FY11-12 WPI TSG Research Discussion

G. Taylor

M. Podestà

NSTX WPI TSG Meeting

November 18, 2010

FY11-12 campaign will be the last opportunity to acquire data before the 2012-14 NSTX-U upgrade shutdown

- We need to review proposed HHFW & WP related research milestones before FY11-12 Milestone Discussion on Dec 3:
  - Given our results from FY10 campaign, are the proposed FY11-12 milestones still appropriate?
  - If they are appropriate, do we need to change the scope or wording?
  - Should we propose different HHFW or EP related milestones?
- HHFW operations in FY10 were seriously compromised by the copious amounts of lithium injected into the vessel:
  - How can we improve HHFW plasma operation during the FY11-12 campaign?

Proposed NSTX FY2010-12 Research Milestones

(base and *incremental*)

	FY2010	FY2011	FY2012
Expt. Run Weeks:	15 w/ ARRA	14 (20)	14 (20)
1) Transport & Turbulence		Measure fluctuations responsible for turbulent ion and electron energy transport	Compare measured turbulence fluctuations to theory & simulation
2) Macroscopic Stability	Assess sustainable beta and disruptivity near and above the ideal no-wall limit	*Assess RWM and rotation damping physics at reduced collisionality*	
3) Boundary/Lithium Physics	Assess H-mode characteristics as a function of collisionality and lithium conditioning	Assess relationship between lithiated surface conditions and edge and core plasma conditions *Assess pedestal and SOL response to externally applied 3D fields*	Assess very high flux expansion divertor operation
4) Wave-Particle Interaction	R(10-2): Characterize HHFW heating, CD, and ramp-up in deuterium H-mode (joint with solenoid-free start-up TSG)		IR(12-1): *Assess predictive capability of mode-induced fast-ion transport*
5) Solenoid-free start-up, ramp-up			R(12-3): Assess confinement, heating, and ramp-up of CHI start-up plasmas (joint with WPI-HHFW TSG)
6) Advanced Scenarios & Control		R(11-2): Assess integrated plasma performance versus collisionality	Investigate physics and control of toroidal rotation at low collisionality (joint with MS TSG)
Joint Research Targets (3 US facilities):	Understanding of divertor heat flux, transport in scrape-off layer	Characterize H-mode pedestal structure	Understanding of core thermal and particle transport

Key Goals for HHFW & EP Research in FY11-12

- Measure & minimize NBI fast-ion acceleration by the HHFW
- Modify core plasma collisionality by coupling HHFW to NBI-heated H-mode **R(11-2)**
- Assess effect of RF heating on core impurity accumulation
- Understand effect of edge transients on HHFW, especially ELMs
- Assess HHFW heating of CHI plasmas to high T_e **R(12-3)**
- HHFW coupling/heating efficiency during I_p ramp-up **R(12-3)**
- Develop predictive capability for fast-ion transport driven by EP-instabilities **IR(12-1)**
- Test linear and non-linear fast-ion instability models

Milestone R(11-2): Assess the dependence of integrated plasma performance on collisionality [ASC TSG]

The high performance scenarios assumed for next-step ST devices such as NHTX and ST-CTF are based on operating at lower Greenwald density fraction and significantly lower pedestal collisionality than NSTX. Building on the research of the FY2010 boundary physics milestone R(10-3), Milestone R(11-2) would extend research on high-performance plasmas toward lower density and collisionality and systematically assess integrated performance (such as non-inductive current fraction, confinement, core and pedestal stability, pulse-duration, impurity content) of long-pulse H-modes. Two possible tools for accessing reduced plasma collisionality are the Liquid Lithium Divertor (LLD) and the upgraded HHFW system capable of higher power and with resilience to ELMs. Based on a successful demonstration of particle pumping in FY2010, the LLD would be utilized to vary plasma density and temperature by varying its pumping through control of parameters such as the strike-point position, flux expansion, the temperature, and thickness of the lithium layer. Further, the plasma integrated performance would be assessed as a function of boundary shape, in particular the strike point location and triangularity, to assess the possible trade-off between improved MHD stability (higher triangularity) and increased pumping efficiency (lower triangularity). Building upon recent successful electron heating by HHFW in low neutral beam power H-modes, the upgraded HHFW system will be used to heat electrons in order to decrease the collisionality and to increase non-inductive currents in high-power, long-pulse H-mode scenarios. The influence of these advanced pumping and heating capabilities on NSTX high-performance plasmas will be compared to time-dependent simulation codes such as TSC and TRANSP to develop a predictive capability for advanced ST operating scenarios.

