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NBI driven shear Alfvén waves in the presence of ECR heating and EC driven current in the TJ-II stellarator

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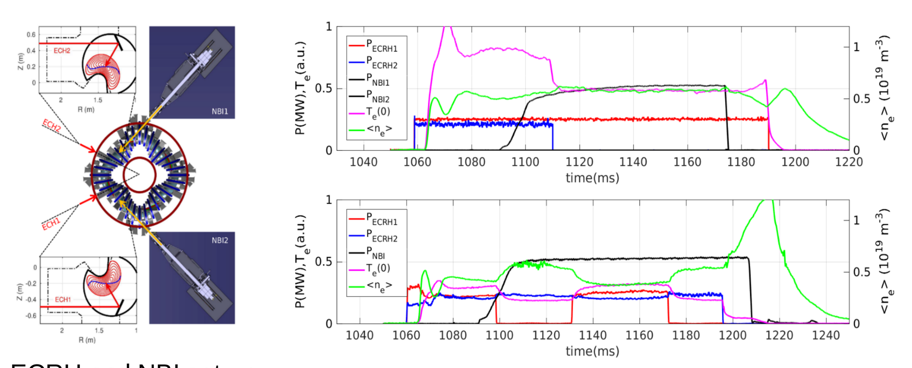
ABSTRACT

- TJ-II experimental results illustrating the influence of ECRH and ECCD on NBI-driven Alfven Eigenmodes (AEs) are summarized. For the experiments that explore the impact of **on-axis** ECRH and ECCD, the output of linear stability simulations using FAR3d is consistent with the observed mode frequencies and measured radial amplitudes. The chirping modes experiments scanning different the ECRH power deposition show very different chirping patterns related to changes in plasma temperature. A comprehensive poloidal and toroidal mode number analysis is still needed to support on-going work towards theory validation.

BACKGROUND

- ECRH and ECCD are considered as external "actuators" for AEs control in magnetic confinement devices [1]. This topic has been the subject of extensive experimental activity in the TJ-II stellarator [2-4].

