Numerical Simulations of NBI-Driven Sub-Cyclotron Frequency Modes using the HYM Code

E. V. Belova, N. N. Gorelenkov, E. Fredrickson (PPPL)

NSTX Results/Theory Review, PPPL September 2009

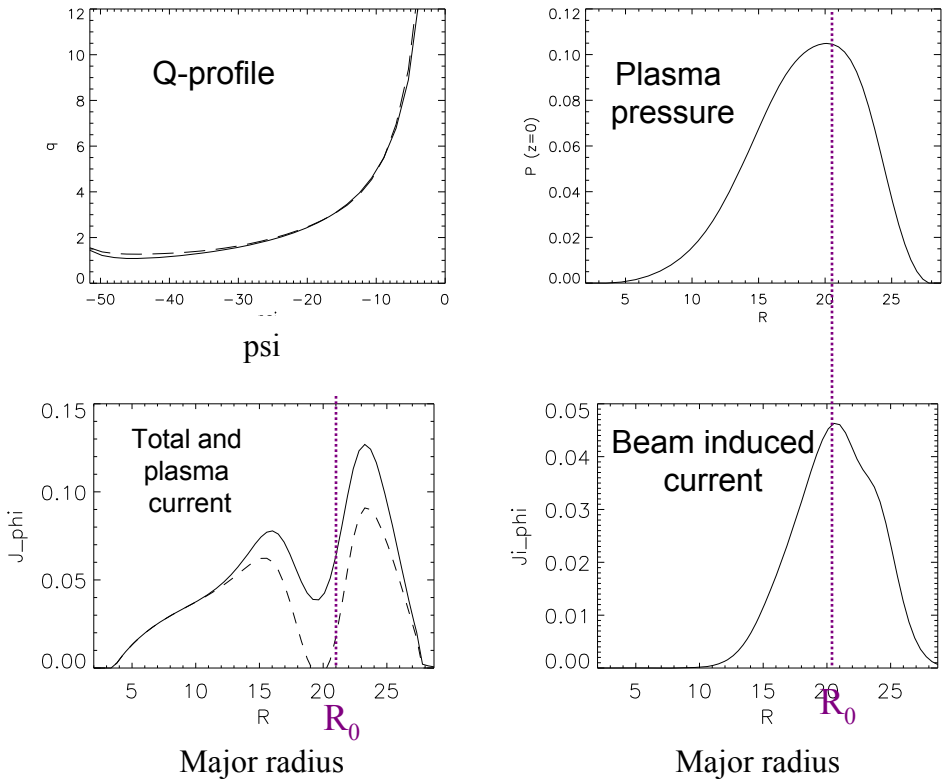
HYM simulations for NSTX shot 135419

• HYM code has been modified to include more accurate description of the beam induced current:

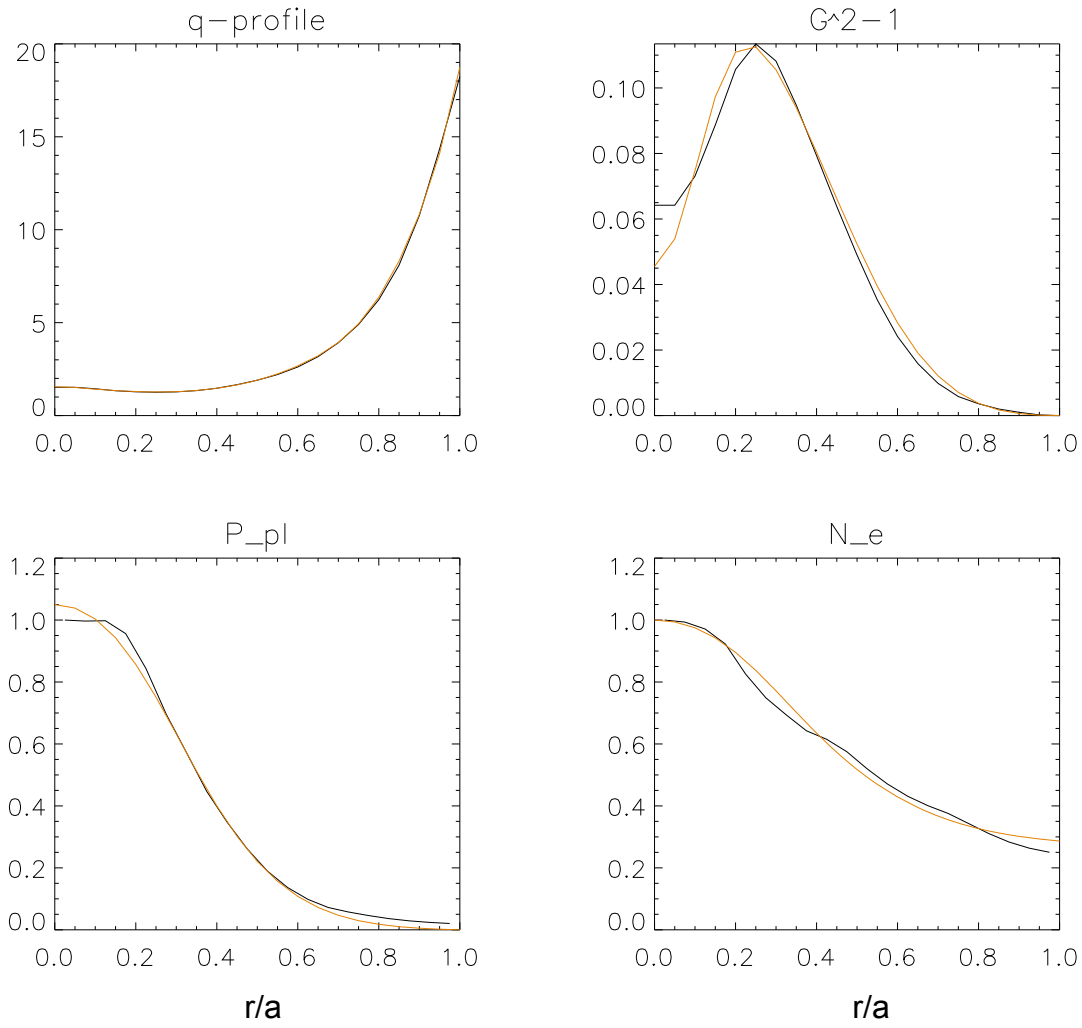
$J_{beam} \rightarrow J_{beam} - (Z_b/Z_{eff})\, J_{beam\ ||}$

• Significantly modifies poloidal component of beam current.

• Improved fit to TRANSP profiles.

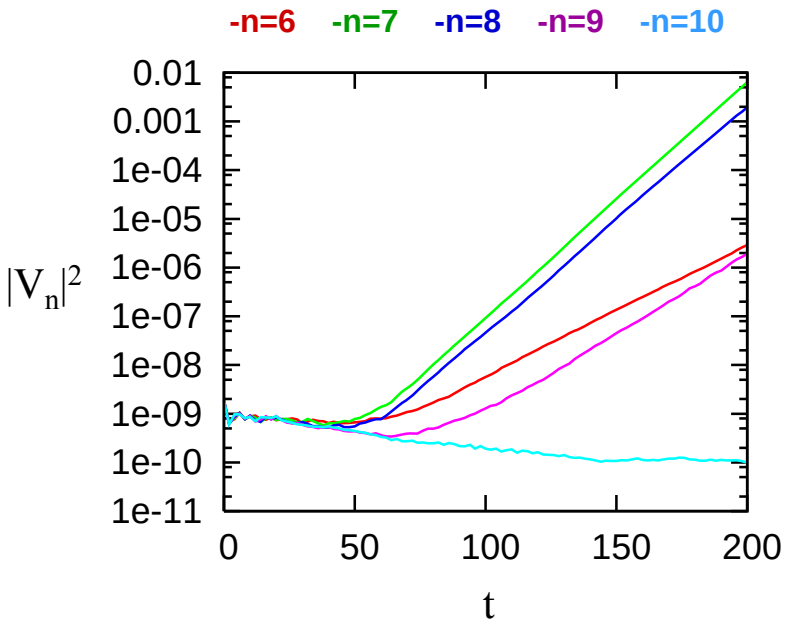


Equilibrium profiles NSTX shot #135419



HYM simulations comparison with experimental results for NSTX shot#135419 [E. Fredrickson et al]

