NSTX-U

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NSTX Upgrade Project Status, Facility and Diagnostic Overview

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for the NSTX Research Team

NSTX PAC-31
PPPL B318
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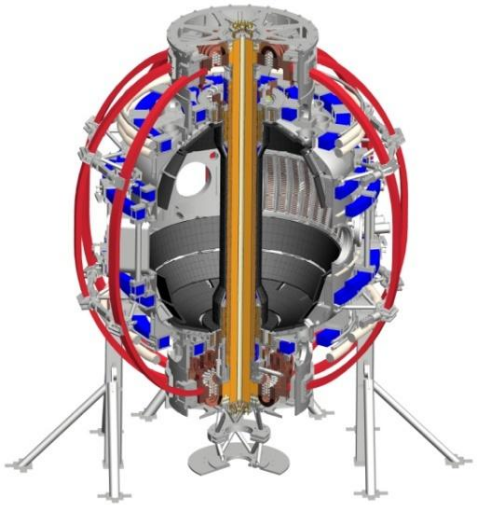

Talk Outline

- Operations Summary and Status
- NSTX Upgrade Project Status
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NSTX Started Upgrade Outage Six-Months Earlier

We were able to determine the cause of the TF Fault

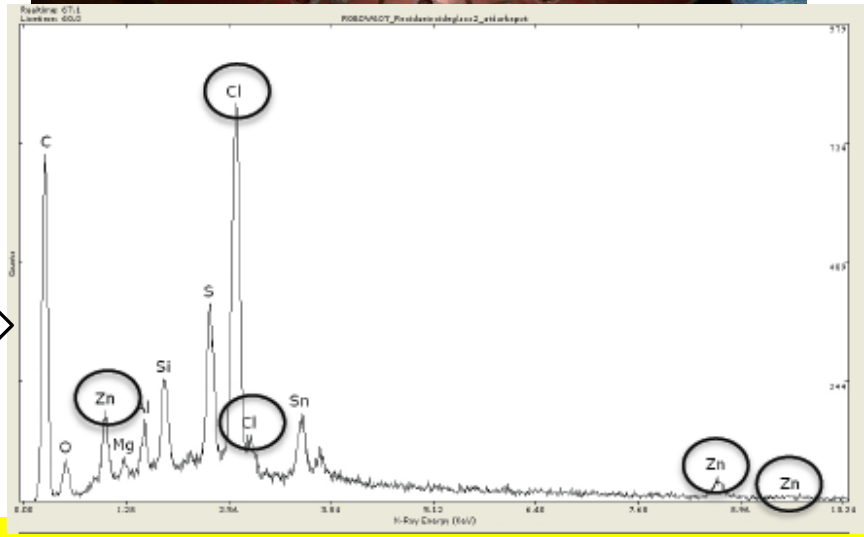
- Achieved 4.2 run weeks with 839 plasma shots on October 25, 2010 which represents a record ~ 200 plasma shots per run week.
- Completed the 2011 outage including diagnostic installations and calibrations in June 2011 and prepared to resume operation.
- During the recommissioning ISTP, an electrical fault in the toroidal field (TF) coil inner bundle occurred on July 20, 2011
- Dissection of the bundle revealed that the fault was caused by a gradual deterioration of the insulation by residues of a flux containing zinc-chloride used during fabrication of the TF bundle in 2003.
- A panel of external experts in magnet construction conducted an independent review of the TF fault on September 7, 2011 endorsing the findings.
- After carefully assessing options, it was decided to proceed directly to the planned NSTX Upgrade Project outage as of Oct. 1, 2011, which would result in an acceleration of its upgrade schedule by six months.
- A number of improvements will be implemented in manufacturing the new TF bundle for the upgrade from lesson learned from the TF fault.

NSTX TF Fault Occurred on July 20, 2011

TF Bundle Operated for 7+ years for 20,000 shots

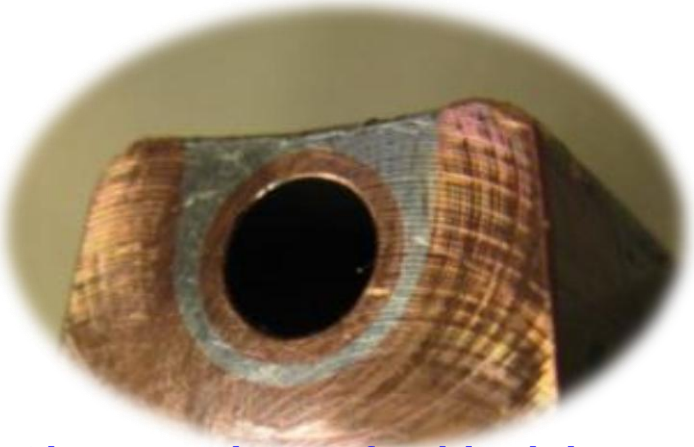
- TF bundle short occurred ~ 2 feet from the bottom in a relatively low mechanical stress area.
- TF bundle dissection and analyses showed no sign of fatigue.
- Zinc chloride based flux used for cooling water tube soldering was the cause of insulation failure.

Dissection of shorted region



TF Upgrade will use resin flux and improved procedures for removing the flux residues

Developed new soldering technique with resin-based flux in response to TF bundle fault lesson-learned



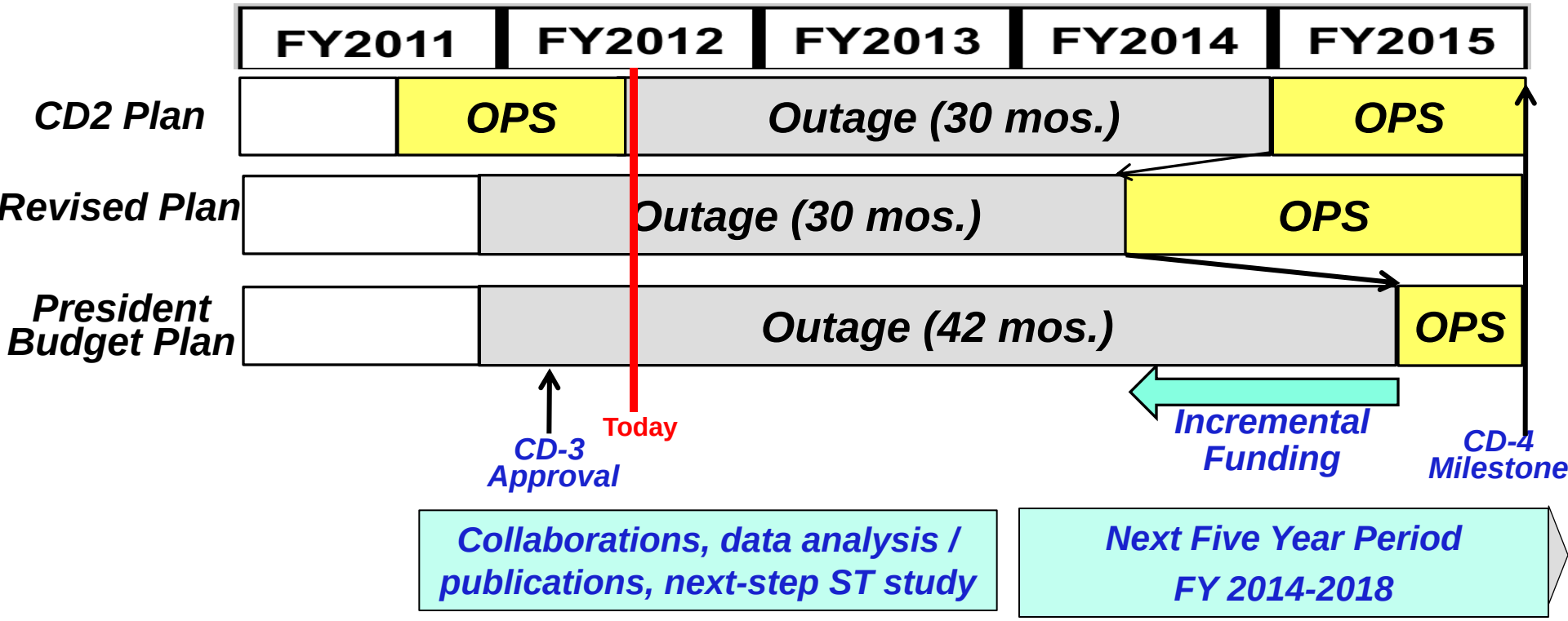
Images of tubes pull tested to ultimate strength of the solder . Note good wetting of both the tube and copper bar, indicating effectiveness of flux.

Close up views of solder joint

Solder paste injection over cooling tube

The manufacturing procedure and the soldering-line is nearing completion.

The Base Plan Delays NSTX-U Operation to FY2015
Incremental Budget Restores Accelerated Schedule



- The Presidential budget is $6.6M lower for FY 2013 / $8.1M lower for FY2014 compared to the CD-2 NSTX-U Program budget profile and will seriously impact the NSTX Program Plan:
  - Delays NSTX-U operation by one year which is a huge loss for the OFES program.
  - Increases the NSTX-U project cost due to increased standing army and overhead cost.
  - Loss of experienced as well as junior staff increases risks to the NSTX-U operations.
- Incremental funding will restore the NSTX-U first plasma date of mid-FY 2014 and maintain research and operation staffs necessary to support NSTX-U Program.

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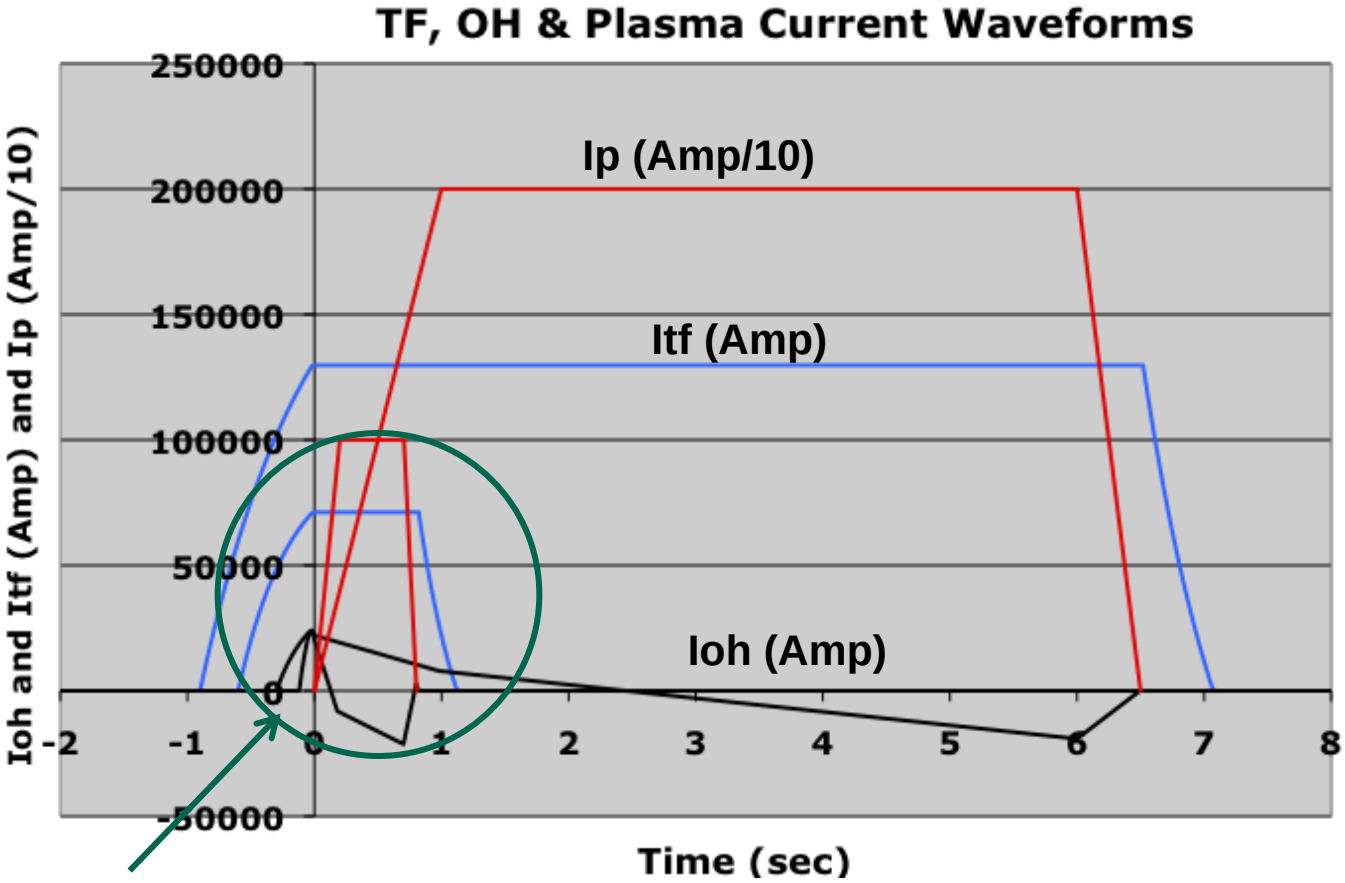
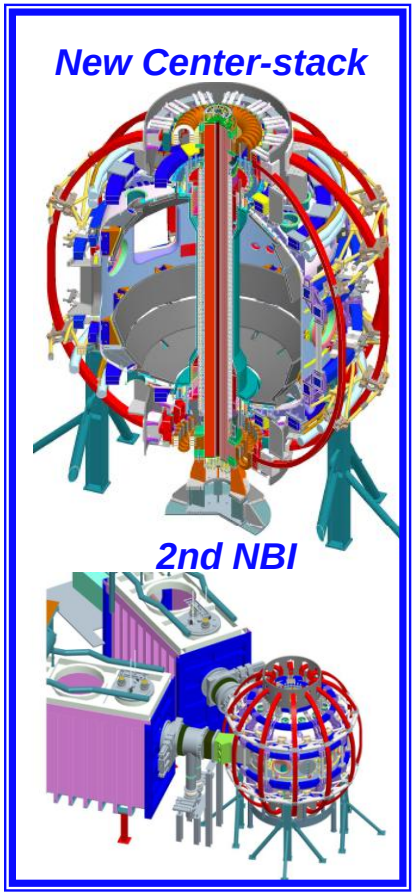
Upgrade Substantially Increases B_T, I_p, τ_{pulse}, P_{NBI}

