Local ties control in application of laser time transfer

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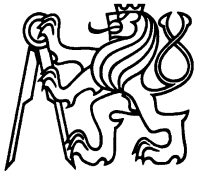
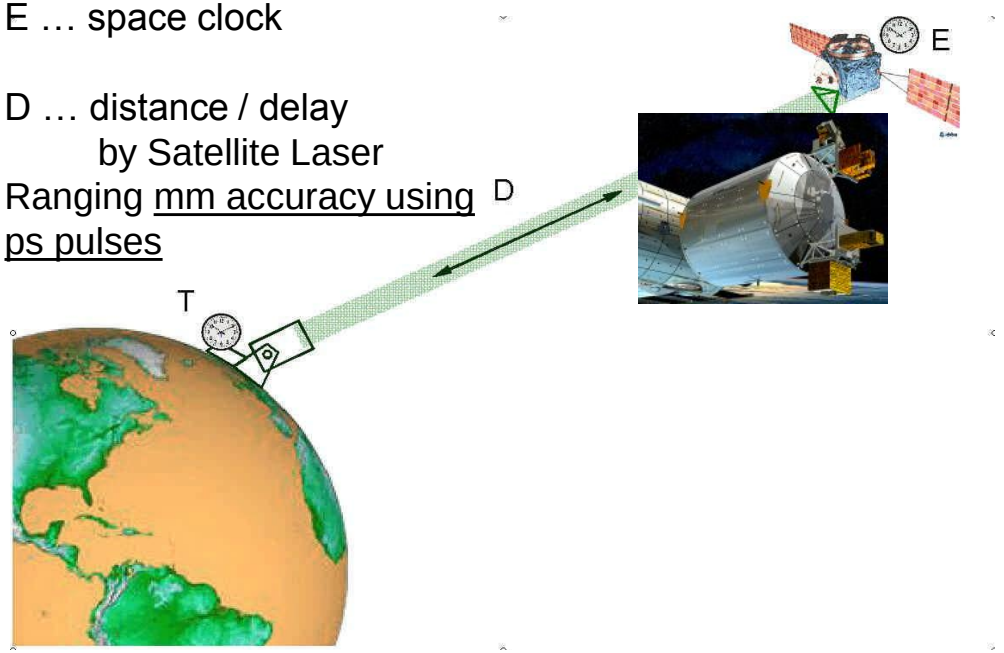
FOR1503



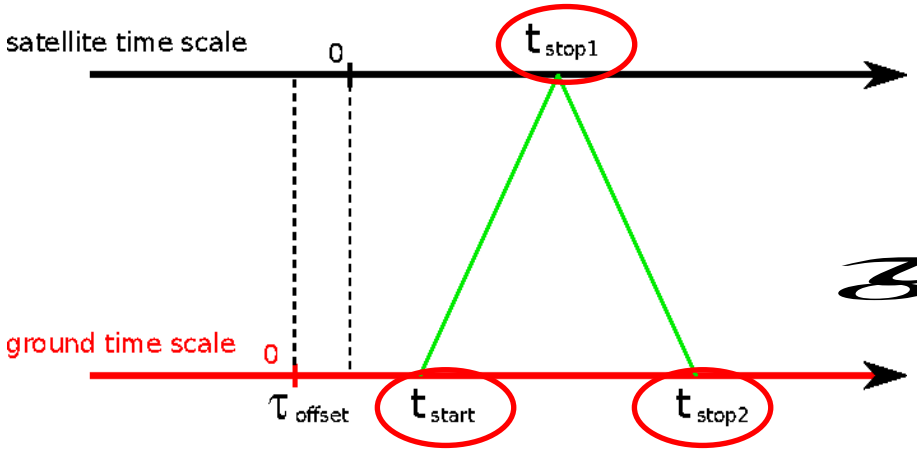
Motivation – optical time transfer ground to space

