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Relativistic Runaway Electrons[1]

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This talk covers recent developments in the theory of runaway electrons in a tokamak with an emphasis on highly relativistic electrons produced via the avalanche mechanism. The rapidly growing population of runaway electrons can quickly replace a large part of the initial current carried by the bulk plasma electrons. The magnetic energy associated with this current is typically much greater than the particle kinetic energy. The current of a highly relativistic runaway beam is insensitive to the particle energy, which separates the description of the runaway current evolution from the description of the runaway energy spectrum. A strongly anisotropic distribution of fast electrons is generally prone to high-frequency kinetic instabilities that may cause beneficial enhancement of runaway energy losses. The relevant instabilities are in the frequency range of whistler waves and electron plasma waves. The instability thresholds reported in earlier work have been revised considerably to reflect strong dependence of collisional damping on the wave frequency and the role of plasma non-uniformity, including radial trapping of the excited waves in the plasma. The talk also includes a discussion of enhanced scattering of the runaways as well as the combined effect of enhanced scattering and synchrotron radiation. A noteworthy feature of the avalanche-produced runaway current is a self-sustained regime of marginal criticality: the inductive electric field has to be close to its critical value (representing avalanche threshold) at every location where the runaway current density is finite, and the current density should vanish at any point where the electric field drops below its critical value. This nonlinear Ohm's law enables complete description of the evolving current profile.

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