Time Calibration of the ATLAS Tile Calorimeter using an Integrated Laser System

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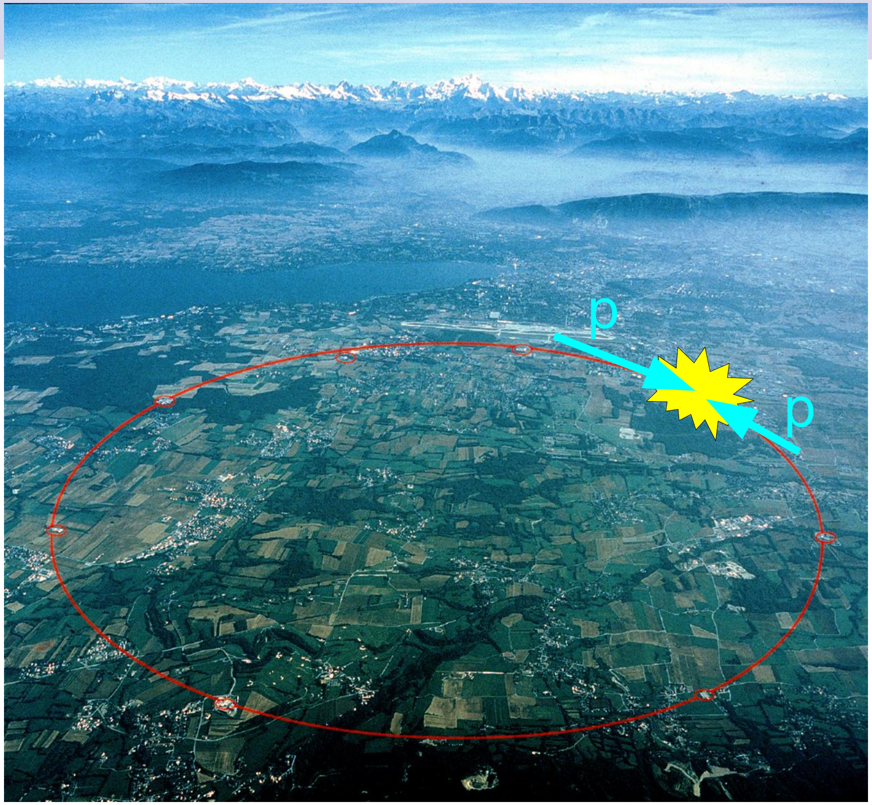
(on behalf of the ATLAS Tile Calorimeter Collaboration)

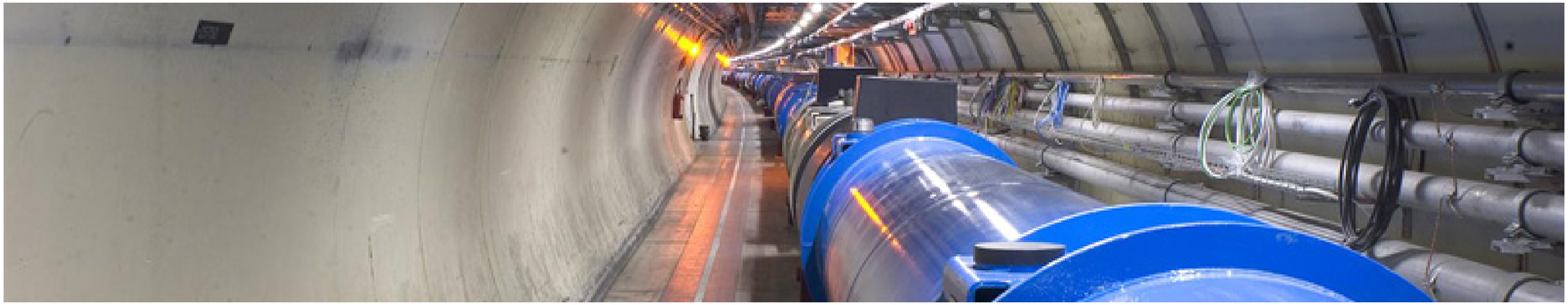
CHEP 2009 – online computing

For further info: ATL-TILECAL-PUB-2009-003

The Large Hadron Collider



Proton-proton (pp) collider	
Circumference	27 km
pp center of mass	14 TeV
Bunch crossing (BC) rate (collision every 25 ns)	40 MHz
Protons/bunch	1.15*10^11
Stored energy	360 MJ/beam
Dipole field	8.3 T



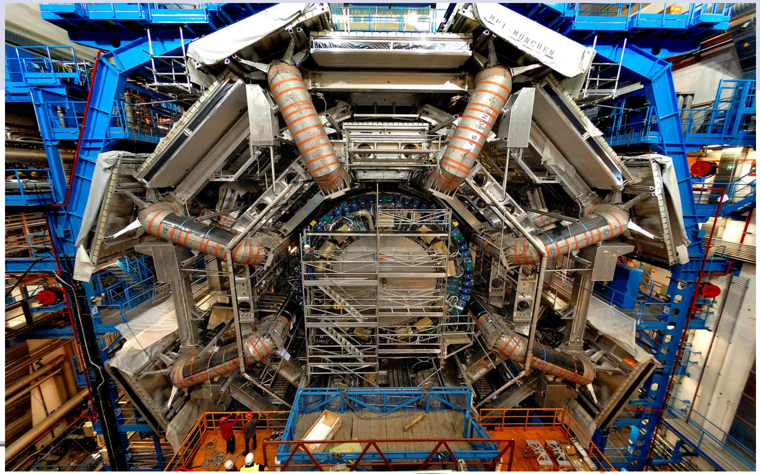
The ATLAS Detector

- The largest colliding beam experiment ever built.

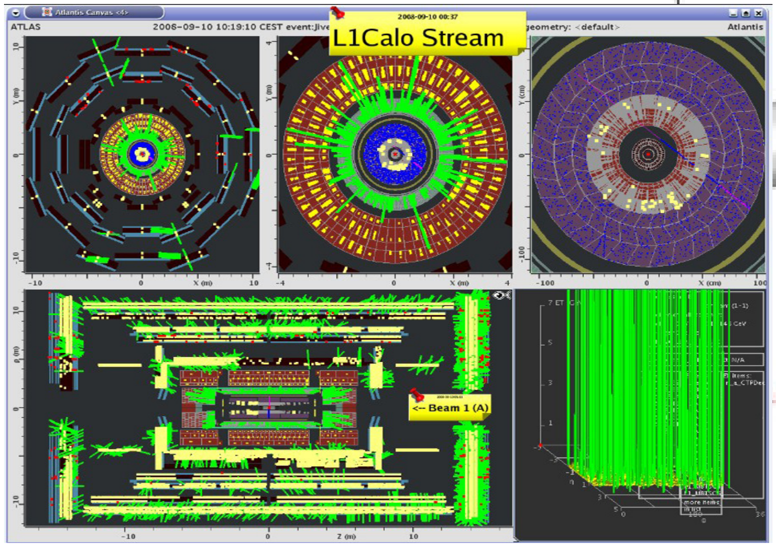
- Designed to search for the Higgs boson, SUSY and evidence for any new physics at the TeV scale.

