Trigger overview and early physics

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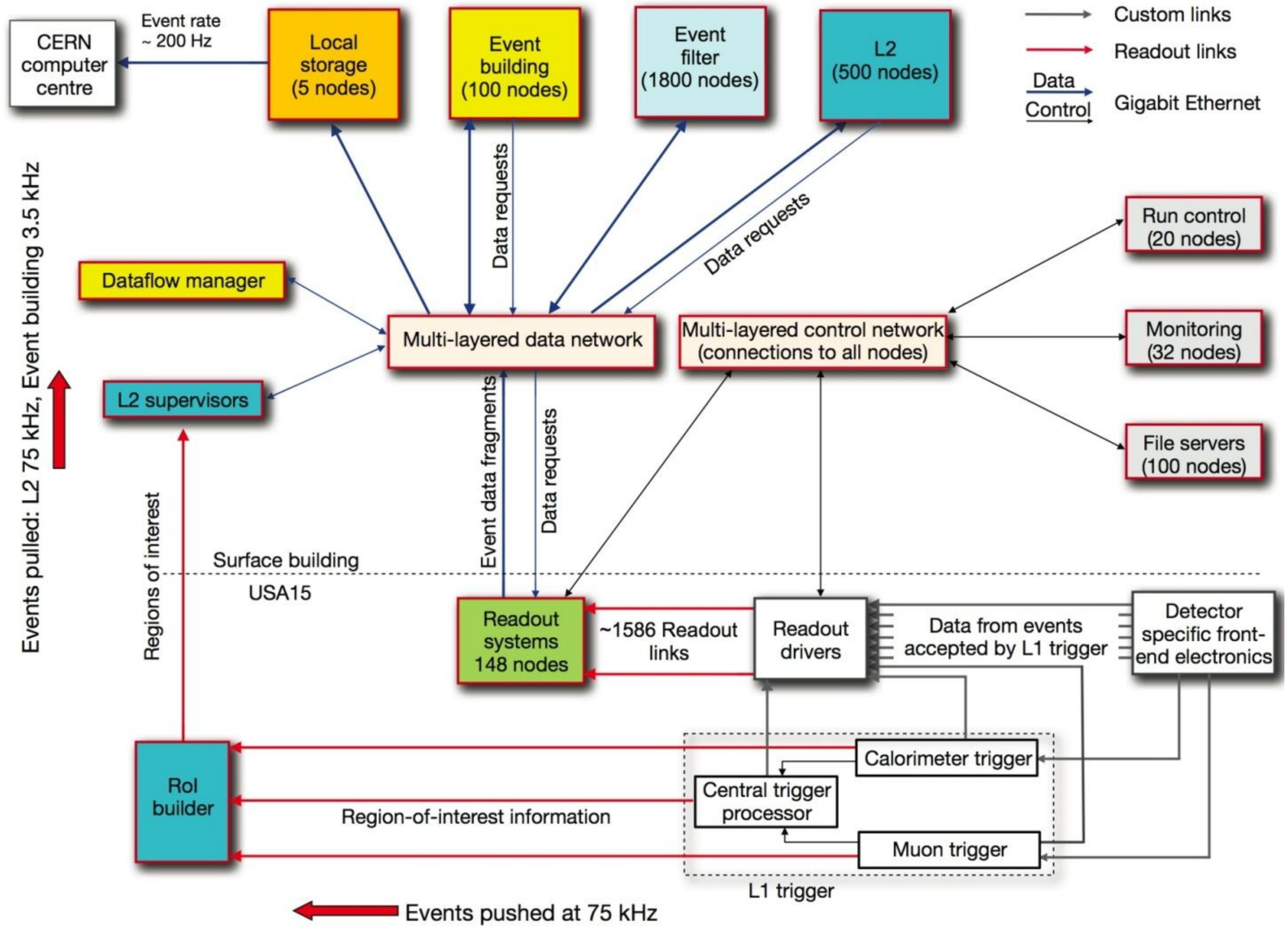
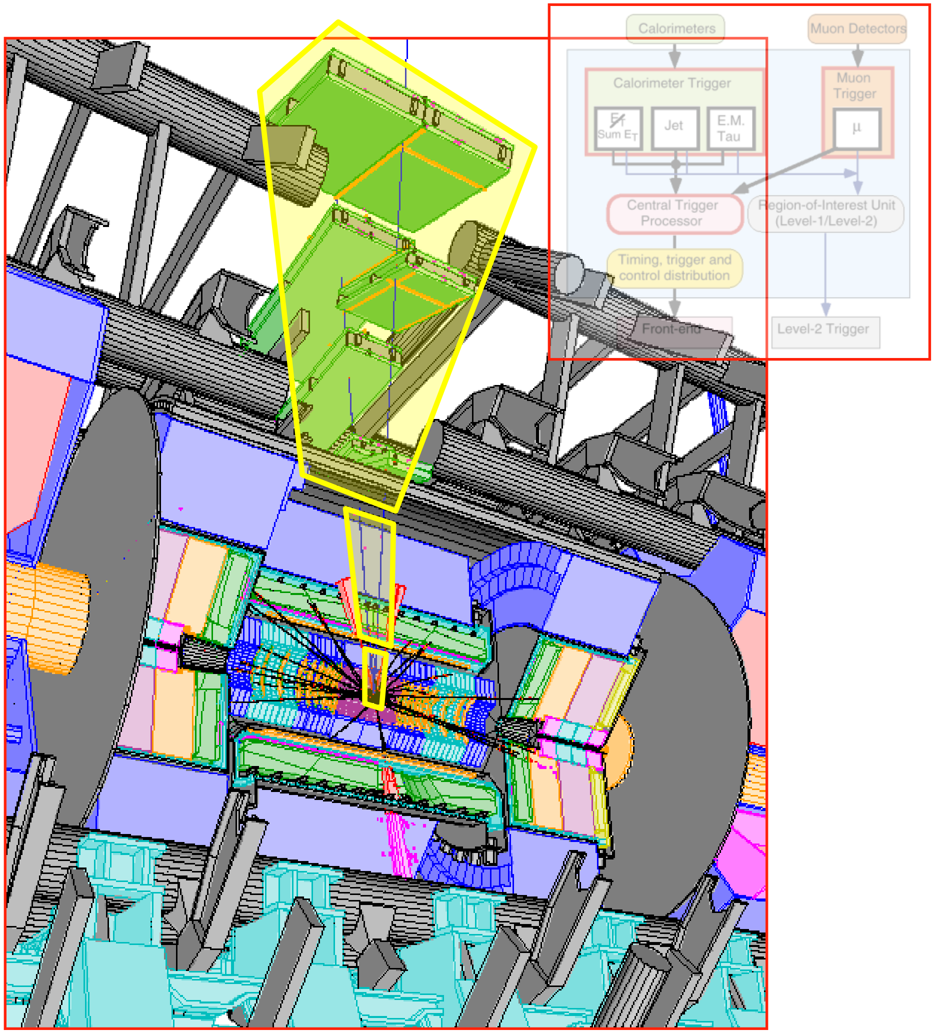
The Atlas TDAQ



