Time and Frequency Activities

GUM, Poland

Albin Czubla

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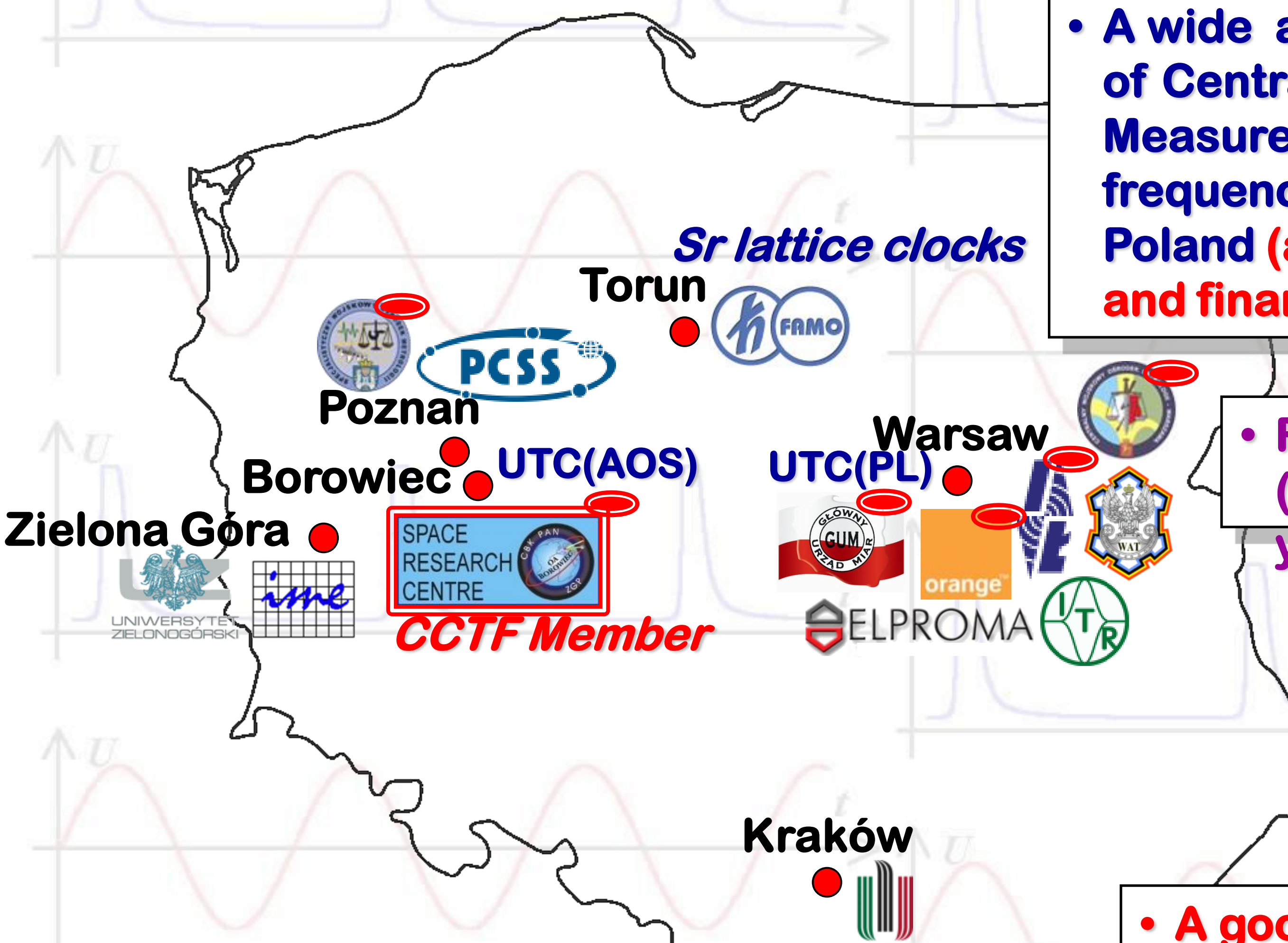
Introduction 1/2

Central Office of Measures (GUM – polish: *Główny Urząd Miar*) is a National Metrology Institute responsible for the highest level of measurement traceability in the most metrology domains in Poland. Established in 1919.

Introduction 2/2
(Time and Frequency community in Poland)

GŁÓWNY URZĄD MIAR GUM

- A wide area of cooperation of Central Office of Measures within time and frequency community in Poland (according to formal and financial capabilities)



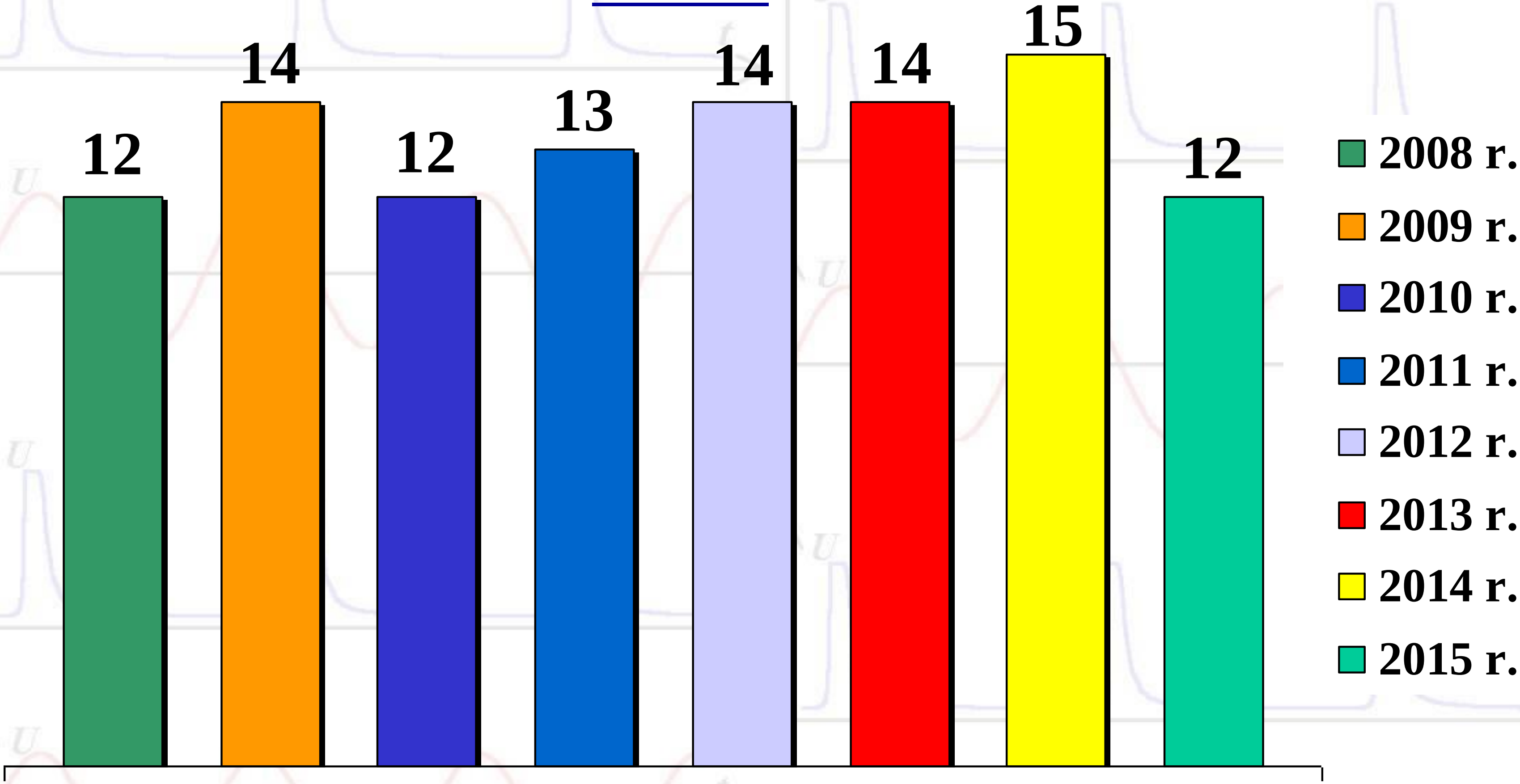
- Regular meetings (once or twice a year)

- Common projects and/or working cooperation/ consultation

- A good environment to discuss new ideas, improvement methods, ...

- atomic clocks compared against UTC(PL) and participating in TAI and UTC

A wide contribution of the Polish clocks in TAI / UTC



Number of Polish clocks contributing in TAI and UTC

This requires GUM to analyse measurement data, recognize any abnormal behaviour and regulary determine differences between clocks and UTC(PL)

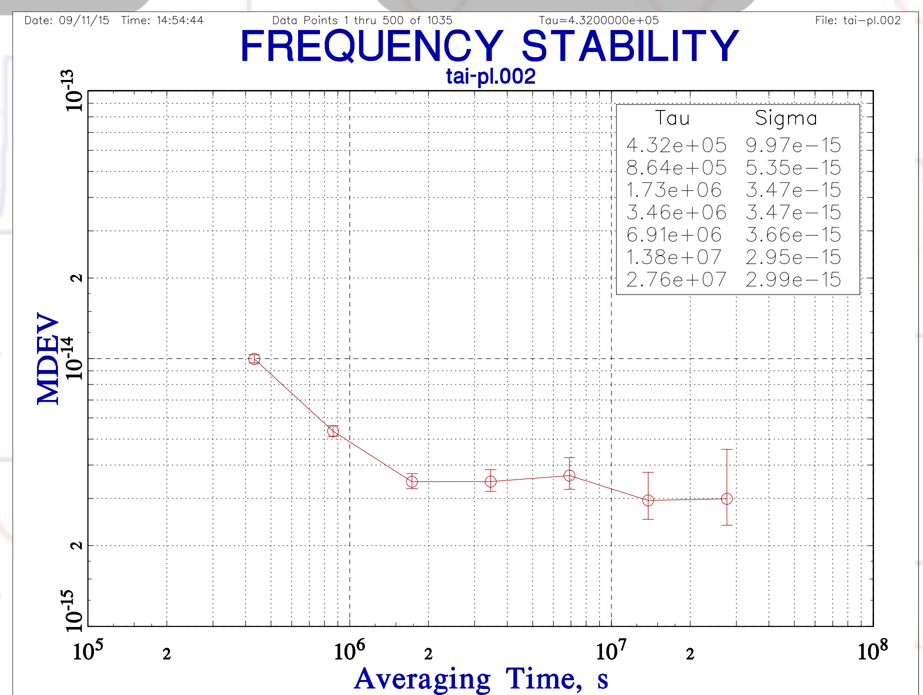
The Polish independent atomic timescale TA(PL)

Published in Circular T since 2001

$\{UTC(PL) - Clock(x)\}$ $\{TA(PL) - Clock(x)\}$

GUM → AOS SRC PAS → TA(PL) TA(PL) TA(PL)

computed scale



10^{-13}

10^{-14}

10^{-15}

10^{3} 10^{4} 10^{5} 10^{6}

contributing clocks

CONTINUOUS COMPARISONS

Main T&F activities at Central Office of Measures

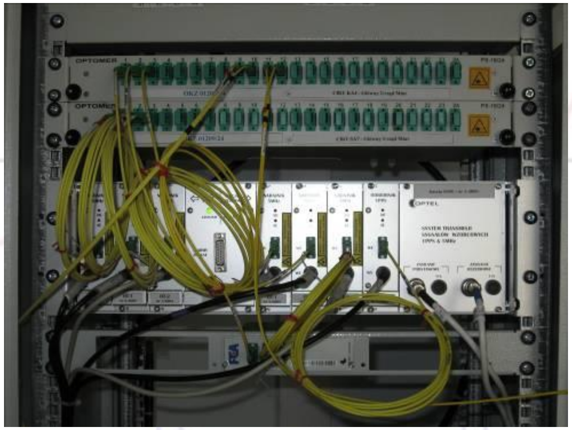
1. T&F national standard, UTC(PL), TA(PL) and coordination in-country comparison within participation of PL in TAI and UTC

2. Precise time and frequency transfer over optical fiber links

3. GNSS time transfer system performance monitoring

4. Analysis of precise time interval measurements performed with Time Interval Counters

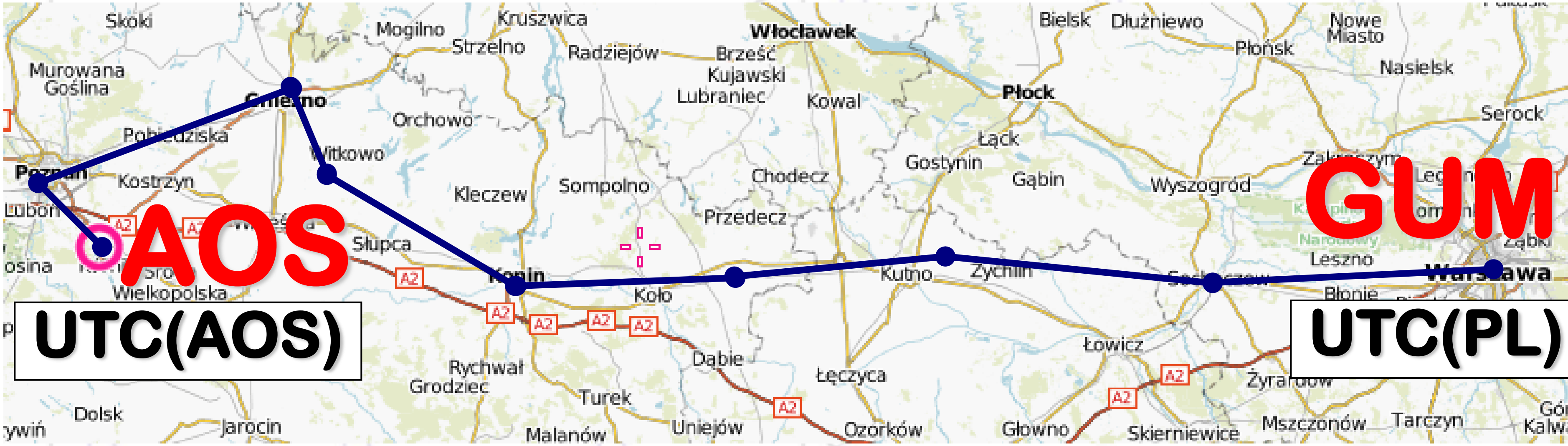
Active participation in the activities of TCTF EURAMET - sharing the knowledge and experience



