Gain Uniformity Measurements

Kathryn Janzen

Department of Physics, University of Regina, Regina, SK, S4S 0A2

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Abstract

Preliminary gain uniformity measurements of the first SiPMPlus delivered in 2008 by SensL have been carried out at the University of Regina. This new array showed significant improvements in packaging and ease of use, signal quality, and gain uniformity on previous arrays tested in Regina. Testing procedures and preliminary results are outlined herein.

1 Introduction and Setup

Preliminary gain uniformity measurements of the first 4×4 cell SiPMPlus (silicon photomultiplier array) delivered in 2008 by SensL were carried out at the University of Regina. Each cell of the SiPMPlus is a 3×3 mm^2 SiPM. This array incorporated improvements both in the silicon processing as well as in the electromechanical connections and packaging, as compared to the first array tested under the Phase 1 contract[1].

The equipment used for these tests included an oscilloscope[2], a movable x-y stage[3], a laser with an SMA fiber output[4], and a short (∼30 cm) green scintillating fiber[5] with SMA connectors attached on each end. A stand was built in Regina to accommodate the x-y stage and to hold the output fiber from the laser head (see Figure 1(a)). The fiber output from the laser was connected to the scintillating fiber with an SMA connector built into the top support on the stand. The other end of the scintillating fiber was connected to the bottom support where a 1.48 cm long collimator with an aperture of 1 mm diameter was located (see Figure 1(b)). With the SiPMPlus mounted on the x-y stage, such a setup allowed the SiPMPlus to be moved around in two dimensions while the stationary fiber illuminated a 1 mm diameter spot on any cell in the array.

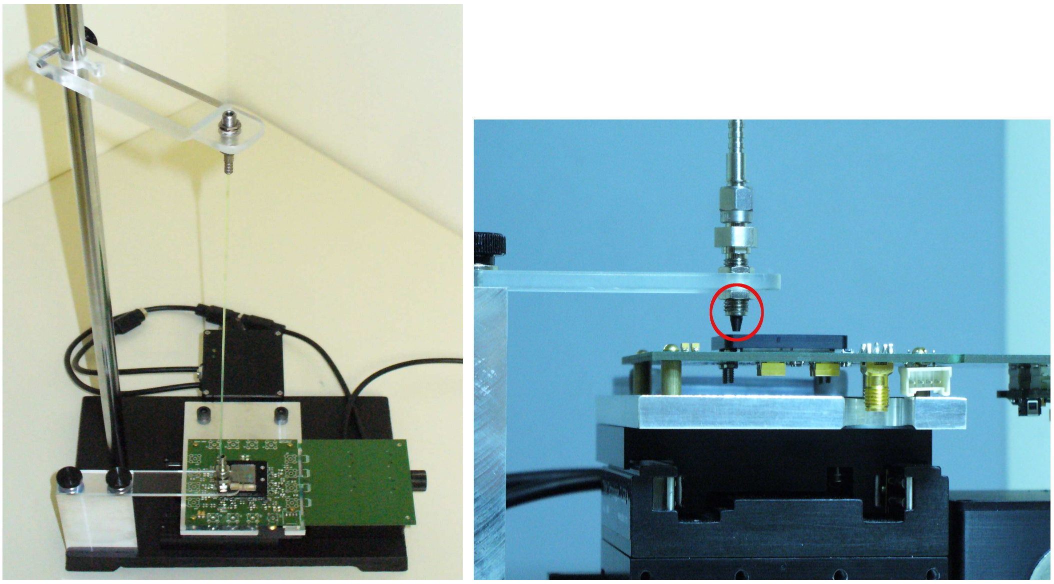
2 Measurements

The bias voltage for the SiPMPlus was provided by a power board which was sent along with the SiPMPlus. This voltage was optimally set by SensL and is typically 2 V above the breakdown voltage (in this case, V_{br} = 28.3 V). While this bias voltage may be adjusted using a potentiometer on the power board, it was not altered for these tests.

