Signal Reconstruction of the Atlas Hadronic Tile Calorimeter: Implementation & Validation

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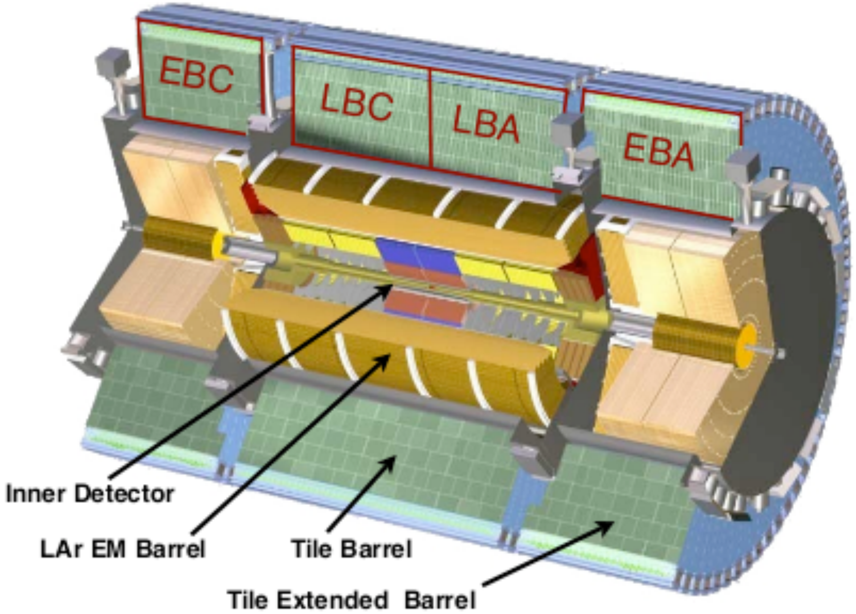
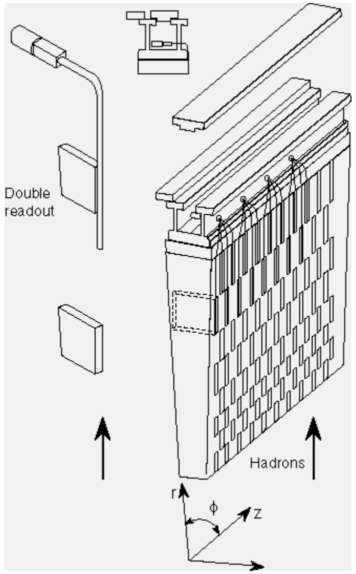
Overview

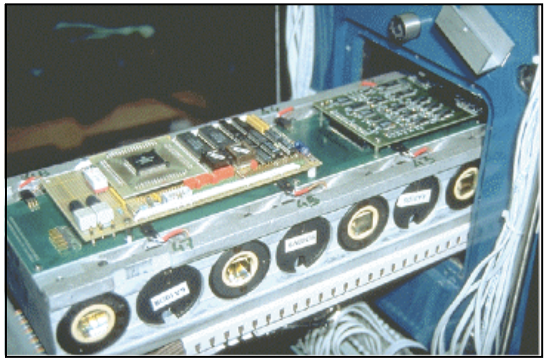
- Read-out principles
- Requirements for the online reconstruction and DSP Implementation
- Signal pulse shapes and Optimal filtering reconstruction
    - Validations of results
        - CIS Calibrations events
        - pseudo event injected in the DSP
        - Physics events

ATLAS Tile Calorimeter



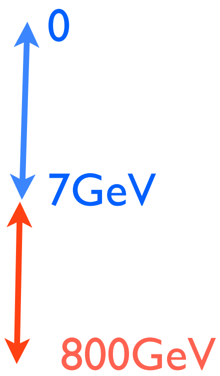


see also talk from V.Rossetti and M. Simonyan.

