ICHEP 2022 BOLOGNA
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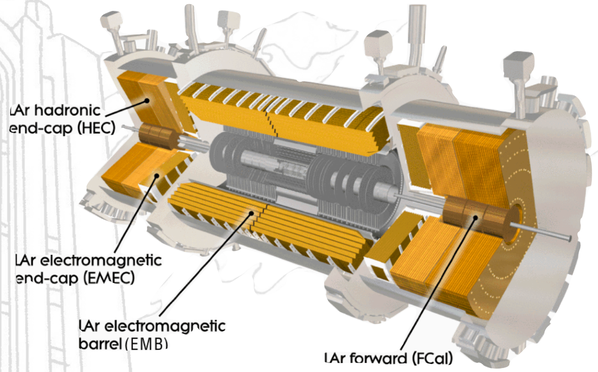
ATLAS EXPERIMENT



ATLAS LAr Calorimeter Commissioning for LHC Run 3

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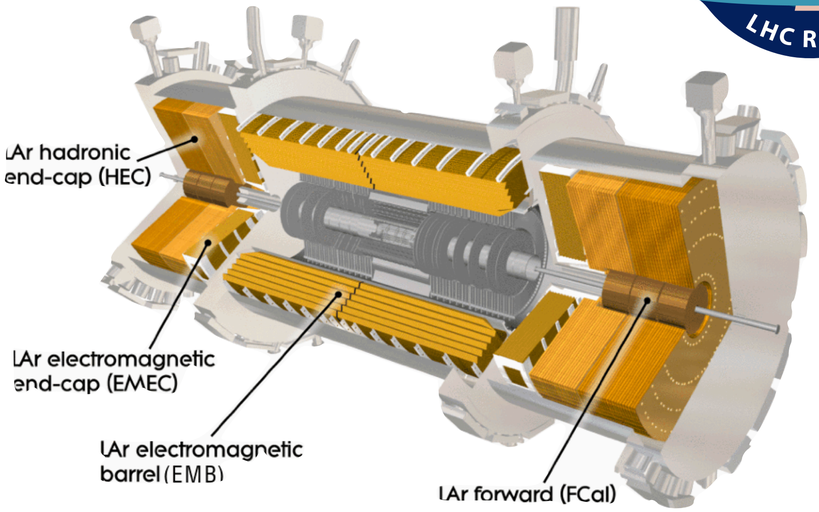
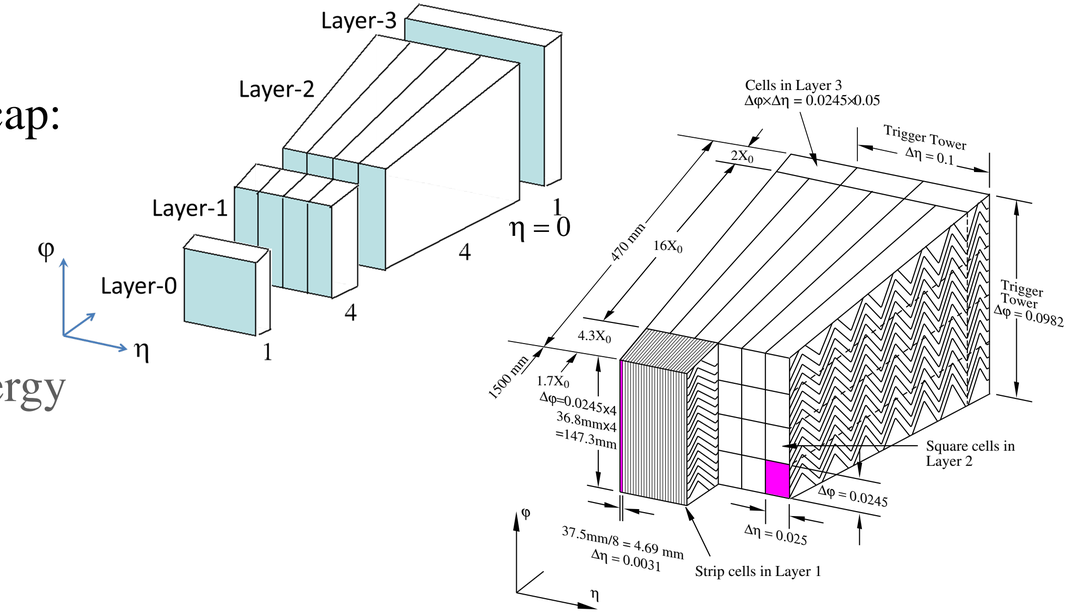
On behalf of the ATLAS LAr Group

University of Pittsburgh

ATLAS liquid argon calorimeter

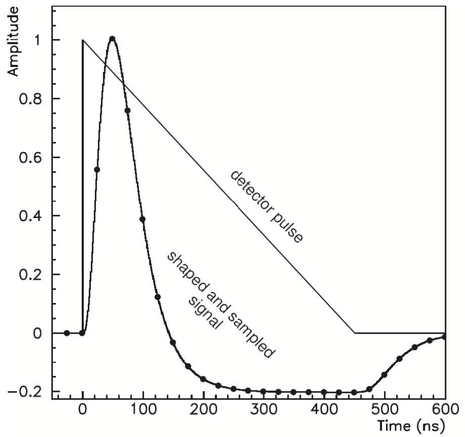
- Sampling calorimeter:
  - Absorber material: lead, copper and tungsten.
  - Active material: liquid Argon (LAr).
- Four major components:
  - Electromagnetic calorimeter in the barrel (**EMB**) and endcap (**EMEC**), hadronic endcap calorimeter (**HEC**) and forward calorimeter (**FCAL**).
  - Separated by A ($\eta > 0$) and C side ($\eta < 0$).
- LAr detector comprises four layers in the barrel and most of the endcap:
  - **Presampler**: measure energy loss before the calorimeter.
  - **Front layer**: fine segmentation, used to distinguish π^0 from γ.
  - **Middle layer**: deepest layer, most of the EM shower deposits energy here
  - **Back layer**: catch the tail of EM shower.





LAr legacy readout system

- Front-end boards (FEBs):
  - 1524 FEBs, with 128 channels on each FEB.
  - Split into 3 gains scales (low/medium/high) and shapes.
  - The triangular pulse shaped and digitised at 40MHz and stored in a buffer.



- Signal Level-1 calorimeter (L1Calo) trigger:
  - Receives analog signal build by tower builder boards (TBBs) and send L1 accept (L1A) back to FEB.
  - FEB select the proper gain, digitise the signal and transmit to read out drivers (RODs), and further to ATLAS DAQ system.

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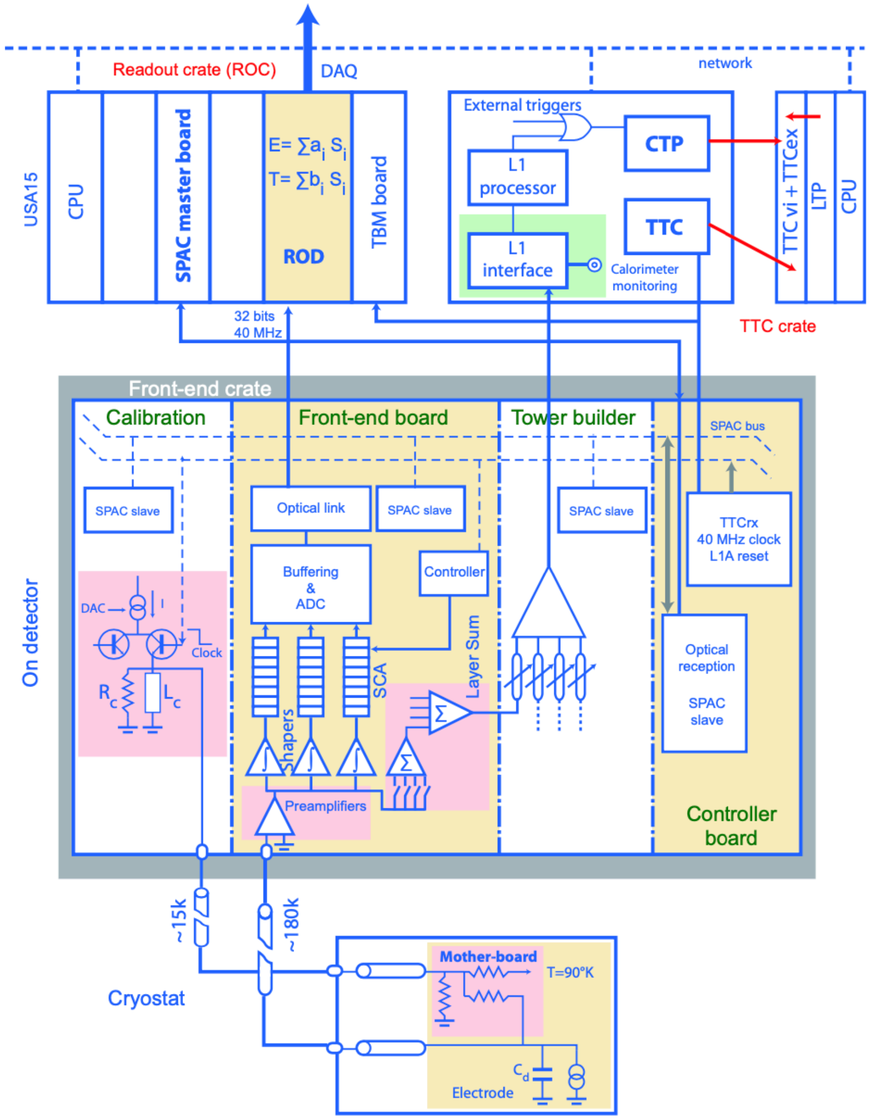
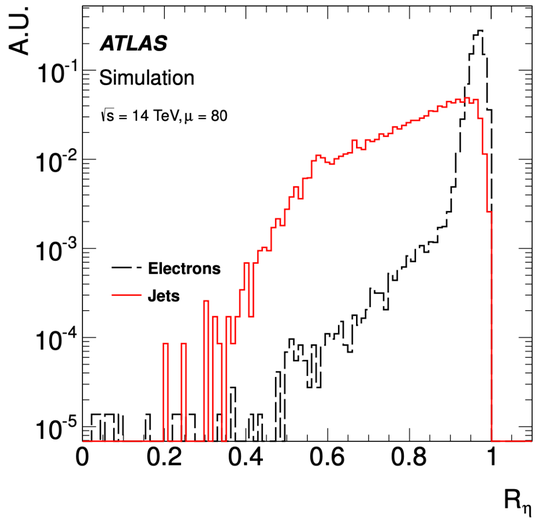


