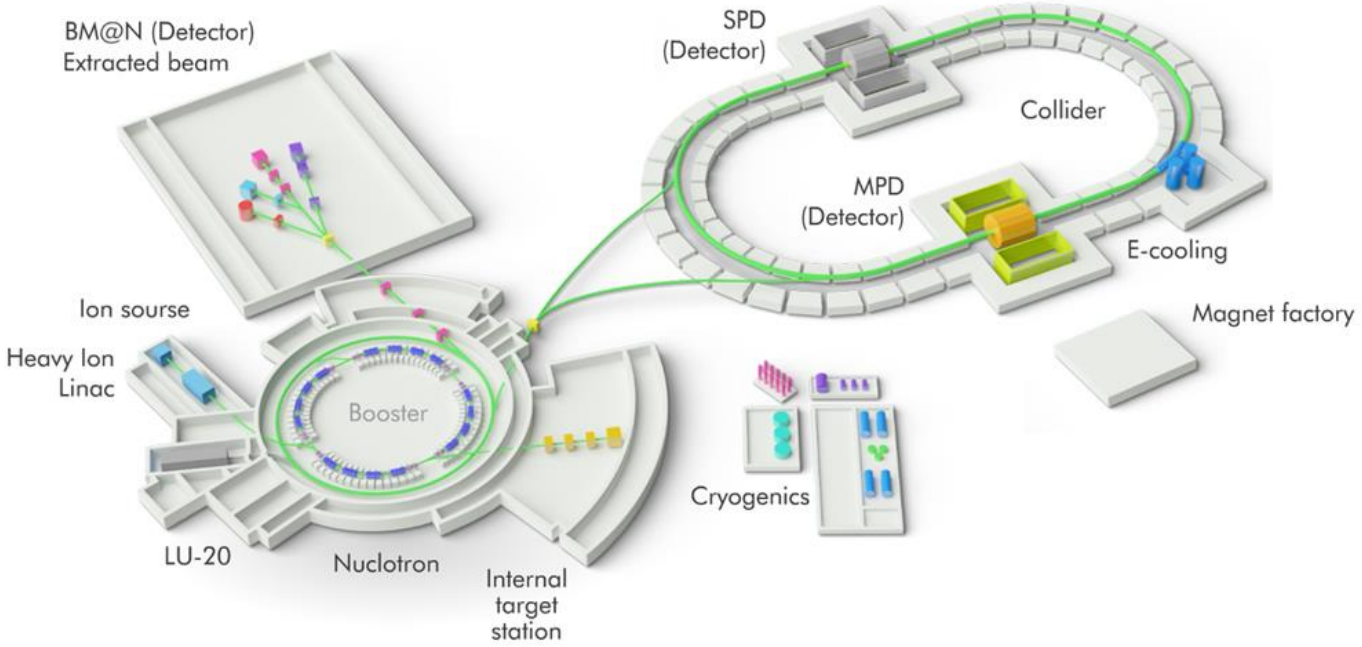
Study of the scintillation detector prototype for the upgraded polarimeter at the Internal Target Station at the Nuclotron

A.V. Tishevsky for DSS team

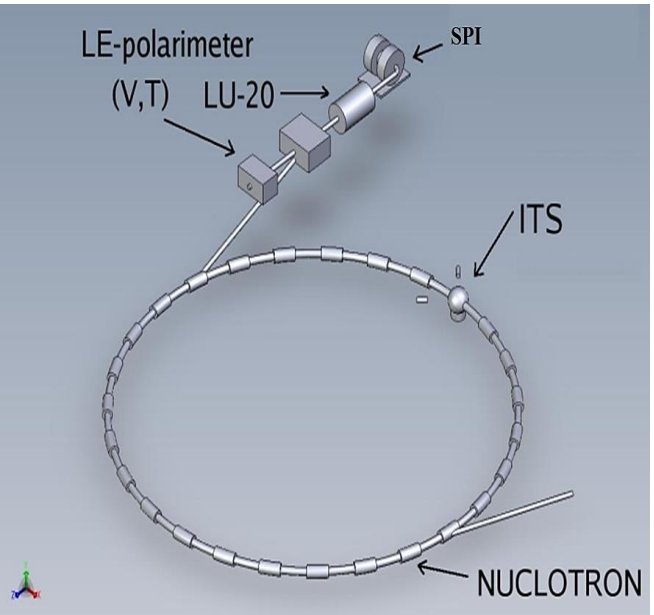
The XXVI International Scientific Conference
of Young Scientists and Specialists (AYSS-2022)
24 October 2022

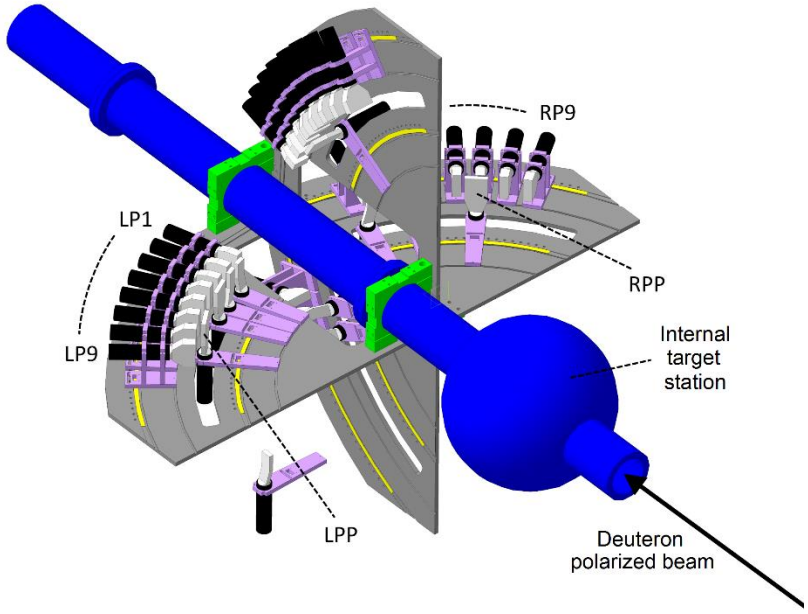
Introduction

The Internal Target Station (ITS)



The polarimeter based on the use of dp-elastic scattering at large angles in center-of-mass system was developed at ITS at Nuclotron accelerator complex.



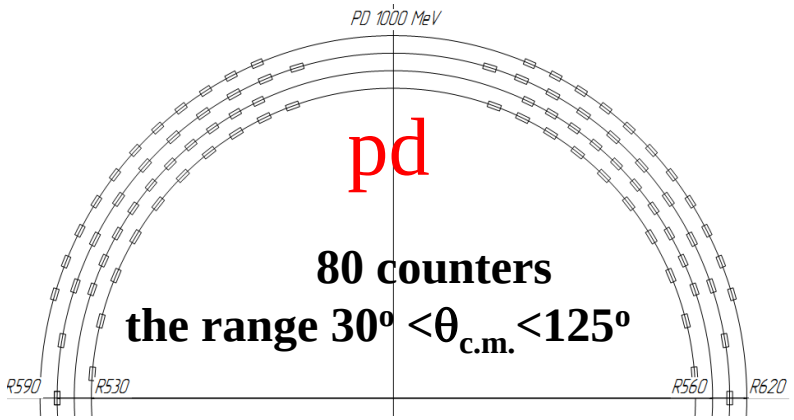


- ✓ to get new data on the spin structure of the SRC
- ✓ to measure the beam polarization values

Motivation

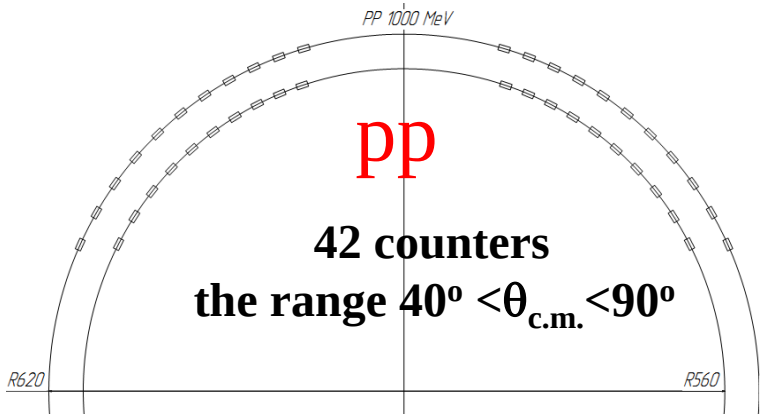
One of the way of the upgrade

to increase the effective area of the counters

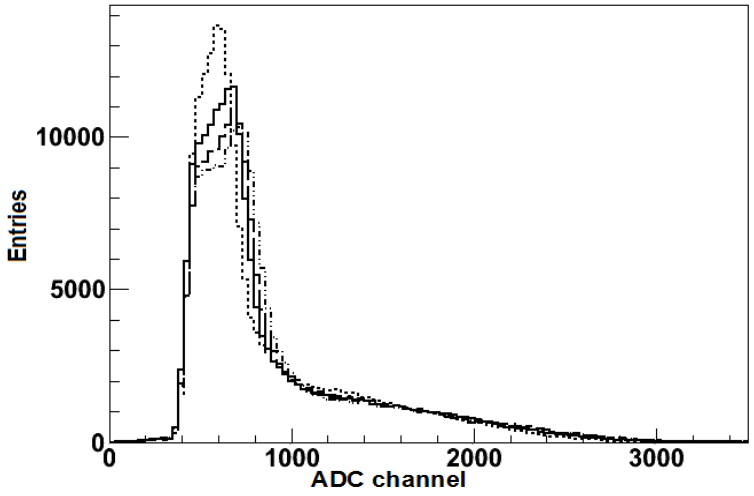


New scintillation counters

sizes: 2x2x2 cm^3, 3.5x6x2 cm^3, and 2.3x6x2 cm^3



Amplitude signal from one of counters



The calculation using the Pluto simulation by A. Terekhin

A. Terekhin, A. Tishevsky at al. //J.Phys.Conf.Ser V.1435, 012051 (2020)

The 16-channel scintillation prototypes

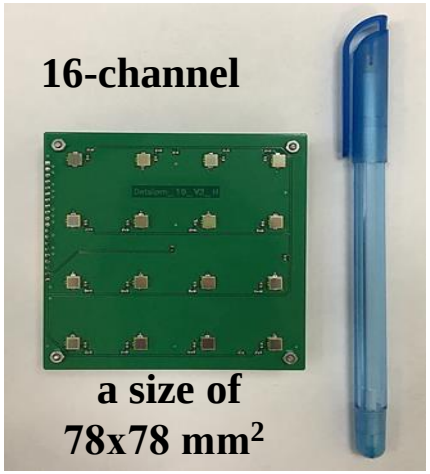
another way of upgrading

This one is an increase the aperture of the counter with an increase in its granularity at a fixed scattering angle .

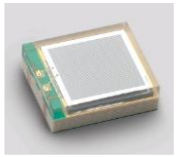
Advantages	Disadvantages
▪ low bias voltage	▪ sensitivity to external temperature changes
▪ insensitivity to magnetic fields	▪ some have low radiation hardness
▪ compact size	

Each prototype are implemented on two PCBs. They contain power supply for sixteen SiPMs. The bias voltage is set remotely via the HVsys program.

The 16-channel scintillation prototypes of detector with SiPM readout produced by Ketek and Hamamatsu were developed.