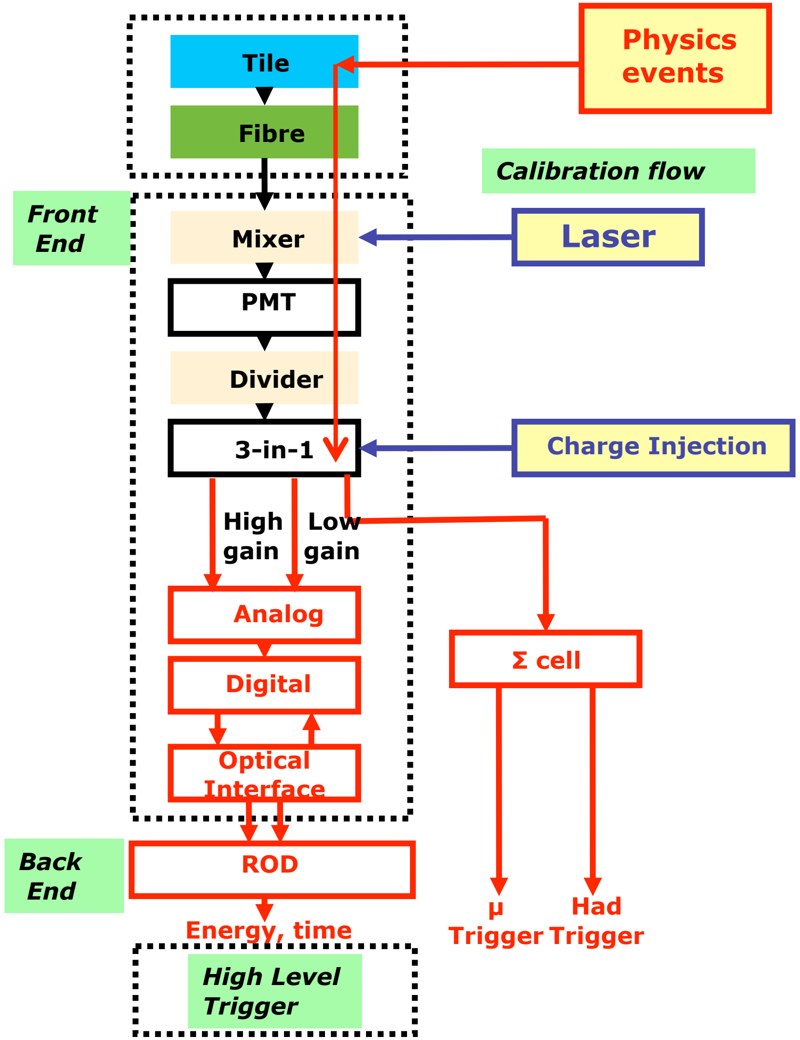


- Central part (η<1.7) of the ATLAS Hadronic Calorimeter.
- Sampling calorimeter: iron/scintillating tiles, placed perpendicularly to particle directions; double PMT readout using wave length shifting fibres.
- 10K readout channels in 256 electronics "drawers", data sent over fiber links.
- Trigger analog signals from each tower to LVL1 trigger system.

Read out principle

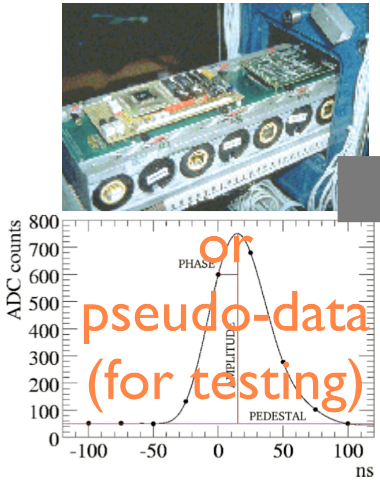


- designed to measure energy deposition in a cell between ~30 MeV and ~1.6TeV.
- PMT signal shaping and amplification, two outputs: High Gain and Low Gain with a gain ratio of 64.
- analog signals for each tower for the LVL1 trigger.
- Digitization at 40 MHz with two ADC (10 bit) High Gain and data samples are stored in pipelines
- after the LVL1 trigger the samples are sent to the Back End electronics.

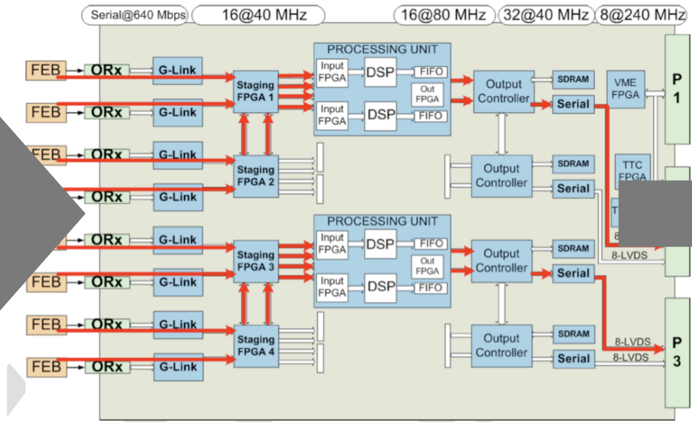


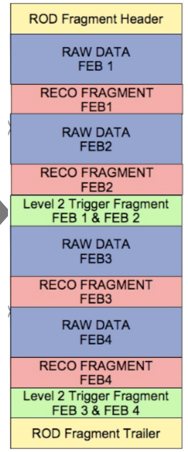
Read Out Driver

data samples



or pseudo-data (for testing)

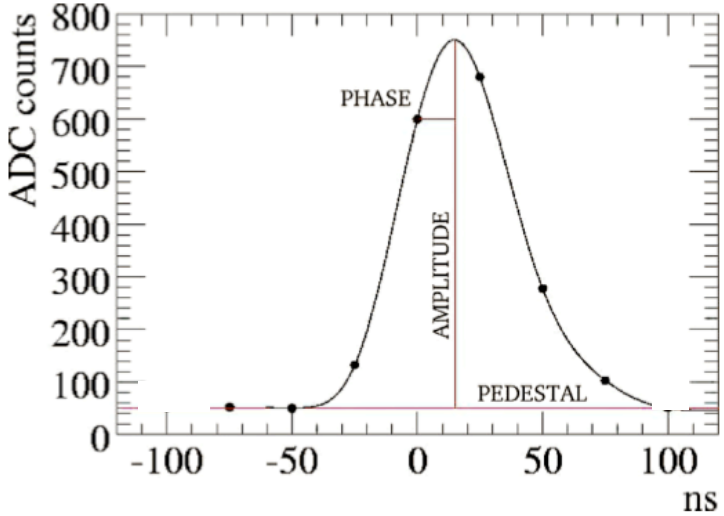




Energy
time
quality factor
+
RAW DATA

- The Read Out Driver(ROD) is the main Back End component.
- Positioned between the L1 and the L2 trigger systems provide, real time, energy and time reconstruction in less than 10 μs.
- Harsh programming environment with limited precision.
- Commissioning of the reconstruction algorithm: for ~ 1 year we save always also the RAW DATA samples.

