The CERN Accelerator School

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Electron Cloud and Instabilities

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In beam dynamics, low intensity particle beams can be satisfactorily modelled using the single particle approach, in which it is sufficient to describe the motion of particles through the external electromagnetic fields, while neglecting all other types of interactions. Conversely, the evolution of high intensity particle beams must be described including not only the externally applied electromagnetic fields but also the mutual interactions between beam particles as well as the interactions of beam particles with their surrounding environment. All the perturbations to the motion induced by the additional driving terms associated to these interactions are known as collective effects. The powerful tools of the kinetic theory in plasma physics and self-consistent multi-particle simulations including the beam-induced fields are needed to model the dynamics of particle beams in this regime.
Beside the beam's own space charge, collective effects are typically triggered by the direct electromagnetic interaction of the beam with the external chamber and equipment, described through wake fields and beam-coupling impedances, and the interaction of the beam with electron or ion clouds generated in the vacuum chamber through vacuum or surface processes. They manifest themselves as macroscopic responses of the particle beams to intensity dependent excitations, resulting in observables such as coherent tune shifts, coherent instabilities or emittance growth.
Collective effects are important because they define the machine and beam parameter space, outside of which instabilities or incoherent processes cause intolerable beam quality degradation. For example, the intensity threshold due to impedance represents the upper limit to the number of particles that can circulate in an accelerator or storage ring.

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