National Research Nuclear University MEPhI
(Moscow Engineering Physics Institute)

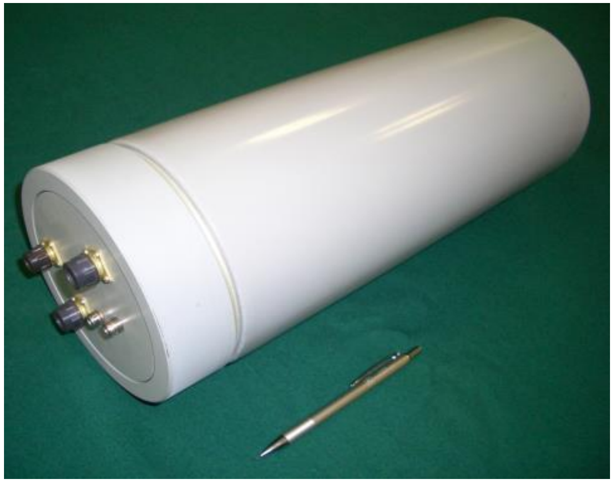
Xenon gamma-ray detector with electronic compensation of the anode pulse shape dependence on the ionization coordinate

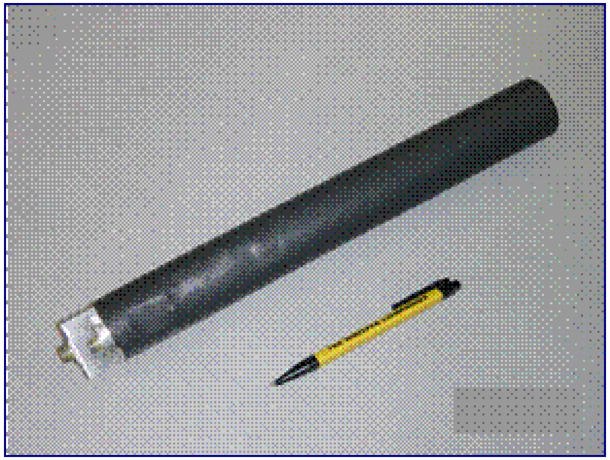
Grachev V.M.*, Chernysheva I.V., Dmitrenko V.V., Novikov A.S., Petrenko D.V., Shustov A.E., Vlasik K.F., Ulin S.E. and Uteshev Z.M.
*e-mail: VMGrachev@mephi.ru

The 3rd International Conference on Science, Application, and Technology of Xenon Radiation Detectors (XeSAT)
April 3rd - 7th, 2017

Xenon gamma-ray detector with high energy resolution

Current modification of Xenon Gamma-ray Spectrometer (HPXe) has energy resolution 1.7 ± 0.1 % at 662 keV. It is one of the highest values for detectors based on ionization chambers. However, the theoretical limit of energy resolution at 662 keV equals ~0.5%. Nevertheless, there are fields of application where high energy is not required. This report describes a new concept for a Xenon Gamma-ray Spectrometer for such fields of applications.





Xenon gamma-ray detector
Main features and components

Radiation Laboratory of Experimental Nuclear Physics and Cosmophysics Department of NRNU MEPhI is developing and producing a Xenon Gamma-ray Spectrometer (HPXe) based on an ionization chamber filled with high pressure xenon. Key features of the detector:

- Thin wall ionization chamber to decrease low energy threshold;
- Signal processing by FPGA (Field-Programmable Gate Array) electronics to remove microphone effect [1];
- Frisch grid – third electrode to remove pulse shape dependency on ionization position.

Frisch grid makes construction of the detector complex. It requires high precision steel mesh and increases cost of detectors.

