Scintillation detector prototypes for

Beam-Beam Counter at NICA SPD

Tishevsky A.V.

LXXI International conference "NUCLEUS – 2021"

22 September 2021

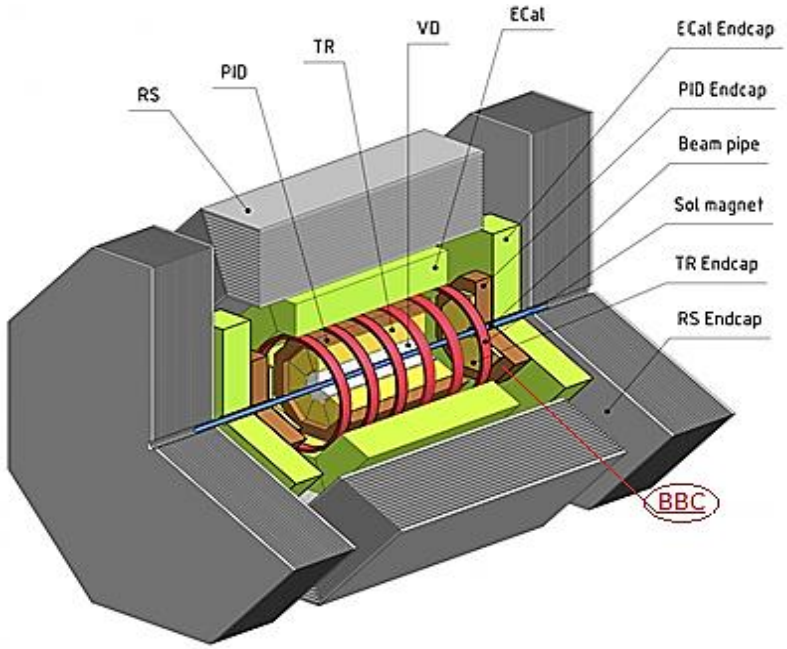
Introduction

The prototype

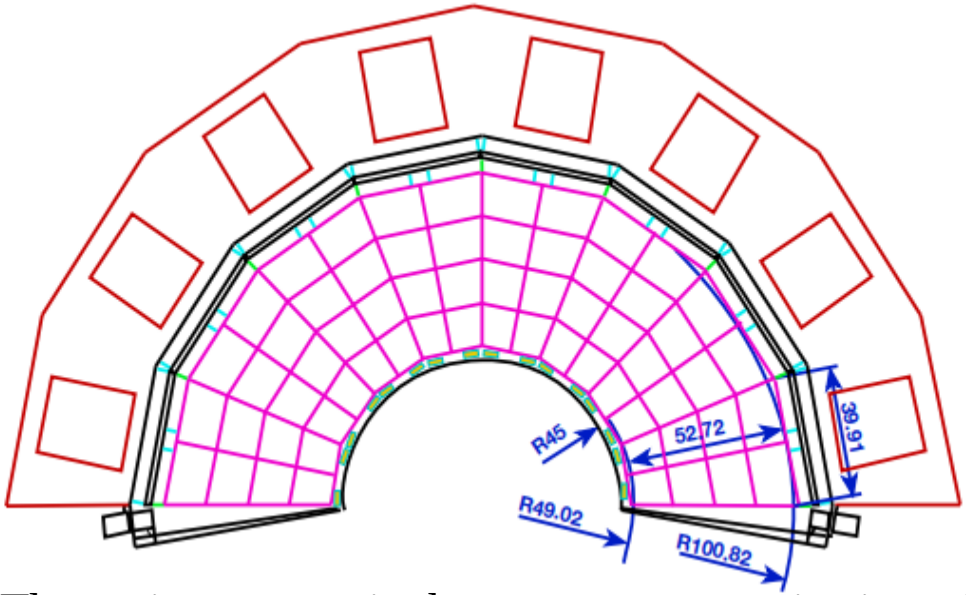
The equipment

Results

The Spin Physics Detector (SPD)



The Beam-Beam Counters (BBC) for SPD



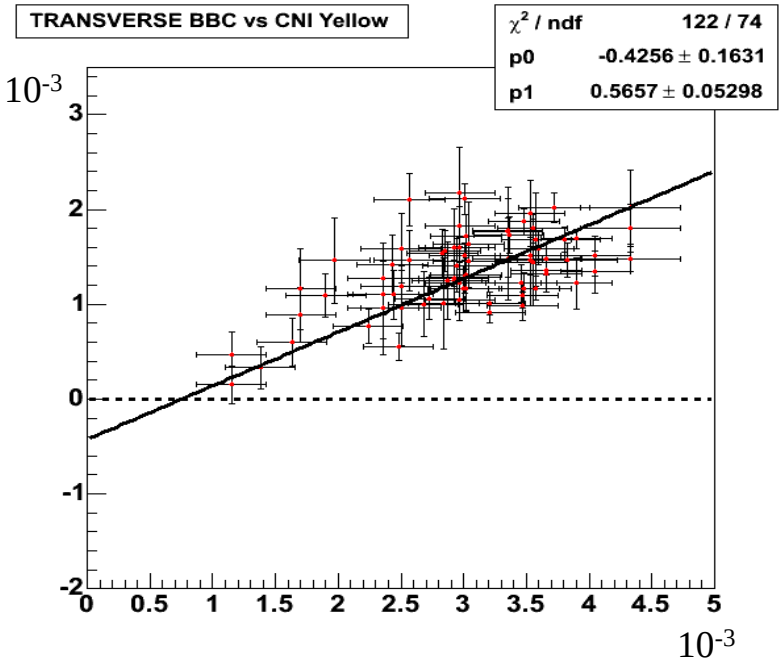
The main purpose is the permanent monitoring of the beam polarization using the azimuthal asymmetry of the inclusive charged particles yield.

Concept:

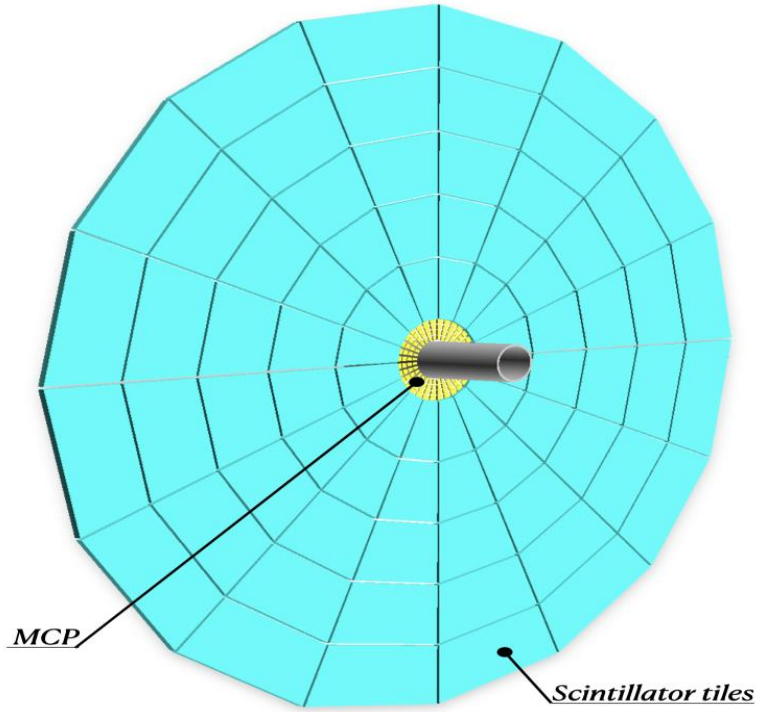
inner part – microchannel plates based detectors

outer part – high granularity scintillator tiles with SiPM readout

BBC: scintillation tiles



Correlation between CNI polarimeter and STAR BBC asymmetries.



MCP can be used for luminosity estimation and possibly for local polarimetry for pp- and dp- elastic scattering.

Local polarimetry by the analysis of the azimuthal asymmetry in inclusive production of charged particles in forward direction.

Current option for BBC

1. 2 BBCs: Left and Right

2. Inner part covers **30-60 mrad**

– 4 layers ***32 sectors = 96 channels MCP**

3. Outer part covers **60-500 mrad**

– 5-6 layers ***16 sectors* 2 SiPM = up to 192 channels**

Simulation for polar angle granularity is required!

4. FEE **less than 20 W/channel**

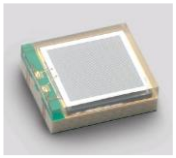
5. TDC **25ps/channel or better (HPTDC)**

6. Holding **carbon plastic**

7. Needed place **about 5 cm in front of PID (TOF)**

8. Weight **50-80 kg**

Properties of SiPM, Front-end electronics

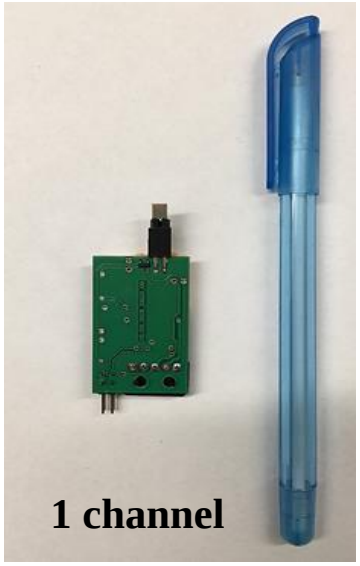


S12572-010P, **HAMAMATSU**
(3x3 мм^2, 10 μm/cell)

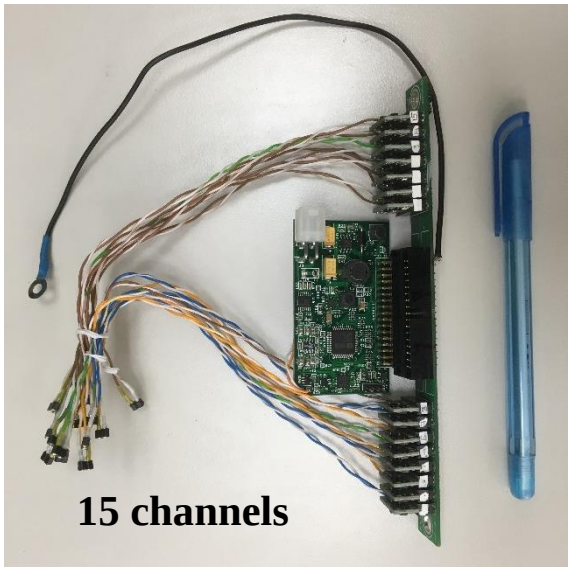
Applications:

✓ BBC

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



FEE ToT

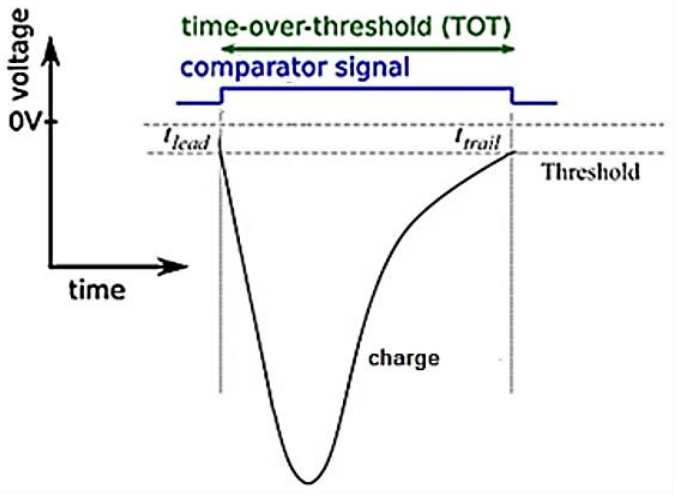


FEE DANSS (DANSS experiment)

Properties

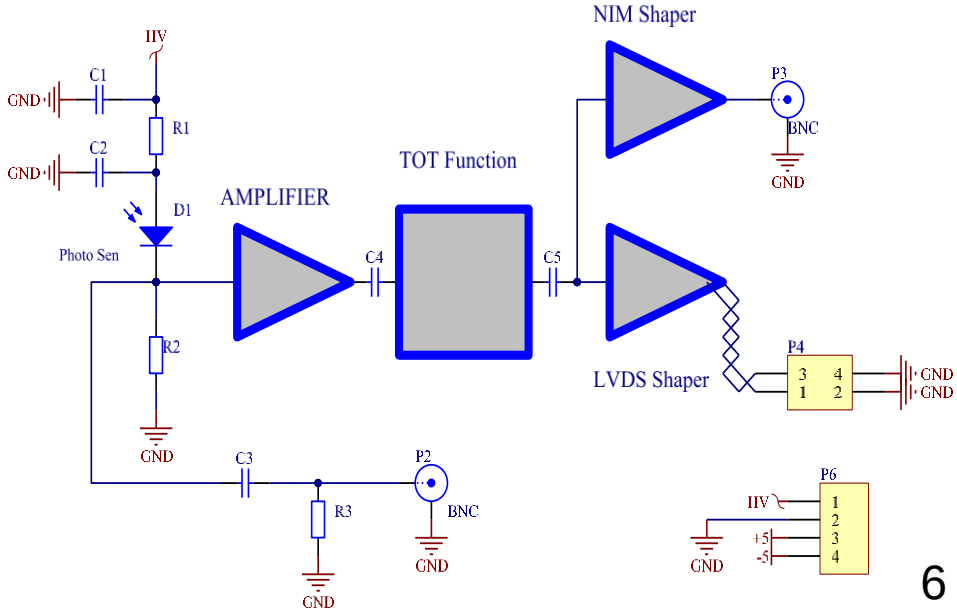
- pixel density 10^4- 2x10^4 mm^{-2},
- size from 1x1 to 6x6 mm^2,
- wide dynamic range 5-15000 p.e.,
- photon detection efficiency from ~ 15%,
- high counting rate ~ 10^5 Hz

