GEOMETRICALLY WEIGHTED CdZnTe FRISCH GRID NUCLEAR RADIATION DETECTOR

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Introduction

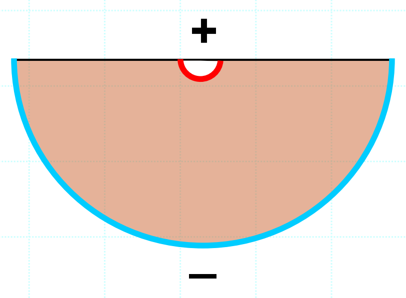
One of the first geometrically weighted devices is a hemispherical detector. The well knows hemispheric detector geometry is optimal to achieve single charge collection in detectors made from wide band semiconductor material with large difference of the transport characteristics for electrons and for holes. The design of hemispheric CdZnTe detectors is one of the ways to achieve good spectrometric performance. Now are available hemispheric detectors with volume from very small of 0. 5 mmi to 1.5 cmi. More recent way is utilization the coplanar-grid charge-sensing technique based on the Frisch grid concept. This technique allows achieving high energy resolution with large-volume CdZnTe gamma-ray detectors.

Recently were described a trapezoid prism style Frisch grid CdZnTe detector. This semiconductor Frisch grid detector has the geometrically weighted design.

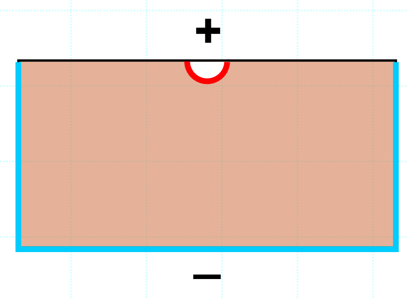
In our work we describe a modified hemispherical style Frisch grid detectors. The geometric weighting effect and good electron charge collection in the hemispherical detectors provide advantage of these devices. The Frisch grid application additionally improves energy resolution of the detectors. Our geometrically weighted detectors with 1 cmi in volume were fabricated from CdZnTe material supplied by eV PRODUCTS. Detectors have shown at room temperature energy resolution of 1.5% FWHM for ^{137}Cs 662 keV line.

Hemispherical and quasi-hemispherical detectors

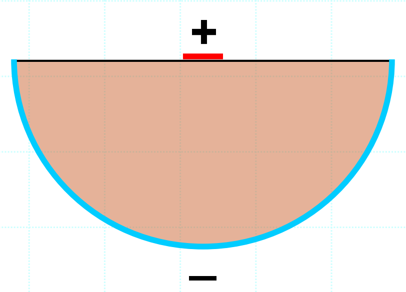
The manufacturing hemispherical detectors with ideal hemispherical geometry is a labour-consuming process. It is possible to approach ideal hemispherical geometry by using of quasi-hemispherical detectors (types 1 and 2). But for simplification of manufacturing process, in practice are used quasi-hemispherical detectors (type 3). Their sensitive volume has a rectangular parallelepiped shape with the relationship of the sides AxAxA/2. Distribution of an electrical field in the quasi-hemispherical detector differs from an ideal distribution in an ideal hemispherical detector. Research has shown, that the replacement of an ideal geometry of the detectors with quasi-hemispherical ones worsen the spectrometric performance only a little.



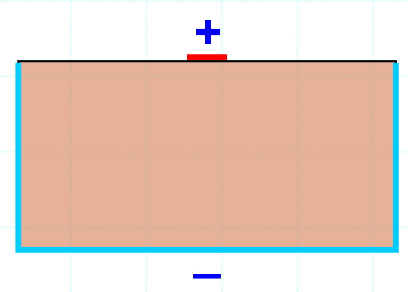
Cross-section of ideal hemispherical detector



Cross-section of quasi-hemispherical detector (type 1)



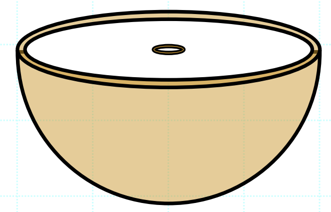
Cross-section of quasi-hemispherical detector (type 2)



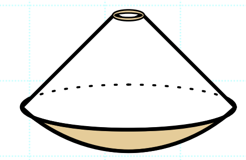
Cross-section of quasi-hemispherical detector (type 3)

Quasi-spherical sector detector as a modification of quasi-hemispherical detector

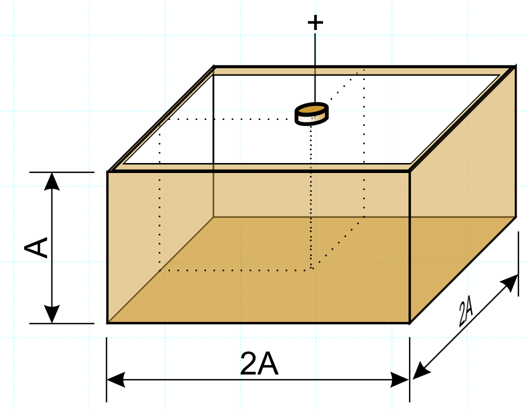
The hemispherical detector (1) and spherical sector detector (2) have the same properties as geometrically weighted detectors. If we divide the quasi-hemispherical (3) detector in four parts, each part will have the same properties as whole detector. One-fourth part of quasi-hemispherical can be considered as a quasi-spherical sector detector (4). We have made such quasi-spherical sector detectors. The sensitive volume of these detectors has a cubic shape with dimensions 1.0x1.0x1.0 cm. One of the cube corners was cut for flat triangular region formation (5). In the centre of the triangular region a small "point" electrode was placed (6). On the three opposite sides was placed second large area electrode.



