Pilot Comparison of Time Interval Measurements with High Speed Oscilloscopes – initial results

P. Krehlik, Ł. Śliwczyński
Department of Electronics
AGH University of Science and Technology
Krakow, Poland

A. Czubla, P. Szterk
Time and Frequency Laboratory, Electricity Department
Central Office of Measures (GUM)
Warsaw, Poland

M. Yogun, R. Hamid
Ulusal Metroloji Enstitüsü (UME)
TÜBİTAK
Gebze, Kocaeli, Turkey

K. AlDawood, F. Almuhlaki
A. Aljawan, I. Alboraih
Nationala Meassurement and Caibration Center (NMCC)
SASO
Riyadh, Saudi Arabia

B.Pinter
Metrology Department
Slovenian Institute of Quality and Metrology (SIQ)
Ljubljana, Slovenia

M. Marszalec, M. Lusawa
Central Chamber for Telecommunications Measurements
Nationa Institute of Telecommunications (NIT)
Warsaw, Poland

INTRODUCTION

This pilot comparison is realized within **the EURAMET Project #1288** and is aimed **to better characterise** the developed by AGH and GUM **electronic based Time Interval Generator (TIGen) as a time interval standard** for **a new Inter-Laboratory Comparison planned as a Supplementary Comparison in the KCDB**.

So far, the obtained results for TIGen confirm the stability of generated time intervals at **the single picoseconds level**, but the absolute values of the generated time intervals have not yet been compared between different institutes.

At the same time, high speed oscilloscopes are considered to be ones of the most accurate instruments for precise time interval measurements. So, **this pilot comparison is additionally aimed to verify and confirm the metrological quality of high speed oscilloscopes for absolute time interval measurements.**

The previous experience with **a cable delay measurement within the EUROMET Project #828** showed that a cable delay is **not well-defined measured quantity** and its value is **significantly dependent on the shape of signals used for cable delay measurements.**

