The ATLAS Trigger System in Run-2

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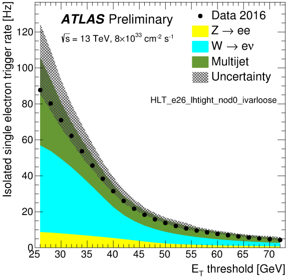
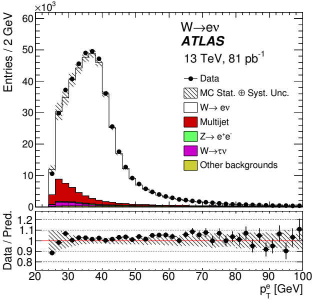
Particle Physics Seminar

Introduction

- In Run-2 of the LHC increased centre-of-mass energies and instantaneous luminosity have lead to increases in the trigger rate but this is constrained by hardware requirements.
- The easiest solution to reduce the rate again would be to increase the energy thresholds used by the trigger, however this would severely curtail the ATLAS physics programme.
- This required significant upgrades at Level-1 and optimisations in the HLT to maintain signal efficiency while reducing the rate of events.

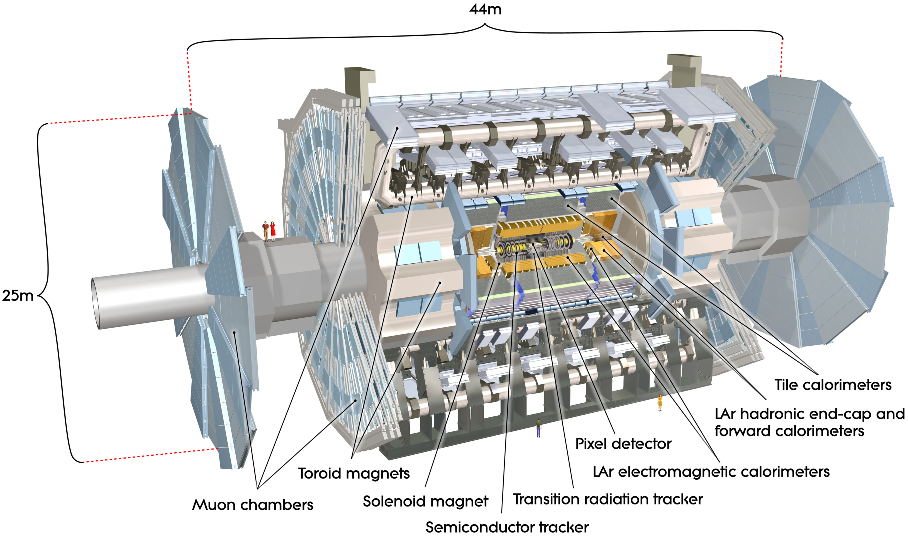


EgammaTriggerPublicResults



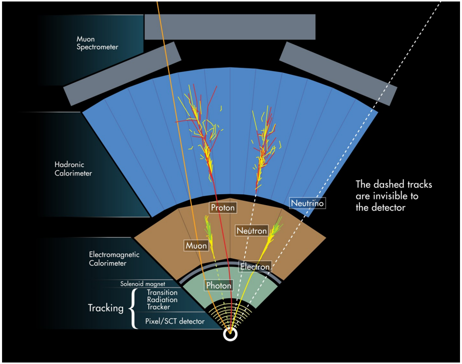
Phys. Lett. B 759 (2016) 601

The ATLAS Detector



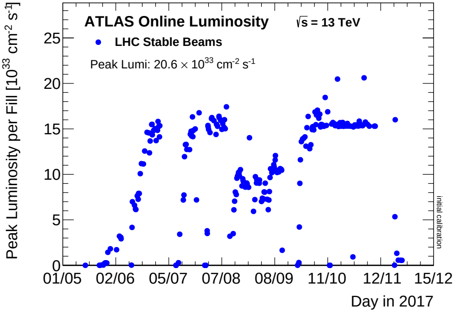
The ATLAS Detector: Sub-detectors

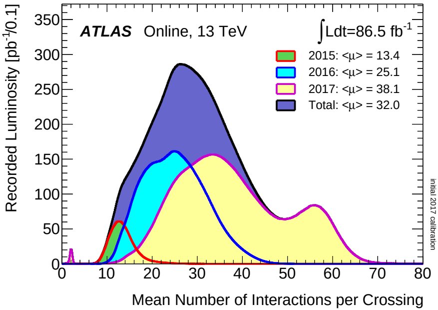
- General purpose detector at the LHC.
- Several detector technologies and components used to detect and identify final state particles.
- Can be roughly split into layers, tracking, calorimetry and muon spectrometry.
- Responsibility of the trigger and data acquisition system to select and record "interesting" events at a reduced rate to disk.
- Due to detector design different information available to trigger system as the trigger decision progresses.



Run 2 Conditions

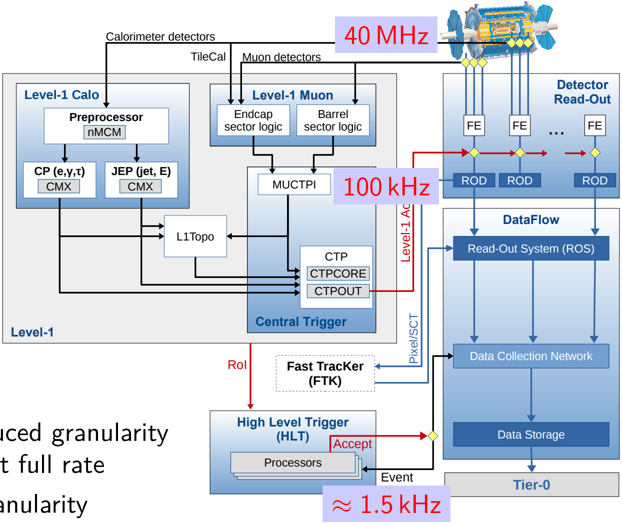
- LHC bunches filled with protons collide at 40 MHz
- Providing an instantaneous luminosity which peaked at $20.6 \times 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
- This leads to a large number of p-p interactions which could all produce a signature of interest.





