NSTX

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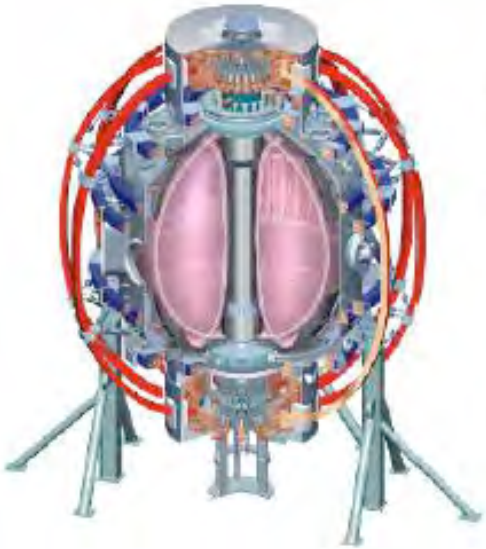
OFES FY 08 Q4 Review Report
NSTX Project/Program

Masayuki Ono / Jon Menard
For the NSTX Team

PPPL-OFES/DOE

October 27, 2008



College W&M
Colorado Sch Mines
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Nova Photonics
New York U
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ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

NSTX Completed Successful FY 2008 Run

- NSTX has completed 16.6 weeks of experimental operations meeting the FY 08 operational Joule milestone (out of our planned 15). Produced 2571 plasma shots in 16+ weeks which compares well with similar 2460 plasma shots in 2004 but it took 21 weeks.
- Dual LITER system has been working flawlessly. LITER also largely eliminated He-GDC which improved operational efficiency. Dual LITER were reloaded with lithium three times (total ~ 200g) during the operations.
- Lithium shaker was tested. It appears to reduce the density and impurity radiation during the long-pulse ELM-free H-mode discharges.
- The EF/RWM feedback control system are now routinely used as a tool for advanced long-pulse operation.
- The run concluded on July 14. Vent by late July, perform diagnostic calibrations, and then begin in-vessel activities in late August.

Run Coordination

- 72 days of experiments performed
- 56 Experimental Proposals (XP) and Machine Proposals (MP) conducted
- Run-day distributions (and XPs performed) by Topical Science Group:
  - Transport & Turbulence: 12.5 (10)
  - Boundary Physics: 14 (11)
  - Macroscopic Stability: 12 (8)
  - Solenoid-free Startup: 8 (1)
  - Wave-Particle Interactions: 6 (7)
  - Advanced scenarios & Control: 6 (5)
  - ITER support: 6 (2) Two ITER reports (RMP for ELM control and Vertical Stability) written.
  - Cross-cutting and enabling: 7.5 (12)

22 NSTX Related IAEA Presentations

"Overview of Resultsfrom the NSTX" D.A.Gates
"Suppression of Turbulent Transport in NSTX Internal TransportBarriers" H. Yuh (Nova);
"Momentum Transport inElectron-Dominated Spherical Torus Plasmas" by S. M. Kaye;
"Plasma Performance Improvement with Li-Coated PFCs in NSTX" R. Kaita;
"Divertor Heat Flux Mitigation in H-mode Plasmas in NSTX" V.Soukhanovskii (LLNL);
"An Experiment to Tame the Plasma Material Interface" R. Goldston;
"Edge Turbulance, Blob Generation" D. D'Ippolito (Lodestar Research Corp.);
"Spectral Effects on Fast Wave Core Heating and Current Drive" C.K. Phillips;
"Advances in Global MHD Mode Stabilization Research on NSTX" S. Sabbagh (Columbia);
"Tokamak Plasma Response to 3D Magnetic Fields" J-K. Park (Student);
"Investigation of EBW Coupling in NSTX" S. Diem (Student)
"Gyrokinetic Simulations and Theory" W. Wang;
"Small ELMs in Alcator C-MOD, MAST, and NSTX" R. Maingi (ORNL);
"Turbulent Fluctuations with the Electron Gyro-Scale in NSTX Plasmas"E. Mazzucato;
"Alfvén acoustic coupling in toroidal fusion plasmas" N. Gorelenkov;
"Solenoid-free Plasma Start-up in NSTX using Transient CHI" R. Raman (U. Washington);
"Toroidal Alfvén Eigenmode Avalanches in NSTX" E. Fredrickson;
"Electrostatic Dust Detection and Removal for ITER" C. Skinner;
"Energetic Particle-induced Geodesic Acoustic Mode" G-Y. Fu;
"ECCDin Spherical Tokamaks with Application to ITER"A. Ram (MIT).
" Correlation between Electron Transport and GAE Activity in NSTX" D. Stutman (JHU)
"Magnetic ELM Pace-making with 3-D Applied Fields in NSTX " J. Canik (ORNL)

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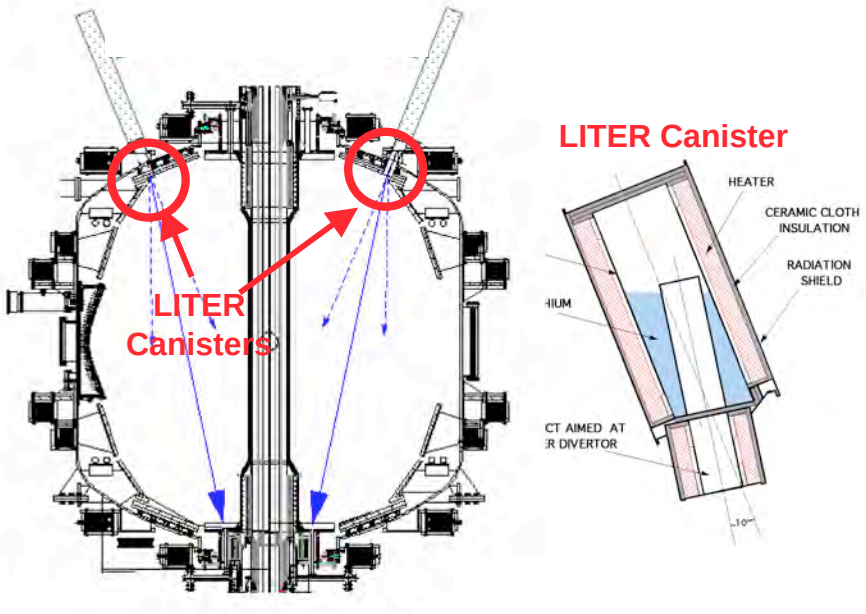
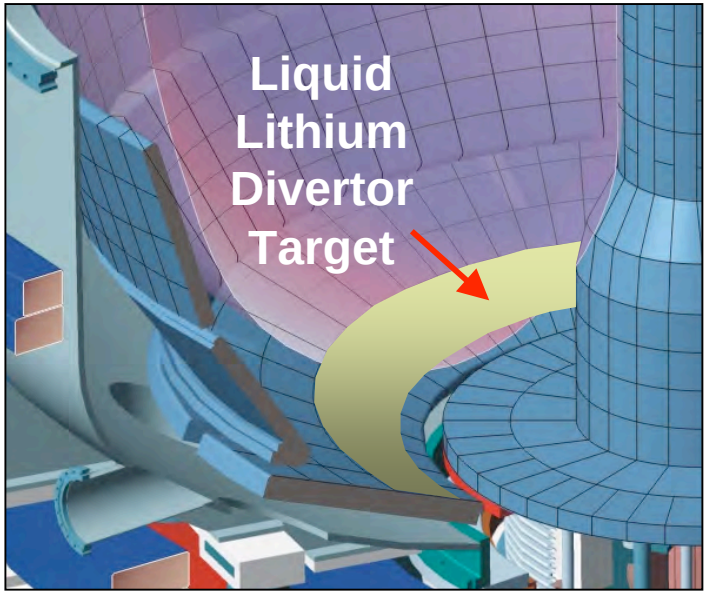
Boundary: Liquid Lithium Divertor (LLD) for Particle Control

