Triggering in ATLAS in Run 2 and Run 3

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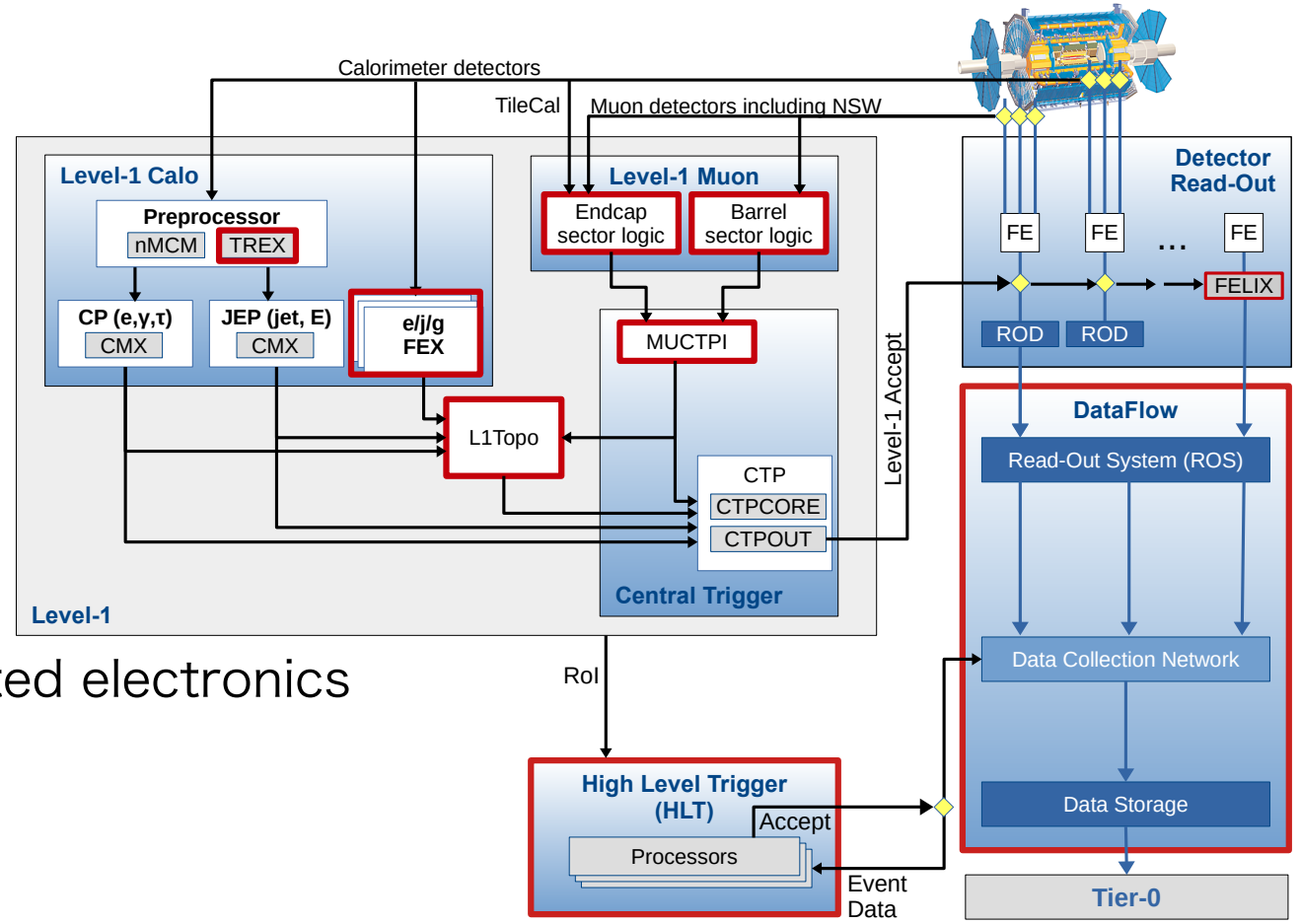
On behalf of the ATLAS collaboration

