The Legacy L1Calo Trigger – Timing and Energy Calibration

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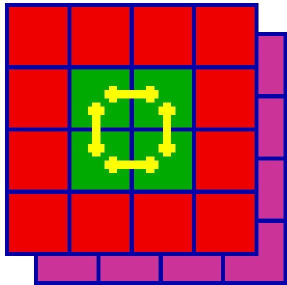
HighRR BiWeekly Seminar

09.03.2022



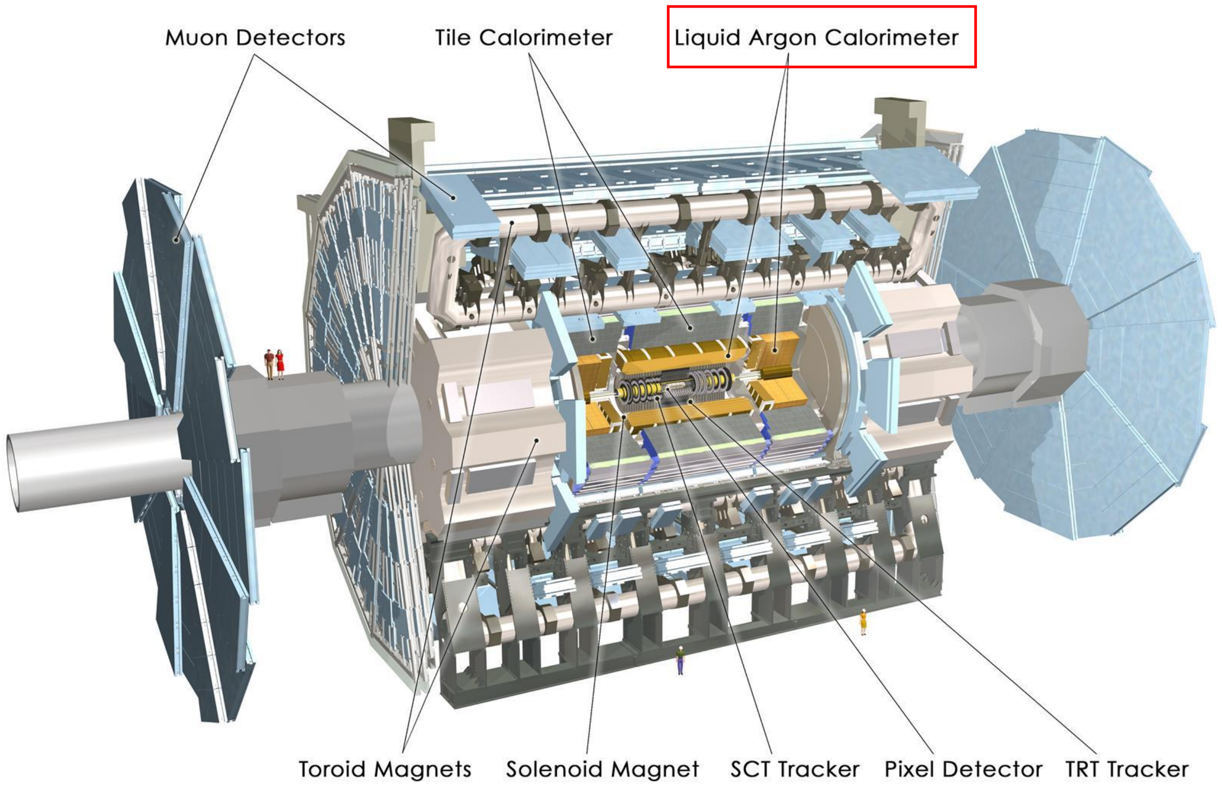
Contents

- ATLAS
- Liquid Argon Calorimeter Electronics

- Moving to Run 3, the Upgrade
- How was the timing chain effected?
  - Tower Builder Boards
  - Input Timing
  - Splashes & Pilot Run
- Energy Calibration

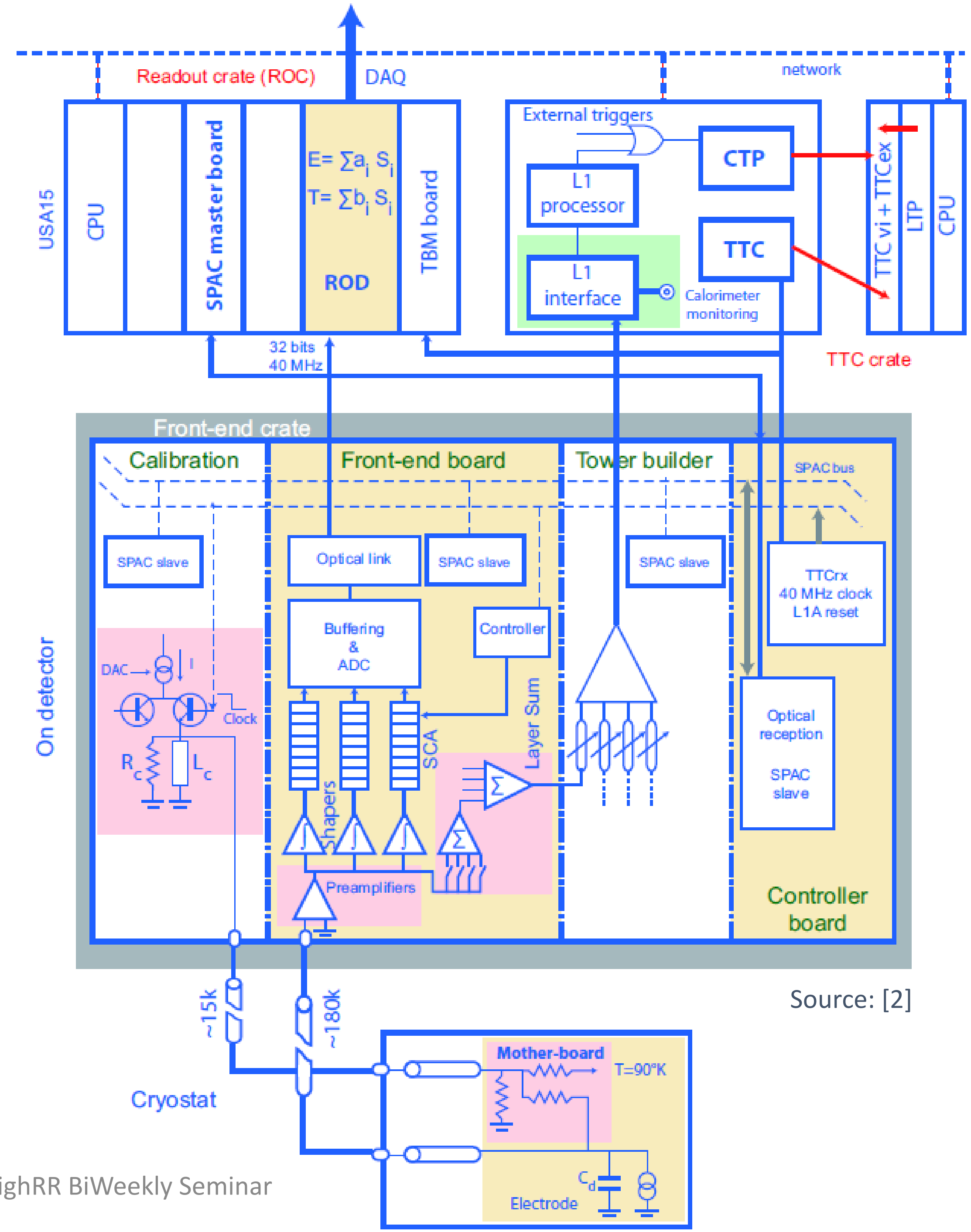
ATLAS at the LHC

- LHC (large hadron collider) at CERN in Geneva
- ATLAS is one of four major experiments
  - Multi-purpose detector
  - Layered design
  - Layer of interest → Electromagnetic (LAr) calorimeter
- ATLAS currently receives the Phase-I Upgrade



Source: Cern, [1]

Liquid Argon Frontend Electronics

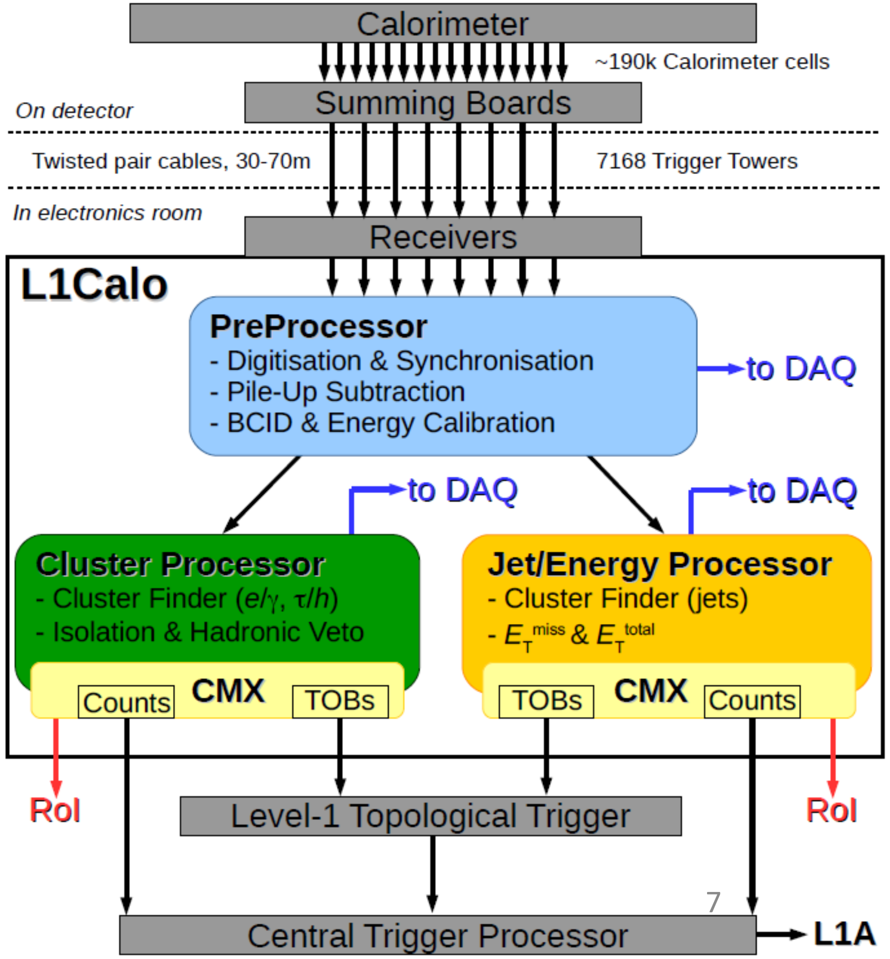


Source: [2]

What is the Level-1 Calorimeter Trigger?

- ATLAS Calorimeter input at 40MHz collision frequency
- Hardware based selection tool to filter for interesting events
- Processes reduced calorimeter information
- Reduces event rate to 100kHz
- Identifies interesting physics objects
  - (e-, tau, jet, E^T_miss)
  - Forwards those to the High Level Trigger

Source: [3]



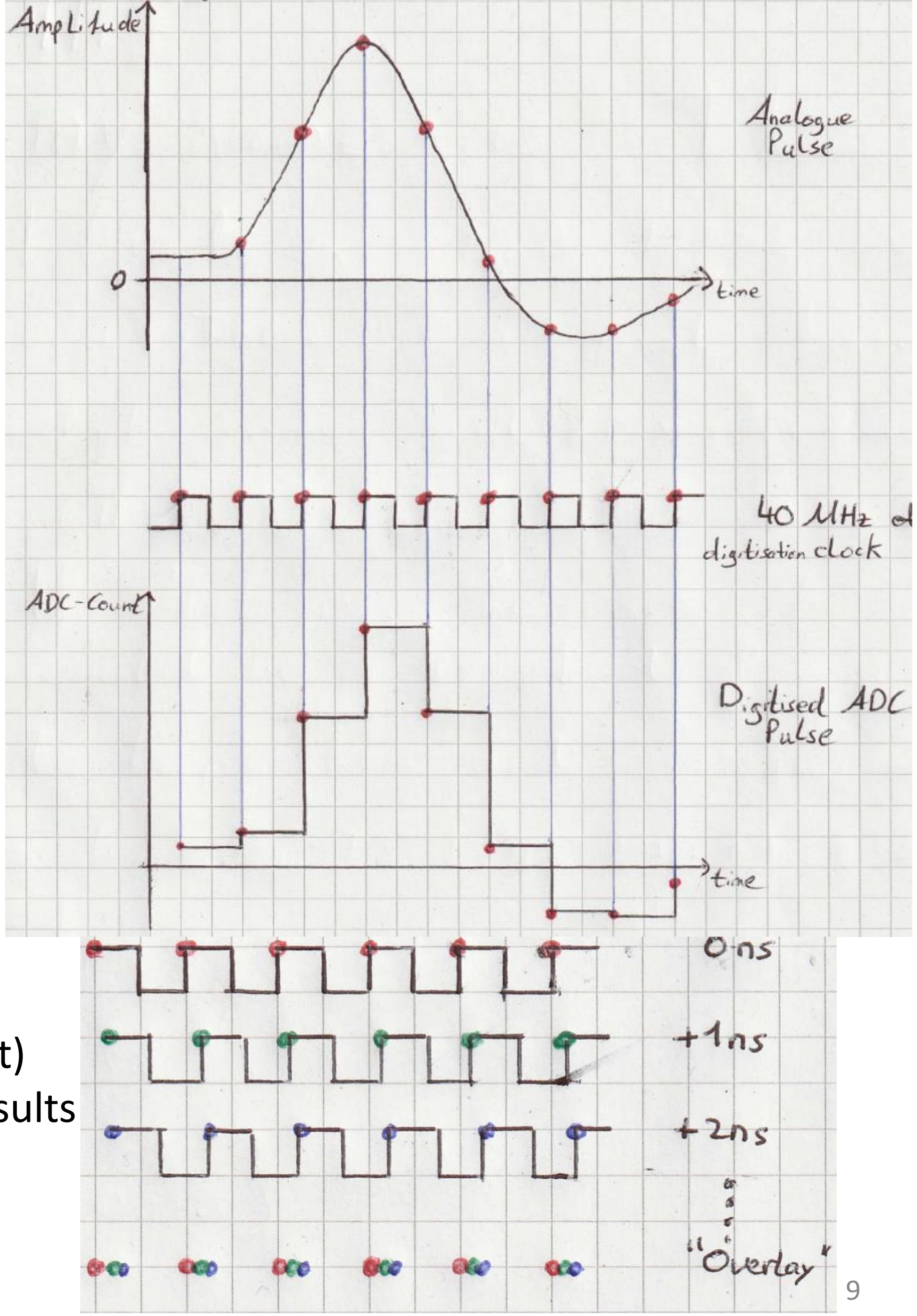
PPM Input Timing

- Input Timing allows for correct digitisation and alignment of all TT into the same BC
- Input Timing has two „components“
  - Coarse timing
  - Fine timing

- Coarse timing adjusts TT signal timing in multiples of whole BCs (25ns)
- Fine timing adjusts TT signal within one BC in steps of 1.04ns

