NSTX

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NSTX Upgrade diagnostic discussion meetings
Program Overview – Goals and Priorities

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for the NSTX Research Team

Diagnostic brainstorming
PPPL – B318
July 21, 2011

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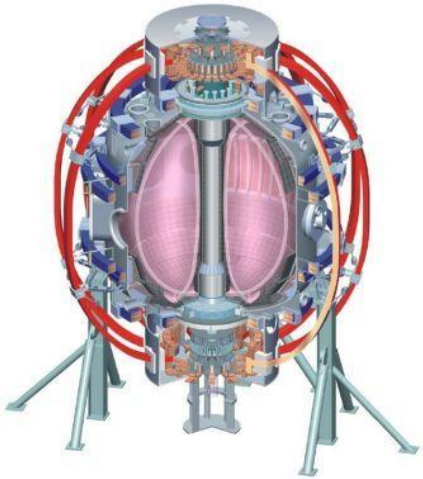

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Overview

- Purpose of this meeting is to discuss and brainstorm on diagnostic needs and ideas for NSTX Upgrade
  - Needed for FES diagnostic solicitation (2012-2015)
  - Also needed for upcoming 5 year planning process
  - Any team member can present brief idea description
- Program letter status:
  - Draft program letter to be sent to PAC Tuesday, July 26
  - Team invited to comment on letter priorities (see below)
  - PAC review of letter Aug 1 or 2, final letter issued Aug 8
- This talk provides overview of:
  - Draft 5 year plan research elements
    - To be discussed in-depth in future meetings, but is anything major missing?
  - Draft research priorities for program letter

5 year plan goals and diagnostic collaboration program letter priorities for:

Macroscopic Stability

2015	2016	2017	2018
Utilize rotation control using 3D fields and 2 NBI system to optimize rotation profile for global and edge stability	Utilize real-time RFA measurements + beta feedback control for real-time prediction and avoidance of stability limits. Exploit in-vessel 3D field coils if installed/available.	Combine rotation + RFA/beta control to improve scenario stability and sustainment - project to sustainable beta achievable in FNSF/Pilot	Incorporate real-time q profile information into rotation and beta control and optimization to improve scenario stability and sustainment

Draft priorities for diagnostic collaboration program letter:

I-1. *Understand the role of kinetic effects in RWM stability and toroidal rotation damping to optimize RWM stability and control in ITER and future facilities.*

I-2. *Study the impact of low aspect ratio, high beta, large ion gyro-radius, magnetic shear, and flow shear on classical and neoclassical tearing mode stability.*

I-3. *Assess neoclassical toroidal viscosity, plasma equilibrium and stability response to 3D fields, and the physics and control of toroidal rotation at reduced collisionality.*

I-4. *Characterize the dynamics of disruptions at low aspect ratio and high beta by measuring halo currents and thermal and current quench characteristics.*

5 year plan goals and diagnostic collaboration program letter priorities for:

Transport and Turbulence

2015	2016	2017	2018
Implement new high-k system, measure low-k turbulence response to reduced nu* at higher Ip and Bt in Upgrade	Measure high-k turbulence at reduced nu* at higher Ip and Bt to determine modes responsible for e-transport, utilize global confinement trends to project size and power requirements for FNSF/Pilot	Compare low-k and high-k turbulence to measured diffusivity trends to determine dominant instabilities for e-transport and i-transport	Utilize turbulence understanding and ST confinement trends to finalize FNSF/Pilot size, power requirements

Draft priorities for diagnostic collaboration program letter:

II-1. *Develop/utilize diagnostics to determine the modes (low-k, high-k, electrostatic, electromagnetic, Alfvénic) responsible for causing anomalous electron transport - with particular emphasis on the development of internal measurements of magnetic field fluctuations and high-k density fluctuations.*

II-2. *Determine role of low-k turbulence in causing anomalous energy and momentum transport, understand influence of rotation on low-k, high-k turbulence.*

II-3. *Determine the relationship between the measured particle and impurity transport and simulated micro-turbulence and neoclassical transport.*

II-4. *Compare turbulence measurements with theory and simulation using a suite of micro-turbulence codes.*

5 year plan goals and diagnostic collaboration program letter priorities for:

Boundary Physics

	2015	2016	2017	2018
Pedestal	Assess pedestal structure (especially Te height) and SOL heat-flux width at higher field and current up to 1.5MA	Assess pedestal and SOL at up to 2.0MA, project size, power, heat-flux mitigation requirements for FNSF/Pilot. Design real-time control of divertor gas/impurity puffing for heat flux mitigation.	Utilize divertor radiation and new 3D field coils to modify/optimize pedestal transport, divertor detachment and performance. Implement divertor real-time gas/impurity puff control.	Real-time control of snowflake + radiation + 3D fields to control and mitigate divertor heat flux
Divertor	Assess impact of modified pedestal and SOL at high Ip on snowflake divertor performance, initial usage and assessment of cryo-pumping performance	Assess impact of modified pedestal and SOL at highest Ip=2MA on snowflake divertor performance, and assess cryo-pumping performance with snowflake divertor	Assess synergies of snowflake divertor, radiative impurities, and 3D fields for particle and power exhaust at very high unmitigated heat flux - project to FNSF/Pilot	

NOTE: There may be insufficient resources to implement cryo-pumping by 2015-16

Draft priorities for diagnostic collaboration program letter:

III-1. *Measure and interpret energy and particle transport and turbulence in the SOL, and understand the linkage between SOL parameters and the peak heat flux to the divertor to develop means for heat-flux mitigation and control.*

III-3. *Measure and understand boundary plasma response to applied 3D magnetic field perturbations and other perturbations designed to control edge plasma transport and stability.*

5 year plan goals and diagnostic collaboration program letter priorities for:

Lithium Research

	2015	2016	2017	2018
High-Z walls	Assess impact of full wall coverage of solid Li on particle pumping, plasma performance. Install high-Z PFCs on outboard walls.	Assess impact of full coverage high-Z PFCs + Li on particle pumping, plasma performance. Assess/design hot wall (using bake-out) capability.	Utilize hot first-wall capability with Li on high-Z PFCs, assess impact on particle pumping, plasma performance.	Incorporate Li-wall results into other facilities (EAST collaboration), and into designs of FNSF/Pilot and other next-step facilities.
Next-gen LLD	Test next-gen LLD prototype(s) on PMI test-stand (at PPPL or other, as available), iterate as needed on design. Implement RDM on Upgrade.	Test next-gen LLD on RDM in NSTX Upgrade. Utilize high heat-flux plasma to characterize lithium performance and LLD power handling capabilities. Iterate design. Perform preliminary projection of next-gen LLD to FNSF/Pilot.	Complete design, begin fabrication of complete toroidal coverage next-generation LLD for NSTX Upgrade.	Implement and test full toroidal coverage next-gen LLD for pumping and/or power handling capabilities - project performance to FNSF/Pilot

NOTE: There may be insufficient resources to implement high-Z walls, RDM, or next-gen LLD by 2015-16

Draft priorities for diagnostic collaboration program letter:

III-2. *Measure and analyze the surface characteristics of lithiated and non-lithiated divertor and first-wall plasma facing components, relate these characteristics to the core and edge plasma confinement and stability under both steady-state and transient edge conditions.*

5 year plan goals and diagnostic collaboration program letter priorities for:

Waves and Energetic Particles

	2015	2016	2017	2018
Energetic Particles	Measure *AE activity observed to be driven by more tangential 2nd NBI - compare to existing more perp NBI. Implement upgraded *AE antenna.	Simulate *AE activity observed to be driven by more tangential NBI, extend non-linear models to Upgrade plasmas with 2nd NBI, compare simulations to new data. Extend simulations of avalanches to FNSF/Pilot sustainment phase.	Utilize *AE predictive capability to optimize/minimize *AE activity during non-inductive current ramp-up with 2nd NBI. Compare simulations to experimental results.	Extend simulations of *AE avalanches to FNSF/Pilot current ramp-up phase, assess implications for FNSF/Pilot design, in particular NBI injection geometry, expected current drive.
RF - HHFW	Assess HHFW performance at higher magnetic field and higher plasma density - especially compatibility with high-power NBI operations. Design EHO antenna using HHFW straps, or same location in NSTX-U	Utilize HHFW to assist start-up plasma formation - compare to short-pulse ECH. Also assess impact of HHFW e-heating on NBI current ramp-up. Simulate/mock-up performance using reduced number of straps. Implement EHO antenna compatible with HHFW requirements.	Modify actual HHFW antenna system to have reduced number of straps. Test EHO antenna for impact on density/particle control.	Utilize modified HHFW system heating and CD to optimize plasma start-up, ramp-up, and NBI sustainment.
RF - ECH	Implement short-pulse, high-power ECH system for plasma start-up support (0.5-1MW, 10-50ms)	Test short-pulse, high-power ECH system for plasma start-up support - assess impact on close-flux current achieved, pulse-length extension, non-inductive fraction.	Upgrade ECH system power and pulse-length for EBW heating studies (1MW, 0.2-0.5s)	Pending successful EBW heating results, further upgrade ECH system power and pulse-length for EBW heating studies (2-4MW, 1-5s), project EBW CD performance to FNSF/CTF