The pulses coming from the fiber output of the laser had a repetition frequency of 2.5 MHz, and a pulse width of approximately 60 ps. These pulses passed through one coupling point (laser to scintillating fiber) and through the ∼30 cm long scintillating fiber before illuminating the SiPMPlus. With a 60 ps laser pulse duration, the resultant pulse width from the scintillating fiber is ∼5 ns due to the intrinsic time structure of the fiber.

The electronics sent along with the SiPMPlus included an SMA output. Using an

[1] GlueX-doc-926-v4
[2] Tektronix TDS 5104 Digital Phosphor Oscilloscope
[3] Two Zaber T-LS Series Motorized Linear Stages connected for movement in two dimensions
[4] PicoQuant PDL 800-B Picosecond Pulsed Diode Laser with LDH-P-C-375B Laser Head
[5] Saint-Gobain BCF-20 Fast Green Scintillator



(a) (b)

Figure 1: (a) The stand built in Regina for gain uniformity testing of SensL SiPMs. Missing from the picture is the output fiber from the laser head which is inserted in the connector on the top support. (b) Note the black tapered collimator protruding from the bottom connection point, circled for clarity.

SMA-to-BNC adaptor and a ∼1.5 m long RG-58 coaxial cable, this output was connected to the oscilloscope which was then used to observe signals from each cell of the SiPMPlus. A typical signal can be seen in Figure 2.

To test the gain uniformity of the 16 cells in the array, measurements were taken of the amplitude of signals from the SiPMPlus while a 1 mm diameter spot was illuminated at the center of individual cells[6]. For each measurement, signals were viewed on the oscilloscope, which averaged the amplitudes over 30 seconds. Measurements were taken over four days and at various times of day.

The entire array was scanned 10 times and the results can be seen in the following surface plots. Figure 3 shows how the SiPMPlus cells correspond to the plots. A surface plot constructed using the average of ten measurements for each cell can be seen in Figure 5. Some early measurements for cells (1, 4), (2, 4), (3, 4), and (4, 1) gave amplitudes which were very different than results from subsequent measurements. This behaviour seems to have been limited to the first four measurements taken of the array, and is believed to be linked to intermittent electrical connections. SensL is aware of this behaviour and is working

[6]The position of the x-y stage was controlled using software provided by Zaber and modified for gain uniformity testing in Regina. The x-y stage has precision on the order of microns.

