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The NSTX FY2005 Run Plan

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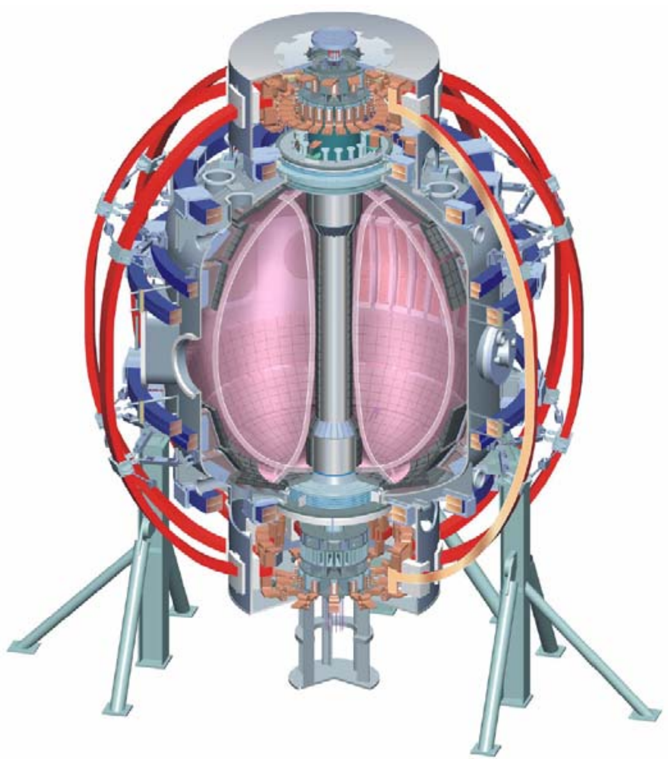
Presented for the NSTX Team



17th NSTX PAC Meeting

January 20 – 21, 2005

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NSTX is advancing fusion science through research on many topical fronts

- NSTX research goals reflect an ultimate goal of integrating:
  - Sustained operation with β far above the no-wall stability limit
  - Plasmas with benign, or possibly beneficial fast-ion-driven instabilities
  - An understanding of core thermal transport to the point of controlling it
  - Good edge stability and transport while avoiding reactor damage
  - Plasma initiation techniques to eliminate the solenoid in a reactor
- These goals apply to tokamak fusion reactors in general and are not unique to the spherical torus.
- This presentation will describe:
  - Organization of the NSTX research team
  - Overview of NSTX research goals
  - Specific plans for the FY05 run to achieve these goals
  - **NSTX contributions to ITER-relevant research & the world program**

Experimental Task Group Structure

- **Experimental Task (ET) groups, leaders, and deputies:**

1.	Macroscopic Stability*	(D. Gates, S. Sabbagh)
2.	Wave-Particle Interactions*	(C. Phillips, R. Wilson)
3.	Transport and Turbulence*	(S. Kaye, D. Stutman)
4.	Edge Physics*	(R. Kaita, J. Boedo)
5.	Solenoid-free Startup	(R. Raman, M. Bell)
6.	Integrated Scenario Development	(R. Maingi, C. Kessel)
–	Cross-cutting/Enabling	(All ETs eligible)

*** → tightly coupled to Priority Panel & ITPA structures**

Overview of highest priority research goals:

1. Macroscopic Stability

   Produce and characterize strongly shaped rotating plasmas close to the "wall-stabilized" pressure limits with error field correction.

2. Wave-Particle Interactions

   Assess the effects of supra-Alfvénic fast-ion-driven instabilities on driven current in plasma core.

3. Core Transport and Turbulence

   Characterize the effects of variations in the magnetic shear and gradients in T_e on electron transport in low-aspect ratio plasmas.

4. Edge Physics

   Characterize the plasma edge pedestals and scrape-off layer of low-aspect ratio, high confinement, high P/R plasmas.

5. Solenoid-free Startup

   Increase plasma current and duration of both CHI and PF-only generated solenoid-free startup plasmas.

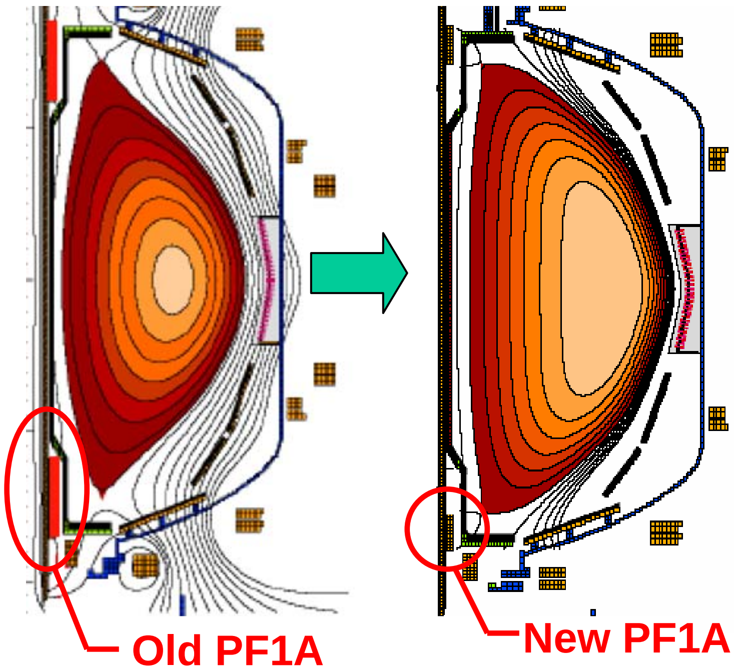
6. Integrated Scenario Development

   Characterize strongly-shaped low-A plasmas with high bootstrap fraction and low loop-voltage lasting for many current redistribution times.

