Reduced model prediction of electron temperature profiles in microtearing-dominated NSTX plasmas

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NSTX-U

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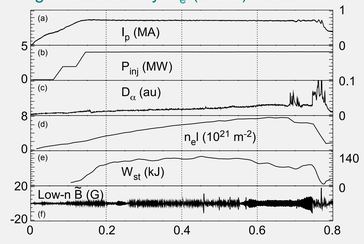
Objective: Examine predictive capability of reduced microtearing-induced electron transport model for NSTX H-mode plasmas

Methodology:
- Examine specific discharge
- Study profile variations
- Determine microinstability characteristics
  - Parameter variations
  - Linear stability calculations (GYRO)
- Select and apply reduced transport model for χ_e

The discharge used for this study comes from series of discharges scanning I_p and B_T in discharges that used helium glow discharge cleaning+boronization for wall conditioning.

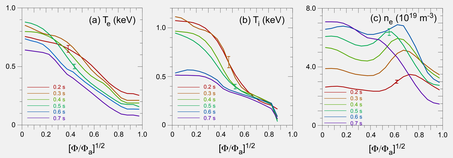
The discharge had I_p=0.7 MA, B_T=0.35 T, P_{NBI+OH}~ 4 MW, κ~2.1

- "High" collisionality: $\nu_e^*(x=0.5) = 0.2$



- L-H transition at 0.14s, H-L back-transition at 0.68 s
- Type V ELMs during H-phase
- Increase of low-n MHD activity after 0.58 s
- For this study, data/results will be shown for 0.2, 0.3, 0.4, 0.5, 0.6, 0.7 s

Profile evolution during discharge (using spline fits to the data)

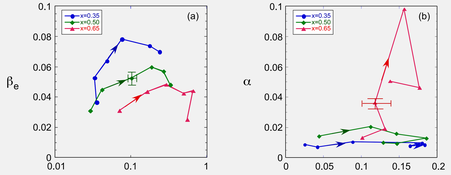


- T_e profiles reasonably self-similar
- T_i profiles self-similar up to 0.5 s (large decrease in core)
- n_e profiles show carbon-fueled electron density "ear" in outer region; ear disappears after H-L back-transition
- Uncertainties reflect measurement + spline-fitting uncertainties

Examine parameter variations that reflect various microinstabilities (advancing time from 0.2 s ⟶)

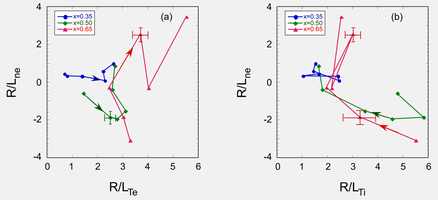
(a) β_e vs ν_e^*:
- both low at early times➔electrostatic modes important (ITG/TEM/ETG)
- Both increase with time into regions where KBM and microtearing may be important

(b) $\alpha = (q^2R_0/B)dp/dr$ vs $\beta_e R/L_{Te}$
- Large α indicates KBM, large $\beta_e R/L_{Te}$ indicates microtearing at x=0.65
- Parameter variations suggest KBM+microtearing at later times (some mixed modes)



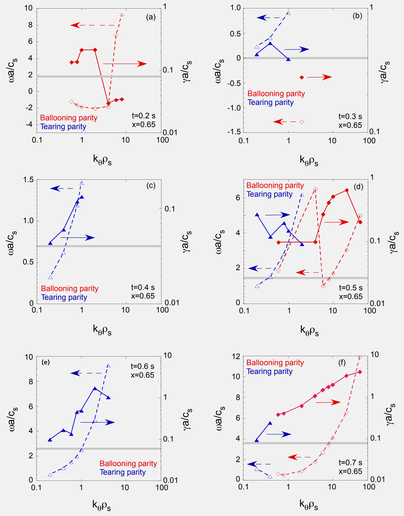
(a) R/L_{ne} vs R/L_{Te}:
- Low values of drive terms at early times for x=0.35, 0.5
- R/L_{Te} larger at x=0.65 suggesting grad T_e drive
- R/L_{ne} also large later at x=0.65 – these have large α (KBM+microtearing may co-exist)

(b) R/L_{ne} vs R/L_{Ti}
- Large R/L_{Ti} early for x=0.5, 0.65, suggesting grad T_i-driven electrostatic (low β) modes (ITG)
- grad-T_i drive decreases later on



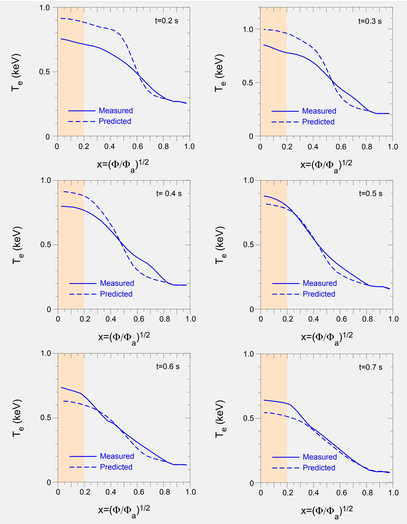
Emerging trends:
- Low-β e-s modes driven by grad T_e, grad T_i expected early
- Microtearing and KBM expected at later times (co-existing?)
- grad T_e-driven modes expected late at x=0.65

Trends confirmed by linear microinstability properties using GYRO
- Profiles and equilibria from TRANSP
- Miller equilibrium used in GYRO
- Evaluate from $k_\theta\rho_s$ = 0.2 to 40
- Show results for x=0.65 (similar results for x=0.5)

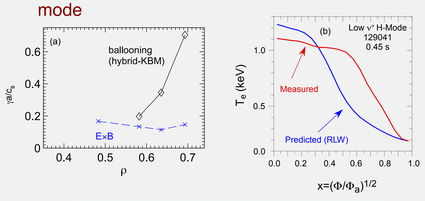


Assess role of microtearing for electron transport using reduced model
- Rebut-Lallia-Watkins (1985): microtearing-based
- Use TRANSP to predict T_e using RLW from x=0.2-0.8
- Use measured T_i, n_e, n_{imp}, etc
- Ad-hoc χ_e for x<0.2 to take into account CAE-induced e$^-$ transport

$$\chi_{e,RLW} \sim \left[\left(\frac{\nabla T_e}{T_e}\right) + 2\left(\frac{\nabla n_e}{n_e}\right)\right]\left(\frac{T_i}{T_e}\right)^{1/2}\left(\frac{R}{r}\right)\left(\frac{q^2}{\nabla qBR^{1/2}}\right)$$



RLW does poor job in predicting T_e in "low" collisionality discharge
- $\nu_e^*(x=0.5) = 0.05$
- Hybrid TEM/KBM calculated to be most unstable mode



Summary and Conclusions
- Microtearing can control electron transport in outer regions (x>0.5) in NSTX H-mode discharges
  - High collisionality
  - RLW reduced transport model does good job when/where microtearing expected to be dominant unstable mode, poor job when/where it is not
  - Dangerous to extrapolate to future STs (NSTX-U, FNSF)
    - Important to first establish where microtearing is unstable
    - Simple extrapolations do not give answer
    - Need first principles calculations