Microstability analysis of NSTX plasmas

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Outline

- Generalities
- Stability analysis of NBI and RF plasmas
  - Effect of geometry and β
  - Effect of collisions
  - Effect of T_i/T_e
- Non-linear simulation
- Conclusions and perspectives

Generalities

- Tool: linear local gyrokinetic electromagnetic code

  solve Vlasov+Maxwell eq. : initial value code GS2
- Purpose:
  - identify unstable modes
  - isolate key parameters for stabilization
- Unique features of Spherical Tokamak:
  - different curvature/∇B drifts: more trapped particles, passing particles more on good curvature side
  - β higher $\longrightarrow$ $\delta B \nearrow$ + stronger Shafranov shift

The 2 plasmas analyzed

NBI: #104001, 0.28 s

1.5 MW, $\beta_T \sim 9$ %

$B_{T0} = 0.4$ T

$n_{e0} = 4.2\ 10^{19}$ m^{-3}

$V_\varphi^{max} = 200$ km/s

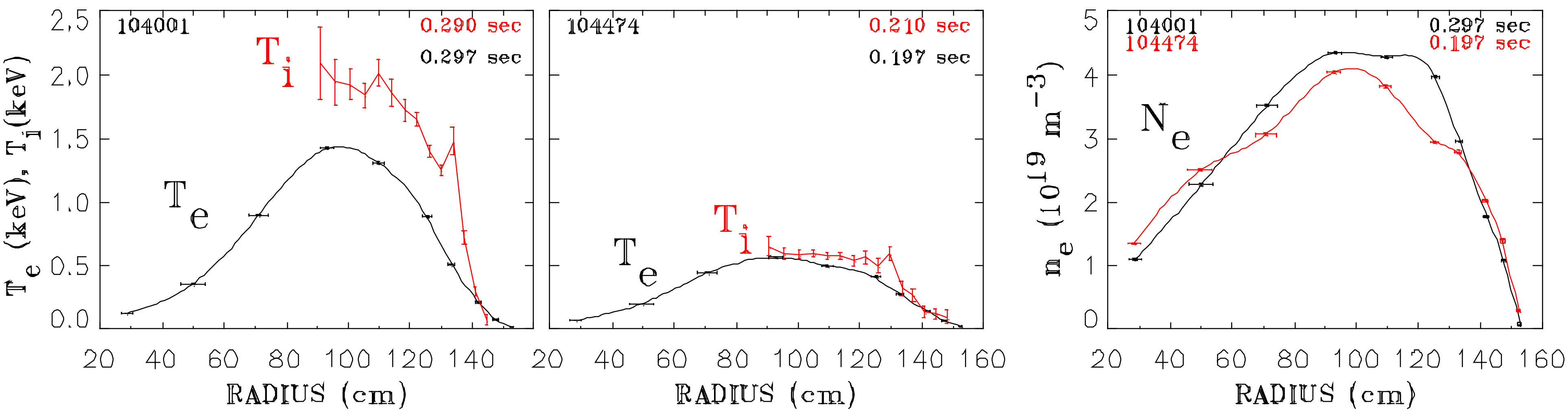
RF: #104474, 0.21 s

2 MW, $\beta_T \sim 8$ %

$B_{T0} = 0.3$ T

$n_{e0} = 4.2\ 10^{19}$ m^{-3}

$V_\varphi^{max} = 22$ km/s



Microstability analysis using GS2, NBI heated plasma, $\beta_T \sim 9$ %

- $k_\theta \rho_i < 1$: stable for r/a < 0.6

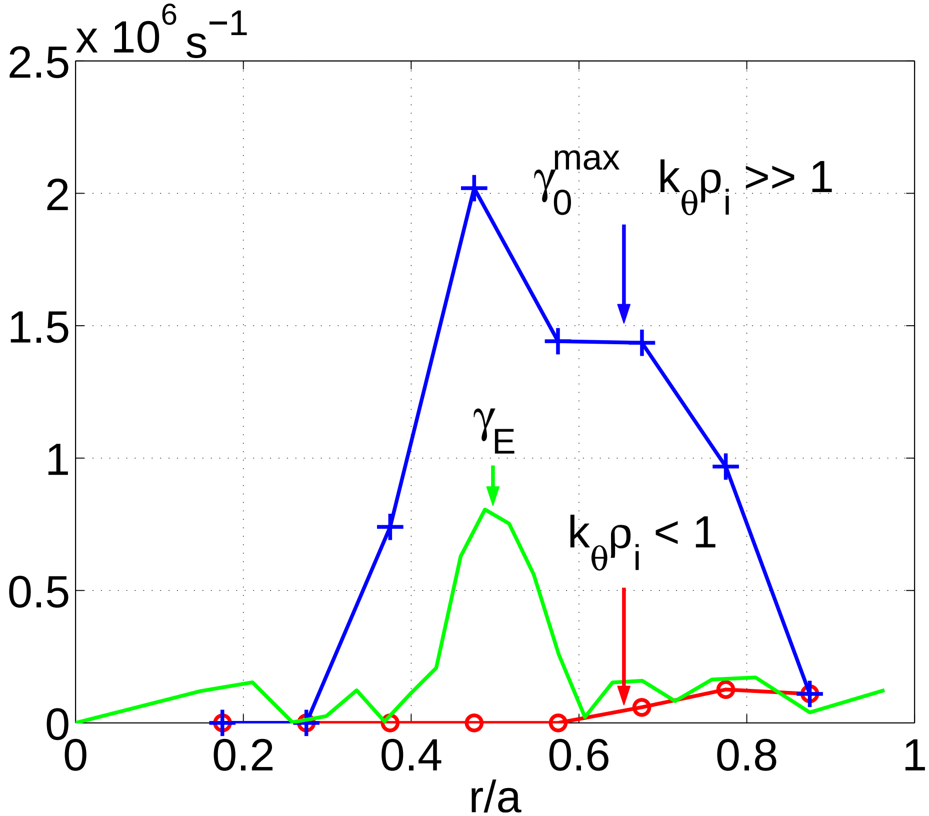
near edge $R\nabla T_i/T_i$ up to 20

$\gamma_0^{max} \sim < \gamma_E$

- $k_\theta \rho_i >> 1$ ETG modes unstable across most of r/a

- **E**x**B** shearing rate, γ_E, dominated by $\nabla_r V_\varphi$

