Characterization of GAE modes and their effect on electron thermal transport

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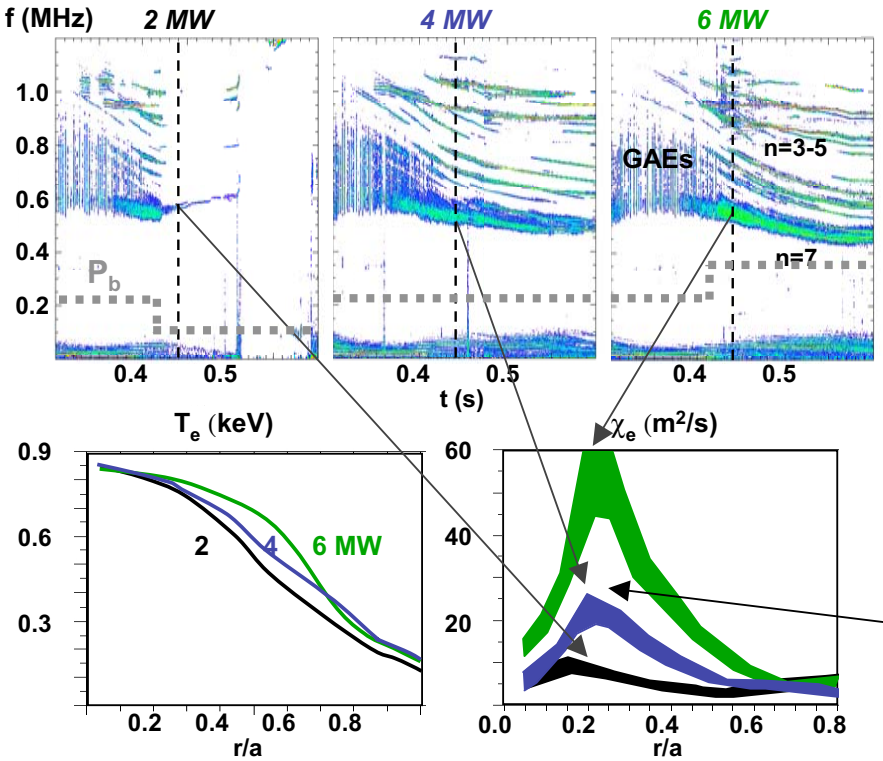
Joint T&T - WPI XP921

NSTX T&T Results Review 2009

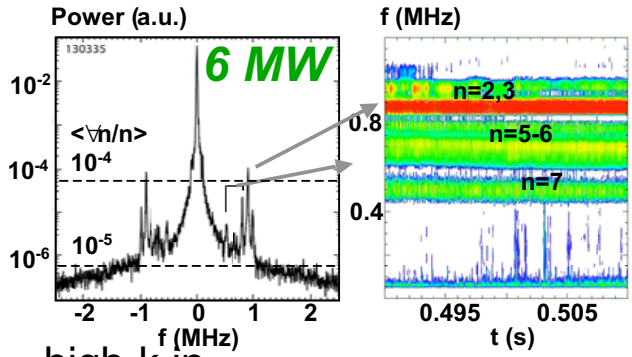
Motivation:

- **Flat electron temperature profiles in NSTX core have no validated explanation**
- **Central temperature and density gradients too low to drive microturbulence**
- **Fast ion phase-space gradients can drive energetic particle modes which overlap and cause stochastic electron particle orbits**
- **Theoretical connection between GAEs and electron thermal transport demonstrated numerically**

