17th European Fusion Theory Conference
9 - 12 October 2017, Athens - Greece
EFTC 2017

# Modelling of Alfvén modes properties in TJ-II plasmas

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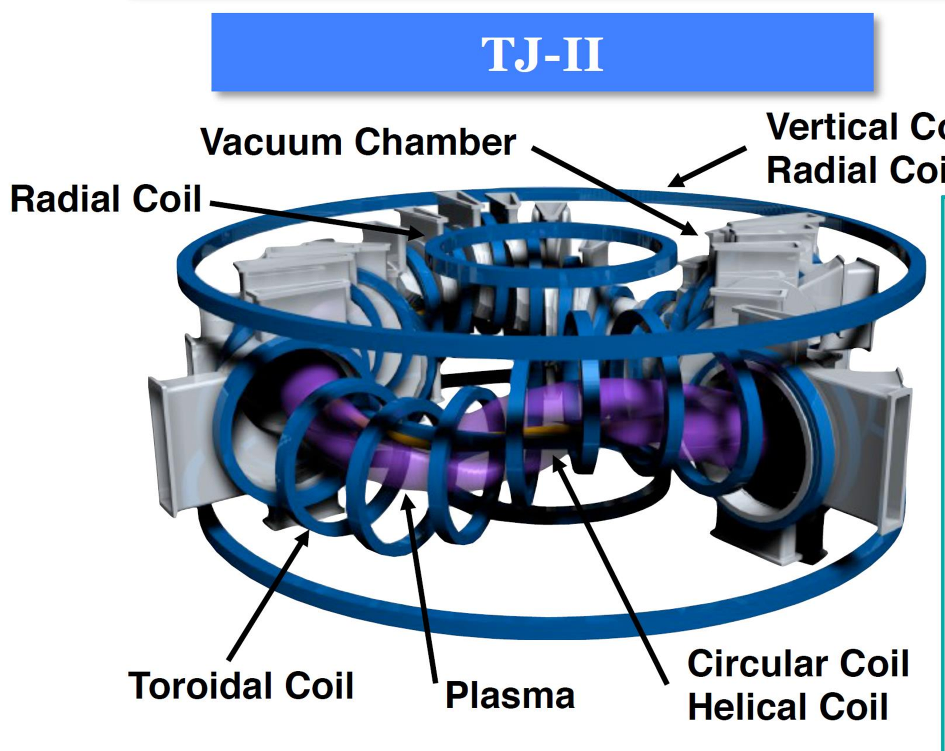
## INTRODUCTION

- Alfvén Eigenmodes (AEs) are MHD waves of the shear Alfvén type. These waves could be excited by a radial gradient of fast ions via wave-particle resonant interaction. If the wave amplitudes becomes high, AEs could cause redistribution and losses of energetic fusion-born $\alpha$ particles, which can result in the degradation of self-sustained plasma heating, ignition margin and plasma-facing materials in a fusion reactor.
- We investigate AEs in the low-magnetic-shear flexible Heliac TJ-II (Fig.1) using a reduced MHD shear Alfvén model [3]. We focus on the modelling of AE properties in H plasmas with Neutral Beam Injection and a ramp in the rotational transform $\iota/2\pi$ in time.




**Flexible Heliac**

- $R = 1.5$ m, $\langle a\rangle \leq 0.22$m
- $B_t \simeq 1$ T,
- $0.9 \leq \iota/2\pi \leq 2.2$
- $N_f = 4$
- $P_{ECH} < 300$ kW x 2
- $P_{NBI} < 600$ kW x 2
- $E_{NBI} < 40$keV (H)

***Figure 1*** *TJ-II Stellarator*

## EXPERIMENTAL RESULTS

- In NBI-heated TJ-II discharges with a ramp in the rotational transform $\iota/2\pi$ in time, transitions from chirping and steady AEs and vice versa are observed [4] (Fig. 2).

