The ATLAS Trigger: High-Level Trigger Commissioning and Operation During Early Data Taking

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Outline

- The ATLAS High-Level Trigger
  - Overall system design
  - Selection algorithms and steering
- Trigger strategy for initial running
  - Trigger algorithm organisation
  - Trigger strategy for initial running
  - Status
- High-Level Trigger Commissioning
  - Technical runs
  - Cosmic-ray runs
- Summary and outlook

The ATLAS High-Level Trigger

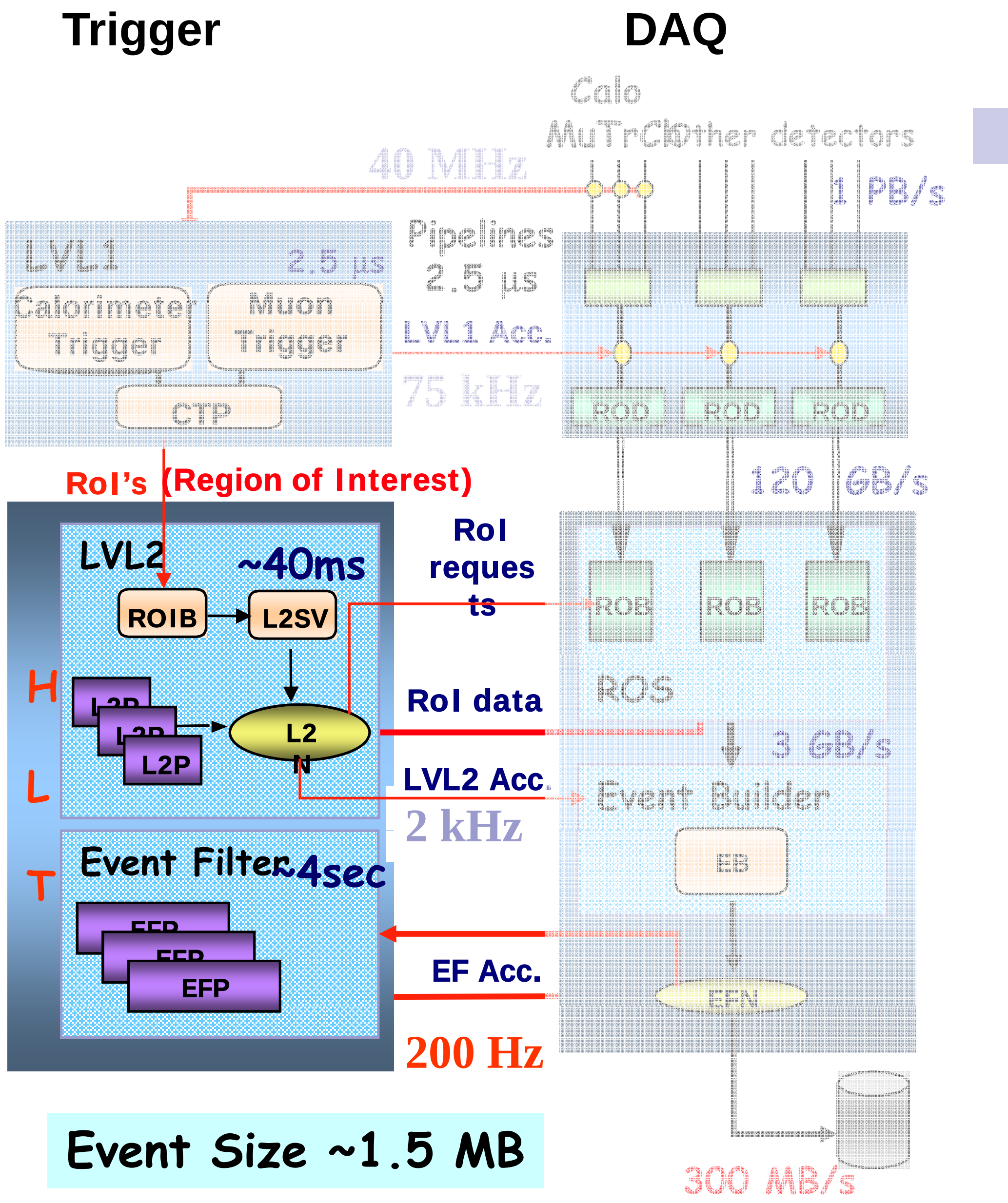
- Three trigger levels:
- Level 1:
  - Hardware based
  - Calorimeter and muons only
  - Latency 2.5 µs
  - Output rate ~75 kHz

- Level 2: ~500 farm nodes(*)
  - Only detector **"Regions of Interest" (RoI) processed - Seeded by level 1**
  - Fast reconstruction
  - Average execution time ~40 ms(*)
  - Output rate up to ~2 kHz

- Event Builder: ~100 farm nodes(*)