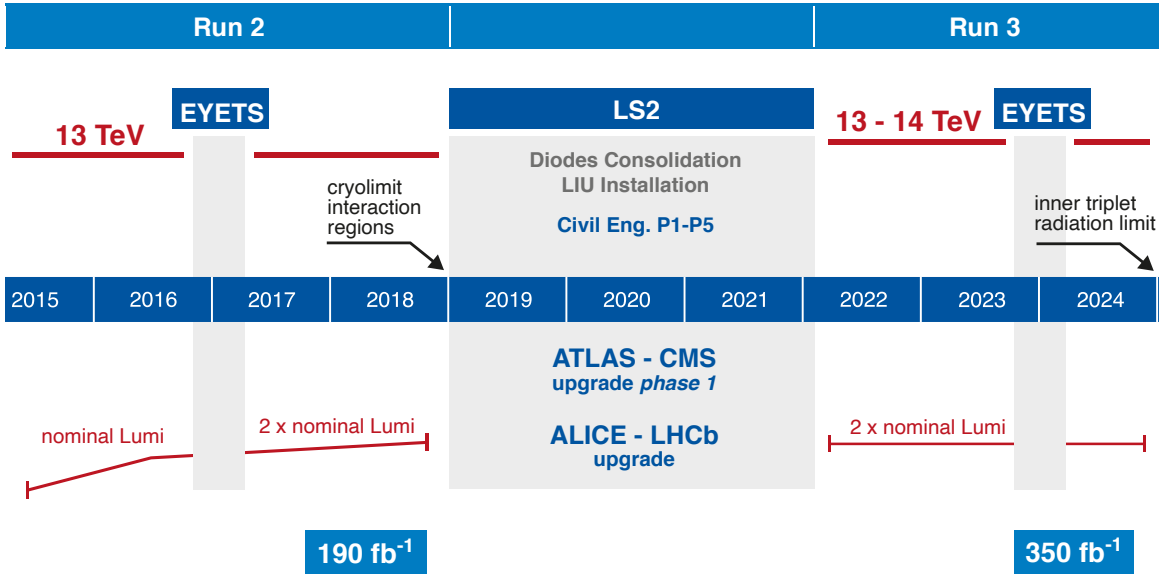
ATLAS Trigger and DAQ

- Online event selection:
  - Allows us to store the events of interest within bandwidth limitation of DAQ system
  - Realizes efficient use of computational resource
- Triggering in ATLAS
  - Level 1 (L1) (100 kHz, 2.5 μs)
    - Hardware-based system with dedicated electronics
    - L1Calo, L1Muon, L1Topo, CTP
  - High Level Trigger (HLT) (1-1.5 kHz, 500 ms on average)
    - Exploits software-based object reconstruction running on commodity CPU farm with networking based on commercial technologies
    - HLT algorithm is based on Region of Interest (RoI) given by the L1 for fast reconstruction



Scope of today's talk

- Triggering in Run 2
  - Typical peak luminosity
    - 2015: 0.5e34 $cm^{-2}s^{-1}$ (max $<\mu>$~18)
    - 2016: 1.3e34 $cm^{-2}s^{-1}$ (max $<\mu>$~40)
    - 2017: 1.6e34 $cm^{-2}s^{-1}$ (max $<\mu>$~70)
    - 2018: 2.1e34 $cm^{-2}s^{-1}$ (max $<\mu>$~60)



- Triggering in Run 3
  - Typical peak luminosity
    - 2.0e34 $cm^{-2}s^{-1}$ (max $<\mu>$~60)
    - Levelling at peak $<\mu>$
    - Typically, ~ 6 – 10 hours

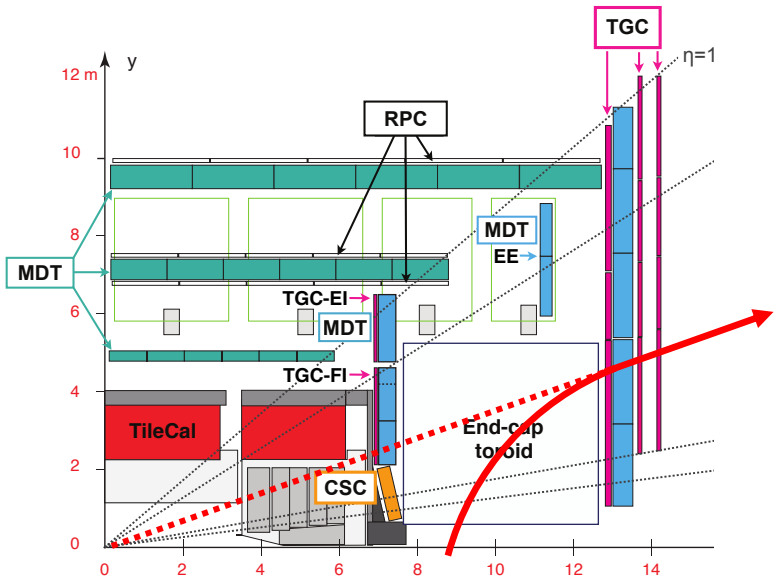
Evolutions in Run-2 in L1 and HLT to cope with increase of luminosity

