Algorithms for the ROD DSP of the ATLAS Hadronic Tile Calorimeter

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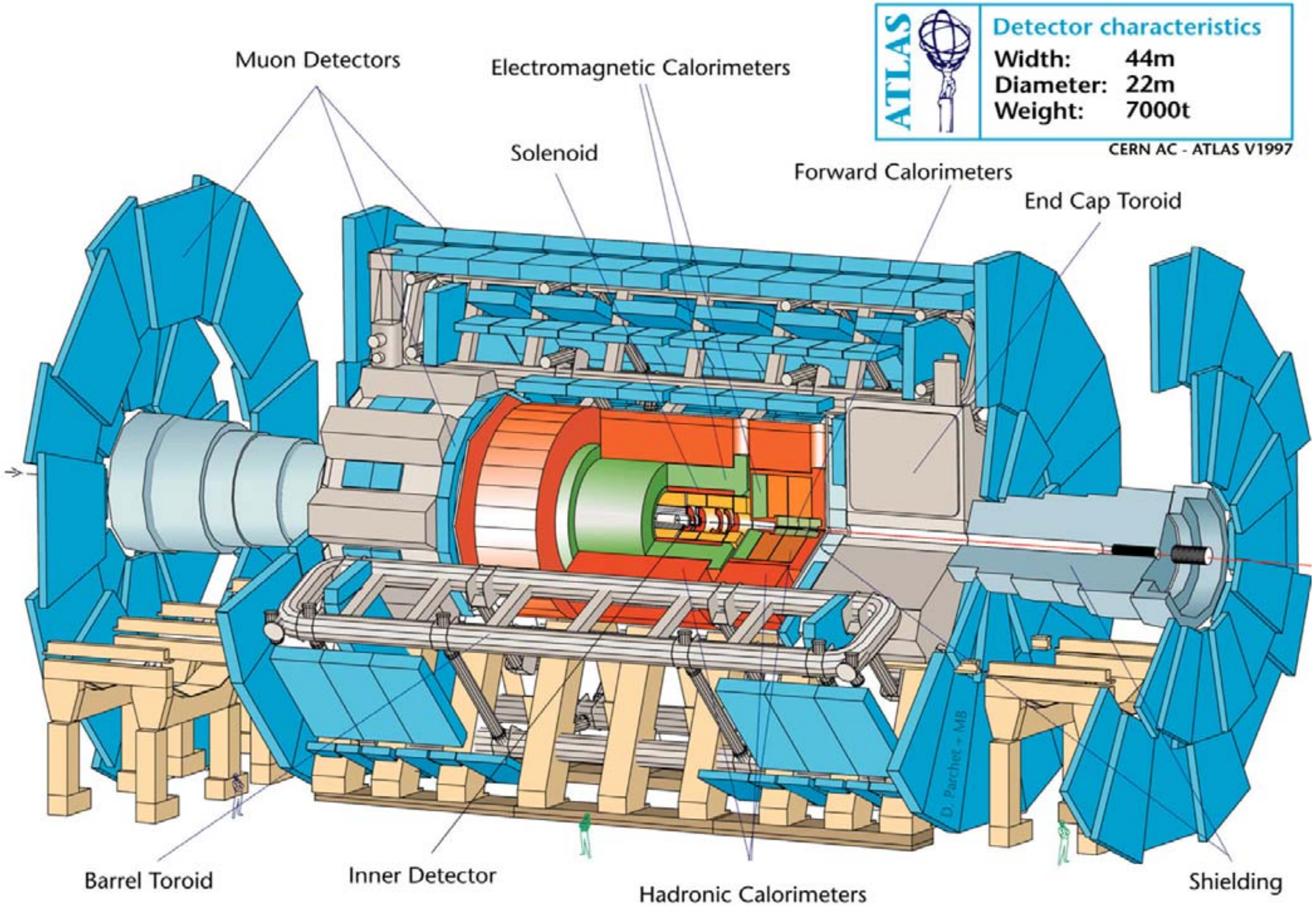
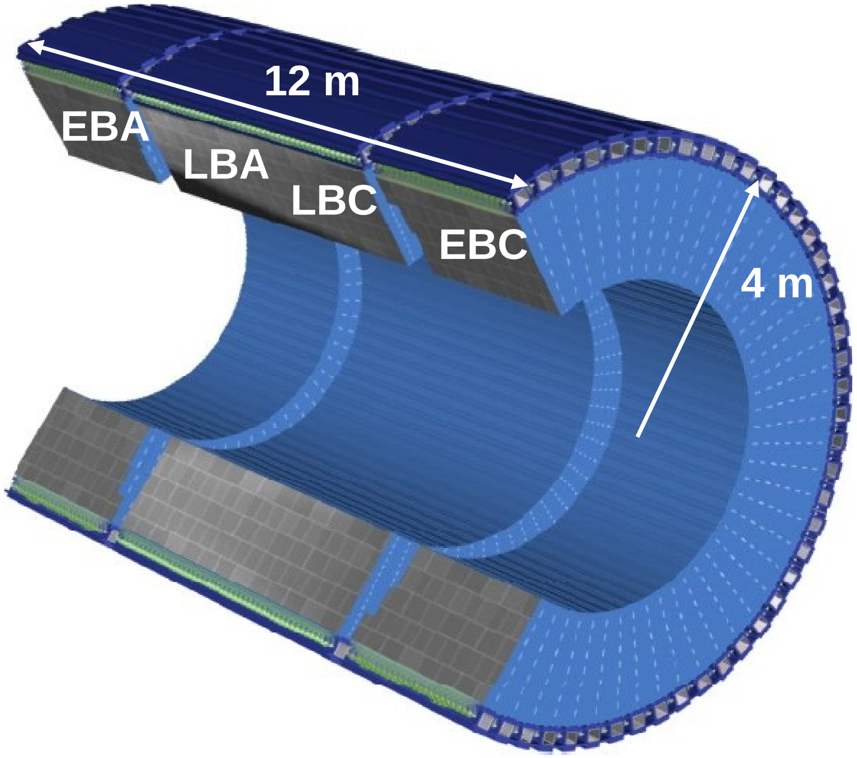
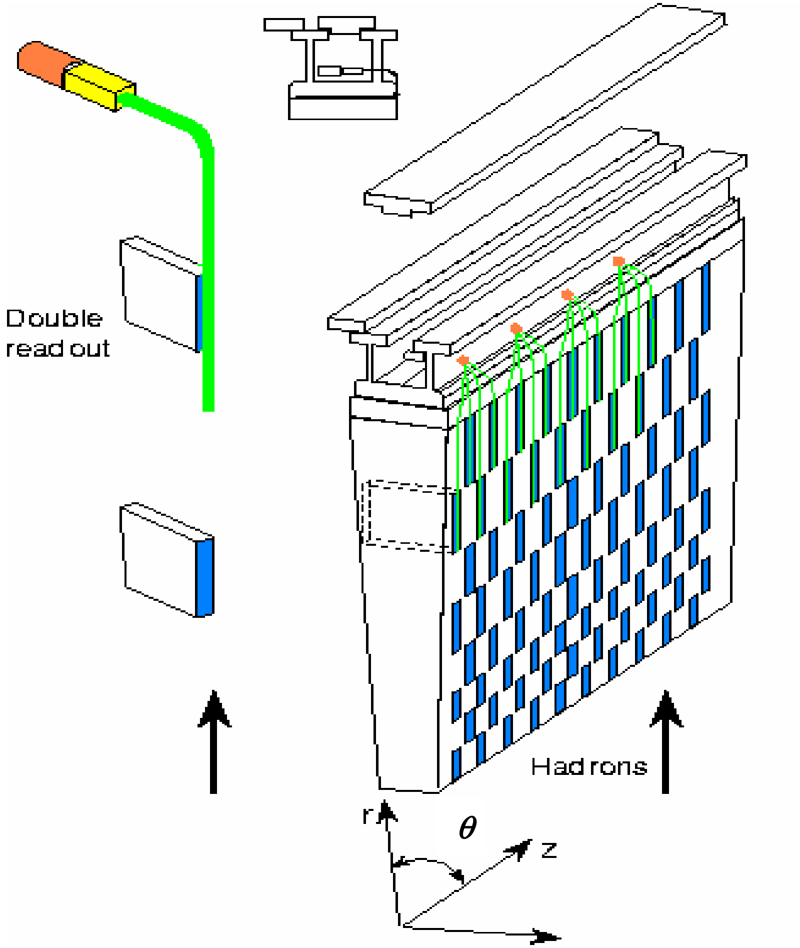
12th Workshop on Electronics for LHC and Future Experiments