Higher B_T and I_P narrows gaps to Fusion Nuclear Science Facility



Present NSTX



Relative performance of Upgraded NSTX vs. Base:

NBI power increased 2 x
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)

Center Stack Upgrade and Related Enhancements

Construction started and components being fabricated

Since B and J increase x 2, the E&M forces increase x 4

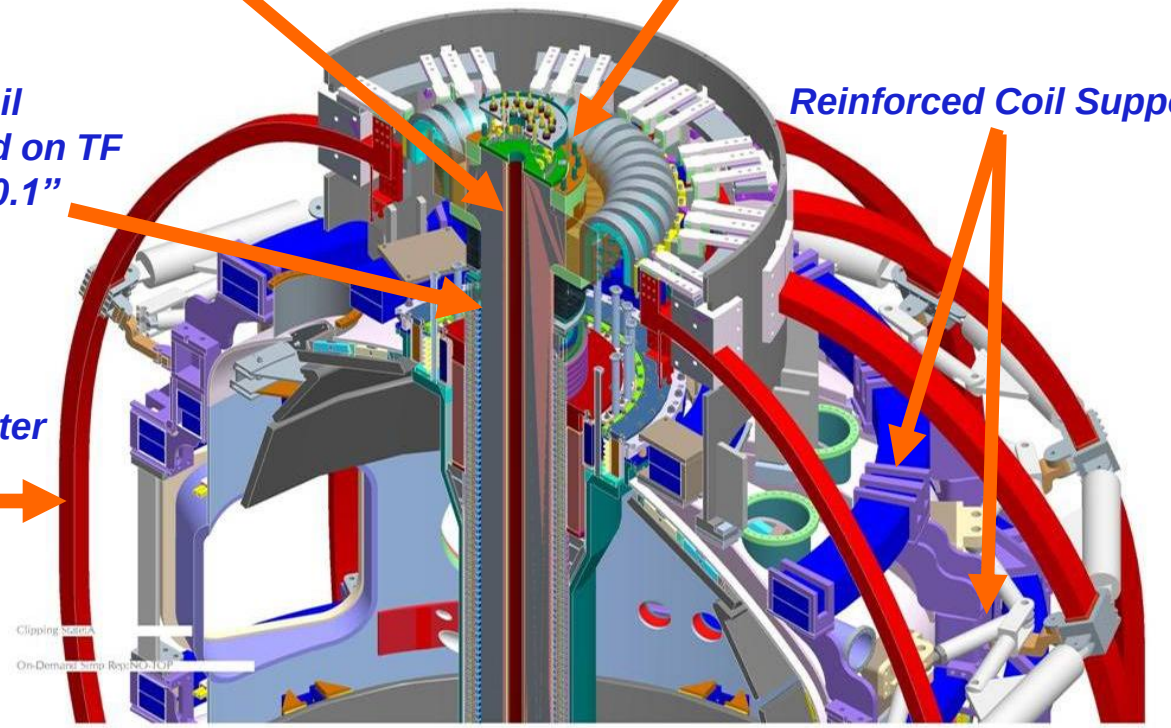
Simpler Inner TF design (single layer of TF conductors)

Improved Joint Design

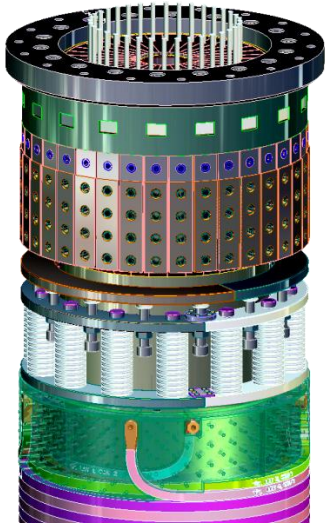
OH coil wound on TF (with 0.1" gap)

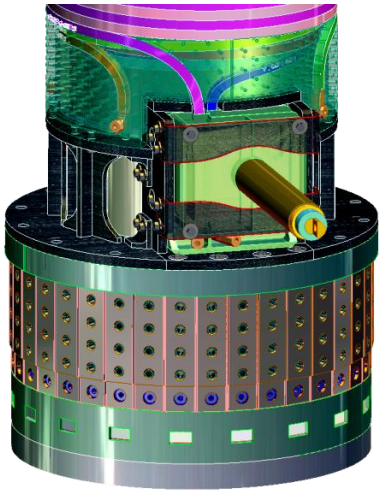
Reinforced Coil Supports

Existing outer TF WITH water cooling



Upper TF/ OH Ends



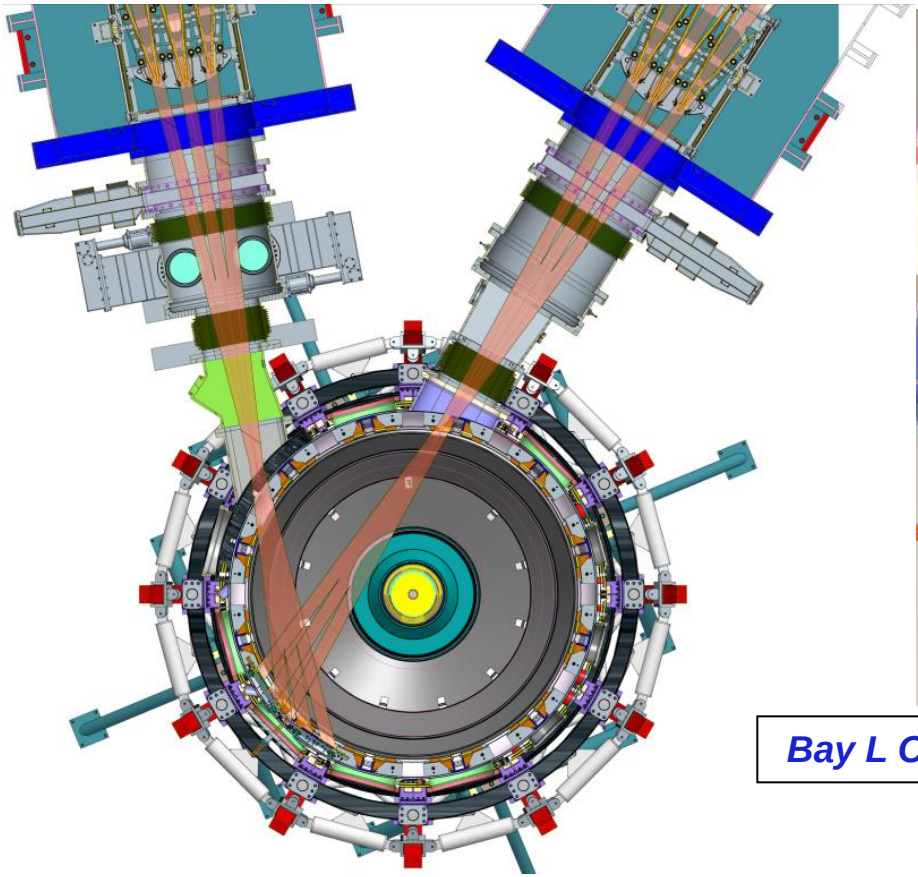


Lower TF/ OH Ends

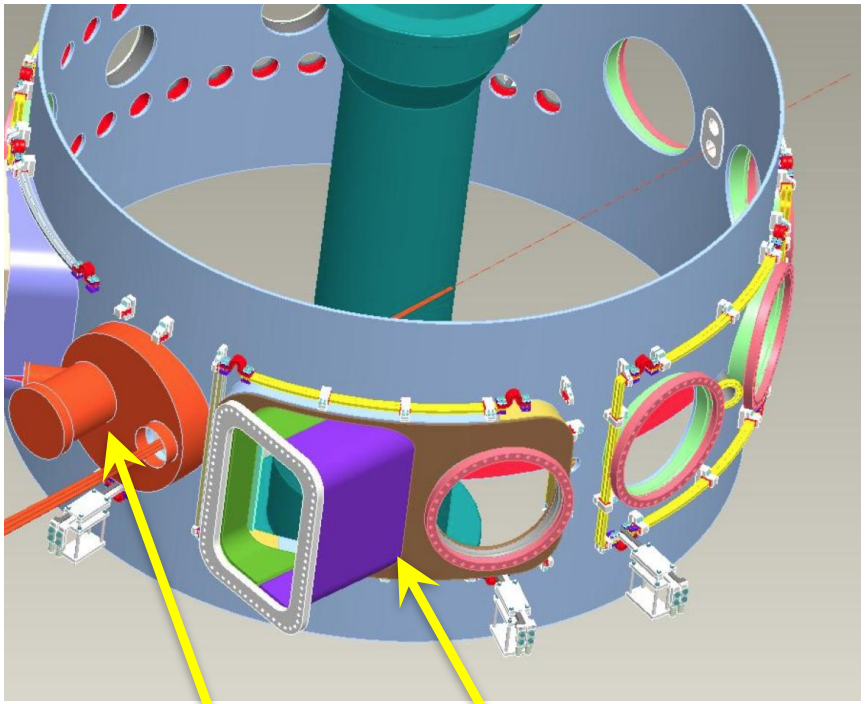
2nd NBI requires relocation of a TFTR NBI system to NSTX and relocation of NSTX diagnostics from Bay K to Bay L

New 2nd NBI
(R_{TAN}=110, 120, 130cm)

Present NBI
(R_{TAN}= 50, 60, 70cm)