TRAVELLING STANDARD UNDER CHARACTERISATION

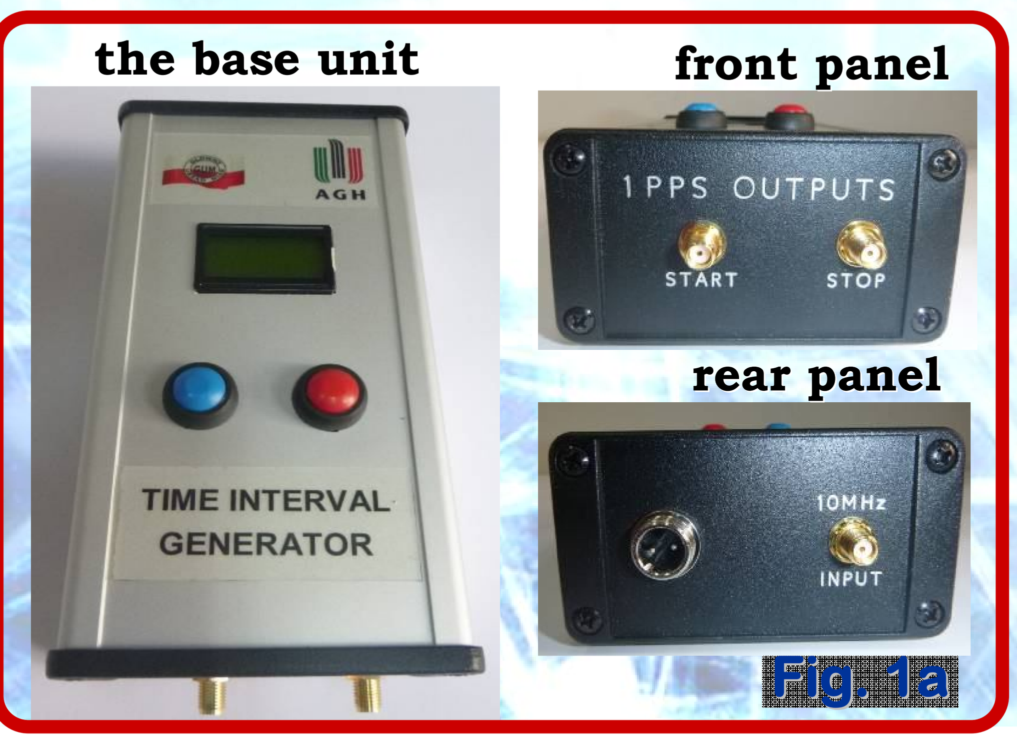

Fig. 1a

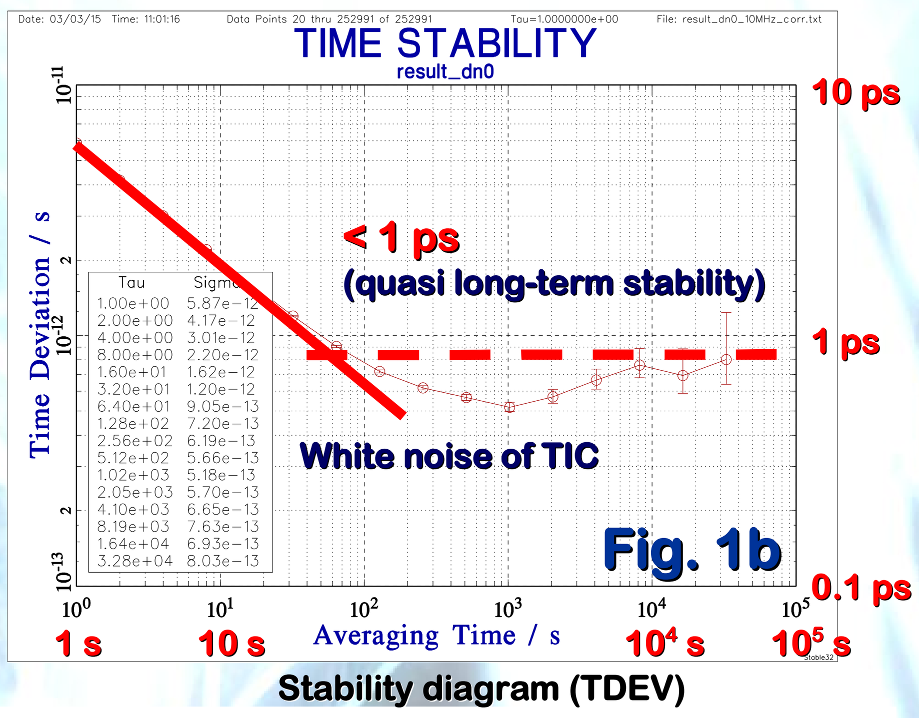

Fig. 1b

Stability diagram (TDEV)

The specially developped for TI comparison travelling standard TIGen is **an electronic based time interval generator (with PLL lines and programmable logic and internal counters)**. TIGen generates **127 (randomly selected) different time intervals** between 1 pps outputs **from about 20 ns to 12 μs**. 1 pps outputs are **precisely matched**, so the parameters of 1 pps output signals are closely the same. Together with very sharp slopes (rise time < 500 ps), it allows to minimize the undesirable effects of start/stop trigger errors and trigger level timing errors. TIGen **requires 10 MHz input frequency** with fractional frequency not worse than 1E-7 (10 MHz ± 1 Hz). All signal inputs/outputs are **SMA-female connectors**.

The assumed stability, repeatability and reproducibility of the phase difference between output signals is at **the level of single picoseconds**. A general view of TIGen and its stability diagram are shown in FIg. 1a and 1b.

THE PREVIOUS EXPERIENCE WITH CABLE DELAYS MEASUREMENTS (within the EURAMET PROJECT #828)