NCLASS, W. Houlberg



#104001 at 0.28 s

RF heated plasma, $\beta_T \sim 8$ %

- $k_\theta \rho_i < 1$: stable for r/a < 0.5

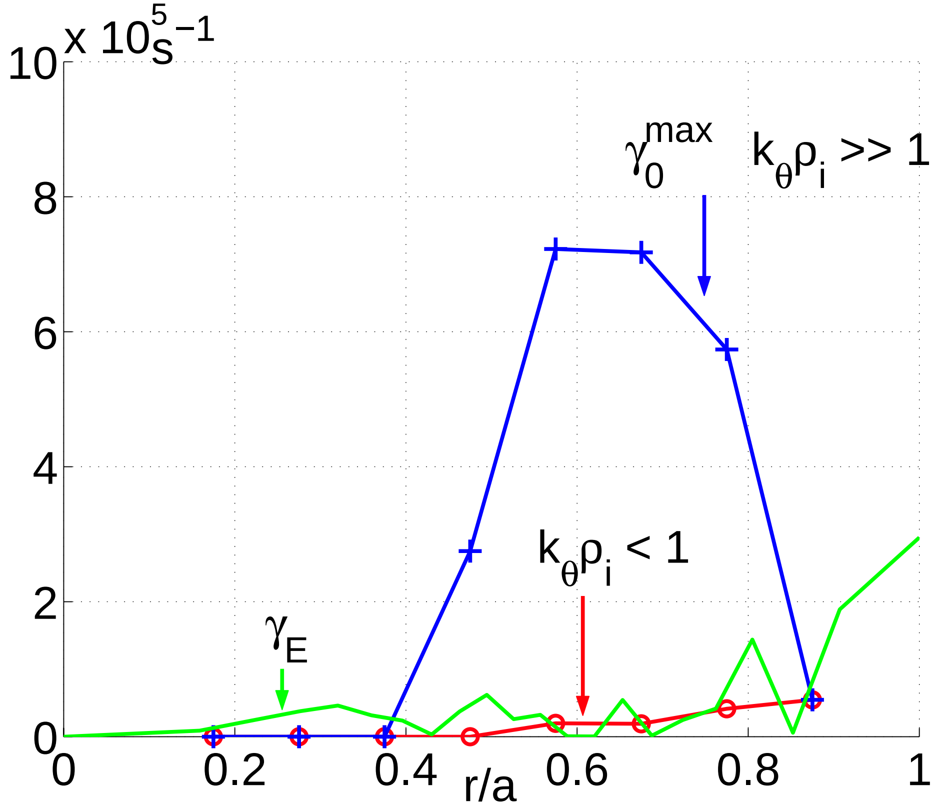
near edge large $R\nabla T_i/T_i$

$\gamma_0^{max} \sim \gamma_E$

- $k_\theta \rho_i >> 1$ ETG modes

unstable across most of r/a

- γ_E sensitive to $\nabla_r P$, V_θ

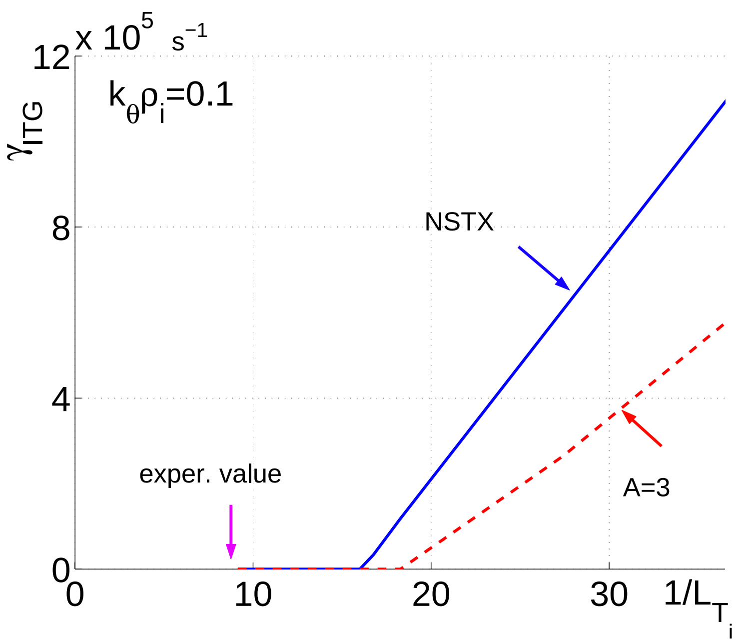


#104474 at 0.21 s

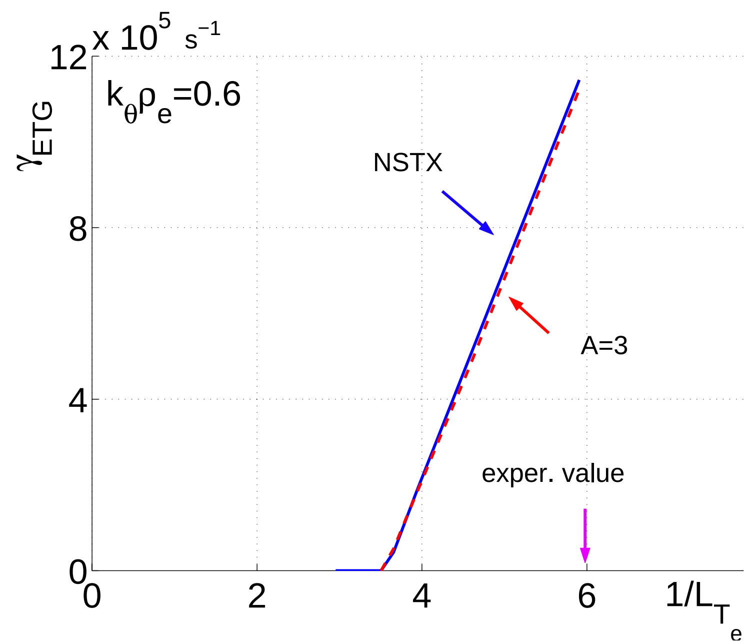
Understanding dependence on aspect ratio not straightforward

- Lower A found stabilizing Rewoldt et al q_{95} and β id. I_p and $B_T \neq$
- No effect of A Kotschenreuther et al $\beta \neq$ kept near β_c
- Here, EFIT copying NSTX same B_{T0} and β with A = 3

