Data Reduction Aqueye+/Iqueye/IFI+/EFI

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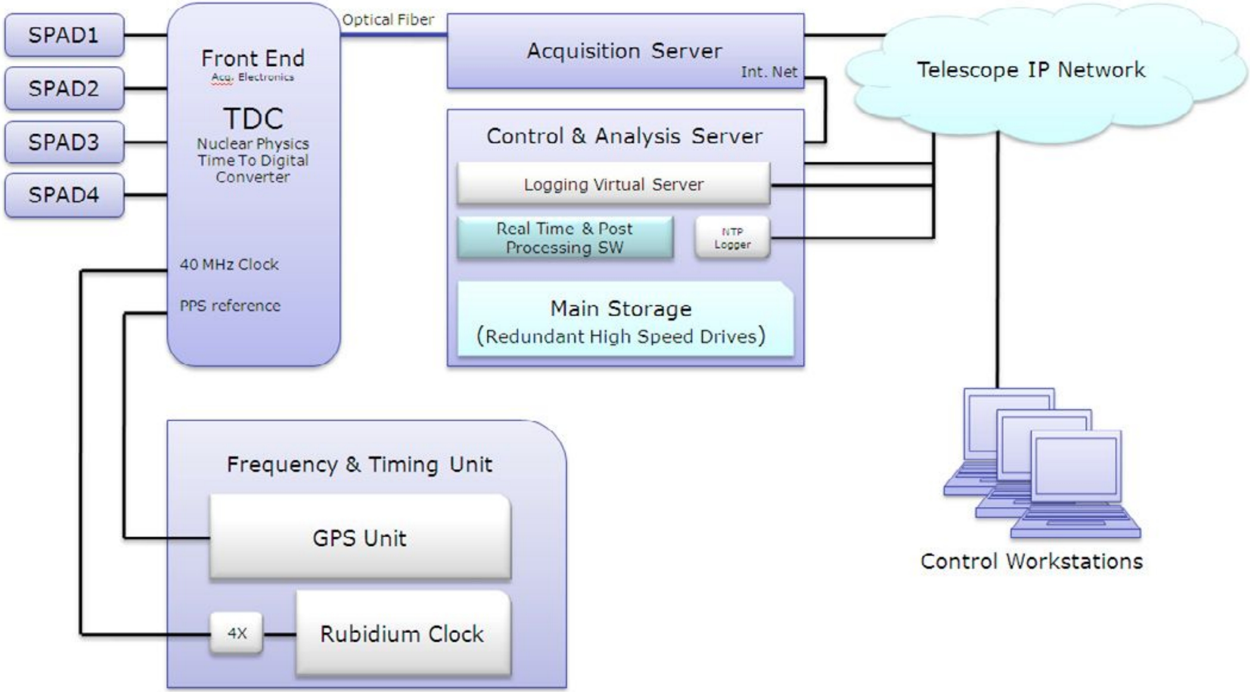
Workshop on Fast Optical Bursts - Asiago - 04-07/05/2026

Iqueye data acquisition system (IDAS)

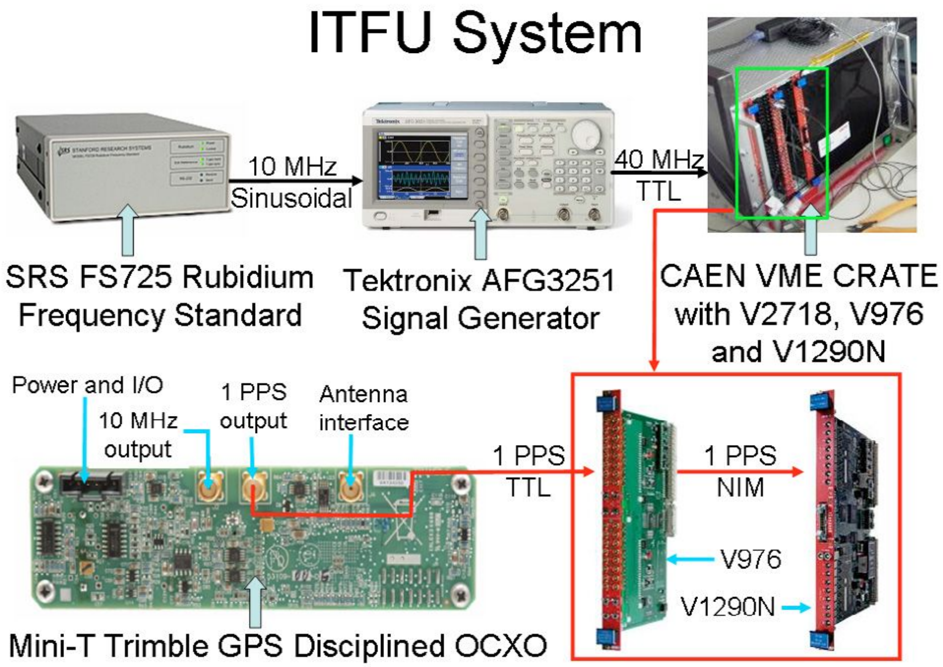
https://www.aanda.org/articles/aa/pdf/2009/46/aa12862-09.pdf



IDAS collect pulses produced from each SPAD when a photon is detected, assign a very accurate absolute time tag to each event, and store the time tags in the external memory.

