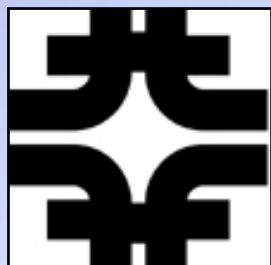


Level-3 Calorimeter Resolution available for the Level-1 and Level-2 CDF Triggers



VIRGINIA GRECO

INFN Pisa and University of Siena

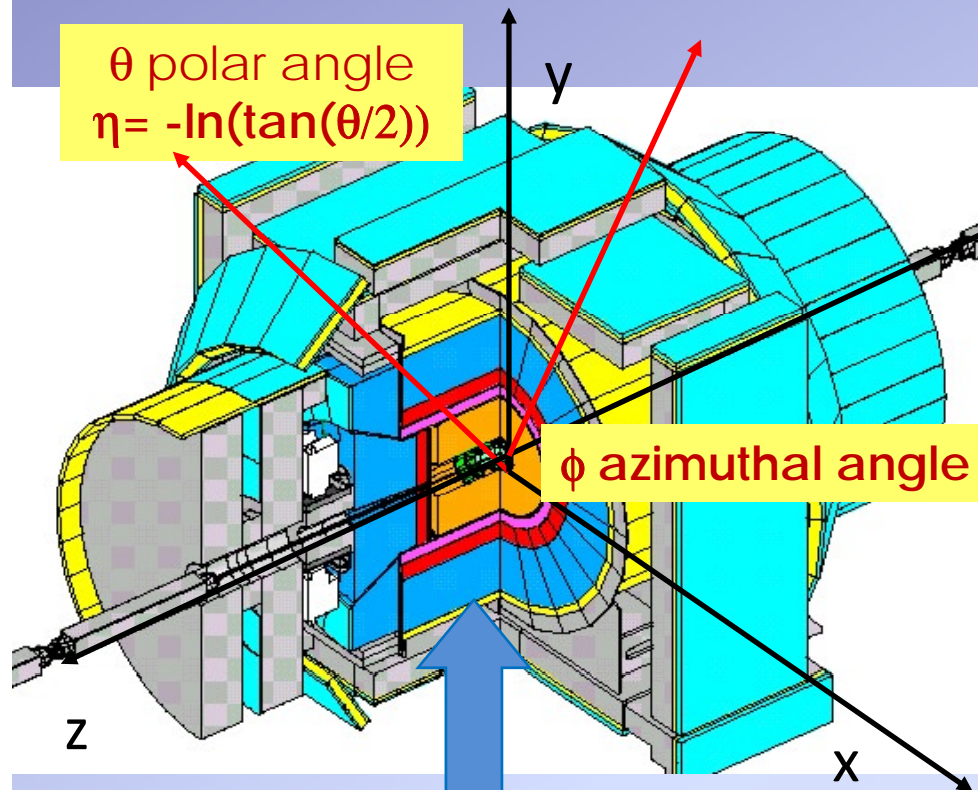
*for
the Calorimeter Trigger Group at CDF*



Introduction

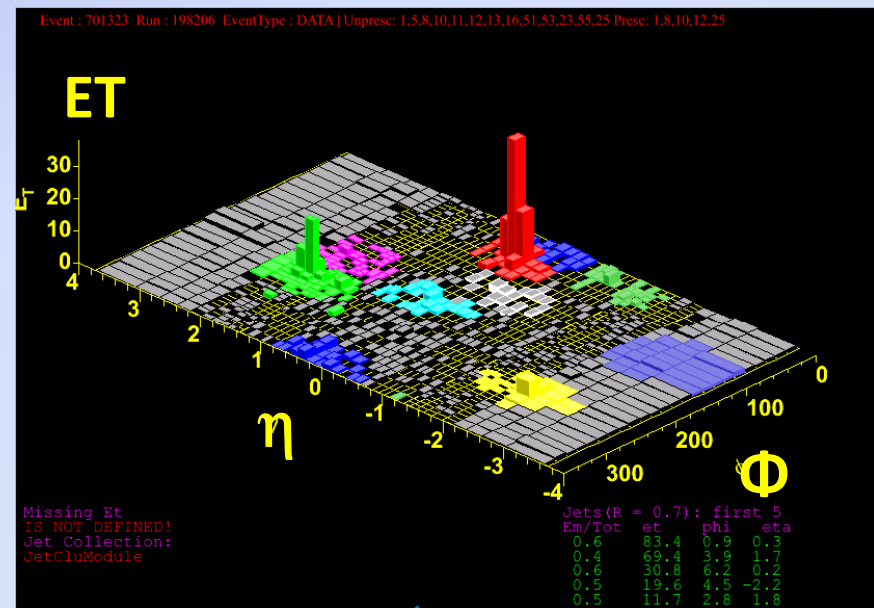
- Tevatron luminosity has been increasing
 - a more complex and precise trigger system has been required in order to be efficient in selecting rare events among a very huge background
- CDF has decided to **push the offline algorithm resolution down to trigger selection** as much as possible
 - **Level-1 and Level-2 trigger subsystems upgraded**: new CDF calorimetric trigger system more efficient selecting events for high-Pt physics

CDF Calorimeter Detector



The calorimeter detector is divided in **24x24 trigger energy towers** in η - Φ plane.

JET ONLINE reconstruction



The Calorimeter Trigger

Crossing Rate 1.7 MHz
Digitization at 132 ns clock cycle

The Trigger system

- ➡ is made up of 3 levels;
- ➡ each level provides **events rate reduction** to the next level;
- ➡ **Level 3 ~ offline reconstruction.**

PC farm performs reconstruction on the full event readout



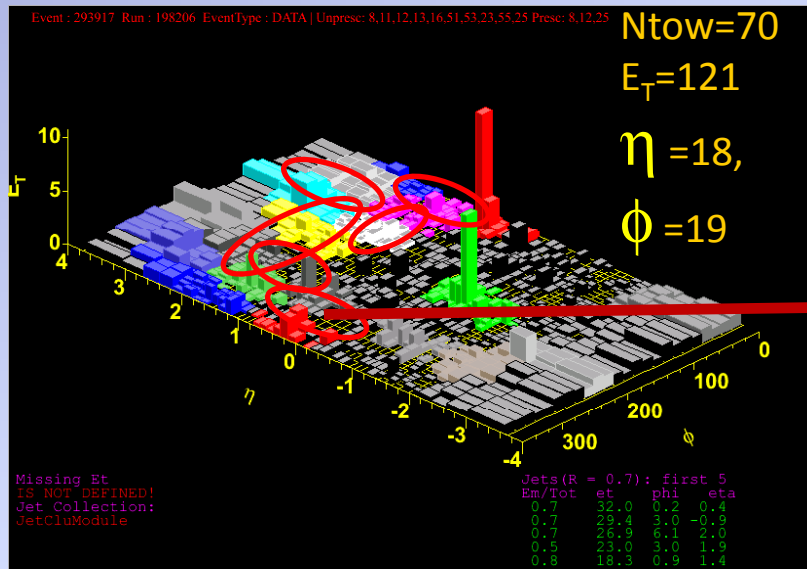
The energy information is sent to Level-1 and Level-2 at the same time, in **sets of 10+10 bits (EM+H energy)** for each tower.

