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The ATLAS trigger menu: from Run 2 to Run 3

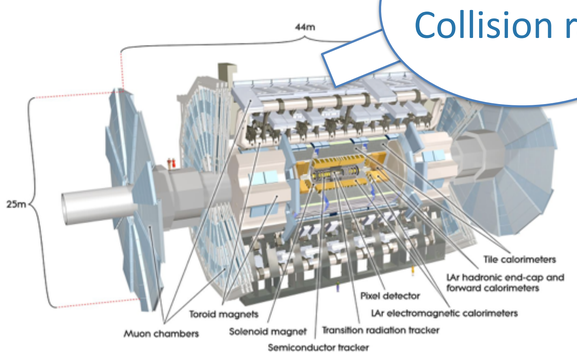
Emma Torró, IFIC - Valencia
on behalf of the ATLAS Collaboration

ATLAS EXPERIMENT

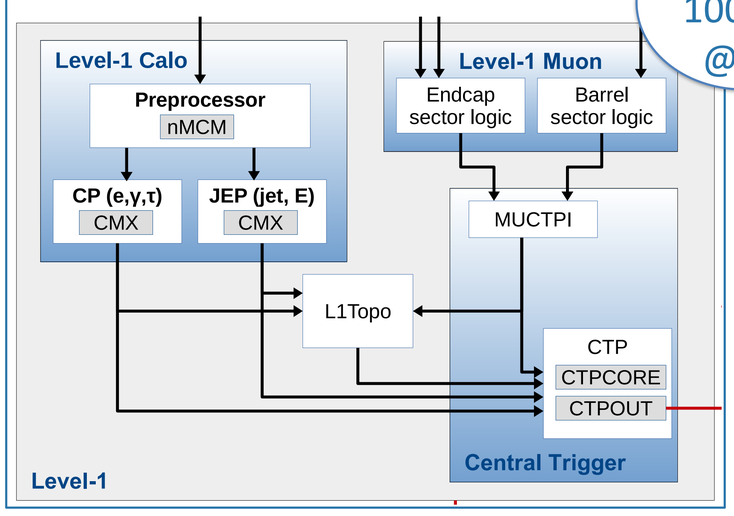
CSIC · Universitat de València

Trigger and Data Acquisition

40 MHz Collision rate



Level 1 (L1)
(hardware) 2.5 μs processing time



Peak of 100kHz @ L1

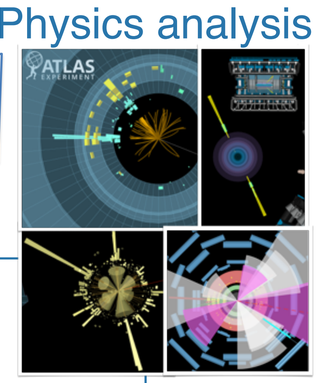
High Level Trigger (HLT)
(software)

Processors O(45k) CPU cores

O(250 ms) processing time (average)

Average of 1kHz @ HLT

For Physics analysis

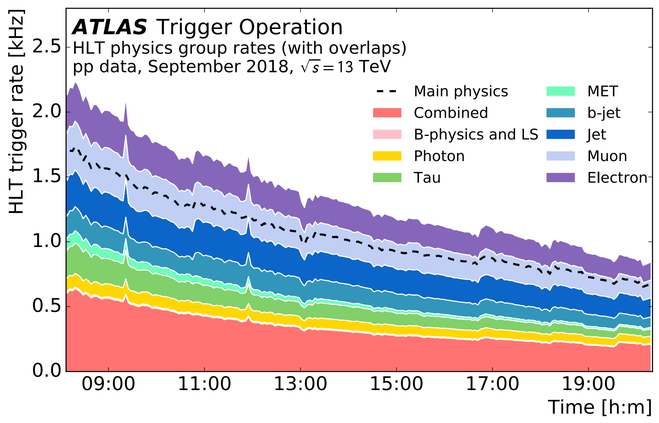


offline-like reconstruction paired with **early-rejection algorithms** for CPU minimisation