Unique Capability for Diverted H-mode

NSTX Dual "LITER"Lithium Eevaporators



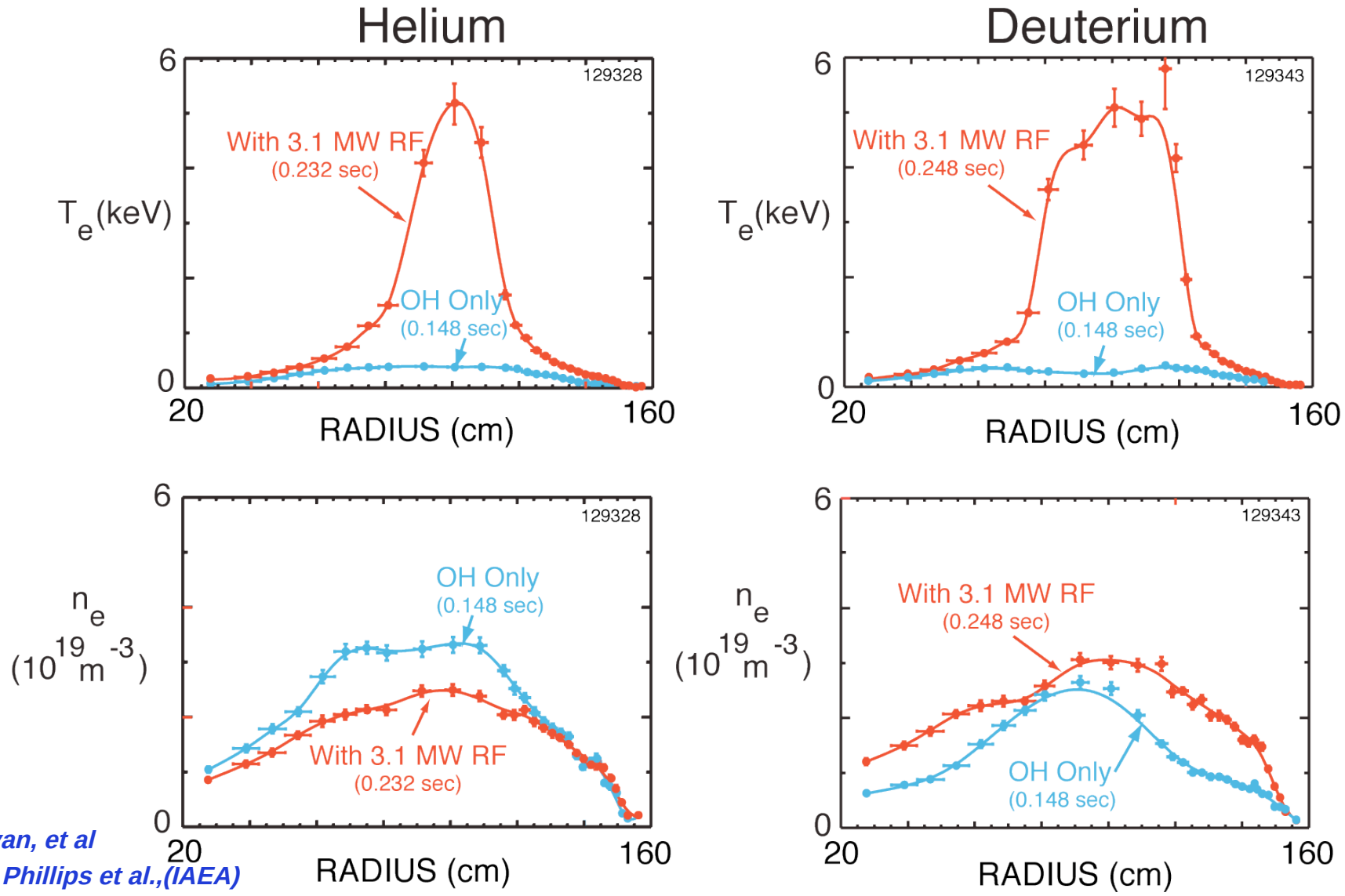


- **Worked reliably in FY 08 evaporating ~ 200 g lithium**
- **Reloaded 3 times (takes one day to reload)**
- **Will be used to coat the LLD surface in 2009**

- **Install LLD (with SNL) with temperature control**
- **Start LLD operation in 2009**
- **Long-pulse divertor in 2012**
- **Core fueling in 2012**
- **Very high power flux divertor in 2013 (Incremental)**

D, He Plasmas Heated to 5 keV with 3 MW HHFW at $k_{||} = 14\ m^{-1}$

(Lithium has helped HHFW performance in deuterium, H-mode, and NBI)

