Event Time and Amplitude Meter: High-Precision Measurement Device Based on Enhanced Event Timing Principles

Contract no. 1.1.1.1/20/A/076.

NATIONAL DEVELOPMENT PLAN 2020

EUROPEAN UNION
European Regional Development Fund

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Event registration technology developments at EDI

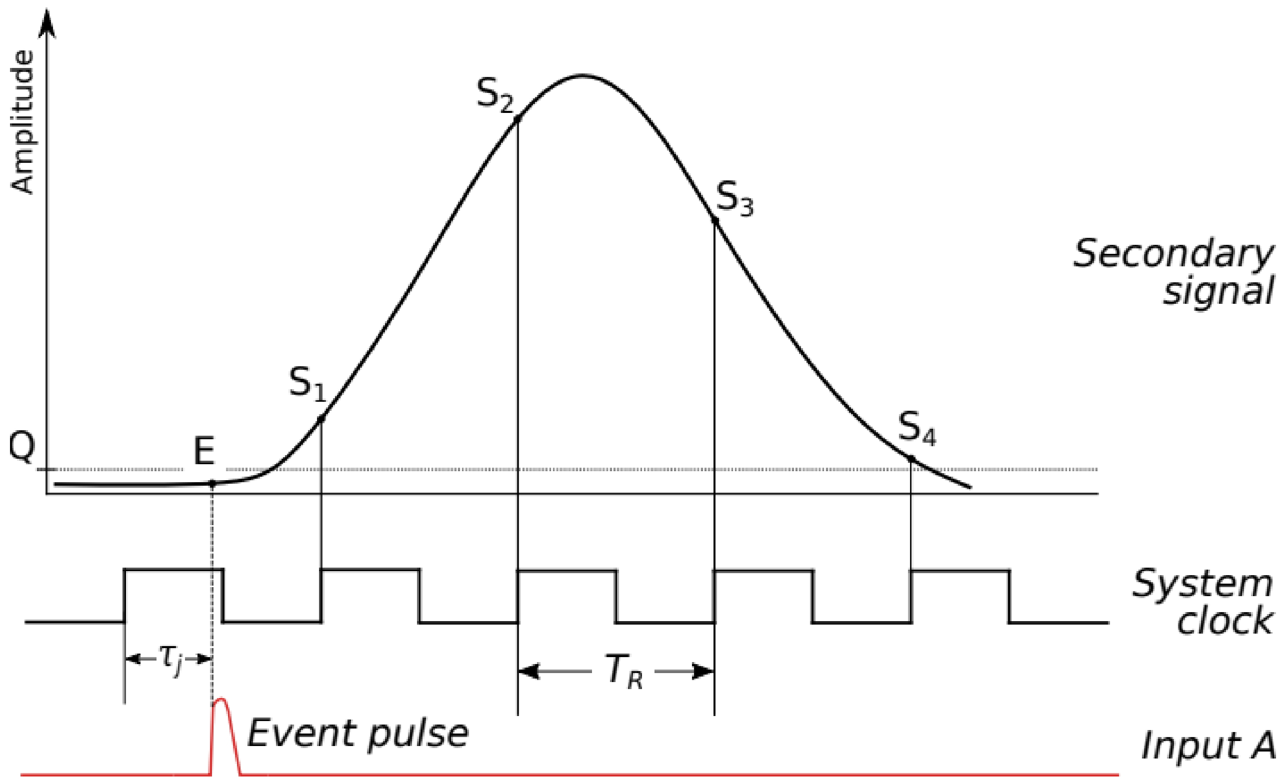
- EDI is working on a new system for simultaneous time of arrival and amplitude measurement of nanosecond width pulses – Event Time and Amplitude Meter (ETAM).
- New timing technology is evolution of the A040-ET, which itself was derived from A033-ET in the scope of an earlier ERDF financed project.
- Employed pulse amplitude measurement technology is based on digitization of peak-detected signal.

Enhanced event timing (EET)

Each event j occurring at time t_j gives rise to an analog secondary signal $u(t_j)$, whose scale resembles an isosceles triangle. The secondary-signal sequence is digitized with period T_R of the clock pulses to give digital readings $\{S_j\}$, which are processed to estimate:

$$t_j = N_j\, T_R + \tau(S_{j1}),$$

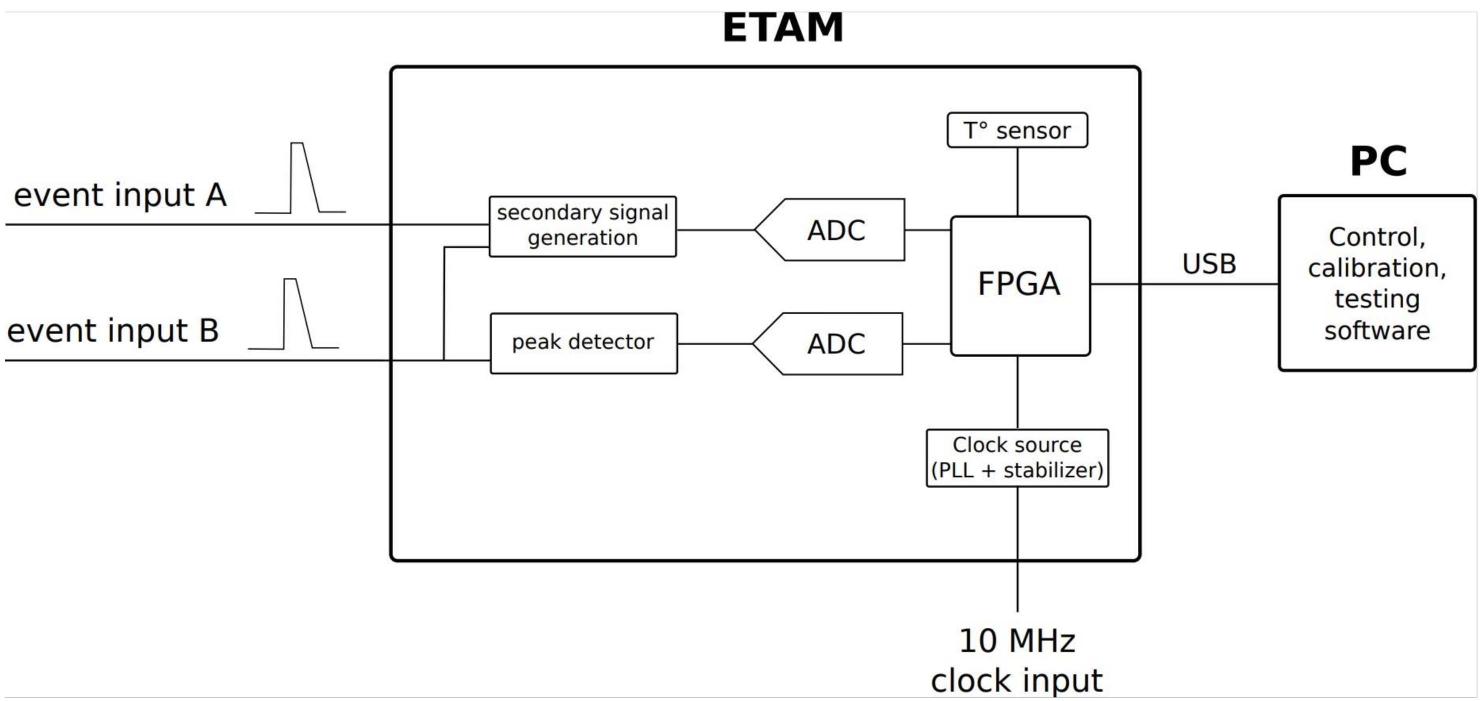
t_j – time of the j-th input event
T_R – period of the system's clock pulse (10 ns for a 100 MHz system clock)
N_j – number of the system's clock pulses at the time of the event
S_{j1} – digitized amplitude measurement of the secondary signal generated after the event