ATLAS detector



Hadronic Tile Calorimeter





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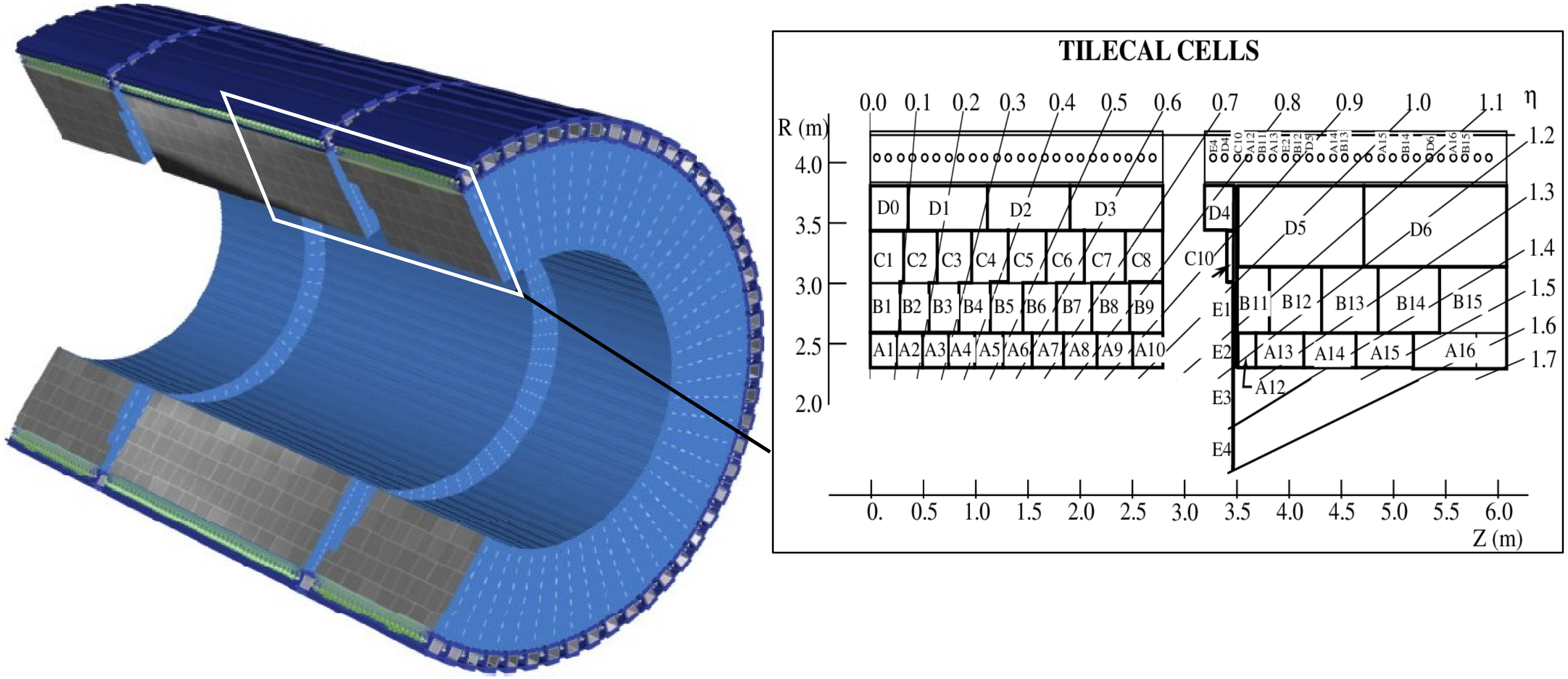
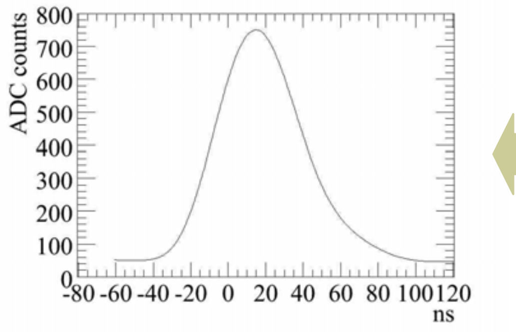


