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The Level-1 Global Trigger for the CMS Experiment at LHC

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The trigger of the CMS experiment consists of two stages: the first stage, or Level-1 Trigger is implemented in hardware processors while the second stage, or High-level Trigger is implemented in software running on a computer farm. The Level-1 Trigger has to deliver a trigger decision for each LHC bunch crossing, i.e. at a rate of 40 MHz. The Level-1 Global Trigger uses objects supplied by the calorimeter and muon trigger systems. Its decision is based not only on energy and momentum thresholds but also on complex event topology, making use of space, charge and quality information calculated by the Global Calorimeter and Global Muon Trigger electronics.

Summary

At the CMS experiment, the event rate at the nominal LHC luminosity will approach 1 GHz (about 20 events at each “bunch crossing” every 25 ns). This enormous rate will be reduced to the data taking capacity of 100 Hz in a two-stage process, where the first, hardware-based stage of the “Level-1 Trigger”has to reduce the rate by a factor of 10,000 to below 100 kHz. Due to the limited length of the digital pipelines in the various subdetectors, the Level-1 trigger decision must be available within 3.2 microseconds. The Level-1 trigger and therefore also the L1 Global Trigger will operate in an intrinsically dead-time free, synchronous mode, where a yes/no decision is calculated for each bunch crossing and becomes available at a fixed delay after the event. Information from calorimeters and muon triggers systems is used to calculate this decision for up to 128 different trigger algorithms, which are calculated in parallel. Different downscaling factors can then be

applied to these 128 trigger bits, which are subsequently combined into a
single decision ('FinalOr'). Based on this decision, a "Level-1 Accept"
trigger signal is issued if all parts of the CMS detector and read-out
systems are ready to accept a trigger.
The primary trigger objects are electrons or photons, muons, taus, jets,
and very weakly interacting particles detected indirectly through missing
transverse energy. Muons are detected by three systems built up of drift
tubes, cathode strip chambers, and resistive-plate chambers. The
information from these three systems is combined in the "Global Muon
Trigger"(GMT), which also receives information from the calorimeters to
see if a muon candidate is isolated or not, and if it corresponds to a
minimum-ionizing particle. Information on all other particles is yielded by
the electromagnetic and the hadronic calorimeters and combined first in the
"Regional"and then in the "Global Calorimeter Trigger".
The hardware of the Level-1 Global Trigger consists of custom-built VME
modules using FPGA technology, which are housed in one 9-U VME crate
together with the module of the Global Muon Trigger and the central trigger
control module. Signals from the muon systems are received by the GMT
module while signals from the calorimeters are sent to "Pipeline
Synchronizing Buffer"input modules, which assure that all signals
referring to one particular event enter the "Global Trigger Logic"(GTL)
module at the same time. All trigger algorithms are implemented in the
firmware loaded into the FPGAs of the GTL module and may thus be changed at
any time. The "Final Decision Logic"module combines the trigger bits
calculated by the GTL as well as "technical"trigger bits sent by other
systems (for purposes of calibration etc.) after applying the individual
downscaling factors and sends its decision to the "Trigger Control System"
module (TCS), which also receives information on the state of the various
subsystems ("ready", "busy", "overflow warning", "error state"etc.) and
then issues a "Level-1 Accept"(L1A) signal if a trigger is requested and
the detector is ready to accept it. Eight independently

running control
units (PTC) allow to combine subdetectors to groups during
calibration and
test periods.

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