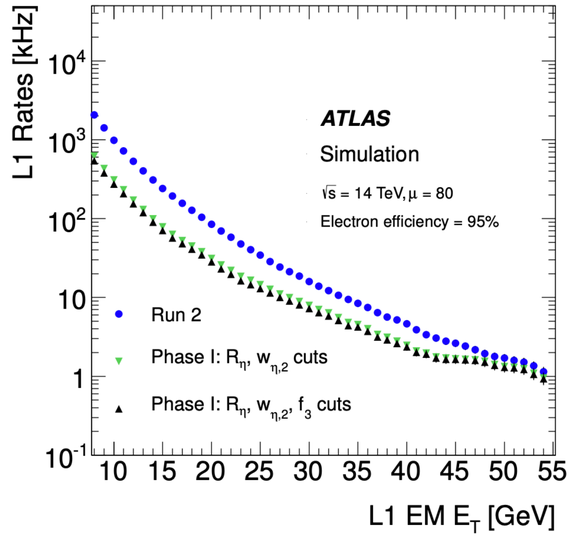
Motivation for LAr Phase-I upgrade

- First thing first: Run 2 operation was a huge success…

Year	2015	2016	2017	2018
ATLAS data efficiency	87.1%	93.0%	93.6%	95.7%
LAr data efficiency	99.4%	99.8%	99.5%	99.5%

- However, in LHC Run 3:
  - Instantaneous luminosity and pile-up will increase, but the sustainable ATLAS L1 trigger will remain the same as Run 2.
    - 100kHz at maximum, **20kHz for electrons and photons**.
  - Using shower shape variables, such as R_η, $w_{\eta,2}$,f_3.
    - Better distinguish electrons and jets
    - Remains a low E_T thresholds ~28 GeV, 7 GeV lower than Run 2 algorithm.
  - So, how can we retrieve better shower shape information?



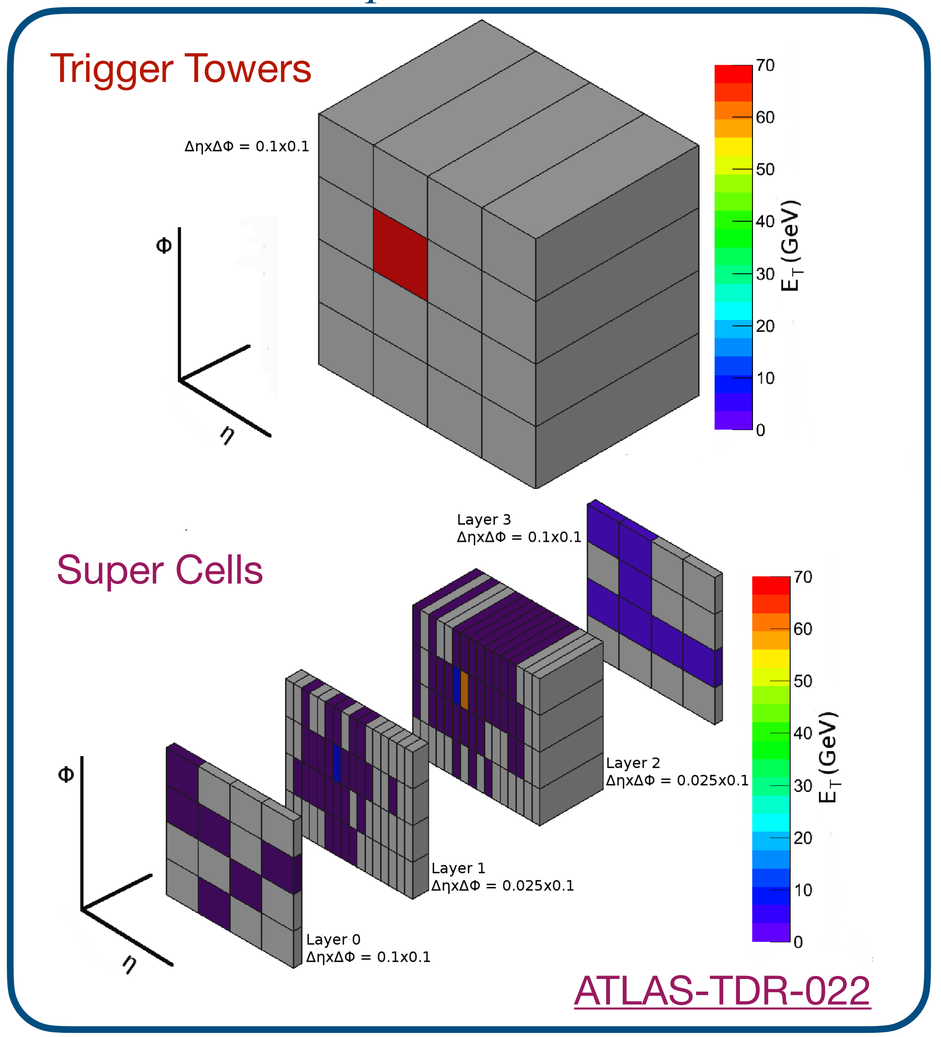


ATLAS-TDR-022

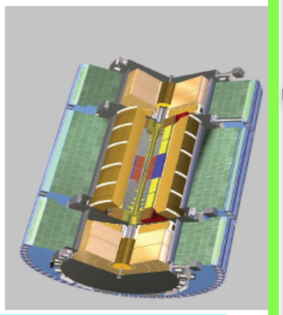
LAr Phase-I upgrade: super cells

- In the legacy system, L1Calo trigger decision is based on ~5.4k trigger towers from 180k cells.
  - Transverse energy E_T in all four layers are summed.
    - Losing the shower shape information.
  - Using analog signals, digitised on trigger backend.
- Super cells (SC) proposed for the Phase-I upgrade
  - Using ~34k SC from 180k cells.
    - Finer granularity for triggering, by a factor of 10.
  - Increased resolution in front and middle layer. E_T in each layer is retained.
    - Access to the longitudinal shower shapes.
  - Move to digitised signals → **LAr digital trigger system**.

An electron with $E_T = 70$ GeV seeing by:



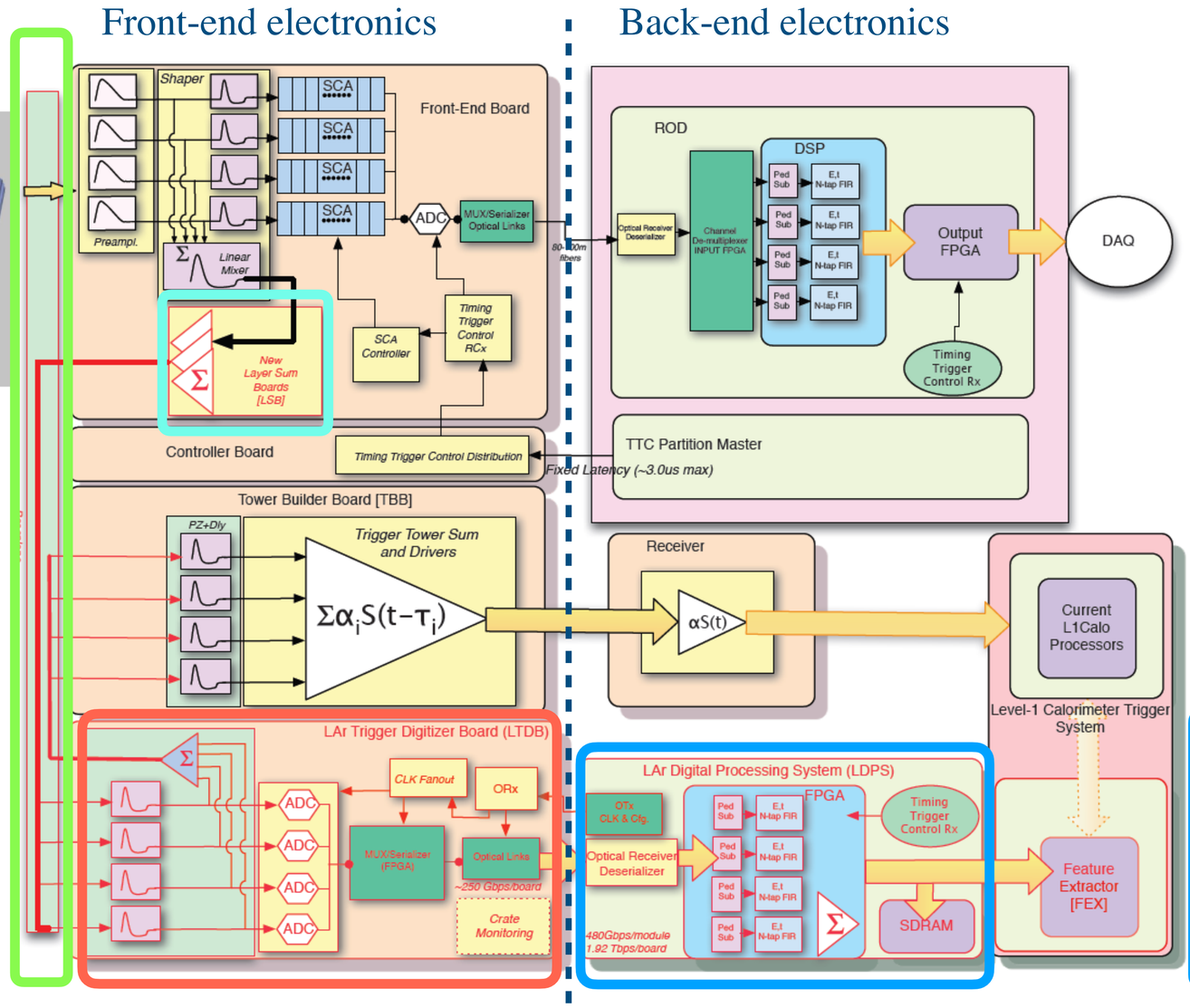
LAr Phase-I upgrade: electronics readout



New Layer Sum Boards (LSBs) summing calorimeter cells to super cells.

Baseplane replacement to handle the increased transmission of signals.

LAr Trigger Digitizer Board (LTDB) to digitise super cell signals and send it to back-end electronics.



