Non-linear MHD modelling of Edge Localized Modes suppression by Resonant Magnetic Perturbations in ITER.

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DE LA RECHERCHE À L'INDUSTRIE

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JOREK MODEL

The non-linear resistive MHD JOREK code[1,2] with realistic tokamak geometry (X-point, divertor, walls, SOL), realistic spectrum of RMP coils, toroidal rotation, the bi-fluid diamagnetic effects and neoclassical poloidal friction represent a minimum model which permits to reproduce RMP experimental results (for example in ASDEX-Upgrade [3] and KSTAR [4]).

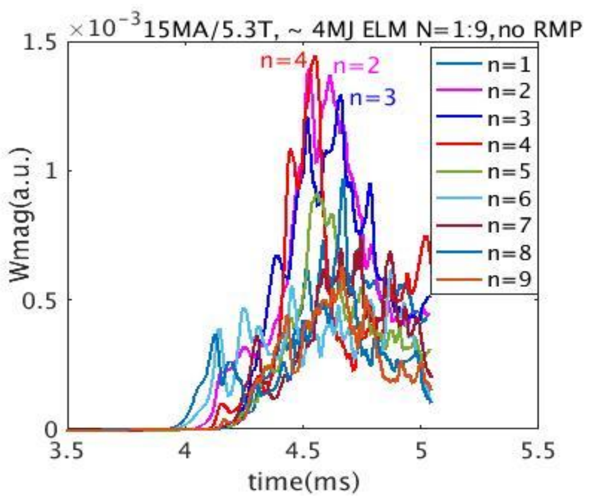
ELM suppression criterion? Vacuum criterion of ELMs suppression [5] with islands overlapping is not valid because of plasma response: screening, amplification of RMPs.

Role of kink-peeling response in ELM suppression? Linear resistive MHD MARS-F criterion with plasma response (maximum displacement near X-point =kink response) give better predictions of the experiments [6,7] Here the optimisation of RMP coils phasing was done by MARS-F code [7]. The vacuum RMPs generated by external coils were calculated by the vacuum code ERGOS [8] and are imposed at the computational boundary of JOREK code progressively increasing on a time scale of a few ms until stationary RMPs.

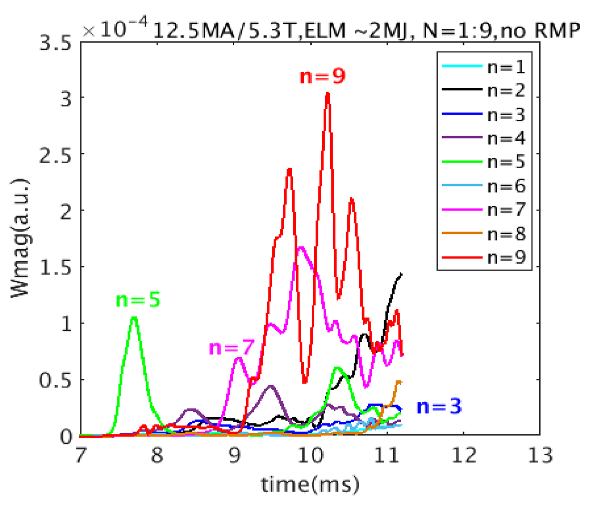
ITER SCENARIOS: 15MA 12.5MA, 10MA,5.3T (initial conditions: ASTRA code [9])