EET timing principles. The shape of the secondary signal is shown, in relation to the timing of the input pulse (event) and the system clock. (Q – digital amplitude threshold)

Event Time and Amplitude Meter (ETAM) highlights

- Simultaneous event pulse timing and amplitude measurement
- Greately improved timing stability in temperature
- Improved timing precision
- Improved built-in gate signal generator

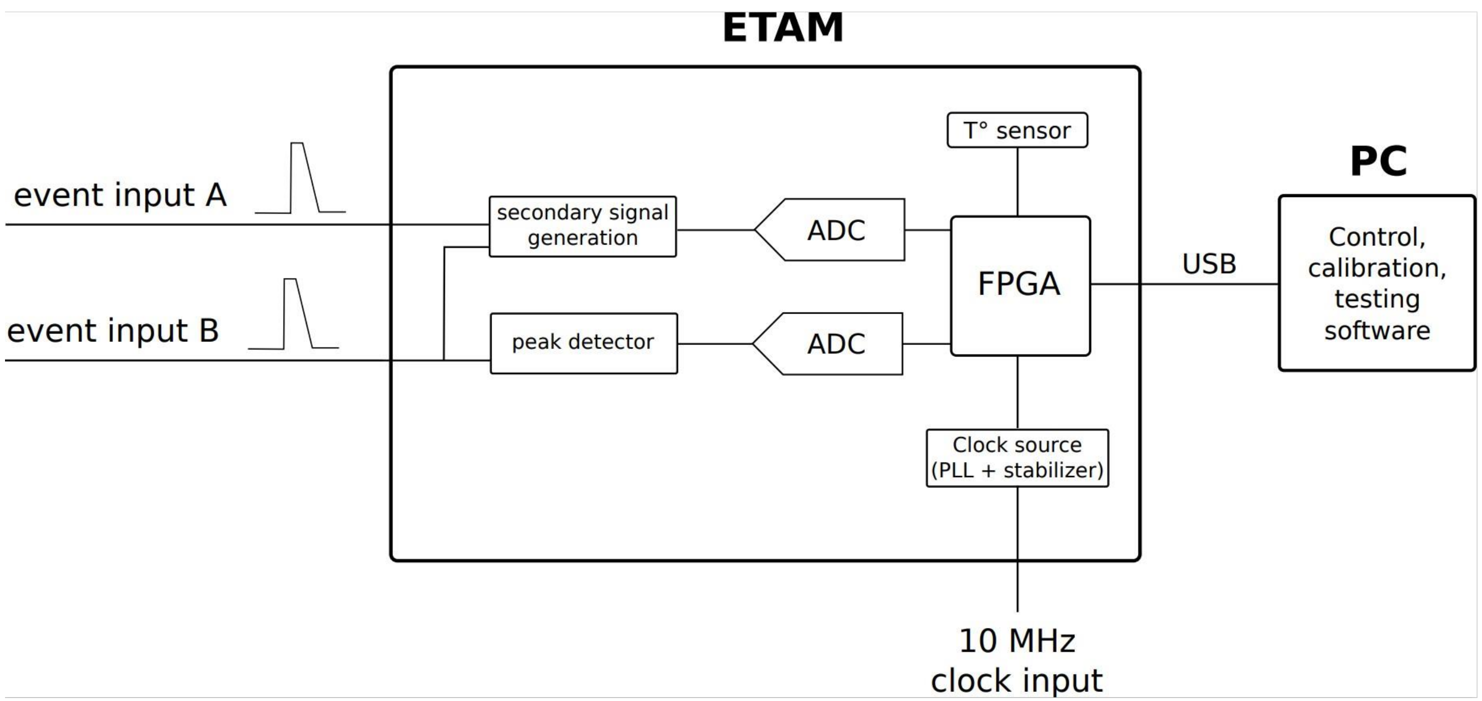


The architectural overview of the ETAM device.

Event Time and Amplitude Meter (ETAM) inputs

Analog Event signal inputs (input A and input B):

- -2V .. 2V range
- User controlled threshold voltage
- User selected Event edge (leading / trailing)
- User selected Event pulse polarity (positive / negative)

