Stability analysis of TJ-II stellarator NBI driven Alfvén Eigenmodes in ECRH and ECCD Experiments

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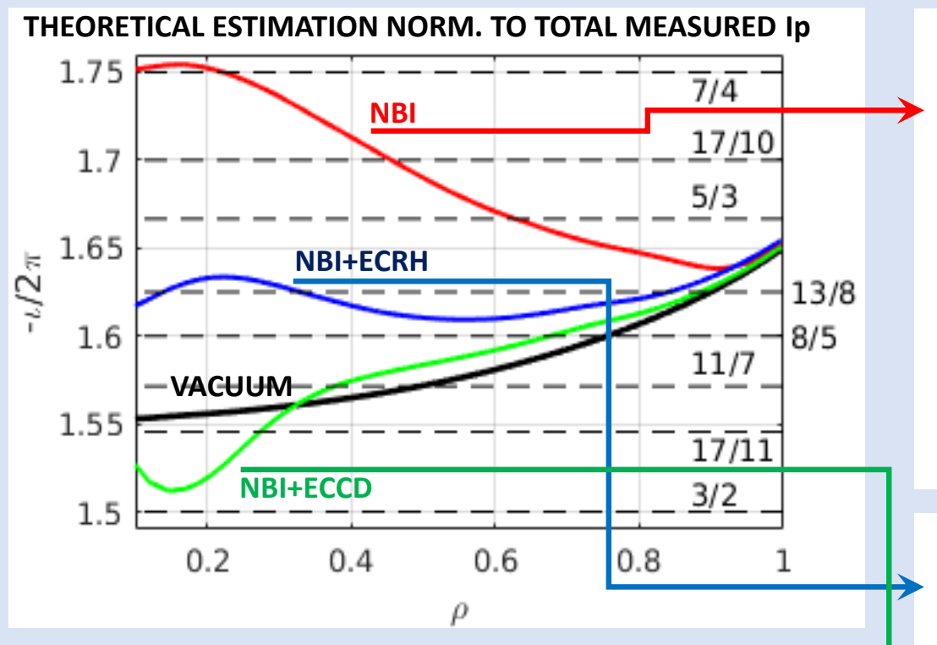
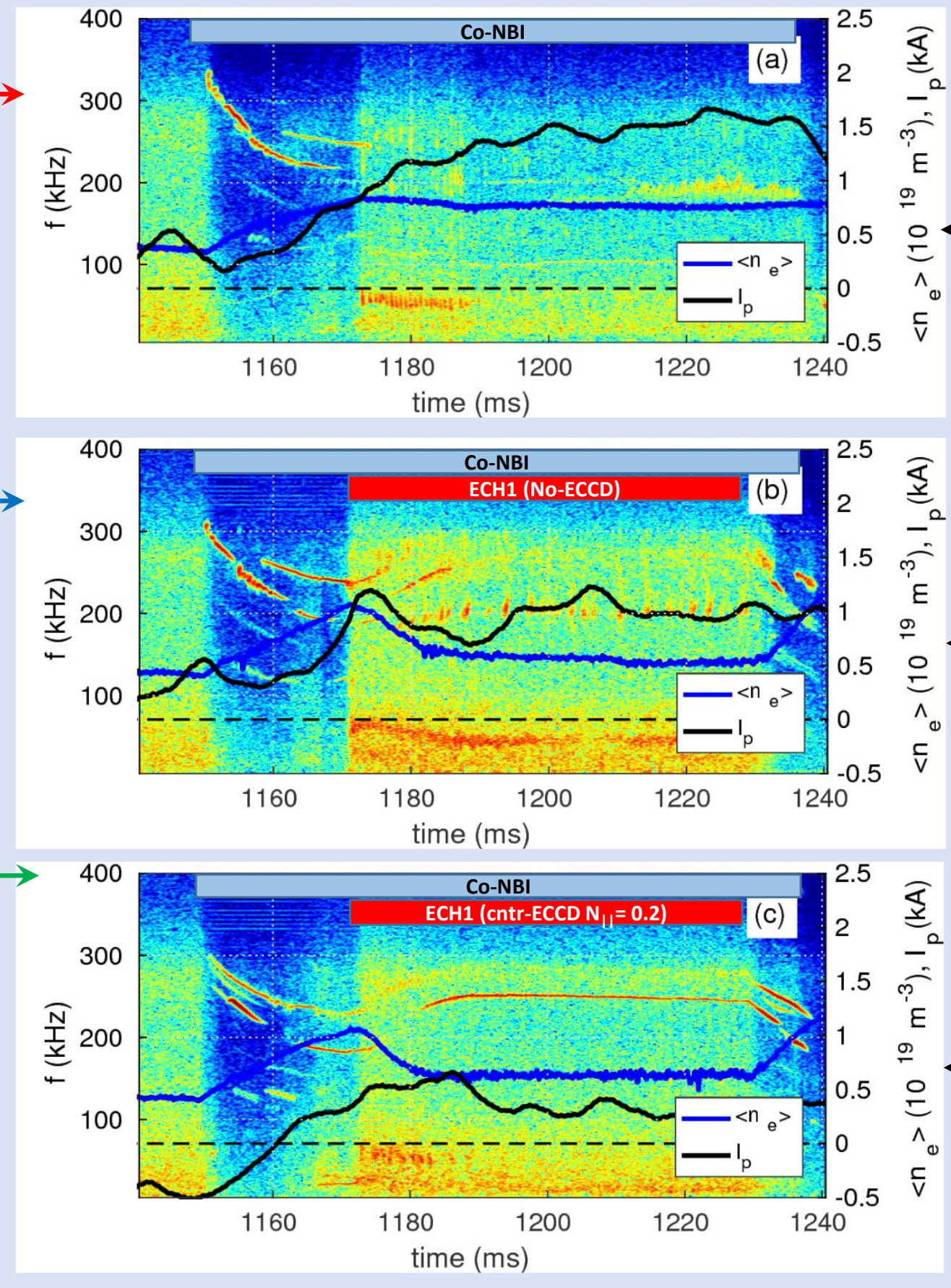
ABSTRACT