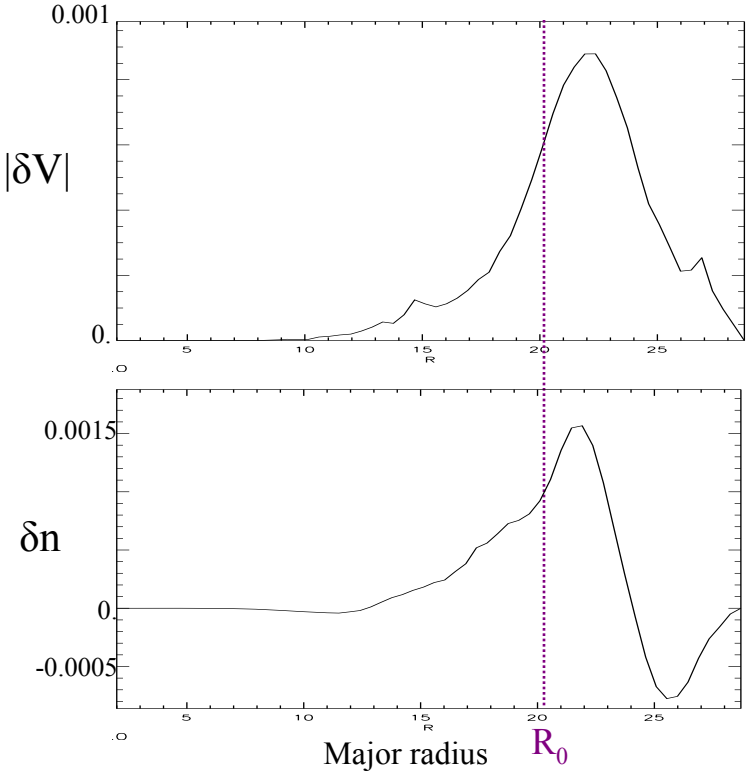
- Several modes are unstable with toroidal mode numbers n=6 - 9 and frequencies f=0.4-0.8MHz (plasma frame) compared to experimental results of n=9 - 11, and f=0.8-1MHz.
- GAE modes.
- Linear growth rate as inferred from observed growth time $\gamma \approx 0.005\omega_{ci}$ compared to numerically calculated $\gamma \approx 0.02\ \omega_{ci}$ (no damping $\gamma_d=0$).
- Similar mode structure.



Time evolution of kinetic energy from 5 linearized simulations with n=6-10 (zero damping parameter).

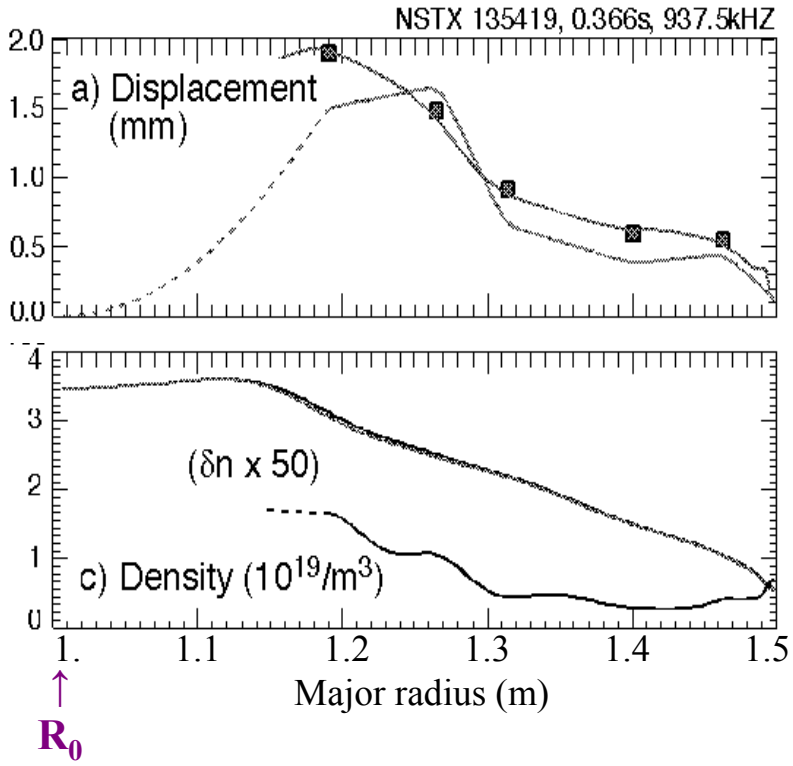
Mode structure: velocity and density profiles (n=9)