T … ground clock
E … space clock

D … distance / delay
by Satellite Laser Ranging mm accuracy using ps pulses

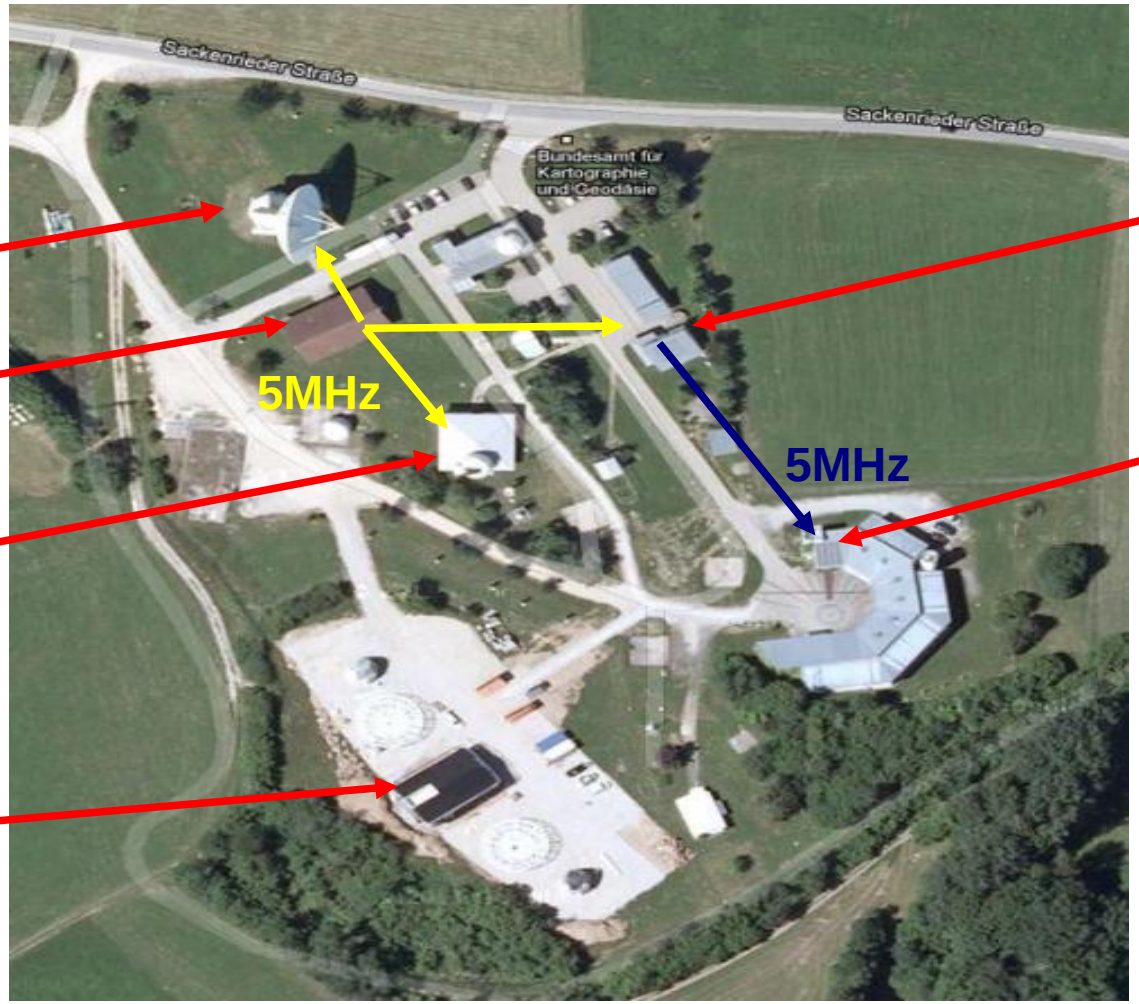


- Based on existing SLR network
- Several projects in space or in development
  - T2L2 – France
  - LTT – China
  - ELT – ESA
  - Glonass
  - Space to ground comparison of clocks 4 ps @ pass,7 ps @ 10^6 s, **accuracy 50 ps**
  - Used to calibrate MWL
- Time transfer is actually realized between space scale and scale kept inside event timer => requires deep understanding of timing systems of SLR stations