2. Precise time and frequency transfer over optical fiber links

Avaliable optical fiber connections - locally

Long distance optical fiber connection:
GUM-AOS



270 km – the distance in a straight line

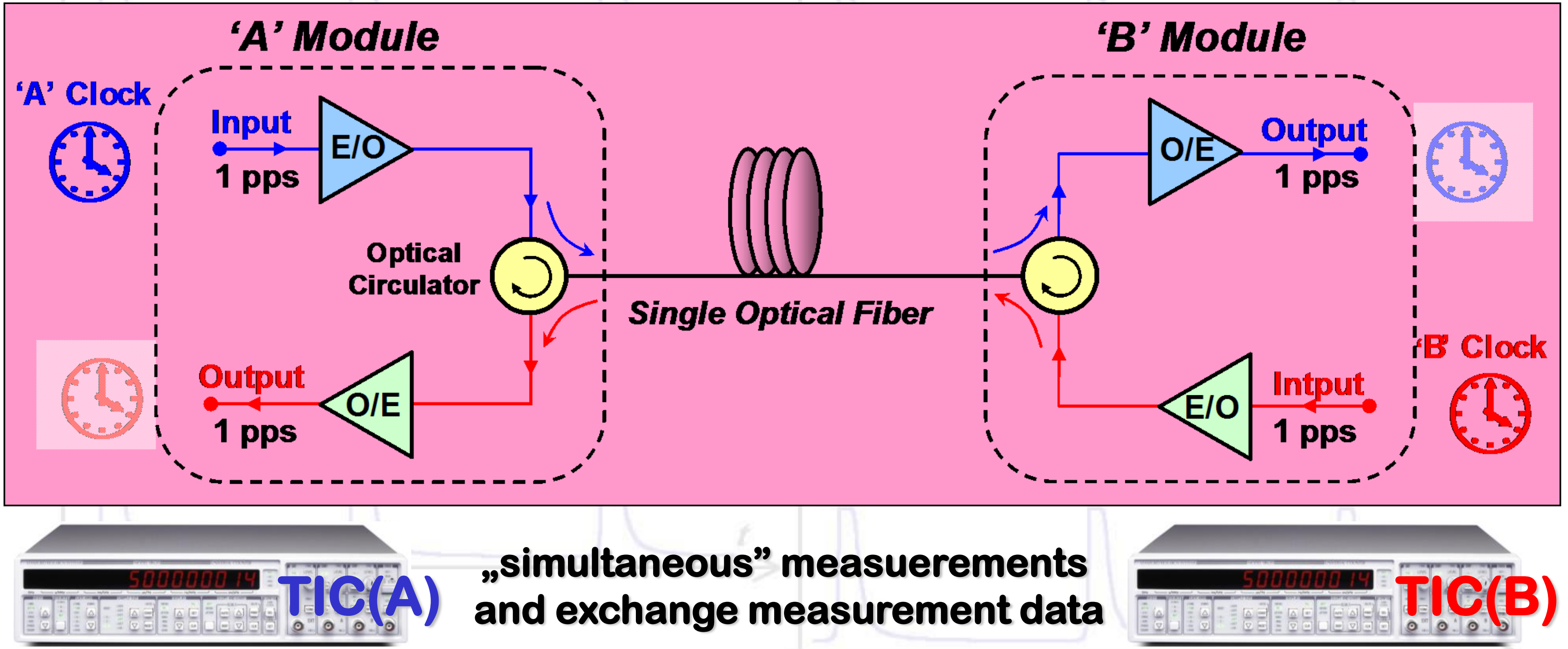
420 km – the distance along optical fiber

120 dB – attenuation (6 amplifiers)

300 ns – annual variations of optical fiber delay

1700 ps/nm – accumulated chromatic dispersion

Applied methods: standard Two-Way Method

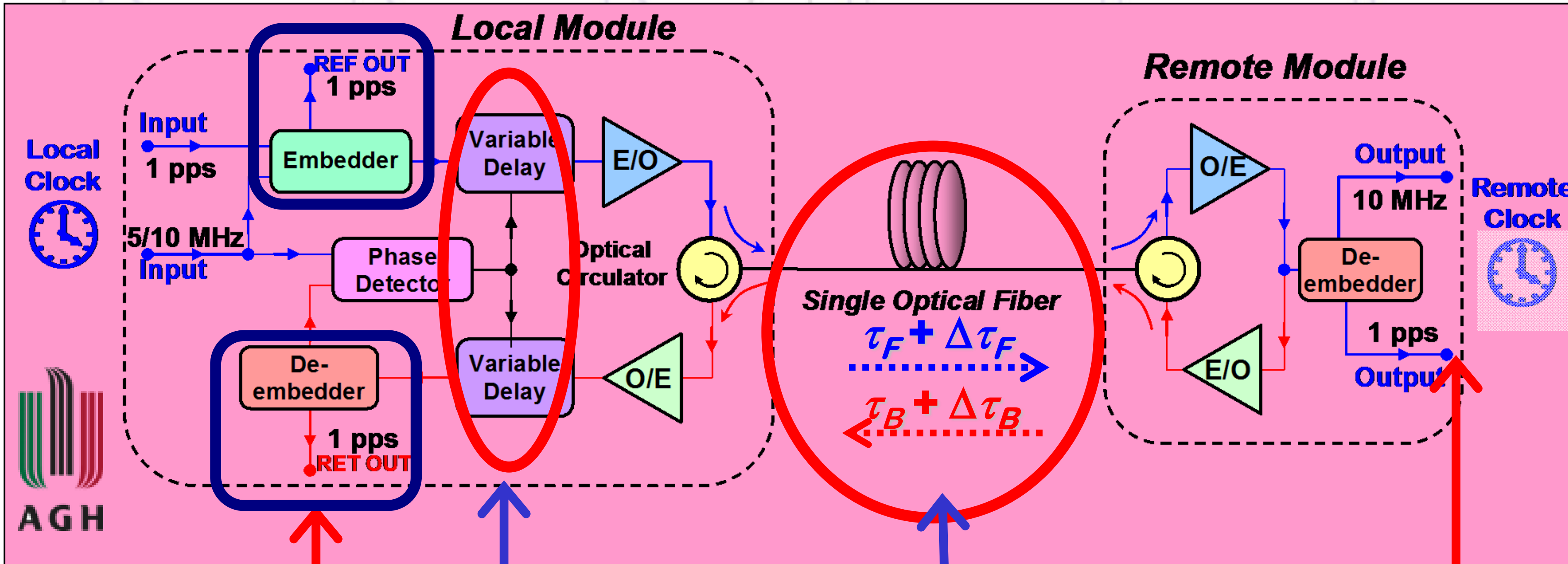


„simultaneous" measuerements and exchange measurement data

$$Clock(A) - Clock(B) \approx \frac{TIC(A) - TIC(B) - Dly_{B \to A} + Dly_{A \to B}}{2}$$

$$U_{cal} \approx 0.6 \text{ ns}$$

Applied methods: stabilization of propagation delay



Possible calibration during operation of the link

Electronic Variable Delay Lines

Optical fiber subject to change Delay

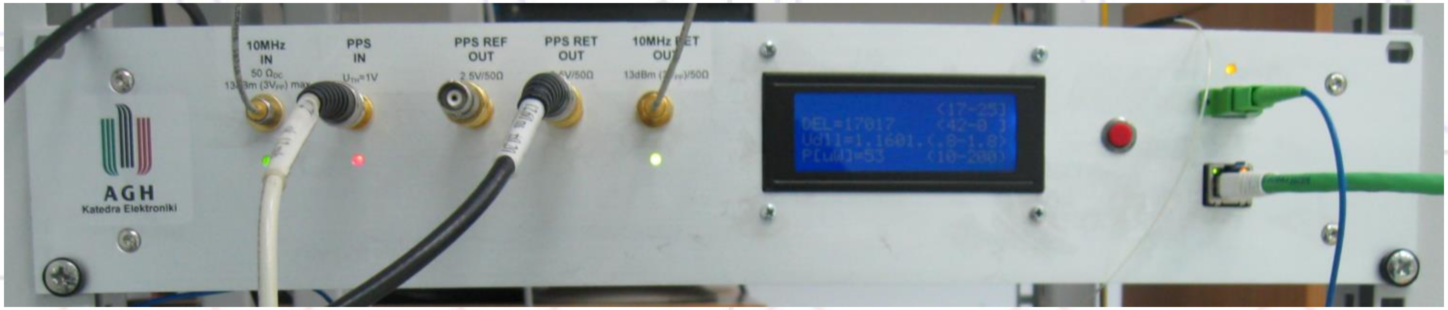
Stabilised propagation Delay

$$\Delta\tau_F \approx \Delta\tau_B$$

$$\Delta\tau_{DF} \approx \Delta\tau_{DB}$$

$$\Delta\tau_{DF} + \Delta\tau_F = \Delta\tau_{DB} + \Delta\tau_B \approx 0$$

Calibration of the link: calibration avaliable „*on request*”



$$\tau_{IN \to OUT} = \frac{1}{2}\tau_{REF \to RET} + \tau_{IN \to REF} + \frac{1}{2}\left(\tau_{FIB\_F} - \tau_{FIB\_B}\right) + \frac{1}{2}\tau_H$$

During 3½ years of operation of the link GUM-AOS:

3 – times there occured planned intentionaly small changes of the optical fiber connection

8 – times there occured unexpected braeking of optical fiber connection (need to weld breaks)

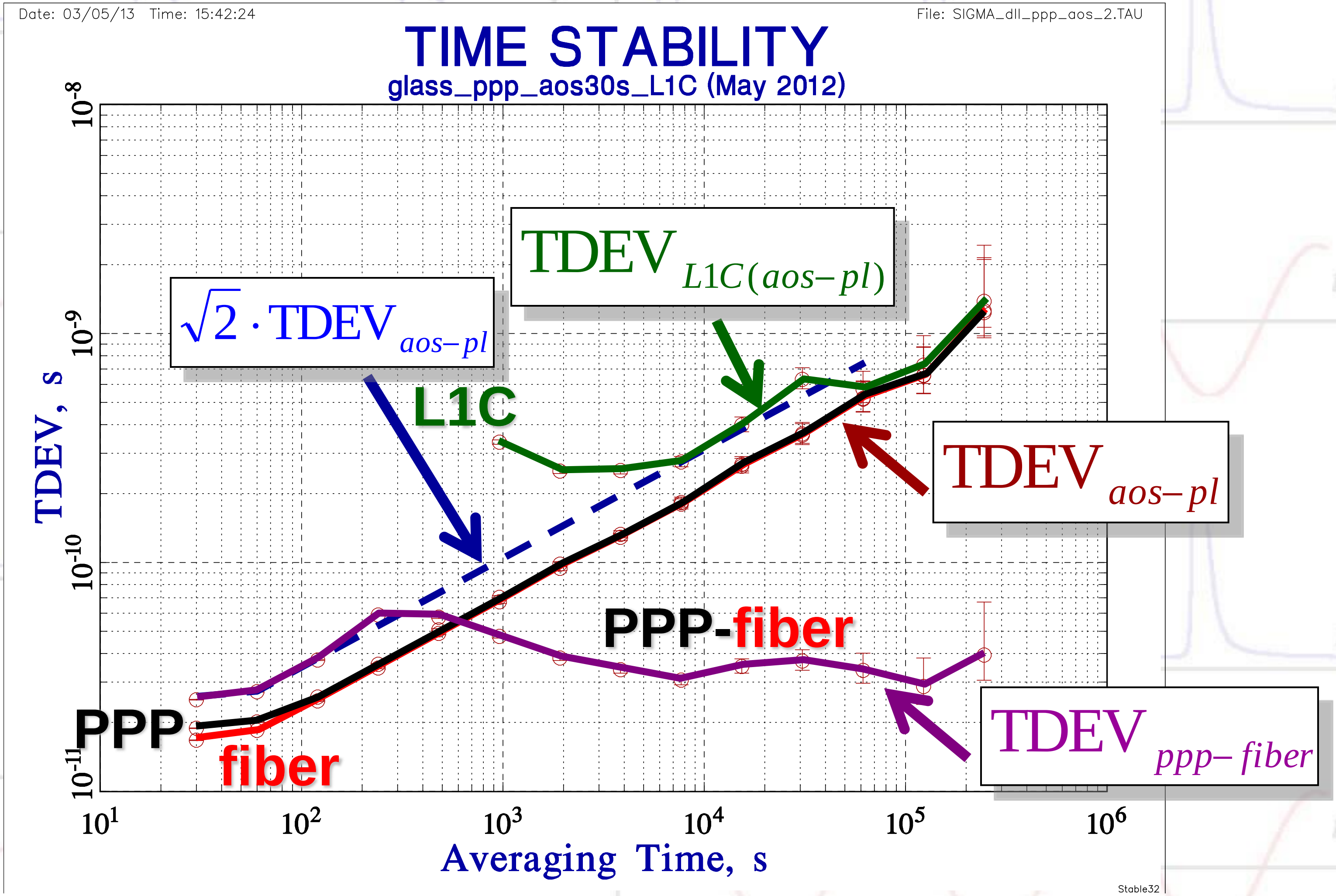
Examplary uncertainty budget of calibration of the link GUM-AOS

	determined quantity	estimate	sensitivity coefficient	standard uncertainty	uncertainty contribution
1	$\tau_{UTC(PL)\rightarrow REF}$ (a)	420.17 ns	1	100 ps	100 ps
2	$\tau_{REF\rightarrow RET}$ (a)	4 093 944.73 ns	0.5	100 ps	50 ps
3	$\tau_{\Delta\lambda}$ (b)	2.950 ns	0.5	19 ps	9.5 ps
4	τ_{S} (c)	-1.686 ns	0.5	5 ps	2.5 ps
5	τ_{B} (d)	0 ns	0.5	1.2 ps	0.6 ps
6	τ_{H} (e)	26.565 ns	0.5	8.8 ps	4.4 ps
	$\tau_{UTC(PL)\rightarrow OUT}$	2 047 406.45 ns	complex uncertainty:		112.3 ps

For TIC with u = 10 ps, it is possible to obtain uncertainty of calibration of 16 ps

