The ATLAS Trigger Menu: design for higher luminosities in Run 2

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What is a Trigger Menu?

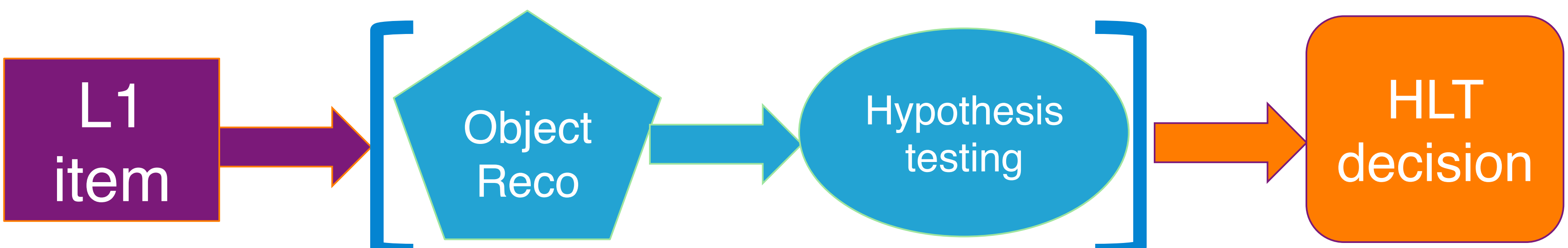

trigger menu

- electron
- photon
- muon
- tau
- jet
- missing energy
- …

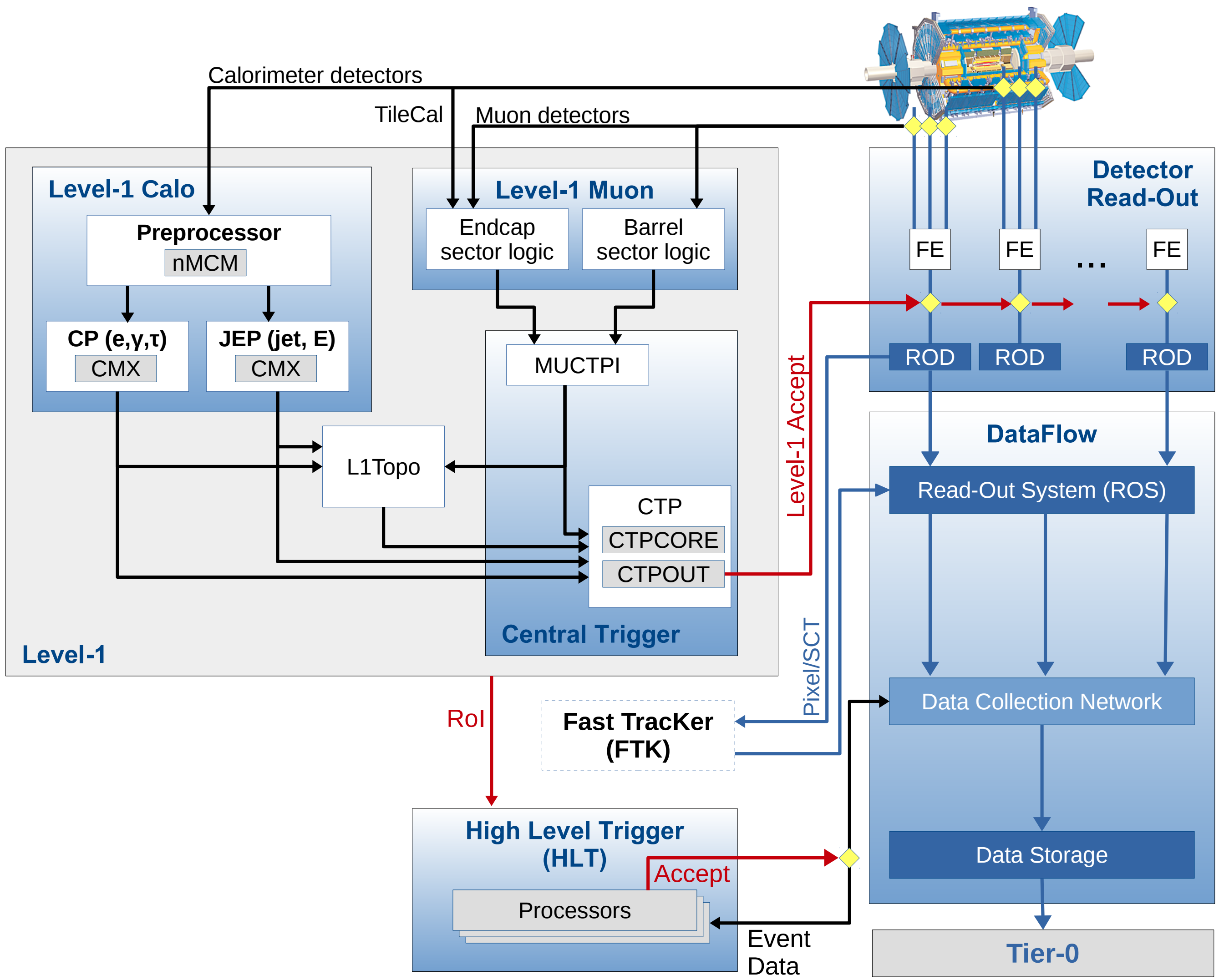
List of the types of events we select in each bunch crossing

- Each type of event is configured in the menu with a *chain**
- Each chain has a cost, in terms of rate and CPU usage
- Select the number of each item we want dependent on cost and physics motivation

Chain:



The ATLAS trigger system



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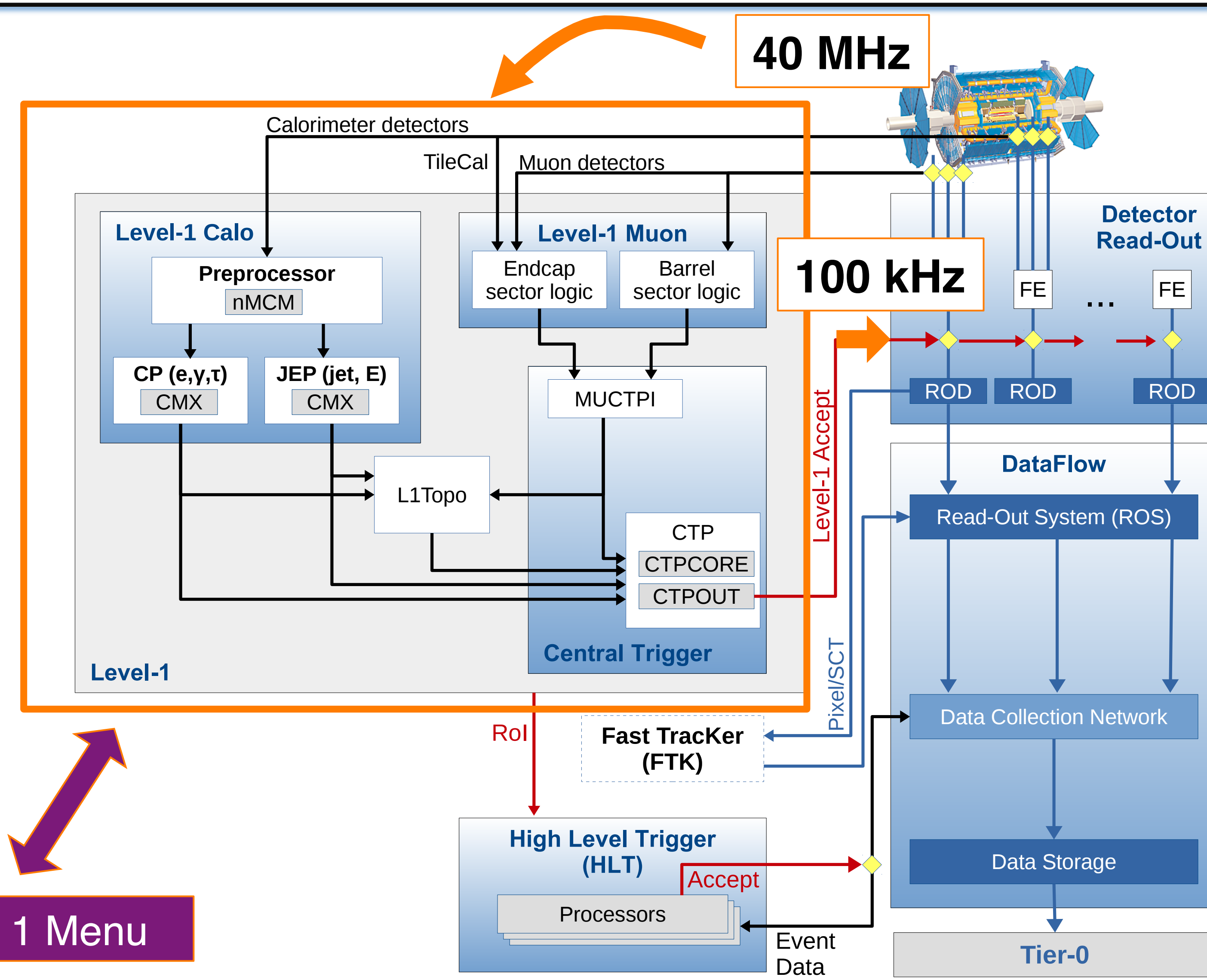

Level 1 Menu

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

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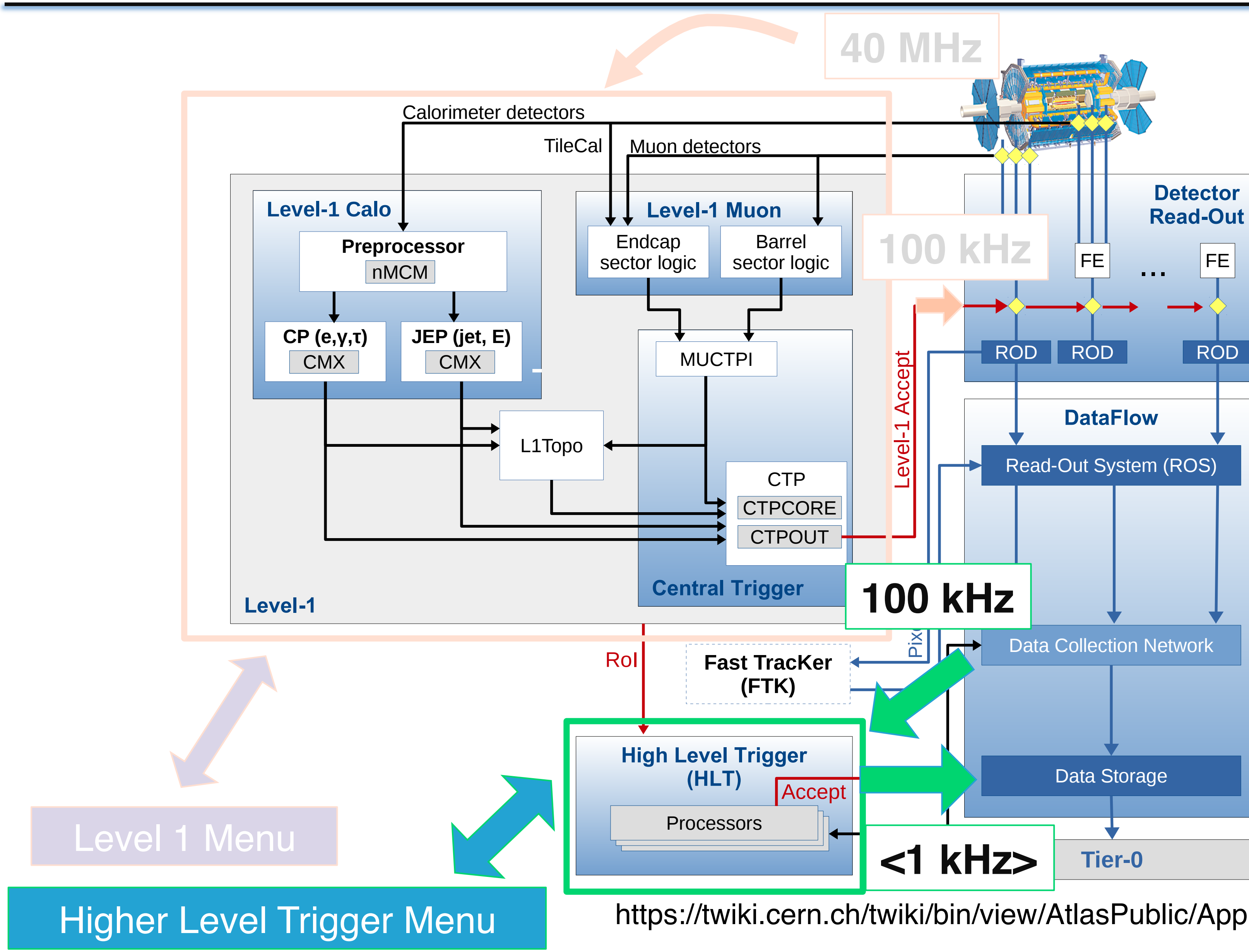

