NSTX

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NSTX Upgrade Plan and Status

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Nova Photonics
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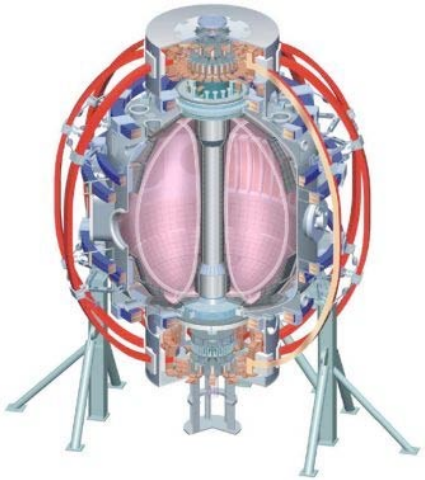
U Maryland
U Rochester
U Washington
U Wisconsin

Masayuki Ono
NSTX Project Director

For the NSTX Research Team

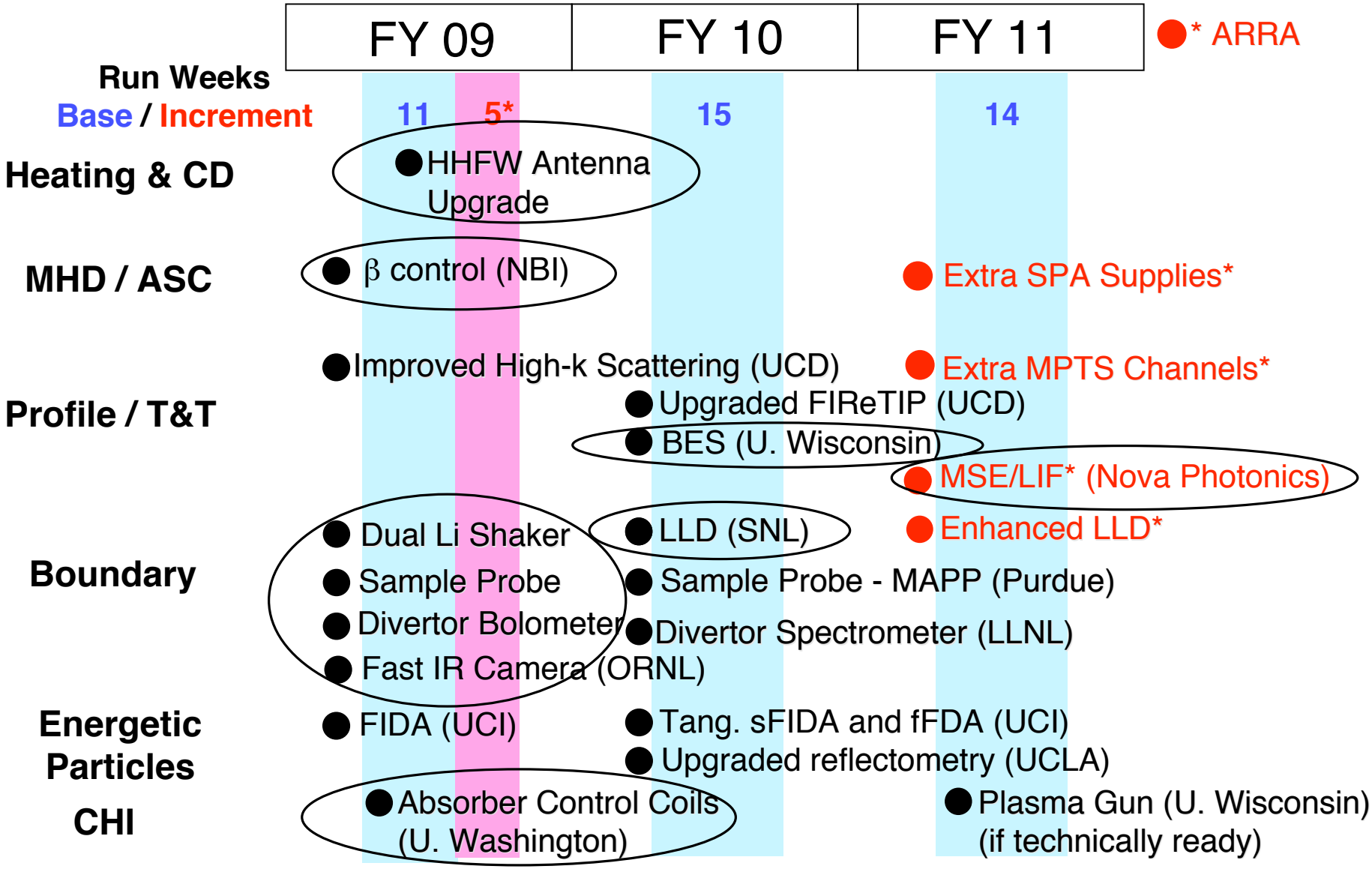
APS-DPP Meeting 2009, Atlanta, GA
November 2-6, 2009



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

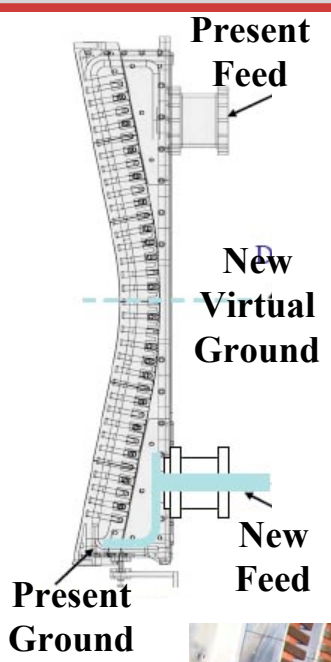
NSTX Near Term Upgrade Plan

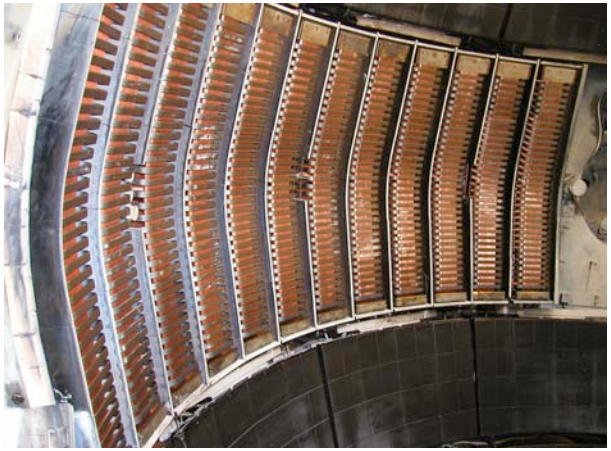
ARRA Funding Significantly Enhances Research Capability

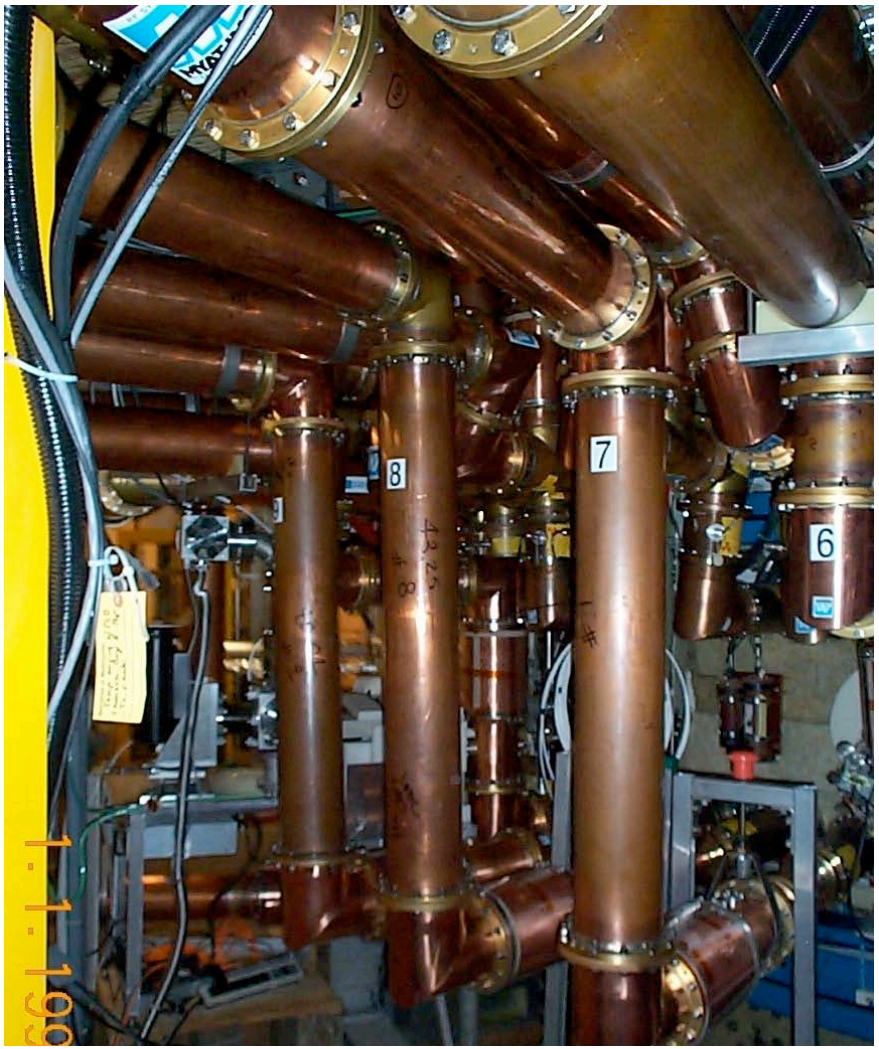


HHFW System Upgrades Completed

Successful Loop Installation During NSTX Operations

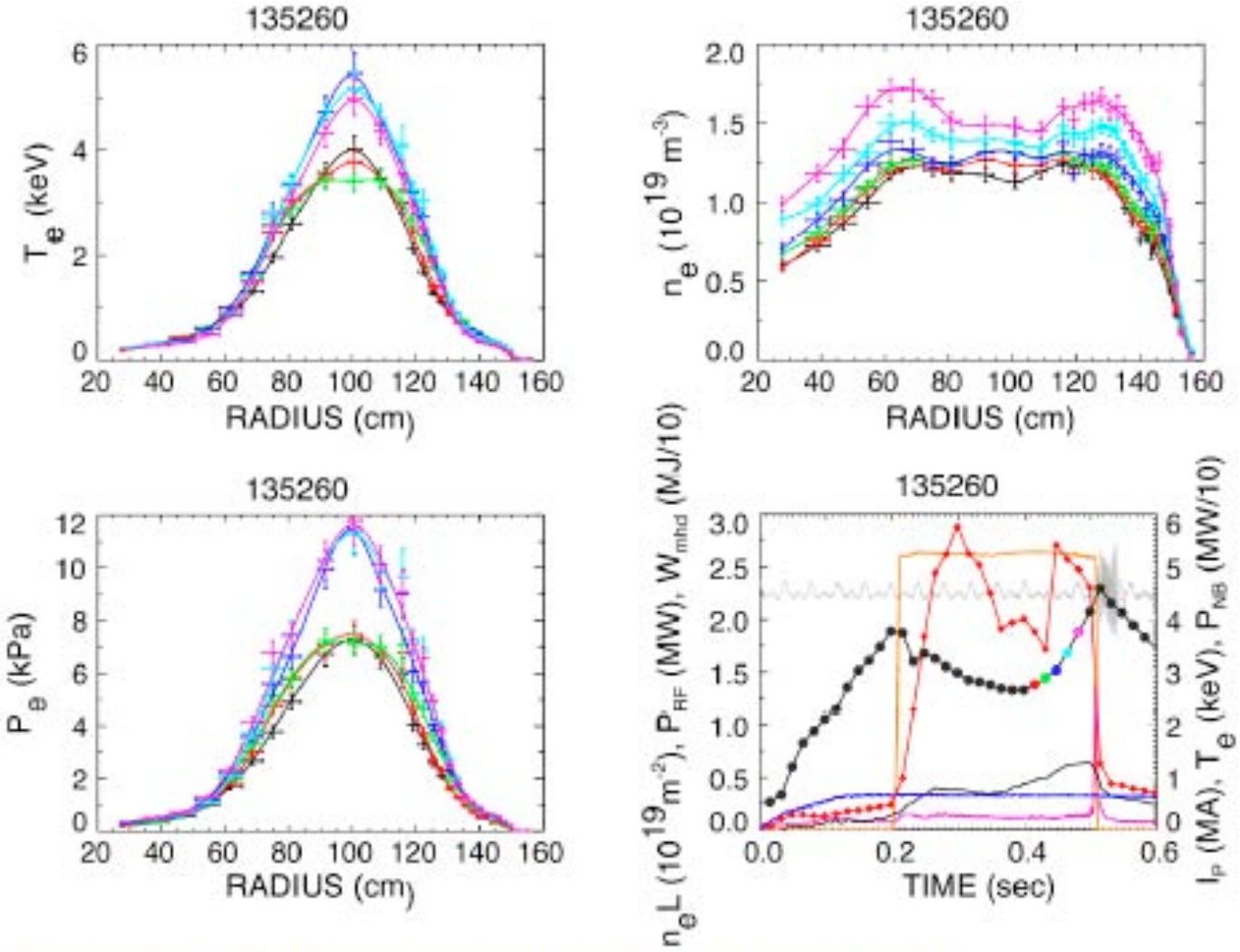






- 2009 Double-feed upgrade shifts ground from end to strap center.
- Double power per strap for the same plasma load. *J. Hosea, R. Ellis (PPPL) et al.,*