Ability to operate far above the ideal-plasma no-wall limit reliably would significantly improve the efficiency of future fusion reactors

- Goal of sustained operation near ideal-wall limit motivates strong emphasis on error-field and RWM physics research
  - **Potential for high-performance (Q>5) steady-state scenarios in ITER**
  - Important element in achieving fully non-inductive operation in NSTX
  - NSTX is contributing strongly to this topical area with several new capabilities:

Enhanced shaping to increase no-wall and ideal-wall stability limits



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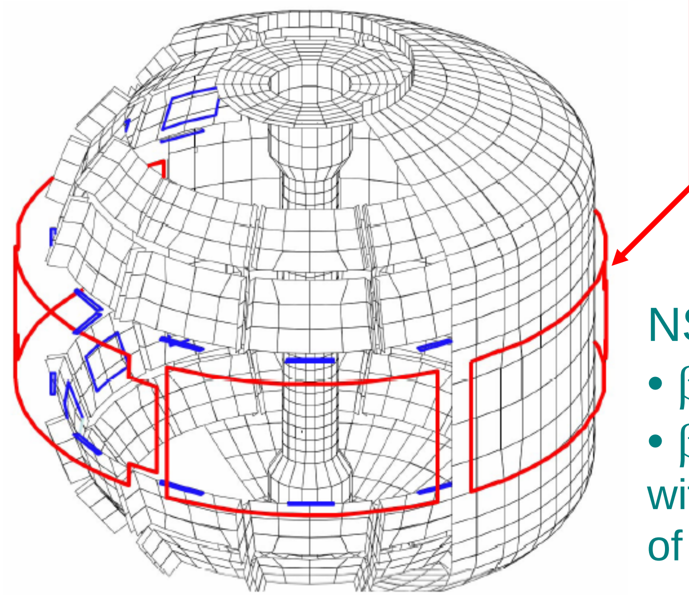
Ex-vessel non-axisymmetric coils to reduce error-fields and study/control RWM



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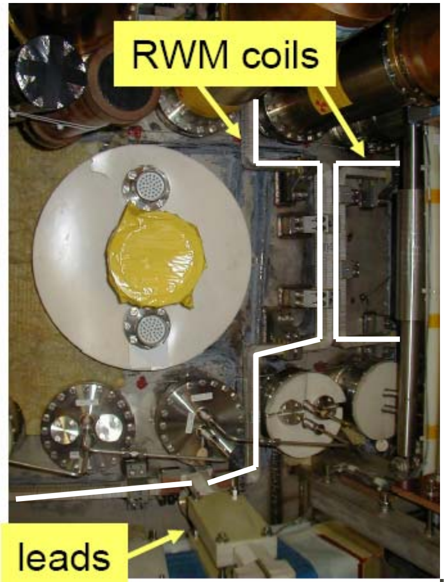
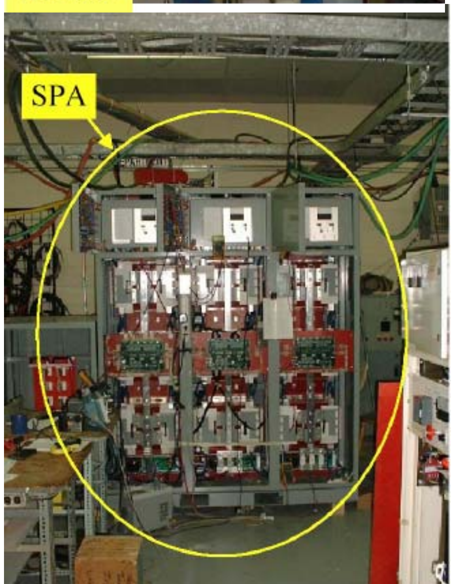
NSTX GOAL of:
- $\beta_N \approx 8$, $f_{BS} \approx 0.6$
- $\beta_T \approx 40\%$

with development of desired q profile

The full NSTX RWM/EF control system will be available and used by several topical groups in FY05





- All major hardware components now installed
  - 6 RWM/EF coils (vs. 2 coils in FY04)
    - Opposing coils to be connected anti-series
      - Odd-n only, but n=2 possible with coils in series
  - Switching Power Amplifier (vs. TRANSREX in FY04)
    - Can drive 3 coil-pairs independently
    - 7kHz switching frequency → < 1% ripple

- RWM/EF coil current control plan is in place
  1. Start with pre-programmed current capability
  2. Coil currents proportional to PF coil currents for pre-programmed error-field correction
  3. Implement real-time mode detection algorithms
  4. Develop closed-loop feedback algorithm
  5. Close feedback loop, begin control studies in FY06

Macroscopic Stability Overview

- FY05 research goal
  - Produce and characterize strongly shaped rotating plasmas close to the “wall-stabilized” pressure limits with error field correction

- Study impact of enhanced shaping (high κ + high δ) from new PF1A coils on macroscopic stability limits – both pressure and current limits

- Study impact of error field correction and RFA suppression on rotation dynamics, stabilization of RWM, and access to the ideal-wall limit
  - Study locking threshold physics, further correct intrinsic error fields in NSTX
  - Study critical rotation physics, develop rotation control techniques
  - Measure dispersion relation of stable RWM using MHD spectroscopy

- Utilize enhanced diagnostic and reconstruction capabilities to study stability physics near the ideal-wall limit (MSE & hi-res edge Thomson)
  - Already published sustained operation above the no-wall limit for $\tau >> \tau_{Wall}$
  - But, the ideal-wall limit is more sensitive to the q, p, and Ω_ϕ profiles.

Macroscopic Stability Experiments

- Impact of enhanced shaping
  - Stability limits vs. normalized current at high δ with new PF1A
    - *Quantify stability changes with higher edge q and q-shear*

- Error fields and RWM/RFA
  - Error-field/locked-mode physics studies using RWM coils
    - *Understand mode-locking threshold physics, correct NSTX error fields*
  - Suppression of resonant field amplification at high β_N
    - *Understand & suppress response to intrinsic & applied error fields*
  - Active control of rotation damping in RWM plasmas
    - *Quantify and control flow damping from RWM & other modes*

Macroscopic Stability Experiments (continued)

- RWM/EF physics
  - MHD spectroscopy of wall-stabilized high β plasmas
    - *Measure marginally stable RWM frequency and damping rate by measuring plasma response to applied n=1 traveling wave and compare to theory*
  - DIII-D/NSTX RWM similarity experiment
    - *Explore RWM physics in devices with similar $\Omega_\phi / \omega_{sound}$, different $\Omega_\phi / \omega_{Alfvén}$*
  - Dissipation physics of the RWM
    - *Use critical rotation measurements to study dissipation physics*

- Other global MHD
  - Onset and saturation characteristics of the 1/1 internal kink mode
    - *Study effect of rotational shear vs. diamagnetic flows on 1/1 stability at high-β*
  - Aspect ratio effects near high β_P equilibrium limit
    - *Examine aspect ratio dependence of rotation effects on high β_P & β_N equilibria*
  - Study of NTM excitation by fast-ion-driven instabilities
    - *Explore fundamental physics of NTM seeding*

