NUCLEAR TECHNOLOGY
EXPERIMENT

TWO-COORDINATE SCINTILLATION HODOSCOPE ON THE BASIS OF THE FEU-85 EXPERIMENT SPASCHARM AT THE U-70 ACCELERATOR COMPLEX

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Abstract. A two-coordinate scintillation hodoscope is presented, assembled using domestic photoelectron multipliers FEU-85 and highly sensitive formers developed and manufactured at IHEP. The design features are shown and its characteristics are given when operating as part of an experimental setup on beams of channel 14 of the U-70 accelerator complex.

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1. INTRODUCTION

In the multi-purpose experiment SPASCHARM (spin asymmetries in charmonium formation) At the National Research Center “Kurchatov Institute” – IHEP, on channel 14 of the U-70 accelerator complex, an extensive program is currently ongoing research [1]. The SPASCHARM experimental setup [2] includes four stations of two-coordinate scintillation hodoscopes, which are located at a fixed distance from each other along the beam axis before it enters the target [3]. These detectors are designed to calculate the coordinates of the point of interaction of the beam particle with the target substance.

This paper describes the original technical solutions used in the development of the design and manufacture of the first station's hodoscope, and provides some experimental results characterizing the importance of this detector for qualitative data analysis.

2. HODOSCOPE DESIGN

The required geometric dimensions of the sensitive area and the coordinate resolution of the hodoscope are determined by the beam size at its location at a distance of ten meters from the center of the polarized target. Based on the results of experiments that were conducted earlier on channel 14 [4], it was decided to manufacture a hodoscope covering an area of about 5×5 cm^2 and determining the coordinate of a charged particle with an accuracy of not worse than 2 mm.

The sensitive area of each of the coordinate planes of the hodoscope consists of 24 scintillation strips made of polystyrene and has dimensions of 50×2×4 mm^3 (corresponding to the length, width, and thickness along the beam). All strips are wrapped in aluminized mylar with a thickness of 25 μm and fit tightly against each other. The planes are located one after another at a minimum distance. Optical light guides made of plexiglass, having the same cross-section as the scintillators, are glued to them with optical epoxy resin and are also wrapped in aluminized mylar along the entire length up to the junction with the photodetector.

As a detector for the scintillation signal, an inexpensive and reliable small-sized photomultiplier tube PMT-85 (photocathode diameter is 25 mm with a bulb length of 107 mm) with an antimony-cesium photocathode, which has high spectral sensitivity and low dark current, was selected. Its temporal and spectrometric parameters are well studied [5] and are suitable for successfully solving the assigned task.

The light-proof aluminum housing of the hodoscope has a square shape. Inside it, along each side, 12 PMTs are placed, separated by thin textolite partitions. Resistive high-voltage voltage dividers are manufactured according to the scheme recommended for this type of PMT. The resistance of each of them is about 2.2 MΩ. Power supply for all PMTs is provided from a common high voltage source. For individual adjustment of each counter, multi-turn potentiometers of the SP-37B type (1 W, 2.2 MOhm) are used, connected in series with the dividers. They are mounted on two identical printed circuit boards. The axes of the potentiometers are brought out to the front panel of the module designed for them. High voltage from the source (in operating mode it is 1100 V) is supplied to the connector installed on the rear panel of this module. There are also two multi-pin connectors of the RM32 type, from which the supply voltages for the PMTs are transmitted via multicore cables to two similar connectors mounted on the hodoscope housing. The high-voltage source and adjustment module are installed in the electronics rack in the hut with the recording equipment of the data acquisition system, where signals from the hodoscope arrive. This technical solution allows for adjusting individual channels of the hodoscope directly during beam operation.