https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2

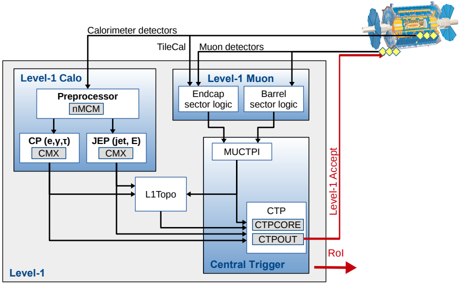
The ATLAS Detector: Trigger / DAQ

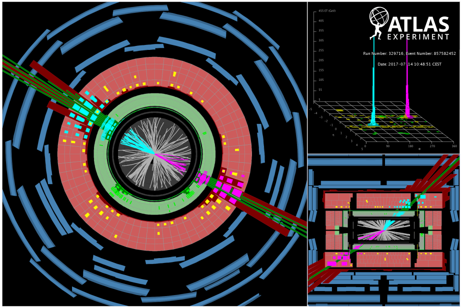


- Level-1 - reduced granularity information at full rate
- HLT - full granularity information at reduced rate

Level-1 Trigger

- Level-1 - reduced granularity information at full rate
- Hardware based trigger
- Primarily derived from calorimeter and muon systems
- Provides a rate reduction from 40 MHz to 100 kHz limited by the maximum readout rate of the front end electronics.
- Also provides Regions Of Interest (ROIs) as the starting point for software algorithms.
- Significant hardware and firmware updates in Run-2

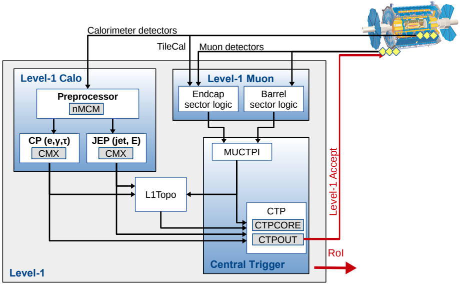




EventDisplayRun2Physics

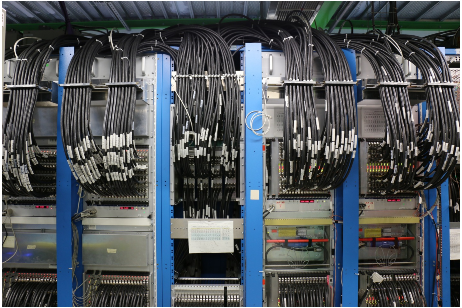
Level-1 Trigger: Updates

- The largest update was the inclusion of Topological triggering with the L1Topo module.
- Other systems need to provide L1Topo with information
- This is done with Trigger OBjects (TOBs) which represent the potential physics objects which have been detected.
- Similar to the ROIs which are sent to the HLT.



Level-1 Trigger: L1Calo

- The Level-1 calorimeter trigger.
- Analogue sum of calorimeter cells provided by both electromagnetic and hadronic calorimeter.
- Fast digitisation performed to produce "trigger towers" (typically 0.1×0.1 in $\Delta\eta \times \Delta\phi$)
- Separate sub-systems then search for clusters compatible with electromagnetic, tau and hadronic jet like energy deposits



Cables carrying analogue signals from calorimeters.

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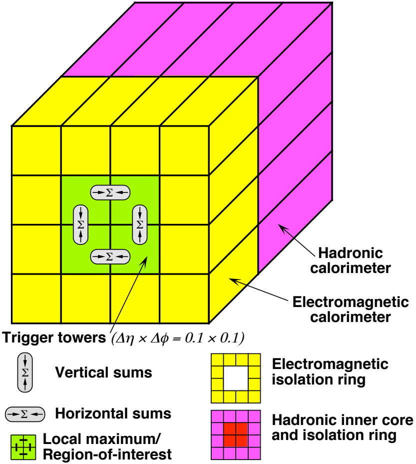
- Separate sub-systems then search for clusters compatible with electromagnetic, tau and hadronic jet like energy deposits
- The electromagnetic algorithm is based on windows such as this, where the sums of towers around a local maximum are calculated.



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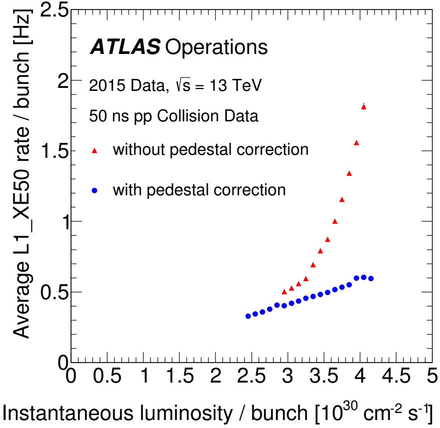
Level-1 Trigger: L1Calo - Run 2 Upgrades

- Digitisation
  - nMCM - new Multi Chip Module, updated digitisation and dynamic baseline subtraction.
- Processing
  - CPM - Cluster Processor Module, updated algorithm to allow E_T-dependent isolation
- Architecture
  - CMX - Common Merger eXtended, merge Trigger OBjects (TOBs) instead of threshold counts and forward to the Level-1 topological system.