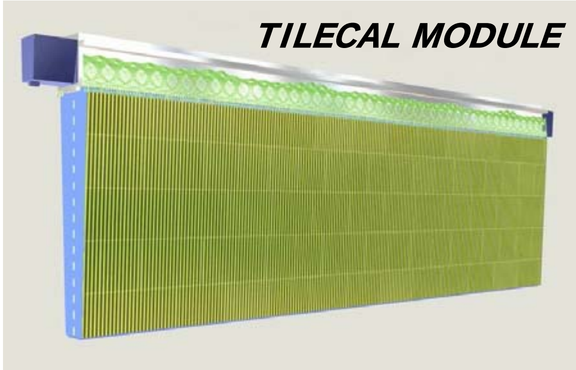
Read Out Chain

SHAPER

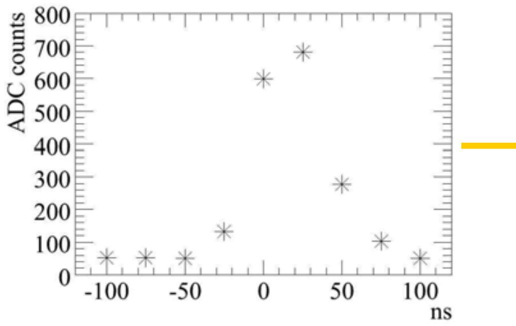


PMT

TILECAL MODULE

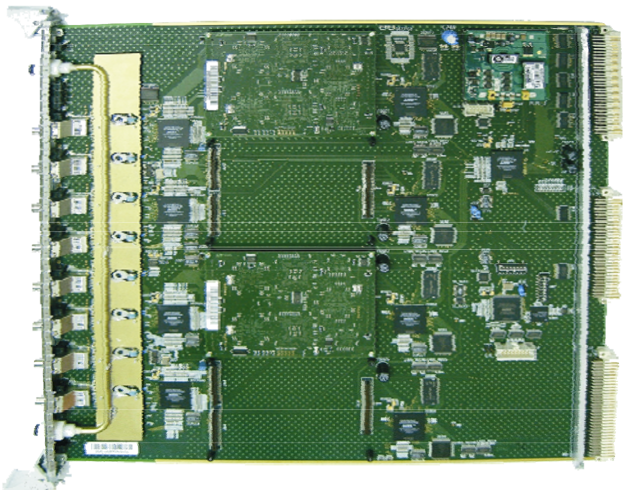


DIGITIZER

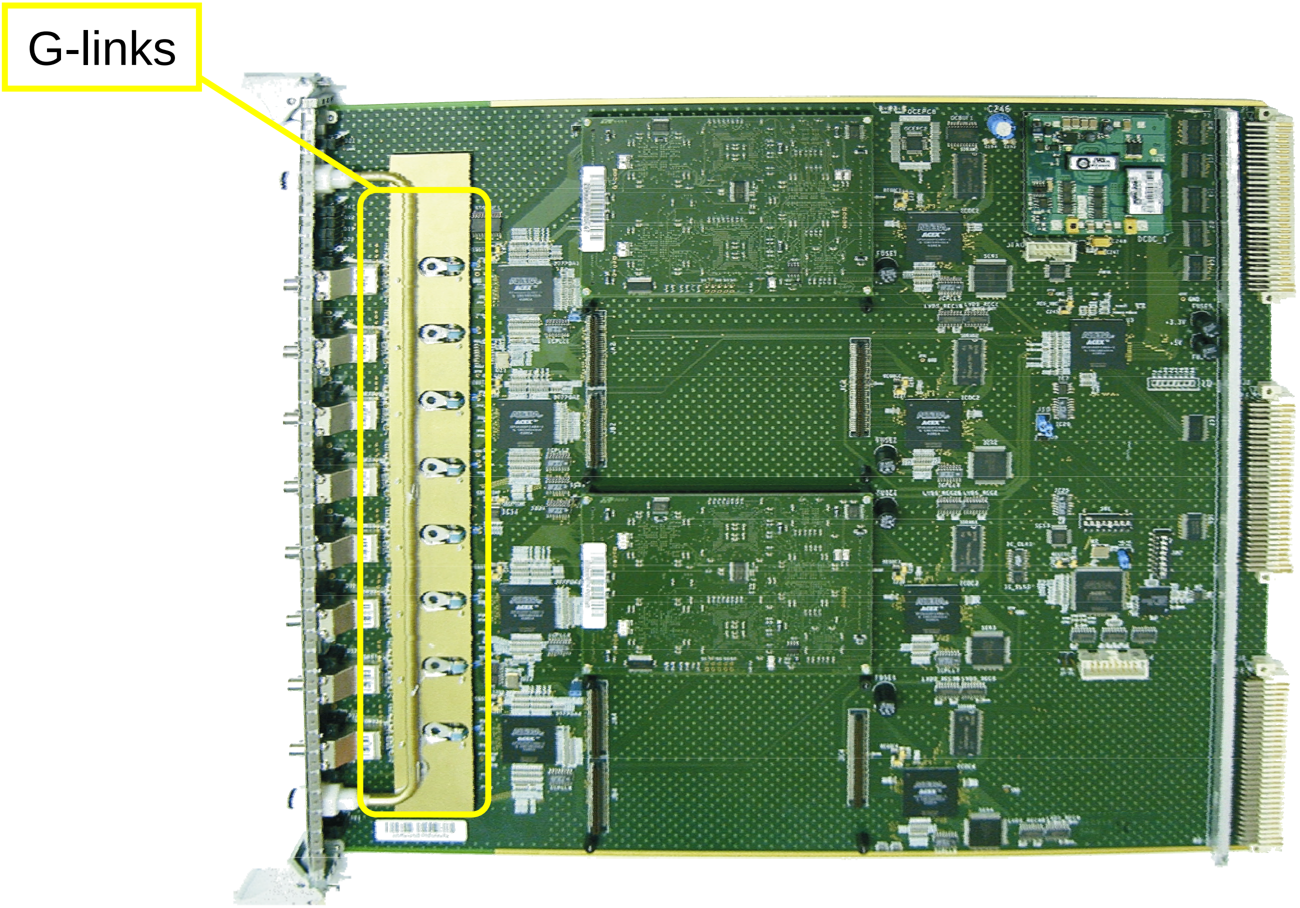


Optical Fibers

READ OUT DRIVER SYSTEM



Read Out Driver board



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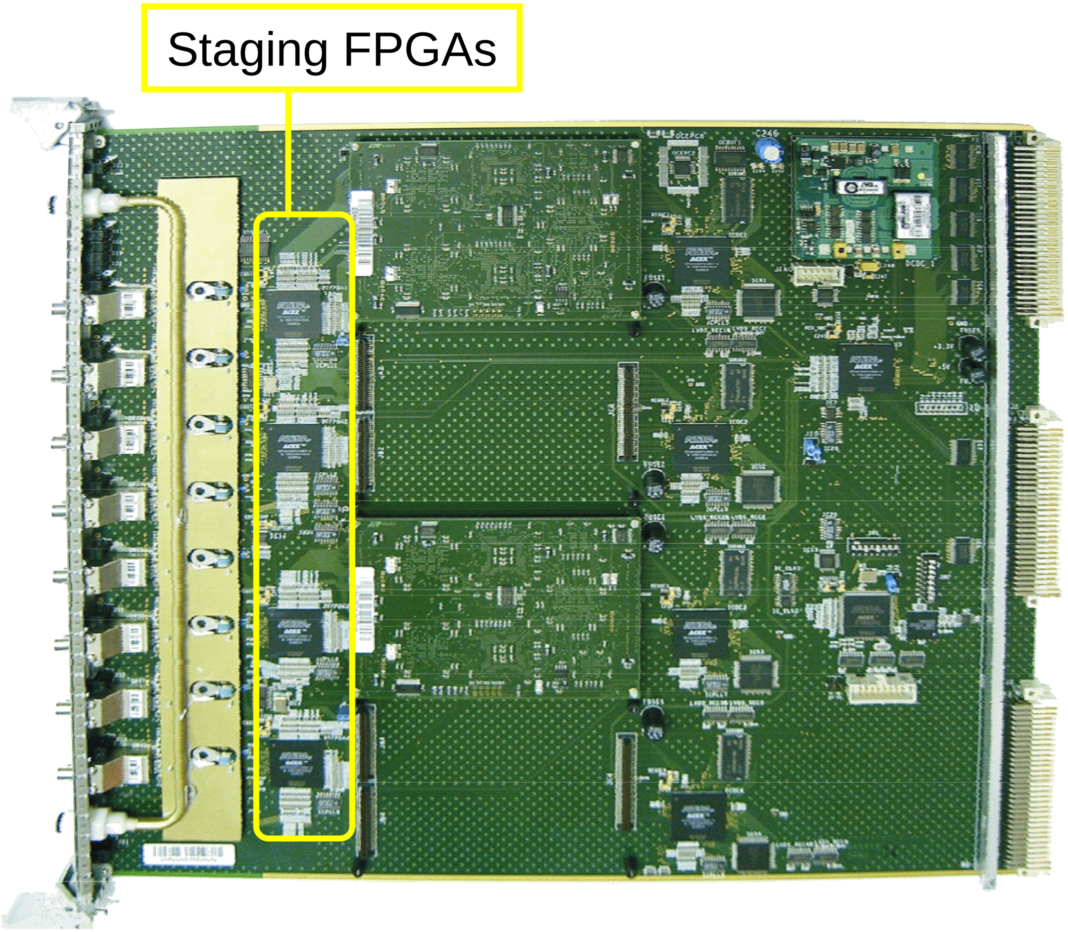

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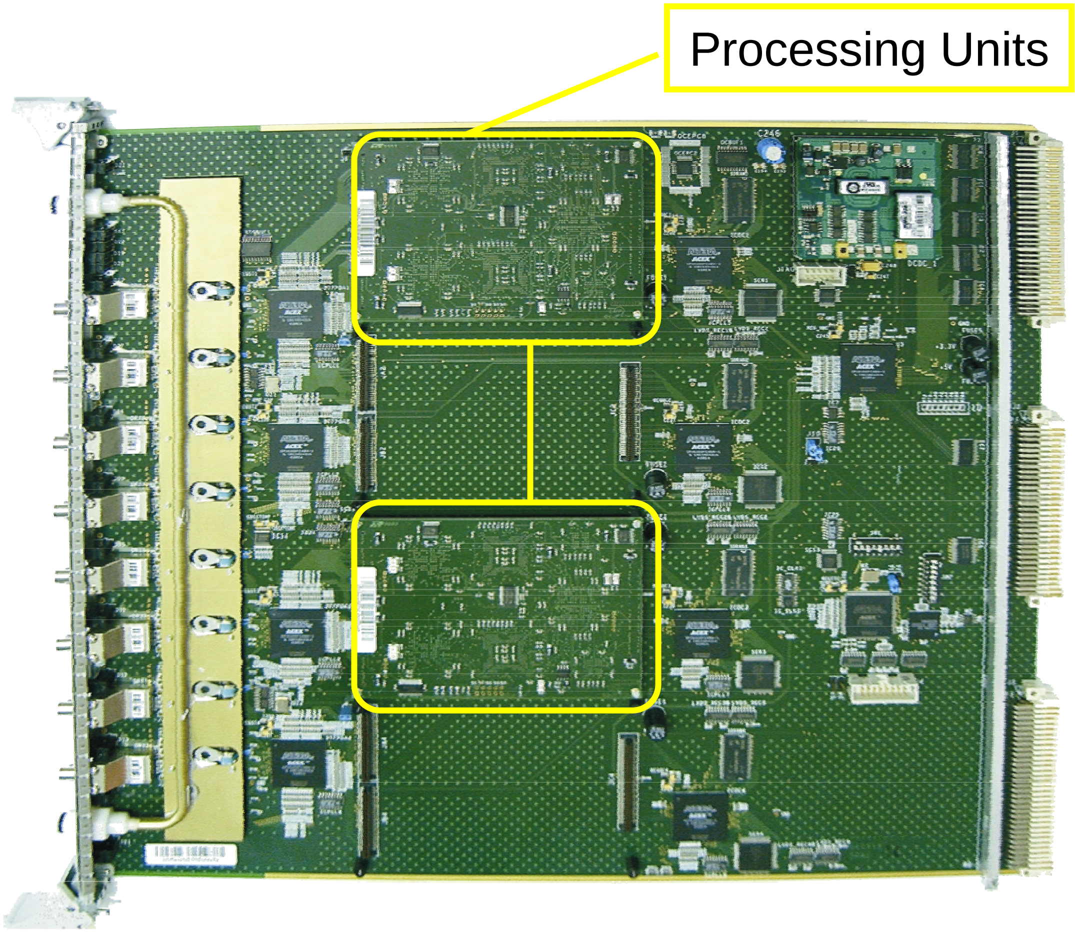