$$\tau_{offset} = \frac{t_{stop1} + t_{stop2}}{2} - t_{start}$$

Geodetic Observatory Wettzell



VLBI antenna

H-Maser
EFOS 1,18,39

SLR

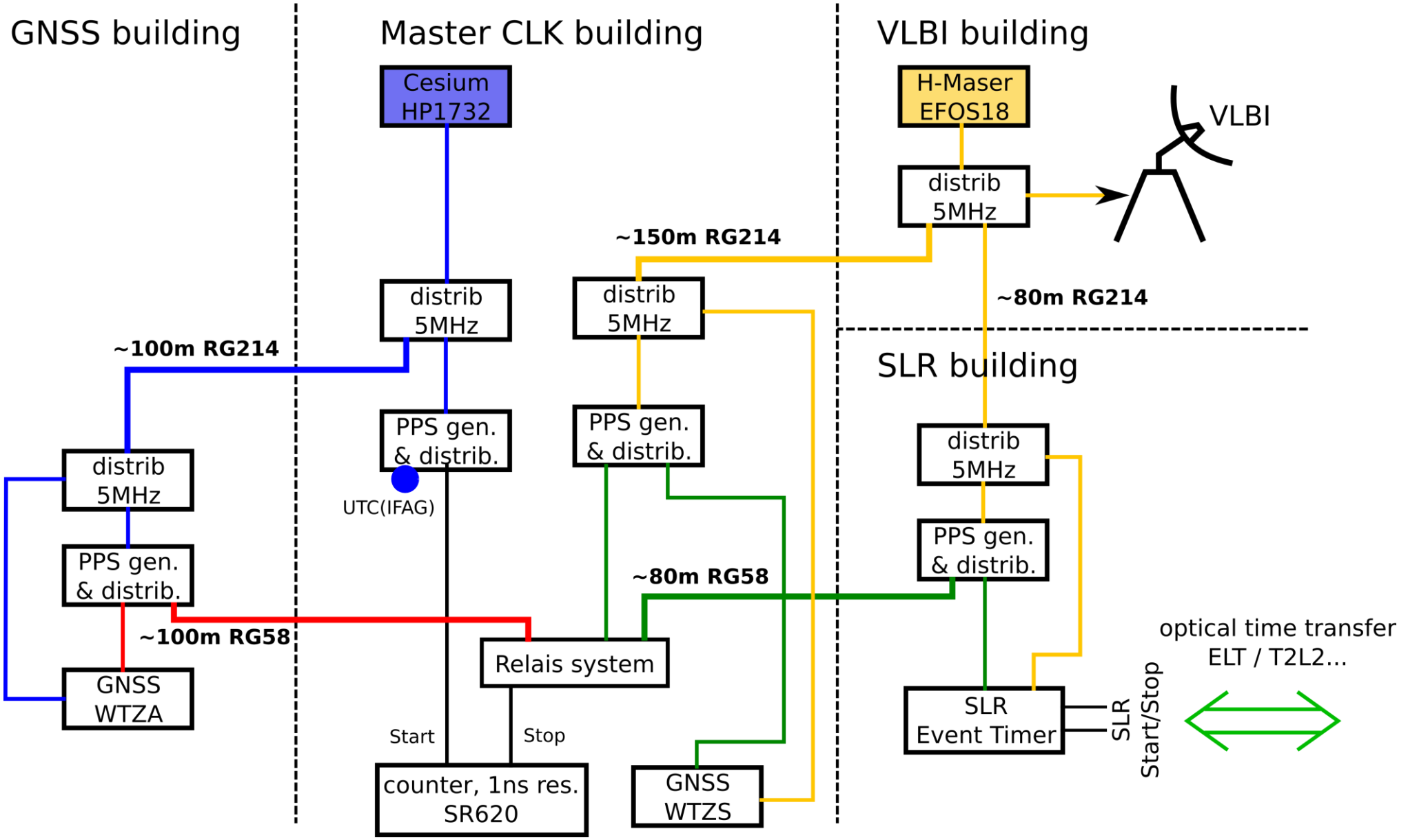
H-Maser
EFOS 60

5xCs
HP1732 - UTC(IFAG)
WTZS – PolarX2

GNSS laboratory
WTZA – Ashtech Z12T

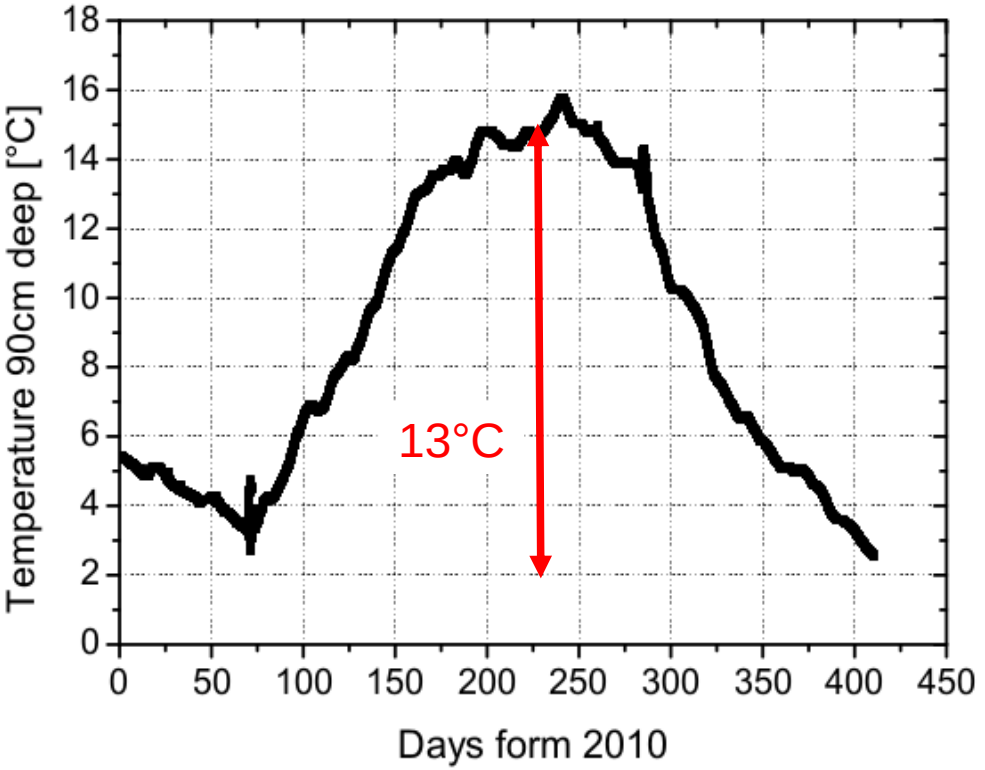
- 5x Cs clocks, HP1732 – UTC(IFAG) reference point
- 4x H Maser clocks, SLR and VLBI are running from EFOS 18
- Building separations (50 – 100m long interconnecting cables)

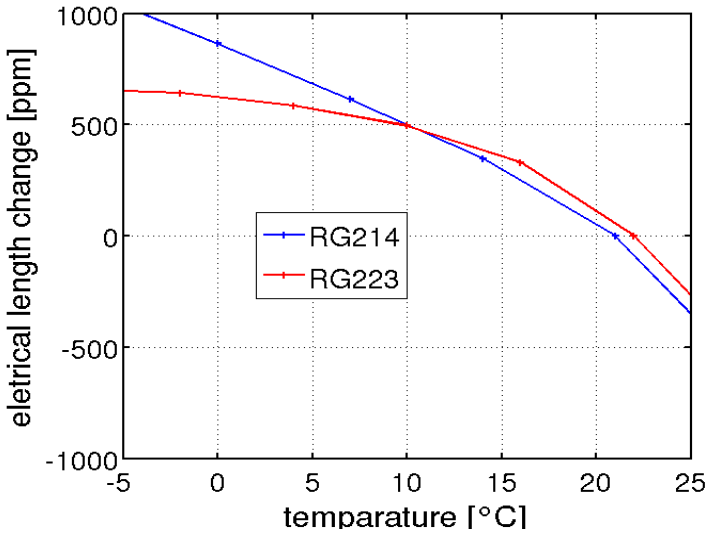
Timing system in Geodetic Observatory Wettzell