NOTE: There may be insufficient resources to implement higher power ECH by 2015-2016

IV-1. *Measure the transport of supra-Alfvénic fast ions due to Alfven eigenmode avalanches and other Alfvenic instabilities with particular emphasis on the possible redistribution of neutral beam current drive.*

IV-2. *Measure the eigenfunctions and dynamics of Alfvenic instabilities to aid in the validation of advanced numerical simulations and the development of a predictive capability for fast-ion transport relevant to FNSF and ITER.*

IV-3. *Measure and simulate interactions between high-harmonic fast-waves (HHFW) and neutral beam fast-ions with application to optimizing plasma heating and current-drive by the HHFW.*

5 year plan goals and diagnostic collaboration program letter priorities for:

Start-up, Ramp-up, and Sustainment

	2015	2016	2017	2018
Start-up	Utilize CHI and/or plasma guns to form 0.3MA closed-flux plasma	Utilize CHI and/or plasma guns to form 0.5MA closed-flux plasma	Utilize CHI and/or plasma guns to form 0.5-1MA closed-flux plasma	Optimize start-up for 100% non-inductive sustainment and high beta & confinement
Ramp-up	Ramp up 0.3-0.4MA plasma to 0.6MA with 2nd NBI	Ramp up 0.4-0.5MA plasma to 0.8MA with 2nd NBI, perform assessment of implications for FNSF/Pilot	Ramp up 0.4-0.5MA plasma to 0.8-1.0MA	Optimize ramp-up for 100% non-inductive sustainment and high beta & confinement
Sustainment	Access 100% non-inductive for several tau-E using 2nd NBI	Access 100% non-inductive for 1 tau-CR - perform assessment of sustainable scenario for FNSF/Pilot	Extend 100% non-inductive to relaxed q profile (2-3 tau-CR)	Integrate non-inductive start-up, ramp-up, and sustainment, project performance to FNSF/Pilot

Draft priorities for diagnostic collaboration program letter:

V-1. *Measure and optimize the formation, confinement, and heating of solenoid-free start-up plasmas created using Coaxial Helicity Injection (CHI) and other techniques such as poloidal-field ramp-up and plasma gun start-up.*

V-2. *Measure and optimize the non-inductive current ramp-up of low-current target plasmas driven by high-harmonic fast wave (HHFW) and/or neutral beam injection (NBI) heating and current drive.*

5 year plan goals and diagnostic collaboration program letter priorities for:

Scenario Development and Control

	2015	2016	2017	2018
Optimization and control	Demonstrate qmin variation with NBI source using 2nd NBI	Utilize 1st + 2nd NBI source mix to optimize stability and transport	Develop/comission real-time control of current profile for high non-inductive fraction plasmas (~1MA)	Utilize current profile control to maintain high confinement and stability - project to requirements for FNSF/Pilot
Long pulse, high current	Extend 1MA plasmas from 1s to 2-4s, increase flat-top current to 1.5MA for 1-2s	Extend 1MA plasmas to 5s, extend 1.5MA flat-top to 2-4s, increase flat-top current to 2MA plasmas for 1s - perform assessment of scenario performance for FNSF/Pilot	Extend 0.7-1MA plasmas to beyond 5s, extend 1.5MA flat-top to 5s, extend 2MA plasmas to 2-4s flat-top	Extend 2MA plasmas to 5s and/or highest power to enable high P/R and P/S PMI studies for FNSF/Pilot

Draft priorities for diagnostic collaboration program letter:

VI-1. *Develop real-time diagnostics for advanced plasma control, including for example: measurements of the safety factor profile, temperature and density profiles, and divertor heat-flux, radiation, and/or surface temperature measurements in support of advanced operating scenarios in NSTX Upgrade.*

VI-2. *Develop new or utilize existing diagnostics for the identification of disruption onset and/or MHD precursors for potential use in triggering controlled plasma shut-down and/or disruption mitigation techniques.*

Any questions?

- Please feel free to e-mail or discuss any comments or suggestions on the program letter priority areas

- Thank you for contributing your diagnostic ideas!