Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending July 6, 2019, are as follows:

NSTX-U RECOVERY (R. HAWRYLUK) AND RESEARCH (S. KAYE)

Recovery (R. Hawryluk):

TF Bundle — PPPL's sample fabrication activity is complete. Static short beam shear (SBS) turn-to-turn sample testing was completed at the Element Materials Technology lab in California. A single, turn-to-turn cyclic test will be performed and the tests will generate quadrant-to-quadrant samples in order to determine the relative strength of turn-to-turn vs. quadrant-to-quadrant insulation. Turn-to-turn tensile testing is underway at Composite Technology Development (CTD) in Colorado. All quadrant-to-quadrant copper parts for tensile samples were shipped from PPPL to CTD and sample fabrication for the quadrant to quadrant tests is underway. The final report on modulus and coefficient of thermal expansion (CTE) testing was submitted by CTD. The fracture mechanics (FM) and tensile sample testing is underway at the PPPL Materials Test Lab as well as tensile testing. The high fidelity and delamination growth rate analyses have been completed to the extent possible with the available data and have been documented and submitted for checking. The delamination simulation model continues to be refined. The FEA model for analysis of the effect of delamination on the external load path is ready for running cases in order to determine the boundary of maximum allowable delamination. The draft presentation for the director's review was completed and preparation of the interim report is underway. Once the remaining material test data becomes available, the calculations will be finalized prior to the Stage 2 review scheduled for August 7-8.

Research (S. Kaye):

Publications — A number of NSTX-U researchers either first-authored or co-authored initiative/white papers submitted for the MFE community workshop to be held in Madison, Wisconsin, in July 2019. The initiatives will be discussed at this workshop as a first step in the community planning process that will lead to the development of a strategic and prioritized plan for fusion science and technology R&D, leading to a net-electricity producing device.

The paper titled, "Error field impact on mode locking and divertor heat flux in NSTX-U," by N. Ferraro et al. was published in *Nuclear Fusion*: https://doi.org/10.1088/1741-4326/ab22c4. This paper describes experimental observations and modeling of the effects of error fields in NSTX-U. The results of IPEC and M3D-C1 perturbed equilibrium calculations are used to assess the impact of various sources of error fields on the plasma, including toroidal braking from neoclassical toroidal viscosity (NTV) and

resonant electromagnetic fields, and also the resulting non-axisymmetries in the divertor heat flux. The researchers found that misalignment of the TF and PF5 coils are likely responsible for the locked modes observed in low-density NSTX-U L-mode discharges. The calculations are used to inform tolerances on magnet and PFC alignment in NSTX-U.

U.S. ITER FABRICATION (H. NEILSON)

An ITER diagnostics delegation, consisting of A. Basile, A. Gattuso (General Atomics), and H. Neilson, visited the project site in St. Paul-lez-Durance, France, for discussions on a wide range of design integration topics. Ex-vessel captive component requirements for U.S. diagnostics were significantly clarified. Two U.S. diagnostics will require ceiling-mounted supports for structures that transmit signals across the gallery. They need to be installed prior to first plasma, as the ceiling attachment points will become inaccessible, or captive, thereafter. A standard, off-the-shelf system will be used; the U.S. will be able to order the components it needs from a catalog. Recently, it has become clear that crowded conditions at the tokamak building wall make it necessary to also install equipment associated with wall penetrations, such as valves and windows, prior to first plasma. Components and installation instructions for captive components will be needed in 2020 in order to support the IO's assembly sequence.

The site visit also provided an opportunity for face-to-face discussions with Russia's port integration team, most of whom have relocated to the project site in order to more efficiently manage the design of Equatorial Port 11, which hosts the U.S. Low Field Side Reflectometer (LFSR). Design details of the LFSR antenna assembly interface with the port structure have matured in recent weeks; the focus has now shifted to the in-vessel waveguide assemblies that extend from the antennas to the vacuum window on the closure plate. Local shielding, or so-called "backfilling" is required to fill the irregular-shaped cavities surrounding these diagnostic components inside the shield box. Agreements were reached with Russian colleagues on the division of responsibilities for backfilling design around the LFSR waveguide assemblies.

ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson):

Research:

S. Haskey was session leader for a two-part experiment using the main-ion and impurity charge-exchange recombination (CER) spectroscopy systems on DIII-D, verifying new measurement capabilities. The first experiment was aimed at assessing the effects of

Zeeman broadening on impurity CER temperature measurements for various impurities as well as the main-ions (D+). The second focused on extending main-ion CER measurements to include poloidal rotation using new techniques including a combination of high-field and low-field side toroidal rotation measurements. This experiment utilized new high-field-side sightlines and spectrometer upgrades that occurred during LTO3.

Operations:

Three college engineering student interns supervised by A. Nagy have completed their first month at DIII-D. Each student is tasked with separate project related to power and granule dropping; alternate powder dispensing using a conveyor belt, periodic and singular granule dropping, and an in-vacuum scale with 1 mg resolution for calibrating powders. The team activities consist of design modeling, 3D printing of parts, and assembly/fabricating of vacuum systems and testing design ideas. A weekly meeting is held where each student reports their progress and takes input and discussion from the group for one hour, fostering team learning and growth. Each student will present their work to the D3D engineers at the end of August.