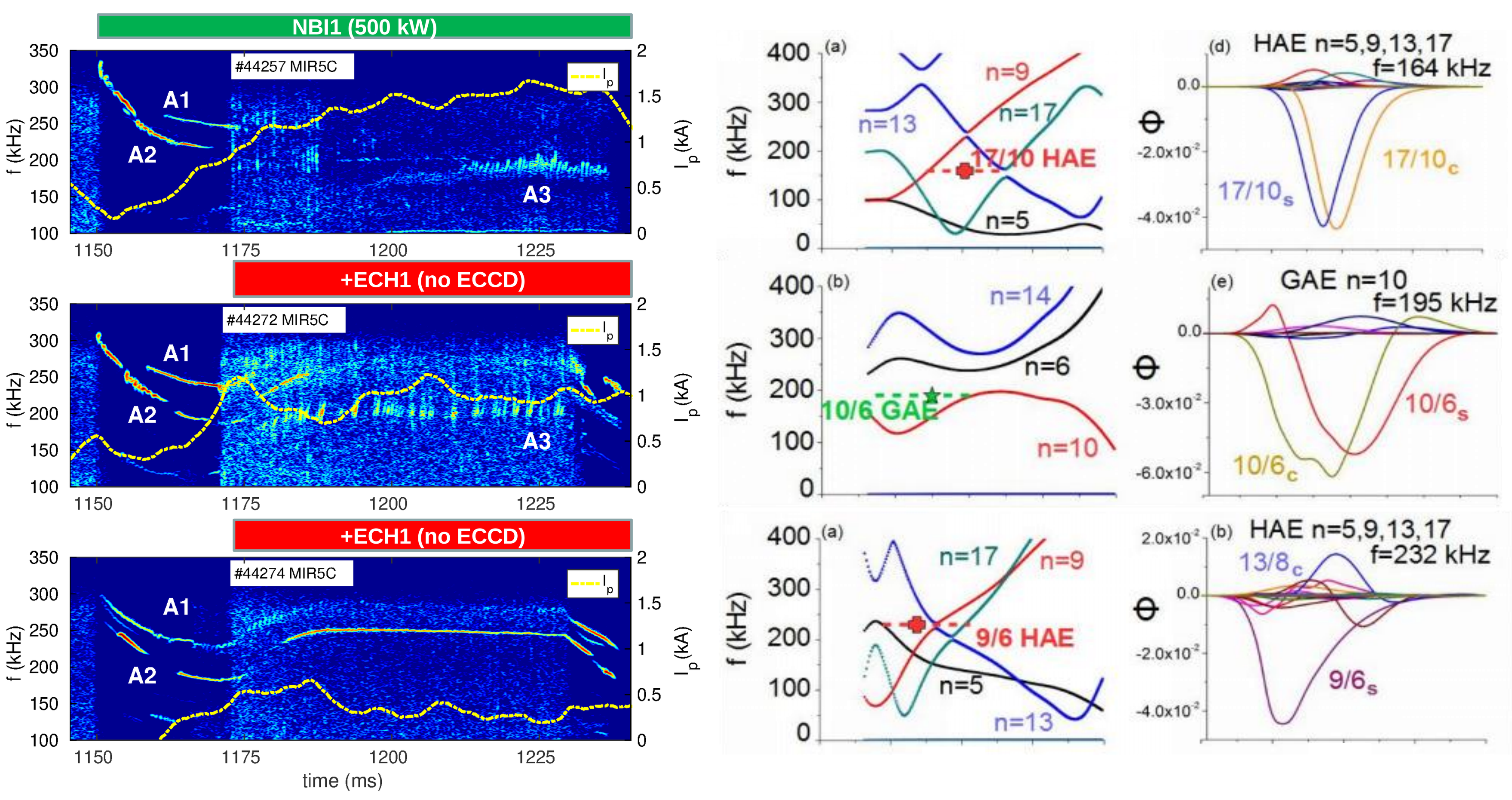


ECRH and NBI set-up

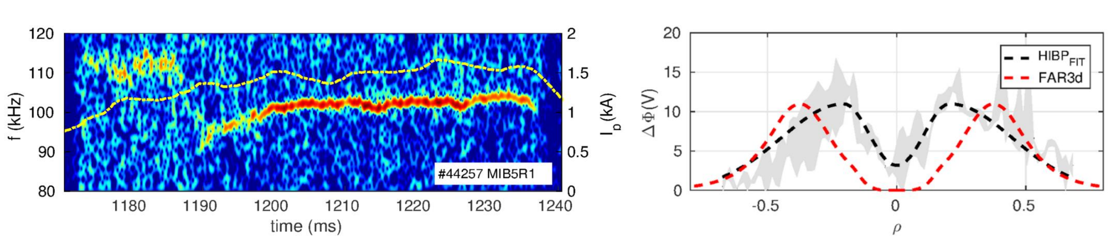
- Several scenarios have been explored leading to very different results.
- The results provide a valuable input for the validation of 3D MHD simulations with codes such as STELLGAP [5] or FAR3d [6].

