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3D effects on energetic particle confinement and stability[1]

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Understanding the confinement and stability of energetic particle (EP) populations in 3D magnetic configurations is crucial to the future of all toroidal devices. Tokamaks will have weak symmetry-breaking effects from discrete coils, heterogeneous distributions of ferritic materials and non-symmetric (ELM/RWM) control coils, while stellarators and helical RFP states have dominant 3D features by design. Significant EP issues for 3D systems include: modifications of the plasma equilibrium and potential amplification of field errors, asymmetry enhanced EP losses and their impact both on wall heat loads and the confined EP distribution, 3D modifications to the Alfvén gap and mode structure, and the stability properties of EP-destabilized Alfvén modes. 3D equilibria that resolve localized TBM (test blanket module) asymmetries have now been developed for DIII-D and ITER. Such symmetry breaking leads to enhanced EP losses and focused wall deposition. 3D effects also modify the Alfvén spectrum by increasing the number of possibilities for mode coupling and introducing new gap structures, including the helical and mirror gaps, fine scale ripple-induced gaps and continuum crossing gaps. Improved methods have recently been developed for evaluating these modes and their stability, taking into account the large number of coupled modes and finite orbit width effects. Successful Alfvén mode identifications have been made for a range of stellarators, including W7-AS, LHD, HSX and TJ-II. A comprehensive understanding of energetic particle physics with 3D effects is a necessary prerequisite for wall protection, plasma control and flexibility and for new diagnostic development possibilities in future ignited systems.

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