ELMs w/o RMPs. Harmonics N=1:9

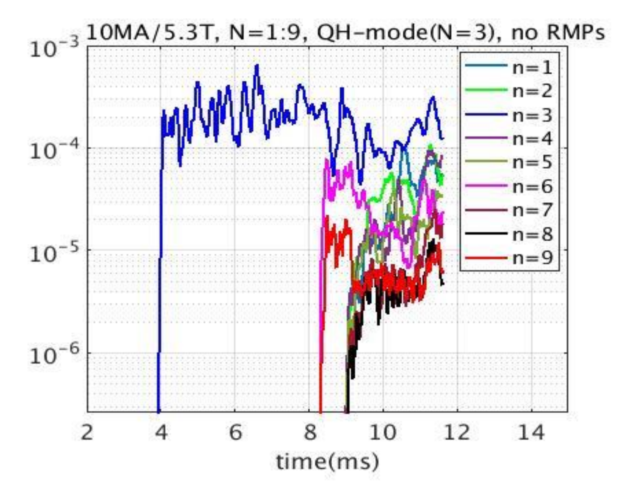
15MA/5.3T, 4MJ ELM

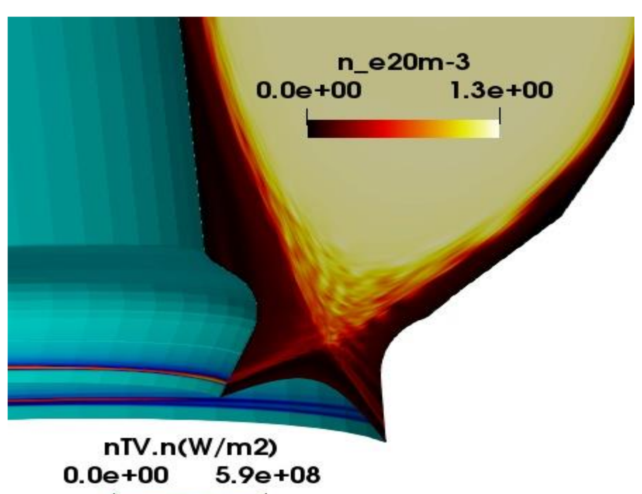


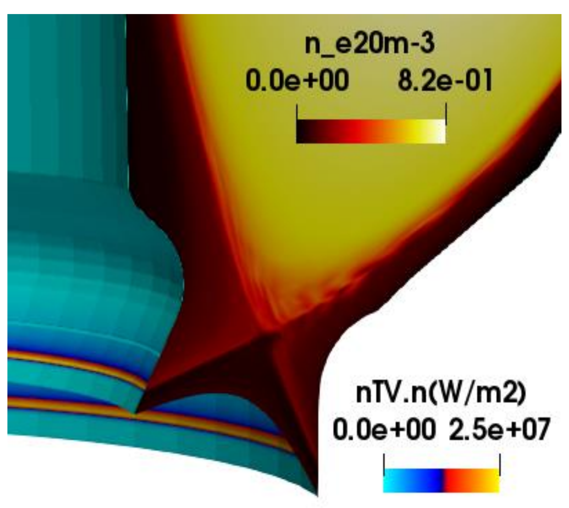
12.5MA,2MJ ELM

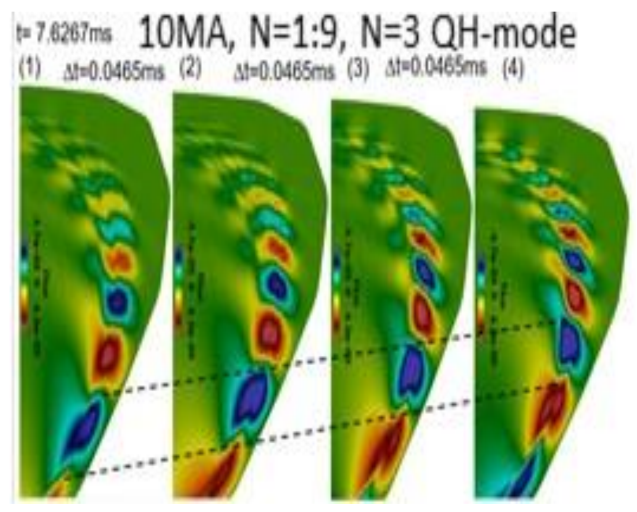


10MA (rotating QH-mode N=3)