PM3350,**KETEK**
(3x3 мм², 50 μm/cell)

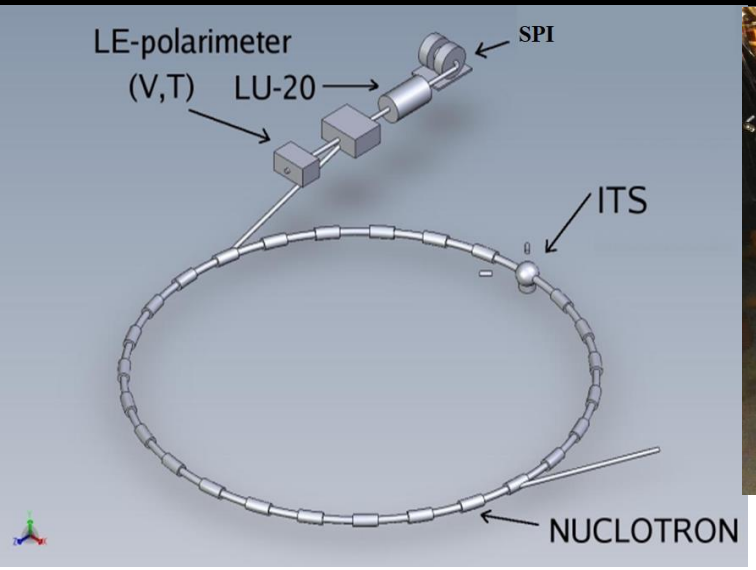


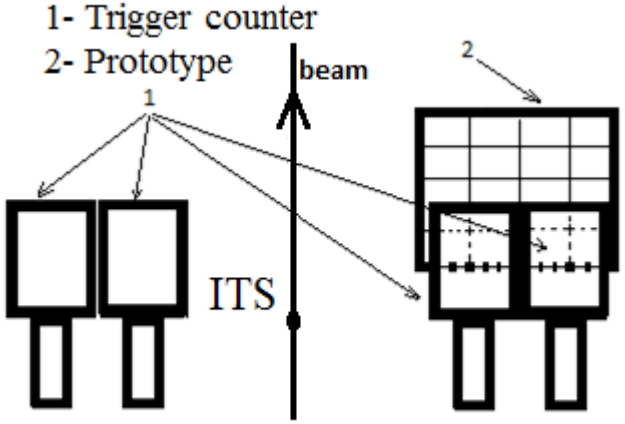
S12572-010P, **HAMAMATSU**
(3x3 мм², 10 μm/cell)

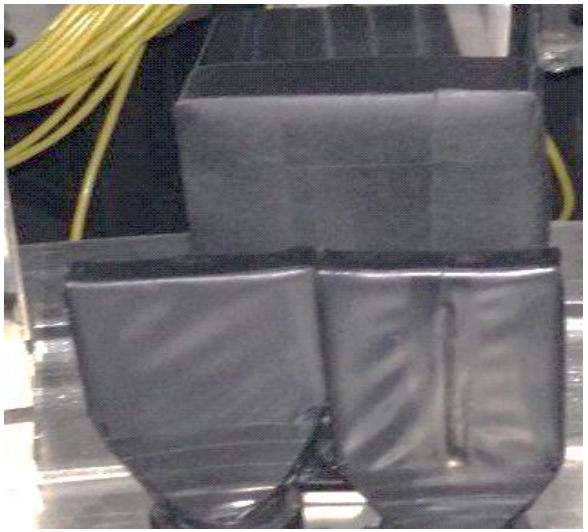
A. Tishevskiy et al. //Phys.Atom.Nucl., Vol. 83, No. 11 (2020)

Prototype studies

Experimental conditions







Hamamatsu H741MOD photo-multiplier tube

U_{bias} =23,0 – 24,7 V

the energy 4 GeV / nucleon

the intensity $1x10^6$—$8.5x10^8$

The trigger was the coincidence of two scintillation counters from different sides of the Nuclotron ion pipe.

$$\begin{cases} \sigma_1^2 = \sigma_L^2 + \sigma_R^2 \\ \sigma_2^2 = \sigma_L^2 + \sigma_{Ch}^2 \\ \sigma_3^2 = \sigma_R^2 + \sigma_{Ch}^2 \end{cases} \quad (1)$$

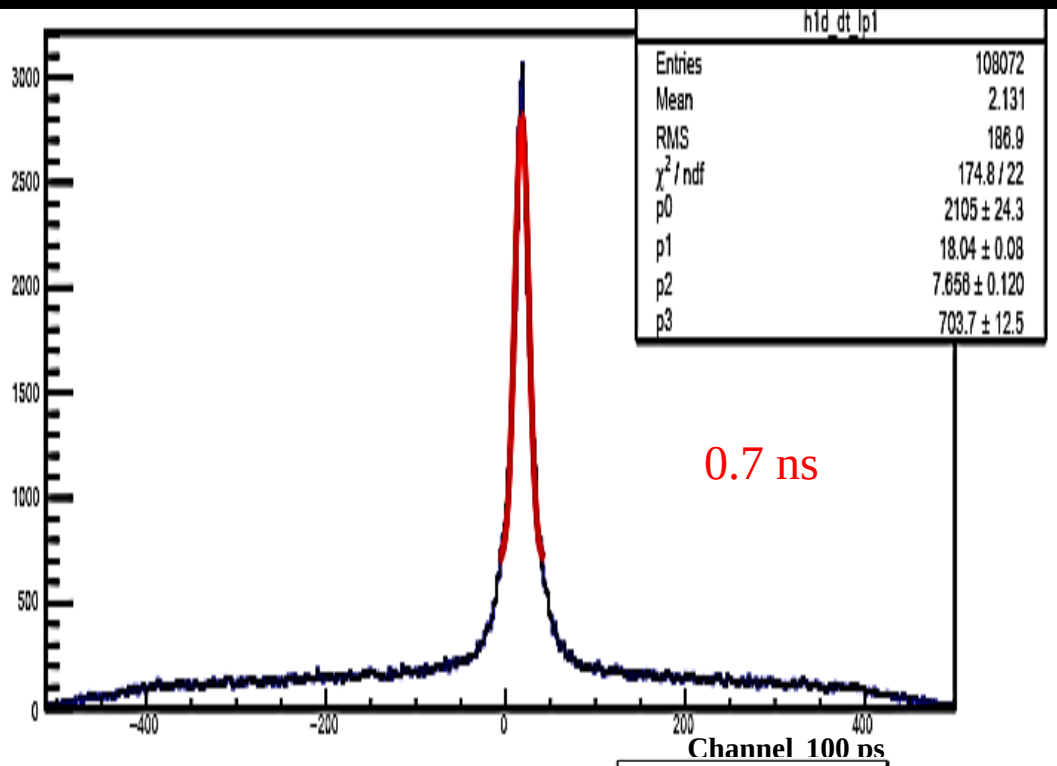
$$\left.\begin{aligned} \sigma_L^2 \approx \sigma_R^2 = \sigma_0^2 \\ \sigma_1^2 = 2\sigma_0^2 \end{aligned}\right] \quad (2)$$

$$\sigma_{Ch} = \sqrt{\sigma_2^2 - \sigma_0^2}$$
$$\sigma_{Ch} = \sqrt{\sigma_3^2 - \sigma_0^2} \quad (3)$$

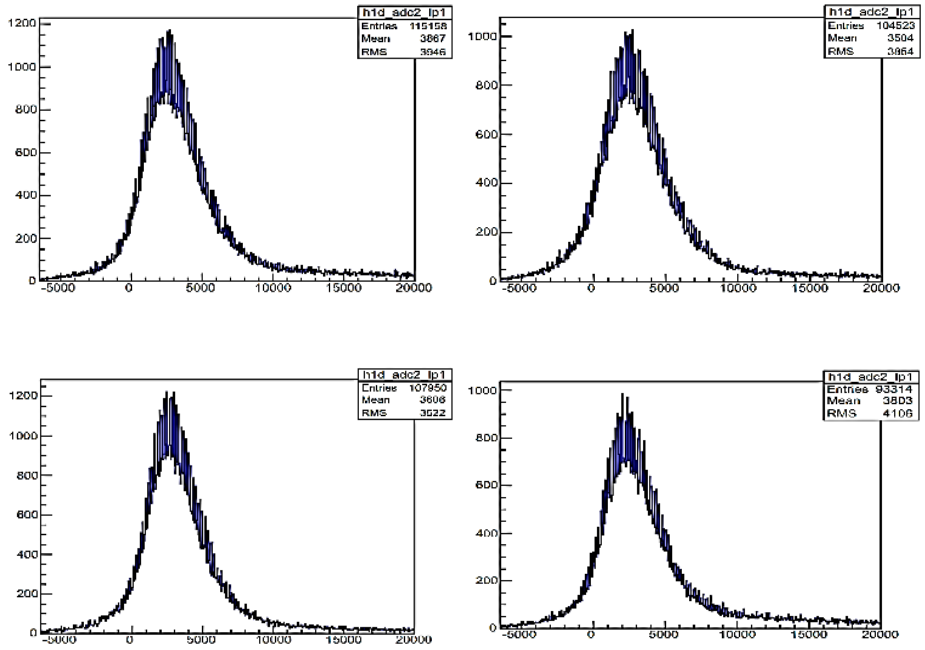
A. Tishevsky et al. //AIP Conf. Proc., 2377, 030017 (2021)

