Fast particle transport: from present-day experiment and modelling towards control of burning plasmas

S.E.Sharapov
Euratom/UKAEA Fusion Association, Culham Science Centre, Abingdon, UK

The transport properties of fusion-born alpha-particles and energetic ions produced by auxiliary heating are crucial for burning plasma, since these properties will determine the plasma heating profiles, the plasma dilution due to the 'helium ash' accumulation and the power loading upon the first wall. Possible resonant interactions between alpha-particle motion and Alfvén Eigenmodes (AEs) may lead to alpha-particle behaviour different from the classical alpha-particle transport, causing less favourable profiles of the plasma heating and losses of alpha-particles in excess of, e.g., the limit 5%, required for preventing first wall damage during ITER's life time. The complete set of implications for operating in burning plasma scenarios with unstable AEs has yet to be investigated in burning plasma experiments, but the most important points for such investigations can and should be assessed by predictive modelling tools well in advance of the burning plasma experiments. Present day theory, modelling, and experiment for energetic particle physics are reviewed in this talk, and the key issues to be assessed during next three/five years are discussed.

Among the theory aspects that require improvement, synergetic effects between magnetic topology and different types of MHD modes as well as between different populations of energetic ions are underlined. The effects of AE-induced ripple trapping of fast ions and shear reversed equilibria with ripples re-directing loss fluxes of fast ions are reviewed. AE-induced or fishbone-induced redistribution of fast ions, which causes sawtooth crashes, as well as fishbone or energetic particle mode triggering of long-lived MHD modes, such as NTMs, may start to play a significant role in burning plasmas and should be assessed theoretically. The main qualitative effects associated with multi-mode coupling and the importance of a systematic study of fast ion transport in the presence of multiple modes are then reviewed. The interplay between different populations of super-Alfvénic ions is considered and the possibility of using such an interplay for controlling the AE excitation/ amplitude is discussed. Other positive aspects of energetic particle physics, such as MHD spectroscopy and resistive wall mode stabilisation in burning plasmas are considered.

In energetic particle modelling, the present-day suite of codes and how they embody the theory are described. The importance of accommodating real geometry/ equilibrium in such codes is underlined in view of the correct identification of AEs that are sensitive to the equilibrium details. Predictive modelling of the effects of AE instabilities on profiles and losses of fast ions is identified as the main aim of the modelling tools, and the ways to achieve this aim are discussed.

The best ways to test experimentally the theory and the codes on present-day machines are then considered. So far, MHD spectroscopy is found to be one of the most useful aspects of the AE physics; it provides a significant amount of information simultaneously driving improvements in diagnostics, theory, and modelling of AEs. Further improvement of fast ion diagnostics, especially the diagnostics of fast ion losses is then underlined. The importance of testing some key aspects of fast ion physics in dedicated well-designed experiments, e.g. in trace tritium experiment, is discussed.

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