The ATLAS Run 3 Trigger Menu

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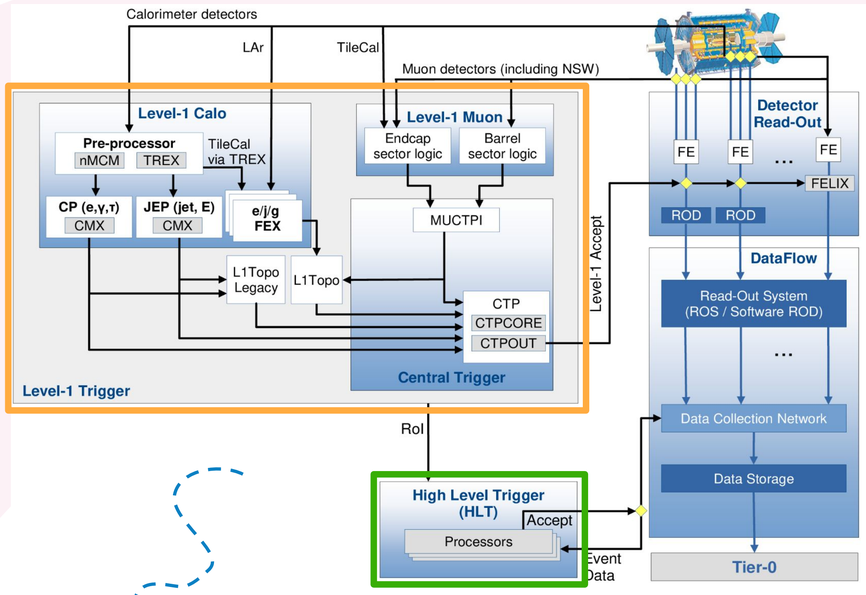
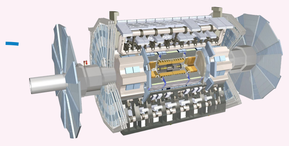
ATLAS Trigger System

- *Level-1 (L1):* custom hardware, latency <2.5 μs
- *High-Level-Trigger (HLT):* software-based, computing farm of 60k CPU cores, ~600 ms processing time





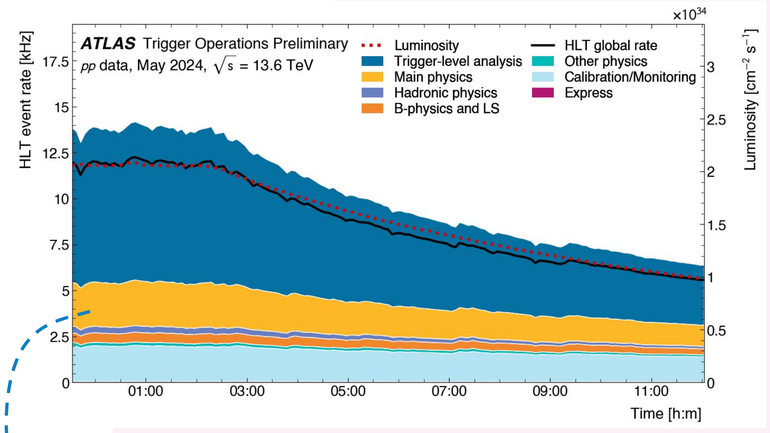
LHC collision rate & event size
40 MHz **3 MB**

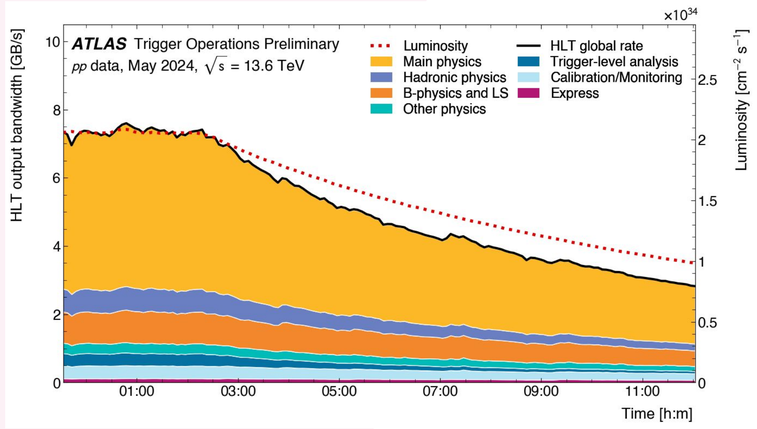
Level-1 accept rate
100 kHz **300 GB/s**