The Time-over-Threshold (ToT) method



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

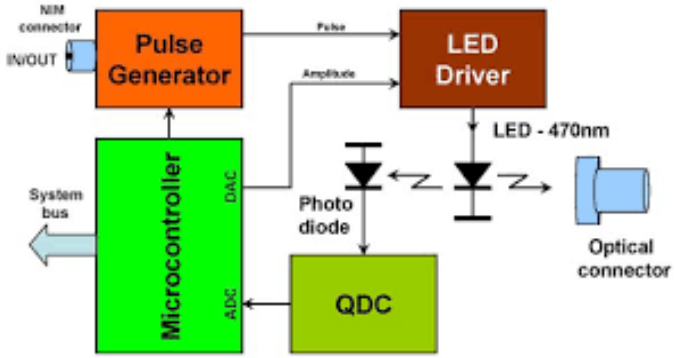
Front-end electronics with ToT technique



TQDC16
(16-channel
time and charge
digitizer)

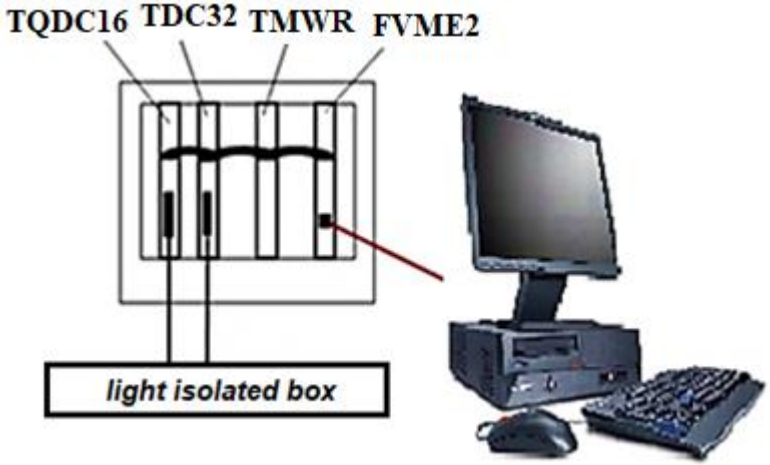
TDC32
(32-channel
time digitizer)

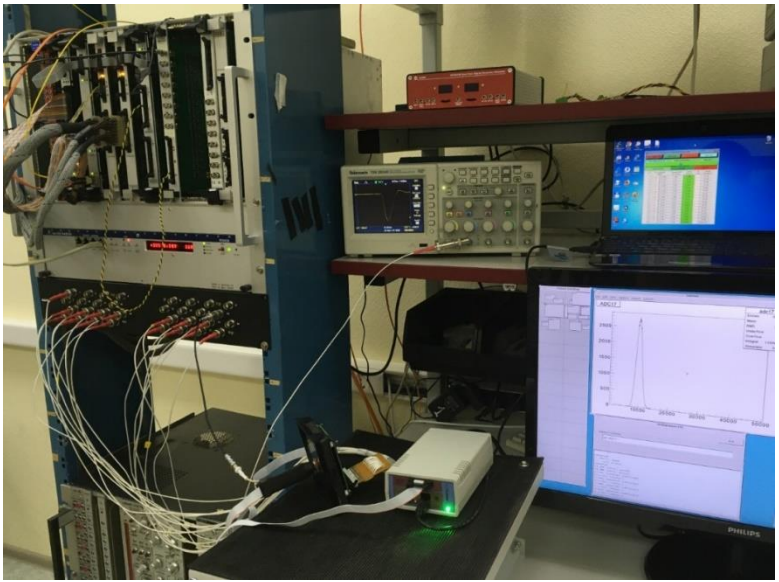
Schematic view of the LED



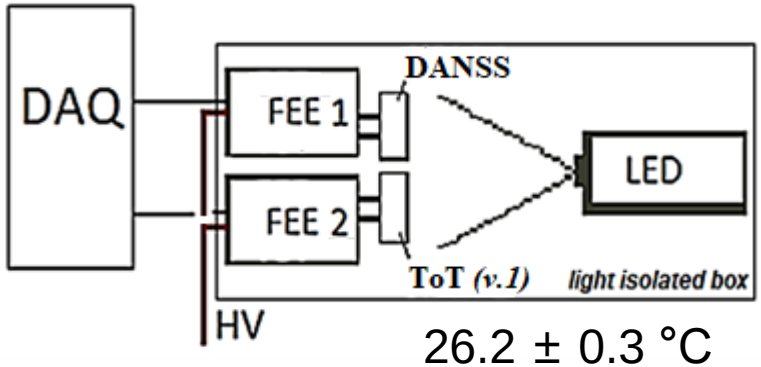
The data were accumulated with a VME based data-acquisition system (DAQ)

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



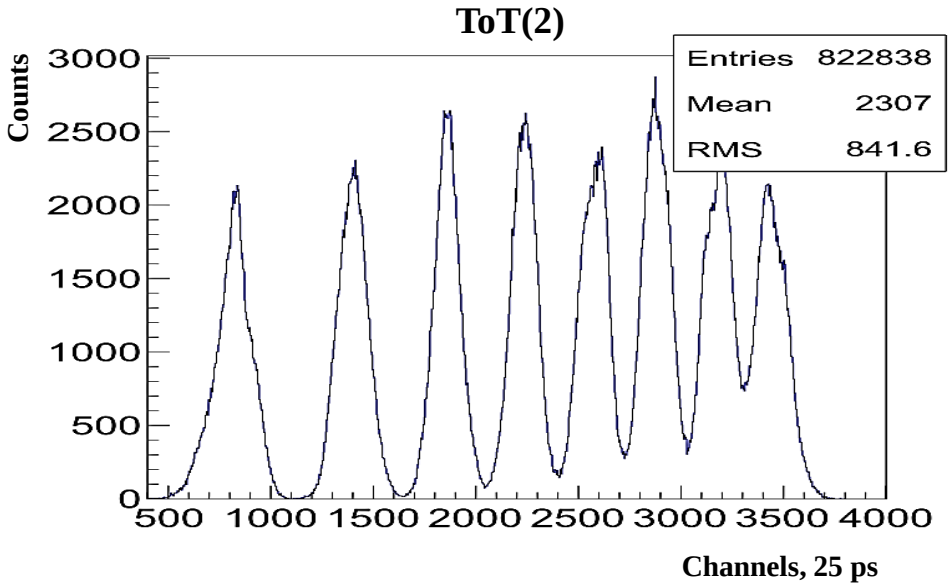


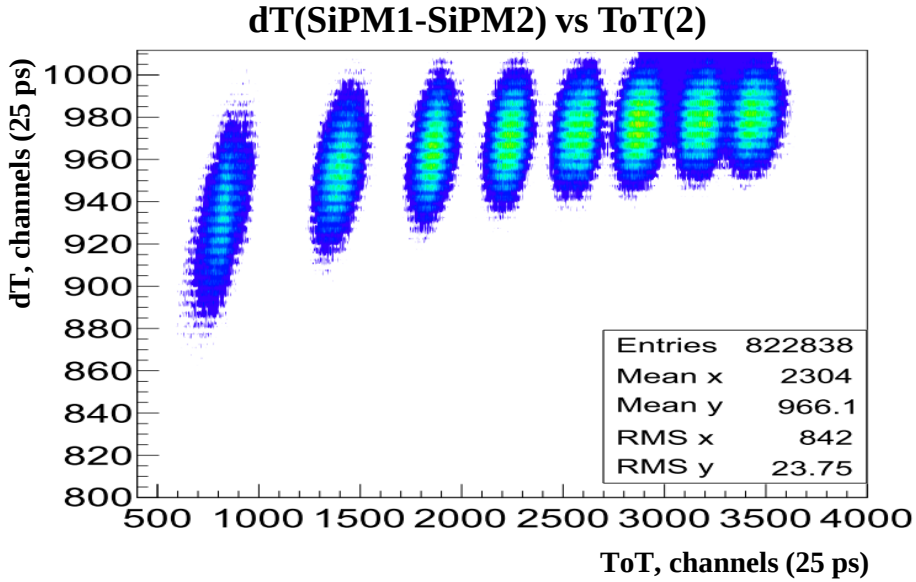
Schematic view of the test

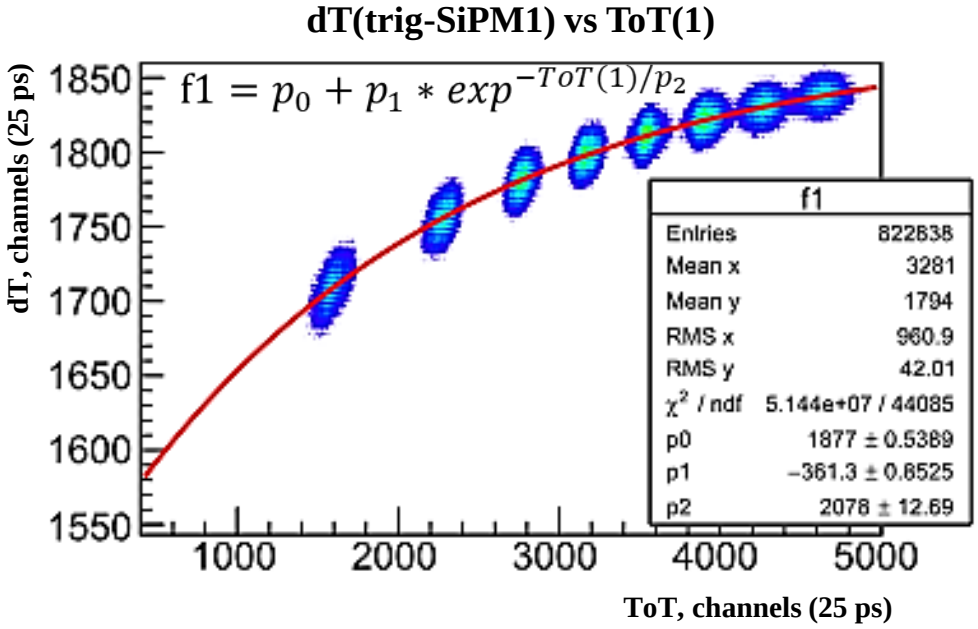


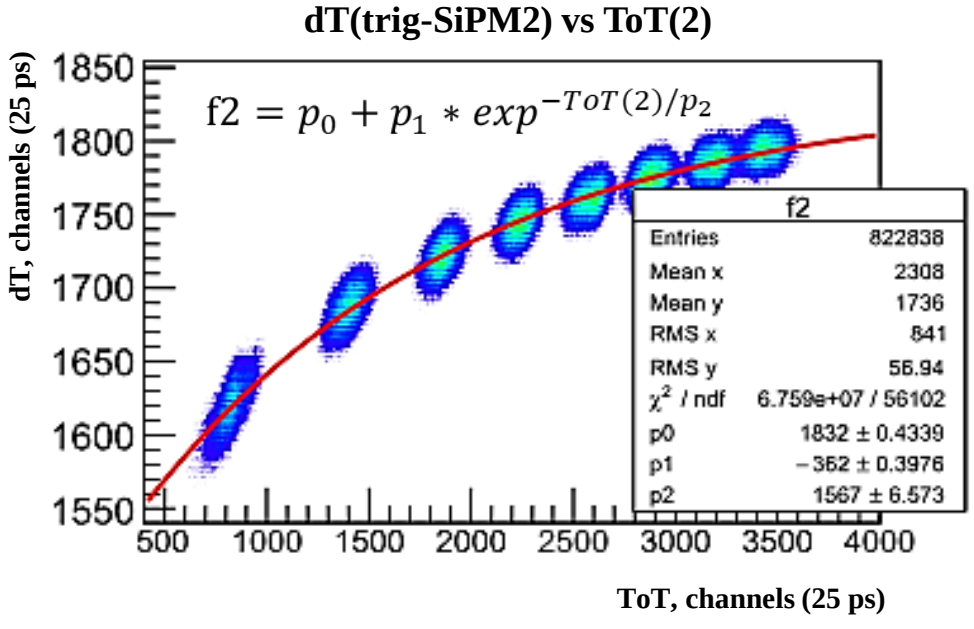
26.2 ± 0.3 °C

Extracting correction parameters FEE ToT (version №1)



