ON THE ORIGIN OF LOW ENERGY 'TAIL' FOR MONOENERGETIC NEUTRON SOURCES

N.V. Kornilov, A.B. Kagalenko
Institute of Physics and Power Engineering
249020, Kaluga region, Obninsk, Russia

ABSTRACT. The model was developed to describe the neutron energy distribution for monoenergetic neutron sources. The factors which makes the major contribution into RF formation was discussed. An additional neutron source was introduced to describe the low energy peak asymmetry. However we can not explain the origin and the properties of this 'tail' neutron source.

INTRODUCTION

This report is one of the series of works on inelastic neutron cross sections measurements for separated nuclei levels. When the peaks are properly separated, the cross section determination does not course any problem and consist in estimating the square under each peak and calculating the multiple scattering (MS) contribution. In the case of closely located or overlapping peaks the detail information on the response function of the spectrometer (RF) becomes to primarily importance. To describe the RF properly all the factors (including MS in the sample) contributing to time and energy neutrons spread should be taken into account. It is the neutron source which makes the major contribution into RF formation. This report is devoted to investigation of this particular component of RF.

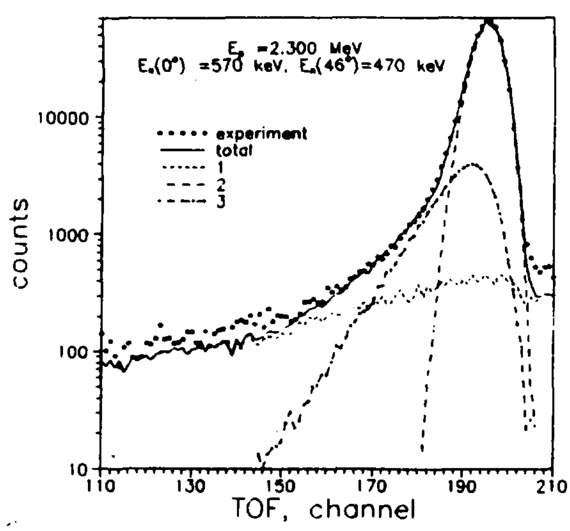

Fig. 1 TOF monitor spectra. Experiment (stars) and MC calculation. 1-target environment, 2-main neutrons, 3-'tail' neutrons.

Lets consider this problem with respect to inelastic scattering of neutrons by ^{238}U (Q=45keV) for incident energies 300-600 keV. The time of flight technique was used for neutron spectra measuring. Proton pulse width was ~1ns. The main detector was placed into massive collimator. The flight path of this detector was 200cm. The time resolution of the detectors was ~3ns. The Li(p,n) reaction was used as a neutron source. The metallic Li-target was prepared inside of accelerator beam pipe 'in situ'. The target was evaporated on steal polished backing 0.05cm thick. The thickness of the targets varied from 0.13 mg/cm^2 to 0.2mg/cm^2. The water layer 0.1cm thick cooled the target. The carbon elastic scattering was used to normalize the experimental data. The factor complicating the measurement process is the Li-target instability. Since the target properties varied during the experiment the neutron source parameters should be specified for each experimental run. The monitor placed at 46.2-deg with respect to proton beam was applied to estimate neutron source parameters. The monitor flight path was 310cm. To avoid the time unfolding

procedure a rather simple neutron source model has been developed. This model parameters were chosen from comparing of experimental and calculated monitor TOF-spectra.
The calculations have been performed by Monte-Carlo method.

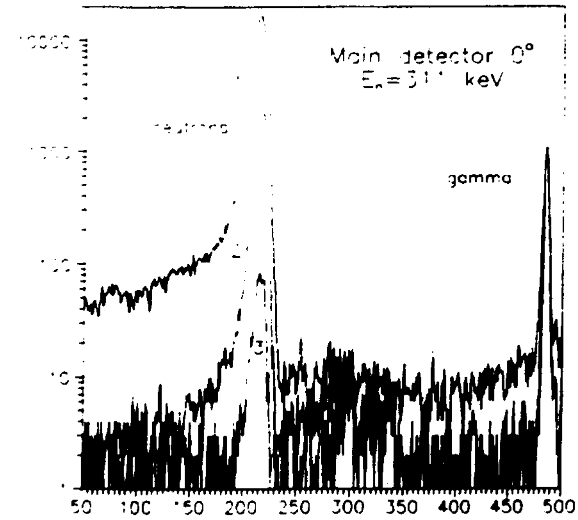

Fig.2 TOF spectra for different PH groups. PH3 > PH2 > PH1.