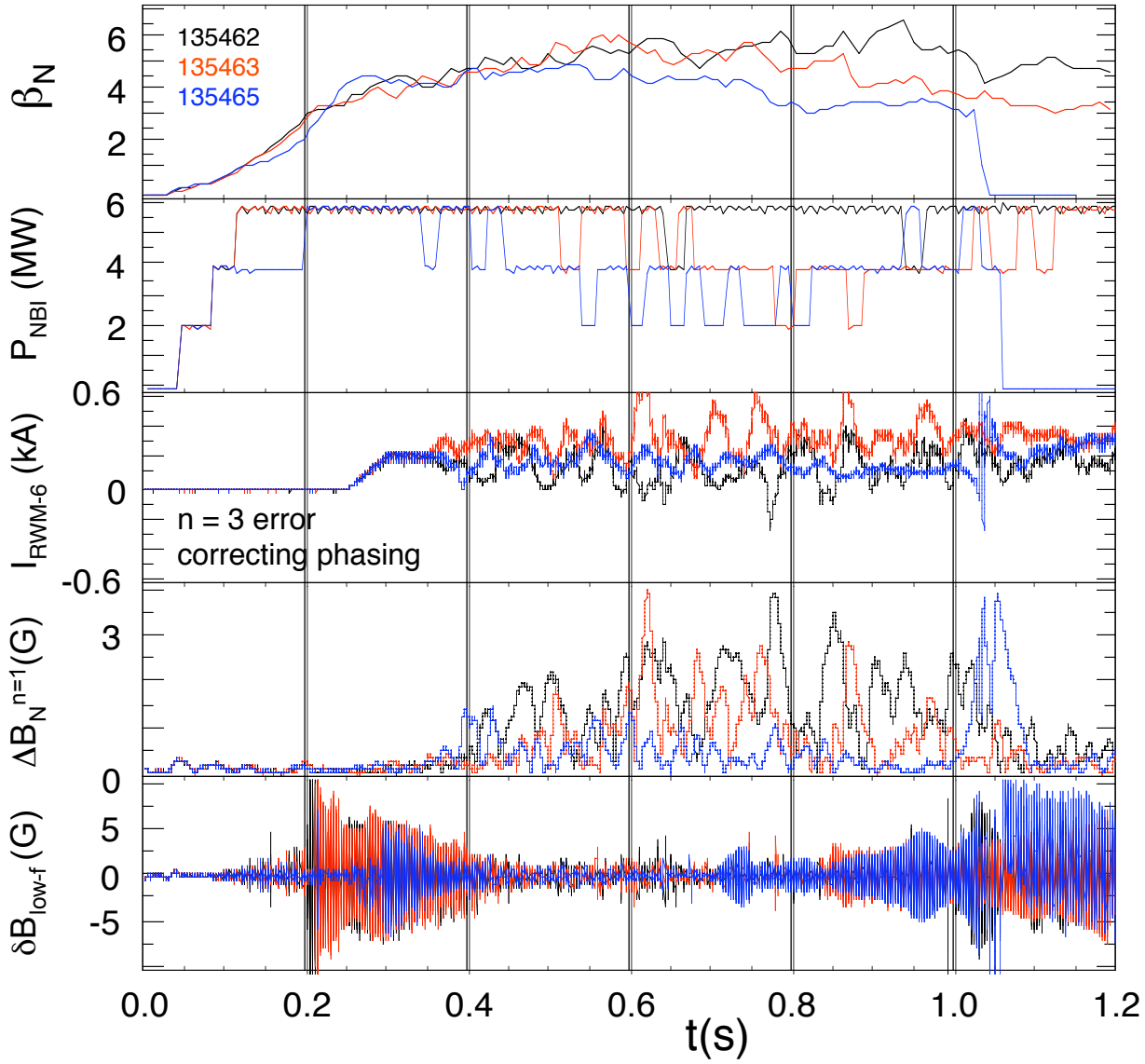
Upgraded HHWF System Yielded High Te (over 6 keV) for P_{HHFW} = 2.7 MW in He L-Mode Plasmas



- T_e ~ 5.8 keV early and ~ 5.5 keV late in RF pulse
- Transition to H-mode at end of RF pulse

P. Ryan (ORNL) et al.,

Successful NBI power limitation via β_N feedback in 2009 run

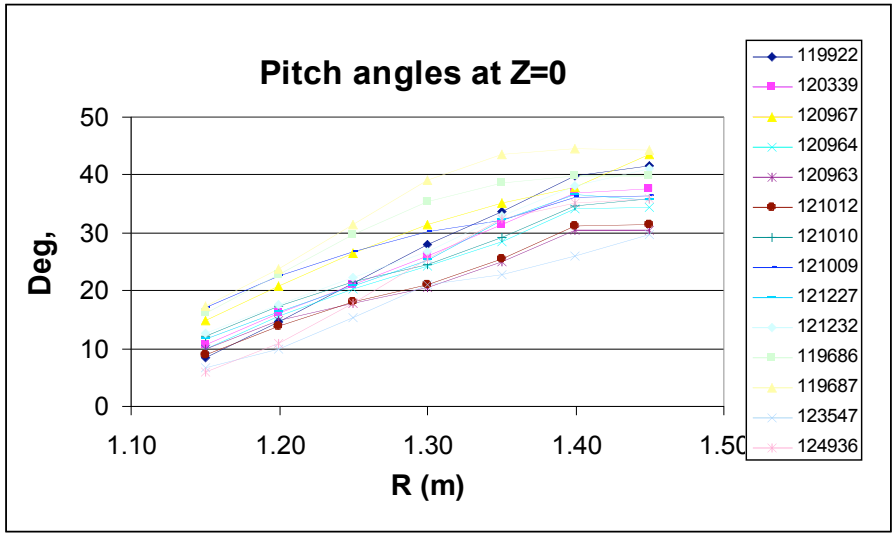


- Cases with n = 3 correcting field (highest ω_ϕ)
  - Nominal targets β_N = 4,5,6
  - NBI blocking shows FB
    - NBI power turned back on when n = 1 rotating mode appears
  - Higher activity in n = 1 locked mode detector at highest β_N

S. Sabbagh (Columbia U) et al.,

Beam Emission Spectroscopy Diagnostic

With High-k to Provide Comprehensive Turbulence Diagnostic Set

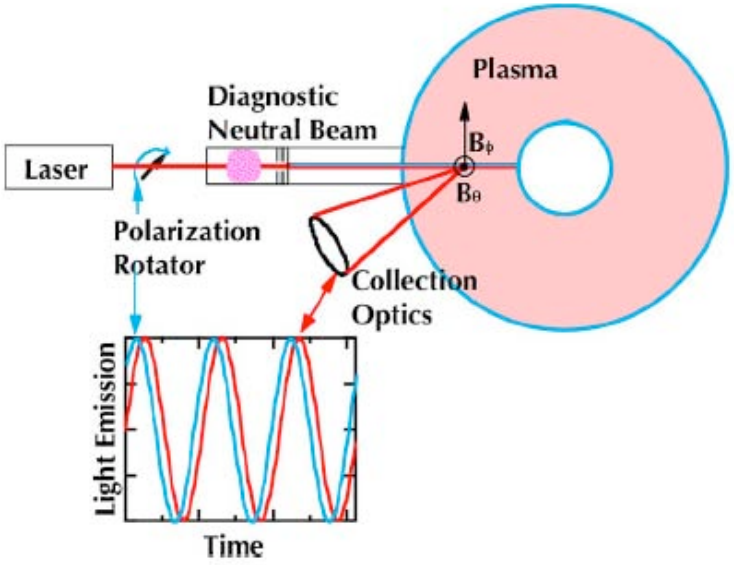


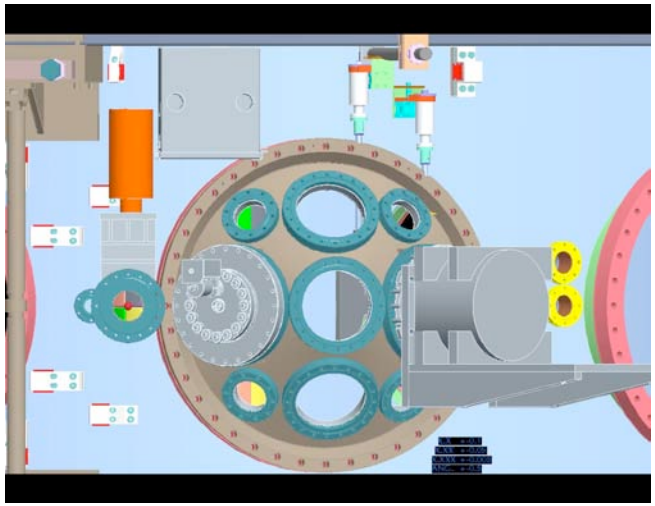
- Two re-entrant sets of optics required to match field line pitch over most of outer plasma radius (r/a=0.3-1.0)
- New ports on vacuum vessel installed in 2008 outage
- Optics, fibers, and detectors are being installed during current outage
- Low-noise, cooled PIN photodiode detectors being fabricated by University of Wisconsin (32 channels)
- Plan to take initial data in spring 2010

G. McKee, R. Fonck, D. Smith (U. Wisconsin), B. Stratton, G. Labik (PPPL) et al.,

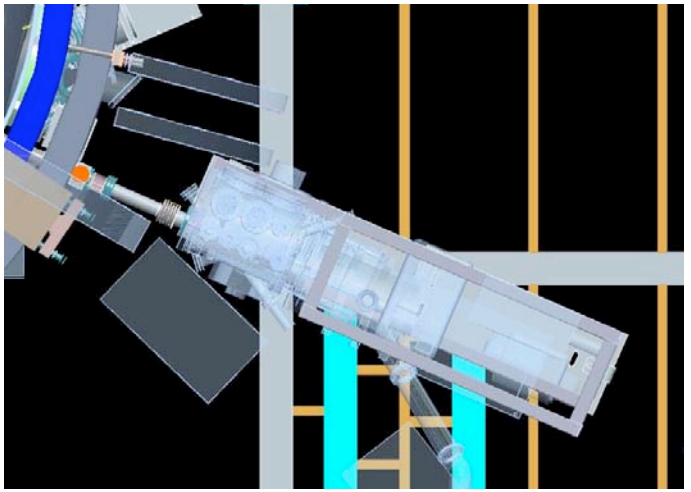
Motional Stark Emission-Laser-Induced Fluorescence

