Investigation into the zeroth time bin anomaly in the SCT barrel modules in the ATLAS detector

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Abstract

In this report an investigation into the zeroth time bin anomaly in the ATLAS SCT barrel modules was carried out. Eight problematic modules were identified as the cause of this anomaly, of which there were three distinct classes, each class pointing towards a different type of problem. The causes of this anomaly were identified as appearing at the harness, chip and channel level.

1 Introduction

The work presented in this report was an investigation into the noise in the SCT barrel modules for a particular barrel configuration. Specifically this report focused on investigating the zeroth time bin anomaly. The method involved analysing a set of SCT data which was taken during the cosmic ray commissioning of the SCT whilst the SCT was on the surface and after insertion of the SCT into the TRT. Also it should be noted that although there are 2112 SCT barrel modules in total only 468 of these were actually active for this configuration relevant for this work. The SCT data used corresponded to run number 003076 and was taken on the 22/06/2006. The setup was such that a 30kHz pulsed trigger (so it was not in time with the cosmic rays) was employed, with the threshold potential on the chip set at 0.9fC and with only the SCT active, the TRT was clocked but not triggered. In total 9,150,835 events were generated for this data run distributed amongst 100 data files. However, for this work only one file was used corresponding to 91,159 events. The analysis of the data was carried out using a private event decoder which then allowed plots to be produced.

2 The analysis and results

Two important definitions are now given. Firstly a time bin is a set period of time during which data is recorded by the SCT modules. For this work three of them were employed at one time. Each time bin has a duration of 25ns corresponding to one bunch-crossing at the LHC which is the rate of data arrival expected for ATLAS. The data was collected whilst running in expanded mode and three consecutive time bins were then readout centred on level 1 (Lv1) trigger. The time bins are labelled -1, 0, +1 with the centre one corresponding to the number 0. Secondly a bit field or bit word is a value made up of binary digits which indicates that a noise hit has been recorded by the SCT in one, two or all three of the time bins. The particular setup of the trigger and clock was such that it was run in "any hit" mode which meant that a hit packet was sent off the detector if a hit occurred in any of the three time bins. If no hits are found in the three time bins then no hit packet should be sent out. If there were hits found for this bit field value then this would indicate a problem. This was indeed observed, the so called zeroth time bin anomaly. Figure 1, which is for all modules, shows this anomaly and because of this further investigation was warranted.

The first step was to try and identify those sides of the modules which had recorded noise hits in the zeroth time bin (they were temporarily assigned the label "bad module sides"). Each side can be uniquely identified by four numbers which locate each side of a module within the SCT coordinate system. The first is on which layer the side resides and there are four layers, layer 0 being the layer closest to the interaction point. The second is which side of the module one is dealing with, side 0 or the bottom part being the side closest to the interaction point. The final two are the η and ϕ values which act as a 2D coordinate system on each plane of modules, for each side. In total 14 bad sides were identified which corresponded to eight problematic modules. However, initially it was found that there were three different classes of module, each corresponding to possibly different problems. Table 1 shows all 14 bad sides together with their unique numbers and noise occupancy (here the noise occupancy is defined as the number of noise hits recorded per event, per strip) values for both cases of noise hits in the zeroth time bin and the

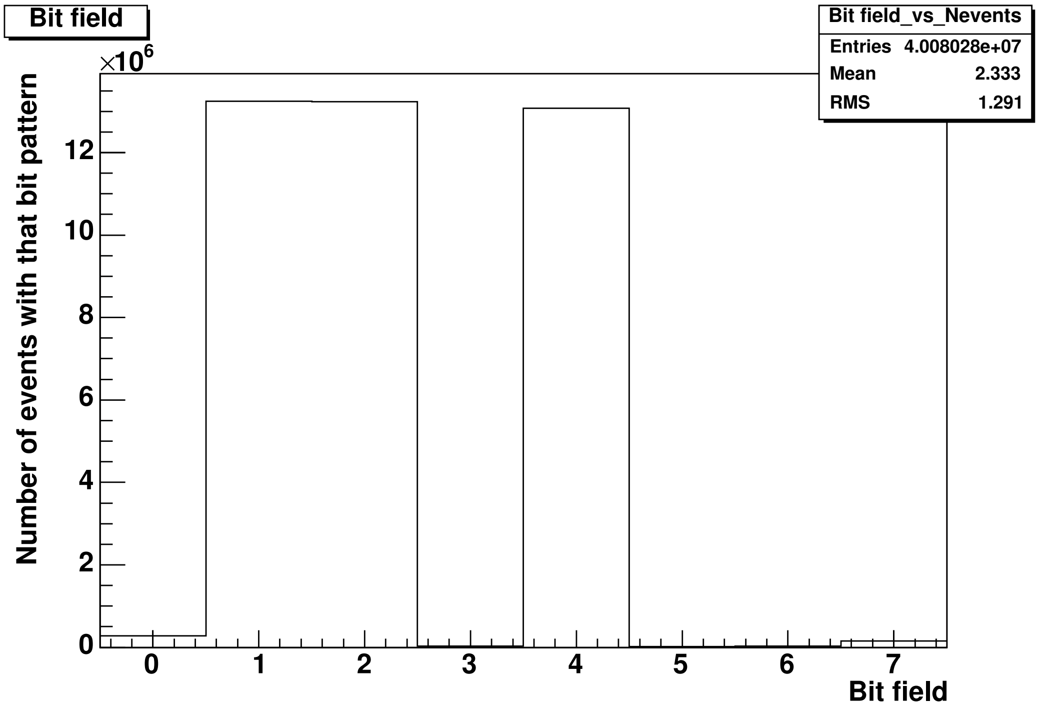

Figure 1: Distribution of bit field value versus number of events with that corresponding bit pattern. Note the entries in bin 0 which is the zeroth time bin anomaly and warranted further investigation. This is for all modules.

central time bin.

The first class contained 6 modules who had recorded hits on both sides of the modules (so 12 sides in total) and values for the ratio of noise occupancy(000)/noise occupancy(x1x) were very similar. The second and third classes each contained one side of a module, each side from a different layer and only one side of the modules recorded these anomalous hits in the zeroth time bin. In addition to this they also had values for the ratio of noise occupancies that were different to those of the first class of modules. One side of a module from the first class was selected together with the two sides from the second class and a series of plots were made to try and decipher what the cause for the anomaly could be. The three sides selected were:

- Side of the module with layer=0, side=0, η=-1, ϕ=8
- Side of the module with layer=2, side=1, η=-2, ϕ=6
- Side of the module with layer=3, side=1, η=-3, ϕ=11

The first set of plots were produced to see what value the bit field was for each of the three sides selected. The second set of plots were produced to see how the hits in

Class	Layer	Side	η	ϕ	Noise Occupancy(000)	Noise Occupancy(x1x)	Ratio
A	0	0	-1	8	0.000283854	0.000397005	0.714988
A	0	0	-2	8	0.000202865	0.000260937	0.777448
A	0	0	-3	8	0.000225651	0.000314844	0.716707
A	0	0	-4	8	0.000451953	0.000745964	0.605864
A	0	0	-5	8	0.000134245	0.000198828	0.675182
A	0	0	-6	8	0.000142318	0.000189583	0.75069
A	0	1	-1	8	0.000240625	0.000321354	0.748785
A	0	1	-2	8	0.000214583	0.00029401	0.729849
A	0	1	-3	8	0.000196484	0.000254036	0.773449
A	0	1	-4	8	0.000440625	0.000689323	0.639214
A	0	1	-5	8	0.000142969	0.000178385	0.801463
A	0	1	-6	8	0.0001125	0.000132292	0.850392
B	2	1	-2	6	0.00122266	0.00019375	6.3105
C	3	1	-3	11	$9.11458\text{x}10^{-7}$	0.000292969	0.00311111

