Method for Reconstruction the Spectra of Short-Range Charged Particles in Stopped π^--Mesons Absorption by Nuclei

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In studies of the interaction of stopped negative pions with nuclei, attention is paid to the registration of short-range particles - helium isotopes, which are characterized by significant distortions of their energy spectra. The main source of distortion is the loss of energy of these particles in the thickness of the target, as well as incomplete registration of particles at low energies. Reducing the thickness of the target, as a way to reduce such errors, is not always justified, since it leads to a significant increase in the measurement time. Previously, we proposed a method for monitoring the beam using semiconductor detectors (SCD), based on the analysis of energy losses of pions for selecting events corresponding to stops in the thickness of the target.

The paper considers the possibilities of a semiconductor monitor system in the changes in the spectra of secondary charged particles, whose runs are comparable or less than the thickness of the target.

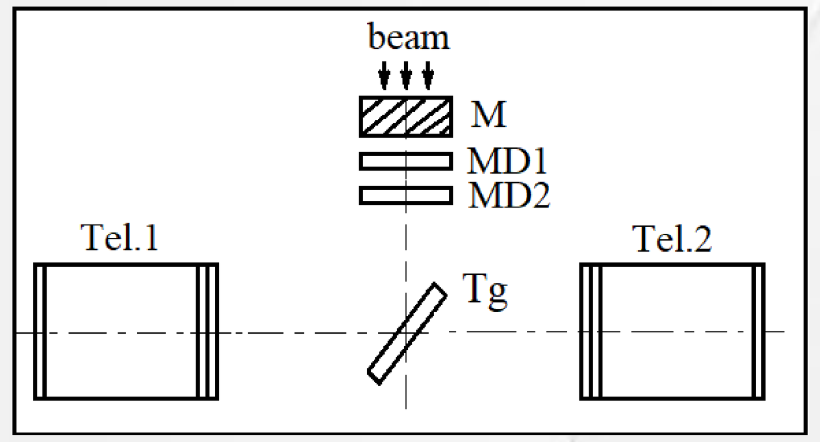

Fig. 1. *The scheme of the experimental setup.*

A beam of π^--mesons, passing through a moderator M and a monitor system consisting of two semiconductor detectors MD1, MD2 with a diameter of 32 mm and a thickness of 350, 250 µm, stops at the target Tg. The target is a plate of the material under study with a diameter of 32 mm and a thickness of about 0.1 g/cm^2. Secondary charged particles formed during the absorption of pions by the target nuclei are recorded by the Tel.1 and Tel.2 semiconductor telescopes.

The analysis of the spectrometric information from each of the detectors of the monitoring system allows us to determine the depth of the pion stop in the target. The relationship between the energy release and the stopping depth most fully reflects the probability density distribution W (h, ε) of the pion stopping at the depth h with the energy release ε in the second monitor in the MD2 detector.

The type of distribution of the stop density W (h, ε) depends on the thickness and energy resolution of the detectors, the geometry of the installation, the characteristics of the beam, and the overlays of spectrometric signals. Knowing the division distribution W (h, ε), it is possible to determine the remaining parameters of the system aiming and, in particular, get information about its spatial (coordinate) resolution.

The measurement of the distribution of stops was performed using the decay reaction of the stopped positive pions $\pi^+ \to \mu^+ + \nu_\mu$. The fixed energy of muons $E_\mu \approx 4.12$ MeV is sufficient for their registration from any point of the target and allows us to determine the stopping depth of pions h from the residual anergy of the muon E_{Tel} in the telescope: $h = R(E_\mu) - R(E_{Tel})$, where $R = R(E_\mu)$ is the run curve for the muon.

The results of calibration measurements for the second MD2 monitor are shown in **Fig.2**. Here we show a two-dimensional distribution of pion stops over the variables h and ε for a silicon target with a thickness $W \approx 440$ µm. The depth h is plotted along the X axis, and the energy release ε in the MD2 detector is plotted along the Y axis.