Measures j (r) and B(r) without MSE-CIF and E_r(r) with MSE-CIF





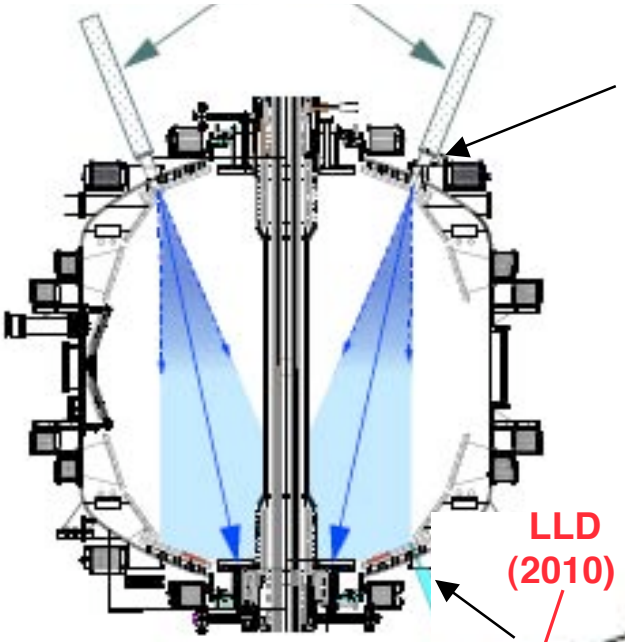
- **A collaboration with Nova Photonics under DOE Innovative Diag. Initiative**
  - **Provides DNB/laser, optics, and detectors**
  - **DNB packaged for installation on NSTX**
  - **Diode laser being tested**
- **PPPL provides diagnostic interface and infrastructure needed for DNB/laser**
- **Design nearly complete**
- **Readied for operation in FY 2011 run**



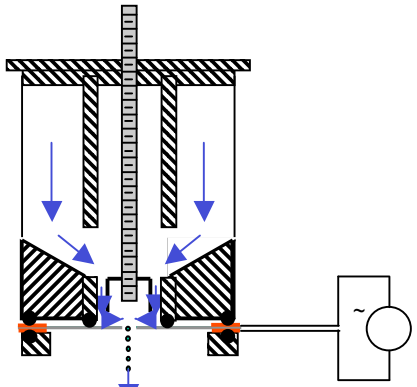
E. Foley, F. Levinton (N. Photonics), B. Stratton (PPPL) et al.,

New Capability for Boundary Physics
Dual LITER, Dual Lithium Dropper, Sample Probe, Fast IR Camera

Dual Liquid Lithium Evaporator
For Li wall coatings
Now routinely used



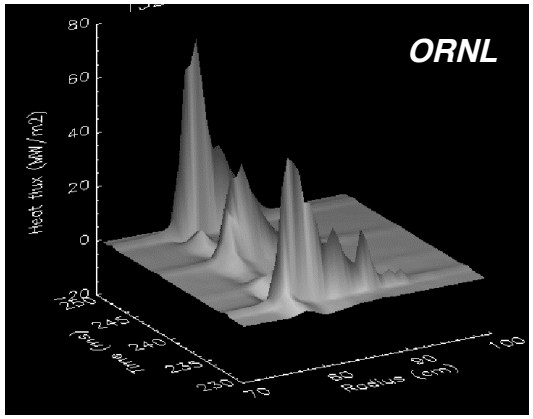
H. Kugel, R. Kaita (PPPL) et al.,



Dual Lithium Powder Dropper

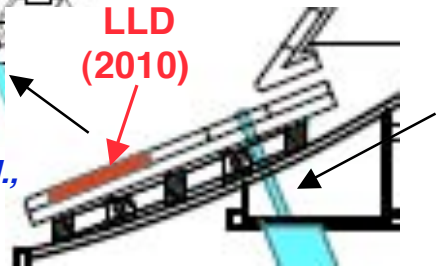
D. Mansfied (PPPL) et al.,

Fast IR Camera Operational
ELM-resolved heat flux



J-W Ahn et al.,

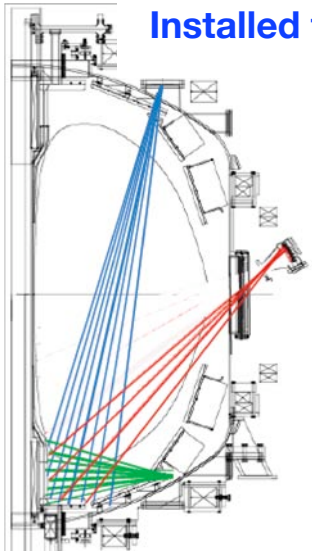
LLD (2010)



SAMPLE PROBE for retention measurements
C. Skinner (PPPL) et al.,

and surface analysis
Purdue U

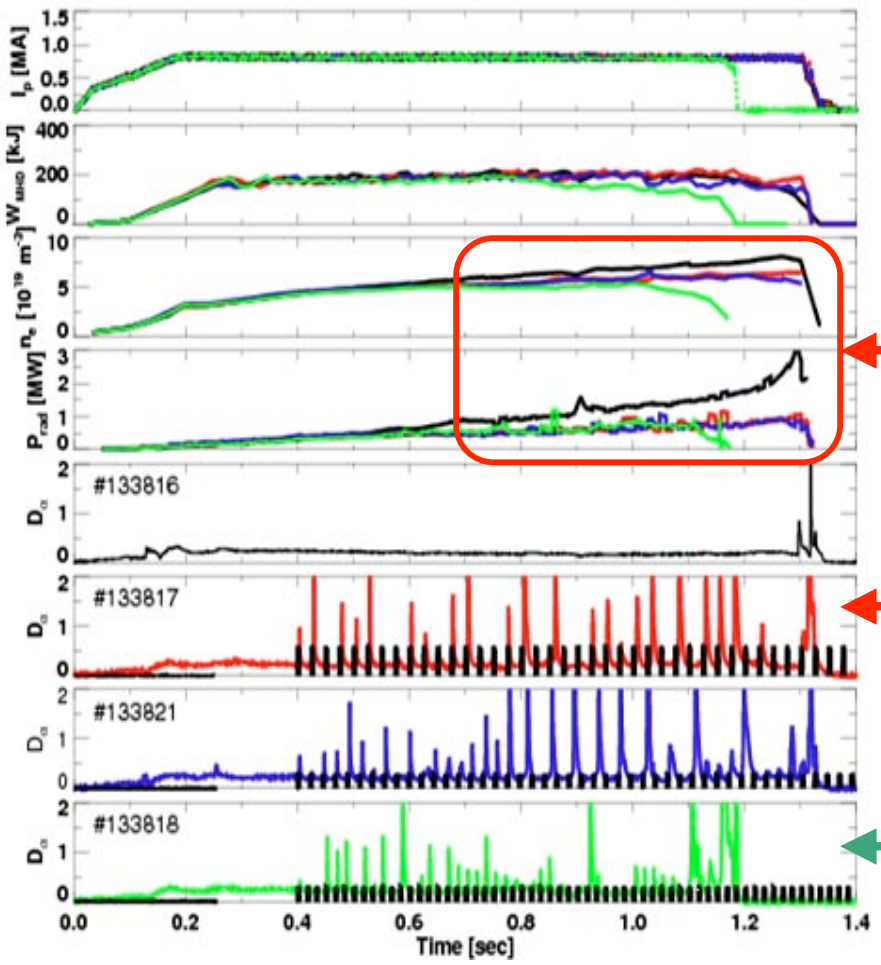
Three-view Divertor Bolometer
Installed for divertor radiation



Repaired electronics received at PPPL and checked out on the bench; will be installed this week and ready to operate next week

S. Paul (PPPL) et al.,

ELM triggering using n=3 perturbations is being optimized to control density and radiation, maintain high confinement

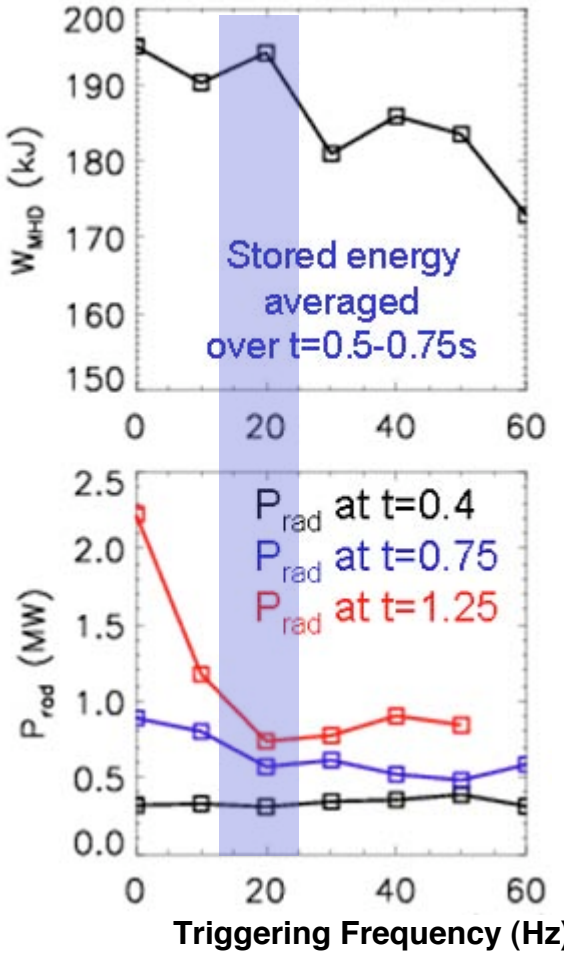


n_e & radiation rise arrested

But ELM size can be large ($\Delta W/W_{TOT}$= 10-15%)

Higher $f_{trigger}$ reduces size ($\Delta W/W_{TOT}$ ~ 5%)

Favorable n=3 amplitude and triggering frequency found

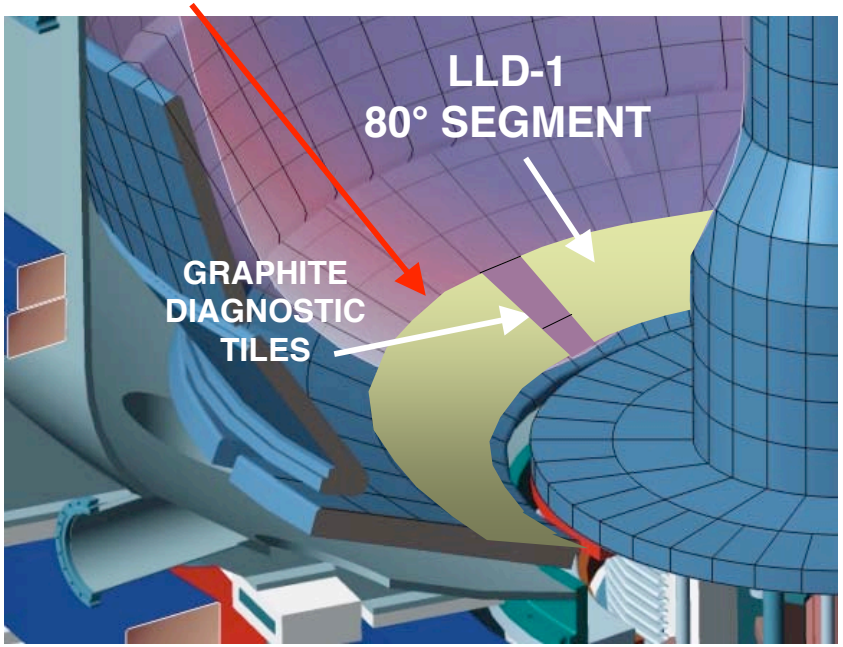


J. Canik, R. Maingi (ORNL) et al.,

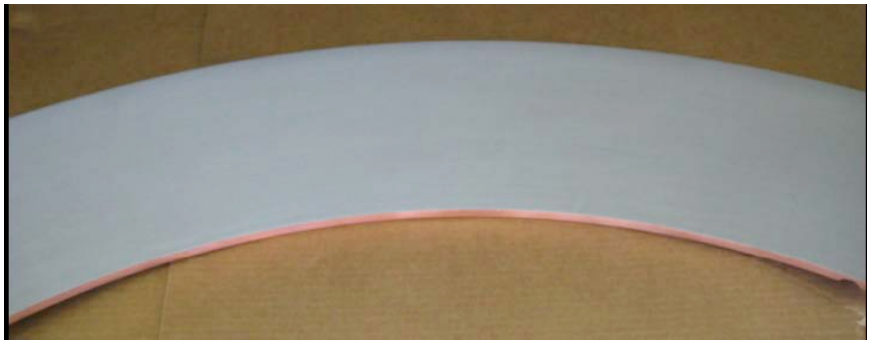
Liquid Lithium Divertor to Test Pumping Effectiveness

