

Application of an enhanced control-variate scheme for particle-in-cell simulations with and without collisions

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Particle-in-cell methods combined with a δf approach constitute an established and powerful method for simulating collisionless kinetic equations in plasma physics. Including collisions in such simulations requires a modified approach leading to a two-weight scheme, which has the drawback of giving a statistical error that increases with time. As in the collisionless case, the collisional scheme can be interpreted as an application of an ordinary control variate.

The classical interpretation of the δf approach as an ordinary control variate method offers new possibilities (e.g. for electromagnetic simulations). Nevertheless, it does not use the full flexibility of the method, which is provided by the enhanced control variate approach. The usefulness of this approach is illustrated for a model problem where it leads to a much better behaviour of the error, which, instead of growing indefinitely, becomes bounded by the error of a full- f scheme. A further application of the enhanced control variate is demonstrated for a collisionless simulation of ITG turbulence. Here it can be used as a diagnostic tool and as a means to eliminate the spurious violation of particle number conservation inherent to δf simulations due to statistical noise.