The Magnetic Fusion Program at PPPL

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Fusion Power Associates

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U.S. DEPARTMENT OF ENERGY

PRINCETON UNIVERSITY

PPPL PRINCETON PLASMA PHYSICS LABORATORY

Overall Strategy

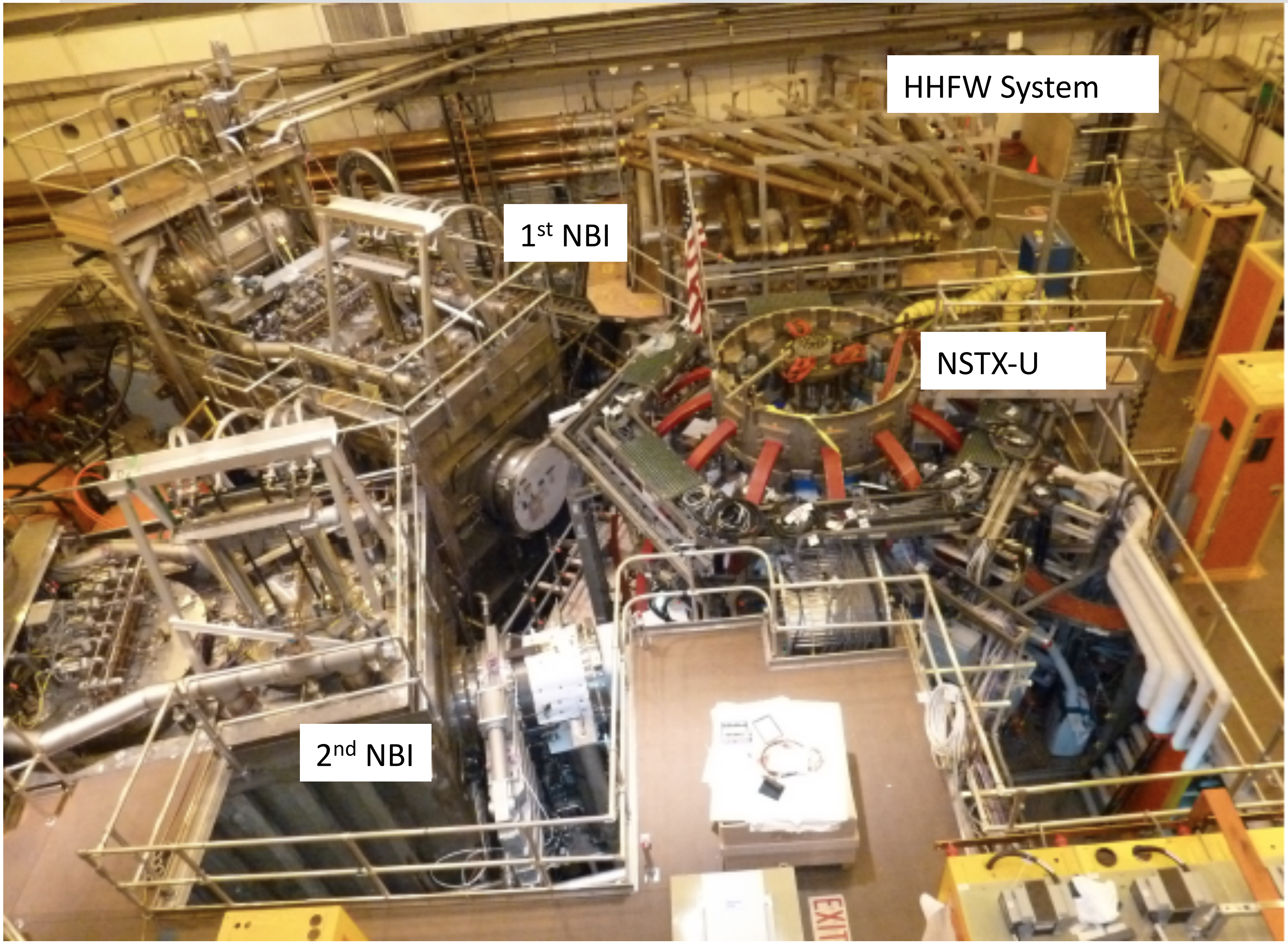
- Contribute to and prepare for ITER

- Focus on questions & innovations with breakthrough potential
  - Where the US can lead and have impact
  - That can improve prospects and feasibility of fusion energy

- Develop critical science needed for a fusion energy development program
  - In the US
  - With International Partners