International PMI (R. Maingi):

A new experiment to evaluate the effects of lithium powder in mixed helium/deuterium plasmas was executed remotely by PPPL staff (Z. Sun, A. Diallo, R. Maingi) in collaboration with ASIPP staff. A comparison of lithium powder effects as a function of density and two values of Ip (0.45 and 0.5 MA) was obtained.

A paper titled, “A Promising High-Confinement Regime for Steady-State Fusion,” by G. Xu, Q. Yang, N. Yan, Y. Wang, X. Q. Xu, H. Guo, R. Maingi, L. Wang, J. Qian, X. Gong, V. Chan, T. Zhang, Q. Zang, Y. Li, L. Zhang, G. Hu, and B. Wan, was published in *Physical Review Letters*. The paper details a new small ELM regime discovered in EAST, and interpretive edge stability analysis, along with BOUT++ time dependent analysis of the ELM crash cycle.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

Three stellarator white papers were submitted to the APS-DPP community planning process. The first, authored by D. Gates and D. Maurer of Auburn University was entitled, “The stellarator path to a low-cost pilot plant.” This paper described the benefits of the stellarator concept as a pilot plant option. The second, authored by S. Lazerson, was entitled, “International stellarator research in support of a low-capital-

cost pilot plant." This paper presented a plan for enhanced research operations using international superconducting stellarators such as W7-X and LHD. The third paper, authored by M. Zarnstorff, was entitled, "Initiative to simplify optimized stellarators and test key properties." This paper described a plan for a new initiative to build and operate a radically simplified stellarator that uses permanent magnets for 3D shaping.

The LHD powder dropper arrived at the National Institute for Fusion Science (NIFS) in Toki, Japan, on June 30. E. Gilson and F. Nespoli will travel to NIFS in July to help with the testing and installation. Experiments will be planned for the coming LHD run period which is now planned to start in the October time frame.

THEORY (S. HUDSON)

A comment paper by M.-G. Yoo was published in *Nuclear Fusion* on June 24: https://dx.doi.org/10.1088/1741-4326/ab265a This paper points out critical numerical flaws of recent particle simulation studies on the ohmic breakdown, which mislead the physical mechanisms.

N. Ferraro attended the 11th International Conference on Computational Physics (ICCP11) at Zhejiang University in Hangzhou, China, and presented an invited talk titled, "Magnetohydrodynamic Simulations of Fusion Plasmas with M3D-C1."

A paper by N. Ferraro and others titled, "Error field impact on mode locking and divertor heat flux in NSTX-U," was published by *Nuclear Fusion*: https://doi.org/10.1088/1741-4326/ab22c4

J. Chen, S. Ethier, C. Ma, and M.-G. Yoo attended a five-day "GPU Hackathon" organized by the Oak Ridge Leadership Computing Facility (OLCF/ORNL) and the Princeton Institute for Computational Science and Engineering (PICSciE). During this coding event, teams of developers port their applications to run on GPUs, or optimize their applications that already run on GPUs, with help from experts from Nvidia and OLCF. The PPPL participants worked on the GTS and M3D-C1-K codes and made significant advances in porting these applications to GPU and achieving higher performance.

The letter. "Self-driven current generation in turbulent fusion plasmas," by W. Wang, T. Hahm, E. Startsev, S. Ethier, J. Chen, M.-G. Yoo and C. Ma, has been published by *Nuclear Fusion*: https://dx.doi.org/10.1088/1741-4326/ab266d. In this letter, GTS multi-physics simulations based on a global gyrokinetic model with self-consistent coupling of neoclassical and turbulent dynamics show that turbulence can significantly affect plasma self-driven macroscopic current generation in tokamaks.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard):

The Office of Communications posted the 2019 edition of *Quest*, PPPL's annual research magazine, which summaries in short, easy-to-digest format much of the research that occurred at PPPL over the last year: www.pppl.gov/Quest

The Office of Communications also posted three press releases to the PPPL website. One announces the launch of the latest version of *Quest*; another notes that PPPL physicist W. Fox has won the 2019 Thomas H. Stix Award for early contributions to plasma physics; and a third highlights research by PPPL physicists R. Lunsford and R. Maingi into the use of beryllium granules to stabilize fusion plasmas. The stories were also posted to the *Newswise* and *EurekAlert* press release distribution services.

A large number of groups toured PPPL in June. A public tour on June 7 was led by M. Ono; a group of staff members from Princeton University's Office of Information Technology visited on June 12 and were led by R. Camp; a group from Princeton University's Career Services office visited on June 13, led by J. Guttenfelder; about 100 Princeton University ushers visited on June 19, led by A. Zwicker, R. Camp, C. Smiet, M. Cole, S. DePasquale, A. Brereton, and Y. Zhai; a group of warrior scholars based at Princeton University visited on June 20 and were led by S. Greco; a public tour on June 21 was led by S. DePasquale; a tour for a group of engineering interns on June 21 was led by D. Gates, D. Battaglia, B. Kraus, and A. Dominguez; a tour on June 24 from Hutchins Scholars at the Lawrenceville School was led by J. Schwartz; another tour for engineering interns on June 25 was led by M. Cole; a tour for Princeton University's vice president for finance and treasurer was led by D. Battaglia; a tour on June 27 for S. Cowley visitors was led by D. Gates; and another tour on June 27 for interns in a PSE&G sustainability program was led by R. Sheneman, S. DePasquale, and R. Camp.

This report is also available on the following web site:

http://www.pppl.gov/publication-type/weekly-highlights