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Overview of NSTX FY2010-12 Program Letter for Laboratory Collaborations

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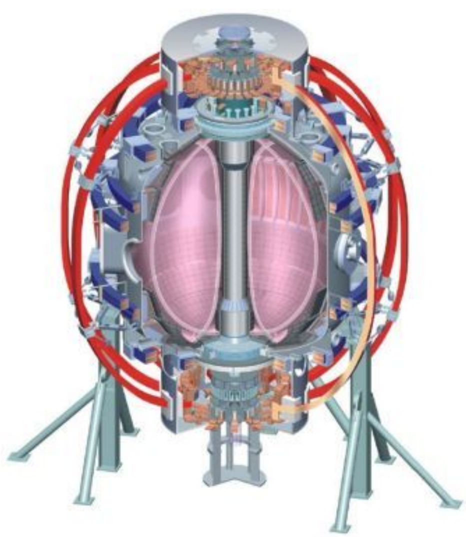
For the NSTX Research Team

NSTX PAC-26 Teleconference
PPPL - DCR
July 20, 2009



College W&M
Colorado Sch Mines
Columbia U
CompX
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
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PSI
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ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
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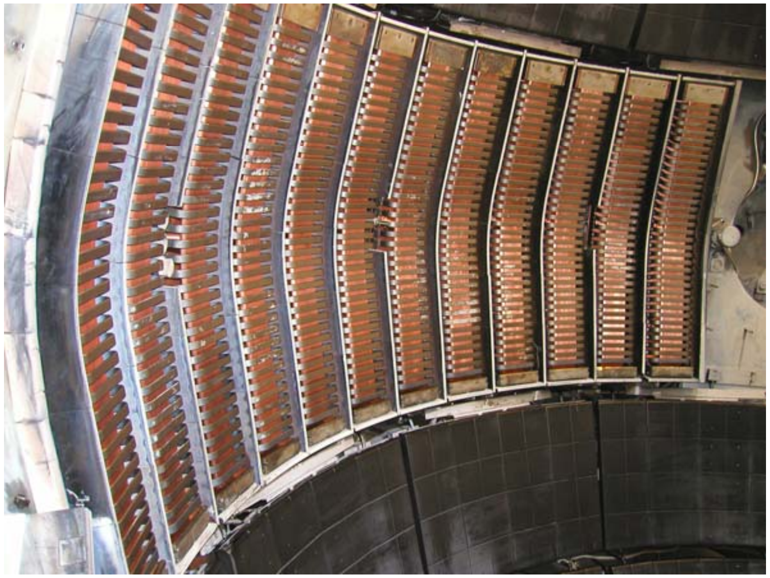
NSTX FY2009 Facility Operations Update

ARRA Funding Significantly Enhancing Research Capability

- Planning 16 week run this year - 11 Base + 5 ARRA
  - 11 run weeks with 1,705 plasma shots achieved for Base, 1.2 for ARRA
  - Scheduled to complete this run by Aug 14th
- Completed facility modifications/upgrades:
  - HHFW upgrade installation completed and began operation
  - Dual lithium shaker installed and began operation
  - CHI absorber coils commissioned with SPA sources
  - Leaking NBI calorimeter bellows replaced during maint. weeks
- LLD and BES preparations ongoing for summer outage
  - LLD plates to be delivered to PPPL from PPI this week
- Good progress on ARRA-funded upgrade planning
  - +10 TS chans, complete MSE-LIF, enhance LLD, 2 post-docs, 2nd SPA
  - But no HHFW hybrid ELM resilience system due to funding reduction
- Good progress on NSTX Upgrade Project (new CS + 2nd NBI)
  - Planning for PPPL/PU CDR in Oct., Lehman (SC) Review in Dec.

HHFW upgrade successfully completed during FY09 run

- Internal views of HHFW antenna, external resonant loops:



NSTX FY09 Research Milestone Data Successfully Obtained

- DOE Joint milestone: *"Conduct experiments on major fusion facilities to develop understanding of particle control and hydrogenic fuel retention in tokamaks"*
  - Gas balance measurements show high (~90%) prompt retention values during ohmic and NBI-heated discharges, higher with Li
  - Sample probe enabled post-shot analysis of surface chemistry during normal and Li operation (in collaboration with Purdue)

