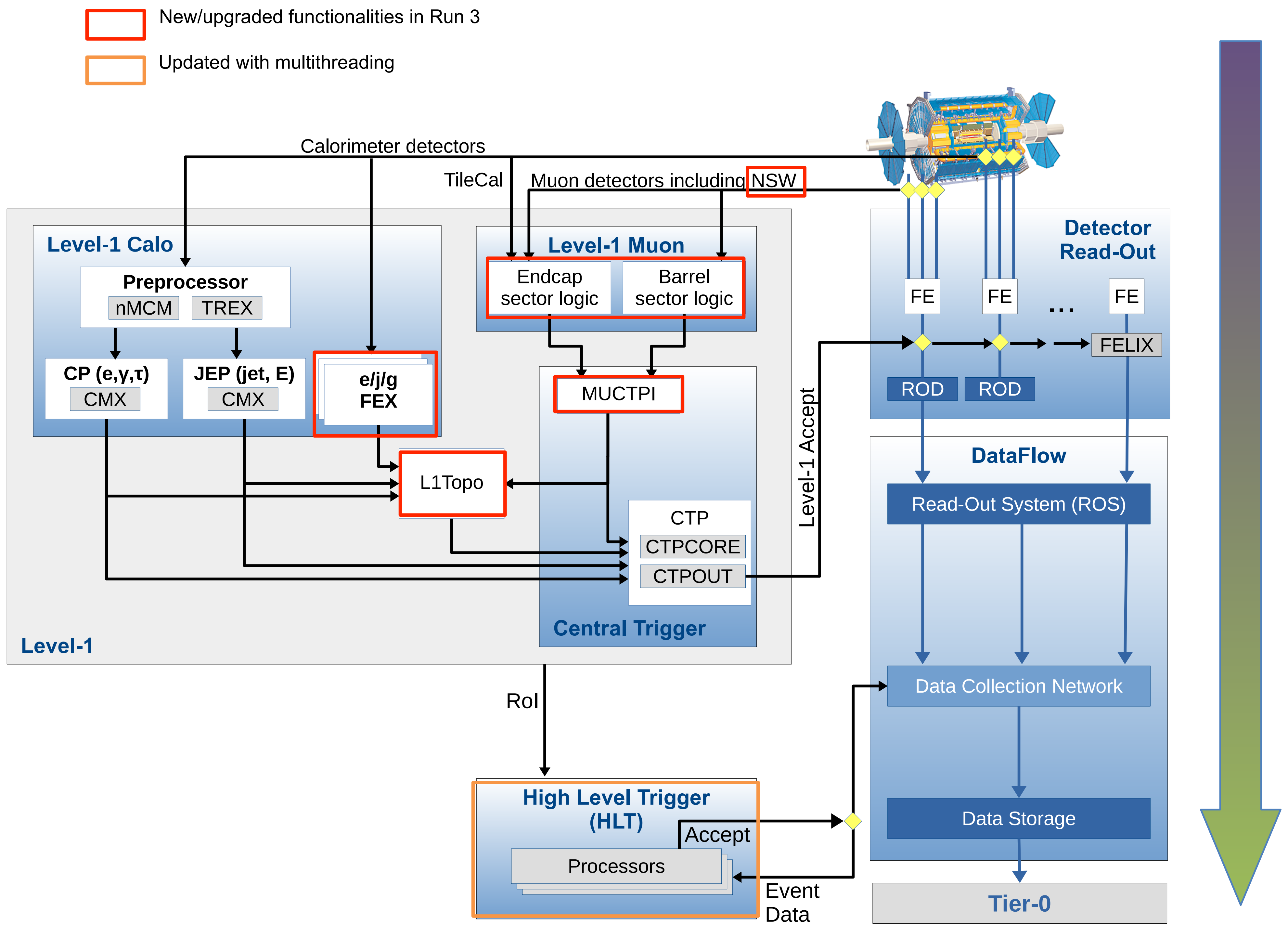
Triggering in ATLAS in Run 2 and Run 3

LHCP2021 Online
The Ninth Annual Conference on Large Hadron Collider Physics
7-12 June 2021 Paris (France), Sorbonne Université



