NSTX

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NSTX Project
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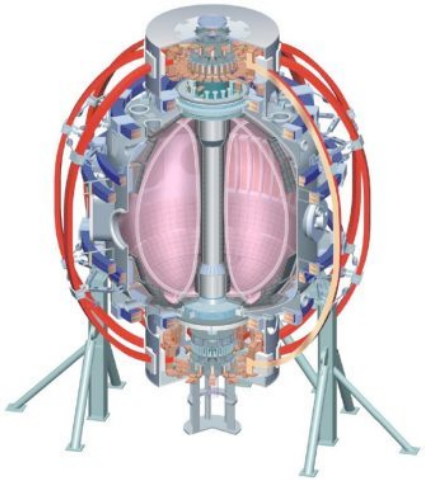
Masa Ono, PPPL

and the NSTX Research Team

FY 2011 Budget Planning Meeting
March 31, 2009



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NSTX Facility Supports World-Leading ST Research and Strong Contributions to ITER & Toroidal Plasma Science

Outline:

- Research Capability to Support FY 2009 Research Operations
- Near Term FY09 - FY 11 Science Topical Area Upgrade Plan (New CS and 2nd NBI Upgrade Project discussed by Mike Williams)
- Research Team Operations Summary
- Budget
- CS and 2nd NBI Plan
- Summary

Outage Completed for FY 09 Run

LLD Deferred to FY 10 Due to Manufacturing Challenge

Upgrade Activities:

- HHFW Antenna upgrade to provide a double power feed installation complete - external piping installation on-going
- Enhanced Boundary Physics Capability
  - 20 ch three view divertor bolometer and fast IR camera
  - Edge sample probe
  - Dual Lithium shakers to complement dual LITER
- LLD proto-type plate trial fitted, PPPL -SNL LLD work on going in preparation for the summer 2009 installation
- BES Vacuum Vessel Ports/Interfaces Complete
- MSE-LIF Platforms complete

Operational Readiness:

- Inspection and maintenance of all TF joints completed
- TIV/Shutter System upgrades for improved control/more channels
- Neutral Beams ready for the run with 2 spare ion sources
- 14-day bake-out completed for improved vacuum conditions
- FY 09 Run started in mid-March to be completed in July

Extensive Diagnostic Systems Operational with Strong Collaboration Contributions

Collaboration contributions

MHD/Magnetics/Reconstruction

- Magnetics for *equilibrium reconstruction (CU)*
- Diamagnetic flux measurement
- 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: $T_i(R)$ and $V_\phi(r)$ (51 ch)
- P-CHERS: $V_\theta(r)$ (75 ch)
- *MSE-CIF (15 ch) (Nova)*
- *FIReTIP interferometer (119mm, 6 ch) (UCD)*
- Midplane tangential bolometer array (16 ch)

Turbulence/Modes Diagnostics

- *Tangential microwave high-k scattering (UCD)*
- *Microwave reflectometers (UCLA)*
- *Ultra-soft x-ray arrays – tomography (JHU)*
- *Fast X-ray tangential camera (2ms) (PSI)*

Energetic Particle Diagnostics

- Neutal particle analyzer (2D scanning)
- SSNPA
- Fast lost-ion probe (energy/pitch angle resolving)
- Neutron measurements
- *Fast Ion D_α profile measurement (UCI)*