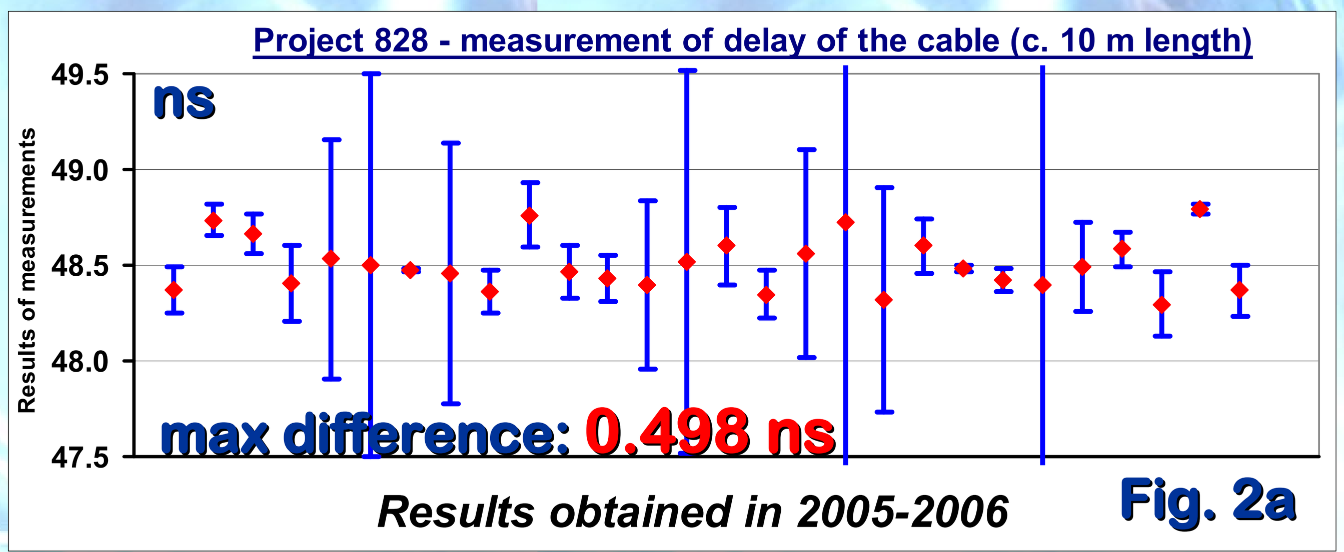

Fig. 2a

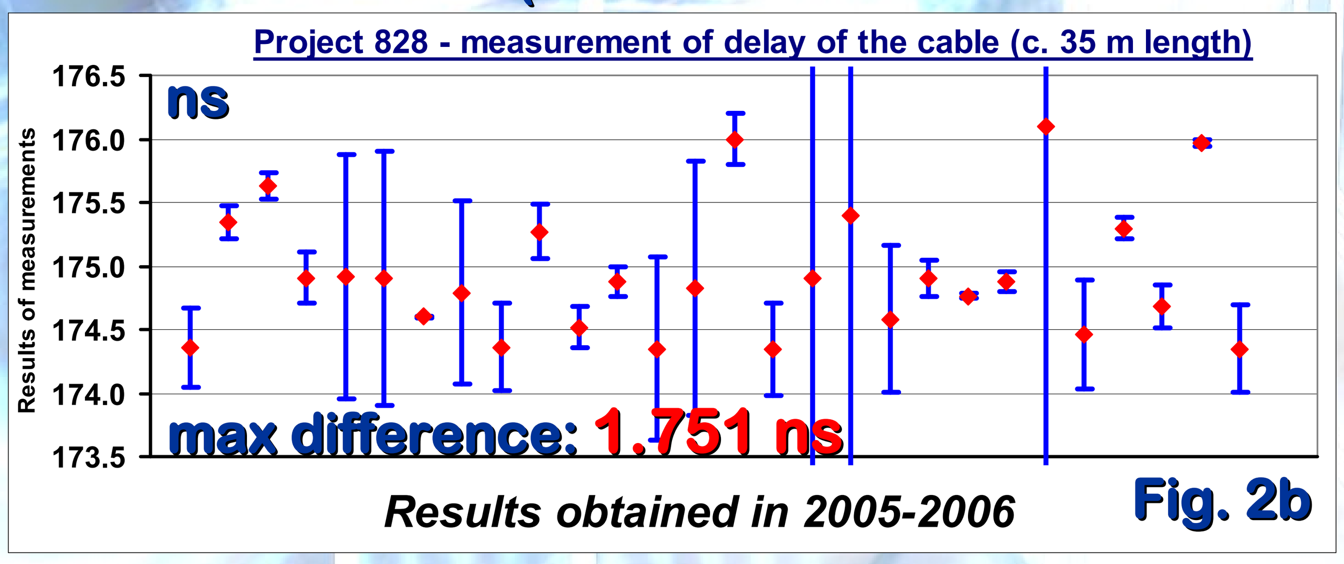

Fig. 2b

The results of measurements of cable delays, presented in the Figs. 2a and 2b, were obtained by participants of **the project #828** and showed **a big discrepancy following different shapes of pulse signals used for delays measurements.**

Cable delay is not well-defined measured quantity. The results are not comparable.