- FAR3D [1] code is used to model the NBI-driven Alfvén Eigenmodes activity in the TJ-II stellarator when ECRH, with and without ECCD, is applied. Preliminary mode identification and growth rates calculation is performed and reasonable agreement is found in most cases.
- Lack of mode number measurements prevents further confirmation and discrimination among different modes with similar frequencies.

BACKGROUND

- ECRH and ECCD are considered as external “actuators” for AEs control [2].

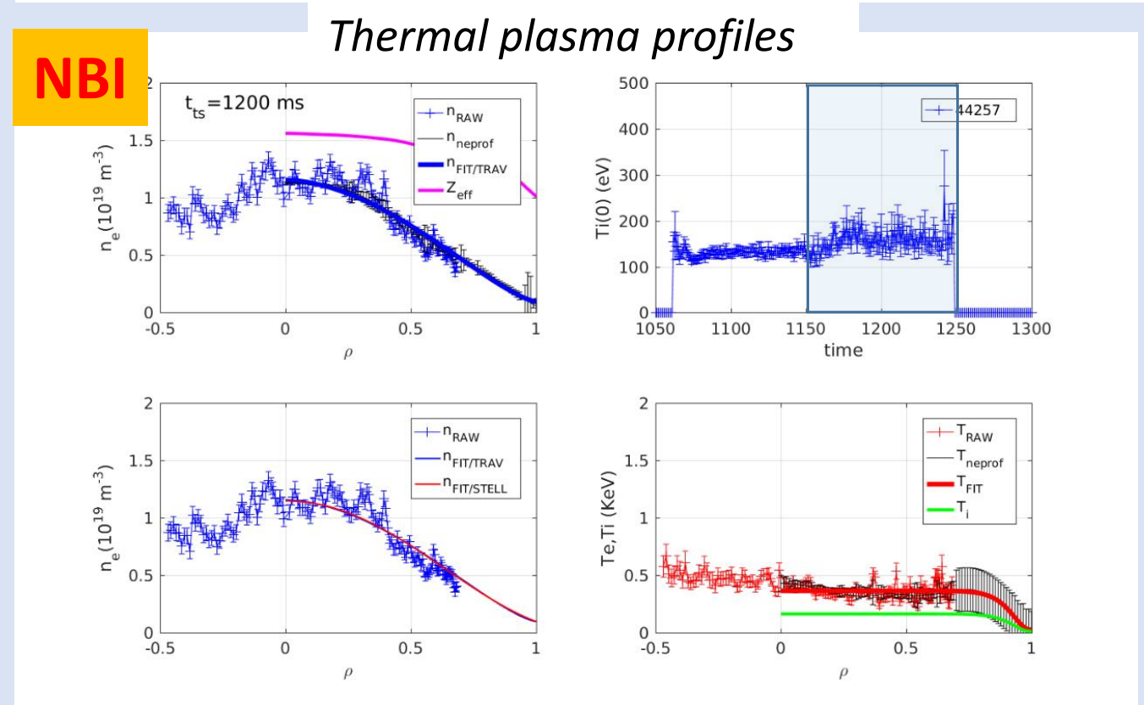




