GlueX Note-zzz
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Determination of event timing with the FCAL *

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Abstract

Event timing using FCAL cells digitized by FADCs is considered. It is shown that the arrival time of a photon in FCAL does not depend on photon energy and, to a very good approximation, direction or vertex location.

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1 Introduction

Event timing using photon hits in the FCAL and its associated FADCs gives a measure of the overall event time that, unlike TOF measurements for charged particles, does not depend on track momentum or vertex position.

1.1 Geometric considerations

The propagation time from target to anywhere depends on β. A momentum measurement is required to determine β if the particle is massive. For photons, β is known exactly and is independent of momentum.

It can be seen that, to a very good approximation, the time of a photon hit in FCAL does not depend on the position of the event primary vertex. Since

$$t_p = t_0 + \frac{z_t - \delta z}{c} + \frac{z_g + \delta z}{c \cdot \cos\theta} \tag{1}$$

with symbols defined as in fig 1,it can be seen that (neglecting the constant time offset z_t/c)

$$t_0 = t_p - \frac{z_g}{c \cdot \cos\theta} + \frac{\delta z}{c}\left(1 - \frac{1}{\cos\theta}\right). \tag{2}$$

Since θ never exceeds 14 degrees and δz is at most 15 cm the last term in eqn. 2 never exceeds 15 ps and so is negligible. If this term is neglected, it can be seen that t_0 as determined by a FCAL photon hit does not depend on the vertex position.

The angle θ in eqn. 2 is a simple geometric constant known for every cell of FCAL so t_p measures t_0 directly.

1.2 Shower fluctuations

It can be seen from figure 2 that a shower starting some depth x into a lead glass block emits a Cerenkov that arrives at the PMT photocathode at a time

$$t = \frac{1}{c}(x + n^2 l) \tag{3}$$

where n is the index of refraction of the glass, typically 1.6. The time for a shower starting at $x + \delta x$ can be calculated from 3 by replacing x with $x + \delta x$ and l with $l - \delta x$. The time difference associated with the variation δx of the shower initial point is then easily seen to be

$$\delta t = \frac{\delta x}{c}(n^2 - 1) \tag{4}$$

Taking δx to be one radiation length or 3.1 cm, δt is seen to be approximately 160 ps.

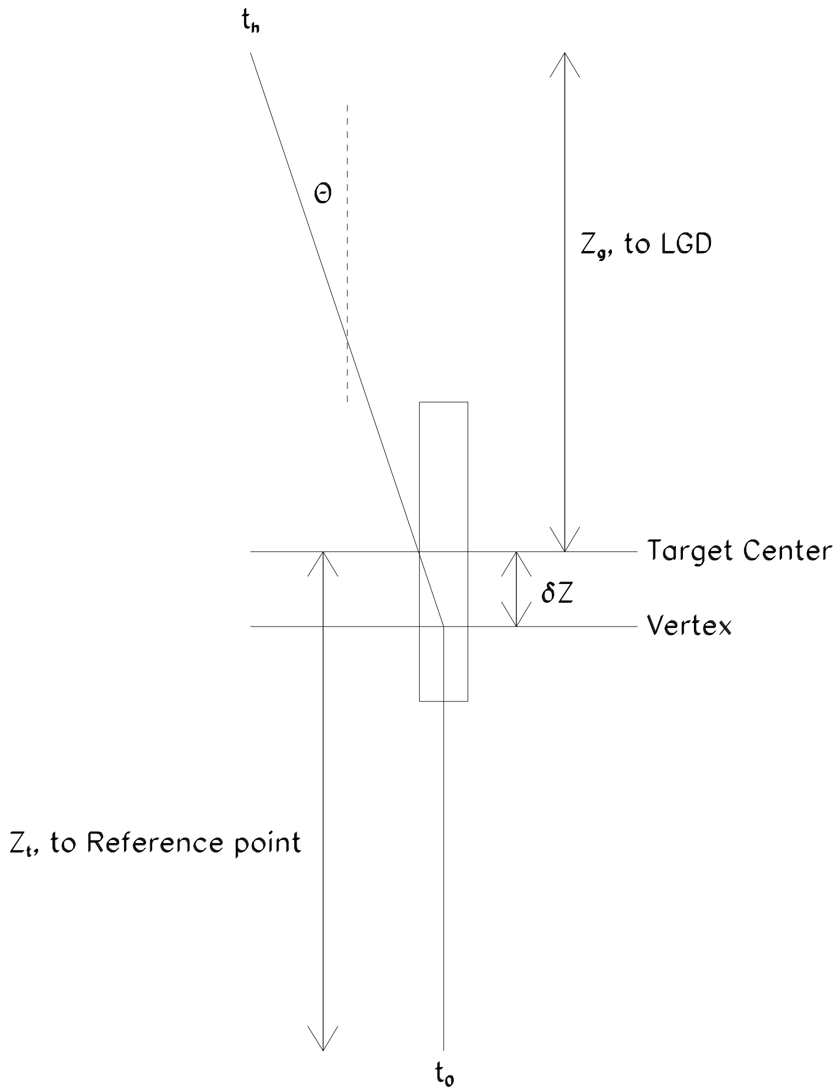

Figure 1: The relevant path lengths used to derive eqn, 1. t_0 is the time the beam photon crosses some fixed plane taken to be a reference location. t_p is the time of a phototube pulse in FCAL.

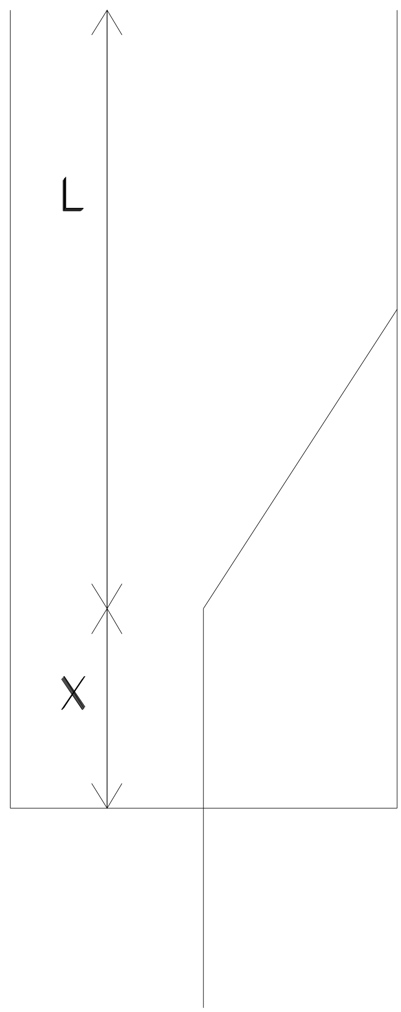

Figure 2: The relevant path lengths used to derive eqn, 3.

2 Conclusion

It has been shown that the arrival time of Cerenkov light from electromagnetic showers initiated by photons in the lead glass is to a very good approximation independent of the location of the event vertex and photon direction. Fluctuations in the location of the initial photon conversion contribute timing fluctuations of order 160 ps. Since a typical photon shower occupies several lead glass blocks, averaging over a shower reduces fluctuations associated with pulse shape, amplitude and sampling phase. Additional improvement in determination of the event time can be achieved for those events with several photons in FCAL. It is concluded that this technique provides an excellent reference time for the class of events with photons in FCAL.