Tail Correction in Quasi-monoenergetic Neutron Source

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III. 1. Tail Correction in Quasi-monoenergetic Neutron Source

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Mono-energetic neutron source plays an important role for cross-section measurement, dosimetry development, testing of semi-conductors for single-event effects and so on. In the energy region above 20 MeV, the ^{7}Li(p,n) and ^{9}Be(p,n) neutron source have been employed as an intense "monoemnergetic" neutron source. Actually, however, they are not purely mono-energetic but quasi-monoenergetic because continuos spectrum neutrons (tail) are produced from breakup reactions and accompany with the main peak neutrons.

In the measurement using such sources, large errors comes from the background due to low energy tail as well as limited intensity of the peak neutrons. To improve the situation, we have installed and characterized an intense quasi-monoenergetic neutron source at CYRIC1). Now we are promoting the study of the applicability of the "tail correction" method which is the correction for backgrounds due to tail, reported by R.Nolte et al. for 200 MeV proton beams2). Their tail correction is based on the fact that the high-energy peak neutron decreases rapidly with angle whereas the shape of the "tail" neutrons does not change considerably. Therefore we can get corrected quasi-monoenergetic neutron spectrum by subtracting the data in larger angle from that in smaller angle (zero-deg.).

In order to inspect the applicability of this "tail correction method" in our energy range, we carried out experiment for 70 MeV protons and obtained neutron spectrum from a Li target, and Be target at 5th target room at CYRIC. The experimental method was almost the same with these in previous experiments3). A thin target of lithium (4.69 mm thickness), a thin target of beryllium (3.0 mm thickness) and a thick target of copper (10 mm thickness) in order to determine the timing of prompt gamma ray event were prepared.

The neutron spectra were measured with time-of-flight method using a beam swinger system over a wide range (5-70 MeV) of secondary energies at seven laboratory angles for lithium and nineteen angles for beryllium respectively, between 0- and 110-deg. The results are shown in Fig. 1 and Fig. 2. These figures show that peak neutrons from lithium and beryllium tend to decrease very rapidely with the neutron emission angle but the low-energy tail show much milder angle-dependence.

Let two neutron spectra measured at 0 deg. and θ (larger than 0 deg.) be φ_0 and φ_θ. We normalize the spectra to the same flux in the low-energy tail region by multiplying the spectrum φ_θ by a factor k. The normalize factor is determined in order to avoid negative value of subtracted spectrum. The subtraction equation as follows:

$$\Phi = \varphi_0 - k \cdot \varphi_\theta$$

where Φ is the corrected spectrum,

φ_0 is spectral fluence at angle 0 deg.

φ_θ is spectral fluence at angle θ.

k is a normalize factor.

Figure 3 indicates 0 deg. spectrum and 30 deg. spectrum normalized to 0 degree‘s low-energy tail region.

With a view to select optimum angle for the “tail correction”, we evaluated the three quantities: 1) peak-to-total flux ratio, 2) chi-square test on each energy bin, 3) feature of the spectrum. Table 1 summaries peak-to-total flux, and table 2 shows the results of chi-square test. From the three quantities, 30 degree seems to be an optimum angle for the tail correction. Figure 4 indicates subtracted spectrum of neutrons from lithium and beryllium respectively. In the near future, we will prepare 30-deg. port by punching a hole in a collimator and apply the port to the neutron cross section measurement and semi-conductor single-event upset experiment.

References

1) Meigo S., Nucl. Instr. Method in Phys. Res. A**400** (1997).
2) Nolte R., et al., Nucl.Instr. Method in Phys. Res. A**476** (2002).
3) Hagiwara M., et al., Fusion Sci. Tech **48** (2005).

Table 1. Peak to total ratio.

	Li	Be
FOM	72.7 %	62.4 %

Table 2. Result of chi-square test.

	Li	Be
χ^2	5.17×10^7	1.12×10^{10}

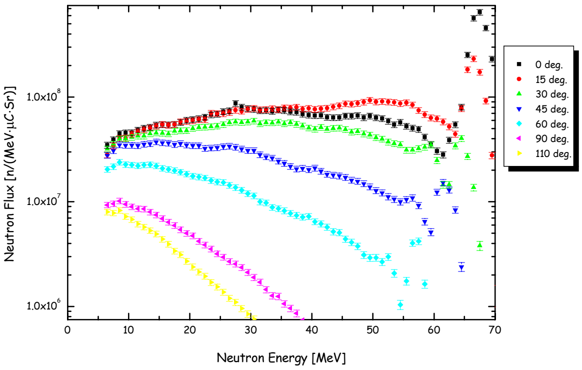

Figure 1. Neutron spectrum for Li.

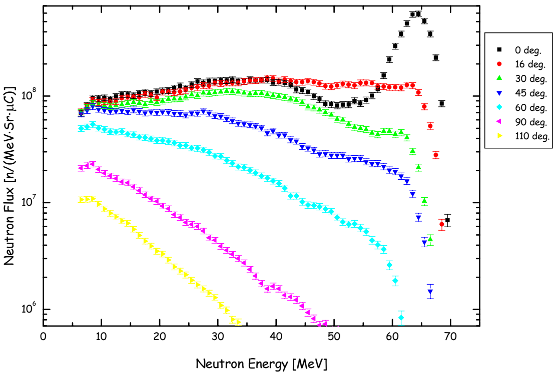

Figure 2. Neutron spectrum for Be.

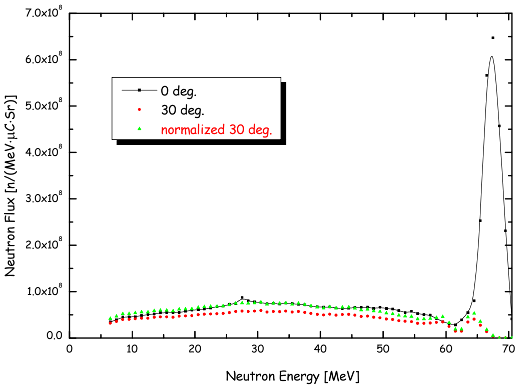

Figure 3. Normalization to 0 deg. low-energy.

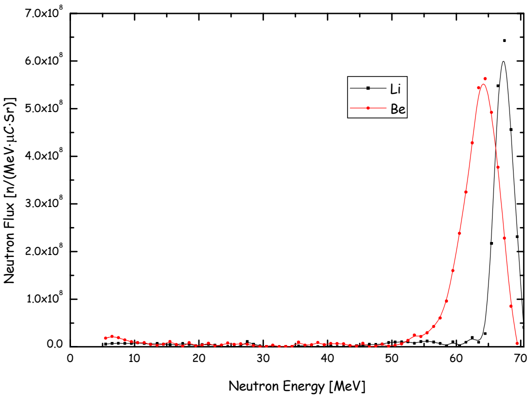

Figure 4. Subtracted spectrum.