ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E1 - 5098

R.G. Astvatsaturov, M.N. Khachaturyan,

I.F. Kolpakov, V.A. Smirnov

ЛАБОРАТОРИЯ ВЫСОКИХ ЭНЕРГИЙ

TIME-OF-FLIGHT AND COORDINATE MEASUREMENTS IN A 130 CM SCINTILLATION COUNTER

1970

E1 - 5098

R.G. Astvatsaturov, M.N. Khachaturyan,

I.F. Kolpakov, V.A. Smirnov

TIME-OF-FLIGHT AND COORDINATE MEASUREMENTS IN A 130 CM SCINTILLATION COUNTER

Submitted to ПТЭ.

In a number of cases, e.g. when one detects rare resonance decays, it is necessary to measure recoil neutron velocities by the time-of-flight method and the neutron emission angle with a high detection efficiency[2,3,4,5]. In this case the extension of scintillator dimensions is inevitable.

In ref.[1] a $1 \times 12 \times 40$ cm^3 scintillation counter has been tested, and the possibility to determine an interaction point ($\pm$ 2.5 cm) by the time interval between the arrival of the light signals at the photomultipliers at two opposite ends of the flat scintillator has been found.

This paper is devoted to the investigation of the precision determination of a coordinate by the time interval between the arrival of the light signals at the cathodes at two opposite ends of a plastic scintillator and the accuracy in the measurement of the time-of-flight with a $8 \times 8 \times 130$ cm^3 plastic scintillator used as one of the basic counters.

1. Counter Description

The counter under investigation consisted of a 8x8x130 cm^3 plastic scintillator, two light guides of organic glass and two photomultiplies of type-56-AVP.

The plastic scintillator is pasted of two pieces 8x8x65 cm^3 each. The light guides are made in the form of a right truncated cone with the bases $D = 8$ cm and $d = 5$ cm. The 5, 15 and 25 cm light guides were used in the measurements. The plastic scintillator and the light guides have been optically polished and are coated with aluminium foil.

The pion beam ($E_\pi = 4$ GeV) of the Dubna synchrophasotron was used for investigating the counter.

2. The Accuracy in the Determination of the Coordinate in a Scintillation Counter

In order to investigate the accuracy in the determination of the coordinate in the 130 cm scintillator, the diagram given in Fig.1 was used. Two photomultipliers of 56 AVP type 4.2 cm in diameter of the photocathode were applied in the counter. A special selection of photomultipliers has not been done. The measurements were made using the light guides of 0.5, 15 and 25 cm long at the points distant by 5, 25, 45, 65, 85 and 125 cm from one end of the scintillator.

The pion beam was selected with the help of two counters S_1 and S_2 2.5 cm in diameter and 1 cm thick (see Fig. 1).

The linear gate circuits (LG) with an opening time of 50 nsec were controlled by the output pulse of the coincidence counters S_1 and S_2 . The signals from the photomultipliers were fed to the LG inputs and then to the circuit of the "start"-"stop" time-amplitude converter.

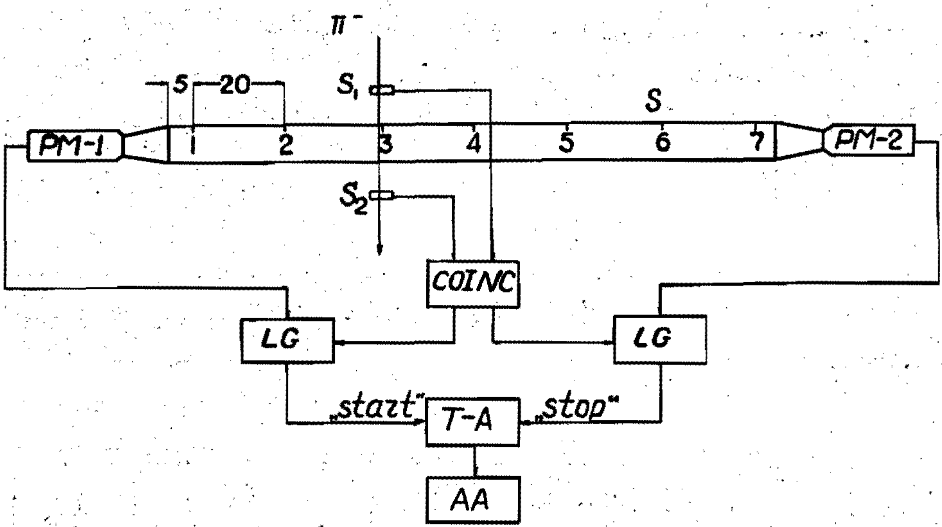

Fig.1 Diagram of measuring the interaction coordinate.