NSTX macroscopic stability experiments are tightly linked to ITPA high-priority research

Low aspect ratio + new MHD control and diagnostic capabilities

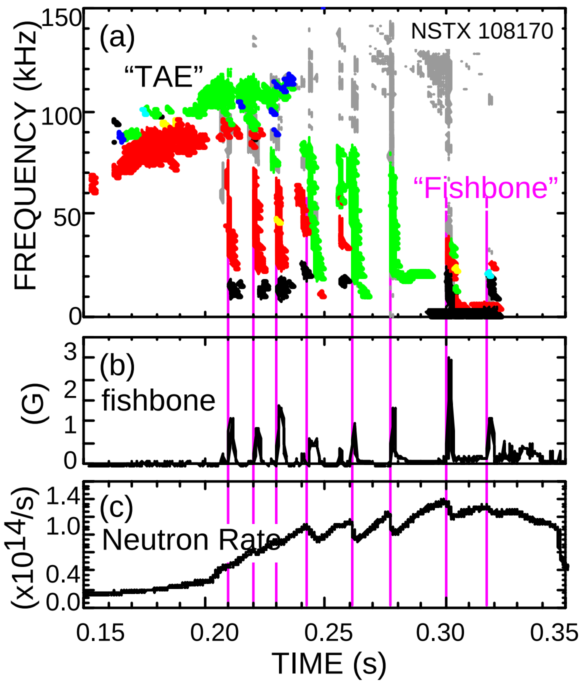
→ strong role in the MHD, disruption, and control (MDC) ITPA group

- MDC-2 Joint experiments on RWM physics
  - Studying RWM physics across devices aids understanding & application to ITER
  - NSTX is only ST with significant wall stabilization, active coils, and MSE
- MDC-4 NTM physics – aspect ratio comparison
  - Improve understanding of NTM seeding and mode coupling
- MDC-5 Sawtooth control for NTM suppression
  - 1/1 mode stability experiment to improve understanding of sawtooth and NTM
- MDC-6 Low-beta error-field experiments
  - ST offers unique low-B_T regime and geometry for understanding locking physics

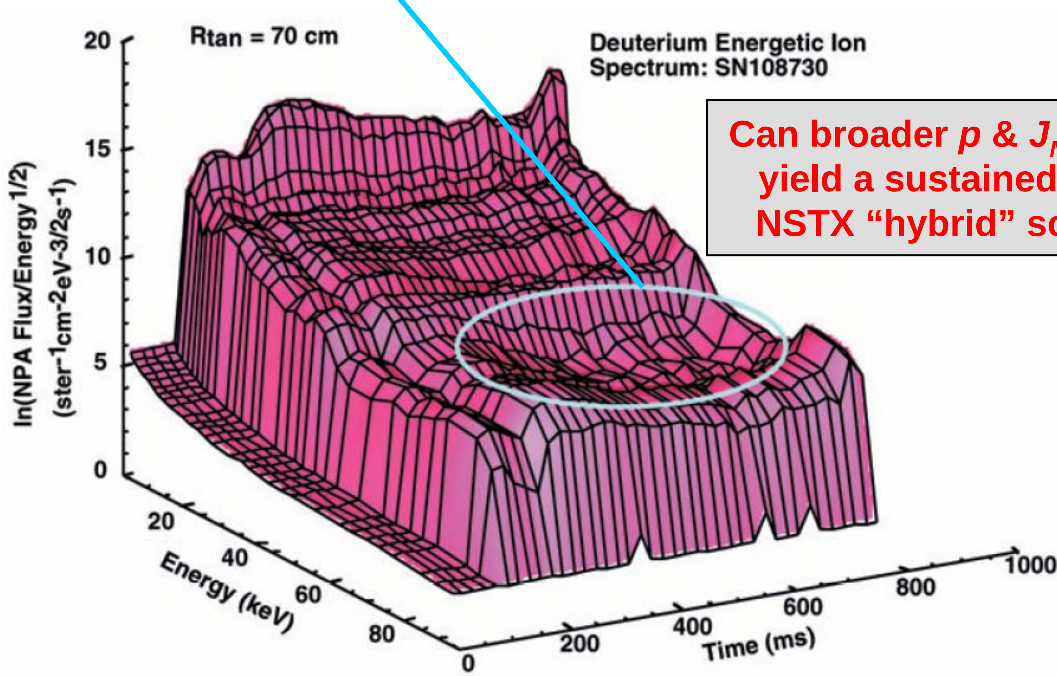
Good confinement of energetic particles is an obvious requirement for any burning plasma device

- Fast-ion-driven instabilities and associated energetic particle diffusion or loss could significantly impact device performance
  - **Expect "sea" of high-n TAE modes in future tokamak reactors such as ITER**
  - As in ITER, NSTX fast ions have $v_{fast} >> v_A$ and can excite several instabilities:

TAE and fishbone modes impact fast-ion population:



Continuous n ≥ 2 MHD leads to apparent fast-ion diffusion/loss above injection ½ energy → modified power deposition & J_{NB} ?



Can broader *p* & J_{NB} profiles yield a sustained q(0) > 1 NSTX "hybrid" scenario?

Wave-Particle Interaction Overview

- FY05 research goals:

  Assess the effects of supra-Alfvénic fast ion driven instabilities on driven current in plasma core.

- Study impact of fast-ion-driven instabilities on driven current
  - NSTX $v_{NBI\text{-}fast} / v_A \approx v_{NB,\alpha} / v_A$ in ITER - unique opportunity for ST contribution
  - Investigate changes in current profile resulting from fast-ion diffusion
  - Develop methods to modify fast-ion-driven instability behavior (NBI, HHFW)

- Integrated study of fast-ion MHD mode stability
  - Compare mode type, ω, **k**, and amplitude to *AE theory ***w/ known q profile***
  - Determine dependence on plasma parameters – especially operational scenario
  - Correlate fast ion loss/diffusion (FLIP, NPA, neutrons) with MHD activity

