The LHCb L0 Calorimeter Trigger

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On behalf of the LHCb collaboration

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The L0 calorimeter Trigger

- The design of the L0 calorimeter trigger is the result of a common effort by:
  - LAL Orsay- INFN Bologna: ECAL and HCAL
  - Barcelona-Clermont: PreShower and SPD
The L0 calorimeter Trigger
Working Principles

- The L0 calorimeter trigger has to identify the cluster types:
  - **Electromagnetic** (by ECAL & PreShower & SPD):
    - Charged (electron/positron)
    - Neutral: Photon, Neutral pion
  - **Hadronic** (by HCAL & ECAL)
  - Selecting the clusters with the highest $E_T$
    - High $E_T$ is a few GeV.
    - For L0 decision we need only the highest $E_T$ (the 2nd highest also, for hadrons)
L0 Calorimeter Trigger Implementation (I)

- The L0 calorimeter trigger processing is entirely synchronous.
  - No dependence on occupancy and history
  - Easy to understand and to debug

- Minimal cabling complexity
  - Local selection of the highest candidate on the FE board: by measuring the shower energy over $2 \times 2$ cells area and selecting the highest (local maximum).
    - This selection is performed in the identical way both for ECAL and HCAL calorimeter. 200 maxima for ECAL, 50 for HCAL, starting from 6000 channels of ECAL and 1500 of HCAL.
  - Use a dedicated backplane for as many connections as possible (front-end board communications).
L0 Calorimeter Trigger Implementation (II)

- The L0 calorimeter trigger is performed in three steps:
  - The local maximum is searched
  - Each local maximum is validated as electromagnetic cluster or as a hadron cluster (by using the PreShower and the SPD auxiliary signals)
  - Highest cluster for each cluster type is selected for triggering
Calorimeter Triggers for LHCb
FE Board Main Features

- 12 bit ADC produces 8-bit $E_T$ transverse energy
- 32 sums of the $2\times2$ $E_T$ values are calculated and the highest candidate is selected
- Neighbouring cells are transmitted/received via the crate blackplane (9) or by point-to-point LVDS links (4)
Calorimeter Triggers for LHCb
### ECAL 188 FE cards

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**Outer Section**
- 2688 channels
- Crates 1 and 2

**Middle Section**
- 1792 channels
- Crates 4 and 5

**Inner Section**
- 1472 channels
- Crates 6, 7

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**Calorimeter Triggers for LHCb**
The Backplane of the Calorimeter

Services

Calorimeter Specific

Outside Connections

Neighbouring connections

Validation Cards

ReadOut
Cluster Validation

**ECAL Validation**
- A cell-by-cell PreShower-SPD coincidence is used to identify electron and photon: it requires some activity in the PreShower cells located in front of electromagnetic cluster candidate.

**HCAL Validation**
- Add the ECAL energy released in front of the HCAL candidate.
- Add only the ECAL energy of the ECAL candidates selected by the ECAL FE boards: the complete recovery would take too many links (If the energy deposited in ECAL by the hadron is high enough, it has a good chance to be a local maximum being selected by the ECAL FE card).
The PreShower Front-End Board

- From the ECAL cluster address, after checking the BCID, the PreShower board extracts the bit map of the $2 \times 2$ zone in front of the ECAL cluster: in total twice 4 bits for the PreShower and the SPD.
- The answer is sent to the ECAL Validation Card.

The 64+8+8+1 neighboring bits accessed in the same way as for ECAL/HCAL by blackplane and links.
Validation Card

- One Validation Card treats 8 ECAL front-end cards and up to 4 HCAL front-end cards

- ECAL candidate validation
  - For each cluster type, select the highest candidate, amongst the 8 channels of the card.
  - Sends 4 outputs (one per type) to the Section Crate

- HCAL candidate validation
  - Some of the HCAL candidate (30/50) go to two ECAL Validation Card: the same HCAL information appears twice (copy removal by the Selection Crate is then requested).
  - Search for the ECAL energy in front of the HCAL cluster
Validation Card

- Select the ECAL card to be compared to the HCAL card
- Matching ECAL $E_T$ are compared, the highest is selected
Optical Links

- Optical links are requested to transmit the cluster candidates from the Validation Cards to the Selection Crate.
- The system exploits the G-Link serial protocol: 16-bit @ 80MHz.
- 4×28 (ECAL) + 80 (HCAL) Rx/Tx are needed.
The Selection Crate

- The 4 ECAL types are processed all the same way
  - The highest of the 28 inputs for each cluster type is selected and sent to the L0DU
  - The final address assignment is performed there
    - 14-bit final address from the 5-bit address, by a LUT
- The HCAL processing is more tricky
  - The two copies of the same HCAL candidate, validated by two cards, have to be compared and the highest selected.
  - The final address has to be produced
  - The cluster selection is required to produce the 2\textsuperscript{nd} highest
  - Removal of ghosts is needed
HCAL processing

- This is a two steps processing
  - 7 boards 16 inputs each to handle the 80 candidates (50 +30 copies)
  - Output: the two highest candidates and the 14 bits $\text{SumE}_T$

80 Optical Links

20 Clock Cycles

1° max
2° max

14×30

$E_T$

7×14

Calorimeter Triggers for LHCb
ECAL Selection Crate

- The ECAL selection is simpler
  - 2 identical cards handling 14 optical and 1 LVDS inputs
    - The LVDS input receives the result of the other card, for the final comparison
  - No cleaning of copies
  - No second highest then no ghost cleaning
  - No $\text{SumE}_T$ produced

14 Optical Links
14 Optical Links

1 LVDS Links

10 Cycles

1° max
30 bits

30 bits $\rightarrow$ LVDS

1° max

ECS Control

Calorimeter Triggers for LHCb
Hadronic calorimeter L0 trigger
Simulations-Performances

\[ B_d \rightarrow \pi^+ \pi^- \]

**Efficiency:**
full points, left scale

**Minimum Bias Rejection:**
open points, right scale

- \( E_T = 3.4 \text{ GeV} \)
- \( \varepsilon = 68\% \)
- \( R = 16 \)
- @TP bandwidth

**Efficiency vs \( E_T \) threshold**
Conclusions

- System design is quite advanced
  - Simulations for most of the FPGA has been produced
- Some prototypes have been already built
  - Front-End calorimeter trigger test card
  - Link test beds
- We can write the TDR