The goal of the calorimeter trigger is to trigger on:

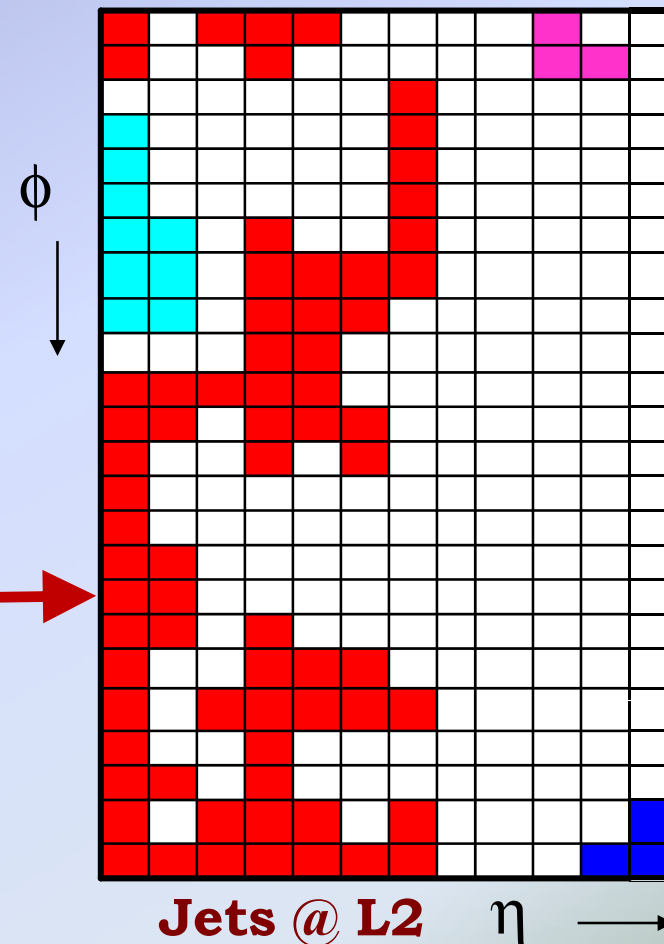
- **electrons,**
- **photons,**
- **jets,**
- total transverse energy (**SumET**),
- missing transverse energy (**MET**).

The L2 problems: jet clustering

- The algorithm (Pac-Man) formed clusters combining contiguous regions of trigger towers with non trivial energy.
- At high luminosity it causes multi-jets clusters merging (**large fake clusters**).



Reconstructed Jets @ L3



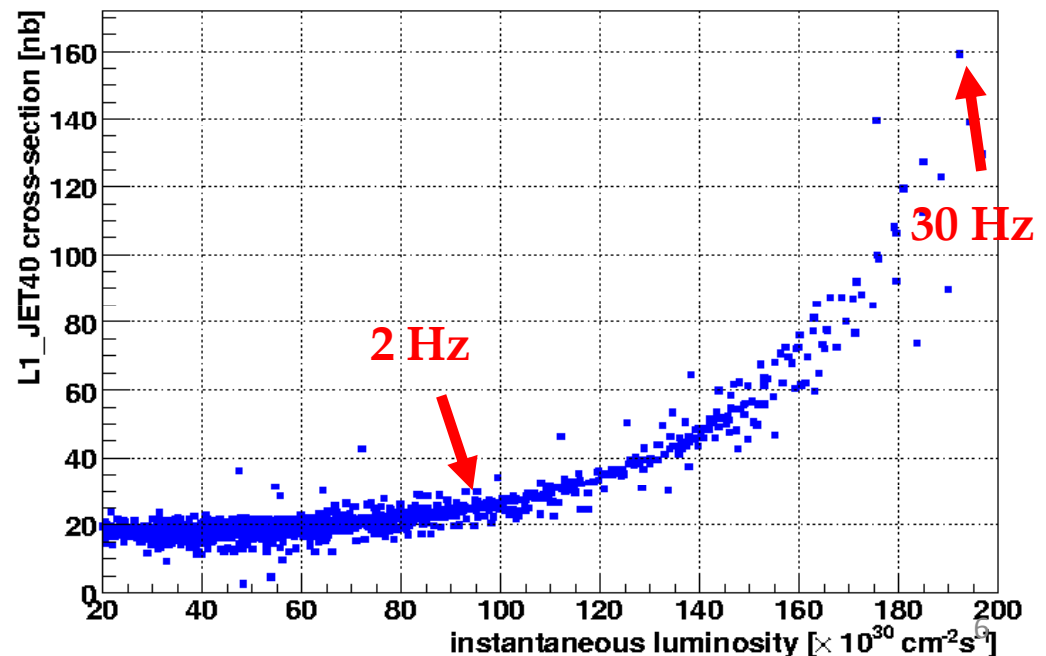
The L2 problems: SumET, MET low resolution

- The L2CAL system uses the **SumET** and **MET** information calculated by the L1CAL system on **8-bits resolution only** (instead of 10-bits).
 - It **limits the selection capability** for triggers with global (or missing) transverse energy requirements.