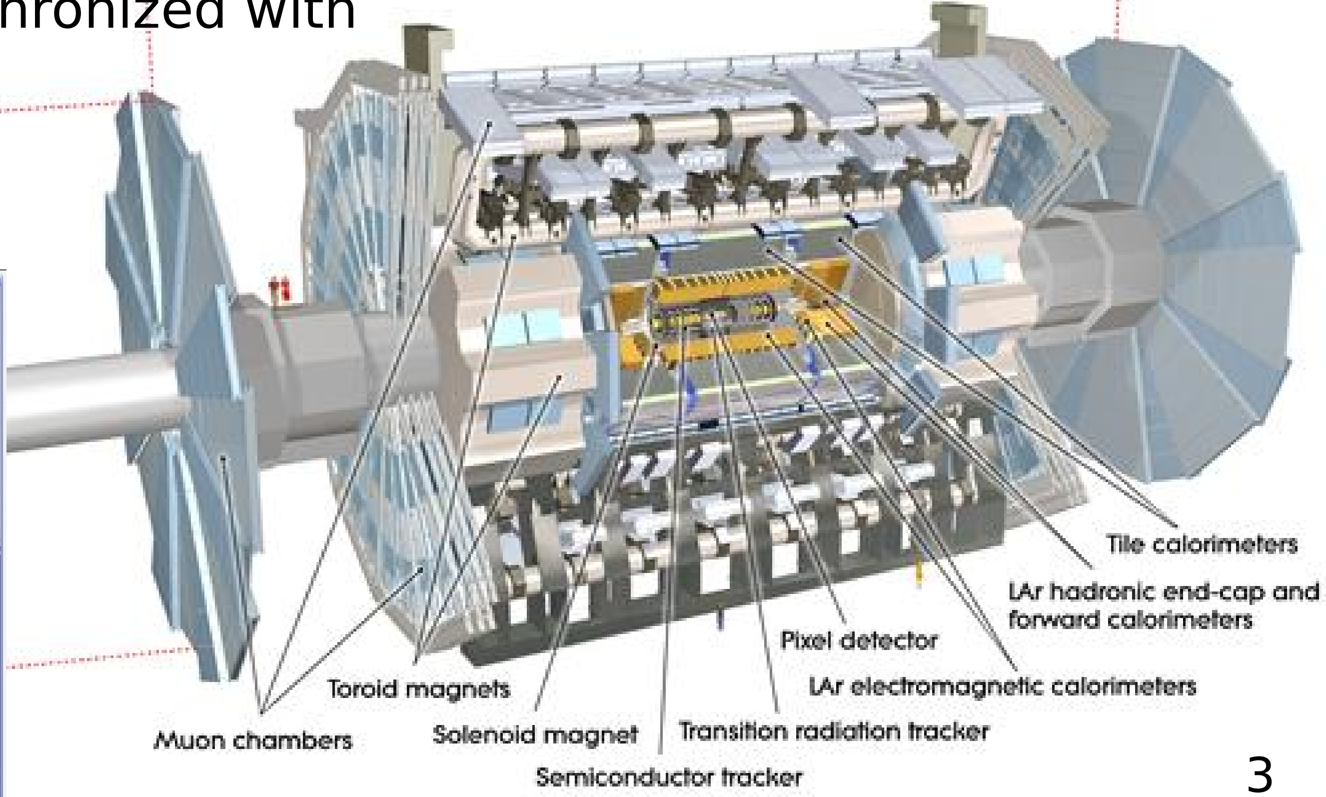
- Measures 44x25 m, weight: 7000 t.

- ATLAS electronics is synchronized with the same clock as the LHC

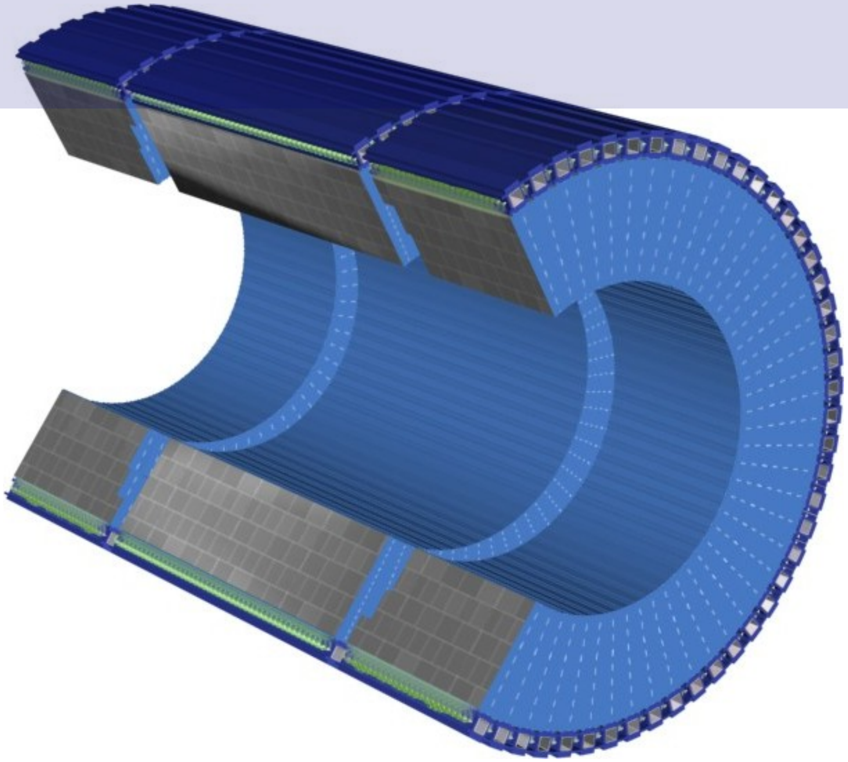


A beam-to-collimator event from first beam.





The Hadronic Tile Calorimeter



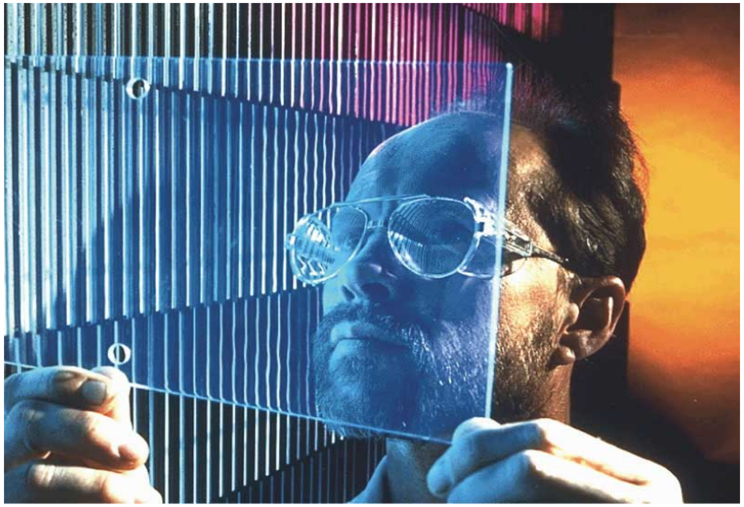
- 256 azimuthally oriented wedge shaped modules, 4 sections.

- Tiles of plastic scintillators (down left picture) and iron absorbers.