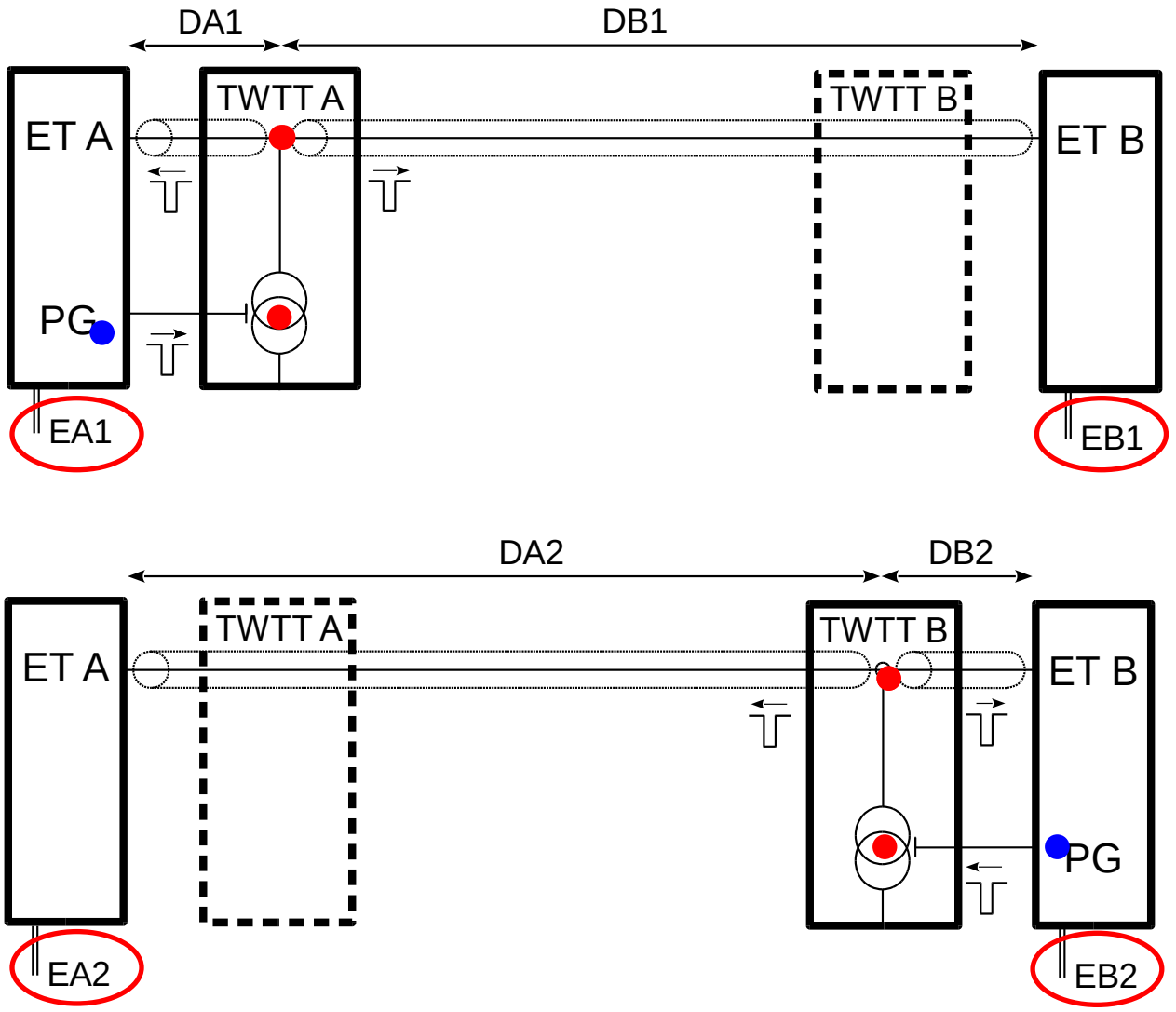
Temperature dependency of cables

- Cables frequently used in Wettzell are RG214, RG58, RG223
- Interconnecting cables are 90 cm underground => annual variation +3 / 16°C
- Temperature stability >1000ppm
- => expected annual changes > 0.5ns/year
- Instrumentation temp. dependency ~20 ps





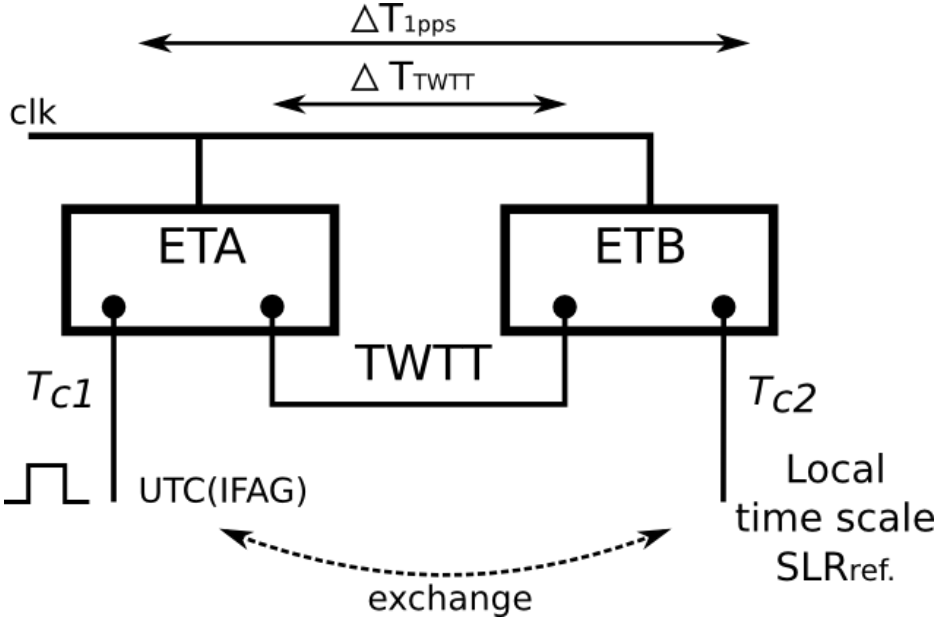
Two Way Time Transfer principal



- Single coaxial cable is used for interconnection of two ET
- TWTT modules activated alternately
- Resulting time scale diff.: **DS** = ((EB1 − EA1) + (EB2 − EA2)) / 2
- TWTT ~1ps rms; < 10ps systematic error for distances > 100m
- Systematic error depends on quality of the interconnecting cable
- LDF4, 100m => 3ps

