Method to Simultaneously Illuminate both SiPMs on a BCAL Readout Cell

A. Semenov, Z. Papandreou *, G.J. Lolos,

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

---

Abstract

The GlueX electromagnetic barrel calorimeter (BCAL) is composed of a lead and scintillating fibre matrix. It will primarily detect photons in the 0.06-3.5 GeV energy range using 3840 silicon photo multipliers (SiPMs) in a 2.2 T surrounding magnetic field and ca. 20° thermal equibrium volume. In order to monitor the *relative* gain of the SiPMs, a monitoring system based on pulsed LEDs is proposed herein. A blue-green LED mounted on a miniature PC board, will be attached to each SiPM light guide and its light will be transported via a short Kuraray ScSF-78MJ fibre to the light guide, at an angle that aims most of the light to the far/opposing SiPM. The system can be designed so that each LED can simultaneously "flash" both near and far SiPMs within a gain factor of two. The LED boards will be powered and pulsed by a controller board, located outside the BCAL's volume. These LEDs have a light variation of 0.5%/°C and the system is projected to degrade by 7%/year in pulsed DC mode.

Key words: gain monitoring, LEDs, scintillating fibres, electromagnetic calorimeter
PACS: 29.40.Mc, 29.40.Vj

---

1 Introduction

The leading candidate for the relative gain monitoring of the BCAL's SiPMs is the pulsed LED system developed by the Athens Group [1]. The system is comprised of a tiny, bright LED mounted on a small board and controlled by a separate larger board. The original concept was to attach the small board and LED directly onto the BCAL's light guides. Tests conducted both at

* Corresponding author. Tel.: +1 306 585 5379; fax: +1 306 585 5659
Email address: zisis@uregina.ca (Z. Papandreou).

Regina [2] and Athens [3] previously, resulted in a dynamic range of 30-50X between near and far PMTs rendering the simultaneous gain check of near and far PMTs not feasible. A fall-back option was considered, in which the LEDs would operate at two biases, low for the near SiPM and high for the far one. Such an operation introduces additional variables in assessing any gain drifts.

In a recent work [4], the light from the LED to the light guide was transported by employing one of our standard Kuraray SCSF-78MJ fibres, used in the construction of the BCAL. By carefully "aiming" the fibre towards the calorimeter module's face, the dynamic range was reduced to within a factor of two, thus solving the above problem. The methodology and results of this study are reported herein together with concepts to address mechanical considerations.

2 Regina Tests

The LED mounted on an Athens LPM board [1] was connected to a light guide using a short (∼5 cm) fibre. The fibre was epoxied into a hole drilled for this purpose into each light guide at an angle of 15° with respect to the guide's long axis, and its other end was epoxied to the Athens LED. The board was supported by a small piece of styrofoam. The intent was to use the Chilean light guide, however, its cross sectional area was 19×21 mm^2. Our photosensor holders – that are attached to either end of the Construction Prototype (Module 49) in our detector lab – can accommodate either SiPMs or PMTs and have a 20×20 mm^2 port for the light guide side that couples to the module; these holders were designed for the Regina Winston Cones, which are 20×20 mm^2 at that end. As constructing new holders would be time consuming and expensive, we decided to use a Winston cone for these tests instead. Both light guides are shown in Figure 1.

A second Winston cone was coupled to the opposing PMT. Both PMTs were 2" Burle 8575, used previously in our cosmic-ray runs [5]. Mu-metal shields and housings surround the light guides and PMTs, and both ends as well as the entire module were covered and protected against light leaks. The PMTs were powered to 2250 V and 2350 V, respectively, were gain balanced only roughly (within 20-25%) and their signal cables were connected to a discriminator and ADC channels. Measurements were taken with the room lights off. The experimental setup is shown in Figure 2.