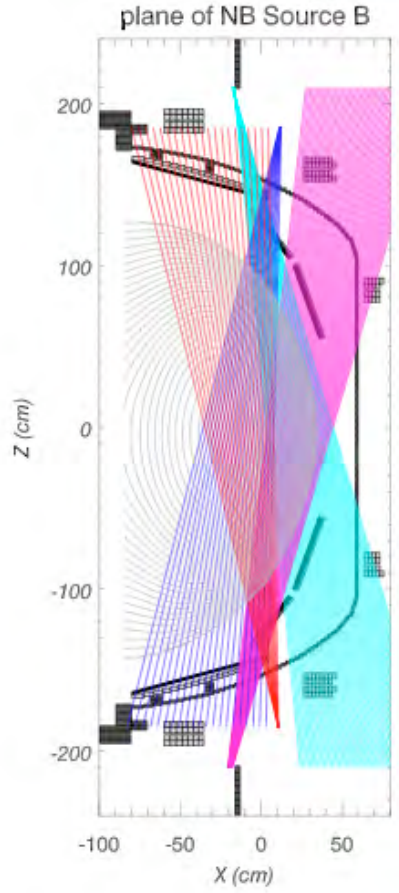


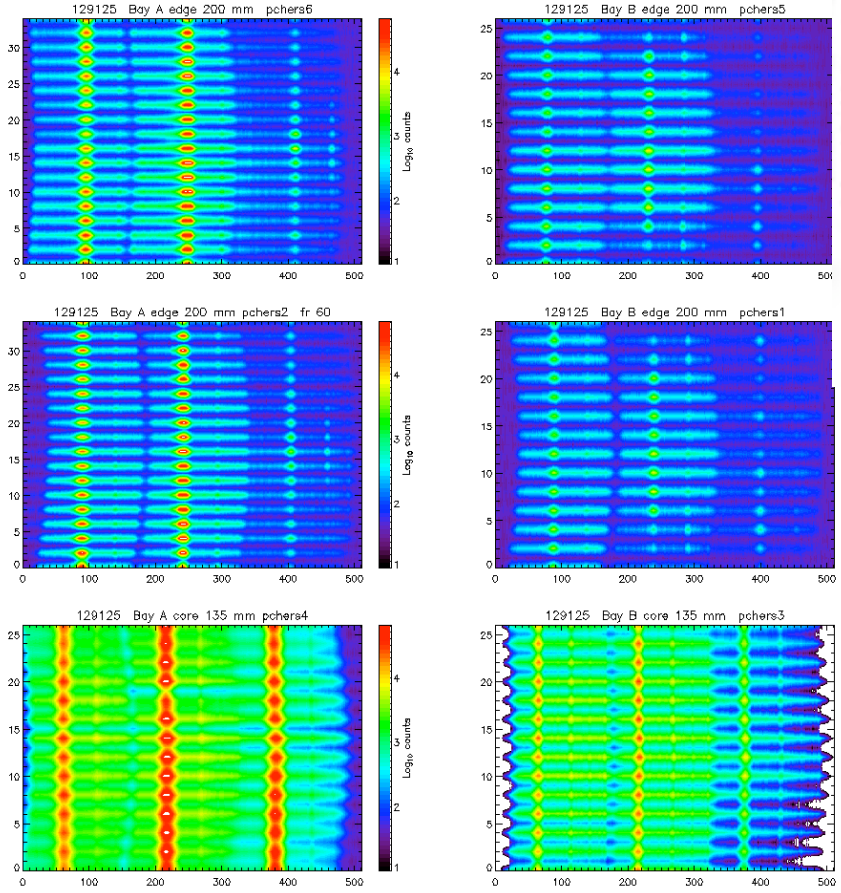
P. Ryan, et al

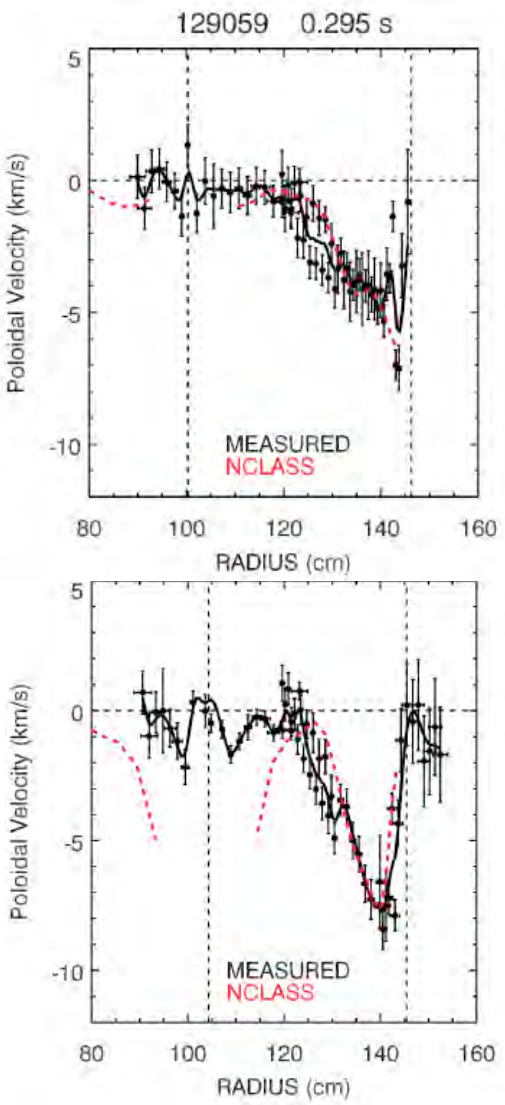
C. K. Phillips et al.,(IAEA)

P-CHERS: D(08-1) Upgrade the poloidal rotation diagnostic using charge-exchange recombination emission spectroscopy to achieve its full spatial resolution and coverage. (September 2008) (Achieved in March 2008)

- Full system (75 ch active and 63 background ch, top & bottom symmetric views, 276 ch total) installed, commissioned and operated routinely for FY 08 run
- Yielded ion-gyro-radius scale poloidal flow structures



