NSTX

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GYRO Simulations of ETG Turbulence in NSTX

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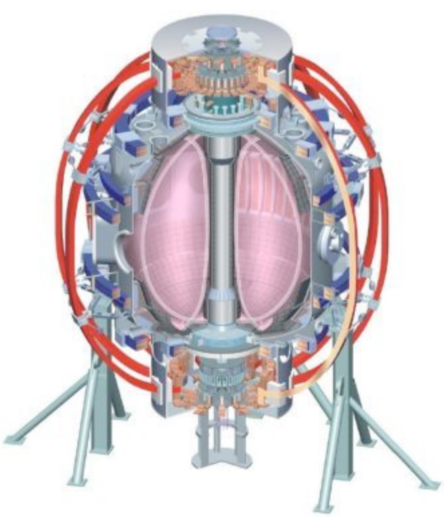


Introduction

In NSTX, strong ExB shearing often quenches low k turbulence.

ETG modes have larger growth rates, should be immune?

Ion thermal diffusivity often near neoclassical, need only χ_e^{anom}

First case study: L-mode plasma with low power NBI at r/a=0.6

- conditions are typical of the 'confinement region'
- in particular, the magnetic shear is ~+1

Second case: L-mode NBI+HHFW plasmas at r/a~0.25

- magnetic shear is near zero to strongly negative
- sometimes see very steep gradients - in everything!
- (see Howard Yuh's Invited talk, TI2.00005)

Effect of ExB shearing on ETG turbulence

ExB shearing quenches ITG/TEM modes with $k_\theta \rho_s < 1$.

makes ETG with kinetic ions more affordable: ignore $k_\theta \rho_s < 1$.

inverse cascade from $k_\theta \rho_e \sim 1$ down to $k_\theta \rho_s \sim 1$ is included.

Simulations are already converged with m_i/m_e as low as 400.

Can use a relatively small mass ratio to speed up simulations.

Dynamic range of k_θ is smaller, fewer modes are needed.

The saturation mechanism is not at electron scales.

ExB shearing sets the saturation level even for ETG modes!

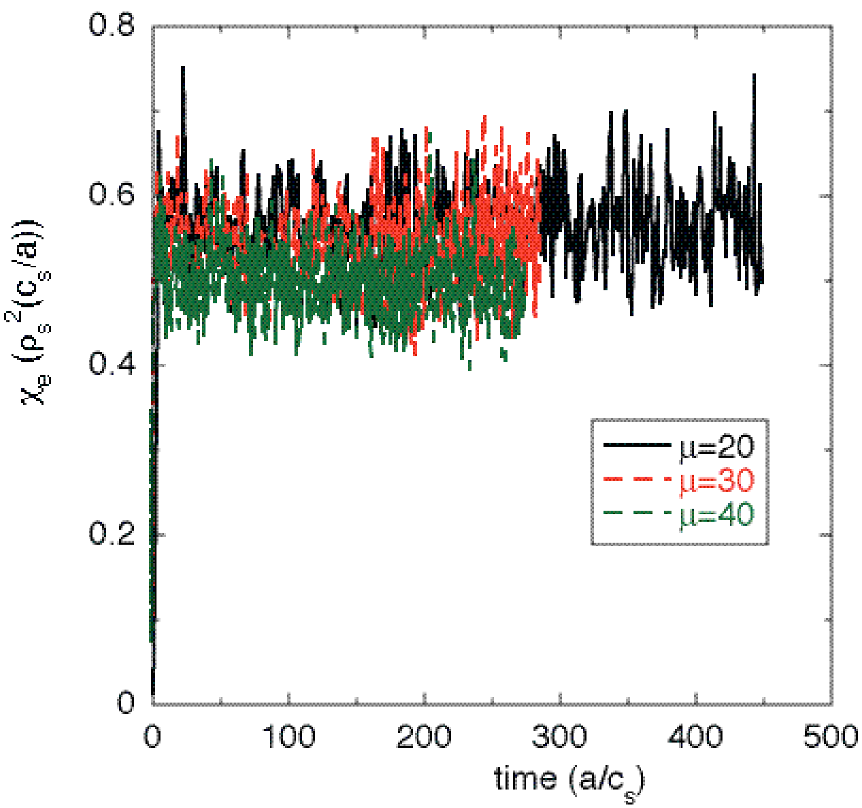
Scaling of eddy size with ExB shear rate is demonstrated.

