

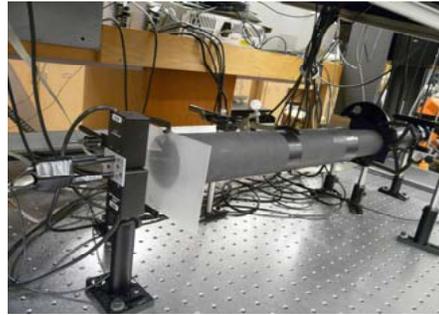


# Measuring Photons from Light Emitting Diode, One By One

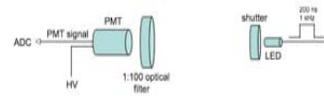
Sponsored by STRIDE and NSF RUI grant "Parity Violation in Electron Scattering at the Jlab Anna Boehle '11 (STRIDE) and Aimee Shore '10 with Piotr Decowski

## Introduction

This project is related to the Lead ( $^{208}\text{Pb}$ ) Radius Experiment (PREx) planned at the Thomas Jefferson National Accelerator Facility in Virginia (JLab). The purpose of PREx is to precisely measure the thickness of the "neutron skin" (the difference between the radii of neutron and proton distributions) in the  $^{208}\text{Pb}$  nucleus (which contains 126 neutrons and only 82 protons). The aimed unprecedented precision of this measurement ( $\Delta R = R_n - R_p$ , determined with accuracy  $\sim 1\%$ ) will eliminate uncertainties in nuclear interaction models. The measurement will be done using scattering of longitudinally polarized high energy electrons from lead target, and extracting the weak interactions sensitive mainly to neutrons from asymmetry of these scattered electrons (difference between flux of electrons with spins oriented along their motion and flux of electrons oriented in the opposite direction). Detectors for electron flux measurement were designed and constructed at Smith College and UMass. An important part of these detectors are the sensitive photomultipliers (PMTs) that register photons produced by electrons as they pass through the detector. In order to achieve the required accuracy, the gains of these photomultipliers need to be precisely known. Gains are investigated using single photons radiated by a light emitting diode (LED). Usually it is assumed that photons are emitted randomly, allowing the gain of the photomultiplier to be calculated from the distribution widths of its electrical pulses. The purpose of the study performed at Smith College is to test this assumption. If the data do not support the assumption, then a different method of gain calculation must be used.



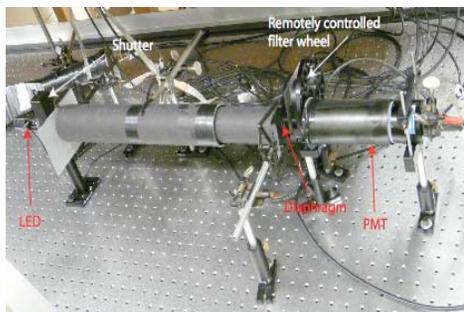
**Figure 2:** A close-up photo of the apparatus. The LED and shutter are in the left foreground. The voltage source for the LED is connected to the rear of the LED. The filter wheel and PMT are in the right background.



**Figure 3:** A schematic diagram of the experimental apparatus. Gate width determines frequency of LED pulses. A shutter blocks the LED during measurement of pedestal. Light is screened from the PMT by an optical filter. The PMT is connected to a high voltage (HV) source and to an ADC cable so its output can be quantified. The output is analyzed using software developed by CERN called ROOT.

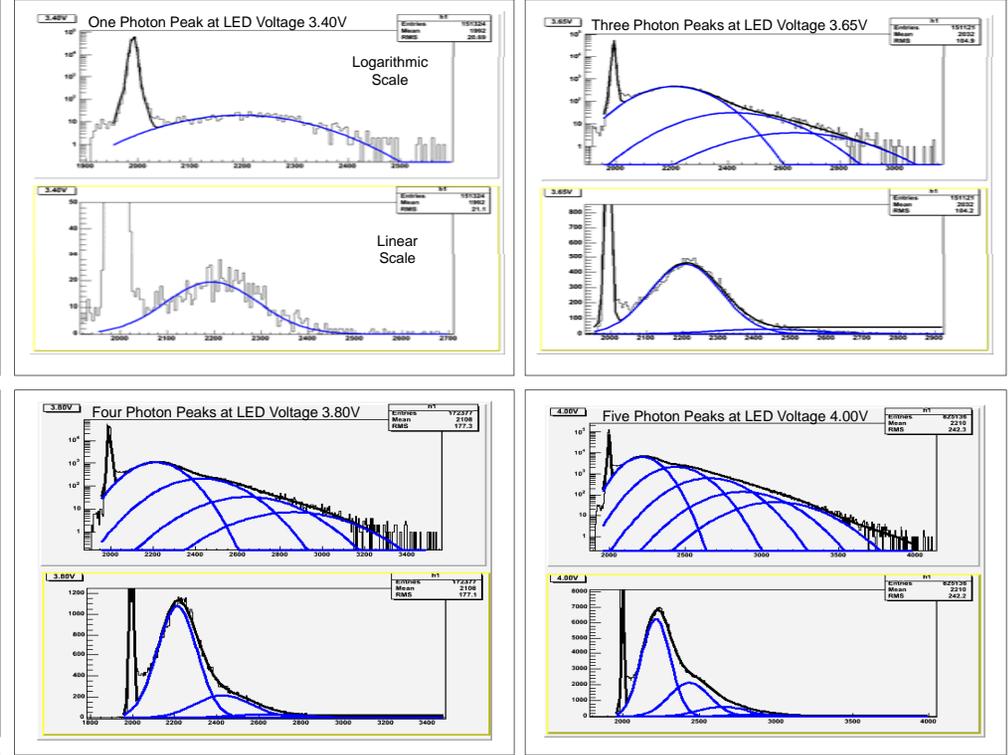
## Procedure

Spectra of photoelectron peaks are examined at different LED voltages and also at different time gate widths. With the LED shutter closed (ie no LED light reaches the PMT) the pedestal is measured at each LED voltage. This corresponds to the probability of the emission of zero PE's from the LED. With the shutter open, the number of PE peaks in the spectrum is tabulated. The time gate width determines the frequency of LED pulses. For this particular set of data, gate width is kept constant at 532 ns and LED voltage is varied in increments of 0.05V from 3.40 to 4.95 V. Spectra for several of these voltage values are plotted to the right.



**Figure 1:** A photo of the apparatus. It is typically housed in a dark environment to minimize the number of stray photons that reach the PMT. Photons emitted by the LED travel to the PMT where they are transformed into an electrical signals. The signal is recorded and then analyzed.

## Data



**Figure 4:** Distribution graphs of electrical pulses from the photomultiplier output. For each pair of graphs, the first one is plotted in a logarithmic scale and the second in a linear scale. As a photon hits the photocathode in the PMT, an electron is emitted (called a photoelectron, or PE). This PE ejects more electrons on its way through the PMT so that the original electrical input is amplified, allowing even one photon to be detected. Each blue peak indicates the number of times one or two or three, etc. PE's were detected during the length of the gate ( $\sim 500$  ns). The initial sharp black peak is the pedestal.

## Summary

From the data shown above, the probability that zero, single, double, triple, etc. photons are emitted by the LED within time of the gate can be calculated. Comparison of the data with the random Poisson distribution can reveal whether photons are indeed radiated randomly from LEDs or if correlations exist between them. It is too early to draw a conclusion about the randomness of photons, but future analysis will entail calculation of the aforementioned probabilities by integrating each PE curve at a certain LED voltage and dividing by the total area beneath all of the PE curves.