Energy resolution of LaBr3:Ce, CeBr3 and Ce:GAGG crystal scintillators in combination with different type photomultipliers, as well as with Si-photodiodes, to be used for detection of cosmic gamma-rays.

D.V. Skobeltsyn Institute of Nuclear Physics,
M.V. Lomonosov Moscow State University

Moscow , 2016

Scientific aims

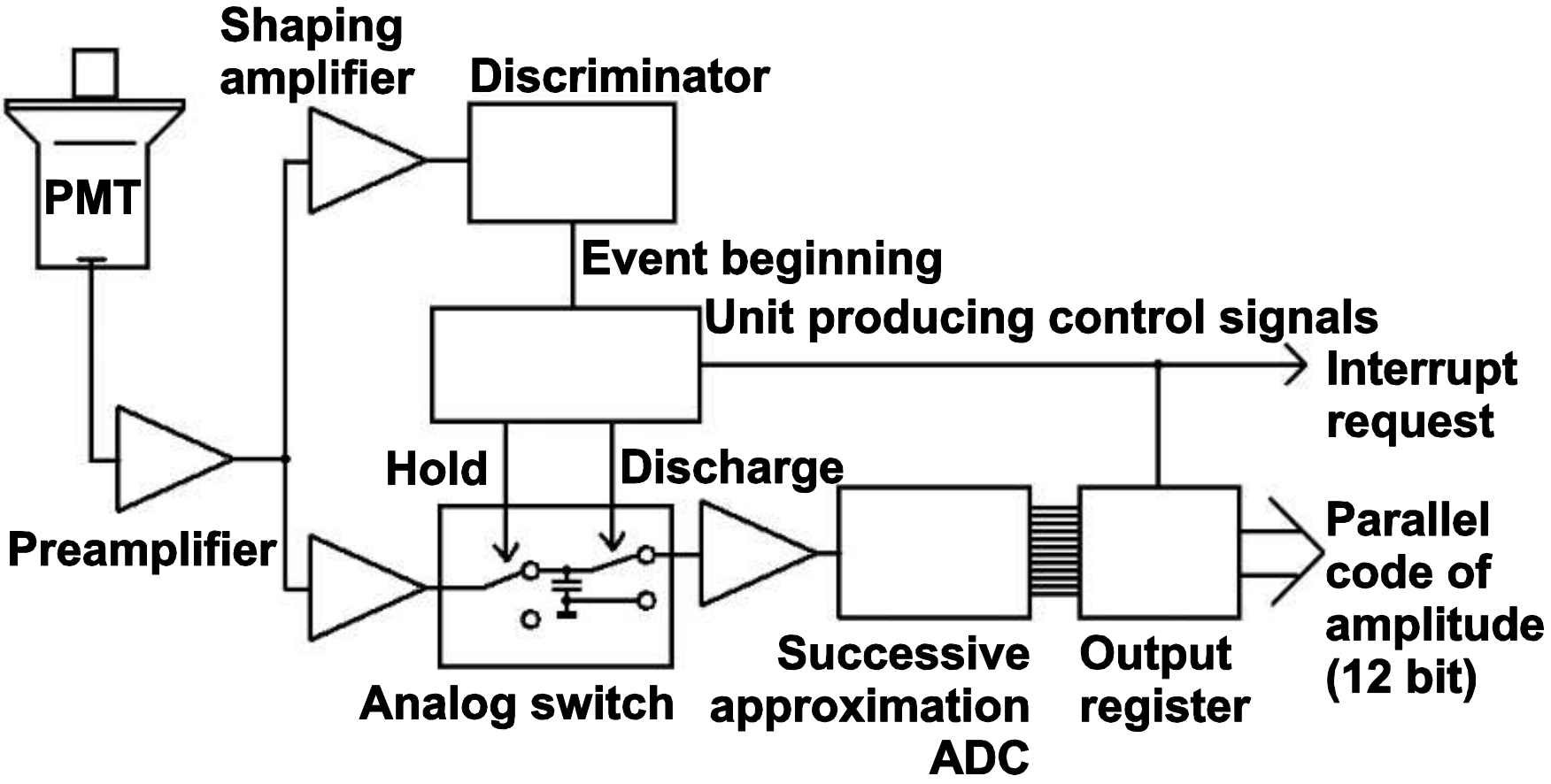
We have studied and report here on the performance of different detectors of cosmic gamma-rays, that are using modern type scintillating crystals like LYSO, YSO, LaBr3:Ce, CeBr3 and Ce:GAGG.

The detector itself is based on the use of scintillating crystal and of different type photosensor which were exposed to the conventional set of radiuoactive isotopes.

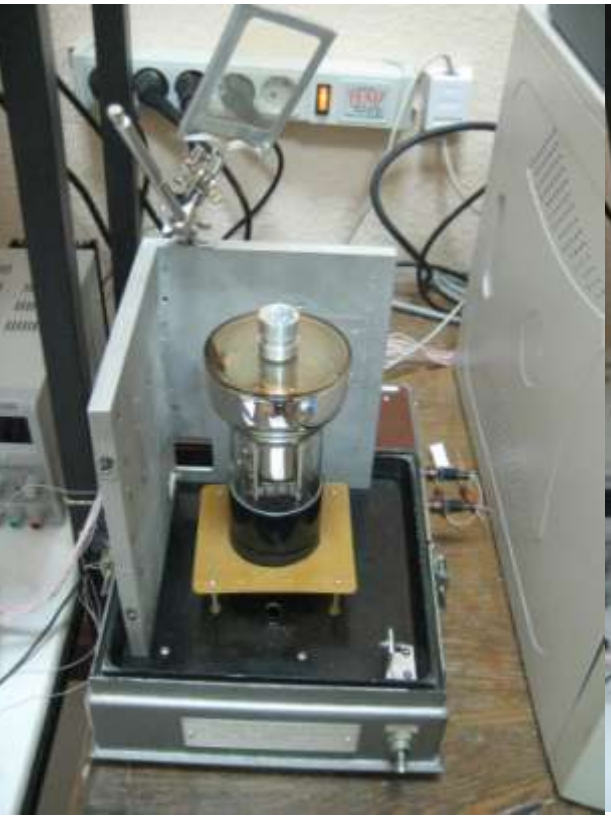
Energy resolution of gamma-ray detectors as derived for different combinations of scintillating crystals and photosensors, and of detector potential use will be discussed in this talk.

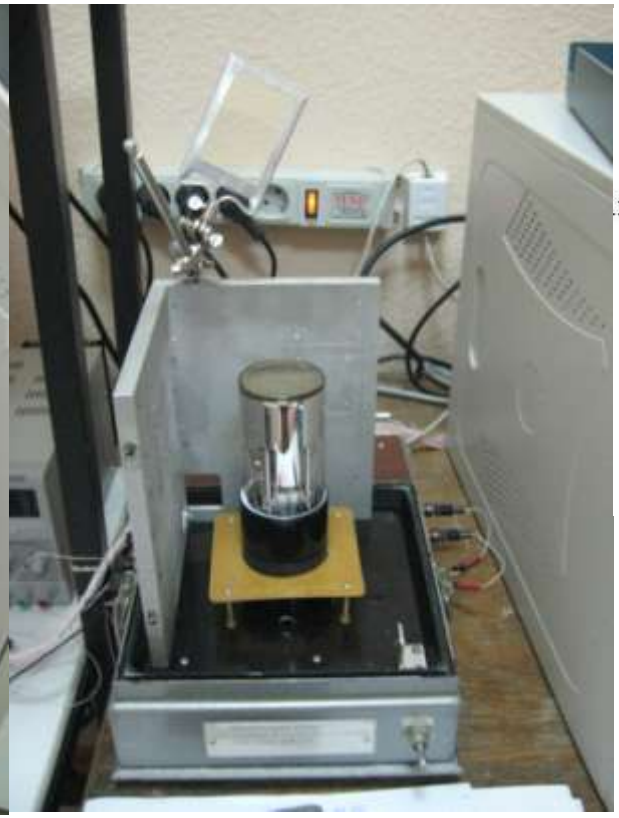
Light output of different scintillator crystals was studied. It was obtained that light output of LaBr3(Ce) и CeBr3 crystals is practically equal, it is maximal for thin scintillators irradiated by high energy gamma quanta (E > 2MeV).

