3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Impact of fast ions on microturbulence and transport: expectations for JT-60SA and ITER

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Microturbulence is one of the main mechanisms leading to energy confinement degradation in magnetically confined plasmas. Recently, it has been shown that fast ions generated by the Neutral Beam Injection (NBI) or Ion Cyclotron Resonant Heating (ICRH) systems can significantly reduce the heat transport driven by microturbulence in Ion Temperature Gradient (ITG) dominated plasmas at JET [1,2]. Such turbulence reduction mechanism is dominant over that provided by the ExB shear in the inner core. However, when fast ions excite electrostatic Energetic Particle Modes (EPM), a transfer of energy from EPM to turbulent modes lead to an increase of turbulence level [3]. Several topics, which might shed some light on this adversarial framework between beneficial and harmful effects, remain so far unexplored: are electro-magnetic Alfvén-like EPM playing the same role as electrostatic EPM in fast ion and thermal species transport evaluation? Is the turbulence reduction mechanism observed in JET universal or does it depend on the regime? Finally, is it possible to extrapolate these results to future devices such as JT-60SA or ITER?
In order to clarify these points, a significant effort dedicated to turbulence analyses has been carried out with the gyro-kinetic code GENE by performing linear and nonlinear simulations of a JT-60U high-ß discharge with a substantial fast ion population produced by NBI [4]. It is found that such plasma is dominated by Trapped Electron Mode (TEM) due to the strong density gradient, and the steep fast ion pressure gradient does not lead to any significant transport reduction [5]. The apparent differences between ITG and TEM plasmas are probably due to the role of zonal flows in the non-linear saturation process, which is identified as the main reason for transport reduction in high-ß ITG simulations [6]. Furthermore, it is shown that low wavenumber electro-magnetic Alfvén-like EPM can be destabilized in the low-k_y spectrum range, causing a very significant fast ion and thermal electron transport when electromagnetic effects are taken into account. This transport increase due to fast-ion-driven instability lead to numerical fluxes matchless with respect to the experimental values. Therefore, a more realistic and accurate ion distribution function based on fast ion sources may be essential in order to fully account for the impact of fast ions on plasma confinement. This is done for high-ß plasmas from JT-60SA and ITER. It is found that in both cases, as the plasmas are mostly in the ITG regime, a significant turbulence reduction is expected due to the fast ions produced by the negative ion beam (JT-60SA) and by the fast alpha particles produced by DT reactions (ITER) as long as no EPM are destabilized.

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