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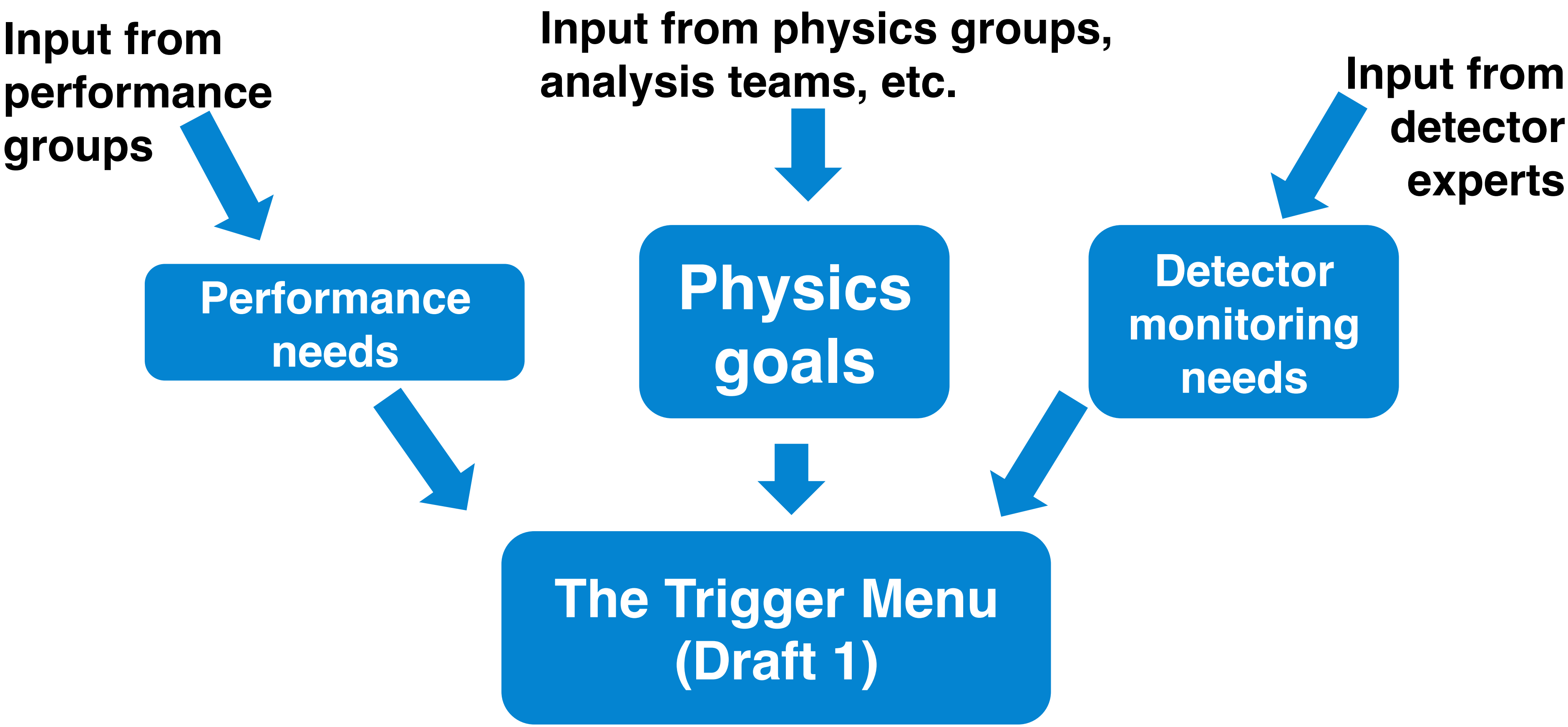
The stages of Trigger Menu development



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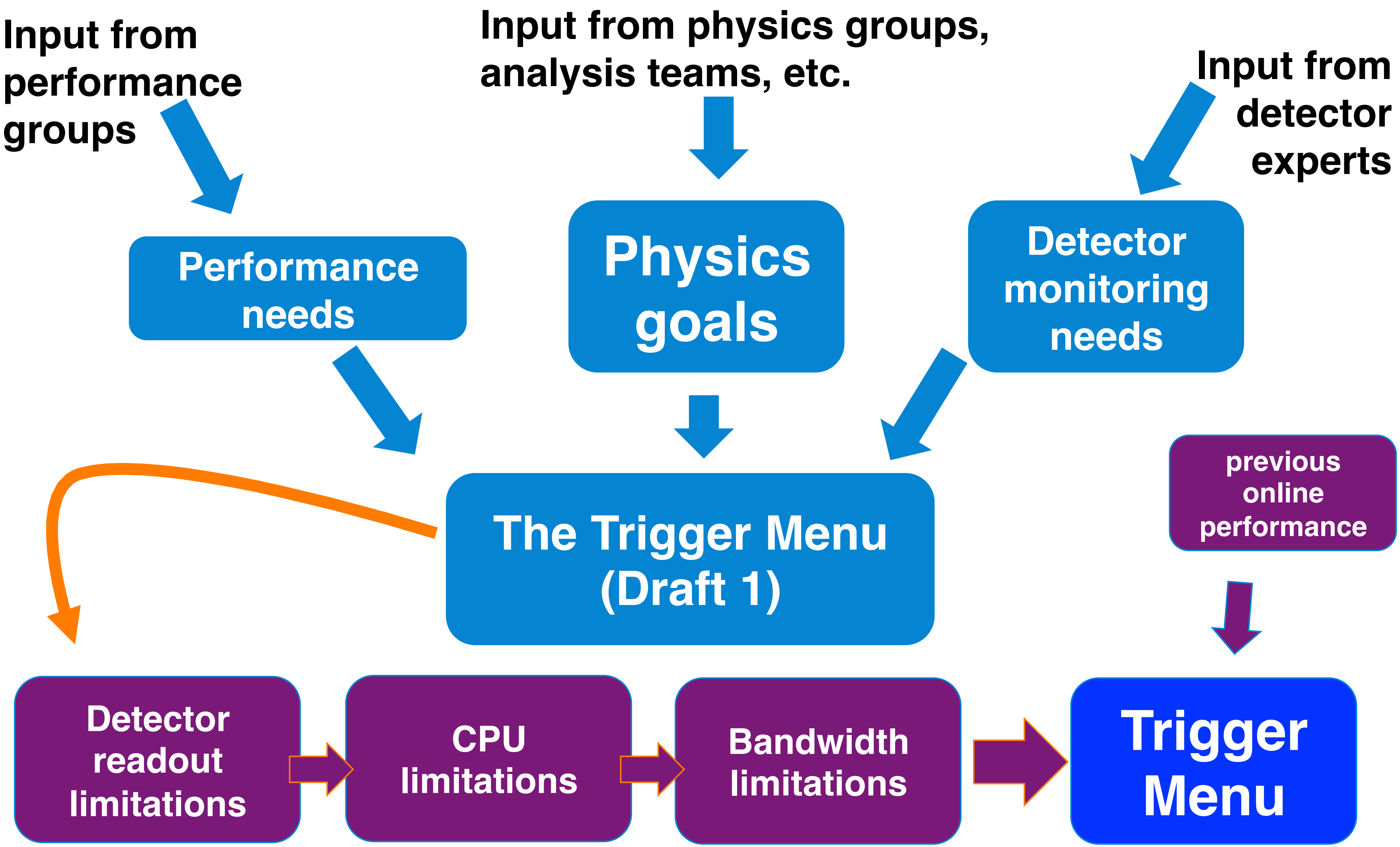