  α ~ 0.7 vs 2, stabilizing, s/q = 1.7 vs 0.9, destabilizing



#104001
0.28s
r/a=0.575



Need extra step with lower β as in standard tokamak

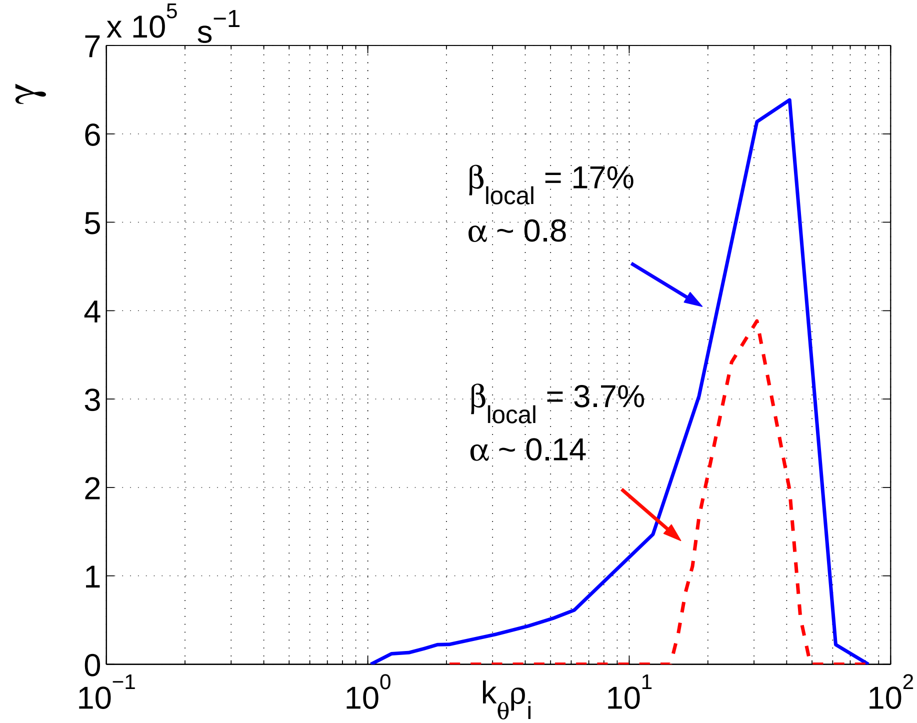
Comparison real NSTX β with a lower β

- β decreased in EFIT, consistently with lower α
- ∇T/T, ∇n/n identical, s and q similar (within 10%)

