SILICON PAD DETECTORS FOR A SIMPLE TRACKING SYSTEM AND MULTIPLICITY DETECTORS CREATION

G.L. Bochek, V.I. Kulibaba, N.I. Maslov, S.V. Naumov, A.F. Starodubtsev

National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine

Silicon pad detectors are working at room temperatures, what is very convenient for creation of simple tracking system and multiplicity detectors. Silicon pad detectors are studied to create a compact detecting systems for active beam collimation and for gamma-radiation multiplicity measurements. The registration efficiency and spectral distributions of gamma-radiation and electrons were studied using isotope radiation sources. The silicon pad detectors were designed at NSC "KIPT".

PACS: 29.40.Wk.

INTRODUCTION

Semiconductor detectors are widely used in physics, health care and various branches of technology [1, 2]. In high energy physics coordinate silicon detectors are broadly applied. There are designed multi-layer registering systems including tens square meters of silicon plates consisting of some millions of separate detectors [1, 3]. Coordinate silicon detectors consist mainly of four detector types. These are planar, point, microstrip, and drift detectors. Fundamentals of the operation of these detectors and basic designs are very similar.

This paper considers the design and characteristics of silicon pad detectors developed at the National Science Center "Kharkov Institute of Physics and Technology". The study is performed aiming at investigating the possibilities of collimating beams of particles and creating a simple detector of gamma-radiation multiplicity. Beam collimation and gamma-radiation multiplicity determination are necessary for an accurate alignment of a thick crystalline target with respect to the axis of a high energy electron beam. [4]. In this case the "collimation" means the separation of the flux of particles filling the body angle limited by the transverse dimensions of the detector in the absence of the absorber with an orifice. Creation of the multiplicity detector proposed in this paper anticipates the performance of some preliminary studies. Part of them has already been done and this paper gives the results obtained.

DESIGN AND CHARACTERISTICS OF THE SILICON PAD DETECTORS

Fig. 1 and Fig. 2 show the cross section and the micrograph of the silicon pad detector.

The detector consists of the p/n-transition (4) located on the silicon plate 350 μm thick. On the back side of the plate an Ohmic contact is made To manufacture a SPD one uses a specially pure crucible-free high resistance n – silicon with the resistivity above one kΩ× cm. Such resistance value of the silicon enables one to make the operating layer over all thickness of the detector at room temperature applying moderate operating voltages <100 V. Operation of silicon pad detectors at room temperature is very convenient for creating simple track system and multiplicity detectors.

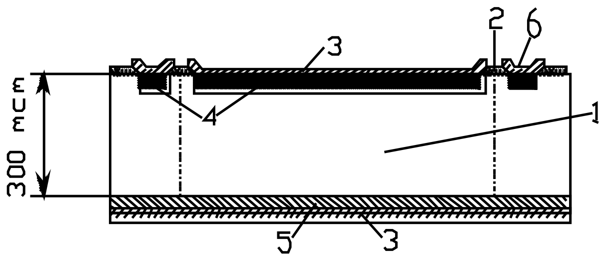

Fig. 1. *Cross section of the silicon pad detector: 1 is the active zone of the silicon detector, 2 is the oxide layer, 3 are Al contacts, 4 are p/n transitions, active zone and protective rings, 5 is the n+-doped silicon layer, 6 is the protective ring, 7 is the ring Al contact of the active zone, 8 and 9 are the contact pads of the protective ring and the active zone*

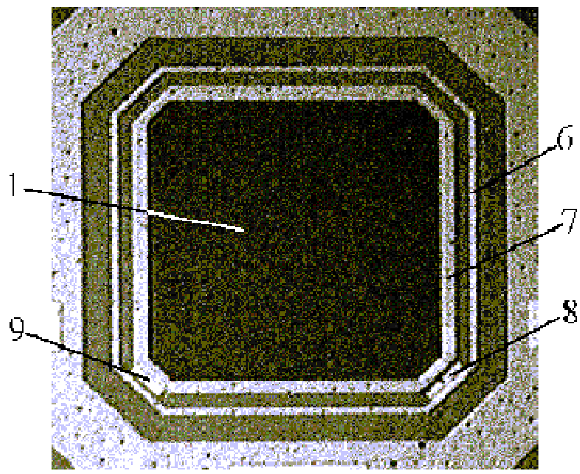

Fig. 2. M*icrograph of the silicon pad detector. The notes are the same as on Fig. 1*

PROBLEMS OF ATOMIC SCIENCE AND TECHNOLOGY. 2001, № 1.
Series: Nuclear Physics Investigations (37), p. 36-39.

