Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending July 13, 2019, are as follows:

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

Recovery (R. Hawryluk):

TF Bundle - The turn-to-turn tensile testing at Composite Technology Development (CTD) in Colorado experienced a major setback. For reasons not known but attributable to some aspect of the sample fabrication process, all samples failed at a very low level with very wide scatter. Fortunately a back-up test program underway at the PPPL Material Test Lab using spare laminate is exhibiting very good results with very low scatter. Moving forward, the tensile testing will rely on PPPL samples tested at both PPPL and CTD, and this effort has been given priority. Static Short Beam Shear (SBS) turn-to-turn and quadrant-to-quadrant sample testing was completed at the Element Materials Technology lab in California. Cyclic testing will begin on the quadrant-to-quadrant samples next. The high fidelity and delamination growth rate analyses have been completed to the extent possible with 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 running cases to determine the boundary of maximum allowable delamination. Once the remaining material test data becomes available, the calculations will be finalized prior to the Stage 2 review scheduled for August 7-8.

PF 4/5 Realignment - A successful preliminary design review (PDR) was held July 10 on the design, fabrication, and procurement of the clamping system for the pancakes of each of the PF 4/5 coils. This clamping system is required to maintain the existing relative position between the pancake pairs, which currently meets the offset requirement defined in the Dimensional Control Requirements Document. These clamps prevent misalignment from happening during the tilt and shift adjustments made to the PF 4/5 coils.

Personnel Safety System Breaker Replacement - A final design review (FDR) was held July 12 for a replacement breaker for the new Personnel Safety System. The Personnel Safety System turns off direct ionizing radiation hazards in the event of an E-stop or door violation or inconsistent state. Existing 13.8 kV circuit breakers are the main interdiction devices, but are not fully fail-safe. The breakers need to be modified to include direct-acting undervoltage trip devices in order to be completely fail-safe. This FDR presented the approach for providing the SV and select S1 and S2 circuit breakers, as identified by the Personnel Safety System (PSS) as being required for interdiction,

with the fail-safe functionality of direct-acting undervoltage trip devices. The review was deemed successful, pending resolution of chits.

Research (S. Kaye):

Y. Ren visited Zhejiang University in Hangzhou, China, during the week of June 24. He worked with W. Xiao to set up and carry out a perturbative experiment on a helicon linear device. He also carried out informal discussion of NSTX experiments with graduate and undergraduate students in Xiao's group. Then during the week of July 1, Ren visited Southwestern Institute of Physics (HL-2A) in Chengdu, China. He worked with HL-2A researchers on coherent CO2 scattering data analysis, including the calculation of scattering locations and volumes taken into account of turbulence anisotropy and the study of high-k turbulence evolution during sawtooth cycle in HL-2A L-mode plasmas. Ren also worked on coherent CO2 scattering diagnostic design for HL-2M and identified a suitable scattering scheme for further optimization.

Two papers on energetic particle physics were published in *Nuclear Fusion*. The paper titled, "Investigation of fast particle redistribution induced by sawtooth instability in NSTX-U," by D. Kim et al. (https://iopscience.iop.org/article/10.1088/1741-4326/ab1f20) describes TRANSP simulations of NSTX-U sawtoothing discharges using a kick model to account for redistribution of neutral-beam fast ions. Results show that the model can recover the phase-space selectivity of fast-ion transport by sawteeth, in reasonable agreement with previous theories. The results suggest that a kick model approach can help the development of an improved sawtooth model in TRANSP.

The second paper by M. Podestà et al. is titled, "Reduced energetic particle transport models enable comprehensive time-dependent tokamak simulations" (https://iopscience.iop.org/article/10.1088/1741-4326/ab3112). TRANSP simulations of NSTX/NSTX-U and DIII-D discharges show that the kick model implemented in TRANSP/NUBEAM can handle scenarios with multiple types of instabilities simultaneously present in the discharge. In addition to Alfvénic modes, tearing modes and fishbones are included in the simulations, resulting in a good agreement between TRANSP results and experimental measurements of mode activity and fast ion transport.

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U.S. ITER FABRICATION (H. NEILSON)

A revised Qualification Summary Report(s) for Low Field Side Reflectometer (LFSR) components was approved by U.S. ITER and submitted for ITER Central Team approval. The document defines the qualification plan for the safety important class (SIC) components of the LFSR system. Safety barrier assemblies are installed at penetrations where the six LFSR transmission lines cross through confinement barriers in the complex. The safety barrier assemblies, consisting of a microwave window and a shutter, are classified as SIC because their operation is required to limit the consequences of an incident or accident that would lead to significant risks of exposure or contamination. This qualification plan outlines the strategy to demonstrate and document that the assemblies will perform their emergency functions and that their leak rate shall be as low as reasonably achievable (ALARA) and below the leak rate limit for wall penetrations of the tokamak complex. The Qualification Summary Report was prepared by design partner General Atomics and is an LFSR design deliverable.

ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson):

Research:

A paper titled: "Enhanced radial energy transport induced by radially Curved Alfven Eigenmode wavefronts," by G. J. Kramer et. al was accepted for publication in *Nuclear Fusion*. Radially curved Alfven eigenmode wavefronts as observed on the Electron Cyclotron Emission Imaging diagnostic, indicate that the modes are associated with a net radial energy flow. This energy flow is due to a radial mismatch in the location of the drive and damping of the mode. Energy transport is created by an enhanced parallel fluctuating magnetic field that is generated by the radial wavefront curvature.