An important feature of the hodoscope is the use of highly sensitive NPF-12 shapers, developed and manufactured at IHEP [6], placed close to the photomultiplier tubes inside the housing. This solution made it possible to reduce their operating voltages and, as a result, decrease dark currents and weaken loading effects. A test with an LED showed that with such a connection, each hodoscope channel can register pulses with a frequency of up to 10 MHz without loss of efficiency. Considering that during data acquisition the beam intensity does not exceed $3 \cdot 10^{6}$ particles/s, there is no need for additional power supply to the last PMT dynodes. Power for all shapers is provided from a negative polarity voltage source with a nominal value of 6 V, located next to the hodoscope. The output signals of the shapers are connected to SR-50 connectors placed on both sides of the hodoscope housing and are transmitted via coaxial cables with a wave impedance of 50 Ohm to the recording equipment of the data acquisition system. Here they are converted into paraphase LVDS (low-voltage differential signaling) pulses and arrive at the inputs of the time-to-digital converter (TDC) EM-4 in the "EuroMISS" system crate [7]. The photograph of the hodoscope with the cover removed, shown in Fig. 1, clearly illustrates the arrangement of all its components inside the housing.

3. EXPERIMENTAL RESULTS

Data obtained during the test session in December 2023 using a 50 GeV/c proton beam extracted to channel 14 was analyzed. Signals from all detectors of the setup were recorded by a common trigger formed from the coincidence of signals from three scintillation beam counters.

Figure 2 shows the total spectra of signal registration times from all hodoscope channels relative to the trigger for the x coordinate (Fig. 2a) and for the y coordinate (Fig. 2b) in a 200 ns time window.

The analysis of results was conducted for all events in the time spectra within a 20 ns time window (from 90 to 110 divisions of the abscissa scale). Beam profiles for both hodoscope coordinates are shown in Fig. 3.

Figure 4 shows normalized multiplicity distributions – probability distributions of the number of hits in each plane per trigger in a given time window. These histograms indicate that the hodoscope inefficiency (zero multiplicity) is about 2.8% for the coordinate x and about 2.0% for the coordinate

y . However, if when calculating efficiency we add the condition of mandatory presence of a track in the central beam area of 10×10 mm ^{2} , reconstructed by other hodoscopes of the setup, then for both planes the value obtained is about 99%.

Figure 5 shows correlations of signals in two coordinates in the channels of the first station hodoscope (horizontal axis) with signals from the scintillation fiber hodoscope (vertical axis) located further along the beam at a distance of 6.75 m.

4. CONCLUSION

The two-coordinate scintillation hodoscope with a 2 mm discretization step presented in this paper demonstrated high operational reliability and parameter stability when working as part of the SPASCHARM experimental setup on extracted beams of charged particles from the U-70 accelerator complex . The efficiency of each hodoscope plane is higher than 97%. Manufactured entirely from domestic components in the express workshop of the IHEP physics laboratory, the hodoscope has low cost and is easy to maintain.

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FIGURE CAPTIONS

Fig. 1. Photograph of the two-coordinate scintillation hodoscope as part of the SPASCHARM experimental setup on channel 14.

Fig. 2. Total spectra of signal registration times from all hodoscope channels relative to the trigger: **a** – for coordinate x , **b** – for coordinate y .

Fig. 3. Beam profiles – statistics of the number of events in the hodoscope channels: **a** – for coordinate x , **b** – for coordinate y .

Fig. 4. Normalized multiplicity distributions: **a** – for coordinate x , **b** – for coordinate y .

Fig. 5. Correlations of signals in channels of two hodoscopes: **a** - by coordinate x , **b** - by coordinate y . The axes show channel numbers: horizontal axes - hodoscope of the first station, vertical axes - scintillation fiber hodoscope.

Fig. 1.