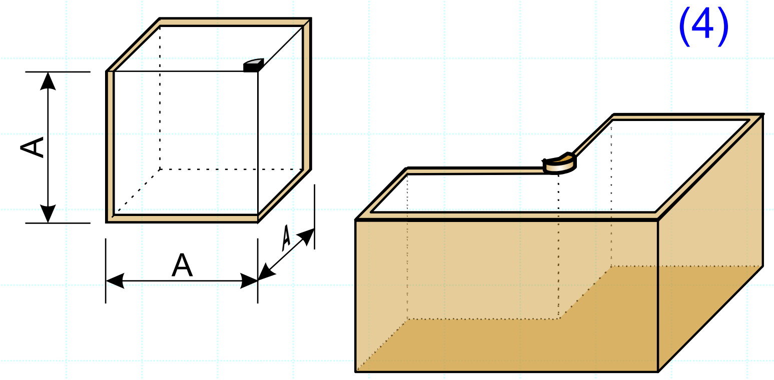
(1)



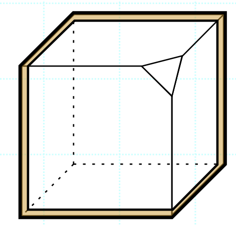
(2)



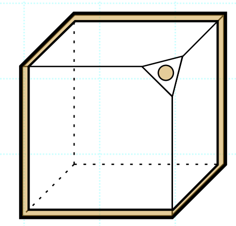
(3)



(4)

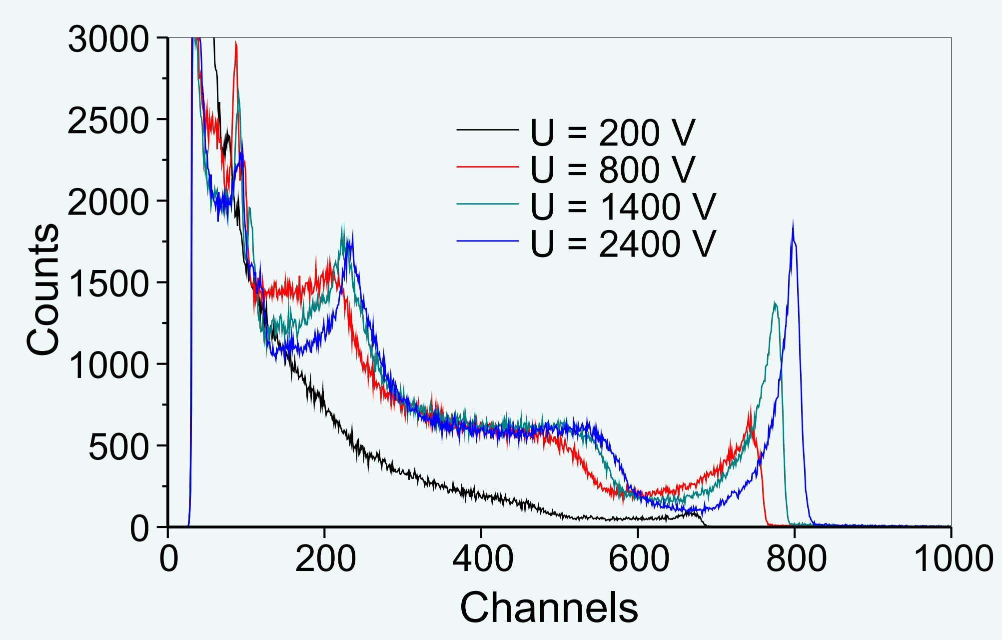


(5)



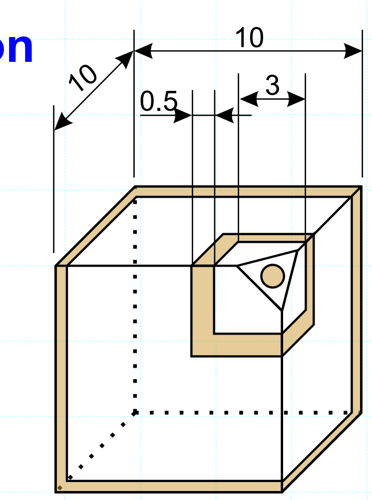
(6)