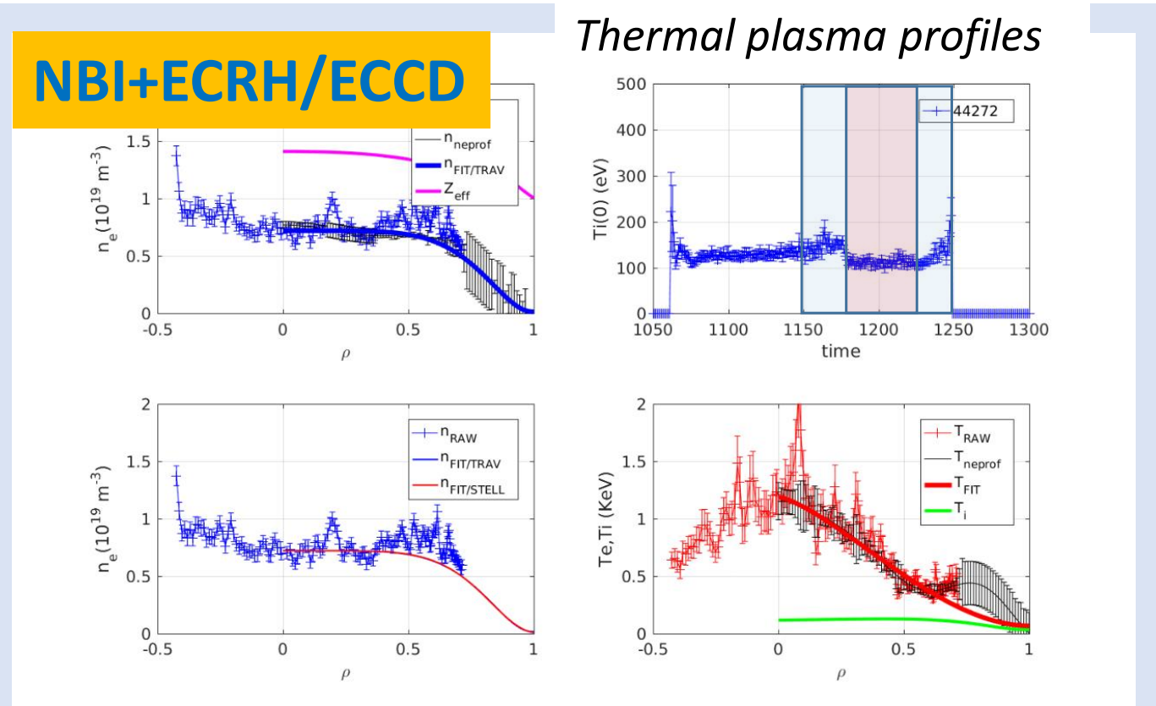
Magnetic fluctuations

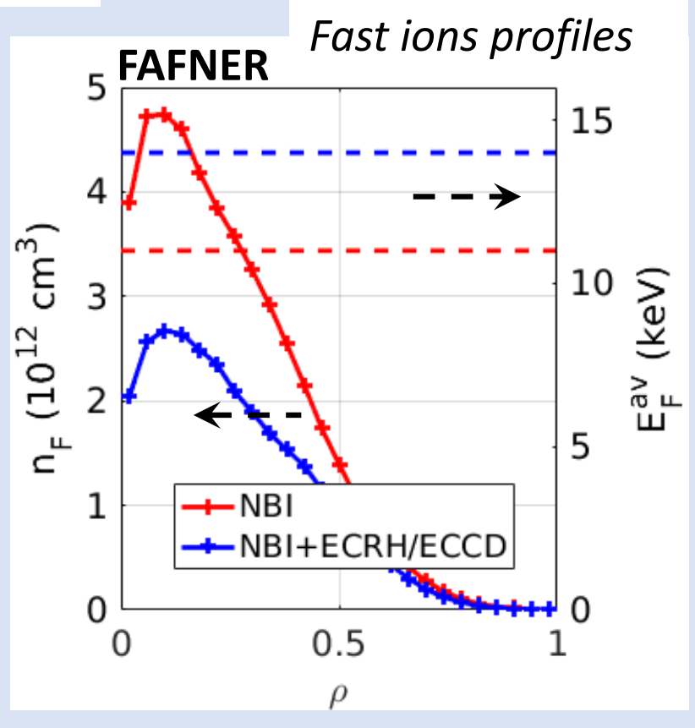
- Experiments in TJ-II show that slight changes in total current have a strong impact on **s**hear **A**lfvén waves **s**pectrum (SAS) [3].
- $\iota(\rho)$ is calculated with VMEC using theoretical plasma current profiles obtained with FAFNER [4], DKES [5] and TRAVIS [6] $\Rightarrow$ STELLGAP [7] and AE3D [8] results shows changes in SAS.
- No $\iota(\rho)$ or n/m measurement **were available** in these shots

