ATLAS TRIGGER SYSTEM FOR RUN 3

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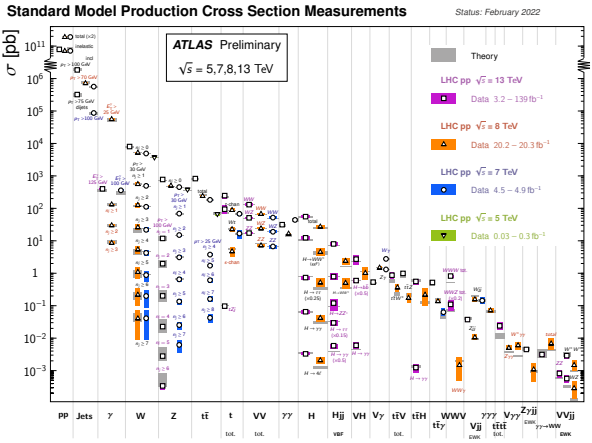
on behalf of the ATLAS TDAQ Collaboration

TRIGGER

- Online event selection for permanent storage
- The trigger decision is irrevocable.

  Rejected events are lost forever
- Two-level trigger system

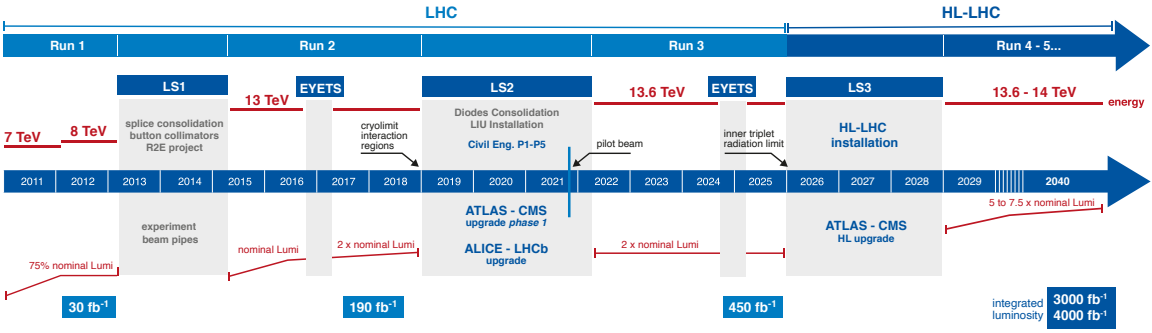
  $40MHz$ collisions $\rightarrow 100kHz$ $L1$ $\rightarrow 3kHz$ HLT $\rightarrow$ storage
- To put rates in context @13 TeV and $2e^{34}cm^{-2}s^{-1}$ we expect $\sim 600Hz$ of $W(\rightarrow lep)$, and $\sim 0.01Hz$ of ttH



ATL-PHYS-PUB-2022-009

Literally like finding a needle in a haystack!

TIMELINE



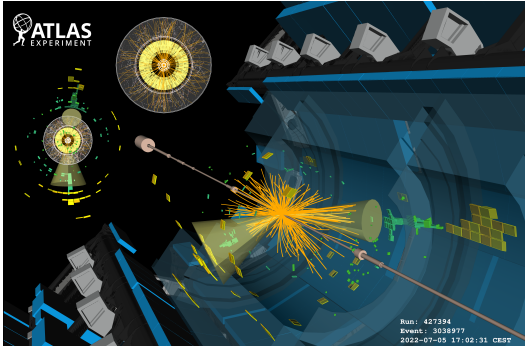
hilumilhc.web.cern.ch/content/hl-lhc-project

ATLAS Phase-I Upgrade, during the Long Shutdown 2: significant upgrades for Run 3 trigger system

RUN 3 HAS STARTED!

