Overview and performance of the ATLAS Level-1 Topological Trigger

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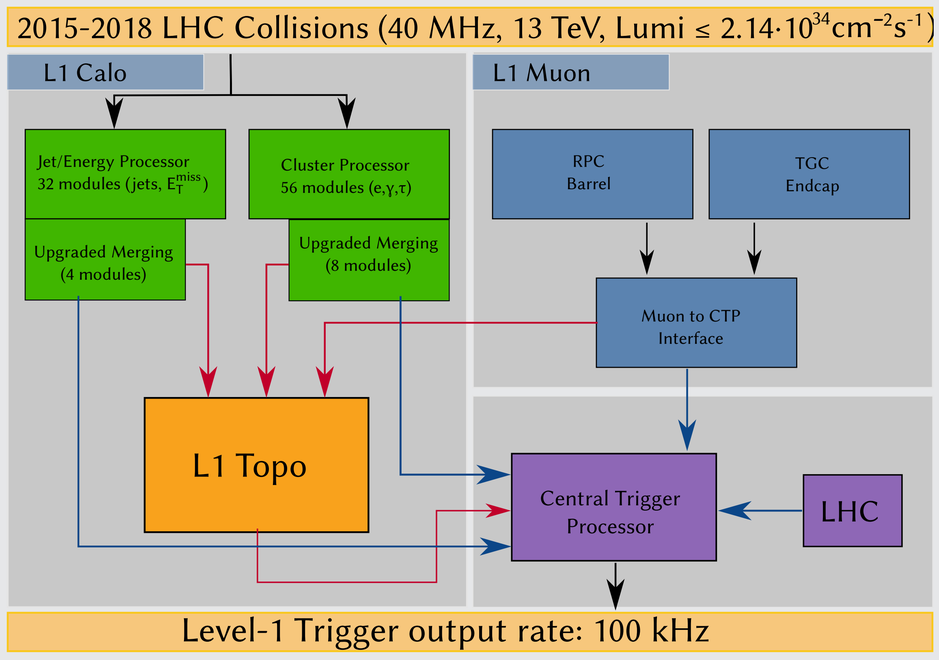
The ATLAS Level-1 Trigger

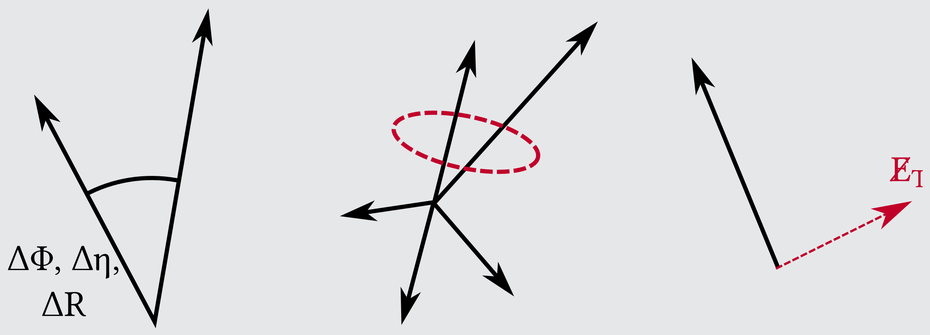
- ATLAS trigger: selects 1 kHz of collision data events for offline analysis
- Level-1 trigger: latency of 2.5 µs, maximum output rate of 100 kHz.
- Level-1 Topological Processor (L1Topo): part of the Level-1 trigger, developed to deal with increasing luminosity and energy.



L1Topo gets inputs from the Level-1 Calorimeter Trigger and the Level-1 Muon Trigger containing information on jets, e, γ, τ and missing energy. Its purpose is to provide trigger decisions based on topological algorithms already on the first trigger level.

Topological Algorithms

Some examples of topological algorithms currently implemented on L1Topo are shown below.



Isolation, overlap removal, b-tagging,...

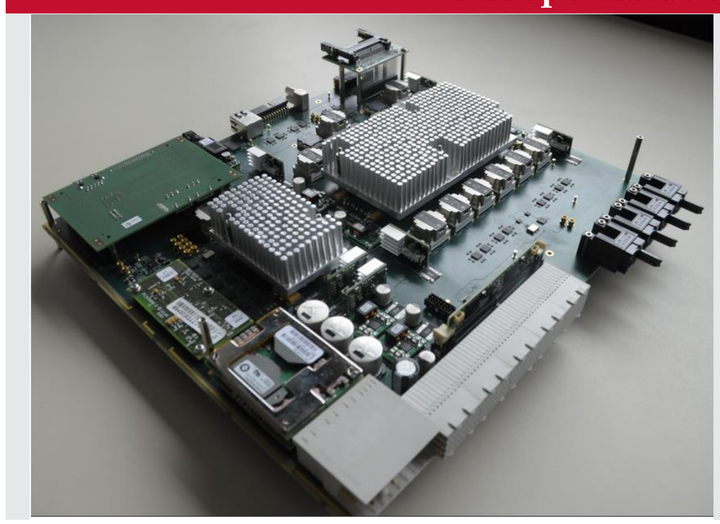
H_T, M_{inv}, Fat jets

M_T, $\Delta\Phi$(jet, $\not{E}_T$)

L1Topo triggers are used for different purposes, both for physics as well as for detector calibrations. Various examples with their physics use cases are listed below.