Bunch crossing: 40 MHz

L1 accept: 100 kHz

Recording: 1 kHz

ATLAS Trigger DAQ System

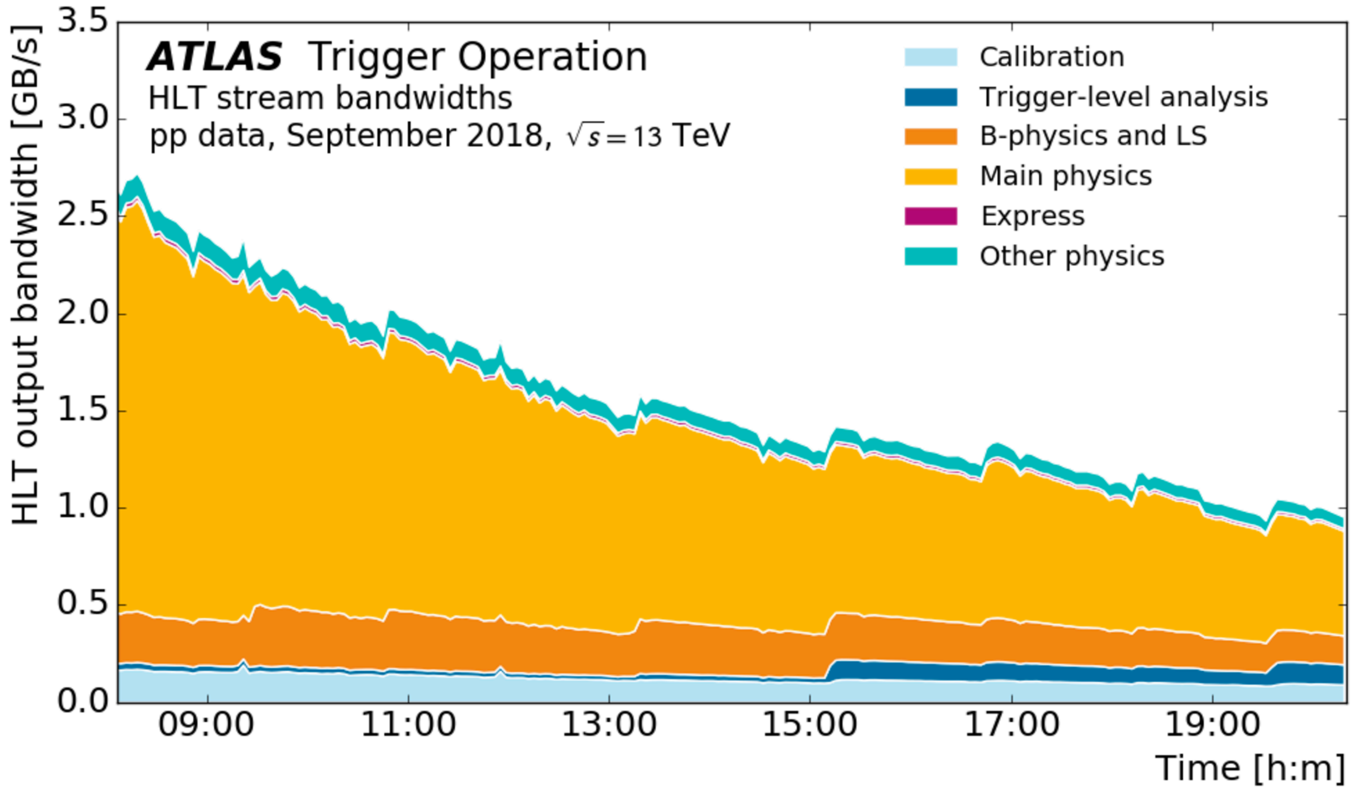
- Object based / topology based
  - High-p_T muons, e/γ, τ, hadron jets, missing E_T, …
- Level 1 (**L1**):
  - Custom-made hardware (latency 2.5 μs)
  - Coarse granularity selection with high-p_T objects
- High-level trigger (**HLT**):
  - Software-based
  - More sophisticated selection
- Trigger-object level analysis (**TLA**)
  - For low-p_T physics, full event selection can be applied online using HLT objects [1]

Run-2 trigger menu

- To fulfill the requirement for the rich physics program of ATLAS, events are selected by ~1500 trigger "chains" in parallel
- **Trigger chains**: defined by the L1 decisions followed by relevant HLT algorithm
- **Trigger menu**: the list of trigger chains used in the data taking, evolved depending on the luminosity

Chain	Target events	L1 threshold	L1 Rate	HLT threshold	HLT rate
Single μ	At least one muon (p_T>27GeV) e.g. W→μν	20 GeV	~16 kHz	26 GeV	~218 Hz
Single e	At least one electron (p_T>27GeV) e.g. W→eν	22 GeV	~31 kHz	26 GeV	~195 Hz
Single jet	At least 1 jet (p_T>435GeV)	100 GeV	~3.7 kHz	420 GeV	~35 Hz
B-phys	2 muon with p_T>6 GeV B→μμ + X	**L1Topo** manages $2<m_{\mu\mu}<9$ GeV@L1	~1.4 kHz	$4<m_{\mu\mu}<8.5$ GeV	~6 Hz
……	**~1500 chains run in parallel** (some of them are "pre-scaled" for efficiency and performance measurements, background estimates or monitoring)				
Total	@2×10^{34}/cm²/s		**~85 kHz**		**~1.75 kHz**

https://cds.cern.ch/record/2693402/files/ATL-DAQ-PUB-2019-001.pdf



- The menu is changed during the run following the inst. luminosity[2]
- The bandwidth for TLA is increased after the luminosity is decreased, by the "end-of-fill" strategy

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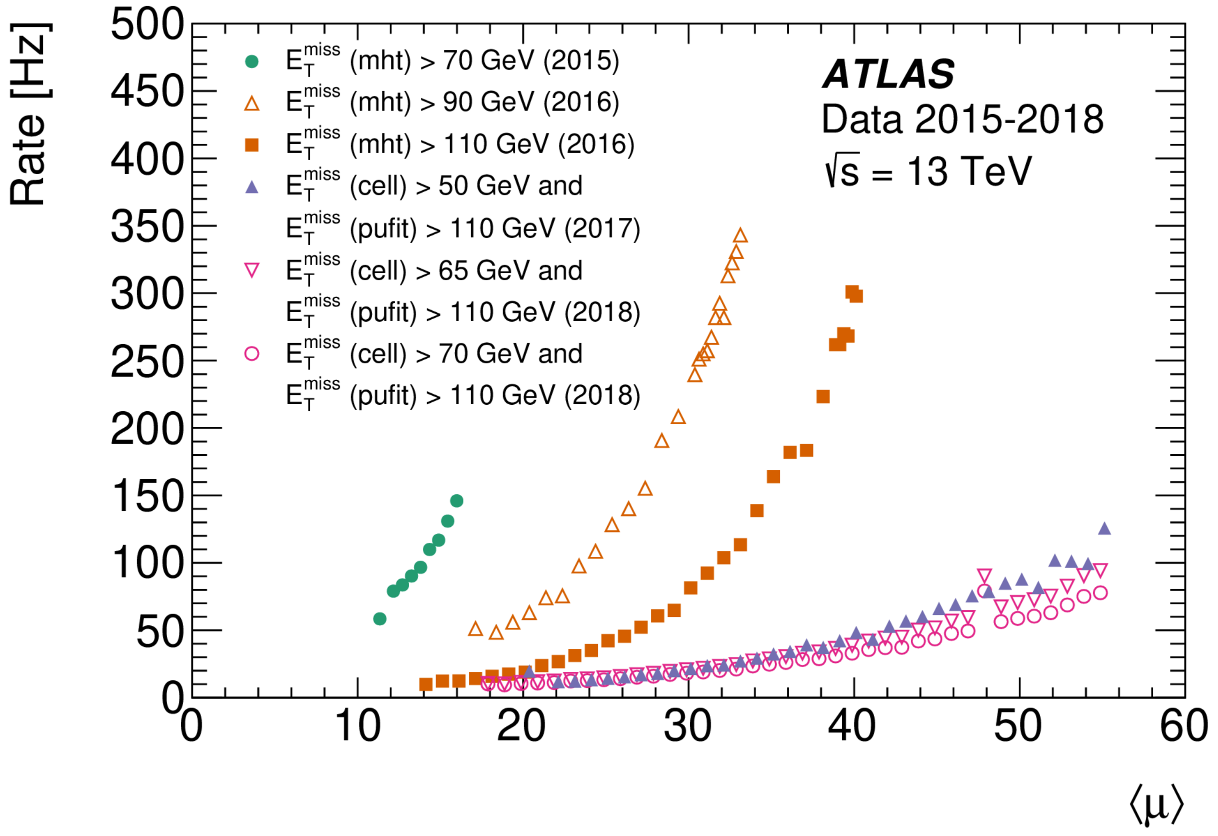
ATLAS EXPERIMENT

