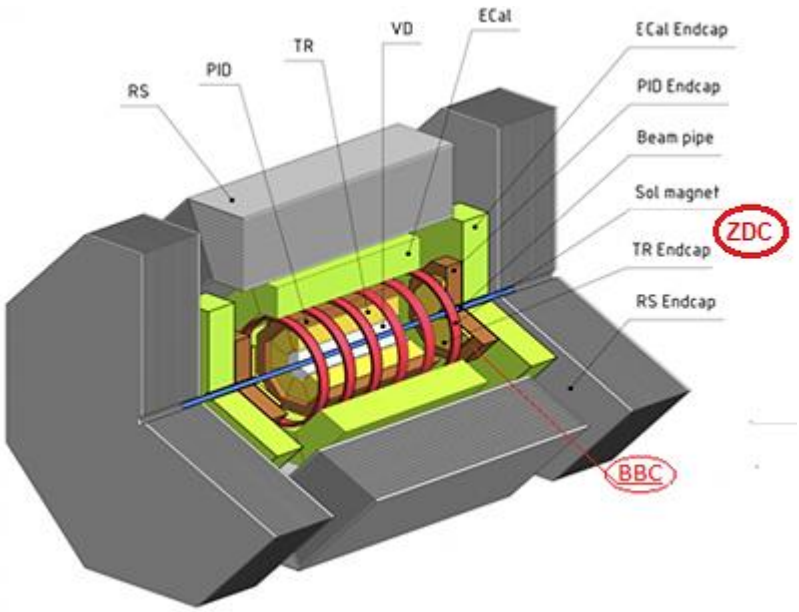
Study of the 16-channel scintillation detector prototype with SiPM readout.

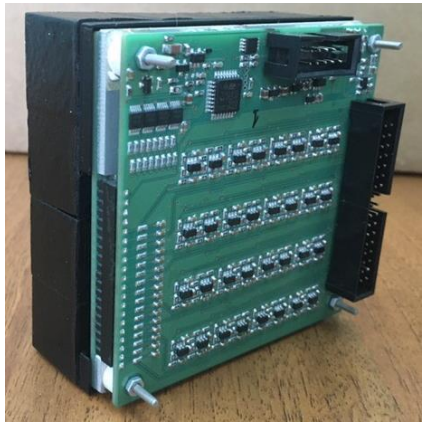
A.V. Tishevskiy

AYSS-2020, Dubna
10 November

The Spin Physics Detector (SPD)



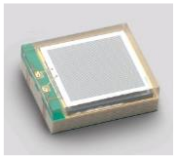
At the Laboratory of High-Energy Physics of the Joint Institute for Nuclear Research, 16-channel prototypes of detectors with SiPM readout produced by Ketek (PM3350) and Hamamatsu (S12572-010P) were developed.



Application:

✓option for Zero Degree Calorimeter (ZDC)

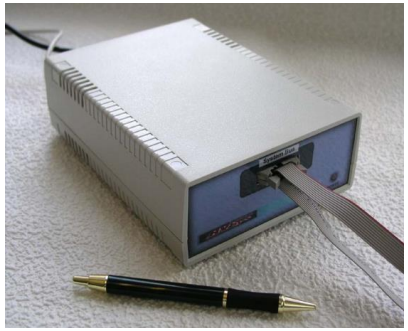
PM3350,**KETEK**
(3x3 мм^2, 50 μm/cell)



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

The prototypes

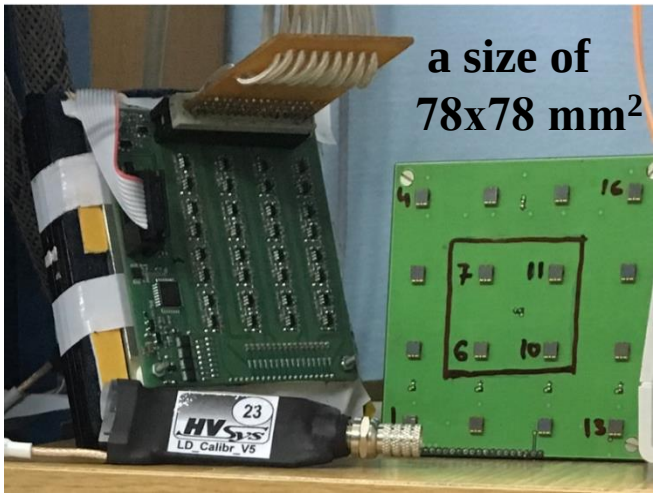
Advantages	Disadvantages
▪ low bias voltage	▪ sensitivity to external temperature changes
▪ insensitivity to magnetic fields	▪ some have low radiation hardness
▪ compact size	