NBI

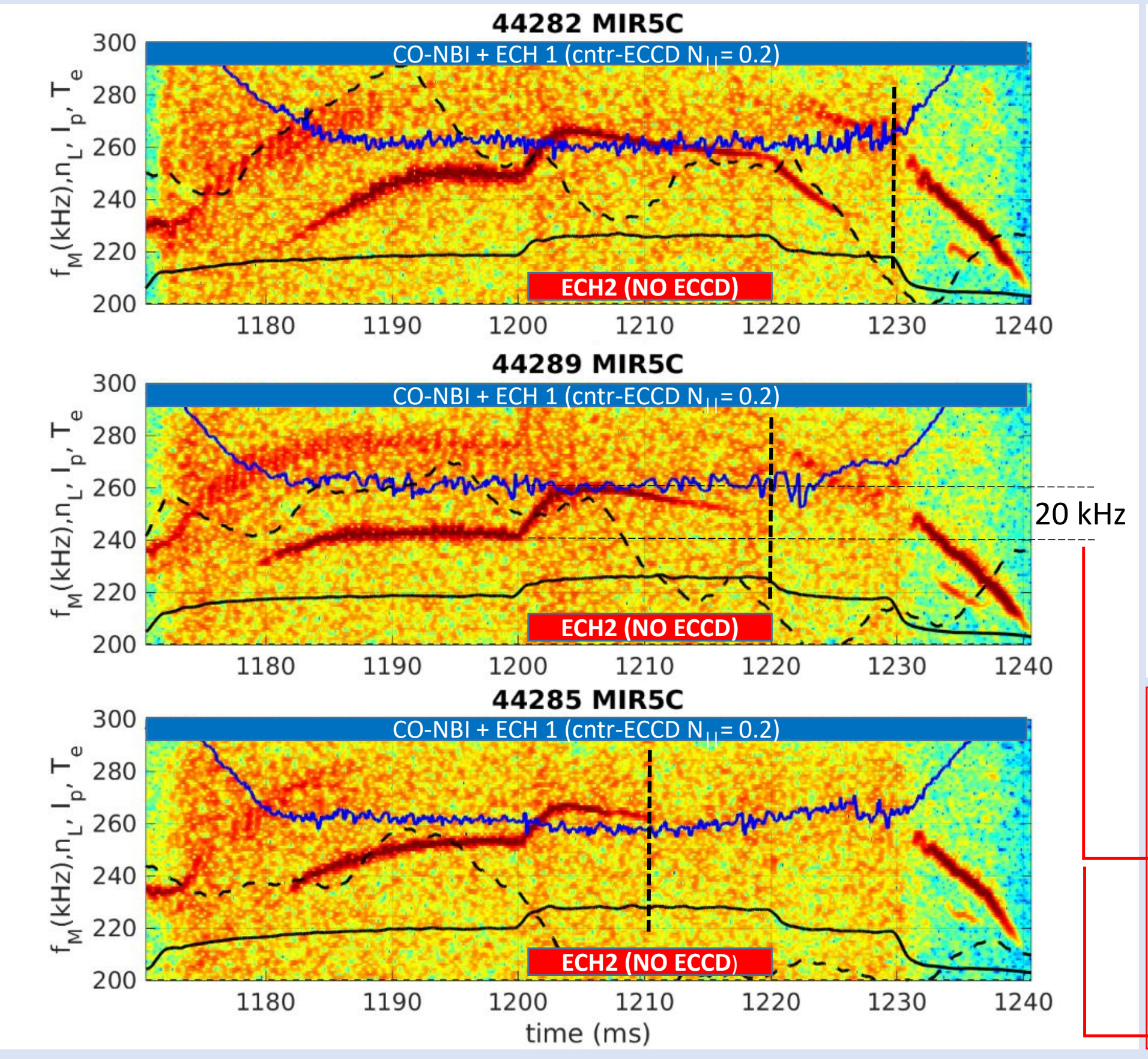


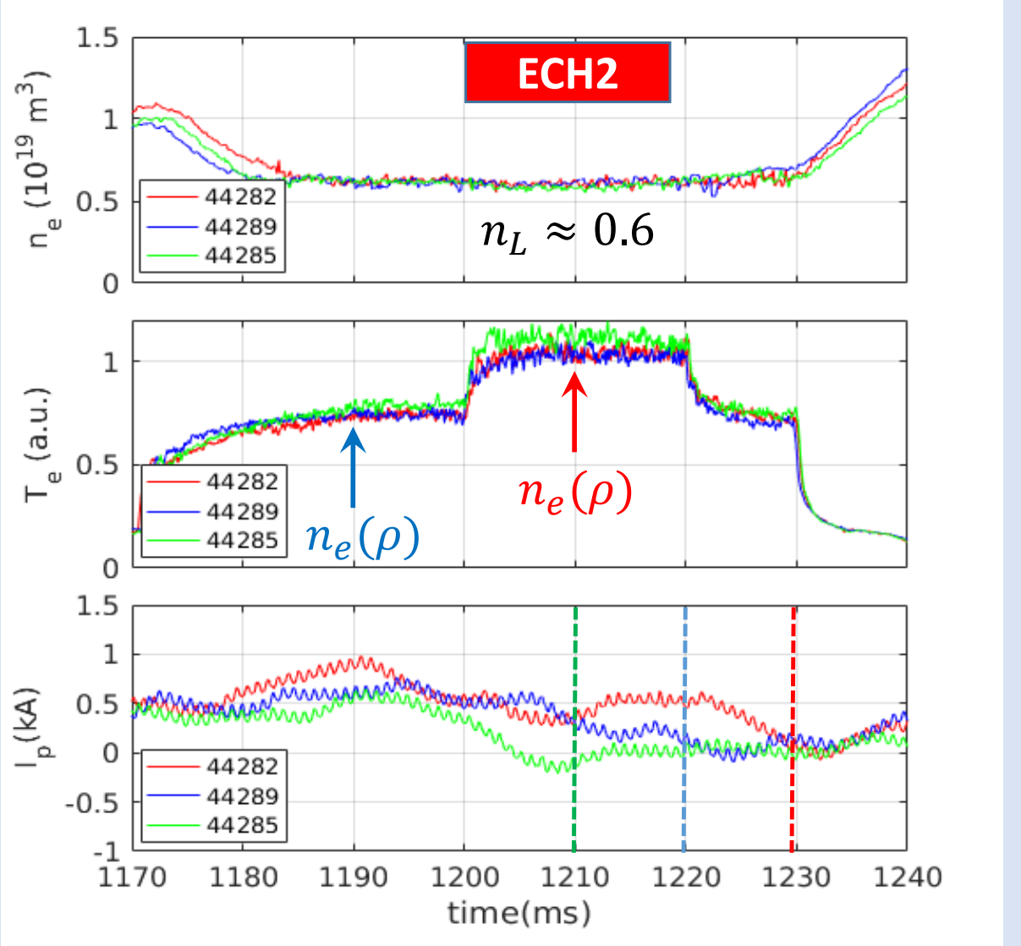
NBI+ECRH/ECCD





- Moreover, mode frequency observed in ECCD experiments is modified by adding ECRH power ($n_e(\rho)\sim constant$, $T_e(\rho)\nearrow$)





Line density is not modified when 240 kW of ECH power is applied

30 % increase in central temperature

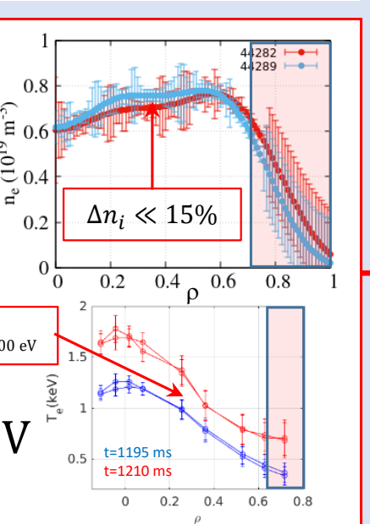
The mode amplitude closely follows plasma current evolution

Alfvénic dep.?: $f\sim 1/\sqrt{n_i}$

$$\frac{\Delta n_i}{n_i}=\frac{f^2}{(f+\Delta f)^2}-1 \Rightarrow \frac{\Delta n_i}{n_i}\cong -0.15$$

Acoustic dep.? : $f\sim C_s$ (@constant Ti)

$$\frac{7/4+T_e/T_i}{7/4+(T_e+\Delta T_e)/T_i}=\frac{f^2}{(f+\Delta f)^2}\Rightarrow \Delta T_e\cong 200\text{ eV}$$



Numerical tools

Implementation of plasma compressibility effects is different each code.

FAR3D gyro fluid simulations [1 and refs. therein]

The code solves the reduced linear resistive MHD equations and the moment equations governing the evolution of the energetic ions density and their parallel velocities, including resonance effects to account for the growth of the MHD perturbations. Stabilizing effects due to electron-ion Landau damping have not been included.

STELLGAP

Calculates 3D shear Alfvén continua

Modes number considered

toroidal (n)	poloidal (m)
n=[5,9,13,17]	m=[2,13]
n=[6,10,14]	m=[3,11]
n=[7,11,15]	m=[3,11]
n=[0,4,8,12]	m=[0,10]