Atlas triggers



- Local L1 selection
  - RoI selected through simple signatures
  - HW
  - Synchronous
  - Pipelined, fixed latency (2.5 μs)
  - 40 MHz clock
- RoI based L2
  - Selection refined moving few % of data
  - SW based
  - Sequential
    - Early rejection
  - Asynchronous
- EF based on full event

Trigger items and trigger menus

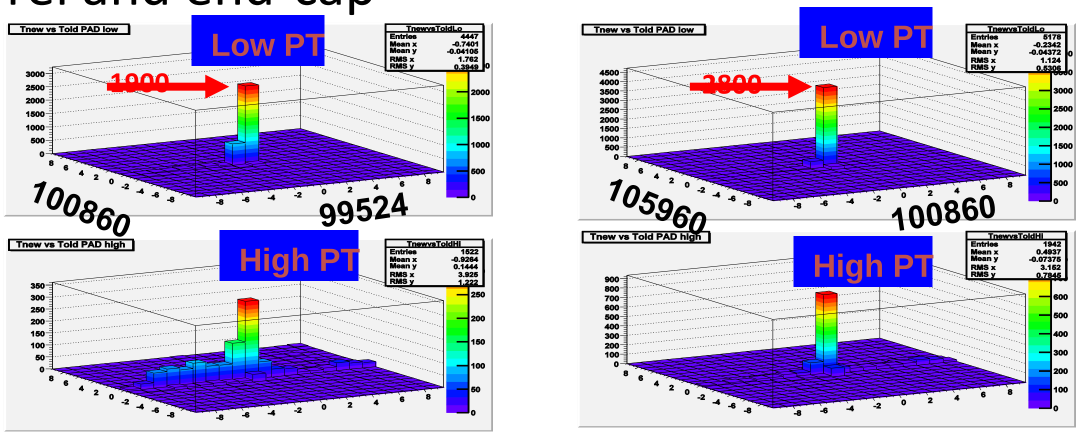
- Trigger item
  - A configuration which identifies a given signature
  - Fully specifies threshold and selection criteria
- Trigger menu
  - Collection of trigger items
    - Incorporates signatures for various objects
    - At the three levels
  - Must include additional trigger items
    - Validation
    - Monitoring
    - Calibration
    - Performance measurements

Level-1 preparation

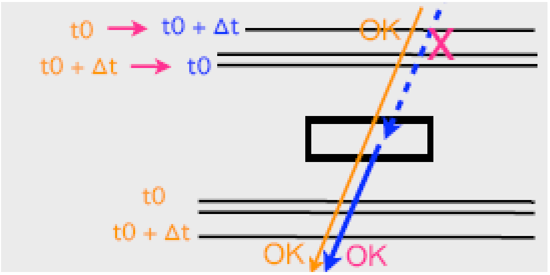
- Trigger HW is completely installed
- Trigger prepared through
  - Timing
    - Critical point!
    - Partially achieved through
      - Delay measurements and adjustment
      - Cosmic ray runs
      - Pulse runs
  - Threshold setup
    - Roads for muons
    - Energy calibration for calorimeter
  - Commissioning runs

Muon trigger preparation (1)