[1]*“New modification of xenon gamma-ray detector with high energy resolution”,* Novikov A.S., Grachev V.M. at el., *Opt. Eng., Vol. 53, 2014, Art. num. 021108*

“Induced effect” of ionization chamber

Main disadvantages of the simplest two electrode ionization chamber is the “induced effect” – pulse shape dependency on the ionization coordinate (fig. 1). A common way to remove this effect is a Frisch grid. It is a third electrode between the cathode and the anode. Its function is electromagnetic shielding the anode from an electron cloud inducing signal while drifting between the cathode and the grid.

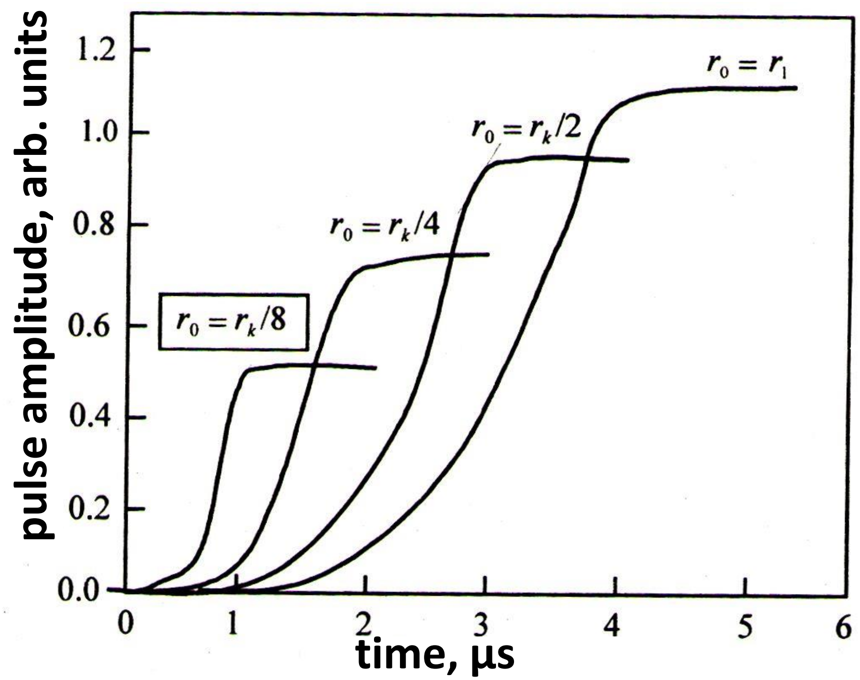


fig. 1

Time and amplitude data acquisition

Time-amplitude dependence of electrical pulses shown on fig 2, 3 has distribution that can be corrected to remove “induced effect”, which will improve energy resolution from 5-6% up to 3-4% at 662 keV for a two-electrode chamber.