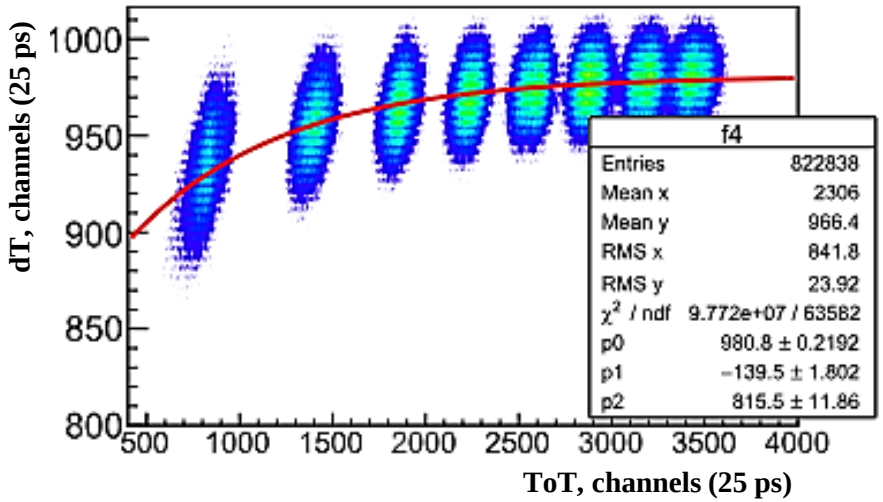




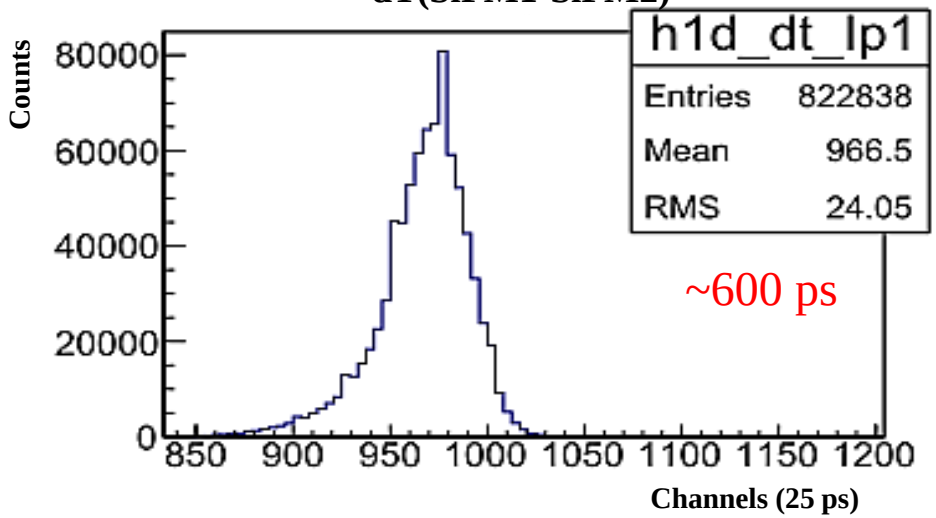


The time difference histogram FEE ToT (version №1)

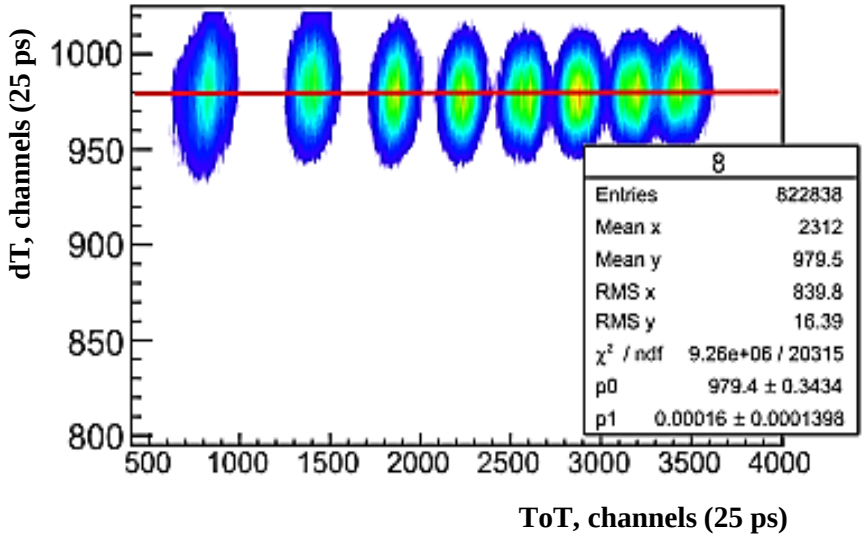
dT(SiPM1-SiPM2) vs ToT(2)



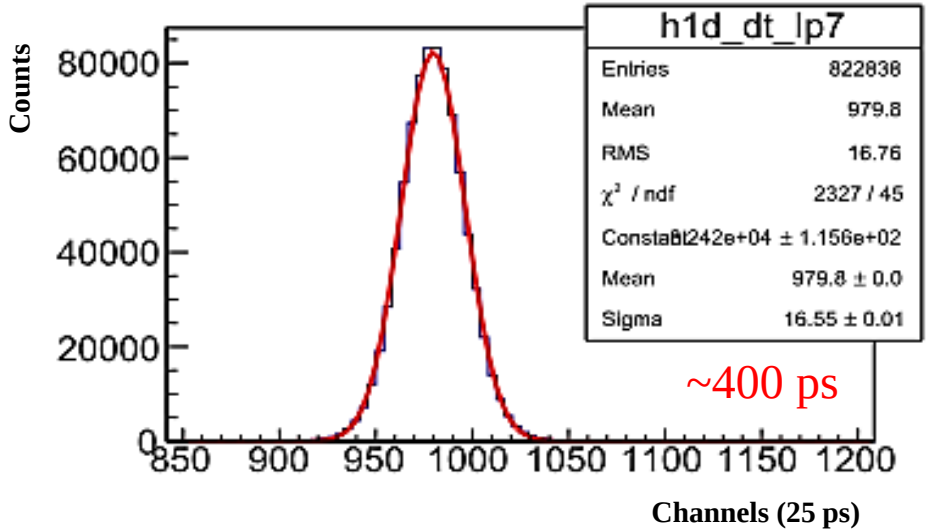
dT(SiPM1-SiPM2)



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

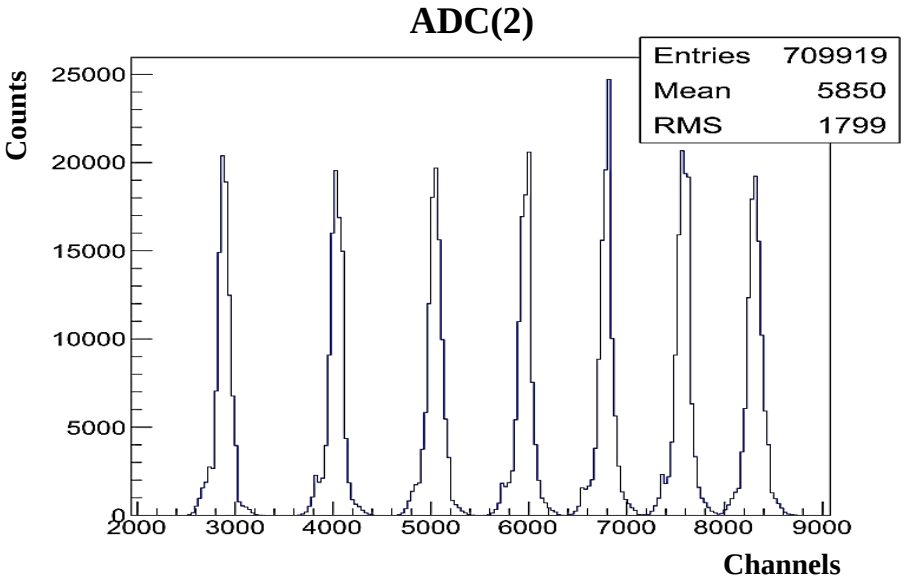


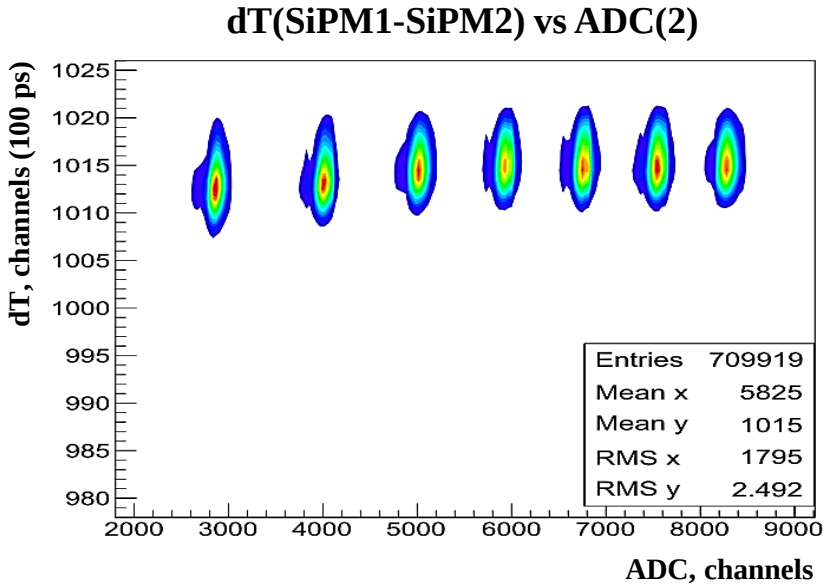
Corrected dT(SiPM1-SiPM2)

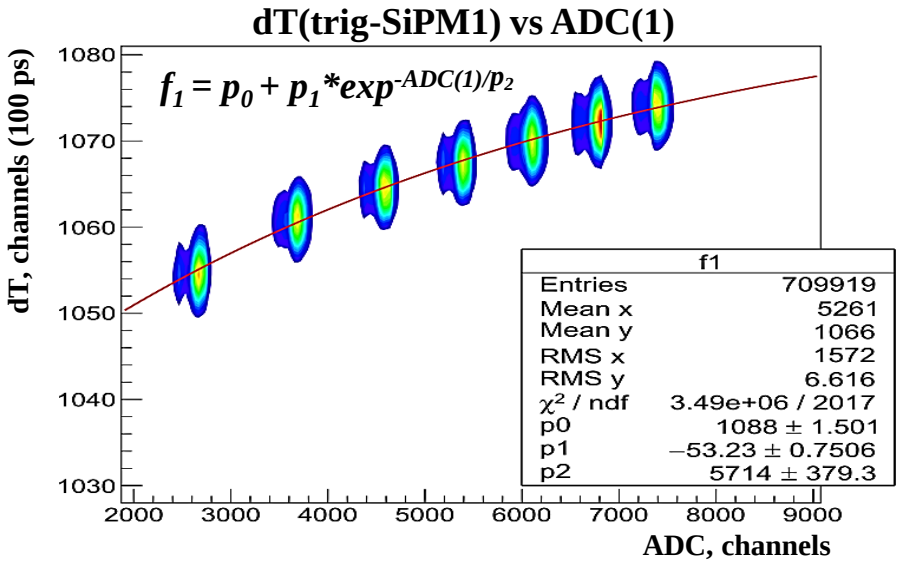


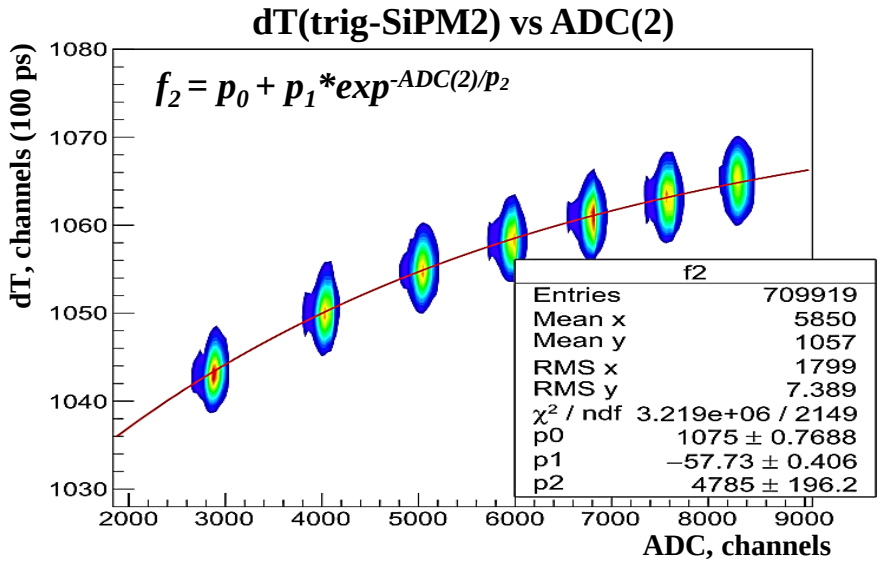
A.V. Tishevskiy et al., J.Phys.Conf.Ser, V.1690, 012051 (2020)

