Further Variations on 'A first look at occupancies in Layer 00'

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1 Results

Following on from the first report, this study considers various configurations for a Layer 00 detector, and evaluates them in terms of hit and track occupancies. Issues such as cost, read-out channels, signal/noise are not dealt with in any detail. The physics process, which was used to model the detector response, was a $t\bar{t}$ event with 5 minimum bias events superimposed.

The results are detailed below and are summarised in the table.

1. The first configuration considered was that which formed the subject of the original report. The detector was an octagon. The strip pitch was 50μm. The silicon width was 300μm. One peculiarity was that the detector was considered to be infinite in extent in the z direction. Only 21% of tracks passed solely between two read-out strips. 33% of tracks left charge on 4-strips. This was due to the large crossing angles incurred in an 8-fold geometry. Thus, to use this geometry, a rather good signal to noise would be required from the silicon and read-out.

   The large crossing angles have implications for occupancy too. 25% of the strips hit were hit more than once. 180 tracks (or 50% of all tracks) produced clusters which overlapped other clusters. The situation was even worse for tracks which came initially from b-decays where typically 6.3 tracks out of an average b-decay multiplicity per event of 12.1, had the potential to be mis-measured.

2. Many of the problems above occurred from overlap with the minimum bias events. These are peaked at low polar angles and so affect a detector which is infinitely long in z. The more realistic z acceptance was now considered, with an active area stretching from -40cm to 40cm. 8 plaquettes were assumed, each with 10cm of active area.

   The crossing angles remained the same as in the last configuration, but now the hit occupancies reduced to 6%. 41 tracks were mis-measured, which was 15% of all tracks entering the active region. 3.6 of the b tracks were mis-measured which was 33% of the total number (10.5) of b decay tracks entering the active area.

3. The third configuration considered was an idealised detector which could not be built but provides us with a 'best possible scenario' against which we can compare our other designs. The strip pitch was 25μm and the width of the detector was only 3μm. Due to the unreasonably

thin detector, practically all tracks leave charge on only two strips. Hit occupancies are only 1% while only 2.5% of tracks are mis-measured (roughly two tracks for each doublely occupied strip.) However, for tracks from b-decays, on average 1.2 tracks or 8% of the total were mis-measured. Thus even with an 'ideal' detector, there is a substantial mis-measurement of tracks from b-decays. This is due to two things: firstly, the narrow opening angle of b-jets; and secondly, the projective effect of the z strips. Tracks from b-decays may be (reasonably) separated in three dimensions, but when projected into the $R\phi$ plane, they line up. There is no way to avoid this with silicon strip detectors (it can be done with pixels.)

To cross-check these occupancy numbers, the distance of closest approach of b-tracks to other tracks was plotted in the $R\phi$ plane. (Fig. 1) 2.1 b-tracks per event lay within 100μm of another track, while 3.4 b-tracks lay within 200μm. Thus, irrespective of strip pitches, detector depth and z segmentation, there would appear to be a hard limit of one or two b-decay tracks which are mis-measured.

4. The fourth configuration is referred to as a BASELINE as it is a reasonably likely scenario and one from which we will make one adjustment at a time to gauge its effect. This BASELINE configuration was an octagon with 8 z segments, each of 10cm between -40 cm and 40 cm. The pitch was 50μm and the depth was 300μm. The $t\bar{t}$ event was generated at $z = 0$ while the minimum bias events were sampled from a Gaussian profile in z of mean zero and width 30cm.

   The crossing angles produced hit profiles as in the second case. The hit occupancies were reduced to 4% while the track occupancies were reduced to 24 tracks or 10%. On average 3.1 tracks from b-decays were mis-measured.

   A comparison of these results with the second scenario shows the effect of the Gaussian profile of the beam. The minimum bias events have a much reduced effect on occupancies when they do not occur at exactly the same production point as the $t\bar{t}$-decay.

5. The first change from the BASELINE was to increase the number of plaquettes in $R\phi$ from 8 to 16, irregardless of the construction problems this might present.

   A large change was observed in the number of strips over which the charge was shared. Nearly all tracks now spread the charge over 2 or 3 strips. Given a poor S/N, it may be necessary on these grounds alone to go to this configuration.

   The hit occupancies were reduced from 4% to 3% with 19 rather than 24 tracks being poorly measured. For tracks from b-decays, the reduction was from an average of 3.1 to 2.5 badly measured tracks.

