Setting the FEB Gain Thresholds for the FCal

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The Front End Boards (FEBs) have the ability to automatically switch between three gains: low, medium, and high. This feature is called the "autogain" mode. To implement this feature, the FEB requires that we specify one of the time samples (the one closest to the peak of the pulse) and two thresholds. The thresholds are specified on the medium gain scale. If the specified time sample falls below the lower of the two thresholds, then high gain is read out. If this time sample rises above the higher threshold, then low gain is read out.

The time samples are in units of ADC counts, including a pedestal level. On the Mod 0 FEBs which we are using in the testbeam, this pedestal level can be set over the SPAC Bus. For the production FEBs to be used in ATLAS, this pedestal level is set via components on the FEB with default setting of about 1000. It cannot be adjusted via computer control. This pedestal level is independent of the choice of gain, that is, it is the same for all of the gains. (There may be small offsets from this pedestal level so pedestals should be determined for each gain setting.)

For the FCal Calibration Test Beam Run in summer 2003 we set this pedestal level at 1000 ADC counts. We set our timing so that time sample number four (counting from one) was, on average, the sample at the peak of the pulse. The threshold to switch from the default medium gain to high gain was set at 1150 ADC counts, i.e. 150 ADC counts above pedestal level (corresponding to about 108 GeV electron energy in a single FCal1 cell). The high to medium gain ratio is about 9.2 so this threshold corresponds to 1385 ADC counts above pedestal on the high gain scale. I will use 12.8 ADC counts/GeV of deposited EM energy on the high gain scale for FCal1 as the energy calibration.

In analyzing data from last year I saw that the negative lobe of the pulse would sometimes saturate on the high gain scale. That is, the sample nearest the minimum of the negative lobe would fall so far below the pedestal level that something in the warm electronics chain would become non-linear. For this reason I decided to review the method used to determine the threshold settings. I was aware that the negative lobe would be the limiting feature of the pulse and attempted to set the thresholds appropriately. But I determined the thresholds based on the pulse shape and failed to account for the fact that the pulse shape is sampled every 25 ns. In the test beam the trigger comes at random times relative to the TTC clock. This means that the time samples come at a uniformly random time relative to the trigger within a 25 ns window. Figure 1 shows the FCal1 pulse and the associated time samples for 9 choices of the phase of the trigger relative to the TTC clock. We had set the trigger timing so that time sample 4 came closest to the peak of the pulse over almost the full 25 ns window.

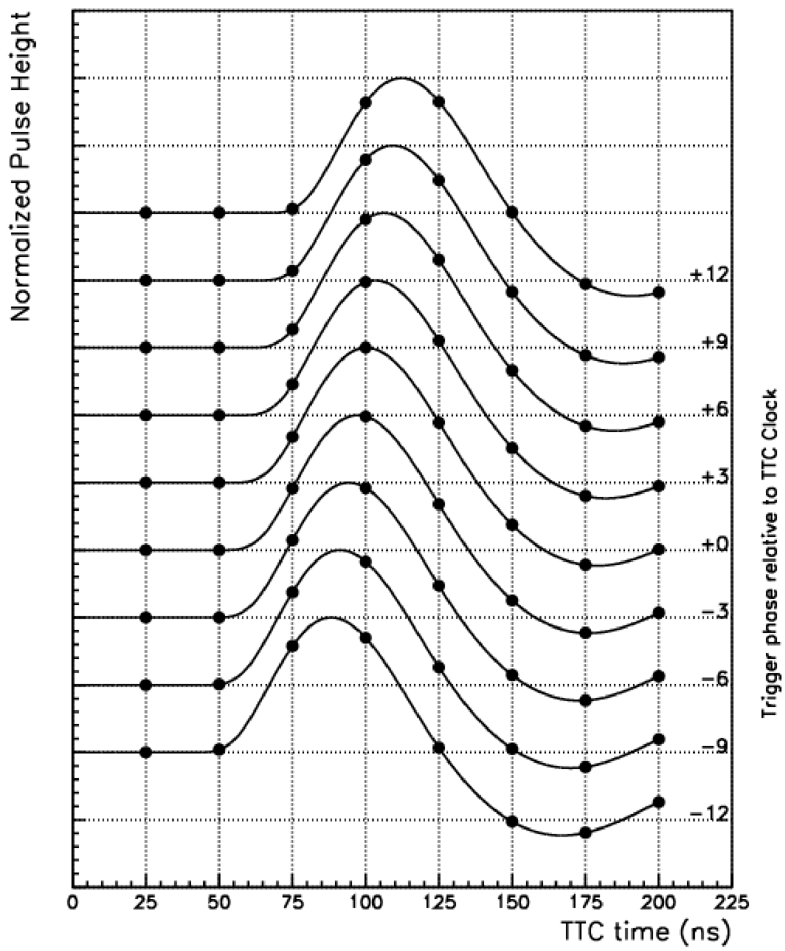

Figure 1. FCal1 pulse shape with time samples superimposed for 9 choices of the phase of the trigger relative to the TTC clock. Each pulse is offset vertically from its neighbors for clarity.

Note that the pulse with relative timing of 0 ns (the label at the right in Figure 1) has time sample 4 at the peak of the pulse. The pulse with relative timing of +12 ns has time sample 4 displaced from the peak by 12 ns so that its amplitude is well below the peak.

