U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

NSTX-U Milestone R(18-3) Q1 report

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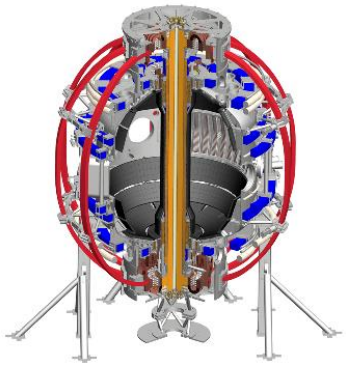
PPPL



R18-3: "Validate and further develop reduced transport models for electron thermal transport in ST plasmas"

- **Focus of the milestone is on core electron thermal transport (ρ~0.4-0.9)**
  - **Main goal is to predict Te profiles from pedestal top inwards**
  - Not modeling the H-mode pedestal
  - Not modeling GAE/CAE-KAW mechanisms near-axis
  - Not focusing on turbulence measurement/validation

- **Three complementary parts of milestone activities**
  1. **Model validation (how well does model predict experimental Te)**
  2. **Model qualification (how well does model recover GK predictions)**
  3. **Analysis (Revisit profile fitting & mapping, EFIT reconstructions → Uncertainty Quantification)**

- **Considering multiple theoretical mechanisms in multiple regions of operating space**
  1. High-β, high-ν → MTM thought important
  2. High-β, low-ν → does NC + KBM set the limit on T_i & T_e?
  3. Low-β → expecting traditional electrostatic ITG/TEM at low aspect ratio
  4. When and where does ETG (electron-scale) fit in for all the above?

Outline of milestone tasks & estimated quarterly timeline (Q1-Q2, Q2-Q3, Q3-Q4)

- **Model validation (how well do profile predictions recover exp.)**

  [MV1] H-mode profile predictions using TGLF, Rafiq-MTM, RLW

  [MV2] L-mode profile predictions using TGLF, MMM

  [MV3] Identify cases where ETG provides non-negligible Q_e (L & H mode)

  [MV4] Develop and implement algorithm for locally constrained KBM profiles

- **Model qualification (how well do models recover linear & nonlinear GK)**

  [MQ1] MTM: Document TGLF & Rafiq-MTM linear & nonlinear with gyrokinetics

  [MQ2] ITG/TEM: Document linear stability, nonlinear saturation dependencies with aspect ratio

  [MQ3] ETG: Do TGLF and MMM recover GK NL ETG predictions?

  [MQ4] KBM: Document TGLF α_{crit} with linear GK

  [MQ5] ITG/TEM: Document non-local deviations from local GK, use to inform local models

  [MQ6] DTEM: Benchmark local GK codes with global GK for DTEM conditions

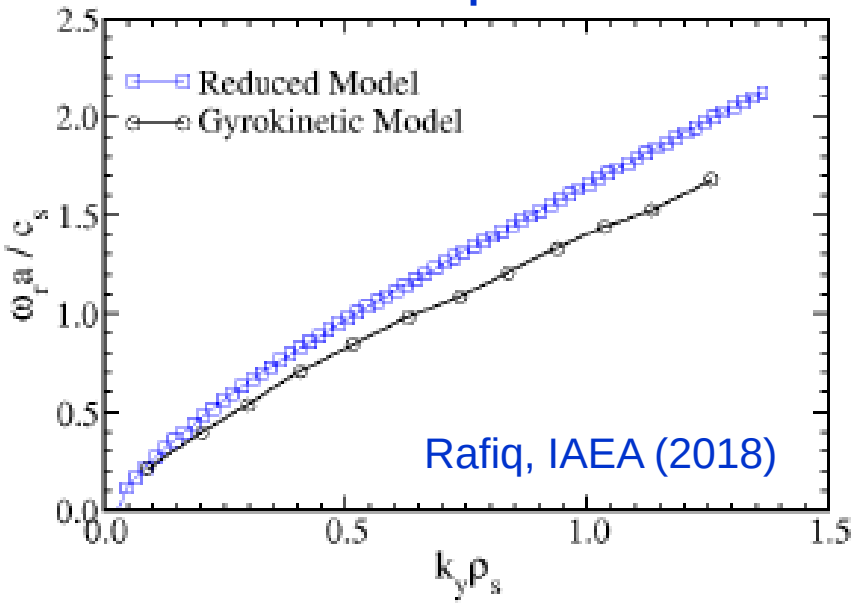
- **Analysis (profile fitting & mapping, EFIT reconstructions)**