The tone of the shaded sections of the graph is proportional to the density of stops

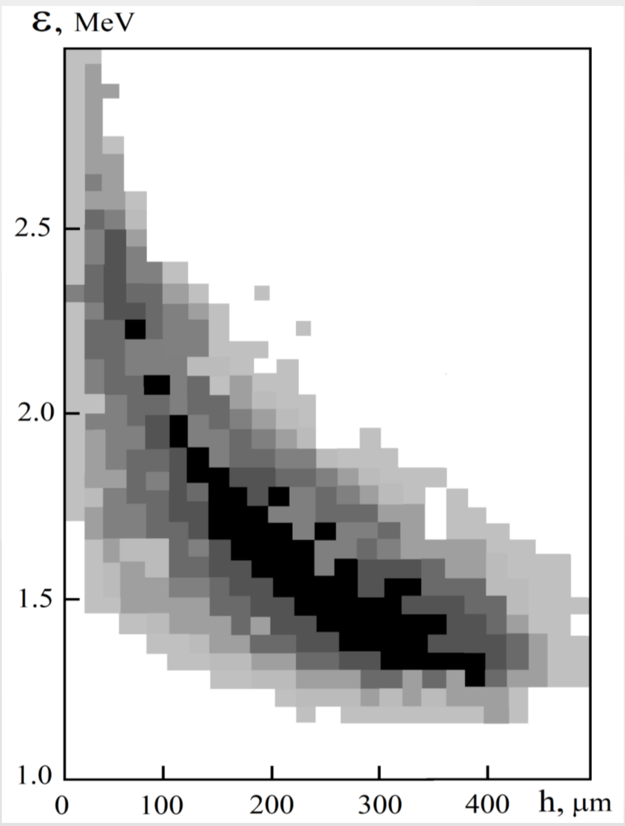

Fig. 2 *The distribution of pion stops over the variables depth* ***h*** *in target and* ***ε*** *in MD2.*

It can be seen from the **Fig.2** that at high energy releases in the monitor, the stops of pions are concentrated near the surface layer of the target. With a decrease in ε, the distribution shifts to the region of greater depths. At the same time, the uncertainty of the place where the peony stops increases.

If this distribution is normalized by the total number of events, then it can be used as an approximation to the true distribution of the probability density of stops W (h, ε).

