The ATLAS Trigger System: Ready for Run-2

Yu Nakahama (KEK/CERN)
for the ATLAS collaboration

CHEP 2015
Okinawa, April 13-17, 2015

Introduction

- The ATLAS trigger system operated successfully in Run-1.
  - Selected events online at $\sqrt{s}$ up to 8 TeV between 2009 and 2013
  - with high efficiencies for a wide range of physics processes in ATLAS
- In Run-2, trigger rates are expected to increase by a factor of ~5.

Period: year	Bunch-spacing	$\sqrt{s}$	Luminosity	Pileup μ_{peak}
Run-1: 2012	50 ns	8 TeV	~8e33	40 (8e33)
Run-2: 2015-2018	25 ns	13 TeV	1-2e34	25-50 (1e34)

  - A factor of ~2 due to energy increase (higher for high p_T jets)
  - A factor of 2-3 due to luminosity
- In this talk, the upgrades to the ATLAS trigger system for Run-2 are reviewed.
  - These improvements help reduce trigger rates to acceptable levels, while maintaining or even improving efficiencies in the challenging conditions.
  - These are the result of the hard work of hundreds of people over the last two years.

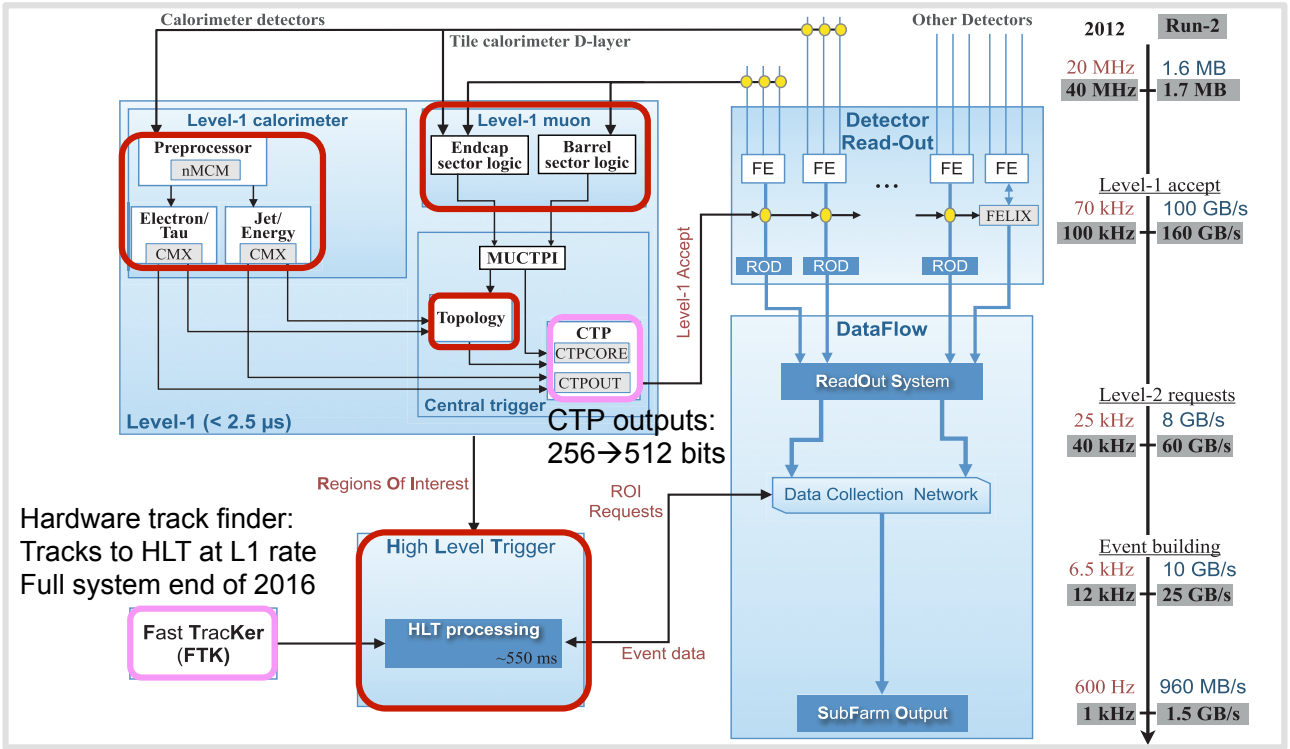
New trigger features in Run-2

- Two staged trigger system (was three-staged in Run-1).

