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Occupancy in SVX-II

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1 Introduction

We report estimates of the occupancy in SVX-II. We compare SVX$'$ Monte Carlo and data occupancies and find that the Pythia min-bias generator underpredicts the physics occupancy by a factor of two. We find that a $\pi\pi$ trigger increases the occupancy significantly. We compare with other collaborator's estimates [1]. We tune the Pythia generator to agree with the data to make final occupancy estimates.

2 Monte Carlo

We start by using the Pythia generator for min-bias with the following talk-to:

```
pythia_parameter
     mstp 131 1                 ! pile up set on
     mstp 132 1                 ! low pt processes (high pt implicitly)
     mstp 133 1                 ! minb event + pile up
     parp 131 .054              ! minb pile-up rate
```

PARP(131) is a number measured in mb^{-1} and it implies the pile-up rate for interactions, PARP(131)= N/σ, where N is the mean number of interactions and σ is the min-bias cross section, 50mb. The value .054 is appropriate for $L = 1 \times 10^{32}$, 396ns intervals which has 2.7 min-bias in each event.

The P_t cutoff is set to 20MeV, lowering it does not significantly affect the occupancy [2]. Particle decays, bremsstrahlung, and conversions are turned on but secondary hadronic interactions are turned off. We use a z distribution with RMS of 30cm. The SVX' Monte Carlo is run with both the old cluster simulation, and the new cluster simulation [3]. The SVX-II Monte Carlo [4] only has a cluster simulation similar to the old SVX' simulation.

3 Comparison of SVX' and Monte Carlo

We have looked at 1B min-bias data from runs 62000, with average luminosity around 5×10^{30}, and 65700 with luminosity around 8×10^{30}. Figure 1 shows the occupancy distributions of data compared to Monte Carlo. The occupancies are determined by counting up the number of strips in clusters with no bad strips. This should be a good measure of real physics occupancy, or at least the occupancy that will be the input to the SVT and tracking. The figure shows the distributions for both the average layer 0 ladder and the layer 0 ladder on the most occupied wedge in the event. The agreement is very good except for 1-2% of the tail in the data.

However, the number of pile-up min-bias events expected in these data and Monte Carlo samples are not equivalent, the data has an average of 1.8 and the Monte Carlo 2.7. Figure 2 shows the average layer 0 physics occupancy plotted *vs* the number of min-bias expected per event. The data is taken with a BBC trigger and the Monte Carlo has essentially the same condition (it doesn't consider empty crossings). Therefore both the conversion of luminosity (data) and the number of min-bias requested (MC) to the number of min-bias expected in the file needs the factor $N/(1-e^{-N})$ to correct for the suppression of empty events.

The figure shows a striking difference between the data and the Monte Carlo. The ratio of the slopes of the two lines in the figure is 2.2. At this point we do not know the cause of the difference. The fact that the data is along a line with an intercept of zero implies that the additional occupancy is physics or at least a source of noise proportional to the physics. In [3], section 5, it is shown that approximately 80-90% of clusters in 1B jet data are used on tracks, which adds weight to the argument that occupancy is physics dominated.

Figure 3, suggested by Paul Shepard, shows the occupancy plotted *vs* the number of strips in the detector layer. We expect that physics occupancy will be essentially flat in this plot (a track leaves one hit in every layer) while pure noise will be proportional to the number of strips. The Monte Carlo, which has no noise, shows a 30% downward slope probably due to particles that exit the detector volume. The data slope is only very slightly different, indicating it is dominated by physics occupancy.

Plotting the number of clusters instead the number of strips *vs* luminosity yields a ratio of slopes of 1.8. Another similar plot using only the number of strips with charge over 48 counts ($\approx 4\sigma$) yields a ratio of slopes of 2.2. We find the the Monte Carlo is also producing 2.4 times fewer CTC tracks per min bias event than the data. We conclude that the generator is producing occupancy at a rate about 2 times less than real life. Ideally we should be able to tune the generator and below we will attempt to do this.