Bay L Diagnostics & Bay K Weldment



Bay L CHERS, MPTS, & others

Bay K-J "bay-window" for 2nd NBI

Construction started and components being fabricated

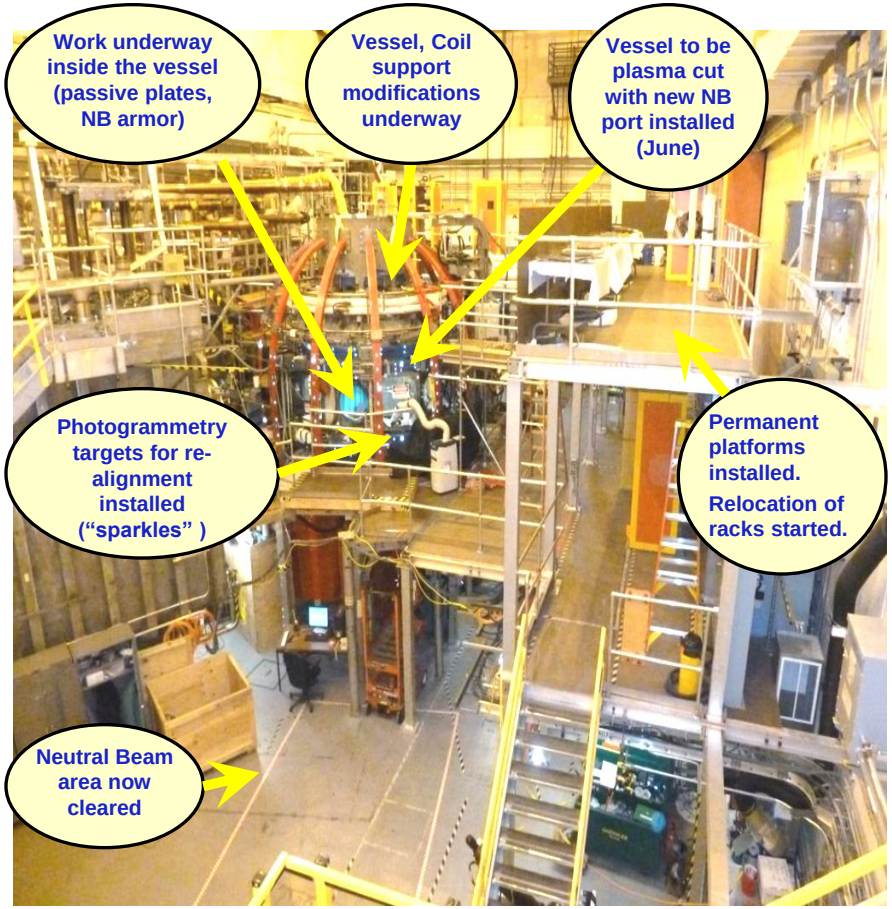
NSTX Upgrade Project Team has made excellent Progress to Date

- ☑ **NSTX-U Final Design Review - June 2011**
- ☑ **NSTX TF Bundle Failure - July 2011**
- ☑ **Successful independent forensic review of TF Failure - September 2011**
- ☑ **DOE-OFES approval to commence outage – October 1, 2011**
- ☑ **EVMS Certification – December 2011**
- ☑ **DOE CD-3 approval received - December 2011**

NSTX Upgrade Outage Started on October 1, 2011
Very good progress made

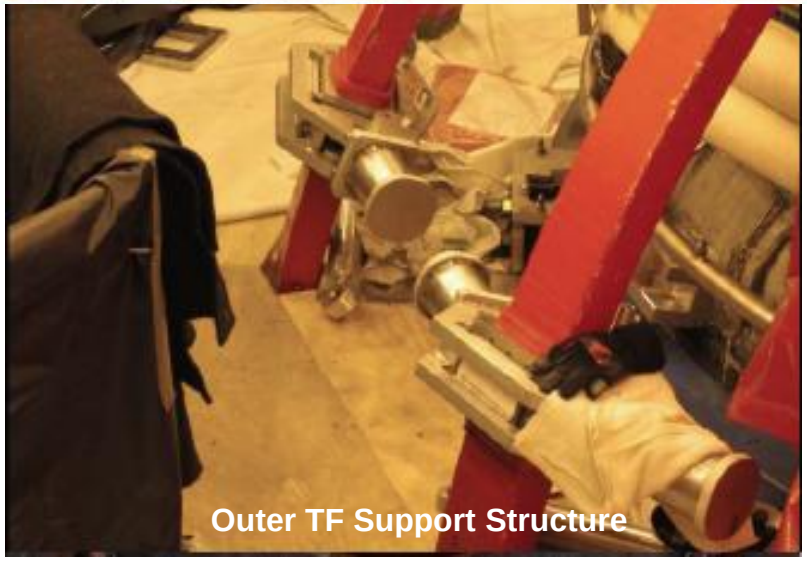
NSTX-U test cell view in October 2011

NSTX-U test cell view in March 2012



NSTX-U Test Cell Pictures

Rapid progress being made in all front!



NSTX Diagnostic Removal Completed

62 Diagnostics - 49 removed, 6 partially removed, 7 remain

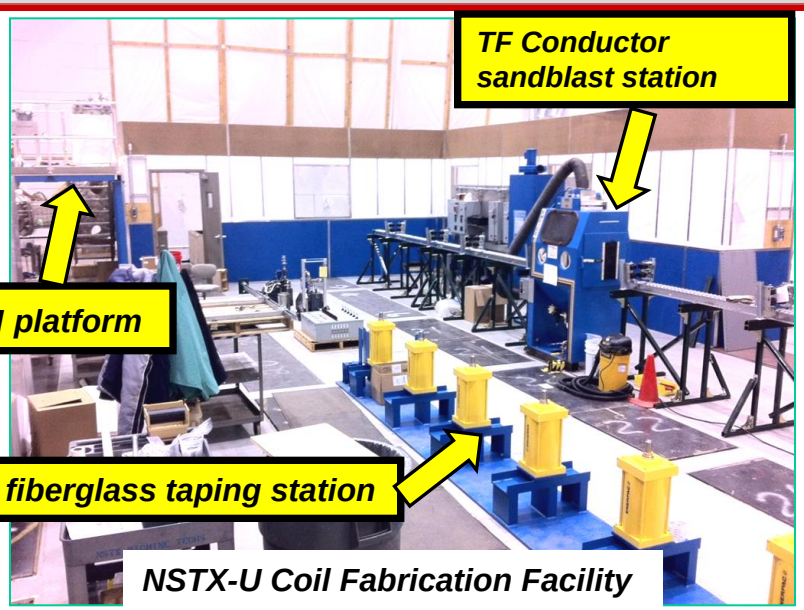
Beam Emission Spectroscopy (BES)
Bolometer - divertor array
Bolometer - midplane array
CHERS - poloidal
CHERS - toroidal
Edge bias & Langmuir probes - inter-LLD
Edge deposition monitors
Edge pressure gauges
Edge Rotation Diagnostic (ERD)
Fast cameras - divertor & LLD
Fast Ion D-Alpha (FIDA) Radial view
Fast Ion D-Alpha (FIDA) Tangential view
Fast lost ion probes
Filterscopes, 1-D D-alpha cameras (EIES)
FIReTIP - multi-chord interferometry
Gas puff imaging - divertor
Gas puff imaging - midplane
High-k scattering
Infrared cameras
Interferometry/forward scattering - 1 mm
Langmuir probes - PFC tiles
Langmuir probes - fast eroding
Langmuir probes (baffled) - outboard
Langmuir probes (high density) - inter-LLD
Magnetics - diamagnetism
Magnetics - flux loops
Magnetics - locked modes
Magnetics - outboard divertor halo current
Magnetics - Rogowski coils
Magnetics - RWM sensors

MAPP
Mirnov coils - high frequency
Mirnov coils - poloidal array
Mirnov coils - three-axis
Mirnov coils - toroidal array
MSE-CIF
MSE-LIF
Neutron detectors
NPA - E || B scanning
NPA - solid state
Plasma TV
Reflectometer - 65 GHz backscattering
Reflectometer - correlation
Reflectometer - fixed freq.
Reflectometer - FM/CW
RF Probe - lower dome
Spectroscopy - Divertor UV/visible
Spectroscopy - LOWEUS EUV
Spectroscopy - Lyman-alpha array
Spectroscopy - SPRED VUV
Spectroscopy - SWIFT 2D flow
Spectroscopy - VIPS visible
Spectroscopy - XEUS EUV
Spectroscopy - X-ray crystal - horizontal
Spectroscopy - X-ray crystal - vertical
Thomson scattering - MPTS
Visible bremsstrahlung
X-rays - "Optical" array
X-rays - Tangential TG spectrometer
X-rays - ultrafast pinhole camera
X-rays - Ultrasoft arrays
X-rays - bremsstrahlung spectrum

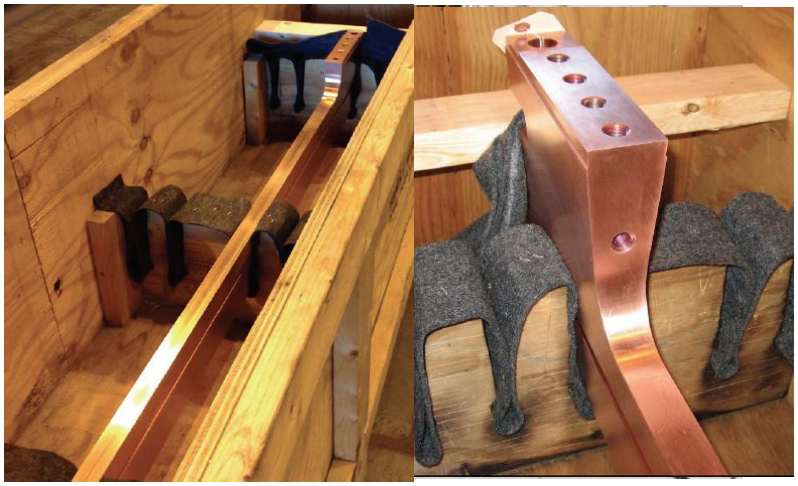
Diagnostics were stored bay-by-bay with good documentation for reinstallation