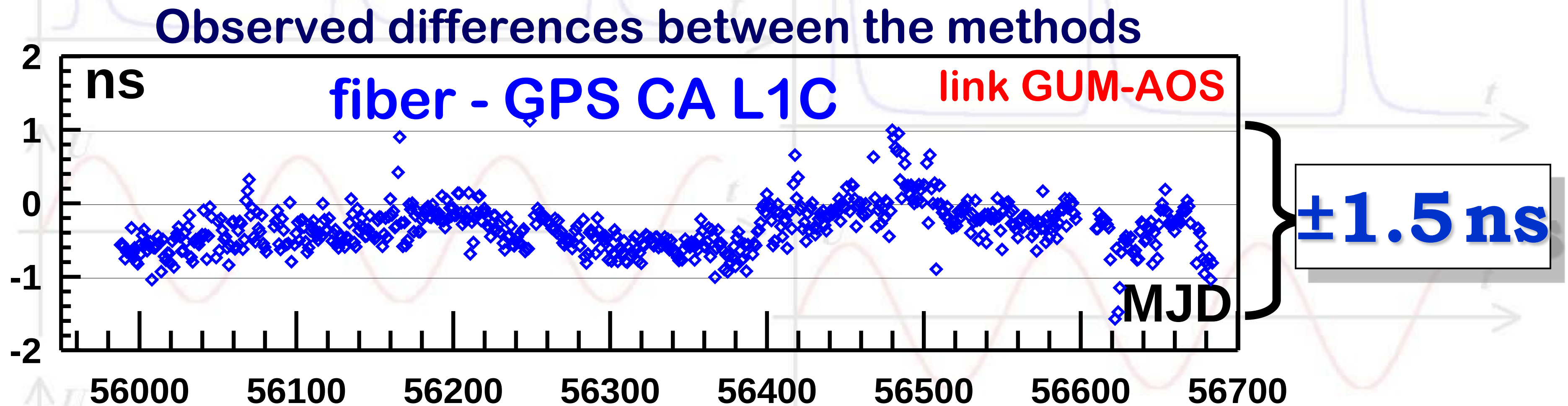
Stability of measurements UTC(AOS)-UTC(PL)

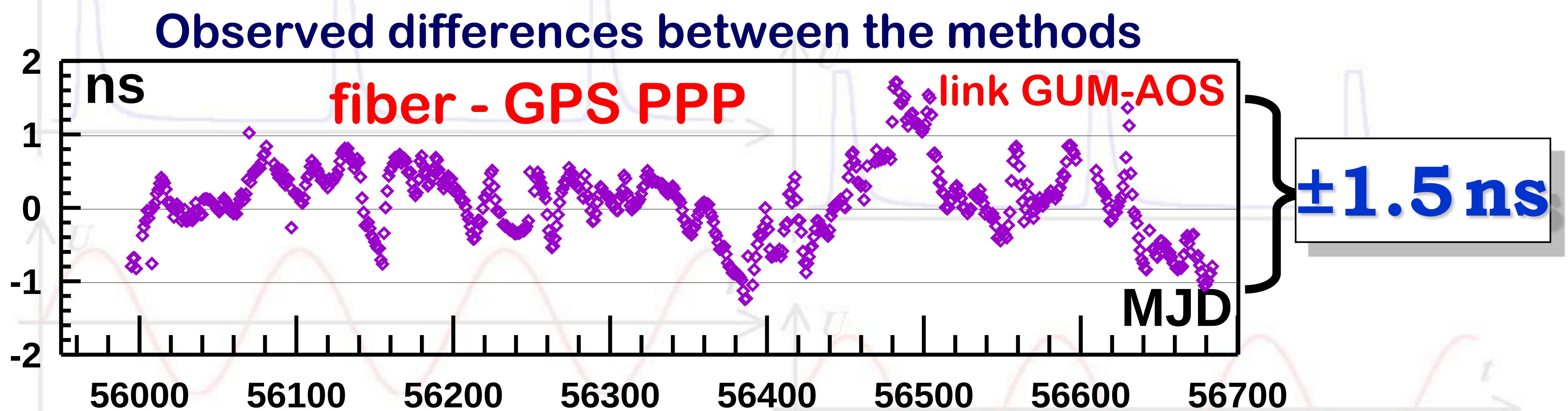
(PPP, fiber link, L1C and a difference: PPP-fiber)



The short-term stability of the PPP and fiber link are practically the same, but …

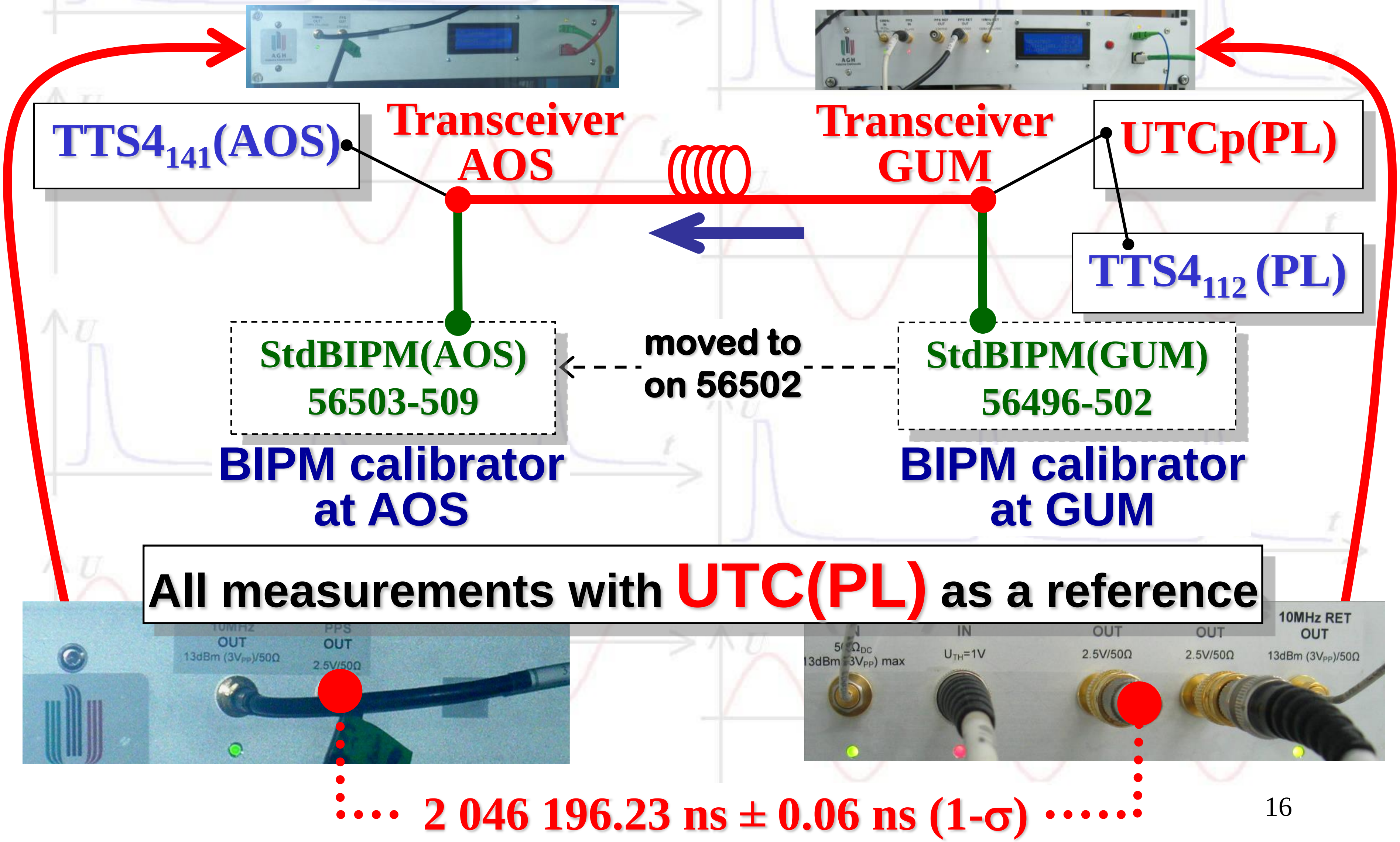
Results of measurements UTC(AOS)-UTC(PL)
(differences: fiber-L1C and fiber-ppp)



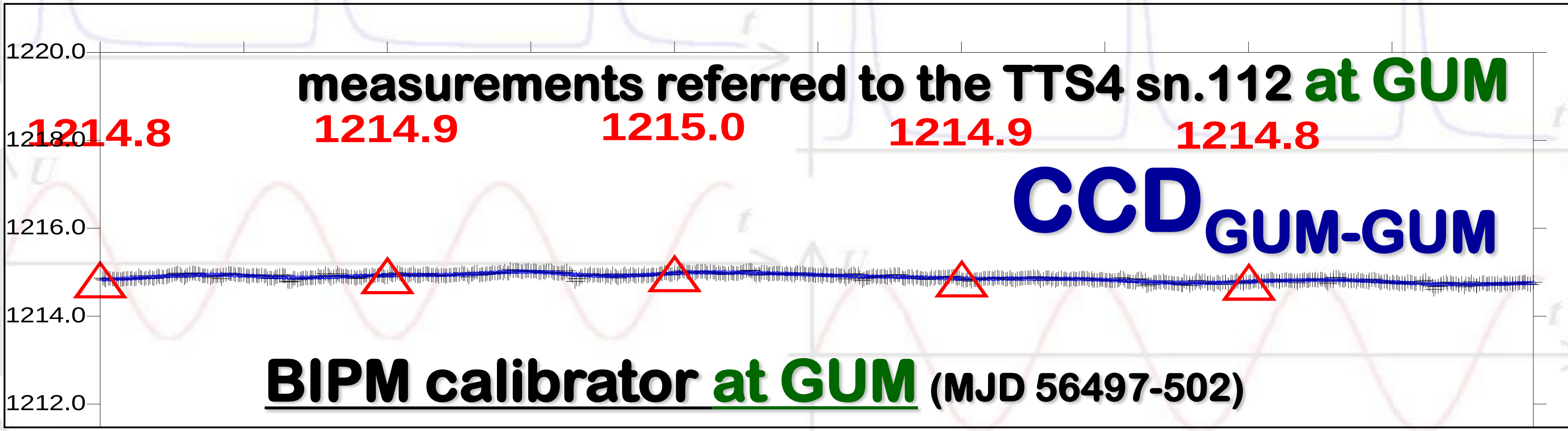


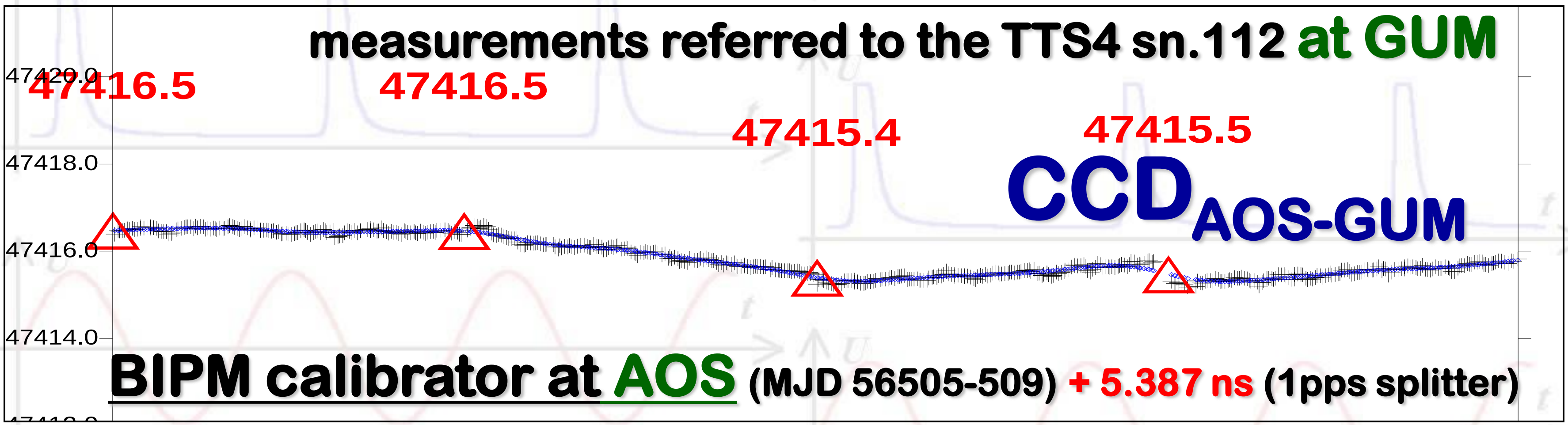
… the observed differences fluctuate within c. ±1.5 ns.
Imperfections of calculations or other effect?

