ATLAS LAr Calorimeter Commissioning for LHC Run-3

Pavol Strizenec

IEPSAS Košice

On behalf of the ATLAS LAr Calorimeter Group

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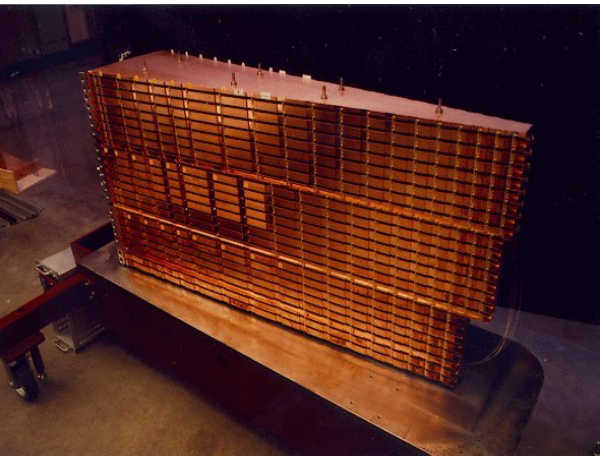
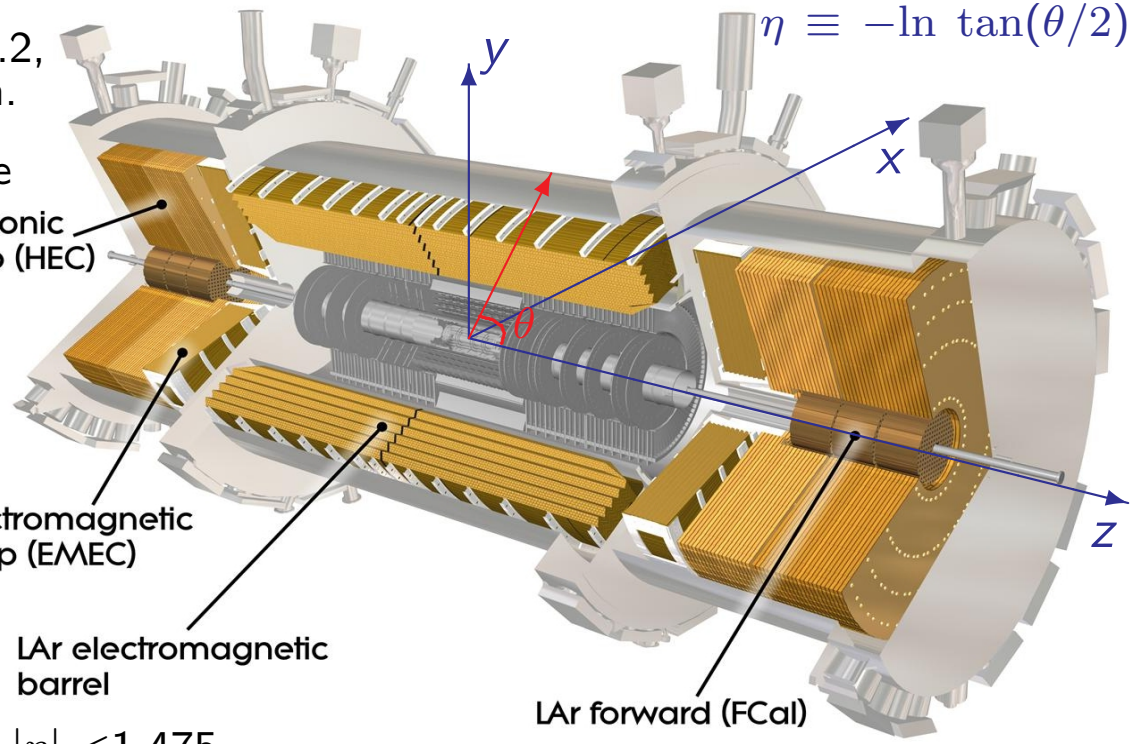
Contents

LAr System in a nutshell



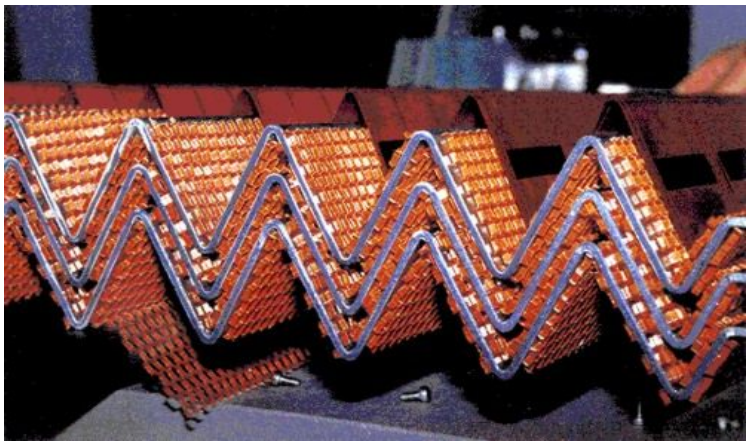
1.5< $|\eta|$ <3.2,
$\sim$ 5.6k chan.
Cu absorber
parallel plate

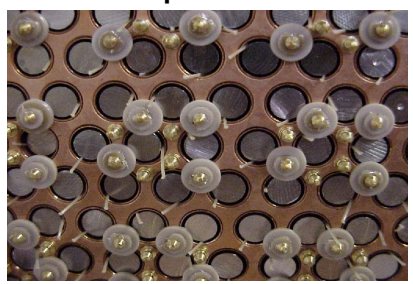


1.375 < $|\eta|$ <3.2
$\sim$ 64k chan.
Accordion geometry
Lead absorber
LAr Presampler in front
of accordion for $|\eta|$ <1.8