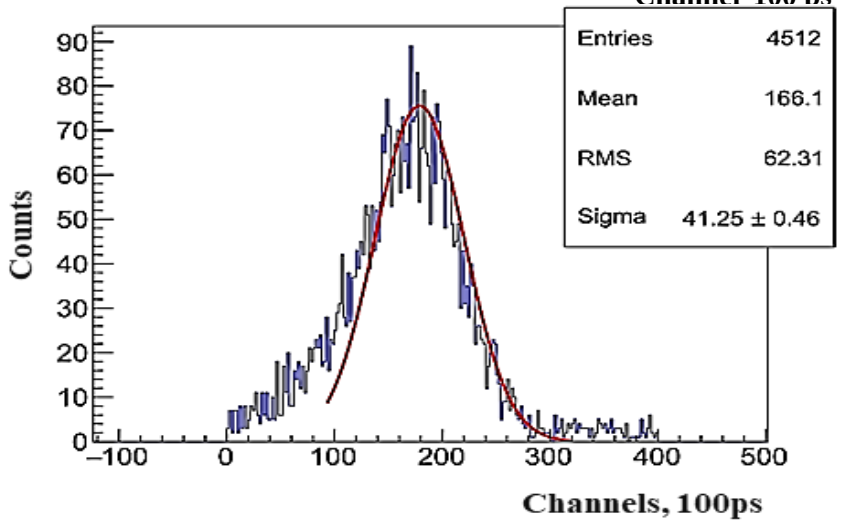
Prototype studies results

The amplitude and time difference histograms

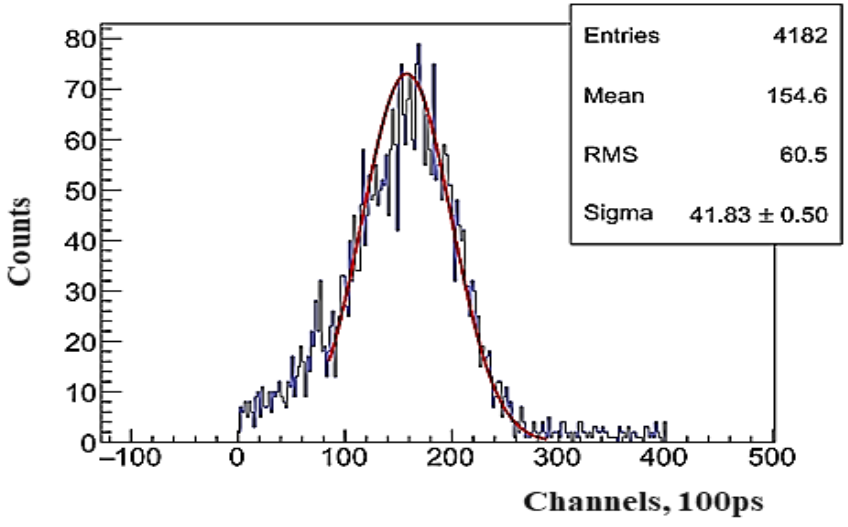


0.7 ns

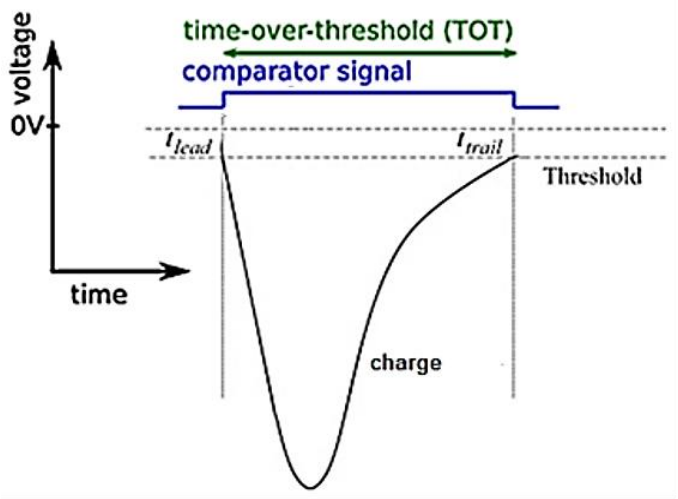




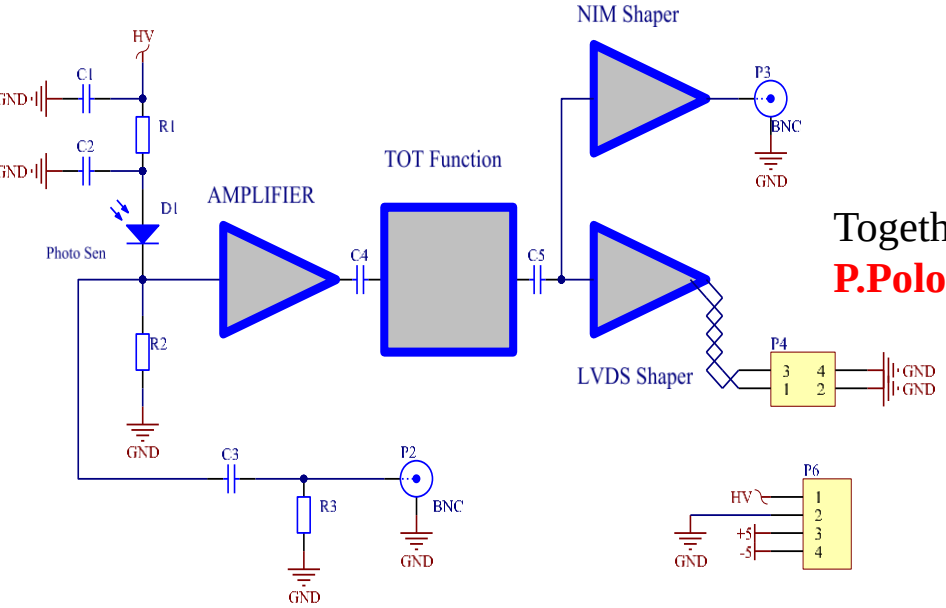
Average
~ 4.0 ns



Developed FEE



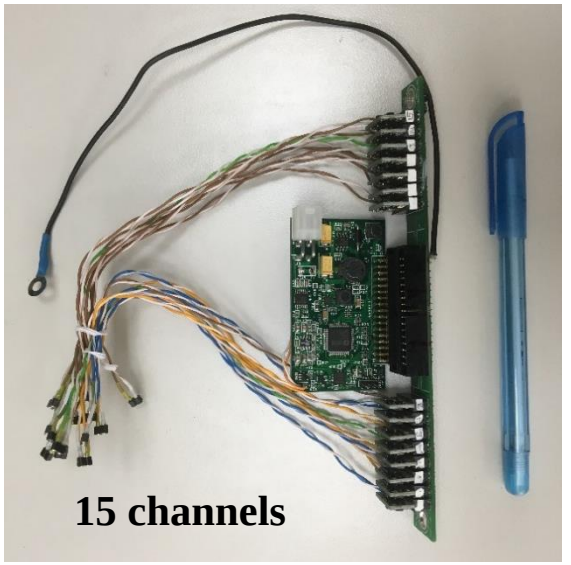
Front-end electronics with ToT technique



FEE ToT

Together with
P.Polozov, T.Kulevoy (KRI ITEP)

FEE DANSS (DANSS experiment)

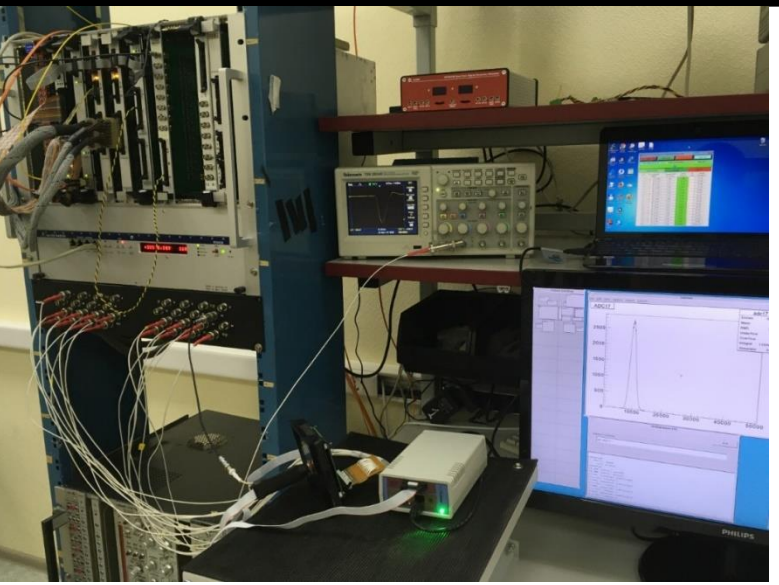


Together with
I.Alexeev, D.Svirida (KRI ITEP)

The ToT is a well-known method which allows to measure the energy deposited in the material.

FEE studies

The stand for FEE tests

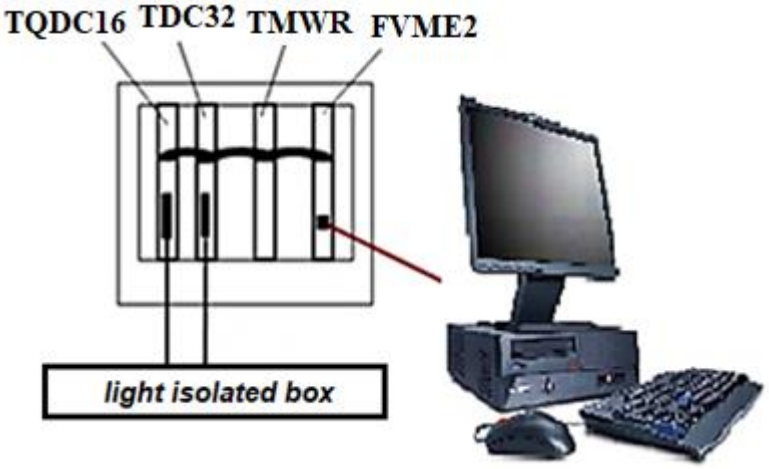


TQDC16
(16-channel
time and charge
digitizer)

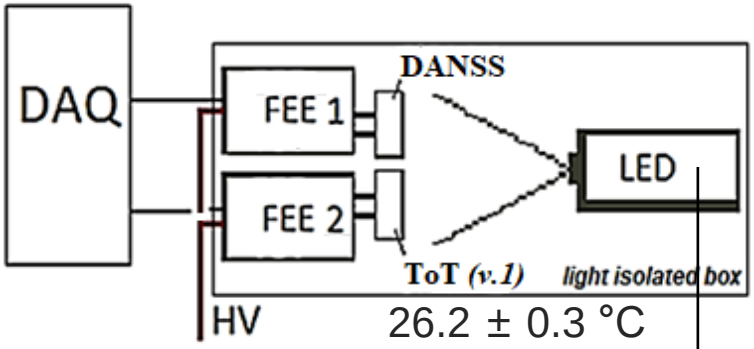
TDC32
(32-channel
time digitizer)

The data were accumulated with a VME based data-acquisition system (DAQ)

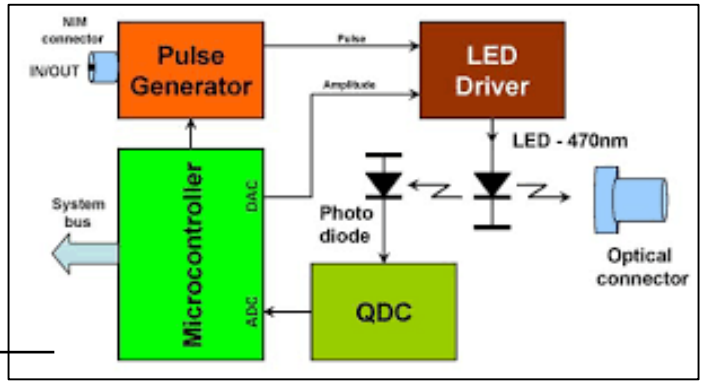
Isupov A.Yu. // EPJ Web Conf. 2019. V.10003. P.204



Schematic view of the test



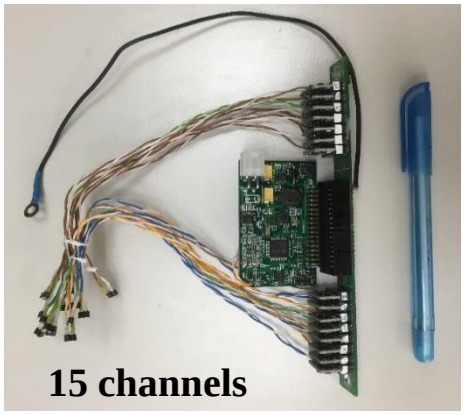
Schematic view of the LED

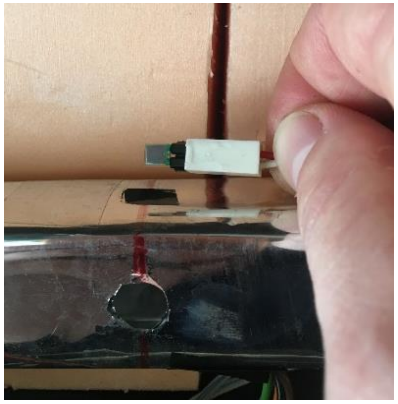


A.Isupov, S.Reznikov, A.Terekhin, I.Volkov, V.Ladygin, Yu.Gurchin, A.Tishevsky…

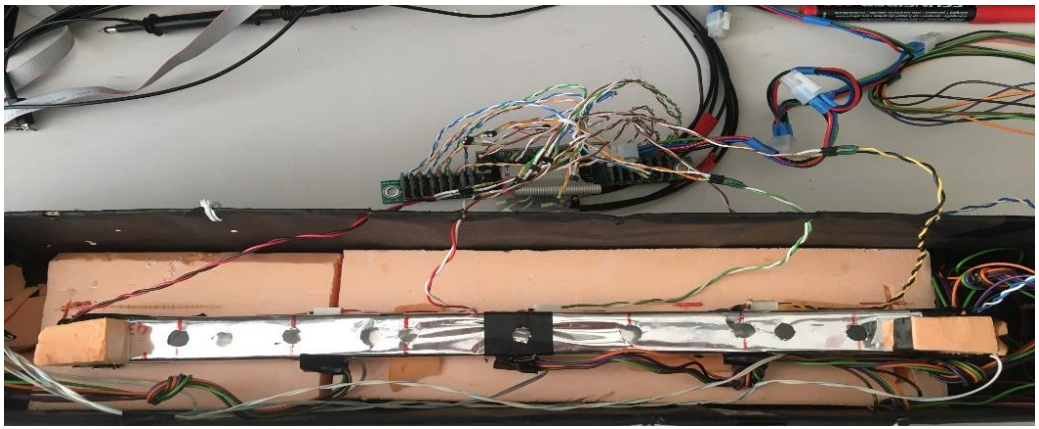
FEE studies

Tests with scintillator



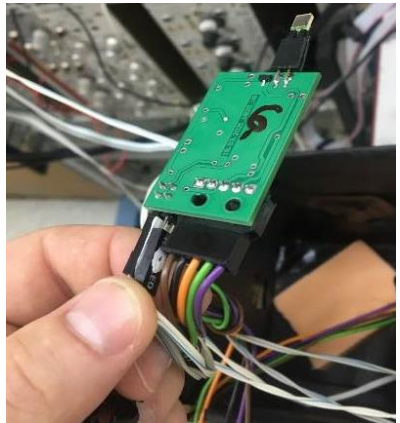


5 channels FEE of DANSS experiment



Plastic Scintillator
40 x 2 x 2 (cm^3)

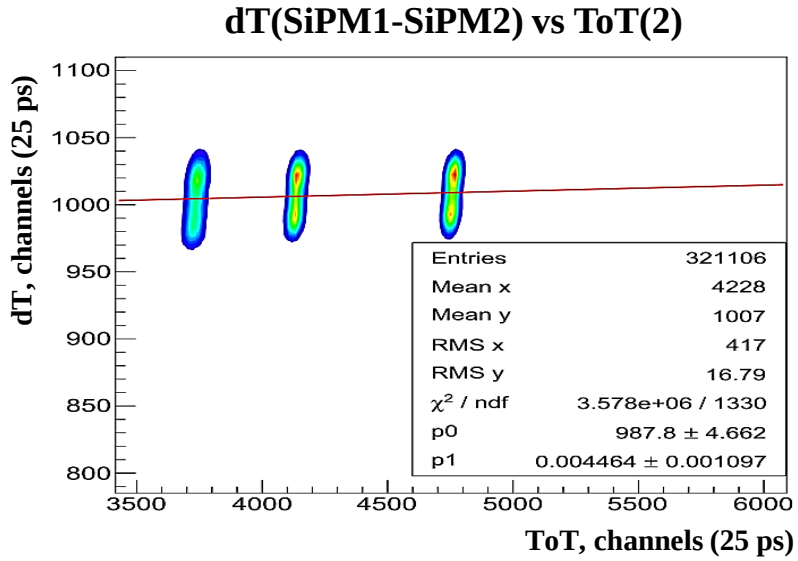
10 pcs HAMAMATSU
(S12572-010P,
3x3 mm^2,
10 μm/cell)

