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Comparative study of forward and backward test-kinetic simulations to investigate anisotropic velocity distribution functions

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In this paper we perform a comparative study of the forward and backward approaches in the test-kinetic modelling of non-gyrotropic velocity distribution functions (VDFs) for particles injected into a shared electromagnetic field distribution. The test-kinetic simulation method is used to compute the velocity distribution function in various regions of a particle cloud moving in the vicinity of a region with a sharp transition of the magnetic field. The electric and magnetic fields are prescribed, steady-state and two-dimensional. Their spatial variation is limited to a transition region whose scale length is an input parameter of the problem. The electric field is everywhere normal to the magnetic field and it is obtained by solving the Laplace equation on a two dimensional rectangular grid, for Neumann boundary conditions. We apply the Liouville theorem to map into the right hand-side of the transition region the velocity distribution function specified at the source region. The numerical results show the formation of an energy-dispersed structure. Ring-shaped VDFs form inside the velocity-dispersed structure. Gyro-phase restricted velocity distribution functions are obtained in the front-side and trailing edge of the cloud due to remote sensing of large Larmor radius particles whose guiding centers rest in the core of the cloud. The velocity distribution functions obtained by both forward and backward approaches are compared and the differences between them are emphasized. In particular we discuss: (a) the coarser spatial resolution of the direct method compared to the finer resolution of the inverse one; (b) the ability of the direct method to illustrate the overall dynamics of the cloud; (c) two different approaches to initialize the velocity distribution function of the test-particles and their effect on the output phase space density.