The Trigger Menu limitations

Detector readout limitations

Only 100 kHz can be sent to the HLT – have to carefully balance rate allotment between physics requests, also accounting for monitoring needs.

CPU limitations

HLT farm is not infinite! For example, cannot perform full inner detector tracking on every event. Physics requests with high-CPU usage must be carefully considered.

Bandwidth limitations

HLT physics output is limited to ~1 kHz average over each run. Each physics request should ensure their unique rate is as small as possible without compromising the physics potential.

The Final Trigger Menu

ATL-DAQ-PUB-2017-001

Trigger	Typical offline selection	Trigger Selection		Level-1 Peak Rate (kHz)	HLT Peak Rate (Hz)
		Level-1 (GeV)	HLT (GeV)	$L = 1.2 \times 10^{34}$ cm^{-2}s^{-1}	
Single leptons	Single isolated μ, $p_T > 27$ GeV	20	26 (i)	13	133
	Single isolated tight e, $p_T > 27$ GeV	22 (i)	26 (i)	20	133
	Single μ, $p_T > 52$ GeV	20	50	13	48
	Single e, $p_T > 61$ GeV	22 (i)	60	20	13
	Single τ, $p_T > 170$ GeV	60	160	5	15
Two leptons	Two μ's, each $p_T > 15$ GeV	2×10	2×14	1.5	21
	Two μ's, $p_T > 23, 9$ GeV	20	22, 8	13	30
	Two loose e's, each $p_T > 18$ GeV	2×15	2×17	8	7
	One e & one μ, $p_T > 8, 25$ GeV	20 (μ)	7, 24	13	2
	One loose e & one μ, $p_T > 18, 15$ GeV	15, 10	17, 14	1.5	2.6
	Two τ's, $p_T > 40, 30$ GeV	20 (i), 12 (i) (+jets)	35, 25	6	35
					7
					9
Three le					< 0.1
					3
					4
					0.2
					0.1
One pho					30
Two photons	Two loose γ's, $p_T > 40, 30$ GeV	2×15	35, 25	8	40
	Two tight γ's, $p_T > 27, 27$ GeV	2×15	2×22	8	16
Single jet	Jet ($R = 0.4$), $p_T > 420$ GeV	100	380	3	38
	Jet ($R = 1.0$), $p_T > 460$ GeV	100	420	3	35
E_T^{miss}	$E_T^{miss} > 200$ GeV	50	110	6	230
Multi-jets	Four jets, each $p_T > 110$ GeV	3×50	4×100	0.4	18
	Five jets, each $p_T > 80$ GeV	4×15	5×70	3.5	14
	Six jets, each $p_T > 70$ GeV	4×15	6×60	3.5	5
	Six jets, each $p_T > 55$ GeV, $\|\eta\| < 2.4$	4×15	6×45	3.5	18
b–jets	One b ($\epsilon = 60\%$), $p_T > 235$ GeV	100	225	3	24
	Two b's ($\epsilon = 60\%$), $p_T > 160, 60$ GeV	100	150, 50	3	20
	One b ($\epsilon = 70\%$) & three jets, each $p_T > 85$ GeV	4×15	4×75	3.5	19
	Two b ($\epsilon = 60\%$) & one jet, $p_T > 65, 65, 110$ GeV	$2 \times 20, 75$	$2 \times 55, 100$	2.7	25
	Two b ($\epsilon = 60\%$) & two jets, each $p_T > 45$ GeV	4×15	4×35	3.5	56
b–physics	Two μ's, $p_T > 6, 6$ GeV plus dedicated b-physics selections	6, 6	6, 6	4.7	20
Total				85	1500

A small selection of the 512 L1 Items and > 1000 HLT chains contained in the 2016 trigger menu

- Each L1 item and HLT chain has an associated prescale *p*:
  - record only every *p*-th event that passes the item or chain
- Events passing a trigger chain are recorded to different data **streams**
- Streams record events with either full event building (EB) [for physics] or partial EB, where only a subset of the detector data is saved

Trigger Menu Validation – I

- Before being deployed for data-taking, the Trigger Menu is carefully tested to ensure none of the limitations will be encountered online

- Each time the data-taking conditions sufficiently change (e.g. increased pileup or luminosity), a new ***enhanced bias*** dataset is recorded

  Special dataset of ~1M events that is enriched in high-p_T, physics-like events without any bias from HLT selection

  New HLT selection can be studied without any input bias!