- Exclusive menu between barrel and end-cap

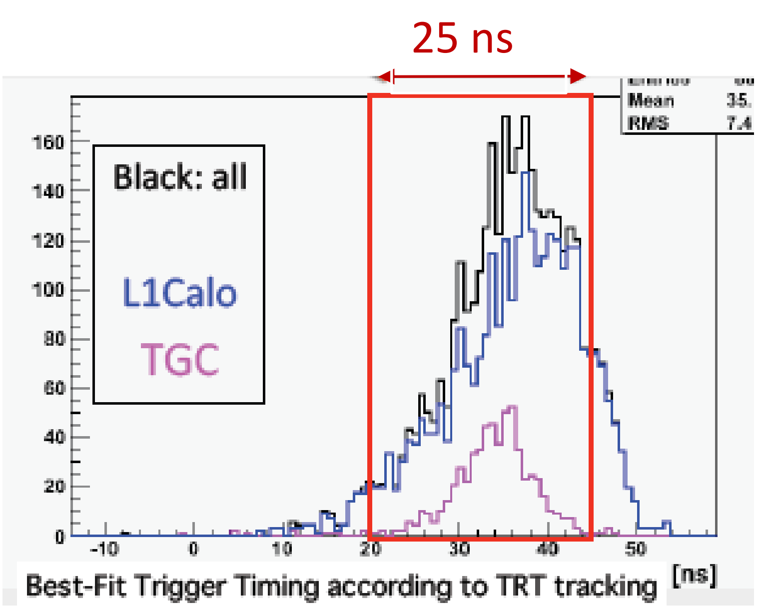


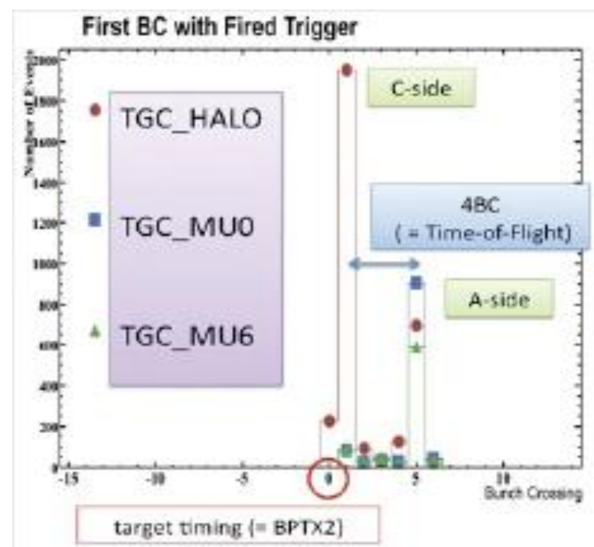
- L1 RPC
  - Timing alignment
    - Fiber length measurement
    - Local alignments
      - Using data
      - Correct internal tower misalignments
      - Run on calibration data @ T2
    - Global alignments
      - Alignment between towers
      - Alignment between sectors
      - Cross checks with MDT, HLT and CTP
    - Initially focused on bottom sectors
      - Tools under preparation for alignment with collisions
    - Developing tools for final calibration with collisions



Muon trigger preparation (2)

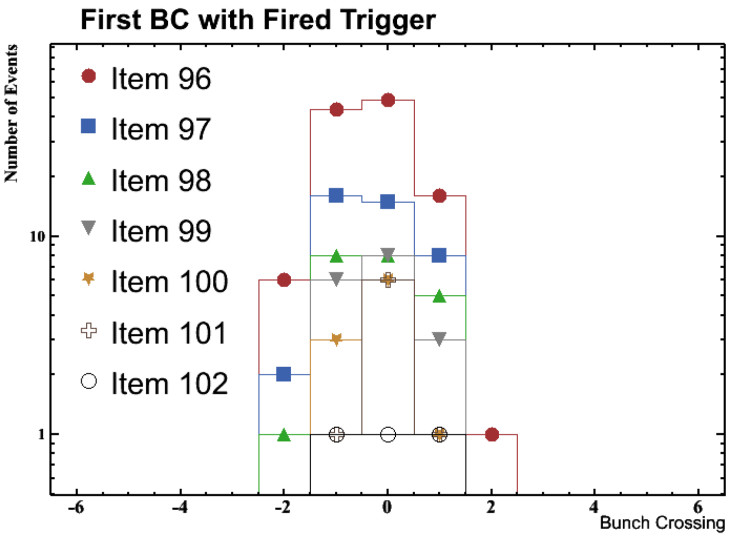
- L1 TGC
  - Track emulation via test pulse
  - Best alignment achieved with single beam
    - < 1 BC
    - Repeat in 2009





Calorimeter trigger preparation

- L1 Calo
  - Time and energy calibration
  - Currently focused on timing
    - Via pulse system
      - Intra-partition calibration possible
    - Tested during run with TRT trigger
  - Cosmic timing is inevitably blurred
    - Statistics low for high energy in calorimeter system
    - Nevertheless useful for partition to partition timing
  - Cosmics straddling partition boundaries useful
    - Look at events with large deposits in adjacent towers
    - Compare timings, especially across partition boundaries
- First order timing for LHC beam
  - 10 TeV is far more useful than 900 GeV
    - Timings should be improved within 1-2 weeks
  - Note: timing is an iterative process
    - Most critical is to get correct Bunch-Crossing
      - BC timing should be available quickly
    - To improve energy resolution need good fine timing calibration
      - This may take some time to perfect



HLT preparation

- During detector weeks:
  - “Lay low”: offer service and no trouble!
  - Provide streaming (revert to steering dummy if necessary)
  - If harmless, run algorithms parasitically
- Technical runs
  - Integration tests
- HLT week:
  - Re-establish status as of october 2008:
  - HLT streams based on L1 trigger type
  - Algorithms running parasitically
  - Few additional cosmic-specific algorithms performing selection
  - Calibration streams & the likes
  - Test new algorithms/menu variations/conditions
  - DB access patterns
  - Stability, stability, stability