Seven members of the DIII-D collaboration prested results at the 46th EPS conference on plasma physics in Milan, Italy. Two oral presentations were delivered by A. Ashourvan on “Formation of a staircase pedestal with suppressed Edge-Localized-Modes (ELMs) in the DIII-D tokamak,” and A. Diallo on “Pedestal modes interactions triggering bursts and leading to the onset of edge localized modes on DIII-D.” Five poster presentations were given by A. Bortolon on “Real-time wall conditioning through B powder injection in fusion devices,” S. Haskey on “Advances in Understanding Plasma

Rotation and Ion Thermal Transport Using Main-ion Measurements in DIII-D," Z.R. Wang "Verification of neoclassical toroidal viscosity due to energetic particles," M. Okabayashi on "Coupled resonant layer responses to rotating 3D fields in the presence of static error fields," and R. Nazikian on "The Role of Resonant Magnetic Field Penetration in Edge Localized Mode Suppression in the DIII-D Tokamak."

International PMI (R. Maingi):

A. Bortolon presented a poster at the 2019 EPS conference in Milan titled, "Real-time wall conditioning through B powder injection in fusion devices." E. Gilson also presented a poster titled, "ELM suppression and recycling reduction by boron nitride and boron injection in KSTAR." In addition, boron powder injection results in ASDEX-Upgrade were included in an invited talk by A. Drenik titled, "Nitrogen transport inventory evolution and ammonia formation in N2-seeded discharges on ASDEX Upgrade and JET." Finally contributions to long-pulse development in EAST were included in an oral presentation by X. Gong titled, "Integrated operation in achieving steady-state H-mode plasma on EAST."

R. Maingi presented a lecture for the Summer Undergraduate Laboratory Internship (SULI) program titled, "Principles of magnetic confinement fusion, including auxiliary heating methods and spectroscopic diagnosis." The talk also touched on the role of fusion in the US power landscape, with similarities and differences to nuclear fission power generation.

Z. Sun participated remotely in an experiment on EAST in which ELMs were suppressed with real-time boron powder injection at plasma current (Ip) = 0.55 mega-amp discharges and safety factor (q95) ~ 4 with radio-frequency-only heating; the Ip and q95 both extend ranges from past ELM suppression attempts with boron powder. This extends the Ip and q95 range from earlier experiments in May 2019. Magnetics measurements showed the onset of a mode in the 30 kHz range during ELM quiescence, i.e., substantially higher than the 3 KhZ modes observed previously.

International Long Pulse (F. Poli):

ITER-JET (F. Poli):

A. Teplukhina attended the 46th EPS conference on plasma physics the week of July 8 in Milan, Italy. She presented a poster entitled, "Impact of ICRF and NBI heating on the fast ion distribution function during the ITER plasma termination phase." Simulations for the ITER operation at half-field explore the impact of the ICRF heating scheme on the fast

ion distribution and on the electron heating, with a goal of testing these ideas on JET DT plasmas to inform ITER on how to exit H-mode.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

N. Pablant and S. Lazerson attended the 46th European Physical Society Conference on Plasma Physics (EPS 2019). Pablant presented an oral presentation entitled "Role of the radial electric field in Wendelstein 7-X." This presentation compared measurement of the radial field made by the XICS diagnostic (installed by PPPL) with neoclassical calculation of the ambipolar radial electric field. These measurements show accessibility to the high-density ion-root regime in W7-X and good agreement with the NC calculations.

S. Lazerson presented a poster entitled "Validation of the BEAMS3D deposition model on Wendelstein 7-X." In this poster, he demonstrated that the neutral beam injection model in the BEASM3D code was accurately reproducing the measured neutral beam attenuation in Wendelstein 7-X. This work utilized equilibrium reconstructions performed with the STELLOPT code to provide accurate equilibria and species profiles used in the BEAMS3D simulations. These reconstructions make use of newly implemented XICS modules in STELLOPT and coupling with the TRAVIS code to provide the forward model for ECE measurements. This work opens the possibility for using BEAMS3D in STELLOPT reconstructions to provide forward models for charge exchange and beam attenuation.

THEORY (S. HUDSON)

A. Scheinberg gave an invited talk at the PASC (Platform for Advanced Scientific Computing) conference in Zurich, Switzerland, on June 13. The talk was titled “Porting the XGC gyrokinetic code to Summit.”

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COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard)

A reporter for NJTV, the state's public broadcasting television station, visited PPPL on July 8 for a feature story on fusion energy. The reporter, L. Mishkin, hosted by L. Bernard, interviewed J. Menard and A. Zwicker, and toured the NSTX-U test cell with Zwicker. The story had not aired as of this writing.

The Office of Communications posted three press releases to the PPPL website. The first explained recent research by A. Nelson and E. Kolemen into a new measurement technique that avoids problems expected when mapping the magnetic fields on large and powerful future tokamaks. The second noted that Congressman Andy Kim, who represents New Jersey's District 3, visited PPPL and was excited about the prospects of fusion energy. The third detailed research by E-H Kim into how waves in outer space travel through a planet's magnetosphere. Also stories were also posted to the *Newswise* and *EurekAlert* press release distribution services.

DIRECTOR'S OFFICE (S. COWLEY)

On July 8, J. Menard hosted a visit by Congressman Andy Kim. Congressman Kim was provided with an overview of PPPL, and a tour of our facilities.

On July 8, C. Ferguson and K. Fischer traveled to DOE offices in Germantown, Maryland, to meet with K. Klausing and C. Farmer.

July 8-12, S. Cowley attended the European Physical Society Conference in Milan, Italy.

July 11-12, J. Menard participated in a DOE Basic Energy Sciences Advisory Committee (BESAC) meeting, in Germantown, Maryland.

This report is also available on the following web site:

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