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NSTX

Boundary Physics Plan for NSTX

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Tokamak Planning Workshop

PSFC, MIT

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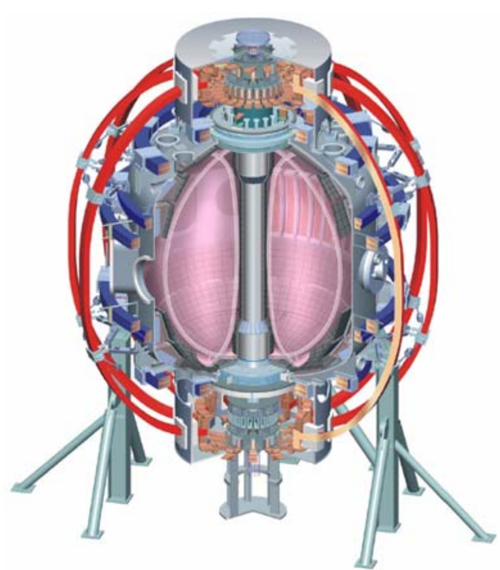

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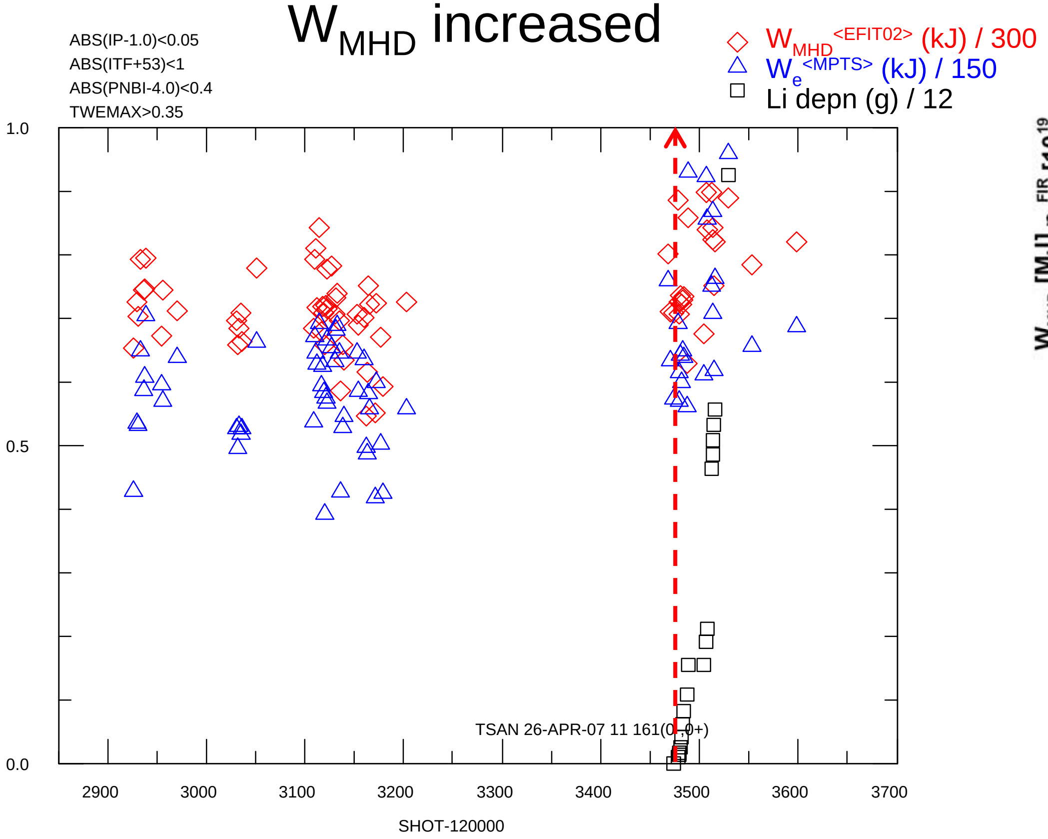
Increased emphasis on boundary physics in NSTX in FY09-FY13 for NHTX and ST-CTF design, and ITER R & D contributions