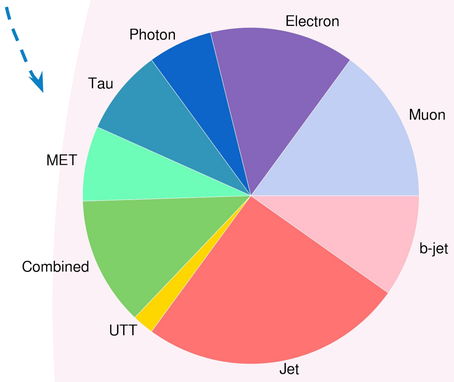
HLT output to storage
3 kHz **6 GB/s**
~10 kHz

Trigger Menu

- Events selected if they satisfy the conditions of one or more trigger *chains*
  - Chain: L1 decision + HLT algorithms
    designed to select a physics signature or for calibration/monitoring
- *Trigger menu:* list of chains used in data-taking
- Accepted events recorded into different data sets (*streams*)







Representative composition of Main stream *(data 2022, $L=1.8\times10^{34}$ $cm^{-2}s^{-1}$)*

Physics *pp* Menu

Goal: exploit the new Run 3 features while maintaining consistency with the Run 2 menu to allow for combined analyses

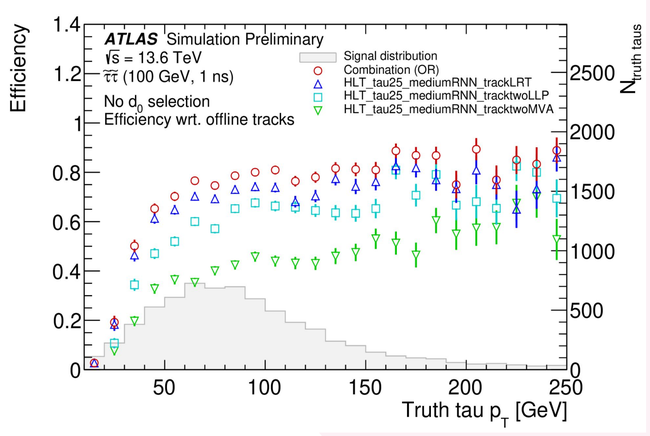
- Physics streams:
  - *Main*: for general physics analyses
  - *B-physics and light states* (BLS): specific to B-physics analyses
  - *Hadronic*: specialised triggers including selections for VBF and HH
- *Trigger-level analysis* (TLA): recording HLT objects only

Events can be reconstructed promptly (Main), or when resources allow (BLS, Hadronic and TLA)

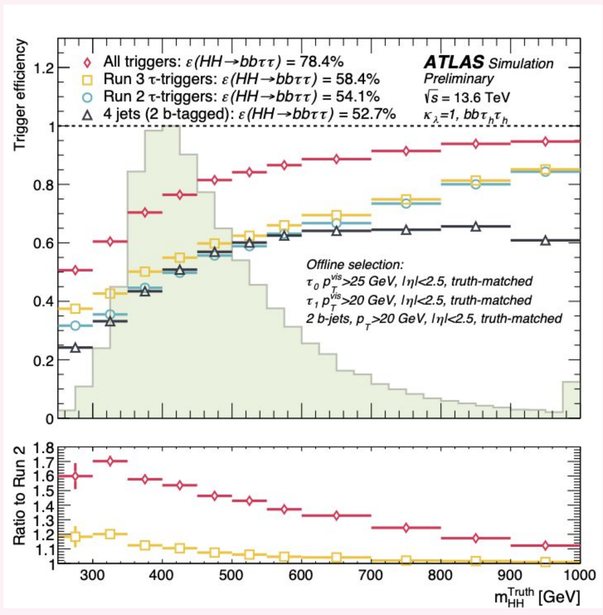
- Menu constructed to dedicate most of the bandwidth to generic physics signatures + analysis-specific signatures (LLP, HH…) → additional bandwidth thanks to Run 3 improvements