Quasi-spherical sector detector



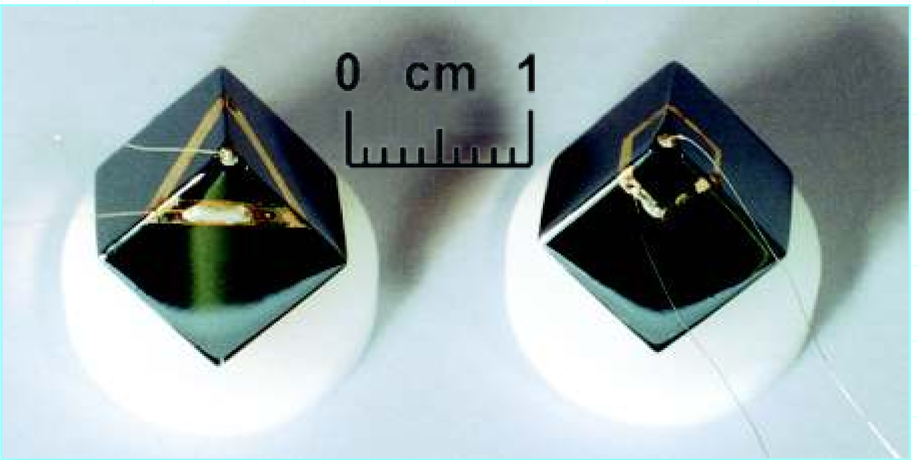
The voltage-dependent spectra of ^{137}Cs obtained with quasi-spherical sector detector.

Frisch grid electrode configuration



Frisch grid contact was placed around the small "point" contact at a distance of 3 mm.

Detector fabrication



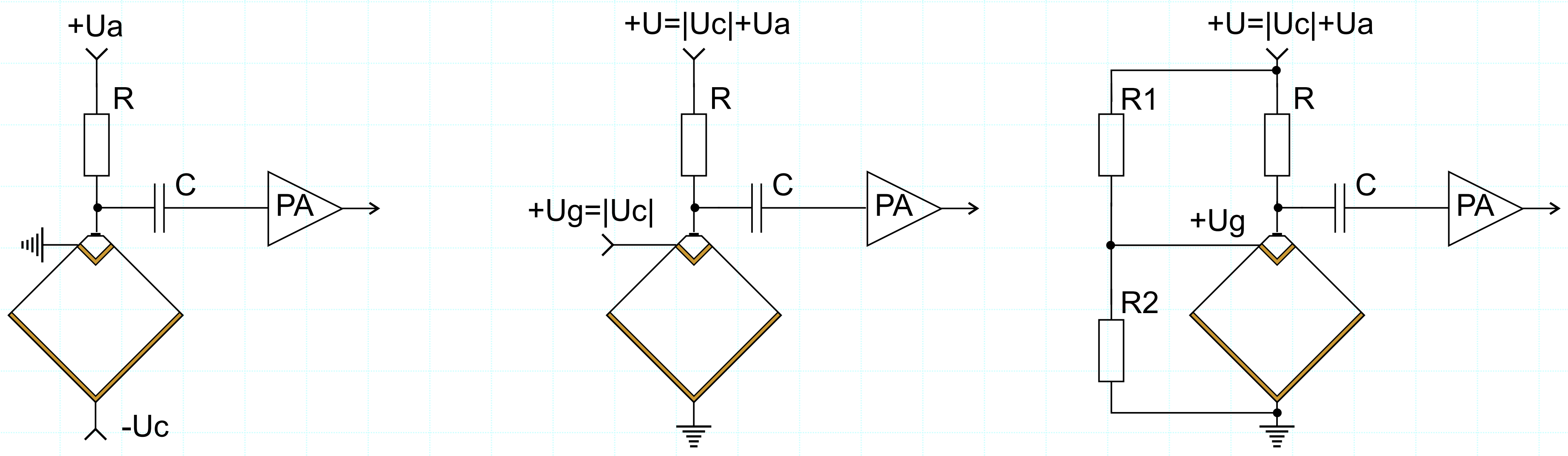
First type of Frisch grid electrode configuration

Second type of Frisch grid electrode configuration

Two Frisch grid electrode configurations were fabricated and tested. The better results were obtained with the second type of the Frisch grid electrode configuration. All experimental results described below were received with detector having this type of electrode configuration.

