The DØ Level 1 Trigger Calibration
Run 1B

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1 Introduction

This note describes the analysis and results of the Level 1 (L1) trigger calibration for run 1B out to the current instrumented range of $\eta = 4.0$. The energy measurement from the level 1 trigger is calibrated relative to the precision measurement from the calorimeter electronics at a calorimeter high voltage setting of 2000 volts. The trigger measures transverse energy in semi-projective electromagnetic and hadronic towers which are 0.2×0.2 in η and ϕ. There are 1216 electromagnetic (32 in ϕ and -19 to $+19$ in η) and 1280 hadronic trigger towers (32 in ϕ and -20 to $+20$ in η).

The L1 trigger calibration analysis and results for run 1A are described in DØ note 1582[1]. The modifications made to the trigger between run 1A and 1B are described in DØ note 1707[2] and include changes to correct the calibration scale and the saturation problem at higher etas. In run 1B, the trigger was extended out to $\eta = 4.0$ from 3.2 in run 1A.

2 Data Analysis

Dedicated runs for the L1 trigger calibration were taken at the beginning of run 1B. There were 10 runs (#72531 – 76724) with approximately 144,000 events used in the analysis. The software used to process the data is described in reference 1.

The transverse energies (E_T) from the electromagnetic and hadronic trigger towers and the E_T from the sums of the corresponding calorimeter cells were calculated and written out to a data file if the E_T in either an electromagnetic (EM) or hadronic (HAD) trigger tower was greater than a threshold value, which varied from 2.0 GeV out to trigger $\eta = 16$ to 1.5 and 1.0 GeV at the highest $\eta's$. The rest of the analysis was done using a short program that read in and analysed the data files.

Figures 1 and 2 show the L1 transverse energy (L1_E_T) versus the calorimeter transverse energy (CAL_E_T) for each value of trigger η after the threshold cuts were made. For the calibration of the L1 energy scale, cuts were applied to remove spurious events which were evident by poor correlation between L1 and calorimeter energies. Therefore the requirement was made that the calorimeter E_T be less than a maximum value for each trigger η. From studying the plots shown in Figures 1 and 2, the following values of the maximum calorimeter E_T were chosen for the electromagnetic and hadronic trigger towers separately and are listed in Table 1.

In run 1B, the L1 trigger did not reach its dynamic range (saturate) at as low an E_T as it did in run 1A, since parts of the trigger hardware were replaced to take care of this problem. The expected saturation values for run 1B are at approximately 60 GeV except at trigger $|\eta| > 14$ where the energy at which the L1 trigger saturates starts to fall. As shown in Figures 1 and 2, the L1 trigger does not saturate at the energies reached in this analysis at the higher values of η.

If a detector calibration data run taken previous to a special L1 trigger run determined that a particular calorimeter channel was not functioning properly, that channel was not written out in the raw data. The trigger towers affected had their points removed from the data sample.

The distributions of number of events surviving the cuts listed above for each of the electromagnetic and hadronic towers are shown in Figure 3. There were $\approx 186,000$ events surviving the cuts in the EM towers and $\approx 65,000$ events in the HAD towers. A least-squares fit of the form

$$\mathrm{CAL\_}E_T = m \times \mathrm{L1\_}E_T + b$$

was applied to calibrate each trigger tower that had at least 10 events surviving the cuts.

After the slope and intercept of the line in the above fit was calculated, the perpendicular distance of each point from the fitted line was calculated. The point was removed from the sample if the deviation from the line was greater than 2.1 GeV. The least-squares fit was then redone to get the final results. Figure 4 shows the L1 versus calorimeter E_T with the cuts applied and fitted line for a single trigger tower.

3 Results

There were 1152 electromagnetic towers and 1199 hadronic towers calibrated. The distribution of χ^2 per degree of freedom for each tower is shown in Figure 5. The distribution of slopes and intercepts from the fits are shown in Figures 6 and 7 and the slopes versus trigger tower η are shown in Figure 8 and the slopes versus trigger tower ϕ for EM and hadronic towers is shown in Figure 9. Table 2 lists the number of ϕ towers calibrated and the average fitted slopes and intercepts for each trigger η. The EM towers at $|\eta| = 7$ were not calibrated due to low statistics because of minimal electromagnetic calorimeter coverage at that value of η. Many of the HAD towers at $|\eta| = 6$ were not calibrated because of the same reason.

Channels which were not calibrated or whose calibration value was more than 17% off from the average were flagged and studied to determine if any hardware problems existed. Figures 10a and 10b shows the L1 versus CAL E_T of two channels which were calibrated and flagged as bad along with the fitted line and lines to indicate the deviation cut. Table 3 lists the slope, the χ^2 and the number of points in the fit to a line for all the channels flagged as bad. The calibration could be off from the average because of bad hardware or because of a hardware failure and then subsequent replacement during the course of the runs analysed. If a channel was not calibrated, it was usually due to poor statistics.

4 Summary

From the analysis to calibrate the Run 1B Level 1 trigger, the average calibration was determined to be 1.05 with an rms of 0.067 for the EM towers and 1.04 for the hadronic towers with an rms of 0.082 with 95% of the channels being calibrated.