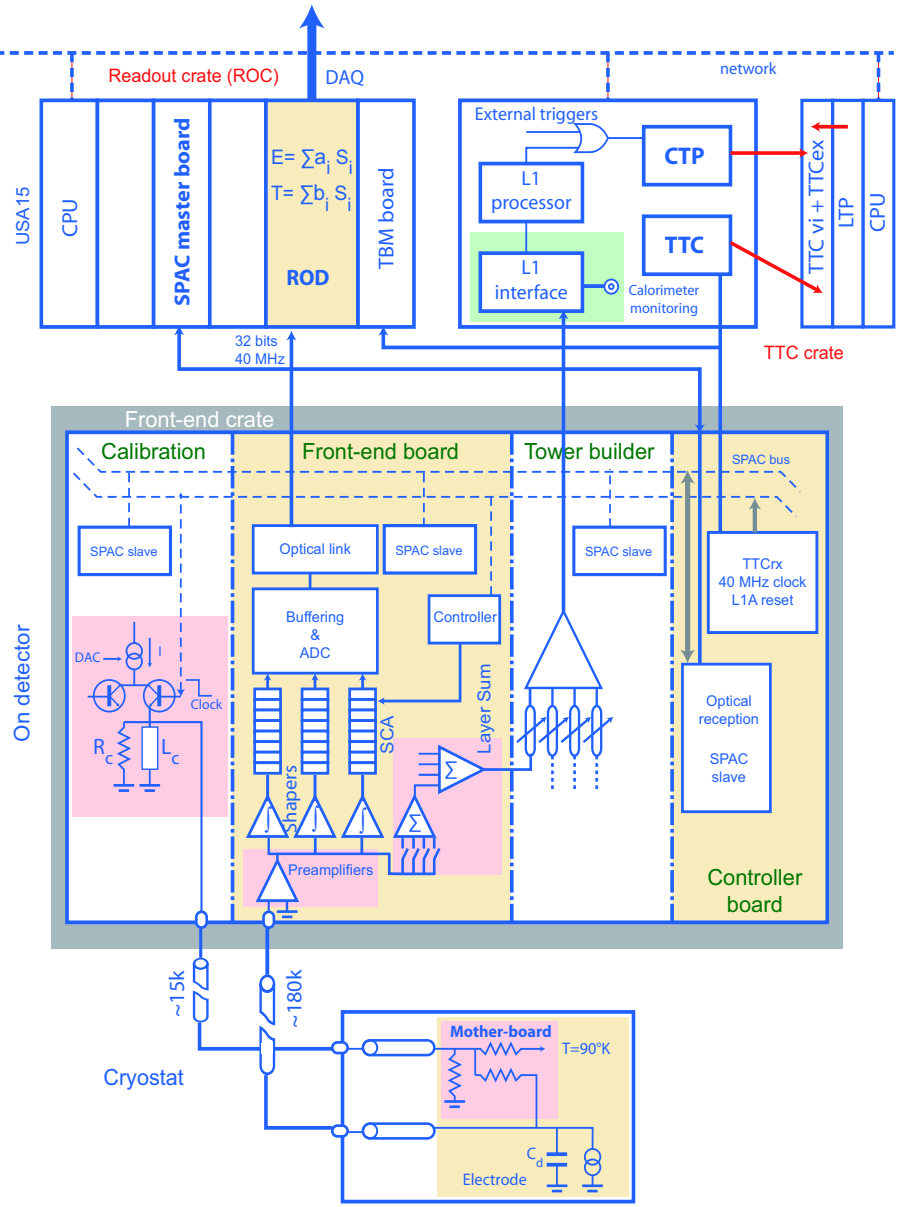
$|\eta|$ <1.475
$\sim$ 110k chan.

3.1< $|\eta|$ <4.9, $\sim$ 3.5k chan.
Cu (EM), W (Had.) absorber
very narrow LAr gaps needed
novel design with cylindrical electrodes parallel to the beam