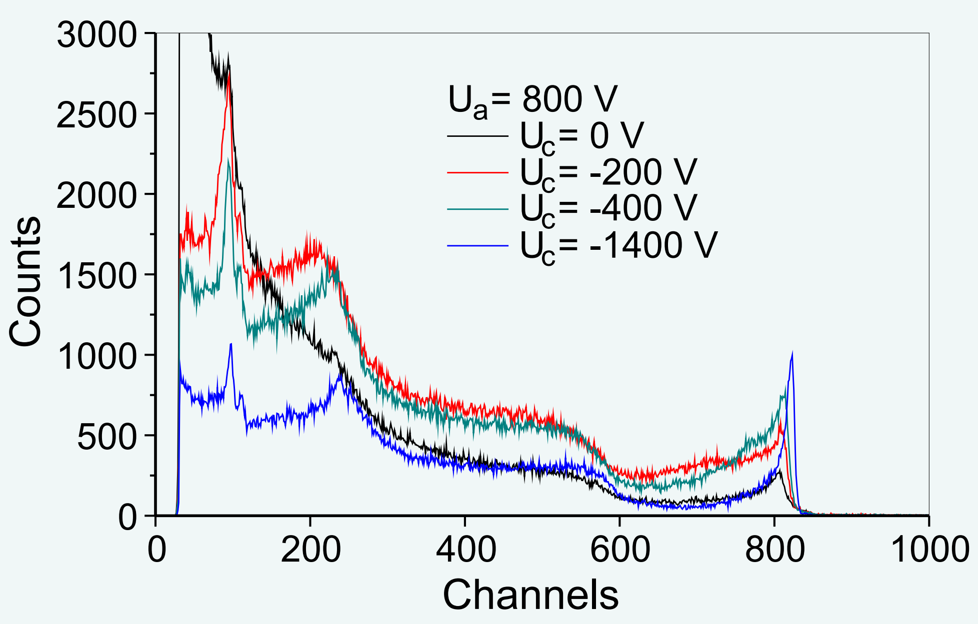
Possible connection circuits

Semiconductor Frisch grid detector is a three terminal device. The single-electrode-readout method was used for detector connection. This method requires only one output to a single preamplifier. Three different connection circuits were tested. Obtained results are approximately the same for all connections.

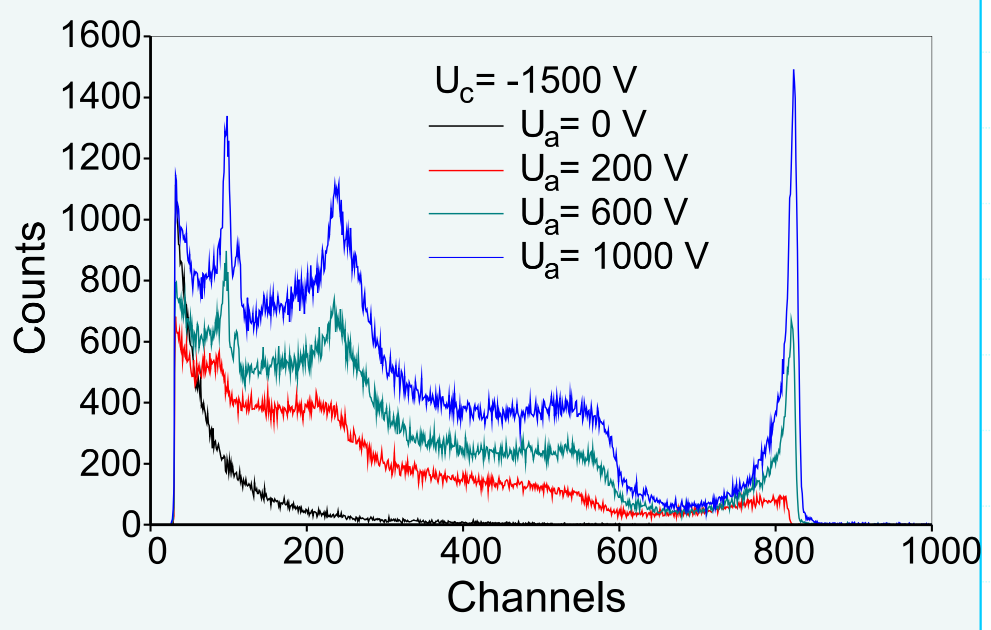


(1) (2) (3)

Experimental results. First connection circuit.