Table 1: CUT VALUES for CALIBRATION of LEVEL 1 TRIGGER

	EM	HAD
L1 η	Max_Cal_E_T(GeV)	Max_Cal_E_T(GeV)
1	30	40
2	40	35
3	50	38
4	50	50
5	50	50
6	50	30
7	20	40
8	50	40
9	80	30
10	50	30
11	40	35
12	35	25
13	40	40
14	40	20
15	35	15
16	25	15
17	20	15
19	15	10
20	50	8

Table 2: AVERAGE L1 TRIGGER CALIBRATION VALUES

L1 η	EM $\#\phi$ towers	EM average slope	EM average intercept	HAD $\#\phi$ towers	HAD average slope	HAD average intercept
-20	-	-	-	13	0.873	-0.114
-19	32	1.020	0.019	32	0.941	0.051
-18	32	1.021	-0.006	32	0.966	0.042
-17	32	1.015	0.005	32	0.981	0.030
-16	32	1.079	-0.021	30	1.072	-0.010
-15	32	1.105	-0.036	31	1.105	-0.035
-14	32	1.120	-0.072	32	1.087	-0.045
-13	32	1.118	-0.032	32	1.111	-0.023
-12	32	1.065	-0.014	32	1.069	-0.010
-11	32	1.069	-0.080	32	1.047	-0.030
-10	32	1.064	-0.045	32	1.035	-0.053
-9	32	1.024	-0.045	32	0.981	-0.055
-8	32	1.070	0.000	32	1.048	-0.001
-7	0	-	-	31	1.077	0.065
-6	32	1.082	0.046	15	1.128	-0.165
-5	32	1.067	-0.029	31	1.040	-0.114
-4	32	1.058	-0.052	32	1.076	-0.080
-3	32	1.068	0.035	32	1.063	-0.023
-2	32	1.069	0.001	32	1.088	-0.081
-1	32	1.089	0.034	32	1.093	0.007
1	32	1.058	0.013	32	1.068	-0.064
2	32	1.038	0.032	32	1.032	-0.035
3	32	1.035	0.027	32	1.010	-0.049
4	32	1.055	-0.062	32	1.060	-0.100
5	32	1.057	0.001	32	1.051	-0.084
6	32	1.089	0.037	10	1.016	-0.037
7	0	-	-	32	1.090	-0.055
8	32	1.052	0.002	32	1.045	-0.009
9	32	0.994	-0.012	32	1.026	-0.018
10	32	1.018	-0.019	32	0.996	-0.013
11	32	1.054	-0.056	32	1.048	-0.043
12	32	1.045	-0.024	32	1.048	-0.057
13	32	1.052	0.007	32	1.061	-0.008
14	32	1.057	-0.012	32	1.057	-0.073
15	32	1.044	-0.062	32	1.050	-0.067
16	32	1.042	-0.006	31	1.028	-0.005
17	32	1.014	0.000	32	1.025	0.012
18	32	1.042	0.010	32	1.008	0.017
19	32	1.011	0.017	32	0.989	0.001
20	-	-	-	15	0.886	-0.146

Table 3: L1 TRIGGER TOWERS WITH BAD CALIBRATION VALUES

	η	ϕ	# points	slope	χ^2/DOF
EM	-18	26	74	0.845	0.012
EM	-14	26	133	0.929	0.040
HAD	-20	8	18	0.713	0.139
HAD	-19	13	103	1.128	0.008
HAD	-19	20	20	0.762	0.034
HAD	-14	26	34	0.814	0.128
HAD	-13	11	115	1.321	0.041
HAD	-12	25	36	0.864	0.084
HAD	-11	3	89	1.231	0.039
HAD	-6	20	15	1.368	0.065
HAD	-6	22	11	0.921	0.141
HAD	-5	1	21	0.853	0.189
HAD	-5	3	26	1.219	0.139
HAD	6	30	12	1.266	0.449
HAD	19	4	35	1.174	0.027
HAD	20	12	51	0.528	0.222
HAD	20	21	23	1.125	0.109