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

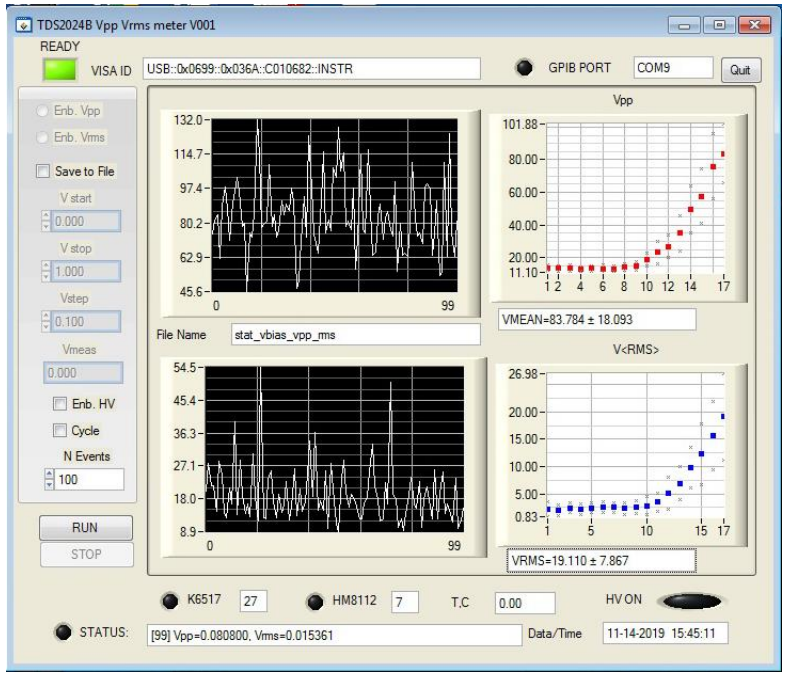
Properties

- 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 method of the bias voltage determining

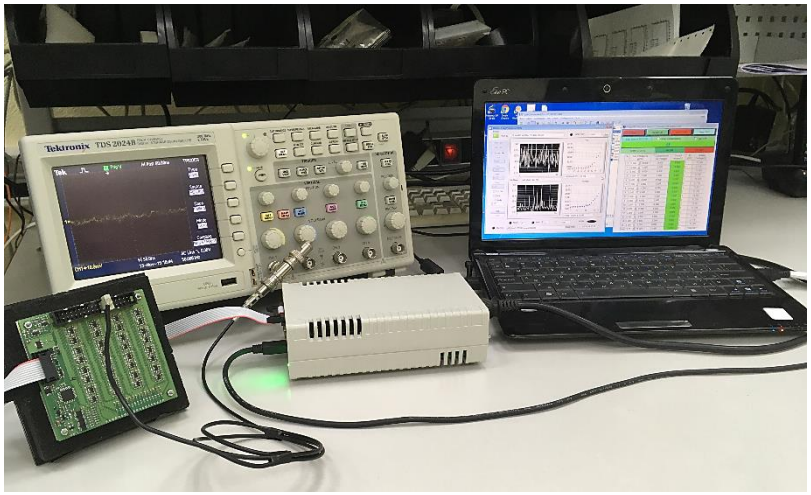
The method based on peak-to-peak amplitudes measuring of the noise signal (V_{pp}), depending on bias voltage (V_{bias}) was proposed



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

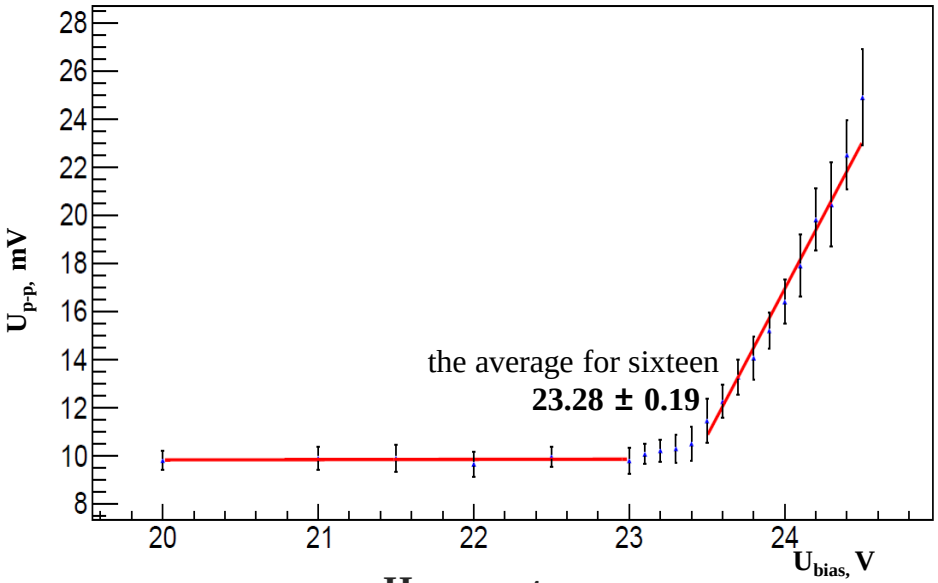


Averaging peak-to-peak amplitudes was performed on 100 measurements with corresponding error to reduce the contribution of noise signal pulses and increase accuracy

