Compressional Alfven Instability to explain "High Frequency" Modes in NSTX

presented by

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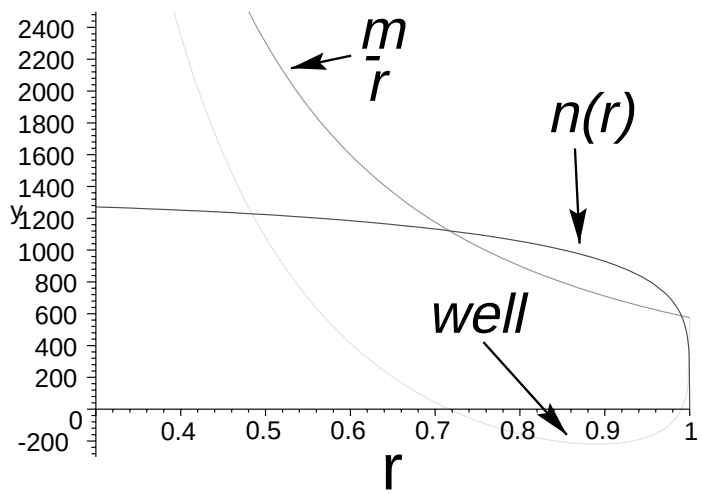
Compressional Alfven Eigenmode (CAE) spectra and eigenmode structure

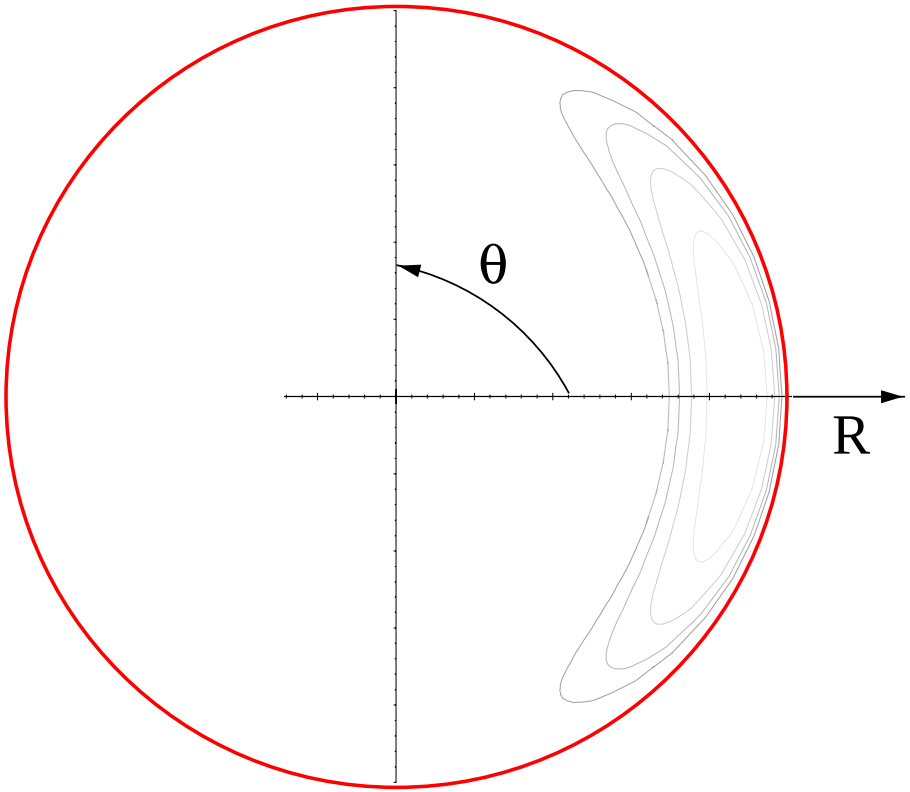
✓ Mode dispersion, $k_\theta = m/r$,

$$\omega^2 = k^2 v_A^2 \;\rightarrow\; k_\parallel^2 + k_\theta^2 - \frac{\omega^2}{v_A^2} = k_r^2 = \frac{\partial^2}{\partial r^2}.$$

✓ Radial "potential" well is formed by density profile and magnetic field space dependence:



CAE poloidal structure



CAE is localized at the low field side edge of plasma cross section.