Correlation between GAEs and χ_e observed in earlier XP



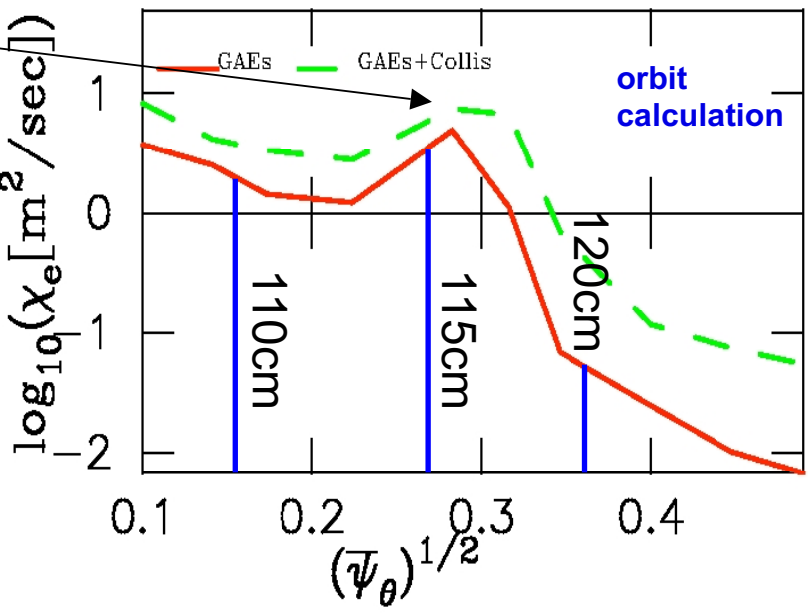
E. Mazzucato



high-k in interferometric mode

magnetics

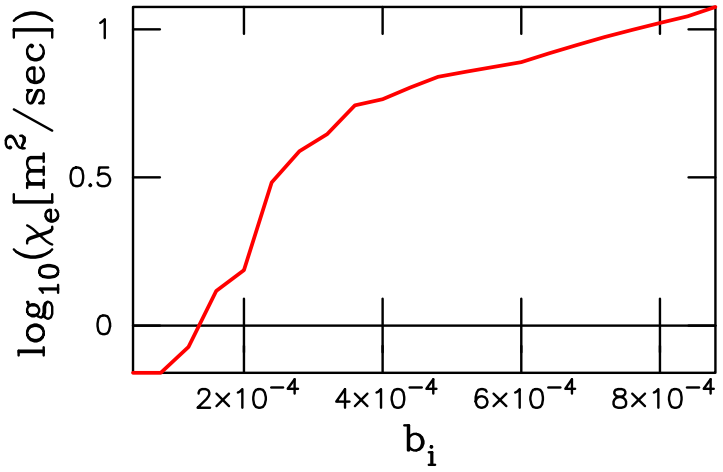
N. Gorelenkov



- P_b steps at fixed q(r), n_e, ω_{ExB}
- GAE $<\delta n>/<n>$ ~1.5 10^{-4} at 6 MW
- Theory predicts χ_e peak at r/a~0.25

Parallel electric field can strongly enhance χ_e

Baseline case, $v_e/\omega_{ce} = 0$, $r/a = 0.22$, $\alpha_0/R = 4\times10^{-4}$.



- Ideal MHD is assumed, but
- $E_{||} = \nabla\Psi$ is included perturbatively via the quasi-neutrality condition due to thermal ion FLR

$$\Psi = \phi_{MHD}\frac{b_i}{1+b_i},\ b_i = \frac{k_\perp^2\rho_i^2}{2},$$

$b_i \sim 0.5\times10^{-4}$ in NSTX, ϕ_{MHD} is such that $E_{||} = 0$.

Other source of $E_{||} \neq 0$ is from two fluid effects, compressibility (~ b_i)

Beam ions do not contribute.

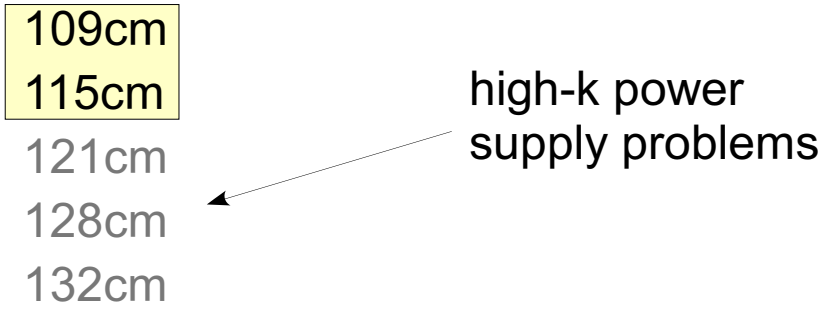
KAW can only if $\omega > \omega_A$ similar to stellarator GAEs (Kolesnichenko, PRL'05). Can they exist in tokamaks?