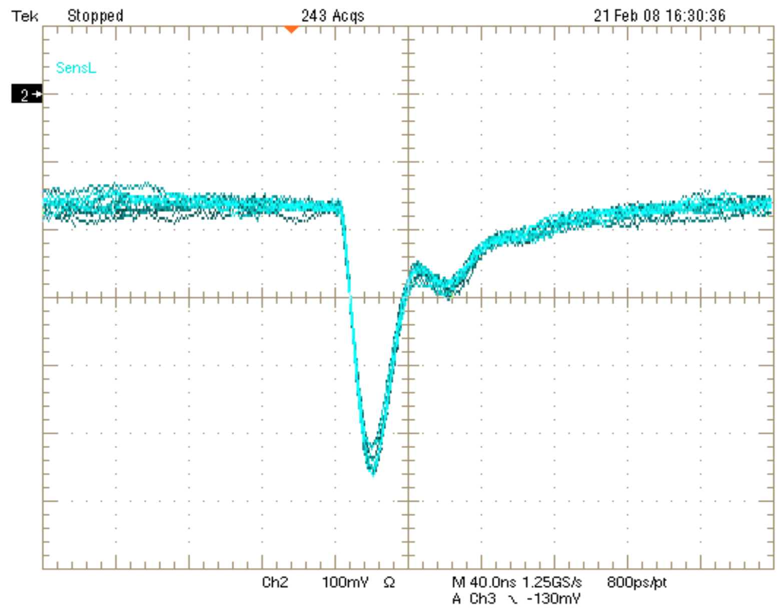


Figure 2: This is a typical signal produced from the SiPMPlus from SensL. The major scale division in the vertical axis is 100 mV and on the horizontal axis it is 40 ns. This particular signal was taken from cell (1, 2) at the time of the amplitude ratio trials, and under the same conditions. As read from the scope, this signal has an amplitude of 0.375 ± 0.019 V, a rise time of 10.8 ± 0.4 ns, and a fall time of 76.91 ± 0.14 ns, although the small reflection seen approximately 40 ns after the initial pulse is increasing the value of the fall time. This is a reflection that is believed to originate somewhere in the setup, and is not indicative of a problem with the SiPMPlus array. Because the pulses used to illuminate the SiPMPlus had a width of only $\sim$5 ns, the source does not account for a significant contribution to the timing of this signal.

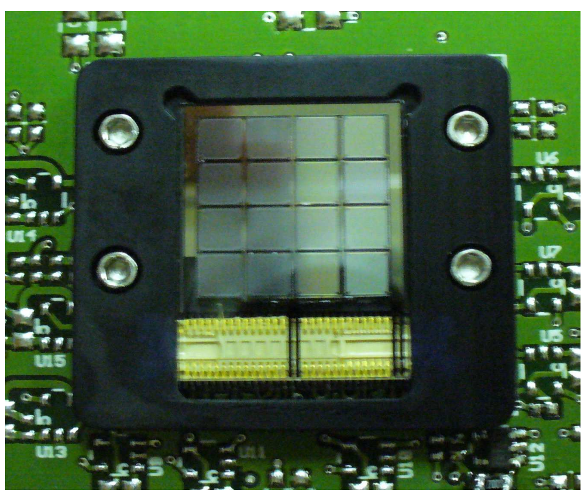


Figure 3: An image of the SiPMPlus array is shown inside its protective packaging. The yellow portion indicates the electronics connector. The 16 cells of the array are clearly visible. In this picture the x- and y-axes run horizontally and vertically respectively. The bottom left hand cell is cell (x, y) = (1, 1).

towards a solution of the problem. Clearly anomalous results were excluded, and after this the standard deviation over ten independent measurements was about one or two per cent in each case.