New features introduced in Run 2

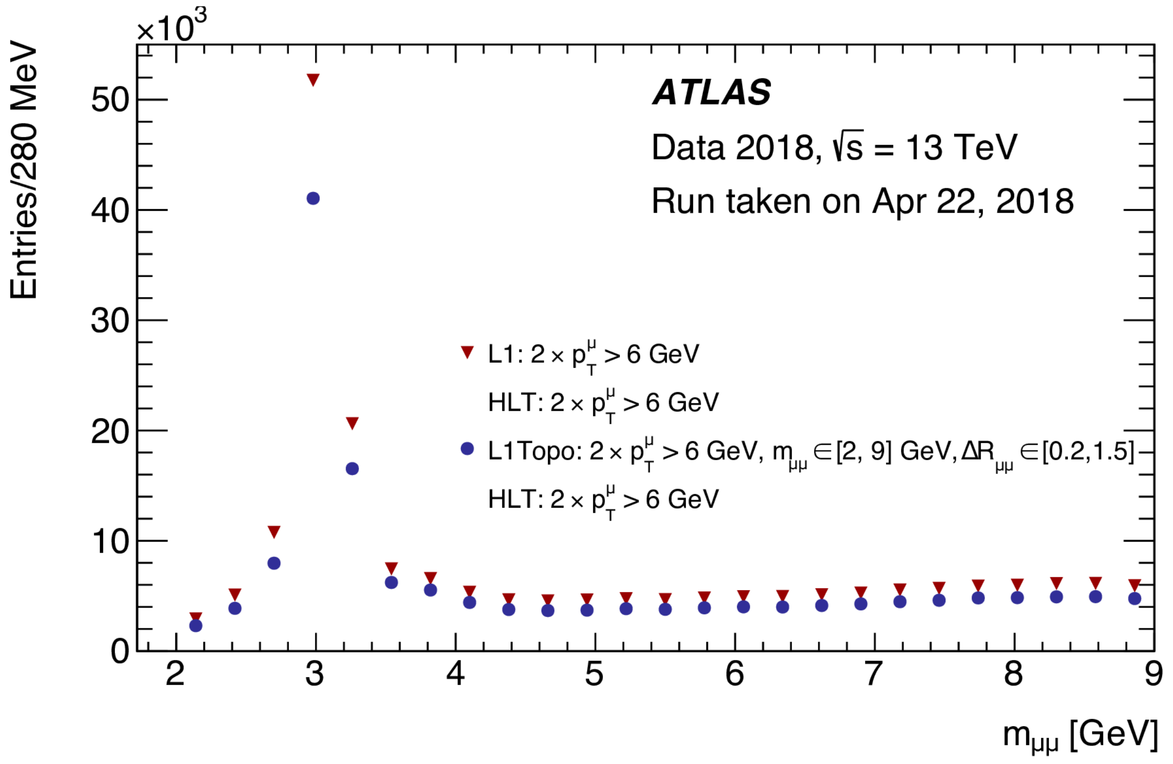
(examples) missing E_T triggers

- The rate did not linearly depend on the lumi. in 2015
- Improved now after the optimization of pileup mitigation technique [3]



Topological triggers

- L1Topo managed the topological cuts at L1 e.g. dilepton mass, ΔR, jet substructure, etc.
- Reduced rate significantly, while keeping high efficiency for the target signals [4]



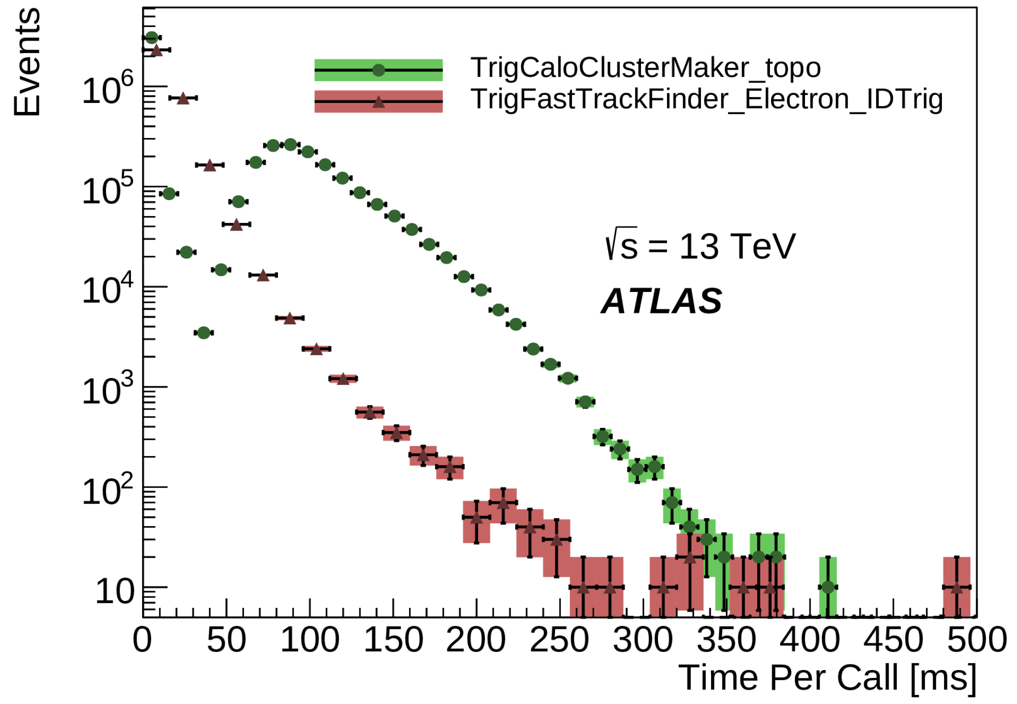
An example of topo trigger (B→μμ + X). ~80% efficiency w.r.t. the standard dimuon trigger v.s. 1/4 rate

