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MEASUREMENT OF PARTIAL NEUTRON SPECTRUM OF AN Am-Be (α,n) SOURCE

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Measurement of Partial Neutron Spectrum from an Am-Be (α,n) Source

A partial neutron spectrum from an Am-Be (α,n) source has been measured by TOF accompanied with γ-ray. In the experiment the 4.43 MeV γ-ray comes from the reaction of $^9Be(\alpha,n)^{13}C^*$ ($^{13}C^* \xrightarrow{61fs} {}^{12}C + n + \gamma(4.43\ MeV)$). The result has been compared with others.

1. Introduction

Am-Be neutron source is useful in an ever-widening variety of application, especially in a neutron physics laboratory. Perhaps one of its most applications is as a neutron spectrum standard to calibrate neutron detectors and instrumentations.

Neutron spectrum of Am-Be souce has been measured by a number of labs, but much differences exist among the measurements, in particular their fine shape of the spectrum and its lower part (below 2 MeV). Even the difference of the spectrum shape measured with the same method is marked. For example, G. Shani etc (1) in 1976 and K. W. Gelger etc (2) in 1964 have measured the same part of the spectrum with the same method. Not only the agreement beteen the two experiments, but also between the experiments and calculated results are poor. Therefore, we try to measure the same part of the spectrum by the same method as Shani and Gelger. Otherwise, it is a simple and cheap way to set a Time-of-Flight spectrometer.

2. Principle and Method

Am-Be neutron source is based on the $^9Be(\alpha,n)^{12}C$ reaction. The relevant modes of decay of the compound nucleus system are the following(3):

(1). $^{13}C \longrightarrow {}^{12}C + n + 5.70\ MeV$

(2). $^{13}C \longrightarrow {}^{12}C^* + n + 1.27\ MeV \longrightarrow {}^{12}C + n + \gamma(4.43\ MeV)$

(3). $^{13}C \longrightarrow {}^{12}C^* + n - 1.95\ MeV \longrightarrow {}^{8}Be + \alpha + n - 1.45\ MeV \longrightarrow 3\alpha + n - 1.571\ MeV$

Because of the half-life of the first excited state of $^{12}C^*$ is 61 fs (4), we only measured the neutron spectrum accompanied with 4.43 MeV γ-ray in our experiment.

A schematic diagram of the experimental arrangment and electronics is shown in Fig. 1. The γ-ray detector consist of a ST-401 plastic scientillator of 5 cm diameter and 2 cm length, viewed directly by a fast photomultiplier tube of type GDB-50L. The neutron detector is consist of a ST-451 liquid scintillator of 10.4 cm diameter and 5 cm length, coupled with a fast, lower noice photomultiplier of type EMI9823KB. The neutron source was bought from

A. E. I. Ch.* and it was made of pieces of pressed disc covered with three layers of stainless steel. Its size is 30×30 mm and the neutron yield is 1.21×10^6/sec.(1 ± 10 %).

For reducing background produced by neutron scattered between γ-ray detector and neutron detector and scattered from wall and ground the neutron detector was put into a shielding with double cut-off cone (see Fig.1).

Compromising the energy resolution, detection efficiency and the ratio of the effect and background events the flight length was chosen as one meter, and the γ-ray detector was 6 cm away from the neutron source.

The signals from the neutron detector were used as the start signals for a Time to Amplitude Converter(TAC) and the stop signals were the delayed fast signals of γ-ray detector. The output signals of TAC were analyzed by a multichannel pulse height analyzer.

The eleventh dynode linear signals of γ-ray detector and twelfth dynode linear signals of neutron detector were amplified by amplifiers and analyzed by Timing Single Analyzer respectively. The lower threshold of γ-ray detector was calibrated by ^{137}Cs.

For raising the time resolution and reducing the random coincidence we shose the lower threshold of neutron detector at 0.8 MeV, and higher threshold at 8 MeV.

We used the oscilloscope Tektronix 7924 (assembled with TDR/Sample 7S12) to calibrated the delay lines which would be used for calibrating the time linearity of the spectrometer. The precision of time for the delay lines was better than 0.1 ns.