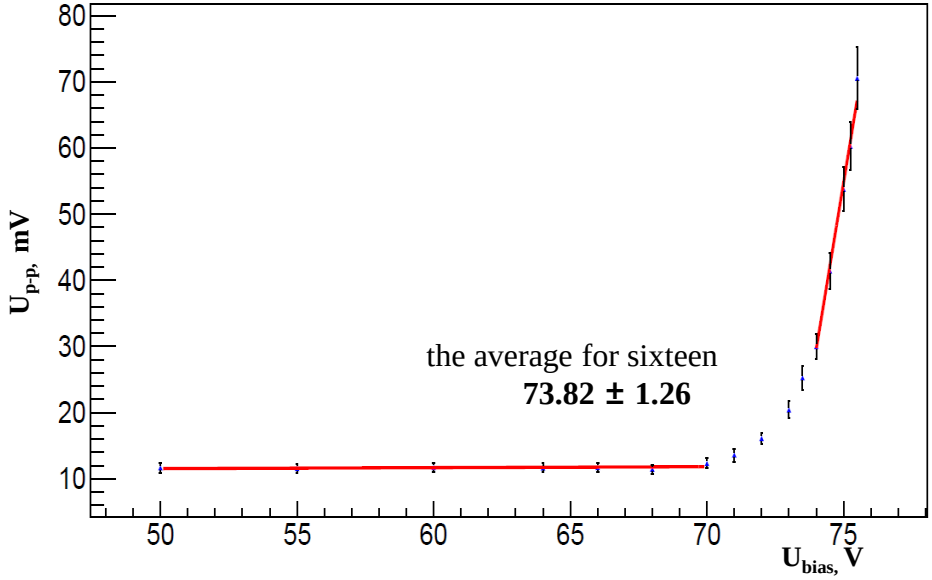
Tishevskiy A.V. et al. // to be published in Phys.Atom.Nucl., 2020, Vol. 83, No. 11

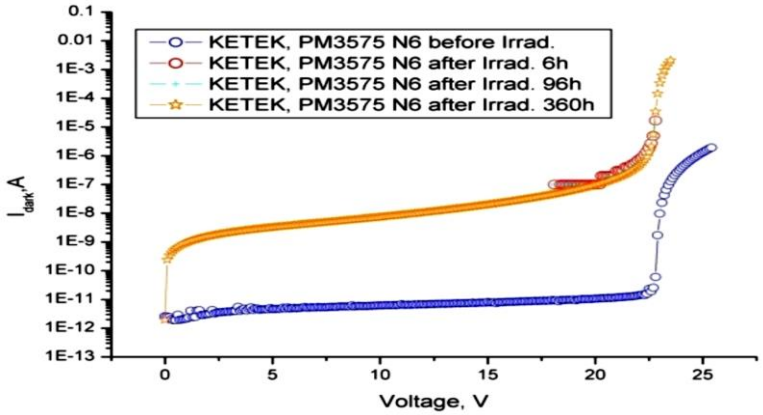
The break points of the noise characteristics (~32 °C)