- Jet invariant mass cuts (VBF)
- ΔR of muons (B-Physics)
- H_T: scalar sum of jet E_T (Susy, Exotics)
- η-ϕ window cuts (detector commissioning)

L1Topo Hardware



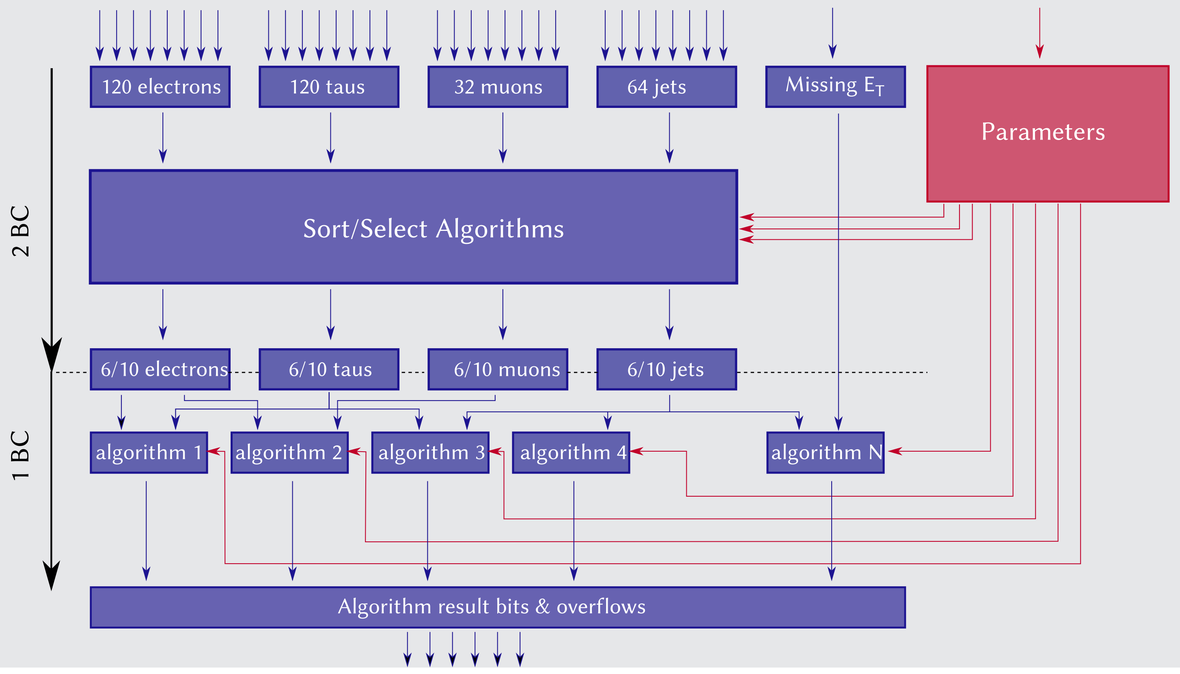
L1Topo processes about 1 Tbit s^{-1} of input data with a fixed latency of ∼200 ns. The input data are received via optical fibres, transformed into electrical signals and then directed into the processor FPGAs (Xilinx Virtex7) where the topological algorithms are applied.

General Algorithm Structure

Two algorithm types are applied to reduce the number of input objects without losing important event information.

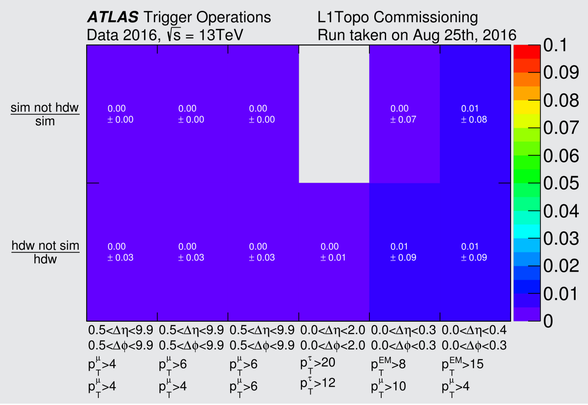
- A *sort algorithm* creates a list of the six leading particles
- A *select algorithm* creates a list of 10 particles above an E_T threshold

These shortened lists are then flexibly combined into various topological *decision algorithms*. In this way, a total number of 113 triggers are implemented in 2018.



