Gyrokinetic Calculations of NSTX and C-Mod H-mode Plasmas

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MOTIVATION: Investigate turbulent microinstabilities in NSTX and CMOD H-mode plasmas exhibiting unusual plasma transport

- Remarkably good ion confinement and resilient Te profiles on NSTX
- ITB formation on CMOD
- Identify underlying key plasma parameters for control of plasma performance

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NSTX: NBI in MHD Quiescent Discharge: $T_i > T_e$, Resilient Te Profiles

$I_p = 0.8$ MA

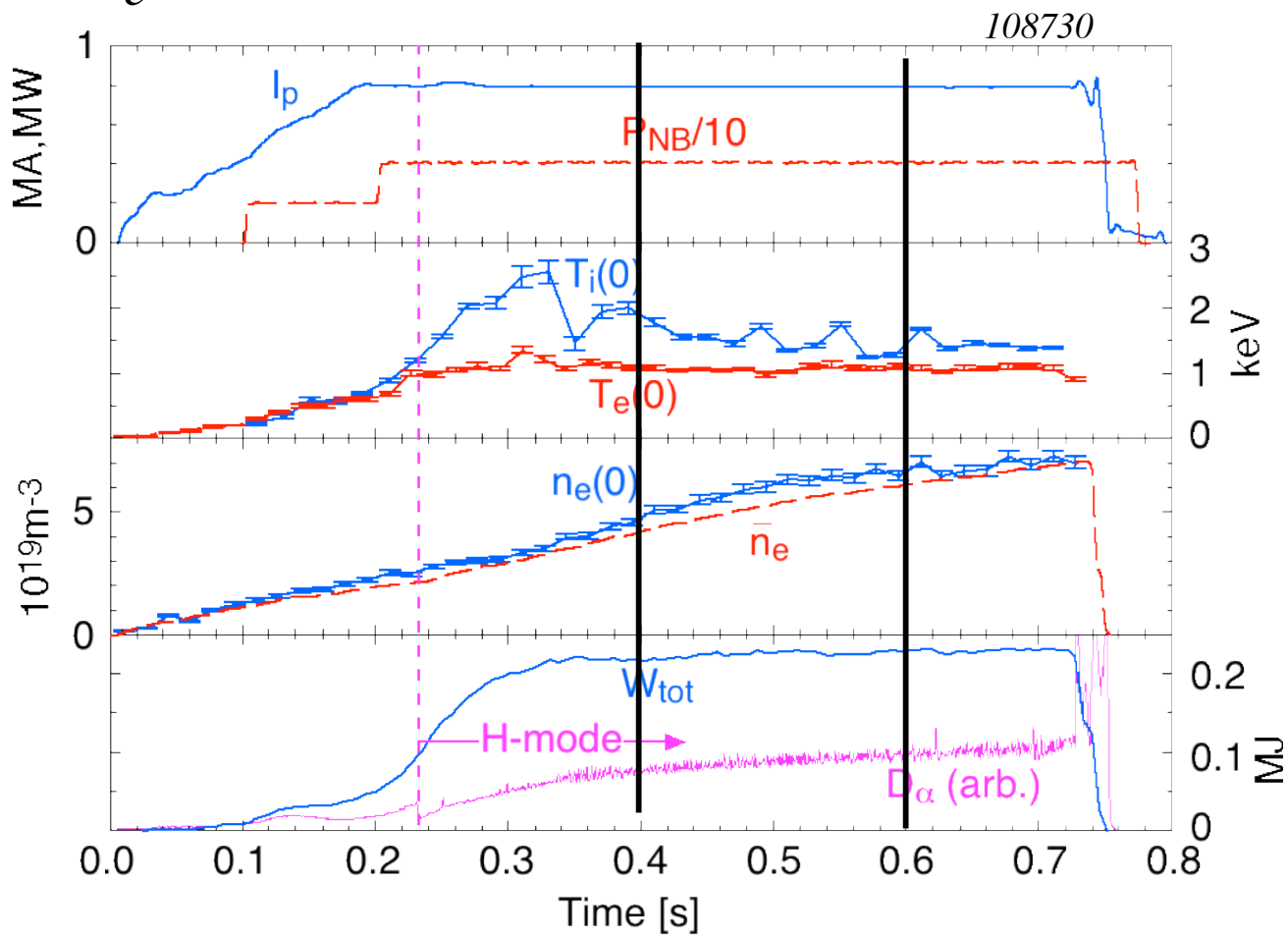
$B_T = 0.5$ T

$P_{NBI} = 4$ MW

$E_{NBI} = 90$ keV

$\beta_T = 16\%$

W = 0.23 MJ



LeBlanc-EPS-03

NSTX H-mode:
Electron Temperature Profile Resiliency

During H-mode

Te(r) remains resilient

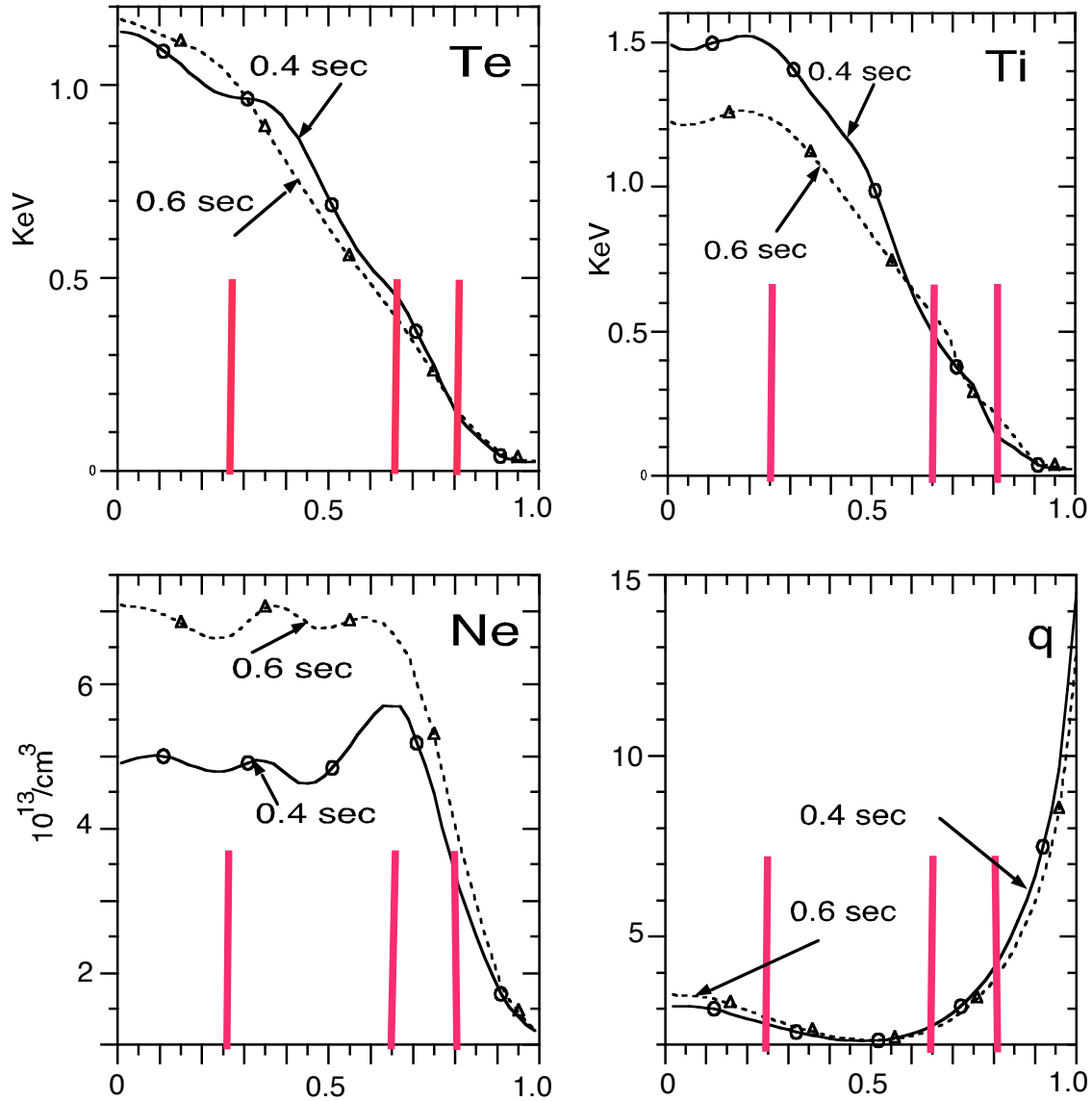
electron density increases

ion temperature decreases

What clamps
Electron temperature profile?

