ALCOR TDC calibration

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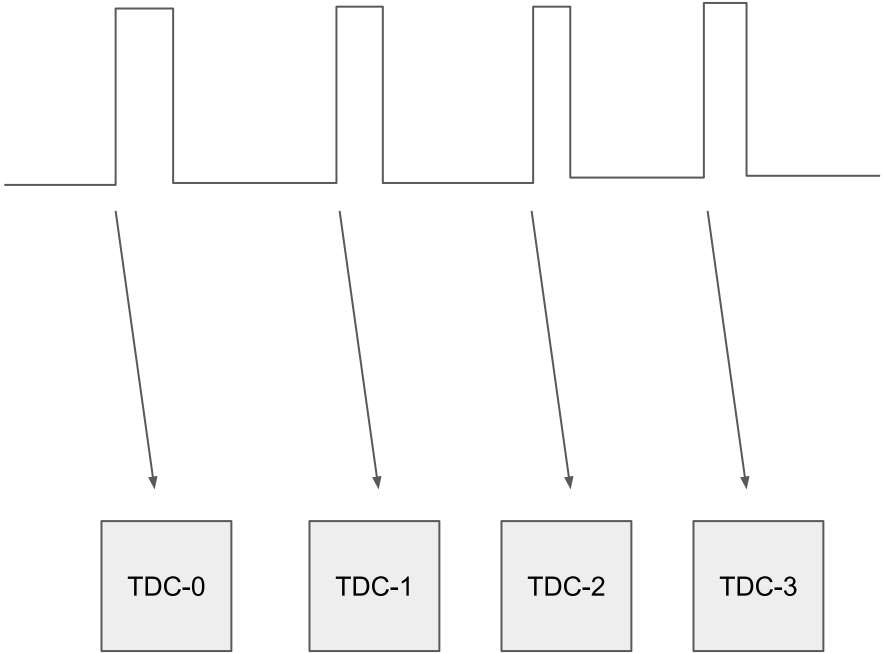
Asynchronous test pulses at constant frequency



each test pulse is recorded by a different, subsequent TDC
reconstruction of pulse period requires calibration of all TDCs

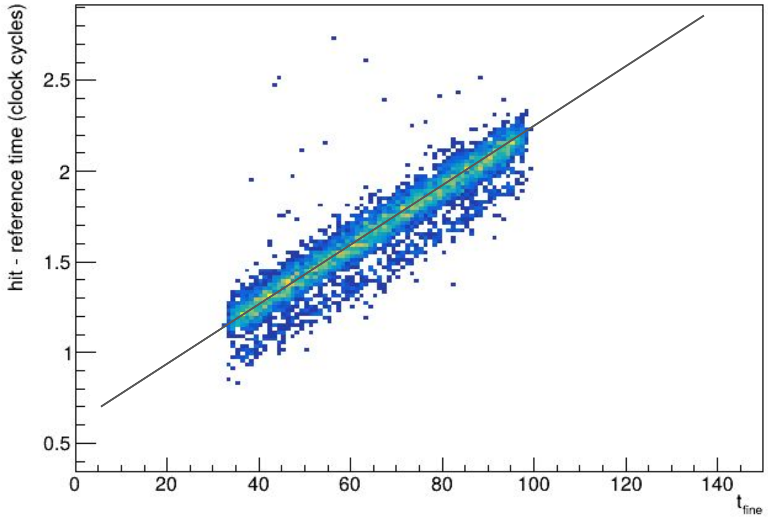
global minimisation calibration approach

Period measurement

$\Delta t = t_{i+1} - t_i$ time between consecutive hits

$t_i = t_{coarse} - t_{fine}$ depends on the coarse time (clock) and TDC phase (wrt. clock) measurement

