Measurement of the time resolution of the ASHIPH counter prototype with a silicon PMT for the Super Tau-Charm Facility

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- Conclusion.

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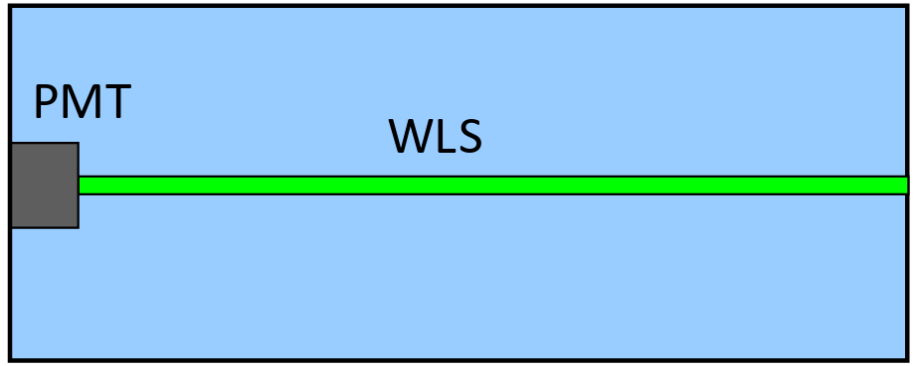
Motivation

For π/K separation up to P = 3 GeV/c on Super Tau-Charm Facility the ASHIPH system is proposed

- The integration time of the signal of this system must be less than the time between beam collisions, i.e. less than 6 ns
- Time resolution of 2 ns was achieved for the ASHIPH system of the KEDR detector (doi:10.1016/j.nima.2003.11.095), then integration time is 10 ns
- The main contribution to the time characteristics of the ASHIPH system is made by the wavelength shifter illumination time, for BBQ it is $\tau_{BBQ} = 15$ ns



ASHIPH method scheme:

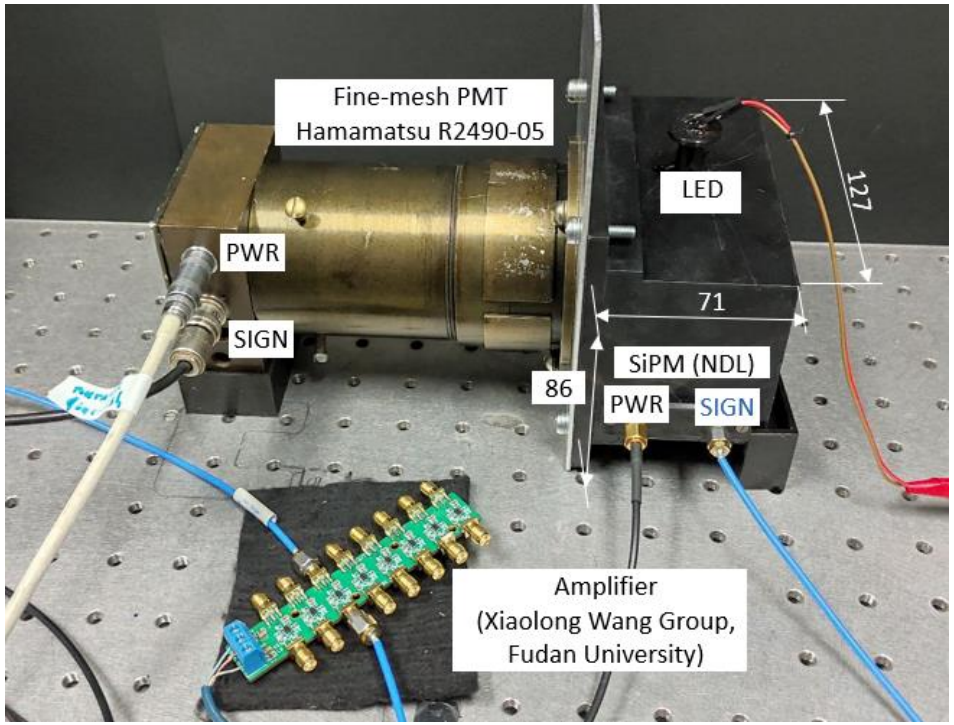
Aerogel – SHIfter – PHotomultiplier

Therefore

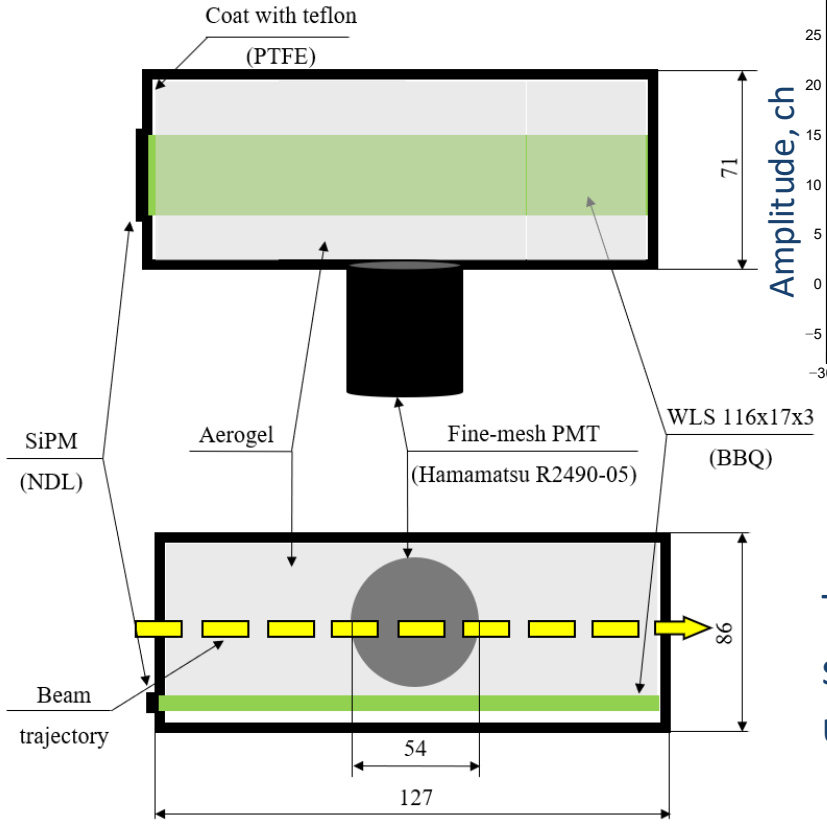
Fast wavelength shifters are required:

- τ_{OSL-8} = 5.4 ns;
- τ_{NOL-1} = 0.74 ns;
- …

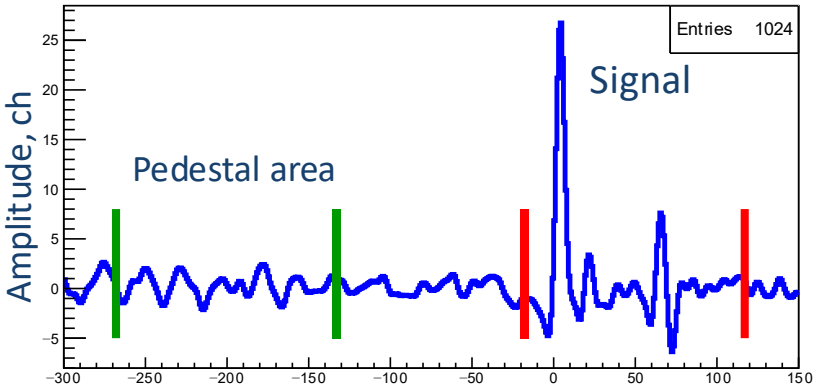
The ASHIPH counter prototype



Assembled prototype of the ASHIPH counter



Scheme of the ASHIPH counter

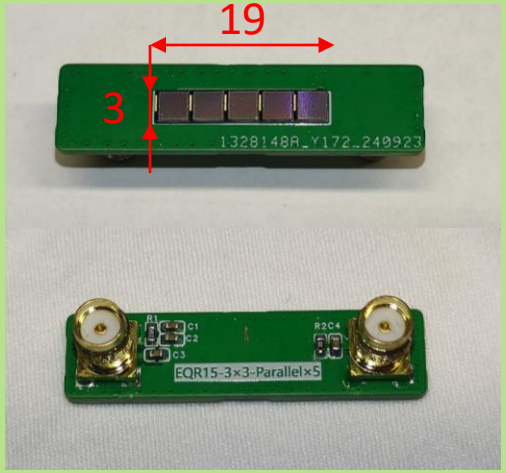


Fine-mesh PMT signal oscillogram

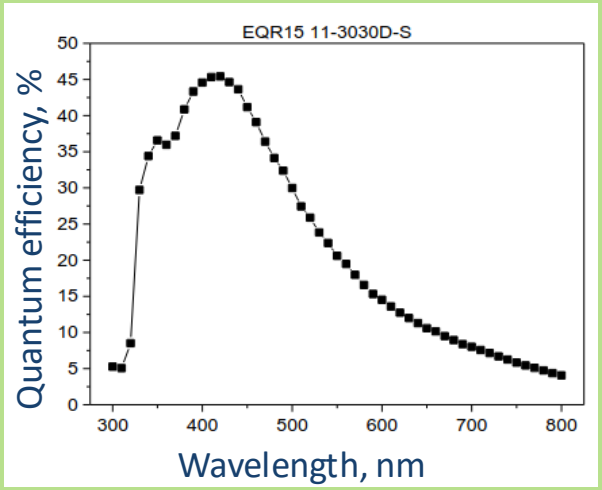
The fine-mesh PMT signal has a sharp front, so the counter can be used without an external trigger

