NSTX-U

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Chapter 3: Research Goals and Plans for Transport and Turbulence (2014-2018)

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and the NSTX team

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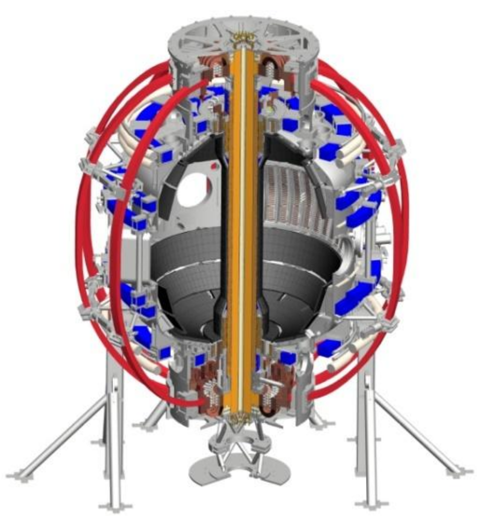

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Chapter 3: Research Goals and Plans for Transport and Turbulence

- 3.1: Overview – **high level goals/research thrusts**
- 3.2: Research Plan
- 3.3: Summary timeline for tool development

3.1.1 Goal: Establish predictive capability for performance of STs/FNSF [Ren]

- 3.1.2 - Thrust 1: Identify mechanisms responsible for thermal, momentum, and particle/impurity transport [Ren, Guttenfelder]
  - **Motivation**: reconcile anomalous electron thermal and momentum transport with neoclassical ion thermal transport; clarify limit of ν_* scaling to next generation STs
  - **Many theoretical mechanisms to consider**: neoclassical, low-k (ITG/TEM, KBM, MT), high-k (ETG), energetic particle (*AE)
  - **"Identification" tied to theory**: T&T measurements + simulations with synthetic diagnostics, experimental control $\Rightarrow$ identify key parametric variations (experimentally and theoretically)
  - Emphasis on both idealized physics scenarios (e.g. dominated by a single mechanism) and ASC-relevant scenarios (e.g. non-inductive discharges)

- 3.1.3 - Thrust 2: Establish and validate reduced transport models [Guttenfelder, Ren]
  - Guided by Thrust 1: identify mechanisms and key parameter scalings
  - Develop/validate available reduced models (TGLF) with simulations and experiment, *revising as required*
  - Develop/integrate $\chi_{e,*AE}$ model; incorporate pedestal BC (empirical scaling, model, …)

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Thrust 1: Neoclassical and low-k_θ turbulence [Ren]

- Determine if ion thermal, particle/momentum transport are described by neoclassical theory in low ν_* H-modes (including emphasis on ASC-relevant scenarios)
  - Identify regimes where discrepancies arise; guide low-k turbulence measurements
- Correlate transport (χ_i, χ_e, χ_φ, D) to low-k turbulence (BES, refl.)
  - Emphasis on all transport channels, in different regimes; guided by GK sims
  - Correlate polarimetry with electron transport in high beta/microtearing regimes
- Compare turbulence and transport with GK predictions + synthetic diagnostics (validation)

Near term (Years 1-2)

- Scaling with extended B_T, I_p, ν_*
- Perturbative momentum experiments (RMP, 2nd NBI)
- Perturbative impurity experiments (ME-SXR + gas puff)
- Utilize 2nd NBI, RMP coils for q, flow profile variation

Long term (Years 3-5)

- Utilize full range of B_T, I_p, ν_*
- Perturbative impurity/cold-pulse experiments (w/ laser blow-off + ME-SXR)
- Utilize 2nd NBI, 3D coils (NCC) for q, flow profile control
- Distinguish key parametric dependences of transport and low-k turbulence

- Investigate transport changes with PFC/divertor conditions
- Investigate ρ_* scaling w/ improved density control ($n \sim \rho_*^{-2}$)

Thrust 1: High-k_θ turbulence [Ren]

Near term (Years 1-2)