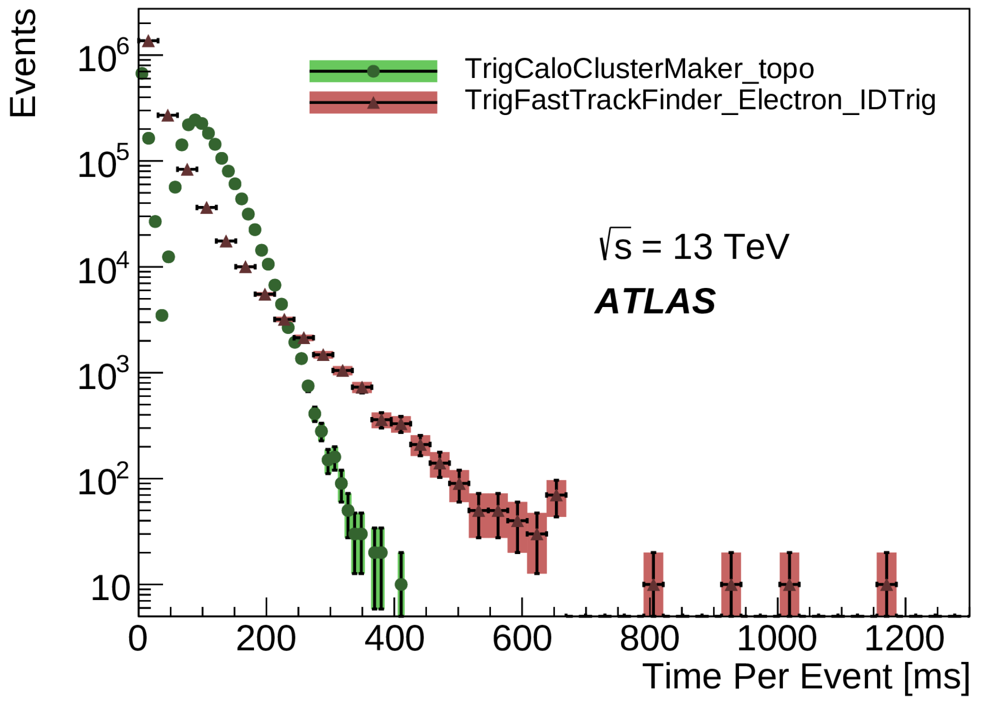
Cost/rate estimation frameworks

- A special "enhanced bias" dataset collected by the OR of L1 items, which can be used to estimate the cost/rate for the given trigger menu using the real data[2]
- With this framework, optimized the menus in Run 2, including the ones for different LHC bunch filling scenarios in 2017
- Menu optimization for Run 3 ongoing