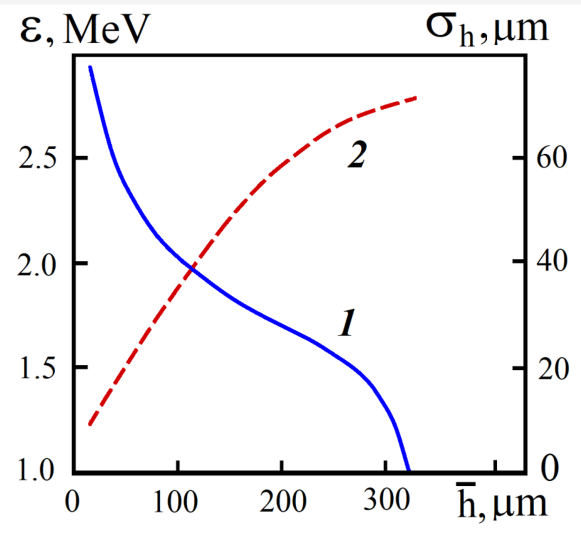

Fig. 3

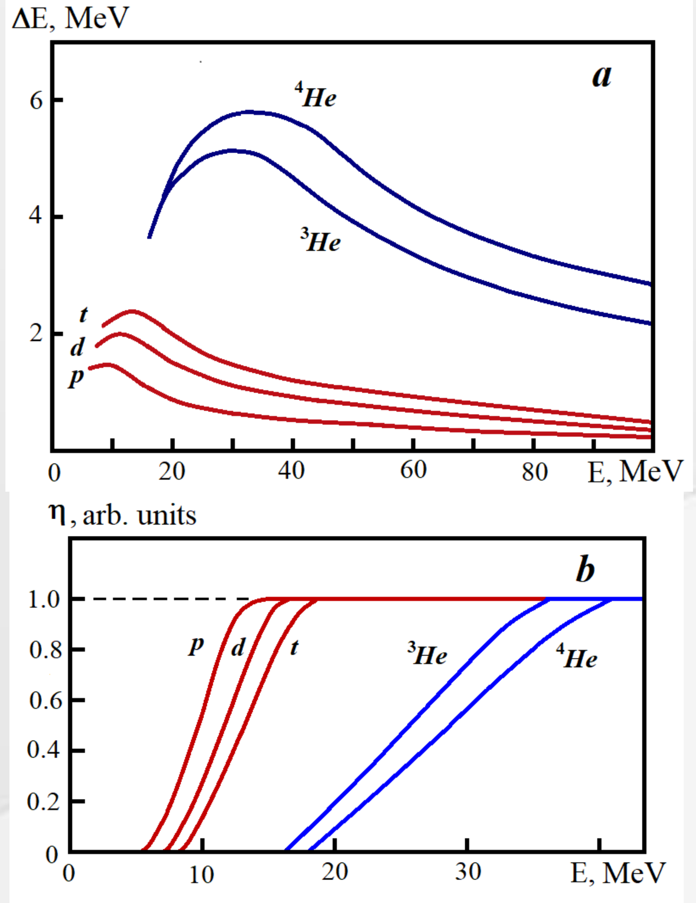

Fig. 4. *The dependence of the energy resolution (**a**) and the efficiency coefficient (**b**) on the particle energy.*

Fig. 3 shows the dependence of the average stopping depth of the pion in the target h on the readings ε of the monitor MD2 (**curve *1***). To reduce the influence of statistical measurement errors, the calibration dependence is averaged over the entire set of experimental points. The curves obtained during measurements with different telescopes are well crosslinked, which indicates the absence of systematic errors. **Fig. 3** also shows the dependence of the value of the standard deviation σh on the average stopping depth of the pion h (**curve *2***).

To study the accuracy characteristics of the technique, numerical calculations of the errors in the recovery of the spectra of monoenergetic particles ***p, d, t***, ^{3,4}**He** in the energy range up to 100 MeV were performed.

In **Fig. 4a** and **4b** show graphs of the dependences of the energy resolution and the efficiency coefficient K_f on the energy of particles obtained for one from the telescope.

Two regions are clearly identified on both graphs, one of them corresponds to high energies when particles are recorded from the entire depth of the target, and the other corresponds to energies at which particles are recorded only from a part of the target. In the first area, the efficiency is close to unity. In the low-energy region, the efficiency drops sharply, and the error in determining the yield of such particles increases.

For energies of 5, 7, 8, 18, 20 MeV for ***p, d, t***, ^{3,4}**He**, respectively, the maximum error in determining the reaction yield regardless of the type of particles is about 4%. The decrease in the energy resolution curve at low E is explained by the fact that short-range particles are recorded mainly with energy releases close to the upper grant of the monitor system readings, i.e. in the region of the best spatial resolution.

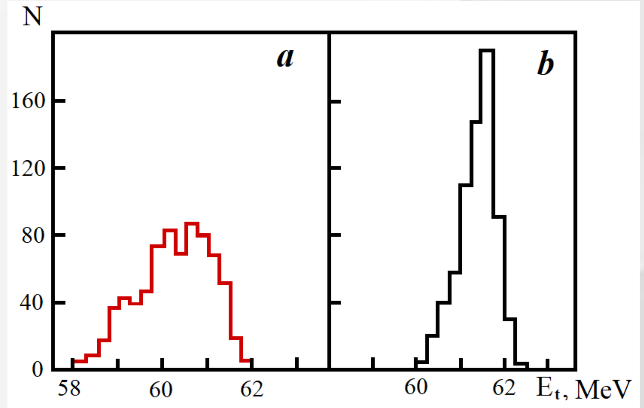

Fig. 5

Fig. 5 shows the spectra of monoenergetic tritons from the reaction $\pi^- + {}^6Li \to t + t$, which demonstrate the correctness of calculations of the energy resolution. The energy distribution recorded by one of the telescopes is shown on the left, and on the right, obtained using the aiming system. We note a significant improvement in the energy resolution and a good agreement between the experimental and calculated values.