Trigger Menu

Design

- The wide ATLAS physics program is achieved by running approximately 1500 triggers.
- Events are selected based on physics signatures: leptons, photons, jets or large missing transverse energy.
- Limitations to be taken into account in the design:
  - Total offline storage: convolute with LHC availability and luminosity profile to get fill-averaged rate.
  - HLT CPU: hard limit, determines what can be run, most notably tracking.
- Detector readout rate: hard limit, determines L1 output.



https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TriggerOperationPublicResults

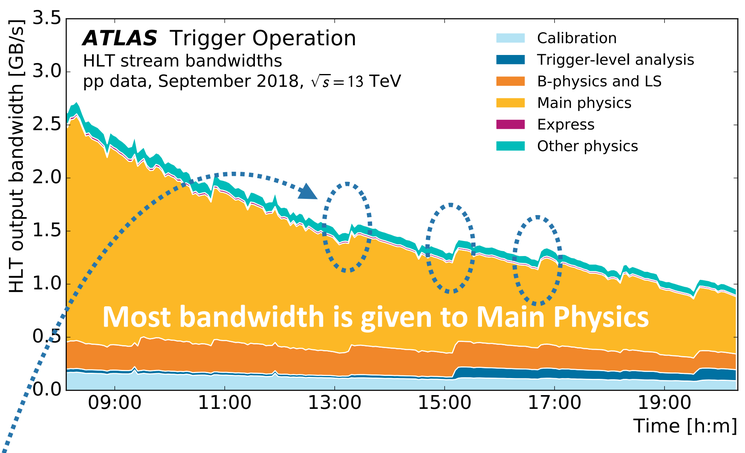
- A Trigger Menu is the compilation of these triggers
  - Must reflect the physics goals
  - Must take into consideration the limitations from the ATLAS detector readout and offline processing farm.
  - Needs to keep a **good balance** between the trigger signature groups
  - For every trigger, it needs to specify
    - the physics selection algorithms
    - selection values
    - the allocated rate