L1CaloTriggerPublicResults

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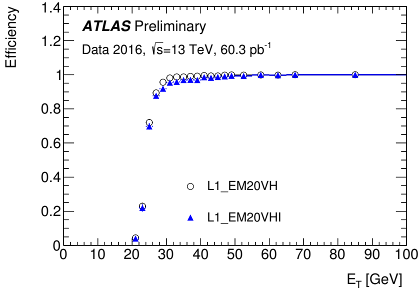
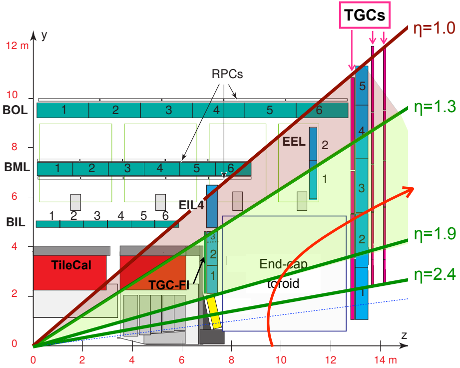


EgammaTriggerPublicResults

Level-1 Trigger: L1Muon

- The Level-1 muon trigger is based on dedicated triggering chambers
- RPCs (TGCs) found in the barrel (endcap)



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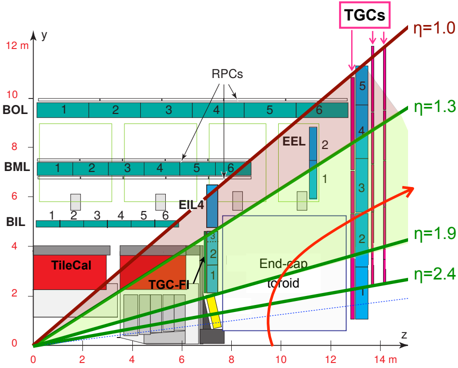
Green: Active, Red: Ready for 2018 data taking.

Level-1 Trigger: L1Muon - Run 2 Upgrades

- Algorithm
  - Additional logic requiring a coincidence between the inner TGC layers (TGC-FI) or the TileCal and the outer layers. Reducing the trigger rate by up to 10% for the unprescaled muon trigger.
- Coverage
  - Additional RPC chambers made operational in the bottom of the spectrometer increase coverage by 3.6%.
- Architecture
  - An additional module MUCTPI2TOPO was introduced to transmit muon TOBs to the Level-1 topological system.



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Green: Active, Red: Ready for 2018 data taking. Arrow indicates path of background beam particle.

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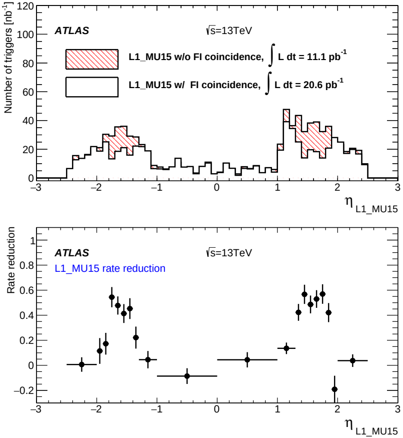

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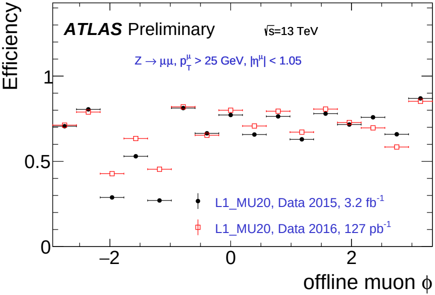
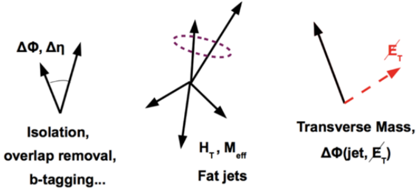


MuonTriggerPublicResults

Level-1 Trigger: L1Topo

- Receives TOBs from both L1Calo and L1Muon systems
  - Muon TOBs represent reduced granularity in η/ϕ and have three energy thresholds.
  - Calo TOBs retain the L1Calo granularity and contain isolation information.
- Topological combinations of trigger objects add discrimination allowing low thresholds to be maintained.



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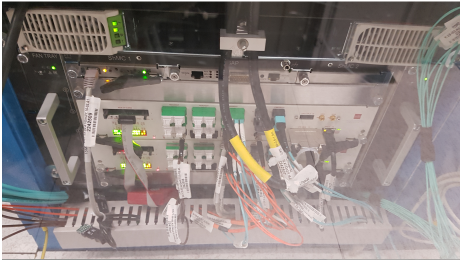
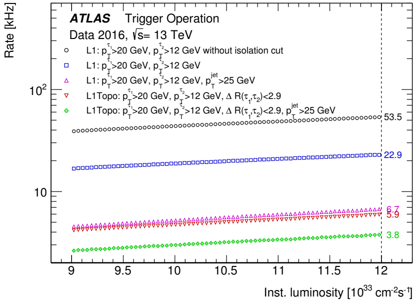


Level-1 Trigger: L1Topo

- An example are 2τ triggers.
- As used for the $H \to \tau\tau$ analysis.
- The di-tau system is expected to be boosted and therefore have a small ΔR separation.
- Adding a requirement $\Delta R < 2.9$ at Level-1 leads to a significant reduction in rates.



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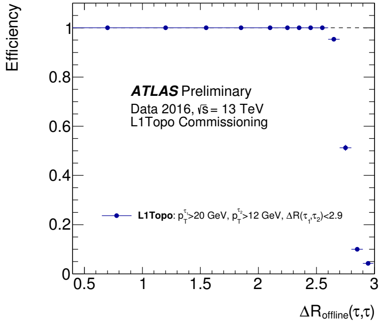

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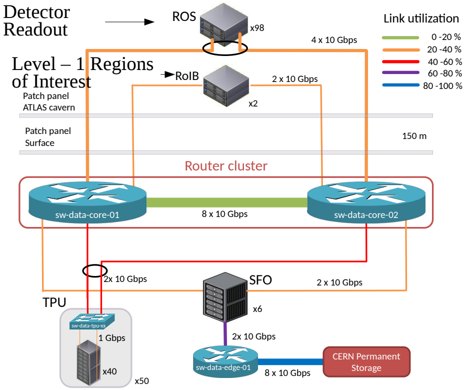
HLT

- The higher level trigger runs offline-like algorithms
- Final trigger decision is an OR of many independent trigger chains.
- Each chain is defined as a series of algorithms with the ability to abort execution part way though to save CPU.