Ketek



Hamamatsu

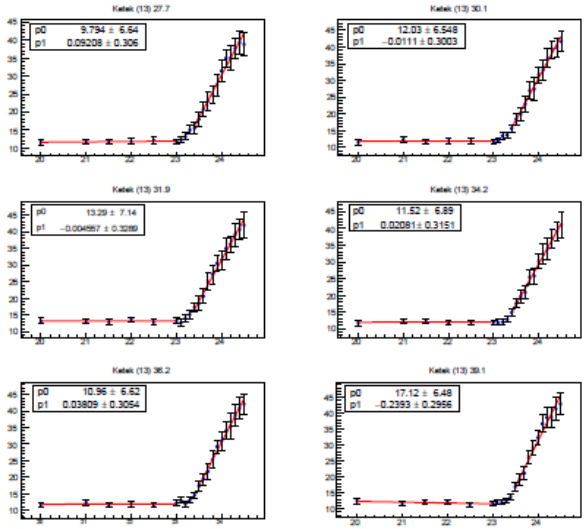


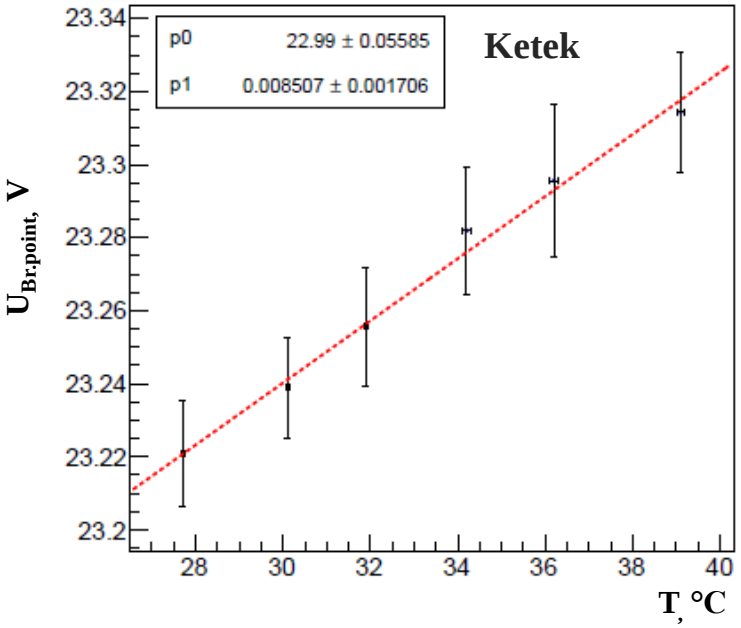


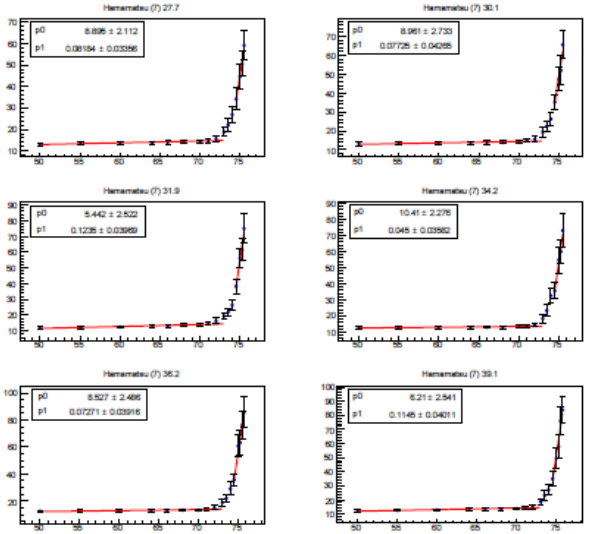
V. Kushpil et al., J.Phys.Conf.Ser. 675 (2016) no.1, 012039

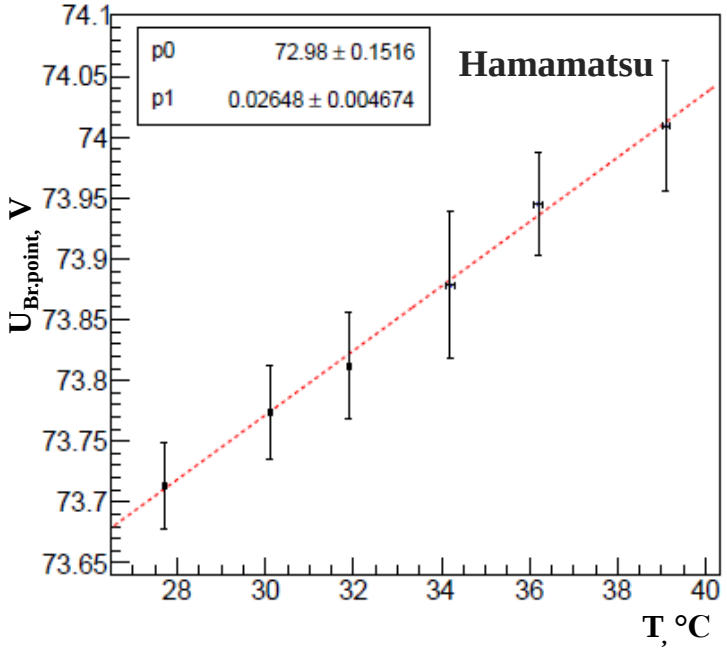
The found break points of the noise characteristics for the prototypes will be used as base to determine the operating bias voltage. The final bias voltage is set according to the type of SiPM and the considerations of the researchers.

Temperature dependence of the break points









The conclusion.

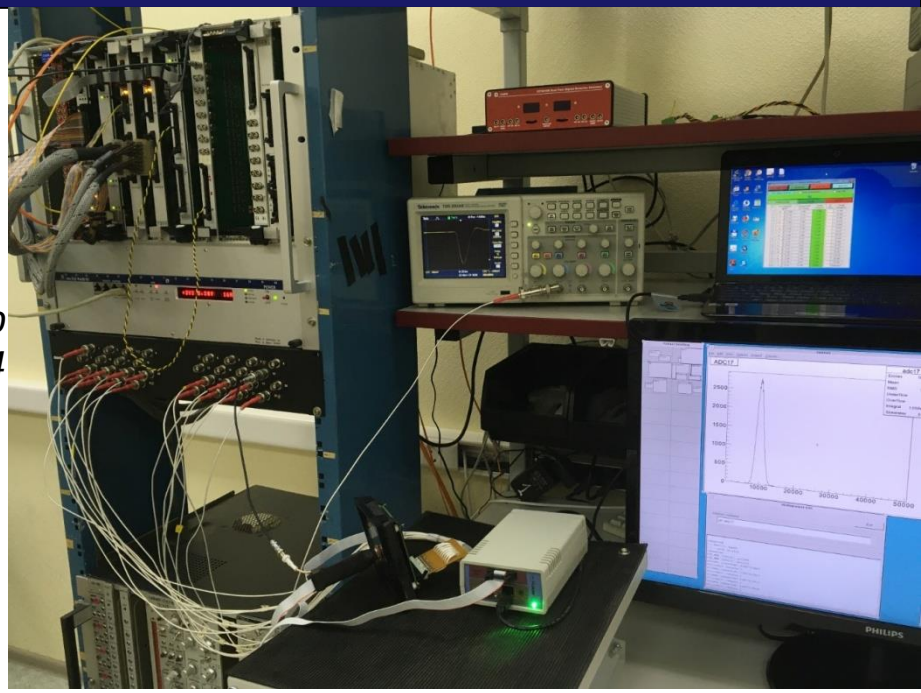
The dependence shows that the change in temperature by °C leads to a change in the bias voltage by about 8.5 mV for the Ketek SiPM and 26.4 mV for the Hamamatsu SiPM