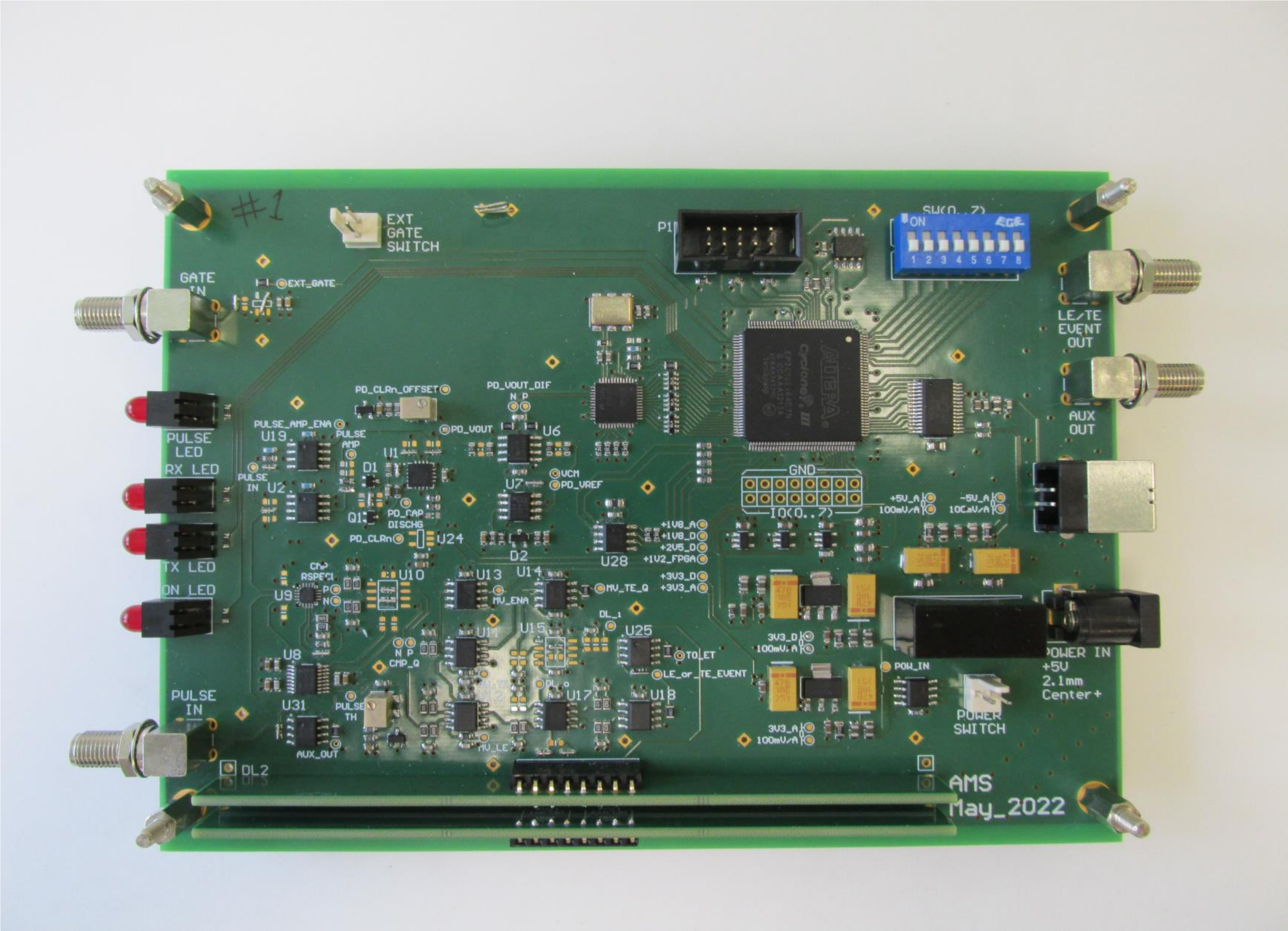


The architectural overview of the ETAM device.

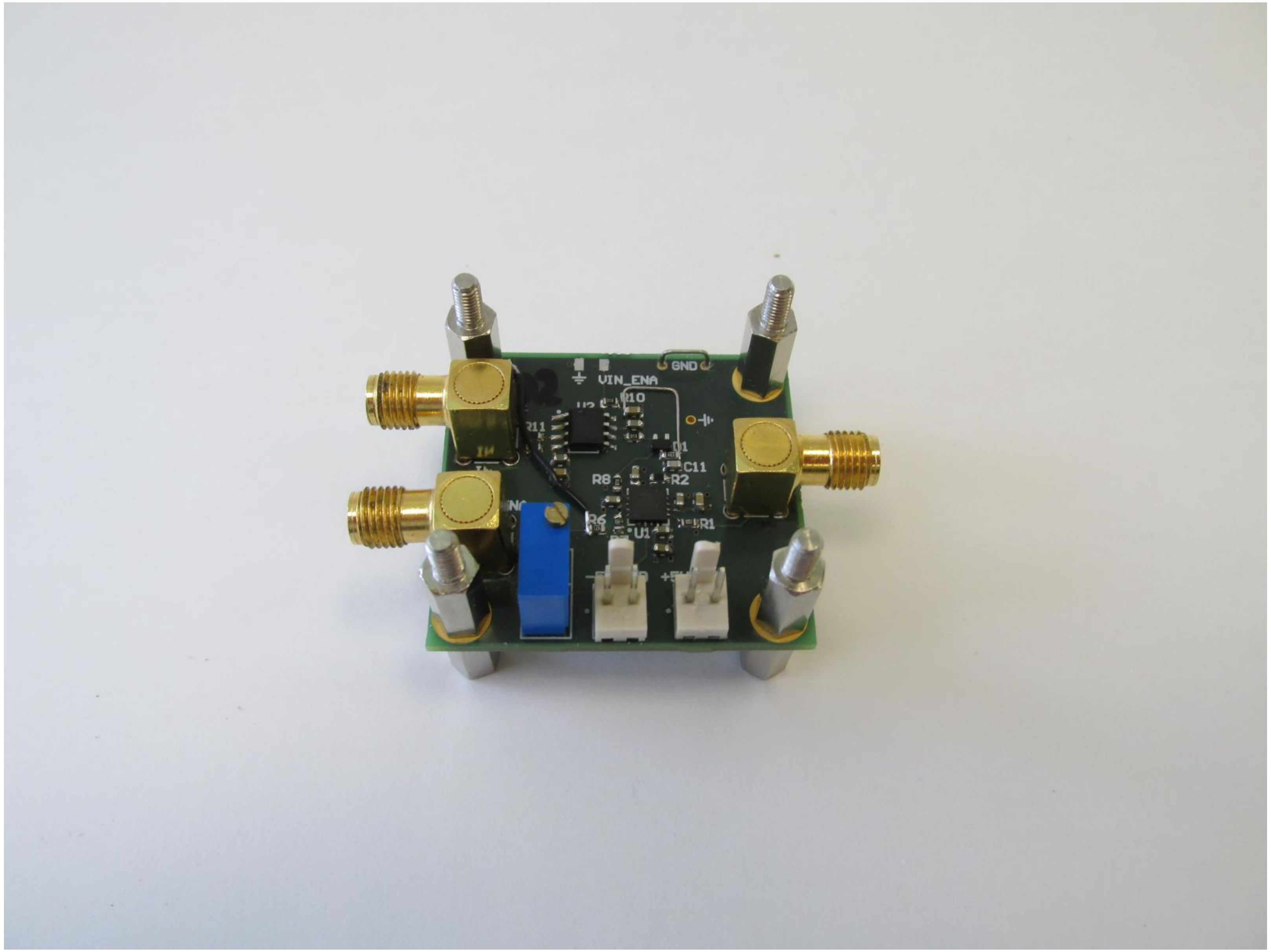
Expected performance of EDI Event Time and Amplitude Meter (ETAM) - preliminary test results

	A040-ET	ETAM (preliminary)
Timing precision (RMSD)	2.5 – 2.7 ps typically	2.1 – 2.4 ps typically
Timing precision (RMSD) stability (Single calibration at 22.5 °C)	<4 ps (15 – 30 °C range)	<2.6 ps (15 – 30 °C range) <3 ps (5 – 40 °C range)
Single-input timing offset drift	<2 ps/°C	<1 ps/°C
Input-to-input timing offset drift	<0.2 ps/°C	<0.2 ps/°C
Dead time	50 ns	30 - 40 ns
Minimum input pulse width	700 ps	700 ps
Pulse amplitude measurement range (positive or negative)	-	50 mV – 2 V
Pulse amplitude measurement precision (RMSD)	-	<3.5 mV (2V pulse amplitude) <2.3 mV (1V pulse amplitude)
Pulse amplitude measurement accuracy	-	<50 mV (any shape and width pulse) <5 mV (if tuned for particular shape and width pulse)

