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Nonmonoenergety of Neutron Source Based on the Solid Tritium Target

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The accurate measurements of neutron-nuclei interaction cross sections needs exact knowledge of the parameters of neutron source used in experiment. In precision measurements usually mono-energetic neutron sources are used for generation of the neutrons with specific and well-defined neutron energy. Typically the T(p,n), Li(p,n), T(d,n) reactions are used for production mono-energetic neutrons in keV – MeV energy range. Even in this case, the source will inevitably produce the neutrons (we will designate them as "nonmonoenergetic") with energies usually less the energy of the neutrons from main reaction. It is rather important to know the absolute yield and energy distribution of these neutrons. In the present work we experimentally and theoretically investigated the contribution of the nonmonoenergetic neutrons from the solid tritium-titanium-molybdenum target under the bombardment of the proton beam with energy varied from 4 to 9 MeV.

The measurements of neutron spectra from tritium solid target have been made by time of flight technique at angles from 0^o to 150^o at fast neutron spectrometer based on tandem accelerator EGP-10M of IPPE. The solid target, as specified by manufacture, was a titanium layer (∅11 mm by 0.96 mg/cm^2 or 2.1 μm thickness) on molybdenum backing (∅11 by 0.3 mm thickness), the ratio of absorbed tritium to titanium atoms - 1.97. It was found that, besides the T(p,n) neutrons, there are low energy neutrons, which contribute 4% to 3000% compare to the main monoenergetic neutrons as proton energy increases from 4 to 9 MeV. The energy spectra of these neutrons are shown in Fig. 1 for the case of proton energy 4 MeV.

The theoretical analyses have shown that there are two physical reasons of these low energy neutrons: neutron scattering on the target assembly and the (p,n) reactions on titanium and molybdenum. Besides on the way to the detector the part of the T(p,n) neutrons inelastically scatters on the detector shielding (collimator). For description of these process the theoretical calculations have been made with Monte-Carlo (MCNP 4.a) and Hauser-Feshbach statistical theory (TNG) codes.

The analyses of the (p,n) reaction thresholds have shown that for some titanium and molybdenum isotopes they are very close to the T(p,n) threshold. It means that titanium absorber and molybdenum backing produce neutrons practically in the same proton energy range as T(p,n) reaction. The calculated by TNG code the energy distribution of the neutrons from the ^{49}Ti(p,n)^{49}V reaction is shown in Fig.1. It demonstrates prominent peaks corresponding excited levels of residual nucleus.

The calculation made with Monte-Carlo technique have shown that neutron scattering on the target materials also results to the structure in the neutron spectra. It turns out that neutrons flying along molybdenum backing and bottom of the target holder gives two neutrons groups with energies of 1.4 and 0.65 MeV (see Fig. 1) resulted from the elastic and inelastic scattering of source neutrons.

The approach tested in the present work could be used for estimation of the nonmonoenergetic neutrons contribution for other neutron producing reactions and target assemblies.

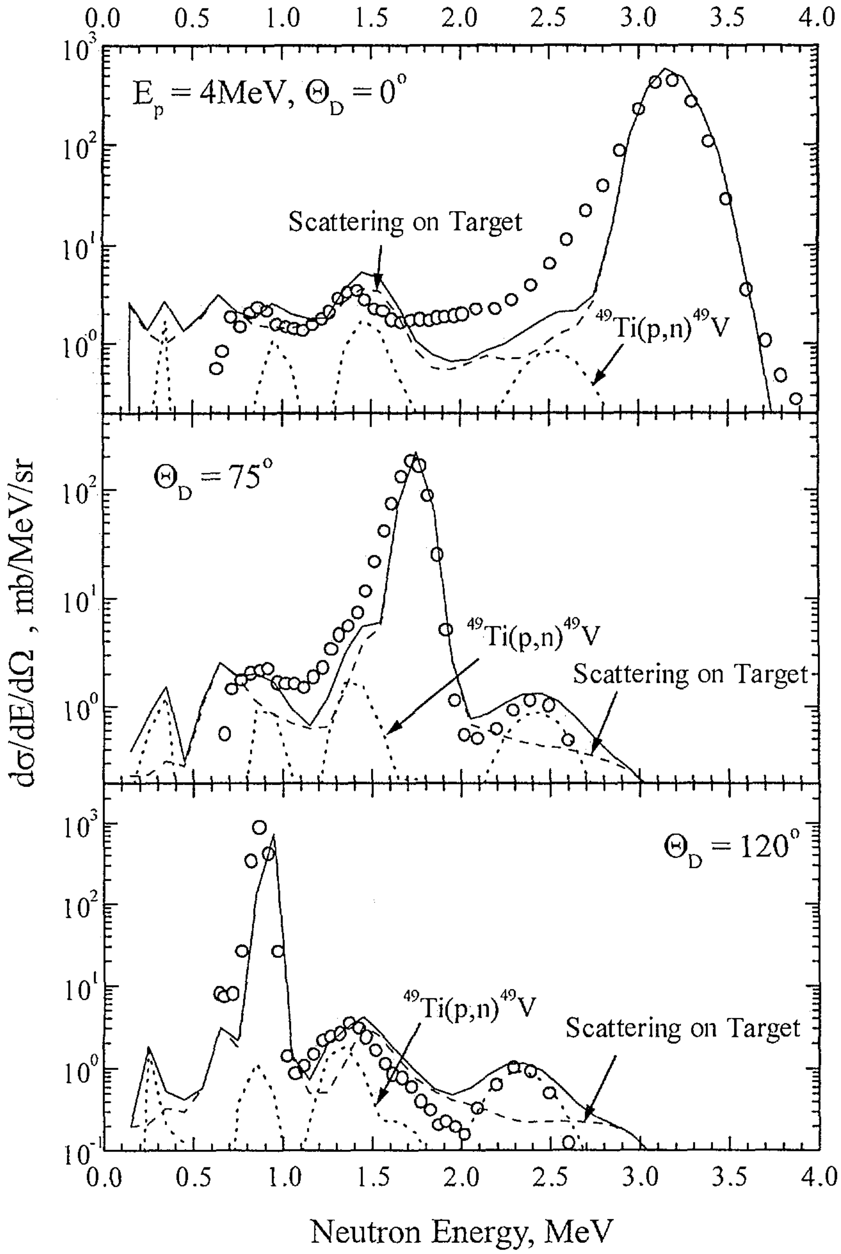

Fig. 1. Energy differential cross-sections from TiT-Mo target at $E_p = 4$ MeV and detector angles $\Theta_D = 0^o$, 75^o, and 120^o. Points – experiment. Curves: dashed – neutrons scattered by the target assembly and collimator, dotted – energy differential cross section for $^{49}Ti(p,n)^{49}V$ reaction, solid – their sum.