Extracting correction parameters FEE DANSS

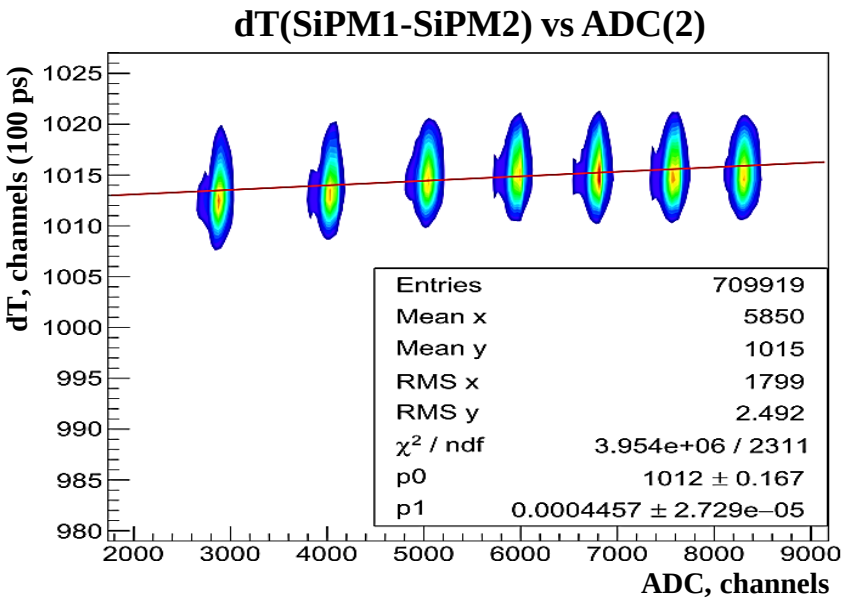


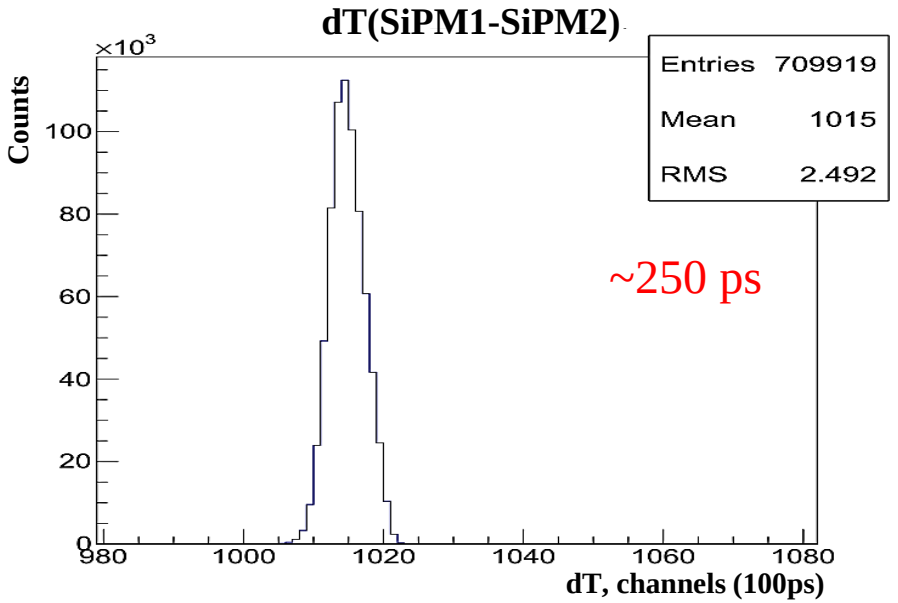


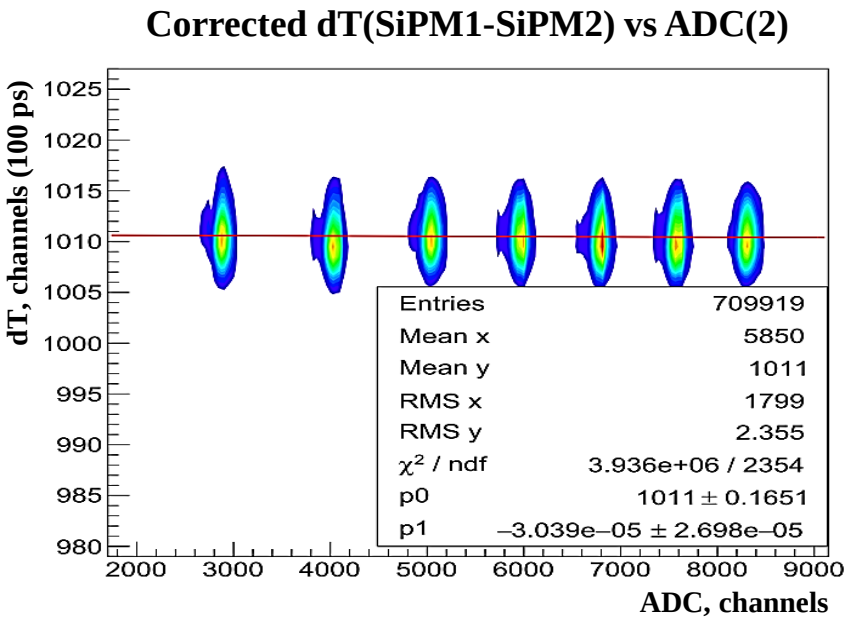


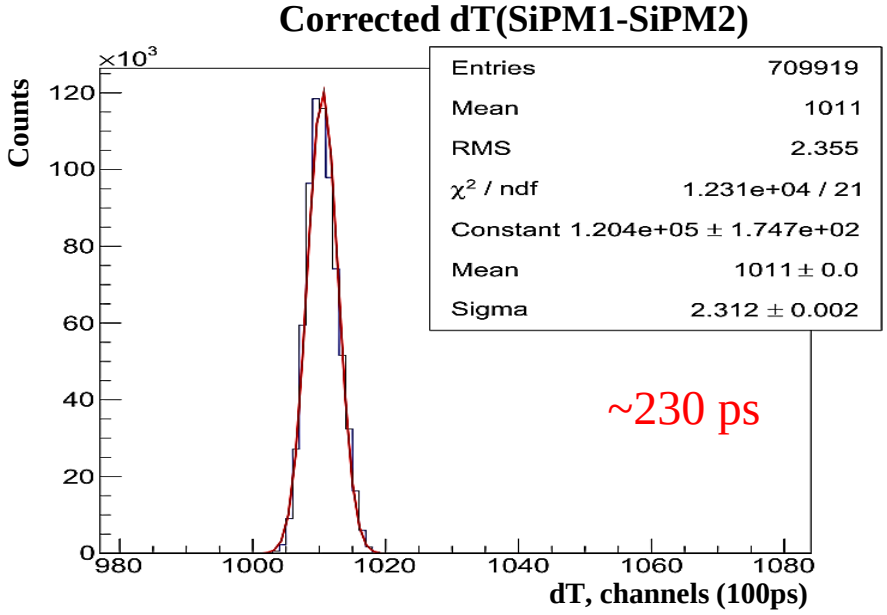


The time difference histogram FEE DANSS

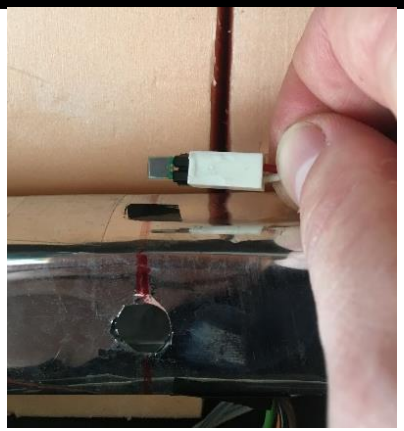




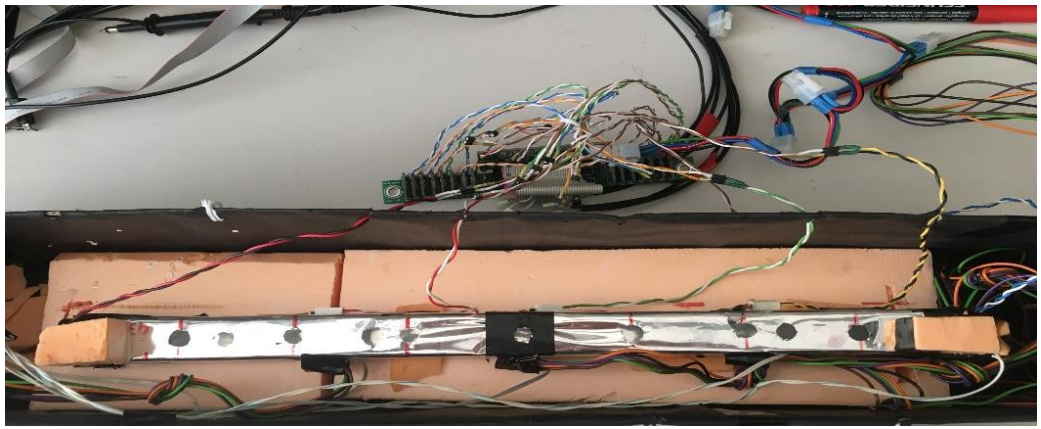




The measurements with scintillator

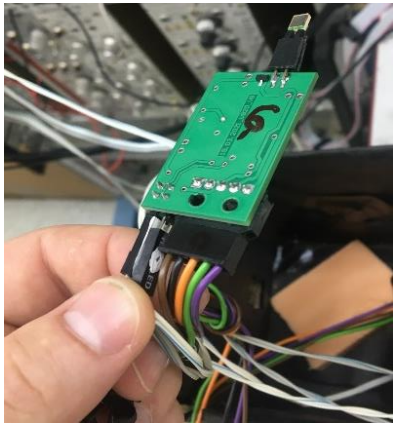


5 channels FEE DANSS



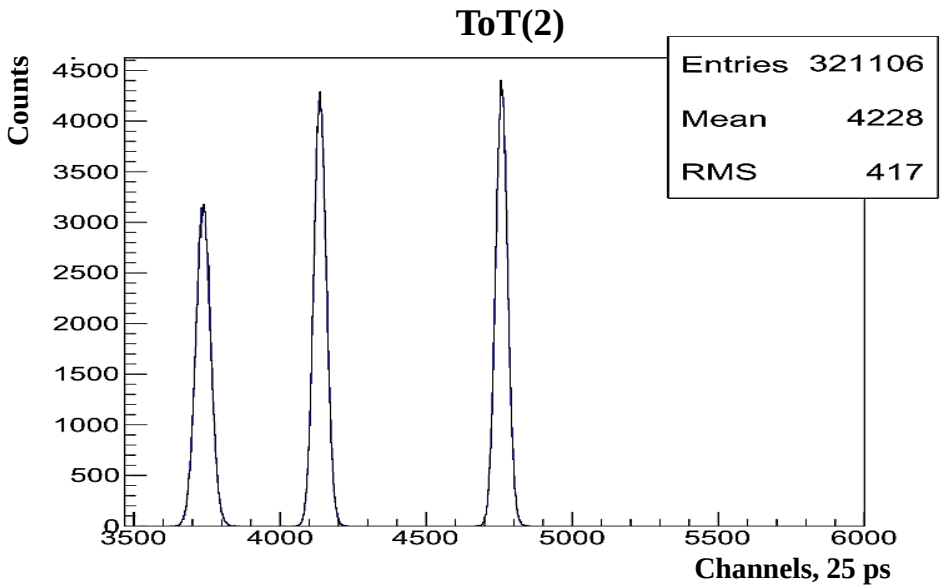
Plastic Scintillator
40 x 2 x 2 (cm^3)

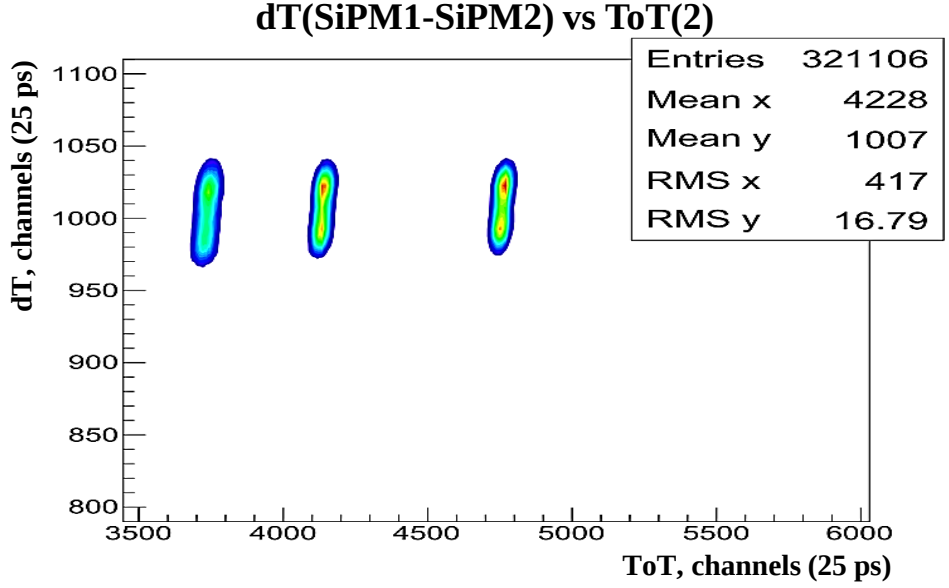
10 pcs HAMAMATSU
(S12572-010P)