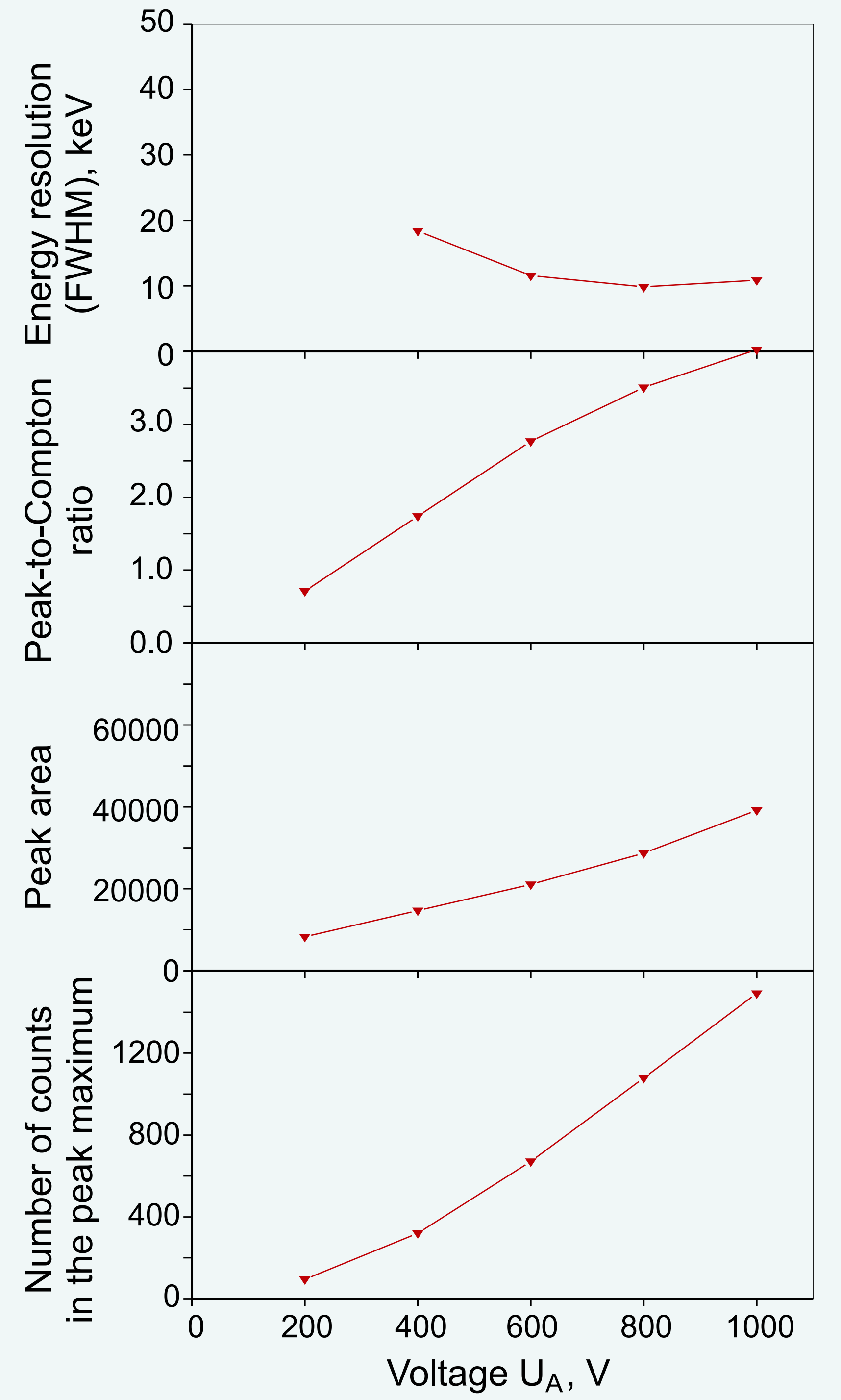


Voltage-dependent spectra of ^{137}Cs obtained with quasi-spherical sector detector with the Frisch grid grounded at different cathode voltage U_c.