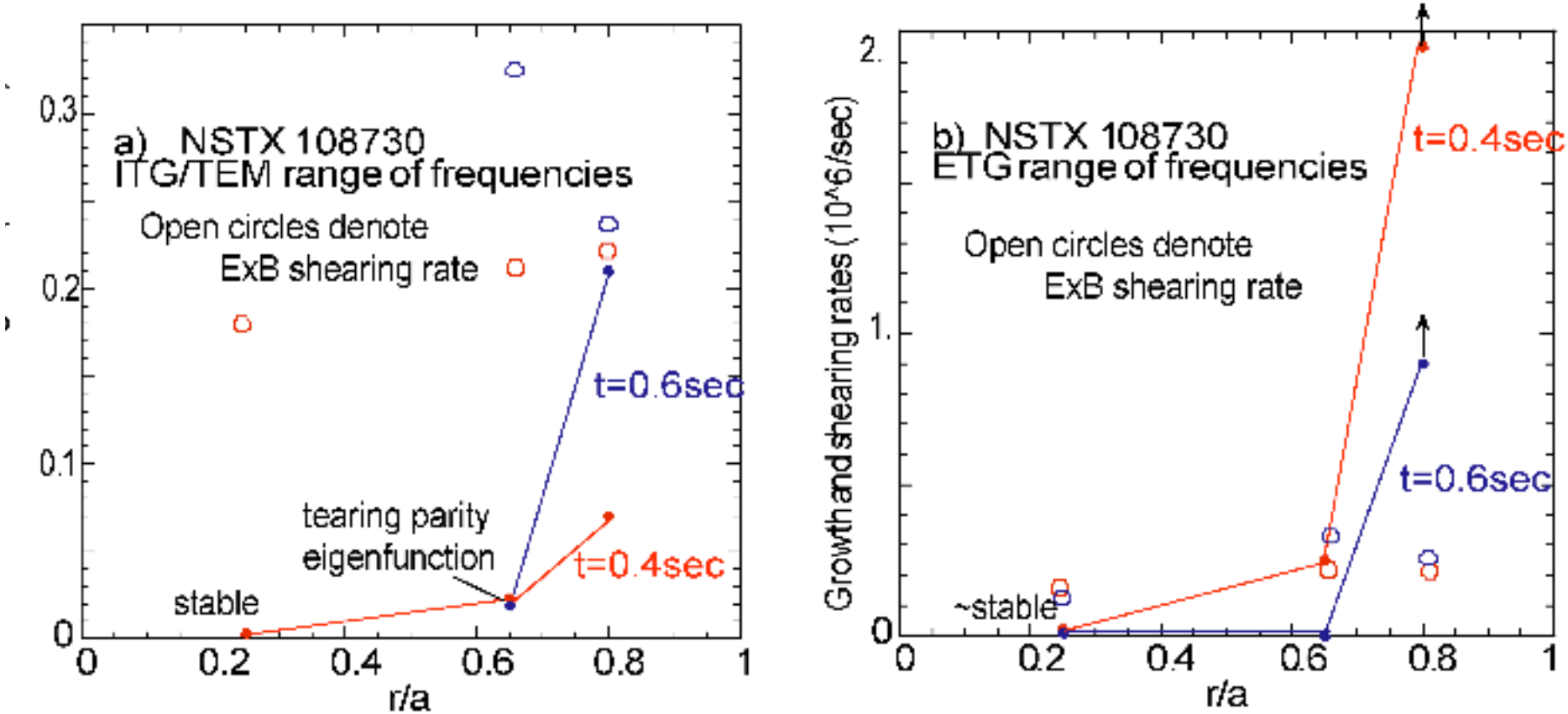
Examine microinstability
Growth rates at 3 zones

q profile: partial kinetic EFIT



NSTX: Examine ITG and ETG Microstability

Find: tearing parity eigenfunction, with broad wave vector spectrum $\gamma(k_\theta \rho_i)$
ITG instabilities, with symmetric eigenfunctions and parabolic $\gamma(k_\theta \rho_i)$



NSTX ITG Near Marginal Stability at 0.8r/a

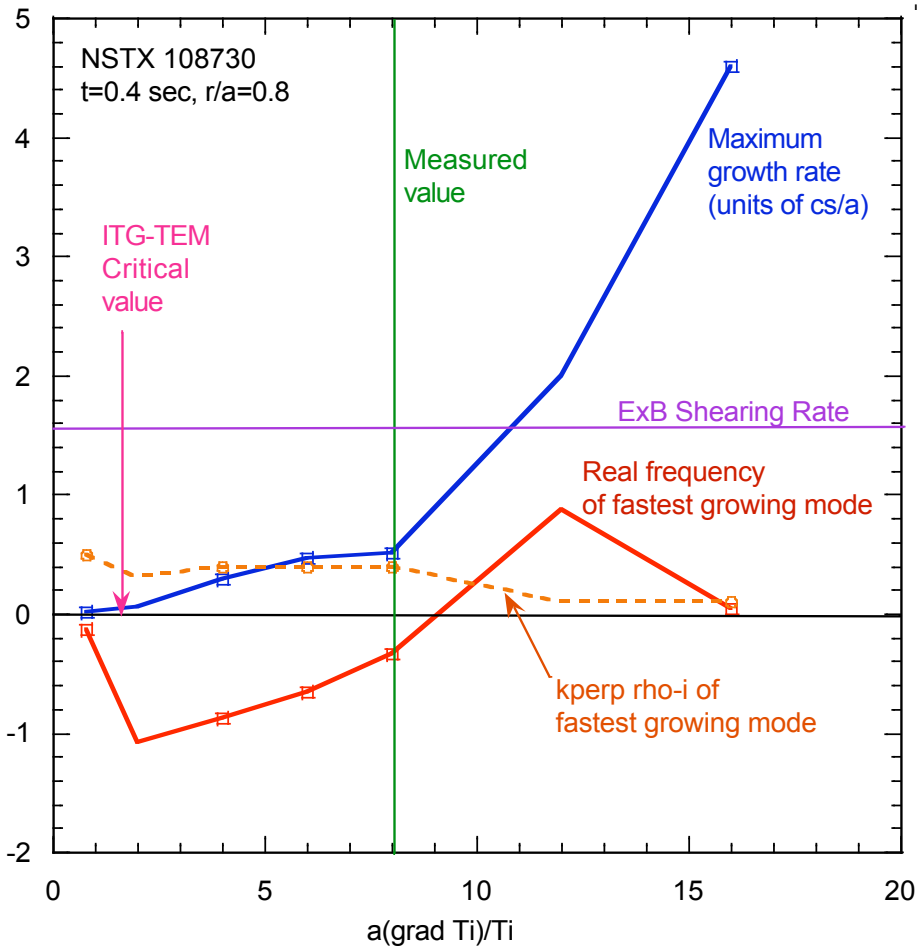
With 25% error bars on shearing rate, ITG possibly stable with