$t_{phase} = a + b\ t_{fine}$ the TDC phase in ALCOR v2.1 can be parameterized by the TDC bin width (b) and and offset (a)
(in ALCOR v1.0 and v2.0 it is a bit more complex because of the "CUT", but not that much different)



if the test pulses are sent asynchronous to the ALCOR clock, we can uniformly populate the full t_{fine} range

uniformly, unless non linearities in t_{fine} binning of ALCOR TDCs

Global minimisation

The fine calibration of each of the TDCs of each ALCOR channel can be performed with data collected sending test pulses. Test pulses must be sent at a constant frequency and must be **asynchronous** to the ALCOR clock in order to uniformly populate the dynamic range of the TDCs. The time difference between consecutive hits is constant. When running **ALCOR in "Leading Edge mode, test-pulse to control logic" (opmode = 2)** the leading edge of the test pulses are digitised by one TDCs after another. Therefore, **the measurement of the time difference between consecutive hits allows one to intercalibrate all TDCs within one ALCOR channel by using a minimisation approach**. The function to be minimised can be defined as

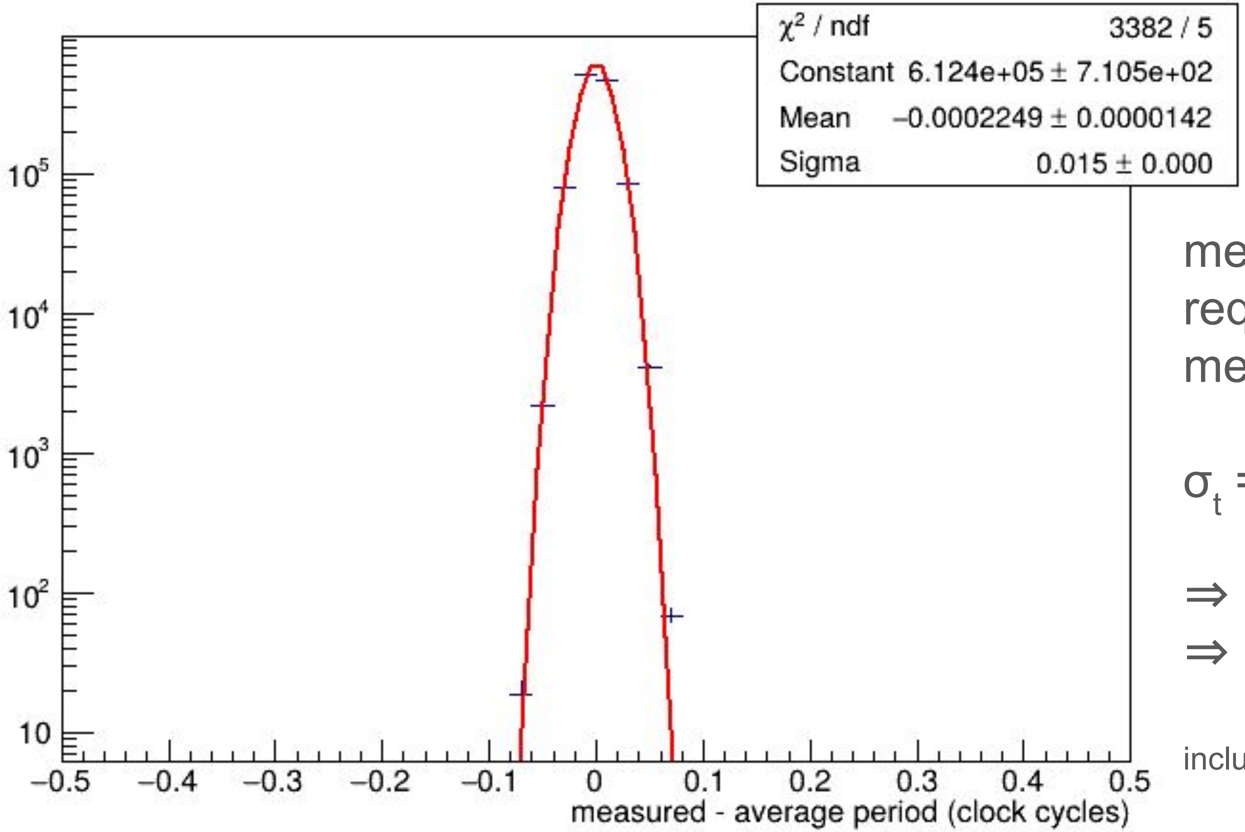
$$\chi^2 = \sum_{i=0}^{N-1} [(t_{i+1} - t_i) - T_{period}]$$