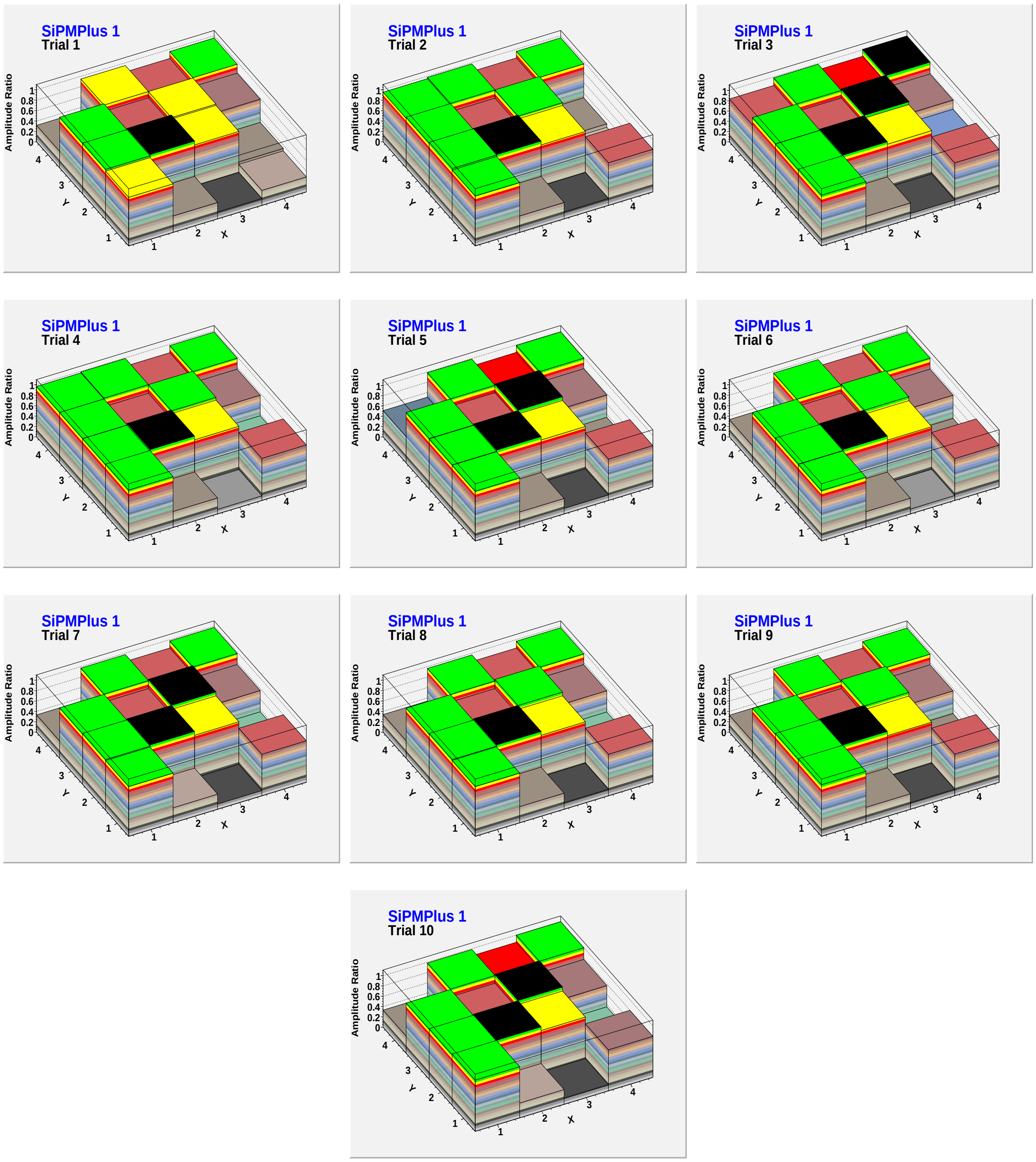


Figure 4: Amplitude ratios (ten measurements) for the first SiPMPlus from SensL in 2008. The amplitude for each cell is compared to the amplitude for cell (x, y) = (2, 2). Each level on the surface plot represents a 5% drop from the maximum amplitude of (2, 2). The scale is shown in Figure 5.

At the conclusion of these tests, it was discovered that the power supply used to provide voltage to the amplifier board was no longer functioning properly. A new power supply was provided by SensL and surface scans of the entire SiPMPlus were repeated. The results

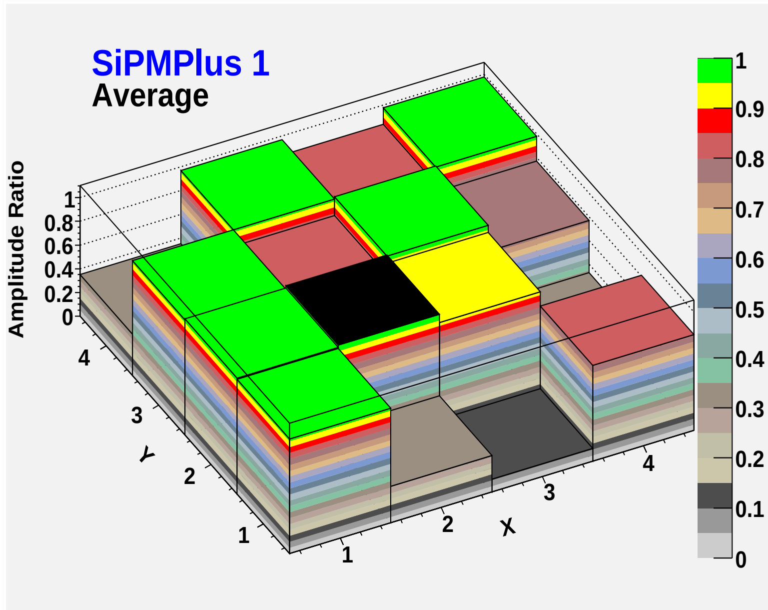


Figure 5: This is the average amplitude ratio for the individual cells of the first SiPMPlus from SensL. Each cell is compared to cell (x, y) = (2, 2) which consistently had the maximum gain for the array.

of these measurements can be seen in Figure 6. These results are slightly different from the results shown in Figure 5, which can be explained by the aforementioned intermittent electrical connections to certain cells in the array.