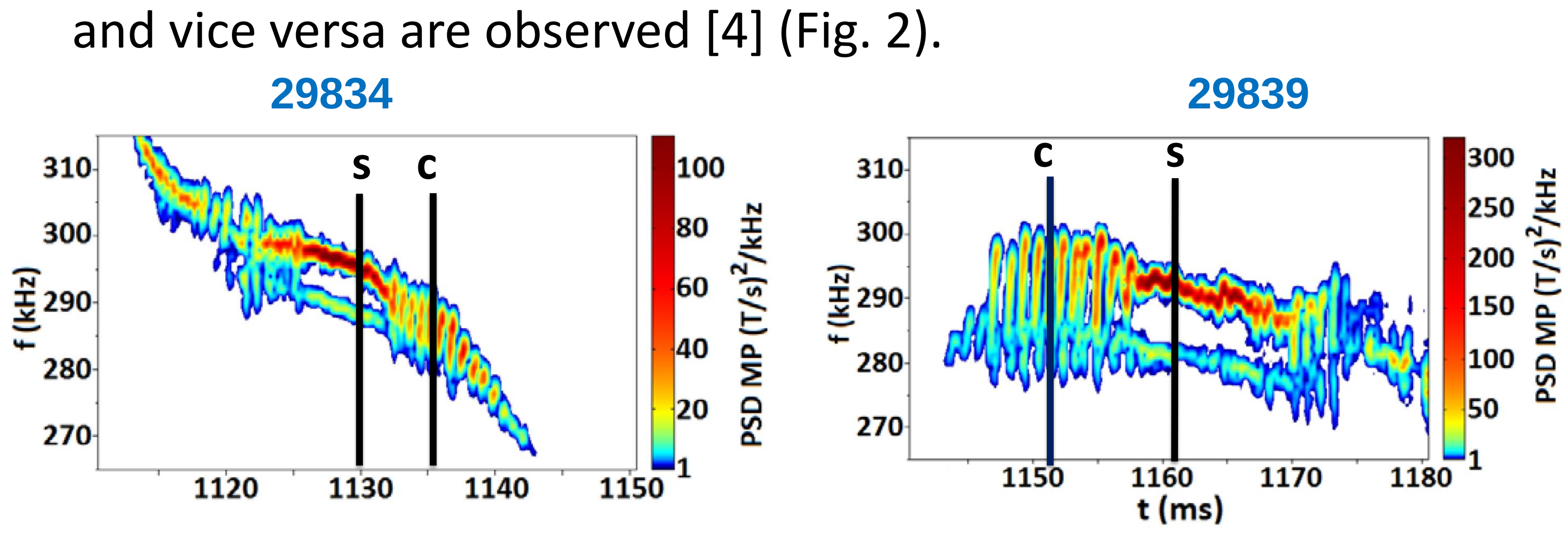



*Figure 2 AEs observed in TJ-II discharges 29834 and 29839 [4]. Time points chosen for modelling of steady (s) and chirping (c) modes are shown by vertical lines. $\iota/2\pi$ changes by about 1% from 1.67 to 1.66 and from 1.63 to 1.65 in the plasma center in discharges 29834 and 29839, respectively, between the chosen time points.*

## MODELLING OF ALFVÉN EIGENMODES

- For understanding the experimentally observed modes, the first step is to calculate the relevant Alfvén continuum and the AE structures as functions of radius. This is the aim of our presentation. We calculate AEs continuum structures with STELLGAP [1] and AEs spatial profiles with AE3D [2] using a reduced MHD shear Alfvén model in 3D geometry [3].
- Eigenvalue equation solved by these codes can be written as

$$\omega^2\nabla\cdot\left(\frac{1}{V_A^2}\nabla\phi\right)+(\boldsymbol{B}\cdot\nabla)\left[\frac{1}{B}\nabla^2\left(\frac{\boldsymbol{B}}{B}\cdot\nabla\phi\right)\right]+\nabla\zeta\times\nabla\left(\frac{\boldsymbol{B}}{B}\cdot\nabla\phi\right)\cdot\nabla\frac{J_{\|0}}{B}=0$$

- So far, we have studied the effects of $\iota/2\pi$ variation only and kept the other parameters fixed in time.

## SIMULATION RESULTS

- We find several AE modes with frequency f and radial location consistent with the measured mode properties [4]. A selection of them is shown in Table 1.
- Examples of simulated Alfvén continuum structures and spatial profiles are shown in Figs 2-6.