New Run 3 trigger efficiency

LLP tau



HH→bbττ



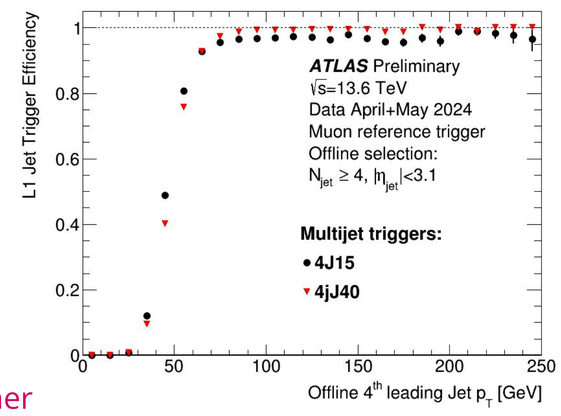
Physics HI Menu

- Big differences with respect to *pp* collisions
  - Large event-by-event variations, azimuthal anisotropy
  - Lower luminosity and √s per nucleon pair
    → lower hard scattering rate
- Two main physics streams:
  - *Hard Probes:* events from inelastic collisions, triggered with high-p_T objects
  - *UPC:* events from ultraperipheral collisions, triggered with low-p_T objects and vetos on energy deposits in forward calorimeters

New in Run 3

Level-1

- New digitised LAr calorimeter readout + L1Calo Feature Extractors (FEXes)
  - Finer granularity reconstruction → better background rejection → lower rate with similar efficiencies
  - Full-calorimeter view → improved computation of global quantities (large-R jets, MET)
- Upgraded L1Muon: NSW + new endcap processor
  - Improved rejection of fake muons → reduced rate while keeping high efficiency

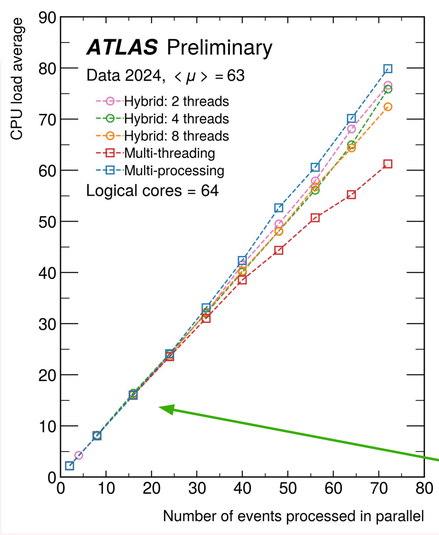


Possible to go to higher luminosity with equivalent thresholds

HLT

- Migration to multi-threaded software
  - Processing of multiple algorithms of an event in parallel
  - Reduced usage of memory per core

Possible to go to higher pile-up without saturating HLT farm



- Track reconstruction speed-up
  - Full scan tracking for hadronic signatures → improved pile-up separation and jet energy resolution at low p_T
  - Large radius tracking → enable many new LLP trigger signatures

2024 configuration: hybrid, 16 forks and 4 threads

Operations

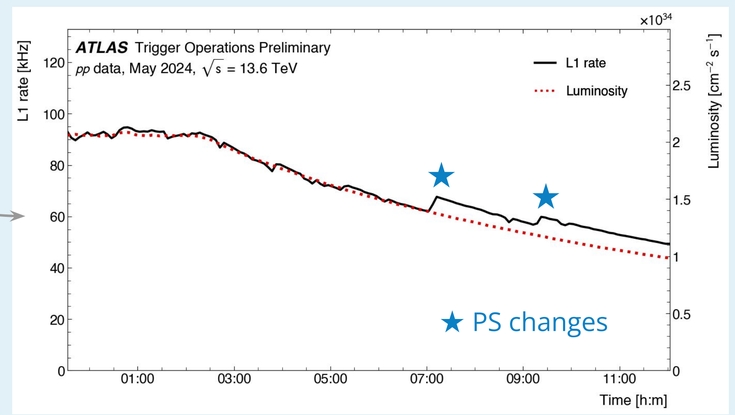
Constraints

- At L1: maximum rate of 100 kHz (detector readout capability)
- At HLT: bandwidth + CPU resources of the HLT farm
- Offline prompt processing capabilities

Trigger menu and prescales are optimized to make maximum use of available resources

Prescale (PS) factors are applied to L1 and HLT triggers

- Allow triggers to be only executed for a fraction of events and to be enabled/disabled
- Can be changed during data-taking to adapt to decreasing luminosity
  - *End-of-fill (EOF) strategies* crucial for low-p_T B-physics and TLA
  - Enable/unprescale additional/resource-heavy triggers when luminosity declines



- *Primary triggers:* for physics analysis, unprescaled (except for dedicated EOF triggers)
- *Triggers for background studies:* enabled/unprescaled with decreasing luminosity in a fill
- *Supporting and monitoring triggers:* kept at fixed output rate

References

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