CAE properties

✓ Spectrum is discrete, m is dominant number for the eigenfrequency:

$$\omega^2 = \frac{m^2 v_A^2}{r^2}\left(1 + \frac{r^2 k_\parallel^2}{m^2}\right).$$

✓ Each m mode frequency is splitted by toroidal number:

$$k_\parallel = \frac{m - nq}{qR} \ll k_\perp.$$

✓ Poloidally and radially localized at the Low Field Side of the plasma.

✓ Eigenfrequency spectrum extends from zero to hybrid frequency $> 10\omega_{cD}$.

CAE instability

✓ Drive is coming from superalfvenic particles via
fast particle - wave Doppler shifted cyclotron resonance.
(N. N. Gorelenkov, C. Z. Cheng, Phys. Plasmas 2, 1961 (1995))

$$\omega - k_{\|} v_{\|b} - k_{\theta} v_{dr} - l\omega_{cD} = 0$$

– STs have larger Doppler shift $k_{\|} v_{\|b} \simeq \omega = k_{\theta} v_A \simeq \omega_{cD}/2$, than in tokamaks due to

$$k_{\|}/k_{\theta} \simeq v_A/v_{\|b} \ll 1,$$

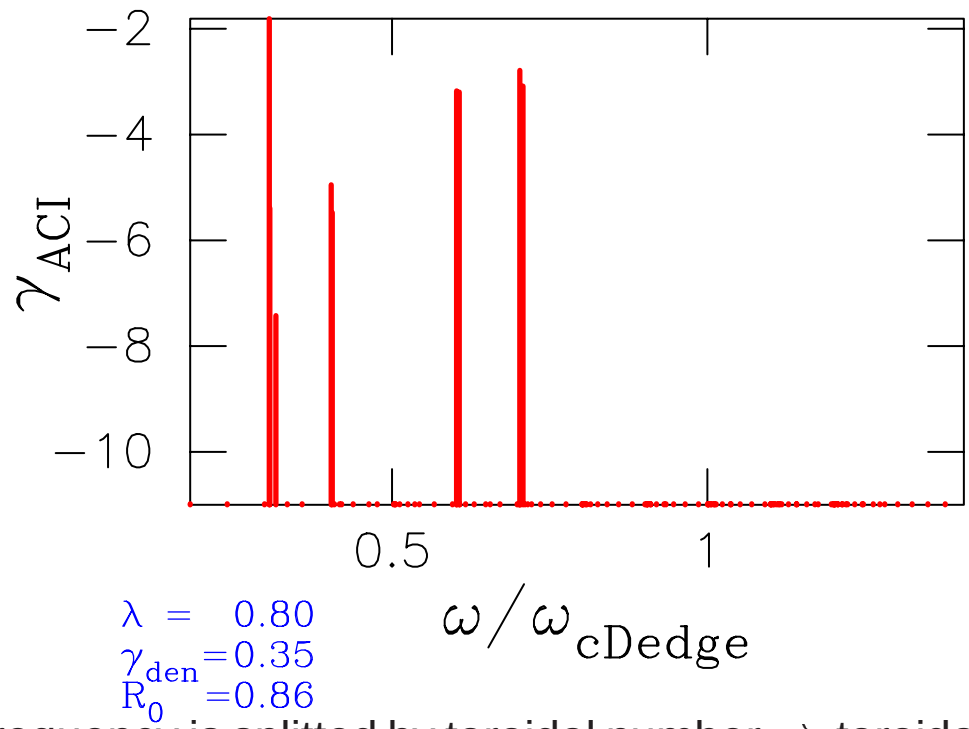
– follow fast particle orbit to compute wave-particle resonance.

