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Small-sized and low-powered of a satellite telescope - Spectrometer of charged particles

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Abstract. The project small-sized, small weight and low-powered of a satellite telescope-spectrometer of charged particles is offered. The device consists of two silicon detectors, arranged sequentially concerning a particle flux, and then scintillation detector. The silicon detectors have depth within the limits of 150-300 microns and fissile area 5 cm^2. The scintillation detector consists of a chip CsJ(Tl) and photoconverter, which role executes the same silicon detector. The measurement ΔE1- ΔE2- E allows to identify signals from different particles: electrons, protons and more massive ions.

The essential difficulty is connected to necessity of simultaneous fulfilment for silicon detectors of two conflicting objective: the large active area and high responses on a charge suffices which should provide reliable registration of high energy electrons. The escaping of this inconsistency is retrieved in division of the detector into separate sections, the signals from which strengthen in different channels and then special mode are admixed. It allows in N of time (N - number of sections) to reduce an electrical detector noise and channel of amplification.

Therefore silicon detectors are made as matrix 2x2 units. If necessary to determine angular distributions of particles silicon detectors place on definite distance from each other, that allows to conduct measurements in 16 solid angles.

Experimental outcomes on the obtained matrixes: an electrical noise of each matrixes units is 11 keV, energy resolution on α-particles ^{241}Am - 23 keV. The frequency of spurious noise impulses with energy is higher 15 keV makes less than 1 for 5 minutes. Such characteristics allow confidently to abjoint signals of mip-particles from electric noises.

The channels of processing of signals of silicon detectors have the following characteristics: initial intake noise is 7 keV, declination of a noise performance 15 eV/pF at time of formation τ=3 μS. A volume range not less than 55 dB.

The computational volume of detectors and analogue part of an electronics engineering of a telescope - spectrometer makes no more 0,5 litre, weight - less 0,5 kg and consumed power - about 1 W.

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1 Introduction

In the given activity the experimental development of a part of a spectrometer, small-sized and low powered, - telescope of charged particles are set up. The registration of charged particles in this device is made with the help of two silicon transient diodes and scintillation detector, fig. 1. The silicon detectors have depth 150-300 microns.

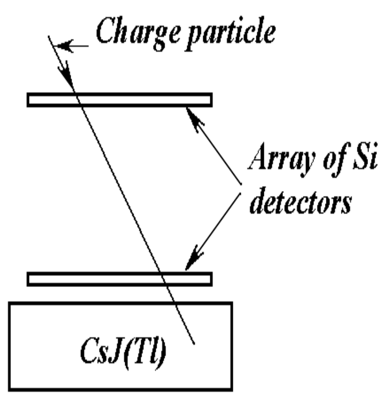

Fig. 1. Schematic drawing of the a satellite telescope-spectrometer of charged particles

The scintillation detector consists of a chip CsJ(Tl) and photoconverter, which role executes also silicon detector. The measurements DE1-DE2-E allow to identify signals from different particles: electrons, protons, α-particles and more heavy ions. In that case, when the spectrometer works as a telescope, the angular distributions of particles are determined in 16 solid angles at the expense of separation of each silicon detector into 4 sections.

2 Silicon detectors

One of main specifications assigned at mining of a silicon detector of radiation, is the fissile area of the detector. As a rule, the small frequency of registered events forces to select large enough values S_a. In the given activity preset S_a = 5 см^2. Difficulty of implementation large S_a consists that with increase of the area of the semiconductor detector the leakage current of the detector and its electrical noise is augmented. Besides thus capacity of the detector and accordingly noise of the charge sensitive preamplifier of a signal of the detector grows. The situation is aggravated some more subjects, that the noise of the silicon diode is augmented in ~ 1,5 times at increase of temperature on 10 ^{o}C from room, so at T=60 ^{o}C he will be in ~5 times more, than at T=20 ^{o}C.

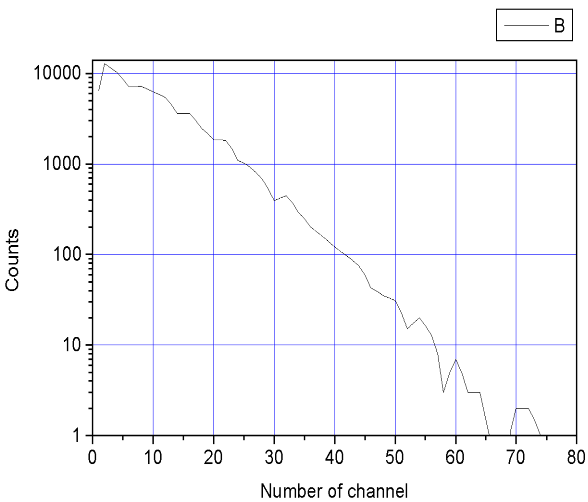

Fig. 2. The noise spectrum measured on a silicon detector (dE=0.183 kev/channel, full scale is 2000 channel).

