SDC-91-100

SDC
SOLENOIDAL DETECTOR NOTES

PROPOSAL FOR THE SDC LEVEL 1 TRIGGER DESIGN OR IS A SIMPLE L1 ADEQUATE FOR SDC?

April 19, 1992

M. Contreras, H. Frisch, C. Grosso-Pilcher, S.C. Eno, M. Miller,
L, J. Rosenberg, H. Sanders, M. Shochet and G. Sullivan
University of Chicago

SDC-91-00100
April 10, 1992

Proposal for the SDC Level 1 Trigger Design or Is a Simple L1 Adequate for SDC?

M. Contreras, H. Frisch, C. Grosso-Pilcher, S.C. Eno, M. Miller,
L.J. Rosenberg, H. Sanders, M. Shochet, G. Sullivan
Univ. of Chicago

1 Introduction

In a hadron collider the trigger is the start of the physics event selection process. At SDC the trigger will analyze on the order of 10^8 events per second. The analysis is done in real time, and there is no going back to recover mistakes. A decision to retain an event for further consideration has to be made every 16 nsec. It is essential for publishing correct and timely physics to know the efficiencies for different physics signatures, to check that everything is working, and to have clear and adequate book-keeping.

In the broadest terms, the trigger must process the $\approx 10^8$ interactions per second and reduce this to the $50 - 100$ Hz that can be written to tape. The physics rate from Top, $W's$, and $Z's$ alone is on the order of 50 Hz, so the necessary 10^6 rejection must be achieved with very little room to spare on the physics.

The intent of this note is to motivate and describe a design for the Level 1 trigger. We believe this design fits well within the overall structure of the multi-level trigger and represents a reasonable balance of loads between level 1 and level 2.

The guiding principle behind this level 1 design was to keep things as simple as reasonably possible. In an alternative Level 1 design, described elsewhere [1, 2], more emphasis was placed on the desire to get the lowest possible inclusive thresholds in

level 1 at the expense of some added complexity. There are obvious tradeoffs between the two designs. Where the tradeoffs are made are a matter of physics requirements and, in some sense, philosophy. In our judgement the simpler design is sufficient to do the physics and the added complexity is not justified by the incremental decrease in threshold which is achieved. We believe that the virtues inherent in any simpler system (i.e. reliability, ease of use, understandability, and economy) apply here. A simpler Level 1 system, with the main purpose of just reducing the rate to the point were Level 2 can operate, will be more reliable, easier to use, and easier to characterize. Then, Level 2 can operate on the data with more sophisticated algorithms in a much more economical way, and has the further benefit of increased programmability.

The design as we present it below has optical fibers [3, 4] bringing up trigger signals to a mapping of the detector in the control room. However in some systems it makes sense to do the pattern recognition on the detector; this is particularly true of tracking systems with a large number of channels where the fiber count would be enormous. The advantage to downstairs is the decrease in fiber count- the advantages to upstairs are access and the clean interface between front-end and trigger responsibilities. In reality we will probably end up with a mix. There are still open questions here for several of the subsystems and for the trigger as a whole.

One final introductory comment- the trigger is only as good as the quality of the signals from the detector. The problem of digitizing signals from an extended scintillator source at 60 MHz is not trivial. It will be necessary to have collaborative efforts with front-end groups to certify the quality of the fast-out signals.

1.1 Level Structure of the Trigger

A three level structure lends itself quite naturally to the problem of triggering at the SSC. Trigger components that must operate at the full 60Mhz beam crossing rate would require fast, and therefore, expensive electronics. Also, the constraint of minimal latency, to match the size of front-end buffers, necessitates that the algorithms used at 60MHz speeds must be essentially hardwired and limited in sophistication. For these reasons there is a lot to be gained by immediately "knocking down" the rate with a modest level 1 trigger. The second level trigger can then work at more economical speeds, with pipelined steps on the order of $10\mu S$, to reduce the rate to that at which a high level commercial computer farm can readout and process the events. The third level essentially has the full power of an offline reconstruction to select the $50 - 100$ Hz of events, at the required high purity, that are written to tape. A schematic diagram of the dataflow for SDC is shown in Fig. 1.

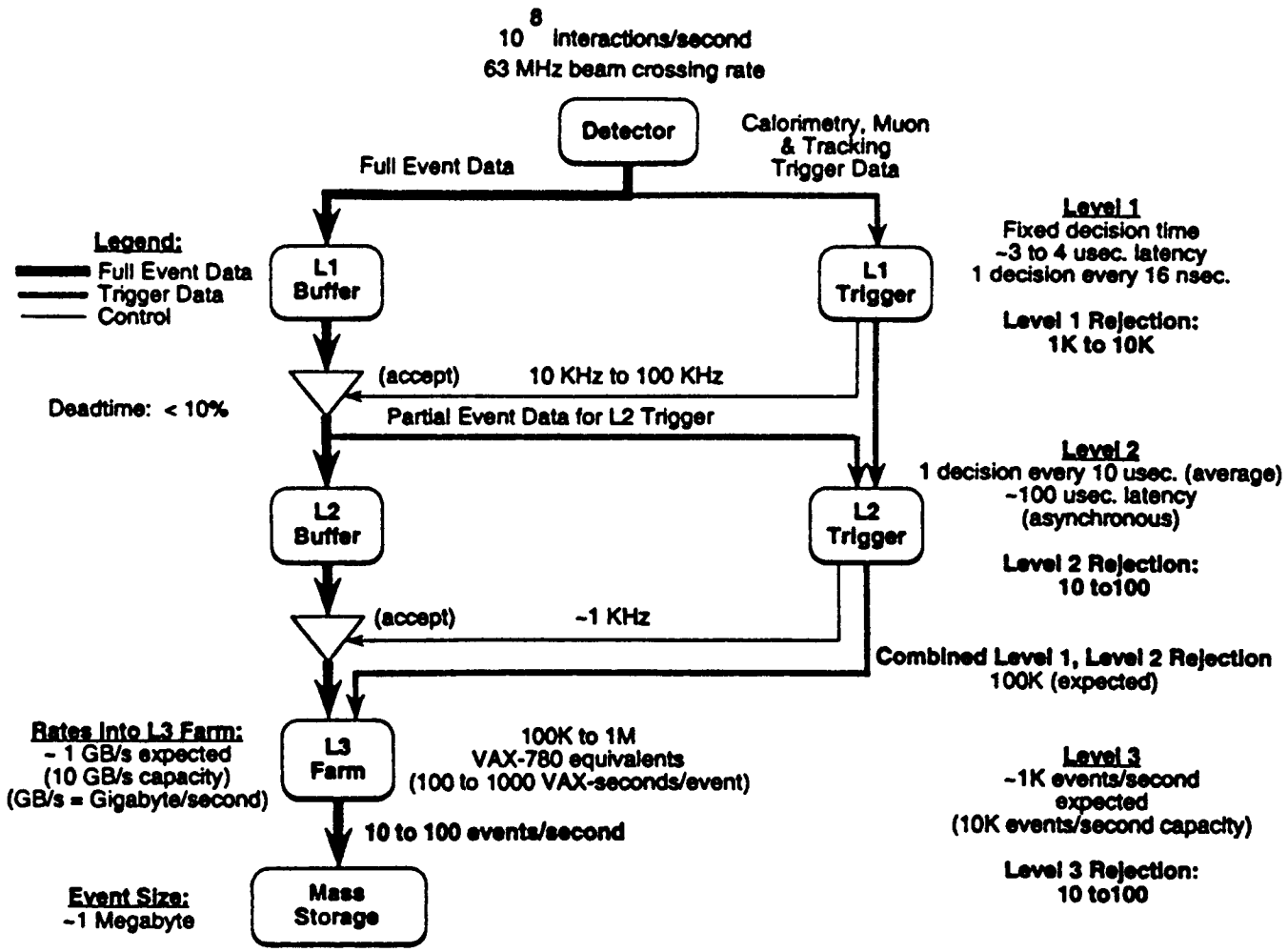

Figure 1: The SDC data flow and trigger structure (from TDR).

Level 1

Level 1 is the first level trigger, and operates synchronously at 60 MHz within the time that every crossing is stored in the data pipeline ($\sim 4\mu S$) so that it is nearly deadtimeless. Simply stated, the goal of the Level 1 trigger is to reduce the rate from 60M MHz to the $10 - 100$ kHz at which Level 2 can operate with a high efficiency for the physics processes of interest to SDC. The target rate for Level 1 has been chosen to be $20 - 30$ kHz at 10^{33} divided equally between muon and calorimeter triggers [4]. To achieve this goal Level 1 makes "local" decisions based on trigger towers over threshold, stiff track segments, and muon segments to find electron, photon, muon, hadron, and jet candidates. Global energy sums are made to form triggers from ΣE_T and missing E_T.

Level 2

Whereas Level 1 has to make a decision within 4 microseconds of every crossing (and of the 4 microseconds less than 2 are available to L1- the rest are in transit times) and is synchronous at 60 MHz, Level 2 can take up to ~ 50 microseconds, and is asynchronously buffered at the Level 1 trigger rate of approximately $20 - 30$ KHz. These two differences make Level 2 much more flexible than Level 1 since commercial processors using programmable algorithms can be used. Level 2 is the place then that we deal with information that arrives too late or is too complicated to use in Level 1. Level 2 must reduce the rate to a few kHz, the rate at which the detector can be read out and Level 3 process the events.

Level 2 has access to all of the same information that Level 1 does through the trigger crate bus structure. In addition Level 2 can access information not available at Level 1 time, such as the information from the silicon vertex detector, refined tracking information, refined muon information, and detailed shower-max information; all of which have a separate data path upstairs and are therefore available to Level 2. Level 2 uses this refined information in "clustering" algorithms to generate a digital list of electrons, muons, photons, hadrons, and jets from which a final decision is made.

Level 3

Level 3, which consists of an array of commercial computers, does reconstruction and event filtering with the primary goal of making data sets of different signatures on easily accessed media. We envisage that data sets of processes with clear signatures (e.g. multileptons, W's, Z's, high P_T leptons, large missing E_T, etc.) would be

selected in Level 3 for the final analyses. "Tape" would be used largely for archival purposes and for those analyses not yet mature enough to move the event selection into Level 3.

2 Trigger Rates and System Considerations

In order to study the issues of subsystem segmentation and inclusion, at Levels 1 and Level 2, a fast monte carlo was developed to study trigger rates at the SDC [5]. The results shown here are from a refined version of the simulation used in the previous study which now includes electron bremsstrahlung, tracking inefficiencies, and the shower-maximum detector. The background trigger rates shown here are from QCD two-jet events, for jet P_T between 20 and 200 GeV, with minimum bias events for a luminosity of 10^{33} overlayed. These results include the calorimeters for both the barrel and endcap regions ($|\eta| < 3.0$).

