JOHANNES GUTENBERG UNIVERSITÄT MAINZ

JG|U

ATLAS EXPERIMENT http://atlas.ch

The ATLAS Level-1 Topological Trigger

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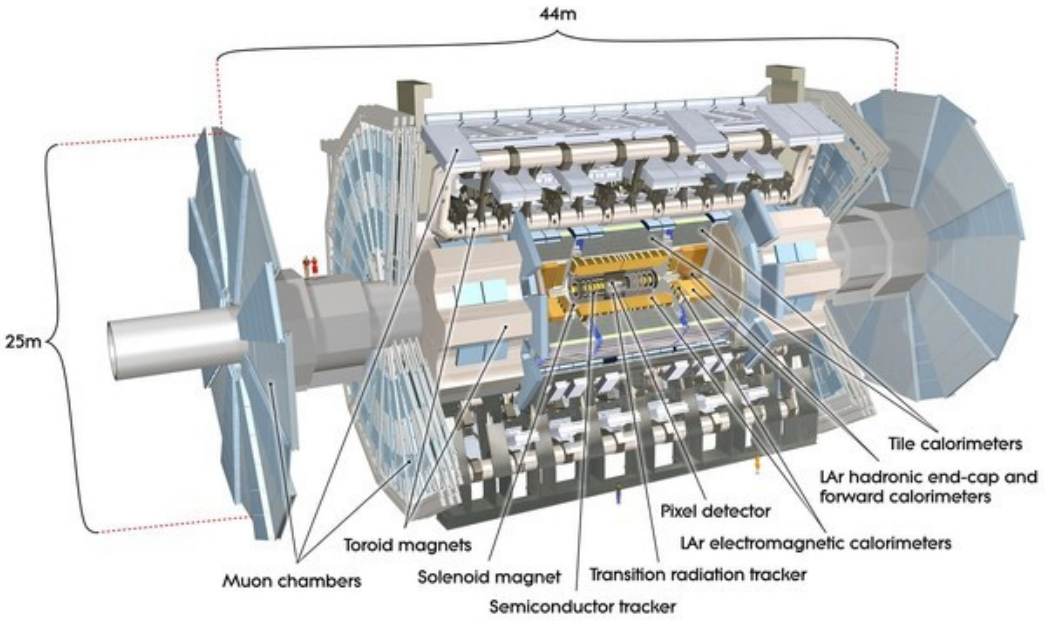
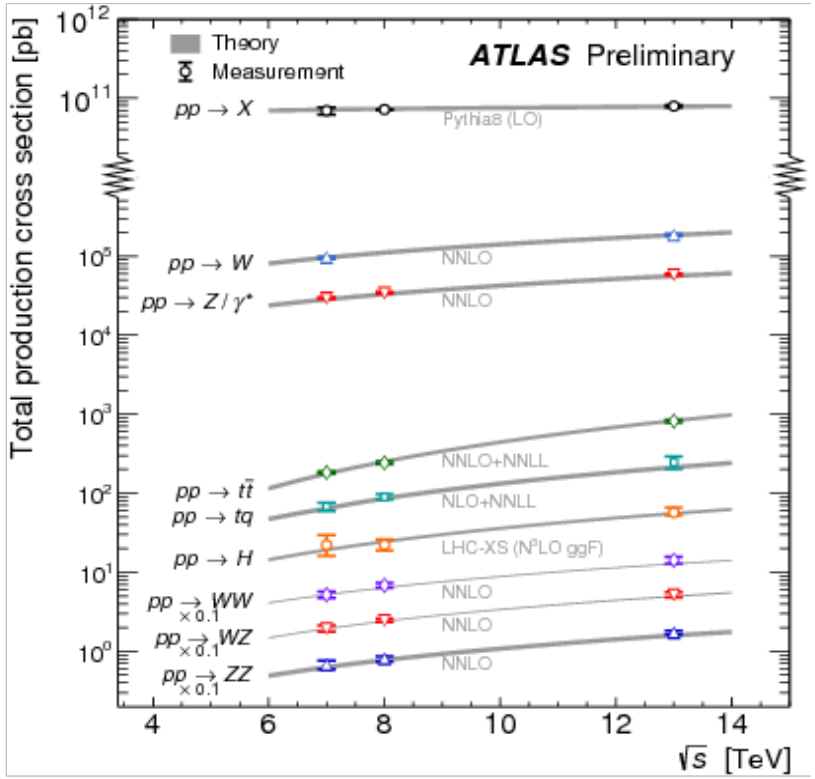
The ATLAS Detector @ LHC



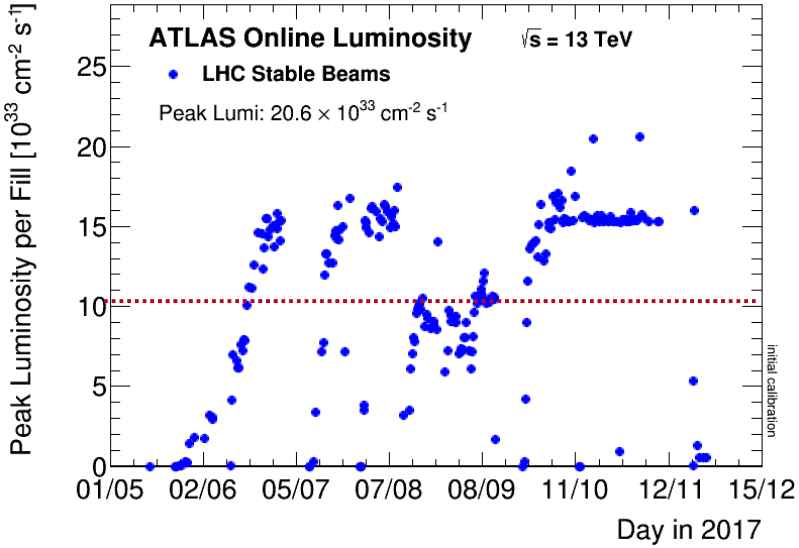
- High-precision silicon and straw-tube gaseous detector
- Fine granularity/longitudinal segmented calorimeter
- Air-core toroid muon spectrometer