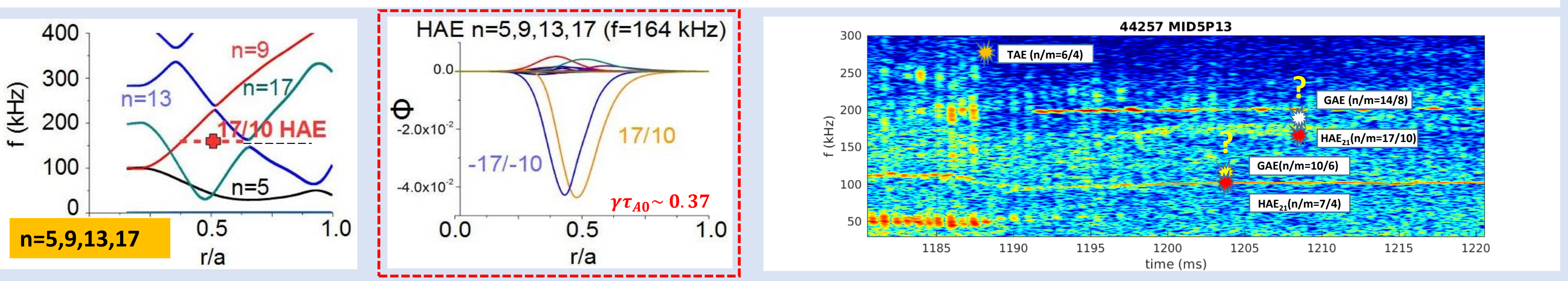
REFERENCES

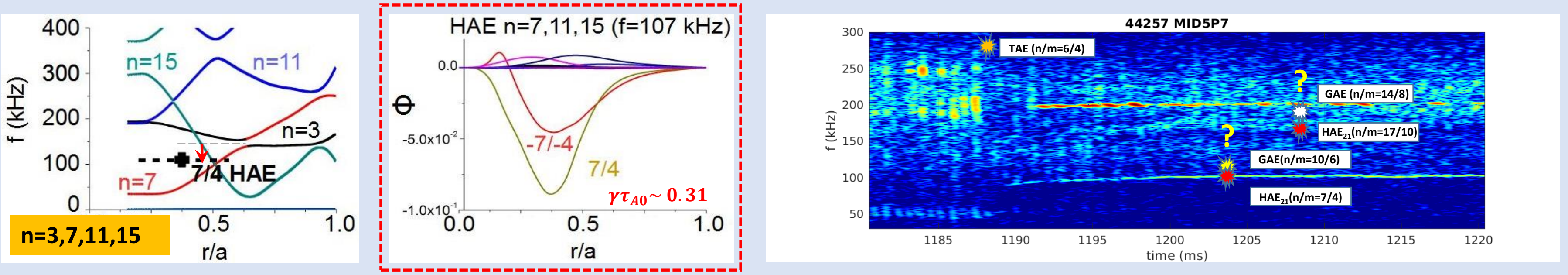
[1] J. Varela et al, Nucl. Fusion **57** 046018 (2017).
[2] M. Garcia-Munoz et al, Plasma Phys. Control. Fusion **61** 054007 (2019).
[3] A. Cappa et al, **45th** EPS Conf. on Plasma Phys. P4.1040 (2018).
[4] J. Guasp et al, Fusion Tech. **24** 251 (1993).
[5] J.L. Velasco et al, Plasma Phys. Control. Fusion **53** 115014 (2011).
[6] N.B. Marushchenko et al, Comput. Phys. Commun **185** 165 (2014).
[7] D. Spong et al, Phys of Plasmas 10, 3217 (2003).
[8] D. Spong et al, Phys of Plasmas 17 022106 (2010).

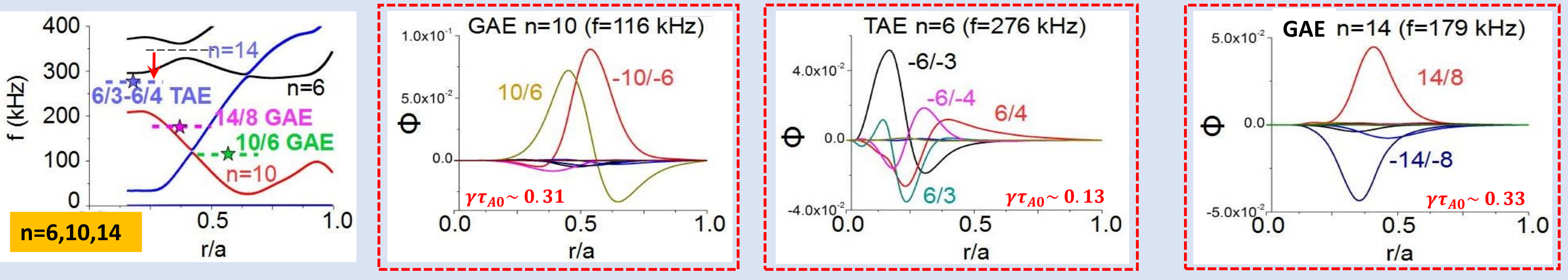
RESULTS

NBI: instabilities compatible with TAE, HAE and GAE

$\tau_{A0}=\frac{R_0}{v_{A0}}=R_0\frac{\sqrt{\mu_0\rho_m}}{B_0}$ $\tau_{A0}^{NBI}=0.33\ \mu s$