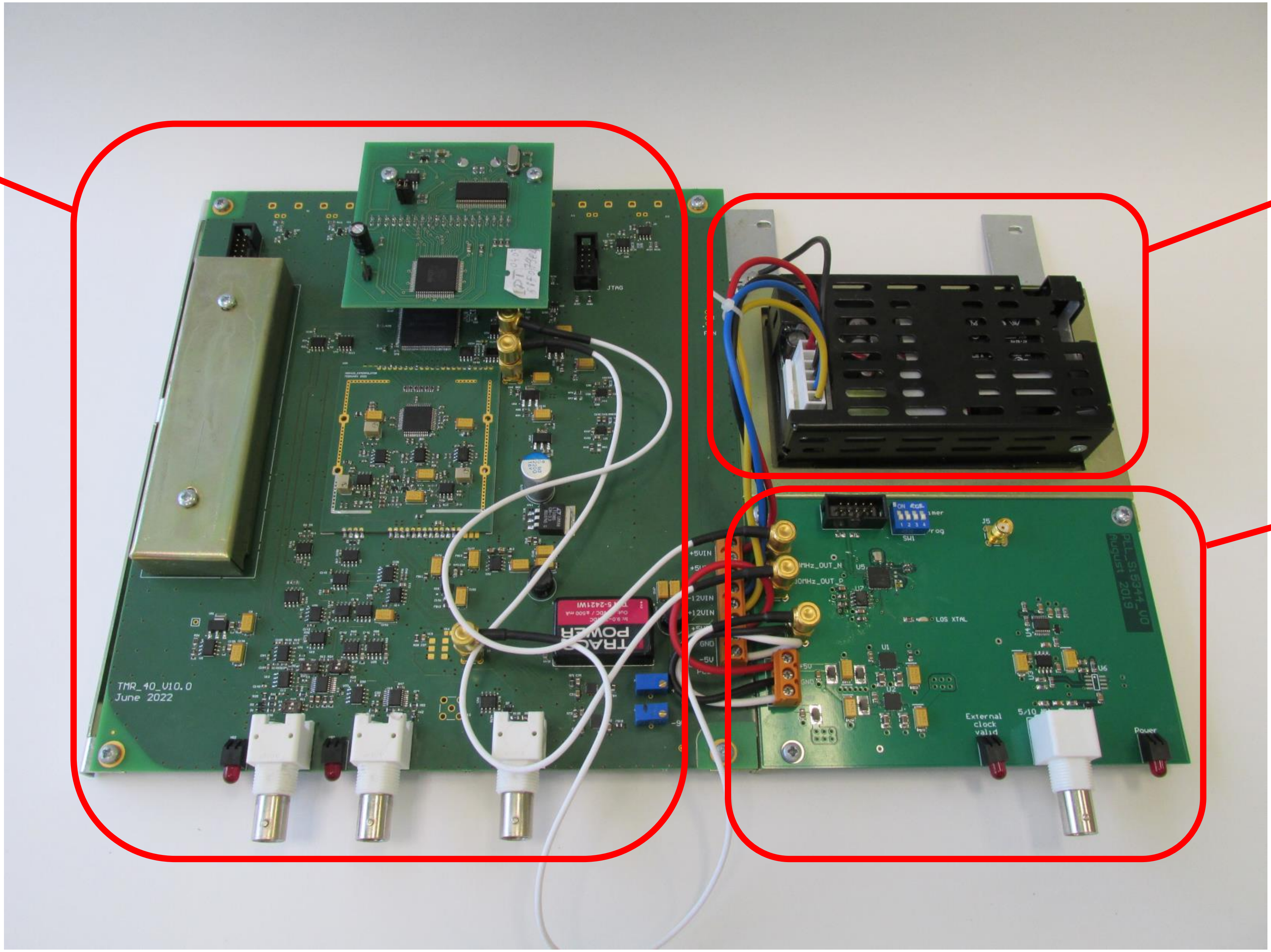
Amplitude measurement device



One pulse peak detector



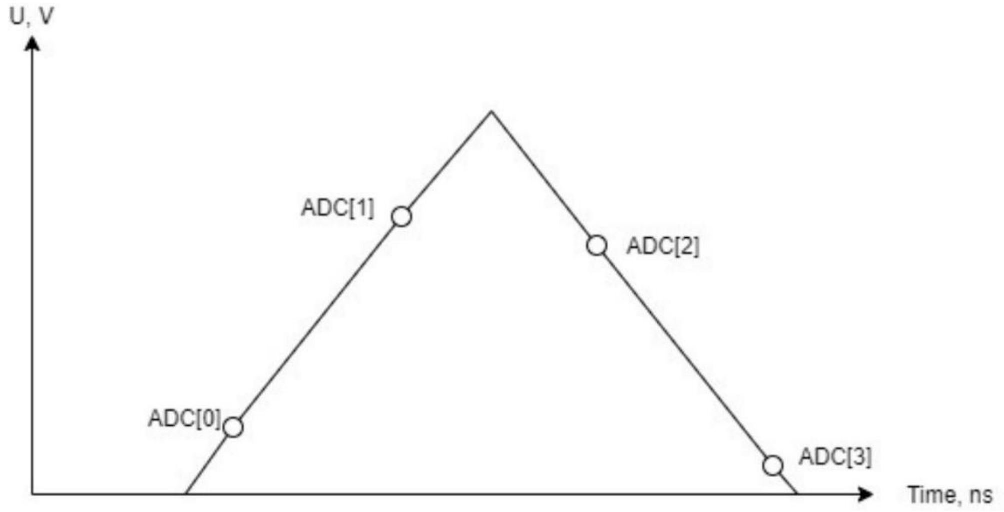
Timer T40 v10.0 with improved parameter stability



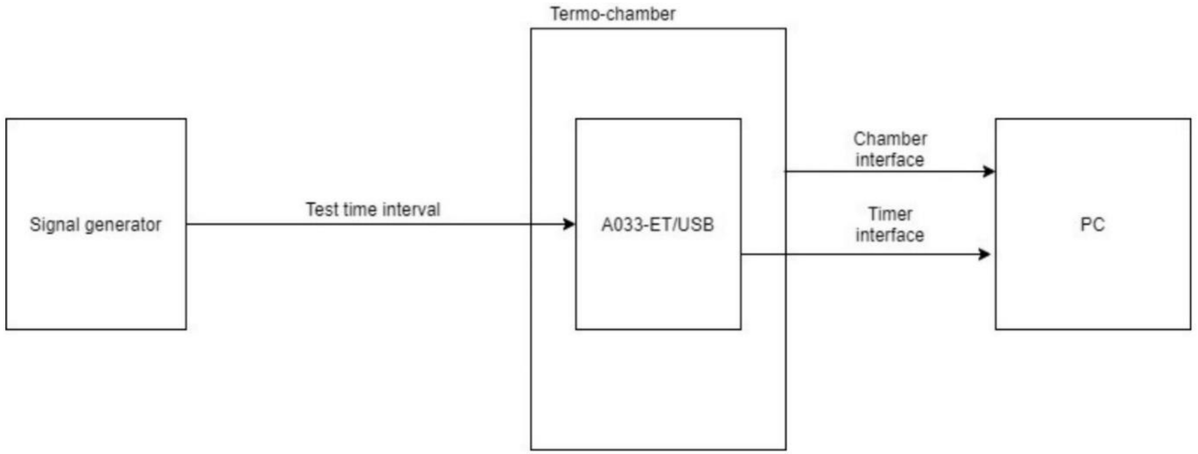
Timer precision experiment

The purpose of the method is to ensure the precision stability of the event timer interpolator by monitoring the current precision value and calling the calibration procedure if the specified maximum precision value is exceeded. Precision monitoring is based on tracking changes in the slope of the interpolation signal.

The result of the experiment is a graph of the dependence of the standard deviation of the timer time interval measurement on the steepness of the slope of the interpolation signal.