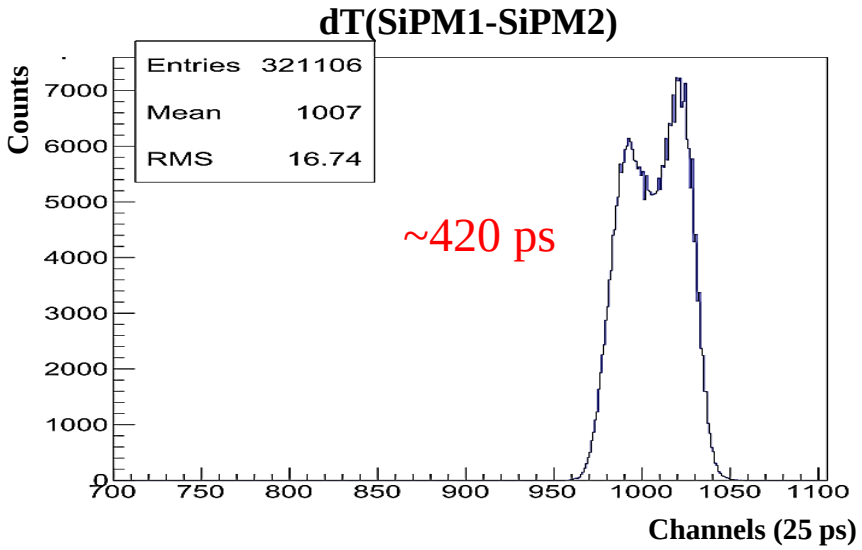


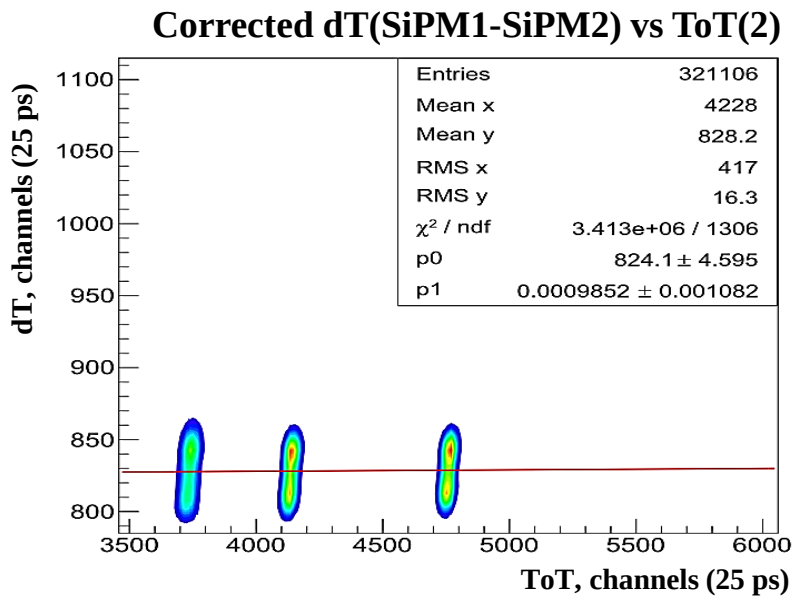
5 channels FEE ToT (v02 and v03)

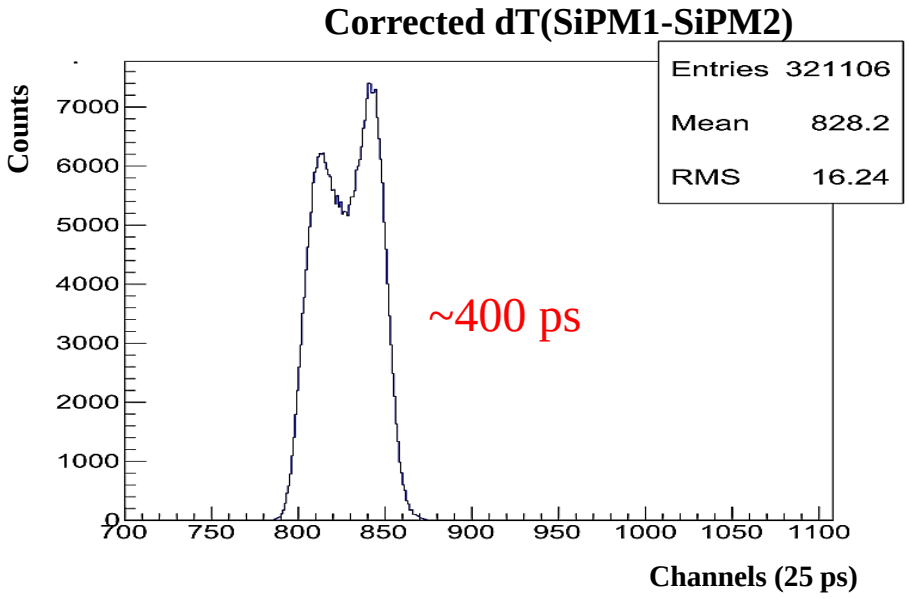
FEE studies results

The time difference histogram FEE ToT (version 02)



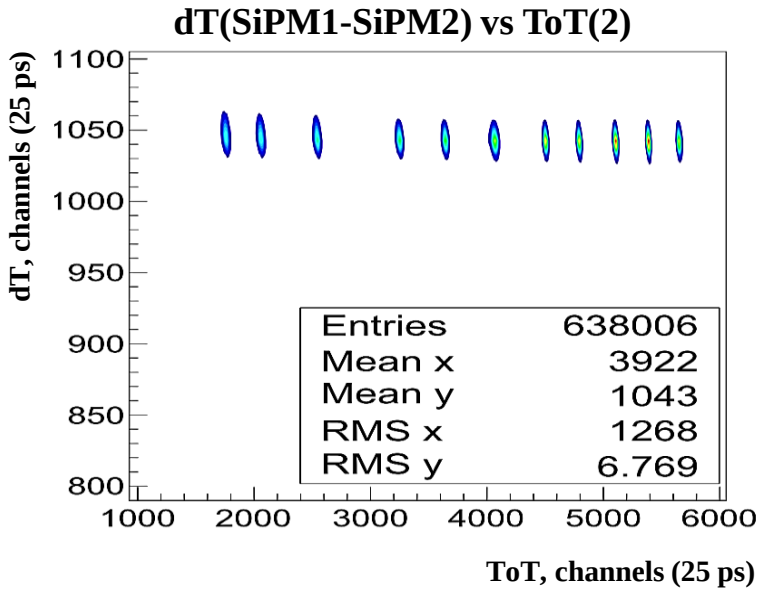


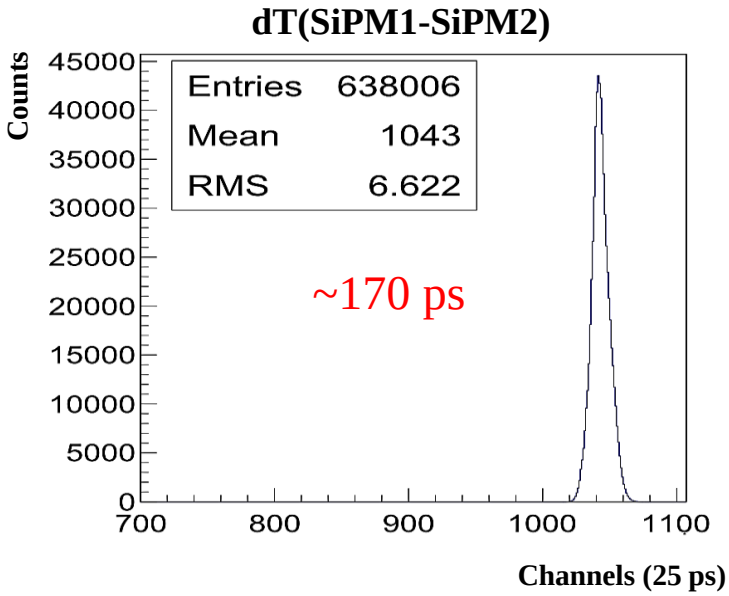


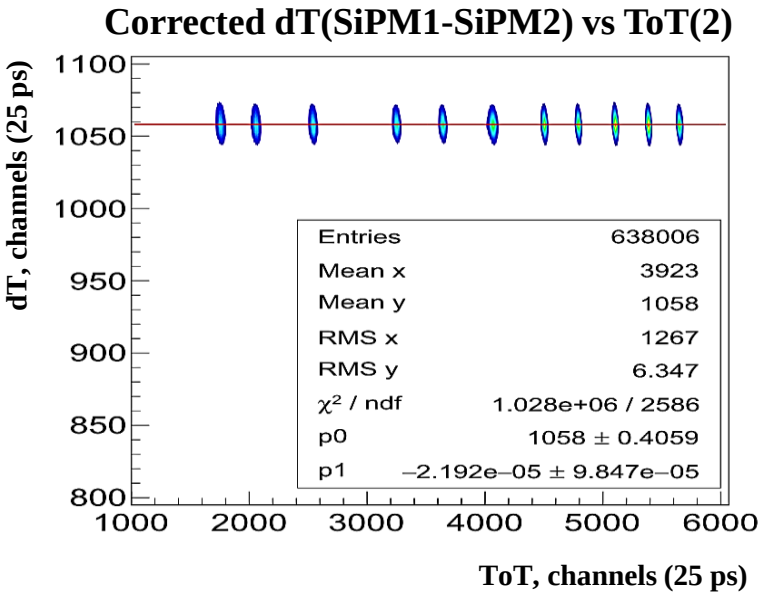


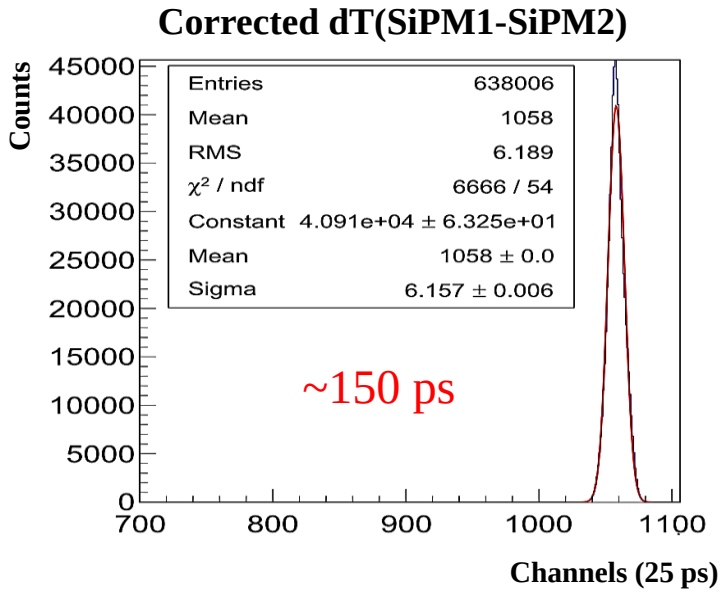
FEE studies results

The time difference histogram FEE ToT (version 03)