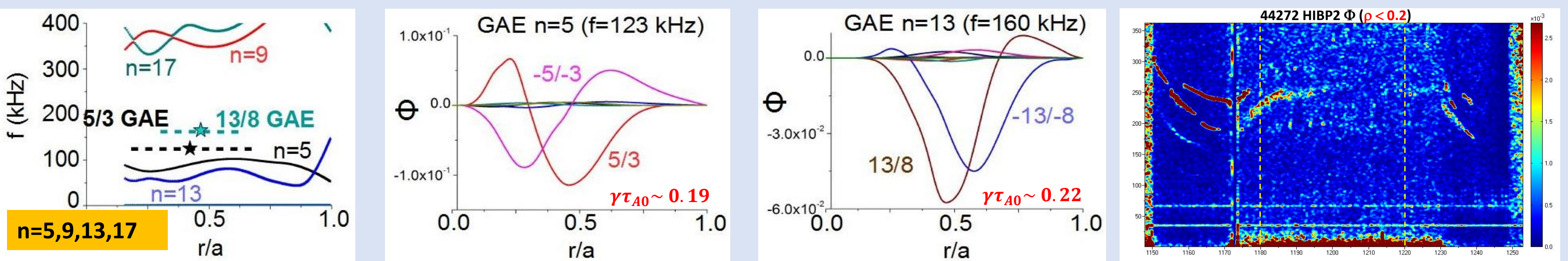


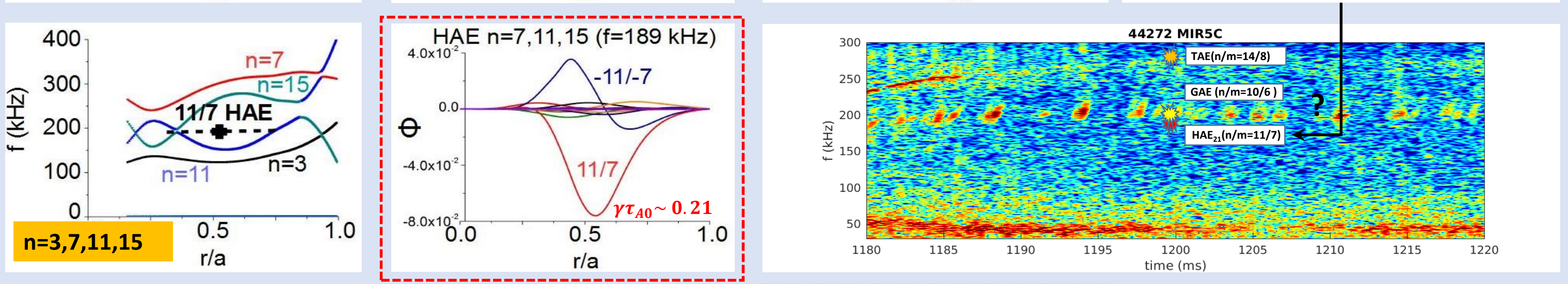


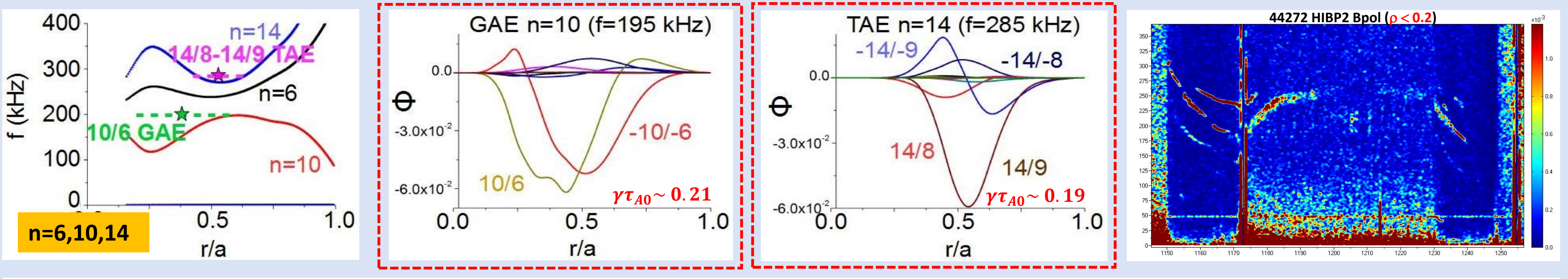
NBI+ECRH: instabilities compatible with HAE, TAE and GAE