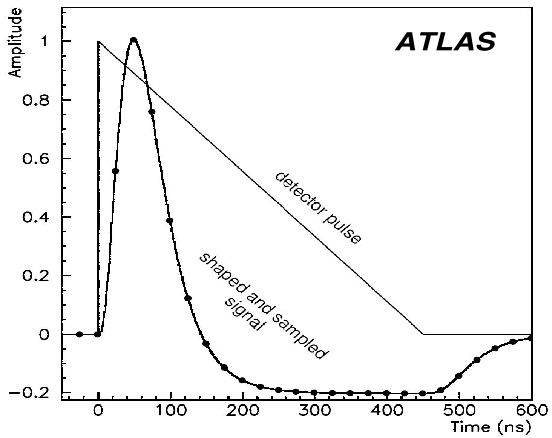




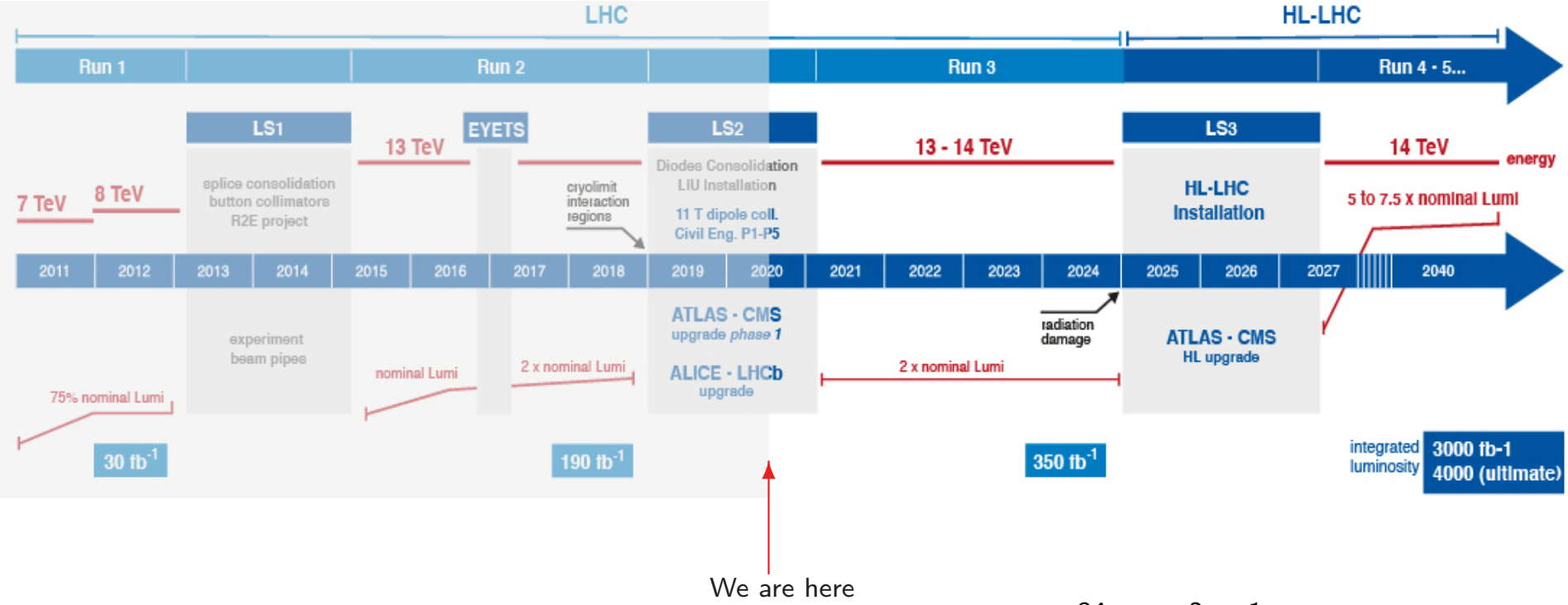
LAr Calorimeter Readout



- signal is amplified outside of cryostat at 1524 **F**ront **E**nd **B**oards, with 128 channel each, (located in **F**ront **E**nd **C**rates on cryostat feed-throughts), split into 3 gain scales (1/9.9/93) and shaped
- signal is then sampled at 40MHz and stored in analogue pipelines, once L1-accept signal arrives, the proper gain is selected, digitized and transmitted to back-end
- analogue signal (before last integration in shaper) is sent to L1 trigger system
- with ∼2 mm gaps at 2kV the drift time is ∼450 ns



LHC Plans

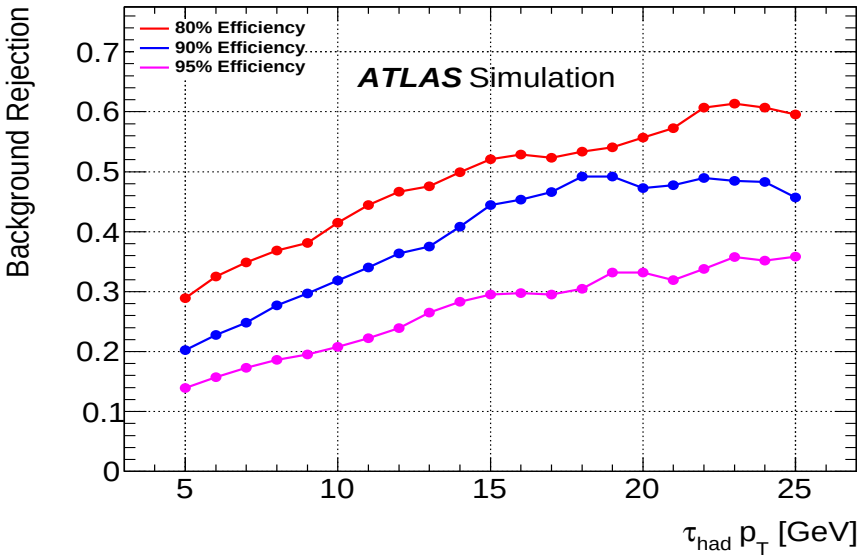


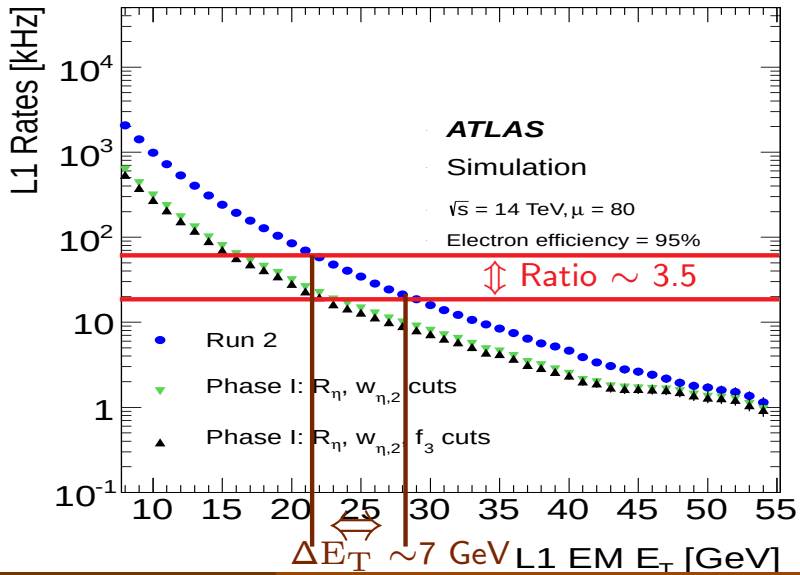
We are here

- in Run-2 (year 2018) ATLAS ran with $\mathcal{L}_{\max} = 2.1 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, $< \mu >= 36.1$
- in Run-3 2x nominal luminosity is planned, $\mathcal{L}_{\max} = 3 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, $< \mu >= 80$; already achieved in Run-2 for short time
- increasingly more challenging to select the "right" event
- ATLAS plans to stay with L1 at 100 kHz (out of which ~20 kHz e^{+-}/γ)
- Phase-I Upgrade currently being installed (and commissioned) during LS2