Simulations n=9



a) Radial profile of velocity amplitude,
b) density perturbation profile.

NSTX #135419

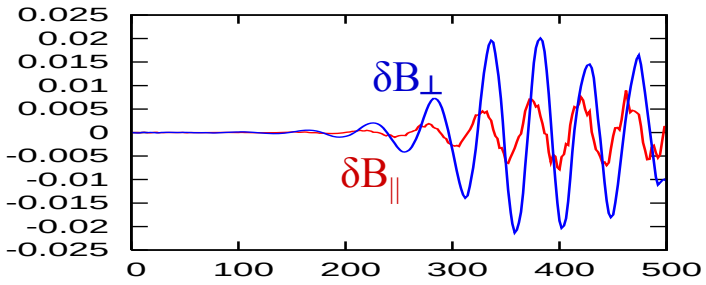


a) Mode amplitude profile,
b) density profile [E. Fredrickson et al, 2009]

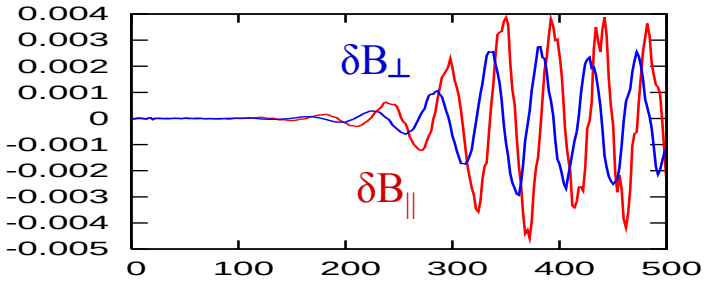
At the edge the compressional component dominates $\delta B_{||} > \delta B_{\perp} \sim 10^{-4} B_0$.

