The CMS Phase-2 Level-1 Global Trigger

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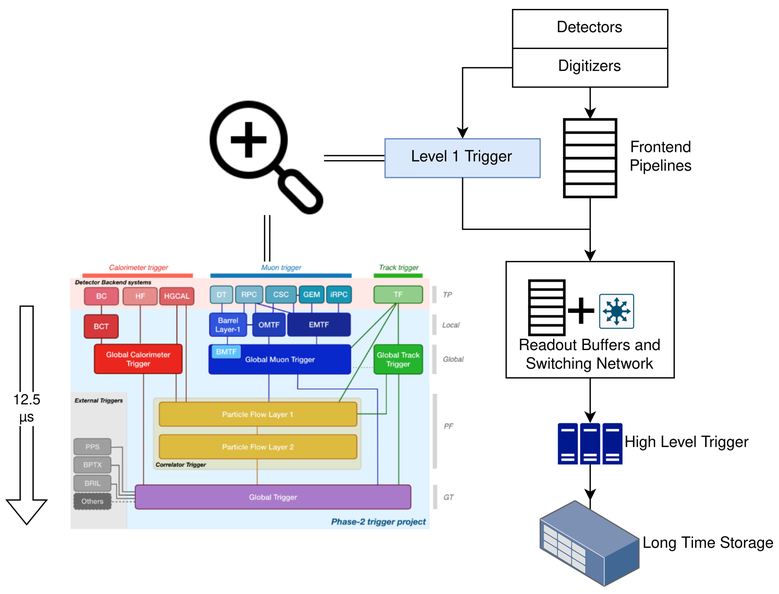
Overview



The Phase-2 Level-1 Trigger (L1T) in the CMS experiment is a pipeline of hardware (FPGA based) triggers, which receive condensed data from the CMS detector. It decides whether an event should be read out or discarded at a fixed latency of $\approx 12.5\mu s$. With the increased latency budget, compared to the $\approx 3.5\mu s$ of the current system, the inclusion of tracker information and high-granularity calorimeter information the Phase-2 Level-1 Trigger aims to tackle an ambitious physics program at unprecedented levels of luminosity.

The final stage of the L1T, the Global Trigger (GT), receives high precision inputs from all regional triggers, as well as the Correlator Trigger. It outputs the final trigger decision *L1 accept* to the Timing Control and Distribution System. This decision triggers the readout of the event, which is then further processed by the High Level Trigger (HLT). The GT consists of up to 13 Serenity custom ATCA boards (12 algorithm, 1 Final OR), designed by the CMS collaboration, each equipped with a Xilinx Ultrascale+ FPGA. Each of the twelve algorithm boards will receive a copy of all upstream system inputs. The Global Trigger is planned to evaluate up to 1000 configurable cut based and neural net algorithms, the so called *Menu*, in a timing budget of $1\mu s$. The outputs of all 12 algorithm boards are sent to the final OR board, where they are combined, prescaled and monitored. To evaluate and test the functionality of the GT algorithms, a bitwise compatible emulator in the CMS software framework (CMSSW) has been developed.

Interface

The pre-production prototype of the GT is able to receive 26 collections of physics objects, each of them typically containing 12 objects. The collections are received on 66 $25Gb/s$ optical links, in a time multiplexed format at two different time multiplexing periods. Three out of the four upstream systems use time multiplexing period six, the Global Track Trigger (GTT), Global Calorimeter Trigger(GCT)* and Correlator layer 2 (CL2), while the Global Muon Trigger (GMT) sends data at time multiplexing period 18.

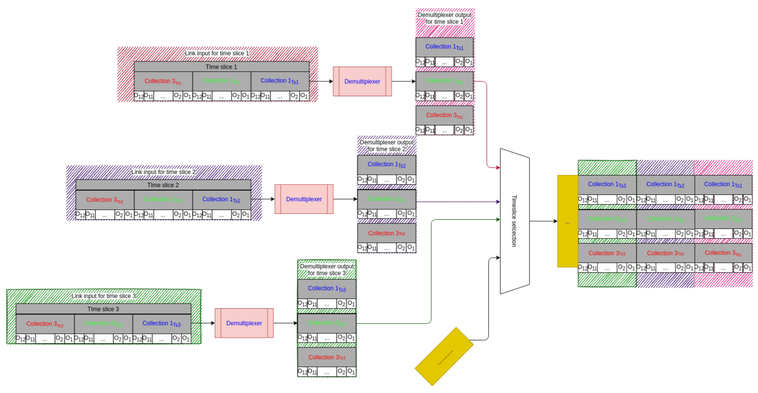
Global Muon Trigger	Global Track Trigger	Global Calorimeter Trigger	Corelator layer 2
track matched muons	prompt jets	non isolated e/γ	jets
standalone prompt muons	displaced jets	isolated e/γ	taus
standalone displaced muons	prompt jets HT sums	jets	electrons
topological objects	displaced jets HT sums	taus	photons
	ET sums	HT sums	HT sums
	hadronic taus	ET sums	ET sums
	ϕ meson candidates		
	ρ meson caandidates		
	Bs meson candiates		
	primary vertex		