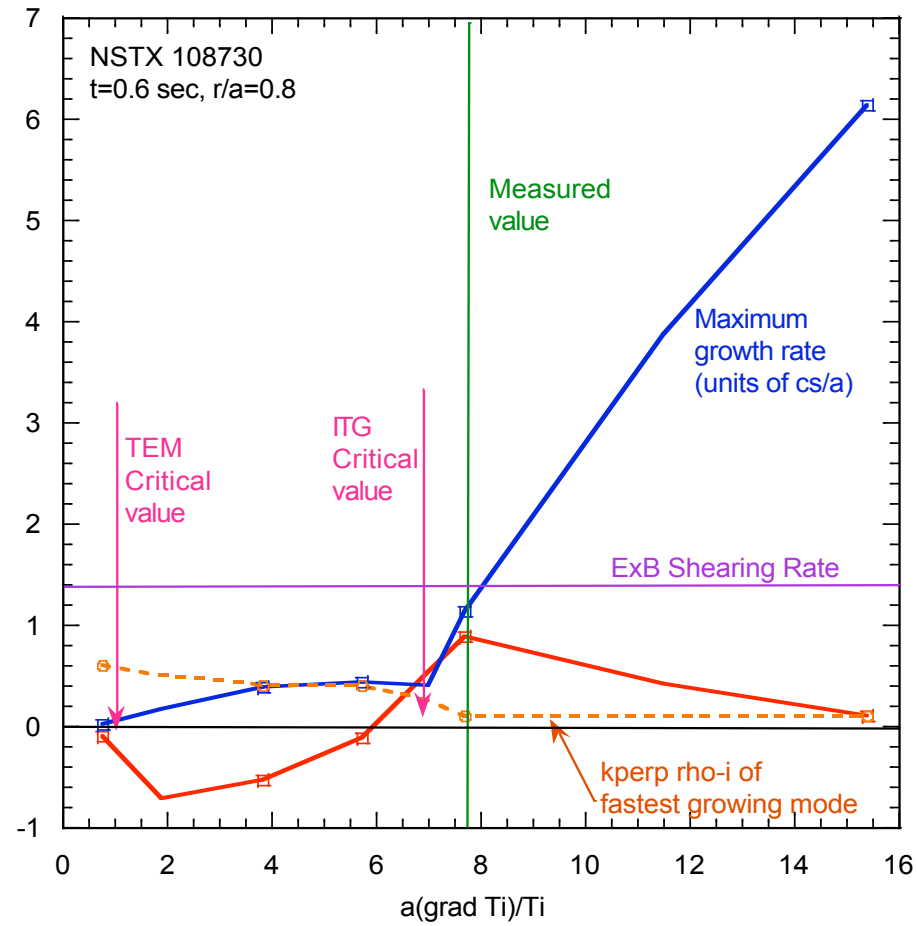
$2\gamma_{TG} > \gamma_{ExB}$ criterion

What should be the criterion for ITG stability?