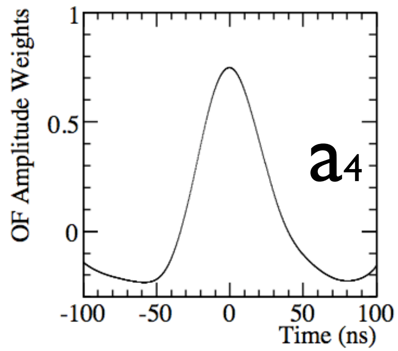
Optimal Filtering

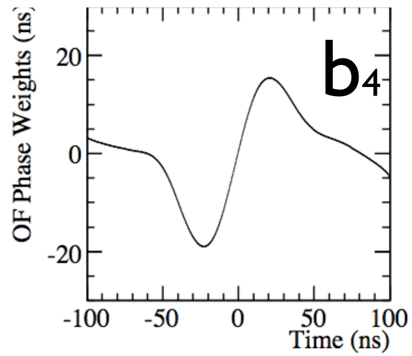


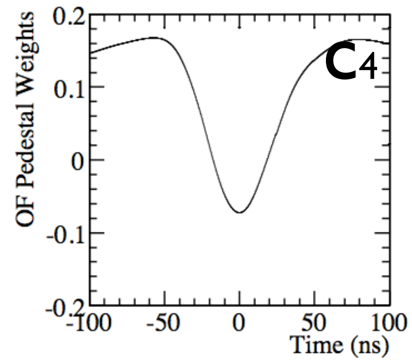
$$A = \sum_{i=1}^{n} a_i S_i$$

$$A\tau = \sum_{i=1}^{n} b_i S_i$$

$$p = \sum_{i=1}^{n} c_i S_i$$





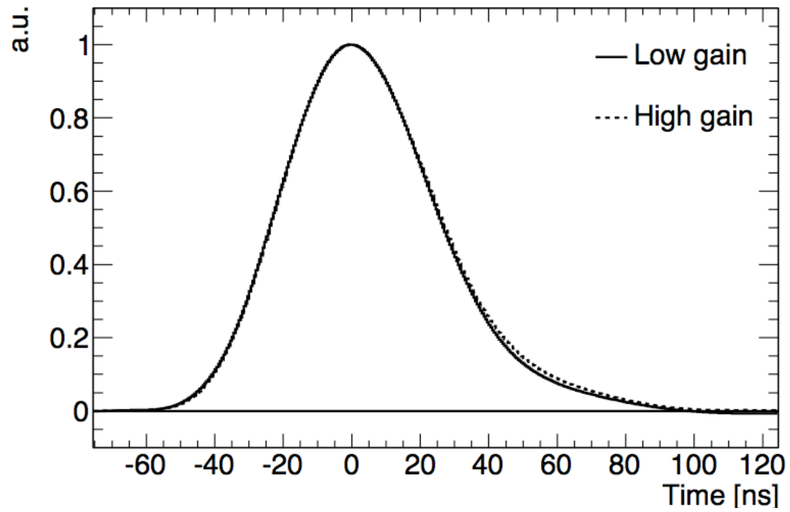


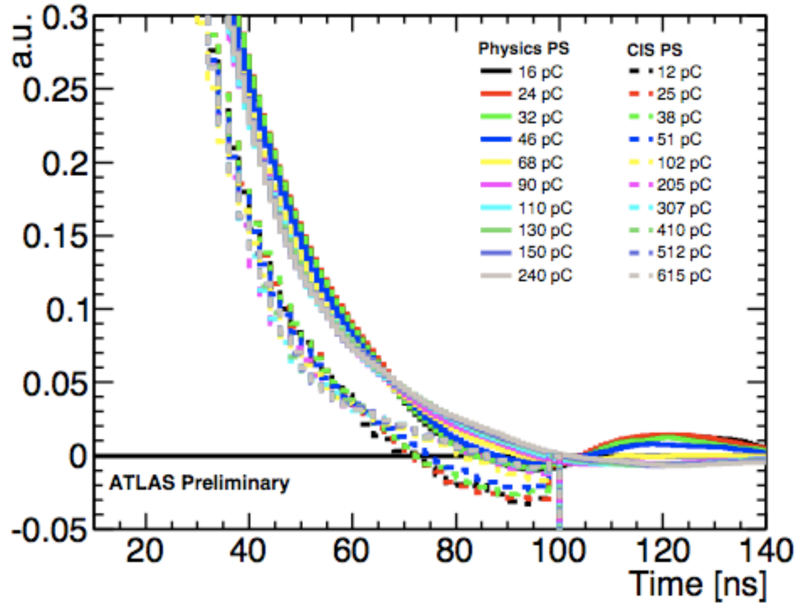
- The weights (a,b,c) are defined by the signal shape and the noise ACM. The method require an initial knowledge of the signal phase.
- For asynchronous data (e.g. cosmics) or to avoid a prior definition of timing we use also one iterative method.

Pulse shapes

- The signal shapes were extracted and studied with Test Beam data:
  - channel by channel differences are within 2%,
  - slightly energy dependent deformation in the tail region observed.
  - Systematics in the measured energy are <~0.5%.
- used also to define the reconstruction Quality Factor:

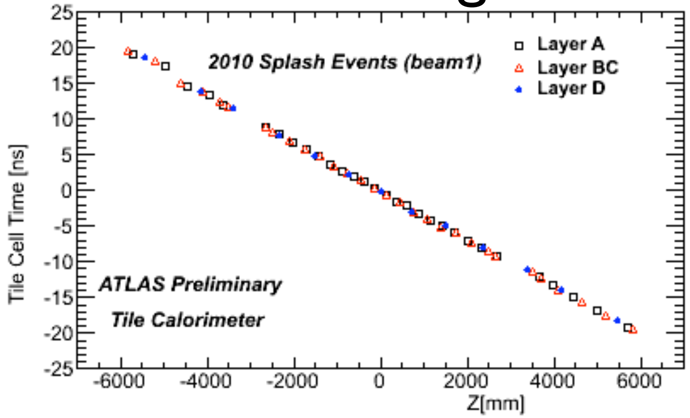
$$Q = \sqrt{\frac{1}{32}\sum_{i=1}^{7}\left(S_i - (Ag_i + A\tau g' + ped)\right)^2}$$