IEEE, 2012, p. 1-7. ISBN 978-1-4577-1821-2

Calibration of the TWTT method for comparing 1pps time scales

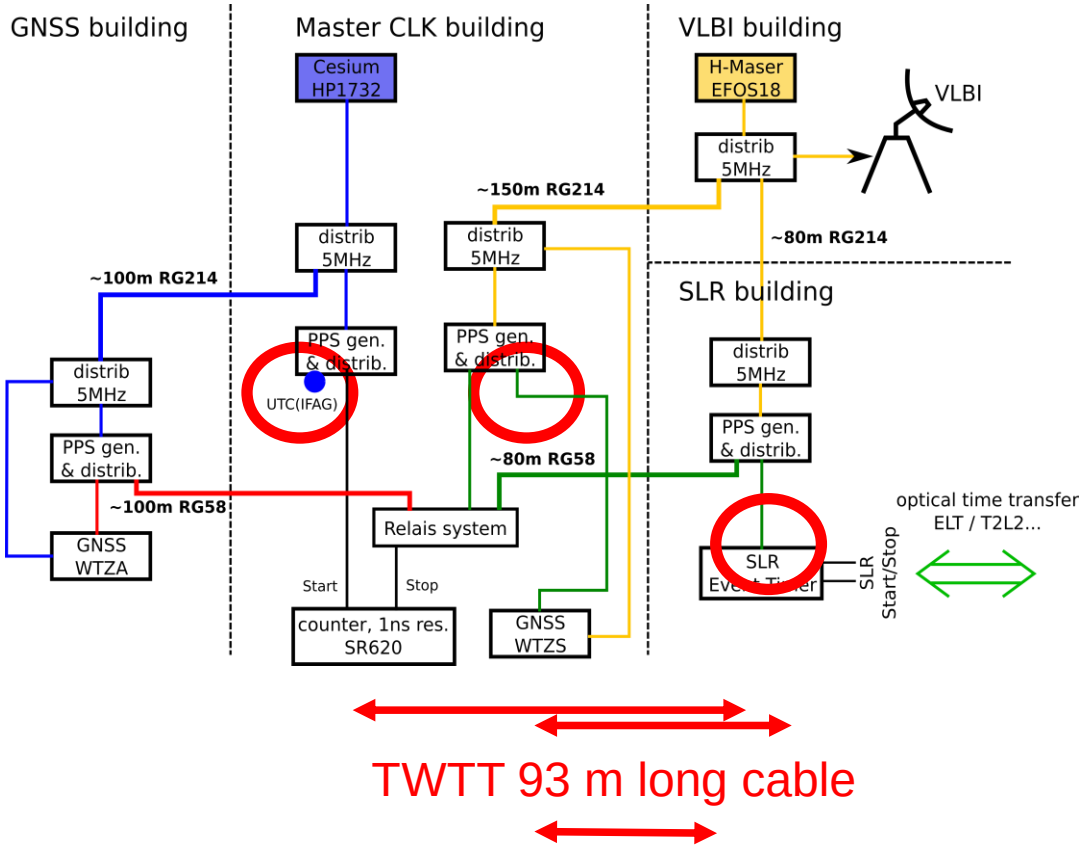


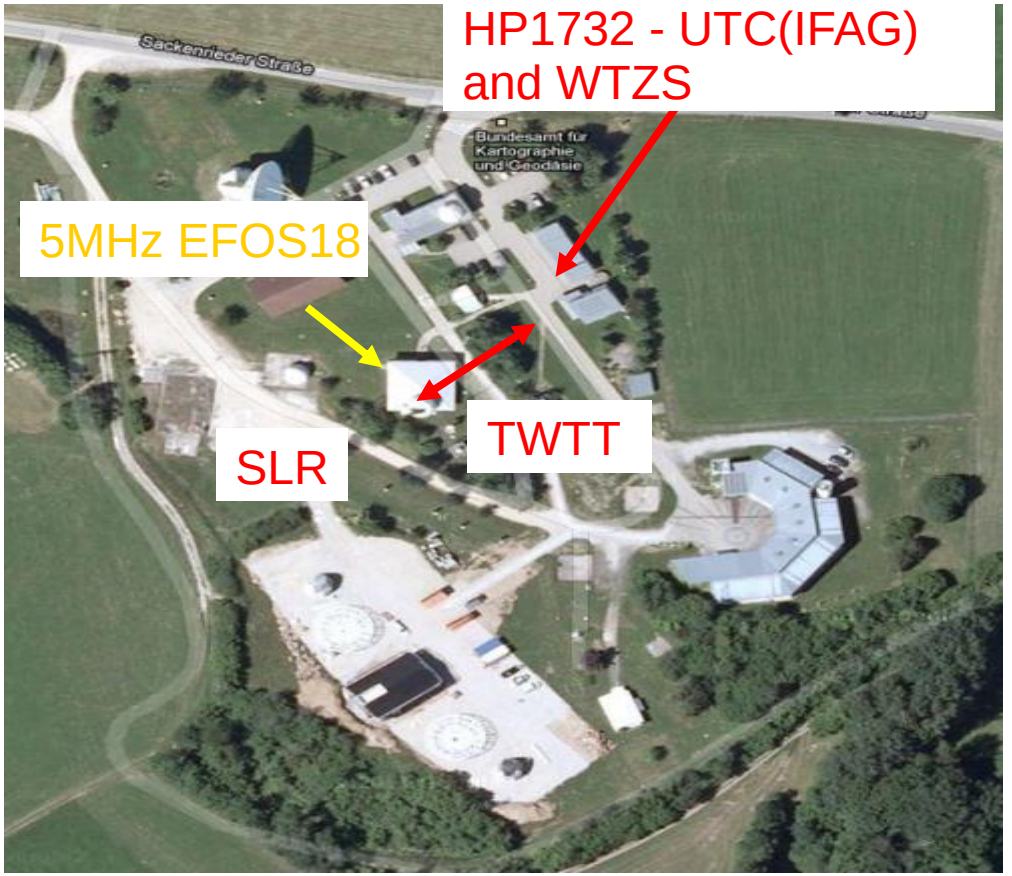
- TWTT method is used to set "0" between Event timers
- 1pps are connected to 2nd input => additional calibration
- Measuring difference of 1pps and TWTT input (using spitted pulses); ΔET = 3.6 ps
- Connecting to ref. points with cables τ_{C1} and τ_{C2} and exchanging them => $\Delta\tau_C = \tau_{C2} - \tau_{C1} = 10.183$ ns