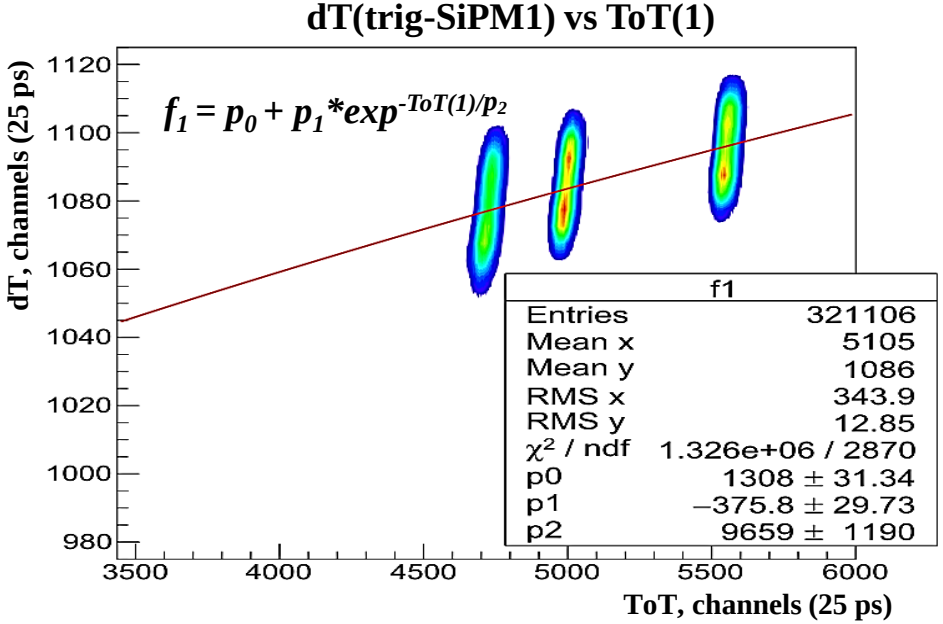


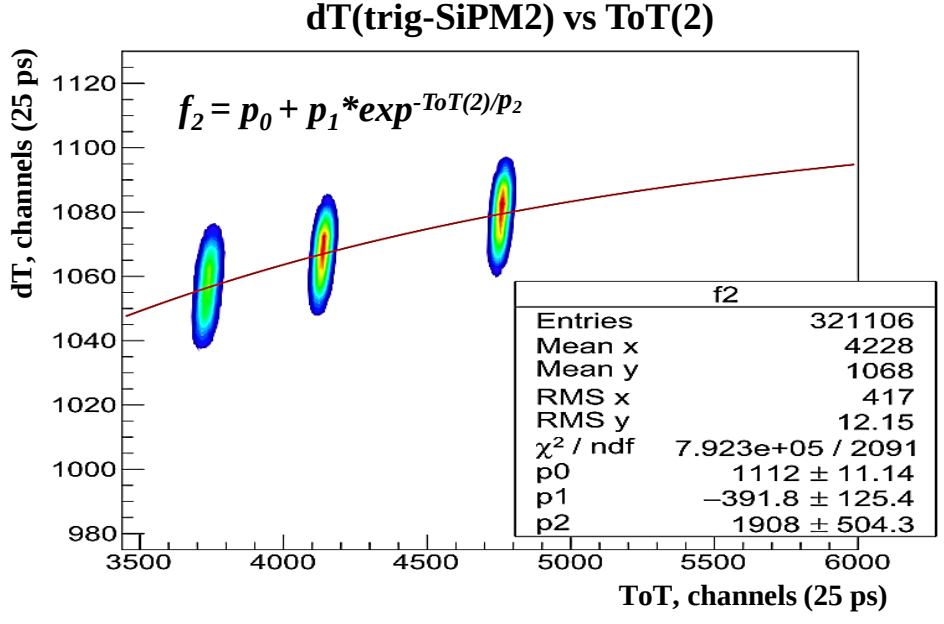
5 channels FEE ToT (version №2)

Extracting correction parameters FEE ToT (version №2)

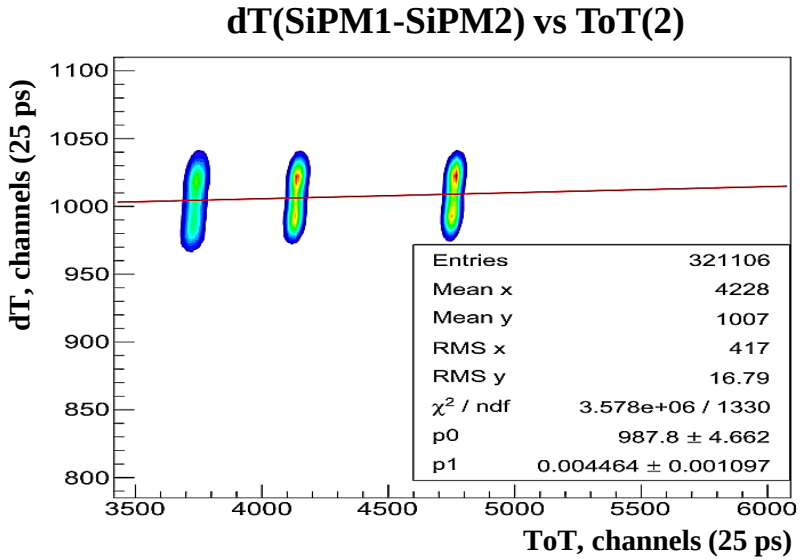


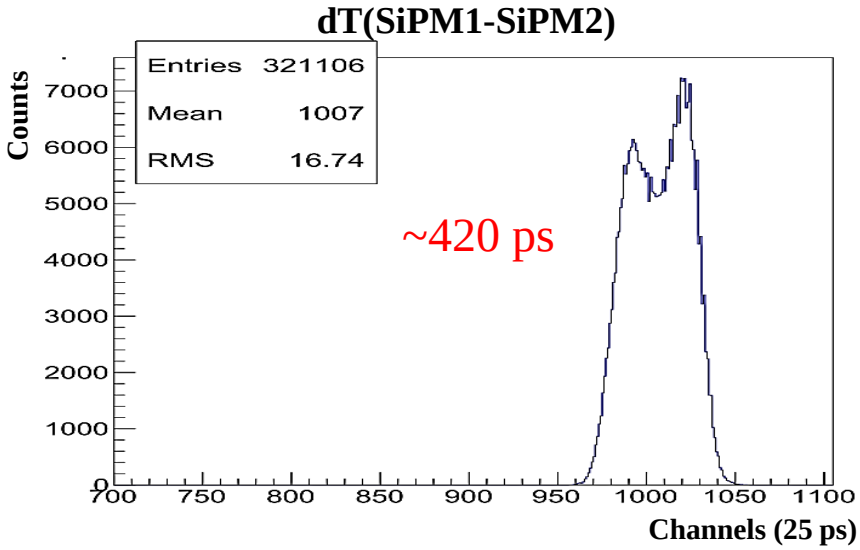


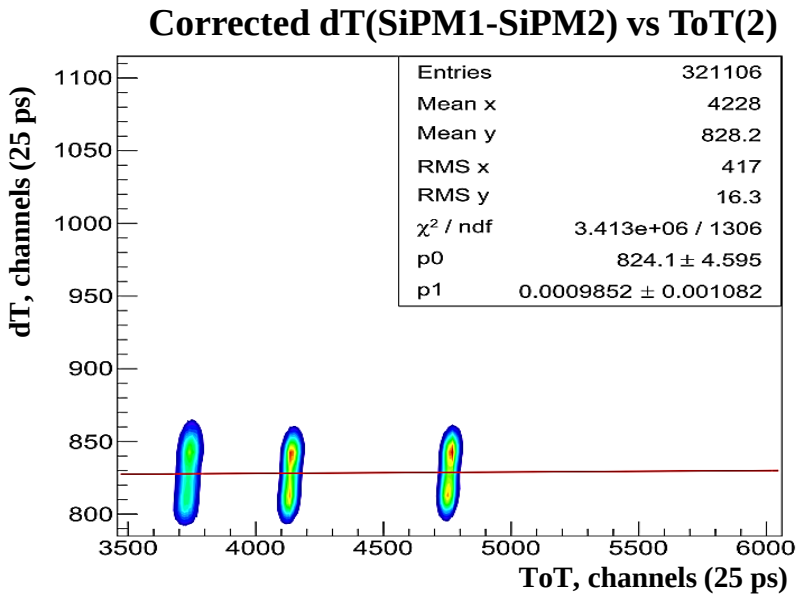


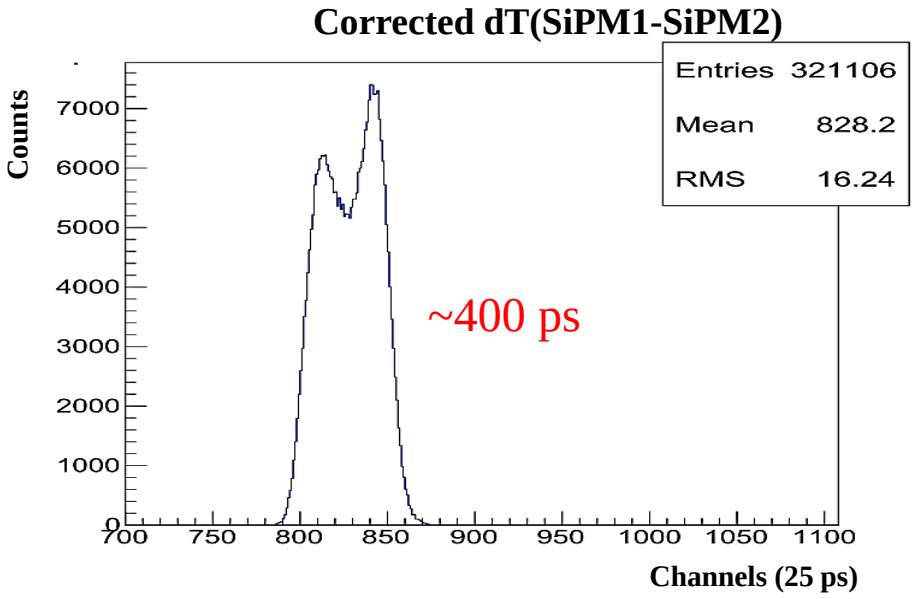


The time difference histogram FEE ToT (version №2)

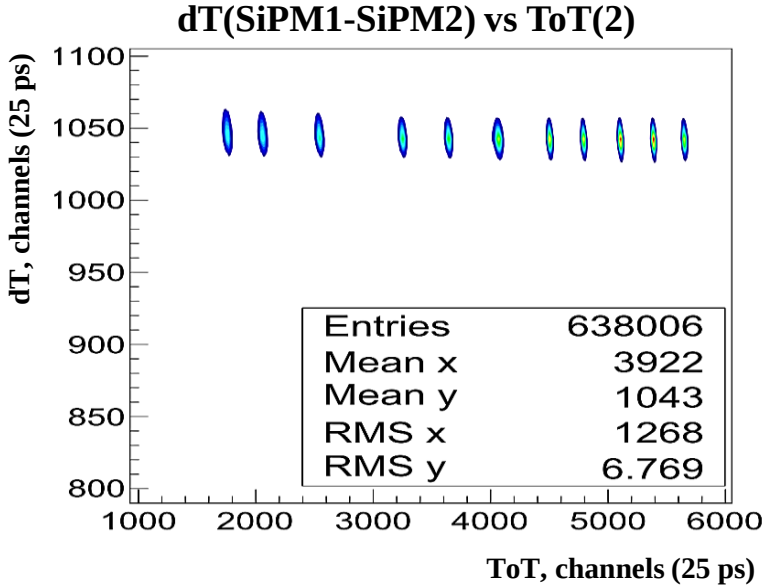


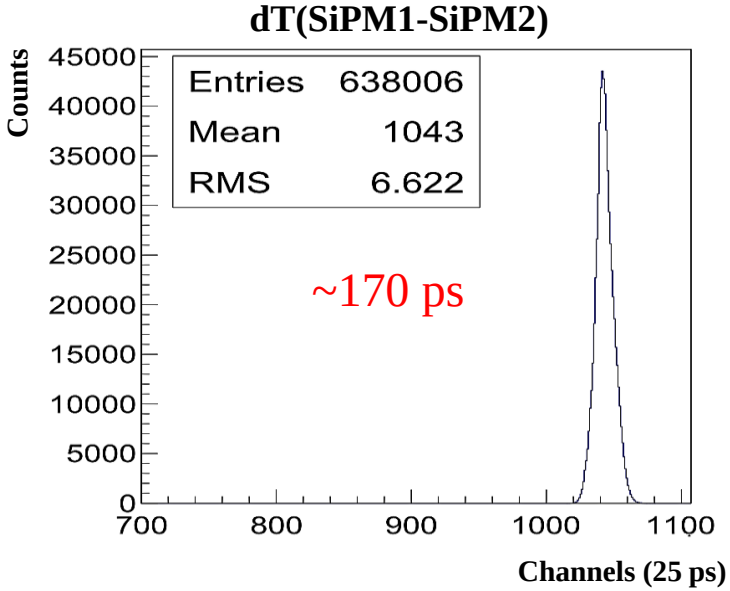


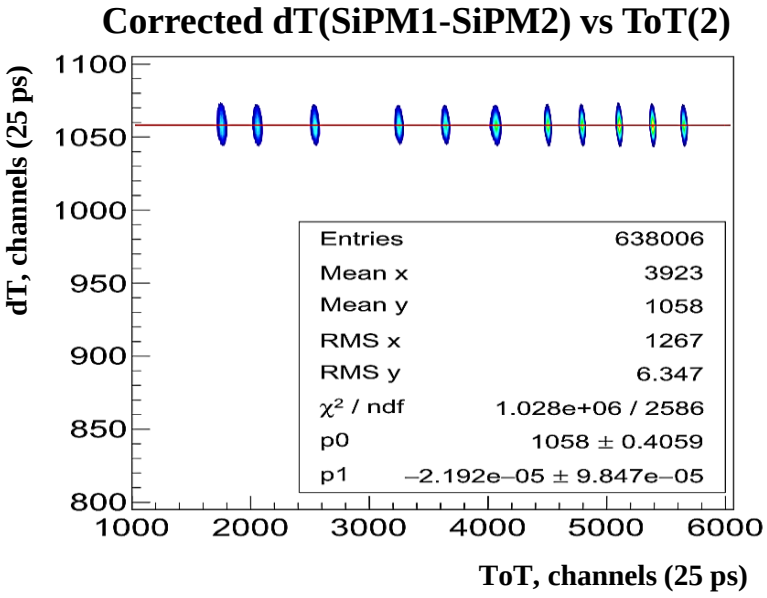


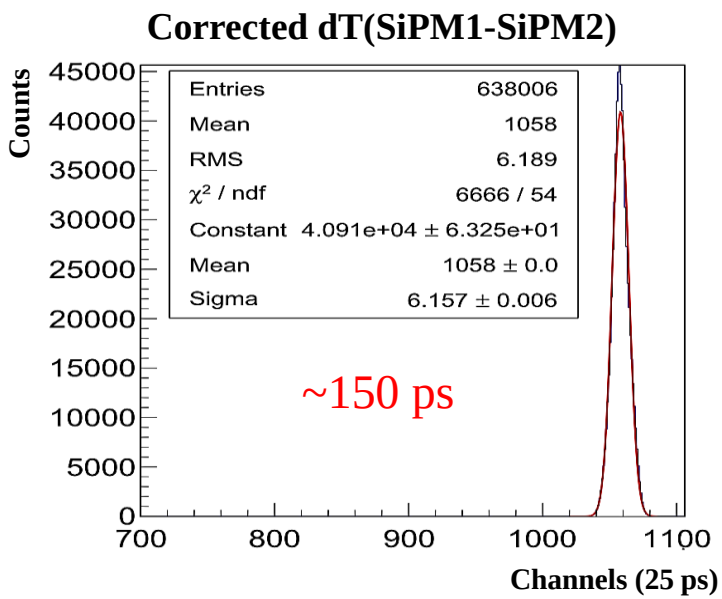


The time difference histogram FEE ToT (version №3)