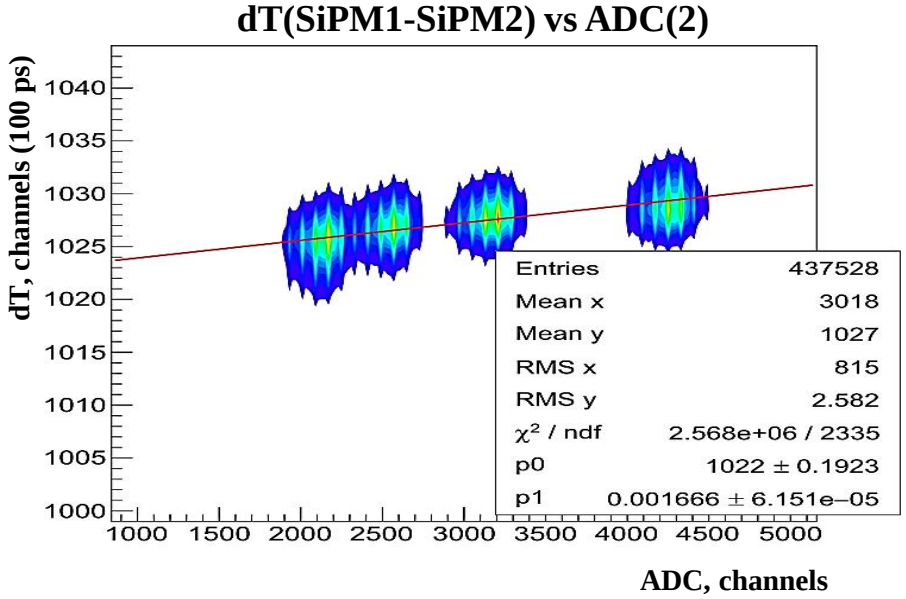


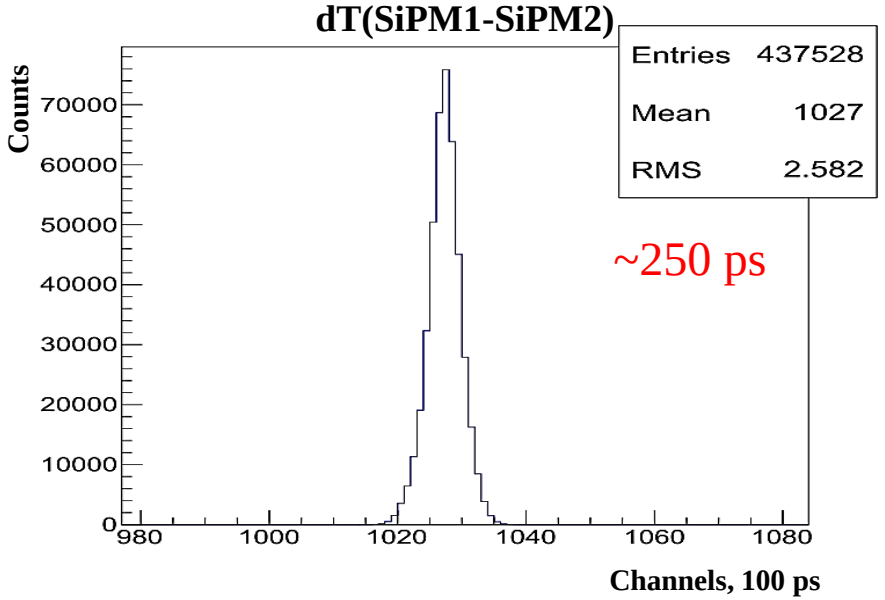


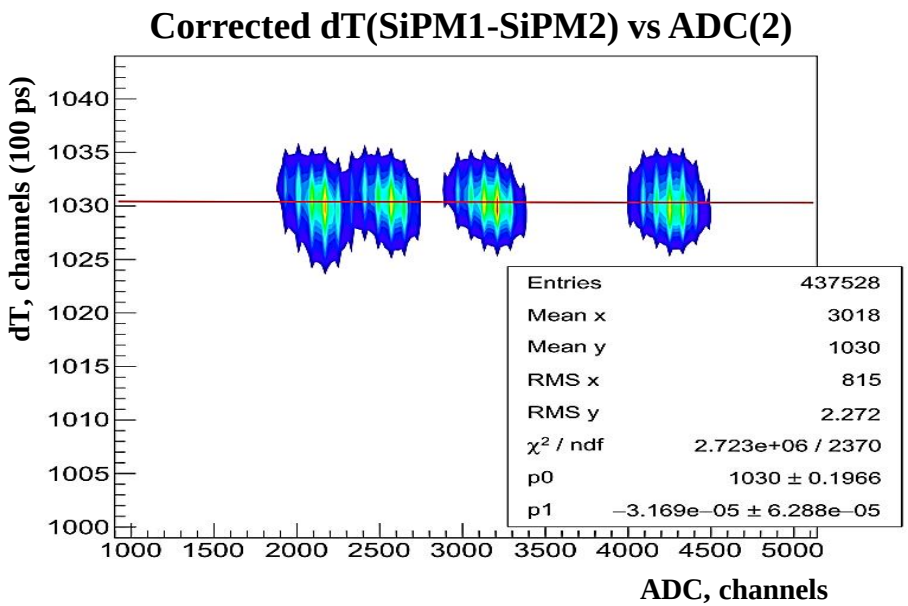


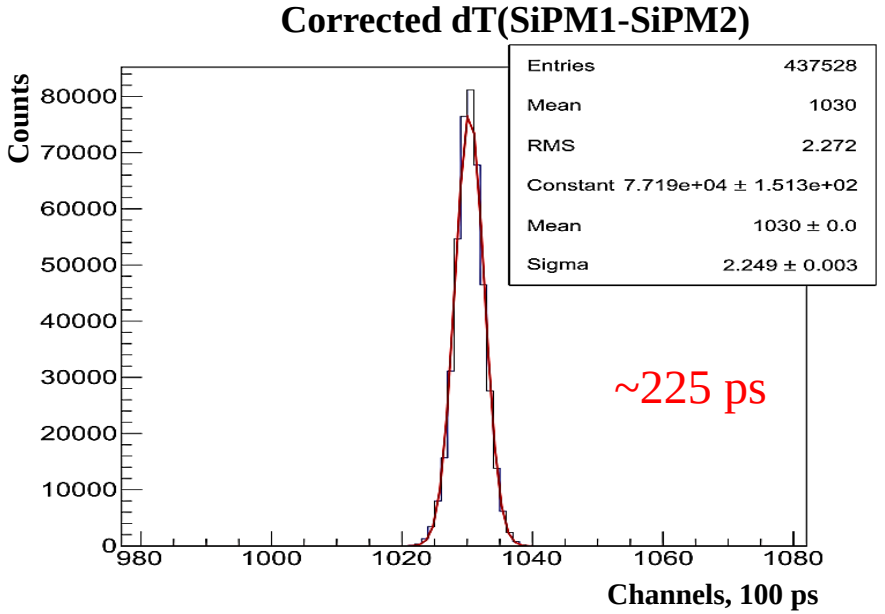
FEE studies results

The time difference histogram for FEE DANSS





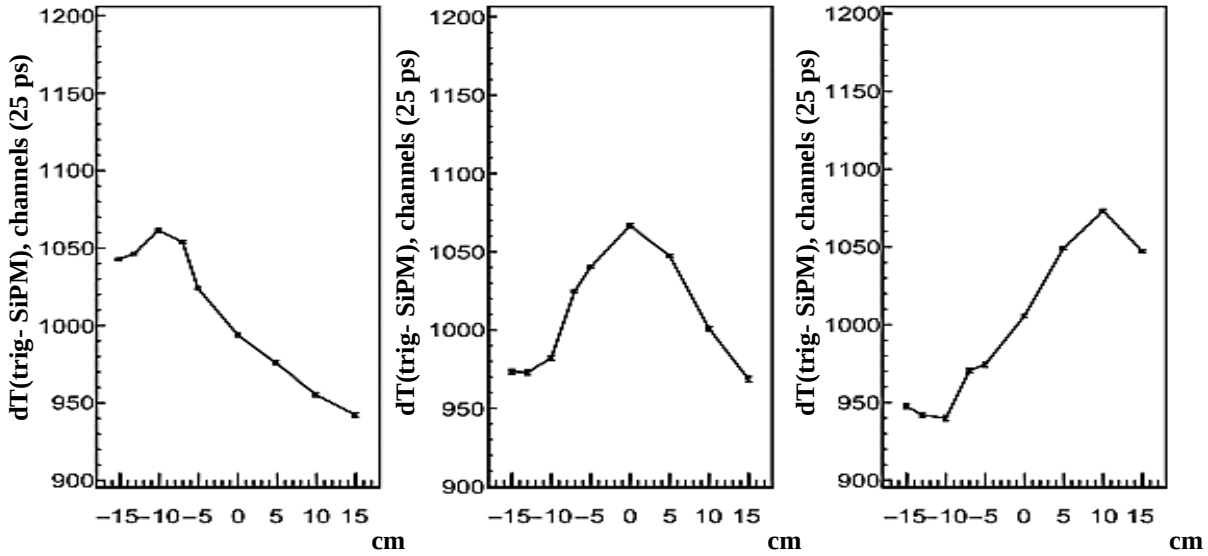




FEE studies results

Comparison of electronics Scanning by source position (Amplitude 4000)

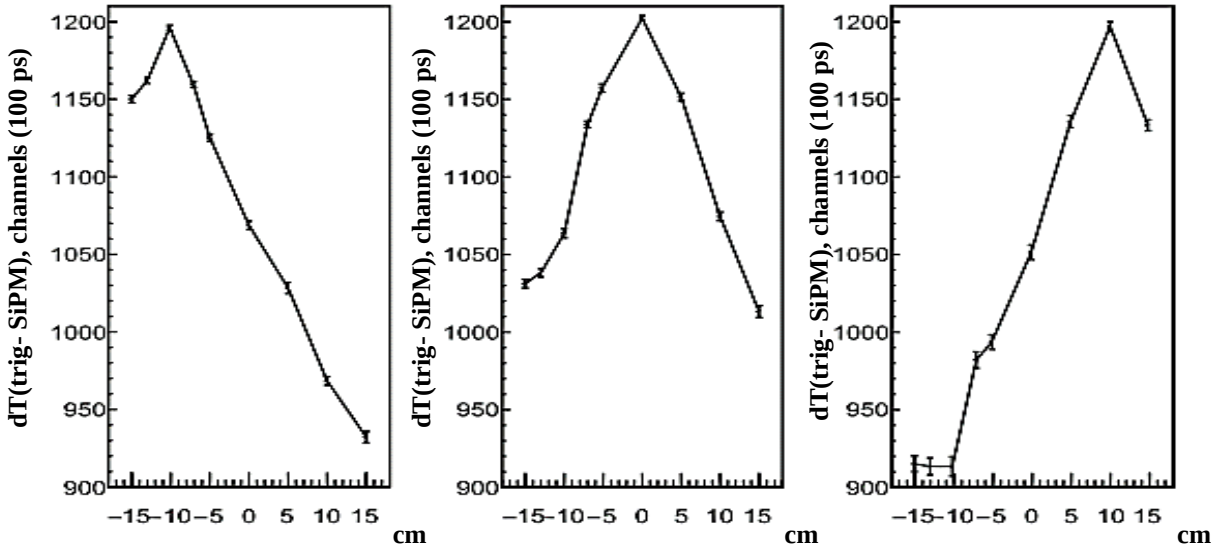
FEE ToT



SiPM2 **SiPM3** **SiPM4**

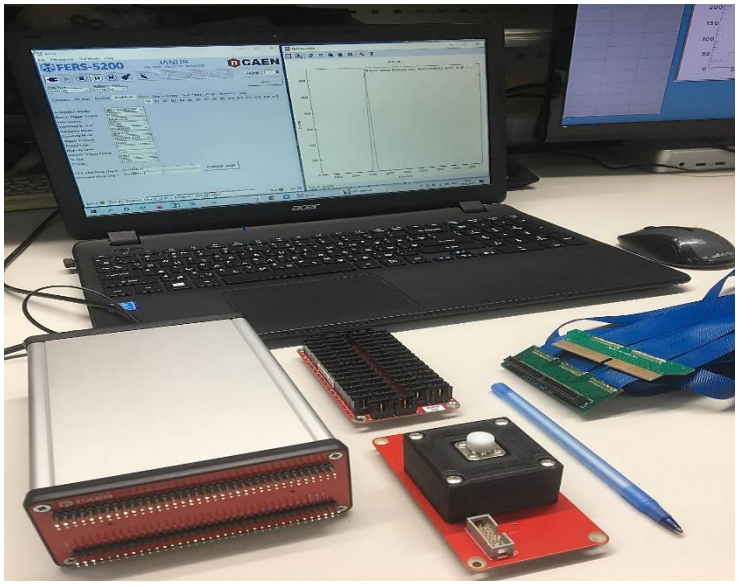
(plastic center)