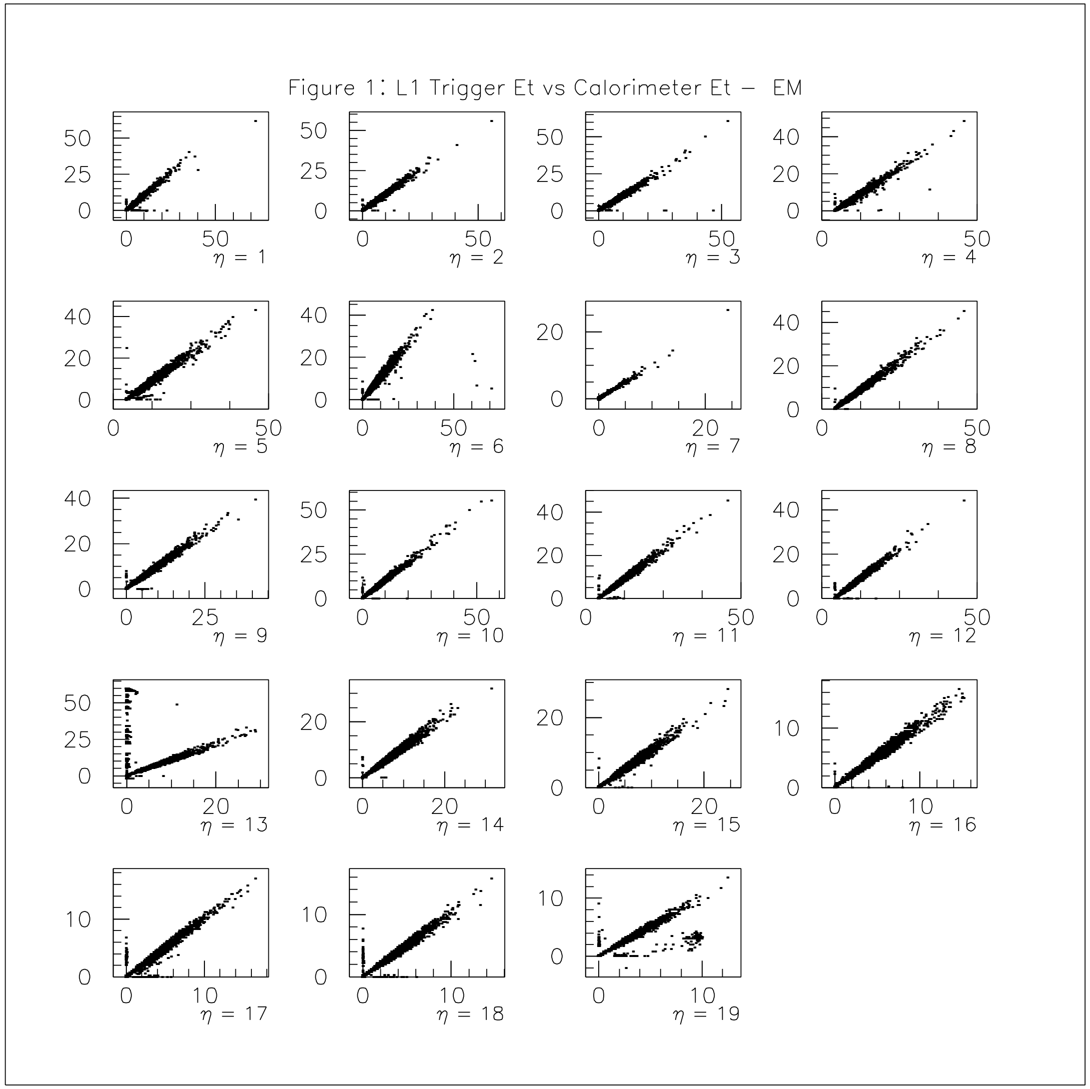

Figure 1: EM: L1 vs CAL for all ϕ and each η - no cuts

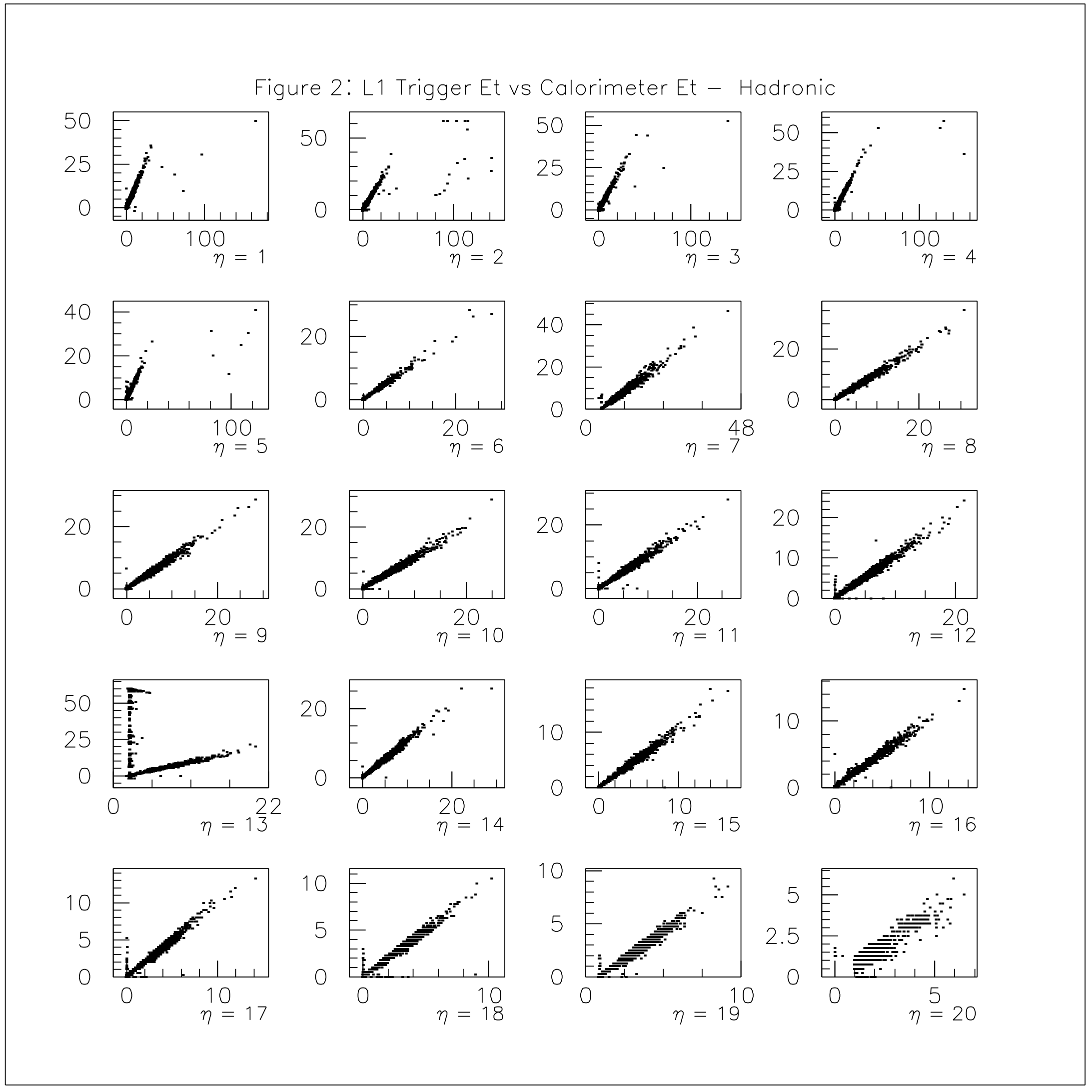

Figure 2: HAD: L1 vs CAL for all ϕ and each η - no cuts

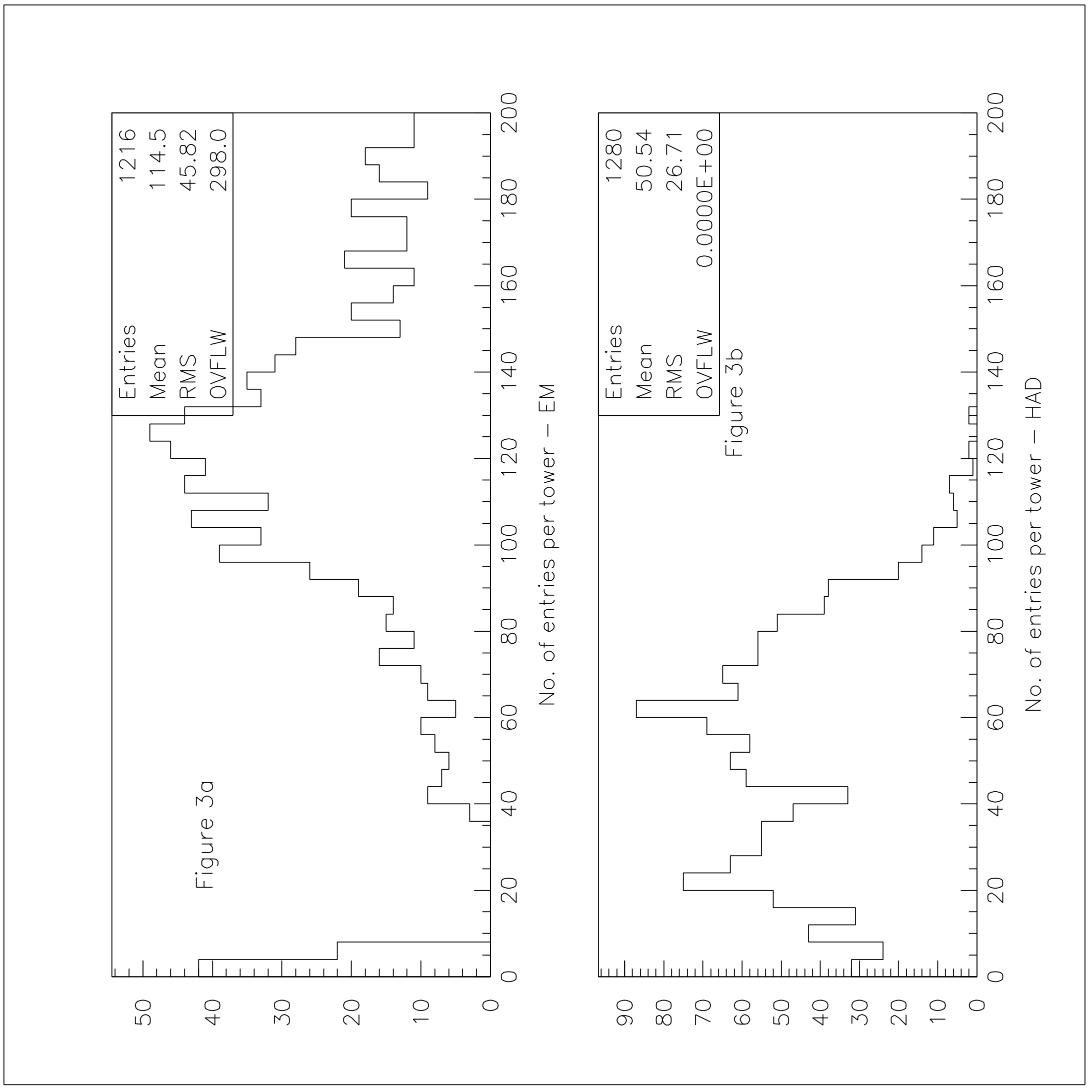

