Development of the ATLAS Liquid Argon Calorimeter Readout Electronics for the HL-LHC

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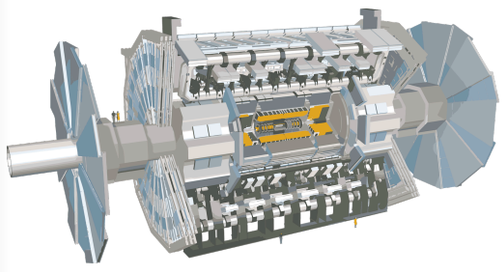
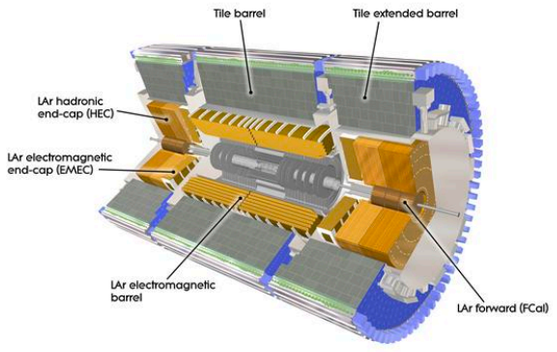
ATLAS and the LAr Calorimeter...





- ATLAS is a general-purpose detector used to study particles produced by high-energy proton-proton collisions at the LHC.
- Consists of a sampling calorimeter with liquid argon as the sampling medium. Made up of 182,468 channels.
- Signal is amplified, shaped and digitized at 40 MHz.

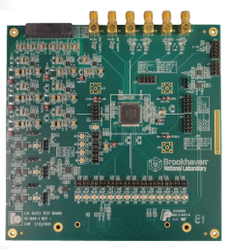
... and the HL-LHC

- The LHC is scheduled to undergo an upgrade during LS3 in 2026-2028 $\Longrightarrow$ **HL-LHC.**
- Instantaneous luminosity up to $5 - 7.5 \times 10^{34}$ cm^{-2}s^{-1} (5 to 7 x nominal) with pileup up to $< \mu > \approx 140 - 200$
- To differentiate signal from noise, higher granularity shower information needs to be sent to the trigger.
- ATLAS TDAQ system will evolve to a trigger rate of 1 MHz, increasing the latency time for the LAr Calorimeter
- High radiation dose to front-end electronics is expected, exceeding current electronics limits.
- As a result, the LAr Calorimeter's on-detector and off-detector components need to be upgraded

On-detector Upgrades

Preamplifier - Shaper

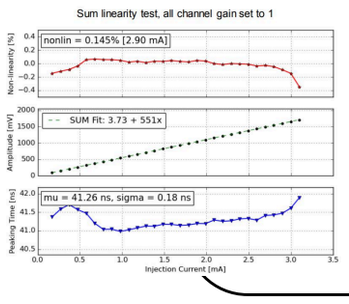
Objective:

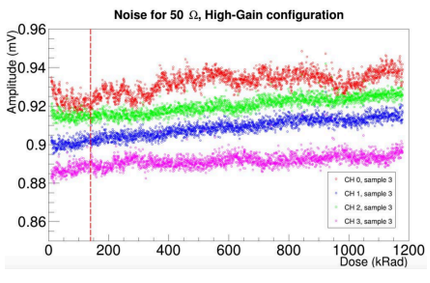


- Amplifies and applies a CR-(RC)^2 shaping function and produces 2 overlapping gains
- Large dynamic range (10 mA for 25 Ω channels), low noise 350 nA for 10 mA channels

Status: ALFE2 ASIC

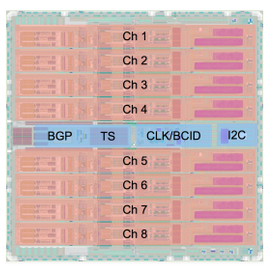
- Based on 130 nm CMOS technology
- Cross-talk, linearity and noise exceeding specifications
- TID tests demonstrated sufficient radiation tolerance





ADC

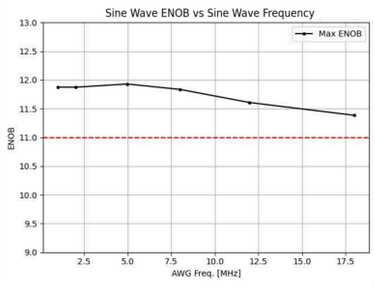
Objective:

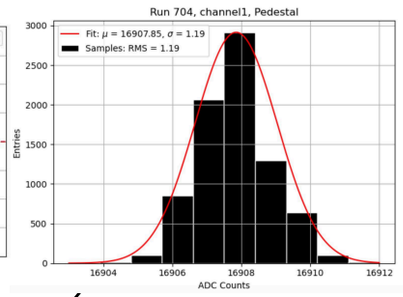


- Digitizes analog signals at 40 MHz on two gains
- 14-bit dynamic range with >11-bit precision

Status: COLUTAv4

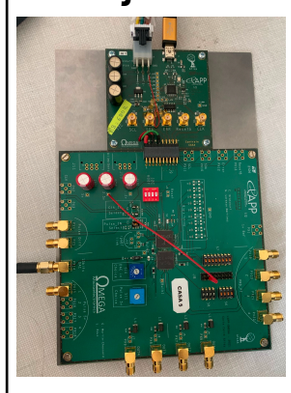
- 40 MHz pipeline ADC MDAC in combination with a 12-bit pipeline SAR ADC
- ENOB > 11 bits for up to 18 MHz input sine wave frequency
- Pedestal noise: 1.2 ADC Counts RMS