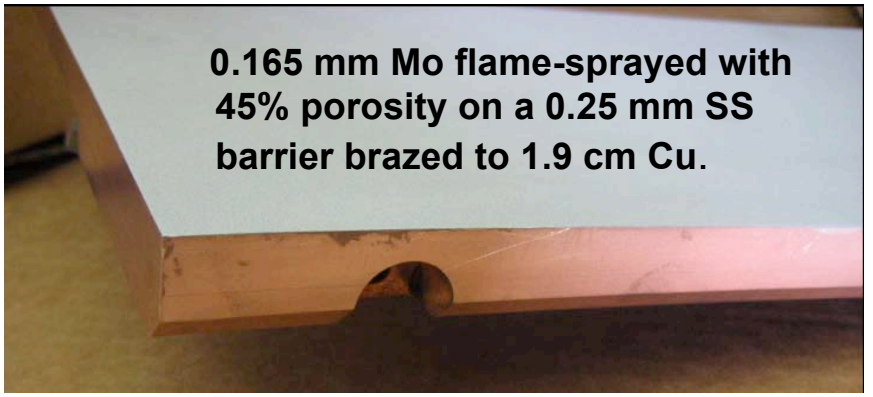
LLD Plates To Operate at Lithium Melting Temperature (200 - 400 °C)

Liquid Lithium Divertor (LLD)



H. Kugel, R. Kaita (PPPL) et al.,





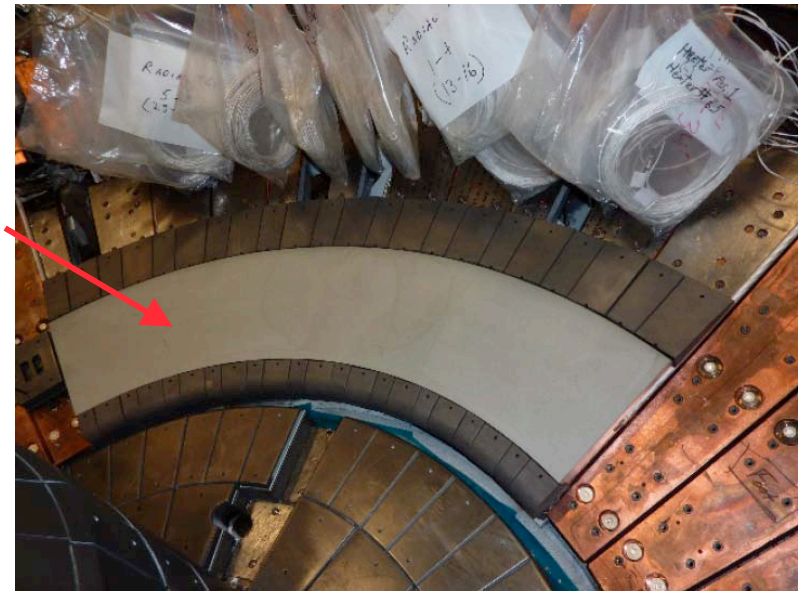
Moly-Coated LLD Plate

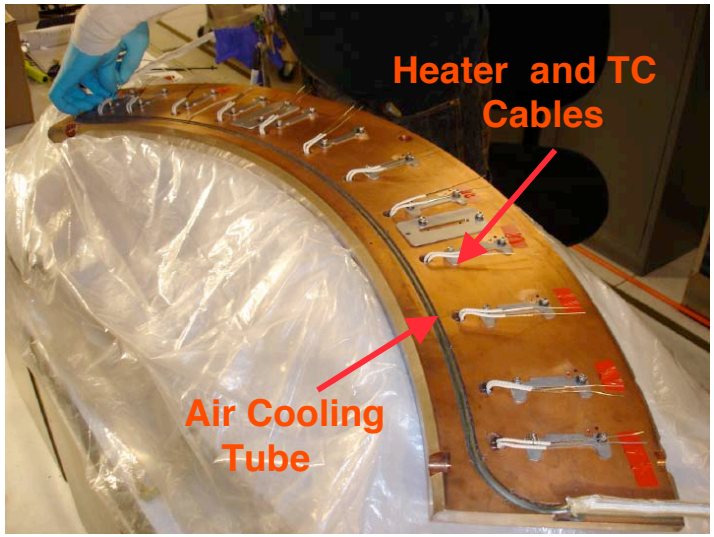
R. Nygren (Sandia NL) et al.,

- **LLD installation started for FY 2010 run (completion next few weeks)**
- **Enhanced LLD to achieve density control - improved diagnostics and improved fill system - to be installed for FY 2011 run**

LLD Installation Proceeding on Schedule

1st LLD Plate Installed in NSTX





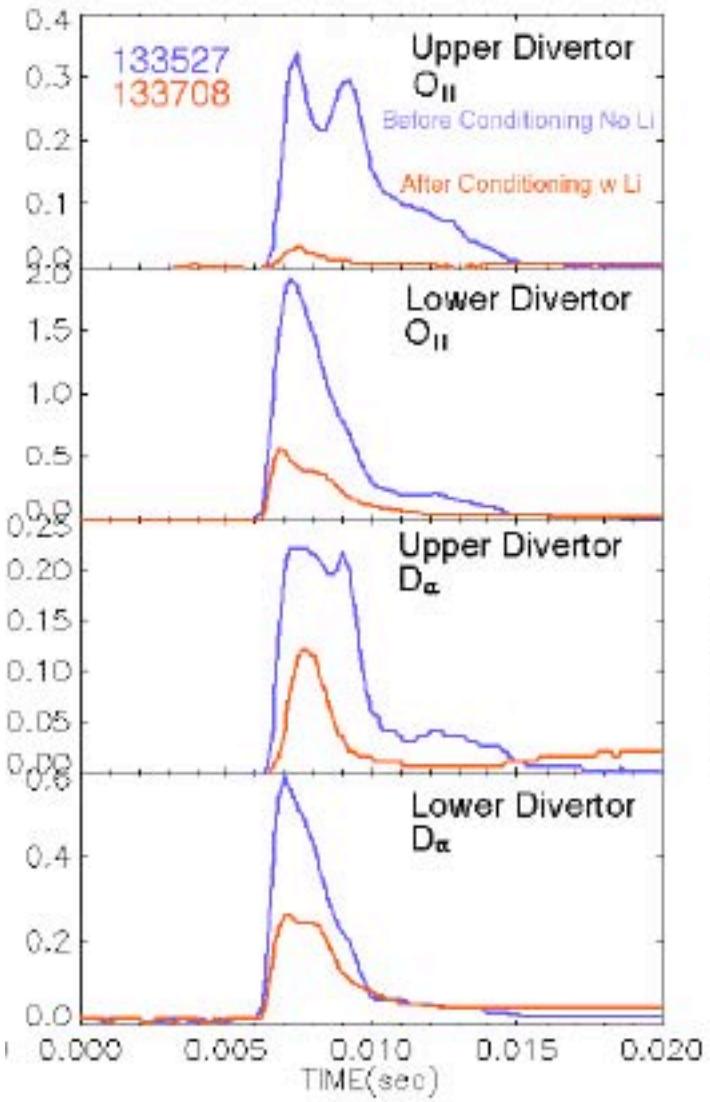
All Heater and TC elements installed in all 4 LLD Plates

LLD Control Being Tested Off-Line

M. Viola, H. Schneider et al.,

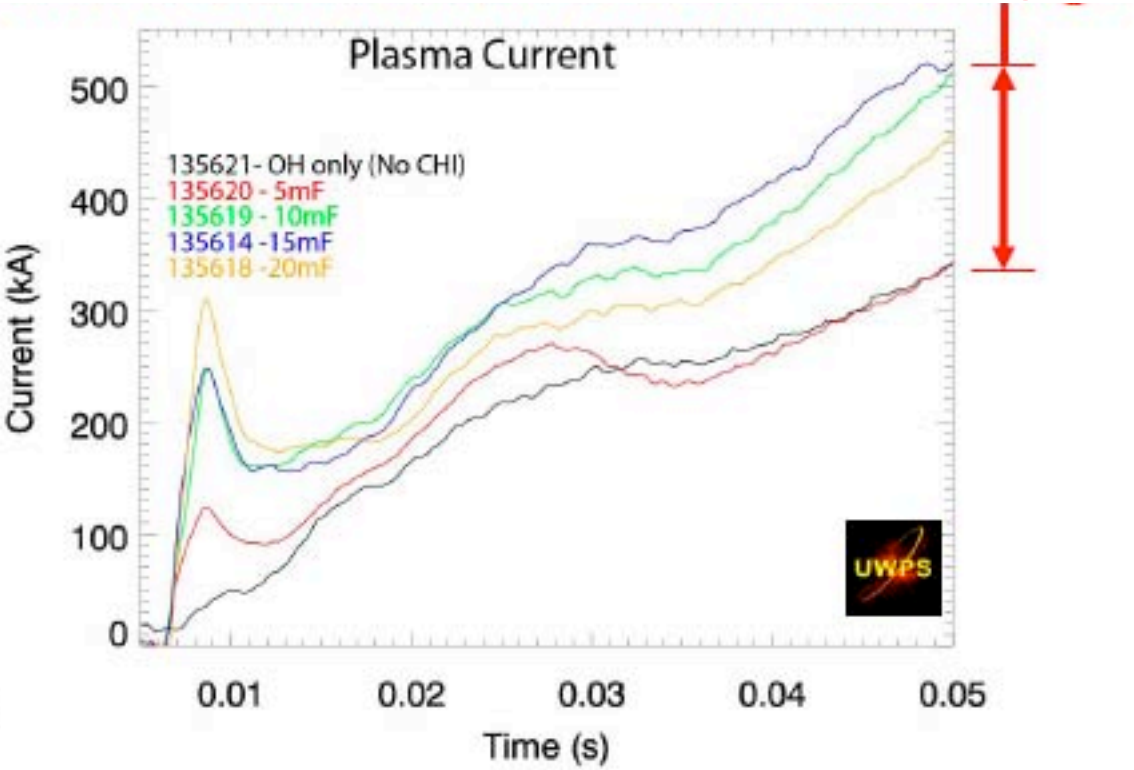
CHI Successfully Saved Ohmic V-S of ~ 200 kA!

Enabled by Absorber Coil Energization and Impurity Control



- Upper divertor conditioned with NBI-heated USN plasmas
- Lower divertor conditioned with sustained CHI plasma
- LI evaporation used to reduce oxygen, increase D pumping
- CHI voltage duration (absorber arcs) reduced

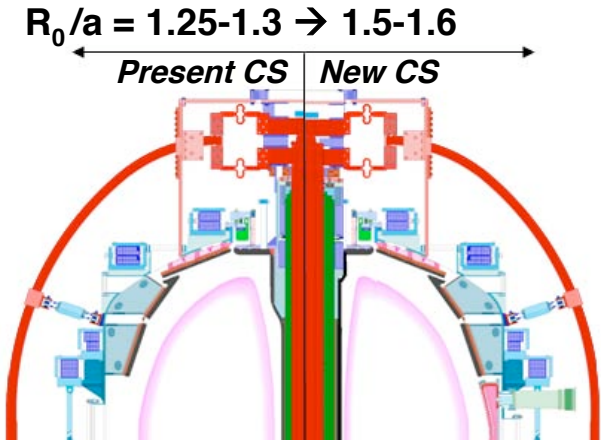
CHI coupled to induction + NBI-heated H-mode
with ~ 200 KA sustained current savings

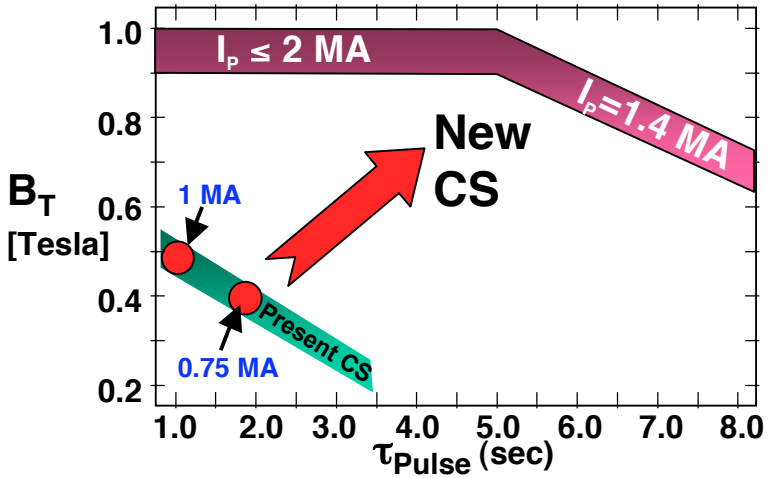


R. Raman (U. Washington) et al.,

Major Facility Upgrades Planned to Bridge the Device and Performance Gap Toward Next-Step STs

