NSTX

Supported by

U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX Project
Facility Operations, Enhancements and Budget Plans

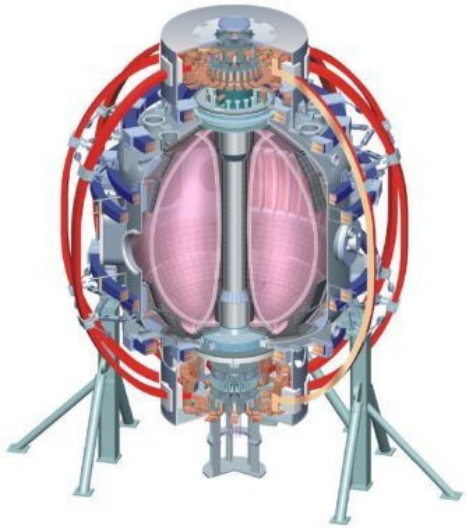
College W&M
Colorado Sch Mines
Columbia U
CompX
General Atomics
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin

Masa Ono

For the NSTX Team

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
Seoul Nat. U
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

NSTX PAC-29
PPPL B318
January 26-28, 2011



Talk Outline

- FY 2010 Plasma Operations Summary
- FY 2010 Facility / Diagnostic Accomplishments
- FY 2011-2012 Facility / Diagnostic Upgrade Plan and Status
- Major Upgrade Project Status: New Center-stack and 2nd NBI
- Budget
- Summary

Productive FY10 Plasma Operations Completed

- **All of the NSTX FY2010 Milestones completed on or ahead of schedule including the Joint Research Target**
  - Final year-end reports submitted to DOE-FES
  - Latest NSTX results presented at IAEA and APS
- **15.4 run weeks: total 2941 plasma shots, highest total plasma shots and plasma shots per week (191/week) for NSTX due to lithium conditioning**
  - FY09: 16.8 run weeks: 2748 shots or 163 plasma shots / week
  - FY08: 16.5 run weeks: 2571 shots or 156 plasma shots / week
- **50 XP/XMPs performed: ~ half of XPs led by collaborators**
- **New capabilities in FY10 contributed to science productivity**
  - Liquid Lithium Divertor (LLD) installation and commissioning
  - Two-Color Fast IR camera for lithium surface heat flux measurements
  - Beam Emission Spectroscopy for low k fluctuation/modes
- **4.2 run weeks completed in October for FY 2011**
- **New significant facility/diagnostic capabilities readied for FY2011:**
  - 2nd SPA supply for non-axisymmetric feedback coils, extra MPTS channels, MSE-LIF, Tangential fast ion D-alpha diagnostics

NSTX had strong publications and conference participation
Strong collaborator contributions

- *57 NSTX scientific papers published in refereed journals including four PRLs in 2010:*
  - *Resistive Wall Mode (RWM) Instability at Intermediate Plasma Rotation, (Berkery, Columbia University, et al): Kinetic model unified understanding of RWM*
  - *On demand triggering of edge localized instabilities (ELMs) using external non-axisymmetric magnetic perturbations in toroidal plasmas (Canik, ORNL, et al): ELM control*
  - *Demonstration of Tokamak Ohmic Flux Saving by Transient Coaxial Helicity Injection on NSTX (R. Raman, University Washington, et al): High quality start-up*
  - *Triggered Confinement Enhancement and Pedestal Expansion in High-Confinement-Mode Discharges in the National Spherical Torus Experiment, (Maingi, ORNL et al): HH ~ 1.7*

- *The NSTX team members presented twenty-five IAEA papers with eight oral presentations and ten Invited Talks at the APS-DPP meeting this fall. (the most for NSTX)*

Half of invited talks and refereed journal publications by collaborators

NSTX had active community contributions and recognition
Strong collaborator contributions

- The NSTX research team actively participated in 26 ITPA joint experiments in 2010.
- The NSTX research team participated in ten ITPA and ITER workshops
- The NSTX team members served in the leadership positions in the T&T, dust, Energetic particles, Operations and Control for ITPA/ITER and the US BPO management.
- Three NSTX young researchers (LLNL, Purdue U and PPPL) received 2010 DOE OS Early Career Awards.
- S. Sabbagh (Columbia University) was honored at IAEA (Daejeon, Korea) for his Nuclear Fusion Paper Award.
- J. Menard and S. Sabbagh (Columbia University) were selected to become the APS-DPP Fellows .
- J-K Park received the 2010 Marshall N. Rosenbluth Outstanding Doctoral Thesis Award.

NSTX leads lithium experimental program in the growing world program (NSTX, LTX, FT-U, T11M, TJ-II, EAST, RFX, KTM)

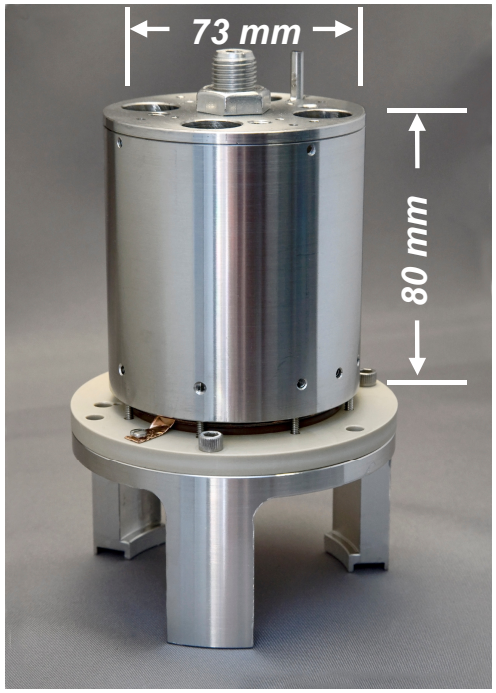
NSTX Lithium Program uniquely contributes to world program: Diverted H-mode experiments

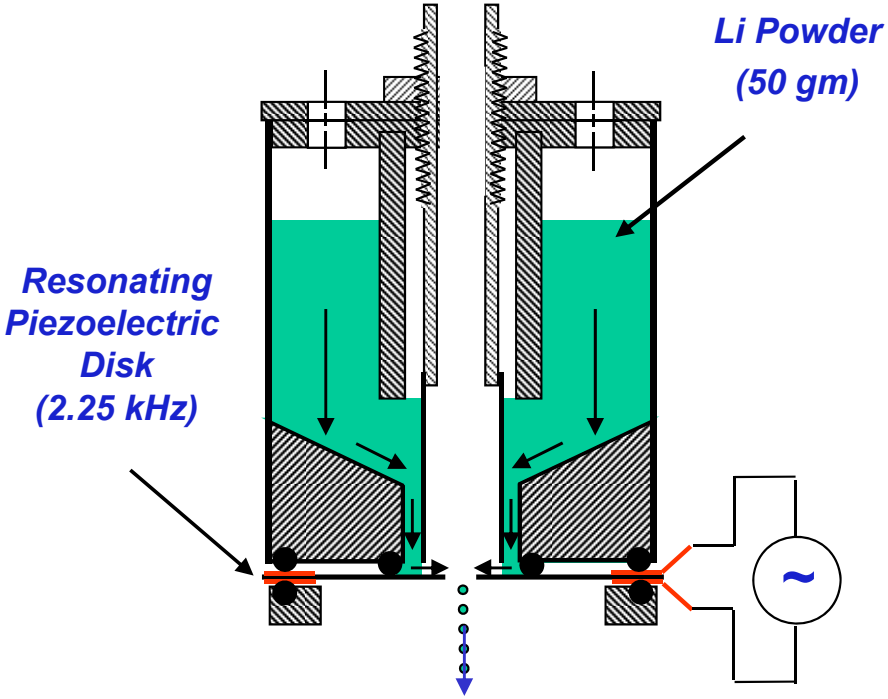
Lithium in NSTX yielded many important results:

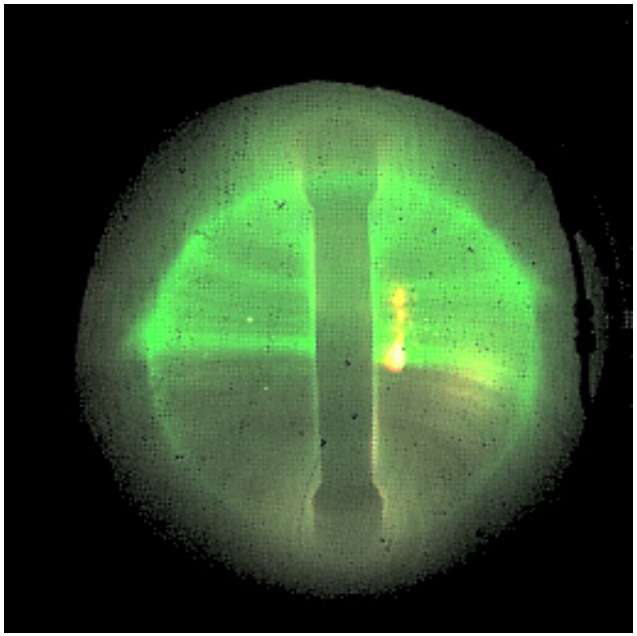
- Improved plasma operations: shots / week increased ~ 40% over pre-lithium.
- Global confinement improved through electron confinement improvement by ~ 20 – 30%. Contributed to the highest confinement H-mode with HH98y2 $\leq$ 1.7.
- H-mode power threshold significantly reduced ~ 20 – 30%
- Completely stabilized ELMs.
- Contributed to the non-inductive CHI start-up success by controlling impurities.

2nd Lithium Symposium to be held at PPPL on April 27 – 29, 2011 (http://isla2011.pppl.gov/)

NSTX Lithium Dropper was Installed on EAST
Facilitated Wall Conditioning and H-mode Access







"ELMy H-modes have also successfully been achieved with the combination of LHW and ICRF heating. By the baking of PFC and extensive Li wall conditioning, H/(H+D) ratio can be controlled in the range of 6-10%. This enables effective ICRF heating in both electron and ion dominated heating scenarios with optimized plasma wave coupling." (News - EAST H-mode)

The EAST tokamak is investigating the use of Li in much longer discharges. We will continue our collaborations with EAST in order to benefit from those experiments.

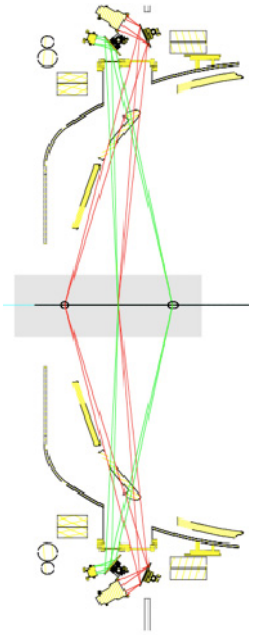
New Capabilities for Liquid Lithium Divertor and Boundary

Divertor Diagnostics and Supporting Personnel Greatly Enhanced

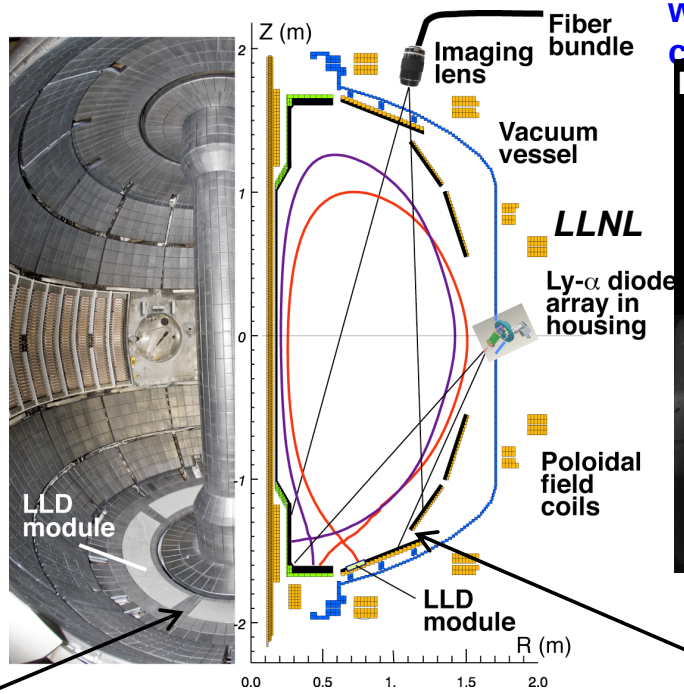
PAC27-3 PAC27-16

PAC27-8

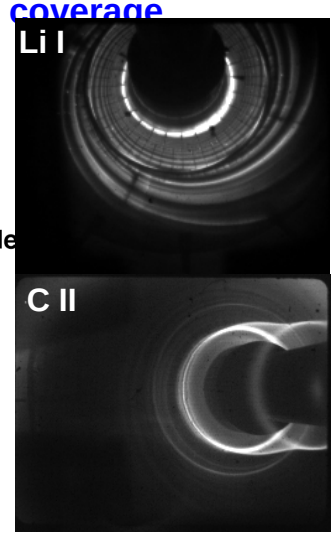
Lithium CHERS



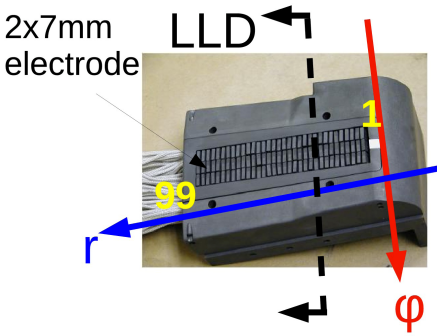
Divertor Imaging Spectrometer



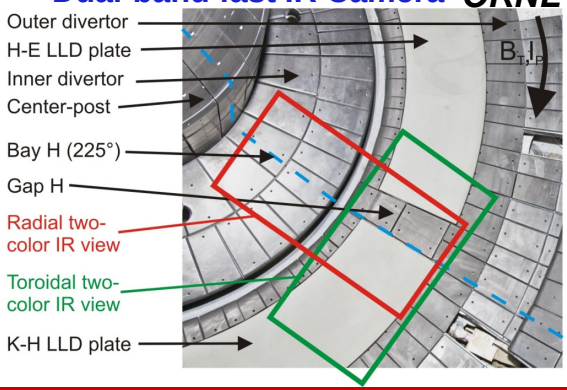
Two fast 2D visible cameras with full divertor coverage



Dense Langmuir Probe Array



Dual-band fast IR Camera *ORNL*



PMI Probe

Purdue

New Researchers in Boundary Area!