For these tests, the LED bias was set to 9.3 V, somewhat on the low side of its range since at this setting the far PMT had a signal amplitude on a scope of 5 V whereas the near one had 2 V in the Run 1 setup. We did not study

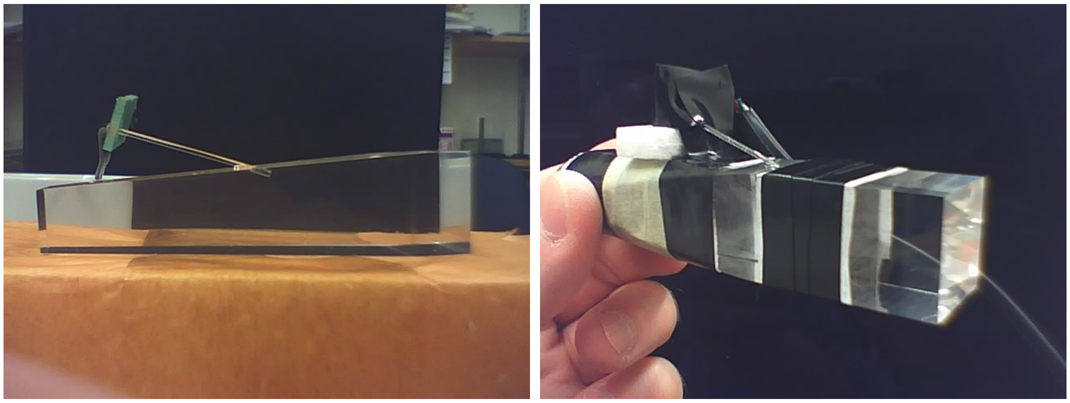

Fig. 1. A short Kuraray SCSF-78MJ fibre is inserted into the Chilean trapezoidal light guide (left) and the Regina Winston cone light guide (right). The fibre is epoxied into a shallow (few mm deep) hole drilled into the Plexiglas material at a angle of 15°.

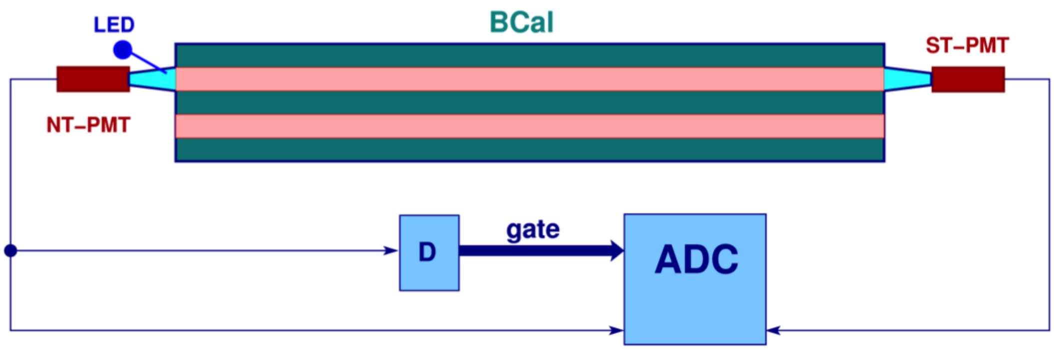

Fig. 2. The test setup is shown. The PMTs were labelled north-top (NT) and south-top (ST), respectively, with the PMT coupled to the light guide with the LED system on it defining the trigger, after passing through a discriminator set at a threshold of 50 mV. Two runs were taken, the first as shown and the second with the LED-light guide switched over to the south PMT. Care was taken during the switch to achieve a good optical contact, although a factor was introduced in the analysis to account for any such difference between Runs 1 and 2.

issues of stability at this bias, and it is possible that the LED did not return to this exact value following the powering down in the light guide swaps from north to south PMT. However, this and the differences in the optical coupling (grease was used) between Runs 1 and 2 were accommodated in the analysis using a LED-light coefficient (R_{LED}). The difference in gains between the two PMTs was handled using a second coefficient (R_{PMT}). Both PMTs had their pedestals at channel 17.

