NSTX

Supported by

U.S. DEPARTMENT OF ENERGY | Office of Science

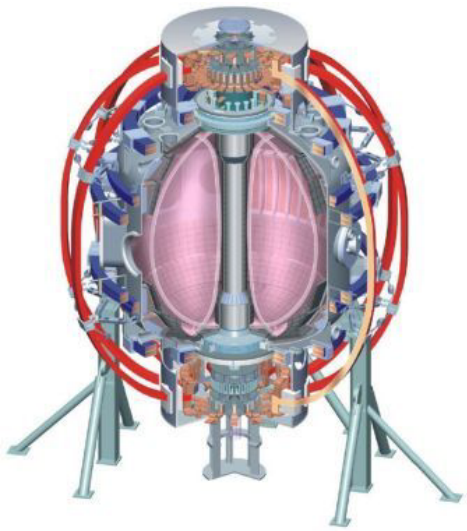
# NSTX FY 2009 Run Plan


**R. Raman (Run Coordinator)**
**University of Washington**

**E. Fredrickson (Deputy)**
**Princeton Plasma Physics Laboratory**


**25th NSTX PAC Meeting**
**February 18-20, 2009**
**PPPL, Princeton, NJ**

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
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin



Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

# Outline

- FY 2009 Research goals
- Research program organized by Topical Science Groups (TSGs)
  - Macro-Stability (Steve Sabbagh, Stefan Gerhardt)
  - Wave Particle Interactions (Gary Taylor, Eric Fredrickson)
  - Transport and Turbulence (Kevin Tritz, Stan Kaye)
  - Boundary Physics (Vlad Soukhanovskii, Rajesh Maingi)
  - Solenoid-free plasma startup (Dennis Mueller, Roger Raman)
  - Advanced Scenario Development (Dave Gates, Jon Menard)
  - Lithium Research Thrust (Charles Skinner, Bob Kaita)

**Collaborators**

- Run plan schedule

# Program Planning Steps

- NSTX Results Review (August 6-7, 2008)

- NSTX Research Forum (December 8-10, 2008)
  - *NSTX Milestones and direct ITER high priority research &*
  - *ITPA contributions* used to guide research plan
  - 106 experimental ideas, totaling 112 days (for 14 week run)
    - Strong influence from ITER/ITPA tasks
    - Most proposals consistent with TAP recommendations

- 14 – 20 Run Weeks (70 to 100 days) during 2009
  - 32 collaborators proposed experimental ideas
  - Expect to execute 30-40 proposals
  - Under 20 week plan
    - Likely operate with reversed Toroidal Field
    - Considering possibility of reversing plasma current as well

# FESAC Toroidal Alternates Panel (TAP) recently prioritized issues and gaps for the Spherical Torus (ST) for the ITER era

**"Tier 1" issues and key questions from TAP, and NSTX goals:**

1. **Startup and Ramp-Up:** Is it possible to start-up and ramp-up the plasma current to multi-MA levels using non-inductive current drive w/ minimal or no central solenoid?
   - Increase solenoid-free startup currents and ramp 200kA discharge using HHFW

2. **First-Wall Heat Flux:** What strategies can be employed for handling normal and off normal heat flux consistent with core and scrape-off-layer operating conditions?
   - Lithium as a divertor component, study SOL thermal transport, ELM suppression and controlled ELM triggering, test disruption mitigation

3. **Electron Transport:** What governs electron transport at low-A & low collisionality?
   - Confinement scaling with beta, GAE modes, TAE avalanches and their effect on transport

4. **Magnets:** Can we develop reliable center-post magnets and current feeds to operate reliably under substantial fluence of fusion neutrons?
   - Design studies in support of NSTX-U and NHTX

# Run Plan Addresses NSTX FY2009 Research Milestones

- DOE Joule milestone: *"Conduct experiments on major fusion facilities to develop understanding of particle control and hydrogenic fuel retention in tokamaks"*
  - *…identify the fundamental processes governing particle balance by systematically investigating a combination of divertor geometries, particle exhaust capabilities, and wall materials.*
  - *…NSTX is pursuing the use of lithium surfaces in the divertor…*
- R(09-1) Understand the physics of RWM stabilization and control as a function of rotation
  - RWM stabilization mechanisms will be characterized over a wide range of plasma rotation and collisionality conditions
- R(09-2) Study how j(r) is modified by super-Alfvénic ion driven modes
  - Emphasis on the effects of AE modes on the beam CD profile
- R(09-3) Perform high-elongation wall-stabilized plasma operation
  - Assess BS current at high k and q, and NBICD at low density - operating near the ideal-wall limit, preparing to implement NBI beta feedack

# Structure of the NSTX FY2009 Run

- Early Run (weeks 1-4)
  - Begin research on FY09 Joule Milestone on hydrogenic retention
  - Pre-Li operation phase (need to complete pre-Li experiments)
  - Begin research milestones
- Mid Run (weeks 5-10)
  - Start with Li-dropper test
  - Continue with high priority research milestones
  - Goal is to complete research milestones during first 10 weeks

