

# The ATLAS Level-1 Topological Processor

## Experience and upgrade plans

**Paula Martínez Suárez** on behalf of the ATLAS Collaboration

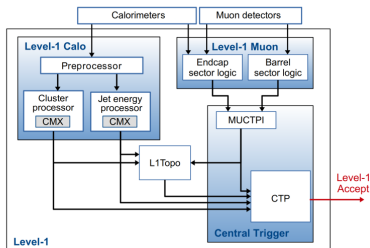
LHC Physics Conference 9th Edition (2021)



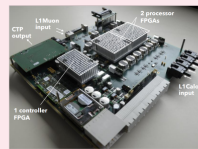
## The ATLAS Level-1 Topological Processor (L1Topo)

The Level-1 (L1) trigger is the first stage of the ATLAS trigger system, and performs hardware-based online event selection in order to reduce the event rate from 40 MHz to 100 kHz, which is the maximum detector readout rate.

**L1Topo** combines trigger objects (TOBs) from the L1 calorimeter trigger (**L1Calo**) and the L1 muon trigger (**L1Muon**) to calculate topological quantities that can be used to take a decision in the central trigger processor (CTP).

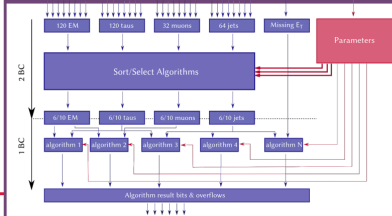


## L1Topo architecture



The L1Topo system consists of two AdvancedTCA-compliant modules, each of them equipped with two processor FPGAs (Xilinx Virtex7) to run the algorithms and one controller FPGA (Kintex7) to communicate with the external trigger systems. Each processor FPGA can hold up to 32 **topological algorithms**. The total latency of the L1Topo system is around 200 ns, equivalent to 8 LHC bunch crossings.

## L1Topo algorithms



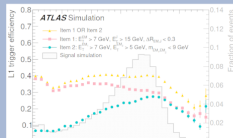
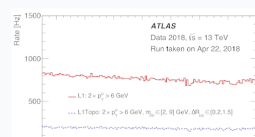
The **sort/select algorithms** are used to produce filtered lists and reduce the possible number of combinations between different types of objects.

The **topological algorithms** are used, among other things, to:

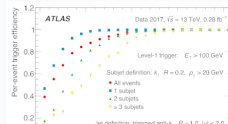
- compute  $\Delta\eta$ ,  $\Delta\phi$ ,  $\Delta R$  and compare  $(\eta, \phi)$  positions.
- calculate  $m_{\text{inv}}$ ,  $m_T$  and event hardness.
- compute energy ratios.
- perform large-R jet clustering.

The algorithm result bits are sent to the CTP.

## Trigger performance during Run 2



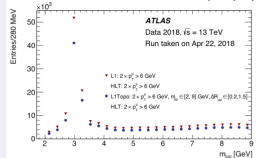
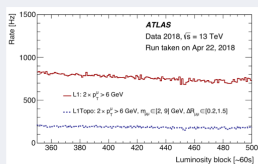
Long lived particles (LLP) studies also benefit from topological algorithms. Using  $\tau$  detection techniques allows to select events with low-energy collimated jets coming from the decay of a light LLP (low- $E_T$  CalRatio). L1Topo can also detect late muon decays produced in the



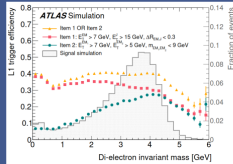
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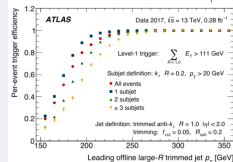
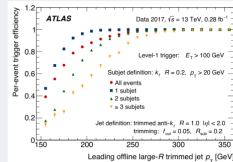
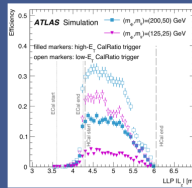
Topological requirements reduce the rate of B-Physics dimuon triggers up to a factor of 4 while largely preserving the signal acceptance.



The process  $B^0 \rightarrow K^{*0} e^+ e^-$  is an example of the combination of two algorithms in L1Topo. The first one triggers on two electrons, each of them contained in a region of size  $\Delta\eta \times \Delta\phi = 0.2 \times 0.2$ . But when they are collimated and overlap, the resulting object does not fit in this window, so a larger object (a  $0.8 \times 0.8$  jet) is used to capture the total energy of the  $e^+ e^-$  pair.

Topological algorithms are also used, for example, to identify the two jets coming from  $H$  production via VBF. They are specially useful to study  $H \rightarrow$  invisible.

Long lived particles (LLP) studies also benefit from topological algorithms. Using  $\tau$  detection techniques allows to select events with low-energy collimated jets coming from the decay of a light LLP (low- $E_T$  CalRatio). L1Topo can also detect late muon decays produced in the following bunch crossing.

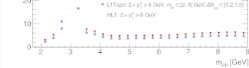


Non-topological triggers fail to capture the total jet energy for large-R jets. L1Topo can combine the energy within a larger  $\Delta R$  cone, lowering the threshold at which the trigger becomes fully efficient.

## What is new in Run 3? (Phase-I upgrade)

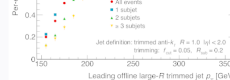
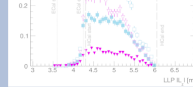


The L1Calo cluster processor (CP) and the jet energy processor (JEP) will be replaced by the electromagnetic and jet Feature Extractors (eFEX and jFEX), providing higher granularity.



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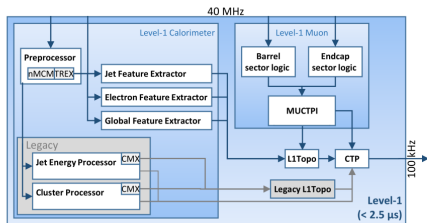
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Another subsystem, the global Feature Extractor (gFEX) will be added in order to identify large- $R$  jets and calculate quantities such as  $E_T^{\text{miss}}$  or  $\sum E_T$ .

Using the information from the new FEXes, L1Topo will be used to calculate the multiplicity of the different L1Calo TOBs.

The L1Muon endcap region will benefit from the New Small Wheel (NSW) detector, which will feature high-rate tolerance and improved resolution. In addition, an upgraded Muon to Central Trigger Processor Interface (MuCTPI) will provide full-granularity muon ROI information to L1Topo.

The new L1Topo system will consist of three modules with two processor FPGAs each (XilinxUltrascale+ XCVU9P). During the beginning of Run 3, legacy L1Topo and L1Calo systems will be used for triggering while the new systems are under commissioning. This will not be the case in L1Muon, where the challenge will be the use of the NSW.

## References

- [1] The ATLAS Collaboration. Performance of the ATLAS Level-1 topological trigger in Run 2, 2021 (arXiv:2105.01416)
- [2] The ATLAS Collaboration. Technical Design Report for the Phase-I Upgrade of the ATLAS TDAQ System, 2013 (CERN-LHCC-2013-018, ATLAS-TDR-023)
- [3] C. Kakra. New Jet Feature Extraction and Topological Processor Modules for ATLAS Phase-I Upgrade: from design to commissioning, 2019 (ATL-DAQ-SLIDE-2019-876)