➔ MET, SumET and some-jets trigger **cross sections grow strongly with increasing luminosity.**

L2 Cross Section for Jet Trigger
with $E_T > 40$ GeV

(September-October 2006)



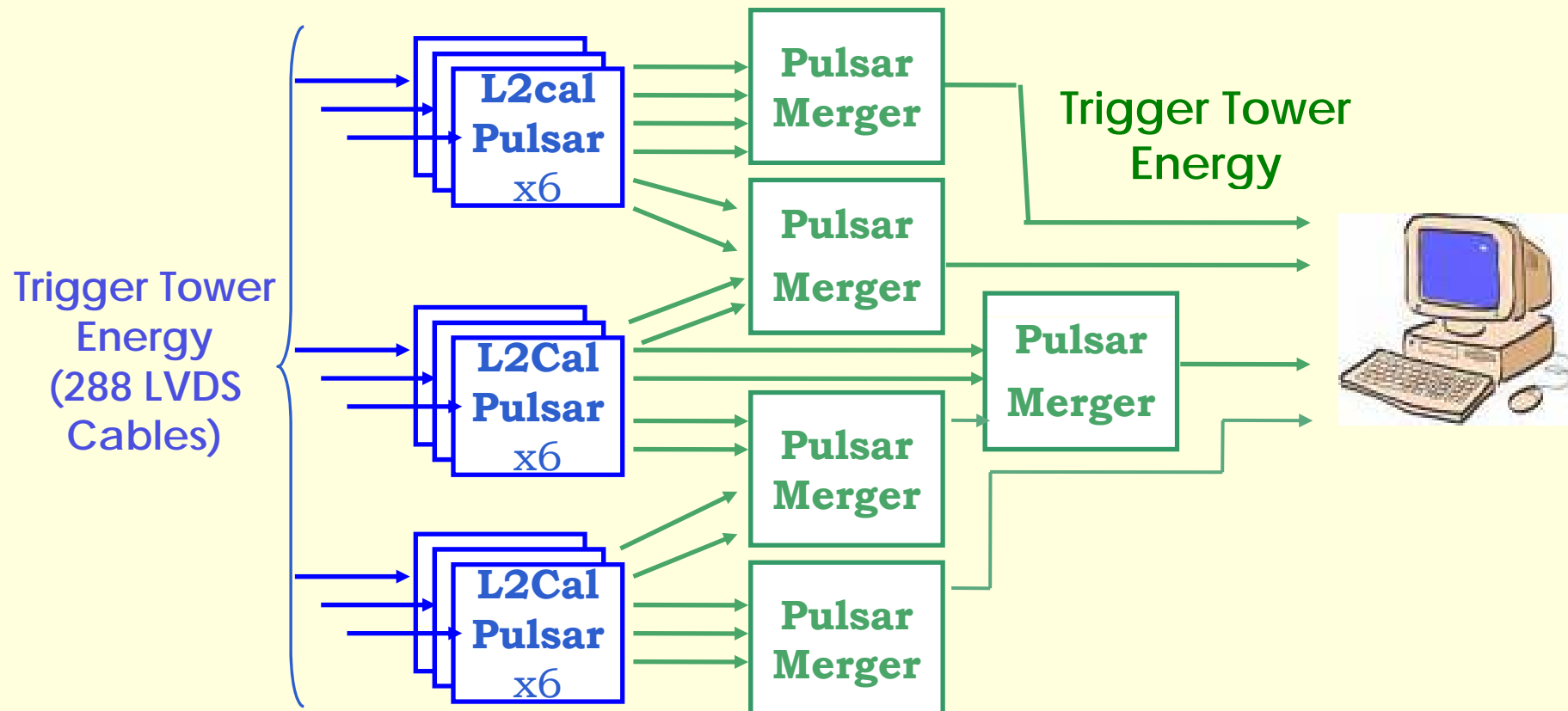
The L2CAL Upgrade

- The Pac-Man clustering algorithm has been replaced by **a more complex and efficient algorithm** (the “cone” alg.).
- The trigger system has been improved in order to calculate **SumET and MET with a 10-bits resolution**.

L2CAL Hardware Architecture (1)

- Mix of custom hardware and commercial processors.

Custom hardware receives trigger towers, merges and sends them to the PC.



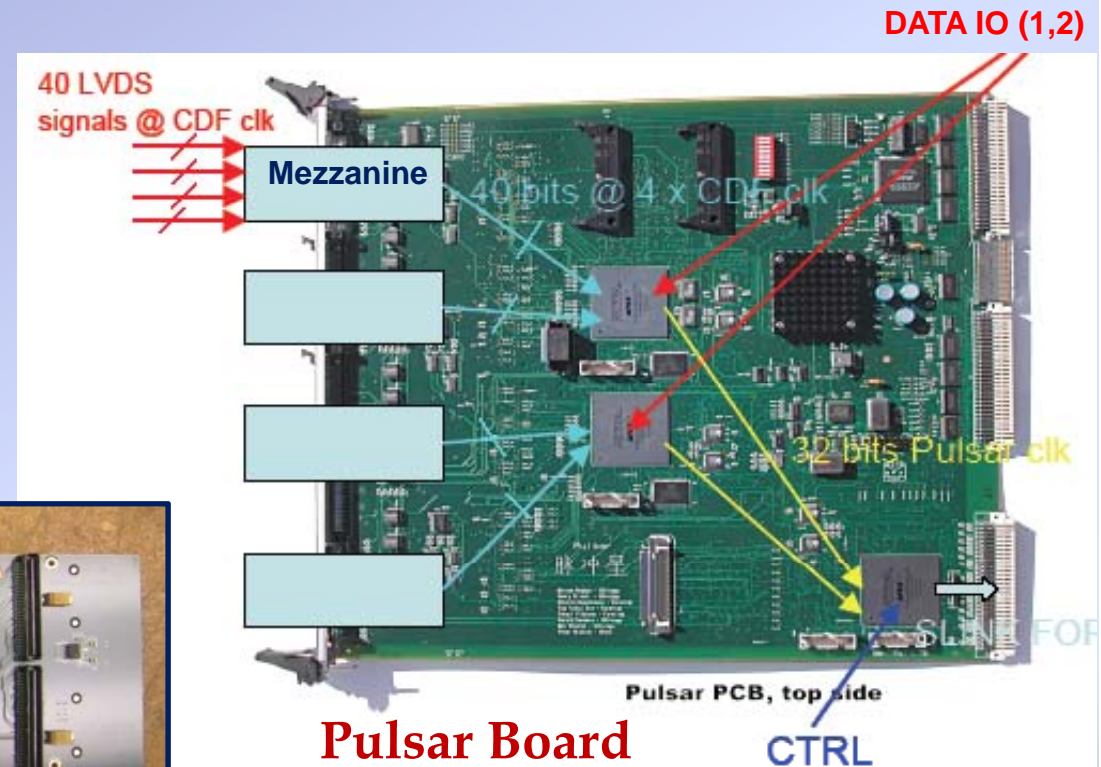
L2CAL Hardware Architecture (2)

The new hardware path is based on a general purpose VME board, developed at CDF, called **PULSAR**, on which 3 large Altera APEX **FPGAs** are allocated.

● **18 Pulsar boards** receive all the calorimeter **energy trigger tower information**, at the CDF clock frequency, through **72 mezzanine cards** (4 for each Pulsar).