NPET see Thursday afternoon

$$SLR_{ref.} - UTC(IFAG) = ppsDiff - \Delta\tau_C - \Delta ET$$

TWTT UTC(IFAG) ↔ SLR



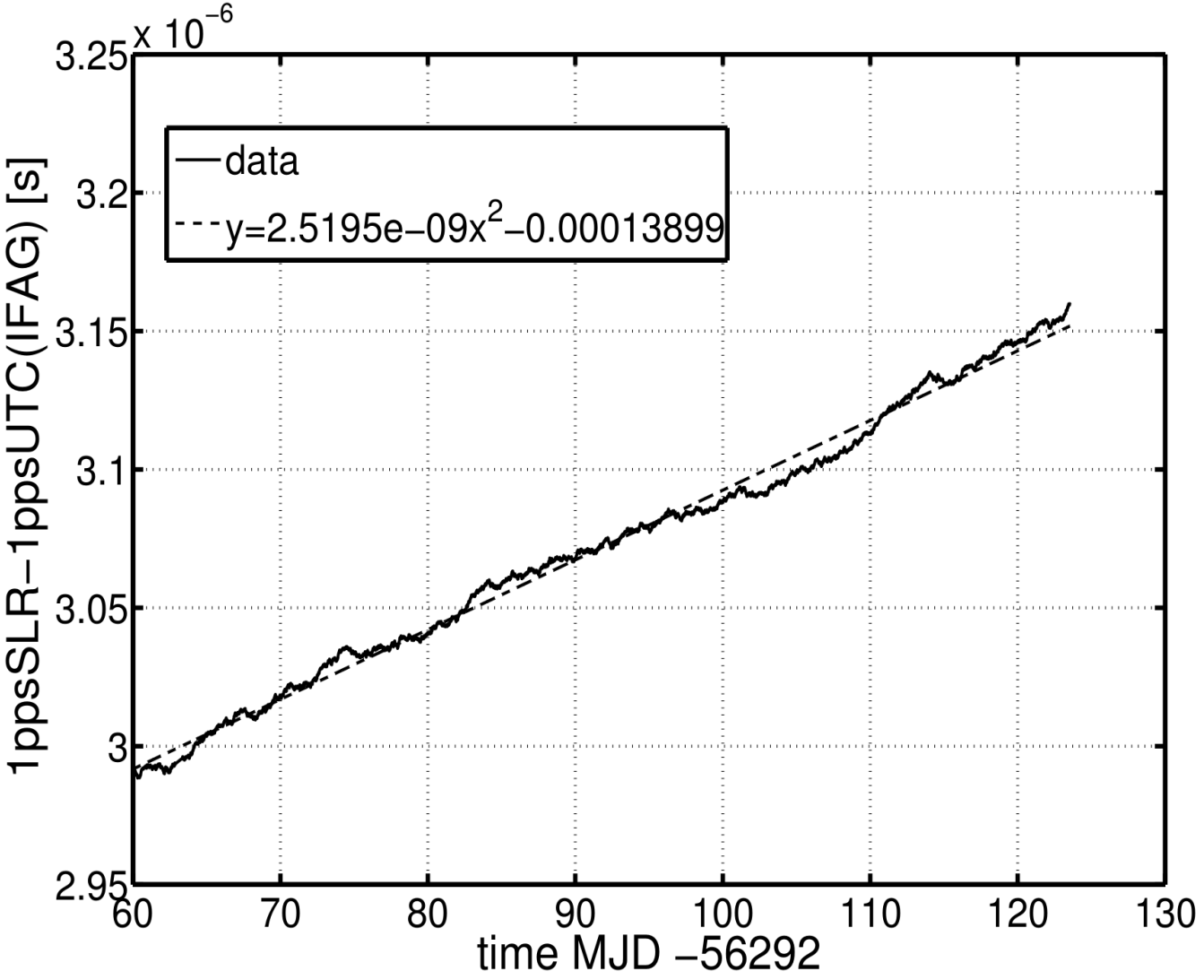


1) UTC(IFAG) SLR ref. point

2) GNSS WTZS SLR ref. point; comparing H masers

TWTT UTC(IFAG) ↔ SLR

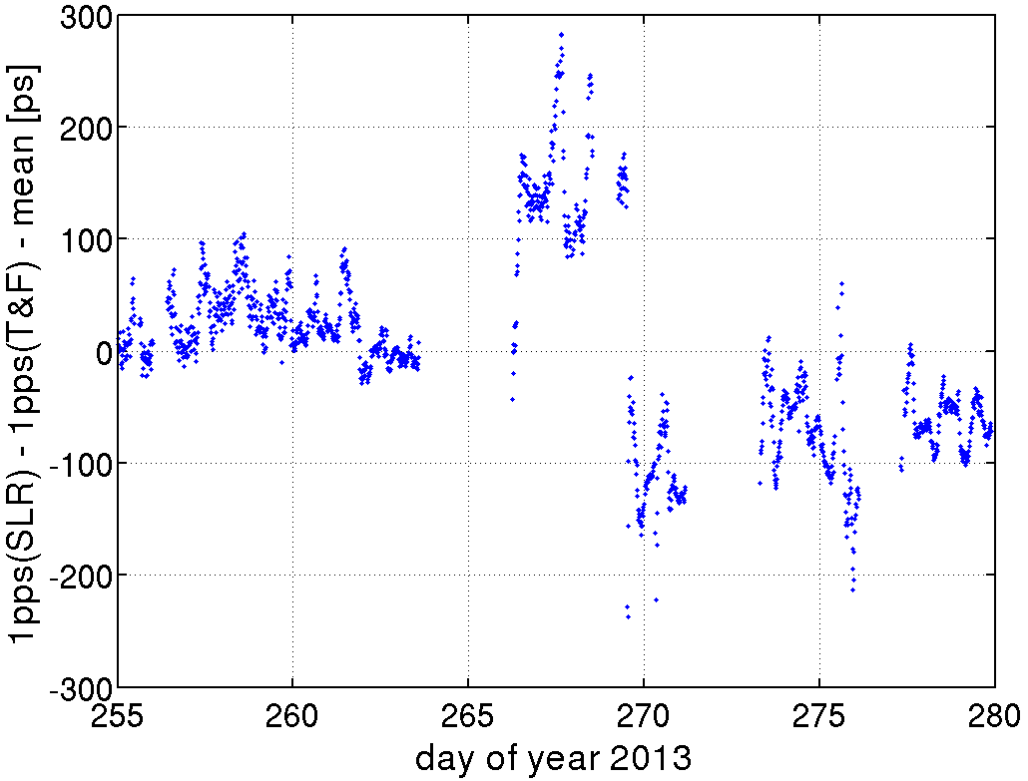
two different clocks



- UTC(IFAG) time scale is derived from Cesium
- SLR time scale is derived from H maser EFOS 18
- TWTT time scale comparison < 1ps rms
- T2L2 and ELT requires picoseconds control of local time scales