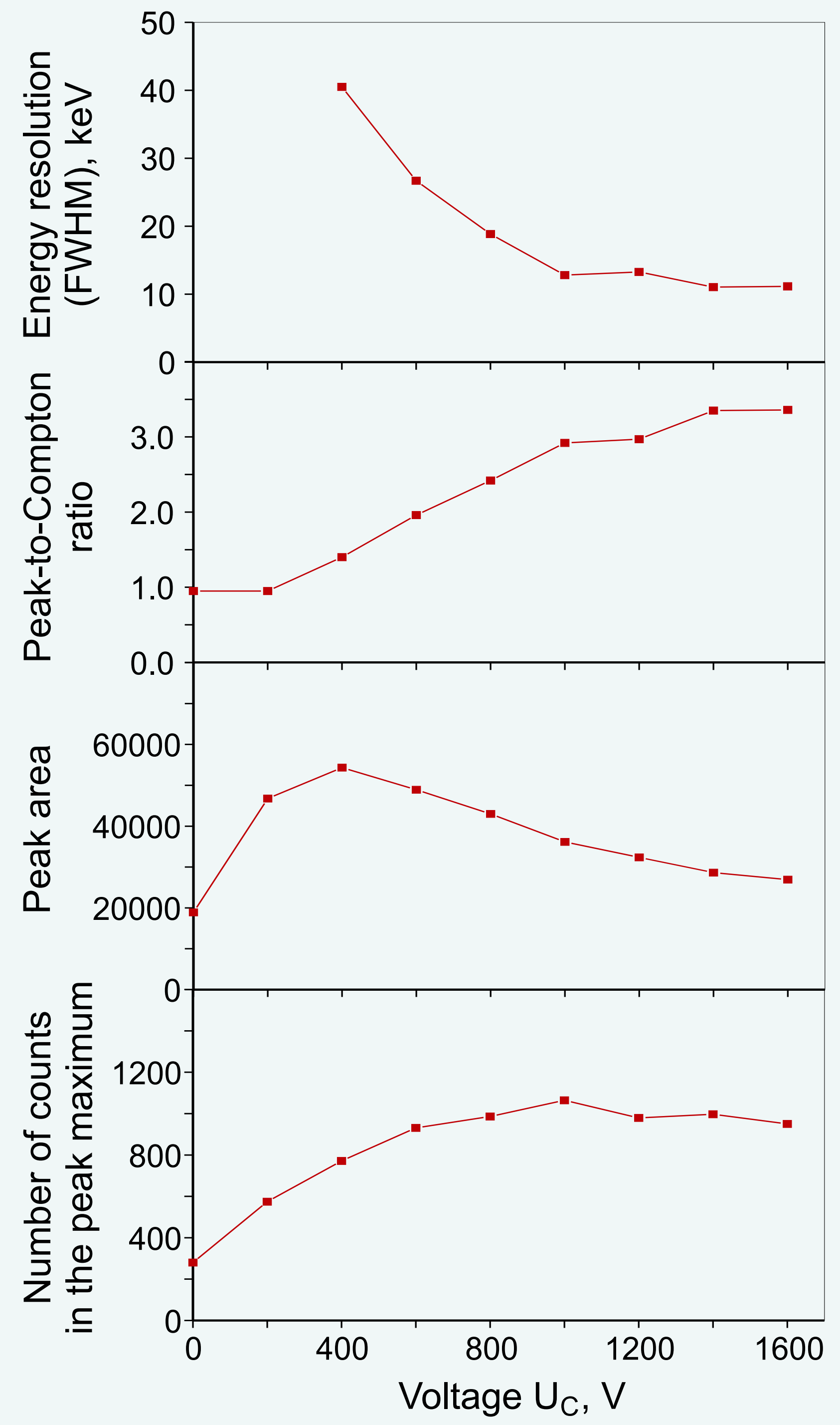


Voltage-dependent spectra of ^{137}Cs obtained with quasi-spherical sector detector with the Frisch grid grounded at different anode voltage U_a.

Results of application. First connection circuit.



Energy resolution, peak-to-Compton ratio, peak area and number of counts in the peak maximum for ^{137}Cs 662 keV line versus anode voltage U_a. The cathode voltage U_c was held at -1500 V.

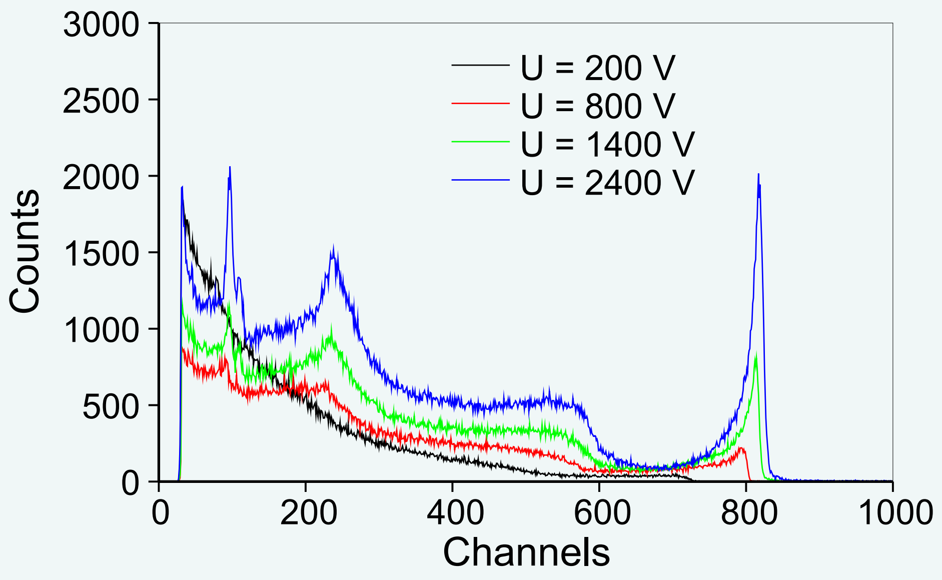


Energy resolution, peak-to-Compton ratio, peak area and number of counts in the peak maximum for ^{137}Cs 662 keV line versus cathode voltage U_c. The anode voltage U_a was held at +800 V.

The strongly different behaviours of detector's characteristics versus cathode and anode operation voltages were obtained. Detector's spectrometric performance continuously improves with anode operation voltage increasing at given cathode operation voltage. Improving of energy resolution, peak-to-Compton ratio was also observed with increasing of cathode operation voltage at given anode operation voltage. But peak area and number of counts in the peak maximum in the beginning are increased and then decreased with increasing of cathode operation voltage. Rising of anode operation voltage can increase peak area. The maximum anode operation voltage of +1000 V and cathode operation voltage of -1600 V were reached. High levels of leakage current limits further rising of the anode and cathode operation voltages.