Magnetic field and density perturbations for n=9

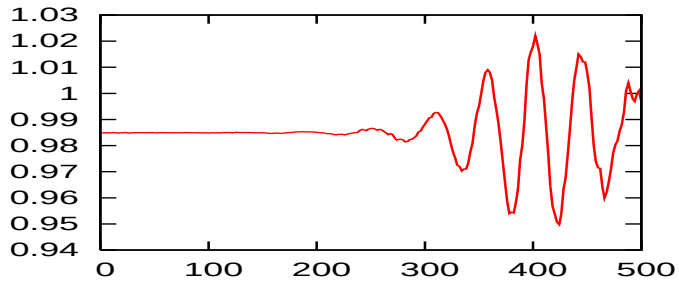
δB core



δB edge

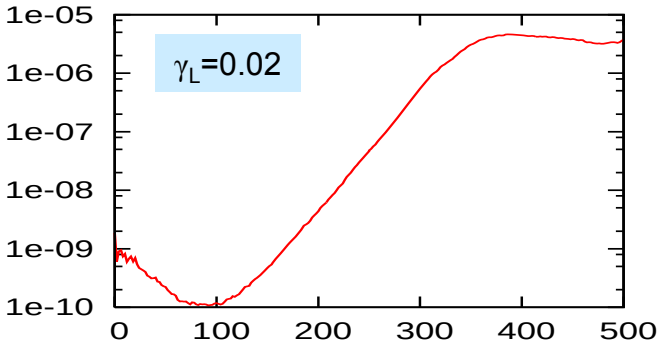


δn/n core



$t\omega_{ci}$

$|V_n|^2$

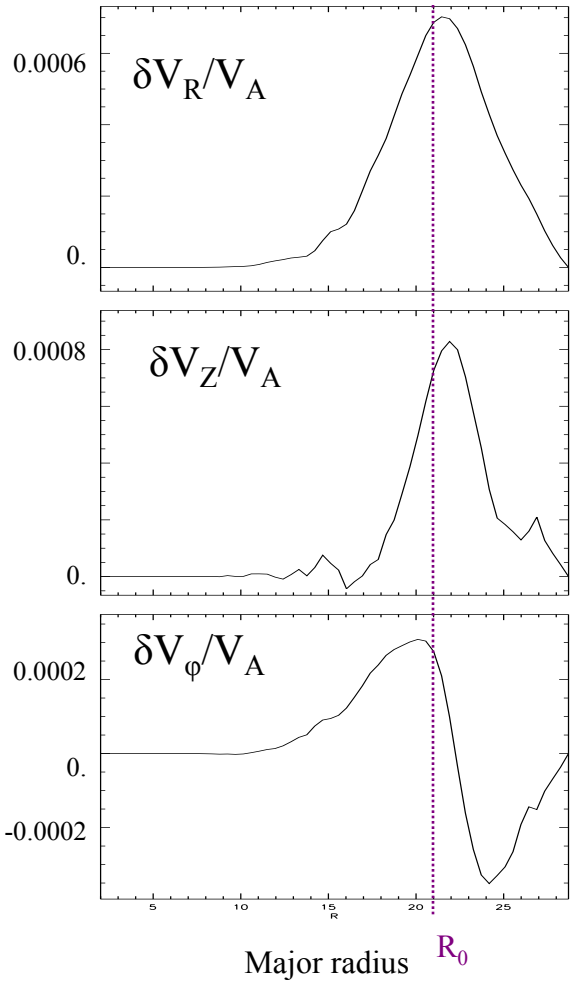


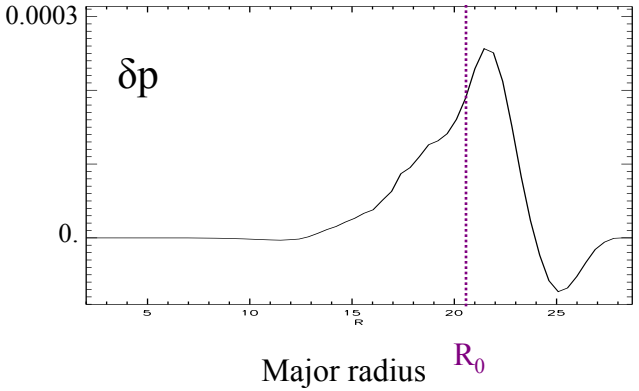
$t\ \omega_{ci}$

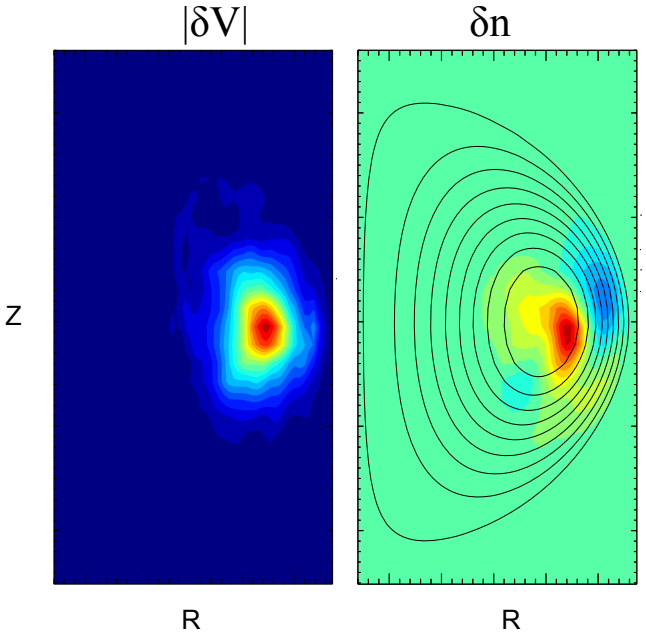
Time evolution of kinetic energy from nonlinear simulations with zero damping parameter.

