The ATLAS Run-2 Trigger Menu

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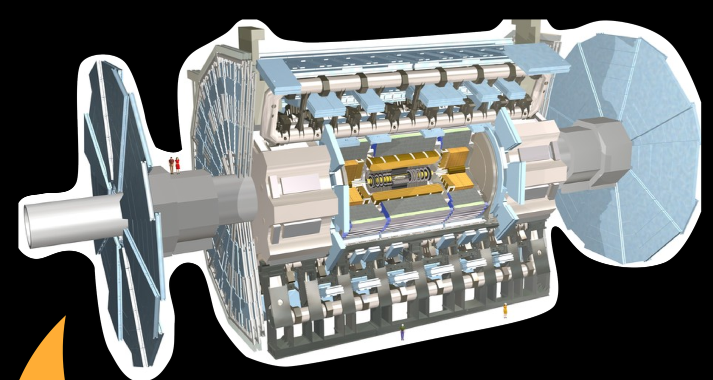
On behalf of the ATLAS Collaboration

Trigger and data acquisition workflow



40 MHz

Level-1 trigger (hardware)
2.5 μs processing time

calorimeter trigger (e/γ, τ, jet, E_T^{miss})

muon trigger

other L1

topological trigger

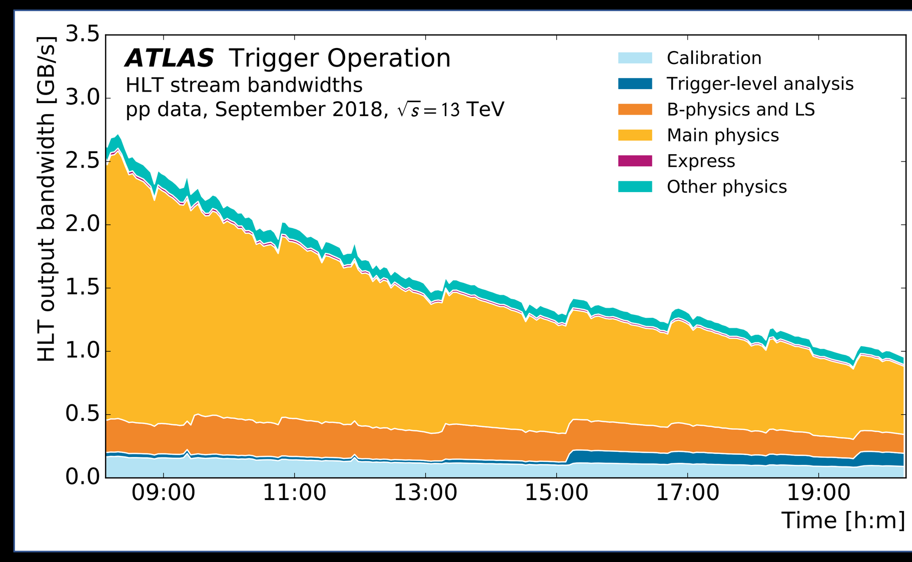
100 kHz

High level trigger (software)
~400 ms processing time

$\mathcal{O}$(40,000) CPU cores rapidly process events with **offline-like reconstruction** paired with **early-rejection algorithms** for CPU minimisation

Trigger menu of 512 L1 **items** and $\mathcal{O}$(1500) HLT **chains** defines the selection of events at each step