***Table 1*** *Properties of selected AEs as given by modelling. Here, s and c refer to steady and chirping modes, respectively.*

| Discharge | (m, n) | Frequency f (kHz) | Radial location ρ |
|---|---|---|---|
| 29834 | (11, -19) | 276 (s), 292 (c) | 0.65 (s), 0.75 (c) |
| | (8, -14) | 285 (s), 322(c) | 0.80 (s), 0.80 (c) |
| 29839 | (10, -17) | 289 (c), 254 (s) | 0.70 (c), 0.55 (s) |
| | (7, -12) | 292 (c), 250 (s) | 0.70 (c), 0.55 (s) |

## RESULTS FOR DISCHARGE 29834 WITH A RAMP DOWN OF $\iota/2\pi$

As $\iota/2\pi$ decreases, AEs move radially outward and their f increases slightly due to its dependence on $n_e$ (Figs 3-4).

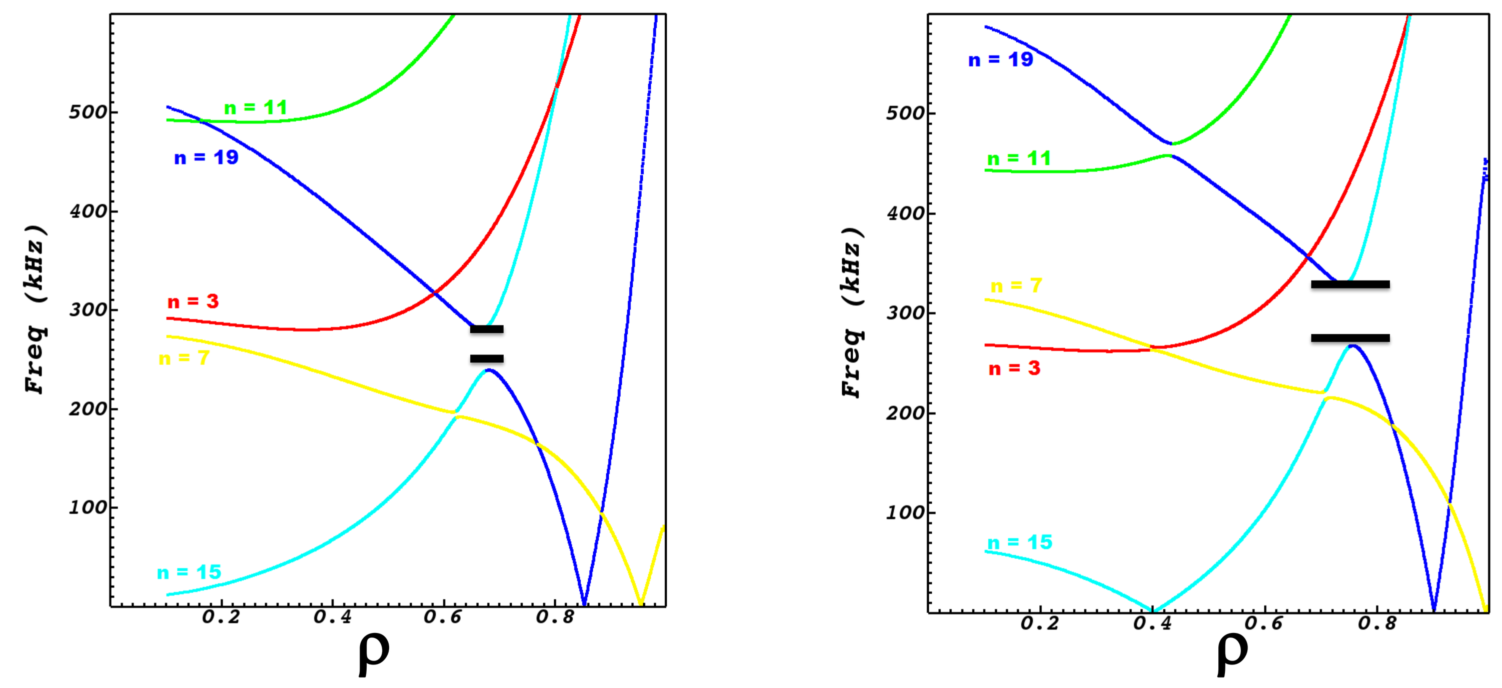



***Figure 3*** *Alfvén continuum structures for steady (left) and chirping (right) modes in discharge 29834. Black lines locate the AEs gaps and their lengths scale with the radial extent of AEs i.e. FWHM of potential (c.f. Fig 4).*

