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Turbulent fluctuations with the scale of the collisionless skin depth in NSTX

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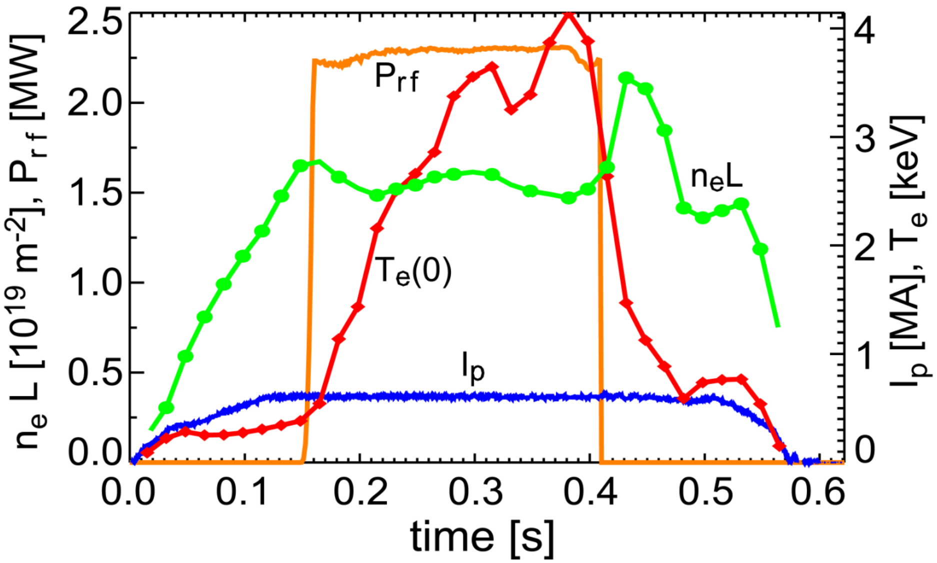
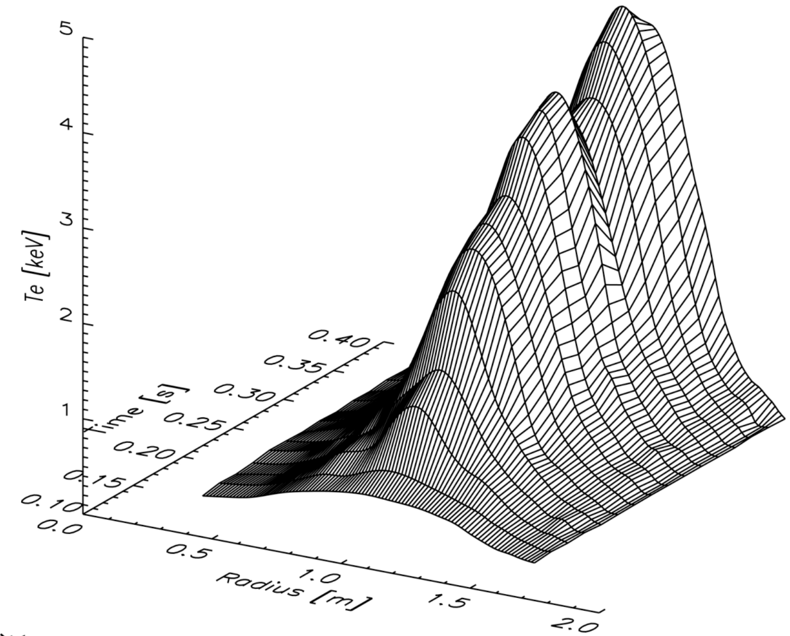
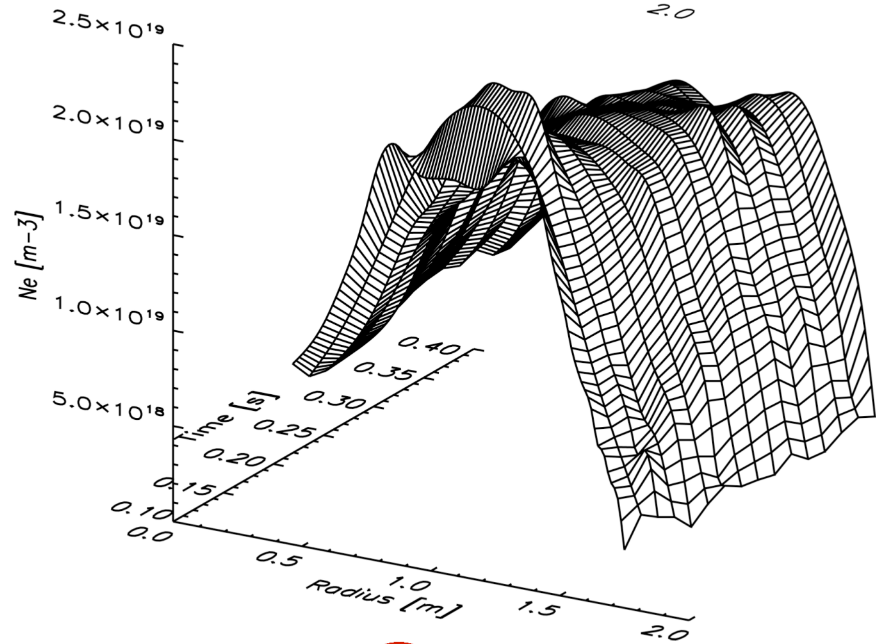
Motivation