Mezzanine Card

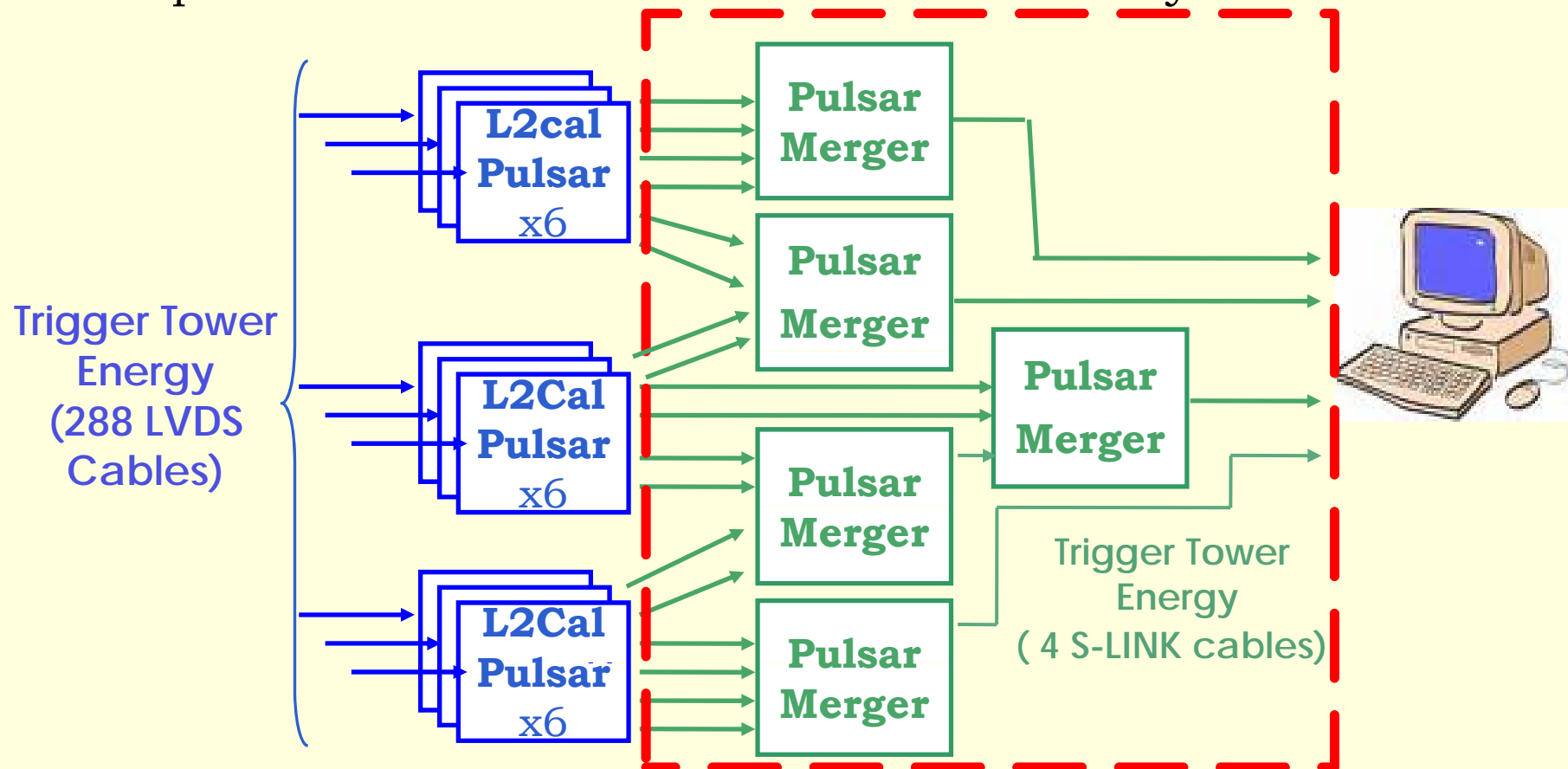


● The **3 FPGAs** on the Pulsars **process, merge and convert the data into the SLINK-32 format**.

L2CAL Hardware Architecture (3)

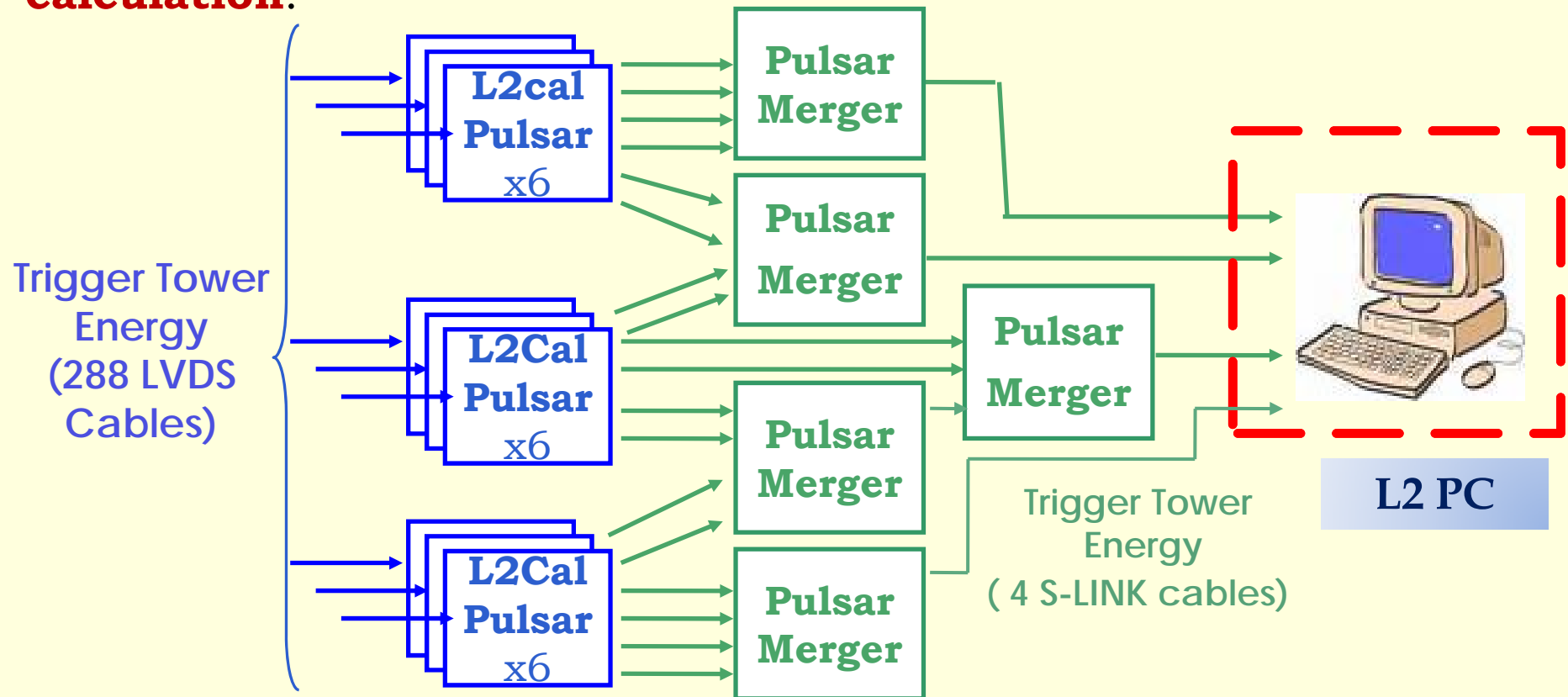
● A second set of **SLINK Merger Pulsars** receive and merge the 18 SLINK data streams into 4 SLINK data streams which are sent to the L2 CPU.