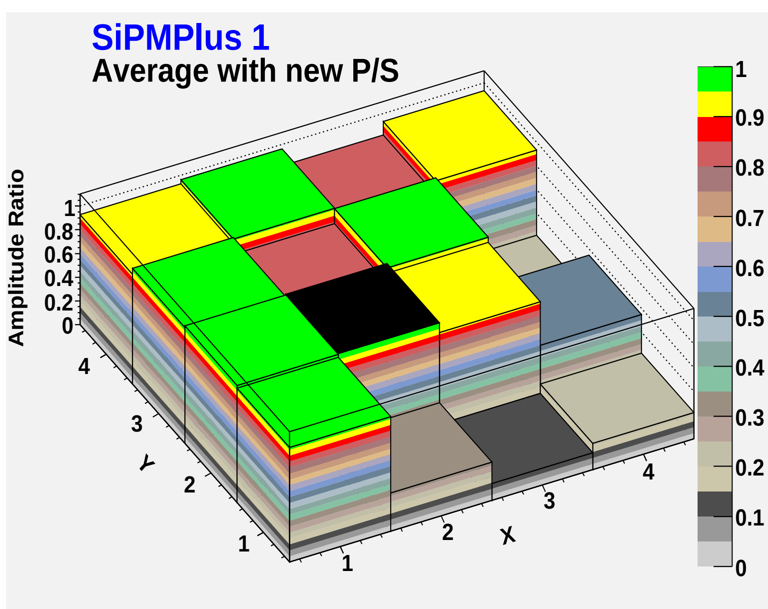


Figure 6: This is the average amplitude ratio for the individual cells of the first SiPMPlus from SensL as taken with the new power supply provided by SensL. Each cell is again compared to cell (x, y) = (2, 2) which consistently had the maximum gain for the array.

As a final preliminary test, the gain uniformity of individual cells within the SiPMPlus was measured. The procedure was similar to that of the gain uniformity tests on the entire array. For these tests, the 1 mm diameter light spot was used to illuminate the lower left-hand corner (referring to Figure 3) and was then moved along the cell in increments of ~ 0.35 mm in the x- and y- directions. A fringe of ~ 0.5 mm (one radius of the light spot) was left untested around the edge of each cell in order to eliminate geometric effects at the edges of the cells. The results of these tests can be seen in Figure 7. Comparing Figure 7 to Figure 6, it is notable that well-functioning cells (those with high amplitude ratios) show better uniformity across the cell than poorly-functioning cells (those with low amplitude ratios such as cells (2, 1), (3, 1), (4, 1), (2, 4), and (3, 4)).