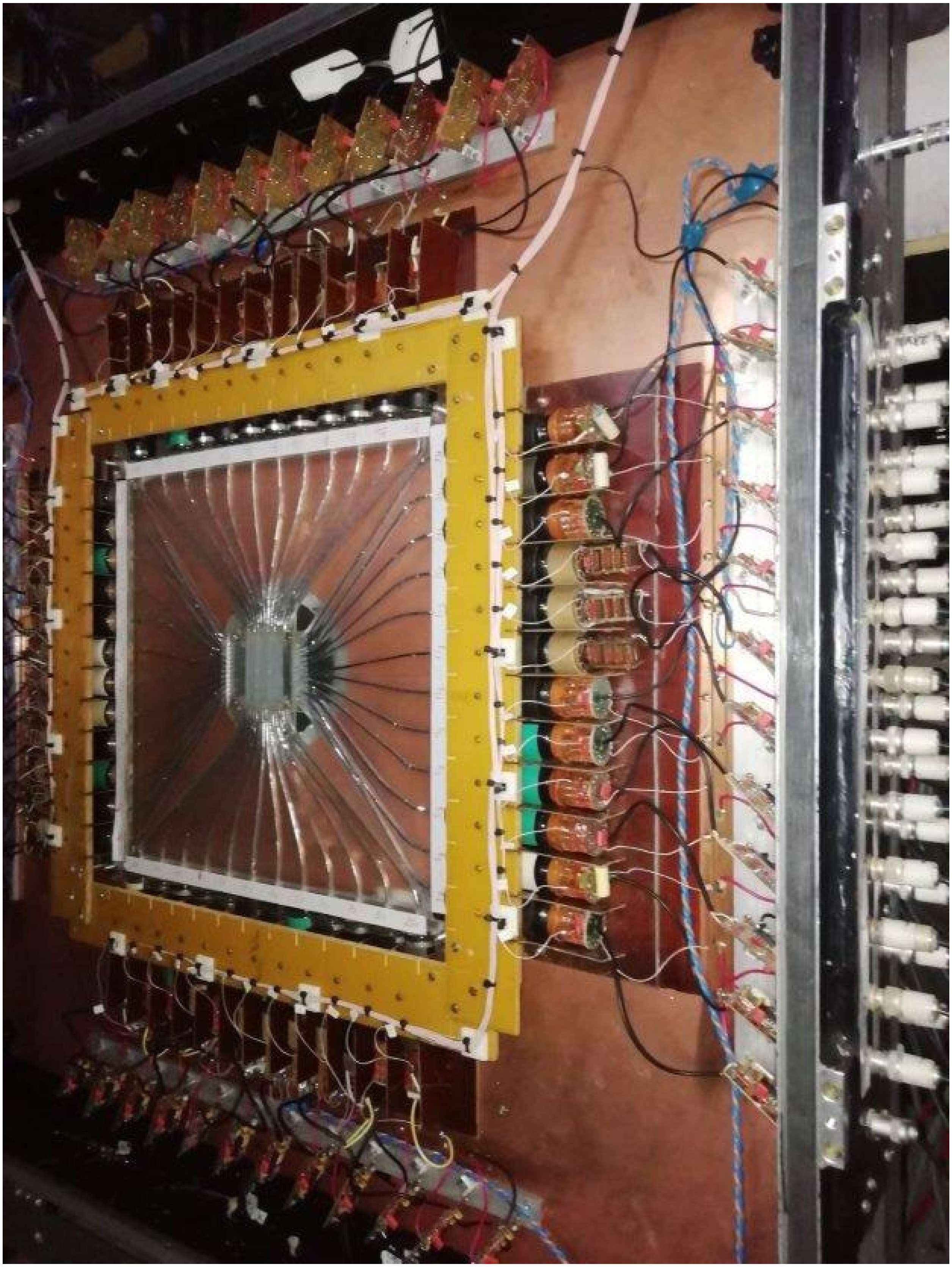


Fig. 1.