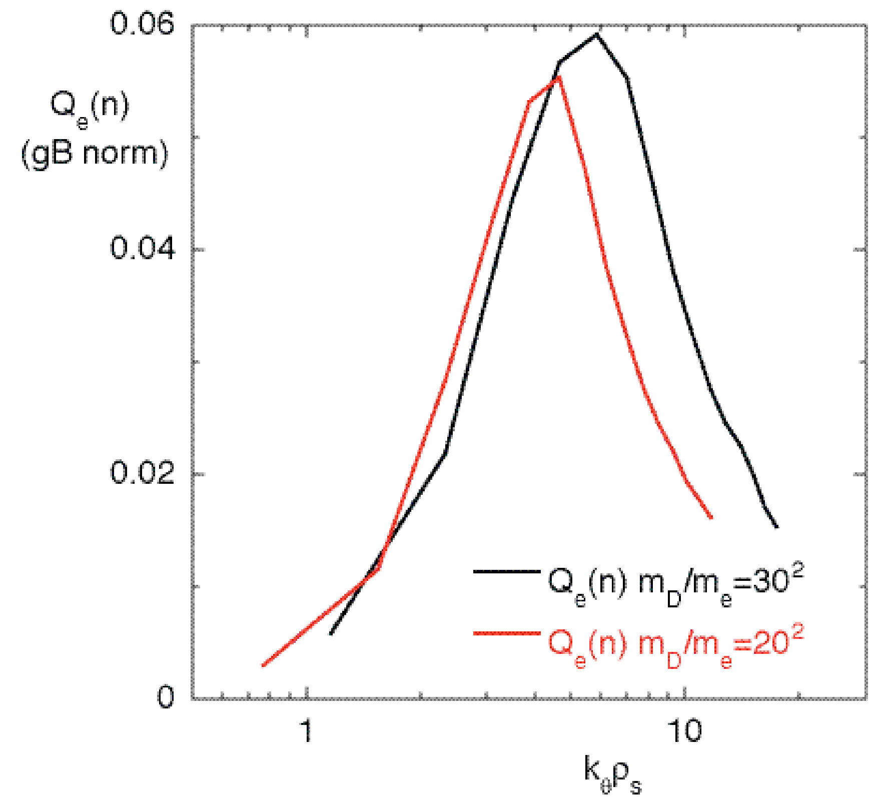
See D. Smith's invited talk YI2.00005, Friday AM

Converged with Small Mass Ratio

Varied m_D/m_e from 20^2 to 40^2, but electron heat flux drops only ~20%.

k_θ spectrum is not pinned to either ρ_s or ρ_e scales, peak drive $k_\theta\rho_e$~0.4, saturation affects $k_\theta\rho_s$<5



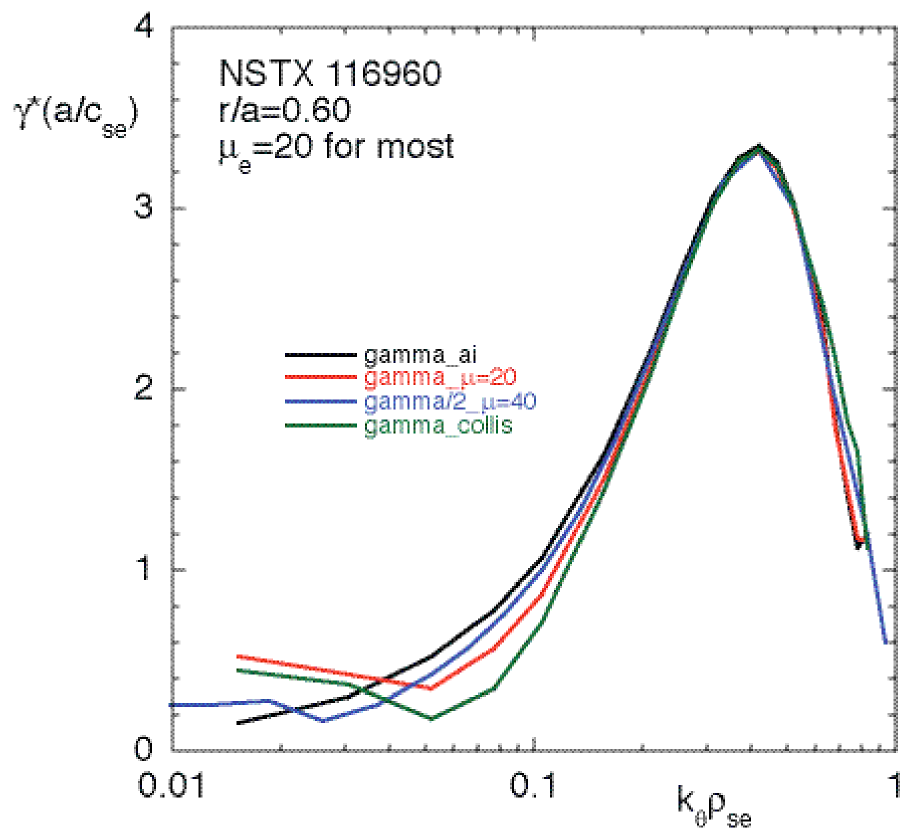


Transport not set purely by electron scales

Growth rates in electron units are independent of m_D/m_e

If saturation processes were also tied to electron scales, then χ_e expressed in ion units should drop with m_e/m_D.