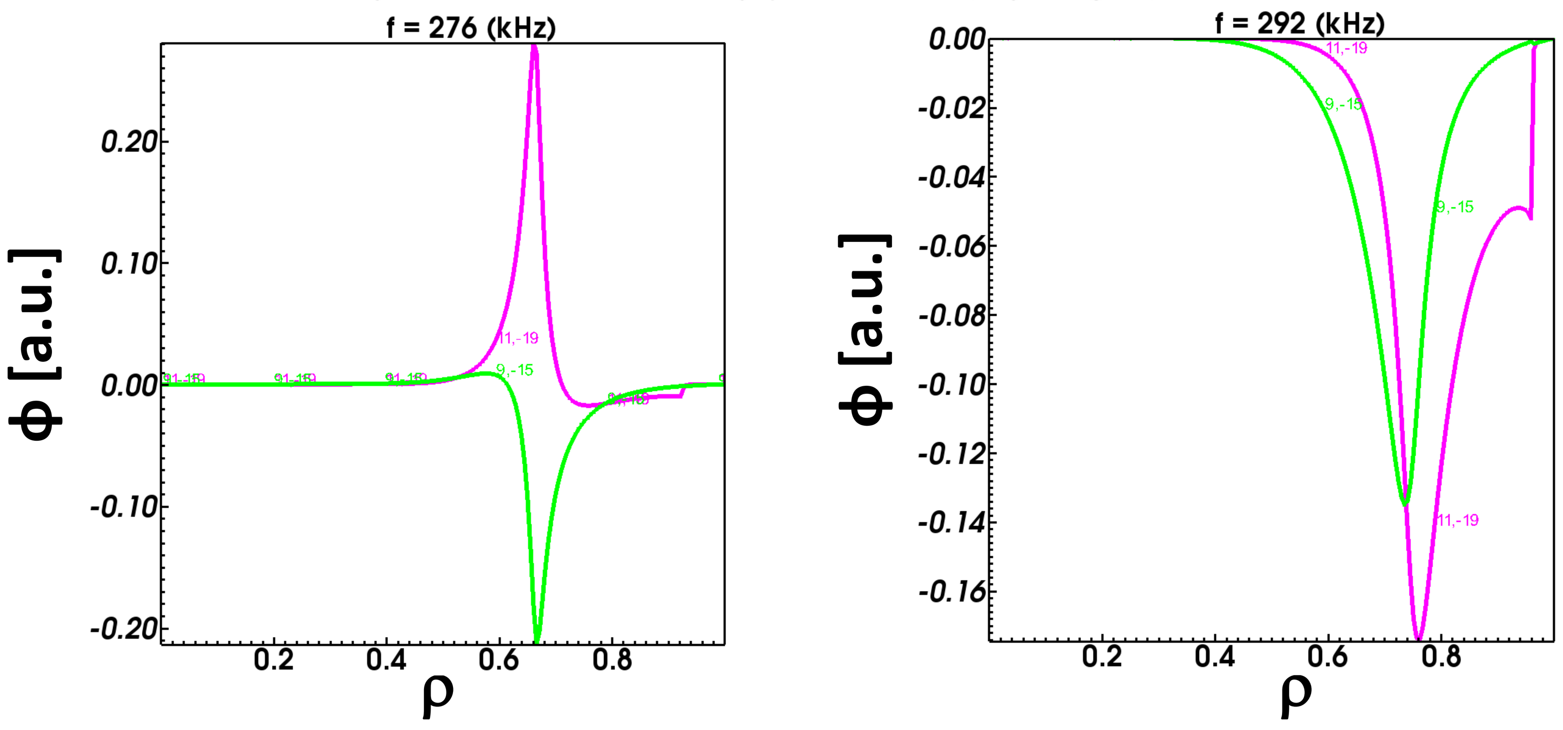



***Figure 4*** *AEs for steady (left) and chirping (right) modes in discharge 29834.*

## RESULTS FOR DISCHARGE 29839 WITH RAMP UP OF $\iota/2\pi$

As $\iota/2\pi$ increases, AEs move radially inward and their frequency decreases due to its dependence on $n_e$ (Figs 5-6).