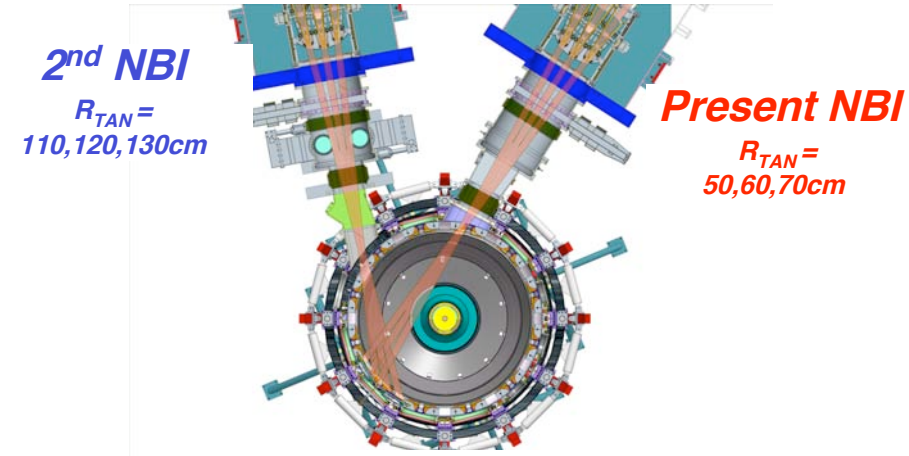
New center stack for 1T, 2MA, 5s to access reduced ν^*, 100% non-inductive ST plasmas



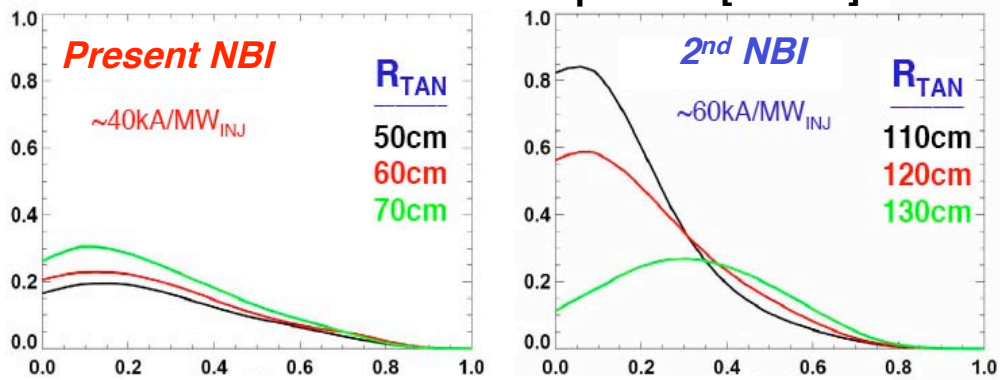


Magnet operation at ~1T (vs. 0.55T) → within a factor of 2 of next-step STs

2nd NBI with larger $R_{tangency}$ for sustained and controllable 100% NICD + high β at low ν^*



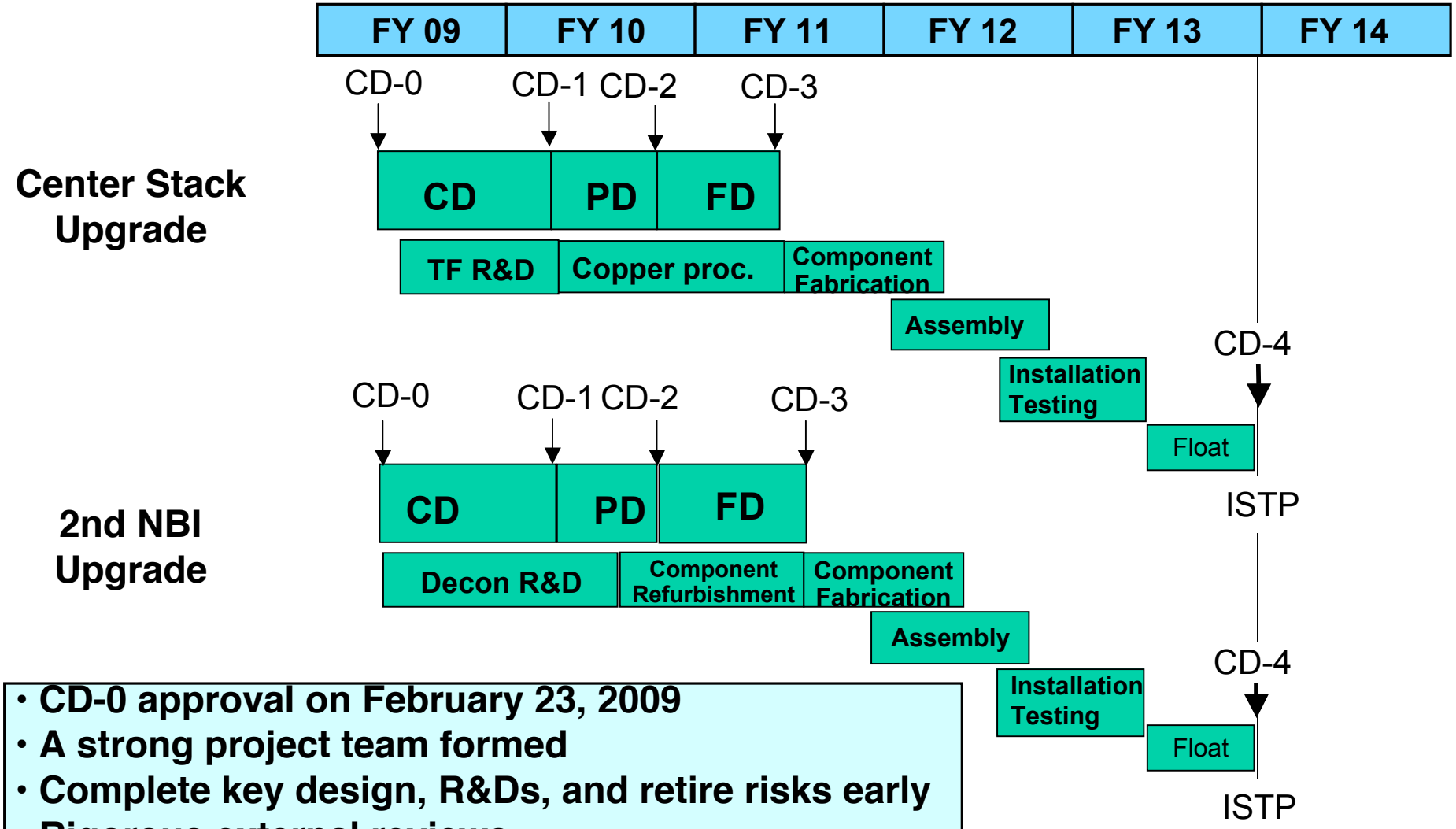
NBI current drive profiles [MA/m²]



Normalized minor radius

Up to 2 times higher NBI current drive efficiency, and current profile control

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

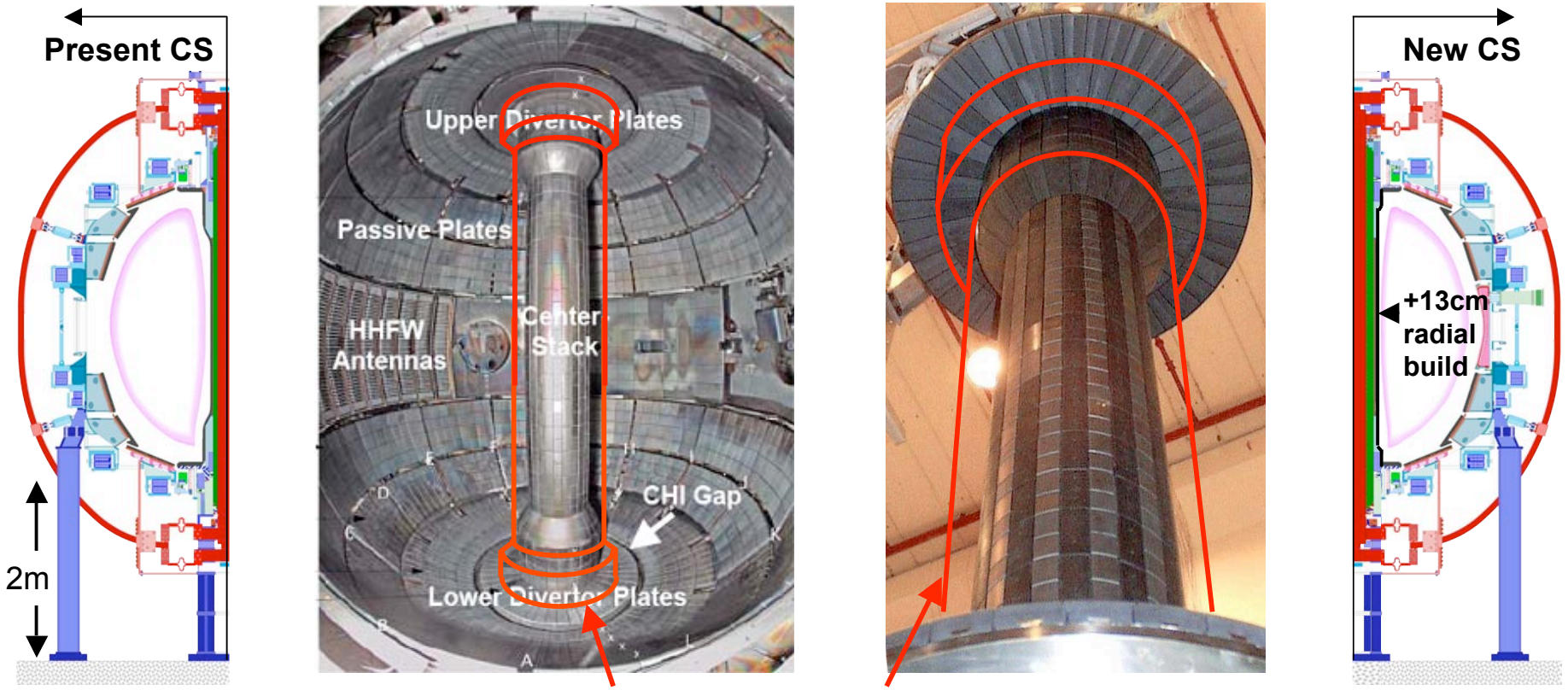


- CD-0 approval on February 23, 2009
- A strong project team formed
- Complete key design, R&Ds, and retire risks early
- Rigorous external reviews
- CDR on Oct. 28 - 29, 2009.