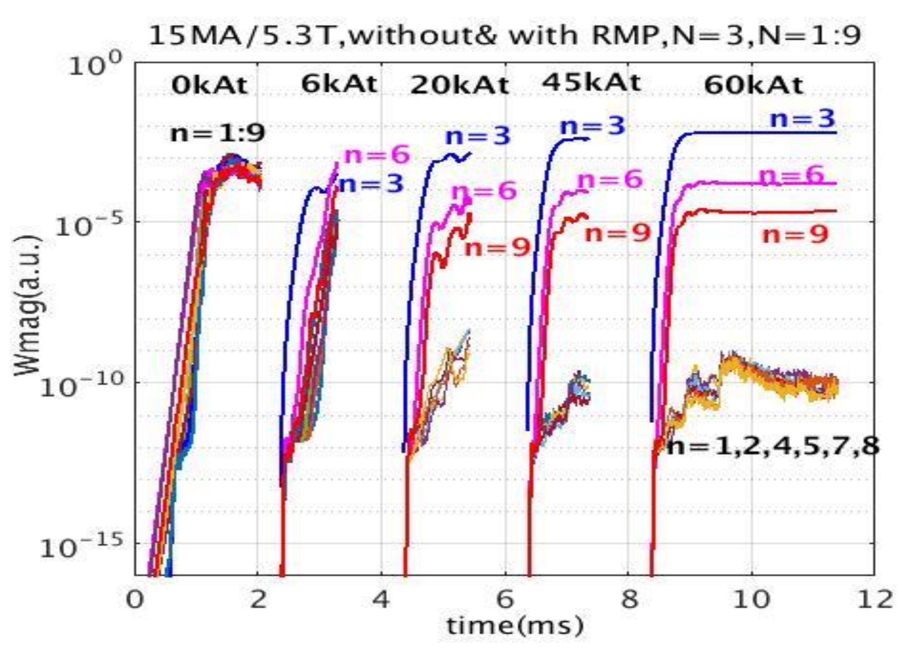


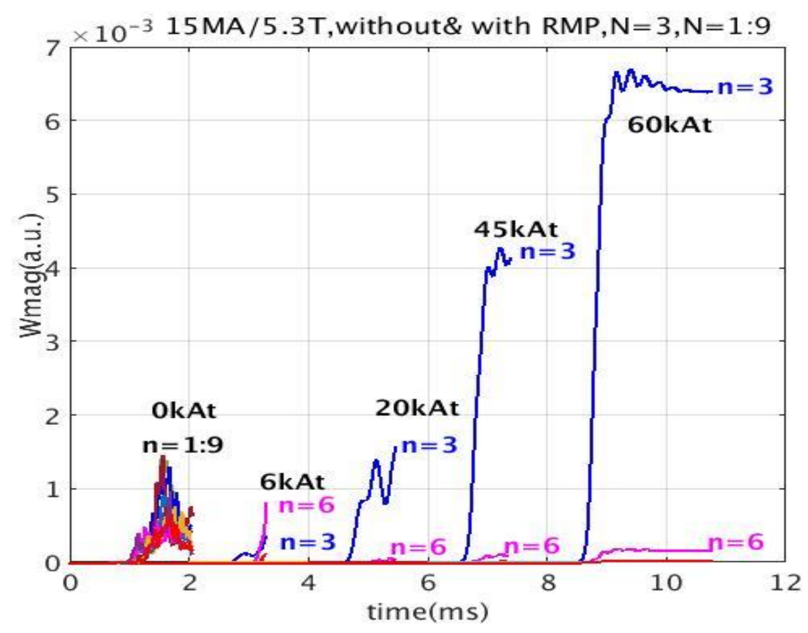




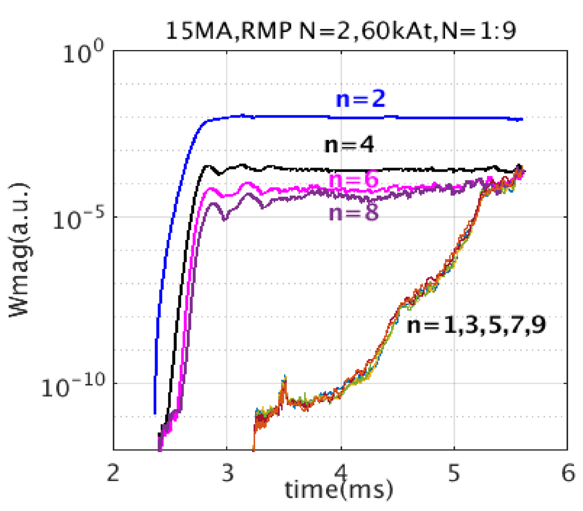


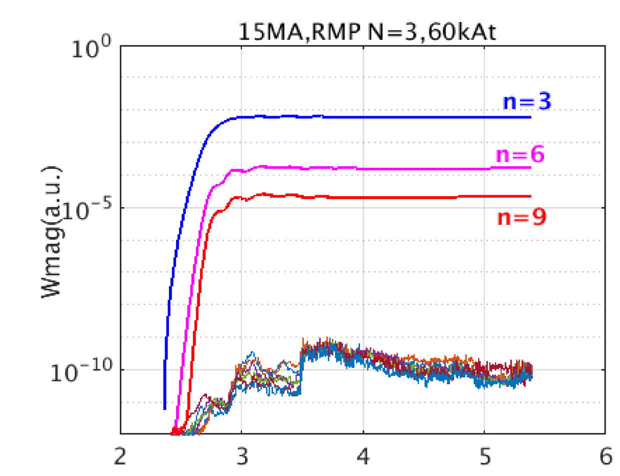
ELMs SUPPRESSION BY RMPs: RMP THRESHOLD: 45-60kAt in 15MA/5.3T