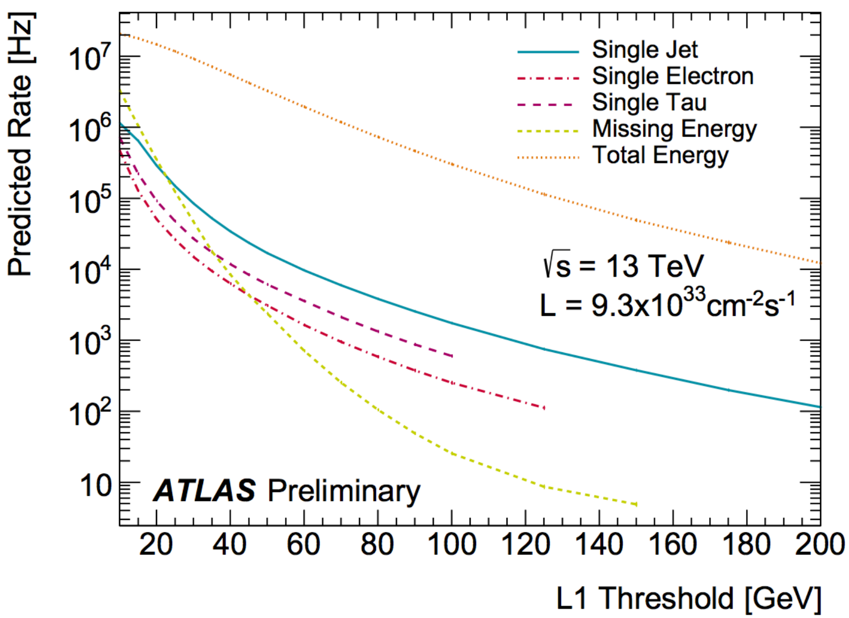
- **Simulate** the new menu using the input enhanced bias dataset, with two very important goals:

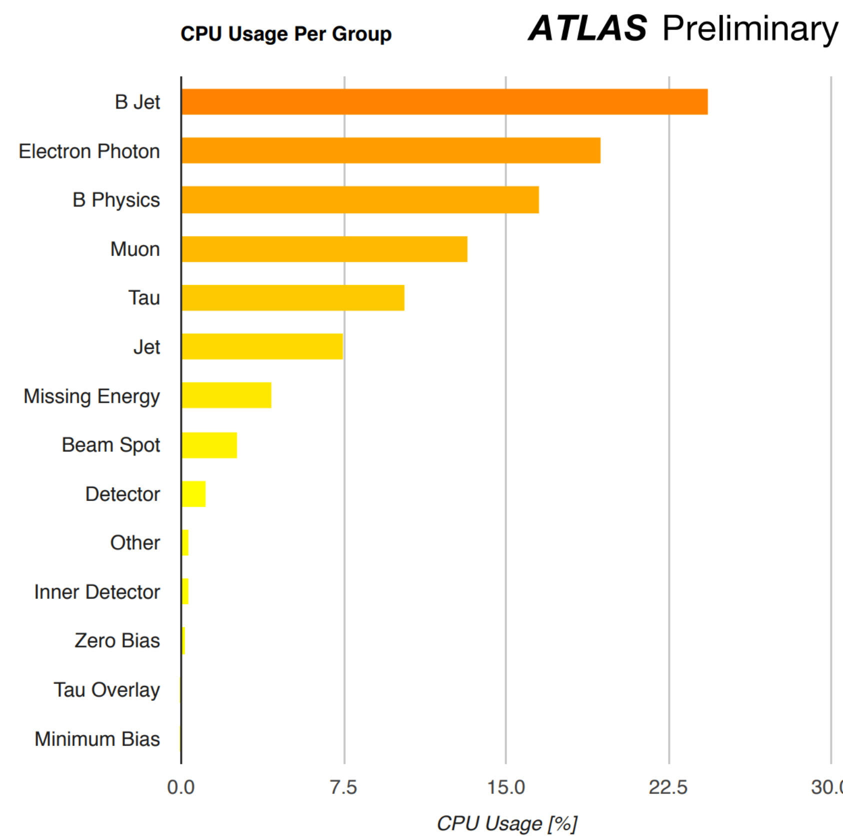
  - Ensure that all CPU and rate constraints are not violated, for both L1 and HLT menus
  - **Validate** the menu, ensuring all algorithms and chains are performing as expected

Trigger Menu Validation – II

Rates can be predicted for new thresholds, allowing for precise rate allotment and menu design:

ATL-DAQ-PUB-2016-002





CPU usage of each algorithm and chain is also predicted, allowing for rapid feedback on CPU improvements and potential HLT farm usage

Using a Trigger Menu for data-taking

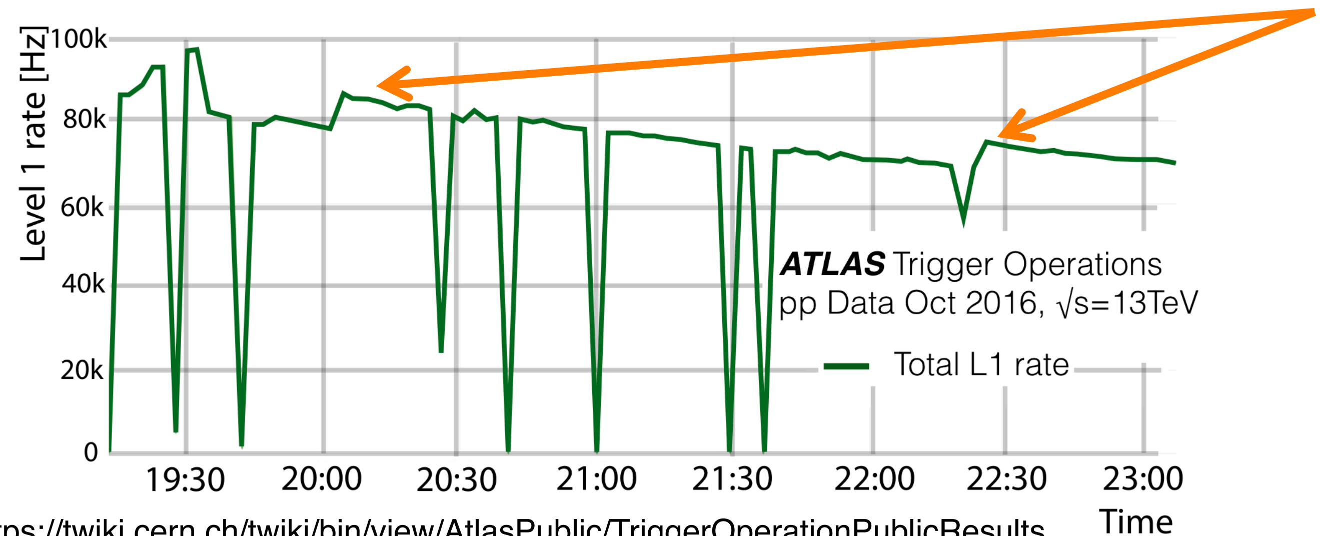
Individual trigger **rates** depend on the **luminosity**

A trigger menu is deployed with a set of **prescales**, which dictate:

(1) What rate each L1 Item is passed to the HLT at

(2) What rate each HLT item runs at (prescales are applied *before* the HLT runs a chain!)

