Trigger Commissioning and Early Running Strategy

John Baines

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- Preparation for first beams
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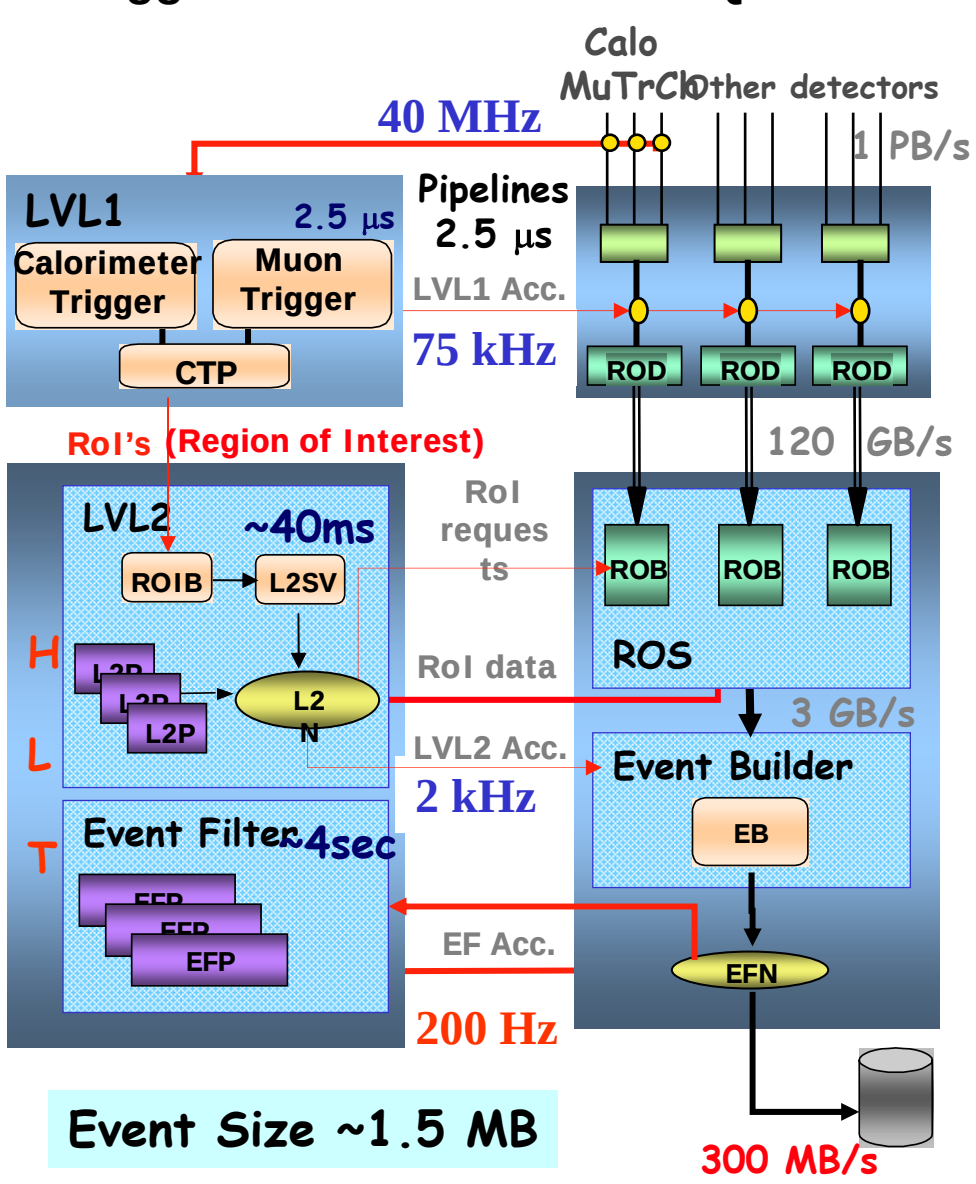
- Summary

Introduction

- The Trigger is essential to :
  - reduce the event rate from 40MHz BC rate to ~200Hz recording rate
  - select events for physics studies, alignment, calibration & efficiency measurements
  - assign events to streams for data recording :
    - physics streams to facilitate data access for analysis
    - express stream for rapid feedback on alignment, calibration & efficiency
  - online (real-time) monitoring
- This must be achieved fast & with limited resources
- The trigger provides the first set of "cuts" for physics analysis – must be carefully chosen & tuned like all successive cuts.
- Vital to:
  - provide robust selections for early data: incl. different luminosities and detector & beam conditions.
  - optimise the cuts w.r.t. trigger rate and efficiency.
  - develop techniques to measure trigger efficiency from data
  - understand biases introduced via trigger cuts (as far as possible using data).
- The active participation of the physics groups is vital for this work! – there are many areas seeking additional effort.