Figure 3: Number of events after cuts for each L1 tower

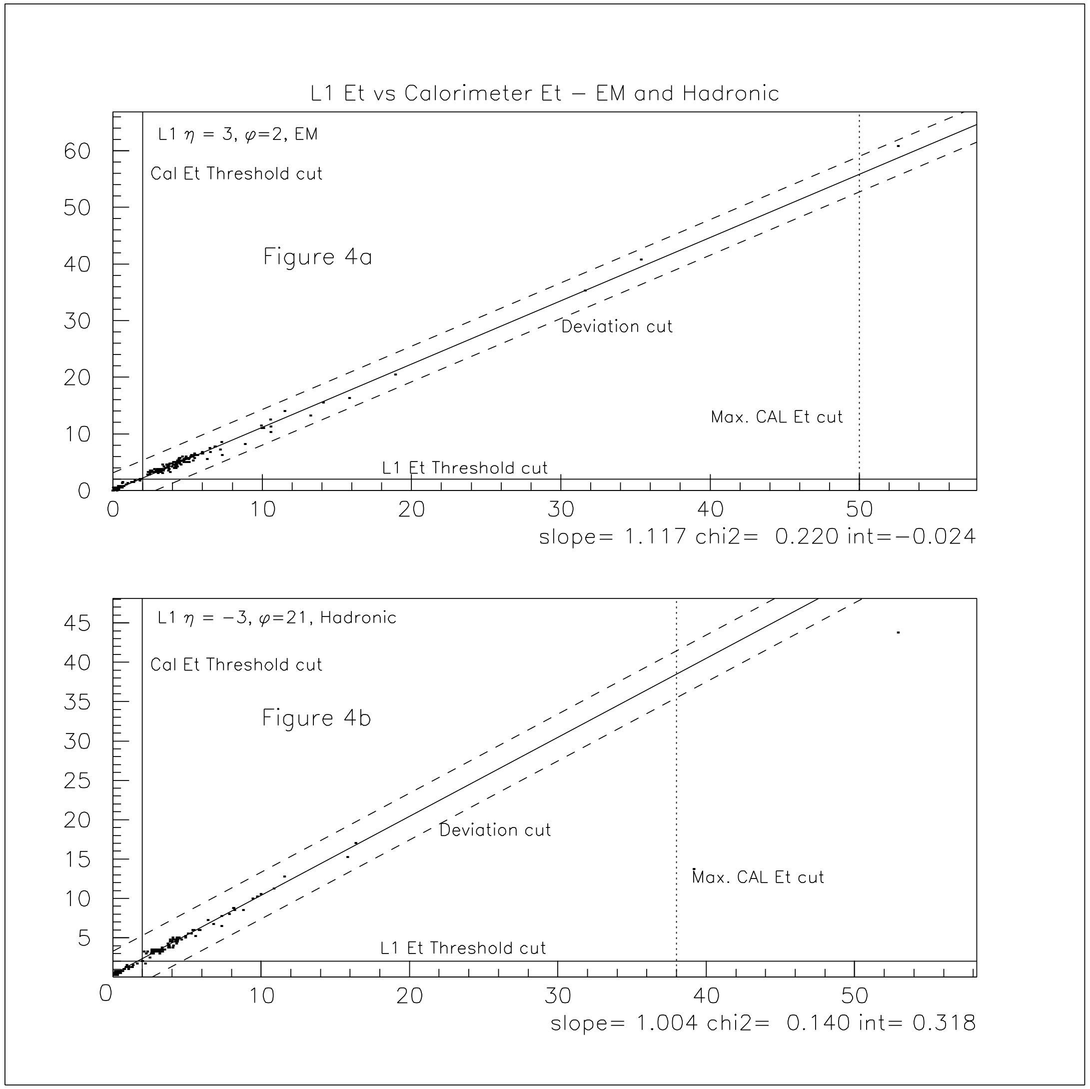

Figure 4: L1 vs CAL E_T for 1 tower with threshold, max calorimeter E_T and deviation cuts and fitted line shown

