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L.G.Afanasyev, M.A.Ivanov, V.V.Karpukhin, V.I.Komarov, A.V.Kulikov*, V.V.Yazkov*

WIDE APERTURE SCINTILLATION HODOSCOPE WITH FEU-143 PHOTOMULTIPLIERS

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*Unstitute of Nuclear Physics, Moscow State University, Moscow, Russia

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A high time resolution is an indispensable condition in the experiment on $\pi^+\pi^-$-dimesoatom research [1] undertaken at the "Positronium" setup [2]. High rate of accidental coincidences between two arms of magnetic spectrometer limits tolerant beam intensity and a speed of data accumulation.

In this paper scintillation hodoscopes are described that have improved 3 times the setup time resolution. Presented below characteristics were obtained at Protvino 70 GeV accelerator during a usual statistics run.

HODOSCOPE CONSTRUCTION

The scheme of experimental setup [2] and the position of hodoscopes H are seen in Fig.1.

The hodoscope consists of 8 scintillation elements each of 1400x56x56 mm dimensions (Fig.2). The elements are oriented horizontally and form 1400x448 mm vertical wall. The scintillators are viewed from both ends by photomultipliers FEU-143 (40 mm photocathode diameter) without lightguides. Eight photomultipliers at each side of the hodoscope have a mutual magnetic shield consisting of double iron housing and a permalloy screen. Besides, every PM has its individual permalloy screen. The photomultipliers have an optical contact with scintillator and are pressed to it by bolts screwed into the scintillator ends. The hodoscope elements together with magnetic shield rest on a rigid adjustable frame.

Polystyrol based scintillator doped with p-terphenyl and POPOP was produced in Laboratory of Nuclear Probl ms, JINR, its characteristics being presented in [3]. The scintillator was manufactured as blocks and then was sawed into 700x56x56 mm bars (a length was limited by the size of a bath). After polishing of all sides the bars were

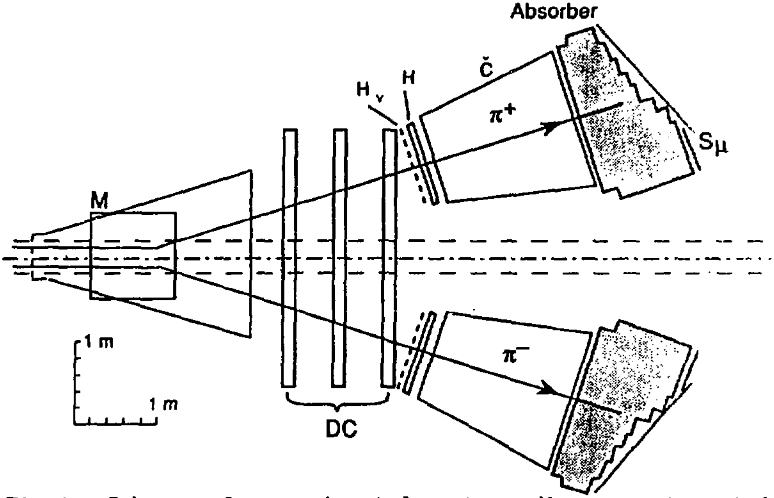


Fig.1. Scheme of experimental setup. M – spectrometric magnet, DC – drift chambers, H_V – hodoscopes with vertically oriented elements, H – hodoscopes described in this paper, C – gas Cherenkov counters, S_μ – counters for detection of muons

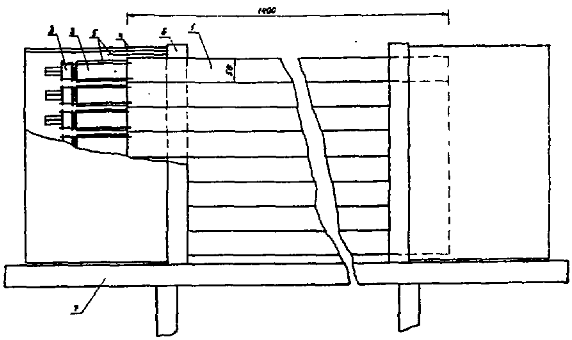


Fig.2. Design of a hodoscope. 1 – scintillator element, 2 – photomultiplier, 3 – HV divider, 4 – iron magnetic shield, 5 – permalloy screen, 6 – light protection frame, 7 – rigid base frame

welded in pairs to get 1400 mm length (welding was done in Physical Institute of Academy of Sciences using developed there technology).