Trigger Overview

- Level 1:
  - Hardware based : Calo + Muon
  - Latency 2.5 μs
  - Output rate ~75 kHz
- Level 2: ~500 farm nodes(*)
  - **"Regions of Interest" (RoI)** to guide reconstruction
  - Custom algorithms
  - Average execution time ~40 ms(
  - Output rate up to ~2 kHz
- Event Builder: ~100 farm nodes
- Event Filter (EF):~1600 farm nodes(
  - Seeded by level 2
  - Access to full built event
  - Offline algorithms
  - Average execution time ~4 s(*)
  - Output rate up to ~200 Hz
- Current Farm: ~7% final system : 161 PCs installed
- Major purchases this year



(*) 8CPU (four-core dual-socket farm nodes at ~2GHz)

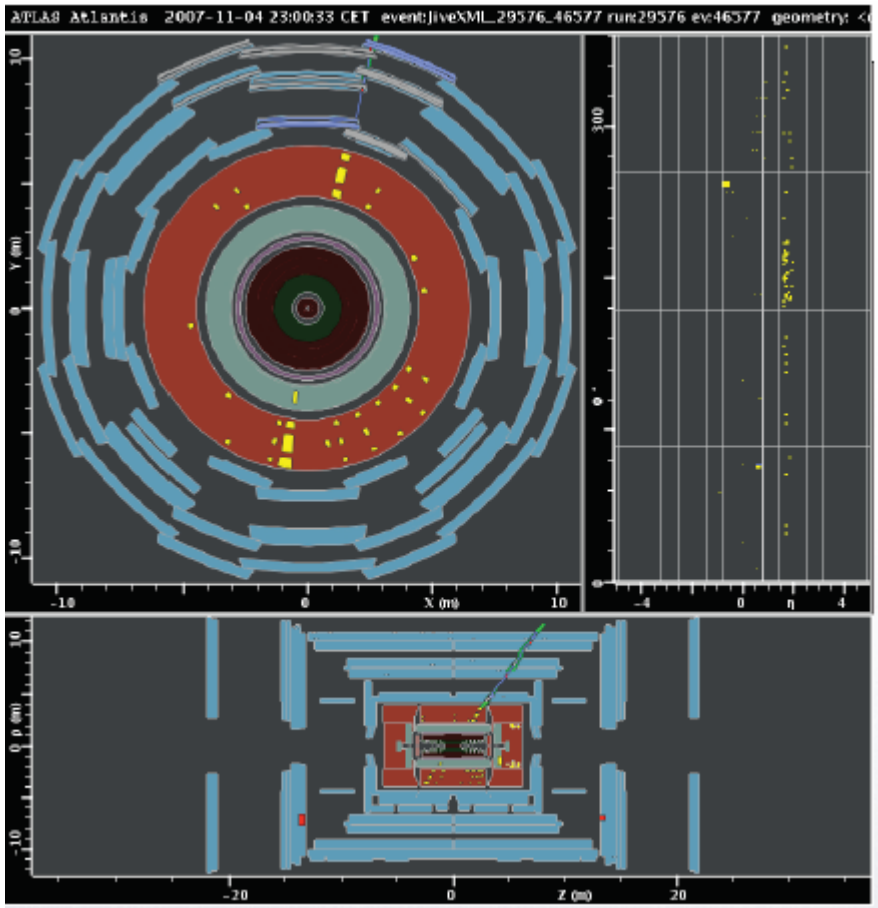
Trigger Commissioning

Several strands to Commissioning the Trigger ready for first physics:

- Offline Running:
  - Run LVL1 trigger emulation + real High Level Trigger algorithms as part of Reconstruction in Athena
  - Develop & optimise selection chains & menus.
    - Measure trigger rates using bulk samples of min bias & di-jet events.
    - Measure trigger efficiencies for signal samples
  - Perform Trigger aware physics analysis
- Tests on the pre-series and dedicated Trigger/DAQ machines
  - Special versions of athena emulate the environment for algorithms running online in LVL2 (athenaMT) and the Event Filter (athenaPT)
- Cosmic runs:
  - Exercises many components of the final system incl. readout chain & DAQ
  - Test integration of trigger with different detectors, separately and combined
  - exercises software with real data (real noise, real errors etc.)
  - using trigger algorithms either specific to, or adapted for, cosmic running
- Technical runs:
  - Simulated data downloaded to the Read Out Buffers
  - Tests the full algorithms and menus running on the online farms.
  - Also tests replaying real cosmic data downloaded to the Read Out Buffers

