BCAL Signal Timing Distributions

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What I did

- Single photon events from 0-2 GeV simulated at $\theta=12^o$
- GEANT tracking steps written to ROOT file
  - Energy deposition
  - Position
  - Time
- Energy from steps propagated to each end of module
- Energy distributions smeared using σ parametrically calculated for sampling fluctuations (includes θ dependence … sort of)
- Dark pulses added at random times
- Electronic pulse shape convoluted with the attenuated/smeared, energy distributions
- For course segmentation, multiple electronic pulse shapes added together to get summed pulse shape
- Time at which electronic pulse exceeds threshold recorded
- Timewalk corrections determined and applied

Relating MeV to Signal Amplitude

Calculation shown on 6/30/2011 did not include factor of 1/20 due to increased gain in test setup used to derive 61.67 value.

Also, factor of 10 in gain for TDC signal is now included

From CalibDB

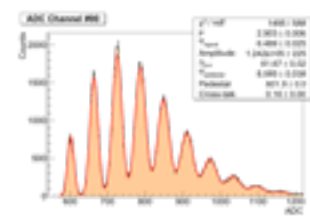
75 photons/side/MeV in fiber
0.21 PDE
0.095 Sampling fraction

→ 0.668 MeV/PE

n.b. for this, Fernando uses a value of 88 photons (not PE) due to 60MeV deposited at the far end. This results in a value of:
*60MeV/(88*0.21*3) = 1.08 MeV/PE*
where the 3 is due to attenuation

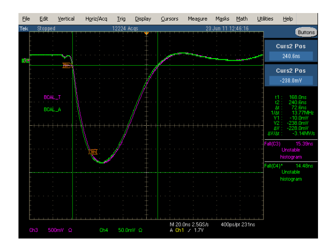
61.67 QCD counts/PE
CAEN V792 QCD: 100fC LSB
1/20 for increased gain in test

→ 0.461 pC/MeV



SiPM pulse shape:
1.20 nC for 2.293V peak

→ 0.882 mV/MeV fADC
8.82 mV/MeV TDC



alternate calculation gives 5.46 mV/MeV for TDC

Discriminator Thresholds

• Until recently, values used to design the electronics system assumed 60MeV was the low end of what was achievable/desired for reconstruction (represented as the 88 photons mentioned on previous slide).

60 MeV on far side will, after attenuation through whole module, give a signal amplitude of: 8.82*60/3.67= 144mV (or 5.46*60/3.67 = 89.3mV)

• Realistically, to reconstruct 60MeV particles with high efficiency, we set the threshold lower to correspond to ~30 MeV so divide by factor of 2 (72mV or 44.7mV)

• For TDC signals, it is undesirable to have threshold right at peak value as it degrades timing resolution. However, for 60MeV particles, the threshold will be at half signal amplitude for the worst case (far end of module). Therefore, no further reduction in signal amplitude is needed

• Effective thresholds calculated from bandwidth limitations are ~3.5 times smaller than the present calculation (8-9MeV vs. 30MeV). For the purposes of the current study, a value of **44.7mV** will be used.

from June 2nd presentation

	inner	outer
fine (near)	**2.3 MeV**	**2.3 MeV**
fine (far)	**8.4 MeV**	**8.4 MeV**
course (near)	**2.4 MeV**	**2.6 MeV**
course (far)	**8.8 MeV**	**9.5 MeV**