lowest shear case

$\tau_{A0}^{NBI+ECRH}=0.26\ \mu s$

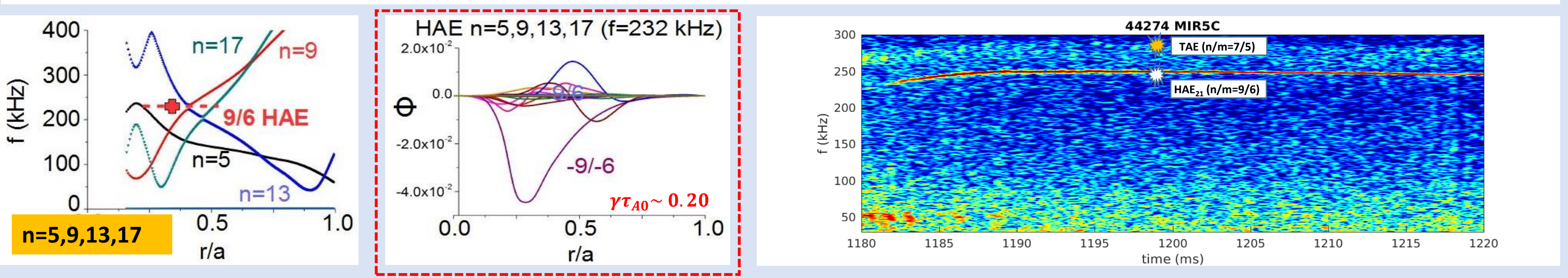


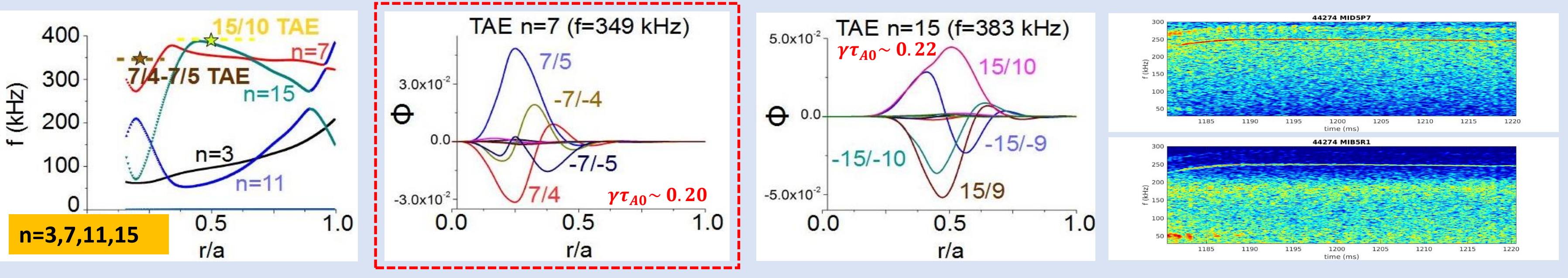


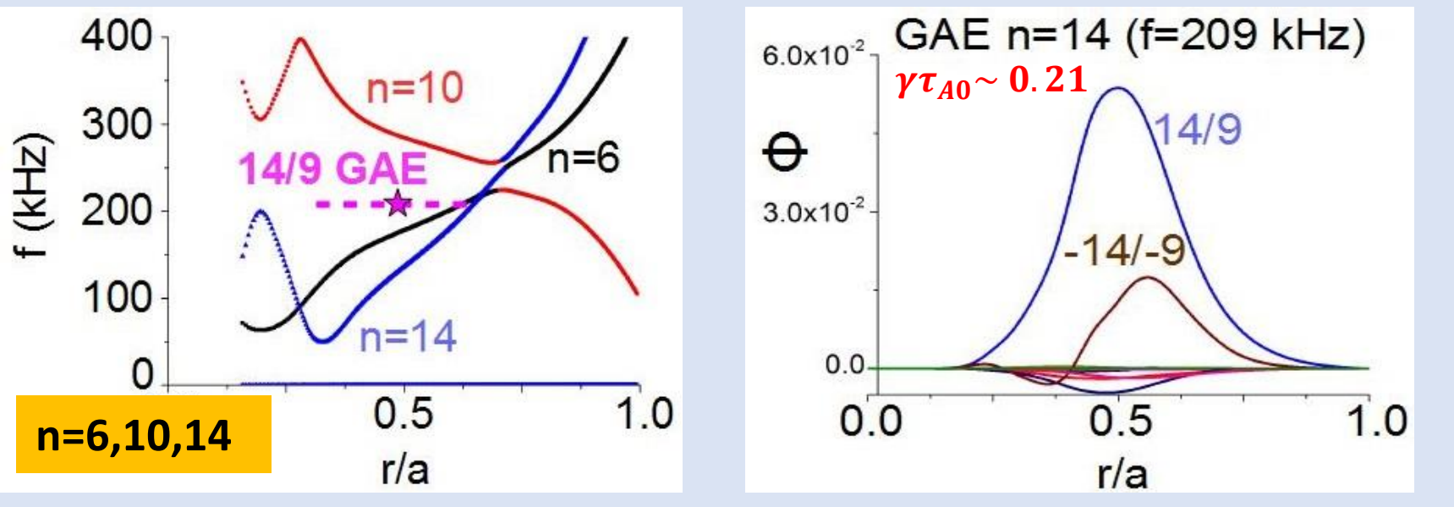


NBI+ECCD: instabilities compatible with HAE and TAE

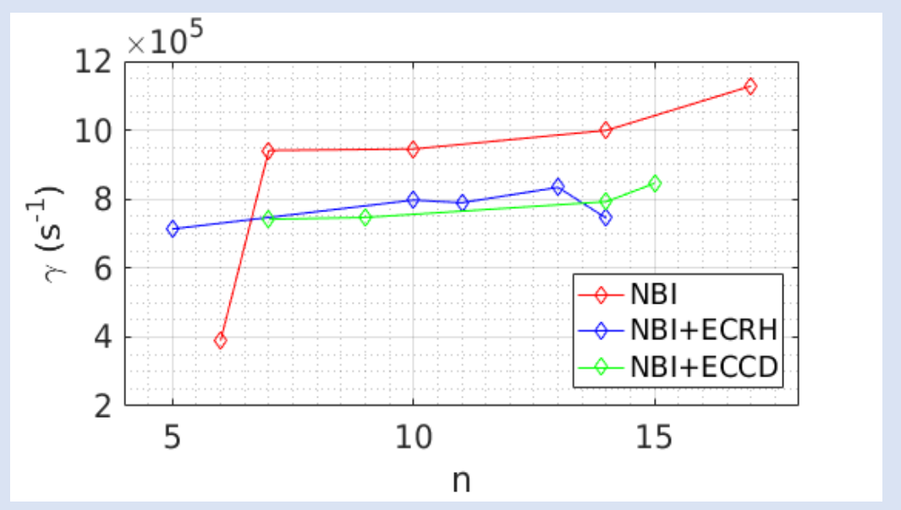
$\tau_{A0}^{NBI+ECRH}=0.26\ \mu s$







- Steady frequency mode observed around 250 kHz is compatible with HAE$_{21}$ n/m=9/6 mode.
- Frequency increase (~20 kHz) when ECRH power is added may be caused by changes in the plasma resistivity or in τ_S.



CONCLUSION

- Several instabilities with frequencies compatible with the different modes observed in each case are found.
- Modes with the highest observed frequency are consistent with faint TAEs.
- Rest of modes observed at intermediate/high frequency are consistent with HAEs and GAEs.
- Mismatch between gap frequency determined by STELLGAP and FAR3D probably to different implementation of compressibility effects and overestimated electron temperature in STELLGAP calculations.
- Uncertainties related to rotational transform profile or the absence of electron-ion Landau damping processes (not yet included) may explain why several predicted instabilities are not observed in the experiments.