Cosmic Running

- Several cosmic runs in 2007. M3 and & M4 collected 2 & 3 Million events respectively
- M5 lasted 22 Oct to 5 Nov. Ran with Calorimeter and Muon Detector
  - Level-1 Calorimeter & Muon triggers
  - HLT Muon and Calorimeter Triggers
  - HLT running on ~100 nodes, 8 cores each (6% of final EF and ~1/3 of final L2)
  - 12 Million Events Recorded



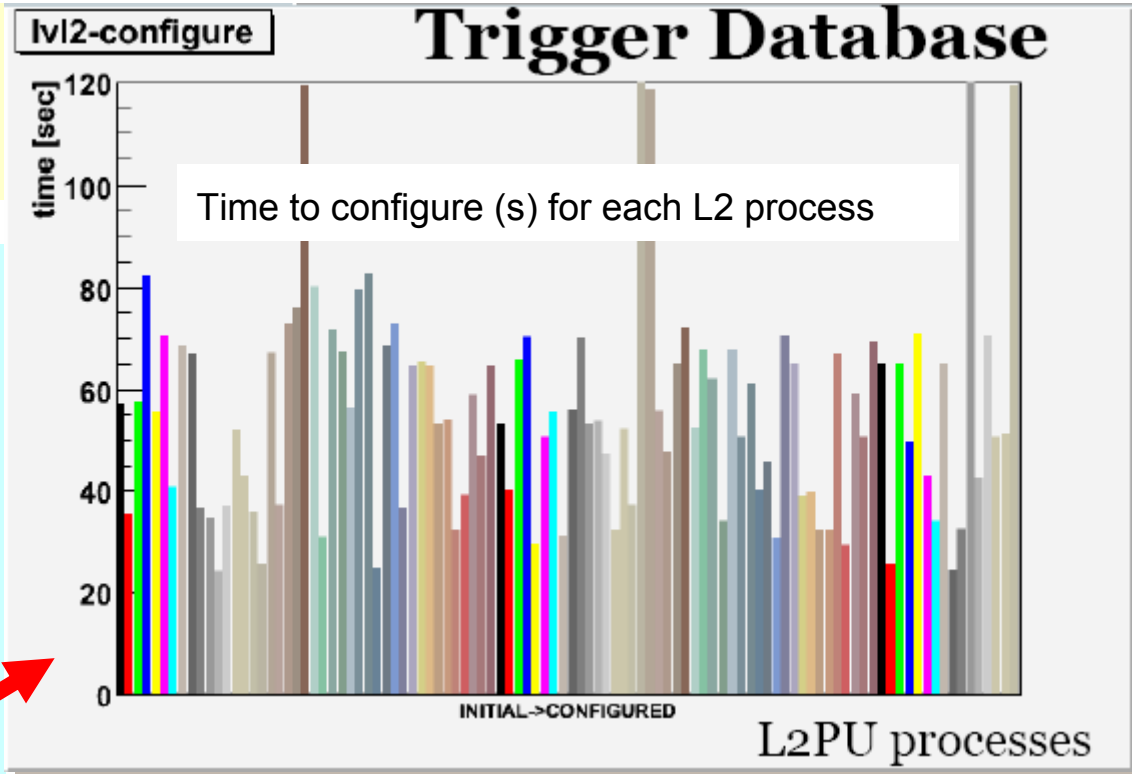
- Calo:
  - Tile (~55%)
  - LAr (70 to 90%)
- Muons:
  - MDT (~25%)
  - RPC (12.5%)
  - TGC (~25%)
- Trigger:
  - L1: CTP, MUCTPI, L1 Calo, RPC, TGC, Tile
  - HLT (details later)
- DAQ/Monitoring:
  - All integrated detectors+Pixel, SCT
- Dataflow, Controls & Configuration, Monitoring, Sysadmin
- ...and the people!