- **Lithium as a divertor plasma-facing component for integrated power and particle control solution**
  - **Density and impurity control, heat flux handling**
  - **Effect on plasma performance**
- SOL and divertor physics
- Pedestal and ELM Physics

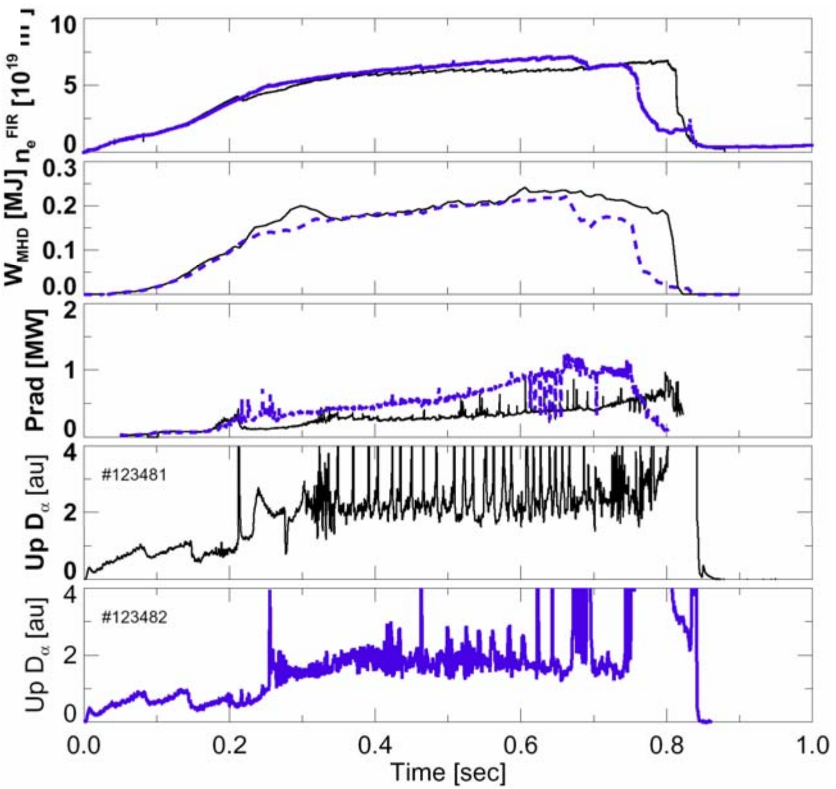
Lithium goal is to provide density control, and it can improve plasma performance

- **Large n_e reduction and τ_E increase in CDX-U and TFTR**
- ***Signs of improved τ_E and ELM control in NSTX***