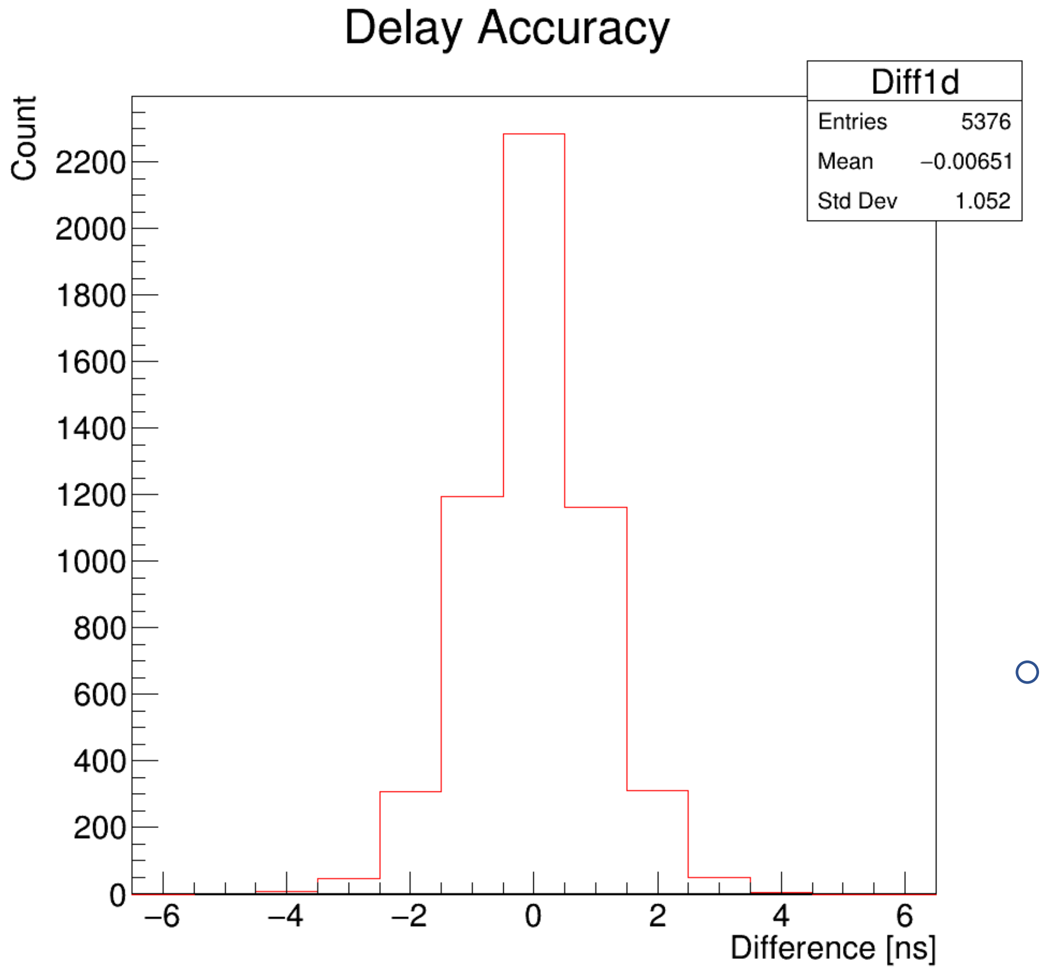
Phos4Scans

- Use PulserRuns to control changes
- 1ns resolution by overlapping many signals

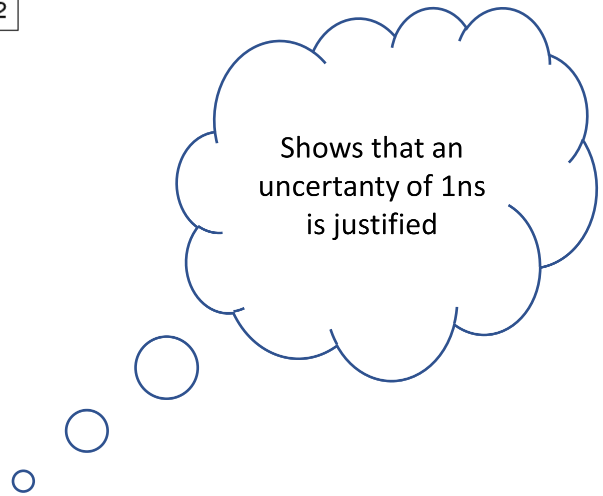


Shifting the clock (digitisation point) relative to signal and overlaying results in high resolution

Precision of Measurements



3 runs with exactly the same setup
→Compared differences in resulting delays



Moving to Run 3

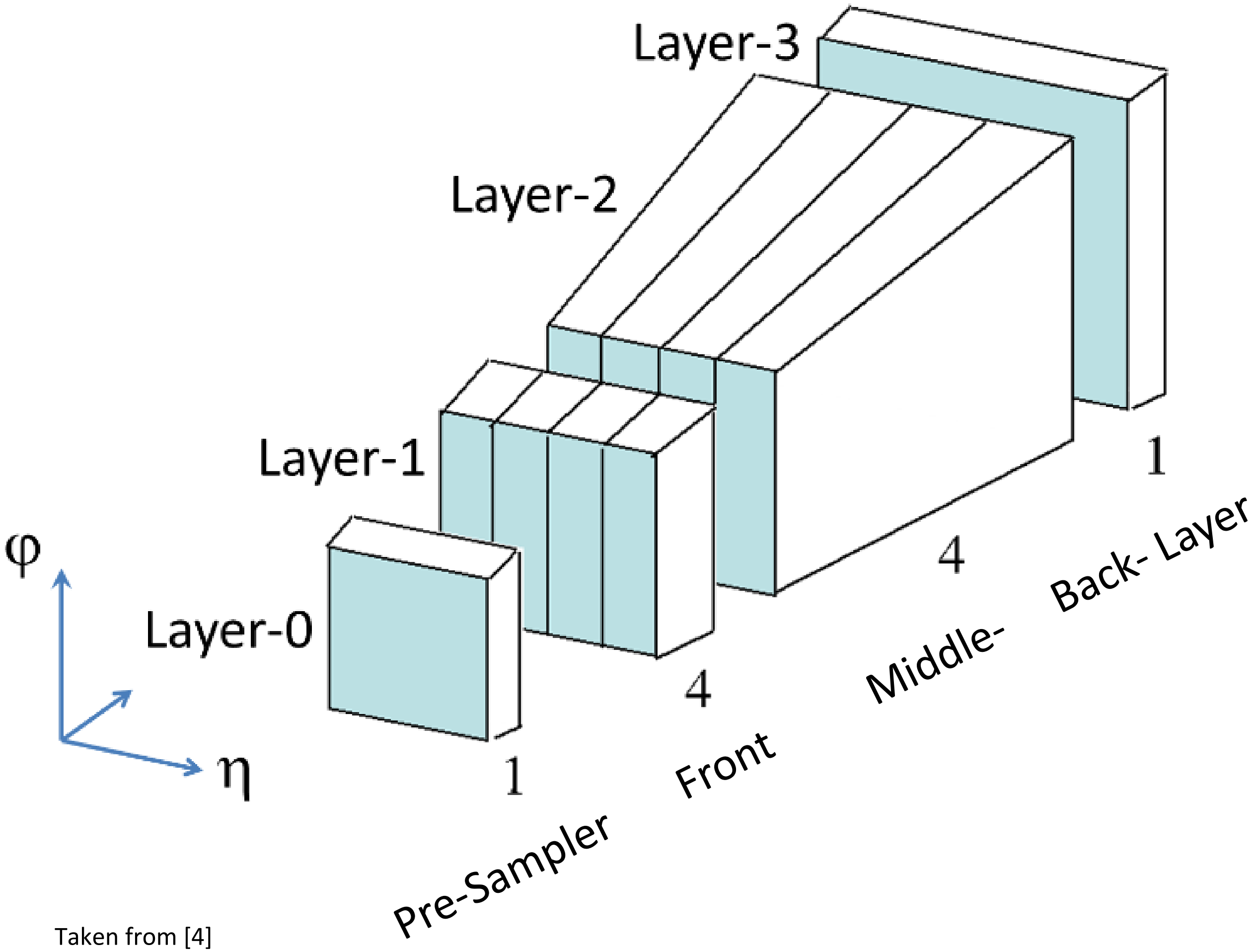
The Phase-I Upgrade

Why have a Phase-I Upgrade for the Trigger?

- Allows for efficient triggering at higher instantaneous luminosities
- Upgrading feature extractors to run more sophisticated algorithms
- Run finer granularity input for the Level-1 Calorimeter Trigger
- Switch from analog to digital system

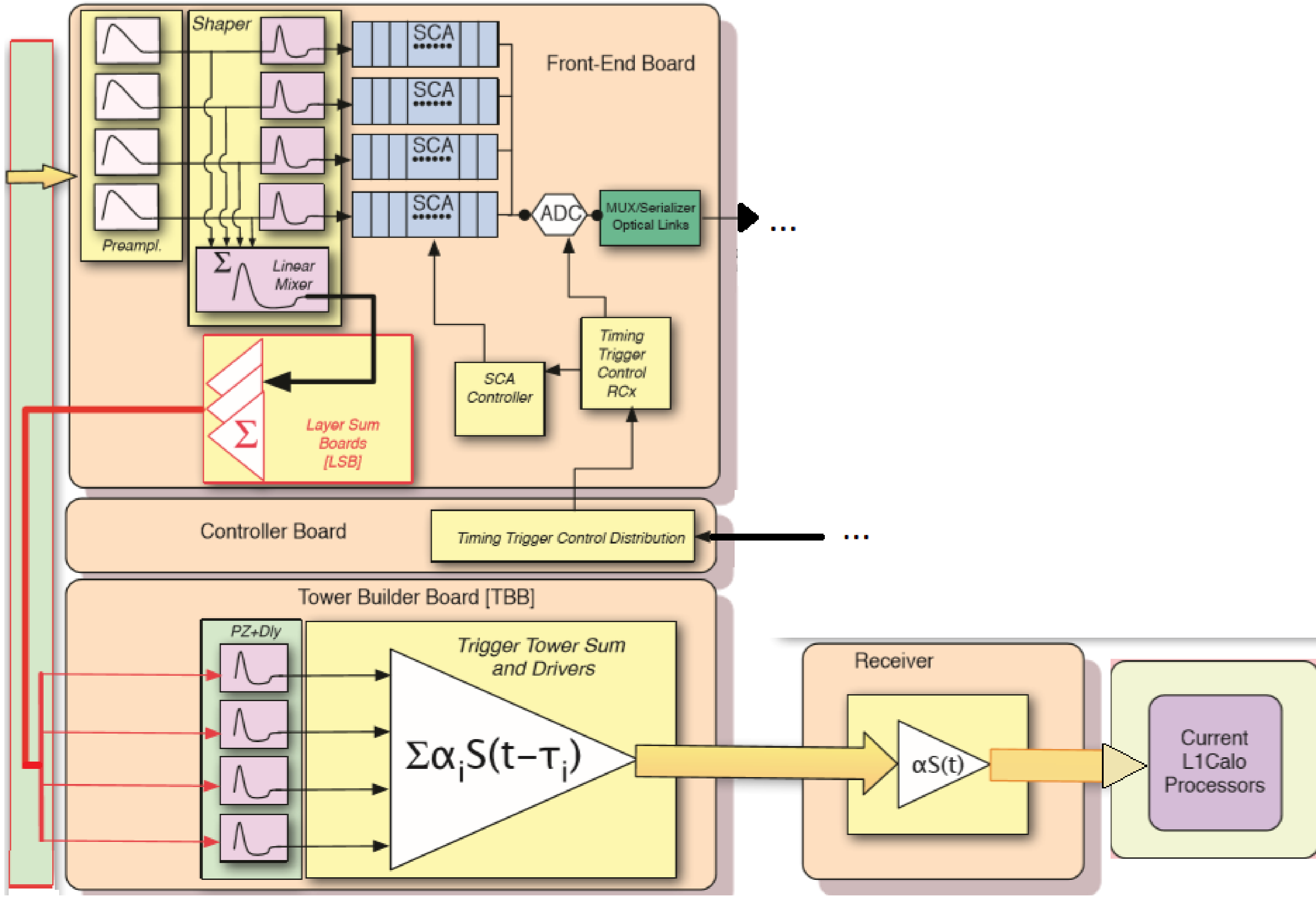
- The legacy (analog) system is kept and will run atleast in the beginning of Run 3

How is one Trigger Tower build up?



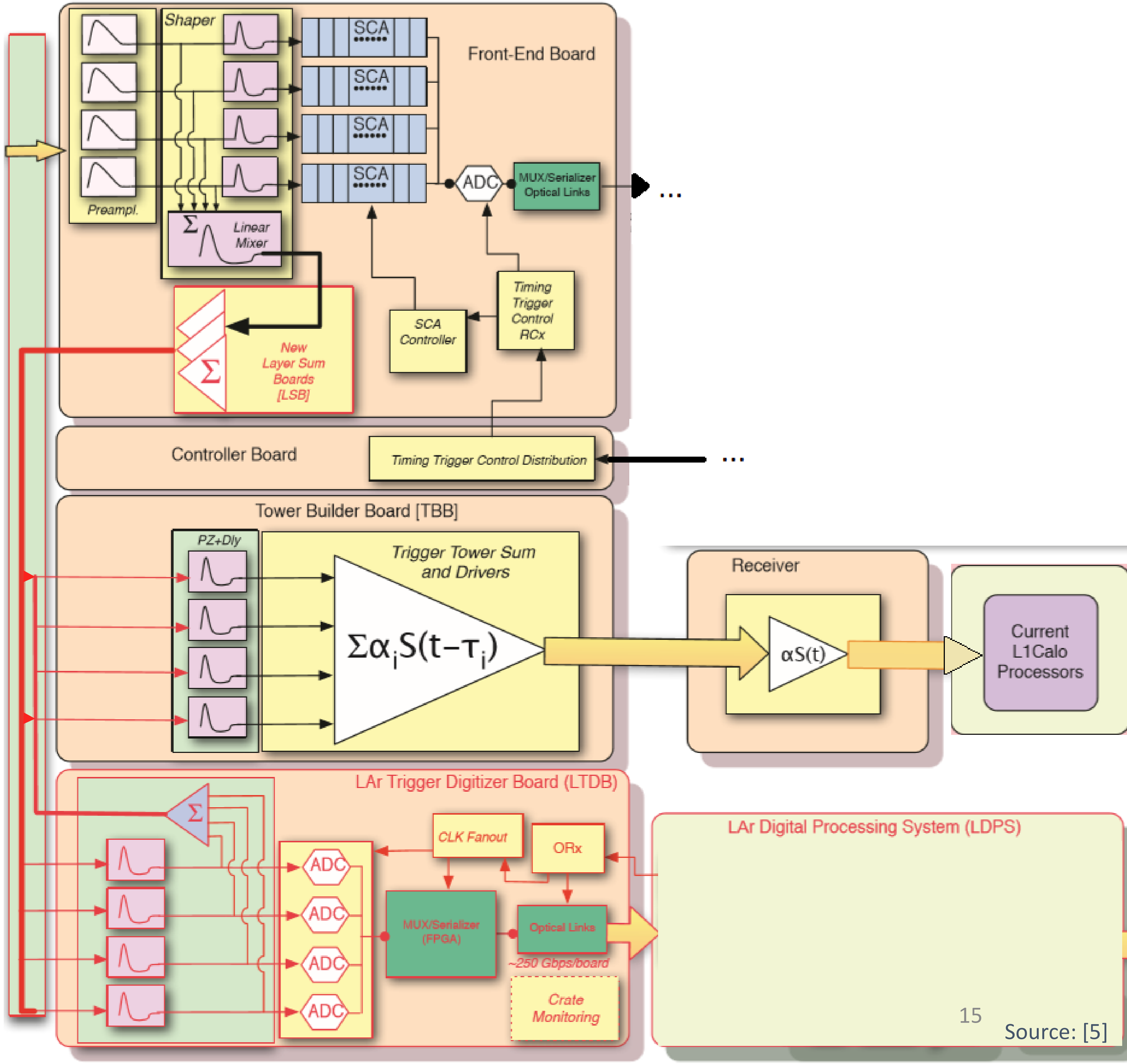
Taken from [4]

Why do we need to derive new TBB Delays?



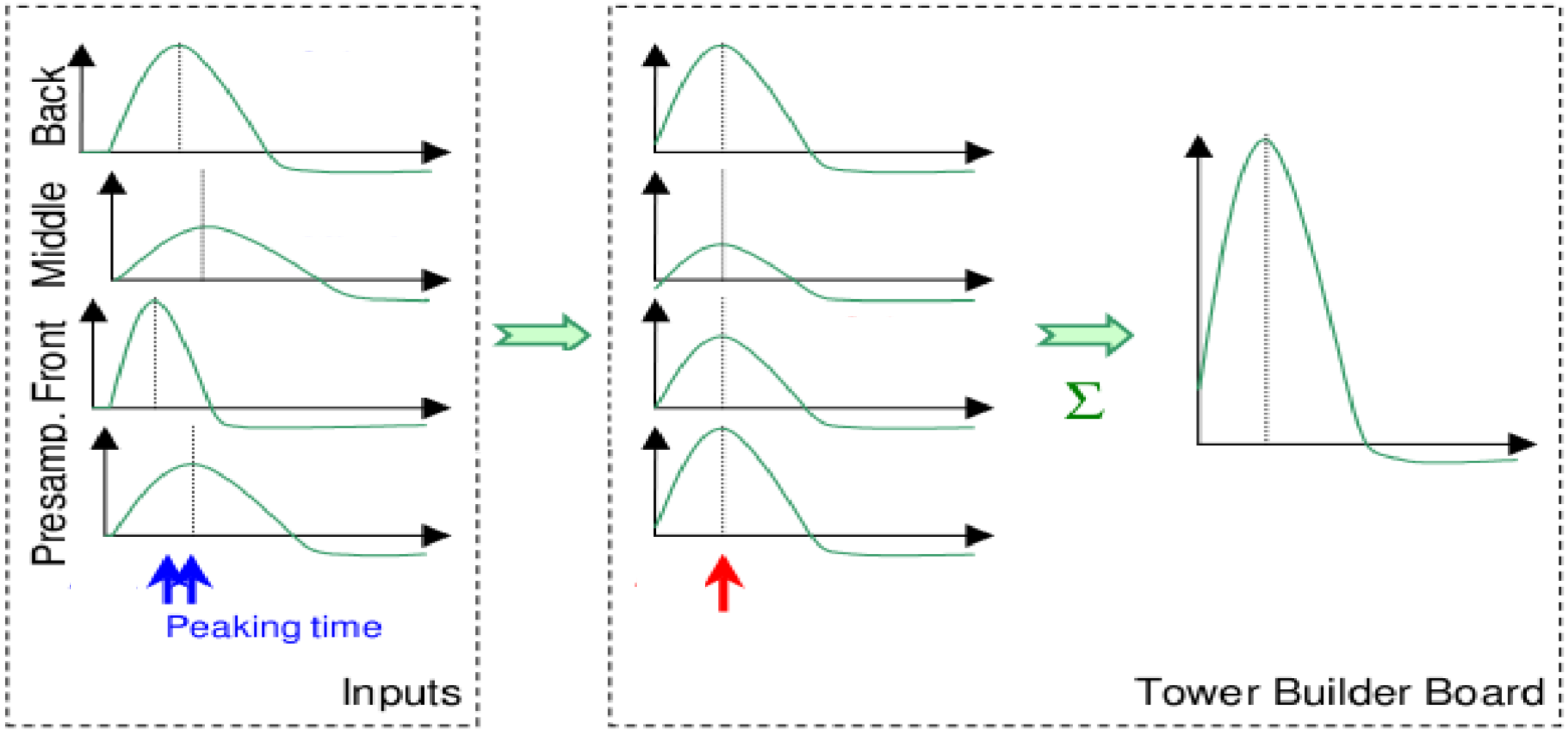
Source: [5]

