VERIFICATION OF ENERGETIC AND ANGULAR DISTRIBUTIONS OF NUCLEAR FUSION PRODUCTS IN PLASMAS

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Yields and spectra of neutrons belong to central subjects of physics of controlled fusion neutron sources and prospective energy reactors. Flux densities of primary neutrons from plasma are the key parameters for the design of a fusion device from the viewpoint of practical applications such as tritium breeding, production of fissile nuclides, minor actinide burning, neutron physics research and others, as well as from the viewpoint of the selection of structural and functional materials for the reactor systems and estimations of their operating regimes and durability.

The purpose of this work is to describe new analytical results obtained for the integral energetic distributions and integral angular distributions of nuclear fusion products in plasmas with general anisotropic distributions of fuel nuclei velocities.

In the work [1] calculations of such integral characteristics of a fusion neutron source as the energy resolved counting rate $\frac{dg}{dE_n}$ [MeV^{-1} s^{-1}] of a collimated neutron detector and the number of primary neutrons with a certain energy $\frac{d\Gamma}{dE_n}$ [MeV^{-1} cm^{-2} s^{-1}] per unit area per second at a certain point of the first wall of a reactor were first described on the basis of the work [2].

In addition to the four verification methods considered earlier in [1], the new analytical results are essential for verification purposes as they allow independent calculations of integral distributions of fusion products. In particular, verifications of the total angular

$$\frac{dR_{12}}{d\Omega_3} = \int_0^\infty \upsilon^3 d\upsilon \int_0^\pi \frac{d\sigma(\upsilon,\xi)}{d\Omega_{C.M.}} \sin\xi d\xi \int_0^\infty \mathrm{V}^2 d\mathrm{V} \int_0^\pi \sin\vartheta d\vartheta \int_0^{2\pi} d\varphi \int_0^{2\pi} d\Phi \; f_1(\mathrm{v}_1,\vartheta_1)\, f_2(\mathrm{v}_2,\vartheta_2) \tag{1}$$

and the total energetic

$$\frac{dR_{12}}{dE_3} = \frac{4\pi^2}{m_3} \int_0^\infty \mathrm{v}_1^2 d\mathrm{v}_1 \int_0^\pi \sin\vartheta_1 d\vartheta_1\, f_1(\mathrm{v}_1,\vartheta_1) \int_0^\infty \mathrm{v}_2^2 d\mathrm{v}_2 \int_0^\pi \sin\vartheta_2 d\vartheta_2\, f_2(\mathrm{v}_2,\vartheta_2) \int_0^{2\pi} d\varphi_2 \frac{\upsilon J(\cos\xi)}{\mathrm{V}\mathscr{L}(\upsilon)} \frac{d\sigma(\upsilon,\xi)}{d\Omega_{C.M.}} \tag{2}$$

distributions of neutrons and charged fusion products will be presented. In (1) and (2) $f_{1,2}(\mathrm{v}_{1,2},\vartheta_{1,2})$ designate velocity distributions of fuel nuclei of sorts "1" and "2", $\mathbf{V}$ and υ are the centre of mass velocity and the relative velocity correspondingly, ξ is the polar angle in the centre of mass frame, E_3 and Ω_3 designate the kinetic energy and the laboratory emission angle of the reaction product "3" with mass m_3.

In the recent bibliography pertaining to the neutron emission of toroidal devices with magnetic plasma confinement, various experimental and theoretical works are described, being carried out on prospective and operating tokamaks such as [3,4] as well as on stellarator/heliotron devices, e.g. [5]. The use of fast neutral beam injection is being considered as the main method for the production of the population of high-energy particles enabling non-inductive generation of the electric current in the plasma and making the predominant contribution to the production of primary neutrons in fusion neutron sources based on tokamaks. Our general results primarily described for the case of neutral beam heated tokamak plasmas are readily applicable for the modelling of fusion products in other configurations including stellarator/heliotron plasmas and inertially confined plasmas.