  [A1] Revisit EFIT w/ Pfast, rotation… influence on GK stability, thresholds

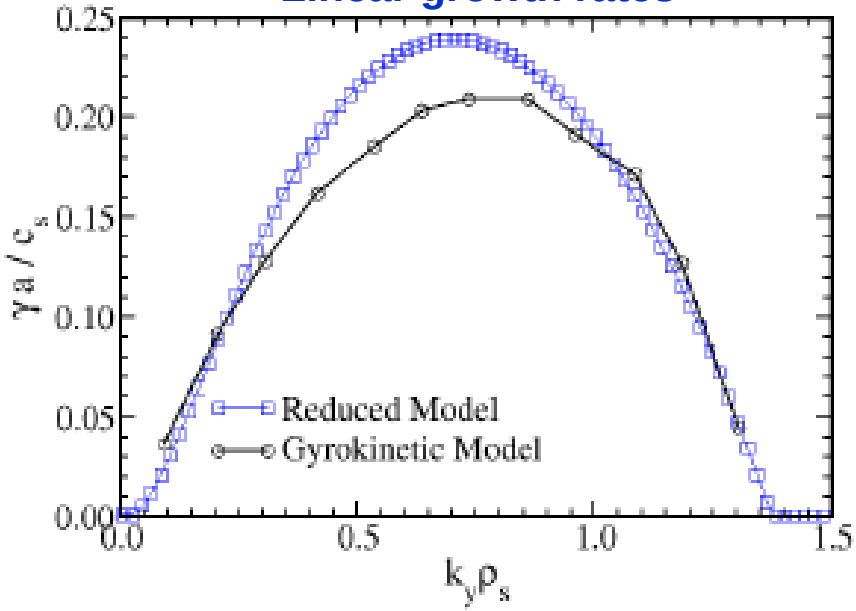
[MQ1] Qualifying new MTM model with gyrokinetics for high-β NSTX discharges

- Multi-Mode Model (MMM) (Rafiq, PoP 2014) has been updated to included new hybrid-kinetic/fluid microtearing mode (MTM) transport model (Rafiq, PoP 2016)
- Captures many trends predicted by linear gyrokinetics (GYRO) in high-β NSTX H-mode (Guttenfelder, PoP 2012)