W_{MHD} increased



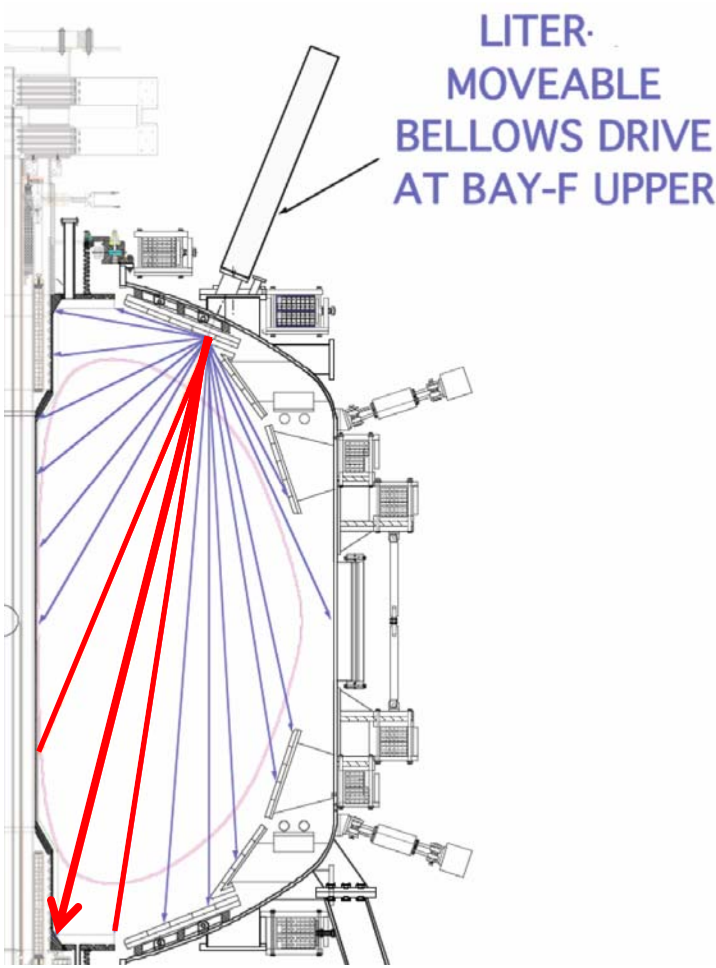
Large ELMs mitigated



- Complements Mo/carbon PFC work at C-MOD/DIII-D
  - Substantial expertise in Li handling and use at PPPL

Lithium program in NSTX proceeding in stages

- Li pellets : FY 2005-
- Li evaporator (LiTER): FY 2006-
- Li powder injection: FY 2007-
- Second Li evaporator: FY 2008-
- *Liquid Li divertor (LLD): FY 2009-*
- *Divertor upgrade: FY 2012-*



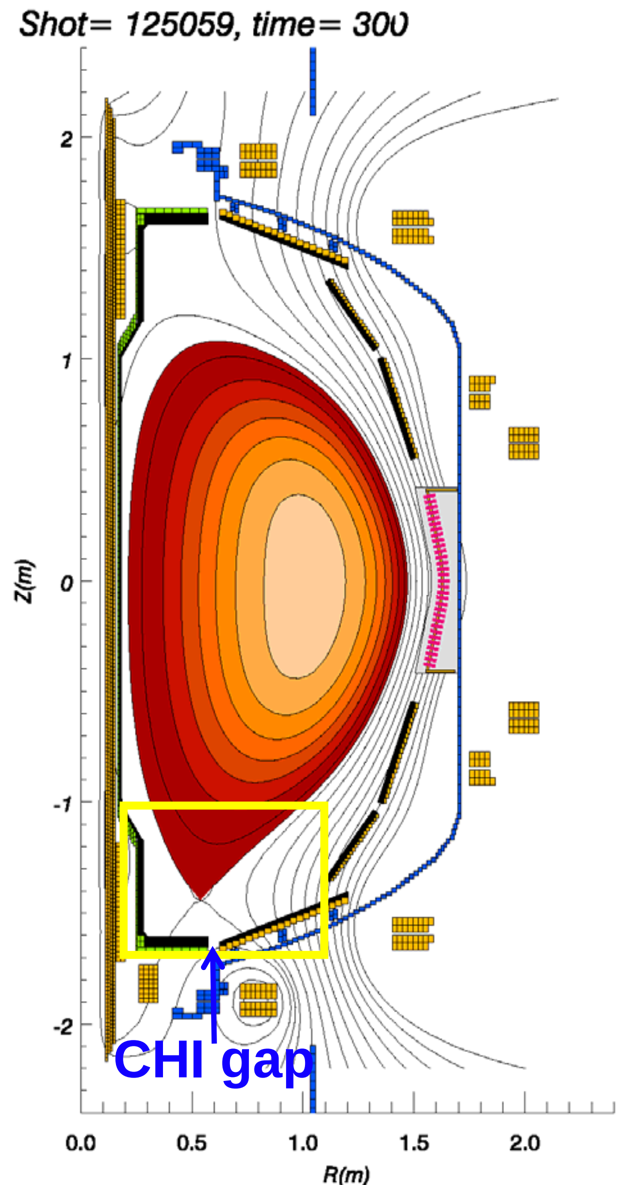
– Builds on Li success in CDX-U and TFTR

– Complements (and relies on) LTX mission of evaluating Li as the primary PFC

Liquid lithium divertor module goal is to provide density control in both low and high triangularity shapes