Values based on data rate. These are NOT used in the current study

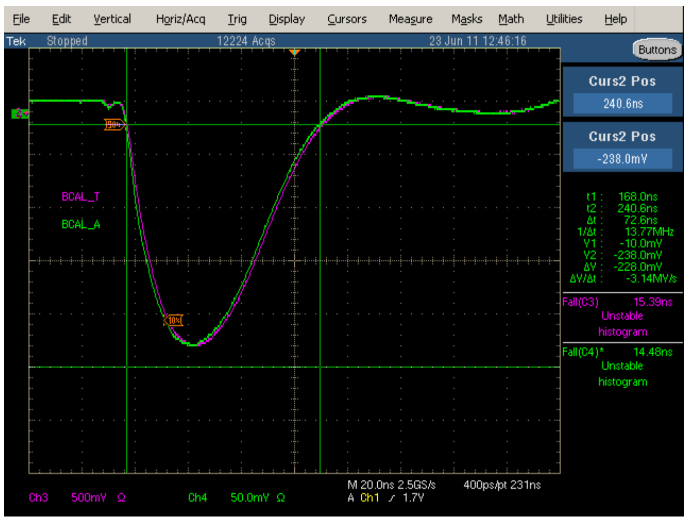
	inner	outer
fine	20.3 mV	20.3 mV
course	21.2 mV	22.9 mV

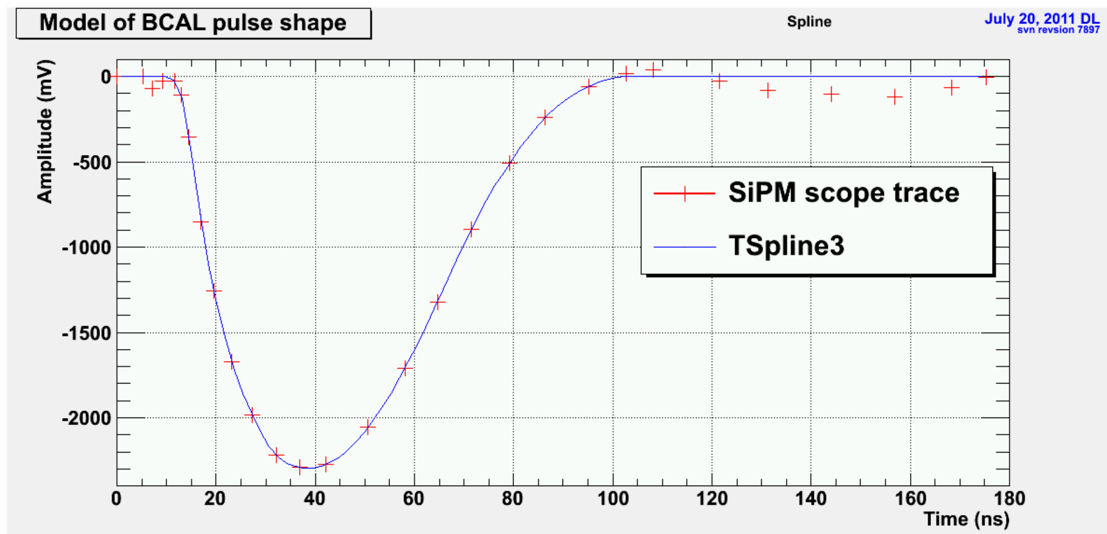
Values calculated using 8.82 mV/MeV from previous slide

SiPM pulse shape

Piece-wise pulse shape led to discontinuity on rising edge. This was replaced with a spline using ROOT's TSpline3.

For the purposes of this study, the preceding and after pulses were zero'd out explicitly