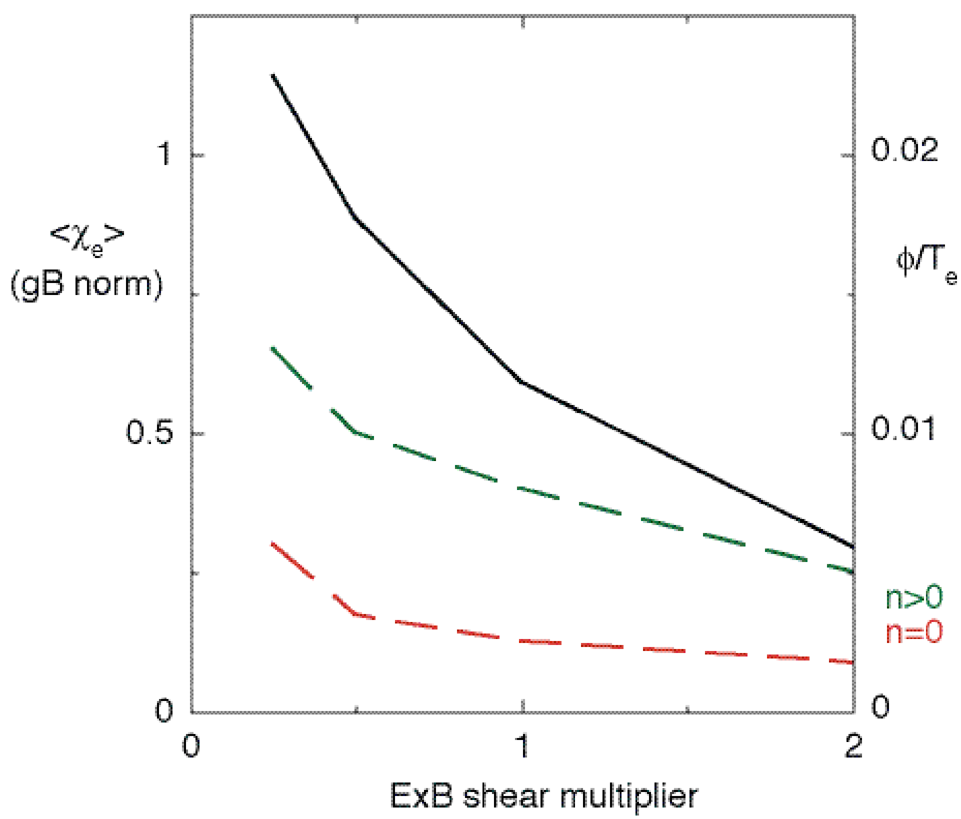
But transport in ion units is independent of m_D/m_e