At peak amplitude $\delta B_{||} \sim 1/3\ \delta B_{\perp}$; at the edge the compressional component dominates $\delta B_{||} > \delta B_{\perp}$.

Mode structure: velocity and density profiles (n=9)



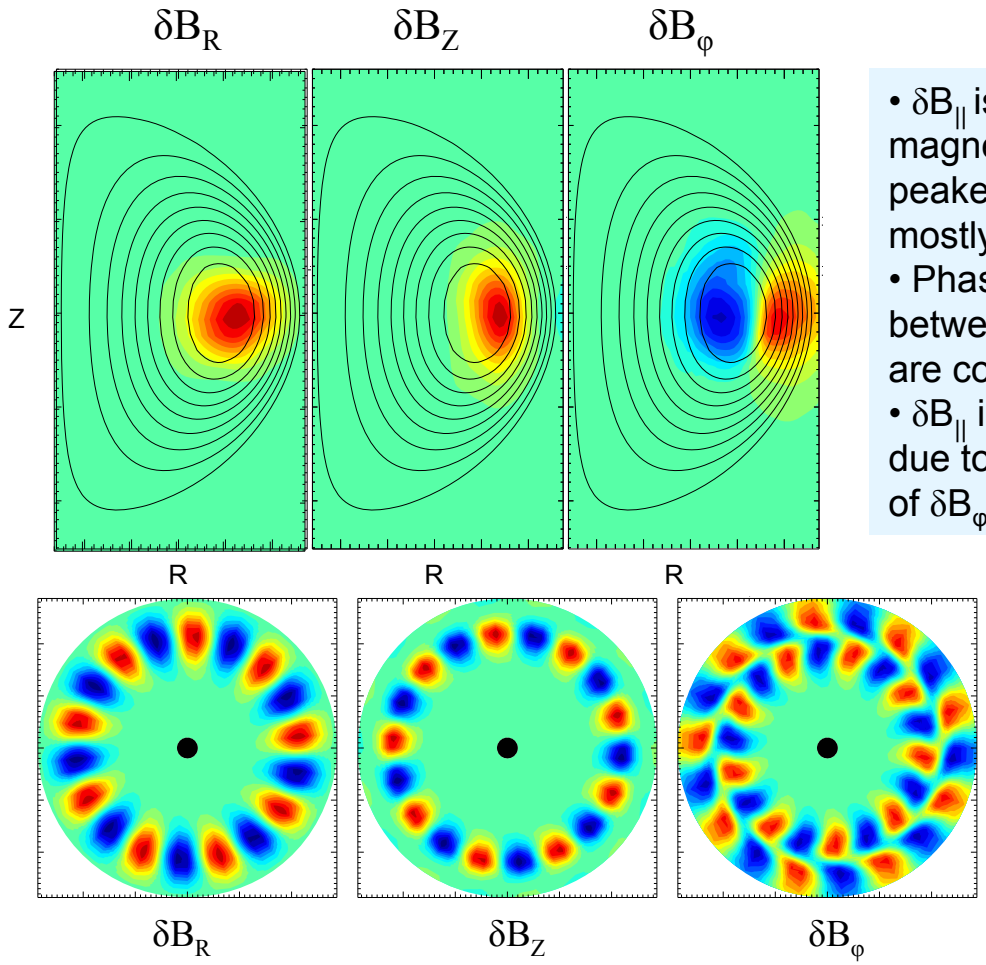




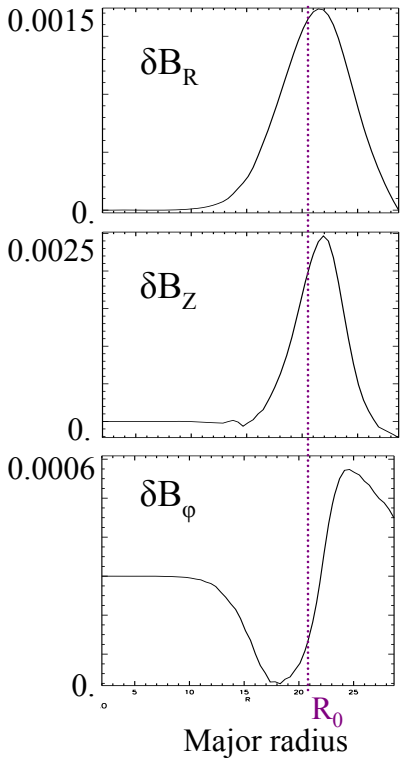
Radial profiles of velocity and pressure perturbations.