Dimits (PoP 2001) requires $4\gamma_{TG} > \gamma_{ExB}$

Nonlinear Calculations including ExB shear would resolve this



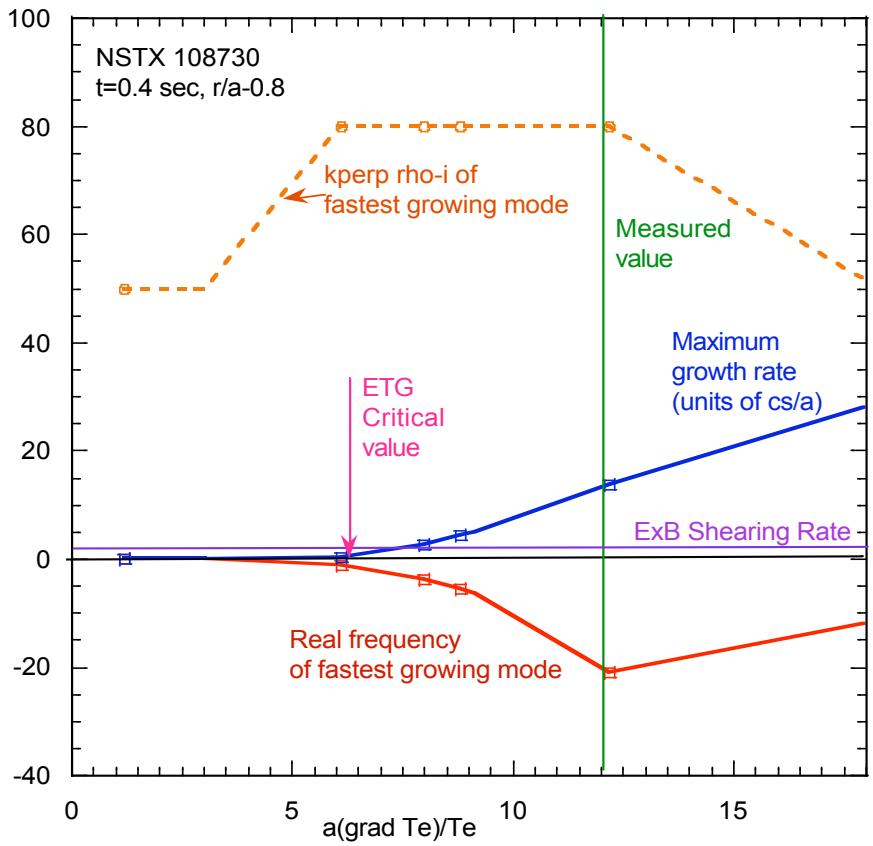


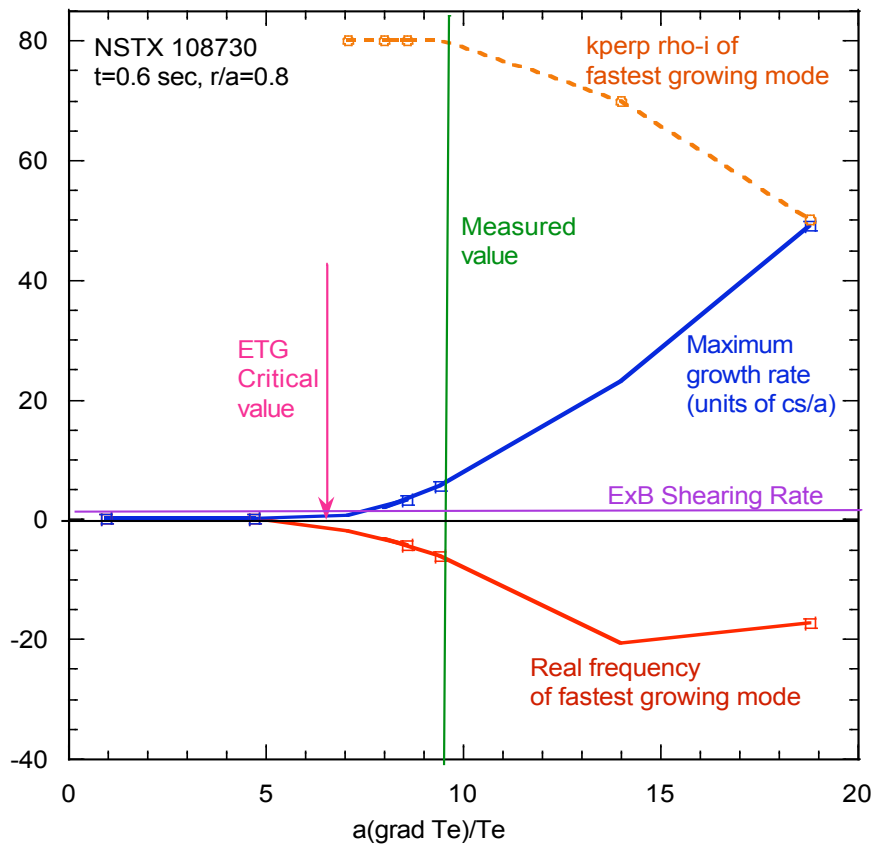
NSTX: ETG Instrinsically above Marginal Stability