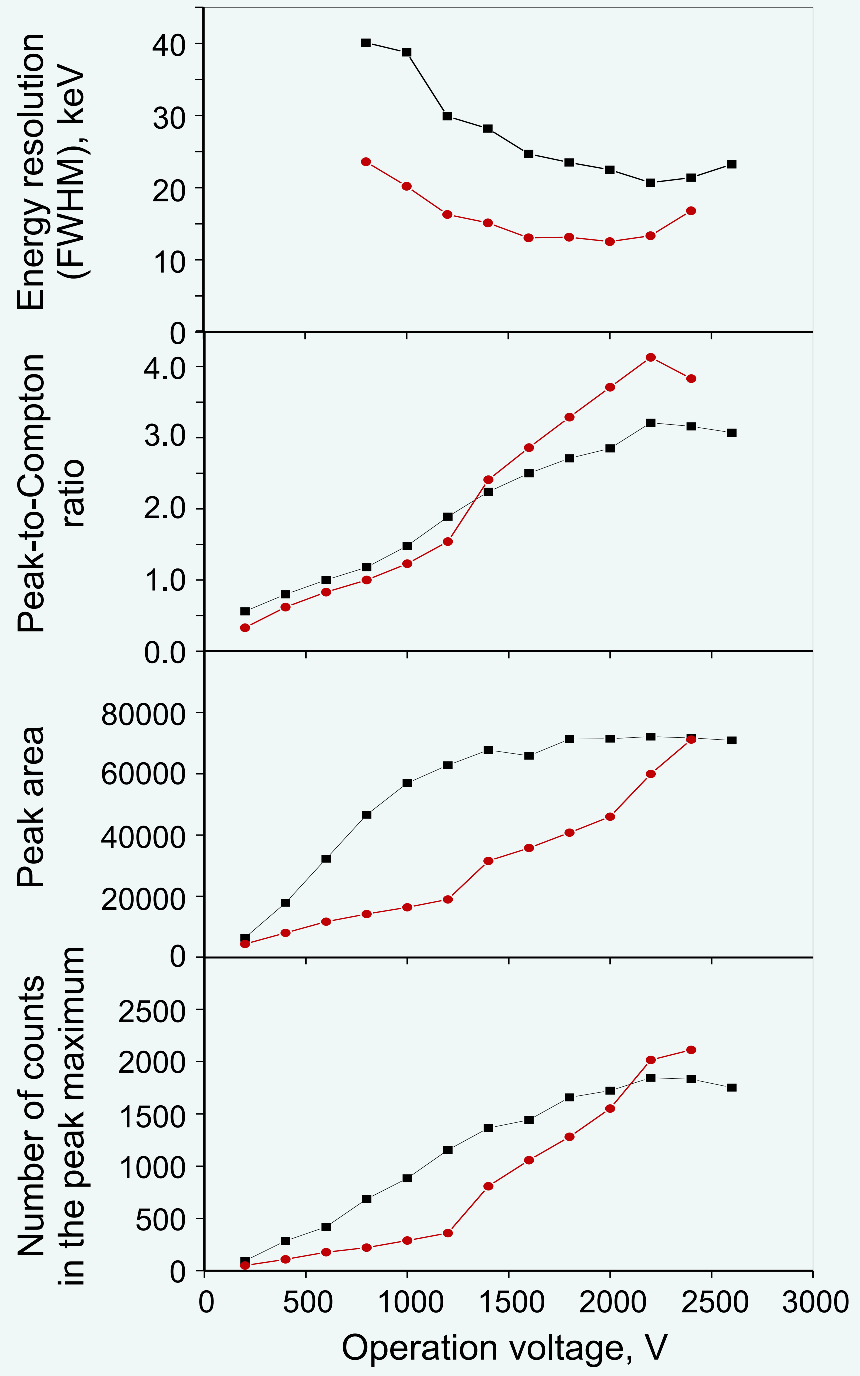
Experimental results. Third connection circuit.

For detector connection was used a simple resistive divider. This device can operate with one power supply. Resistors R1 and R2 of resistive divider sets the optimal ratio between operation voltages U_a and U_g. Value of resistors R1 and R2 must be lower then the detector resistance $R_{anode\text{-}grid}$ and $R_{grid\text{-}catode}$ at operation voltage.



Voltage-dependent spectra of ^{137}Cs obtained with quasi-spherical sector detector with the Frisch grid.

Results of application. Third connection circuit.