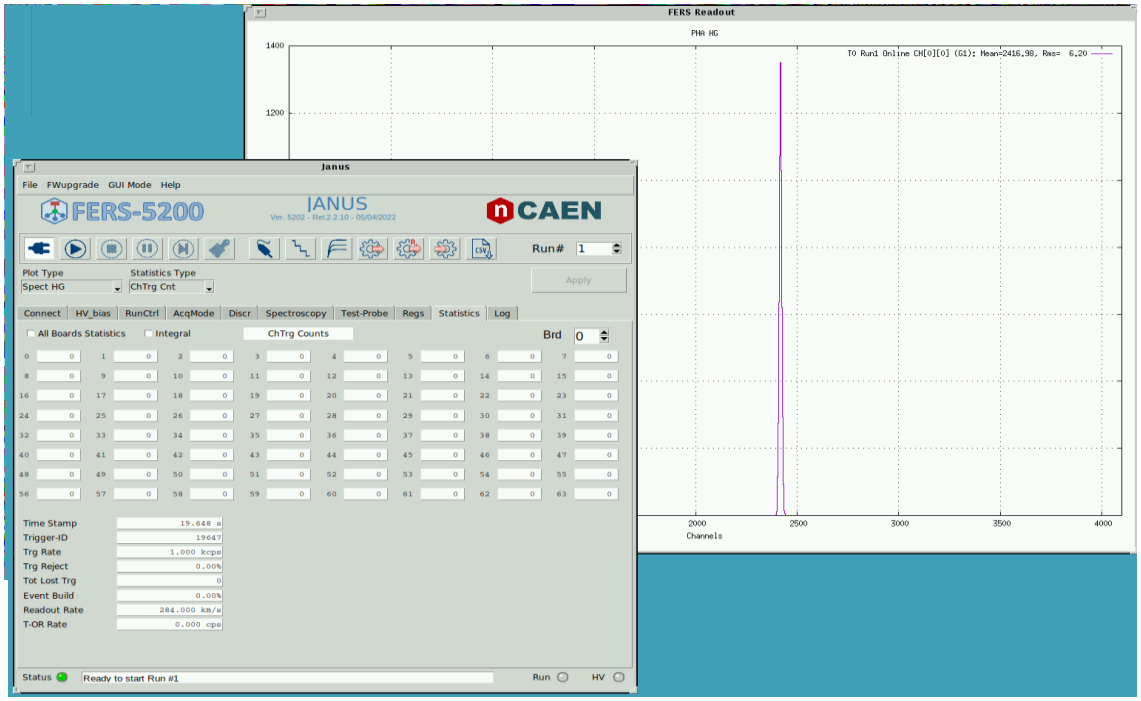
FEE DANSS

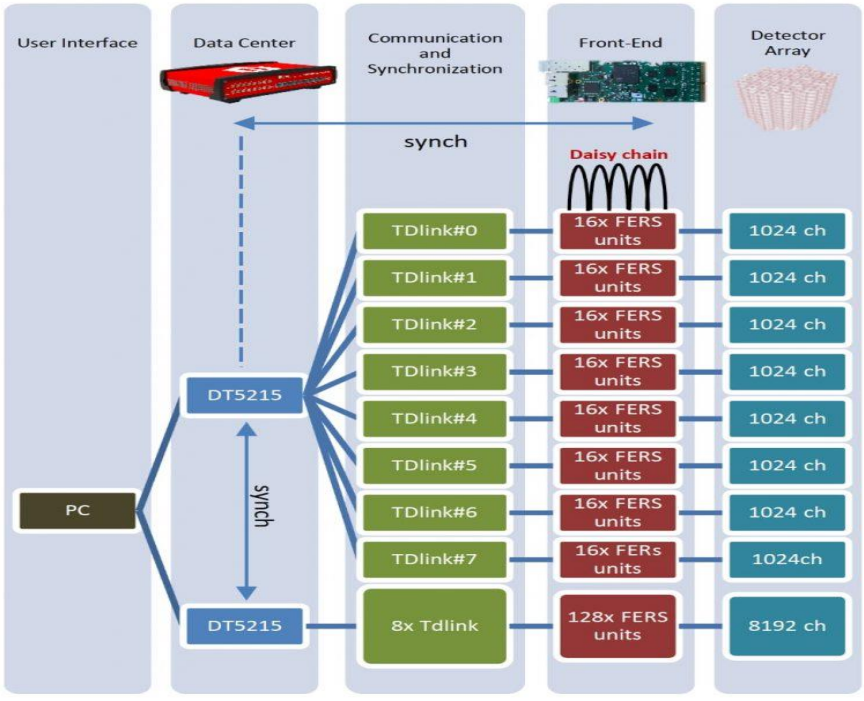


FEE studies

FERS5200 application







FERS5200 is an extendable high speed system based on the DT5202 64-channel module for SiPM.
The system can be extended up to 8192 channels using data concentrator DT5215.

First tests with one DT5202 module are started.
We expect the delivery of the DT5202 and DT5215.

Conclusions

Obtained results

I. The scintillation detector prototypes of detector with SiPM readout has been developed and studied.

II. The 16-channel scintillation prototype of detector with Ketek was tested at the deuteron beam of the JINR Nuclotron with energy of 4 GeV/nucleon. The time resolution of 4.0ns was obtained, which requires significant improvement.

III. The results on the time resolution of 2 types of FEE developed at KRI ITEP are promising.

Conclusions

To do list

- Simulation of the detector at a fixed scattering angle is required
- Test another types of SiPM.
- Preparation of several prototypes with the sizes of scintillation tiles 10x10 (cm^3) and 30x30 (cm^3) for a run at the Nuclotron.
- tests of scintillator prototypes with electronics manufactured by CAEN

Thank you for the attention!

Tests on the Nuclotron were performed as part of the DSS project.
We are grateful to the Nuclotron accelerator group.

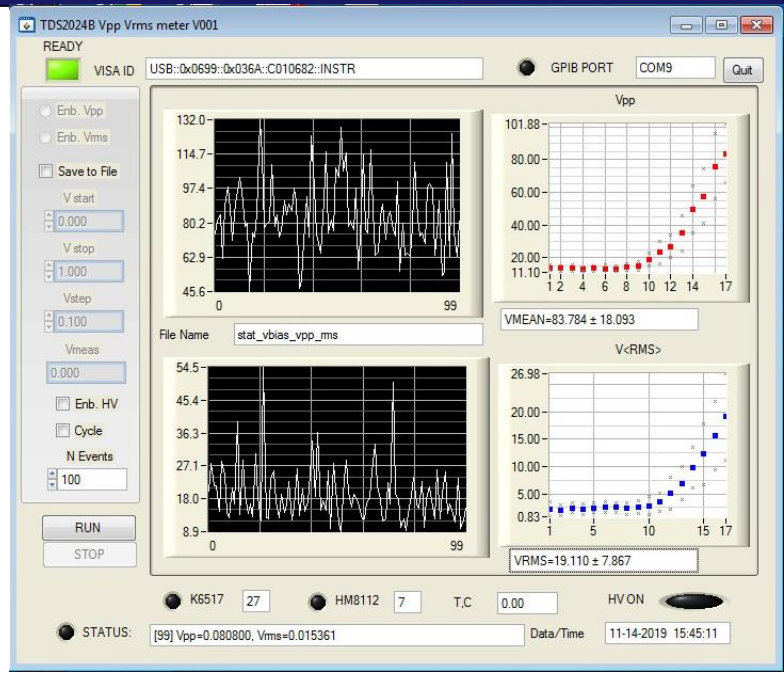
Backup

The method of the bias voltage determining

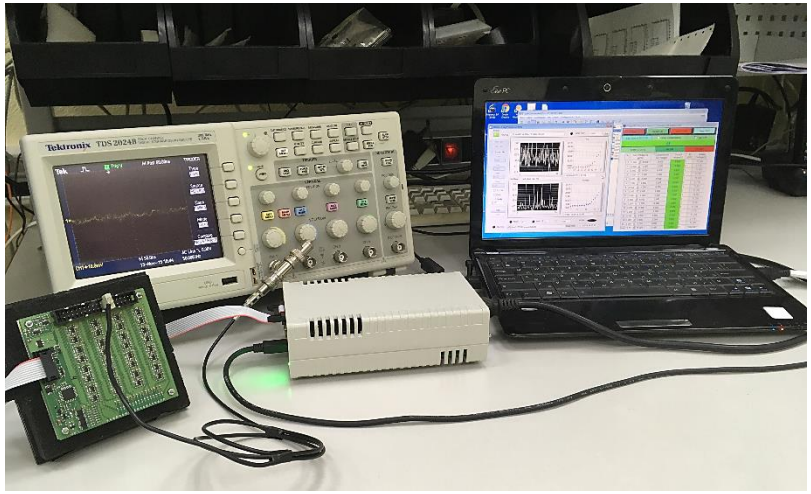
The method based on peak-to-peak amplitudes measuring of the noise signal (V_{pp}), depending on bias voltage (V_{bias}) was proposed

Advantages of the method

- ❑ the opportunity to quickly find the break point of the noise characteristic
- ❑ use this value as a normalizing value
- ❑ adjust the voltage during continuous operation in ionization fields (requires additional study)



Tektronix TDS2024B



Averaging peak-to-peak amplitudes was performed on 100 measurements with corresponding error to reduce the contribution of noise signal pulses and increase accuracy

Ketek

the average for sixteen
23.28 ± 0.19

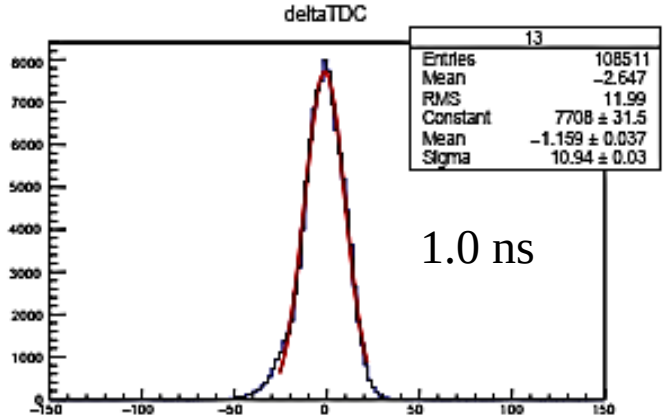
Hamamatsu

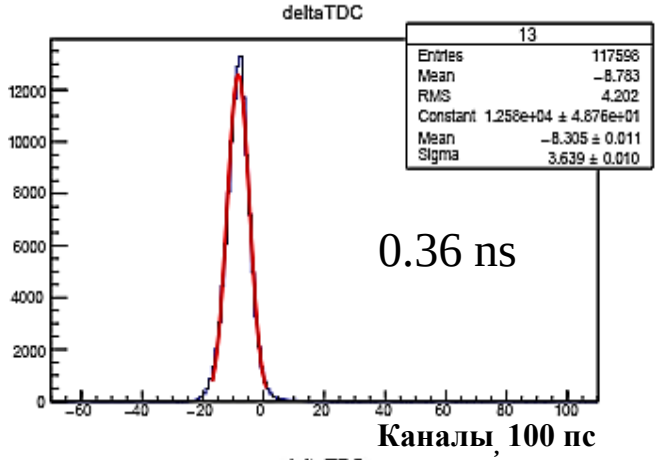
the average for sixteen
73.82 ± 1.26

A. Tishevskiy et al. //Phys.Atom.Nucl., Vol. 83, No. 11 (2020)

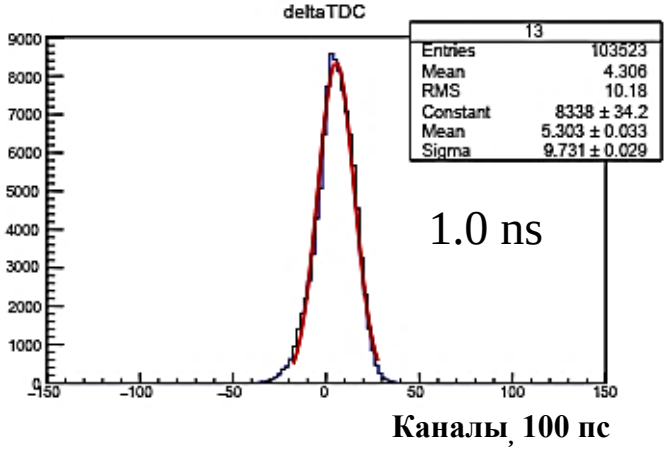
Properties

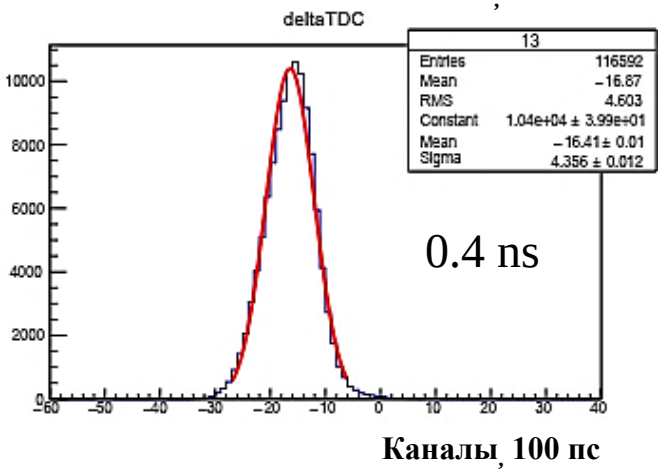
- pixel density 10^4- $2x10^4$ mm^{-2},
- size from 1x1 to 6x6 mm^2,
- wide dynamic range 5-15000 p.e.,
- photon detection efficiency from ~ 15%,
- high counting rate ~ 10^5 Hz