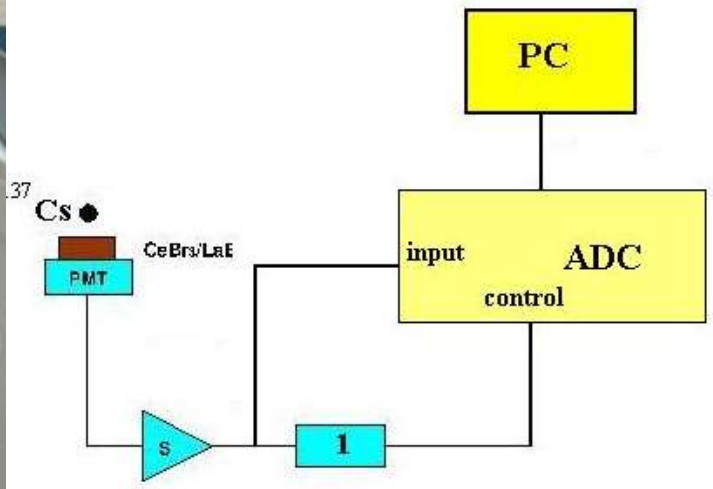
The general view of experimental facility for scintillator parameters study.



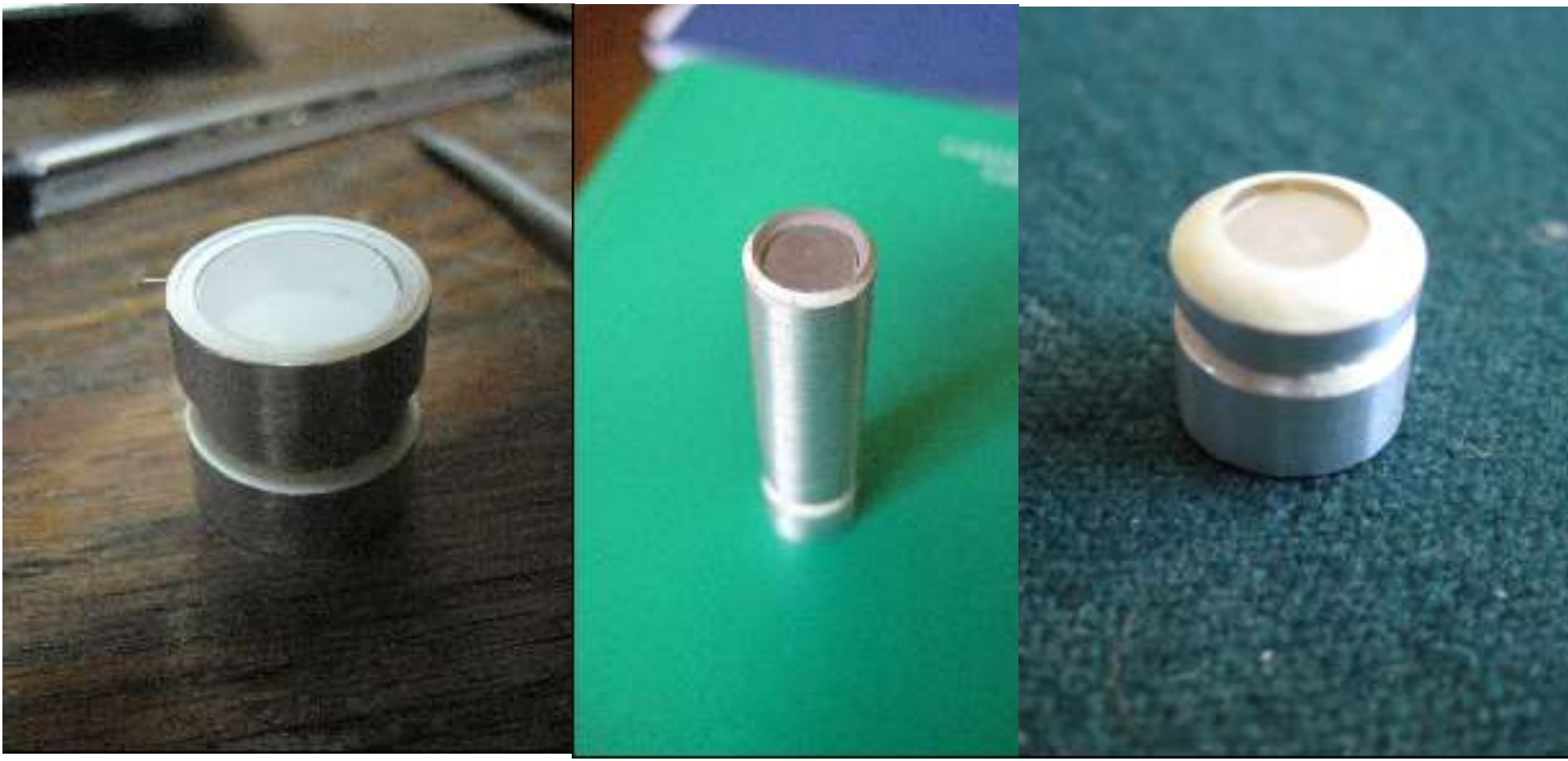
The wire diagram of energy resolution unit





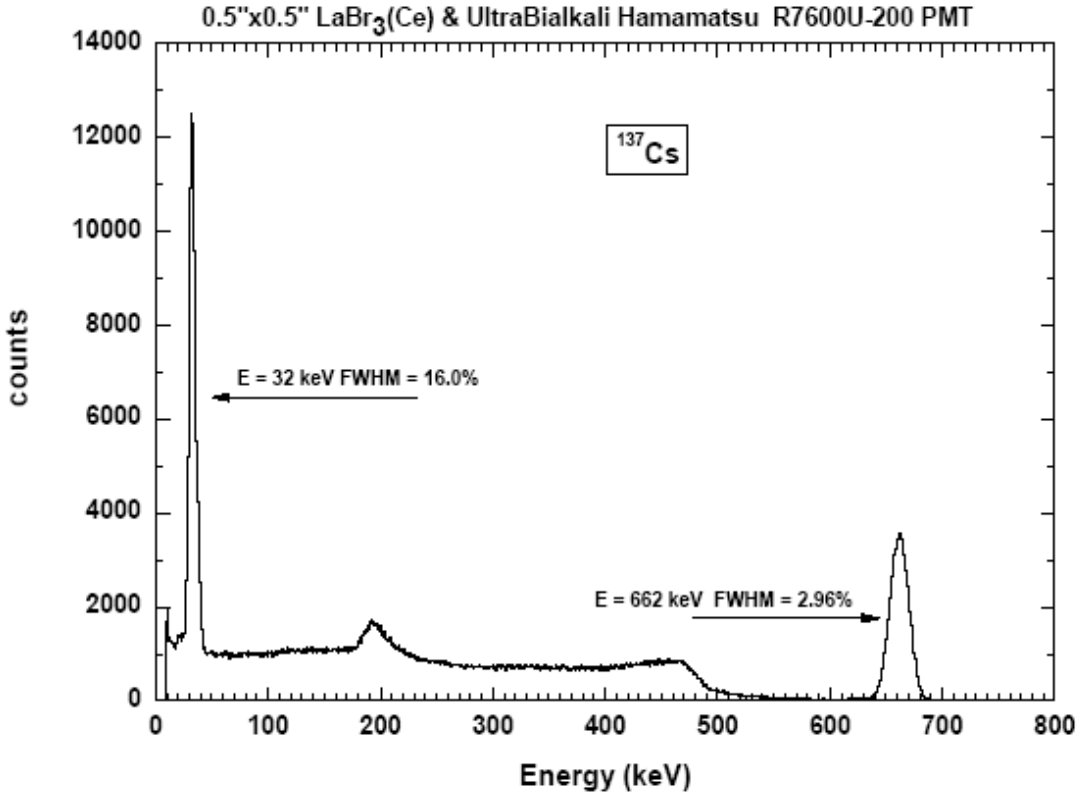


Energy resolution unit with the use of ^{137}Cs source and PMT. S means the shaper, PC is computer, for spectrum output and processing, 1 is Shmitt trigger, ADC is analogous digital converter.



