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Energy confinement in He and D plasmas: on the role of central electron heating

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Helium is one of the gas foreseen for the non-nuclear phase in ITER [1], in part due to a H-mode power threshold close to deuterium plasmas [2]. However, energy confinement times in He plasmas have been consistently observed to be lower by approximately 30% [2,3] than those in D plasmas, which is in contradiction with the gyro-Bohm scaling of the turbulent transport, where He is expected to have better confinement than D.

To explore these discrepancies, companion discharges in helium and deuterium at ASDEX Upgrade are compared and analysed with theory-based modelling tools. Plasmas in both H and L-mode regimes with various combinations of electron cyclotron resonance and neutral beam heating powers are considered, producing different ratios of electron and ion heating fractions. In contrast to several previous results [2,3], regimes are identified in which helium plasmas have the same good confinement properties as the corresponding deuterium plasmas.

The stored energy or equivalently the energy confinement time (matched input powers) in helium is found to be comparable to that of deuterium when ECRH provides the dominant fraction of heating power, at comparable electron density profiles. In this regime, the ion temperature profile in helium is higher than that in deuterium due to a reduced ion density. Concurrently, and interestingly, also the electron temperature is higher in these conditions, where electrons are significantly hotter than ions. The increased temperatures are shown to be related to a change in the equipartition (energy exchange between electrons and main ions), which, in the presence of dominant electron heating, allows a strong increase of the ion (and electron) temperature in He, large enough to compensate the reduction by a factor 2 of the main ion particle content in helium plasma, at the same electron density of a deuterium plasma.

Consistently with previous observations [2,3], low energy confinement times are instead recovered in helium (compared to deuterium) when the neutral beam heating is dominant. In these conditions, the electron and ion temperature profiles are very close in both D and He plasmas. The He temperature is hindered to significantly exceed the electron temperature, despite the factor 2 reduction of the total number of main ions, resulting in an overall reduction of the total stored energy. This reduction of the core stored energy in helium is attributed to a concomitant destabilisation of the electron temperature gradient instability and to a reduced background core rotation and ExB shearing. Such mechanisms are investigated via local gyrokinetic simulations using the gyrokinetic code GKW [4].

References

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