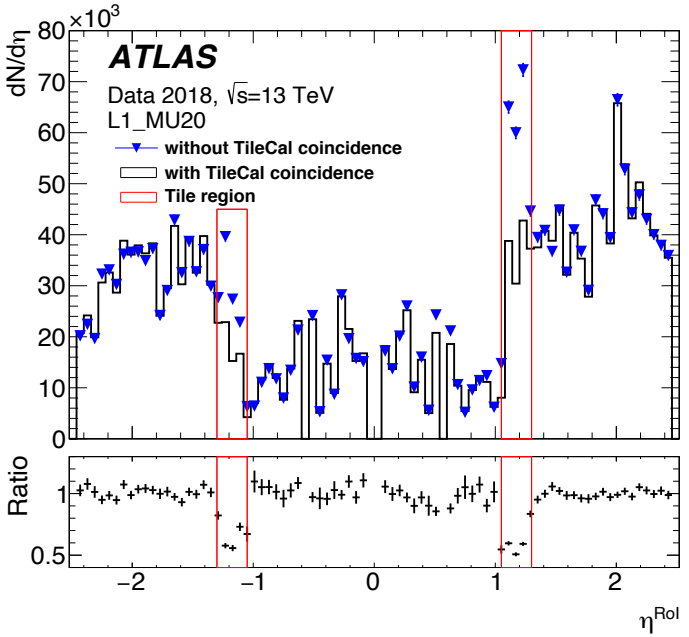
New features for Run-3 triggering

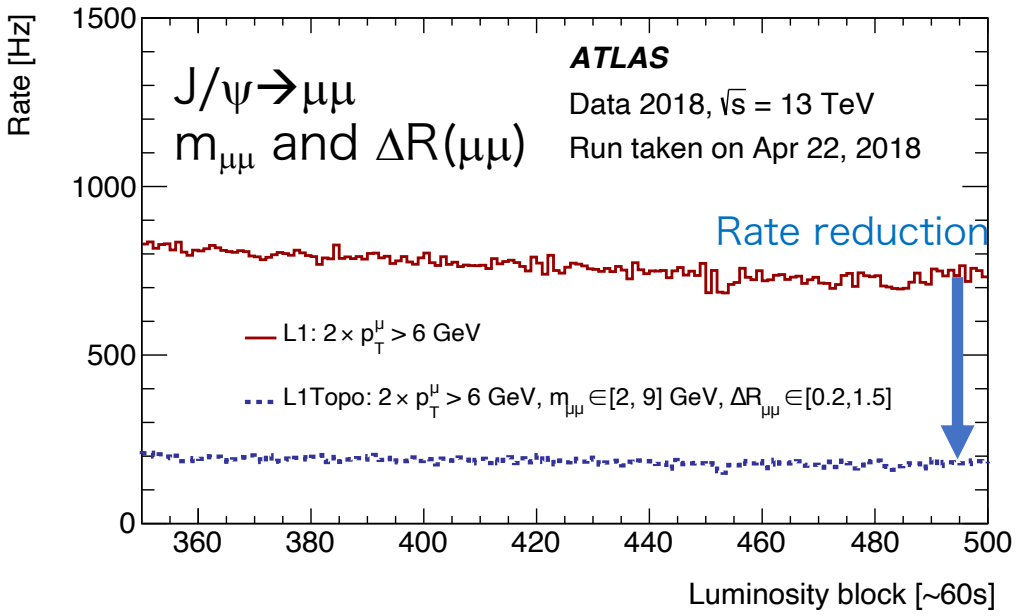
- multithreaded software framework,
- new hardware

Evolutions in L1 Trigger in Run 2

- Evolution of L1 muon trigger to gain fake rejection
  - Exploiting additional coincidence with inner station of muon (EI/FI), and tile hadronic calorimeter
    - FI (2015), EI (2016), and tile (2018) are integrated in the L1 operation
- New FPGA-based L1Topo processor is in operation since 2017
  - Topological requirements: kinematics relations between objects
    - Such as angular selections: $\Delta\eta$, $\Delta\phi$, ΔR and invariant mass using L1 trigger objects from L1Calo and L1Muon
    - Rate reduction owing to topological requirement besides simple object multiplicity-based requirements