- Study HHFW edge interactions, loading, and core heating

- Measure EBW emission to model and optimize EBW launcher

Wave-Particle Interaction Experiments

- Current profile modifications from fast-ion MHD
  - Characterize J evolution of existing nearly “hybrid” scenarios
    - *Infer fast-ion diffusion by comparing diagnostic signatures to model (TRANSP)*
  - Develop techniques to modify fast ion population and MHD
    - *Needed for controlled study of fast-ion MHD impact on background plasma*
    - *Tools: NBI beam source, timing, voltage, target density (+ possibly HHFW)*
- Fast-ion MHD and associated fast-ion diffusion and loss
  - Study of fishbone mode and the beam-ion distribution function w/ SSNPA
    - *Vary fast-ion ω_{bounce} and $\omega_{precession}$ - study fast-ion diffusion caused by fishbone*
  - Study of TAE stability vs. central shear and q(0)
    - *Use improved knowledge of q to compare *AE theory to expt.*
  - Study of low-n continuous MHD diffusion/loss of fast ions in H-mode
    - *NPA spectrum → significant fraction of fast ions above 40keV can be lost*
  - DIII-D/NSTX CAE similarity experiment
    - *Study behavior vs. q and density, measure internal density fluctuations*

Wave-Particle Interaction Experiments (continued)

- HHFW experiments
  - Complete power modulation experiments
    - *Measure power deposition profile and electron transport properties*
  - Measure loading and heating with different equilibrium **B** and shape
    - *Reverse B_T, reverse I_P, reverse both together*
    - *Determine role of boundary geometry: LSN ←→ DND ←→ USN*
  - Fast ion damping scaling experiments on NSTX and DIII-D
    - *Study high-harmonic ion damping physics with similar v_{ion} / v_A*
  - Edge Interaction measurements
    - *Determine impact of parametric decay & sheath currents on power coupling*
- EBW experiments
  - Measure 20-40GHZ “O-mode” EBW emission
    - *28GHz is the proposed frequency for a MW-level EBW current drive system*
  - Measure X-mode emission with over-dense plasma
    - *Use local gas-feed to overcome previous under-dense conditions*

NSTX WPI group will contribute to both MD&C and Steady State Operations (SSO) ITPA research

- MDC-9 Fast-ion redistribution from *AE modes
  - The large fast-ion population, extreme geometry, and high β of the ST challenge and improve our understanding of fast-ion MHD for future burning plasmas
- SSO-2.1 Complete mapping of hybrid scenario

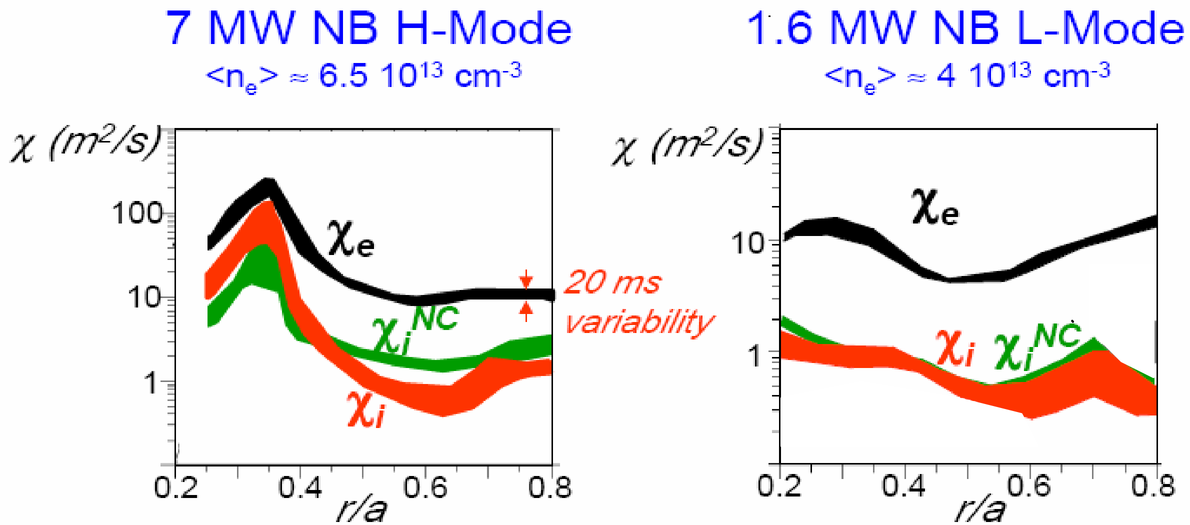
Background: The ITPA SSO group is expending considerable effort developing the "hybrid" scenario for ITER.

- A "hybrid" scenario is defined as a partially-inductively-driven discharge with _stationary_ current profile w/o sawteeth and with β < no-wall limit
  - *Variety of MHD modes appear to aid maintenance of q(0) > 1 in tokamaks*
- NSTX will begin its "mapping" by measuring current profile evolution and comparing to theory in long-pulse discharges
  - *Data already suggests fast-ion diffusion effects could be important*
  - *Very useful operational scenario until EBW-CD is ready*

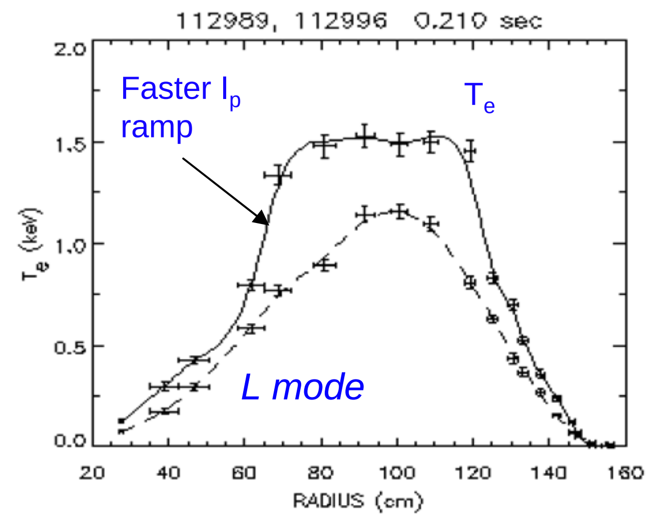
Understanding electron thermal transport remains a critical yet elusive element in extrapolating to future burning plasma devices

- Majority of heating power from α-slowing-down goes to electrons
  - **Energy confinement extrapolations to ITER based largely on scaling studies**
  - Ion transport better understood than electron, but much more work remains
  - **NSTX is a powerful laboratory for studying electron & ion transport physics:**

$\chi_e >> \chi_i$ in many scenarios & dominates power loss. $\chi_i \approx \chi_i^{NC}$ also commonly observed in rapidly rotating/high-β plasmas.



NSTX will study apparent dependence of electron transport on *q*-shear



Transport and Turbulence Overview

- FY05 research goal:

  Characterize the effects of variations in the magnetic shear and gradients in T_e on electron transport in low-aspect ratio plasmas

- Determine role of *q*-shear and ∇T_e in barrier formation
  - Use MSE-constrained reconstructions for 1st time in transport expts.

