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Trigger tower organization and summing in $\eta - \phi$ space for Run II and beyond

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This updated note contains several significant changes:

- E_t **weighting will be done on the front-end cards.**
- **Since there are no phototubes on CHA tower 8 it has been removed from all lists.**
- **Since PHA tower 11 is very small, consisting of only 2 layers of iron and scintillator, it will not be used in the trigger. However, it is instrumented on the front-end cards.**
- **There is no change in the number of front-end cards needed. There are changes in the number of channels used on the CHA cards and trigger sums output on the PHA cards.**

1 Introduction

For Run II and beyond the Tevatron bunch spacing will be smaller either 132 or 396 nsec. We will also have a new plug calorimeter[1] with a new tower organization. In order to trigger with the shorter bunch spacing, a fully pipelined L1 trigger is being designed with a latency of approximately 4μs and producing a L1 accept or reject every bunch crossing (e.g. 132nsec). A group of us has been thinking about L1 for a long time [2, 3, 4]: this note describes only the organization of the trigger towers in $\eta - \phi$ space, and makes a first crack at the tower organization on the front-end cards.

2 Calorimeter physical towers

The proposed $\eta - \phi$ map of the hadron (HAD) and electro-magnetic (EM) calorimeters for Run II are given in Table 1 [5, 6]. Included is the $\sin\theta$ for the center of each tower.

The hadron calorimeter is organized in 44 towers in η (22 per side) by either 15 degrees (15 of the 22) or 7.5 degrees (7 of the 22) in ϕ. The HAD and EM towers have a one-to-one correspondence in η and ϕ except for tower 10 where the EM (plug) has a ϕ segmentation of 7.5° while the HAD(wall) has a ϕ segmentation of 15°. This has to be taken into account in the front end cards both for channel count and for trigger summing, and is discussed below.

3 Trigger towers

The trigger is organized as 24×24 towers in $\eta - \phi$ space, for a total of 576 towers each for the EM and HAD calorimeters (1152 total) compared to 1008 each (2016 total) currently. The physical towers are summed into trigger towers of 15° in ϕ by approximately 0.2 in η. The last column of Table 1 lists the trigger tower corresponding to each physical tower.

Table 2 lists the trigger towers, the corresponding η regions, $\sin\theta$'s (E_t weight) and corresponding physical calorimeter towers. Also listed is the number of phototubes included in each trigger tower from each component (central, wall, or plug; EM or Had) of the calorimeter. Trigger towers 9 and 10 each consist of only one physical tower in η to maintain the approximately 0.2 segmentation for $|\eta| < 2.6$. In the Central and wall regions the ϕ segmentation is 15° and 2 phototubes per physical tower, resulting in 4 phototubes per trigger tower sum. In the plug, trigger towers 5-8 have a ϕ segmentation of 7.5° and 1 phototube per physical tower again giving 4 phototubes per trigger tower sum. Trigger towers 9-11 in the plug have fewer tubes summed since the physical ϕ segmentation is only 15°.

The tubes involved in each trigger tower from a given detector section (CEM, PEM, CHA, WHA and PHA) will be summed on the front-end cards after digitization. Since there is overlap between the CHA and WHA in trigger tower 4, the trigger tower sums from the CHA and WHA for this tower will be summed into one signal upstairs. The front end boards output individual signals for 576 EM trigger towers and 624 HAD trigger towers (1200 total). Upstairs the hadron portion is reduced to 576 towers.

4 E_t Weighting

All Level 1 and Level 2 trigger thresholds are set in E_t rather than E. Therefore, the raw energies digitized and summed on the front-end cards must be weighted by the $\sin\theta$ of the trigger towers for input to the trigger. Table 2 gives the $\sin\theta$ for each trigger tower which range from about 1 to 0.1. The trigger will have a dynamic range of 10 bits in E_t. To minimize the required bandwidth for the cable plant between the front-end cards and the trigger this weighting will be done on the front-end cards.

5 Summing physical towers into trigger towers

Table 3 describes the breakdown of the trigger tower summing for the Central, Wall and Plug detector regions. The second and third columns of the table give the physical tower number and its η_{min}. The fourth and fifth columns list the width in ϕ of the physical towers. The last three columns list the number of physical towers/phototubes summed for each trigger tower in EM, HAD and total. In the plug, there is one phototube per physical tower so only one number is given.

The number of phototubes summed into trigger towers has an impact on the number of input channels per front-end card. We outline a scheme which uses 2 types of cards:

Central Cards with 20 inputs and 5 trigger outputs and trigger sums consisting of 4 inputs.

Plug Cards with 20 inputs and 7 trigger outputs. The summing required for each channel of card type 2 is listed in Table 5.