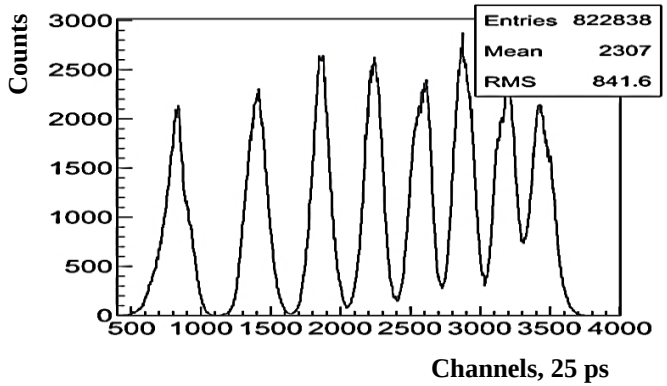




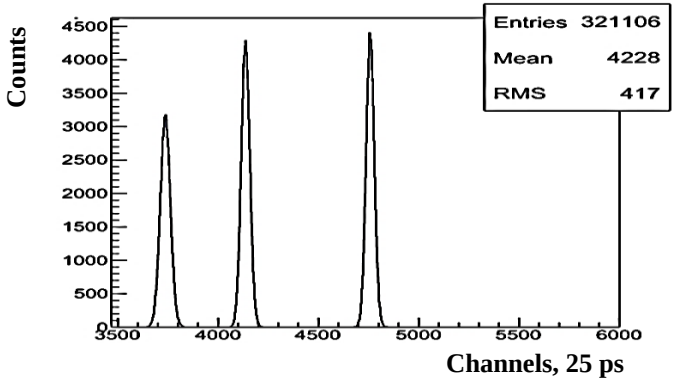


Comparison of FEE ToT versions

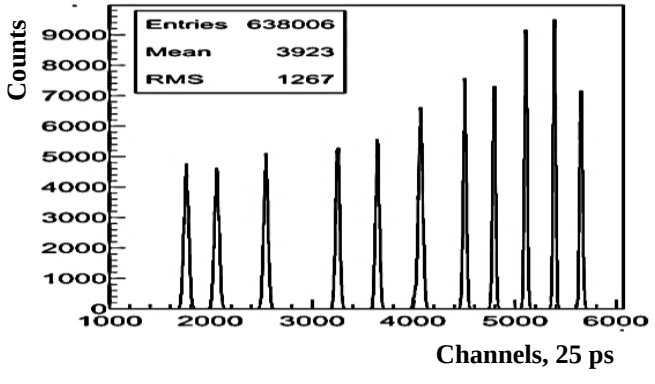
ToT



v.1

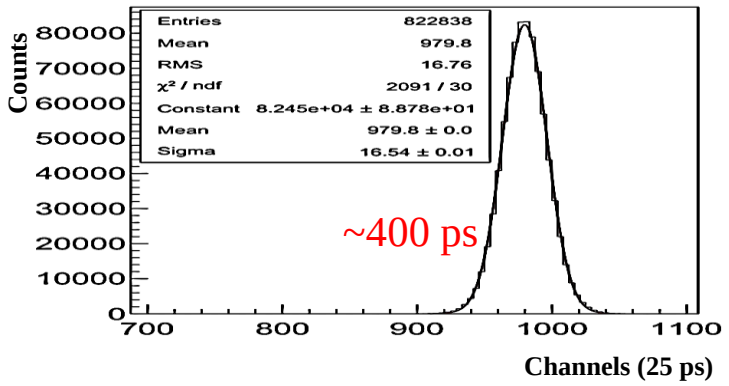


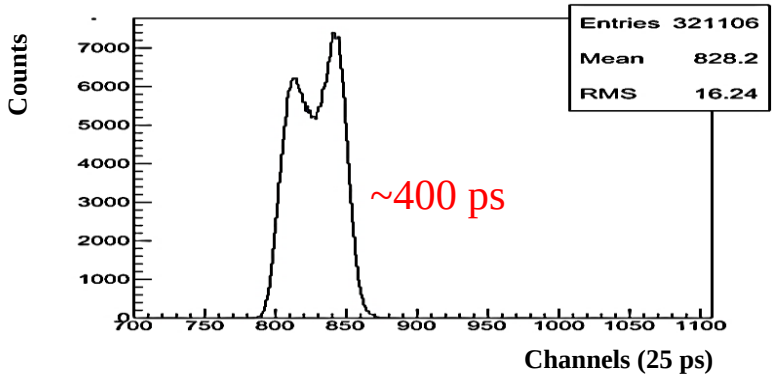
v.2

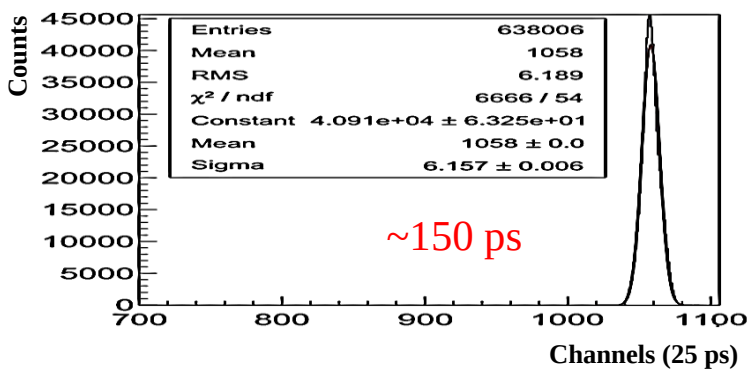


v.3

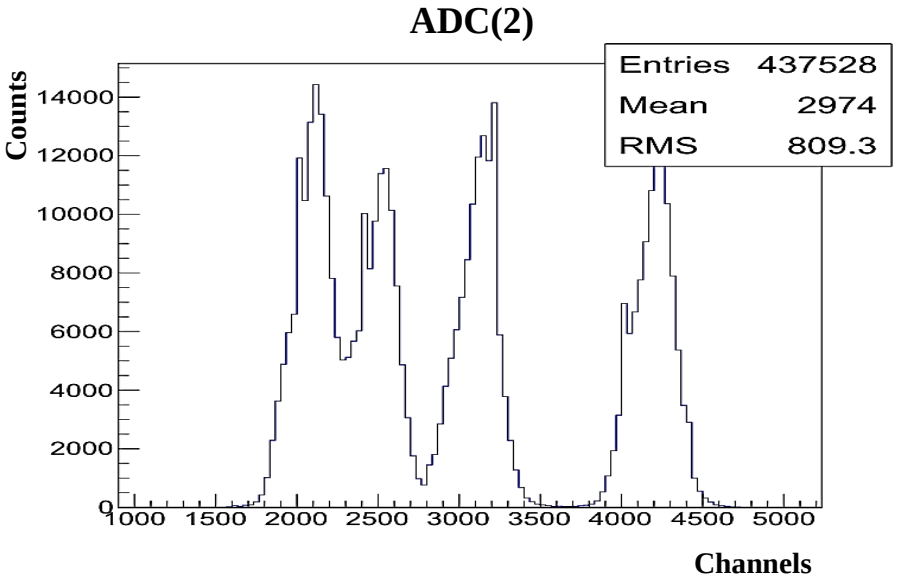
Corrected dT(SiPM1-SiPM2)