The Monte Carlo for this test was run with the improved cluster simulation but the SVX-II Monte Carlo does not have this option yet. To see the effect of using the old cluster simulation, we ran the SVX$'$ Monte Carlo with old and new clusters. We find the new simulation produces 13% more occupancy than the old simulation.

3.1 Level 1 Trigger Effect

The SVT will not be seeing min-bias events, but events that pass the L1 requirements. We can estimate the effect of this using the 1B data. Since the $\pi\pi$ trigger will be a considerable part of the L1 bandwidth, we will use it to simulate L1. We count the number of tracks with $P_t > 2$ that have hits on superlayer 6 or 8 and call 2 or more a trigger. In the data 5% of events pass this requirement, in the Monte Carlo about 3%, with large errors. We expect the Monte Carlo trigger rate to be somewhat lower because we believe it is not producing as many tracks.

Figure 4 shows the average layer 0 occupancy plotted *vs* the number of CTC tracks passing cuts. In the data there is is a clear factor of 2 increase in the average occupancy in going from 0 to 2 tracks. The Monte Carlo needs more statistics but is consistent with the data. We could imagine that the most occupied wedge would feel less of an increase with the trigger, but we find the same factor of 2 for the most occupied wedge.

Requiring 2 or more tracks in the data, we find the occupancy is 1.86 times greater than the average occupancy. We are not sure if this factor is conservative or not. The trigger will include other components which may have lower occupancy, but the actual $\pi\pi$ requirements will be more stringent, tending to increase the occupancy.

4 Tuning Pythia

We modified a tuning suggested by H.Y. Chao. The final tune is shown here. In addition, we turned on secondary interactions and changed the maximum looper turning angle from 5π to 100π.

```
mstp 61  1                ! initial state radiation on
mstp 71  1                ! final state radiation on
mstp  2  2                ! 2nd order running alpha_s
mstp 33  2                ! K factors in x-sec for qq
mstp 82  2                ! structure of pile up
parp 82  .85              ! pt scale, default=1.7
mstp 131 1                ! pile up set on
mstp 132 1                ! low pt processes (high pt implicitly)
mstp 133 1                ! mb event + pile up
parp 131 .054             ! minb pile-up rate
```

We found that all modifications produced very little change in occupancy except for the PARP(82) parameter. The Pythia documentation is unclear to us on what exactly PARP(82) does, but it seems to be a P_t scale, the lower it is the more the P_t is boosted. This makes some more high P_t tracks and many more low P_t tracks. Figure 2 shows the result of this tuning, that it does produce as much occupancy as the data.

We then repeated the trigger effect study. We now find that a tuned Monte Carlo with 2.7 min-bias shows only a factor of 1.25 more occupancy when the $\pi\pi$ trigger is required. It might be expected that a higher luminosty, higher occupancy data set would show less of a trigger effect. The higher the occupancy is on average, the less the trigger jet stands out above all the min-bias occupancy. Table 1 shows the effect. The table also shows there is some residual disagreement.

Sample	Min-bias	Scale	Trigger Rate
data	1.4	2.4	.05
data	1.6	1.9	.05
tuned MC	1.6	1.6	.02
tuned MC	2.7	1.3	.05

Table 1: The $\pi\pi$ trigger effect in data and Monte Carlo. "Min-bias" is the average number of interactions per event. The column labeled "Scale" is the occupancy in events with 2 tracks above 2GeV divided by the average occupancy in all events. "Trigger Rate" is the fraction of events passing the trigger requirement.

5 Computing SVX-II Occupancy

5.1 Comparison with Previous Estimate

We attempted to reproduce the numbers in table 1 from reference [1]. Table 2 in this note compares the result for $r-\phi$ readout of modules 2 and 3 for min-bias events. Since [1] used the untuned Monte Carlo, we also use the untuned Monte Carlo for this comparison. The reference [1] numbers are for 1 min-bias event. We ran with 2.7 and divided our occupancies by 2.7. All other running conditions were the same. Signal-to-noise, defined as the 1-MIP peak (assumed to be 24 counts in SVX-II) divided by the RMS of the pedestal, is set to 16. Nearest neighbors readout (where both strips adjacent to a strip over threshold are read out regardless of their ADC counts) is turned on. The readout threshold is set to 3σ over the pedestal.