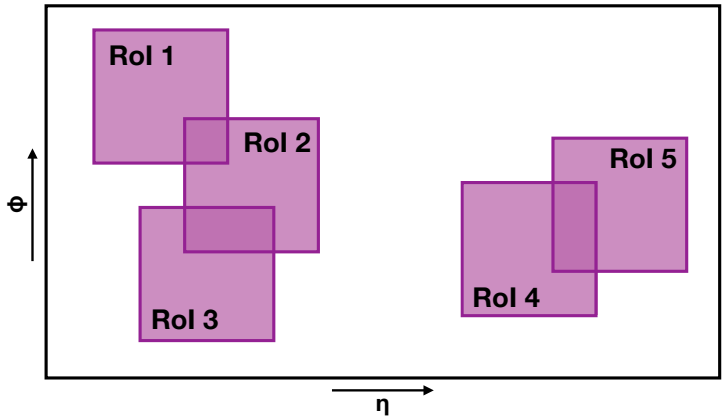


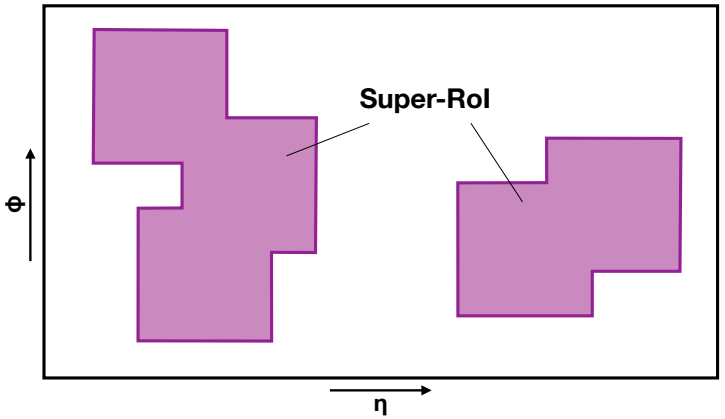


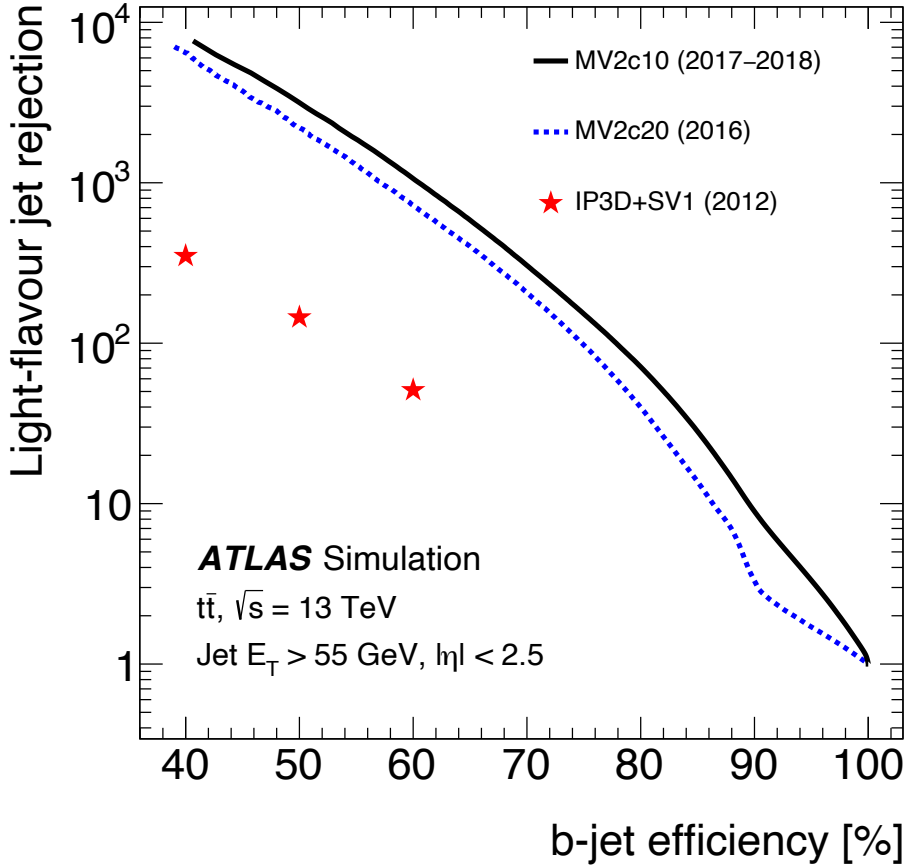


Evolutions in HLT algorithms in Run 2

- Evolutions of HLT algorithms for higher pileup
  - Both of performance and CPU cost are the important factors in operation
  - e.g. Improvement of B-jet trigger based on (computationally expensive) online tracking
    - Constant improvement of CPU usage
      - Super-RoI for efficient online tracking
      - Multi-staging tracking as an optimal strategy
    - Performance improvement
      - Major improvement from Run 1 due to new pixel layer (Insertable B-Layer) in operation since 2015
      - Optimal use of MV2 algorithm improves light flavor rejection by factor 1.5
        - While CPU usage reduced by ~30%