- *This work stems from results of various theories and numerical simulations supporting the conjecture that the ubiquitous problem of electron anomalous transport may arise from a short-scale turbulence driven by the electron temperature gradient, with large radial structures on the scale of the collisionless skin depth ($\delta_{sk} \equiv c/\omega_{pe}$)*
- *Our primary goal was to check whether this type of turbulence was present in NSTX plasmas*
- *Measurements were performed in plasmas with High Harmonics Fast Wave (HHFW) heating – best tool for controlling and modifying the gradient of T_e in NSTX*
- *Turbulent fluctuations were measured with coherent scattering of 280 GHz waves using a novel scattering geometry with good spatial resolution (see PoP **10**, 753 (2003))*

He plasmas with B_t=5.5 kG, I_p=0.7 MA, P_{rf}~2 MW

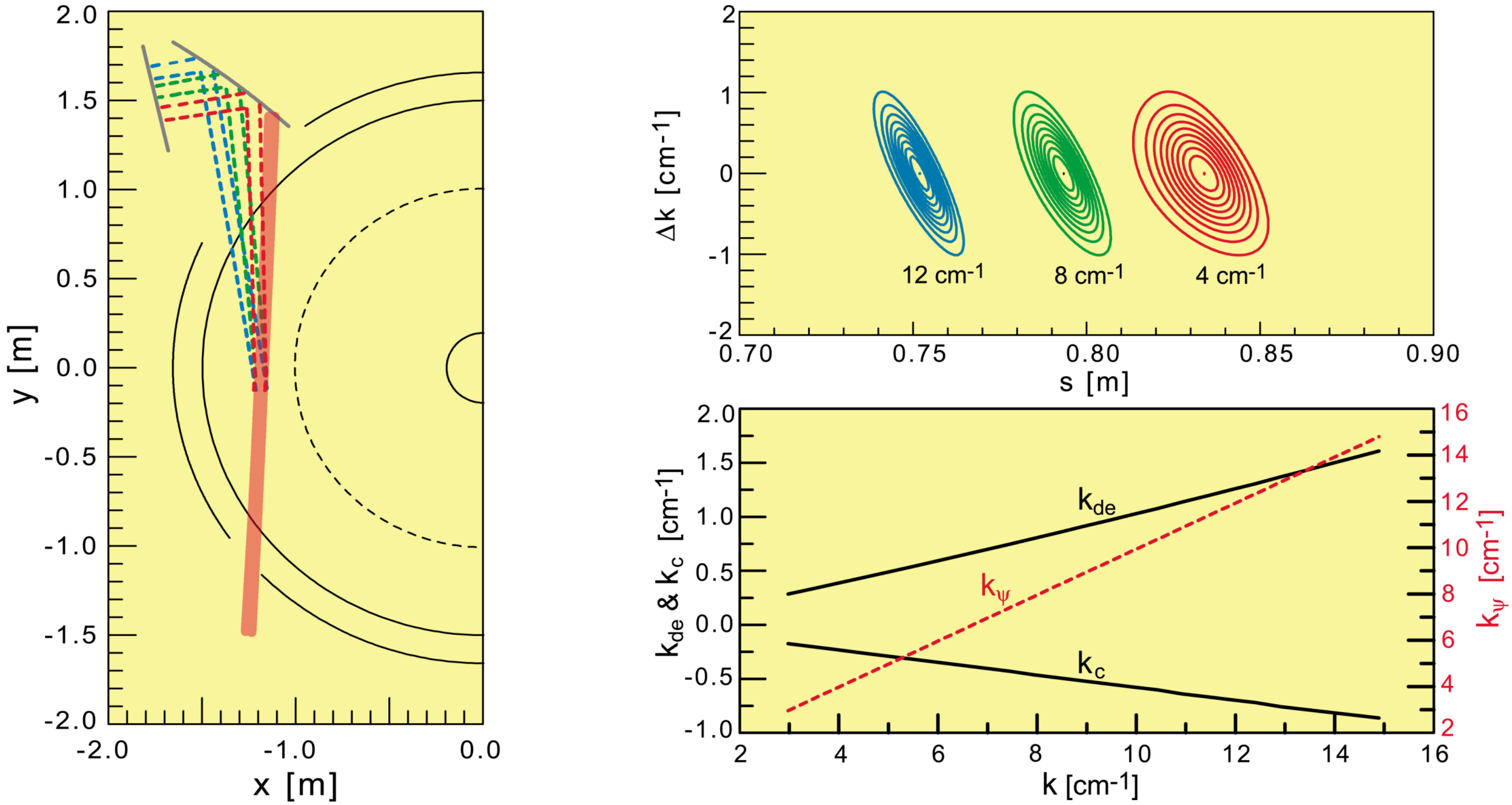






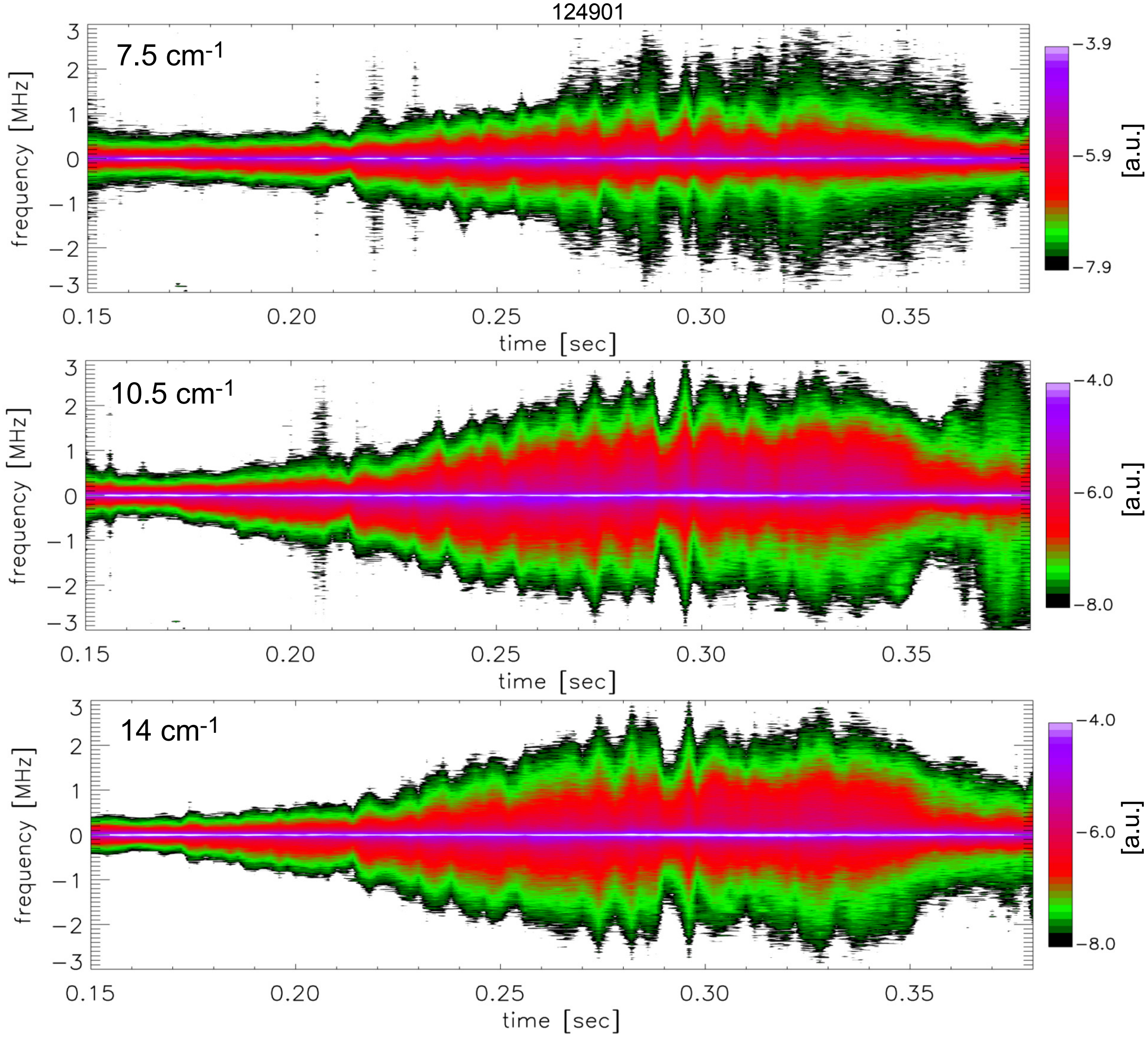
- *Measurements were done in He plasmas with B_t=5.5 T, I_p=0.7 MA and P_{rf} of up to 2.2 MW*
- *Use of He plasmas for reliable RF operation (see invited talk by J.C. Hosea, Tuesday afternoon)*
- *Application of 2 MW of HHFW resulted in peaked T_e profiles with central values in excess of 4 keV – 4 times T_i*
- *Broad n_e profiles after RF*