The purpose of showing these rates here is to motivate the use of a simple single-tower-over-threshold trigger without using isolation at Level 1.

Fig. 2 shows QCD background rate versus the trigger tower E_t threshold for the inclusive electron and photon triggers. The solid curve is for tower E_t above threshold only, the requirement of tower $HAC/EM < 0.05$ gives the non-isolated single photon rate (dashed curve), and finally requiring a track with $p_t > 10$ GeV to match in ϕ with the tower gives the inclusive non-isolated electron rate (dotted curve). Fig. 3 shows the efficiency of the inclusive non-isolated electron trigger for $W \rightarrow e + \nu$ events. Fig. 4 shows the QCD background rate versus the trigger tower E_t threshold for the di-electron and di-photon triggers. The first curve (solid) is for any two towers above E_t threshold, requiring $HAC/EM < 0.1$ yields the di-photon rate (dashed), additionally requiring a track with $p_t > 10$ GeV to match in ϕ with the tower gives the non-isolated di-electron rate (dotted curve).

We have studied which background processes contributed significantly to the electron using detailed information about the particles incident at the calorimeter face of the electron trigger tower rates [5]. These studies indicated that the main contribution to the level 1 trigger rate is conversion electrons. Therefore, using the shower maximum detector, to reduce the background from the ϕ overlap between a photon and charged track, should only slightly reduce the level 1 rate. Fig. 5 shows the effect of using the shower maximum detector to reduce the background from overlaps. The figure shows the QCD rate versus the trigger tower E_t threshold for the inclusive electron trigger. The solid curve is for tower E_t above threshold only, requiring $HAC/EM < 0.05$ and a track with $p_t > 10$ GeV to match in ϕ with the tower gives

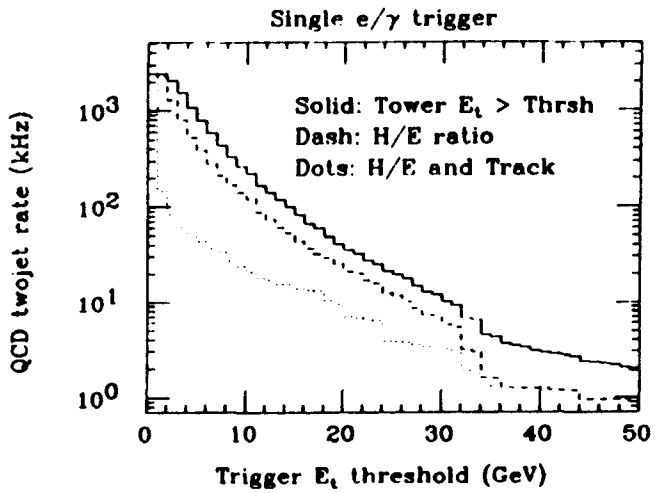

Figure 2: Barrel plus Endcap inclusive electron and photon trigger rate vs. trigger tower E_t for tower E_t only (solid), HAC/EM < .05 (dash), and HAC/EM plus track with $p_t > 10$ GeV matched in ϕ with tower (dotted). The dashed curve represents the non-isolated inclusive photon trigger rate and the dotted curve the non-isolated inclusive electron rate for $|\eta| < 3.0$.

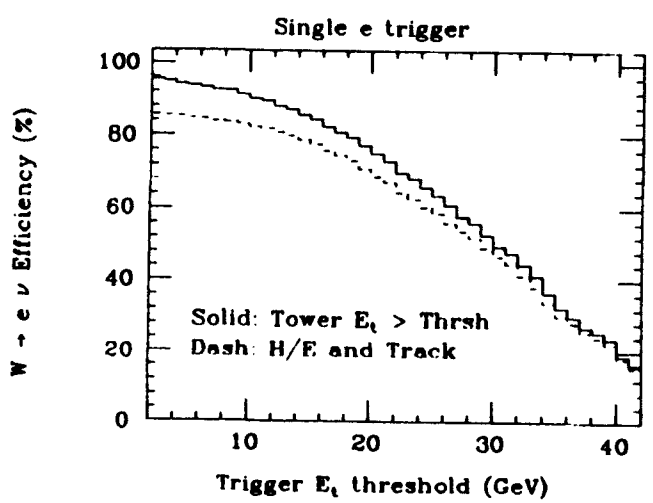

Figure 3: The $W \rightarrow e + \nu$ level 1 trigger efficiency for $|\eta| < 3.0$ from the inclusive electron trigger vs. trigger tower E_t for tower E_t only (solid), and HAC/EM < .05 plus track with $p_t > 10$ GeV matched in ϕ with tower (dashed).

Trigger Threshold (GeV)				Rate (kHz)
e	$2e$	γ	2γ	$@10^{33}cm^{-2}S^{-1}$
20	10	30	20	9.8
20	10	40	20	8.1
25	10	40	20	5.0
25	15	40	30	4.7
30	20	45	30	3.8
20	–	–	–	7.0
–	10	–	–	0.3

Table 1: Combined level 1 trigger rate for the main electron/photon triggers in the Barrel plus Endcap calorimeters ($|\eta| < 3.0$) versus various combinations of threshold energies. Where $e \equiv$ electron requires 1 tower H/E< 0.05 and track $p_t > 10$ GeV matched in ϕ with tower, $2e \equiv$ di-electron requires 2 towers with H/E< 0.1 and track $p_t > 10$ GeV, $\gamma \equiv$ photon requires 1 tower with H/E< 0.05, and $2\gamma \equiv$ di-photon requires 2 towers with H/E< 0.05.

the standard non-isolated electron rate (dashed curve), finally requiring the track to match a shower maximum ϕ strip, with a pulse height over the nominal electron strip response, at granularity in 1024 ϕ bins gives the dotted curve. Since the decrease in Level 1 inclusive electron E_t is small, the use of the shower maximum detector is restricted in the design to one of confirmation of the calorimeter electromagnetic energy. For this reason the shower max is read out in 64 ϕ bins in level 1. The principal use of the shower max is in Level 2, where more sophisticated algorithms are employed to reduce the background from conversions as well.

The trigger rates of the combined electron, di-electron, photon, and di-photon level 1 triggers ($|\eta| < 3.0$) are shown in Table 1 for various combinations of E_t thresholds on the four triggers. The study indicates that the rate is dominated by the inclusive single electron rate and is well within the target level 1 calorimeter trigger rate of 15 kHz. We have concluded from this that we do not need isolation or fine granularity shower maximum information in the Level 1 electron/photon triggers.

Fig. 6 shows the QCD background rate versus the "cluster" E_t threshold for the jet triggers. The successive curves are for successive sizes of fixed trigger sum sizes. The $\Delta\eta \times \Delta\phi$ sums range in size from $.1 \times .1$ to $.8 \times .8$. Examining Fig. 6 for $.1 \times .1$ trigger towers shows an E_T threshold of 50 GeV gives a trigger rate of ~ 4 kHz. This is nearly 100% efficient for 300 GeV jets.

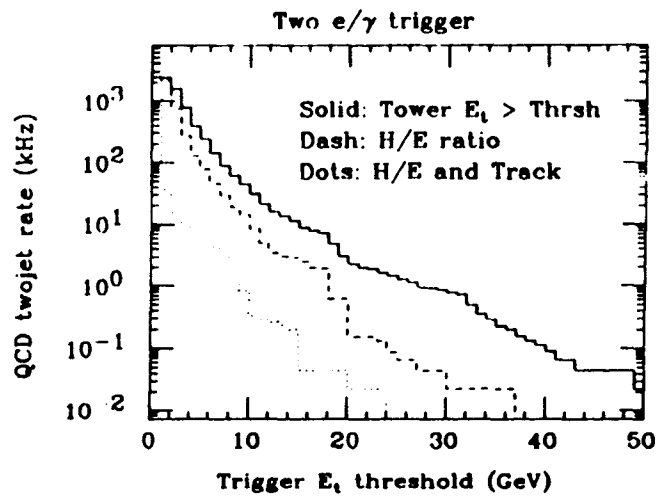

Figure 4: Barrel plus Endcap di-electron and di-photon trigger rate vs. trigger tower E_t for tower E_t only (solid), HAC/EM < 0.1 (dash), and HAC/EM plus track with $p_t > 10$ GeV matched in ϕ with tower (dotted). The dashed curve represents the non-isolated di-photon trigger rate and the dotted curve the non-isolated di-electron rate for $|\eta| < 3.0$.

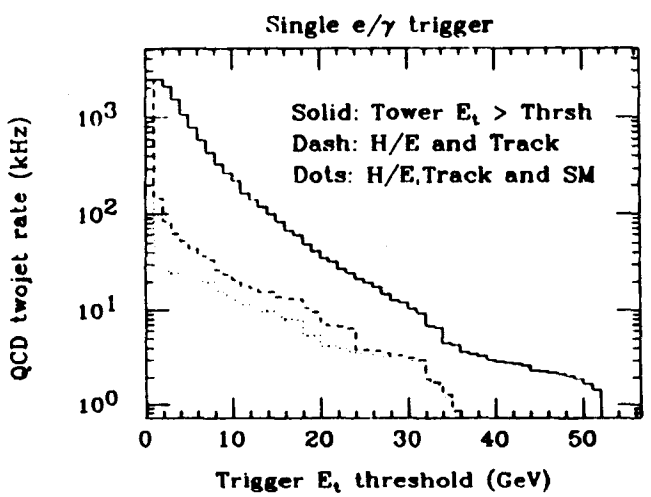

Figure 5: The effect on the level 1 rate of requiring a shower max ϕ strip over a threshold to match to a track with $p_t > 10$ GeV at a ϕ granularity of 1024. Shown are the rates vs. trigger tower E_t for tower E_t only (solid), HAC/EM $< .05$ plus track with $p_t > 10$ GeV matched in ϕ with tower(dashed), and HAC/EM plus shower max-track match in 1024 ϕ bins (dotted).

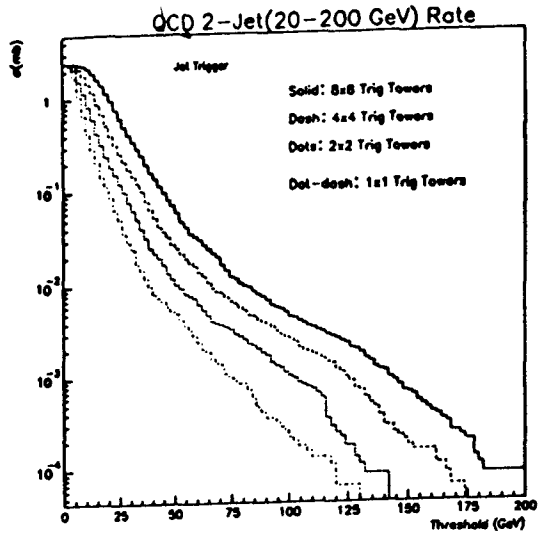

Figure 6: The level 1 inclusive jet trigger rate versus the E_T threshold for various tower sizes.