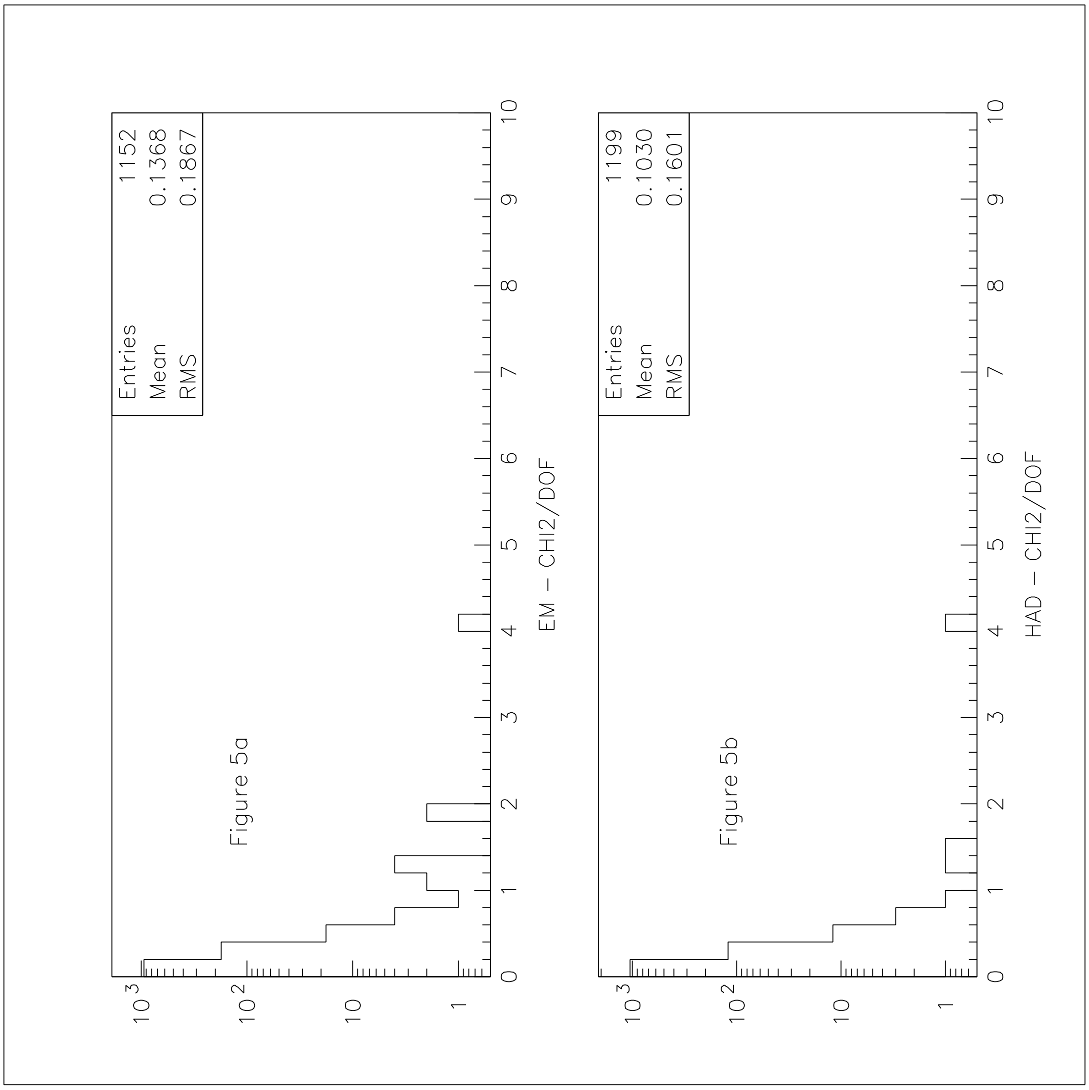

Figure 5: χ^2 per degree of freedom of fit for all EM and HAD towers

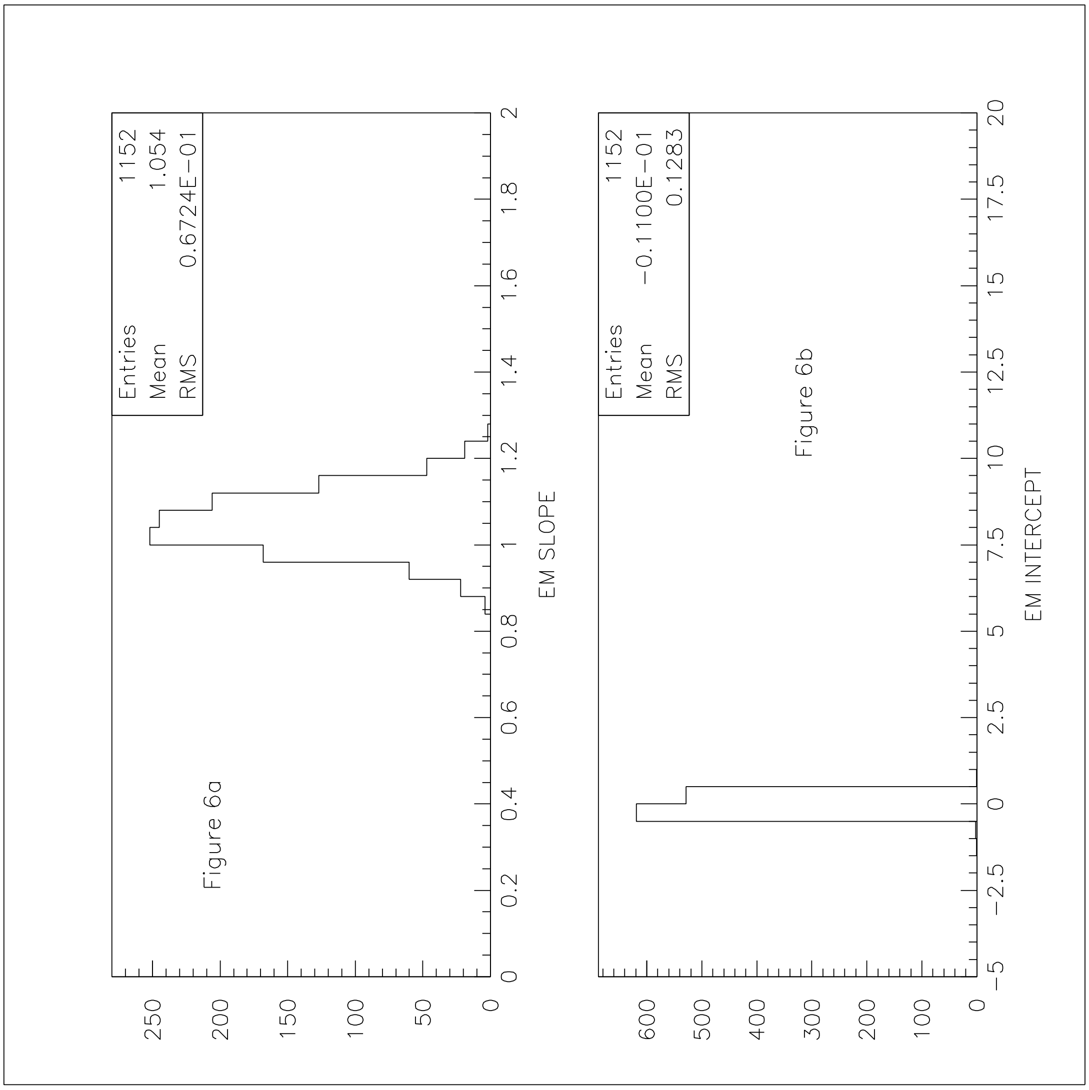