Stage	Functionalities	Components	Latency	Rate reduction
Level-1 (L1)	Fast custom-made electronics finds regions of interests using Calorimeter/ Muon data with coarse info	L1Calo, L1Muon, L1Topo, Central Trigger Processor	< 2.5 μs	40 MHz → 100 kHz
High-Level Trigger (HLT)	Fast algorithms in RoI, or offline-like ones with full-event info on PC farm	(FTK,) HLT farm	~0.2 s (average)	→ 1 kHz (average)

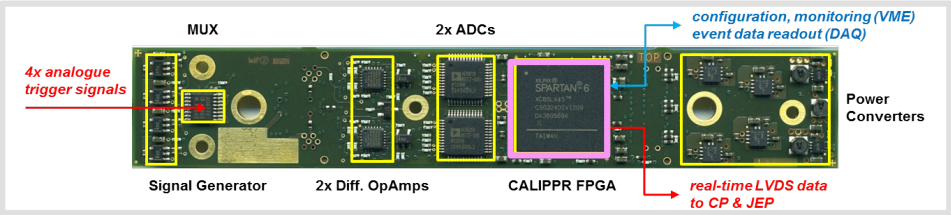
- Many new features in Run-2
  - This talk will focus on the ones in red.

See talk on CTP by Julian Glatzer



L1 Calorimeter trigger

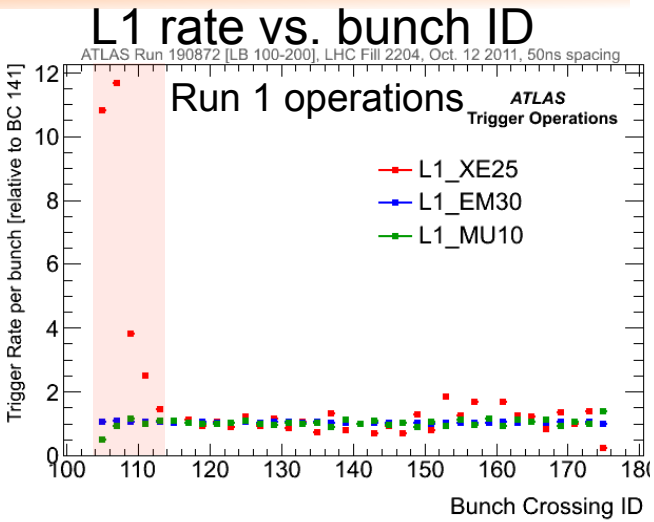
- In Run-1, L1 E_T^{miss} rates were severely affected by pile-up at start of bunch train.
  - Due to unbalanced overlapping of bipolar signal shapes in the EM calorimeter
- In Run-2, more flexible signal processing at new Multi-Chip Module

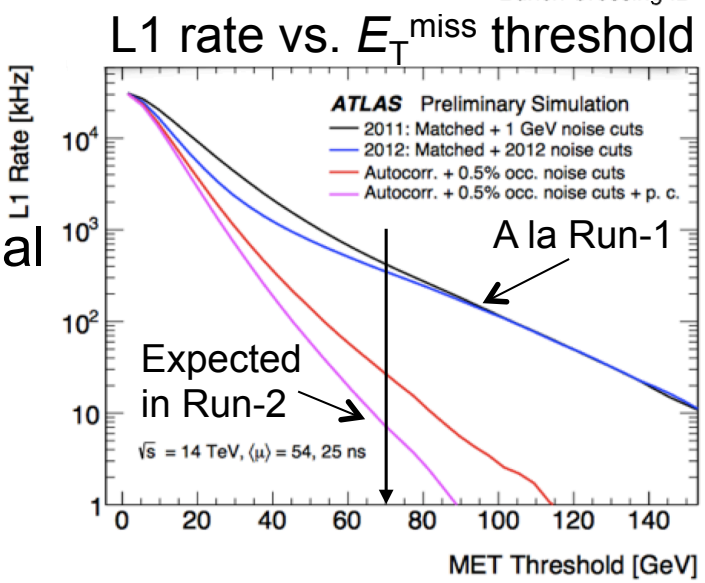


  - Dynamic pedestal subtraction based on global cell occupancy and in-bunch train positions

→ Huge reduction of E_T^{miss} rates

- More thresholds can be defined for more varieties of L1 combined triggers
  - Jets, forward jets: 8+4 → 25. EM, tau clusters: 8 → 16 each