3 Is a simple single-tower L1 trigger sufficient to do our physics?

In this section we propose a Level 1 trigger based upon single towers over threshold. Again, this is motivated by the desire to keep the Level 1 system simple. More specifically, we propose to use single towers over threshold with minimal shower maximum data and no isolation in Level 1. The central question here for the collaboration is; Can we do the physics we want with this trigger?

The triggers and approximate thresholds for the proposed Level 1, which are based upon the rate studies shown here and elsewhere [5, 4], are shown in table 2. Echoing what was stated in the introduction: we believe these Level 1 thresholds are easily low enough to achieve the physics goals of the SDC as stated in the TDR. The decrease in electron/photon thresholds by using isolation in Level 1 is modest and, in our judgement, would not impact the physics capabilities of the SDC. Additionally, the added cost and complexity itself, although modest, certainly does not gain you anything.

Trigger	Threshold (GeV)
electron	20
di-electron	10
photon	30
di-photon	20
1 twr. Jet	50
di-Jet	<50
muon	20
di-muon	<20
e-mu	10-20
missing E_T	80

Table 2: Proposed Level 1 trigger table with the approximate thresholds for a single-tower trigger. The 50 GeV single tower threshold for the jet trigger is nearly 100% efficient for 300 GeV inclusive jets.

4 L1 Subsystem Detector Organization: what data are included? (The bottom- edge that touches the front-end.)

The systems sending information to be used at Level 1 are [3, 4]: calorimetry, tracking (central and intermediate), shower max, and muons. The information from each of these systems is described below. A summary of the Level 1 trigger system information and segmentation is presented in Table 3.

Tracking

The barrel tracking covers the region $|\eta| < 1.8$. The tracks are found in 1024 $\Delta\phi = 0.00625$ regions. The tracking trigger logic puts out two bits of p_t for the highest p_t track for each of 64 $\Delta\phi = 0.1$ bins for each half of the barrel ($-1.8 < \eta < 0$, $0 < \eta < 1.8$). These $\Delta\phi$ bins correspond to those of the calorimeter, shower max and muon systems. The two bits of p_t allow for one threshold and the sign of the particle charge. The intermediate tracker covers the range $1.8 < |\eta| < 2.8$. Again, as in the barrel, the tracking trigger logic puts out two bits of p_t for the highest p_t track for each of 64 $\Delta\phi = 0.1$ bins for each end. However, unlike the barrel, where there is a single η bin, the intermediate tracker logic has 4 physical η bins, which are combined in Level 1. Both barrel and intermediate trackers have 1024 physical $\Delta\phi$ bins that are combined into the 64 bins used in the Level 1 trigger logic. The full granularity

of both trackers is used in the Level 2 trigger logic and can be made available to the Level 1 as part of a future upgrade.

Calorimetery

The barrel calorimeter consists of 64 total wedges (32 ϕ wedges/side) with a wedge spanning 1.4 in η. The 2×2 EM physical towers are summed to give $0.1\eta \times 0.1\phi$ EM trigger towers and the two longitudinal $0.1\eta \times 0.1\phi$ HAC physical towers are summed into a single 0.1×0.1 trigger tower for a total of $64\phi \times 14\eta \times 2$ sides trigger towers from the barrel. Within a wedge there are $2\phi \times 14\eta = 28$ trigger towers with each tower having an electromagnetic and a hadronic section. The energy for each section within a trigger tower is digitized on an 8 bit nonlinear scale and sent to the Level 1 trigger.

The endcap calorimeter consists of 8 octants/end covering the rapidity range $1.4 < |\eta| < 3.0$. As described in the chapter on calorimetry, the physical towers are summed to give $64\phi \times 8\eta \times 2$ ends trigger towers total. Within an octant there are $8\phi \times 8\eta$ trigger towers with each having an electromagnetic and a hadronic section. Again, the energy for each section is encoded into an 8 bit nonlinear scale for input to Level 1. The forward calorimeter covers the rapidity range $3.0 < |\eta| < 5.0$. The physical towers for each end are summed to give a total of $8\phi \times 8\eta$ trigger towers with energies on an 8 bit nonlinear scale.

Shower Maximum Detector

The shower max detector is composed of 1024ϕ bins in thirty 0.2 η sections over the range $-3.0 < \eta < 3.0$. There are two barrel sections $|\eta| < 1.4$ and two endcap sections $1.4 < |\eta| < 3.0$. Each section is divided into 32ϕ wedges. In the barrel there are $32\phi \times 8\eta = 256$ bins for each wedge. For the Level 1 there is a bit for every group of 8 strips indicating whether a ϕ strip is above a preset "electron" threshold, yielding bins of $\Delta\phi = 0.1$ by $\Delta\eta = 0.2$. The endcap shower max is divided into octants. There are $128\phi \times 8\eta = 1024$ bins for each octant. As for the barrel Level 1 trigger, these are combined into bins of $\Delta\phi = 0.1$ by $\Delta\eta = 0.2$ hit flags. The full granularity of the shower max detector is available to the Level 2 trigger logic and can be made available to the Level 1 logic as part of a future upgrade.

Muons

The barrel muon system covers the range $|\eta| < 1.0$ and has a scintillator segmentation of $32\phi \times 46\eta \times 2$ ends. This gives $4\phi \times 46\eta \times 2$ ends per octant. The Level 1 muon trigger

system uses the θ trigger layers outside the toroid (BW2 and BW3). For Level 1 the octant is logically divided into $4\phi \times 5\eta$ regions, with each region $0.2\phi \times 0.2\eta$ in size. The muon trigger logic outputs 2 bits of p_t for the two highest p_t tracks in each region. The two bits of p_t allow for two thresholds and the sign of the particle charge.

The intermediate and forward muon systems cover the region $1.0 < |\eta| < 2.5$ with a scintillator segmentation of $32\phi \times 36\eta$ for each end. There are $4\phi \times 36\eta$ segments per octant. As for the barrel, the intermediate and forward muon Level 1 trigger systems use information from the two θ layers outside the toroid. For Level 1 each octant is logically divided into $4\phi \times 8\eta$ regions, with each region $0.2\phi \times 0.2\eta$ in size. As it does for the barrel, the muon trigger logic outputs 2 bits of p_t for the two highest p_t tracks in each region.

5 How the L1 system functions. (The top- edge that touches the trigger table.)

At the "top" of the Level 1 trigger is the global Level 1 trigger decision which implements the trigger table (see section 3). In order to implement the table the global Level 1 trigger receives a list, or count, of the electron, photon, jet, hadron, muon, and other various prescaled or programmable objects as well as sum E_T and missing E_T, upon which a decision is made to accept or reject the event in accordance with the trigger table. The actual details of how these lists are generated is left for a later section. The subject here is what to implement in defining the objects, not how it is implemented. It is important to point out here that for each type of trigger object there will actually be several definitions with varying thresholds and "cuts". For example, the di-lepton triggers will have lower thresholds ,and most likely looser cuts, then the inclusive lepton triggers.

The electron trigger object is defined as a single $.1 \times .1$ tower over a programmable threshold with the HAC/EM ratio below a programmable ratio and a track of sufficient P_T matched to the tower in phi. Additionally, a signal from the shower max detector at a coarse granularity can be required for confirmation. The photon objects are similar to the electron objects except there is no track requirement and different thresholds.

The hadron and jet trigger objects are a single $.1 \times .1$ tower over a programmable threshold. Global energy sums over the calorimeter are used for the sum E_T and missing E_T.

The Level 1 muon trigger will come from signals from the muon scintillator and muon chambers located outside the muon toroid [6, 4]. The scintillators provide

	Level 1 Segmentation per half/end	Level 1 Data/bin	Level 2 Segmentation per half/end	Level 2 Data/bin
Silicon	– –	– –	2048ϕ x 6η	5 p_T bits
Barrel Track	64ϕ	2 p_T bits	1024ϕ	4 p_T bits
Int. Track	64ϕ	2 p_T bits	1024ϕ x 4η	4 p_T bits
Cal $\|\eta\| < 1.8$				
Cal Towers	64ϕ x 18η	EM & HAC 8 bits Egy	64ϕ x 18η	EM & HAC 8 bits Egy
Sh. Max Layer X	64ϕ x 9η	Hit Flags	1024ϕ x 9η	8 bits Egy
Sh. Max Layer Y	– –	– –	144η x 32ϕ	8 bits Egy
Cal $1.8 < \|\eta\| < 2.6$				
Cal Towers	64ϕ x 8η	EM & HAC 8 bits Egy	64ϕ x 8η	EM & HAC 8 bits Egy
Sh. Max Layer X	64ϕ x 4η	Hit Flags	512ϕ x 4η	8 bits Egy
Sh. Max Layer Y	– –	– –	64η x 32ϕ	8 bits Egy
Cal $2.6 < \|\eta\| < 3.0$				
Cal Towers	32ϕ x 2η	EM & HAC 8 bits Egy	32ϕ x 2η	EM & HAC 8 bits Egy
Sh. Max Layer X	64ϕ x 2η	Hit Flags	256ϕ x 2η	8 bits Egy
Sh. Max Layer Y	– –	– –	16η x 32ϕ	8 bits Egy
Cal $\|\eta\| > 3.0$	8ϕ x 4η	EM+HAC 8 bits Egy	8ϕ x 4η	EM+HAC 8 bits Egy
Muon $\|\eta\| < 1.0$	32ϕ x 5η	2 p_T bits	1024ϕ x 5η	5 p_T bits
Muon $1.0 < \|\eta\| < 2.5$	32ϕ x 8η	2 p_T bits	1024ϕ x 8η	5 p_T bits

Table 3: The level 1 trigger data (from SDC Detector Parameters).

a low momentum cutoff and provide the timing tag needed to associate a muon with a specific crossing. The muon chambers give better momentum resolution than the scintillators; the limit is imposed by multiple scattering and the spread in the interaction point along the Z direction.

6 What's between the top and the bottom: a Level 1 Implementation

An implementation of the Level 1 trigger is shown in figure 7. The trigger information from the various subsystems on the detector is sent over 1 Gbit/sec optical fibers creating a "map" of the detector at the trigger crates upstairs. Once the data is upstairs the electronics generates lists, or counts, of electromagnetic and jet objects which are fanned into the global trigger where a final decision is made. Using 1 Gbit/sec fiber at 60MHz leads to a basic unit of 16 data bits per fiber. The various pieces are described in more detail below, and sample "real" trigger table showing how things would get downloaded in this system is shown in appendix A.