Figure 6: Slope and intercept of fit to a line for EM towers

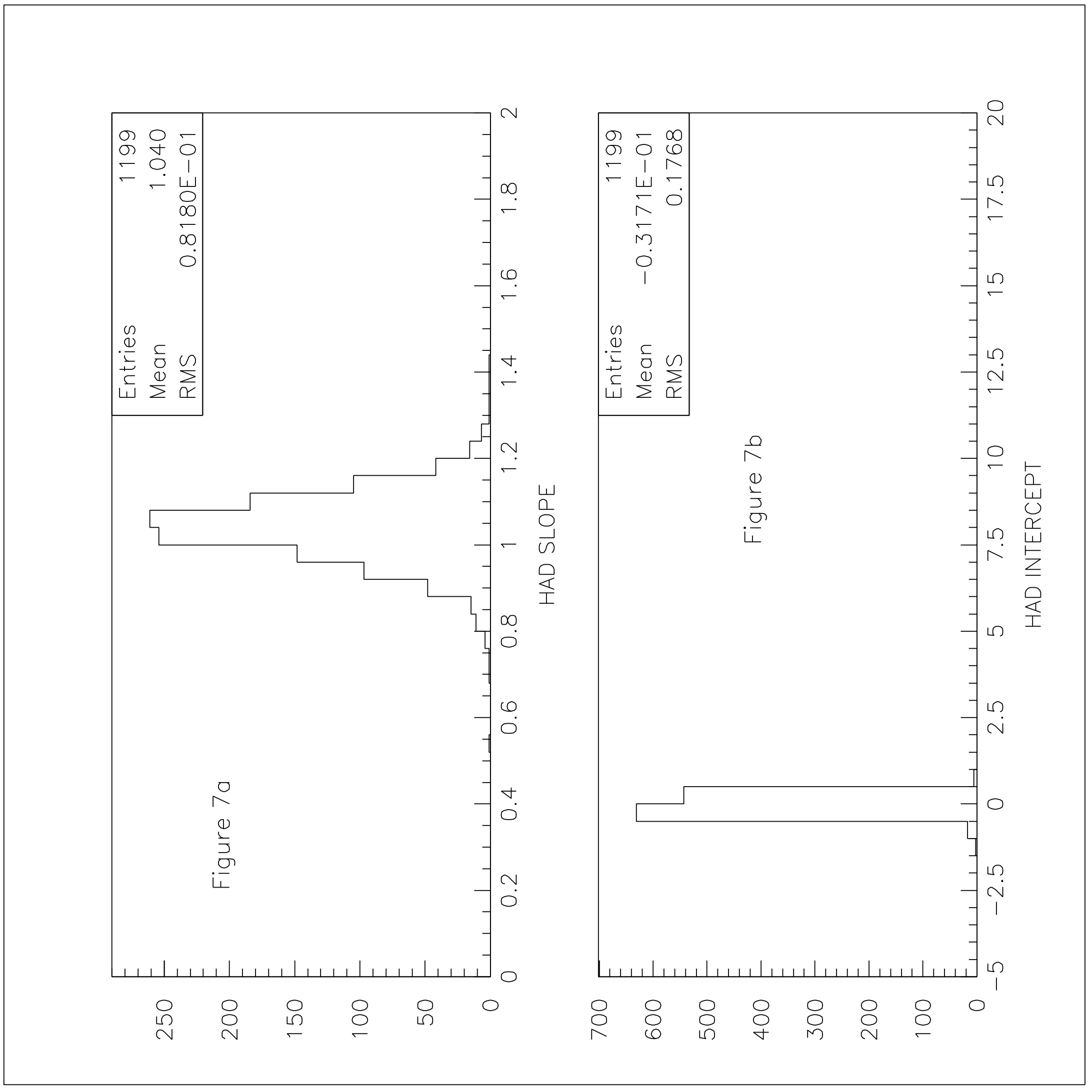

Figure 7: Slope and intercept of fit to a line for HAD towers

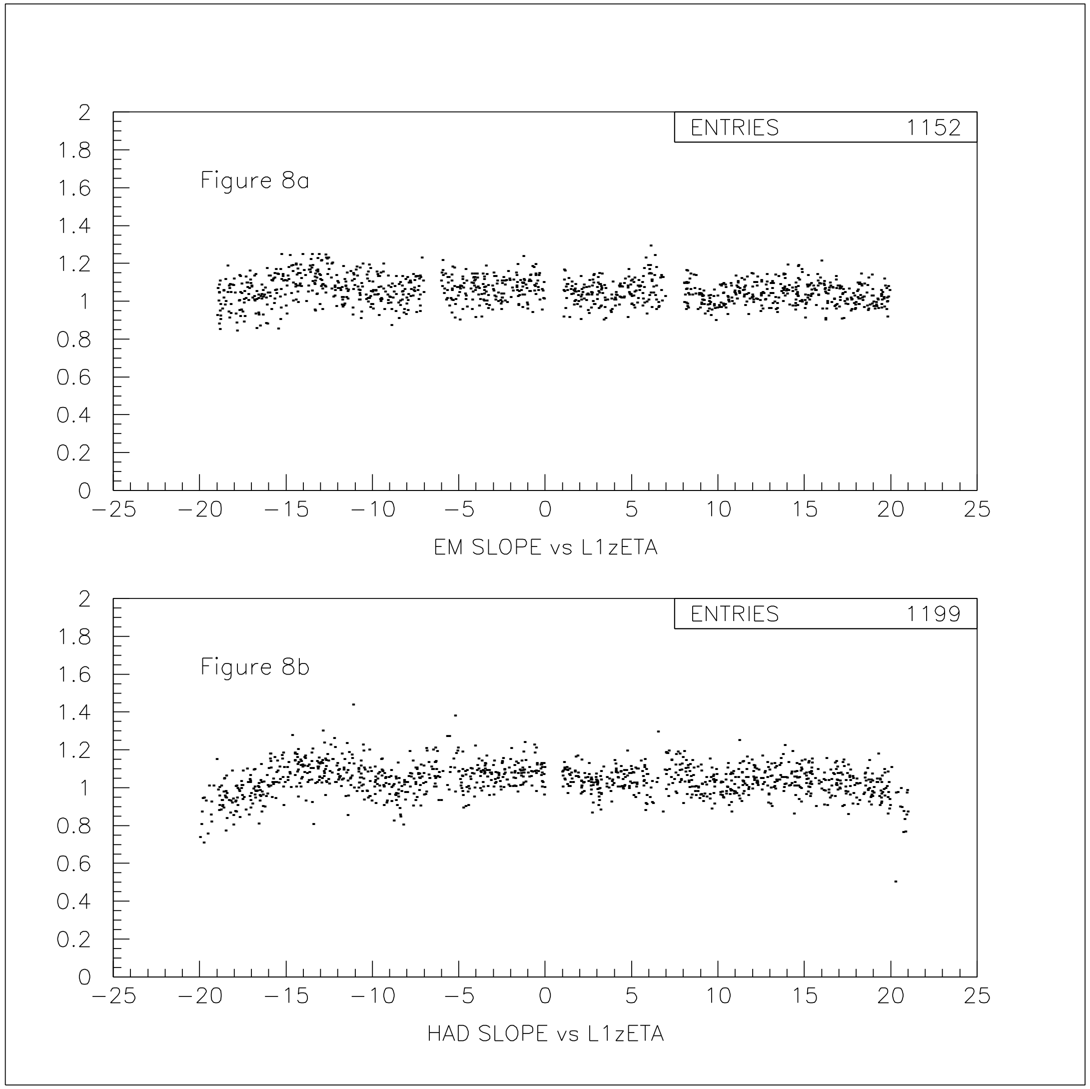