At predetermined luminosity points, the prescales are **evolved** to maintain trigger rates:

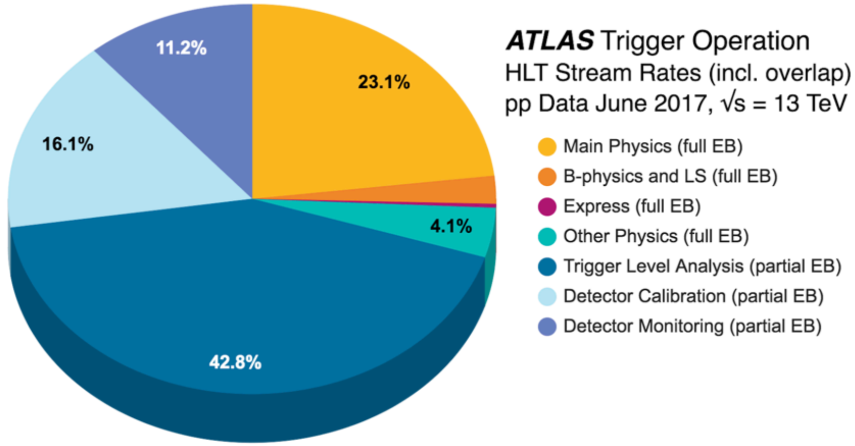


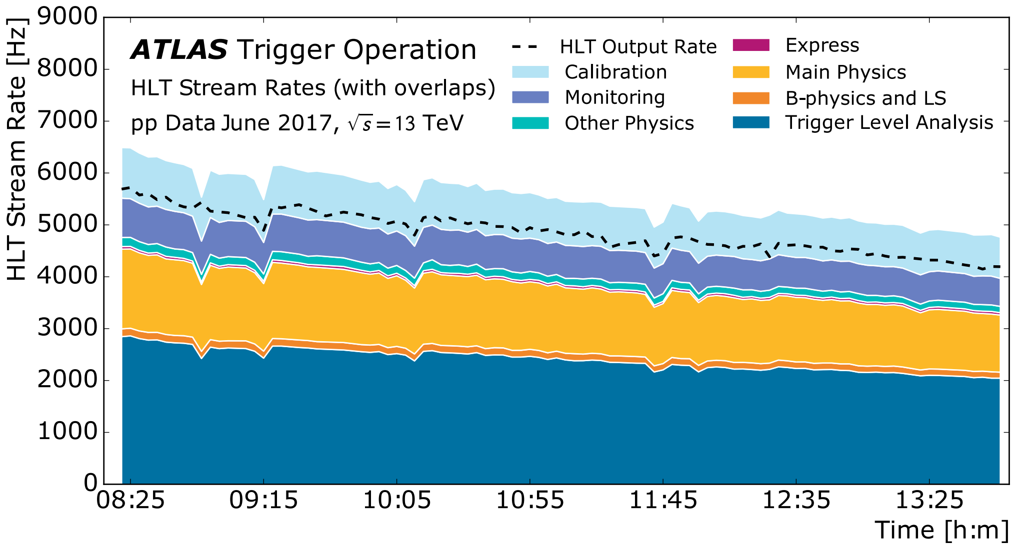
Trigger chains that normally produce too high rate or CPU usage are enabled as the luminosity falls

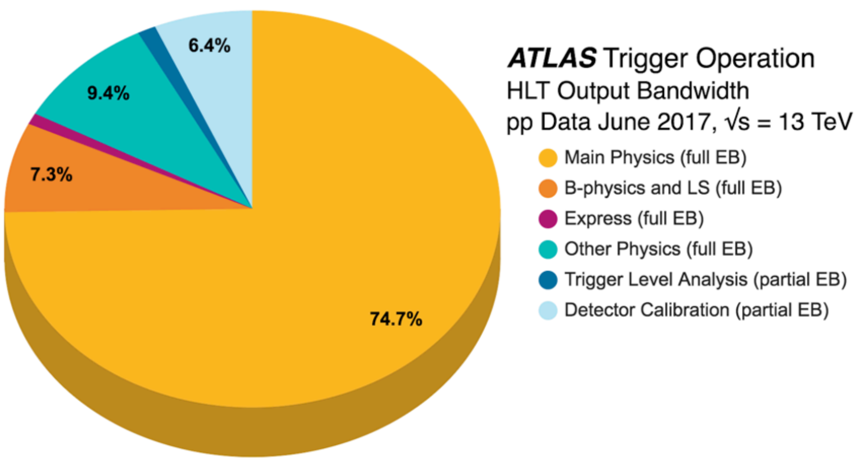
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TriggerOperationPublicResults

Trigger Menu performance in 2017

- Main physics stream output rate ~ 1 kHz
- New B-physics and light states stream: output ~180 Hz, smaller events saved on recording
- Trigger level analysis stream has a very large rate, but tiny event size