The calorimeter sends the raw trigger tower energies to the trigger. Each tower sends 8 bits hadronic plus 8 bits electromagnetic energy for each beam crossing, giving 16 bits/beam crossing $\times$ 60 MHz or approximately 1 Gbit/Sec per trigger tower. This requires 1 fiber per trigger tower. Given the segmentation shown in Table 3, there are 1760 per side $\times$ two sides = 3520 fibers.

The shower max detector sends a 1 bit hit flag for $.1\phi \times .2\eta$. This means about 2 1 Gbit/Sec fibers per wedge in the barrel and 8 1 Gbit/Sec fibers per octant in the endcaps for a total of $\sim$ 256 fibers.

The tracker outputs 2 bits P_T per ϕ trigger tower or 1 fiber/wedge. This gives 1 fiber/wedge x 32 wedges x 4 = 128 total fibers from the tracker and intermediate tracker combined.

The data from the calorimeter, shower max detector, and tracking system are received on the optical fiber in crates in the control room. One such crate for one octant in the central region is shown in Fig. 8. The crate is organized as four wedges with local wedge level pattern logic being performed in the group of four cards as shown schematically in Fig. 9. The Level 1 Calorimeter Card (L1CC) is shown in Fig. 10. Fig. 11 shows the Level 1 Local Decision Card (L1LDC).

The four wedge level decision cards (L1LDCs) in one crate, that together make up an octant, send their "counts" of objects to the Level 1 Output Card (L1OC). This is shown schematically in Fig. 12. The L1OC (shown in Fig. 13) then combines the lists and E_t sums and generates the summary of these for the entire crate. The

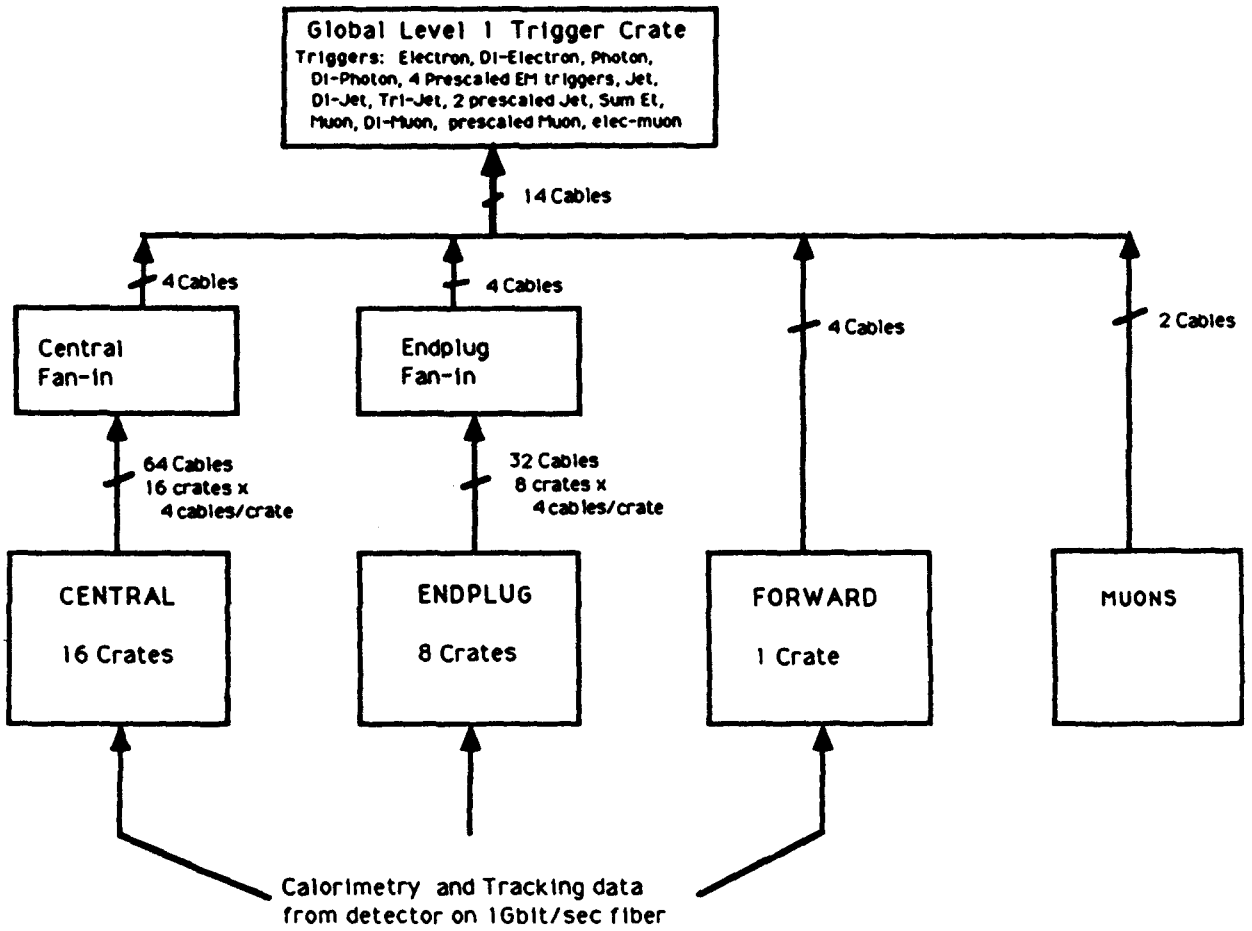

Figure 7: An implementation for the SDC level 1 trigger.

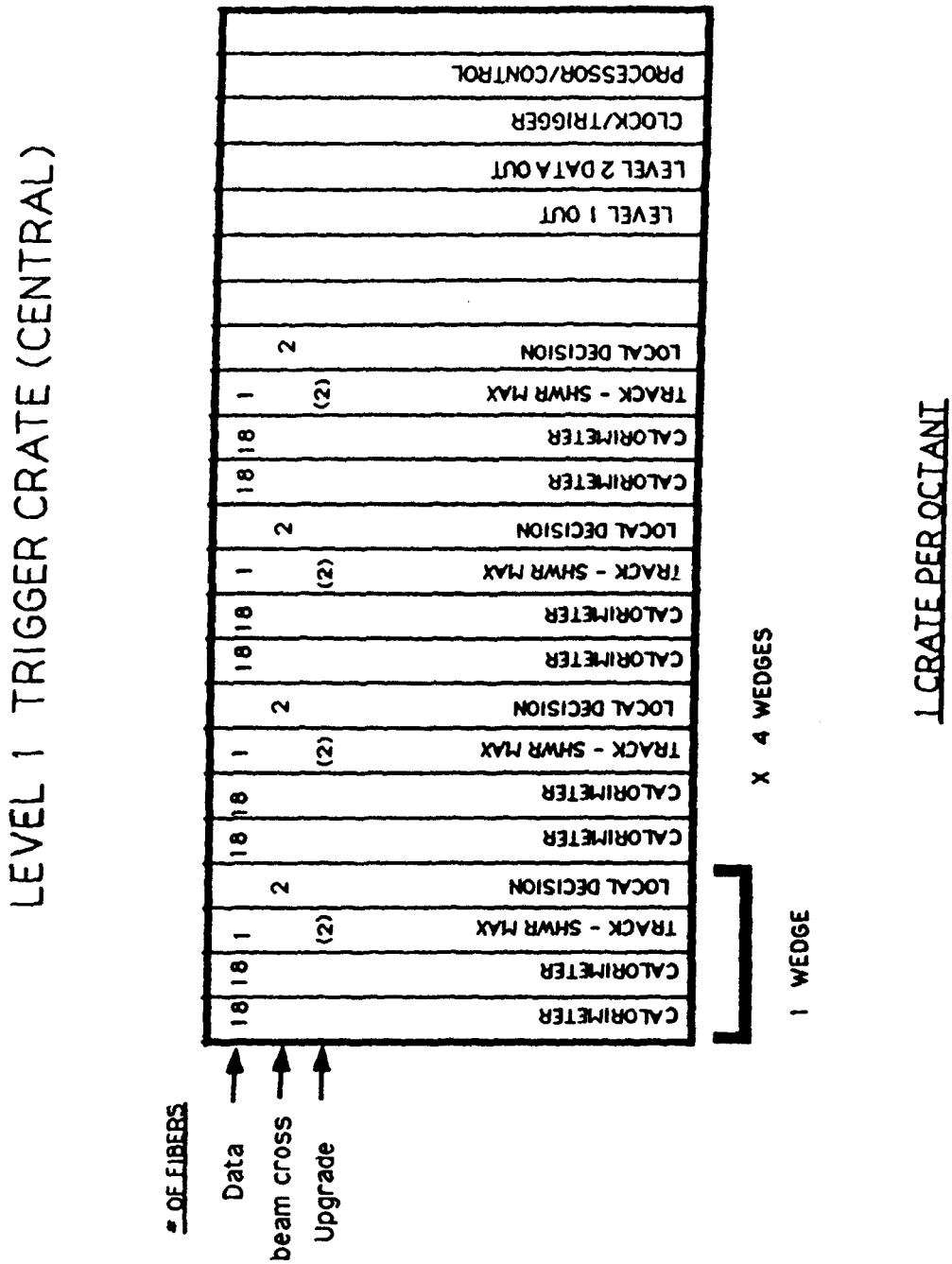

Figure 8: Organization of the level 1 calorimeter trigger crate.