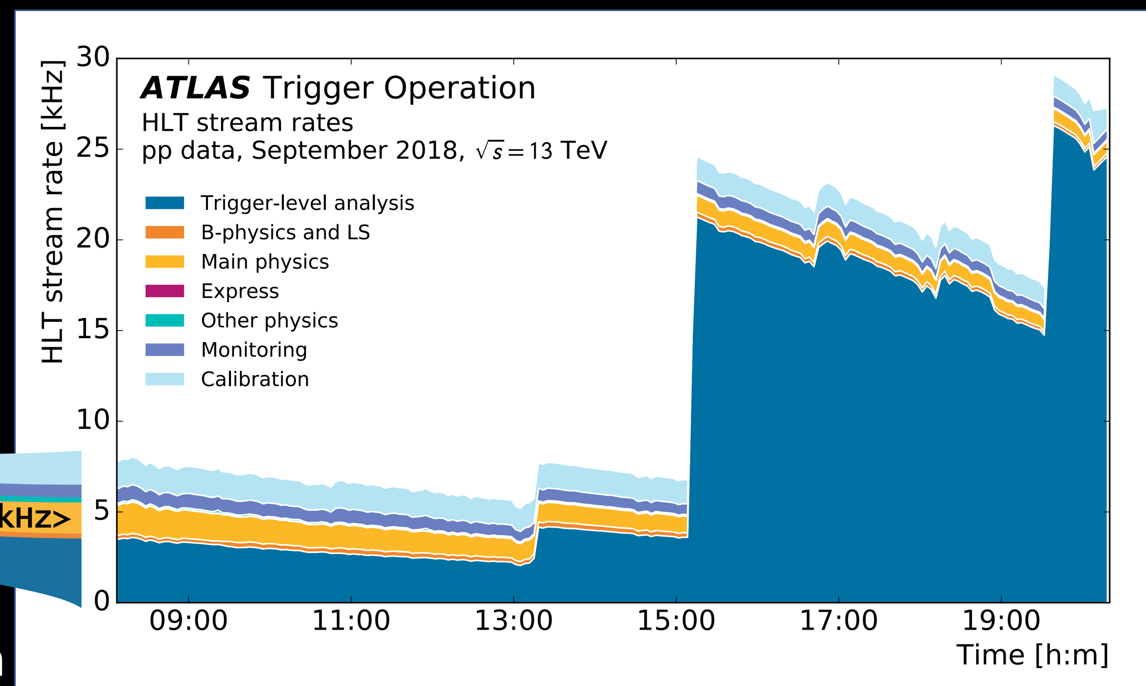
Event sizes can be very different between streams: most **bandwidth** is allocated to events for **physics analysis**



Events are written out into different **streams**

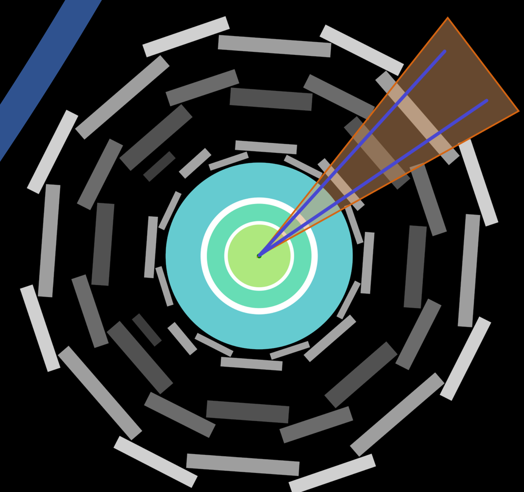
$\mathcal{O}$(10 kHz)

<1 kHz>



Streams can contain different **event content** and can be individually **stored** and **processed**

The **rate** of a trigger is proportional to the **luminosity** and the **number of interactions per bunch crossing** (pileup). As a fill progresses, when L1 rate, output bandwidth, HLT CPU, etc. allow, thresholds can be **lowered** and/or **new triggers** can be enabled.



Partial **E**vent **B**uilding (PEB) techniques shrink event size by only saving **sub-detectors**, **modules**, or **trigger information** explicitly required for offline study

Smaller event sizes mean we can **record more events**

e.g.: Trigger-level analysis saves only trigger object information: no detector readout recorded

Events for low-p_T muon performance save only data in cone around $J/\psi \rightarrow \mu\mu$ candidate

A trigger menu…

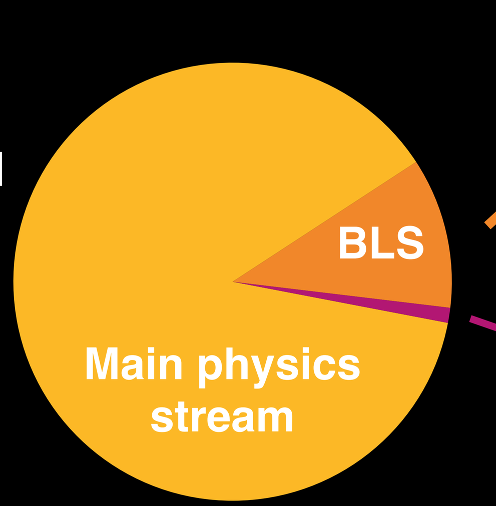
specifies both which types of events to select in the hardware (L1) and software (HLT) triggers and how many of each type to save