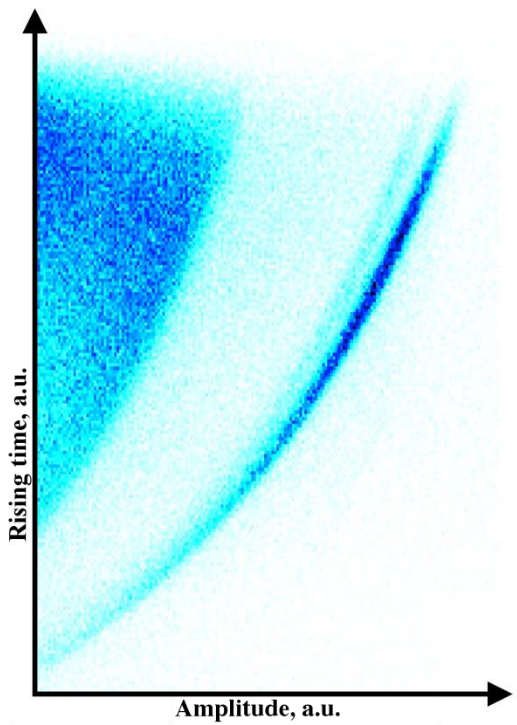


fig. 2

Lacy J.L. et al., IEEE Nucl. Sci. Symp. Conf. Rec., Vol. 1, 2004, pp. 16-20

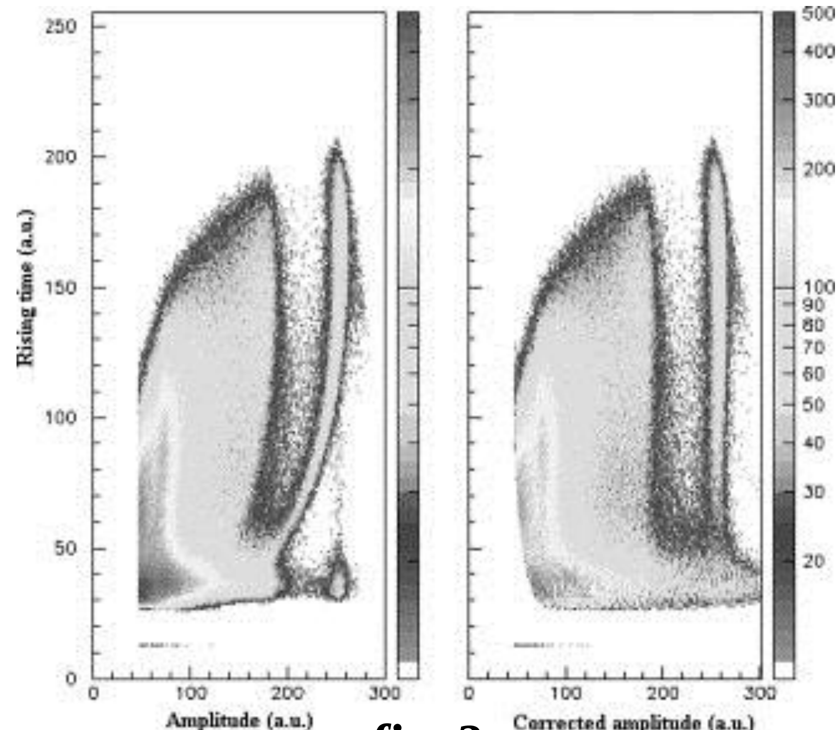
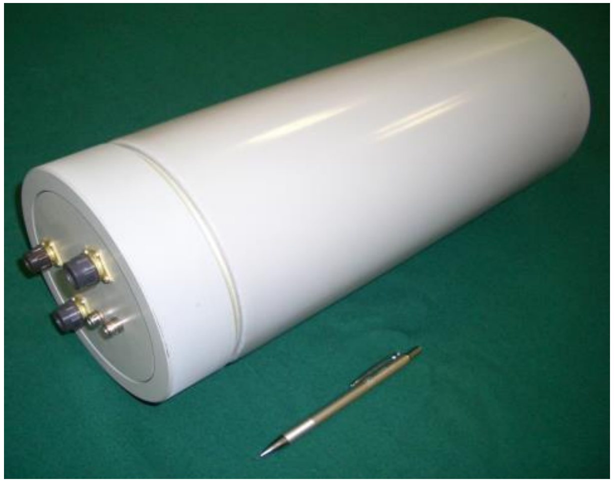


fig. 3

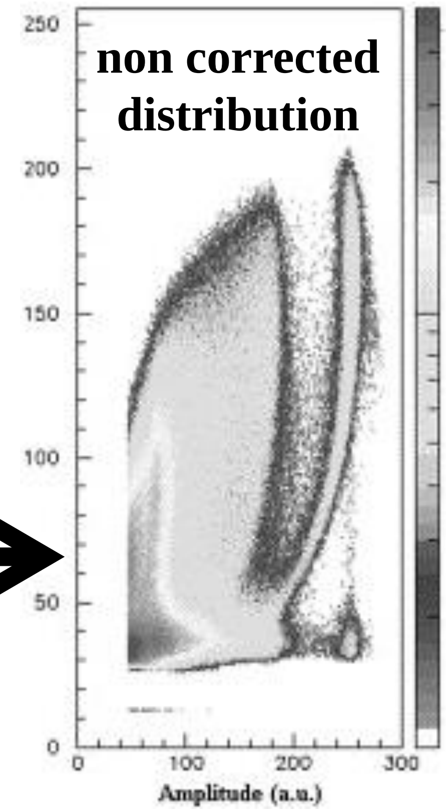
Ottini-Hustache S., Grachev V.M. et al., Nucl. Instr. Meth. Phys. Res. B, Vol. 213, p.279