- Collaborate broadly to achieve goals

NSTX Upgrade Project Is Nearly Complete



Double B : 1 T

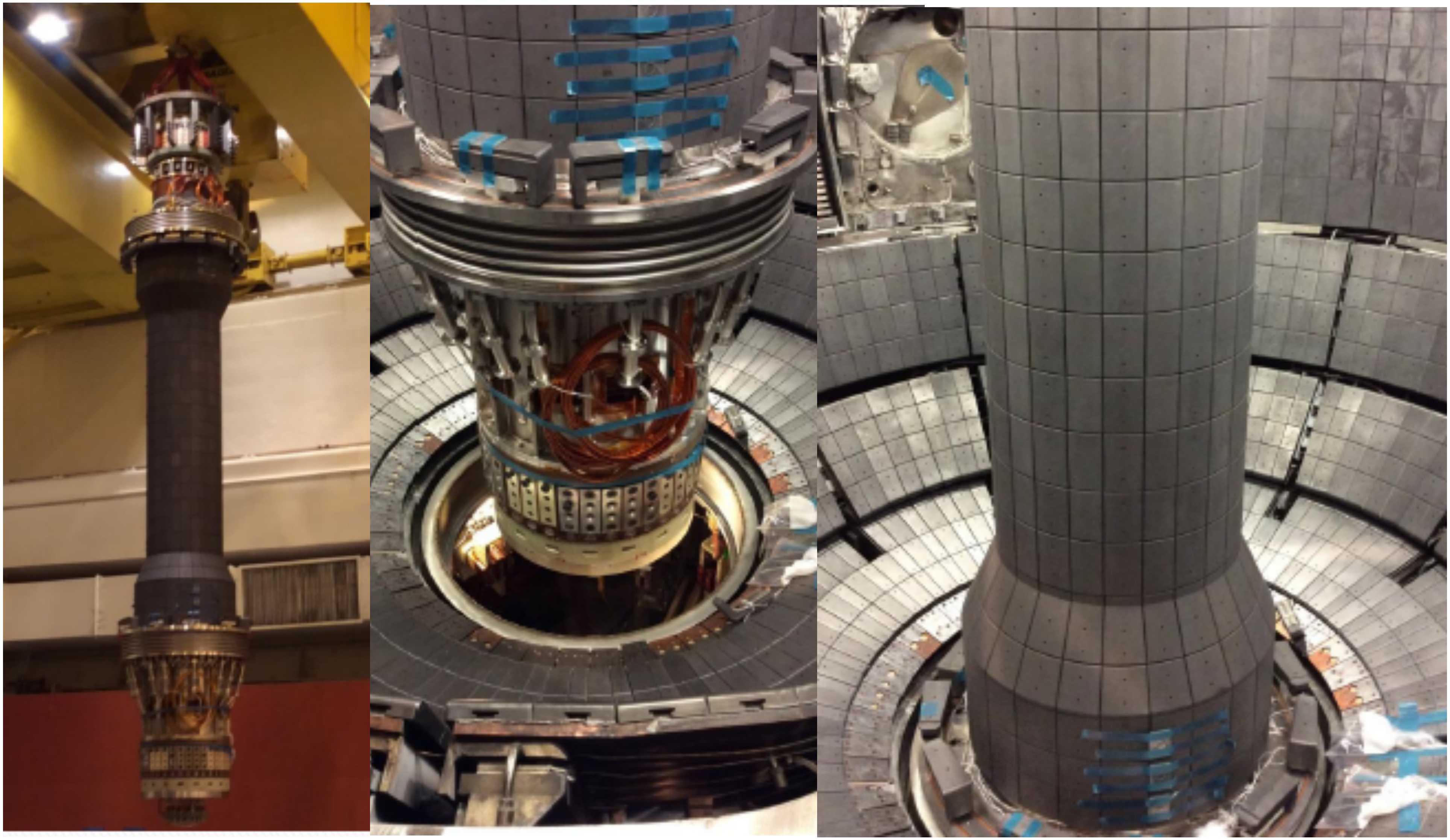
Double I_P : 2 MA

Double NBI Power

5X in pulse length to 5 sec

First plasma scheduled: Mar. 2015, Research operation: May 2015.

New Center-Stack is Installed In NSTX-U

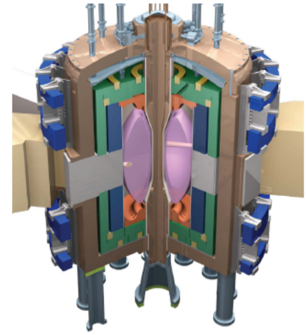


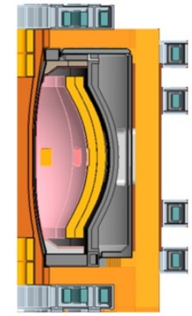
NSTX-U Mission Elements

- Advance understanding of ST towards burning-plasma regimes
  - Lower collisionality, higher T
  - Non-inductive sustainment

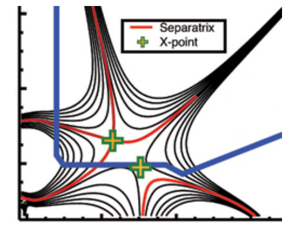
- Develop solutions for the plasma-material interface challenge

- Explore unique ST parameter regimes to advance predictive capability - for ITER and beyond