- **R(09-1) Understand RWM stabilization and control vs. rotation**
  - Data-set varying fast-ion density and source-mix obtained and under analysis
- **R(09-2) Study how j(r) is modified by super-Alfvénic ion driven modes**
  - Variations in NBI power modified BAAE/EPM burst frequency, enable time-resolved measurement of MSE → J(r,t) (in progress)
- **R(09-3) Perform high-elongation wall-stabilized plasma operation**
  - Record low flux consumption, sustained β_T = 15-20% extended to 20-30%

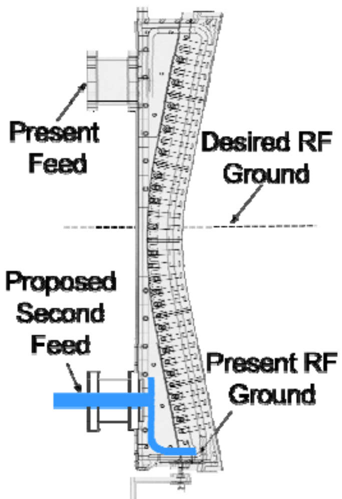
NSTX FY2009-11 Research Milestones
(base and incremental)

	FY2009	FY2010	FY2011
Expt. Run Weeks:	16 w/ ARRA	17 (20)	14 (20)
1) Transport & Turbulence			Study turbulence regimes responsible for ion and electron energy transport (formerly FY2010)
2) Macroscopic Stability	Understand physics of RWM stabilization & control vs. rotation	Assess sustainable beta and disruptivity near and above the ideal no-wall limit	Assess sustained operation above the no-wall limit at reduced collisionality
3) Boundary Physics		Assess H-mode characteristics as a function of collisionality and lithium conditioning	Relationship between lithiated surface conditions and edge and core plasma conditions
4) Wave-Particle Interaction	Study how j(r) is modified by super-Alfvénic ion-driven modes	Characterize HHFW heating, CD, and ramp-up in deuterium H-mode *Joint milestone w/ solenoid-free TSG*	Assess predictive capability of mode-induced fast-ion transport
5) Solenoid-free start-up, ramp-up			
6) Advanced Scenarios & Control	Perform high-elongation wall-stabilized operation at lower n_e	←	Dependence of integrated plasma performance on collisionality *(FY2010 incremental accelerates this by 1yr if LLD and/or HHFW achieve FY2010 goals)*

Joint Research Targets (3 US facilities):

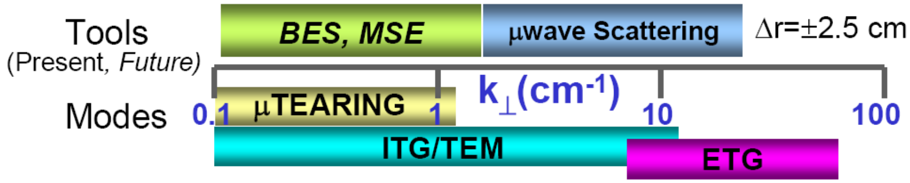
	FY2009	FY2010	FY2011
	Particle control and hydrogenic fuel retention	Understanding of divertor heat flux, transport in scrape-off layer	Characterize H-mode pedestal structure

NSTX FY09-11 Upgrades Support High Priority Research



2009-11

Higher-power fast-wave e-heating + ELM avoidance for ramp-up and sustainment of H-mode plasmas

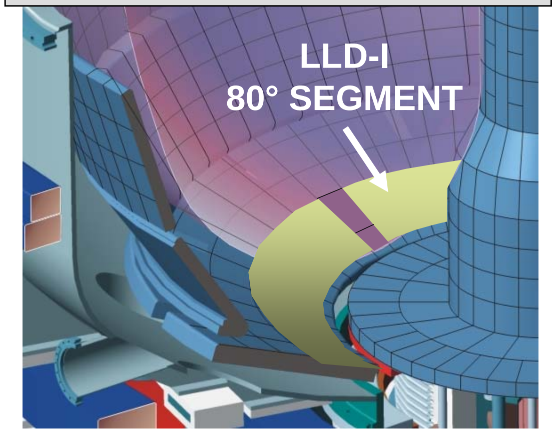


2010-11

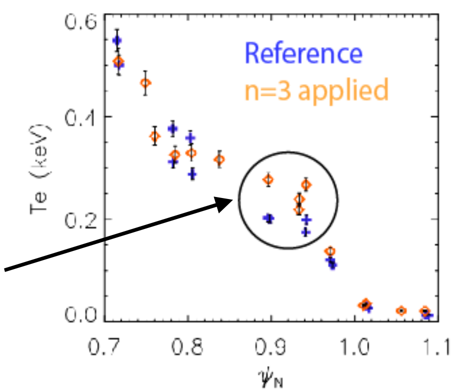
BES to complement high-k scattering e-turbulence measurements to develop predictive capability for ST transport, measure Alfvén eigenmode ξ(r, t)