In case of unforeseen issues, both legacy and digital trigger system will be running concurrently in early Run 3!

LAr Digital Processing Blade (LDPB) to reconstruct transverse energy with LATOME, and send to L1Calo system

ATLAS-TDR-022

LAr Phase-I upgrade: electronics readout

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Baseplane replace handle the incr transmission of

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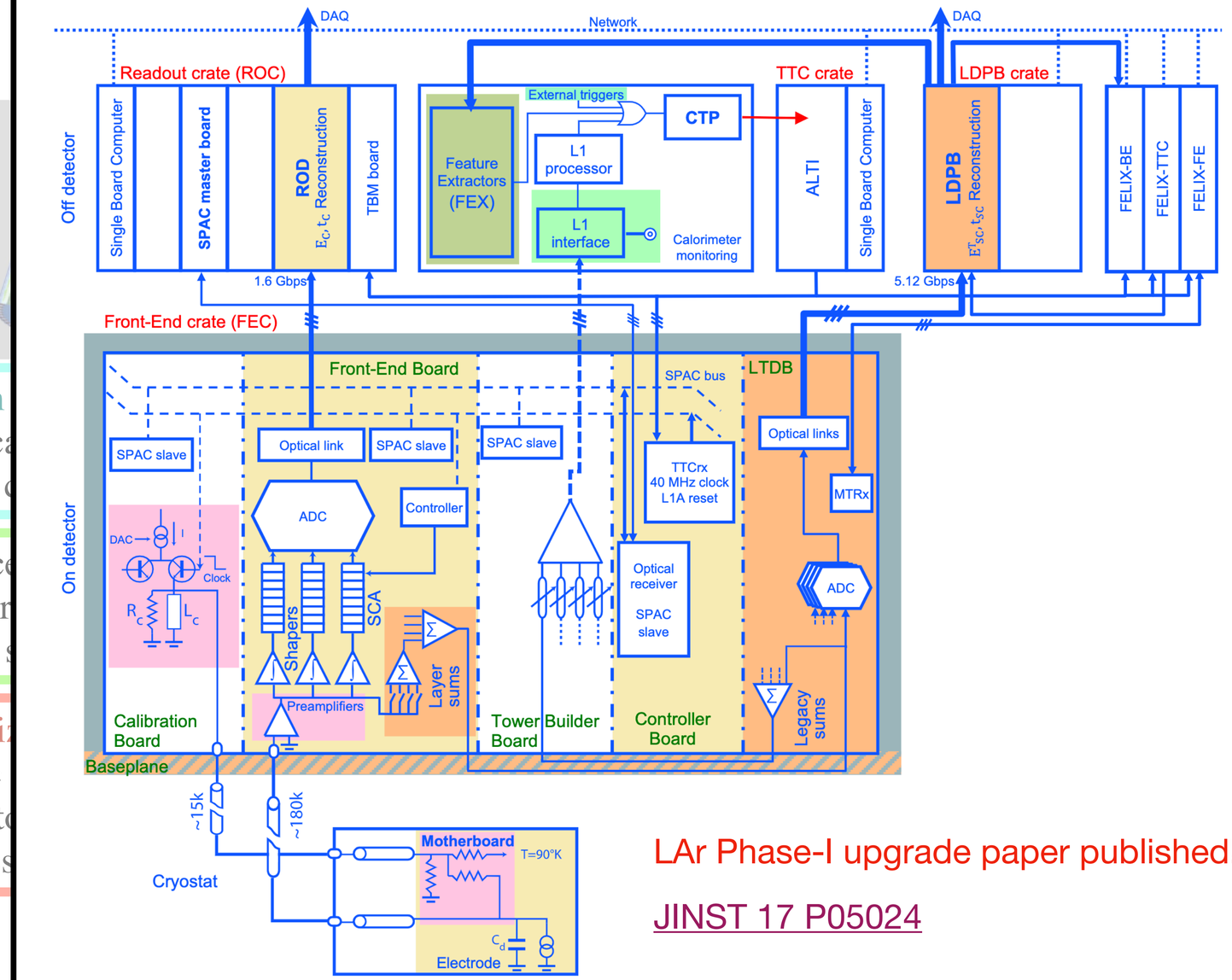

LAr Phase-I upgrade paper published!

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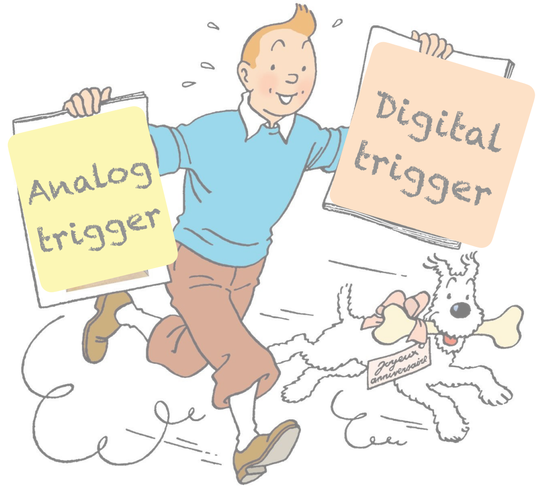


In case of unforeseen issues, both legacy and digital trigger system will be running concurrently in early Run 3!

LAr Digital Processing Blade (LDPB) to reconstruct transverse energy with LATOME, and send to L1Calo system

Front-end installation

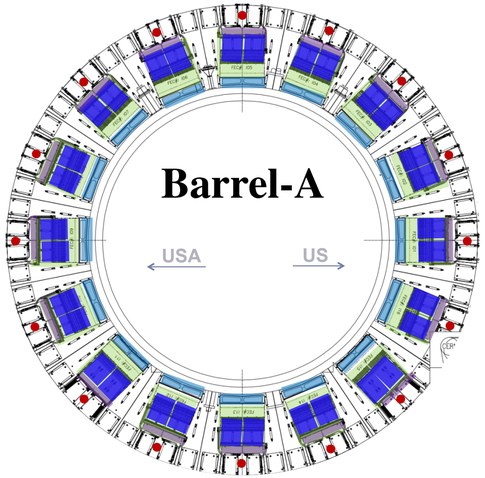
Baseplane exchanged

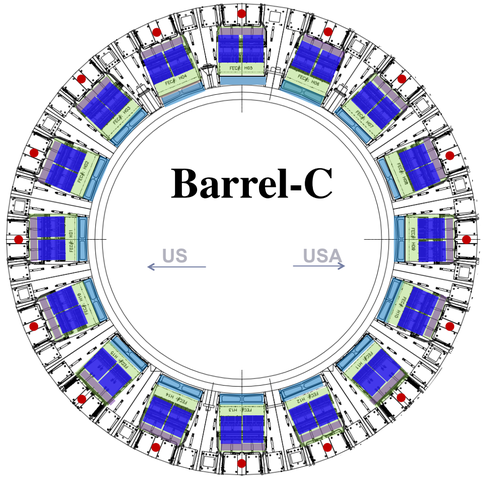
Re-cabled for commissioning

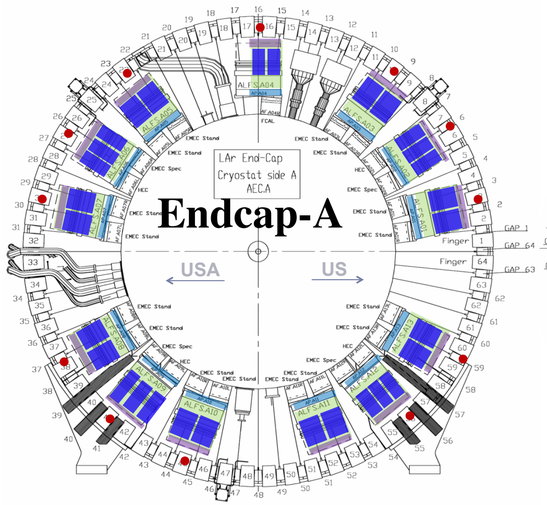
Boards reinserted

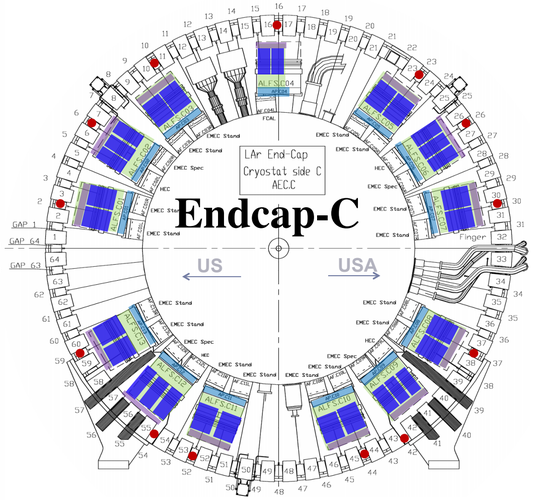
LTDB installed, In commissioning

LVPS cooling hose replaced



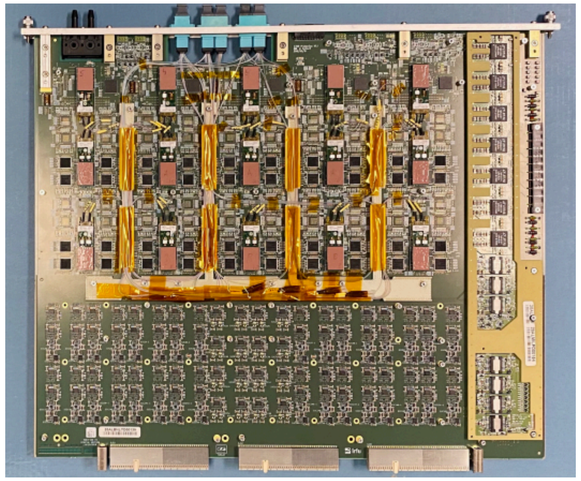






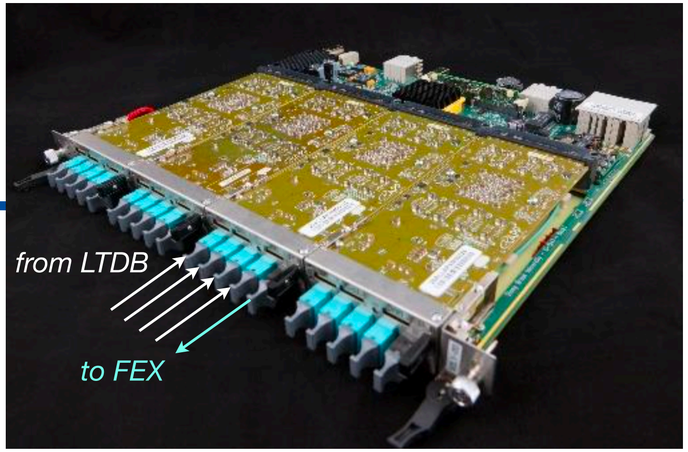
- All baseplanes and front-end boards (FEBs) refurbished and reinserted.
  - In total 114 new baseplanes.