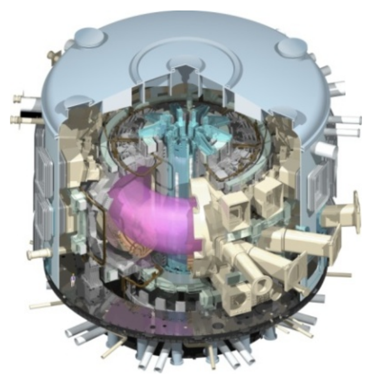




Liquid Lithium

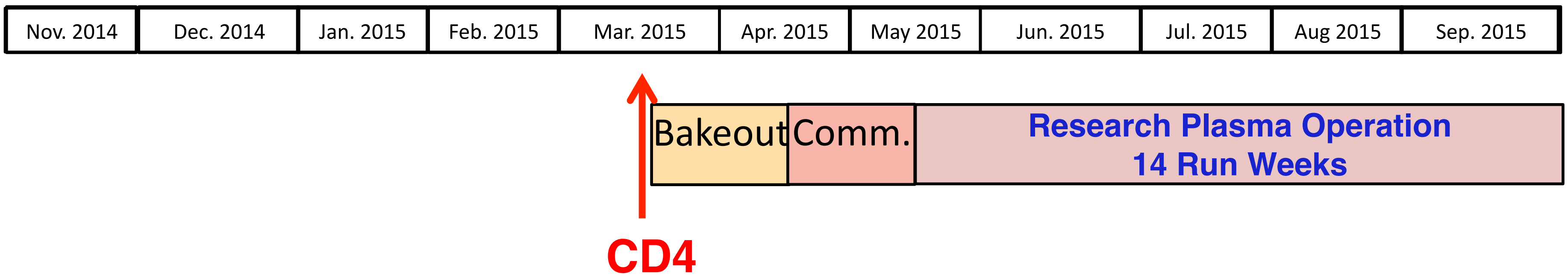


“Snowflake”



ITER

Expected NSTX-U run schedule for FY2015



- Research Forum : 24 – 27 Feb. 2015
  - Plan research experiments and program

- Pre-Forum meeting: 28 – 29 Jan. 2015
  - Update status of all systems for Research Operation
  - Status of XP solicitations

Burning Plasma: High Power

ITER preparation

Design and fabrication activities

Physics Analysis: specific topics; scenario development

ITER and beyond: Understanding development

Collaborations on DIII-D, C-mod, EAST, KSTAR, JET

NSTX-U, when operation resumes

Theory

Core & edge transport

MHD Stability

Fast ion stability

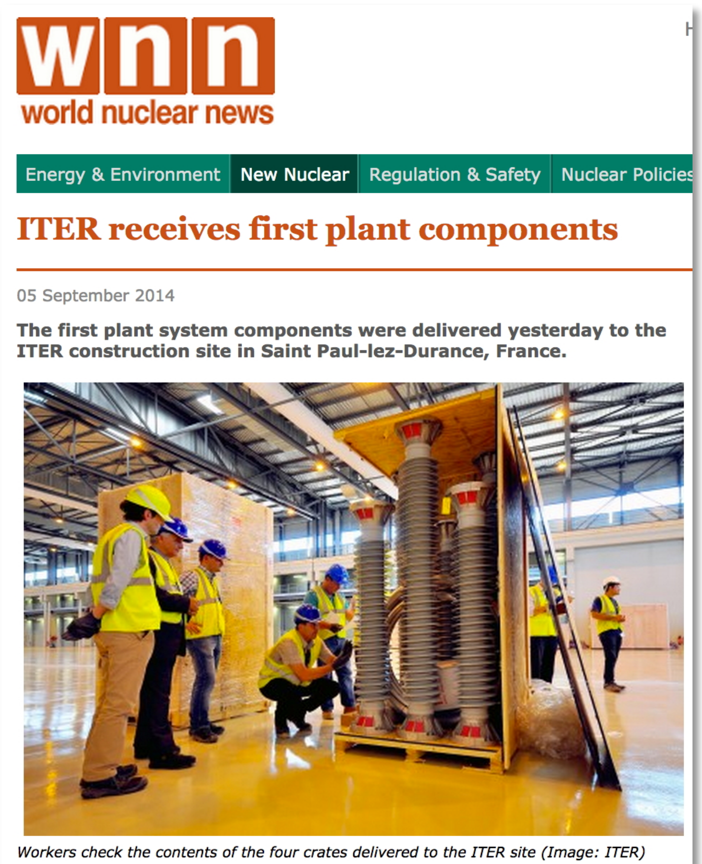
Disruptions and ELMs

Plasma control, including advanced divertors

Integrated scenario modeling

Pervasive: in all research departments and engineering

Steady-State Electrical Network Components Delivered!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ITER receives first plant components

