NSTX

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NSTX Theory/Computation Needs Brainstorming Workshop - Introduction -

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PPPL
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Motivation

- Preparation for 2014-2018 Five Year Plan forming the basis of the research plan for NSTX-U

- The meeting will attempt to address key issues from the perspectives of both experiment and theory (including modeling/CPPG), and seeks:

  – Ideas and presentations from members of the NSTX-U experimental research team describing needed capabilities from existing or new theory and simulation to support NSTX-U research goals

  – Ideas and presentations from the NSTX-U and PPPL theory and simulation communities describing what new experiments and/or measurements are needed to better support the development or interpretation of theory and simulation

Macrostability

- Can we develop a full 3D model for equilibrium and stability?
  - Kinetic effects, rotation, RWM, etc
  - Lowest level (i.e., linear)
- How do non-linear effects impact the equilibrium and stability?
  - NTMs, islands
- How does the high density gas plume (for disruption mitigation) penetrate through the SOL and into the plasma edge?
  - Only a fraction gets through

Macrostability

Category	Existing efforts	Associated physics issues
Improved equilibrium reconstruction including toroidal rotation, MSE, and SOL currents, and stability analysis	- EFITs including rotation - LRDFITs including rotation - (E,LRD)FITs + FLOW - (E,LRD)FITs + FLOW + M3D-C1	- Stability boundary with toroidal rotation? - Stability boundary including separatrix? - Can be routinely available between shots, with real time MSE, in NSTX-U?
Quasi-linear 3D equilibrium modeling including islands, neoclassical, and kinetic MHD effects	- IPEC with tensor pressures and islands + POCA + Inner-layer - FLOW, MARS-F, MARS-K - M3D-C1	- 3D equilibrium with opened islands? - 3D equilibrium with rotation? - 3D equilibrium with anisotropic pressures? - Self-consistent modeling for NTV in NSTX-U?
Quasi-linear stability modeling including neoclassical and kinetic MHD effects	- MISK with improved theory including anisotropic pressure - MARS-K, NOVA-K - M3D-C1	- RWM passive stability with 2nd NB in NSTX-U? - Effects of self-consistent eigenfunction? - Second RWM code with full kinetic treatment?
Non-linear (as well as linear) 3D modeling for time-evolving dynamics of islands, neoclassical, full kinetic MHD effects	- M3D-C1 with distribution function solver (Ramos theory or NTV theory) - XGC0	- Non-linear effects in 3D equilibrium and stability, including SW (q=1) and NTM? - Two fluid effects in 3D equilibrium and stability? - Full kinetic effects in 3D equilibrium and stability?
Disruption simulation, including MCI, gas penetration physics, and runaway electrons	- DEGAS2 for gas penetration - TSC for runaway electrons - M3D for disruption simulation - Use of 3D equilibrium sequence	- Gas penetration with atomic physics? - Runaway electrons in NSTX-U? - Coupling gas and plasma modeling? - Why does mode locking cause a disruption? - What is the origin of a density limit disruption?
Full 3D modeling of external structure for RWM dynamics	- Multi-mode VALEN3D - Plasma permeability with neoclassical and kinetic MHD effects - VALEN3D + Plasma permeability	- Full 3D current effects on RWM? - Effects of full 3D + kinetic plasma permeability on RMW stability and control? - RWM state space controller.

Lithium Research

- Why does lithium alter the core plasma transport and suppress ELMs?
- (How) Can we use lithium for particle and power handling?
- Can we develop a predictive capability for PMI and near-surface plasma behavior?
  - + technology -> Can we develop viable Li-based PFCs for future devices?