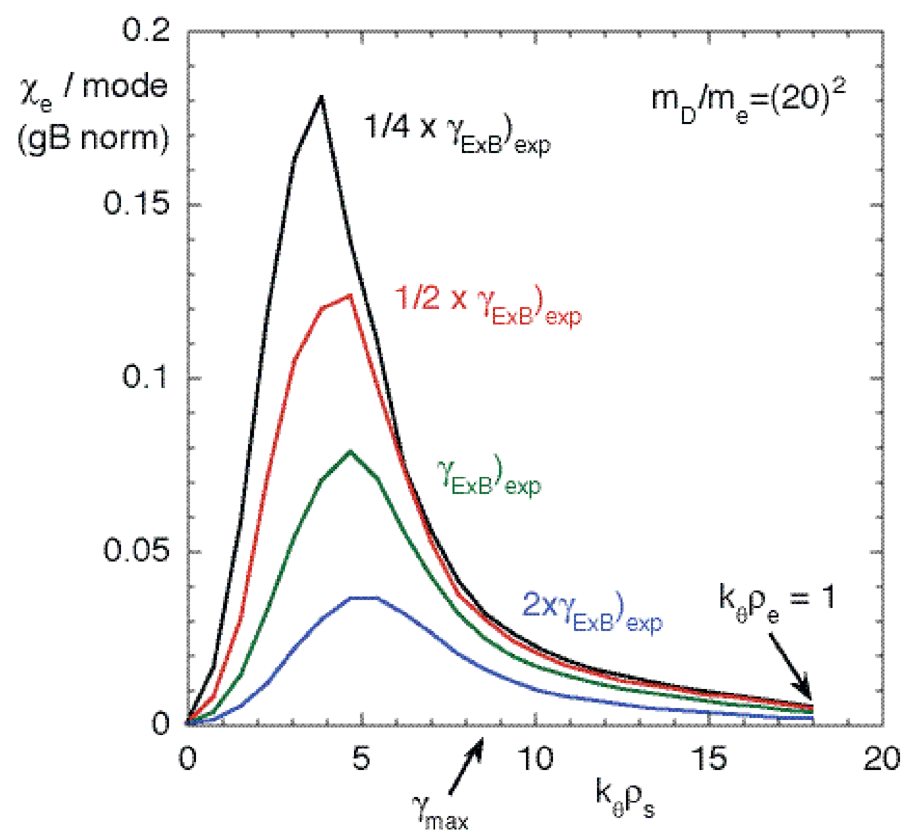


ExB Shearing Rate Sets the Heat Flux

Reducing ExB shearing rate raises χ_e, and the fluctuating potential amplitude, ϕ/T_e, also rises; k_θ spectrum downshifts slightly.

Need $k_\theta \rho_s \sim 1$ to converge when ExB rate is low.

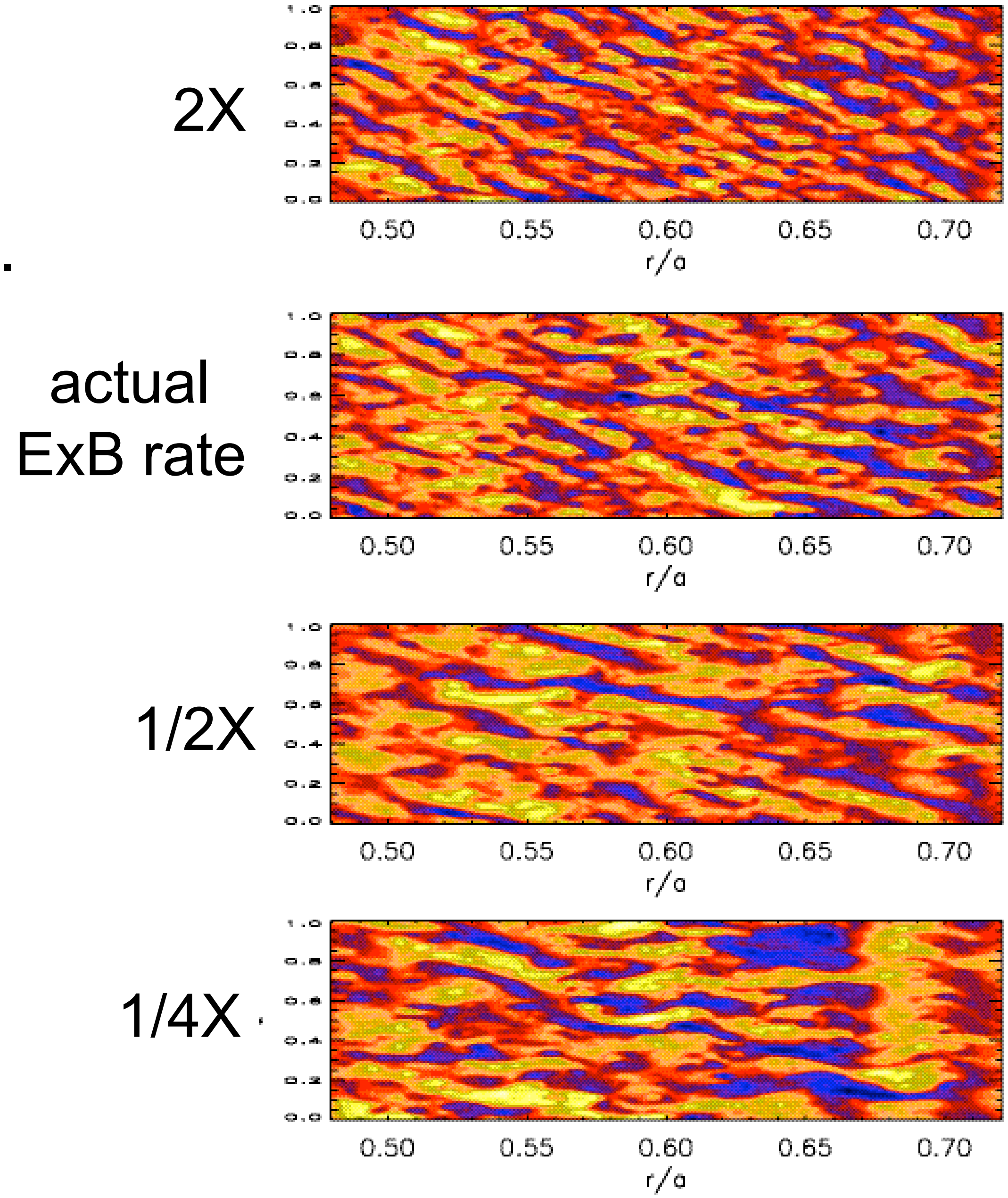




ExB Shear Controls Eddy Size

Eddies grow (in 2D) as shearing rate is reduced.