Edge Divertor Physics

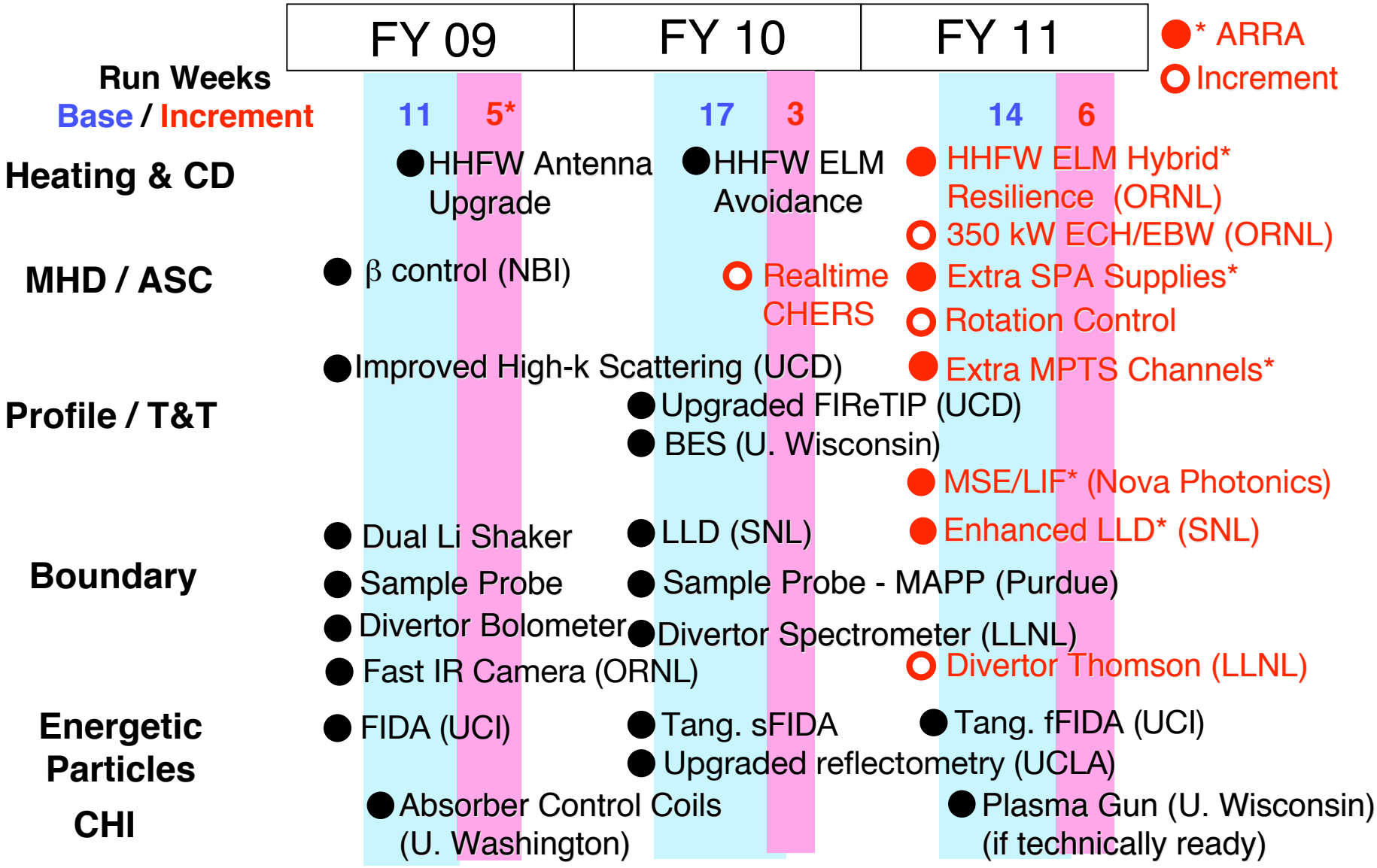
- *Reciprocating Edge Probe (UCSD)*
- *Gas-puff Imaging (2ms) (Nova)*
- *Fixed Langmuir probes (24) (ORNL)*
- Edge Rotation Diagnostics (T_i, V_ϕ, V_{pol})
- *1-D CCD H_α cameras (divertor, midplane) (ORNL)*
- *2-D divertor fast visible camera (Nova)*
- Divertor bolometer (12 ch)
- *IR cameras (30Hz) (3) (ORNL)*
- Tile temperature thermocouple array
- Dust detector
- Edge Deposition Monitors
- *Scrape-off layer reflectometer (ORNL)*
- *Edge neutral pressure gauges (U. Washington)*

Plasma Monitoring

- *Fast visible cameras (Nova)*
- Visible bremsstrahlung radiometer
- Visible survey spectrometer
- UV survey spectrometer
- *VUV transmission grating spectrometer (JHU)*
- *Visible filterscopes (ORNL)*
- *Graphite Tile Analysis (SNL)*
- *X-ray crystal spectrometer (astrophysics)(LLNL)*

NSTX Near Term Upgrade Plan

ARRA Funding Significantly Enhances Research Capability



Enhancement of Profile and Turbulence Diagnostics

For Comprehensive Transport and Turbulence Research

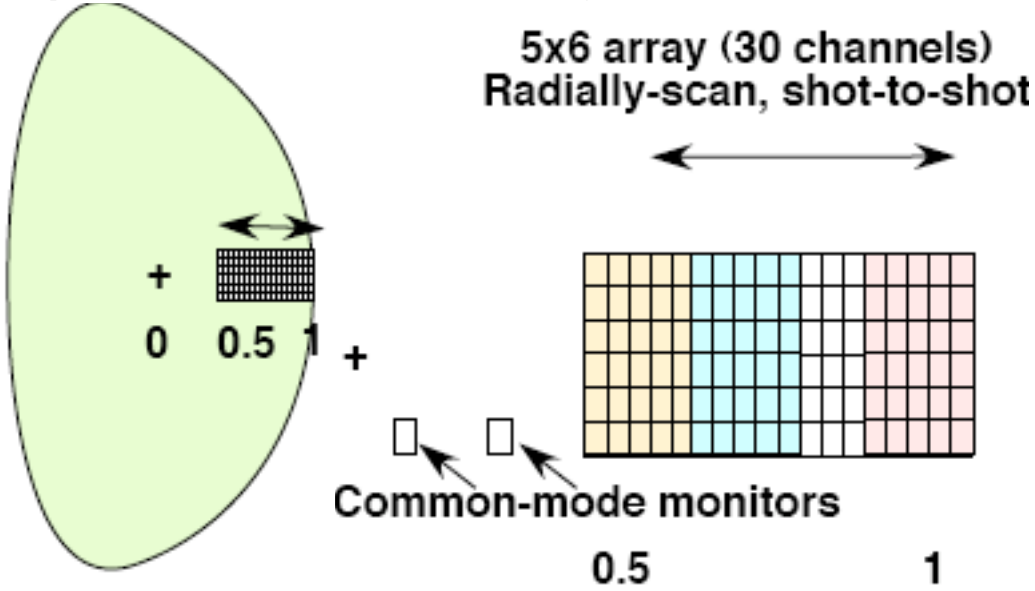
	FY 09		FY 10		FY 11	
Run Weeks						
Base / Increment /ARRA*	11	5*	17	3	14	6