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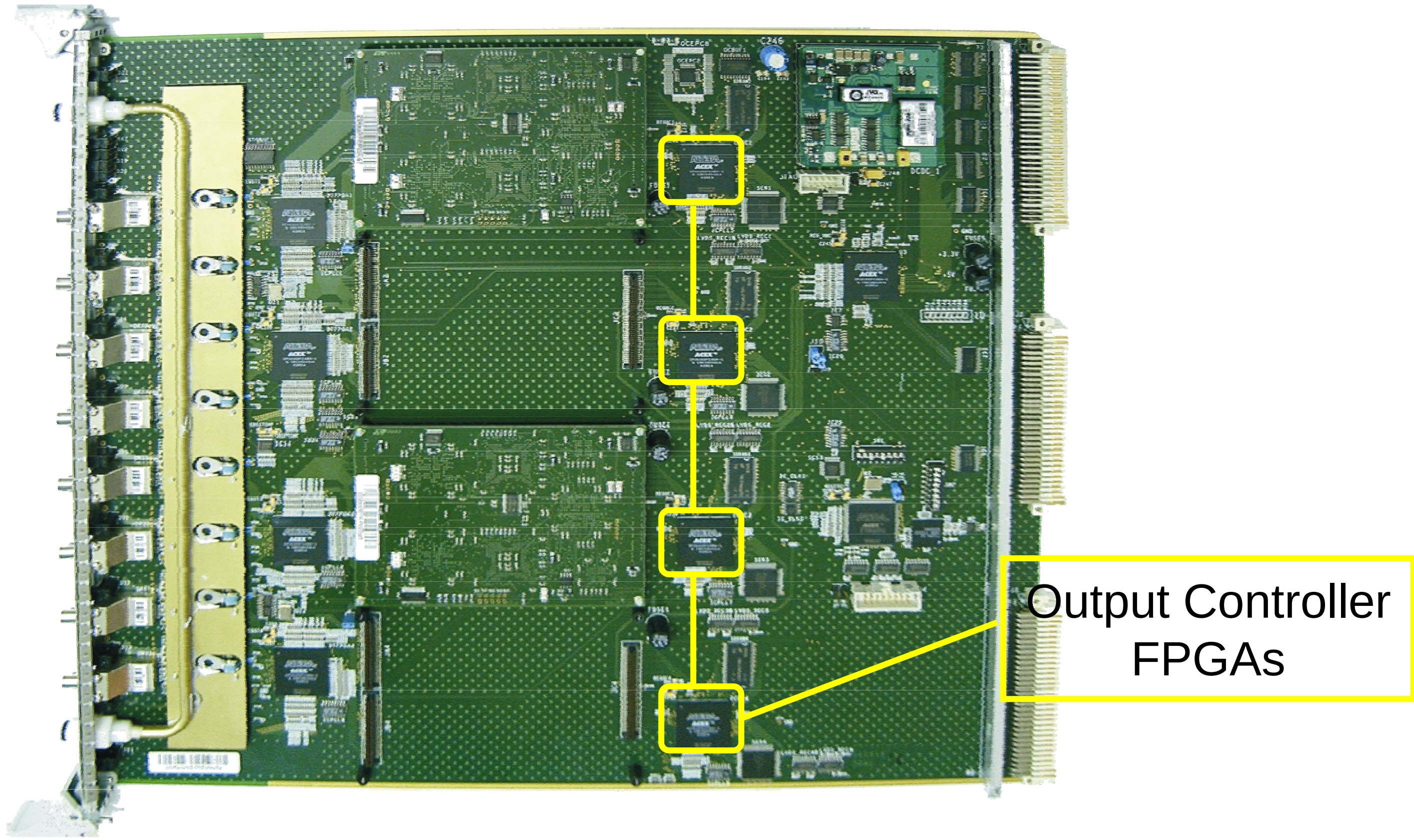

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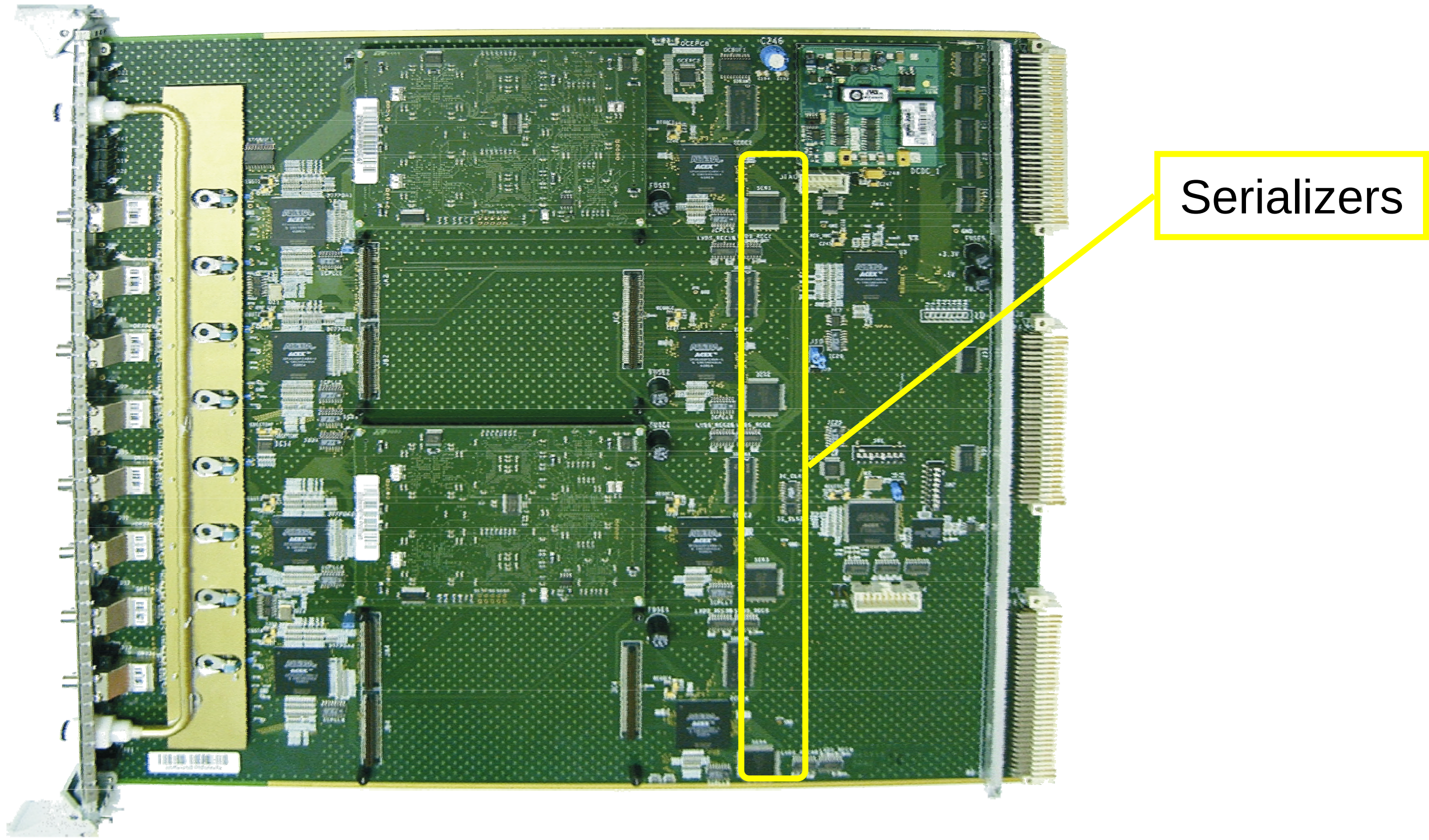