Extent of radial domain is ~400 ρ_e.



Effect of Magnetic Shear on ETG Turbulence

HHFW L-mode plasmas at r/a~0.3 have

large R/L_{Te} and relatively low ExB shear.

Negative magnetic shear has a strongly stabilizing effect.

High $\tau = Z_{eff} T_e / T_i$ is common, and is also stabilizing.

Large R/L_{Te} is correlated with strongly negative magnetic shear.

see Howard Yuh's Invited talk, TI2.00005 (Thursday AM)

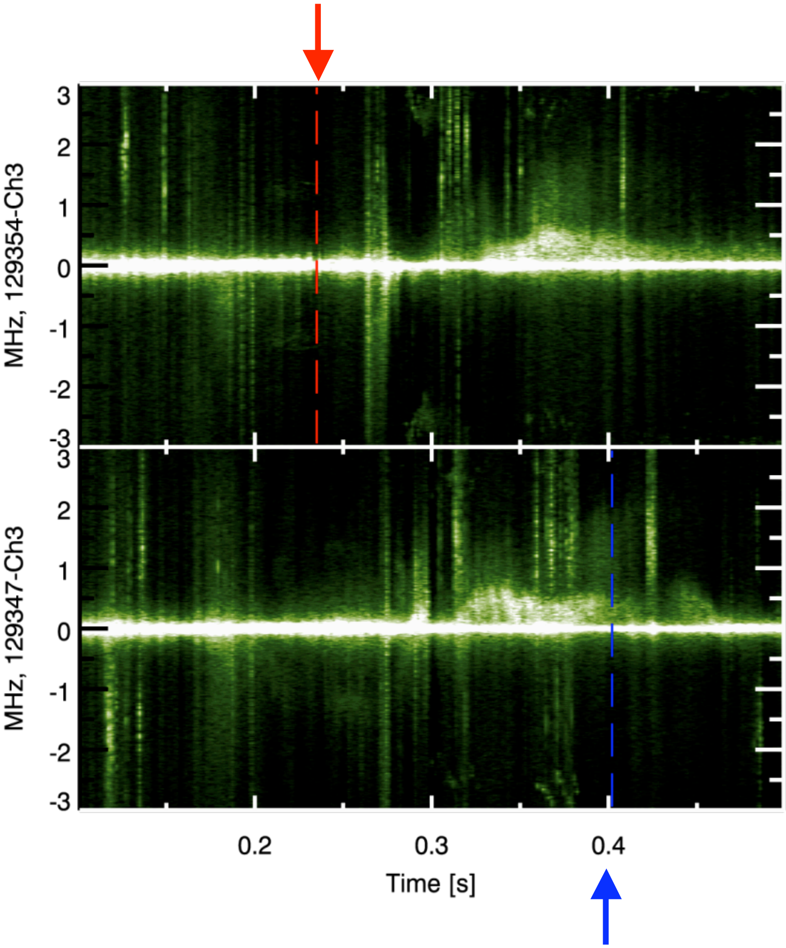
Focus on fully documented NBI+HHFW discharges.

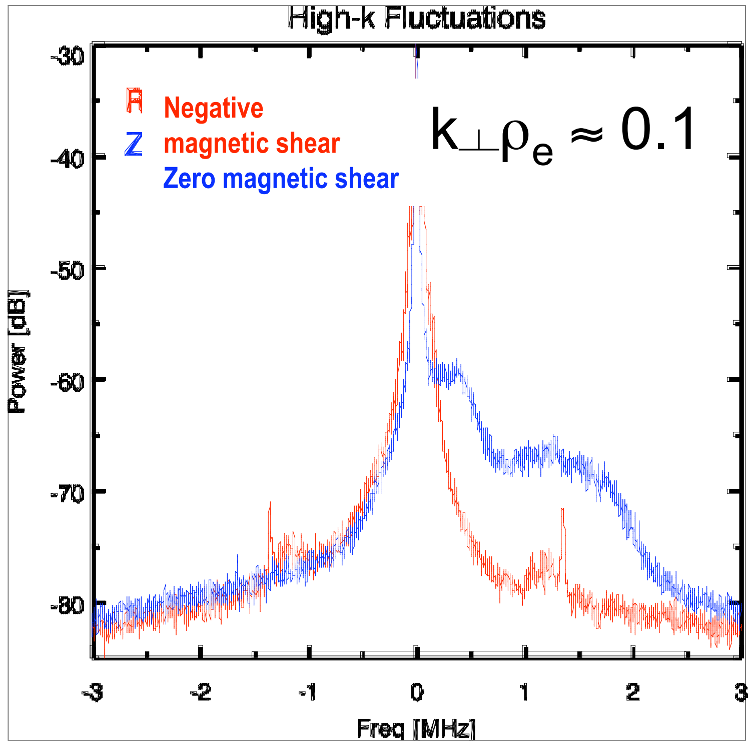
vary τ, magnetic shear and R/L_{Te} to map parameter space.