HLT

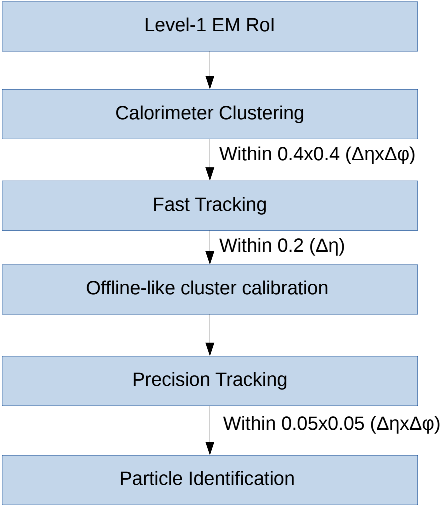


https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsDAQ

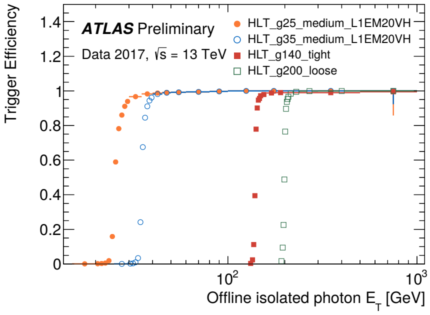
- In Run-1 HLT consisted of two levels, the first one with faster algorithms and mostly regional reconstruction, and the second one with full event reconstruction with higher precision.
- Updated in Run-2 to be an integrated system to save resources and simplify processing.

HLT: Electrons and Photons - Algorithm

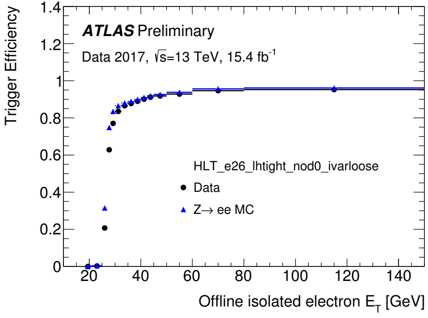
- Trigger reconstruction of electrons and photons share a similar chain of algorithms.
- Both seeded by L1Calo EM regions of interest.
- Calorimeter clustering is performed using higher granularity calorimeter cells (typically 0.025×0.025 in $\Delta\eta \times \Delta\phi$)
- Precision tracks extrapolated to the second layer of the EM calorimeter.
- Electrons use a likelihood based identification using calorimeter, tracking and transition radiation information.
- Photon identification based on calorimeter variables only.



HLT: Electrons and Photons - Performance



EgammaTriggerPublicResults

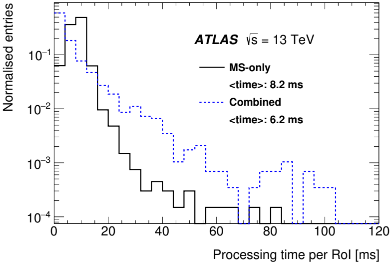


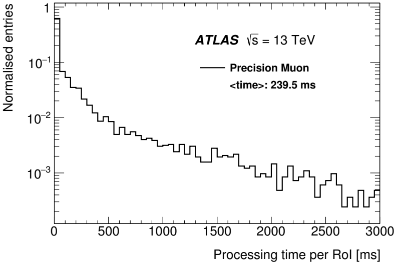
EgammaTriggerPublicResults

- The electromagnetic triggers performed well during 2017.
- The single unprescaled electron threshold was maintained at 26 GeV with a loose track based isolation.
- The single unprescaled photon threshold was 140 GeV.

HLT: Muons - Algorithm

- Muon reconstruction proceeds in two stages.
- A first “fast” reconstruction is performed on each Level-1 muon candidate with the p_T assigned by a lookup table based on MDT measurements.
- These tracks are then extrapolated to the inner detector to create combined muons.
- The second “Precision” pass produces a more accurate fit of the track at the cost of processing speed.





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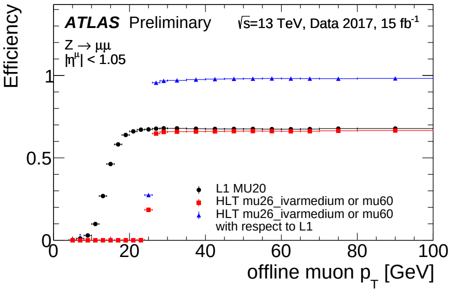
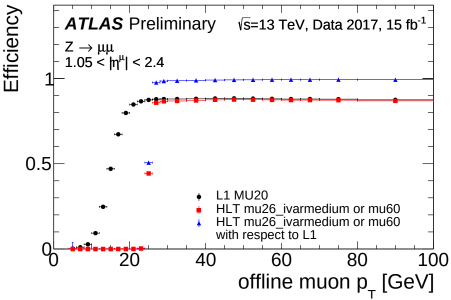
HLT: Muons - Performance

Barrel



MuonTriggerPublicResults

End-cap

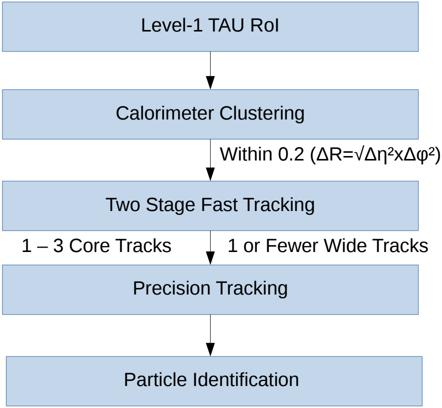


MuonTriggerPublicResults

- HLT Muon reconstruction is ≈ 100% with respect to the Level-1 trigger.
- Single unprescaled muon threshold set at 26 GeV

