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Analysis of the runaway electron distribution in an ASDEX Upgrade disruption using synchrotron radiation

Relativistic runaway electrons emit synchrotron radiation, which can be used to experimentally diagnose features of the runaway electron distribution function. In this contribution, we present the analysis of visible-light camera images of synchrotron emission from runaways in the ASDEX Upgrade discharge #35628. We perform both forward (solution of a fluid-kinetic equation system) and backward (constraining the distribution function from measured data) modelling.

We employ a coupling of the electron kinetic code CODE [1,2] and the fluid code GO [3-5], which self-consistently solves Faraday's law for the electric-field evolution and rate equations for the evolution of the temperature and ion charge states in the presence of cold argon impurities. This coupled kinetic-fluid framework is utilized to simulate the evolution of the 1D2P (radius, energy, pitch) runaway electron distribution function during the current-quench and runaway plateau phases of the disruption, with a prescribed runaway seed profile which is assumed to have survived the thermal quench. The simulations reveal that the evolution of the runaway distribution is well-described by a two-component picture: an initial hot tail seed population, which is accelerated to energies between 25-50 MeV during the current quench, together with an avalanche runaway tail which has an exponentially decreasing energy spectrum. During the runaway plateau the evolution of the runaway distribution is found to mainly consist of pitch-angle relaxation. We find that, although the avalanche component carries the vast majority of the current, it is the high-energy seed-remnant that dominates synchrotron emission.

With insights from the fluid-kinetic simulations, an analytic model for the evolution of the runaway seed component is developed. The model allows us to formulate an inverse problem for the distribution function with significantly fewer free parameters than without this theoretical insight. With weight functions calculated using the synthetic synchrotron diagnostic SOFT [6], we solve this inverse problem. The inverted distribution functions suggest that a sudden change in the synchrotron pattern, observed between two video frames—which is also correlated with a small current spike—is caused by a radial redistribution of the runaway electrons.

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