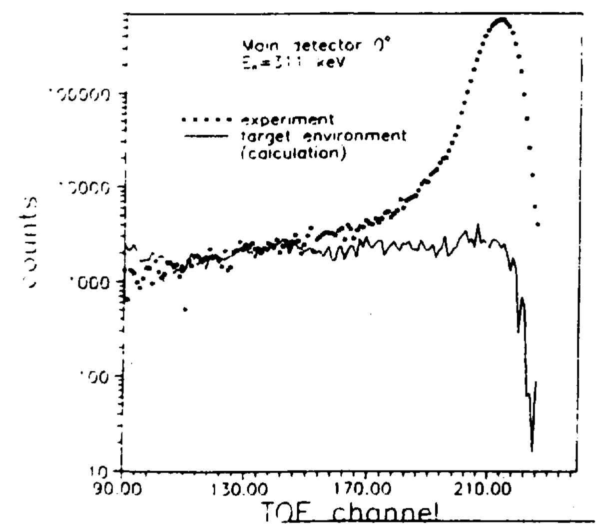

Fig.3 TOF spectra for main detector summed for all PH groups. Solid line present MC calculation.

NEUTRON SOURCE MODEL

While developing the neutron source model we fell in with recommendations given in ref.[1].

This model covered the following factors:

1 - the Li nuclei distribution in the target. The error function was used to describe Li-nuclei distribution. The average target thickness and variance were determined from experimental and calculated data comparison;
2 - the energy distribution of the incident protons. Gauss distribution was assumed;
3 - the real geometry of experiment;
4 - energy losses of protons, energy and angular straggling;
5 - time resolution determined from gamma-peak shape;
6 - the Li(p,n) reaction kinematics [2];
7 - the neutron scattering on the target environment;

Besides the detector efficiency was also taken into account. It was measured against ^{252}Cf neutron source.

Fig.1 shows monitor TOF-spectra calculated in the framework of this model and the corresponding experimental data. The above mentioned factors 1-5 enable us to give a detail description of the main neutron peak in the area where the intensity falls ~10 times (curve 2). The neutron scattered by target environment result in smooth distribution and form a complete low energy part of neutron spectrum (curve 1). However we failed to reproduce intermediate area (the neutron peak asymmetry). The authors of the similar investigations also observed the large neutron peak asymmetry. The authors of the work [3] associated it with time neutron distribution due to the neutron scattering on the collimator. However we can not make a similar conclusion.

Fig.2 shows TOF-spectra of the main detector measured for various pulse heights (PH). The detector was located at 0-deg with respect the neutron beam. Fig.3 describes the experimental spectrum summarized over all PH groups and calculated spectrum of the neutrons scattered by target environment. The data analysis allow us to make the following conclusions:

- the target scattered neutrons make the major contribution in low energy region;

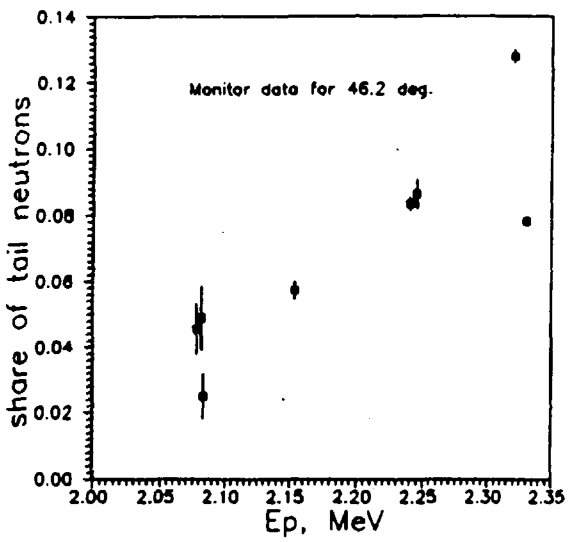

Fig.4 The 'tail' neutron contribution based on the monitor data versus the proton energy.

- the main peak asymmetry is not associated with the time resolution (proton beam shape or detector resolution in the low PH region);
- The Monte-Carlo results show that total yield of the neutrons scattered by the collimator is small (~0.3%), and their spectrum is rather smooth, and does not contribute into the peak asymmetry. Besides the main detector and monitor were located at various flight path and had different collimator.

The observed asymmetry sources may be the following:

- additional energy distribution of the incident protons due to proton scattering on 'slit', for example;
- additional Li-target inhomogeneity. These two factor giving the same results are practically inseparable.

