Interaction between neutral beam fast particles and plasma in fusion experiments

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To reach fusion relevant temperatures, auxiliary heating systems are used in present day experiments. The injection of energetic neutral particles in the plasma (by Neutral Beam Injectors NBIs) is one of the most used techniques to heat the plasma, since early 1970s [1]. NBI lead to significant breakthroughs like the discover of plasma high-confinement mode – H-mode – in 1982 at ASDEX Tokamak [2], a high performing plasma scenario which represents the basis for present day experiments and future fusion reactors. During 1990s experiments equipped with several MW of NBI power were the first to produce a significant amount of energy from fusion reactions. Nowadays NBI is a robust system to provide plasma with heating and non-inductive currents, and, for small- and medium-sized devices, NBI can represent also a relevant source of particles and plasma torque.
Basic physics phenomena are involved in the interaction between energetic neutral particles and the plasma. These include beam ionization by collisions with plasma electrons and ions and by charge exchange processes, and the thermalization of the newly born fast ions in the background plasma by Coulomb collisions ("slowing down" process). In order to estimate NBI's contribution to plasma sustainment, many modelling tools have been developed which are widely used in interpretative and predictive studies.
The Large Helical Device (LHD) [3] is a superconducting helical device (heliotron type) capable of studying current-less plasmas, equipped with 5 NBI systems. NBI-plasma interaction analyses for LHD experiment are currently performed by FIT3D code, a module of TASK3D-a analysis suite of codes. It calculates radial profiles of NBI absorbed power, beam pressure, beam source and induced momentum. FIT3D has been recently upgraded [4] to enable the analysis of D experiments, which will be performed in future LHD campaigns. Upgraded FIT3D is capable to analyze H, D and T plasmas with multi-impurity species using updated beam stopping coefficients.
During the 18th LHD experimental campaign 4 similar shots have been run varying the plasma composition from H to He majority. A better ion confinement has been observed with increased He concentration. FIT3D code has been adapted to analyze the NBI heating with different plasma composition and has been used to investigate the contribution of NBI deposition to the observed better confinement [5]. As example of NBI-plasma interaction study, the analysis of NBI power deposition of the 4 shots with different main plasma composition is here presented.

References

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