TWTT GNSS WTZS ↔ SLR

same clock, different passes

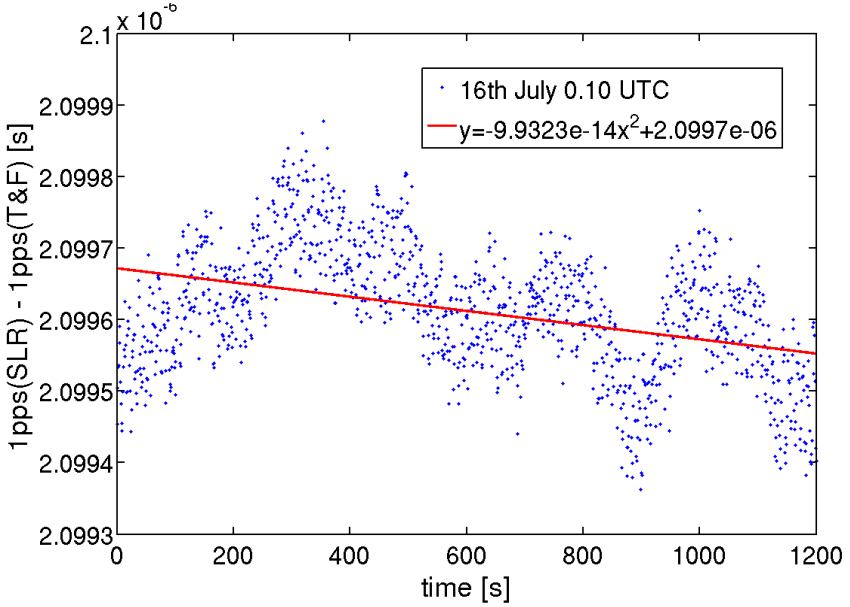


600 ps

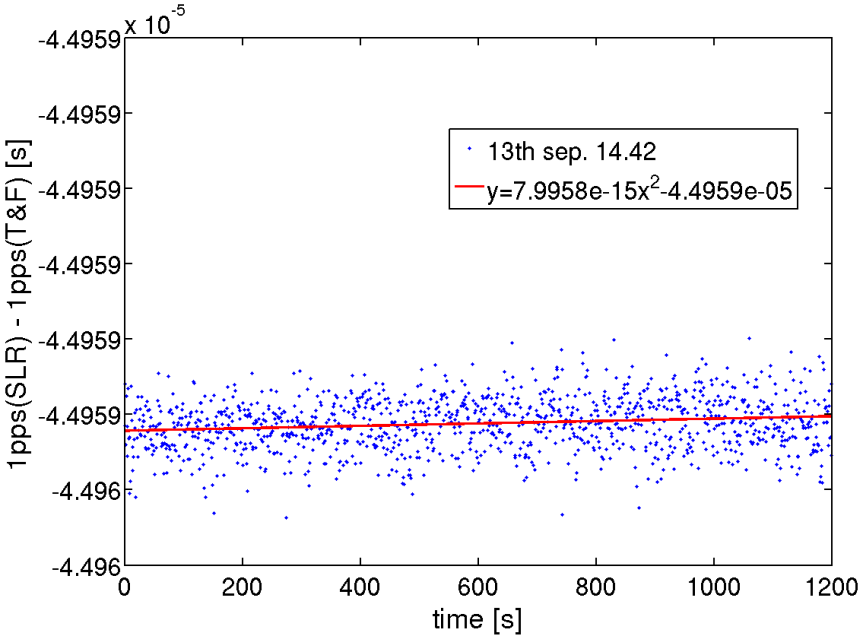
- Implementing TWTT method to support T2L2 and ELT time transfers
- Comparing T2L2 and GNSS time transfer
- TWTT was calibrated several times; consistency < 50 ps (BNC connectors)
- During the T2L2 campaign Wettzell was calibrated
- Comparing T2L2 calibration and TWTT results:
  - biggest difference 252 ps