Figure 8: Slope of fit to a line versus L1 η for EM and HAD towers

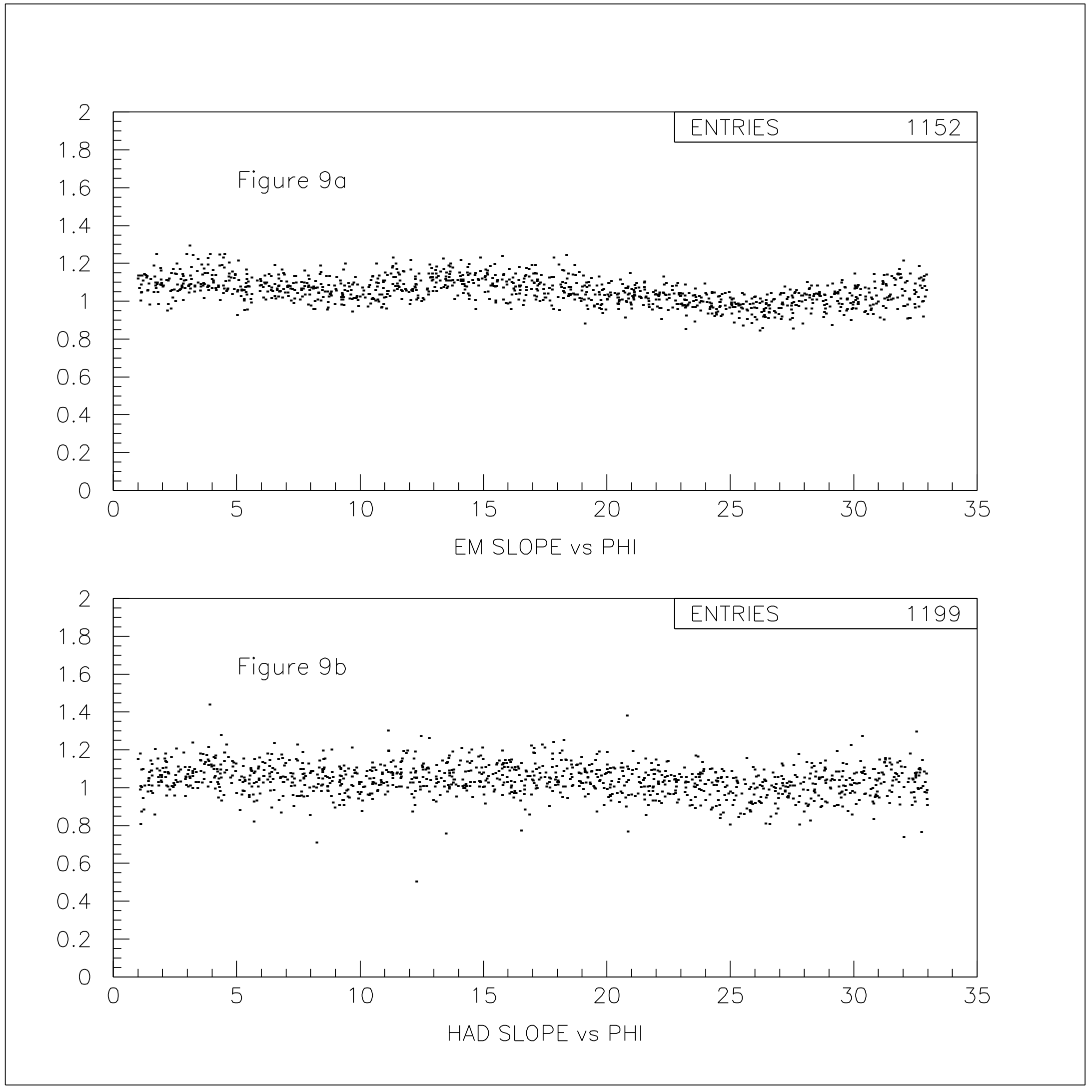

Figure 9: Slope of fit to a line versus ϕ for EM and HAD towers