$LaBr_3$:Ce scintillator crystals: left ∅15×18 mm, center ∅5×30 mm, right Ce Br_3 crystal ∅5×5 mm

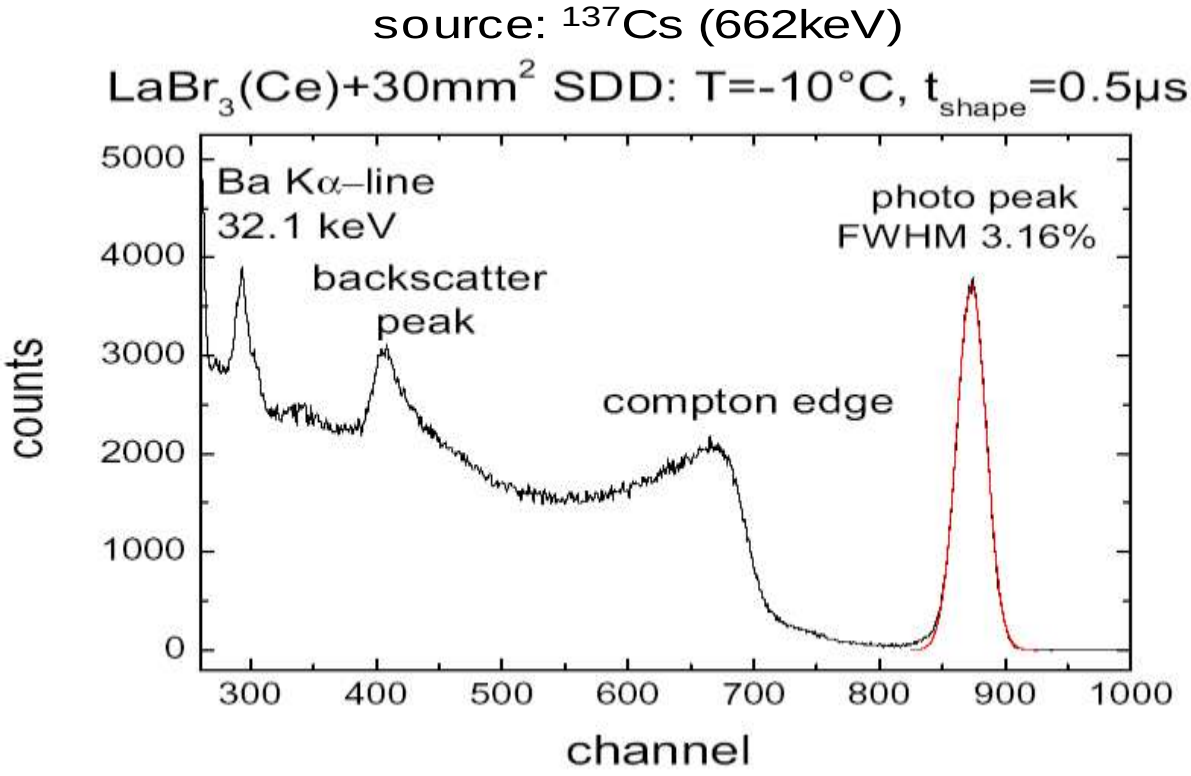
Energy	Isotope		Energy	Isotope
26.34	Am241		511	Na22
30.9	Ba133		569.7	Bi207
32	Cs137		661.65	Cs137
40	Eu152		778.9	Eu152
59.54	Am241		867.38	Eu152
75	Bi207		964.1	Eu152
81	Ba133		1063.66	Bi207
101	Am241		1173.2	Co60
121.78	Eu152		1274.5	Na22
244.7	Eu152		1332.5	Co60
344.28	Eu152		1408	Eu152
356	Ba133		1770	Bi207



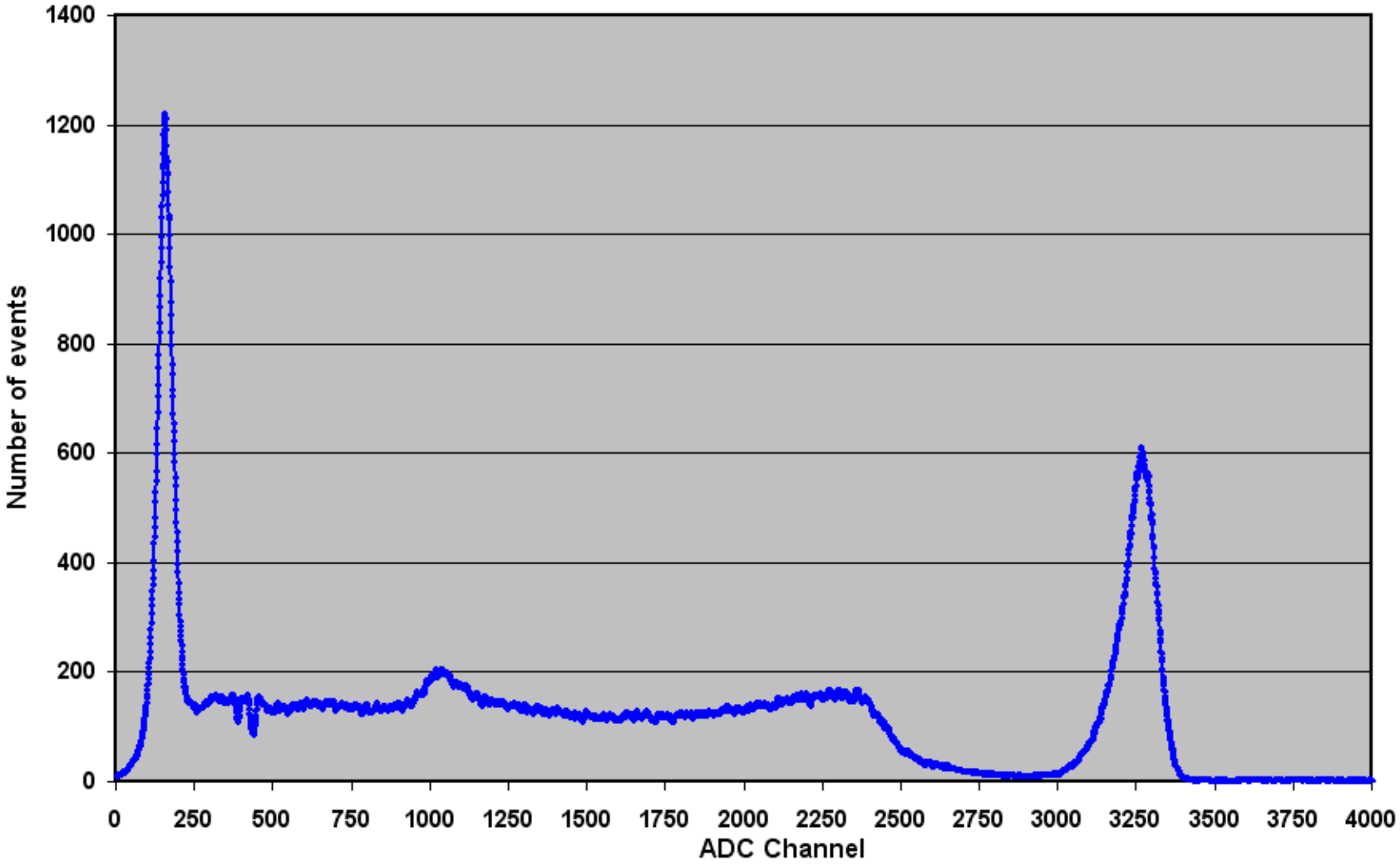
Energy spectrum of $LaBr_3$:Ce (1.5 % Ce) scintillator pulses irradiated by 662 keV gamma-quanta from ^{137}Cs radioactive source. HAMAMATSU R7600U-200 PMT with UltraBialkali photo-cathode and optical window transparent for UV photons , was used as photo sensor. Energy resolution for 662 keV line was obtained as 2.96% (FWHM). The pulse shape time was equal 0.3 mcs.

measurements with $LaBr_3(Ce)$

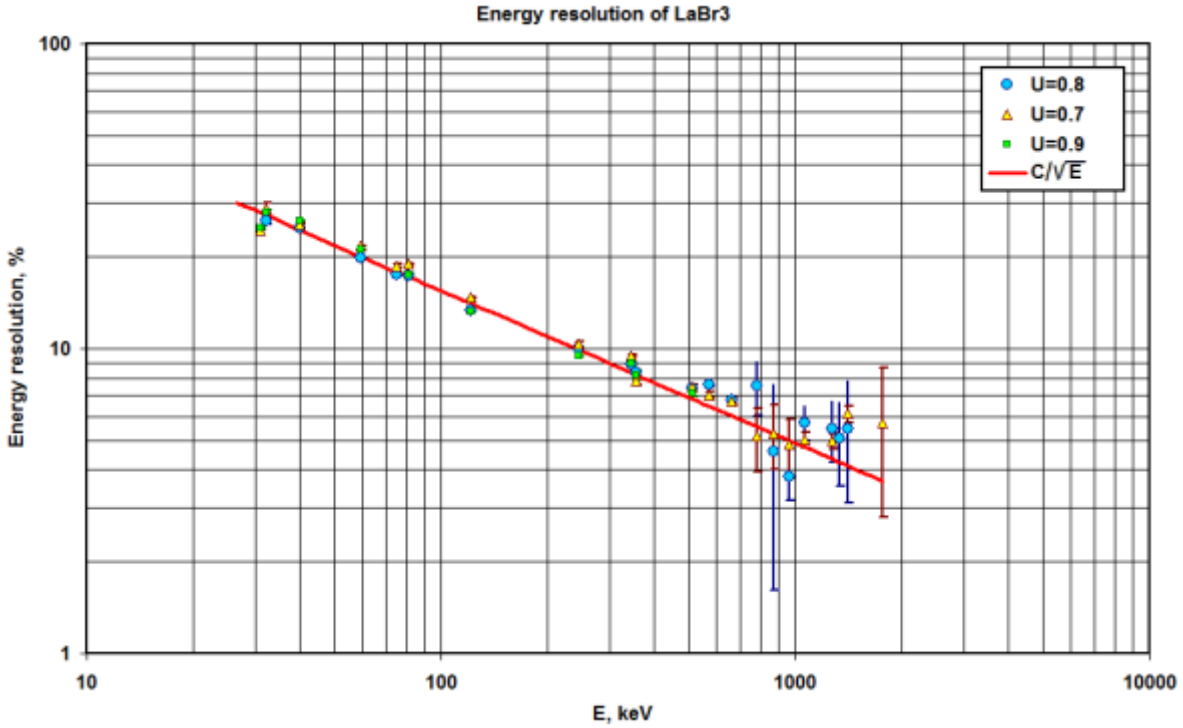
$LaBr_3(Ce)$ (5x10 mm) wrapped in teflon tape and packed in a hermetically sealed aluminium housing with a 3mm thick sapphire window