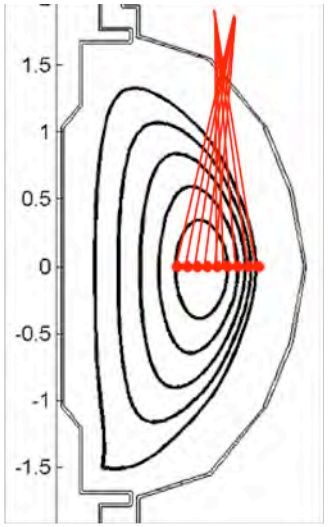


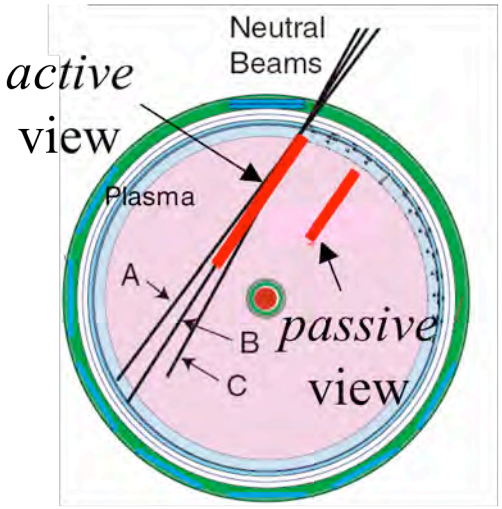


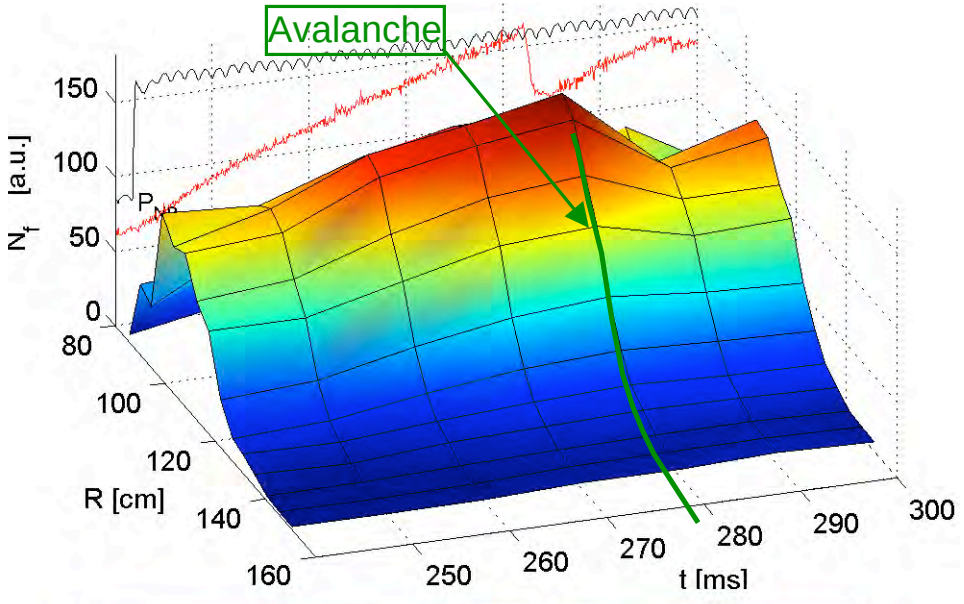
FIDA diagnostic Successfully Implemented on NSTX

- **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**

FIDA diagnostic on NSTX (2008)







M. Podesta, UCI, APS

NSTX 2008 Outage Activities For New Facility Capability

- TF joint inspected (joint resistance stable over three years of operation up to 0.55T) - joints good condition
  - All joint surfaces were cleaned and re-plated.
- New OH bus to reduce error fields being installed and rerouted CHI bus
- HHFW Antenna Upgrade
  - Old antenna components cleaned and modified
  - New antenna parts are readied for installation in mid-Nov.
- Dual LITER and Lithium shaker systems available
- Installation of Liquid Lithium Divertor (To be commissioned in FY 09)
  - R&D of LLD plates being performed
  - Trial fit of aluminum test plates planned to facilitate LLD installation
- Installation of 20 Ch Three-view Divertor Bolometer readied in November
- Installation of edge sample probe being readied
- In-vessel installation of BES ports on-going (To be commissioned in FY 09)
  - Cable tray installed and detector room being prepared
- MSE with Laser-Induced Fluorescence (To be commissioned in FY 10)
  - Platform extension completed.
  - Utilities and cable tray being installed

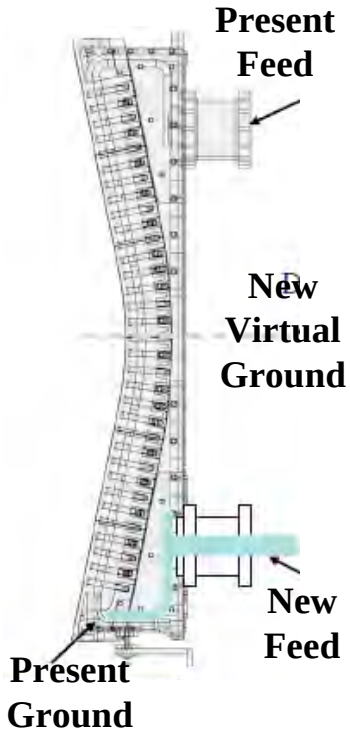
Tentative Schedule for FY09 Run Preparation

- Delays in the LLD have prompted a plan to resume operations early, and schedule a mid-run opening.
- By November 21 th, complete the HHFW Antenna upgrade, the new OH bus, TF joint inspections, the new Divertor Bolometer, and the penetrations/mounting structures for the new BES diagnostic.
- In-vessel diagnostic calibrations in between Nov 15th and December 12th.
- In-vessel prep, cleaning, photos and install the NB duct to be able to pump down by Dec 19th, and complete leak checking by the holidays.
- A two week vessel bake will start immediately following the holidays.
- A period of post-bake diagnostic calibrations (including Rayleigh/Raman Scattering calibration of MPTS) will be followed by the ISTP during the last week in January.
- In this plan, NSTX plasma operations will start on February 2nd.
- A mid-run opening, tentatively scheduled for April (could slide to June), to install the LLD tray segments and tiles, and the BES optical head, limiter and fiber-optics. If delayed to June, the MSE-LIF installation will be also completed at this time.

F(08-2) Design and fabricate the components for the symmetric end-feed HHFW antenna system (September 2008) (Achieved: HHFW new components, new antenna straps and back plates, fabricated by vendors)

Upgraded Antenna Main Features:

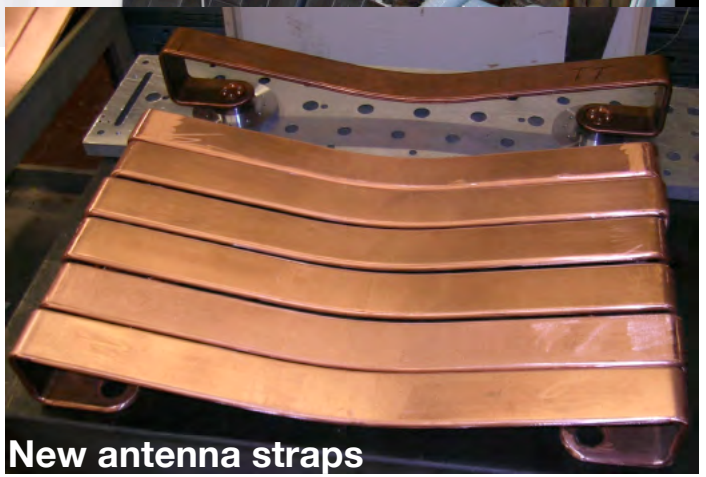
- Symmetric feed
- Virtual ground at antenna mid-plane
- Maximum radiation at mid-plane
- Voltage at feed-thru reduced by ~ 1.4
- Power capability should be up by ~ 2