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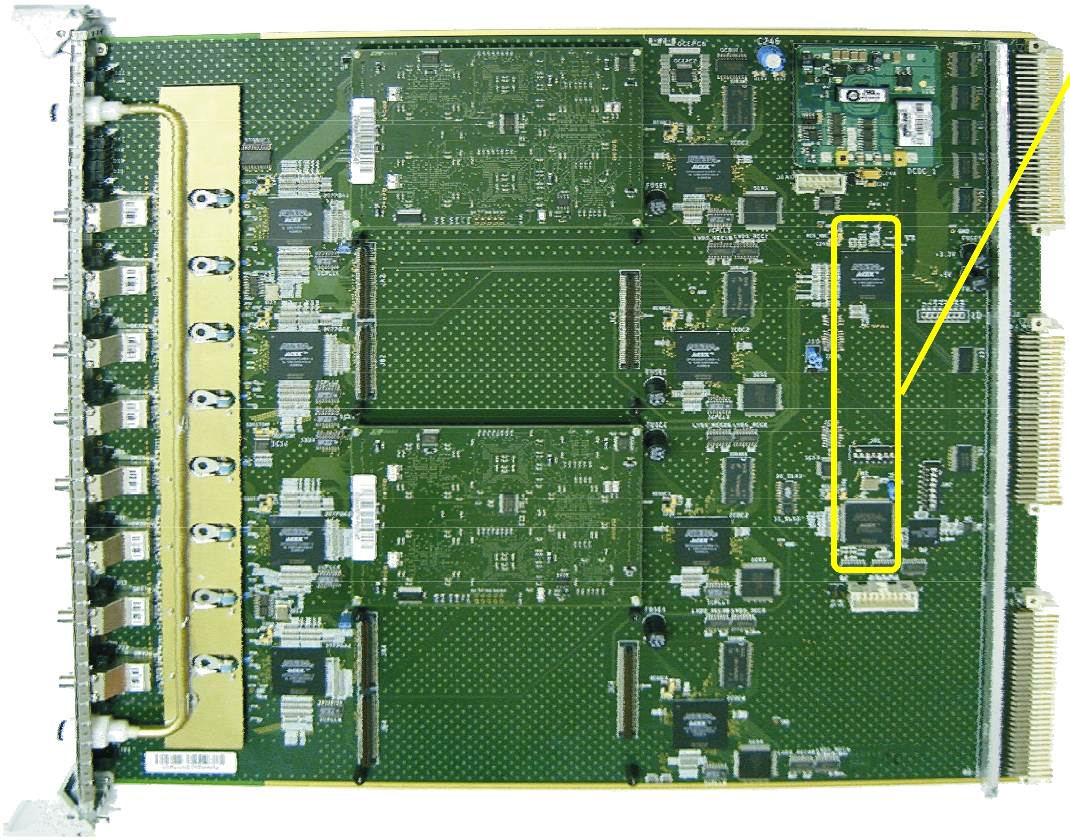
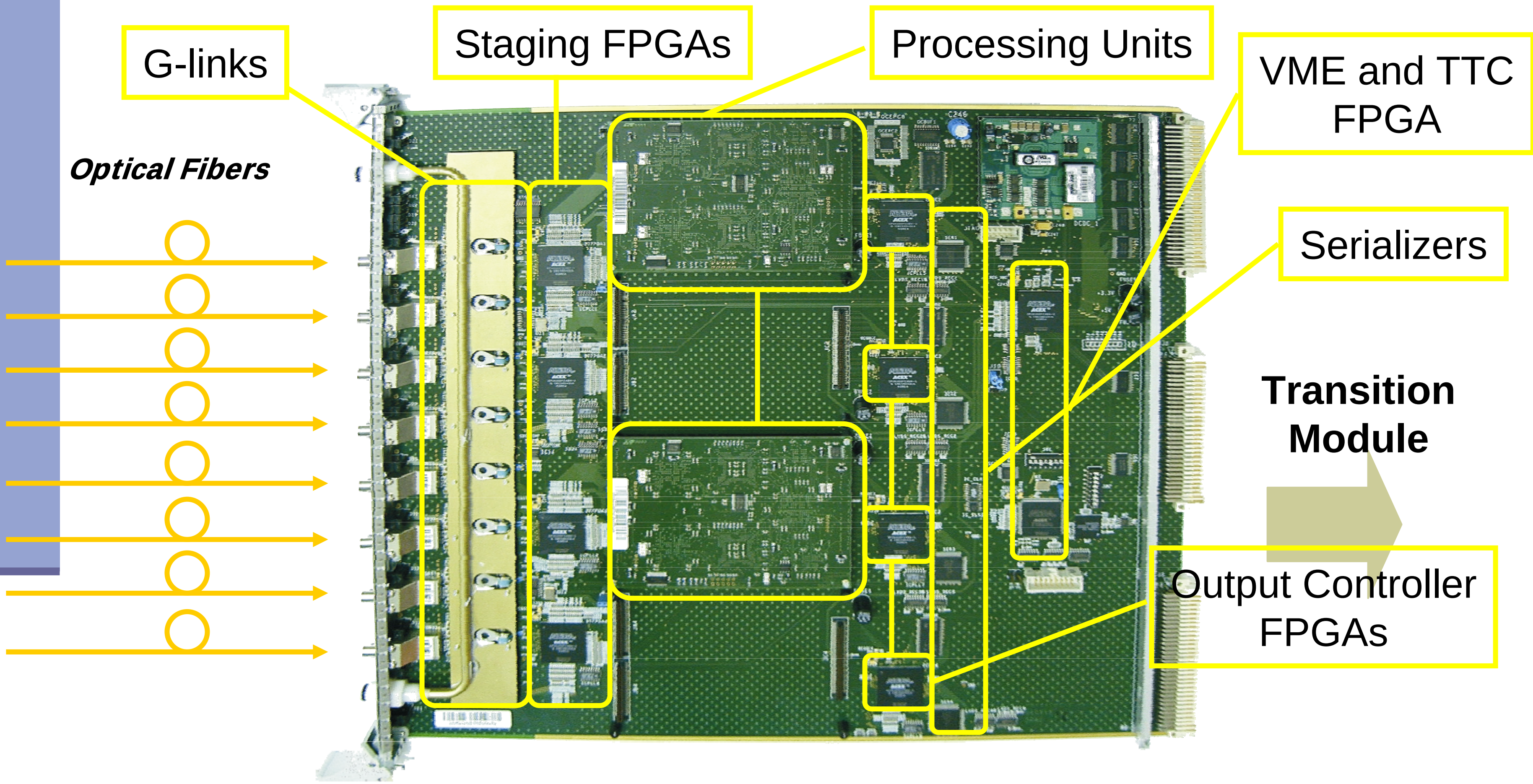


VME and TTC FPGA

Read Out Driver board



Processing Units: DSP

- Eight functional units:
  - 2 multipliers
  - 6 arithmetic and logical units
- 8/16/32-bit data support
- 40-bit arithmetic options
- Clock cycle of 720 MHz
- Memory: 1056 Kbytes
  - 32 Kbytes cache
  - 1024 Kbytes RAM
- Real time fixed-point processor

TMS360C6414xTM Texas Instruments

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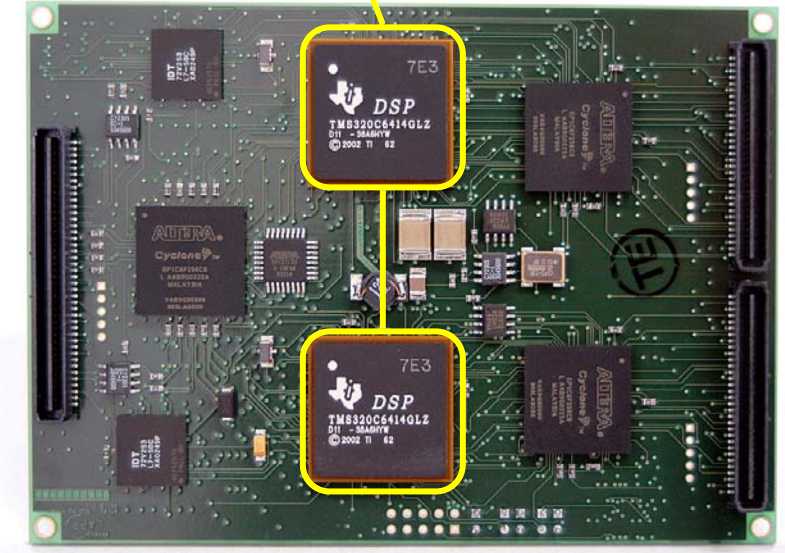
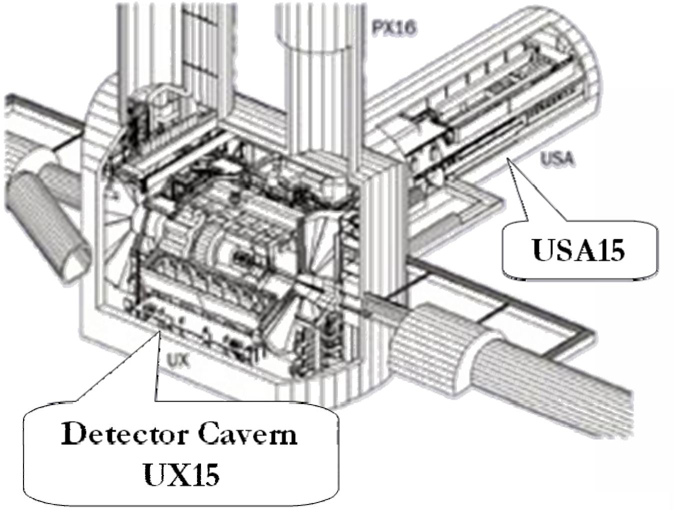
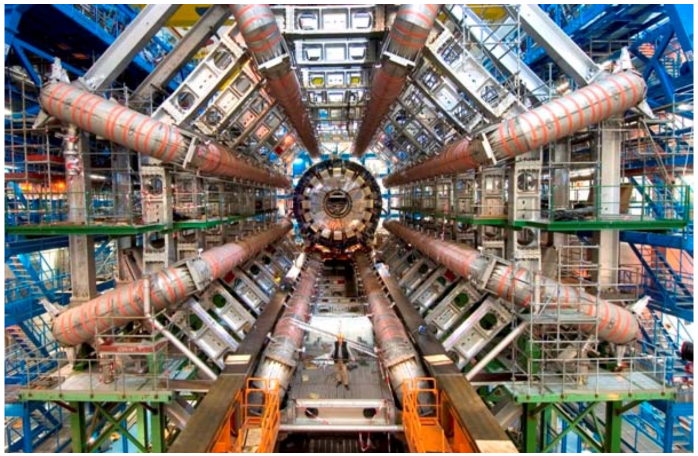
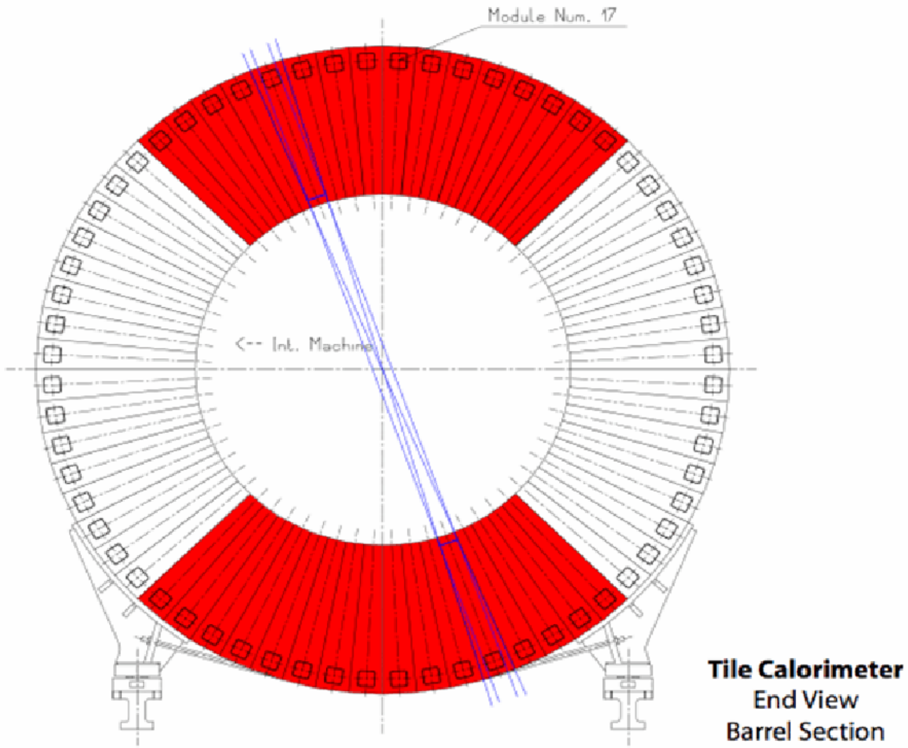