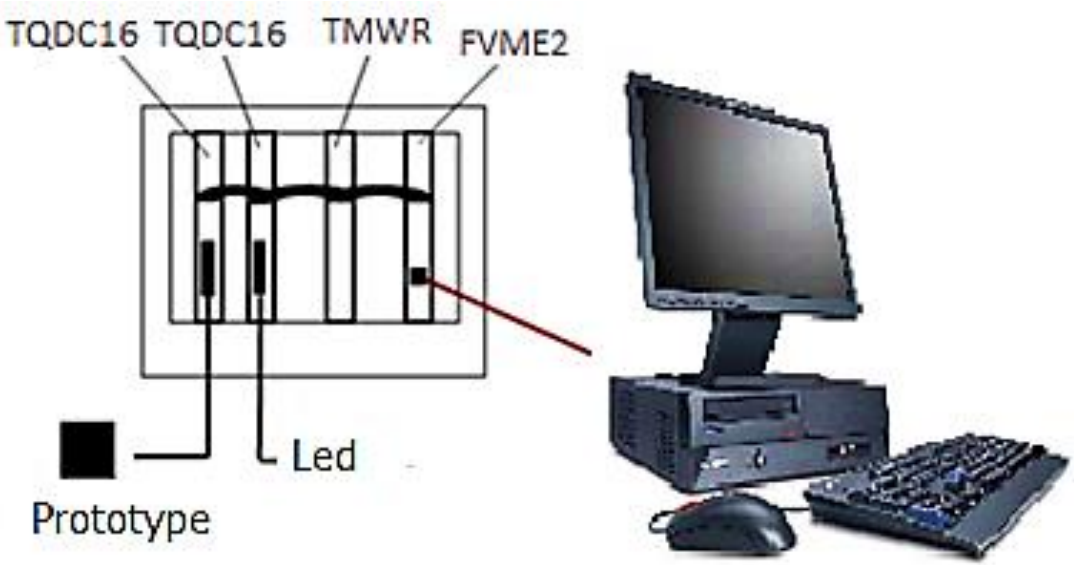
The equipment

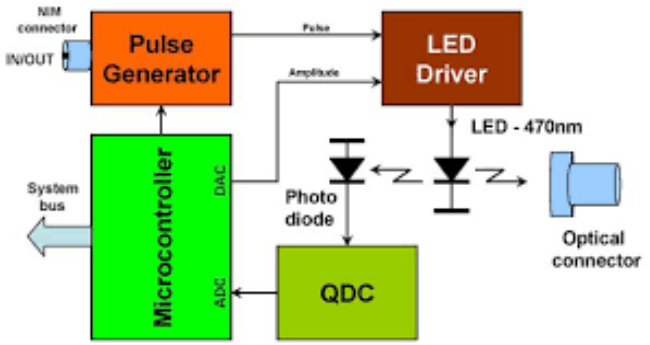
TQDC16
(16-channel time and charge digitizer)