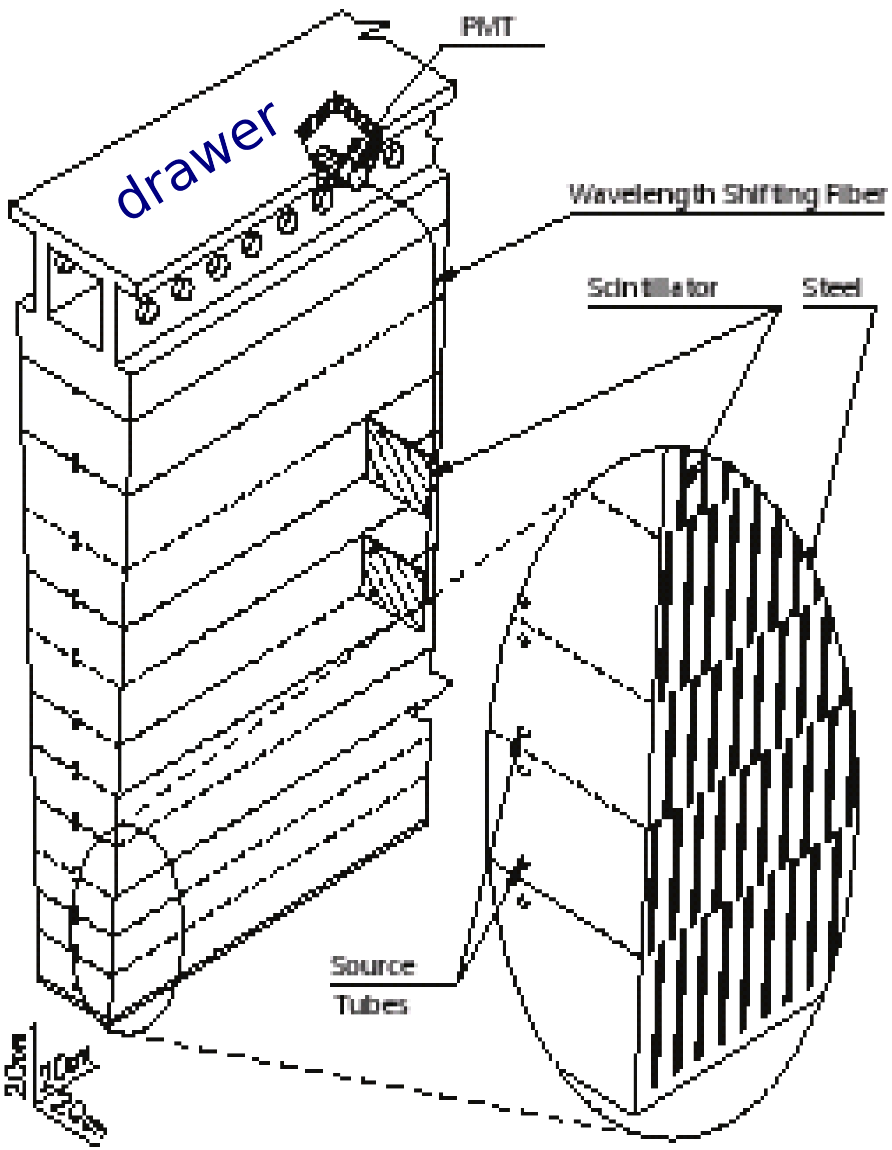
- 10,000 PMT:s measuring the light.

- Designed to measure energy of hadrons and jets and to contribute to measurements of E_T^{miss}.

- An important part of the ATLAS trigger system.