Table 1: The table displays the three classes which contain the 14 bad sides with their unique ID numbers that were identified in this report along with their corresponding noise occupancy values for both cases of noise hits in the zeroth time bin and the central time bin. Finally the ratio of these two numbers (i.e. noise occupancy(000)/noise occupancy(x1x)) are also given.

the zeroth time bin varied per chip and strip (readout channel) for each side. Note the convention used for the chip and strip numbers for each side was the following. The strip number runs from 0 to 767 per side and the chip number runs from 0 to 5 for side 0 and from 8 to 13 for side 1. Also note that the channel and chip ID's were *online* (hardware) numbers whilst the module ID's were *offline* numbers. These plots were also produced for the case of when there was at least one hit in the central time bin (x1x) to see if there was any correlation with the case of zeroth time bin hits for each side. Finally the third set of plots show the variation of the x1x and 000 hits with time (event number). The results for each side will now be discussed in turn.

2.1 Side of the module with layer=0, side=0, η=-1, ϕ=8

The set of plots for this side of a module are shown in figures 2-7. From the first figure, figure 2, it is apparent that there is a large number of these spurious 000 hits for this side. The figure also suggests that approximately 11,500 entries have migrated from bin four to bin zero. The second set of plots, figures 3-6, seem to suggest that not one strip or chip appears to be problematic. This can be seen from the uniformity of these distributions. It appears that the whole side of the module is bad. Finally, figure 7 shows the number of 000 and x1x hits and their variation in time. From the flatness of these distributions one can say that there was no visible correlation with time.

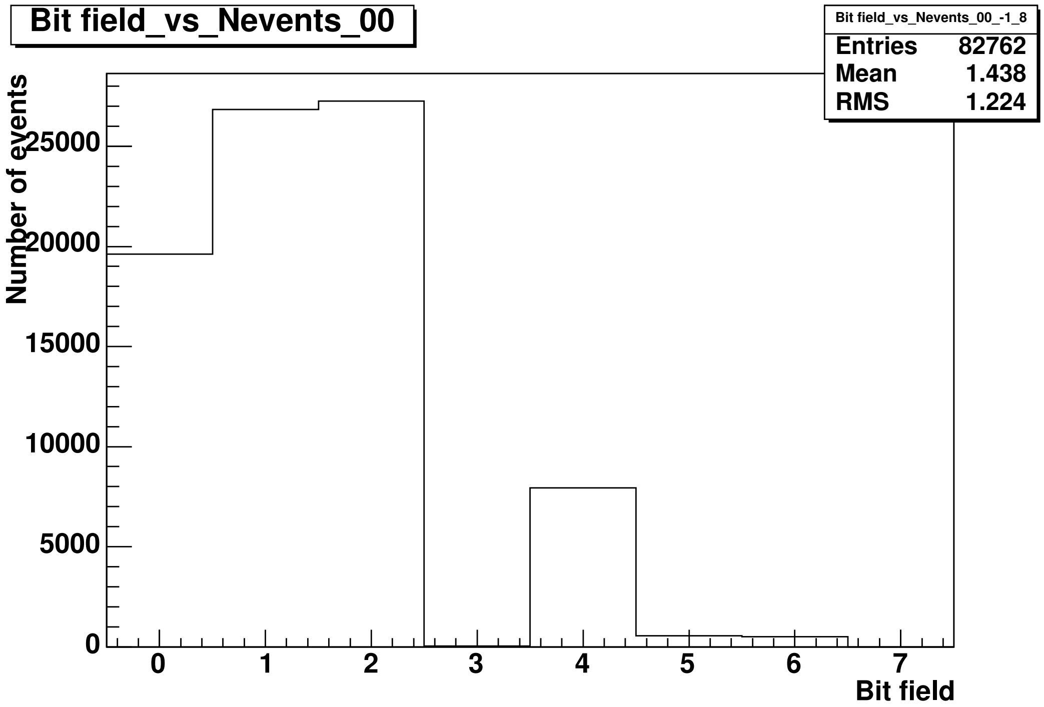

Figure 2: Distribution of the bit field value versus number of events with hits in the zeroth time bin for the side (layer=0, side=0, η=-1, ϕ=8). Side 1 was also similar.

2.2 Side of the module with layer=2, side=1, η=-2, ϕ=6

Figures 8-13 show the relevant distributions for this side. From figure 8 it, again, shows that there are a large number of these spurious 000 hits for this side and that there have been apparent migration of entries from bins one, two and four to bin zero. However, closer inspection of the same distribution as in figure 8 but for the other side of this module suggests that it is not migration but rather there is just a large excess of these spurious 000 values. As can be seen from figures 9 all of the 000 hits occurred on channel number 623. This channel was identified as residing on chip number four. It should also be mentioned that there exists a noisy channel for the case of x1x hits, but this is a different channel to the one causing the spurious 000 hits shown in figure 9. This then also warranted further investigation. So by plotting the distributions of the number of

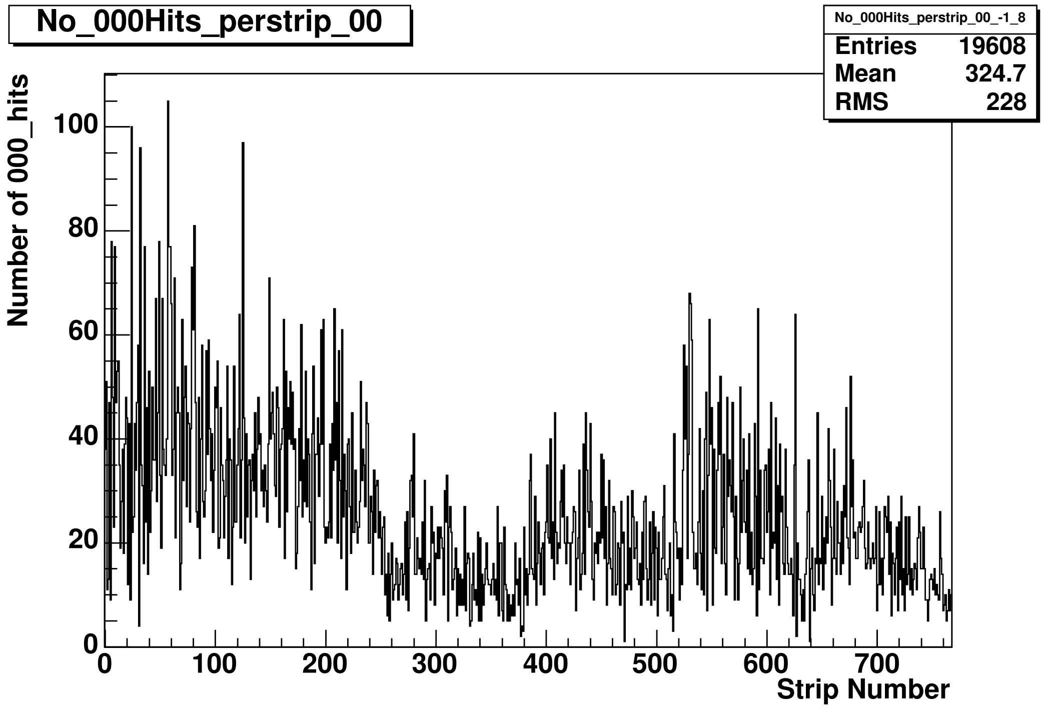

Figure 3: Distribution showing the number of 000 hits and it's variation with channel for the side (layer=0, side=0, η=-1, ϕ=8). Side 1 was also similar.