LAr Phase-I motivation

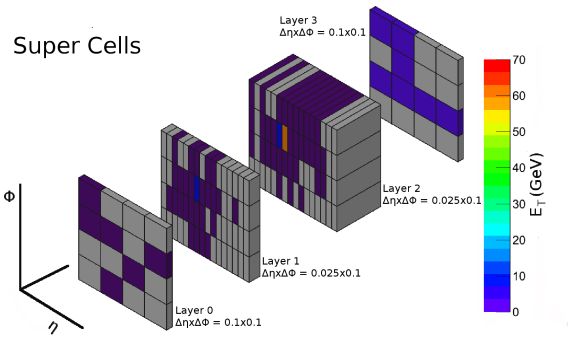
- Phase-I upgrade should cope with increasing trigger rates, current EM trigger selection would be 270 kHz in Run-3 luminosity and pile-up conditions
- need to reduce EM triggers to 20 kHz without important acceptance loss, so preferably not increasing the E_T threshold
- using higher granularity in trigger should maintain or even increase efficiency, reduced transverse energy (E_T) thresholds will increase the acceptance for measuring Higgs properties and looking for new physics including SUSY and extra dimensions
- using some shower shape variables (like $R_\eta = E_{3\times2}/E_{7\times2}$) allows better distinguish between electrons and jets and keep E_T thresholds low (28 GeV) (right plot)
- apply rejection criteria similar to offline algorithms, in order to reject the QCD background jets (left plot)





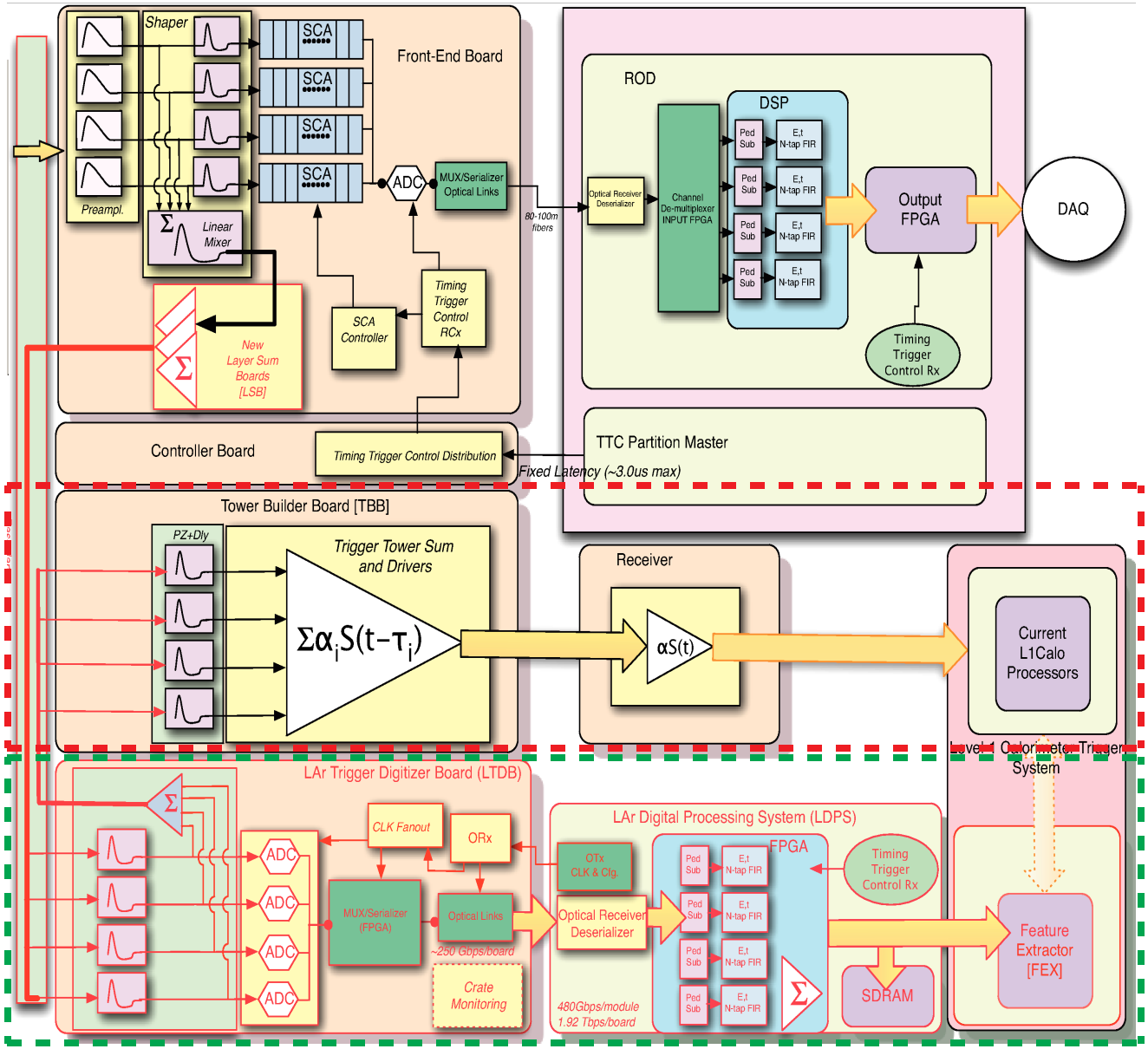
Phase-I - L1 Trigger Upgrade

New granularity, 4 layers, $\Delta\eta \times \Delta\Phi = 0.025 \times 0.1$ in Front and Middle, Super Cells (SC)