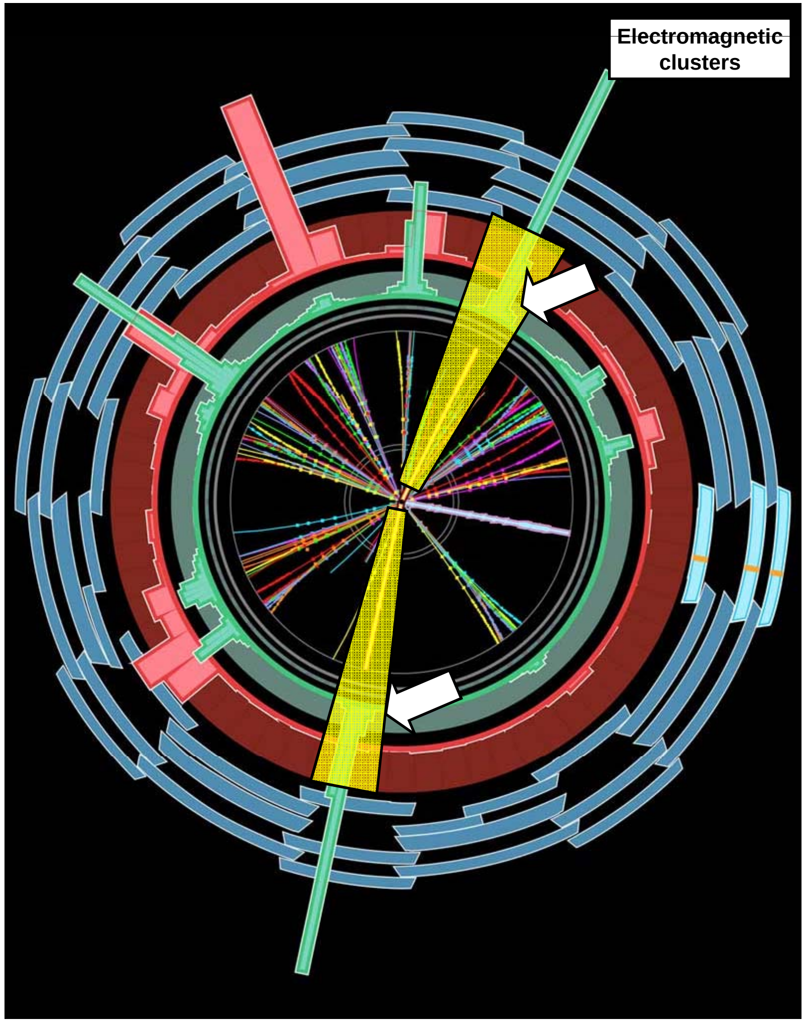
- Event Filter (EF):~1600 farm nodes(*)
  - Seeded by level 2
  - Potential full event access
  - Offline algorithms
  - Average execution time ~4 s(*)
  - Output rate up to ~200 Hz

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



Selection method

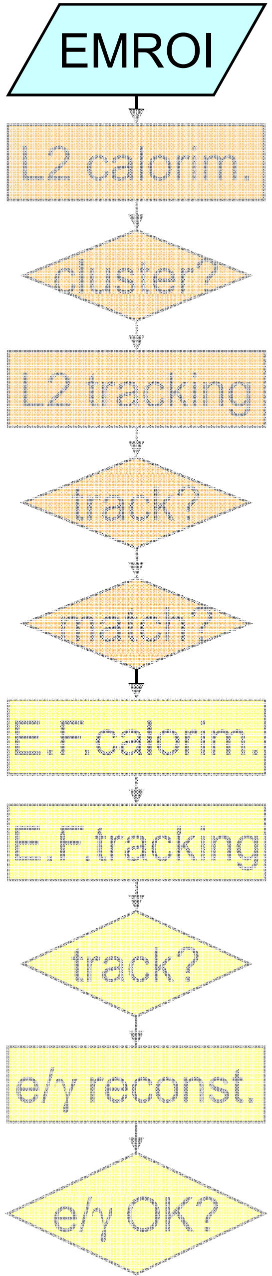
Event rejection possible at each step



Level1 **Region of Interest** is found and position in EM calorimeter is passed to Level 2