Real frequencies



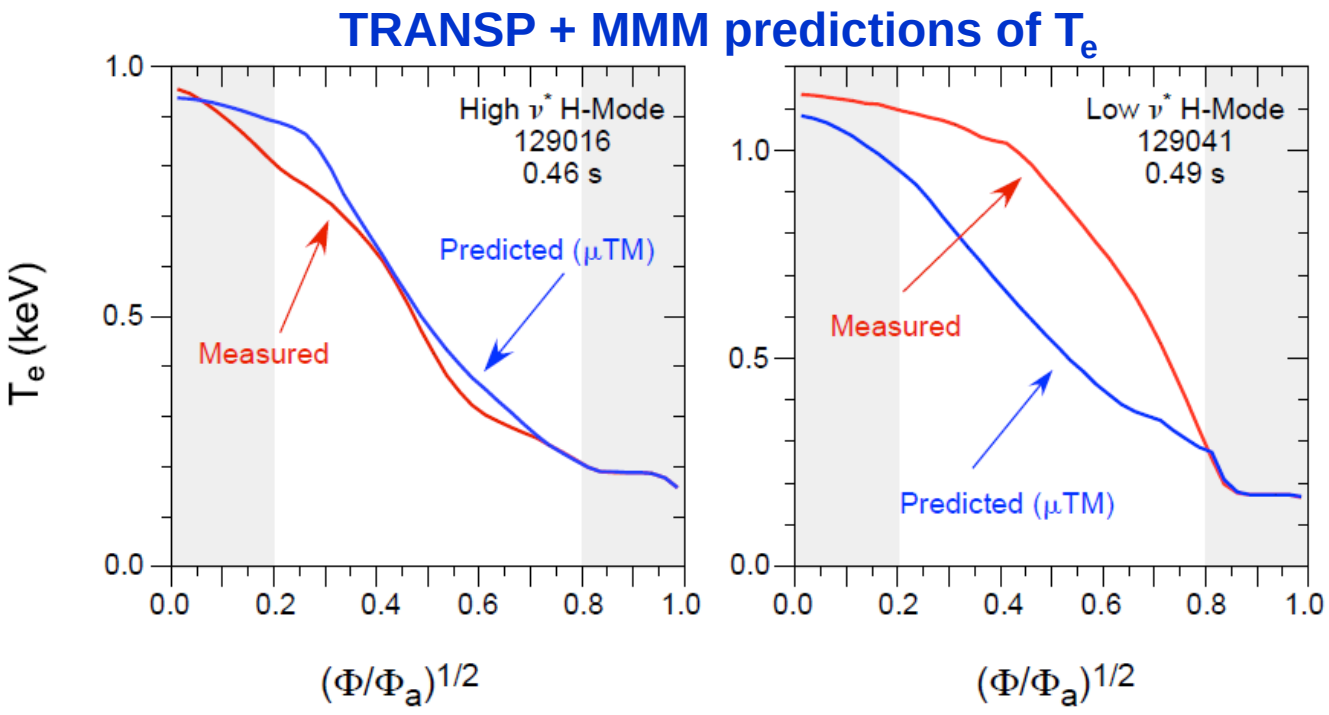
Linear growth rates



- Also reproduces scaling with ν_e, β_e, a/L_{Te}
- Does not capture complete scaling with magnetic shear

[MV1] MMM-MTM model can successfully predict T_e in high-β, high-ν_* NSTX H-mode discharges

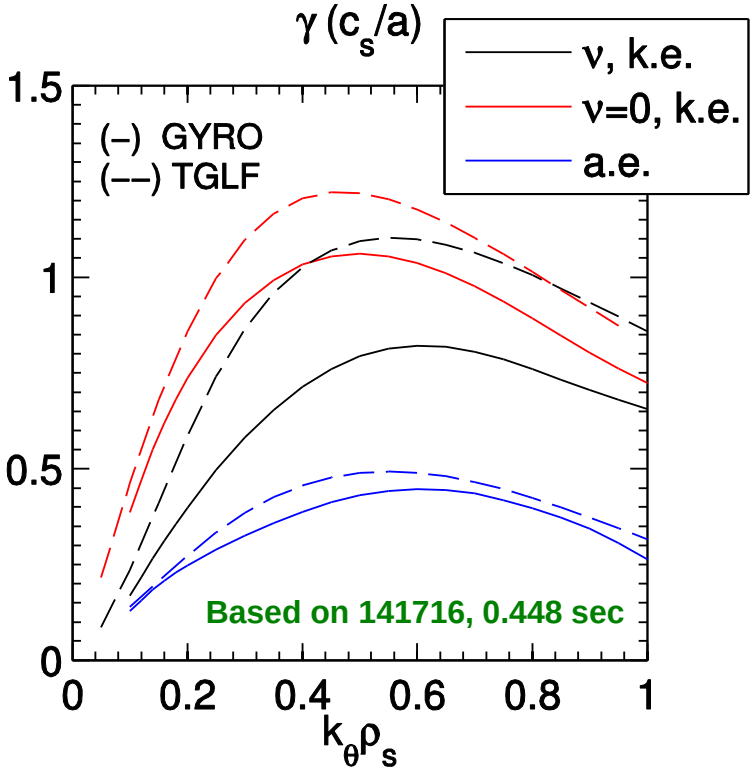
- Fails to predict T_e at low-ν_* → will begin testing TGLF predictions of KBM expected at low-ν_* (Guttenfelder, NF 2013) in task [MQ4]