E. Perry et al.,

Modular design of NSTX enables removal of present CS and replacement with a new higher-performance CS

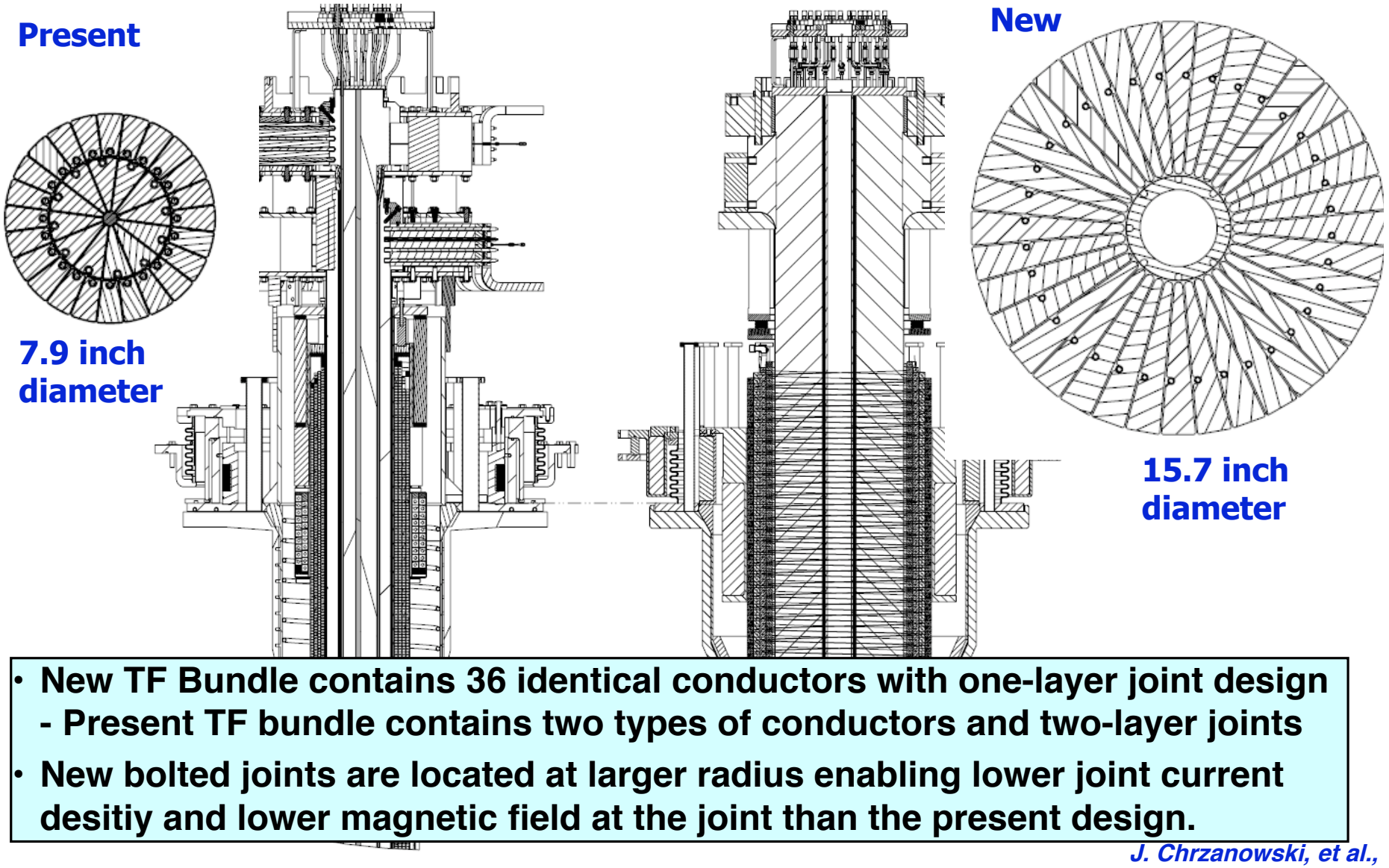
- Present CS has been removed and re-installed several times for maintenance
- New CS would have larger radius for increased conductor area and toroidal field current, while maintaining low aspect ratio A ≥ 1.5
- Construction tolerance requirements are similar to present NSTX CS



Approximate outline of new Center-Stack

I.. Dudek, C. Neumeyer, P. Titus, J. Chrzanowski, P. Heitzenroader et al.,

Toroidal Field Coil Cross Section Increased by ~ 4 to Support 1T, 5 sec Pulses (Present 0.55 T, 1 sec)

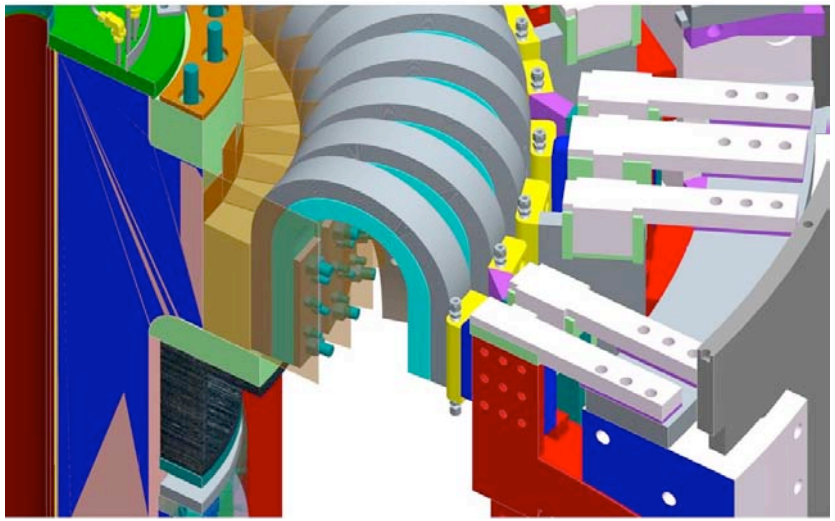


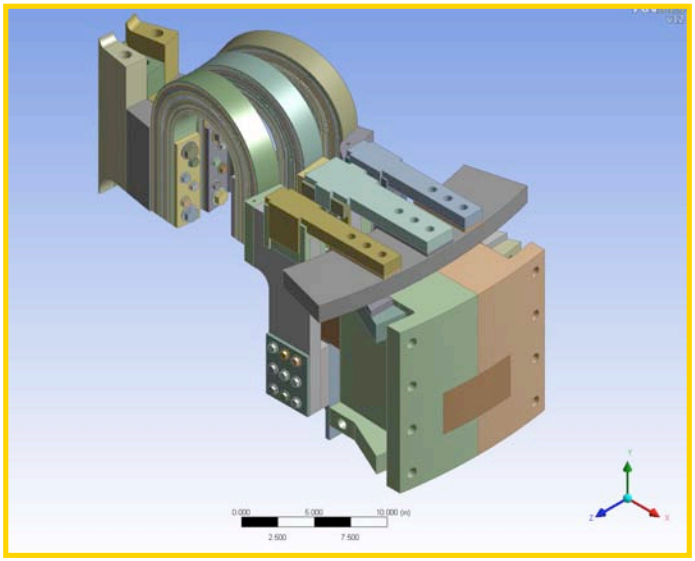
- New TF Bundle contains 36 identical conductors with one-layer joint design - Present TF bundle contains two types of conductors and two-layer joints
- New bolted joints are located at larger radius enabling lower joint current desitiy and lower magnetic field at the joint than the present design.

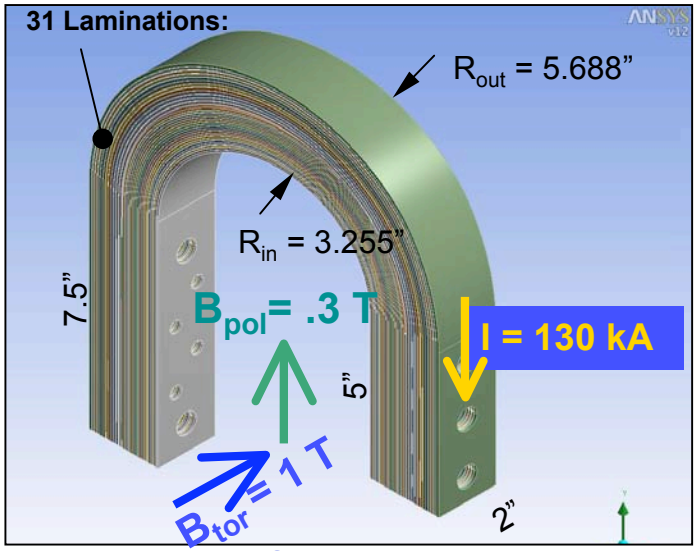
J. Chrzanowski, et al.,

Single Segment 3-Strap Assembly with Supports

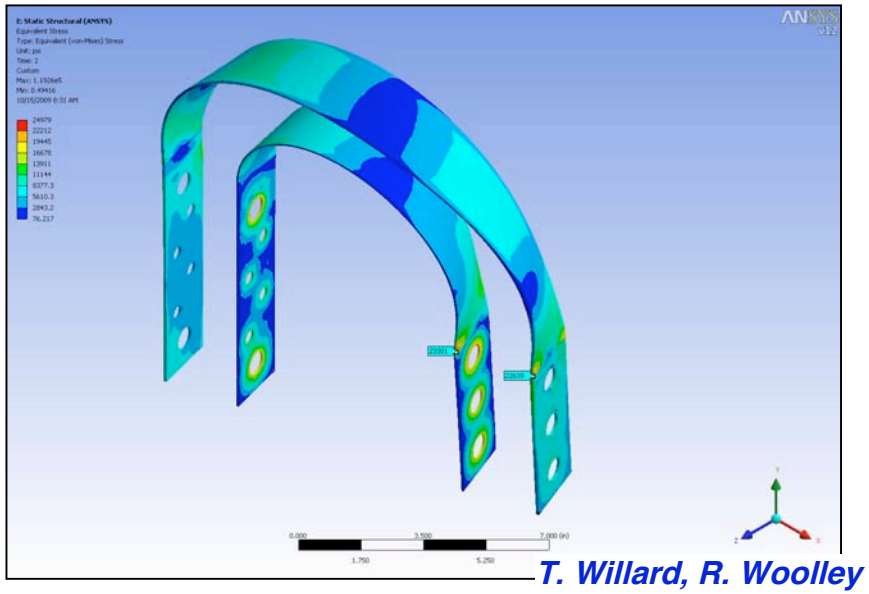
New Joint Design Eliminates Joint Lift-Off and Enables Joint Simplification





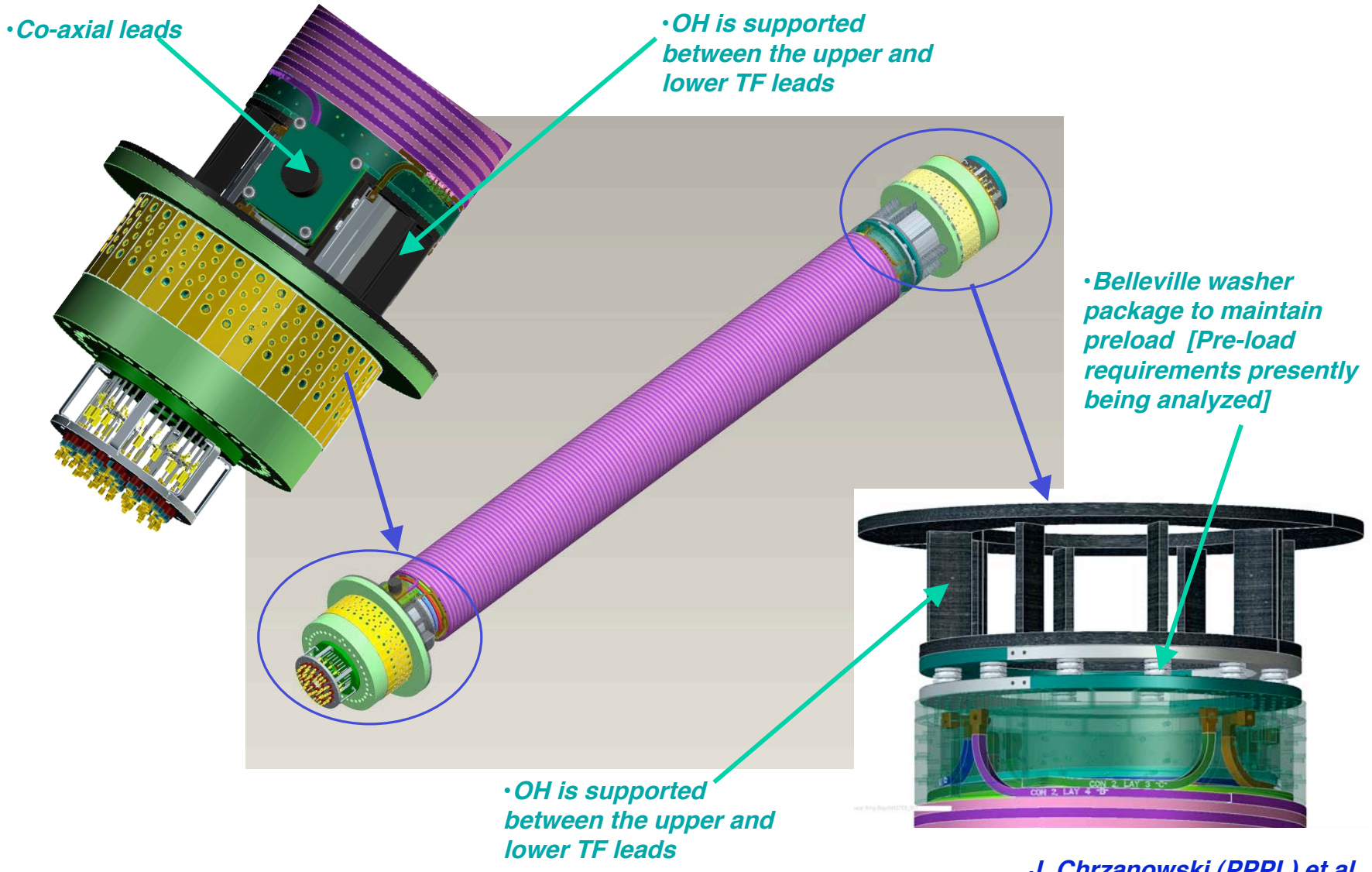


Laminated Strap Assembly with Applied Fields and Current



T. Willard, R. Woolley et al., ,

OH Flux Increased ~ x 3-4 to Support 2 MA, 5 sec Pulses (Present 1 MA ~ 1 sec, ~ 0.6 V-S)