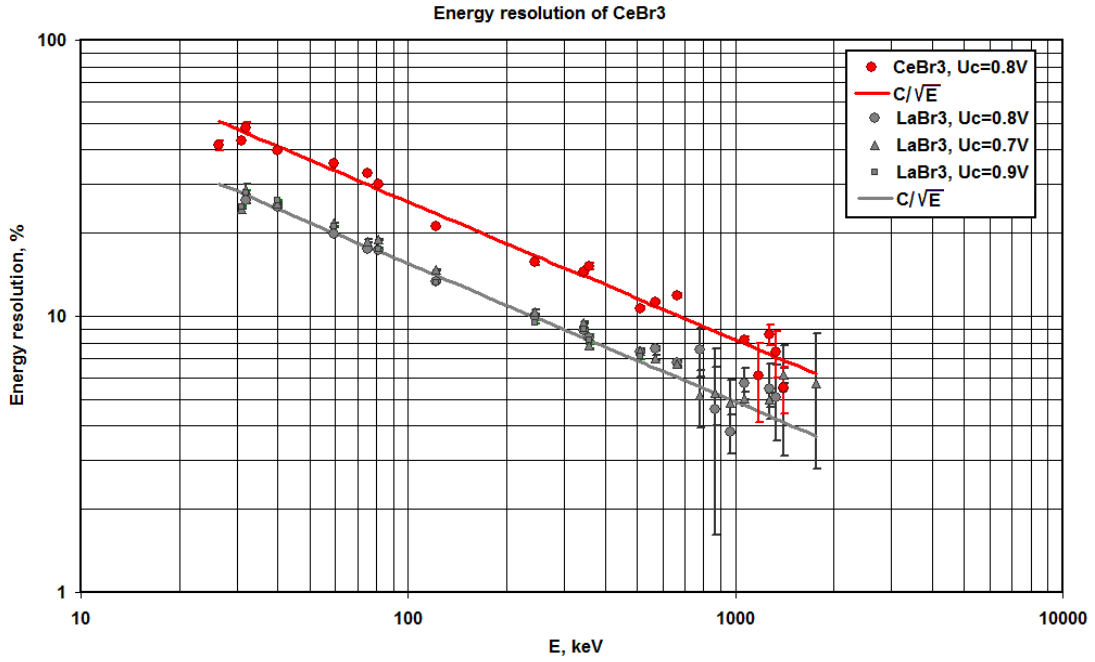


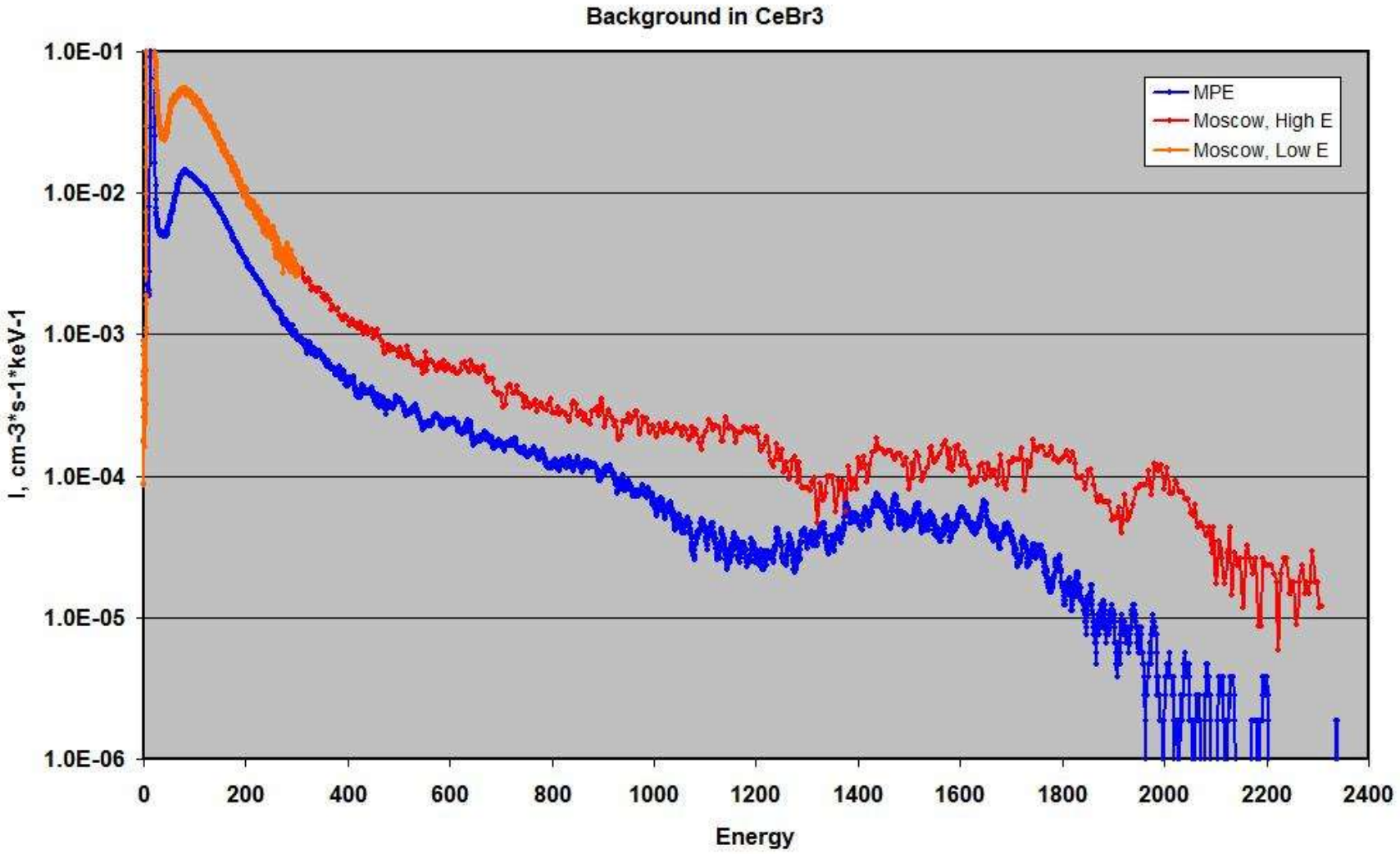
Energy spectrum of ∅5×10 mm $LaBr_3$:Ce scintillator output pulses from ^{137}Cs source (82 keV line). The drift photodiode of Max Planck Semiconductor laboratoryc was used as photo-sensor. The drift diode diameter was 3 mm with changed composition and thickness of protection layer. Energy resolution for 662 keV line (ADC channel 880) was equal 3.16 % (FWHM). The energy threshold was choose as 25 keV. Temperature of crystal and drift diode was -10° C, integration time was 500 ns.