Old method of correction for Xenon gamma-ray detector



In the previous experiments to correct an energy spectrum of a two electrode xenon gamma-detector a NIM crate with measuring modules for data acquisition and PC for offline processing and correction were used.

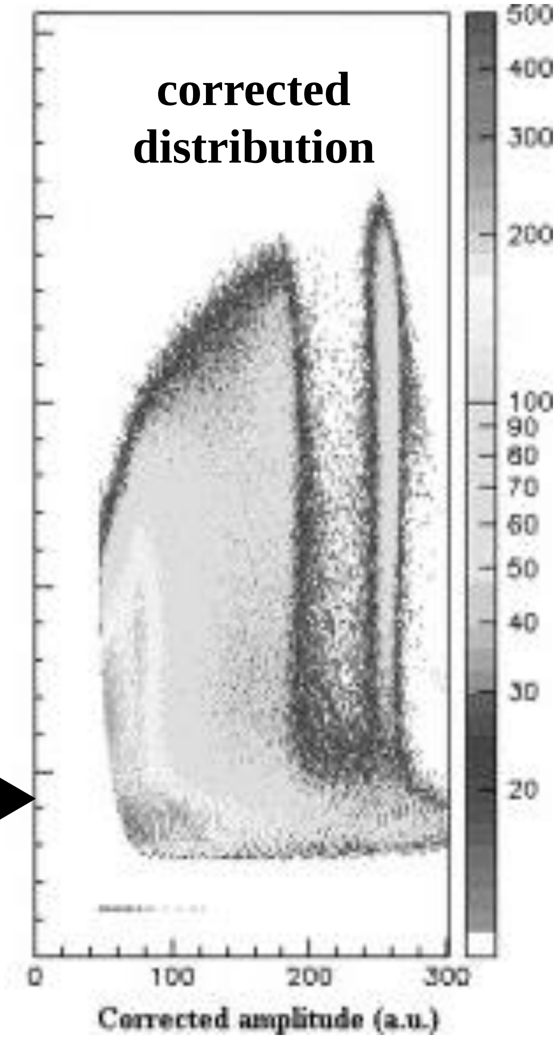
NIM module called BIPAR for amplitude and front rising time measurement



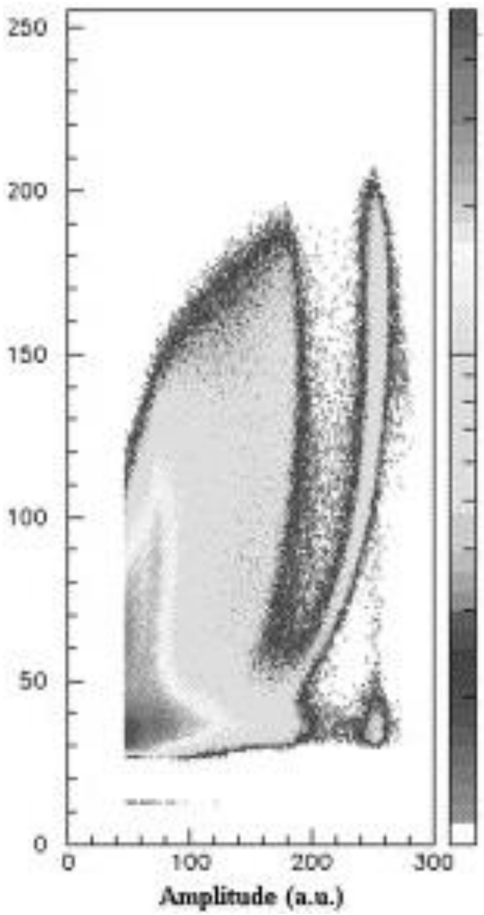
Old method of correction for Xenon gamma-ray detector

Personal Computer with special software for analysis of time-amplitude distribution and correction of energy spectra. It is an offline method and a slow way of improving spectra.