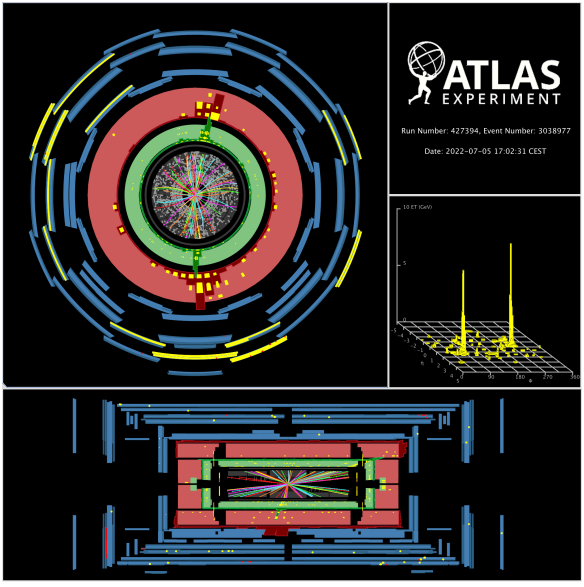
Stable beams & 13.6 TeV collisions since last Tuesday

Very exciting time ahead of us!



Collision event recorded in ATLAS on 5 July

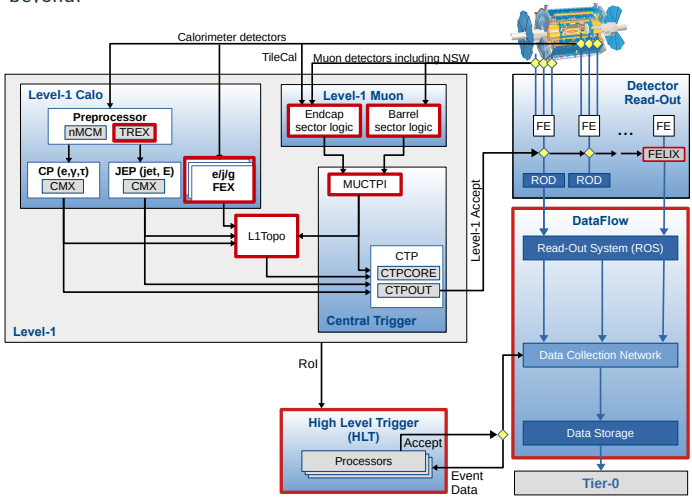
EventDisplayRun3Collisions



RUN 3 TRIGGER AND DATA ACQUISITION SYSTEM

New **hardware** installed during LS2 for Run 3 and beyond:

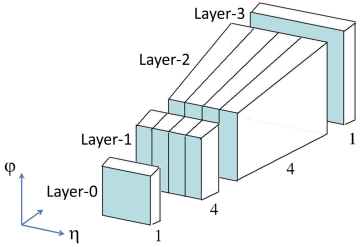
- Level-1 Calo:
  - Tile Rear Extension (TREX)
  - e/j/gFEX
- Level-1 Muon:
  - New Small Wheel
  - RPC BIS78
  - Barrel Sector Logic
  - Endcap Sector Logic
- L1Topo:
  - 1 object-counting board
  - 2 multi-object topological combination boards
- Central Trigger:
  - Muon to Central Trigger Processor Interface (MUCTPI)
- Front End Link eXchange (FELIX) readout
  - more details during Carlo's talk
- ROS (Readout System) refurbishment
- HLT (High Level Trigger) farm upgraded



New hardware projects will continue their commissioning with beam in early 2022 data taking. ApprovedPlotsDAQ

ATLAS PHASE-I UPGRADES FOR RUN 3

- Liquid Argon (LAr) upgrade (ATLAS-TDR-022)
  - Increased granularity of LAr calorimeter inputs (SuperCells)
- TDAQ upgrade (ATLAS-TDR-023)
  - electron/jet/global Feature EXtractors (e/j/gFEX)
    - more details regarding gFEX during Cecilia's talk
  - TREX (Tile Rear Extension): digitizes analogue signals from Tile for the FEX processors
  - L1Topo: Increase number of p_T thresholds for L1Calo based triggers
  - L1Muon Sector Logic: finer p_T granularity and charge information available for the muon endcaps
  - MUCTPI: Increase number of p_T thresholds for L1Muon based triggers
- New Small Wheel (ATLAS-TDR-020)
  - Reduction of rate dominated by fakes in the endcaps ($1.3 < |\eta| < 2.7$)
- New Resistive Plate Chamber beam interlock system (RPC BIS78):
  - Fake rejection in the Barrel-Endcap transition region ($1 < |\eta| < 1.3$)