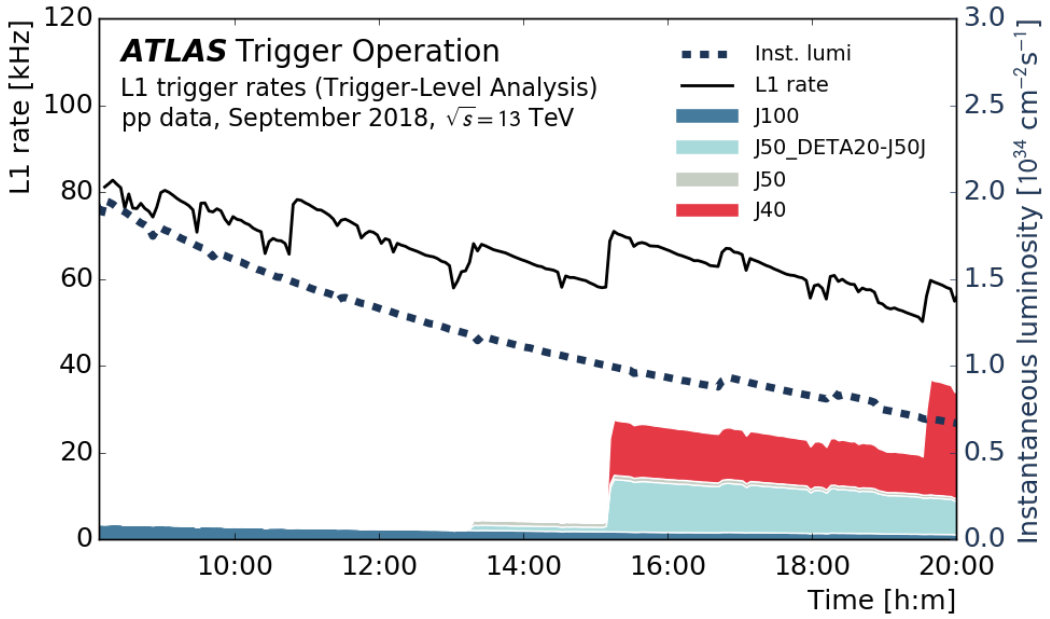


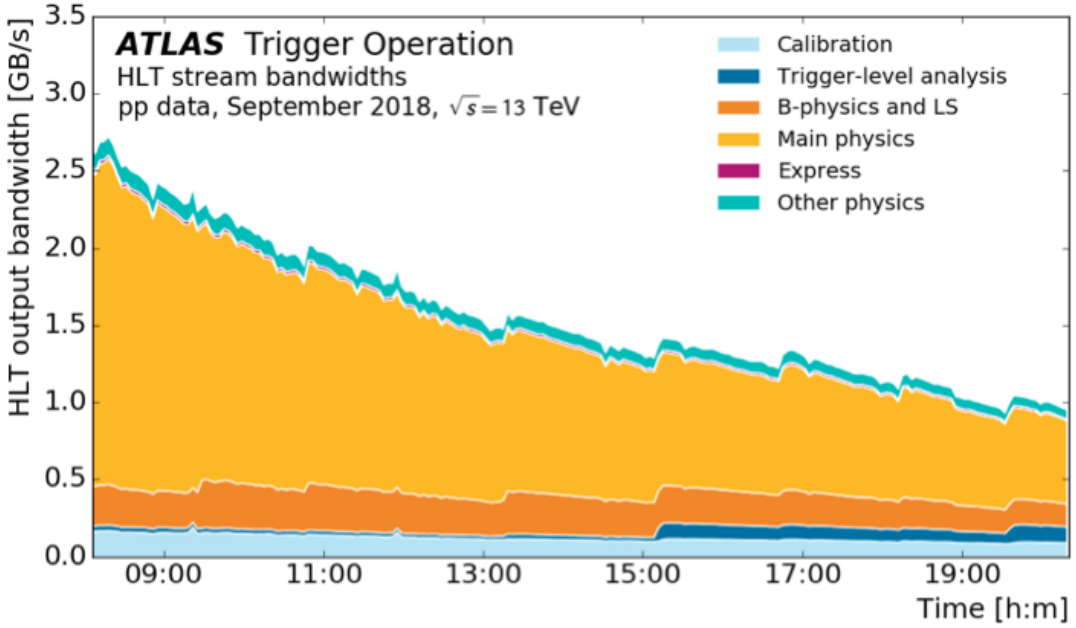




Trigger operation in Run 2

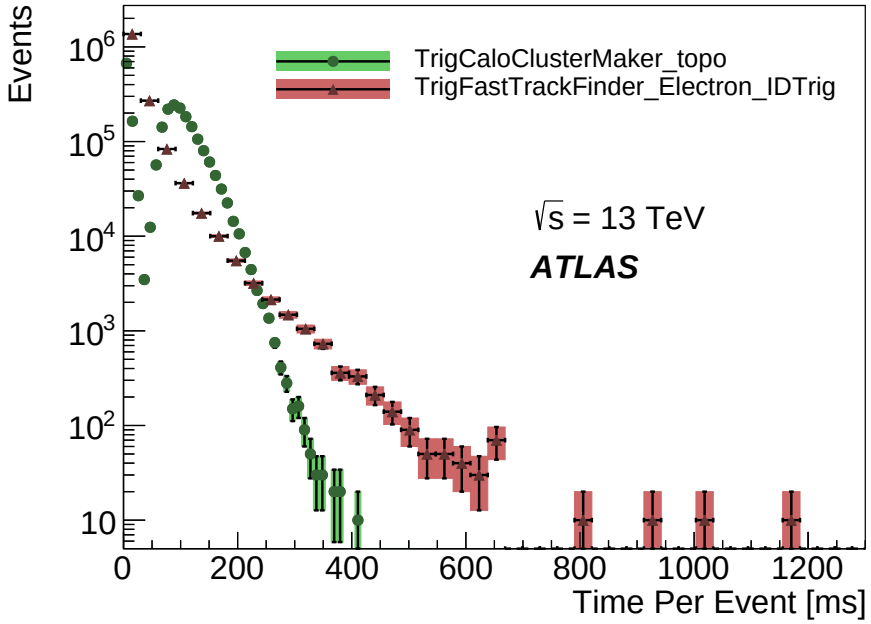
- Operation models with menu, prescale, and streaming developed
  - Collection of HLT-L1 chains (menu) and prescale factors are being evolved according to the LHC conditions of filling scheme
  - Additional streams defined in ATLAS data taking besides Physics Streams
    - Express, Debug, Calibration, Trigger-Level Analysis, and Monitoring streams
  - Prescale to control L1 trigger rate and HLT output bandwidth
    - Dynamically configured during the data taking for decay of instantaneous luminosity