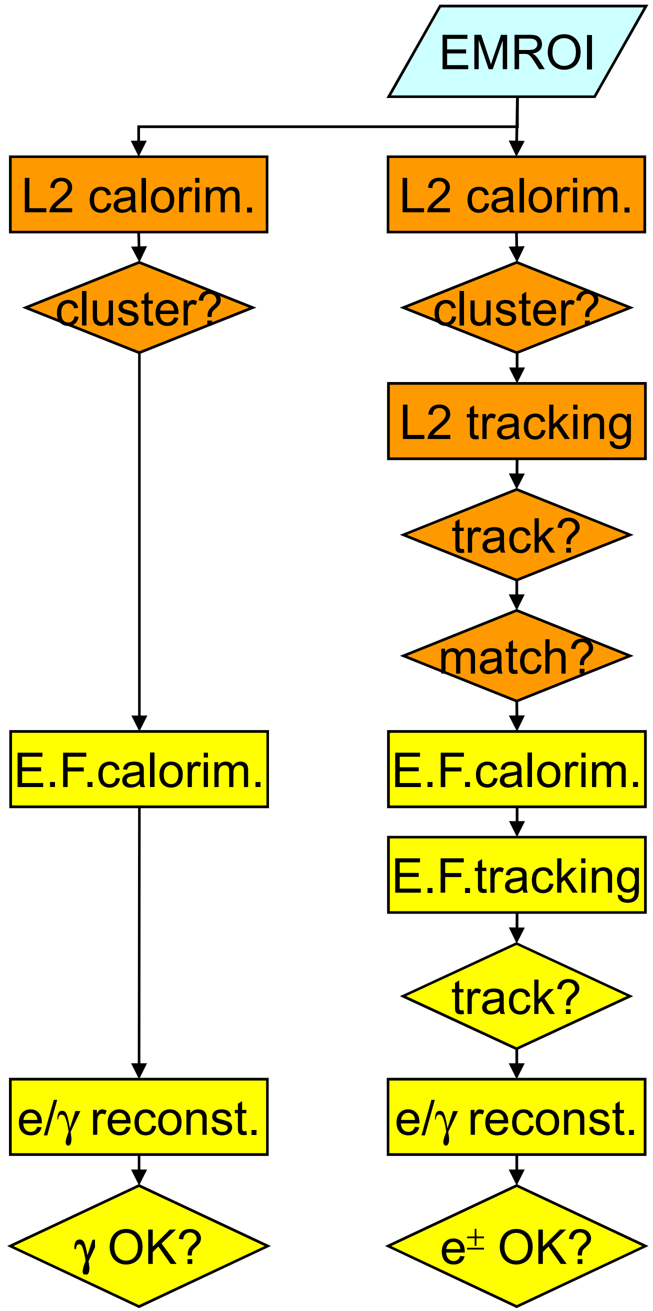
Level 2 seeded by Level 1
Fast reconstruction algorithms
Reconstruction within RoI

Ev.Filter seeded by Level 2
Offline reconstruction algorithms
Refined alignment and calibration



Steering

- Algorithm execution managed by Steering
  - Based on static trigger configuration
  - And dynamic event data (RoIs, thresholds)
- Step-wise processing and early rejection
  - Chains stopped as soon as a step fails
  - Reconstruction step done only if earlier step successful
  - Event passes if at least one chain is successful
- Prescale (1 in N successful events allowed to pass) applied at end of each level
- Specialized algorithm classes for all situations
  - Topological: e.g. 2 μ with $m_{\mu\mu} \sim m_Z$
  - Multi-objects: e.g. 4-jet trigger, etc…...



Trigger Strategy for Initial Running

Trigger algorithms

- High-Level Trigger algorithms organised in groups ("slices"):
  - Minimum bias, e/γ, τ, μ, jets, B physics, B tagging, E_T^{miss}, cosmics, plus combined-slice algorithms
- For commissioning
  - Cosmics slice used to exercise trigger – already started!
- For initial running:
  - Crucial to have minimum bias, e/γ, τ, μ, jets
  - B physics will take advantage of initial low-lumi conditions (not bandwidth-critical)
    - Lower event rate allow low transverse momentum thresholds needed for B physics
  - E_T^{miss} and B-jet tagging will require significant understanding of the detector
- Will need to understand trigger efficiencies and rates using real data
  - Zero bias triggers (passthrough)
  - Minimum bias:
    - Coincidence in scintillators placed in front of calo.
    - Counting inner-detector hits
  - Prescaled loose triggers
  - "Tag-and-probe" method, etc

1. Select good offline $Z \to \mu\mu/ee$
2. Randomly select "**tag**" lepton; if triggered, use second lepton as "**probe**"
3. ε = #(triggered probes)/#(all)

Trigger strategy for initial running

- Major effort ongoing to design a complete trigger list ("menu") for initial running
  - Commissioning of detector and trigger; early physics
  - Start with $\mathcal{L}=10^{31}\ cm^{-2}s^{-1}$ benchmark and scale accordingly

- Many sources of uncertainty:
  - Background rate (dijet cross section uncertainty up to factor ~2)
  - Beam-related backgrounds
  - New detector: alignment, calibration, noise, Level 1 performance (calo isolation?), etc
  - Event occupancy

- Must be conservative and be prepared to face much higher rates than expected

- Need many "handles" to understand the trigger:
  - Many low-threshold, prescaled triggers, several High Level triggers will run in "pass-through" mode (take the event even if trigger rejects it)
  - Monitoring framework (embedded in algorithms, flexible and with small overheads)
  - Redundant triggers
    - e.g. minimum bias selection with inner detector and with min.bias scintillators

- Expect the menu to evolve rapidly, especially once it faces real data

Status

- Trigger information routinely available in simulated data
  - Trigger decision and reconstructed objects easily accessible in simulated data
  - Generated much work and feedback from physics groups

- Trigger decision can be re-played with different thresholds on already reconstructed data: important for optimisation of selection

- Tools being developed for trigger optimisation
  - Estimate efficiency, rate and overlaps
  - Need to be able to react quickly to changing luminosity conditions

