Disclaimer

This note has not been internally reviewed by the DØ Collaboration. Results or plots contained in this note were only intended for internal documentation by the authors of the note and they are not approved as scientific results by either the authors or the DØ Collaboration. All approved scientific results of the DØ Collaboration have been published as internally reviewed Conference Notes or in peer reviewed journals.

D0 Note # 2379

FLAGGING CALORIMETER NOISY CELLS

S. Fahey, Jan Guida, Joan Guida
R.D. Schamberger, R.P. Smith
December 20, 1994

ABSTRACT

We describe a technique designed to identify and flag certain types of noisy calorimeter cells for each run. The cells flagged in each run are logged in the run-summary database so that they are suppressed by CAHITS during offline reconstruction and thereby removed from subsequent physics analysis. CAHITS scales the spurious energy recorded in each flagged noisy cell to a negligible quantity, but by using the flags in the CAEP bank the original energy in a noisy cell can be reexamined if desired.

1 GENERAL REMARKS

Certain hardware failures can cause arbitrary amounts of spurious energy to appear in calorimeter cells during normal data taking. When a cell shows exceptional energy for an excessive fraction of the events in a run, it can be classified as "noisy" and the readout from that cell considered meaningless. Such a cell should be suppressed in offline software and thereby removed from subsequent physics analysis.

Routine periodic pedestal measurements by the calorimeter CALIB program suppress calorimeter cells which exhibit bad hardware behavior detectable by CALIB at the time the measurements are made. These cells are suppressed in the hardware and not read out thereafter (until CALIB is run again). Typically during Run Ia, fewer than 10 cells were so suppressed by CALIB at any one time.

However, a hardware failure occurring after the time the pedestals are measured, or a problem which occurs infrequently or asynchronously with the pedestal measurements so as not to be apparent at the time CALIB is run, can arise which causes spurious "energy" to appear in calorimeter cells during any data runs taken while the problem persists. It is these cells that are flagged by software and suppressed in the CAHITS package. Because the software suppression of bad cells detected by CAHITS is analogous to the hardware suppression done by CALIB it is essentially unbiased and can be factored into overall detection efficiencies in the same way.

Note there is a second hot cell package in CAHITS, AIDA. AIDA suppresses cells on an event-by-event basis. AIDA is described in write-ups on the DØ reconstruction program RECO.

2 IDENTIFICATION OF NOISY CELLS

Clearly, real energy flow into the calorimeter from collisions centered in the detector should appear symmetrically in ϕ when summed over many events. It is known however during Run 1a that the calorimeter was not centered on the luminous region but was displaced $\simeq$ -10 cm in z and a few mm in x and y. The lateral misalignment generates a sinusoidal non-uniformity in ϕ for both occupancy and energy that can be seen when very large numbers of events, with e.g. electrons at intermediate η, are analyzed. The misalignment in z is seen most readily as an asymmetry in $\pm\eta$, e.g. jets or electrons, at large η.

The variations in ϕ have been measured to be less than 10% for $|\eta| \leq 3.0$, and less than 20% for $|\eta| > 3.0$ (G. Forden, private communication, 2/93). They vary smoothly in a sinusoidal fashion with ϕ and we have not found it necessary to correct for them in what follows since we are concerned with single-cell exceptions.

Thus we assume ideal ϕ-symmetry and identify isolated noisy cells on the basis of their severe departure from this general symmetry.

3 DETAILS OF THE METHOD

After summing over all events in the data stream for a give run, then for every ϕ, the cell occupancy and energy per event is calculated for each channel. Next over each ϕ-ring the mean occupancy and mean energy per event, as well as the standard deviation, σ, for both of these means is calculated. The occupancy of a cell is defined as the ratio of the number of hits in that cell during a run divided by the number of events in the run; the energy per event in a cell is defined as the total energy in the cell summed over the run divided by the number of events in the run. A hit in a cell occurs when the measured energy in the cell exceeds the zero-suppression threshold of the cell.

Cells in a given ϕ-ring exceeding the average by more than $\pm\ 3\sigma$ are flagged and the average (energy or occupancy) recalculated without them. New σ's for these means are also calculated. The number of standard deviations ("significance") each cell in each ϕ-ring deviates from the average for that ϕ-ring is calculated, and it is these significances in occupancy and energy that form the basis for the noisy cell identification of CAHITS.

To develop efficient cuts on the quantities discussed above which flag noisy cells in an unbiased way, we have relied on events collected in the calorimeter online EXAMINE which looks at all triggers in standard global runs. We have shown that the events in the express line for Run 1a (approximately 10% of the events in the Run 1A global runs that pass Level 2) serve equally well for the analysis we detail by performing identical analysis on a run from the ALL and the EXPRESS streams.