The output pulses of the time-amplitude converter were fed to a 512-channels amplitude analyser. A calibration characteristic of the time-amplitude converter obtained with the help of a pulse generator is shown in Fig.2.

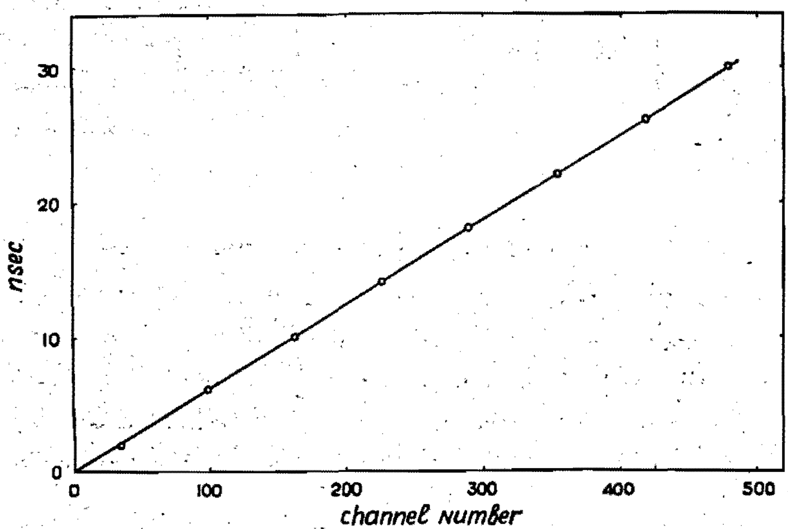

Fig.2 Calibration characteristic of the time-amplitude converter.

The main experimental results are presented in Table 1. The values of the "average light velocity" in the counter obtained with the light guides $h_{\ell g}$ = 0, 5, 15, 25 cm are given in the second column of Table 1.

Table 1

h cm	$\bar{U}$ $\times 10^{10}$ cm/sec	U_{min} $\times 10^{10}$ cm/sec	scale of one channel of AA		σ		δ%
			nsec	cm	channel	cm	
0	1.12	1.20	0.063	0.35	6.2	± 2.2	9.1
5	1.21	—	0.063	0.38	6.5	± 2.5	5.7
15	1.34	1.41	0.063	0.42	6.6	± 2.8	1.0
25	1.26	1.32	0.063	0.39	8	± 3.1	—

Analysing the path of rays in the counter of this configuration, one can see that straight rays have a minimum path to the photocathod and rays propagating at an angle of whole internal reflexion have a maximum path. There is an effective angle which depends on the height of the light guides. This dependence varies the "average propagation speed" of the light in the counter. The time interval from the moment of the light flash in the scintillator to the current pulse on the anode of the photomultiplier was measured in the experiment.

Since the rays coming to the photocathode due to multiple reflexions make a principal contribution to the formation of the pulse this gives a significant increase of the time interval measured. Consequently, the average propagation speed of the light signal should be smaller than the propagation speed of light in the scintillator ($v=c/n$ where n equals 1.59 is the refraction coefficient of the scintillator).

The thrid column of the Table gives the calculated values of the minimum possible value of the light signal speed on the assumption of the meridional path of the light.

The "minimum light velocity" was estimated by the formula v_{min} = kv, where $k = \ell / L_{max}$ (ℓ is the length of the scintillator with the light guides, L_{max} is the maximum light propagation length possible for our system).

As is seen from the Table, the "minimum velocity" of light is larger than the average propagation velocity of the light signal. The latter is the reason of the fact that a greater part of light energy in similar systems propagate along the curved screw-shaped line (6). The time (Δt) and space ($\Delta s = v \cdot t/2$) intervals corresponding to one channel of the analyser are presented in the fourth column of the Table.

The accuracy of the coordinate localization (σ) in the counter averaged over seven points along the scintillator (5, 25, 45 ... 125 cm) for the light guides 0, 5, 15 and 25 cm long is given in the fifth column (neglecting S_1 and S_2).

As it follows from the data obtained, with the decreasing of the height of the light guide the precision in the determination of the coordinate increases. For the light guides (0, 5, 15) this, to a great extent, is the reason that the average propagation of the light signal in the counter decreases. And only in the case of the 25 cm light guide the error in the determination of the coordinate is introduced by the light guide itself.

When the length of the light guide is 0 and 5 cm one observes the dependence of the average propagation velocity of the light signal on the flash coordinate. This dependence is explained, for example, by the difference in optical paths of the light signal (at the ends of the scintillator light propagates to the nearest photocathode with a shorter optical path) and by the light attentuation in the scintillator.