Calibration Board

Objective:



- Injects a pulse of known amplitude and shape directly on calorimeter cells for 128 channels
- Must cover full dynamic range: 320 mA, up to 7.5 V output: requires HV-CMOS

Status: Pulser and DAC ASICs

CLAROCv3 Pulser ASIC

- Based on XFAB HV-CMOS 180 nm technology with 4 calibration channels

LADOCv1 16-bit DAC ASIC

- Based on TSMC 130 nm CMOS technology

New prototypes LADOCv2 and CLAROCv4 submitted, expecting improved linearity and radiation tolerance

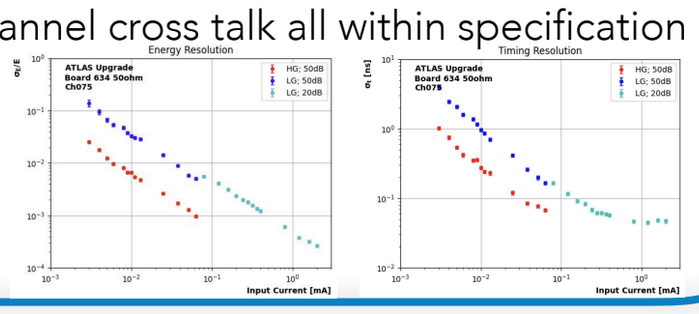
Integration - Front End Board (FEB2)

Objective:

- Integrates PA/S, ADC and optical links
- 1 FEB2 board handles 128 channels

Status: Prototype - FEB2 slice testboard

- 32 channels test with same FEB2 channel density
- Functionality of full readout chain and multi-channel performance demonstrated with noise, sine wave, and pulse measurements
- Energy resolution < 0.1%, timing and multi-channel cross talk all within specification



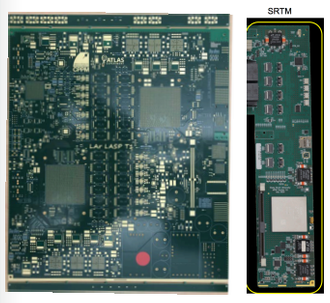
Off-detector Upgrades

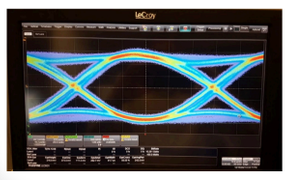
LAr Signal Processor

Objective:

- Receives digitized waveform from 8 FEB2s
- Determines energy and timing of signals for up to 1024 channels at up to 1.8 Tbps
- Output data at 200 Gbps to the Global Event Processor and to the fFEX at up to 1 Tbps
- Sends data, energy and timing to the DAQ at 60 Gbps upon receiving a trigger accept

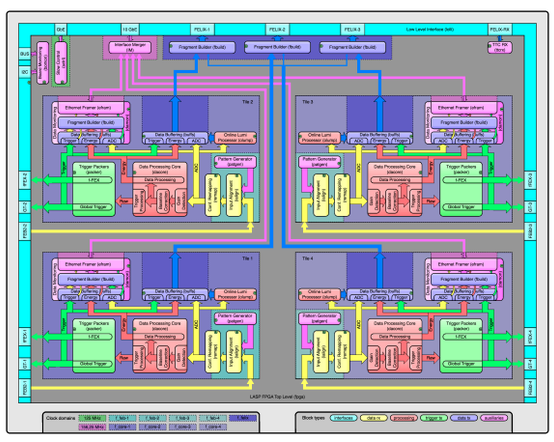
Status: LASP Test Board + SRTM





- Implemented using 2 Intel Stratix-10 FPGAs
- Optical testing of transceivers produces >65% open eye-diagrams

Status: LASP Firmware (FW)



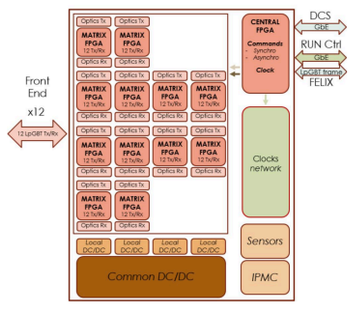
- A more modular redesign of the FW brings about 1 tile/ FEB2 option
- Successful injection of external data to test functionality
- Deep testing underway

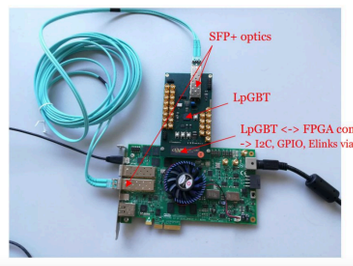
LAr Timing System

Objective:

- Distributes trigger, timing and control (TTC) signals to FEBs and Calibration boards

Status: LATOURNETTE





- One central and 12 matrix Cyclone10 GX FPGAs
- Currently testing lpGBT interfaces: I2C, GPIO, and FMC Elinks
- Testing optical integrity with SFP+ links

Picture References: CERN-LHCC-2017-018