Use elaborate trigger system and adjust continuously with harsher LHC conditions



LHC Luminosity Evolution

Exploit LHC's full potential through a staged upgrade program



Already operating at luminosity
higher than nominal 1x10^{34} cm^{-2}s^{-1}

7, 8 TeV
10^{27} cm^{-2}s^{-1} → 7x10^{33} cm^{-2}s^{-1}
~25 fb-1

13 TeV
0.5-2x10^{34} cm^{-2}s^{-1}
~150 fb-1

14 TeV
3x10^{34} cm^{-2}s^{-1}
~300 fb-1

14 TeV
7.5x10^{34} cm^{-2}s^{-1}
~3000 fb-1

Phase-0

Phase-1

Phase-2

Today

Detector is optimized for 1x10^{34} cm^{-2}s^{-1}

Run 1
2010-2012

Run 2
2015-2018

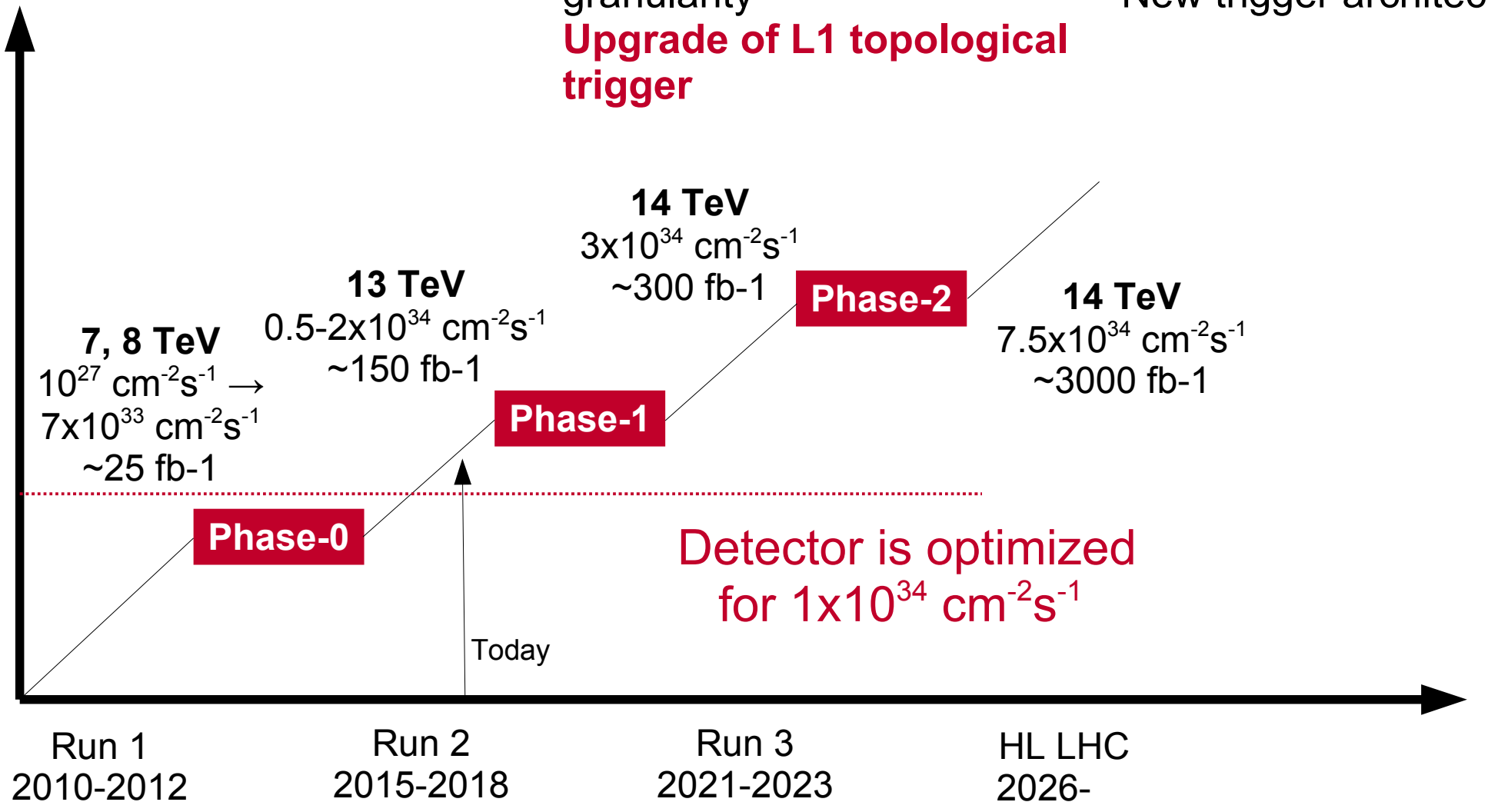
Run 3
2021-2023

HL LHC
2026-

Phase-0:
New inner pixel layer
New L1 topological trigger

Phase-1:
New forward muon detectors
Increase Level-1 calorimeter granularity
Upgrade of L1 topological trigger

Phase-2:
Most electronics replaced
New inner tracker
New trigger architecture



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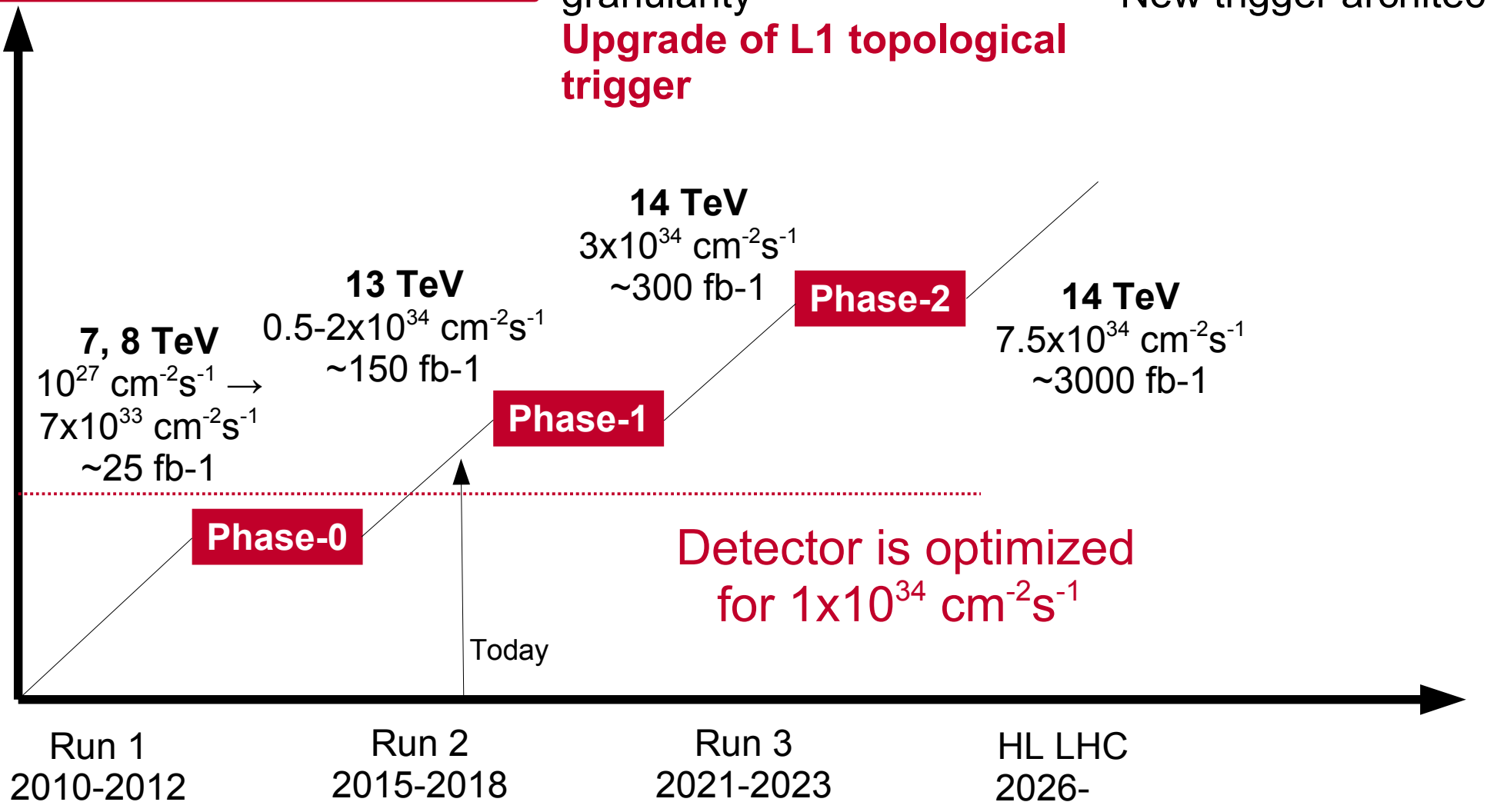
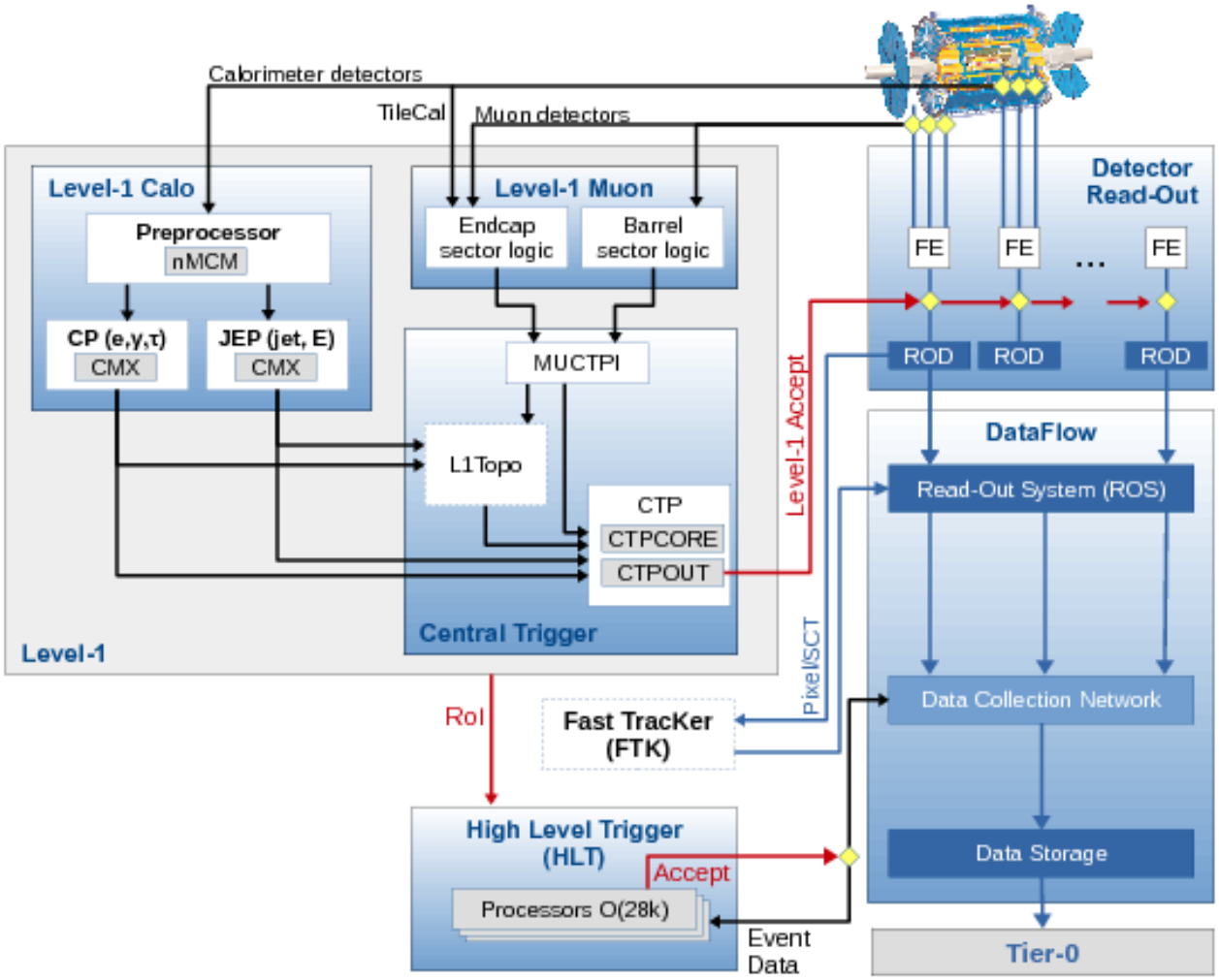