As a result, a slight non-linearity of the counter calibration is also observed. The calibration for the light guides (0.5 and 15 cm) is presented in Fig.3. As is seen, the calibration of the 15 cm light guide is closest to the linear one. The estimate of the calibration non-lineary for the 0.5 and 15 cm light guides is given in the last column of the Table.

In the same arrangement (see Fig.1) the 56 TVP photomultipliers and the 15 cm light guides were used for another measurement (see Fig.1).

In this case diode voltages of the photomultipliers were adjusted by a minimum value of the jitter with a light diode (Gallium Phosphide).

The jitter in the centre of the photocathode found to be equal to 0.15 nsec.

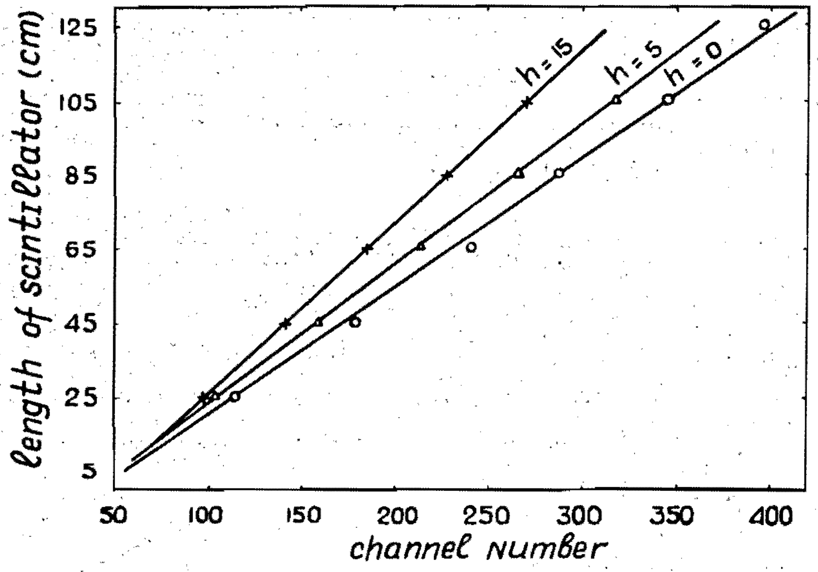

Fig.3. Calibration characteristic of the counter with the 0, 05 and 15 cm light guides.

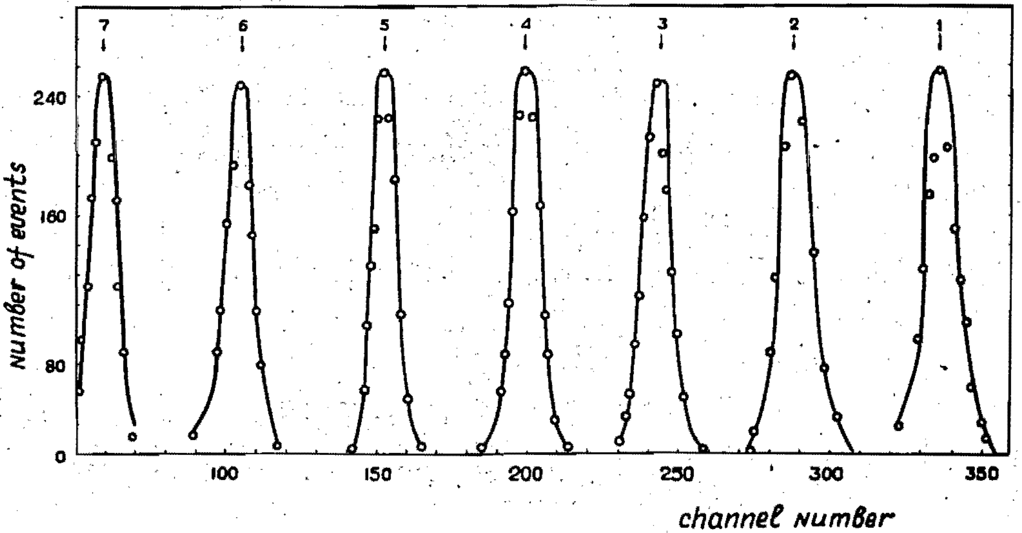

Fig.4. Spectra of the spatial resolution for seven points shifted by 5,25...125 cm from the end of the scintillator.

The results obtained are given in Fig.4. The accuracy in the determination of the coordinate, averaged over seven points and taking into account the dimensions of the counters S_1 and S_2, is equal to ± 1.7 cm. As is seen from Fig.4, the spatial resolution is practically independent of the particle entrance point in the counter. The calibration linearity is 1%.

