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STUDY ON POSITION SENSITIVE NEUTRON DETECTION SYSTEM*

H.Q. Qi, Y.C. Liu, Z.P. Chen, X.C. Wu, W.H. Wang, J. Zhang,
Q.K. Chen, G. Xu
Department of Physics
Tsinghua University, Beijing, China

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H.Q.Qi Y.C.Liu Z.P.Chen X.C.Wu
W.H.Wang J.Zhang Q.K.Chen G.Xu
Dept. of Physics, Tsinghua Univ. Beijing, China

Abstract: The position sensitive neutron detection system had been assembled. The detector essentially consists of two photomultipliers looking at a liquid scintillator. The position of incident neutrons is determined by time difference between signals from the photomultipliers. The properties of the system had been measured.

1. Introduction

The scattering measurements of fast neutrons at small angles are more difficult than the usual differential cross section measurements for which $\theta < 15^{\circ}$. Not only because of a higher angular resolution is required but also for the solid angle available is very small. In order to obtain a good result the following tasks are considered as important.

(1) The signal-to—background ratio is optimized.

(2) The efficiency of measurements is increased.

A position sensitive neutron detector which is favourable for above tasks had been developed.[1][2]

We had assembled an equipment which was based on the similar principle.

2. Brief description of position sensitive neutron detector

(1) Construction

The detector essentially consists of a liquid scintillator encapsulated in a quartz tube, 55cm in length and 3.8cm in diameter, with both end-faces in optical contact with GDB-49 photomultipliers (PM), sketched in fig 1. The position of incident neutrons (X) is determined by the time difference, (t1-t2), between

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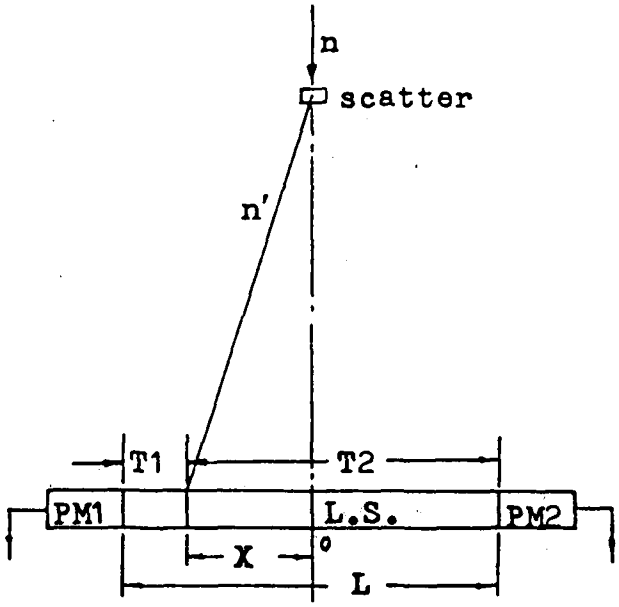
the output signals of the two PM, as

$$X=(t_1-t_2)v/2,$$

where v is the effective velocity of the scintillation light traveling in the scintillator.



L.S.: Liquid Scintillator

PM1, PM2: Photomultipliers

X: The position of incident neutron

T1, T2: The travel times of scintillation light between X and PM1, PM2

Fig 1. Schematic diagram showing principle of a position sensitive detector

(2) Arrangement

The position resolution depends on the time resolution of the detector. The time resolution had been optimized by choice of proper dynode voltages and reflective coating surrounding the liquid scintillator tube. The following three types of reflective coating had been tested:

A. The coating with Aluminum plated responds to mirror reflection.

B. Uncoated tube responds to total reflection at the interface between the quartz and the air.

C. The tube is loosely surrounded by a Al foil responds to total reflection and partial mirror reflection.

The pulse height had been measured in the above three cases. The signals from 11th dynode of GDB-49 PM fed into a amplifier and a pulse shaper, then into a multichannel analyzer. The pulse height was represented by the half height of Compton plateau of gamma spectra. The results show that the pulse heights of B-type is similar to that of C-type, and three times that of A-type. The effective decay length 1 (the average distance in which pulse height reduce by a factor of e) was as follows:

A-type   l=63cm

B-type   l=88cm

C-type   l=90cm

The resolving time had been measured too. B-type and C-type are slightly better than A-type, finally the B-type was used.

3. Performance tests

Performance tests and measurements were carried out with the Am-Be neutron source and the neutron beam produced in $T(d,n)^4He$ reaction from a Cockcroft Walton accelerator.

The measuring geometry of positional resolution is shown schematically in fig 2.