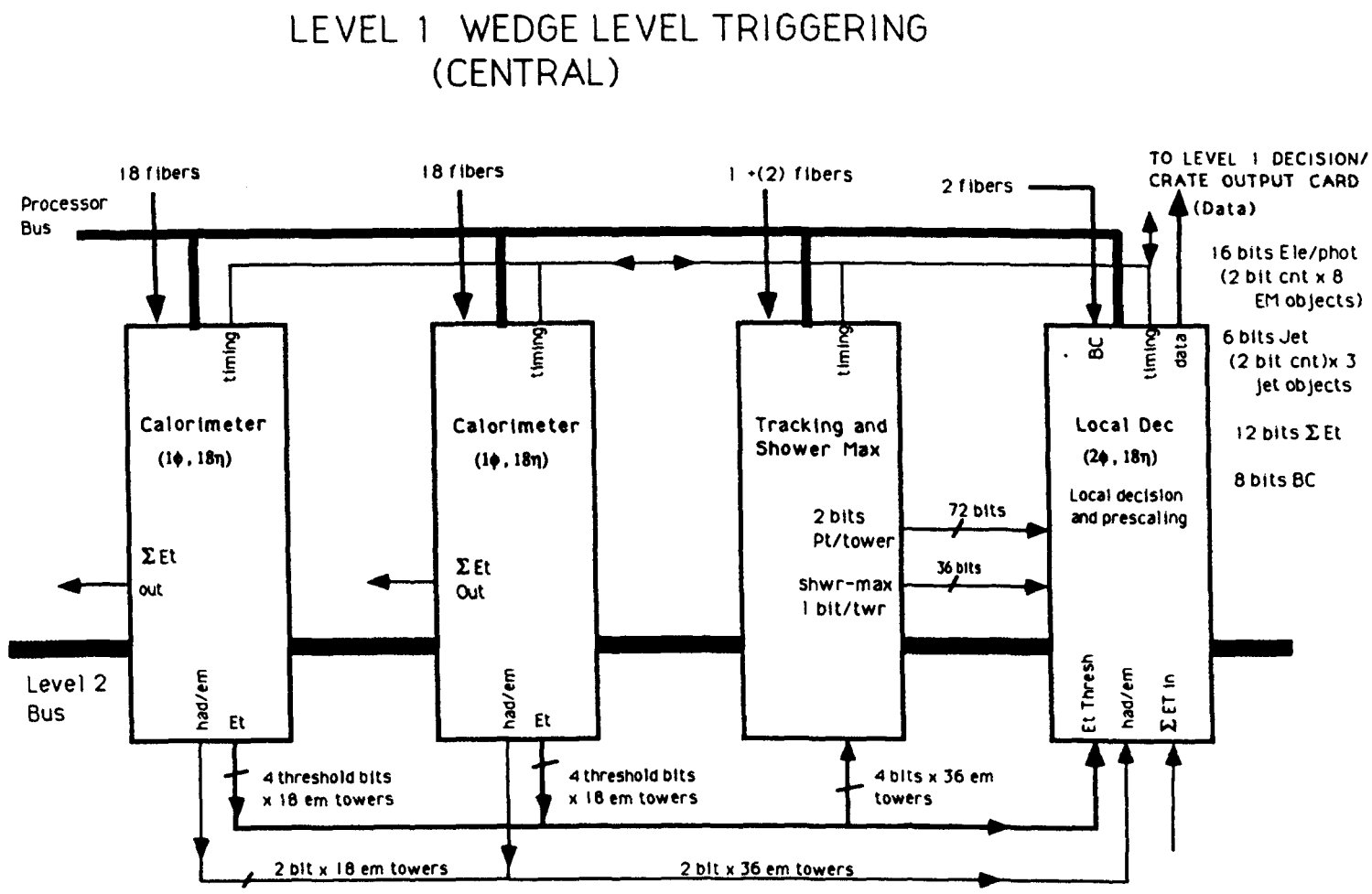

Figure 9: The local decision logic performed in the calorimeter trigger crates. The logic is done at the wedge level in a group of four cards.

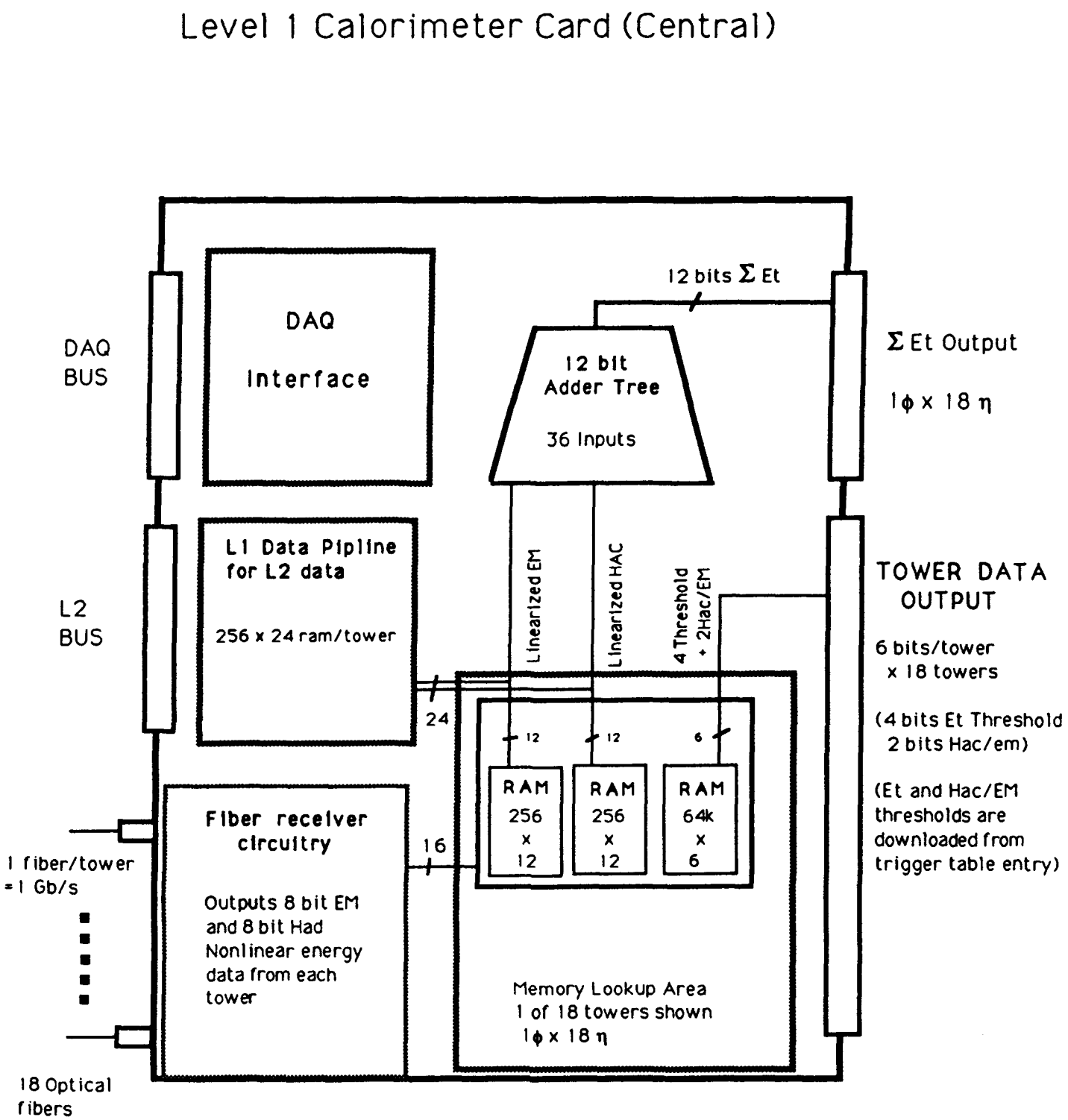

Figure 10: The Level 1 Calorimeter Card for the barrel region.

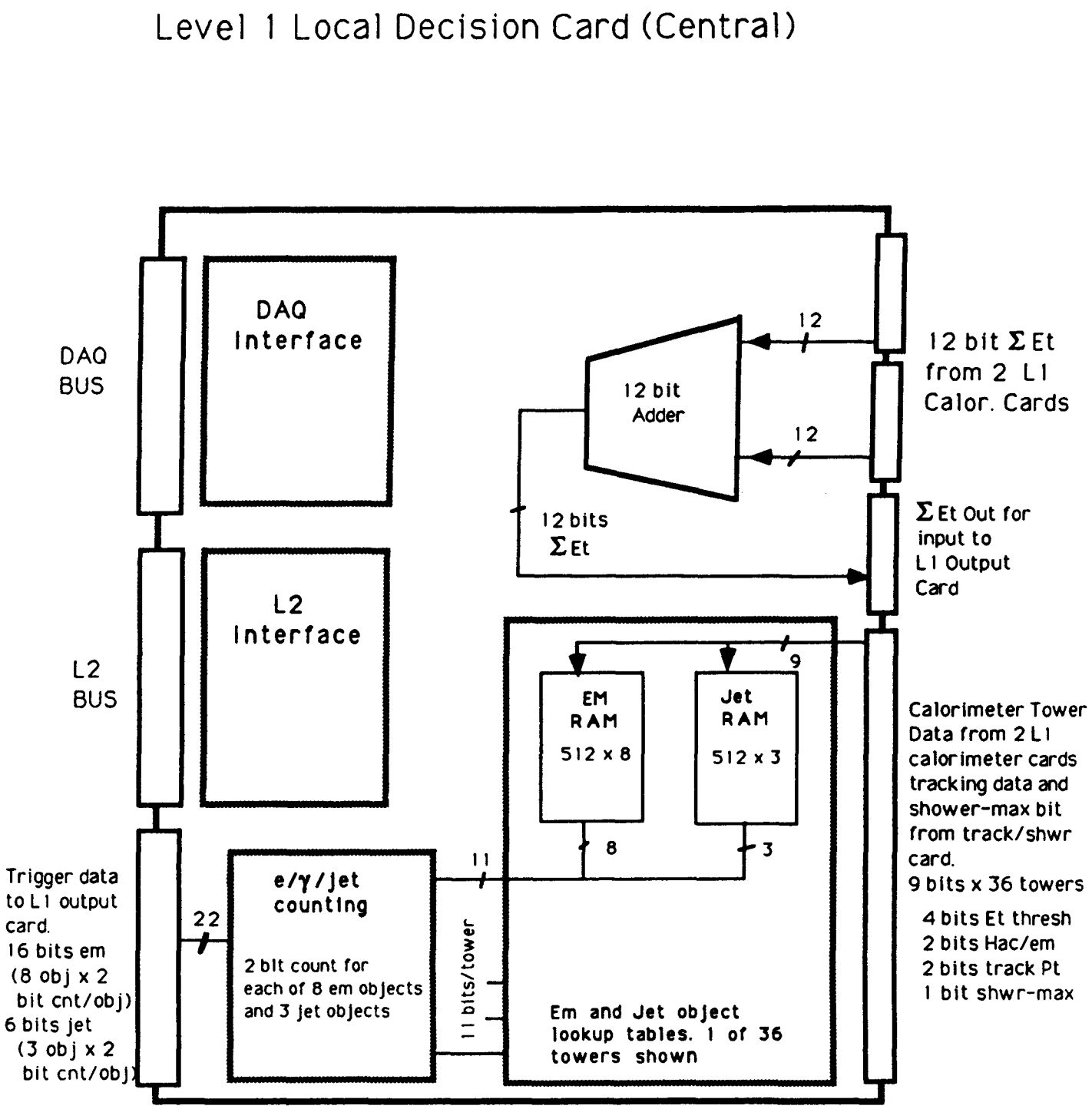

Figure 11: The Level 1 Local Decision Card for the barrel region.

lists and E_T information for the crate is then transmitted to the global Level 1.