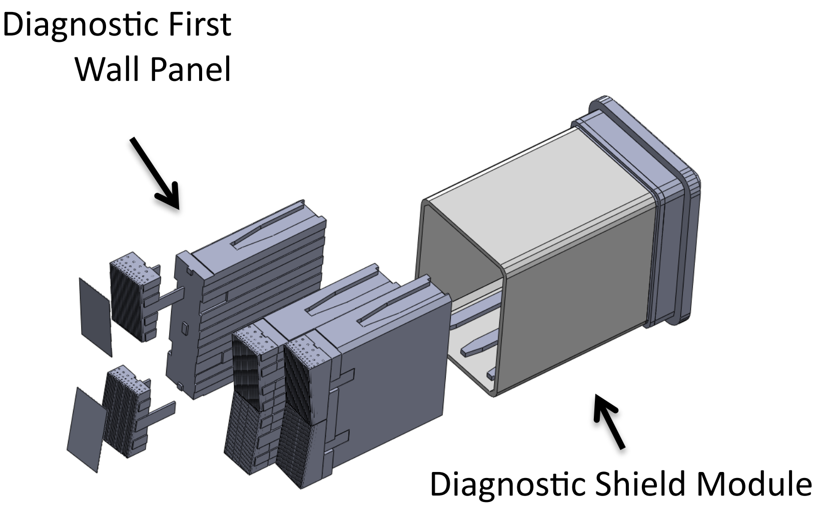
05 September 2014

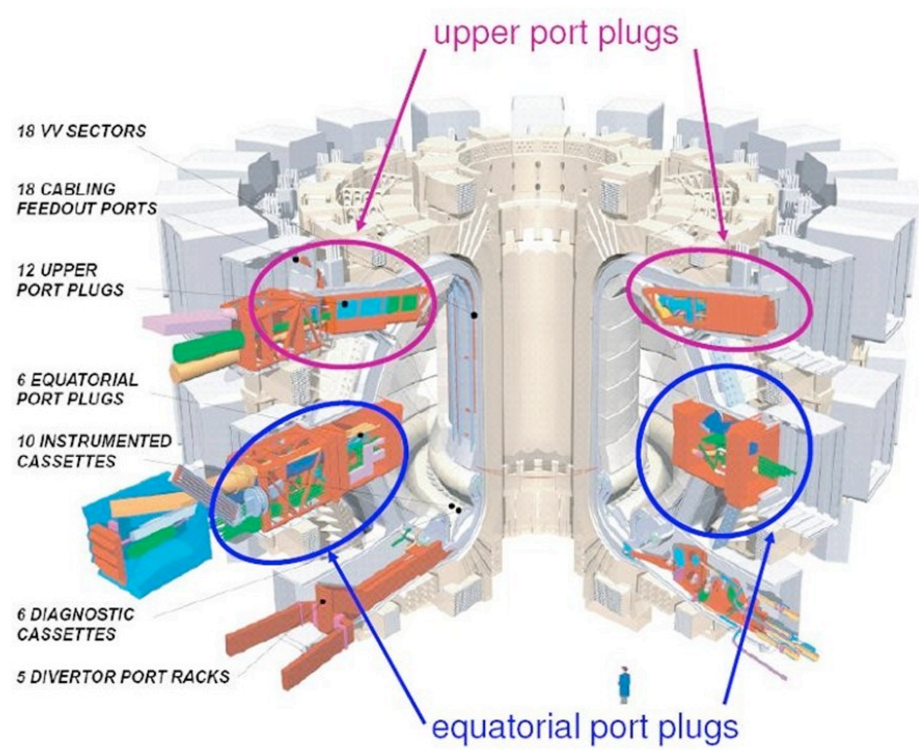
The first plant system components were delivered yesterday to the ITER construction site in Saint Paul-lez-Durance, France.

Workers check the contents of the four crates delivered to the ITER site (Image: ITER)