6. The second change from the BASELINE was to double the segmentation in z. The crossing angles did not change, but this had a larger effect than expected on the occupancies. The hit occupancies were reduced from 4% to 2.7% with 16 rather than 24 tracks being poorly measured. For tracks from b-decays, the reduction was from an average of 3.1 to 2.8 badly measured tracks.

7. The third change from the BASELINE was to reduce the strip pitch to 25μm. This had a major impact on the number of strips over which the charge was spread. Because the pitch had been halved, 47% of tracks deposit their charge over 5 or more strips ! On account of noise problems, this fact is probably sufficient to kill this design. Nonetheless, there was an improvement as expected in track mis-measurements with an average of 21, while for those from b-decays, the average was 2.5

8. The fourth deviation from the BASELINE was to reduce the depth of the silicon bulk to 250μm. This had a reasonable impact in terms of increasing the number of 2,3 and 4-strip

clusters. The hit occupancies reduced to 3.8% with typically 22 tracks mis-measured and typically 2.9 tracks from b-decays.

9. The fifth change to the BASELINE combined two of the effects which would appear to reduce track occupancies whilst still being within the bounds of what is technically feasible. The pitch was reduced to 25μm but a 16-fold geometry was assumed in $R\phi$. Because the geometry was doubled while the pitch was halved, it is interesting that the two effects cancel so as to give similar cluster sizes as in the BASELINE.

   Hit occupancies were considerably reduced to 2.2% while the number of track mis-measured also improved to 13 on average or 1.8 in b-decay events. These numbers are the closest to our 'idealised' solution.

10. Introducing 25μm strips would double the number of read-out lines (notwithstanding a probable deterioration in signal to noise.) To compensate for this, suppose the number of z plaquettes were reduced by a factor of two through multiplexing. Surprising, this small change had a relatively large effect on the mis-association rates. Comparing with the previous configuration, typical numbers of mis-measured tracks rose from 6% to 9%. The effect on tracks coming from b-decays was not so great (due to the smaller cone in which they occur) rising from 16% to 18%.

11. We now considered the effect of tilting each plaquette in the BASELINE through 10^0 (Fig. 2.) This scheme or something similar will be necessary in any final design in order to maintain 2π coverage despite the dead regions at the side of the plaquettes.

    Interestingly, the number of 2,3,4 and 5-strip clusters does not change with respect to the baseline.

12. It might be thought that this tilt would have more effect in the 16-fold geometry. However, comparison of these results with configuration 5 shows a minimal impact.

13. From the BASELINE configuration, it was seen that a sizeable number of tracks spread over 4 or 5 strips. With likely signal to noise ratios of 12:1, this is clearly unsatisfactory. One solution is (perhaps paradoxically) to *increase* the strip pitch rather than reduce it. This would improve the signal to noise by ensuring that the charge is spread over 2 or 3 strips. It would also reduce the noise due to the reduced capacitance. In addition, fewer readout channels would be required, reducing costs. Finally, although the assymptotic impact parameter term would be practically unchanged by adding a course strip pitch, the multiple scattering term would be almost as good as with the finer strip pitch (accurate numbers to be presented in another memo.) One would however expect a degradation in the hit and track occupancies.

    Results for the BASELINE design, but with 75μm pitch are given in row 13 of the table. As expected, only 12% of tracks spread the charge over 4 strips. The percentage of hits which were caused by two or more tracks rose from 4.0% to 5.1%. The percentage of tracks which were potentially mis-measured rose from 10% to 12% while now 3.6 tracks from b-decays were typically mis-measured instead of 3.1 in the BASELINE design.

14. For the BASELINE design with 100μm pitch, 98% of tracks spread their charge on 2 or 3 strips. The occupancy rates rose however: 6.2% of hits overlapped instead of 4.0%; 14% or tracks overlapped instead of 10%; and typically 4.0 tracks from b-decays were mis-measured instead of 3.1.