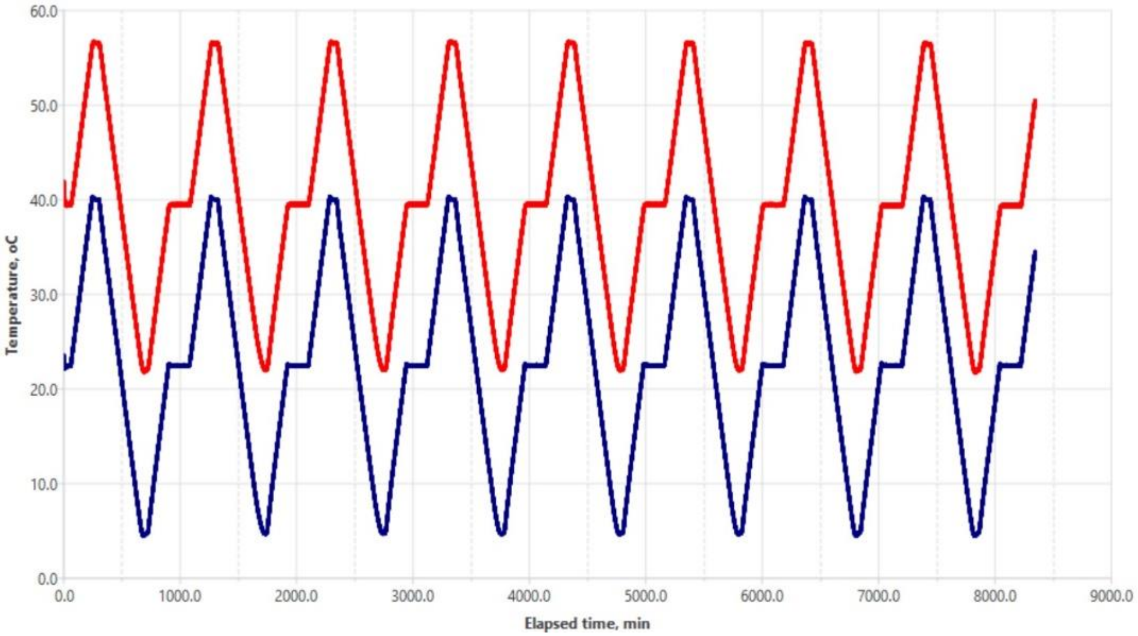
Interpolation signal ADC samples



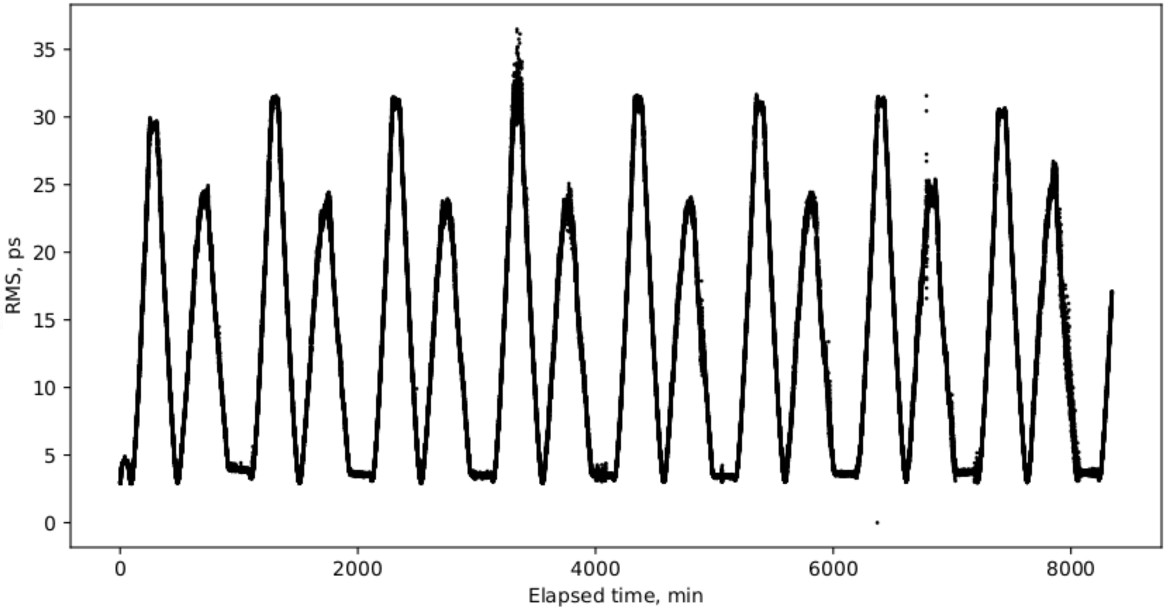
Block diagram of the experiment

Timer precision experiment

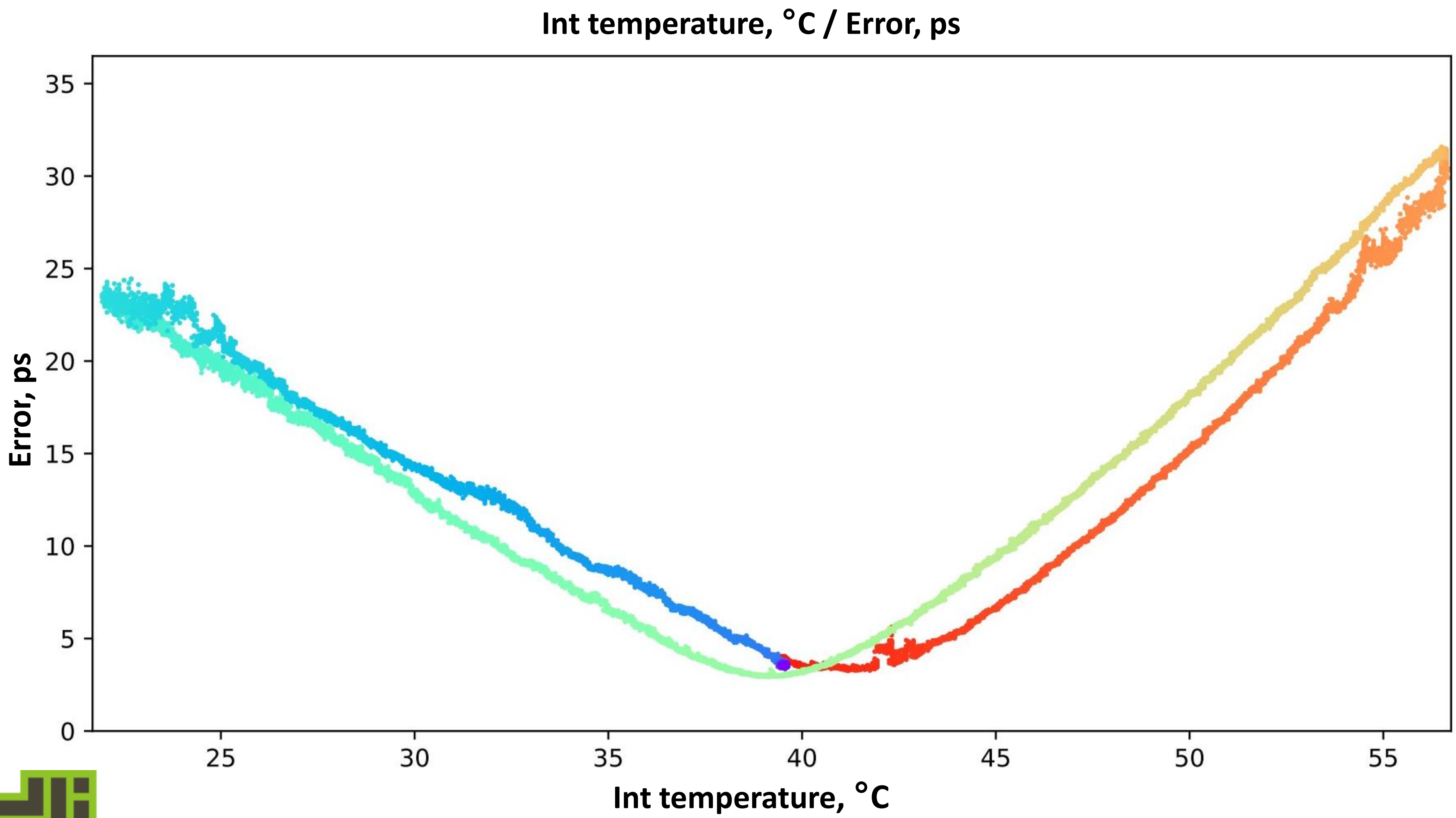
Temperature profile (red - timer internal temperature, blue - thermal chamber temperature)