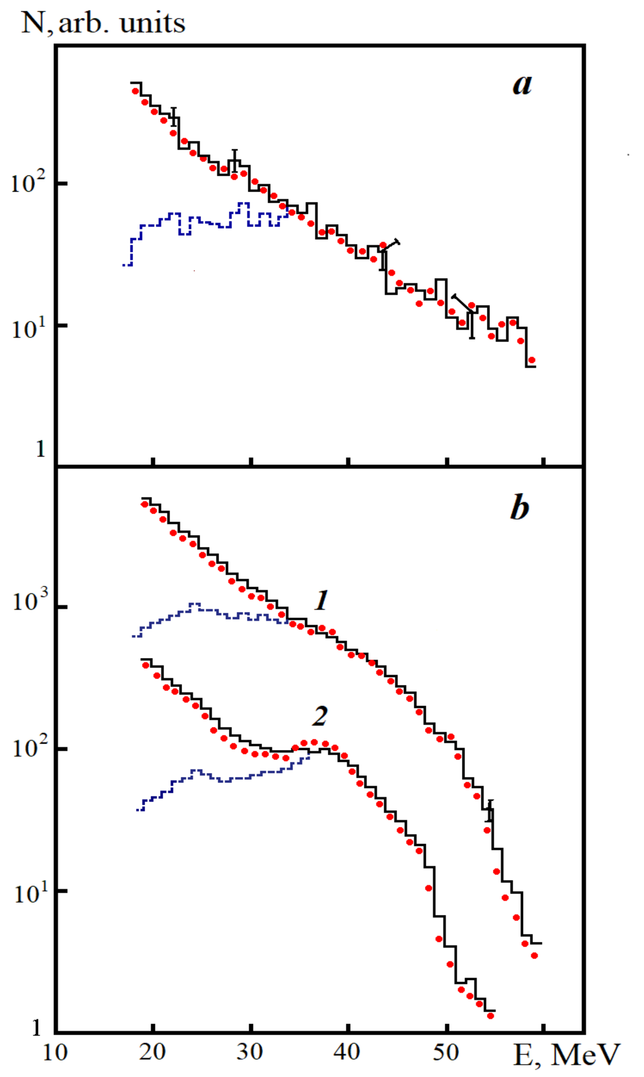

Fig. 6

Fig. 6a compares the results of measuring the spectrum of **α-particles** formed during the absorption of pions by ^{28}**Si** nuclei in the case of thick (h≈ 440 µm, solid histogram) and thin (h ≈ 80 µm, dots) targets. The dotted line shows the distribution of the registered energies, which clearly demonstrates the area in which the effect of particle loss in the target substance is manifested. There is a good agreement of the measurement results in the low-energy part of the spectrum.

Fig. 6b (1, 2) show the inclusive spectra of **α-particles** formed during the absorption of pions by ^{6,7}**Li**. The points here represent the distribution of particles obtained as a result of numerical modeling, taking into account the distribution of stops W(h, ε). A good agreement of the results obtained by both recovery methods is visible. Small differences in the area of low energies can also be associated with the inaccuracy of the description of W(h, ε).

Conclusion

A method for reconstructing the spectra of short-range charged particles in experiments to study the absorption processes of stopped π^--mesons by nuclei is presented. The method is based on the possibility of measuring the depth of the pion stop in the target by the amount of energy loss in the detector of the monitor system. The use of this approach makes it possible to increase the efficiency of research by combining the requirement of maximum statistical security of measurement results with the advantages of experiments on thin targets.