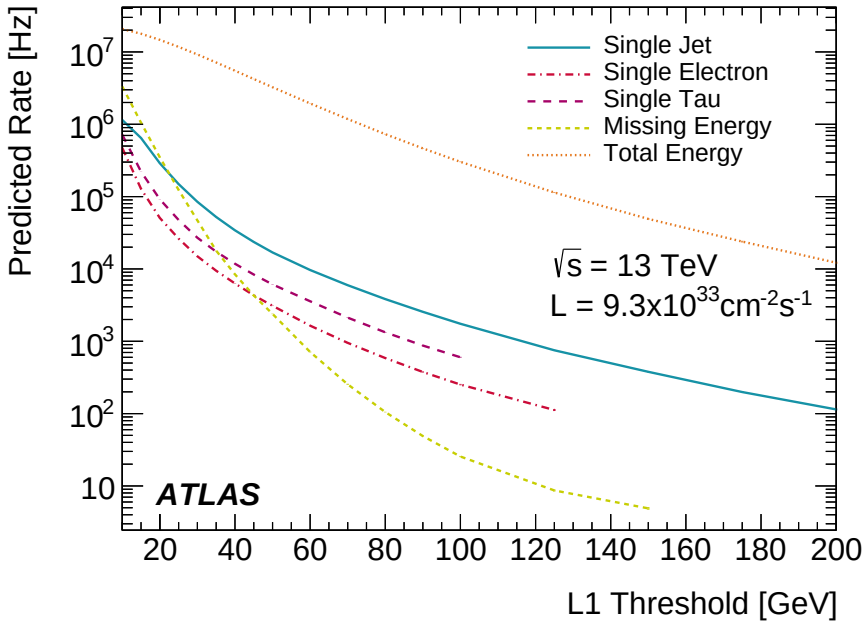




Framework to monitor & predict resource usage

- Prediction is a key technique to prepare trigger menu and prescale configuration in advance of operation
  - Developed cost monitoring/prediction for CPU usage and data-flow over network
  - Precise L1/HLT rate prediction is allowed by enhanced bias dataset and gaining statistical power over several orders of magnitude for L1-accepted events
    - Confirmed that predicted trigger rate is consistent with the actual rate
  - Proven to be essential for Run 2 operation and Run 3 operation preparation





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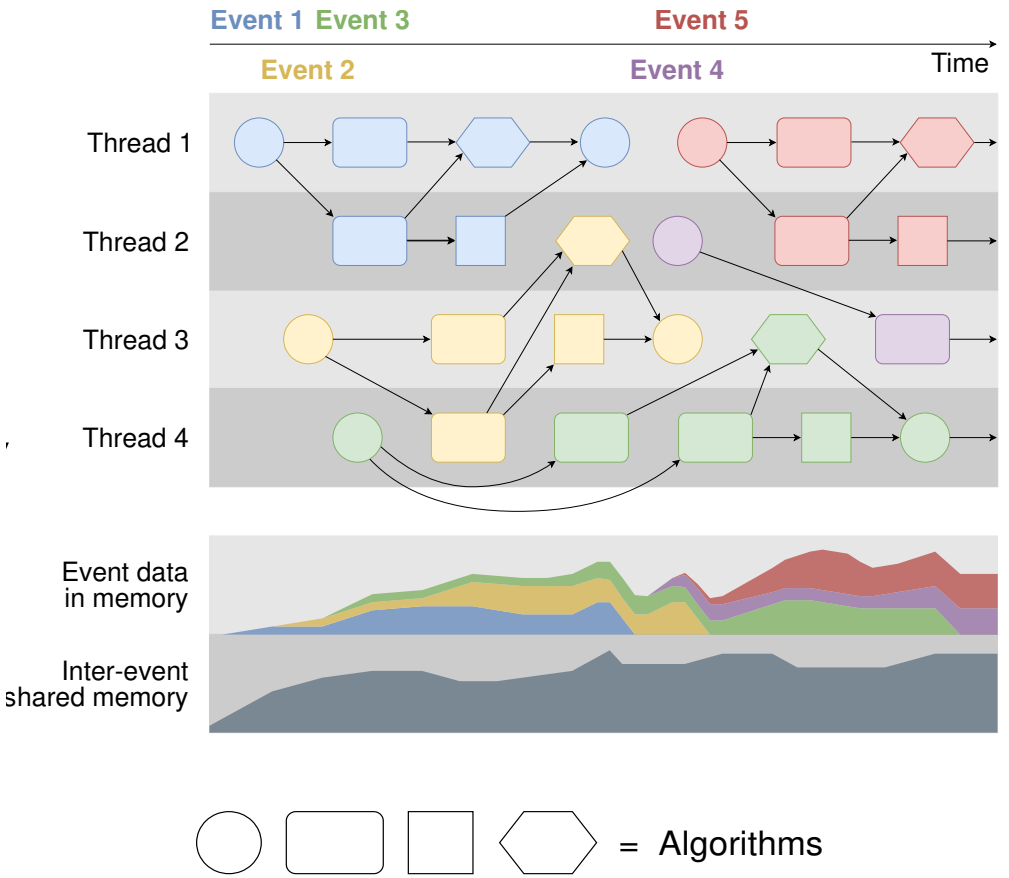
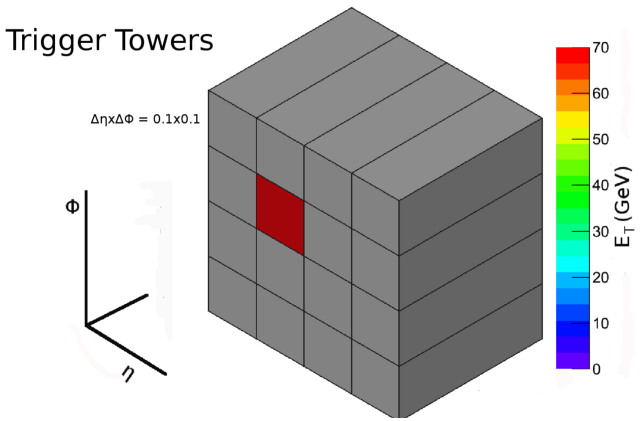
New Run 3 HLT Framework