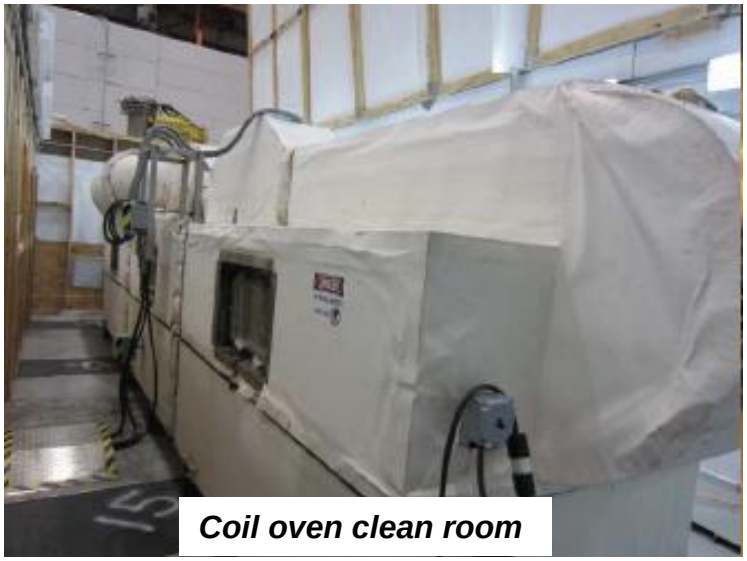
Removed **Partial Removal** **Remain**

NSTX-U Coil Fabrication Facility
Ready for Fabrication of the New Center-Stack



NSTX-U Coil Fabrication Facility

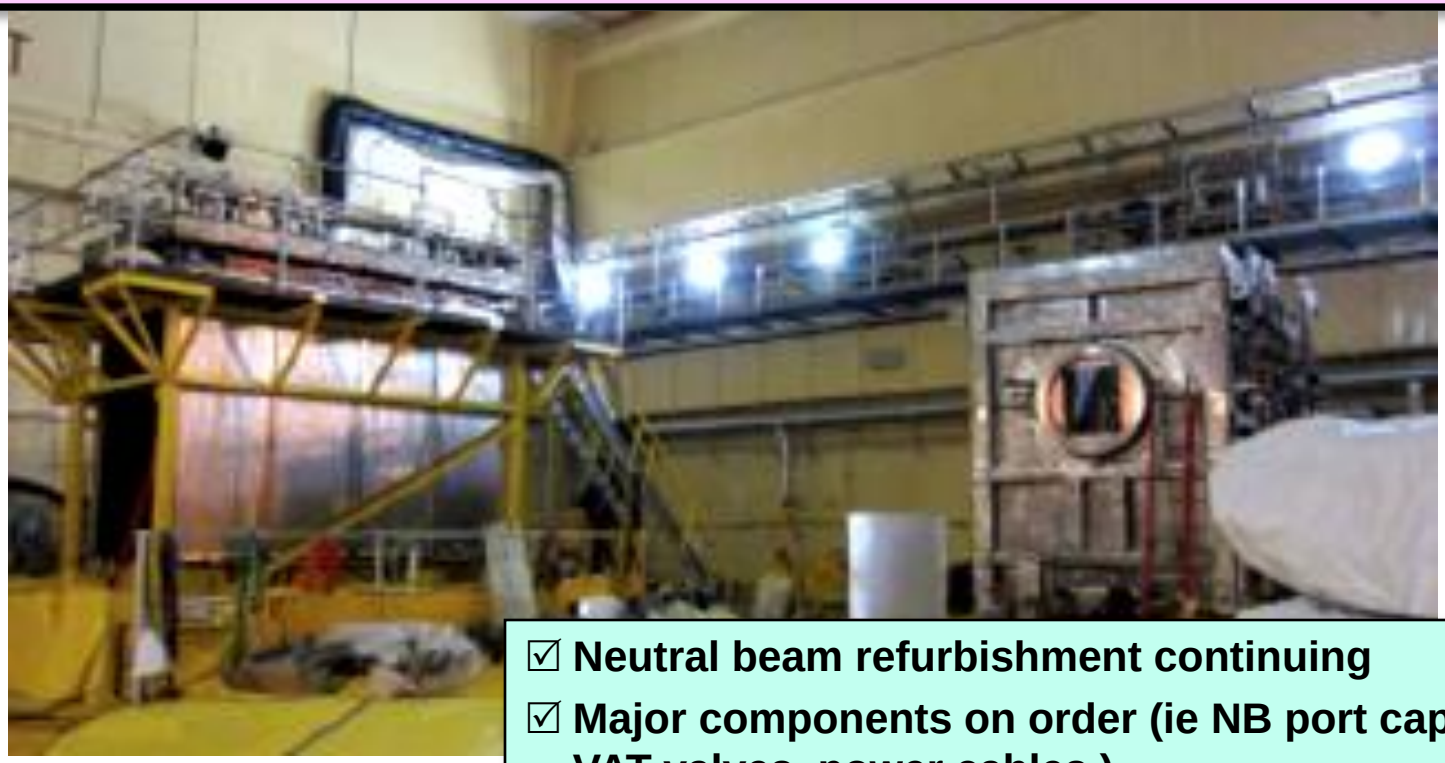

First TF conductor arrived on April 13


Coil oven clean room


TF Conductor priming clean room

Excellent progress to date on the NSTX-U 2nd Neutral Beam Injection (NBI) system

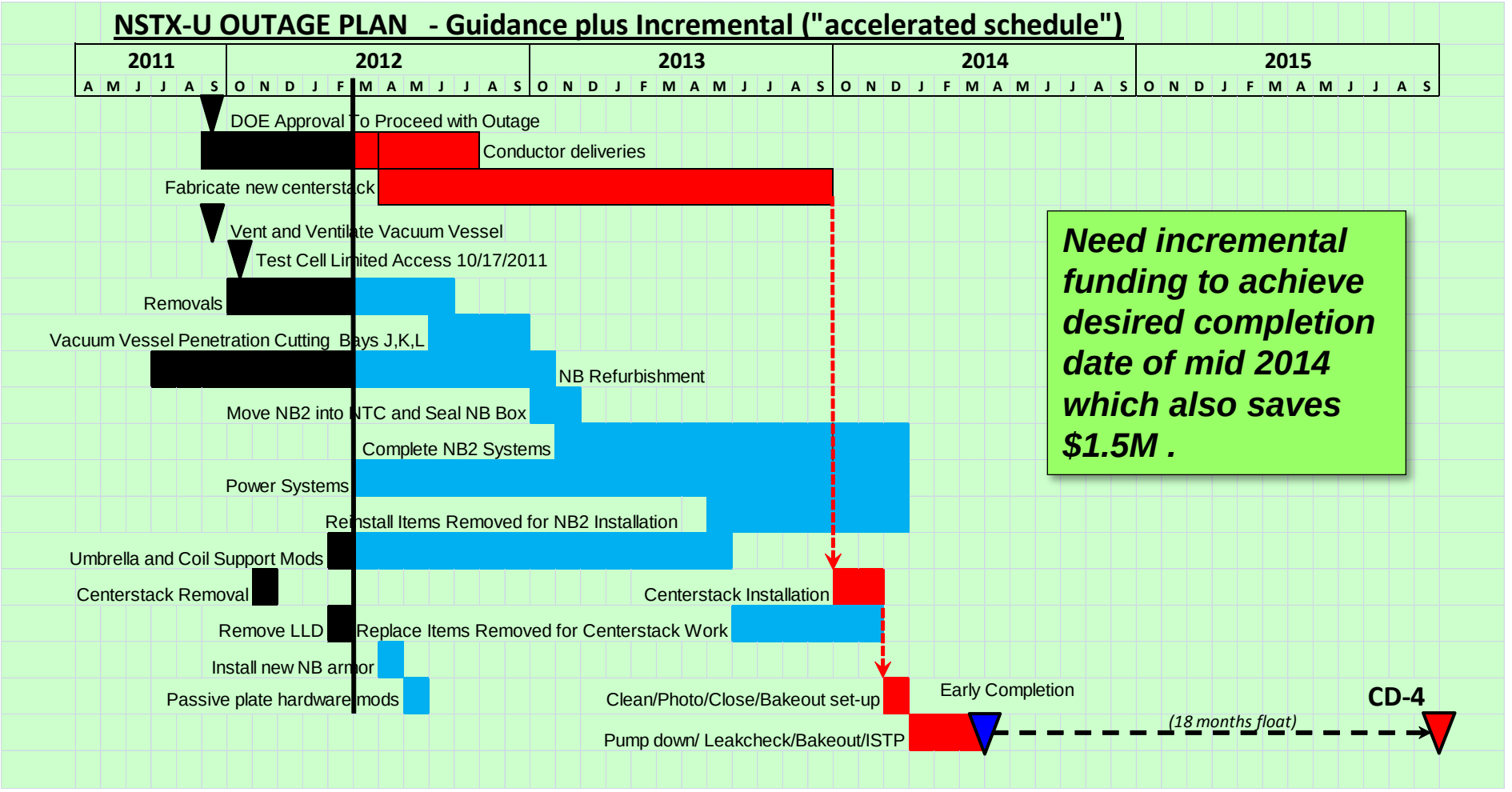
NSTX-U 2nd NBI ready to move from the TFTR Test Cell (TC) into the NSTX Test Cell



- ☑ Neutral beam refurbishment continuing
- ☑ Major components on order (ie NB port cap, large VAT valves, power cables)
- ☑ Rectangular bellows fabricated!
- ☑ Six ion sources (for 2 beamlines) ready to go!
- ☑ Relocation into NSTX TC targeted for October 2012

Optimized Upgrade Schedule Developed

Present budget will cause one year delay and increase risks



To conserve cash, we are beginning to delay procurement.

NSTX-U Commissioning and Operations

Requires careful planning and oversight

- **Need adequate monitoring / diagnostics to confirm that measured values are consistent with expectations.**
- **Need to be conservative, bringing up the field and plasma current gradually with increasing levels forces and stresses.**
- **Need to inspect key areas including flex joints during maintenance periods.**
- **Initially the emphasis will be to increase pulse-length rather than increase to full field and current values (to develop non-inductive operations.)**
- **If all looks ok, increase the field and current to full values with short pulse.**
- **Reach full operational capability by the end of the third year of operation.**

Time Line	B_T(T)	t-pulse (sec)	Ip (MA)
Year 1	0.55 – 0.65 for commissioning. 0.75 by end	1 – 2 sec for commissioning 5 sec by end	~ 1 for commissioning ~ 1.5 by end
Year 2	0.75 routine 1T by end	5 sec routine 1 sec	1.5 MA routine 2 MA
Year 3	1 T routine	1 sec routine 5 sec by end	2 MA routine

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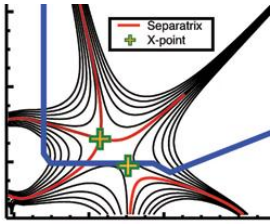
Formulating FY2014-18 5 year plan to access new ST regimes with Upgrade + additional staged & prioritized upgrades

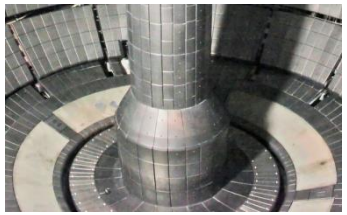
2009	2010	2011	2012	2013	2014	2015	2016	2017	2018

1 MA Plasma

- CHI Control Coils
- LLD
- Moly-tile
- HHFW Upgrade



"Snowflake"

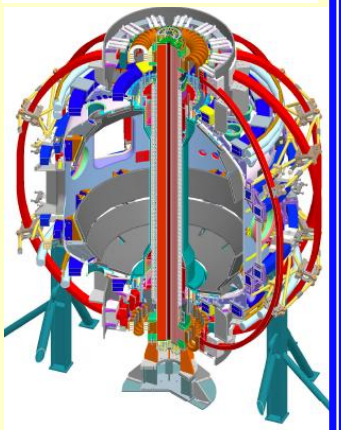


Lithium

Upgrade Outage

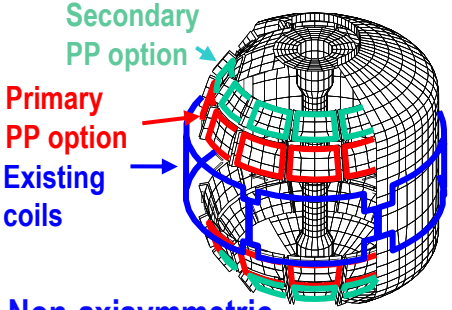
- New Center-Stack
- 2nd NBI

New Center-stack



1.5 → 2 MA Plasma

- 0.5 MA CHI
- 1 MA CHI / Plasma Gun
- ECH/EBW
- 1MW → 2 MW
- 0.5 MA Plasma Gun
- Long–pulse Divertor
- NCC Upgrade



Non-axisymmetric Control Coils (NCC)

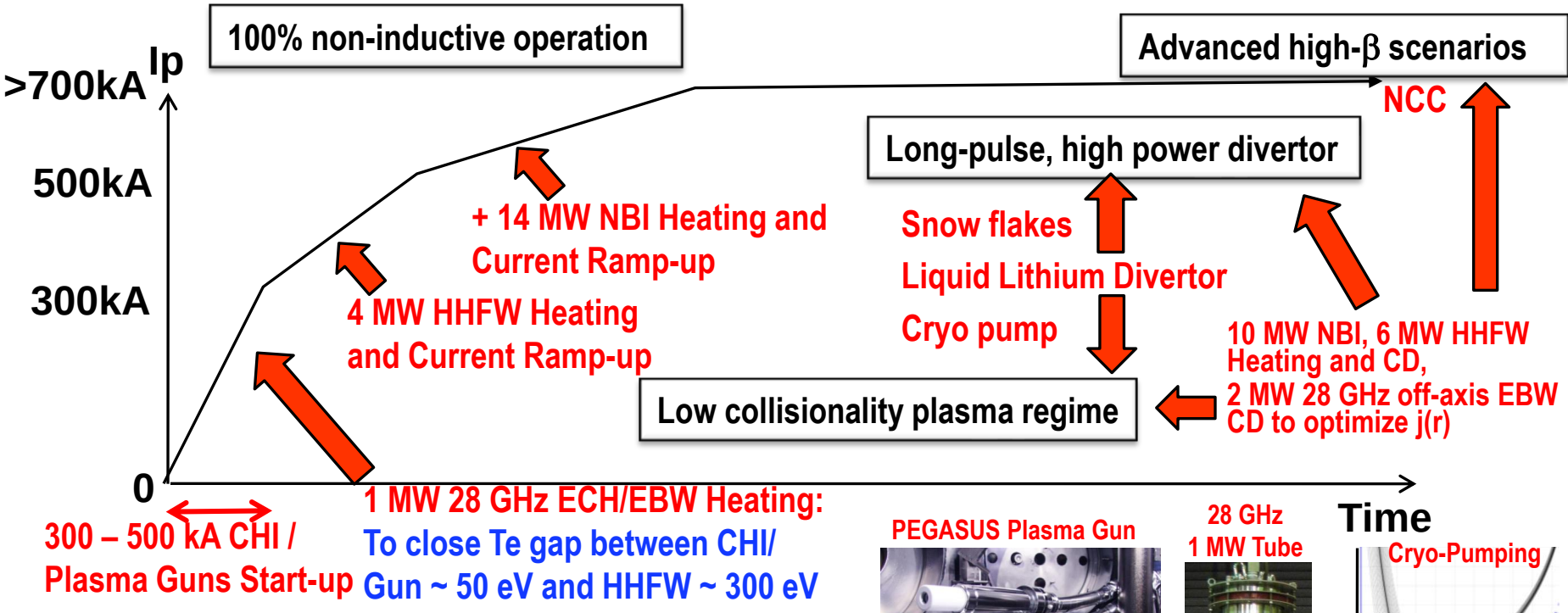
NSTX Upgrade research goals in support of FNSF and ITER