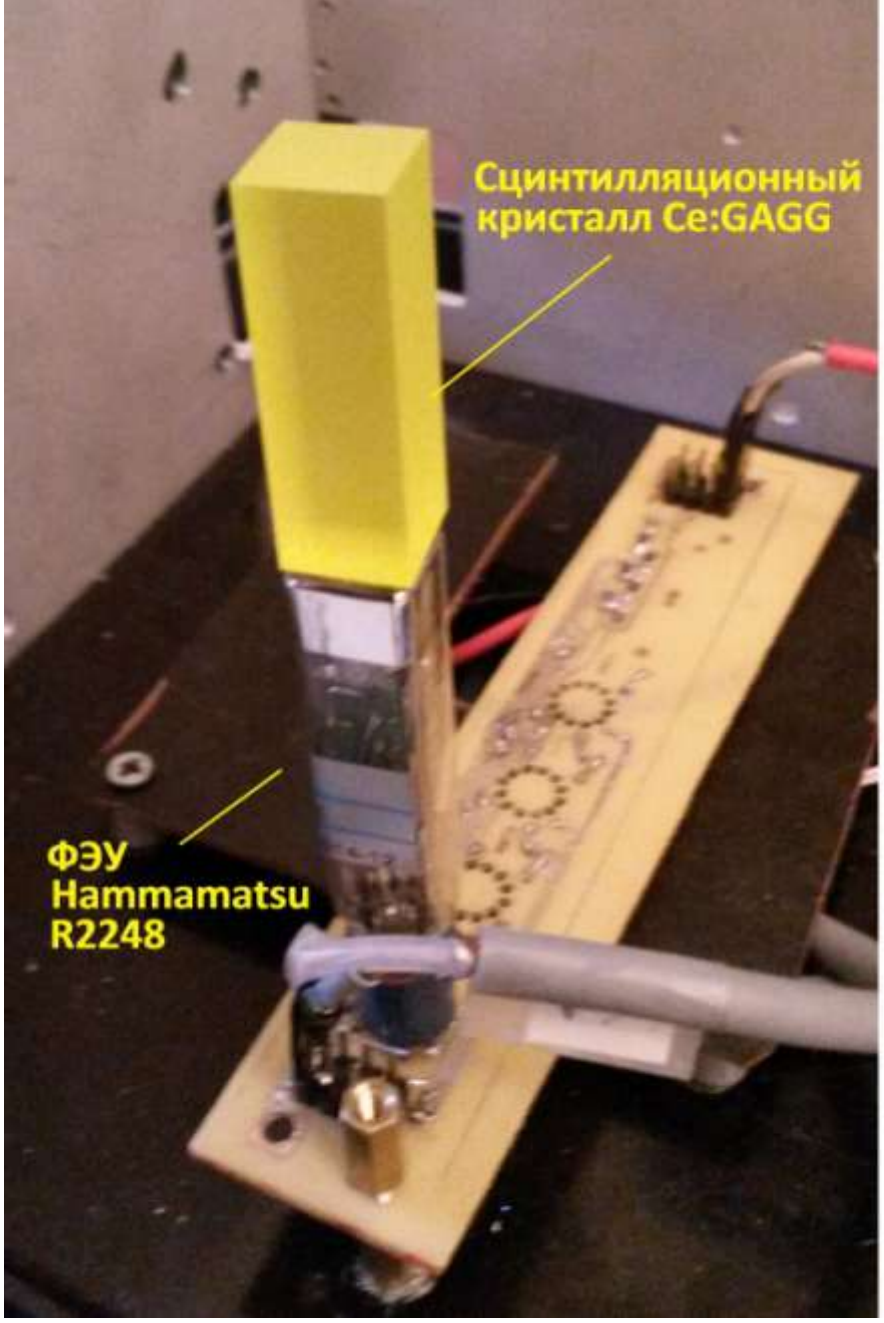
Energy spectrum of ∅15×18 mm $LaBr_3$:Ce crystal outputs from ^{137}Cs source (line 662 keV). PMT Uspekh was used as photo-sensor with optic window covered UV band. Energy resolution at 662 keV (ADC channel 3250) was 3.2 % (FWHM).


Energy resolution of LaBr3
100
10
1
Energy resolution, %
10
100
1000
10000
E, keV
U=0.8
U=0.7
U=0.9
C/√E

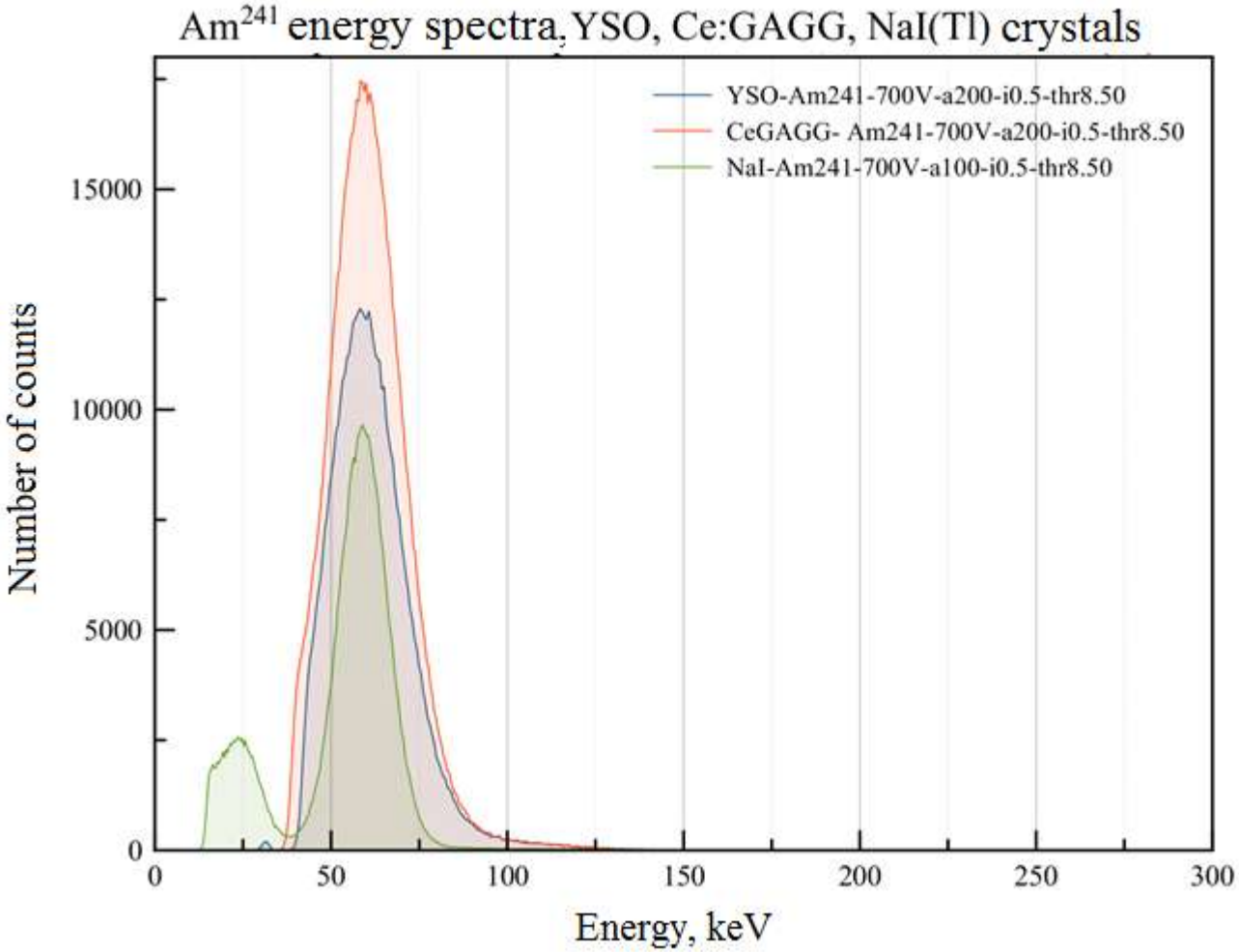

Energy resolution of CeBr3
100
10
1
Energy resolution, %
10
100
1000
10000
E, keV
CeBr3, Uc=0.8V
C/√E
LaBr3, Uc=0.8V
LaBr3, Uc=0.7V
LaBr3, Uc=0.9V
C/√E

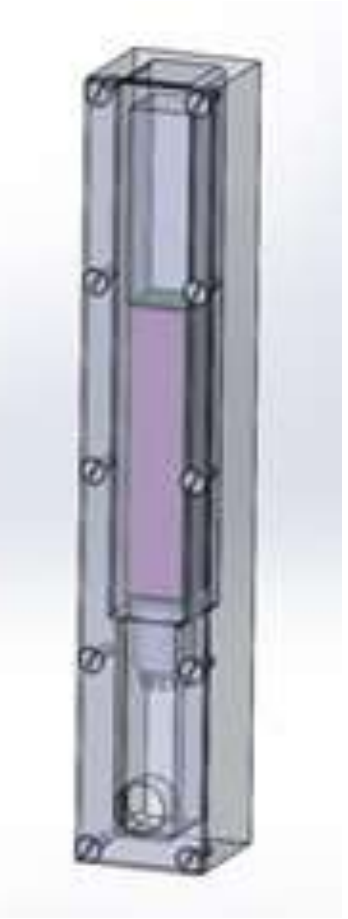

Background in CeBr3
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
I, cm-3*s-1*keV-1
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Energy
MPE
Moscow, High E
Moscow, Low E