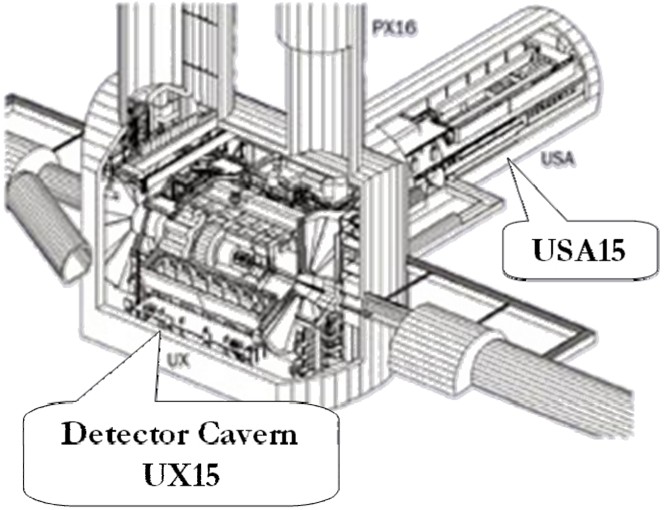
TileCal commissioning setup

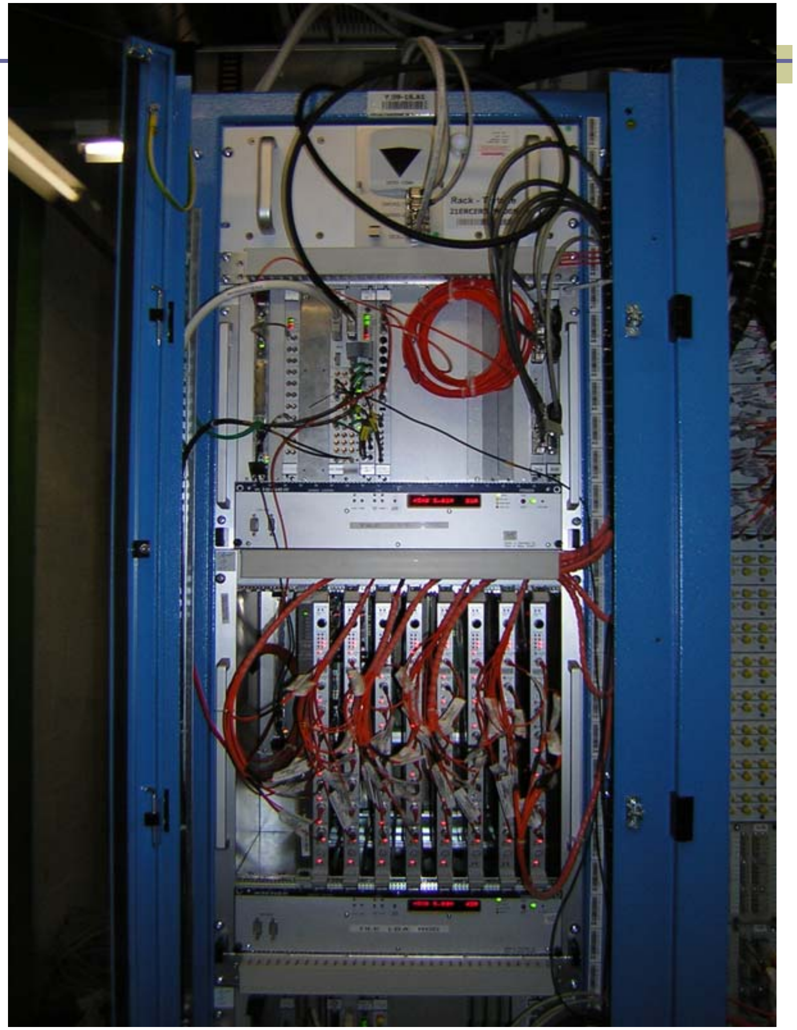






TileCal commissioning read out





Reconstruction Algorithms

- Requirements:
  - Send reconstructed information to the 2nd level trigger
  - Work in real-time at 1st level trigger rate
    - LHC rate: 100 kHz
    - First years rate: ~50 kHz
    - Commissioning rate (during July-August 2006): ~1Hz

- Proposed algorithms:
  - Optimal Filtering:

    Reconstruction of the energy and arrival time of the particles
  - Muon Tag:

    Identification of low transverse momentum muons

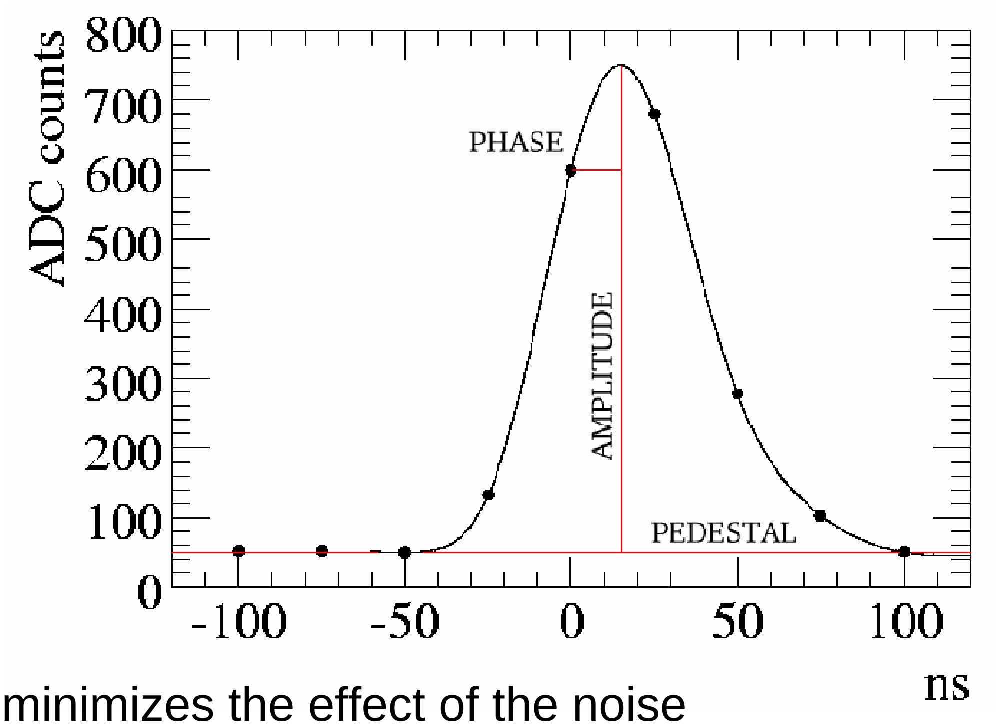
Optimal Filtering

AMPLITUDE

$$A = \sum_{i=1}^{n} a_i (S_i - p)$$

PHASE

$$\tau = \frac{1}{A} \sum_{i=1}^{n} b_i (S_i - p)$$



WEIGHTS

The process to calculate a, b, minimizes the effect of the noise in the amplitude and time reconstruction. But they are calculated assuming small phases.

