Neutral Beam Slowing-down and Current Drive with BTR model [[1]](#footnote-1)\*)

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Neutral beam injection (NBI) performs the maximum current drive efficiency among all the heating and current drive (CD) systems. To achieve the optimum scenarios of plasma operation and to get maximum NB efficiency for a given injected power, the beam energy and aiming geometry, i.e. the beam axis tangent point and tilting, need to be chosen with account of plasma magnetic configuration, temperature and density profiles. The injected beam power deposition is highly sensitive to the beam shape (in space and velocity coordinates), especially when the beam is not thin compared with plasma core cross-section. The expected NBCD profiles will be affected by the injected beam dimensions and internal structure, since the prompt fast ion current and finally the overall beam driven current are defined by the ionization points distribution in plasma and the ions velocity versus magnetic field.

The NB capability to drive off-axis current is especially interesting from the perspective of steady-state operation of fusion neutron sources (FNS). The energetic atoms could provide a reliable method of plasma heating, fueling, and non-inductive current generation with possibility to control the current profiles in FNS plasmas, typically reduced in size as compared with classical tokamaks. For neutron generation purposes, the nuclear fusion reactions occurring when a high-energy beam is slowed-down in plasma look the most attractive. *Beam-plasma* fusion is expected to be the *main source* of neutrons in FNS tokamaks, since the reactions on the high-energy "tails" bring the largest contribution to the neutron generation rates. This implies a specific requirement to the fast particles distribution function to have a relatively high fraction of hot ions in the spectra.

BTR code (*Beam Transmission with Re-ionization*), which is used for neutral beamlines design and studies [1], is finally applied to calculate the injected beam stopping, beam ionization and fast ions thermalization in plasma. Plasma magnetic geometry and kinetic profiles are set analytically, the injected beam is supposed not to perturb the plasma target. Due to BTR inherently high level of statistics, the simulated beam penetration and the ions distributions in space and velocity coordinates can be delivered with refined resolution. By implementing the analytical expressions for ions slowing-down in plasma [2], the distribution functions of fast ions in plasma are calculated and compared for different plasma parameters and injection geometry. The result radial profiles of beam current, the beam-driven fusion rate, and the overall neutron yield are calculated. The analysis of beam deposition and CD efficiency confirms the initial assumption on the current sensitivity to the beam finite shape and targeting; even for a fixed value of beam energy the overall current drive efficiency can vary in a wide range, thus the optimum interval of system parameters may be shifted as well. Another important result obtained is that the off-axis injection in general produces lower current than on-axis. Moreover, the off-axis beam-driven effects are way more sensitive to beam-plasma parameters variations, compared with on-axis beams.

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References

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2. J. Wesson, *Tokamaks*, 4th Edition, Oxford: Oxford University Press, 2011
1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/XLVIII/Mu/ru/CC-Dlugach.docx) [↑](#footnote-ref-1)