THE APPLIED METHODS DURING THIS PILOT COMPARISON

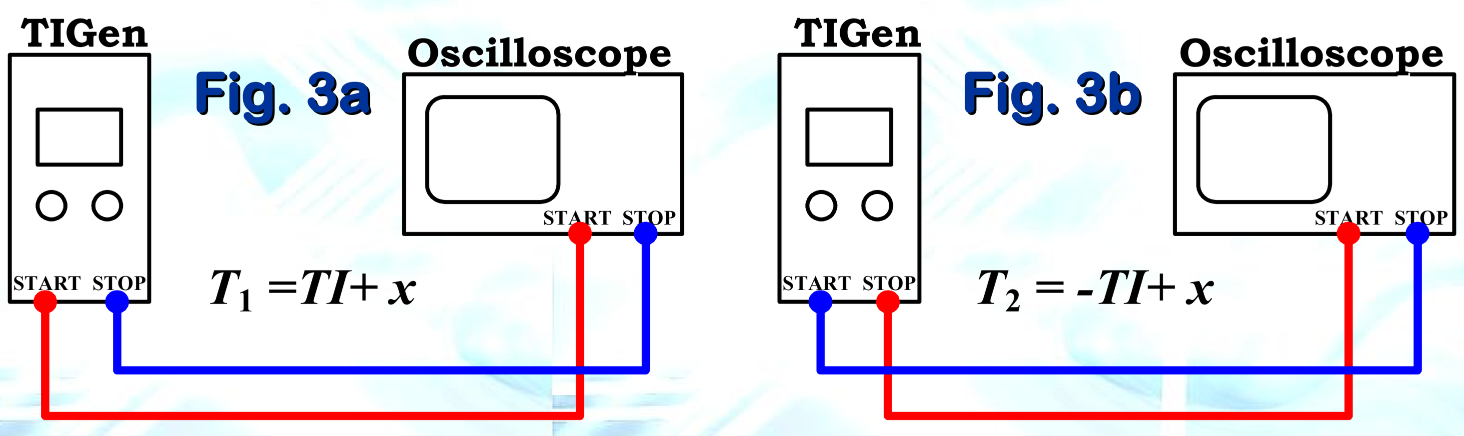

Fig. 3a, Fig. 3b

$$TI \approx \frac{T_1 - T_2}{2}$$

I. TWO CONSEQUTIVE SERIES OF MEASUREMENTS: IN NORMAL CONFIGURATION **(Fig. 3a)** AND WITH REPLACED THE CABLES BETWEEN **THE START AND STOP OUTPUTS OF TIGen (Fig. 3b)**

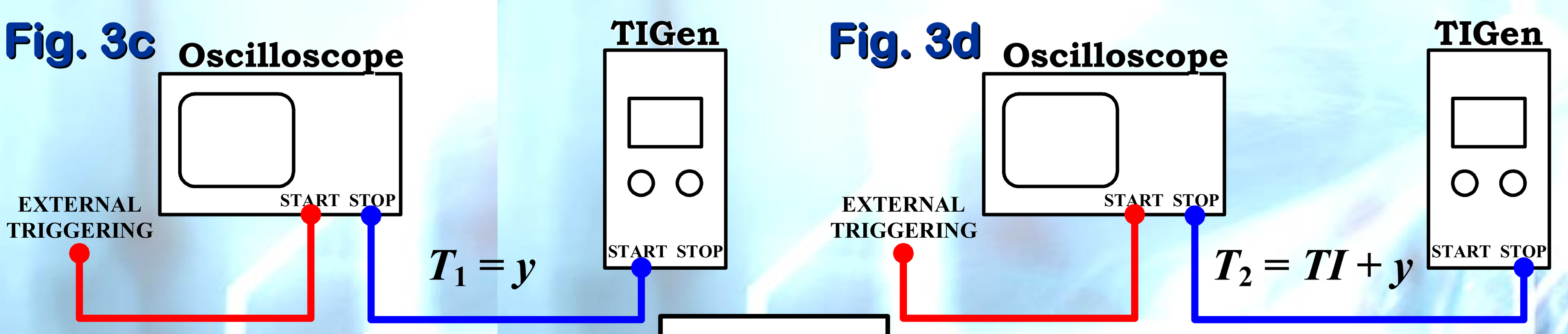

Fig. 3c, Fig. 3d

$$TI \approx T_2 - T_1$$

II. TWO CONSEQUTIVE SERIES OF MEASUREMENTS BETWEEN THE EXTERNAL TRIGGERING SIGNALS AND STOP SIGNALS TAKEN FROM **THE START OUTPUT OF TIGen (Fig. 3c)** AND **THE STOP OUTPUT OF TIGen (Fig. 3d)**

