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Users Guide for Level 1 Electron, Photon and Jet Triggers

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1 Introduction

This note describes the capabilities of the Level 1 calorimeter trigger for run II focusing on what types of tower based triggers are possible. The goal is to describe what is possible for anyone who is designing trigger requirements for Run II. We will not discuss in detail the design of the trigger hardware as this can be found in previous notes[1, 2, 3, 4]. The basic architecture divides the functions into triggers with thresholds applied at the trigger tower level (electron, photons, and jets) and globally ($\not{E}_{\mathrm{T}}$,ΣE_T).

The tower based triggers are divided into those where a single instance in the whole detector is required, single object triggers, and those where two or more are required, di-object triggers. For each single object trigger, a single bit is allocated on each DIRAC board which is then ORed across the whole detector. For di-object triggers, two bits are allocated and summed across the whole detector. There is some flexibility in the latter stages which permits ϕ correlation in di-object triggers; these capabilities will be described in Section 5.

2 Trigger Tower Segmentation

The trigger tower segmentation is the same as for the central detector in Run 1: 0.2×15^o in $\eta - \phi$ space[5]. Each DIRAC board covers 6 towers in η (same ϕ), with both EM and HAD inputs for each tower. Each 15^o wedge is divided among 4 DIRAC boards:

East Plug $-3.5 < \eta < -1.3$

East Central $-1.3 < \eta < 0.0$

West Central $0.0 < \eta < 1.3$

West Plug $1.3 < \eta < 3.5$

The two Central boards for each wedge receive 8 track bits from the XTRP, corresponding to whether a track passing a specified threshold was found to point at the wedge. The threshold can include sign and whether the track has the SL6 (high-η) bit set. Since there is no stereo tracking information at Level 1, both Central boards receive the same tracking information. No tracks are available for the Plug boards but the hardware is capable of handling them if they were available.

3 Tower Thresholds

Sixteen thresholds are defined for each trigger tower: eight for electromagnetic (EM) triggers and eight for jet triggers (TOT=HAD+EM). Each threshold corresponds to a specific combination of tower E_T and track P_T. Table 1 shows the inputs for each trigger tower decision. The calorimeter energy is 8 bits (EM or Total) with a least count of 250 MeV[1]. If a tower has an energy above the full scale, all bits will be turned on indicating a full scale energy. For the electromagnetic triggers, 3 bits of hadronic energy from the same tower is available to provide HAD/EM cuts for low energy electron triggers. The thresholds are applied using one Static RAM for each EM tower (8 output bits) and one for each TOT tower (8 output bits). Since the decisions are made in memory, both upper and lower thresholds can be applied. In the case of EM triggers this feature can be exploited on the 3 bits of HAD energy to limit HAD/EM.

Table 1: Inputs per trigger tower

Input	Bits	Least Count	Full Scale
Electromagnetic Triggers:			
EM Energy	8	250 MeV	63.75 GeV
Tracks	4		
HAD Energy	3	125 or 250 MeV	875 or 1750 MeV
Jet Triggers:			
EM + HAD Energy	8	250 MeV	63.75 GeV
Tracks	4		

The size of the SRAMs will not permit routing all 8 tracking bits received from the XTRP into each trigger tower decision. Instead each tower receives 4 bits of tracking information, encoding up to 8 different track thresholds. A description of the tracking inputs appears in the next section.

A maximum of 8 different EM triggers and 8 different TOT triggers are possible. A total of 16 bits can be passed between the DIRAC and CRATESUM boards. Under certain circumstances, fewer than 16 total triggers can be passed on from the DIRAC boards. If some of the di-object triggers are to allow for more than one tower on a single DIRAC card this will take a second bit thus restricting the output to CRATESUM. The default configuration[2, 3] has 10 single bit triggers and 3 di-object triggers defined on DIRAC. The allocation of these 13 triggers between EM and TOT type triggers is down-loadable.

In hardware, the thresholds for trigger bits are defined independently for each tower in the detector allowing for η dependent thresholds. For example, the high E_T photon trigger bit could require $E_T > 10$ GeV in the Central and $E_T > 15$ GeV in the Plug using the

[1] A register can be set changing the lsb for all energy to 500 MeV if the full scale is too low with 250 MeV.

same bit. This is similar to the L1 Calorimeter trigger in Run 1 when the EM and HAD threshold results were OR'd into one trigger bit (except the low $P_T$di-electron). In addition, each trigger must have a threshold defined (could be infinite) for each tower since the bits are summed across the detector (bit 1 in plug will be summed with bit 1 in central etc). However, we will not maintain a database of thresholds for all 576 towers. Instead, the plan is to implement common thresholds within the 4 η regions listed in Table 2. This structure will be implemented in the trigger table and loading software. Since RAMs are used, thresholds can be set as windows and undesirable regions can be excluded by forcing the output bit to always be 0 (infinite threshold).

Table 2: Regions of different thresholds for a given trigger

Region	$\|\eta\|$ Range	Board	Tracking
Central	0.0-1.1	Central	4 Layer (SVT at L2)
Outer Plug	1.1-1.3	Central	3 Layer
Plug	1.3-2.6	Plug	No
Inner Plug	2.6-3.5	Plug	No

4 Tracking Inputs

The basic track thresholds are applied in the XTRP and projected out to calorimeter wedges. Eight thresholds are allowed per wedge. Each threshold can cut on the following information: P_T, Sign, SL6/8 bit (3 or 4 layers), and Isolation bit. These 8 bits are sent to the two central cards for each wedge. Table 3 lists a possible assignment of the 8 thresholds.

