Numerical Techniques Used in Neutral Beam Injection Modules

Alexei Pankin[1], Robert Budny[2], Glenn Bateman[1],
Arnold Kritz[1], Douglas McCune[2], and Irina Voitsekhovitch[1]

[1]*Lehigh University, Bethlehem, PA 18015, USA*
[2]*PPPL, Princeton University, Princeton, NJ 08543, USA*

This report describes and compares the numerical techniques for computing the Neutral Beam Injection (NBI) physics used in NBI modules in several integrated modeling codes. Neutral Beam Injection (NBI) is one of the major mechanisms for auxiliary heating of tokamak plasmas. Accurate simulation of the heating profiles is crucial for self-consistent integrated modeling of tokamak plasmas, which are used for interpretation of the existing experiments, testing theoretical hypothesis and planning future experiments. The NBI modules include the physics of neutral beam deposition, fast ion two dimensional orbiting, power deposition, beam driven current and momentum transfer, and it accounts for particle collisions, ionization, charge exchange, and transport of beam particles. The Monte-Carlo and Fokker-Planck approaches are two major alternatives used in the NBI modules. For example, the sophisticated Monte-Carlo NBI technique used in the NUBEAM module [1] is an essential element in the TRANSP code, which is used for time dependent analysis of tokamak data. In addition to the basic NBI physics, the NUBEAM module also calculates the anomalous diffusion of fast ions, the effects of large scale instabilities, the effect of magnetic ripple, and finite Larmor radius effects, and it treats fusion product ions that contribute to alpha heating and ash accumulation. The NUBEAM module has been recently extracted from the TRANSP code, using standards of the National Transport Code Collaboration (NTCC), and is available in the NTCC module library [2]. Another approach to the simulation of the NBI physics is based on the direct solution of the Fokker-Plank equation. This approach is employed by the NBI modules used in the ASTRA (Automatic System for TRansport Analysis) and BALDUR codes, which are predictive integrated modeling codes. The ASTRA code exploits a module for the neutral beam heating and current drive [3], which uses the pencil-beamlet technique for the calculation of beam deposition. Attenuation of the neutral beams due to ionization and charge-exchange collisions, capture and losses of the new-born ions, and the thermalization of the super-thermal ions and their contribution to the plasma heating, current drive and toroidal rotation are computed [4]. The BALDUR code also uses an NBI module that computes the neutral beam deposition physics using a Fokker-Planck approach. The shine-through, orbit losses of beam particles and deposition profiles will be compared in simulations that utilize the NBI modules described above.

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[3] A. Polevoi, H. Shirai, and T. Takizuka, Tech. Rep. **JAERI-Data/Code 97-014**, Japan Atomic Energy Research Institute (1997).

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