Impacts of high β and fast particles on turbulence in spherical tokamak reactors.

Ben Fynney McMillan[1] and Jugal Chowdhury[2]

[1]University of Warwick, UK
[2]Sikkim University, India

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We present results from linear and nonlinear simulations of spherical tokamak discharges demonstrating the impact of β and fast particle content on core turbulence and stability of spherical tokamak (ST) reactors. The focus is to understand how turbulence in reactor-sized tokamaks will differ from that in current-day devices, and thus a geometry similar to MAST-U is chosen; we examine how the instabilities and turbulence change as collisionality is lowered to reactor relevant conditions, and as the relative energy of the fast particles increases.

Pressure gradients in the chosen ST configuration are likely to be hard-limited by the onset of ideal-MHD balooning modes, and a set of linear gyrokinetic simulations is presented showing the onset of related kinetic ballooning modes (KBM) occurs as β increases, as well as the evolution of other electrostatic and electromagnetic instabilities. For reactor-relevant fast particle populations the onset of KBM is at very long wavelength.

Nonlinear simulations show, like for conventional tokamaks, a decrease in turbulence levels with β below some critical β, but, depending on parameters, very high fluxes due to either a non-zonal transition, or the onset of KBMs near the ideal MHD stability boundary. As for conventional tokamaks, fast alphas provide a dilution effect that significantly reduces transport.

Near the KBM stability boundary, strong activation of marginally stable MHD-like modes are seen in the mode spectrum; this effect is somewhat stronger than in conventional tokamak geometry, even without direct fast particle drive, because of the higher β of the ST configuration. A range of modes, including marginally stable KBM, as well as TAE and zonal SAW modes are driven. We explore how the drift-wave turbulence can drive these modes. Such modes may provide an observational signature of this transport regime.