ORNL: Divertor Physics, IR camera
- *A. McLean*
- *J-W Ahn,*
- *T. K. Gray*
- *D. Battaglia*

LLNL: Snowflakes, Divertor Physics
- *F. Scotti (PU) – Fast camera*
- *Divertor physics post doc to be added*

Purdue University - PMI / MAPP
- *C. Taylor*
- *Bryan Heim*

University of Illinois – Divertor probe
- *Vijay Surla*

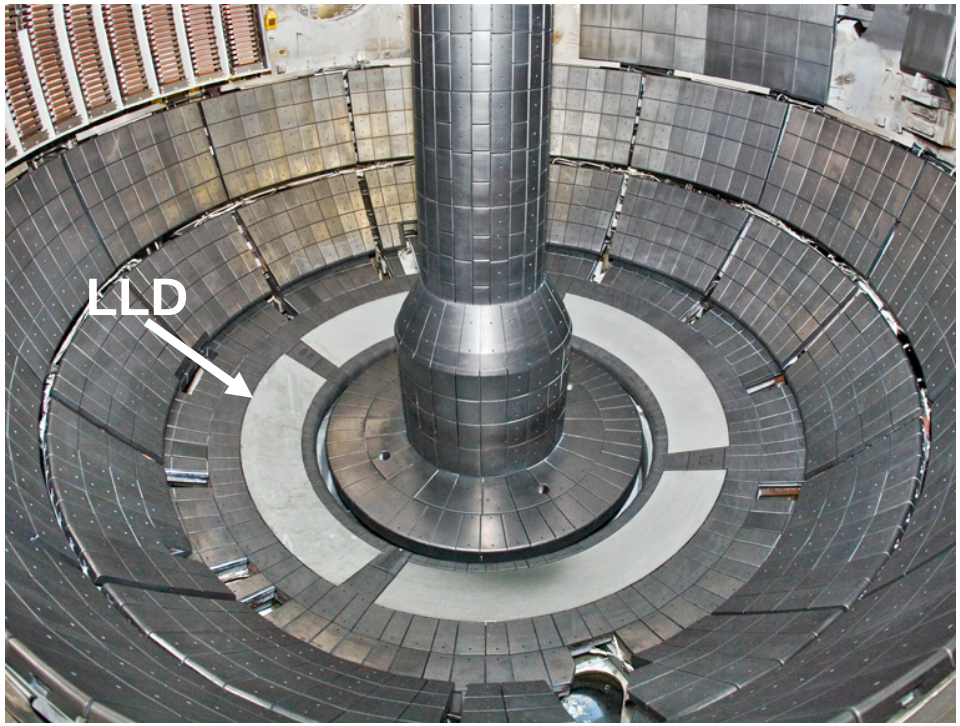
John Hopking U – Edge x-ray
- *D. Clayton*

PPPL :
- *M. A. Jaworski – LLD Physics*
- *A. Diallo - MPTS*
- *M. Podesta - CHERS*
- *E. Kolemen – Strike-point control*
- *Spectroscopy post doc to be added*
- *J. Kallman (PU) – Dense Probe Array*
- *T. Abrams (PU) – LLD R&D*

ASIPP:
- Three researchers coming to work in the boundary physics area in FY 2011-12

Liquid lithium divertor target system commissioned

Utilized in four LLD experimental proposals in three campaigns



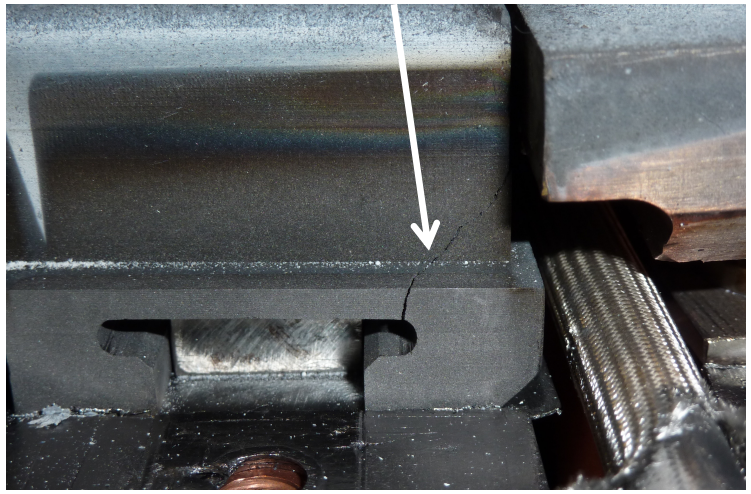
LLD plate covered with lithium
Significant over-flow evident consistent with evaporating 2 x fill capacity

- Liquid Lithium Divertor (LLD) aims to provide volume D pumping capacity (> solid Li surface) for longer pulses with self healing.
- LLD installed, commissioned and filled with 67 g-Li by evaporation (1300 g total).
- LITER gate valve and shutter failures necessitated argon vents. Rapid plasma recovery.
- LLD electrical heater failed during the operations then augmented by air heater.
- LLD surface temperatures 160 – 350 °C (> Li melting temperature of 180 °C)
- Plasma surface heating found to be effective $\Delta T \sim 200°C$. Strike point controlled on LLD.
- No significant Li nor Mo influx observed even with strike point on LLD.

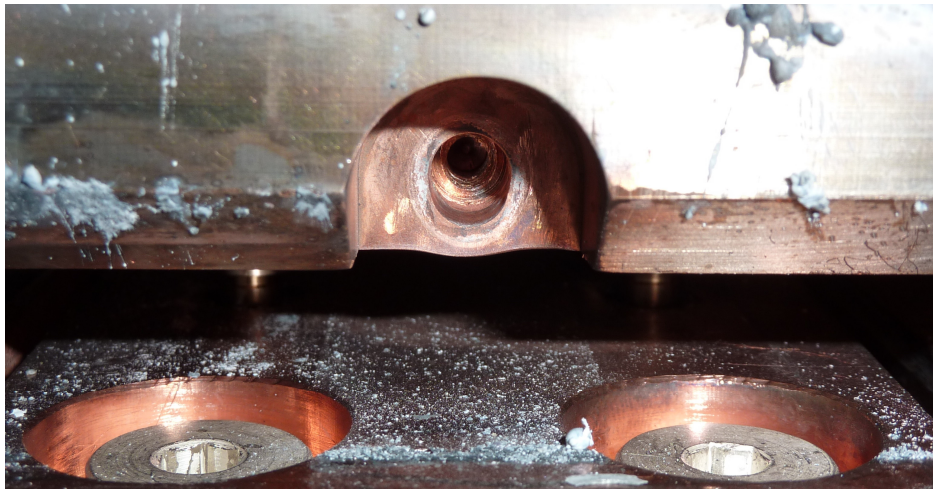
Post-run LLD Inspection Revealed Damage

Damage indicates LLD motion during disruptions

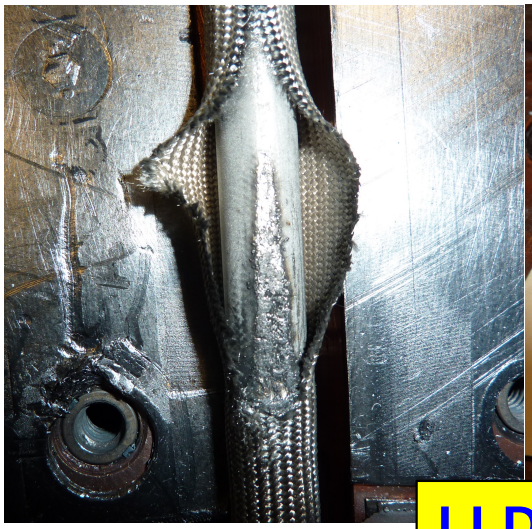
Neighboring graphite tiles damaged



LLD support hole elongated due to excessive stress



Arc damage in LLD heating tubes and Center Post

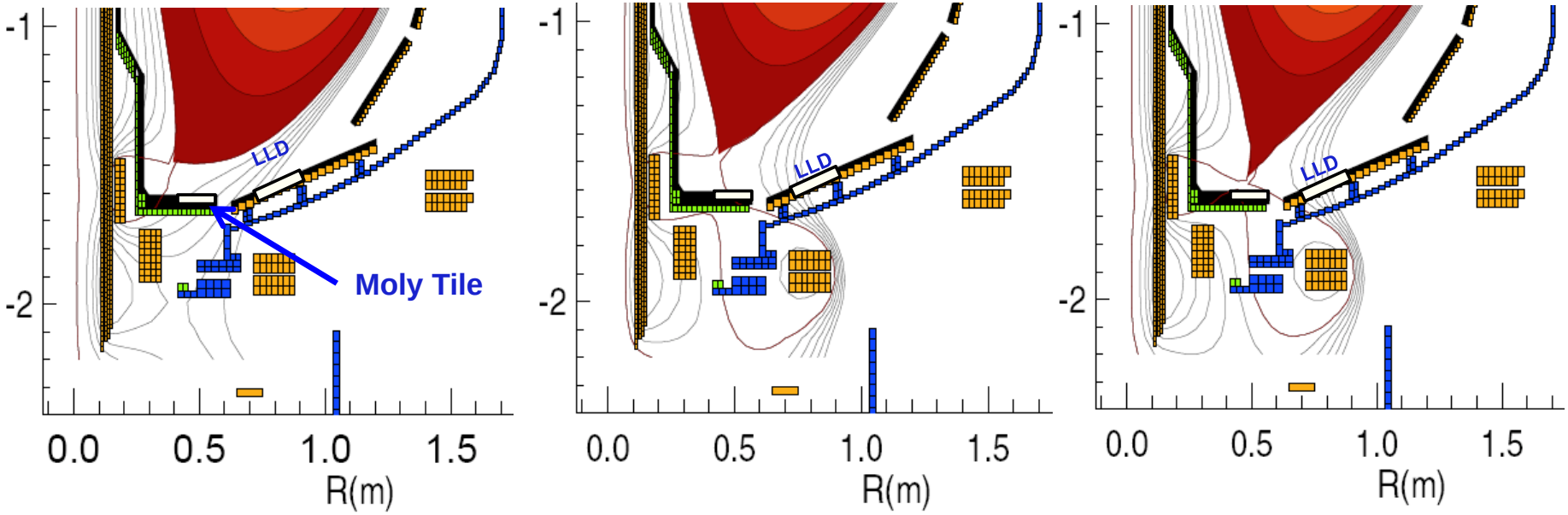


LLD plate support structural damage

LLD plates will be repaired and re-installed

Addition of IBD Mo tiles would enable important divertor studies and extend liquid lithium & moly divertor research

- *Help quantify fraction of core C coming from lower divertor for high-δ shapes*
- *Potentially reduce C content of Li ELM-free scenarios*
- *Characterize Mo performance to inform choice of div/CS PFC in Upgrade*
- *Apply Li (LiTER) to divertor moly surfaces for partial/full liquid lithium*
- *Provide metal cathode surface for CHI to reduce impurity generation*



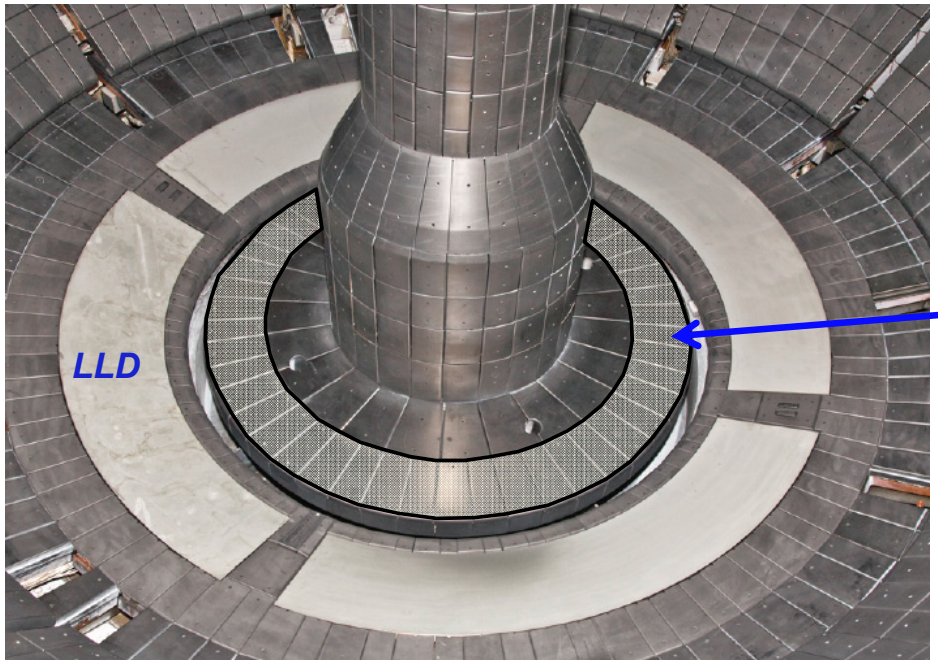
Standard divertor on C *Standard divertor on Mo* *Snowflake on moly*

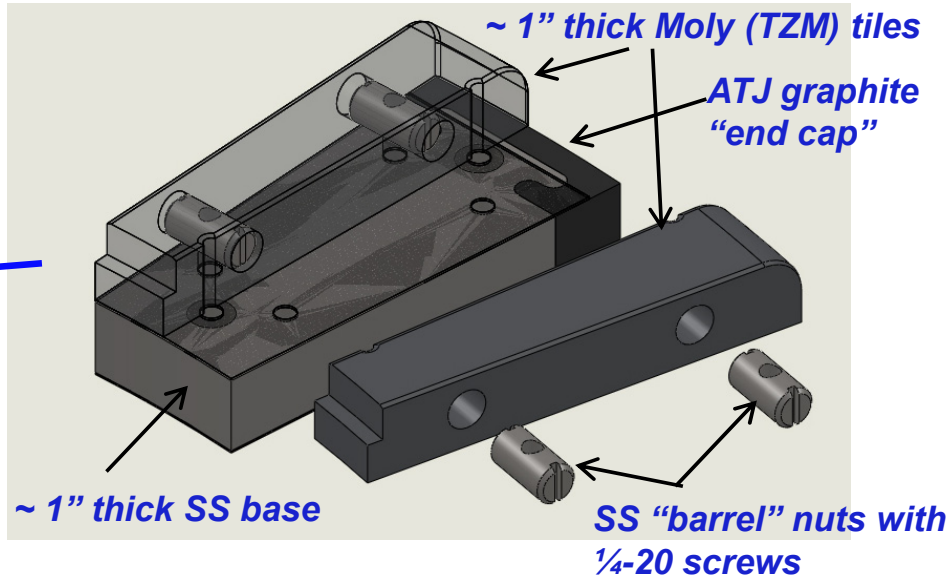
PAC27-18

In-board Moly Divertor Tiles

Split-top Moly on SS tile satisfies design requirements

PAC27-4 | PAC27-18





Molybdenum tiles on inboard divertor

- Replace the second row tiles with 1” moly tiles similar thickness to C-Mod moly tiles
- Lithium coating with LITER ~ 2 x outer LLD rate
- ~ inboard divertor area similar to the upgrade

