T&T-specific milestone modifications

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NSTX-U

PRINCETON UNIVERSITY

R(18-5): Assess importance of multi-scale effects in NSTX/NSTX-U turbulent transport

Description: Electron scale ($k_q r_i$ >> 1) ETG turbulence has been predicted to be important in various NSTX and NSTX-U L-mode and H-mode plasmas. In some of these cases, gyrokinetic simulations indicate that ion scale ($k_q r_i$ < 1) turbulence should be completely suppressed by E´B shear such that only electron scale turbulence should remain. However, in many cases the ion scale turbulence is not predicted to be completely suppressed, or the predicted transport from ETG is insufficient to account for experimental electron heat flux levels. This milestone will focus on using gyrokinetic simulations and recently updated reduced models to clarify when and where ETG can be an important contributor in ST transport, and to begin addressing whether ETG can be considered in isolation from ion scale turbulence. Single-scale nonlinear gyrokinetic simulations will be used to predict transport based on experimental profiles, as done previously. Systematic parameter scans in driving gradients and E´B shearing rate will then be used to better quantify when ion scale transport dominates electron-scale transport, or vice versa. The region between these limits of single-scale transport should help demarcate where multiscale effects are expected to be important. To help guide the more computationally expensive gyrokinetic simulations, the TGLF reduced transport model will be used to predict similar boundaries in gradient-E´B shearing rate parameter space. Although the TGLF model has not yet been validated for ST parameters, it has been recently updated to recover the importance of multi-scale effects in conventional tokamak plasmas. In combination, we expect the results of the TGLF modeling and single-scale gyrokinetic simulations will be used to identify ST cases most suitable for multi-scale simulations. Initial results from simulations that begin to approach the multi-scale limit will be pursued to identify any computational challenges that may require special consideration.

R18-5 cont'd

- Multiscale simulations very time/resource intensive
  - Possibly be able to perform multiscale g-k simulation on only one case
  - DIII-D or NSTX(-U)?
- Alternative milestone is for (a) validating reduced transport models in ST regimes, (b) preparing an ST-based GYRO results database for TGLF enhancement
  - Talking about this for several years now with Gary
  - Golden opportunity to do this (WG will be dedicating much time on DIII-D collaboration
  - Essentially a rewrite of this Milestone

R(18-5 rewrite): Validate and develop further reduced (drift wave) transport models for electron thermal transport with NSTX and NSTX-U plasmas

Description: The design of next generation spherical tori (STs) will be influenced by the scaling of energy confinement. While ion thermal transport is often near neoclassical levels in H-modes, gyrokinetic simulations have indicated a number of potential drift wave turbulence mechanisms that can influence electron thermal transport. Reduced transport models that capture the key physics and scaling of the computationally expensive first-principles gyrokinetic simulations are required to more thoroughly validate the modeling against experimental data, which can then be used to infer the key physics that determines the overall energy confinement. A variety of reduced transport models based on drift wave turbulence have been developed and tested extensively for conventional tokamaks. These models encompass much of the physics expected to be important in STs, although they have been tested much less rigorously for ST parameters (low aspect ratio, high beta, strong flow). In order to improve the fidelity of reduced transport models (like TGLF, RLW and MMM), experimental NSTX, NSTX-U and possibly MAST and MAST-U data will be used to examine predictions based on these models to assess their suitability for ST plasma. The physics accuracy of these fluid-based models will be also be qualified by comparing directly to first-principles gyrokinetic simulations over a range of conditions. The dependence of electrostatic ITG and TEM instabilities on aspect ratio will evaluated by comparing L-mode cases to established conventional aspect ratio conditions. Validation with high beta H-mode data will push the limits of the available reduced models to recover electromagnetic instabilities like MTM and KBM. A key outcome of this milestone will be to determine the physics regimes in which further model development is required. The first-principles gyrokinetic simulations based on ST parameters will form the basis for enhancements of the TGLF reduced model.

R(19-3): Assess H-mode energy confinement, pedestal and ~~scrape-off layer~~ characteristics with higher B_T, I_p, and NBI heating power

Description: Future ST devices such as ST-FNSF will operate at higher toroidal field, plasma current and heating power than NSTX. To establish the physics basis for future STs, which are generally expected to operate in lower collisionality regimes, it is important to characterize confinement, pedestal and scrape off layer trends over an expanded range of engineering parameters. H-mode studies in NSTX have shown that the global energy confinement exhibits a more favorable scaling with collisionality ($Bt_E \sim 1/n^*_e$) than that from ITER98y,2. This strong n^*_e scaling unifies disparate engineering scalings with boronization ($t_E \sim I_p^{0.4} B_T^{1.0}$) and lithiumization ($t_E \sim I_P^{0.8} B_T^{-0.15}$). In addition, the H-mode pedestal pressure increases with $\sim I_P^2$, while the divertor heat flux footprint width decreases faster than linearly with I_P. With double B_T, double I_P and double NBI power with beams at different tangency radii, NSTX-U provides an excellent opportunity to assess the core and boundary characteristics in regimes more relevant to future STs and to explore the accessibility to lower collisionality. Specifically, the relation between H-mode energy confinement and pedestal structure with increasing I_P, B_T and P_{NBI} will be determined and compared with previous NSTX results, including emphasis on the collisionality dependence of confinement and beta dependence of pedestal width. Coupled with low-k turbulence diagnostics and gyrokinetic simulations, the experiments will provide further evidence for the mechanisms underlying the observed confinement scaling and pedestal structure. ~~The scaling of the divertor heat flux profile with higher I_P and P_{NBI} will also be measured to characterize the peak heat fluxes and scrape off layer widths, and this will provide the basis for eventual testing of heat flux mitigation techniques. Scrape-off layer density and temperature profile data will also be obtained for several divertor configurations, flux expansion values, and strike-point locations to validate the assumptions used in the physics design of the cryo-pump to inform the cryo-pump engineering design.~~ During FY2019, significant effort will be put toward profile and turbulence diagnostic commissioning for these experiments on NSTX-U, and if NSTX-U cannot support plasma operations during FY2019, emphasis will be placed on collaboration on MAST-U to support the core transport and pedestal structure research goals of this milestone.

R19-3 cont'd

- SOL physics to be done by MAST-U or outside-PPPL collaborating teams
  - Cannot take credit for that work in PPPL Milestone
- Core transport: Kaye, Ren
- Pedestal structure: Diallo