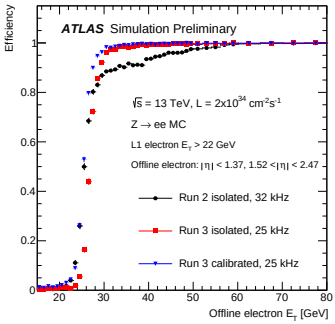


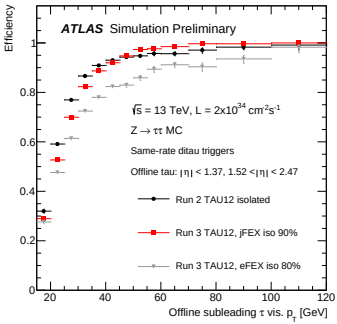
PHASE-I L1CALO - PREDICTED PERFORMANCE PLOTS

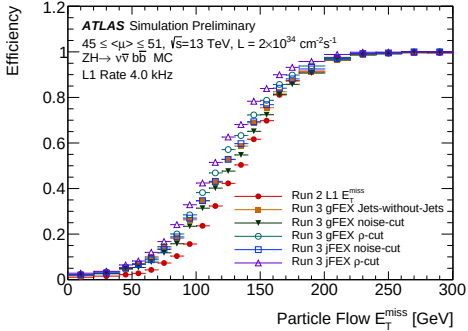
In Run 3:

- L1 eFEX EM trigger: sharper turn-on curve and 20% rate reduction with respect to the legacy Run 2 trigger by applying more sophisticated jet discriminant cuts, possible using the higher LAr calorimeter granularity
- L1 combined (eFEX/jFEX) TAU trigger: isolation requirement on jFEX matches Run 2 ditau trigger performance
- L1 jFEX and gFEX MET trigger: various algorithms proposed, outperforming the legacy Run 2 trigger for same rate

Have a look at Bryan's poster!





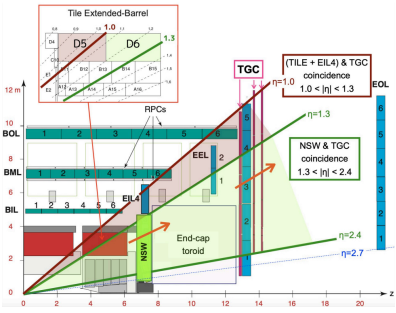


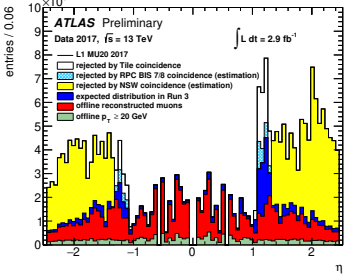
L1CaloTriggerPublicResults

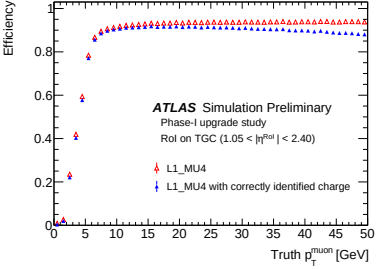
PHASE-I L1MUON - PREDICTED/EARLY PERFORMANCE PLOTS

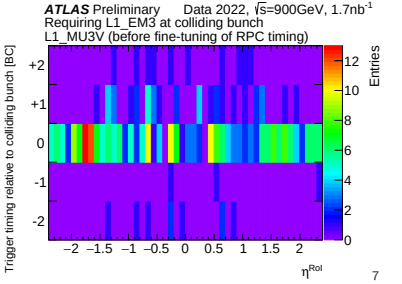
Important improvements in the L1Muon endcap for Run 3:
(more details during Andrea's talk and Yuichiro's poster)