Iqueye time and frequency unit (ITFU)

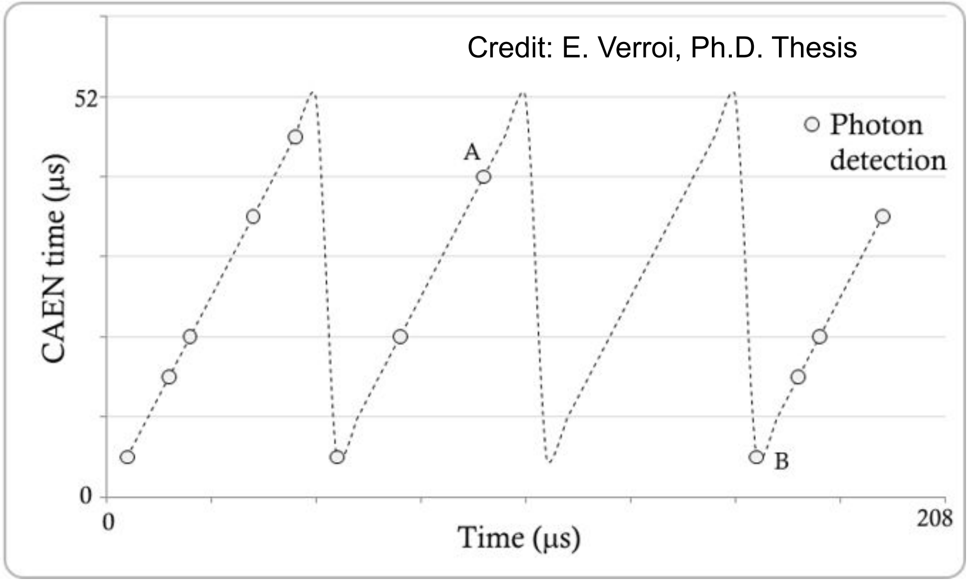
https://www.aanda.org/articles/aa/pdf/2009/46/aa12862-09.pdf



ITFU needed to correct the long-term drift of the reference frequency provided by the rubidium oscillator by means of a post-processing algorithm that uses the PPS signal provided by a GPS receiver.
The GPS also provides the synchronization to UTC.

Rollover

https://www.aanda.org/articles/aa/pdf/2009/46/aa12862-09.pdf



Data acquisition electronics is fed with an external signal to avoid to lose any rollover

The times of arrival are stored in a buffer using 21 bits for the time tag. This means that after 2^{21}·25 ps ≈ 52 μs the counter is reset and the counting re-starts from zero, so the time tags coming from the TDC are actually number digitalized at 25 ps spanned in the range [0÷52 ms]. That implies the non-uniqueness of each tag. We called **rollover** each reset of **these 52 μs period**.

Absolute and relative timing performances

https://www.aanda.org/articles/aa/pdf/2009/46/aa12862-09.pdf

Absolute time accuracy

$$\sqrt{25^2 + 35^2 + 50^2 + 50^2} \approx 100\ ps$$

Resolution TDC + Detector jitter + Stochastic residual noise rubidium clock + Residual jitter in electronic chain

Time accuracy wrt UTC

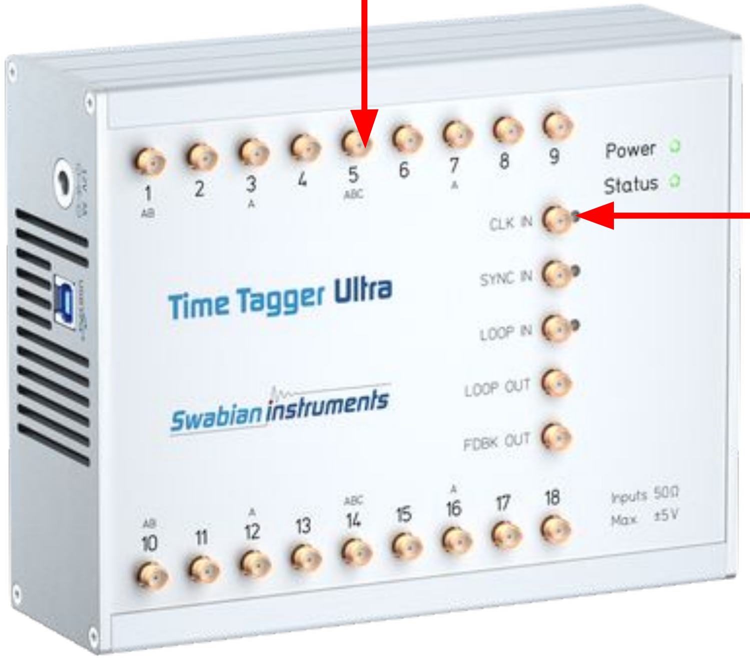
$$\sqrt{100^2 + (25000/\sqrt{3600})^2} \approx \sqrt{100^2 + 400^2} \lesssim 500\ ps$$

PPS rms uncertainty approximately ±25 ns → Interpolation reduces the error associated with the starting time in a way proportional to the number of acquired PPS →After one hour the uncertainty become ~400 ps.