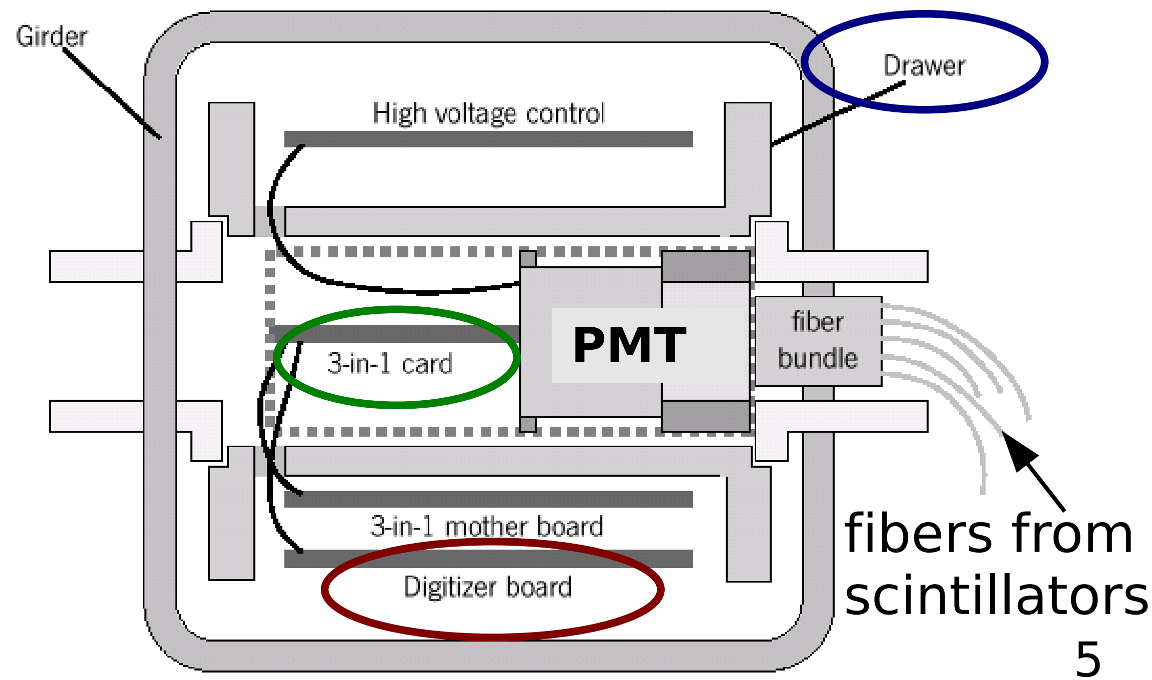


Optics and Electronics

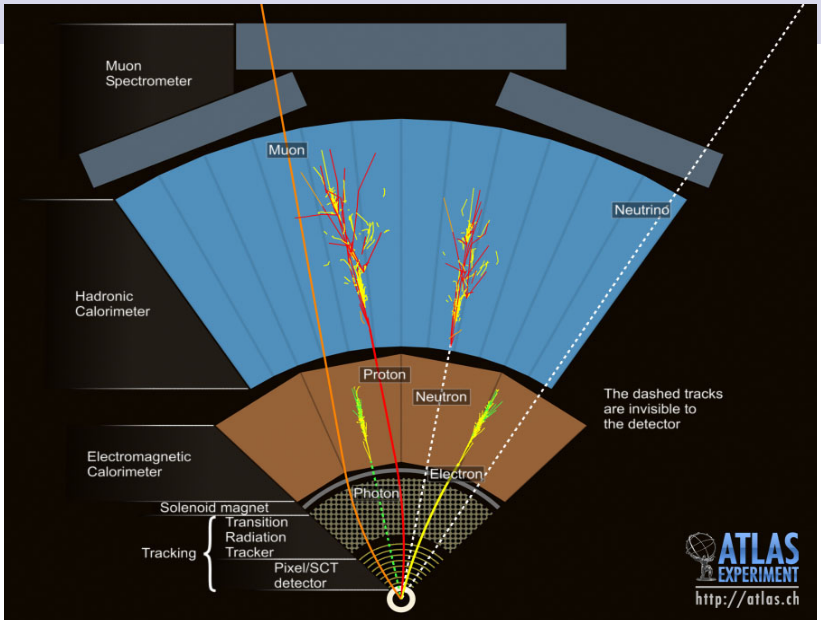


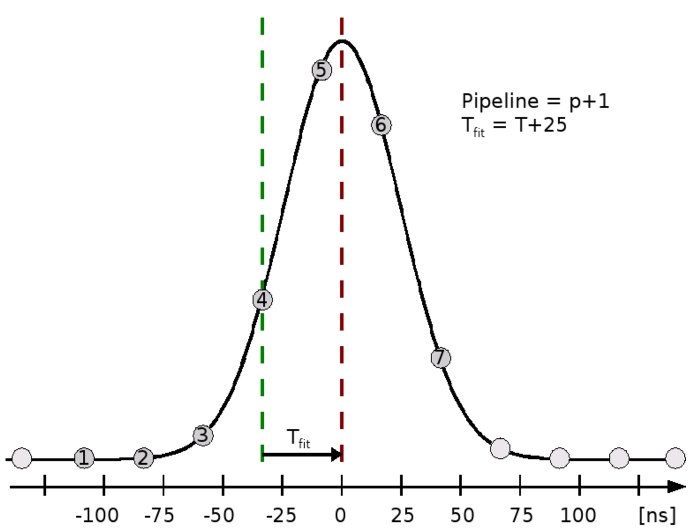
- Scintillating light is collected by Wavelength Shifting Fibers and distributed to PMT:s located inside a "drawer" at the back of the module.

- The PMT signals are:
    - shaped and amplified by the 3-in-1 card.
    - digitized and locally buffered by the digitizer board.



Motivation for TileCal Timing





Coarse timing:
- An event occurs potentially every 25 ns. Data are locally buffered. Decision to keep an event (Trigger Accept) arrives ~2.5 μs (100 BC:s) later. Need to set the local memory such that exactly the data from the time of the event are read out.

Fine timing:
- Optimal energy reconstruction of hadrons and jets and ToF measurements of muons and possible meta-stable particles requires:

1) sampling of PMT signals close to the peak

2) excellent time resolution

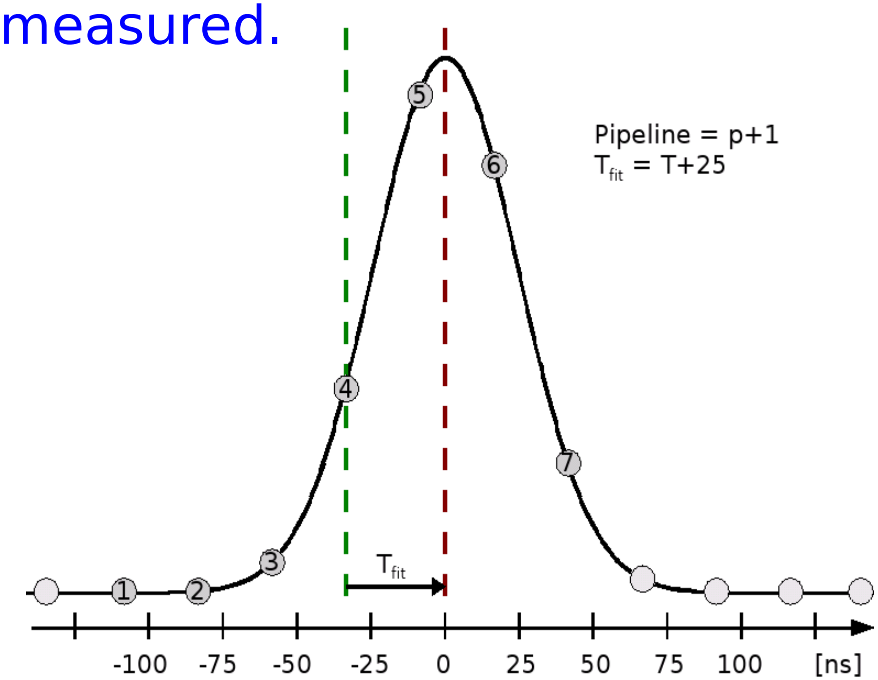
3) precise knowledge of the residual channel-to-channel phase after calibration. Precision of < 1 ns is required.

Pulse Reconstruction

- The PMT signals is sampled every 25 ns

- A fit to the function $f(t) = Ag(t - \tau) + c$ is performed using 7 consecutive samples

- The 4:th sample should be as close to the signal peak as possible. The residual phase must be measured.



- Tfit is the parameter measuring the time between pulse maximum and the 4:th sample

Tfit > 0 $\Longleftrightarrow$ the signal is sampled to early

Tfit < 0 $\Longleftrightarrow$ the signal is sampled to late

- Time of the sample is controlled by the “Sampling Clock”

- Which sample are called “1”, is controlled by the “pipeline memory” setting

- The front-end electronics retrieves the sample clock and pipeline settings from a run configuration data base before the start of each data taking

Signal Paths Causes Delays

- ATLAS Timing, Trigger & Control (TTC) system distribute the system clock to the digitizer boards.

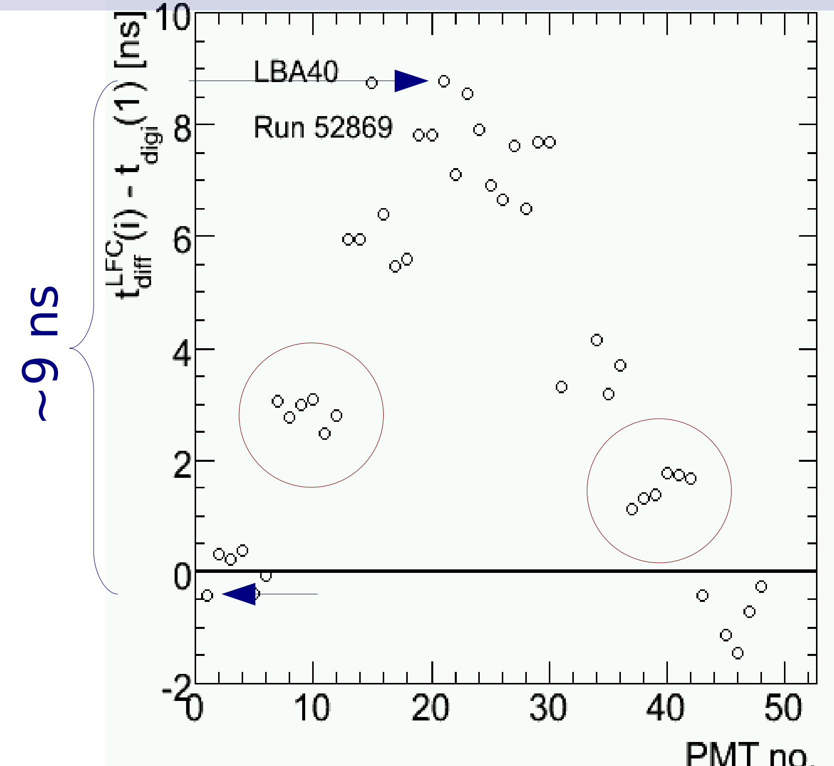
- Propagation of the clock signal take longer time to the outer boards.

