Experimental study of the fast-ion confinement in W7-X based on FIDA spectroscopy

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Excellent fast ion confinement is one of the fundamental requirements for the successful operation of future fusion power plants since fast alpha particles heat the background plasma by collisions and, if lost, might damage the reactor walls. However, the necessary good fast-ion confinement has not yet been demonstrated experimentally in fusion experiments based on the stellarator concept. This is why the magnetic field structure of the Wendelstein 7-X (W7-X) stellarator experiment has been optimized for good fast-ion confinement and experimental verification of this aspect has been identified as one of the device's main objectives [1]. To study the fast-ion confinement, W7-X has been equipped with two 1.7 MW neutral beam injectors, each generating fast hydrogen ions with a maximum energy of 60 keV.

Here, we report on dedicated fast-ion transport experiments, conducted in the high-mirror magnetic configuration of W7-X, which is expected to exhibit the best fast-ion confinement. In addition to studying the effect of neutral beam injection on the plasma stored energy, the fast-ion Balmer-alpha (FIDA) technique has been applied to obtain information on radial profiles and the velocity space distribution of fast-ions. This was possible thanks to an existing multi-view spectroscopy system [2] and the implementation of the FIDASIM code at W7-X [3].

Significant absorption of the neutral beam in the SOL plasma has been observed which reduces the core NBI heating power and introduces a strongly localized prompt-loss fast-ion population that could be linked to intense and localized passive FIDA signals. In addition, clear core-localized active signals from confined fast ions are observed which agree with predictions of 5D fast-ion distribution functions by the ASCOT4 code. This demonstrates within measurement uncertainties that fast ions are well confined in W7-X and motivates for further enhancement of the FIDA diagnostic capabilities at W7-X.

References

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