Measurements with BIPM calibrator at optical fiber link GUM-AOS



PPP results: BIPM -TTS4 sn.112 GUM



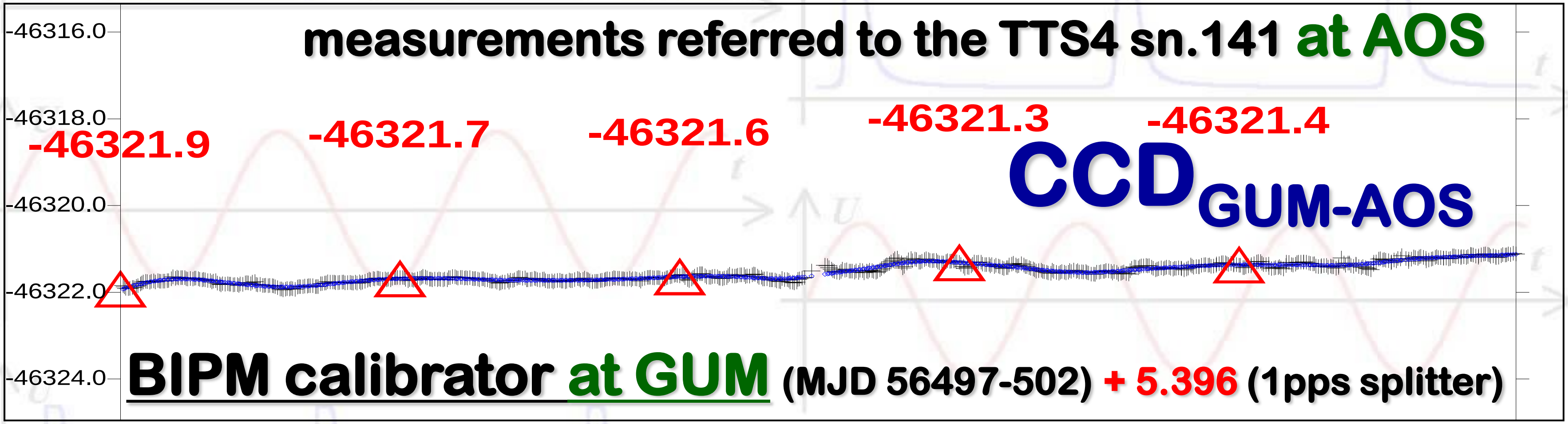


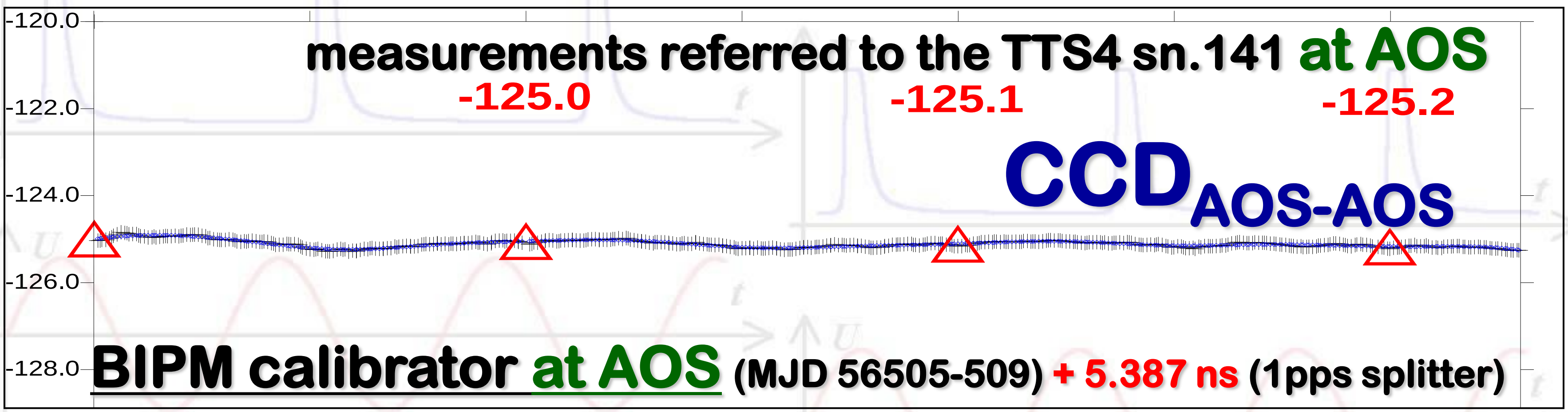
2 046 195.37 ns ± 0.67 ns

2 046 196.23 ns ± 0.06 ns

PPP – OF = -0.86 ns ± 0.67 ns

PPP results: BIPM -TTS4 sn.141 AOS





2 046 195.96 ns ± 0.67 ns

2 046 196.23 ns ± 0.06 ns

PPP – OF = -0.27 ns ± 0.67 ns

3. GNSS time transfer system performance monitoring

Own earlier works at GUM and … works within the 1152 Project

1152

Started in 2010

GNSS receiver performance monitoring

nges of
elays of different
nt data taken
so the data taken
clocks, but with
ce

TARGET

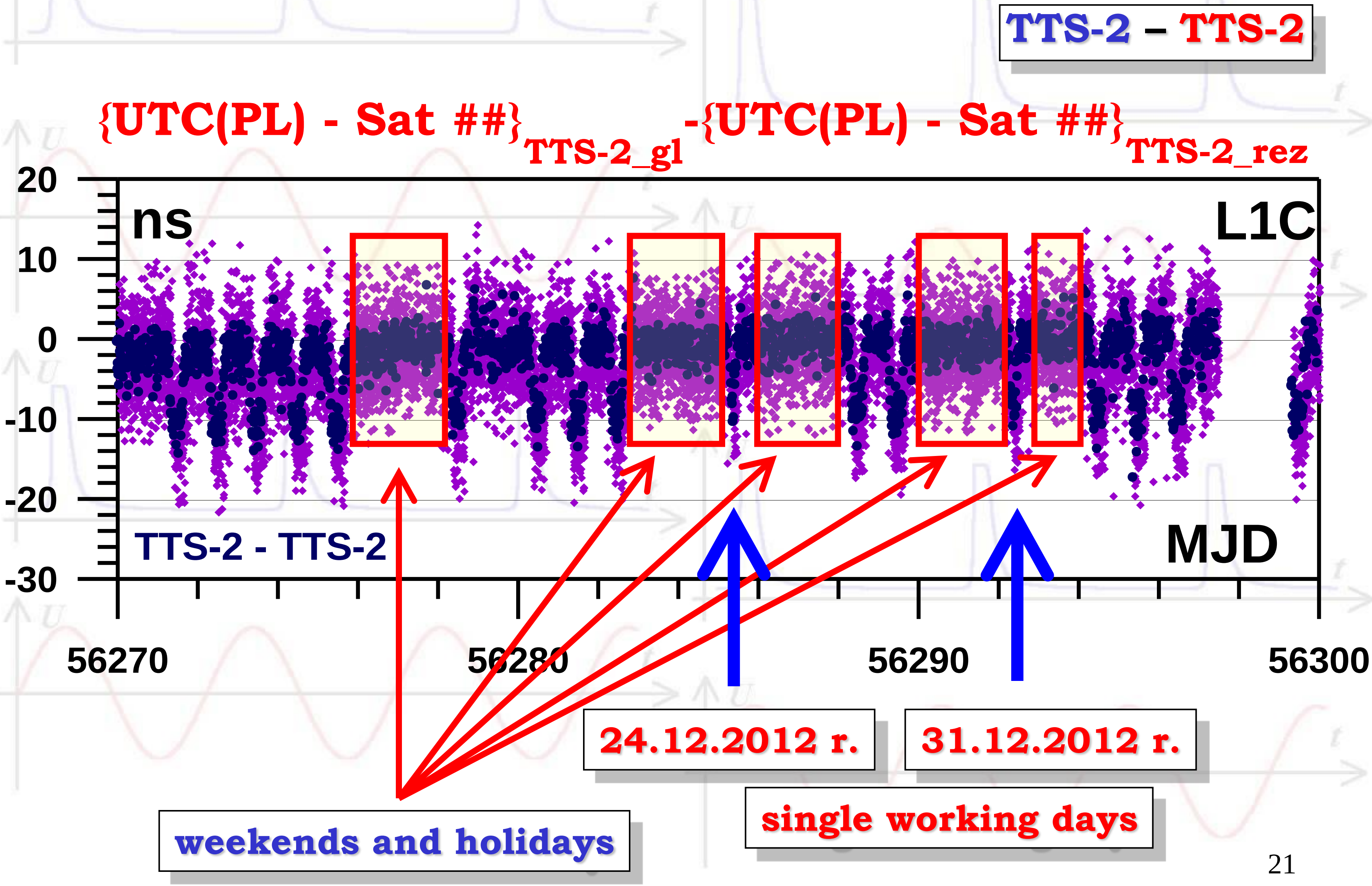
… to monitor a difference between two or more GNSS receivers located at the same Lab and steered with the same Ref 1 pps signal …

practically, this difference can vary due to
equipment, different type of antennas ar
assumed that the data will be collected a
permanent observations. The analysis will
measurement data in CGGTTS format.
calibrated because the subject of investiga
one in the pair.

PARTICIPANTS

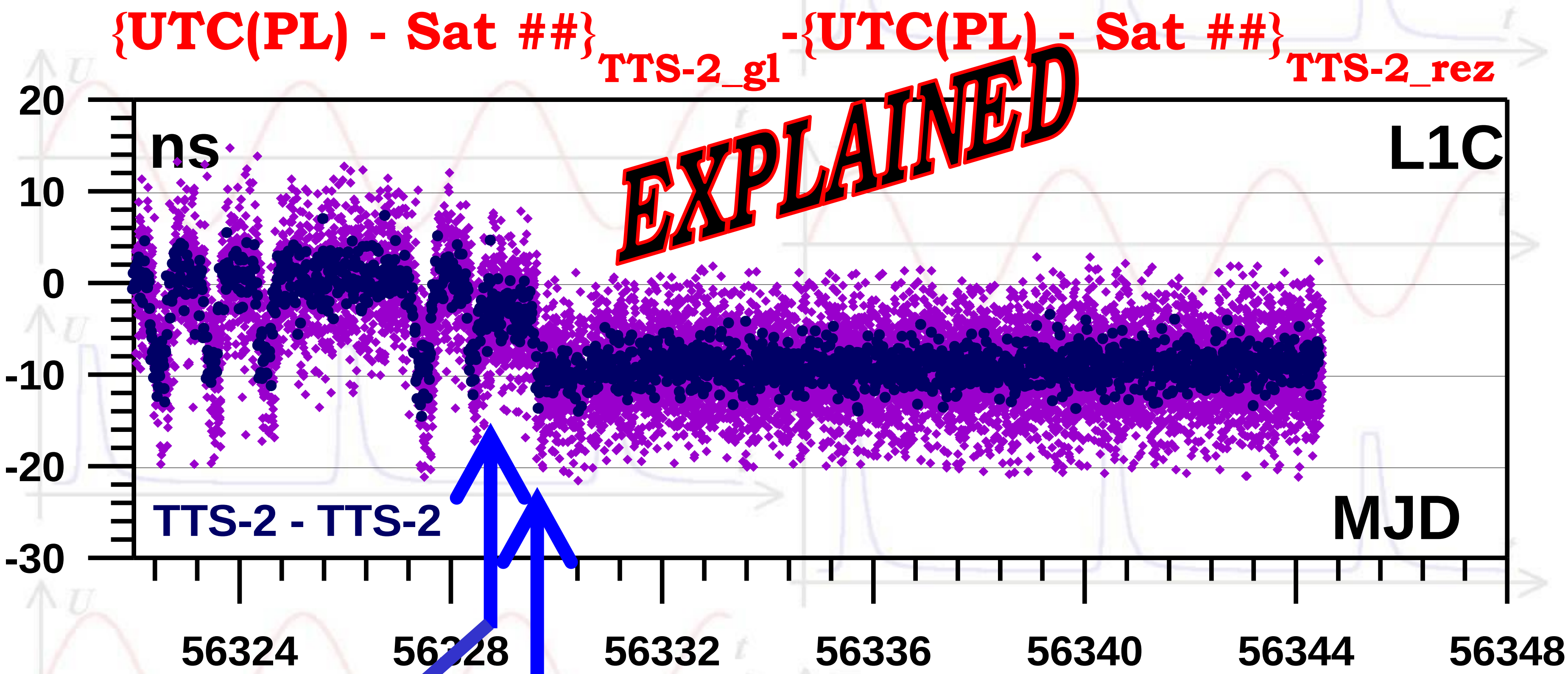
BEV (Austria)
ÙFE/IPE (Czech Republik)
PTB (Germany)
SP (Sweden)
GUM (Poland),
…

GPS CV - code CA L1C: GUM



GPS CV - code CA L1C: GUM

TTS-2 – TTS-2

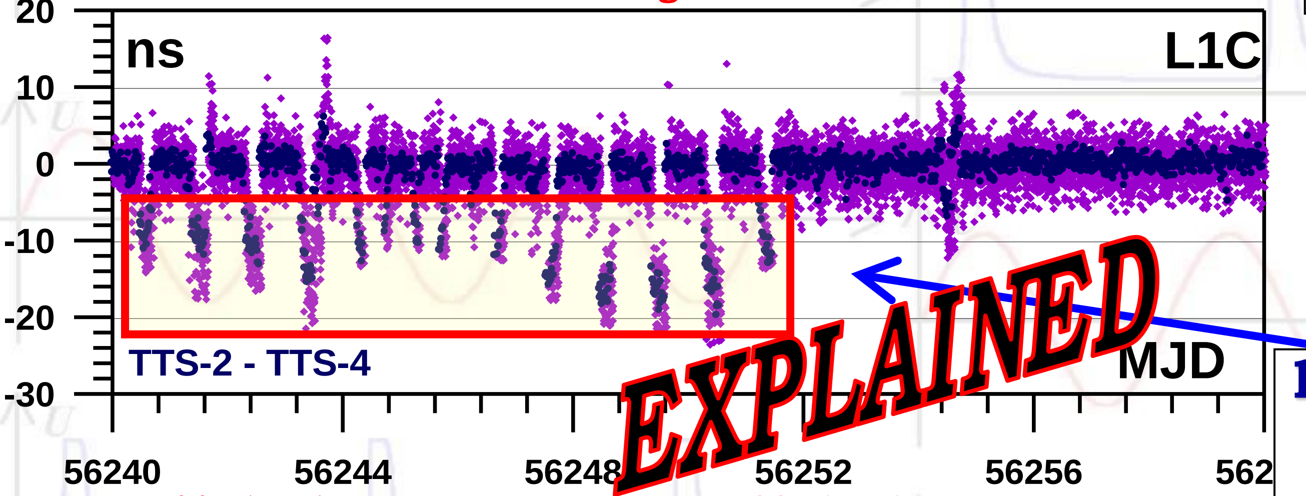


1. the change of localization of GPS receiver and antenna cable (further away from the monitor)

2. removal of dirty inside the receiver (corroded sponge flooded electronic inside receiver)

GPS CV - code CA L1C: GUM

{UTC(PL) - Sat ##}$_{TTS\text{-}2\_gl}$-{UTC(PL) - Sat ##}$_{TTS\text{-}4}$

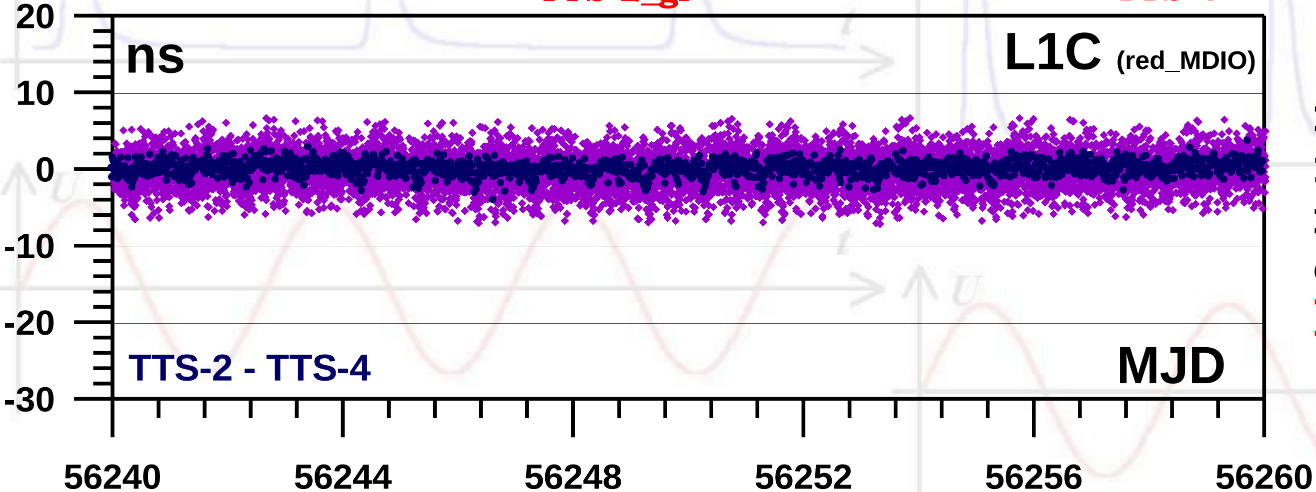


TTS-2 – TTS-4

results with modelled ionospheric corrections (MDIO)