LAr Phase 1-Upgrade



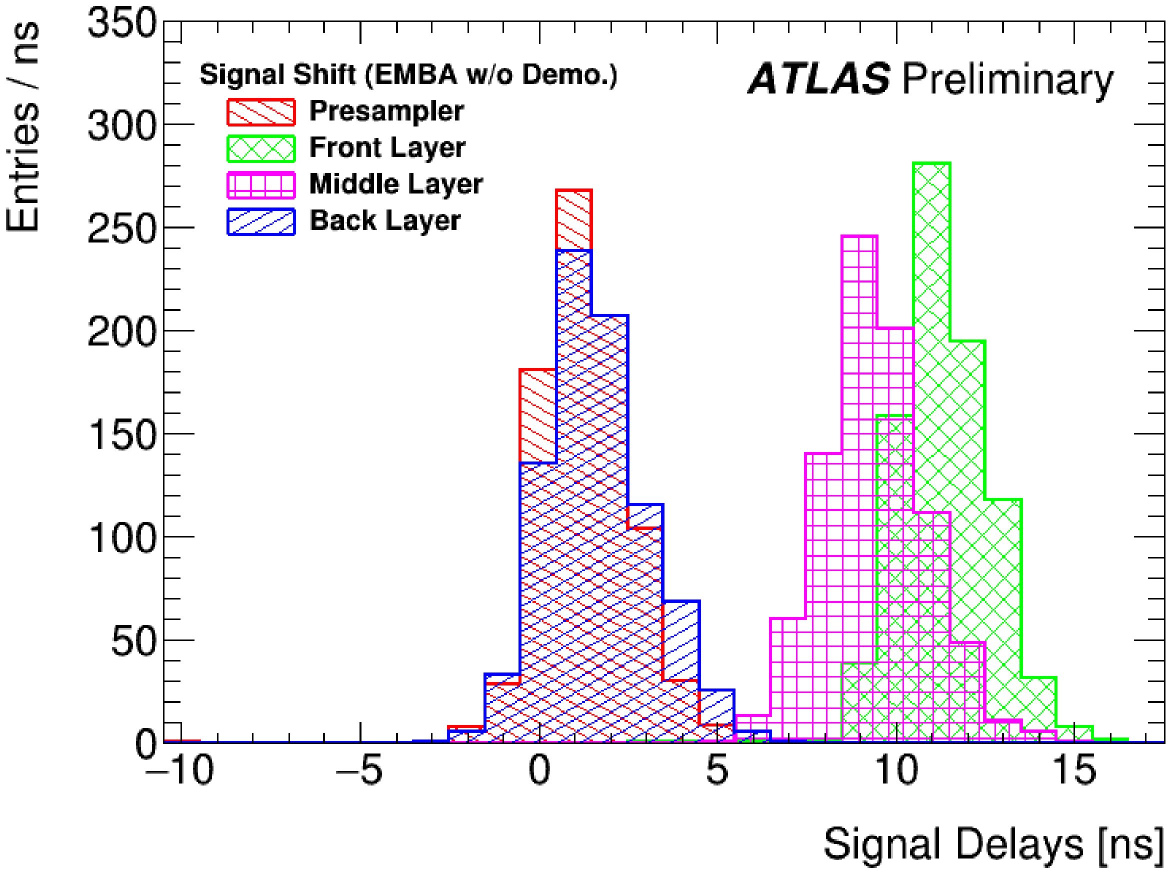
Source: [5]

TBB Functionality

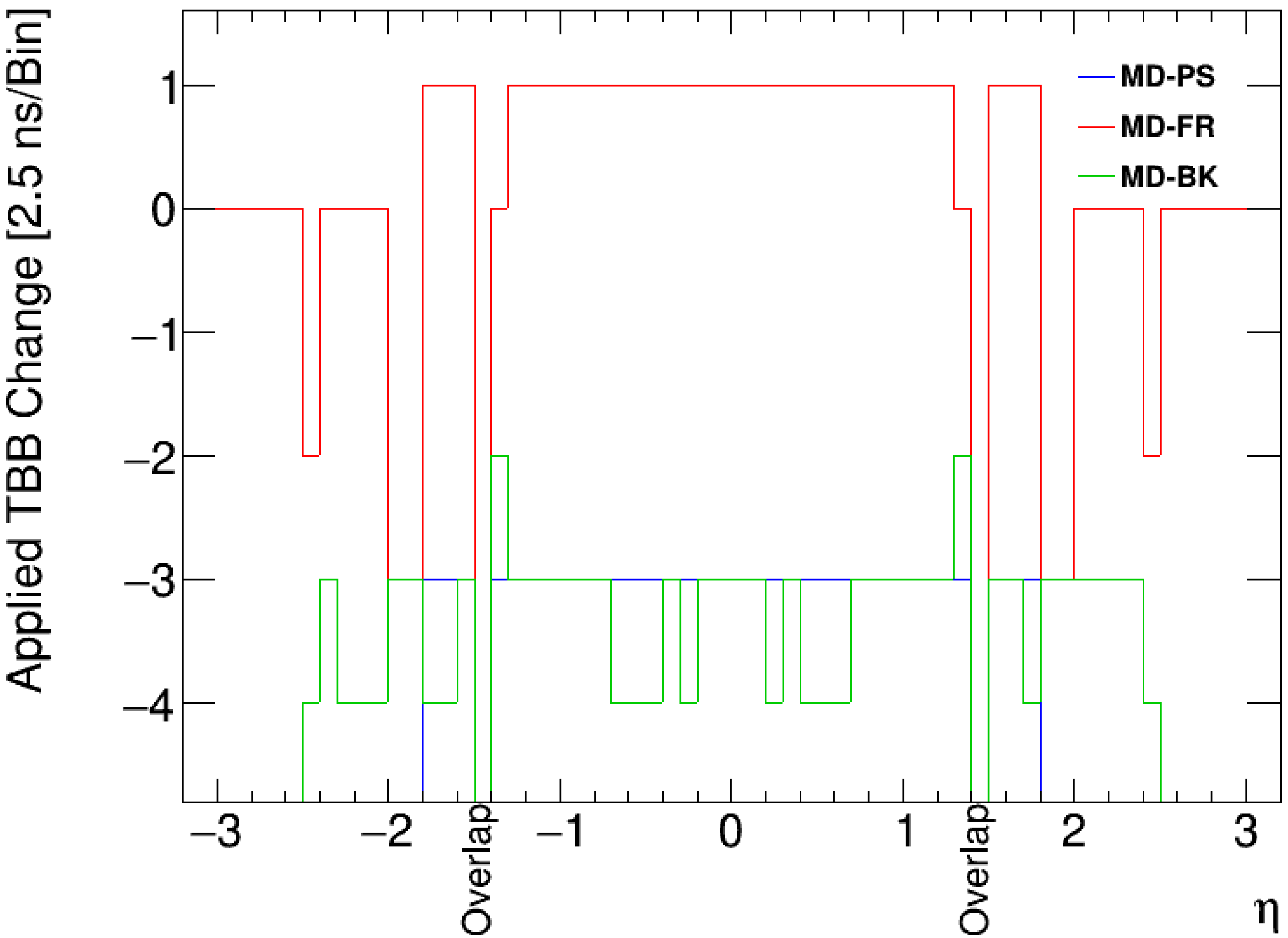


Taken from [6]

Change of Layer Sums relative to Run 2

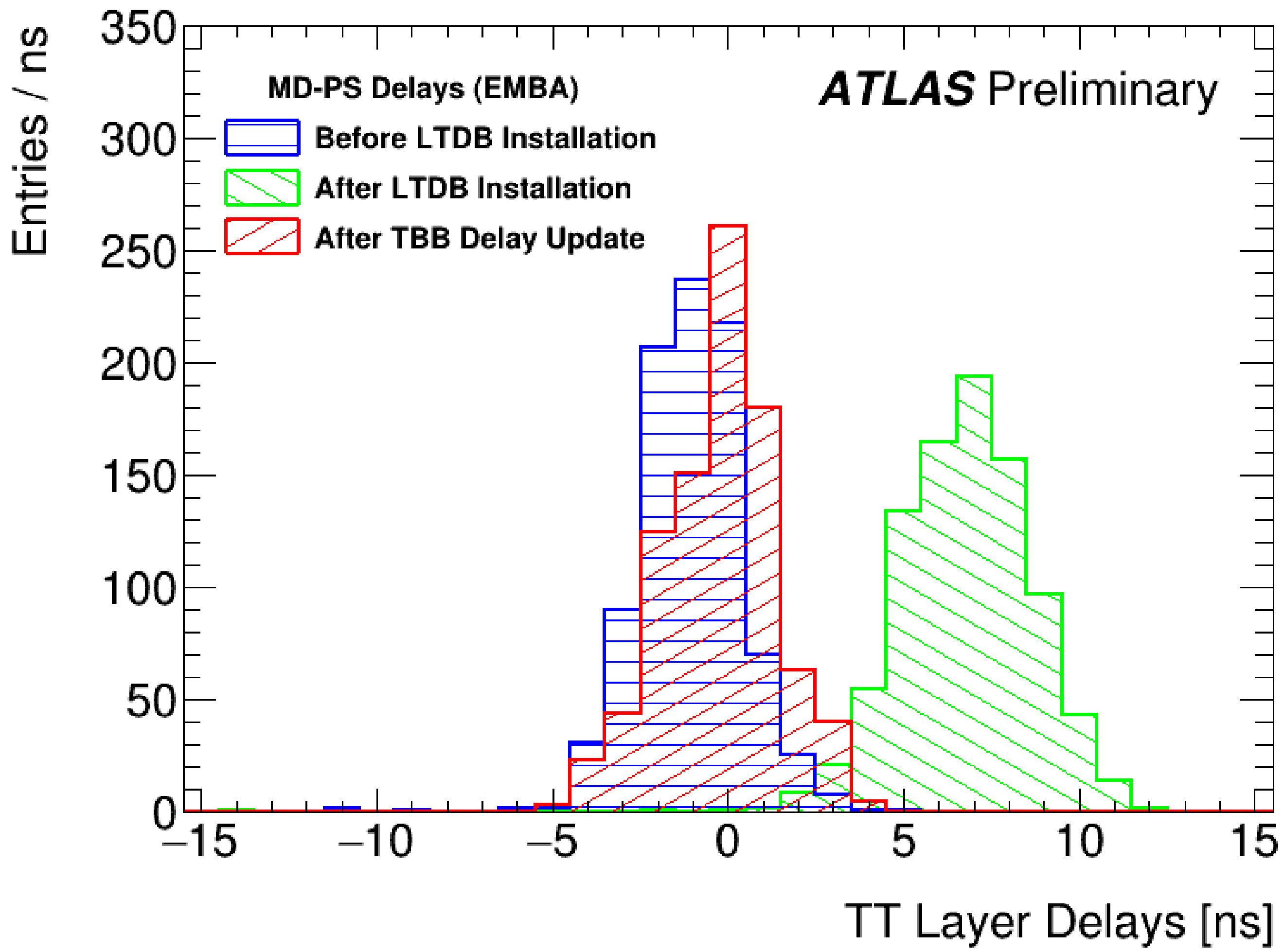


TBB Alignment

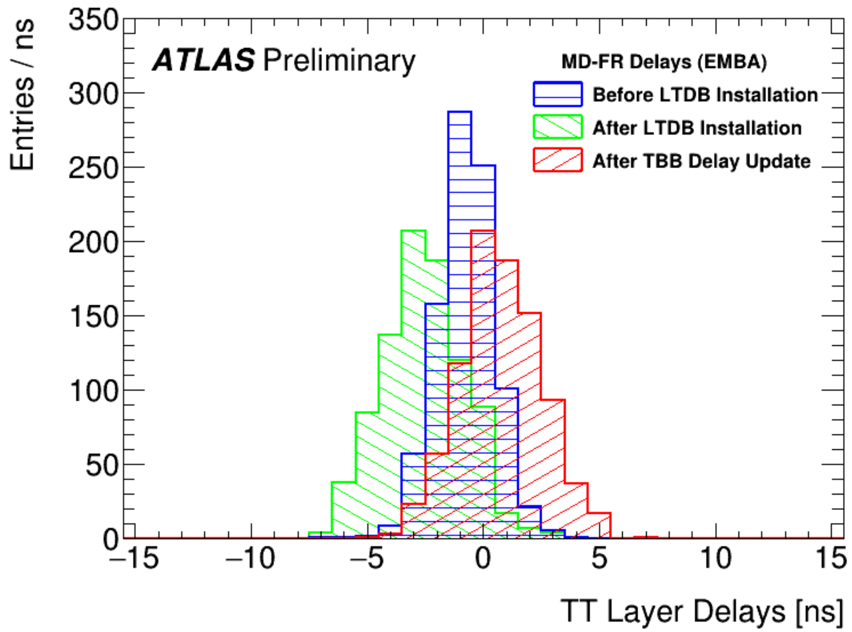


- Average corrections in eta
  - Increases chance to derive systematic change
  - Lowers impact of outliers

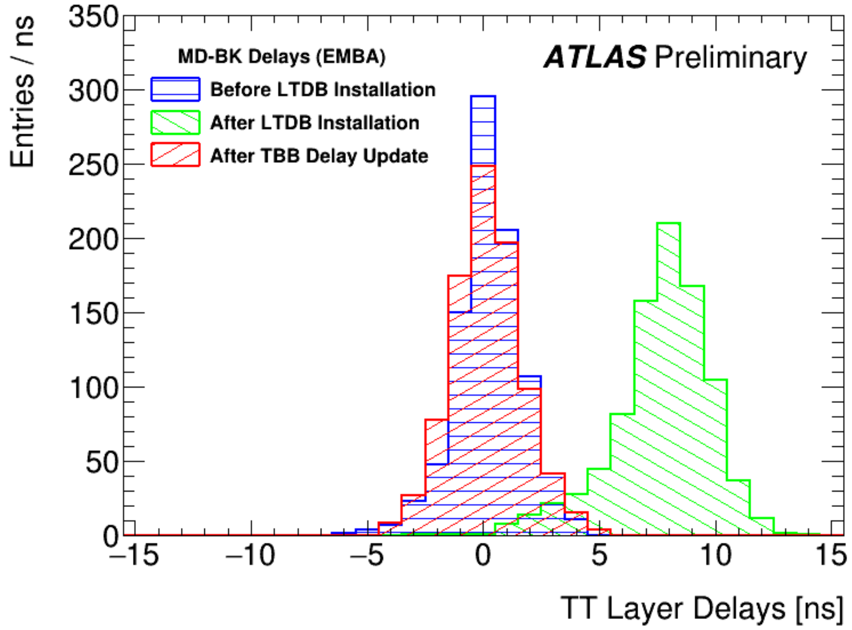
TBB Results



MD-PS Delays (EMBA)
ATLAS Preliminary
Before LTDB Installation
After LTDB Installation
After TBB Delay Update
Entries / ns
TT Layer Delays [ns]