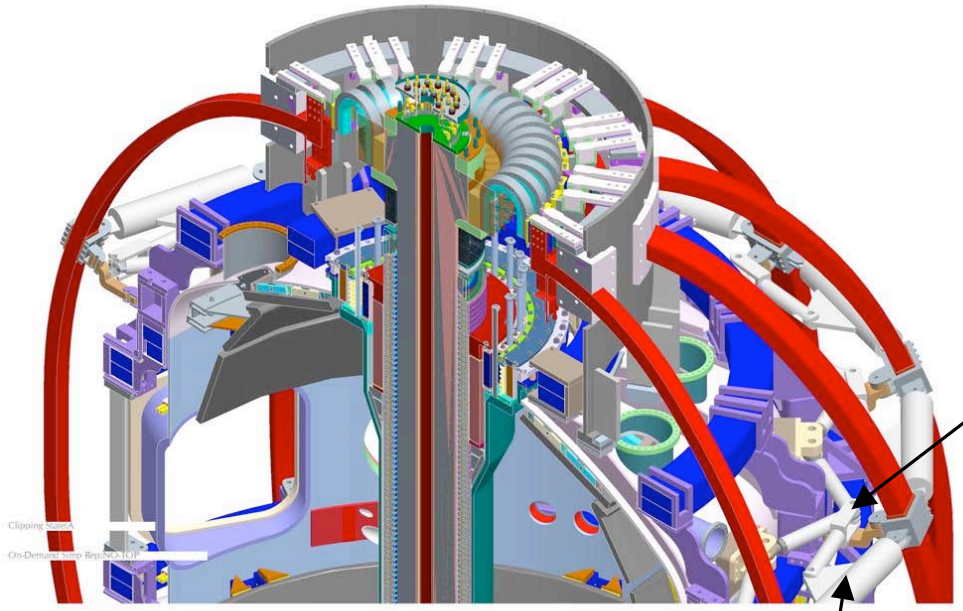


J. Chrzanowski (PPPL) et al.,

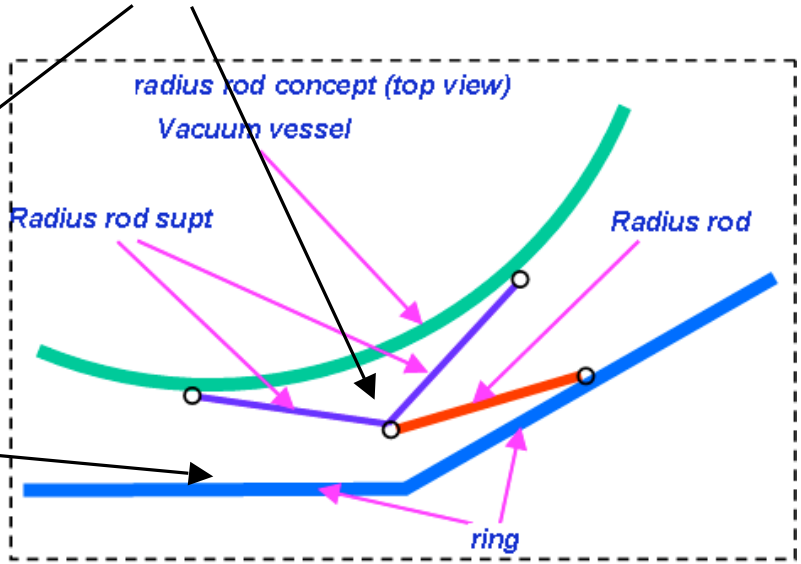
Extensive Analyses Performed Using Global and Local Analysis Codes

Static, Dynamic, Fatigue Analyses for Electro-Magnetic, Thermal, Mechanical Loads

Outer TF, Vessel, Umbrella Structure, Reinforcements



- **Tangential Radius Rod Concept Supports Out-of-Plane Loads; Allows Radial Growth During Bake-Out**
- **Utilizes Space Used by the Present TF Support Truss**

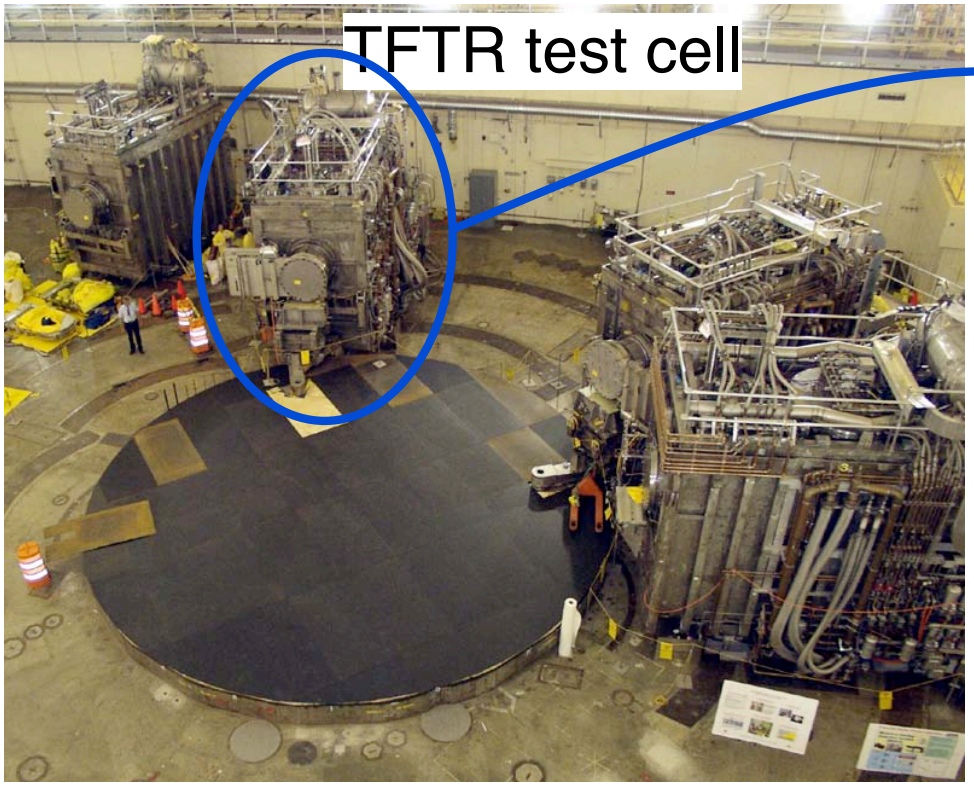


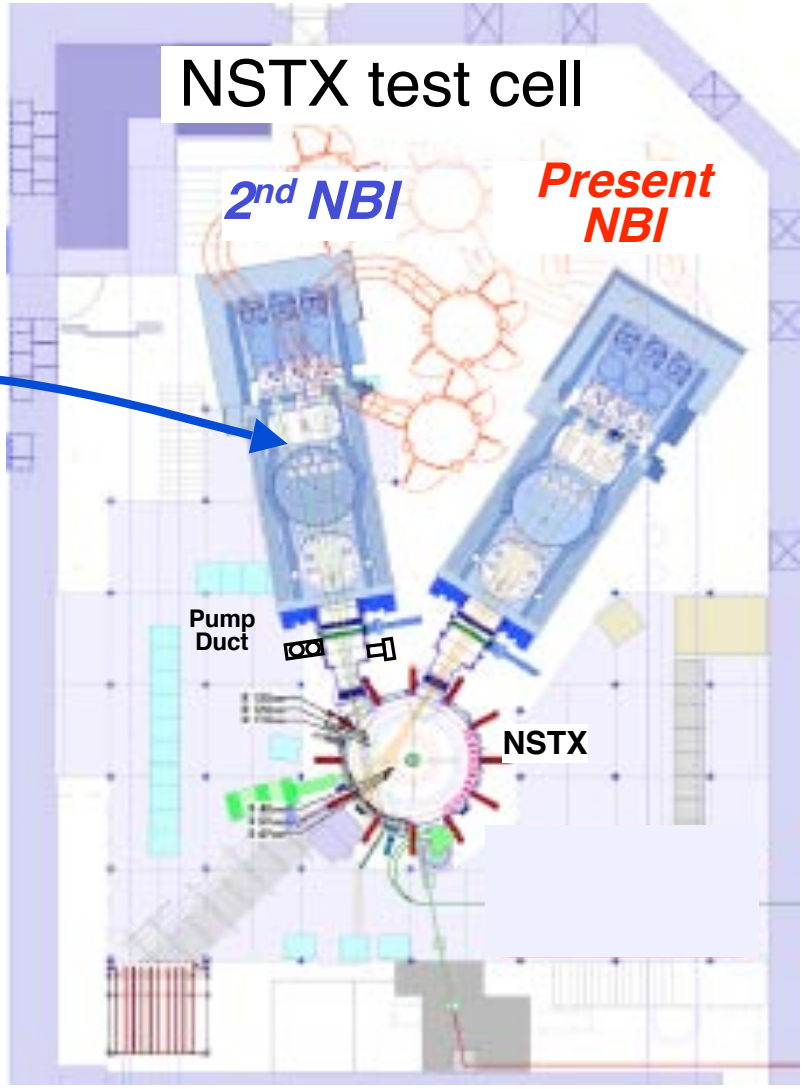
- **Toroidal-Ring Supports In-Plane Loads**

P. Titus, H.Zhang, S.Avasarala, A.Zolfaghari, A.Brooks, L.Myatt

An NBI heating system available from TFTR could be moved to the NSTX test cell and installed next to the present NBI

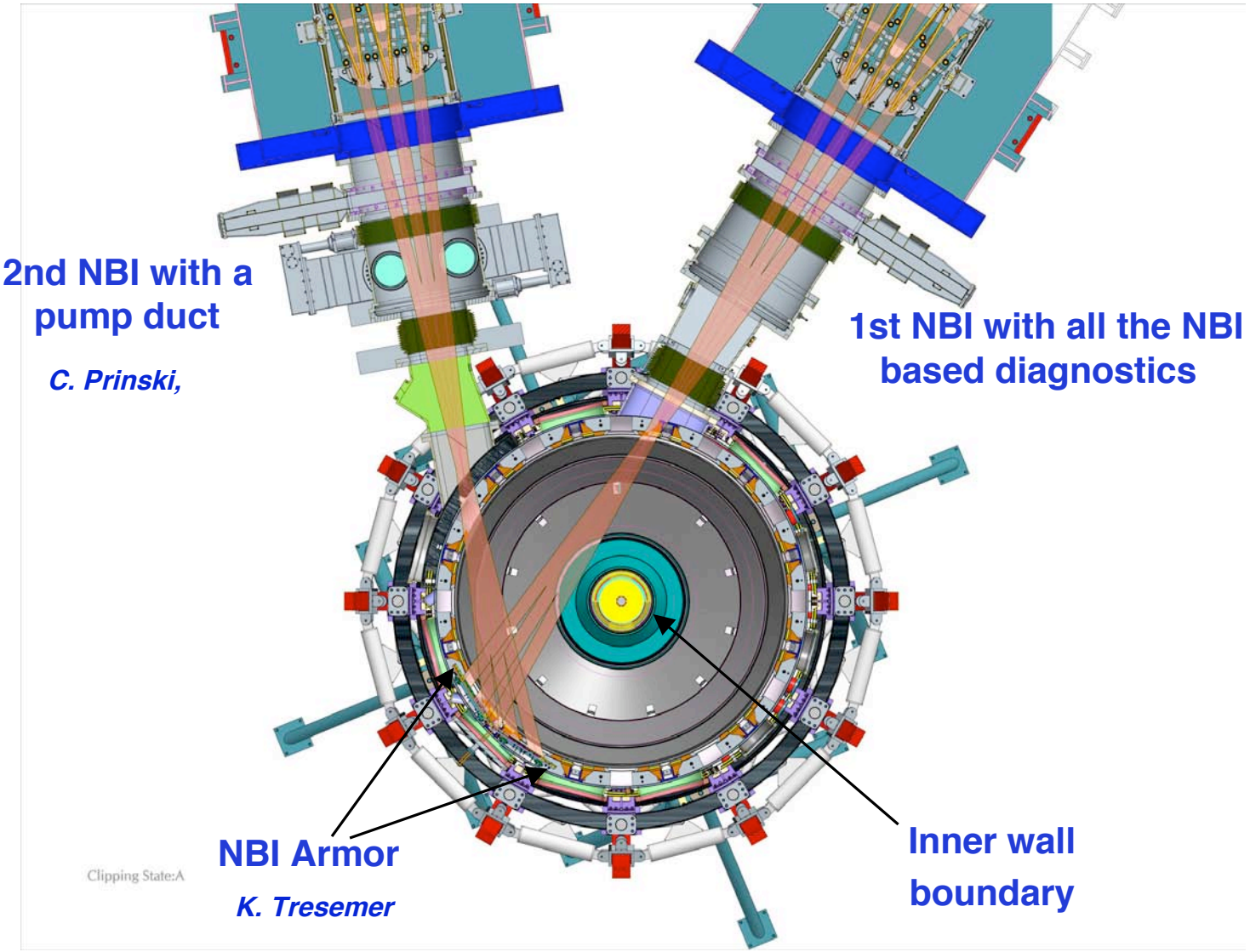
- PPPL has extensive experience operating, maintaining, refurbishing NBI
- NBI is well understood and has provided reliable heating to high β values in NSTX