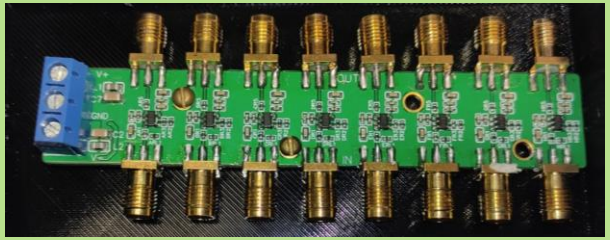
Photomultipliers

SiPM NDL

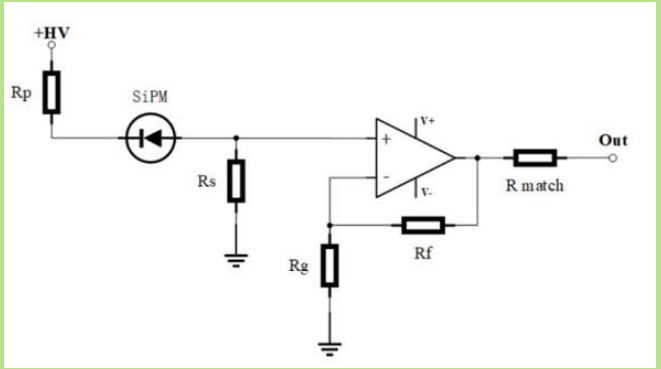


5 SiPM NDL array





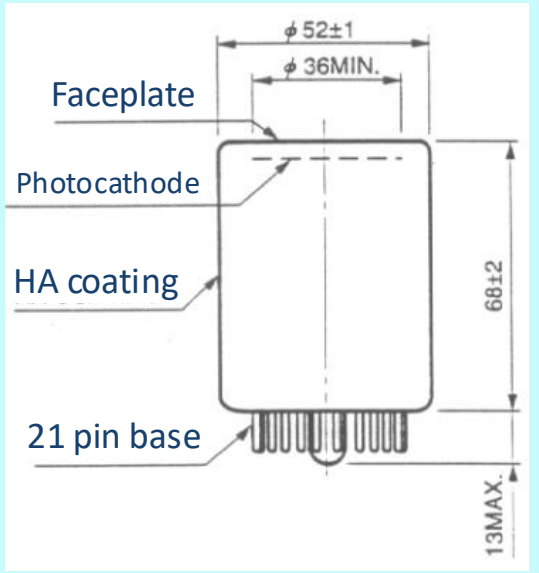
SiPM preamplifier

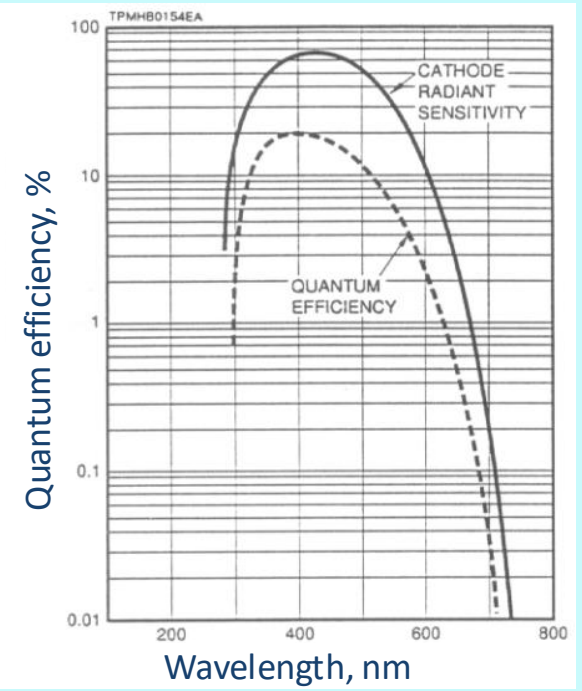


SiPM signal amplification circuit

- Gain: +20 V/V
- Power supply: ±5 V

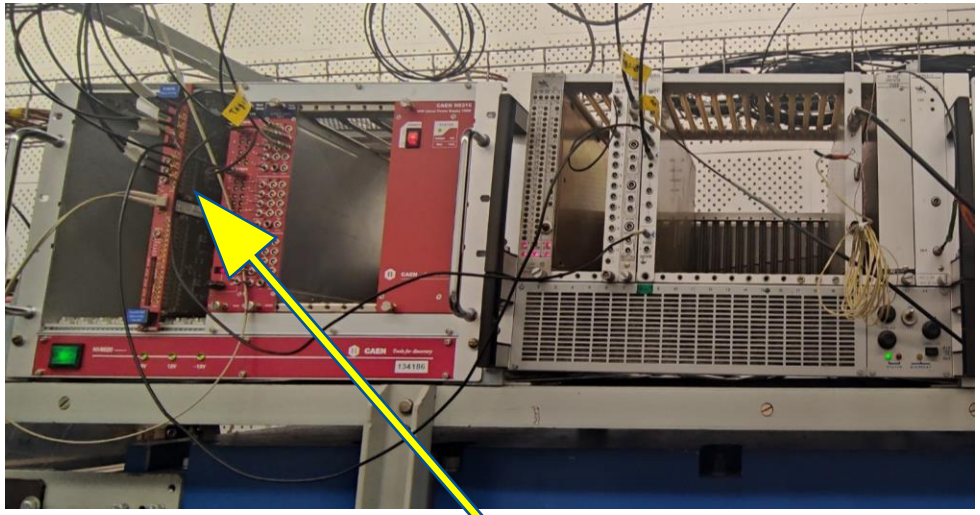
Fine-mesh PMT Hamamatsu R2490-05





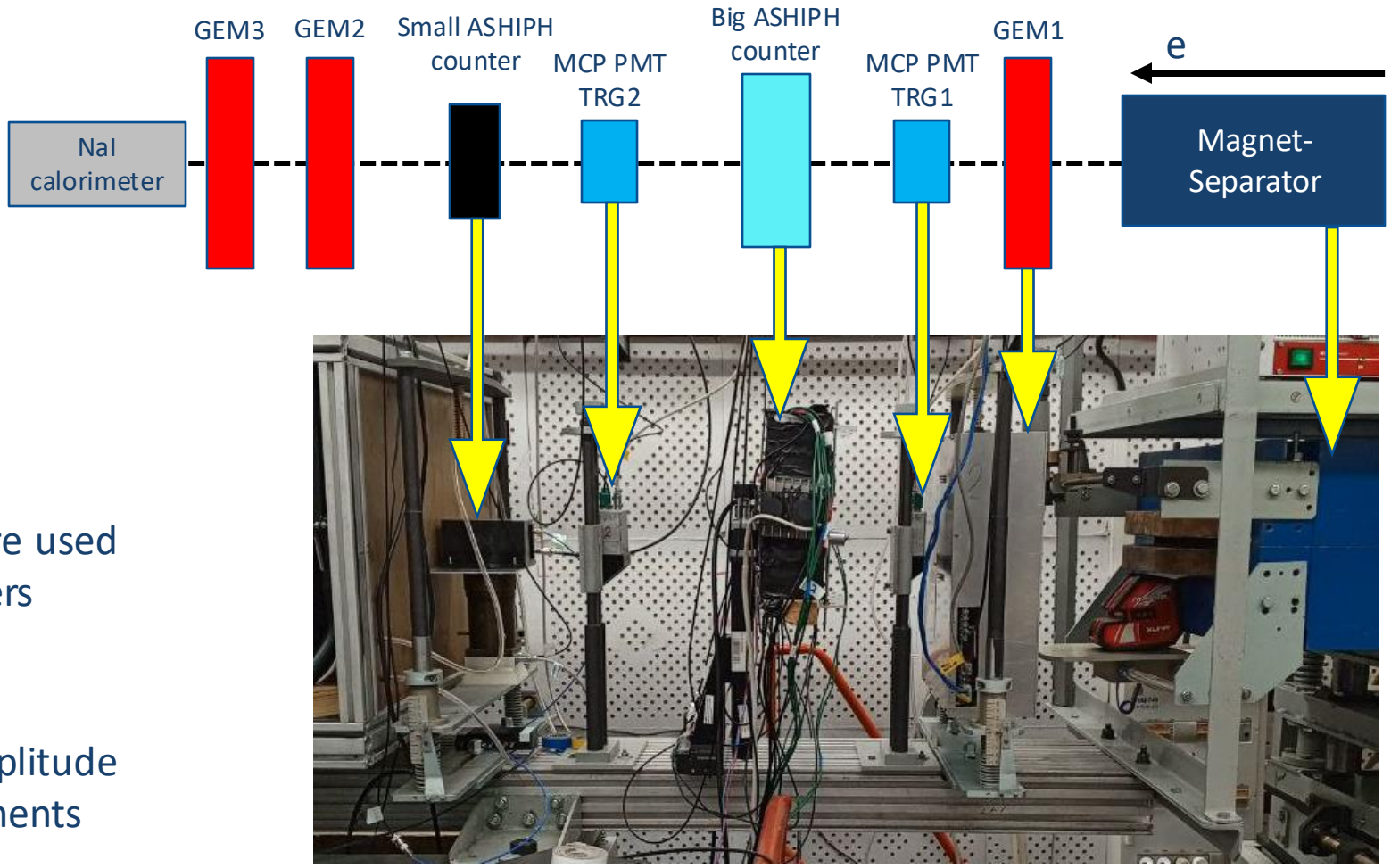
Used as an internal trigger!!