Example (from ASTRI-SI^3 BEE laboratory test)

Accuracy achievable using a TDC + GPS receiver + Rubidium clock

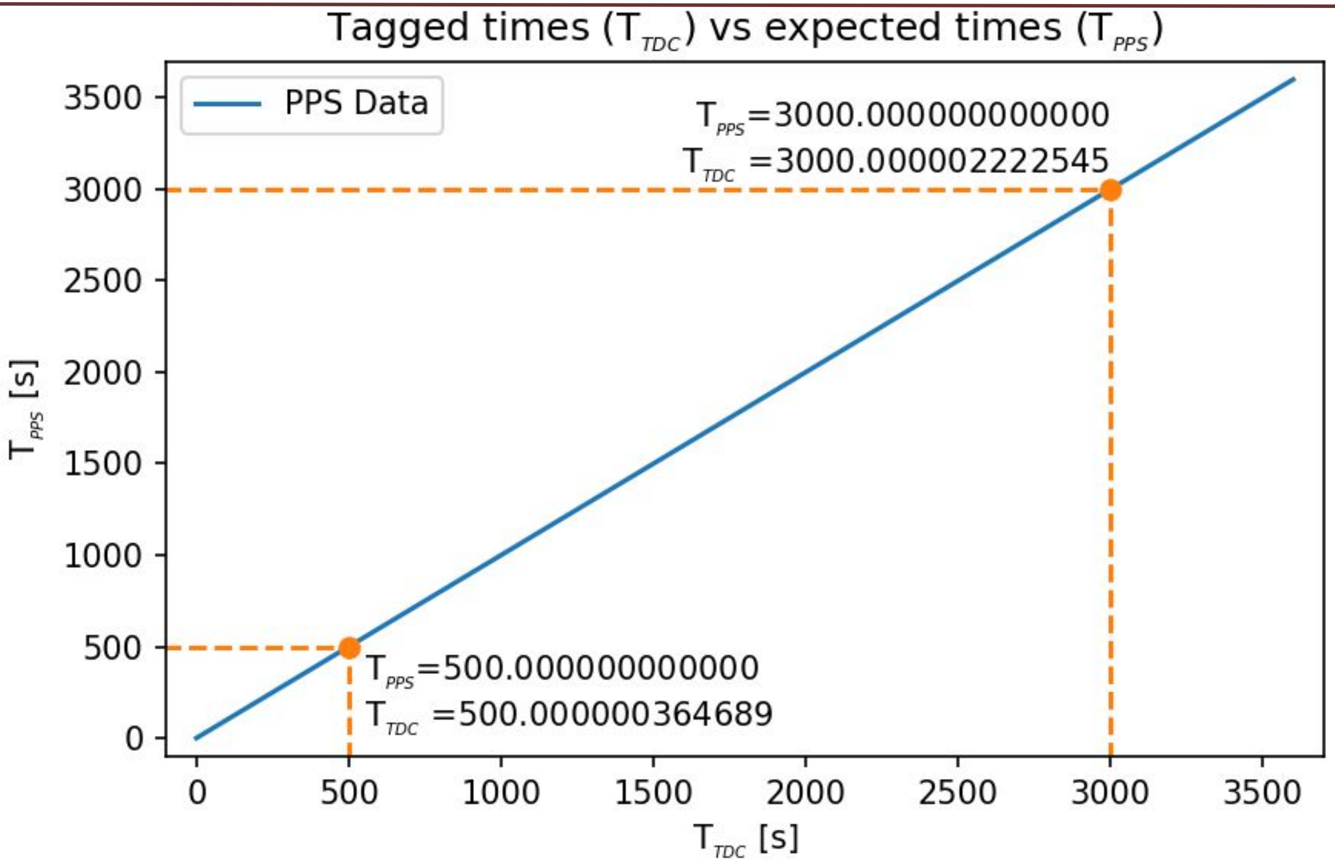
Setup



Thunderbolt E GPS (PPS Generator)
Accuracy <15 ns wrt UTC

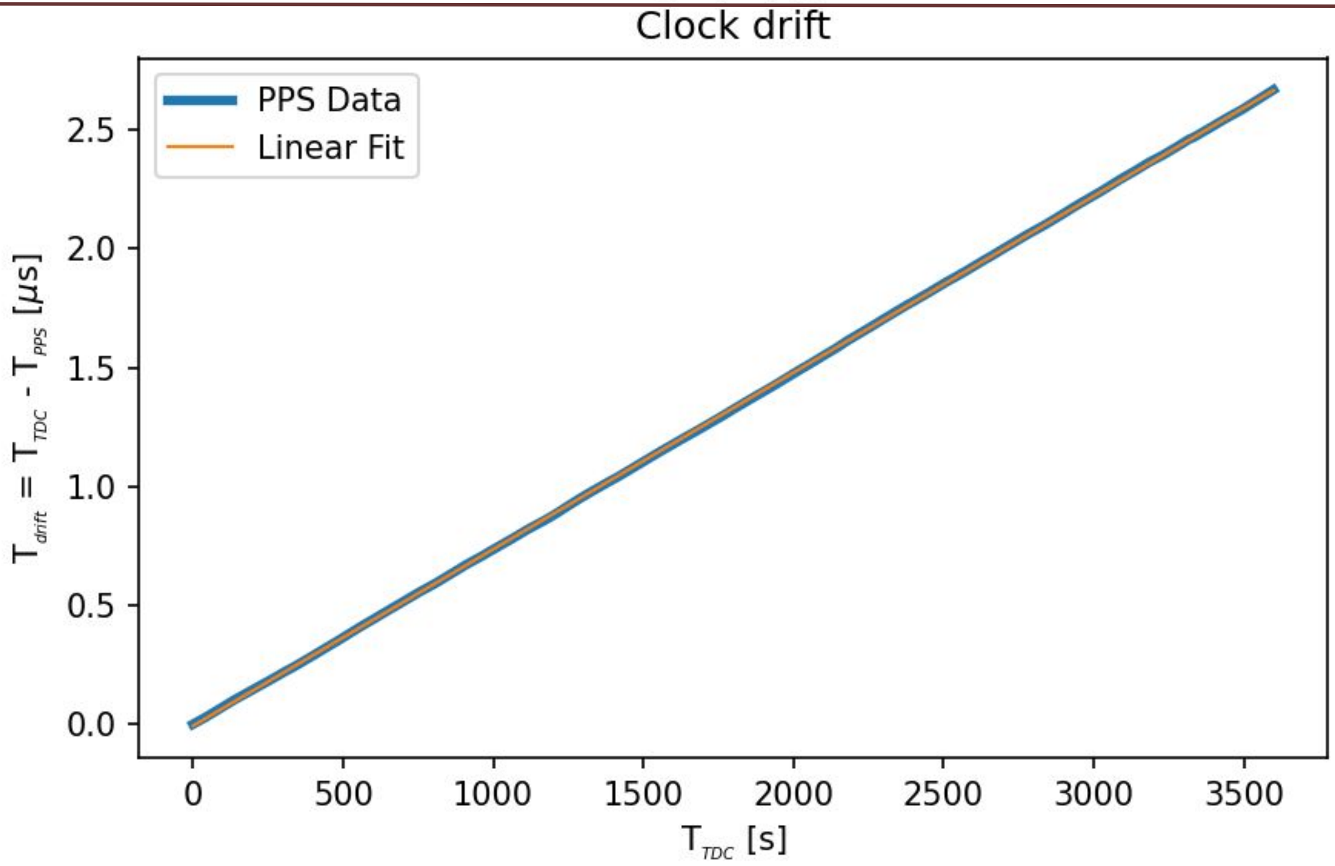