We have reasonable agreement although the numbers from this study are about 15% lower.

5.2 Readout Schemes

The current clustering algorithm will make a cluster from three or more adjacent strips if their ADC'S are 2σ over threshold, two adjacent strips if their ADC'S are 2.5σ over threshold, and a lone strip if its ADC is 4σ over threshold.

The obvious way to preserve this algorithm is to set the readout threshold at 2σ. This will cause a 2.3% occupancy just from strips with a pedestal fluctuating

layer	2386	this study
0	1.31	1.12
1	.918	.817
2	.732	.618
3	.660	.567

Table 2: Comparison of the average min-bias occupancies (in %) from reference [1] and this study.

over threshold. If pedestals started shifting relative to each other, the threshold would have to be set at the 2σ point for the average strip. (There is only one threshold for all 128 strips on one chip.) This threshold will be lower than 2σ for some strips and greater than 2σ for others.

The other option is nearest neighbors readout. Here the threshold is set relatively high, probably $3-4\sigma$, and the strips adjacent to each strip over threshold are read out. The assumption is that every real cluster has at least one large pulse height strip and the lower pulse height strips that may be used in the cluster will be in the neighbors. This handles the shifting pedestal problem mentioned above. It has the disadvantage that every noise strip causes 3 strips to be read out. Reference [3] and table 3 from [1] show that the assumption of at least one high pulse height strip is very good.

5.3 Noise Occupancy

First we look at the noise occupancy. Using a simple Gaussian model as in [1], table 3 lists the counts we expect (NN indicates nearest neighbors).

layer	2.5σ	2.5σ, NN	3σ	3σ, NN
0	1.6	4.8	.33	1.0
1	2.4	7.2	.50	1.5
2	4.0	12	.83	2.5
3	4.8	14	1.0	3.0
4	5.6	17	1.2	3.6

Table 3: The number of $r-\phi$ strips read out due to Gaussian noise occupancy.

5.4 Physics Occupancy

Here we will use the SVX-II Monte Carlo with the tuned Pythia generator. We require two tracks above 2GeV as the trigger. Table 4 lists the $r-\phi$ occupancies and figure

5 shows the distribution.

The parameters are: a z distribution of 30cm, 2.7 min-bias, S/N of 16, and a readout threshold of 3σ. We do not expect the physics occupancy to depend strongly on the readout threshold as long as nearest neighbors is used; [1] found only a 3% change in the number of strips readout when the threshold is varied from 2 to 4σ. Nearest neighbors are being read out. If nearest neighbors are not read out (but the threshold is the same), the occupancy is about a factor of two lower.

barrel	layer	$r-\phi$
0,5	0	11
	1	10
	2	9
	3	9
	4	9
1,4	0	14
	1	13
	2	12
	3	11
	4	11
2,3	0	15
	1	14
	2	13
	3	12
	4	11

Table 4: Physics occupancy for SVX-II with nearest neighbors readout and a 2-track trigger requirement. Occupancy is in number of strips.

In addition, we search each event for the the most occupied wedge in the most occupied barrel (search over 72 subdetectors). The average occupancies in the most occupied wedge for layers 0-4 are: 55, 44, 39, 38, and 33. The average occupancy could be characterized as 6% or less, and 20% or less for the most occupied wedge.

In an earlier version of this note we used the untuned Monte Carlo and scaled the result by a factor of 4 to account for the factor of 2 for the generator and another factor of 2 for the trigger. The results presented in this version indicate the scale factor is closer to 3. The current results are about 20-30% lower for the average wedge and about 40% lower for the most ocupied wedge compared to the previous estimate. The difference is the trigger effect discussed above; in a high occupancy environment, the trigger requirement effects the occupancy less.