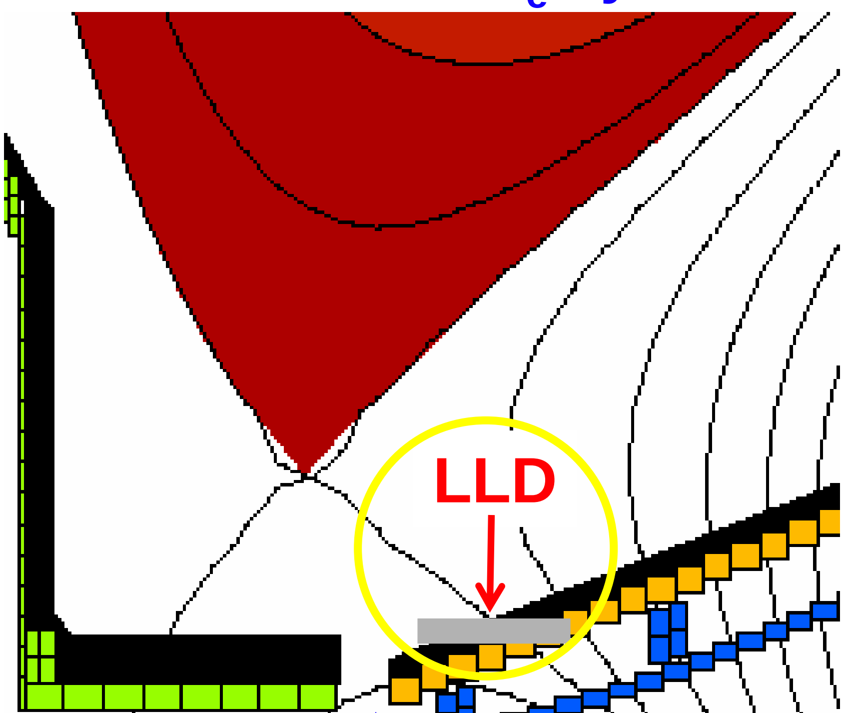
- Goals
  - **Low δ : reduce n_e by 50%**
  - **High δ : reduce n_e by 25%**
- Features
  - 15 cm wide
  - 5 cm outboard of CHI gap
  - Desired $T_{surface}$ ~ 300-400 ^oC

- Installation ~ summer 2008
- Experiments in 2009



Density reduction will depend on proximity of outer strike point to LLD module

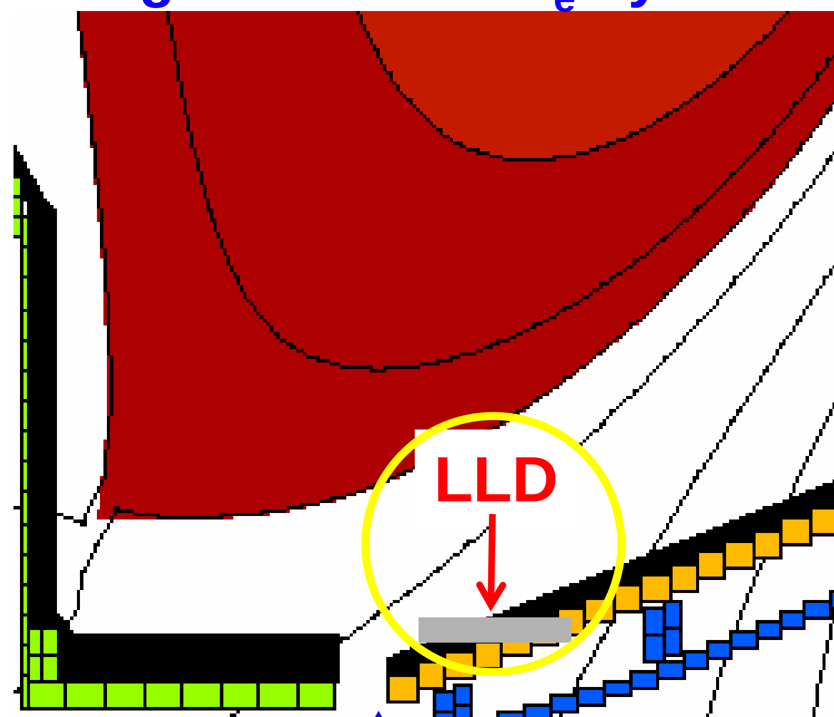
Low δ : reduce n_e by 50%



CHI gap

δ_l=0.45 (#125059 @ 0.3 sec)