Example (from ASTRI-SI3 laboratory test)

Comparison between the times in output from the Time Tagger and the "expected" times of the PPS.



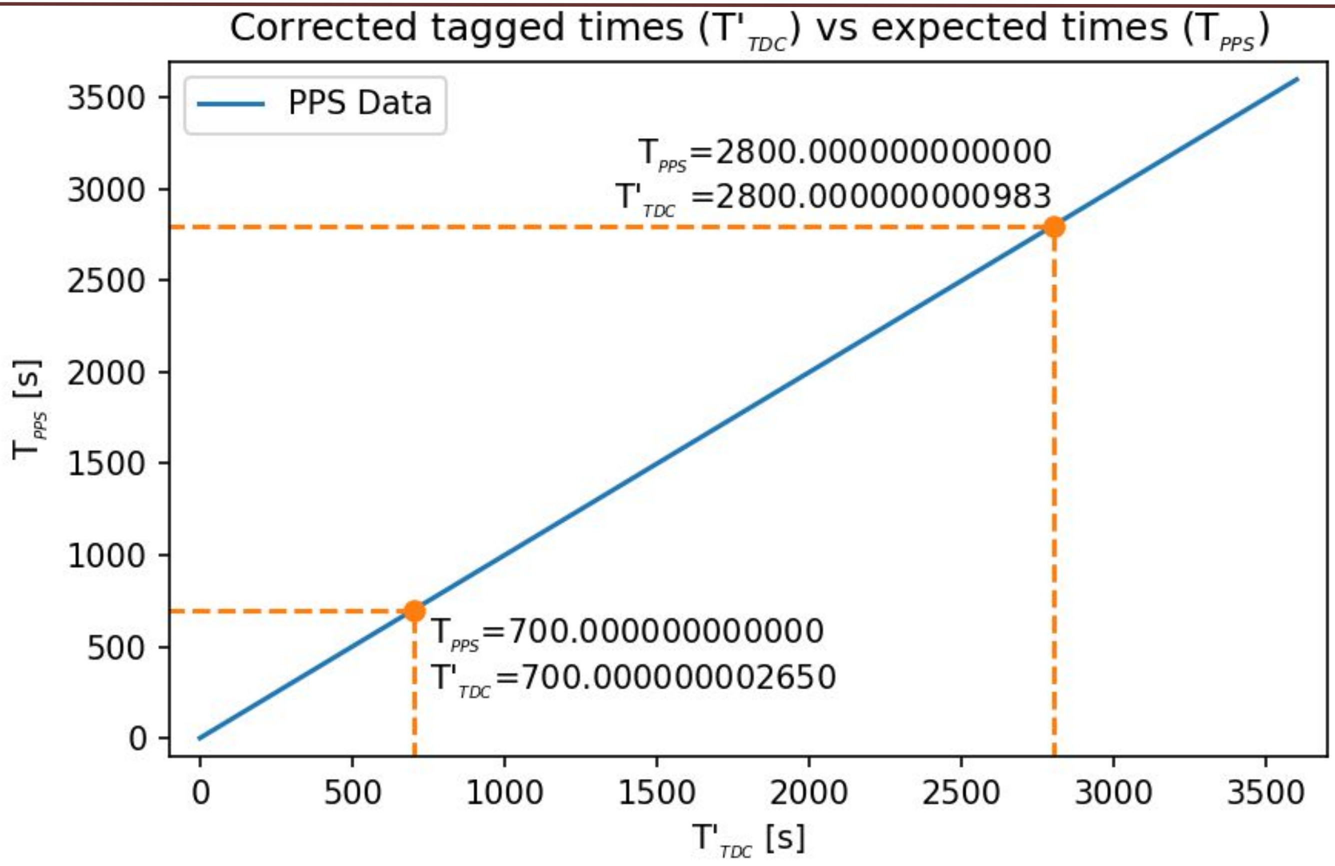
Example (from ASTRI-SI3 laboratory test)