- Low collisionality plasma regimes
- 100% non-inductive operation
- Long-pulse, high power divertor
- Advanced high-β scenarios

NOTE: Upgrade operation would be delayed ~1 year to mid-2015 w/o incremental, other follow-on upgrades are further delayed

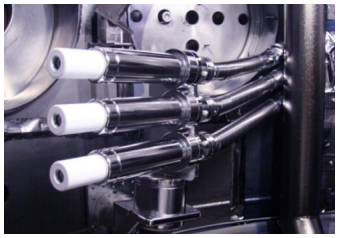
Key Research Tools to Enable NSTX-U Research Goals

In support of ST-Based FNSF and ITER Operations



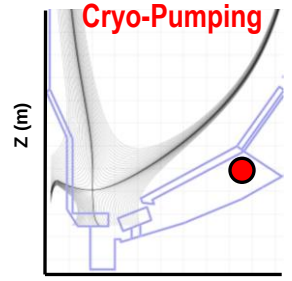
- CHI – Modest upgrade required
- Plasma Gun – New System
- 4 – 6 MW HHFW – Modest upgrade required
- 1-2 MW 28 GHz – New System
- 10 – 14 MW NBI - Part of the Upgrade Project
- 4 – 6 MW HHFW – Modest upgrade required
- LL and Cryo Divertors – New system
- NCC / Off-midplane coils – New System

PEGASUS Plasma Gun

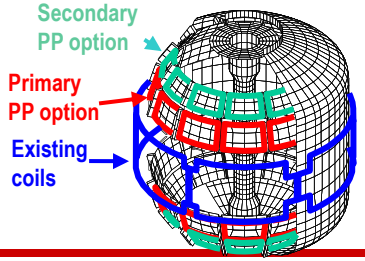


28 GHz 1 MW Tube

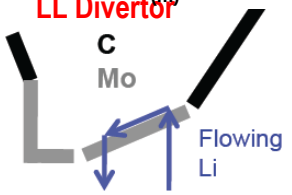
Cryo-Pumping



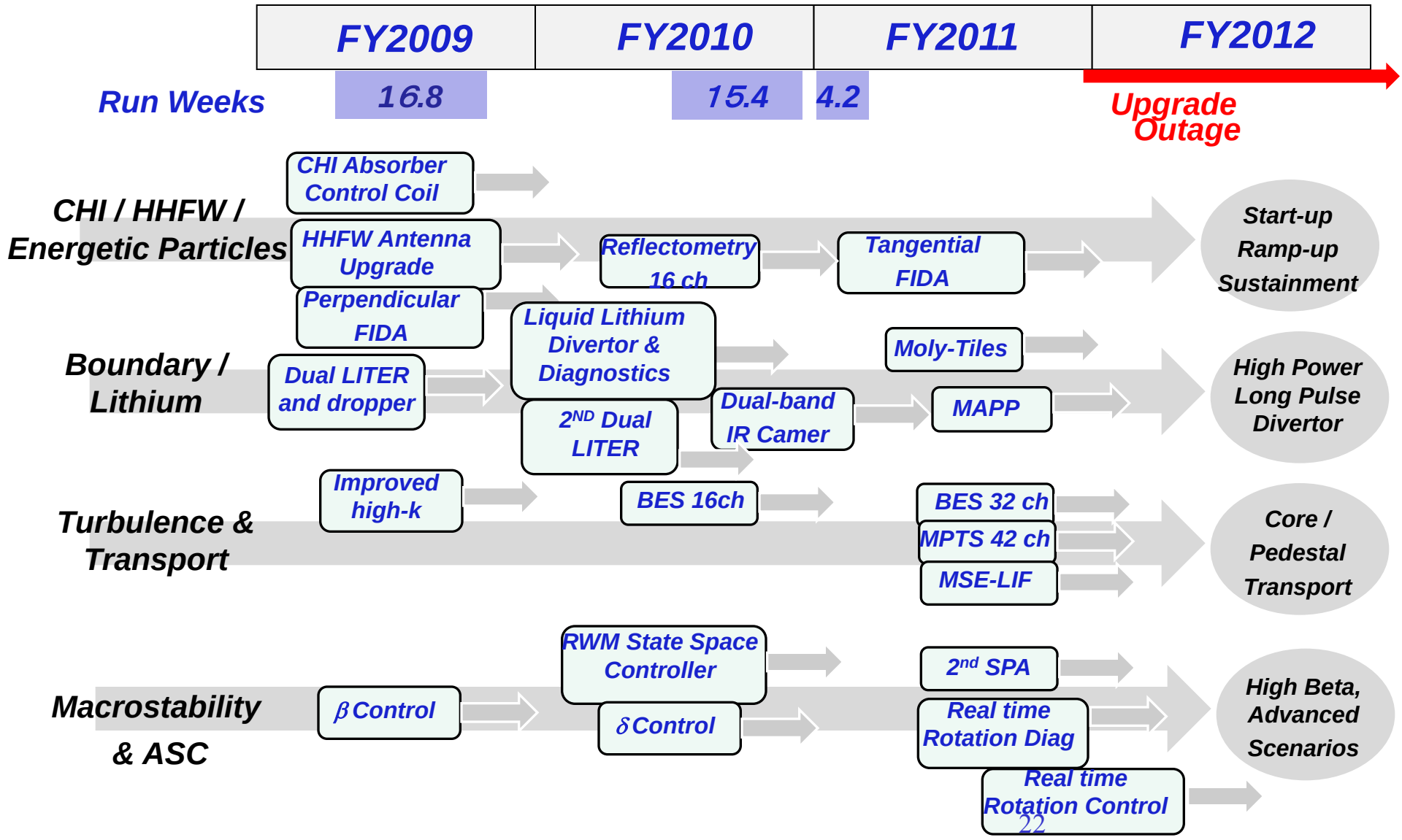
NCC



LL Divertor



Significant Facility Enhancements Implemented
To Support NSTX Mission Elements and Upgrades



Facility and Diagnostic Upgrade Plans for FY 2012 – 2014
In Support of the NSTX-U Operation and Research Plan

Facility and Diagnostic Milestones:

- FY 12: Identify possible high priority facility and diagnostic enhancements for the post upgrade operations
- FY 13: Complete the conceptual design of high priority facility and diagnostic enhancements for NSTX-U operations
- FY 14: Implement high priority facility and diagnostic enhancements for NSTX-U operations as the resource permits (if for example, the upgrade project under runs)

Other Related Activities:

- NSTX-U Team Facility – Diagnostic Upgrade Brainstorming Meetings in July 2011 and Feb. 2012 (a large numbers of great ideas!)
- New 2012 DOE NSTX-U collaboration diagnostic grants selected
- DOE advanced diagnostic grant solicitation and NSTX-U laboratory collaboration proposal solicitation in 2013
- NSTX-U physics collaboration grant solicitation in 2014

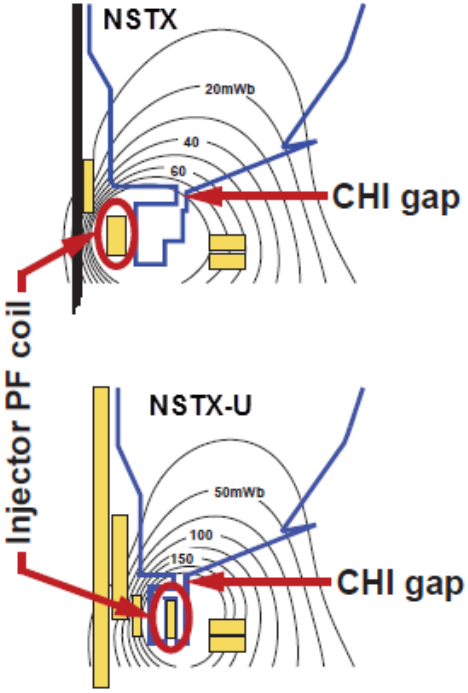
Solenoid-free Start-up

High priority goal for NSTX-U in support of FNSF

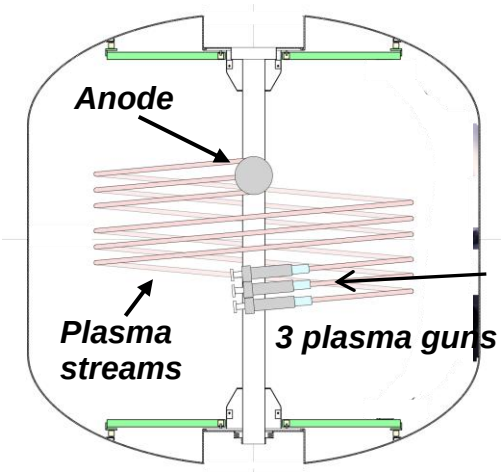
CHI Start-Up

- Inj. Flux in NSTX-U is about 2.5 times higher than in NSTX
- NSTX-U coil insulation greatly enhanced for possible higher voltage operation

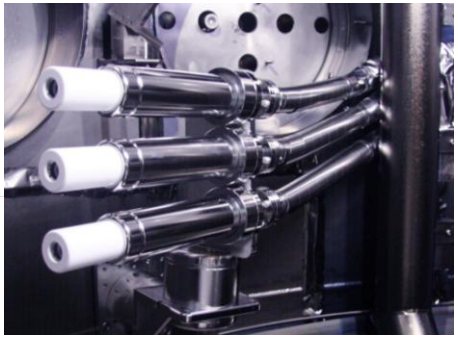
U Washington



PEGASUS Mid-plane Injection



PEGASUS Plasma Gun



U Wisconsin

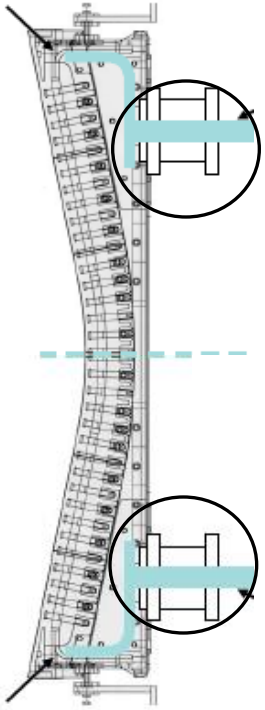
FY 2013-14 Non-Inductive Start-up Systems Design for Post-Upgrade Operations

- CHI will start with the present 2 kV capability then enhanced to higher voltage as needed.
- PEGASUS gun start-up producing exciting results Ip ~ 160 kA. The PEGASUS gun concept is technically flexible to implement on NSTX once fully developed. High current gun for the NSTX-U will be developed utilizing the PEGASUS facility in collaboration with University of Wisconsin
- Conceptual design of the MA-class ECH/EBW system to be performed in FY 13-14

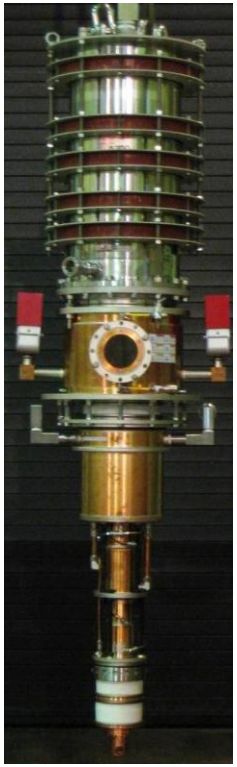
Perform HHFW Antenna Refurbishment

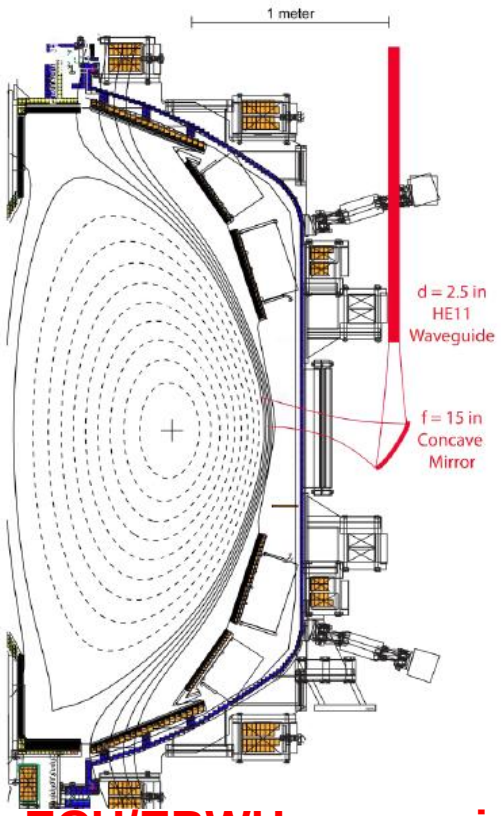
Start Design of a MW-Class ECH/EBW System

HHFW antenna enhancement in the feedthru area



28 GHz 1 MW Tube





28 GHz ECH/EBWH waveguide and mirror concept

- **FY 2012-13 - HHFW Antenna enhancements against disruptive loads**
- **FY 2013/14 – Start MW-class ECH/EBW system design for non-inductive operations (US-Japan)**

NSTX Leads a Growing World Lithium Program (NSTX, LTX, FT-U, T11M, T-10, TJ-II, EAST, HT-7, RFX, KTM)

NSTX Goal: To investigate effectiveness of lithium for divertor heat and particle control while enhancing plasma performance.