    (Did not measure *q*-shear and barrier formation simultaneously in '04)
  - Measure response of electron transport to heating perturbations

- Several diagnostic enhancements will aid transport studies
  - Enhanced Thomson resolution will increase accuracy of ∇T_e
  - Fast "two-color" SXR to measure rapid T_e profile changes
  - Low-k correlation reflectometry to measure core density fluctuations
  - MSE for measurements of coherent magnetic fluctuations (< 100kHz)

Transport and Turbulence Experiments

- Electron transport properties
  - Access e-transport change with varying *q*-shear
    - *Document existing transport barrier scenarios at 4.5kG*
    - *Vary e-heating during ramp to vary barrier (degree of q-reversal)*
  - Perturbative T_e studies of electron transport
    - *Perturb with HHFW modulation, low-Z impurity pellet, ELMs*
    - *Measure profile response with 2 color fast SXR arrays*
- Ion transport properties
  - MAST-NSTX ion ITB similarity experiment
    - *Study barrier formation as function of rotation rate and ExB shear*
  - Effect of ExB shear on turbulence levels
    - *Attempt to control rotation and shear to modify turbulence*
- Core fluctuation measurements – possibly piggyback
  - High-k scattering diagnostic commissioning/XMP
  - Low-k turbulence measurements

Transport and Turbulence Experiments (continued)

- Confinement/Transport Scaling
  - H-mode confinement scaling (with MAST) – finish B_T scan
    - *Determine if scaling variation with B is due to MHD or transport effects*
  - ν^*, β_T dimensionless scaling studies
    - *Differentiate electrostatic vs. electromagnetic turbulence induced transport*
  - ρ^* scaling – DIIID similarity
    - *Study ρ^*, β, A dependence of transport with matched shape, n, ν^*, and β_{pol}*
- H-mode physics
  - L-H threshold – MAST/NSTX identity (finish)
    - *Impact of magnetic balance on L-H threshold: DND ←→ SN with rtEFIT*
  - Ohmic H-mode physics
    - *Monotonic n_e profile → simultaneous core & edge fluctuation measurements*
- Reversed B_T and/or counter injection campaign at end of run
  - MAST & DIII-D → significant transport changes with counter-injection
  - Reversed B_T impacts L-H threshold (also early-H-mode USN long-pulse)

NSTX is making important contributions to the ITPA confinement database and transport physics

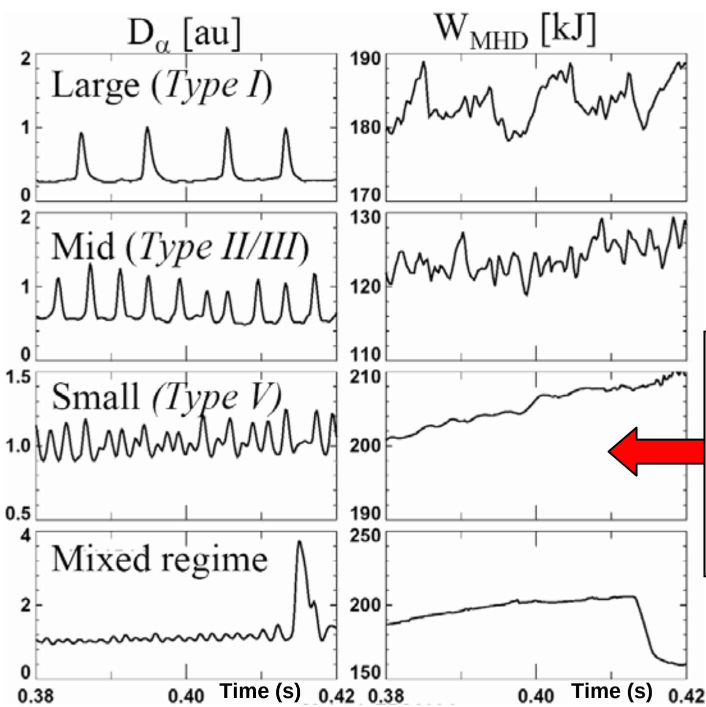
Contributions to the Confinement Database and Modeling (CDM) and Transport Physics (TP) ITPA groups:

- CDB-2 ELMy H-mode scaling with β
  - ST provides unique data at high-β for understanding H-mode confinement scaling
- CDB-6 Improvement of ELMy H-mode global and pedestal confinement scaling database for low-A devices
  - ST provides low-aspect-ratio data to improve and extend confinement scalings
- TP-8 MAST/NSTX ITB similarity experiments
  - ST aids understanding of transport barrier physics important for burning plasmas
- TP-9 DIII-D/NSTX ρ^* and aspect ratio comparison
  - ST probes large ρ^* limit of transport with similar poloidal dimensionless params.

Edge heat and particle fluxes must be minimized and controlled in future burning plasma devices

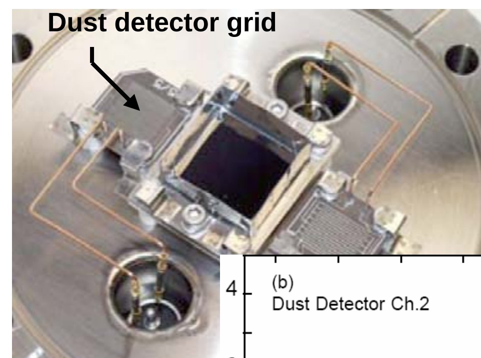
- H-mode operation improves global confinement and stability, but…
  - **Large divertor heat load transients from ELMs are unacceptable in ITER**
  - Understanding and controlling pedestal confinement/stability will be essential
  - **NSTX can study this boundary physics with reactor-relevant heat-loading:**

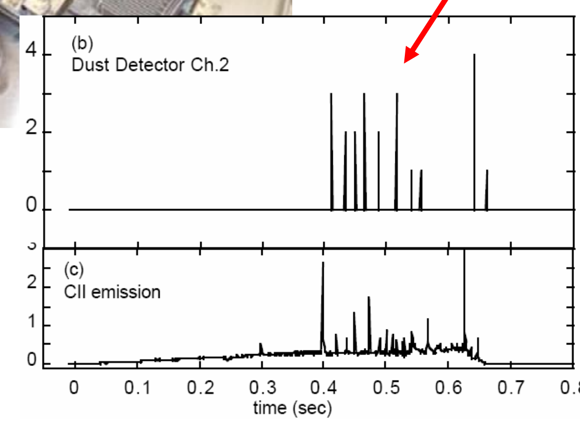
ELM type varies with shape & ν^*_e.
Role of squareness and high δ will be measured



