TFB High/Low Gain channel ratios M.Raymond – 15/4/09

The ratio between the high and low gain channels on the TFB are determined by the ratio of the two capacitors C_{HI} and C_{LO} in figure 1 below.

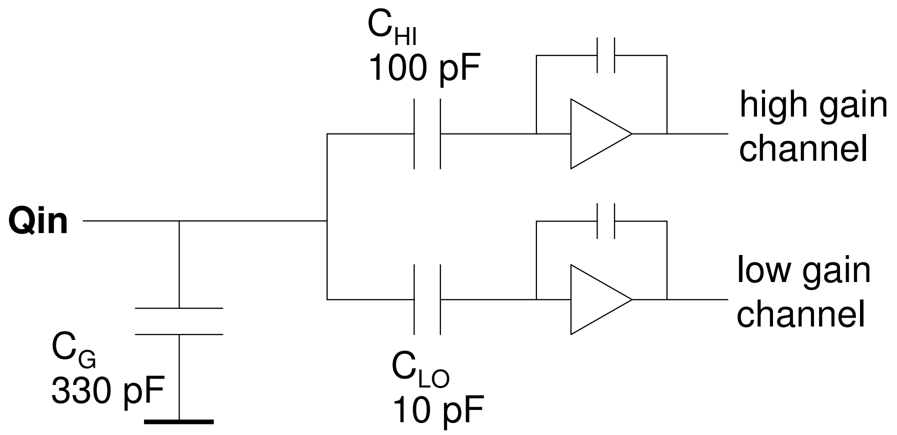

Figure 1. Simplified schematic of one TFB channel.

For the capacitor values shown one would assume that the ratio would be a factor 10. Note that all capacitors have a 5% tolerance. The overall gain can be adjusted by choosing a value for capacitor C_G , and a value of 330 pF has been fitted to all production TFBs, but one should also add the additional SiPM cable capacitance and any additional stray capacitance to this.

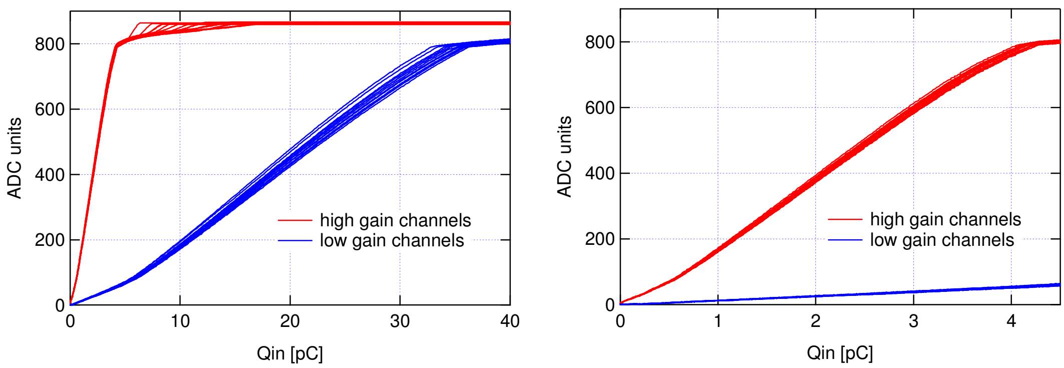

Figure 2. TFB Trip-T gain measurement

Figure 2 shows a gain measurement for all channels on one Trip-T on a TFB using the on-board charge injection circuitry. The spread between curves can be attributed to the tolerance of the capacitors (including the charge injection capacitor – not shown in figure 1). The right plot has an expanded scale for the charge axis to show the high gain channel data more clearly. Examining this plot first it can be seen that there is a linearity discontinuity in the region of ~0.5 pC, where signals less than ~0.5 pC have a lower gain than signals above this value. This non-linearity is a feature of the Trip-T chip, and is also visible in the left plot for the low gain channels.

How the input charge Q_{IN} is shared between high and low gain channels depends on signal size. For low values of Q_{IN} the charge is shared in the ratio of the capacitors in figure 1, so the high gain channel takes a fraction 100/(330 + 100 + 10) = 23% of the charge and the low gain channel takes a fraction 10/(330 + 100 + 10) = 2.3%. So for low gains the ratio should be a factor 10 (simply the ratio of the capacitors).

For higher values of Q_{IN} the high gain channel Trip-T amplifier saturates and can no longer integrate the incoming charge. So C_{HI} is effectively removed from the circuit and the charge is shared between C_G and C_{LO}. The low gain channel will therefore integrate a fraction 10/(330 + 10) = 2.9% of the charge, implying an increase in the low channel gain when the high gain channel saturates. This would also give rise to a discontinuity for the low gain channels in the left plot figure 2, but the transition is not clear because the high gain channel saturation occurs at a similar point to the linearity discontinuity.