ATLAS Run-2 Trigger and DAQ System



Level-1 (L1):

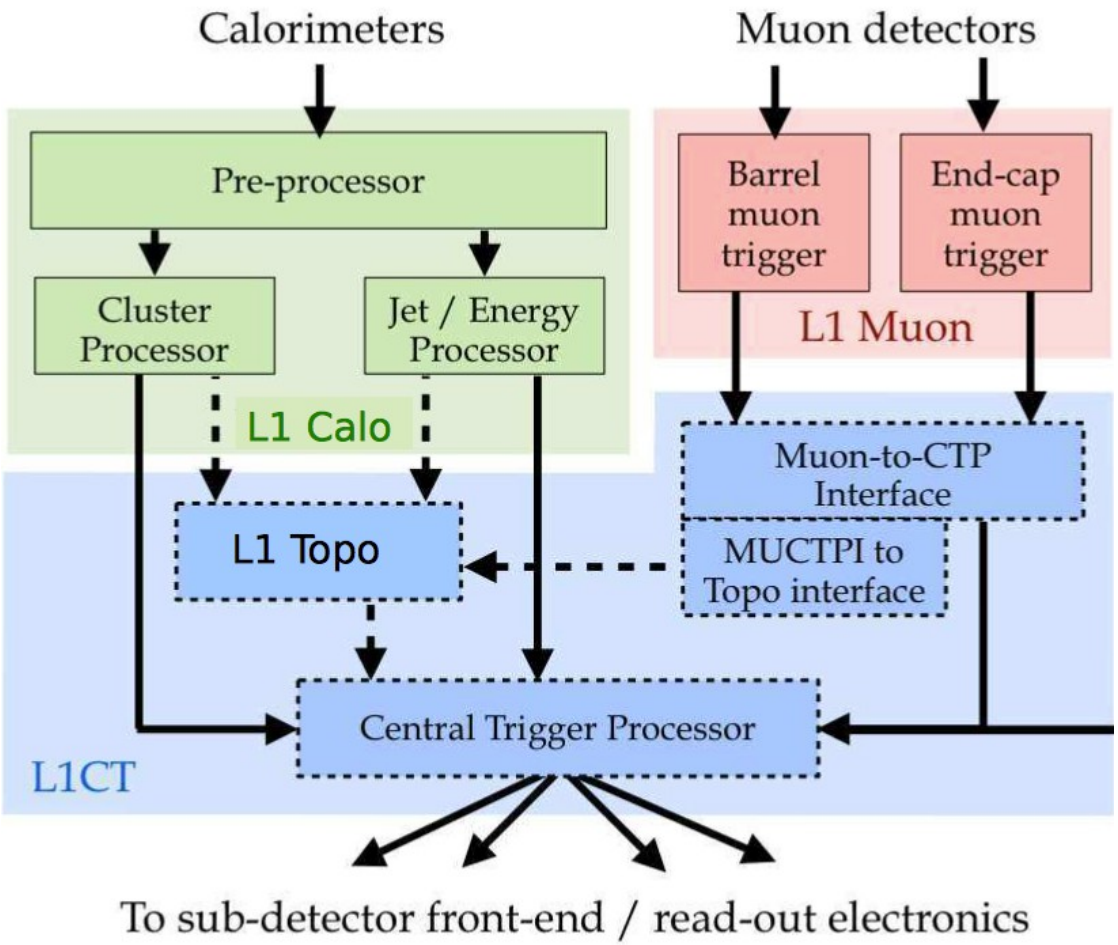
- hardware based
- find energetic clusters and muon segments
- Decision within 2.5 μs
- Output: 100 kHZ

Higher Level Trigger (HLT):

- software based
- find energetic electrons, muon, etc in Region of Interest
- Full detector information for some events
- Decision within 1 s
- Output: 1 kHZ (limited by storage/Tier0)

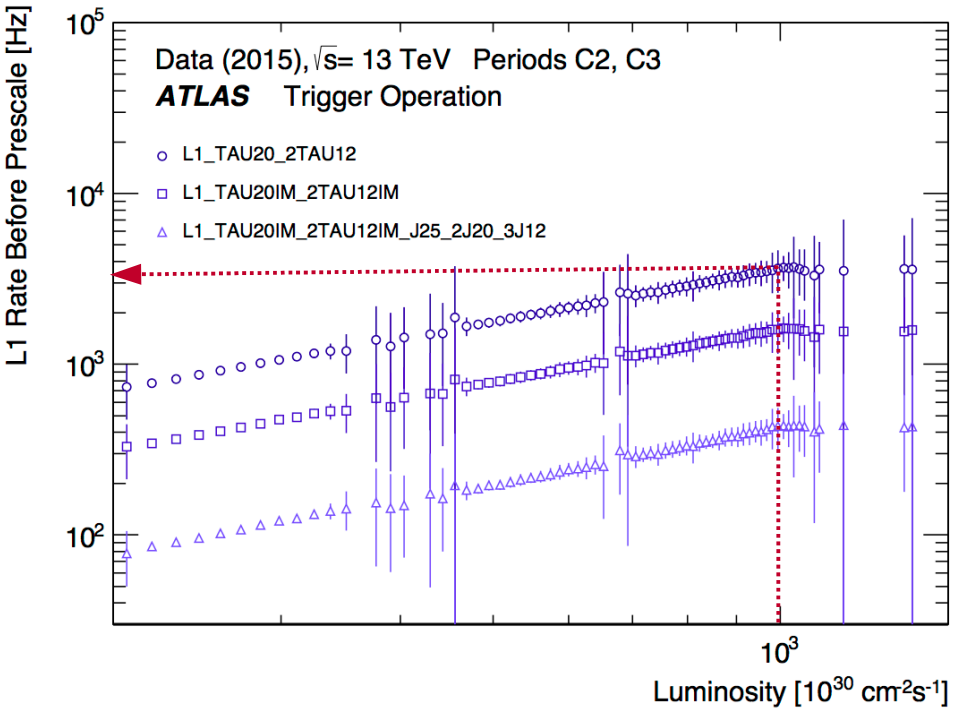
L1 in Run-1: based on ET and cluster counting
Operating at highest thresholds already