Small ELM regime found for $\nu^*_e > 1$ for wide range of q_{95} =5-10

Quartz microbalance and e-static particle detectors measure deposition and dust
Dust particle formation/transport correlated with ELMs:





Edge Physics Overview

- FY05 research goals:

  Characterize the plasma edge pedestals and scrape-off layer of low-aspect ratio, high confinement, high P/R plasmas

- Systematically vary edge plasma parameter regime and study full range of boundary transport mechanisms
  - Vary boundary shape, density, temperature, and fueling
  - Study ELMs, broadband transport, and intermittent transport "blobs"
  - Characterized H-mode pedestal height, width, and gradient
  - Characterize impact of ELMs and reconnection events on the edge pedestal, divertor, and plasma facing components

- Implement new impurity injection and fueling techniques

Edge Physics Experiments

- Pedestal and ELM physics
  - Pedestal scaling – DIII-D and MAST collaboration
    - *Pedestal height, width, gradients in ELMy H-mode vs. A and wall proximity*
    - *ELM radial extent, amplitude, frequency vs. A and wall proximity*
  - ELM dynamics, classification, and structure
    - *Obtain complete profile dataset to test edge stability before and after ELMs*
  - Type I ELM heat pulse propagation
    - *Use 2-color SXR to determine ratio of conductive/convective heat loss*
  - ELM control with RWM coils – DIII-D collaboration
    - *Apply $n > 1$ field with RWM/EF coils and measure pedestal response*
  - Study of small ELM regimes – C-MOD and MAST collaboration
    - *Compare NSTX Type-V ELM regime to high-β EDA mode on C-MOD*
  - Study ELM type/size versus boundary shape
    - *Vary elongation, triangularity, and squareness*

Edge Physics Experiments (continued)

- Edge transport and turbulence
  - Diagnose “simple-as-possible” MHD-quiescent L-mode plasma
  - Fast 2D tangential imaging of edge turbulence (“blobs”)
    - *NSTX/C-MOD turbulence scale-size comparison to resistive ballooning theory*
  - Role of edge flows on L-H transition using edge rotation diagnostic
- Divertor physics
  - SOL width scaling, profiles, and power balance measurements
  - Study outer divertor leg detachment physics
    - *Determine operational boundaries, develop radiative divertor regime*
  - Study MARFE physics and measure X-point fueling efficiency
- Fueling and edge control development and characterization
  - Lithium pellet injector (LPI): pellet deposition vs. mass, velocity, timing
  - Supersonic gas injector (SGI): quantify fueling efficiency
  - Edge biasing for density pumping and SOL control in H-mode plasmas

NSTX edge physics experiments are contributing directly to ITPA high-priority research

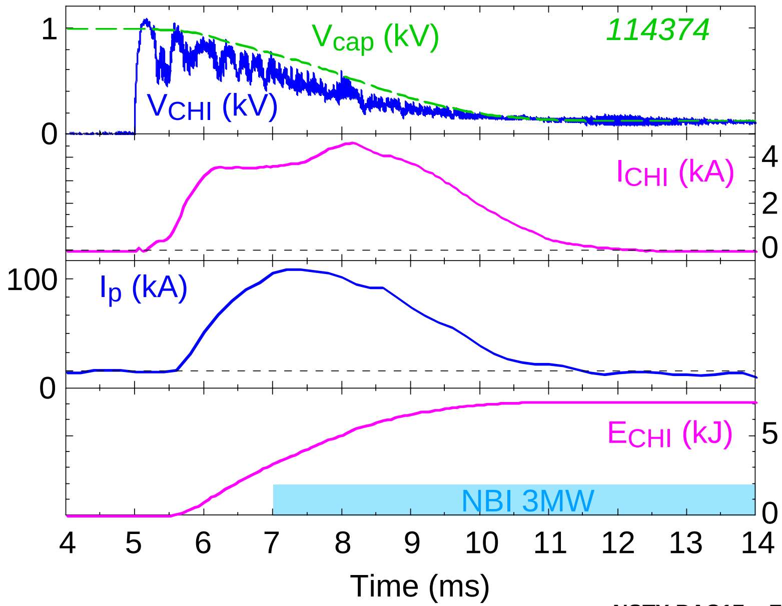
Contributions to the Pedestal and Edge Physics (PEP) and Divertor and SOL (DSOL) ITPA groups:

- PEP-9 NSTX-MAST-DIIID pedestal similarity
  - Exploit different aspect ratio and wall proximity to study pedestal and ELM physics
- PEP-16 CMOD-NSTX-MAST small ELM comparison
  - Understand physics leading to small ELM regimes essential for ITER
- DSOL-NEW Carbon migration/deposition
  - Develop and use new deposition & dust detection diagnostics applicable to ITER
- DSOL-15 Inter-machine comparison of blob characteristics
  - Study non-diffusive, intermittent transport dominant in SOL of fusion experiments

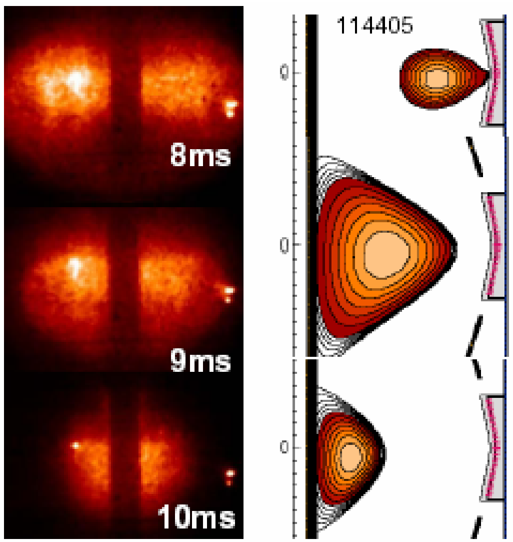
Development of solenoid-free startup techniques would benefit future reactors, and would be essential for a next-step ST