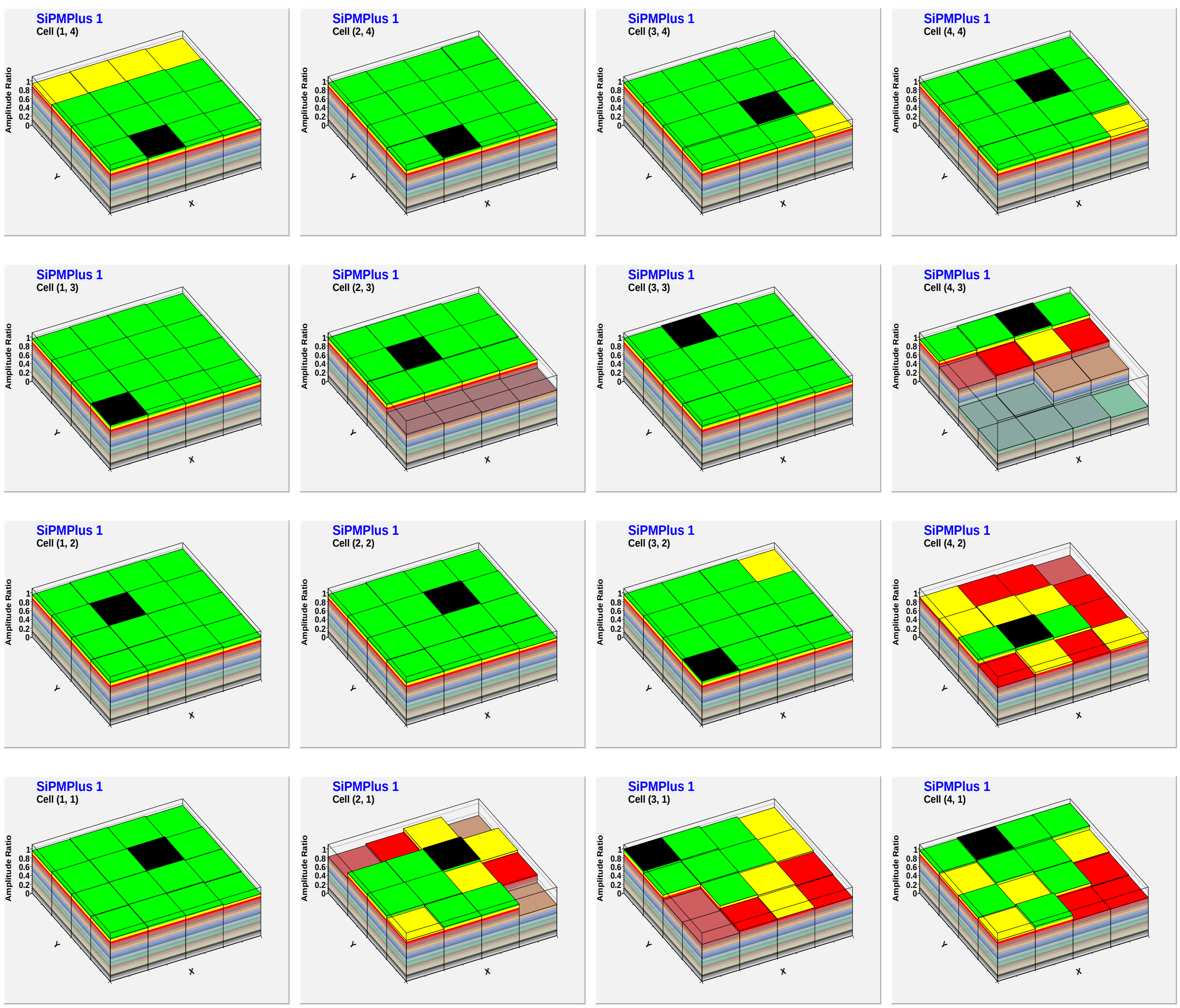


Figure 7: The amplitude ratio results of surface scans of each individual cell in the SiPMPlus array. Orientation of the plots corresponds to Figure 3. Note that each plot represents a set of independent measurements, and that in each case the measurements were normalized with respect to the black square which represents an amplitude ratio of one. The scale can be seen in Figures 5 and 6.

3 Preliminary Conclusions

Gain uniformity measurements of the second SiPMPlus array were performed , using a movable x-y stage and a system of fibers and SMA connectors that channeled light from a diode laser to the surface of the array. Whereas the first (Phase 1) array exhibited amplitude variations up to factors of two, this new array showed significant improvements in the silicon process and electromechanical assembly and packaging. Specifically, once clearly anomalous measurements were excluded from the analysis, the standard deviation in the relative amplitude of each cell was 1-2%. Furthermore, eight of the cells had amplitudes within 10% of each other, another four were within ∼20% with the remaining four appearing to be non-functioning.

The improvement in the signal quality of the 2008 SiPMPlus is impressive over the first arrays. However, before these arrays can be coupled to the Winston cones of the GlueX Barrel Calorimeter and used routinely to extract the number of photoelectrons, further improvements are needed so that all cells of the array produce signals within 10% of each other.