The DØ Level 1 Trigger Calibration

DØ Note 1582
17 December 1992

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1 Introduction

This note describes the analysis and results of the level 1 trigger calibration out to the current instrumented range of $\eta = 3.2$. The energy measurement from the level 1 trigger is calibrated relative to the precision measurement from the calorimeter electronics at calorimeter high voltage settings of 2500 and 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 currently 1024 electromagnetic and 1024 hadronic trigger towers, 32 in ϕ and 32 in η (16 for $+\eta$ and 16 for $-\eta$).

2 Analysis

2.1 Calor_Off

The software package L1TRIG was written and put into the CALOR_OFF framework and used to process raw data runs read in from FATMEN. All trigger types were processed. The transverse energies (E_T) from the electromagnetic and hadronic towers in the trigger were obtained from the TRGR bank and the E_T's from the calorimeter readout cells were obtained from the CAEH bank. The information from the TRGR bank was pedestal subtracted and converted to GeV, and the information from the CAEH bank was pedestal subtracted and corrected by gains and sampling fractions and converted to GeV. The corrections were the same for the 2000 and 2500 volt data sets. For each trigger tower, the corresponding calorimeter cells were summed to form the respective calorimeter electromagnetic and hadronic towers. In each event, the code looped over all the trigger towers and if the E_T in either an EM or HAD trigger tower was greater than 3 GeV, then an entry was made to a data file listing the η and ϕ and the E_T's in both the EM and HAD trigger towers, the E_T's of the corresponding EM and HAD calorimeter towers and the E_T in each separate calorimeter cell in the tower. There were 38 runs (#50226 – 51271) with approximately 180,000 events analysed with the calorimeter high voltage set at 2500 volts and 23 runs (#52551 – 52796) with approximately 50,000 events at 2000 volts.

2.2 Saturation and Cuts

The rest of the analysis was done using a short program that read in and analysed the data files. A separate program made ntuples from the data files for PAW analysis. The saturation and cut values were chosen by studying plots of level 1 trigger E_T ($L1\_E_T$) versus calorimeter E_T (CAL_E_T) for each eta bin ($|\eta|$) for all the events written to the data files described above.

For each η, the trigger reaches its dynamic range at a certain E_T and saturates. The saturation value for each trigger η was measured in this study and was used to adjust the online triggering thresholds where necessary. Figure 1 shows the $L1\_E_T$ versus CAL_E_T for each value of trigger η for calorimeter high voltage = 2500 and Figure 2 shows the same plots for high voltage = 2000. The saturation values in E_T for each η are listed in Table 1 and shown in Figure 3.

TABLE 1

Level 1 trigger E_T saturation point				
	CAL HV = 2000 volts		CAL HV = 2500 volts	
L1 η	EM	HAD	EM	HAD
1	62	62	62	62
2	62	62	62	62
3	62	62	62	62
4	62	62	62	62
5	56	44	55	60
6	46	38	48	60
7	35	37	38	46
8	24	36	29	40
9	23	30	23	30
10	18	25	19	28
11	15	20	16	22
12	12	16	12	18
13	10	12	10	13
14	8	10	8	11
15	6	8	7	9
16	5.5	7	6	7

For the calibration of the L1 energy scale, cuts were applied to ensure that the events were below saturation, that they were above noise, and to remove spurious events. The calorimeter noise was evident by poor correlation between L1 and calorimeter energies. From studying the plots shown in Figures 1 and 2, the following cuts were chosen for the electromagnetic and hadronic trigger towers separately

- $L1\_E_T > 3$ GeV
- $\mathrm{CAL}\_E_T > 3$ GeV
- $\mathrm{CAL}\_E_T < \mathrm{Max\_Cal}\_E_T(\eta)$
- $L1\_E_T > m(\eta) \times \mathrm{CAL}\_E_T + b(\eta)$.

The values of $\mathrm{Max\_Cal}\_E_T$, m and b are listed in Table 2 for each η.