Timewalk Correction

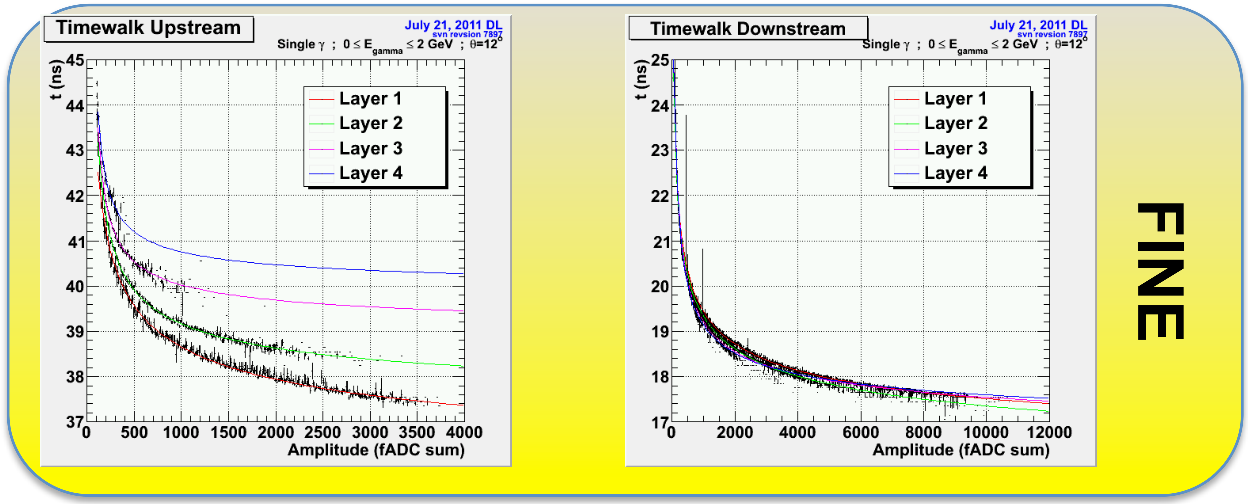
- Layers corrected for timewalk individually

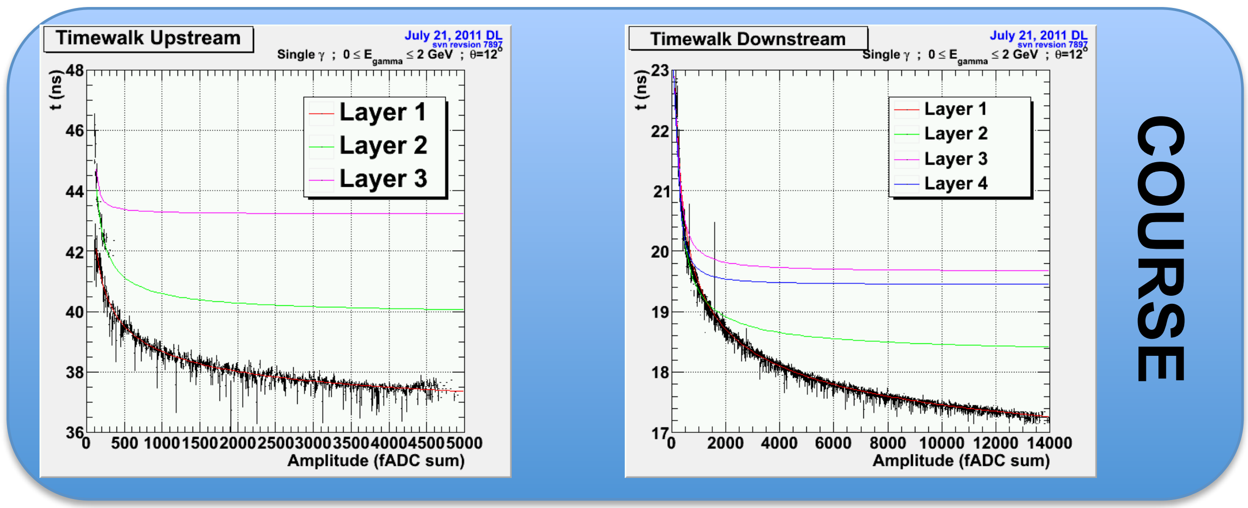
- Fits done for each layer, end, segmentation