5.5 A Check Using SVX′ Data

As a quick check of these cluster occupancies we can scale up the occupancy seen in the SVX′. Running SVTSIM, the SVT high-level simulation, produces a distribution of the number of clusters sent to each AM system (one ϕ slice). The data is a recent special run requiring only two CFT tracks as the trigger. The mean number of clusters sent to an AM system is 42 clusters. Since SVX-II coverage is larger than SVX′ coverage, we multiply by 2, yielding 84 clusters, which will be somewhat of an overestimate. The luminosity was a little low during this run with only 1.2 min-bias events expected per crossing. To scale up to 2.7 min-bias we assume the additional min-bias contibute only about 75% of what the 2-track trigger event contributes.

This results in an estimate of 136 clusters per AM system on average. This can be compared to the tuned Monte Carlo used above which produces 80 clusters per AM system on average. While we know we are overestimating the projection from the data, this result tends to confirm that the occupancies given above are realistic, but possibly still underestimated.

5.6 Outstanding Questions

The real trigger table may cause an L1 occupancy that is significantly different than assumed here. If the occupancy is larger than we expect, can we run without nearest neighbors? What would that do to offline cluster resolution?

What will be the occupancy due to hot channels? In SVX′ there are less than a percent hot channels, what can we expect for SVX-II? Is it part of the specifications?

What occupancy can be expected from cross-talk? Do we expect any noise from hits in the previous or following crossing?

What are the failure modes of the pedestals? What channel-to-channel variation can be expected in the means and widths of the pedestals? Will this change with age? How can it be handled, and with what impact on cluster resolution?

References

[1] Hsaio Ying Chao and Jaroslav Antos *Occupancy Study for the SVXII* CDF note 2386, Nov 21, 1994.

[2] H.Y. Chao.

[3] H.Y. Chao *et al* *The SVX' Monte Carlo Simulation* CDF note 2946, Feb 1, 1995.

[4] Jaroslav Antos, G.P. Yeh, and Ping Yeh *Implementation of SVX-II into CDFSIM* CDF note 2383, Nov 21, 1994.

