The Phase-1 Upgrade of the ATLAS Level-1 Calorimeter Trigger

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On behalf of the ATLAS Collaboration

Ldt=146.9 fb

2015: $\langle \mu \rangle = 13.4$ 2016: $\langle \mu \rangle = 25.1$ 2017: $\langle \mu \rangle = 37.8$ 2018: $\langle \mu \rangle = 36.1$ Total: $\langle \mu \rangle = 33.7$

Ref [1]

60

0.8

0.6

0.4

0.2

30 40 50

Run 2 <u> = 33.7 !

THE UNIVERSITY OF

CHICAGO

L1Calo

Jets, τ , $\Sigma E_T E_T^{mi}$

Jets, $\Sigma E_T E_T$

lan Brawr

(ŋ, o) Extractor

ATLAS Level-1 Calorimeter Trigger

L1Calo is a low latency hardware trigger which reads in real time data from the Liquid Argon (LAr) and Tile calorimeters. The system identifies physics objects such as electrons, photons, taus, jets, and missing transverse energy and sends them to the L1 Topological trigger (L1Topo) and then to the L1 Central Trigger (L1CTP) for the final level 1 accept.



- Harsh LHC conditions in Run 3 with increasingly challenging pileup levels (<µ> at least 2x higher than Run 2!)
- 10x higher granularity of LAr inputs provide improved resolution
- New and improved L1Calo algorithms can take advantage of this resolution resulting in better performance!



Phase I Upgrades for Run 3

- New ATCA based Feature EXtractor (FEX) modules ^{LAr} (digital sector)
- New infrastructure: TREX, FELIX, FOX
- Digitized data distributed by new Fiber-Optic eXchange (FOX)
- New Tile Rear EXtension (TREX) module provides digitized data to Legacy and new systems New Front End Link eXchange (FELIX) system for
- readout Legacy L1Calo & Phase I upgrades will run in parallel during commissioning at the beginning of Run 3

Expected Performance

jFEX 3 jet events Ref [3]

ATLAS Simulation Preliminary

Online: 3 jets required

Anti-k, from jTowers

150 200 250 300 350 400

Offline Jet p _ [GeV]

Run 2 L1

Run 3 jFEX

 $\sqrt{s} = 14 \text{ TeV}, <\mu > = 60$

Offline: p₊ > 30 GeV, |η| < 2.5

t least 1 jet within $\Delta R < 0.6$

eFEX electron events Ref [3]



gFEX large radius jet events

Ref [4]

Legend

Phase I Upgrades

Legacy



New L1Calo Hardware and Infrastructure

Tile Rear Extension (TREX) electron Feature Extractor (eFEX) 24 ATCA modules 32 modules 4 Xilinx Virtex 7 processor FPGAs Processes all Tile trigger towers □ 1 Xilinx Virtex 7 control FPGA Extension of the Run 2 PPM Utilizes full calorimetry granularity Bridge between legacy and phase I systems Identifies electron, photon, and tau objects Production & installation complete! Production in progress! Fiber Optic Link Exchange global Feature Extractor (gFEX) Hub & Readout Driver (ROD) (FOX) 6 boxes map ~7.5k fibers from LAr and Tile calorimeters to FEXs Topo-FOX maps ~1.5k fibers from L1Calo & L1Muon to 1 ATCA module 8 ATCA modules 3 Xilinx Virtex Ultrascale+ FPGAs 1 Zynq Ultrascale+ System on Chip Entire calorimeter on one board_ Sends clock and other signals, and collates and buffers data for one shelf of eFEX/jFEX modules Large R Jets, missing E_{T} , and ΣE_{T} Production & hardware testing complete! 1Topo Production & hardware testing Production complete! Boxes installed, cable installation complete!

underwav!

jet Feature Extractor (jFEX)

- 6 ATCA modules
 - 4 Xilinx Virtex Ultrascale+ FPGAs
 - □ 1 Zynq Ultrascale+ control FPGA

- Large & small radius jets Taus, missing E_{T} , and ΣE_{T} Production completed, hardware testing underway at home institute



Level-1 Topological Trigger (L1Topo)

3 ATCA modules

EX racks

- 2 Xilinx Virtex Ultrascale+ FPGAs
- 1 Zynq Ultrascale+ control FPGA Topological algorithms with FEX and L1Muon trigger object inputs
- Production complete, hardware testing underway at home institute



Installation & Commissioning



P1 Installation Status

- FEX racks and shelves installed along with a number of infrastructure PCs
- FEX installation beginning late Summer 2021
- FOX boxes installed, cable installation ongoing
- TREX installation complete
- FELIXs installed
- Legacy system being re-commissioned in parallel to Phase-I upgrade installation and

commissioning









FEX racks

References

[1] ATLAS Public Luminosity Results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2 [2] ATLAS Collaboration, Technical Design Report, ATLAS Liquid Argon Calorimeter Phase-I Upgrade, CERN-LHCC-2013-017 [3] ATLAS Public L1Calo Trigger Results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/L1CaloTriggerPublicResults [4] ATLAS Public Jet Trigger Results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/JetTriggerPublicResults