<u>functional form:</u>

$$tw(x) = b_0 + \frac{b_1}{cos(b_3) + sin(b_3) \cdot x^{b_4}}$$

where "x" is the number fADC counts





Quick Review

Adding/subtracting uncorrelated values:

$$z = x + y$$
$$\sigma_z^2 = \sigma_x^2 + \sigma_y^2$$

Weighted average:

$$t_{avg} = \sum_i w_i \cdot ti \qquad \sigma_{avg}^2 = \sum_i (w_i \sigma_i)^2$$

where: $w_i = \frac{1}{\sigma_i^2} \cdot \xi$

$$\xi = \frac{1}{\sum \frac{1}{\sigma_j^2}}$$

Two component average:

$$t_{avg} = (w_a t_a) + (w_b t_b) \qquad \sigma_{t_{avg}}^2 = (w_a \sigma_a)^2 + (w_b \sigma_b)^2$$

$$t_{avg} = \frac{\frac{t_a}{\sigma_a^2} + \frac{t_b}{\sigma_b^2}}{\frac{1}{\sigma_a^2} + \frac{1}{\sigma_b^2}} = \frac{t_a \sigma_b^2 + t_b \sigma_a^2}{\sigma_b^2 + \sigma_a^2}$$

In limit where $\sigma_a = \sigma_b = \sigma$ $\quad \sigma_{t_{avg}} = \frac{1}{\sqrt{2}} \sigma$

Time difference (position):

$$\Delta t = t_a - t_b \qquad \sigma_{\Delta t}^2 = \sigma_a^2 + \sigma_b^2$$

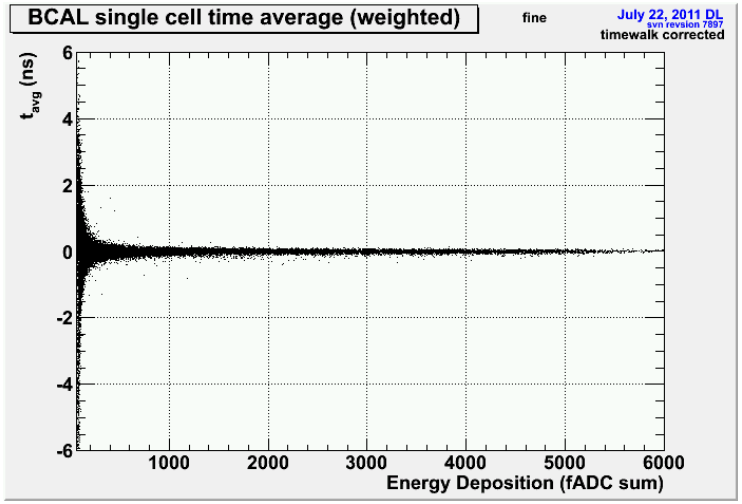
In limit where $\sigma_a = \sigma_b = \sigma$

$$\sigma_{\Delta t} = \sqrt{2} \sigma$$

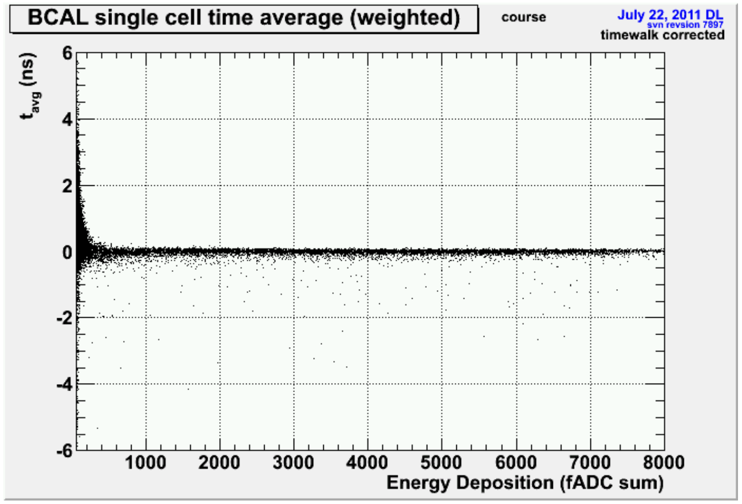
Shower positions will be calculated as a weighted average of positions in individual cells.