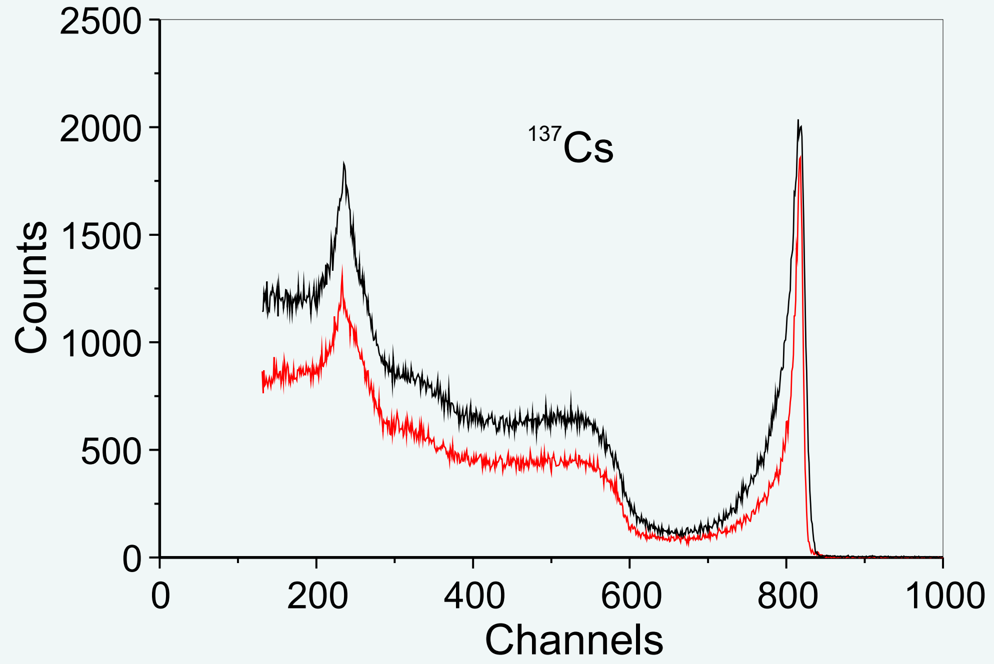


Energy resolution, peak-to-Compton ratio, peak area and number of counts in the peak maximum for ^{137}Cs 662 keV line versus operation voltage U.

Quasi-spherical sector detector with Frisch grid connected (—•—) and disconnected (—▪—).

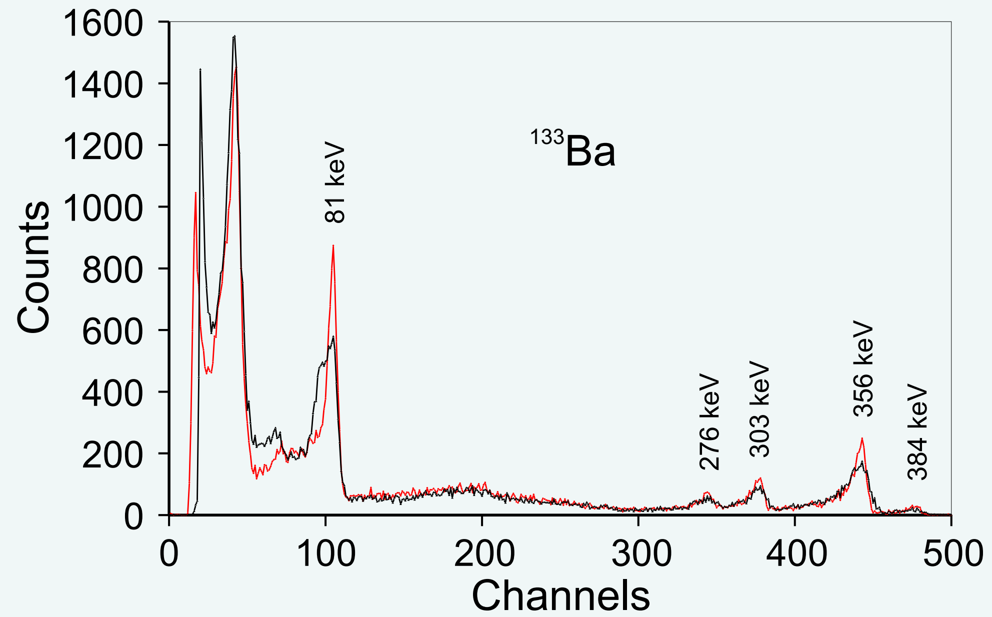
At all operation voltages detector with connected Frisch grid shows better energy resolution, but with reduced peak area. At the high operation voltages both detectors have approximately the same peak areas.

Comparison of quasi-spherical sector detector with the disconnected and connected Frisch grid



Spectra of ^{137}Cs obtained at the same operation voltage with a 1 cm^3 CdZnTe quasi-spherical sector detector with the Frisch grid connected ( ) and with the Frisch grid disconnected ( ). Operation voltage 2200 V. Time of measurement is the same for both

The best energy resolutions of 20.7 keV and 9.8 keV (1.5%) at 662 keV line were correspondingly obtained with the Frisch grid disconnected and with the Frisch grid connected. Peak-to-Compton ratios at the same time were 3.2 and 4.0 correspondingly.



Spectra of ^{133}Ba obtained at the same operation voltage with a 1 cm^3 CdZnTe quasi-spherical sector detector with the Frisch grid connected ( )and with the Frisch grid disconnected ( ). Operation voltage 2200 V. Time of measurement is the same for both

Summary

1 cm^3 CdZnTe geometrically weighted quasi-spherical sector Frisch grid nuclear radiation spectrometric detector have been manufactured and tested. High energy resolution 1.5% FWHM at 662 keV line has been achieved. Various single-electrode-readout connection circuits for a three terminal device such a semiconductor Frisch grid detector have been tested. The device can operate with one power supply.

The some decreasing of a peak area (peak efficiency) was observed with increasing of potential difference between the anode and cathode. The increasing of potential difference between the anode and grid leads to improving of all detector's characteristics. Further optimization of electrodes configuration improves a spectrometric performance of suggested device.