Baseplane replacement in UX15



- All LTDBs are installed and connected.
  - 124 LTDBs, with 7 “flavours” depending on the location.
  - 4 boards (C side) and 3 boards (A side) have been replaced upon the validation.

Back-end system of digital trigger



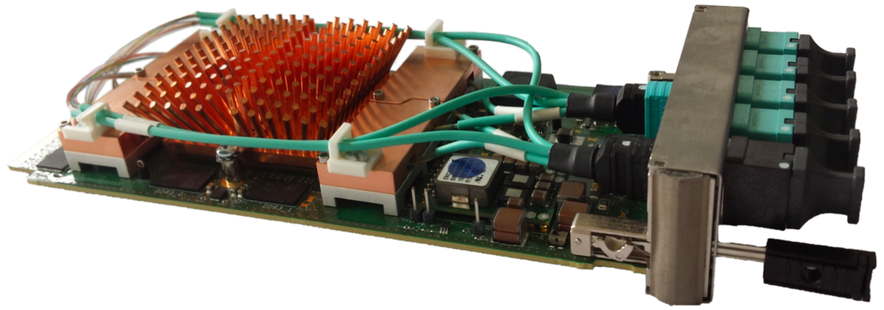
- 1 LDPB = 1 LArC + LATOMEs + IPMC.
  - 4 LATOMEs on each LArC, except 2 special ones with only 2 LATOMEs.
  - Totally 30 LArCs and 116 LATOMEs for full system at P1.

LAr Carrier (**LArC**):

- Global&local readout.
- Providing trigger, timing and control signals to LATOMEs.

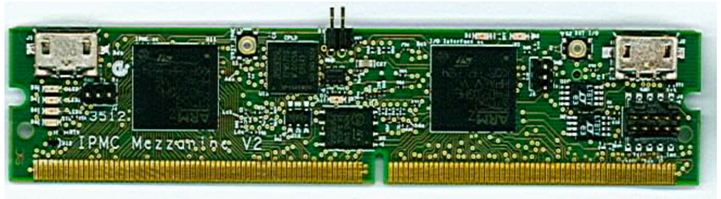
LAr Trigger prOcessing MEzzanine (**LATOME**): JINST 17 P05024

- Receive up to 48 high speed input links from LTDB at 40 MHz.
- Reconstruct super cell E_T and identify BCID.
- Transmit results to L1Calo FEX.



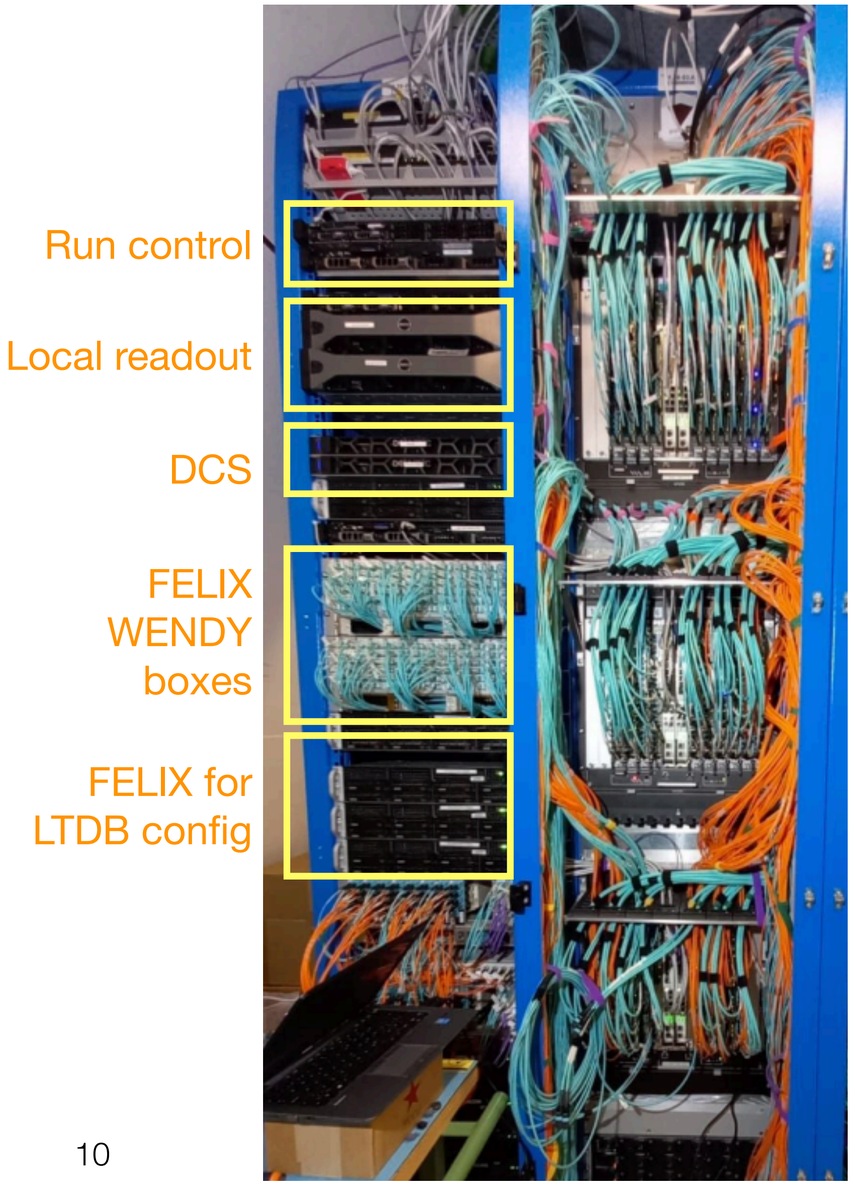
Intelligent Platform Management Controller (**IPMC**):

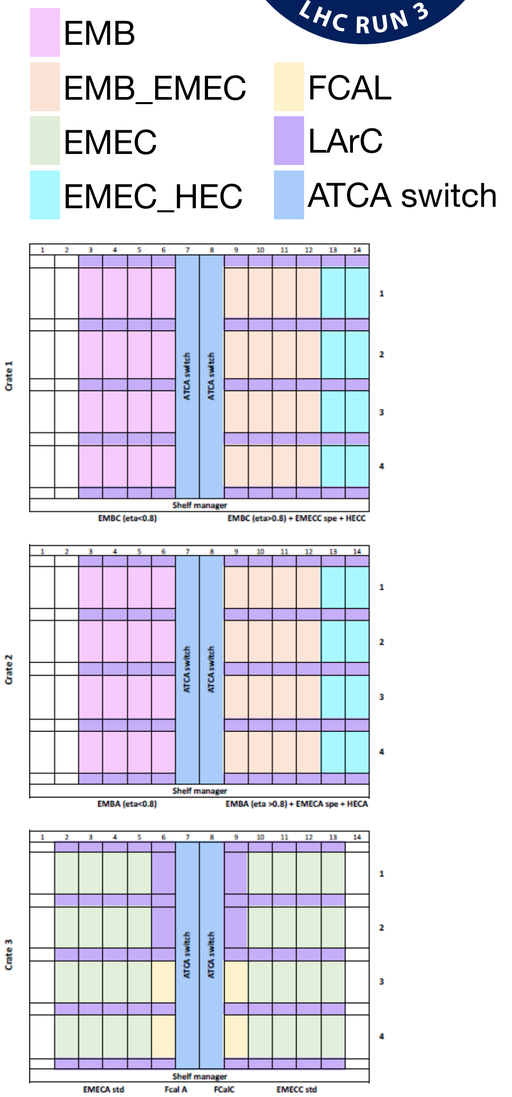
- An intelligent hardware management system for ATCA boards and ATCA carrier boards.
- Control, monitor, generate alarms.



Back-end installation

- All 30 LDPBs installed in **3 ATCA crates**.
- **Connection** done.
  - 100% LATOMEs connected to LTDBs.
  - 100% LATOMEs connected to L1Calo FOX system.
- Finalising **firmware** for the Run 3 data taking.
  - LATOME fw v4.3.0, added pulse rate monitoring, able to match complex deadtime with ATLAS.
  - LArC fw v2.2, improved stability.
  - More stable IPMC firmware deployed.
- All **network/TTC/TDAQ readout connections** in place.
- **Monitoring and control system** ready.

