BCAL Geometry Specifications

Z. Papandreou [a,b]

[a] *Department of Physics, University of Regina, Regina, SK, S4S 0A2, Canada*
[b] *Prairie Particle Physics Institute, Regina, SK, S4S 0A2, Canada*

Abstract

Geometry specifications for the GlueX Barrel Calorimeter modules, light collectors and Silicon Photomultiplier readout packaging are presented herein. This information will be used in our Geant-based detector simulation package.

1 Calorimeter Modules

The electro-magnetic barrel calorimeter (BCAL) for the GlueX Project consists of alternating layers of thin (0.5 mm) lead sheets and 1-mm-diameter scintillating fibers (SciFi). The lead sheets are grooved after passing through a swaging machine. The fibers are glued in the grooves with an optical epoxy. The resulting matrix has a fiber pitch of 1.35 mm in the horizontal direction and 1.18 mm in the vertical. The BCAL is segmented into 48 modules with each module comprised of approximately 15,000 390-cm-long fibers, thus requiring a total of over 2,600 km of fibers, after machining (3,100 km for the construction). For more details the reader is directed to references [1,2].

The inner and outer radii of the BCAL are 65 cm and 90 cm, respectively. The BCAL modules will have a 1” aluminum backing plate, resulting then in a BCAL Pb/SciFi thickness of 22.46 cm. The radiation length thickness is $\sim 16X_0$ (X_0=1.45 cm). The volume ratio of lead:fibers:glue is 37 : 49 : 14 and the approximate relevant chemical formulae for the determination of the effective mass and atomic numbers are C_8H_9 for the scintillating fibers and $C_{60}H_{79}O_3N_2$ for the BC-600 two-component optical epoxy [3].

* Corresponding author’s e-mail: zisis@uregina.ca

[1] This paper reports on research carried out on behalf of the GlueX/Hall D collaboration at Jefferson Lab in Newport News, VA USA

The effective speed of light in the fibers was measured to be ∼16 cm/ns from cosmics and TRIUMF data (manufacturer's specifications: 18.75 cm/ns). The attenuation length was 266 cm from cosmics and 235 cm from the Hall-B test beam data. The numbers 16 cm/ns and 235 cm should be used in the code.

Based on reviewers' comments, strong justification exists for using a uniform (in area) readout for the BCAL since a non-uniform segmentation would adversely affect the floor term of the energy resolution. Nevertheless, other practical considerations may lead us to a hybrid design both in type of fibers and readout devices, such as the energy deposition that is high in the inner regions and very low in the outer ones (see Figure 1), the use of blue-sensitive devices for the outer layers and cost.