- Rate dominated by fakes in the endcap in Run 2 will be suppressed in Run 3 by requiring TGC coincidence with NSW ($1.3 < |\eta| < 2.7$) and RPC BIS78 ($1 < |\eta| < 1.3$)
- Muon charge information will be exploited to further reduce L1Muon rate in the endcaps
- 900 GeV collisions performance study: distribution of η and trigger timing of Region-of-Interest (RoI) relative to colliding bunches





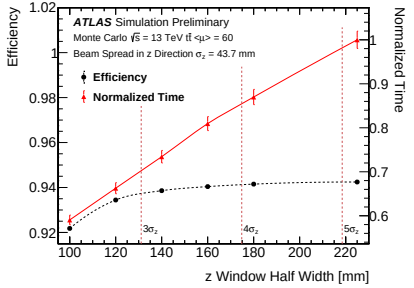


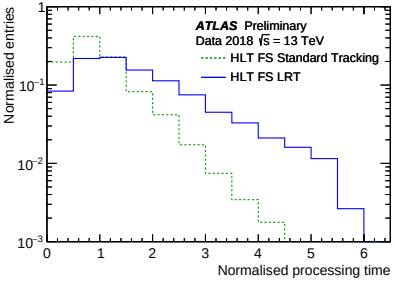


HLT IMPROVEMENTS FOR RUN 3 - PREDICTED PERFORMANCE PLOTS

- HLT software framework fully redesigned to be multi-threaded compliant (AthenaMT for Run 3)
- Full scan tracking to be used for hadronic signatures
  - Processing time optimization as tracking is CPU intensive by using dynamic RoI size
- Large radius tracking to increase acceptance for displaced signatures, long-lived particles [ATL-PHYS-PUB-2017-014]
- Egamma: moving from sliding window reconstruction to superclusters (as offline) [JINST 14 (2019) P12006]
- Jet: moving from EM topological clusters to Particle Flow reconstruction (as offline) [EPJC 77 (2017) 466]
- b-jet: moving from MV2 to the more performant DL1 tagger (multivariate classification algorithm based on deep learning techniques) [ATL-PHYS-PUB-2017-013] - Have a look at Maggie's poster!

HLTTrackingPublicResults





HLT IMPROVEMENTS FOR RUN 3 - PREDICTED/EARLY PERFORMANCE PLOTS

Early restults from Inner Detector Trigger MinBias tracking in 900 *GeV* collsions

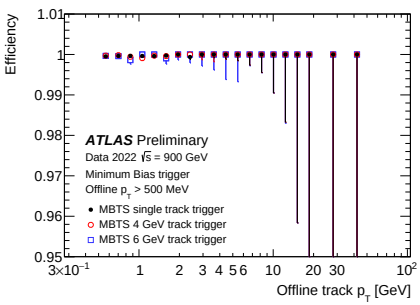
- The 4(6) *GeV* track-triggers have an unbiased tracking spectra below 4(6) *GeV* & very high efficiency

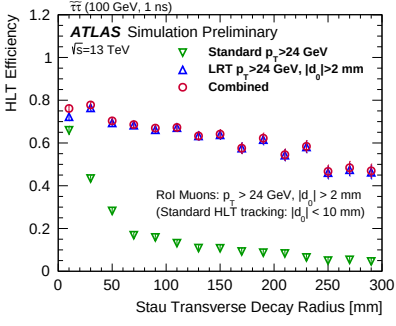
Improvements to the offline large radius tracking (LRT) allow it to be used online in the trigger improving efficiency