Engineering effort ramped up

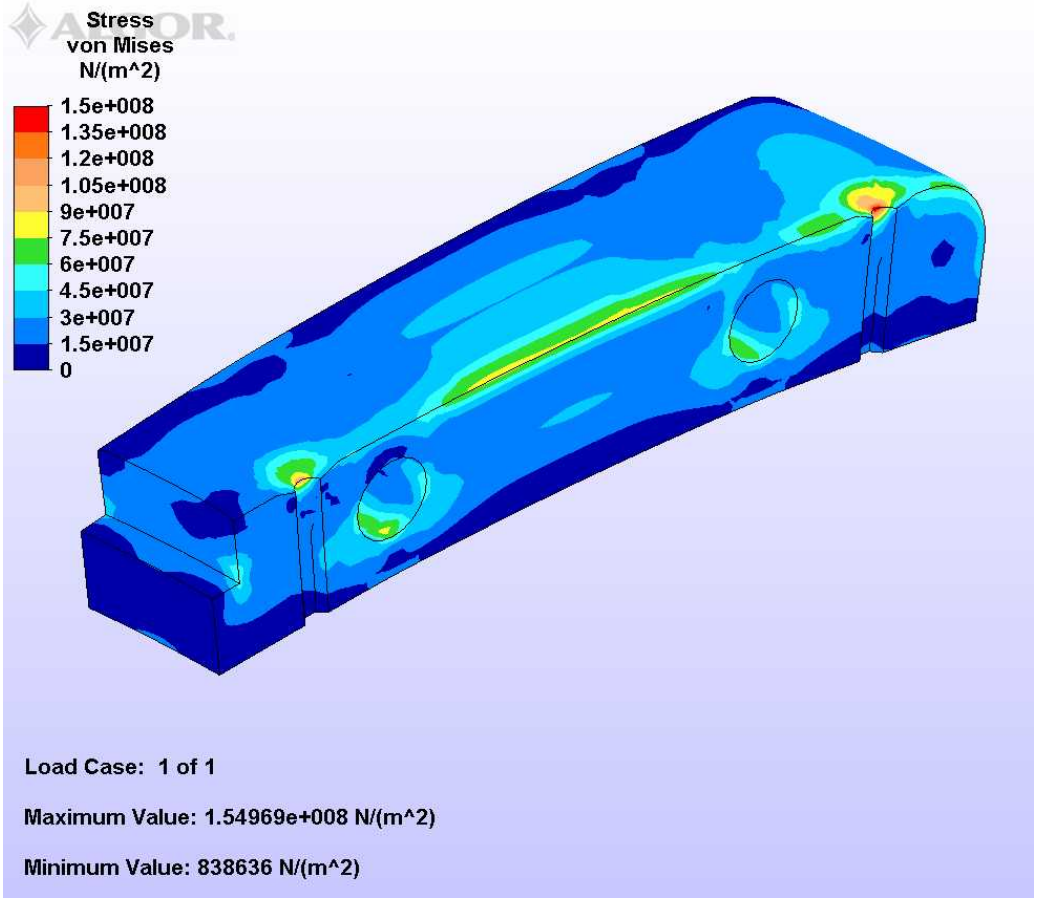
- Moly plate material secured
- Successful FDR conducted
- Moly tile procurement initiated
- Installation schedule being formulated
- Consulting FES on run schedule for FY 2011-2012

• Plasma heating ΔT ~ 200°C should be sufficient to get the moly tile surfaces to the liquid lithium temperature by controlling the strike-point location.

In-board Moly Divertor Tiles Designed

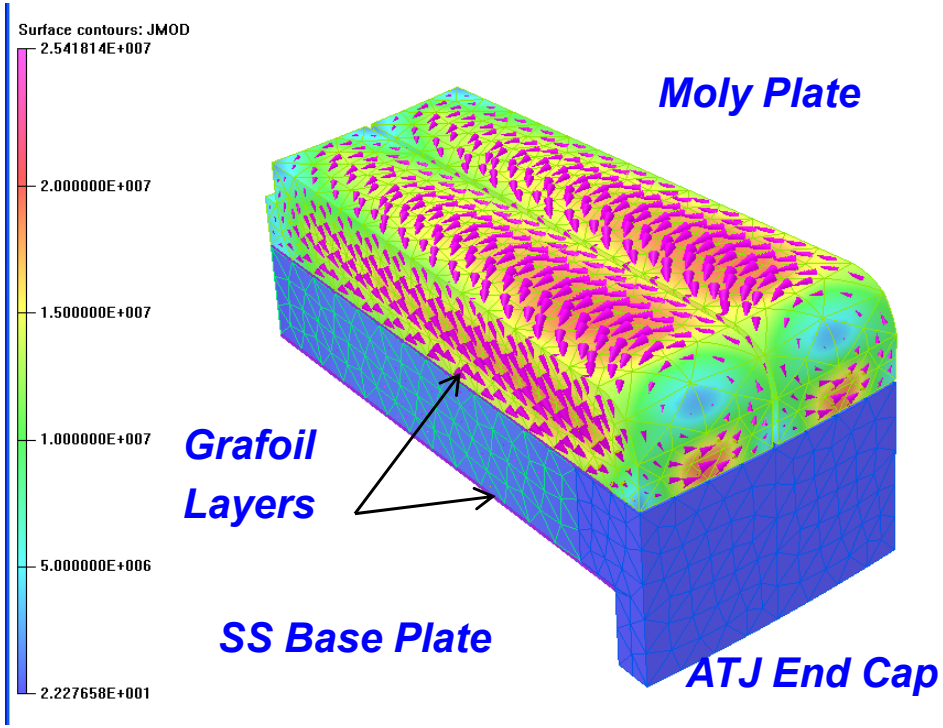
Robustly designed against thermal and disruption forces

Thermal Response Analysis



Mechanical stress significantly reduced well below the TZM allowable (<400 MPa) when moly tile is allowed to bow upwards (P_{AV} = 1MW/m^2 for 2 second)

Eddy Current Loads and Current Distribution on Moly (TZM) Tiles



- *Radial Split in Moly Plates*
- *On full SS Base Plate*
- *Fx= 13.7 N* *Mx=-51.5 N-m*
- *Fy= -52.8 N* *My= 6.8 N-m*
- *Fz=-127.7 N* *Mz= 28.8 N-m*

NSTX Lithium Strategy for 2011-2012

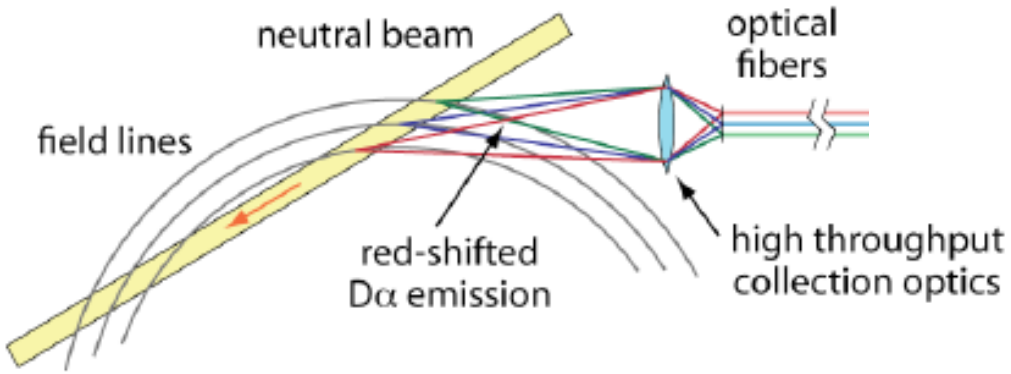
Need to make priorities to stay on course toward the upgrade

Proposed Strategy: The schedule and resources are tight driven by the NSTX Upgrade Project schedule which is our highest priority

- **Retain lithium capability through LITER.**
- **Install in-board moly tiles to further test the desirability of moly divertor PFCs allowing high δ high performance discharges with or without liquid lithium and reduce carbon influx.**
- **Re-install LLD plates to provide moly surfaces for further LLD research and carbon impurity reduction: LLD plates needs to be better supported to minimize contact with neighboring tiles to reduce arcing**
  - **Enhance corner supports (a successful review conducted)**
  - **Use separate center post mechanical support and improved center grounding (eliminate finger sliding joint)**
  - **Eliminate electrical and air heaters to minimize arc issues**
  - **Clean LLD plates with vinegar before installation**

D(10-1): Commission the Beam Emission Spectroscopy in collaboration with U. Wisconsin for transport studies

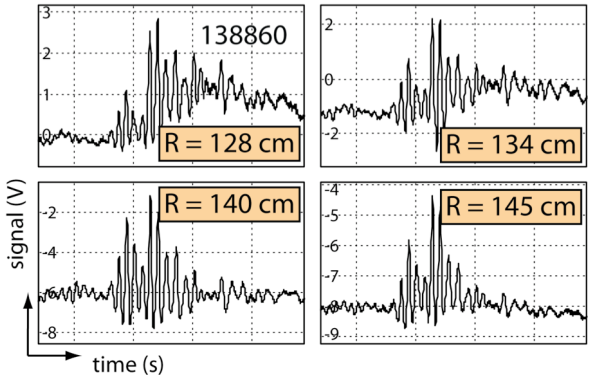
BES together with high-k to provide a comprehensive turbulence diagnostic set

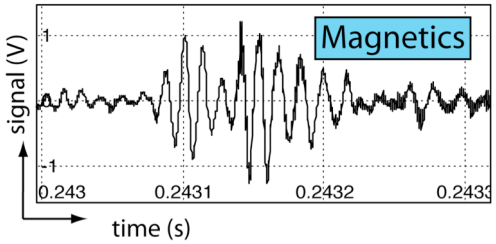


Turbulence and Transport

- **New Beam Emission Spectroscopy (BES) diagnostic shows ion-gyro-scale (low-k) density fluctuations in many experiments including H-mode and energetic particle modes.**
- **High-k with a new solid-state source is running more reliably.**
- **BES + existing high-k scattering diagnostic will provide full coverage of turbulent k-spectrum**

TAE Burst





Diagnostic Systems Growing with Strong Collaboration Contributions

MHD/Magnetics/Reconstruction

- Magnetics for *equilibrium reconstruction*
- Halo current detectors
- High-n and high-frequency Mirnov arrays
- Locked-mode detectors
- RWM sensors (n = 1, 2, and 3)

Profile Diagnostics

- Multi-pulse Thomson scattering (30 ch, 60 Hz)
- T-CHERS: $T_i(R)$, $V_\phi(r)$, $n_C(R)$, $n_{Li}(R)$, (51 ch)
- P-CHERS: $V_\theta(r)$ (71 ch)
- *MSE-CIF (15 ch)*
- *FIReTIP interferometer (6 ch)*
- Midplane tangential bolometer array (16 ch)

Turbulence/Modes Diagnostics

- *Tangential microwave high-k scattering*
- *Beam Emission Spectroscopy*
- *Microwave reflectometers*
- *Ultra-soft x-ray arrays – tomography (4 arrays)*
- *Fast X-ray tangential camera (500kHz)*

Energetic Particle Diagnostics

- Neutral particle analyzer (2D scanning)
- *Solid-State neutral particle analyzer*
- Fast lost-ion probe (energy/pitch angle resolving)
- Neutron measurements
- *Fast Ion D_α profile measurement*

(Collaboration contributions)

Edge Divertor Physics

- *Gas-puff Imaging (500kHz)*
- *Fixed Langmuir probes*
- High density Langmuir probe array
- Edge Rotation Diagnostics (T_i, V_ϕ, V_{pol})
- *1-D CCD H_α cameras (divertor, midplane)*
- *2-D divertor fast visible camera*
- Divertor bolometer (20ch)
- *IR cameras (30Hz) (3)*
- *Fast IR camera*
- Tile temperature thermocouple array
- Dust detector
- Edge Deposition Monitors
- *Scrape-off layer reflectometer*
- *Edge neutral pressure gauges*
- *Plasma-Material Interactions Probe*
- *Divertor Imaging Spectrometer*
- *Lyman Alpha (Ly_α) Diode Array*

Plasma Monitoring

- Fast visible cameras
- Visible bremsstrahlung radiometer
- Visible survey spectrometer
- UV survey spectrometer
- *VUV transmission grating spectrometer*
- *Visible filterscopes (hydrogen & impurity lines)*
- *Wall coupon analysis*
- *X-ray crystal spectrometer (astrophysics)*

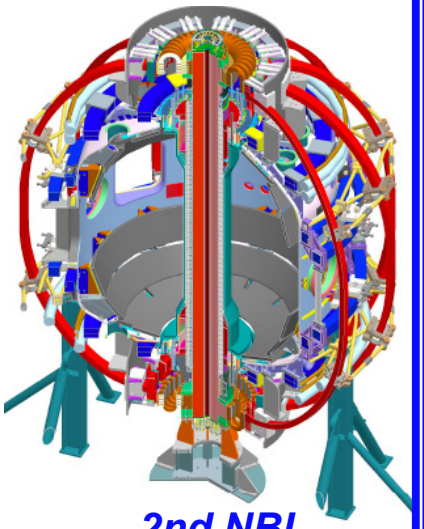
NSTX Near Term Facility Plan

ARRA Funding Significantly Enhances Research Capability

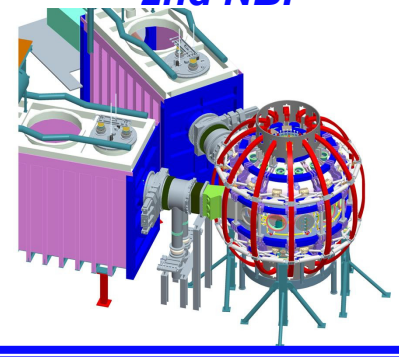
	FY 10		FY 11		FY 12	FY 13
ARRA Run Weeks	1	14	4	10	10	Upgrade Outage FY 2012-14
Base	LLD (SNL)			Moly Tiles		
Boundary / Li	PMI Probe Lithium CHERS Divertor Spectrometer (LLNL)			Materials Analysis Particle Probe (MAPP) (Purdue)		
MHD and ASC	Two-Color Fast IR Camera (ORNL) β control (NBI)	RWM State Space Controller		2nd SPA Supplies Real Time Rotation Diagnostic	Real Time Rotation Control	
T&T	Upgraded FIReTIP (UCD)					
ITER/CC	BES (U. Wisconsin)			MPTS Extra channels MSE-LIF (Nova Photonics)		
Heating & CD	HHFW Antenna Upgrade					
Energetic Particles	Upgraded reflectometry (UCLA)			Tangential FIDA(UCI)		
Start-Up	CHI Absorber Control Coils (U. Washington)					

PAC27-3

New Center-stack



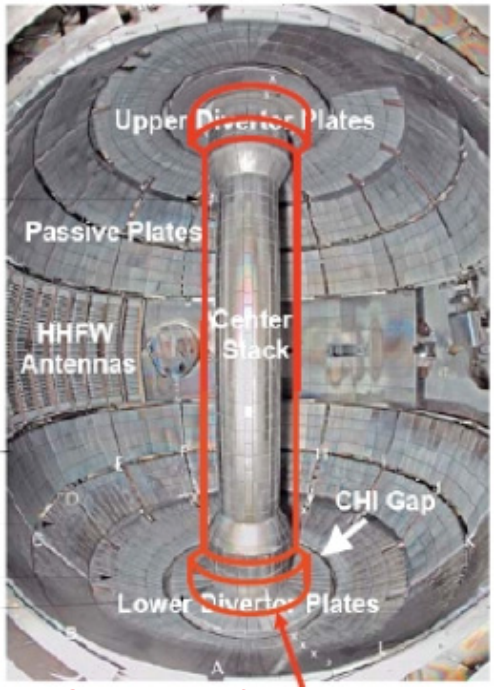
2nd NBI



Upgrades provide major step along ST development path
(next factor of 2 increase in current, field, and power density)