Scattering geometry



- The scattering geometry takes advantage of the anisotropy of plasma fluctuations ($k_\perp >> k_{||} \sim 1/qR$) and the curvature of magnetic field lines for minimizing the scattering volume
- Use of a probing beam with a radius of 3 cm results in a wave number resolution of ±1 cm^{-1} and a radial resolution of ±3 cm
- Wave vectors of fluctuations are mainly perpendicular to the magnetic surfaces (k_Ψ), but have also small components along the electron diamagnetic velocity (k_{de}) and the plasma current (k_c)
- Since $k_{de}k_c < 0$, a plasma velocity along the plasma current causes a frequency Doppler shift with the sign of ω_i*

Core fluctuations (R≈1.2 m)



$k\rho_e = 0.11 - 0.19$
$k\rho_s = 4.82 - 8.57$
$k\delta_{sk} = 1.05 - 1.33$

$k\rho_e = 0.16 - 0.27$
$k\rho_s = 6.75 - 12.0$
$k\delta_{sk} = 1.47 - 1.86$

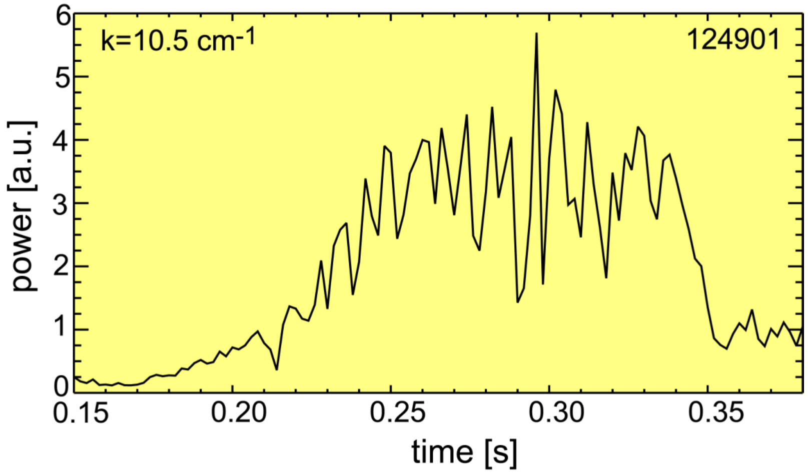
$k\rho_e = 0.21 - 0.36$
$k\rho_s = 9.00 - 16.0$
$k\delta_{sk} = 1.96 - 2.48$

- *Both amplitude and spectral width increase as T_e increases and its radial scale decreases*

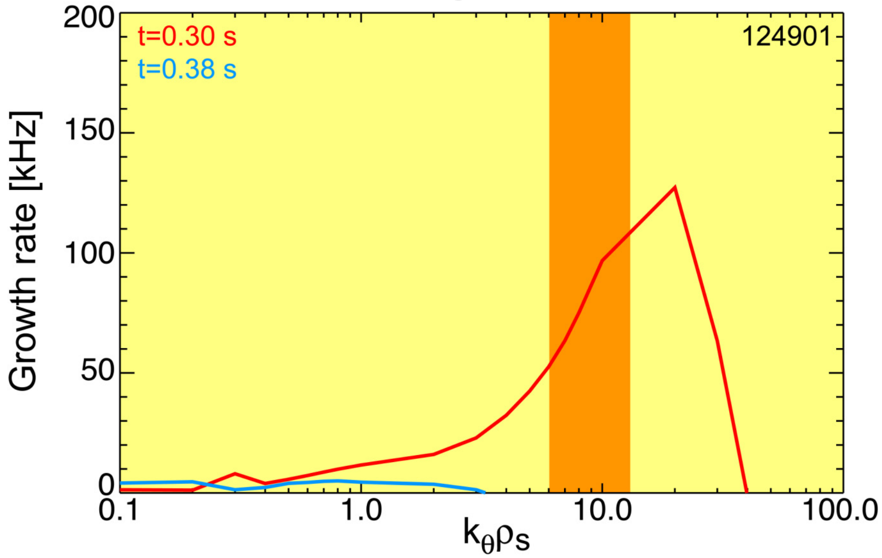
$k\rho_s$=5 ÷16 and $k\delta_{sk}$ = 1 ÷ 2.5 → scale of fluctuations ≈ δ_{sk}