HLT commissioning strategy

- First collisions
  - 10^{26}-10^{27} → MB rate 10 to 100 Hz
  - Complete L1 commissioning and understanding
- Phase 1 − phase already exercised in 2008 −:
  - HLT not running
  - The HLT menu (SM Key and cache) is validated in the CAF
  - Output rate is adjusted by changing L1 pre-scales
- Phase 2:
  - HLT in pass-through mode
  - Streaming according to L1 trigger type
  - The HLT menu is validated offline in the CAF through:
    - Tier0 monitoring
    - Offline trigger aware analysis in ESD / AOD
  - Output rate is adjusted by changing L1 and HLT pre-scales
- Phase 3 − exercised for triggering cosmic rays in 2008 −:
  - Only when the need comes (i.e. output rate to Tier0 too high):
  - The HLT in active mode in a controlled and simple way first
    - L2, EF priority ?
  - Activating the chains going to reduce the L1 rate first
    - pre-prepared according to rate calculations through the “enhanced” minimum bias sample)
  - Output rate is adjusted by changing L1 and HLT pre-scales

Trigger classification

- Primary triggers
  - These are our selection triggers for physics analysis
  - Generally not pre-scaled
- Supporting triggers
  - Efficiency/monitoring of primary triggers
  - Tracking/isolation studies…
- Calibration triggers
  - Explicitly collect detector calibration data
- Backup triggers
  - Alternative primary triggers in case of rate/resource problems
  - Only present during commissioning
    - unless they replace a primary trigger
- Commissioning triggers
  - Present during initial running but not in the physics menu
- Test triggers
  - MC menu only

Trigger requirements

- Menu preparation driven by requirements
  - Establish priorities
  - Pre-scale factors based on rate control
- Trigger requirements in 2009-2010
  - Different sources
    - Detector requirements
    - Combined performance requirements
    - Early physics requirements

Detector requirements

- Special triggers outside normal runs
  - Outside the scope of this talk
    - Example: calibration triggers
- Special triggers during empty bunches
  - Even for 25 ns operation, 2808/3564 fill fraction
    - 21% of the crossings empty
    - It is possible to define “bunch groups”
  - Possibility to accommodate empty bunch triggers
  - Use partial EB and possibly HLT to reduce bandwidth
  - Must not interfere with the normal colliding-beam triggers
- Special Triggers during “filled” bunches (with collisions)
  - Could be considered combined performance triggers

Special triggers during empty bunches

- Pedestal and occupancy triggers (random level 1)
  - Mainly used by pixel, ~10 Hz
- Test pulse triggers
  - Requested by tile calorimeter
- Cosmic trigger
- Beam triggers to look at background
  - LArg and TileCal have requested to use L1Calo with low threshold
  - Possible more systematic approach
    - Look at physics triggers during empty bunches
- Pile-up triggers:
  - Specific trigger windows around the filled bunches to measure the "out of time" pile-up.

Special triggers during filled bunches

- Random trigger
  - “Zero bias” readout of ATLAS
    - Requested by LArg and TileCal
  - Useful to measure beam pickup or other effects
    - To be compared with equivalent empty bunch trigger
- Detector calibration trigger
  - Mainly used by calorimeters
  - Parasite on the general ensemble of physics triggers
  - Use Partial Event Building to reduce bandwidths
  - LArg community would include
    - EM triggers to study and optimize pulse shapes
    - “Single hadron” triggers for improved understanding of hadronic calibration
  - TileCal would also like an isolated muon trigger for calibration

Combined performance triggers (1)

- Understand and document performance
  - Need enough data for each object type
- Start with few and simple chains
  - Avoid too much ambition in HLT algorithms
  - Test track triggers against minimum bias data
- Minimum bias data are very important
  - Bandwidth mostly dedicated to MB in the beginning
    - ~100 Hz $\Rightarrow$ 1-2 M per fill
  - Measure:
    - basic detector efficiencies
    - Track reconstruction efficiencies
    - Material using photon conversion
  - Critical for tracking and eγ slices
- I only give some example in the following

Combined performance triggers (2)

- Understanding jets
  - Bootstrap from min. bias events:
    - jet with ET > 20 GeV and $|\eta| < 2.5$ is ~ 6% in MB events
    - ~ 10^5 jets unbiased by any trigger for one fill
  - Very high priority
    - Understanding L1 (and HLT) biases on jet reconstruction
  - In parallel, need to collect γ-jet events (g20 trigger):
    - σ (γ + X, with $E_T > 20$ GeV and $|\eta_\gamma| < 2.5$) ~ 200 nb @ 10 TeV
    - g20 would deliver ~ 2M events for 10 pb^{-1} with purity of ~ 50%
    - Main initial uncertainty due to ε_γ
- Non-isolated leptons from un-pre-scaled e10 and mu10
  - Main aims:
    - Unbiased trigger (from tau viewpoint) for Z to ττ
    - Inter-calibration of the EM calorimeter
    - Detailed alignment of inner detector and muon spectrometer
  - High signal rates expected are high
    - 3-5 M events for each lepton flavor with 10 pb^{-1}
  - Reasonable purity for electrons.