4 AN EXAMINATION OF CALORIMETER DATA

For a typical Run 1A global run (Run 51235), the occupancies and energies per event (as functions of a "channel number" – a packed integer which encodes the eta/phi/layer of the cell) are seen in Figure 1. High occupancies and energies at large channel number (large $|\eta|$) are seen as expected, as are certain other exceptional values in isolated channels. (The discontinuities in the occupancy plot near cell numbers ± 12000 correspond to the transition between the Central and End Calorimeters).

Evidently, if in any cell an exceptional (high) occupancy corresponds to an exceptional (high) energy per event, that would be a candidate for a noisy cell. The regular pattern of exceptional (and slightly negative) energies seen in the central region is caused by a contamination of "Main Ring" events in the data. (These of course are not noisy cells in the sense of this note, and must not be tagged by this noisy cell analysis).

For Run 51235 the significances, Δ/σ, of the deviations Δ in occupancy and energy per event of every cell for the ϕ-ring to which it belongs are shown in Figure 2.

While the significance distributions each show reasonable widths, the tails extend to $\pm$ 100 or more. (Energy deviation significances beyond 999 σ are arbitrarily truncated to 999). In what follows we will show that genuine noisy cells are to be found in the tails of these distributions.

As seen in Figure 2, the significance distributions are asymmetric and peak below zero. Because of the pedestal thresholds (cut at $\pm$ 2 pedestal σ zero suppression as determined by the CALIB program), the average energy of a ϕ-ring necessarily includes events with excess positive ADC counts due to uranium noise, which in turn leads to ϕ-ring means biased toward positive values, hence to individual cell deviations biased negatively. The presence of good physics events in these distributions produces a (less prevalent) opposite bias.

In Figure 3 is shown the occupancies plotted against the average energies, for run 51235. As expected, the cells at high $|\eta|$ constitute the portions of the plot at the high occupancies, and main ring events are often visible as cells with slightly exceptional average energies in the low occupancy regions. (The energies can be either positive or negative depending on whether high main-ring losses causes pile-up in the main ring cells leading to saturation in the preamps, and depending on the timing relationship between occurrence of the main ring "event" and the level 0 event trigger). While very high occupancies at central values of $|\eta|$ are potential noisy-cell candidates, the same at high $|\eta|$ are not.

In Figure 4 the significance of the occupancy is plotted against the occupancy for run 51235. We will show that the cells at high occupancy significance are noisy cells if they contain significant energy.

5 LOOKING AT A NOISY CELL

In Run 51235 there is an exceptional cell at $(\eta, \phi, layer) = (6,31,6)$ which surely should be considered noisy and suppressed by software since the information it contributes to the events in the run is grossly misleading. The cell has an occupancy of 99.9% and an energy per event of 0.86 GeV; it is seen in Figure 4 at an occupancy deviation significance of about 60 and occupancy 1.0. Its occupancy is $+55\sigma$ from the mean occupancy in the ϕ-ring for this η and layer, and the energy is $+694\sigma$ from the mean energy per event in the cells in this ϕ-ring. In Figure 5 is shown the occupancy and energy per event; in Figure 6 is shown the deviations from the means in occupancy and energy, and in Figure 7 are shown the significances of these deviations, for all cells in the ϕ-ring at $(\eta, layer) = (6{,}6)$. Clearly we want to set cuts on the appropriate parameters to suppress such cells without jeopardizing genuine physics signals.

In Figure 4 we note a few other cells in this run that are isolated in the significance of the occupancy variable; none has an average energy exceeding 0.01 Gev per event, nor a significance of the energy deviation greater than 1.8. Such cells evidently cause no concern and need not be identified as noisy.

We might also calculate the energy per hit for each cell instead of the energy per event in each cell, and the two variables tend toward equality for highly populated cells, but this alternative energy variable does not provide as much discrimination between high-occupancy noisy cells and rarer "physics" cells.

6 CUTS WHICH FLAG NOISY CELLS

To refine our notions of just where our cuts should be set to define noisy cells, we analyzed one at a time 42 runs from Run 1A to ensure that some dozens of genuine noisy cells were available for scrutiny. Some of the runs occurred when there were known pathologies in the calorimeter BLS system, which typically generate a specific pattern of noisy cells in (η, ϕ) space; others were randomly-selected runs at various luminosities and with varying main-ring conditions. Some of the runs analyzed were sequential in time so if a hardware problem persisted in more than one of these runs, it might have caused the same cell to have exceptional values in more than one run for the variables we define.

In Figure 8 is shown, collected together for the 42 runs, a distribution of the occupancy vs. energy per event for all cells with occupancy significance greater than 5. For this loose cut on the occupancy significance we see the clump of main ring events around occupancy ≈ 0.1 with average energies extending out to about 0.1 GeV. This cut on occupancy significance is clearly too loose for our purposes since most of the cells remaining in Figure 8 should not be classified as noisy.