At plasma Edge: $\gamma_{ExB} < 2\gamma^{TG}$

Fastest Growing ETG Drift Mode Wavelengths
and Growth Rates Decrease as $a(\nabla T_e)/T_e$ is Reduced

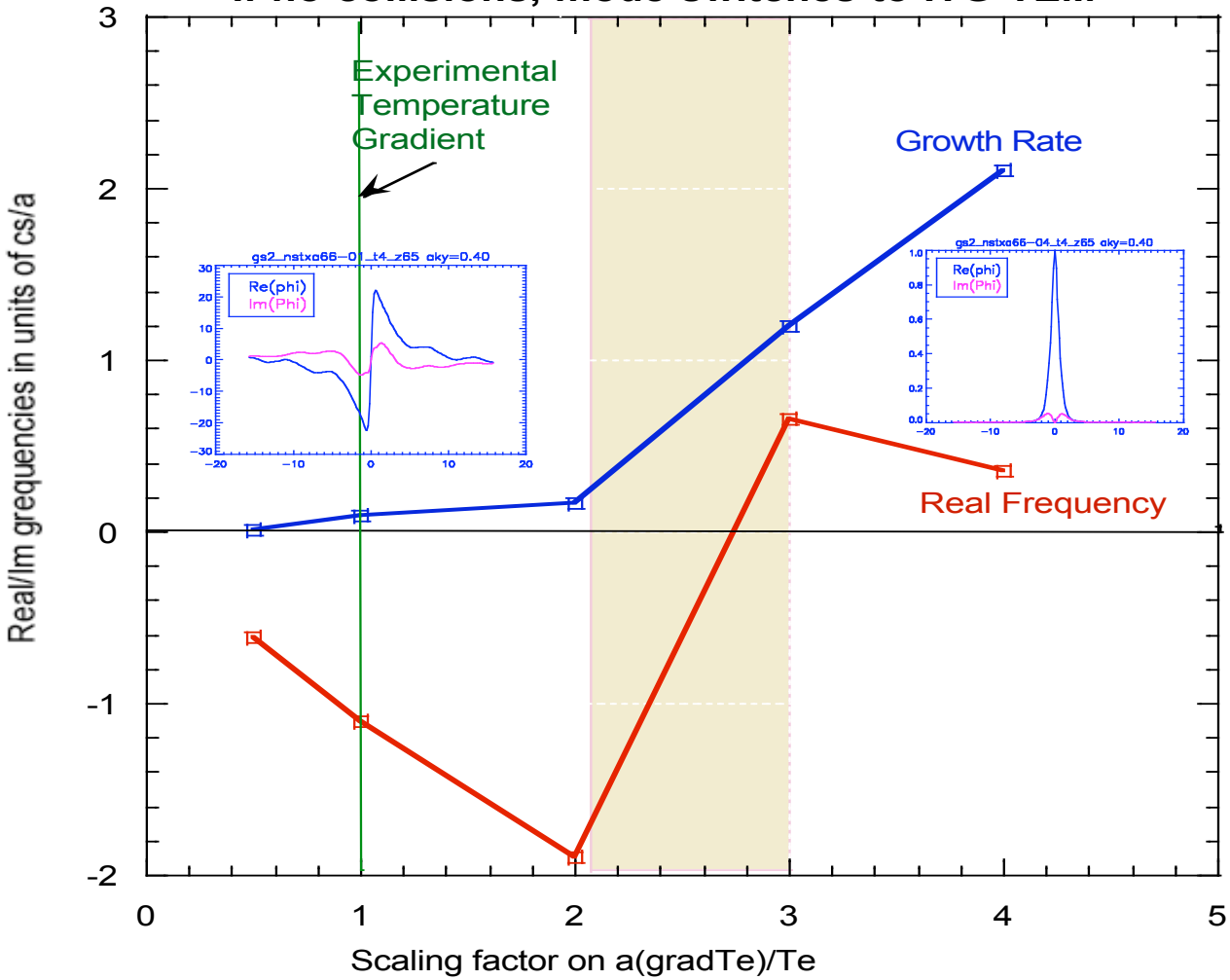
Higher Critical Gradient for ETG than TEM, Similar to ITG