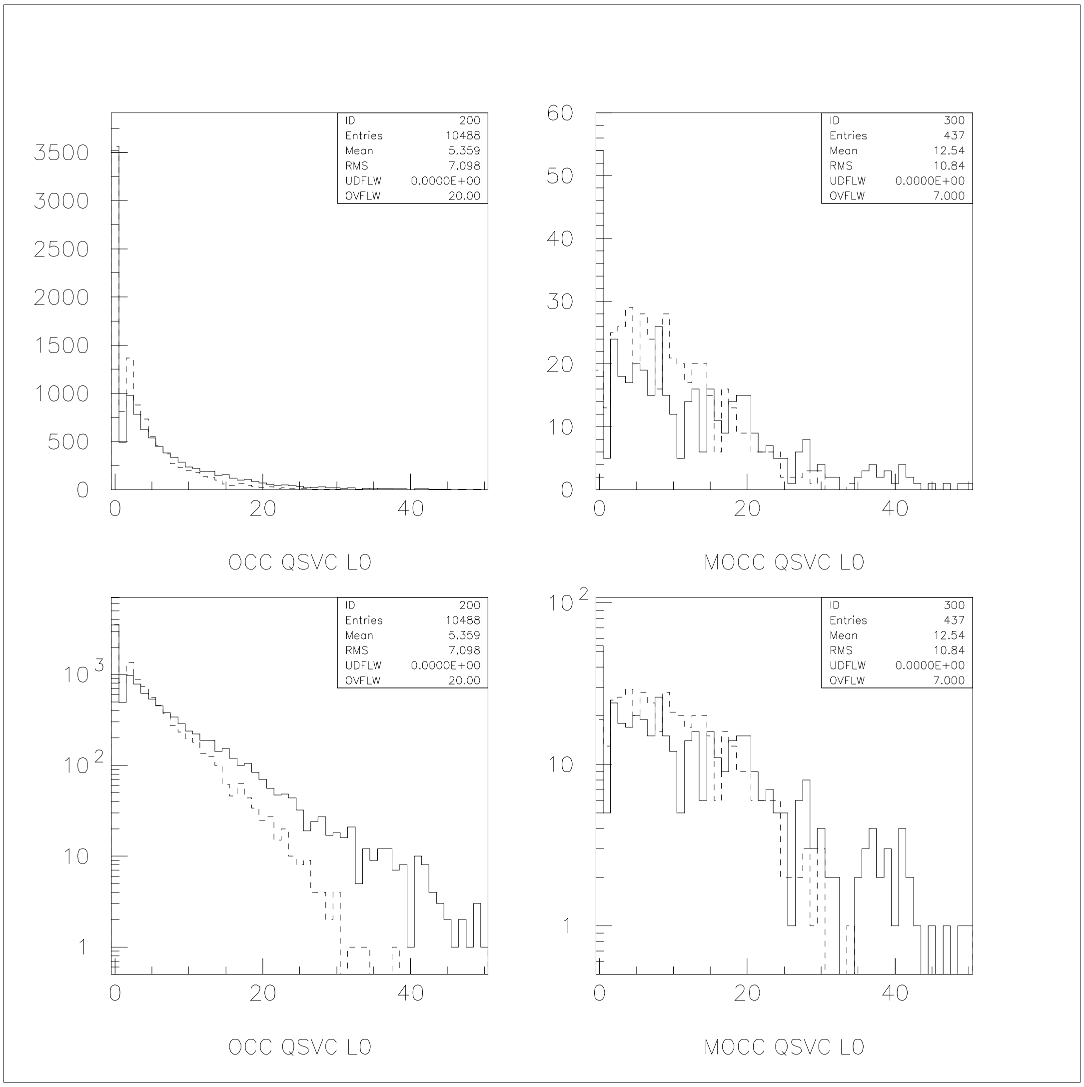

Figure 1: Physics occupancies for layer zero in data (solid) and Monte Carlo (dashed). Upper left is for the average wedge, upper right is the most occupied wedge, the lower histograms are the same as the upper but with a log scale.