Ketek(24.7 V)

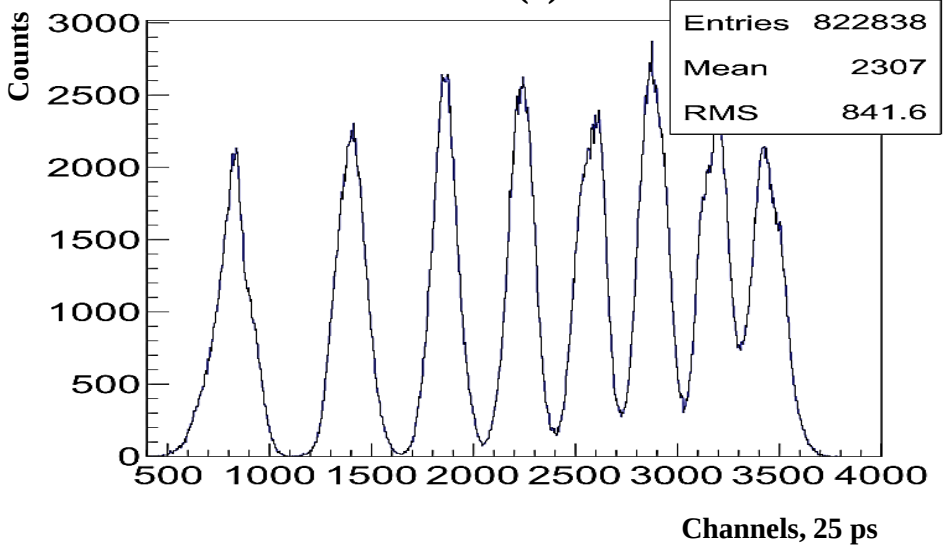




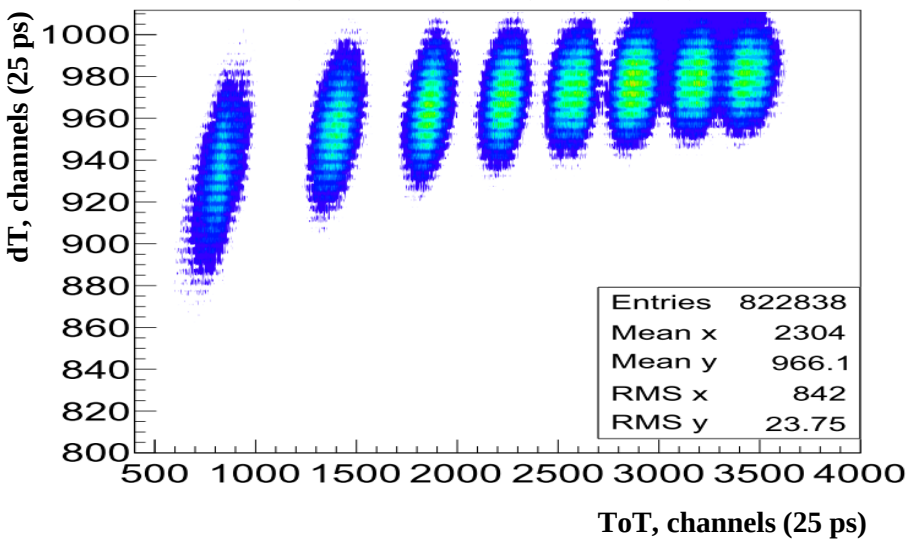
Hamamatsu (71.7 V)

Extracting correction parameters FEE ToT (version №1)

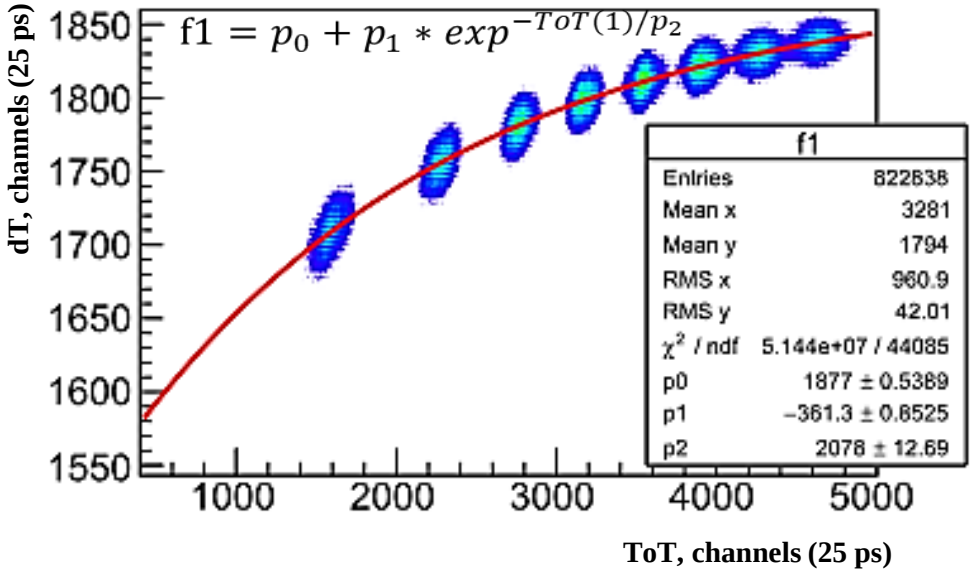
ToT(2)



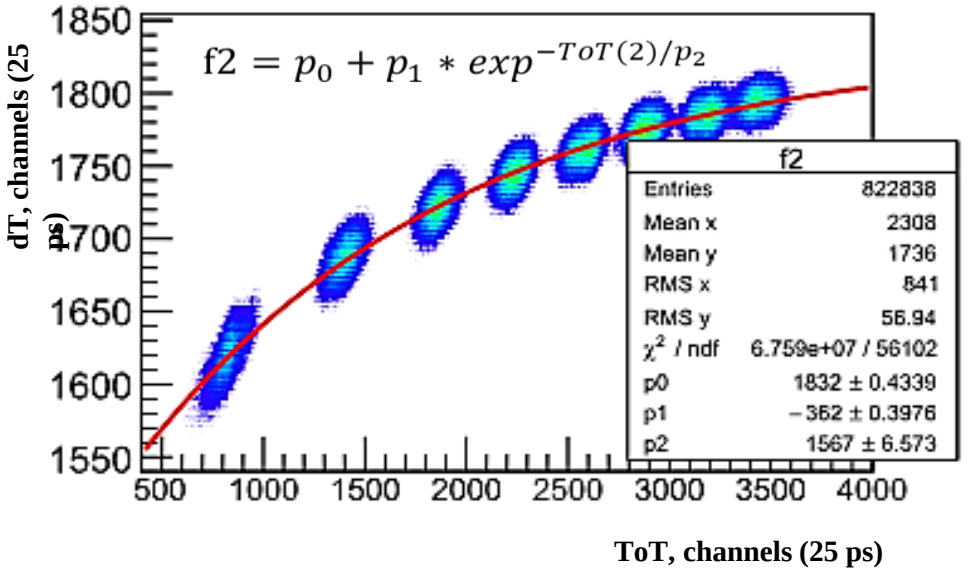
dT(SiPM1-SiPM2) vs ToT(2)



dT(trig-SiPM1) vs ToT(1)

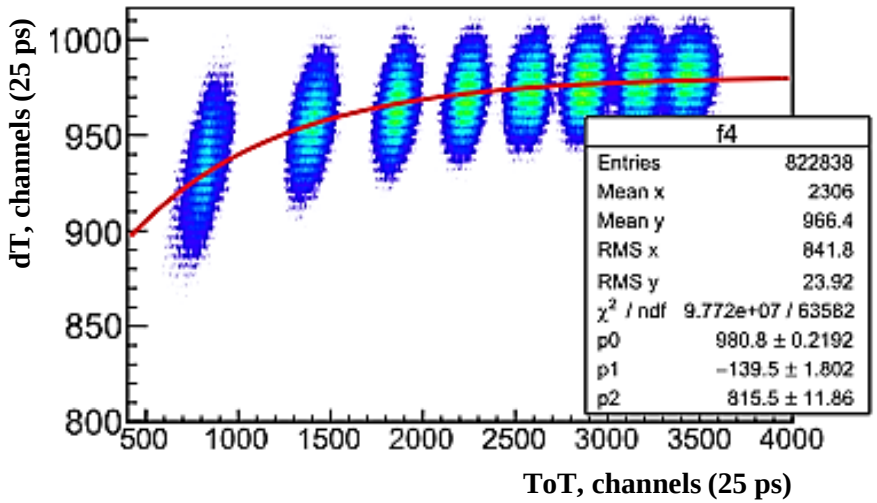


dT(trig-SiPM2) vs ToT(2)

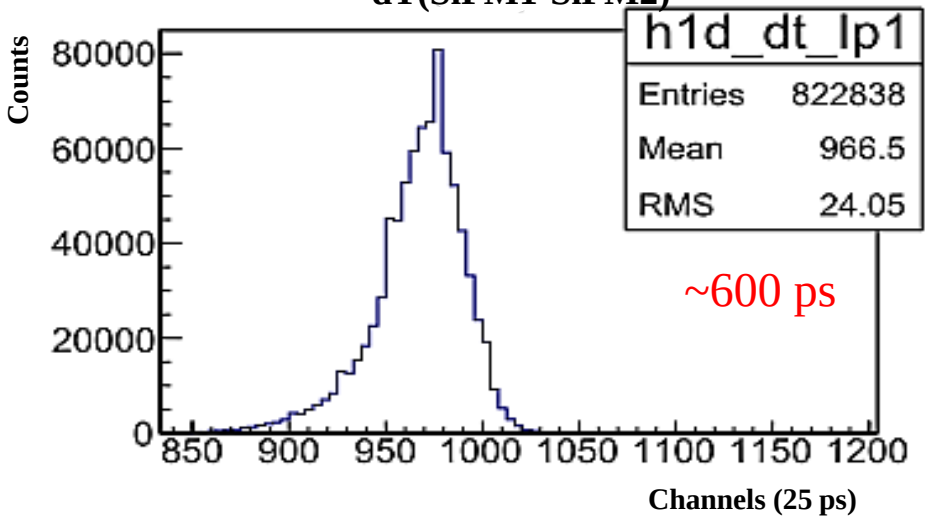


The time difference histogram FEE ToT (version №1)

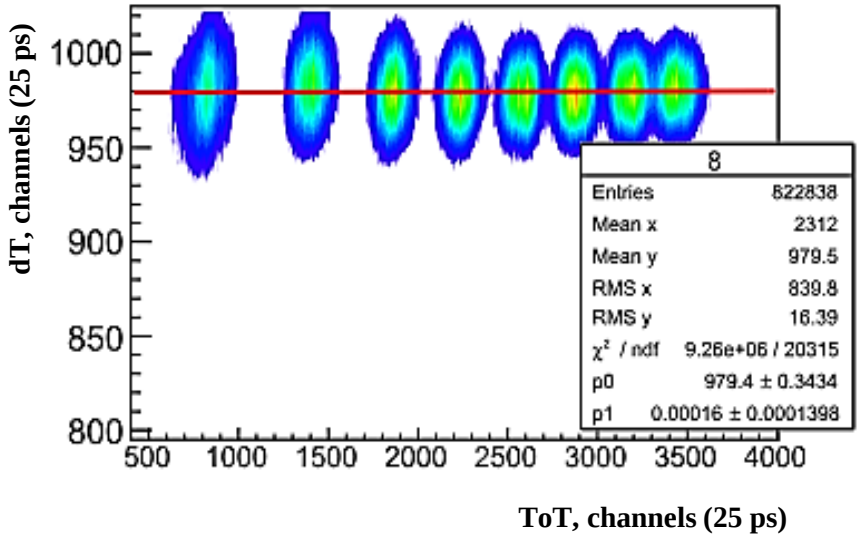
dT(SiPM1-SiPM2) vs ToT(2)