The global Level 1 trigger is shown in Fig. 14. The information from the barrel and endcap L1OCs are sent to the Level 1 Fan-in Cards (L1FC). These combine the counts of objects into counts for the barrel and endcap regions which are then forwarded to the Level 1 Global Processor Crate (L1GPC) along with the data from the Level 1 forward calorimeter crate and muon trigger crates. The L1GPC is shown in Fig. 15.

Cards and Crates

Table 4 shows the various Level 1 crates and contents for this Level 1 implementation. Listed in Table 5 is the crate count, while Table 6 shows the various types and quantities of the cards for this design.

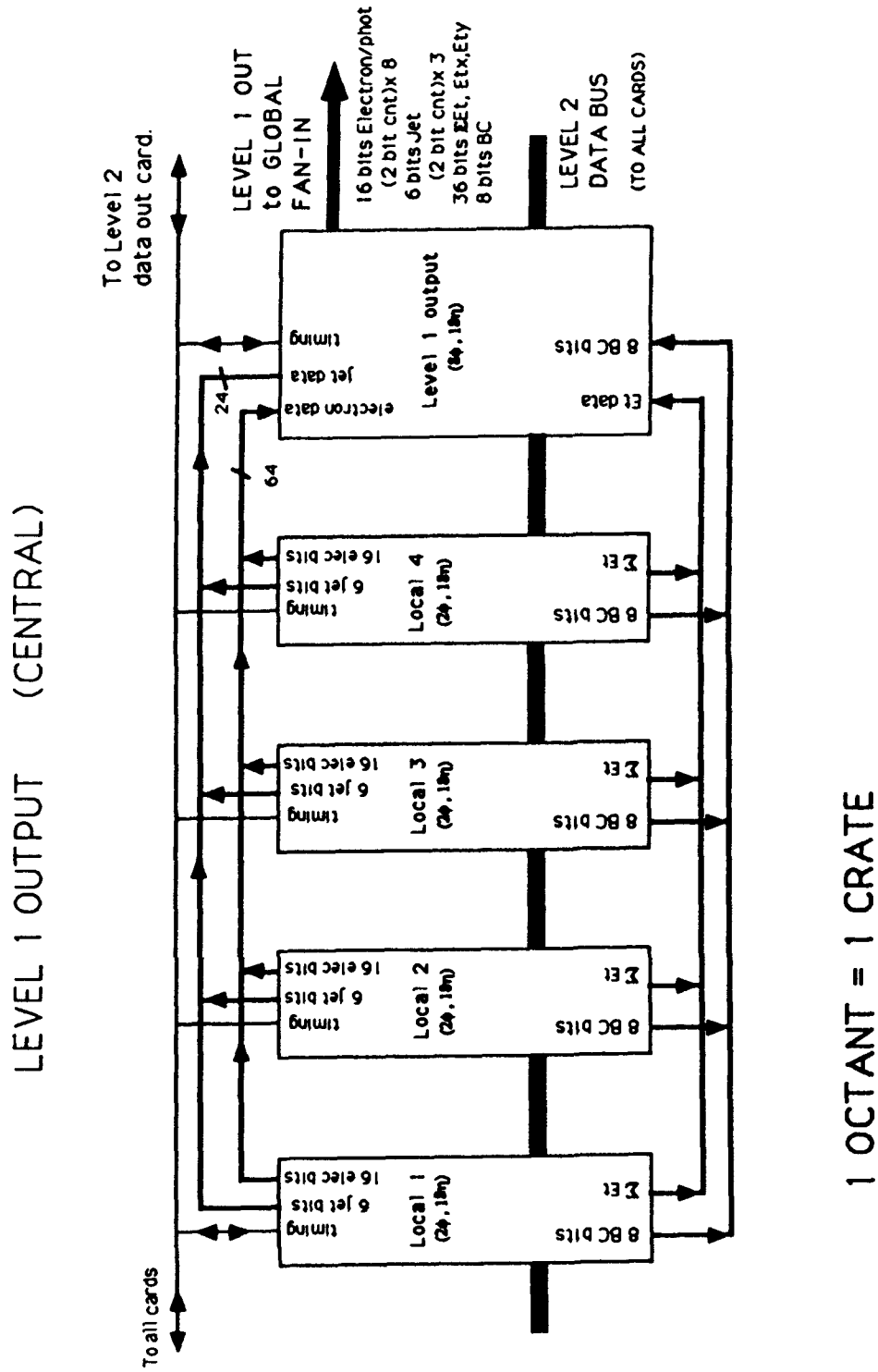

Figure 12: The combination of the four wedge level trigger data into a summary for the crate (= 1 octant) by the level 1 output card in the calorimeter trigger crate. The data is forwarded to the global level 1 decision logic.

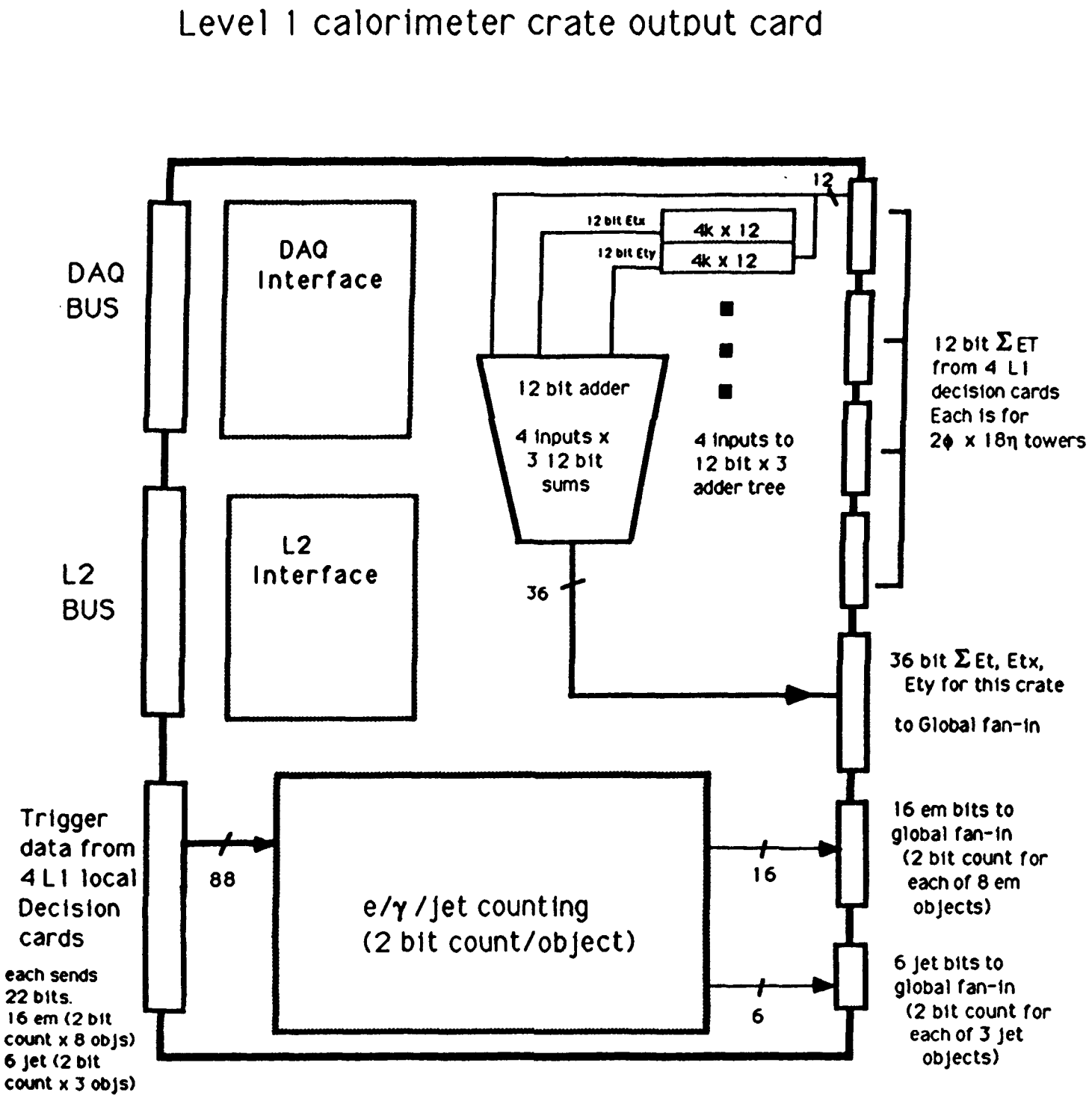

Figure 13: The Level 1 Output Card. This card outputs the list of trigger objects and E_T sums for this Level 1 trigger crate (=1 octant) to the global Level 1.