ATLAS Run-2 Level-1 Trigger

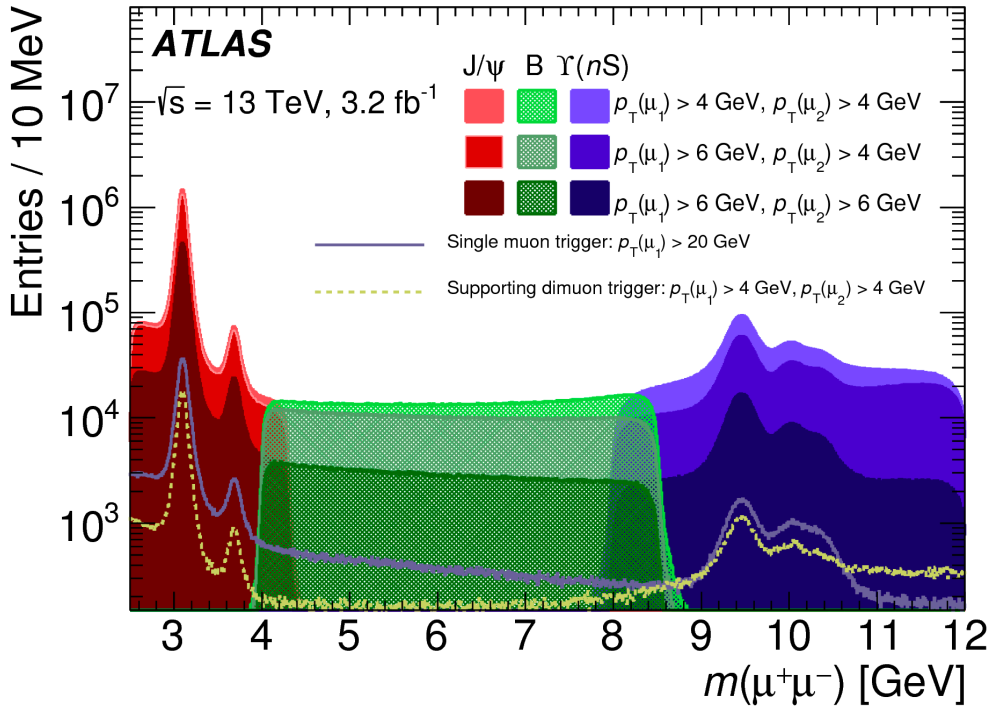


- L1 upgrades during LS1:
  - Electronics upgraded with new firmware
  - New custom-made electronics
- CMX: Common Merger eXtended
  - Provides Trigger Objects to L1Topo and multiplicities/thresholds to CTP
- MUCTPI to Topo Interface
  - New interface between L1Muon and L1Topo
- L1Topo: Level-1 Topological Trigger
  - Calculates event topological variables
  - Combines information from L1Calo and L1Muon systems

Current di-tau trigger already at maximum allowed rate



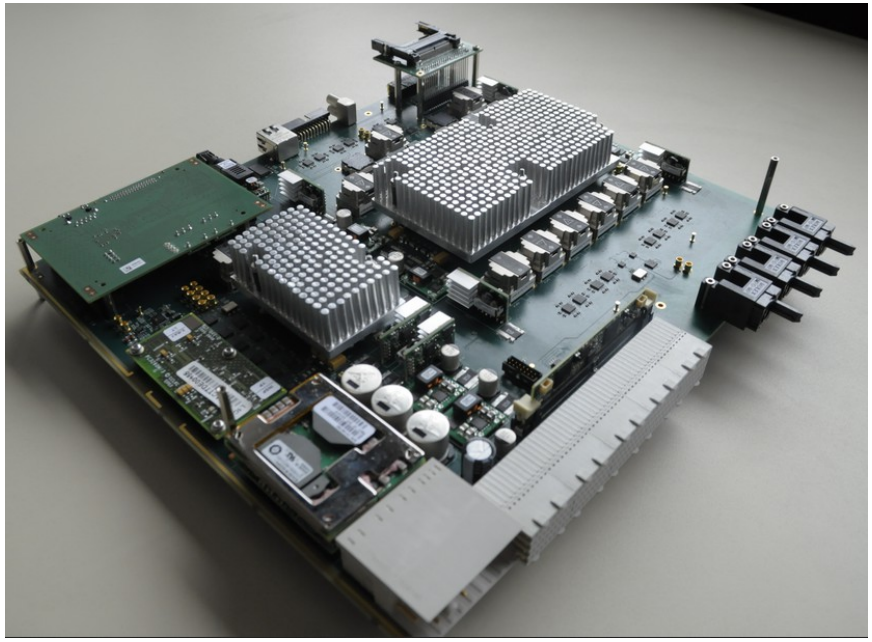
Not possible to keep B-physics program with conventional single or di-muon triggers