Optimal Filtering

Configuration for LHC

AMPLITUDE

$$A = \sum_{i=1}^{n} a_i \left(S_i - p\right)$$

PHASE

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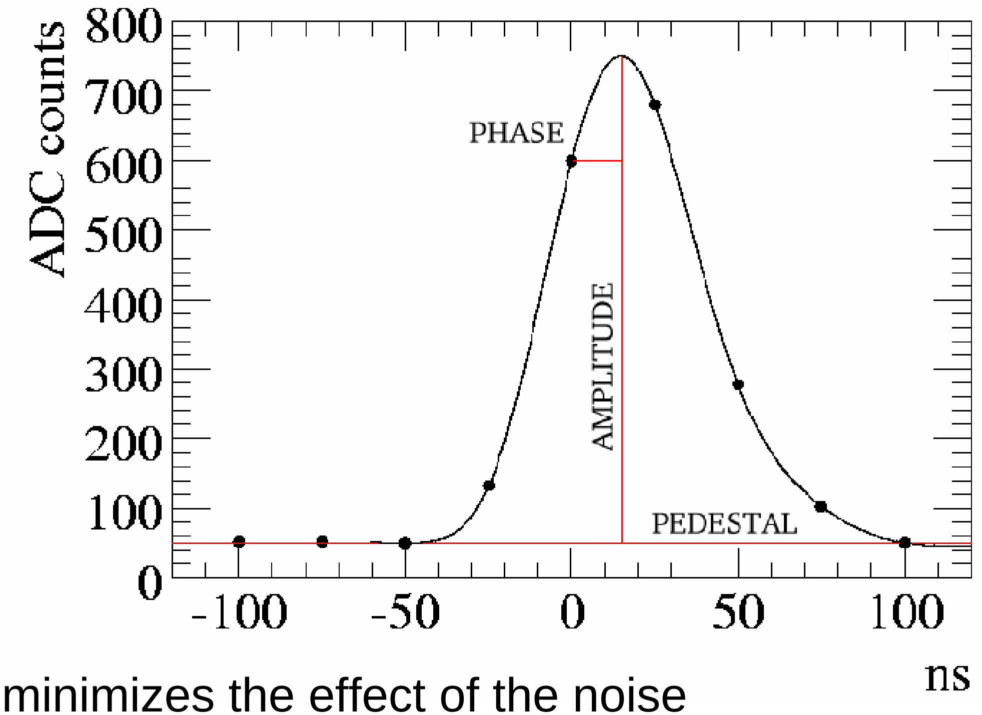

WEIGHTS

The process to calculate a, b, minimizes the effect of the noise in the amplitude and time reconstruction. But they are calculated assuming small phases.

Optimal Filtering with 1 iteration

Commissioning configuration

First iteration:

AMPLITUDE

$$A_1 = \sum_{i=1}^{n} a_i\Big|_{\tau=0} (S_i - p)$$

PHASE

$$\tau_1 = \frac{1}{A_1} \sum_{i=1}^{n} b_i\Big|_{\tau=0} (S_i - p)$$

Second Iteration:

AMPLITUDE

$$A_2 = \sum_{i=1}^{n} a_i\Big|_{\tau=\tau_1} (S_i - p)$$

PHASE

$$\tau_2 = \frac{1}{A_2} \sum_{i=1}^{n} b_i\Big|_{\tau=\tau_2} (S_i - p)$$

Optimal Filtering with 1 iteration

Commissioning configuration

First iteration:

AMPLITUDE

$$A_1 = \sum_{i=1}^{n} a_i\big|_{\tau=0} (S_i - p)$$

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$$\tau_1 = \frac{1}{A_1} \sum_{i=1}^{n} b_i\big|_{\tau=0} (S_i - p)$$

Second Iteration:

AMPLITUDE

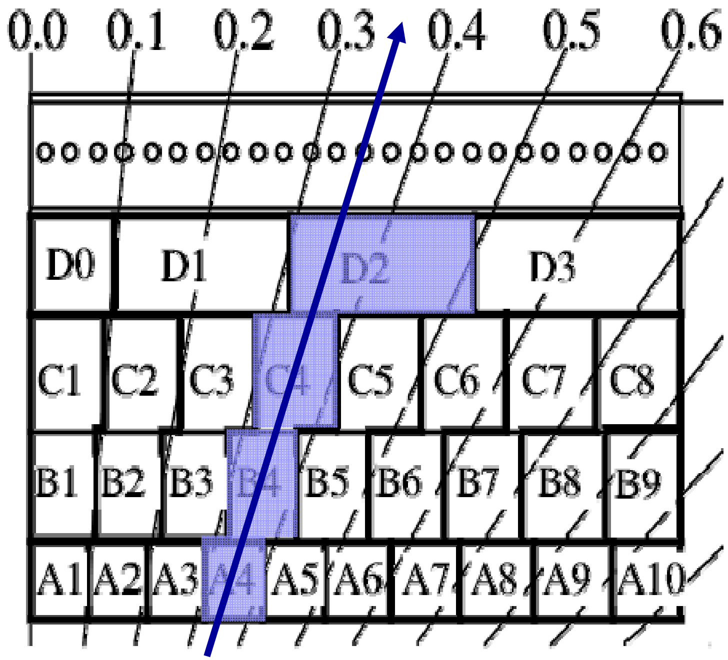
$$A_2 = \sum_{i=1}^{n} a_i\big|_{\tau=\tau_1} (S_i - p)$$

PHASE

$$\tau_2 = \frac{1}{A_2} \sum_{i=1}^{n} b_i\big|_{\tau=\tau_2} (S_i - p)$$

Muon Tag

1. Look into cells D → Possible muon
2. Look into cells BC, following η → Possible muon
3. Look into cells A, following η → Muon identified

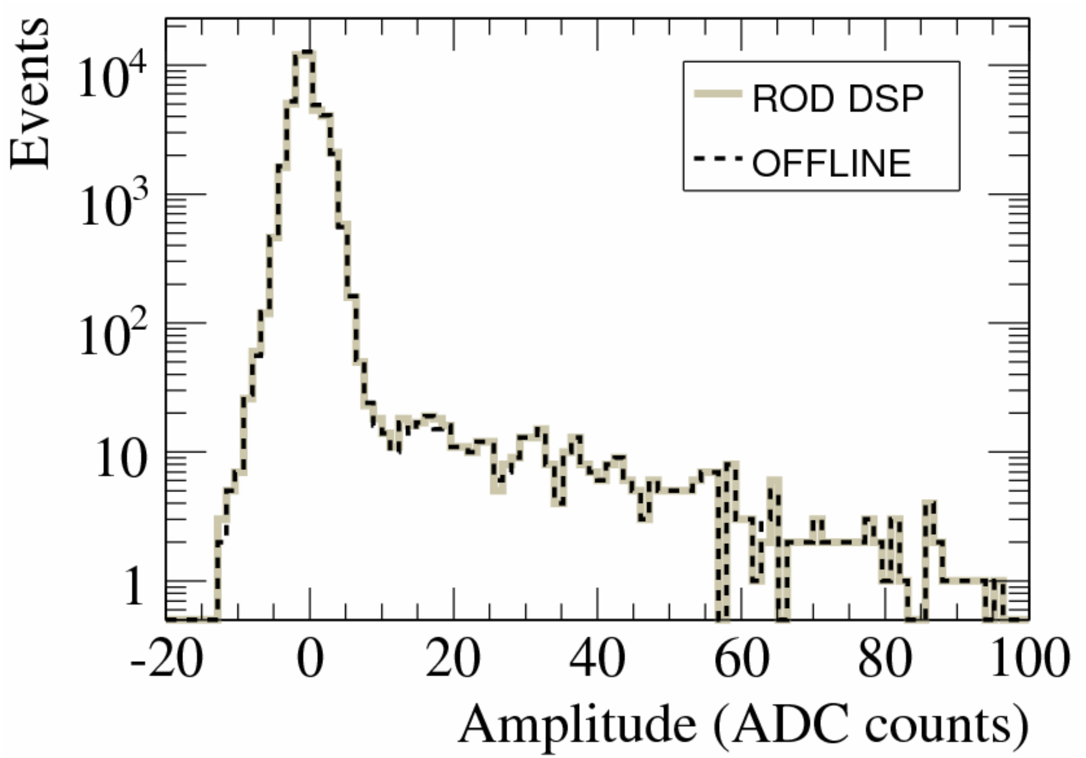


- Deposited energy in the cell i should verify:

  $$Thr_{low} < E_i < Thr_{high}$$

- High threshold: Cut for jets
- Low threshold: Cut for noise and minimum bias

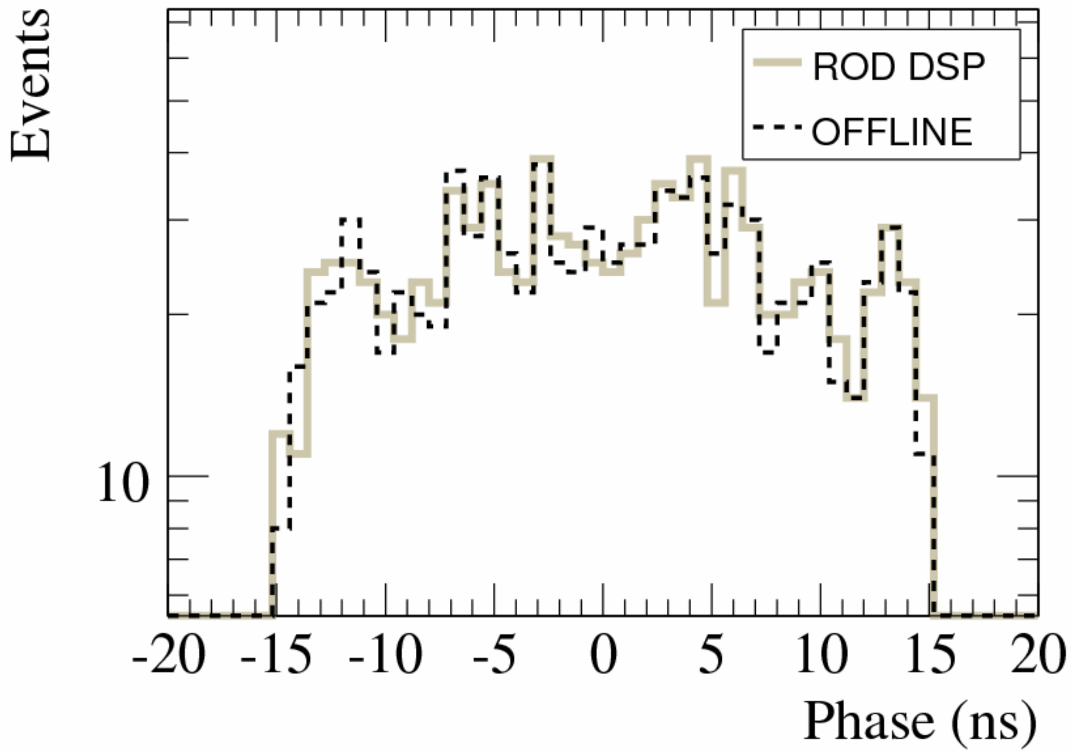
Results: Optimal Filtering



Amplitude (energy) reconstruction of cosmic muons

For E > 3σ of the noise differences < 1%

Results: Optimal Filtering

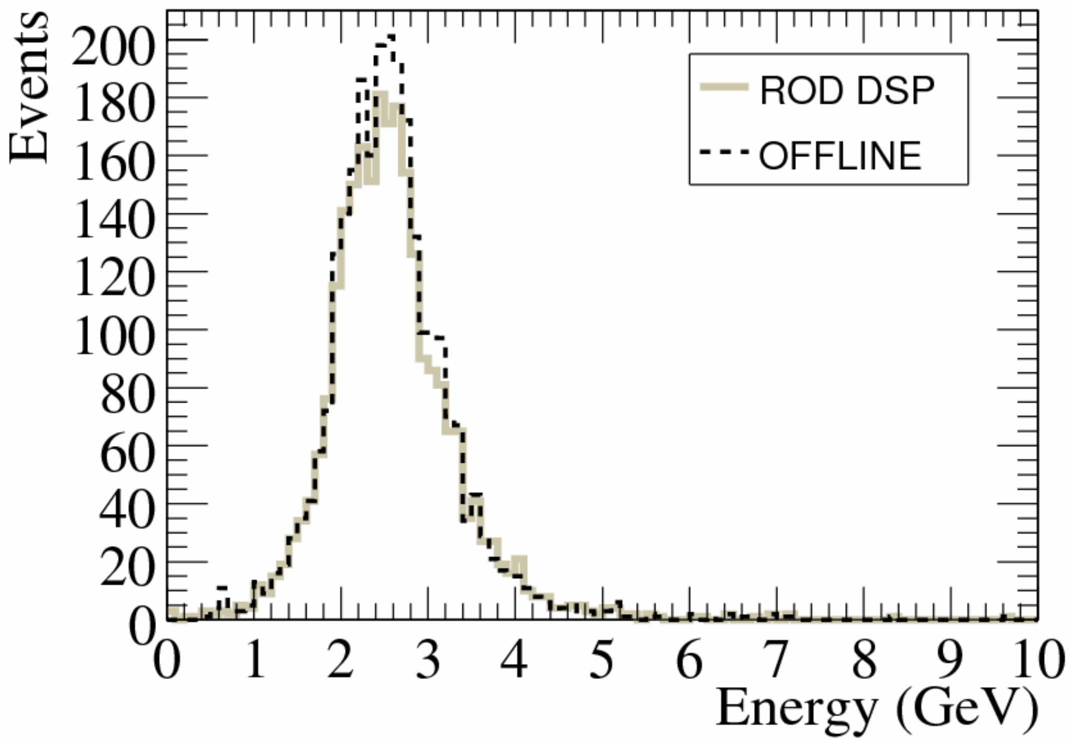


Phase interval [-15,15] ns

Phase differences ~5%

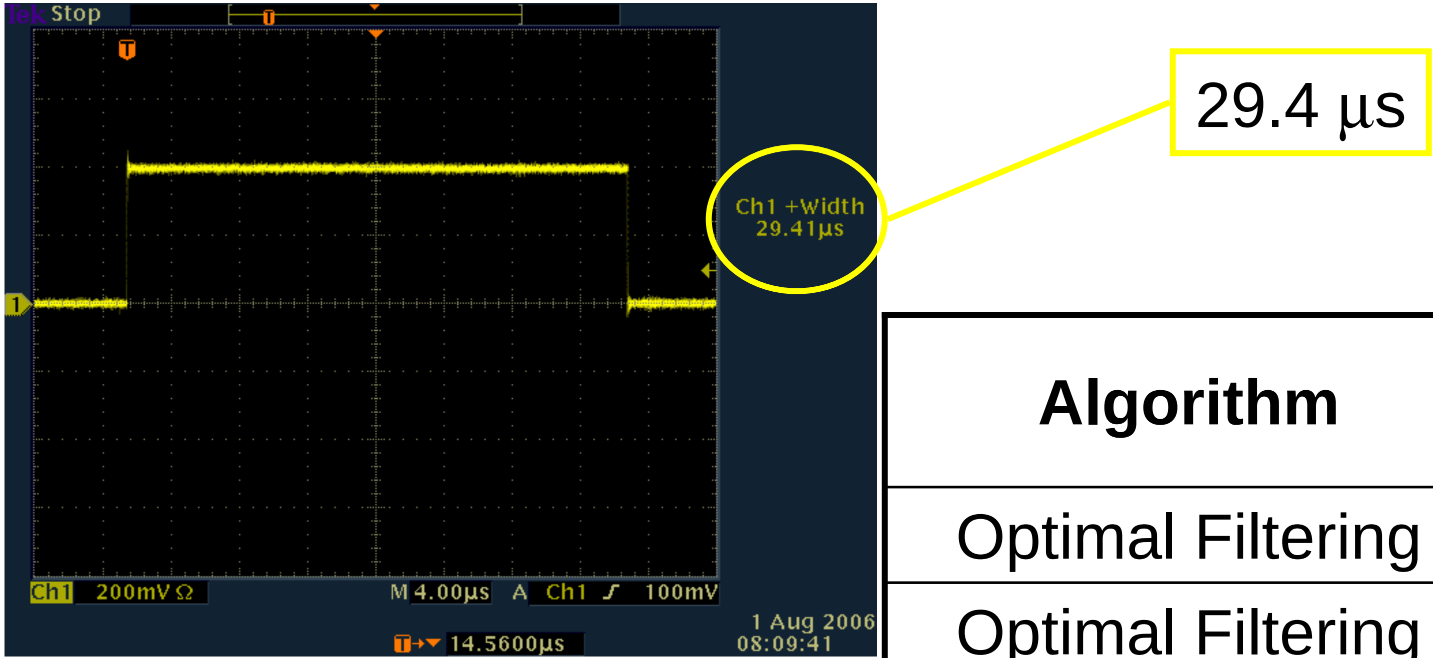
$$\tau_2 = \frac{1}{A_2} \sum_{i=1}^{n} b_i \Big|_{\tau=\tau_2} (S_i - p)$$

Results: Muon Tag



85% of offline tagged muons are tagged online

Result: Processing Time



Algorithm	Time (µs)
Optimal Filtering	27.1
Optimal Filtering and Muon Tag	29.4

Conclusions

- Optimal Filtering and Muon Tag algorithms were running during TileCal commissioning July and August 2006
- Optimal Filtering:
  - Amplitude accuracy > 99% for $E>3\sigma$
  - Phase accuracy around 95% for $E>3\sigma$
- Muon Tag:
  - 85% of coincidence offline/online
- Processing time:
  - Opt. Filt and Muon Tag: 29.4 μs
  - Fulfills TileCal commissioning requirements
  - Improvements on the time are expected in the change to assembler