Testing of the prototype at the testbeam line of the VEPP4-M complex



Readout electronics in the experiment

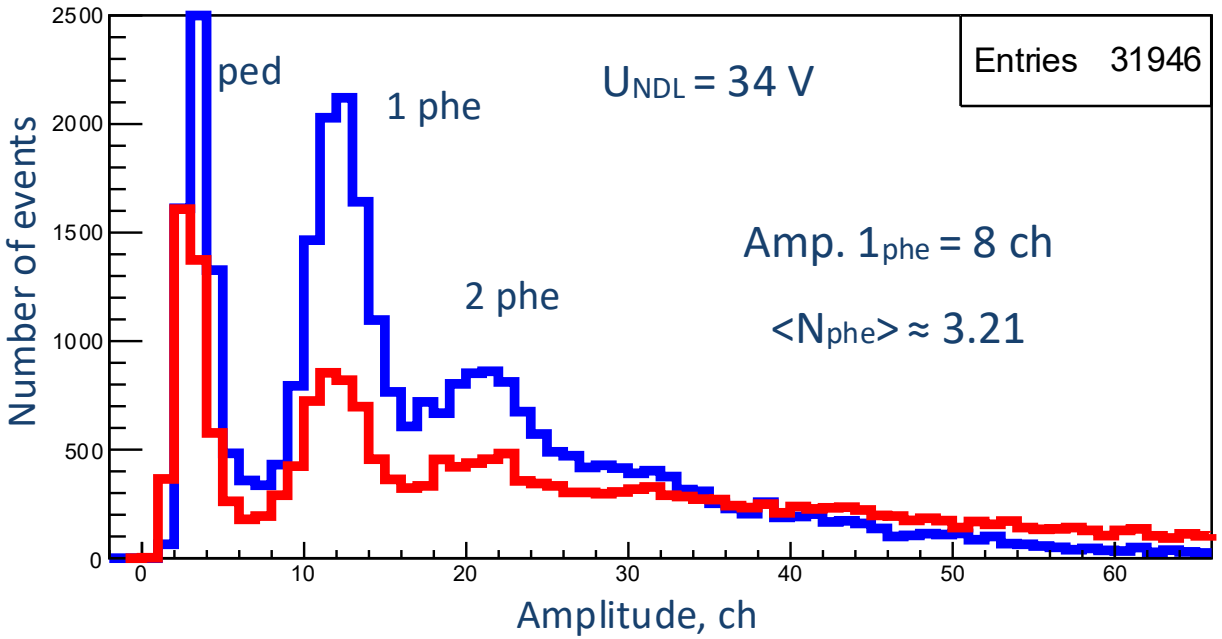
- 8 channels of the V1742 digitizer (CAEN) were used for recording signals from counters and triggers
- 50000 events in each dataset
- The sampling frequency is 1 Gs/s for amplitude measurements and 5 Gs/s for time measurements

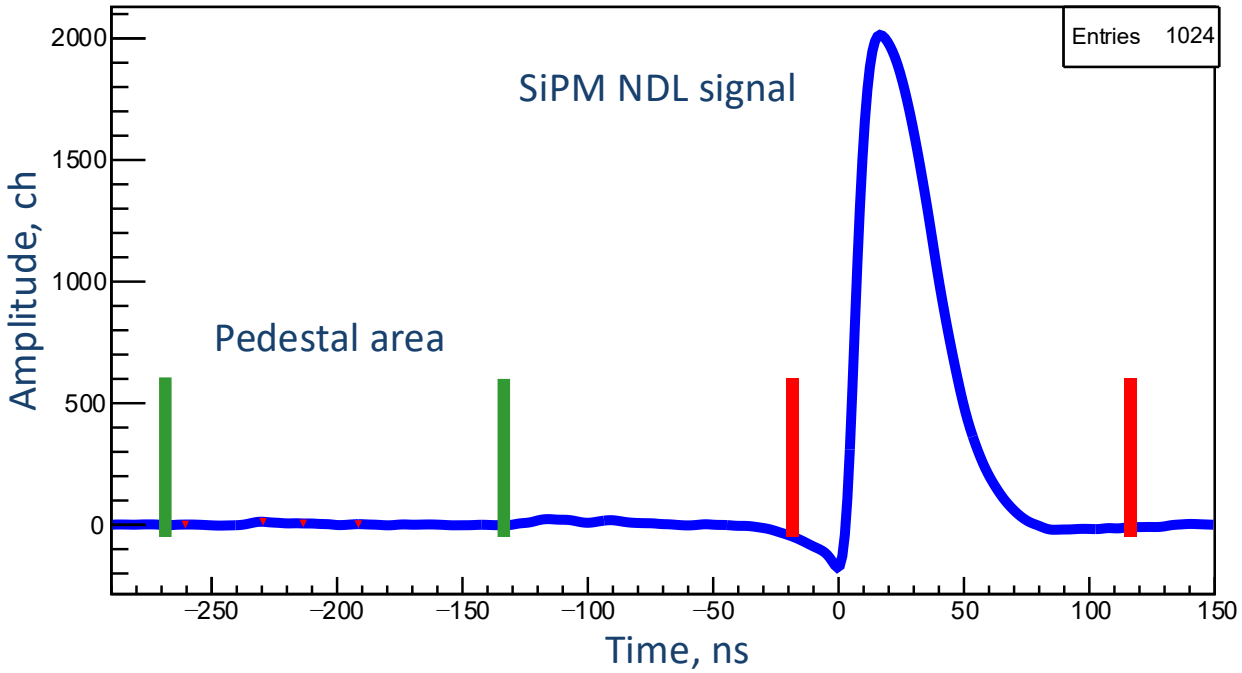


Experiment and it's scheme

Amplitude characteristics

- A supply voltage scan was performed, the operating point for SiPM NDL was chosen to be 33-34 V
- Amplitude distributions were constructed:
  a) The distribution in the signal area is shown in red;
  b) In the pedestal area – in blue.