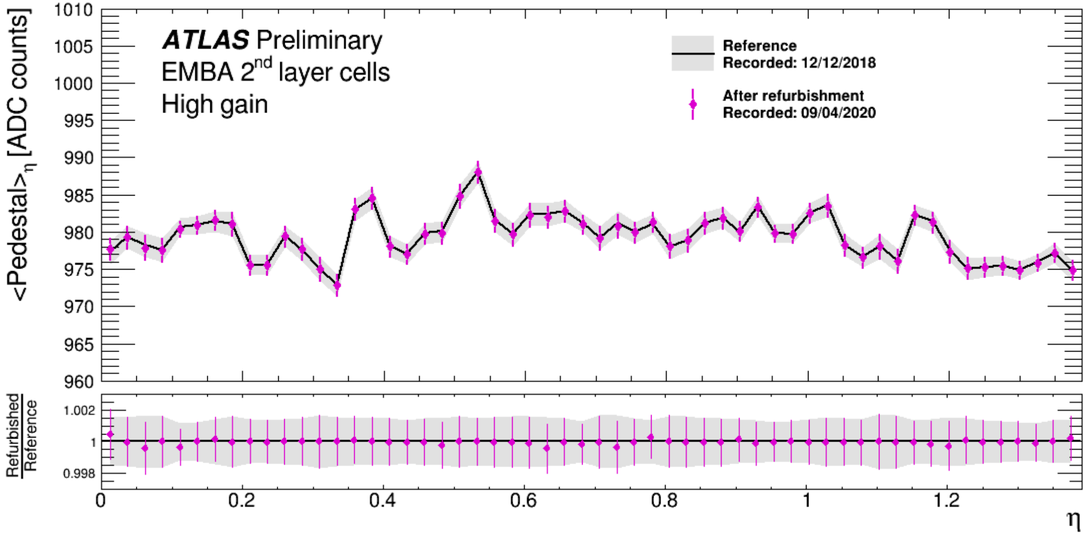


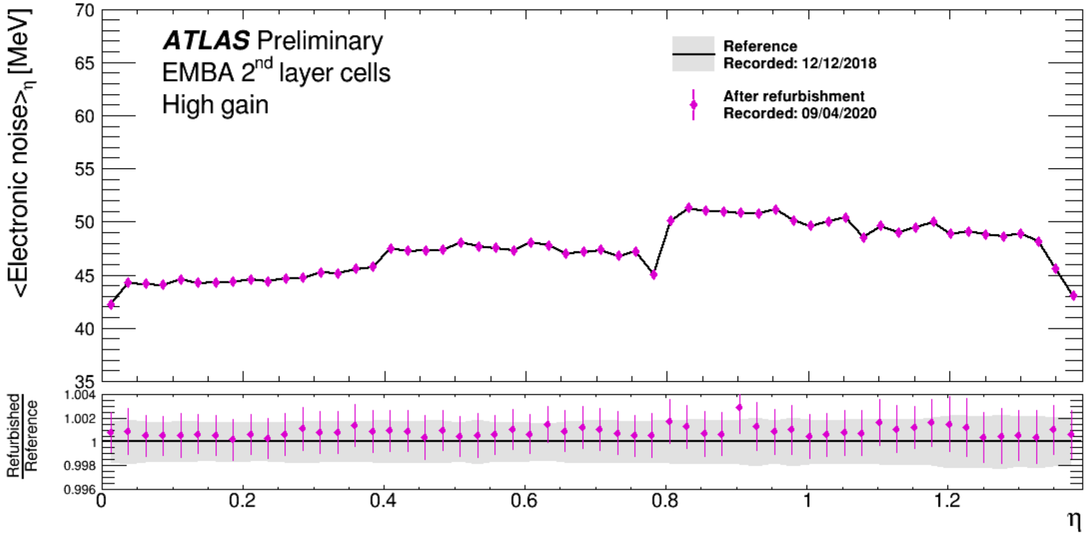


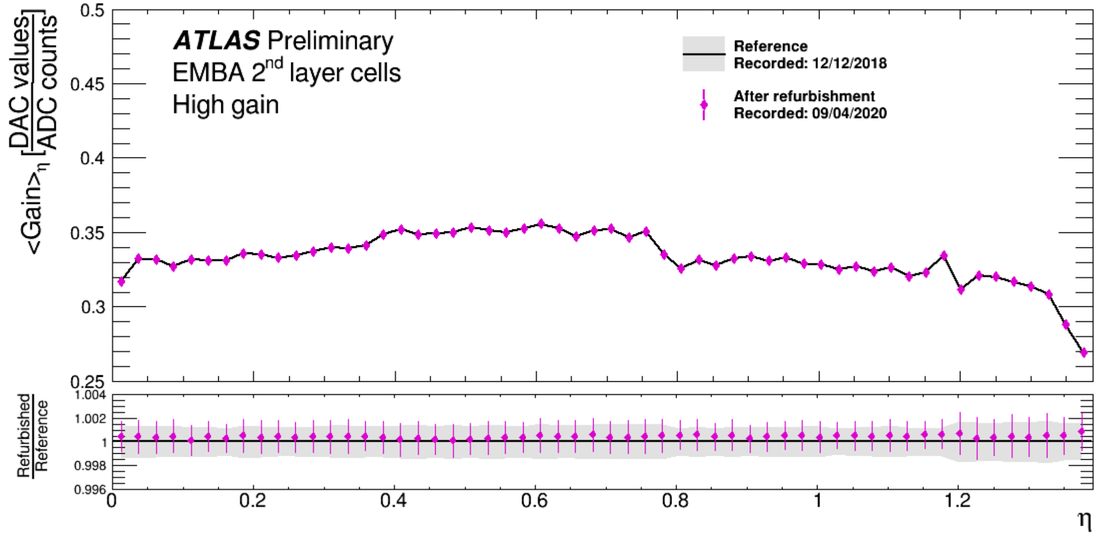
Validation of the main readout

- Comparing between:
  - Data taken after the FEB refurbishment.
  - Data recorded at the end of Run 2.
- In the level of pedestal ADC values, RMS in ADC counts, electronic noise and mean value of gains.
- No significant change observed after the Phase-I upgrade installation.

LArCaloPublicResultsLS2







Calibration procedure

- Both main readout (legacy system) and the digital trigger (Phase-I system) calibrated by daily and weekly calibrations.
  - Pedestal: without injecting any pulse to the FE electronics.
    - Also used to study the electronic noise.
  - Ramp: the peak ADC wrt the pedestal as a function of E_T for the pulse.
    - Saturation at ~800 GeV.
  - Delay: pulse samples by introducing delay between injection and readout time.

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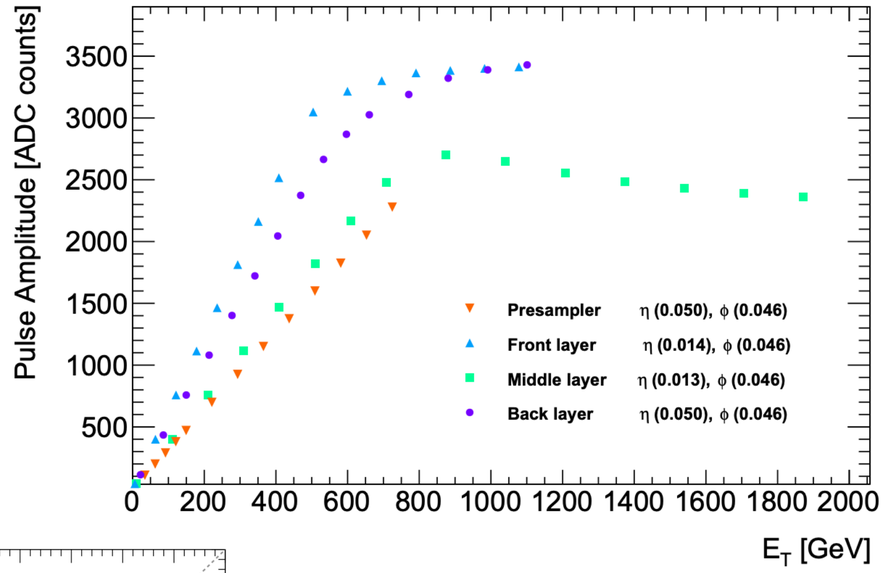
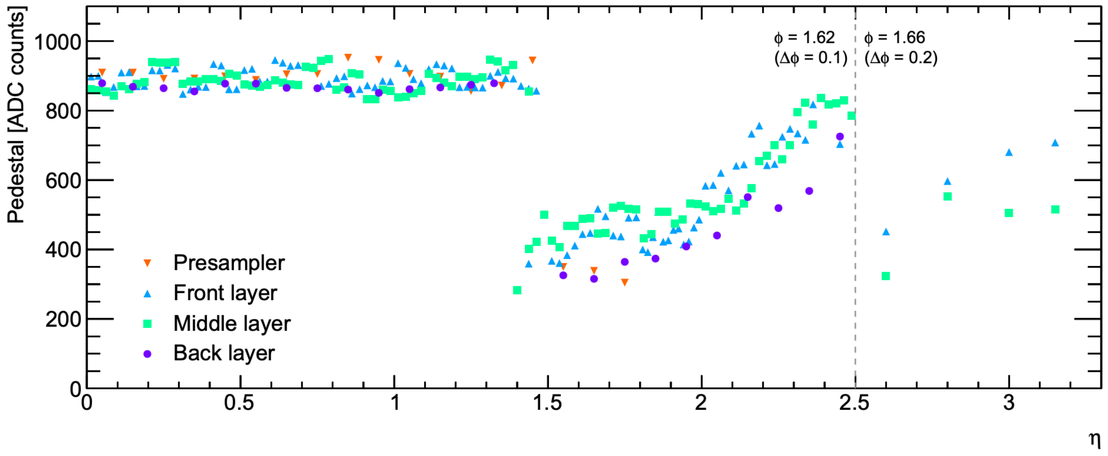
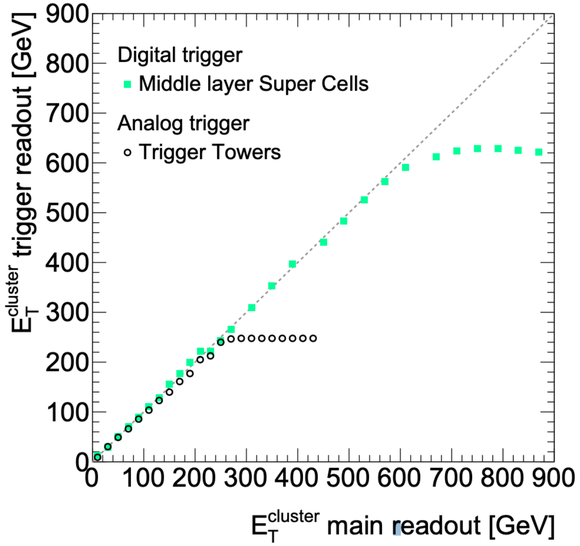