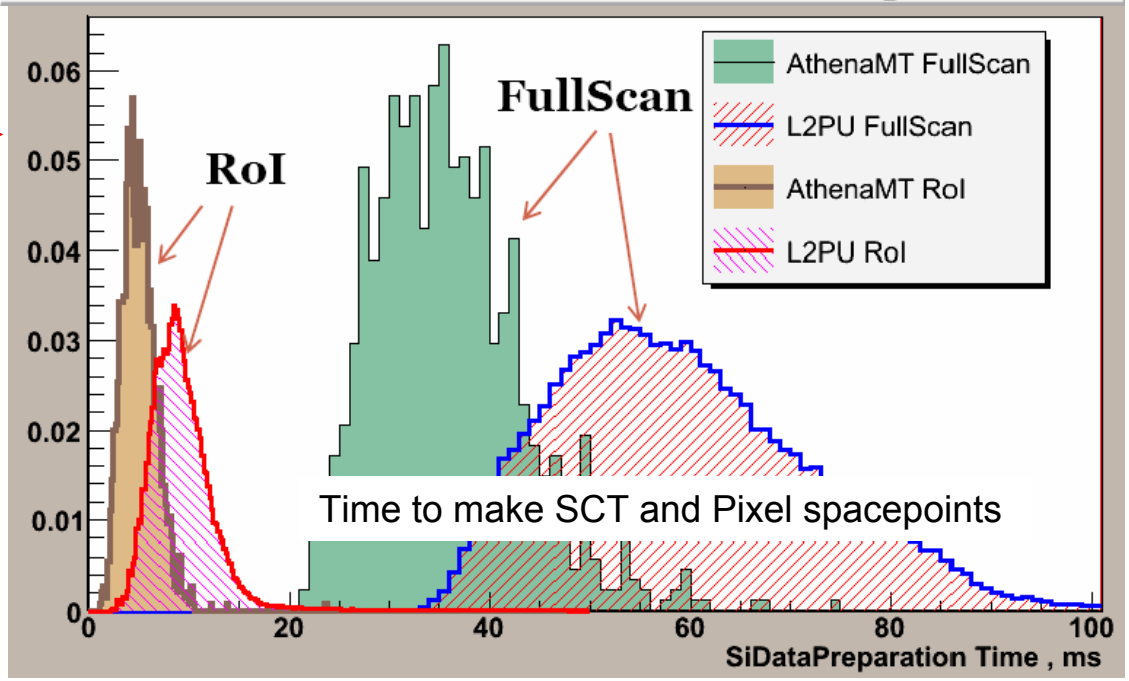
Evolving towards the full system:
- growing complexity
- important coordination exercise
- Mx are providing the first real ATLAS data!

Technical Runs

Several technical runs in 2007, last in November

- ~7% of the "final" HLT farm
- 5 racks of 31 machines for L2 and EF processes
- Run with full 10^{31} Menu
- Access to quantities that can only be measured online:
  - Configuration times for algorithm on HLT farm
  - Execution times including Data Access
- Tests collection and display of monitoring histograms in real time
- First exercise of TriggerTool to edit trigger menus from run-to-run.





Preparation for Running in 2008

Timescale (Success Orientated Schedule):

- Machine closed April 2008
- Beam commissioning starts May 2008
  - 450 GeV operation now part of normal setting up procedure for beam commissioning to high-energy
  - Gradual increase in current - up to 156 bunches/beam
- Pilot physics:
  - Un-squeezed initially $\rightarrow$ partial squeeze
  - Luminosity $\leq 10^{32}$ $cm^{-2}s^{-1}$

HLT Priorities for this year:

- Add last missing components & functionality for offline release 14.0.x incl.:
  - MBTS min. bias. trigger, HLT forward jet triggers…
- Test and improve robustness of code – tests with corrupted data, misalignment, miss-calibration, long runs, cycling through states etc.
- Select key monitoring histograms and set up reference histograms
- Finalisation of Trigger Menus and strategies for coping with beam & detector conditions etc.
- Complete techniques for extraction of efficiency from data
- Technical runs, cosmic runs, runs with first beam

Menus

A huge amount of progress during 2007

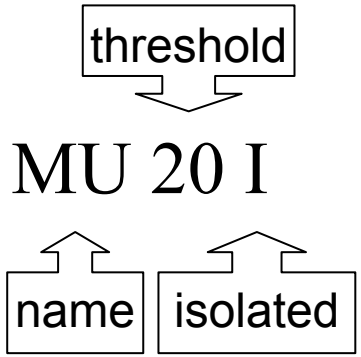
- **Results at June TP week were based on menus in 12.0.X which included:**
  - just 43 signatures:
    - the main signatures for 10^{33}
    - plus low thresholds to enable algorithm development and optimisation
    - no combined signatures, no pre-scaled triggers, no pass-through

    (Essentially the same menu was in 13.0.20)
- **New in 13.0.30 (presented at November TP week):**
  - 285 signatures defined in total, 200 in 10^{31} menu.
    - Menus targeted at start-up : first version of 10^{31} menu & draft 10^{32} menu
    - Combined signatures (e.g. tau + Missing ET) – almost 50 defined
    - pre-scaled signatures – use of LVL1 and some HLT pre-scales
    - Pass through signatures: passL2, passEF, passHLT
  - Since then, small changes to modify or remove a few items with too high rate
- **Exercised in massive offline productions and sustained running in Technical runs**
- Menu in 13.0.40 will be used to produce ByteStream Datasets for the Full Dress Rehearsal
- Menus will continue to evolve.