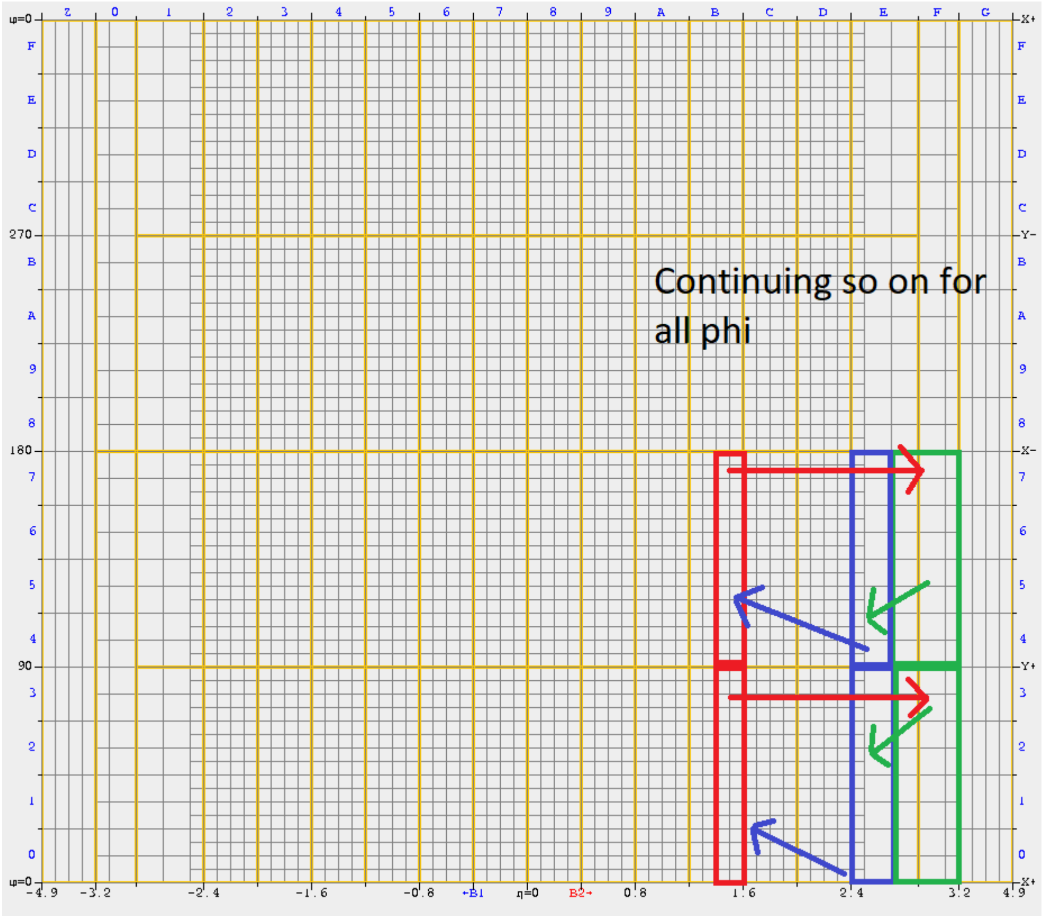


ATLAS Preliminary
MD-FR Delays (EMBA)
Before LTDB Installation
After LTDB Installation
After TBB Delay Update
Entries / ns
TT Layer Delays [ns]



MD-BK Delays (EMBA)
ATLAS Preliminary
Before LTDB Installation
After LTDB Installation
After TBB Delay Update
Entries / ns
TT Layer Delays [ns]

Mapping Error Summary



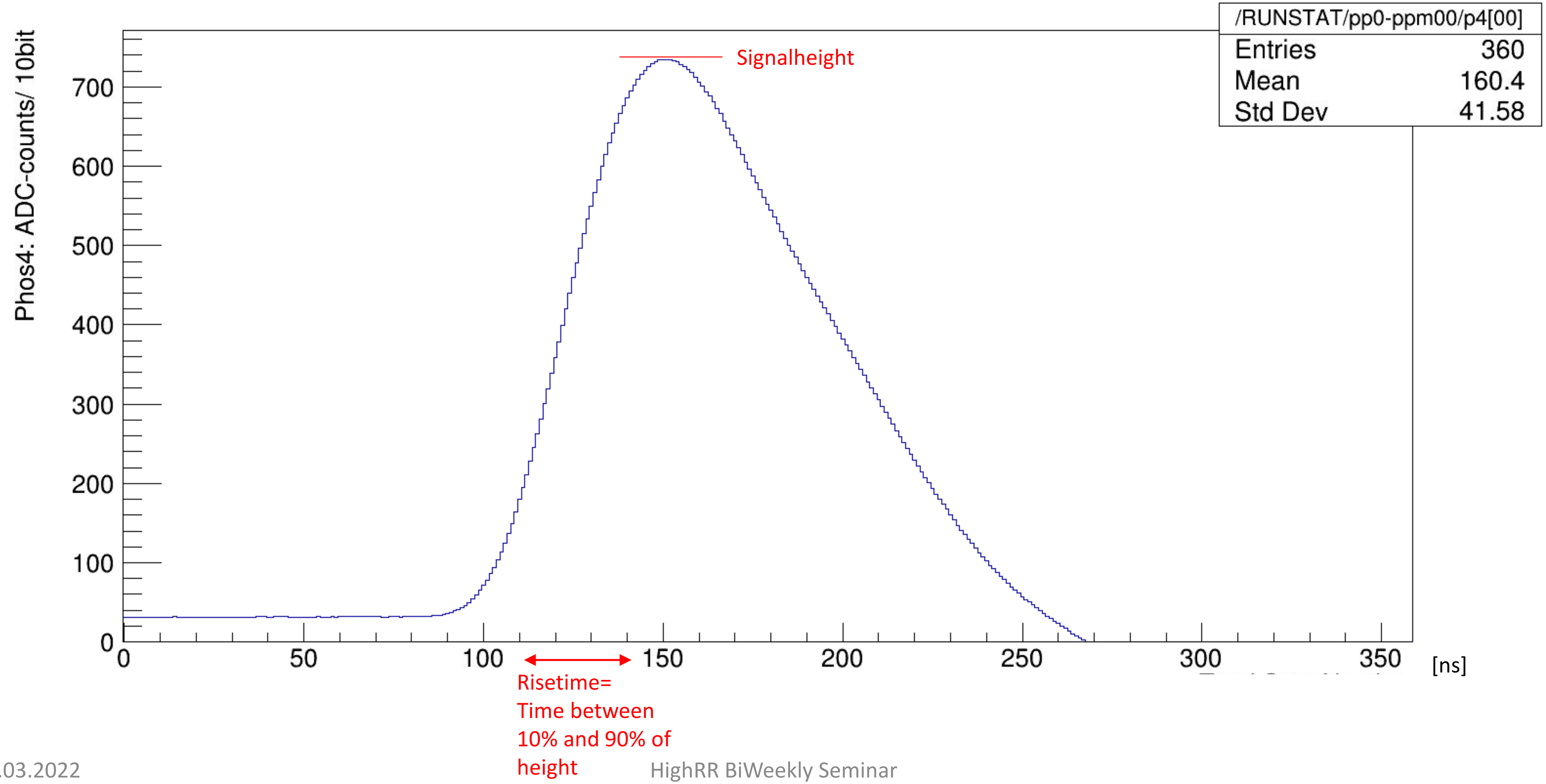
- Problematic to spot due to:
  - Red TBB using channel 0-31
  - Blue TBB using channel 4-29, w/o 18
  - Green TBB using channel 4-32
- Complications due to red TBBs covering the overlap/LAr special crates
- Additionally, swapped numbers were rather close w.r.t. to measurement accuracy

Pulse Shape

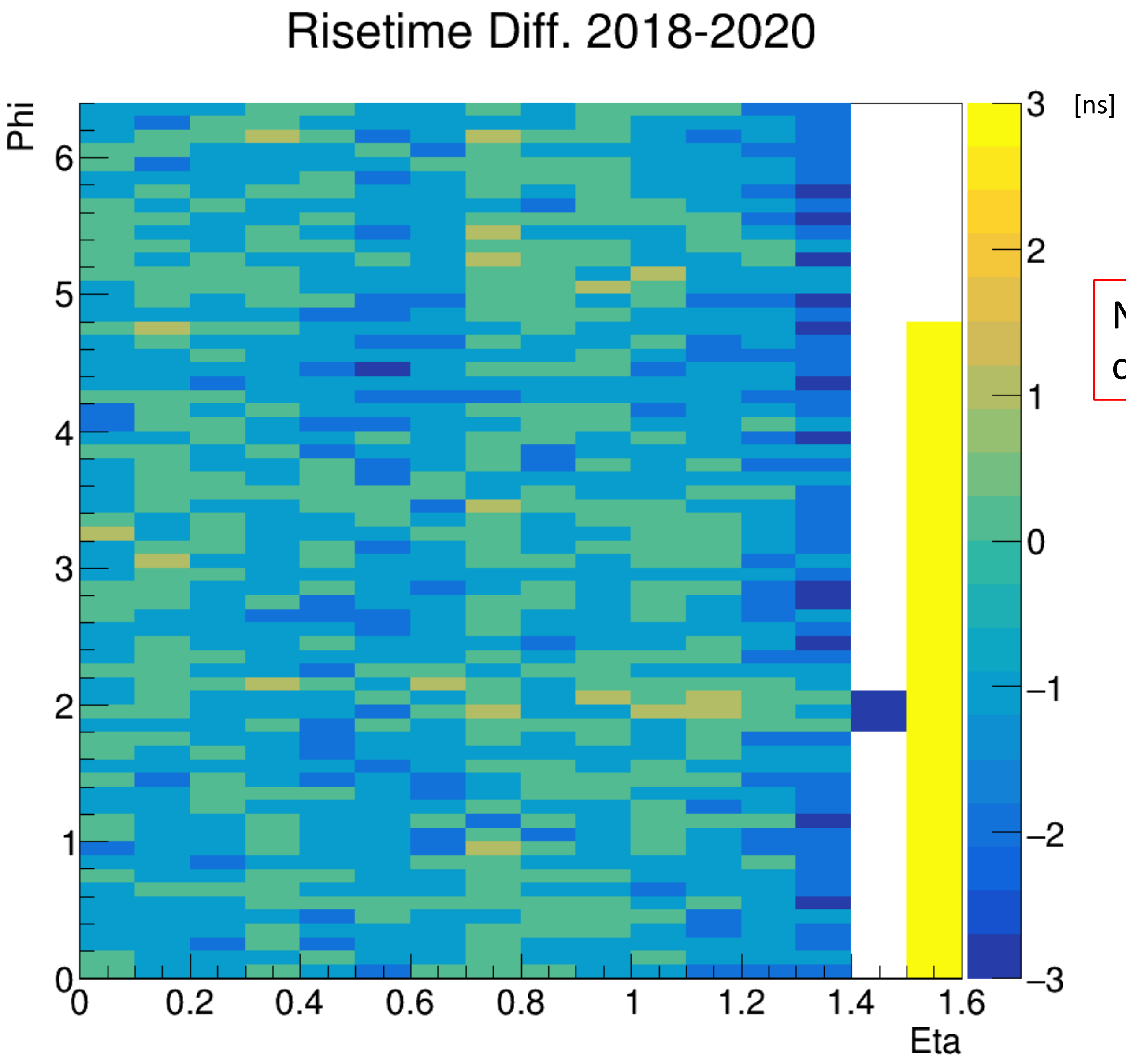
Expecting some loss in signal height

Shape/Risetime should stay the same

Pulse Shape

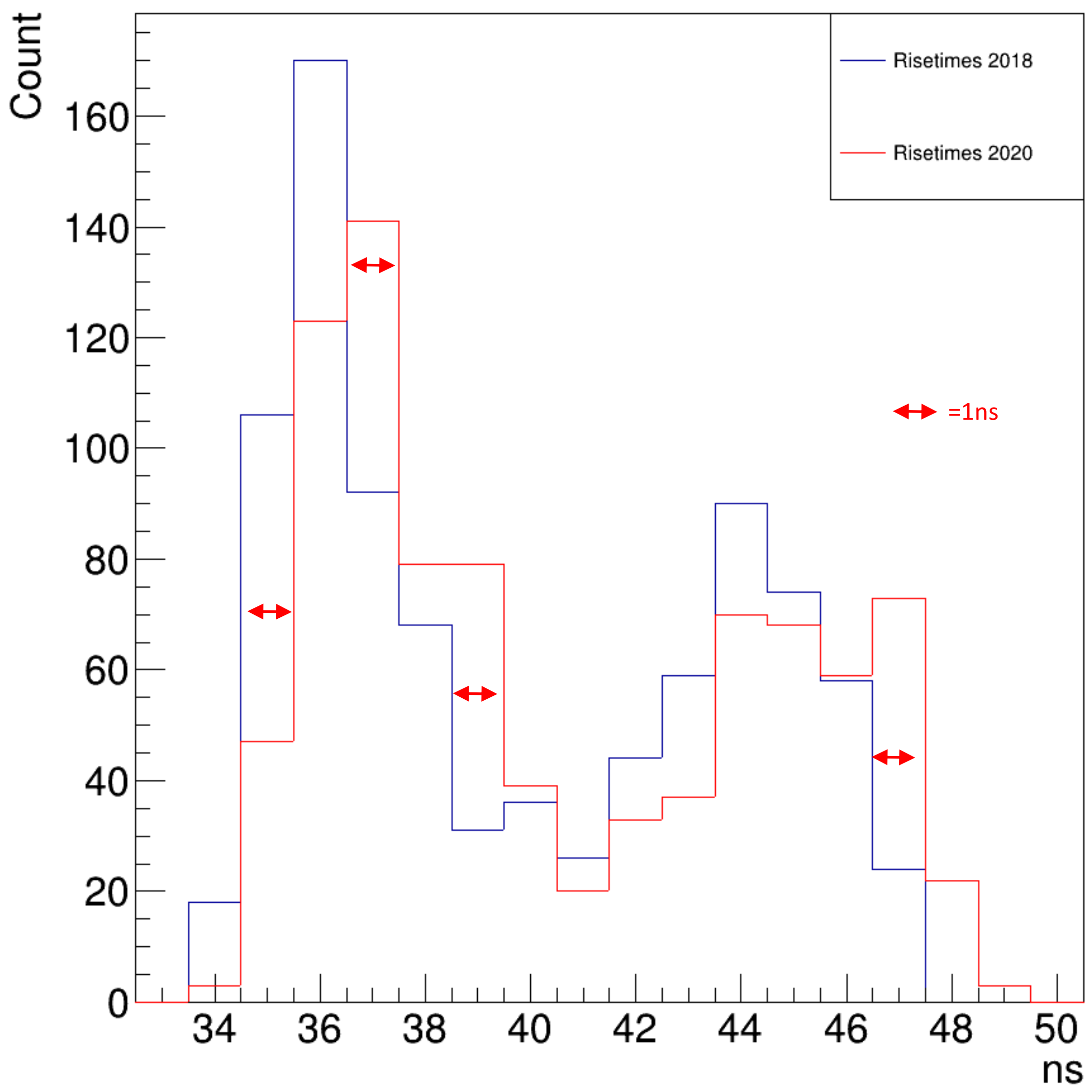


/RUNSTAT/pp0-ppm00/p4[00]
Entries 360
Mean 160.4
Std Dev 41.58
Signalheight
Phos4: ADC-counts/ 10bit
0
100
200
300
400
500
600
700
0
50
100
150
200
250
300
350
[ns]
Risetime=
Time between
10% and 90% of
height