Сцинтилляционный
кристалл YSO
Фотоэлектронный
умножитель R2248


Сцинтилляционный
кристалл Ce:GAGG
ФЭУ
Hammamatsu
R2248

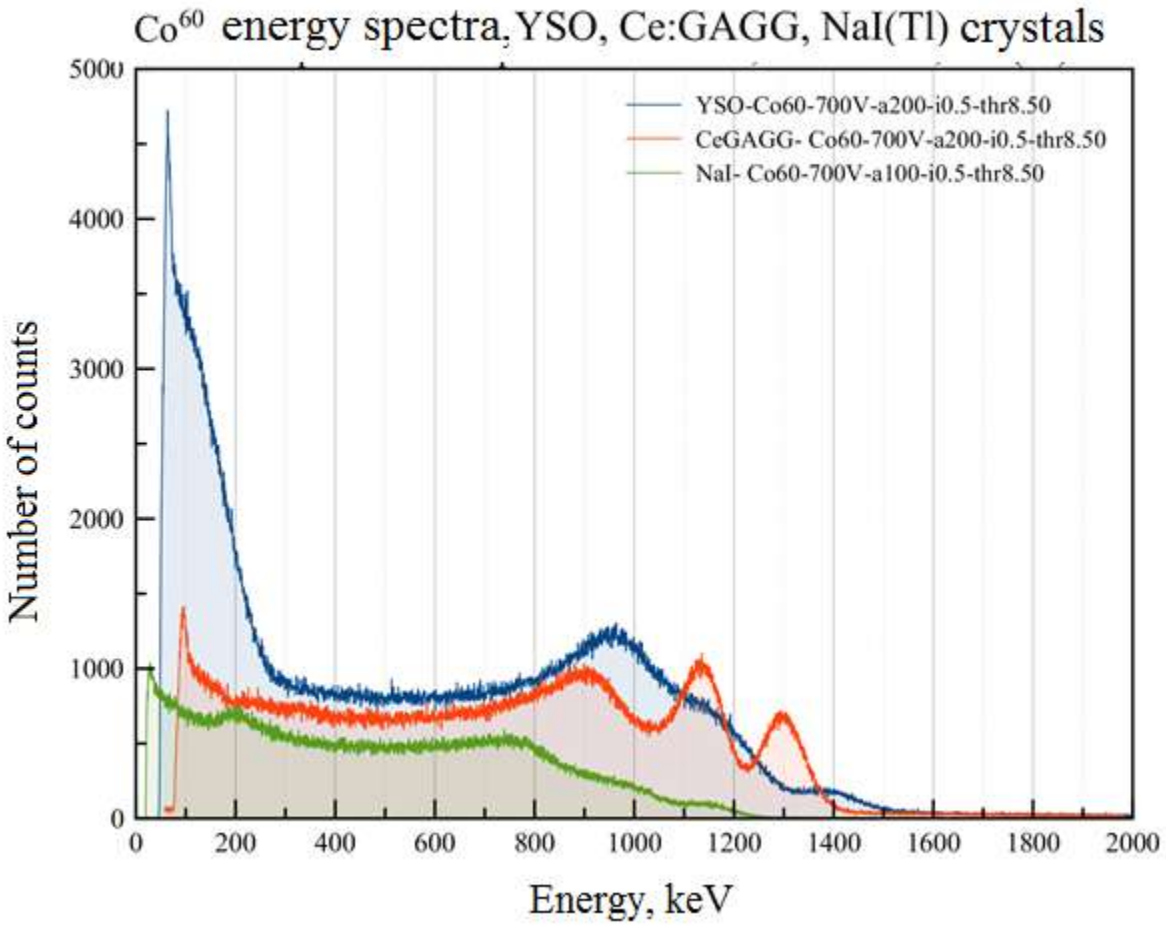
Comparison of spectra obtained with the different scintillator crystals viewed by PMT R2248.





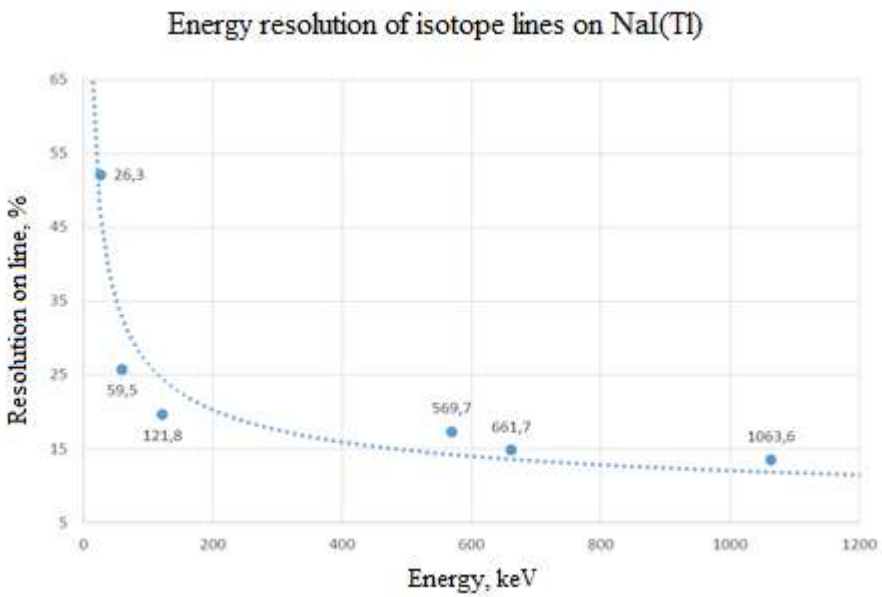
Energy spectra from Am-241 source measured by PMT R2248 with different scintillator crystals.

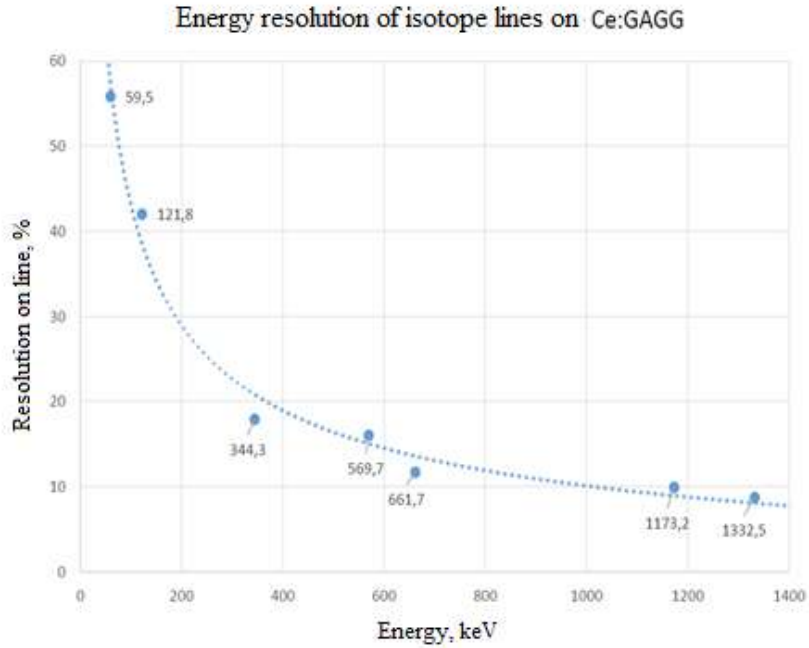
Comparison of spectra obtained with the different scintillator crystals viewed by PMT R2248.



Energy spectra from Bi-207 source measured by PMT R2248 with different scintillator crystals.

Comparison of spectra obtained with the different scintillator crystals viewed by PMT R2248.



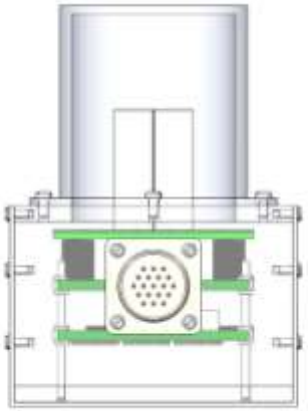


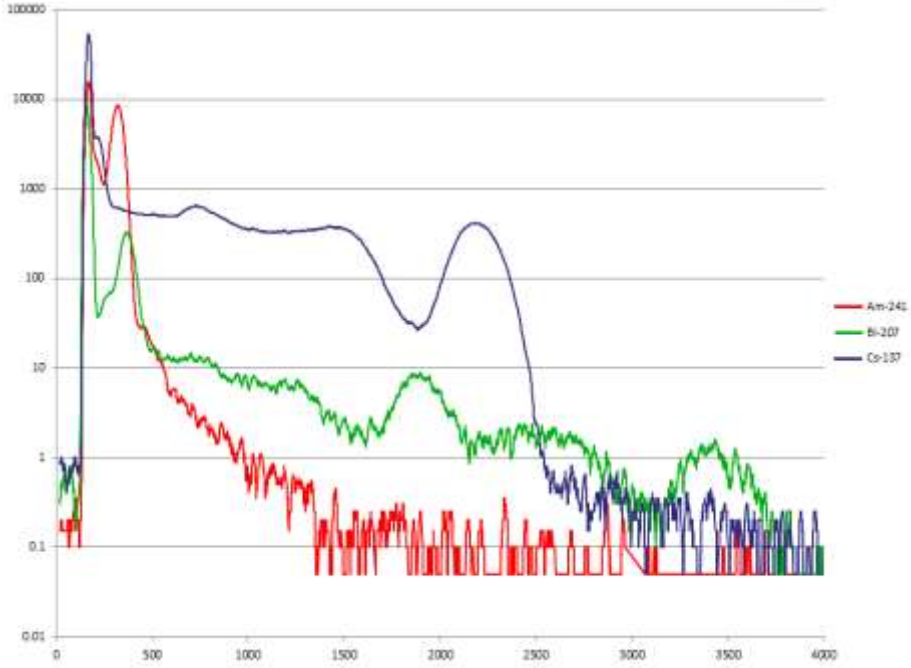
Energy resolution of NaI(Tl) scintillator detector viewed by PMT R2248