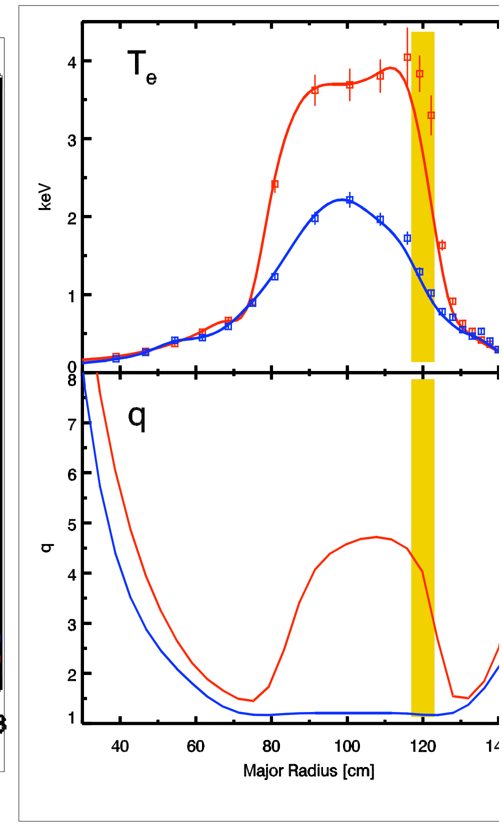
Also see Luc Peterson's neighboring poster NP6.00094

Magnetic shear scan

From H. Yuh







Identical discharges heated by HHFW, but 50ms beam blips for MSE & CHERS.
Early phase of discharge has strongly reversed shear with very steep T_e gradient.
Stronger high-k fluctuations later with **lower** T_e gradients, but with magnetic shear ~0.
Small ExB shearing rate at early time; magnetic shear suppresses ETG modes?

Background: Linear ETG Threshold

Analytic threshold formula: Jenko, et al., Phys. Plasmas **8** (2001) 4096

Decreasing magnetic shear is stabilizing, but $0.2 < s < 3$, while in NSTX at r/a~0.25 we often see $-2 < s < 0.1$

With the adiabatic ion model, Z_{eff} and T_e/T_i dependences are combined in a single parameter, $\tau = Z_{eff} * T_e/T_i$. Raising τ is stabilizing, and in NSTX plasmas $2 < \tau < 15$

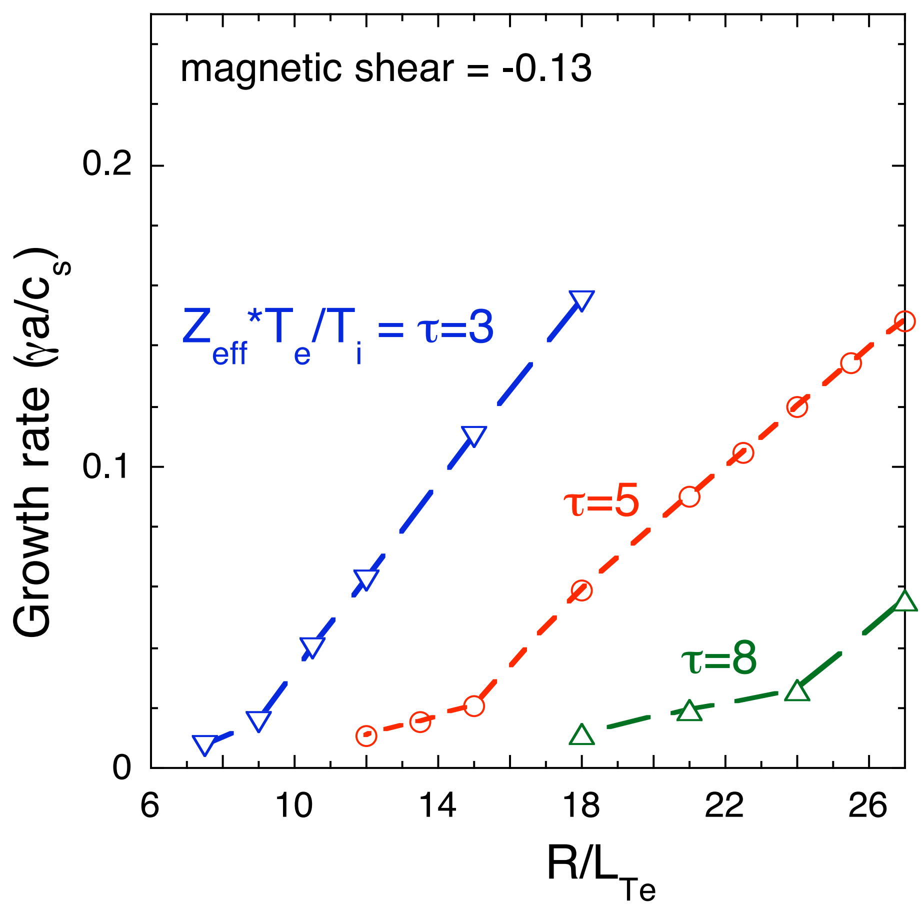
Weaker dependences on q, r/R, κ, δ, collisionality and R/L_{ne}.