1xx and xx1 hits and how these varied per strip (channel) it emerged that there seems to be one (the same one) noisy channel in each of the three time bins, identified as channel number 599. A possible cause for this can be drawn from the apparent strong correlation between the bunch crossing ID (BCID) and the three time bins. In fact it was found that the hits on this channel in a time bin were always separated by an integer number of twelve BCID's: with BCID%12=5 for time bin -1, BCID%12=6 for time bin 0 and BCID%12=7 for time bin +1. This suggests a stuck cell in the chip pipeline register. Lastly, as was the case for the previous side, there appears to be no correlation with time as can be seen in figure 13.

2.3 Side of the module with layer=3, side=1, η=-3, ϕ=11

The third and final side appeared to have a much smaller number of entries in bin 0 (see figure 14) compared to the previous two sides, which identifies this zeroth time bin anomaly. From looking at the distributions of the number of hits and how this varies with chip and strip (figures 15-18) it is apparent that although there was a large number of bad channels discovered they were all found to be from the same chip, chip number five. Although, again, as was the case for the previous side, a noisy channel, channel number

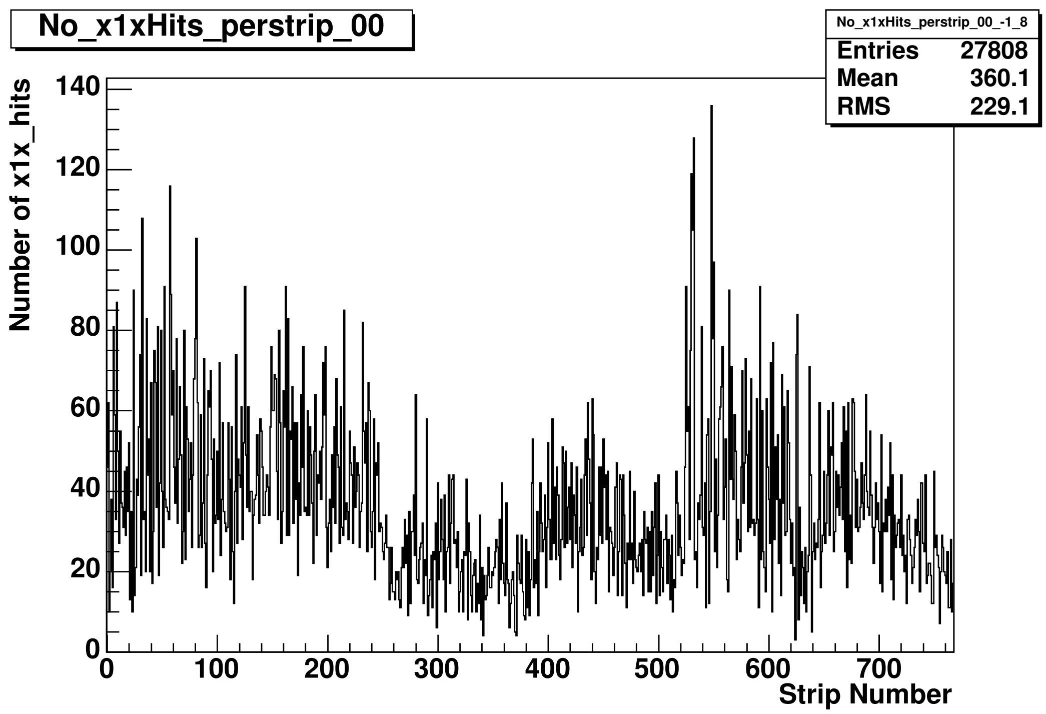

Figure 4: Distribution showing the number of x1x hits and it's variation with channel for the side (layer=0, side=0, η=-1, ϕ=8). Side 1 was also similar.

727, is clearly visible in figure 16. This then warranted the distributions of the number of 1xx and xx1 hits and how these varied per strip to be plotted. The results of these plots show that there are no noisy channels in either case (for 1xx and xx1 hits). So for this side it is apparent that there is one noisy channel in only one of the time bins, the central time bin. It was also noted that for this channel 727, there existed a strong correlation between the Lv1 ID of the noise hits on the strip and the trigger number. It was found that the Lv1 ID registered hits every eight events or for every eighth trigger. This suggests an error in the ABCD chip readout buffer. And finally figure 19 shows that there was no correlation of the number of hits (000 and x1x) with time for this particular side.

3 Conclusion

From the work presented in this report it was apparent that there were three distinct classes of modules/sides each one corresponding to three different types of problems which had caused this zeroth time bin anomaly. The first class, e.g. side (layer=0, side=$\{0,1\}$, $\eta = -1 \rightarrow -6$, ϕ=8) under study was problematic. There was no channel or chip that

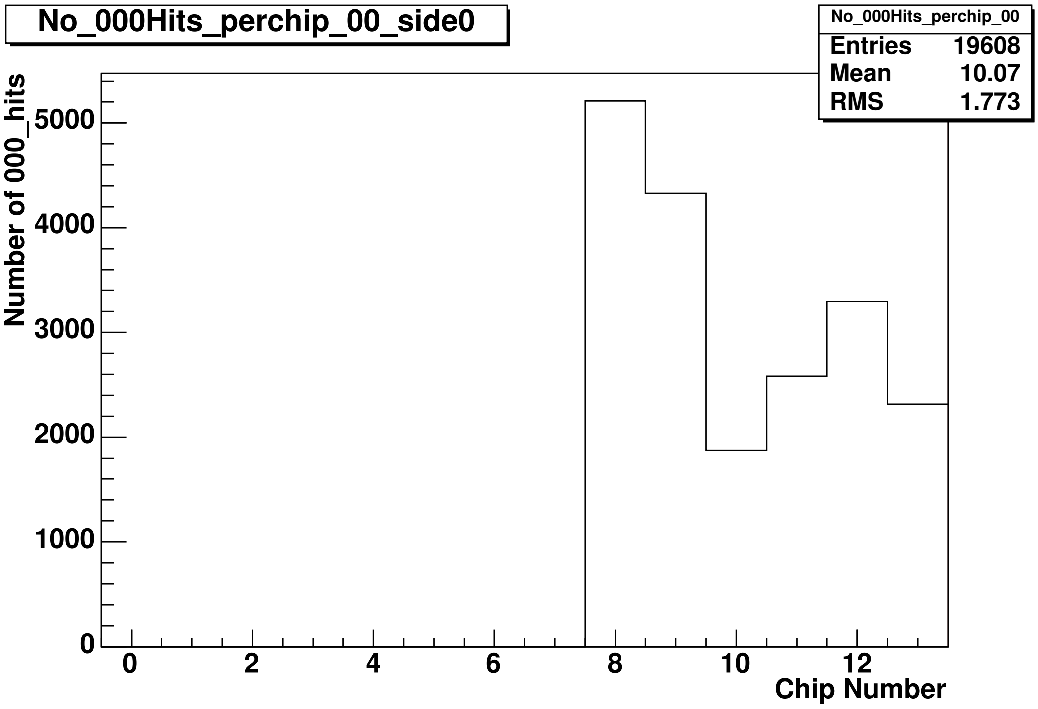

Figure 5: Distribution showing the number of 000 hits and it's variation with chip for the side (layer=0, side=0, η=-1, ϕ=8). Side 1 was also similar.

was singled out as the cause for the anomaly which affected all six modules all of which were attached to the same harness. Normally twelve modules are served by the same SCT BOC TX plugin. However, for this data run the other six modules on this TX were not active and so as a result these six modules were the only ones served by the both a single RX and TX plugin. Since this TX plugin had poor mark-space behaviour, it is possible that the problem may be associated with a high-jitter clock. But alternative explainations might be a problem with the RX or the ROD event decoding.

