GlueX-doc-620
GlueX Beam Test Request
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Request for Beam Time in Hall B to Measure Energy and Time Resolution of the BCAL Prototype Module

GlueX Collaboration

Abstract

This is a request from the GlueX collaboration for one week of beam time delivered to Hall B during the period in 2006 when the CEBAF accelerator is running at 687 MeV. The electron beam will produce a photon beam using the Hall B tagger system. Photons of various energies will be used to measure the response of a 4 m-long lead/scintillating fiber (Pd/SciFi) prototype module for the GlueX barrel calorimeter (BCAL). The 687 MeV endpoint energy will provide the minimum photon energies needed for these tests. The module will be mounted on a support system in the Hall B alcove area. The module will be illuminated at several positions along its length and at several angles, from 0° to 80° with respect to normal incidence. The data will allow us to measure energy resolution, time resolution and linearity and will also allow a validation of our Monte Carlo simulations.

Introduction

Figure 1 shows a schematic of the proposed barrel calorimeter (BCAL) to be used inside the GlueX detector superconducting solenoid that produces a field of 2 T. The BCAL detector is essential for achieving the hermeticity and resolution required of the GlueX detector to carry out amplitude analyses of a large variety of exclusive reactions. The decay products of mesons produced in these reactions, including charged particles and photons, must be detected and measured with excellent acceptance and resolution. The task of BCAL is to measure the positions and energies of photons emitted from interactions in the GlueX target from 10° to 117° with respect to the beam direction. The photon position resolution of BCAL is determined by the time resolution. The timing information from BCAL will also be used to determine the time-of-flight information for charged particles entering BCAL after passing through layers of straw drift tubes (central drift chamber - CDC) surrounding the target.

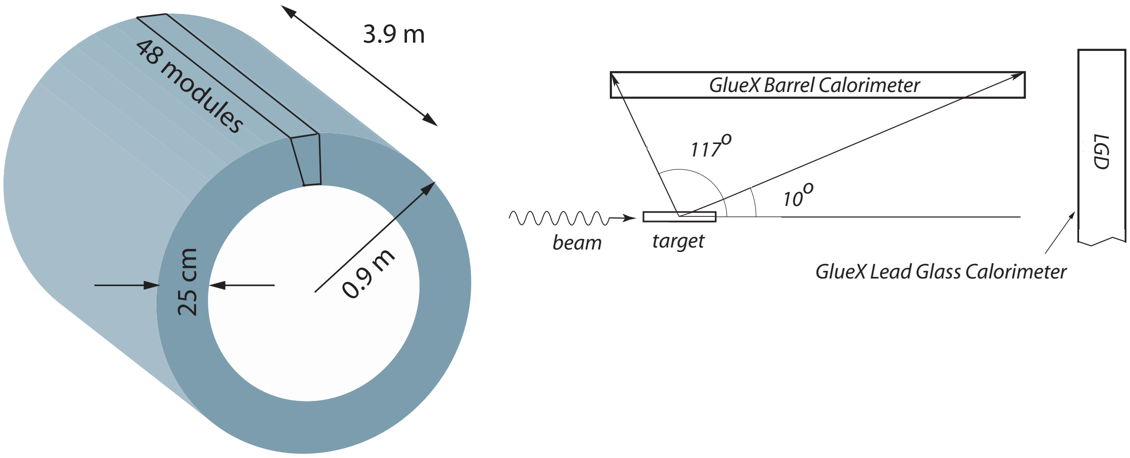

Figure 1: Schematic of the GlueX Barrel Calorimeter (BCAL) and its placement in the GlueX detector (not to scale).

BCAL will be 3.9 m long, with an outer radius of 0.9 m and an inner radius of 0.65 m. It will consist of 48 modules, each with a trapezoidal cross section. The modules will be constructed using scintillating fibers (SciFi) embedded in a lead (Pb) matrix. Such Pb/SciFi techniques have been employed in the construction of cylindrical electromagnetic calorimeters in the JetSet experiment at CERN and more recently in the KLOE experiment. Indeed the GlueX BCAL design draws heavily on the KLOE experience [1] – the KLOE detector has 24 modules that are 4.3 m long and 23 cm thick, operating in a field of 0.6 T.