Milestone R(12-3): Assess confinement, heating, and ramp-up of CHI start-up plasmas [Joint milestone with SFSU TSG]

Elimination of the central solenoid is essential for ST-based nuclear fusion applications, and it would reduce the cost/complexity of all tokamak reactors. TSC simulations indicate that at the higher B_T and higher RF power anticipated in NSTX-U, RF coupling should be considerably higher than in NSTX, and this combined with NBI allows for the possibility of a fully non-inductive start-up, ramp-up and sustainment demonstration in NSTX-U. Methods to reduce low-Z impurities in NSTX allowed substantial progress in coupling the CHI-initiated discharges to induction, and these have been successfully coupled to induction in neutral beam heated H-modes in NSTX. While these results are favorable, the confinement properties of CHI start-up plasmas have not been characterized. Understanding CHI plasma confinement is important for projecting non-inductive start-up and ramp-up efficiency to next-steps. HHFW is the only available tool for heating these target plasmas in NSTX. Early HHFW heating (during ramp-up) of ohmic targets was demonstrated in FY2008 and will be further developed in FY2010. In FY2011-12, HHFW heating will be applied to a CHI initiated discharge transitioning to an inductive discharge to compare the confinement and heating efficiency versus OH-only targets. For the FY2012 milestone research, the HHFW heating and CD will be applied progressively earlier in the target plasma to increase the β_P and bootstrap fraction. The degree to which the OH flux consumption can be reduced toward zero (i.e. achievable level of non-solenoidal start-up and ramp-up) will be assessed. During 2011/2012, the possible utilization of an all metal divertor is expected to further improve CHI start-up as a result of a further reduction of low-Z impurities.

Incremental Milestone IR(12-1): Assess predictive capability of mode-induced fast-ion transport

Good confinement of fast-ions from neutral beam injection and thermonuclear fusion reactions is essential for the successful operation of ST-CTF, ITER, and future reactors. Significant progress has been made in identifying the Alfvénic modes (AEs) driven unstable by fast ions, and in measuring the impact of these modes on the transport of fast ions. However, theories and numerical codes that can quantitatively predict fast ion transport have not yet been validated against a sufficiently broad range of experiments. To assess the capability of existing theories and codes for predicting AE-induced fast ion transport, NSTX experiments will aim at improved measurements of the mode eigenfunction structure utilizing a new Beam Emission Spectroscopy (BES) diagnostic and enhanced spatial resolution of the Far-Infrared Reflectometer. NSTX will also make new measurements of the internal magnetic field structure of AEs using far-infrared polarimetry (if available) and improved measurements of the fast-ion distribution function utilizing a tangentially viewing Fast-Ion D-alpha (FIDA) diagnostic. In order to broaden the range of discharge conditions studied to those relevant to future devices, experiments will be conducted for both L-mode and H-mode scenarios. Specific targets for the experiment-theory comparison are those between the measured and calculated frequency spectra and spatial structure. Both linear (e.g., NOVA-K, ORBIT) and non-linear (e.g., M3D-K, HYM) codes will be used in the analysis.

How can we improve RF plasma operation when LITERs/LLD are operating during the FY11-12 campaign?

- Modify the boron nitride limiters around antenna
- Boronization early in run campaign
- Avoid oxygen contamination from openings during campaign
- Improve collimation on LITER closest to antennas
- Shield above the antenna
- Develop a plasma configuration to “scrub” the antenna surface
- Bake the antenna