Sensitivity of a new-developed neutron detector

PENG Tai-Ping[1], ZHU Xue-Bin[1], YANG Hong-Qiong[1], YANG Jian-Lun[1], YANG Gao-Zhao[1], LI Lin-Bo[1], SONG Xian-Cai[2]

([1] *Institute of Nuclear Physics and Chemistry, China Academy of Engineering Physics, Mianyang 621900;*

[2] *Institute of Electronic Engineering, China Academy of Engineering Physics, Mianyang 621900)*

Abstract We develop a kind of neutron detector, which consists of a polyethylene thin film and two PIN semiconductors connected face-to-face. The detector is insensitive to γ-rays. Its sensitivity to neutron has been calculated with MCNP program and calibrated by experiments, and the results indicate that the neutron sensitivity of the compensation detector will vary with polyethylene converter. The compensation PIN detector can be employed to measure pulse neutron in neutron and gamma mixture radiation field.

Keywords Sensitivity, PIN detector, Neutron, Pulse radiation, Polyethylene converter

CLC number TL811

1 Introduction

In order to measure neutrons in some neutron and gamma mixture radiation field, especially in some fission field, we have developed a kind of neutron detector insensitive to γ-ray, the compensation PIN detector. As shown in Fig.1, the compensation detector consists of a thin polyethylene film and two face-to-face connected PIN detectors. Parameters of the two PINs are almost the same. As a converter, the thin polyethylene film will emit protons in neutron radiation field, then the emitted protons will loss all energy in the first PIN detector and generate the current signal. At the same time, γ-rays will produce almost the same but contrary current in both PIN detectors, and the compensation detector will produce no signal at all. So the detector is sensitive to neutrons and insensitive to γ-rays.

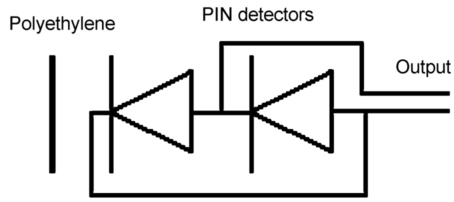

Fig.1 Structure of the compensation detector.

A prototype detector was developed according to the principle, and the dissymmetry of the two PINs was compensated by a special circuit. Its neutron sensitivity was calculated with MCNP4B program, both neutron and gamma sensitivities are calibrated by experiments.

2 Calculation of neutron sensitivity

2.1 Relation between sensitivity of detector and thickness of polyethylene film

The sensitivity of detector can be defined as

$$S(E)=\frac{\int I(E,t)\mathrm{d}t}{\int \varphi(E,t)\mathrm{d}t} \tag{1}$$

where $\int I(E,t)\mathrm{d}t = Q(E)$ and $\int \varphi(E,t)\mathrm{d}t = \phi(E)$ are the electric charge output from the detector and the neutron intensity received by the detector respectively.

The calculation program of neutron sensitivity has been developed and applied to the recoil proton chamber.[1] We reformed and employed the program to calculate the neutron sensitivity of the newly developed compensation detector.

The combination PIN detector records the recoiled protons emitted from the thin polyethylene film converter, then produces current signal which indicates the characteristics of measured neutrons. Obviously，the output signal will depend on the number and energy of the recoiled protons.[2] The density plasma focus (DPF) neutron source can radiate ~10^{10} neutrons (14.1MeV) per pulse with a waveform width of ~10 ns, and then it is suitable for calibrating sensitivity of the compensation detector. In order to com-

Received date: 2004-04-06

pare the calculated sensitivity with experiment results, the curve of sensitivity to 14.1 MeV neutrons vs. thickness of target has been calculated and shown in Fig.2.

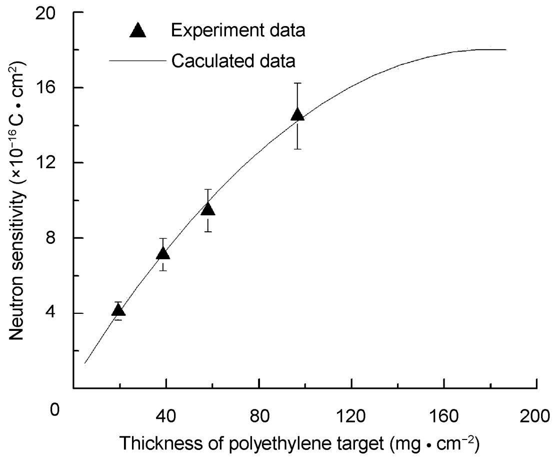

Fig.2 Relation between sensitivity and thickness of polyethylene target.

Fig.2 indicates that the detector will become more sensitive to neutrons with the increasing of polyethylene's thickness. Because of self-absorption of the film, the sensitivity will not change when the film's thickness exceeds its threshold.

2.2 The detector's response to neutrons with different energies

In most radiation field, the detected neutrons are not with single energy, and their energy spectrum cannot be measured through experiments. The sensitivities of detector to neutrons with different energies must be calculated. The calculated results are shown in Fig.3.

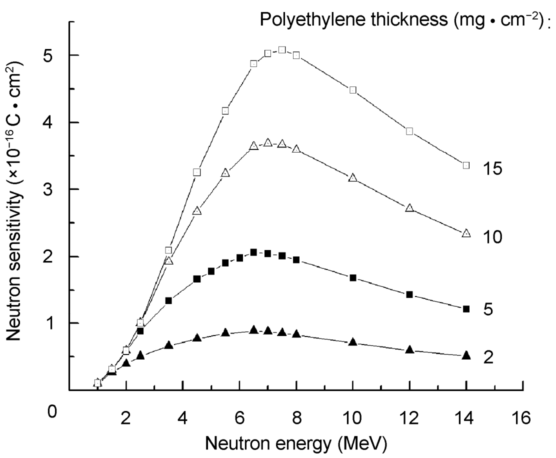

Fig.3 Response of detector to neutrons with different energies.