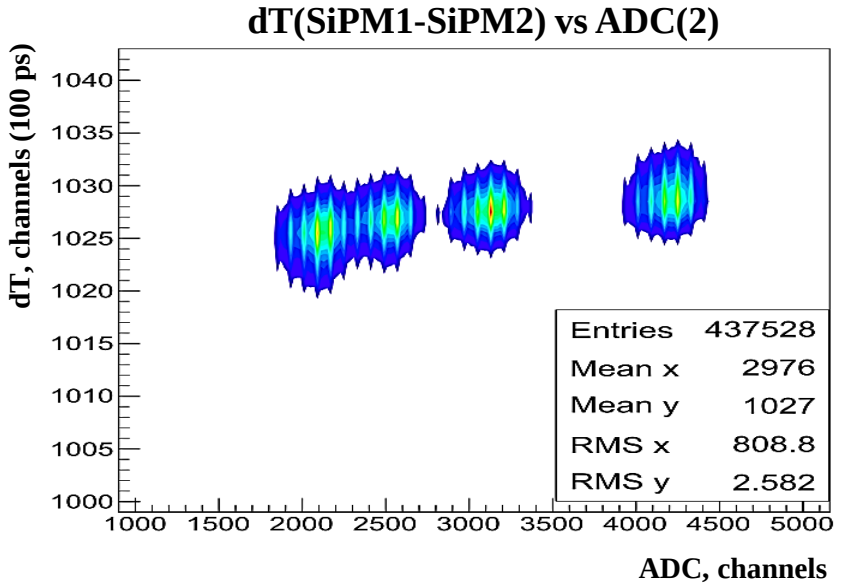


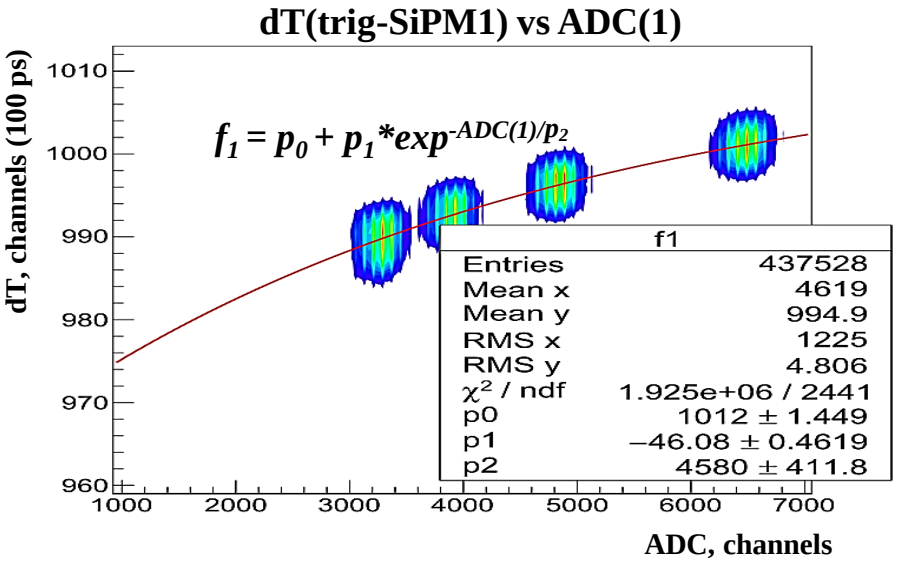


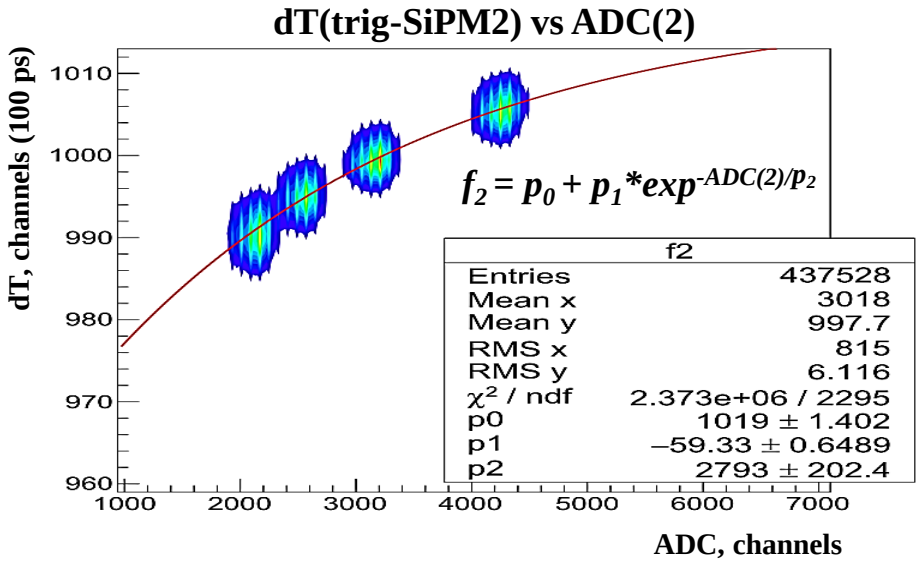


Extracting correction parameters FEE DANSS

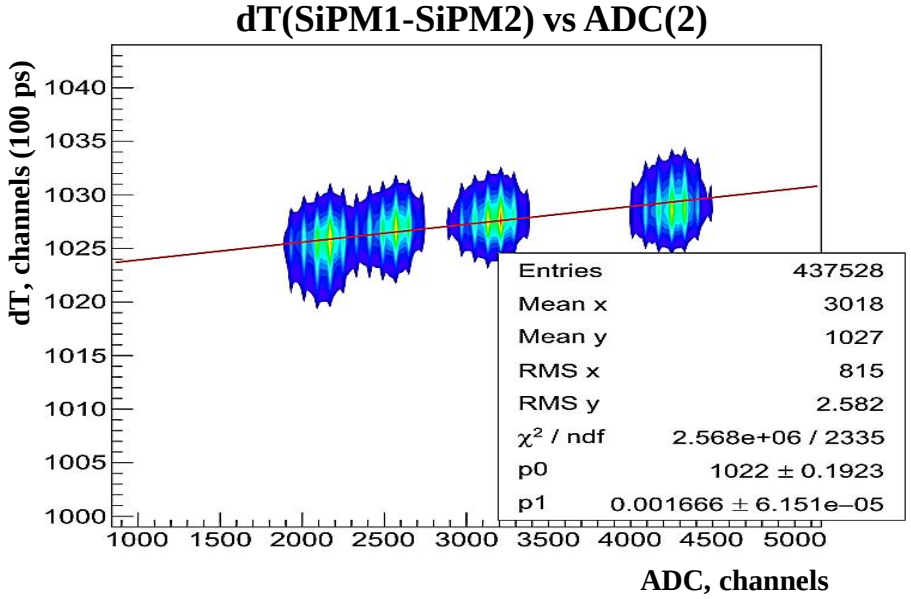


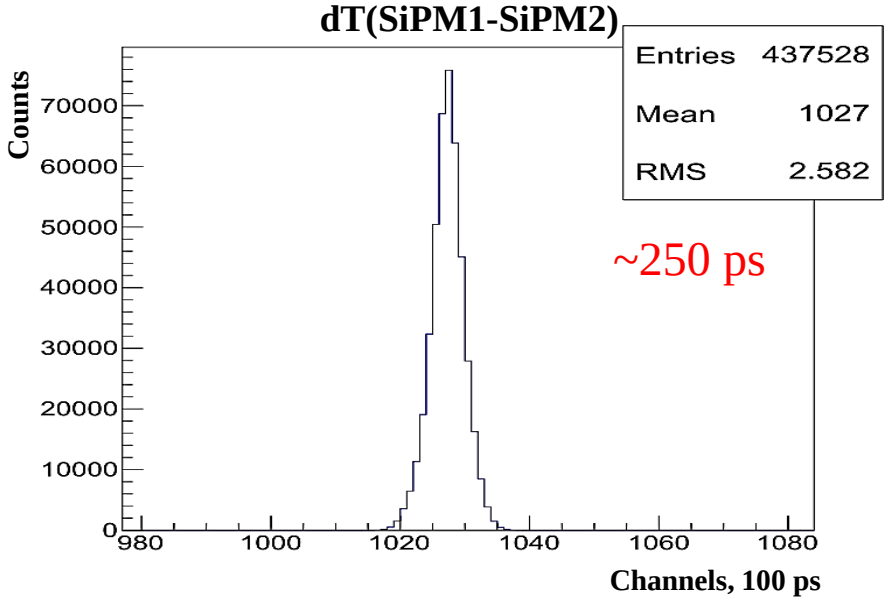


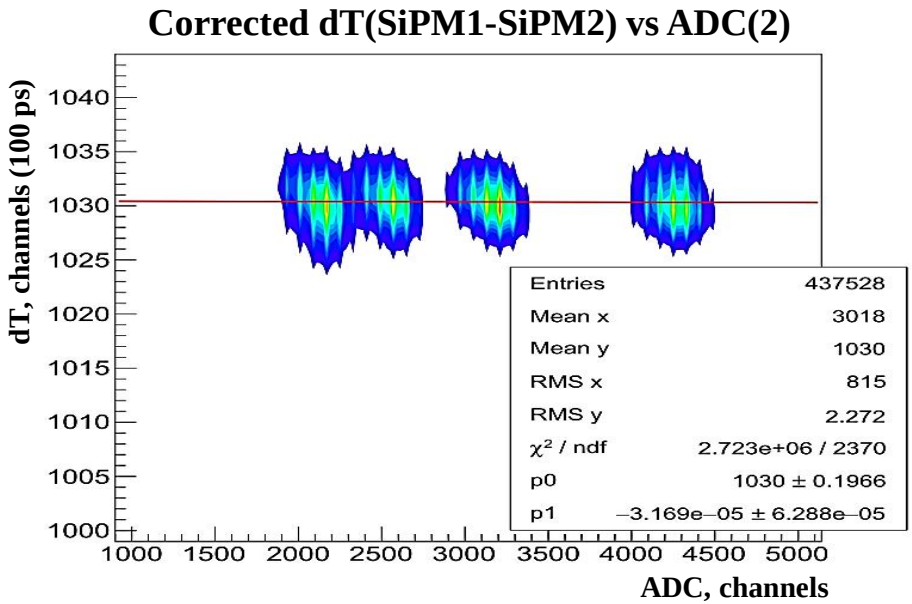


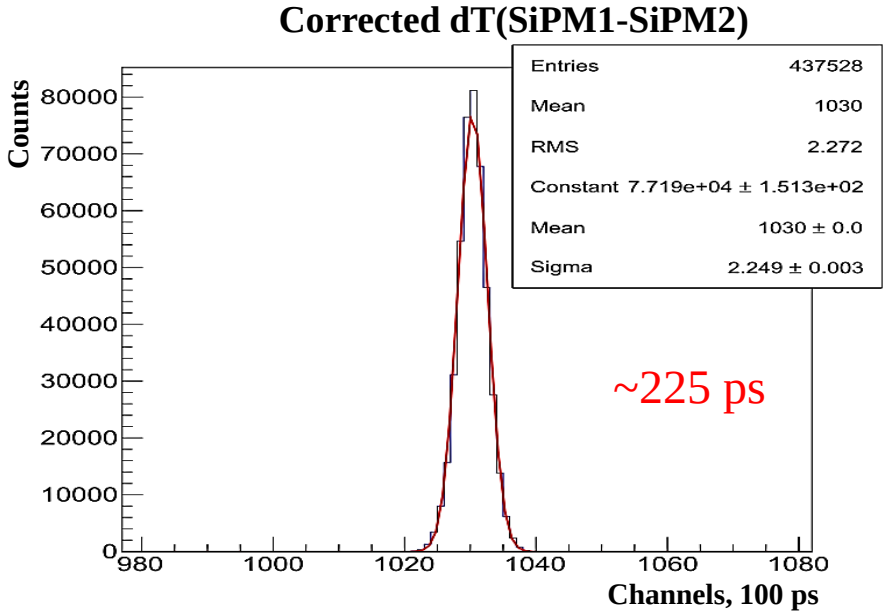


The time difference histogram FEE DANSS



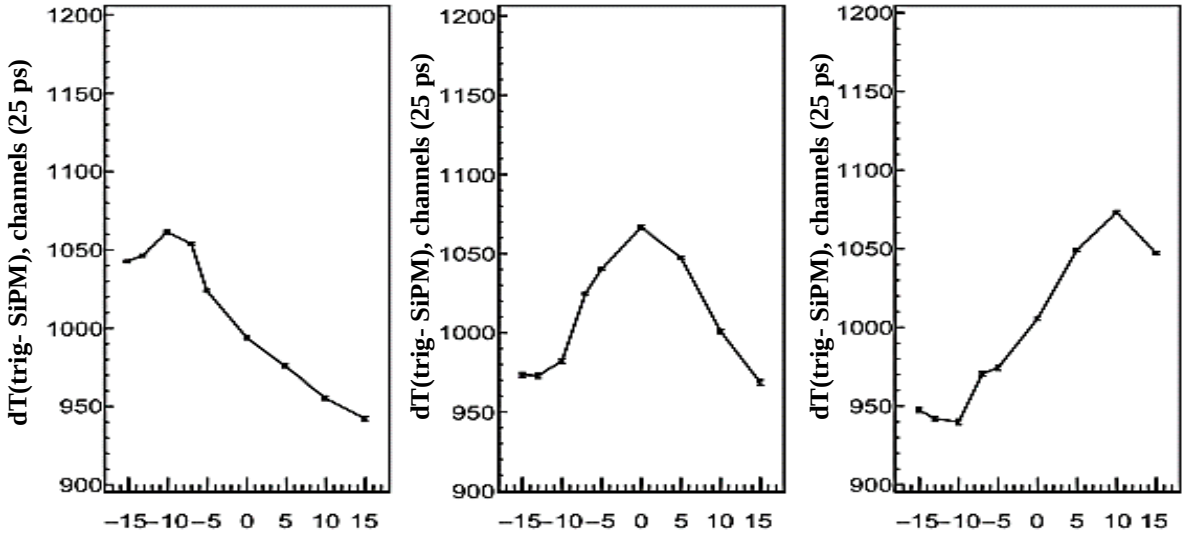






Comparison of electronics
Scanning by source position
(Amplitude 4000)

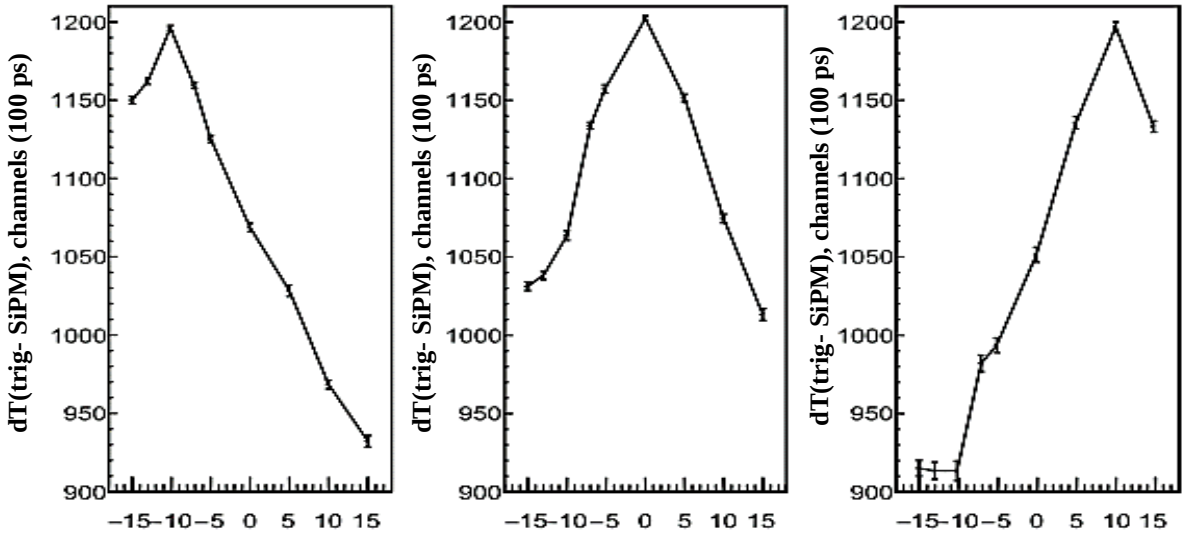
FEE ToT



SiPM2 **SiPM3** **SiPM4**

(plastic center)

FEE DANSS



To do list

- Testing the 3rd version of the TOT electronics with new power sources.
- Analysis of the recorded data set and determine the coordinate resolution.
- Test another types of SiPM.
- Preparation of several prototypes with the sizes of scintillation tiles 10x10 (cm^2) and 30x30 (cm^2) for a run at the Nuclotron.

I. The first version of the scintillation detector prototypes with two types of FEE for the future Spin Physics Detector at NICA with Hamamatsu (S12572-010P) SiPM readout have been developed.

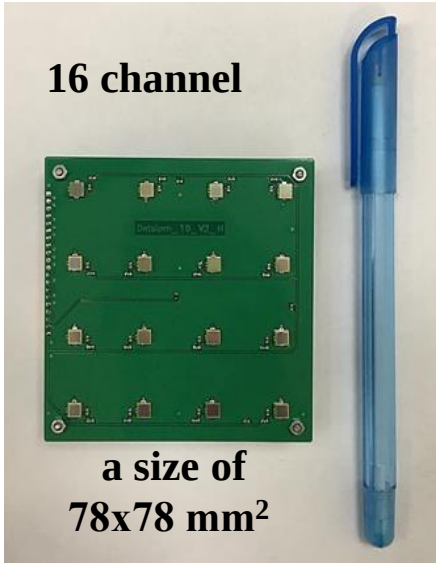
II. Two versions of Front-end electronics based on the Time-over-Threshold method have been tested. The test of the next version of electronics is required.