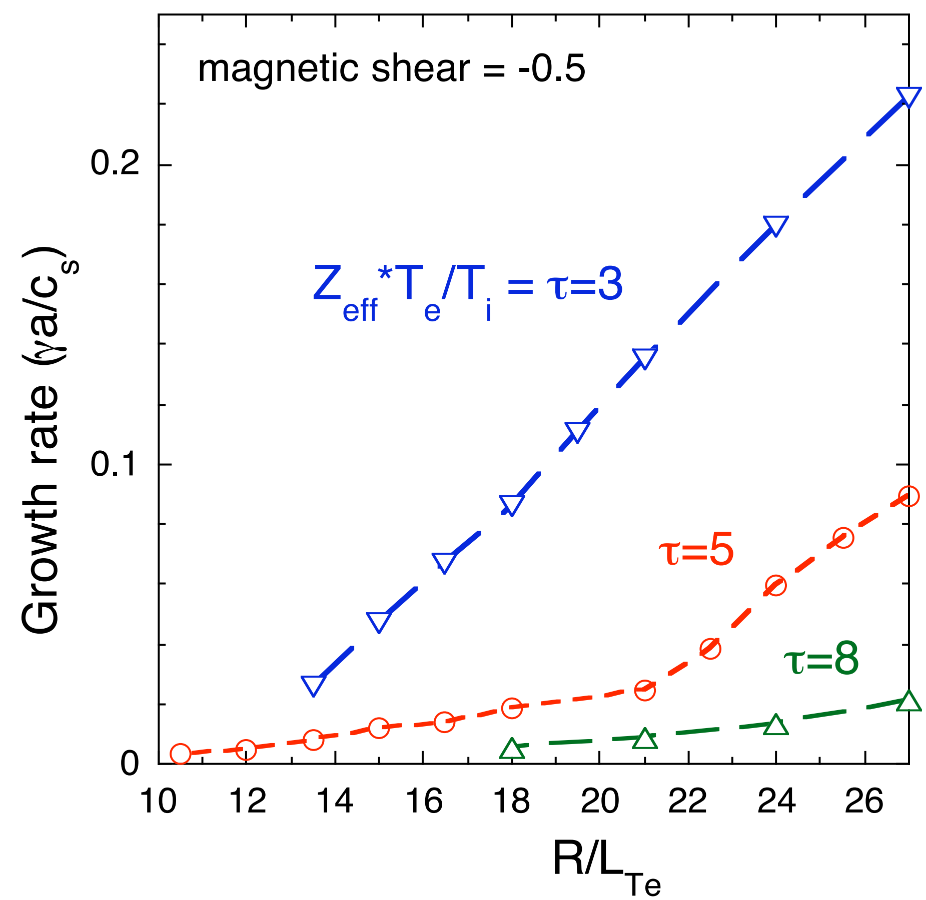
Linear Thresholds for NSTX with HHFW

New calculations with -1.5 < s < 0.1 and 3 < τ < 8

Realistic geometry, r/R=0.2, q=1.2, κ=1.5, δ=0.04

Scan R/L_{Te} for several combinations of s and τ.