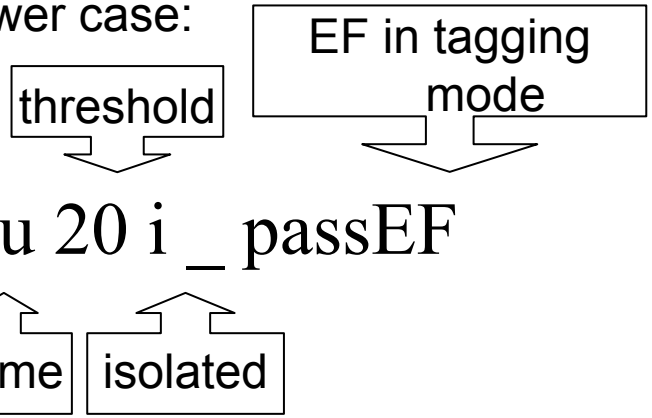
Naming Convention

First Level Trigger (LVL1)

Signatures in capitals e.g.



HLT in lower case:



New in 13.0.30:

- Threshold is cut value applied
- previously was ~95% effic. point.

LVL1	HLT	type
EM	e	electron
	g	photon
MU	mu	muon
HA	tau	tau
FJ	fj	forward jet
JE	je	jet energy
JT	jt	jet
TM	xe	missing energy

- More details : see :https://twiki.cern.ch/twiki/bin/view/Atlas/TriggerPhysicsMenu

Trigger Rate Measurements

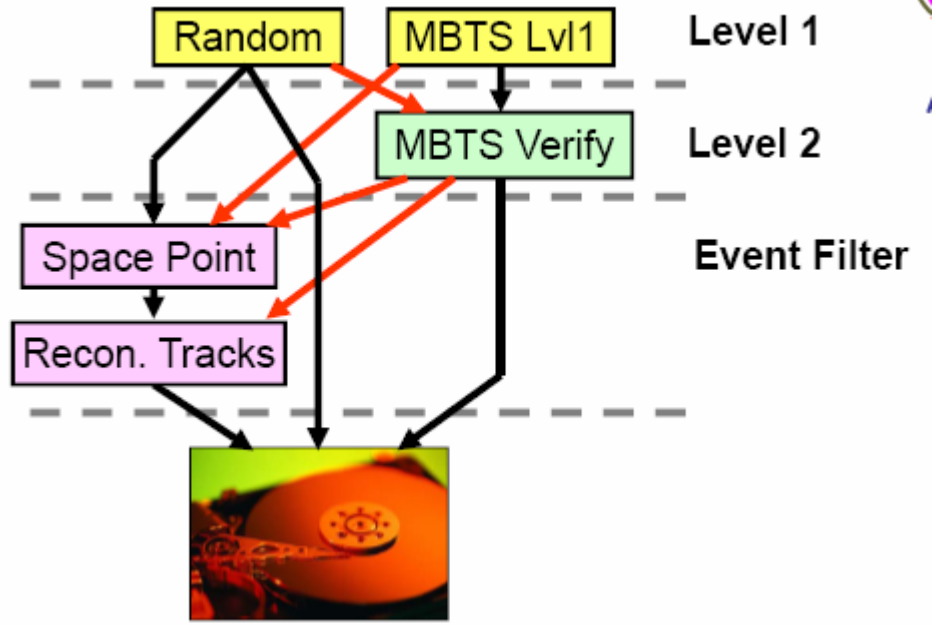
- Runs Trigger on min bias and dijet datasets to produce AOD
  - Use 10^{31} menu without pre-scales.
- Using TriggerRateTools to calculate rates taking into account overlaps
- Pre-scales applied by TriggerRateTools (increased statistics).
- Run on 6.7M Min. Bias events (cross-section for this sample : 70mb)

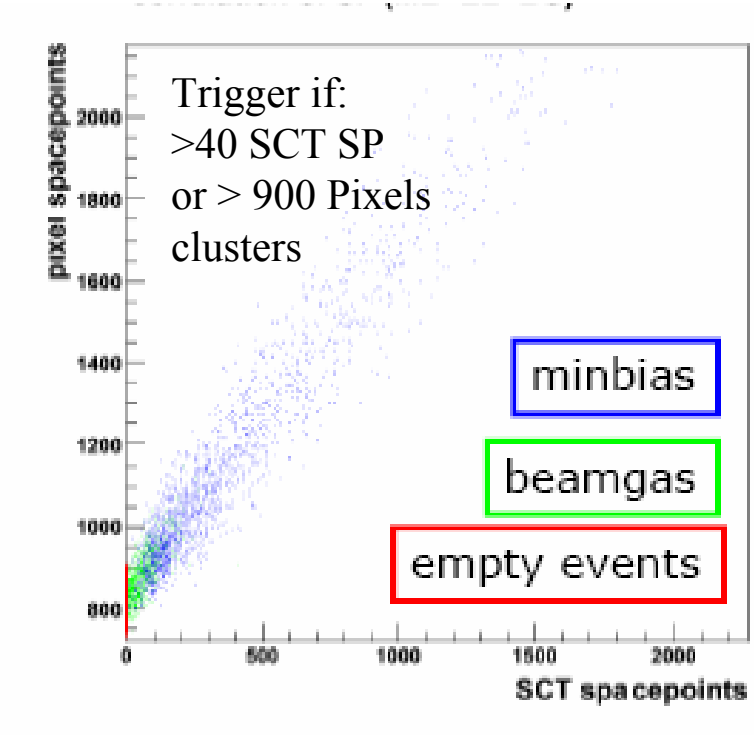
Rate Constraints	Design	Early Running
L1	75 kHz	45 kHz
L2	2 kHz	1 kHz
EF	200 Hz	200 Hz