These procedures are made within a ~ 10 μ s latency time.



L2CAL Hardware Architecture (4)

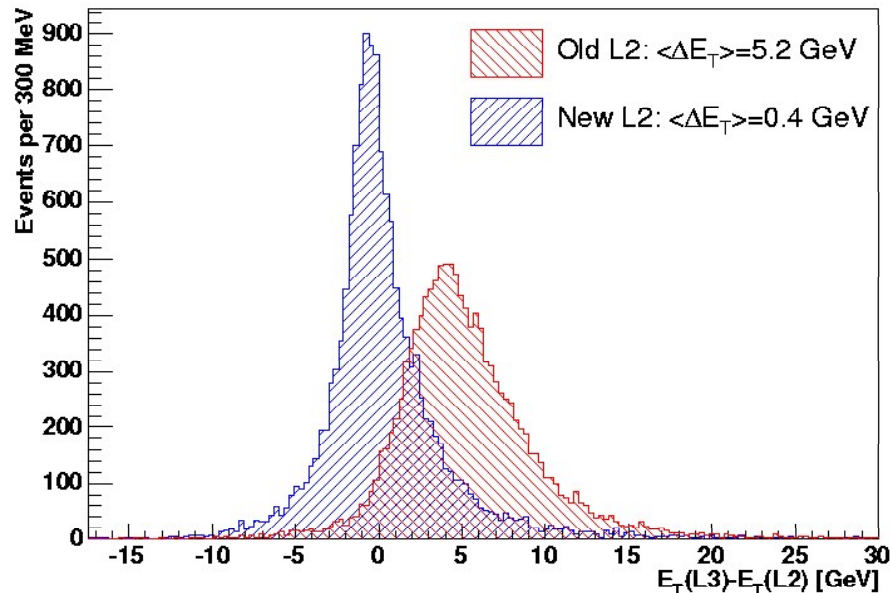
- The L2 **PC** performs the improved **jets clustering** and **MET calculation**.



- The Pac-Man algorithm was fully implemented in hardware.
→ The new one is fully implemented in the L2 PC.
- PC offers highest level of flexibility for more complex algorithms.

L2CAL Upgrade: toward L3 resolution

Jet transverse Energy

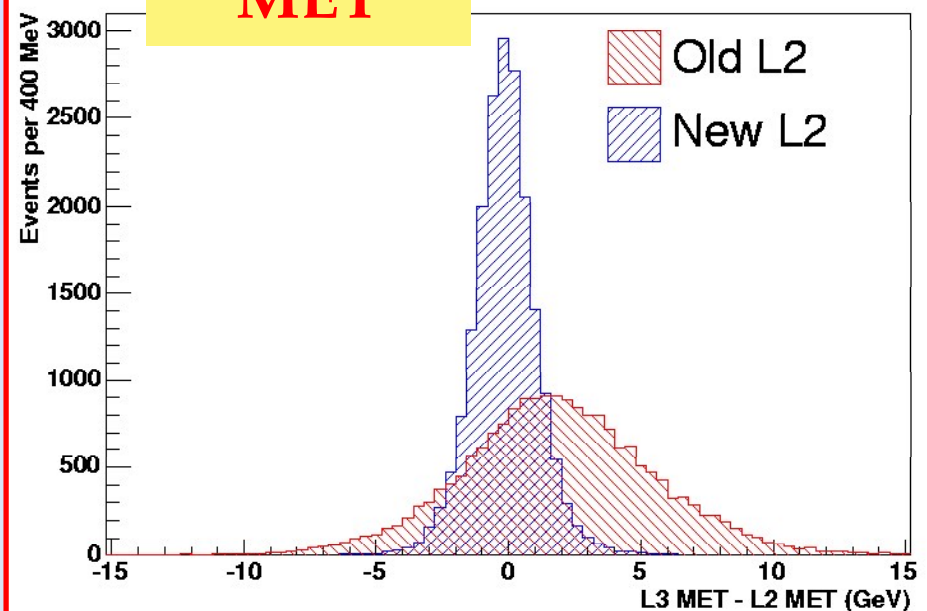


- ☀ ~ 50% of the L2 CDF triggers benefit from this upgrade;
- ☀ new dedicated triggers for Higgs are implemented.

System Commissioned in 6 months.
Official system since August 2007.