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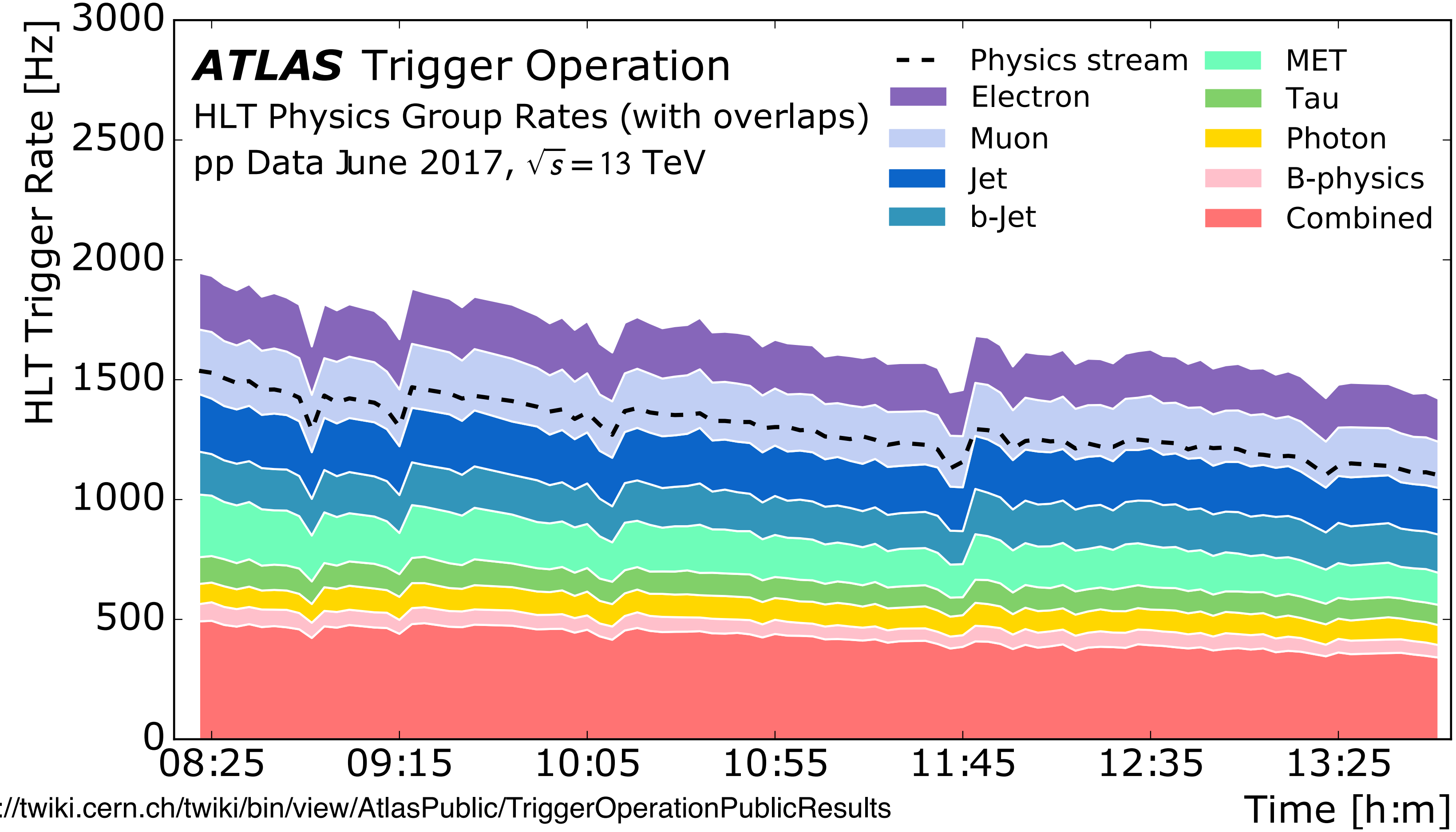
Trigger Menu physics stream in 2017

Rate is shared between physics signatures:



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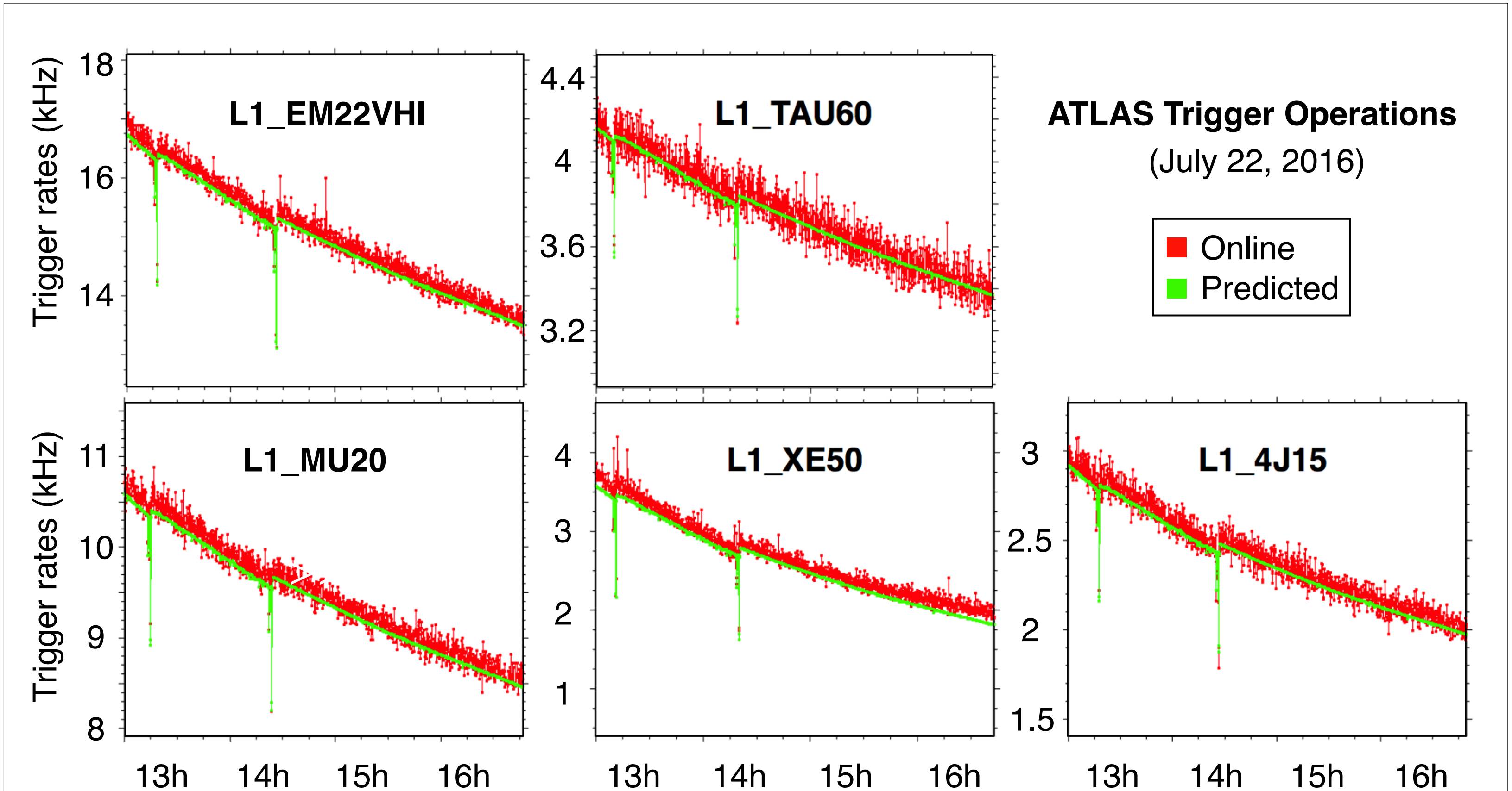
Rates decrease with decreasing luminosity – at certain pre-determined thresholds, higher rate or CPU usage items are enabled

Monitoring trigger performance - rates

Important to know **immediately** if a trigger is not operating as expected. **Online monitoring** is performed by a **Trigger shifter** in the ATLAS control room.