We fit T_{drift} (the difference between TTDC and TPPS) → $T_{drift,fit} = f(T_{TDC}) = a + b*T_{TDC}$



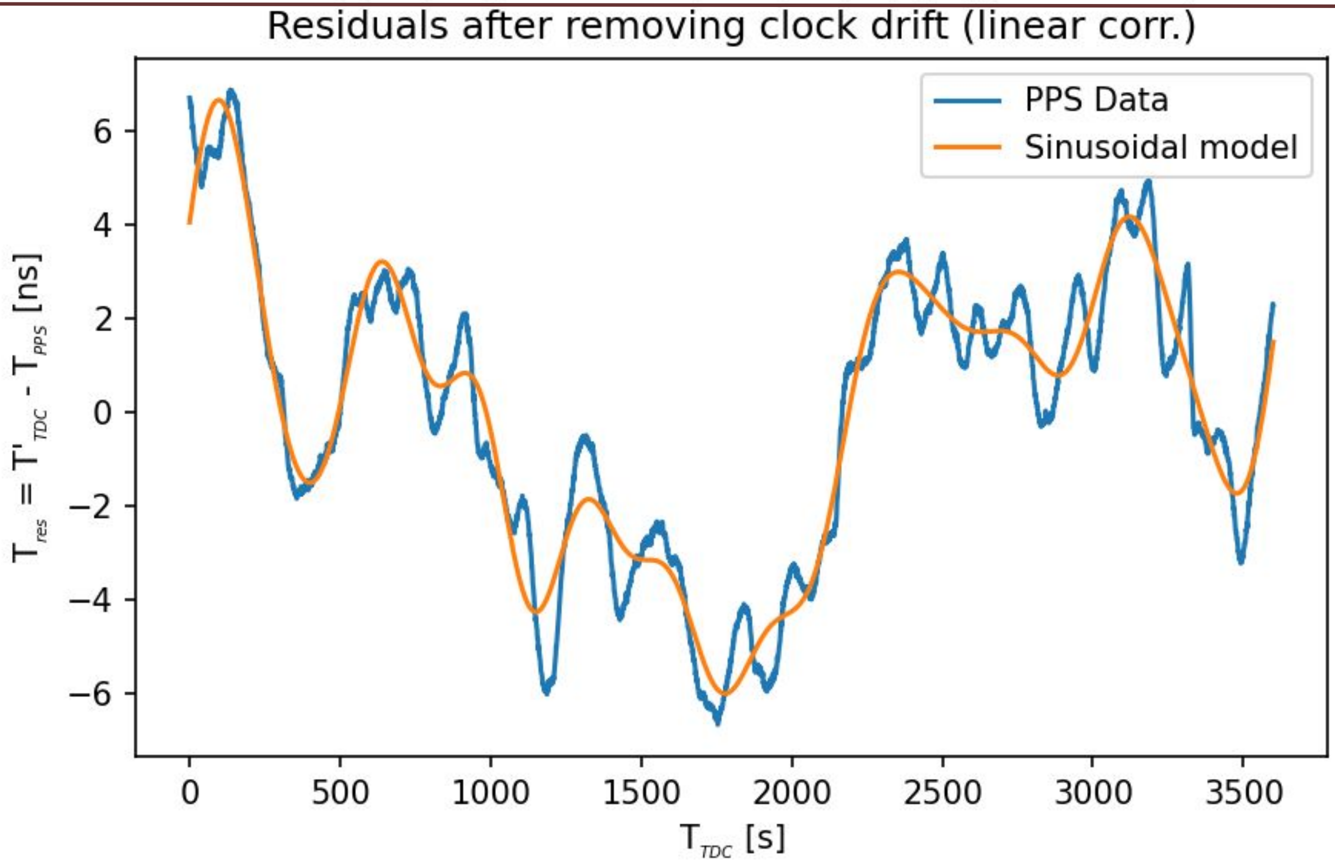
Example (from ASTRI-SI3 laboratory test)

Removing $T_{drift,fit}$ to T_{TDC} we correct for the linear drift of the clock.