Requirements from early physics

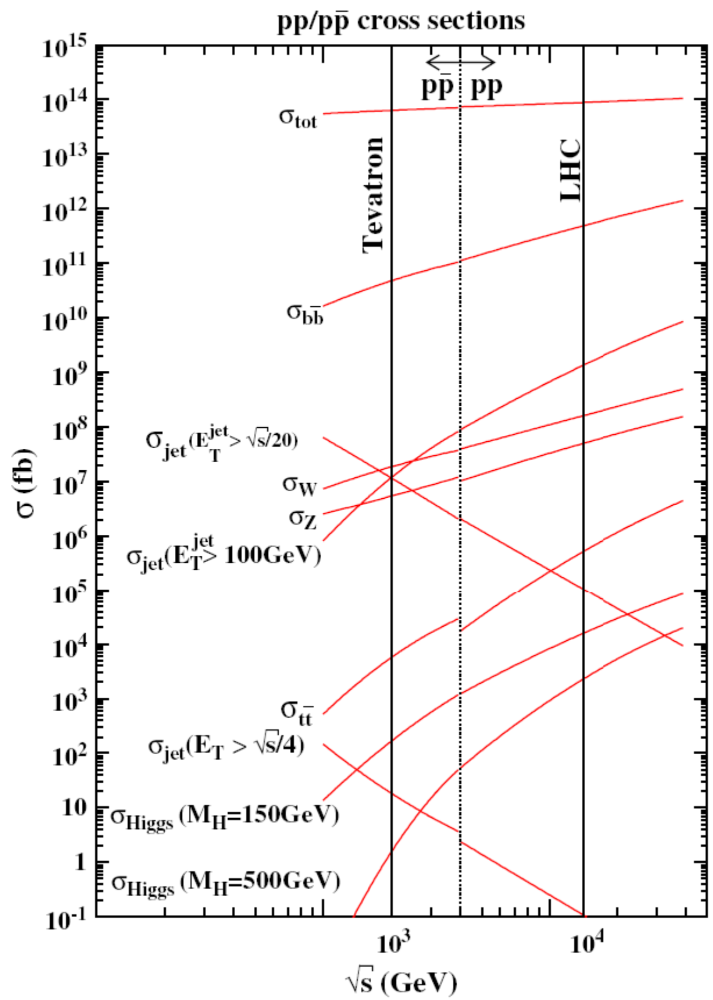
- Assumptions
  - Phase “A”:
    - 2-3 months
    - ~10 pb^{-1} of data @ 10 TeV
  - Phase “B”:
    - A few 100 pb^{-1} of good data @ 10 TeV
- What gap between A & B?
- Main focus
  - What do we do with ~10 pb^{-1}?
  - Bear in mind that the “gap” may be short

Initial physics

- Initial physics is *nearly all*
  - Understanding detector, object triggering and performance
- High priorities in the first data:
  - Understand "simpler" object triggering, reco, ID & backgrounds
  - e/γ
  - μ
  - Jets
- At same time, start commissioning more complex signatures
  - τ
  - E_{Tmiss}
  - Flavor tagging
- Will be establishing physics signatures at the same time
  - trigger, physics and performance are very intertwined
- HLT is not really needed in the beginning
  - Increase the usage with luminosity (and understanding)
  - Keep it SIMPLE !

Early physics

- For 10 pb^{-1}: (10^{31} = 0.036 pb^{-1} h^{-1})
  - High cross section SM signatures
  - Min bias σ ~ 70 mb
    - Rate limited at a few 1027
    - at 5 Hz ~ 100k in a 5 h fill
    - or O(10 M) in 2-3 months
  - Dijets with E_T>100 GeV σ ~ 1 μb
    - O (10 M) in 10 pb^{-1} (before prescale)
  - J/ψ→μμ p_T
    - μ > 6,4 |η|< 2.4 σ ~ 10 nb
    - O (100 k) in 10 pb^{-1}
  - W→ℓν ~ 20 k selected
  - Z→ℓℓ ~ 4 k selected
    - < 2% stat error!
  - tt →qqℓνbb σ ~ 100 pb
    - a search
- Low p_T cut, loose selection criteria



Trigger for early physics (1)

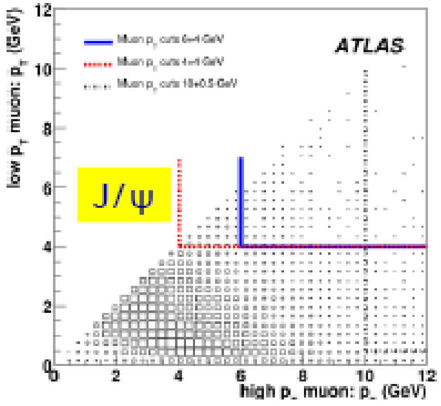
- Minimum bias
  - Track multiplicity
  - p_T distribution
  - Rapidity distribution
- Electronic and Muonic W and Z
  - Early measurements:
    - σ(W) / σ(Z)
    - W, Z kinematic distributions
    - W, Z cross-sections
  - Single e/μ triggers essential:
    - Loose inclusive electron
    - Loose inclusive muon
    - Threshold of 20 GeV suffices
    - Stability, and looseness, matters more than the precise threshold
  - Large (prescaled) j20 sample useful to study background
  - Efficiency will need Z's
    - Inclusive E_{Tmiss}

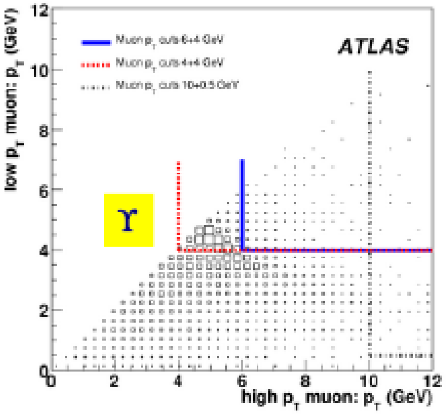
Trigger for early physics (2)

