Improved understanding of energetic ions impact on plasma confinement from theory and experiments.

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Self-plasma heating by the MeV fusion born alpha particles from Deuterium-Tritium (DT) reactions is one of the essential pillars of magnetically confined plasmas as a realistic energy source. On the other hand, energetic particles have some effects that are not optimum from the generation of energy point of view. For instance, they transfer their energy mostly to the electrons rather than to the thermal ions or they can resonate with Alfvén waves leading to turbulent transport that can degrade the fusion power output. However, experimental validation of such expectations has been elusive due to the inherent difficulties to produce highly energetic ions in present day tokamak plasmas, which mostly use deuterium plasmas.

In this talk, we review recent theoretical and experimental progress that contributed to a significant improvement in understanding the impact of energetic ions on the confinement of thermal plasma in fusion devices. Dedicated studies performed in a broad variety of plasma conditions with Neutral Beam Injection (NBI) or Ion Cyclotron Resonant Heating (ICRH) in several tokamak devices, such as JET [1,2], ASDEX-U [3] and DIII-D [4], have shown that the ion thermal energy confinement is improved in the presence of energetic ions and electromagnetic fluctuations. In particular at JET, increasing ion temperatures were observed in plasmas with strong core electron heating from MeV ions in dedicated electron heating power scans. This result is in contrast with plasmas with pure electron heating by Electron Cyclotron Resonant Heating (ECRH), in which the clamping of the ion temperature with increasing electron heating power was observed [5].

Our dedicated numerical studies have revealed the physics mechanisms behind this – at first sight, unexpected – difference in experimental observations in electron-heated plasmas. Our results show that plasmas with a large fraction of highly energetic ions are a complex non-linear multiscale system, from small electron to large Alfvén scales, in which thermal ion turbulent radial heat transport can be reduced or even suppressed in the presence of energetic ions, notably at MeV ion energies [6]. Importantly, electron transport is not significantly enhanced in these conditions although strongly destabilized Alfvén activity is observed to couple to electron scales as deduced from Doppler Back Scattering (DBS) experimental measurements. Such numerical results are corroborated by means of novel diagnostics at JET showing significant reduction of the level of density fluctuations in plasmas with a large fraction of energetic ions close to fusion born DT alpha particles energy. In this talk, we also demonstrate this phenomena in mixed JET H-^{4}He plasmas, and thus with a similar composition as solar corona plasmas where such mixtures are dominant.

The beneficial impact of energetic ions increases at high beta and contributes to significant deviations from scaling laws that predict strong energy confinement degradation with increasing input power, as obtained in DIII-D and JET [7,8,9]. Therefore, the presence of fusion born DT alpha particles has a prospect for additional beneficial and unforeseen effects on thermal plasma confinement in reactor relevant conditions. This will be further exemplified with the first results from the recent JET-DT campaign.

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