Gorelenkov: e-transport due to GAEs

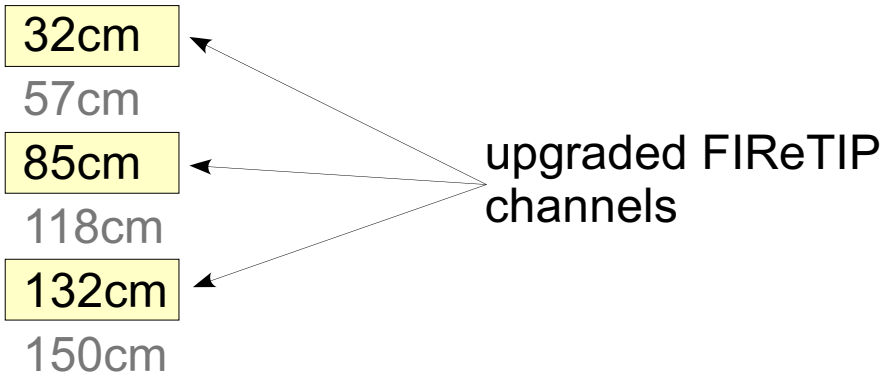
XP921 - Experimental run plan

- Characterize GAE mode structure and amplitude

  - radial scan using high-k diagnostic in interferometric mode



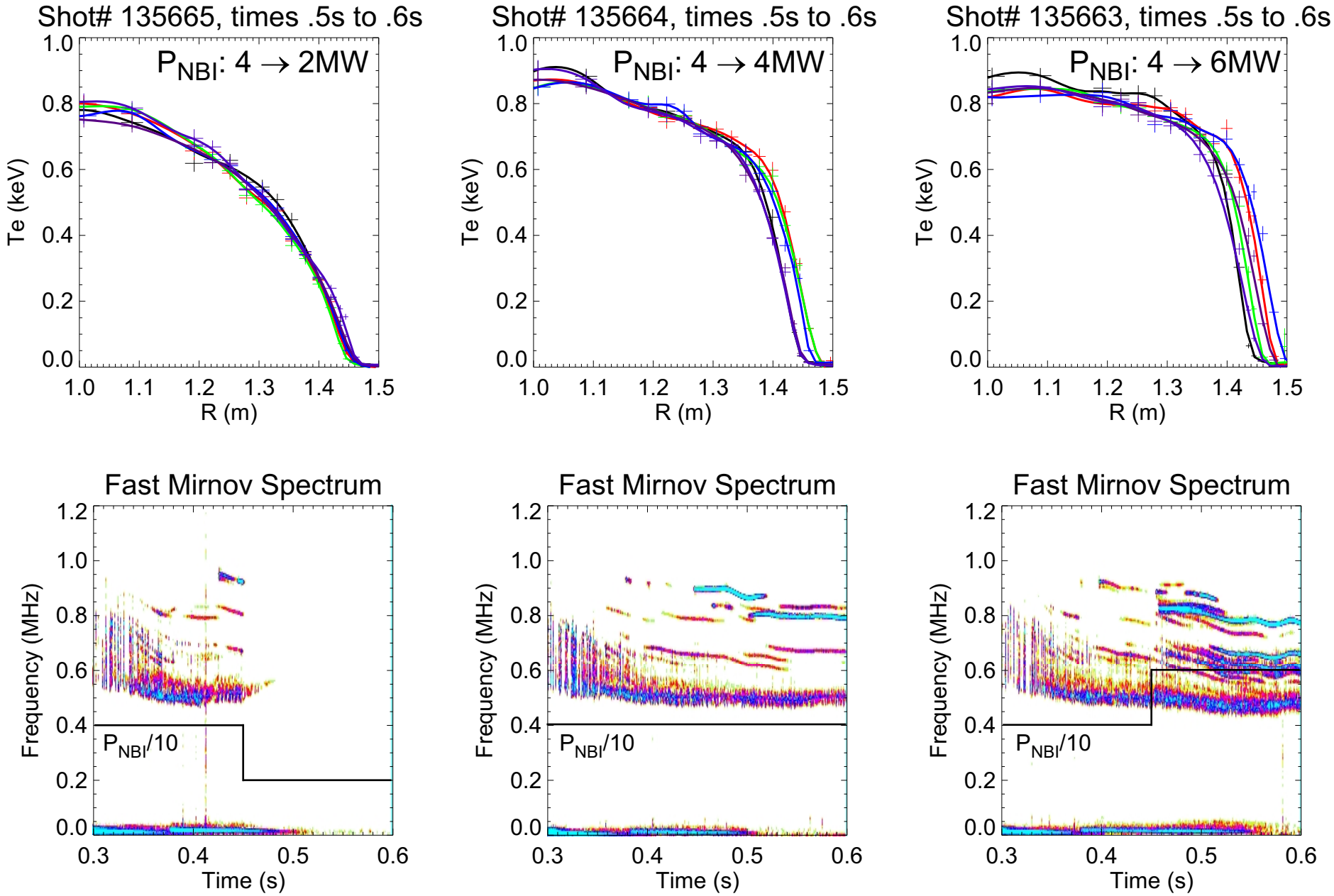
  - use FIReTIP with bandwidth upgrade



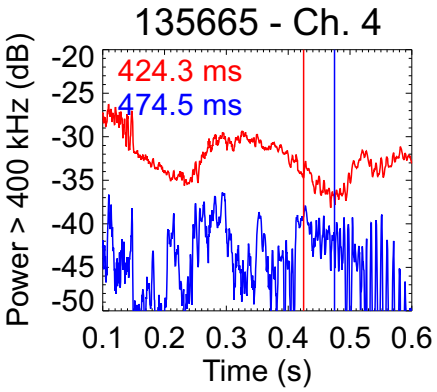
- Modify GAE activity, look for impact on transport

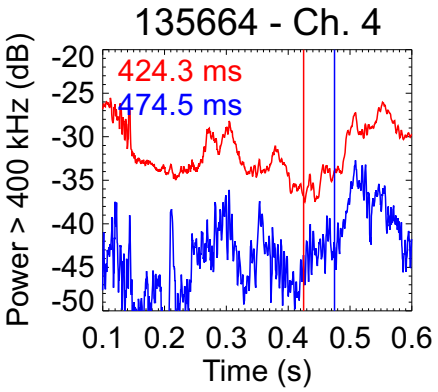