- W/Z + jets
  - W and Z provide triggers via leptons
  - Avoid biases against activity where possible
    - Loose lepton selections,
    - Special care with isolation cuts
- Di-bosons
  - Cross-sections are small; relatively easy to trigger
  - Wγ, Zγ
    - just a few events with 10 pb^{-1}, even for low $E_{T\gamma}$ cuts
  - Eventually (>~100 pb^{-1}) WW, WZ, ZZ

Trigger for early physics (3)

- J/ψ and ϒ→ μμ
  - Very high statistics very fast
  - $p_T(\mu_1)>6$, $p_T(\mu_2)>4$, $|\eta| < 2.4$ – 10 k J/ψ per pb^{-1}
  - Measuring efficiency relies on (prescaled)
    - single-μ trigger
  - 2μ4 trigger increases
    - J/ψ statistics by ~25%,
    - ϒ by factor ~10
    - gives access to zero p_T





Trigger for early physics (4)

- Top Physics
  - With ~10 pb^{-1} at 10 TeV, expect:
    - ~200 usable l+jets events
    - ~50 usable lljj events
  - Establishing signals
  - High priority:
    - Single lepton triggers which should be efficient by 20 GeV
    - Early: measure efficiencies with Z events and map to ttbar
    - Loose, or no, isolation requirements
    - Later: tighten isolation rather than raising threshold
    - Some other triggers for cross-checks
  - Lower priority at start – commissioning studies:
  - t to τ decays
    - once tau triggering & ID understood on data
  - Hadronic top – will always be tough
  - Single top – tough signature (but single ℓ is the key trigger again)

Triggers for discovery (1)

- Start studying new physics
  - Possible after 10 pb^{-1}
    - if data, detector, trigger well understood
  - SUSY
    - Discovery sensitivity beyond Tevatron with a few 10's of pb^{-1}
    - First analyses: l+jets+E_{Tmiss}
      - Require lepton until E_{Tmiss} understood in multijet events
    - Eventual golden trigger: Jets • E_{Tmiss}
    - Important to start understanding the multijet triggers early
      - for commissioning and as an independent trigger
    - Multi-lepton channels generally easier
    - Single lepton triggers give redundancy

Triggers for discovery (2)

- Start studying new physics (2)
  - W', Z'
    - High p_T single ℓ (e or μ), single γ, single jet trigger
    - Sum-E_T trigger could be a useful complement
    - How to check high p_T efficiency?
  - SM Higgs
    - A few 100's pb^{-1} to start competing with Tevatron on exclusion
    - H→WW→ℓνℓν channel sensitive first, assuming ℓ-ID, E_{Tmiss} understood
    - Single lepton triggers
    - Commission more complex triggers
      - Single photon trigger , tau trigger, E_{Tmiss}, forward jet…

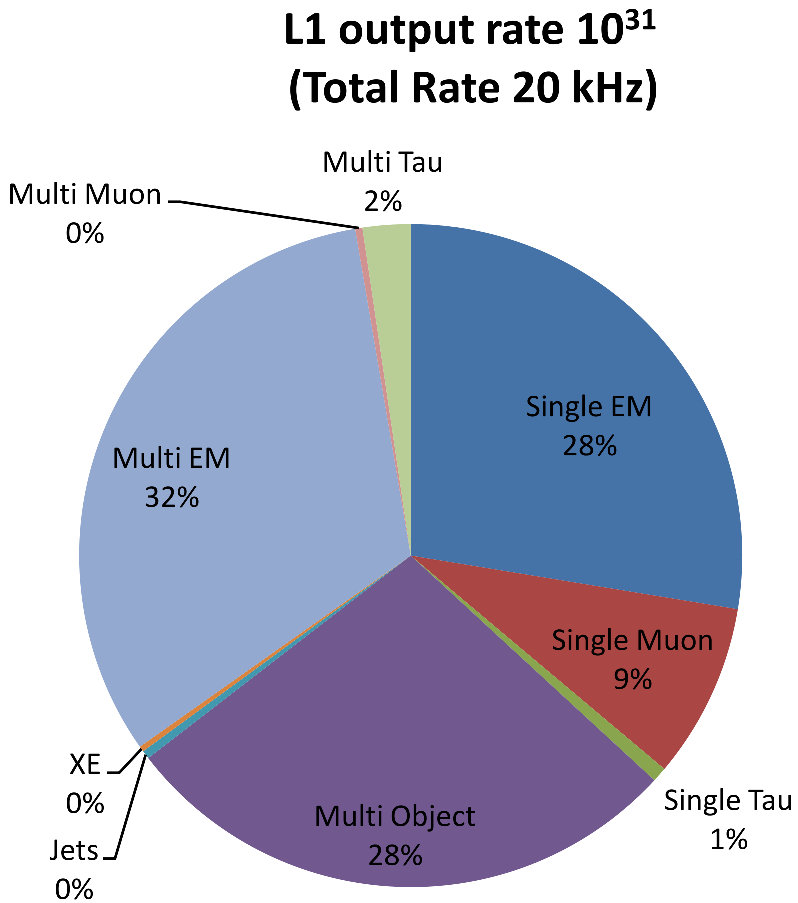
Trigger rates

- Trigger bandwidth is a limited resource
  - Gets worse with increasing luminosity
  - Need to justify where bandwidth is spent
  - Ensure that triggers in menu will be used
  - Designing a trigger menu requires iterations
    - Several iterations of selection optimization
    - Ensure that output rate is within allowed bandwidth
- We need:
  - Trigger motivation studies
  - Trigger rate control