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

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



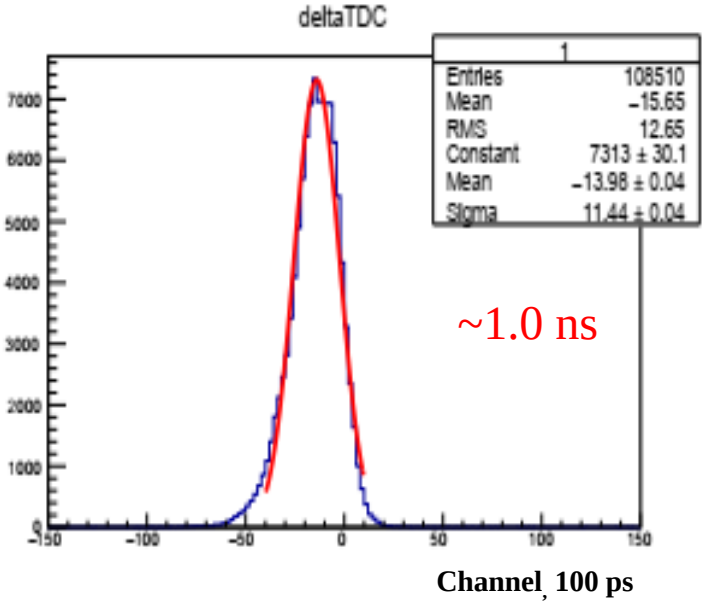




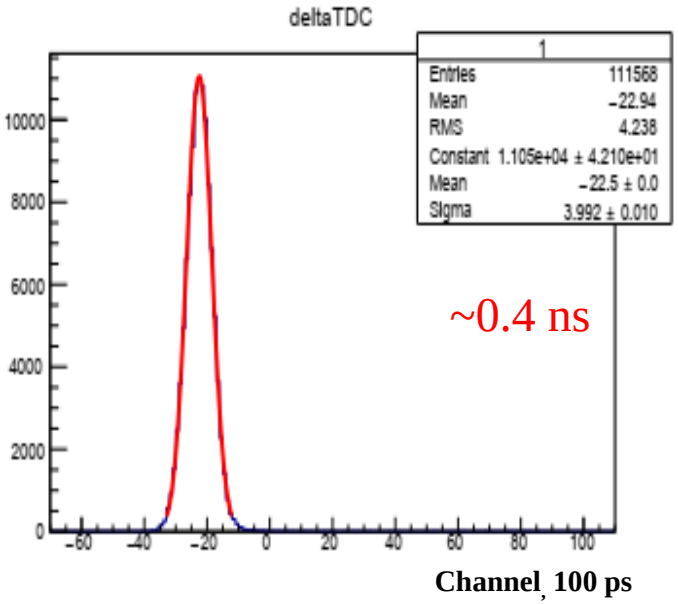
http://hvsys.ru/images/data/news/5_small_1368802948.pdf

The time difference histogram

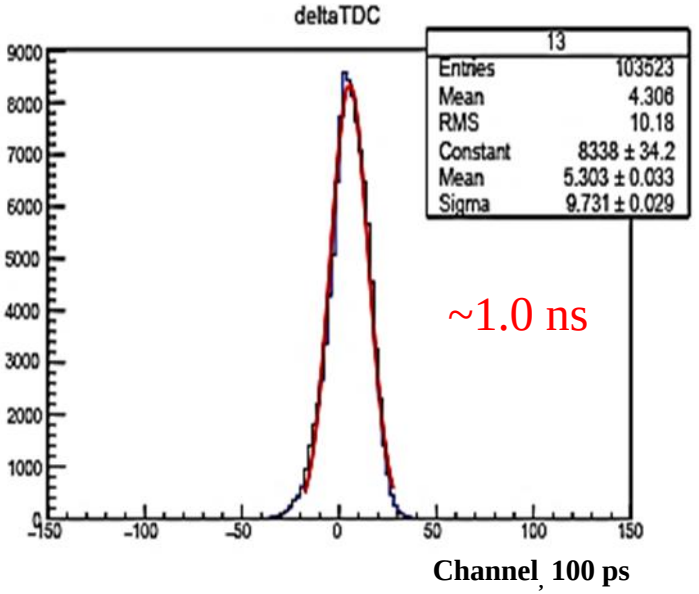
Uniform light

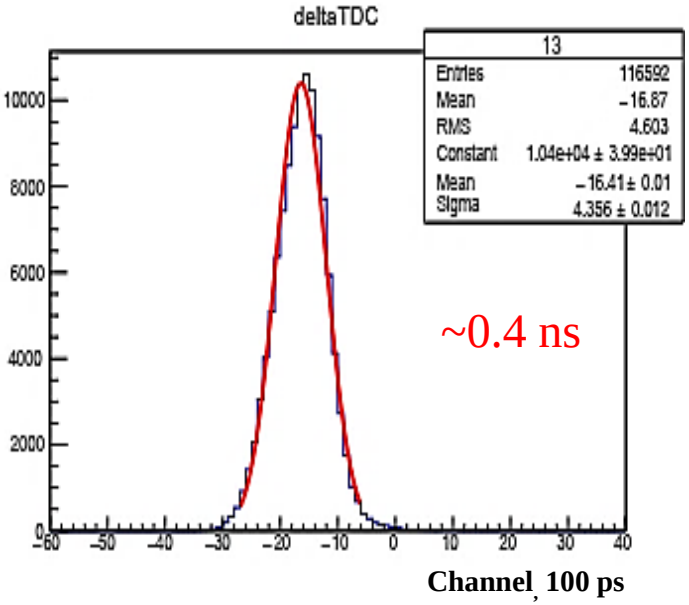


Fiber



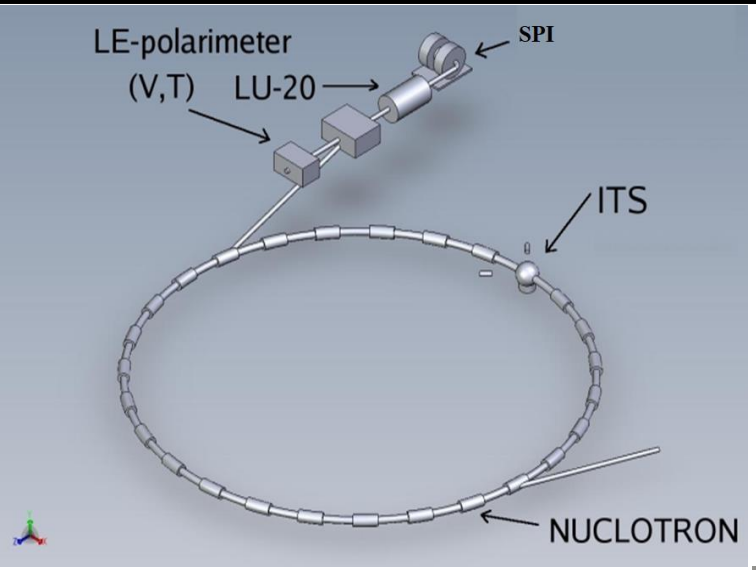
Ketek
(26 °C, 24.7 V)