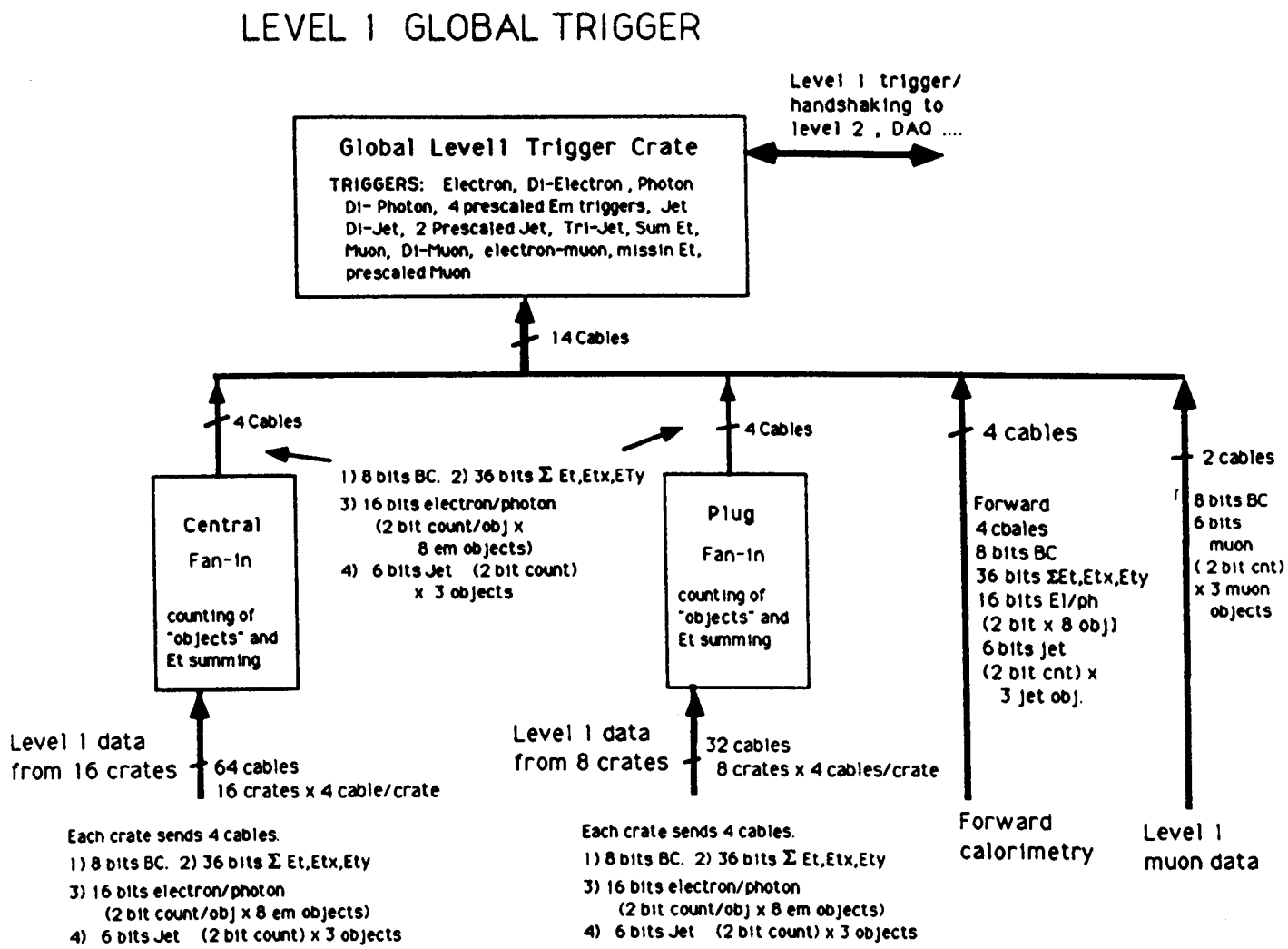

Figure 14: The global Level 1 trigger.

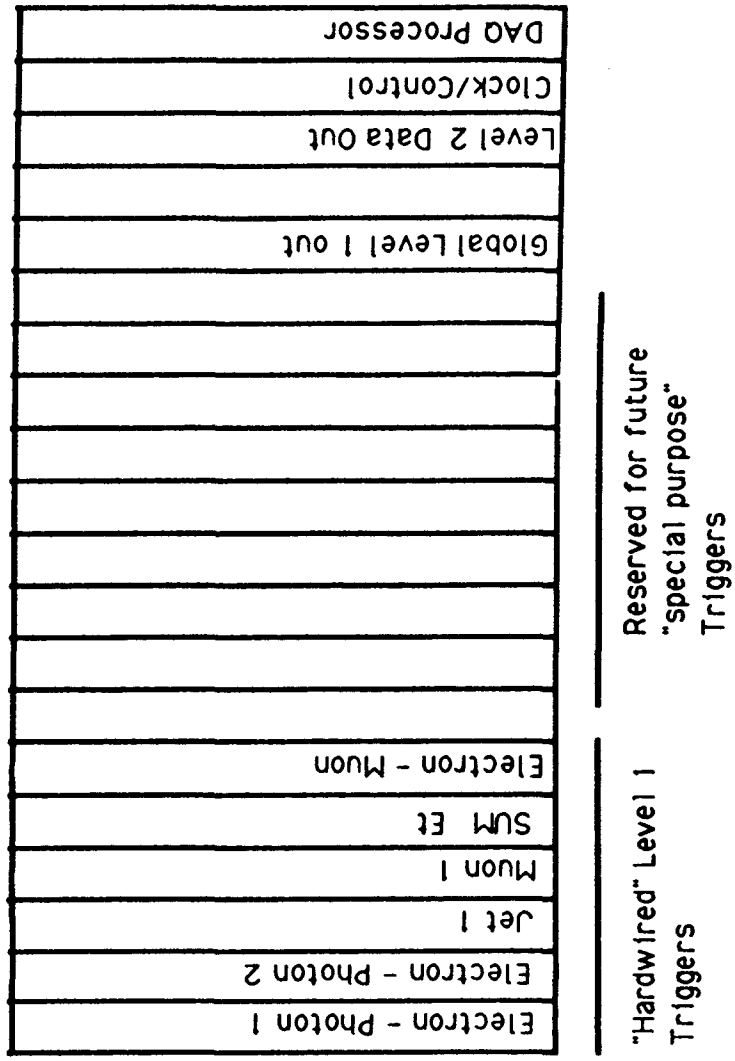

Figure 15: The Global Level 1 Trigger Crate.

CONTENTS OF LEVEL 1 TRIGGER CRATES

(minus DAQ Processor and Clock Cards)

Central Crates (16 total)

- 8 L1 Calorimeter
- 4 L1 Track and shwr-max
- 4 L1 Local Decision
- 1 L1 Output
- 1 L2 Data Out

18 cards

Forward Crate (1 total)

- 4 L1 Calorimeter
- 2 L1 Local Decision
- 1 L1 Output
- 1 L2 Data out

8 cards

Endplug Crates (8 total)

- 8 L1 Calorimeter
- 4 L1 Track and shwr-max
- 4 L1 Local Decision
- 1 L1 Output
- 1 L2 Data Out

18 cards

Endplug Fan-in (1 total)

- 3 Sum Et fan-in
- 3 electron/gamma fan-in
- 1 Jet fan-in
- 1 L2 Data Out

8 cards

Central Fan-in (1 total)

- 5 Sum Et fan-in
- 5 electron/gamma fan-in
- 1 Jet fan-in
- 1 L2 Data Out

12 cards

Global Level 1 (1 total)

- 2 electron/gamma trigger
- 1 Jet trigger
- 1 Muon trigger
- 1 sum Et trigger
- 1 e-mu trigger
- 3 programmable
- 1 Global L1 Accept
- 1 L2 Data out

11 cards

Table 4: The Level 1 crates and their contents.

LEVEL 1 CRATE COUNT

TYPE	QTY.
1) Central Calorimeter Crates	16
2) Endplug Calorimeter Crates	8
3) Forward Calorimeter Crate	1
4) Central Fan-in Crate	1
5) Endplug Fan-in Crate	1
6) Global Level 1 Crate	1
Total:	28 Crates

Table 5: The Level 1 Crates.

LEVEL 1 CARD COUNT

TYPE	QTY.
1) L1 Calorimeter (Central)	128
2) L1 Calorimeter (Endplug)	64
3) L1 Calorimeter (Forward)	4
4) L1 Track and shwr-max (Central)	64
5) L1 Track and shwr-max (Endplug)	32
6) L1 Local Decison (Central)	64
7) L1 Local Decison (Endplug)	32
8) L1 Local Decison (Forward)	2
9) L1 Calorimeter Crate Output (Central)	16
10) L1 Calorimeter Crate Output (Endplug)	8
11) L1 Calorimeter Crate Output (Forward)	1
12) L2 Data Out	28
13) Sum Et Fan-in	8
14) electron/photon Fan-in	8
15) Jet Fan-in	2
16) e/gamma Trigger 1	2
17) Jet trigger 1	1
18) Muon trigger 1	1
19) Sum ET trigger 1	1
20) e-mu trigger	1
21) Programmable trigger	3
Total:	471 Cards

Table 6: The Level 1 card types and quantities.

References

[1] W.H. Smith et al., *SDC Trigger Preliminary Conceptual design*, SDC note SDC-91-00090, 1991.

[2] T. Gorski, J. Lackey, W.H. Smith, *Isolated electron pattern logic design and performance at the SSC*, SDC note SDC-91-00087, 1991.

[3] A. Lankford et al., *Conceptual Design of the SDC Trigger from the SDC Trigger Group*, SDC note SDC-91-00098, 1991.

[4] *The SDC Technical Design Report (TDR)*

[5] G. Sullivan and M. Miller, *Calorimetry trigger rates at the SDC*, SDC note SDC-91-00099, 1991.

[6] J. Chapman and R. Thun, *SDC Muon Trigger Preliminary Conceptual Design*

A An example of a detailed Level 1 Trigger Table.