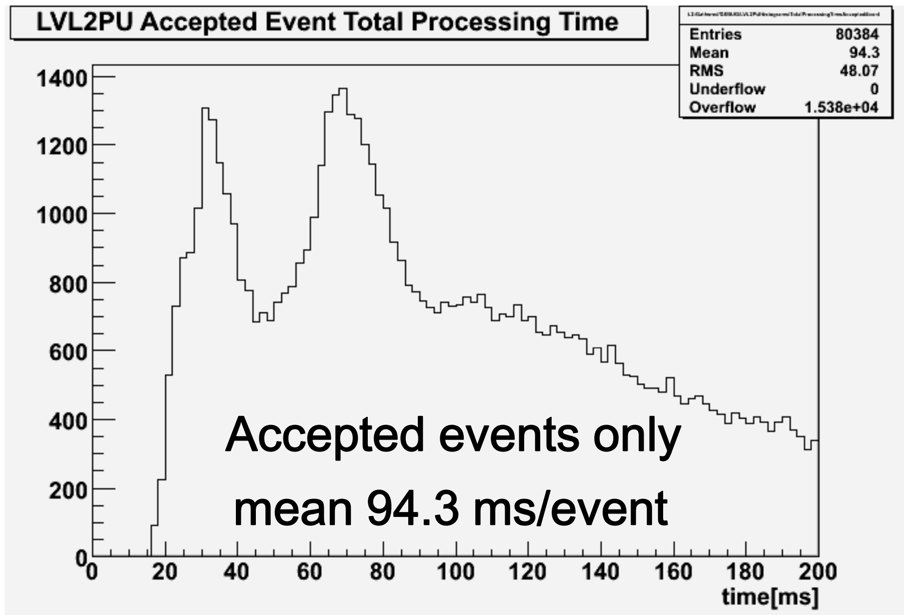
- A draft menu exists with some 90 triggers
  - Much work is under way to optimise it and test it against the expected conditions

- Rates, efficiencies and overlap between selections being studied for the menu
  - Including misaligned detector in simulation
  - Including overlapped events per bunch crossing
  - Including natural cavern radiation (for muons)

High-Level Trigger Commissioning

Technical runs

- A subset of the final High-Level Trigger CPU farm and DAQ system were exercised in "technical runs"
- Simulated (Level 1 triggered) Monte Carlo events in raw data format preloaded into DAQ readout buffers and distributed to farm nodes
- Realistic trigger list used (e/γ, jets, τ, B physics, E_T^{miss}, cosmics)
  - HLT algorithms, steering, monitoring infrastructure, configuration database
- Measure/exercise:
  - Event latencies
  - Algorithm execution time
  - Monitoring framework
  - Configuration database
  - Network configuration
  - Run-control