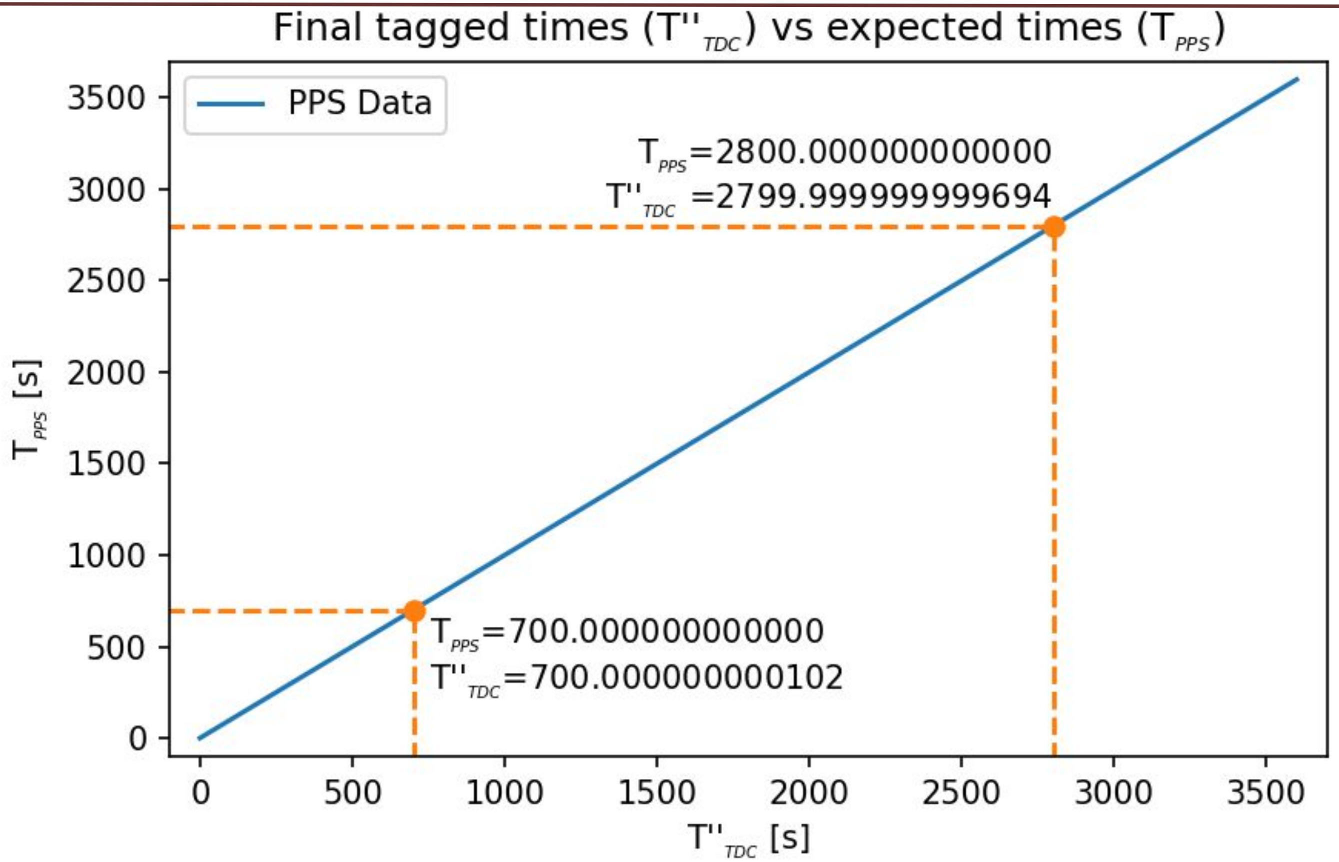
Example (from ASTRI-SI3 laboratory test)

PPS signal residuals (T'_{TDC} - T_{PPS}) after removing the drift of the clock using a linear fit→$T_{res,fit} = g(T'_{TDC})$