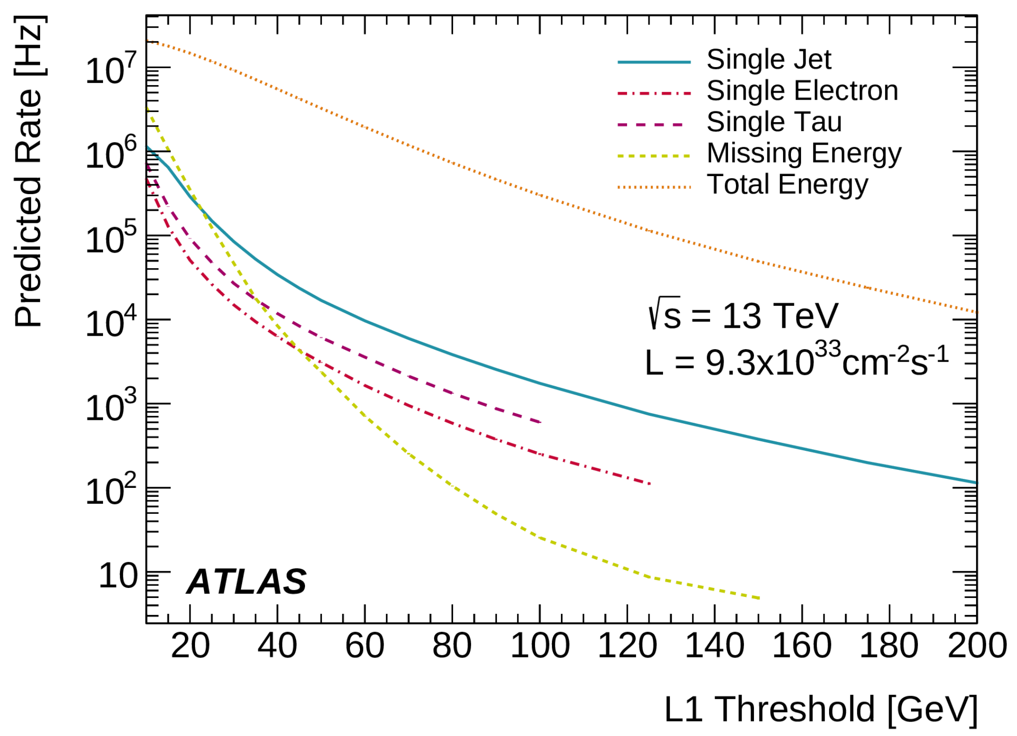
Cost monitoring

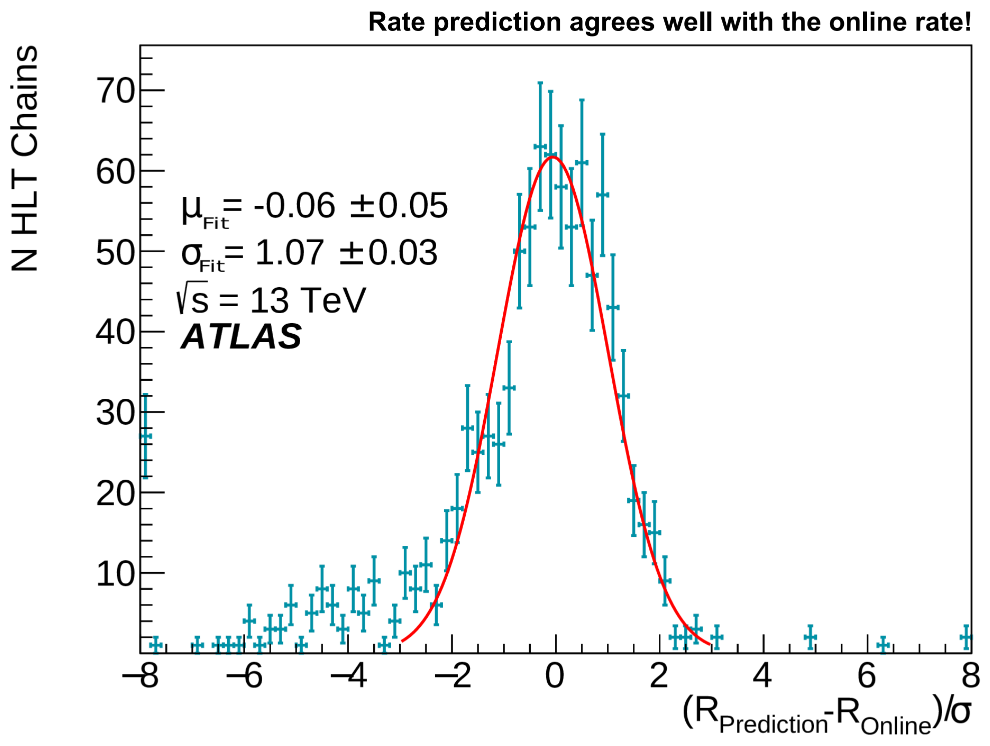
- To check CPU usage and data-flow over DAQ network





Rate monitoring





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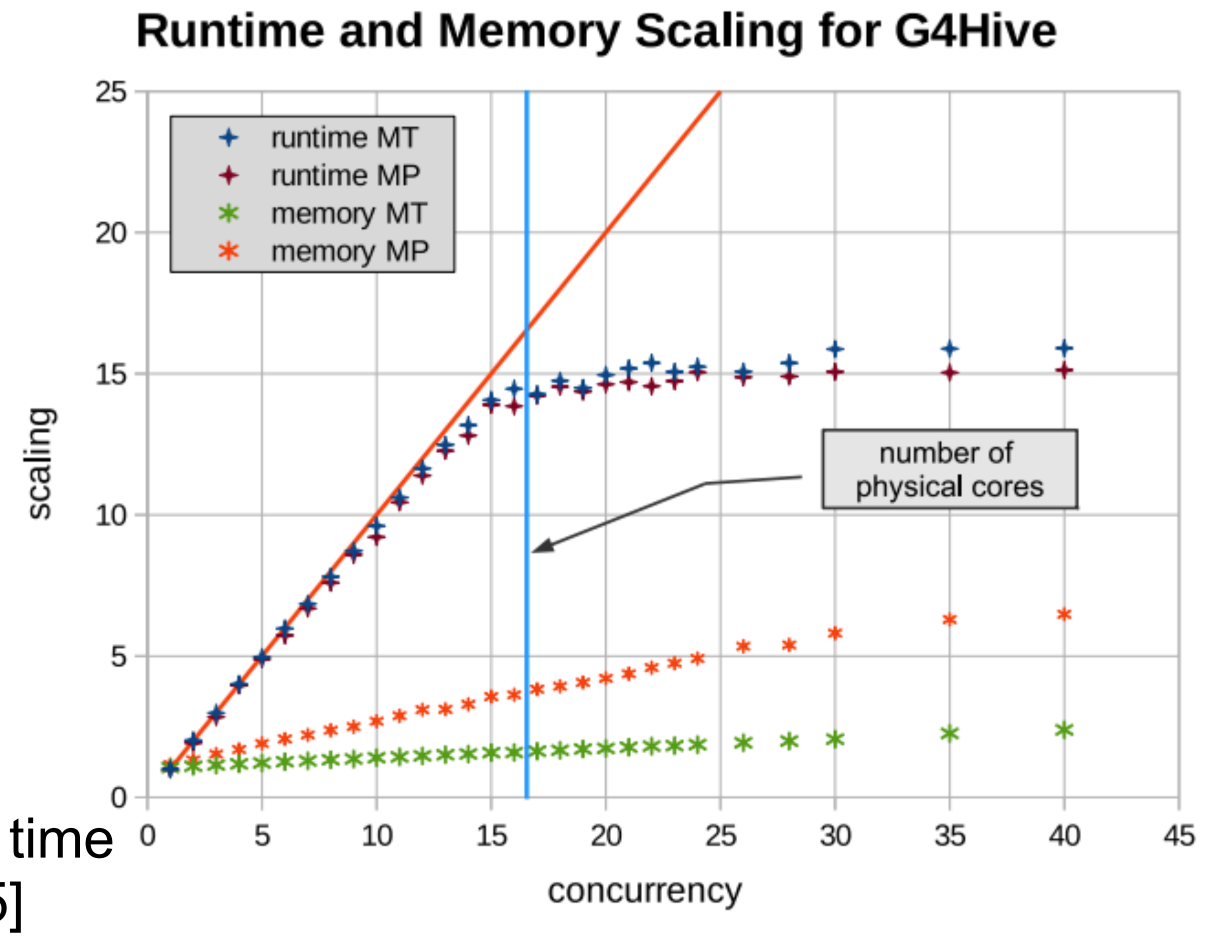
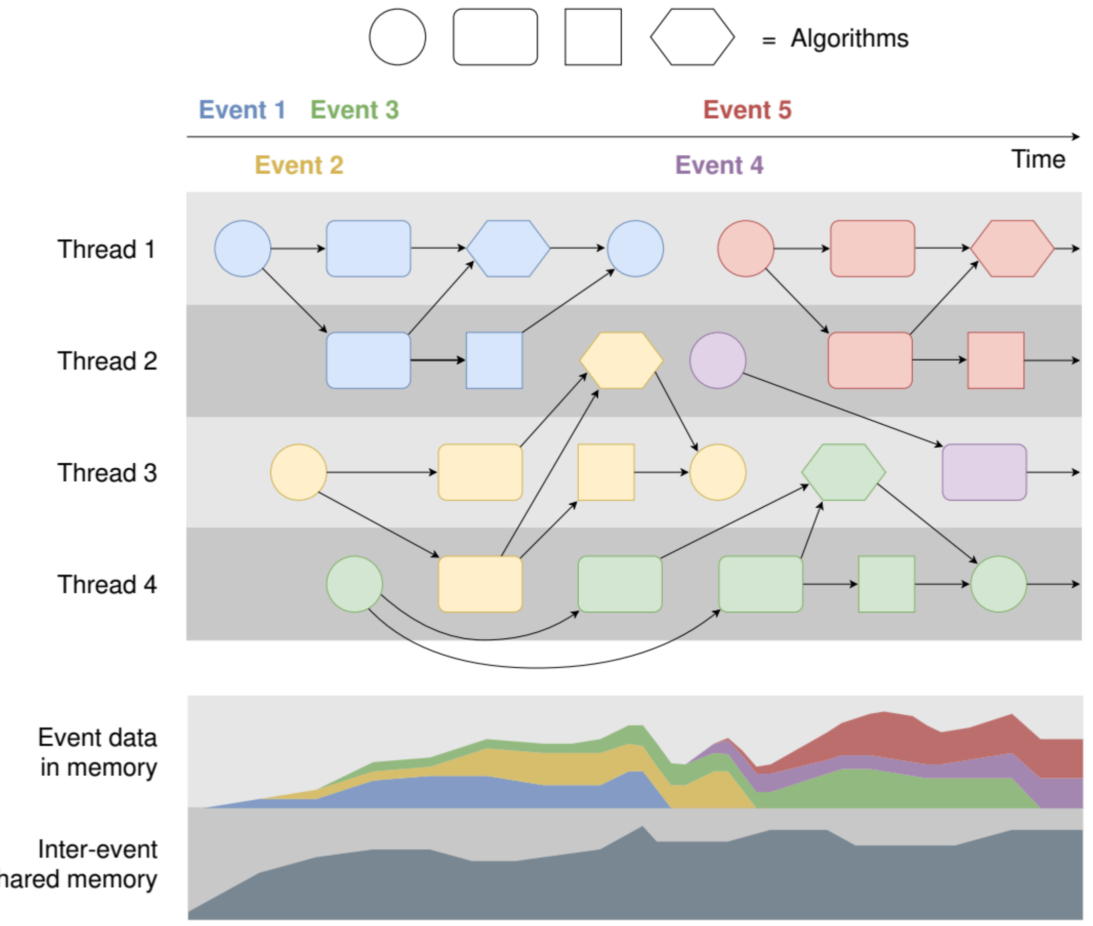
athenaMT for Run-3 HLT