Table 3: Example of assignment of track thresholds for calorimeter triggers

Bit	P_T Threshold (GeV/c)	Sign	Number of Layers
0	2.0	+	4
1	2.0	-	4
2	4.0	+ or -	4
3	8.0	+ or -	4
4	12.0	+ or -	4
5	6.0	+ or -	3
6	10.0	+ or -	3
7	15.0	+ or -	3

After receipt by the DIRAC card, the 8 threshold bits are sent to SRAMs which map them into six sets of 4 bits which are sent to the 6 trigger towers on the board. Each of the six sets can be mapped independently allowing higher η towers to receive different bits than lower η towers. The same set is used for both the EM and HAD decisions for each tower. Table 4 describes how the tracking thresholds might be encoded into this 4 bit "word". In this example, the lowest 2 bits are used for a signed low P_T di-electron threshold. The upper 2 bits encode the threshold of the upper unsigned thresholds.

Table 4: Example of track words to a tower in central DIRAC cards

Track Word(0:1)	Track Word(2:3)	Track(s)
0	0	No Track
1	-	2.0 GeV (negative)
2	-	2.0 GeV (positive)
3	-	2.0 GeV (both signs)
-	1	4. GeV
-	2	8. GeV
-	3	12. GeV

5 Defining Di-object Triggers

The counting of di-object triggers (e.g. di-electrons) can be done in several different ways within the calorimeter trigger. The rules for summing are that a maximum of 2 bits per trigger will be allowed as an output from each hardware level (DIRAC or CRATESUM). The following list describes the different methods of forming di-object triggers:

1. Count all towers above threshold across all η-ϕ (except for regions with thresholds set to ∞). This is the default method which has been implemented in CRATESUM and PreFRED. This requires 2 bits out of each DIRAC card and 2 bits out of each CRATESUM card.

2. Allow only one object per DIRAC card (one quarter wedge) and start summing at the CRATESUM level forming the number of DIRAC cards with a tower over threshold. This requires 1 bit out of each DIRAC card and 2 bits out of each CRATESUM card.

3. Same as number 2 except OR together 4 DIRAC cards from each wedge and transmit 1 bit per wedge to PreFRED for summing (only one object per edge). Because of the flexibility of the PreFRED design, it is possible to make requirements correlating the ϕ between the towers in this case (e.g. non-adjacent wedges or not back-to-back). This requires 1 bit out of each DIRAC card and 2 bits out of each CRATESUM card.

4. Same as 3 except allow only one bit per CRATESUM board (one object per two wedges) and sum only at the PreFRED level. Again can require ϕ correlations. This requires 1 bit out of each DIRAC card and 1 bit out of each CRATESUM card.

5. At CRATESUM could also do η correlations between DIRAC cards in 2 wedges. For example, form forward and backward bits instead of wedge bits. This requires 1 bit out of each DIRAC card and 2 bits out of each CRATESUM card.

6. At PreFRED require ϕ correlation between single bit of two different thresholds. For example, an opposite charge not back-to-back di-electron for $\psi \to e^+e^-$ (See below). This requires 2 bits out of each DIRAC card and 2 bits out of each CRATESUM card.

Only the first method is being implemented at this time. Implementing the other methods will require modifying the FPGA programs that perform the summing on the

CRATESUM and PreFRED boards. This is not a terribly difficult task but will not be done frequently or without significant justification. Also note that there is a limit to the total number of bits passed between these boards. This will restrict how many special cases can be satisfied.

5.1 Example: low pt di-electron trigger

A possible way to significantly increase the trigger efficiency for $\psi \to e^+e^-$ is to lower the $\mathrm{E_T}$ threshold but impose restrictions on the sign and angular separation of the electron and positron. The following is an example of how this could be done. Actual rates for such a trigger will have to be determined.

DIRAC At the quarter wedge level have 2 single-bit triggers requiring: $\mathrm{E_T} > 2.0$ GeV, $\mathrm{P_T} > 2.0$ GeV/c, $HAD/EM <?$. One would be set for positive tracks and the other for negative tracks. In the case where a track of each sign is present, set both bits.

CRATESUM OR together the 8 positive bits for 2 wedges and OR together the negative bits for 2 wedges. Output is an Electron bit and a positron bit.

PreFRED Receive 12 positron bits and 12 electron bits. Require at least one positron and one electron which satisfy: $\Delta\phi(e^+ - e^-) < 120^o$.

Note that if there are opposite sign tracks pointing at a single tower they can fire this trigger. This is necessary since it is not known *a priori* whether to pass the electron or the positron on to the next stage. If both aren't passed on then there is a loss of events where two tracks point at one leg of the ψ. The effect on rates of this arrangement will have to be measured.

References

[1] H. Frisch, M. Shochet, G. Sullivan, D. Toback, J. Wahl and P. Wilson *Conceptual Design of the L1 Calorimeter Trigger for the Run II Upgrade*, CDF/DOC/TRIGGER/CDFR/2909, (1994).

[2] J. Wahl, *DIRAC - The FINAL Specification*, CDF/DOC/TRIGGER/4225, (1997).

[3] D. Toback, *CRATESUM - Upgrade for Run II*, U.Chicago Trigger note TGN-91, (1995).

[4] A. Amadon, M. Bogdan, and P. Wilson, *Specifications and Design of the Level 1 Calorimeter Trigger PreFRED Modules fo rhte Run II Upgrade*, CDF/DOC/TRIGGER/4340, (1997).

[5] H. Frisch, M. Shochet, G. Sullivan and P.J. Wilson, *Trigger Tower organization and summing in $\eta - \phi$ space for Run II and beyond*, CDF/DOC/TRIGGER/CDFR/2045, 1994.