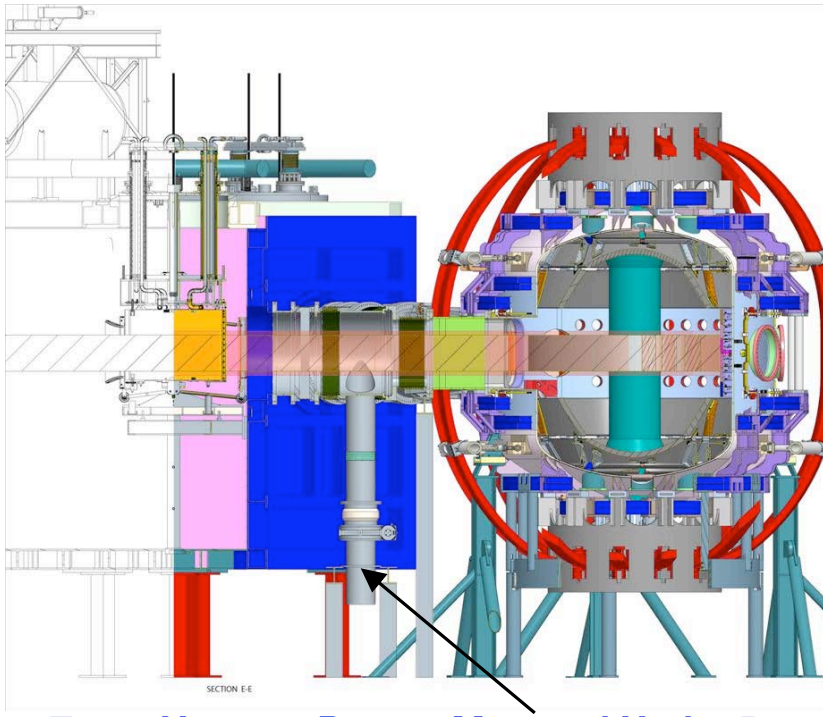
T. Stevenson, et al.,

Top View of Second Neutral Beam

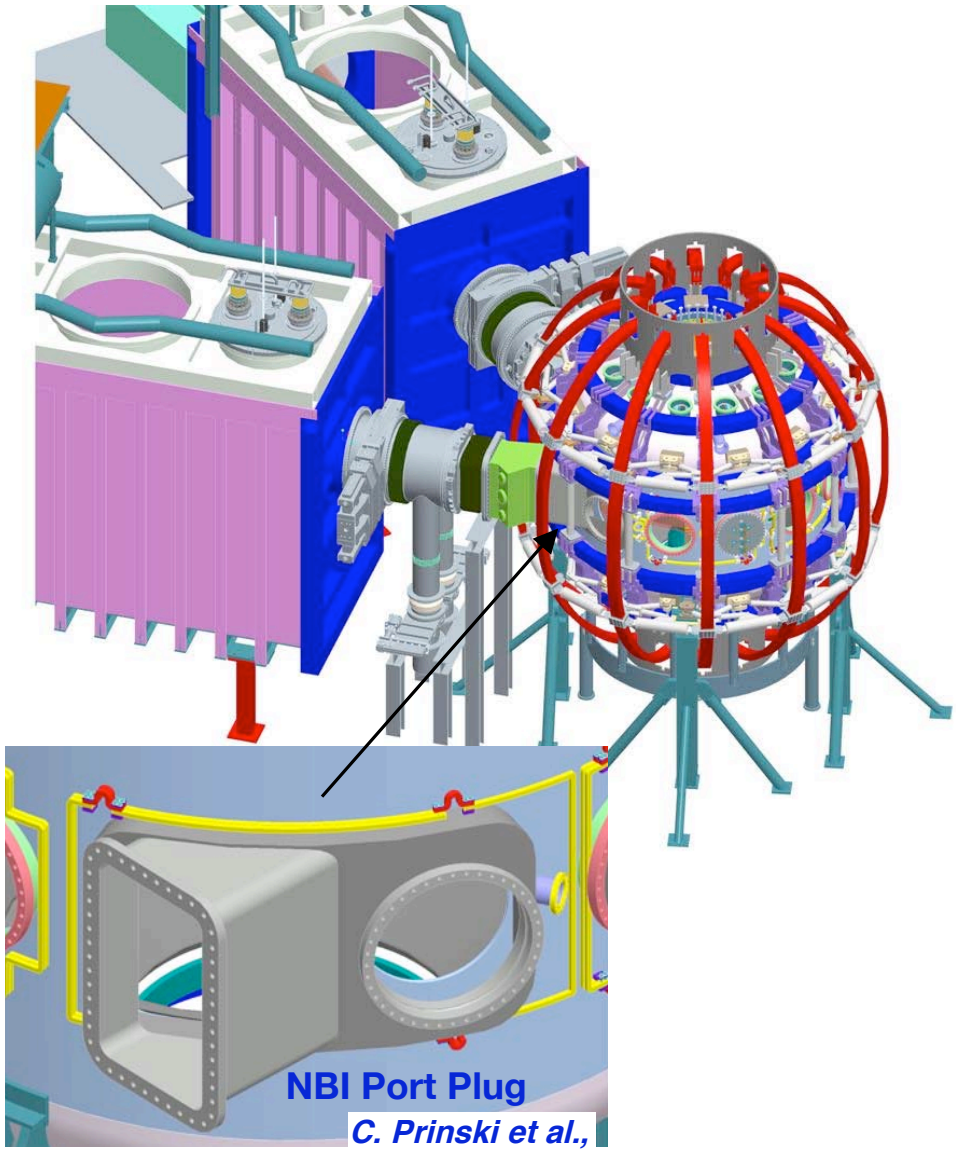


Second Neutral Beam Design

NB2 with Vacuum Vessel Turbo Pumps Mounted Under Duct



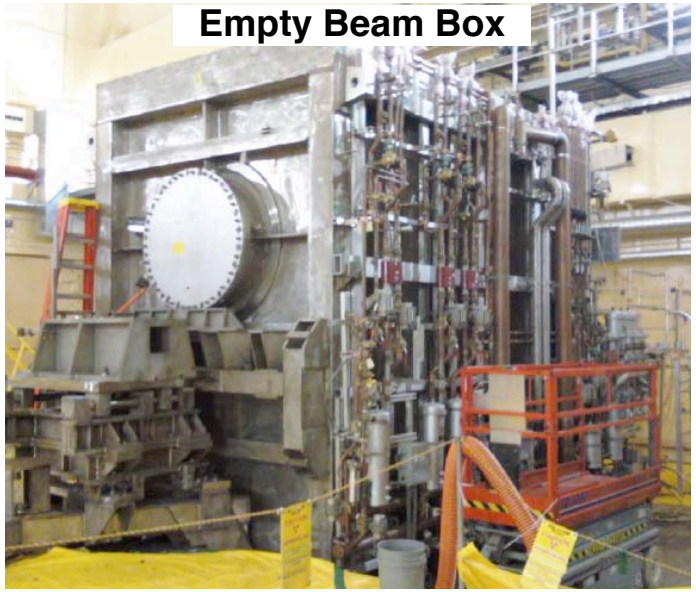
Torus Vacuum Pumps Mounted Under Duct



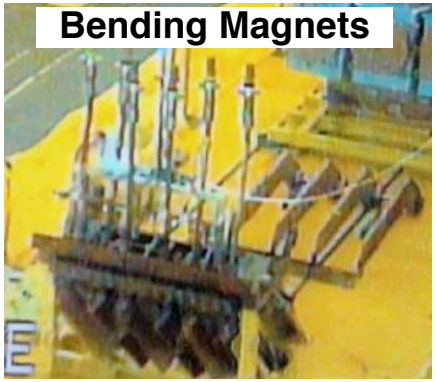
TFTR Neutral Beam Line #4 Disassembled

Tritium Contamination Level Assessed - Looks Excellent Thus Far!

Empty Beam Box

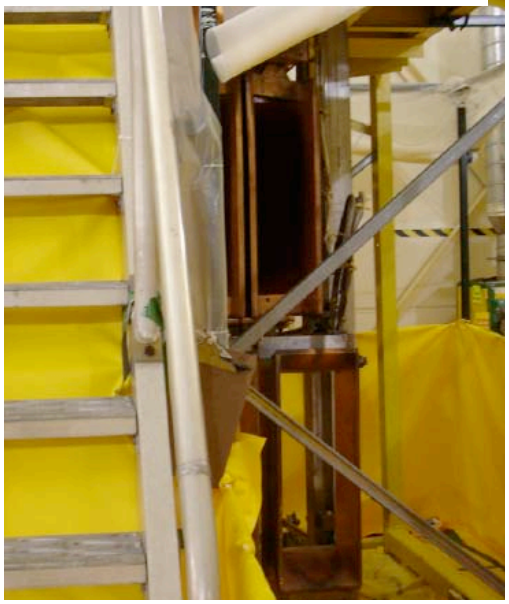


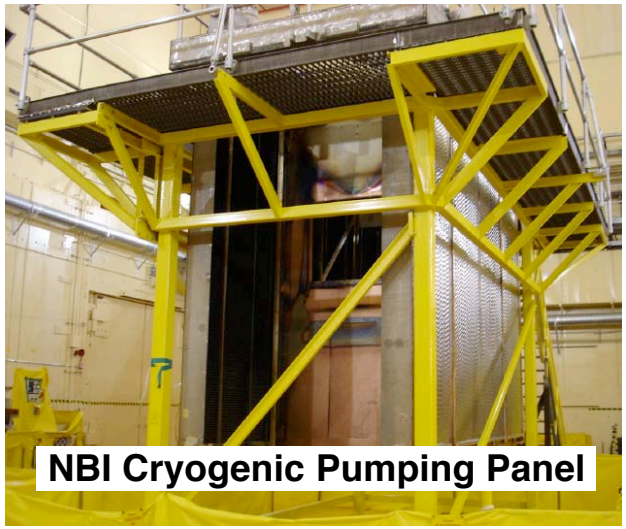
Bending Magnets



Ion Source Side Flange

Calorimeter





NBI Cryogenic Pumping Panel

Ion Beam Dump

Radiologically Controlled Clean Area

T. Stevenson et al.,

Facility and Diagnostic Plan Being Implemented to Support Exciting NSTX Research Plan

NSTX contributes to the World ST/Fusion Program with unique and complementally capabilities:

- High degree of facility flexibility
- Innovative facility and diagnostic systems
- Highly accessible plasmas enabling unique facility tools and diagnostics

High Priority Near Term Facility Upgrade Being Implemented:

- HHFW antenna upgrade completed in 2009
- Lithium capability being enhanced with LLD in 2010
- BES system being installed for 2010
- MSE-LIF system being prepared for 2011
- Other upgrades in pipeline - Extra MPTS channels, Extra SPA sources for non-axisymmetic coils, Divertor diagnostics, Tangential FIDA in 2010-2011

Major Upgrade Design Effort Started with Strong Team:

- Much more robust and simpler design developed for the new center-stack design and support structures. TF joint risks largely retired.
- 2nd NBI design also maturing. Tritium decontamination assessment has begun. The decontamination prospect is thus far excellent.