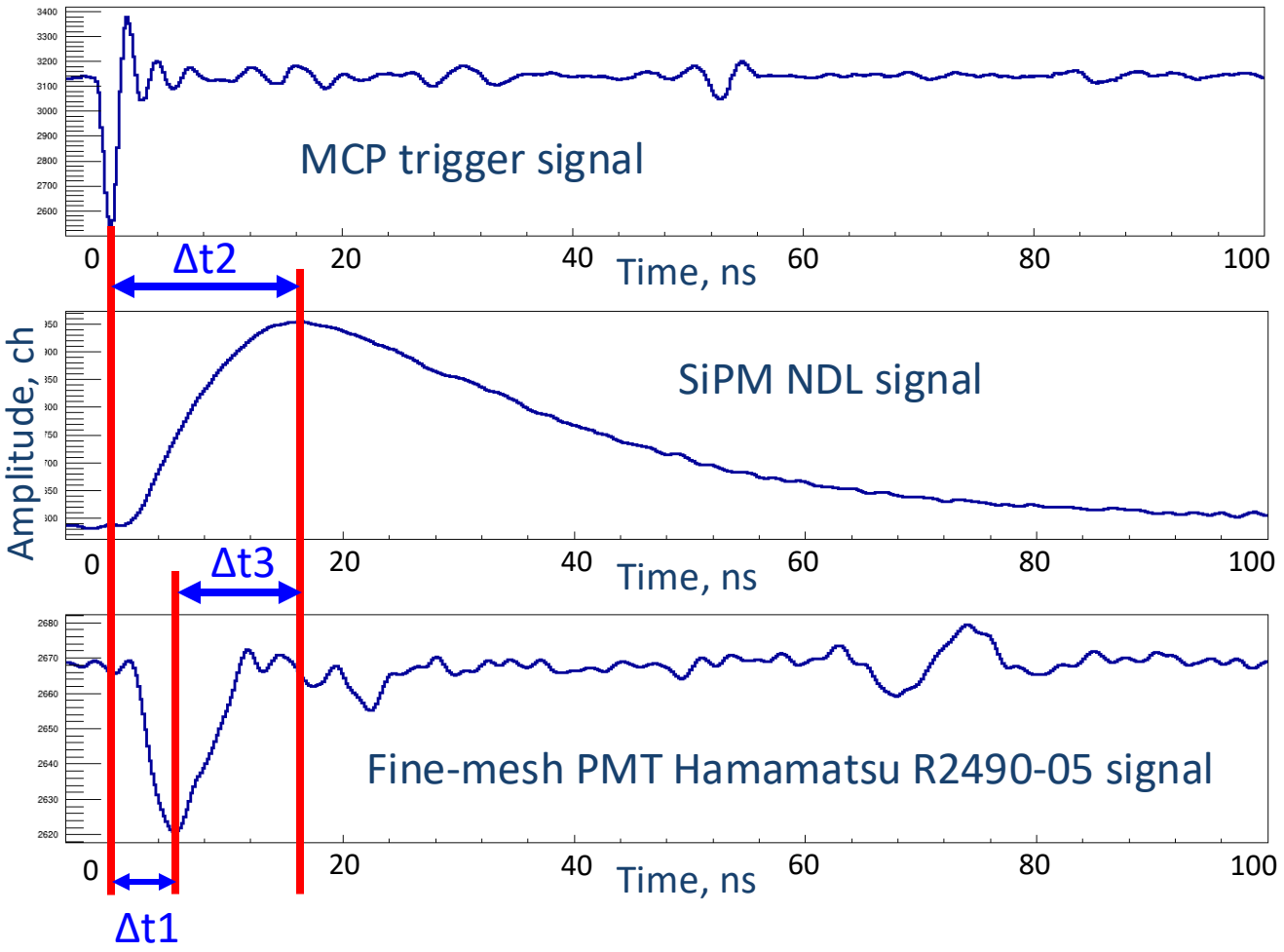


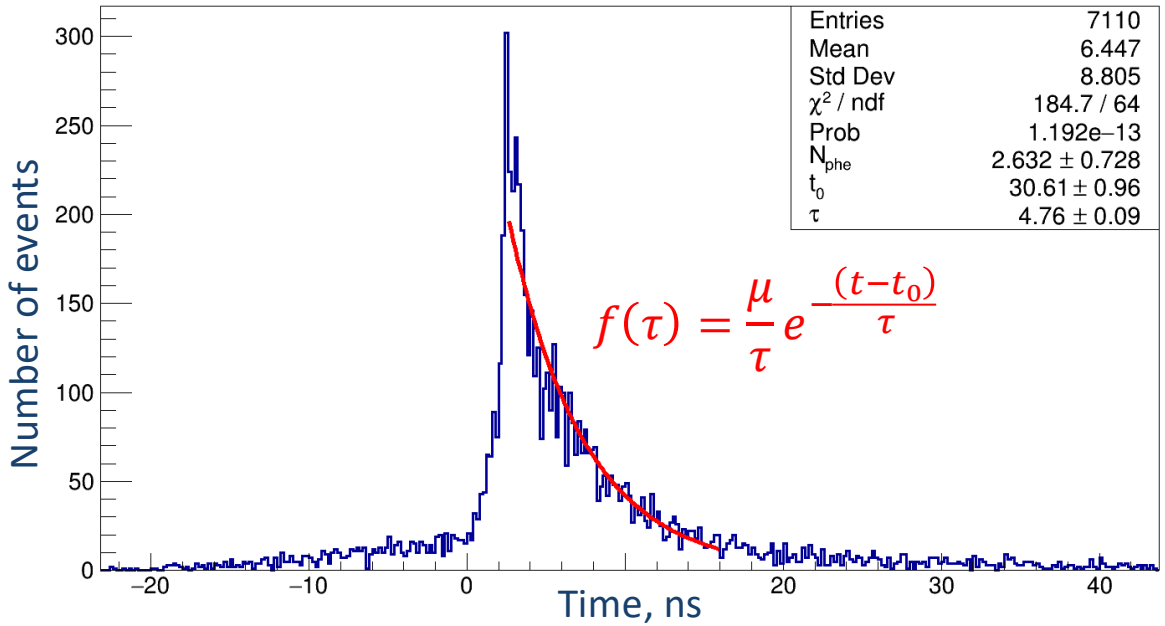
SiPM NDL signal oscillogram

- Estimation of time resolution:

$$\sigma \approx \frac{\tau_{BBQ}}{N_{phe}} = \frac{15\ ns}{3.21} = 4.67\ ns$$

Timing characteristics





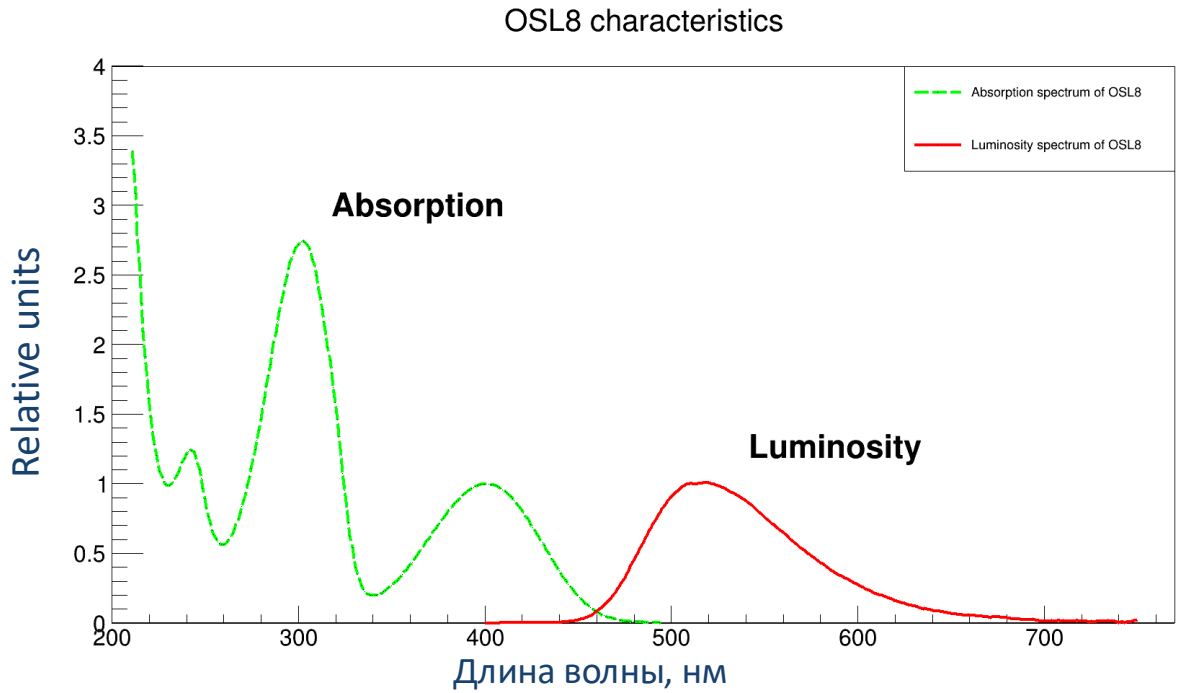
- Distribution of difference between photomultipliers firing time is fitted with the following formula:

$$f(\tau) = \frac{\mu}{\tau} e^{-\frac{(t-t_0)}{\tau}}$$

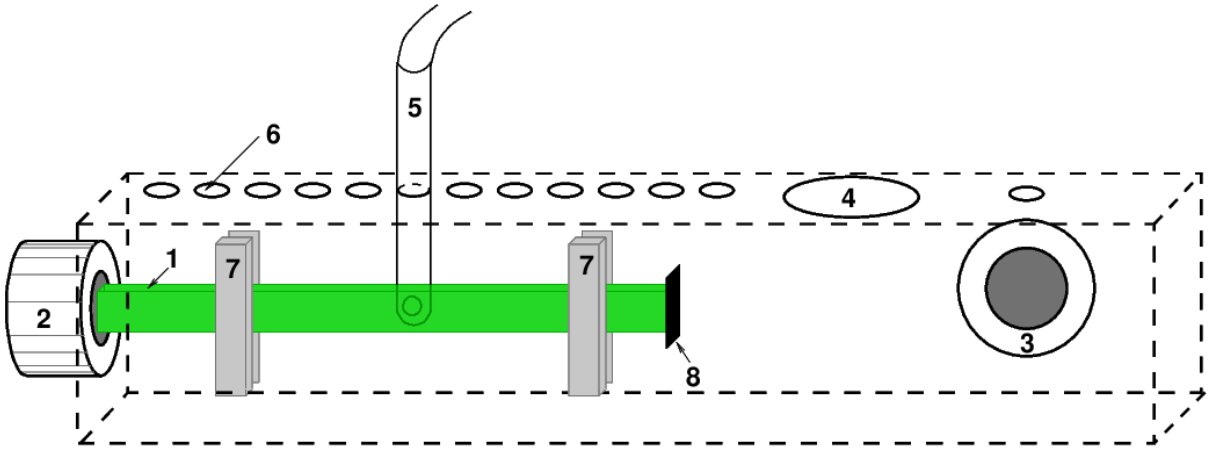
- Obtained from the fit values of parameters **μ**=2.632±0.728 and **τ**=(4.76±0.09) ns are in good agreement with estimations based on τ_{BBQ} = 15 n.

Wavelength shifter OSL-8

τ_{OSL-8}=5.4 ns < τ_{BBQ}=15 ns!!



Spectral characteristics of WLS OSL-8. Green line is an absorption srectrum and red line is a luminosity spectrum.



Scheme of WLS testing stand. Numbers: 1 – shifter; 2 – photomultiplier; 3 – calibration photomultiplier; 4 – place for photomultiplier for bend shifter measurements; 5 – periscope; 6 – holes for periscope; 7 – shifter holders; 8 – black paper or reflector.