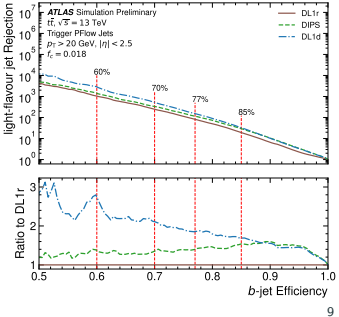
- LRT outperforms standard tracking decision; example of supersymmetric tau (stau) decay radius

Better jet and b-jet performance

- B-jet efficiency of the new DIPS and DL1d algorithms outperforms the benchmark DL1r algorithm





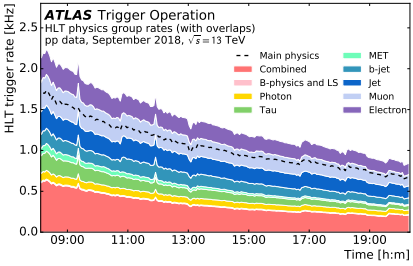


ATLAS TRIGGER MENU

The wide ATLAS physics program is achieved by running more than 1500 triggers.

Events are selected based on physics signatures: leptons, photons, jets or large missing transverse energy.

The trigger menu implements and maintains the configuration of all triggers.



Trigger	Typical offline selection	Trigger Selection		Level-1 Peak Rate (kHz)	HLT Peak Rate (Hz)
		Level-1 (GeV)	HLT (GeV)	$L = 5 \times 10^{33}$ cm^{-2}s^{-1}	
Single leptons	Single iso μ, $p_T > 21$ GeV	15	20	7	130
	Single e, $p_T > 25$ GeV	20	24	18	139
	Single μ, $p_T > 42$ GeV	20	40	5	33
	Single τ, $p_T > 90$ GeV	60	80	2	41
Two leptons	Two μ's, each $p_T > 11$ GeV	2×10	2×10	0.8	19
	Two μ's, $p_T > 19, 10$ GeV	15	18, 8	7	18
	Two loose e's, each $p_T > 15$ GeV	2×10	2×12	10	5
	One e & one μ, $p_T > 10, 26$ GeV	20 (μ)	7, 24	5	1
	One loose e & one μ, $p_T > 19, 15$ GeV	15, 10	17, 14	0.4	2
	Two τ's, $p_T > 40, 30$ GeV	20, 12	35, 25	2	22
	One τ, one μ, $p_T > 30, 15$ GeV	12, 10 (+jets)	25, 14	0.5	10
	One τ, one e, $p_T > 30, 19$ GeV	12, 15 (+jets)	25, 17	1	3.9

TriggerOperationPublicResults (Run 2)

Designing the Trigger menu is a balance between analysis requests (store all physics!) and system constraints:

- Peak L1 rate below detector readout (100 kHz)
- Average HLT rate bellow storage and prompt reconstruction constraints ($\sim$ 3 kHz)
- Trigger decision should be delivered within 500ms on average (available CPU in the HLT farm)

Targeted research programs, e.g. Heavy Ions, have their own dedicated trigger menus.

TRIGGER MENU IMPROVEMENTS FOR RUN 3

Upgrades for Run 3:

- Run 3 trigger menu selections aligned with latest offline reconstruction techniques
  - Want to store only events that are actually going to be used
- Keeping menu as inclusive as possible in term of signatures
  - New triggers for unconventional signatures - Have a look at Ismet's poster!
- End-of-fill triggers (typically for B-physics) activated at lower instantaneous luminosity where there is bandwidth available

Upgraded monitoring tools:

- new Trigger Rate Presenter
- new Trigger Tool

CONCLUSIONS

- LS2 and Phase-I upgrades will bring many improvements delivered by ATLAS
  - Phase-I L1Muon endcap improvements will reduce fakes with NSW & RPC BIS78
  - Phase-I LAr / L1Calo will allow higher granularity, more sophisticated algorithms, higher efficiencies / resolutions & improved background rejection.
  - Brand new HLT software framework with better sharing of offline code & Multi-Threaded compliant
  - Run 3 trigger menu aligned with most performant offline reconstruction techniques
- Trigger system ready for data taking once again
- Run 3 has already started!