Table 4 lists cards needed for a wedge giving the detector section, physical input, trigger towers output, number of inputs used and number of outputs used. There are two Central Cards for each 15° wedge (east or west), one for CHA and one for CEM. The last four input channels and their corresponding trigger sum on the CHA card are not used. For every three WHA wedges there are 36 inputs and 9 trigger sums fitting on 2 Central cards. One WHA card has wedge 0 plus 2/3 of wedge 1 while the next card has 1/3 of wedge 1 plus all of wedge 2. There are two Plug cards for each 15° wedge (east or west), one for PHA and one for PEM.

Table 5 describes how the trigger tower summing is done on the Plug boards. The first 4 trigger outputs are the sum of 4 inputs each, the 5th and 6th outputs consist of single inputs, and the 7th output is the sum of of the 2 inputs. On the PHA card the first inputs and the first trigger output are not used. This trigger output is the sum of the first 4 channels but energy deposition expected in the 3rd and 4th channels does not justify their use in the trigger.

Table 6 enumerates the number of front-end cards and channels used in each section of the detector. There are 224 total cards: 128 central cards and 96 plug cards.

References

[1] The CDF Collaboration, *Proposal for an upgraded CDF Detector*, CDF/DOC/PUBLIC/1172, 1990.

[2] Claudio Campagnari, M. Miller and G. Sullivan, *Preliminary Design for the 1993 Level 0 Trigger*, CDF/DOC/TRIGGER/CDFR/1167, 1990.

[3] Claudio Campagnari, M. Miller, M. Shochet and G. Sullivan, *Estimates of trigger rates and efficiencies for the 1993 CDF calorimeter Level 0 Trigger*, CDF/DOC/TRIGGER/CDFR/1180, 1990.

[4] E. Blucher *et al.*, *Conceptual Design of a Dead-timeless Trigger for the CDF Trigger Upgrade*, CDF/DOC/TRIGGER/CDFR/2038, 1993.

[5] Hans Jensen, *Eta - phi segmentation of the CDF Calorimeter*, CDF-0139 (1986).

[6] The new plug segmentation is courtesy of mail messages from Peter Limon.

Table 1: Calorimeter tower organization for one half of the calorimeter (east or west). The tower boundaries in η and θ are given along with $\sin\theta$ of geometric tower center. The last column lists the trigger tower into which each physical tower is summed.

Physical Tower	η_{min}	η_{max}	$\Delta\eta$	θ_{max} (Degrees)	θ_{min}	$\sin\theta$	$\Delta\phi_{had}$ (Degrees)	$\Delta\phi_{em}$	Trig. Tower
0	0.000	0.131	0.131	90.00	82.53	0.998	15.0	15.0	0
1	0.131	0.260	0.129	82.53	75.30	0.981	15.0	15.0	0
2	0.260	0.384	0.124	75.30	68.51	0.951	15.0	15.0	1
3	0.384	0.503	0.119	68.51	62.31	0.909	15.0	15.0	1
4	0.503	0.616	0.113	62.31	56.73	0.862	15.0	15.0	2
5	0.616	0.723	0.107	56.73	51.79	0.812	15.0	15.0	2
6	0.723	0.823	0.100	51.79	47.43	0.762	15.0	15.0	3
7	0.823	0.916	0.093	47.43	43.61	0.714	15.0	15.0	3
8	0.916	1.004	0.088	43.61	40.26	0.668	15.0	15.0	4
9	1.004	1.100	0.096	40.26	36.82	0.623	15.0	15.0	4
10	1.100	1.200	0.100	36.82	33.52	0.576	15.0	7.5	5
11	1.200	1.317	0.117	33.52	30.00	0.526	15.0	7.5	5
12	1.317	1.415	0.098	30.00	27.31	0.479	7.5	7.5	6
13	1.415	1.523	0.108	27.31	24.60	0.438	7.5	7.5	6
14	1.523	1.643	0.120	24.60	21.89	0.395	7.5	7.5	7
15	1.643	1.777	0.134	21.89	19.20	0.351	7.5	7.5	7
16	1.777	1.931	0.154	19.20	16.50	0.306	7.5	7.5	8
17	1.931	2.112	0.181	16.50	13.80	0.261	7.5	7.5	8
18	2.112	2.331	0.219	13.80	11.10	0.216	15.0	15.0	9
19	2.331	2.611	0.280	11.10	8.40	0.169	15.0	15.0	10
20	2.611	3.000	0.389	8.40	5.70	0.123	15.0	15.0	11
21	3.000	3.510	0.510	5.70	3.43	0.079	15.0	15.0	11

Table 2: The 12 trigger towers in η on one side of the detector with the correspondence to the physical tower numbering. The minimum η and width in η are given. The polar angle of the tower (θ_{tr}) is calculated using the mean η of the tower ($\eta_{tr} = \eta_{min} + \Delta\eta/2$). The E_T weight of the trigger tower is given by $\sin\theta_{tr}$. Also given are the number of phototubes per trigger tower (15° in ϕ) in each section of the calorimeter.