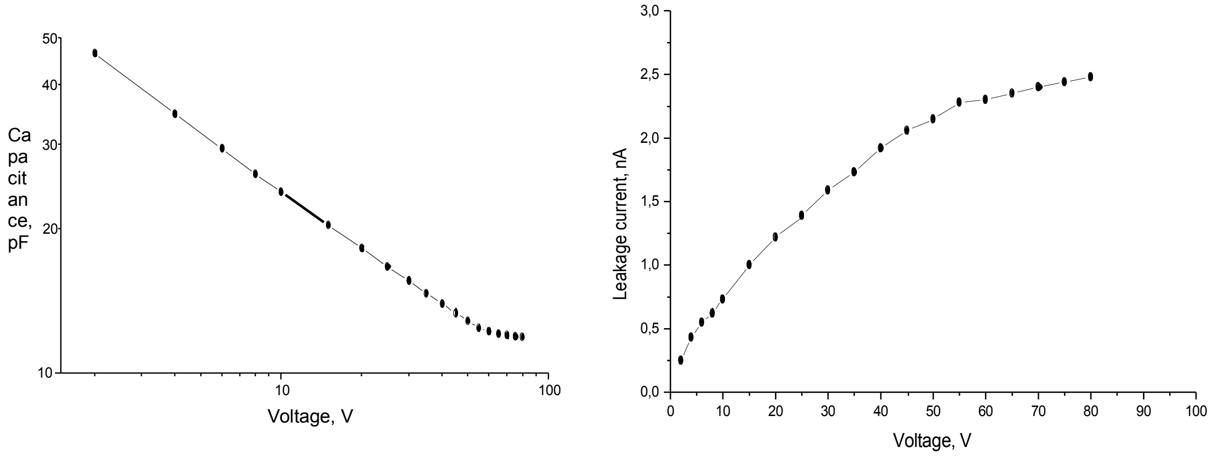

Fig. 3. *Current-voltage and capacitance-voltage characteristics of the pad detector*

Protection ring (6) builds up a depletion zone around the active area of the detector. Applying a protection ring enables one to make a sharp boundary of the active area of the detector and to improve the detector characteristics. Improvement of detector characteristics results mainly due to the decrease of leak currents and the detector capacitance. As is known, leak current and detector capacitance are two main parameters determining noise characteristics and spectral resolution of the detector. Fig. 3 presents the current-voltage and voltage-capacitance characteristics of the pad detector. The position of the inflection point on the voltage-capacitance characteristic determines the value of the total depletion voltage of the detector. Registration efficiency and spectral resolution of detectors have been studied using isotope β- and γ-sources. Fig. 4 shows the measurement scheme.

Spectrometric channel registering γ-quanta consists of detector 1 (Det1), preliminary amplifier (PA), amplifier 1 (A1), amplitude-to-digital converter (ADC) and a computer (IBM) for data accumulation and processing.

For registering the signal from a β-particle, one uses collimator (Col) and a trigger channel recording only the events caused by electrons having passed detector 1 at the angle close to 90 degrees. The trigger channel consists of detector 2 (Det2), preliminary amplifier, amplifier 2 (A2), discriminator (Dis) and shaper (Sh).

In the measuring as well as in the trigger channel one uses the detector with the active zone area of $5\times 5\ mm^2$. The active zone is limited with the $50\ \mu m$ accuracy.

Fig. 5 shows the spectral distributions of gamma-radiation from the sources Am^{241} and Co^{57}. Fig. 6 depicts the form and energy position of the spectral distribution from the β-source. In the measurements the Sr-Y-source of β-radiation was used with the maximum energy of β-particles 2.27 MeV.