Here, higher β destabilize ETG

not systematic

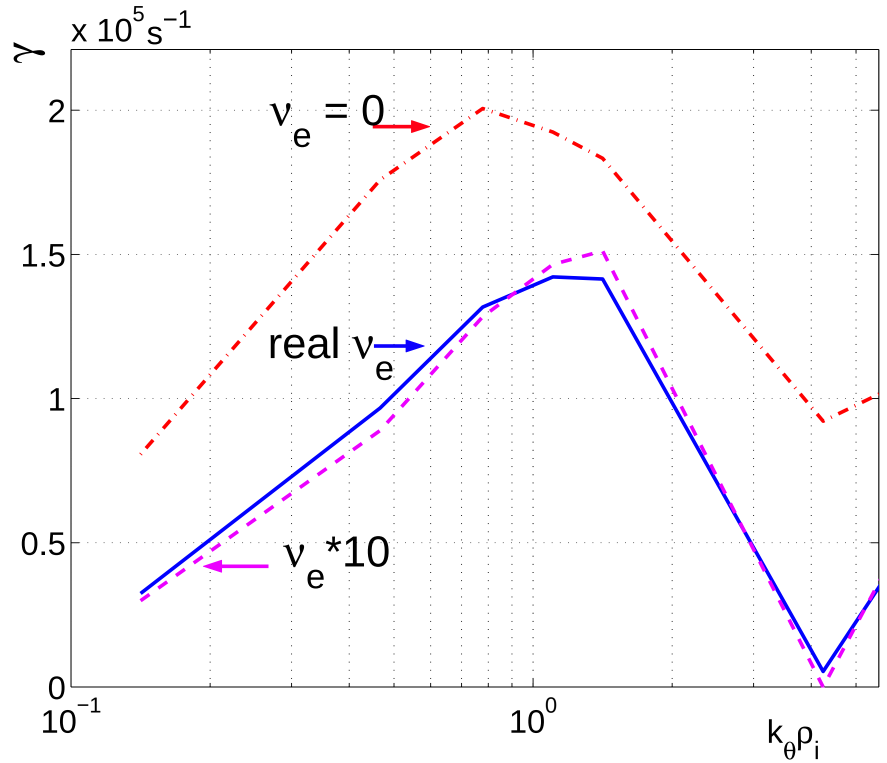
β↗: α↗ and δB↗



104001 at 0.28s, r/a=0.375

Effect of collisions on TEM

- TEM stabilized by collisions
- Actual ν_e high enough to stabilize TEM

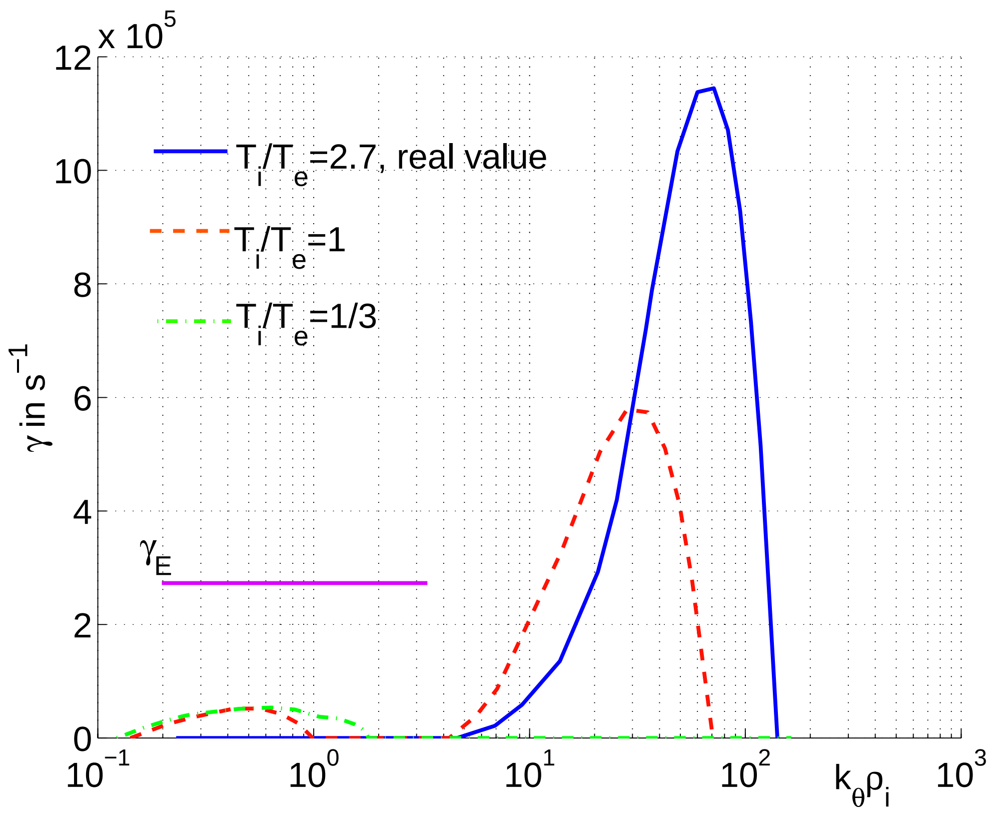


#104001 at 0.28 s, r/a=0.775

Effect of T_i/T_e on a spectrum

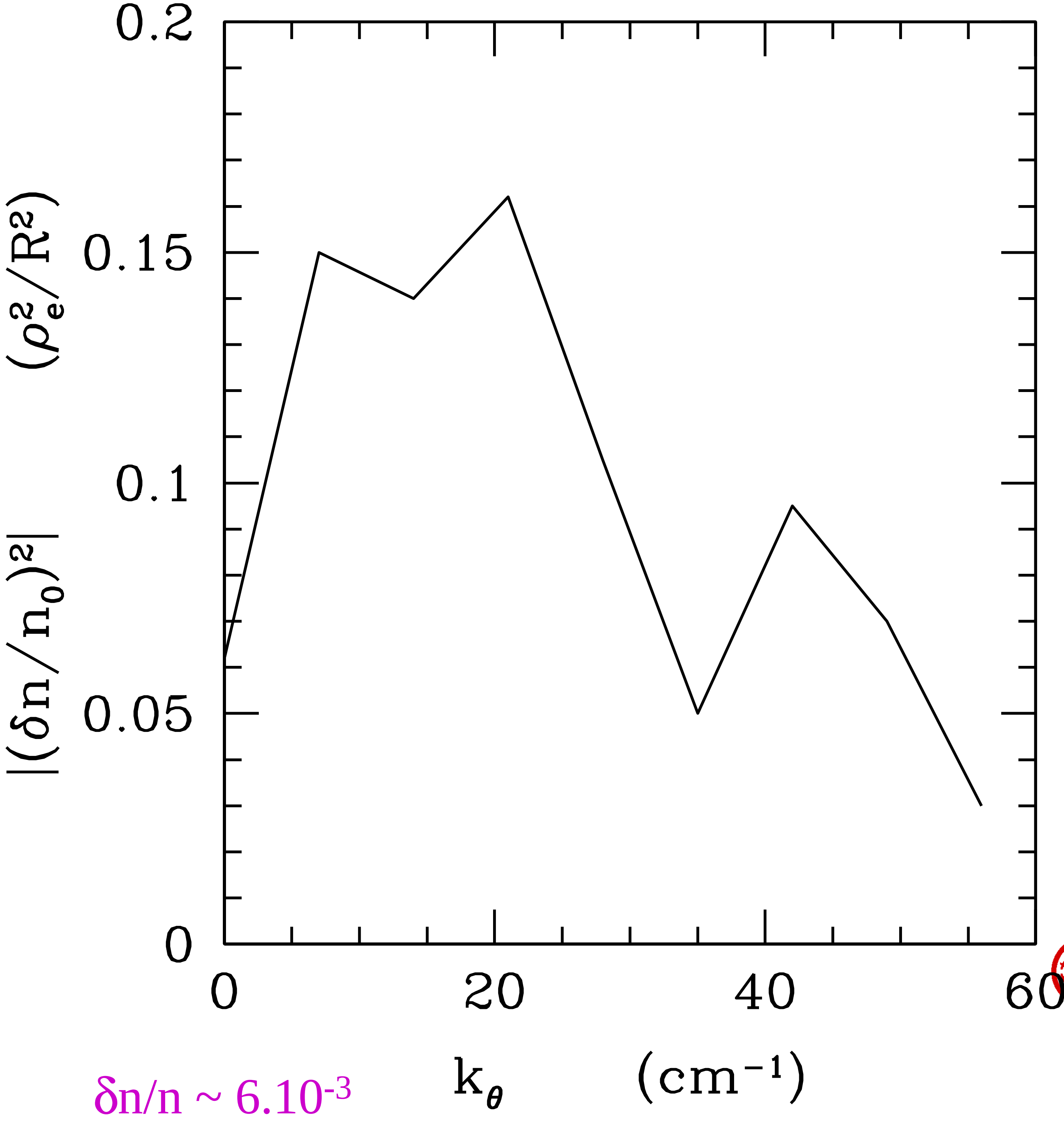
- High T_i/T_e: destabilizing for ETG, stabilizing for ITG

#104001 at
0.28 s and r/a=0.575



First non-linear results on ETG

#104001 at 0.28 s r/a=0.575



$\delta n/n \sim 6.10^{-3}$

$\chi_e \sim 0.5\ m^2/s$, similar to quasi-linear value

Provided by Bill Dorland, GS2

Conclusions

- ETG:
  - High β destabilize
  - High T_i/T_e strongly destabilize
- ITG
  - High T_i/T_e stabilize
- TEM
  - Collisions stabilize

Unstable ETG consistent with NSTX evidence that heat electron transport dominates

Perspectives

- T_i/T_e variation tested experimentally in plasmas with HHFW where $T_i/T_e \sim 1/3$, check consistency with χ_e given by TRANSP analysis (need solve power balance issues)

- Non-linear simulations: if elongated radial structures called streamers then higher electron transport expected from ETG

- Microwave scattering could establish ETG existence in ST