Figure 4 suggests that the proper occupancy significance cut should be at about 20, and in Figure 9 we show the significance of the energy deviation for all cells with an occupancy significance cut of 20 for the 42 runs of Figure 8 (recall that in the cells at 999 are collected all those cells that actually overflowed this value). Figure 9 shows that we can cut on the energy significance variable at about 60 to further isolate noisy cells. Only cells which have energy deviation significance greater than 60 remain as candidates for noisy cells.

In Figure 10 is shown the occupancy distribution for the cells with occupancy significance greater than 20, and in Figure 11 are shown the same cells with the added cut on the energy deviation significance.

Returning to Figure 8 we see that it is desirable to add a final cut on the energy per event at about +500 Mev and -200 Mev to safely retain properly operating cells (at very low average energies) and ensure that only genuinely pathological ones, with average energies beyond these cuts, are suppressed. This cut allows e.g. for small offsets in the electronics which do not significantly affect the physics algorithms.

For EM cells, the final cut on average energy of 500 MeV corresponds to approximately 150 ADC counts (depending on the precise sampling fraction the cell represents); the pedestal σ as measured by CALIB is less than 5 ADC counts for these cells. For FH cells, a 500 MeV cut corresponds to about 100 ADC counts and the CALIB pedestal σ for these cells is less than 15 ADC counts. For CH cells the 500 MeV energy cut corresponds to about 20 ADC counts and the pedestals for these cells have a σ less than 5 ADC counts. This corresponds to cuts of at least 30, 6, and 4 σ for EM, FH, and CH cells respectively. Thus our selected energy cut is certainly conservative with respect to normal hardware function.

In Figure 12 we present the ϕ *vs* η distribution for the cells in the 42 runs which fail the combination of the three cuts – occupancy significance greater than 20, energy significance greater than 60, and energy per event greater than +500 MeV or less than -200 MeV.

In Figure 12 are seen a few of the patterns which typify a failed BLS hybrid. With the cuts we have defined set as conservatively as we have set them, we find that an average of 1.2 cells are flagged per run as "hot" in typical runs; this fraction has been inflated slightly by our inclusion of several runs which have BLS problems in them, which generally spoil several cells at once.

7 STATISTICS REQUIRED FOR MEANINGFUL DISCRIMINATION

We have studied the number of events required to generate sufficient population of the calorimeter cells for the above analysis to be meaningful. Evidently if there are more than $\simeq$ 200 events in a given run, then our analysis is useful. In fact, even if fewer events are available the method does not "diverge" i.e. flag ever increasing numbers of exceptional cells. In any case, no analysis will be offered for any run resulting in fewer than 200 events in the stream we analyze.

8 FUNCTIONALITY OF THE NOISY CELL FINDER PACKAGE

Functionally the noisy cell algorithm described above requires a two pass system for implementation. The first pass finds the noisy cells and the second pass suppresses the energy of each noisy cell. Both of these functions are incorporated into CAHITS.

If D0_HOTFIND is set true in CAHITS.RCP, then the finding function is activated. Since typically D0RECO is run on one part at a time rather than on an entire run, the noisy cell finder is itself divided into two pieces. The first piece, CHOTINFO, accumulates statistics for each part of a run. It writes this information to a temporary file which is used in the second piece. After all parts of a given run have been processed through D0RECO with the hot-finder activated, then the CHOTFLAG package is run. It uses all the temporary files created by CHOTINFO for the run, and it accumulates all the statistics required for the entire run and imposes the cuts described in section 6 above. The cells failing the cuts (the noisy cells) are written to the run summary database.

The second pass of the system suppresses the energy in the noisy cells flagged in the first pass. If while running FULL_D0RECO, D0_HOTSUP is true in CAHITS.RCP, then the noisy cells tabulated in the run summary database are suppressed by multiplying the cell energy by HOTSUP. In addition, the seventh bit of the cell flag in the CAEP bank is set.

Since the noisy cell finder must run before the production version of D0_RECO, it must run automatically and within one day or so after the data has been taken. Thus it is run on the express nodes on the data sent to those node, typically the express stream during Run 1A and the GM stream during Run 1B. The CHOTFLAG program is run by the Global Monitor Shift personnel and it produces an eta-phi plot of the flagged cells. Unless there has been a significant recent hardware failure, this plot will show only a small number (0 or 1) of flagged cells.

9 RESULTS FROM RUN 1A

The noisy cell package was run on 1113 global runs from the Express Stream from Run 1A. A total of 873 runs were successfully processed. Another 224 runs were processed but failed to have the required minimum number of events (200) for implementation of the noisy cell flags.