	Description	2-strip	3-strip	4-strip	5-strip	Hit Occ	Track Occ	B-track Occ
1	8-fold $R\phi$ Infinite z 50μ pitch 300μ depth	21 %	41%	33%	5%	25%	180 (50%)	6.3 (59%)
2	As 1 but 8-fold 10cm z	21%	41%	33%	5%	5.9%	40 (15%)	3.6 (33%)
3	64-fold $R\phi$ 8-fold z 25μm pitch 3μm depth	99.5%	0.5%	0 %	0%	1%	(2.5%)	1.2? (8%)
4	BASELINE: 8-fold $R\phi$ 8-fold 10 cm$z$ 50μm pitch 300μm depth 30cm bspot	21%	41%	33%	5%	4.0%	24 (10%)	3.1 (29%)
5	As BASELINE but 16-fold $R\phi$	42%	55%	2%	0%	3%	19 (8%)	2.5 (23%)
6	As BASELINE but 16-fold 5cm z	21%	41%	33%	5%	2.7%	16 (7%)	2.8 (26%)
7	As BASELINE but 25μm pitch	11%	21%	21 %	47%	6.6%	21 (9%)	2.5 (23%)
8	As BASELINE but 250μm depth	25%	49%	25%	1%	3.8%	22 (9%)	2.9 (26%)
9	As BASELINE but 16-fold $R\phi$ 25μm pitch	21%	42%	32%	5%	2.2%	13 (6%)	1.8 (16%)
10	As 9 but 4-fold z	21%	42%	32%	5%	3.4%	21 (9%)	2.1 (18%)
11	As BASELINE 10^o tilt	21%	41%	33%	6%	4.0%	24 (10%)	3.1 (29%)
12	As 5 10^o tilt	41%	54%	4%	1%	3.3%	19 (8%)	2.5 (23%)
13	As BASELINE but 75μm pitch	32%	56%	12%	0%	5.1%	29 (12%)	3.6 (33%)
14	As BASELINE but 100μm pitch	42%	55%	2%	0%	6.2%	34 (14%)	4.0 (38%)

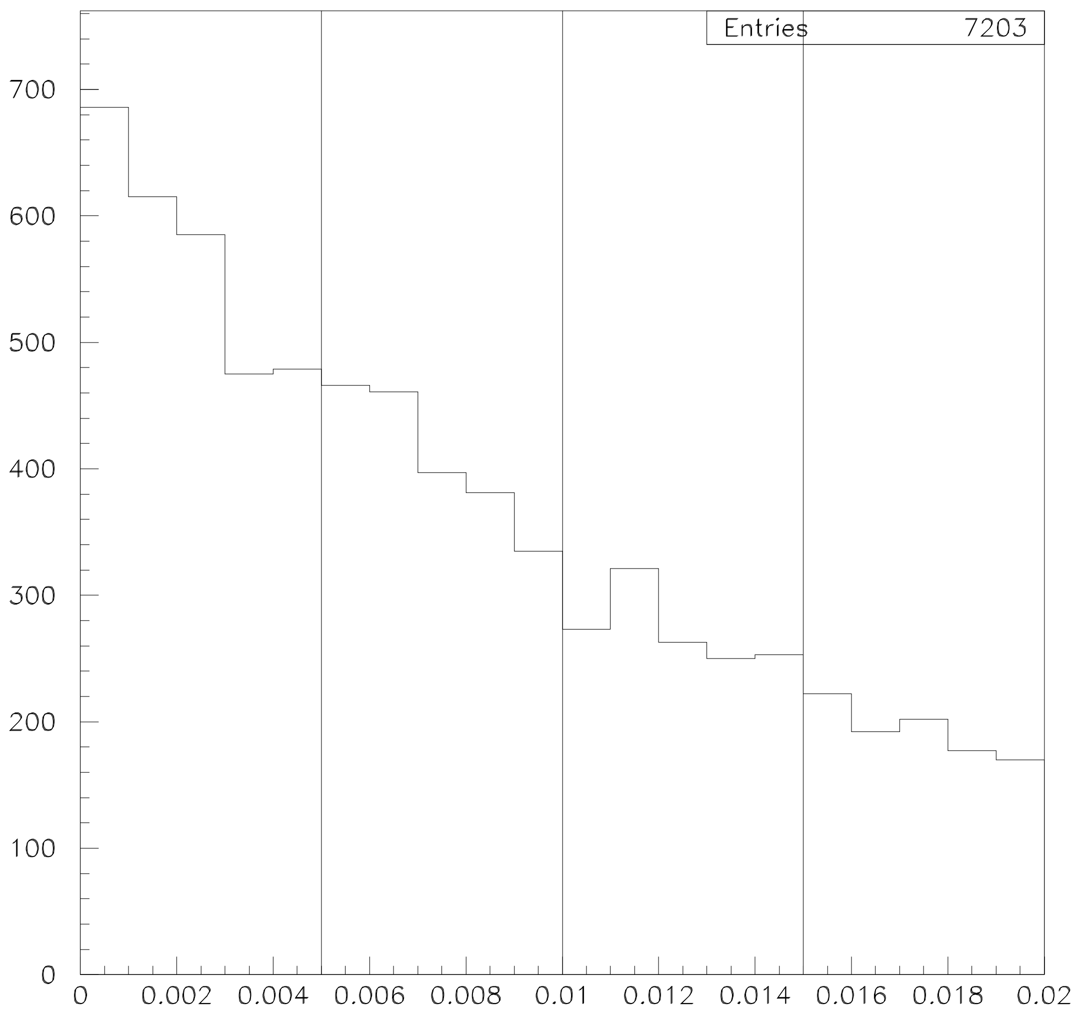

Figure 1: Distance (in the transverse plane) to closest track for tracks emanating from b decays.

