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# Advanced energetic ion and impurity ion physics in 2D and 3D magnetically confined plasmas

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The VENUS-LEVIS code [D. Pfefferle, *et al*, Compt. Phys. Communs. **185**, 3127 (2014)] has been optimised for full orbit and guiding centre simulations in fully 3D electromagnetic fields. Curvilinear flux coordinate systems are deployed, with analytic (Fourier) representation of the fields for accurate simulation over slowing down time scales of fast particles and heavy impurities. An important recent application includes the viability of ICRH [J. Faustin, *et al*, Nucl. Fus. **56**, 092006 (2016)] and synergetic NBI-ICRH in Wendelstein-7X. Optimisation of fast ion generation and core heating is identified via variation of magnetic configuration, and methods of heating and associated properties (e.g. 3-ion species heating, minority heating, ICRH heating of NBI minority ions etc). Higher harmonic ICRH is a recent upgrade of the SCENIC ICRH package [M. Jucker, *et al*, Comp. Phys. Commun. **182**, 912 (2011)] that will permit various heating scenarios to be validated in advance of experiments. Recent updates to the VENUS-LEVIS code include higher order drift effects [S. Lanthaler, et al, Plasma Phys. Control. Fusion 59, 044014, (2017)], and advanced switching between full orbit and higher order drift orbit approximation during particle motion, as required in order to maintain accuracy and numerical efficiency. Applied for example to the current European DEMO design it is found that the magnetic ripple associated with 16 toroidal field coils has a weak affect on the radial transport of alpha particles, increasing the power flux due solely to prompt losses by a factor of about two. In addition, higher order guiding centre modelling has facilitated implementation of a 5 1/2D ICRH modelling scheme into SCENIC, which has many advantages over the standard quasi-linear operator approach. The VENUS-LEVIS code has also been updated [M. Raghunathan, *et al*, Plasma Phys. Control. Fusion **59**, 124002 (2018)] to include strong toroidal plasma rotation and the neoclassical effect of collisions in the frame of the diamagnetic flows of thermal ions in three dimensions. This upgrade has been applied to the transport of tungsten in JET hybrid scenarios susceptible to *m=n=1* continuous modes. Neoclassical collisional transport effects in 3D rotating magnetic fields can cause strong core accumulation of tungsten.

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