Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending February 1, 2020, are as follows:

NSTX-U RECOVERY (J. GALAYDA) AND RESEARCH (S. KAYE)

Recovery (J. Galayda):

Coils — Coil fabrication continues at Sigmaphi in France. Winding of the PF1A and PF1B coils is complete, and Sigmaphi and PPPL are reviewing readiness to transition to the VPI molding process. The PF1A #2 mandrel and PF1C mandrel #1 were built, tested, and are now in France. Delivery at Sigmaphi is expected next week.

CSC — The Center Stack Casing (CSC) components are being prepped for assembly and welding at the Turtle Creek facility in Pennsylvania. The angled sections are currently being machined. A weld consultant, the engineering COG, and Quality Assurance have been on site providing oversight of the assembly process. NSTX-U Recovery Project leadership and the ORT/Holtec project team met to discuss potential schedule recovery methods that could be employed to recover increasing concern about the delivery schedule.

HTT HTP — The machining of the heat transfer plates continues at Hollis Line in New Hampshire. The contractor has successfully straightened the plates and achieved flatness. Accessory parts are being fabricated and PPPL engineering will be visiting the facility next week to review progress and provide oversight.

NSTX-U Test Cell (NTC) Shielding — BOA Subcontractor 3BD Contracting completed pumping of shielding grout into the ground floor-accessible ports. Pumping will continue upon installation of scaffolding required to reach upper elevations. Also, 3BD commenced installation of scaffolding in the NTC.

Radiation Monitoring System — Powers Electric continues installation of the radiation monitoring system.

NSTX-U Personnel Safety System FDR — The final design review (FDR) for the NSTX-U Personnel Safety System was held on Jan. 28 and 29. This Herculean effort was the successful culmination of almost two years of design reviews and peer reviews for this scope. The scope grew out of a need to re-design the existing NSTX-U hardwired interlock system in order to be consistent with community expectations and commercial industry standards.

Alternate to Aerodag FDR — An FDR was held Jan. 30 to assess the final design of an alternative to the Aerodag spray-on coating used to darken areas of the NSTX-U vacuum vessel. The FDR reported on the process since the conceptual and preliminary design reviews. The proposed redesign consists of covering relevant areas of the vacuum vessel with blackened stainless-steel plates per Mil-C-13924 Class 3 black oxide treatment.

Machine Instrumentation: Sling Pre-Load Sensor and Vessel Thermal Displacement Measurement FDR — A final design review was held Jan. 30 to assess a proposed measurement system to gather data on the preload for the inner PF Coils. An earlier FDR was held on Oct. 25, 2019 that covered additional scope not addressed in this review.

Research (S. Kaye):

Community-wide video conferences were held on Jan. 27 and 30 to elicit input for the development of the NSTX-U Five Year Research Plan (2021-2025). W. Guttenfelder led the Jan. 27 presentation/discussion on Objective 1 of the Five Year Plan titled, “Extend confinement and stability physics basis at low-A and high beta to lower collisionality relevant to burning plasma regimes,” and D. Battaglia led the Jan. 30 presentation/discussion on Objective 2 titled, “Develop operation at large bootstrap fraction and advance the physics basis required for non-inductive, high-performance and low-disruptivity operation of steady-state compact fusion devices.” The third video conference will be held on Feb. 3 on Objective 3 titled, “Develop and evaluate conventional and innovative power and particle handling techniques to optimize plasma exhaust in high performance scenarios.” This presentation/discussion will be led by R. Maingi.

F. Poli traveled to New Mexico to visit Los Alamos National Laboratory and Sandia National Laboratory as part of the Oppenheimer Science and Energy Leadership Program Cohort 4 (OSELP). The Cohort, which includes future leaders representing the DOE national labs across the nation, met with directors and group leaders to learn their best practices and organizational structure and to discuss operational procedures and challenges. The visit, which is unclassified, included a tour of some of the laboratory facilities.

U.S. ITER FABRICATION (H. NEILSON)

The ITER Diagnostics Team continues its progress in the final design of the in-vessel antenna assembly for the Low Field Side Reflectometer (LFSR). Integration of the equipment into the Port 11 diagnostic shield module (DSM) has required an extended design effort, now completed, to resolve space conflicts within the crowded confines of the DSM. The space management task has been coordinated by engineer M. Duco, who

this week formally uploaded a so-called “skeleton” model to the ITER plant modeling system. Following confirmation of the LFSR model by the Port Integration team and ITER management, the LFSR space claim within the DSM will be finalized, enabling the team to proceed with details and documentation for a final design review, now planned for June 2020.

The Laboratory’s ITER team has received authorization to resume work on diagnostic projects that have been suspended since mid-2017. Actions have been initiated toward placing new subcontracts with partner institutions. A staffing plan is being developed in cooperation with PPPL Engineering, and recruiting efforts are under way. Resumption of this work will enable U.S. ITER to address critical design integration issues that could otherwise impede progress on the work of other ITER parties or put U.S. diagnostics at risk.

ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson)

Research:

On Jan. 27, N. Logan gave a seminar presentation to the MST1 Eurofusion task force entitled, “Empirical Scaling of the n=2 Error Field Penetration Threshold.” The presentation introduced a new multi-device, multi-parameter scaling for the n=2 error field (EF) threshold in ohmic and L-mode plasmas. The n=2 threshold is shown to be on the same order of magnitude as n=1 in current machines, and has notable similarities in its scaling behavior. There was genuine interest in the new EF threshold work, and discussions pointed out opportunities for Eurofusion machines to contribute valuable data to the ITPA MDC-19 database.