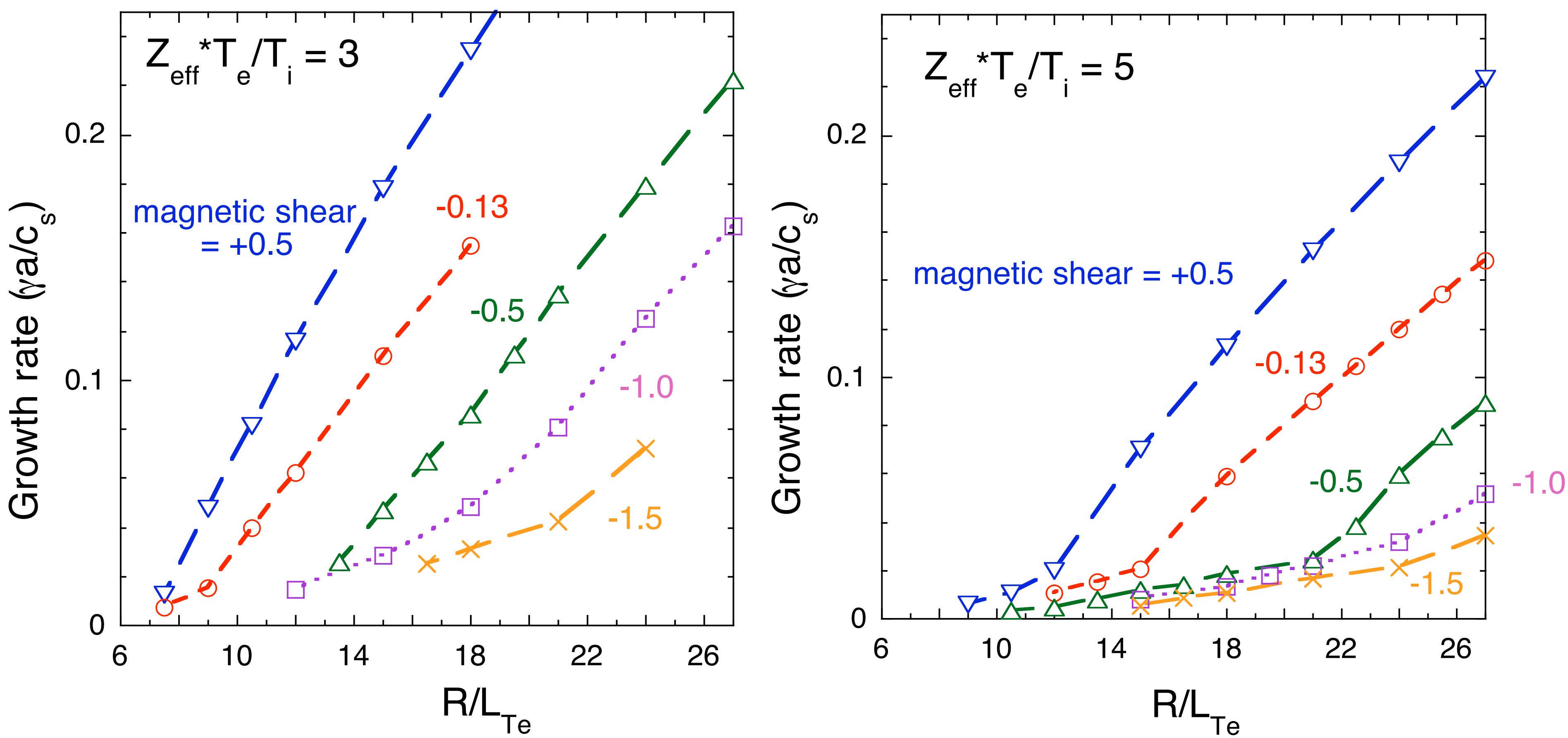


Previous Trends are Continued

Thresholds are increased as τ rises and for more negative s.

Need nonlinear simulations: streamers? Significant transport?

without streamers, high-k activity does not imply transport.



Nonlinear background: streamers needed

Radial streamers are required for significant heat transport

Dorland, et al., Phys. Rev. Letters **85** (2000) 5579,

Jenko, et al., Phys. Rev. Letters **89** (2002) 225001.

s-α geometry, $Z_{eff}{*}T_e/T_i = \tau$=1, R/L_{Te}=7, mostly 0 < s < 1

Streamers occur only for magnetic shears > +0.5

A few simulations with negative magnetic shears; no *survey*.

Strong negative magnetic shear, s=-1, leads to weak transport.

Need to re-define where streamers exist, with realistic geometry, larger R/L_{Te} and τ, broader range of negative shears. Such a survey will be initiated soon.

Future work

Mass ratio convergence study at r/a=0.6 in NBI L-mode,
with lower ExB shearing rate and higher maximum $k_\theta \rho_s \sim 1$.

Map parametric dependences for different q, r/R, others?.

Look for experimental validation of stabilization by:
negative mag. shear, high T_e/T_i and Z_{eff}.
large body of candidate shots already identified by H. Yuh.

Nonlinear studies in selected plasmas with high-k data.
compare electron heat flux with experiment.
simulate what the high-k scattering diagnostic would see.