Energy resolution of Ce:GAGG scintillator detector viewed by PMT R2248

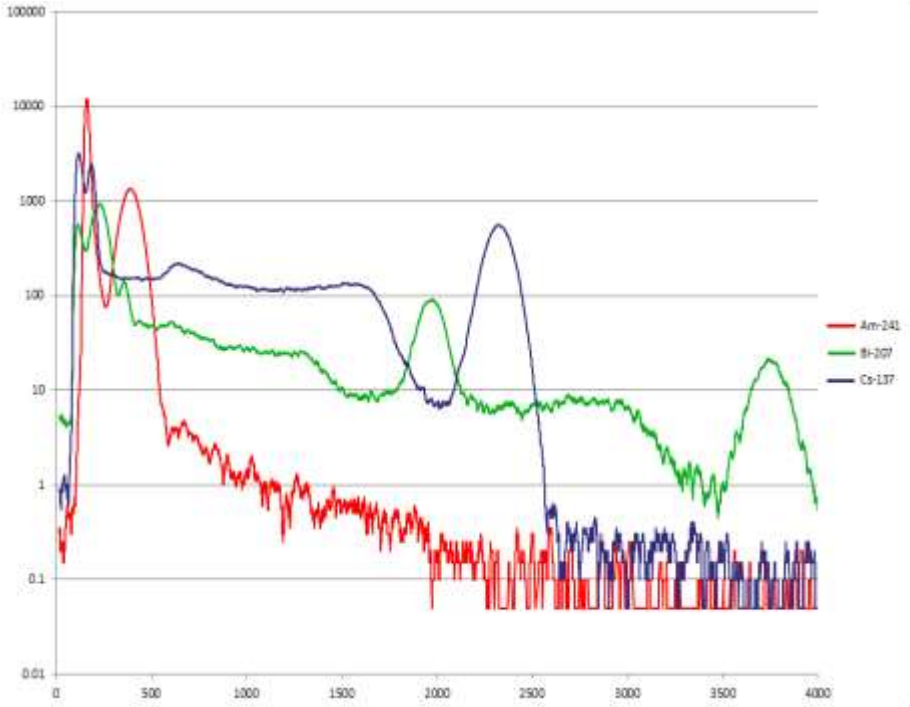

Усилитель-формирователь
Гибридный ЗЧУ
Сцинтилля-
ционный
кристалл
Лавинный фотодиод
S8664-1010

Measurements with avalanche photo-diode.



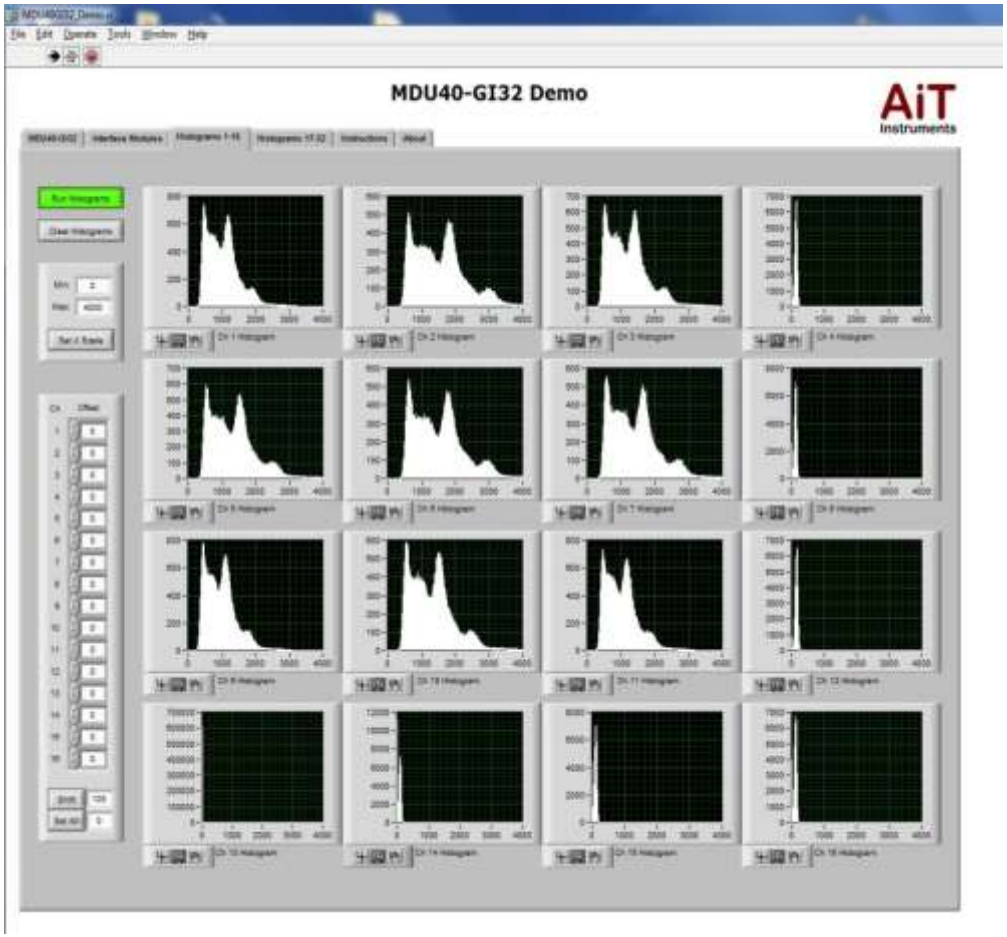


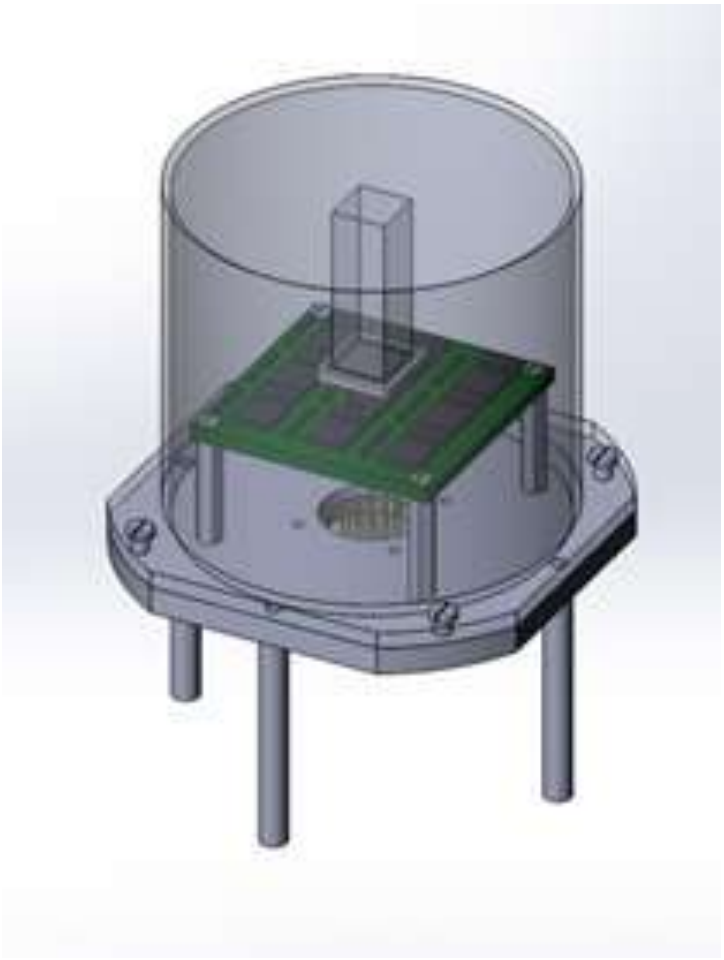
Energy spectra of different gamma ray sources measured by APD photo sensor and *∅10×10 mm* NaI(Tl) crystal at APD bias voltage 370V