The Run 1A noisy cell summary is shown in Figure 13, which counts the number of cells flagged in each of the 873 runs processed. On average about one cell per run is flagged, with more than half of the runs having no cells flagged. In one run (which overflows the plot), 279 cells were flagged. This was caused by a blown fuse on a BLS card. For comparison, in Figure 14 is shown the count of cells flagged by CALIB pedestal runs and thus suppressed in hardware. The average number of cells so suppressed during Run 1A was 7.5. For completeness, the count of cells flagged bad by CALIB gains runs is shown in Figure 15. The run with 222 bad cells was taken during machine studies and thus real energy was deposited into the calorimeter during the run; the runs with 125 bad cells (all near the end of Run 1A) were due to a bad pulser cable. Nominal gains will be used for all cells flagged by CALIB gains runs.

In Figure 16 is shown the eta-phi plot of the noisy cells flagged for the 873 runs. Nothing grossly systematic is seen, but the cluster of cells at positive eta and small phi are due to the blown fuse described above. The cells at positive eta and $\phi = 49$ are due to an erratic BLS.

Evidently noisy cells as flagged by the algorithms described did not constitute a major problem during Run 1A. Such cells however can distract data analysis if they are not suppressed, and flagging them promptly after a given run can aid in promptly diagnosing the electronics problems which cause them. Note that cells which become noisy due to high voltage problems are located by this system.

10 RESULTS FROM RUN 1B

The noisy cell package has been running routinely during Run 1B currently underway. The noisy cell suppression summary, the CALIB cell suppression summaries, and the eta-phi plot of flagged noisy cells, for runs to date, are shown in Figures 17 – 20.

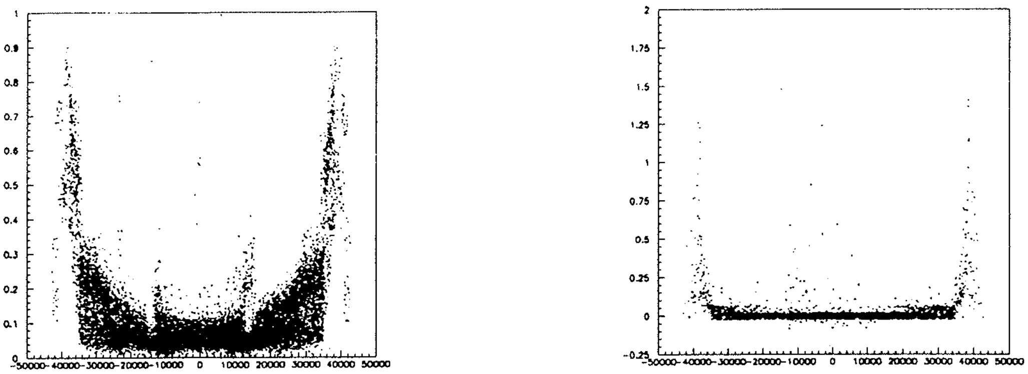

Figure 1: Cell Occupancy, and Energy per Event, Global Run 51235

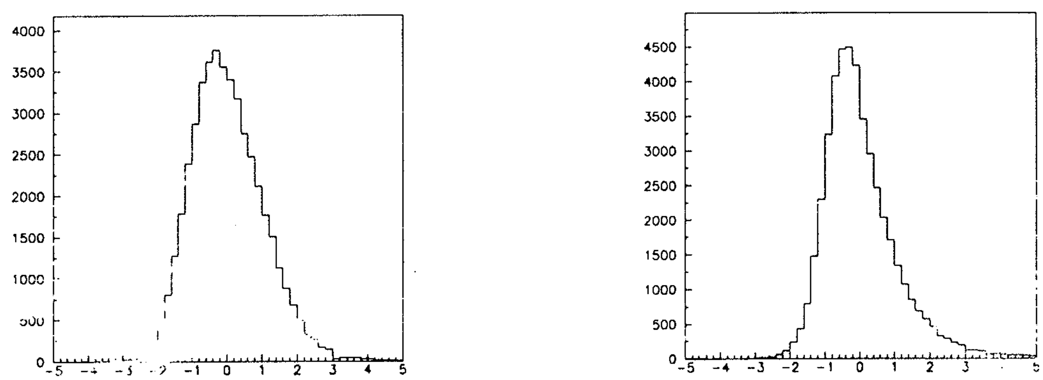

Figure 2: Significance = Δ/σ for Occupancy, and Energy per Event, Global Run 51235

