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Full-orbit and backward Monte Carlo simulation of runaway electrons

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High-energy relativistic runaway electrons (RE) can be produced during magnetic disruptions due to electric fields generated during the thermal and current quench of the plasma. Understanding this problem is key for the safe operation of ITER because, if not avoided or mitigated, RE can severely damage the plasma facing components. In this presentation we report on RE simulation efforts centered in two complementary approaches: (i) Full orbit (6-D phase space) relativistic numerical simulations in general (integrable or chaotic) 3-D magnetic and electric fields, including radiation damping and collisions, using the recently developed particle-based Kinetic Orbit Runaway electron Code (KORC) and (ii) Backward Monte-Carlo (MC) simulations based on a recently developed efficient backward stochastic differential equations (BSDE) solver. Following a description of the corresponding numerical methods, we present applications to: (i) RE synchrotron radiation (SR) emission using KORC and (ii) Computation of time-dependent runaway probability distributions, RE production rates, and expected slowing-down and runaway times using BSDE. We study the dependence of these statistical observables on the electric and magnetic field, and the ion effective charge. SR is a key energy dissipation mechanism in the high-energy regime, and it is also extensively used as an experimental diagnostic of RE. Using KORC we study full orbit effects on SR and discuss a recently developed SR synthetic diagnostic that incorporates the full angular dependence of SR, and the location and basic optics of the camera. It is shown that oversimplifying the angular dependence of SR and/or ignoring orbit effects can significantly modify the shape and overestimate the amplitude of the spectra. Applications to DIII-D RE experiments are discussed.