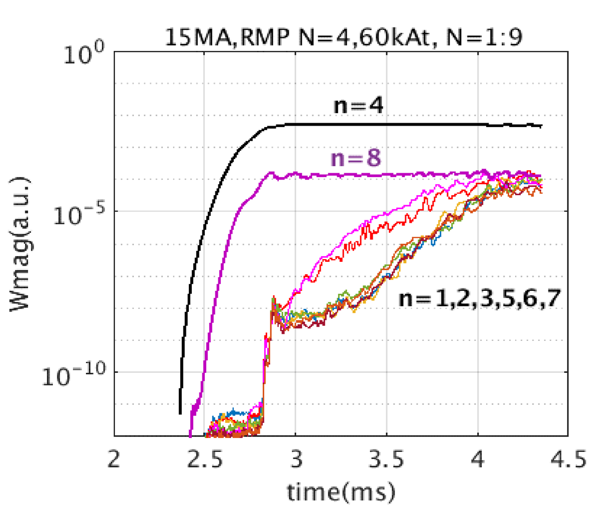


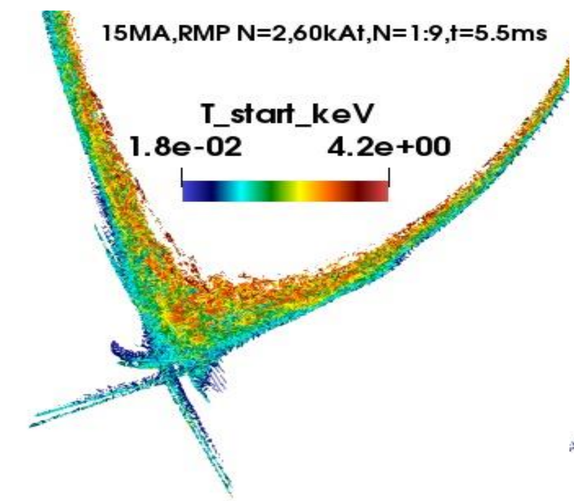


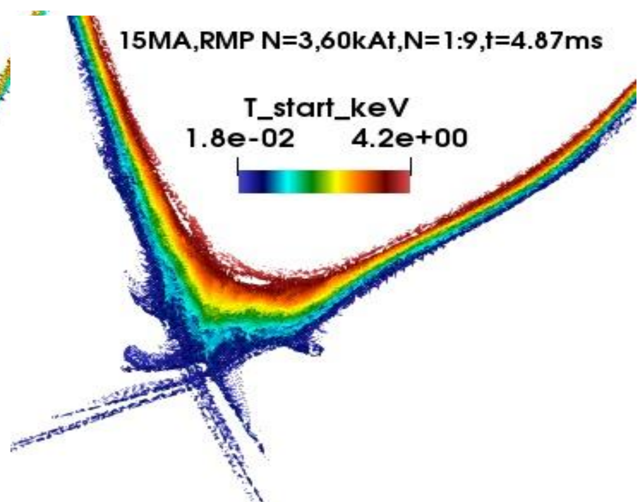
ELMs SUPPRESSION BY RMPs in 15MA/5.3T SCENARIO: N=2,3,4,60kAt