* ARRA

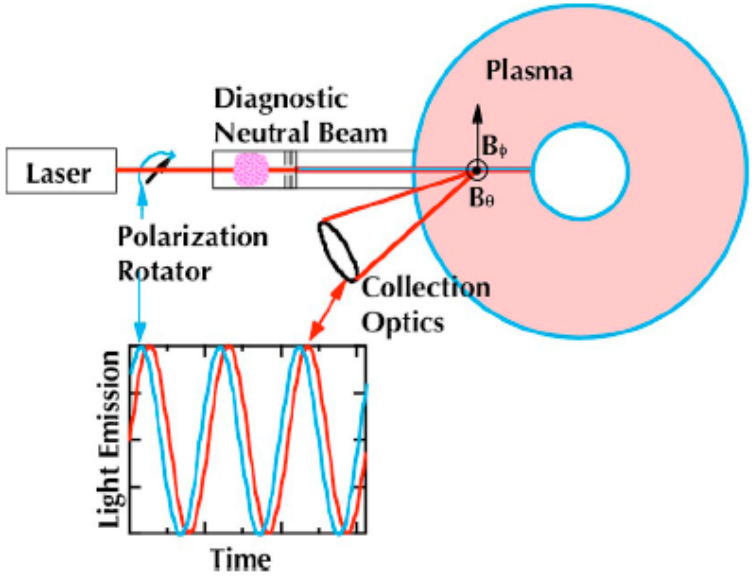
Profile / T&T

- Improved High-k Scattering (UCD)
- Upgraded FIReTIP (UCD)
- BES (U. Wisconsin)
- Extra MPTS Channels* (Improve spatial resolution for e-ITBs)
- MSE/LIF (Nova Photonics)*

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



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

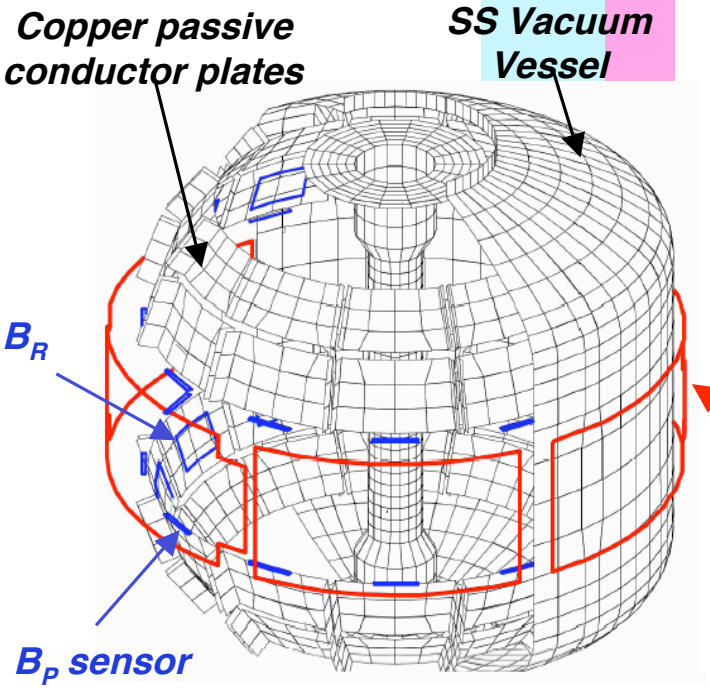


Macrostability

Sustain β_N and Understand MHD Near and Above No-Wall Limit

	FY 09		FY 10		FY 11	
Run Weeks						
Base / Increment /ARRA*	**11**	**5***	**17**	**3**	**14**	**6**
MHD / ASC	● β control (NBI)		○ Realtime CHERS		● Extra SPA Supplies* ○ Rotation Control ○ Non-magnetic RWM-ID JHU	

● * ARRA
○ Increment



VALEN Model of NSTX (Columbia Univ.)

6 ex-vessel midplane control coils

- **Extra SPAs to improve spectral control for EF/ RWM/ RMP (enabling all six coils to be independently controlled)**
  - **RWM spectrum dependence**
  - **Rotation and beta effects on NTMs**
  - **Response to 3D fields for EF, ELM and Neoclassical Toroidal Viscosity physics**
  - **Disruption physics** Columbia U, GA, ORNL
- **Rotation control as increment**

To provide basis to extrapolate high-beta operation to next-step STs and to support ITER physics