Rate control

- Output rate within allowed bandwidth
  - Avoiding DAQ dead-time
- Fill the bandwidth
  - As luminosity decreases during the fill
- How to use it?
  - As the physics analysis needs stability
    - Short term
      - Via pre-scaling
      - Tower masking in case of problems
    - Long term
      - Via threshold and menu adjustment

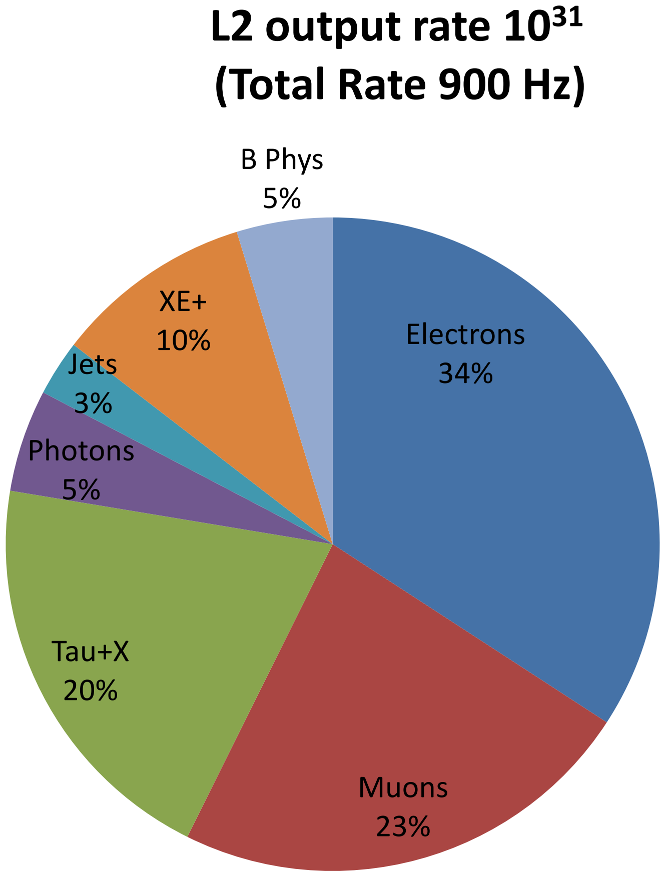
Level-1 rate @ 10^{31} (14.4.0)



Trigger Group	Rate (Hz)
Multi EM	6400
Multi Object	5500
Single EM	5500
Single Muon	1700
Multi Tau	470
Single Tau	150
Jets	80
Multi Muon	70
XE	50
TOTAL	20000

Removing overlaps between single+multi EM gives 18 kHz
Total estimated L1 rate with all overlaps removed is ~ 12 kHz

Level-2 rate @ 10^{31} (14.4.0)



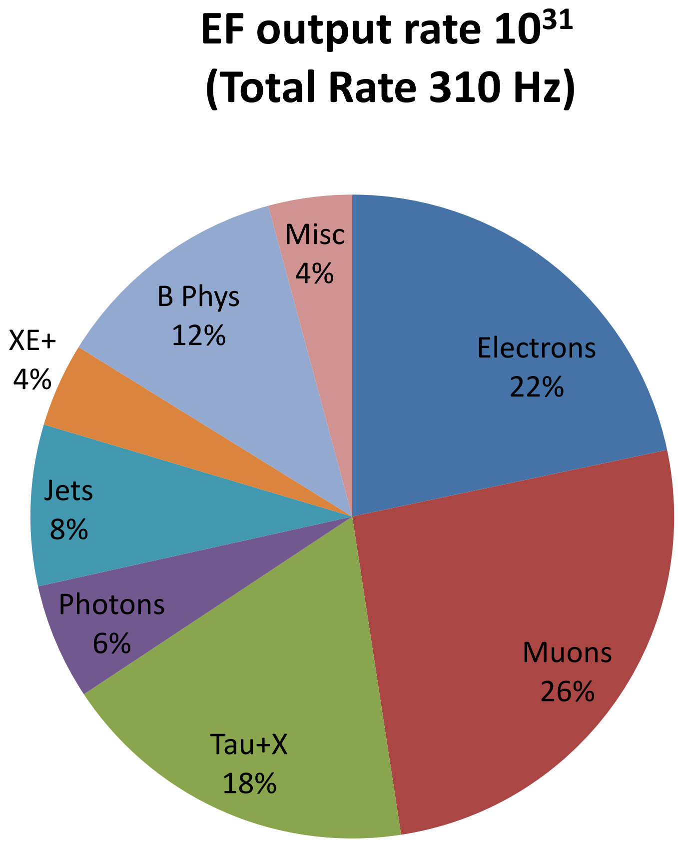
Trigger Group	Rate (Hz)
Electrons	310
Muons	210*
Taus+X	180
XE+	82
Photons	46
B Phys	43
Jets	22
TOTAL	900

X=anything; + includesJE, TE, anything with MET except taus; Bphys includes Bjet

* Manually pre-scaled off pass-through triggers mu4_tile, mu4_mu6

Total estimated L2 rate with all overlaps removed is 840 Hz

EF rates @ 10^{31} (14.4.0)



Trigger Group	Rate (Hz)
Muons	80
Electrons	67
Tau+X	56
B Phys	37
Jets	25
Photons	18
XE+	13
Misc	13
TOTAL	310

91 Hz total is in pre-scaled triggers;
51 Hz of pre-scaled triggers is unique rate

Total estimated EF Rate with overlaps removed is 250 Hz
Evaluations with different pre-scales give the required 200 Hz

10^{31} menu

https://twiki.cern.ch/twiki/bin/view/Atlas/L31TriggerMenu

Towards 10^{31} physics menu

- Backup and primary triggers will be consolidated after behaviour/rates of various triggers are understood with real data
- Choices will (hopefully) be made between competing algorithms (SiTrack, IDScan…) leading to fewer chains
- Physics streams will be enabled gradually (minbias, jets muons..)