Linear gyrokinetic GS2 code

- *Amplitude of fluctuations drops towards the end of RF pulse*



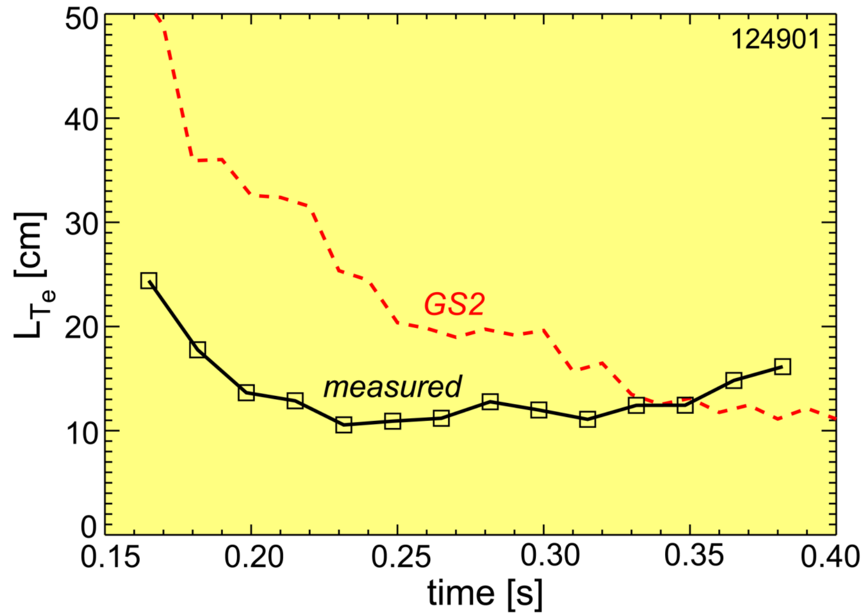
- *GS2 growth rate*



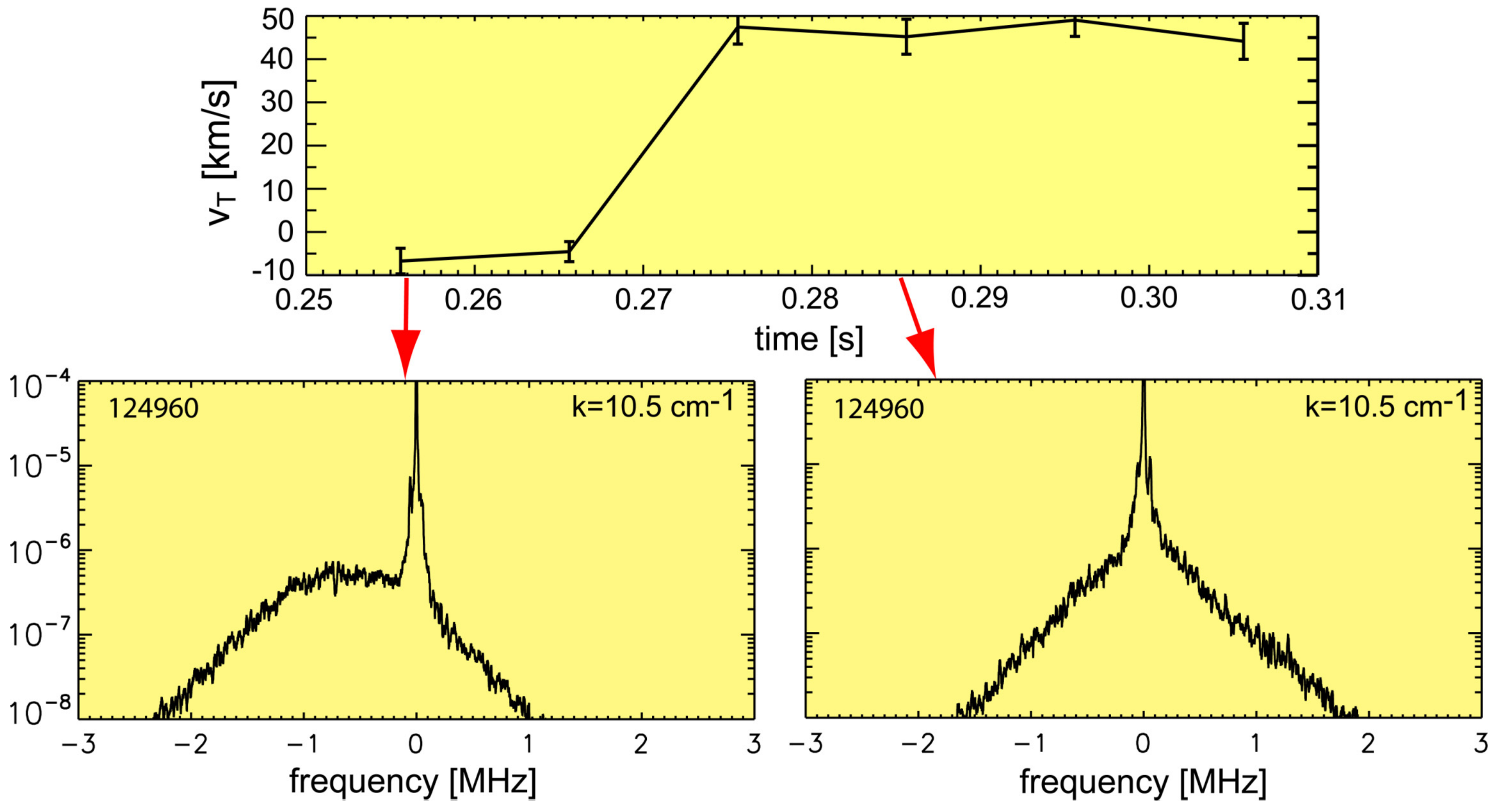
Unstable @ *t* = 0.30 s   *Stable* @ *t* = 0.38 s