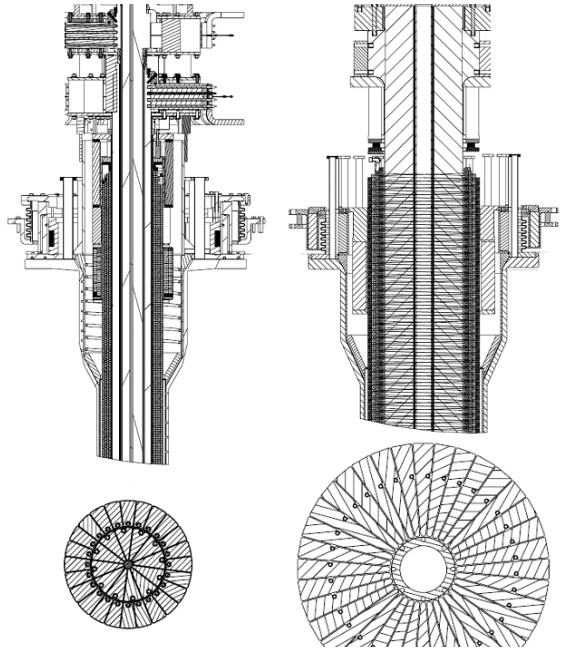
	NSTX	NSTX Upgrade	Plasma-Material Interface Facility	Fusion Nuclear Science Facility
Aspect Ratio = R_0 / a	≥ 1.3	≥ 1.5	≥ 1.7	≥ 1.5
Plasma Current (MA)	1	2	3.5	10
Toroidal Field (T)	0.5	1	2	2.5
P/R, P/S (MW/m,m^2)	10, 0.2*	20, 0.4*	40, 0.7	40-60, 0.8-1.2

** Includes 4MW of high-harmonic fast-wave (HHFW) heating power*



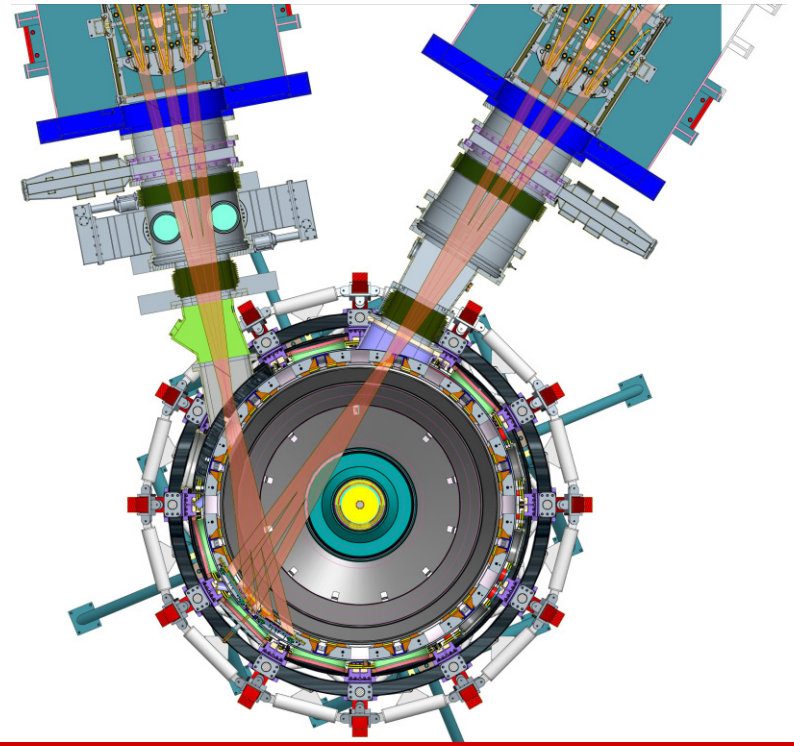
Outline of new center-stack (CS)

Present CS ***New CS***

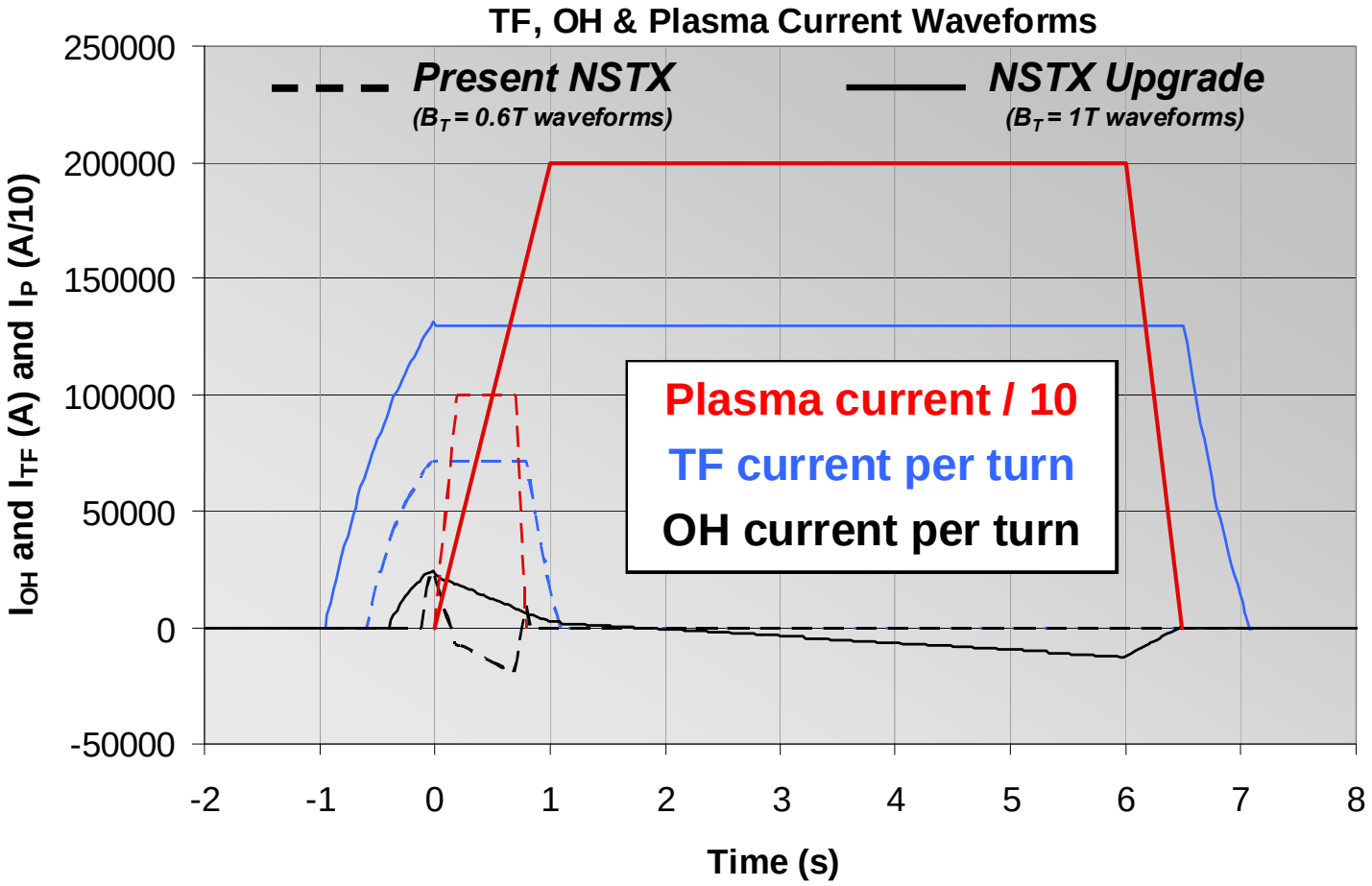


TF OD = 20cm *TF OD = 40cm*

New 2nd NBI ***Present NBI***
(R_{TAN}=110, 120, 130cm) ***(R_{TAN}= 50, 60, 70cm)***



Upgrade provides substantial increase in device performance
An order of magnitude enhancement in $n\tau T$



	Base NSTX	NSTX Upgrade
R_0 [m]	0.854	0.934
Min. aspect ratio	1.28	1.5
I_p [MA]	1	2
B_T [T]	0.55	1
T_{pulse} [s]	1	5
$T_{repetition}$ [s]	600	1000
$R_{center\_stack} = R_0 - a$ [m]	0.185	0.315
$R_{antenna} = R_0 + a$ [m]	1.574	1.574
Total OH flux [Wb]	0.75	2.1

Relative performance of Upgraded NSTX vs. Base:

- Center-stack radius increased 13cm → A=1.3 → 1.5
- Available OH flux increased 3x, 3-5x longer flat-top
- I_P increased 2x, B_T increased 2x at same major radius
- Plasma stored energy increased up to 4x (0.25→ 1MJ)

NSTX Upgrade Project
Good Progress to Date

☑ **CD-0 Approved - *February 2009***
- *Approval of mission need*
- *Begin Conceptual design*

☑ **Conceptual Design Review - *October 2009***

NSTX PAC-27

☑ **CD-1 Approved - *April 2010***
- *Approval of Alternate selection and cost range*
- *Begin Preliminary Design*
- *Begin Capital costing*

☑ **Preliminary Design Review - *June 2010***

☑ **CD-2 Approved - *December 2010***
- *Approval of performance baseline*
- *Technical, cost and schedule baseline frozen!*

NSTX Upgrade Project Baselined at CD-2

Cost and Schedule is now "locked-in"

PAC27-1

- Baselined December 2010
- Begin Upgrade Outage: April 2012
- Base Completion Date: September 2014

NSTX-U Baselined funding plan is fixed

Ops	Ops	Ops	Op	30 month Outage		
FY09	FY10	FY11	FY12	FY13	FY14	FY15
$5.10	$8.30	$9.60	$14.60	$25.30	$27.50	$3.80

- *In FY12, the NSTX operations team shifts to the Upgrade Project on April1, 2012.*
- *It is therefore critically important to end the NSTX operation in February 2012 so that we can start the Upgrade Outage on schedule.*

Boundary with H-Mode Pedestal Physics for JRT

MPTS Extra Channels, MSE-LIF, MAPP Probe

	FY 10	FY 11	FY 12	FY 13
ARRA				
Run Weeks Base	1 14	4	10	10

Upgrade Outage FY 2012-14

Boundary / Li / Pedestal

- Upgraded FIReTIP (UCD)
- BES (U. Wisconsin)
- LLD (SNL)
- PMI Probe
- Lithium CHERS
- Divertor Spectrometer (LLNL)
- Two-Color Fast IR Camera (ORNL)
- MPTS Extra channels
- MSE-LIF (Nova Photonics)
- Moly Tiles
- *Materials Analysis Particle Probe (MAPP) (Purdue)*
- ME-Pedestal-20 channel SXR (Johns Hopkins)

Enhanced LLD: Molybdenum tiles on inboard divertor

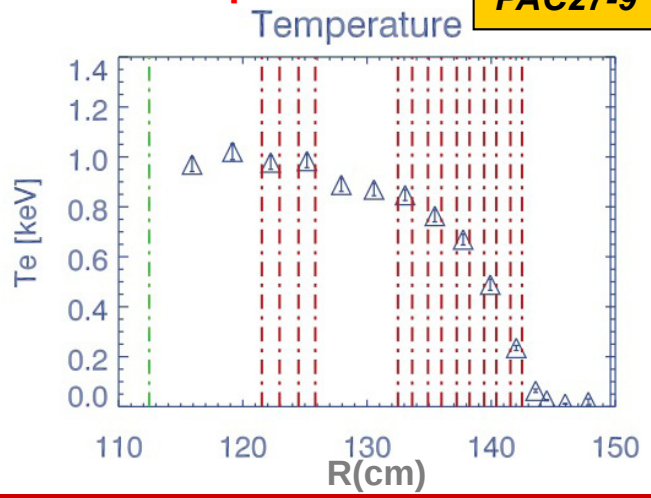
-- To reduce carbon influx

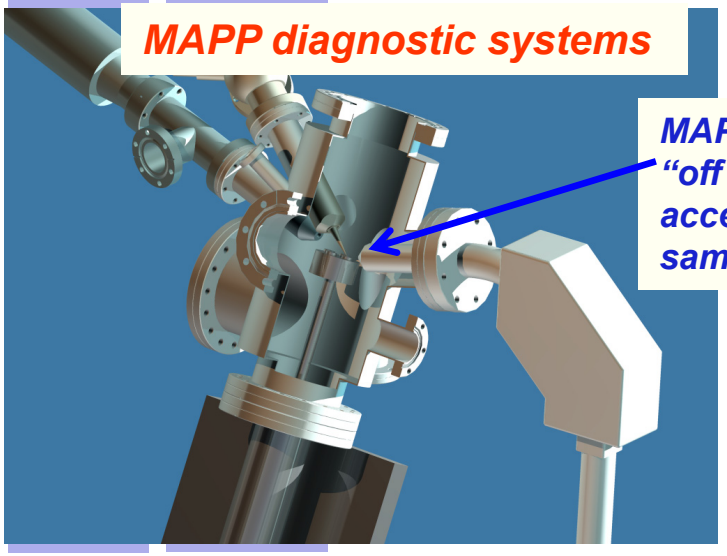
- Facilitate CHI

- Provide additional liquid lithium pumping surfaces

Additional 12 MPTS channels will enhance resolution in H-mode pedestal

PAC27-9

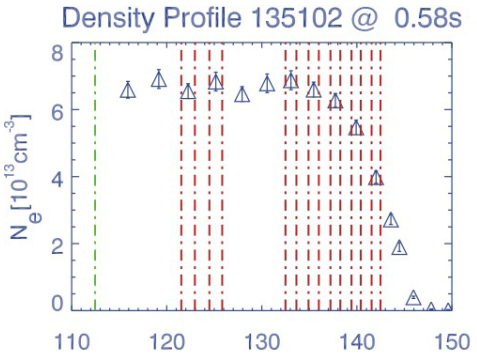


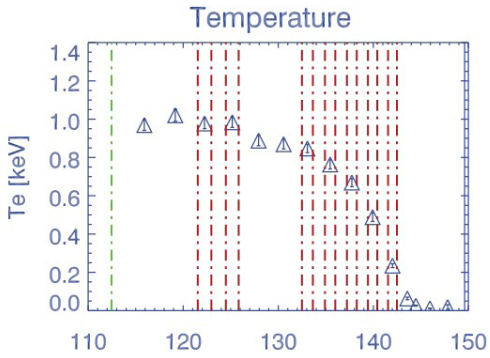


MPTS Extra Channel Upgrade Status

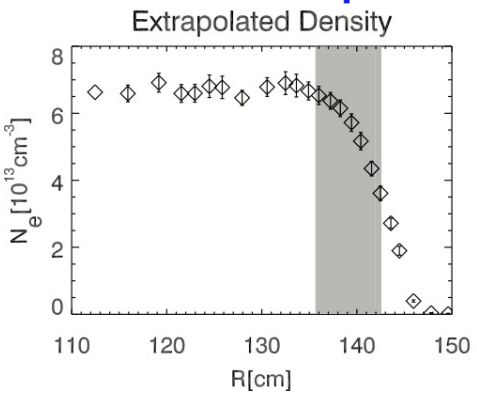
To support H-mode pedestal JRT milestone