lack of conformity of ionosperic models

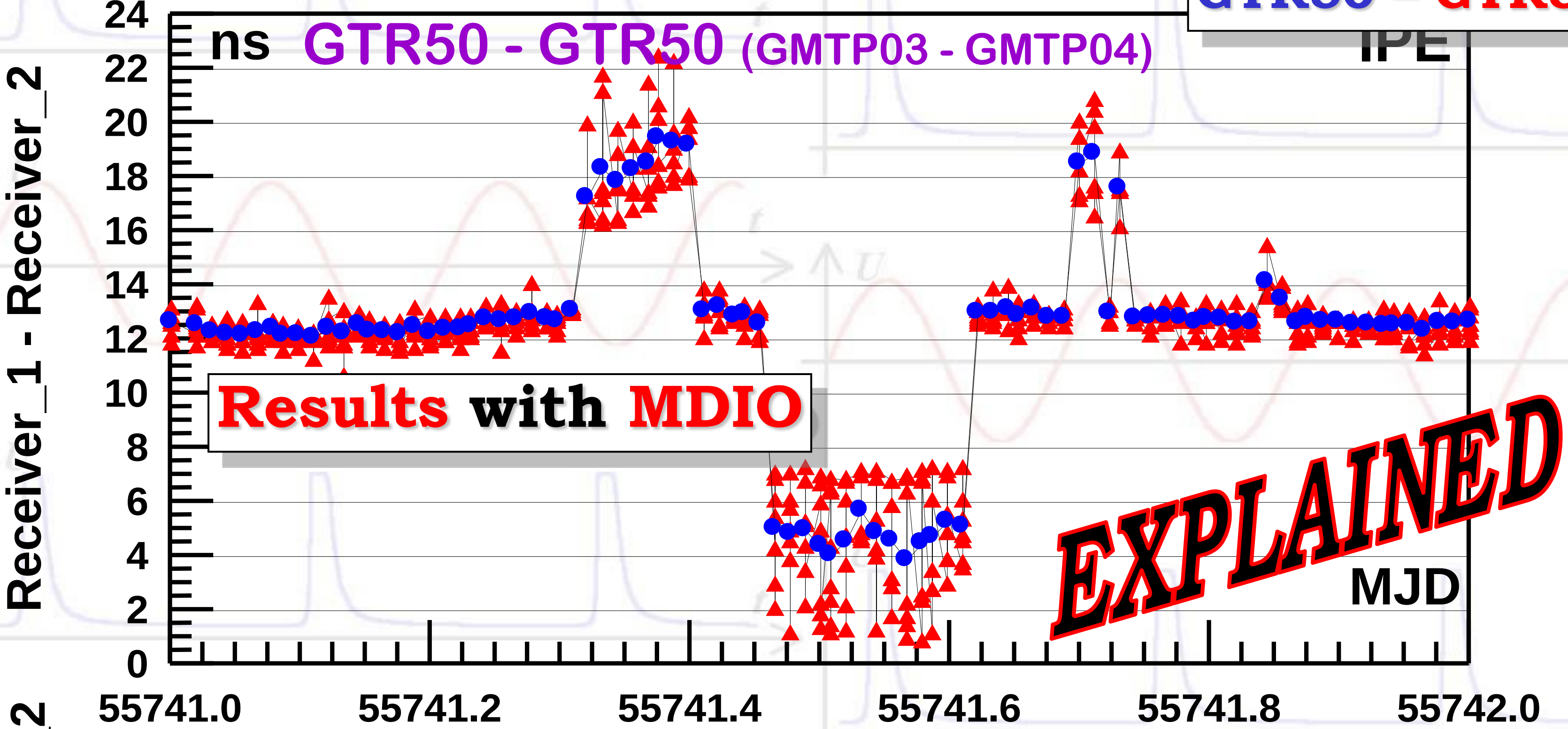
{UTC(PL) - Sat ##}$_{TTS\text{-}2\_gl}$-{UTC(PL) - Sat ##}$_{TTS\text{-}4}$

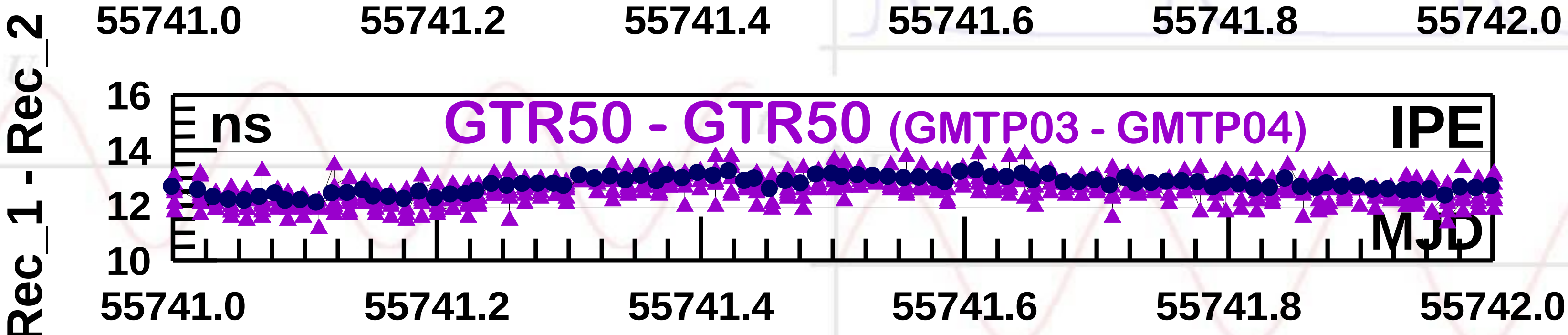


results without modelled ionospheric corrections (no MDIO)

GPS CV - code CA L1C: IPE

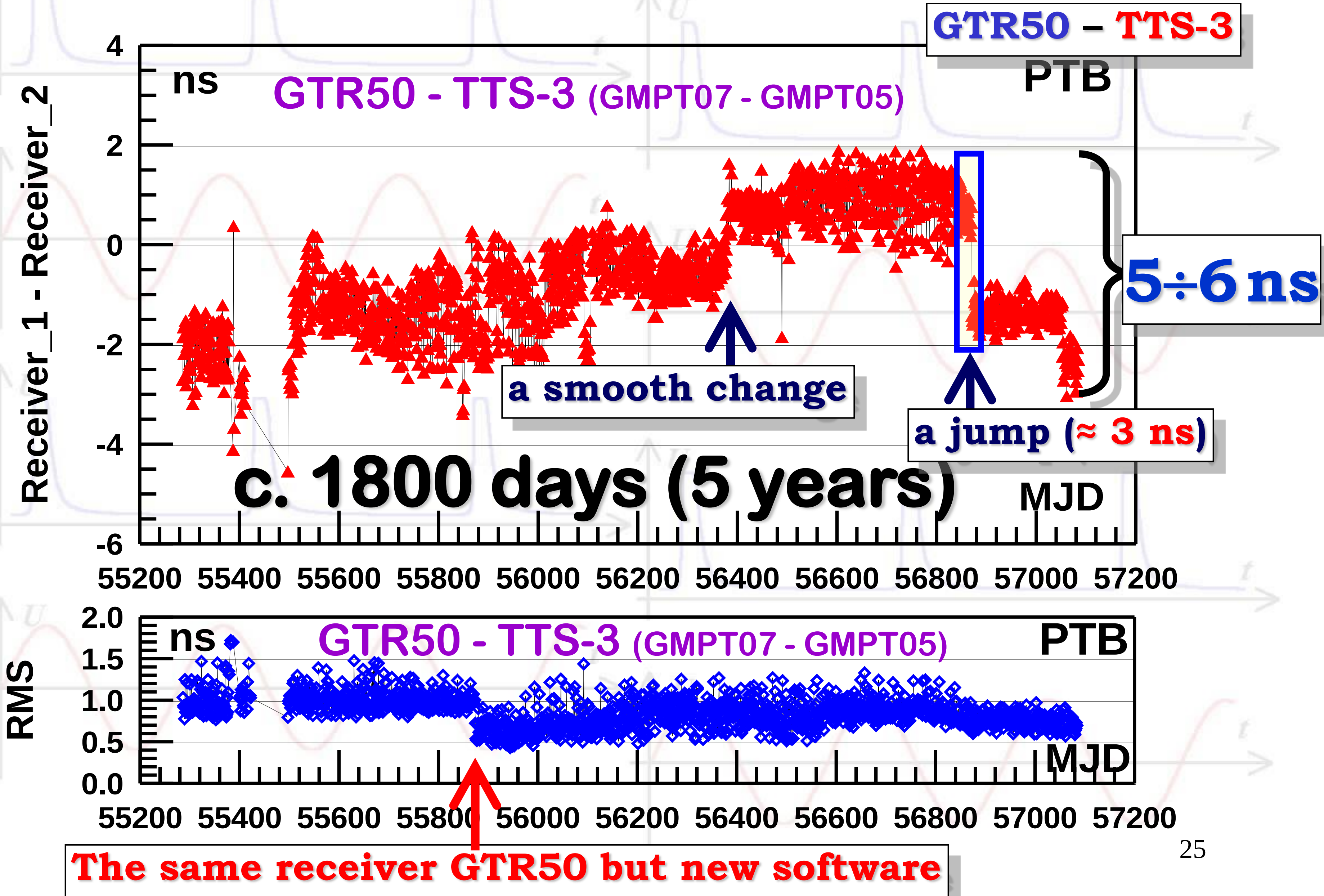
GTR50 – GTR50



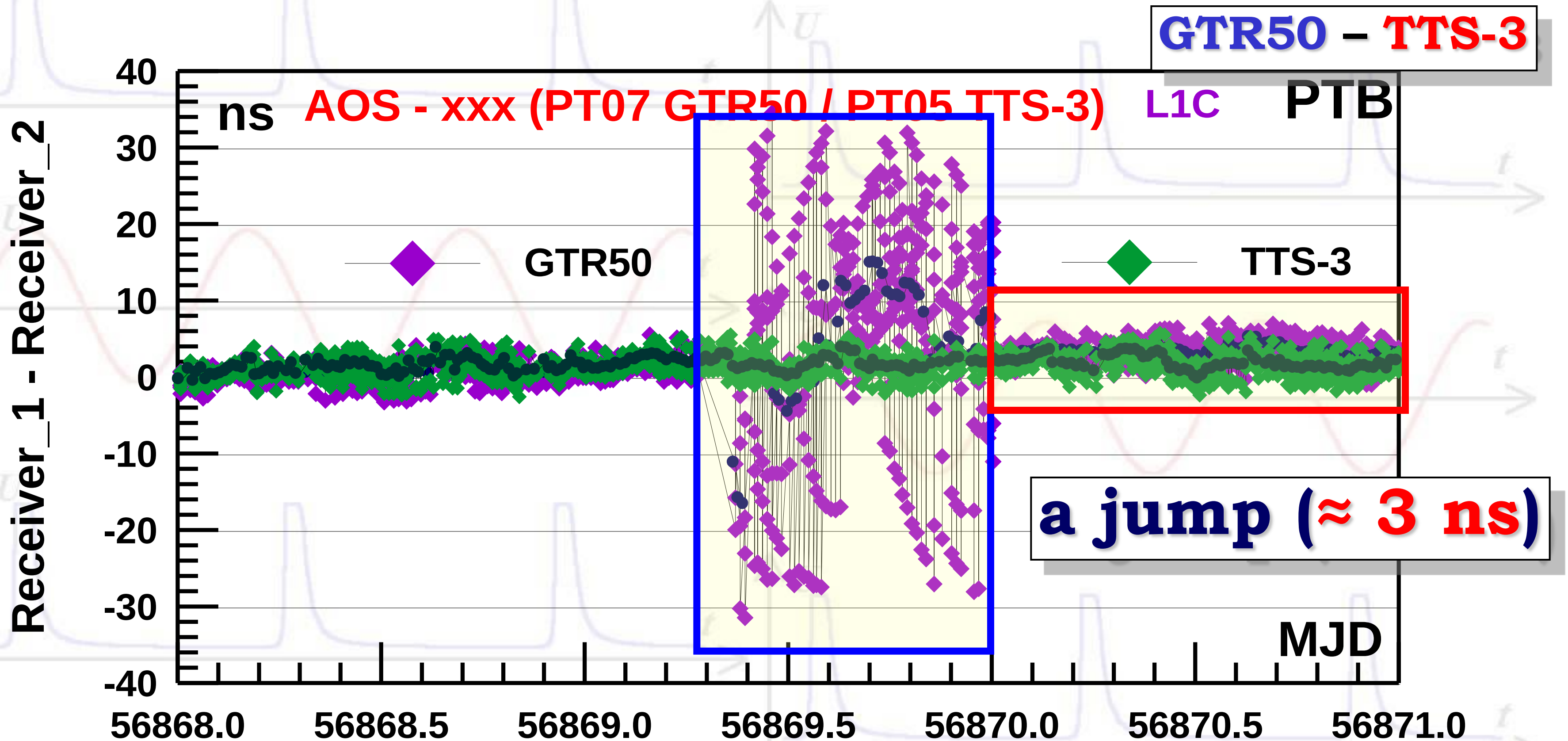


Results without MDIO

GPS CV – L1C: PTB



GPS CV – L1C: PTB



Measurments results around the change

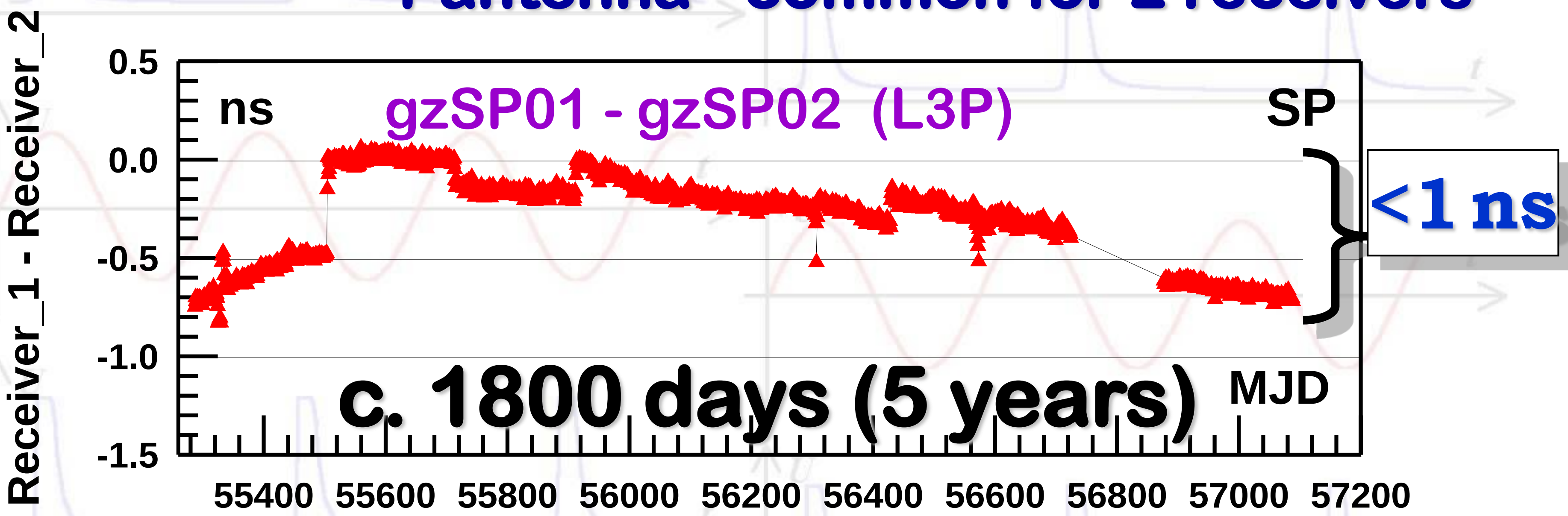
(referred to an external timescale: here to UTC(AOS))