OF implementation

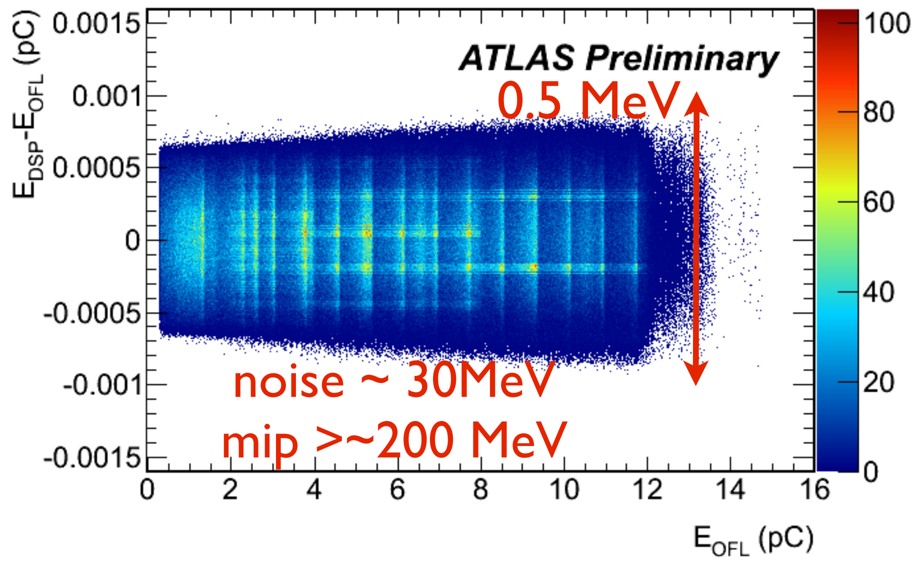
timing

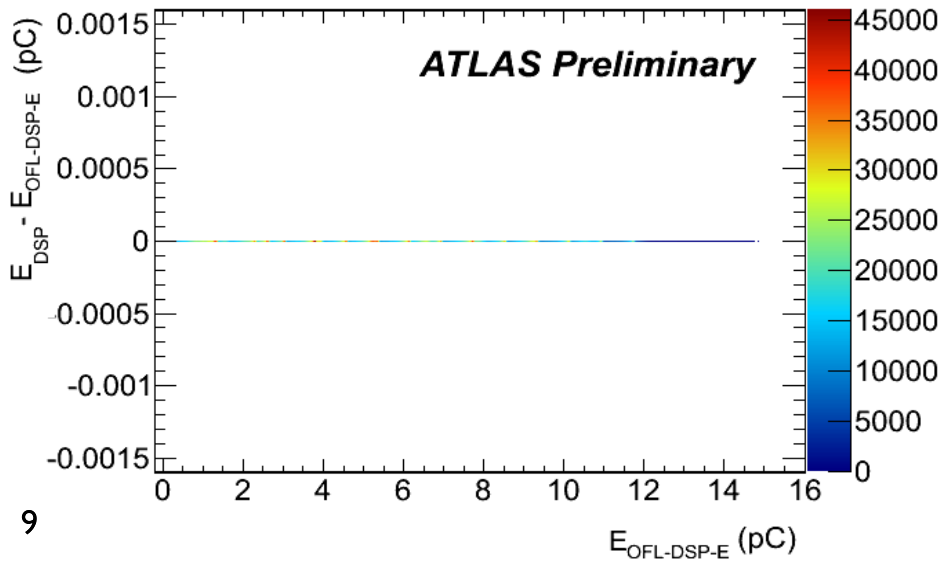


- OF algorithms are implemented in the RODs and in the Offline software:
  - The iterative algorithm do not need precise timing and was used up to recently, it is slow and more sensitive to noise fluctuation.
  - The non iterative algorithm is the design method that matches the time constraints. Is running NOW and being validated.
  - Three options with currently sustainable rates:
    - OF_NIter+RAW:46 KHz
    - OF_NIter: >100 KHz
    - OF_NIter +conditional dump of RAW Data (up to 25% ch) : 85 KHz

Validation with charge injection events
amplitudes in the High Gain

- Comparison with offline reconstruction:
  - residual difference consistent with DSP limitation due to fixed point arithmetic and limited precision in the calibration constants
- Comparison with offline DSP emulation:
  - identical results





Validation with charge injection events
amplitude in Low Gain

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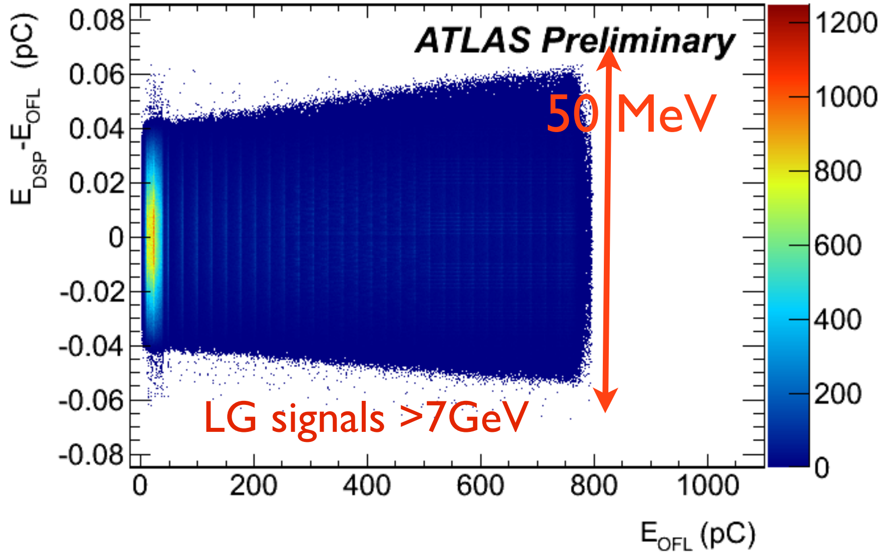
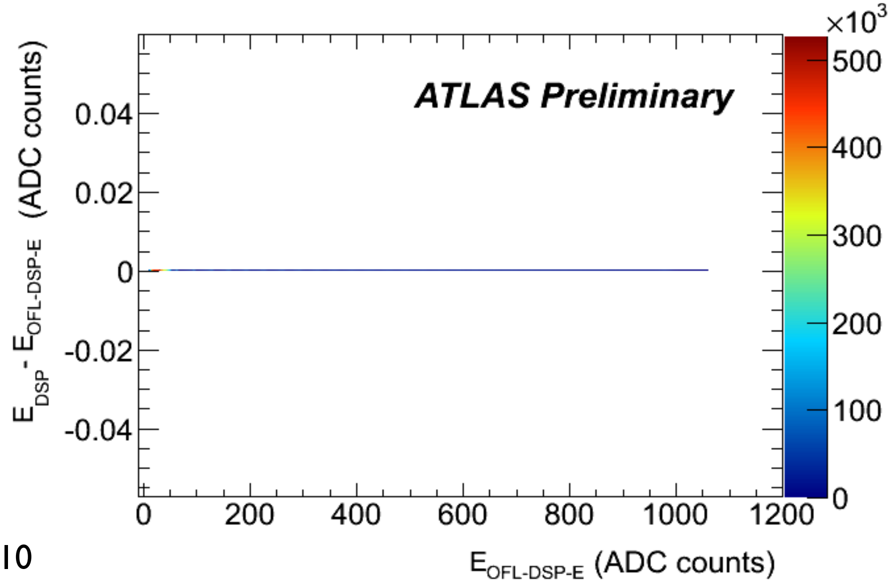