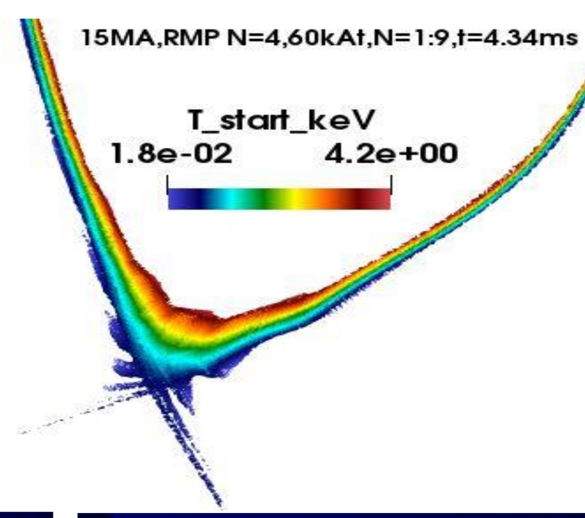


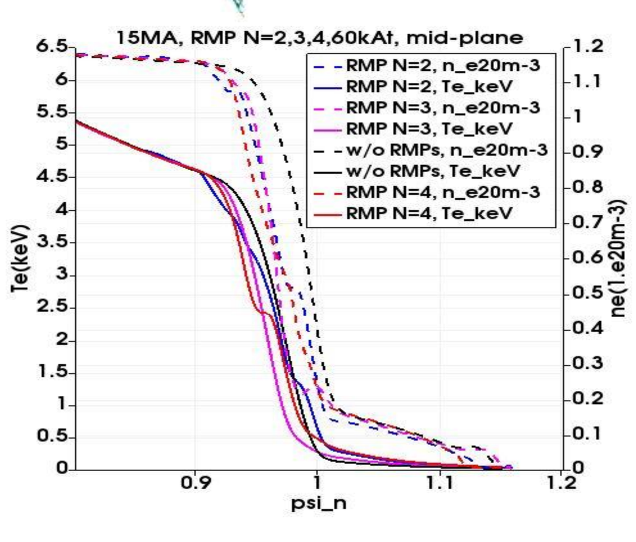


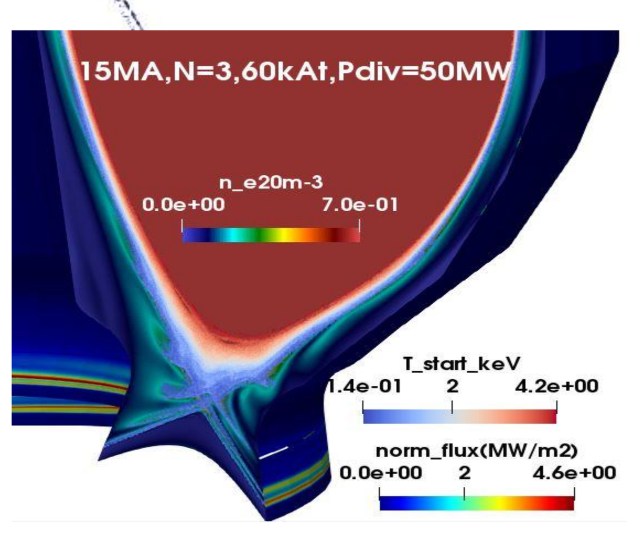


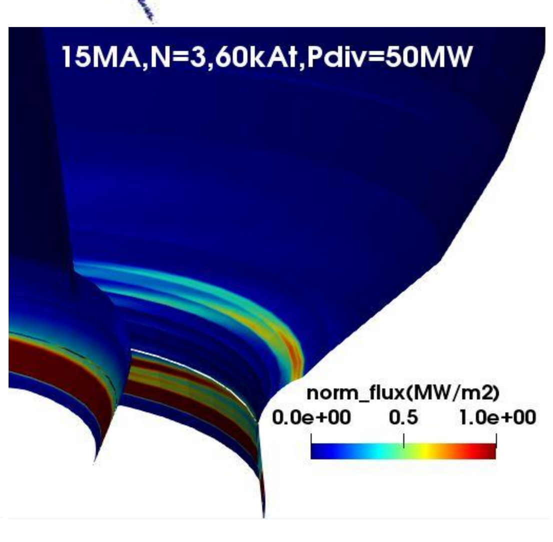




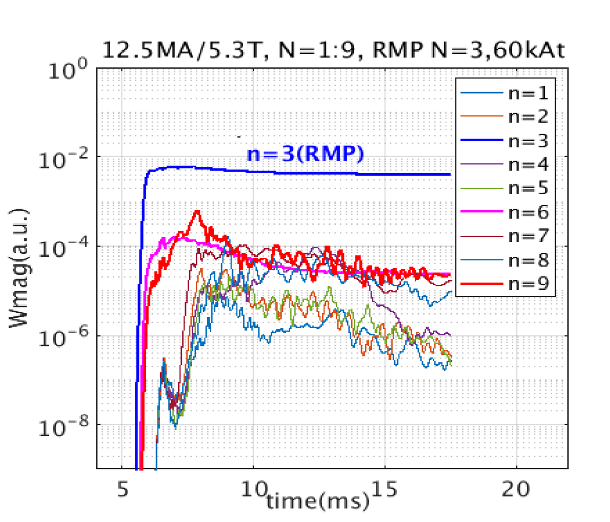