- Standard and low-aspect-ratio tokamak reactor design is significantly simplified if a central solenoid is not used for current drive.
  - **No incentive to give up solenoid yet - ITER τ_{burn} > 20 min. w/ hybrid scenario**
  - Difficult to achieve low aspect ratio while retaining a solenoid in an ST reactor
  - To minimize and/or eliminate the solenoid in the ST, NSTX is developing plasma formation techniques suitable for subsequent heating and current ramp-up:

Transient CHI - I_P < 140 kA, $I_P/I_{injector}$ < 40



PF-only startup - I_P < 20 kA



Solenoid-free startup overview

- FY05 research goal:

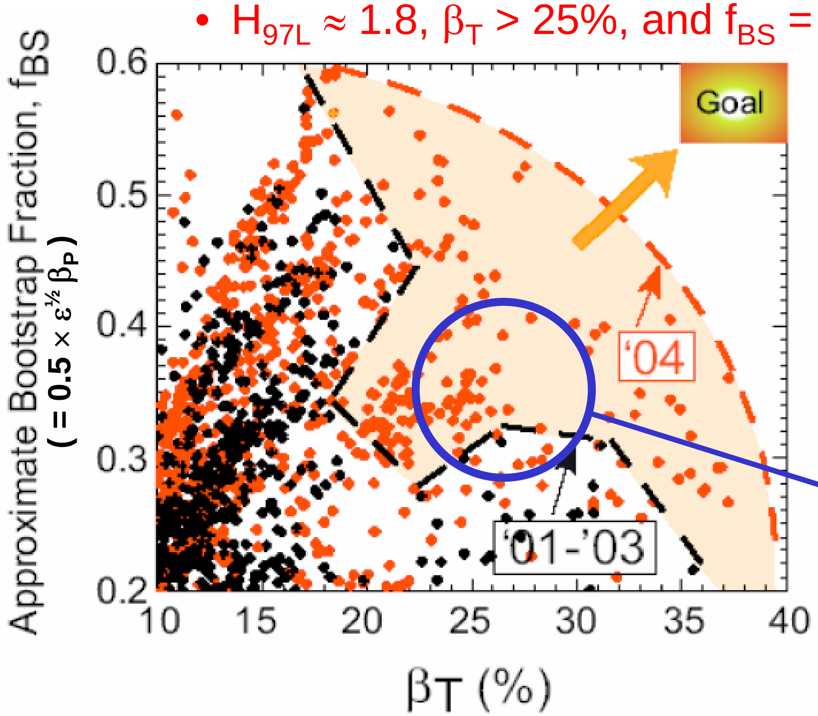
  Increase plasma current and duration of both CHI and PF-only solenoid-free startup plasmas
- CHI experiments will increase plasma formation efficiency by taking advantage of several technical improvements:
  - Lower pre-fill from pre-ionization in lower divertor chamber (ECPi)
  - Higher injector voltage = 2kV (was 1kV)
  - Faster cap-bank turn-off to measure I_P persistence (flux closure)
  - New electrostatically shielded I_P Rogowski coils for noise reduction
- PF-only start-up experiment will benefit from other upgrades:
  - Increased HHFW power for break down: 4 → 12 straps
  - CD_4 pre-fill, and/or use SGI for local pressure enhancement
  - PF4 and PF5 in opposite polarity for high-stored-flux scenario
  - Higher TF capability

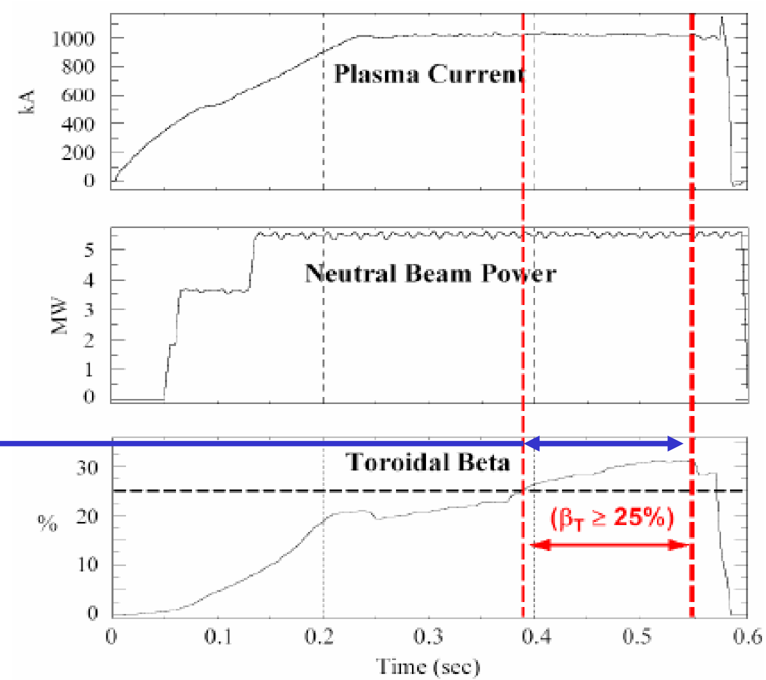
Solenoid-free Startup Experiments

- CHI experiments
  - Transient CHI
    - *Measure plasma current persistence and electron kinetic profiles*
    - *With suitable target, apply OH to transient CHI target*
  - Drive edge/SOL current in Ohmic LSN target with transient CHI
    - *Investigate evidence for edge current drive (as on HIT-II) – monitor l_i, n_e, T_e*
- Outer-PF only Startup
  - Large stored flux scenario using PF4
    - *Produce measurable plasma current, then optimize*
  - Small stored flux scenario will large null
    - *Improve radial position evolution to increase I_P from 20kA to 100kA*
  - Merging-compression using PF1A and PF5
    - *Induce plasma at X-pts near outboard divertor plates, then merge*
- Absorber field-nulling capability for high-I_P CHI
  - Commission absorber magnetic sensors

Integration of high-β, good confinement, and tolerable edge heat flux in steady state remains a fundamental challenge for magnetic fusion

- AT scenarios at standard aspect ratio are often limited by the available off-axis current drive needed to maintain desired *q*-profile
  - **In ITER, beam + BS current allow steady-state operation with Q > 5**
  - For ST's, EBW-CD is envisioned as the dominant off-axis *J*-profile control tool
  - In the near-term, NSTX will focus on raising f_{BS} (β_P) via shape & *q* profile
    - $H_{97L} \approx 1.8$, $\beta_T > 25\%$, and f_{BS} = 30-40% maintained for $4\tau_E \approx$ 160ms





Integrated Scenario Development Overview

- FY05 research goals:

  Characterize strongly shaped low-aspect ratio plasmas with high fractions of bootstrap current and low toroidal induction voltage for durations that allow internal currents to redistribute.