For each TDC the hit time is defined as

$$t = t_{coarse} - (a_j + b_j\, t_{fine})$$

where t_{coarse} and t_{fine} are the measured coarse and fine time, a_j and b_j are the calibration parameters for the TDC $j = 0, 1, 2, 3$ and T_{period} is the test-pulse period. The global minimisation of the χ^2 function with the nine free parameters allows one to determine the calibration parameters of the four TDC and the test-pulse period. It has to be noticed that one of the four a_j parameters cannot be independently determined and therefore its value can be fixed during the minimisation step.

Test pulse TDC resolution results (with default TDC interpolation factor = 64)



measured period (T) requires two hit time (t) measurements

$\sigma_t = \sigma_T / \sqrt{2}$

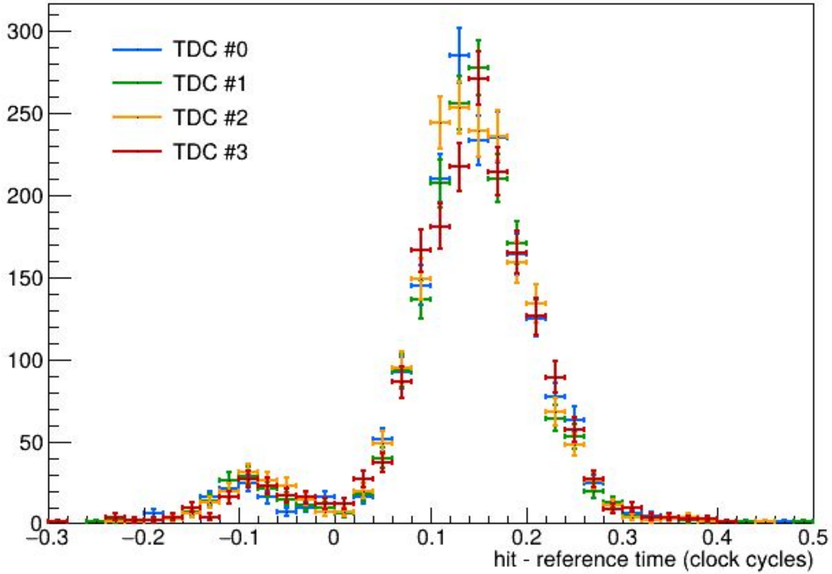
⇒ 0.01061 clocks @ 320 MHz
⇒ σ_t = 33 ps

including jitter from the pulse generator

Cross check with laser

the assumption to intercalibrate the four TDC in one ALCOR channel is that the signal generated by the test pulse follows the "same path" as the signal generated by the discriminator to reach the TDC

the offsets between different TDCs seen by a test pulse are the same as those seen by a real pulse and therefore, given that there is only one "analog path" the offsets can be used also for SiPM hits



this plot was obtained with nothing else more than the TDC calibration obtained with test-pulse data and a common offset to bring it closer to zero

ToT is not easy business, because one can calibrated the TDCs without physics data, but just with a simple approach.

Yes, sending test pulses synchronous with the clock is probably simpler than this, but one has to implement delays to populate different regions of the TDC fine

Easy ToT measurements when things are calibrated

before, to make ToT measurements I was running a special leading-only laser run to measure the calibration of all TDCs

when running in ToT mode it is not possible to calibrate with "physics" hits the TDCs 1 and 3, because they see the falling edge of the signal, which is not time-correlated with the laser pulse

ToT reconstruction seems to be working well, only a few cases where ToT is not reconstructed (report on this another time)