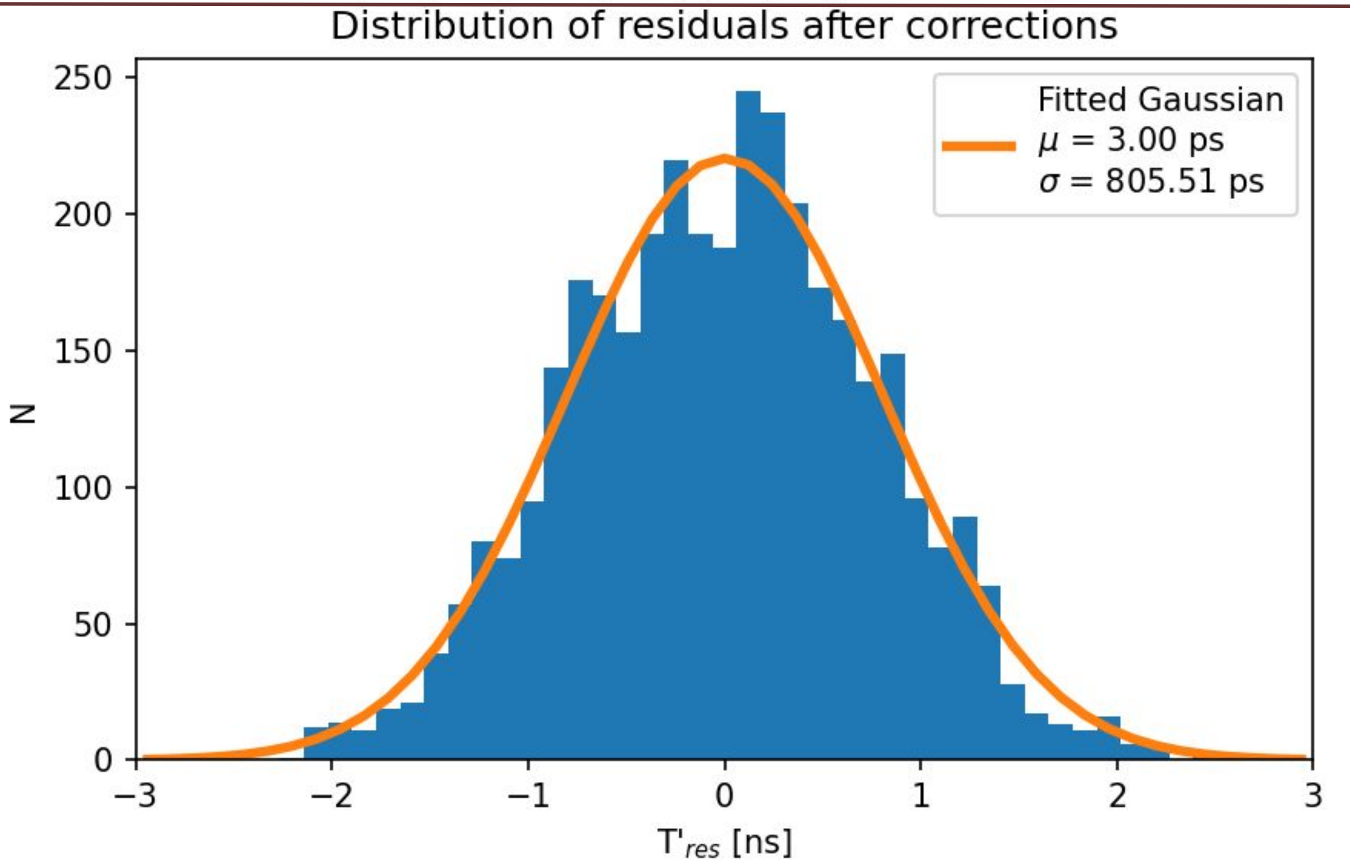
Example (from ASTRI-SI3 laboratory test)

Substracting $T_{res,fit}$ to T'_{TDC} removes much of the sinusoidal pattern.



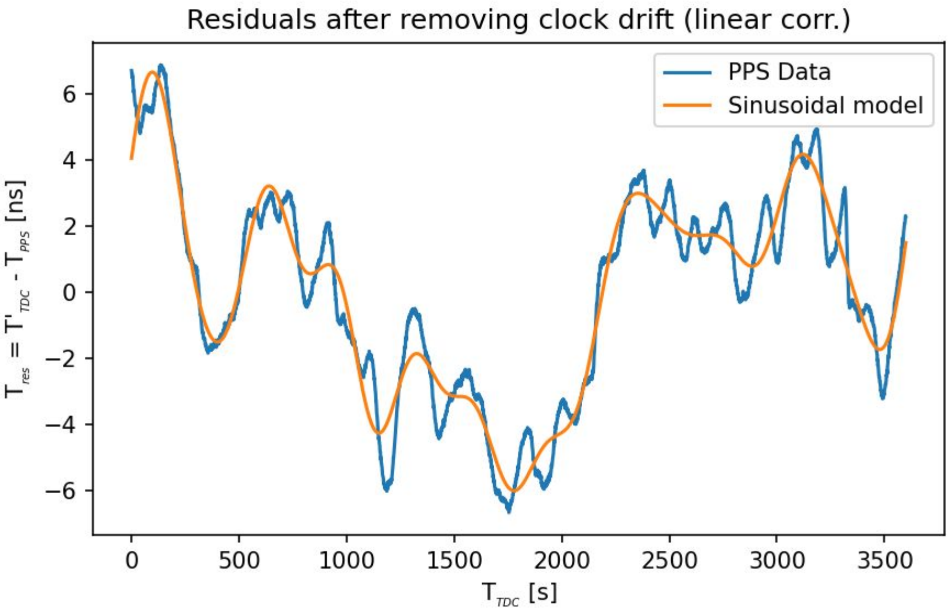
Example (from ASTRI-SI3 laboratory test)

Distribution of the PPS signal residuals after all the corrections.