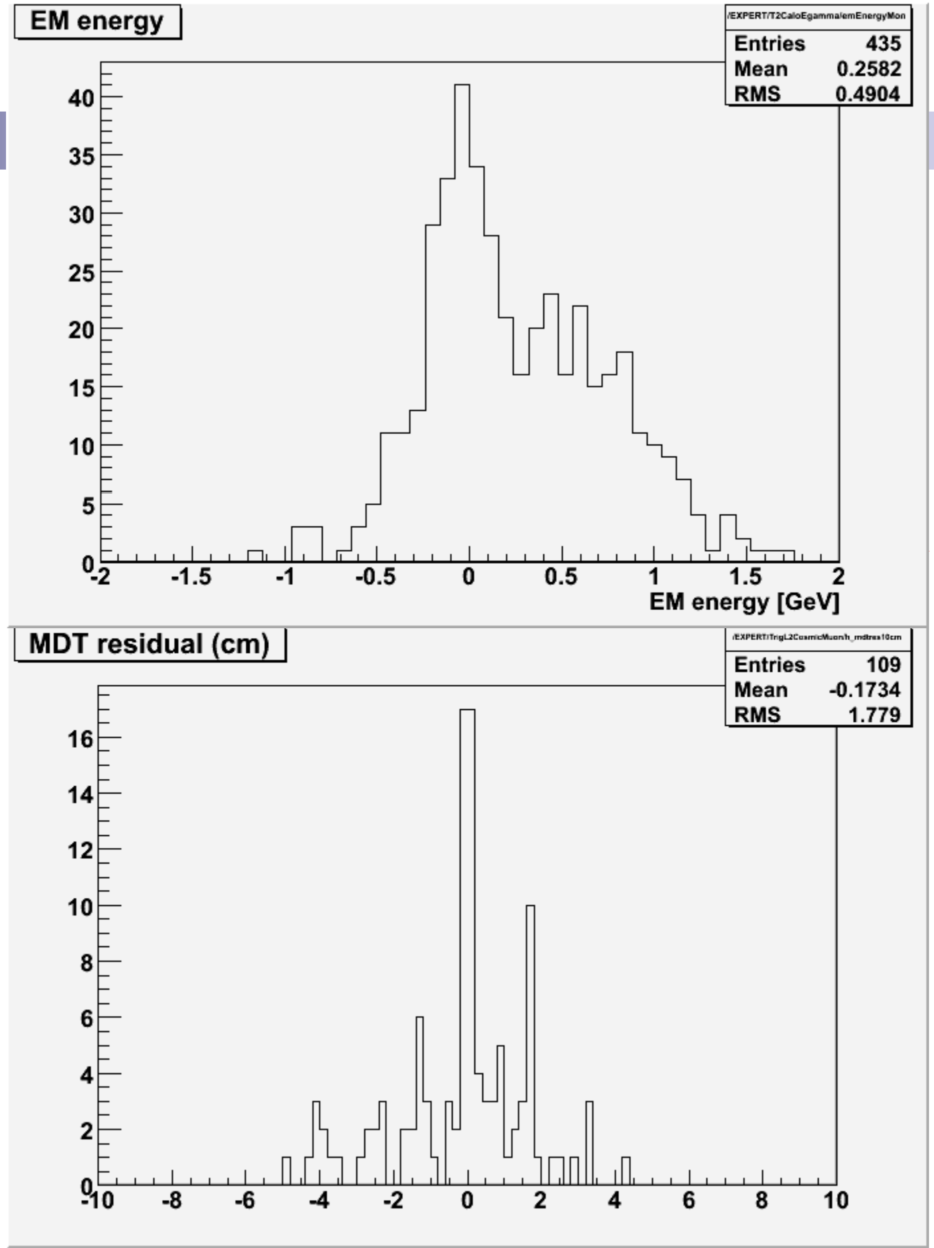


Data: 40% W/Z + 60% di-jets

Cosmics runs

- A section of the detector was used in cosmics runs (see previous talk) including:
  - Muon spectrometer
  - Tile (hadronic) calorimeter
  - LAr (electromagnetic) calorimeter