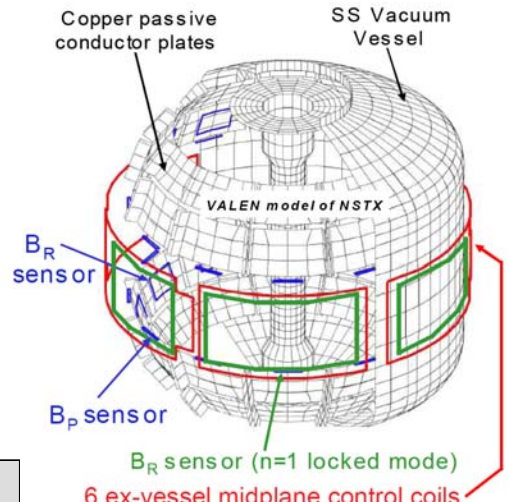
2010-11

Liquid lithium divertor (LLD) for particle control for higher NBI current-drive fraction, assess impact of liquid Li on edge transport and ELMs



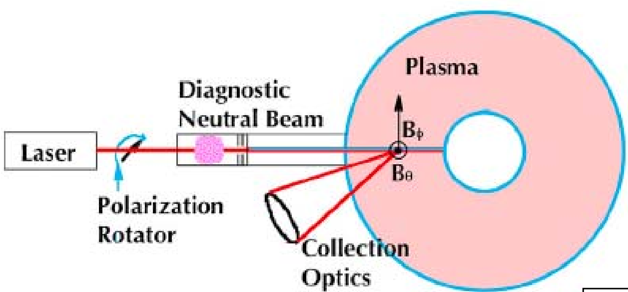
Pedestal change during n=3 RMP ELM triggering





2011

Higher resolution edge Thomson + independent control of all 6 3D field coils for improved edge diagnosis and control



2011

MSE-LIF for pitch angle & |B| w/o heating beam, E_r(r) – especially beneficial for HHFW and energetic particle research

High Priority Research Areas Identified in Program Letter:

- Operation of the Liquid Lithium Divertor
- Understanding H-mode pedestal structure
- Scrape-off-layer transport, divertor power exhaust
- Upgraded HHFW system for heating and I_P ramp-up

- NSTX research in preparation for NSTX Upgrade
  - Long-pulse pumping, power-handling
  - Enhanced control capabilities

Subsequent pages show the "Key Collaboration Opportunity" text from the program letter with

most important elements highlighted in red

Key Collaboration Opportunities in I. Macroscopic Plasma Physics

- **Exploit improvements in fast-wave heating** of high-beta predominantly NBI-heated H-mode plasmas **to improve understanding of RWM and NTM** stability as a function of **varied fast particle content, toroidal rotation, and core electron/ion collisionality**.

- Aid in the development of **real-time diagnosis and control of rotation** using magnetic braking to enable **controlled variations of the plasma rotation for RWM and NTM** stability and confinement research

- Aid in the diagnosis, analysis, and simulation of **disruption precursor onset and disruption evolution** – especially the thermal quench and halo-current dynamics.

- Assess and develop **novel techniques for disruption mitigation via** very rapid density build-up from **efficient edge and/or core fueling**.

Key Collaboration Opportunities in
II. Multi-Scale Plasma Physics

- Lead or assist in the development and implementation of **high time and spatial resolution rotation diagnostics for the near-edge region** to improve understanding of **flow-damping from 3D magnetic fields**, the relationship between the flow and flow-shear and turbulence in the **H-mode pedestal region**, and the physics of the **H-mode transition**.

- Develop, utilize, and optimize the **upgraded high-harmonic fast-wave** system for **core electron heating for electron transport and turbulence studies** in L-mode and H-mode, and as a means of producing low collisionality plasmas with **reduced momentum and particle input** for momentum and particle transport studies.

- Participate in diagnosis, experiments, and analysis **exploring impurity transport** from the edge to the core, and linkages to inward momentum pinch physics. Utilize existing and/or new main-ion and impurity **edge particle sources for perturbative particle transport** experiments.