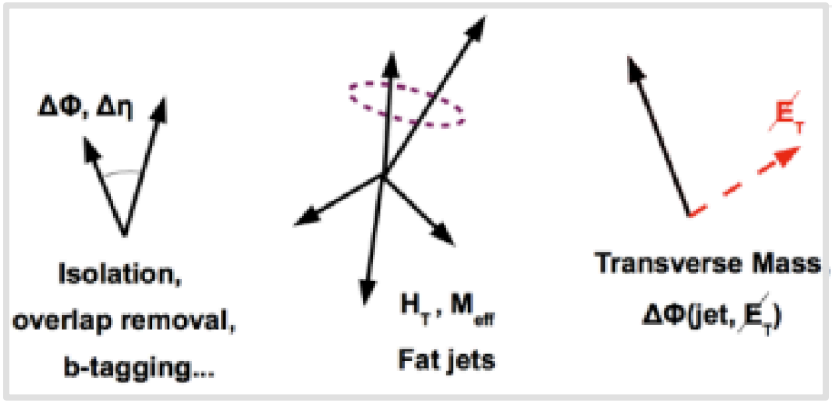


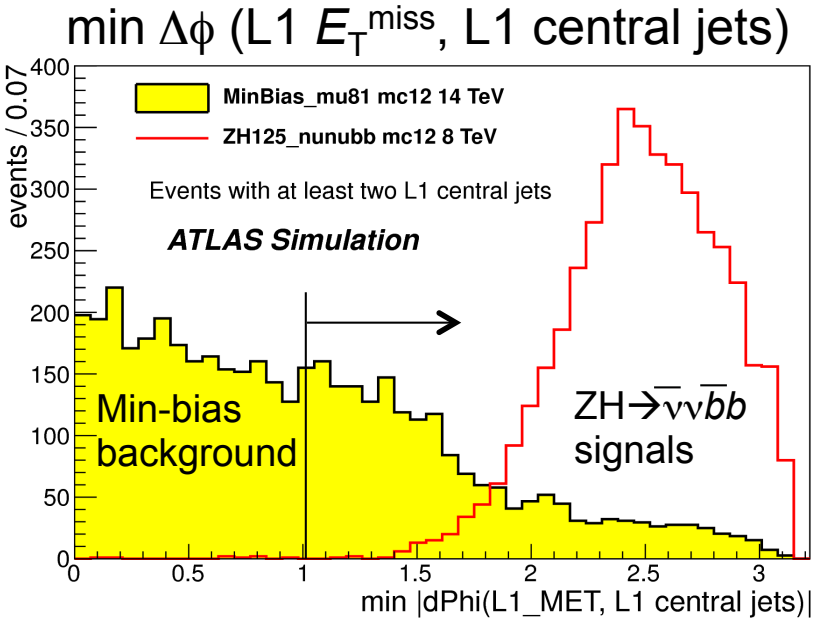
New L1 Topological trigger module

- In Run-2, event topological selections between L1 objects are used to keep low L1 thresholds.
  - Decisions on FPGA within L1 latency
  - Variety of algorithms (~15): e.g. angular separation, invariant mass, global quantities like H_T (sum of jet E_T)
  - Essential to final states with E_T^{miss}, jets and taus: e.g. for SM Higgs ZH→$\nu\nu bb$ and H→$\tau\tau$

→ For ZH→$\nu\nu bb$, loose selection to the smallest $\Delta\phi$ (L1 E_T^{miss}, L1 central jets). L1 E_T^{miss} threshold: 70 GeV → 50 GeV, while keeping efficiencies.