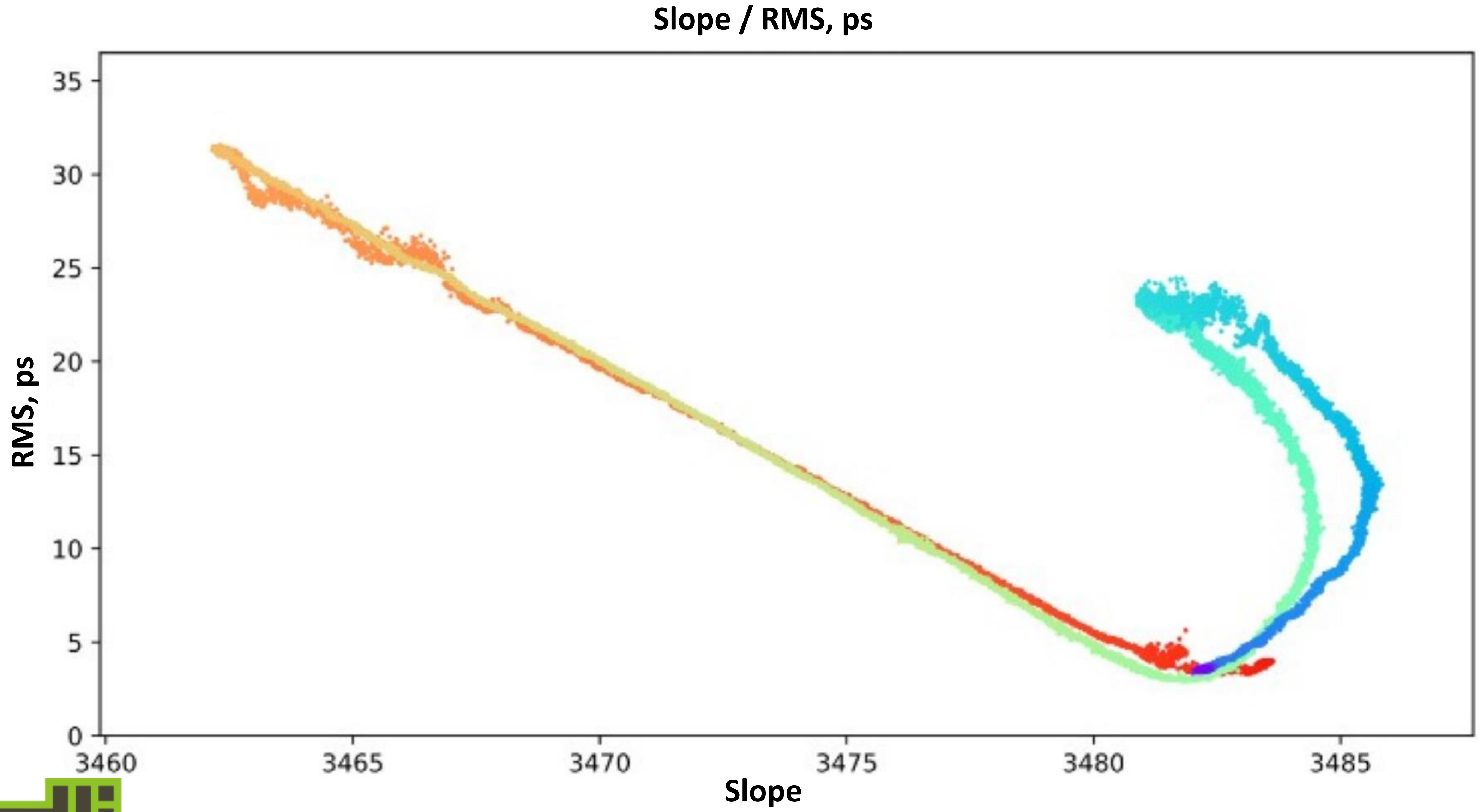
Time vs RMS, ps



Timer precision depending on temperature



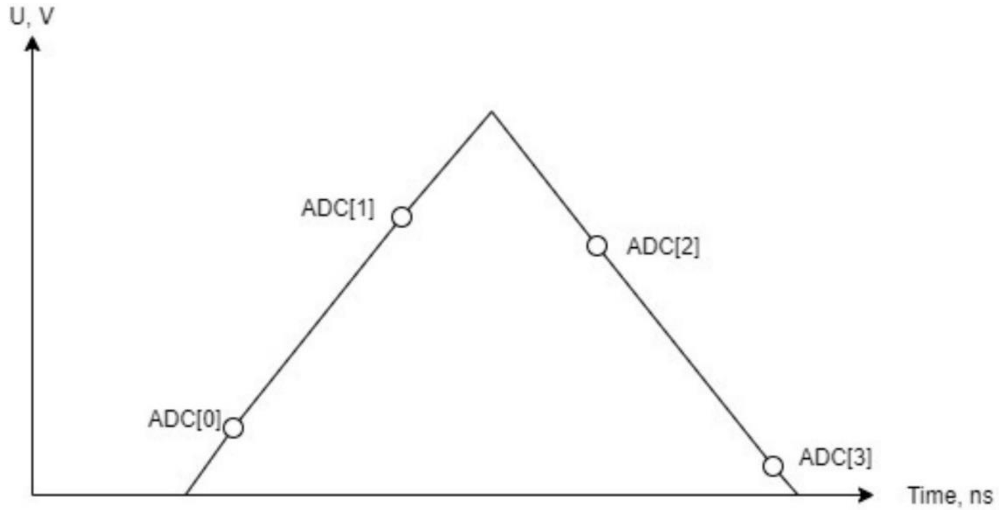
Random error dependence on steepness of interpolator signal