Boundary Physics Capability for Joint Research Milestones

Particle transport / Divertor Heat Flux / H-mode Pedestal Physics

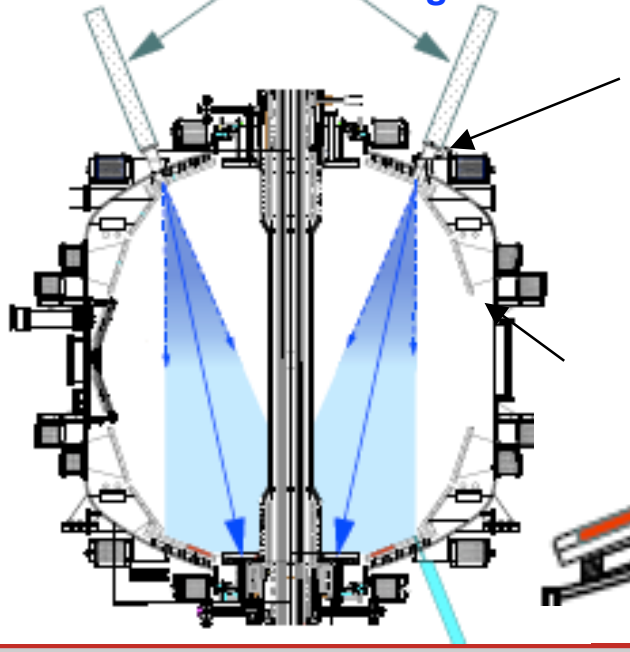
	FY 09		FY 10		FY 11	
Run Weeks Base / Increment /ARRA*	11	5*	17	3	14	6

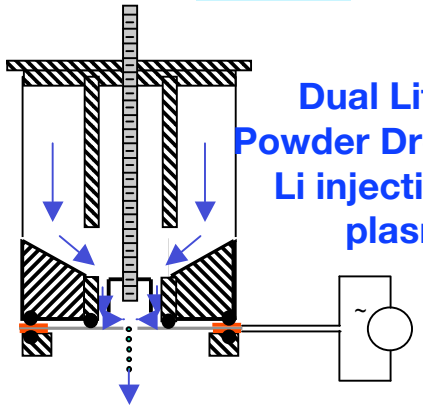
● * ARRA
○ Increment

Boundary

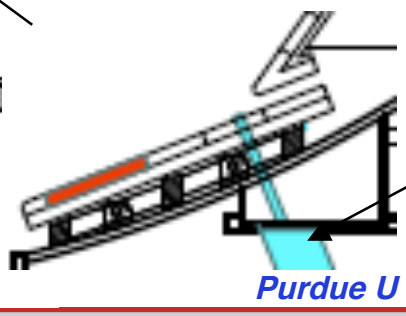
- ● Dual Li Shaker
- ● Sample Probe
- ● Divertor Bolometer
- ● Fast IR Camera (ORNL)
- ● Sample Probe - MAPP (Purdue)
- ● Divertor Spectrometer (LLNL)
- ● Extra MPTS Channels*
- ○ Divertor Thomson (LLNL)

Dual Liquid Lithium Evaporator For Li wall coatings





Dual Lithium Powder Dropper for Li injection into plasma

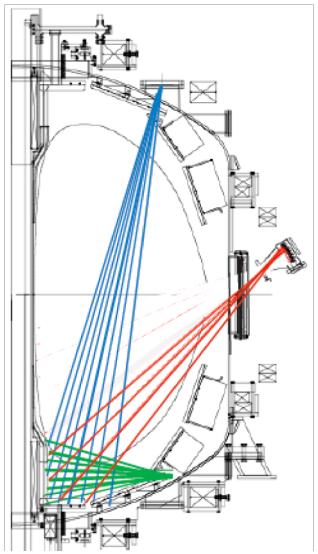


SAMPLE PROBE for retention measurements and surface analysis

To be upgraded - Material Analysis Particle Probe (MAPP)

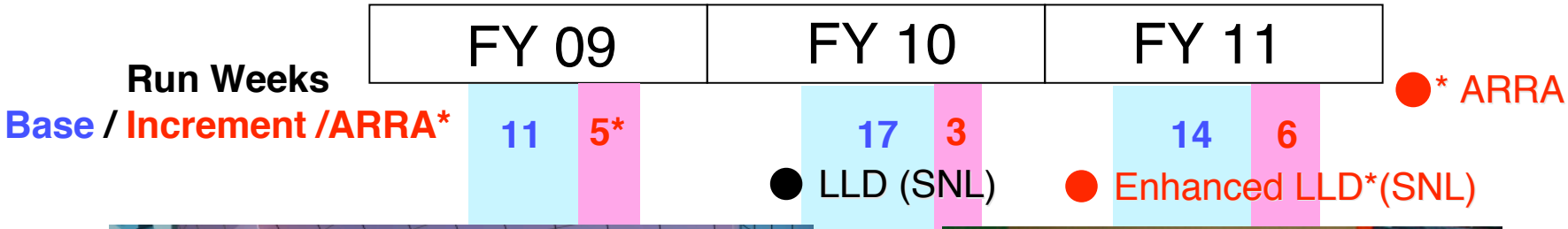
Purdue U

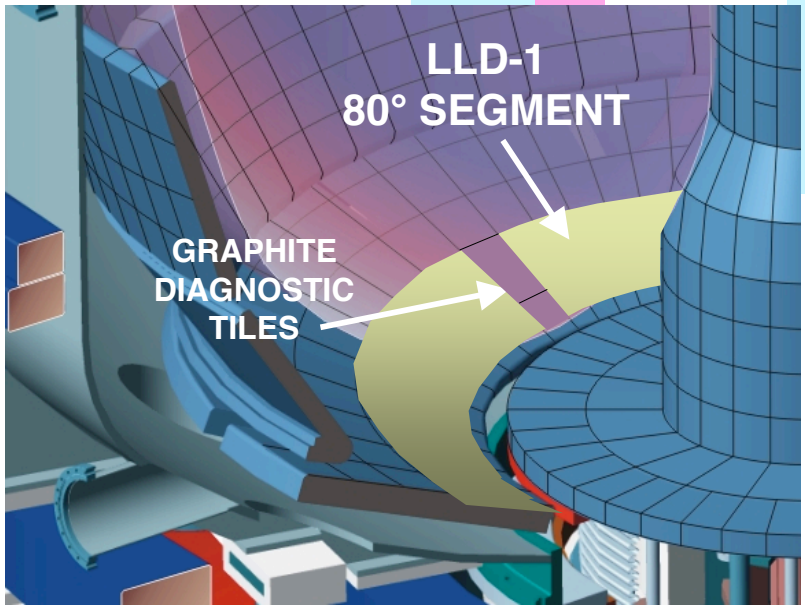
Three-view Divertor Bolometer Installed for divertor radiation