The measurements are shown in Figure 3. The top panels are from Run 1 and the bottom ones from Run 2. The red-filled spectra correspond to the PMT having the LED coupled to its light guide, and conversely the green-filled spectra reflect the opposing (or far) PMT. Gaussian fits were used to obtain the means of the distributions. The two simultaneous measurements from both runs allowed us to solve a system of four equations with four unknowns:

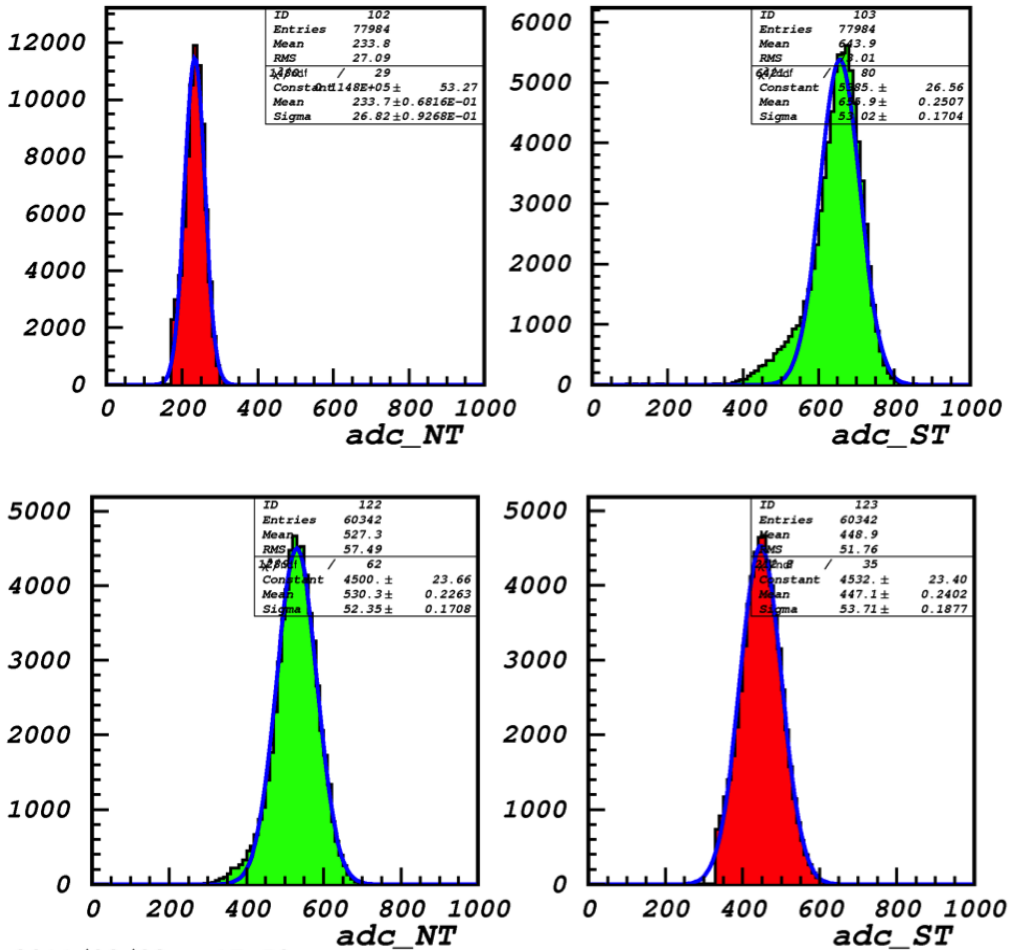

Fig. 3. ADC spectra from both north and south PMTs from Run 1 (top panels) and Run 2 (bottom panels). Gaussian fits and their parameters are shown in the inlets. Tails at the low side of some ADCs may be attributed to light bouncing multiple times in a light guide before entering the PMT.

$$ADC_1 = (234 - 17) = 217 \tag{1}$$
$$ADC_1 \cdot R_{PMT} \cdot R_{far-to-near} = (656 - 17) = 639 \tag{2}$$
$$ADC_1 \cdot R_{LED} \cdot R_{far-to-near} = (530 - 17) = 513 \tag{3}$$
$$ADC_1 \cdot R_{LED} \cdot R_{PMT} = (447 - 17) = 430 \tag{4}$$

where all numbers represent ADC channels and equations (1-4) correspond to Run 1 north and south, and Run 2 north and south spectra, respectively. The ratio $R_{far-to-near}$ is the sought-after number displaying the overall factor between far and near PMTs, that expresses the effective dynamic range of the simultaneous illumination of both PMTs. The resulting solution was:

$$ADC_1 = 217 \quad (5)$$
$$R_{PMT} = 1.57 \quad (6)$$
$$R_{LED} = 1.26 \quad (7)$$
$$R_{far-to-near} = 1.87 \quad (8)$$