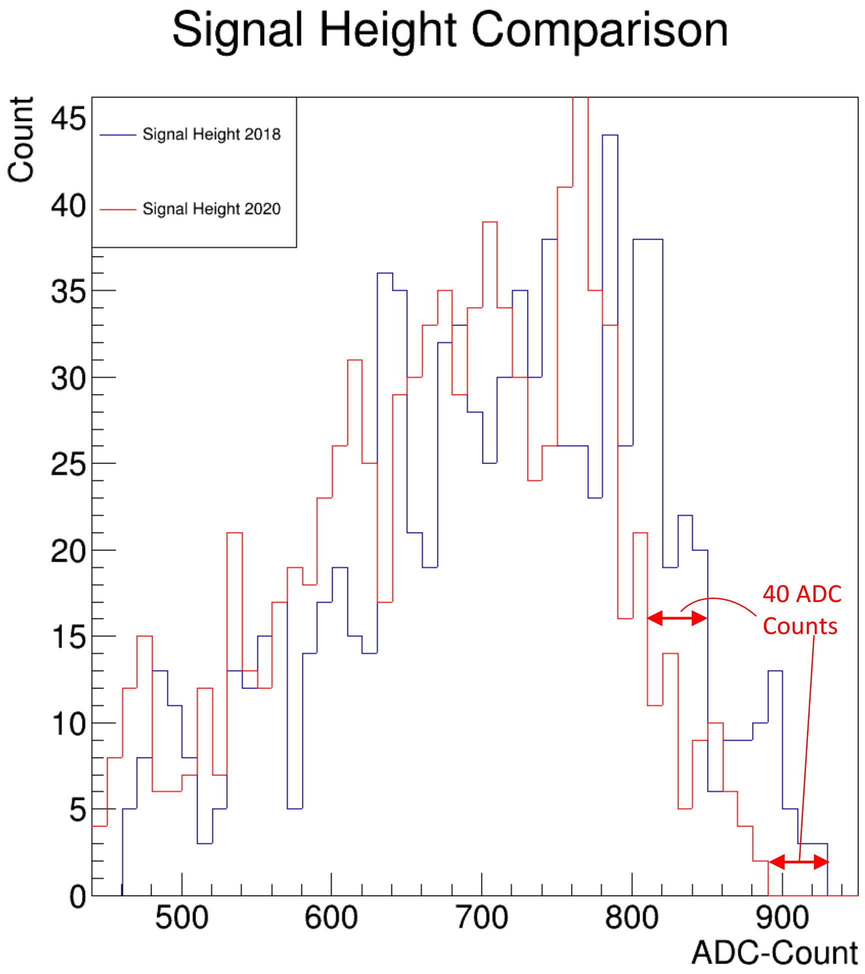


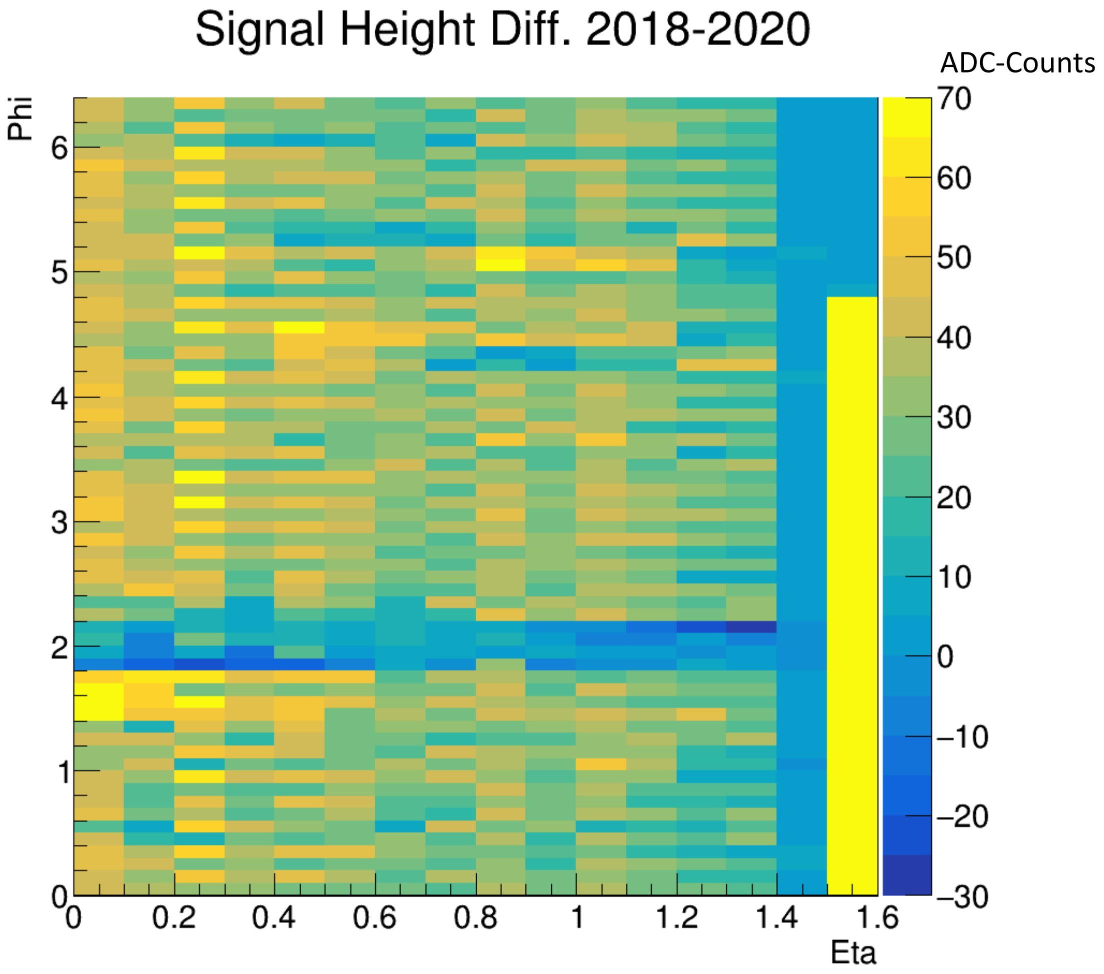
Note: No pattern in change!

Risetimes

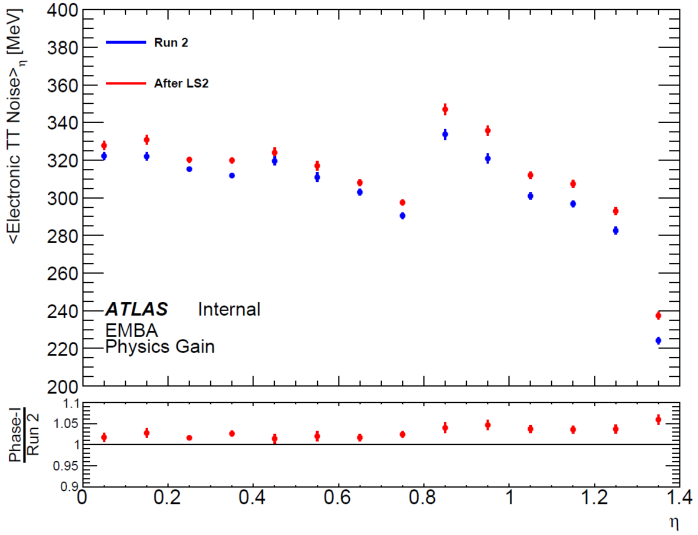

Count
160
140
120
100
80
60
40
20
0
34
36
38
40
42
44
46
48
50
ns
Risetimes 2018
Risetimes 2020
=1ns

Pulse Shape


Signal Height Comparison
Count
Signal Height 2018
Signal Height 2020
40 ADC
Counts
ADC-Count
0
5
10
15
20
25
30
35
40
45
500
600
700
800
900


Signal Height Diff. 2018-2020
ADC-Counts
Phi
Eta
0
1
2
3
4
5
6
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
70
60
50
40
30
20
10
0
−10
−20
−30

Noise Studies

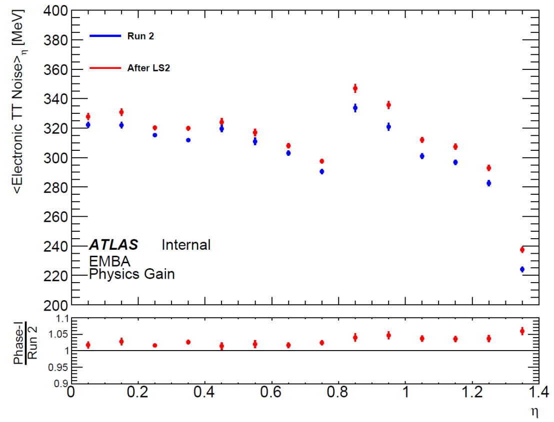


- Noise per TT in EMBA (averaged over phi)

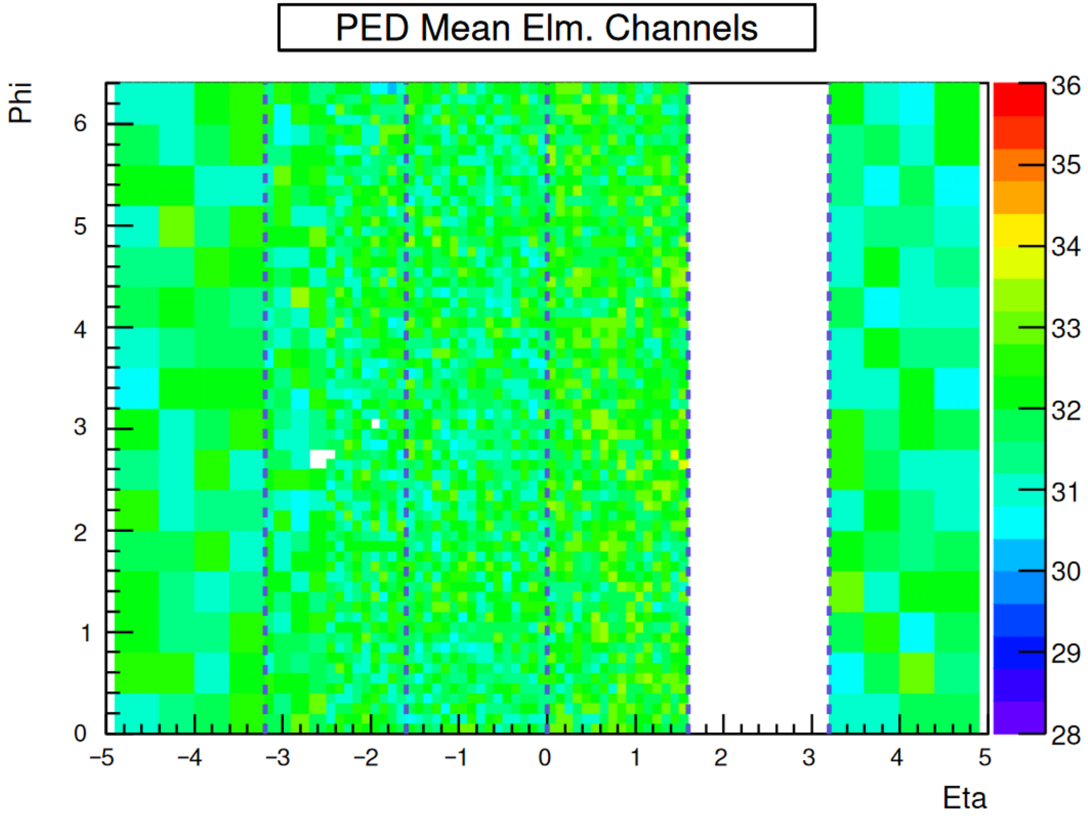
- So-called ‚Noise Runs'
  - Sets physics gains in receivers and includes upstream calorimeter contributions
  - Random data taken over 15 mins
  - Essentially samples the pedestal value multiple times

- Noise = standard deviation of the discrete pedestal distribution

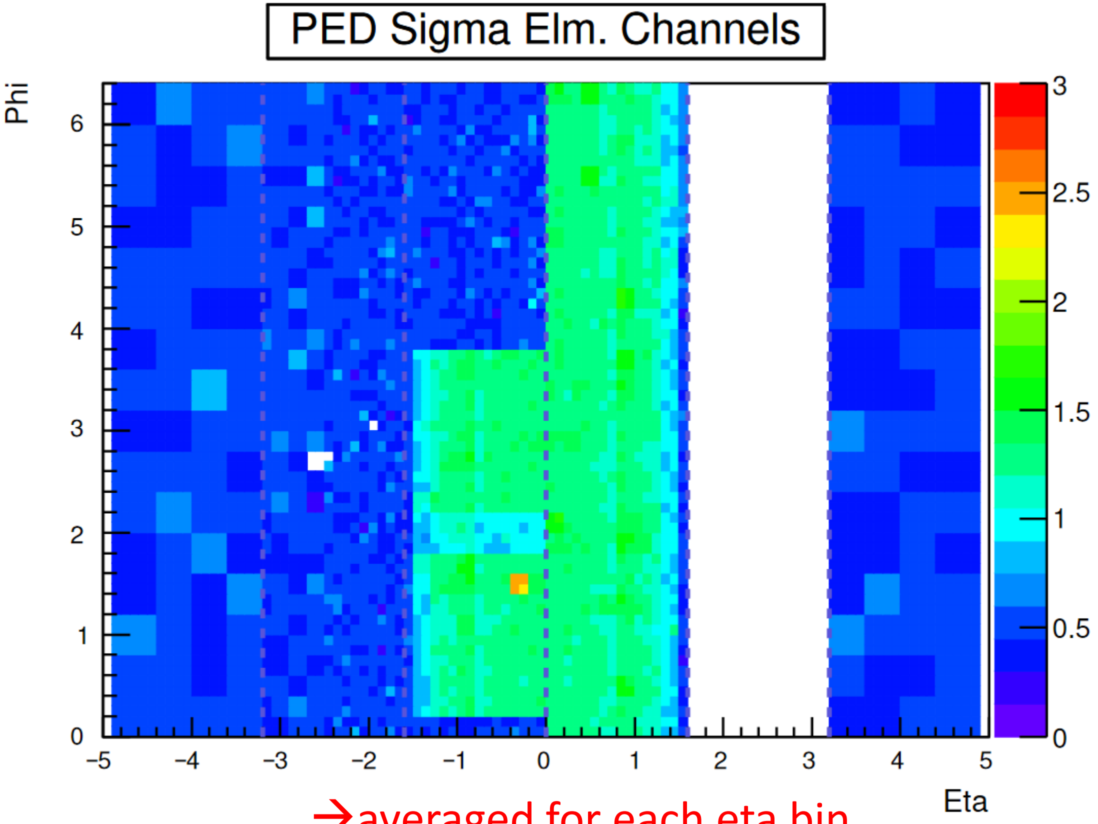
What is shown?



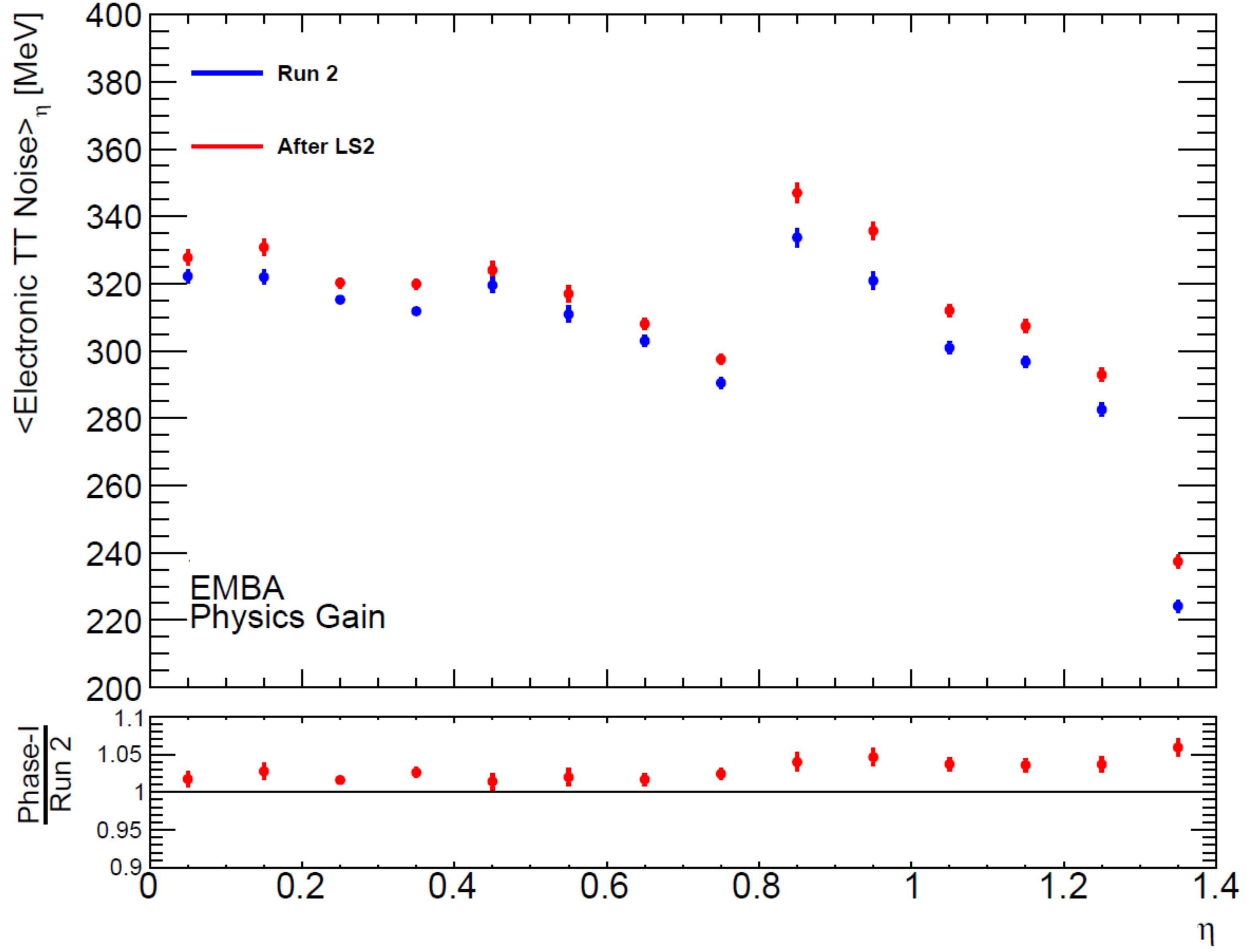
Pedestal in ADC-Counts



Noise in ADC-Counts



→averaged for each eta bin



<Electronic TT Noise>$_\eta$ [MeV]
Run 2
After LS2
EMBA
Physics Gain
Phase-I / Run 2
η

The Result

Intermediate Conclusion

- Tower Builder Boards re-aligned
  - Verified proper building of all TT signals
- Examination of change in signal shape
  - No meaningful change in risetime
  - Signal height observed to be lower by around 5%
  - Slight increase in noise

→Run 2-like signal re-established

Differences in Calibration and Physics

Calibration

- TBB Delays measured in Phos4Scans (1ns resolution)
- Layers get pulsed individually which allows to compare them
- PPM Input Timing corrections directly measurable
- Tower by tower corrections possible and exact (up to technical limitations)