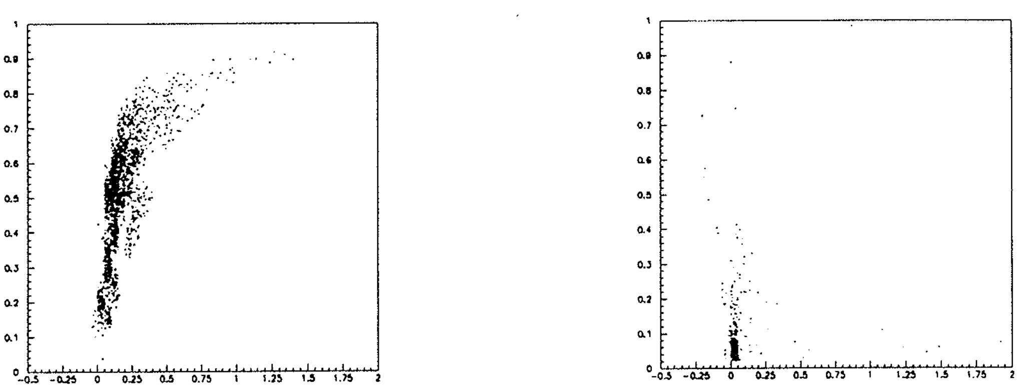

Figure 3: Occupancy vs Energy per Event, $|\eta| > 3.2, |\eta| < 3.2$, Global Run 51235

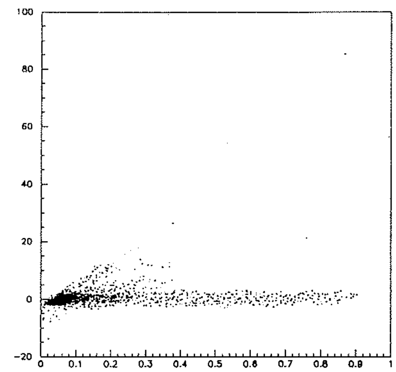

Figure 4: Occupancy Deviation Significance vs. Occupancy, Global Run 51235

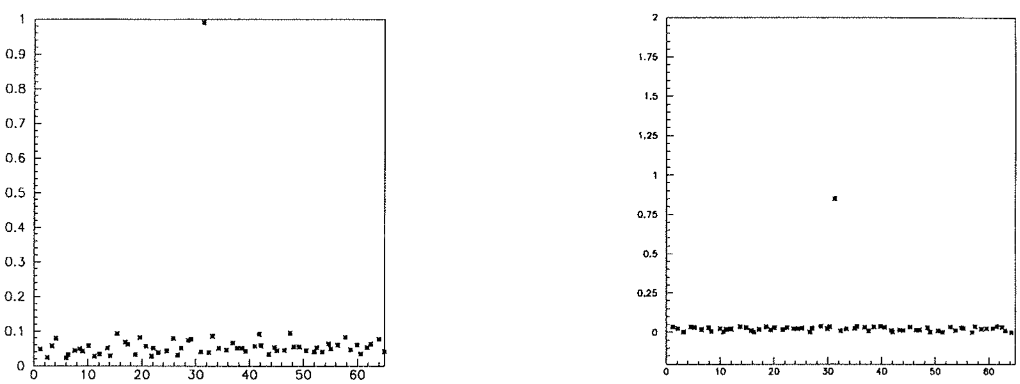

Figure 5: Occupancy, and Energy per Event, for a ϕ-ring that contains a noisy cell in Global Run 51235

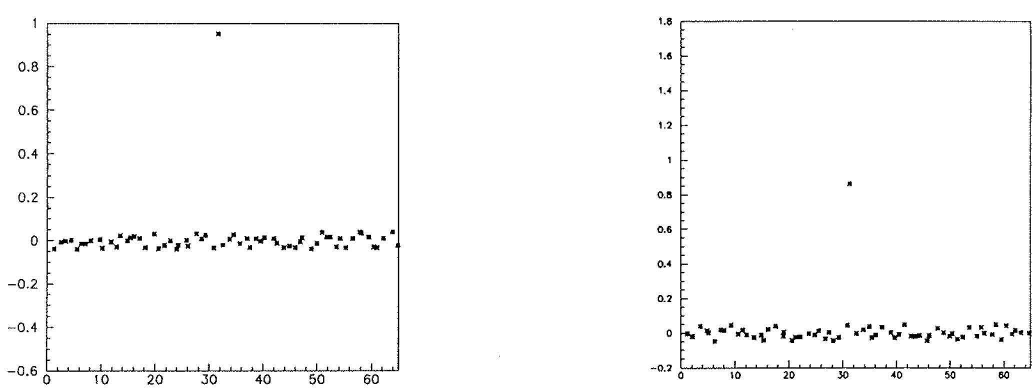

Figure 6: Deviations from the means in Occupancy, and Energy per Event, for a ϕ-ring that contains a noisy cell in Global Run 51235