Kept old boards for compatibility

New LAr Trigger Digitizer Board (LTDB)



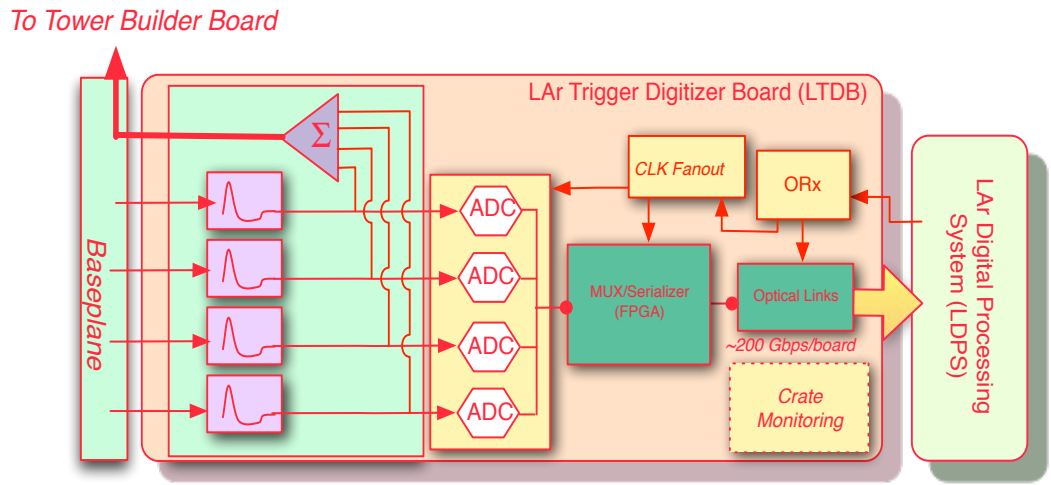
More sophisticated system allows advanced algorithms for object selection and ID

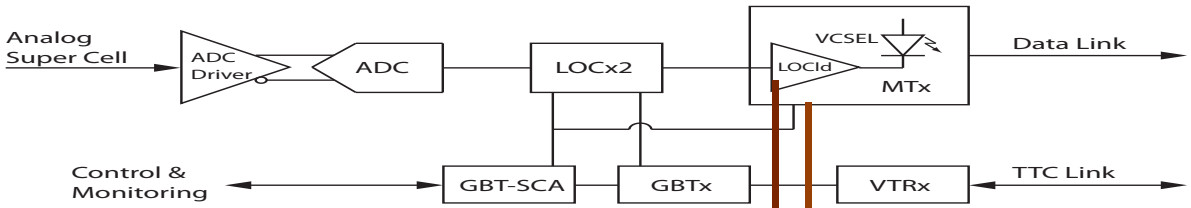
Phase-I - Baseplanes & Layer Sum Boards

- 10× more channels on baseplane, 6 different topologies, production done, more than 80% installed
- Layer Sum Boards produced, delivered to CERN
- from February 2019 FEBs are being refurbished on site by external contractor
  - cooling plates removed, LSB replaced, new cooling plates and hoses installed and tested for leaks
  - tedious work, quite happy to out-source it
  - works very well: target of 50+ FEBs/week achieved
  - FEBs tested and reinstalled on detector (already 3/4 reinstalled) to make space in lab

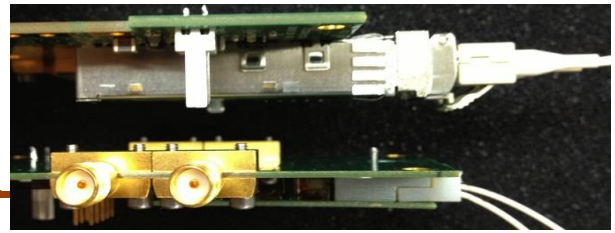
Phase-I - Digitizer and Data Transmission

- each LTDB processes up to 320 SC signals
- high performance ADC (40 MHz, low power consumption), custom design produced
- LTDB designed for digital precision 32 MeV in Front and 125 MeV in Middle layers



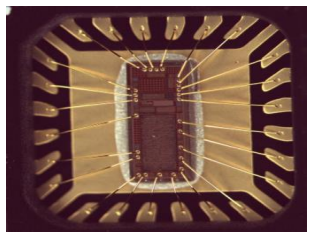


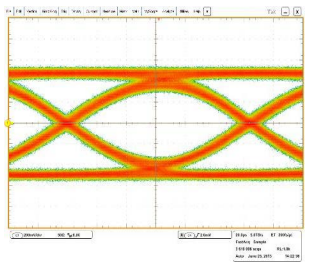
- physical size of transceiver crucial, no commercial modules with height < 6 mm available
- serialization of multiple ADC channels required - 8 multiplexed to 5.12 Gbps stream
- in total 20 2-channel transmitter modules per LTDB



SFP+ (14 mm)

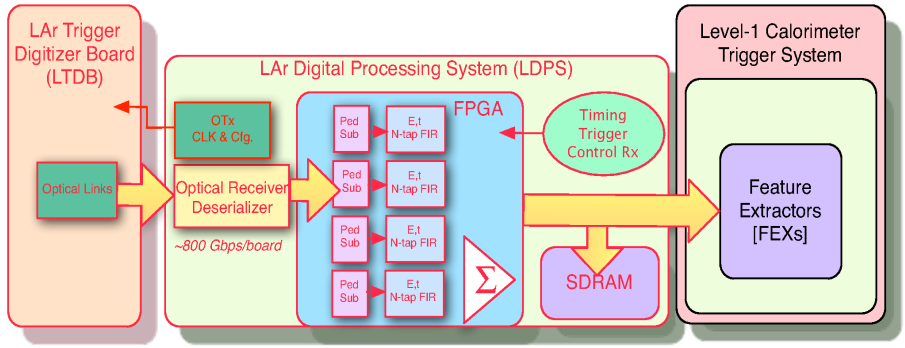
MTx (6 mm)