  - P_{NBI} beam steps to change mode amplitude, overlap
  - Raise I_P, B_T at constant q to investigate effects of parallel electric field

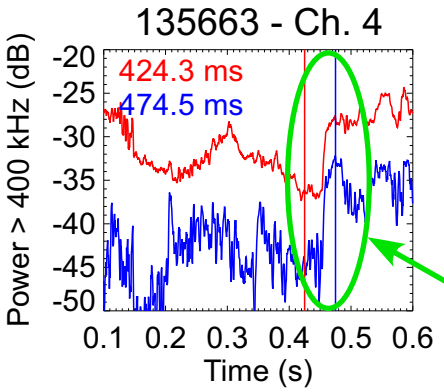
GAE activity and electron temperature profiles show expected response to P_{NBI} steps

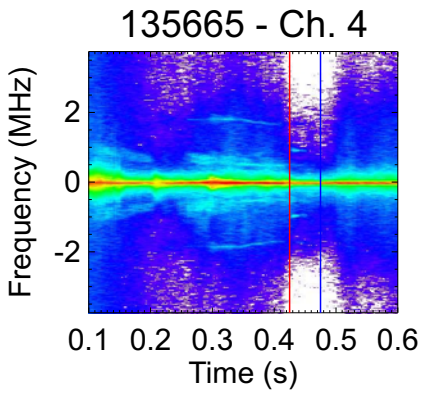


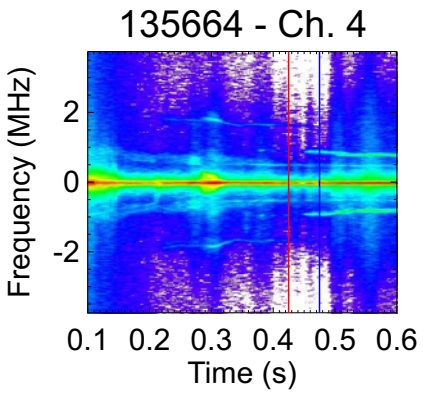
High-k interferometric signals show strong increase in GAE-induced density fluctuations for P_{NBI} step-up