In this respect the energy distribution of protons exposing the target was described by the following expression:

$$f(E) = (1-\alpha)\cdot\delta(E-E_0) + \alpha\cdot\beta\cdot\exp(-\beta\cdot(E_0-E)),\ E<E_0$$

where β=50 MeV^{-1} for incident energy range 300-600keV. The curve 3 in fig.1 represents the second term of this equation. Only when these additional neutrons were taken into account we managed describe the experimental spectrum (fig.1) The α values versus incident proton energy are given in fig.4. Though the data spread is rather large it can be seen that the 'tail' neutron contribution grows with incident proton (or neutron) energy. The neutron source model with all above mentioned factors (1-6) and proton distribution (eq.1) was used in Monte-Carlo codes, which simulate the experiment.

The multiple neutron scattering in the sample was also taken into account. The calculation results and the experimental data for carbon sample are given in fig.5. It is quite clear that an additional neutron source with the parameters taken from the monitor spectra is required to describe the experimental data. The similar conclusion was made with respect to other neutron energies. However as to the angles close to zero degree these neutrons contribution turned out to be higher than the contribution obtained from the monitor data. The α(~0-deg)/α(46-deg) ratio versus incident proton energy is depicted in fig.6.

CONCLUSIONS

1. The neutron source model described in this report allows us to predict neutron energy distribution from metal Li-target. The main model parameters were estimated on the basis of the experimental data.

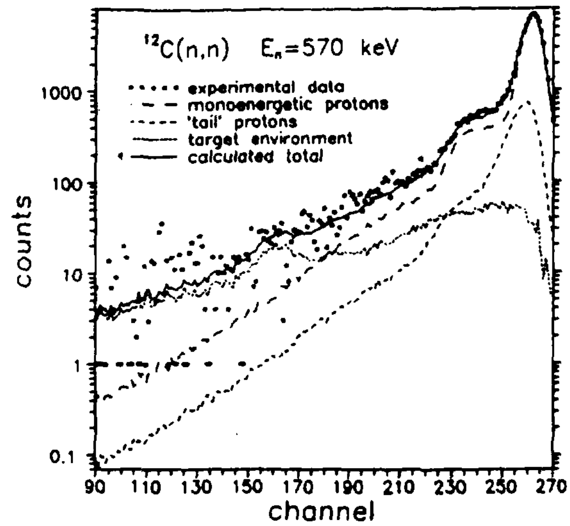

Fig.5 Experimental (points) and calculated (lines) TOF spectra of carbon scattered neutrons.

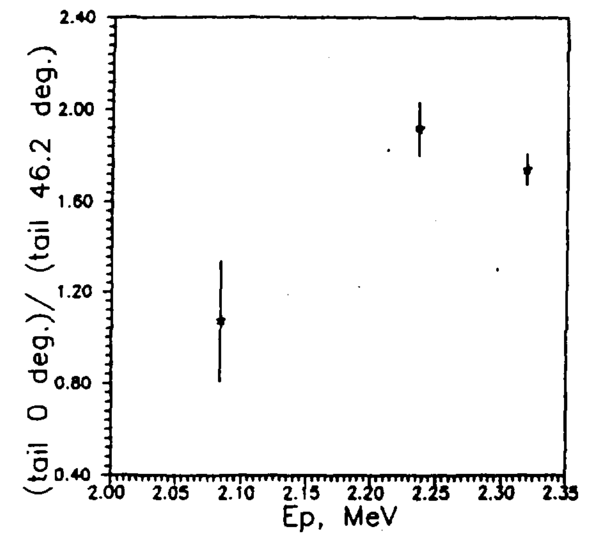

Fig.6 α(0-deg)/α(46-deg) ratio versus the proton energy.

2. The neutron scattering on target environment contribute much into the low energy region of the neutron spectrum. However this factor can not explain the neutron peak asymmetry.

3. Additional neutron source was introduced to describe the peak asymmetry. The share of the 'tail' neutrons was estimated from monitor data for 46.2-deg. and as far as the small angles are concerned it was adjusted from carbon scattering data. The 'tail' neutron contribution dependence on incident energy and angle turned out to be rather unexpected. It is difficult to explain the origin and the properties of this 'tail' neutron source by 'slit' proton scattering or some Li-nuclei distribution peculiarities. This phenomenon requires additional investigations.

REFERENCES

1. N.V.Kornilov, Proc. of an Advis. Group Meeting on Neutron Source Properties, Leningrad, 1986, IAEA report,IAEA TECDOC-410, 1987, p 230.
2. H.Lisken, A.Paulsen, Atomic Data and Nuclear Data Tables, 15, 57-84, 1975,
3. G.H.R. Kegel, et. all, Nuclear data for Science and Technology, Mito, 1988.