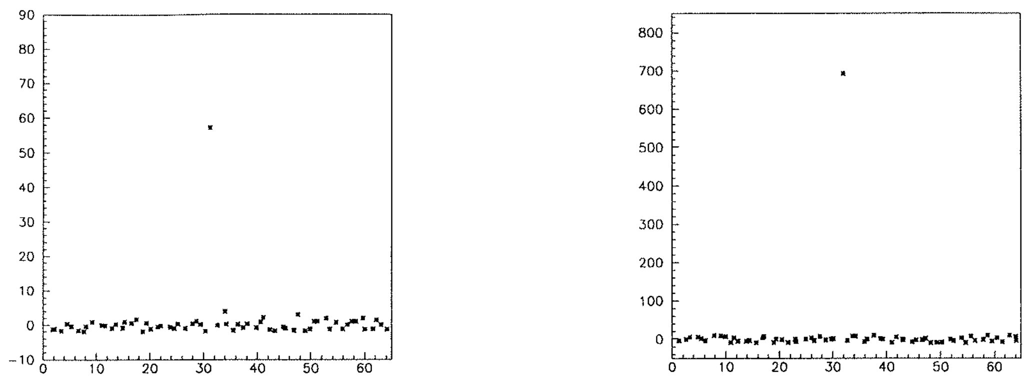

Figure 7: Significance of the Occupancy, and Energy per Event, Deviations for a ϕ-ring that contains a noisy cell in Gobal Run 51235

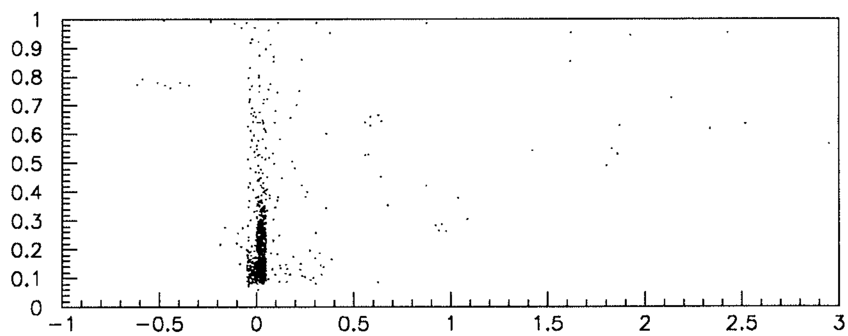

Figure 8: Occupancy vs Energy per Event for all Cells with Occupancy Significance greater than 5, 42 Global Runs

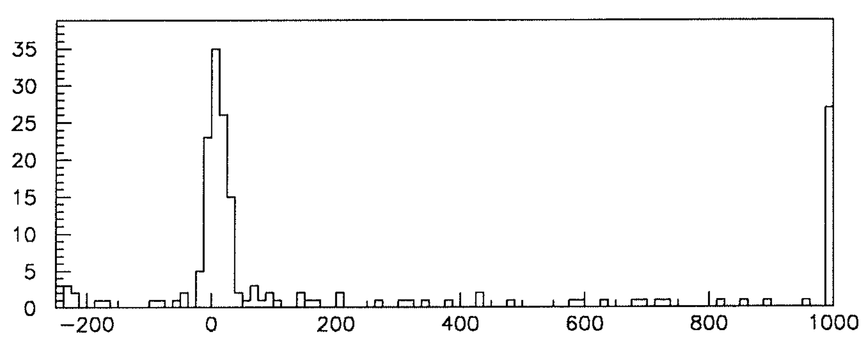

Figure 9: Energy Deviation Significance for all cells with Occupancy Significance greater than 20.0, 42 Global Runs

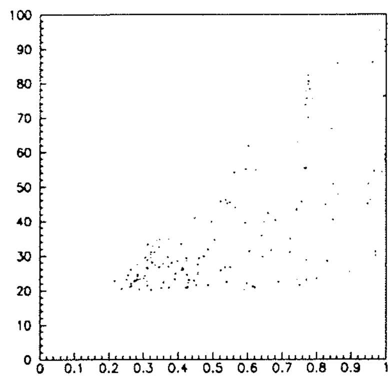

Figure 10: Occupancy Significance vs Occupancy of all Cells with Occupancy significance greater than 20.0, 42 Global Runs

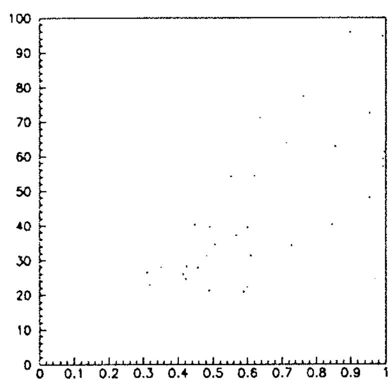

Figure 11: Occupancy Significance vs Occupancy of all Cells with Occupancy significance greater than 20.0, and Energy Significance greater than 60.0, 42 Global Runs

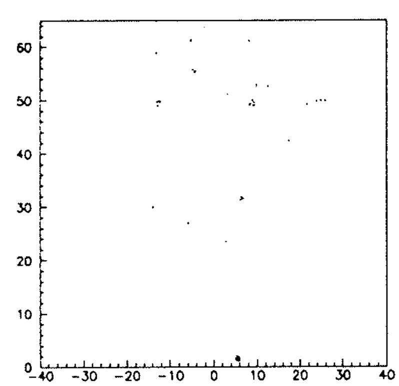

Figure 12: Iphi vs. Ieta for Cells Selected by the Cuts Described, 42 Global Runs