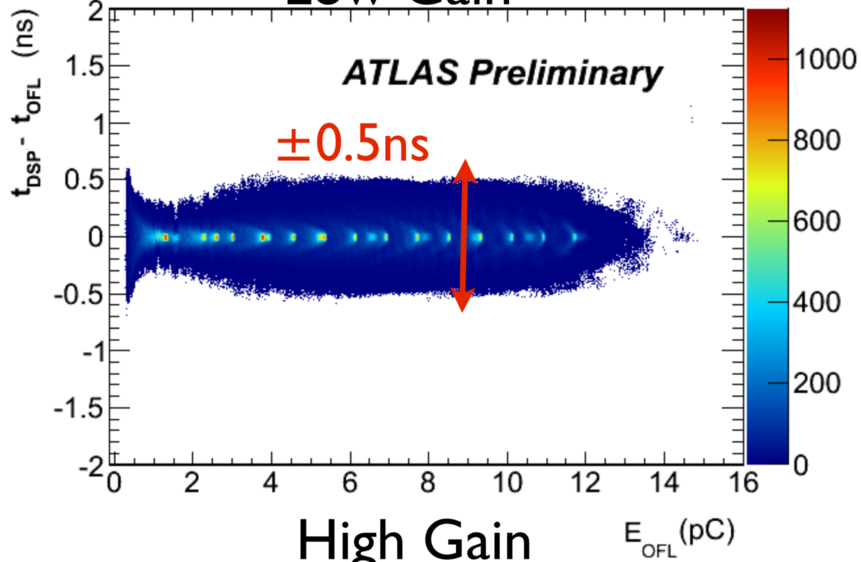
Validation with charge injection events

reconstruction of time

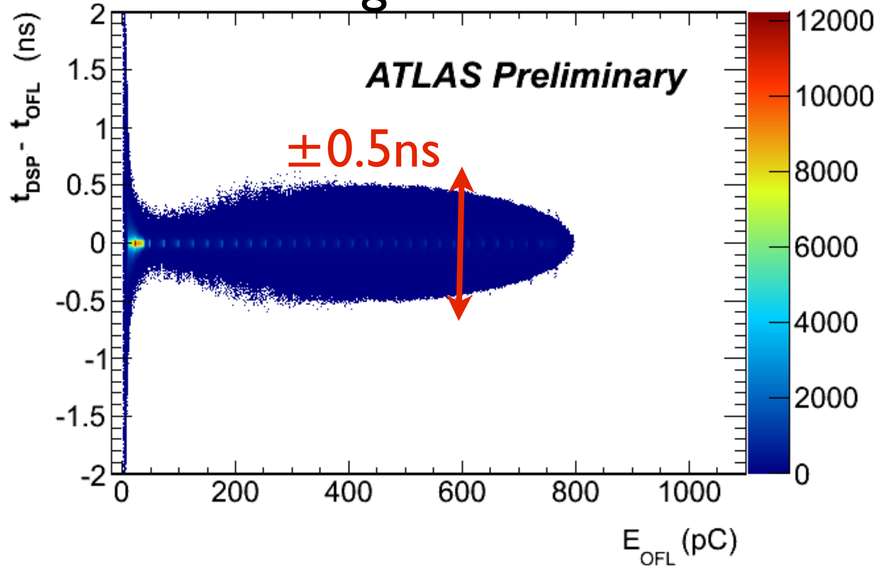
- Comparison with offline reconstruction:
  - the precision of DSP time is limited by the use of fixed point arithmetic and the look up table for the divisions.

$$A\tau = \sum_{i=1}^{n} b_i S_i$$

Low Gain



High Gain



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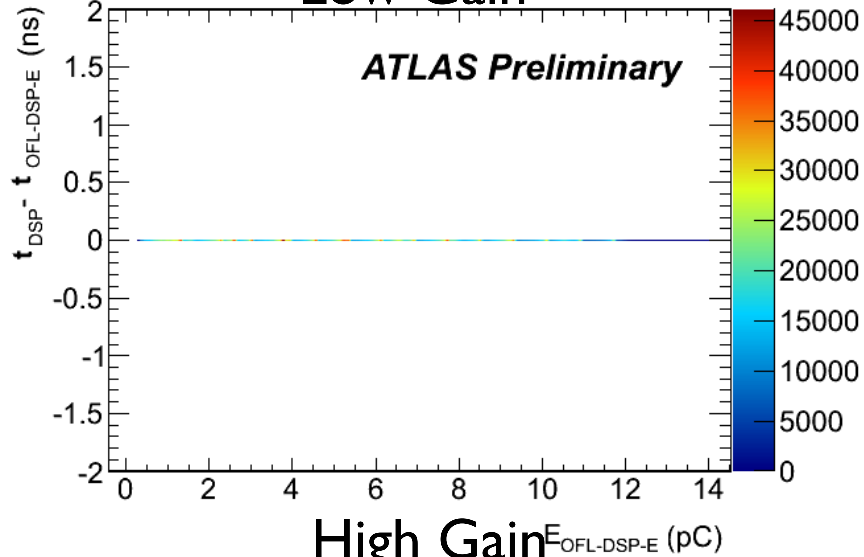