RESULTS

Impact of on-axis ECRH and ECCD: the role of rotational transform profile

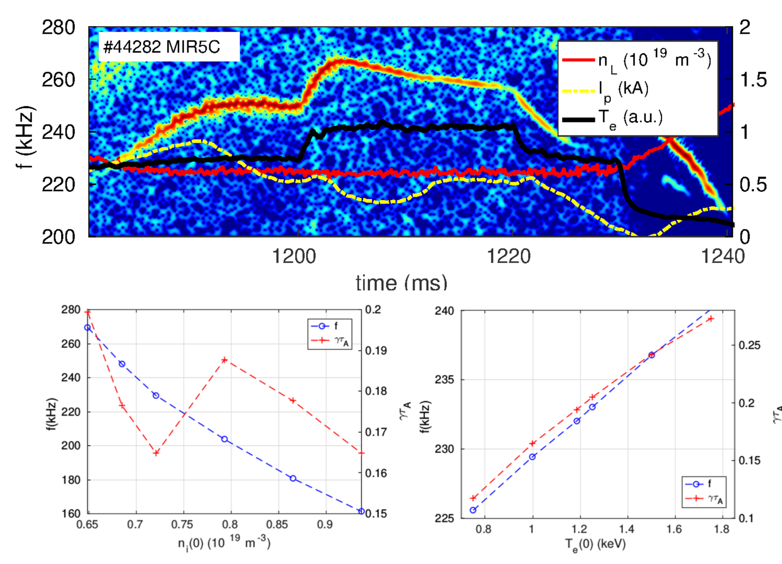


- $\iota(\rho)$ in steady state is calculated with VMEC using theoretical plasma current profiles obtained with FAFNER, DKES and TRAVIS [3]. Linear FAR3d simulations [7] predict AEs destabilization compatible with frequency of observed modes.
- The profile of potential perturbations measured by the dual heavy ion beam probe (HIBP [8]) is consistent with the profile of the predicted dominant mode (although we are comparing linear vs. fully developed instability).