Lithium Research

- Effects of Li on core plasma transport and ELMs
- Use of Li as a plasma-facing material to
  - Control core plasma deuterium and impurity content
  - Increase heat load/pulse length handling
- Quantification of Li-related effects
  - Amount of radiation in divertor and SOL
  - Impact on character of disruptions
- Study of plasma-material interactions and/or near-surface plasma behavior
- Development of viable PFC concepts for FNSF, DEMO, and other future devices
  - Include flowing liquid metal systems (Li or other)

Waves and Energetic Particles

- How do you maximize the HHFW power to the core plasma?
  - Minimize fast ion absorption, SOL losses
- Can we describe non-linear coupling between the fast ion population and fast ion (and other MHD) modes?
  - AE stability and quasi-linear diffusion

Waves and Energetic Particles

- Improve and validate tools for *AE calculations
  - Include externally-driven perturbations into existing codes (TAE-CAE/ GAE)
- Improve computation of fast ion distribution evolution in TRANSP
  - Validated *AE transport models; close loop between experiment and models
- Model RF power losses in SOL in NSTX-U H-modes
  - Extend RF models: divertor regions, RF sheaths, PDI
- Model HHFW current drive in HHFW-only and HHFW+NBI H-modes
  - Supports goal of 100% non-inductive operation
- Model HHFW interaction with NB ions
  - Orbit/RF code coupling; non-linear coupling

Solenoid-Free Startup

- What is the mechanism that allows for the formation of closed flux surfaces, and how does it scale?
  - Coaxial and point source helicity injection
- What are the limits as far as current density on electrodes?
  - Erosion/recycling/transport

Solenoid-Free Startup

- Use of resistive 3D model for determining conditions of generating flux-surface closure
  - Understand scaling of CHI current generation to larger devices
- Use 2D and 3D MHD models to determine the scaling of electron heating, temperature, transport etc. with injection parameters
- Develop 3D MHD model of point source helicity injection
- Understand requirements for current drive by NB (RF?) in CHI or point source helicity injection generated target
- Understand the relation between electrode-driven current and impurity generation
  - Impact on performance of resulting discharge

Boundary Physics

- What physical processes are responsible for determining the SOL width?
- What physical processes are responsible for the formation of the edge pedestal?
- What are the roles of transport and atomic physics in determining plasma-surface interactions?

Boundary Physics

- SOL width, transport and turbulence
  - Convective cells, Li effects, edge flows (blobs)
  - Physics of collisionless SOL
- Pedestal and ELM physics
  - Role of Li in suppressing ELMs
  - Pedestal formation: role of neutrals, test and develop testable models, develop predictive capabilities for pedestal height and width
  - SOL currents and ELMs
- Divertor transport, radiation and PMI
  - Validate steady-state and transient transport models
  - Validate radiation models that include high-Z
  - Validate PMI models
  - Perform in standard and snowflake divertor configurations

Transport and Turbulence

- What are the elements necessary for developing a full interpretive and predictive capability for plasma transport?
  - Core, gradient, pedestal regions
  - Develop synthetic diagnostics for validation of turbulence and transport models

Transport and Turbulence

- Pedestal region (r/a>0.9)
  - Develop/validate pedestal models (engineering vs physics variables)
  - Measure pedestal turbulence and validate models with gyrokinetics
  - Prediction of micro-instability thresholds
- Gradient region (r/a~0.4-0.9)
  - Model validation (reduced models vs gyrokinetics)
  - May need global, multi-scale simulations
  - Reconcile anomalous momentum/electron transport with neo ions
- Core region (r/a<0.4)
  - T_e profile flattening; influence of fast ion instabilities
  - Develop reduced models, turbulence spreading between core-gradient
- Develop suite of synthetic diagnostics integrated with numerical codes (facilitate validation)

Advanced Scenarios and Control

- Can we develop viable actuators and algorithms for full axisymmetric control?
  - Profile control (current, pressure,…)
  - Full geometry control (boundary, strike points, …)

- Can we develop a high-b, steady-state ST plasma scenario that projects to fusion power generation?
  - Full non-inductive current drive

Advanced Scenarios and Control

- Realtime control
  - Need reliable algorithms for individual and combined control of current, rotation profiles, β_N
  - Need ability to test algorithms in simulations with high degree of physics fidelity (flight simulator mode)
  - Need ability to predict equilibrium and stability properties of the plasma (present and future)

- Scenario development
  - NBCD with *AE modes
  - Prediction of thermal and momentum transport
  - Accurate models for HHFW, EBW H&CD in codes such as TRANSP