NSTX lithium research interacts broadly and benefitted from the PPPL and outside research groups:

- **Utilized the TFTR and the CDX-U lithium experiences.**
- **Synergy with on-going LTX research activities.**
- **Growing and highly productive lithium collaboration with EAST / HT-7. Lithium dropper has help produce H-mode and long-pulse discharges. Lithium granular injector will be shipped to EAST in the near future.**
- **Emerging collaboration with Princeton University on lithium surface interactions and with other institutions including Penn State, NIFS.**

NSTX hosted 2nd Lithium Symposium held at PPPL on April 27 – 29, 2011

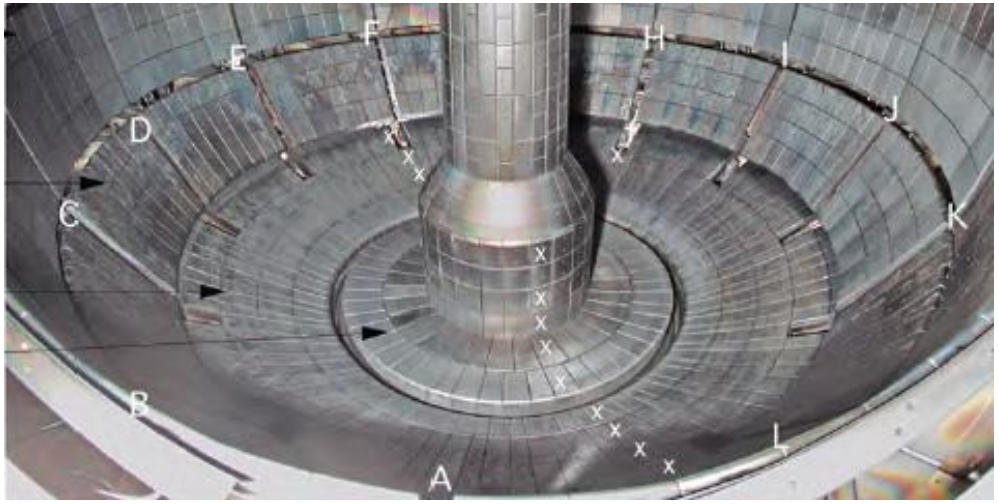
Over 50 presentations from 10 magnetic fusion confinement facilities

- **Multi-machine observations show robustness of lithium beneficial results**
- **Promising high heat flux capable liquid lithium divertor concepts emerging.**

http://nstx.pppl.gov/DragNDrop/Scientific_Conferences/Lithium_Symposium_2011/

Boundary Physics

Need to Assess Heat and Disruption Loads for Advanced Divertor

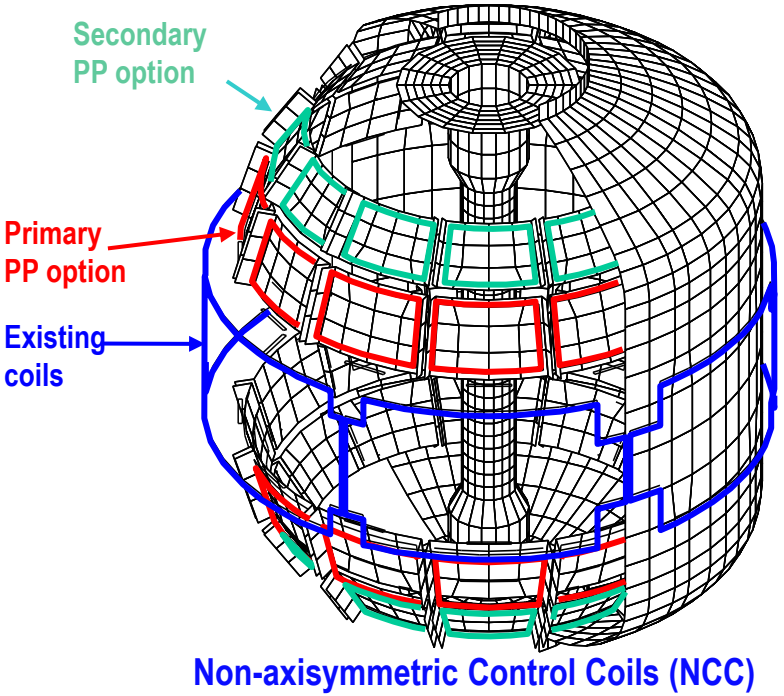


- LLD removed due to the heat and disruption loads concerns
- Lower divertor to start with all graphite tiles for NSTX-U
- LITER system will be available for lower divertor as before

- Assessing installation of inboard divertor moly-tiles for upper divertor and associated upper divertor LITER system
- Moly armor for exposed SS flange surfaces in CHI gap will be installed during the outage

- For FY 12-14, advanced divertor upgrade conceptual design work will commence for the five year plan – e.g., moly-based PFCs, liquid lithium divertor, and upper divertor with cryo-pump.

New MHD and Plasma Control Tools Available for NSTX-U
Sustain β_N and Understand MHD Behavior Near Ideal Limit



Non-axisymmetric Control Coils (NCC)

2nd 3-channel Switching Power Amplifier (SPA) commissioned in July 2011 powers independent currents in six EFC/RWM coils for simultaneous control of n = 1, 2, 3 field harmonics

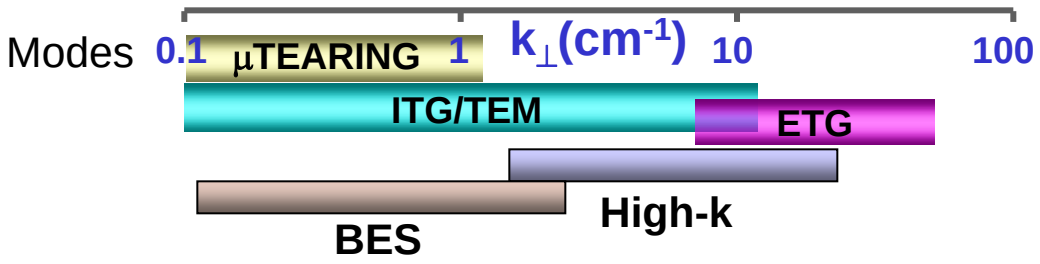
- RWM spectrum dependence
- Rotation and beta effects on NTMs
- Response to 3D fields for EFC, ELM and Neoclassical Toroidal Viscosity physics
- Disruption physics

NCC: physics design FY12-14, engineering conceptual design FY14-15

- **A Real-Time Velocity (RTV) diagnostic (commissioned in 2011) will be incorporated into the plasma control system for feedback control of the plasma rotation profile using the NBI and non-resonant magnetic braking as the actuators.**
- **A new Plasma Control System (PCS) platform with increased capabilities (e.g., 64-bit operating system and ability to support additional I/O points and real-time algorithms) will be implemented for NSTX-U. A similar system will be used for the Digital Coil Protection System (DCPS) for the Upgrade Project.**

Transport and Turbulence

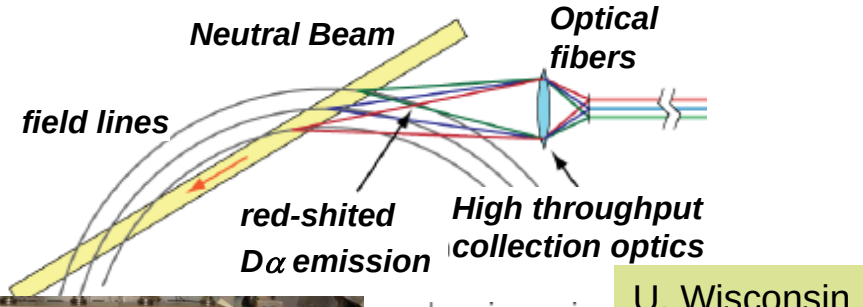
Increase and Understand H-mode Confinement at Lower ν*



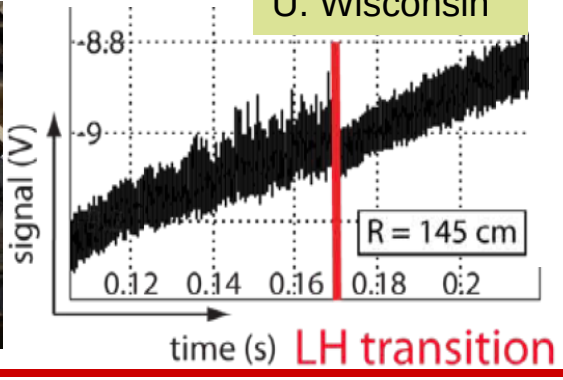
- BES together with high-k to provide a comprehensive turbulence diagnostic set.
- BES - 16 ch BES very worked well in FY 2010-2011 and at least 32 ch BES available for NSTX-U

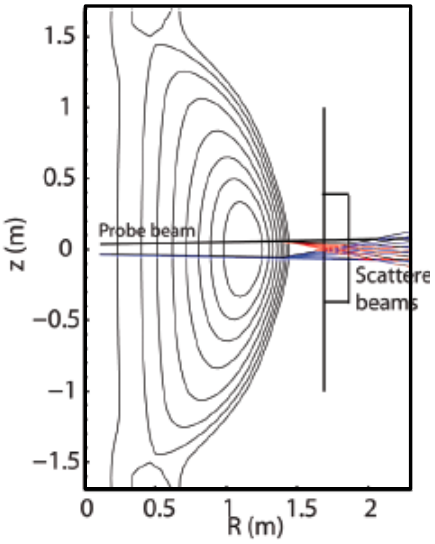
- High-k scattering system has been highly productive in exploring electron-scale turbulence.
- High k Upgrade - Upgraded system with 2-D k spectrum for NSTX-U

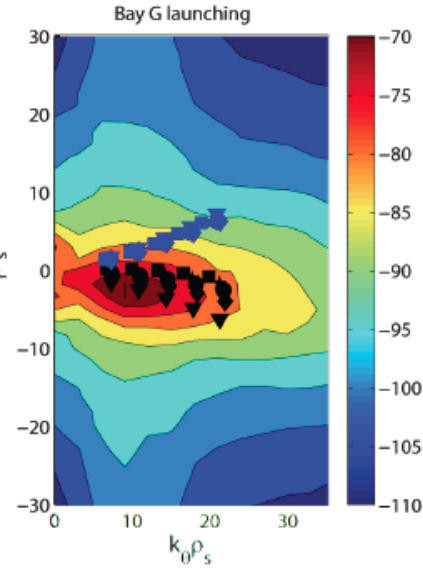
A candidate new high-k scattering system for allowing 2 D k spectrum.