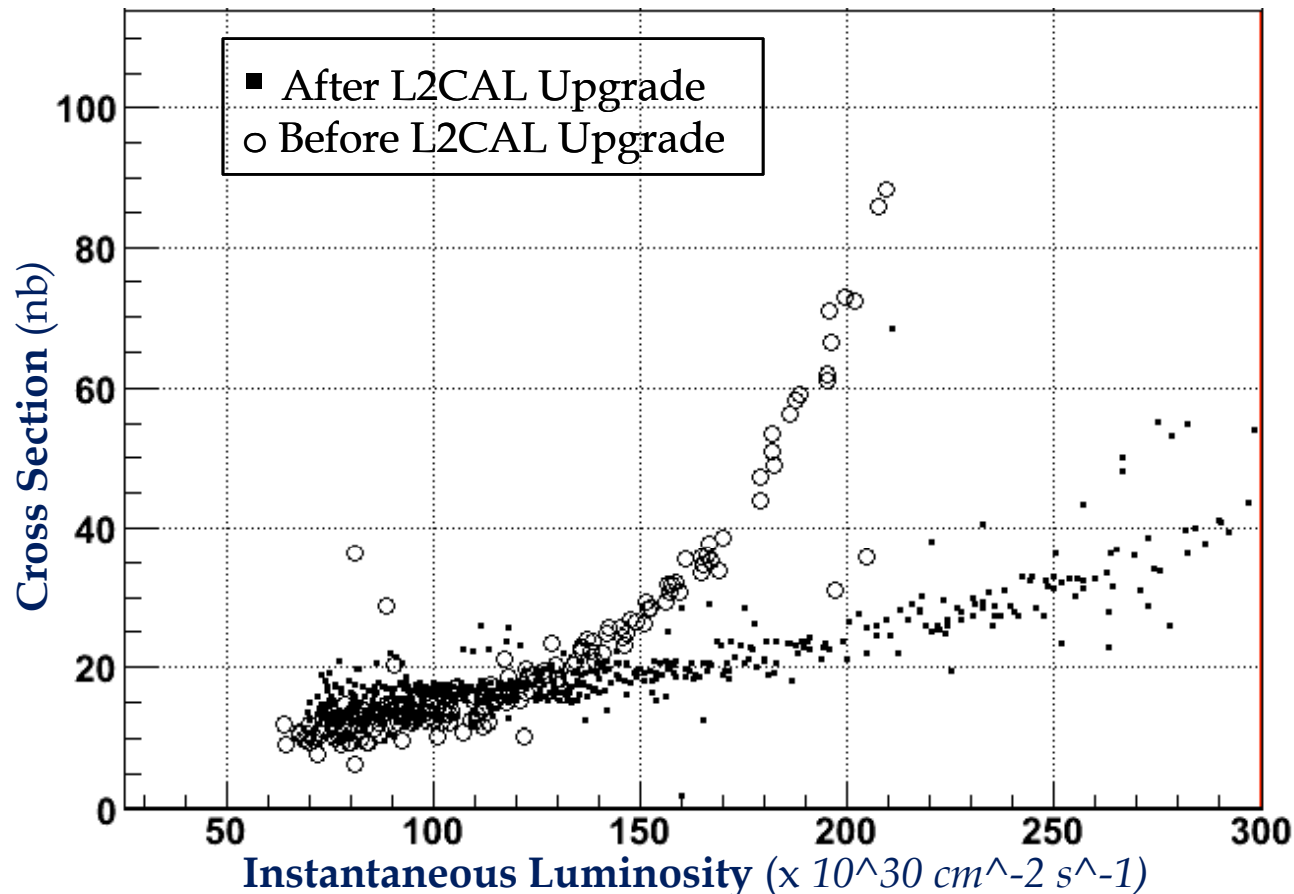
Difference between L2 and L3 jet transverse energy and MET for the old and the upgraded L2CAL systems.

MET



L2CAL Upgrade: less increasing Cross Section

- ➡ **Cross Section** of the jet trigger selection requiring jets above 40 GeV as a function of the **Instantaneous Luminosity**: upgraded L2CAL vs existing L2CAL system.



What about the Level1 trigger?

The L2 SumET and MET resolution has been improved
→ this **increases the efficiency**
taking under control the rate.

Can we do better ?

YES! We can push the offline resolution down to Level1.

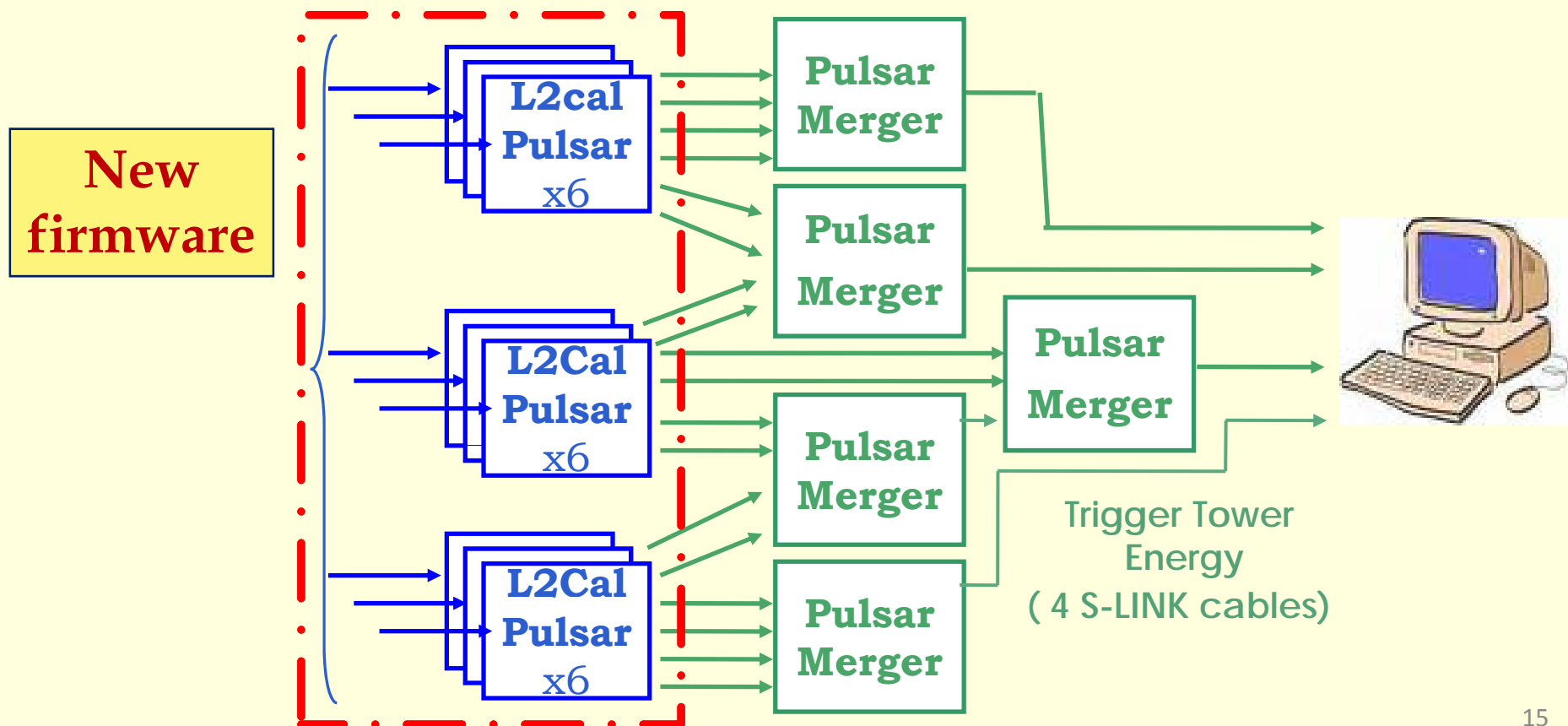


We can measure the **SumET** and the **MET**
at **Level1** with the **full resolution** (10bits),
as at the Level2.