PPPL managing US ITER Diagnostics

- Contracts for US diagnostic contributions
- Designing diagnostic port plugs



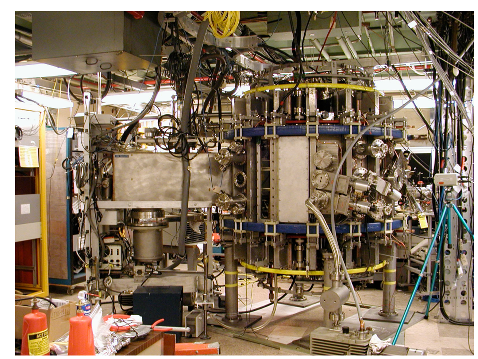


Liquid metals as plasma-facing material

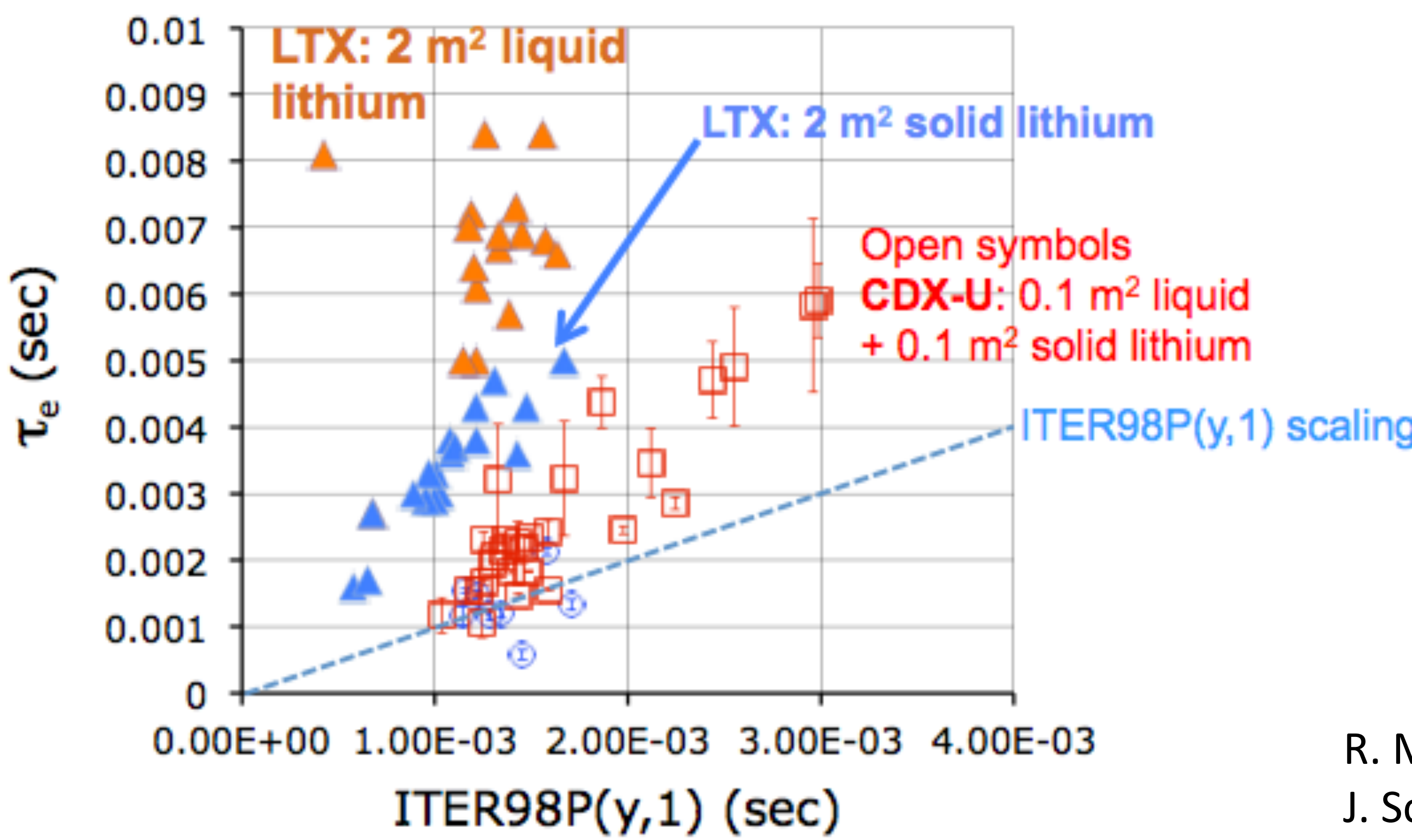
- Self-healing against erosion and damage
- No neutron damage, controllable heat removal
- Highly absorbing: no influx to plasma, improved plasma confinement

<u>Initiative Elements:</u>

- Modeling by material scientists (collaboration)
- Diagnostics for surface composition
- Tests of power handling on linear devices (Magnum PSI)
- Development of lithium deposition and flowing liquid-metal approaches
- Tests on toroidal devices (LTX, EAST, NSTX-U)