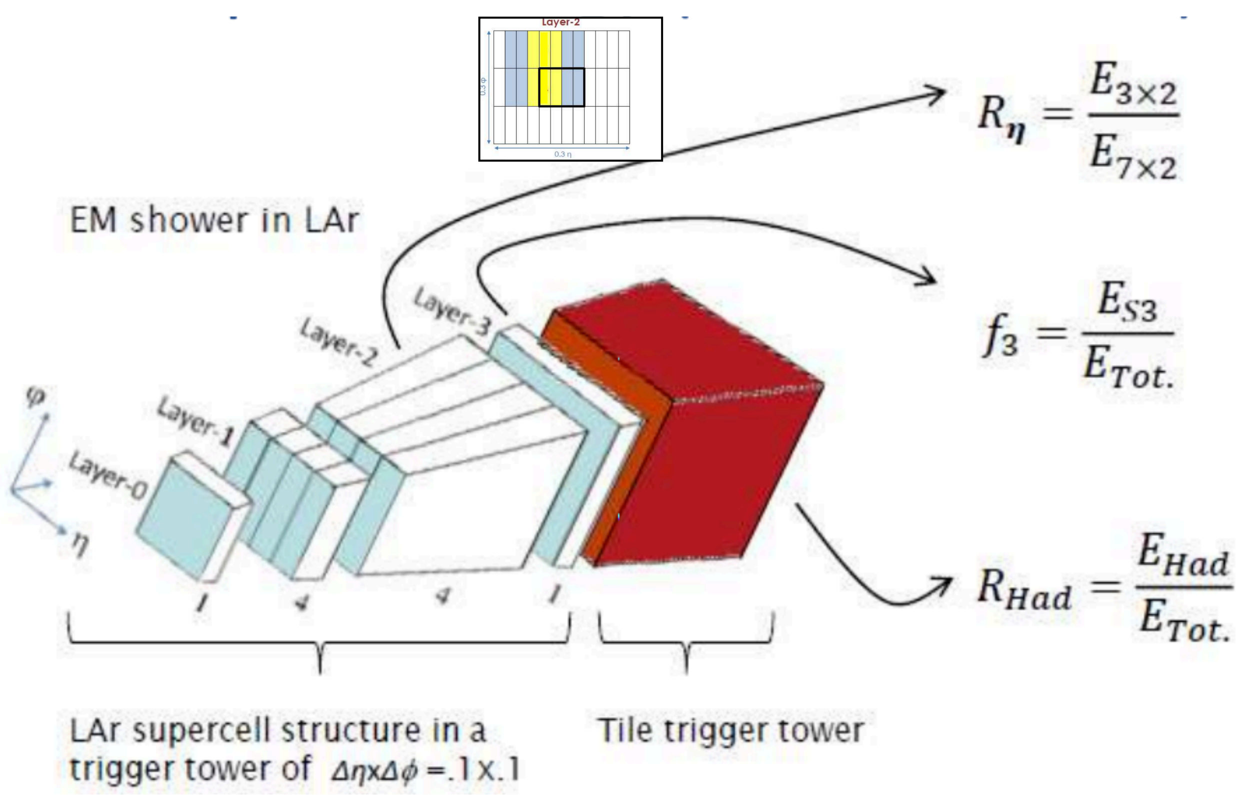
- ATLAS software framework (athena) will be switched to multithreaded implementation (athenaMT)
- 2 types of MT implementation:
  1. Inter-event MT
     * Multiple events in parallel
  2. Intra-event MT
     * Multiple algorithms for an event in parallel
- Less memory usage, although the processing time is equivalent with multi-processing approach[5]