III. The DANSS electronics (ITEP) has been tested and has shown an reasonable results.

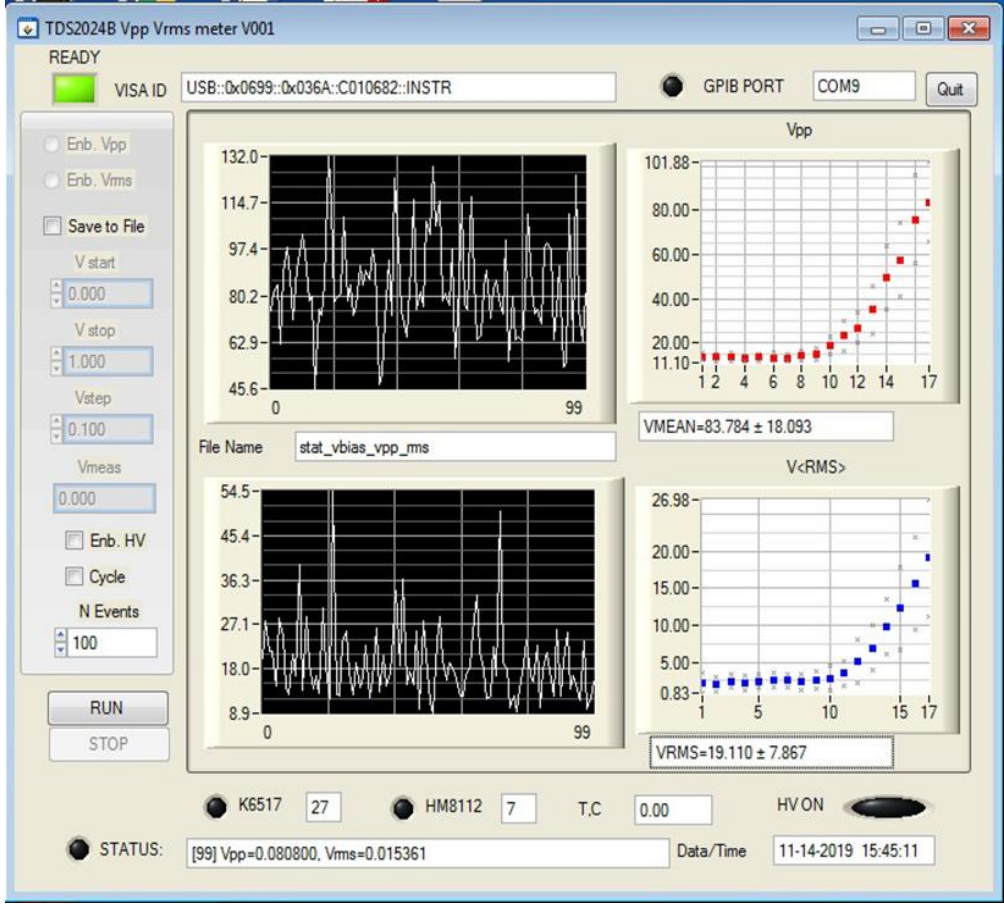
Thank you for your attention!

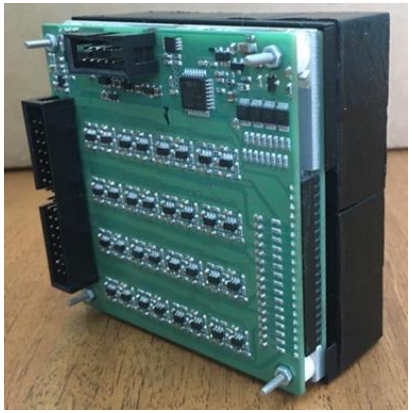
Special thanks to my colleagues from the DSS group

Backup



Ch.	Set Voltage(V) @20C		T Compensated Set Voltage	Current Voltage(V)	Kt (V/C)	Output Voltage(V)
0	1.356	1.356	1.356	1.356	0	73.646
1	1.239	1.239	1.239	1.239	0	73.763
2	1.247	1.247	1.247	1.247	0	73.755
3	1.648	1.648	1.648	1.648	0	73.354
4	1.351	1.351	1.351	1.351	0	73.651
5	1.125	1.125	1.125	1.125	0	73.877
6	1.399	1.399	1.399	1.399	0	73.603
7	1.323	1.323	1.323	1.323	0	73.679
8	1.341	1.341	1.341	1.341	0	73.661
9	1.224	1.224	1.224	1.224	0	73.778
10	1.297	1.297	1.297	1.297	0	73.705
11	1.348	1.348	1.348	1.348	0	73.654
12	1.608	1.608	1.608	1.608	0	73.394
13	1.315	1.315	1.315	1.315	0	73.687
14	1.225	1.225	1.225	1.225	0	73.777
15	1.299	1.299	1.299	1.299	0	73.703
Ped	75.000	75.002	74.998	75.002	0	Pedestal V





It's the 16-channel prototype of detector. This prototype is implemented on two PCBs. They contain power supply for sixteen SiPMs. The bias voltage is set by the HVsys program, which allows to set the total and the individual voltage.

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

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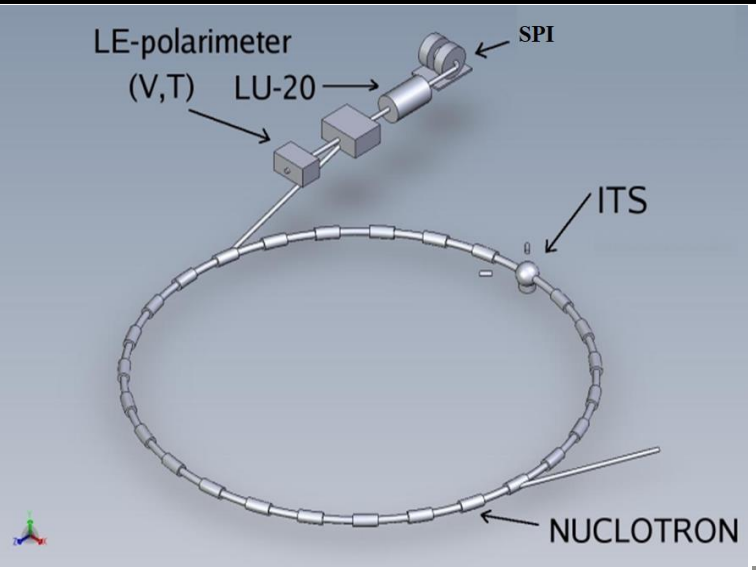
Experimental conditions

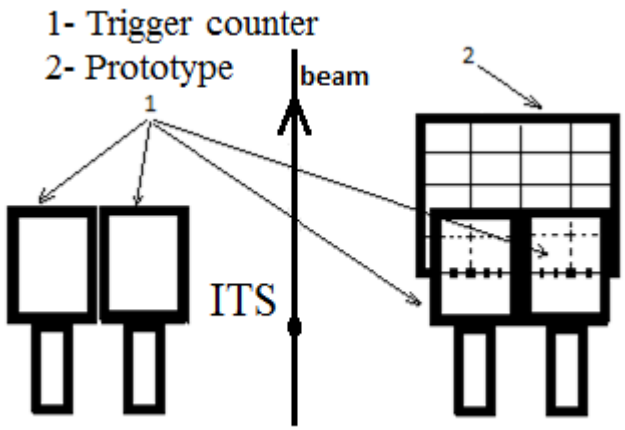


the energy 4 GeV / nucleon

the intensity $1x10^6$—$8.5x10^8$

U_{bias} =23,0 – 24,7 V

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



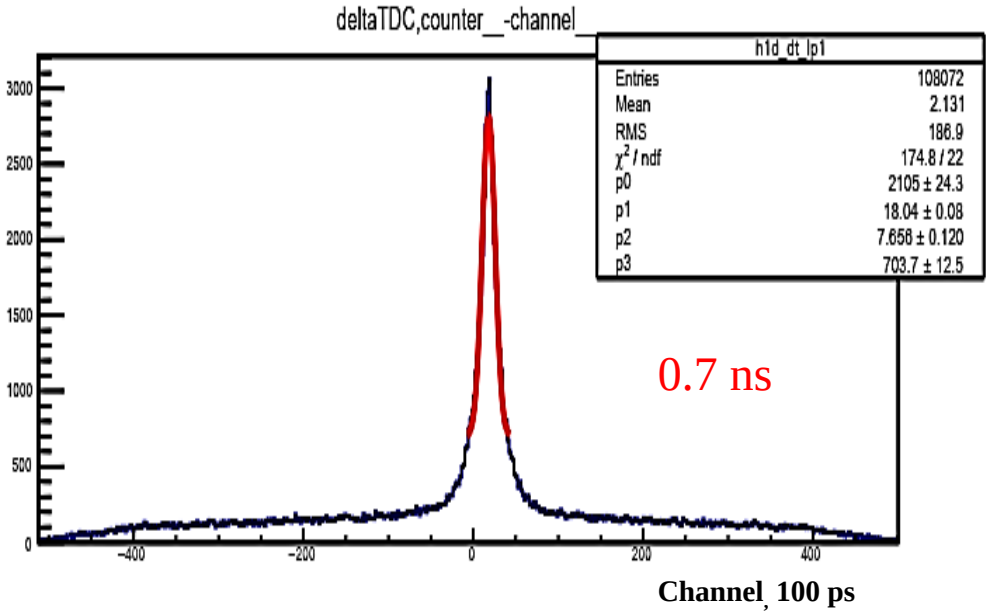
Hamamatsu H741MOD photo-multiplier tube

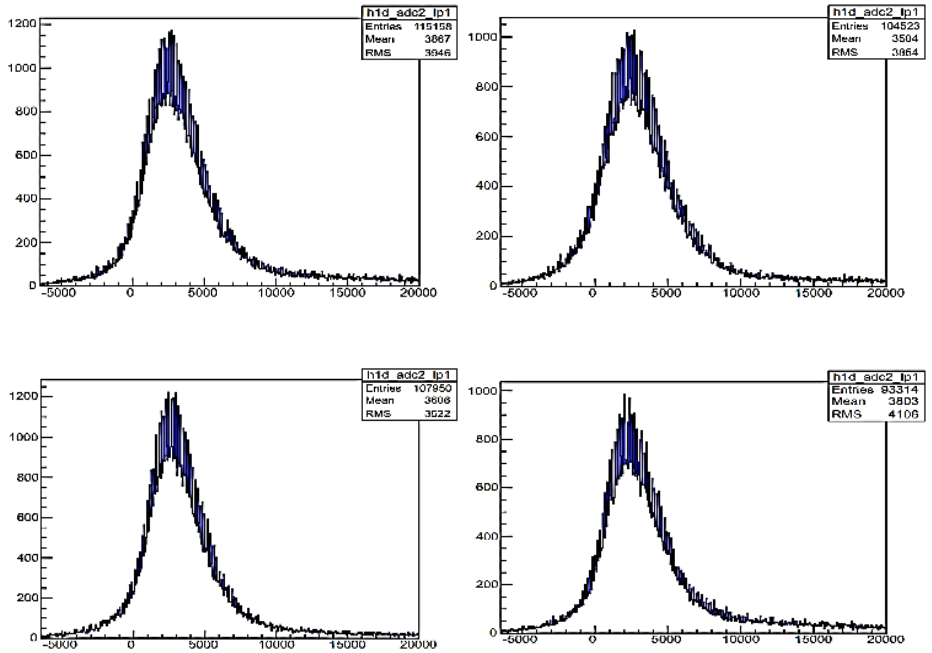
$$\begin{cases} \sigma_1^2 = \sigma_L^2 + \sigma_R^2 \\ \sigma_2^2 = \sigma_L^2 + \sigma_{Ch}^2 \\ \sigma_3^2 = \sigma_R^2 + \sigma_{Ch}^2 \end{cases} \quad (1)$$

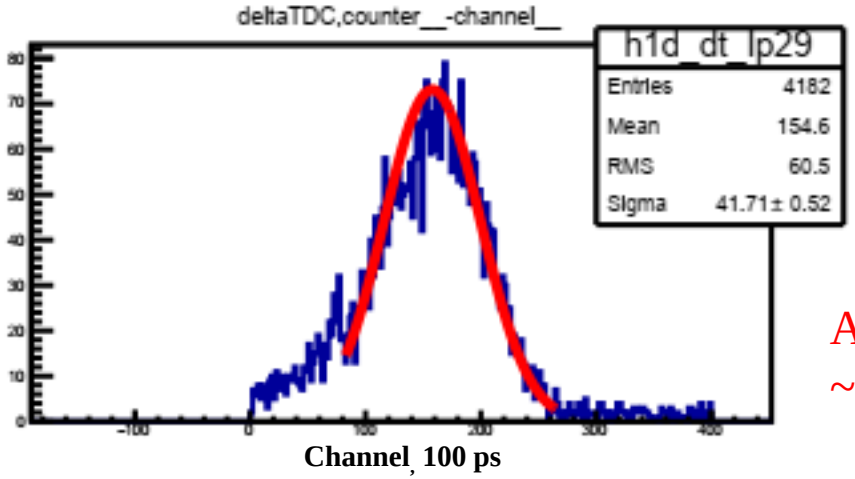
$$\sigma_L^2 \approx \sigma_R^2 = \sigma_0^2$$
$$\sigma_1^2 = 2\sigma_0^2 \quad (2)$$

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

The time difference histogram







Average
~ 4.0 ns