The most serious influence of an electrical noise at registration of particles consists of transit of spurious noise impulses to an information channel. The most adequate information on it is yielded by a noise spectrum. In a fig. 2 the noise spectrum, measured on a silicon detector, manufactured by us, with S_a = 5 cm^2 is adduced. We conditionally adopt a tolerance frequency of noise impulses in an information channel a 1 imp/min. From a fig. 2 follows, that such frequency is implemented for energy of impulses above 30 keV. Therefore, on this energy it is necessary to set a level of the discriminator to divide noise impulses and impulses of particles. If for a room temperature T=20 ^{o}C this condition can be acceptable, at heightened temperatures it becomes invalid. In a fig. 3 the experimental relation of a threshold of energy of noise impulses (under condition of 1imp/mines) from temperature is adduced. At 60 ^{o}C the threshold energy is equal 140 keV.

Besides such high threshold notably reduces range of energies, in which the particles can register, he practically eliminates a capability of registration of electrons. Really, at depth of a silicon slice 300 microns the maximum energy left by an electron in silicon at normal falling, is equal 225 keV. The electrons with energy above called leave for a slice of silicon and their losses decrease with increase of energy sharply. Electrons, which can be registered, i.e. the creating losses are higher 140 keV, lie in range of energies 140-330 keV, that hardly probable is acceptable. The thinning-down of slices of silicon is perspective for dilating power range, in which the particle sorting is possible. However it even more enhances a role of an electrical noise. For example, at depth of a slice 150 microns will register only electrons with energy in range 140-160 keV. The data calculations were made without the count of a bending of a search pattern of electrons in silicon, but we suppose, that the count of a bending of a search pattern will not change the much given situation. Let's mark, that this situation is called by completely not poor quality of silicon diodes. Quality of silicon (corporation Wacker) and the technologies of

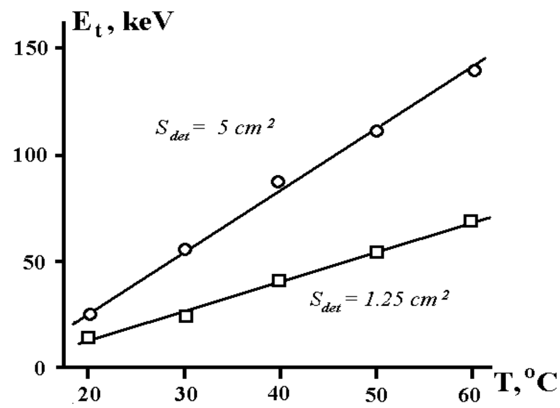

Fig. 3. The experimental relation of a threshold of energy of noise impulses (under condition of 1imp/mines) from temperature.

manufacturing of diodes corresponded to samples of leading firms Ortec, Canberra. For example, the energy resolution of the detector on α-particles is equal 22 keV.

3 Multisectional principle of detection unit design

We have proposed an idea of multisectional detectors which allows one to bypass the mentioned dependency of the noise on the area of a detector (Nimets O. F., et al.,1999; Nimets O. F., Frolov O. S., Shevchenko V. A., 1999; Nimets O. F., et al., 2001; Shevchenko V. A., 2000;). This idea lies in the following. The detector is divided into **n** independent parts (sections) with area **s** of each section. Each section has its own amplification channel. Signals from all channels are applied to a special mixer, which passes them to one bus and then are applied to a counter or an amplitude analyser. The mixer is designed in such a way that it transmits noise only from one channel, in which the signal passes at the moment. So, we have a detector with the area **n×s** but the noise of the detector and its preamplifier is corresponds to the area **s**.

We have produced such multisectional detection modules. A detector with the area of 8 cm^2 and consisting of 8 sections of 1 cm^2 each had complete energy resolution for

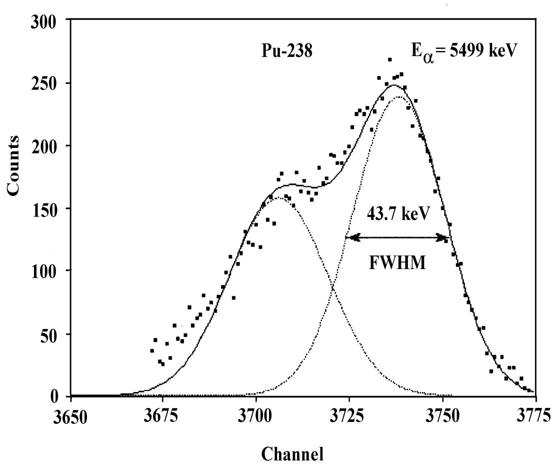

Fig. 4. An α-particle spectrum measured by detector 24 cm^2.

α-particles of 25 keV, while the world best samples of ordinary type reached 32 keV. A detector with the area of 24 cm^2, consisting also of 8 sections had the resolution of 44 keV (the world best samples of ordinary type have 70 keV, (EG&G ORTEC, 1998)). An α-particle spectrum measured with this detector is shown on Fig.4.

Resolution of the whole detector is only 5 - 10 % worse then resolution of one section with the area of 3 cm^2 (see Tab. 1). Here, the quality of silicon diodes used was not very high. Thus, implementation of the proposed method will allow one to achieve record value of the main parameter of the detector using silicon crystals of not the best quality and, correspondingly, of low cost.

