The CMS Electromagnetic Calorimeter detector control and monitoring system

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Compact Muon Solenoid Experiment at the Large Hadron Collider

Electromagnetic Crystal Calorimeter (ECAL)

- measures precisely energy of electrons, positrons and photons
- 75,485 scintillating PbWO₄ crystals in the ECAL barrel and end-cap
- pre-shower detector in the end-cap (lead absorber and silicon strip detectors)
- scintillation light is collected by photo detectors glued on the end face of crystals operating under high voltages of several hundred Volts
- crystals’ light yield and barrel photo detectors’ gain are strongly dependent on their temperature (~2.4% per °C)
- water cooling system used to keep nominal temperature of 18.00°C ± 0.05°C

Trigger Tower – the basic unit of the ECAL readout electronics

- Multi Gain Amplifier shapes and amplifies signals with gains 1, 6 and 12
- ADC digitizes the three signals in parallel with 12 bit and 40 MHz
- a dedicated logic chooses: the highest non-saturated signal
- Front End Board calculates trigger sum of one tower or strip (for barrel and end-cap, respectively), buffers data until reception of trigger and connects optically to off-detector trigger, control and data acquisition systems

Detector Control System tasks

- Precision monitoring of crystals’ and photo detectors’ temperature (±0.01°C)
- monitoring of temperature of electronics components
- detecting water leaks
- automatically protect ECAL in case of problematic situations (hardwired interlocks, predefined control actions, alerting etc.)
- control software for parameterization and operation of the electronics’ low voltage supplies, the photo detectors’ high voltage supplies, the ECAL laser calibration and the cooling system

Data Quality Monitoring (DQM) tests of all ECAL channels

1. Pedestal run (HV on): measures the mean outputs (pedestal) and its fluctuation (RMS) without signal injection.
   RMS is considered as electronic noise which contributes to the ECAL resolution
2. Pedestal run (HV off): finds bad connections between photo detector and readout chain
3. Test Pulse run: tests the readout-chain by measuring amplitudes of injected test pulses
4. Laser run: dedicated laser system injects 532 nm laser pulses in each crystal, tests the whole detector chain including crystals and photo detectors
5. Detector Control Unit run: monitors crystal and electronics temperatures and leakage currents of photo detectors

Classification of problematic channels according to DQM tests

<table>
<thead>
<tr>
<th>Identified hardware problem</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Usable channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Bad connection of Photo Detector and readout-chain</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>NO</td>
</tr>
<tr>
<td>B) Photo Detector broken due to short</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>NO</td>
</tr>
<tr>
<td>C) Read-out channel’s input chip broken</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>NO</td>
</tr>
<tr>
<td>D) Noisy Channel</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>YES</td>
</tr>
<tr>
<td>D) Low laser amplitude*</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>YES</td>
</tr>
</tbody>
</table>

*Channels of the category ‘Low Laser amplitude’ work perfect with cosmic muons → ignore

ECAL single problematic channels in time (total 75,848)

<table>
<thead>
<tr>
<th>Identified hardware problem</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Total not usable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics integration in ECAL in spring 2007</td>
<td>21</td>
<td>6</td>
<td>0</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>ECAL installation in CMS in summer 2007</td>
<td>13</td>
<td>5</td>
<td>4</td>
<td>15</td>
<td>32</td>
</tr>
<tr>
<td>‘Good Health Test’ in Winter 2009</td>
<td>21</td>
<td>6</td>
<td>0</td>
<td>24</td>
<td>49</td>
</tr>
</tbody>
</table>

Conclusions

- The Electromagnetic Calorimeter of CMS has an excellent noise performance of ~1.1 and 2 ADC counts in the highest amplification gain in barrel and end-cap, respectively.
- The contributing resolution terms are ~40 and ~50 MeV in barrel and end-cap.
- In spring 2009 we find 49 single channels, that are unusable for physics measurements.
- 20 channels are dead due to low voltage problems.
- About 8 Trigger Towers have problems with optical links and/or the data integrity.
- In total, we reached a very low plateau of less than 4% unusable channels in the ECAL.

References