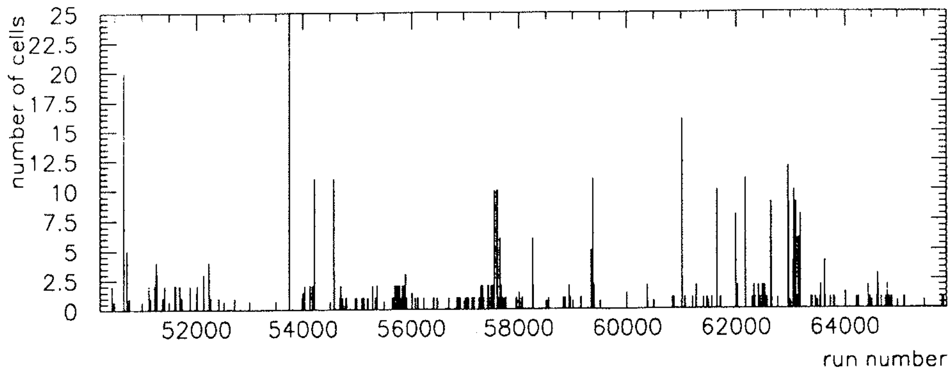

Figure 13: Count of Noisy cells for runs in Run 1A.

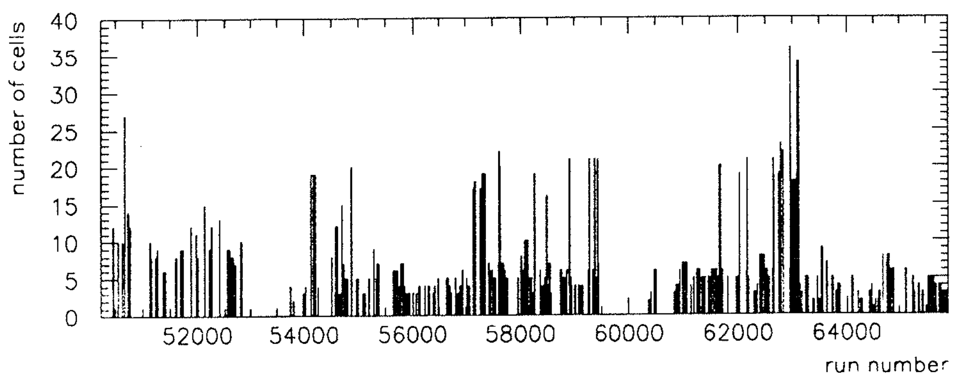

Figure 14: Count of CALIB Pedestal cells suppressed for runs in Run 1A.

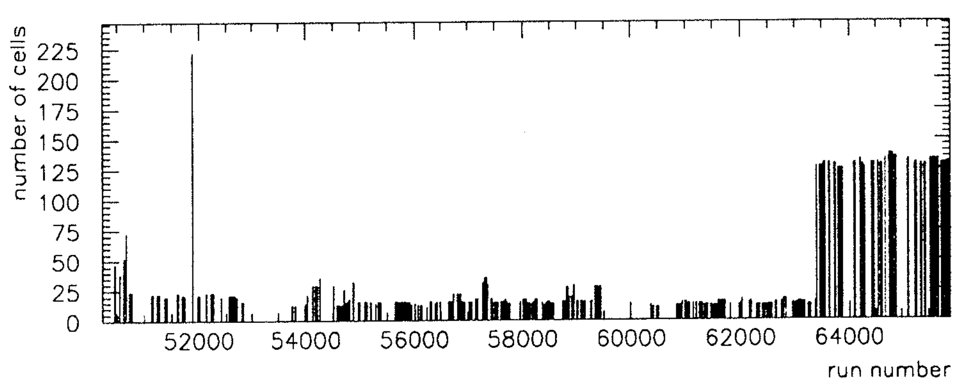

Figure 15: Count of CALIB Gain cells flagged for runs in Run 1A.

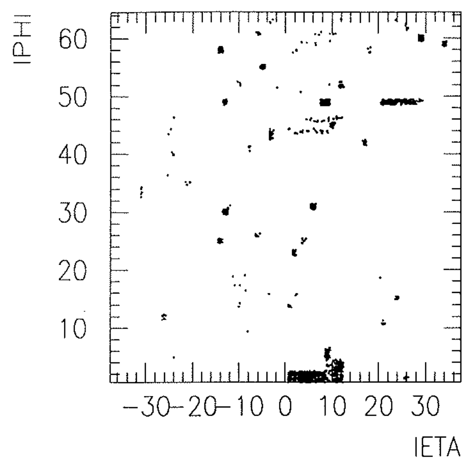

Figure 16: IPHI vs IETA of noisy cells flagged in runs from Run 1A.

