OPTIMUM Neutral BeamS FOR Current Drive IN FUSION NEUTRON SOURCES PLASMA [[1]](#footnote-1)\*)

DOI: 10.34854/ICPAF.2022.49.1.032

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Neutral beam injection performs the maximum current drive efficiency among all the heating and current drive (CD) systems. Stationary operation of fusion neutron sources (FNS) is only available with non-inductive current generation and with the possibility of the current profiles and neutron yield control using high-energy atomic beams. Beam-plasma fusion is the main source of neutrons in the FNS plasma, since reactions on high-energy "tails" make the greatest contribution to the neutron generation. This imposes special requirements on the distribution function of fast particles, namely, on the relative fraction of hot ions in the spectrum.

To achieve the maximum effect from beam injection, it is necessary to match the beam parameters (species, energy, aiming, and inclination) with the plasma magnetic configuration and kinetic profiles. Taking into account the specific features of the FNS geometry, which are usually more compact as compared to classical tokamaks, the injection parameters should be optimized in a way to ensure efficient fast ions capture across the entire beam cross section, as well as high current generation and maximum neutron yield. The search for optimal conditions should take into account the shine-through losses reduction in order to ensure a moderate level of loads on the first wall.

The beam shaping combined with toroidal effects produce a significant effect on the fast ions phase distributions and on the resulting CD profiles and fusion neutrons generation. The influence of geometry is most pronounced in systems with a low aspect ratio (and high mirror ratio) and when the beam cross-dimensions are comparable to the cross section of the plasma core. The internal structure of the beam and the topology of the magnetic surfaces are used to calculate the spatial distribution of ionization, shine-through losses, and initial losses of fast ions, which makes it possible to correct the resulting profiles of current generation.

The BTOR (Beam in TORoids) code is tailored to simulate NB injection to compact and spherical tokamaks with account of toroidal effects. It is used to calculate the capture of a beam in plasma, beam ionization, and thermalization of fast ions along magnetic field lines. The plasma magnetic configuration and kinetic profiles are set analytically; it is assumed that in the stationary operation mode the beam does not disturb the parameters of the plasma target. Due to the beam model high statistics, the penetration of the beam into the plasma and the fast ions distribution in the phase space are simulated with high accuracy. The energy distribution functions of fast ions are calculated using the classical analytical formulas for the deceleration of ions in plasma [2]. The CD radial profiles are obtained; the beam fusion rates and the total neutron flux are estimated. The analysis confirms the initial assumption about the sensitivity of the current and neutron output to the beam spatial-angular structure, to the beam aiming, and to the detailed geometry of the plasma magnetic field.

The work is supported by National Research Center “Kurchatov Institute”, Moscow, Russia.

References

1. Kuteev et al., Nucl. Fusion, vol.57, p. 076039, 2017
2. J.Wesson, *Tokamaks*, 4th Edition, Oxford: Oxford University Press, 2011

1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/XLIX/Mu/ru/BO-Dlugach.docx) [↑](#footnote-ref-1)