On side (layer=2, side=1, η=-2, ϕ=6) all the 000 hits occurred on channel number 623. A possible solution might be to mask off this channel. It's also interesting that this chip suffered from a stuck pipeline cell.

The third and final side (layer=3, side=1, η=-3, ϕ=11) had a bad chip (chip number 5) on which 000 hits occurred. Again this chip had another defect - in this case a defect associated with the ABCD readout buffer.

Finally, it was also apparent that there was no correlation with time for both cases of 000 and x1x hits and there also seems to be no ABCD chip errors that were flagged in any of the events under study.

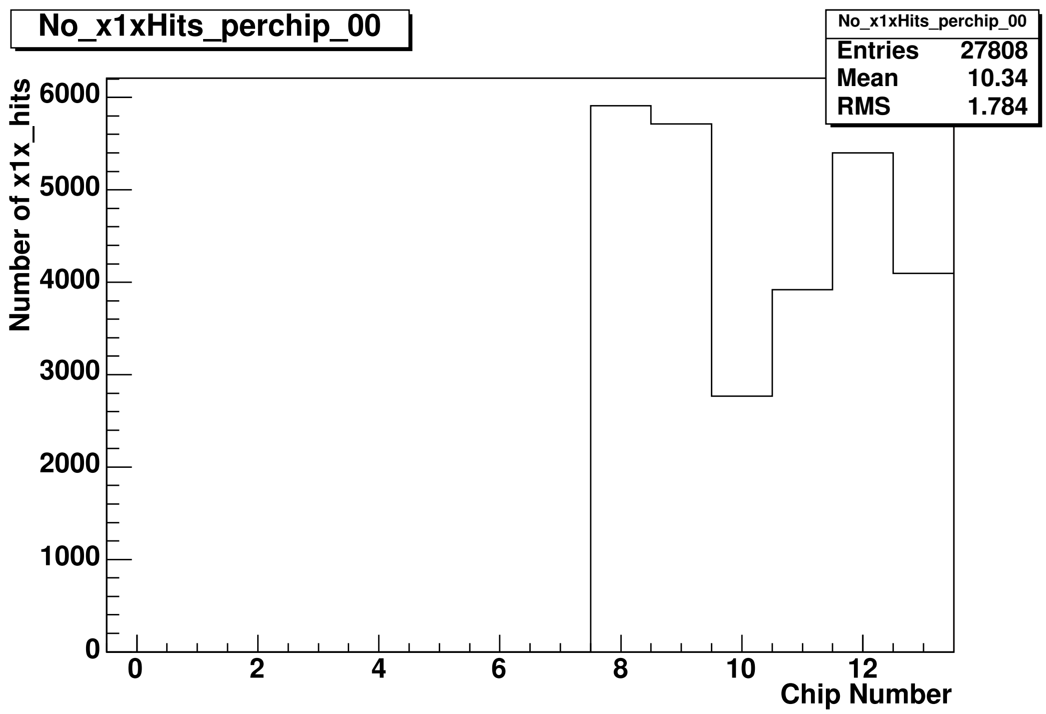

Figure 6: Distribution showing the number of x1x hits and it's variation with chip for the side (layer=0, side=0, η=-1, ϕ=8). Side 1 was also similar.

4 Acknowledgments

We would like to thank Bilge Demirkoz, Bruce Gallop, Chris Lester, Peter Phillips, Dave Robinson, Tony Weidberg and Martin White for their useful and insightful comments.

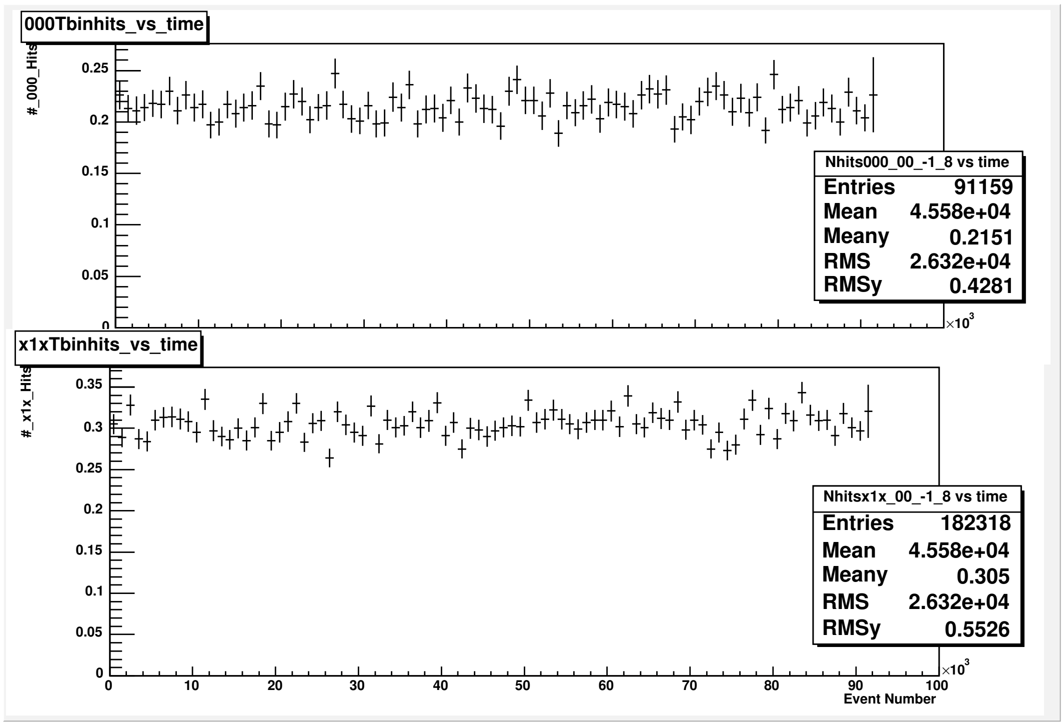

Figure 7: Distributions of the number of 000 (top) and x1x (bottom) hits and their variation in time (event number) for the side (layer=0, side=0, η=-1, ϕ=8).