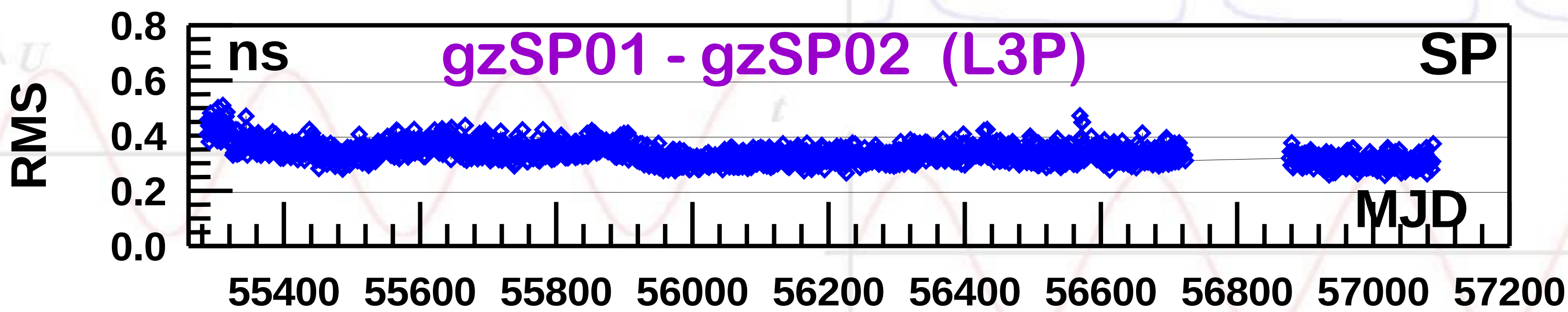
Some operation was done at GTR50 and caused a jump?

(the same is observed for L3P)

GPS CV - L3P: SP

1 antenna - common for 2 receivers





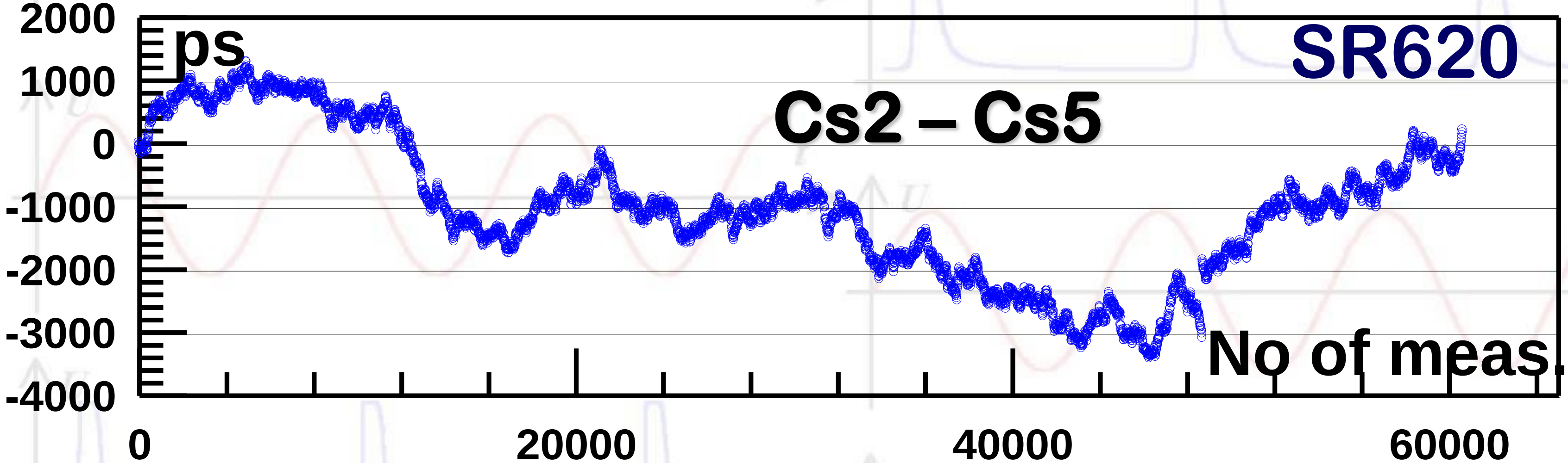
4. Analysis of precise time interval measurements performed with Time Interval Counters

with the help of A7-MX and …

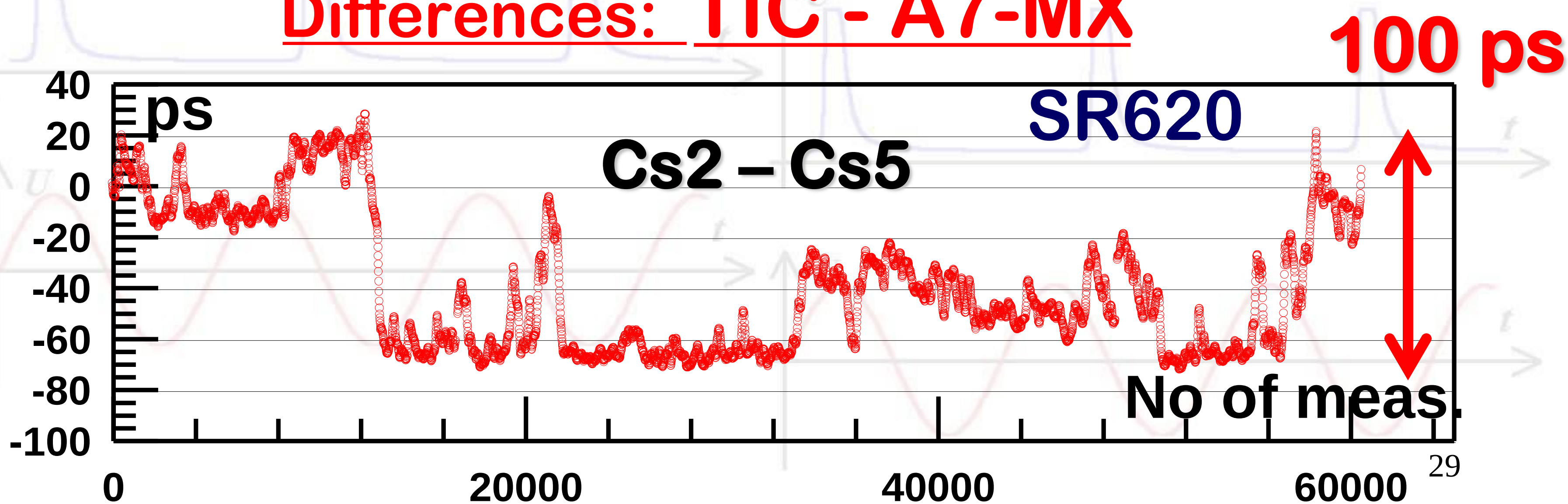
… a dual channel frequency distributor/divider

