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# Level-3 Calorimetric Resolution available for the Level-1 and Level-2 CDF Triggers

*A. Canepa[a], M. Casarsa[b], V. Cavaliere[c], G. Cortiana[d], S. Donati[c], G. Flanagan[e], V. Greco[c], P. Giannetti[c], H. Frisch[f], D.Krop[f], T.Liu[b], M.Piendibene[c], C.Pilcher[f], L.Ristori[c], V.Rusu[b], L.Sartori[c], M.Vidal[g].*

*[a]University of Pennsylvania, USA; [b]Fermilab, USA; [c]Physics Dept and INFN Pisa, Italy; [d]Physics Dept and INFN Padova, Italy; [e]Purdue University, USA; [f]University of Chicago, USA; [g]CIEMAT, Spain.*

## 1 Abstract

As the Tevatron luminosity increases, sophisticated selections are required to be efficient in selecting rare events among a very huge background. To cope with this problem, CDF has pushed the Level 3 calorimeter algorithm resolution up to Level 2 and, when possible, even to Level 1, increasing efficiency and, at the same time, keeping under control the rates. This strategy increases the purity of the Level2 and Level1 samples and produces free-bandwidth that allows to reduce the thesholds. The global effect is an improvement of the trigger efficiency, most notably on important SM Higgs channels. The Level 2 upgrade improves the cluster finder algorithm and the resolution of the Missing Transverse Energy (MET) calculations. The improved MET resolution will be soon available also at Level 1. We describe the CDF Level 2 and Level 1 calorimeter upgrades, the architecture and the trigger performances. The Level 2 upgraded system is running as the official one since August 2007, the Level 1 is under commissioning.

## 2 Overview of the CDF Calorimeter Trigger

The CDF trigger [1] for Run II is a three level system: each stage must reject a sufficient fraction of the events to allow processing at the next level with acceptable dead time. The Level 1 and Level 2 triggers use custom-designed hardware to find physics objects in a subset of the event information. The Level 1 decision is taken on the basis of a limited reconstruction of the muon, track and calorimeter information.



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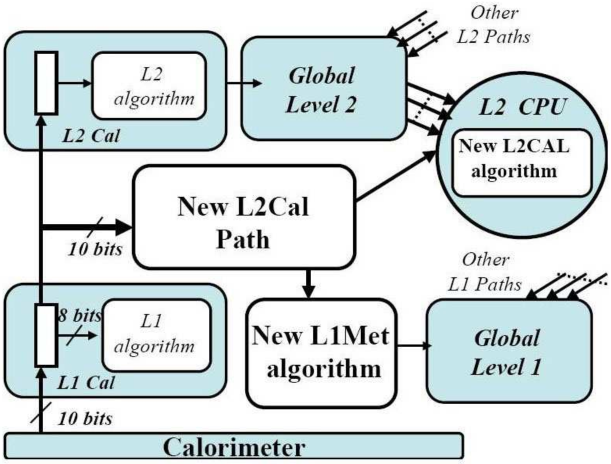


Figure 1: Hardware configuration (L1 and L2) for the Calorimeter Trigger upgrade.

When an event is accepted by the Level 1 trigger, all data are moved to one of four Level 2 data buffers. At the same time, subsets of detector information are sent to the Level 2 trigger system, where some limited event reconstruction is performed and a Level 2 decision is made inside a dedicated PC. Upon a Level 2 accept, the full detector is readout and data are sent to the Level 3. The Level 3 trigger uses the full detector information for complete event reconstruction in a farm of x86 PCs. Only the events accepted at L3 will be sent to mass storage. The goal of the calorimeter trigger (both at Level 1 and Level 2) is to trigger on electrons, photons, jets, total transverse energy (SumET) as well as missing transverse energy (MET).

