Initial analysis of the timing resolution of the GlueX electromagnetic barrel calorimeter

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Blake Leverington
Regina, Saskatchewan, Canada

Abstract

A beam test of the 4m prototype module for the GlueX barrel calorimeter (BCal) was carried out in Hall B at the Thomas Jefferson National Accelerator Facility (Jefferson Lab) with the objective of measuring the energy, timing and position resolution of the module. The data were collected in September 2006. Preliminary analysis results of the timing resolution will be shown here.

1. Introduction and Goals

The prototype module for the GlueX Barrel Calorimeter (BCal) is constructed of alternating layers of pure, grooved lead and blue Poli-Hi-Tech scintillating fibres bonded together with Bicron-600 optical epoxy. Construction took place at the University of Alberta. The design of the BCal is very similar to the KLOE electromagnetic calorimeter which had a reported energy resolution of $5.4\%/\sqrt{E(GeV)}$ plus a negligible constant term and a timing resolution of 54 ps$/\sqrt{E(GeV)}\oplus$140 ps (1). GlueX expects similar resolutions for the BCal.

Email address: leverinb@uregina.ca (Blake Leverington).

2. Experimental Details

2.1. *Alcove*

The module was placed in the down stream alcove of Hall B at Jefferson Lab. The use of a remote controlled cart allowed for the module to be rotated to various angles with respect to the photon beam. A hall access was needed to change the lateral position of the module with respect to the beam. The smaller dimensions of the alcove limited the number of angles and positions the module could be placed in but a length scan from -100 cm to +25 cm perpendicular to the beam was able to be performed along with multiple positions at shallow angles with respect to the beam. Only data where the module was perpendicular to the beam are addressed in this

note.

2.2. *Beam*

The photon beam in Hall B provided a spectrum of photons from 150 MeV up to 650 MeV produced by the 675 MeV electron beam from CEBAF incident on a radiator. The electron beam current was 1 nA. The electrons are tagged and provide us timing and energy information for the photons. The trigger is formed from the Master OR from the tagger of the T-counters and an OR signal from the BCal module. On average, the event rate was around 1 to 4 kHz for the duration of the beam test. The beam was collimated with a 2.6mm collimator giving a beam spot size on the BCal module of 2cm in diameter.

2.3. *Readout and Electronics*

The module was segmented into 18 $3.8cm \times 3.8cm(1.5'' \times 1.5'')$ cells with 6 rows in depth with respect to the beam and 3 columns in width. They were then numbered 1 through 18. The readout scheme can be seen in Figure 2. Square light guides with a 45 degree mirrored surface channelled the light from the fibres to PMTs on the left and right end of the BCal, labelled South and North respectively. Silicon sheets approximately 2.5 mm thick were used to interface the light guides with the BCal and the PMTs. Everything was then enclosed in a steel box to maintain light-tightness. The light boxes and PMT's can be seen in 1. The first three rows are readout using XP2020 photomultiplier tubes because of their better timing characteristics and most of the energy is deposited in the first 12cm of the BCal. The last three rows are readout using Burle 8575 tubes.

The bases for the PMTs were designed with dual BNC outputs on the anode. One signal was sent to a CAEN C 207 (equivalent leading edge) discriminator. An F1 TDC was used. The sum of the discriminator output was sent to a second discriminator and was required to reach a minimum threshold such that at least 4 PMTS each from the North and South end of the BCal must fire. The effect of changing this threshold (number of PMTs that fire) will also be studied. The OR of the BCal end sums AND the Master OR signal of the tagger established the trigger for the BCal beam test.