2.3 Calibration

The distributions of number of events surviving the cuts listed in Table 2 for the electromagnetic and hadronic towers are shown in Figure 4 for the 2500 volt data. A least-squares fit of the form

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

was done to calibrate each trigger tower that had at least 10 events surviving the cuts. For the 2500 volt data, 980 electromagnetic towers and 954 hadronic towers were calibrated. For the 2000 volt data 914 electromagnetic towers and 877 hadronic towers were calibrated.

3 Results

The distribution of χ^2 per degree of freedom for each tower is shown in Figure 5 for the 2500 volt data. The distribution of slopes and intercepts from the fits are shown in Figures 6-9 and in Figures 10-13 for the 2500 and 2000 volt data, respectively. The slopes versus trigger tower η are shown in Figures 14-15 and 16-17 for the 2500 and 2000 volt data, respectively. The slopes versus trigger tower ϕ for EM and hadronic towers for the 2500 volt data is shown in Figure 18. Table 3 lists the number of ϕ towers calibrated and the average fitted slopes and intercepts for each trigger η for the two different voltage settings. A plot of the $L1\_E_T$ vs CAL_E_T for single trigger towers is shown in Figure 19.

Channels which were not calibrated or whose calibration value was more than 20% off from the average where flagged and studied to determine if any hardware problems existed. Figure 20 and 21 show two channels which were calibrated and flagged as bad. The calibration could be off 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.

The calibrations for hadronic towers at $\eta = 7$ are low because the values of the pick-off resistors installed in hardware for the FH1 modules were calculated incorrectly. It is not understood at this time why the calibrations for the hadronic towers at $\eta = 5$ & 6 are low.

TABLE 2

CUT VALUES for CALIBRATION of LEVEL 1 TRIGGER						
CAL HV = 2000 volts						
	EM			HAD		
L1 η	Max_Cal_E_T(GeV)	m	b	Max_Cal_E_T(GeV)	m	b
1	48	.97	-5.8	40	1.25	-7.0
2	50	.96	-2.0	45	1.2	-6.0
3	56	1.08	-8.7	50	1.12	-8.0
4	52	1.09	-7.9	40	1.27	-6.0
5	50	1.08	-6.0	40	1.05	-6.0
6	48	1.08	-6.0	26	1.0	-4.0
7	28	1.0	-2.0	50	0.86	-6.0
8	28	1.03	-3.0	30	1.2	-5.0
9	25	1.0	-3.0	28	1.0	-3.0
10	20	.95	-2.0	19	1.25	-2.0
11	17	1.0	-2.0	16	1.38	-4.1
12	14	1.0	-2.0	14	1.41	-2.8
13	12	.92	-1.5	11	1.27	-1.5
14	10	.89	-.89	9	1.42	-2.4
15	8	.75	-.5	7	1.41	-2.8
16	6	2.17	-8.0	6	1.4	-1.4
CAL HV = 2500 volts						
	EM			HAD		
L1 η	Max_Cal_E_T(GeV)	m	b	Max_Cal_E_T(GeV)	m	b
1	48	.97	-5.8	40	1.3	-13.0
2	50	.96	-5.0	45	1.13	-9.2
3	56	1.08	-8.5	50	1.23	-8.0
4	52	1.09	-7.8	40	1.17	-7.3
5	50	.96	-6.0	40	.94	-3.5
6	48	1.05	-6.0	26	1.0	-7.0
7	38	.90	-3.5	50	.77	-8.7
8	28	1.0	-2.0	30	1.19	-2.8
9	25	1.0	-3.0	24	1.06	-5.4
10	20	1.0	-2.0	19	1.25	-2.0
11	17	.8	0.0	16	1.19	-2.4
12	14	.97	-2.2	17	1.38	-3.0
13	13	.94	-2.67	11	1.27	-1.7
14	11	.75	0.0	9	1.1	-1.0
15	8	.94	-1.5	7	1.0	0.0
16	6	.92	-0.8	6	1.5	-2.0