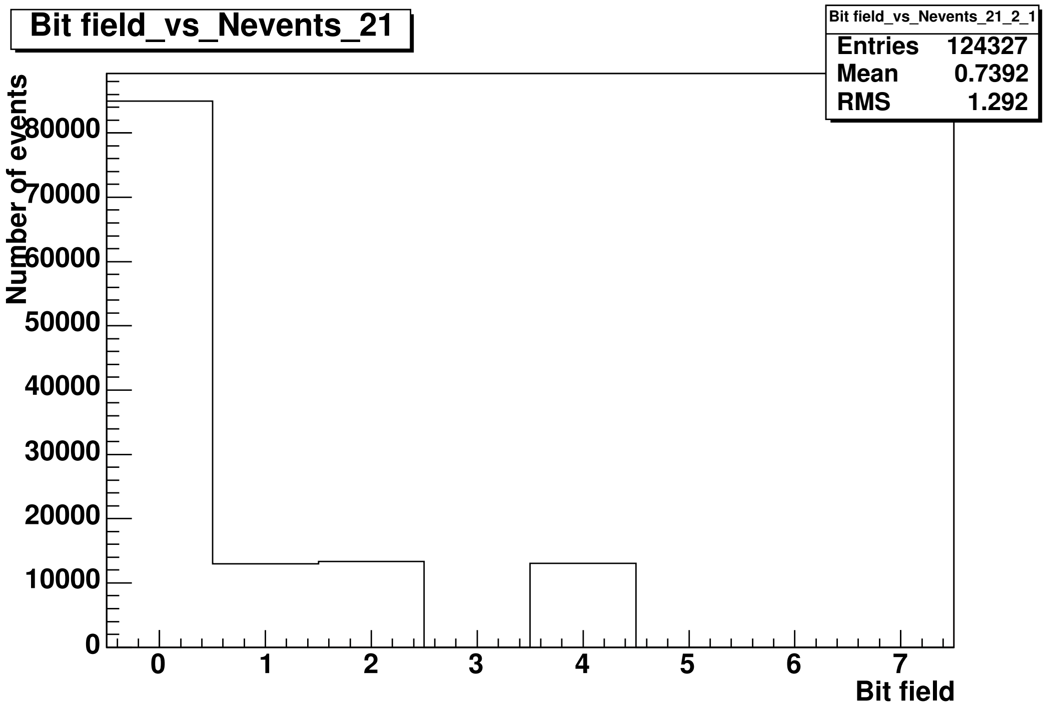

Figure 8: Distribution of the bit field value versus number of events with hits in the zeroth time bin for the side (layer=2, side=1, η=-2, ϕ=6).

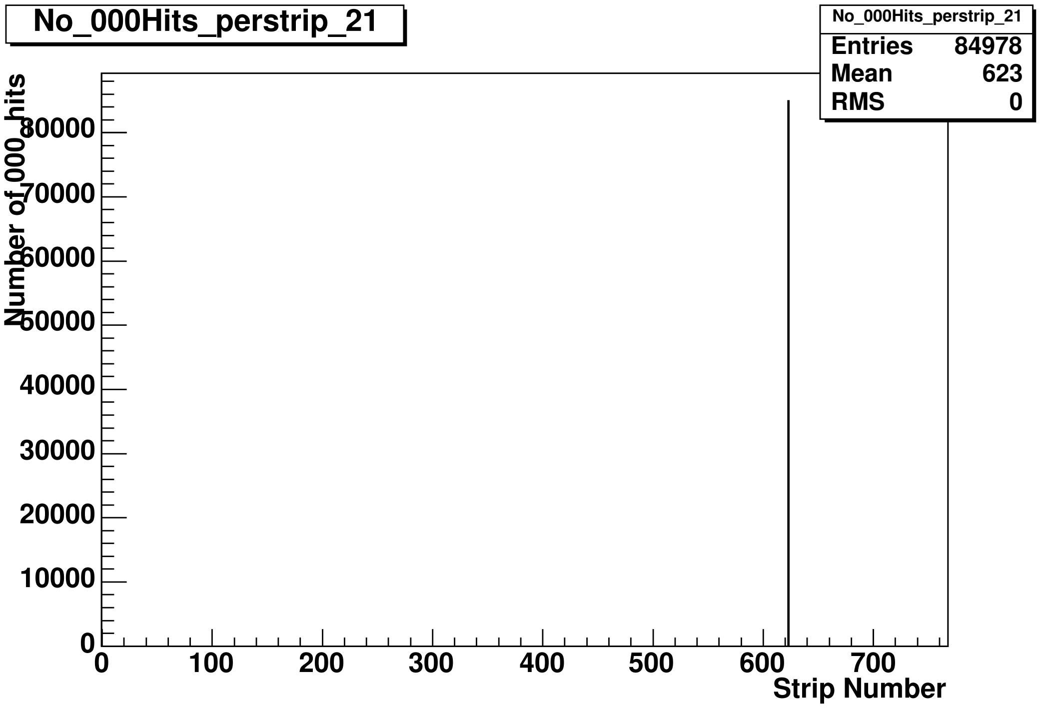

Figure 9: Distribution showing the number of 000 hits and it's variation with channel for the side (layer=2, side=1, η=-2, ϕ=6).

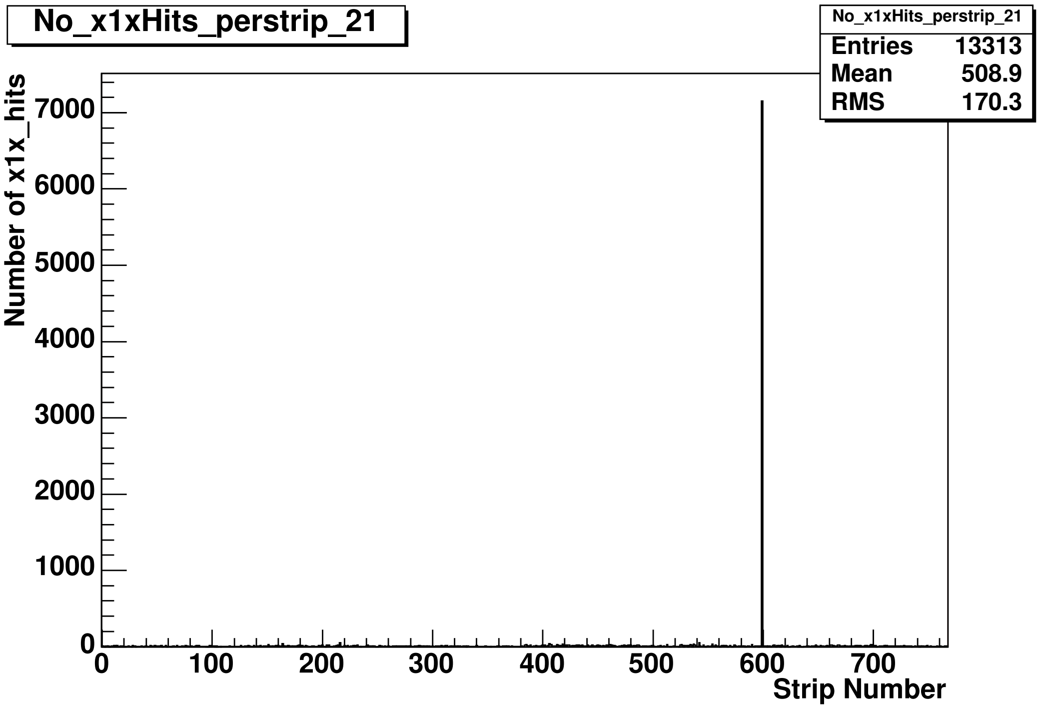

Figure 10: Distribution showing the number of x1x hits and it's variation with channel for the side (layer=2, side=1, η=-2, ϕ=6).