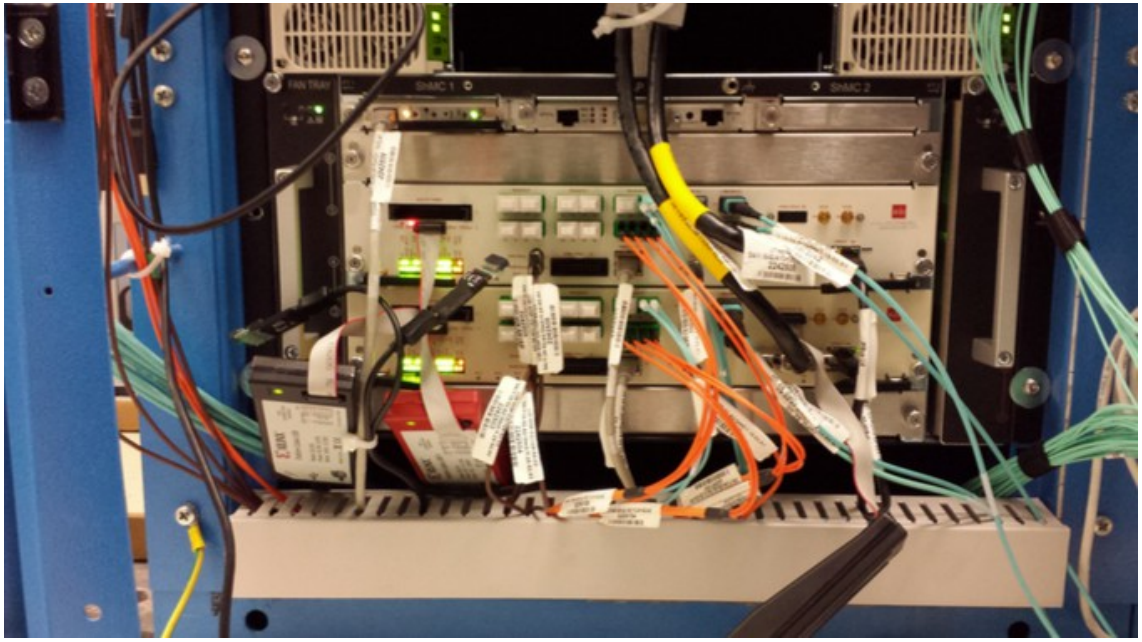
Need topological selection at L1

Level-1 Topological Trigger: Hardware

L1Topo module

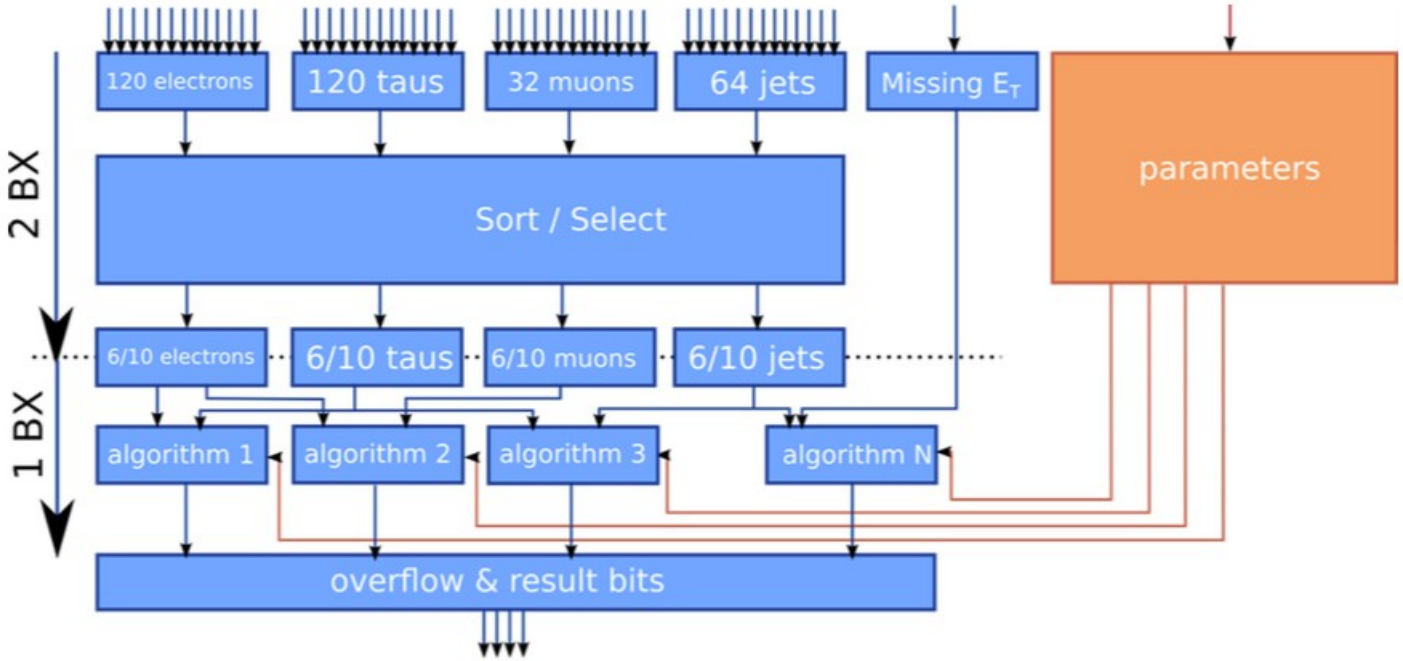


L1Topo placed in ATCA crate



- One AdvancedTCA 6U crate
- Two double-size processor modules
  - 2 Xilinx Virtex7 FPGAs per module for event processing
  - 80 multi-gigabit receivers per FPGA (6.4 Gb/s)
  - 1 Kintex7 FPGA per module for control and readout
  - 22 layers PCB
  - Processes 1 Tb/s with a latency budget of 150ns

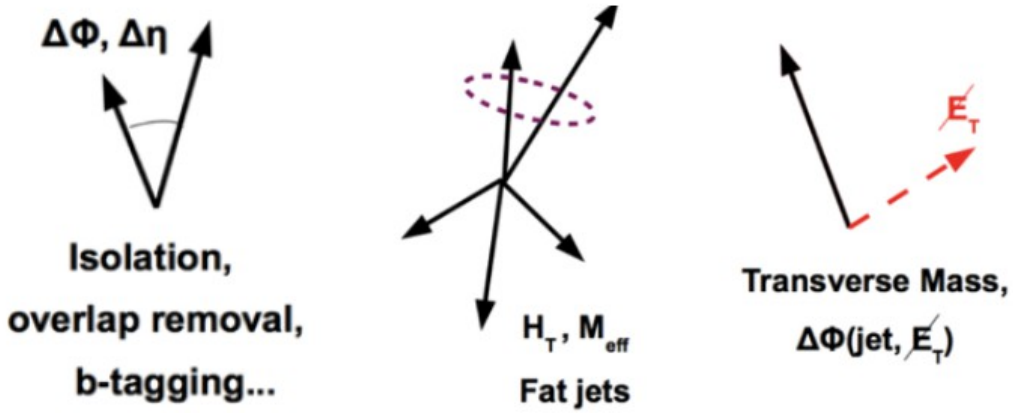
Level-1 Topological Trigger: Functionality



- Receives different types of Trigger Objects (TOBs):
  - Muons, 32 TOBs
  - Electrons, 120 TOBs
  - Taus, 120 TOBs
  - Jets, 64 TOBs
- Executes up to 128 algorithms in 75ns (VHDL)
  - Algorithms are configurable
- Provides trigger decisions to the Central Trigger Processor

Level-1 Topological Triggers in Run2

- Many possibilities of L1 topological selections:
  - Angular requirements
  - Event requirements
  - Mass requirements



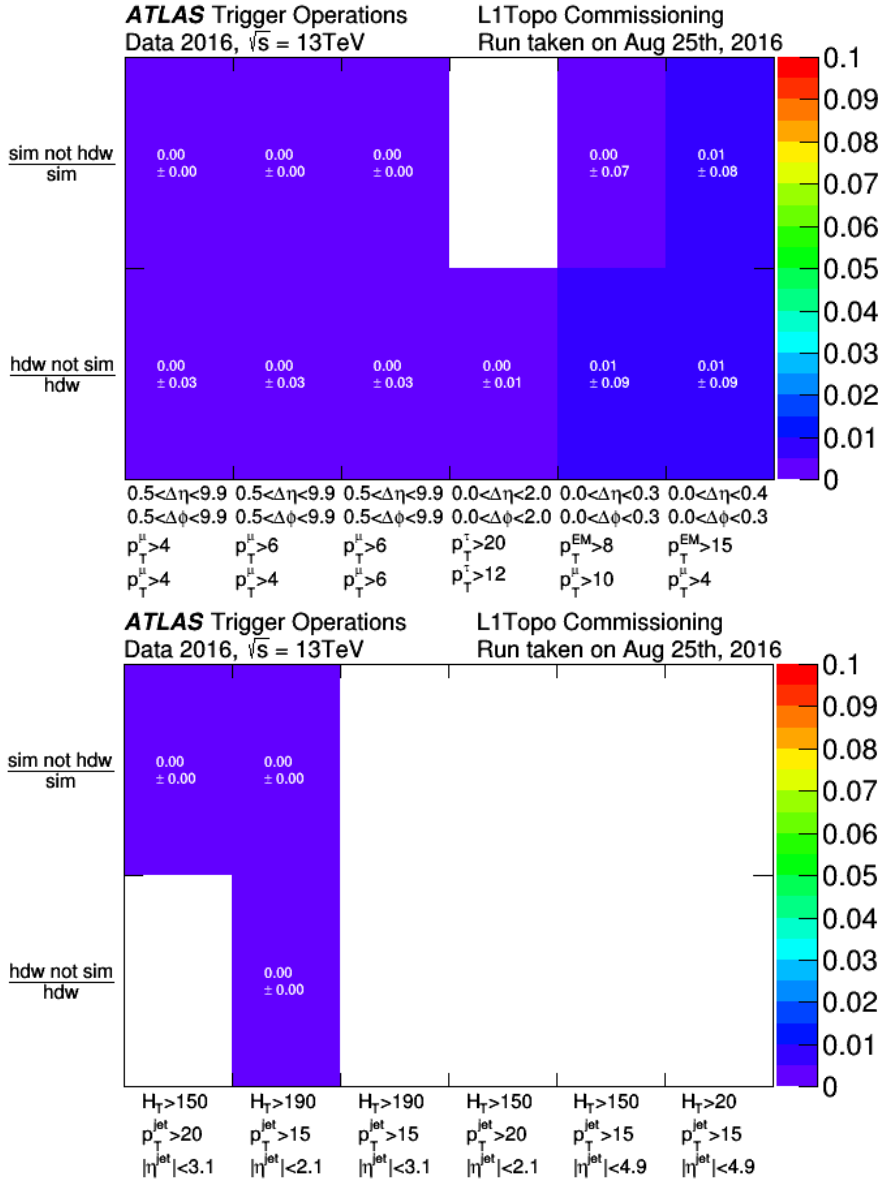
Physics channel target	Input objects	Algorithm
B-physics	muons	ΔR, mass
$H \rightarrow \tau\tau$	tau_had, muons, electrons	$\Delta\eta$, $\Delta\varphi$, mass
SUSY	missing E_T, jets	HT, min $\Delta\varphi$
$W \rightarrow e\nu$	electrons, jets, missing E_T	min $\Delta\varphi$, m_T
Long lived particles	late muons, missing E_T	muon in next bunch

Level-1 Topological Trigger: Commissioning

- Very complex firmware architecture and hardware design
- Standalone validation of firmware:
  - Low-Level simulation in VHDL
  - Processing well-defined input data through hardware via playback mechanism
- Online validation:
  - Hot tower setup for algorithm checks
  - Comparison to L1Topo simulation for each L1 accepted event

