Upgraded Readout and Trigger Electronics for the ATLAS Liquid Argon Calorimeters for Future LHC Running

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Introduction

The ATLAS Liquid Argon (LAr) calorimeters produce almost 200k signals that must be digitized and processed by the front-end and back-end electronics at every triggered event. The current design of the first-level (L1) trigger system was optimized for the nominal LHC luminosity of 10^{34} $cm^{-2}s^{-1}$. However, in future higher-luminosity phases of LHC operation, the luminosity will be 3-7 times higher. In order to improve the trigger performance at such luminosities and high background conditions, it is planned to send higher-granularity, higher-resolution and longitudinal shower information from the calorimeter to the L1 trigger processes are proposed. The upgrade project in the first phase (Phase-I upgrade) in 2018 is discussed below.

Upgrade Strategy for Trigger Readout

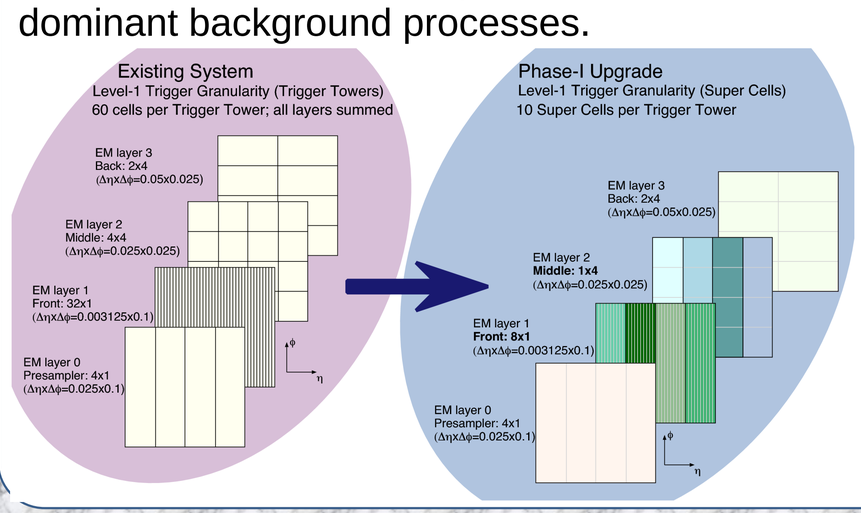
Existing calorimeter trigger: Trigger Tower $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$
New finer granularity scheme : Super Cells $\Delta\eta \times \Delta\varphi = 0.025 \times 0.1$ (in the 1st and 2nd longitudinal component, information on the longitudinal shower development

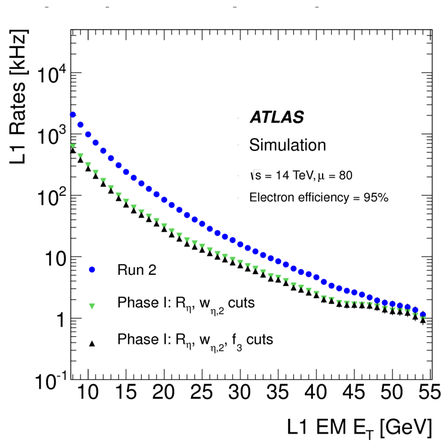
1 Trigger Tower → ~10 Super Cells (~34k in total)

Other upgrades:

- improvement of digitization precision by at least a factor of 4
- improved energy calculation algorithm at each bunch crossing

These upgrades will improve the trigger energy resolution and efficiency for selecting electrons, photons, tau leptons as well as jets and missing transverse momentum (E_T^{miss}) and provide higher dominant background processes.





L1 trigger rates for 95% electron efficiency

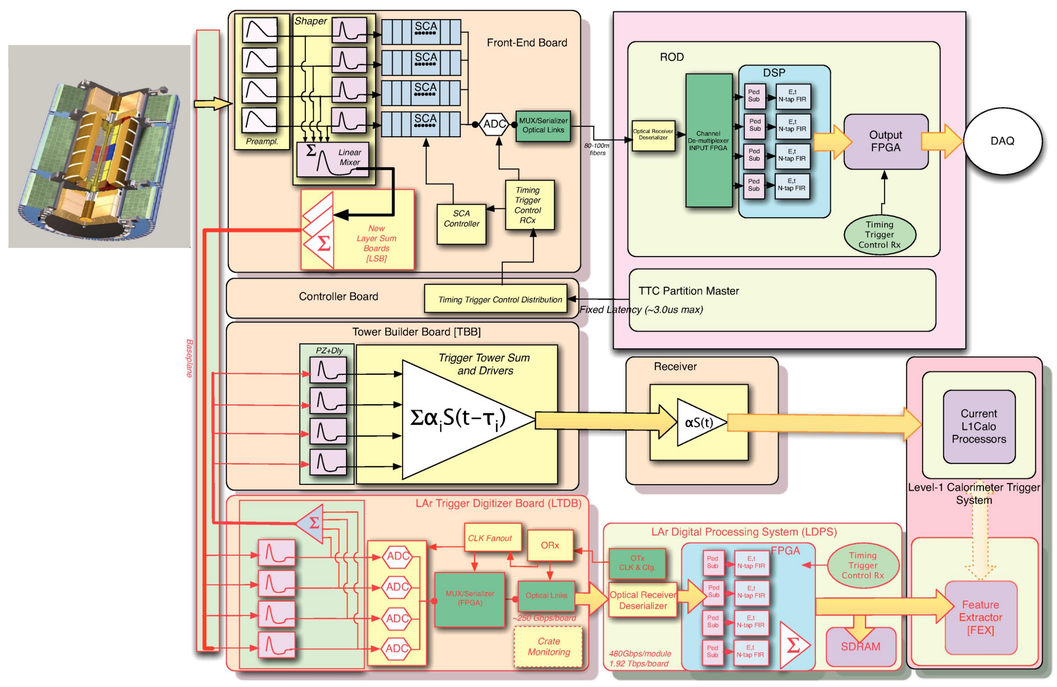
Upgrade of Readout Architecture

New LAr Trigger Digitizer Boards (LTDB)