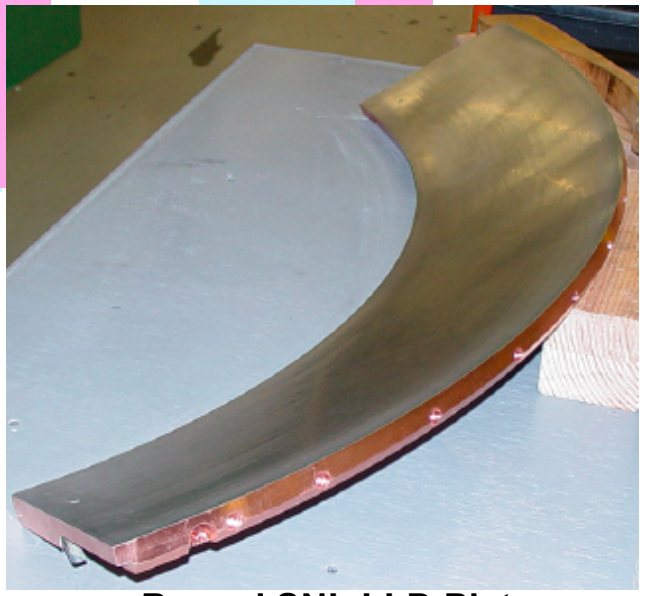


Liquid Lithium Divertor is Critical for FY 09 Outage

LLD Plate Fabrication More Challenging Than Anticipated







Brazed SNL LLD Plate

- LLD Scheduled to be installed for FY 2010 run
- Enhanced LLD to achieve density control - possibilities: outboard mesh, inboard LLD, enhanced fueling - to be installed for FY 2011 run via ARRA

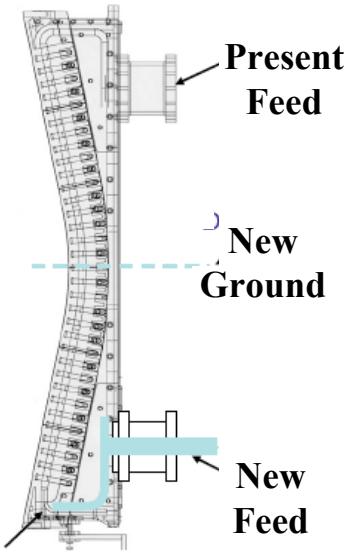
Improve HHFW Power Handling and ELM Resilience

To Support Current Ramp-Up and Sustainment Research in H-mode

	FY 09		FY 10		FY 11	
Run Weeks Base / Increment /ARRA*	11	5*	17	3	14	6
HHFW	● HHFW Antenna Upgrade		● HHFW ELM Avoidance		● HHFW Hybrid ELM Resilience*	