  - Inner detector

- The High-level was exercised successfully on real data in test cosmic runs.



Conclusions and outlook

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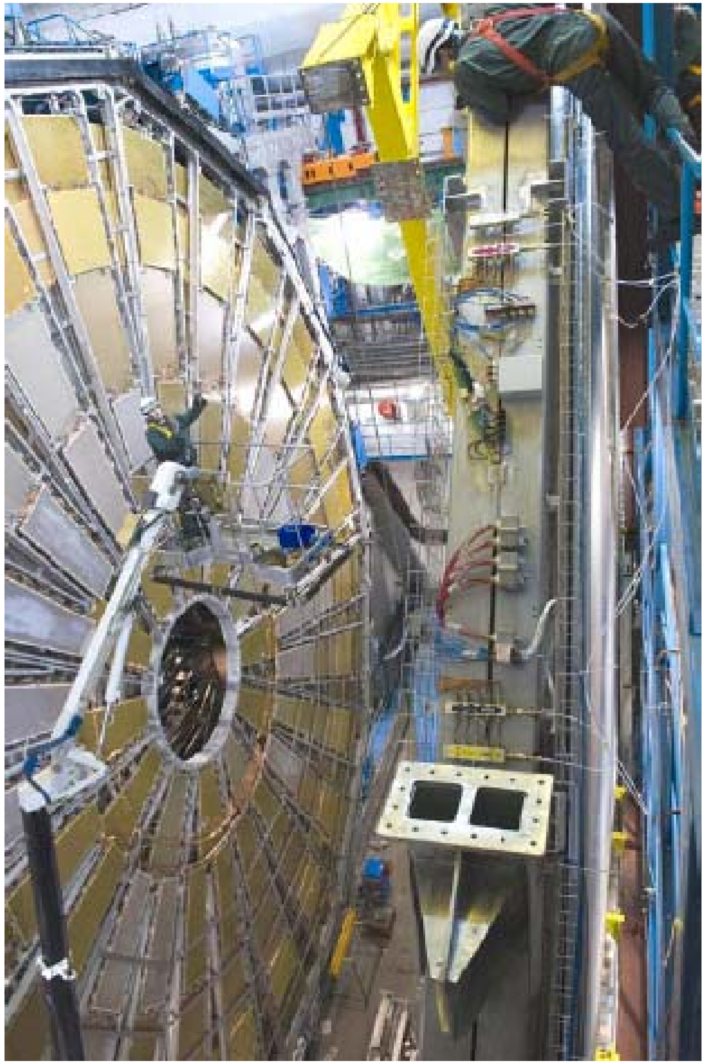
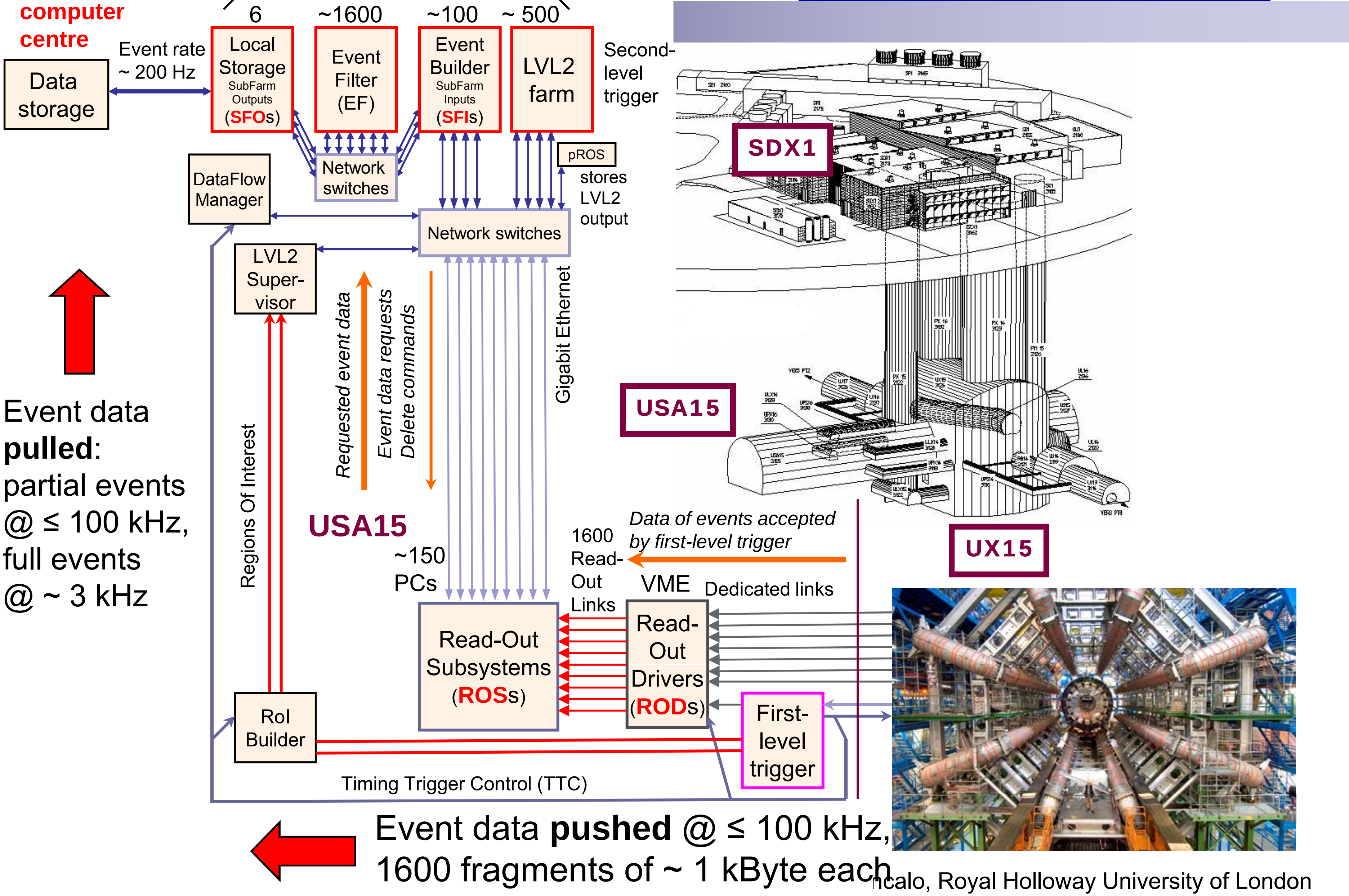