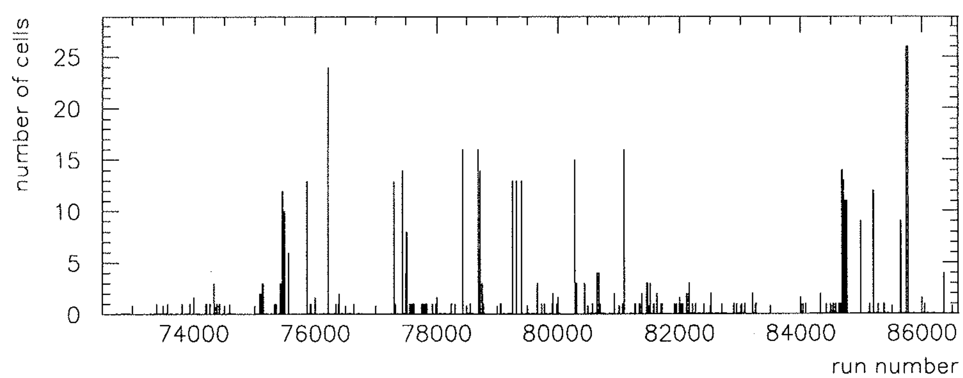

Figure 17: Count of Noisy cells for runs in Run 1B.

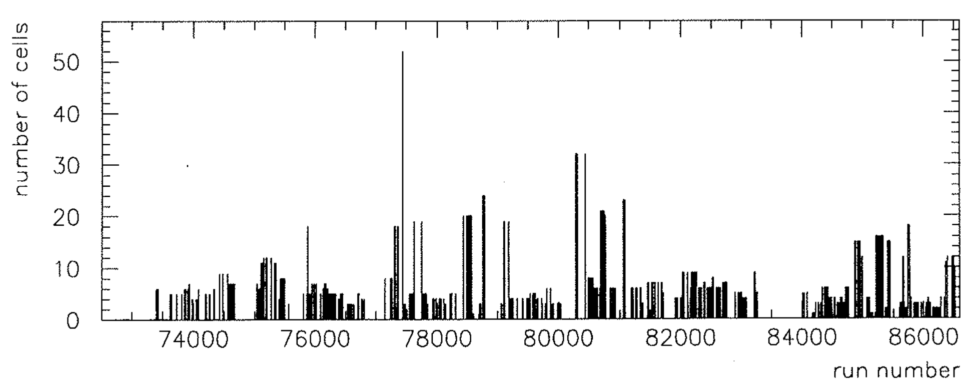

Figure 18: Count of CALIB Pedestal cells suppressed for runs in Run 1B.

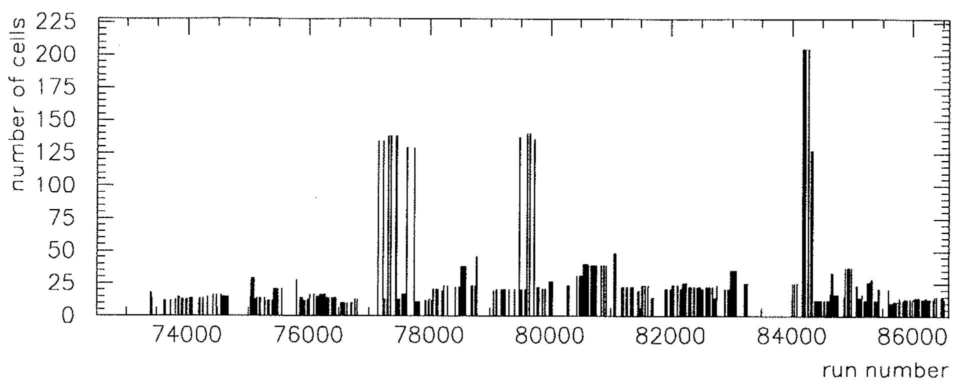

Figure 19: Count of CALIB Gain cells flagged for runs in Run 1B.

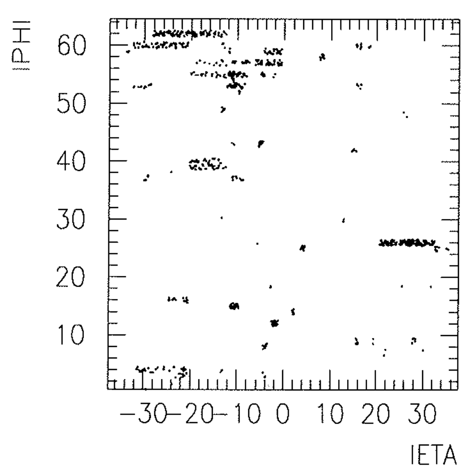

Figure 20: IPHI vs IETA of noisy cells flagged in runs from Run 1B.