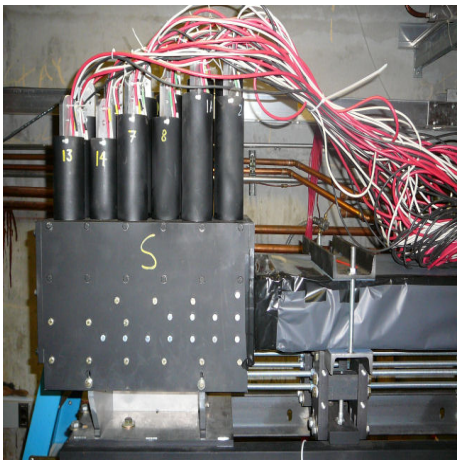

Fig. 1. The black box containing the light guides and PMTs with cables attached. The BCal is wrapped in Tevlar on the right and pressed against the light guides coupled with a silicone cookie.

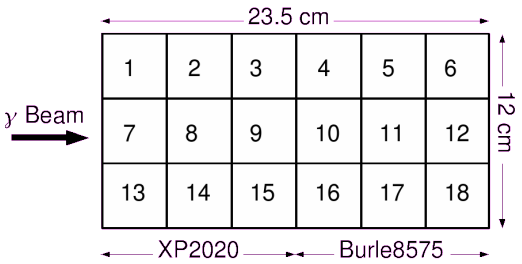

Fig. 2. The segmentation and readout for the BCal module

3. Timing Analysis

3.1. *Time walk corrections*

Because leading edge discriminators were used, the timing had a dependence on pulse height which required a time walk correction. A plot of ADC versus TDC for cell 8 can be seen in Figure 3. Similar fits have been done for North and South cells 7,8,9 and 10 so far. The corrected TDC distribution can be seen in Figure 4.

3.2. *Timing resolution*

The distribution of the mean timer over the entire tagger energy spectrum for cell 8 can be seen in Figure 5. The timing from the tagger, tphoton, has

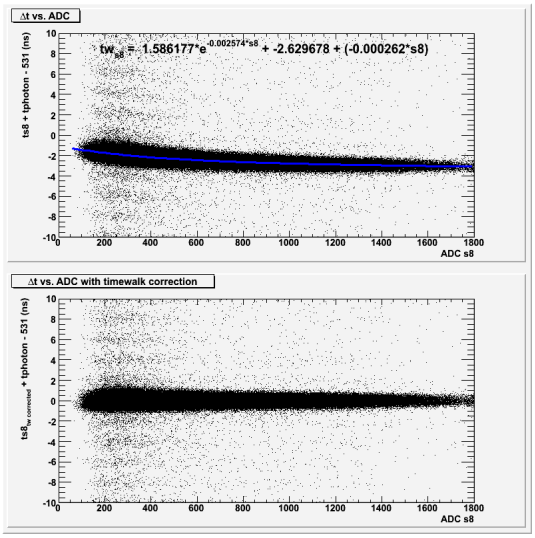

Fig. 3. ADC vs. TDC for cell South 8. The uncorrected time walk is seen in the top plot. The bottom plot shows the corrected time.

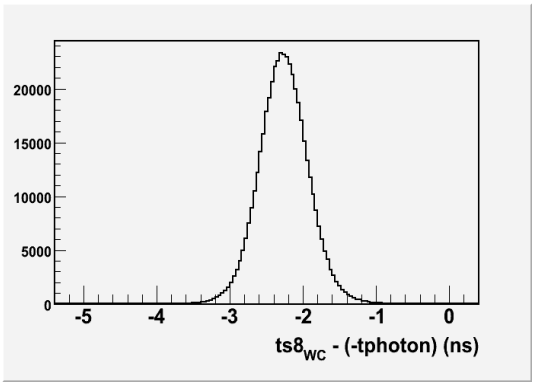

Fig. 4. TDC distribution for South 8 corrected for time walk

been used as the reference time for the BCal which has a contribution to the constant term in the resolution of 113 ps . The distribution for the time difference of cell 8, South minus North, $(ts8 - tn8)$, can seen in Figure 6. The mean value is the offsets $(ts8_o - tn8_o)$. A plot of the timing resolution of cell 8 can be seen in Figure **??**. The width of the photon beam (2 cm) will contribute 123 ps to the time difference resolution (not shown in this note) where the speed of light in the BCal is measured to be 16.2 cm/ns. The width of the em shower will also contribute to the time difference resolution.