HLT: Tau Leptons - Algorithm

- The algorithm starts from the Level-1 TAU ROI.
- Two-stage fast tracking
  - First a leading P_T track is identified within $\Delta R < 0.1$ of the cluster centre.
  - Further tracks are then identified $\Delta R < 0.4$ from the leading track but originating within a fixed window along the beam pipe.
- Tracks are counted as Core $\Delta R < 0.2$ or Wide $0.2 < \Delta R < 0.4$
- Particle identification is provided by a boosted decision tree similar to that used offline



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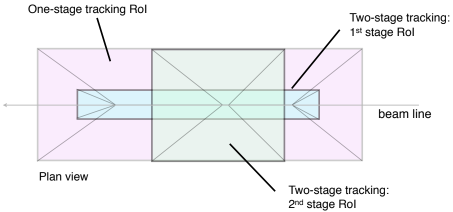

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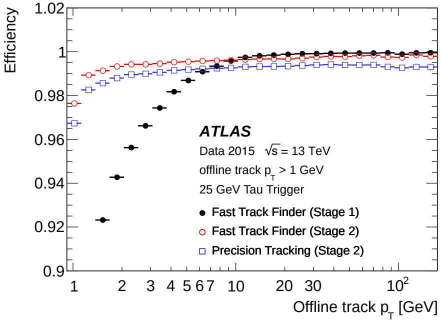

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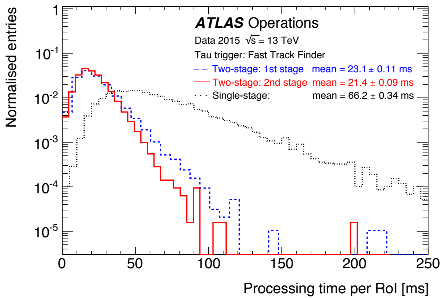

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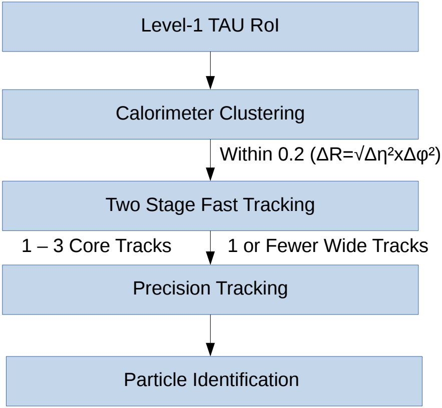

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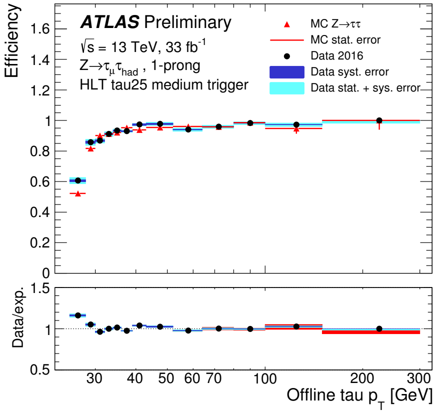

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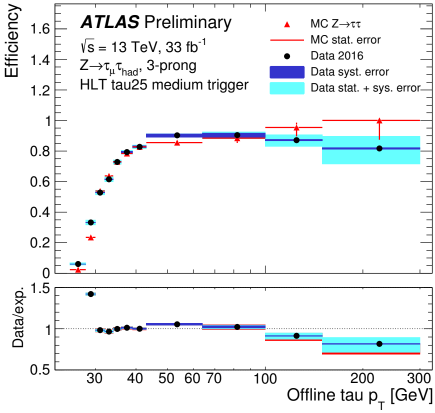

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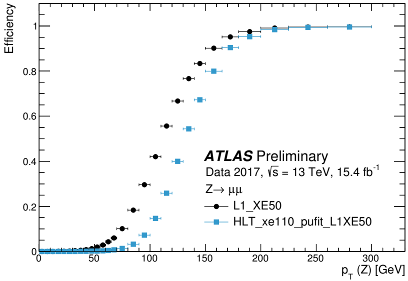
- Single Tau threshold set at 160 GeV
- Use of two level tracking essential to identify candidates against increasing hadronic backgrounds.

HLT: Missing Transverse Momentum

- The increased number of hadronic interactions makes these triggers sensitive to the increase in instantaneous luminosity.
- The improvements to the Level-1 digitisation mean it is possible to keep the threshold relatively low (50 GeV)
- This is needed for a typical analysis selection of 200 GeV
- Several algorithms are run in parallel but due to the overlap between the resource intensive parts (clustering) this does not add much overhead.
- The algorithm `pufit` is used extensively to reduce the rate from pile up contributions.



MissingEtTriggerPublicResults

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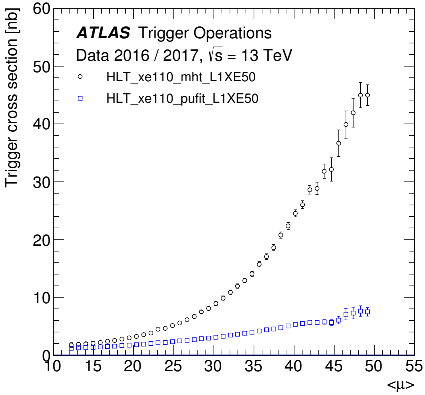
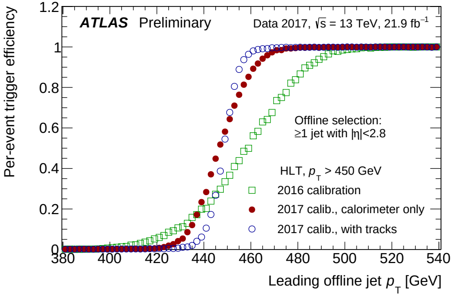


MissingEtTriggerPublicResults

`pufit` Details: Eur. Phys. J. C 77 (2017) 317

HLT: Hadronic Jets

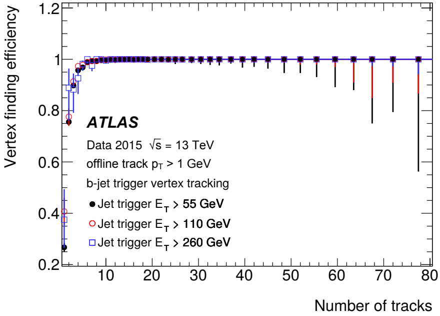
- Jet triggers cover single and multi-jet topologies
- Jets are constructed using the anti-kT algorithm operating on calorimeter clusters.
- Radius parameters 0.4 and 1.0 are used.
- Some chains also include tracking information in order to improve the resolution subject to resource constraints.