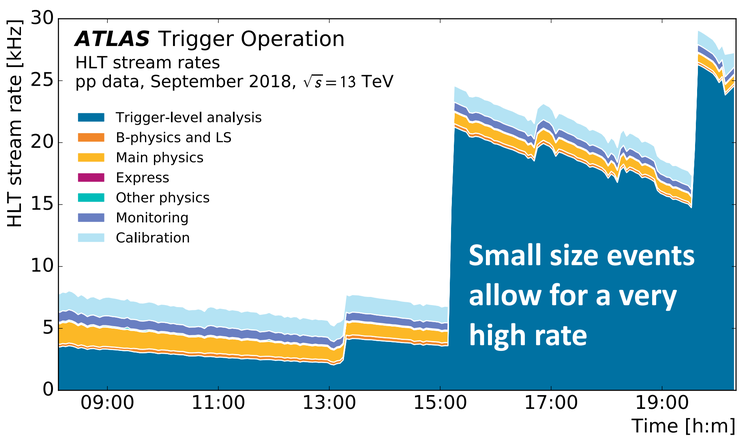
Trigger	Typical offline selection	Trigger Selection L1 [GeV]	Trigger Selection HLT [GeV]	L1 Peak Rate [kHz] $L=2.0\times10^{34}$ cm^{-2}s^{-1}	HLT Peak Rate [Hz]
Single leptons	Single isolated μ, $p_T > 27$ GeV	20	26 (i)	16	218
	Single isolated tight e, $p_T > 27$ GeV	22 (i)	26 (i)	31	195
	Single μ, $p_T > 52$ GeV	20	50	16	70
	Single e, $p_T > 61$ GeV	22 (i)	60	28	20
	Single τ, $p_T > 170$ GeV	100	160	1.4	22
Two leptons	Two μ, each $p_T > 15$ GeV	2 × 10	2 × 14		
	Two μ, $p_T > 23,9$ GeV	20	22,8		
	Two very loose e, each $p_T > 18$ GeV	2 × 15 (i)			
	One e & one μ, $p_T > 8, 25$ GeV	20 (μ)			
	One loose e & one μ, $p_T > 18, 15$ GeV	15, 10			
	One e & one μ, $p_T > 27, 9$ GeV				
	Two τ, $p_T > 40, 30$ GeV				
	One τ & one isolated μ, $p_T > 30, 15$ GeV				
	One τ & one isolated e, $p_T > 30, 18$ GeV				
Three leptons	Three very loose e, $p_T > 25$				
	Three μ, each p_T				7
	Three μ,				9
	Two			2.2	0.5
Single				2.3	0.1
			140	24	47
			2 × 50	3.0	7
			35, 25	3.0	21
		2 × 15 (i)	2 × 20 (i)	2.0	15
		100	420	3.7	35
		111 (topo: $R = 1.0$)	460	2.6	42
b-jet	> 45 GeV	111 (topo: $R = 1.0$)	420, $m_{jet} > 35$	2.6	36
	285 GeV	100	275	3.6	15
	$p_T > 185, 70$ GeV	100	175, 60	3.6	11
	$\epsilon = 40\%$) & three jets, each $p_T > 85$ GeV	4 × 15	4 × 75	1.5	14
	Two b ($\epsilon = 70\%$) & one jet, $p_T > 65, 65, 160$ GeV	2 × 30, 85	2 × 55, 150	1.3	17
	Two b ($\epsilon = 60\%$) & two jets, each $p_T > 65$ GeV	4 × 15, $\|\eta\| < 2.5$	4 × 55	3.2	15
Multijets	Four jets, each $p_T > 125$ GeV	3 × 50	4 × 115	0.5	16
	Five jets, each $p_T > 95$ GeV	4 × 15	5 × 85	4.8	10
	Six jets, each $p_T > 80$ GeV	4 × 15	6 × 70	4.8	4
	Six jets, each $p_T > 60$ GeV, $\|\eta\| < 2.0$	4 × 15	6 × 55, $\|\eta\| < 2.4$	4.8	15
E_T^{miss}	$E_T^{miss} > 200$ GeV	50	110	5.1	94
B-physics	Two μ, $p_T > 11, 6$ GeV, $0.1 < m(\mu,\mu) < 14$ GeV	11, 6	11, 6 (di-μ)	2.9	55
	Two μ, $p_T > 6, 6$ GeV, $2.5 < m(\mu,\mu) < 4.0$ GeV	2 × 6 (J/ψ, topo)	2 × 6 (J/ψ)	1.4	55
	Two μ, $p_T > 6, 6$ GeV, $4.7 < m(\mu,\mu) < 5.9$ GeV	2 × 6 (B, topo)	2 × 6 (B)	1.4	6
	Two μ, $p_T > 6, 6$ GeV, $7 < m(\mu,\mu) < 12$ GeV	2 × 6 (Υ, topo)	2 × 6 (Υ)	1.2	12
Main Rate B-physics and Light States Rate				86	1750 200

512 L1 items + O(1500) HLT chains to maximize the reach of ATLAS physics program

Data Streams

- Triggers require either **full Event Building (EB) or partial EB**, using only some sub-detector information
- Events selected by triggers are recoded in different data streams:
  - **Main Physics**: contains most of the triggers (primary and support) used in Physics analyses and object calibration
  - **B-physics and Light States**: triggers specific to B-physics analyses to be reconstructed later
  - **Express stream and Detector Calibration**: for fast offline monitoring and detector calibration
  - **Trigger Level Analysis**: only records Trigger data, used in di-jet resonance searches





https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-DAQ-PUB-2019-001

- **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 γ+γ 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