Looking at Figure 8, a single mean value for the offset of $(ts8 + tn8)/2 - (t_{tagger})$ is expected. However, there is a deviation from the expected value by over 100 ps at some energies. t_{tagger} is the reference time from the tagger.

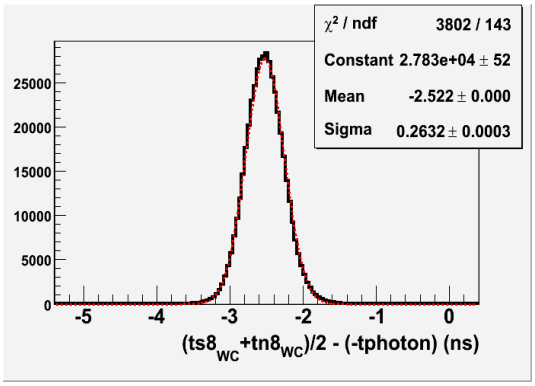

Fig. 5. The mean timer distribution of cell 8 corrected for time walk and referenced with the tagger

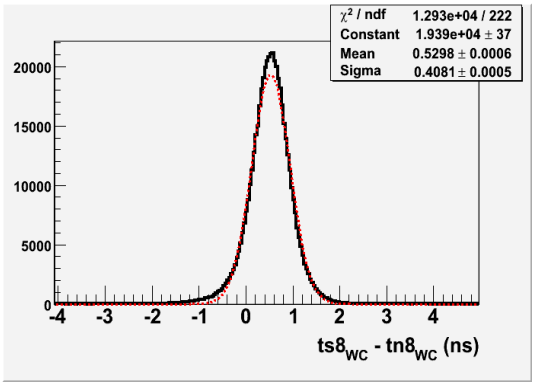

Fig. 6. The distribution of the difference between North 8 and South 8

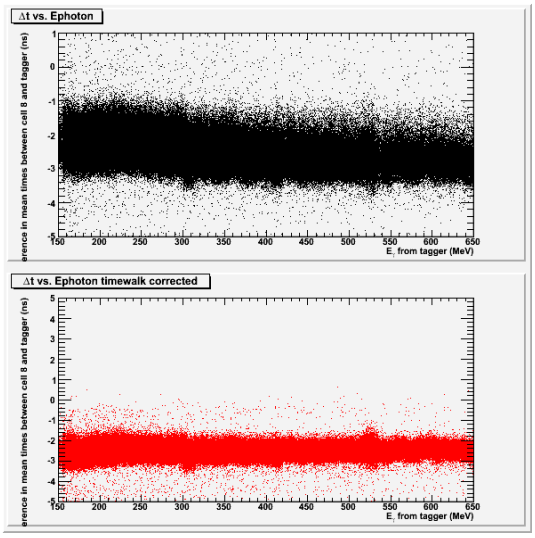

Fig. 7. (tn8+ts8)/2 - (-tphoton) vs. Tagger Energy(MeV for Cell 8). The top plot is before time walk corrections. The bottom plot is after walk corrections.

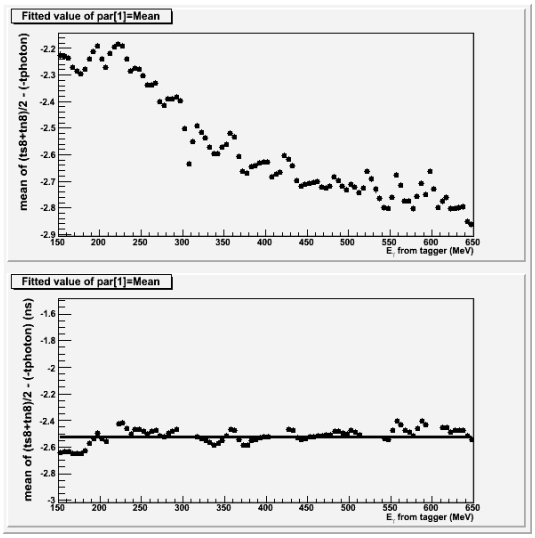

Fig. 8. The mean of the distribution in Figure 7 The top plot is before time walk corrections. The bottom plot is after corrections.

