A four-layer gaseous detector allowing to measure the energy of charged particles

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1. Introduction
Multilayer proportional detectors of charged particles are widely used both in particle physics and in applied studies [1]. Repeated measurement of ionization losses is used to identify charged particles in high energy physics [2]. At energies of several MeV, this method also makes it possible to determine the energy of charged particles. At the same time, with increase in the number of detector layers $n$, the accuracy of energy determination improves proportionally to $n^{-0.46}(lP)^{-0.32}$ [3], where $l$ is the layer thickness in cm, $P$ is the pressure in bar.

The purpose of this work is to create a multilayer electron detector, which allows one to determine the energy of the detected electrons, using the multiple absorption method of thin layers. Such gas particle detectors have the ability of radiation resistance and low sensitivity to gamma quanta and X-rays. Careful sealing of the detector, the use of non-emitting materials and filling by cheap, non-polymerization gas mixture of argon and carbon dioxide makes the use of a gas detector preferred in many applications.

2. Detector design
A four-layer gas detector of electrons and other charged particles has been developed. The detector scheme is shown in figure 1. The detector consists of a sealed housing with an input window of polyimide with thickness of 20 - 70 microns, depending on the experimental requirements. Inside the case there is an assembly of four consecutive flat proportional chambers, which includes the first cathode made of gold coated beryllium bronze wire 50 μm in diameter, four cathodes made of aluminum foil 70 μm thick, and four signal anodes made of gold plated tungsten-rhenium wires 20 μm in diameter. All cathodes are connected to high-voltage power, while the signal anodes to individual amplifiers.
A charged particle passing through a thin window produces ionization in four consecutive gas gaps separated by 70 μm aluminum absorbers decreasing the energy in all layers. The absorbers are simultaneously the cathodes of the system of four successive proportional chambers. Determining the number of events recorded by each chamber, we find the number of particles passed through different layers of gas and aluminum. The electron energy corresponding to the maximum of the spectrum is determined by the half-absorption length formula.

Registration of amplified signals from the wire anodes is performed using a CAEN DT5720 digital signal processor gated by a signal from the 1st detector channel. Figure 2 shows the waveforms of the recorded signals.

Before the experiment, the detector was filled by Ar + 20% CO₂ gas and was used without gas flowing. Figure 3 shows the counting characteristic of the detector at a detection threshold of 0.5 keV. It has been established that the plateau of the characteristic does not change during the experiment for 2-3 hours and is located at supply voltage of 2600 - 2700 V.
Figure 3. The counting characteristic of the detector.

Electron spectra were obtained with and without the $^{90}$Sr beta source, as well as a difference spectrum. An example of such spectrum is shown in figure 4 for the 1st channel of the detector.

Figure 4. Amplitude spectrum with $^{90}$Sr ($^{90}$Y) beta source for the first channel of the detector.

Determining the number of events in the spectra for the four detector chambers, we obtain the dependence of the electron flux attenuation on the transmission thickness, which is shown in figure 5.

According to the experimental electron flux function, $J_\beta (d)$ taken in the range of thicknesses $d$ of the absorber, where $0.5 J_0 \leq J (d) \leq 0.9 J_0$ and $J_0 \leq J (d = 0)$ we define two values $J_\beta (d_1), J_\beta (d_2)$. Then we calculate the attenuation coefficient using the formula:

$$\mu = \ln \left[ \frac{J_\beta (d_1)}{J_\beta (d_2)} \right] / (d_2 - d_1) = 8.383468 \text{ cm}^{-1}. \quad (1)$$

As $d_1$ and $d_2$ points, we take the first two experimental points that satisfy the above inequality. Then the thickness of the half attenuation layer is found

$$d_{1/2} = \ln 2 / \mu = 0.08268 \text{ cm}. \quad (2)$$
The energy at the maximum of the electron energy distribution is found using the empirical formula

$$E_{\text{max}} = \left(\frac{d_{1/2}}{0.095 A/Z^{2/3}}\right)^{2/3} = 1.48 \pm 0.10 \text{ MeV.} \quad (3)$$

The error is determined mainly by the accuracy of empirical formulas, which is estimated as ~ 7%.

![Graph](image)

**Figure 5.** Dependence of the number of electron events on the absorber thickness.

**Conclusions**

A four-layer gas detector for electrons and other charged particles is developed. A charged particle passing through a thin window produces ionization in four consecutive gas gaps separated by absorbers. The gas gain about of $10^4$ allows one to determine four signal amplitudes under the control of any combination of these signals. Simultaneous measurement of the ionization losses of the particle in the successive layers of the detector makes it possible to determine the energy of the passing particle.

**References**

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