U. Wisconsin







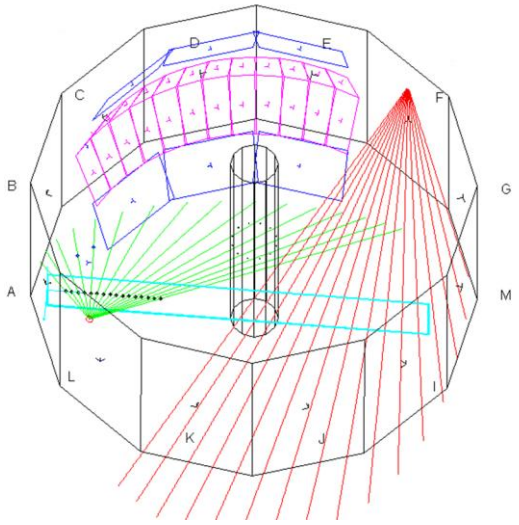
Receivers to relocate from Bay K to Bay L

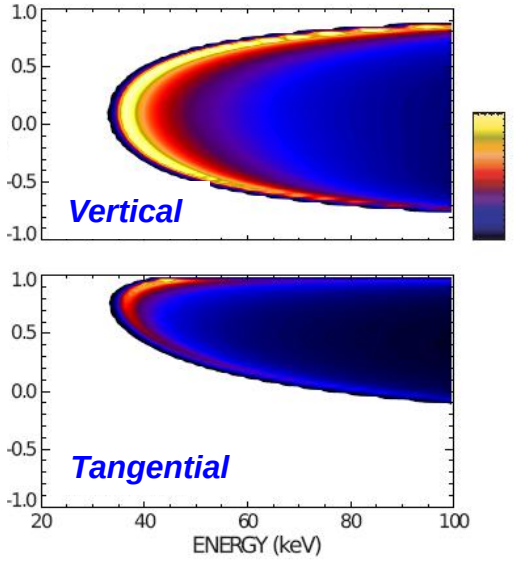
UCD

Tangential-FIDA for Energetic Particle Research
For NBI fast ion transport and current drive physics

Tangential FIDA Views
UC Irvine

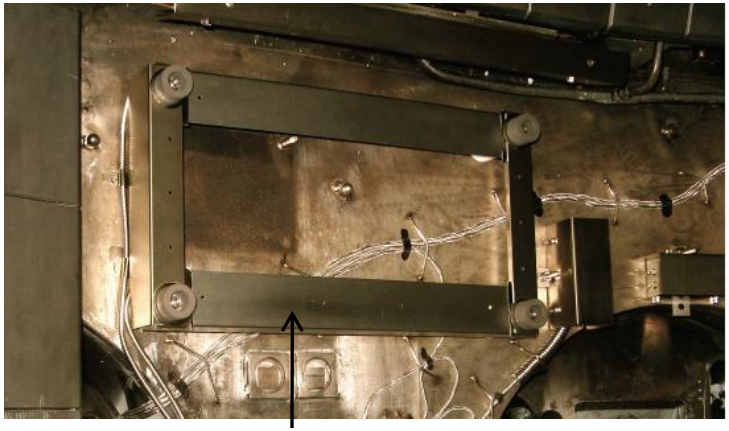
- **T-FIDA upgrade will provide two new views of plasma.**
- **Two new ports in vacuum vessel are being installed.**
- **Expect to have installation complete and ready for commissioning at start of next run.**





FY 2013 - 14 Energetic Particle Conceptual Design and Diagnostic Upgrade

- **Active TAE antenna**
- **Possible SS-NPA enhancement due to removal of scanning NPA (UCI)**



5-turn radial active TAE antenna installed in 2011

NSTX had strong publications and conference participation

Growing Number of Highly Capable Young Researchers

- *58 NSTX scientific papers published in refereed journals including six PRLs in FY 2011. 28 engineering technical papers also published*
- *The NSTX team members presented six Invited Talks at the APS-DPP meeting last fall and 13 additional invited talks at other conferences.*

Highly regarded research team:

- Strong contributions from young researchers : 18 post-docs and 21 students
- Two Presidential Early Career Award and three DOE OS Early Career Research Program Award recipients
- Experienced senior researchers: 17 APS Fellows

NSTX Research Team Membership

	PPPL	Non-PPPL
Researchers	69	210
Post Doc.	6	12
Grad. Students	4	6
Undergrad.	1	10

NSTX-U FY 2014 FWP Budget Summary ($M)
Base Budget is Highly Constrained

	FY 2011	FY2012	FY 2013		FY2014	
Budget cases	**Actual**	**Base**	**Base**	**Incr.**	**Base**	**Incr.**
Facility Operations	22.9	11.9	8.8	3.9	8.8	2.9
Fac. Enhancements	3.1	0.4	1.7	1.0	0.5	0.7
Upgrade Project	7.6	22.0	19.7	5.7	19.8	3.9
Facility Total	**33.6**	**34.3**	**30.2**	**10.6**	**29.1**	**7.5**
PPPL Research	10.6	10.0	10.0	0.3	11.1	0.4
Collab Diag Interf.	0.7	0.2	0.3	0.3	0.3	0.3
Collaborations	5.8	6.0	5.8	0.5	5.8	0.6
Science Total	**17.1**	**16.2**	**16.0**	**1.1**	**17.2**	**1.3**
NSTX Total	**50.7**	**50.5**	**46.2**	**11.7**	**46.2**	**8.8**

- **NSTX-U Project has the highest priority and funded largely from the base program. However, budget reduction directly impacts the upgrade construction.**
- **The present base plan is $6.6M lower for FY 2013 and $8.1M lower for FY2014 compared to the CD-2 NSTX National Program budget profile.**
- **Under the base plan, NSTX-U Project still needs ~ $10M in FY 2015 to complete.**

NSTX Upgrade Project Making Excellent Progress

Exciting Opportunities and Challenges Ahead

- **NSTX started the upgrade outage in FY 2012 six months earlier**
  - Researchers are working on data analysis, collaboration, next five year plan and preparation for the NSTX-U operation
  - NSTX operations technical staff are being shifted to the Upgrade Project tasks in FY 2012
- **NSTX Upgrade Project is making excellent progress**
  - Successful DOE OFES CD-3 Approval in Dec 2011
  - Upgrade activities are ramping up rapidly in all areas, currently in pace to complete in April, 2014 well ahead of the Sept 2015 CD-4 completion target
- **FY 2013 / FY 2014 budget guidance presents difficult challenges**
  - FY 2013/FY2014 budget guidance will result in significant staff reduction at PPPL and NSTX, and it will delay the NSTX-U completion by 1 year with increased cost
  - Incremental funding will enable the accelerated schedule
- **NSTX-U Research Team is looking forward to NSTX-U Operations and the next Five Year Facility Plan**
  - Exciting ideas are being pursued
  - Implementation of the plan depends on the budget level

Supplemental Slides

ARRA Funding Greatly Enhanced Research Capability

All Planned ARRA Upgrades Completed on Schedule

Extra 12 channels for the multi-pulse Thomson scattering system for improved H-mode pedestal and plasma edge spatial resolution to support the FY 11 joint research milestone.

Enhancement to the liquid lithium divertor target capability for modifying edge collisionality, including two lithium evaporators, and LLD diagnostics.

Post Doctoral Fellows to support the enhanced research capabilities.

2nd switching power amplifier system for improved error field/resistive wall mode/resonant magnetic perturbation spectra to control the edge error field.

Motional Stark Effect Laser Fluorescence advanced diagnostic system for internal magnetic and electric field measurements was installed and commissioned.

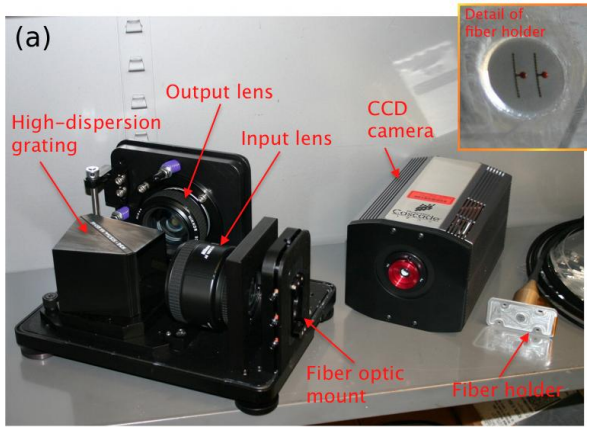
Inboard Divertor Molybderum Tiles for assessing the viability of molybdenum tiles as a divertor PFC for NSTX-U (upper divertor being considered).

Li Granule Injector for triggering ELMS in a controlled manner. Commissioned and planned to be tested in RFX (Italy), EAST and possibly on DIII-D

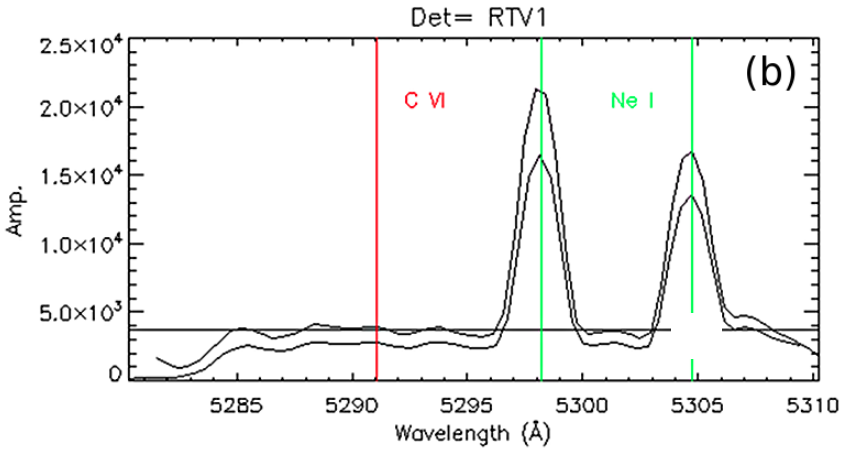
Real Time Velocity Diagnostics – An Important Tool for Advanced Plasma Control

A Real-Time Velocity (RTV) diagnostic will be incorporated into the plasma control system for feedback control of the plasma rotation profile using the NBI and non-resonant magnetic braking as the actuators

- **Based on active charge-exchange recombination spectroscopy (CHERS)**
- **Measures at six radial locations and a sampling rate of 5 kHz.**
- **Uses two toroidally separated views to distinguish the heating NB view from the background (intrinsic) contribution.**
- **Installed and commissioned on NSTX in July 2011**

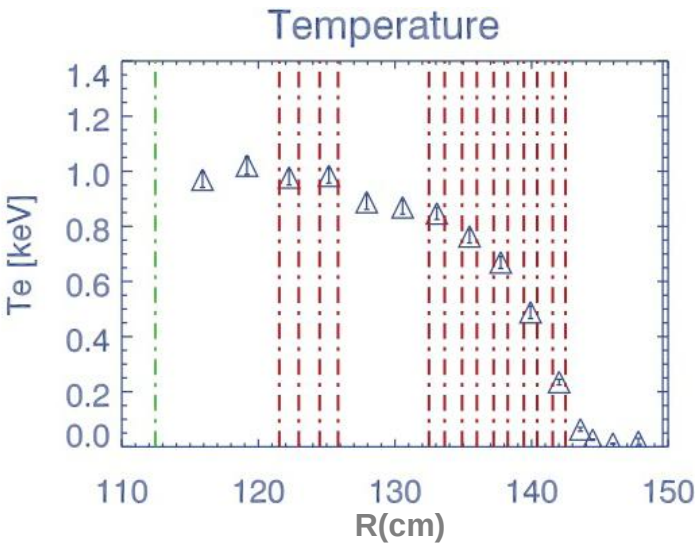


RTV hardware including CCD camera & spectrometer



Example of spectra measured on two channels during a Ne glow.

