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Energetic Particles in Magnetic Confinement Fusion Plasmas

Wei Chen(陈伟)[1*] and Zheng-Xiong Wang(王正汹)[2†]

[1]*Center for Fusion Science, Southwestern Institute of Physics, Chengdu 610041, China*
[2]*School of Physics, Dalian University of Technology, Dalian 116024, China*

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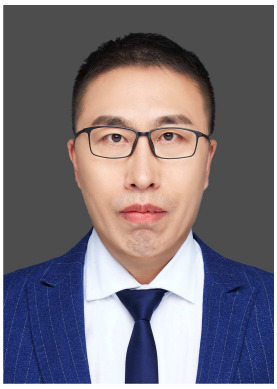
In magnetic confinement fusion (MCF) plasmas, energetic particles (EPs), also known as fast, superthermal, hot and high-energy particles, can be produced by high-power neutral beam injection (NBI) and radio-frequency (RF) wave heating in current fusion devices (e.g., HL-2A and EAST), as well as be born by deuterium–tritium (D–T) fusion reaction in the future reactors, such as ITER and CFETR. Generally, the energy of EPs is from several tens to hundreds of keV, and the fusion-born EPs are called α-particles which have 3.5 MeV energy. Compared with thermal particles, the EPs depart from Maxwellian distribution and are major minority due to their low density, large kinetic energy and high pressure in the reactors. The EPs are expected to play a critical role in plasma heating, current drive, momentum transport, energy transfer and plasma stability. Therefore, it is especially important to study EP physics theoretically and experimentally in MCF plasmas. In particular, a good α-particle confinement is essential to realize a fusion power reactor. Namely, an important physics subject in burning plasmas is interaction between EPs and thermal background plasma. The corresponding nonlinear interaction is important due to high α-particle pressure and α-particle self-heating. In ITER, high-energy NBI is used to drive a significant fraction of plasma current in addition to plasma heating. Alfvénic and acoustic-type magnetohydrodynamics (MHD) instabilities may be excited by EPs in MCF plasmas, such as various discrete Alfvén eigenmodes (AEs) and continuum energetic particle modes (EPMs) (e.g., Alfvénic zoology). These MHD instabilities can cause significant losses of hot energy and particles, which are very harmful for the plasma confinement and the first wall, resulting in deterioration of plasma performance. These instabilities can redistribute EPs and consequently influence the profile of driven current. The EPs can also potentially stabilize or destabilize internal kink mode, resistive wall mode and neoclassical tearing mode as well as induce monster sawtooth.

Currently, the study of EP physics is focused on the following aspects and submissions with respect to those are welcomed by *Special Issue: Energetic Particles in Plasmas of Chinese Physics Letters*. (i) α-particle physics in burning plasmas; (ii) destabilization of AEs and EPMs; (iii) interaction of EPs with background MHD; (iv) EP transport and losses; (v) decay and channeling of EP driven instabilities; (vi) impact and consequences of EPs on bulk plasmas; (vii) effect of EPs on plasma turbulence; (viii) suppression of EP induced instabilities and mitigation of EP losses. Finally, the EPs can be used as mediators of nonlinear multi-scale couplings in the MCF plasmas. EP physics mentioned here is extremely complex which covers not only wave–particle resonance interactions but also wave–wave couplings. Meanwhile, it also refers to various spatio-temporal scales, which, thus, brings a big challenge for the theory, numerical simulation and experiment of burning plasmas.



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*Guest Editor. Email: chenw@swip.ac.cn
†Editorial Board Member. Email: zxwang@dlut.edu.cn
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