The zero time for the spectrometer was determined by prompt peak of ^{60}Co γ-ray. The time defference of γ-ray flight from ^{60}Co source located at the neutron souce position to two detectors was used for calibrating the flight length of neutron. The time resolution of ^{60}Co γ-ray prompt peak was ±910ps FWHM for the spectrometer.

The Time-of-Flight spectrum obtained in this way is shown in Fig.2. There are two peaks near the zero time channel. The lower one was produced by γ-ray scattered between two detectors, its half width could be used for determining the time resolution of the spectrometer. The higher one was produced from coincidence of neutrons detected by γ-ray detector and γ-ray detected by neutron detector.

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After scattering background subtraction measured with a copper cone of 45 cm length and random coincidence subtraction, the time spectrum was obtained and shown in Fig. 2 .

3. Result and Discussion

The energy spectrum corresponding to Fig.2 is shown in Fig.3. The energy region which the spectrum covered is from 1.3 MeV to 6.4 MeV. It was campared with the results calculated by F. Deguarrinie etc[5] and by A.D. Vijaya etc[6], and was campared with the spectra measured by the same method by G. Shani etc[1] and by K. W. Gelger etc[2] (see Fig.4).

From our energy spectrum the higher side energy conforme to the results calculated by F. Deguarrinie etc and by A. D. Vijaya etc, and almost conforme to the spectrum measured by G. Shani etc. But it is not agreeable to the spectrum measured by K. W. Gelger etc, who gave the higher energy limit of 7.4 MeV that is impossible according to the reaction dynamics.

The lower side energy limit in our spectrum is about 1.3 MeV, Which is different to the calculations. All measurements have demonstrated that the neutrons associated with 4.43 MeV γ-ray at the region below 1.7 MeV still exist. And they have also shown that there are more events at the region from 3 MeV to 5 MeV than the calculation.

The difference between experiments and calculations is reasonable because of the technique and physical state of the neutron source are not identical. The lowest energy limit of 1.7 MeV of the spectra calculated by the two labs may be got from the lowest energy limit of 1.5 MeV α particles. It might be unrealistic because of that the yield of neutron at the region below 1.5 MeV couldn't be negligible if the amount of lower energy α particals was large. The actual situation of the Am-Be source is too complex to calculate its spectrum on the simple supposition. The reason of having different spectrum shapes between experiments and calculations is similar to the lower part mentioned above.

A. D. Vijaya has mentioned the same problem on his thesis and pointed out that the better agreement (between theory and experiment) might be sought by improving and including some of the factors that enter into the primary spectrum calculation such as the alpha particles stopping-power, elastic scattering of alpha particles and nonhomogeneity of the source medium.

The partial spectrum measured by us showed that there were no any neutrons associated with 4.43 MeV γ-ray at the region below 1.3 MeV. The result is the same as of K. W. Geiger(2), but much different to G. Shani(1). G. Shani's measurement showed that the intensity of neutrons at the retion below 1.3 MeV was greater than any other part of the spectra, and there was a peak around 0.8-0.9 MeV. And they mentioned that the peak at 0.8-o.9 MeV would be due to multibody break-up process $^{9}Be + \alpha$ ---- $3He^{4}$ + n . But according to E. W. Lees(4) the excited states in ^{9}Be from (α, α') reactions decay almost entirely by neutron emission to give ^{9}Be (α, αn) with no observable gamma-ray. G. Venkataraman etc(7) also pointed out that the energy of the alpha-particles produced in the multibody break-up process was too low to contribute neutron or gamma-ray yields. Hence the measured spectrum by G. Ghani etc(1) at the same energy region by the same method as ours seems doubltful. And their exposition for the spectrum might be incorrect.

Now let us inspect the peaks in the spectrum. The two peaks in our spectrum are marked and agreement with others. But there could be a peak at 2.2 MeV in our spectrum. Hence it is possible that G. Shani(1) has pointed out that there was a peak at 1.9 MeV in their spectrúm.