So, whereas the past measurements resulted in a ratio $R_{far-to-near} = 0.02 - 0.03$, with this setup we achieved a reversal of a factor close to 100, yielding $R_{far-to-near} \approx 2$. With the settings in these tests, we have demonstrated that the simultaneous illumination of the readout devices at both ends of a module's cells can be achieved within a minimal dynamic range, and with little additional effort the number can be brought closer to unity.

3 Conclusions

The objective of this study was to examine whether an arrangement could be devised to allow for a simultaneous illumination of the SiPMs at both ends of each of the BCAL's readout cells, using the Athens-designed LED system.

Previous attempts with the LED coupled directly to the light guides had resulted in dynamic range factors between near and far PMTs ranging of 30-50, rendering such a solution unusable. In this study we have shown that a short fibre added between the LED and light guide, acts as light transporter, collimator and wavelength shifter, and reduces the dynamic range between far and near end to a factor of 2. Although a Winston cone was used in this study, the results should hold for the USM (Chilean), truncated-pyramid light guide design.

This method is the 'proof of principle'. Additional studies are needed to determine the optimal location along the light guide of the hole and fibre entry, as well as the optimal inclination angle. The small Gaussian tails could be investigated further as can TDC spectra, although none of these are expected to be show-stoppers.

What remains mainly to be investigated are mechanical issues.

- Drilling a shallow 1-mm diameter hole poses no technical challenge as long as this is done after the light guides are machined and before they are attached to the BCAL. Inclination angles of 10-20° should be investigated: whereas the former may be difficult to achieve mechanicly without causing "crazing" on the light guide's surface, the latter may end up directing to much light to the near PMT. However, as far as the drilling goes, all that is necessary is to blow out the fillings from the hole. There is no need to polish the interior of the hole as the epoxy will fill all minute cracks and crevices.

- The LED board is very compact, although the location and orientation of the LED on it is not suitable for the coupling to the fibre. One solution would involve detaching the LED from the board and having it connected via short wires. This will allow flexibility in accommodating the optimal angle of fibre to light guide axis.
- The entire system must be made compact in order to fit in the tight space between adjacent light guide on the BCAL. This may entail locating the insertion hole closer to the light guide's small end (that couples to the SiPM) where more space exists owing to the tapering of the Chilean light guides.
- The Athens LEDs, despite their small size, have a domed top that complicates the gluing of the fibre to it. A jig could be designed to facilitate the coupling, and concurrently provide a rigid mount for LED and fibre. Such a jig would have to have a small footprint so as not to disturb the light collection capabilities of the light guide.
- Finally, the option of using a small, orthogonal prism to redirect the light from the detached LED into a fibre and then into the light guide, could also be investigated, although this adds optical complexity to the system.

4 Acknowledgments

This work was supported by NSERC grant SAPJ-326516 and DOE grant DE-FG02-0SER41374 as well as Jefferson Science Associates, LLC. under U.S. DOE Contract No. DE-AC05-06OR23177.

References

[1] P. Ioannou, C. Kourkoumelis, G. Voulgaris, “Development of a Calibration System for the GlueX Calorimeter and TOF Detectors”, GlueX-doc-1285-v1 (2009).

[2] G. Voulgaris, Z. Papandreou, A. Semenov, “Options for the Pulsing System”, GlueX-doc-1486-v2 (2010).

[3] C. Kourkoumelis, Z. Papandreou, E. Smith, G. Voulgaris, “Update on the Calibration for the Fcal and the Bcal’, GlueX-doc-1687-v1 (2011).

[4] A. Semenov, Z. Papandreou, G. Lolos, “Injection of the light from Athens micro-board LED”, GlueX-doc-1709-v1 (2011).

[5] A. Semenov, G. Lolos, Z. Papandreou, I. Semenova, “Injection of the light from Athens micro-board LED”, GlueX-doc-1582-v2 (2010).