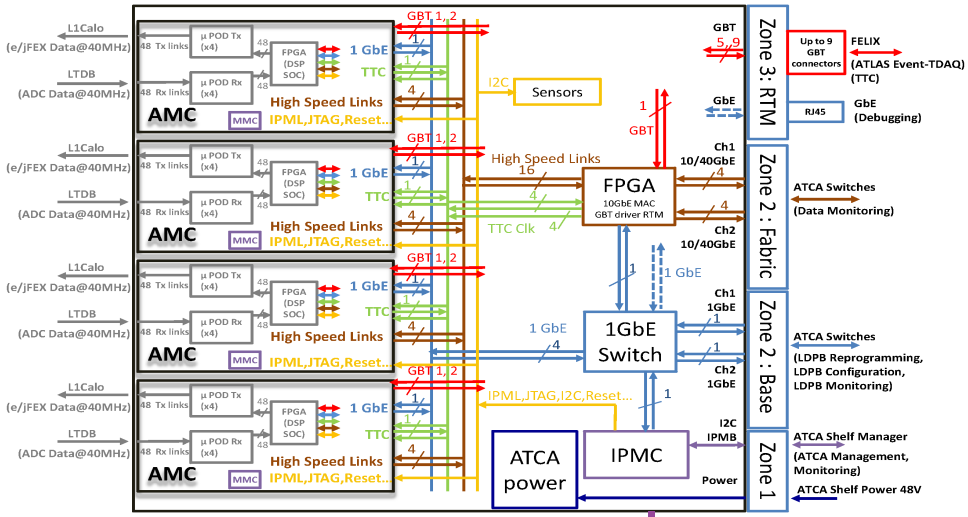


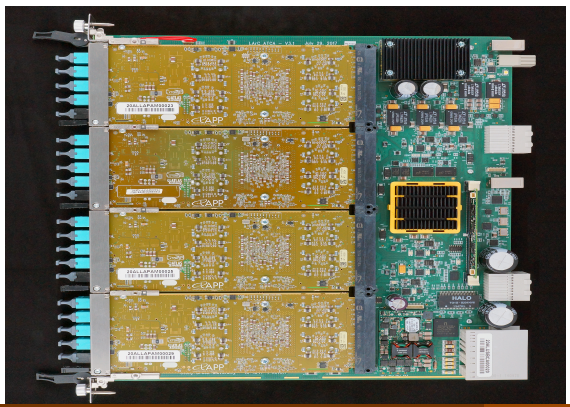


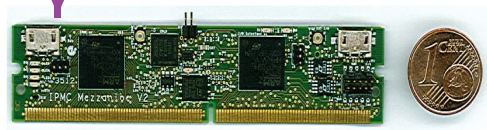
Phase-I - Data Processing

- LAr Digital Processing System (LDPS) gets data from LTDB (~25 Tbps), reconstructs E_T, time and transmit to L1 Calo Trigger (~41 Tbps)
- LAr Digital Processing Blade (LDPB) is ATCA carrier board, with 4 Advanced Mezzanine Cards (AMC) for data processing
- 31 LDPBs required, with 124 AMCs in total (including spares)
- strict latency limit for E_T and time algorithm (5 to 6 bunch crossing)
- several options for filtering investigated:*5 samples OF, OF_{max} - current L1 Calo, OF_{χ}, Wiener filter with forward correction*



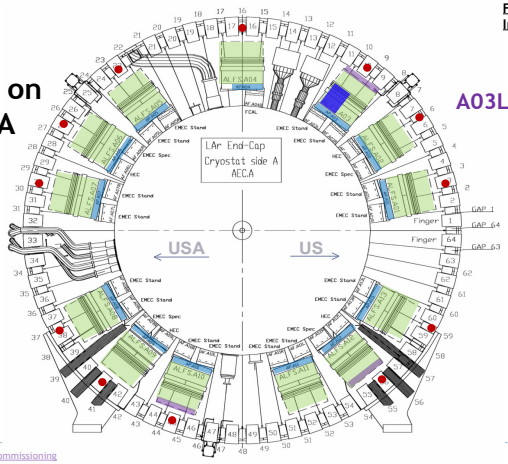






Phase-I - Installation status

Overview of Front-End interventions on ENDCAP side A



A03L:

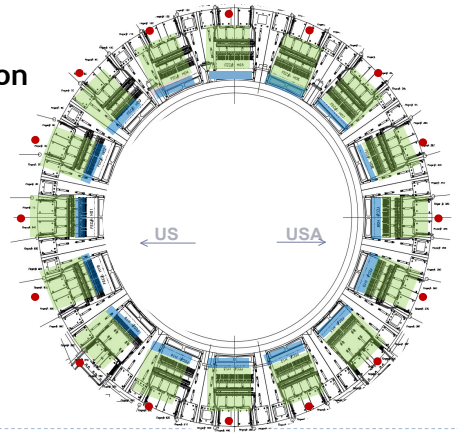
Front-end Crate Intervention Summary

- 13 crates — Baseplane exchanged
- 3 crate — Re-cabled for commissioning
- 13 crates — Boards reinserted
- 0.5 crate — LTDB installed, in commissioning
- 12 crates — LVPS cooling hose replaced

