Component Testing of Ultra-Low Background Experiments with LArGe

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Abstract

The liquid argon germanium detector, known as LArGe, at the Center for Experimental Nuclear Physics and Astrophysics (CENPA), is in the preliminary component testing stage. The immersion of a sensitive detector in a bath of liquid argon promises to offer both a passive shield and an active veto for potential background sources in highly sensitive experiments, including dark matter detection or neutrinoless double-beta decay detection. In the LArGe experiment, four photomultiplier tubes, mounted on a $30.3 ft^3$ dewar, will be used to detect liquid argon scintillation photons; prior to this, their functionality must be verified and energy calibration spectra must be collected and analyzed for future reference.

1 Experimental Setup

Two tests were performed on the photomultiplier tubes (PMTs): a dark current test to verify PMT functionality and output linearity; followed by the collection of data for energy calibration, using an LED pulser to incite photoelectric interactions.

Each PMT was paired with a Preamp, also known as a PMT base, which provides high voltage inputs and anode outputs. Each PMT/base combination was tested in a light-tight box, which sealed it to outside sources of photons and other potentially disruptive radiation. A small LED pulser was placed near the bottom of the box, which, when turned on, shone upward towards a reflective aluminum shield at the top, intended to reflect the pulses toward the photocathode of the PMT. The fully assembled light box is shown in Figure 1.

1.1 Data Acquisition System

In order to collect spectra for energy calibration, we used a series of modules and translators which will be described below. The software with which we graphed the incoming pulses was ORCA, which effectively creates histograms from ADC data.

Our full signal and gate paths are described in Figure 3. Both "Signal Out" and "Gate Out" paths lead into the corresponding inputs on a LeCroy 2249W ADC.

The 2249W ADC utilized for our tests was limited by the rate of the incoming pulses; pulse rates much higher than 100 Hz would cause our ADC

Figure 1: Fully assembled light box. LED pulser is located on the bottom right-hand side.

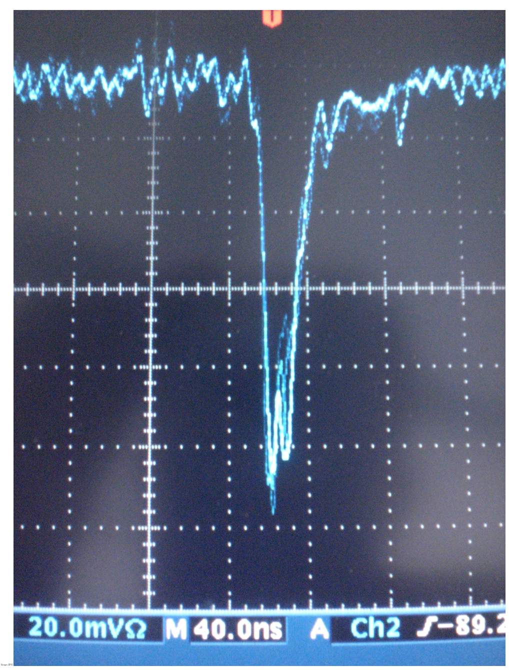

Figure 2: Sample PMT Pulse on Oscilloscope

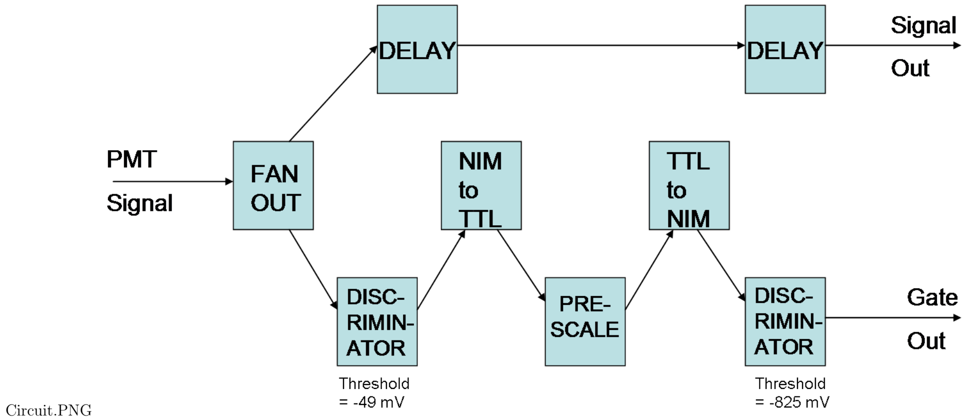

Figure 3: Data acquisition signal path. Both signal and gate outputs lead into a LeCroy 2249W ADC, which leads into a computer running ORCA data analysis software.

to stop registering counts prematurely. The solution was to use a Prescale Module to divide the incoming count rate by either 2 or 10 to decrease it to near 100 Hz or less, as measured by a LeCroy 2551 Scaler. This was sufficient to perform data runs of 30 minutes, which was all that was deemed necessary for these tests.

This data acquisition system was required only for the collection of energy spectra, not for the dark current measurements.

1.2 Dark Current Measurements

To perform tests of photomultiplier functionality and output linearity, dark current measurements were taken. With the LED pulser off, a series of increasingly higher biases (100V, 200V, 500V, and 1kV) was applied and the corresponding current of electrons emitted by the PMT was measured. The results were compared to previous measurements to ensure no change in output parameters.

1.3 Energy Calibration Spectra

To set standard output conditions for all four PMTs, the anode of each base was, from inside the light box and each in turn, connected to an oscilloscope to measure the pulse heights. With the LED pulser on, we adjusted the bias on our high voltage so that the output pulse was as near to 60 mV as could be achieved by 100 V intervals in the bias. A sample PMT pulse on the oscilloscope is shown in Figure 2.