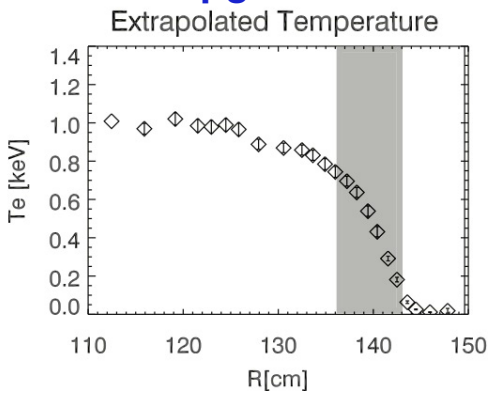
PAC27-9





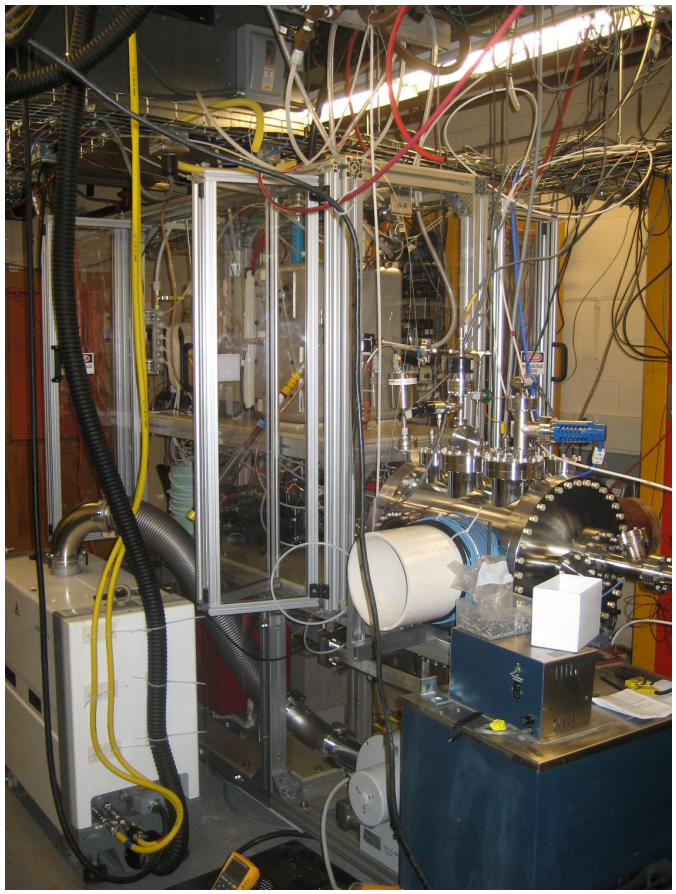
MPTS spatial locations after upgrade

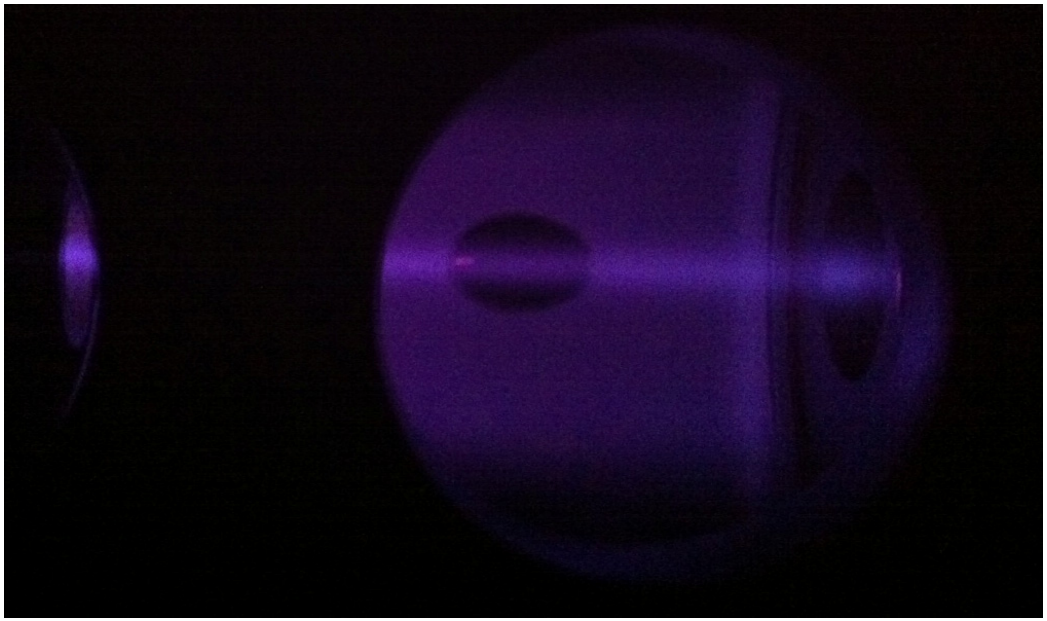




- 12 new polychromators have been been assembled, tested, and installed at D-site (shown above).
- Splitting of fiber bundles started mid-January.
- **Expect to have 12 additional MPTS channels installed and calibrated by start of next run.**
- **Will provide improved spatial resolution in H-mode pedestal and ITB regions.**

Motional Stark Emission – Laser Induced Fluorescence (MSE-LIF, Nova Photonics) Status

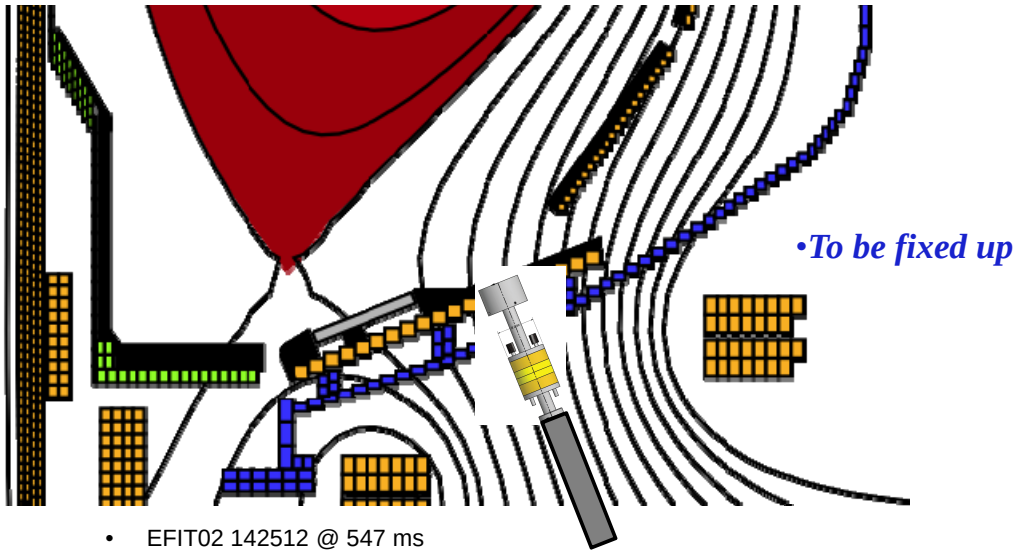




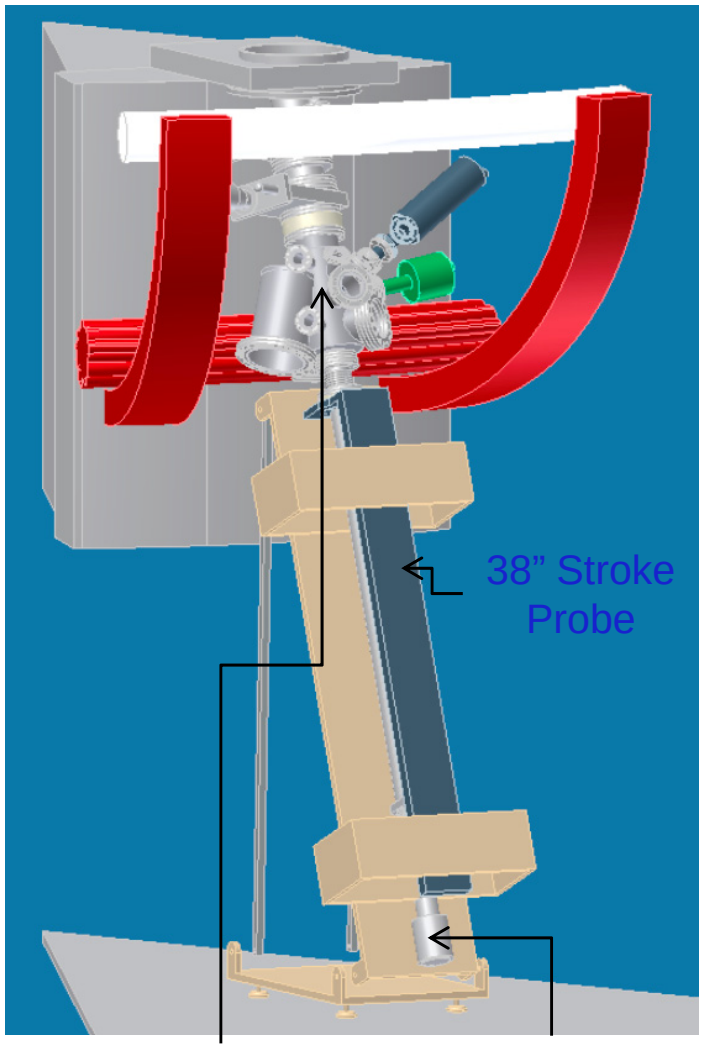
- Diagnostic Neutral Beam has been reconfigured for installation on NSTX and tested in lab (shown above). Laser has been tested in lab and works well.
- Modifications to NSTX infrastructure needed to support installation of DNB, laser, and viewing optics are going well.
- **Expect to have installation complete and ready for commissioning by start of next run.**

Materials Analysis Particle Probe (MAPP) will be installed with Purdue University

- MAPP is the first in-vacuo surface analysis diagnostic directly attached to a tokamak, capable of shot-to-shot chemical surface analysis of material samples (solid Li, liquid Li, Mo etc) .
- MAPP will enable the correlation of plasma facing component (PFC) surface chemistry with plasma conditions and point the way to improved plasma performance.

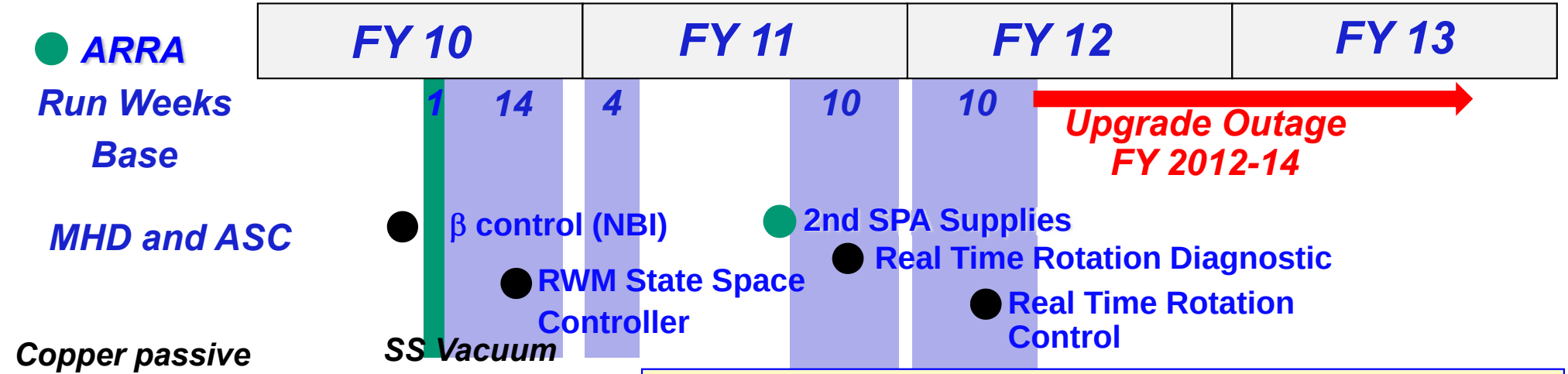


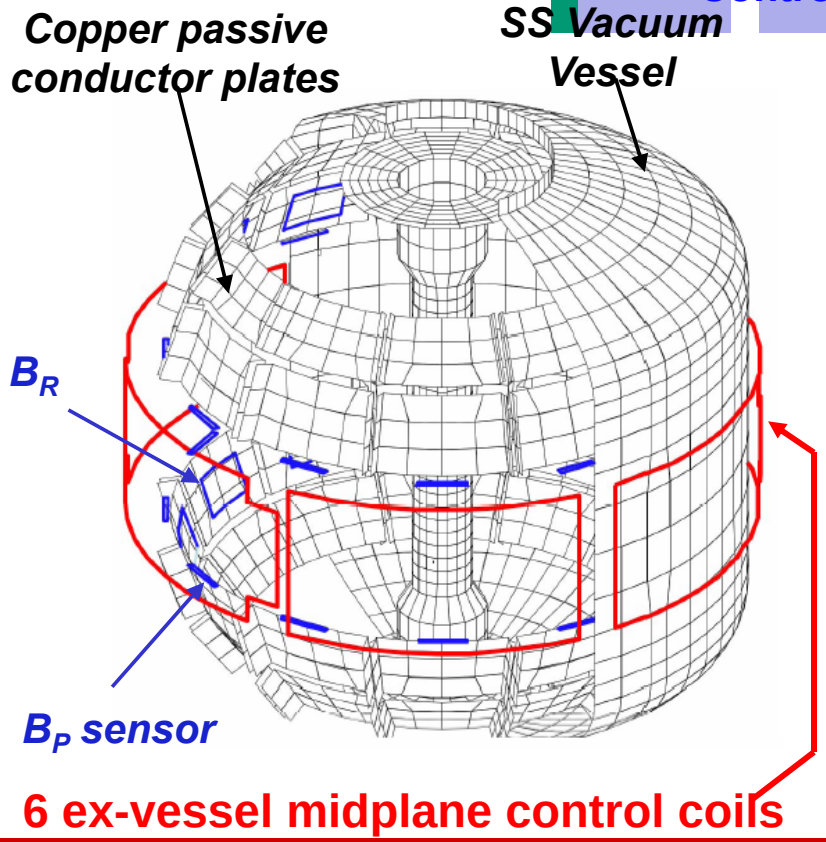
- EFIT02 142512 @ 547 ms



Macrostability and Plasma Control

Sustain β_N and Understand MHD Behavior Near Ideal Limit





Real Time Rotation Diagnostic Status: Provide fast, real-time measurement of toroidal rotation velocity at 4 spatial locations in plasma. On schedule to take data in FY 2011.