Physics

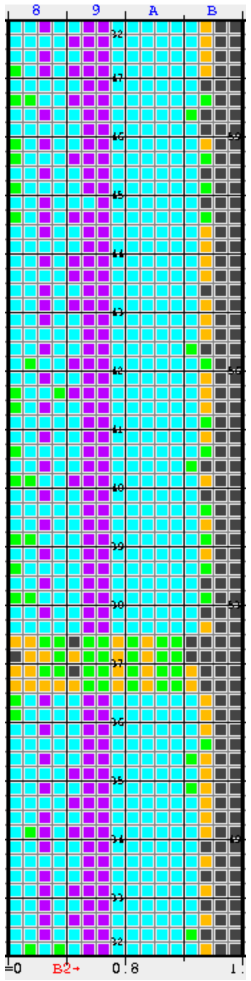
- Timing checks can be done by fitting Pulses (resol. 80MHz) w/ established pulse parameters
- TBB Delays not measurable while maintaining data, need masking of layers via shape switches
- Measuring timing takes time, good „starting point“ is beneficial

Input Timing Prediction

"Delay" can be negative here,can also reduce amount of delay which was used in Run 2 for FR and MD

Calorimeter	Electronics (assumed) Shift	TBB Change
PS | PS	PS | PS	PS | +Delay. PS
FR | FR	FR | ~10ns FR	FR | ~10ns+Delay. FR
MD| MD	MD| ~ 8ns MD	MD| ~8ns+Delay. MD
BK | BK	BK | BK	BK | +Delay. BK

Input timing correction (predicted)

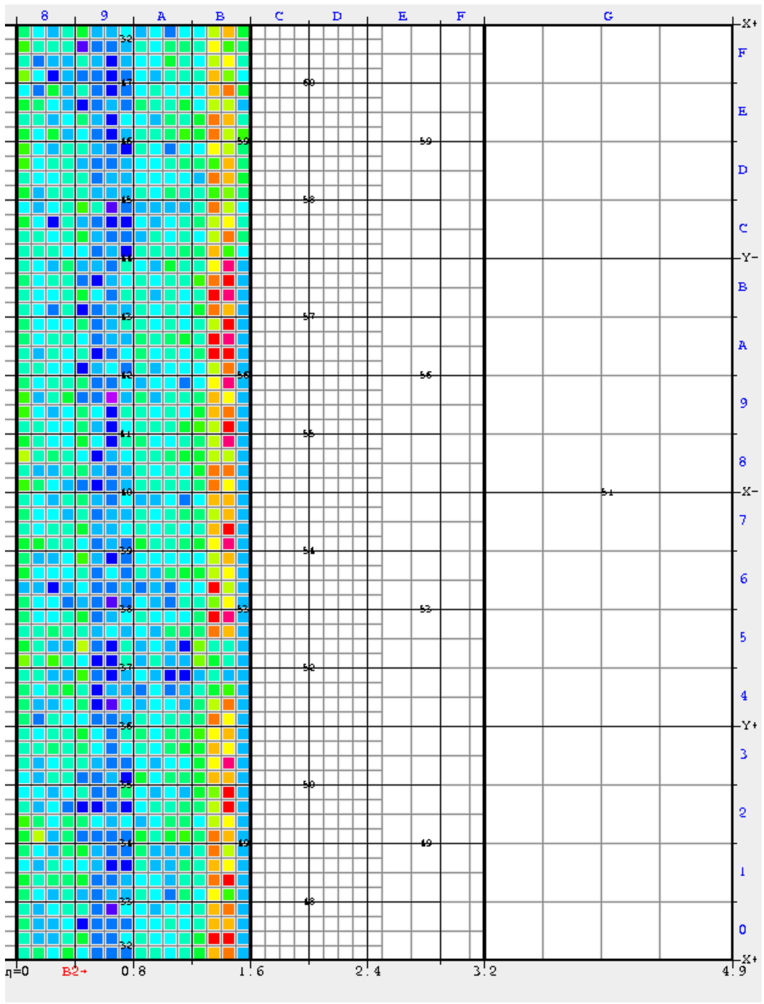


← Prediction

Note that the central ridge (η~0.6) gets correctly predicted!

Predicting the demonstrator is hard
Has already been timed once and it is not clear what to assume for it now

Accurate Measurement →



Physics Timing

- Before Run 3 starts: 2 possibilities to check timing

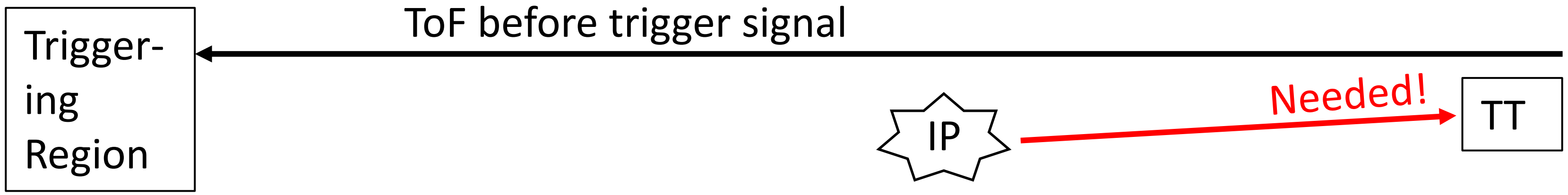
- Beam Splashes:
  - October 2021
  - High statistic, every cell hit
- Pilot Run:
  - October/November 2021
  - Low statistics, few cells hit

Beam Splashes

Testing the legacy L1Calo PPM timing in Run 3

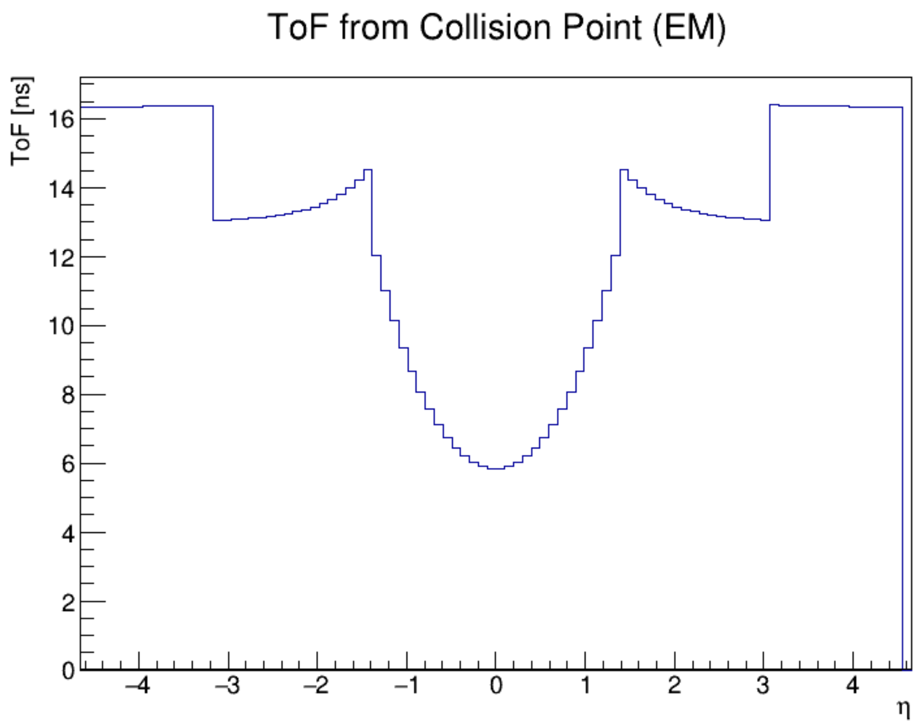
Beam Splash Setup

- Beam hits collimator roughly 100m from ATLAS
- Created shower/splash of particles traverse ATLAS
  - Benefit: every cell is hit in every splash, high statistics
- Drawback: particle flight path is different to usual collision
  - Time-of-Flight corrections are important for a correct timing
- Timing resolution not good, uncertanties high