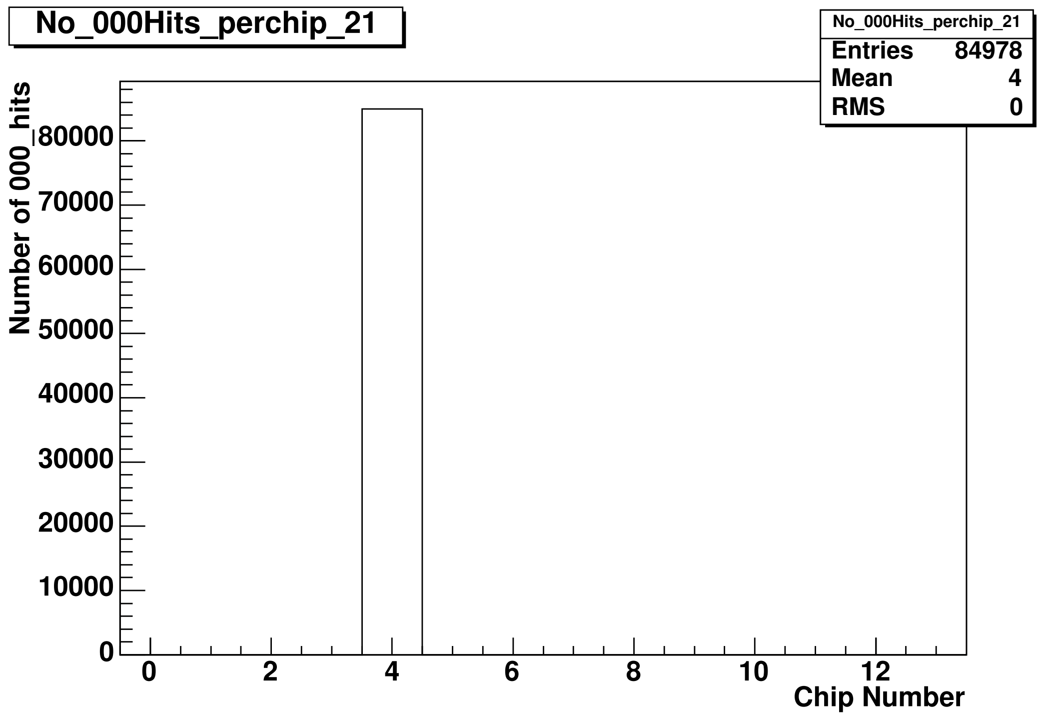

Figure 11: Distribution showing the number of 000 hits and it's variation with chip for the side (layer=2, side=1, η=-2, ϕ=6).

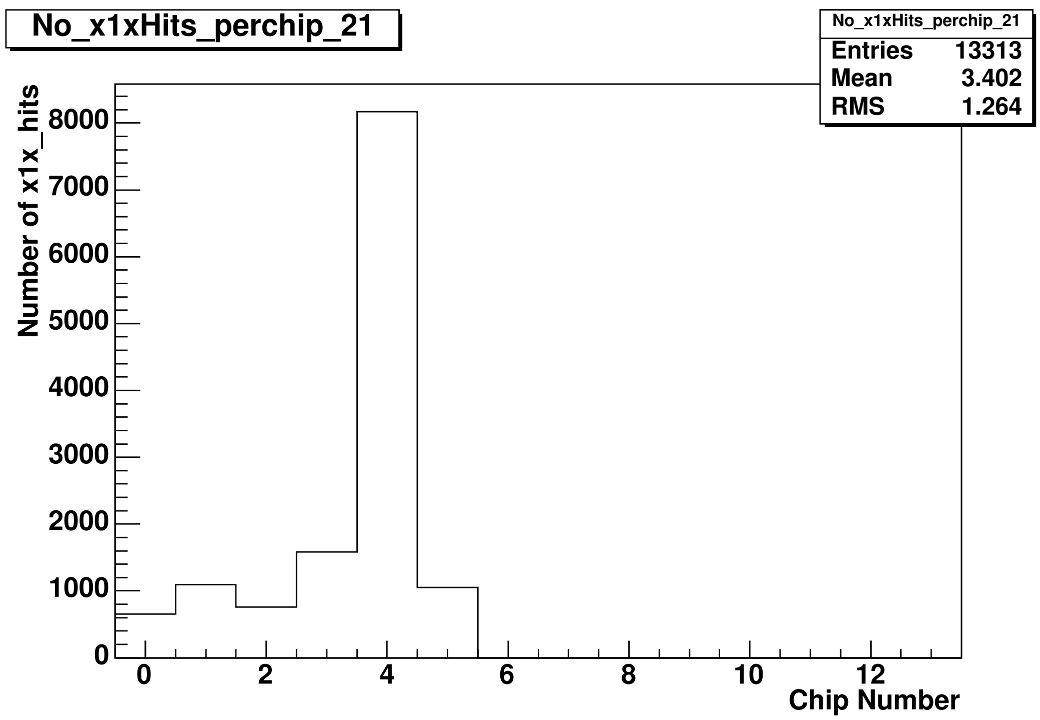

Figure 12: Distribution showing the number of x1x hits and it's variation with chip for the side (layer=2, side=1, η=-2, ϕ=6).

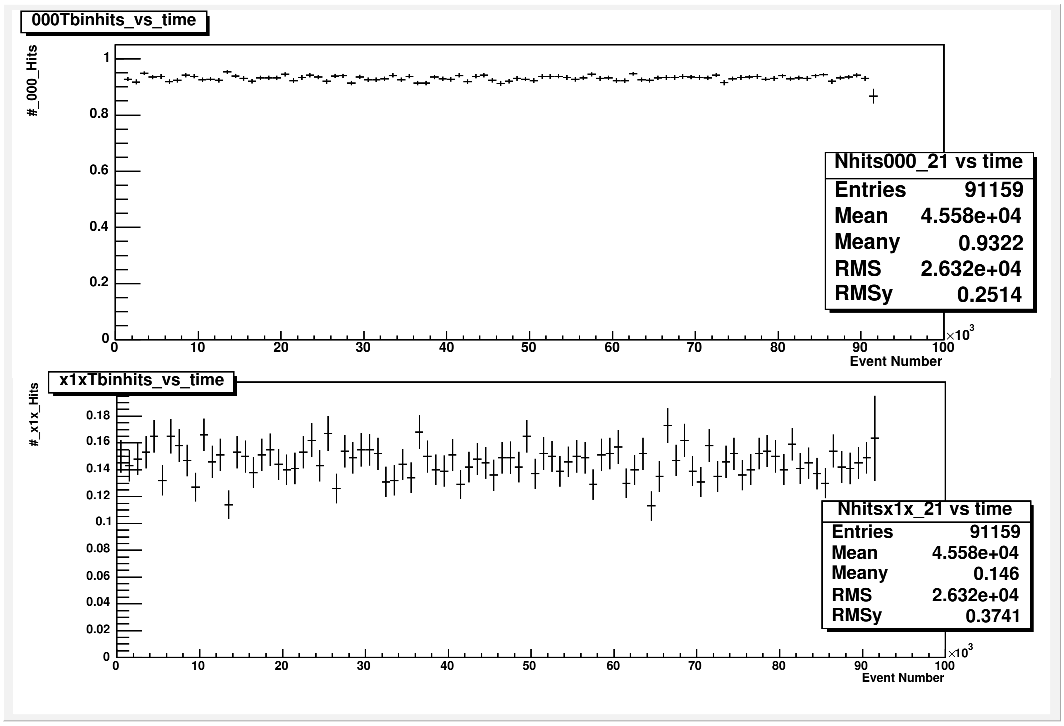

Figure 13: Distributions of the number of 000 (top) and x1x (bottom) hits and their variation in time (event number) for the side (layer=2, side=1, η=-2, ϕ=6).