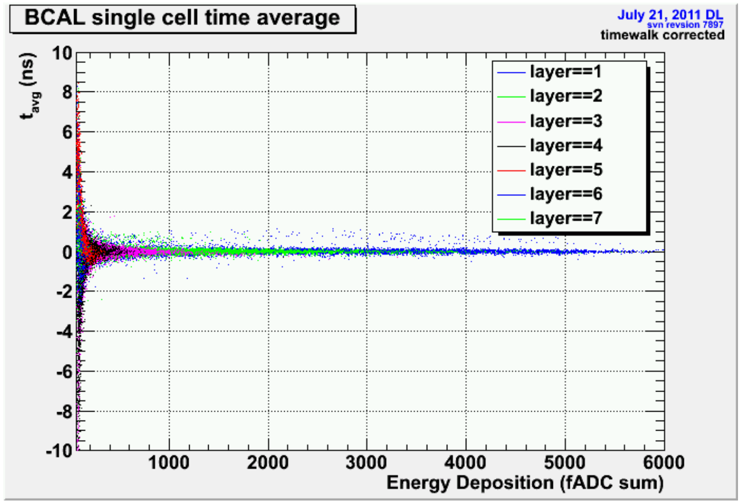
Cell Timing Resolutions

FINE



COURSE





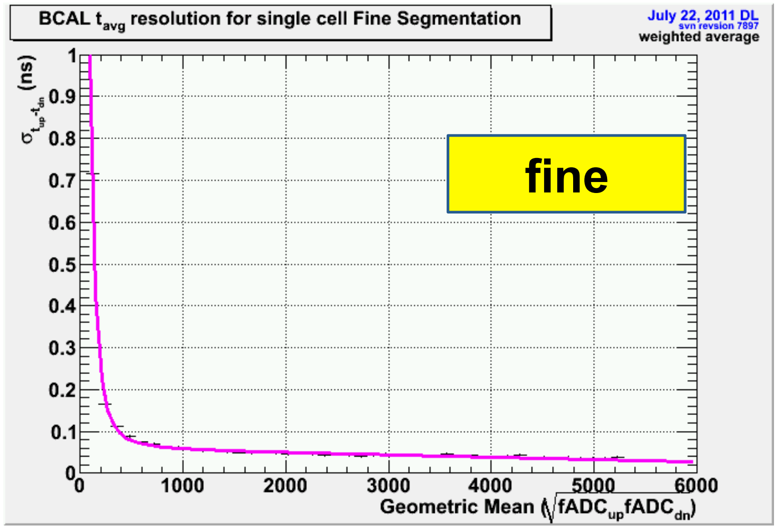
The above plots show the weighted time average as a function of geometric mean.

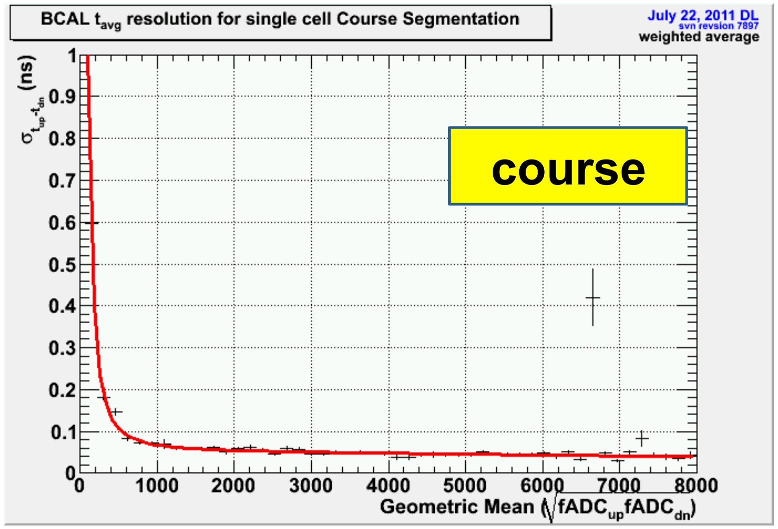
The plot to the left is similar (straight average, not weighted), but color coded by layer.