Min Bias Triggers

Min. Bias Trigger available for the first time in 13.0.30.3

- Based on SP Counting
- Trigger if:
- >40 SCT SP or > 900 Pixel Clusters





To be done: add MBTS trigger

Define 3 MBTS triggers:

- MBTS_1 – 1 or more MBTS above threshold
- MBTS_2 – 2 or more MBTS above threshold
- MBTS_1_1 – At least 1 MBTS above threshold either side.

MBTS – Scintillators on the inside of endcap calorimeter giving LVL1 info.

Electron Menu Coverage for $L=10^{31}cm^{-2}s^{-1}$

16 LVL1 Thresholds for EM (electron, photon) & HA (tau)

EM3, EM7, EM13, EM13I, EM18, EM18I, EM23I, EM100

Trigger	Physics coverage	Rate
Single electron triggers and pre-scaled triggers with HLT pass-thru' for commissioning needs	Selections with isolated/non-isolated LVL1 thresholds Triggers with L2 and/or EF pass-through e.g. e15, e15i, e15_passHLT, e15i_passHLT, e20_passL2, e20_passEF	5 Hz
Low mass pairs	J/ψ, Υ→ee, DY are sources of isolated e with large stat., useful for calib. at low-p_T, efficiency extraction at low-p_T e.g. 2e5, 2e10, e5+e7, e5+e10	6 Hz
Low-medium-p_T double/triple e-trigger	Z→ee, Susy, new phenomena e.g. 2e10, 2e15, 3e15	5 Hz
High-p_T single e-trigger (LVL1 p_T~18 GeV)	W→eν, Z→ee, top, Susy, Higgs, Exotics etc. Loose selections and lots of redundancy e.g. e20, e20i, e25i, e15_xE20, e10_xE30, e105	5 Hz
Very high-p_T e-trigger	Exotics, new phenomena e.g. em105_passHLT	1.5 Hz
Low p_T single e-trigger (LVL1 p_T~7 GeV)	Electrons from b,c decays (e typically not well isolated) Useful for E/p studies. Need tighter cuts to limit rate e.g. e12	17 Hz

Photon Menus for 10^{31}

Trigger Item	Examples	Physics Coverage	Rate
Low pt item HLT pre-scale 10 or 100	g10, g15, g15i	Hadronic calibration, inclusive and di-photon cross section	4 Hz
High pt item, no pre-scale	g20, g20i, g25, g25i	Direct photon, hadronic calibration	7 Hz
Very high pt item non isolated	g105, g120	Exotics, SUSY, unknown, hadronic calibration	
Multi photon, no Isol. no HLT prescale	2g10, 2g15, 2g20, 3g10	Di-photon cross section, Exotics, SUSY, calibration	5 Hz
Triggers for commissioning with LVL1 prescale and HLT in tagging mode	em15_passHLT, em_15i_passHLT g10_passL2 g10_passEF	Selections with/without L1 isolation, triggers with L2/EF pass-through	

Total rate (including overlaps) ~10 Hz

Muon Triggers

Six LVL1 thresholds : MU4, MU6, MU10, MU15, MU20, MU40

Isolation can be applied at the HLT

Triggers	Examples	Motivation	Rate
Prescaled Low p_T single μ	mu4, mu6	B-physics, J/ψ, $\Upsilon \rightarrow \mu\mu$, DY	4 Hz
Unprescaled Low p_T dimuon	2mu4, mu4+mu6, 2mu6		2.5 Hz
Prescaled triggers with HLT pass-thru' mu20i with calculating but not applying isolation	mu20_passHLT	commissioning	0.5 Hz
high p_T triggers with/without isolation	mu10, mu15, mu20, mu20i, mu40 2mu10, 2mu20	high-p_T physics: $Z(\mu\mu)$, Susy, Higgs, Exotics etc.	20 Hz