Examplary results – for SR620

Changes of the measured time interval

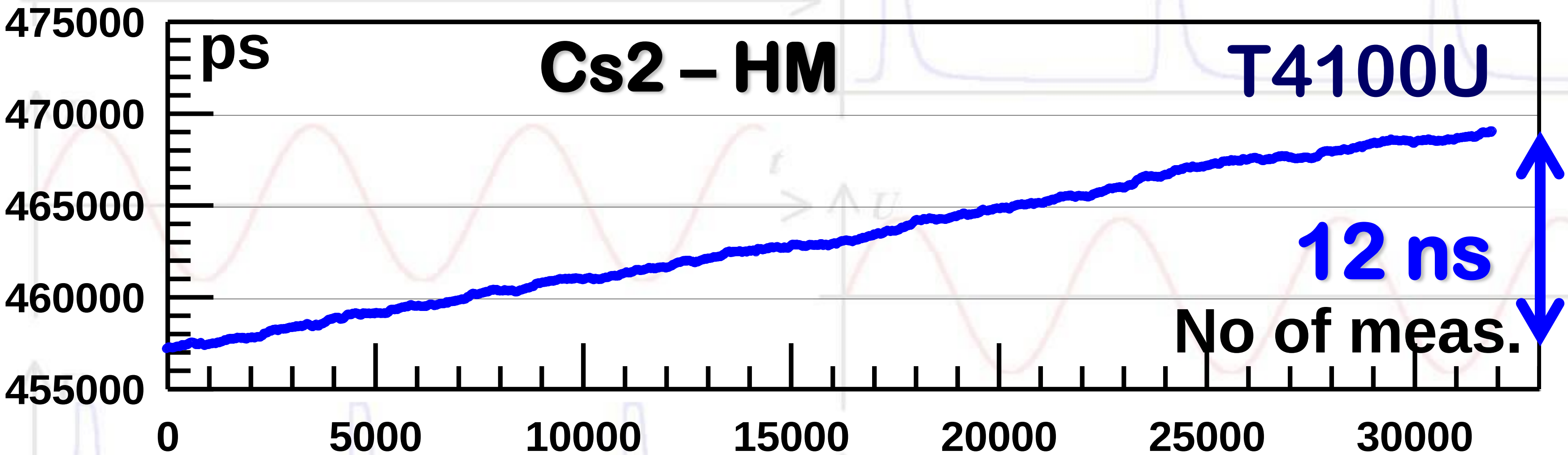


Differences: TIC - A7-MX

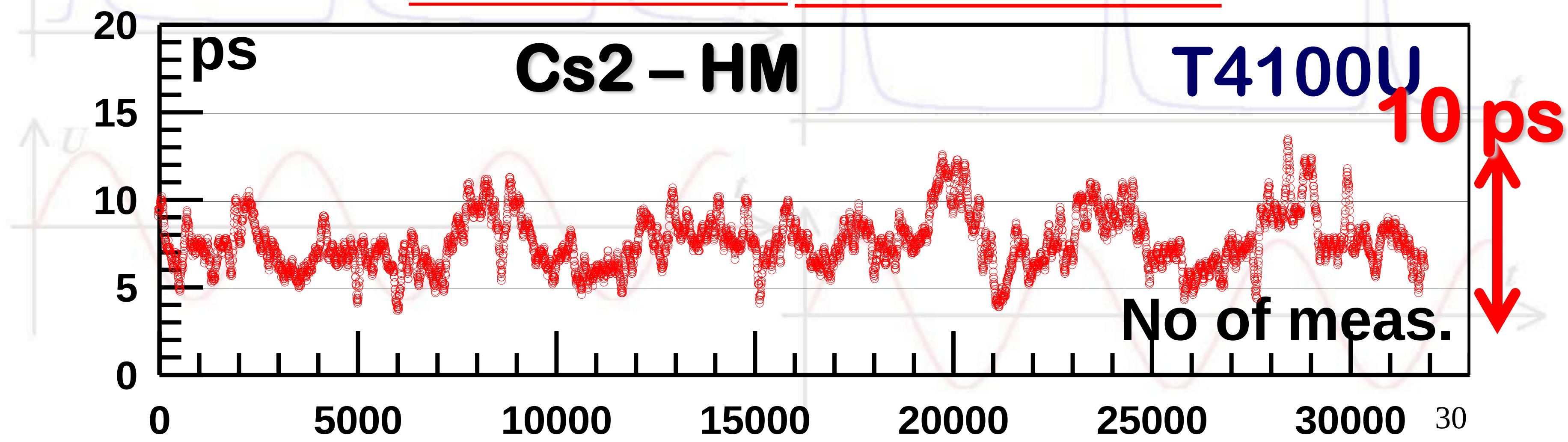


Examplary results – for T4100U

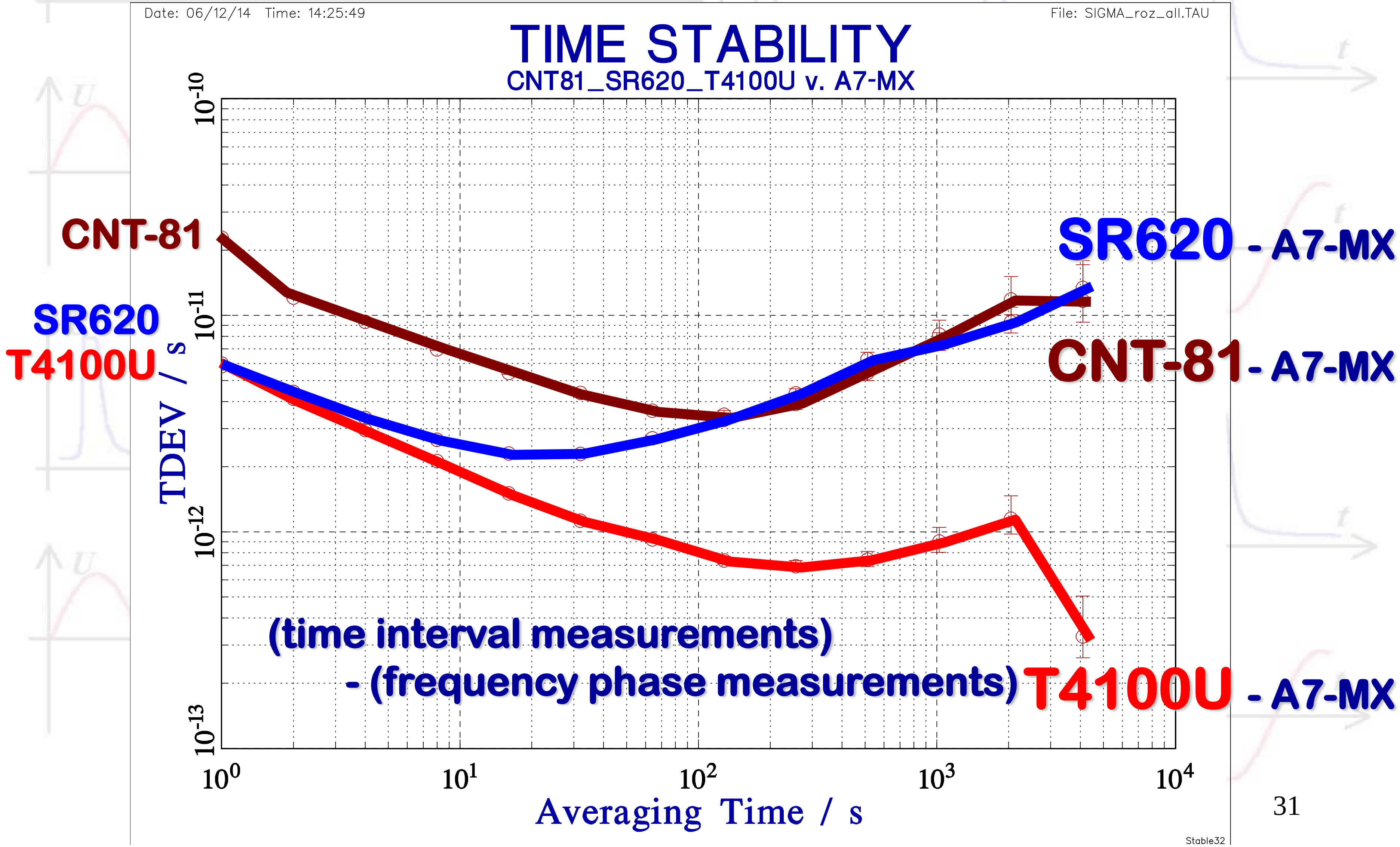
Changes of the measured time interval



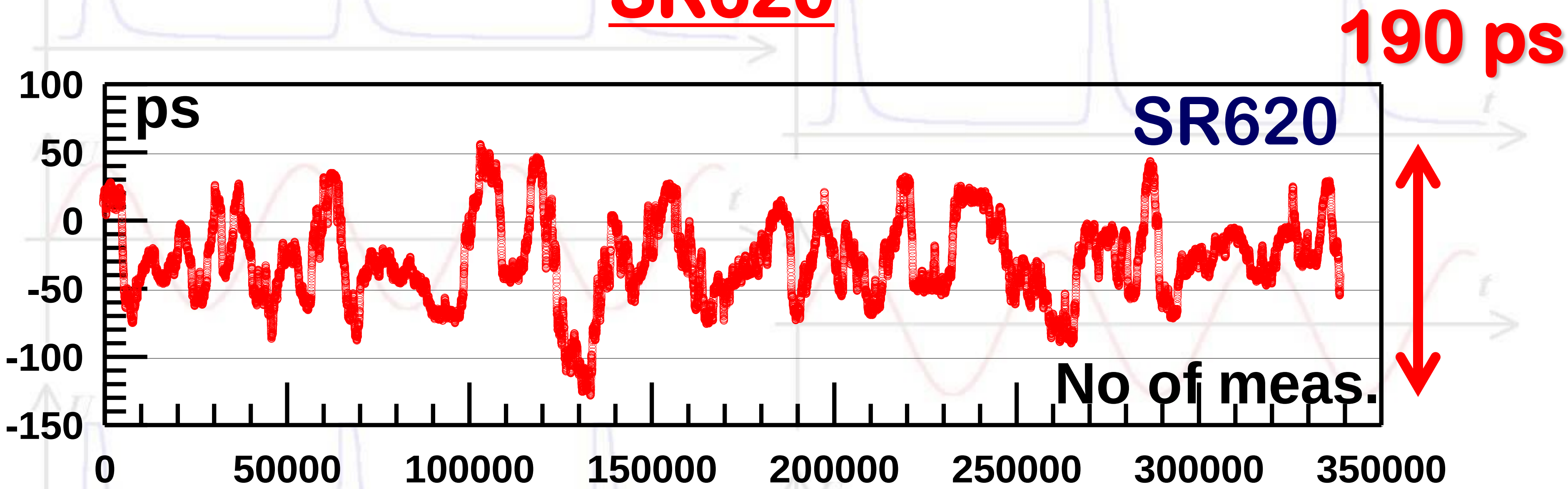
Differences: TIC - A7-MX

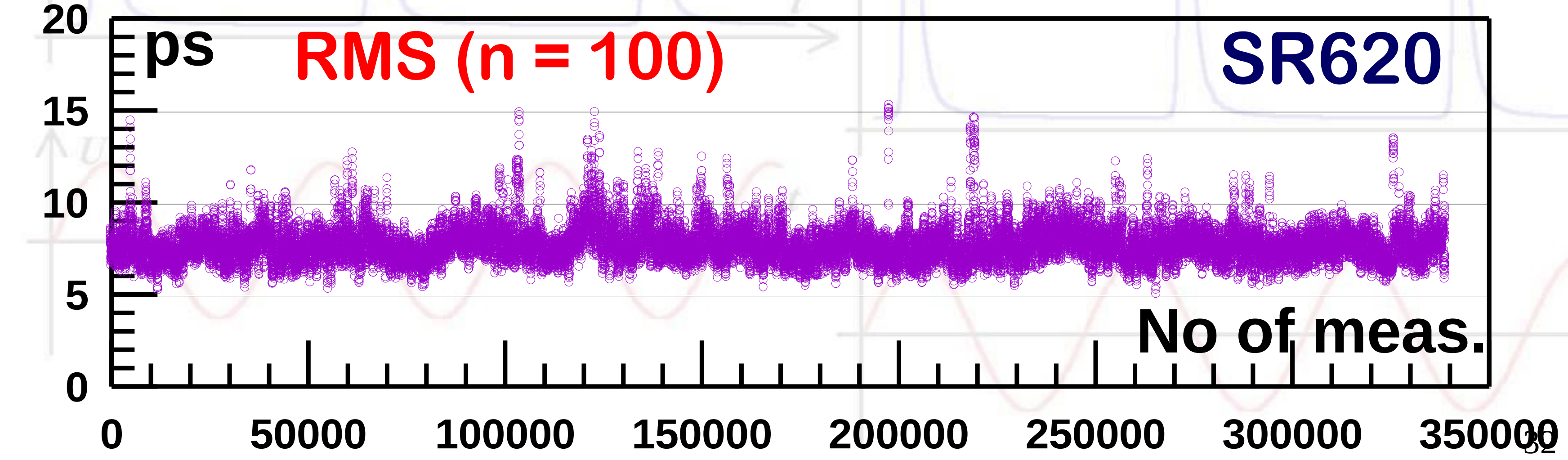


Measured continuously changed time interval – TDEV for TIC - A7-MX

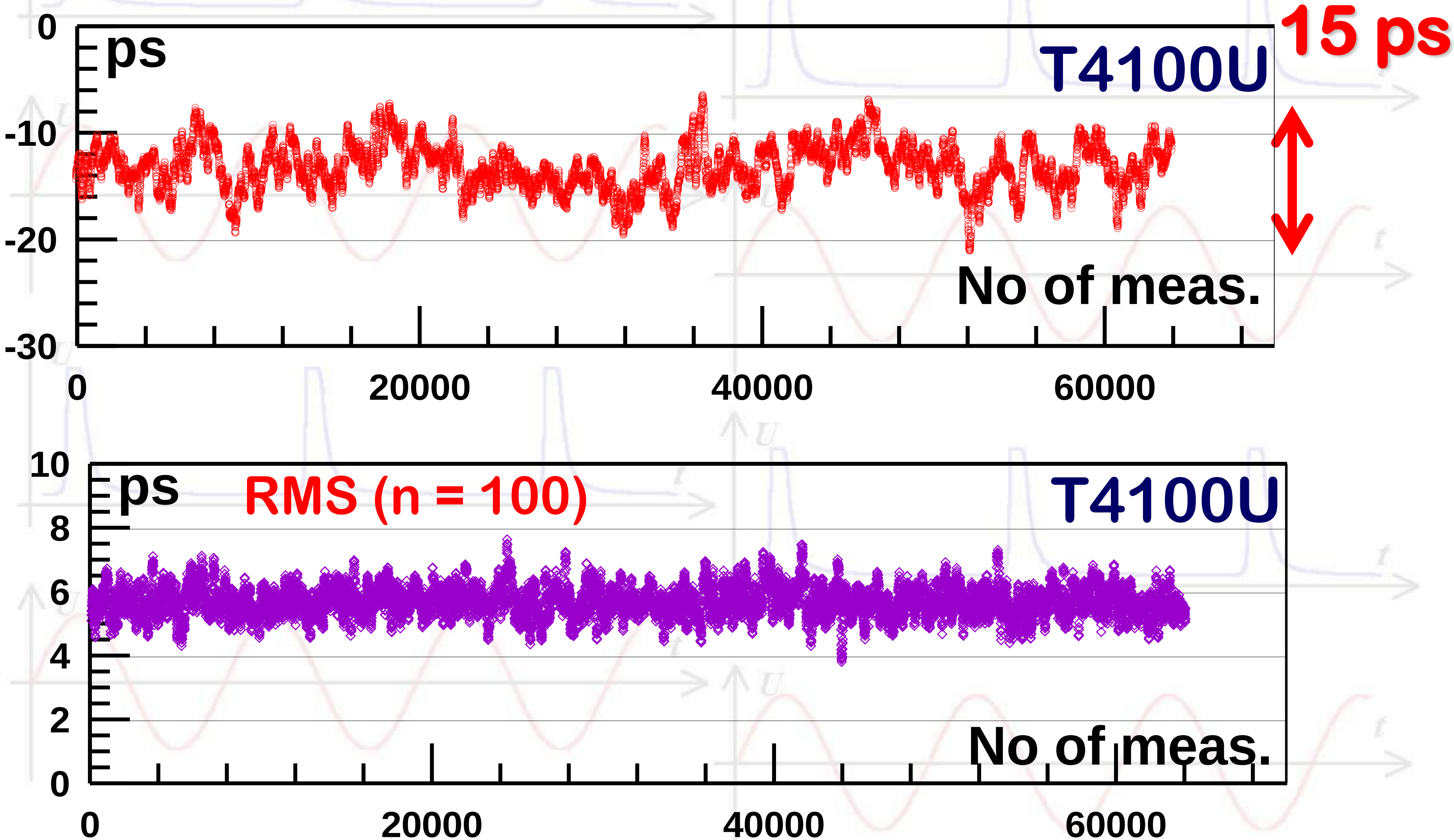


Measurement of the constant time interval – SR620

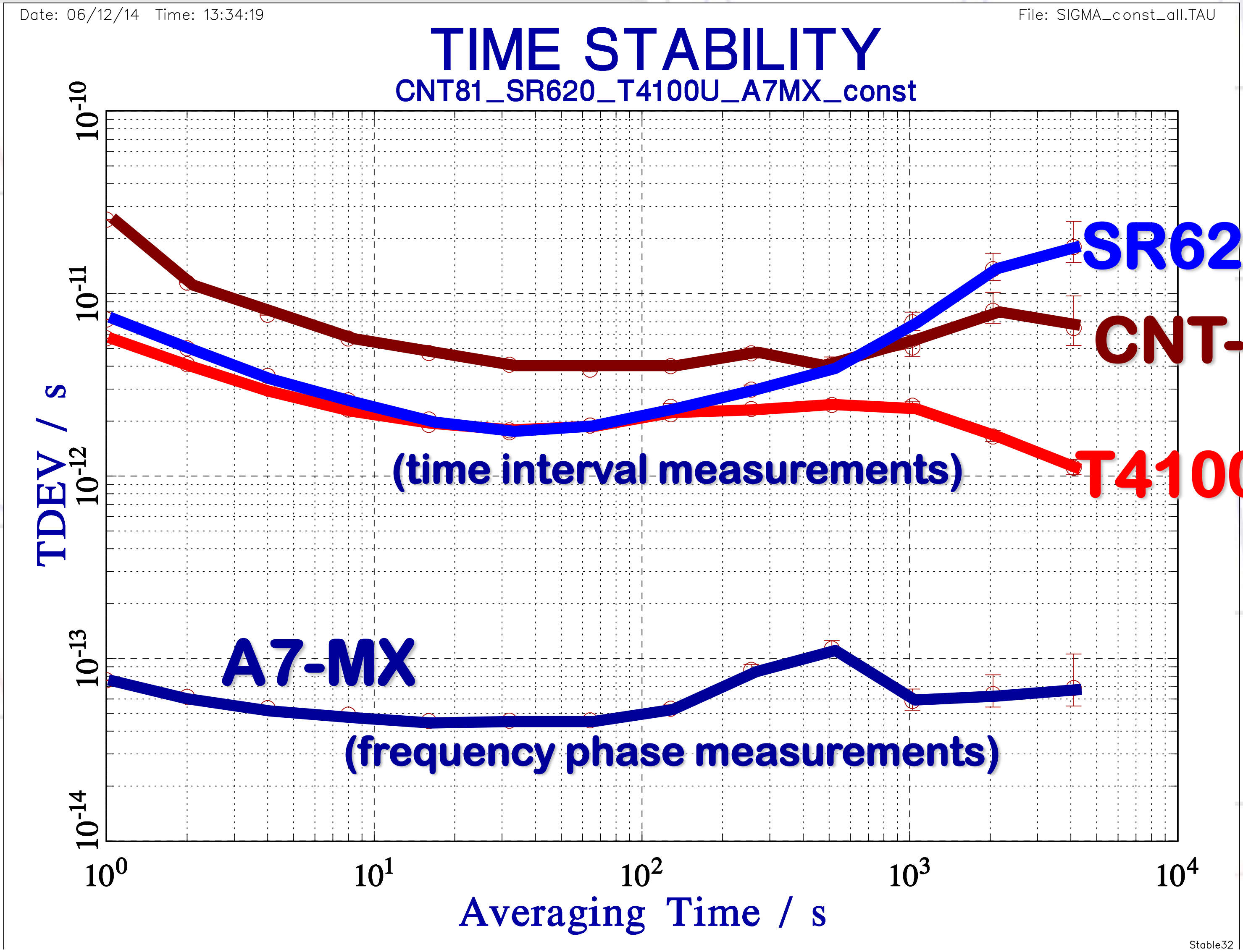




Measurement of the constant time interval – T4100U



Measured constant time interval – TDEV
SR620, CNT81, T4100U



Active participation in the activities of TCTF EURAMET - sharing the knowledge and experience

1152 Project – GNSS Receiver performance monitoring

GNSS receiver performance monitoring

COORDINATOR

Albin Czubla (GUM)

The aim of this project is differential verification of short-term and seasonal changes of calibration constants of GPS receivers, including variation due to changes of delays of different parts of equipment. The base method is collection and analysis of measurement data taken from pairs of GPS receivers working with the same local reference timescale, so the data taken from pairs of GPS receivers working with different local reference timescales/clocks, but with supplementary results of direct measurements between the used as a reference timescales/clocks, are accepted.