See talk by Eduard Simioni

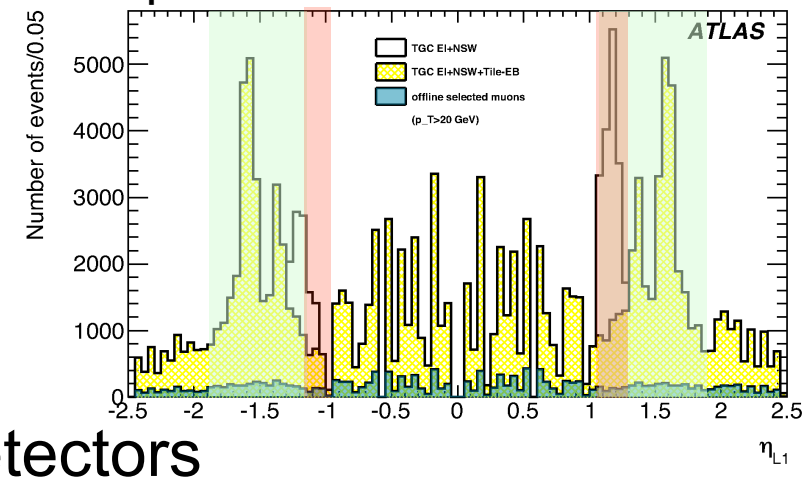




Improvements in the L1 Muon system

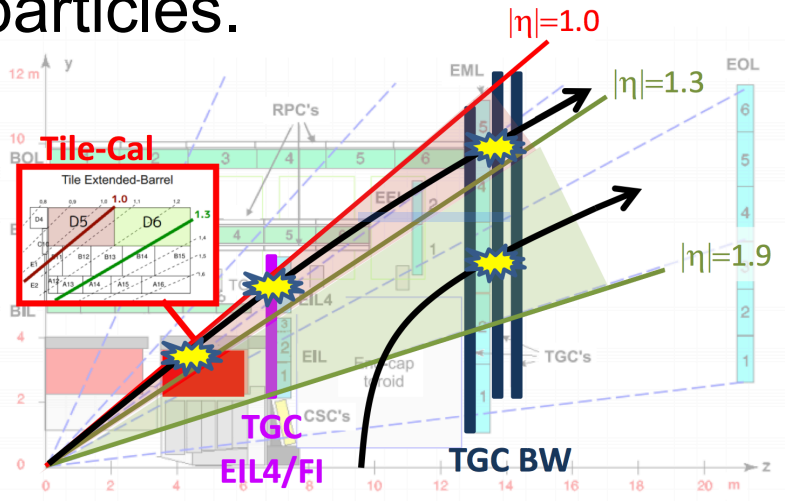
- In Run-1, L1 muon rates in the forward region were polluted by low-p_T charged particles (protons) from out of IP.
  - Significant rate increases at 25 ns

η distribution of L1 muons



- In Run-2, coincidences with inner detectors are used to clean up these charged particles.
  - With the inner muon chambers placed before the toroid
  - Further with the extended barrel region of the Tile Calorimeter

  → ~ 50 % rate reduction for L1 muons with p_T > 20 GeV, 1.0<|η|<1.9 at 25 ns

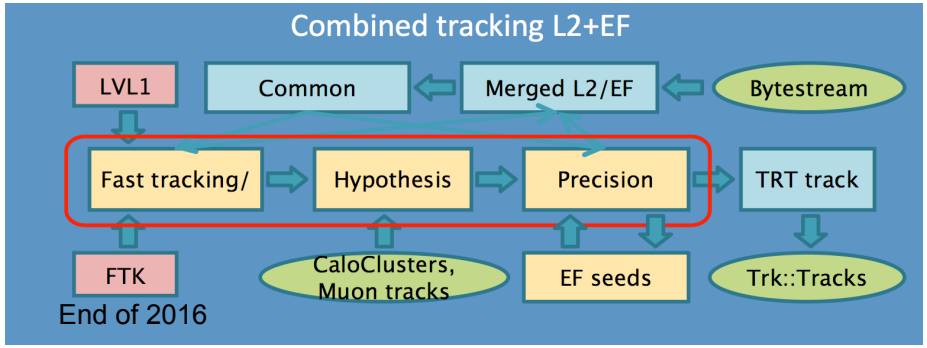


- Additional trigger chambers in the feet of the barrel region
  - 4 % larger acceptance for L1 muons

Improvements in the HLT system

- In Run-2, L2, Event Builder & EF farms are merged to a unique HLT farm for simplification and dynamic resource sharing.
  - BW bottlenecks from network were replaced by in-memory transfer.
  - Algorithms mainly reconstruct in region of interest, but can now also do more unseeded reconstruction for specific detectors (Calo, Muons).
  - New fast HLT algorithms with full-data access, closer to offline → Reduce rates in early stage against high pileup: e.g. offline-like tracking and clustering run straight after L1.