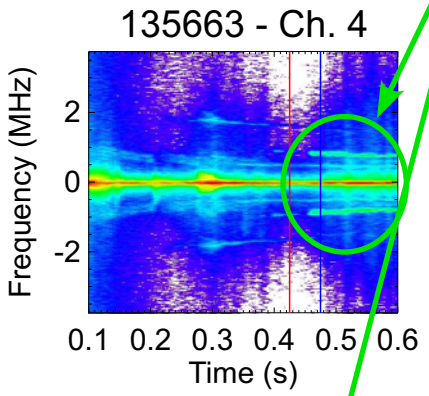


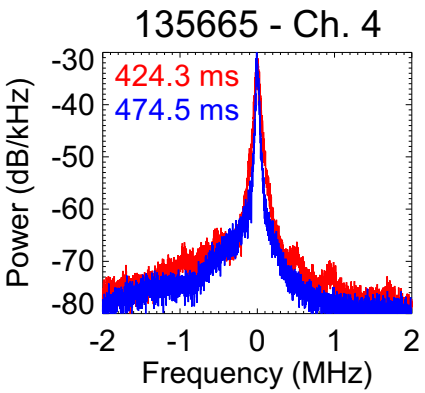


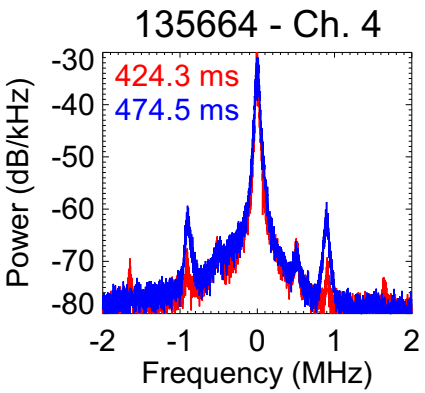


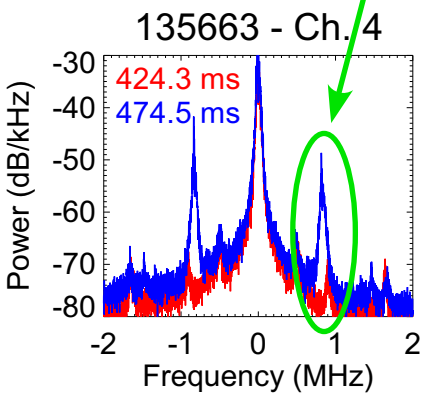




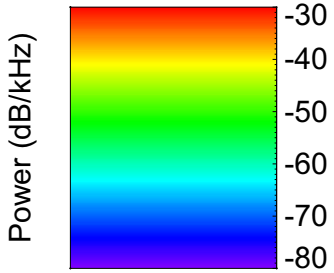








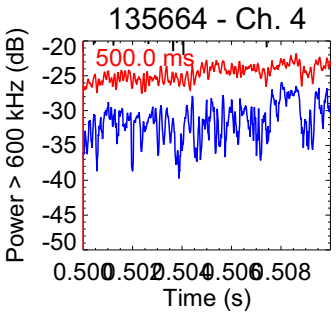
Density fluctuation power in 0.5-1MHz frequency band increases strongly at beam step



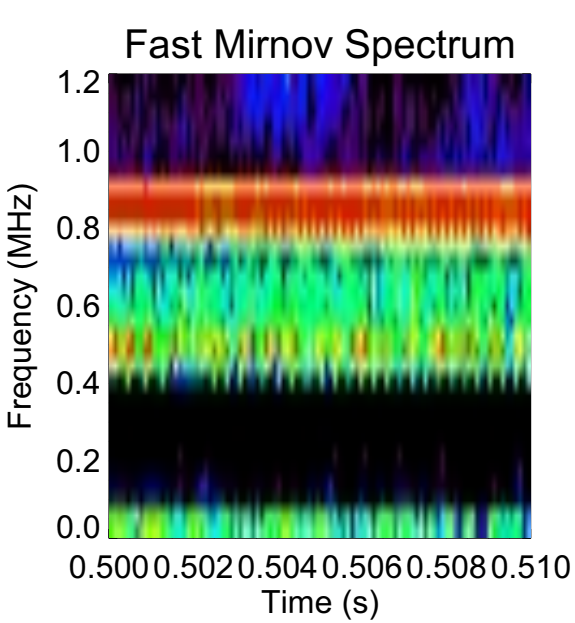
Samples per FFT: 8192
FFT Window (ms): 1.092
Freq Res (kHz): 0.92
Smoothing points: 17
Norm Radius (cm): 110.0
Hann window applied
Data oversampled by 2x