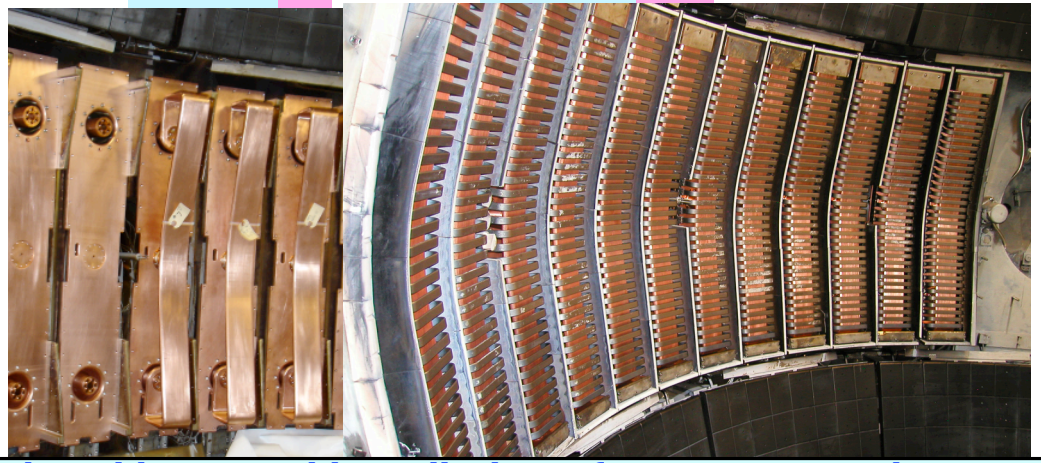
● * ARRA

Symmetric Antenna Main Features



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

Antenna Installation is complete



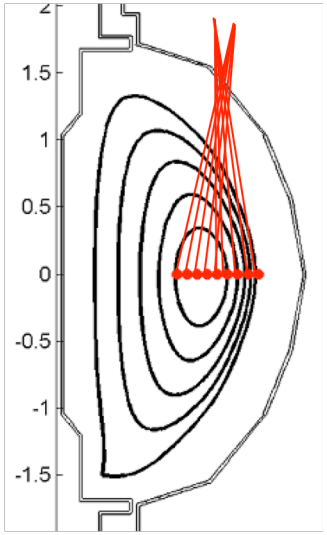
- Completed in-vessel installation of new symmetric antenna. External loop being installed for FY 09 run
- HHFW ELM Avoidance system to be implemented in FY 10
- HHFW Hybrid ELM Resilience system for FY 11 as ARRA upgrade in collaboration with ORNL

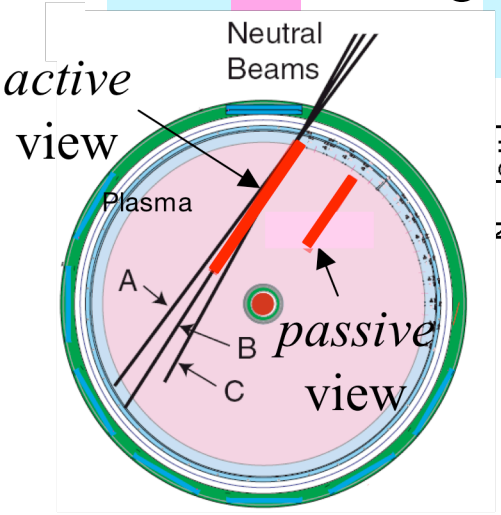
Powerful Energetic Particle Research Tools

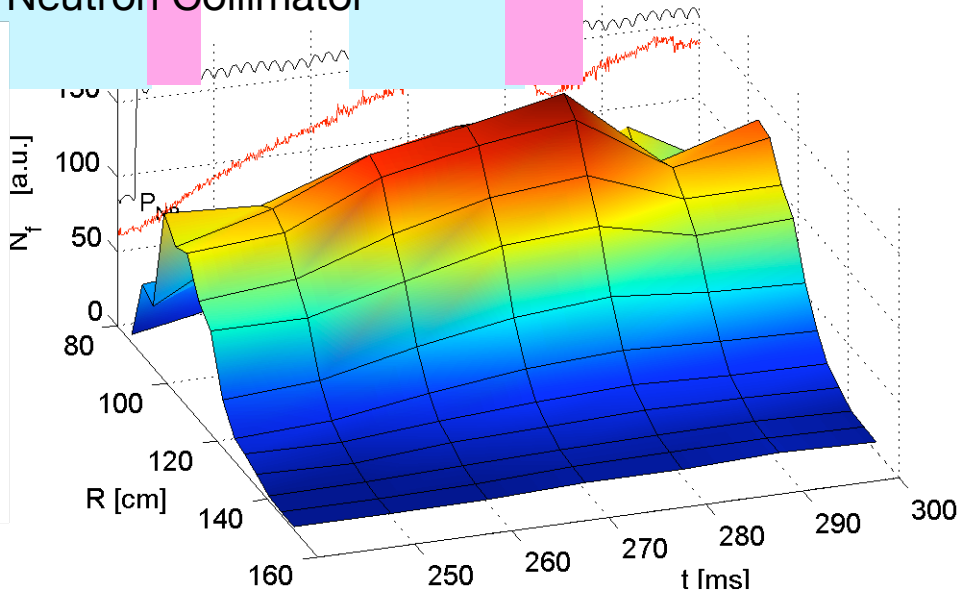
FIDA diagnostic Successfully Implemented on NSTX

	FY 09		FY 10		FY 11	
Run Weeks						
Base / Increment /ARRA*	**11**	**5***	**17**	**3**	**14**	**6**
Energetic Particles	● FIDA (UCI)		● Tang. sFIDA ● Upgraded reflectometry (UCLA) ● Neutron Collimator		● Tang. fFIDA (UCI)	

● * ARRA







- **Density profile of fast ions (15 – 65 keV) deduced from Doppler-shifted D_α emission by energetic neutrals created by charge-exchange with NBI neutrals**

- **During TAE avalanches, measured fast-ion losses up to 30%**
  - **Consistent with neutron rate drop**
  - **Profile remains peaked**

Solenoid-free Start-up

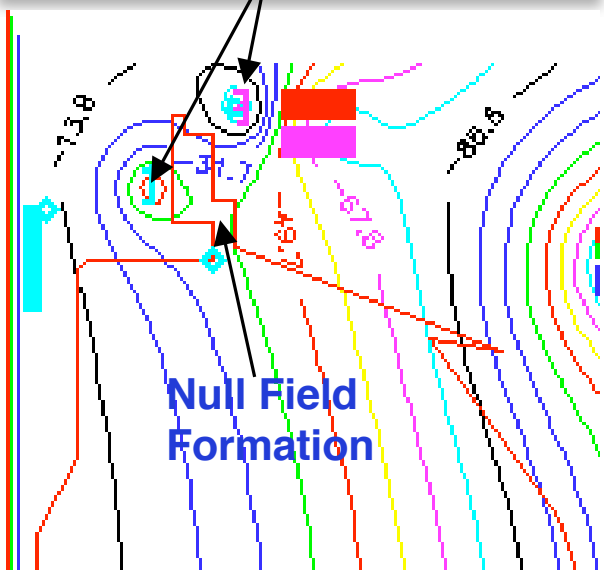
Demonstrate and Understand Non-Inductive Start-up