HHFW Antenna Area Prepared

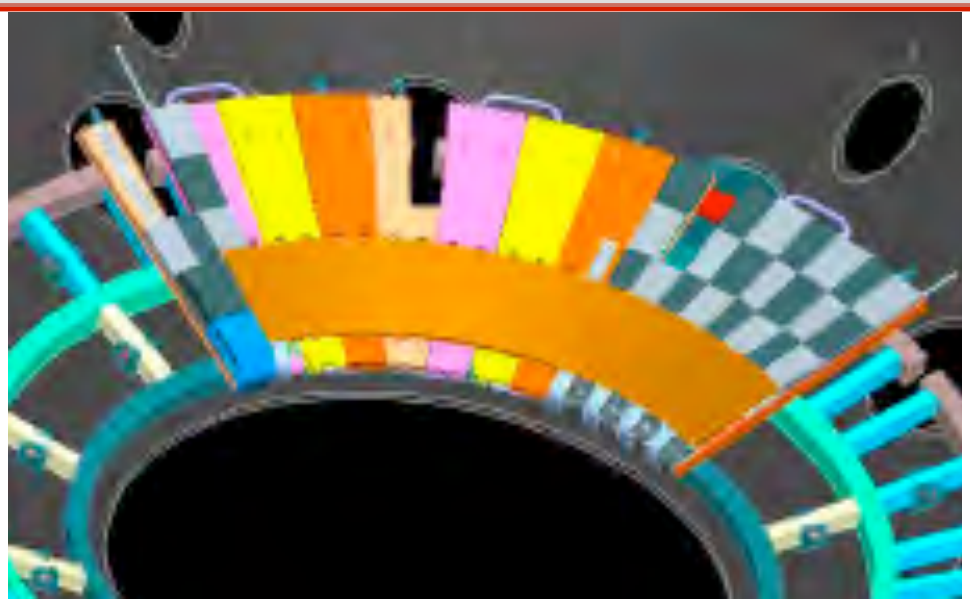

Antenna Feed-thrus


Feed-thru Adopters


New antenna straps

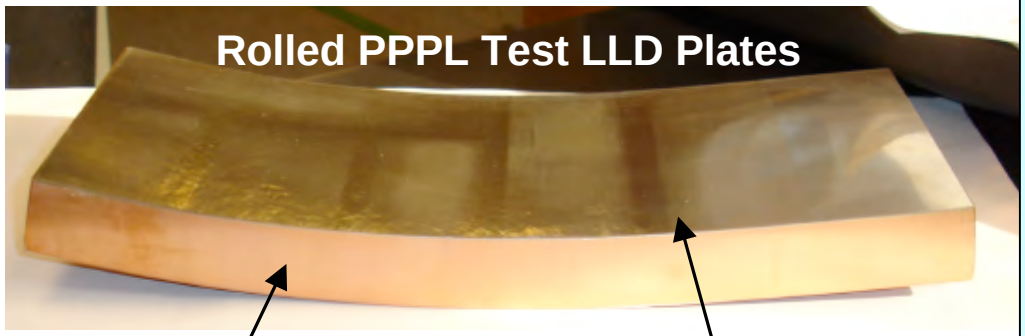
Antenna Installation Scheduled in Mid-November

Liquid Lithium Divertor (LLD)



Liquid Lithium Divertor

- FDR for basic modules held 4/22/08
- SNL now procuring LLD Plates
- SNL preparing control system
- PPPL performing design, R&D and installation support
- PPPL preparing LLD diagnostics with university collaborations



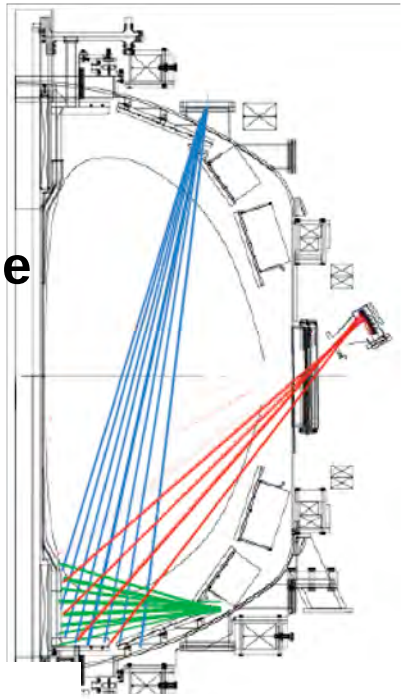
Issue: The delayed SNL LLD plate delivery schedule appears to match our mid-run schedule. However, there are some questions.

- NSTX is working on a back-up plan to manufacture them at PPPL
- LLD installation may shift toward summer time if delivery is delayed
- Perform LLD commissioning in September if the delivery is delayed

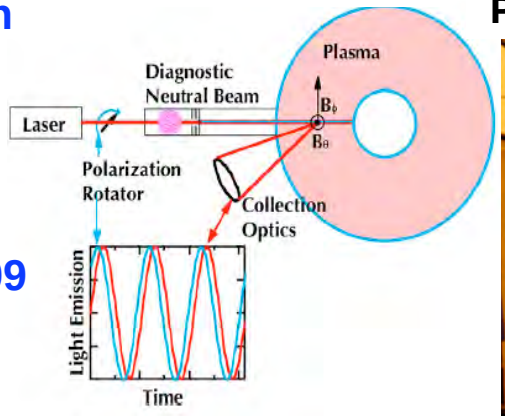
Diagnostic Upgrade Activities for FY 09

- **Divertor bolometer to strengthen divertor research**
  - Bay J upper installation to be installed in November
  - Full System should be ready for FY 09 Run
- **Edge Sample Probe to support FY 09 Joule Milestone**
  - Collaboration with Purdue University
  - The probe should be available for FY 09 Run
- **BES diagnostic**
  - BES viewing ports being installed / lens being procured
  - U. Wisconsin manufacturing detectors
  - Cable trays and diagnostic room being readied
  - Aiming to commission during the FY 09 run
- **MSE-LIF diagnostic**
  - MSE-LIF platform extension completed
  - PDR to held in Dec. 2008
  - Final installation planned in summer of 2009