Bphysics

LVL1 + Muon at HLT

- 2mu4 : 2.5 Hz
- mu4 & mu6 pre-scaled : 4 Hz

LVL1 + ID & MU at HLT:

- mu4_DsPhiPi_FS, MU4_Jpsimumu_FS, MU4_Upsimumu_FS,
- MU4_Bmumu_FS, MU4_BmumuX_FS

} Loose selections ~10Hz

Tau Triggers

16 LVL1 Thresholds for EM (electron, photon) & HA (tau)

HA5, HA6, HA9I, HA11I, HA16I, HA25, HA25I, HA40

Signature	Example	Motivation	Rate
Single tau prescaled single tau unprescaled	tau45, tau45i tau60, tau100	exotics and heavy Higgs	15 Hz
Tau+MET	tau20i+xe30	W ->τν at low luminosity and H–>τν, SUSY, etc at high lumi.	5 Hz
TauTau	2tau25i, 2tau35i	H->tautau	3 Hz
tau+e,mu,tau,jet	tau20i_e10, tau20i_mu10, tau20i_j70, tau20i_4j50, tau20i_bj18	Z tt, preparation for 10^{33} SUSY, Charged Higgs	5 Hz

Single Jet Triggers

- Strategy:
- Initially use LVL1 selection with no active HLT selection and b-jet trigger in tagging mode
- 8 LVL1 Jet thresholds:
  - Highest un-prescaled, value determined by rate considerations (Aim for ~20Hz)
  - Other threshold set to equalize bandwidth across the E_T spectrum
  - Lowest threshold used to provide RoI for Bphysics trigger.

Trigger	Overall Prescale	Rate (Hz)	
j400	1.0	8.6	(± 0.9)
j200	1.0	8.6	(± 0.9)
j120	1.0	8.6	(± 0.9)
j70	15.0	4.2	(± 0.2)
j42	100.0	3.71	(± 0.06)
j35	500.0	1.37	(± 0.02)
j23	2000.0	1.37	(± 0.008)
j18	6000.0	1.02	(± 0.004)
j10	42000.0	3.9	(± 0.003)
j5	300000.0	0.9470	(± 0.0004)

Jet Triggers (contd)

	Triggers	Motivation
single jet	j5,j10,j18,j23,j35,j42,j70,j120,j200,j400	QCD, Exotics
multi-jet	3J10, 4J10, 3J18, 3J23, 4J18, 4J23, 4J35	searches pp->XX, X->jj, top, SUSY
forward jets	FJ10, FJ18,FJ26, FJ65, 2FJ10, 2FG26, 2FJ65, FJ65_FJ26	VBF
jet energy sum	JE280, JE340	SUSY

Trigger Rates for multi-jets

Trigger	Overall Prescale	Rate (Hz)	
4j23	1.0	5.3	(± 0.7)
4j18	100.0	0.10	(± 0.01)
4j10	300.0	0.036	(± 0.004)
3j18	100.0	0.71	(± 0.03)
3j10	1500.0	0.048	(± 0.002)

Trigger Rates for Forward Jets

Trigger	Overall Prescale	Rate (Hz)	
2fj70	1.0	0	
2fj35	1.0	1.6	(± 0.4)
2fj18	100.0	0.94	(± 0.03)
Multi-Fjets		2.49	(± 0.08)
fj120	1.0	0.9	(± 0.3)
fj70	20.0	1.15	(± 0.08)
fj35	700.0	0.68	(± 0.01)
fj18	7000.0	1.04	(± 0.004)
Single-Fjets		3.76	(± 0.01)

Bjet Triggers

- Jets tagged as B-jets at HLT based on track information
- Will allow lower LVL1 jet thresholds to be used
- For initial running the Bjet triggers will be in tagging mode. Active selection will be switched on once the detector & trigger are understood.

Trigger	Overall Prescale	Rate (Hz)		Cumulative Rate (Hz)	
3b23+3L1J23	1.0	0.2	(± 0.1)	0.2	(± 0.1)
2b23+3L1J23	1.0	2.7	(± 0.5)	2.7	(± 0.5)
2b23+3L1J23 passHLT	1000.0	0.0028	(± 0.0005)	2.7	(± 0.5)
3b18+4L1J18	1.0	0.2	(± 0.1)	2.8	(± 0.5)
3b18+4L1J18 passHLT	1000.0	0.0002	(± 0.0001)	2.8	(± 0.5)
Multi-bjets		2.8	(± 0.5)		
b70	15.0	4.2	(± 0.2)	6.9	(± 0.3)
b42	100.0	3.71	(± 0.06)	10.6	(± 0.2)
b35	500.0	1.37	(± 0.02)	11.9	(± 0.1)
b23	2000.0	1.37	(± 0.008)	13.3	(± 0.08)
b18	6000.0	1.02	(± 0.004)	14.3	(± 0.06)
Single-bjets		11.60	(± 0.05)		