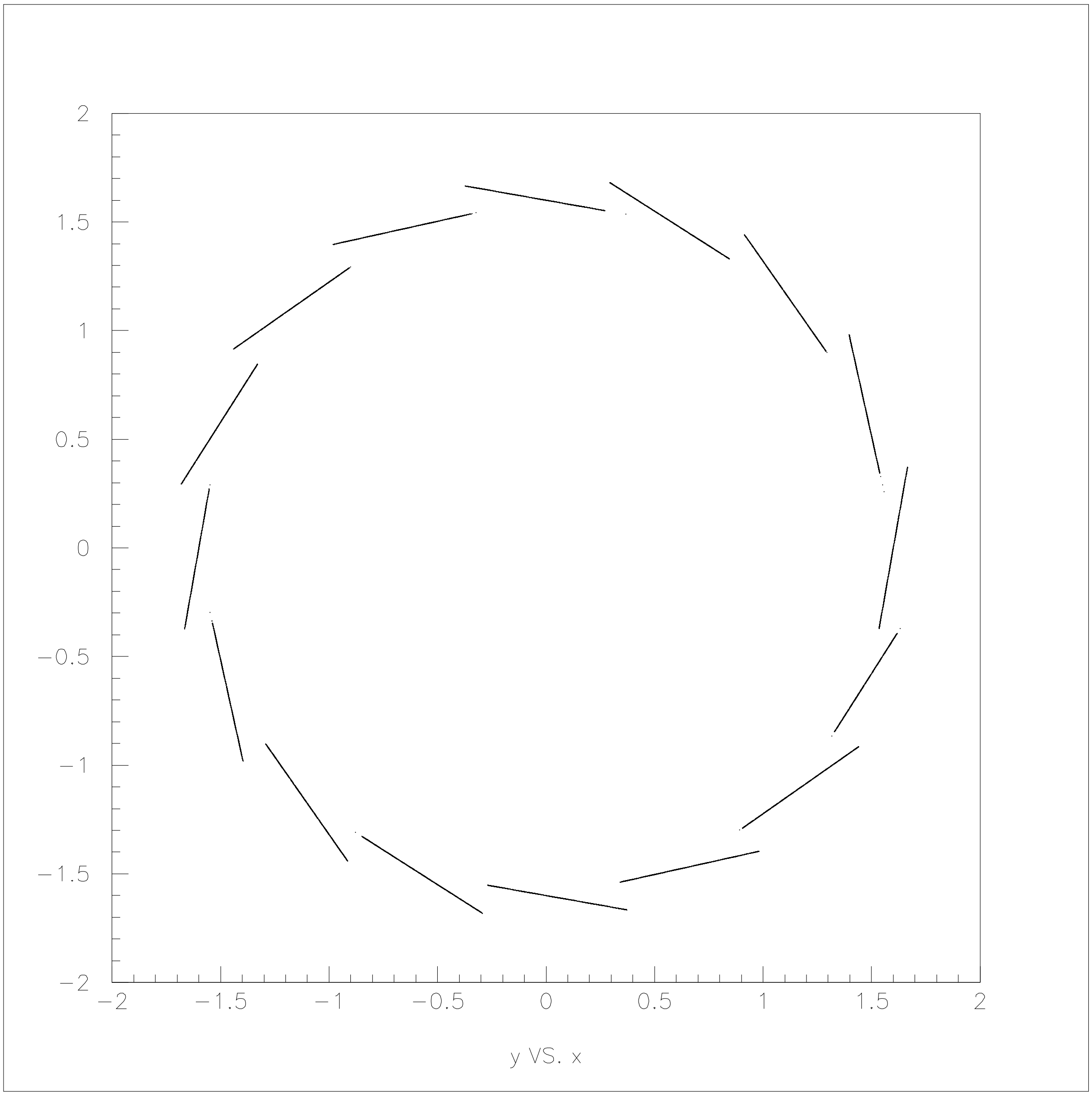

Figure 2: 10 degree tilt on a 16 fold detector