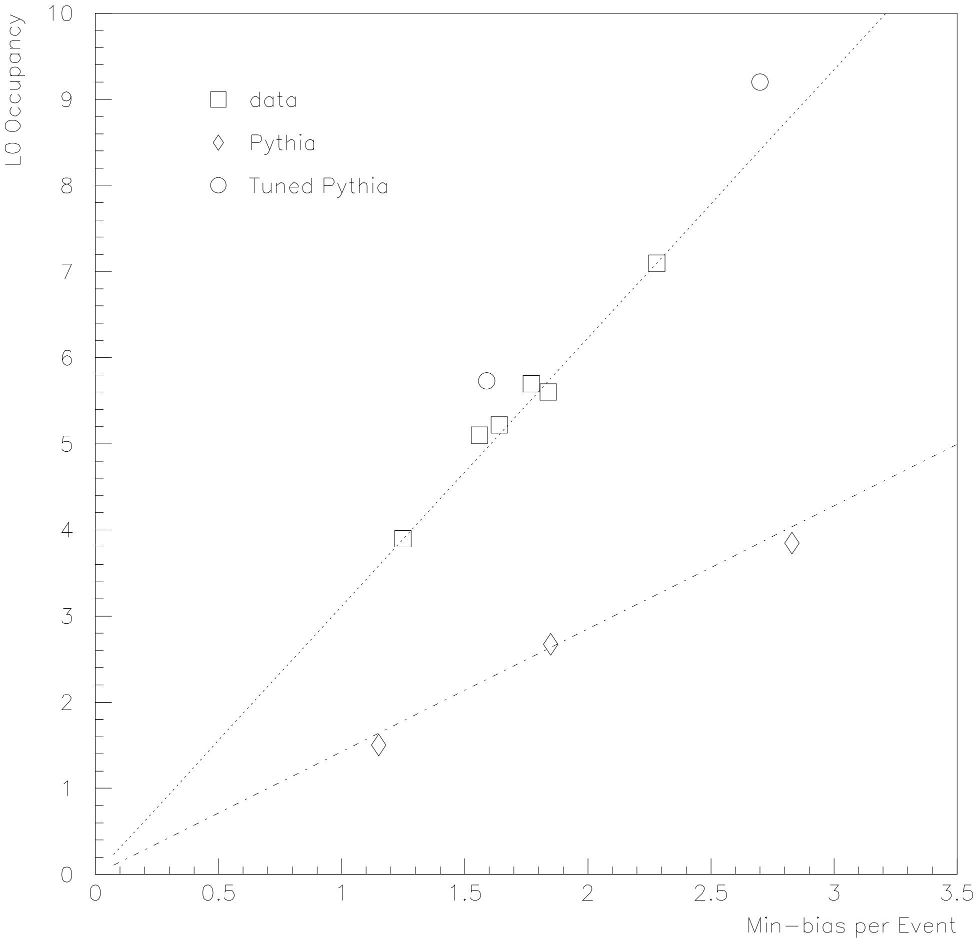

Figure 2: Occupancy *vs* the number of min-bias events expected in min-bias data (squares), Pythia (diamonds), tuned Pythia (circles). All points have been corrected for the BBC trigger.