The L1MET Upgrade (1)

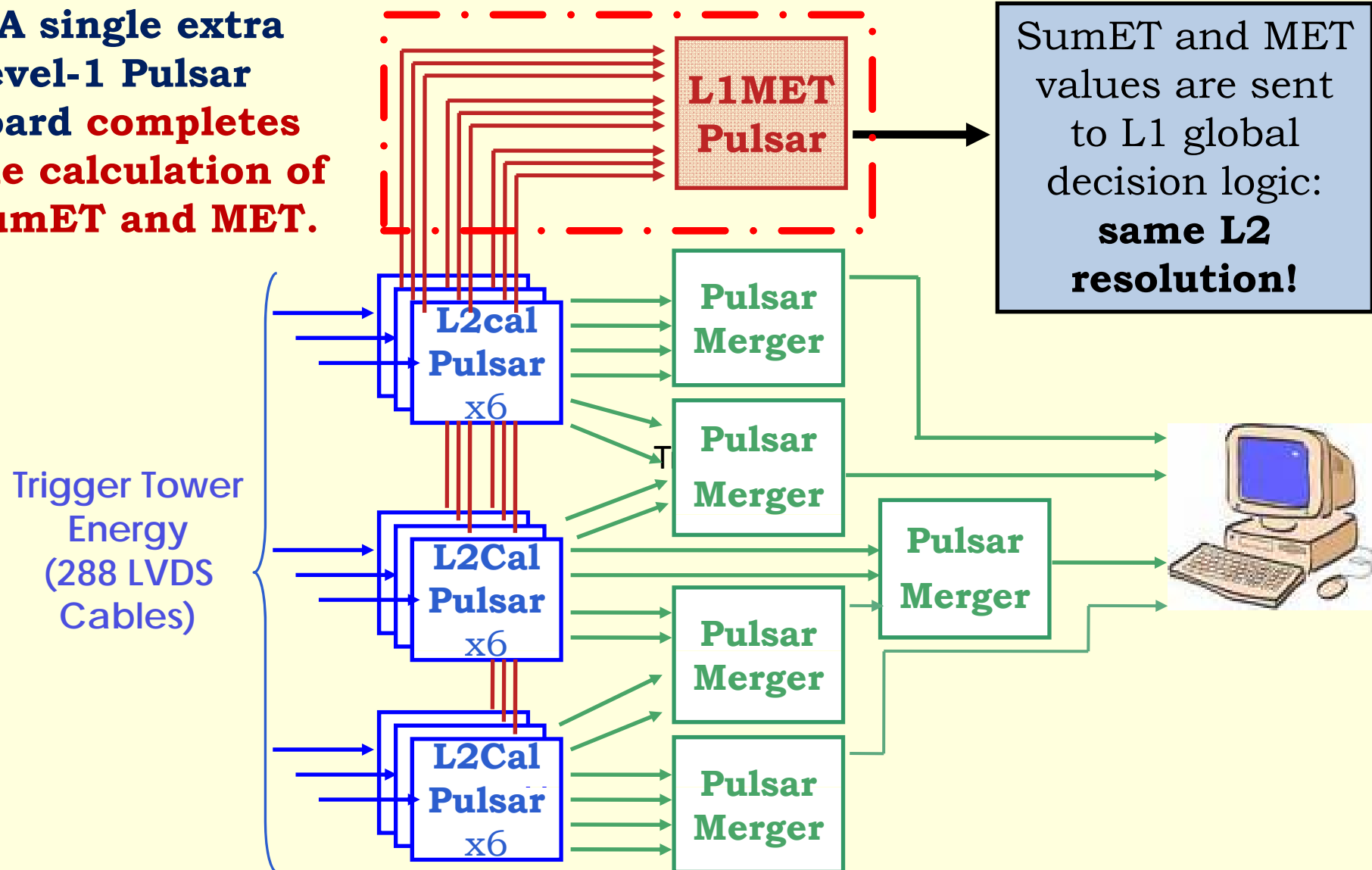
- The SUMET and the MET are computed on full resolution at Level-1 **using part of the electronic resources of Level-2.**

➔ FPGAs on the 18 first-set Pulsar boards of Level-2 execute a first step of the SUMET and MET calculation.

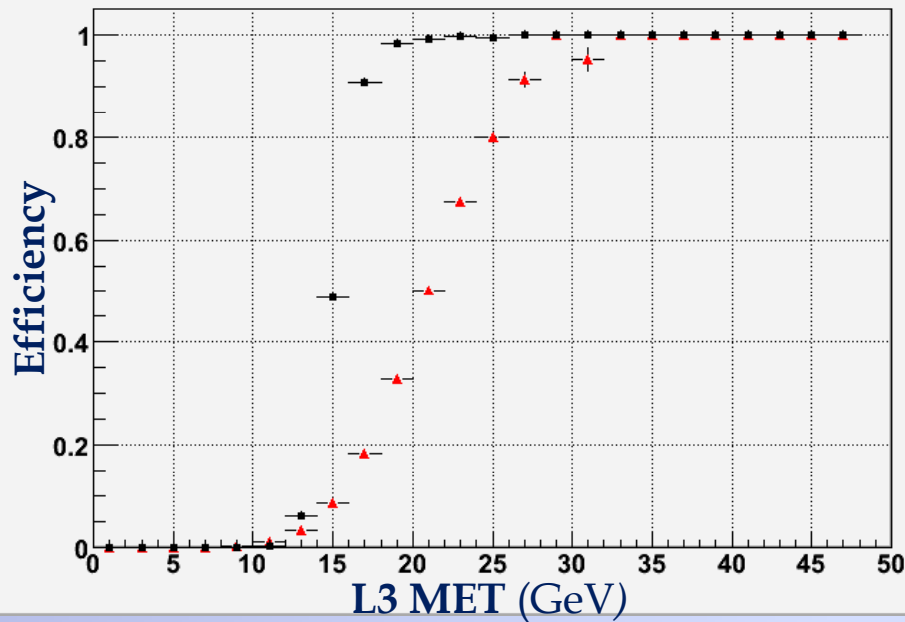


The L1MET Upgrade (2)

- A single extra Level-1 Pulsar board completes the calculation of SumET and MET.