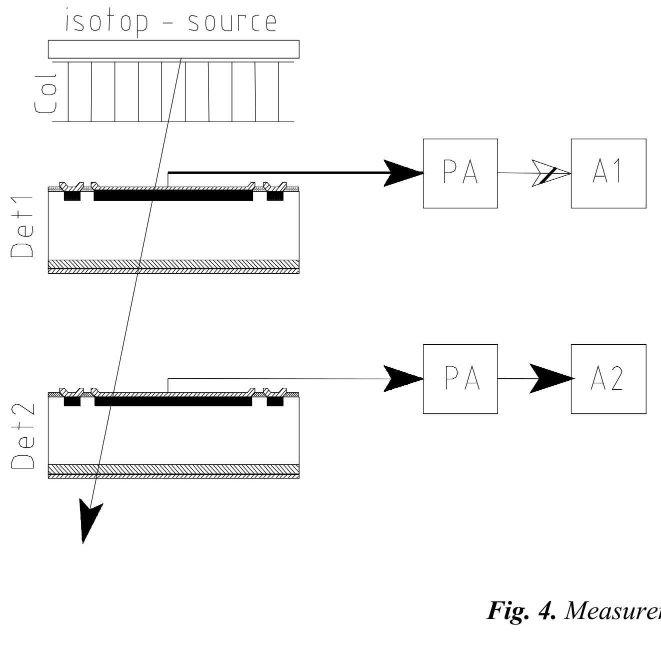

Fig. 4. *Measurement scheme*

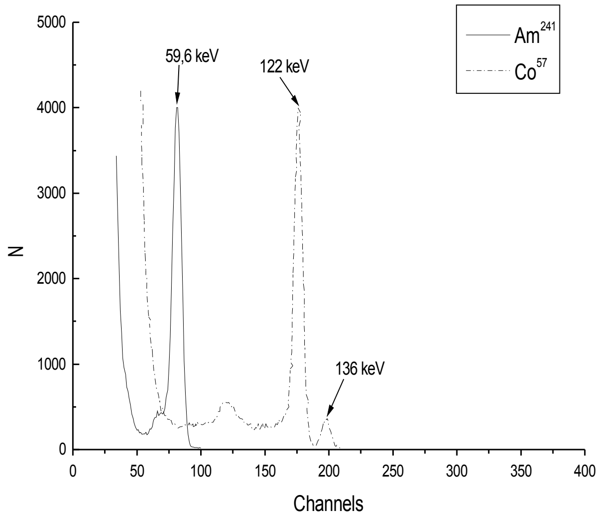

Fig. 5. *Spectral distributions of gamma-radiation from the sources Am^{241} and Co^{57}*

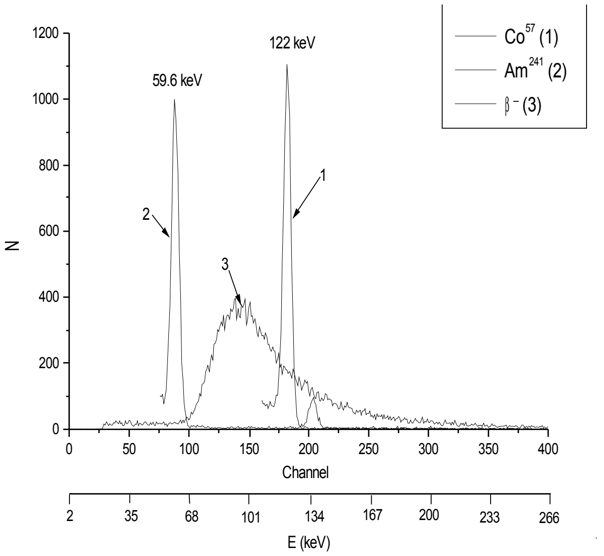

Fig. 6. *Form and energy position of the spectral distribution from the β-source*

Registration efficiency of gamma-radiation with the energy 57 keV and 122 keV amounts to 4.6×10^{-3} and 1×10^{-3}, respectively. Measurement errors due to the sources being not point ones are evaluated as ±10 %. Naturally, the efficiency of registering electrons equals 1.

Energy loss of the β-particle having passed the silicon 350 μm thick is approximately 90 keV. The spectral distribution has the form of the Landau's distribution in agreement with calculation results (not shown in the figure).

Ratio of the charge collected during the passage of the β-particle to the equivalent noise charge is order of 40 and it is mainly determined by noise characteristics of the preliminary amplifier. In the scheme described above one employed 1005A preliminary amplifiers made in Poland with the value of equivalent noise ± 0.9 keV without the detector, and ±2.4 keV with the detector connected to it with the bias voltage of the detector equalling 40 V.