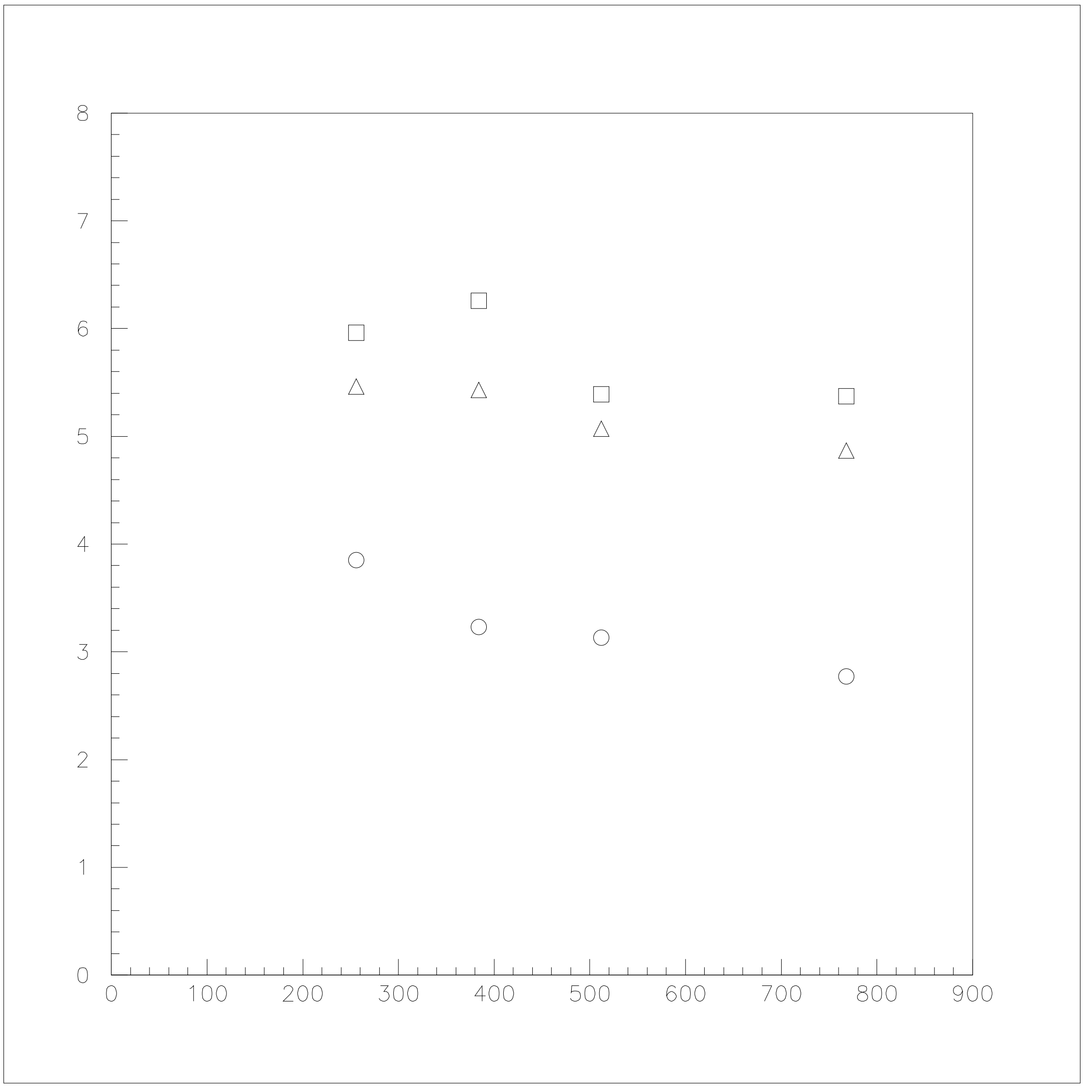

Figure 3: Occupancy *vs* the number of strips in the detector layer. The circles are the Monte Carlo and the squares and diamonds are two different data samples. We expect physics occupancy to be approximately flat in the plot while random noise should be proportional to the number of strips.