TWTT implementation in to the observation

Comparing Cs vs. H maser during the pass

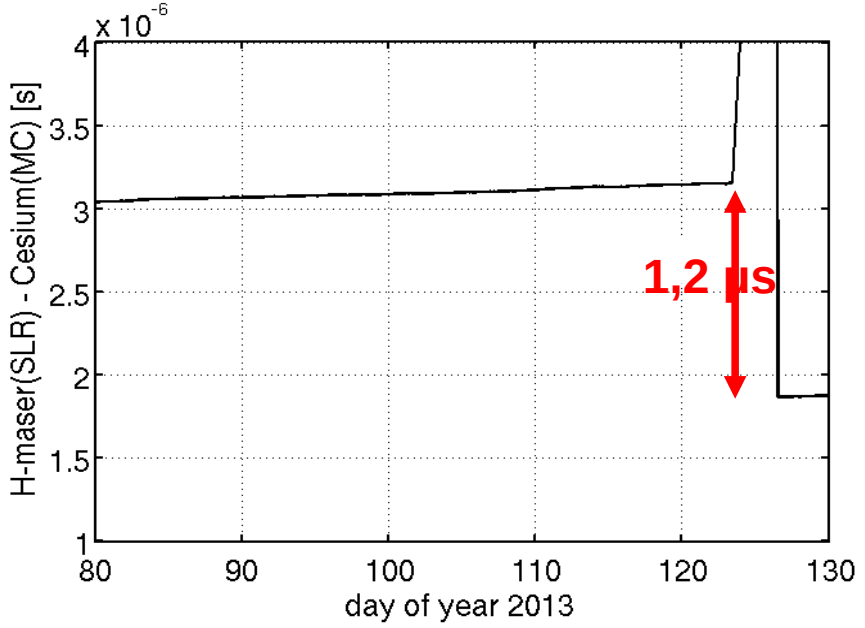


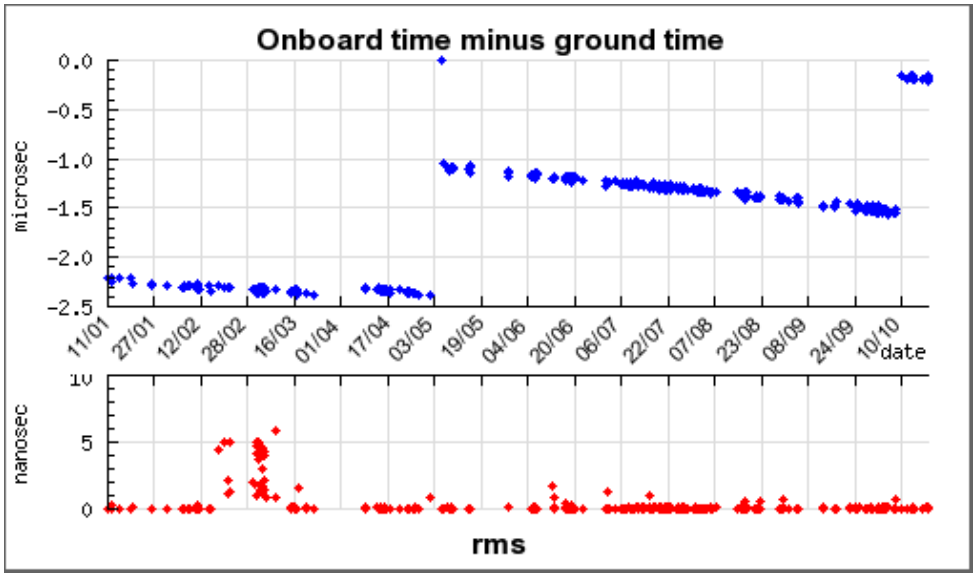
Comparing H maser vs. H maser during the pass



- Comparing Cs vs. H maser during 20 min pass
  - Observation must be corrected piecewise with linear fit
- Comparing H maser vs. H maser during 20 min pass
  - Observation can be corrected with linear interpolation
- *.NPT and .FRD (rate data) unchanged
- *.FRF - changed - including TWTT measurements and calibration T2L2/ELT

TWTT UTC(IFAG) ↔ SLR, problems





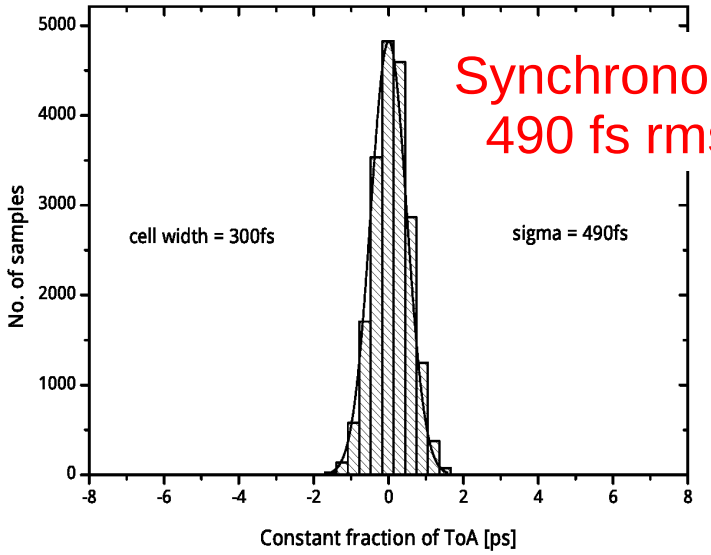
http://www.geoazur.fr/t2l2/en/data/v4/

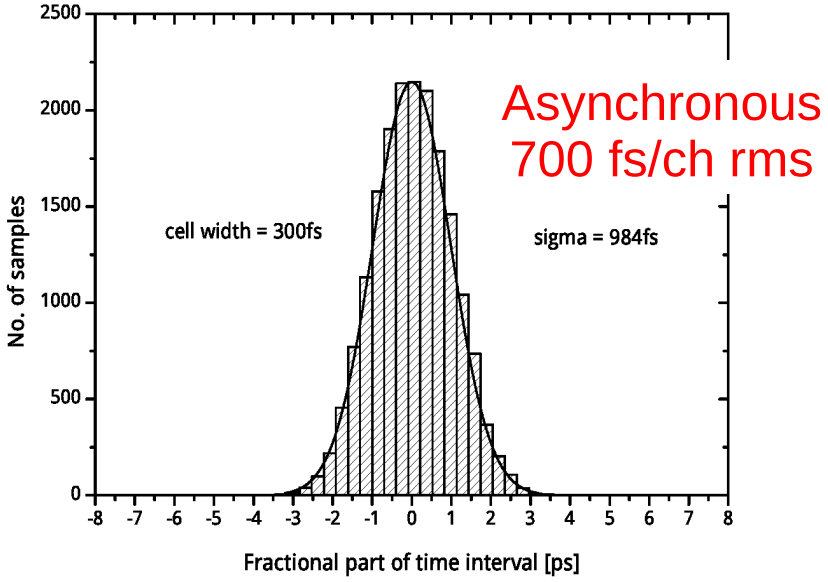
- Jumps in clocks in SLR; during storms
- The time bias is not corrected to the same value
- Problems when T2L2 calibrate us, the calibrations are not valid after the jump
- Mission calibration should be related only to SLR
- Time difference between SLR and another techniques (GNSS, MWL, …) must be reported
- Time setting in SLR Event timer works with uncertainty > 1 ns

Conclusion

- The possible implementation of Two Way Time Transfer method using two event timing systems was investigated in Geodetic Observatory Wettzell
- The absolute calibration for comparing time scales of TWTT was done (reproducibility < 50 ps)
- In the frame of T2L2 campaign Wettzell was calibrated. Calibration is within 250 ps compared to TWTT
- In future it is planned to apply TWTT measurements in to *.FRF

Event timing system - New Pico-Event Timing





Temperature dependence ~170 fs/K

TDEV < 4 fs (τ= 300 s up to 2 h)

Timing jitter:

- Synchronous pulse ~ 490 fs rms
- Asynchronous pulse ~ 700 fs/ch rms

TWTT systematic error < 10ps

> 4 kHz measurement rates, depends on quality of interconnecting cable