See talk on HLT algorithms by Carlo Schiavi



- Ready for increased bandwidth from the DAQ limits
  - L1 total rates: 70 kHz → 100 kHz
  - HLT output rates to storage: 600 Hz → 1~1.5 kHz (at peak luminosity)

See talk on data flow by Reiner Hauser

New trigger strategy in Run-2

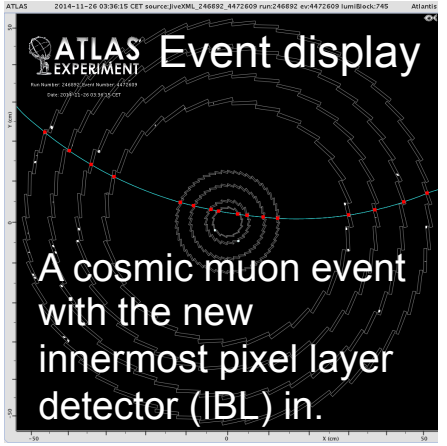
- Using these new features, trigger strategy for bandwidth allocation was developed to maximize physics coverage.
  - More flexible with more L1 items than in Run-1
  - Most bandwidth is given to generic triggers as in Run-1: e.g. inclusive single electron/muon triggers with thresholds of 25-30 GeV
  - More dedicated/multi-object triggers

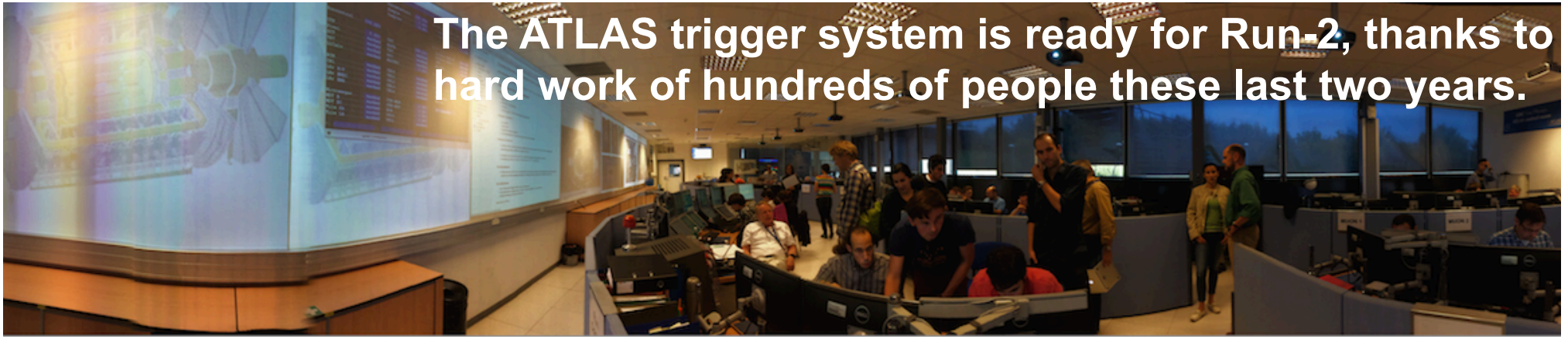
- A huge set of trigger selections was implemented.
  - ~300 types of selections at L1 and ~1000 types at HLT
  - Validation is ongoing both online and in MC simulation.

  → With these selections, no significant efficiency loss is expected in the planned physics programme of ATLAS Run-2, despite the challenging conditions.

Re-commissioning of the ATLAS trigger system

- Testing and debugging step by step in the control room with DAQ and the ATLAS detector for ~1 year. Achieved milestones.
  - Installation of new L1Calo/L1Muon/L1Topo/CTP
  - Intense integration tests of the HLT system
  - Data collection with L1 and HLT selections
  - Operation and monitoring tools functional. Operating the system by shift crews with on-call supports.





- Final commissioning is progressing well using the LHC beam towards a successful physics data-taking in Run-2.

Conclusions

- The ATLAS trigger system was upgraded to cope with harsh conditions in Run-2, while keeping good physics coverage.
  - Many new components or improvements
    - L1Calo, L1Muon, L1Topo processors to keep L1 thresholds low
    - Merged HLT farm for offline-like HLT selections to keep lower rates
  - Flexible trigger strategy for the increased bandwidth
    - No significant efficiency loss is expected in the planned physics programme of ATLAS Run-2.
  - Commissioning is progressing well towards imminent restart of the beam-data-taking. The ATLAS trigger system is ready for Run-2.

- Following the LHC future roadmap and physics programmes for higher luminosities, preparation to the Run-3 trigger upgrade has already started, mainly on L1 systems.