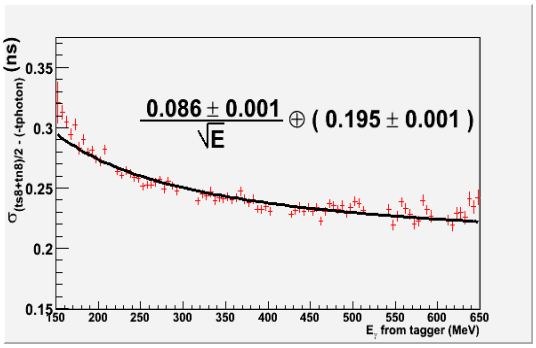

Fig. 9. Timing resolution from fitting the slices of Figure 7

Subtracting the contribution of the tagger to the resolution, 113 ps, we are left with a resolution for the mean timer,$\sigma((ts8 + tn8)/2 - (t_{tagger}))$, of cell 8 equal to

$$\sigma_{t8_{MT}} = \frac{86ps}{\sqrt{E(GeV)}} \oplus 159ps \quad (1)$$

where $\oplus$ indicates addition in quadrature. The resolution of the mean timer of cell 7 is

$$\sigma_{t7_{MT}} = \frac{61ps}{\sqrt{E(GeV)}} \oplus 176ps \quad (2)$$

Since this is the result for the sum of 2 detectors the resolution for reading out one end will be $\sigma_{t7_{MT}} * \sqrt{2}$. The resolutions for one end of cell 8 and cell 7 respectively are then

$$\sigma_{t8} = \frac{122ps}{\sqrt{E(GeV)}} \oplus 225ps \quad (3)$$

$$\sigma_{t7} = \frac{86ps}{\sqrt{E(GeV)}} \oplus 249ps \quad (4)$$

Weighting the time of each cell by $1/\sigma_i^2$ the time for a cluster is equal to

$$t_{cl} = \frac{\sum_i \frac{t_{MT}(i)}{\sigma^2_{MT}(i)}}{\sum_i \frac{1}{\sigma^2_{MT}(i)}} \quad (5)$$

where there are i cells in the cluster. For now, just adding cells 7 and 8 (4 PMTs) together gives a resolution of

$$\sigma_{t7\&8} = \frac{60ps}{\sqrt{E(GeV)}} \oplus 187ps \quad (6)$$

Subtracting the contribution from the tagger then gives

$$\sigma_{t7\&8} = \frac{60ps}{\sqrt{E(GeV)}} \oplus 149ps \quad (7)$$

One also has to be careful when making cuts on the adc value of each cell. This has an effect mostly on the energy dependent term of the resolution, especially for the cells which do not see much energy like cells 9 and 10. Here, the fluctuations are large and the statistics are low for low energy photons. An ADC cut which is too small or too large will affect the resolution fit.

Adding in cell 9 gives a timing resolution of $78ps/\sqrt{E} + 132ps$ which has a much higher energy dependent term than (6) but this is possibly from the low statistics in the lower energies where one cuts on a large enough ADC signal seen in each cell in the cluster or there is still some miscalibrations in the BCal or tagger. Adding in cell 10 gives a wholly unreasonable resolution. This needs to be studied further.

References

[1] Andolfini, M. et al., The KLOE electromagnetic calorimeter, 2002, Nucl. Instrum. Meth. A482, 364-386.