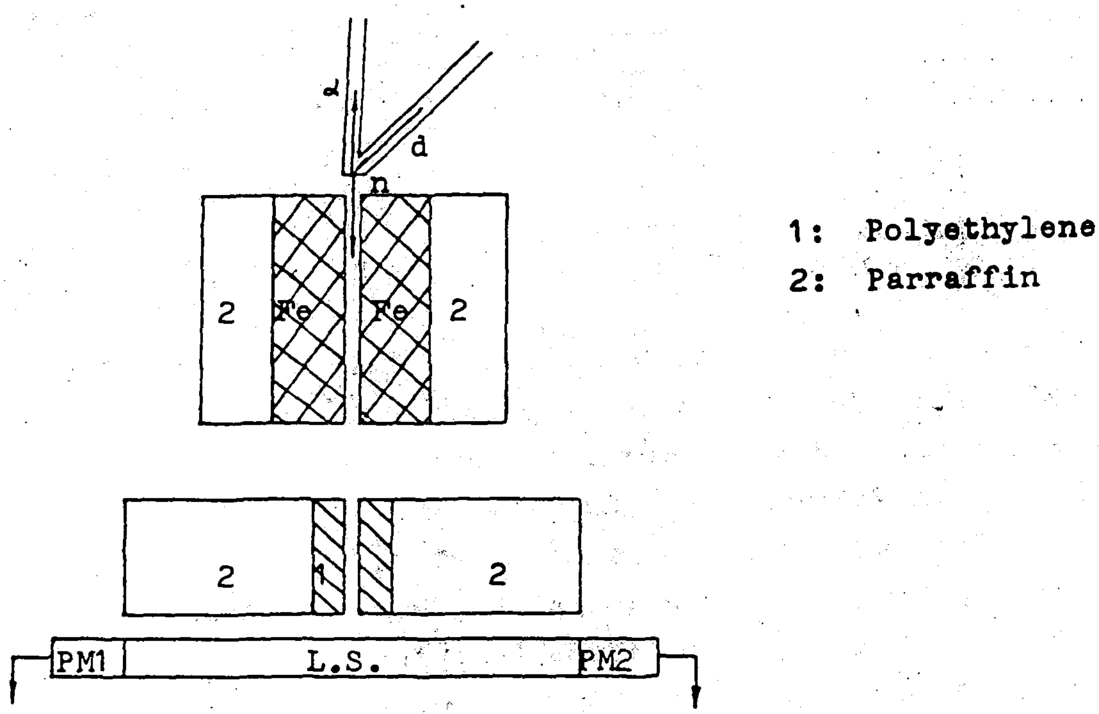
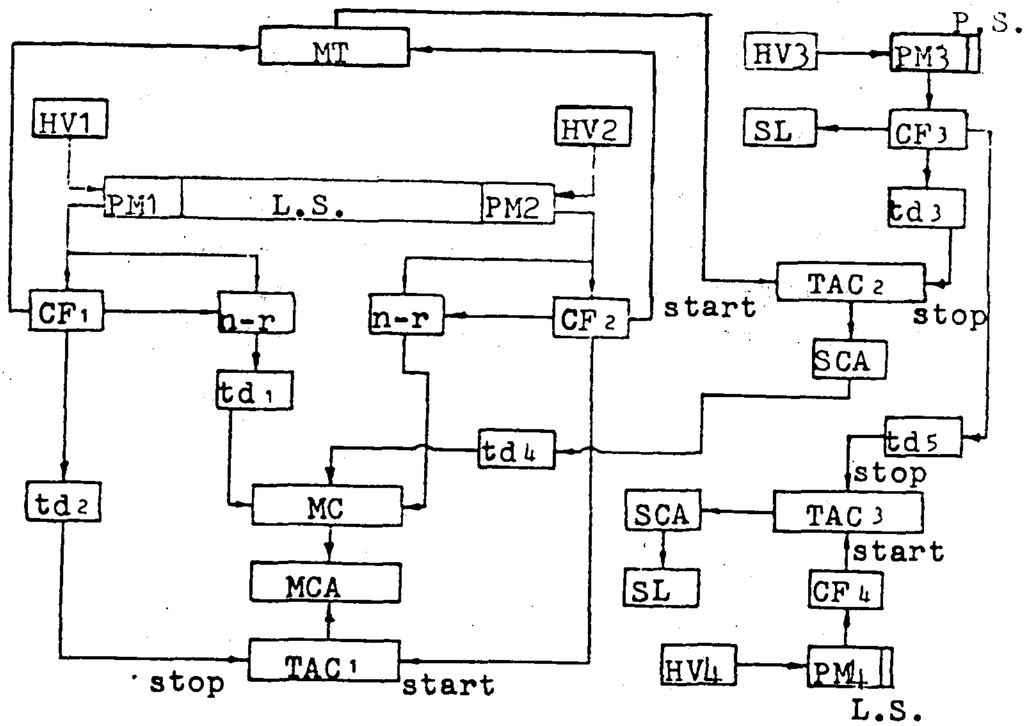