Physics goals | System limitations

Physics menu composition

*At L = 2 x 10^{34} cm^{-2}s^{-1}

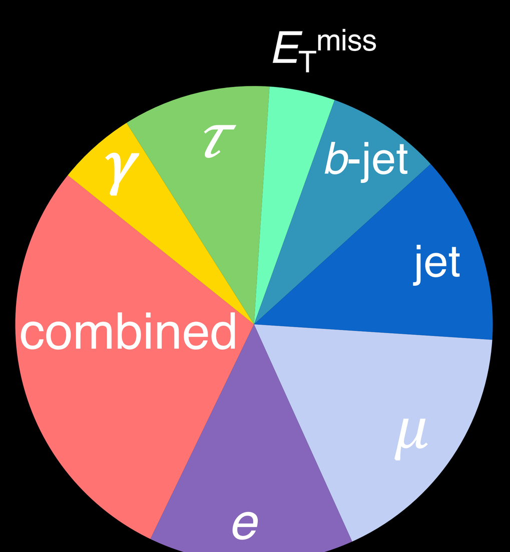
Representative sizes of full event streams intended for physics analysis



B-physics and Light States (BLS) stream multi-lepton triggers targeting low-mass resonances. Small overlap with Main stream and flexibility by analyses allows for delayed processing to circumvent offline reconstruction limitations. Events are kept only on tape and not reconstructed until there is sufficient CPU available. Also exploits **end-of-fill** strategies.

New in 2018: triggers for di-electron final states

Express stream: ~20 Hz of rapidly processed events for data quality, overlapping mostly with the main stream



Representative composition of the main physics stream

Main physics stream averages 1 kHz over the year, and composition is balanced between different types of events

Highlights of 2018 changes:

- **Muon** isolation loosened to mitigate effects from increasing pileup
- **Tau** identification updated to use recurrent neural network (RNN) tuning that improves efficiency
- E_T^{miss} triggers added an additional selection on the calorimeter cell-based E_T^{miss}, decreasing rate without impacting efficiency
- ***b*-jet** flavor-tagging algorithm was retuned with $Z' \rightarrow t\bar{t}$ in addition to $t\bar{t}$ simulated events to improve identification at high-p_T
- **Dedicated triggers** added for photon + multi-jet final states, low-mass diphotons, stopped gluinos, and displaced muons
- **Vector boson fusion** (VBF) triggers targeting di-jet or di-jet + additional object topologies were introduced using an L1 topological item requiring m(jet, not forward jet) > 500 GeV

Other menus

Configurations other than nominal p–p collisions have their own trigger menus optimised for the targeted research program, e.g.:

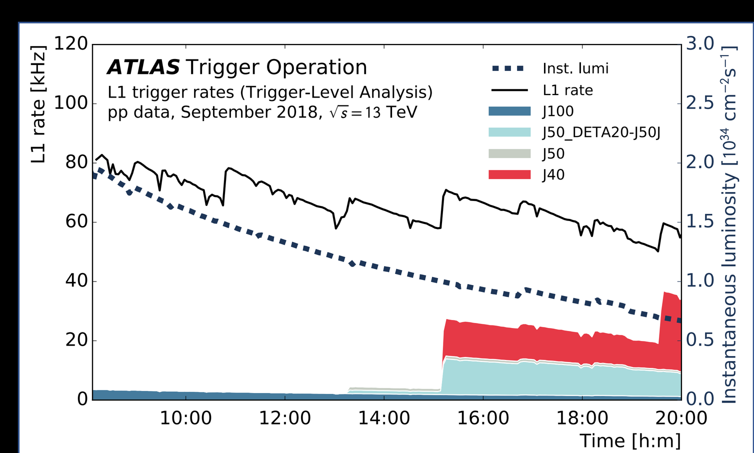
Heavy Ions: events with varying centrality selected by total energy triggers, in addition to dedicated muon, electron, photon, jet, and *b*-jet triggers.

Ultra-peripheral $\gamma+\gamma$ and γ+A collisions are selected by triggers for dedicated topologies

Low-pileup, low-energy, high β^*, and Van-der-Meer scan configurations also have dedicated menus

End-of-fill

Nominal menu is designed for L = 2 x 10^{34} cm^{-2}s^{-1}, but 85% of data was collected with L ≤ 1.7 x 10^{34} cm^{-2}s^{-1}, and more than 40% with L ≤ 1.2 x 10^{34} cm^{-2}s^{-1}!



Increases in L1 rate correspond to the enabling of new L1 items or reduction of L1 prescales

Triggers that are not part of the nominal menu (e.g. limited by **L1 rate** or **HLT CPU)** can be **disabled** or **prescaled** at high luminosities, and only enabled when the luminosity decays such that there are no longer system limitations.

End-of-fill strategies are crucial for **low-p_T *B*-physics** events and the **Trigger Level Analysis**

References: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TriggerOperationPublicResults
ATL-DAQ-PUB-2017-003, ATL-DAQ-PUB-2018-002