One EMEC-spe crate (A12) re-cabled for testing

No access anymore-will have access again Spring 2020

Overview of Front-End interventions on BARREL side C



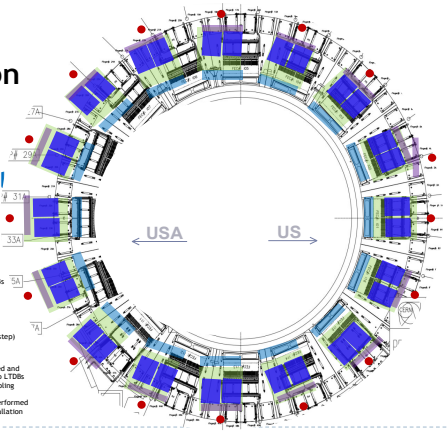
Front-end Crate Intervention Summary

- 16 crates — Baseplane exchanged
- 16 crates — Boards reinserted
- 16 crates — LVPS cooling hose replaced

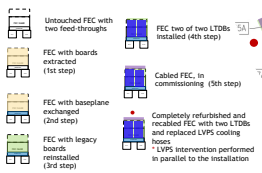
Maintain list at [twiki:/LArCrateCommissioning] to keep track of interventions, validation status

Overview of Front-End interventions on BARREL side A

Access to EMBA until early 2020



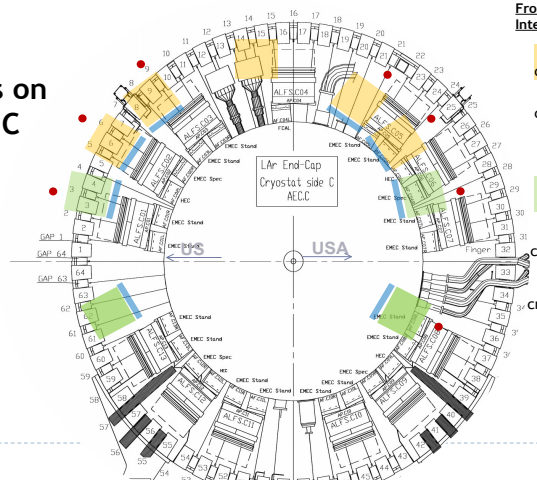
Legend and order of interventions



Front-end Crate Intervention Summary

- 16 — Baseplane exchanged
- 16 crates — Boards reinserted
- 16 crate — Re-cabled for commissioning
- 16 crates — LVPS cooling hose replaced
- 16 crates — LTDB installed, in commissioning

Overview of Front-End interventions on ENDCAP side C

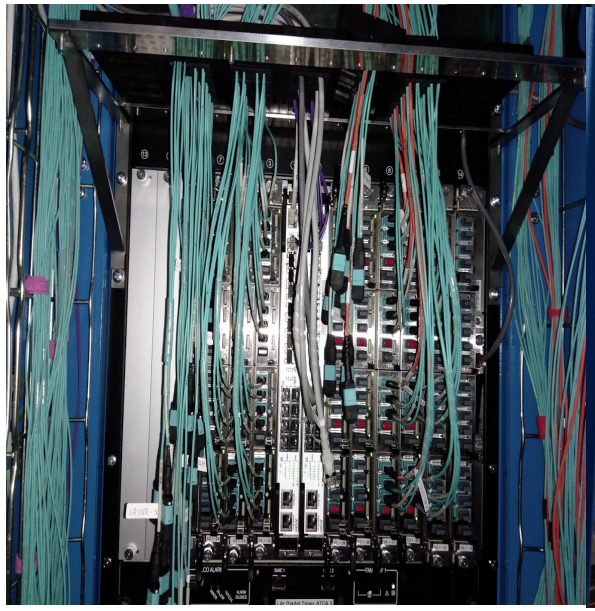
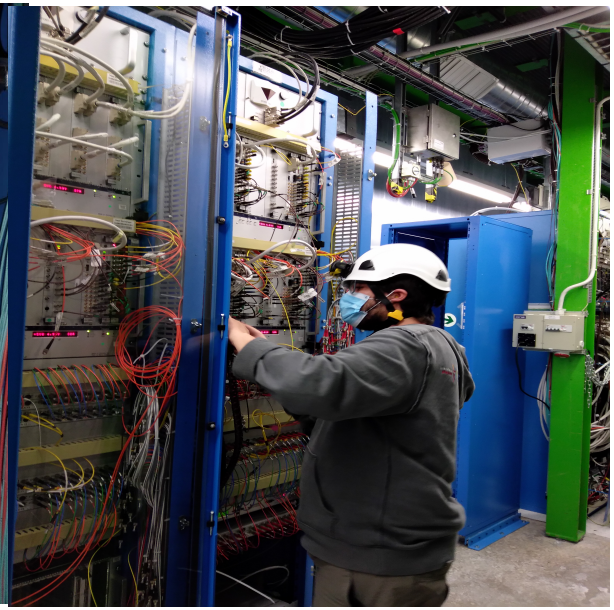


Front-end Crate Intervention Summary

- 5 crates — Boards extracted
- 8 crates — Baseplane exchanged
- 0 crate — Re-cabled for commissioning
- 4 crates — Boards reinserted
- 0 crate — LTDB installed, in commissioning
- 7 crates — LVPS cooling hose replaced