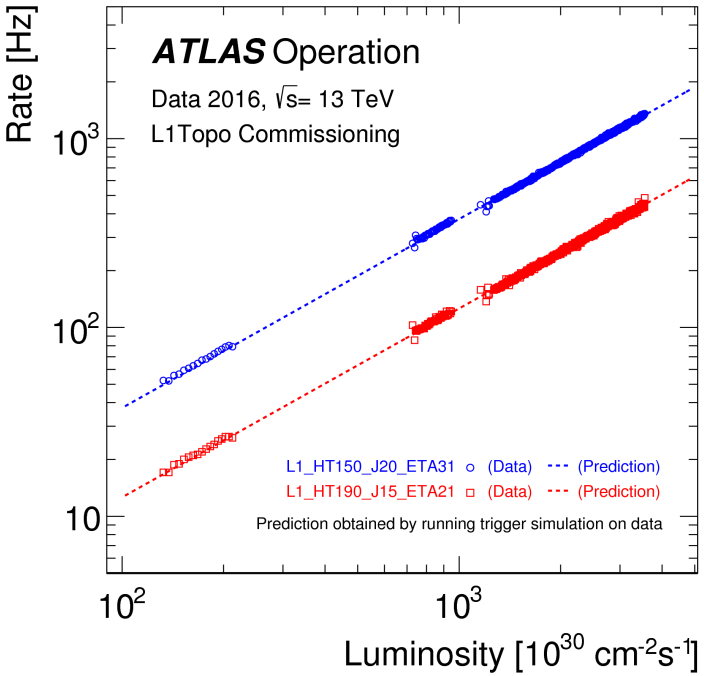
L1Topo system successfully commissioned in 2016

Fraction of discrepancies hdw-sim per L1Topo trigger

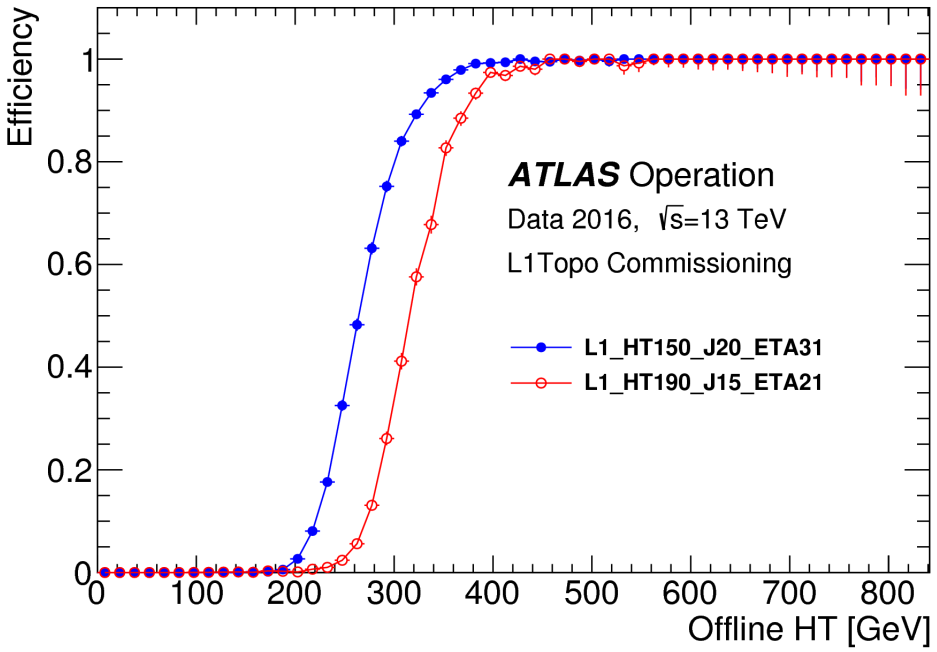


Level-1 Topological Trigger: Performance

L1 H_T topological trigger rate



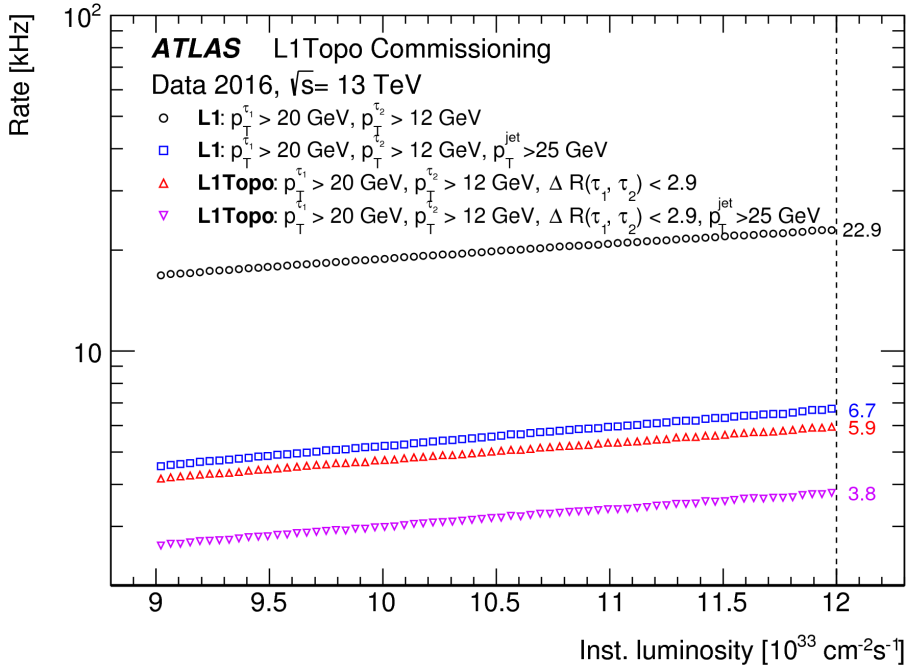
L1 H_T topological trigger efficiency



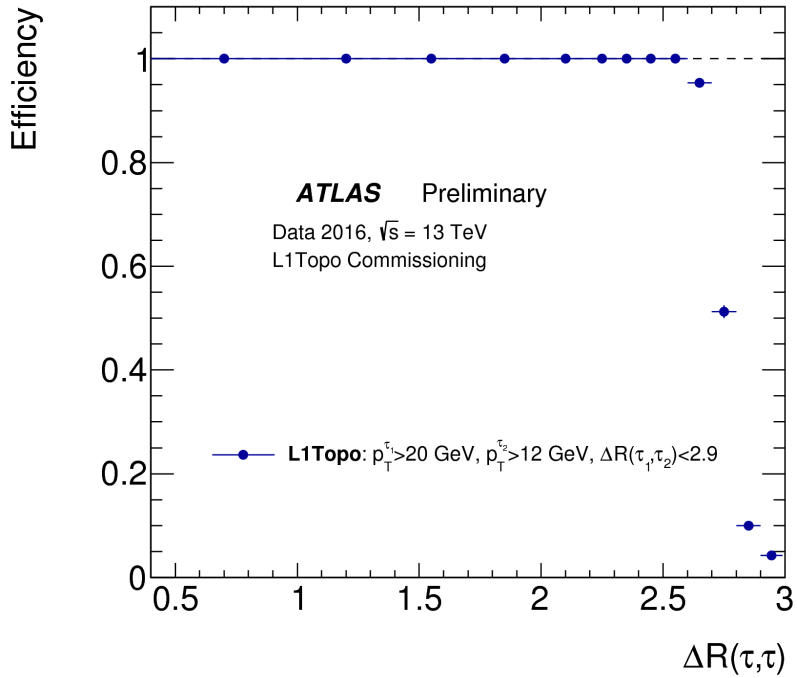
- Good agreement of actual L1Topo performance with respect to predictions
- Reducing L1rate significantly while maintaining high efficiency

