IAEA FEC 201

Contribution ID: **104** Type: **Poster**

Verification of a Configuration Space Method for Evaluating the All-Orders Linear Kinetic Plasma Response to RF Power

Wednesday, 19 October 2016 14:00 (4h 45m)

Linear kinetic solvers are the workhorse tools for predicting the core plasma response to applied radio-frequency (RF) power in magnetically confined fusion devices. These codes are typically frequency-domain spectral, or a combination of spectral and finite-element that require the inversion of a large, dense, or block-dense, ill-conditioned double complex matrix. On the engineering side of the RF system are the antenna codes used in designing the high power antennas. These linear cold-plasma solvers have a frequency (but not wave vector) dependent anisotropic dielectric, that is straight forward to implement in methods that allow geometry conforming meshes. To address the issues of designing RF launching structures that minimize plasma-material interactions, it has become evident that an antenna-to-core simulation capability that resolves both the geometric fidelity of the plasma facing components, and the kinetic physics of the confined plasma is required. Various couplings of antenna and core codes are being developed to allow prediction of the complete antenna-to-core problem. Such couplings are required due to the present lack of a solver that can support a geometry conforming mesh, kinetic physics where required, and is computationally tractable in 3-D geometries. Here we present a verification of a computational kernel for evaluating the kinetic plasma current that will ultimately provide the kinetic plasma current operator, in an operator-split algorithm whose scaling properties will allow 3-D kinetic calculations at both the high fidelity and on arbitrary meshes for the first time. The kernel is based on a configuration space evaluation of the solution to the linearized Vlasov equation, which not only removes the restrictions of the Fourier spectral method, but also includes additional physics such as violations of the stationary phase assumption. For verification of perpendicular ion kinetics, we choose the 1-D fast-wave to ion-Bernstein-wave case. This problem requires the algorithm to resolve perpendicular ion kinetics; with parallel electron kinetics already being verified. We solve the problem with the AORSA for the reference solution. A successful verification for perpendicular ion kinetics is shown where the kernel reproduces the AORSA plasma current, given the AORSA wave-electric field as input.

Paper Number

TH/P4-30

Country or International Organization

USA

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Session Classification: Poster 4

Track Classification: THW - Magnetic Confinement Theory and Modelling: Wave–plasma interactions; current drive; heating; energetic particles