Neutral sampling vs. particle-identity conservation in a coupled fluid-kinetic Monte-Carlo code environment

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Since early 1990s the magnetic confined fusion community utilises coupled code environments for a self-consistent description of plasma flow and neutral gas transport in the edge region of toroidal fusion devices [1]. Usually, the plasma is treated with a fluid approach and the neutral gas transport requires a kinetic consideration. In two dimensions the plasma solution is often calculated with implicit discretization schemes (cf. B2, EDGE2D, SOLEDGE-2D), whereas the neutral gas distribution is acquired via a Monte-Carlo technique to solve the linearized Boltzmann equation (cf. EIRENE, Degas 2). Consequently, the origin of neutrals is sampled from a distribution which adds numerical noise to the simulation result. Especially in large divertor tokamak geometries, noise effects are difficult to separate from physically driven instabilities [2]. Therefore, various noise cancellation techniques such as “correlated sampling” have been implemented to overcome this problem [3].

In contrast, plasma solutions for three-dimensional geometries are usually calculated based on a diffusion-advection Monte-Carlo technique that solves the fluid equation after transformation to Fokker-Planck form (cf. EMC3 [4]). This can be understood as a particle-like treatment of fluid parcels in the transport code. In other words, the particle-identity can be conserved in the interface between the fluid and kinetic code. In the code package used here (EMC3-EIRENE), neutral sampling is the default option; however, particle-identity conservation may bring an advantage to the numerical stability. Internally, EMC3 already uses a very strict particle-identity conserving scheme, which is one reason for the strength of EMC3 compared to other approaches for three-dimensional fluid solvers. In this contribution, we describe the currently developed particle-identity conserving interface and compare it to the sampling approach.

References

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