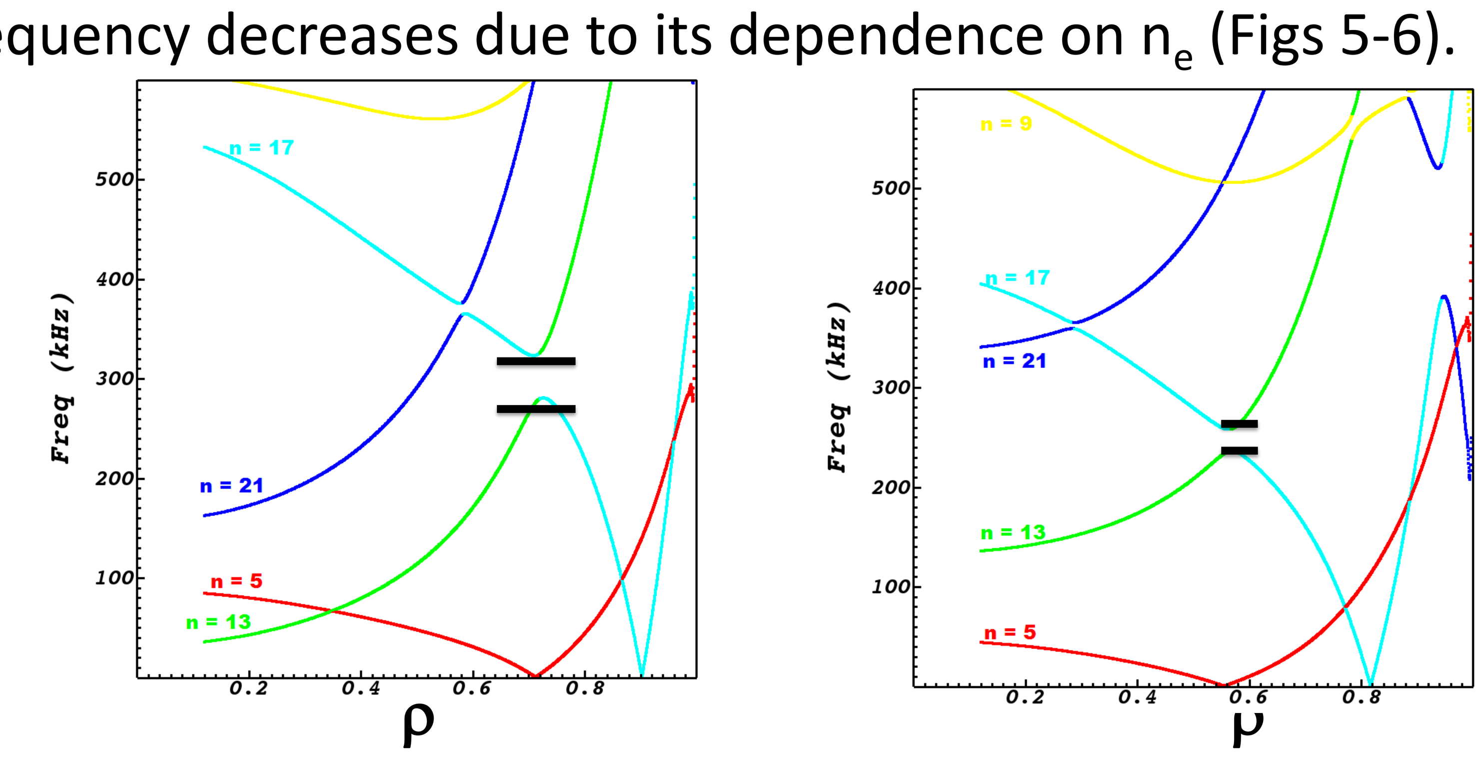



***Figure 5*** *Alfvén continuum structures for chirping (left) and steady (right) modes. Black lines locate the AEs gaps and their lengths scale with the radial extent of AEs i.e. FWHM of potential (c.f. Fig 6).*