Hamamatsu
(26 °C, 71.2 V)

Experimental conditions

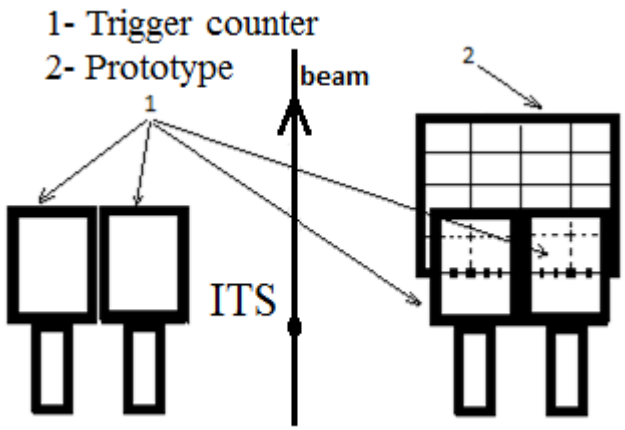


the energy 4 GeV / nucleon

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.



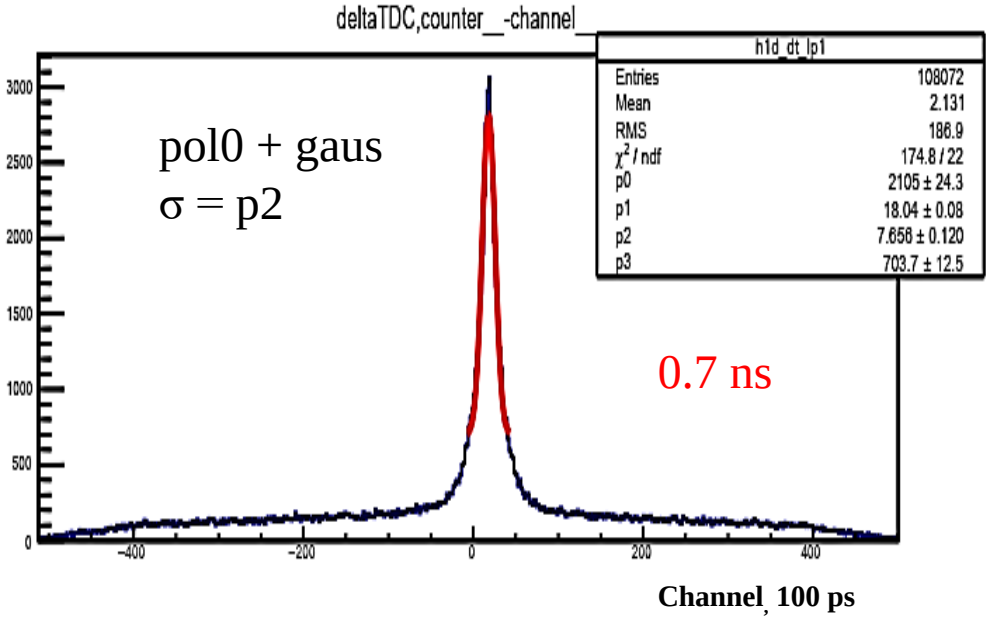
Hamamatsu H741MOD photo-multiplier tube

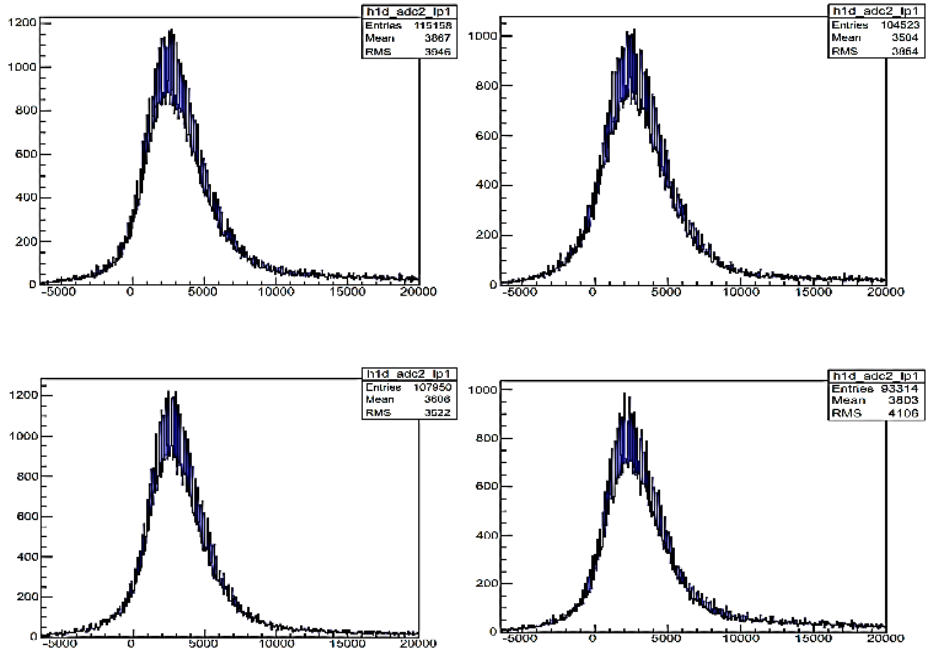
$$\begin{cases} \sigma_1^2 = \sigma_L^2 + \sigma_R^2 \\ \sigma_2^2 = \sigma_L^2 + \sigma_{Ch}^2 \\ \sigma_3^2 = \sigma_R^2 + \sigma_{Ch}^2 \end{cases} \quad (1)$$