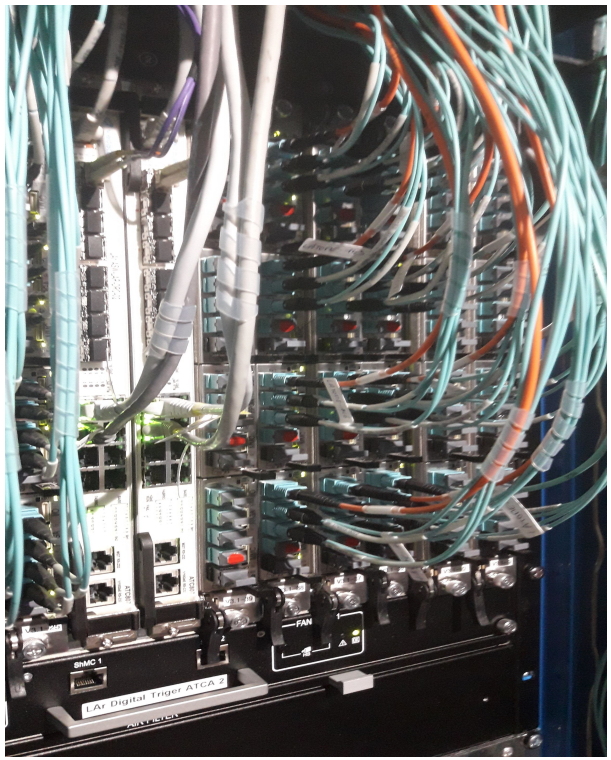
Phase-I - Installation status

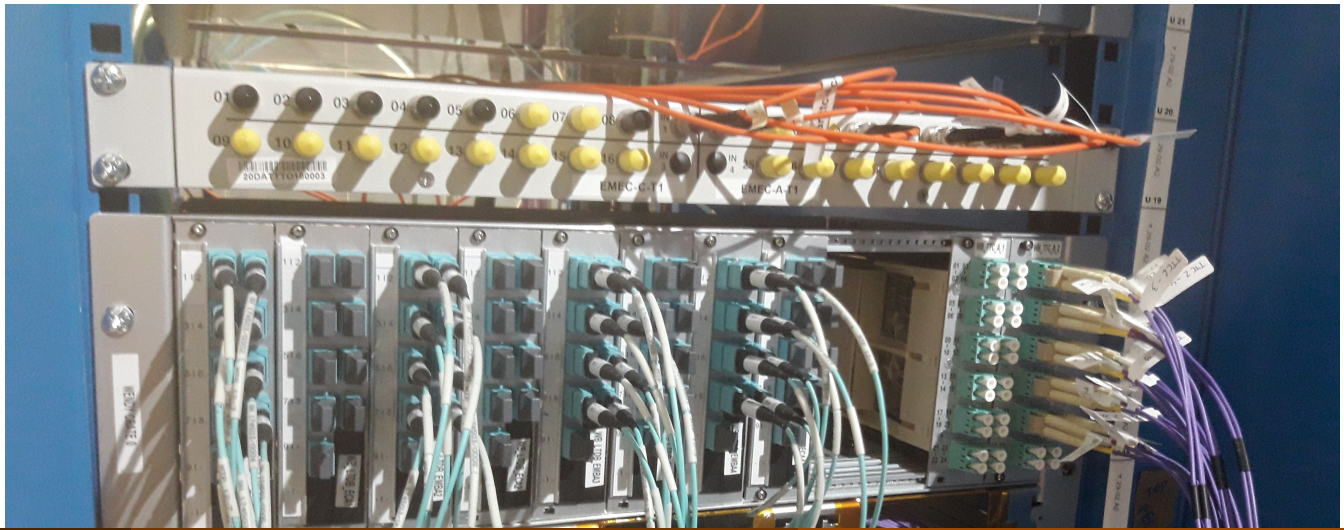
- despite COVID-19 lockout, we managed to keep the system running, so firmware/software development was not interrupted. Installation in ATLAS restarted from mid-May
- production of LTDB restarted, should finish after summer
- LDPB production finished, delivered early July
- in parallel backend installation continues, many fibers (742 fibers in 53 cables) to route from experimental cavern to counting room

Phase-I - Installation status

- 34 LArCarrier boards produced (4 spares) as well as 150 LATOME boards (34 spares)
- integration tests and commissioning on the real system has already started
- FELIX (control/monitoring/DAQ) servers tests has also started, lower photo shows Wendy boxes, where all the EMBA LTDB (each blue fiber) is now connected to FELIX and then can be controlled
- data-taking and recording from the full digital trigger system chain already tested





LAr preparation for LHC Run-3

Run-3 preparation covers all areas of detector infrastructure:

- Offline software
  - memory consumption of offline reconstruction jobs was not compatible with higher μ and flat budget for ATLAS computing
  - offline software is migrated to multi-threading (MT) framework, LAr part was successfully migrated and is extensively tested now
  - code clean-up and speed-up done at the same time (although LAr reco has only very small fraction of overall ATLAS)
- Data Quality
  - data quality infrastructure, which helped to achieve high quality of data for physics is undergoing modernization
  - migration of monitoring to MT done, now in testing phase
  - migration to new OS (CentOS 7), code clean-up and speed-up

LAr preparation for LHC Run-3

- Online software
  - detector specific control and monitoring software migrated for the new version of ATLAS TDAQ framework (ver. 9.0.0)
  - inclusion of packages into online SW that configure Phase-I elements
  - migration to python3 ongoing
- Detector control systems, two projects are under development:
  - monitoring and control parameters of Phase-I back-end system (ATCA crate and LTDB)
  - monitoring parameters of LTDB, during commissioning stage this project is used to configure these boards

Conclusions

- ATLAS LAr Calorimeter has achieved excellent performance and stability during the Run-2, without any significant hardware or software problems
- constantly improving the hardware, monitoring and data quality procedures, ATLAS LAr team was able to achieve >99% efficiency of data GOOD for physics, whole this infrastructure is modernized, to keep the same efficiency also in Run-3 with higher luminosity
- Phase-I upgrade installation and commissioning is ongoing well, no major delays developed during lockdown, on schedule to be ready in time for LHC restart