The results obtained demonstrate the feasibility of applying the detectors developed for registering β-particles and low energy γ-quanta. Applying the generation and registration of electron-positron pairs one can perform collimation and determine the multiplicity of high energy γ-radiation.

DESIGN OF THE DETECTOR OF γ-RADIATION MULTIPLICITY BASED ON SEPARATE SI PAD DETECTORS

One assumes to apply the pad detector for determining the multiplicity and angular distribution of γ-radiation from oriented single crystal target. The energy of primary electrons is 10 GeV, the thickness of the single crystal tungsten target is 8 mm. The calculations show [5] that under such conditions the multiplicity value may approach 50.

The multiplicity detector consists of the hybrid board with separate Si pad detectors located on it (Fig. 7) and the hybrid board of readout electronics. A converter for transforming γ-quanta into electron-positron pairs is positioned before the detector. The hybrid board of the detector includes around a hundred separate Si pad detectors, connecting lines and capacitive filters. The hybrid board of readout electronics comprises a 128-channel "Viking" readout chip (IDEAS firm, Norway), input and output extenders-matchers and controlling circuits. Input and output extenders serve for connecting the circuits of separate Si pad detectors and controlling circuits to input and output contact pads of "Viking" possessing a small step (100 μm).

The measurement scheme for the multiplicity detector (Fig. 8) based on the multi-channel "Viking" chip consists of modules recommended by the IDEAS firm (Norway) developed at CERN. The measurement scheme is determined by the properties of the small-noise integrated 128-channel chip of the amplifier-multiplexer "Viking".

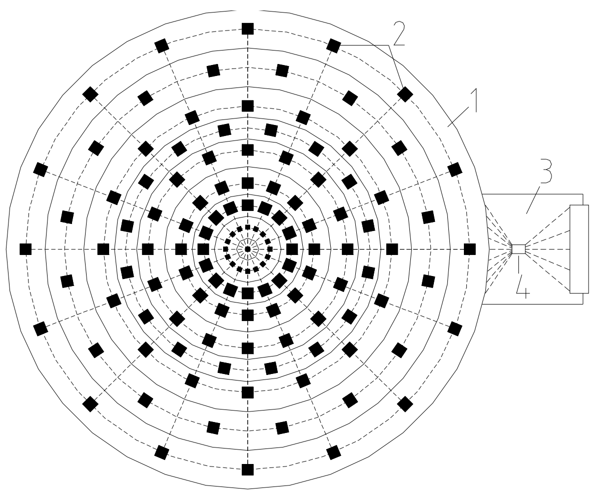

Fig. 7. *Detector of gamma-radiation multiplicity. 1 is the hybrid board with Si detectors located on it (2), 3 is the hybrid board of readout electronics, 4 is the "Viking" readout chip*

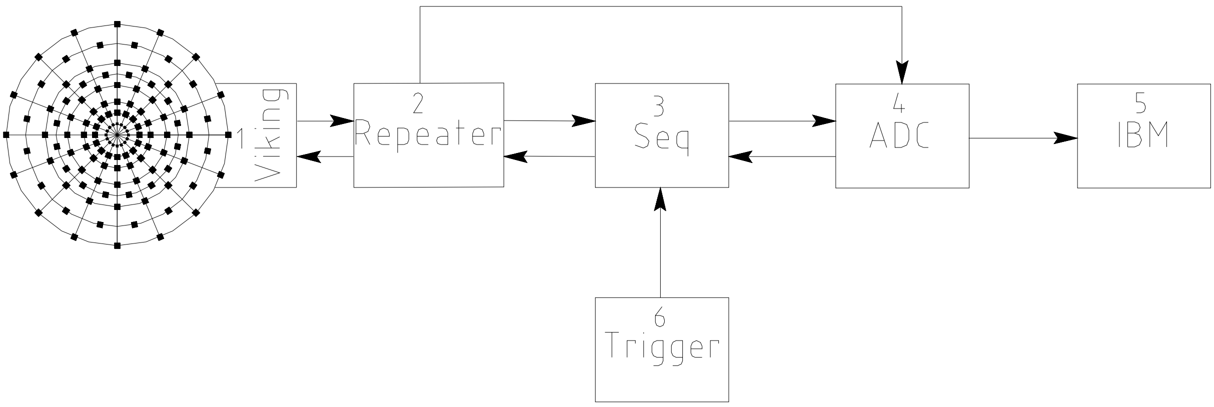

Fig. 8. *Measurement scheme for the multiplicity detector. 1 is the readout electronics module, 2 is the signal forming module (controlling module), 3 is the generator of sequences of control pulses, 4 is the amplitude-to-digital converter, 5 is the data accumulation and processing system, 6 is the trigger unit*