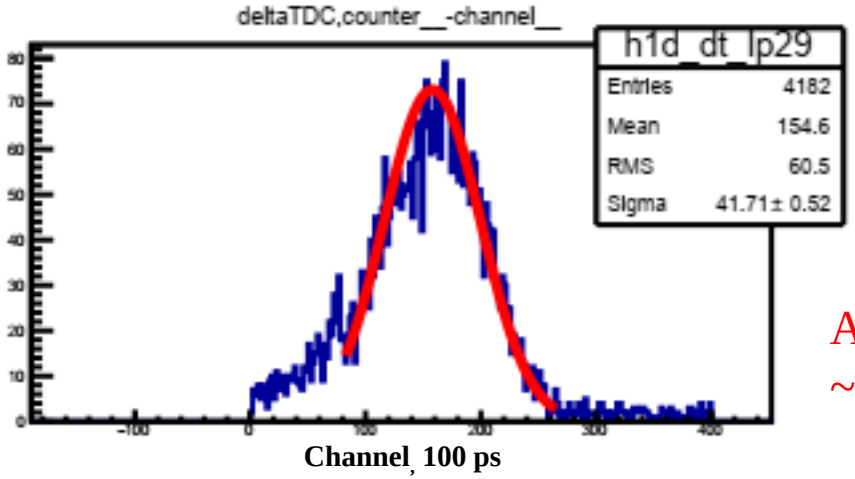
$$\sigma_L^2 \approx \sigma_R^2 = \sigma_0^2$$
$$\sigma_1^2 = 2\sigma_0^2 \quad (2)$$

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

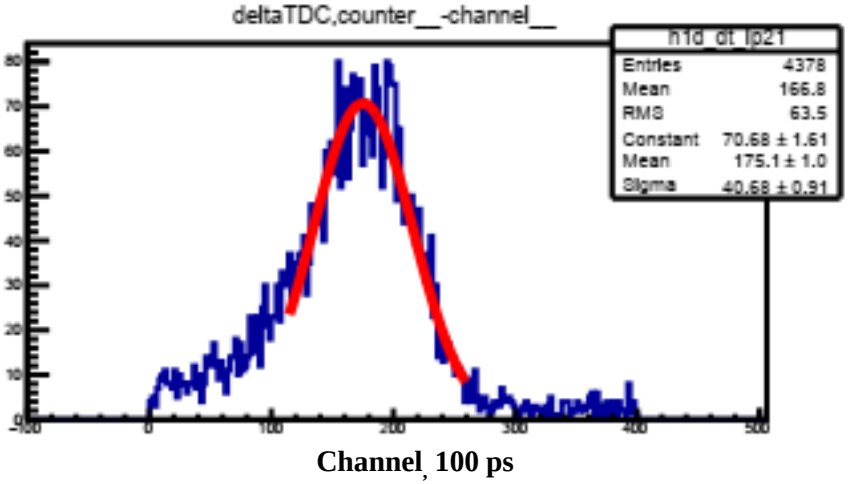
The time difference histogram







Average
~ 4.0 ns



Conclusions

I. The scintillation detector prototypes with Ketek (PM3350), and Hamamatsu (S12572-010P) SiPM readout have been developed and tested by LED. The time resolution was approximately 1.0 ns for the uniform light and about 0.4 ns for fiber for both prototypes.

II. The proposed method of the bias voltage determining according to noise characteristics is useful also for adjusting the voltage during continuous operation in ionizing fields (requires additional study).

III. The scintillation detector prototypes with Ketek was tested by the deuteron beam of the Nuclotron of the JINR at energy of 4 GeV/nucleon. As a result of the test, we estimated the average time resolution to equal 4.0 ns.

IV. We expect our proposed prototypes to become important part of the development for local polarimetry and local luminosity monitoring. Taking into account the SiPM suboptimal for precise time measurements for ZDC the result is promising.

Thank you for your attention!

Tests on the Nuclotron were performed as part of the DSS project. We are grateful to the Nuclotron accelerator group and to our foreign colleagues V. Kushpil, M. Janek, and O. Mezhenska for the help in preparing and carrying out the tests.