Level-1 Topological Trigger: Performance

L1 di-tau trigger rate



L1 di-tau topological trigger efficiency

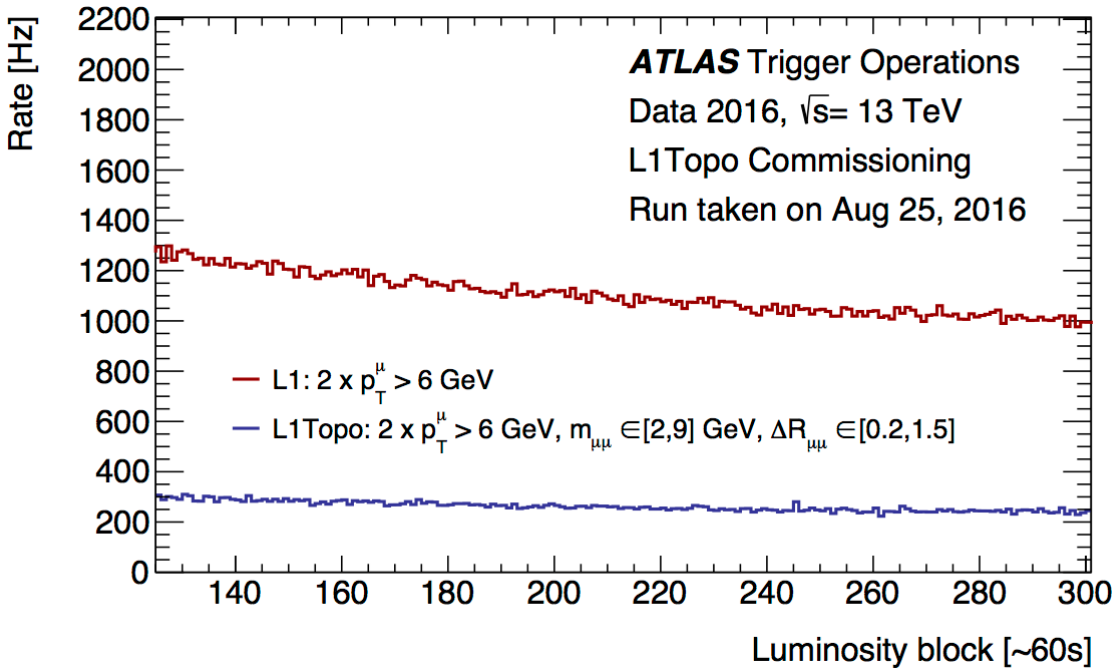


- Topological trigger adds ΔR requirement to di-tau trigger (ΔR(τ,τ)<2.9)
- Angular requirement reduces rate by a factor of 3.9

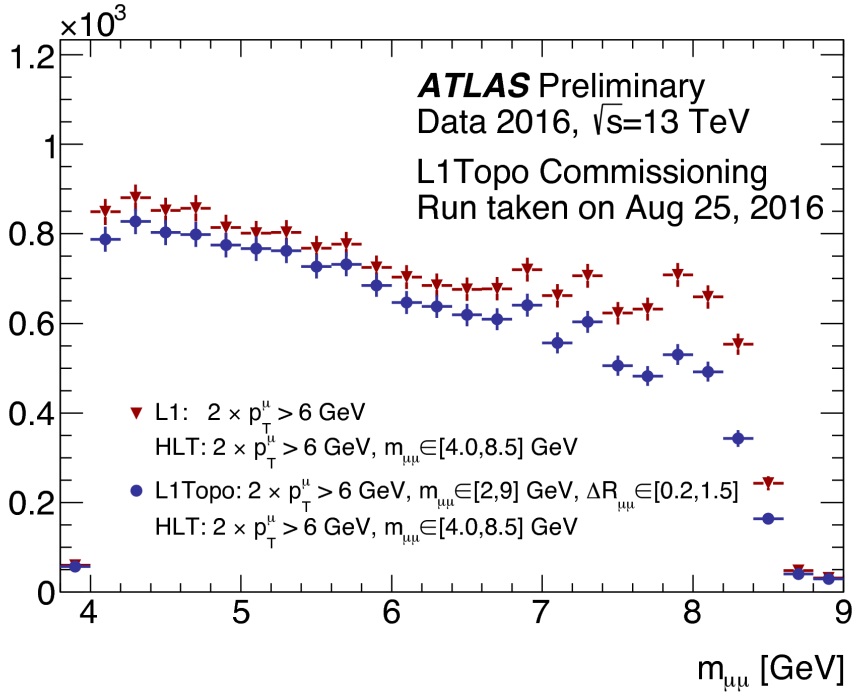
- Trigger efficiency is 100% up to ΔR(τ,τ)~2.5

Level-1 Topological Trigger: Performance

L1 di-muon trigger rate



Di-muon trigger efficiency

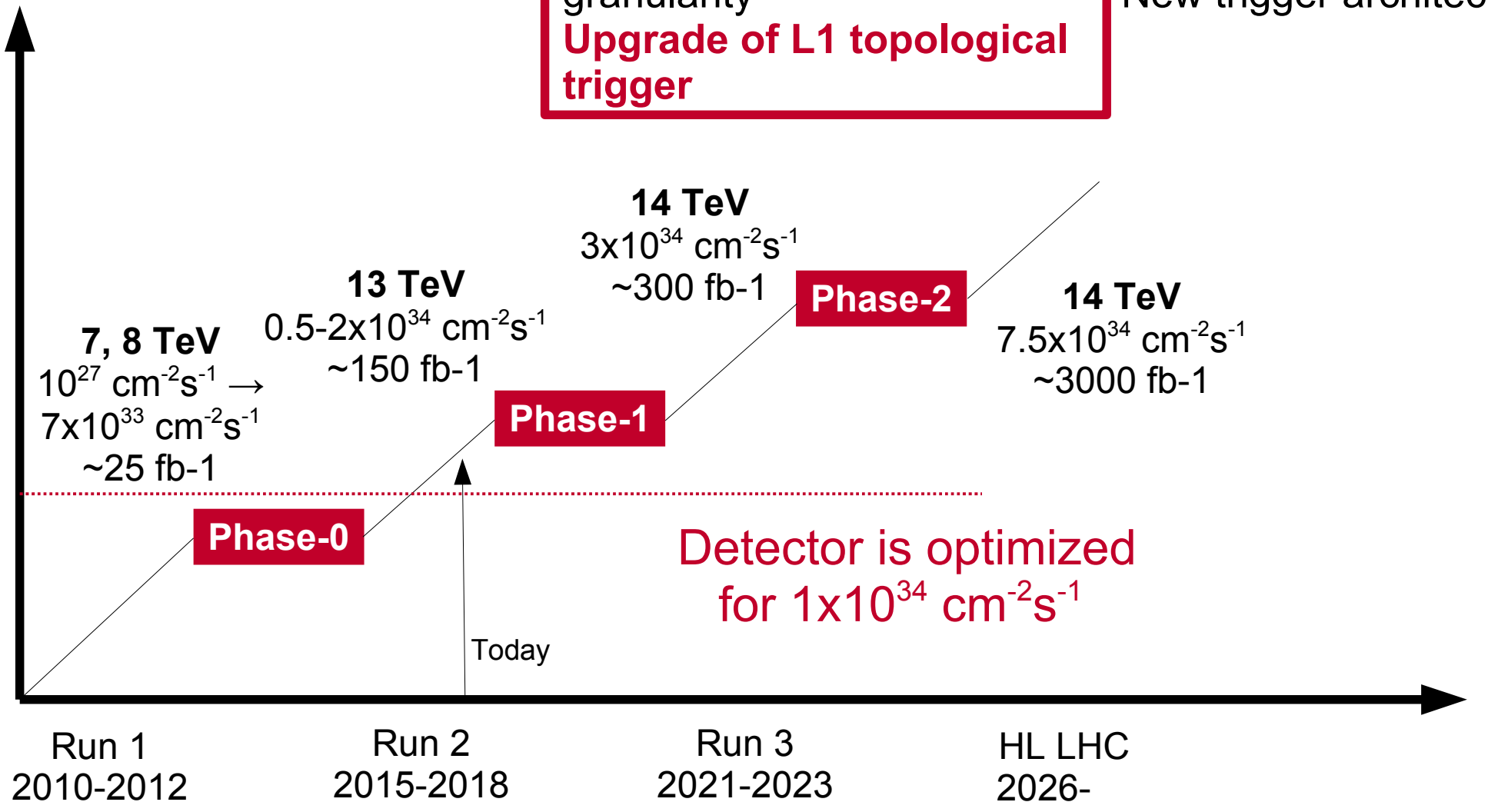


- L1 di-muon topological trigger:
  - 2μ p_T>6 GeV, 2 GeV<M(μμ)<9 GeV and 0.2<ΔR<1.5
  - Reduces L1 rate by a factor ~4, while maintaining high efficiency at HLT
  - Allows to keep B-physics program in ATLAS