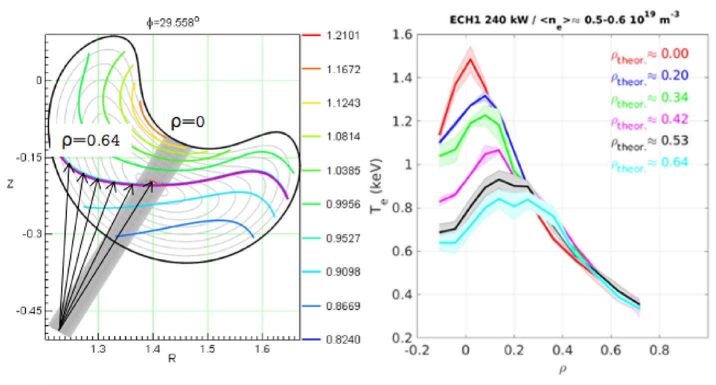


Adding on-axis ECRH power

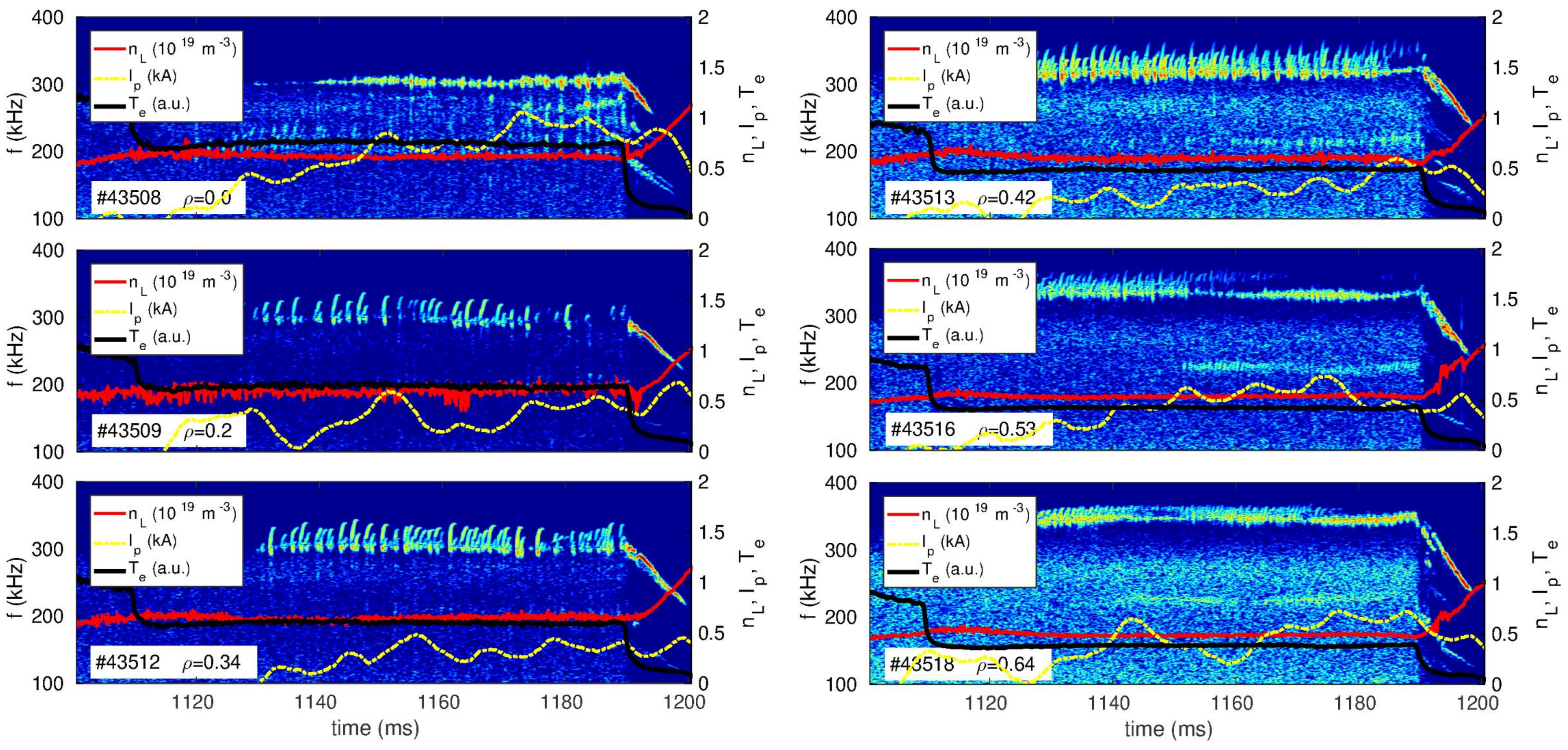
- Additional on-axis ECRH power in ECCD scenarios modifies the mode frequency.
- FAR3d simulations accounting for changes in $n_e(\rho)$ and $T_e(\rho)$ and considering the combined effect on mode drive (higher β_{fast}) an damping (lower η $\rightarrow$ higher stability) predict a similar jump in frequency.



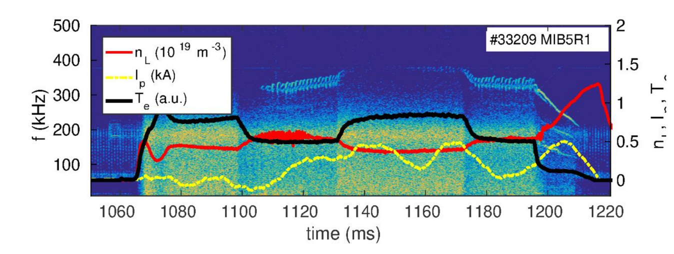
Chirping modes in off-axis ECRH heating

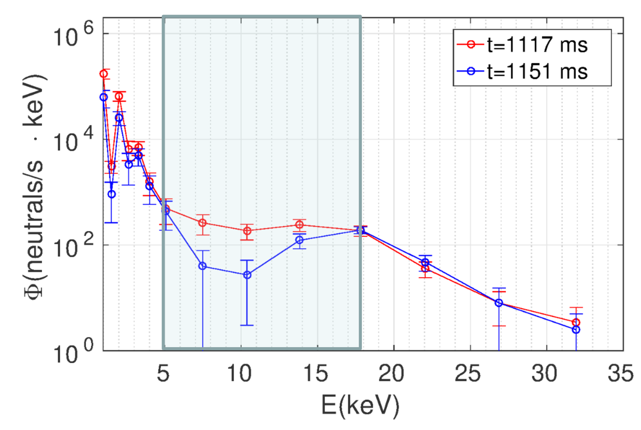


- Off-axis ECRH power scan modifies temperature profile (also density and current to a lesser extent).
- Chirping mode pattern changes accordingly (mode drive and damping are modified)