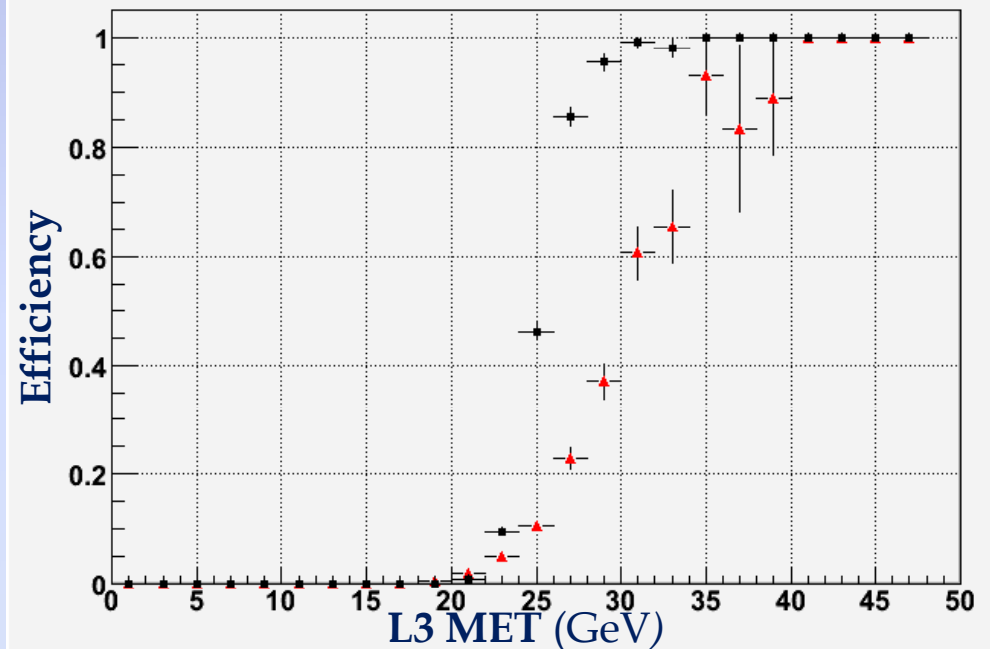


L1MET: first measured performances



- Existing System
- New System

Efficiency vs MET for L1 jet trigger
with **15 GeV** threshold
with **25 GeV** threshold



- Additional checks and studies are ongoing.
- The new hardware works well and soon the new L1CAL system will replace totally the old one.

Conclusions

The Tevatron luminosity has been increasing reducing the efficiency of the CDF trigger system in selecting rare events inside an huge background.

■ CDF has pushed the offline calorimeter resolution down to the L1 and L2 trigger system, upgrading:

➡ **Level 2** → Clustering, MET, SumET

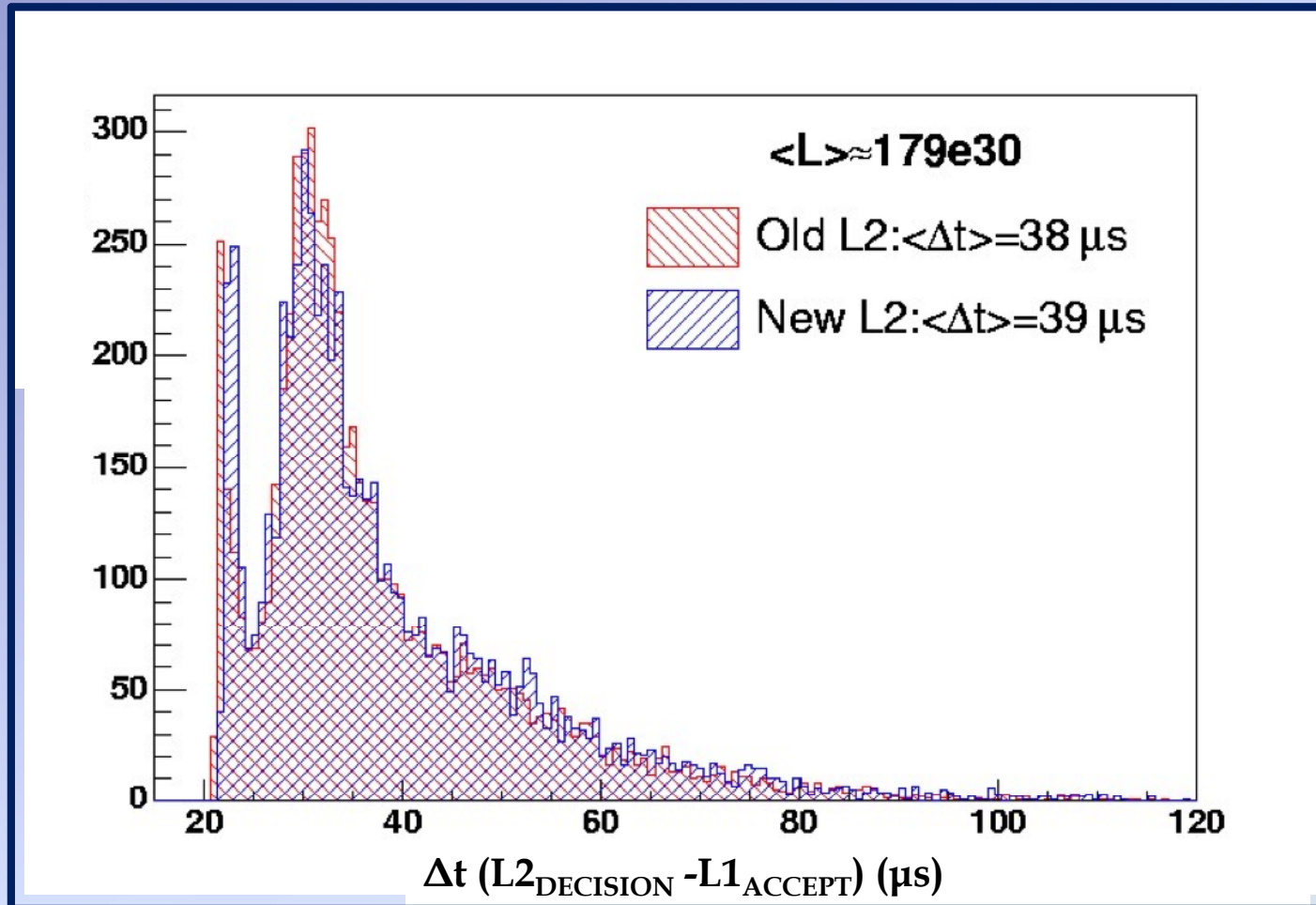
➡ **Level 1** → MET, SumET

Custom hardware has been realized or adapted.

Global effect: increase of the signal efficiency in CDF important search channels (in particular SM Higgs channels).

Backup

L2 Timing



Level 2 latency measured on-line: processing time from the L1 Decision to the completion of the L2 Decision.