Phase-0:
New inner pixel layer
New L1 topological trigger

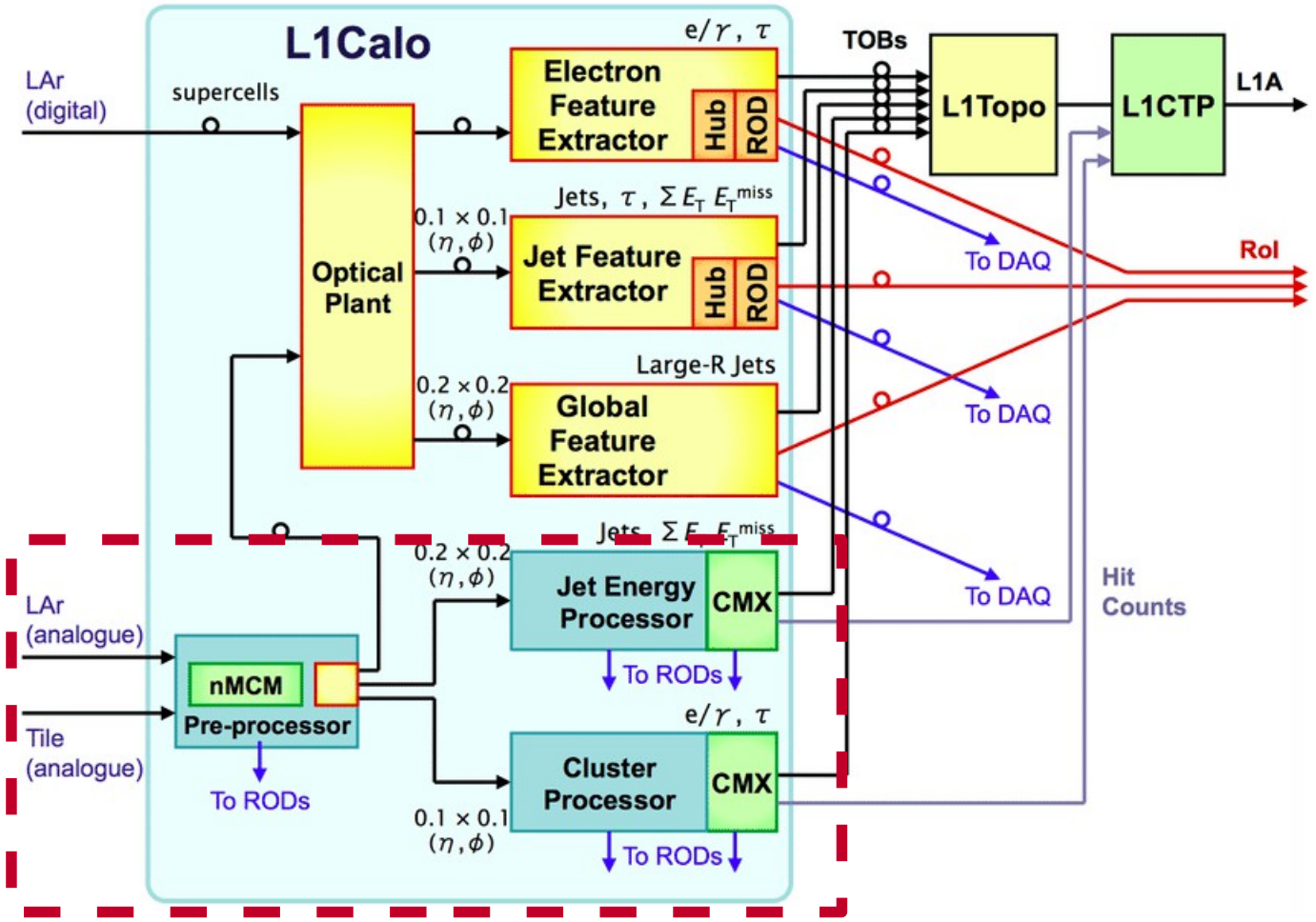
Phase-1:
New forward muon detectors
Increase Level-1 calorimeter granularity
Upgrade of L1 topological trigger

Phase-2:
Most electronics replaced
New inner tracker
New trigger architecture



ATLAS Run3 L1Calo Trigger System

New architectures of the ATLAS L1Calo trigger system have been developed for Phase-1 to allow finer L1 calorimeter granularity



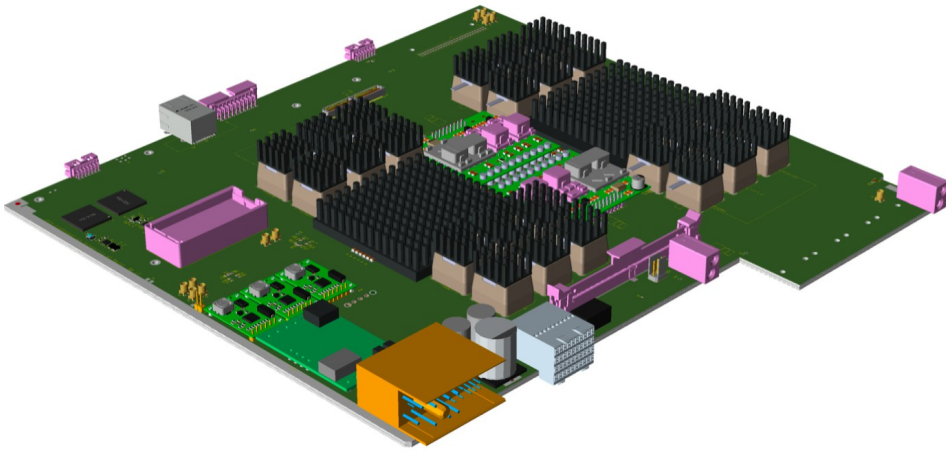
Run 2 system will run in parallel with the new system until validation

ATLAS Level-1 Topological Trigger @ Phase-1

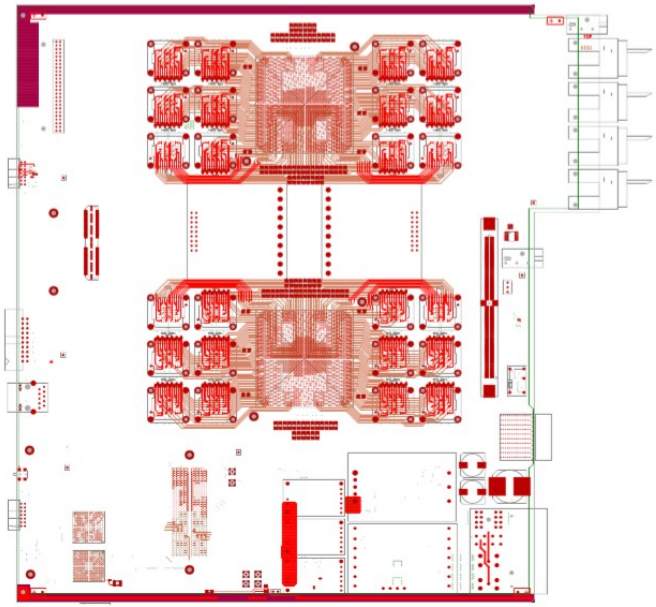
- 3 double-sized processor modules
- 2 Ultrascale+ FPGAs per module
  - 118 input fibres per processor FPGA (6.4, 11.2 and 12.8 Gb/s)
  - 24 output fibres per processor FPGA (6.4 and 12.8 Gb/s)
- Inter-FPGA connectivity 64 Gb/s
- 20 layers PCB
- Electrical and optical output to CTP
- Schematics finalised, board layout in progress
- First prototype expected in June
- Work on Firmware ongoing in parallel

Increase in processing power by a factor ~3 with respect to current system

L1Topo Placement Guide



L1Topo Layout



Summary

- LHC excellent performance beyond the nominal design values requires advanced modifications to ATLAS trigger system
- New topological trigger system was built and installed at Level-1 during LS1
- L1Topo successfully commissioned in 2016 and is used to collect data since September 2016
- Initial performance results show that topological triggers increase acceptance for physics channels
- Upgrade activities ongoing in order to reach the full potential of the LHC machine and explore physics up to its frontier
- First prototype expected in June 2018