High δ : reduce n_e by 25%



CHI gap

δ_l=0.7 (#121238 @ 0.3 sec)

- Divertor upgrade: FY 2012-
  - Second or upgraded LLD, or a cryopump
  - Long pulse PFC upgrade

Lithium program plan

NSTX

2008-2009

- Install and characterize Liquid Lithium divertor (LLD) module
- Perform hydrogen retention and pumping efficiency studies
- Optimize efficiency of gas injector fueling

New tools: LLD + diagnostics, Penning gauge near pumps, upgraded supersonic gas injector, programmable center stack gas injector

2010-2011

- LLD performance with higher power input, long pulse
- Utilize core fueling (pellets, compact toroids)

New tools: new divertor diagnostics, 2nd NBI, D_2 pellet injector, CT injector

2012-2013

- Optimize divertor pumping and divertor PFC materials for long pulse
- Advanced core fueling (Compact toroids)

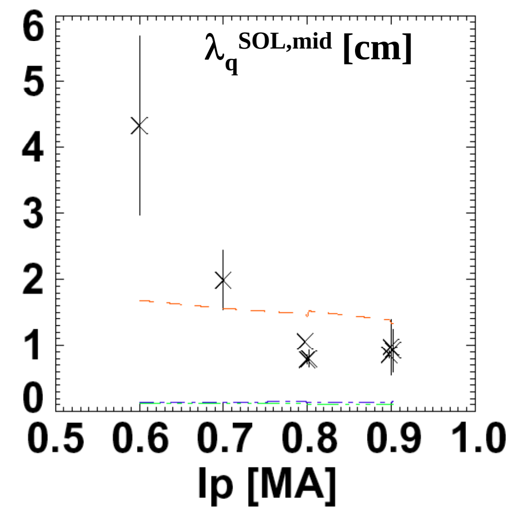
New tools: New/additional LLD module or cryopump, new PFCs

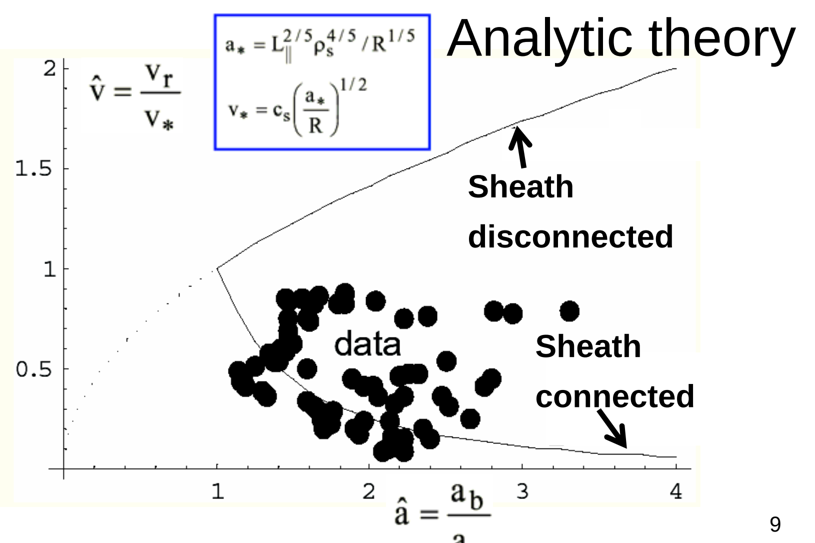
Outline

- Lithium as a divertor plasma-facing component
- **SOL and divertor physics for prediction of plasma-wall interaction footprint with theory-based cross-field transport**
  - **Edge transport and turbulence ⇔ SOL width**
  - **Divertor heat and particle flux optimization**
- Pedestal and ELM Physics