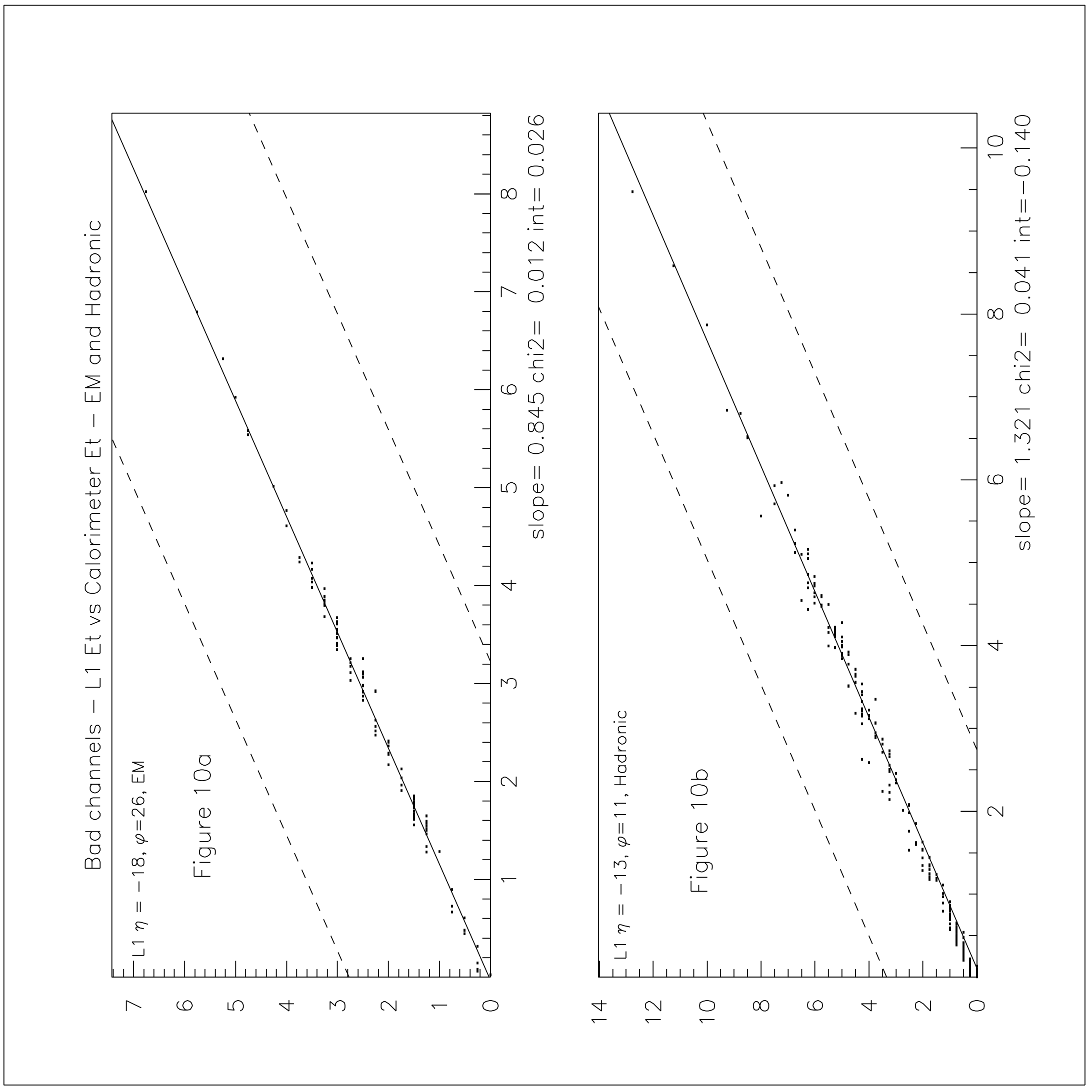

Figure 10: L1 vs CAL E_T for two trigger towers flagged as bad - the fitted line and deviation cut lines are also shown