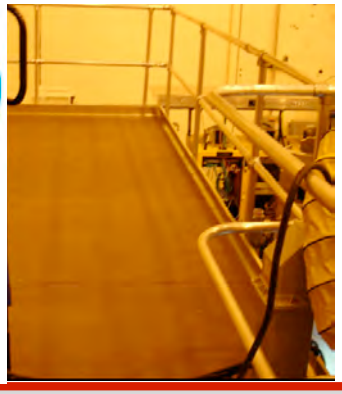
Three-view divertor bolometer



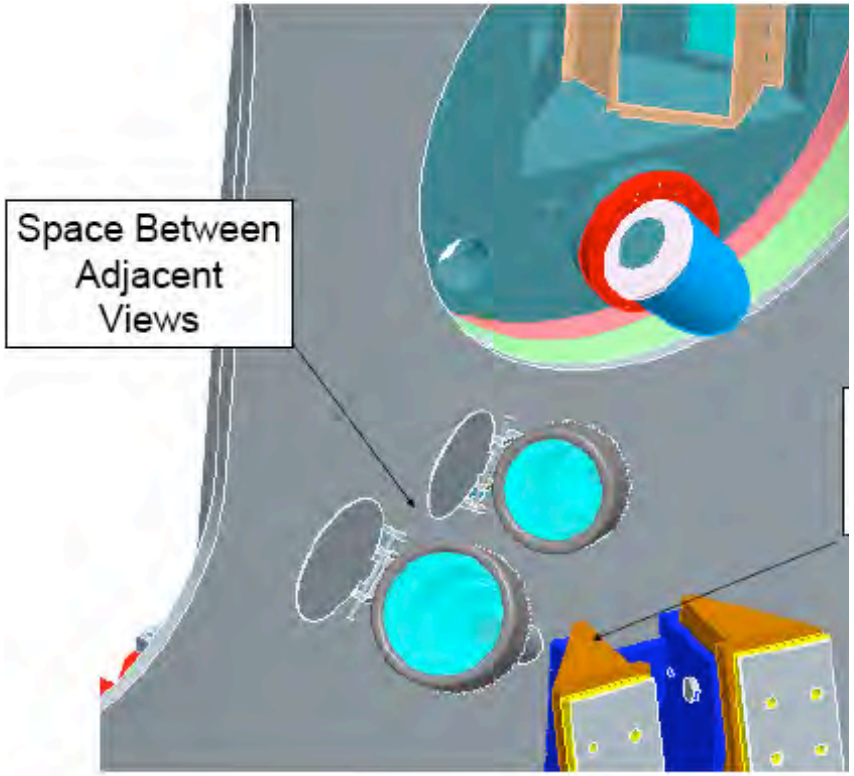
MSE-LIF



Platform Extension



Beam Emission Spectroscopy for FY 09



BES Ports Machining Set-up

BES diagnostic

- BES viewing ports being installed / lens being procured
- U. Wisconsin manufacturing detectors
- Cable trays and diagnostic room being readied
- Aiming to commission in FY 09

FY 09 Facility and Diagnostic Milestones

FY 2009	Facility Milestones	FWP	Forecast
F(09-1)	Operate NSTX Facility for 11 Experimental Run Weeks.	Sep 09	14 Run weeks
F(09-2)	Commission the liquid lithium divertor target for particle pumping.	Apr 09	Sep 09

Note: LLD commissioning forecast is now Sept. 09 due to the delay in the SNL LLD plate delivery.

FY 2009	Diagnostic Milestones	FWP	Forecast
D(09-1)	Upgrade the divertor bolometer to three views with 20 channels.	Sep 09	Mar 09
D(09-2)	Install and commission the Beam Emission Spectroscopy system for transport studies.	Sep 09	Sept 09

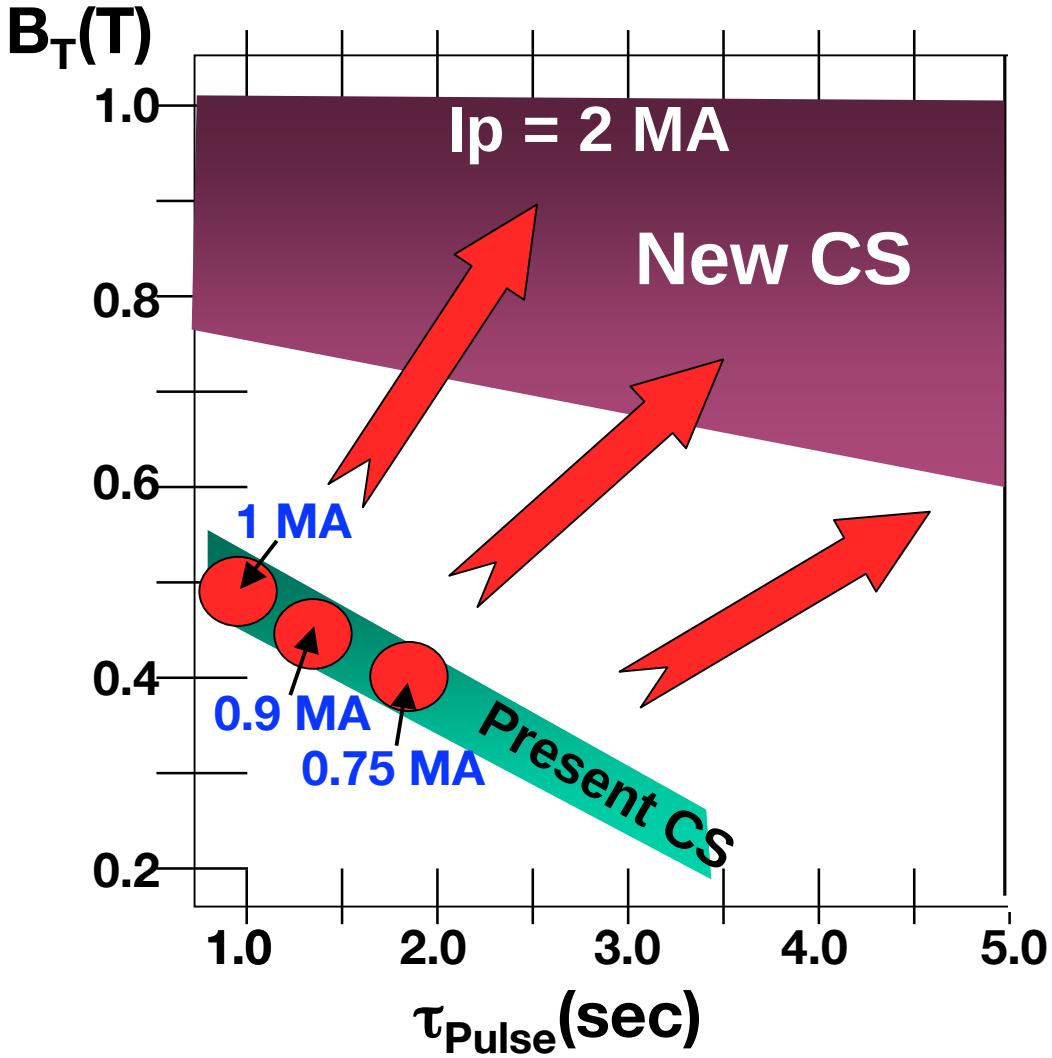
Note: Divertor bolometer is ahead of schedule and will be available at the start of the FY 09 run.

ASIPP-PPPL Collaboration Activities

- **NSTX OH Spare**
  - OH coils is completed and being readied for shipment
  - NSTX will make final inspection and testing after its arrival
  - NSTX will complete adopting fixtures for future installation
- **EAST diagnostic status**
  - ECE grating polychromator and ion source arrived at ASIPP
  - Germanium PHA detector shipped to ASIPP
  - Neutron (^{3}He) detectors shipped to ASIPP
  - NPA being tested;
- **ASIPP researchers' visits to NSTX/PPPL for tokamak code training**
  - Two researchers are visiting for one year. Learning tokamak simulation and analysis codes (TSC, pTRANSP, etc.)
- **Assisting EAST operations**
  - The head of NSTX plasma operation, Dennis Mueller, visited EAST to help the first plasma and the second campaigns. Dennis returned to EAST for the third campaign this summer.