- **Install 2nd Switching Power Amplifier (SPA) to enable all six EFC/RWM coils for control of n = 1, 2, 3 simultaneously in FY 11**
  - RWM spectrum dependence
  - Rotation and beta effects on NTMs
  - Response to 3D fields for EFC, ELM and Neoclassical Toroidal Viscosity physics
  - Disruption physics

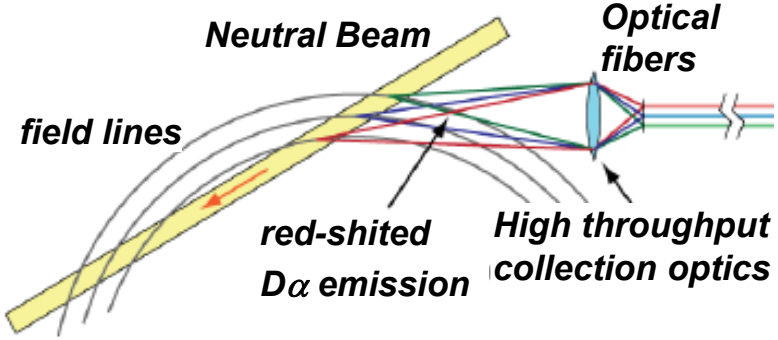
Columbia U, GA, ORNL

Transport and Turbulence

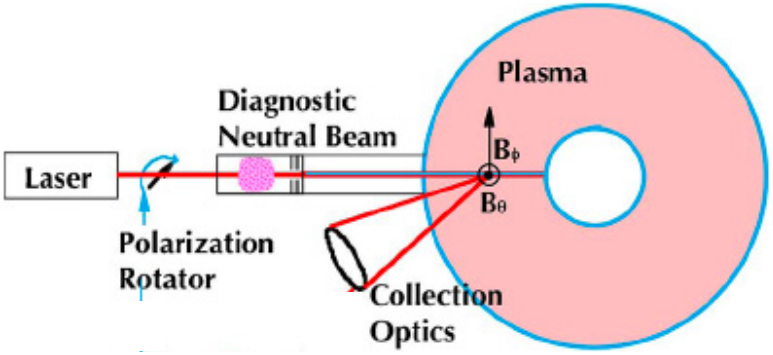
Increase and Understand H-mode Confinement at Lower n_e, ν^*

	FY 10	FY 11	FY 12	FY 13
ARRA Run Weeks	1	14	4	10
Base				10
				Upgrade Outage FY 2012-14
T&T	Upgraded FIReTIP (UCD)			
				MPTS Extra channels
	BES – 16 channels (U. Wisconsin)			BES – 32 channels (U. Wisconsin)
	Solid-state high-k Source			MSE-LIF (Nova Photonics)

- BES together with high-k to provide a comprehensive turbulence diagnostic set.
- High-k with a new solid-state source is running reliably.

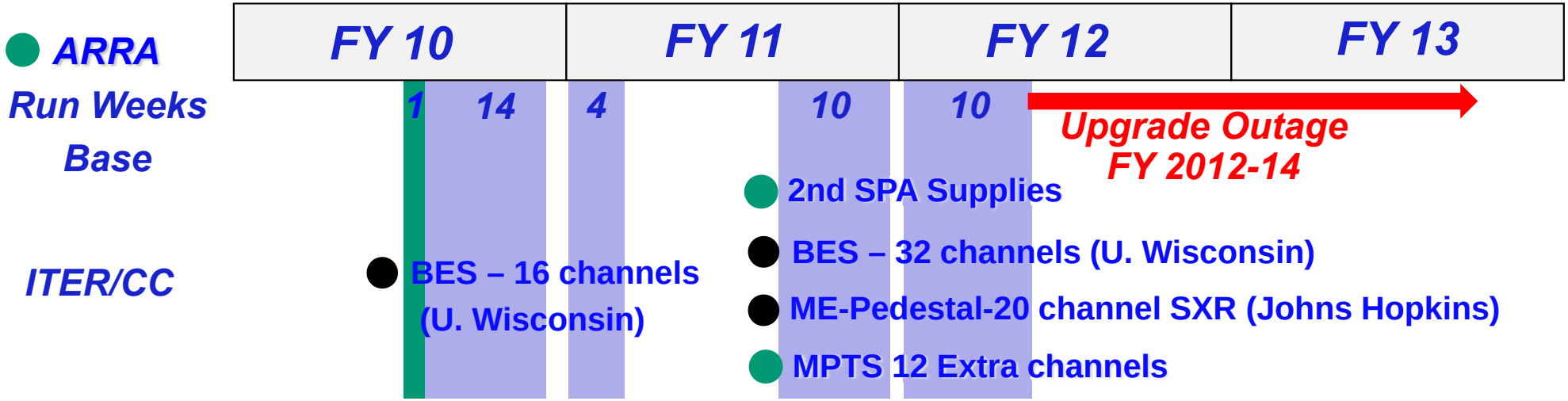


MSE-LIF to Measure $E_r(r)$, B(r)



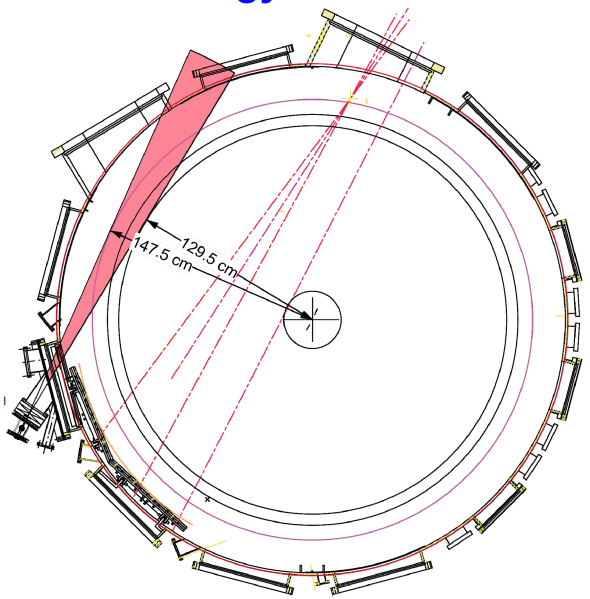
ITER and Cross-Cutting Research

3D field milestone supported by 2nd SPA, MPTS and BES



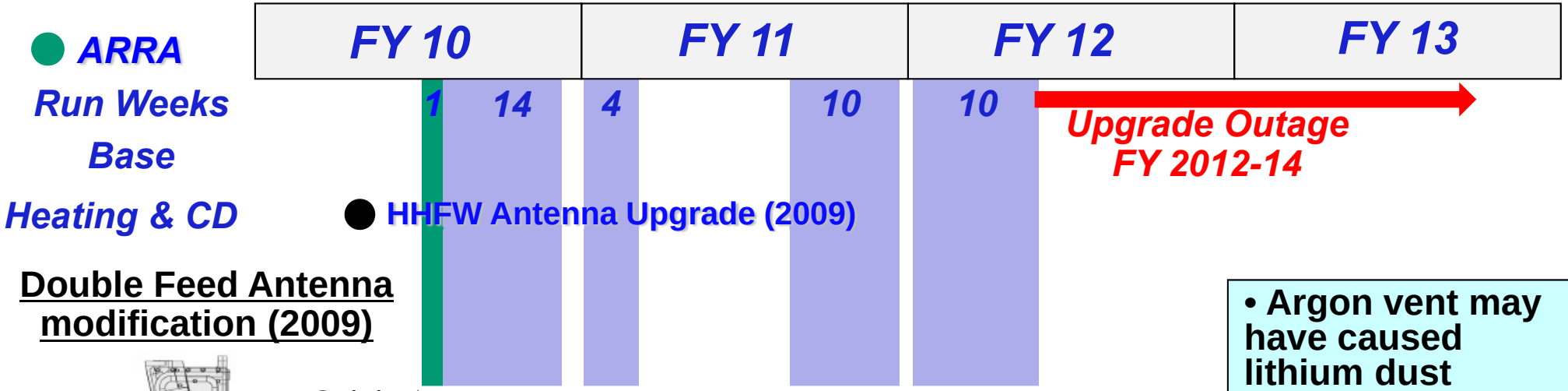
- 2nd Switching Power Amplifier (SPA) to enable n = 1, 2, 3 simultaneous control of 3D fields in FY 11
- BES to be expanded to 32 channels together with high-k to provide a comprehensive pedestal turbulence diagnostic set.
- 20 channel New Multi-Energy Soft-X-Ray Diagnostic (JHU) measures emission from the pedestal with ~ 1 cm resolution
- 12 additional MPTS channels improves the pedestal spatial resolution to ~ 1 cm

Multi Energy -Pedestal-SXR

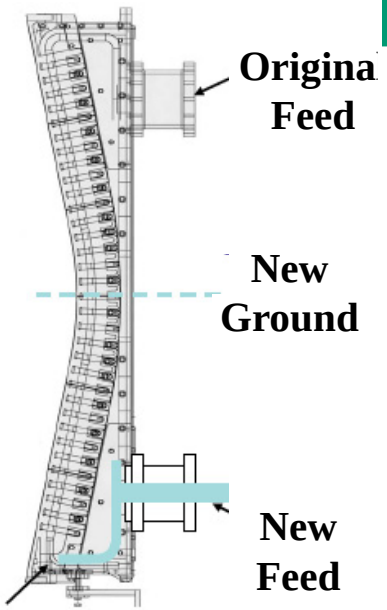


HHFW Operations Encountered Power Limit due to Heavy Lithium Use

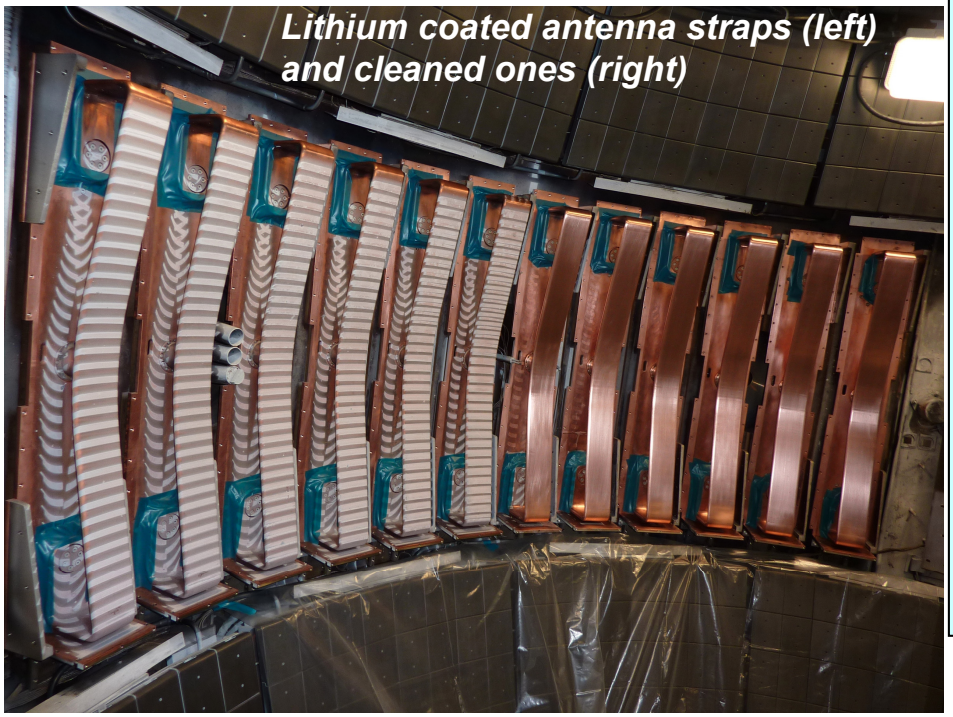
Heavy lithium coating and lithium particulates were observed on the antenna



Double Feed Antenna modification (2009)



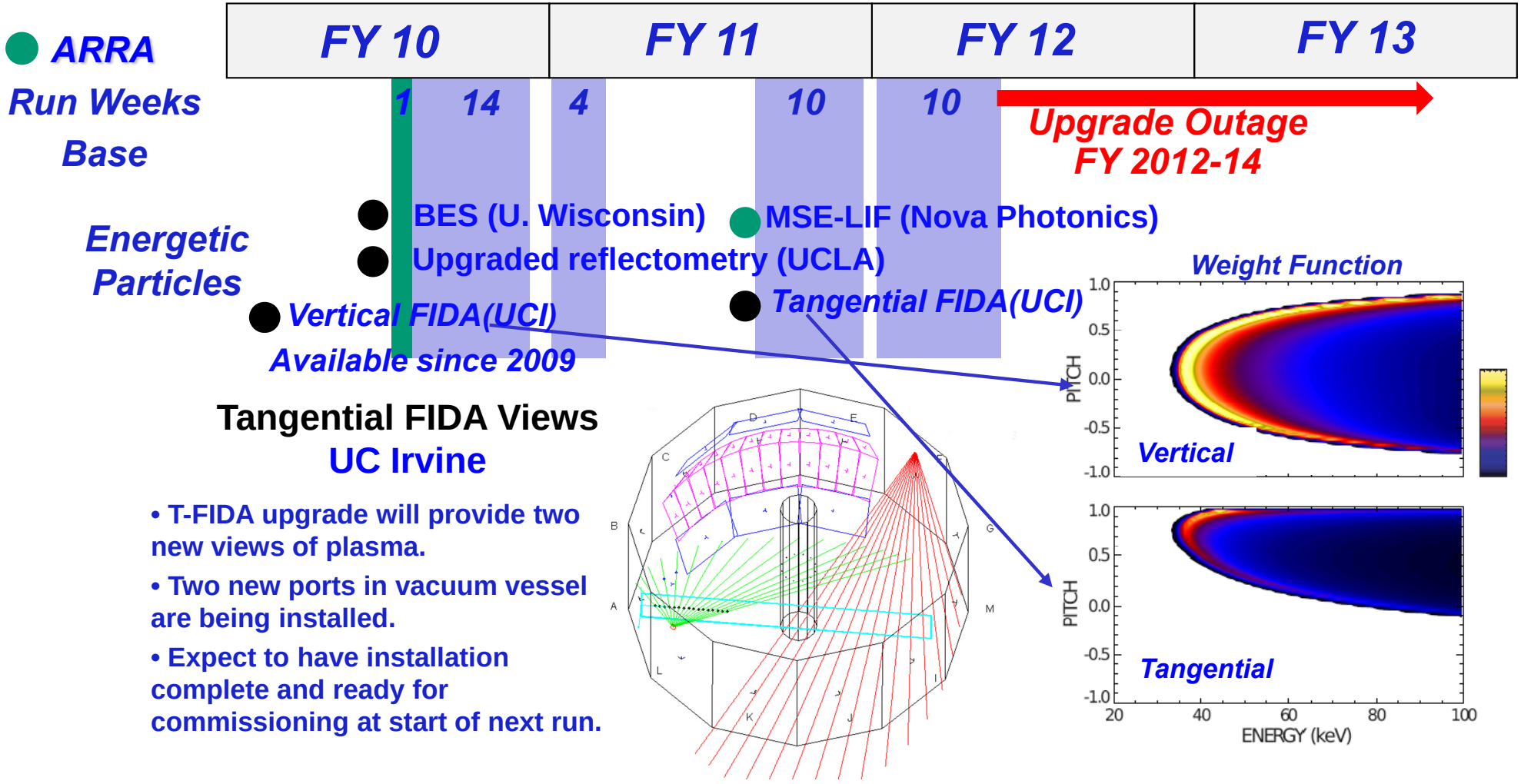
- Maximum radiation at mid-plane
- Power capability should increase by a factor of 2



- Argon vent may have caused lithium dust formation resulting in arcing
- Lithium related issues need to be resolved with early HHFW operations and improved RF conditioning
- Reliable high power operation in H-mode is high priority goal

PAC27-28

Innovative Diagnostics for Energetic Particle Research Being Implemented on NSTX



- Utilize present Fast Ion D-Alpha (FIDA) system design with spectrometer: 2x16 channels
- Enhanced signal, better localization in velocity space weighted toward parallel velocity
- Well suited to investigate NBI fast ion transport and current drive physics