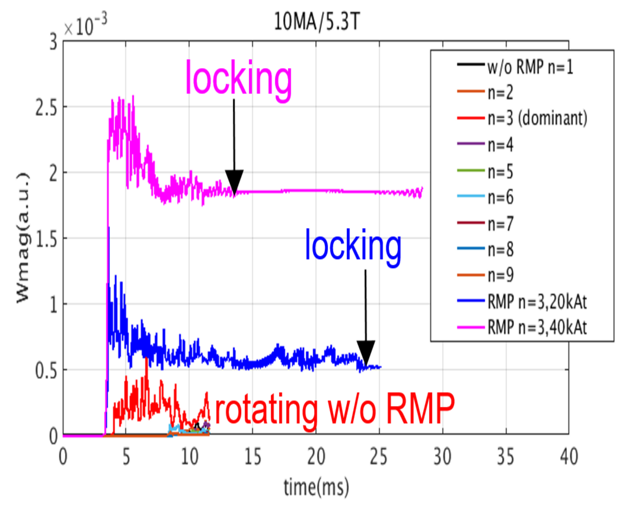


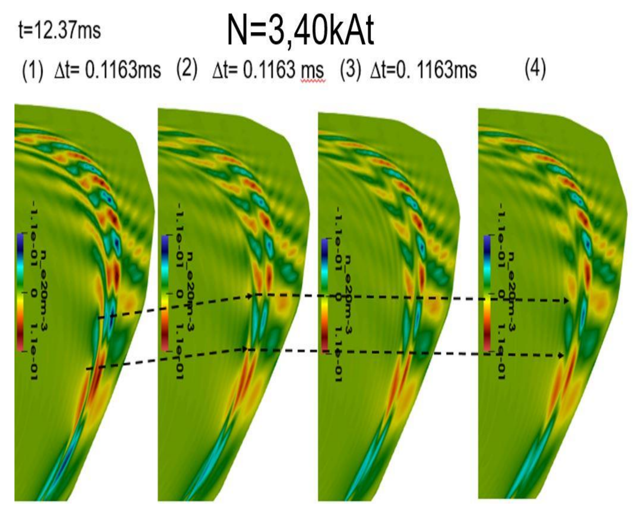


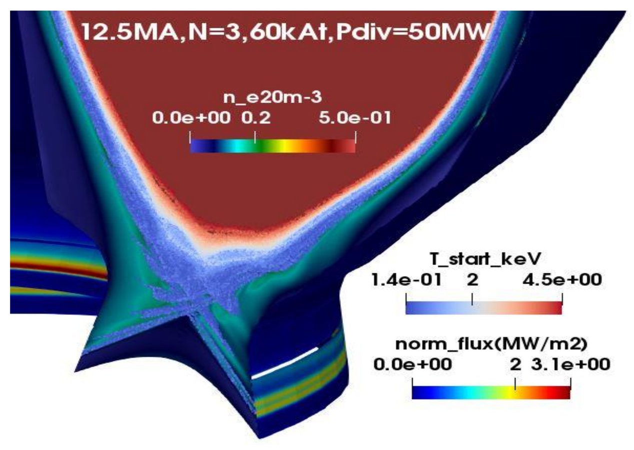


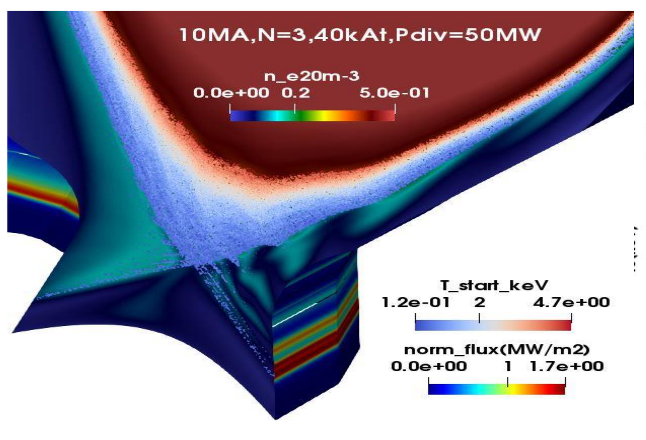
ELMs SUPPRESSION BY RMPs N=3 in 12.5MA,10MA SCENARIOS