General comments (1)

- Many weeks or even months between first collisions and 10^{31} operation
  - Time to understand the trigger and its performance
  - Reduce the number of chains for simpler commissioning
  - Focused on the balance of data samples needed at each luminosity
- Commissioning is a messy and non-linear business:
  - Many parallel activities, lots of iteration, and many surprises
  - Flexibility required
  - Prepare a broad set of tools, and don't expect to get it right the first time
- Validation tends to focus on checking for the expected
  - Need to constantly look in areas where nothing is expected
    - empty bunches
  - Look for the unexpected before declaring commissioning complete...

General comments (2)

- Understanding ATLAS detector performance
  - Leads to clear strategy on how to assign bandwidth
    - Versus evolution of luminosity and of trigger commissioning
    - Versus requirements of collecting large samples of certain datasets
  - Examples:
    - Large datasets required to understand basic performance
      - Calibration, fake rates
    - Large datasets required, if well justified, to measure efficiencies and backgrounds from data
- Early trigger
  - Level 1 stable after commissioning
  - HLT trigger studies and rate adjustment
    - $\Rightarrow$ flexibility
  - Data analysis
    - $\Rightarrow$ HLT stability both in <u>menus and algorithms</u>
  - Both require simple and well understood starting points
- Triggers for discovery
  - To be sensitive it is crucial
    - Having simple, stable triggers
    - Measuring performance and backgrounds with data
    - Key triggers stable as early as possible

Backup

Central trigger and distribution

- CTP: minor firmware changes
  - CTPIN: enabling/disabling inputs in the CTPIN
  - CTPCORE: measurement of the 40 MHz BC frequency with a precision of better than 1 Hz (using GPS as time reference) (done)
  - CTPCORE: trigger type handling for calibration requests (under development)
  - CTPCORE: 16-bit simple dead-time for LAr 32-samples (under development)
- MuCTPI
  - BCID alignment of the trigger path is in progress (not critical). Started with the TGC, defining the procedure. RPC will follow in the following weeks.
  - Status of new boards: (16xMIOCT: final version ; 1 MIROD + 1 MICTP, fully functional prototypes, will be replaced by newer versions with the same functionality)
    - MIROD/MICTP board production: 2 modules available and tested, 2 more being assembled (2 weeks). 2 more will follow once the MICTP tests are completed.
    - MIROD firmware: done.
    - MIROD software: low-level done, controller under development.
    - MICTP firmware: currently being tested.
    - MICTP software: to be done.
- TTC:
  - TTC distribution to sub-detectors is complete
  - Clock phase test ongoing
  - LTPi parallel links for muons and ID still need to be commissioned.
  - Calo loops are working.
  - ZDC and LUCID integrated

Level-1 trigger evolution

Two different cosmic setups

	~ 30th June	1st July ~ End of Single Beam			start collision ~ timing calibration		Trigger Road Calibration		~ 2010
	Menu 2008		**step 1.**		**step 2.**		**step 3.**		**E31 (2009)**
	NAME0	**NAME1**	**TGC**	**RPC**	**TGC**	**RPC**	**TGC**	**RPC**	**NAME2**
PT1	MU0_TGC_HALO	**MU0**	**MU0**		**MU0**		**MU0**		**MU0**
PT2	MU0_RPC_LOW	**MU6**	**MU6**		**MU6**		**MU6**		**MU6**
PT3	MU6_RPC	**MU10**	**MU10**		**MU10**		**MU10**		**MU10**
PT4	MU0_TGC	**RPC_TEST**	**x**	**MU0_HIGH**	**x**	**MU0_HIGH**	**x**	**MU11**	**MU11**
PT5	MU6_TGC	**TGC_TEST**	**MU0_HALO**	**x**	**MU15**	**x**	**MU15**	**x**	**MU15**
PT6	MU0_RPC_HIGH	**MU20**	**MU20**		**MU20**		**MU20**		**MU20**

Mimmo, Francesca, Hisaya & Masaya
(March 10 , 2009 v1)

- Conceptually few changes
- Four physics thresholds
- Two test thresholds

Combined performance triggers

- 2mu4/mu4mu6 and 2e5 triggers
  - Provide the first and most abundant source of isolated lepton pairs
  - Understand the detector performance in certain areas, …
  - Critical to
    - early performance measurements
  - Initial physics results for muons and electrons
- tau16(i) + xe30 and XE40
  - for 10 pb-1, the first one will be the only source any significant sample of hadronic τ-decays (a thousand signal events with limited purity)
  - the second one, if proven to be viable once detector tails have been cleaned up, is presumably the best example of possible orthogonal triggers for early physics in ATLAS: it can serve to verify both the electron and tau trigger streams through the extraction of W to eν and W to τν decays (again here we speak of about one thousand events)