A coordinate system is defined by the polar angle $\theta$, measured from the proton direction, and the azimuthal angle $\phi$, measured from the Tevatron plane. The pseudorapidity is defined as $\eta = \ln(\tan(\theta/2))$. All calorimeter tower energy information, including both electromagnetic (EM) energy and hadronic (HAD) energy, is digitized every 132 ns and the physical towers are summed into trigger towers. So, the entire detector is represented as a $24 \times 24$ map of trigger towers in the $\eta - \phi$ plane. The tower energy information is then sent to both L1 and L2 calorimeter trigger systems with 10-bit energy resolution. The Level 1 calorimeter (L1CAL) subsystem only uses 8 of the 10 available bits for each trigger tower; it also calculates global SumET and MET using that lower resolution.

The main task of the existing L2CAL was to find clusters using the transverse energy ($E_T$) of trigger towers. The cluster finding algorithm was based on a simple algorithm, implemented in dedicated hardware, which forms clusters by simply combining contiguous regions of trigger towers with non-trivial energy. Such algorithm has worked well at lower luminosity, but now, at high instantaneous luminosity, large "fake clusters" are likely to be formed: this because the occupancy of the detector increases since towers which are unrelated to any jet activity have their $E_T$ boosted above clustering thresholds. One more limitation of the existing hardware-based L2CAL system is that it does not re-calculate SumET and MET using the full 10-bit resolution energy information available, instead it uses the SumET and MET information directly from current L1CAL (based on 8-bit resolution). This design feature limits its trigger selection capability, or rejection power, for triggers with global transverse energy requirements.

# 3 The Calorimeter Trigger Upgrade

## 3.1 Hardware Architecture

The full 10 bit resolution calorimeter trigger tower energy information is now received, preprocessed and merged by a set of electronic boards, before being sent to the Level 2 decision CPU, where a more sophisticated cluster finding "'cone"' algorithm (replacing the old "'pac-man"' one) can reconstruct jets. At the same time the MET and SumET are calculated exploiting the full 10 bits resolution of the trigger tower energy information.

The system is based on the PULSAR [2], a general purpose VME board developed at CDF and already used for other upgrades [3]. It is equipped with three FPGA chips (APEX 20K400BC-652-1XV [4]): two DataIO and one Control. A first set of 18 identical Pulsars receives the raw (full 10-bit resolution) trigger tower energy information from L1CAL, over 288 LVDS cables, through a new Pulsar Mezzanine card, specifically designed for this upgrade. The trigger tower data are converted into 32-SLINK format [5] and delivered to a second set of 5 SLINK Merger Pulsars, which receive and merge the eighteen SLINK channels into four and then send the data to the Level 2 decision PC, using FILAR [6].

The same bunch of 18 Pulsar boards can be used to perform a first step of the MET and SumET calculation (with 10 bit resolution) for the Level1. The results are sent to an additional LVDS Pulsar board, which completes the MET and SumET calculation and makes the L1 trigger calorimeter decision within the L1 timing constraints($5.5 \mu s$). The LVDS Pulsar boards start to elaborate the L2 information when they receive back the global L1 decision (see figure 1).

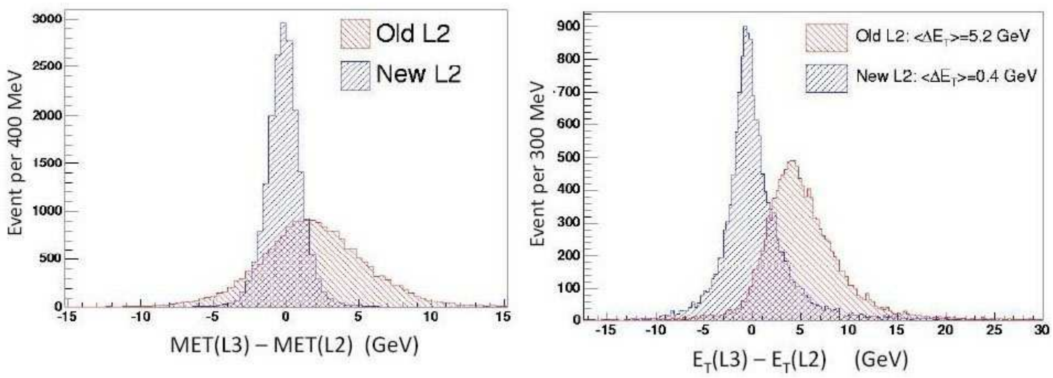


Figure 2: Difference between L2 and L3 MET (left) and Jet transverse energy (right) for existing and upgraded L2CAL. The average luminosity is $180 \times 10^{30} cm^{-2} s^{-1}$.