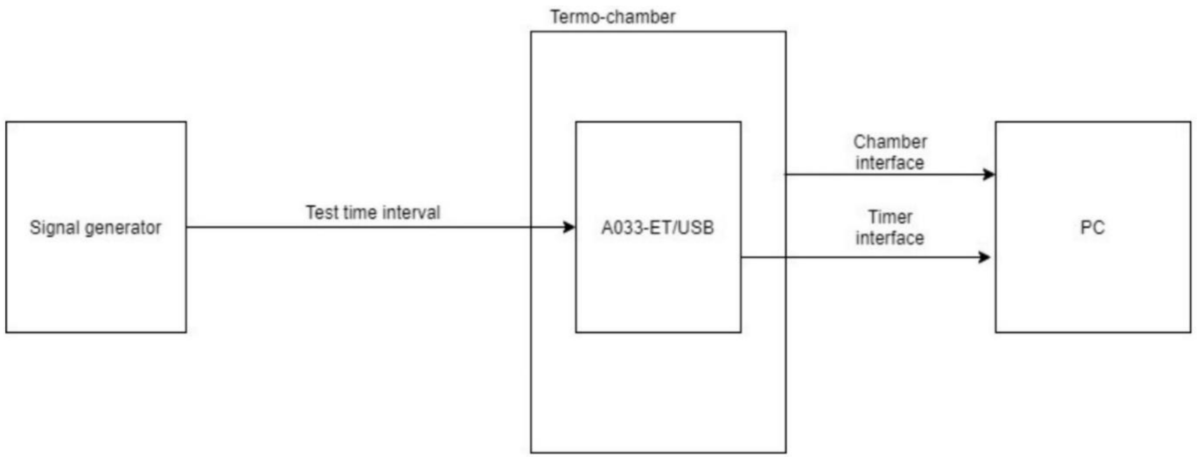
Temperature calibration

To ensure precise measurements, the timer requires calibration. During the calibration process, a table of the interpolator transfer characteristic is created, which is used to process samples from the interpolator ADC. Under changing external conditions (temperature), the transfer characteristic of the interpolator changes and the table loses its relevance.

Each table has a signal reading that corresponds to a phase shift of the interpolation signal in time.



Interpolation signal ADC samples



Block diagram of the experiment

Replacing the calibration table with a polynomial

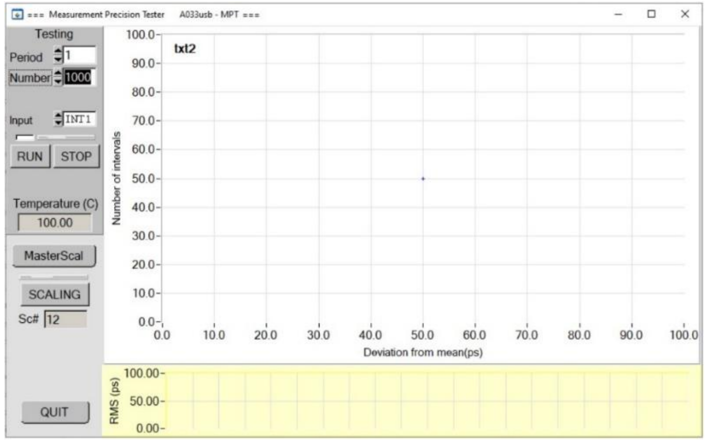
The full formula of the calibration function is

$$f_c(x,T) = K(T,0) + K(T,1)\cdot x + K(T,2)\cdot x^2 + .. + K(T,N)\cdot x^N$$

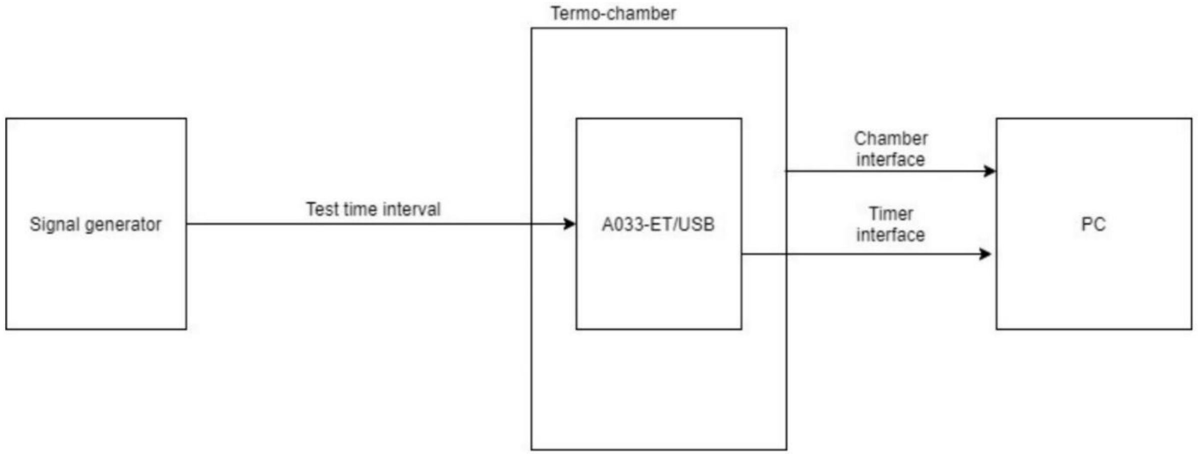
x – Interpolation signal ADC sample reading difference

T – timer internal temperature

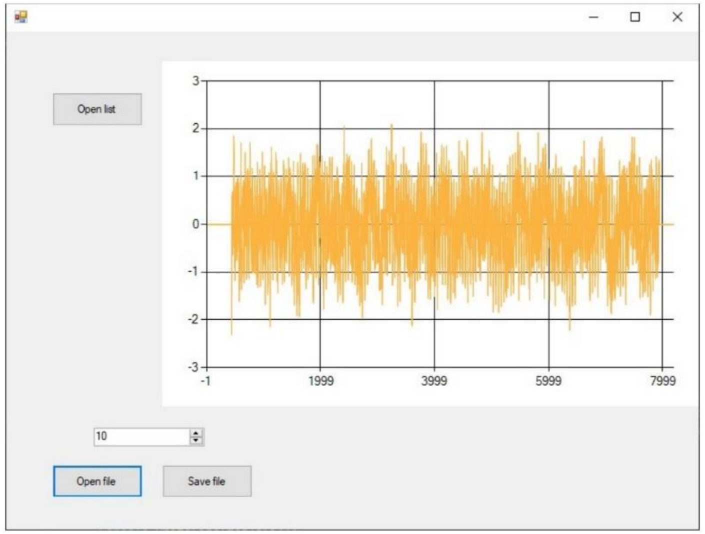
N – ordinal number of the polynomial coefficient $f_c(x,T)$