Edge T & T studies will focus on connection between measured turbulence characteristics and SOL widths

- Motivated by the high divertor and first-wall heat loads in NHTX, ST-CTF, *and* ITER
  - Peak heat flux in NSTX $\geq$ 10 MW/m^2 (NHTX $q_{peak} \geq$ 40 MW/m^2)
- Dependence of heat flux width ($\lambda_q^{SOL,mid}$) not well understood in tokamaks
  - $\lambda_q^{SOL,mid}$ larger in NSTX than high aspect ratio tokamak scalings
  - NSTX $\lambda_q^{SOL,mid}$ strong I_P dependence
- Turbulence modeling already connecting to analytic theory of blob formation, and more detailed numerical modeling





Edge T & T Physics Plan

2008-2010

- Comparison of midplane and divertor turbulence characteristics with models
- Scaling of midplane λ_n, λ_T, λ_Γ, λ_q with major parameters
  - Comparison with SOL width models
  - Comparison with turbulence characteristics
- Edge biasing with local electrodes and probes for SOL width control

New tools: fast IR camera

2011-2013

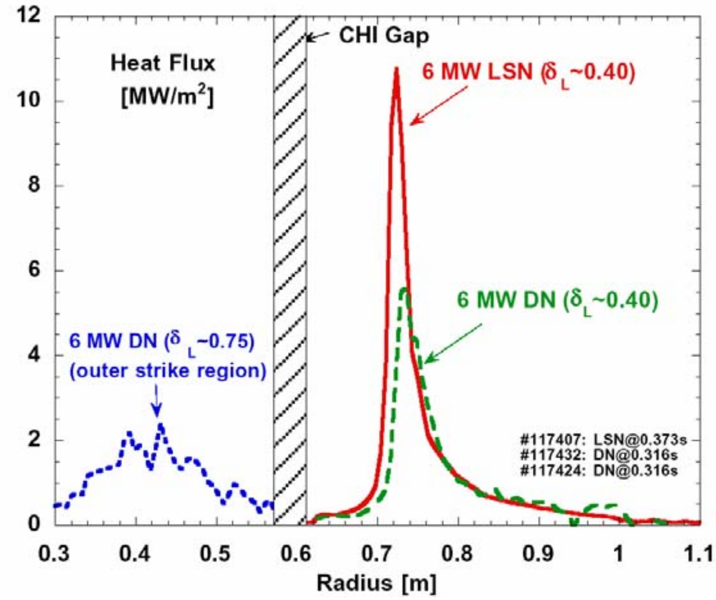
- SOL turbulence and widths with higher input power
- Divertor turbulence with X-point probe
- Upgraded biasing capability, if warranted

New tools: 2nd NBI, new divertor diagnostics, X-point probe

Divertor physics and detachment physics program needed for NHTX and ST-CTF design

NSTX

- ST effects: low $l_{||}$, small R, large outboard side surface area make outer detachment difficult
  - — *Power management through flux expansion and detachment may be required for heat dissipation in high power ST's*
  - — *ST effects above allow broader test of detachment physics in 2-D codes*
- Heat flux management through plasma shaping and detachment shows promise in NSTX



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Divertor and detachment Physics Plan

NSTX

<u>2008-2009</u>

- Lower divertor power accountability and transient loading studies
- Improved detachment control for long pulse discharges
- MARFE characterization studies
- Divertor performance dependence on geometry

New tools: Fast IR camera, divertor bolometer

<u>2010-2011</u>

- Detachment and heat flux mitigation with higher input power and reduced density
- Private flux region physics studies
- Development of MARFE dynamic models

New tools: X-point probe, divertor imaging spectrometer, 2nd NBI

<u>2012-2013</u>

- 2-D divertor physics: parallel vs. perp. transport
- Closed divertor?