Compared to the KLOE experiment, the photon trajectories in GlueX present more of a challenge for energy and spatial measurements. The KLOE calorimeter subtends polar angles between 49° and 131°, a region that has an approximately uniform population of photons. Measured with respect to the normal to calorimeter modules, the angular range is between 0° and 41°. In contrast, the photons to be detected by BCAL (see Figure 1) have angles of incidence, measured with respect to the normal, from 0° to 170° with a much larger population near the larger angles – these photons coming from the decays of mesons that are preferentially produced in the forward direction. The energy and position measurement of photons at large angles of incidence will be a primary goal of the proposed beam tests.

Our design goals for the energy and timing resolution dependence on photon energy, based on the KLOE calorimeter [1] experience, are:

$$\frac{\sigma(E)}{E} = \frac{5\%}{\sqrt{E(\mathrm{GeV})}} + 2\% \tag{1}$$

$$\sigma_t = \frac{200 \text{ ps}}{\sqrt{E(\text{GeV})}} \tag{2}$$

Prototype Module

A 4 m-long prototype module was constructed in 2004. The module, shown schematically in Figure 2, has a rectangular cross section of 13×23.0 cm^2 active area of Pb/SciFi. Over 70 km of double-clad fiber and 12 kg of epoxy were used in its construction. The scintillating fibers were made by PolHiTech and are blue-emitting with a peak emission wavelength of 420 nm and an attenuation length of 350 cm. The fibers have a diameter of 1 mm (with 3% and 1% being the thickness of the first and second cladding layers) and the thickness of the lead sheets is 0.5 mm. The module has 186 planes of Pb/SciFi. The total weight of the module is 0.76 metric tons (including associated aluminum and steel plates). The composite has a Pb:SciFi:Epoxy ratio of 37:49:14 and an overall density of ≈ 5 gm/cm^3 and a radiation length (X_0) of 1.5 cm. Each layer of the module to be tested has 96 SciFi's spaced 1.38 mm apart (center-to-center) and the layers are such that they do not present any gaps in SciFi coverage thus presenting a uniform SciFi density across the shower path.

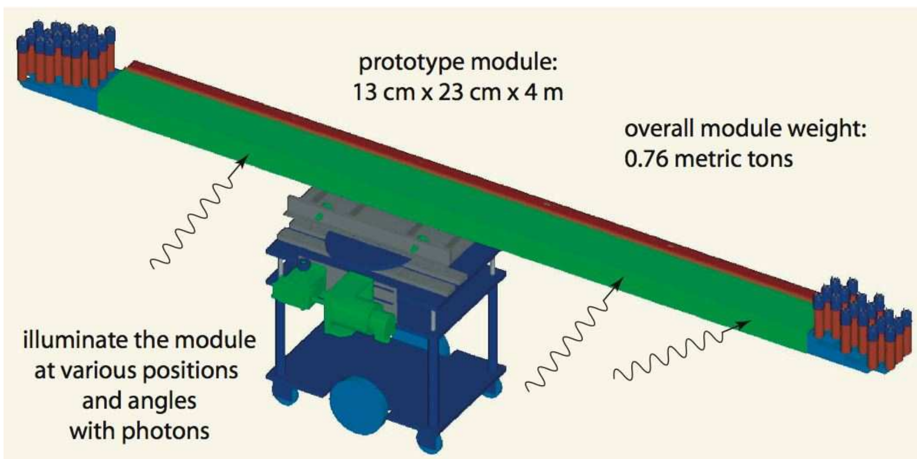

Figure 2: Schematic of the prototype BCAL module with its proposed readout scheme and support cart.

For purposes of the beam tests, the readout will be based on a segmentation scheme of 3×5 light-guides, each with a cross section of 4×4 cm^2, coupled to XP2020's at each end – a total of 30 channels. This segmentation is based on extensive Monte Carlo simulations of the detector [2]. The choice of phototube is based on providing the best timing measurement.

Simulation Studies of BCAL

We have a stand-alone GEANT-based Monte Carlo package to do simulations for a single module and/or for three adjacent modules (see Figure 3). This expedites simulations for energy deposit as a function of depth as well as simulation of the number of photons produced for readout purposes. The code has been supplemented by custom-routines that do optical ray tracing in the fibers as well as further simulation of the optical photons through light guides/collectors. We also have the full-48 module code embedded in the GlueX C++ reconstruction framework (DANA), to allow simulation of physics channels and testing of the BCAL reconstruction code using simulated events.