Missing ET, Total SumET

8 LVL1 Missing ET thresholds

Trigger	Overall Prescale	Rate (Hz)		Cumulative Rate (Hz)	
xe80	1.0	0		0	
xe70	1.0	0.2	(± 0.1)	0.2	(± 0.1)
xe50	4.0	1.1	(± 0.2)	1.2	(± 0.2)
xe40	20.0	0.84	(± 0.07)	2.0	(± 0.2)
xe30	200.0	0.54	(± 0.02)	2.53	(± 0.08)
xe25	1500.0	0.297	(± 0.005)	2.83	(± 0.04)
xe20	7000.0	0.327	(± 0.002)	3.15	(± 0.02)
xe15	30000.0	0.579	(± 0.001)	3.73	(± 0.009)
te650	1.0	0.3	(± 0.2)	0.3	(± 0.2)
te360	40.0	0.23	(± 0.02)	0.53	(± 0.06)
te250	1100.0	0.256	(± 0.005)	0.79	(± 0.02)
te150	100000.0	0.1370	(± 0.0004)	0.925	(± 0.003)
je340	1.0	0.1	(± 0.1)	0.1	(± 0.1)
je280	2.0	0.4	(± 0.1)	0.5	(± 0.2)
je220	10.0	0.61	(± 0.08)	1.0	(± 0.1)
je120	150.0	0.64	(± 0.02)	1.67	(± 0.05)

Combined Triggers

- Menu contains large no. combined signatures

Type	Examples	Motivation
tau+e, tau+mu, e+mu	tau15i_e10, tau25i_mu6, tau20i_mu10, e10_mu6	tt, SUSY
tau+Missing ET	tau45_xe40, tau45i_xe20	W, tt, SUSY, exotics
tau+jet	tau25i_j70	W, tt, SUSY, exotics
mu+jet	mu4_j10	exotics
jet + missing ET	j70_xe30	SUSY, exotics

Total Rate 46 Hz

Total Rates

	Rate (Hz)
LVL1	47,000
LVL2	865
EF	200

LVL1

Slice	Rate (Hz)	
Jet	242.0	(± 0.1)
Egamma	9770	(± 20)
Tau	570	(± 1)
Muon	1730	(± 10)
Missing E_T	38.40	(± 0.04)
Total E	6.27	(± 0.004)
Total Jet E	1.67	(± 0.05)
Combined	5880	(± 20)
Minimum Bias	35700	(± 40)

LVL2

Slice	Rate (Hz)	
Jet	36.7	(± 0.02)
bjets	23.9	(± 0.1)
Electron	155.0	(± 0.4)
Photon	35.6	(± 0.07)
Tau	351	(± 0.7)
Muon	212	(± 3)
Missing E_T	32.4	(± 0.04)
Total E	6.27	(± 0.004)
Total Jet E	1.67	(± 0.05)
Topological + B-physics	25.5	(± 2)
Combined	134	(± 2)
Minimum Bias	0.0994	(± 0.0002
Calibration	310	(± 6)

EF

Slice	Rate (Hz)	
Jet	34.9	(± 0.01)
bjets	14.3	(± 0.06)
Electron	33.7	(± 0.08)
Photon	8.99	(± 0.02)
Tau	33.5	(± 0.07)
Muon	34.7	(± 0.7)
Missing E_T	3.73	(± 0.009)
Total E	0.925	(± 0.003)
Total Jet E	1.67	(± 0.05)
Topological + B-physics	13	(± 1)
Combined	46	(± 1)
Minimum Bias	0.0994	(± 0.0002)
Calibration	15	(± 5)

Summary

- A lot of progress with Trigger Commissioning during 2007:
  - Final hardware installed in P1 including ~7% of HLT farm
  - Cosmic runs including Trigger & DAQ
  - Technical runs on simulated full ATLAS data downloaded to RoBs
  - Development of Trigger Menus for 10^{31} & 10^{32}
- Work continues this year with preparation for first beams in 2008 :
  - Further technical and cosmic runs. Full Dress Rehersal
  - Tests with corrupted data, misalignment, miss-calibration, long runs, cycling through states etc.
  - Finalise Trigger Menus and strategies for varying beam & detector conditions.
  - Optimise the cuts w.r.t. trigger rate and efficiency for signal samples.
  - Complete techniques for extraction of efficiency from data
  - Understand possible biases introduced via trigger cuts (from data if possible)
- Still plenty to do - your help is vital.
  - many areas seeking additional effort - scope for student projects looking at the very first data!
- **Looking forward to goal of first physics running later this year!**