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The role of plasma response on fast-ion losses induced by edge 3D fields in the ASDEX Upgrade and DIII-D tokamaks

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A joint experimental effort on the DIII-D and ASDEX Upgrade (AUG) tokamaks shows that fast-ion confinement is quite sensitive to both edge localized modes (ELMs) and the externally imposed magnetic perturbations (MPs) used to mitigate ELMs.

In DIII-D, the role of plasma response to extermanlly applied MPs, and its impact on fast ion loss, is studied by varying the relative phase between the upper and lower I-coils across shots in ELMy H-mode plasmas with rotating n=1 perturbations. A large perturbation is observed on a magnetic probe for 0° relative phasing, while a much smaller response is measured for 240° phasing. These changes are caused by changes in the plasma response associated with coupling to resonant and non-resonant internal kinks. When the MP is applied, the oscillating n=1 fast-ion loss signal more than doubles for the phasing that couples to the resonant internal kink. Companion experiments conducted at AUG similarly show that fast-ion losses increase with plasma response. As in DIII-D, changes in the poloidal phase of the MP have a strong effect on the plasma response and, consequently, the fast-ion losses. The calculated losses are largest when the phase is resonant for fast-ions.

Unmitigated ELMs are observed to cause significant fast-ion losses in a bursting fashion that resemble the filamentary structure of the intra ELM perturbation. Time-dependent full orbit simulations have been carried out during an ELM crash in 3D fields calculated with JOREK. The dominant (for this case) n=8 ELM structure is clearly visible on the simulated first wall heat load. The time-scale of the simulated losses is consistent with the observed ELM induced filamentary losses. Simulations further indicate that the large fast-ion bursts observed in low collisionality plasmas appear correlated with ELM perturbations that are radially extended.

The results presented here prove that the plasma response plays an important role in determining the impact externally applied 3D fields have on the fast-ion population and ultimately on the interaction between fast-ions and edge perturbations in general. The ability to tune the perturbation poloidal spectra (and coupling to internal modes) may help finding a coils configuration that maximize the ELM mitigation while keeping the associated fast-ion losses under acceptable levels.

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