Trigger Tower	η_{min}	$\Delta\eta_{tr}$	θ_{tr} (Deg)	$\sin\theta_{tr}$	Physical Towers	Number of Tubes Included				
						CEM	CHA	WHA	PEM	PHA
0	0.000	0.260	82.65	0.992	0,1	4	4	-	-	-
1	0.260	0.243	68.80	0.932	2,3	4	4	-	-	-
2	0.503	0.220	57.05	0.839	4,5	4	4	-	-	-
3	0.723	0.193	47.70	0.740	6,7	4	4	4	-	-
4	0.916	0.184	40.22	0.646	8,9	4	-	4	-	-
5	1.100	0.217	33.41	0.551	10,11	-	-	4	4	-†
6	1.317	0.206	27.30	0.459	12,13	-	-	-	4	4
7	1.523	0.254	21.90	0.373	14,15	-	-	-	4	4
8	1.777	0.335	16.50	0.284	16,17	-	-	-	4	4
9	2.112	0.219	12.45	0.216	18	-	-	-	1	1
10	2.331	0.280	9.75	0.169	19	-	-	-	1	1
11	2.611	0.899	5.91	0.103	20,21	-	-	-	2	2

† There is a small PHA Tower 11 which will not be used in the trigger.

Table 3: Trigger tower summing. Number of towers and phototubes summed per 15° wedge for each trigger tower.

Tower		η_{min}	$\Delta\phi_{had}$	$\Delta\phi_{em}$	Towers/Tubes per 15°		
Trg	Phy		(Degrees)		N_{had}	N_{EM}	Total
Central:							
0	0	0.000	15	15	1/2	1/2	2/4
	1	0.131	15	15	1/2	1/2	2/4
1	2	0.260	15	15	1/2	1/2	2/4
	3	0.384	15	15	1/2	1/2	2/4
2	4	0.503	15	15	1/2	1/2	2/4
	5	0.616	15	15	1/2	1/2	2/4
3	6	0.723	15	15	1/2	1/2	2/4
	7	0.823	15	15	1/2	1/2	2/4
4	8	0.916	-	15	0	1/2	1/2
	9	1.004	-	15	0	1/2	1/2
Total:					8/16	10/20	18/36
Wall:							
3	6	0.723	15	-	1/2	0	1/2
	7	0.823	15	-	1/2	0	1/2
4	8	0.916	15	-	1/2	0	1/2
	9	1.004	15	-	1/2	0	1/2
5	10	1.100	15	-	1/2	0	1/2
	11	1.200	15	-	1/2	0	1/2
Total:					6/12	0	6/12
Plug							
5	10	1.100	-	7.5	0	2	2
	11	1.200	-	7.5	0	2	2
6	12	1.317	7.5	7.5	2	2	4
	13	1.415	7.5	7.5	2	2	4
7	14	1.523	7.5	7.5	2	2	4
	15	1.643	7.5	7.5	2	2	4
8	16	1.777	7.5	7.5	2	2	4
	17	1.931	7.5	7.5	2	2	4
9	18	2.112	15	15	1	1	2
10	19	2.331	15	15	1	1	2
11	20	2.611	15	15	1	1	2
	21	3.000	15	15	1	1	2
Total:					16	20	36

Table 4: Front-end card organization using 2 card types. All of these cards cover a 15° wedge except the WHA which uses 2 cards for every 3 wedges.

Card	Calor. Section	Card Type	Towers Input	Trigger Output	Inputs Used	Outputs Used
1	CEM	Cent.	0-9	0-4	20	5
2	CHA	Cent.	0-7	0-3	16	4
3	WHA	Cent.	6-11	3-5	20,16	5,4
4	PEM	Plug	10-21	5-11	20	7
5	PHA	Plug	11-21	6-11	18	6

Table 5: Trigger summing for Plug cards.

Trigger Output	Trigger Tower	Input Towers	Input Channels
1	5	10,11	1-4
2	6	12,13	5-8
3	7	14,15	9-12
4	8	16,17	13-16
5	9	18	17
6	10	19	18
7	11	20,21	19,20

Table 6: Front-end card card count. Central cards have 20 inputs and 5 trigger outputs while Plug cards have 20 inputs and 7 trigger outputs. Also listed is the number of front-end channels used/unused in each region.

Region	Cards/15° per side	Card Type	Total Cards	Input Channels Used	Unused	Total
Central	2	Cent	96	1728	192	1920
Wall	2/3	Cent	32	576	64	640
Plug	2	Plug	96	1824	96	1920
Total:	4 2/3		224	4128	352	4480