3. Accuracy in Time-of-Flight Measurements.

The time-of-flight of pions between the 8x8x130 cm^3 counter (with the 15 cm light guides) and the basic counter 2,5 cm in diameter and 1 cm thick measurements are presented by the diagram, given in Fig.5. The 56 TVP photomultipliers were used for counter S, and the photomultipliers-36 - for counter S_2.

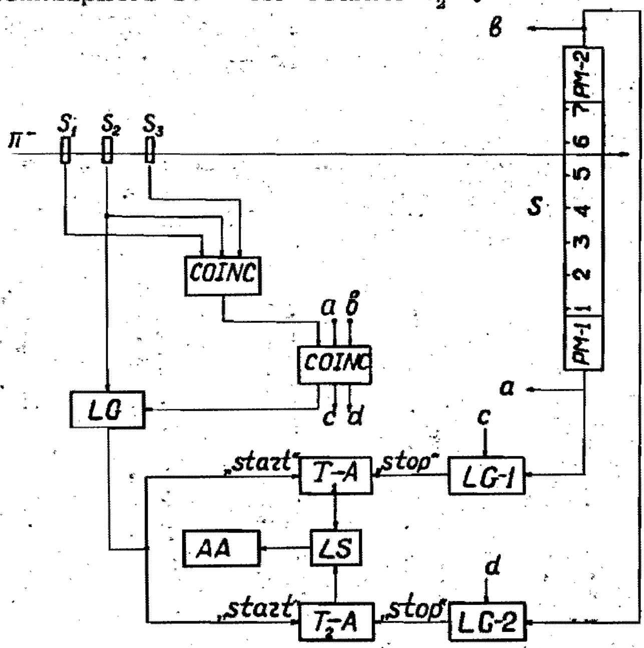

Fig.5. Diagram of the time-of-flight measurement between counters S_2 and S.

The time signal from basic counter S_2 is fanned out into two pulses. They are simultaneously fed to the inputs "start" of two time-amplitude converters 1 and 2. The pulses from the corresponding ends of counter S are fed to the inputs "stop". After linear adding the output pulses of the time-amplitude converters are fed to the input of the 512-channels amplitude analyser. The method described permits to determine time-of-flight independently of the particle entrance point in the counter /1/.

For the diagram calibration and delay adjustment the light diodes mounted in the counters were used.

The time-of-flight has been measured in seven points of the counter (5,125... 125 cm). The accuracy in the measurement of the time-of-flight, averaged over seven time spectra, is equal to ± 0.38 nsec. The maxima of the time spectra (for seven points along counter S) were practically registered in the same channel of the analyser. . The accuracy of compensation of the light signal propagation time in counter S is not worse than 70 nsec.

Conclusions

1. To a first approximation, the light propagation velocity may be a parameter, characterizing the optical system.

2. The light guides in the form of a right truncated cone decrease spatial resolution in long scintillators and improve linearity.

3. The light guides with the cross section equal the cross section of the scintillator are the optimal ones in the systems of similar nature. Such a light guide should combine good spatial resolution with linearity.

4. The counter non-linearity effects on the accuracy in time-of-flight measurements due to the deterioration in compensation of the propagation time of the light signal in the counter.

In conclusion, the authors would like to express their gratitude to V.P. Lesnikov, V.I. Prokhorov and A.A. Ryumin for their help.

References

1. G. Charpak, L. Dick and Feuvrais. Nucl. Instrum. & Meth., 15, 323 (1962).
2. S. Buniatov and E. Zavattini et al. Phys.Lett., 25B, N9 (1967).
3. D. Bollini, A. Buhler-Broglin, P. Dalpiar, T. Massam, F. Navach, F.L. Navarria, M.A. Schneegans, A. Zichichi. Nuovo Cim., 56A, N2, 531 (1968).
4. D. Bollini, A. Buhler-Broglin, P. Daépier, T. Massam, F. Navach, F.L. Navarria, M.A. Schneegans, F. Zetti and A. Zichichi. Nuovo Cim., 61A, 125 (1969).
5. P.G. Astvatsaturov, A.M. Baldin, M.N. Khachaturyan, M.S. Khvastunov, V.A. Kramarenko, V.T. Matyushin, G.L. Melkumov. Dubna, JINR, Lab. of High Energies, B2-1-4329 (1968).
6. N.S. Kapani. "Fiber Optics", "Mir", Moscow, 1969.

Received by Publishing Department
on May 4, 1970.