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Final Report: Impurity Transport in Tokamak Edge Plasmas

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Final Report: *Impurity Transport in Tokamak Edge Plasmas*

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The Plasma Theory and Simulation Group (PTSG) is collaborating with LLNL in order to model the edge region of a tokamak plasma and its interaction with the diverter plate. In the overall framework of the project, MHD will be used to model the bulk plasma. Near the edge, the MHD model will interface with the gyrokinetic code UEDGE developed at LLNL. Since the UEDGE model approximations may not be accurate within a few cyclotron radii of the diverter plate, the UEDGE code will interface with a collisional PIC-hybrid code developed by the PTSG under this project.

The PTSG PIC code will include a self-consistent potential with kinetic or fixed hydrogen ions. The sputtering profile of the plate, under development at LLNL, will be used as input to the PIC code in order to correctly model the kinetic behavior of sputtered carbon. These carbon products will interact with hydrogen according to known chemistry cross-sections. While some kinetic electrons may be used to model the fast tail of the distribution function (if necessary), the bulk of the electron population will be modeled as being in thermal equilibrium using the Boltzmann relation, resulting in a significant improvement in code speed. Coulomb collisions may also be considered.

The Boltzmann model has been implemented with various features in three of the PTSG codes: XPDP1 and OOPD1 (both 1d-3v), and OOPIC (2d-3v), according to the methodology of Cartwright [1]. When the model is fully implemented, it will include fluid interaction with the boundaries, energy conservation through the temperature term, and take into account collisions with the Boltzmann species.

A more rigorous convergence analysis has been developed than is outlined in [1]; boundary effects are included explicitly in a formulation valid in arbitrary coordinate systems. In OOPD1, the Boltzmann model is included in an object-oriented manner as part of a general fluid model framework. The basic Boltzmann solver has been implemented and shown to give self-consistent results. The details and results were described in detail in a talk presented at LLNL (updated slides attached).

Currently, the output of the three codes is being compared for a test case of a current-driven DC discharge. Computational speed-up and accuracy will be compared between PIC and the Boltzmann-PIC hybrid. A framework for general binary and three-body collisions is being developed for OOPD1. Given known cross-sections or reaction rates, this will function as a chemistry model for the code. The framework may then be imported into OOPIC.

[1] Cartwright et al., “Nonlinear hybrid Boltzmann-particle-in-cell acceleration algorithm”, *Physics of Plasmas* **8**, 3252-3264 (2000).