What is the Instability at 0.65r/a on NSTX? What Effect Does It Have on Transport?

Character of Most Unstable Mode Changes to ITG-TEM
Appears to be microtearing mode, driven by a(gradeTe)/Te
if all other gradients =0, mode ~ unchanged.
If no collisions, mode switches to ITG-TEM



Summary: NSTX H-mode Gyrokinetic Results

If 2-3γ_{lin} < γ_{ExB} stabilizes ITG, ITG may be stable everywhere.

γ_{ExB} suppression of ETG and microtearing modes not yet known

NSTX electron losses and resilient Te profiles as yet unexplained

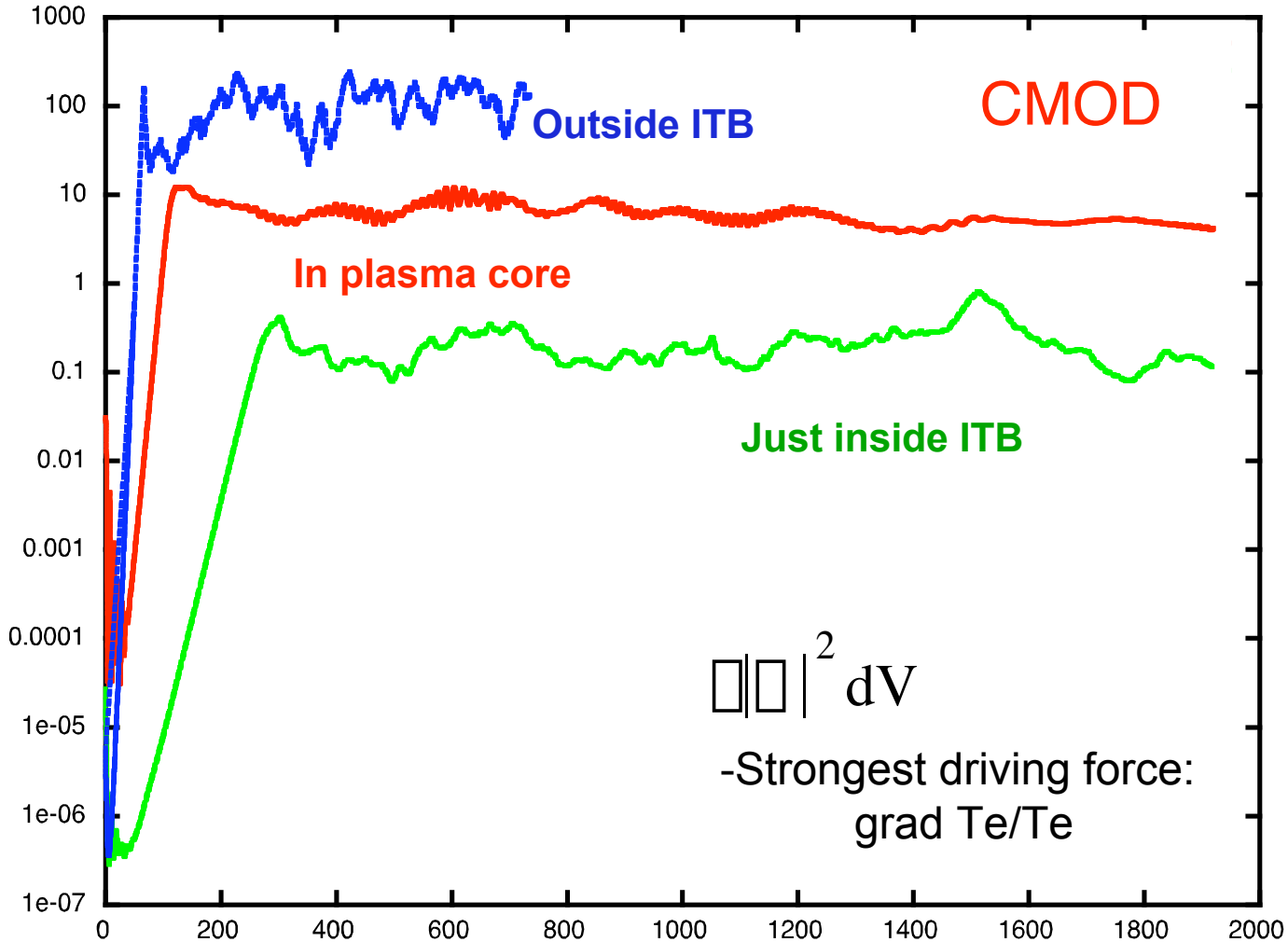
NOTE: γtearing, ETG core driving forces (a∇Ne/Ne, ∇Te/Te) unchanged during plasma evolution.