The relative intensity of the various neutron groups at 3.2 and 4.4 MeV present in the spectrum are different from each other. This phenomena were supported by the point of view what was emphasized by E. A. Lorch(8). He has mentioned that it is well known that the spectral features are dependent on the source construction and especially on the particulate size of the AmO_2 and Be powder, as this will strongly influence the distribution of alpha particle energies. He has also point out that the ratio of the peaks would be a function of particulate size, and the ratio measured by them may therefore be taken as cheracteristics of the neutron source produced in their laboratory. Hence we also compared our data with Zhang Yi(13) and Li Anli(14) because of that the Am-Be neutron sources were made in the same laboratory. And the agreement is very well.

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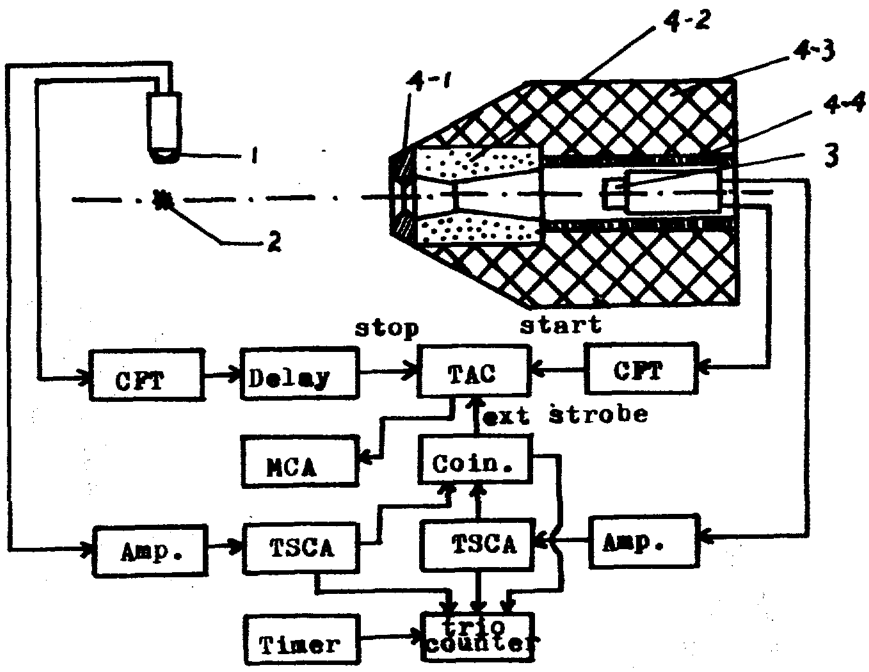

Fig. 1. Experimental set-up

1 plastic sci. 2 neutron source 3 liquid sci.