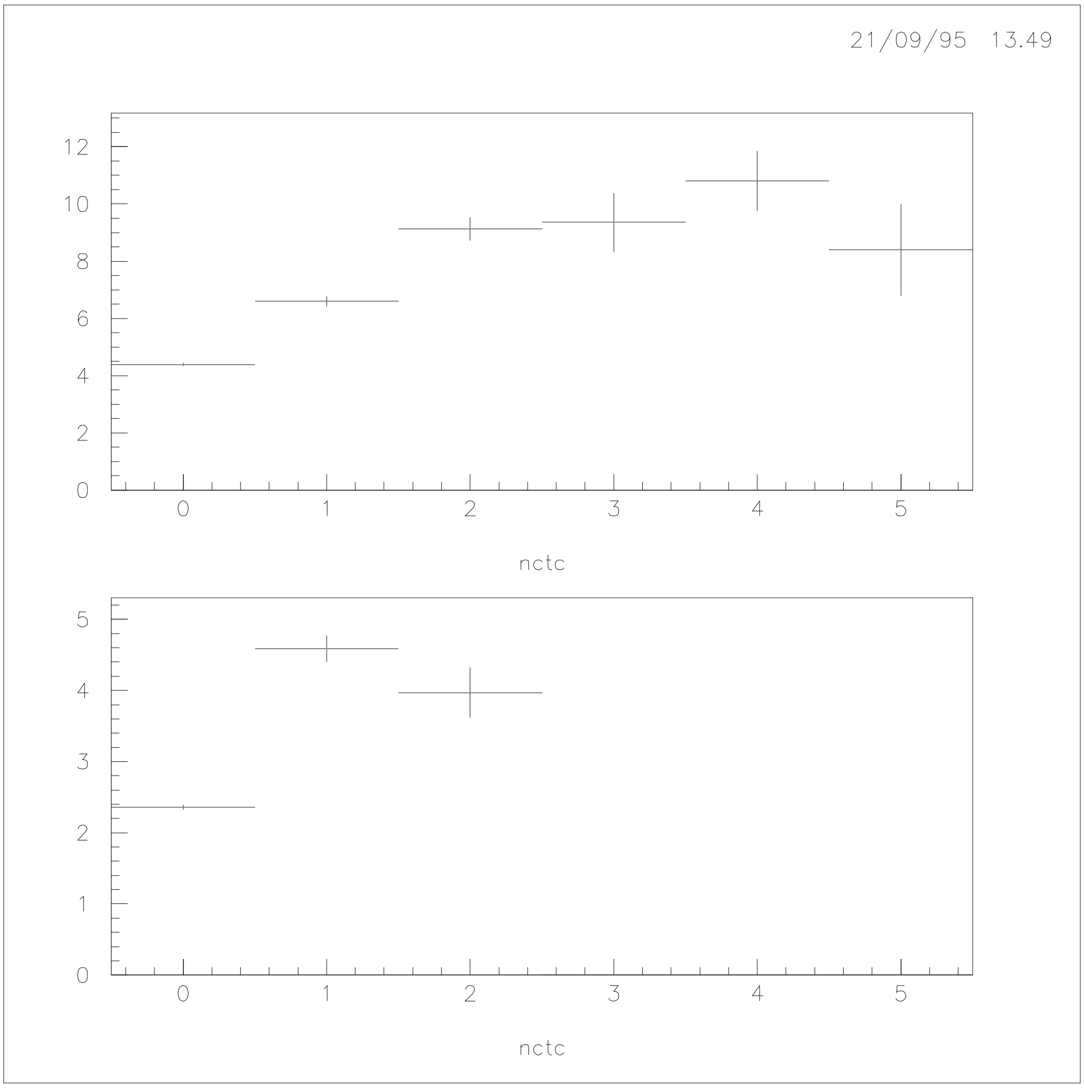

Figure 4: The average layer 0 occupancy plotted *vs* the number of CTC tracks with $P_t > 2$ and hits in SL 6 or 8. The upper is data and the lower is Monte Carlo.

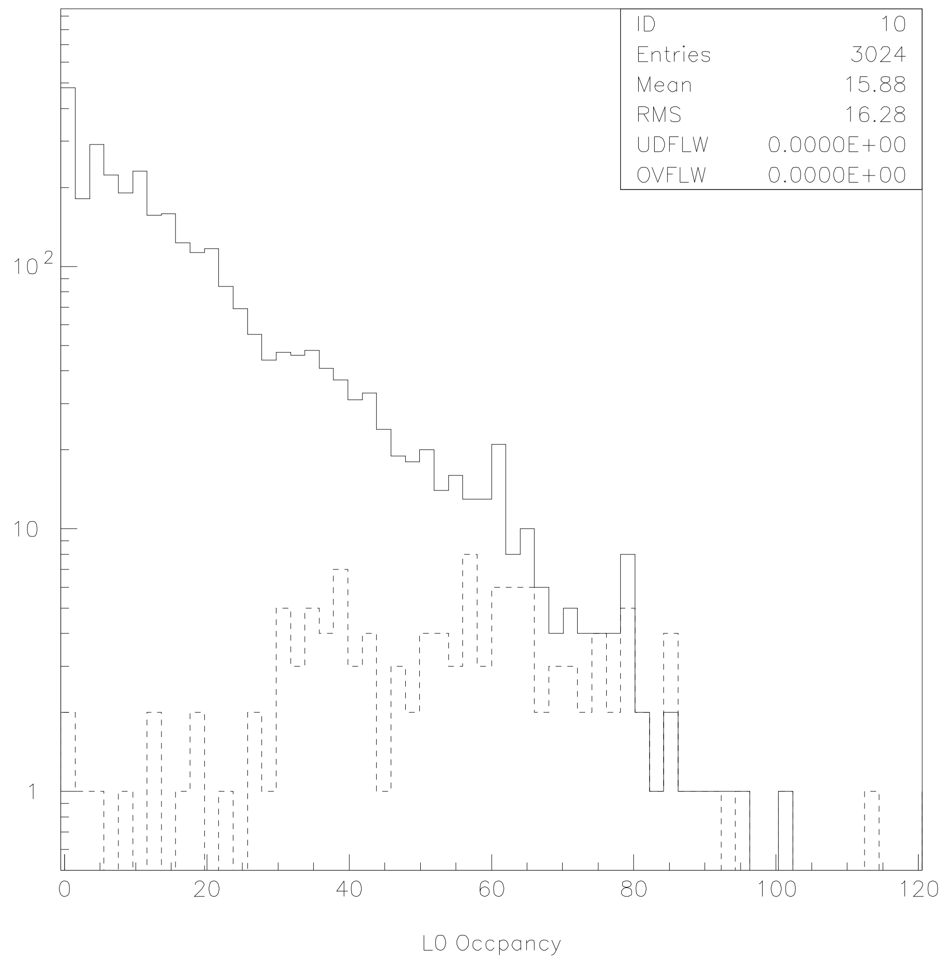

Figure 5: The distribution of layer 0 occupancy for the average wedge on barrel 2 or 3 (solid) and the most occupied wedge (dashed). The data is tuned Pythia Monte Carlo with a 2-track trigger requirement.