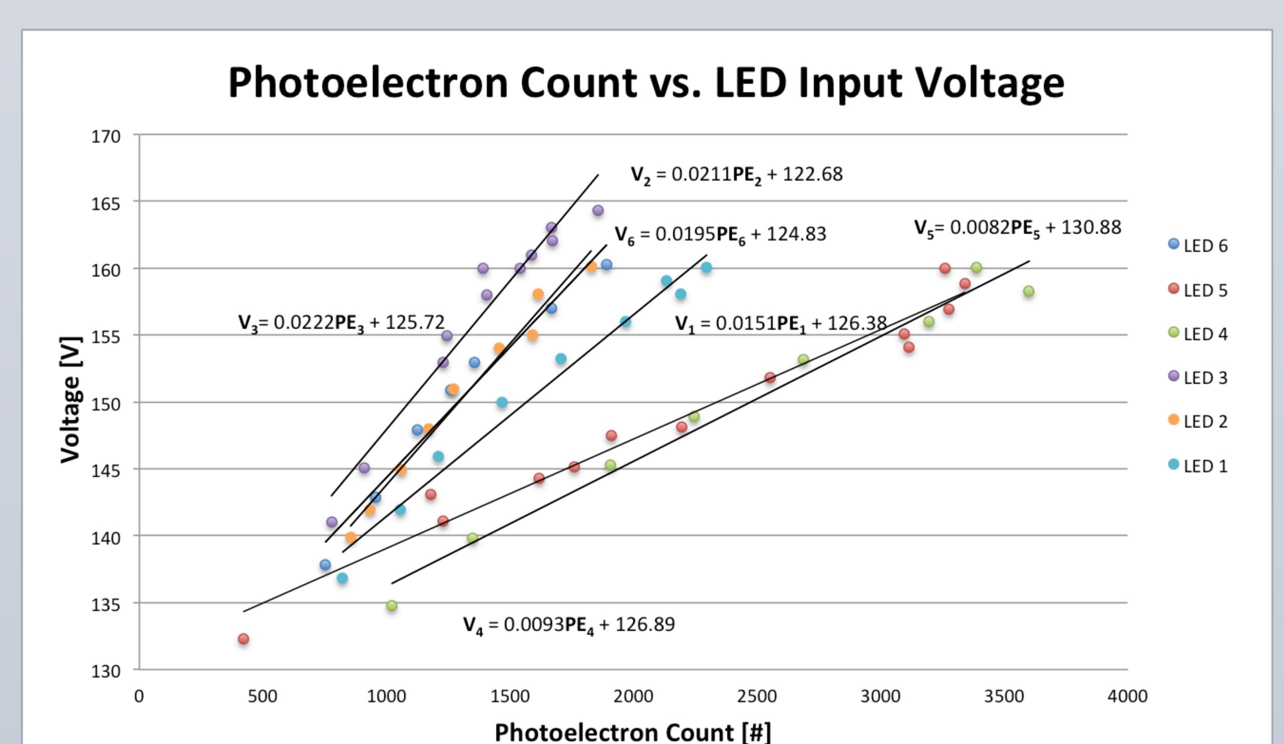
clk_fix(*)	LEDs on	Mean [nVs]	Relative Diff
4	3	13.35	-
5	1, 3	13.65	2.25%
4	3	13.37	-
6	2, 3	13.81	3.29%
4	3	13.35	-
12	4, 3	13.28	0.52%
4	3	13.34	-
20	5, 3	13.35	0.07%
4	3	13.26	-
36	6, 3	13.31	0.38%
4	3	13.23	-
63	All	13.84	4.61%



The cross-talk is further reduced with introduction of a grounding plane and baffling between LEDs. Pictured right is the clock (green) and pulse (blue).

PHOTOELECTRON COUNT vs LED VOLTAGE

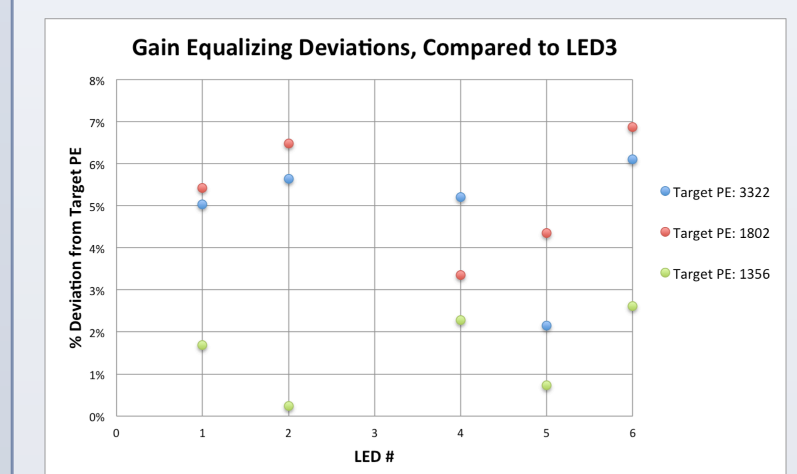
Due to variations in the manufacture process of circuit components, the output of each LED is unique. This uniqueness is best characterized by the relationship between PE count and LED input voltage:

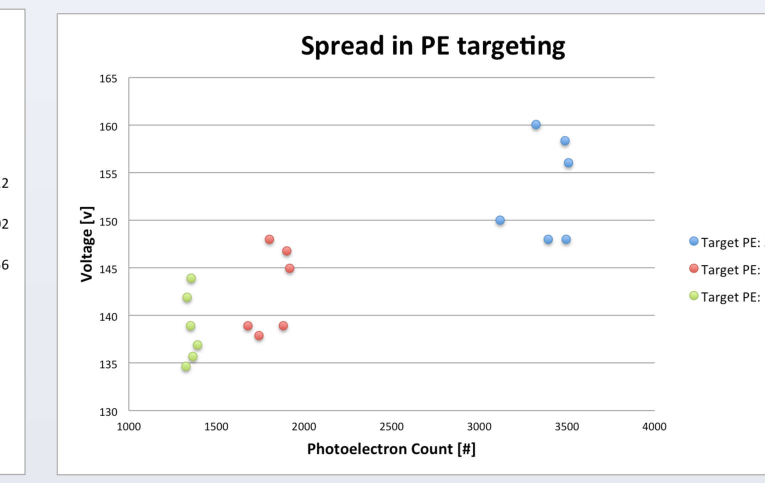


To first order, we assume linearity in the PMT. There seems to be a convergence at ~800 PE for 135V. This isn't enough PEs to work with, so we examine optical fiber ends, improve cutting techniques, increasing PE counts by ~200%.

GAIN EQUALIZATION

A major consequence of LED uniqueness is that some LEDs are brighter than others at the same applied voltage. Voltage adjustment equations can be generated to equalize PE counts on all LEDs to targets with three different PE counts. These targets are selected from areas that exhibit a linear relationship between PE count and input voltage. We are limited only by the nonlinear regimes of the PMT and pulser's high voltage 1V increment adjustments.





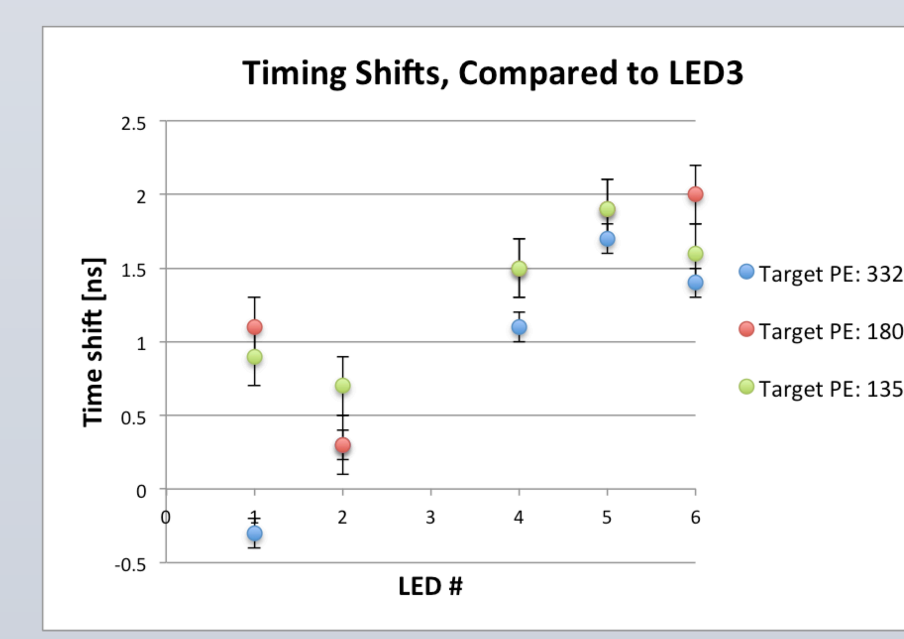
The cause of spread in voltage, even with PE targeting, is thought to be due to artificial widening/narrowing of peaks, or fluctuation of the peak itself.

The PE counts are also susceptible to changes in capacitance (400% PE increase for doubling in pF) and inductance (250% PE increase for quadrupling in nH).

TIMING RESIDUALS

During gain equalization, it is important to check that the peak itself isn't wandering in the time domain. This would result in a single reconstructed pulse which is smaller than the superposition of its constituent pulses.

To check this, we compare the time position at half maximum of each LED's light curve. Here, we compare positions at different target PE counts compared to those of LED3.



CONCLUSIONS

The measurement techniques used here have been well-developed to the point where another (smaller) underlying source of error, which is not associated with statistical error, begins to dominate. This requires re-examination of our original assumption of pure Poisson statistics for the next phase of array development: characterizing multi-fiber setups for multiple LEDs.

ACKNOWLEDGEMENTS

Prof. Brian Quinn (supervision) & Peter Marchetti (board design)