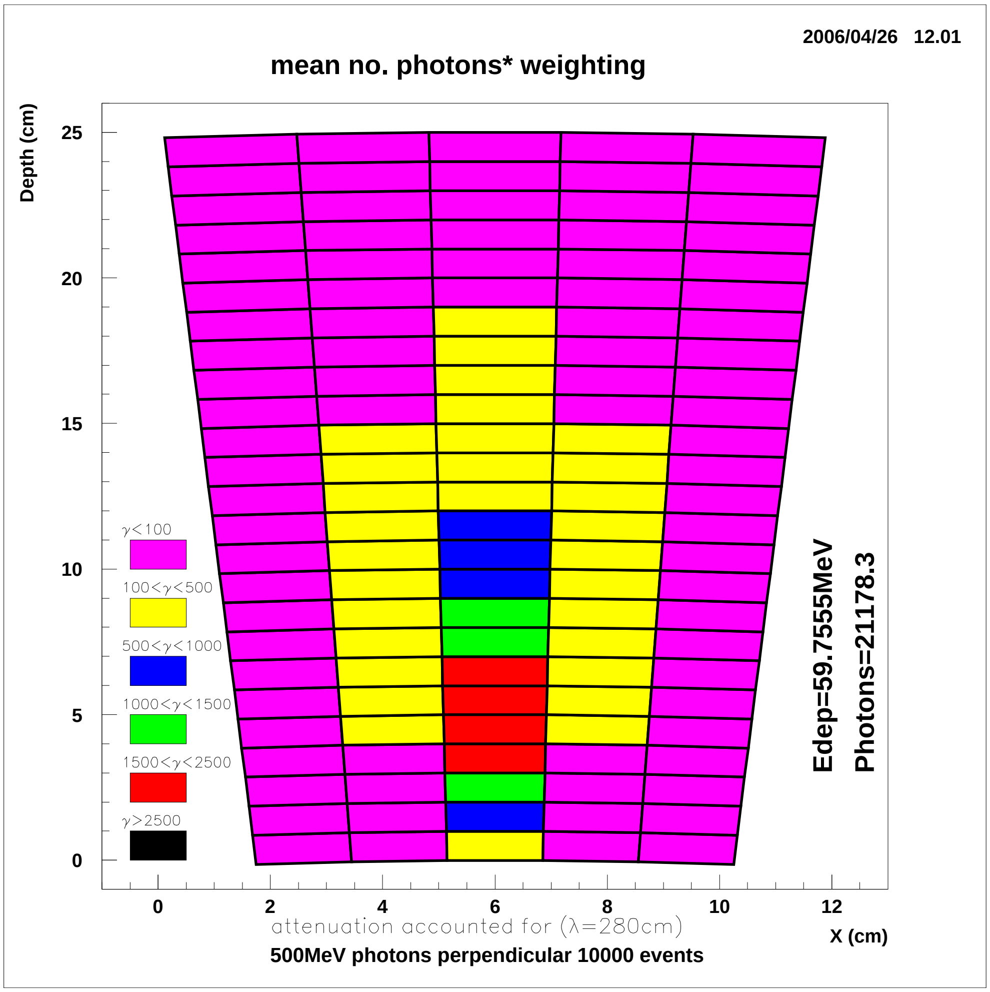

Fig. 1. Energy deposition profile for a 500 MeV photon incident at an angle of 90^o (perpendicularly). Each layer has a thickness of 1 cm. The first 12 layers are the inner ones and most of the energy is deposited there. At larger incident angles, even if the photon is more energetic, the energy deposition is concentrated further inside the inner layers, and in fewer of them. The simulation does not include the Aluminum backing plate. The plot is courtesy of Blake Leverington.

The properties and features of the BCAL are summarized in Table 1. Additional parameters are shown in Table 9 of reference [3].

Property	**Symbol**	**Value**
Module Length	L	390 cm
Module Inner Cord	c_i	8.51 cm
Module Outer Cord	c_o	11.77 cm
Module Thickness	d	22.46 cm
Inner Layer Depth	d_i	12.00 cm
Outer Layer Depth	d_o	10.46 cm
Aluminum Backing Plate	d_{Al}	2.54 cm
Module Azimuthal Bite	$\Delta\phi$	7.5^o
Sensor Azimuthal Bite (Inner)	$\Delta\phi_i$	1.875^o
Readout Azimuthal Bite (Outer)	$\Delta\phi_o$	3.75^o
Inner Layer Ring Area (per side)	a_i	5353 cm^2
Outer Layer Ring Area (per side)	a_o	5404 cm^2
SensL Sensor Area	a_s	1.26 cm^2
Radial Fiber Pitch	p_r	1.18 mm
Azimuthal Fiber Pitch	p_ϕ	1.35 mm
Volume Ratios	Pb:SciFi:Glue	37:49:14
Effective Mass Number	A_{eff}	179.9
Effective Atomic Number	Z_{eff}	71.4
Effective Density	ρ_{eff}	4.88 g/cm^3

Table 1
List of the BCAL's properties and features.

Using the numbers in Table 1 and assuming we use SensL large-area Sensor Modules (SMs) throughout the module, we obtain:

- Uniform readout: 4224 readout channels.
  - It has been argued that using uniform cell readout across the BCAL is advantageous, and this point will be discussed further below. In a 4×11 division of the entire thickness (with the lightguides of the last layer being thicker than 2 cm) we obtain 4224 readout channels. This option has been eliminated based on cost (based on SM cost per unit of \$300-\$400) and low light production in the outer layers.

Once again, using the numbers in Table 1 and assuming we use SMs for the inner layer readout and either Planacons [4] or Hamamatsu R5924-70 PMTs [5] (H6614-70 if one includes the base, made from non-magnetic materials), we have:

- **Non-uniform readout: 2688 readout channels.**
  - · A 4×6 division (sectors times layers) of the inner 12 cm. This yields 24 readouts per module per side, or 2304 SM readouts for the inner layers.
  - · A 2×2 division of the outer 10 cm. This yields 4 readouts per module per side, or 384 readouts for the inner layers.

This option should be used in HDGEANT.

Discussion is underway on the type of fibers and readout to be used for the outer layers. If devices that are sensitive to blue wavelengths are selected, then fibers such as BCF-12 from St. Gobain (Bicron) are a better match. The Planacon devices offer certain advantages (compactness, cost per channel), however, concerns have been raised on their pad-to-pad amplitude uniformity, especially in a magnetic field (even a reduced one slightly outside the solenoidal region), as well as on their reliability. On the other hand, the Hamamatsu PMTs are quite expensive ($3000 per unit), but they are field resistant.