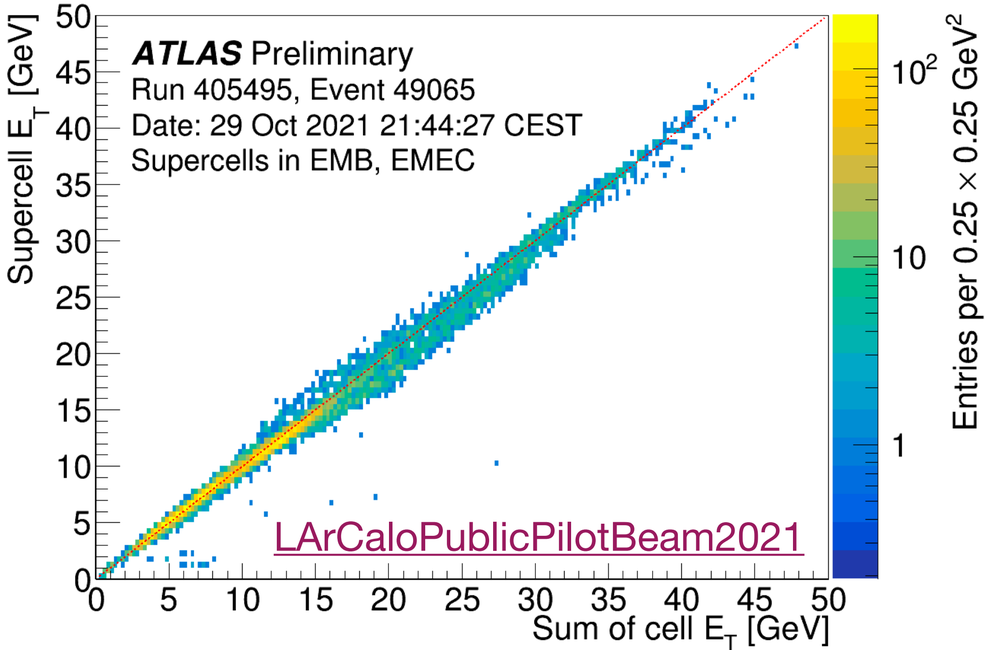




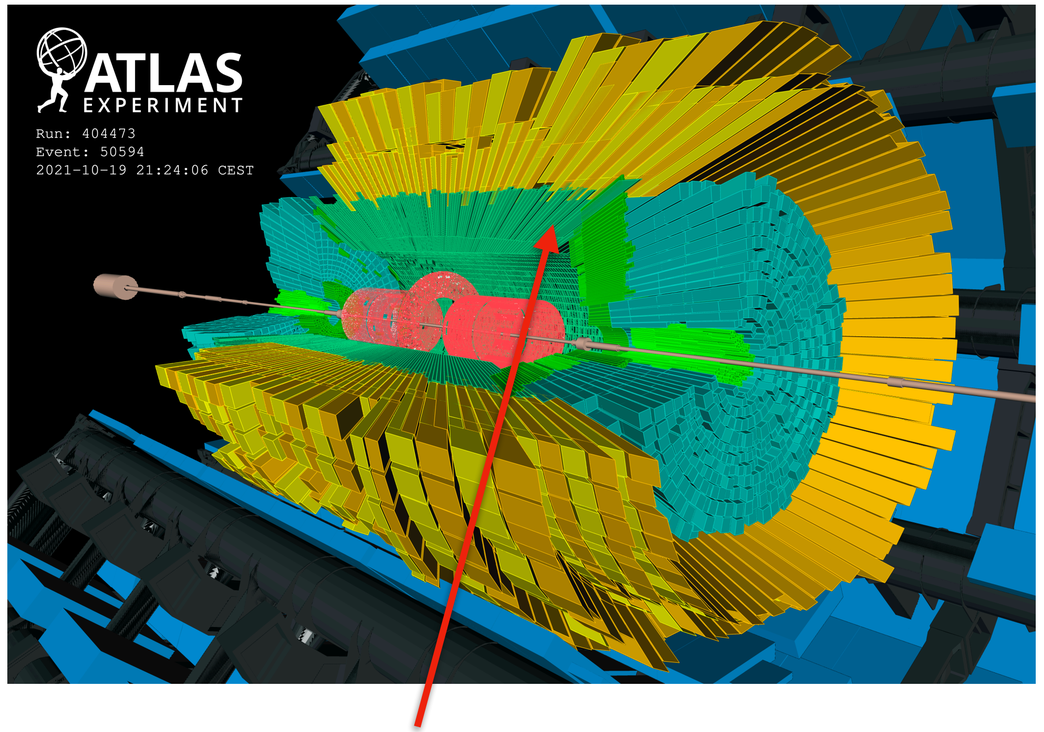
Good agreement between the main readout and digital trigger, where digital trigger has higher saturation limit.

LHC pilot run fall 2021

- Fruitful outcome during the LHC pilot run in October, 2021
  - First LHC beam delivered after Run 2, after 3 years of LS2.
  - Used to test system after Phase-I upgrade, for both main readout and digital trigger system.
    - Good agreement between supercell (digital trigger system) and summed cell energy obtained from the main readout.



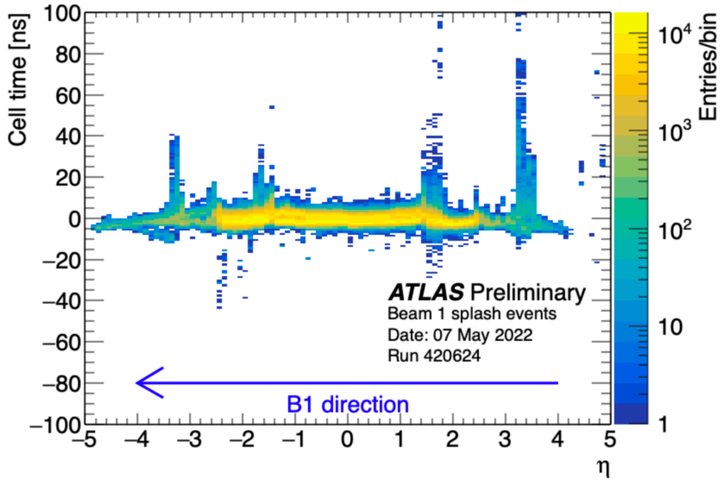
EventDisplayPilotBeam2021

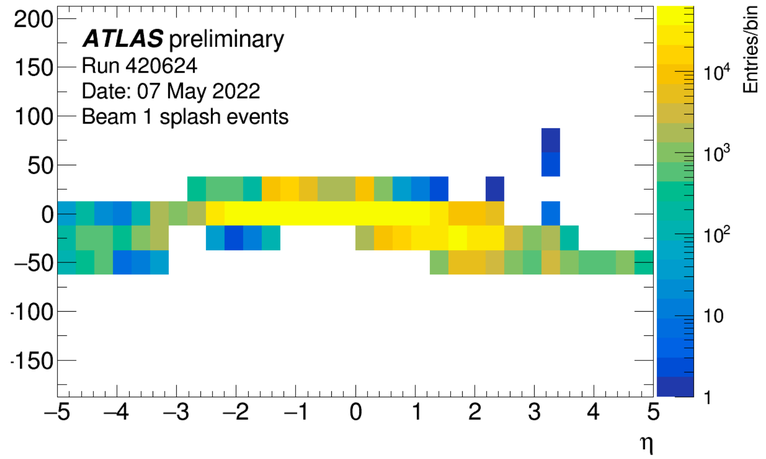


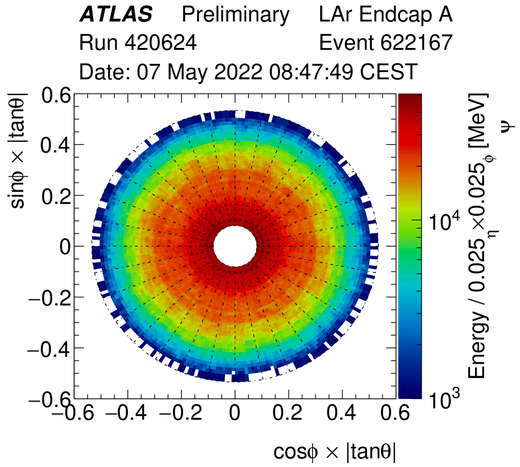
Green boxes show energy deposits in the LAr calorimeter.

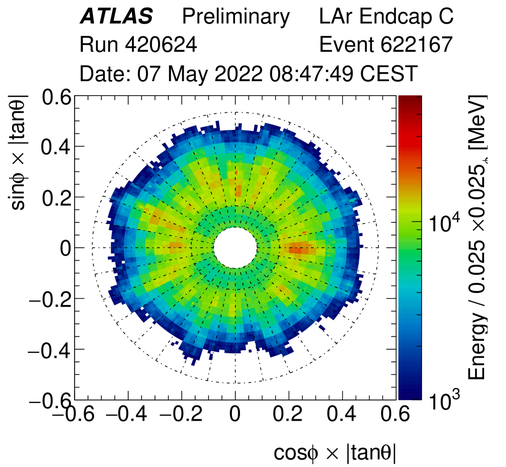
LHC pilot run: beam splash

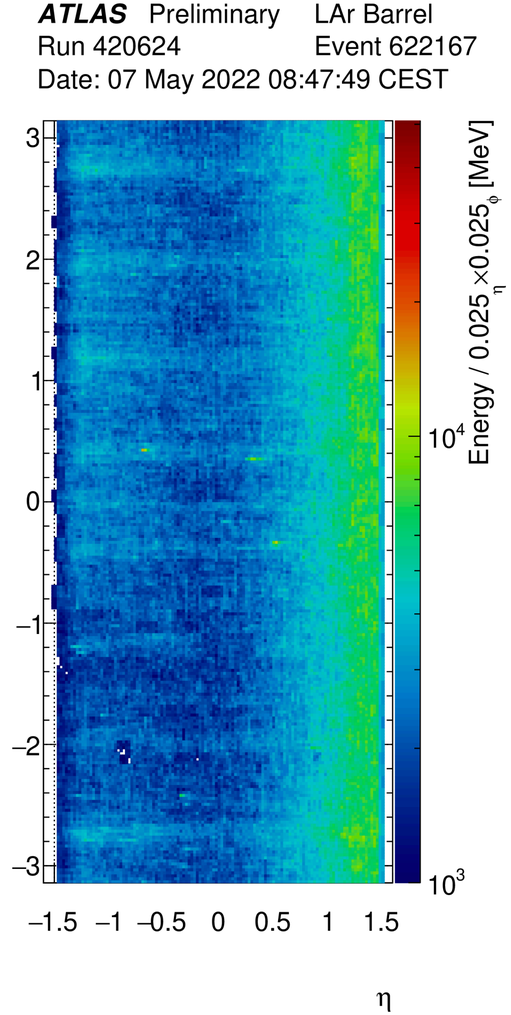
- Beam splash delivered by LHC during the pilot run in fall 2021 and test run early 2022.
- Using beam splash to align the timing for the full LAr system.
  - Main readout aligned to ns level.
  - Digital trigger system aligned at BCID level (25ns), will be aligned to ns level in the future.