TABLE 3a

AVERAGE LEVEL 1 TRIGGER CALIBRATION VALUES HV = 2000						
		EM			HADRONIC	
L1 η	$\#\phi$ towers	average slope	average intercept	$\#\phi$ towers	average slope	average intercept
-16	4	1.124	-0.270	0	0.000	0.000
-15	30	1.034	0.046	1	1.325	-0.089
-14	32	1.005	0.088	23	1.331	0.137
-13	32	1.064	-0.012	32	1.324	0.070
-12	31	1.055	0.068	32	1.337	0.108
-11	32	1.099	-0.014	32	1.320	0.133
-10	32	1.104	0.047	32	1.338	0.046
-9	31	1.134	0.034	31	1.148	0.044
-8	32	1.129	0.005	32	1.165	-0.103
-7	2	1.085	-0.013	32	0.829	0.228
-6	32	1.098	0.037	24	1.001	0.091
-5	32	1.076	0.012	32	0.997	-0.073
-4	32	1.090	0.031	32	1.150	-0.027
-3	32	1.080	0.107	32	1.137	0.160
-2	32	1.081	0.052	32	1.139	0.068
-1	32	1.113	0.016	32	1.180	0.000
1	32	1.091	0.056	32	1.144	0.024
2	32	1.073	0.059	32	1.131	0.083
3	32	1.074	0.063	32	1.096	0.116
4	32	1.099	0.082	32	1.119	-0.060
5	32	1.065	0.066	32	0.961	0.009
6	32	1.055	0.107	25	1.030	-0.076
7	3	1.022	0.012	32	0.914	0.081
8	32	1.195	-0.049	32	1.258	-0.136
9	32	1.103	0.025	32	1.180	-0.016
10	32	1.099	0.108	32	1.372	0.094
11	31	1.104	0.027	32	1.376	0.036
12	32	1.083	0.060	31	1.404	0.061
13	32	1.064	0.117	31	1.358	0.197
14	32	0.993	0.209	30	1.354	0.195
15	31	1.003	0.102	9	1.341	0.255
16	15	1.070	-0.025	0	0.000	0.000

TABLE 3b

AVERAGE LEVEL 1 TRIGGER CALIBRATION VALUES

HV = 2500

	EM			HADRONIC		
L1 η	$\#\phi$ towers	average slope	average intercept	$\#\phi$ towers	average slope	average intercept
-16	29	1.042	0.042	2	1.278	0.267
-15	32	1.038	0.038	23	1.290	0.130
-14	30	0.985	0.431	32	1.301	0.176
-13	30	1.036	0.146	30	1.339	0.064
-12	32	1.080	-0.020	32	1.332	0.149
-11	32	1.116	-0.008	32	1.347	0.063
-10	32	1.124	0.059	32	1.364	-0.017
-9	31	1.150	0.037	32	1.158	0.019
-8	32	1.149	0.043	32	1.174	-0.044
-7	9	1.043	-0.018	32	0.834	0.403
-6	32	1.111	0.063	32	1.052	-0.129
-5	32	1.078	-0.002	32	1.013	-0.007
-4	32	1.106	0.071	32	1.167	-0.017
-3	32	1.108	0.069	32	1.174	0.115
-2	32	1.093	0.053	32	1.182	0.050
-1	32	1.132	0.040	32	1.208	-0.010
1	32	1.116	0.063	32	1.178	0.090
2	32	1.094	0.118	32	1.158	0.057
3	32	1.095	0.065	32	1.133	0.075
4	32	1.130	-0.005	32	1.153	0.005
5	32	1.068	0.076	32	0.976	0.022
6	32	1.082	0.053	31	1.040	-0.054
7	22	1.107	0.106	32	0.934	0.186
8	32	1.224	0.067	32	1.283	-0.129
9	32	1.129	0.070	32	1.177	0.074
10	32	1.116	0.101	32	1.408	0.003
11	32	1.127	0.016	32	1.407	0.045
12	32	1.110	0.035	32	1.408	0.165
13	32	1.069	0.179	32	1.389	0.129
14	32	0.993	0.279	32	1.370	0.199
15	32	1.026	0.084	30	1.398	0.115
16	29	1.047	0.120	6	1.422	0.168

4 Summary

From the first pass of the level 1 trigger calibration, the average calibration was determined to be ≈ 1.1 for the EM towers and ≈ 1.2 for the hadronic towers with a spread of approximately 10%. This analysis also allowed determination of the saturation points which were used in determining trigger thresholds and gave another handle on finding bad hardware.