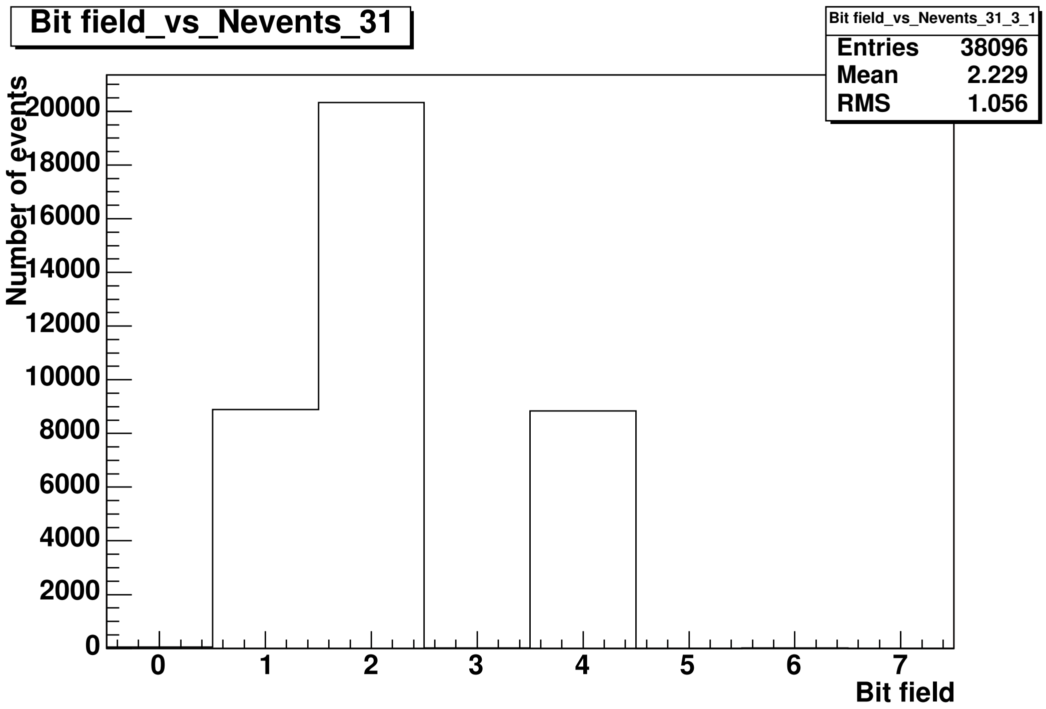

Figure 14: Distribution of the bit field value versus number of events with hits in the zeroth time bin for the side (layer=3, side=1, η=-3, ϕ=11).

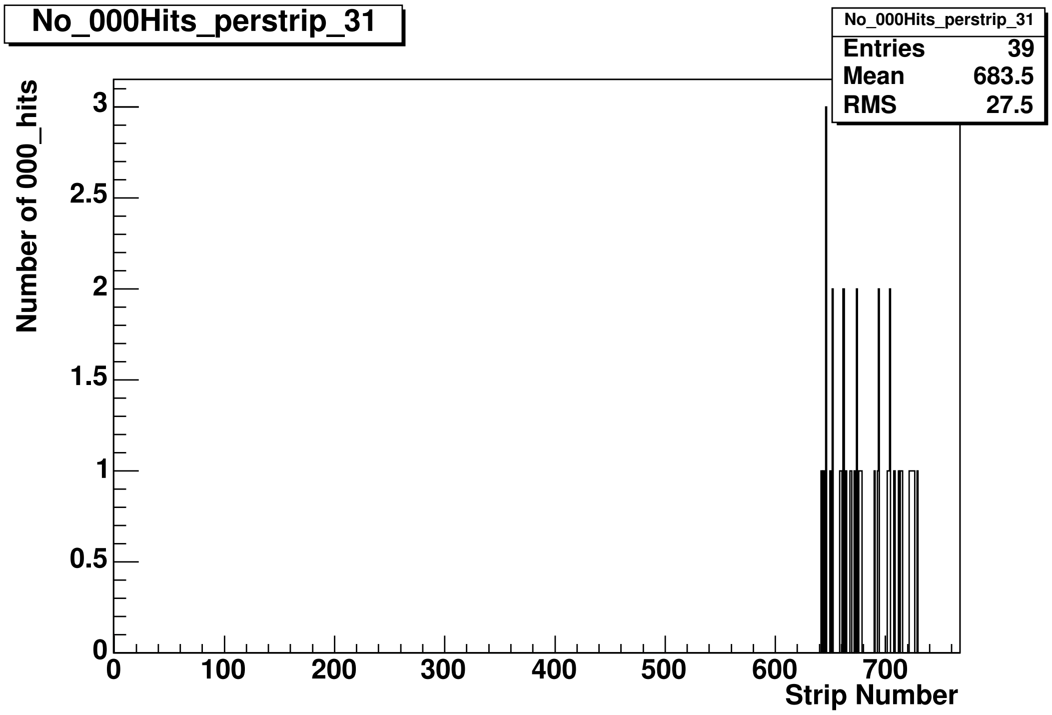

Figure 15: Distribution showing the number of 000 hits and it's variation with channel for the side (layer=3, side=1, η=-3, ϕ=11).

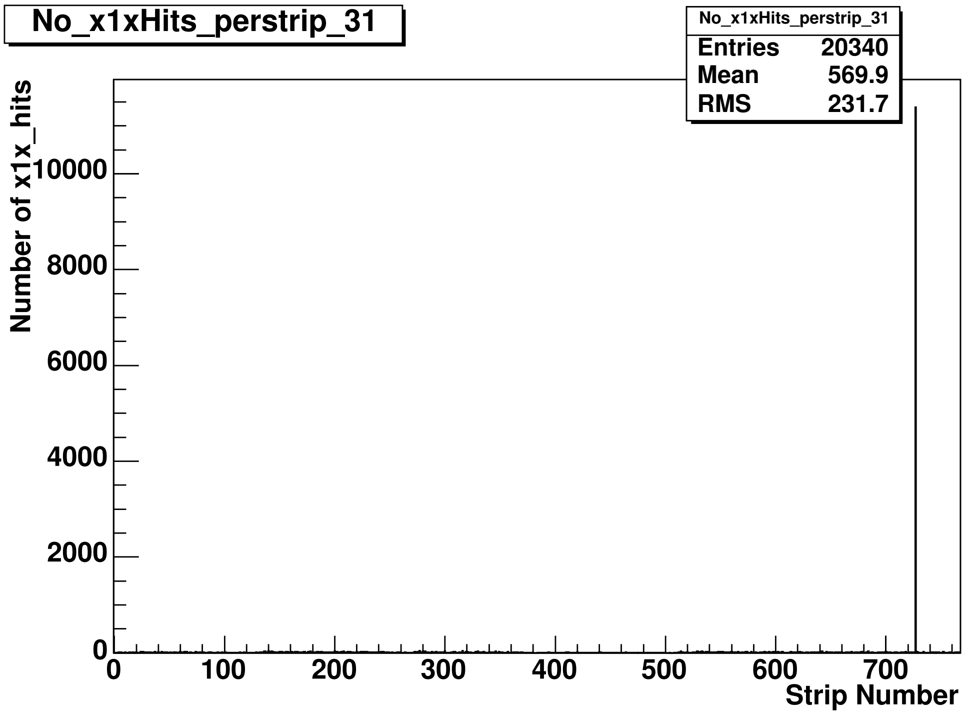

Figure 16: Distribution showing the number of x1x hits and it's variation with channel for the side (layer=3, side=1, η=-3, ϕ=11).