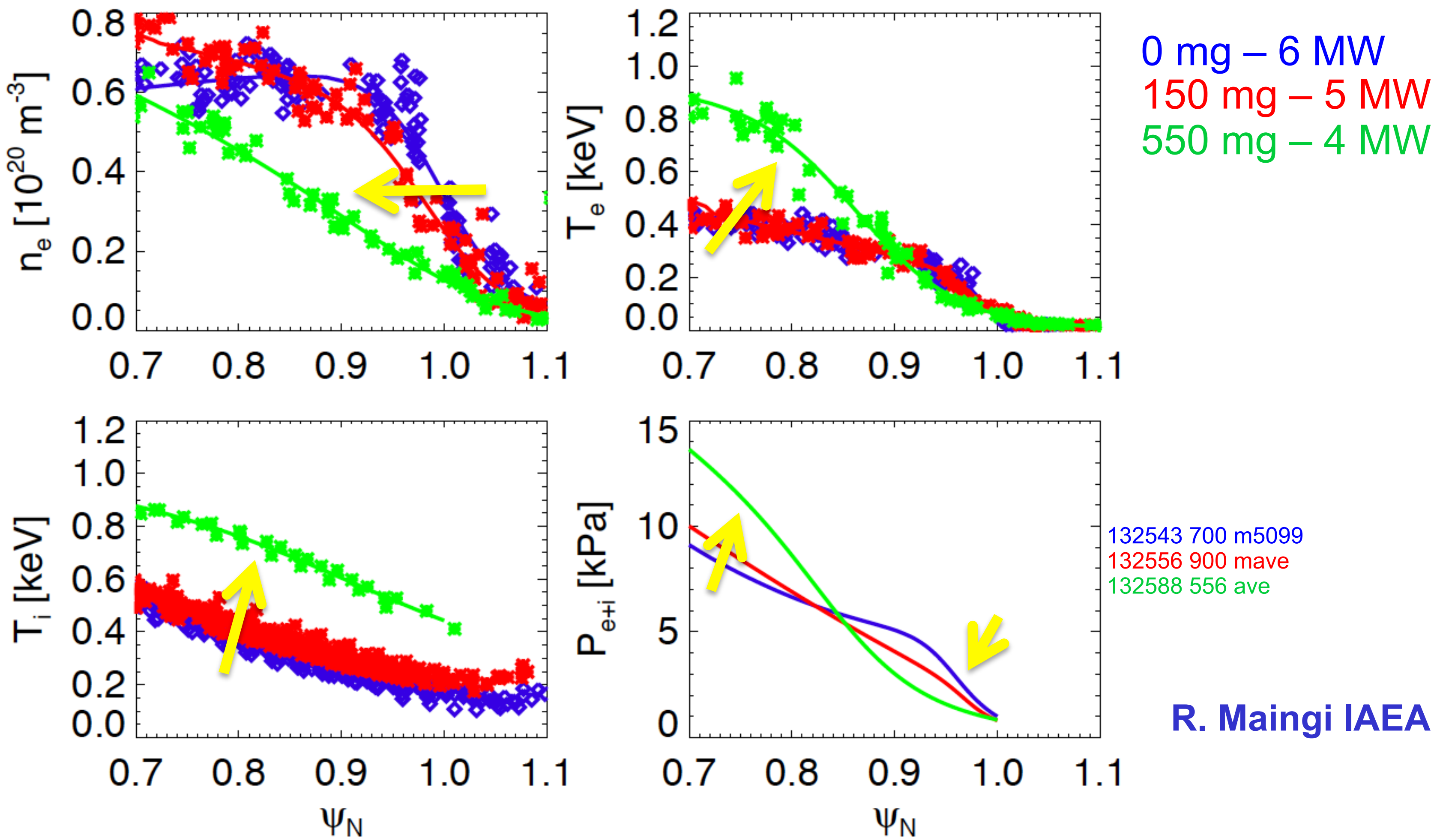
LTX -- Greatly Enhanced Confinement with Liquid Li Boundary



R. Majeski
J. Schmidt

- Confinement enhancements up to 10x standard scaling with liquid surface
- Will extend to 4 m^2 of liquid lithium surface
- Initial tests on EAST of flowing liquid lithium limiter (very recent)

•Edge profiles change markedly with increasing Li in NSTX and DIII-D



R. Maingi IAEA 2014

Recent experiments in DIII-D see transient doubling of pedestal pressure and width

Lithium injection extended to DIII-D, NSTX & EAST many similarities

	DIII-D	NSTX	EAST
Delivery method, Rate	Dropper, 18 mg/s	Inter-shot evaporation, 150-300 mg	Dropper 40 mg/s (Morning evap. 30-40 g]
Pedestal Width	**Increased**	**Increased**	**?**
Pedestal Height	**Increased**	**Increased**	**?**
H-factor	**Increased**	**Increased**	**Unchanged**
Edge fluctuations	**Increased**	**Decreased**	**Increased**
Radiated power without ELMs	**Steady**	**Ramps**	**Steady**
Effect on ELMs	**Delayed**	**Eliminated**	**Eliminated**
Recycling	**Unchanged**	**Reduced**	**Reduced**

- Need to understand differences and effects

Stellarators and 3D Shaping

Established method to achieve

- Steady-state, disruption free
- Confinement similar to tokamaks

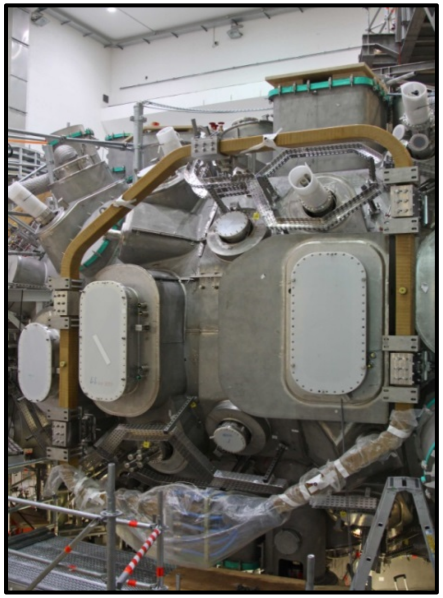
Potential for simpler, more efficient fusion system