Theoretically, the difference between GPS receivers in such pairs should be constant, but practically, this difference can vary due to individual sensitivity on external temperature of the equipment, different type of antennas and different type of receivers and software. It is assumed that the data will be collected and analysed for the period of at least one year of permanent observations. The analysis will be performed for GPS C/A code mainly, so with measurement data in CGGTTS format. The involved GPS receivers do not have to be calibrated

SUBJECTS

Time and Frequency (TF)

COORDINATING

GUM (Poland)

PARTICIPATING PARTNERS

BEV (Austria)

PTB (Germany)

SP (Sweden)

ÚFE/IPE (Czech Republic)

FURTHER PARTNERS

SPI, Lithuania

1288 Project – Time interval comparison Pilot Study

Time interval comparison Pilot Study

COORDINATOR

Rado Lapuh (MIRS)

In 2007 the EUROMET TF.TI-K1 Comparison of time interval (cable delay) measurement was completed and the final report was issued by BEV. The main goal of that project was to The main conclusion was: The EURAMET 828 project showed that the transmission delay of any signal through a cable depends on several parameters and does not well define a measurement quantity “time interval” and we should be more aware of the fact that the value of a “cable delay”, even for the same cable, is not a fundamental constant. The project results did not immediately support the (then) defined T&F Key Comparison and it was not considered as a Supplementary Comparison. It is believed that a successful ILC on time interval is nevertheless possible, with the goal to support current CMCs for time interval and to gain better understanding of the time interval measurement through cable delay or other measurement techniques. For that, we need first to implement a successful Pilot Study.

COORDINATING

MIRS (Slovenia)

PARTICIPATING PARTNERS

EIM (Greece)

GUM (Poland)

IMBiH (Bosnia and Herzegovina)

METAS (Switzerland)

MIRS/SIQ/Metrology (Slovenia)

NPL (United Kingdom)

SP (Sweden)

UME (Turkey)

Construction and characterisation of TI-generator (together with AGH)

Reqiured:
Ext. 10 MHz input

127 different Time Intervals between 1 pps outputs (from about: 20 ns to 12 µs)

Auxiliary display

1 pps outputs

Precise matching of 1 pps outputs = close the same shape of output signals

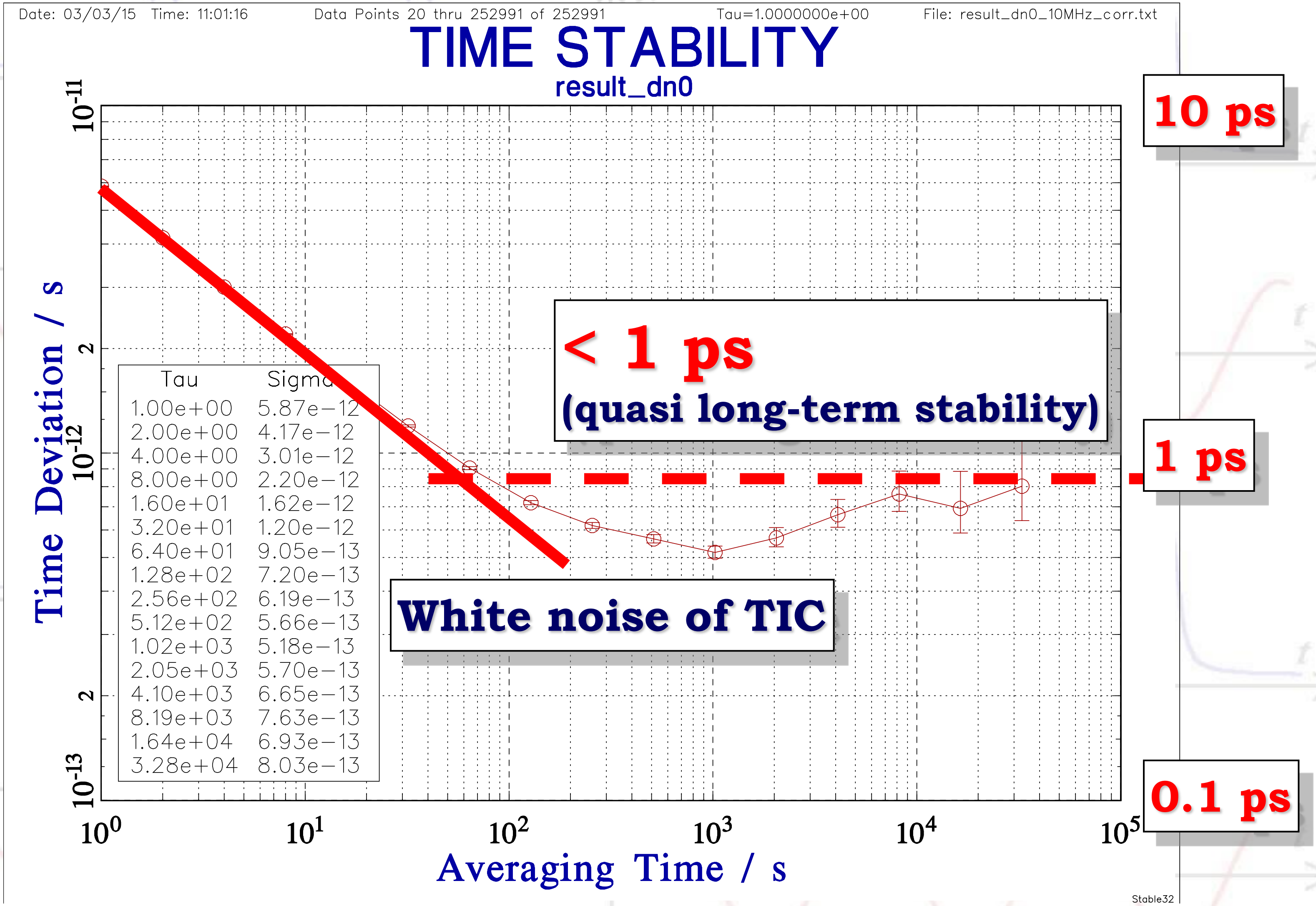
Rising slope: < 0.5 ns/V

SMA connectors

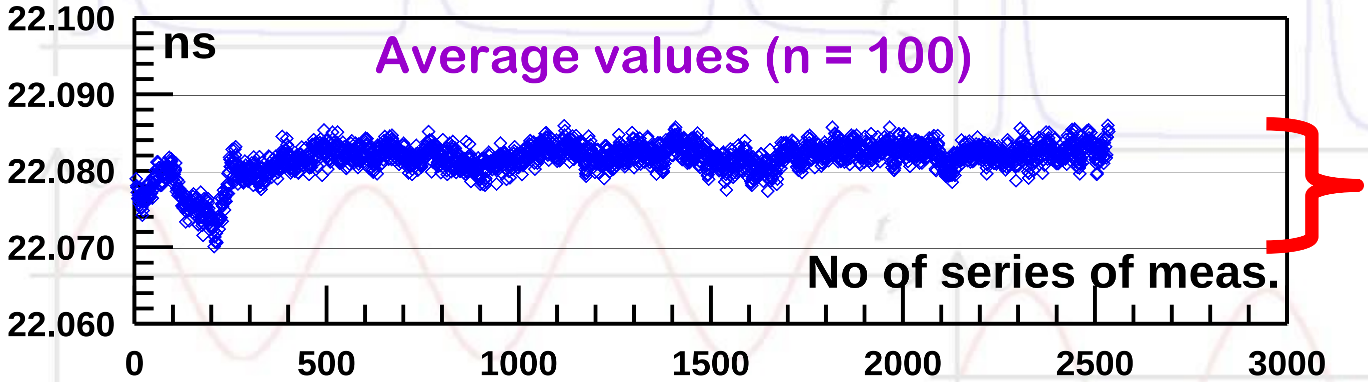
Electronic based Time Interval generator

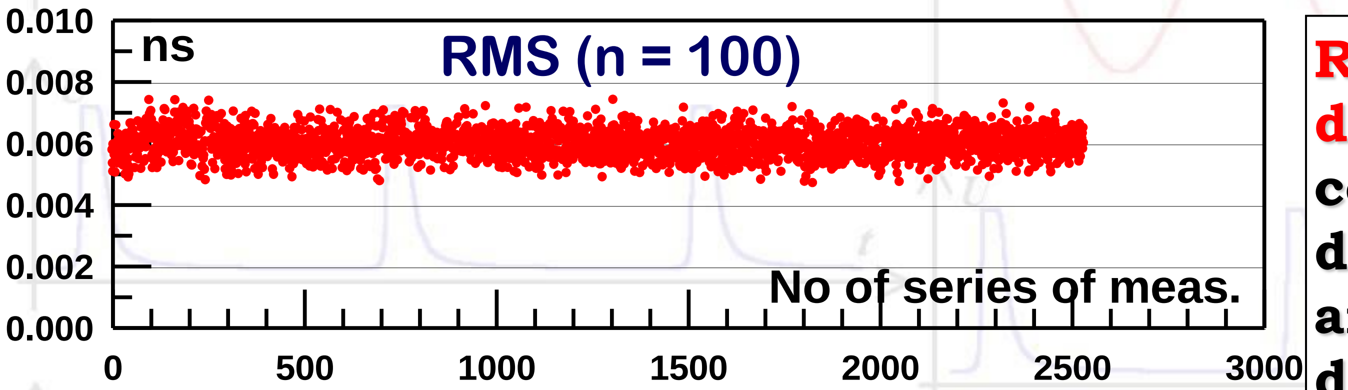
(PLL loops and programmable logic and counters)

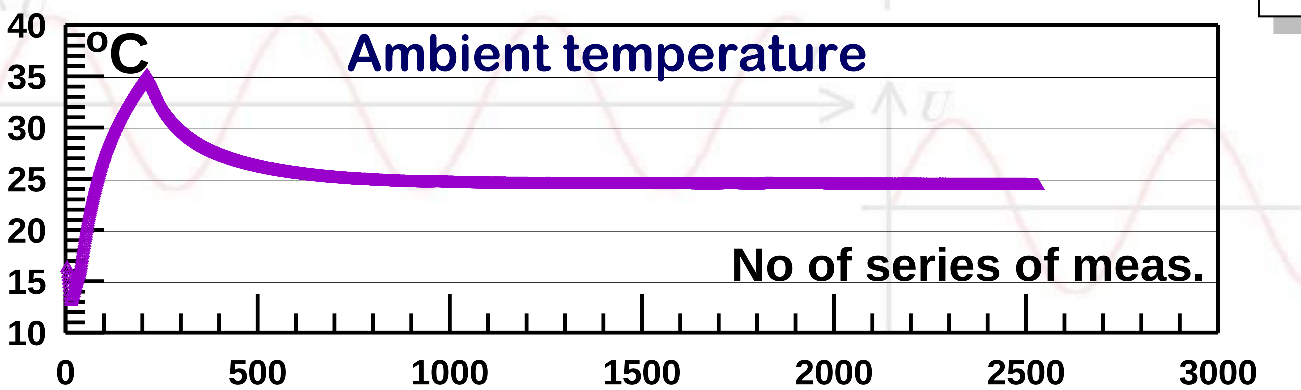
TDev of output TI measurements



Examplary continuous measurements of output signals







TI ≈ 20 ns

13 ps (peak-to-peak)

Raw measurement data - no correction for differential cables and channels delays

No significant influence of temperature

Publications

Publications – 1/3

1. Jiang Z., Czubla A., Nawrocki J., Lewandowski W., Arias E. F.: Comparing a GPS time link calibration with an optical fibre self-calibration with 200 ps accuracy, *Metrologia*, vol. 52 (2015), pp. 384-391

2. Śliwczyński Ł., Krehlik P., Czubla A., Buczek Ł., Lipiński M.: Dissemination of time and RF frequency via stabilized fiber optic link over the distance of 420 km, *Metrologia*, vol. 50 (2013), pp. 133-145

3. Kaczmarek J., Miczulski W., Kozioł M., Czubla A.: Integrated System for Monitoring and Control of the National Time and Frequency Standard, *Instrum. and Meas., IEEE Trans. on*, vol. 62, poz. 10 (2013), pp. 2828-2838

4. Czubla A., Konopka J., Nawrocki J.: Realization of atomic SI second definition in the context of UTC(PL) and TA(PL), *Metrol. Meas. Syst.*, vol. 13 (2/2006), pp. 149-160

5. Azoubib J., Nawrocki J., Lewandowski W.: Independent atomic timescale in Poland – organization and results, *Metrologia* 40 (2003), pp. S245-S248

6. Czubla A., Osmyk R., Szterk P., Krehlik P., Śliwczyński Ł., Szplet R., Jachna Z., Różyc K., Verification of TIC Characteristics for Precise Optical Fiber Time Transfer Links, *in Proc. of European Frequency and Time Forum (EFTF)*, 2014

Publications – 2/3

7. Jiang Z, Czubla A, Nawrocki J, Lewandowski W and Arias F: Towards accurate optical fibre time transfer in UTC, *in Proc. of European Frequency and Time Forum (EFTF)*, 2014

8. Adamowicz W., Bińczewski A., Bogacki W., Czubla A., Dunst P., Igalson J., Kołodziej J., Krehlik P., Lemański D., Lipiński M., Nawrocki J., Nogaś P., Ostapowicz P., Pawszak T., Pieczerak J., Stroiński Maciej, Śliwczyński Ł., Turza K.: OPTIME – time and frequency dissemination system based on fiber optical network – PIONIER, *in Proc. of European Frequency and Time Forum & International Frequency Symposium (EFTF/IEC)*, 2013 Joint

9. Marszalec M., Lusawa M., Czubla A., Lewandowski W.: Research on Timescale algorithms in Database for TA(PL), *in Proc. of European Frequency and Time Forum & International Frequency Symposium (EFTF/IEC)*, 2013 Joint

10. Czubla A., Osmyk R., Szterk P., Adamowicz W., Marszalec M., Śliwczyński Ł.: Optical Fiber Time and Frequency Transfer inside Urban Telecom Network in Warsaw – Results of Initial Tests, *in Proc. of European Frequency and Time Forum (EFTF)*, 2012

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Thank you
for your attention

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