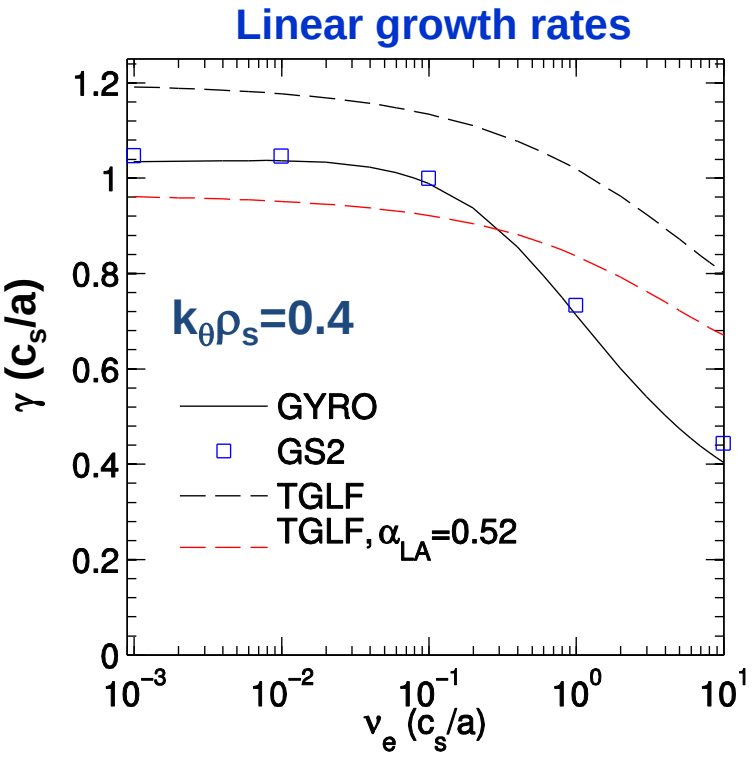


- A much wider comparison of TRANSP predictions (using RLW, MMM, TGLF) over a database of discharges has already been initiated (S. Kaye)
  - Repeating using updated TGLF settings per G. Staebler recommendations
  - Have also started TRANSP-TGYRO verification/benchmark

[MQ2] Have started qualifying TGLF for linear ITG/TEM based on NSTX L-mode

- Low beta (L-mode) experimental case (Ren, NF, 2013) to avoid EM effects
- Good agreement to GYRO in adiabatic electron limit (a.e.)
- Increasing discrepancy with kinetic electrons (collisionless & collisional)
- TGLF stabilization with increasing collisionality not as strong as GYRO/GS2 → need to improve trapped electron response

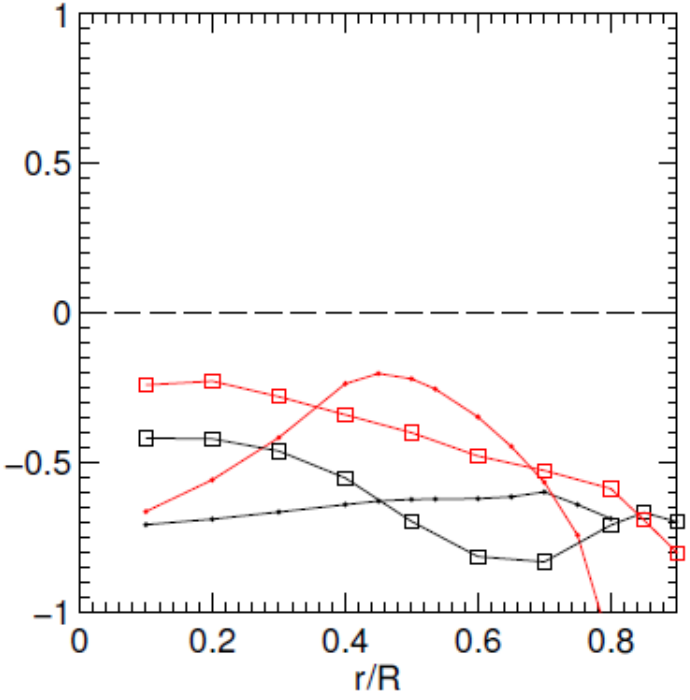




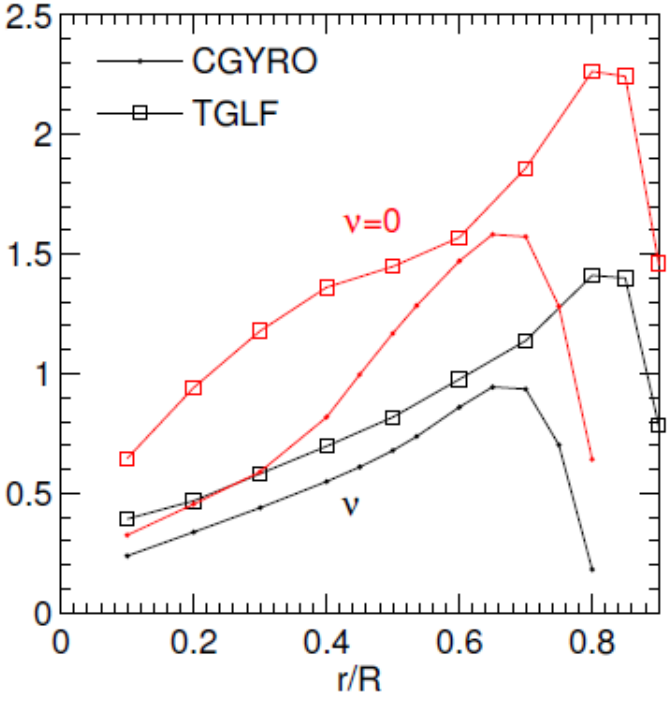
[MQ2] Using aspect ratio scan to clarify TGLF trapped particle response