Conclusion

- The ASHIPH counter prototype with a BBQ wavelength shifter has been developed and assembled;
- The data collected in prototype test at the "Extracted beam" installation on the VEPP4-M accelerator complex were processed:
  - Average number of photoelectrons per pulse was obtained for the NDL SiPM and the Hamamatsu fine-mesh PMT R2490-05;
  - Time characteristics of the ASHIPH counter prototype with a BBQ wavelength shifter and NDL SiPM were obtained;
- Fast luminophore (OSL-8) was chosen for future tests.

- Plans:
  - Produce and test wavelength shifter doped with OSL-8;
  - Assemble and test ASHIPH counter prototype with WLS doped with OSL-8.

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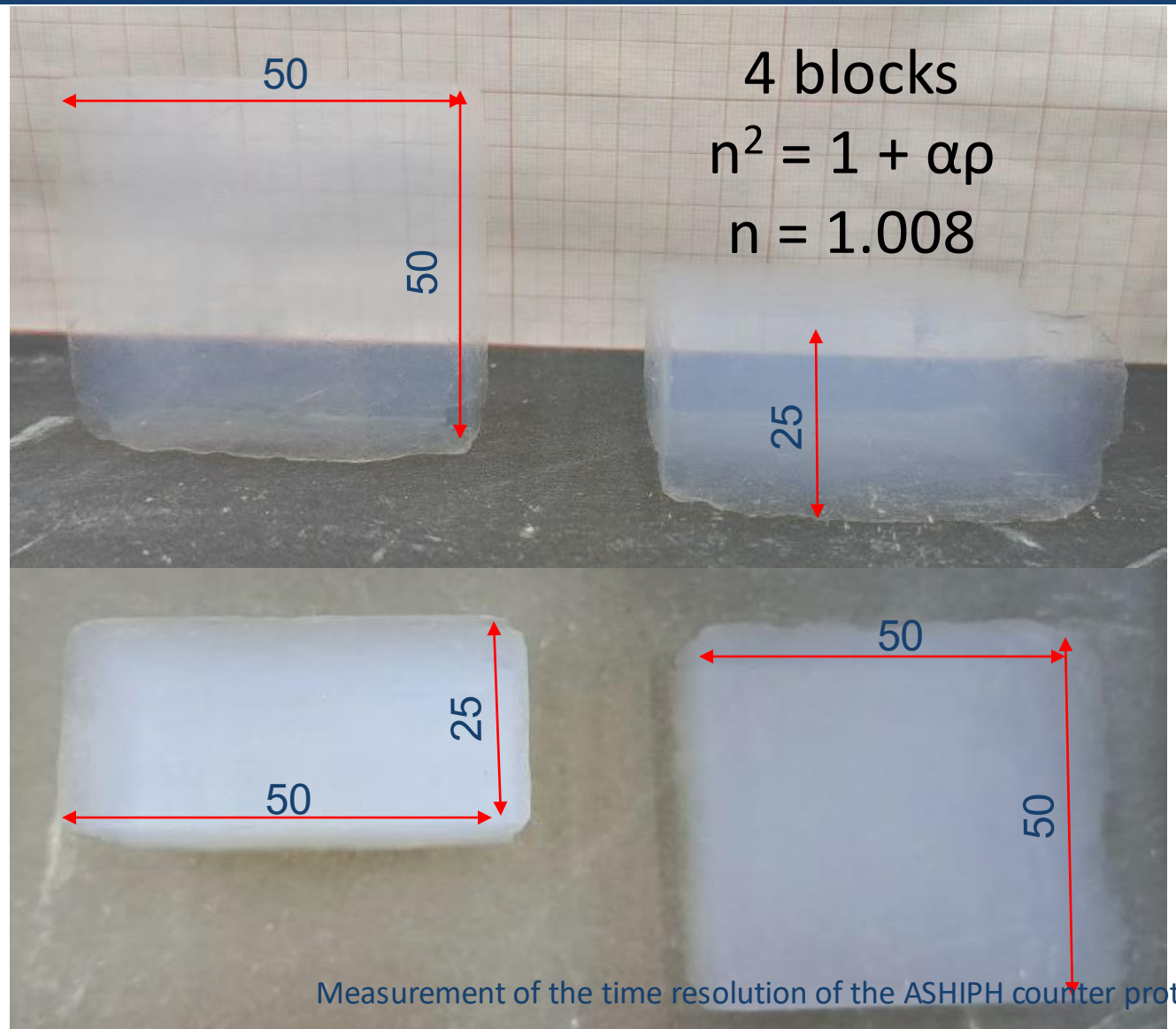
BACKUPS