‘Bursting’ GAE activity may significantly enhance electron transport

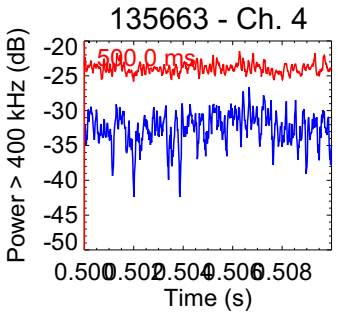
high-k dn/n



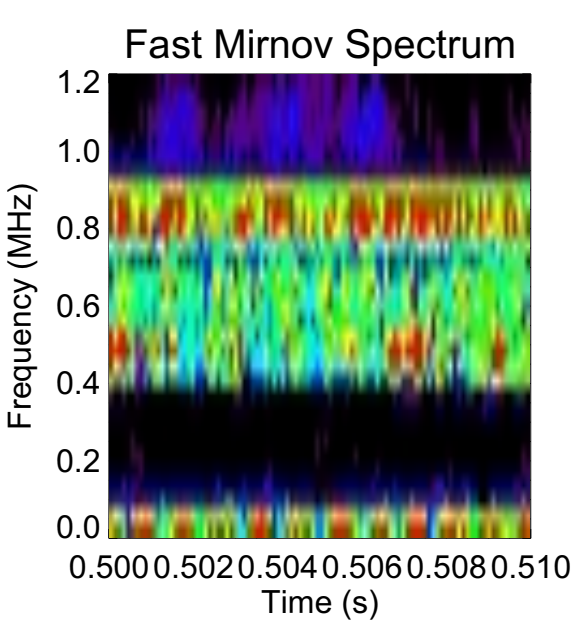
P_{NBI}: 4 → 4MW



high-k dn/n

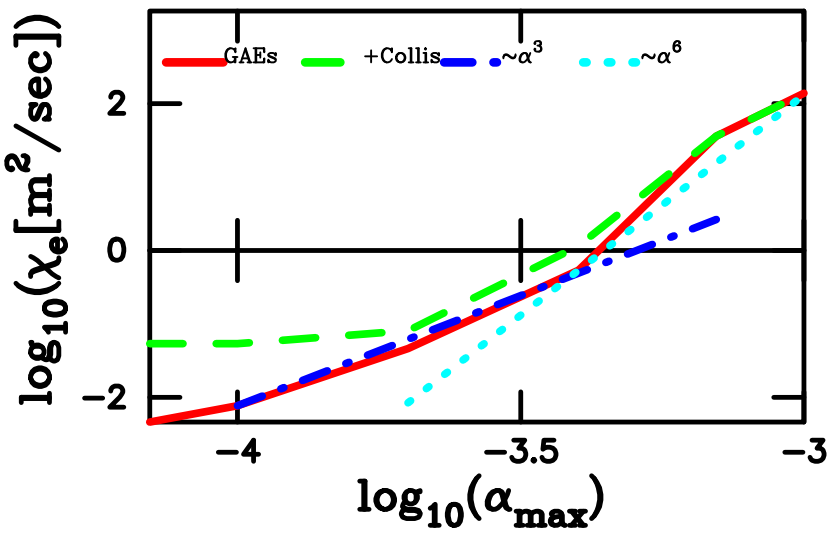


P_{NBI}: 4 → 6MW

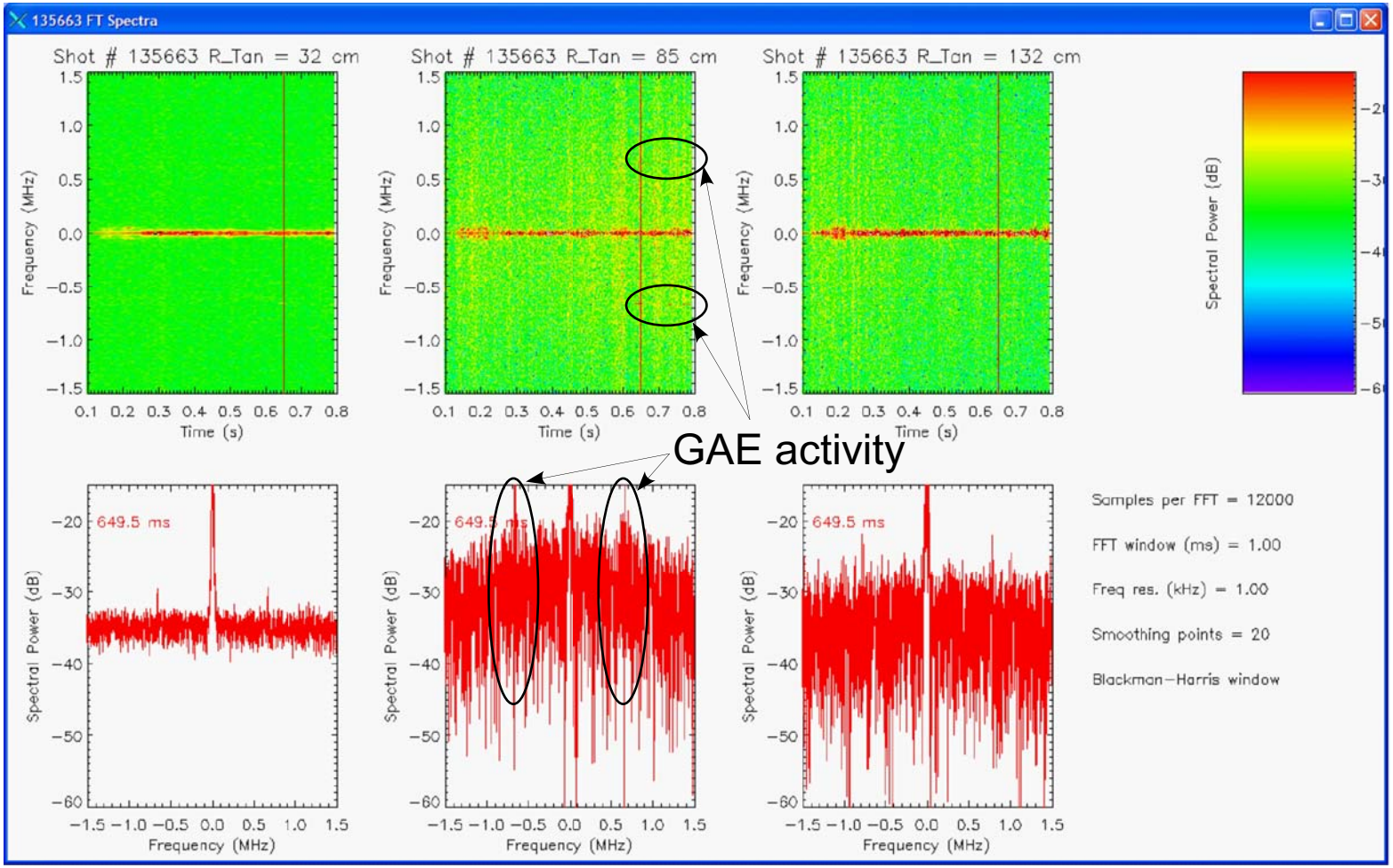


GAE bursts may have amplitude much larger than time-averaged δn/n

Strong non-linear dependence of transport on mode amplitude (χ_e vs α_{max}) suggests bursting modes may dominate electron thermal transport



FIReTIP data also indicates density fluctuations in GAE range



FIReTIP signal: GAE amplitudes low for 85cm channel ($\sqrt{\psi_n}$ ~ .32) and absent for 32cm ($\sqrt{\psi_n}$ ~ .97) and 132cm ($\sqrt{\psi_n}$ ~ .6) - consistent with central mode

Process for analyzing GAE/transport relationship involves constraining models and fitting measurements

- Use high-k interferometric data and FIReTIP data to calculate line integrated $\delta n/n(R,f)$
- Constrain model of GAE using measurements
  - i) assume peaked mode 'localizes' line-integrated signal
  - ii) fit synthetic line-integrated fluctuation signal to measurements
- Use constrained GAE model in ORBIT to predict χ_e
- Perform LRDFIT equilibrium reconstructions for TRANSP
- Use TRANSP to calculate experimental χ_e
- Neon injection SXR results may show changes in particle transport

Future work: Use BES to obtain localized measurements of GAE modes, confirm no low-k microturbulence