ELECTRONICS

A scheme of electronics is presented in Fig.3. Only the hodoscope branch of the whole experiment electronics is shown.

Signals of two photomultipliers placed at the opposite ends of a hodoscope element get to a mean timer MT [4]. It includes two constant fraction shapers, a coincidence circuit and a scheme that ensures independence of the signal time position on coordinate of particle passage through scintillator. The mean timer module has also analogue outputs for both channels.

To remove the dependence of time on coordinate at the level of tens picosecond a precise tuning of mean timers is needed. This was done with a generator and a variable delay that imitated a change in time of light transporting in scintillator. A quality of tuning may be characterized by a mean square deviation σ_{MT} of the output signal time position while changing a delay between channels. Those modules were selected that had $\sigma_{MT} < 100$ ps in the range of delay ±10 ns (that corresponds to ±1400 mm change in coordinate). A mean value of σ_{MT} for 16 selected modules was 55 ps. For one of elements the results were checked with cosmic rays at a test stand where trigger counters of 50x50x50 mm dimensions were moved along the scintillator.

In real experiment conditions 8 mean timers were used for each of two hodoscopes (one module per scintillation element), their outputs got together in two "OR"'s. The summed signals, strobed by the first level trigger, came to "start" and "stop" inputs of TDC. The output time code got

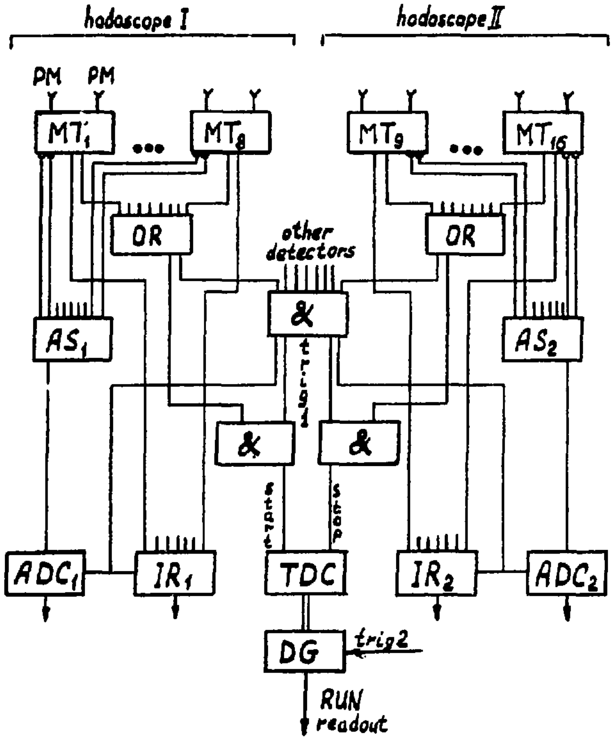


Fig.3. Scheme of hodoscope electronics. (See the text for explanation.)

to a module DG ("digital gate") that, in the case of code being inside preset limits, produced a signal to start up a readout system. The limits were set by the CAMAC controller. Input registers IR served to record the numbers of hit elements.

Preliminary alignment of delays between summed hodoscope channels was made by appropriate choice of cable lengths. Precise values of relative delays between channels were obtained in a special calibration measurement using e^+e^- trigger: time shifts between every element from the first hodoscope and a single element from the second one (and vice versa) were measured [5]. Obtained thus table of relative delays was loaded to computer for further corrections of time values.

High voltage at photomultipliers was kept constant with an accuracy $\leq$ 2V to ensure stability of time parameters.