✓ Electron Landau damping through Cherenkov resonance limit the number of eigen-modes by restricting $k_{\|}$. Its minimization is essential for ACI.
$\omega - k_{\|} v_{\|e} = 0$ damping should be $\gamma_e \sim e^{-\omega^2/k_{\|}^2 T_e} \Rightarrow$ low $k_{\|}$ are less damped.

✓ Background *ion cyclotron damping* does not control the damping rate
$v_{\|pl} \ll v_{\|b}$.

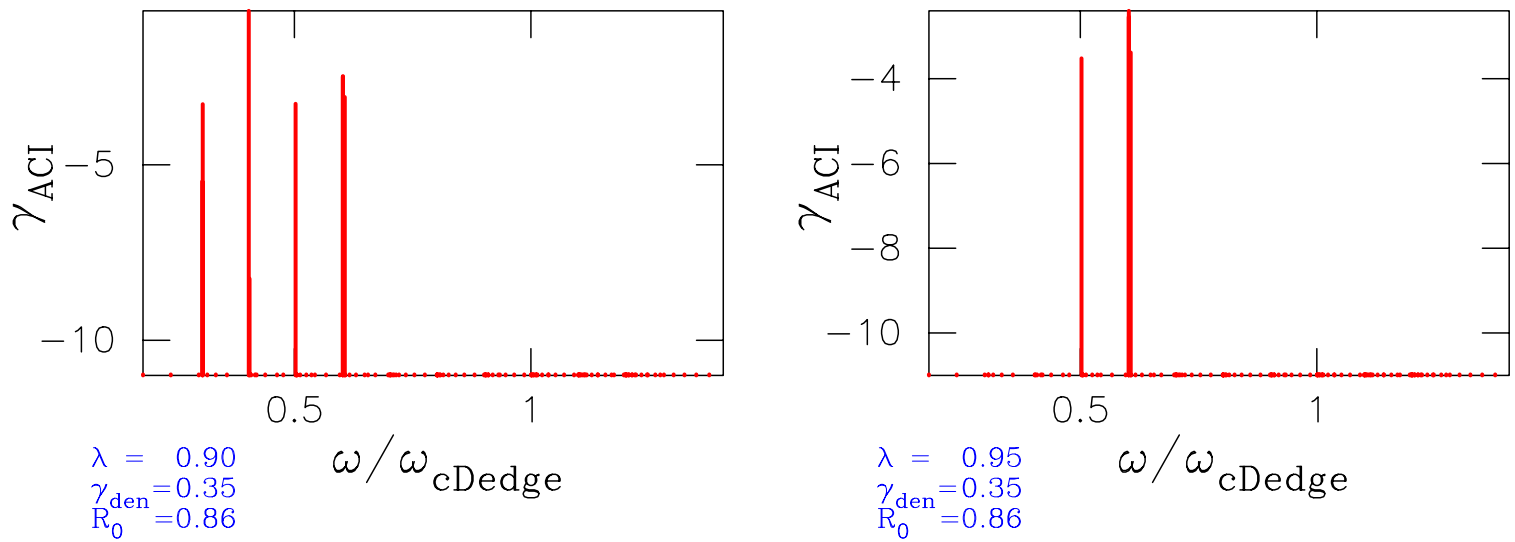
CAE instability calcilations

✓ Single pitch angle distribution of NBI ions $\lambda = ((R_0+\rho)^2 - R_t^2)/(R_0+\rho)R_0$ is not a bad approximation (see D. Darrow's APS-2001 report).



Each m mode frequency is splitted by toroidal number $\Rightarrow$ toroidal rotation will further disperse them.

CAE instability is sensitive to beam pitch angle



✓ Change in pitch angle changes number of unstable modes

✓ Results are in agreement with experiment if we assume that single pitch angle distribution is formed at $\rho = 0.4a$, so that $\lambda_B = 0.91$ and $\lambda_C = 1$