*) The GCT is not a time multiplexed system but will send time multiplexed data

Reference:
The Phase-2 Upgrade of the CMS Level-1 Trigger Technical Design Report
url: https://cds.cern.ch/record/2714892

Demultiplexing

Data arrive at the GT in a time multiplexed format. The GT works in a non time multiplexed way, in order to be able to trigger on objects from ±3 bunch crossings in a tight timing budget. After this collection-wise parallelization, the individual objects are streamed to the algorithm units. Further, the demultiplexer unit converts upstream objects into an internal GT format and crosses the clock domain from 360 to 480 MHz.



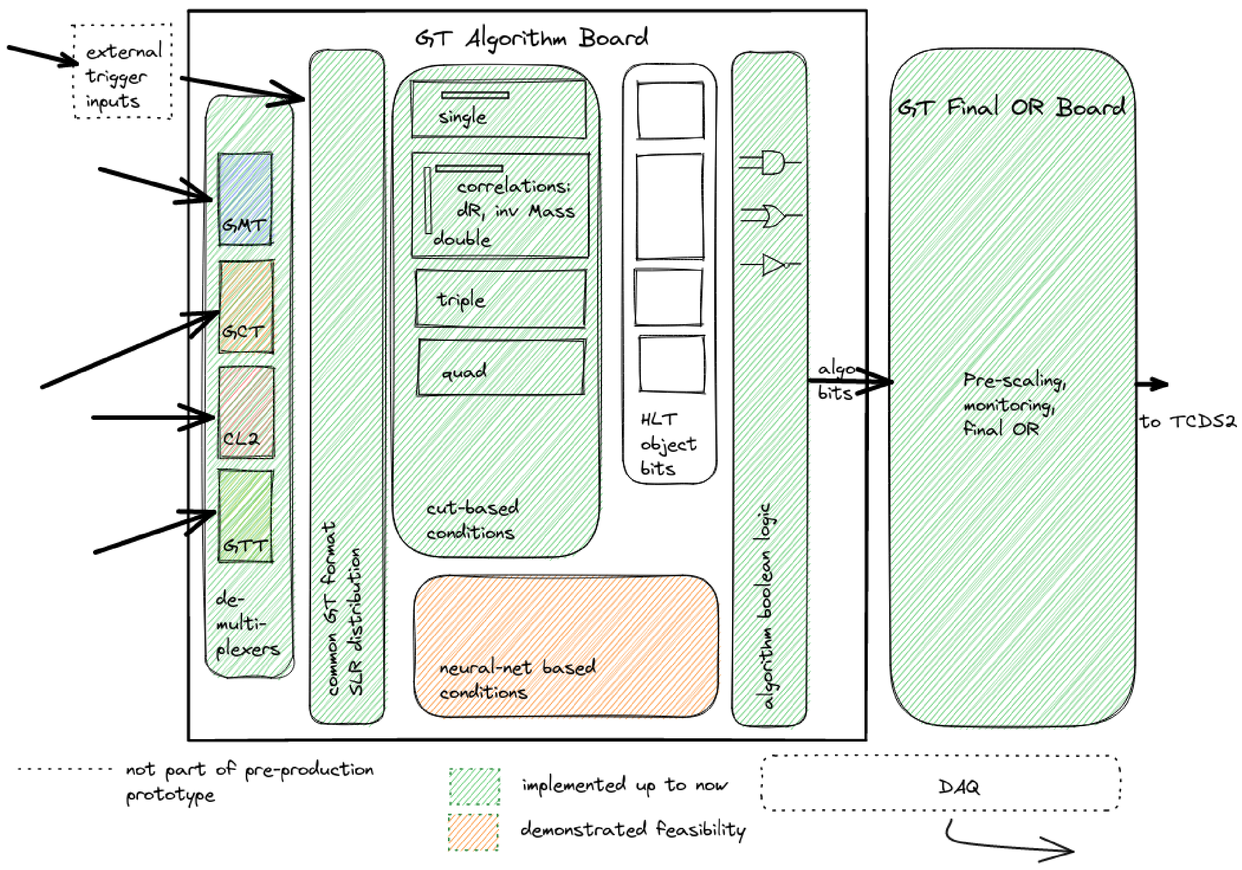
Internal GT object

To simplify the development of algorithms the GT uses a common internal object, which is a superset of all particle-like upstream objects. After the conversion, objects share common bitwidths and scales on every parameter. Where necessary, the scales of the upstream objects are converted into a common internal GT scale.