New tools: Divertor Thomson, 2-D divertor spectroscopy, new divertor hardware

Outline

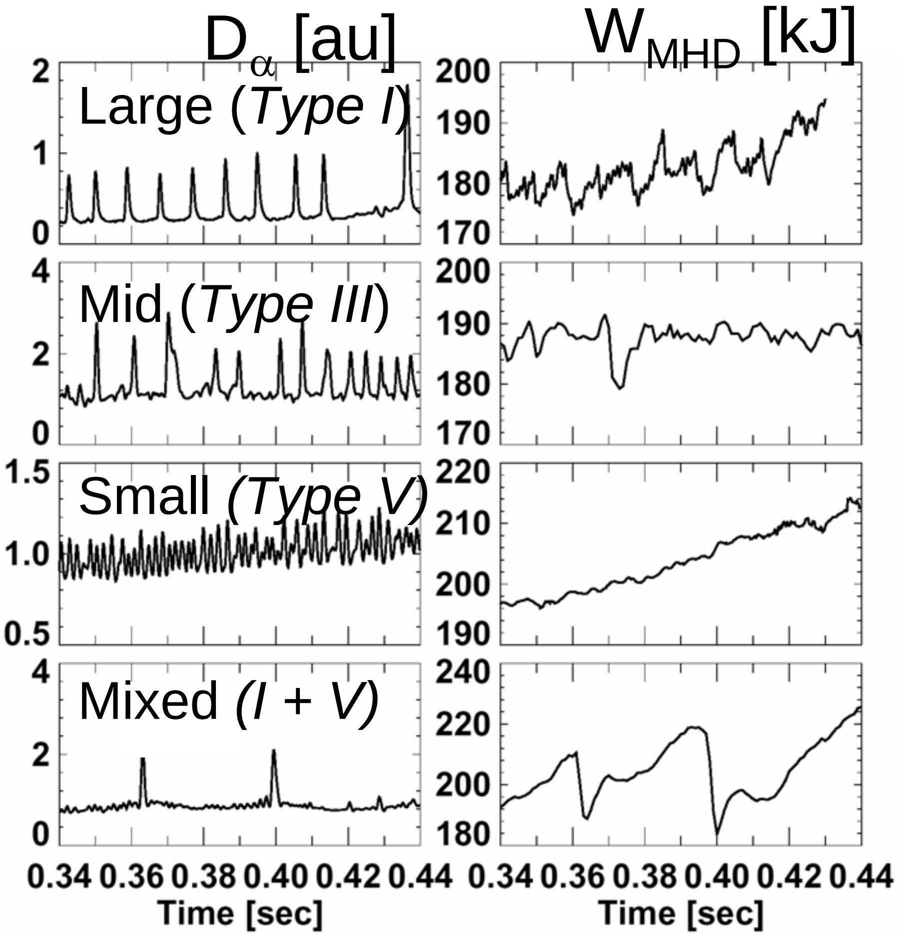
- Lithium as a divertor plasma-facing component

- SOL and divertor physics

- **Pedestal and ELM Physics toward pedestal width prediction and improved understanding of ELM suppression with applied 3-D fields**
  - **Characterization and theory comparison at low R/a**
  - **Active control with resonant magnetic perturbations**

ELM and Pedestal studies motivated partly by occurrence of giant ELMS at low collisonality