The measurement of amplitudes was done after summing (in AS modules) of PM signals from mean timer analogue outputs. The PM high voltage values were set so that all PM's had equal mean amplitudes at particle crossings through the centers of scintillators.

All used modules, except specially developed DG and AS, are serially produced by JINR electronics facility.

MEASUREMENT CONDITIONS

Presented below results were obtained after the handling of data derived during an accelerator run in experiment on the $\pi^+\pi^-$-dimesoatom observation.

Particles produced at the accelerator internal target came to the setup (Fig.1) through the straight line 40 m channel. The momentum range of magnetic spectrometer was from 0.8 to 2.4 GeV/c. Counting rates were about $2\cdot10^5 s^{-1}$ in every spectrometer arm. Trigger could arise from e^+e^--pairs, $\pi^+\pi^-$-pairs or in a one-arm mode.

TIME RESOLUTION

The hodoscope time resolution was investigated in e^+e^- and $\pi^+\pi^-$ trigger modes. Those events were excluded from analysis if there were more than one particle detected in every arm of spectrometer.

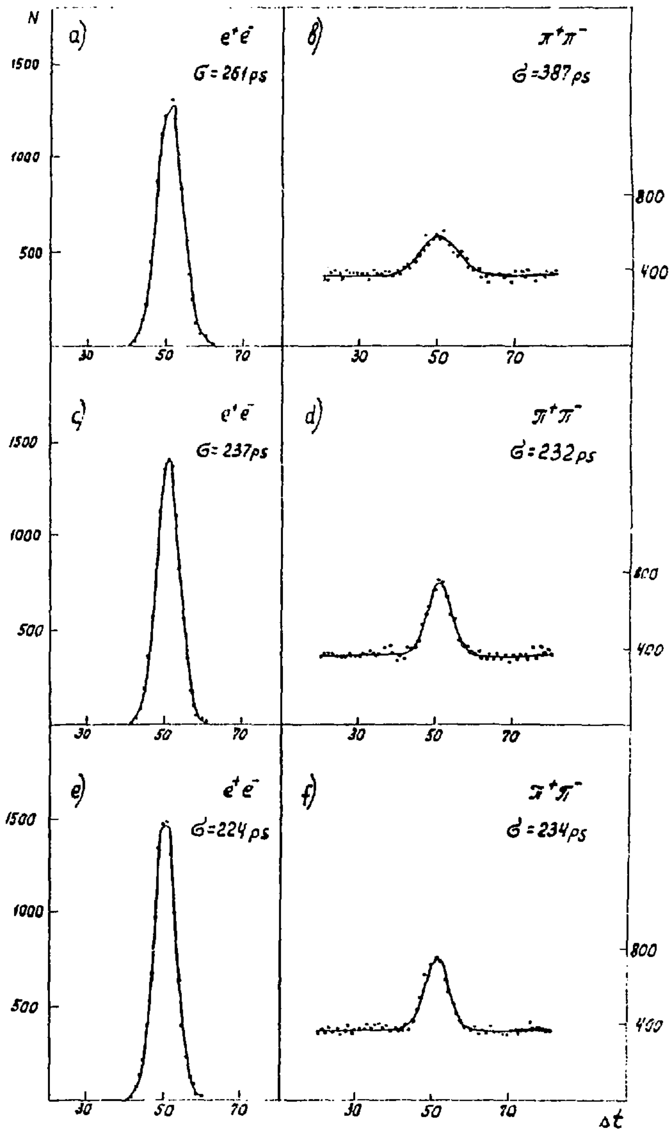
The shape of a coincidence peak is well described by the Gaussian distribution. But the pion pairs time distributions content a significant background caused by accidental coincidences, therefore time spectra were fitted by a sum of uniform and Gaussian distributions.

Fig.4a and 4b present distributions over two hodoscopes time difference Δt at e^+e^- and $\pi^+\pi^-$ pairs detection after corrections of relative delays in the channels. These and further corrections were made at off-line data handling. (Accidentals used for uniform background fitting extend as long as ±4 ns from the peak and are shown in the figure partly). The pion distribution is remarkably wider ($\sigma_{\Delta t}$=387 ps) than the electron-positron one ($\sigma_{\Delta t}$=261 ps). This is caused by a difference in momenta of two pions that leads to their different time of flight along the 45 m way from a target to detectors. This effect is negligible for electrons.