- *Jenko's critical gradient for linear excitation of ETG mode (PoP* ***8****, 4096, 2001)*

$$(R/L_{T_e})_{crit} \propto 1 + Z_{eff} T_e / T_i$$

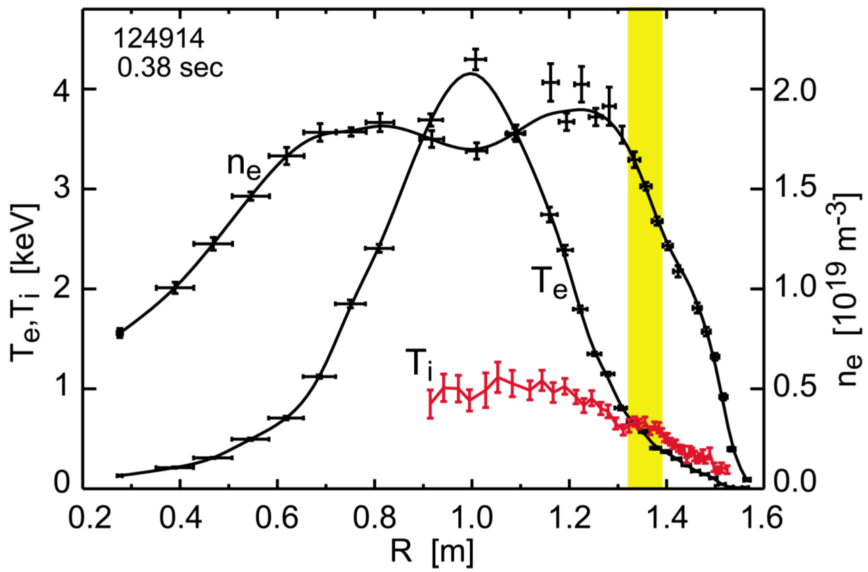


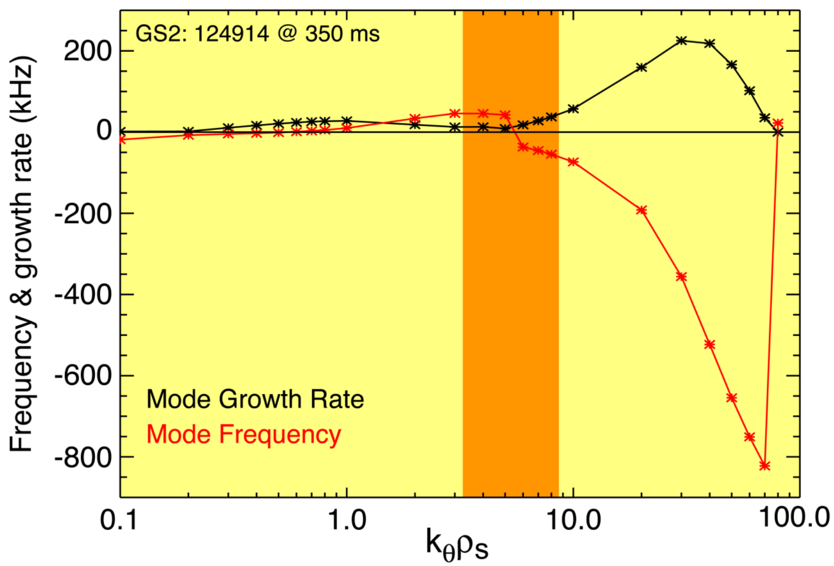
Frequency Doppler shift by toroidal rotation



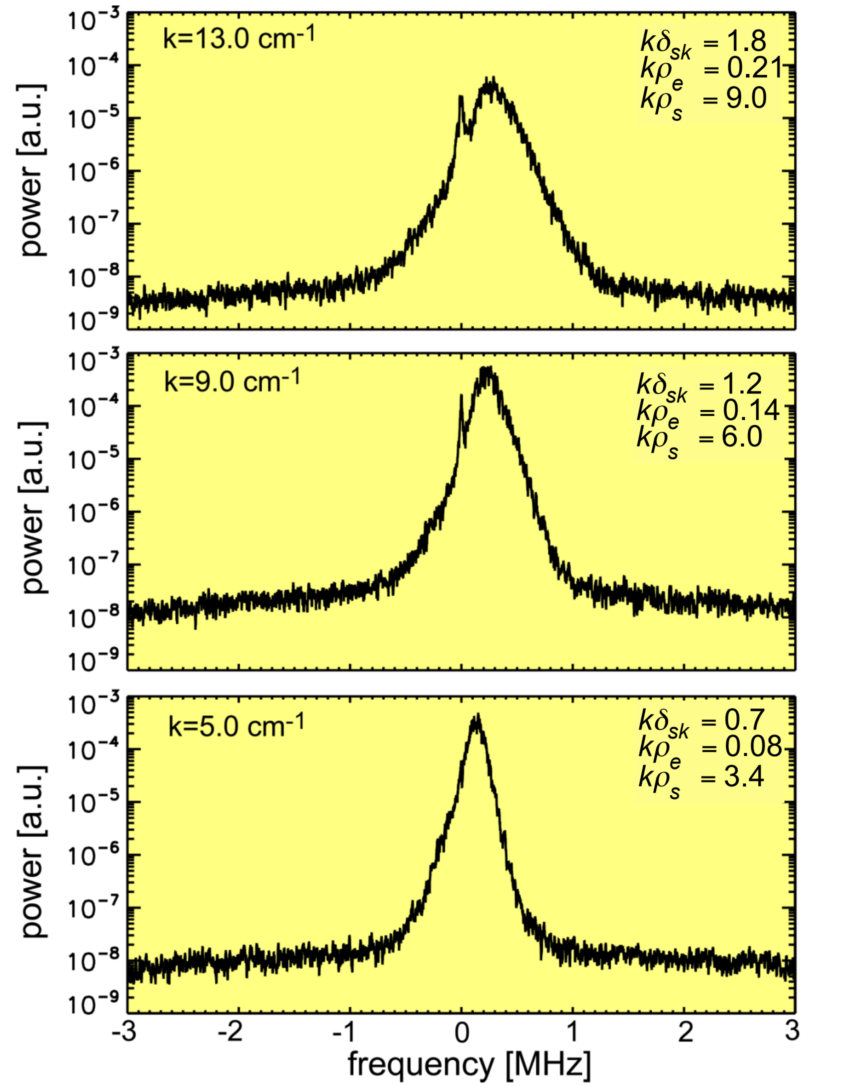
- *Fluctuations appear to propagate along the electron diamagnetic direction in the plasma rest frame (v_T =0),*
- *A sudden change in toroidal velocity (probably due to the onset of a locked mode) causes a frequency Doppler shift towards the ion diamagnetic side*

Outer fluctuations (R≈1.35 m)