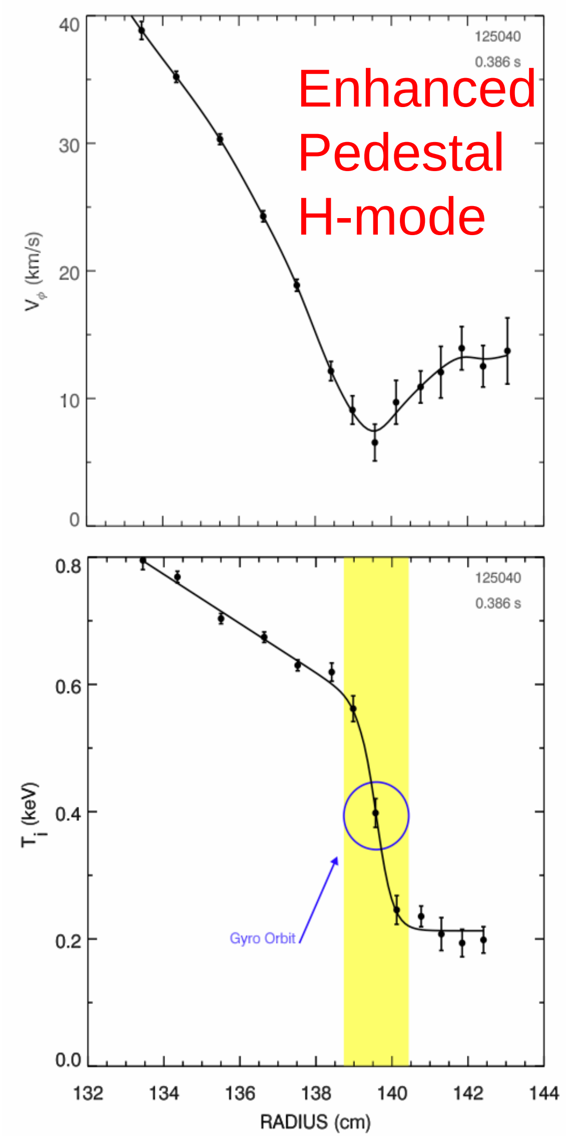
- Many ELM types observed in NSTX, including promising small ELM regime
  - Do small ELMs in different devices have common physics?
- Pedestal studies to reveal R/a dependence of gradients and widths
  - Low R/a allows broader test of stability models used to predict max. edge P' limit for ITER
  - Does the low R/a enable improved edge stability?
- Certain pedestal models predict a B_t and R/a dependence of T_{ped}
  - NSTX T_{ped} ~ 200-300 eV
  - How to increase T_{ped}?



ELM and Pedestal Physics plan: 2008-2009

<u>2008-2009</u>

- Assess edge stability of different ELM types and impact of aspect ratio
- Compare small ELM regimes with other devices
- Identify shape dependencies of ELM regimes
- Investigate effect of Lithium on ELMs
- Assess effects of RMP on edge stability
- Determine relation of pedestal and core stored energy
- Measure dependence of pedestal width on parameters
- Identify physics of Enhanced Pedestal H-modes e.g. orbit squeezing physics
- Compare pedestal parameters with CPES and ESL codes



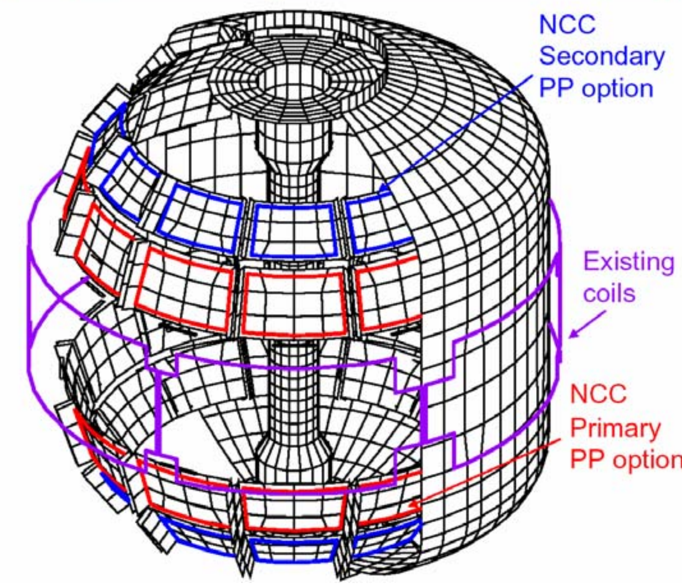
ELM and Pedestal Physics plan: 2010-2013

2010-11

- RMP effects of heat flux spreading
- Develop quasi-steady small ELM scenarios with high input power
- Investigate role of SOL current in ELM stability
- Extend Enhanced Pedestal H-modes

New tools: Upgraded Edge rotation diagnostic, edge SXR, five extra edge Thomson channels

Proposed Non-axisymmetric Control Coil (NCC)



2012-2013

- High m,n RMP impact on ELMs and heat flux
- Triggering of localized transport barriers with localized rotation control by RMP

New tools: Internal Non-axisymmetric Control Coils (NCC)

Boundary physics program time line FY09-FY13