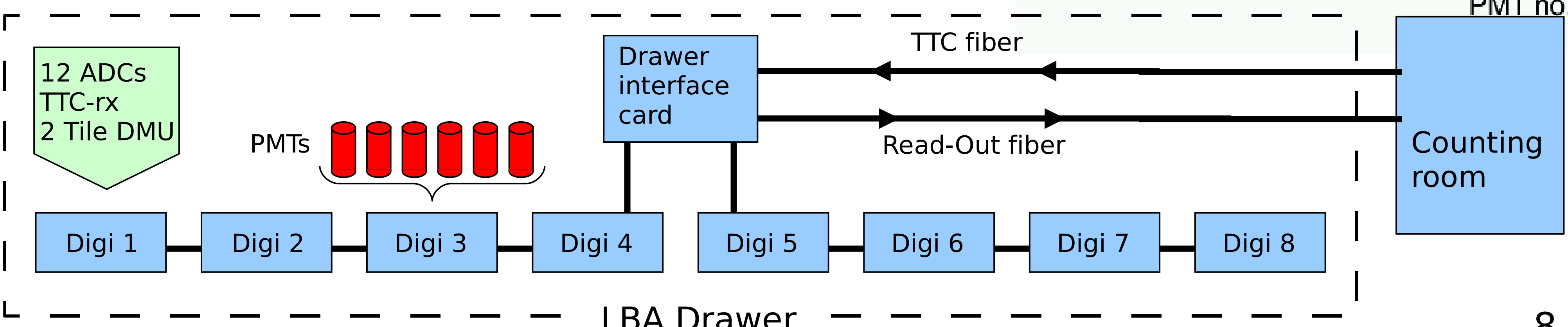
- Looks like a 9 ns difference b/w PMT no. 1 and PMT no 22.

- Delay the sampling clock of PMT 22 by 9 ns w.r.t. system clock to equalize.

- This can only be done per digitizer --> a six-channel granularity

Measured pulse times for simultaneous injected pulses





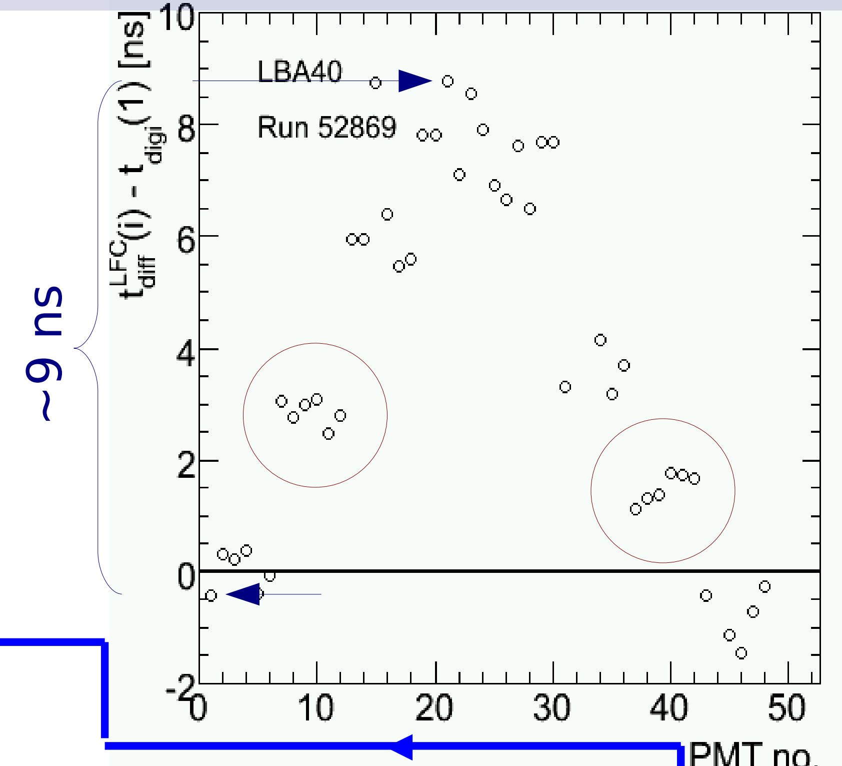
The Laser System

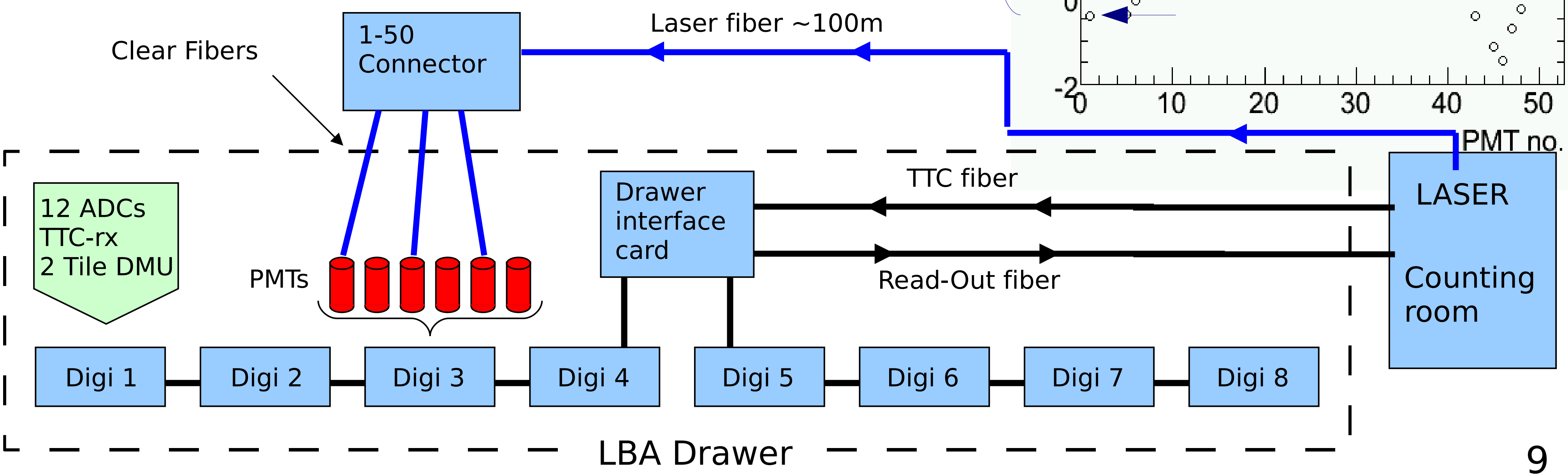
- The laser sends simultaneous light pulses into each PMT.

- Analyze the response and compute timing corrections.

- Store corrections in <u>run config database</u> and use to configure the electronics before each calorimeter data taking.