Key Collaboration Opportunities in

III. Plasma Boundary Interfaces (I)

- **Particular emphasis will be placed on** characterizing and understanding the particle pumping, thermal response, and power-handling of **the liquid lithium divertor (LLD)** module under both steady-state and transient conditions (such as ELMs and disruptions).

- **Enhance spectroscopy and other diagnostics of the divertor and main chamber to improve understanding of divertor and wall pumping, retention, and impurity generation** - including transport of lithium and other impurities from the plasma edge into the pedestal and core.

- Also, perform scoping studies and initial testing of **high efficiency core and edge fueling techniques for LLD operation**.

- Perform experiments and simulations to aid in the development of predictive capability for **SOL and divertor thermal, particle, and heat-flux widths**. Develop **techniques for heat-flux mitigation** compatible with the anticipated enhanced divertor particle pumping of the LLD.

Key Collaboration Opportunities in
III. Plasma Boundary Interfaces (II)

- **Participate in LLD operation**, experiments, and data analysis contributing to the research, development, and laboratory tests of **long-pulse, high-heat-flux, and high particle pumping efficiency divertor concepts** applicable to NSTX, the proposed NSTX Upgrade, and future fusion devices.

- Implement diagnostics, and perform experiments, data analysis, and simulations to develop a predictive capability for the **H-mode pedestal structure and stability**.

- **Optimize the H-mode performance for high thermal confinement, small/no ELMs, density control, and acceptable impurity accumulation.** Utilize evaporated and liquid lithium, externally applied 3D fields, boundary shaping, and other techniques to develop edge localized mode (ELM) suppression, triggering, and control.

Key Collaboration Opportunities in

IV. Waves and Energetic Particles

- **Measure HHFW wave-fields** and RF-induced changes in the plasma core and edge **to test fast wave heating and coupling simulation codes**.

- Characterize the impact of HHFW power on the edge plasma and structures near the antenna, and **develop means to maintain high heating efficiency during edge transients** – in particular during edge-localized-mode (ELM) activity associated with H-mode operation.

- Perform experiments to **measure fast-ion acceleration by the HHFW** and develop means to modify and **minimize the interaction between the HHFW and NBI fast-ions**. Utilize several of the measured moments of the fast-ion distribution function to test linear and non-linear fast-ion instability simulations and **develop a predictive capability for fast-ion transport** by fast-ion-driven instabilities for CTF and ITER.

- Perform additional measurements and experiments to **determine the correlation between edge density fluctuations and fluctuations in the B-X-O transmission** efficiency.

Key Collaboration Opportunities in
V. Start-up and Ramp-up

- Measure HHFW wave-fields in the plasma core and edge to **assess HHFW coupling and heating efficiency during the plasma current ramp-up**, measure the production/acceleration of fast ions by HHFW, and measure/infer the sources of **non-inductive current drive during the RF-driven current ramp-up**.

- **Diagnose and simulate CHI plasmas to improve start-up plasma** energy and particle content to **provide higher temperature and beta target plasmas** for non-inductive ramp-up techniques such as HHFW and NBI.

- Measure CHI plasma density, impurity content, and radiated power to **characterize CHI start-up power balance with and without additional heating power (ECH and HHFW)** in the presence of a metallic outboard divertor and lithium.

Key Collaboration Opportunities in
VI. Physics Integration

- **Aid in experiments** to measure and modify non-inductive current drive sources at reduced density, measure possible beam current-drive redistribution from MHD activity and fast-ion instabilities, and measure the energy, momentum, and particle confinement properties and the full spectrum of plasma turbulence of **discharges optimized for high non-inductive current drive fraction and long pulse duration**.

- Test the compatibility and efficiency of **HHFW core electron heating with NBI-driven H-mode operation**, and the impact of RF heating on core **impurity accumulation and control**.

- **Develop real-time diagnostics and analysis tools** for the plasma beta, rotation, current profile, and proximity to stability limits to improve plasma control **to sustain high plasma performance and to avoid and/or mitigate disruptions.**

Summary

- NSTX operating very well in FY2009
- All research milestone data obtained, under analysis

- Exciting FY10-12 opportunities in program letter emphasizing:
  - Operation of the Liquid Lithium Divertor
  - Understanding H-mode pedestal structure
  - Scrape-off-layer transport, divertor power exhaust
  - Upgraded HHFW system for heating and I_P ramp-up
  - NSTX research in preparation for NSTX Upgrade

The NSTX program thanks the PAC for helpful suggestions to improve the program letter!