Simulation and Validation of Algorithms

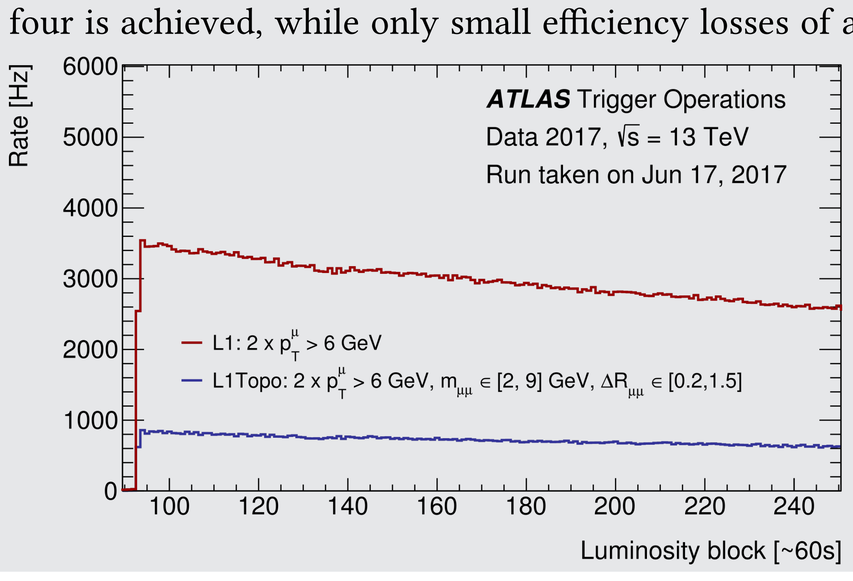
Multiple levels of validation of the topological algorithms are performed:

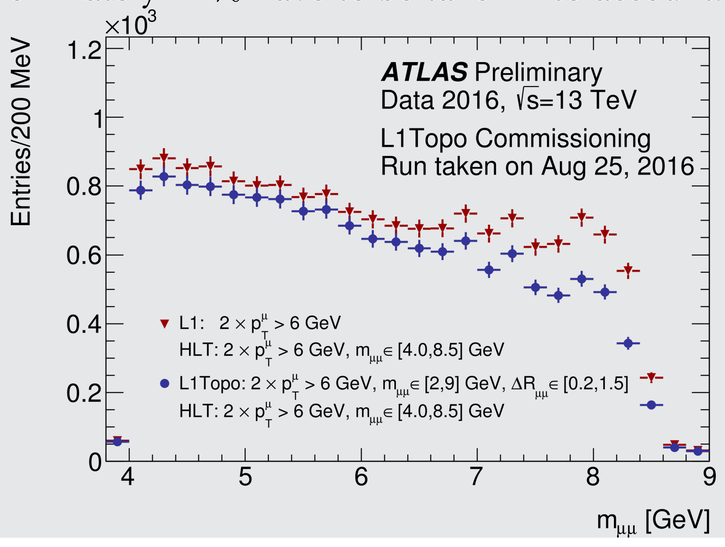


- standalone VHDL simulation of the algorithms
- examine algorithm decisions for well defined input data
- comparison of hardware and simulation results for real events
- $\mathcal{O}(\%)$ mismatches: hardware behavior is very closely simulated

L1Topo Triggers Performance

L1Topo triggers allow to significantly reduce background rates while keeping a good signal efficiency without raising E_T thresholds. The rate reduction and trigger efficiency have been studied and are shown below for B-physics dimuon triggers. An overall rate reduction thanks to the L1Topo requirement of about four is achieved, while only small efficiency losses of approximately 12 % have to be taken into account.





Conclusion

- L1Topo has been successfully installed in the first-level trigger of ATLAS
- It adds new capabilities, such as combining muon and calorimeter information at Level-1
- Many L1Topo triggers have been commissioned and validated successfully
- With L1Topo, the ATLAS trigger system is able to record data at high luminosities without losing signal efficiency
- L1Topo was routinely used in 2017 to trigger events, modified menu in 2018 includes more algorithms

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For more information:

[1] I. Riu, *The ATLAS Level-1 Topological Trigger performance in Run 2*, ATL-DAQ-PROC-2017-002(2017)

[2] ATLAS Collaboration, https://cern.ch/twiki/bin/view/AtlasPublic/TriggerOperationPublicResults