It is interesting to note that even a little difference (up to several cm) of the individual trajectory lengths for particles at the region between magnet entrance and detectors produces a noticeable widening of both pion and electron distributions. Time distributions obtained after time of flight corrections taking into account both momenta and trajectory lengths (calculated at event reconstruction) are shown in Fig.4c and 4d.

Next corrections to Δt values were applied using [illegible] amplitudes. A dependence of time on amplitude [illegible] manifest due to nonideal performance of constant [illegible] shapers that are a part of mean timer. The

Fig.4. Time difference of two hodoscope signals:
a,b - after corrections on relative delays between channels
c,d - after TOF corrections
e,f - after amplitude-time corrections


N
a)
e^+e^-
σ = 261 ps
b)
$\pi^+\pi^-$
σ = 387 ps
c)
e^+e^-
σ = 237 ps
d)
$\pi^+\pi^-$
σ = 232 ps
e)
e^+e^-
σ = 224 ps
f)
$\pi^+\pi^-$
σ = 234 ps
1500
1000
500
800
400
30
50
70
Δt

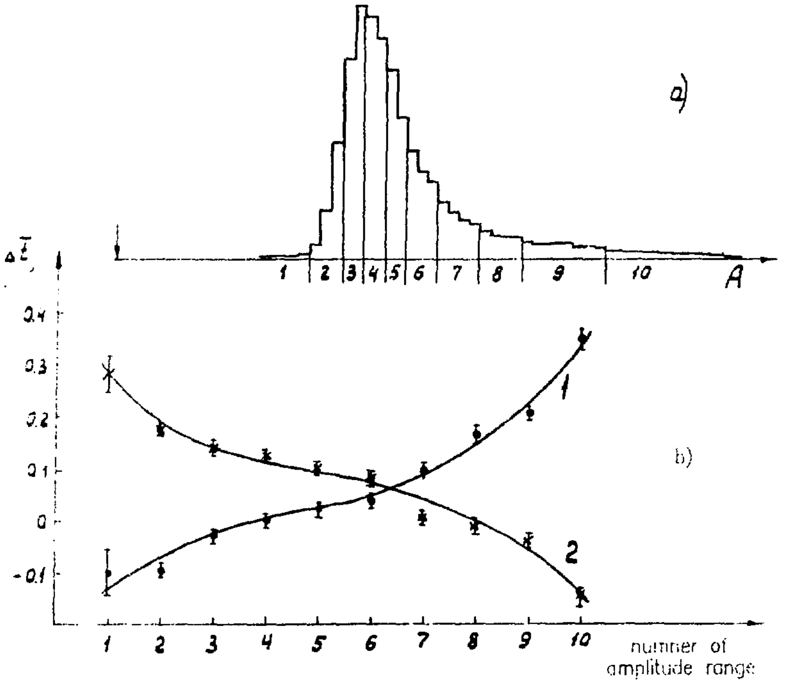


Fig.5. Dependence of time on signal amplitude. a) amplitude distribution for electrons. An arrow shows the pedestal position; b) mean Δt value for separate amplitude ranges shown in Fig.5a. Curve 1 is for the "start" hodoscope, 2- for the "stop" one. One channel corresponds 80 ps

dependence of Δt mean value on signal amplitude is presented in Fig.5.

The amplitude corrections lead to values $\sigma_{\Delta t}$=224 ps for e^+e^- pairs and $\sigma_{\Delta t}$=234 ps for $\pi^+\pi^-$ pairs. Corresponding distributions are given in Fig.4e and 4f.

It was tested if the signal time position depends on coordinate of particle crossing the scintillator. In Fig.6 one can see a change of Δt mean value with coordinate for cases when PM's are switched on at only one or another side of the hodoscopes and for normal total switching on.