Program for creating calibration table

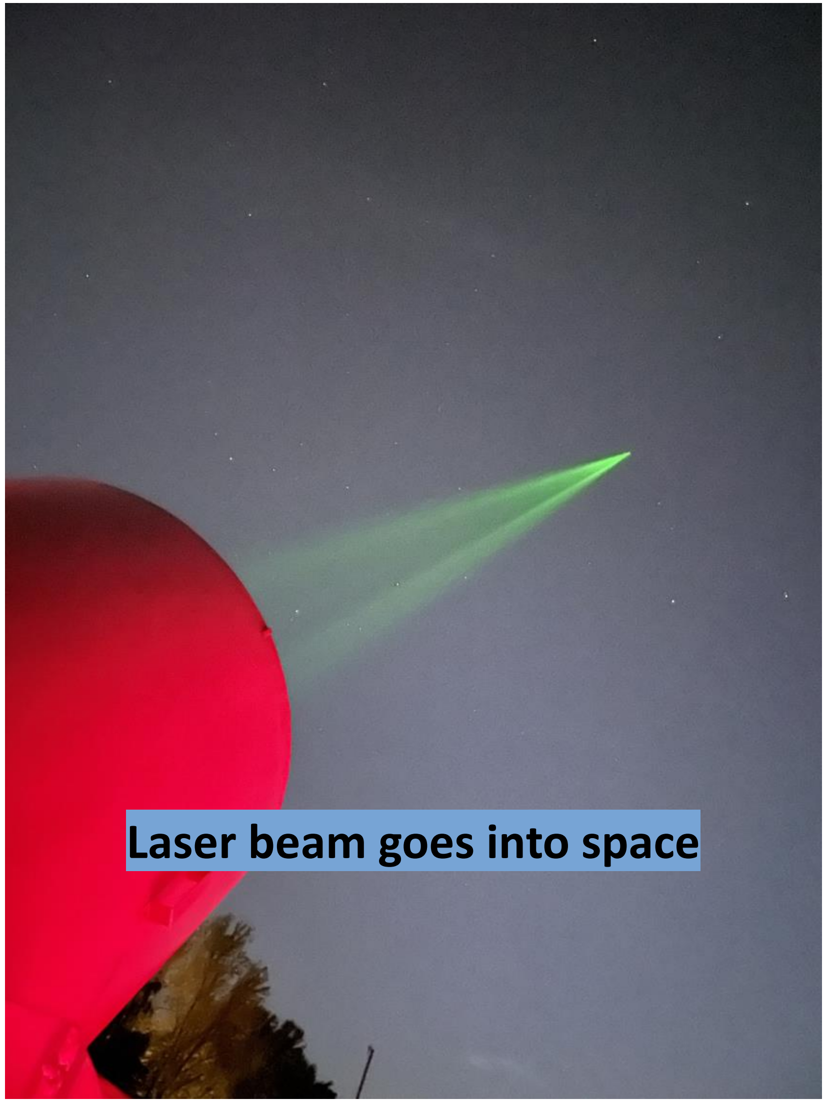


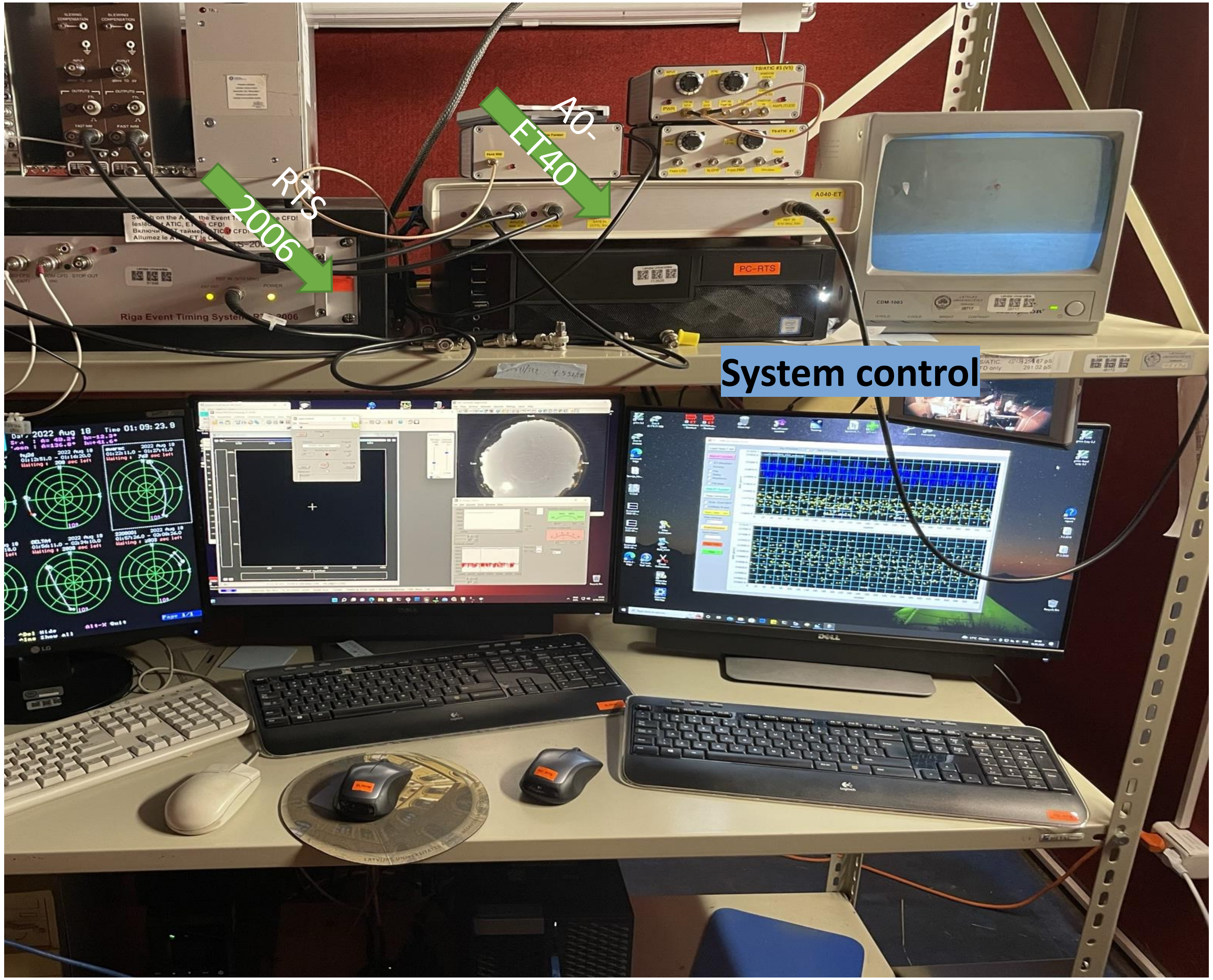
Block diagram of the experiment



Program for reconstructing calibration table with a polynomial

EDI timer application in satellite laser location station "Riga" (LU Institute of Astronomy)





Test setup and results

- Laser: EKSPLA 312/SH 10Hz, 532nm, 130mJ
- Primary detector channel: PMT → TS/Atic → RTS 2006(A0-ET32 based)
- Secondary detector channel HPD: → Ortec 9307 → A0-ET40
- Timing precision (timer scaling procedure): 2.42ps
- Calibration tests: similar performance as of A0-ET33

Thank you for your attention!

Acknowledgements

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Technology for high-precision time-amplitude analysis of event flow (TIME AMP)
Contract no. 1.1.1.1/20/A/076.