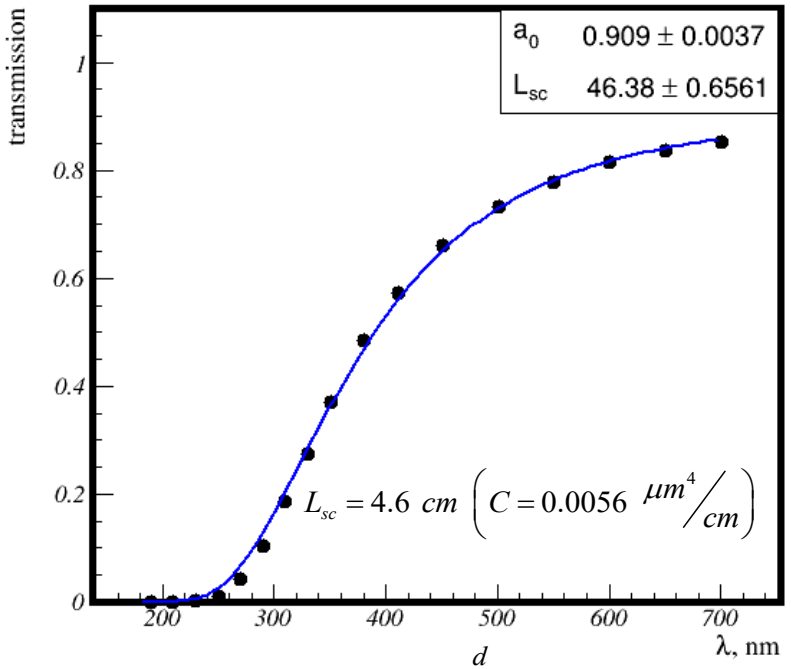
Aerogel



4 blocks

$n^2 = 1 + \alpha\rho$

n = 1.008

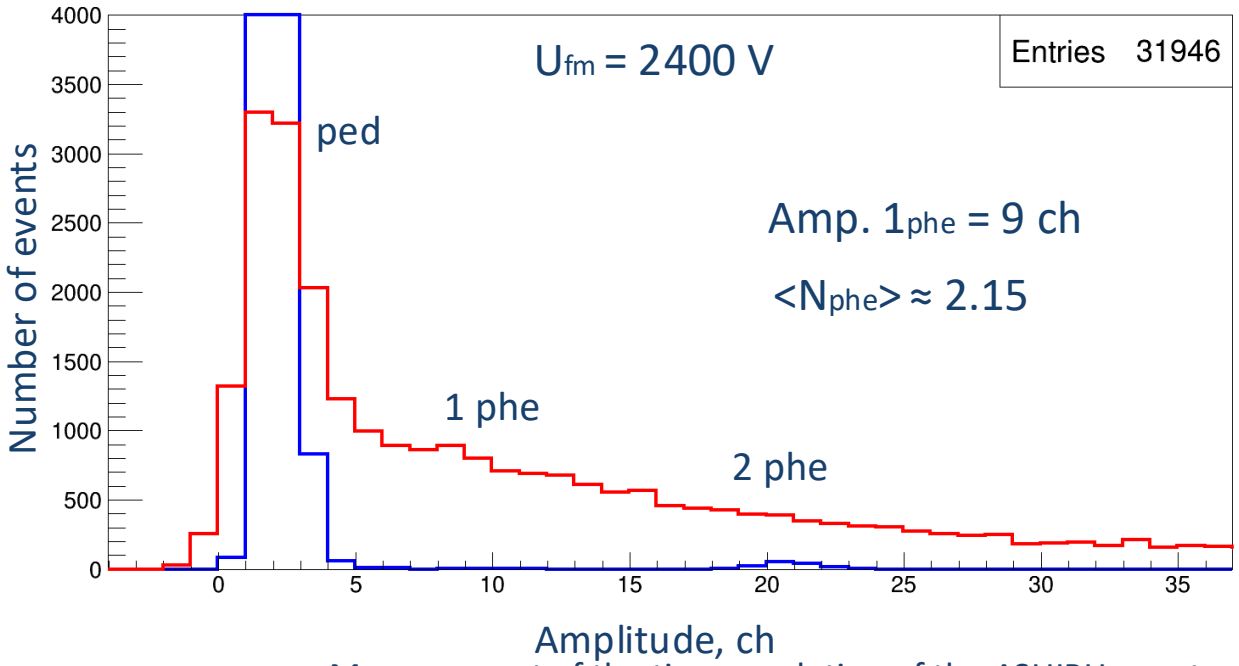


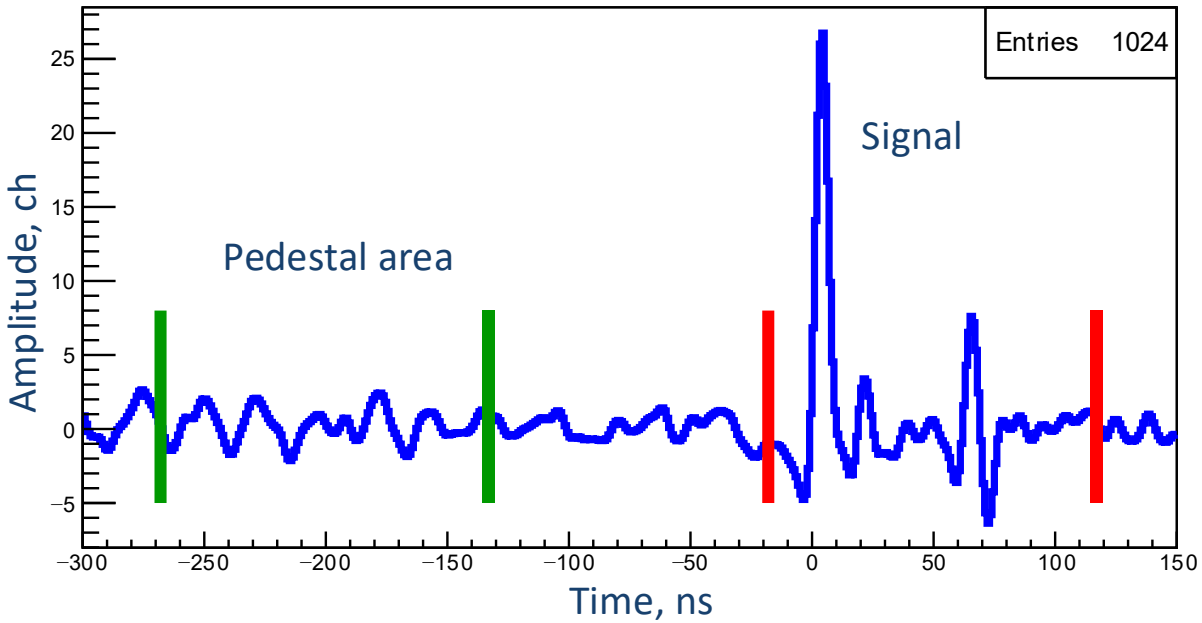
$$T = \frac{I}{I_0} = a_0 \cdot e^{-\frac{d}{L_{sc}\cdot\left(\lambda/400\right)^4}} = a_0 \cdot e^{-\frac{C\cdot d}{\lambda^4}}$$

- d – thickness of a sample
- λ – wavelength, nm
- L_{sc} – scattering length at 400 nm
- a_0 – surface scattering coefficient
- C – clarity coefficient

Fine-mesh PMT

- The operating point for fine-mesh PMT was chosen to be 2400 V
- Amplitude distribution were also constructed:
  a) The distribution in the signal area are shown in red;
  b) In the pedestal area – in blue.





Fine-mesh PMT signal oscillogram