r/a		χ_i	χ_e	ITG	ETG
0.25	t=0.4s	< χ_{neo}	>> χ_i	stable	stable
	t=0.6s			stable	stable
0.65	t=0.4s	< χ_{neo}	>> χ_i	Probably stable ExB effect unknown on microtearing	unstable
	t=0.6s			Likely stable ExB effect unknown on microtearing	stable
0.80	t=0.4s	< χ_{neo}	>> χ_i	Probably stable	unstable
	t=0.6s			Possibly stable	unstable

NONLINEAR GS2 Simulations reproduce linear result

ITB TRIGGER: Before n_e peaks, region of reduced transport and stable ITG microturbulence is established without ExB shear

Quiescent, microturbulence in ITB region
Moderate microturbulence in plasma core
High microturbulence level outside half-radius



SUMMARY

Linear flux-tube calculations of ITG/TEM, Microtearing and ETG microstability:

ST predictions not as clearly connected to observed transport as for tokamak

NSTX

Low χ_i as inferred by TRANSP

- consistent with GS2 result that ITG stable in core and is possibly stabilized by γ_{ExB} near edge
- Impurities, finite ρ^* effects may fully stabilize ITG at edge

High χ_e inferred by TRANSP

- may be consistent with GS2 result that ETG unstable in edge and microtearing modes are intrinsically unstable outside core
- Not consistent with GS2 result of ETG stability in core Reversed shear inferred by EFIT may be incorrect (need MSE)

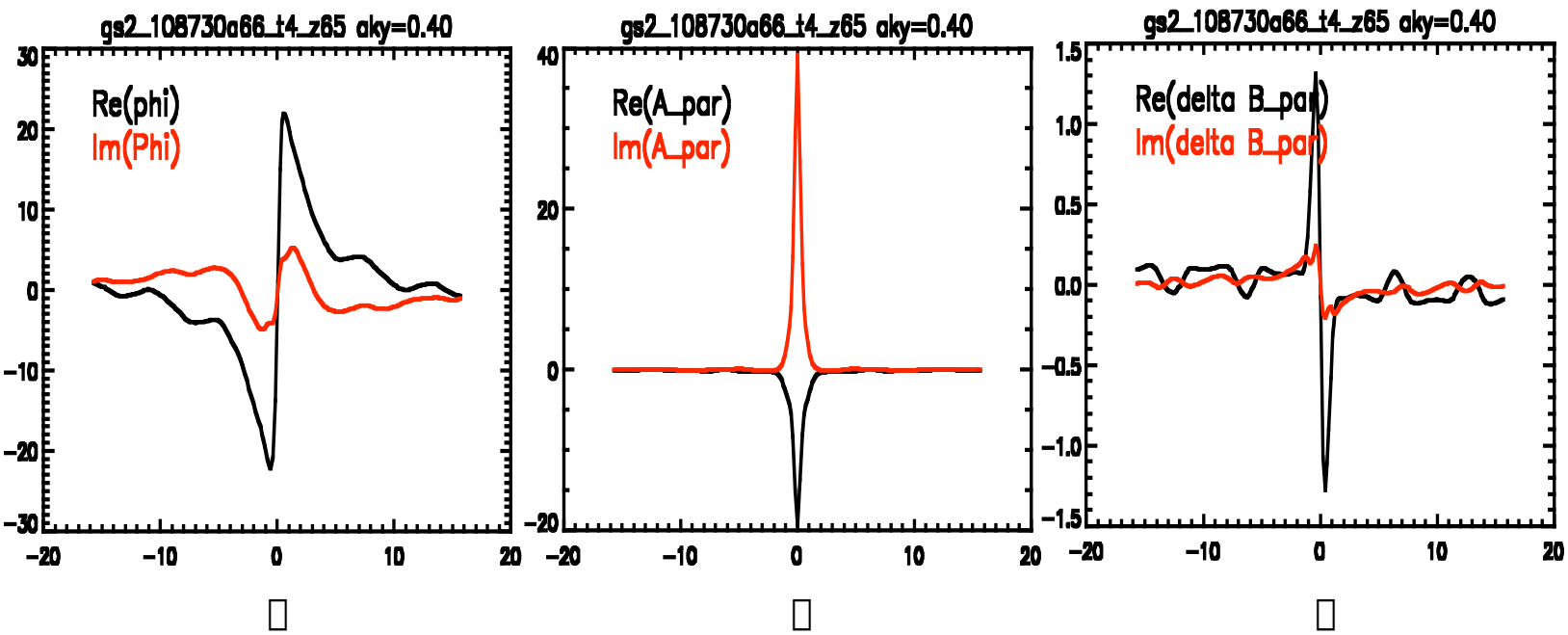
Nonlinear calculations underway to determine level of transport