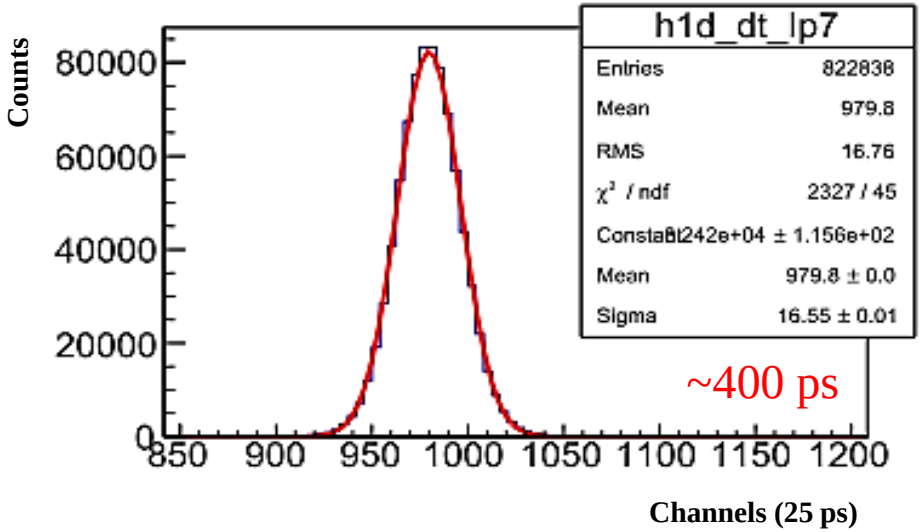
dT(SiPM1-SiPM2)



Corrected dT(SiPM1-SiPM2) vs ToT(2)



Corrected dT(SiPM1-SiPM2)

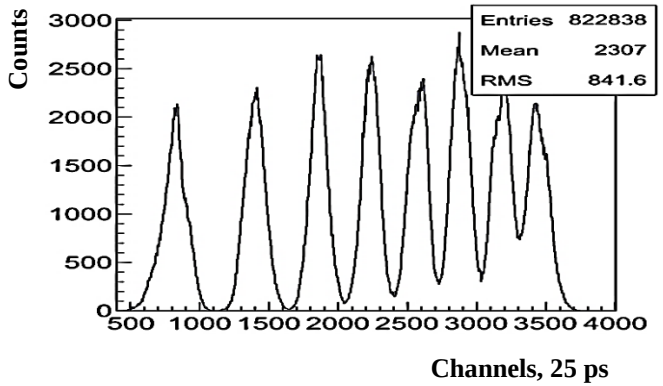


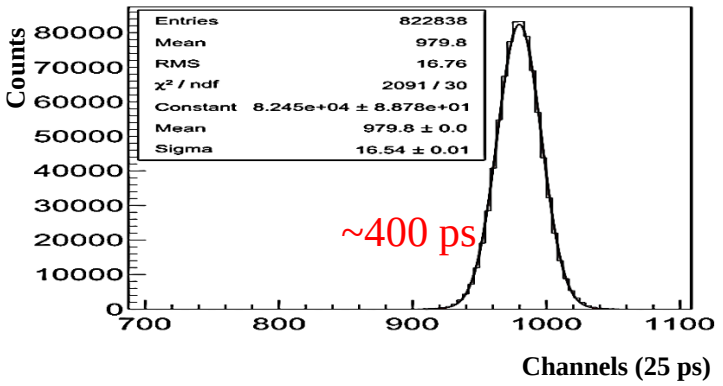
A.V. Tishevskiy et al., J.Phys.Conf.Ser, V.1690, 012051 (2020)

Comparison of FEE ToT versions

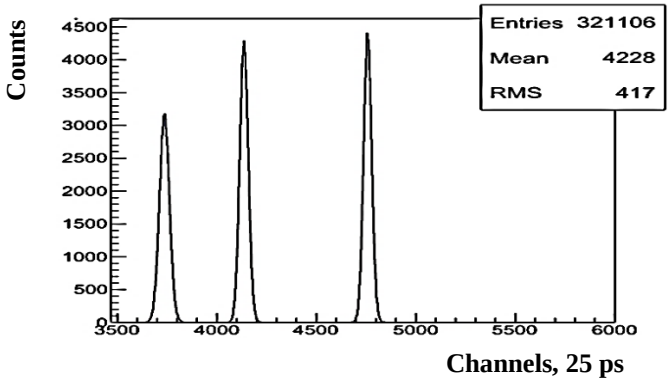
ToT | **Corrected dT(SiPM1-SiPM2)**

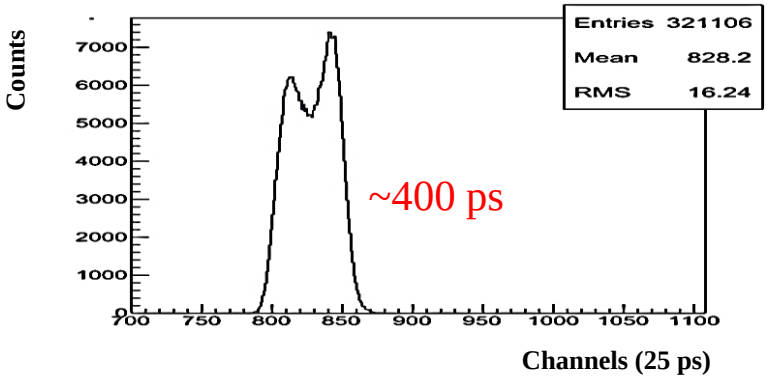
v.1



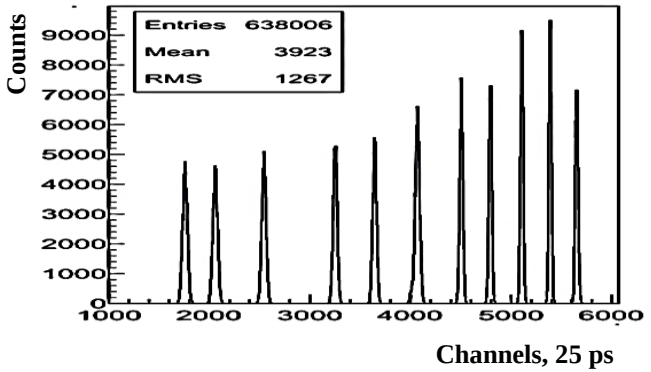


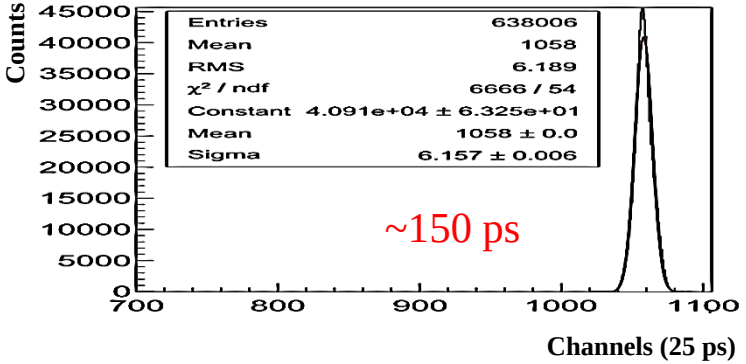
v.2





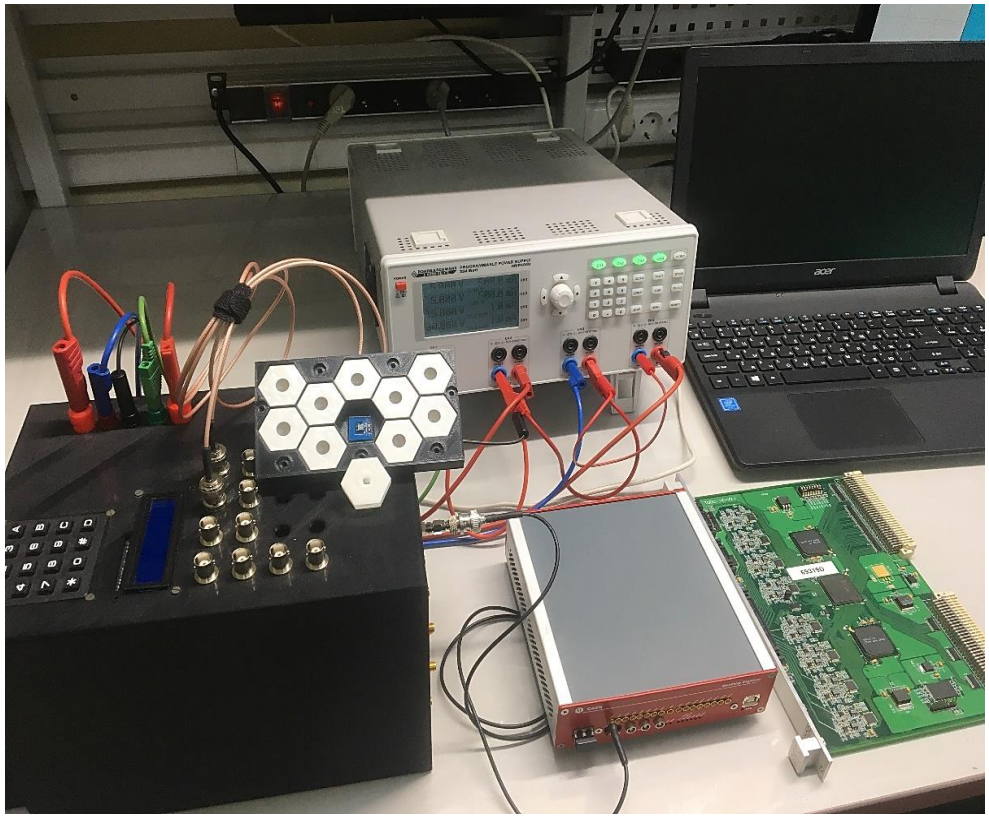
v.3

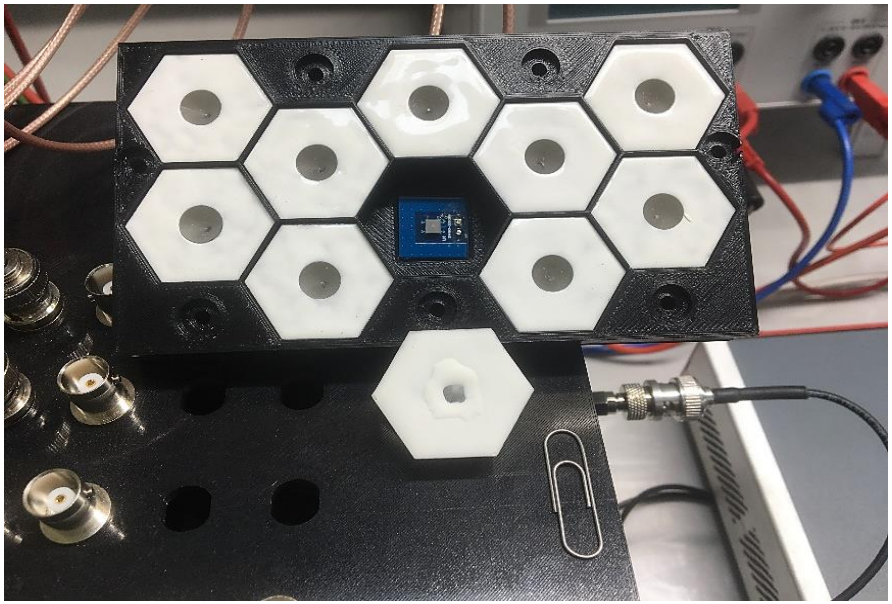




New collaborators

CTEPP Un.AB, Santiago, Chile





10 honey-comb scintillators,
FEE, micro PC control.

Tests at JINR are in preparation.

Together with **E.R.Calderon (CTEPP)**