- Fewer auxiliary systems: no current drive
- No need for stability feedback and control
- High gain, very low re-circulating power

Shared physics understanding with tokamaks

Extensive database from previous experiments.
Large, superconducting experiments in Japan, EU

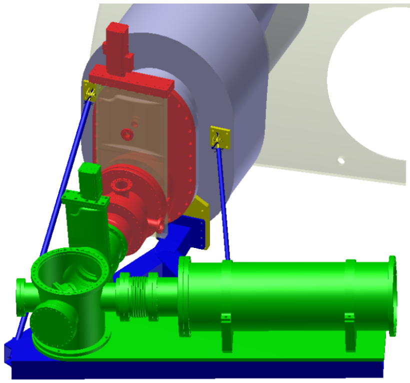
U.S. Contributions to W7X Preparing for Physics Program Engagement



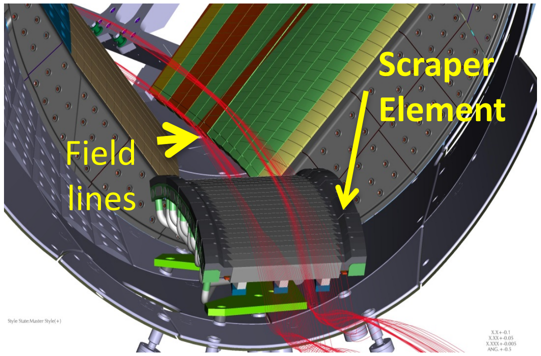
<u>US Partnership on W7X</u>

- PPPL – ORNL – LANL
- Broadened to Univ. & companies in 2014/15

US Hardware contributions anchor physics involvement (PPPL elements)



- Trim coils for control of equilibrium & divertor
- Imaging x-ray spectrometer for T_i, T_e, v-phi profiles
- Initial divertor "scraper element" design (with ORNL)



Experiments start in mid-2015!

New 3D Optimization Strategies are Emerging

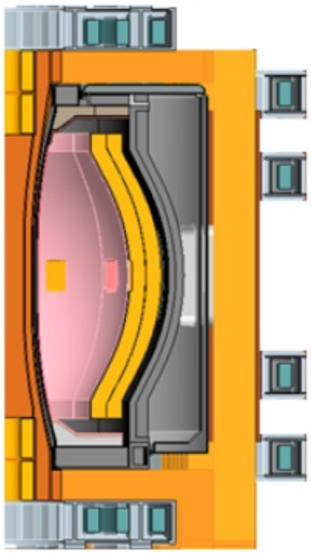
Continued efforts to improve stellarator optimization:

- Configurations with ITG / ETG turbulence eliminated!

- Straight coil outer legs
  - Simplified fabrication and maintenance

Conceptual Studies of Next Step Designs Continue

Explore impact of innovation and advances in understanding.



- Range of missions : CTF to Pilot Plants
- ST, tokamak, stellarator

- Collaborations with CCFE (UK), KDEMO (S.Korea), and CFETR (China) groups.

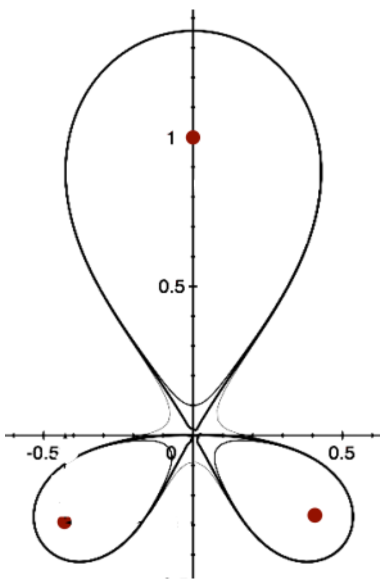
Summary

- NSTX-U construction is almost complete! Research operation will resume in May!
- PPPL's focus is on developing a predictive understanding, and using it to improve the prospects for fusion.
- We continue to look for innovative approaches to make fusion practical, affordable, and simpler.