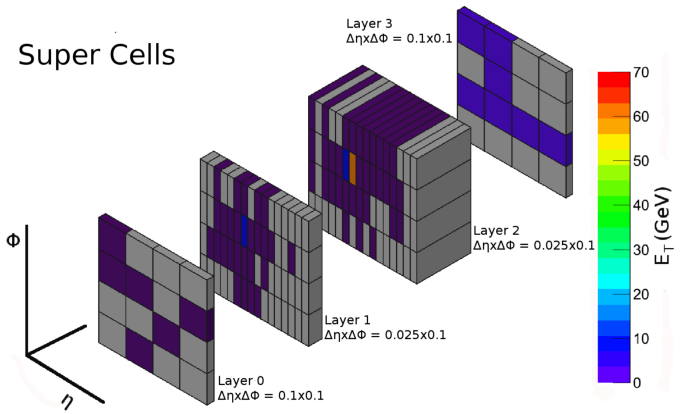
- HLT exploits new “AthenaMT” with multi-threading
  - Based on a concurrent task scheduler with Intel Thread Building Block
  - Efficient memory usage thanks to memory sharing of event-independent data
  - AthenaMT is a common framework between offline and online reconstruction
- Multi-threading parallelization
  - Inter-event:
    - multiple events processed in parallel
  - Intra-event:
    - multiple algorithm running in parallel
  - In-algorithm:
    - a single algorithm multi-threaded

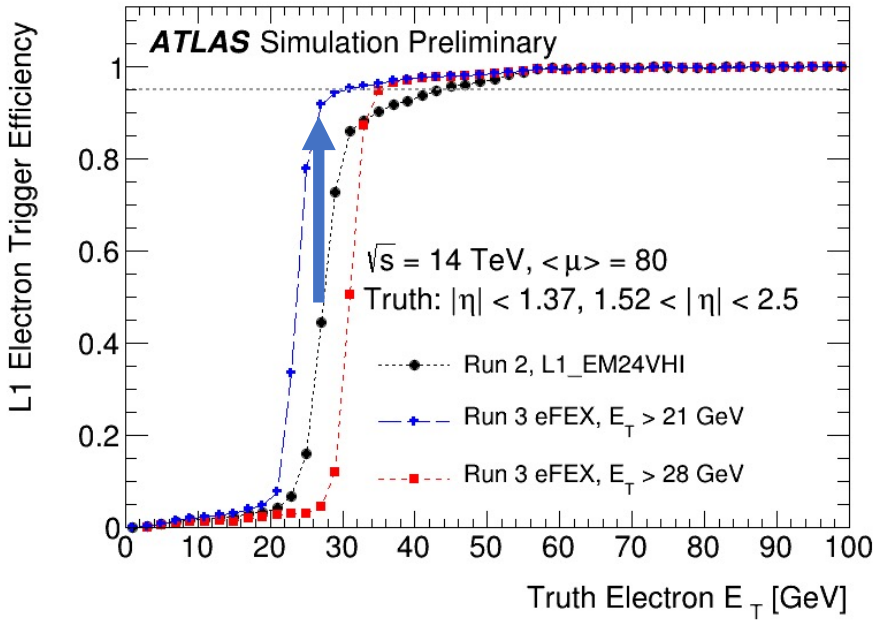


New features in trigger for Run 3

- Upgrade of L1Calo
  - Feature exactors with modern large-scale FPGAs in L1Calo
  - LAr EM calorimeter frontend upgrade to reconstruct super cells in trigger







Efficiency gain for a given trigger rate

- Upgrade of L1Muon
  - To improve inner coincidence with inputs from new detectors