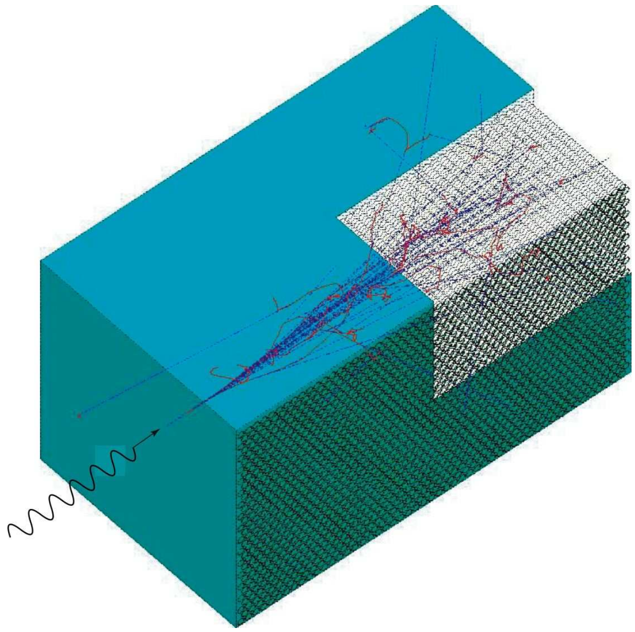

Figure 3: A typical electromagnetic shower in a BCAL module as generated by GEANT.

Independent simulations using GuideIt optical ray tracing have been done for a single fiber, and where possible to compare with the GEANT optical ray tracing, they agree. These are used to understand the optical and bulk properties of fibers. These results have shown, for example, that the effective attenuation of the fiber claddings is of the order of 10 m, in order to explain the increased transmission of light (50-60%) of double-clad over single-clad fibers.

Photon Beam in Hall B

Table 1 summarizes the Hall B tagger characteristics for an electron energy of 687 MeV. The 2.6 mm collimator at the tagger will result in a photon beam spot size of 2 cm diameter at the Hall B alcove.

Photon Energy (MeV)	Fraction of electrons through magnet	Fraction of photons through 2.6 mm collimator
653	0.872	0.067
618	0.934	0.066
550	0.961	0.066
344	0.977	0.070
137	0.983	0.072

Table 1: Hall B tagger characteristics at an endpoint energy of 687 MeV

Module Positioning in the Hall B Alcove

Figure 4 schematically shows the 4 m-long BCAL module in several positions in the Hall B alcove needed to achieve the beam test goals. The 1800 lb module will sit on a cart that can position the module so that the beam can enter at any point along the face of the module. The angle of incidence (with respect to normal) can be chosen to be at 0° or any angle between 45° and 80°. The platform in front of the alcove will have to be modified for this setup.

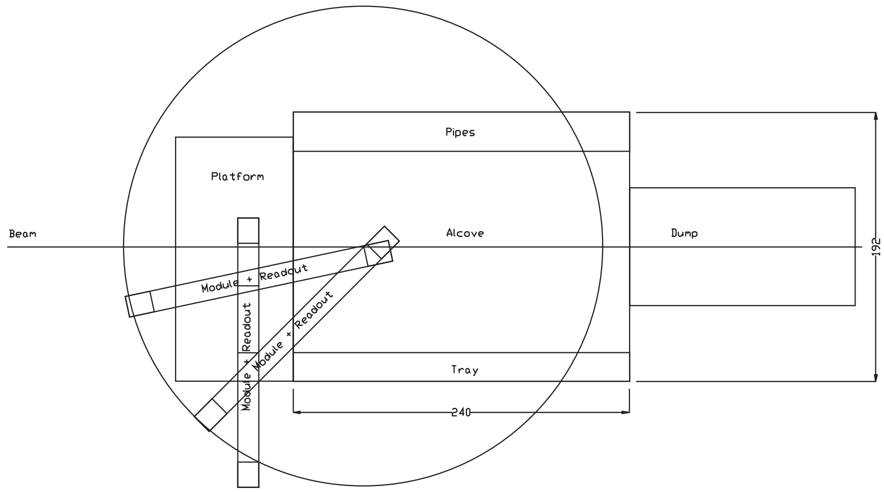

Figure 4: Test setup for BCAL module beam test in the Hall B Alcove. Beam enters from the left.

Trigger, Readout Electronics and DAQ

Figure 5 shows a schematic of the trigger electronics. The event trigger will be derived from the Hall B tagger. Signals from each of the 30 BCAL module phototubes will be sent to TDC's and 12-bit ADC's. Readout electronics will be based on some combination of Fastbus, CAMAC or VME, depending on availability.