Tab. 1. Energy resolution of the multisectional detector 8x3 cm^2.

Energy resolutions (keV).	**S=24 cm^2 (8 detectors placed in parallel)**	**S=8x3 cm^2 (multi-sectional)**	**S=24 cm^2 (single) ORTEC**
Total	145	43.7	69
α-source	6	6	6
Preamp	89	15.5	41
Detector	114	40.4	55

We believe the proposed method is universal and applicable for creation of spectrometers and radiometers of various purpose with detectors of large area and high energy resolution. The following devices 1) α-spectrometer with energy resolution of 35 keV with the detector area of 30 cm^2 and 50 keV with the area of 100 cm^2, which is significantly better then the current level.

2) β-radiometer with silicon detector having active area of 20 - 100 cm^2.

3) γ- spectrometer with energy resolution of about 7% for ^{137}Cs with the detector area up to 1000 cm^2.

4) X-ray spectrometer with high energy resolution. The detector by the common area of 9 mm^2 consists of 8 units. The series application of a principle of a multisection system will allow to reduce a self noise of the detector and in 6-8 times to increase speed of registration.

5) α, β, γ- spectrometer with a two-layer detector (silicon, scintillator + photomultiplier).

The outcomes of experiments are below described which allow to estimate capabilities and limitations of this device.

The diagram of the multisection detector is shown on a Fig. 4. This idea was implemented and approve.

In application to the given activity we offer to divide the fissile area of a silicon detector into 4 sections on 1,25 $см^2$ everyone. Such detectors manufactured. In a fig. 3 the relation of a threshold of a noise to temperature for one section of this detector is adduced. At temperature 60 °C a threshold of a noise and, therefore, threshold of registration of charged particles is equal 70 keV. This value allows

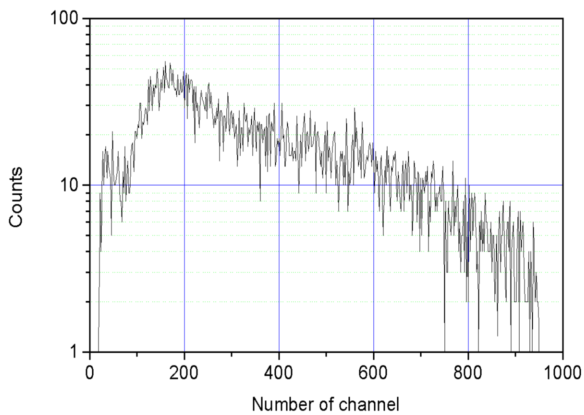

Fig. 5. The spectrum of electrons from a source Y+Sr

confidently to register all high energy electrons at depth of a slice 300 microns, since minimum losses of mip-electrons at this depth about 100 keV. However capability to reduce depth of a slice and in this case is limited: at depth 150 microns of loss of mip-electrons are equal 47 keV. In this case, apparently, the precise optimization of the fissile area, number of sections of the detector, temperature range is necessary.

In a fig. 5 the spectrum of electrons from a source Y+Sr, taken off on one section of the multisection detector is adduced. It is necessary to name it a spectrum of losses of electrons more precisely. On this relation in all range of energies there is a noticeable influence of a noise. The losses from high energy of electrons (about 100 keV) easily register.

The mixing of signals by a special way will be used when there is no necessity to determine an angular distribution of particles. If such necessity is, the signals from each section of the detector pass analogue and digital processing separately. Thus all outcomes and the conclusions about influence of a noise set up above, usable and to activity of a telescope - spectrometer.

4 Channels of amplification - formation

For amplification of signals of silicon detectors and formation of signals of the optimum shape and duration the 8-channel device measuring was designed. Power supply voltage is equal ±9 V, power consumption of a channel 140 mW, charge sensitivity 0,35 In / мэв, pulse duration 7,5 μs. The electrical noise output is equal 4 keV, declination of a noise performance - 18 eV/pF. A volume range - 60 dB. Supression of crosstalks - not less than 50 dB. The channels of amplification - formation operate after irradiation by γ-quanta ^{60}Co up to doses 10^6Rad.

5 Summary

The experiments with silicon matrixes by the area 5 см^2 were conducted which can be utilised for creation of a spectrometer and telescope - spectrometer of charged particles, and also with a multi-channel system of analogue processing of their signals. The outcomes of experiments with the indicated devices display, that on their basis the different type small-sized with small consumption of satellite spectrometers and telescopes - spectrometers can be built. The fulfilment of trial functions of such devices in enough broad bands of temperatures, producing doses and with sufficient reliability can be supplied. The considerable difficulties, bound with an electrical noise in a spectrometer at heightened temperatures, are overcome with the help of a multisection design of the detector.

In the given activity we did not concern problems of analog-to-digital conversion, digital processing and telemetry data transfer, as these problems have more standard solutions and as their consideration, apparently, it is necessary to conduct after a task of concrete specifications to the device.

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