Impact of externally applied 3D magnetic perturbations on fast-ion confinement in the ASDEX Upgrade tokamak

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To ensure the integrity of the divertor and other plasma facing components, future fusion devices must operate in a regime free of type-I edge localized modes (ELMs). The use of externally applied 3D magnetic perturbations (MPs) for ELM control appears as one of the possible solutions. However, it has been shown both numerically and experimentally that the use of MPs can have a deleterious impact on fast-ion confinement [1]. Therefore, MP recipes that provide ELM control while keeping fast-ion losses under a tolerable level need to be developed for ITER and beyond [2].

To this end, a set of experiments in ELM mitigated plasmas have been carried out at ASDEX Upgrade (AUG) with the aim of characterizing the impact of MPs on the confinement of beam ions. In these experiments, the light ion beam probe technique (LIBP) [3] has been applied using scintillator based fast-ion loss detectors (FILD) which allowed to infer the fast-ion orbit displacement as a function of the applied MP spectrum (ΔΦ). Radial (Q8) and tangential (Q7) neutral beam sources were used to investigate different regions of the fast-ion phase-space. The results show that the measured fast-ion orbit displacement ranges between 3-20 mm, with the minimum at ΔΦ~50º. This is compared to the measured plasma boundary displacement close to the midplane, including the correction due to the plasma control system (PCS), which is found to range between 1-10 mm, with the minimum at ΔΦ~0º. In addition, the scaling of fast-ion losses with the intensity of the applied MPs has been measured at two different ΔΦ. It is observed that the scaling is different for fast-ions from different neutral beam sources. A threshold for the onset of the fast-ion losses was found for the tangential beam source, which was not observed for the radial source. These measurements serve as an ideal testbed for code validation, to ensure our predicting capabilities towards future machines. For this reason, the results have been compared to orbit following simulations carried out with the ASCOT code, both considering the MPs in vacuum and including the plasma response. These simulations show that linear and non-linear resonances are responsible for the measured fast-ion orbit displacement, which is found to be sensitive to the velocity-space of the fast-ions.

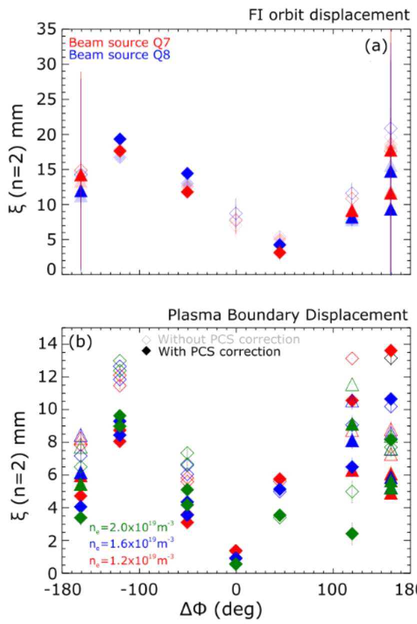

Figure 1: Measured fast-ion orbit displacement (a) and plasma boundary displacement (b) as a function of the applied MP spectrum.

The simulation results together with the experimental findings suggest that the effect of the MPs on ELM control could be decoupled from the effect on fast-ion confinement by an appropriate arrangement of the applied MP spectrum and neutral beam sources.

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*[2] L.Sanchis et al., Nucl. Fusion **61** 046006 (2021)*
*[3] X.Chen et al., Rev. Sci. Instrum. **85** 11E701 (2014)*

* See author list of *H.Meyer et al. 2019 Nucl. Fusion **59** 112014*
** See author list of *B. Labit et al 2019 Nucl. Fusion **59** 086020*