Fig 2. Schematic diagram of the measuring geometry of the positional resolution

The alpha particles emerging from the $T(d,n)^4He$ reaction at an angle $\theta=135°$ were detected in a thin plastic scintillator. The associated neutron passed through a collimator, from 0.5 to 1.0cm in width, which consists of iron, 60cm in thickness, and polyethylene, 70cm in thickness. The liquid scintillation detector could be moved in a normal direction to the collimator.

The block diagram of electronics are shown in fig 3. The time-to-amplitude conversion (TAC1) and the multichannel analyzer were used to analyse the signals of time difference between the two phototubes. The time of flight (TOF) technique was based on the associated particle method.



L.S.: Liquid Scintillator, P.S.: Plastic Scintillator
PM1, PM2: GDB-49 Photomultipliers
PM3, PM4: GDB-50 Photomultipliers
HV: High Voltage Power Supply, MC: Multiple Coincidence
CF: Constant Fraction Discriminator, td: Time Delay
n-r: Pulse Shape discriminator, MT: Meantimer
MCA: Multichannel Amplitude Analyzer
TAC: Time-to-Amplitude Conversion, SL: Scaler
SCA: Single-channel Amplitude Analyzer

Fig 3. Block diagram of the electronics

There was a meantimer since the scintillator was quite long from which the precise timing information were extracted with difficulty. The meantimer was designed to equalize the photon transit time by providing an output pulse at a fixed delay time independent of the position of neutrons incidence. So the resolving time of TOF was optimized. It was 1.1ns at FWHM and 2.2ns at FWTM. The latter corresponds to 14.7±2 Mev neutrons was extrated by a single channel analyzer (SCA). Under the condition, a narrow collimated neutron beam hits the liquid scintillator in the perpendicular direction, one could obtain the spectrum of time difference, which was called respose function of the system. The response function could be described by a Gaussian function as shown in fig 4. The FWHM of Gaussian peak represents the resolution of system. The center position of the peak represents the position of incident neutron and the area under the peak is proportional to the efficiency of the detector.

4. Results and discussion

The results of measurement were summarized in table 1 and fig 5 through fig 7.

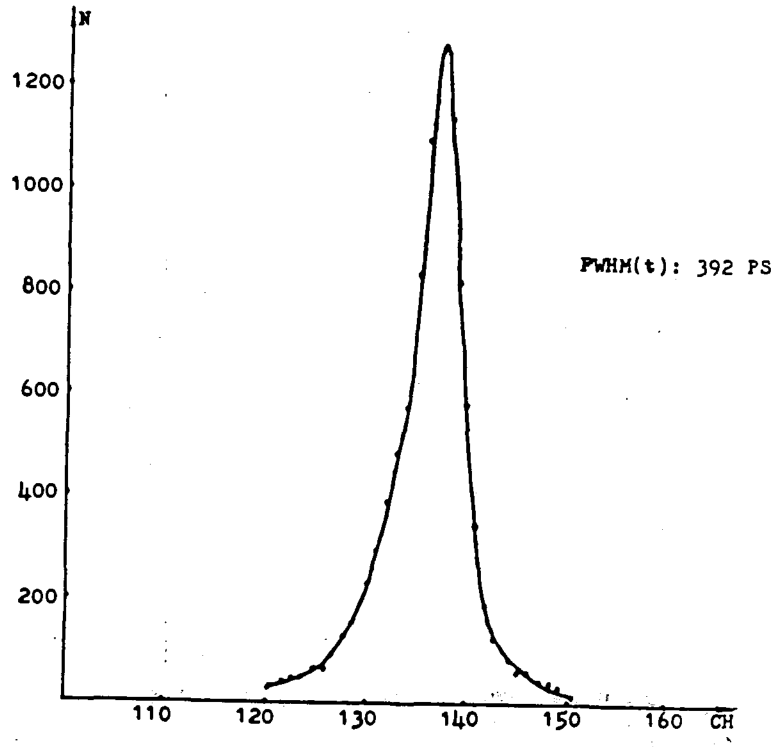


Fig 4. Respose function of the system

Table 1. The properties of the position sensitive detector

X(cm)	peak (channel)	FWHM(t) (PS)	FWHM(X) (cm)	$\sigma(X)$ (cm)
-25	83.0	370.0	2.87	±1.22
-20	92.0	399.0	3.10	±1.32
-15	100.4	392.0	3.04	±1.29
-10	109.3	431.5	3.21	±1.36
-5	118.6	431.5	3.21	±1.36
0	128.3	431.5	3.21	±1.36
5	137.0	392.0	3.04	±1.29
10	146.0	420.8	3.27	±1.39
15	154.9	392.0	3.04	±1.29
20	162.9	399.0	3.10	±1.32
25	170.3	457.0	3.55	±1.51
average*		400.5	3.11	±1.32

