Synergistic fast-ion effects in magnetic fusion plasmas

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Abstract

Plasmas in ITER and future fusion reactors will be primarily heated by alpha particles. However, instead of heating fuel ions, most of the energy of alpha particles is transferred to plasma electrons. The temperature of the fuel D and T ions will be largely determined by the combined effect of the collisional power transfer from electrons to bulk ions, as well as the ion-temperature-gradient instability.

The presence of MeV-range alpha particles in fusion plasmas is also expected to result in a range of fast-ion phenomena, including the sawtooth stabilization, the destabilization of Alfvén eigenmodes (AEs), and the modification of the plasma equilibrium [1]. While the fraction of MeV-range fast ions in most of present-day fusion experiments is low and the fast-ion effects can be studied individually, a non-linear coupling between fast-ion phenomena is expected in future burning plasmas. This makes the extrapolation of alpha particle heating not straightforward.

We discuss recent results from dedicated fast-ion physics experiments at JET, where a large population of MeV-range fast ions was generated with the three-ion ICRF scenarios [2-4]. First, we report on a novel technique to sustain plasmas with an inverted q-profile in the plasma core with ICRF-generated fast ions [5]. Then, we discuss the observation of various types of AEs in these fast-ion experiments, including the axisymmetric $n = 0$ mode and the high-frequency reversed-shear AEs [6]. We proceed with the discussion of the energy-selective confinement of fusion-born alpha particles during sawtooth crashes [7]. Finally, we highlight improved thermal ion confinement in JET plasmas in the presence of MeV-range fast ions and destabilized AEs [8]. These surprising observations underscore the need for additional experimental and modelling studies for a better understanding of the synergistic fast-ion effects in future burning plasmas.

References

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