JetTriggerPublicResults

HLT: b-Jets

- Several analyses rely on "b-jets" where the jet is initiated by the decay of a B hadron indicating a bottom quark in the final state. For example $H \to b\bar{b}$
- The trigger uses the MV2 algorithm which uses inputs from the impact parameter, displaced vertexing and jet structure algorithms in a configuration close to the offline configuration.
- Two stage fast tracking is again employed to aid in the finding of the primary vertex avoiding the performance cost of having to perform tracking over the whole detector.



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Full algorithm details: Eur. Phys. J. C 77 (2017) 317

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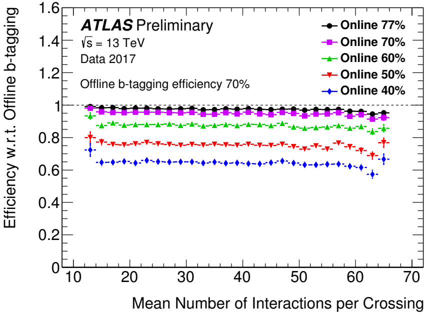
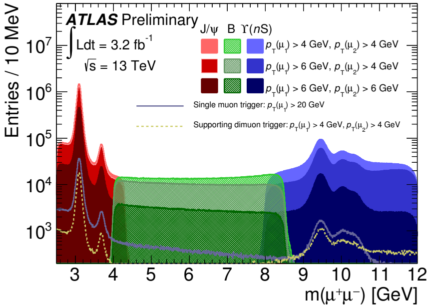


BJetTriggerPublicResults

Full algorithm details: Eur. Phys. J. C 77 (2017) 317

HLT: B-Physics

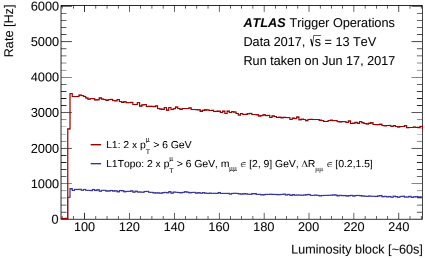
- Several di-muon triggers are defined for selecting J/ψ, B and $\Upsilon(nS)$ states.
- These rely on a low di-muon threshold at Level-1 and the relevant invariant mass selection in the HLT.
- Even small increases in the threshold for either leg can have a large effect on the efficiency.



BPhysicsTriggerPublicResults

HLT: B-Physics

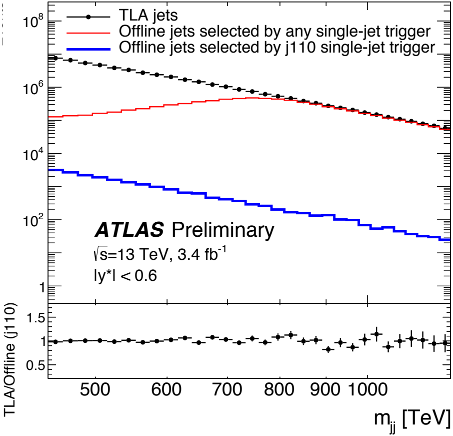
- Several di-muon triggers are defined for selecting J/ψ, B and $\Upsilon(nS)$ states.
- These rely on a low di-muon threshold at Level-1 and the relevant invariant mass selection in the HLT.
- Even small increases in the threshold for either leg can have a large effect on the efficiency.
- A good example of where L1Topo can help alleviate a Level-1 bottleneck.



TriggerOperationPublicResults

Trigger Level Analysis

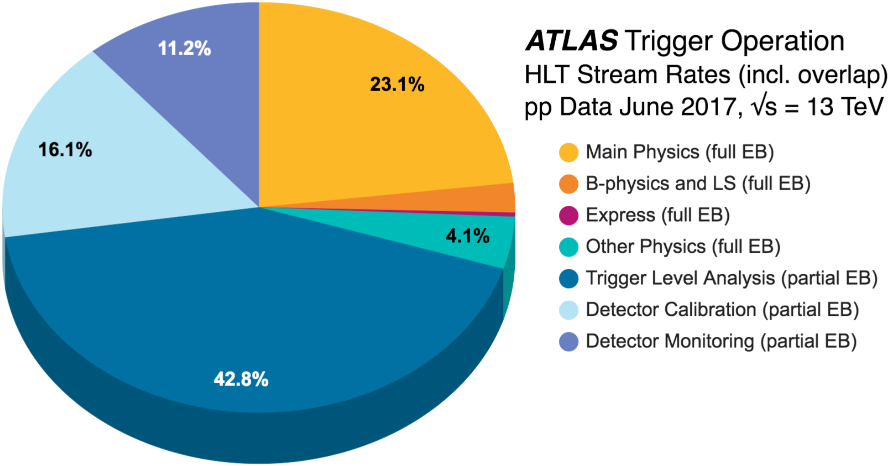
- There are not only rate restrictions at Level-1.
- It is also important to consider the rate to disk from the HLT and the available resources for prompt reconstruction.
- Jets for example have a Level-1 threshold $\mathcal{O}(100 GeV)$ but a HLT threshold $\mathcal{O}(400 GeV)$.
- One solution being considered is to perform the analysis selection online in the trigger and vastly decrease the data volume by only saving the selected objects.
- The plot shows a search for Di-Jet resonances using this technique.



ATLAS-CONF-2016-030

Trigger Level Analysis II

- TLA represents a high HLT rate but tiny bandwidth user.