Measured pulse times for simultaneous injected pulses





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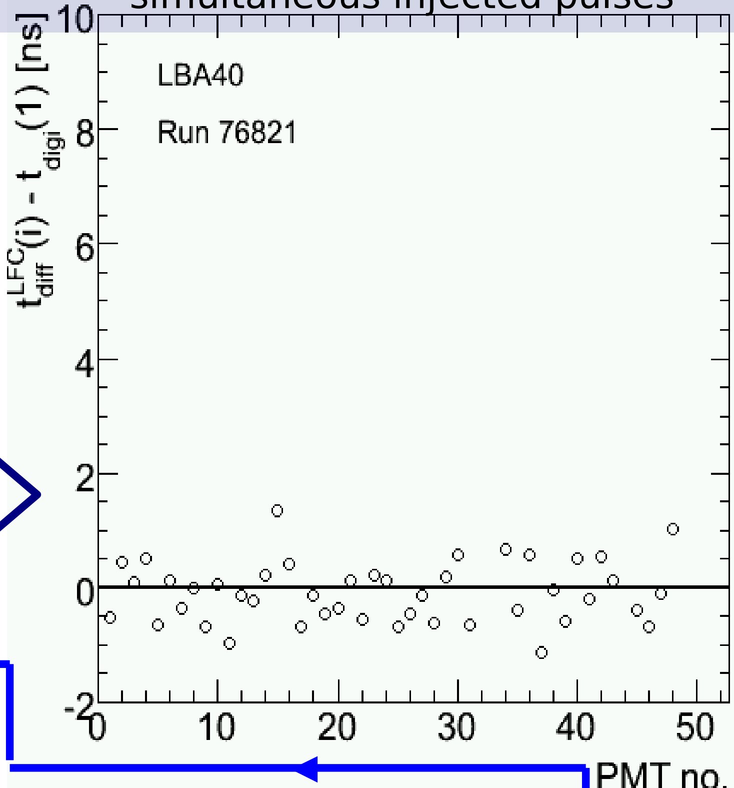
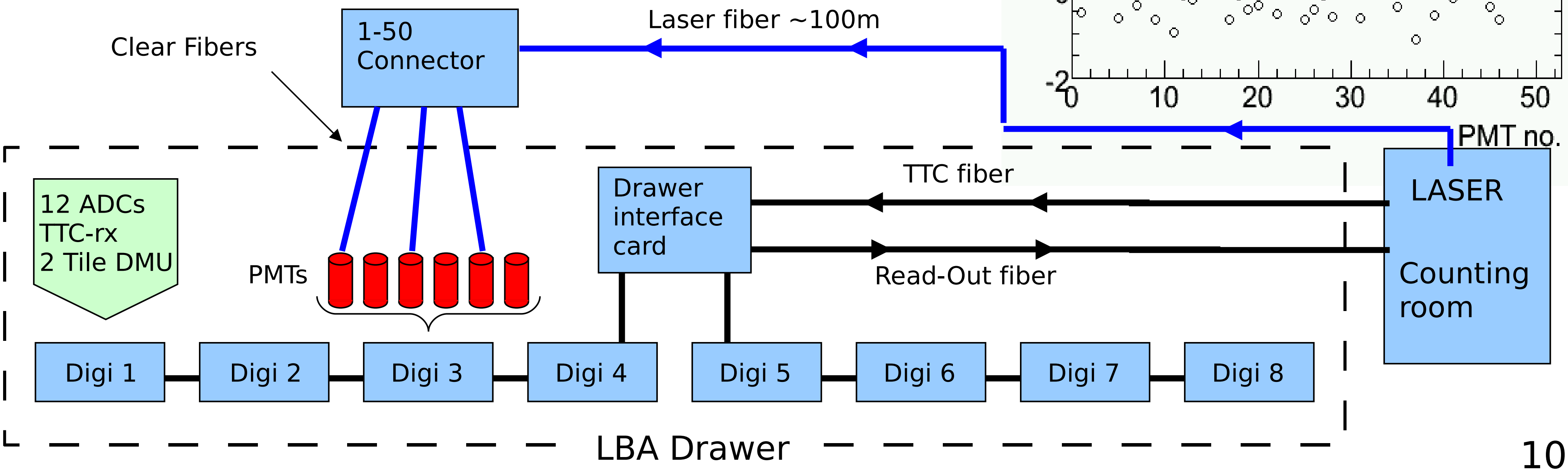