	FY 09		FY 10		FY 11	
Run Weeks Base / Increment /ARRA*	11	5*	17	3	14	6
CHI / Plasma Guns	● Absorber Control Coils (U. Washington)				● Plasma Gun (U. Wisconsin) (if technically ready)	
PF-Only					○ 350 kW EBW/ECH preionization	ORNL

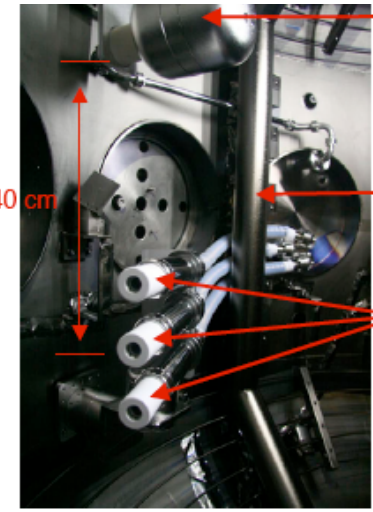
● * ARRA

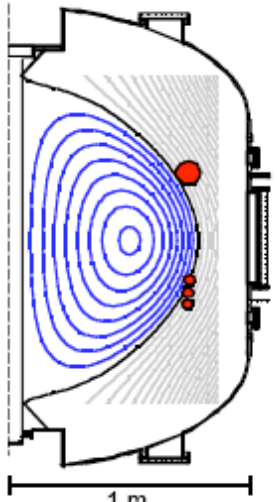
○ Increment

Absorber control coils



PEGASUS Gun Start-up





Ip ~ 100 kA achieved with three guns

Collaborating with DIII-D to test PF-only start-up with ECH

Productive Collaborative Research Team

FY 08 was a productive year for NSTX:

- New tools contributed strongly to the research output:
  - Increased lithium capability: Dual LITER with shutters, Lithium shaker
  - New diagnostics: 71 ch p-CHERS, FIDA, high-k scattering
- 16.6 weeks completed meeting the FY 08 operational Joule milestone of 15 weeks. Produced 2571 plasma shots, most plasma shots per year. 40% increase in shots/week from 2004.
- Presented twenty IAEA presentations and six 2008 APS-DPP invited talks on key research topics
- Educational: 34 post-docs and students

NSTX Research Team

	PPPL	Non-PPPL
Researchers	52	160
Post Doc.	1	14
Grad. Students*	7	12

*Twelve Ph.D. Thesis students

ARRA Funding Greatly Enhanced Research Capability

Significantly Increases NSTX Science Output

Enhanced operation of Major Fusion Facilities in FY09 and FY10

- 5 extra run weeks in FY 09 - FY 10 will enable the NSTX researchers to conduct high priority fusion plasma experiments.

Diagnostics and Facility Upgrades in FY 09 - 11:

- Extra 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.
- Motional Stark Effect Laser Fluorescence advanced diagnostic system for internal magnetic and electric field measurements will be also installed which can also provide important data for the FY 11 joint research milestone.
- Enhancement to the lithium liquid divertor target capability for improved divertor pumping to control edge collisionality for the FY 11 joint research milestone.
- 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 for the FY 11 joint research milestone.
- Hybrid ELM resilience system for HHFW for start-up, ramp-up and plasma sustainment research crucial for ST development path.