- HLT software has been fully upgraded, to be integrated into athenaMT framework
- athenaHLT managed the multi-processing in Run 2 → That feature is retained
- From Run 3, each sub-process is multithreaded[6]

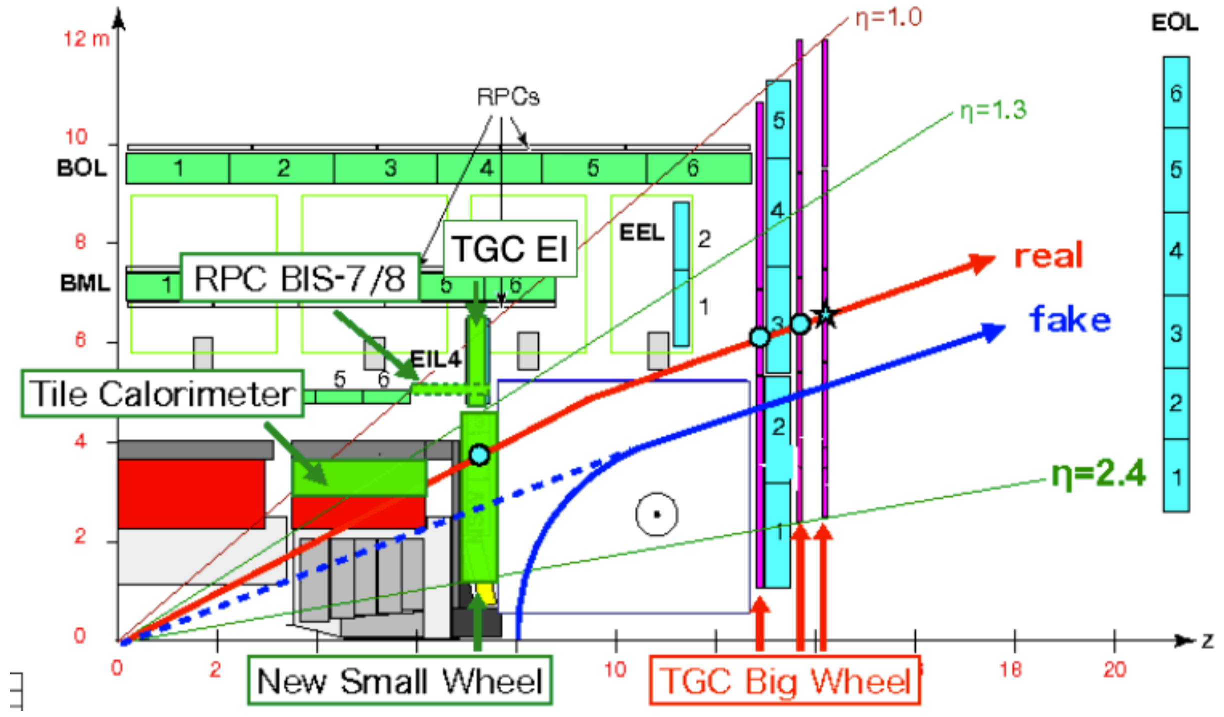


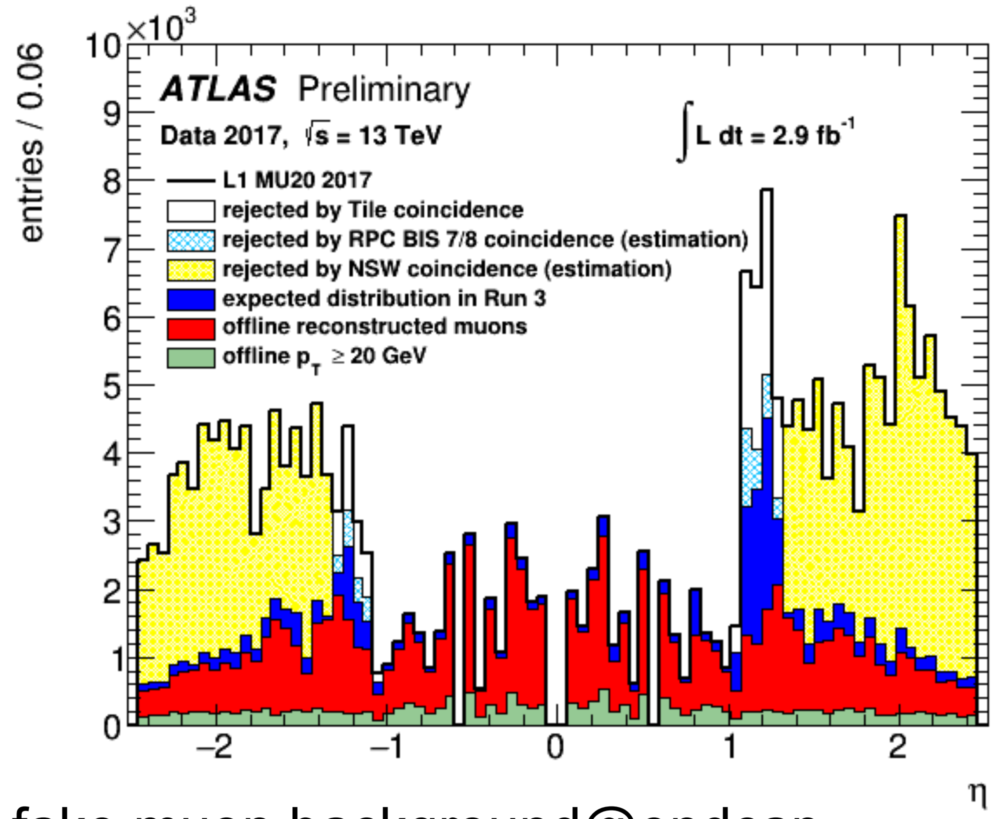
New feature extractor processors (eFEX/jFEX)