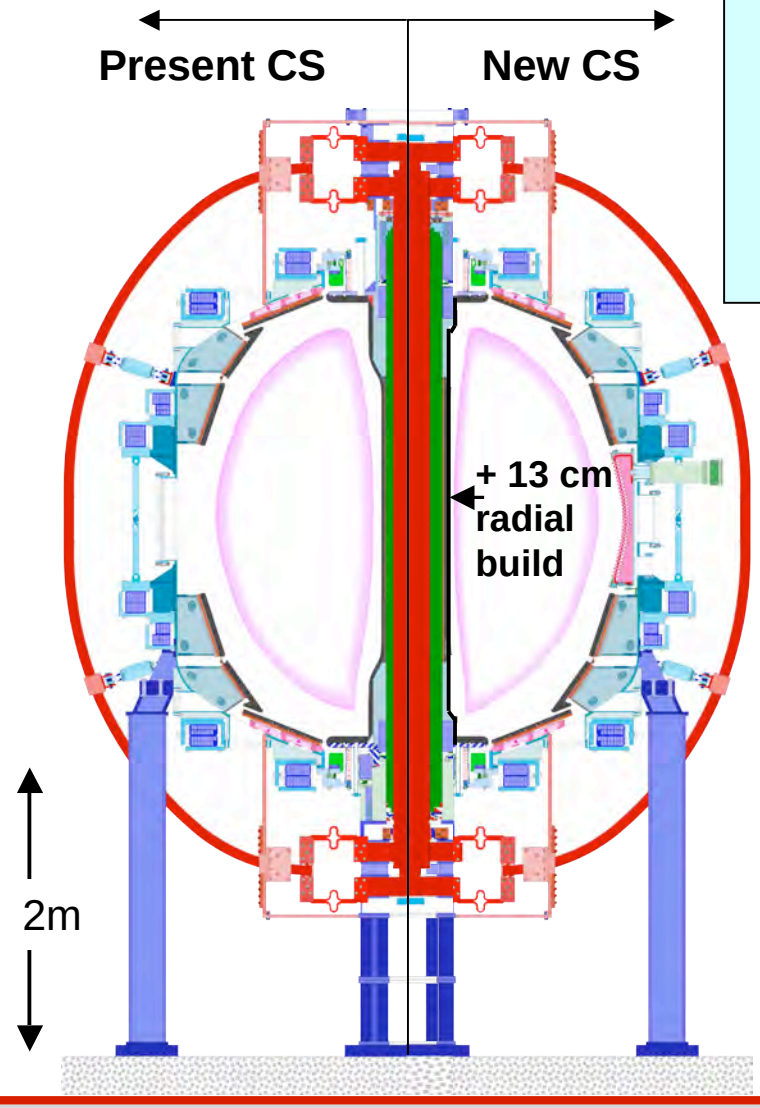
ASIPP Completed Spare OH Coil Fabrication

New High-Performance Center-Stack will Expand Operational Space Toward Next-Step STs

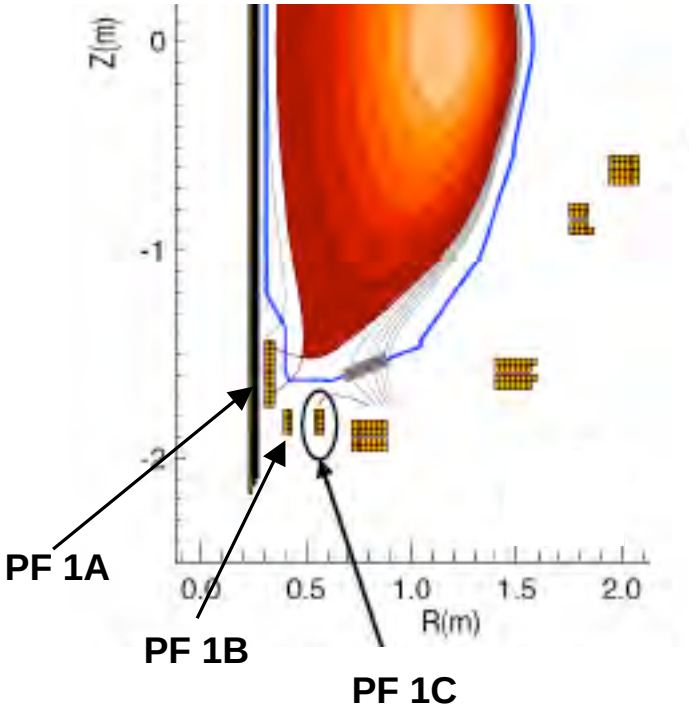


- Determine if the favorable ion and electron confinement scaling, and turbulence variation, observed in NSTX continues to higher magnetic fields and lower collisionality.
- Determine if the MHD stability of neoclassical tearing modes and resistive wall modes is favorable at lower collisionality and higher magnetic field.
- Using the higher magnetic field, which improves the efficiency of plasma heating and current drive both for RF and NBI, push further towards fully non-inductive start-up and current sustainment for long pulses.

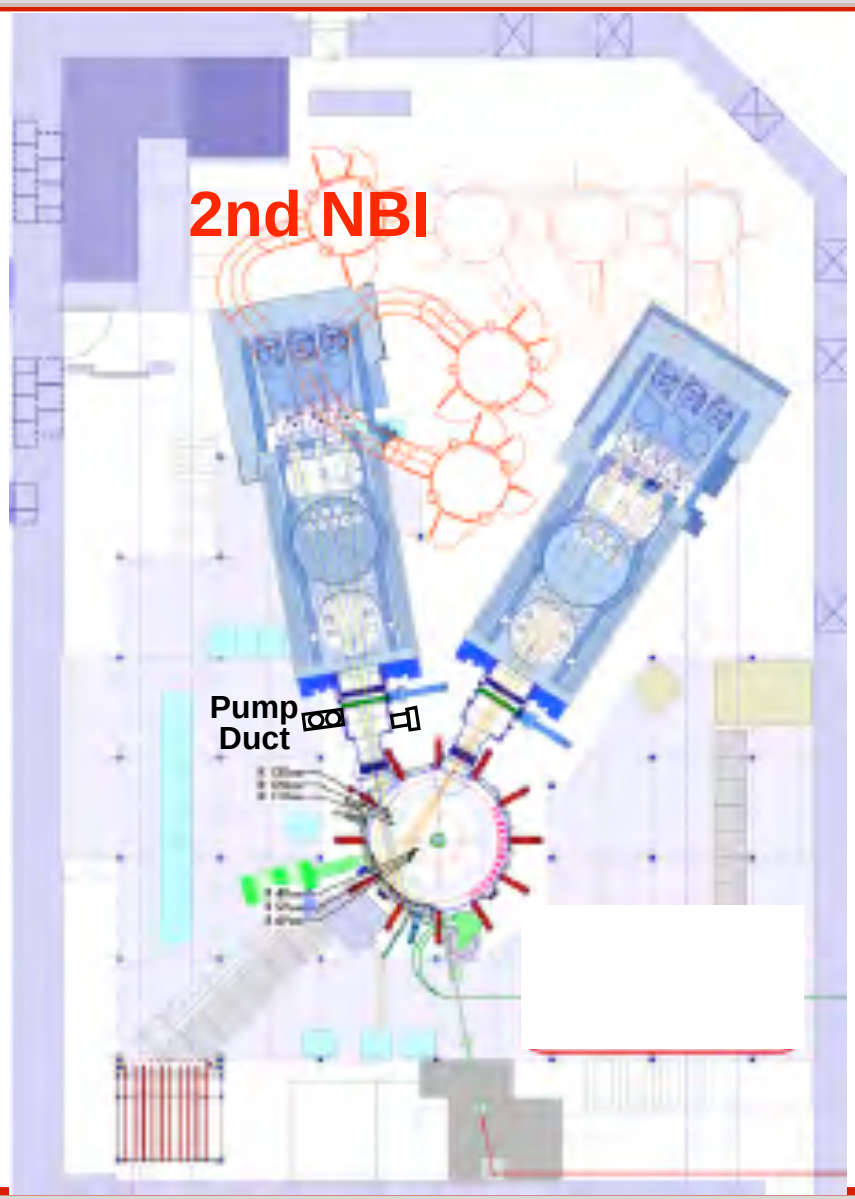
New Center Stack will Utilize Interchangeable Design but will Incorporate Additional Key Improvements