TriggerOperationPublicResults

Trigger Level Analysis II

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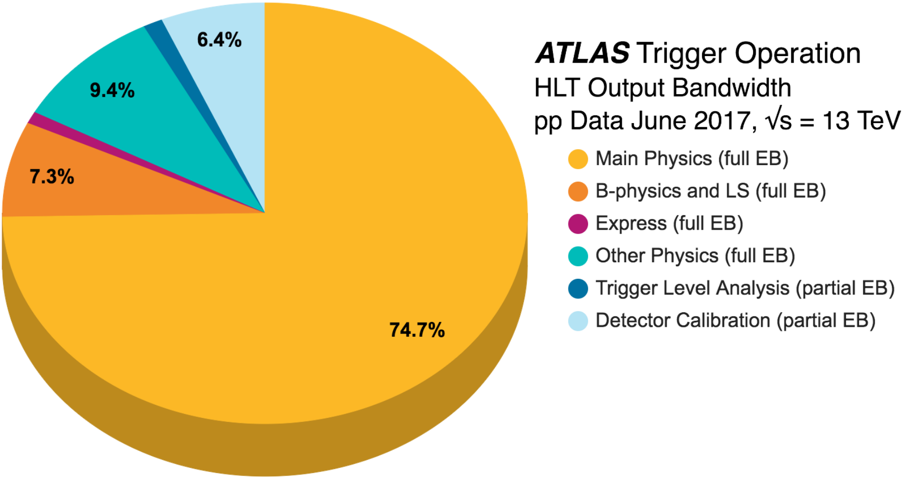


TriggerOperationPublicResults

Summary

- The LHC is performing well and delivering instantaneous luminosities above its design value.
- The increased number of interactions per bunch crossing add pressure to the trigger system due to the increased event complexity.
- Several notable improvements to the trigger system during the first LHC long shutdown provide good tools to mitigate these challenges.
    - Level-1 improved calorimeter isolation and the introduction of topological triggering can avoid a bottle neck at the front end readout and help the HLT by providing better seeds.
    - The single stage HLT allows for chains with a flexible set of algorithms which can share outputs reducing any unnecessary duplication of calculations.
- Given the anticipated running conditions in 2018 the trigger will also be able to perform well for the rest of Run-2 before the next round of planned updates.

Backup

Trigger Rates from 2015 @ $5 \times 10^{33} cm^{-2} s^{-1}$

Trigger	Typical offline selection	Trigger Selection		Level-1 Rate [kHz]	HLT 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
Three leptons	Three loose e's, $p_T > 19, 11, 11 GeV$	15, 2×7	17, 2×9	3	< 0.1
	Three μ's, each $p_T > 8 GeV$	3×6	3×6	< 0.1	4
	Three μ's, $p_T > 19, 2 \times 6 GeV$	15	18, 2×4	7	2
	Two μ's & one e, $p_T > 2 \times 11, 14 GeV$	2×10 (μ's)	2×10, 12	0.8	0.2
	Two loose e's & one μ, $p_T > 2 \times 11, 11 GeV$	2×8, 10	2×12, 10	0.3	< 0.1
One photon	One γ, $p_T > 125 GeV$	22	120	8	20
Two photons	Two loose γ's, $p_T > 40, 30 GeV$	2×15	35, 25	1.5	12
	Two tight γ's, $p_T > 25, 25 GeV$	2×15	2×20	1.5	7
Single jet	Jet ($R = 0.4$), $p_T > 400 GeV$	100	360	0.9	18
	Jet ($R = 1.0$), $p_T > 400 GeV$	100	360	0.9	23
E_T^{miss}	$E_T^{miss} > 180 GeV$	50	70	0.7	55
Multi-jets	Four jets, each $p_T > 95 GeV$	3×40	4×85	0.3	20
	Five jets, each $p_T > 70 GeV$	4×20	5×60	0.4	15
	Six jets, each $p_T > 55 GeV$	4×15	6×45	1.0	12
$b-$jets	One loose b, $p_T > 235 GeV$	100	225	0.9	35
	Two medium b's, $p_T > 160, 60 GeV$	100	150, 50	0.9	9
	One b & three jets, each $p_T > 75 GeV$	3×25	4×65	0.9	11
	Two b & two jets, each $p_T > 45 GeV$	3×25	4×35	0.9	9
$B-$physics	Two μ's, $p_T > 6, 4 GeV$ plus dedicated J/ψ-physics selection	6, 4	6, 4	8	52
Total				70	1400

ATL-DAQ-PUB-2016-001

Trigger Rates from 2016 @ $1.2 \times 10^{34} cm^{-2}s^{-1}$

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
	One τ & one isolated μ, $p_T > 30, 15$ GeV	12 (i), 10 (+jets)	25, 14 (i)	1.5	7
	One τ & one isolated e, $p_T > 30, 18$ GeV	12 (i), 15 (i) (+jets)	25, 17 (i)	3	9
Three leptons	Three loose e's, $p_T > 18, 11, 11$ GeV	15, 2×8	17, 2×10	15	< 0.1
	Three μ's, each $p_T > 7$ GeV	3×6	3×6	0.1	3
	Three μ's, $p_T > 21, 2 \times 5$ GeV	20	20, 2×4	13	4
	Two μ's & one loose e, $p_T > 2 \times 11, 13$ GeV	2×10 (μ's)	2×10, 12	1.5	0.2
	Two loose e's & one μ, $p_T > 2 \times 13, 11$ GeV	2×8, 10	2×12, 10	1.1	0.1
One photon	One loose γ, $p_T > 145$ GeV	22 (i)	140	20	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, $\lvert\eta\rvert < 2.4$	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