### 3.2 Performances

The Pulsar-based calorimeter trigger upgrade has improved both Jet and MET measurements at Level2; at Level1 it will improve the MET measurement too. Figure 2 shows the difference between Level2 and Level3 in MET and Jet transverse energy, for the existing system as well as for the upgraded one, with data taking at an average luminosity of $180 \times 10^{30} cm^{-2} s^{-1}$. The same MET difference has been measured between the future L1CAL system and L3. These improvements allow a significant rate reduction and higher efficiency in Jet and MET based triggers, both at Level1 and Level2. As an example, figure 3(a) shows the Level 2 JET40 trigger cross section growth with luminosity before and after the upgrade. In figure 3(b) we can see the trigger efficiency curve for the Level2 JET15 (Jet with $E_T$ above 15 GeV) trigger, in the upgraded L2CAL system and in the existing one.

## 4 Conclusions

We have presented the design, the hardware implementation and the performance of the Pulsar-based new L2CAL system for CDF experiment. It makes the full resolution calorimeter trigger tower information directly available to the Level 2 decision CPU, where a more sophisticated algorithm is implemented. Both Level 2 jets and MET are made nearly equivalent to offline quality, thus significantly improving the performance and flexibility of the jet and MET related triggers. We have also presented the under-commissioning L1CAL upgrade, easily obtained exploiting the flexibility of the same Pulsar boards used for the L2CAL. We foresee many opportunities for additional improvements in trigger purity and efficiency, most notably for physics

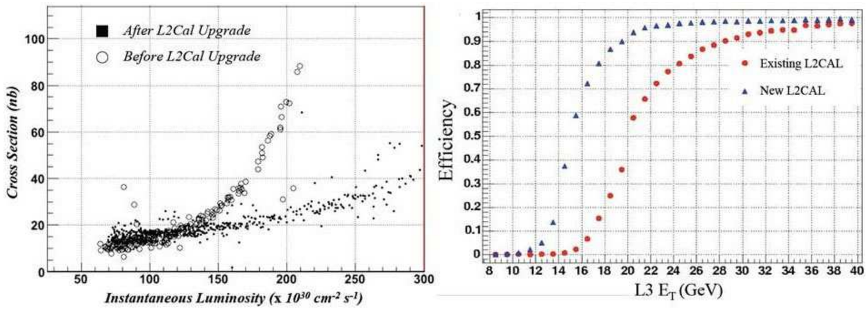


Figure 3: (a)Cross Section of the jet trigger selection requiring jets above 40 GeV as a function of the Instantaneous Luminosity: upgraded L2CAL vs existing L2CAL. (b)Efficiency verse $E_T$ for Level 2 Jet trigger with 15 GeV threshold, existing L2CAL system and new L2CAL.

triggers searching for Higgs and new physics.

# References


[1] R. Blair et al (CDF II collaboration), *The CDF RunII Detector Technical Design Report*, FERMILAB-PUB-96/390 E, 1996.

[2] Pulsar project web page: `http://hep.uchicago.edu/~ thliu/projects/Pulsar`.

[3] K.Anikeev et al., *CDF Level 2 Trigger Upgrade*, IEEE Trans. on Nucl. Sci., Vol.53, No 2, 2006 pp.653-658.

[4] ALTERA Pub, *APEX 20K Programmable Logic Device Family*, Data Sheet v.5.1, 2004.

[5] SLINK web page: `http://hsi.web.cern.ch/HSI/s-link`, Data Sheet v.5.1, 2004.

[6] FILAR web page: `http://hsi.web.cern.ch/HSI/s-link/devices/filar/Welcome.html`.