* Except X=25 cm

Fig 5 shows that the position of incident neutron versus the position of the peak is a stright line with slope of 129ps/cm The maximum possible nonlimearity is less than 1 percent.

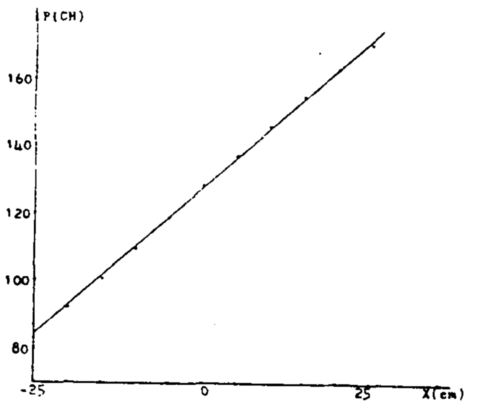


Fig 5. The position of peak versus the position of incident neutrons

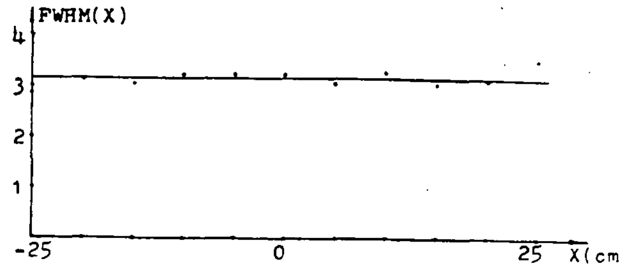


Fig 6. The positional resolution versus the position of the incident neutrons

Fig 6 and fig 7 show that the positional resolution and the efficiency are independent of the positions of the incident neutrons to a great extent.

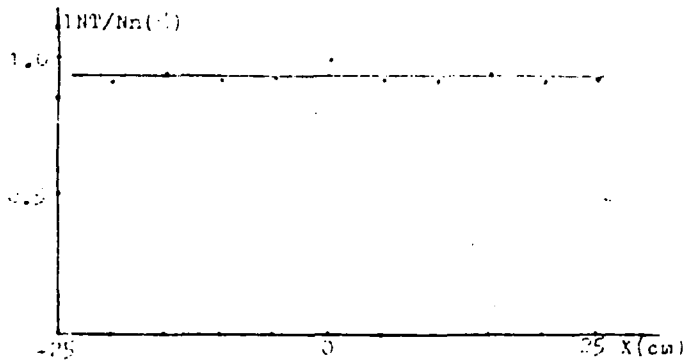


Fig 7. The relative efficiency versus the position of the incident neutrons

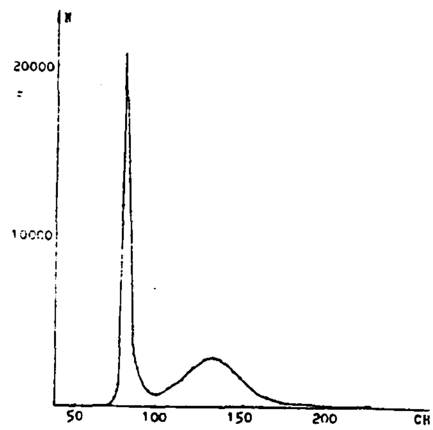


Fig 8. The pulse shape discrimination spectum from 14.7 Mev neutrons

The pulse shape discrimination specta were measured from a Am-Be neutron source and a gamma ray source and from $T(d,n)^4He$ reaction also. The pulse shape discrimination spectrum from 14.7Mev neutrons was shown in fig 8. That the separation of neutrons and gamma rays was not very clear may be caused by the long length of the detector.

The position sensitive detector was designed to investigate the method of the measurement of small angle scattering, so its dimension is rather small, but its properties are suitable for measuring small angle scattering basically.

Reference

1. V. Giordaro et al, Nucl. Instr. Methods 135(1976) 483-487
2. P. Netter et al, Proceedings of the International Conference on Nucl. Phys. August 24-30 1980, Berkley California