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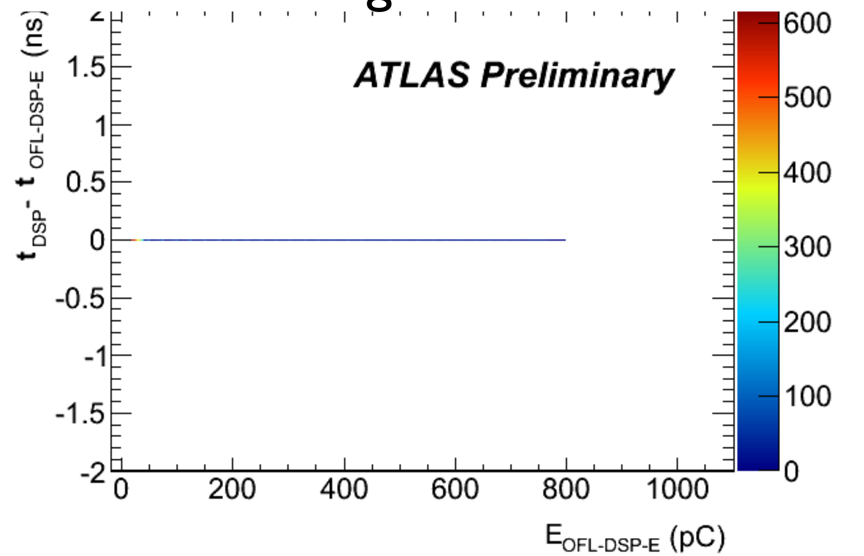
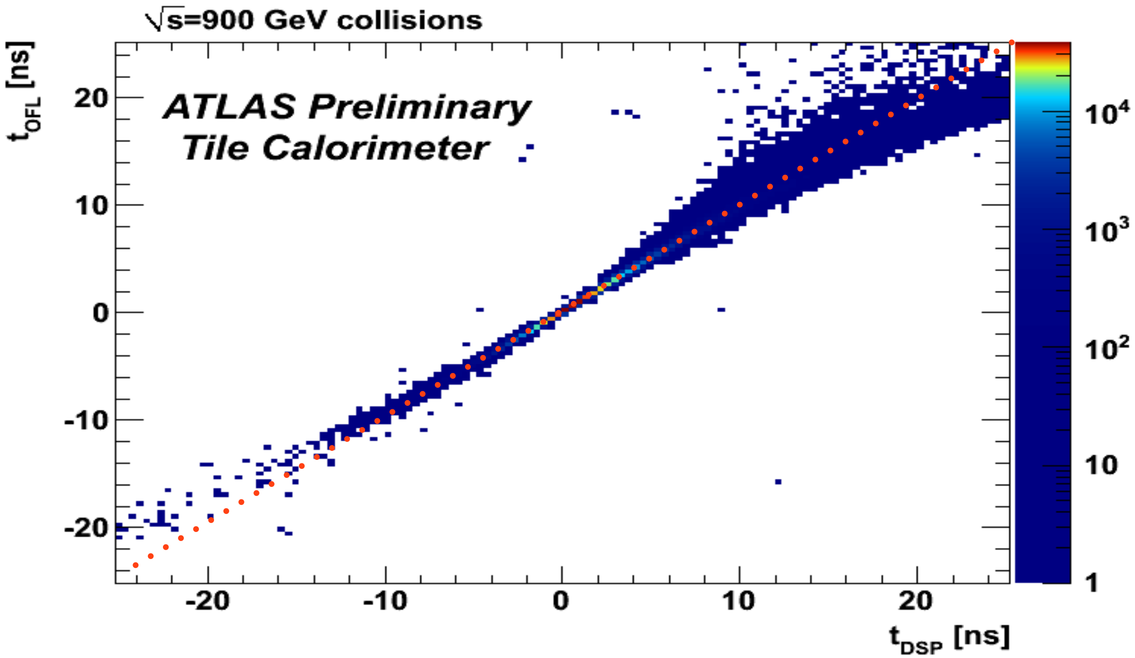


validation with collision data

reconstruction of time

- Collision data at 900 GeV reconstructed online by the DSP (non Iterative) and offline with iterative method.
- deviation from linearity start when the phase is different then the expected by more than 10 ns.
- anomalous large phases or bad reconstruction (QF) trigger the dump of the data sample