Mode structure: magnetic field (n=9)

GAE modes always have significant compressional component at the edge – coupling to CAE modes?

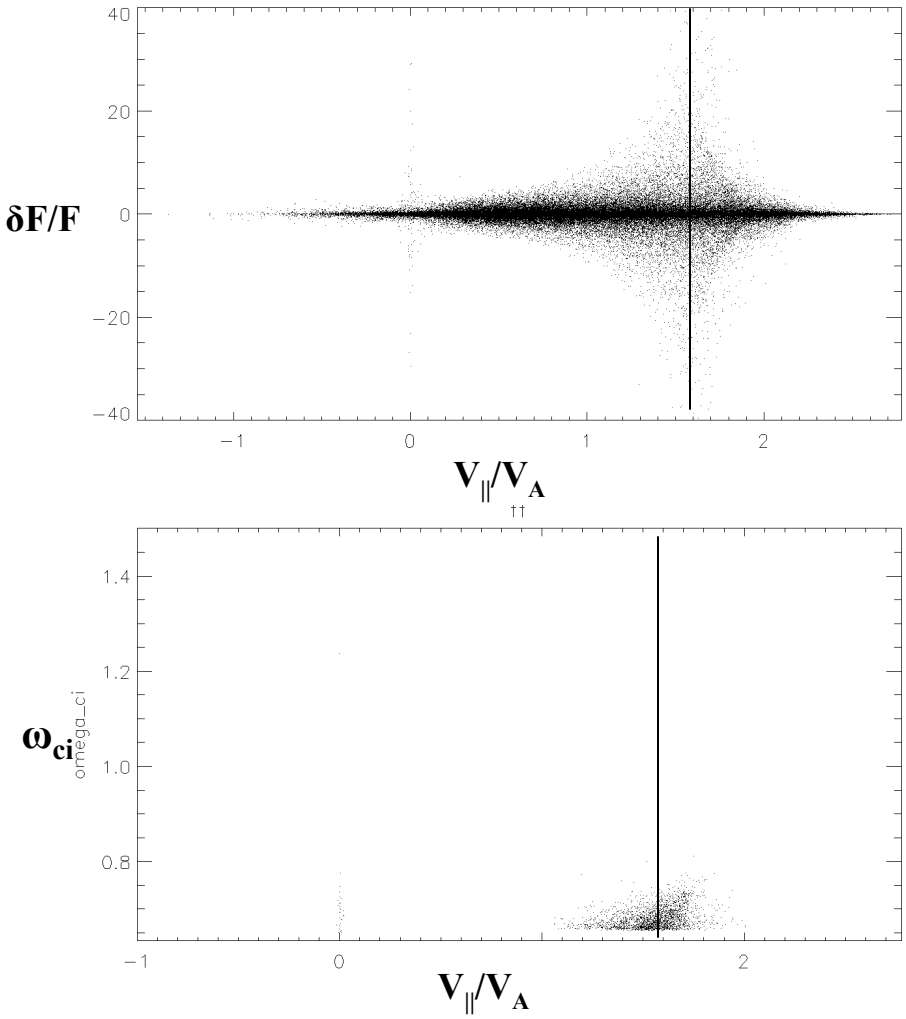


- $\delta B_{||}$ is small near magnetic axis, but it is peaked at low-field side mostly due to large δB_Z.
- Phase relations between δB components are consistent for all R.
- $\delta B_{||}$ is large at the edge due to wide radial profile of δB_φ .



Radial profiles of perturbed magnetic field at the midplane.

Phase-space plots: resonant condition



Resonant velocity $V_{||}/V_A$~1.6.

For 80keV ions, V_0/V_A=2.33 , so for resonant ions: $V_{||}/V_0$~0.7.