Angular Anisotropy of Secondary Neutron Spectra in ^{232}Th+n

V. M. Maslov

Slobodskoy proezd 4, 220025 Minsk, Byelorussia

Neutron emission spectra (NES) of ^{232}Th+n interaction /1, 2/ provide strong evidence of angular anisotropy of secondary neutron emission, another evidence might be predicted in ^{232}Th(n,F) prompt fission neutron spectra (PFNS). In case of NES observed angular anisotropy is mostly due to angular dependence of elastic scattering, direct excitation cross sections of collective levels and pre-equilibrium emission of $(n,nX)^1$ neutrons. In current analysis of ^{232}Th+n data direct excitation, ground state band levels $J^{\pi} = 0^+, 2^+, 4^+, 6^+, 8^+$ are coupled within rigid rotator model, while those of γ –bands with $K^{\pi} = 0^+, 2^+$, octupole band $K^{\pi} = 0^-$ are coupled within soft deformable rotator model /3, 4/ (^{232}Th levels excitation energies U=0~1 MэВ). Afterwards ^{232}Th+n NES were exhaustively are described at E_n~6, ~12, ~14, ~18 MeV (Fig. 1, Fig.2). The net effect of these procedures is the adequate approximation of angular distributions of ^{232}Th $(n,nX)^1$ first neutron inelastic scattering in continuum, which corresponds to U=1~6 MeV excitations for E_n up to ~20 MeV.

In case of PFNS anisotropy would occur because some portion of $(n,nX)^1$ neutrons (see Fig. 2) might be involved in exclusive pre-fission neutron spectra like in ^{235}U(n,xnf) reactions /5/. In ^{232}Th$(n,xnf)^{1,..x}$ and ^{235}U$(n,xnf)^{1,..x}$ reactions PFNS would demonstrate different responses to forward and backward $(n,xnf)^1$ neutron emission relative to the incident neutron momentum. Average energy of $(n,xnf)^1$ neutrons depends on the emission angle θ, i.e. fission cross section, prompt neutron number and total kinetic energy depend on angle θ as well. Exclusive neutron spectra $(n,xnf)^{1,..x}$ at θ~90^o are consistent with observed ^{232}Th(n,F) and ^{232}Th(n,xn) reaction cross sections within E_n~0.01–20 MeV energy range. Exclusive neutron spectra of $(n,xnf)^{1,..x}$, ($n,n\gamma$) and $(n,xn)^{1,..x}$ are calculated within Hauser-Feshbach formalism alongside with (n,F) and (n,xn) reaction cross sections, angular dependence of first neutron $(n,nX)^1$ emission $\omega(\theta)$ being included. Approximation obtained for $\omega(\theta)$ /6/ is consistent the measured double differential NES at E_n ~6–18 MeV. The correlations of angular dependence of $(n,xnf)^1$ neutron emission with emissive fission (n,xnf) contribution to the observed fission cross section and angular anisotropy of NES of ^{232}Th+n and ^{235}U+n are shown.

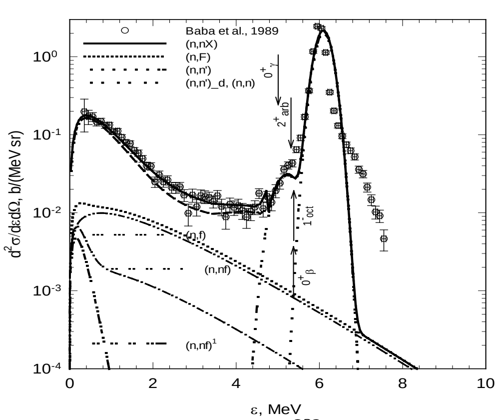

Fig. 1 NES of ^{232}Th+n, E_n= 6 MeV.

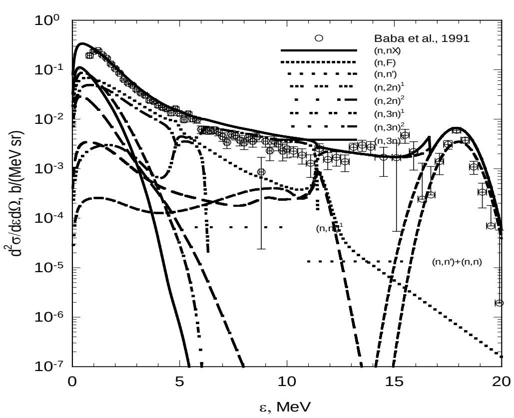

Fig.2 NES of ^{232}Th+n, E_n= 18 MeV.

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