PC and software for correction of obtained data and spectrum improvement



New method based on FPGA electronics

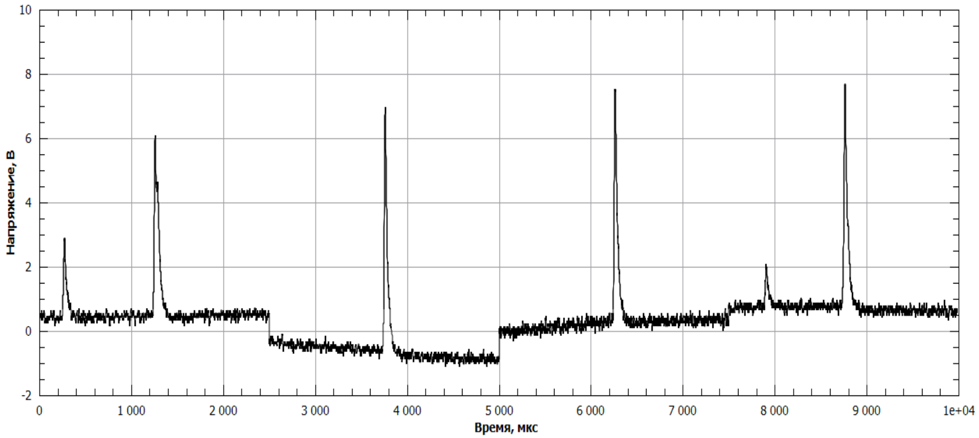


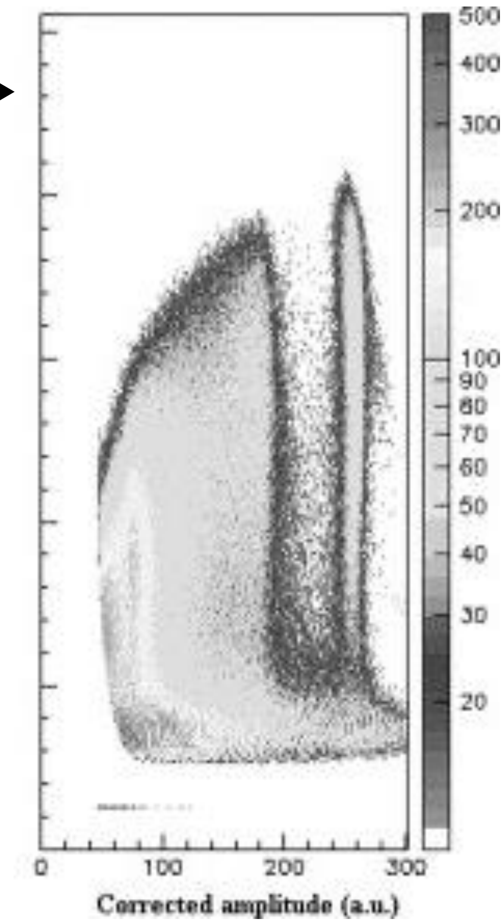
FPGA electronics

Digitizing electrical signal from HPXe

New method based on FPGA electronics

Online algorithm for correction





Signal processing

Conclusion

Signal processing method is proposed for compensation of the anode pulse shape dependence on the ionization coordinate for a xenon gamma-ray detector based on ionization chamber. Signal processing will be implemented by FPGA electronics due to fast and parallel calculation algorithm. The method can simplify mass production of the ionization chamber, provide reasonable energy resolution and remove microphone effect.

Thank you for attention

Questions