- Improved TF joint design to minimize lift off
- PF 1A, 1B, and 1C at both top and bottom for improved divertor control flexibility (e.g. very high expansion for X-divertor)
- Incorporate additional capabilities (e.g. pellet guide tube for inside launch)



Addition of Second NBI Will Produce Plasma Parameters Relevant for Next-Step STs

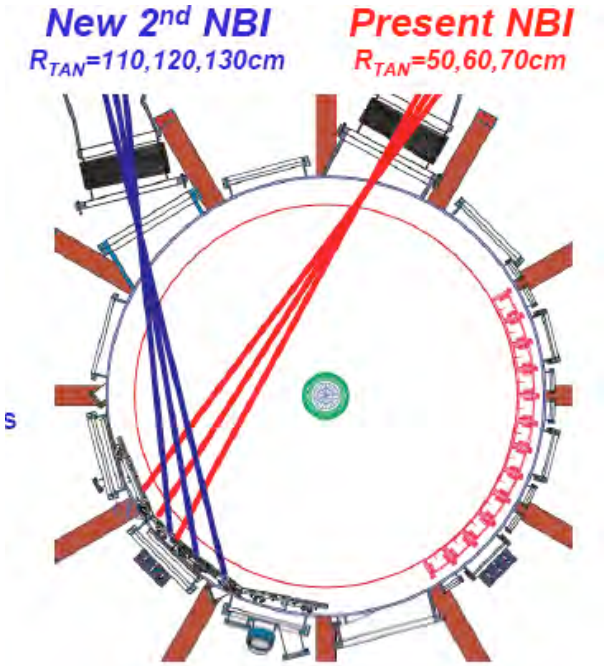


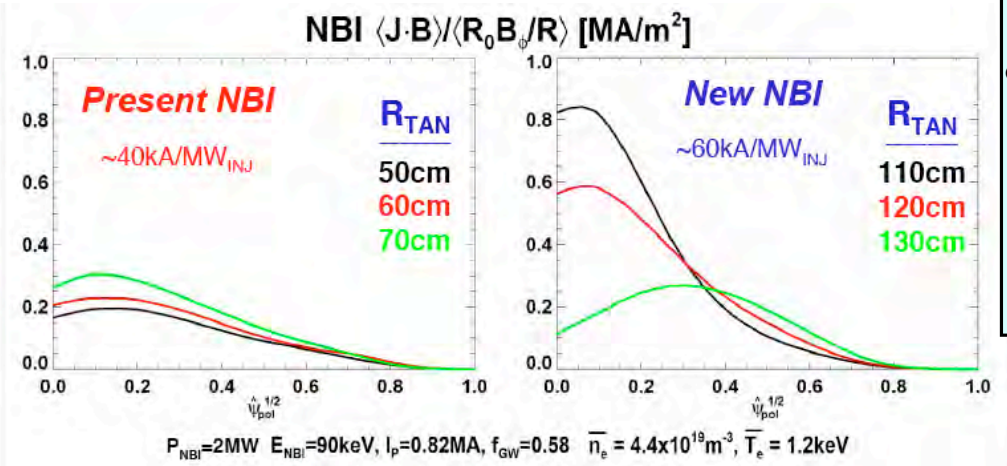
Greatly enhanced capabilities

- Doubles P_{NBI} from 7 to 14 MW (at 95 keV, 2s), 5 to 10 MW (at 80 keV, 5s)
- Higher CD Efficiency and j(r) control

- Extend Confinement scalings to higher power and plasma pressure, and lower collisionality, closer to next-step ST devices.
- Test Magneto-hydrodynamic stability at higher plasma pressure to explore the limits that could be encountered in future devices.
- Challenge the divertor in NSTX beyond the capabilities of any other device in the world (in terms of the scaling parameter, P/R)

More Tangential Injection Enables Profile Control and Fully-Non-Inductive Current-Drive Scenarios





- Test predictions that more tangential injection increases beam current drive efficiency and can sustain a broadened and more MHD stable current profile.
- Increased Alfvén eigenmode activity and fast-ion redistribution/loss could result from more tangential injection and increased fast-ion pressure.
- Test plasma ramp-up using beam injection and demonstrate fully non-inductive sustainment to simulate the scenarios planned for future ST devices.

NSTX Concluded Very Productive FY 08 Run and Preparing for Exciting FY 09 Run

- **NSTX met FY 08 DOE milestones:**
  - Operated for 16.6 run weeks meeting 15 run week milestone.
  - Very productive scientific output - 22 IAEA NSTX related presentations.
  - Lithium has helped HHFW performance in deuterium plasma and with NBI.
  - EBW emission improvement with Lithium in H-mode is shown to be reduced edge collisional absorption.
  - FIDA energetic particle diagnostic produced important data on MHD-induced energetic particle transport.
  - 75 channel P-CHERS has measured important ion-gyroscale poloidal flow .
- **NSTX is implementing new facility capability**
  - HHFW antenna upgrade being installed for early run.
  - LLD delivery by SNL delayed. PPPL manufacturing pursued as backup. Aiming to be available for commissioning in FY 09.
- **NSTX is implementing new advanced diagnostics capability**
  - 20 channel 3 view divertor bolometer being installed for early run
  - Edge sample probe to be available for early run to support FY 09 Joule milestone
  - 32 channel BES system is being installed to complement high-k for FY 09 (latter half).
  - MSE-LIF will measure E_r and B_{total} for the first time for FY 10

The NSTX Team is preparing for Center-stack and NBI Upgrade CD-0 DOE Approval