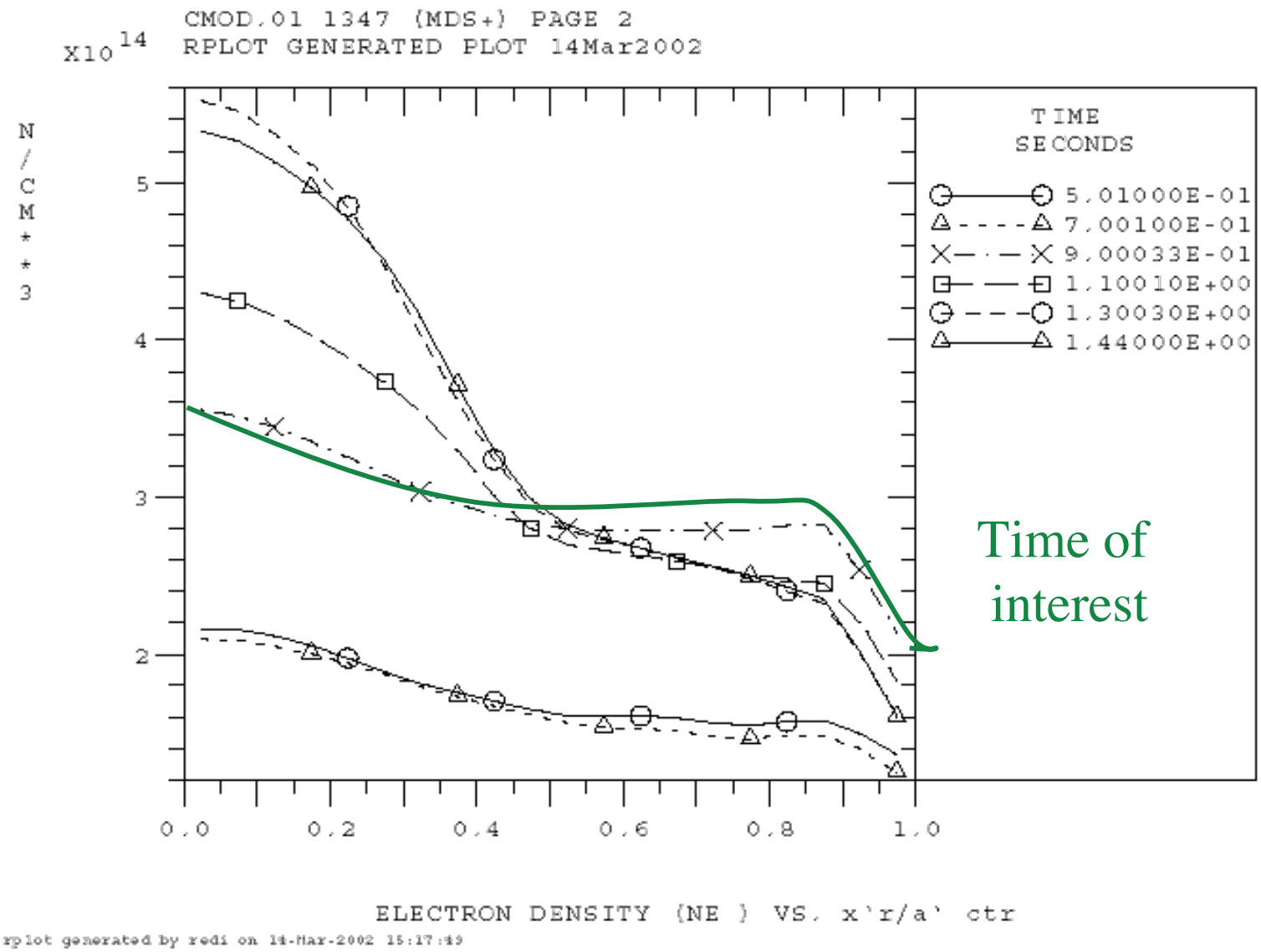
CMOD

Low χ_i, χ_e within the ITB and high χ_i, χ_e outside the ITB as inferred by TRANSP

- consistent with GS2 stability analysis of ITG, TEM, ETG
- Nonlinear and linear GS2 in qualitative agreement
- Sawtooth propagation measurements confirm low transport in ITB region at the trigger time (Wukitch, PoP, 2002).

Microtearing Mode Exhibits Symmetric A_par



= Poloidal angle along field line in radians

Internal Transport Barrier in Density Profile