Time Resolution from Software Log

The Linux/TPP and ptp software periodically report the measured clock offset between network master and network slave clocks. This is derived from the PTP messages and useful as a first measure to evaluate performance. Histogramming hundreds or thousands of reported offset values gives a distribution around an average value, and the FWHM of the distribution is our first measure of performance for the synchronization techniques.

- Resolutions in the PTP network are an order of magnitude better than in the non-PTP network.
- Resolutions can reach ~10ns FWHM or below.
- PHY timestamping is better than FW timestamping which is better than SW timestamping.

Time Resolution from Coincident Pulses

When coincident scintillator pulses are captured in the two Pixie-Net modules, with timestamp T1 and T2, there is a small difference in time stamps ΔT ~ T2 - T1 (from cable delays etc.; normal cables don’t change) but with small variations due to imperfect clocking and variations in pulse shape. Histogramming ΔT from hundreds of thousands of pulses and applying a Gaussian fit to determine the FWHM distribution (Figure 6) is our second measure of performance for the synchronization techniques. A CFD algorithm is applied in cases where the PTP precision approaches the clock period.

- ΔT drifts in the same direction for short sections of the measurement (Figure 5), following the periodic adjustments of the PTP clock.
- Resolutions with sync-E or WR are an order of magnitude better than in the PTP network.
- Resolutions can reach ~200 ps FWHM.
- Detector jitter can be limited for precise acquisition, not the timing measurement.

Summary and Conclusions

The two most promising network time synchronization techniques for nuclear physics applications were WR and PTP PHY timestamping with the DP83640. The PTP83640 obtained time resolutions of ~10-~40 ns in a non-PTP network. In sync-E mode, it reached ~800ps with a pair of LaBr3 detectors and ~200ps with a pulser. With the WR demo kit, resolutions were ~300ps with a pair of LaBr3 detectors and ~190ps with a pulser. A traditional distributed clock reached ~800ps with a pair of LaBr3 detectors and ~20 ps with a pulser.

The DP83640 is therefore a good solution for applications that do not need the most precise timing (e.g. coincident background rejection); it is a 10×10 array that can easily be integrated into the DAQ electronics and does not necessarily need a special network infrastructure. For more demanding applications, such as detector array event building, the DP83640 can be used in a PTP enabled network (which adds cost to the infrastructure). For highest precision applications, such as time of flight measurements, White Rabbit or synchronous Ethernet can be used, but traditional shared clock solutions still provide better performance which maybe necessary for some applications (where the detectors support it).

This precision network time synchronization allows a new kind of data acquisition, with software based trigger and recording decisions rather than hard wired logic.