- Install high-k_θ, preliminary measurements in ETG dominant regimes (guided by GK sims)

Long term (Years 2-5)

- Correlate high-k_θ turbulence with electron thermal transport
- Identify ETG controlled transport using high-k_θ coupled with GK + synthetic diagnostics
- Utilize cold-pulse propagation experiments (w/ laser blow-off, ME-SXR) with high-k_θ measurements to investigate stiffness

Thrust 1: *AE driven χ_e [Ren, Tritz, Podesta]

Near term (Years 1-2)

- Measure *AE mode structure with calibrated BES/refl. (also w/ EP)
- Correlate *AE activity with χ_e over extended I_p, B_T, low ν_*, P_{NBI}

Long term (Years 3-5)

- Refine dependence of χ_e with *AE and range of applicability
- Develop/test available reduced models for *AE driven χ_e (w/ EP)

Thrust 1: Overlap/coupling with boundary (?) [Diallo, Battaglia, Chang, Ren, Guttenfelder]

- Similar goal (identify mechanisms) for transport and turbulence in pedestal
- L-H transition?

Thrust 2: Model development and validation [Guttenfelder, Hammett]

Near term (Years 1-2)

- Establish 0D confinement scaling & profile database at higher B_T, I_p, reduced ν_*
- Predict parametric dependencies from nonlinear simulations for different mechanisms
- Validate TGLF with linear/nonlinear simulations for NSTX-U
  - Explore alternative reduced model development (e.g. semi-empirical, “Multi-Mode”, etc…)
- Test 0D confinement scaling predictions
- Test 1D profile predictions, starting with idealized scenarios (ITG, L-mode; ETG, low-β H-mode, …)
  - Test sensitivity to boundary conditions (constrained to pedestal scalings)
  - Identify where reduced models fail (e.g. correlated with β_{fast}, $\nabla\beta_{fast}$, …)

Long term (Years 3-5)

- Extend 0D confinement scaling to full range of B_T, I_p, ν_* (isolation of W_{core}, W_{ped})
- Project 0D performance to FNSF/Pilot
- Revise TGLF as required for NSTX-U scenarios (w/ GA)
- Continue validation with relevant scenarios
  - Incorporate best pedestal models into integrated predictions (w/ BP)
  - Incorporate best EP/*AE χ_e models into integrated predictions (w/ EP)
- 1D predictions for FNSF/Pilot

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3.3.1 Theory and simulation capabilities

[Guttenfelder, Wang, Chang, Hammett, Ren, Poli, Kaye]

- Neoclassical theory (NCLASS, NEO, GTC-neo, XGC0)
  - Validate theory with multiple-ions, finite flows, non-local orbits, neutral effects
- Local gyrokinetic codes (GYRO, GS2, GENE, GKW)
  - Scaling studies with comprehensive physics (most efficient)
- Global/full-F codes (GYRO, GENE, GTS, XGC1, Gkeyll)
  - Clarify local (large ρ_*) and delta-f assumptions (core/pedestal overlap)
  - EM capabilities likely required
- Synthetic diagnostics (BES, high-k, polarimetry, refl., etc…)
- Transport models (TGLF; *AE; EPED)
- Transport solvers (pTRANSP, TGYRO, TRINITY, XPTOR)
  - Need for robust transport solvers

3.3.2 Diagnostics [Ren, Smith, Tritz, UCLA]

- New FIR high-k_θ scattering system
- Polarimetry system
- Additional BES channels
- In-vessel multi-energy SXR (ME-SXR) arrays
- PCI (scoping intermediate-k diagnostics)

3.3.3 Other facility capabilities [Ren, Tritz, Park, Nova Photonics]

- Repetitive laser blow-off impurity injection system (impurity; cold pulse)
- 2^{nd} NBI (q, flow profile flexibility)
- NCC for 3D fields (rotation flexibility)
- MSE-LIF for q profile (XP flexibility)
- Divertor/PFC/cyro (density control, XP flexibility)

2014-18 Transport and Turbulence Research Timeline