Energy spectra of different gamma ray sources measured by APD photo sensor and 10x10x30 mm Ce:GAGG crystal at APD bias voltage 370V

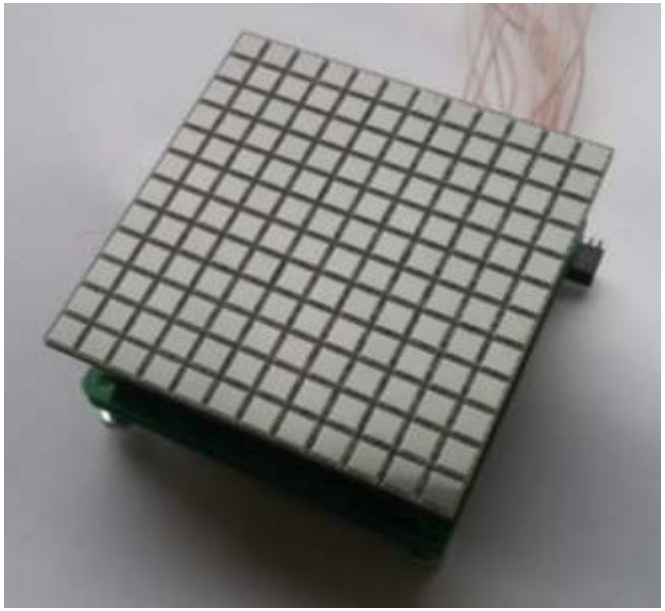
Measurements with units based on 3x3 mm SiPM assemblies and scintillator crystals..



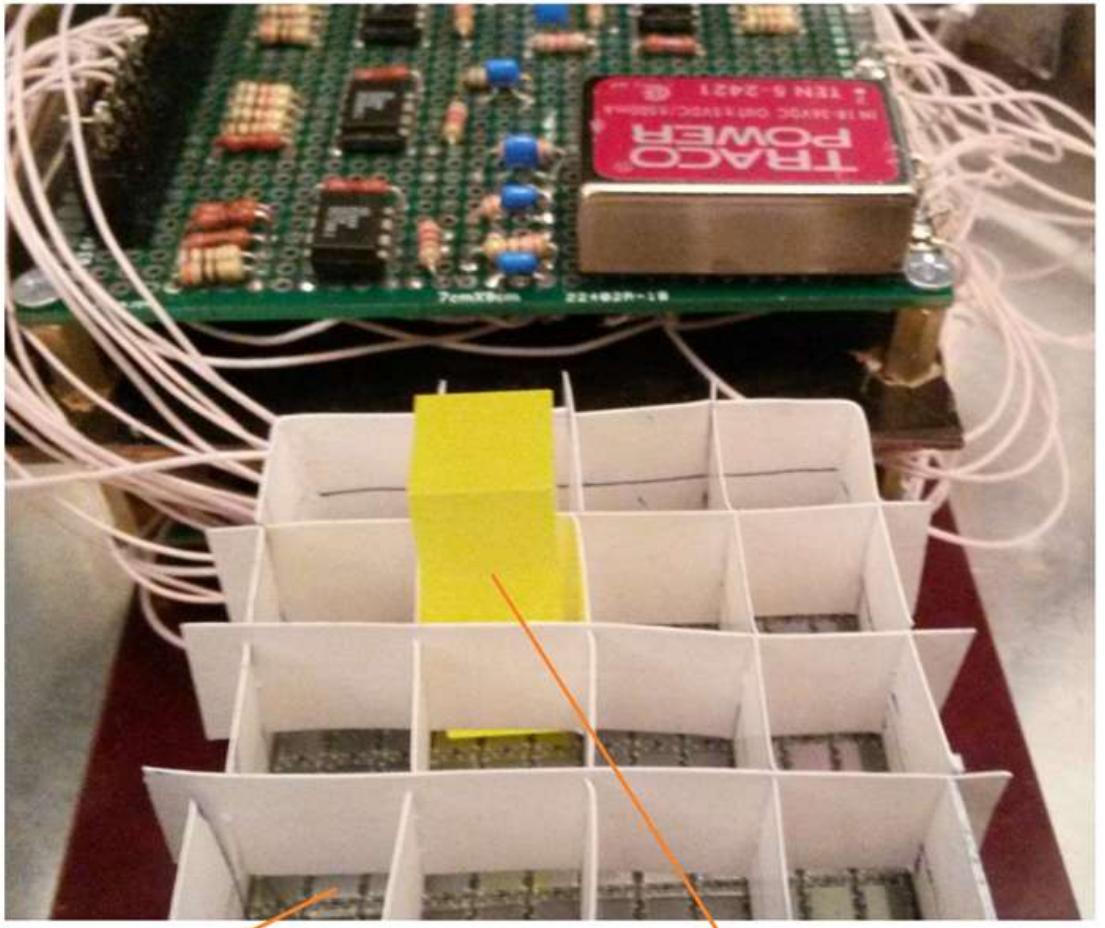


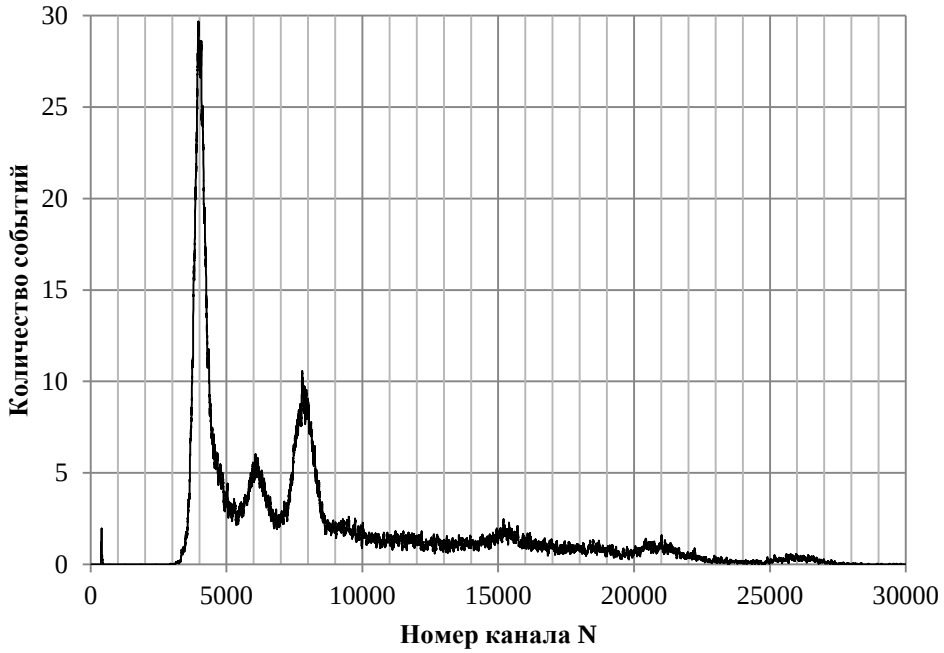
Images for AIT with spectra from all pixels for CeiGAGG crystal and source Bi-207.

Measurements with SiPM matrix AIT 12x12.

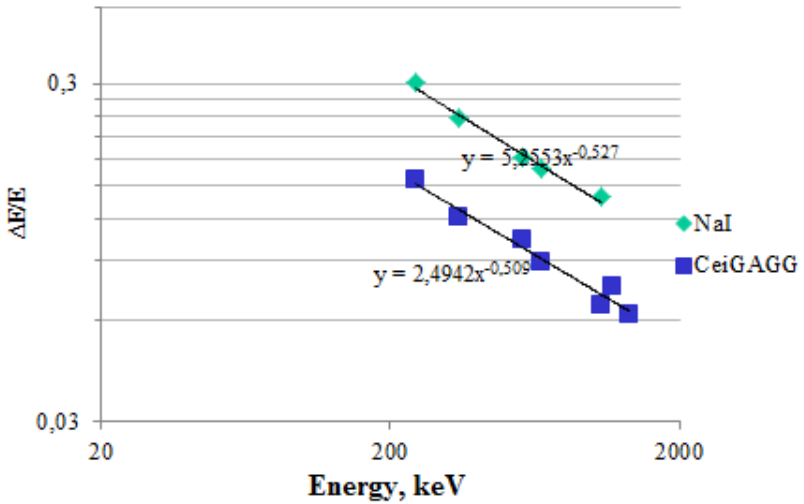


Matrix AIT SiPM 12x12.





Summary spectrum obtained with CeiGAGG crystal and Eu-152 source.



Dependence ΔE/E on energy for NaI(Tl) and CeiGAGG crystals.

Conclusion

Among tested crystals LYSO, YSO, LaBr3:Ce, CeBr3 and Ce:GAGG just Ce:GAGG has the best energy resolution with different type photo-sensors such as PMT, APD, SiPM.