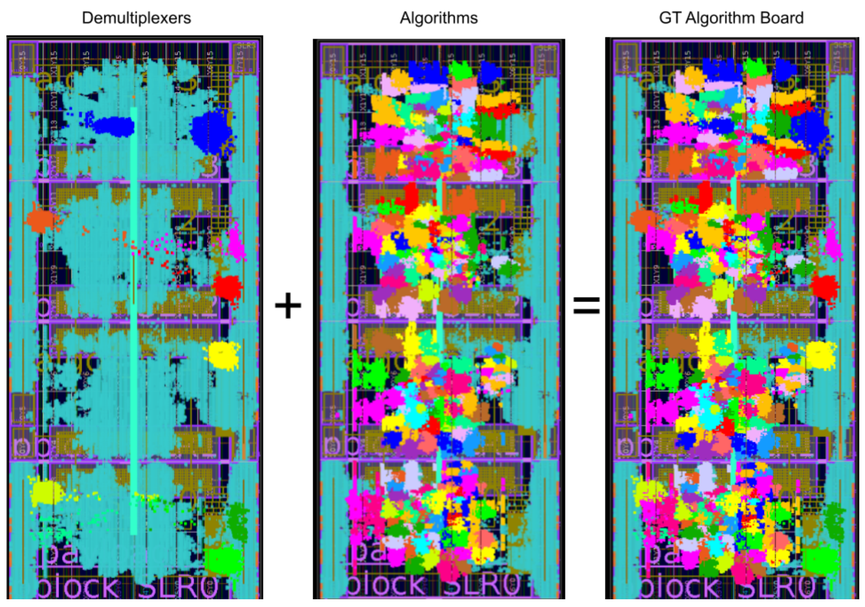
Cut based Algorithms

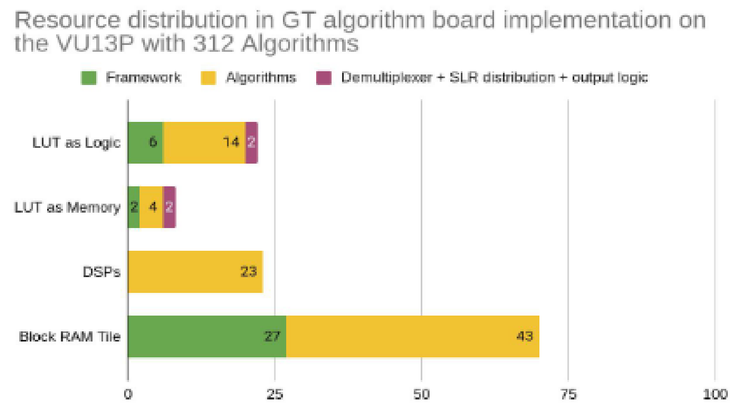
The conditions are written in a generic way and can be applied to any particle-like GT object. The possible cuts include simple cuts such as pT, η or ϕ and correlational cuts which make use of digital signal processors (DSP), such as ΔR or invariant mass. The implementation of these conditions balances resource usage and latency at 480 MHz.

Phase 2 Global Trigger



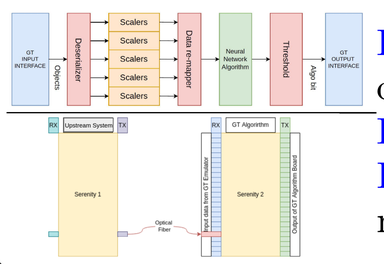
Hardware Implementation





The current pre-production prototype consists of 66 demultiplexer units depicted in groups of subsystems GMT, CL2 (three shades of red), GCT, GTT (four shades of green). After demultiplexing the collections are sent across the chip to 312 algorithms. 96 of these are DSP based correlational cuts.

Ongoing Work



Implementation of neural net based algorithms, such as topological triggers or autoencoders.

Integration tests with upstream systems, as well as GT Algo - GT FinOR.

Development of an automated translation of a CMSSW generated algorithm menu as well as optimizations of currently implemented algorithms.