Energetic and Angular Distributions of Nuclear Fusion Products in Tokamak Plasma

Pavel Goncharov[1]
[1] Advanced Plasma Research Laboratory, Peter the Great St. Petersburg Polytechnic University
e-mail (speaker): p.goncharov@spbstu.ru

Research and development works on fusion reactors, fusion neutron sources and fusion-fission hybrid systems are currently being carried out in various countries of the world. Neutron yield and energy spectrum are the basic characteristics of a source. In fusion devices with magnetic plasma confinement both wave and beam heating techniques induce anisotropic distributions of velocities of fuel nuclei that result in anisotropy of energy distributions of neutrons. Along with the conceptual and technical design of controlled nuclear fusion devices, calculations of the energetic and angular distributions of fusion products are key to neutron flux monitoring, neutron spectrometry and other diagnostics, for physics of suprathermal particles in plasma, for estimations of the reactor first wall loading due to neutrons and other fast particles, as well as for the analysis of processes in blankets.

Energy spectrum and yield of neutrons from a tokamak plasma will be analyzed, as well as energetic and angular distributions of charged fusion products that are important for calculations of their orbits, confinement and interaction with plasma. General analytical results for two-body nuclear fusion reactions with arbitrary velocity distributions of fuel nuclei were obtained in [1]. Reduced formulae were reported in [2,3].

Analytical results [1-3] have found applications in both magnetic and inertial confinement fusion research. Methods of verification of the obtained results will be considered, including the normalization of double differential reaction rate coefficients and a number of important particular cases where independent analytical results can be obtained.

Numerical modeling of distributions of nuclear fusion products in a tokamak plasma, in particular, when neutral beam injection heating is applied, is a complex task consisting of several steps including the modeling of distributions of fast ions in the plasma. Results obtained for a classical and a spherical tokamak will be reported. Figure 1 illustrates the yield and spectra for a fusion neutron source based on a spherical tokamak (FNS-ST). Angular anisotropy of distributions will be analyzed. Potential applications of the obtained results include the development of fusion neutron sources, fusion-fission hybrid systems, such as considered in [4] and references therein, and advanced fusion plasma diagnostics. Other possible applications include the analysis of fast particle behavior, plasma heating, blankets, impact of MeV particles on the reactor first wall, as well as the effect of close collisions between fuel nuclei of deuterium and tritium and fast alpha-particles.

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References

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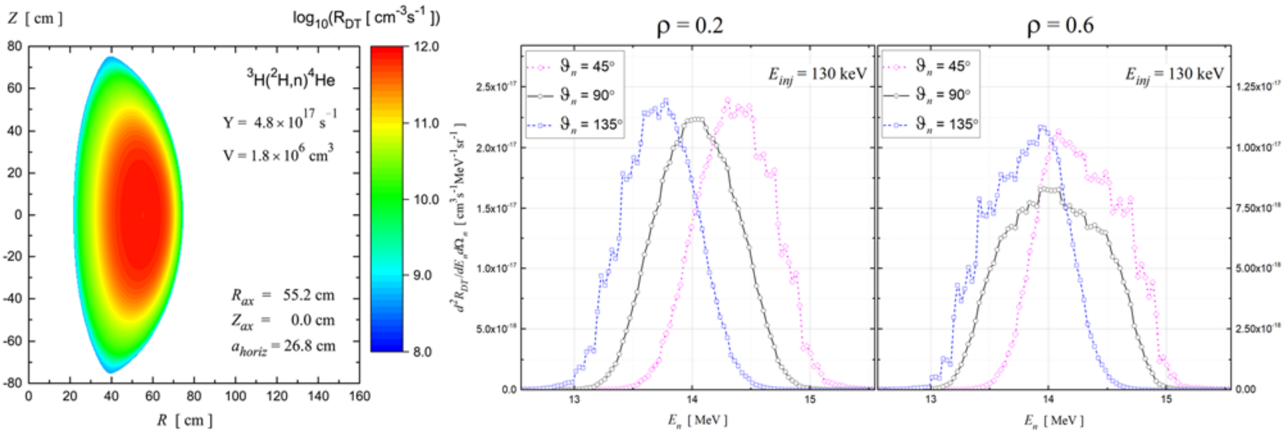

Figure 1. Spatial distribution of the ^{3}H(^{2}H,n)^{4}He reaction rate in the poloidal plane for FNS-ST tokamak (left). Energy spectra of neutrons produced in ^{3}H(^{2}H,n)^{4}He reactions at ρ = 0.2 and at ρ = 0.6 for FNS-ST tokamak (right). Different curves correspond to different neutron emission angles 45°, 90°, and 135°.