Enhanced Thomson Scattering System Implemented for Improved Pedestal and Core Profile Spatial Resolution



Additional 12 channels enhance resolution in pedestal to ~1 cm and improve diagnosis of ITB in plasma core

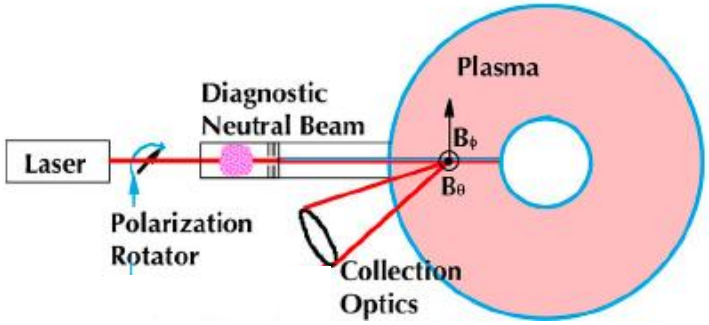
Polychromator assembly

- **Twelve additional channels for the multi-pulse Thomson scattering (MPTS) system were installed and commissioned in July, 2011.**
- **Calibration was performed in situ by employing Rayleigh and Raman scattering of the light from the MPTS laser system by nitrogen and argon introduced into the vacuum vessel**

MSE-LIF Installed for Enhanced Pedestal / Profile Diagnostics
Commissioned and field calibration performed on NSTX

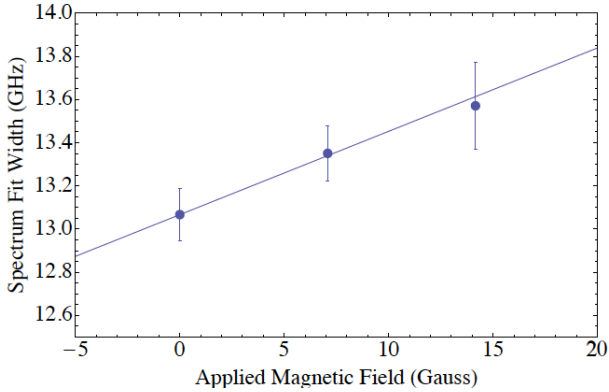
The Motional Stark Effect measurement based on Laser Induced Fluorescence (MSE-LIF) diagnostic will provide measurements of the field line pitch angle profile without requiring injection of the heating neutral beam.

MSE-LIF DNB system on NSTX



Schematic of the MSE-LIF system

Nova Photonics



MSE-LIF Magnetic Field Calibration Scan with ~ 10 Gauss resolution on NSTX

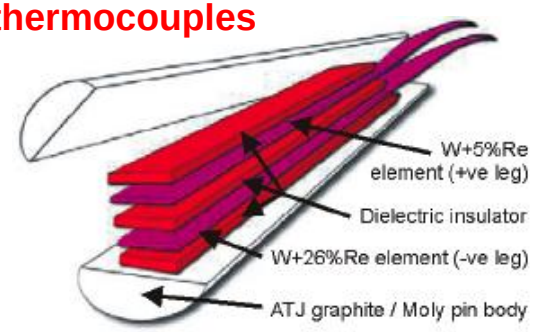
MSE-LIF provides unique capabilities

- **Measure RF-driven current without the heating neutral beam.**
- **Measure total magnetic field in plasma to reconstruct total plasma pressure.**
- **Together with MSE-CIF, yield radial electric field profile**

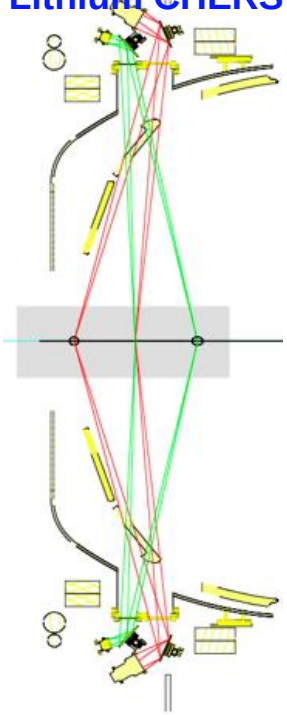
Enhanced Capability for LLD and Boundary Physics

Multi-Institutional Contributions

Divertor fast eroding thermocouples



Lithium CHERS



ORNL

Divertor fast pressure gauges

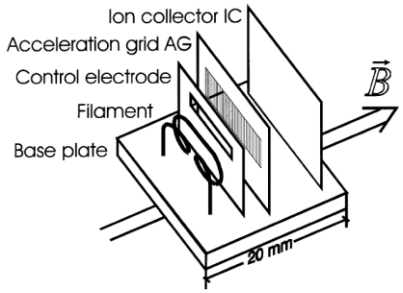
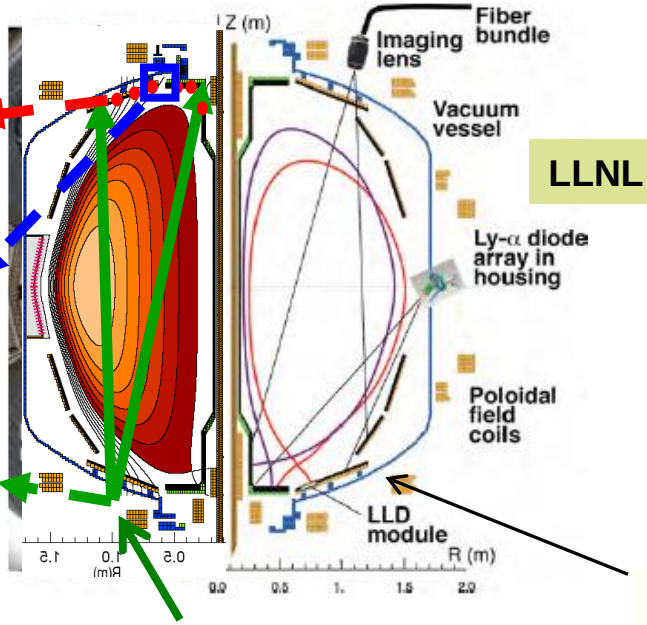


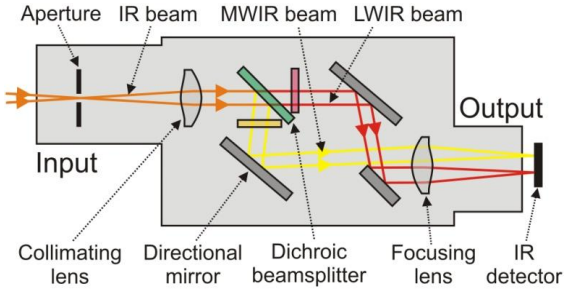
Figure 1. Electrode arrangement of the ASDEX gauge.

Divertor Imaging Spectrometer



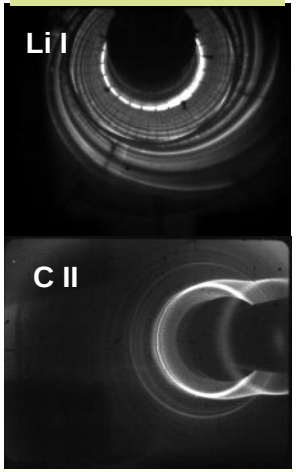
LLNL

Dual-band fast IR Camera

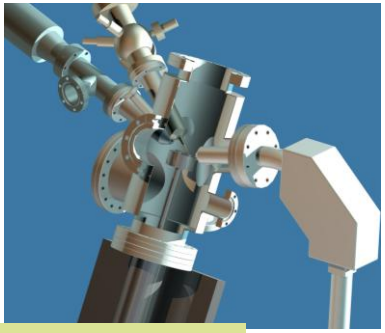


Two fast 2D visible and IR cameras with full divertor coverage

LLNL, ORNL



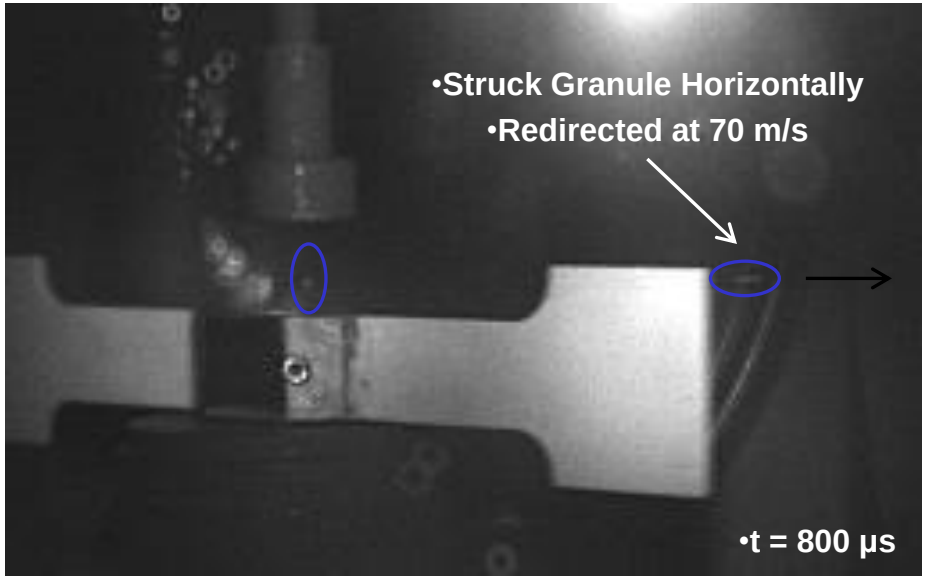
MAPP diagnostic systems

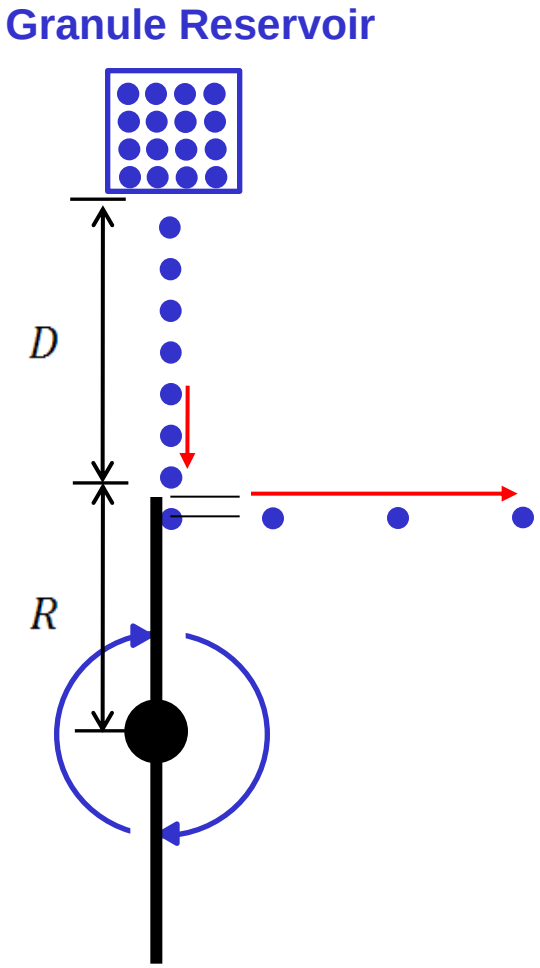


Purdue U.

Lithium Granules Injector for ELM Control Completed Tests on EAST, RFX should proceed during 2012-13

- Spherical Lithium granules (0.6 mm) have been horizontally redirected at speeds approaching 100 m/s.
- Dropping rates (pacing frequencies) of 500 Hz have been readily achieved.
- A dropper apparatus which allows the granule size to be changed between discharges has been built and is being tested.





Incremental Funding Summary ($M)
Enabling NSTX-U Acceleration and Enhancements

Incremental scopes: in order of programmatic priority	FY13 Increments	FY14 Increments
NSTX-U need to get back on Accelerated Schedule	$5.61	$3.95
Restore Planned Collaborators Funds	$0.50	$0.60
Accelerate Fault Detector/Firing Generator (Rectifiers)	$0.40	
Repair MG welds	$1.08	
Plasma Control System Hardware	$0.06	$0.06
Plasma Control System Engineering Enhancement	$0.09	$0.10
Central I&C Critical Staff/Improvements	$0.43	$0.49
HHFW-Critical Staff/Update Sources, RFTF/Probe Work, Antenna Improvement	$1.72	$1.62
Collaborator Interface Support	$0.31	$0.32
High Priority Facility/Diagnostic Enhancements	$0.62	$0.65
Restore Research	$0.33	$0.36
Replace Boundary Physics-Chemist	$0.35	$0.38
NBI Drawings	$0.20	$0.22
Total	$11.69	$8.74

- Restores NSTX-U (PPPL and national collaborators) to Accelerated Plan – allows NSTX-U to be ready for 1st Plasma mid-FY2014
- Allows preserving optimum staff necessary to resume operations in FY2014 and enables necessary facility enhancements to fully take advantage of NSTX-U capability

Note: under the Enhanced Case the amount of run-weeks NSTX can perform in FY2014 is dependent on the amount of un-used contingency NSTX-U can turn back to operations.