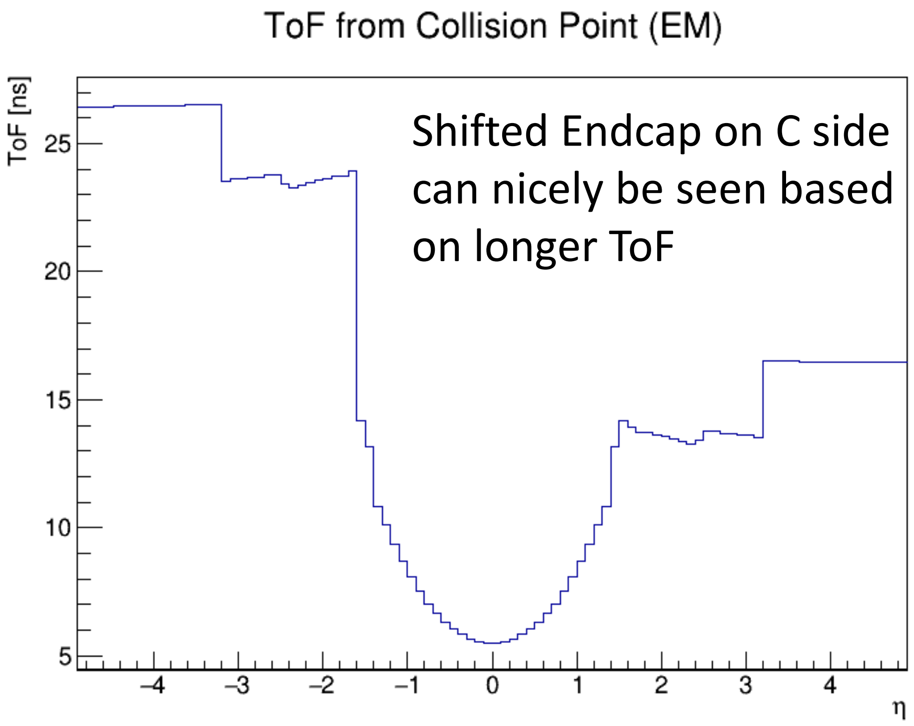


Visualization of Open Detector

Usually

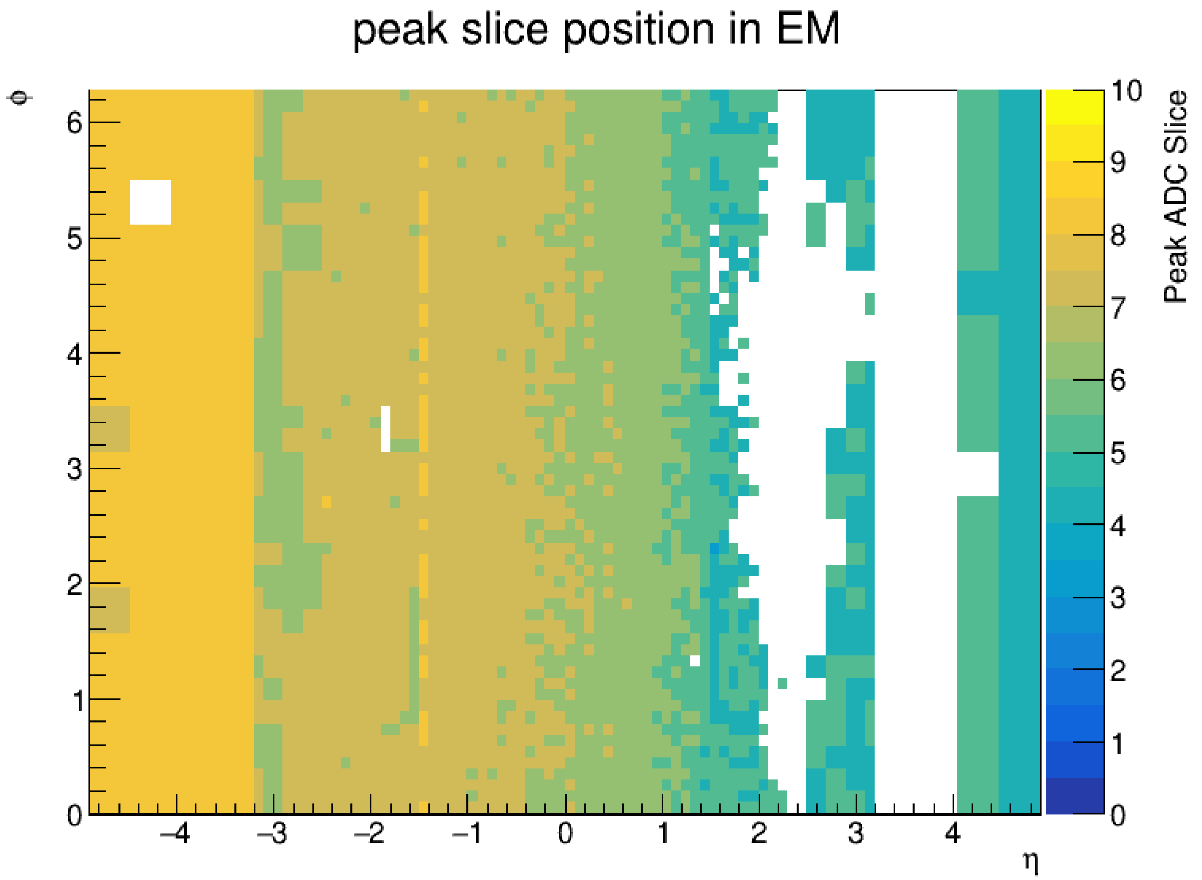


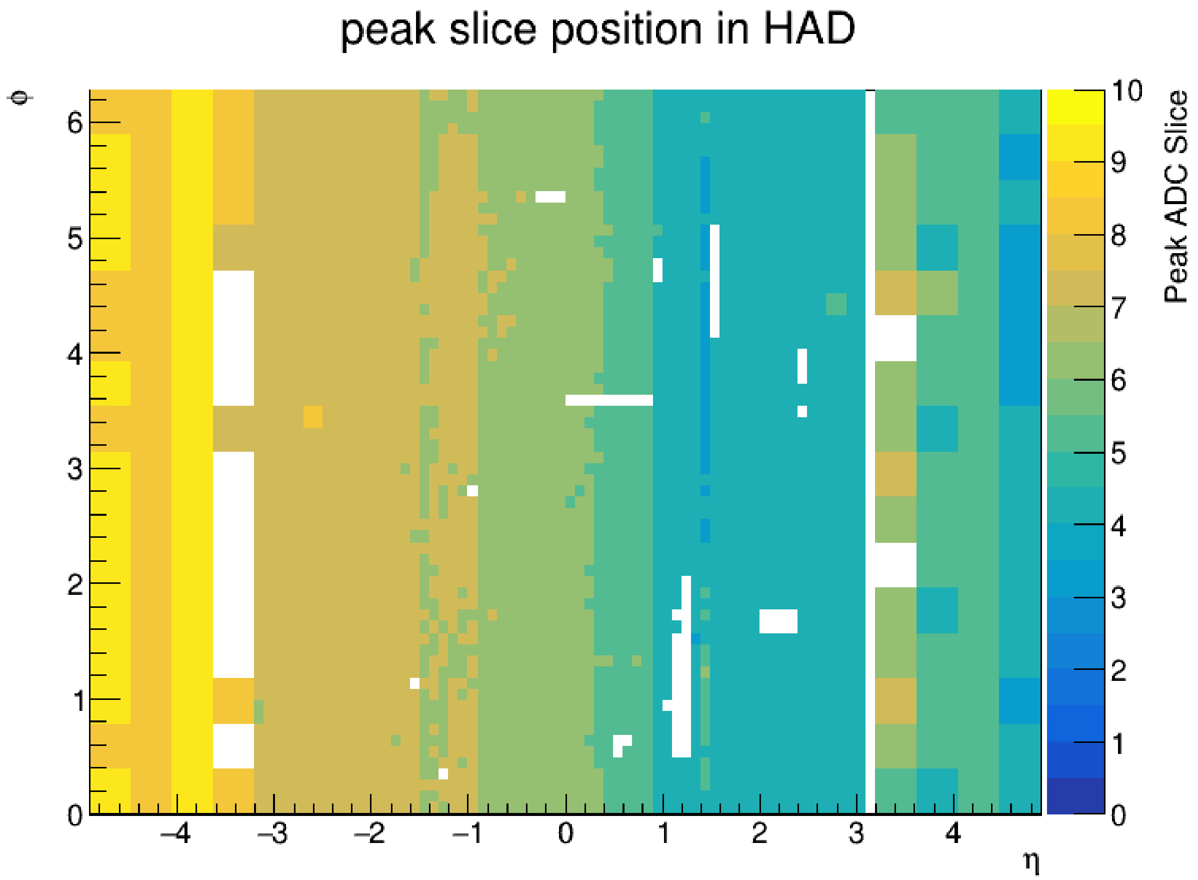
Extended Endcap



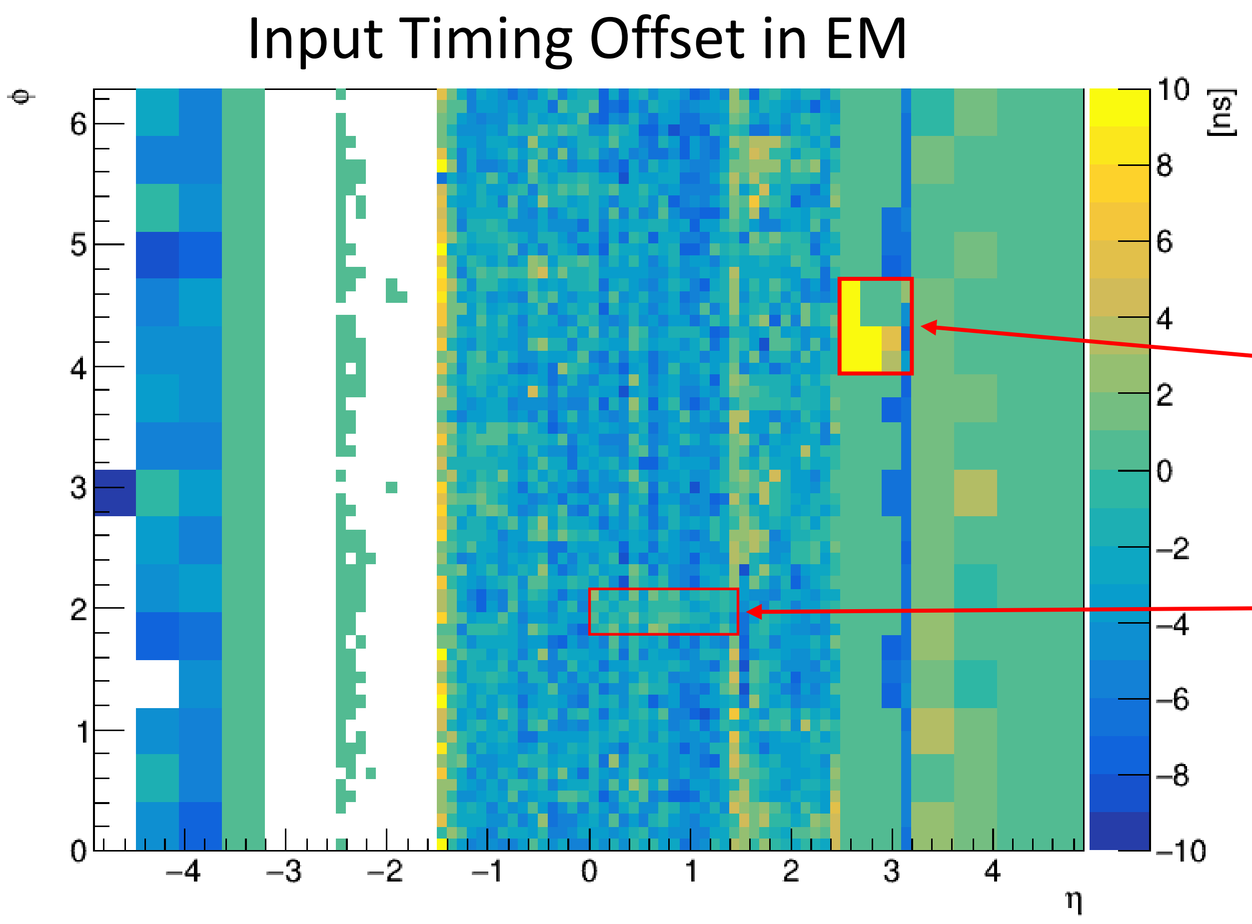
Careful with Axis Range, sorry, realised to late!

Event 373404, Splash from Right





Individual Event Results



Event 101484, Run 404791

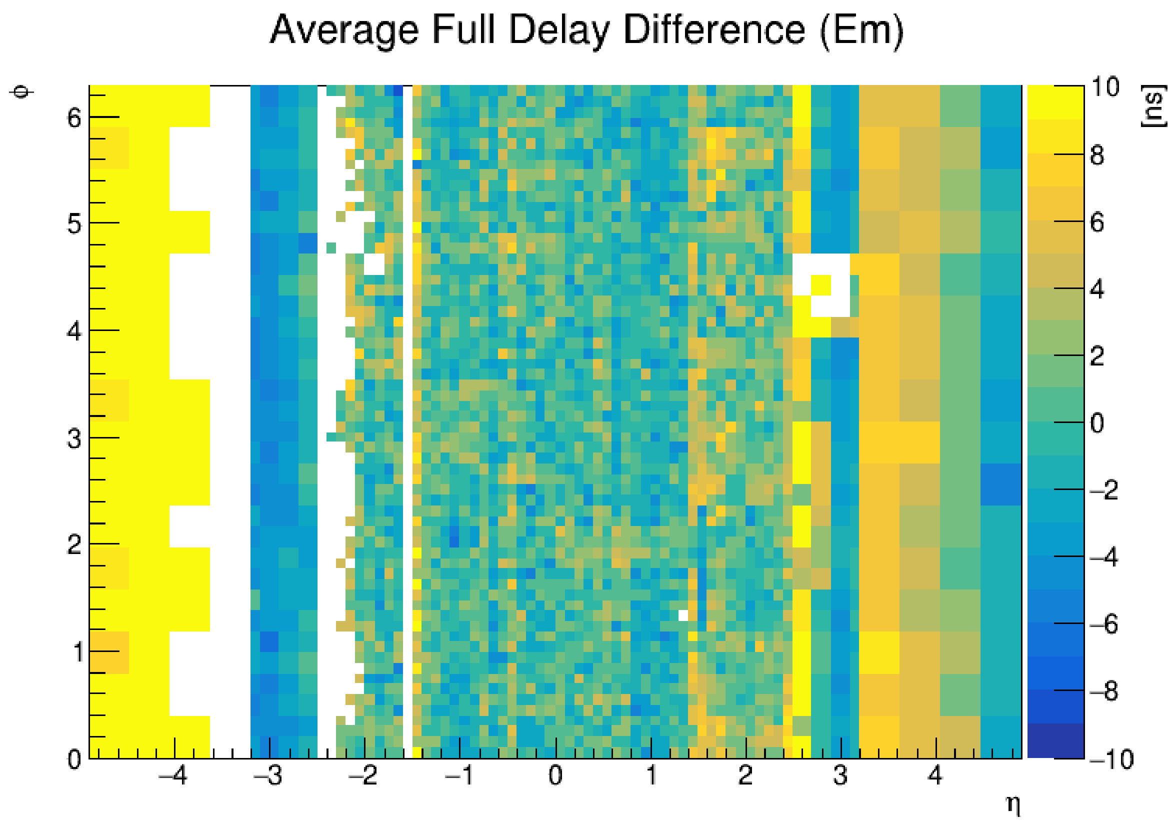
Single Splash Events good to check for Outliers, systematically different regions or other unusual behaviour

Missing card and missing grounds, LAr HV

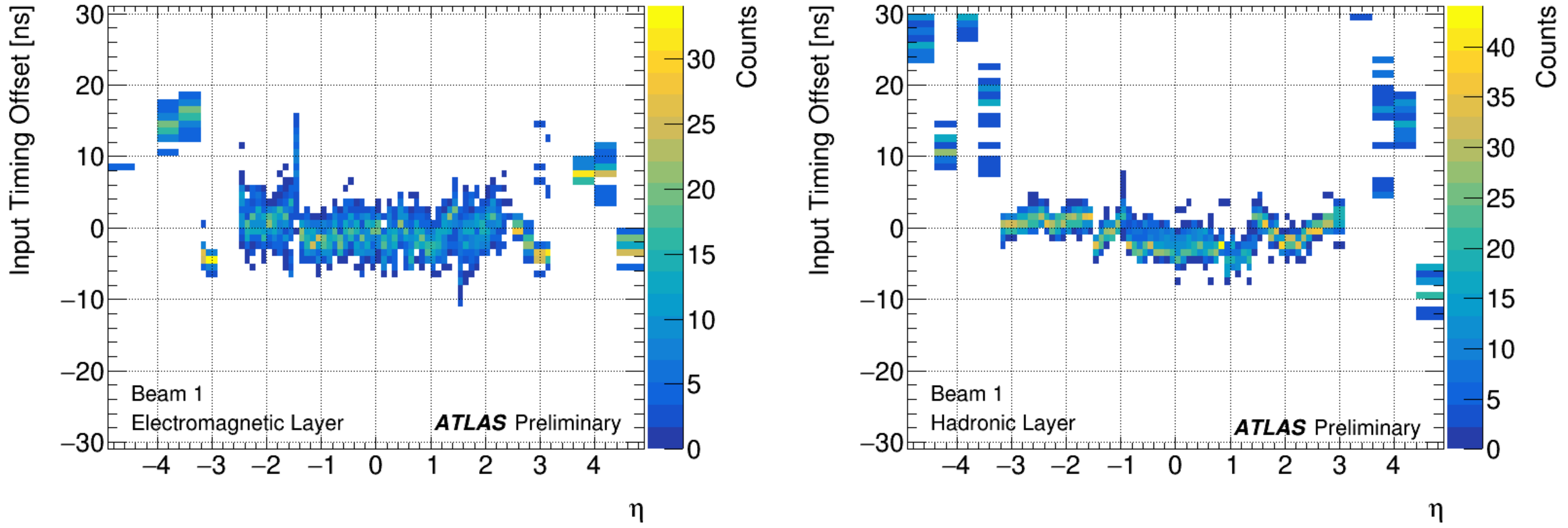
Notice for example the demonstrator being visible due to previous adjustment in Run 2

Combined Results

- Each Run and beam direction is analyzed seperately
- Results to individual Run and beam configuration can be averaged to give an overview of the resulst
- Example for the Input Timing Offset of Run 404473 and Beam 2 can be seen on the right



Splash Results



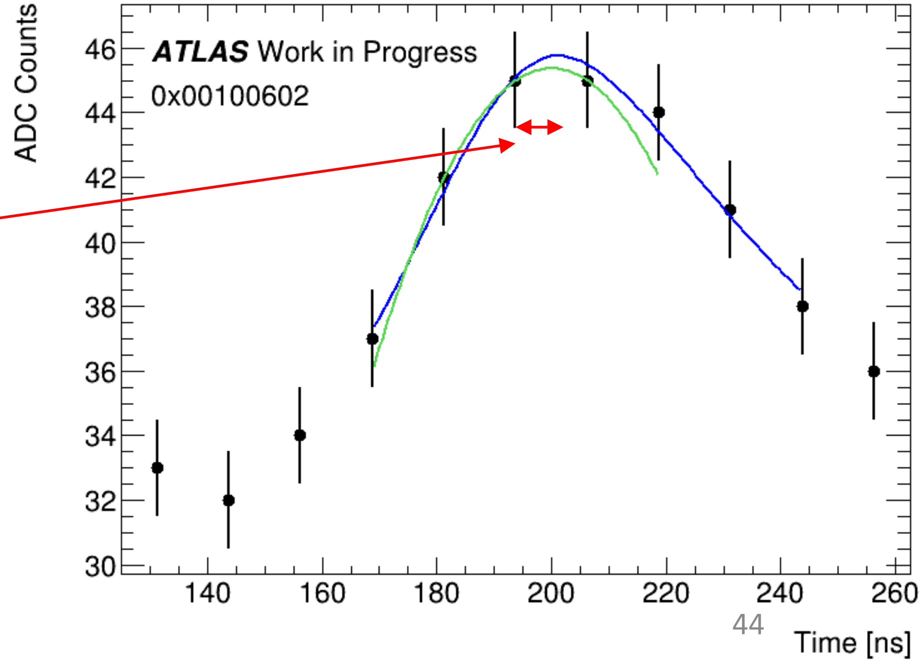
Pilot Run

Testing the legacy L1Calo PPM timing in Run 3

Timing Derivation from Data

- Idea:
  1. Fit calorimeter signal to data
  2. Compare to read out ADC values
  3. Built difference in time between max. amplitude

- Adjustment:
  - Correct the input timing by time difference



The Fits

- Derived during Run 1

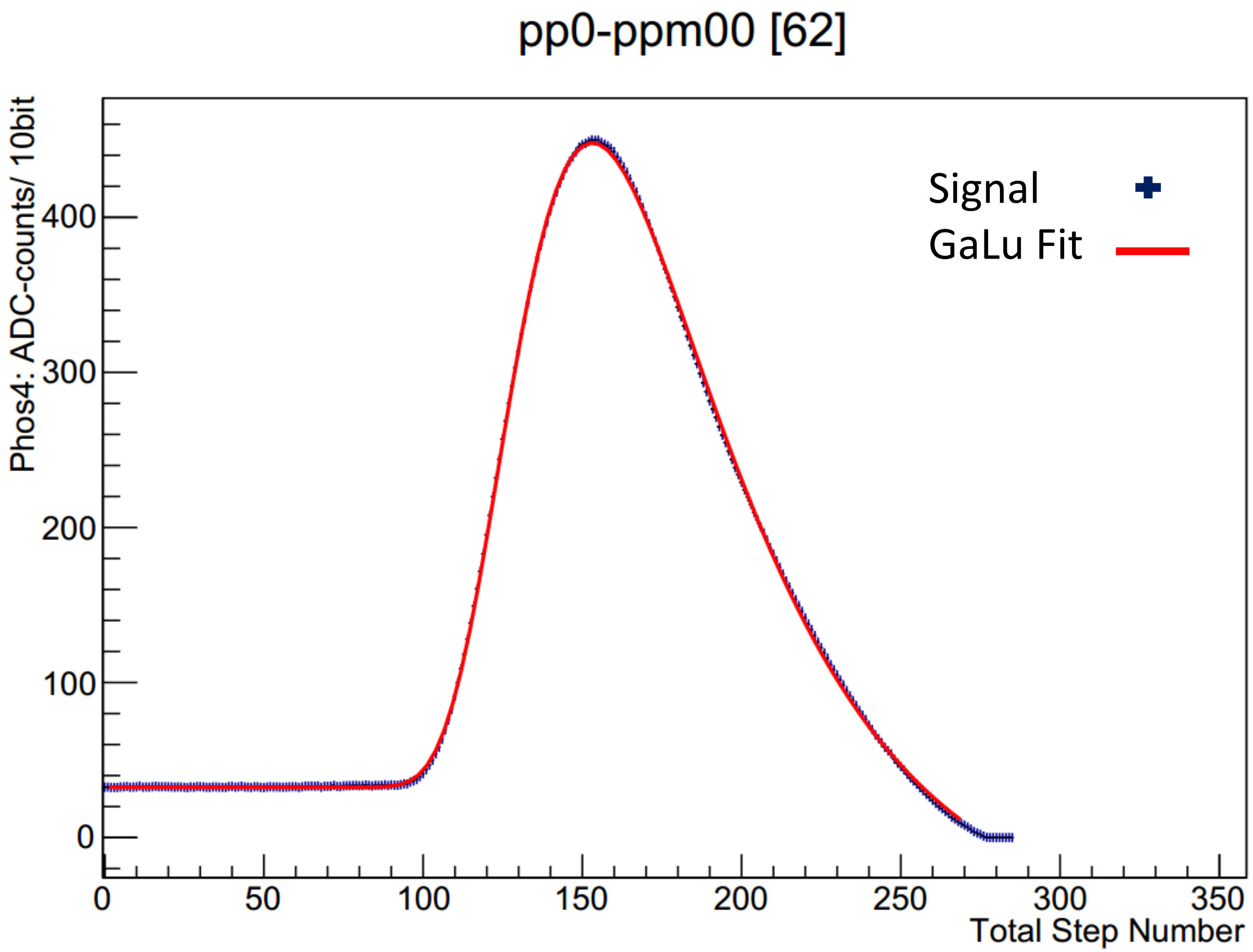
- Right hand side is always a Landau

$$f(x > x_{max}) = \left(A + e^{+1/2} \cdot D\right) \cdot \exp\left(-\frac{1}{2}\left(\frac{x - x_{max}}{\sigma_{Landau}} + \exp\left(-\frac{x - x_{max}}{\sigma_{Landau}}\right)\right)\right) - D + C$$