- The ATLAS High-Level Trigger is getting ready to face LHC data
- The final High-Level Trigger system was successfully exercised in technical runs on simulated data and was shown to be stable
- High-Level Trigger algorithms and machines took part in cosmics test runs
- Trigger information now routinely available in simulated data
  - Used for trigger optimisation
- Looking forward to triggering on LHC data next year!

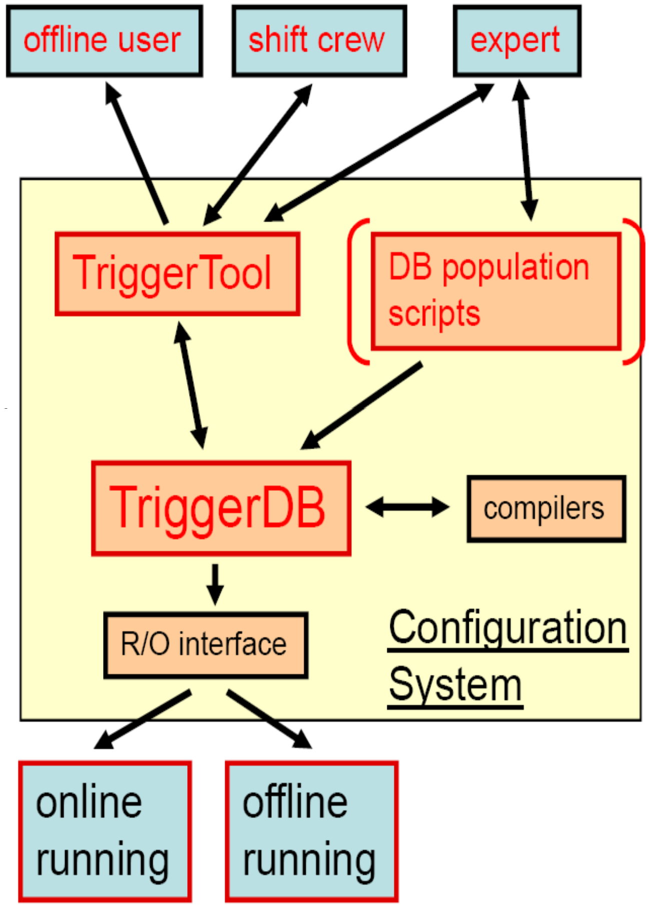
Backup slides

Trigger / DAQ architecture

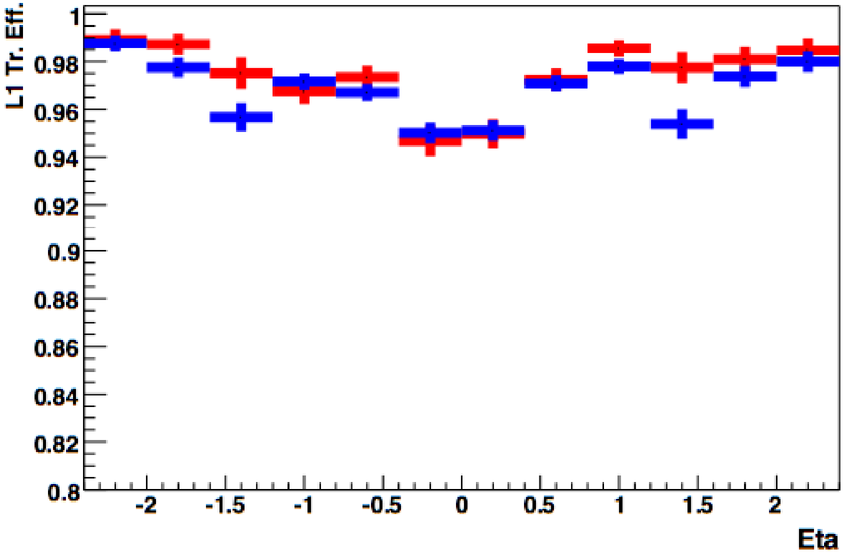


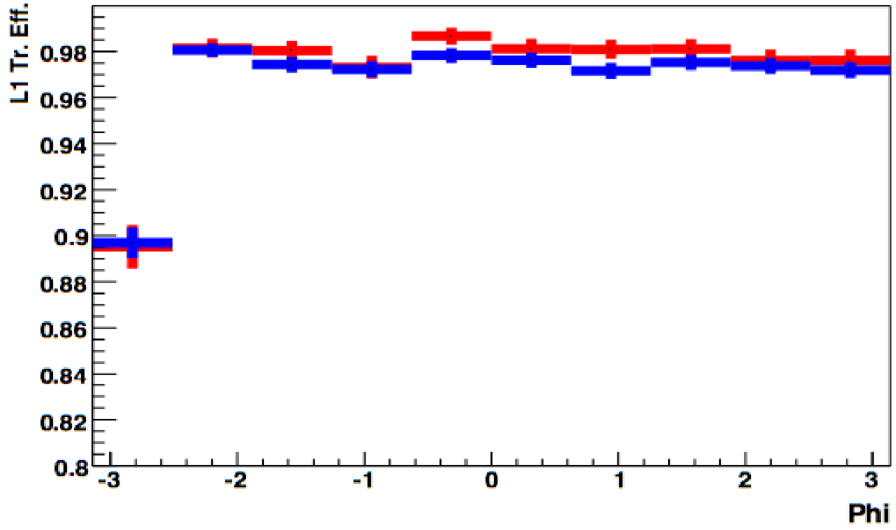
Configuration

- Trigger configuration:
  - Active triggers
  - Their parameters
  - Prescale factors
  - Passthrough fractions
  - Consistent over three trigger levels
- Needed for:
  - Online running
  - Event simulation
  - Offline analysis
- Relational Database (TriggerDB) for online running
  - User interface (TriggerTool)
  - Browse trigger list (menu) through key
  - Read and write menu into XML format
  - Menu consistency checks
- After run, configuration becomes conditions data (Conditions Database)
  - For use in simulation & analysis

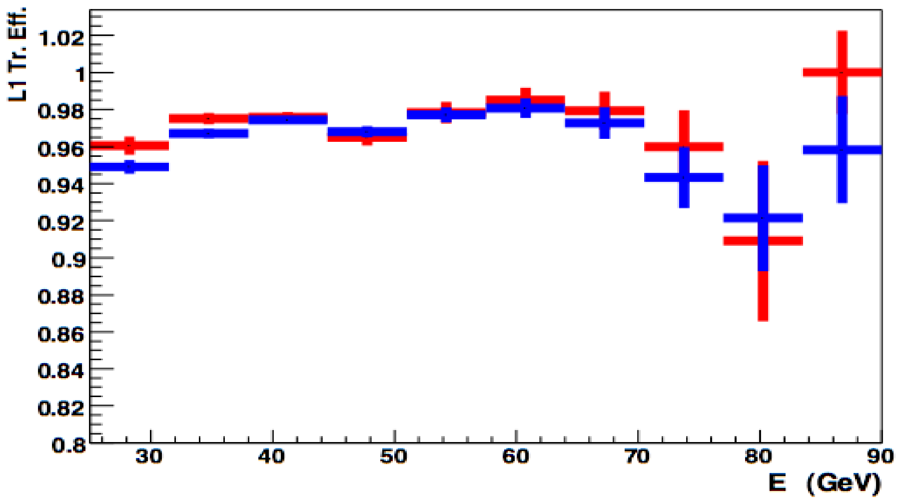


Single-e Tr. Eff. (from $Z \rightarrow e^+e^-$) as a function of η, ϕ and E_T





Misaligned Geometry



Wrt. offline:

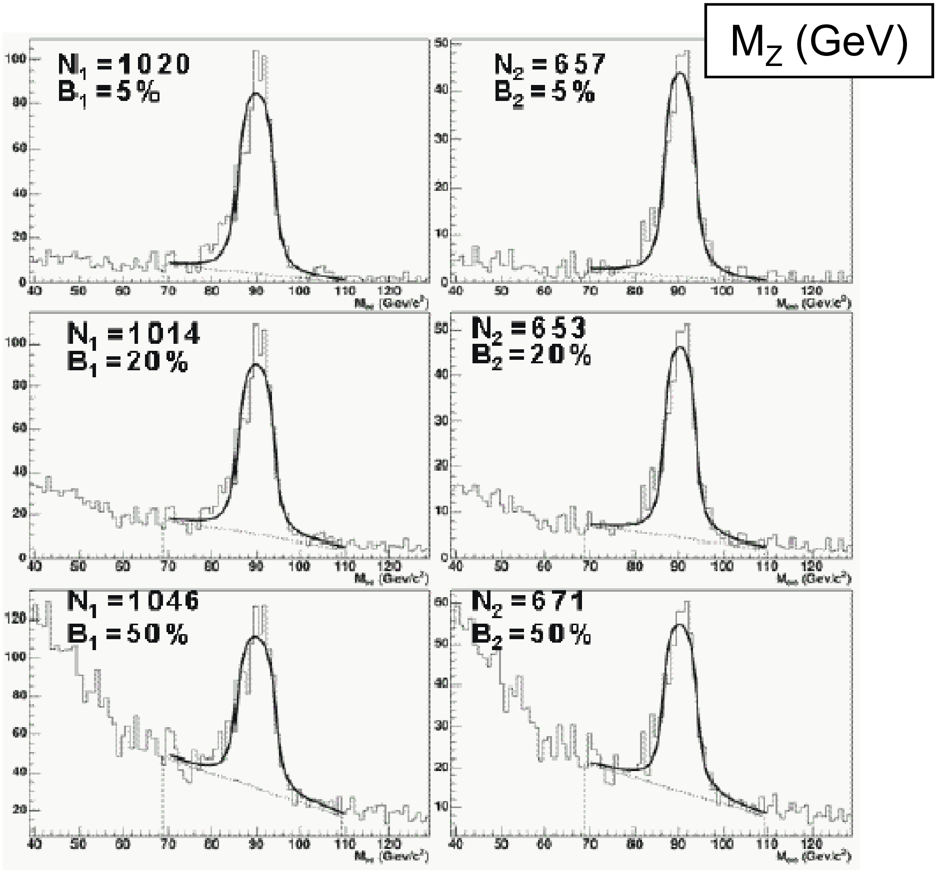
- Loose electron
- Tight electron

Trigger efficiency from data

- Electron trigger efficiency from real $Z \to e^+e^-$ data:
  1. Tag Z events with single electron trigger (e.g. e25i)
  2. Count events with a second electron (2e25i) and

     $m_{ee} \cong m_Z$

- No dependence found on background level (5%, 20%, 50% tried)
- ~3% statistical uncertainty after 30 mins at initial luminosity
- Small estimated systematic uncertainty



Method	$Z \to e^+e^-$	counting
Level 2 efficiency	87.0 %	87.0 %

Trigger	p_T threshold(*)	Obs
Electron	5,10,15,	Prescale
Electron	20,25,100	No presc
Di-electron	5,10	Prescale
Di-electron	15	No presc
Photon	10,15,20	Prescale
Photon	20	No presc
Di-photon	10	Prescale
Di-photon	20	No presc
Jets	5,10,18,23,35,42,70	Prescale
Jets	100	No presc
3 Jets	10,18	B-tag
4 Jets	10, 18	B-tag
4 Jets	23	Express
τ	10, 15, 20, 35	
Di- τ	10+15,10+20,10+25	
Muon	4, 6, 10, 11, 15, 20, 40	Muon spectr.
Muon	4, 6, 10, 11, 15, 20, 40	ID+Muon
Di-muon	4, 6, 10, 15, 20	Passtthr.
ΣE_T	100, 200, 304	prescale
ΣE_T	380	No presc

Trigger	p_T threshold(*)	Obs
ΣE_T (jets)	?	?
E_T^{miss}	12, 20, 24, 32, 36, 44	Prescale
E_T^{miss}	52, 72	No presc
$J/\Psi \rightarrow ee$	Topological	B-phys
$\mu\ \mu$	4	B-phys
$J/\Psi \rightarrow \mu\ \mu$	Topological	B-phys
BsDsPhiPi	Topological	B-phys
$B\gamma X$		B-phys
e + E_T^{miss}	18+12	Prescale
μ + E_T^{miss}	15+12	No presc
Jet + E_T^{miss}	20+30	No presc
2 Jets + E_T^{miss}	42+30	No presc
Jet+ E_T^{miss} +e	42+32+15	No presc
Jet+ E_T^{miss} + μ	42+32+15	No presc
4 Jet + e	23+15	No presc
4 Jet + μ	23+15	No presc
τ + E_T^{miss}	15+32,25+32, 35+20,35+32	
τ + e	10+10	Express
τ + μ	10+6	Express
2 τ + e	10+10	Express

L2PU Timing for Electron Run March