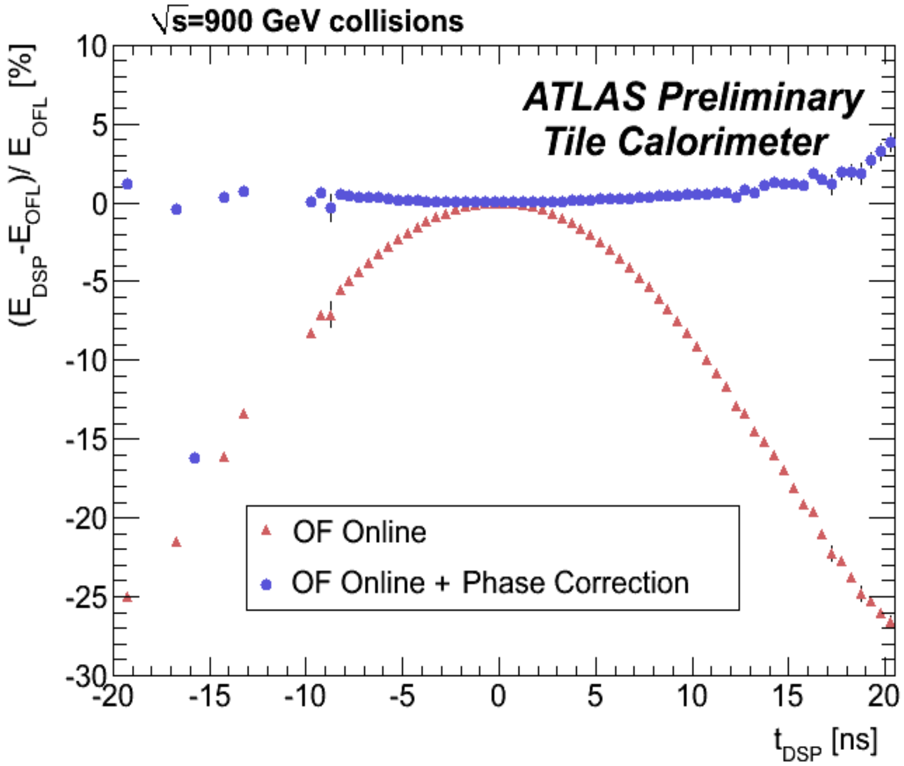
validation with collision data

parabolic deviation

- Collision data at 900 GeV reconstructed online by the DSP (non Iterative) and offline with iterative method.

- Large dispersion in the signal phases biases the OF energy reconstruction.

- after correction the bias is reduced to less than 1%.



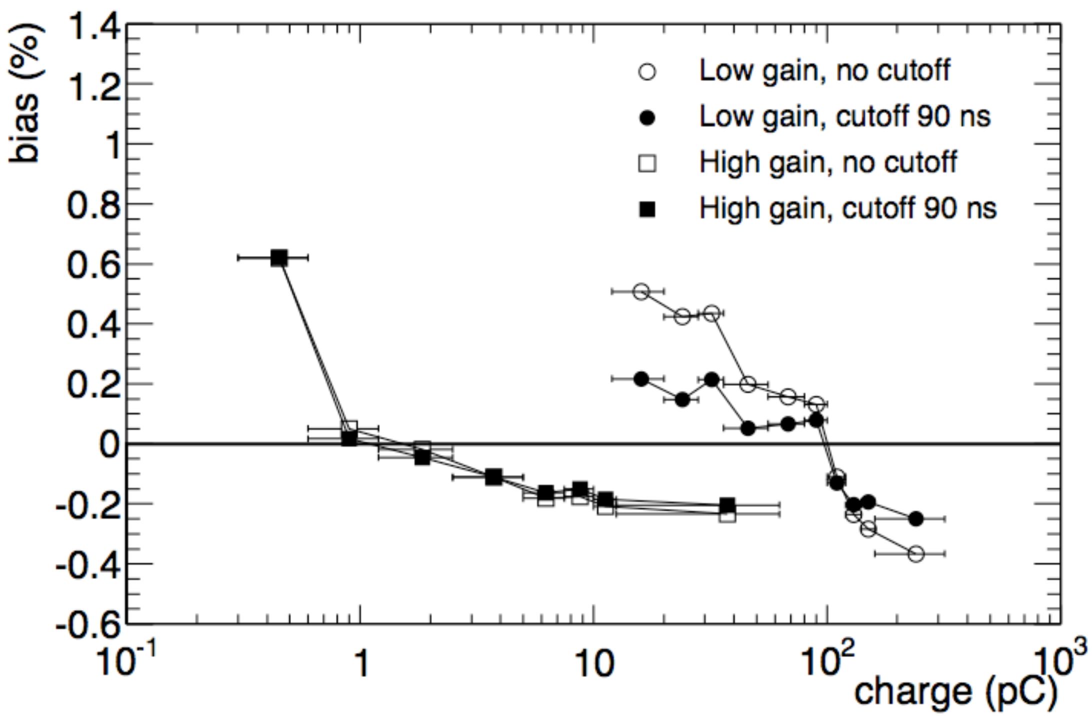
Summary

- The OF reconstruction algorithms in the ROD are processing online the first LHC data and feeding the High Level trigger system.
- The precision of the online reconstruction is adeguate and within the expectations.
- The online results are not used yet in the first ATLAS analysis that can benefit from more mature offline reconstructions.
- This approach is feasible and will be used until the ATLAS LVL1 trigger rate will reach ~40 KHz. After that we will switch to the final reconstruction mode with conditional dump of raw data.

Additional material

energy bias due to Pulse shape distorsion

- sample generated with different pulse shapes
- standard pulse shape used for reconstruction
- results with LS fit
- bias < 1%.