- receive the higher granularity signals
- digitize signals on-detector
- send signals via fast optical links to a new LDPS at off-detector

New LAr Digital Processing System (LDPS)

- applies digital filtering
- identifies significant energy depositions in each trigger channel



(new components are indicated by red)

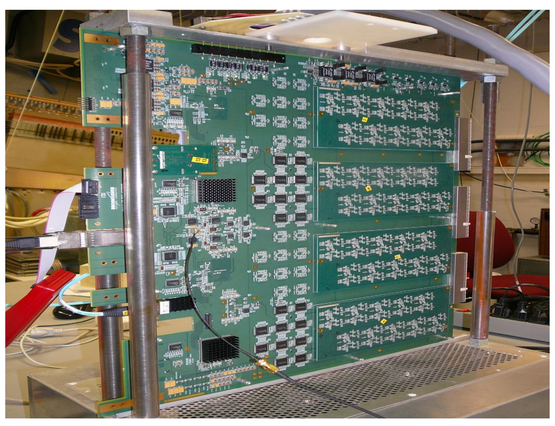
R&D Activities

Mixed signal front-end ASICs (LTDB)

- 320 super cells / board
- Total power < 156 W/board
- 200 Gbps output / board
- Total of 124 boards, 2.5 Tbps
- High speed serializer with 5.12 Gbps optical link to a digital processor for each 8 channels

ADC

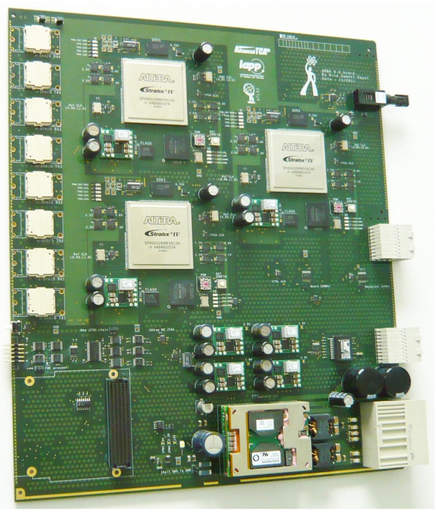
- 12-bit ADC at 40 MHz
- LSB 32/125 MeV for 1st /2nd layer
- 1 commercial option under test / 2 custom ASICs are being designed



Prototype of LTDB

High speed FPGA-based DPS units based on ATCA

- Each has 4 Advanced Mezzanine Cards (AMC)
- 1 AMC handles 48 fibers for reception (RX) and 48 fibers for transmission (TX)
- FPGA with high speed transceivers process the data of up to 320 Super Cells with a latency of 14 bunch crossings
- Filter algorithms in FPGA can take advantage of the history of digital samples to suppress the pileup contributions to energy measurements
- Total throughput of the system: 25 Tbps from LTDB, 41 Tbps to L1 calorimeter trigger system



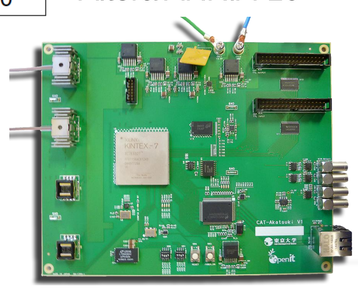
Pre-prototype LAr Digital Processing Board (LDPB)

Two hi-end commercial FPGAs are used for development.

Resource	Estimated Requirement	Specification FPGA-I	Specification FPGA-II
Register [10^3]	184	1424	1300
LUT [10^3]	120	712	900
TX/RX	54	96	96
DSP	778	3360(*)	1518(*)
BlockRam [Mbit]	13.5	67.7	57.0

FPGA-I:
Xlinx Virtex-7
FPGA-II:
Altera ARRIA-10

Tests on high-speed communication and digital signal processing using Avago MicroPOD are also on-going.



Summary and Prospect

Phase-I upgrade project of the ATLAS LAr calorimeter is proposed to enhance the physics reach of the experiment in the high-luminosity environment foreseen in the next 10 years. R&D activities as well as architectural and performance studies are on-going for the upgrade of readout electronics. Tests on demonstrator boards are going well and it was decided to install them to the ATLAS readout system for the run starting in 2015. It is planned to install this demonstrator in the coming weeks in the ATLAS.

In the second upgrade phase planned in 2022-2023 (Phase-II upgrade), all LAr calorimeter readout electronics must be replaced due to radiation damage, ageing and a new ATLAS trigger scheme. The new electronics installed at Phase-I upgrade will be used as a Level-0 trigger and the new Level-I trigger will access the full granularity detector information to further enhance discrimination against backgrounds. Therefore, the Phase-I upgrade project is fully compatible with the ATLAS upgrade long-term plans.

Reference

ATLAS Collaboration, “ATLAS Liquid Argon Calorimeter Phase-I Upgrade Technical Design Report”, ATLAS-TDR-022, 2013