- Varying surface r/R using local equilibrium model (Miller, PoP 1998) with β'_{eq}=0 (not physically realistic but useful to isolate role of trapped particles)
- TGLF recovers GK trends → working towards modifications to improve quantitative agreement (Staebler, GA)
  - Also successfully benchmarked CGYRO & GYRO for NSTX parameters as part of this effort (not shown)

Real frequencies



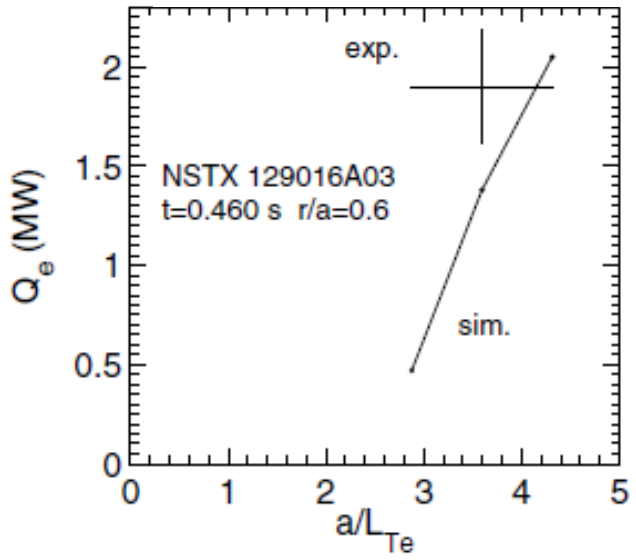
Linear growth rates



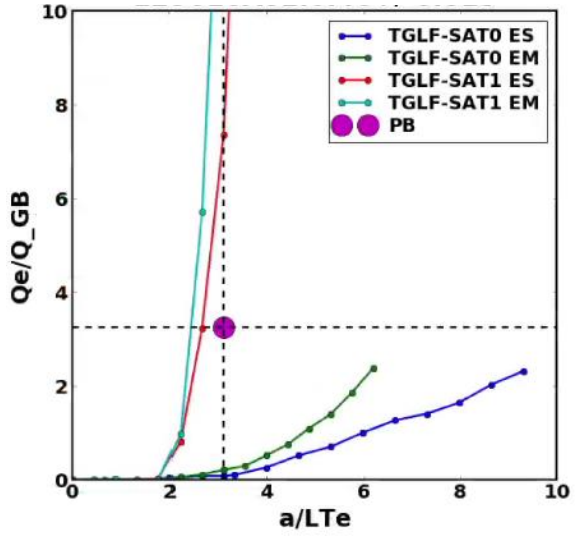
[MV3] Using previously published nonlinear ETG simulations to qualify TGLF-high k model

- Based on H-mode where ETG is significant, at least locally (Guttenfelder, NF 2013)
- TGLF reproduces comparable transport using “sat1” (updated ETG saturation rule based on multi-scale simulations)
  - To-do: compare saturated spectral shapes of $Q_e(k_\theta)$

Nonlinear GYRO sims



TGLF predictions



Q2 priorities

- Update TGLF linear model to reproduce R/a scans → TGLF profile predictions of L-mode plasmas
- Continued TRANSP profile predictions:
  - Using different combination of MMM-MTM and KBM models for high beta tests
  - Using updated TGLF model settings better suited for NSTX
- Continued qualification of TGLF-ETG transport against published nonlinear GYRO simulations
  - Other cases have also been identified for additional tests
- Initial tests of TGLF KBM threshold for high-β, low-ν discharges (to be used in future profile modeling)
- Initial comparison of various equilibria (EFIT, LRDFIT) & profile mapping for select shot(s) to initiate uncertainty quantification