- Study impact of enhanced shaping from new PF1A coils on pulse-length and β utilizing significant non-inductive current drive from BS and NBI
- Progressively move toward lower B_T operation for long pulse-lengths
  - Obviously important for increasing β, but β_P (f_{BS}) drops at fixed β_N
  - Electron transport increases at lower B_T, shortening J diffusion time
  - Further optimize early J-profile modification techniques = early H-mode
- Utilize enhanced diagnostic and reconstruction capabilities to characterize current profile evolution and sources of current drive
  - MSE + rotation constrained reconstructions for J-profile evolution
  - TRANSP and other analysis tools for modeling NI current sources
- Continue to study HHFW coupling and heating issues to find operational regimes where HHFW-CD can supplement other CD sources

ISD Experiments

- Long-pulse development
  - Long pulse DN development with PF1A
    - *Scan plasma current and field and optimize long-pulse performance at high δ*
  - Very early diverting and H-mode
    - *Further reduce flux consumption and raise q with early H-mode*
  - Long flat-top plasmas at lower toroidal fields
    - *Combine results of above experiments, document with lower q for TSC*

- ELM physics for long-pulse
  - ELM amelioration/optimization in long pulse
    - *Apply results from ELM vs. shape XP + fueling variations to reduce ELM size*
  - Development of Upper Null H-modes
    - *Upper shoulder gas injector + USN + clean surfaces → reduce density rise?*

The experiments above contribute directly to hybrid scenario research

- ITPA SSO-2.1   Complete mapping of hybrid scenario

ISD Experiments (continued)

- Advanced fueling
  - Supersonic gas injector fueling for long pulse
    - *Improve H-mode access + ELM mitigation with efficient LFS gas source*
  - Shoulder gas injector fueling
    - *Study impact of inboard off-midplane injector on H-mode access and ELMs*

- Integration of HHFW into high-β long-pulse scenarios
  - Non-solenoidal I_P rampup with HHFW
    - *Make 100kA ohmic target plasma, clamp OH, ramp to higher I_P with HHFW*
  - Combination of NBI and HHFW
    - *Understand conditions in which HHFW can heat in presence of NBI*
  - HHFW-only high non-inductive current fraction
    - *Combine HHFW-only H-mode + HHFW-CD at high β_P for high f_{NI}*

Run time allocation to meet milestones, perform all ITPA experiments within ET, and complete other high-priority XPs

- **Base plan is 17 run weeks = 85 run days**

Task Group:	ET has FY05 Milestone	# XPs linked to ITPA	Initial Allocation # days	Initial Allocation fraction
– Macroscopic stability	✓	4	11	13%
– Wave-particle interactions	✓	2	10	12%
– Transport and turbulence	✓	4	10	12%
– Edge physics	✓	4	11	13%
– Solenoid-free startup			8	9%
– ISD	✓	1	9	10%
– Cross-cutting/enabling			12	14%
– Scientific contingency			14	17%

- **Contingency assigned based on scientific merit & programmatic needs**
  - Goal is to fulfill ITPA and highest-level milestones 2/3 of way into run
    - Will consider reversed B_T and/or I_P at the 2/3 point of run
  - Expect most contingency time to be assigned in last 1/3 of run
- **Flexibility at the end of the run will help maximize productivity**
  - Want to take advantage of any new results and ideas

NSTX FY05 campaign will utilize many new tools to make important contributions to fusion physics and ST science

- Exciting new capabilities:
  - Enhanced shaping, RWM/EF coils, reconstructions w/ MSE
  - Higher spatial resolution MPTS, new fueling techniques
  - First results from high-k scattering diagnostic
- Expect to make significant progress in understanding:
  - RWM & error-field physics
  - Fast-ion MHD, transport, and effect on current profile
  - Edge stability and transport and SOL physics
  - Electron transport and magnetic shear
  - Solenoid-free current generation
- New capabilities and understanding will:
  - Advance the integration of sustained high β, f_{BS}, and τ_E on NSTX
  - **Contribute to world fusion science program and ITER**

Cross-cutting/Enabling activities for FY05

- Diagnostic calibrations (3 days)
  - Magnetic sensors, MSE, other
- rtEFIT development (4 days)

Desired experimental capabilities:

- Isoflux control including all PF coils (add PF1A & B)
- Precise outer gap control, dR_{SEP} variation
  - *HHFW coupling and EBW emission studies, MAST-NSTX L-H threshold*
- Shape control of high performance/long-pulse DND and LSN discharges

Technical requirements and tasks:

- Implement divertor B-probes in rtEFIT for improved X-point control
- Integrate new PF1A coils into isoflux control algorithm
- Establish gap control of moderate κ & δ DND ohmic target with PF1A
- Establish control of DND at low-li for highest elongation & triangularity
- Develop control of LSN discharges for shape comparison studies
- Shape control combining PF1B with new PF1A for squareness control

Cross-cutting/Enabling activities for FY05 (continued)

- HHFW during I_P ramp (2 days)

Desired experimental capabilities:

- – Study coupling and improve target plasma for HHFW experiments
- – Modify ramp-up J profile and attempt NI ramp-up in ISD experiments
- – Modify electron temperature in transport experiments, esp. reverse *q*

Technical issues:

- – Real-time computer too slow for rtEFIT control of boundary during ramp
  - *Old control algorithm required during this phase of discharge*
- – Lack of feedback control of outboard gap makes HHFW coupling difficult
  - *Track Thomson n_e profile evolution to measure outboard gap*
  - *Program outer gap in "feed-forward" fashion based on previous shot evolution*
- – Fast ions from NBI can damage antenna with small outer gap
  - *Assess new limiter plate installed to protect antenna*

Cross-cutting/Enabling activities for FY05 (continued)

- Test impact of n > 1 fields from RWM coils (1 day)
  - Magnetic braking
    - *Rotation control for MHD experiments*
    - *Flow and ExB control for transport studies*
  - Boundary modifications
    - *Stochastic edge for boundary profile and ELM control*
- Impact of supersonic gas injector on performance (1 day)
  - Improved fueling efficiency for use in standard scenarios?
    - *Possible ELM mitigation*
  - Improved breakdown for PF-only startup
- Impact of impurity injection on plasma performance (1 day)
  - Lithium pellets for conditioning and recycling
  - Carbon pellets for edge transport studies