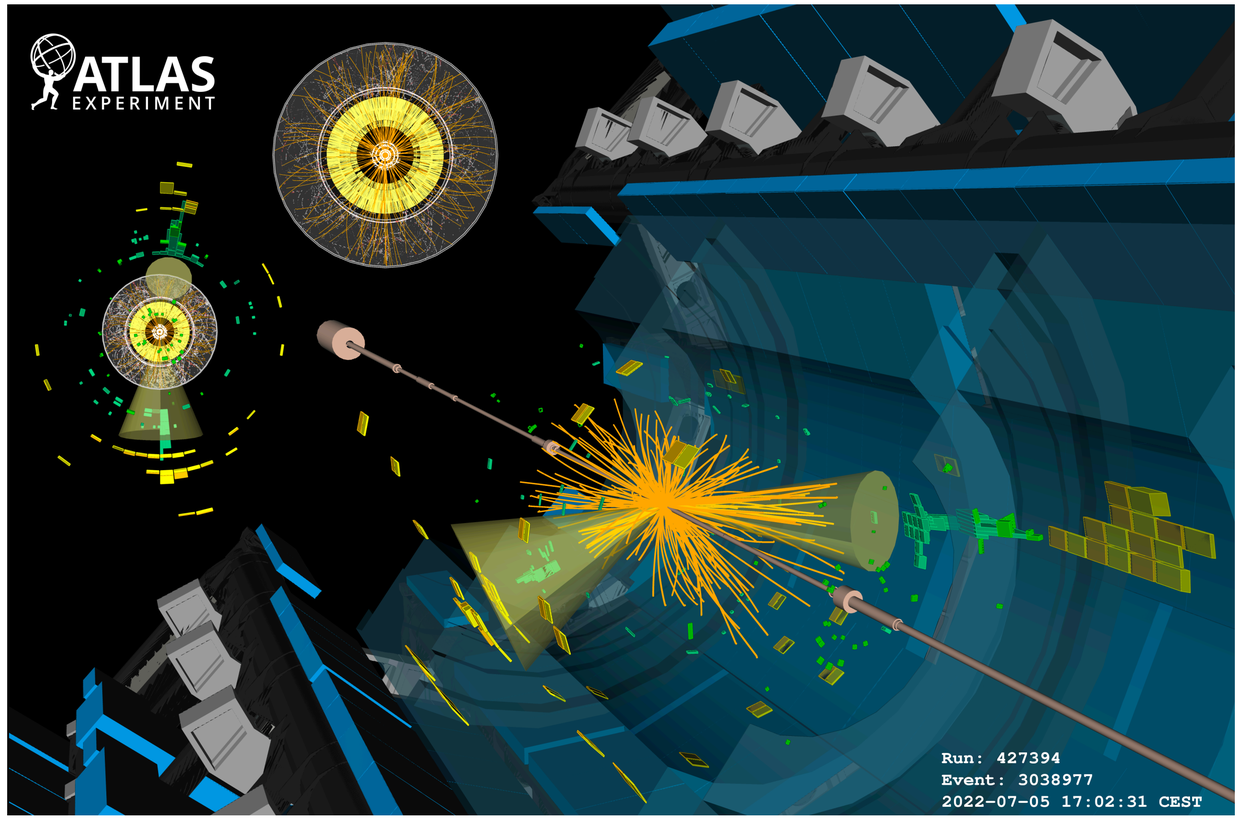




LArCaloPublicBeamSplashMay2022

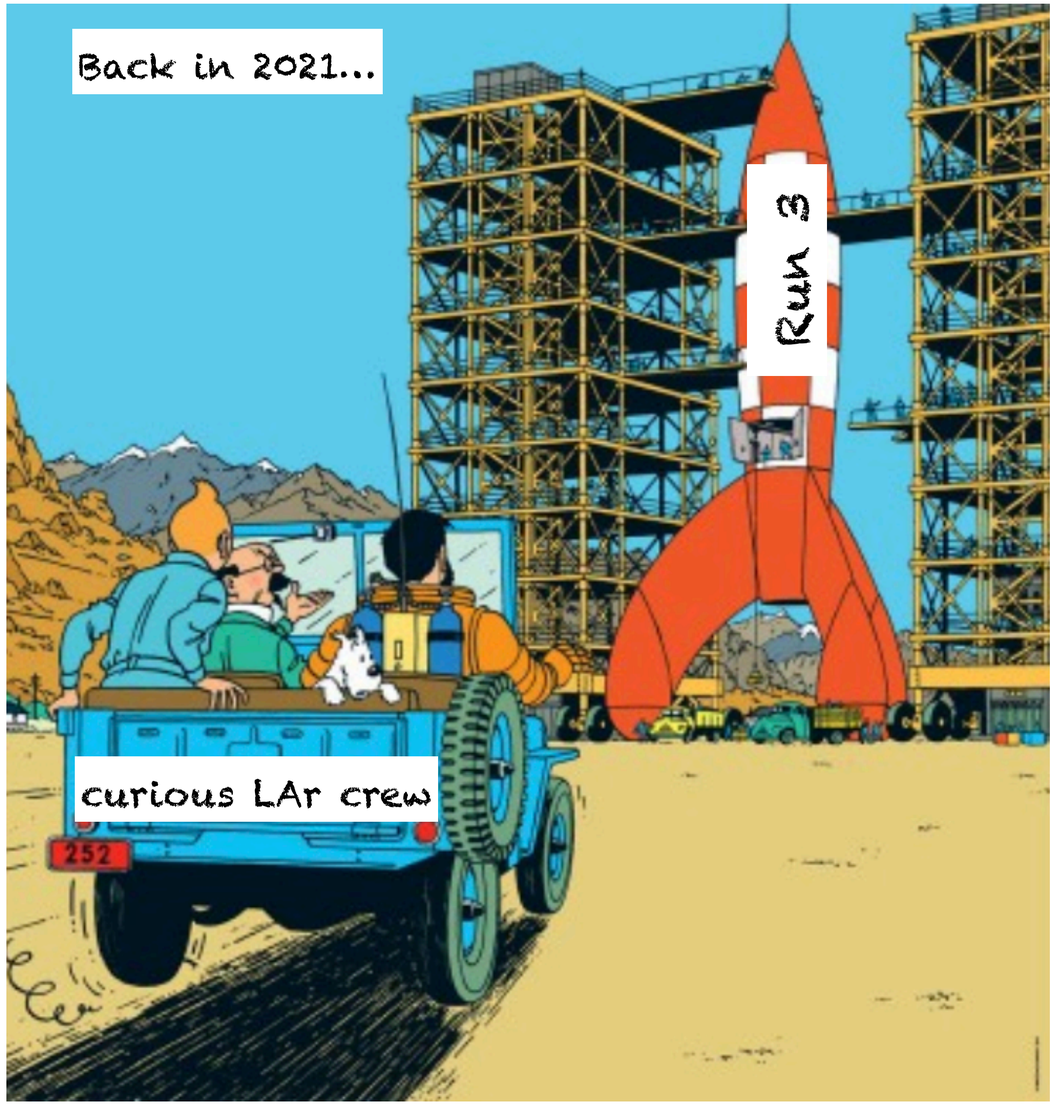
Conclusions

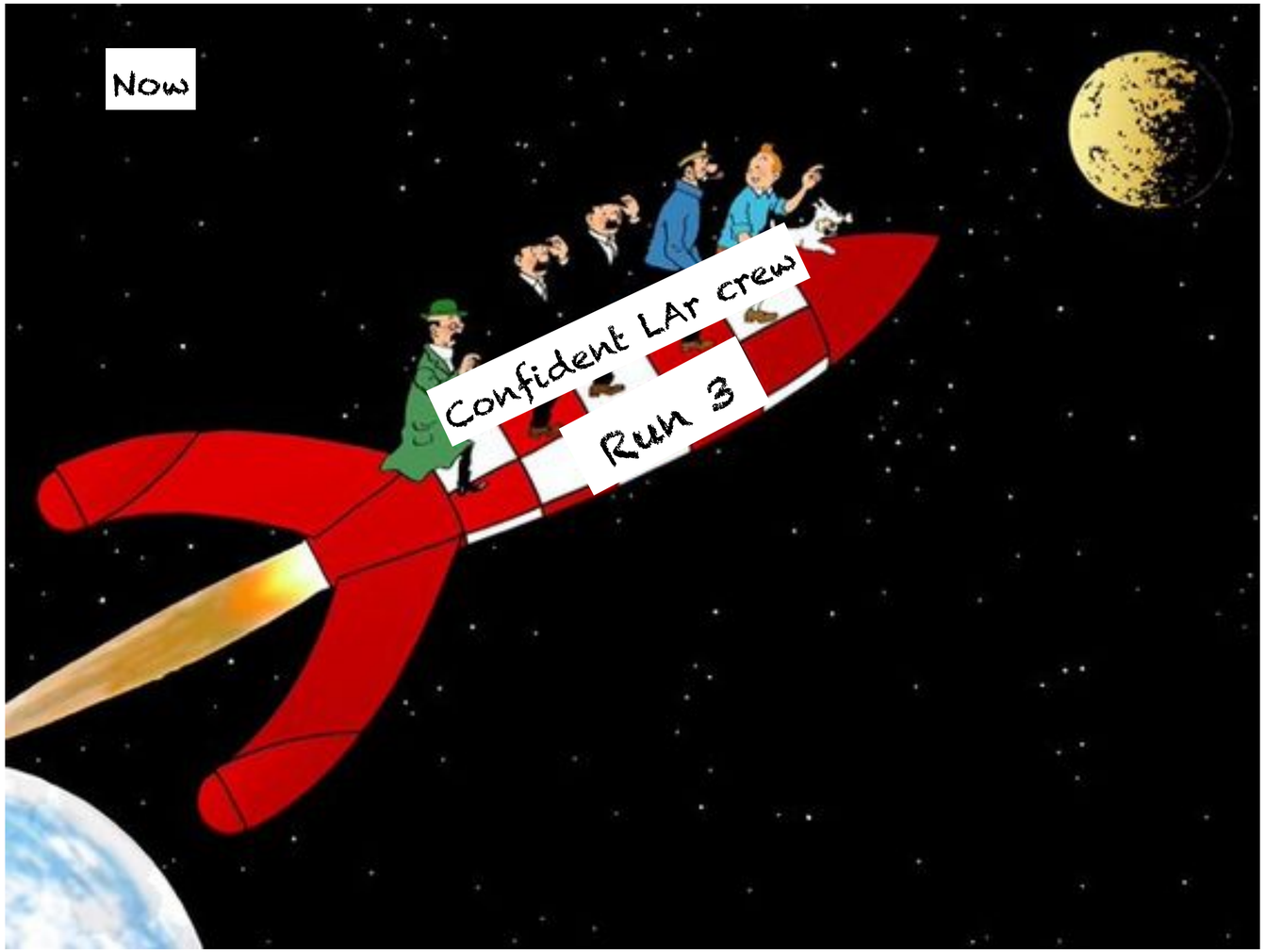
- LAr Phase-I upgrade has successfully complete!
  - Installations on both front-end and back-end are finished.
  - Validated by calibrations and the pilot run in the LHC.
- Keep rely on the legacy system (main readout) at the beginning of the Run 3.
  - To further validate the digital trigger system.
  - The full Phase-I calo trigger path should be operational by the end of this year.
- Beam splashed shows good performance on both main readout and digital trigger system.
  - Timing resolution in ps level.
- **Ready for data taking!**