New features in trigger for Run 3

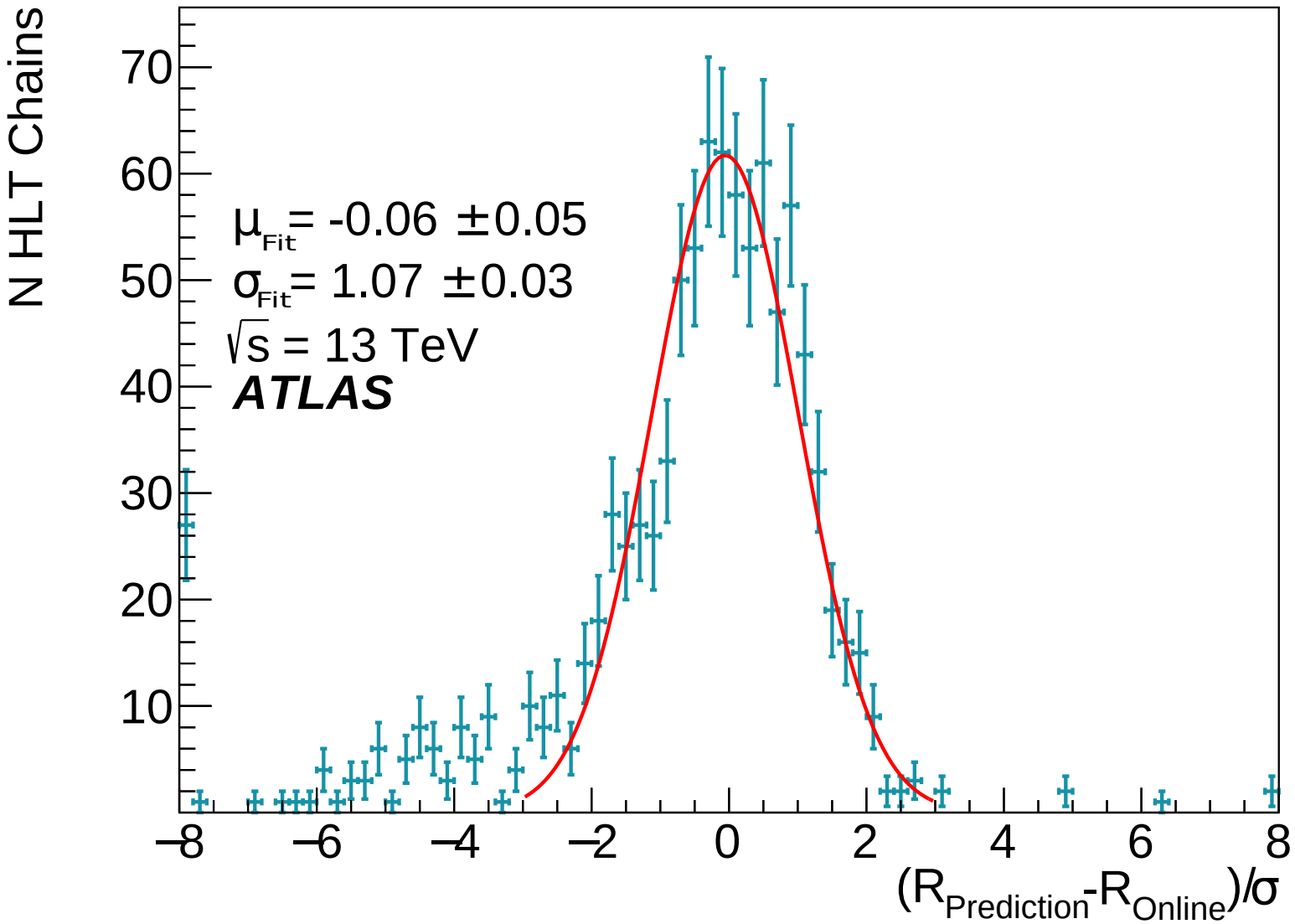
- HLT algorithm developments for Run 3
  - Many new features are being developed at top speed
  - Sharing a lot of features between online and offline using the common AthenaMT framework
  - e.g. Machine Learning implementation for online tracking
    - Online tracking is important for hadronic objects (jets, MET) as well as tracking-based objects (b-jets, and tau)
      - Introduce full scan online tracking for the main physics data Run 3 for the first time
    - ML extends filtering on pixel detector doublet space point
    - Significant speedup without major efficiency loss (~0.7% at $\langle\mu\rangle$=60)

Total Speed-up Factor	Seed Generation	Seed Processing	Track Fitting
2.3×	1.3×	3.3×	1.5×

Summary

- Triggering in ATLAS in Run 2
  - Dynamically and continuously improving L1 system and HLT algorithms according to the evolution of LHC conditions
  - Reliable operation model has been builds along with prediction methods
- Triggering in ATLAS in Run 3
  - New Multi-threaded Athena framework (AthenaMT)
  - Improvements in the L1 trigger and HLT algorithms
- Getting ready for Run 3 data taking starting in 2022!

backup


N HLT Chains
70
60
50
40
30
20
10
μFit = -0.06 ±0.05
σFit = 1.07 ±0.03
√s = 13 TeV
ATLAS
−8
−6
−4
−2
0
2
4
6
8
(RPrediction-ROnline)/σ