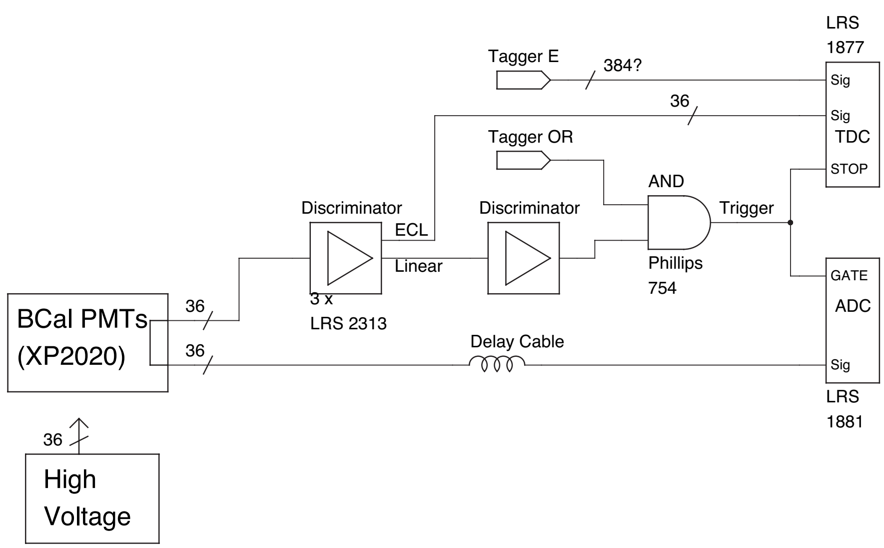

Figure 5: Schematic of the trigger electronics for the BCAL module beam test.

Summary of Beam Test Goals

1. Measure the energy resolution of the center of the module at normal incidence and also determine linearity over the range of photon energies from 137 to 653 MeV. (see Table 1).

2. Measure the timing resolution at the center of the module at normal incidence.
3. Repeat the above energy and timing resolution measurements at the center of the module for four angles of incidence at and between 45° and 80°.
4. Repeat the above energy and timing resolution measurements at normal incidence and at four angles of incidence at and between 45° and 80° for four positions from the center to the end of the module.

The above data will be used to validate the Monte Carlo simulations and the BCAL reconstruction software. These data will also be anchored to results obtained using cosmic rays. At a later date we plan continue these studies further and to specifically simulate other measurement configurations in Hall B beam tests.

Milestones

The milestones below are based on the assumption of data-taking in September 2006.

1. Finalize the design of the light guide system for the prototype module readout (`March`).
2. Collect the phototubes and bases and ship to Regina (`March`).
3. Collect the read out electronics and crates needed to exercise the DAQ and start testing at JLab (`March`).
4. Construct the light guides at TRIUMF and ship to Regina (`April`).
5. Complete construction of the cart (`June`).
6. Assemble the light guides, phototubes and readout system and DAQ and begin module tests with cosmic rays at Regina (`June`).
7. Software development and load testing of the cart (`July`).
8. Complete cosmic ray tests of the module at Regina (`July`).
9. Complete modifications of alcove platform in Hall B (`July`).
10. Ship cart from Indiana to JLab (`early August`).
11. Complete DAQ code development and tests at JLab (`early August`).
12. Ship module and associated electronics from Regina to JLab (`early August`).
13. Assemble and do pre-beam tests of the equipment at JLab (`mid-August`).

GlueX Personnel Participating in the Beam Tests

Indiana U. Eric Scott and Scott Teige are designing light guides and the mechanical support system for the BCAL and will take shifts during the test.

U. of Regina Members of the SPARRO group (Mauricio Barbi, Rafael Hakobyan, Stamatis Katsaganis, Blake Leverington, George Lolos and Zisis Papandreou) are responsible for the module preparation, cosmic ray tests and simulation studies. All the SPARRO group members (except for Katsaganis but including Garth Huber) will take shifts during the test.

JLab Elton Smith will be the test beam run coordinator and will provide liaison with Hall B. Elliott Wolin will be the DAQ coordinator. Both will take shifts during the test.

References

[1] M. Adinolfi *et al.*, Nucl. Instr. and Meth. A 494 (2002) 326.

[2] R. Hakobyan, Z. Papandreou, G. Lolos and B. Leverington, *Simulation of the GlueX Barrel Calorimeter*, GlueX Document `GlueX-doc-529-v5` (2005) available on the GlueX portal `portal.gluex.org`.