4-1 iron 4-2 paraffin 4-3 paraffin + Li_2CO_3 4-4 Lead

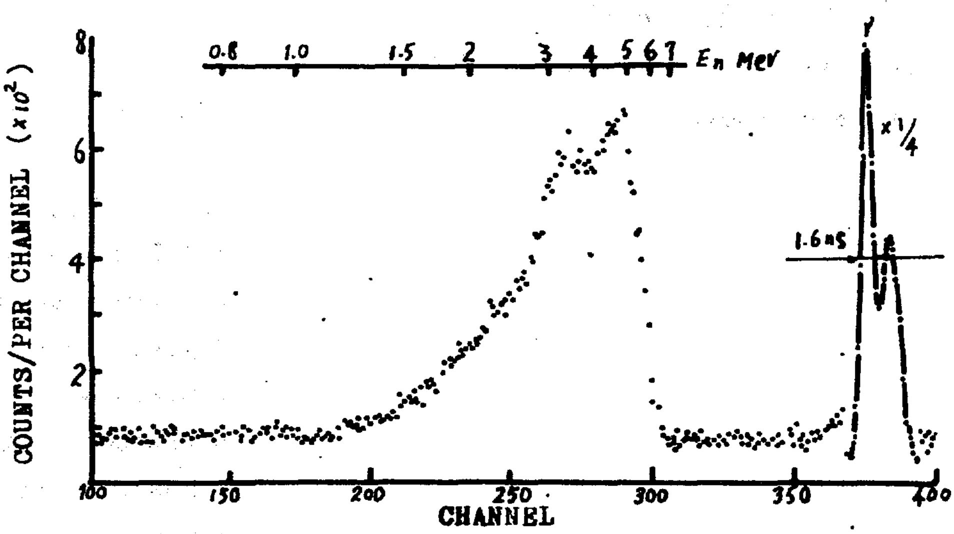

Fig. 2. Partial Time-of-Flight spectrum of Am-Be neutron souce. The threshold level of neutron detector is 0.8 MeV. Width of per channel is 0.335 ns. The flight path is 1.0 M. The time of measuring is 24 houres.

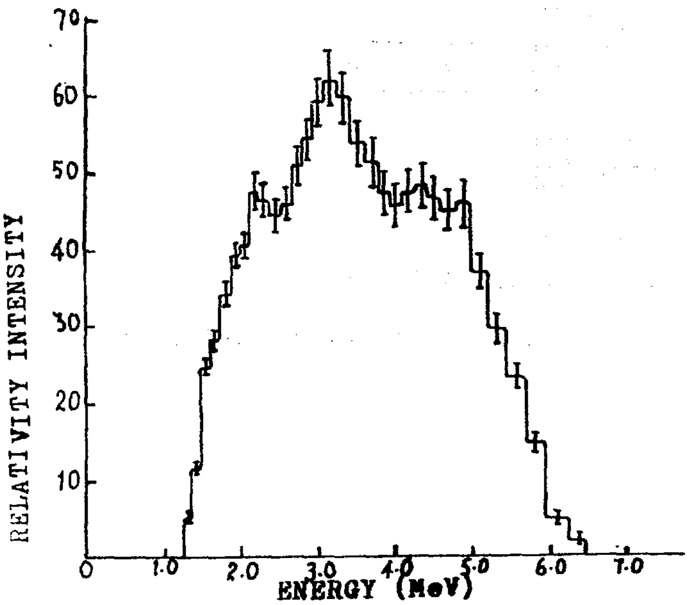

Fig. 3. Partial neutron energy spectrum of Am-Be source.

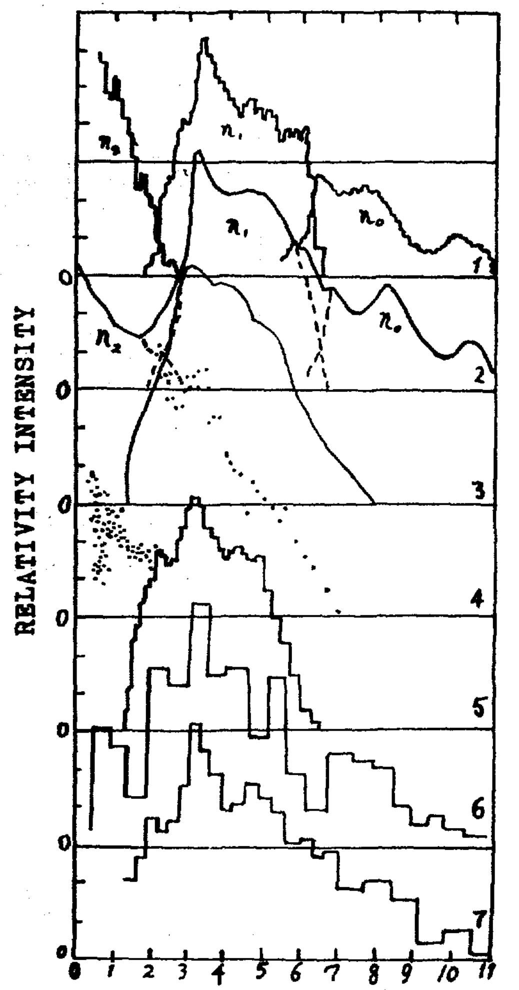

Fig. 4

1 Calculated by F. Degnarrini

22 Calculated by A. D. Vijaya

3 Measured by K. W. Geiger etc

4 Measured by Shani etc

5 Present work

6 Measured by Zhang Yi etc

7 Measured by Li Anli etc

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