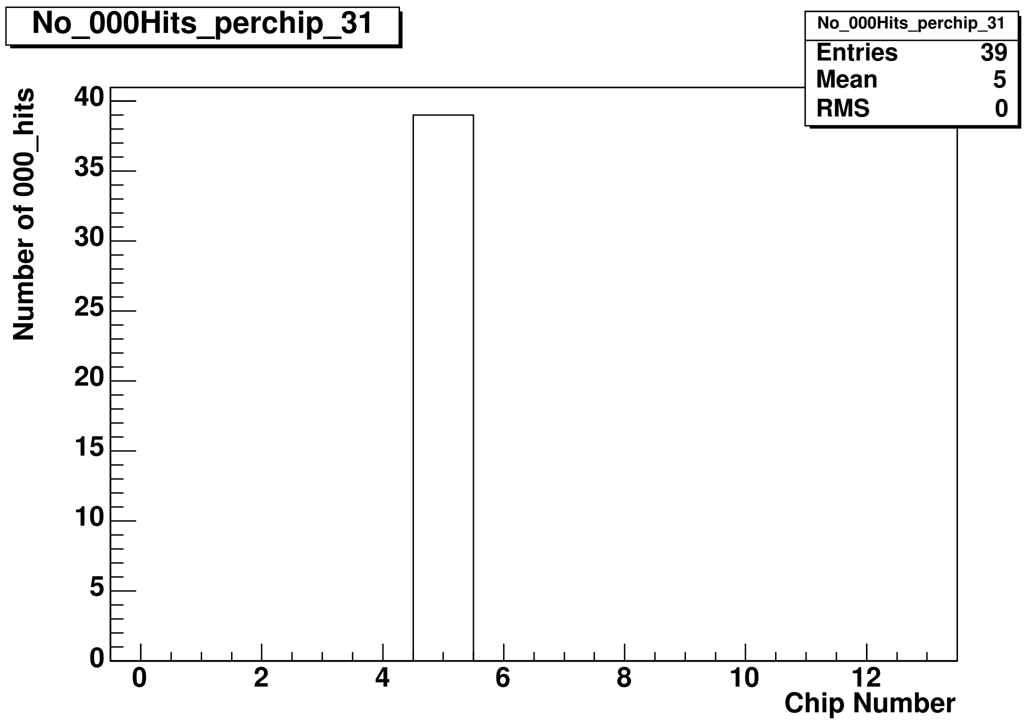

Figure 17: Distribution showing the number of 000 hits and it's variation with chip for the side (layer=3, side=1, η=-3, ϕ=11).

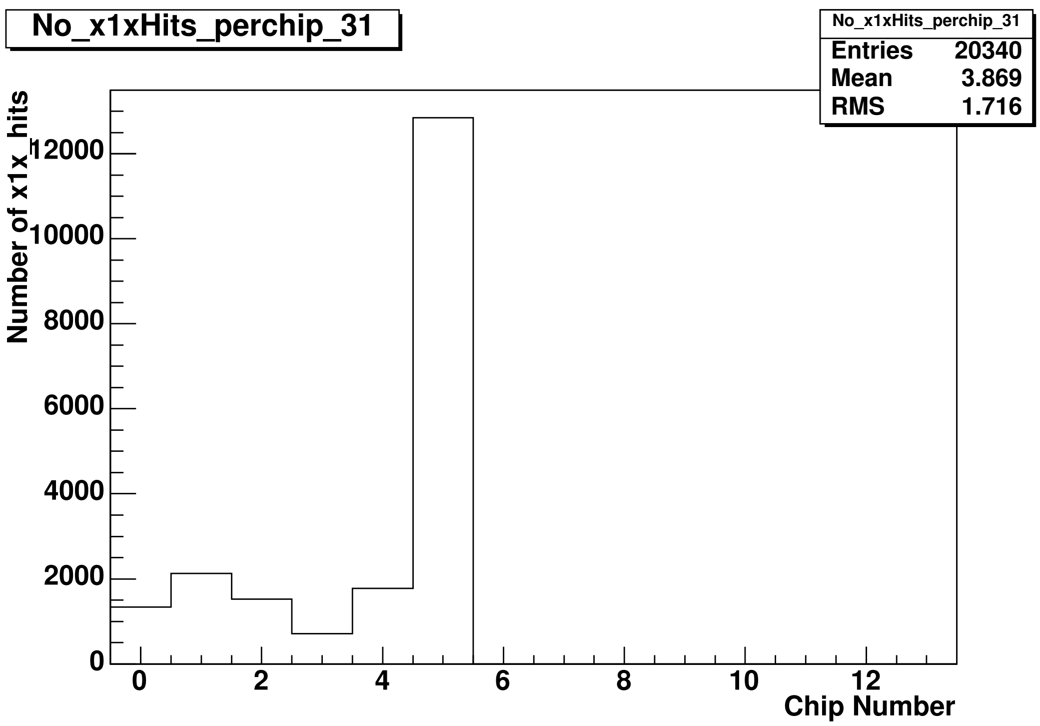

Figure 18: Distribution showing the number of x1x hits and it's variation with chip for the side (layer=3, side=1, η=-3, ϕ=11).

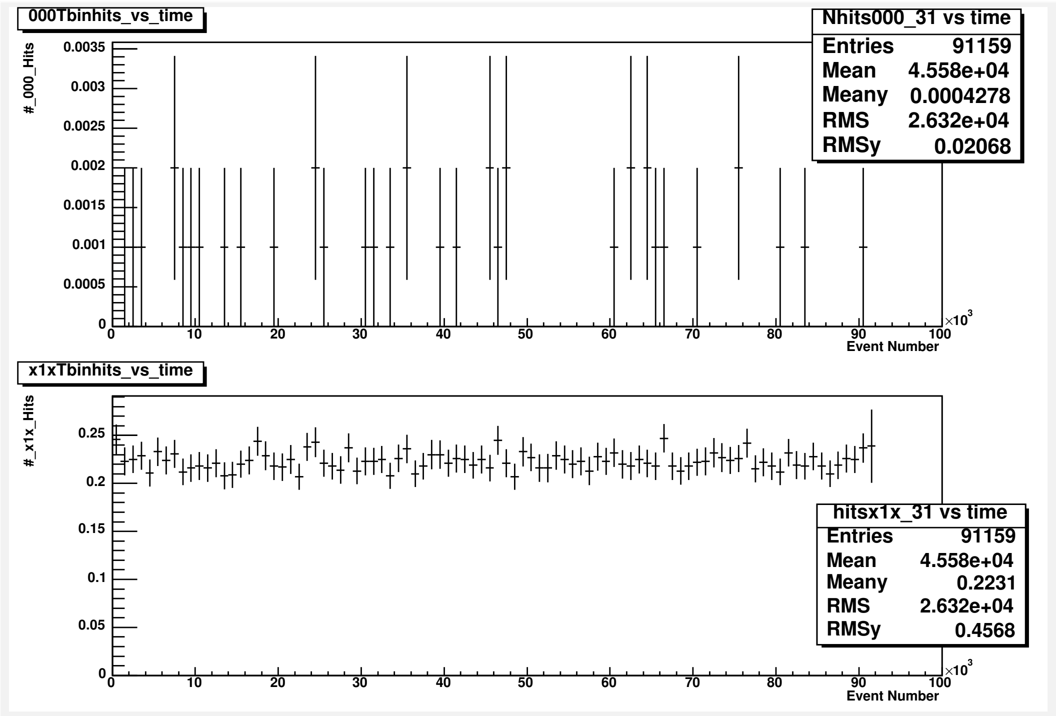

Figure 19: Distributions of the number of 000 (top) and x1x (bottom) hits and their variation in time (event number) for the side (layer=3, side=1, η=-3, ϕ=11).