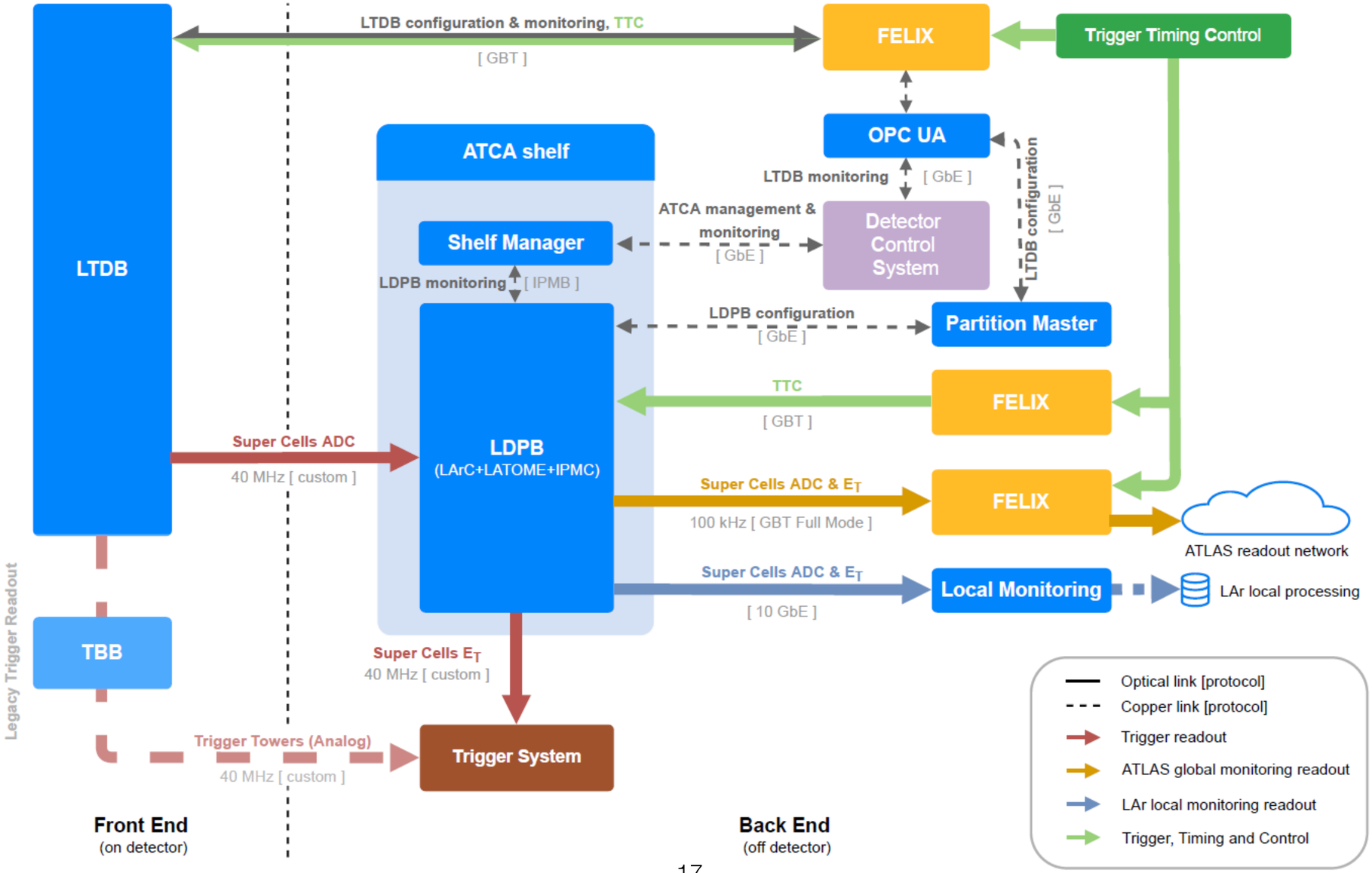
First stable beam collision at 13.6 TeV, recorded on 5th of July 2022.

Thank you!


Back in 2021...
Run 3
curious LAr crew
252

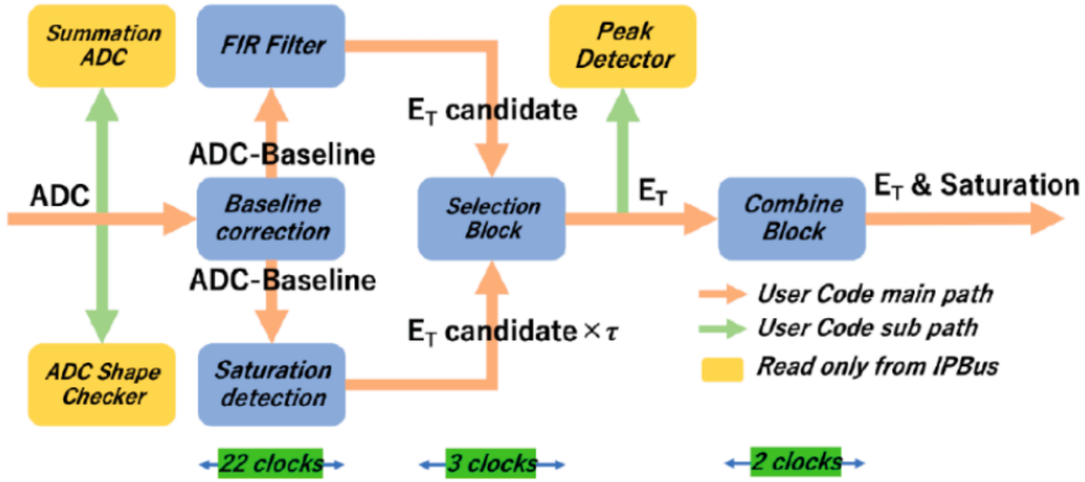

Now
Confident LAr crew
Run 3

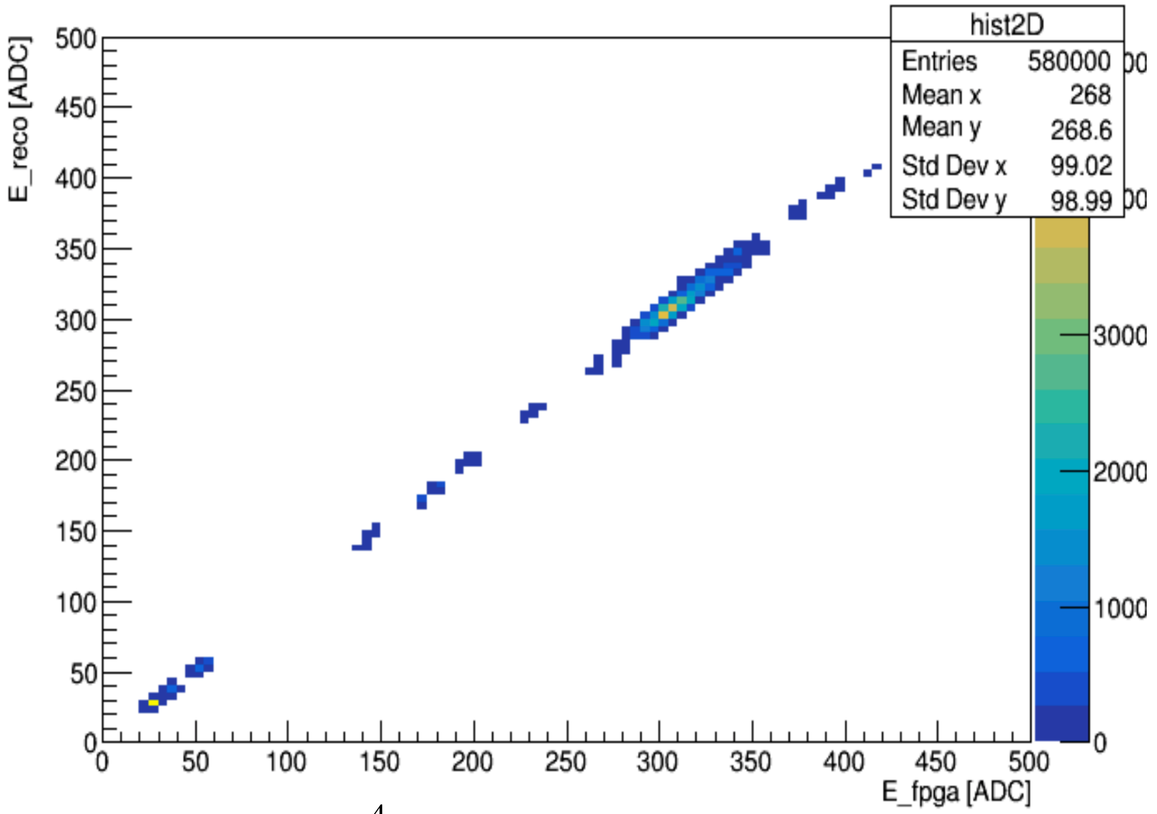
Digital trigger system scheme



Calibration of E_T in LATOME

- Provide correct supercell E_T to the FEX at 40MHz.
  - DSP output E_T: 18 bits.
- Preparing the COOL database for the supercells: OFC, HV, DAC2μA, etc.





$$E_T = \sum_{i=1}^{4} a^{(5-i)}(data_i - pedestal)$$

Comparing LATOME energy computation to full precision computation: ±1 % accuracy