Cell Time Average Resolutions

<u>Fit info:</u>

- timewalk-corrected time averages
- Gaussian functions
- slices in geometric mean (fADC)
- σ's fit to obtain resolution as function of geometric mean





<u>functional form:</u>

$$\sigma_t(x) = b_0 + \frac{b_1}{cos(b_3) + sin(b_3) \cdot x^{b_4}} + b_5 x$$

According to these plots, the fine segmentation scheme has better individual cell timing resolution than the course scheme for the same energy deposition in the cell

Finely segmented cells will, however, have less energy on average than the course.

By the same token, more measurements are made of the position with the fine segmentation so the errors are reduced more (relative to the course) when combining them.

Cell Time Difference Resolution

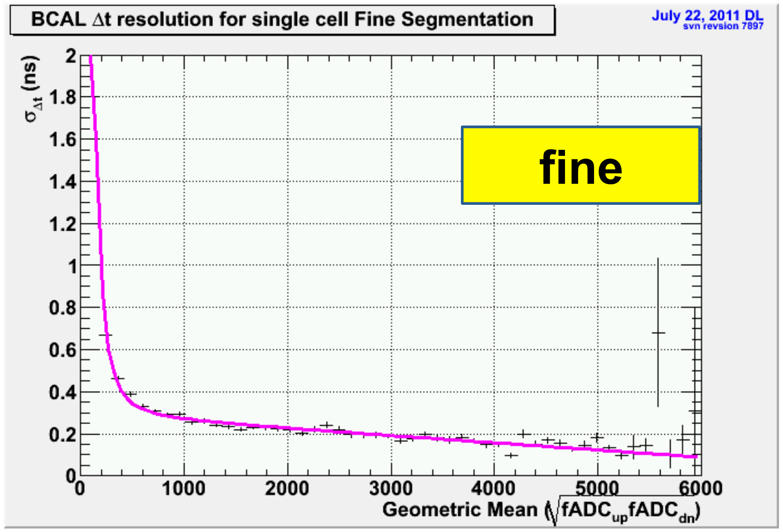
Fit info:

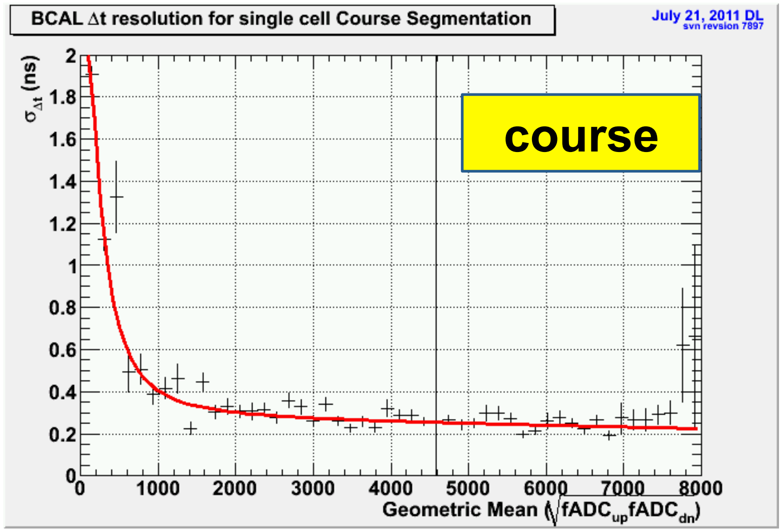
- timewalk-corrected time differences
- Gaussian functions
- slices in geometric mean (fADC)
- σ's fit to obtain resolution as function of geometric mean

functional form:

$$\sigma_t(x) = b_0 + \frac{b_1}{cos(b_3) + sin(b_3) \cdot x^{b_4}} + b_5 x$$

Observations on previous slide apply here as well.





Summary

- Current study indicates smaller cells give better timing resolution
  - Further review may be needed to verify
- Next steps
  - Combine cell tdiff uncertainties to estimate position uncertainty
  - Repeat at 20^{o}
  - Implement 1,2,3 summing (instead of 3,3) and re-test