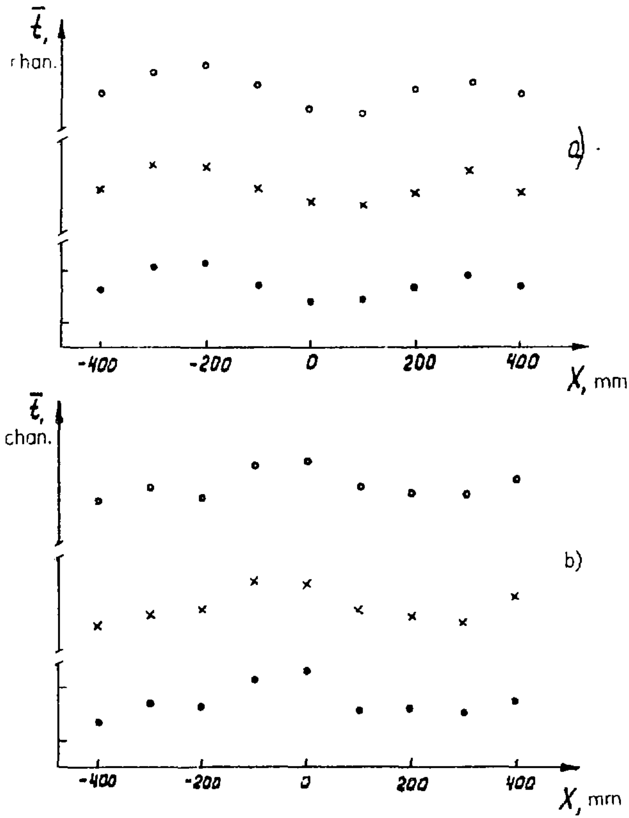


Fig.6. Time on coordinate dependence for the 1-st (a) and the 2-d hodoscopes. o - only left PM's, × - only right PM's, • - all PM's are switched on

The same shape of dependence for all three modes for every hodoscope confirms that the time on coordinate dependence is due to nonideal coordinate compensation in mean timer modules but the scale of this effect is so small (deviation is $\sigma \approx 20$ ps) that coordinate correction was not applied.

A change of coordinate in Fig.6 (and further in Fig.7) is limited by ±(400÷500) mm from the center as the hodoscope edges did not give coincidences because of less aperture of other detectors (the hodoscopes were designed for future configuration of the setup).

Tab.1 accumulates all data on time resolution $\sigma_{\Delta t}$ in ps for the two hodoscopes time difference with consequently applied corrections:

Table 1

Type of corrections	$\sigma_{\Delta t}$ for e^+e^-	$\sigma_{\Delta t}$ for $\pi^+\pi^-$
no corrections	443±3	509±30
relative delays in channels	261±2	387±22
time of flight	237±2	232±9
signal amplitudes	224±2	234±8

As both hodoscopes are identical, the resolution σ_t of one hodoscope is $\sigma_t = \sigma_{\Delta t}/\sqrt{2} = 158$ ps.

Instability of timing manifests through a drift of the coincidence peak position and through the peak widening due to different drifts in the channels. To test the position and the shape of the time peak there was written some number of e^+e^- pairs (tagged by a mark) in every accelerator cycle (besides detected in experiment $\pi^+\pi^-$