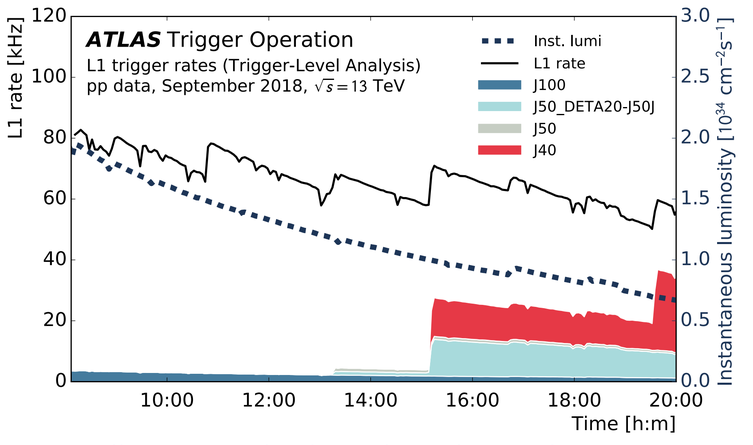
Operation

- The trigger menu implements and maintains the configuration of all 1500 triggers.
- During operation, rates are adjusted via **prescale (PS) sets** to optimise the bandwidth usage, depending on the instantaneous **luminosity**
- New menus are deployed at P1 every few weeks, to add newly requested chains and adjustments.
- Before deployment, the menu is **carefully validated** by reprocessing and rate prediction to determine prescales at each luminosity step

Change in PS set

End-of-fill

- Nominal menu is designed for $L = 2 \times 10^{34}$ cm^{-2}s^{-1}, but more than 40% was collected with $L \leq 1.2 \times 10^{34}$ cm^{-2}s^{-1}!
- Triggers that are not part of the nominal menu (e.g. limited by **L1 rate** or **HLT CPU)** can be enabled only 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**



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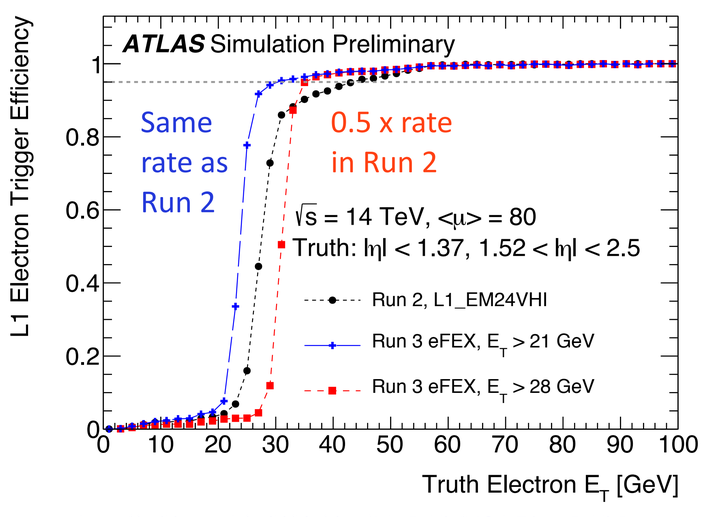
Run 3

- In Run 3, a total integrated luminosity of 100 fb^{-1} each physics production year (2022 - 2024) is expected.
- To facilitate the combination of datasets, the ATLAS approach is to build a trigger menu as stable as possible between Run 2 and Run 3.
- The new Phase-I hardware for Run 3 will impact and benefit the menu in a significant way (Dedicated poster).
- For example, improved performance is expected for L1 EM objects and L1 E_T^{miss} triggers from the upgraded L1Calo system.
- This will incorporate the Feature Extractors which allow smaller granularity for e, γ, tau and jet at L1, and a whole-calorimeter view at L1 for better computation of global quantities, large-R jet and E_T^{miss} (Dedicated poster on jet performance, and on electron/photon performance).

- The Run 2 menu is taken as starting point, trying to expand it to corners of the phase space not covered before and previously unexplored signatures
  - Investigating increased usage of partial-event and trigger-level analysis streams
  - Foresee increased HLT tracking for improved jet (particle-flow) and MET (soft term) reconstruction, possible thanks to HLT farm hardware upgrades and software speedup



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