THE OBTAINED RESULTS (FOR TIs FROM TIGen)

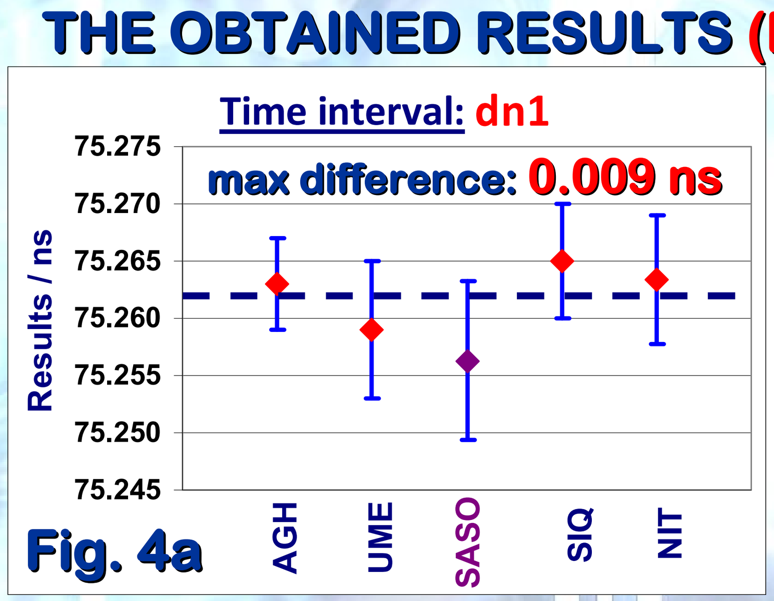

Fig. 4a

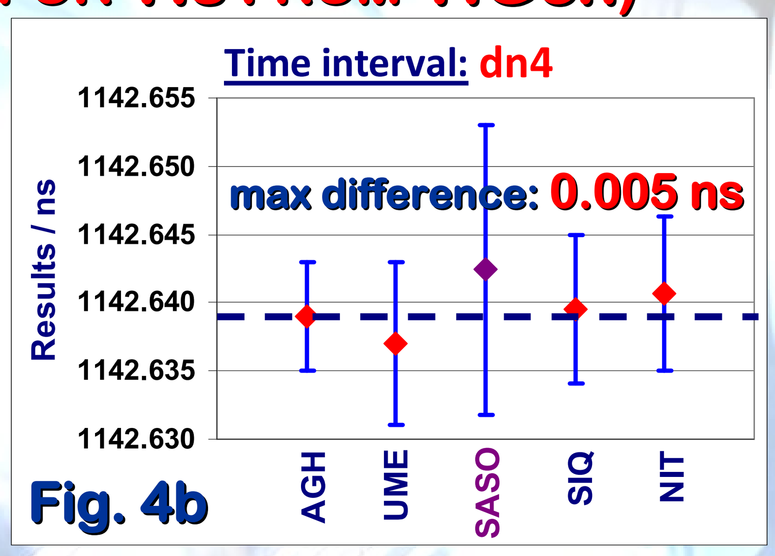

Fig. 4b

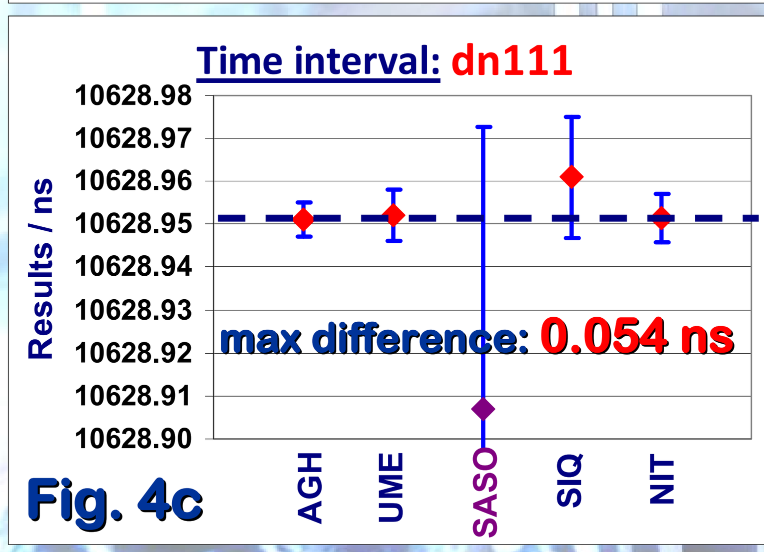

Fig. 4c

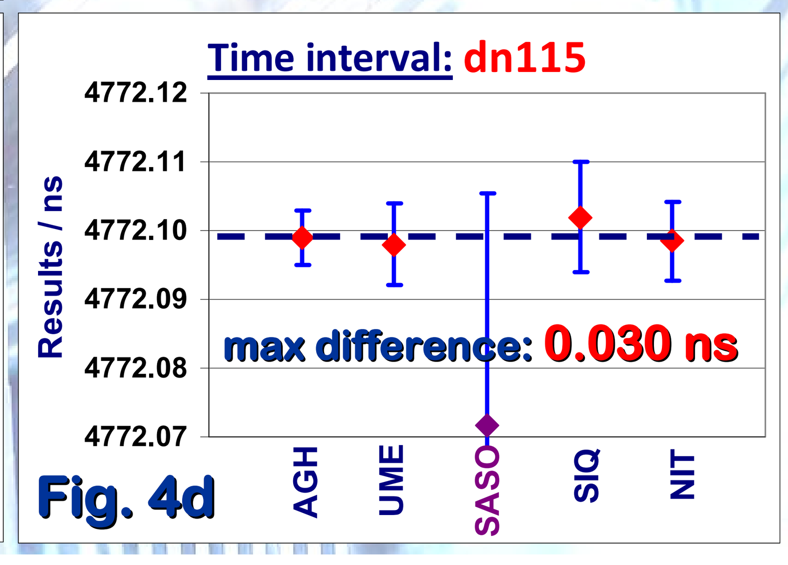

Fig. 4d

Four time intervals: dn1, dn4, dn111 and dn115 (from about 70 ns to about 11 us) were measured. The obtained results are shown in **Fig. 4 a-d**. The observed differences between results do not exceed **54 ps,** even for the longest measured time interval. But, if we omitt the SASO results because of higher uncertainty coused by the lack of external reference input during measurements, these **differences are not greater than 10 ps only**.

DEGREE OF EQUIVALENCE

	dn1	dn4	dn111	dn115
AGH	0.275	-0.026	-0.139	0.122
UME	-0.589	-0.392	0.116	-0.125
SASO	-0.909	0.326	-0.678	-0.805
SIQ	0.668	0.093	0.697	0.438
NIT	0.239	0.325	0.037	-0.040

$$E_n = \frac{\tau_x - \tau_{weighted\_mean}}{\sqrt{U_x^2 - U_{weighted\_mean}^2}}$$

$U_{weighted\ mean} = 3$ ps

$|E_n| \le 1$

All results are consistent with **the weighted mean.**

ACCOMPANIED TIC MEASUREMENTS

UME_SR620
$\tau_{TIC} - \tau_{weig\_mean\_osc} \approx$ from **-69 ps** to **+23 ps**

SASO_SR620
$\tau_{TIC} - \tau_{weig\_mean\_osc} \approx$ from **-2 ps** to **+46 ps**

SIQ_53230A
$\tau_{TIC} - \tau_{weig\_mean\_osc} \approx$ from **+2 ps** to **+26 ps**

NIT_53230A
$\tau_{TIC} - \tau_{weig\_mean\_osc} \approx$ from **-8 ps** to **+21 ps**

CONCLUSIONS

TIGen is ready for Time Interval Supplementary Comparsion:

- about **3 ps of assigned expanded uncertainty** of the travelling standard
- **127 different Time Intervals** between 1 pps outputs (**from c. 20 ns to 12 us**)
- **good stability** and **reproducebility** of generated Time Intervals.

High speed oscilloscopes can achieve single ps absolute accuracy of TI measurements.

e-mail: a.czubla@gum.gov.pl