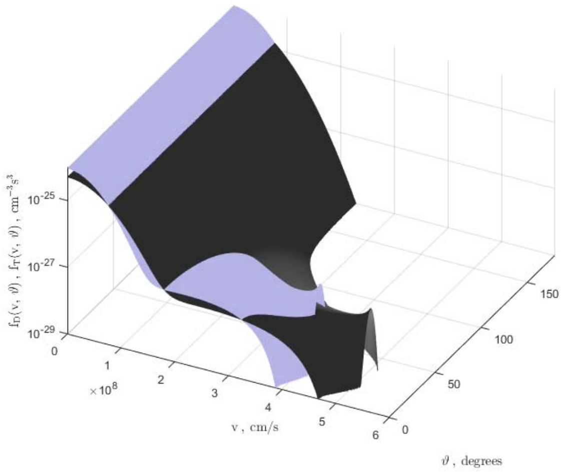

Fig. 1. Velocity distributions of deuterons (dark) and tritons (light).

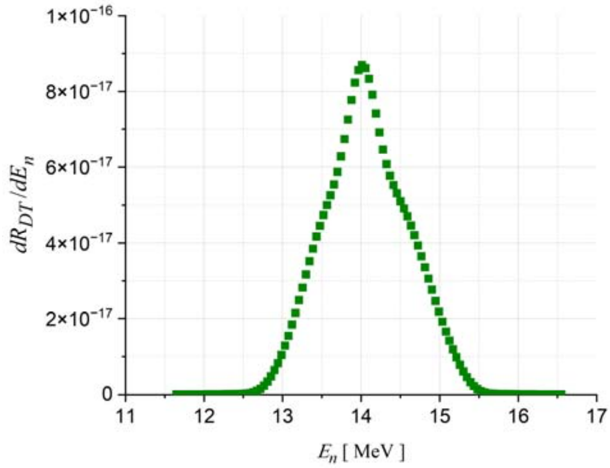

Fig. 2. Integral energy spectrum of DT neutrons.

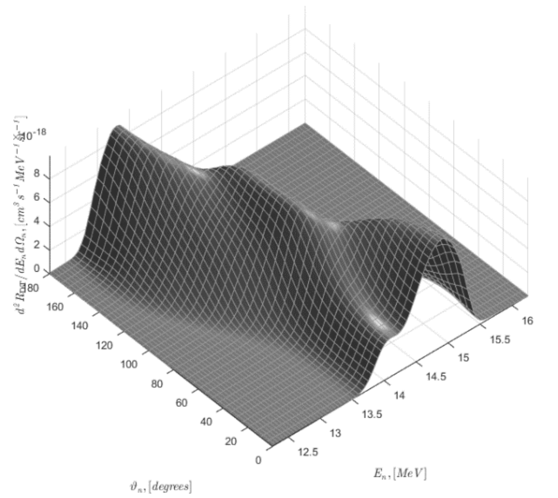

Fig. 3. Double differential DT reaction rate coefficient.

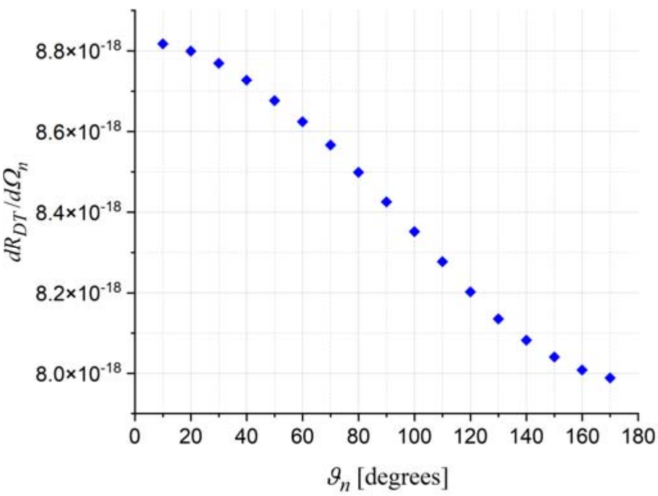

Fig. 4. Integral angular distribution of DT neutrons.

Analytical methods and results for various distributions of deuterium and tritium fuel nuclei will be presented.

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