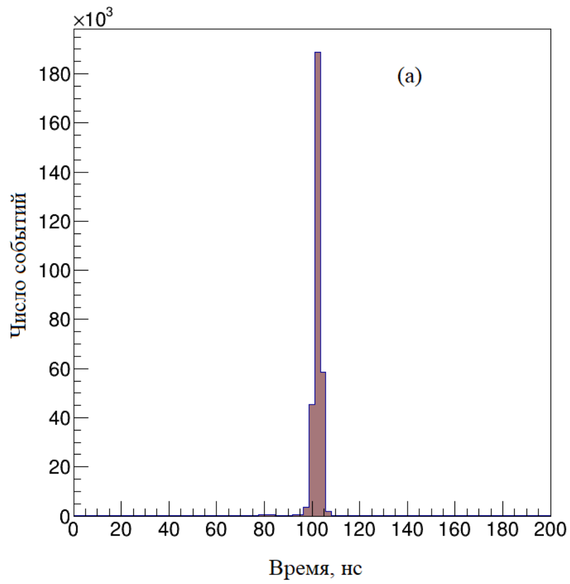

×10³
(а)
Число событий
Время, нс
×10³
(б)
Число событий
Время, нс

Fig. 2.

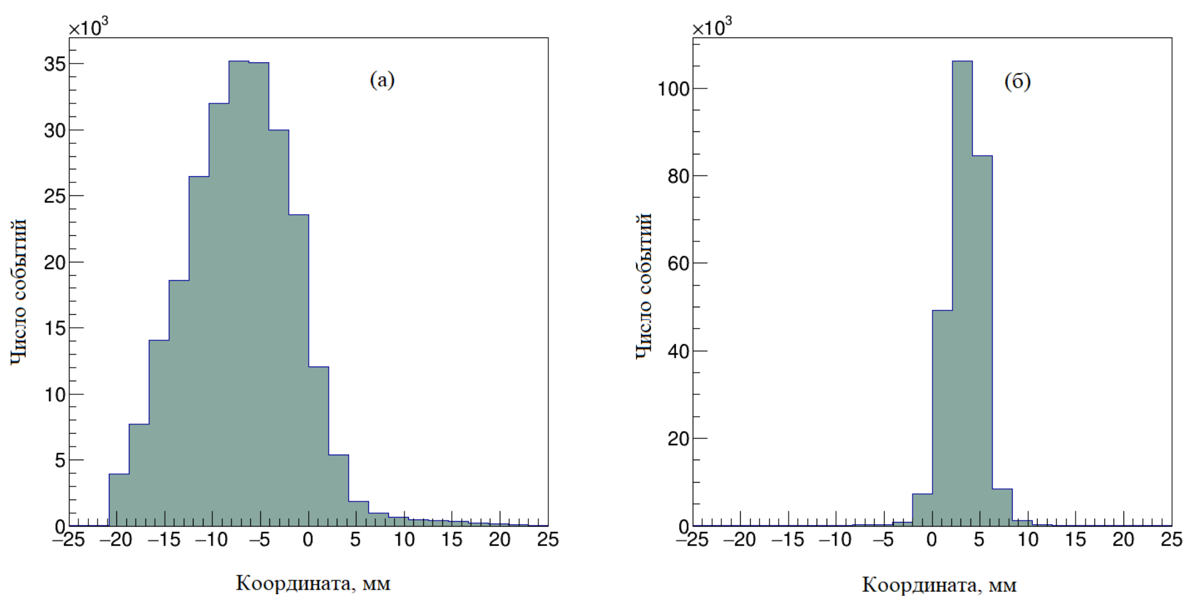
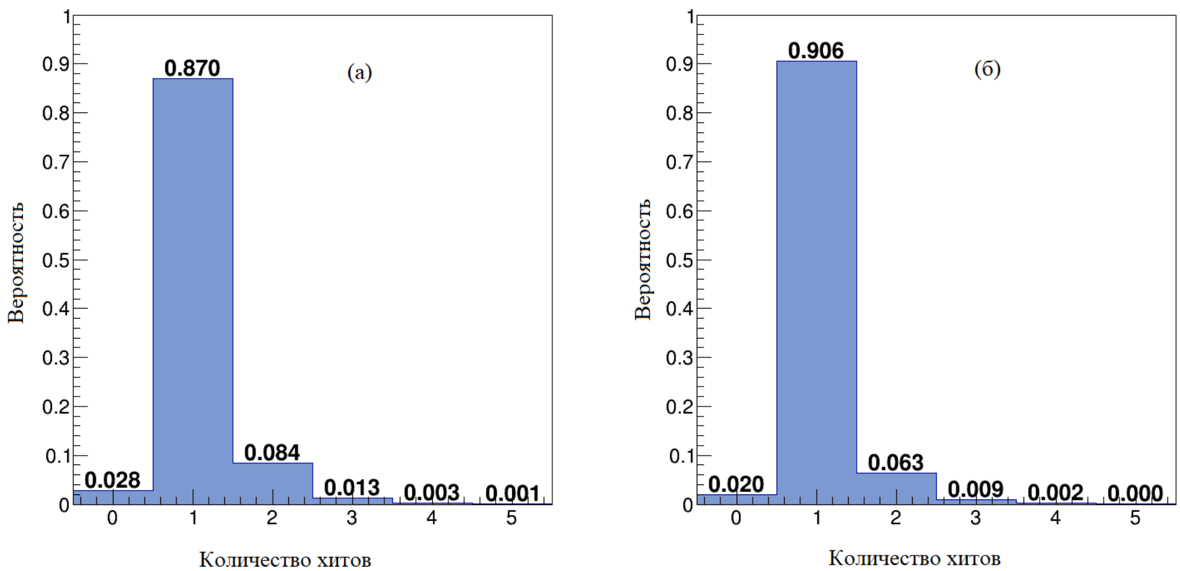
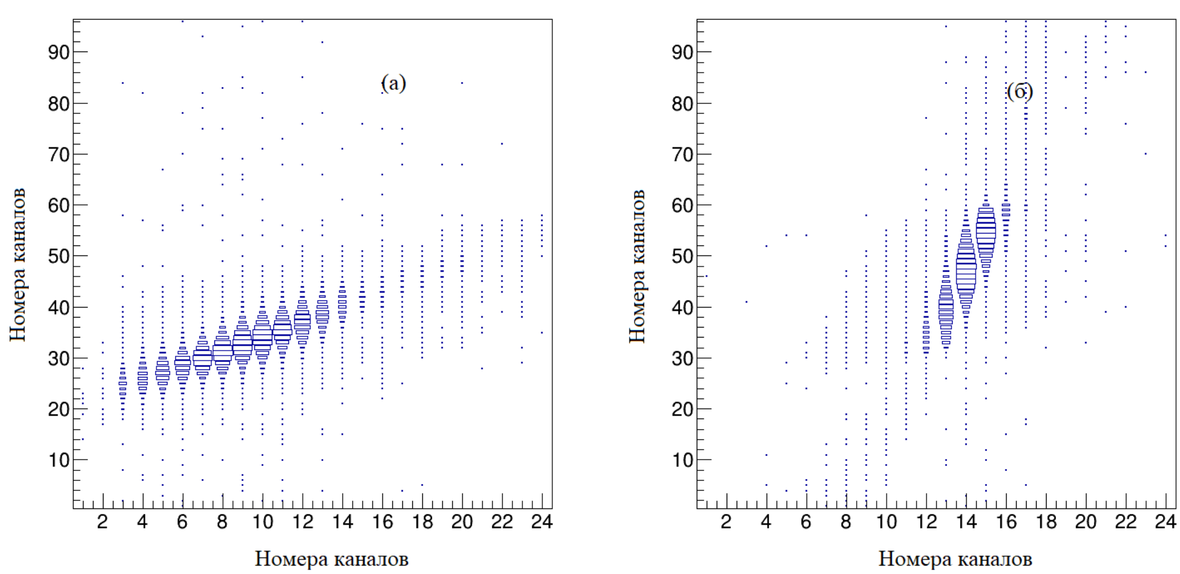

×10³
(а)
Число событий
Координата, мм
×10³
(б)
Число событий
Координата, мм

Fig. 3.



Вероятность
Количество хитов
(а)
0.028
0.870
0.084
0.013
0.003
0.001
(б)
0.020
0.906
0.063
0.009
0.002
0.000

Fig. 4.



Номера каналов
Номера каналов
(а)
(б)

Fig. 5.