Run assessment

  - Progress towards Milestone Achievement
  - Opportunities for further scientific advances
  - Decisions
    - Finalize reversed $B_T$ and/or $I_P$ experiments
- Late Run (weeks 11-14) possibly to 20 weeks
  - Experiments based on Mid Run assessment

# NSTX participation in International Tokamak Physics Activity (ITPA) benefits both ST and tokamak/ITER research

## Actively involved in 21 joint experiments – contribute/participate in 33 total

**MHD, Disruption Control**

- MDC-2 Joint experiments on resistive wall mode physics
- MDC-4 Neoclassical tearing mode physics – aspect ratio comparison
- MDC-12 Non-resonant magnetic braking
- MDC-14 Rotation effects on neoclassical tearing modes
- MDC-15 Disruption database development
- MDC-17 Physics-based disruption avoidance

**Transport and Confinement**

- TC-1 (was CDB-2) Confinement scaling in ELMy H-modes: beta degradation
- TC-2 (was CDB-10) Power ratio – Hysteresis and access to H-mode with H~1
- TC-4 (was CDB-12) H-mode transition and confinement dependence on ionic species
- TC-6 Effect of Rotation on Plasma Performance
- TC-10 (was TP-7) Experimental ID of ITG, TEM and ETG turbulence + comparison w/ codes
- TC-15 Dependence of momentum and particle pinch on collisionality

**Energetic Particles**

- EP-2 Fast ion losses and redistribution from localized *AE

**Pedestal and Edge Physics, Divertor, Scrape-off Layer**

- PEP-6 Pedestal structure and ELM stability in DN
- PEP-19 Edge transport under the influence of resonant magnetic perturbations
- PEP-25 Inter-machine comparison of ELM control by magnetic field perturbations from midplane RMP coils
- DSOL-17 Cross machine comparisons of pulse-by-pulse deposition
- DSOL-21 Introduction of pre-characterized dust for dust transport studies in divertor and SOL

**Integrated Operation Scenarios**

- IOS-4.1 Access conditions for hybrid with ITER-relevant restrictions
- IOS-5.1 Ability to obtain and predict off-axis NBCD
- IOS-5.2 Maintaining ICRH coupling in expected ITER Regime

# Run-time guidance for FY2009 run

- FY2009 run-time allocation = 14 run weeks = 70 run days
- 8 days for cross-cutting + calibrations → 62 run days available for TSGs
- Complete 1st priority experiments with 75% of total → 47 run days
  - Joule and research milestone XPs are highest priority, and should be completed within this run-time allocation
- TSGs should develop plans for 1st +2nd priority according to allocation below
  - TSG's are NOT guaranteed to receive the full allocation shown
  - Actual allocation will be decided at mid-run assessment

| Topical Science Group | 1st priority XP run days | 1st + 2nd priority XPs | Milestones |
|---|---|---|---|
| Boundary Physics | 7 | 9 | Joule |
| Transport & Turbulence | 6 | 8 | |
| Macroscopic Stability | 7 | 9 | R(09-1) |
| Wave-particle Interactions | 7 | 9 | R(09-2) |
| Solenoid-free Start-up | 6 | 8 | |
| Advanced Scenarios and Control | 7 | 9 | R(09-3) |
| Lithium Research Thrust | 3 | 4 | Joule |
| ITER High Priority Research | 4 | 6 | |
| Total | 47 | 62 | |

# Boundary Physics (7 days)

- Milestone (3.5 days)
  - FY09 Retention & Pumping
  - FY10 SOL thermal transport
  - Shear, rotation in ELM & pedestal stability
- ITPA (1 day)
  - Magnetically triggered ELMs
- ITER (1 day)
  - ELM suppression
- Other high priority NSTX/ST research (1.5 days)
  - SGI fuelling
  - Snowflake divertor test (priority 2)

# Lithium Research Thrust (3 days)

- Milestone (1 day)
  - FY09 Retention & Pumping (+1 day from Edge Phys.)
- Other high priority NSTX/ST research (2 days)
  - Li powder dropper (1)
  - Pre-LLD target plasma development (1)

# MHD Physics (10.5 days)

- Milestone (2 days)
  - Fast particle effects in RWM stabilization
  - Improve <beta-N> during pulse
- ITPA (5.5 days)
  - Search for n=3 EF source in NSTX
  - EF threshold in high-beta plasmas
  - Effect of RWM stabilization on background plasma
  - NTV physics at varied $\upsilon_i^*/q\omega_E$ and search for offset rotation
  - Error field influence on 2/1 NTM onset through rotation
  - NSTX DIII-D aspect ratio comparison of 2/1 NTM physics
  - Effects of impurities and wall conditions on NTM stability
  - Disruption mitigation using CHI (priority 2)
- ITER (2 days)
  - Formation and suppression of disruption runaways
  - Effect of toroidally localized field perturbations: ITER Test Blanket assessment
- Other high priority NSTX/ST research (1 day)
  - Optimize squareness