The recoiled proton from polyethylene converter will get higher energy when the detected neutron has higher energy, so the detector becomes more sensitive to neutron with higher energy. At the same time, the N-P reaction cross-section will be smaller for higher-energy neutrons, and then the number of recoiled protons will decrease. These competition processes result in that the sensitivity curve will go up to a maximum and then go down with the increasing of neutron energy.

Fig.3 also shows that the sensitivity curve becomes flatter when a thinner polyethylene film is selected. So the film must be selected as thinner as possible.

3 Measurement of sensitivity of detector to DT neutrons

3.1 Measurement principle[3]

A detector will produce current signal if radiated by an impulse neutron source and the current waveform can be recorded by an oscilloscope can. The total electric charge output from the compensation detector is

$$Q(E) = k\frac{A}{R} \tag{2}$$

where k, A and R is the attenuation coefficient of the recording system after the signal output from the detector, the area of the recorded waveform and the input resistance of the oscilloscope, respectively.

The neutron intensity received by the polyethylene target can be defined as

$$\phi(E) = \frac{Y}{4\pi L^2} \tag{3}$$

where Y and L is the yield of neutron source and the distance between neutron source and polyethylene target, respectively.

According to Eq.(1), the following equation can be established

$$S(E) = 4\pi L^2 k \times \frac{A}{R} \times \frac{1}{Y} \tag{4}$$

3.2 Introduction to experiment

We select ИНГ-103 dense plasma focus apparatus (DPF) as the neutron source. This kind of DPF can radiate neutrons with a yield of 1×10^9~5×10^9 per pulse with FWHM of less than 10 ns. As the DT neutrons are radiated, the DPF also produces electromagnetic interference and γ-rays with energy of ~1 MeV.

In order to shield electromagnetic interference, the detector and coaxial cable connecting the detector and oscilloscope are packed by copper nets. The output current signal is recorded by the digitalized oscilloscope TDS684C with a frequency width of 1 GHz. The yield of the DPF is monitored with the copper activation method. Fig.4 shows the measurement principle.

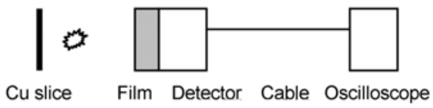

Fig.4 Principle of measuring sensitivity of detector to neutrons.

3.3 Calibration result

According to the monitored neutron yield and output waveform area from the detector, we have got the sensitivity of the compensation detector to 14.1 MeV neutrons. The relative standard uncertainty of the measured result was 12%. In the scope of measurement uncertainty, experiment results shown in Fig.2 match the theoretical curve very well.

4 The γ sensitivity of detector

We took the CΓC67 multiple channels ns/ps pulse generator imported from Russia as the γ-ray impulse source, the compensation PIN detector and usual PIN detector were employed to record the γ-ray signal radiated by ΓPΓ at the same time. The two kinds of detectors had the same parameters including distance from the source, sensitive area, sensitive thickness, etc.

Ignited by pulse radiation generated by CΓC67, the compensation detector and usual PIN detector will produce pulse current signal. The experiment result is shown in Fig.5.

According to the experiment result, we can deduce the sensitivity ratio of the compensation detector to PIN detector. In Fig.5, the upper waveform is the output from normal PIN detector and the lower one from the compensation detector. Then there is

$$S_{\mathrm{COM}}/S_{\mathrm{PIN}} = 0.03 \qquad (5)$$

From this experiment we know that to γ-rays the normal PIN detector is about 100 times more sensitive than the compensation detector.

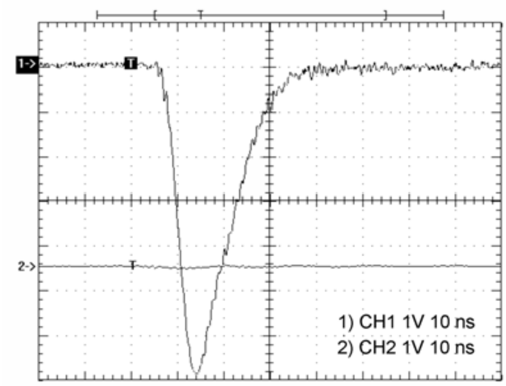

Fig.5 Output signals from the compensation detector and usual PIN detector ignited by the same impulse γ radiation.

5 Conclusion

The new developed neutron detector consists of a polyethylene thin film and two face-to-face connected PIN detectors whose function parameters are almost the same. The experimental and calculated results indicate that sensitivity of the detector to neutrons will vary with the thickness of the thin polyethylene film. The compensation detector is more sensitive to neutrons than to gamma rays. The detector can be employed to measure neutrons in the impulse n and γ mixed radiation field.

References

1 MA Chi. Nucl Electron Detect Technol (in Chinese), 1995, **15**(6): 373

2 Schutz R, Fehrenbacher A, Biersack J P *et al*. Radiat Effects and Defects in Solids, 2002, **157**: 427-444

3 LIU Qing-Zhao. The diagnosis technology of pulse radiation field (in Chinese). Beijing: Science Press, 1994: 117