Solenoid-free Start-up

CHI enabled lower density lower inductance start-up

ARRA

FY 10	FY 11	FY 12	FY 13
Run Weeks: 1	14	4	10
Base			10

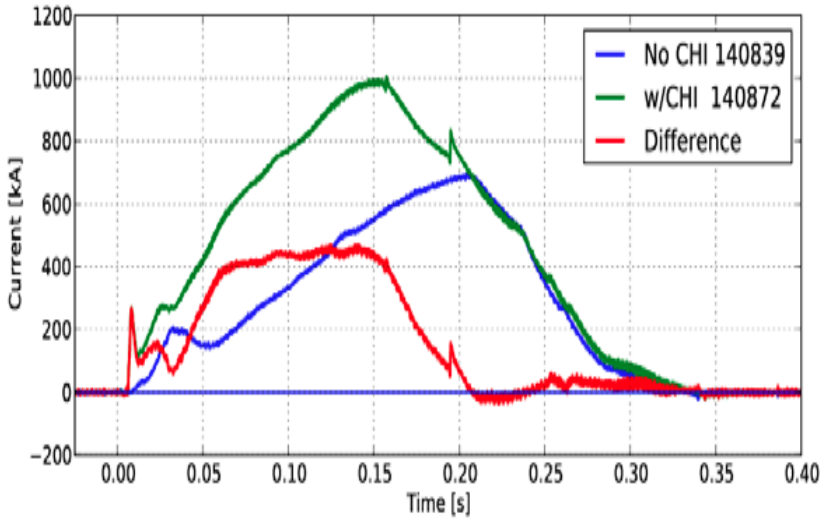
Upgrade Outage FY 2012-14

Start-Up

- LLD (SNL)
- CHI Absorber Control Coils (U. Washington)
- Moly tile cathode

Success of CHI aided by Low-Z Impurity Control

U Washington



Low Z impurity reduction during CHI produced OH compatible plasmas

- Discharge cleaning of lower divertor plates or electrodes
- Avoidance of absorber arcs by control coils
- Lithium evaporation of lower divertor surfaces

Utilizing in-board moly tiles to provide cathode surfaces to reach ~ 0.5 MA

- PEGASUS gun start-up producing exciting results Ip ~ 160 kA. The PEGASUS gun concept is technically flexible to implement on NSTX once fully developed.
- Testing at the end of FY 12 run being proposed utilizing the PEGASUS system in collaboration with University of Wisconsin

Initial Diagnostic Development for Upgrade

New capability and general diagnostic improvements

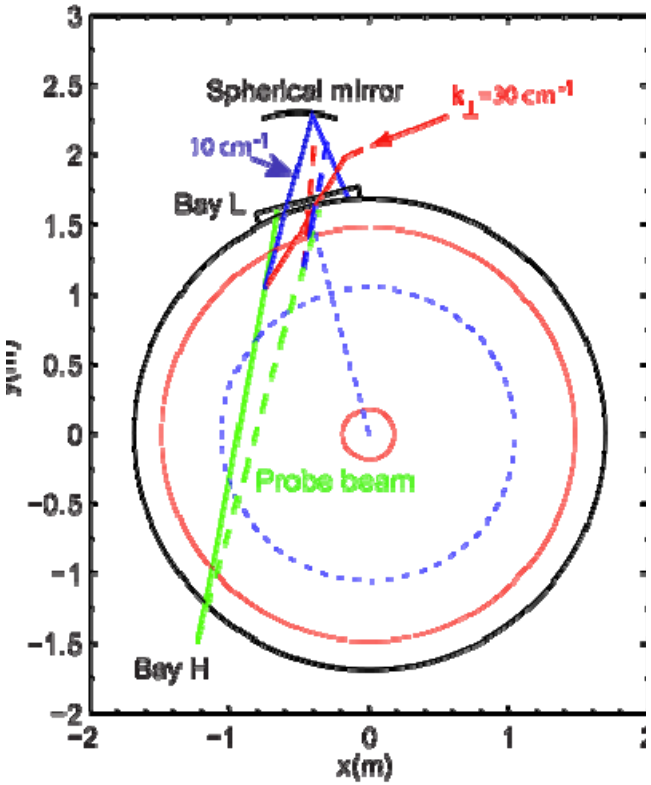
NSTX Diagnostic Proposal will be solicited in 2011 for 2012-2015:

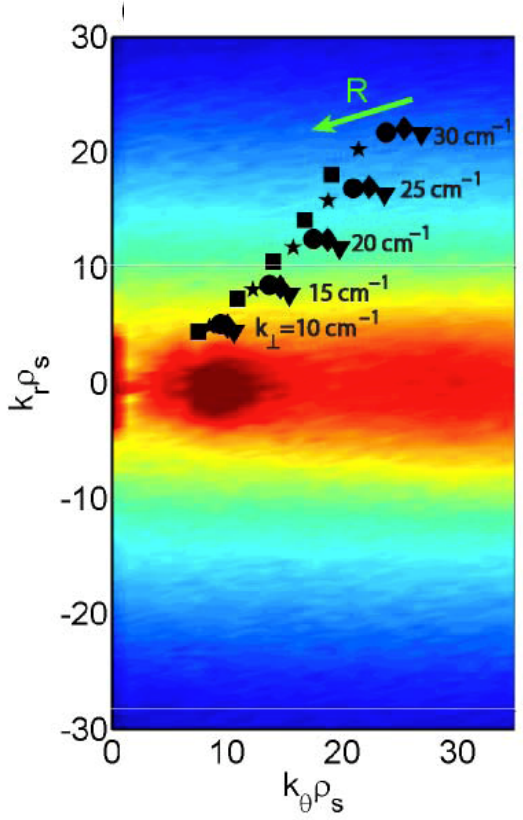
- *T &T : High-k scattering with 2D k spectrum capability?*
- *MHD / control: Real time current profile?*
- *Boundary physics area?*
- *Energetic particle in addition to FIDA?*
- *Wave physics?*

A candidate new high-k scattering system for allowing 2 D k spectrum:

- *The new high-k scattering system will utilize the launching port of the present high-k_r system and its microwave hardware.*

- *Two scattering configurations of the system will allow it to measure 2D k spectrum.*





NSTX FY 2013 FWP Budget Summary ($M)

	FY2011		FY 2012		FY2013	
Budget cases	**Base**	**ARRA**	**Base**	**Incr.**	**Base**	**Incr.**
Run Weeks	**14**	**0**	**12**		**0**	**0**
Facility Operations	21.2	0.4	15.9		7.1	
Fac. Enhancements	0.3	2.4	1.1		1.8	0
CS & 2nd NBI	9.0	0	14.6	4.5	25.3	5.0
Facility Total	**30.5**	**2.8**	**31.6**	**4.5**	**34.2**	**5.0**
PPPL Research	10.0	0	11.7	0	12	0.0
Collab Diag Interf.	0.4	0	0.4	0	0.4	0.0
Collaborations	5.9	0	6.1	0.	6.3	0.0
Science Total	**16.3**	**0**	**18.2**	**0**	**18.7**	**0.0**
NSTX Total	**46.8**	**2.8**	**49.8**	**4.5**	**52.9**	**5.0**

- **Incremental: Greatly enhance the science productivity near term as well as longer term**
  - **+ 10% ($4.5M - $5.0M) incremental funding in FY 2012-2013 enables the upgrade project to accelerate critical path items and reduce the schedule risks and overall cost, accordingly.**
- **10% Cut case: Significant loss of research productivity and personnel**
  - **Loss of 19 Direct FTEs for PPPL including younger researchers**
  - **Delay the upgrade and increase the schedule risks and increase overall cost**

Optimized Plan Developed for FY 2011–13
Exciting Opportunities and Challenges Ahead

- Very productive FY2010 run with all milestones completed
- FY 2011 - 2012 run to start with new capabilities
  - MAPP Probe (Purdue U)
  - Tangential soft-x ray array (JHU)
  - Tangential FIDA (UCI)
  - Real time rotation measurements and control
- ARRA funding enables facility upgrades to support FY 2011–12 research plan
  - MSE-LIF to complement MSE-CIF (Nova Photonics)
  - 2nd SPA for improved RMP/EF/ RWM capability
  - MPTS Extra Channel for improved pedestal resolution
  - Molybdenum In-board Divertor Tiles
- NSTX Upgrade project is making good progress
  - Successful DOE OFES CD-2 Approval in Dec 2010
  - Research activities in FY 2013 - 2014 are being planned
- Incremental budget greatly enhances facility capability and output
  - Accelerate the center-stack and 2nd NBI upgrade schedule and reduce risks

Back-Up Slides

NSTX Lithium Observations

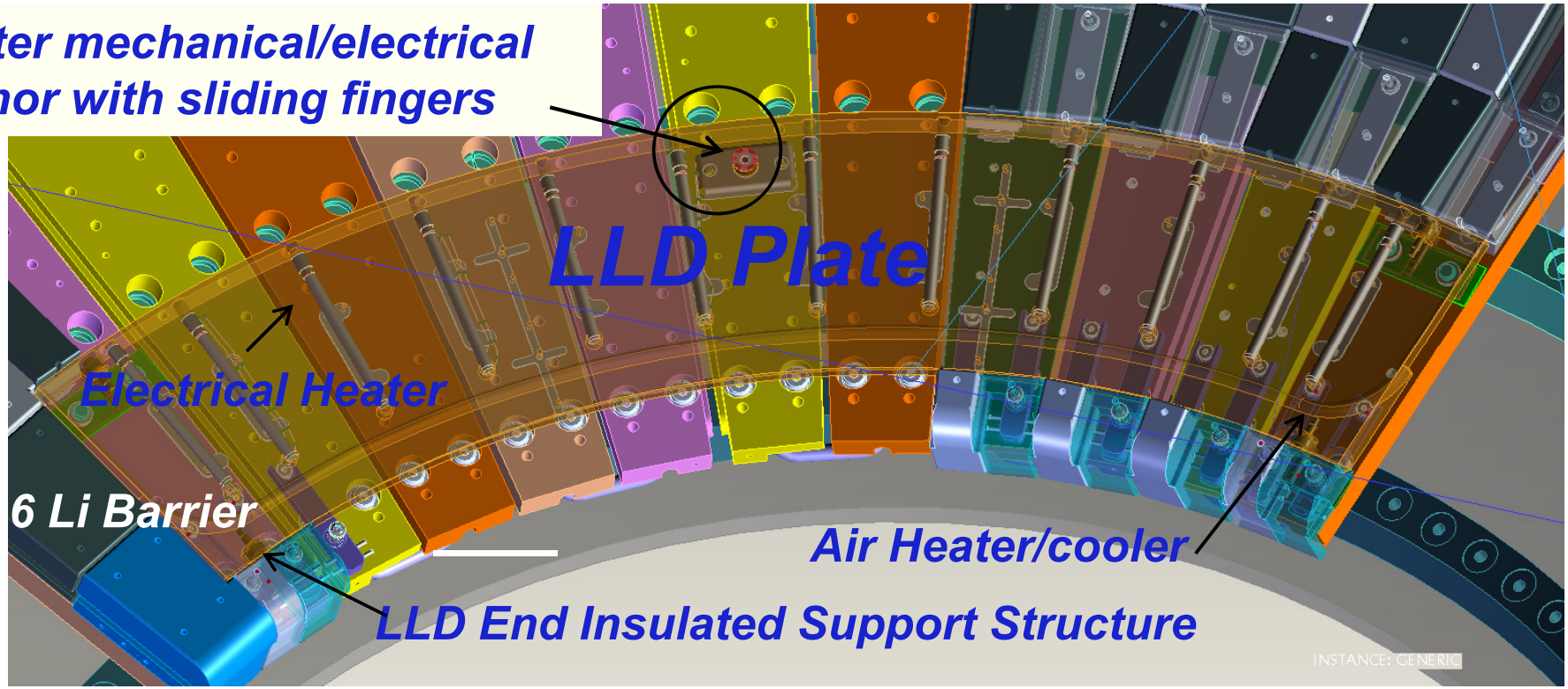
Lithium is an important tool for all science areas

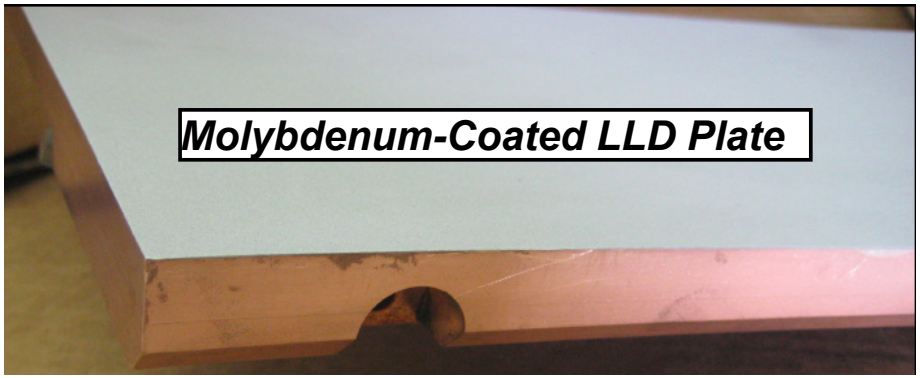
Observations:

- **Lithium evaporators (LITER) produced most dramatic effects thus far and they will be available.**
- **Lithium is pumping deuterium enabling deuterium density saturation in the long pulse discharges.**
- **However carbon impurity accumulation is preventing lower density long-pulse operations - need to minimize carbon influx – e.g., promising result with snowflake divertor.**
- **Molybdenum appears to be a good divertor material from LLD experience – giving us the confidence to move on to the moly-tile inboard divertor.**
- **LLD plates will be repaired and reinstalled.**

Liquid Lithium Divertor (LLD) Schematic Overview

with Porous Molybdenum Face to Hold Lithium





- 0.165 mm Mo plasma sprayed with 45% porosity on a 0.25 mm SS barrier brazed to 22.2 mm Cu.

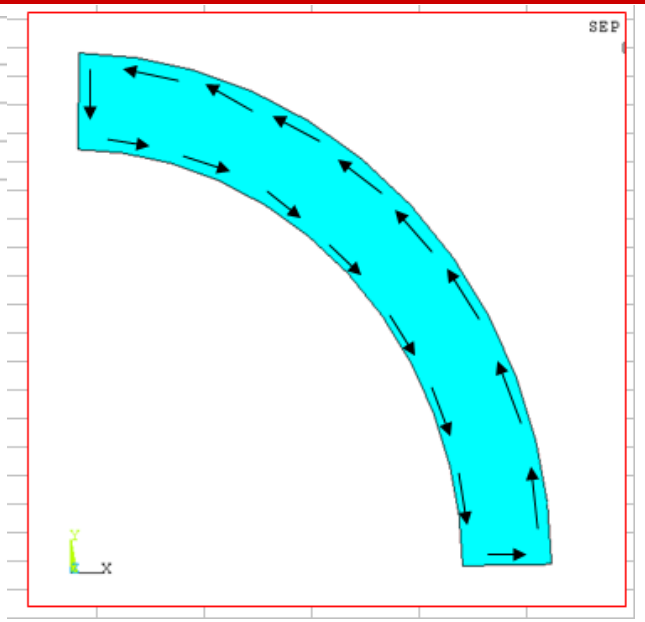
- 4 heated plates (80°each) separated by graphite diagnostic tiles.
- Each toroidal section electrically grounded to vessel at one mid-segment location to control eddy currents.