Figure 3 shows the average of the high and low gain curves in figure 2, together with their ratio (shown on the right hand axis). For low values of Q_{IN}, before the high gain channel has saturated, the ratio is in the range 12 – 16. This is higher than the factor 10 expected, because of the reduced slope (or gain) of the low gain channel for smaller signals in this region due to the Trip-t non-linearity already discussed above.

So if one were to simply plot high and low gain channel against each other and fit a simple straight line to the result, one would get a gain ratio in the region 12 – 16.

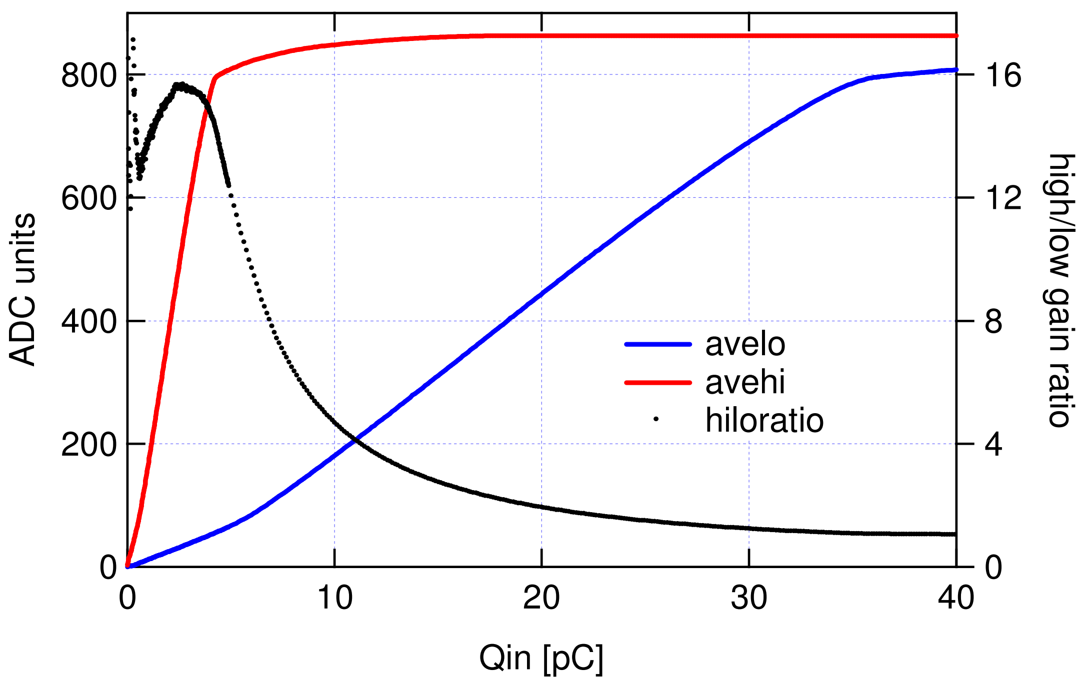

Figure 3. Average high and low channel Trip-T gain measurement and high/low ratio.

The simple capacitive charge sharing argument above predicts that in the optimum region for the high gain channel (up to ~ 4 pC) the fraction of charge that it will see is 23%, whereas for the low gain channel, after the high gain channel has saturated, this fraction is 2.9%. This leads to an expected gain ratio, in their respective optimal operating regions, of 7.9. Figure 4 shows the same picture as figure 2, but just showing the average high and low gain channel curves, with fits to their linear regions. The gradients of the fits are in the ratio 217/26 = 8.3, in good agreement with expectation.

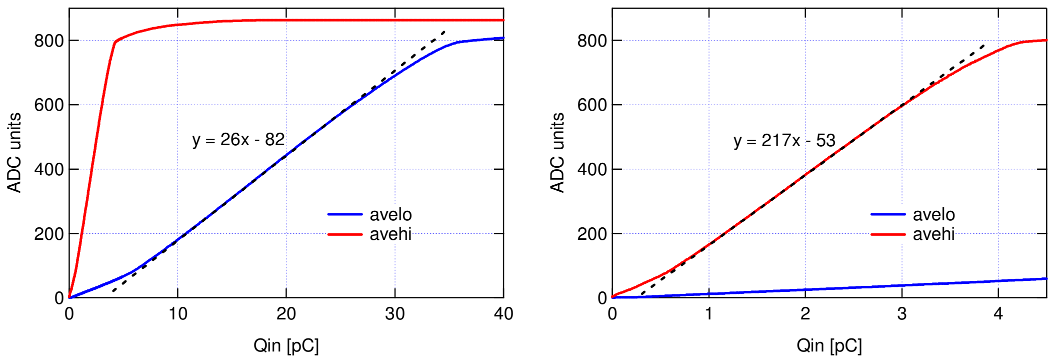

Figure 4. Average TFB Trip-T gain measurements with fits.