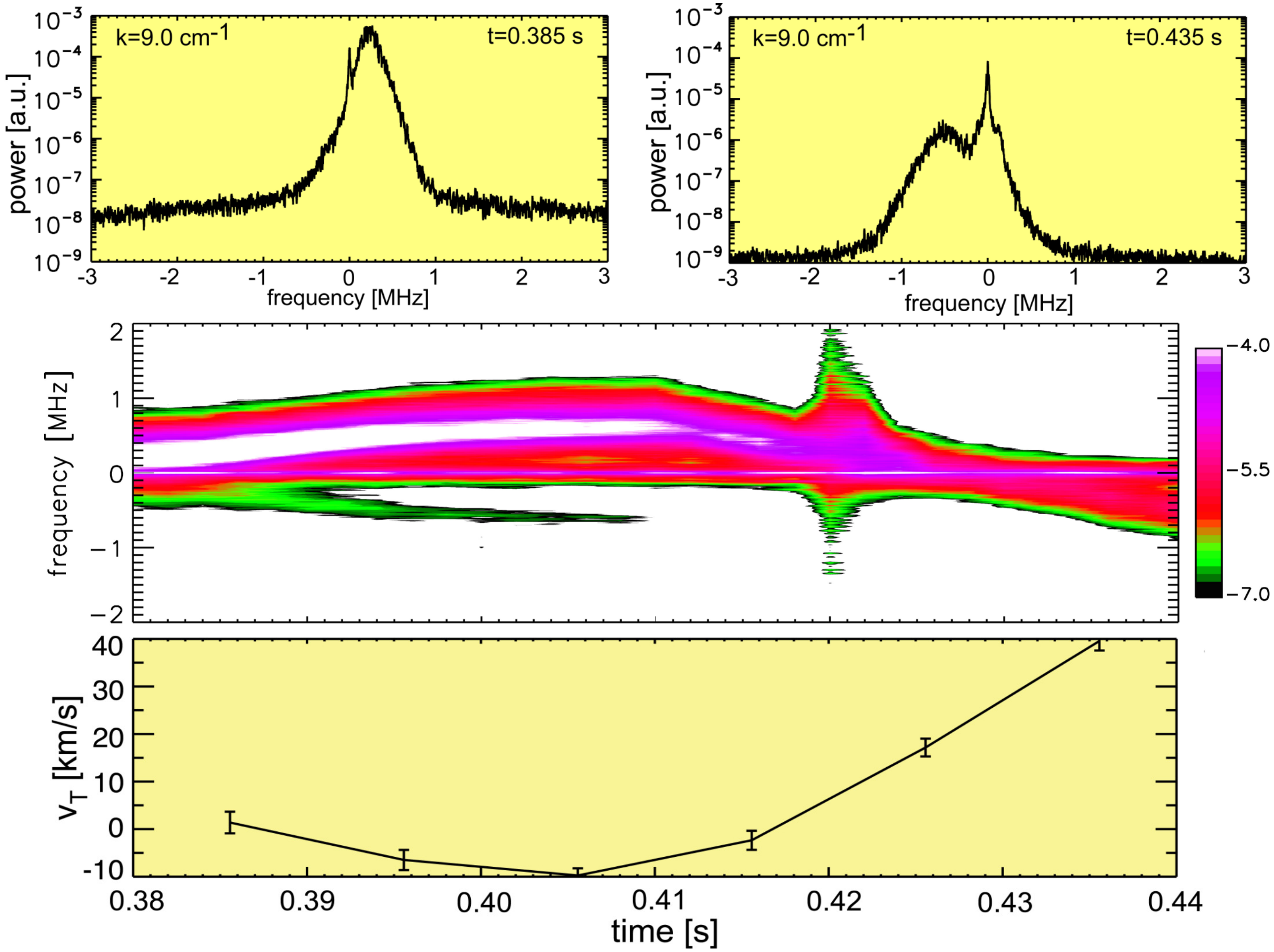


- *Propagation along v_{de} and scale ≈ δ_{sk}*



- *The GS2 results support the conjecture that fluctuations are elongated in the radial direction*

Frequency Doppler shift by toroidal rotation



- *In the plasma frame (v_T =0), fluctuations appear to propagate in the electron diamagnetic direction*
- *A rise in toroidal velocity causes a frequency Doppler shift towards the ion diamagnetic side*

Conclusion

- *Our results indicate the existence of turbulent fluctuations with the scale of the collisionless skin depth*
- *Large values of $k\rho_i$ and wave propagation along the electron diamagnetic direction rule out the ITG mode*
- *Large values of $k\rho_s$ and L_n/R rule out the TEM mode*
- *A qualitative agreement with the predictions of the linear gyrokinetic GS2 code supports the conjecture that the observed turbulence is caused by the ETG instability*
- *However, additional measurements and non-linear numerical simulations are needed for a conclusive identification*