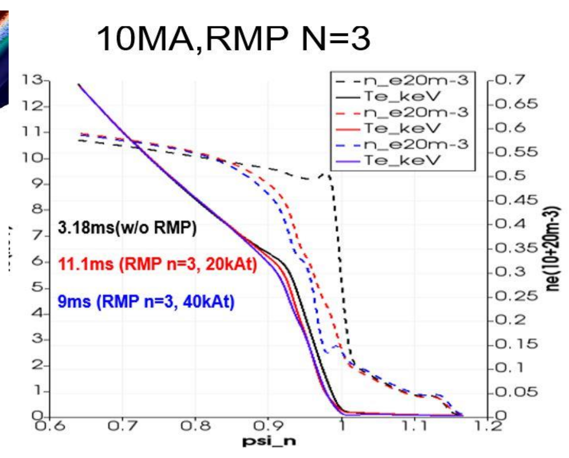




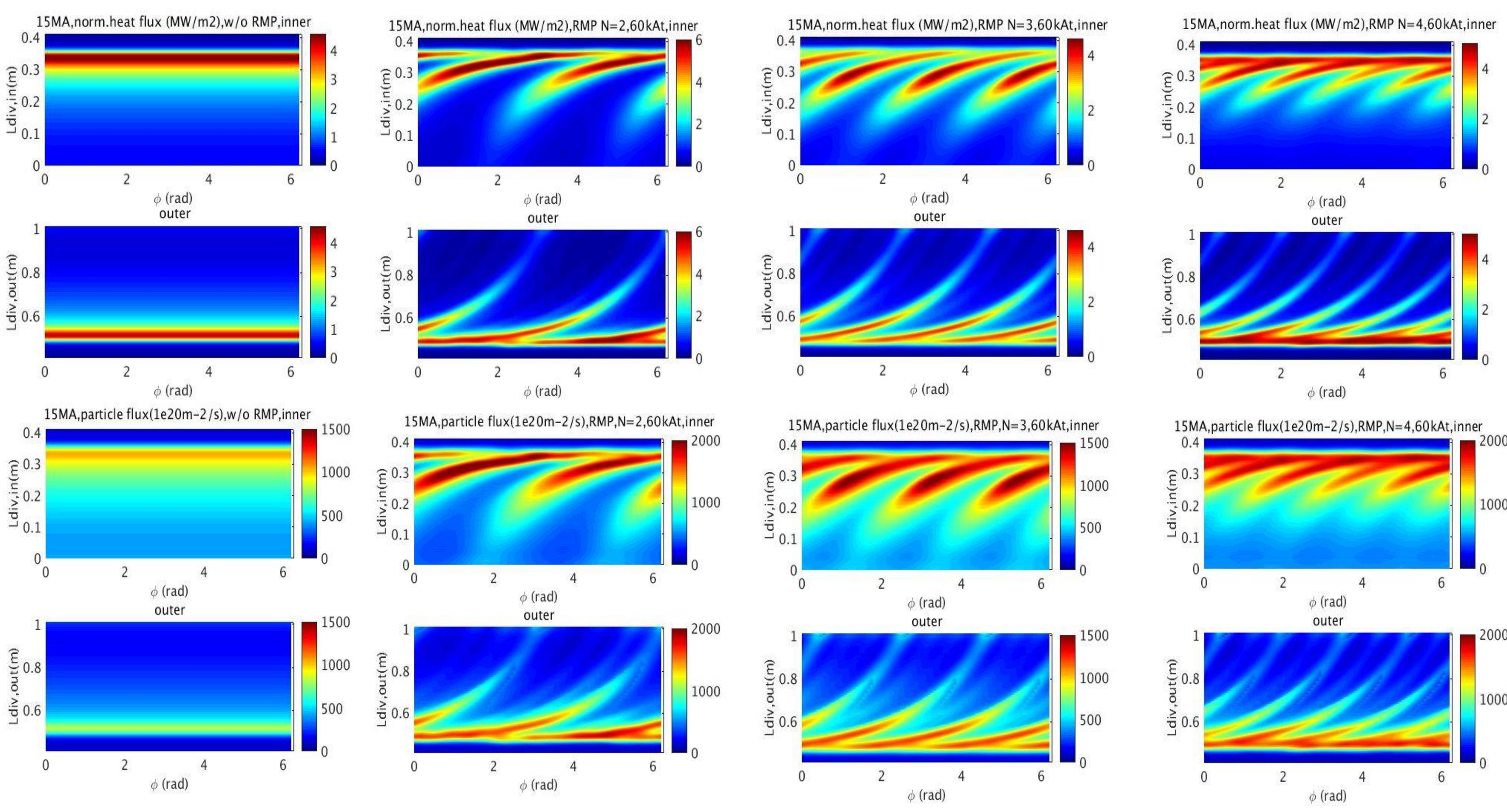








DIVERTOR FOOTPRINTS. Pdiv=50MW



CONCLUSIONS

- Edge Localized Modes (ELMs) suppression by Resonant Magnetic Perturbations (RMPs) was studied with non-linear resistive MHD code JOREK for ITER H-mode scenarios *15MA,12.5MA,10MA/5.3T*, obtained by the ASTRA code .
- RMP spectra, optimized by the linear MHD MARS-F code, with main toroidal harmonics *N=2, N=3, N=4* used as boundary conditions of the computational domain of JOREK including realistic RMP coils, plasma, divertor and wall geometry. The model includes all relevant plasma flows: toroidal rotation, two fluid diamagnetic effects and neoclassical poloidal friction.
- The threshold for ELM suppression was found at a maximum RMP coils current of *45kAt-60kAt* compared to the coils maximum capability of *90kAt*. With RMPs, the main harmonic and the non-linearly coupled harmonics remain dominant at the plasma edge, producing continuous MHD turbulent transport and suppressing ELMs in all scenarios.
- In the high beta poloidal steady-state *10MA/5.3T* scenario a rotating QH-mode without ELMs was observed even without RMPs. *N=3* RMPs induced a static QH-like mode, locked to the RMP fields in this scenario.
- The 3D divertor heat and particle fluxes in the stationary RMP phase show the characteristic splitting with the main RMP toroidal symmetry. The radial extension of the footprints typically was *~20 cm* in inner divertor and *~40 cm* in outer divertor with heat fluxes decreasing further out from the initial strike point from *~6-5MW/m²* to *~1MW/m²* in the stationary regime with RMPs and total power in the divertor *~50MW.* The footprints remain within the divertor target and baffle areas. However in transient regimes when RMPs are switched on, part of plasma thermal energy is lost and these heat fluxes can be much larger; optimization of RMP switch-on needs to be studied further with respect to the ensuing power fluxes and L-H access.

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