Validation with charge injection events
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- Comparison with offline reconstruction:
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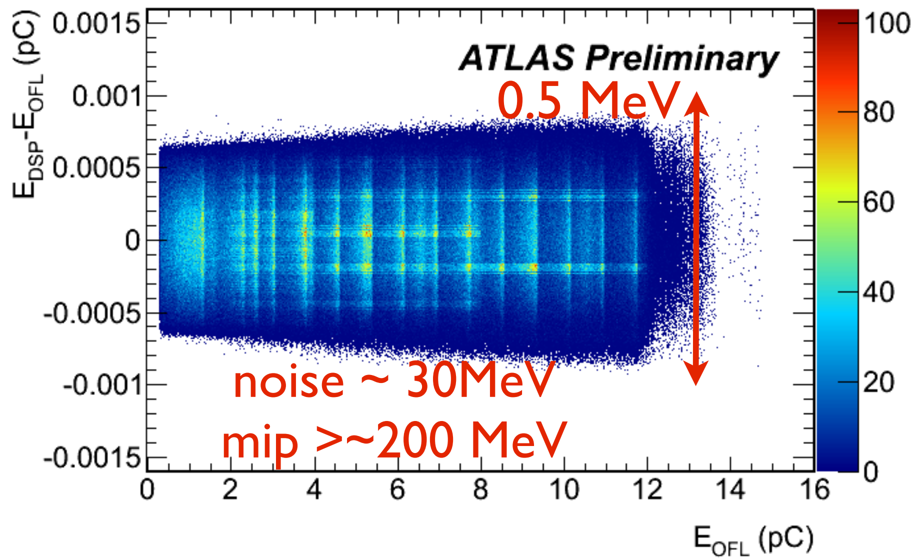
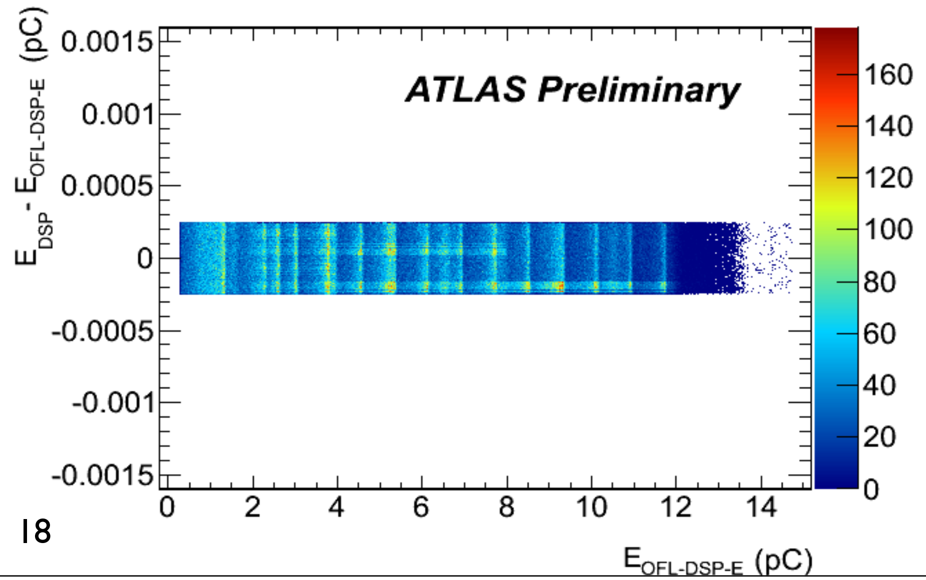
- Comparison with offline DSP emulation:
  - identical results in ADC counts
  - remaining difference is due to different precision in the calibration constants





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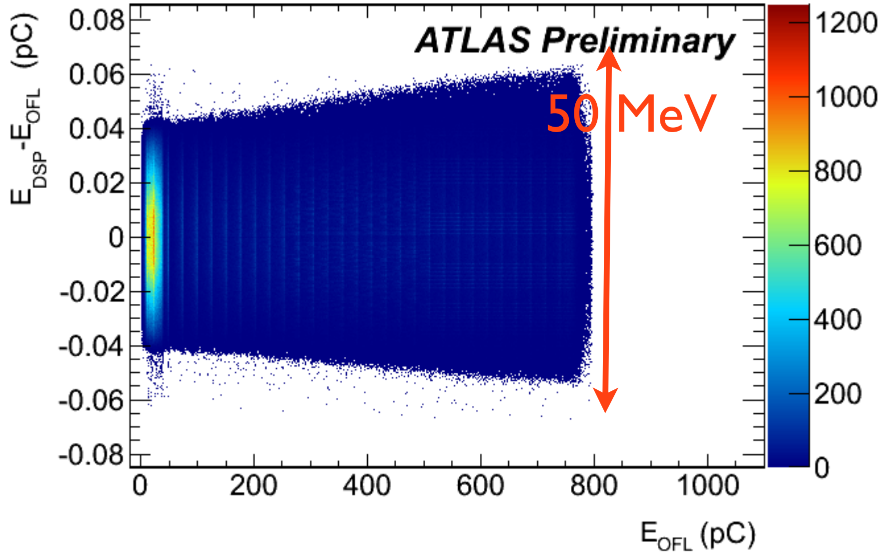

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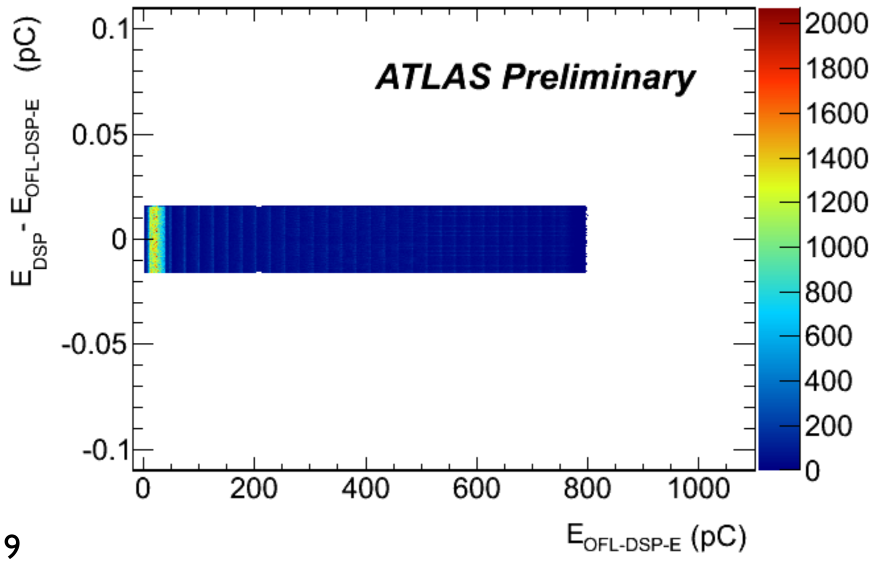

Validation with pseudo events

reconstruction of time

$$A\tau = \sum_{i=1}^{n} b_i S_i$$

- pseudo events spanning the entire energy and time range.
- Comparison with offline reconstruction:
  - the precision in the reconstructed time in the DSP is limited by the fixed point arithmetic and the use of a look up table for the divisions.