- Left side is either a Landau (without undershoot, D=0) or a gaussian

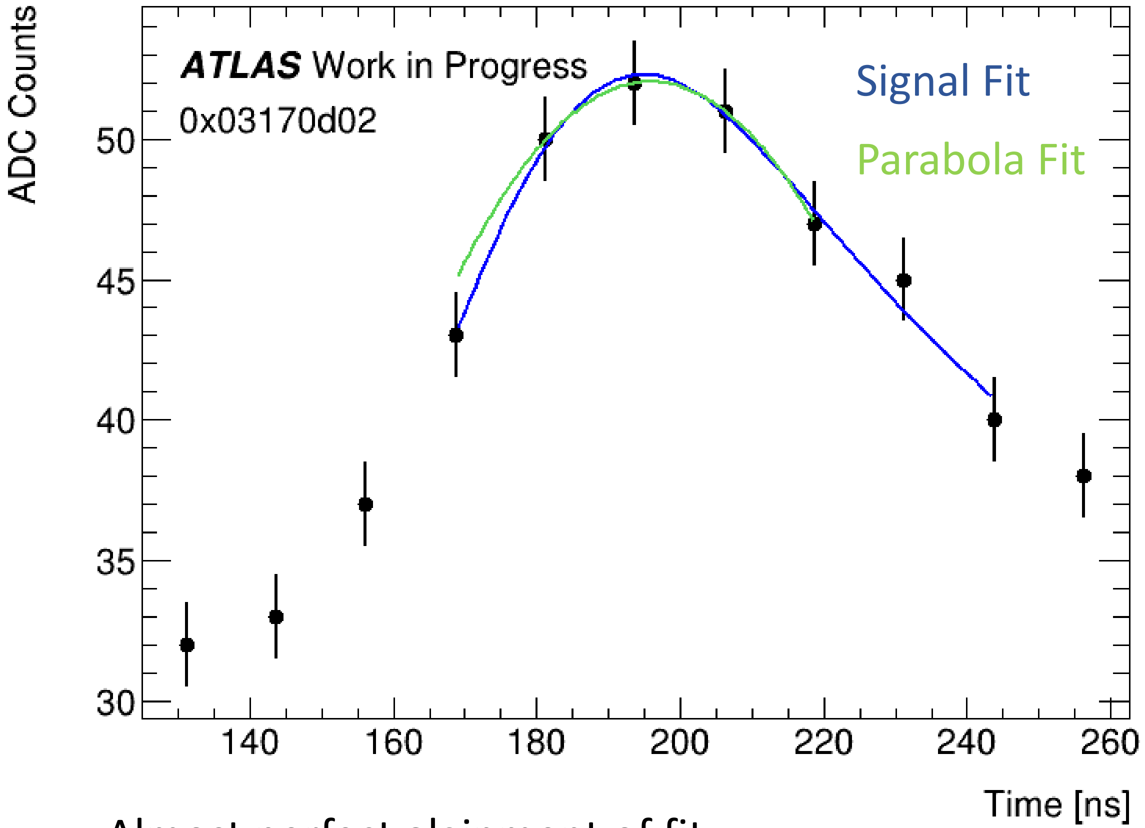
$$f(x \leq x_{max}) = A \cdot \exp\left(-\frac{(x - x_{max})^2}{2 \cdot \sigma_{Gauss}^2} - \frac{1}{2}\right) + C$$

Landau-Landau Fit

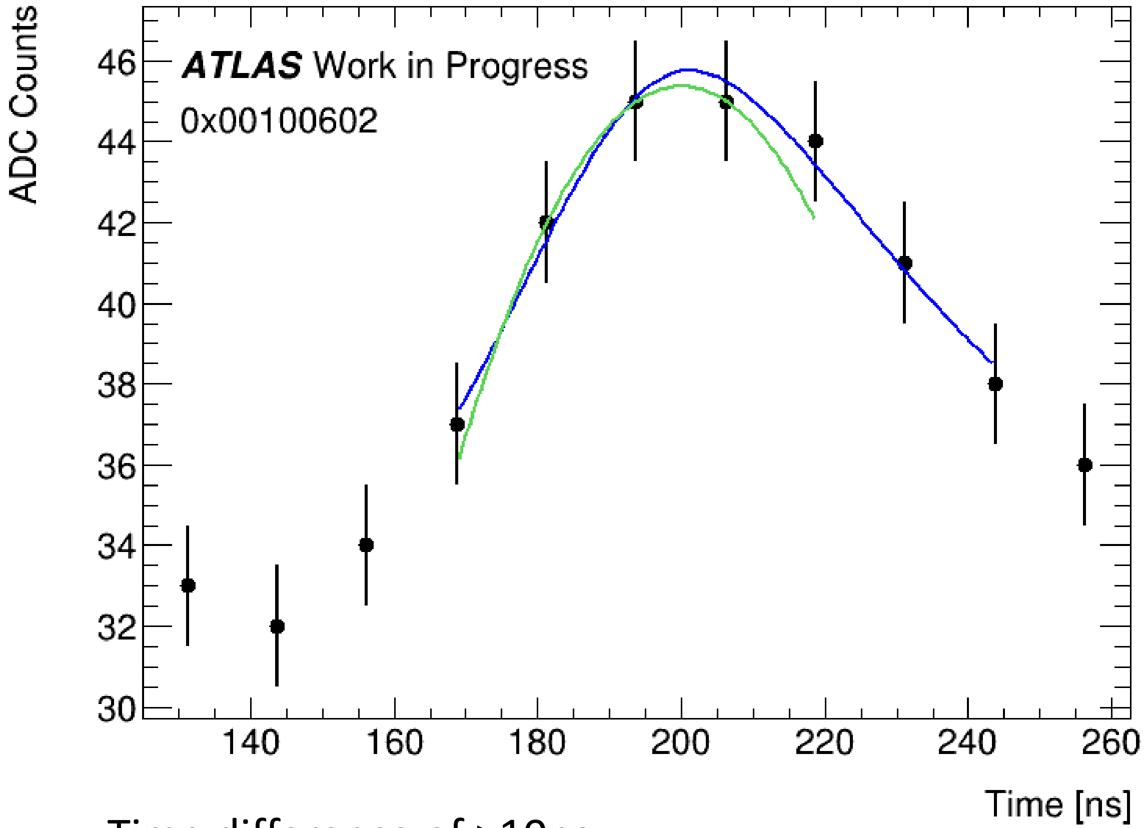


Fixed Offset

Fits

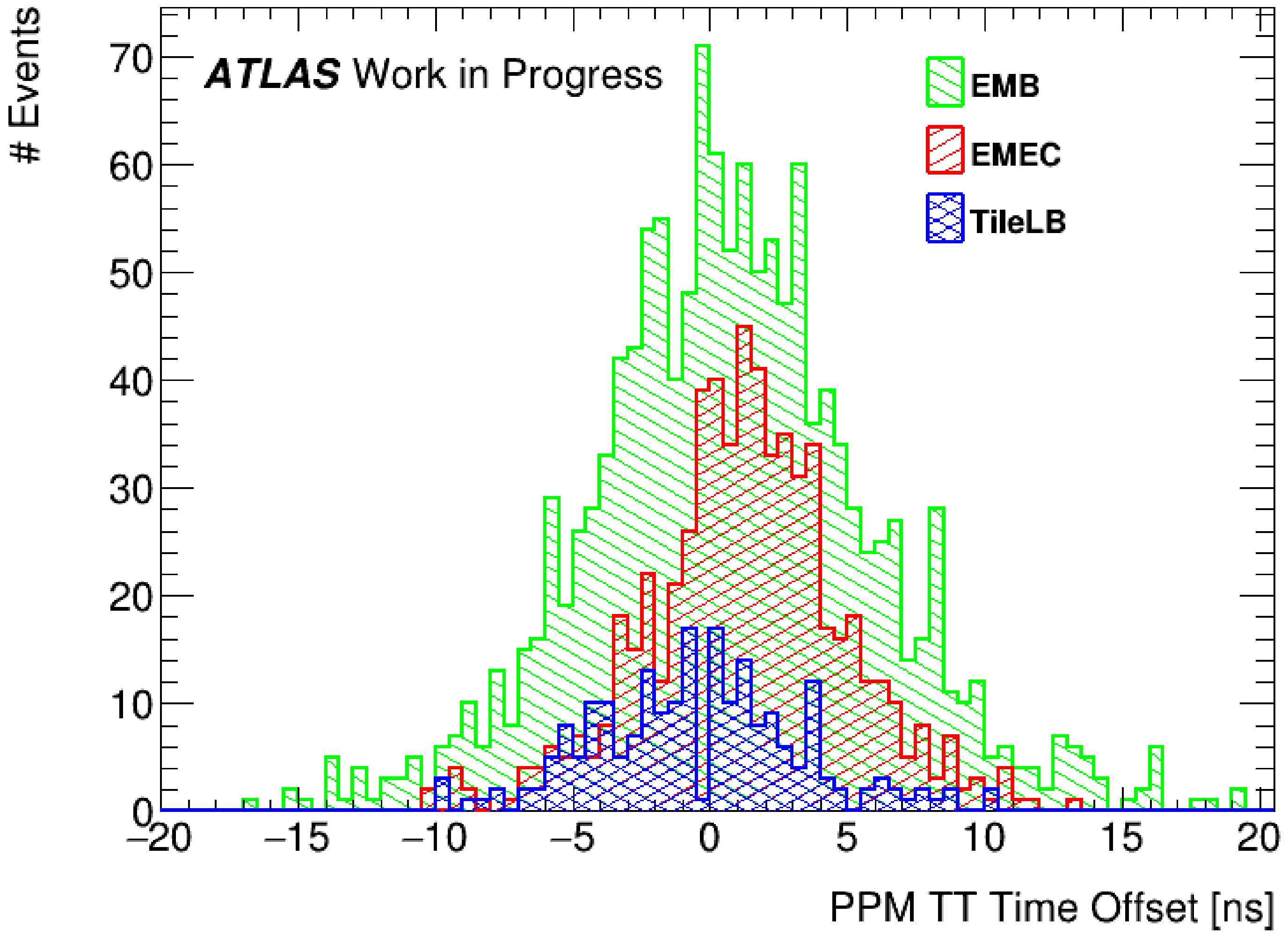


Almost perfect alginment of fit
and ADC maximum



Time difference of >10ns
between fit and ADC maximum

Timing Offset



Intermediate Conclusion

- Physics Timing verified in Splashes and Pilot Beam
- Timing is in a good shape for 3 years of shutdown and upgrades
- Not perfect yet
  - But no systematic changes missed
  - Improvement in coming special runs

Energy Calibration

Different Gains

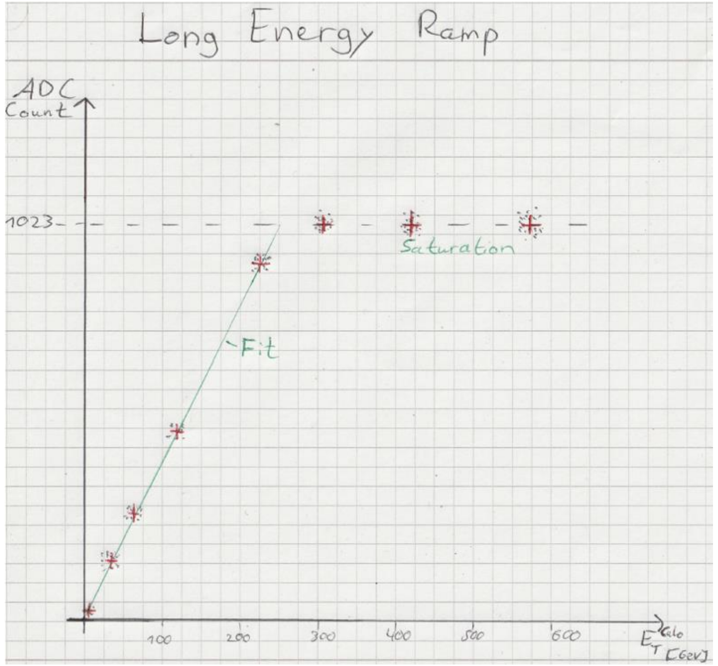
- Receiver gains are composed of multiple factors loaded from database
- Physics: Default=EtConversion*CalibGains*HVCorrection*PhysicsPulseShape

EtConversion	CalibGains	HVCorrection	PhysicsPulseShape
Geometrical effects	Based on Gain=1, raw calibration (cable length…)	High Voltage Correction	Compensates pulse shape differences to Pulser Runs

Energy Ramps

Long Energy Ramps

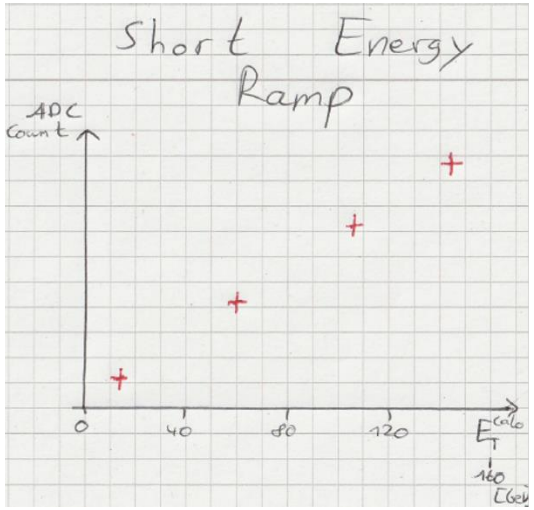
- Check if points near saturation behave normally after upgrade



Short Energy Ramps

- Remember:
  - Signalheight has lost a few %

  →should be visible across the entire energy band
- Comparing the slope of older energy ramps to new ones should should yield similiar results to heights



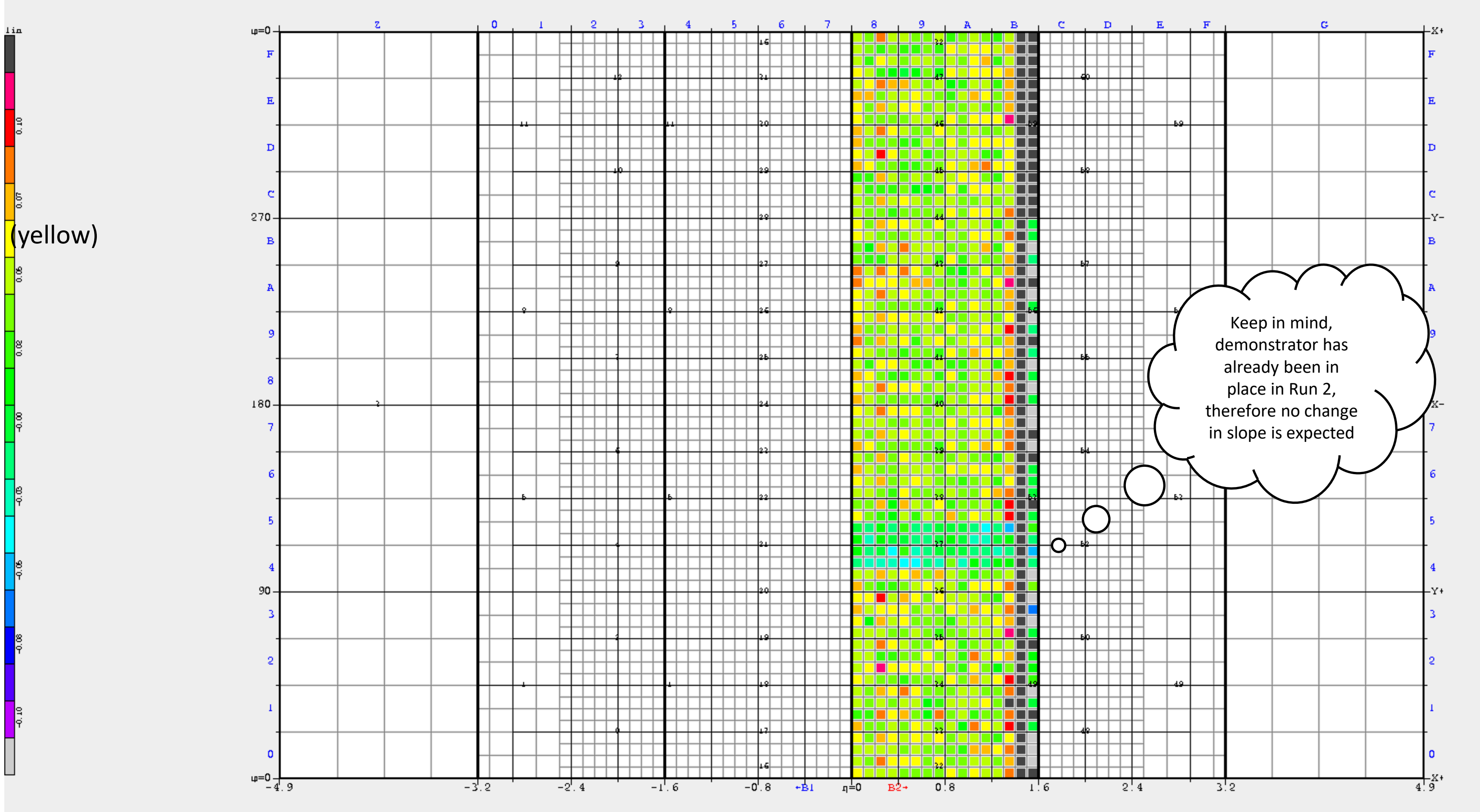
Slope Comparison

6% slope loss (yellow)

5% slope loss

No change in slope

5% slope gain



Conclusion

- Legacy L1Calo Trigger is running after the long shutdown
- Timing in legacy system can be re-established
  - Special runs will improve timing
- Energy calibration will start when last modifications of Phase-I finished

References

(1)https://cds.cern.ch/record/1095924

(2)ATLAS Liquid Argon Calorimeter Phase-I Upgrade : Technical Design Report; cds.cern.ch/record/1602230

(3)https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/TDAQ-2019-01/

(4)ATLAS Collaboration,Technical Design Report for the Phase-I Upgrade of the ATLAS TDAQ System,CERN-LHCC-2013-018, https://cdsweb.cern.ch/record/1602235

(5)ATLAS Liquid Argon Calorimeter Phase-I Upgrade Technical Design Report, http://cds.cern.ch/record/1602230/?ln=de

(6)https://indico.cern.ch/event/829769/contributions/3572284/attachments/1930398/3197767/l1c_20191022_joint.pdf