Adding off-axis ECRH power: chirping mode mitigation

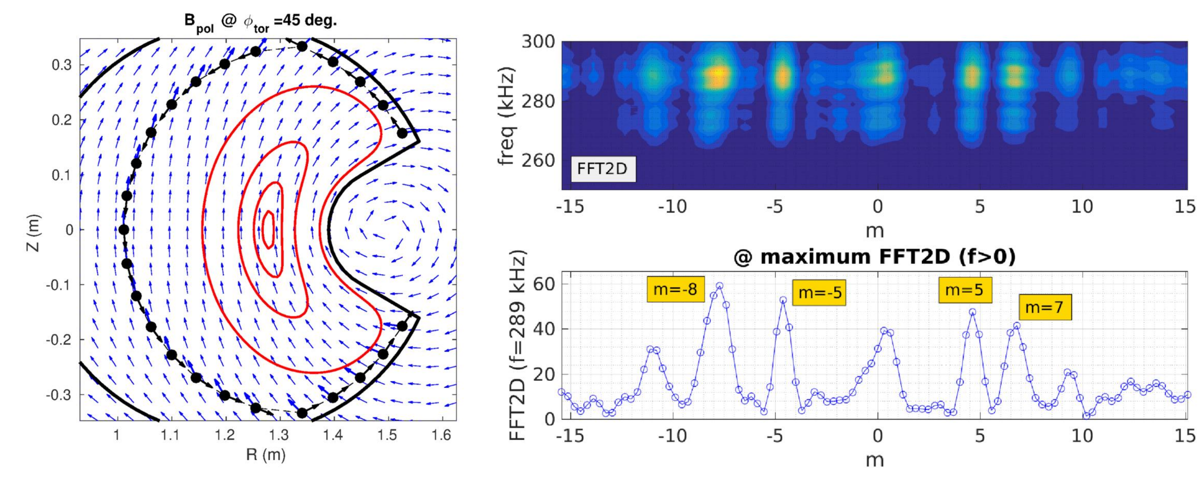


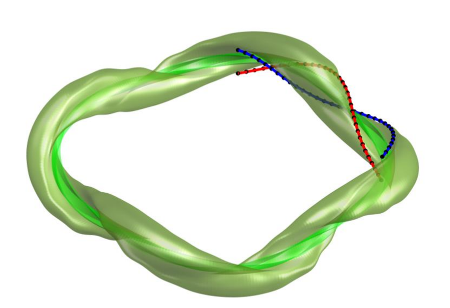


- Similarly to the result of the on-axis ECRH experiment, a jump in mode frequency is again observed (with a larger change in density here)
- In contrast, the chirping mode amplitude is clearly mitigated when additional off-axis ECRH is applied.
- CNPA data shows a decrease of flux of CX neutrals in the middle energy range → indication of mode drive suppression or higher damping not observed in on-axis experiments?
- NBI slowing-down, ECRH deposition (trapped particles fraction) and mode stability simulations are needed to understand mode mitigation.

Mode number measurements using magnetic coils

- Mode number analysis is essential to identify the type of observed mode (TAE / HAE / GAE) and at the same time validate the theoretical predictions.
- Poloidal mode number measurement is available [9] (not in all shots). Commissioning in 2020 of two helical arrays allows toroidal mode number measurements (on-going).





96 coils (3D) in helical array.
25 coils iin poloidal array

SUMMARY

- ECRH and ECCD have a clear impact on NBI driven modes demonstrating their utility as actuators for AEs control either tailoring the rotational transform profile (ECCD) or modifying the drive-damping balance by changing plasma parameters (ECRH).
- The output of several types of experiments exploring different scenarios provides input, i.e. mode frequencies and mode structure (radial profile and mode numbers) helping to validate MHD simulation tools in non-axisymmetric devices, as STELLGAP and FAR3d, or fast particles orbit and slowing down Monte Carlo codes, as ASCOT or FAFNER.

References

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