For key items, online rates are overlaid with predicted rates:



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Monitoring trigger performance - data

Important to know **immediately** if a trigger is not operating as expected. **Online monitoring** is performed by a **Trigger shifter** in the ATLAS control room.

The **characteristics** of **selected events** are also monitored - compared against **previously validated data**:

Green indicates the data matches the reference

Yellow or **red** would indicate a potential problem

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

Conclusions

- The Trigger Menu is a complex integration of physics analysis requirements, detector monitoring needs, and hardware and software limitations

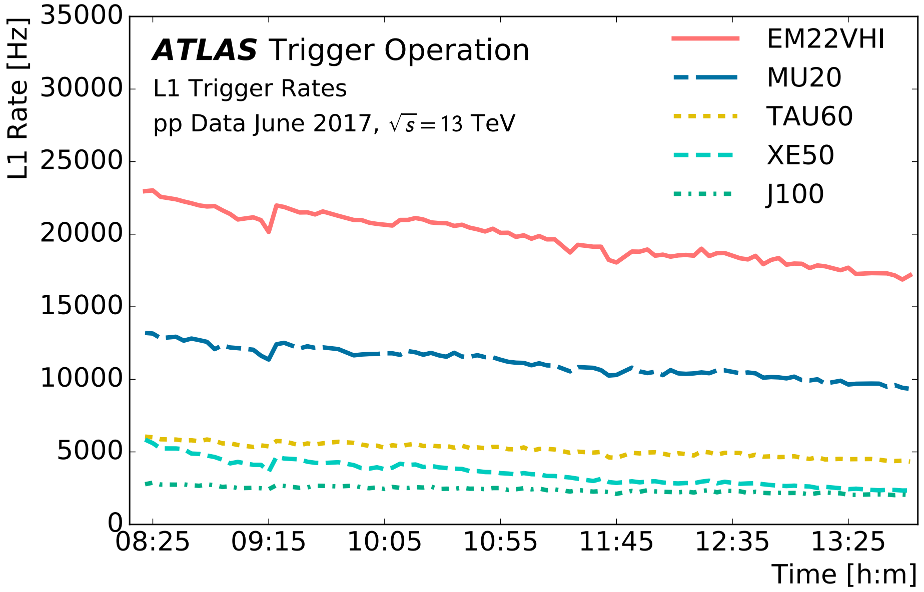
- Careful monitoring and validation are performed before, during, and after using a Trigger Menu

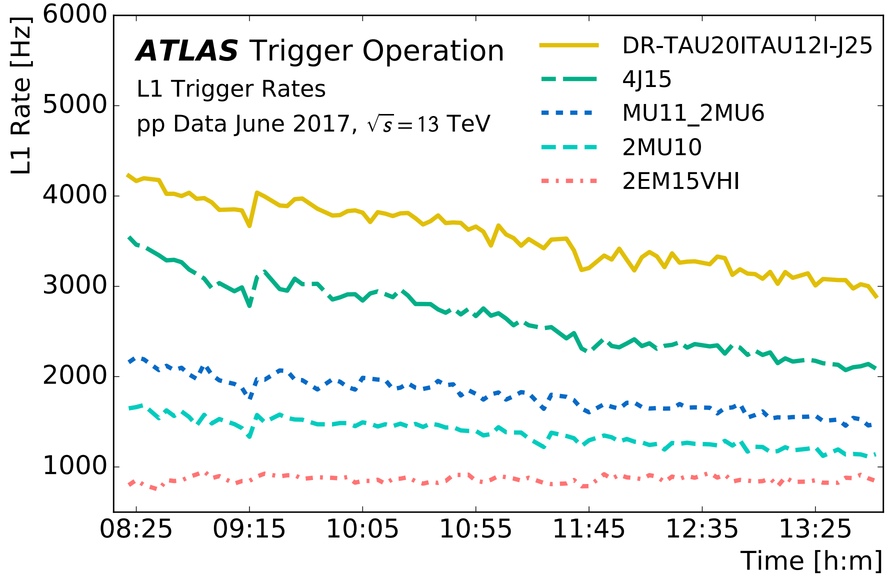
- The Trigger Menu is **constantly** changing, and can readily accommodate new physics ideas

- 2017 performance has been successful so far, and we're ready for the increasing luminosities the LHC will reach!

backup

Level-1 item rates





- ➢ Level-1 rate is shared between single-threshold and multi-threshold items

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Abstract

The ATLAS experiment aims at recording about 1 kHz of physics collisions, starting with an LHC design bunch crossing rate of 40 MHz. To reduce the large background rate while maintaining a high selection efficiency for rare physics events (such as beyond the Standard Model physics), a two-level trigger system is used.

Events are selected based on physics signatures such as the presence of energetic leptons, photons, jets or large missing energy. The trigger system exploits topological information, as well as multivariate methods to carry out the necessary physics filtering for the many analyses that are pursued by the ATLAS community. In total, the ATLAS online selection consists of nearly two thousand individual triggers. A Trigger Menu is the compilation of these triggers, it specifies the physics selection algorithms to be used during data taking and the rate and bandwidth a given trigger is allocated. Trigger menus must reflect the physics goals of the collaboration for a given run, but also take into consideration the instantaneous luminosity of the LHC and limitations from the ATLAS detector readout and offline processing farm. For the 2017 run, the ATLAS trigger has been enhanced to be able to handle higher instantaneous luminosities (up to 2.0x10^{34}cm^{-2}s^{-1}) and to ensure the selection robustness against higher average multiple interactions per bunch crossing.

In this presentation, we describe the design criteria for the trigger menu for Run 2. We discuss several aspects of the process of planning the trigger menu, starting from how ATLAS physics goals and the need for detector performance measurements enter the menu design, and how rate, bandwidth, and CPU constraints are folded in during the compilation of the menu. We present the tools that allow us to predict and optimize the trigger rates and CPU consumption for the anticipated LHC luminosities. We outline the online system that we implemented to monitor deviations from the individual trigger target rates and to quickly react to changing LHC conditions and data taking scenarios. Finally, we give a glimpse of the 2017 Trigger Menu, allowing the listener to get a taste of the vast physics program that the trigger is supporting.