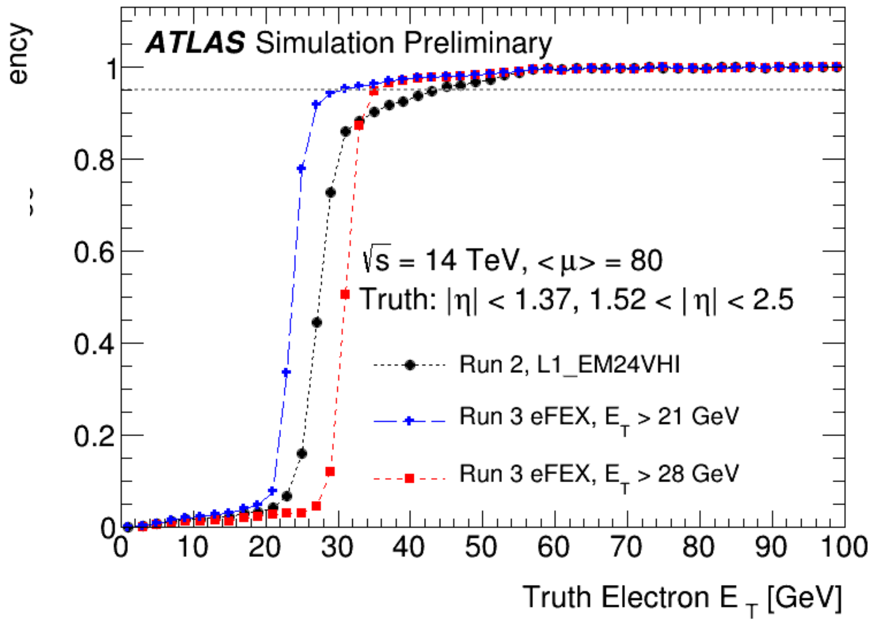
- Upgraded LAr read-out (higher granularity) and new feature extrapolator (FEX) processors
- Tighter isolation and hadron background veto → higher efficiency and better rate reduction [8-9]

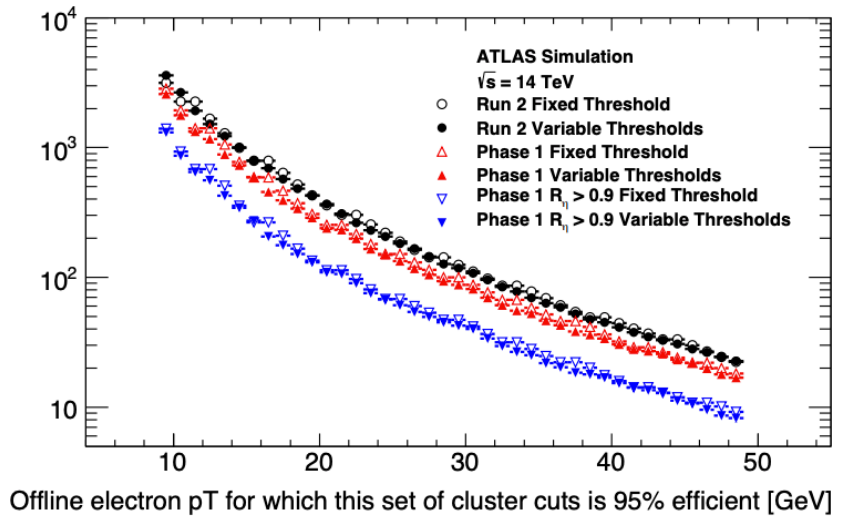
New features for Run 3
(examples)
New muon detectors integration



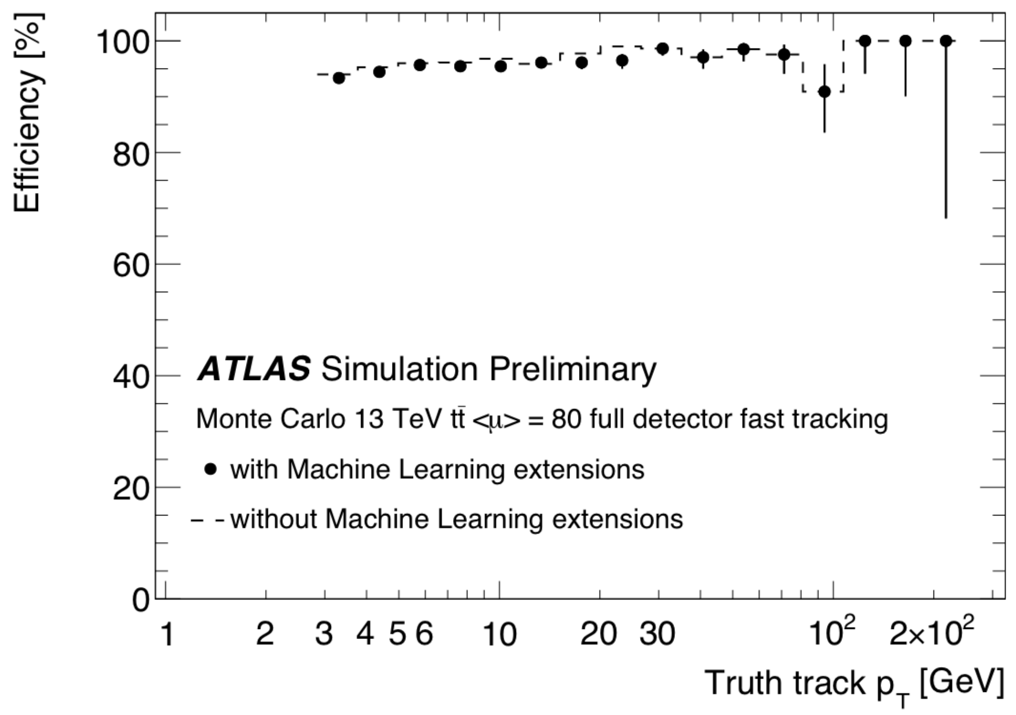


- Inner coincidence can reduce the beam-induced fake muon background@endcap
- High efficiency for signals [7]





Speed up of HLT track seeding w/the machine learning



2.1x faster than the current algorithm @<μ>=60

- Speed of HLT tracking is important especially for b, tau and the trigger for the unconventional signatures (e.g. long-lived particles)
- ML-based algorithm to select pairs of hits belonging to the same track, using angular and pixel cluster width → look-up table used in the trigger [10]

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