# Wave Particles (7.5 days)

- Milestone + ITPA (7.0 days)
  - HHFW edge effects
  - HHFW heating & current phase scans in H-mode
  - HHFW-Assisted startup & ramp-up (assess in WPI & develop in SFPS)
  - TAE Avalanche Transport
  - GAE Modes & Transport
  - Current profile modifications & fast ion loss from BAAE/EPM
  - Search fro EP-induced GAM (EGAM) [Piggy back on HHFW-assisted Ip ramp-up]

- Other high priority NSTX/ST research (0.5 days)
  - FIDA Validation in Quiet Plasma

# Transport & Turbulence (8 days)

- Milestones (0.5 day)
  - Search for micro tearing modes (FY10)
- ITPA (2.5 days)
  - Beta degradation of confinement in weakly shaped plasmas
  - Dependence of momentum and particle pinch on collisionality
  - Characterization of GAE modes & their effect on electron thermal transport
- ITER (2 days)
  - L-H threshold studies
- Other high priority NSTX/ST research (3 days)
  - Dependence of L-H power threshold on x-point radius
  - T&T in negative triangularity plasmas
  - Comp. of impurity poloidal velocity on NSTX & DIII-D
  - Sustained ITBs / H-mode ITBs

# Solenoid-free plasma startup (6 days)

- Other high priority NSTX/ST research (6 days)
  - Improved coupling of transient CHI started discharges to induction with 0 pre-charge
  - CHI absorber arc avoidance
  - HHFW assisted startup and ramp-up using low $I_P$
- Collaborate on DIII-D PF-only start-up experiments

# Advanced Scenarios Control (7.5 days)

- Milestone (3 day)
  - Optimization of high beta-T discharges
  - Optimizing high beta-p scenarios
- ITPA (2.5 days)
  - Validation of NBI-CD models on NSTX
  - Optimization of magnetic ELM pacing for small ELMs
  - Optimize fuelling with ELM control using 3D fields to reach steady state density and radiated power
- Other high priority NSTX/ST research (2 days)
  - Development of intermediate triangularty discharge with Li coatings
  - Strike point control

# NSTX FY2009 run plan contributes strongly to ST development and to ITPA/ITER

- Based on 14 week base plan
  - 49.5 Expt. Run Days
  - 7 days for commissioning
  - 13.5 days to be allocated after

- 35% directly for research milestones
- 60% contribute to Tier 1,2,3 TAP physics issues:
  - Tier 1: Start-up/ramp-up, PMI issues, electron transport
  - Tier 2: Integration, Disruption, 3D Fields & Tier 3:NTMs
- 49% contribute directly toward ITPA tasks
- 10% for high priority ITER research

# NSTX research priorities for possible **increased run-time in FY2009: 14 → 20 run weeks**

**Background:** Topical science groups requested 2x more run-time than is available in 14 run-week campaign

- Boundary physics: 3× over-subscribed, wave-particle interactions: 2-3×
- Increased run-time of ~20 run-weeks would be very well utilized

***Highest priority (3-4 run weeks)***

- Additional run-time for boundary physics
  - Hydrogenic retention with/without Li coatings (FY09 Joule milestone)
  - ELM suppression with Li/RMP, ELM triggering with RMP (ITER)
  - Li powder dropper development, scenario prep for LLD operation
- Additional run-time for wave-particle interactions
  - TAE avalanches and fast-ion transport (FY09 research milestone, ITER)
  - First ops of high-power HHFW antenna, test BS-overdrive ramp-up
- Increased run-time for ITER high priority

***2nd highest priority (3-2 run weeks)***

- Consider first NSTX reversed $B_T$ and/or $I_P$ campaign
  - New physics: RWM damping, momentum transport/NTV, TAE stability

# Rationale for reversed $B_T$ and/or $I_P$ in 20 run week scenario

- Can only perform reversal(s) in ~20 week run due to time required to complete milestones and reconfigure machine
- Several topical science areas could gain significant new understanding from reversed $B_T$ and $I_P$
  - T&T, Wave Particles and MHD would benefit from $B_T$ + $I_P$ reversal
  - Boundary Physics and Solenoid-free startup could benefit from reversal of $B_T$ alone
- Should be done prior to installation/operation of LLD

# Experiments that would benefit from $B_T$ and/or $I_P$ reversal

- Reversed $B_T$ and $I_P$
  - Global confinement scaling with $I_P$, $B_T$, and NBI
  - RWM stabilization physics investigation in counter injection
  - Search for EP-Induced GAM (EGAM)

- Reversed $B_T$
  - Edge characterization - many poloidal drifts change directions
    - Divertor detachment access (grad-B drift dependent)
    - Density pumping with LITER (grad-B dependence?)
    - L-H threshold
    - ELM stability
  - Operation of CHI with outer electrode as cathode (reference discharge for FY10 outer metal divertor)

# NSTX FY2009 run plan contributes strongly to ST development, ITPA/ITER, and toroidal plasma science

We look forward to an exciting and productive

NSTX FY2009 run campaign!