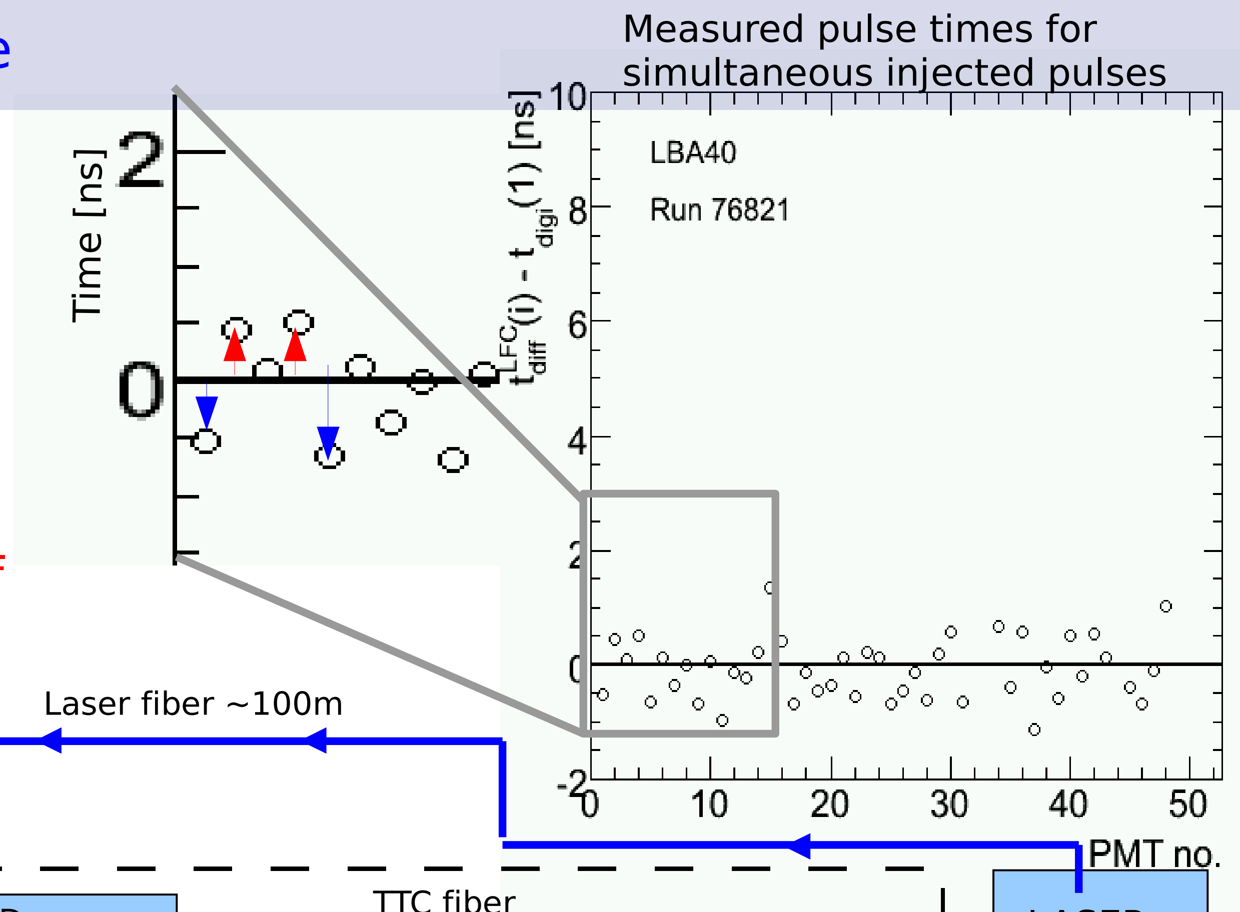
The Laser System

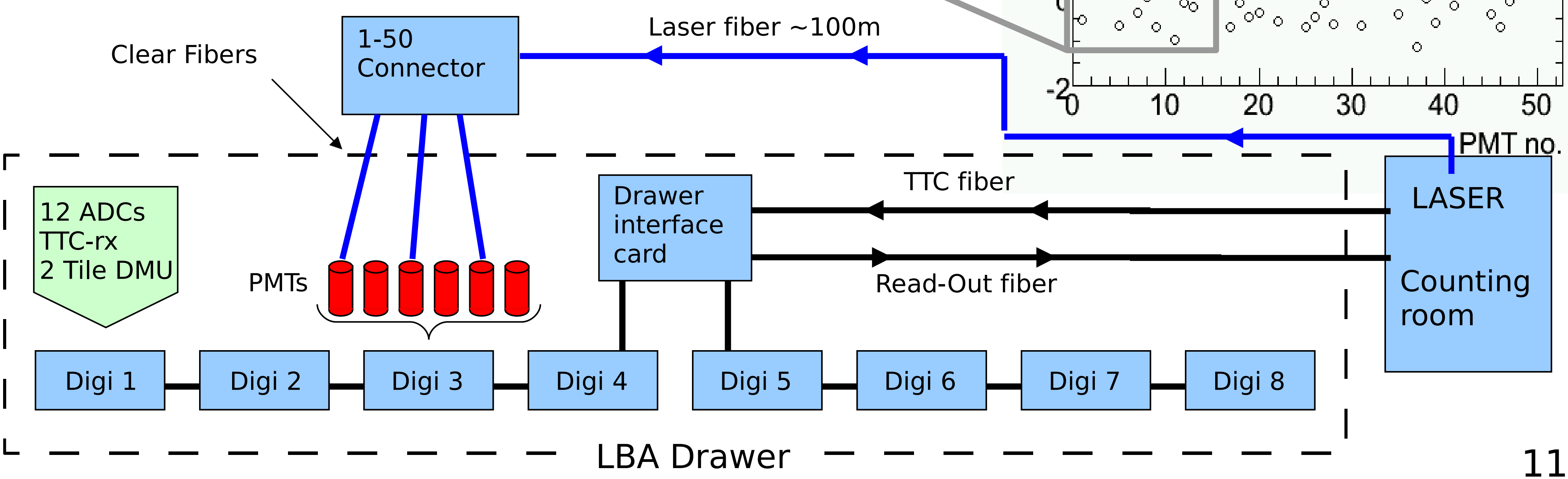
- Remains to determine the residual channel phase.

- Residual phase stored in <u>conditions database</u> and used as

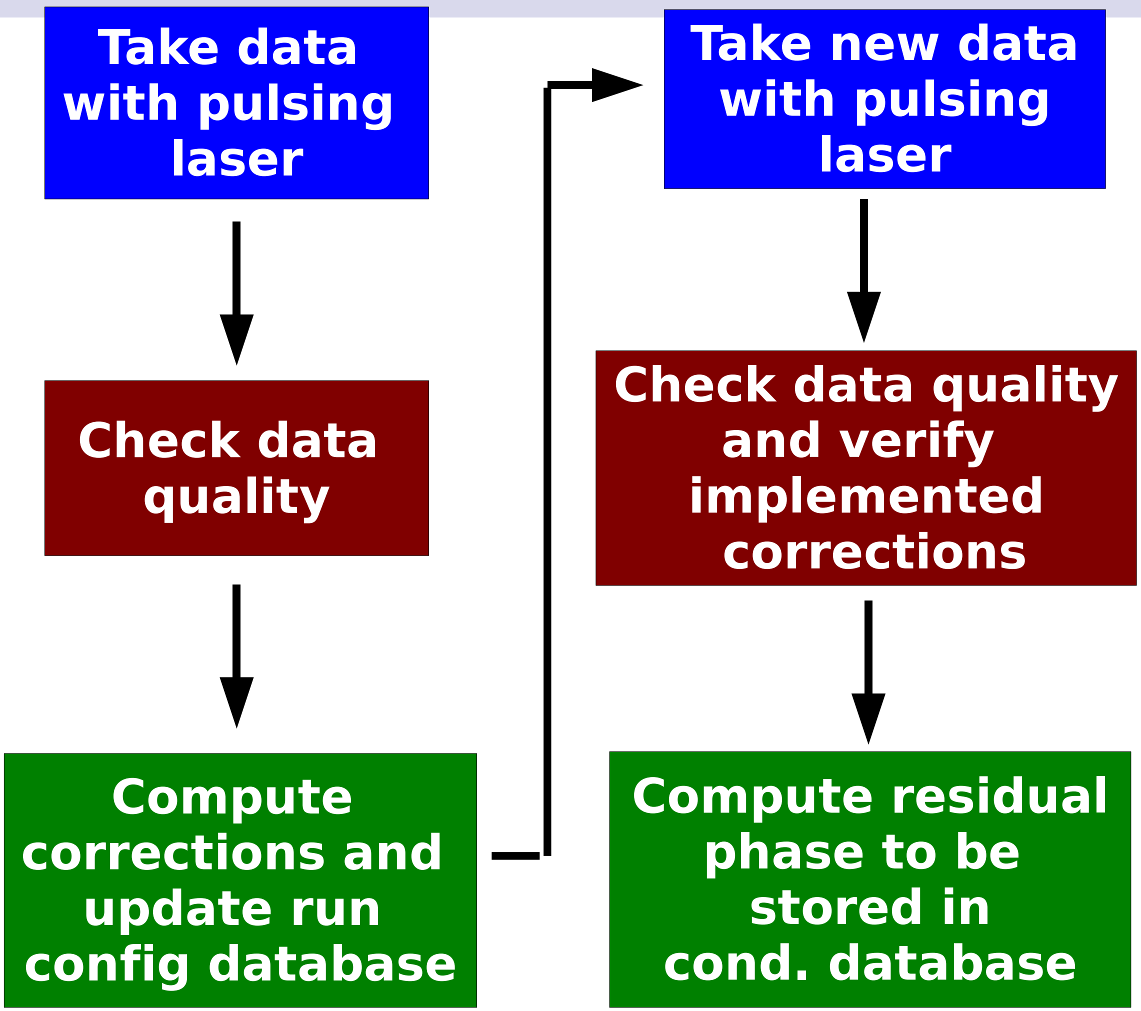
1) input for energy reconstruction algorithm

2) final offline correction of event timing information.





Laser Timing Work Flow

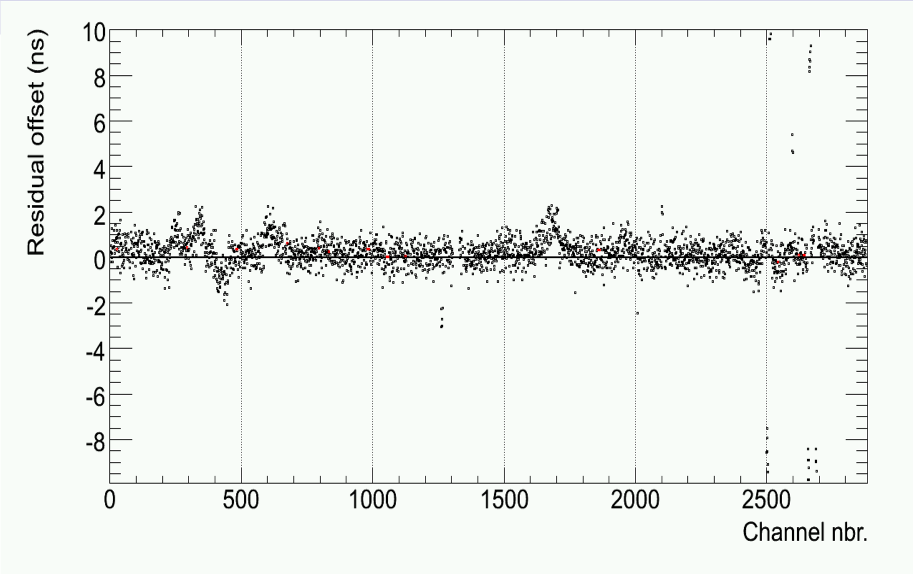


Convenient to have as much of the corrections as possible online. Six channel granularity sets the limit.