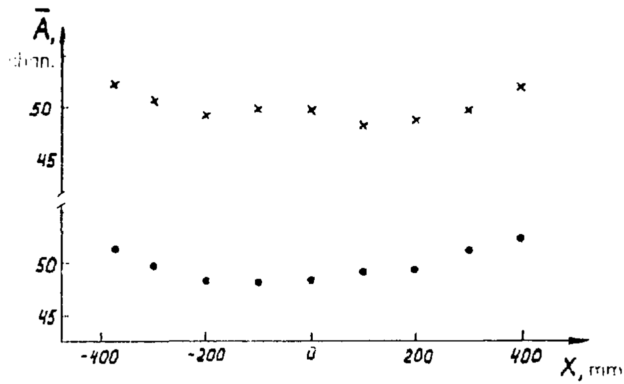


Fig.7. Dependence of signal amplitude on coordinate for every of hodoscopes

pairs), there were no accidentals among these events practically. The schemes "OR" used in this run only were not stable enough: a drift of the mean value Δt during 22 days of measurements was ±0.3 ns, in some channels it reached 1 ns. To reduce the influence of the drift the relative delays between channels were found for every recorded magnetic tape using electron-positron pairs. In this case the time resolution is influenced by the drift for duration of one tape writing only, the last took about 3 hours. The widths of distributions obtained for various tapes differed for ±12% from presented in Tab.1. values.

AMPLITUDE CHARACTERISTICS

Though the main aim of hodoscope development was to obtain a high time resolution, their amplitude characteristics are also of interest, in particular the separation of pions and protons by ionization losses.

Fig.7 shows a dependence of the hodoscope mean amplitude on coordinate. The measurements were done for

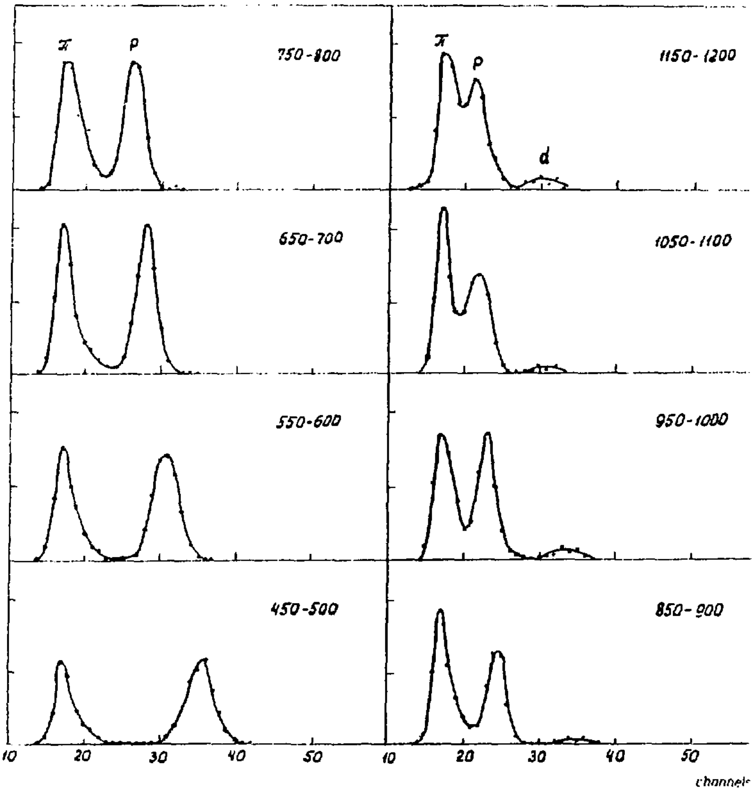


Fig.8. Amplitude spectra of positive particles. The numbers indicate the ranges of momenta in MeV/c

electrons as their dE/dx value is practically constant in the available momentum range.

When the trigger was produced by one arm of spectrometer there were obtained positive particle amplitude spectra at different momenta. To widen available momentum range, the value of magnetic field was being changed. As is seen from Fig.8, the pion and proton spectra are completely separated at momenta under 700 MeV/c, in the range 700<P<1000 MeV/c the spectra are partly overlapped and at higher momenta a strong overlapping of the spectra does not allow to separate pions and protons using ionization losses. At momenta above 850 MeV/c an admixture of deuterons in the beam is seen. The correction of amplitude by coordinate was not applied for spectra in Fig.8.

CONCLUSION

The hodoscopes described in this paper made it possible to obtain in real experiment conditions the time resolution $\sigma_{\Delta t}$=224 ps for coincidences of two hodoscopes. At momenta below 1000 MeV/c a separation of pions and protons by their ionization losses is also provided.

The results obtained show it is feasible to use photomultipliers FEU-143 for production of wide aperture hodoscopes with good time and amplitude parameters.

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