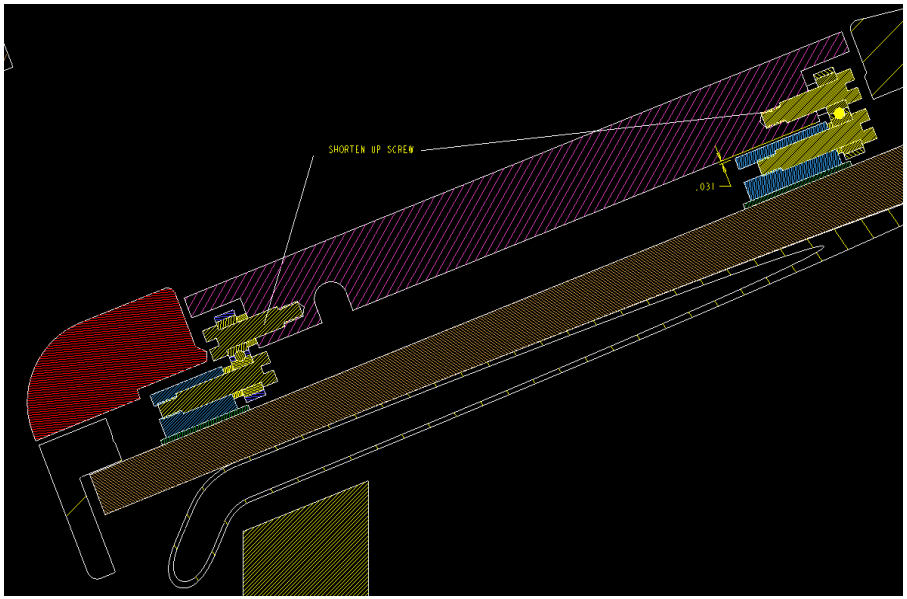
LLD Support Structure Design

Plasma Disruption forces taken into account in the design

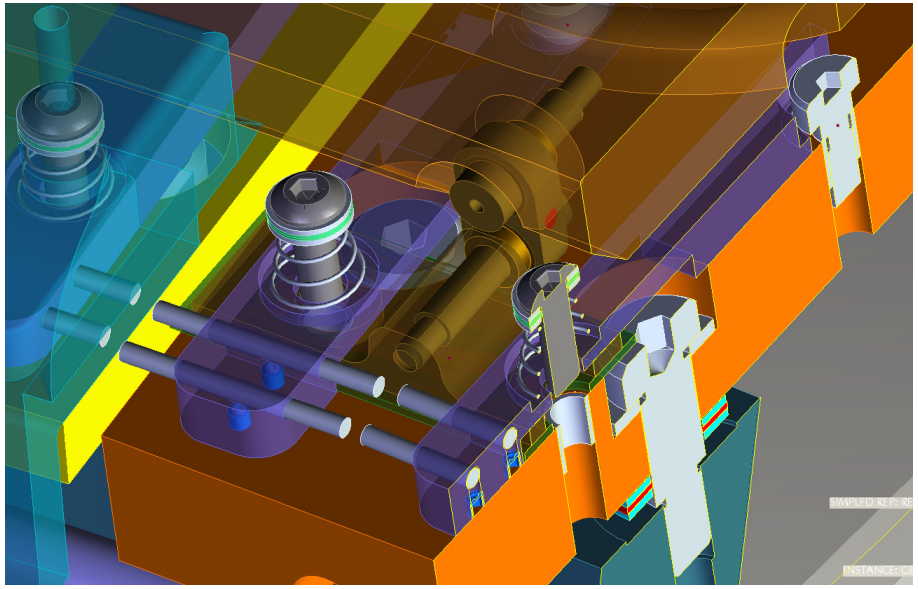
Force Estimates			
Based on LLD Only without VV/PP/CS effects			
Imax	21405	amps	Spark .9 MA Plasma Model with effective dB/dt~60 T/s for 3 ms

	Net Load on Edges, lbs		
	Fr	Fth	Fz
IR	962	0	257
OR	-1347	0	-281
0 deg	0	-193	-490
90 deg	0	193	490
~Total	-384	0	-24





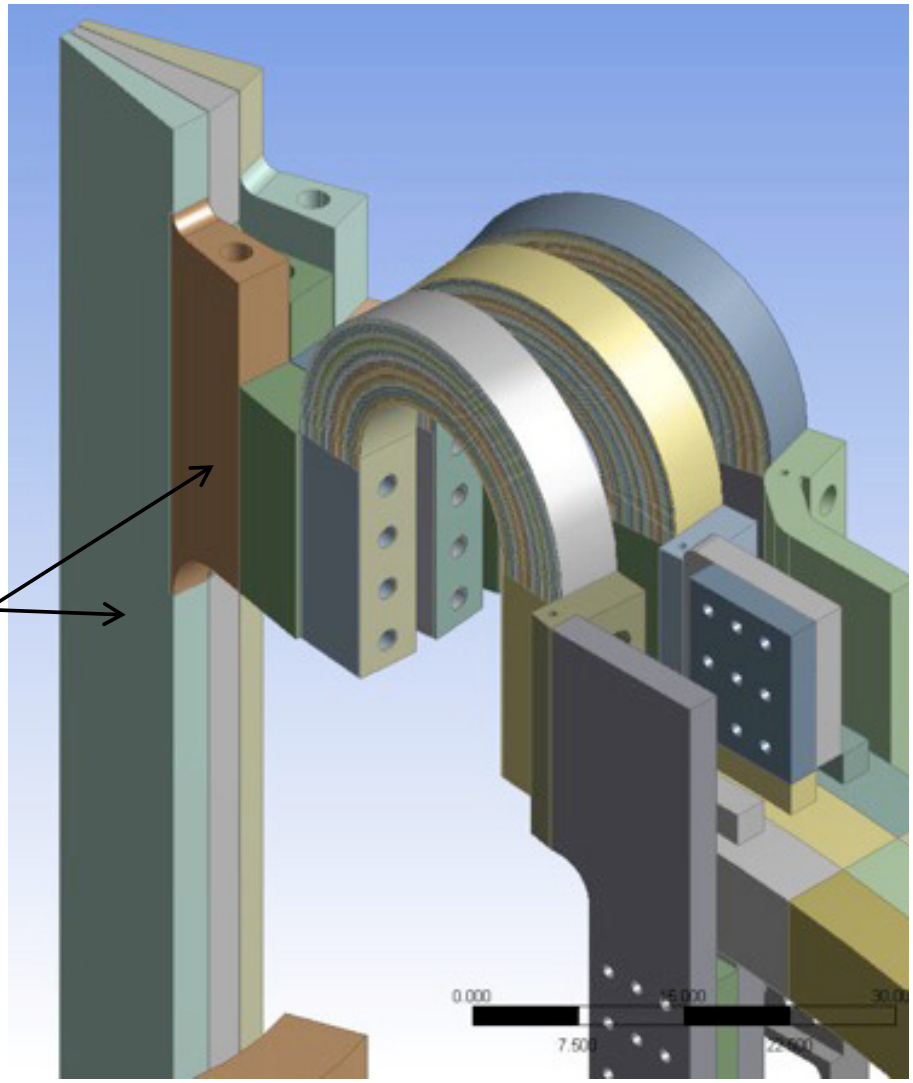
LLD Support AssemblyCross Section View



Front LLD Support Assembly w/o Tile

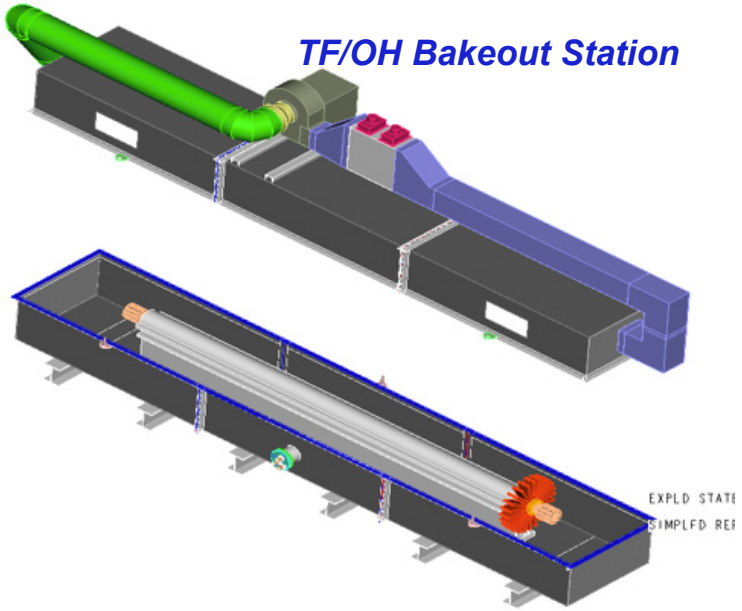
NSTX Upgrade Project Plans for 2011

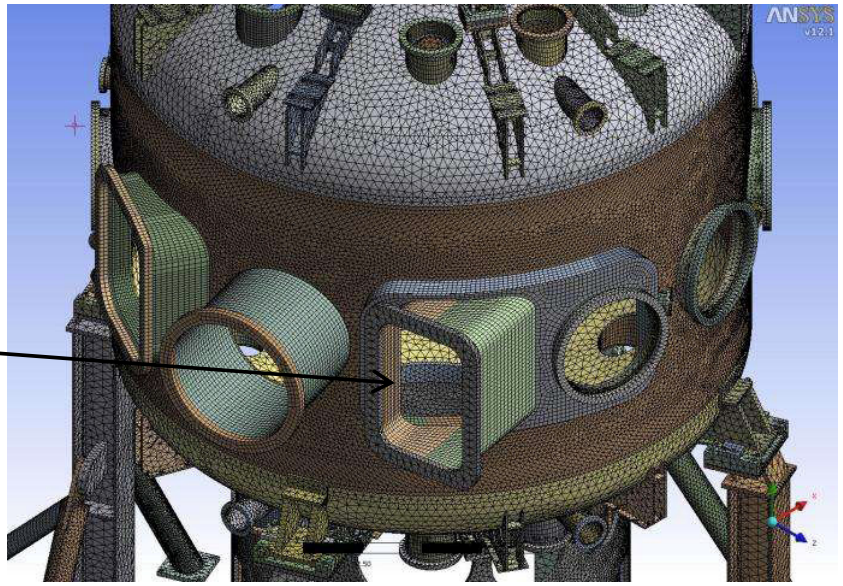
- ☑ **Complete 2nd NBI decontamination and begin refurbishment - *December***
- ❑ **Design Peer reviews**
  - *CS (May)*
  - *NBI (March)*
- ❑ **Award critical and long lead procurements**
  - *Inner TF conductor (January)*
  - *TF Conductor machining (May)*
  - *Lead extensions (May)*
- ❑ **Final Design Review - *June***
- ❑ **SC-OPA (Lehman review) - *August***
- ❑ **Request CD-3 Approval - *September***



NSTX Upgrade Project Plans for 2012

- **CD-3 Approval - *October***
  - *Authorization to begin procurement and fabrication*
- **Begin Assembly of CS incl friction stir weld lead extensions to inner TF conductor - *January***
- **Continue NBI refurbishment**
- **Award critical and long lead procurements**
  - *NB Rect Bellows*
  - *CS PFC's*
  - *Inner PF Coils*
  - *CS Casing*
  - *TF/OH materials*
  - *NBI vessel cap*
- **Complete FY12 operations campaign - *March***
- **Begin outage - *April***
- **Start Diagnostics & Equipt removals**

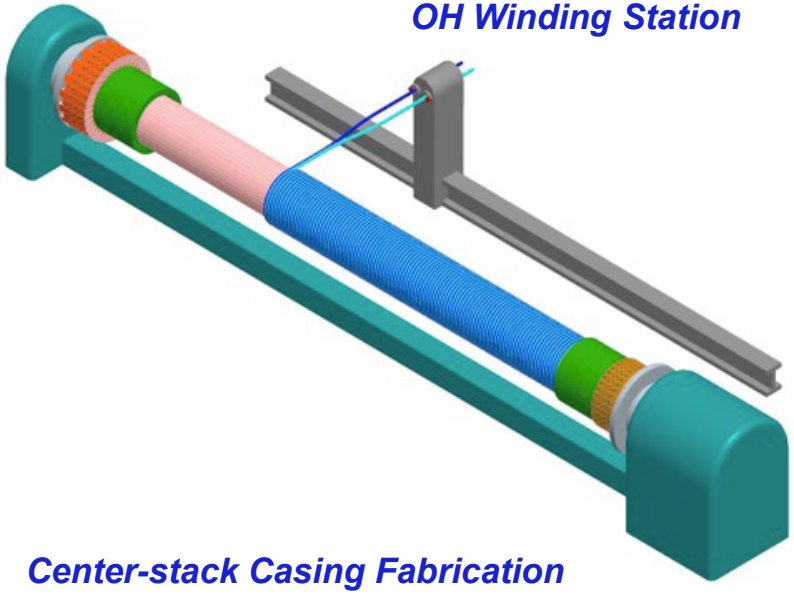




NSTX Upgrade Project Plans for 2013

- Complete Diagnostics & Equipt removals
- Complete fabrication, assembly and test of TF/OH coil
- Begin Final assembly of CS
- Structures modifications
- Existing CS removed
- Complete refurbishment and begin relocation of 2nd NBI\
- CS PFC Tile fabricated and machined
- Deliver NB Vessel Cap
- Begin FCPC upgrade

OH Winding Station

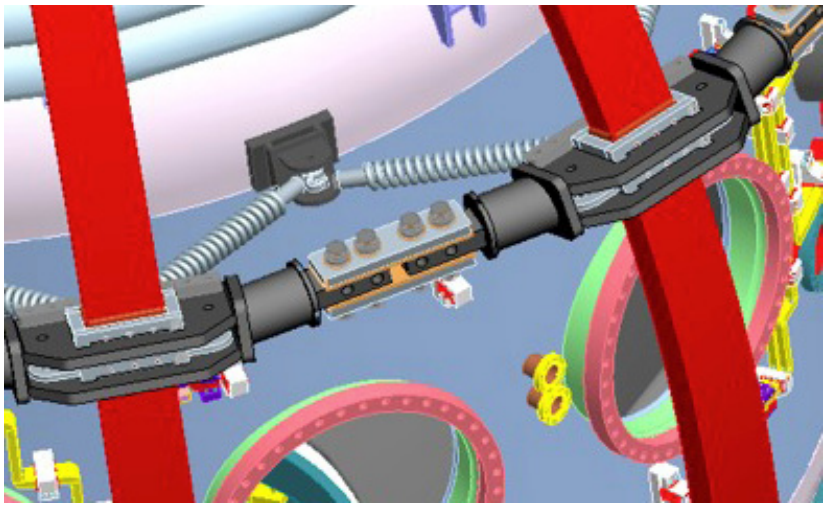


Center-stack Casing Fabrication

NSTX Upgrade Project Plans for 2014

- NBI Vessel Cap Installed
- 2nd Beamline Installed with services connected and tested
- Complete FCPC Power Cable Installation
- Bay L MPTS VV port installed
- Install New Pump Duct
- Complete Structures Modifications
- Re-install Diagnostics
- Complete Assy, Test and Installation of New Center Stack
- Install Remaining Coil Structures and Umbrella
- Complete ISTP
- Project Complete

TF Support Structure Upgrade



Upgraded NSTX Test Cell