Listed here is an example of what an actual Level 1 trigger table might be like for the proposed design. The comments on the right list the hardware that gets downloaded by that section.

```
LEVEL 1 TRIGGER TABLE


****** FIRST DEFINE PRIMITIVES *******

DEFINE PRIMITIVE_CENTRAL_EM
   ET THRESHOLDS
        SET ET_1 = 5.0  (GEV)  -|
        SET ET_2 = 10.0 (GEV)   |
        SET ET_3 = 15.0 (GEV)   |  Download to RAM
        SET ET_4 = 20.0 (GEV)   |   on L1 Calorimter Cards
        SET ET_5 = 25.0 (GEV)   |
        SET ET_6 = 30.0 (GEV)   |
        SET ET_7 = 40.0 (GEV)  -|
   PT THRESHOLDS
        SET PT_1 = 5.0  (GEV)  -|
        SET PT_2 = 10.0 (GEV)   |  Tracker System
        SET PT_3 = 20.0 (GEV)  -|
   HAC/EM THRESHOLDS
        SET HA_1 = 0.05        -|
        SET HA_2 = 0.10         |  RAM on L1 Calorimeter Cards
        SET HA_3 = 0.20        -|
   SHOWER-MAX THRESHOLDS
        SET SM_1 = 1.0  (?)     |  front-end Shower Max card

END


DEFINE PRIMITIVE_ENDPLUG_EM
   ET THRESHOLDS
        SET ET_1 = 5.0  (GEV)
        SET ET_2 = 10.0 (GEV)
        SET ET_3 = 15.0 (GEV)
        SET ET_4 = 20.0 (GEV)
        SET ET_5 = 25.0 (GEV)
        SET ET_6 = 30.0 (GEV)
        SET ET_7 = 40.0 (GEV)
   PT THRESHOLDS
        SET PT_1 = 5.0  (GEV)
        SET PT_2 = 10.0 (GEV)
        SET PT_3 = 20.0 (GEV)
   HAC/EM THRESHOLDS
        SET HA_1 = 0.05
        SET HA_2 = 0.10
        SET HA_3 = 0.20
   SHOWER-MAX THRESHOLDS
        SET SM_1 = 1.0  (?)

END


DEFINE PRIMITIVE_CENTRAL_JET
   ET THRESHOLDS
        SET ET_1 = 25.0 (GEV)
        SET ET_2 = 50.0 (GEV)
        SET ET_3 = 75.0 (GEV)

END
```

```
DEFINE PRIMITIVE_ENDPLUG_JET
   ET THRESHOLDS
        SET ET_1 = 25.0 (GEV)
        SET ET_2 = 50.0 (GEV)
        SET ET_3 = 75.0 (GEV)

END


DEFINE PRIMITIVE_CENTRAL_MUON
   PT THRESHOLDS
        SET ET_1 = 10.0 (GEV)  -|  front-end Muon trigger
        SET ET_2 = 20.0 (GEV)   |    cards
        SET ET_3 = 40.0 (GEV)  -|

END


DEFINE PRIMITIVE_FORWARD_MUON
   PT THRESHOLDS
        SET ET_1 = 10.0 (GEV)
        SET ET_2 = 20.0 (GEV)
        SET ET_3 = 40.0 (GEV)

END


******* DEFINE LOCAL OBJECTS *******   Downloads to RAM on L1 Local
                                        Decision Cards (8 em,3 jet) objects
 CENTRAL ELECTRON/PHOTON

     DEFINE OBJECT_CENTRAL_EM_1      (HIGH ET TIGHT ELECTRON)
             CUT ET >= 25.
             CUT PT >= 10.
             CUT HA <= 0.05
             CUT SM >= 1.0
     END
     DEFINE OBJECT_CENTRAL_EM_2      (LOW ET  LOOSE ELECTRON)
             CUT ET >= 10.
             CUT PT >= 10.
             CUT HA <= 0.1
             CUT SM >= 1.
     END
     DEFINE OBJECT_CENTRAL_EM_3      (HIGH ET TIGHT PHOTON)
             CUT ET >= 40.
             CUT HA <= 0.05
             CUT SM >= 1.
     END
     DEFINE OBJECT_CENTRAL_EM_4      (LOW ET LOOSE PHOTON)
             CUT ET >= 20.
             CUT HA <= 0.05
             CUT SM >= 1.
     END
     DEFINE OBJECT_CENTRAL_EM_5      (HIGH ET LOOSE ELECTRON)
             CUT ET >= 30.
             CUT PT >= 10.
             CUT HA <= 0.1
             CUT SM >= 1.
     END
     DEFINE OBJECT_CENTRAL_EM_6      (HIGH ET LOOSE PHOTON)
             CUT ET >= 40.
```

```
            CUT HA <= 0.1
            CUT SM >= 1.
    END
    DEFINE OBJECT_CENTRAL_EM_7      (HIGH ET LOOSE EM)
            CUT ET >= 30.
            CUT SM >= 1.
    END
    DEFINE OBJECT_CENTRAL_EM_8      (LOW ET LOOSE EM)
            CUT ET >= 15.
            CUT SM >= 1.
    END

CENTRAL JET

    DEFINE OBJECT_CENTRAL_JET_1     (LOW ET JET)
            CUT ET >= 25.
            CUT SM >= 1.
    END
    DEFINE OBJECT_CENTRAL_JET_2     (MID ET JET)
            CUT ET >= 50.
    END
    DEFINE OBJECT_CENTRAL_JET_3     (HIGH ET JET)
            CUT ET >= 75.
    END

CENTRAL MUON

    DEFINE OBJECT_CENTRAL_MUON_1    (HIGH ET MUON)
            CUT ET >= 20.
    END
    DEFINE OBJECT_CENTRAL_MUON_2    (LOW ET MUON)
            CUT ET >= 10.
            CUT PT >= 10.
    END


ENDPLUG ELECTRON/PHOTON

    DEFINE OBJECT_ENDPLUG_EM_1      (HIGH ET TIGHT ELECTRON)
            CUT ET >= 25.
            CUT PT >= 20.
            CUT HA <= 0.05
            CUT SM >= 1.
    END
    DEFINE OBJECT_ENDPLUG_EM_2      (LOW ET  LOOSE ELECTRON)
            CUT ET >= 10.
            CUT PT >= 10.
            CUT HA <= 0.1
            CUT SM >= 1.
    END
    DEFINE OBJECT_ENDPLUG_EM_3      (HIGH ET TIGHT PHOTON)
            CUT ET >= 40.
            CUT HA <= 0.05
            CUT SM >= 1.
    END
    DEFINE OBJECT_ENDPLUG_EM_4      (LOW ET LOOSE PHOTON)
            CUT ET >= 20.
            CUT HA <= 0.05
            CUT SM >= 1.
    END
    DEFINE OBJECT_ENDPLUG_EM_5      (HIGH ET LOOSE ELECTRON)
            CUT ET >= 30.
```

```
                CUT PT >= 10.
                CUT HA <= 0.1
                CUT SM >= 1.
        END
        DEFINE OBJECT_ENDPLUG_EM_6      (HIGH ET LOOSE PHOTON)
                CUT ET >= 40.
                CUT HA <= 0.1
                CUT SM >= 1.
        END
        DEFINE OBJECT_ENDPLUG_EM_7      (HIGH ET LOOSE EM)
                CUT ET >= 30.
                CUT SM >= 1.
        END
        DEFINE OBJECT_ENDPLUG_EM_8      (LOW ET LOOSE EM)
                CUT ET >= 15.
                CUT SM >= 1.
        END

  ENDPLUG JET

        DEFINE OBJECT_ENDPLUG_JET_1     (LOW ET JET)
                CUT ET >= 25.
        END
        DEFINE OBJECT_ENDPLUG_JET_2     (MID ET JET)
                CUT ET >= 50.
        END
        DEFINE OBJECT_ENDPLUG_JET_3     (HIGH ET JET)
                CUT ET >= 75.
        END

  ENDPLUG MUON

        DEFINE OBJECT_FORWARD_MUON_1    (HIGH ET MUON)
                CUT ET >= 20.
        END
        DEFINE OBJECT_FORWARD_MUON_2    (LOW ET MUON)
                CUT ET >= 10.
                CUT PT >= 10.
        END


DO LEVEL 1 TRIGGERS                     Download to L1 Global Decision
                                                Crate.

L1_TRIGGER_ELECTRON
        INCLUDE OBJECT_CENTRAL_EM_1
        INCLUDE OBJECT_ENDPLUG_EM_1
        SELECT N_OBJECT_EM_1 >= 1
END

L1_TRIGGER_DIELECTRON
        INCLUDE OBJECT_CENTRAL_EM_2
        INCLUDE OBJECT_ENDPLUG_EM_2
        INCLUDE OBJECT_FORWARD_EM_2
        SELECT N_OBJECT_EM_2 >= 2
END

L1_TRIGGER_PHOTON
        INCLUDE OBJECT_CENTRAL_EM_3
        INCLUDE OBJECT_ENDPLUG_EM_3
        SELECT N_OBJECT_EM_3 >= 1
END
```

```
L1_TRIGGER_DIPHOTON
      INCLUDE OBJECT_CENTRAL_EM_4
      INCLUDE OBJECT_ENDPLUG_EM_4
      INCLUDE OBJECT_FORWARD_EM_4
      SELECT N_OBJECT_EM_4 >= 2
END

L1_TRIGGER_ELECTRON_PRESCALE
      SET PRESCALE = 4.
      INCLUDE OBJECT_CENTRAL_EM_5
      INCLUDE OBJECT_ENDPLUG_EM_5
      SELECT N_OBJECT_EM_5 >= 1
END

L1_TRIGGER_PHOTON_PRESCALE
      SET PRESCALE = 4.
      INCLUDE OBJECT_CENTRAL_EM_6
      INCLUDE OBJECT_ENDPLUG_EM_6
      SELECT N_OBJECT_EM_6 >= 1
END

L1_TRIGGER_EM_PRESCALE_1
      SET PRESCALE = 8.
      INCLUDE OBJECT_CENTRAL_EM_7
      INCLUDE OBJECT_ENDPLUG_EM_7
      SELECT N_OBJECT_EM_7 >= 1
END

L1_TRIGGER_EM_PRESCALE_2
      SET PRESCALE = 20.
      INCLUDE OBJECT_CENTRAL_EM_8
      INCLUDE OBJECT_ENDPLUG_EM_8
      SELECT N_OBJECT_EM_8 >= 1
END

L1_TRIGGER_MUON
      INCLUDE OBJECT_CENTRAL_MUON_1
      INCLUDE OBJECT_FORWARD_MUON_1
      SELECT N_OBJECT_MUON_1 >= 1
END

L1_TRIGGER_DIMUON
      INCLUDE OBJECT_CENTRAL_MUON_2
      INCLUDE OBJECT_FORWARD_MUON_2
      SELECT N_OBJECT_MUON_2 >= 2
END

L1_TRIGGER_MUON_PRESCALE
      SET PRESCALE = 10.
      INCLUDE OBJECT_CENTRAL_MUON_2
      INCLUDE OBJECT_FORWARD_MUON_2
      SELECT N_OBJECT_MUON_3 >= 1
END

L1_TRIGGER_ELECTRON_MUON
      INCLUDE OBJECT_CENTRAL_EM_2
      INCLUDE OBJECT_ENDPLUG_EM_2
      INCLUDE OBJECT_CENTRAL_MUON_2
      INCLUDE OBJECT_FORWARD_MUON_2
      SELECT N_OBJECT_EM_2 >= 1
      SELECT N_OBJECT_MUON_2 >= 1
```

```
END

L1_TRIGGER_JET_3
      INCLUDE OBJECT_CENTRAL_JET_3
      INCLUDE OBJECT_ENDPLUG_JET_3
      INCLUDE OBJECT_FORWARD_JET_3
      SELECT N_OBJECT_JET_3 >= 1
END

L1_TRIGGER_JET_2
      INCLUDE OBJECT_CENTRAL_JET_2
      INCLUDE OBJECT_ENDPLUG_JET_2
      INCLUDE OBJECT_FORWARD_JET_2
      SELECT N_OBJECT_JET_2 >= 2
END

L1_TRIGGER_JET_1
      SET PRESCALE = 500.
      INCLUDE OBJECT_CENTRAL_JET_1
      INCLUDE OBJECT_ENDPLUG_JET_1
      INCLUDE OBJECT_FORWARD_JET_1
      SELECT N_OBJECT_JET_1 >= 1
END

L1_TRIGGER_JET_4
      SET PRESCALE = 100.
      INCLUDE OBJECT_CENTRAL_JET_2
      INCLUDE OBJECT_ENDPLUG_JET_2
      INCLUDE OBJECT_FORWARD_JET_2
      SELECT N_OBJECT_JET_2 >= 1
END

L1_TRIGGER_SUM_ET
      SELECT SUM_ET >= 800.
END

L1_TRIGGER_SUM_ET_PRESCALE
      SET PRESCALE = 10.
      SELECT SUM_ET >= 500.
END
```