Once the correct bias had been determined, the PMT signal was plugged into the fully assembled data acquisition system (outlined in Figure 3) and analyzed using the ORCA software.

2 Results

2.1 Dark Current Results

The measurements of dark current were found to be very consistent with previous results, and showed that the output of the PMTs were very nearly linear. Dark currents measured in this test are shown in Figure 4.

Current.PNG

	Bias (kV)	**Dark Current**		**Bias (kV)**	**Dark Current**
Base 1, PMT "1/3"	0.1	118.6 μA	**Base 2, PMT "2/3"**	0.1	112 μA
	0.2	237.7 μA		0.2	223.7 μA
	0.5	595 μA		0.5	558 μA
	1.0	1.2 mA		1.0	1.12 mA
Base 3, PMT "PMT"	0.1	105 μA	**Base 4, PMT "3/3"**	0.1	108 μA
	0.2	210 μA		0.2	215 μA
	0.5	540 μA		0.5	537 μA
	1.0	1.05 mA		1.0	1.07 mA

Figure 4: Dark Current measurements for all four PMTs/bases.

2.2 Energy Calibration Results

The spectra collected for three of the four PMTs are shown in Figure 5. The red lines represent spectra collected with the LED pulser off, while the blue lines represent spectra collected with the LED pulser on. As expected, we observed a very large pedestal peak at low energy when the LED pulser is in either position. The position and height of the photon peak at far right may prove useful, either for energy calibration or for reference should some problem arise as LArGe moves forward.

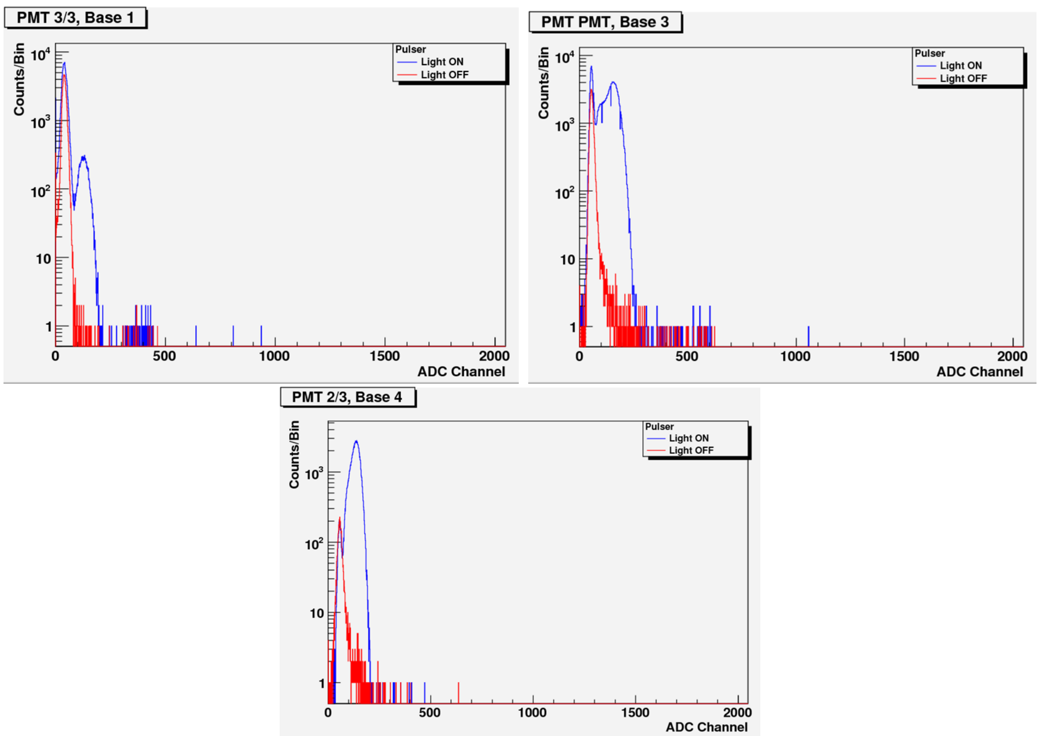

Figure 5: Counts/bin vs ADC channel for 30 min data runs inside the light box. (Blue: LED Pulser ON; Red: LED Pulser OFF.)
Top Left: Base 1, PMT “3/3”. Top Right: Base 3, PMT “PMT”. Bottom: Base 4, PMT “2/3”. Base 2, PMT “1/3” absent.

The fourth PMT/base, whose spectrum is absent in Figure 5, would not produce a pulse as the other three did, and more tests are required to determine the cause. Preliminary tests, whose goal was determine whether the PMT and/or the base have been damaged, have been inconclusive.

3 Future Plans

Once all four fully functional PMTs are securely mounted on the LArGe cryostat, the next step will be to run tests with some gas scintillator and view PMT responses. The likely candidates for the gas scintillator are N_2 or Argon gas. N_2 offers scintillation photons in the ideal range of sensitivity for the PMTs, but with a very low light yield. Argon gas has a much higher light yield and would thus be much easier to resolve, but the wavelengths of its scintillation photons are too low to be detected by the PMTs without the use of a wavelength shifter. This would add an extra variable into what one would expect to be a somewhat simple test. Further study is required to determine which of these two gases can be used most effectively to determine the PMT response in the fully assembled cryostat.

4 Conclusion

In summary, three of the four photomultiplier tubes and bases have been shown to be funtional, and spectra have been collected for future reference. Further testing is required to determine whether the fourth PMT/base will have to be replaced before moving forward.