The "Viking" chip is mounted on a printed circuit board (PCB) with the help of the microwire ultrasound welding. All 128 channels (preliminary amplifier - shaper – analog memory) are multiplexed into one output line. Supply and control signals are fed to the "Viking" readout module via a controlling "Repeater" module. The same module serves for outputting the analog signal and sending it to the analog-to-digital converter. The standard "Sequencer" generator puts out the sequence of controlling signals for the "Viking" chip. The sequence generator is started by the trigger unit synchronized with the primary electron beam. The sequence of analog signals from all separate detectors of the assembly is transformed and stored in the memory cells of the analog-to-digital converter. Processing and accumulation of data is accomplished with the help of a personal IBM computer connected with ADC through a CAMAC system. Calculations and test measurements show that the readout rate of the system described comprises around 100 μs. This rate is sufficient for registering γ-radiation with the multiplicity detector from all electrons under experimental conditions described. Fig. 9 shows the spectral distributions of gamma-radiation from the source Am^{241} using VIKING readout.

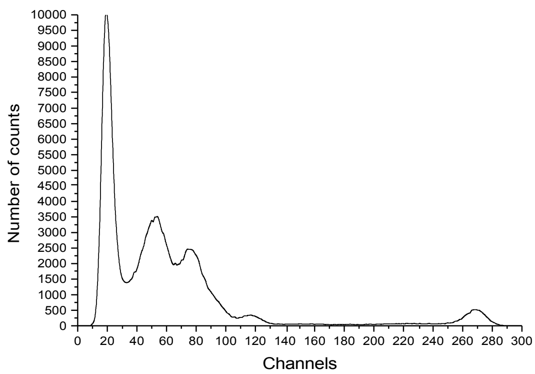

Fig. 9. *The spectral distributions of gamma-radiation from the source Am^{241} using VIKING readout*

CONCLUSIONS

Collimated beams registration and gamma-radiation multiplicity determination are necessary for an accurate alignment of a thick crystalline target with respect to the axis of a high-energy electron beam. The silicon pad detectors developed at the National Science Center "Kharkov Institute of Physics and Technology" were studied for this necessity. The results obtained demonstrate the feasibility of applying the detectors developed for registering β-particles and low energy γ-quanta. Applying the generation and registration of electron-positron pairs one can perform collimation and determine the multiplicity of high energy γ-radiation.

The preliminary study has been done for multiplicity detector creation on the Si pad detectors base and on the base of the multi-channel "Viking" readout chip. Calculations and test measurements show that the readout rate of the system proposed is sufficient for registering γ-radiation from all electrons under experimental conditions described.

ACKNOWLEDGEMENTS

The authors are very thankful to many colleagues for the valuable discussions and constructive remarks. This work was supported by INTAS under the Grant 97-0562.

REFERENCES

1. G. Batignoni et all. Beauty physics and double-sided Si microstrip detectors // *Nucl. Phys. B (Proc. Suppl.),* 1991, v. 23A, p. 297-306.
2. Fabio Sauli. *High-rate, position-sensitive radiation detectors: recent developments and application in particle physics, medicine and technology. CERN-PRE/94-150*, 24 August 1994.
3. ALICE. *Technical proposal*. CERN/ LHCC/95-71 LHCC/P3 15 December 1995.
4. D.I. Adeishvili et all. Apparatus for measurement of spectral and angular distributions of gamma quanta at exit from LUE – 2000 linear accelerator // *Instrum. Exp. Tech.* 1991, v. 34 (2), part 1, p. 294.

5. V.N. Baier et all. Set – up optimization for an experimental test of a positron source using channeling // *Nucl. Instr. and Meth. B,* 1998, v. 145, p. 221-229.