Data quality check: Verification of pulse shapes, amplitudes and convergence of fits (not yet automatized).

Plan is to integrate timing algorithms as part of automatic laser data reconstruction.

Results



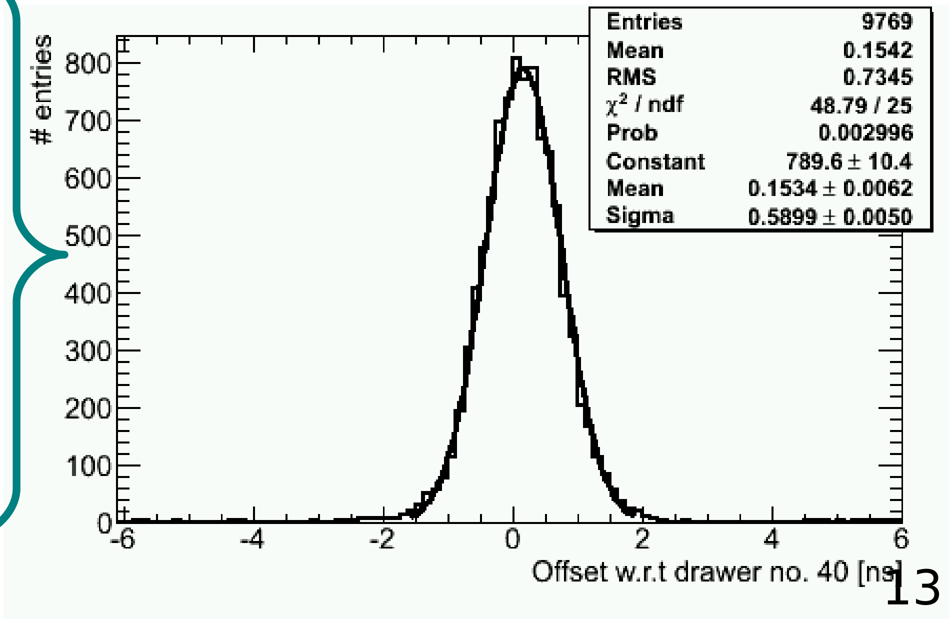
Verification of timing in one section of TileCal after implementing timing corrections.

Each channels residual phase goes into condition database

Distribution of all TileCal channels after implementing online timing corrections. All sections overlaid.

Sigma (~0.6 ns) of the Gaussian gives a lower limit resolution of the method.

Result well within the timing goals.

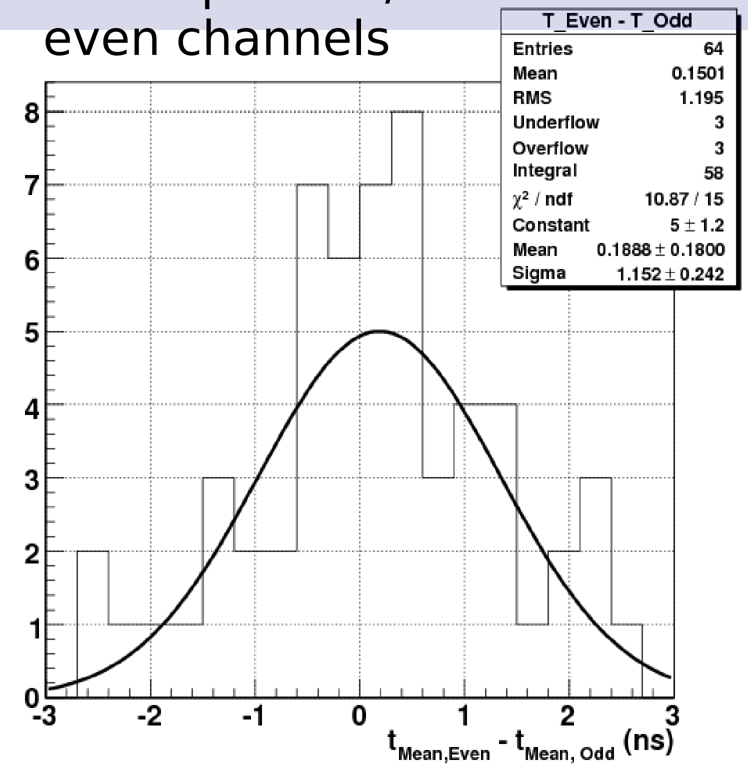


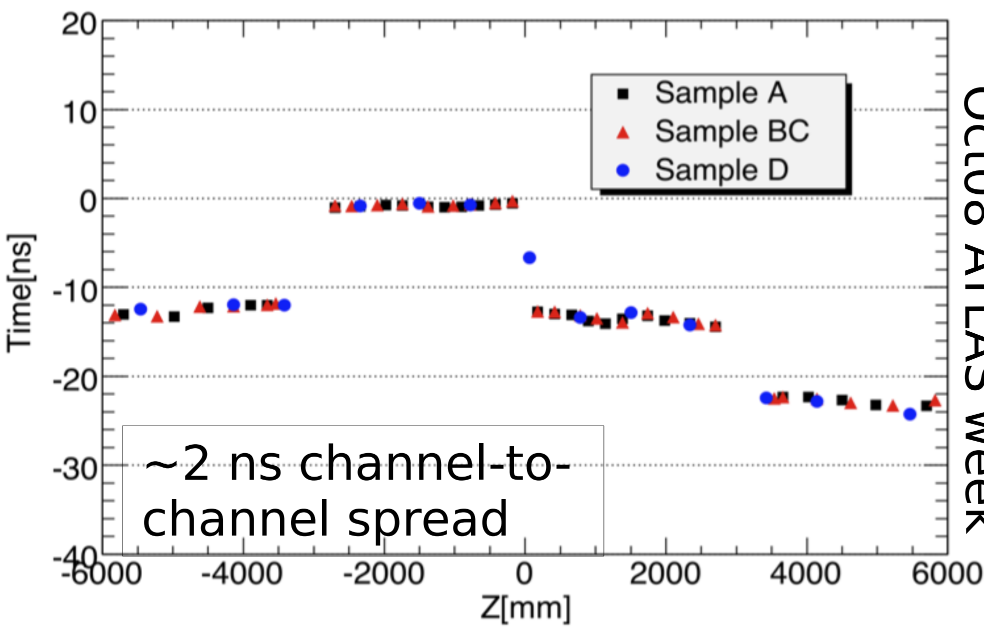
Limitations and uncertainties

- Main limitation of time calibration with laser comes from not knowing the variations in length of laser distributing fibers.

- Laser system can be made independent of fiber length variations if calibrated with respect to beam data (in progress).

Time spread b/w odd and even channels





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Source of uncertainty	Value
Laser fiber lengths	± 1.2 ns
v_{CF} contribution to intra-module	± 1.0 ns
Pulse shape	± 0.4 ns
Fit method time resolution	± 0.35 ns
Clear fiber routing	± 0.5 ns

Conclusions and outlook

The laser system has the potential to synchronize the Tile Calorimeter readout channels to a precision of ~0.6 ns. Well within the timing goals.

Systematic effects due to not knowing variations in length of the light distributing fibers reduces the precision.

Studies of “first beam events” shows a residual channel-to-channel spread of the order of 2 ns.

Laser system can be made independent of the laser fiber lengths if using beam events to calibrate.

One can then benefit from the convenience of using the laser system in future calibration and monitoring.