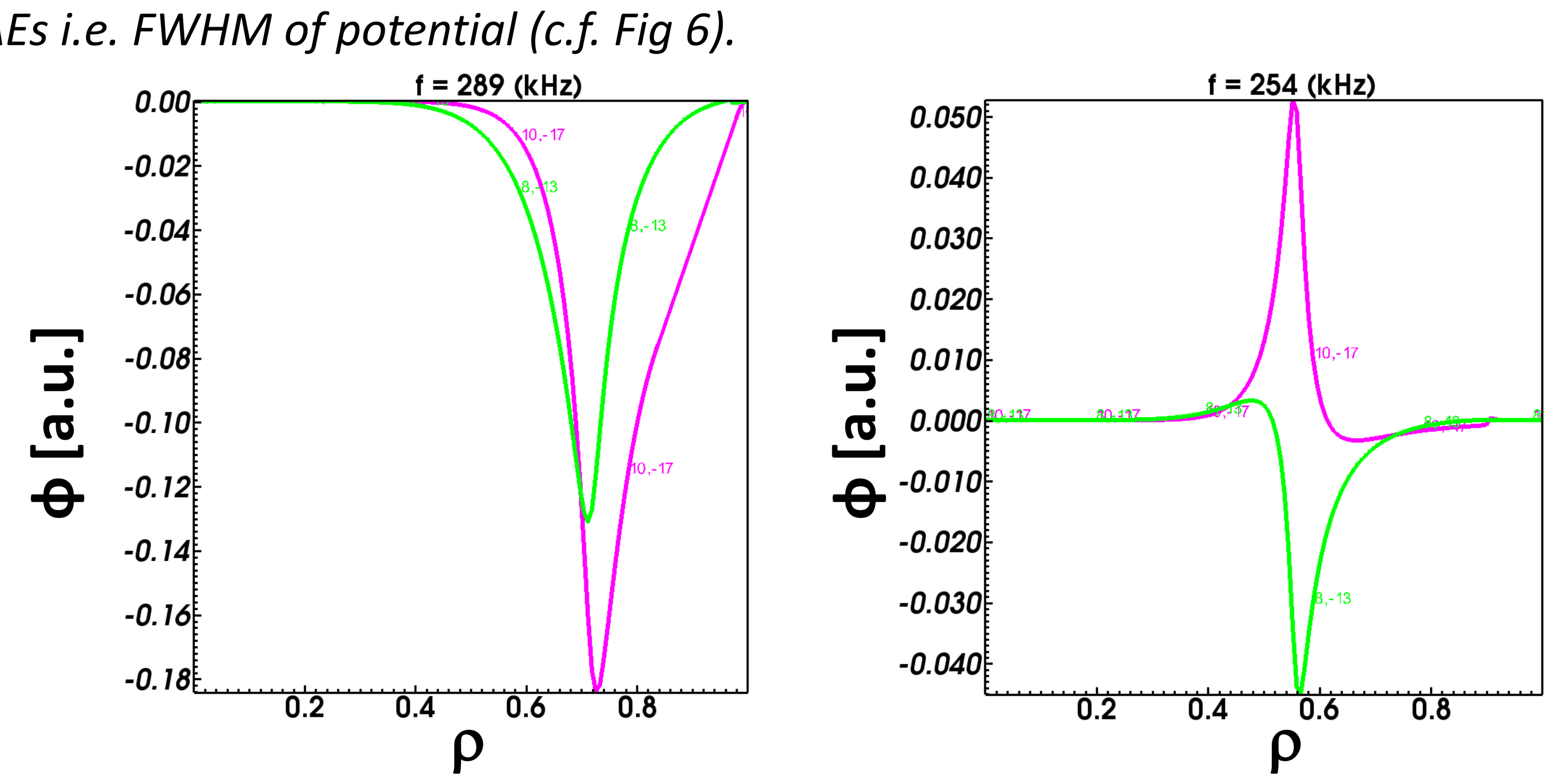



***Figure 6*** *AEs for chirping (left) and steady (right) modes.*

## CONCLUSIONS

- Simulated frequencies and radial locations agree within +/-10% with the observed ones. AEs move radially outward/inward when $\iota/2\pi$ is ramped down/up.
- Our results suggest that the steady modes are located further inside the plasma and have narrower radial widths than the chirping modes.

## REFERENCES

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