Incremental Budget
Significantly Increases Science Output

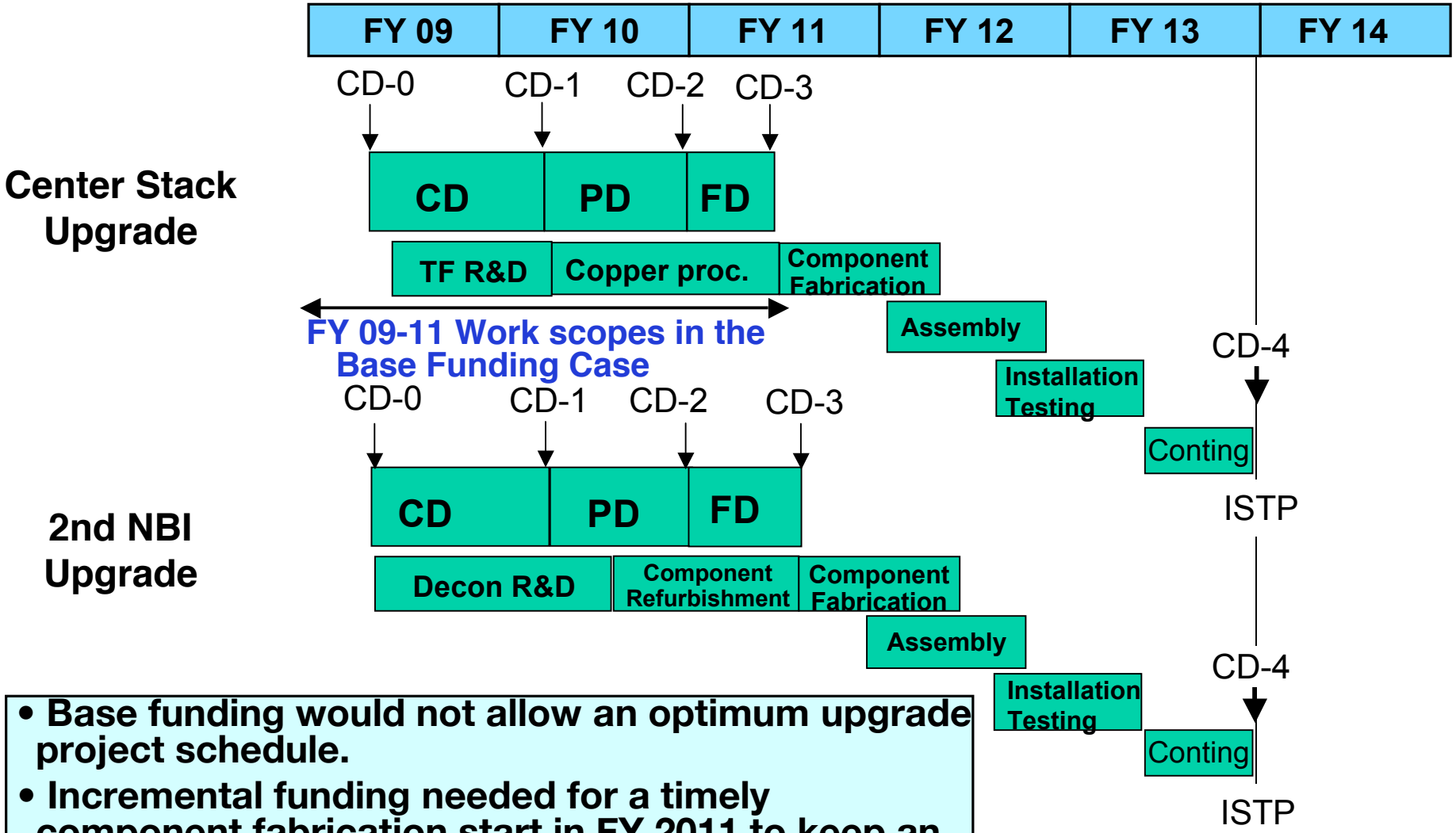
- Increase facility operation to 20 run weeks in FY 2010 and 2011
  - Operations toward full facility utilization
  - Enables high priority key research including start-up ramp-up, boundary / divertor physics and counter-injection campaign.
- Accelerate additional key facility/diagnostic upgrades:
  - Divertor Thomson scattering system for increased boundary physics capability to be implemented in FY 2011
  - Install ECH/EBW System 350 kW for start-up and EBW study to be implemented in FY2011
- Progress on major upgrades (CS and NBI) with more optimum schedule
  - Start major procurements and components fabrication
- Improve facility reliability / availability to achieve full utilization
  - Critical spare parts on hand

10% Budget Cut Case (FY11)

The 10% budget cut case is particularly difficult for NSTX since the base budget is already reduced to provide very little upgrades:

- 50% reduction in runtime (from 14 to 9 weeks)
- NSTX staff reduction of 14 FTE (15 %) relative to the base case
- Further reduce facility and diagnostic upgrades procurement
  - Eliminate HHFW ELM resilience hardware
  - New CS and NBI upgrade activities slowed by 6 months
  - Cut preventive maintenance (increase risk)
- Research progress to slow by ~ 30%
  - Focused on transport studies with BES and exploiting liquid lithium divertor.
  - Eliminate studies of non-inductive startup and high power RF.

Schedule for CS & NBI Upgrades Proposed in "Mission Need Statement" for CD-0



- Base funding would not allow an optimum upgrade project schedule.
- Incremental funding needed for a timely component fabrication start in FY 2011 to keep an optimum upgrade schedule.

NSTX Has Many Exciting Opportunities Ahead

Optimized Facility Plan Developed for FY 2009 - 2011

- **Very productive FY2008 run with all milestones completed**
- **New capability for FY 2009:**
  - Three-View Divertor Bolometer / Edge Sample Probe / Fast IR Camera
  - Dual Lithium Shaker system together with Dual LITER system
  - HHFW antenna upgrade
- **Base facility upgrade fund enables select high priority upgrades:**
  - LLD for low collisionality and BES for low-k turbulence in FY10
  - Enhancement: Tang. FIDA, FIReTIP, Wave Reflectometry, FY 10-11
  - New CS and 2nd NBI design, R&D and copper procurement in FY 09-11
- **ARRA funding significantly enhances science capability:**
  - Five additional run weeks in FY 09-10
  - Enhanced LLD for improved divertor pumping in FY 11
  - Additional SPAs for improved spectra control for EF/RWM/RMP* in FY 11
  - HHFW Hybrid ELM resilience system* for H-mode operation in FY 11
  - MSE-LIF* to complement MSE-CIF and MPTS extra channels* in FY 11
- **Incremental budget enables full facility utilization and major upgrades**
  - Increase the run weeks by ~ 40 % in FY2010-2011
  - ECH for start-up research
  - Divertor Thomson for boundary physics research
  - Enables optimum schedule for New CS and 2nd NBI