The GlueX Detector Review and NSERC reviewers recommended a uniform readout, which corresponds to the 4224 channels described above, with segmentation of 2cm in depth with the last layer (outermost) channel being 2.46cm (due to 25cm minus 1" Al plate to fit in the 65cm to 90cm alloted region for the BCAL). As mentioned above, this option has been eliminated based on cost and expected energy deposition in the outer layers. Our current concept is to establish a non-uniformity between inner and outer layers, but to be consistent within each group. The prevailing thought is to use SMs coupled to St. Gobain BCF-20 green fibers for the inner layers, and BCF-12 coupled to the Hamamatsu PMTs for the outer layer (one or maximum two PMTs per side per module). This choice will present a challenge in the reconstruction, but when the signal from the outer layers is weighted by the energy deposition in them it will contribute weekly to the degradation of the floor term in the energy resolution, which will be dominated by the inner layers at all incident photon energies and angles.

2 Light Guides

The complete information on the light guide plus Winston cones, termed *light collectors*, can be found in reference [6], including dimensions. Ten such light collectors have been manufactured by the TRIUMF machine shop out of a single pieces of acrylic material to these specifications (see Figure 2). This means that the rectangular, tapered and Winston cone segments are not separate. Several of these light collectors are being used in our current SiPM large-array cosmics tests.

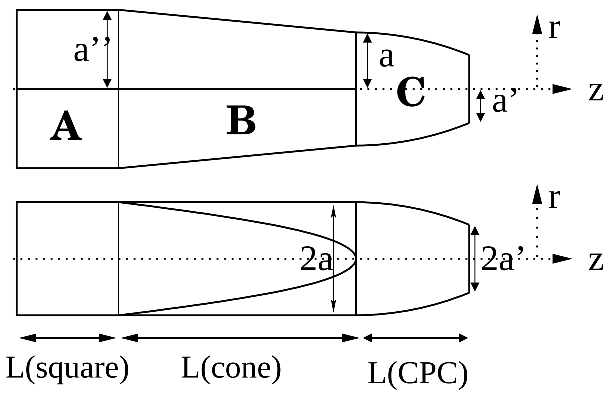

Fig. 2. A schematic drawing of the light collectors [6]. The total length (square plus cone plus CPC) is 10 cm.

The dimensions of the light collectors are summarized as 2×2 cm^2 area coupled to the calorimeter, length of 10 cm, and circular Winston cone area of 1.26 cm^2. The exact details of the shape are presented in reference [6].

3 SiPM Packaging

The packaging that is being envisaged for the SMs would be constructed out of ceramic, G10, or aluminum; all non-magnetic materials. An interim design is shown in Figure 3, where the active area of the SM shows 16 3×3 mm^2 (each marked with the letter 'A'), and immediately below is a Molex pin connector. The device fastens onto an external frame via four nuts and bolts.

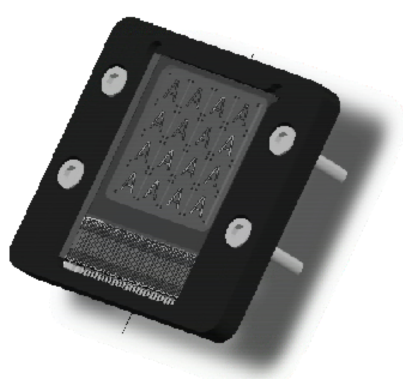

Fig. 3. A schematic drawing of possible SiPM package. The Phase-II packaging will not have a frame as thick as that shown in this figure, as that is not allowed by the close placement of the light collectors.

The final design will not have a thick frame around it as shown in the figure. Its dimensions are expected to be a maximum of 2×2 cm^2 area (in order not to exceed the module readout area and thus require staggering), and a depth (along the long axis of the calorimeter) of $\sim$3 cm. The exact design will be determined as part of the SensL Phase-II proposal that is being currently developed. For purposes of simulation, the material can be assumed to be G10 with some silicon and small circuit boards behind it, with amplifiers and possible discriminators.

4 Conclusions

The *non-uniform* readout option comprised of 2304 inner layer segments and 384 outer layer ones should be used in the HDGEANT, until the issue of the outer layers is further discussed and settled. If the Hamamatsu PMTs are are selected, the outer layer readout segmentation would be one or a maximum of two per side to stay within budget. The light collector design is essentially final, and an approximation for the SMs plus their packaging is indicated herein.

References

[1] Z. Papandreou, "BCAL Geometry and Channel Count", GlueX-doc-708-v2 (2007).

[2] Z. Papandreou, "BCAL Readout Channel Calculation", GlueX-doc-739-v1 (2007).

[3] Z. Papandreou, "BCAL Calorimetry Response", GlueX-doc-840-v1 (2007).

[4] E. Smith, "Readout of the barrel calorimeter based on conventional photomultiplier tubes", GlueX-doc-832-v3 (2007).

[5] C. Kourkoumelis *et al.*, "BCAL Readout Utilizing Field Resistant PMTs", GlueX-doc-712-v2 (2007).

[6] B. Leverington, "Light Guide Design for Phase 1 GlueX Sensor Module R&D", GlueX-doc-651-v3 (2006).