Figure 2 shows the FCal1 pulse at the ADC including the pedestal offset. The vertical scale is in units of ADC counts with ADC count of zero at the bottom. The minimum of the pulse at the negative lobe comes at ADC count of ‘n’. The pedestal level is set at ‘z’. The lowest that the selected time sample (closest to the peak) comes is at ‘t’ and the peak of the pulse is at ‘p’. We define A = p - z, B = t – z, and C = z – n. We also define a = B/A and b = C/A. And finally we define G (=9.2) as the ratio of the high gain scale to the medium gain scale.

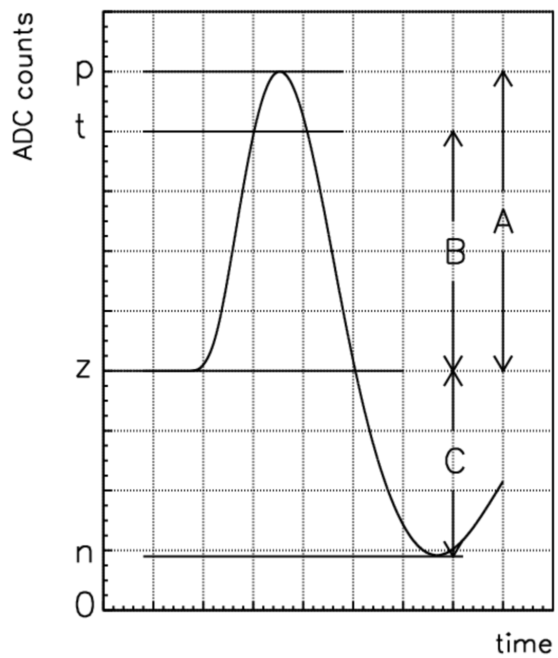

Figure 2. The FCal1 pulse with critical points identified in ADC counts. Note that zero ADC counts is at the bottom of the plot and z is the pedestal level. Usually z = 1000 ADC counts.

We will make the simplifying assumption that the negative lobe is broad enough that one time sample will fall at ‘n’ regardless of the trigger timing. But the chosen time sample (usually time sample 4) nearest the peak will not always fall at the peak of the pulse. In the test beam it can fall 12.5 ns either side of the peak which puts it at ‘t’ rather than ‘p’.

It is easy to show from Figure 2 and our definitions that

$$t = z + (z - n)(a/b)$$

This tells how to set the medium to low gain threshold in the FEB. The parameters ‘a’ and ‘b’ are known parameters of the pulse shape and we have already set the pedestal at ‘z’. If we decide that n must never fall below 200 ADC counts, then we use this formula to calculate ‘t’, which becomes the threshold level. This formula works for calculating the threshold to change from medium to low gain. This threshold is specified on the medium gain scale. For the transition between medium and high gain we must remember that this threshold also is to be specified on the medium gain scale. So the correct formula for this threshold is

$$t = z + (z - n)(a/b)/G$$

Case	G	a	b	z	n	t_{ML}	t_{MH}	E_{ML} (GeV)	E_{MH}(GeV)
1	9.2	0.80	0.65	1000	200	1985	1107	708	77
2	9.2	0.80	0.65	1500	200	3100	1674	1150	125
3	9.2	0.99	0.65	1000	200	2218	1132	875	95
4	9.2	1.00	0.65	1000	100	2385	1150	995	108

Table 1. Four example calculations of the two thresholds. The first threshold is for the transition between medium and low gains while the second is for the transition between medium and high gains. The four examples are described in the text.

Case 1 in Table 1 is the example I suggest we use for CBT-EC2. It is conservative in that 1) I assume 'b' is a bit larger than for most channels and 2) I have set 'n' a bit higher than necessary. Case 2 makes more effective use of the dynamic range available on the FEB. However, because 1) the final ATLAS FEBs don't allow the pedestal level to be adjusted via computer control, only by changing components on the FEB and 2)we will be pressured into using the same FEBs as everyone else for ease of maintenance, we should probably stick with the usual pedestal level of ~ 1000 ADC counts for CBT-EC2.
In ATLAS the trigger is very closely synchronized with the TTC so we will never see the peak time sample displaced from the peak of the pulse by more than about 2 ns. Case 3 corresponds to this ATLAS situation. Therefore we can expect to set the thresholds as shown in case 3 after CBT-EC2 is over. Case 4 shows how we set the thresholds for the FCal Combined Test Beam Run in summer 2003. This was not optimal in that I forgot to account for the factor 'a'. For the few events where the peak time sample was displaced from the peak of the pulse by 12 ns, the pulse near the minimum at the negative lobe could be at ADC count of n = -121. But this is impossible because the ADC counts up from zero. So for such a pulse, the time sample at the negative lobe would be well into saturation. We saw such events.

The same high-to-medium gain threshold will never be exceeded for FCal2 in CBT-EC2 because 1) showers are spread over several readout cells by the time they penetrate to the depth of FCal2 so that the energy deposited in any one readout is small, 2) the EM energy calibration for FCal2 is about 6.5 ADC counts/GeV, nearly half of FCal1, and 3) the value of 'b' for FCal2 is smaller. The same is true for the cold tail catcher (CTC) which has a calculated energy calibration of about 5.8 ADC counts/GeV of deposited EM energy on the high gain scale.

The same gain thresholds should work fine for calibration data as well. The shape of the calibration pulse gives a less pronounced negative lobe (i.e. smaller value of 'b') so if the physics pulse doesn't saturate, then neither will the calibration pulse.