ATL-DAQ-PUB-2017-001

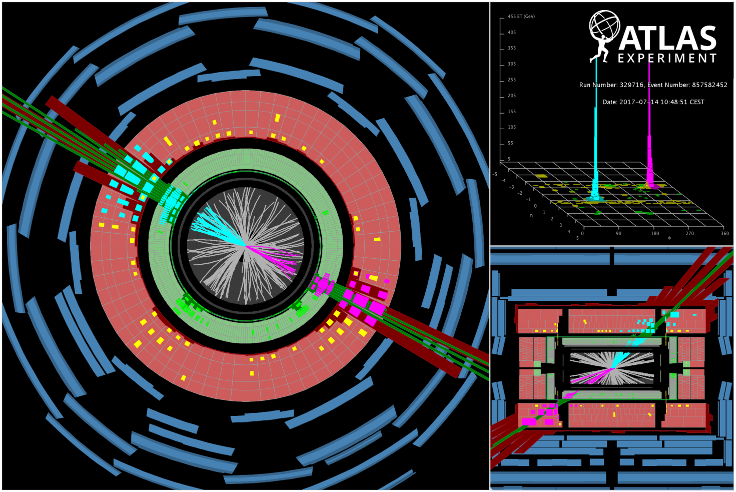
Trigger Rates from 2017 @ $1.7 \times 10^{34} cm^{-2} s^{-1}$

Trigger	Typical of ine selection	Trigger Selection		Level-1 Peak Rate (kHz)	HLT Peak Rate (Hz)
		Level-1 (GeV)	HLT (GeV)	$L = 1.7 \times 10^{34}\ cm^{-2}s^{-1}$	
Single leptons	Single isolated μ, $p_T > 27$ GeV	20	26 (i)	16	187
	Single isolated tight e, $p_T > 27$ GeV	22 (i)	26 (i)	26	178
	Single μ, $p_T > 52$ GeV	20	50	16	65
	Single e, $p_T > 61$ GeV	22 (i)	60	26	17
	Single τ, $p_T > 170$ GeV	100	160	1.2	49
Two leptons	Two μ's, each $p_T > 15$ GeV	2×10	2×14	2.0	30
	Two μ's, $p_T > 23, 9$ GeV	20	22, 8	16	42
	Two very loose e's, each $p_T > 18$ GeV	2×15 (i)	2×17	1.6	11
	One e & one μ, $p_T > 8, 25$ GeV	20 (μ)	7, 24	16	5
	One e & one μ, $p_T > 18, 15$ GeV	15, 10	17, 14	2.0	4
	One e & one μ, $p_T > 27, 9$ GeV	22 (e, i)	26, 8	26	2
	Two τ's, $p_T > 40, 30$ GeV	20 (i), 12 (i) (+jets, topo)	35, 25	5.1	59
	One τ & one isolated μ, $p_T > 30, 15$ GeV	12 (i), 10 (+jets)	25, 14 (i)	2.1	9
	One τ & one isolated e, $p_T > 30, 18$ GeV	12 (i), 15 (i) (+jets)	25, 17 (i)	3.9	16
Three leptons	Three loose e's, $p_T > 25, 13, 13$ GeV	$20, 2 \times 10$	$24, 2 \times 12$	1.2	< 0.1
	Three μ's, each $p_T > 7$ GeV	3×6	3×6	0.2	8
	Three μ's, $p_T > 21, 2 \times 5$ GeV	20	$20, 2 \times 4$	16	8
	Two μ's & one loose e, $p_T > 2 \times 11, 13$ GeV	2×10 (μ's)	$2 \times 10, 12$	2.0	0.3
	Two loose e's & one μ, $p_T > 2 \times 13, 11$ GeV	$2 \times 8, 10$	$2 \times 12, 10$	1.6	0.2
One photon	One loose γ, $p_T > 145$ GeV	22 (i)	140	26	46
Two photons	Two loose γ's, $p_T > 55, 55$ GeV	2×20	50, 50	2.4	6
	Two medium γ's, $p_T > 40, 30$ GeV	2×20	35, 25	2.4	18
	Two tight γ's, $p_T > 25, 25$ GeV	2×15 (i)	2×20 (i)	2.4	15
Single jet	Jet ($R = 0.4$), $p_T > 435$ GeV	100	420	3.4	33
	Jet ($R = 1.0$), $p_T > 480$ GeV	100	460	3.4	24
E_T^{miss}	$E_T^{miss} > 200$ GeV	50	110	4.4	100
Multi-jets	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	4.9	10
	Six jets, each $p_T > 80$ GeV	4×15	6×70	4.9	4
	Six jets, each $p_T > 60$ GeV, $\lvert\eta\rvert < 2.0$	4×15	6×55, $\lvert\eta\rvert < 2.4$	4.9	15
b−jets	One b ($= 40\%$), $p_T > 235$ GeV	100	225	3.4	15
	Two b's ($= 60\%$), $p_T > 185, 70$ GeV	100	175, 60	3.4	12
	One b ($= 40\%$) & three jets, each $p_T > 85$ GeV	4×15	4×75	4.9	15
	Two b's ($= 70\%$) & one jet, $p_T > 65, 65, 160$ GeV	$2 \times 30, 85$	$2 \times 55, 150$	2.7	15
	Two b's ($= 60\%$) & two jets, each $p_T > 45$ GeV	4×15	4×35	4.9	13
B-Physics	Two μ's, $p_T > 11, 6$ GeV	11, 6	11, 6 (di-μ)	3.1	50
	Two μ's, $p_T > 6, 6$ GeV, $2.5 < m(\mu, \mu) < 4.0$ GeV	2×6 (J/ψ, topo)	2×6 (J/ψ)	1.8	59
	Two μ's, $p_T > 6, 6$ GeV, $4.7 < m(\mu, \mu) < 5.9$ GeV	2×6 (B, topo)	2×6 (B)	1.8	7
	Two μ's, $p_T > 6, 6$ GeV, $7 < m(\mu, \mu) < 12$ GeV	2×6 (Υ, topo)	2×6 (Υ)	1.5	10
Total Rate				85	1550

TriggerPublicResults

Full Size Event Display

Dijet event collected in 2017, with $m_{jj} = 9.3\,TeV$.



EventDisplayRun2Physics