Backup

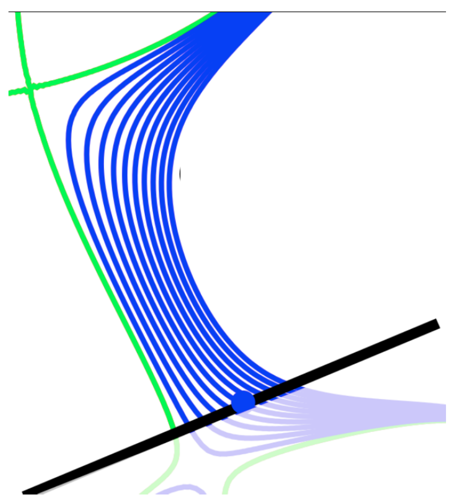
Divertor flux expansion of ~ 50 achieved with Snow Flake Divertor with large heat flux reduction in NSTX

Snow-flake



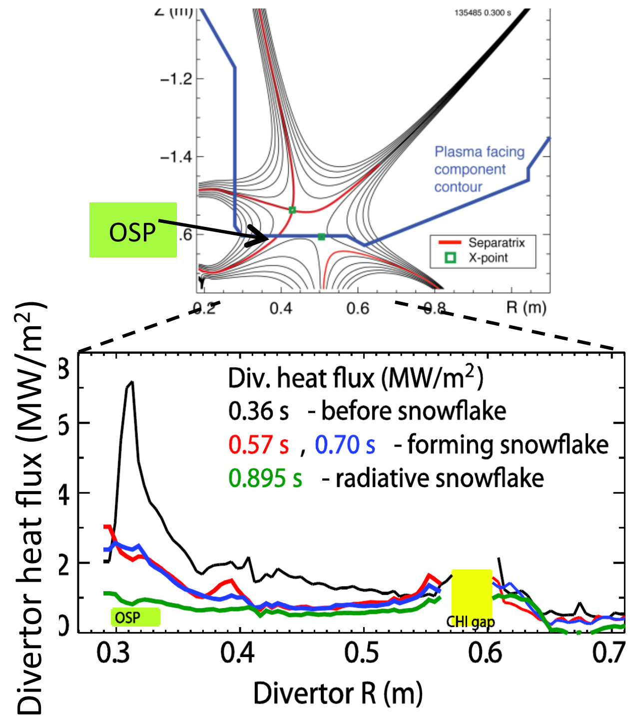
D. Ryutov, et al., PoP (2007)

X-Divertor: CREST



P.M. Valanju, et al., PoP (2009).

Snowflake divertor in NSTX

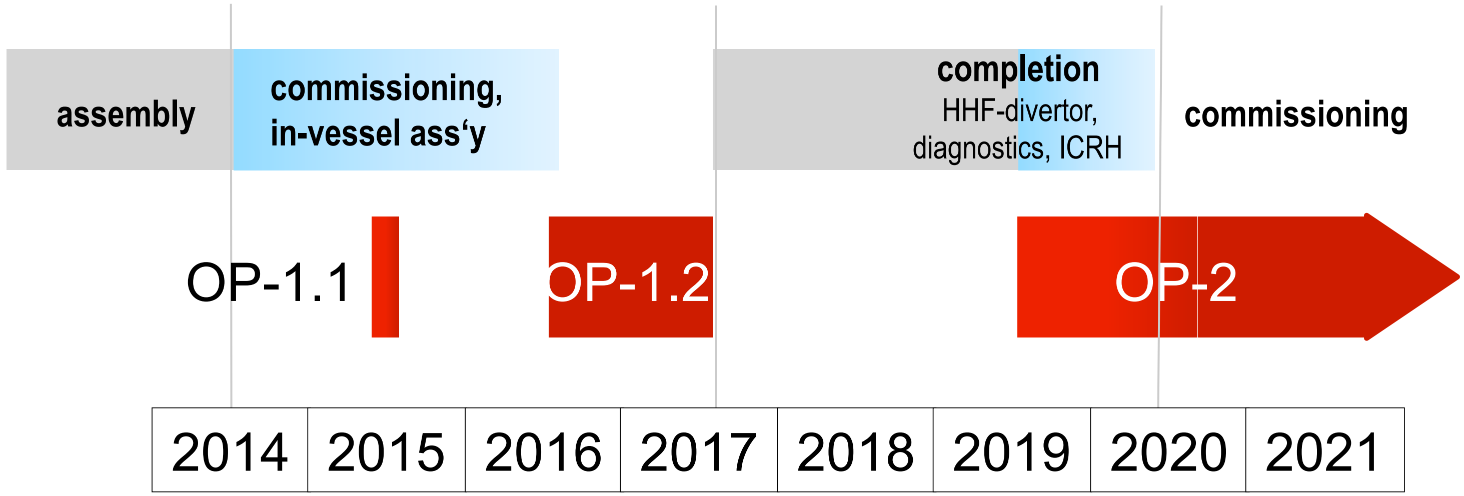


V. A. Soukhanovskii et al., PoP (2012)

NSTX-U will investigate novel divertor heat flux mitigation concepts needed for FNSF and Demo.

- Up-and-down symmetric Snow Flake / x-Divertors
- Lithium + high-z metal PFCs

Wendelstein 7-X Operation Schedule



Operational phase 1.1 (OP-1.1)

- First plasma. Short pulse, electron cyclotron-heated.

Operational phase 1.2 (OP-1.2)

- First divertor tests.
- Increasing plasma input power and pulse length.
- Steady state scenario optimization.

Operational phase 2 (OP-2)

- Extension of 10 MW-heated plasmas to 30 minutes.