A new, fast neural net (NN) has been trained to predict the MHD stability of wide pedestal quiescent H-mode (WPQH) plasmas in DIII-D and neoclassical toroidal viscosity (NTV) torque. This NN has been trained on approximately 1800 runs of the Generalize Perturbed Equilibrium Code (GPEC) using equilibria and associated profiles from the TRANSP run database of WPQH experimental analysis. It provides, at a speed applicable for real-time control, an NTV torque-by-coil matrix that will be used for model-based control of the edge rotation shear thought to be important for WPQH physics.

Operations:

A new machine-learning algorithm for plasma profile prediction and real-time experimental control developed by J. Abbate and R. Conlin (Princeton University, E. Kolemen Group), trained on 10,000 DIII-D shots, has been implemented in the DIII-D plasma control system using a new integrating machine learning and control architecture developed by K. Erickson. With the advantage of making predictions in milliseconds, and only information from past time steps taken as input, this algorithm makes model-predictive control of profiles on DIII-D possible. The fully data-driven machine learning algorithm predicts the evolution of 1D profiles of plasma parameters (Te, Ti, ne, impurity density, rotation) given a set of proposed actuations. This model uses data from experiments spanning 2010-2018, constituting hundreds of thousands of plasma profiles. In a recent experiment led by Abbate and Conlin, the algorithm ran in real time to reach a user-targeted electron temperature profile via control of the injected power and plasma current. By simulating the effect of multiple possible actions at the same time, the algorithm can decide on the action that minimizes the error between the predicted state and a user specified target. Moving forward, the algorithm will be upgraded to control puffed gas and electron cyclotron heating power.

International PMI and FES LM PFC Development Program (R. Maingi):

R. Maingi conducted a periodic technical meeting for the domestic liquid metal plasma-facing component development program. Speakers included S. Smolentsev (University of California - Los Angeles) presenting new liquid metal MHD flow calculations for a reactor concept, E. Kolemen (Princeton University/PPPL) on recent results from the Liquid Metal Experiment, and D. Andruczyk (University of Illinois at Urbana-Champaign) on plans for liquid lithium substrate wetting experiments at UIUC.

R. Maingi presented a Science on Saturday talk at PPPL on Jan. 25 titled, “The Boundary Layer in Fusion Plasmas: Where the Fourth State of Matter Meets the Other Three.” The talk covered:

- the basic principles of interactions between plasma and materials,
- how to design the boundary layer plasma properties and resulting impacts on choices for materials, and
- a growing worldwide effort to determine if liquid metals can be advantageously used next to the boundary layer

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ITER-JET (M. Podestà, F. Poli):

M. Vallar (SPC-Lausanne, Switzerland) visited PPPL Jan. 21-31 to discuss collaborative research within the ongoing PPPL-JET/EU grant on validation of energetic particle (EP) physics models. Matteo worked with M. Podestà (PPPL) on the application of the TRANSP + kick model analysis for EP transport simulations of TCV scenarios. The initial focus is on the effects of sawtooth instabilities in both positive and negative triangularity TCV plasmas, with future work targeting other instabilities such as NTMs and Alfvénic modes. During his visit, Vallar gave a seminar on ongoing EP research activities at SPC-Lausanne, including future plans for the commissioning of additional fast ion diagnostics and a second neutral beam injector on the TCV tokamak in FY-20.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates):

F. Nespoli took part in the 3rd LHD workshop in Toki, Japan, Jan. 30-31 and presented a talk titled, "Impurity powder injection experiments in LHD." The presentation reports on the first successful experiments performed in LHD during December and January, featuring the PPPL-designed and -built impurity powder dropper. In particular, positive wall conditioning effects are observed after the cumulative injection of boron and boron nitride powder.

An article entitled, "A new mechanism for filament disconnection at the X-point: poloidal shear in radial EXB velocity," by F. Nespoli, P. Tamain, N. Fedorczak, D. Galassi, and Y. Marandet was accepted for publication in *Nuclear Fusion* on Jan. 23. The paper evaluates the effect of the steady state sheared flow, naturally arising at the tokamak's X-point, on blob dynamics, concluding it can act together with the local squeezing of the flux tubes to disconnect the turbulent fluctuations in the main scrape-off layer from the divertor legs.

THEORY (S. HUDSON)

On Jan. 21, W. W. Lee gave a seminar, followed by discussions, to Z. Lin's plasma simulation group at University of California at Irvine titled, "Numerical considerations for simulating the H-mode physics using gyrokinetic codes." Collaboration on this topic is underway.

C. Clauser gave a seminar at the Bariloche Atomic Center in Argentina titled, "Disruption studies in tokamaks with the M3D-C1 Code." In the first part, he presented the main features of the code, including the physics and numerical methods. In the second part, he presented how the code addresses the disruption problem in tokamaks and the

studies on vertical displacement events that we are conducting at PPPL showing and discussing the main results.

H. Qin presented a seminar titled, “Structure-preserving geometric algorithms (II)” on Jan. 24 at the Tokamak Disruption Simulation Center Weekly Webinar. The recently developed structure-preserving geometric particle-in-cell algorithms were introduced. Technical details on discrete field theory for particle-field systems, Whitney forms and high-order interpolation forms, discrete gauge symmetry, and explicit non-canonical splitting integrators were discussed.

DIRECTOR’S OFFICE (S. COWLEY)

J. Menard participated in the Innovation XLab Biomanufacturing Summit hosted by Lawrence Berkeley National Laboratory in Berkeley, California, Jan. 28-29. Menard also attended a National Laboratory Chief Research Officers (NLCRO) meeting where discussions took place about long-term strategy.

C. Ferguson hosted a Construction Safety Assessment meeting on Jan. 28. Ferguson hosted an Engineering Program Review Committee Jan. 29-30.

This report is also available on the following web site:

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