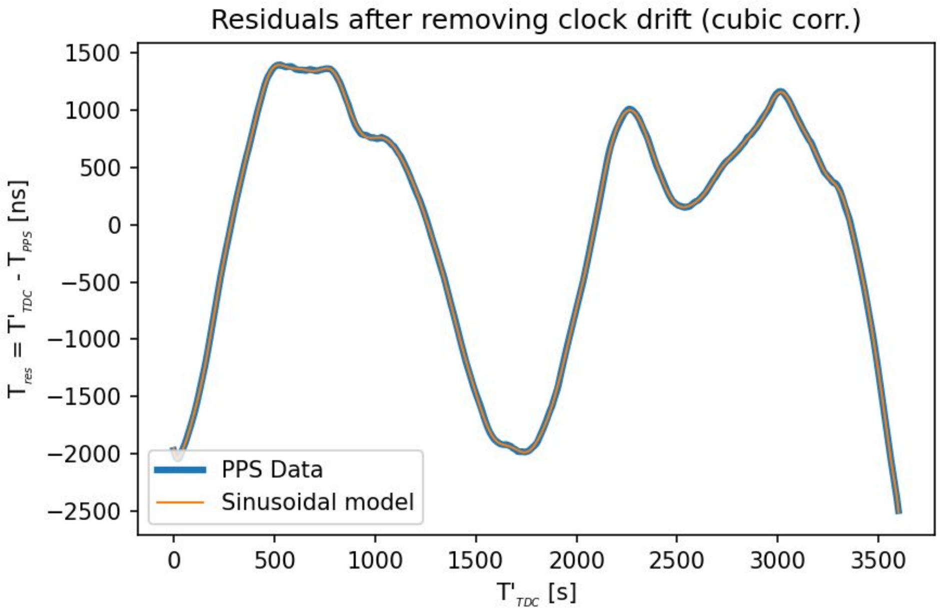


Example (from ASTRI-SI3 laboratory test)

Comparison using the internal clock of the TDC



With Rubidium clock



With internal TDC clock

How to accurately measure the real timing performances?

- Picosecond pulsed laser? → Very expensive!!
- Timing of (ms) pulsars? → Not enough to reach the ps level…

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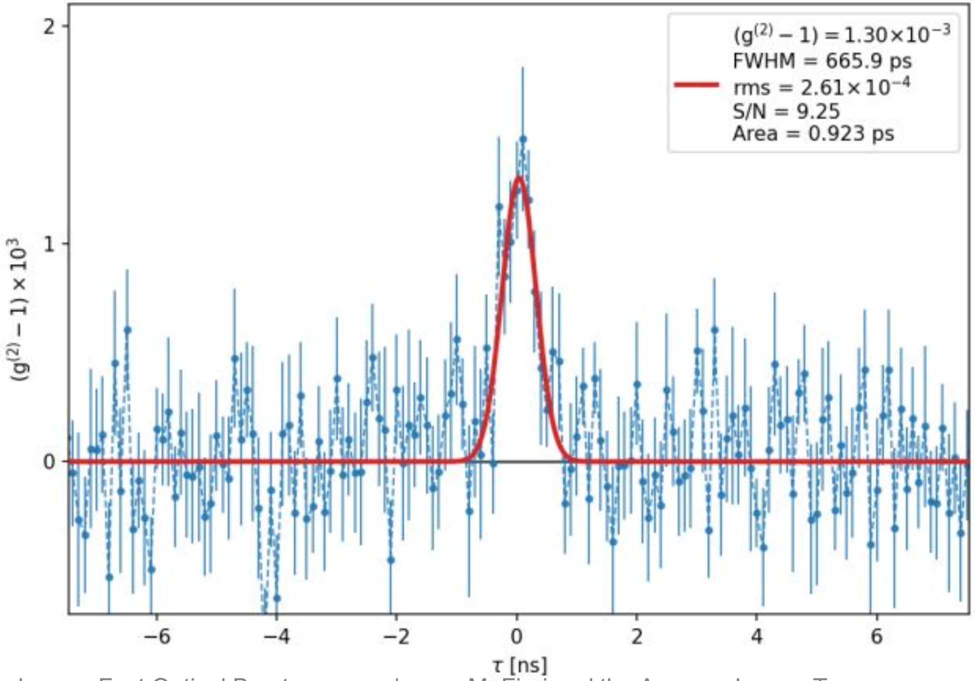
- **Intensity Interferometry measurements!!!**



Acknowledgments

Based on observations collected at the Copernicus telescope (Asiago, Italy) of the INAF-Osservatorio Astronomico di Padova and at the Galileo telescope (Asiago, Italy) of the University of Padova

Presently funded by INAF (Research Grants “Uncovering the optical beat of the fastest magnetised neutron stars (FANS)”, “Coordinated multiwavelength exploration of Fast Radio Bursts (COMEFAR)”) and the University of Padova (DOR grant)

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