Helium transport investigations in ASDEX Upgrade

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The successful operation of future fusion reactors relies strongly on the understanding of helium transport in the plasma as accumulation of helium "ash" in the plasma core would dilute the fusion fuel. To improve our understanding, the effect of electrostatic turbulence and neoclassical transport on the helium density profiles have been investigated in ASDEX Upgrade by means of charge exchange recombination spectroscopy and linear gyrokinetic simulations.

Helium charge exchange measurements are hindered by the so-called "plume" effect [1], a feature which has a strong impact on the measurement and cannot be distinguished from the prompt charge exchange signal. A detailed model for the helium plume emission, which takes into account the diagnostic observation geometry, the reconstructed magnetic equilibrium. the non-Maxwellian emission of the plume and the appropriate atomic data, has been developed. The model delivers very credible information on the helium plume, given that even the spectral emission and its non-Maxwellian features compare well to the experimental observations. Most importantly, accurate helium density profiles are derived, enabling detailed helium transport studies to be performed.

Previous investigations of helium transport at DIII-D have shown that the helium density profile has a similar shape to the electron density [2]. At ASDEX Upgrade it was found that the normalised logarithmic boron density gradients can be qualitatively reproduced by gyrokinetic modelling, if the "roto-diffusive" term, proportional to the normalized gradient of the toroidal rotation, is included [3, 4]. Moreover, gyrokinetic simulations of helium indicate that the thermodiffusive contribution to the particle flux should be more important for helium than for higher-Z impurities such as boron, leading to different peaking of the two profiles [5].

Taking these works into account, dedicated experiments optimised for both helium and boron charge exchange measurements were performed to determine the experimental correlation of these impurity density gradients with theoretically relevant plasma parameters, namely: the normalized gradients of the electron density, the ion temperature and the toroidal rotation. The high quality of the spectroscopic data and the plume emission correction enable this analysis and clearly show differences between the boron and helium transport. In addition, detailed comparisons of the measured impurity density gradients with gyrokinetic simulations of the turbulent transport will be presented.

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