Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending March 2, 2019 are as follows:

NSTX-U RECOVERY AND RESEARCH (J. MENARD)

Recovery:

Project Management: Documentation and presentations for the basis of estimate review (BOER) were made available to the review committee on March 1 to provide a two-week review period in advance of the in-person BOER meeting to be held at PPPL on March 18-20. Informational webinars by the recovery team have also been scheduled to guide panel members through the cost and schedule information and answer any preliminary questions before the panel arrives on site.

Magnets: The inner poloidal field (PF) coil procurement bids are in and under evaluation. The G11 coil spacer is being machined off-site and the mandrel wedge procurement has been placed. The magnet team will take partial shipment on the first set of mandrels required for the first coil pull in a ten-week delivery that is close to the coil critical path. Shipping arrangements are being made to ship some of the conductors from ICAS Tratos in Italy to PPPL, and the remaining conductors will be shipped directly to participating vendors once procurement decisions are made. The coil shop has signed off on the co-winding procedure, and the clean room is being prepared to begin co-winding of the insulation and Kapton tape next week.

Inner PF Replacement Coils: A successful preliminary design review (PDR) was held on Feb. 28 to review the inner PF coil terminal support design, the coil hard bus bar and bus bar support design, and the inner PF flex bus support design. This PDR supports the results of the inner PF replacement coil final design review (FDR) held in March 2018 in which it was determined the coil terminal supports needed design improvements. The PDR was deemed successful, pending resolution of chits.

Research:

Collaborations: M. Ono attended the 2019 KSTAR Conference in Seoul, Korea, Feb. 20-22. The conference also celebrated the 10th anniversary of KSTAR Advanced Tokamak Experiments. Ono gave an invited talk entitled, “NSTX-U Spherical Tokamak Program and Possible Synergistic Collaboration Areas for the KSTAR Program.” As a part of spherical tokamak collaboration, he also visited the VEST spherical tokamak group at the Seoul National University in Seoul.

S. Sabbagh, Y.-S. Park, and K. Erickson attended the 2019 KSTAR Conference and gave presentations on research under a multi-institutional collaboration on disruption prediction and avoidance in long-pulse, high-beta plasmas in KSTAR. The presentations

were titled, “Progress on Disruption Prediction Capability Including Transport and Stability Analysis of High-Performance KSTAR Plasmas,” and “Expanded Study of the Generalized Neoclassical Toroidal Viscosity Offset Rotation Profile in KSTAR” (S. Sabbagh), “MHD stability and active mode control analysis for high-beta plasma operation in KSTAR” (Y.S. Park), and “Real-Time MHD Analysis Computer System Design, Architecture, and Integration with PCS” (K. Erickson). Meetings were held regarding the continuing research and included details on the installation of real-time MHD analysis on KSTAR.

U.S. ITER FABRICATION (H. NEILSON)

The ITER Low-Field-Side Reflectometer (LFSR) team is preparing an important test to refine requirements for mitigating the effects of stray microwave reflections, which can propagate back to the receiving antenna and be detected as noise. Such reflections can result from the presence of neighboring metallic surfaces, including antennas in the LFSR array, local walls, and the antenna support structure. To study this effect, a stray radiation test article, designed to mock-up the local geometry of metallic surfaces in detail, will be fabricated at the Laboratory and installed on the LFSR microwave test stand at General Atomics (GA). Tests will be conducted to measure stray radiation and compare results with earlier tests performed with simpler, non-prototypical reflection environments. This week a design review of the stray radiation test article was conducted. Project scientist C. Muscatello (GA) presented the test plan and test article requirements, while PPPL engineer M. Sibilia presented the design and manufacturing plans. A suggested modification to improve the flexibility of the design was adopted. The review, chaired by PPPL’s M. Safabakhsh, was judged successful pending resolution of two minor chits.

ITER & TOKAMAKS (R. NAZIKIAN)

The paper titled, “Simultaneous detection of neoclassical tearing mode and electron cyclotron current drive locations using electron cyclotron emission in DIII-D,” (https://doi.org/10.1016/j.fusengdes.2019.02.089) by A. Nelson, R. La Haye, E. Austin, A. Welander, and E. Kolemen was published in *Fusion Engineering and Design*. Accurate real-time measurements of magnetic island and electron cyclotron current drive (ECCD) locations are essential for efficient suppression of the neoclassical tearing mode (NTM). To determine these locations, many control systems rely on motional Stark effect constrained equilibria reconstruction and real-time Thomson scattering with TORBEAM current drive evaluation and therefore require time-intensive cross-calibration of at least two different diagnostics. Here we present a simpler, proof-of-concept analysis that uses only a single diagnostic (a radial array electron cyclotron emission radiometer)

for the simultaneous determination of both the radial position of a magnetic island and the deposition location of ECCD. Measurements are compared with the modified Rutherford equation to demonstrate the effect of ECCD alignment on NTM suppression.

DIII-D (B. Grierson):

Research:

N. Logan presented an invited talk at the KSTAR conference titled, "Harnessing the Multi-Modal 3D Response of KSTAR." This talk highlighted the power of the GPEC inherently multi-modal matrix formalism for calculating the 3D perturbed equilibrium. It covered the successes of predicting ELM suppression windows in the five-dimensional KSTAR coil configuration space before showing how recent model improvements can directly optimize the coil configurations for a variety of desired NTV torque profiles. The conference also featured new advanced profile analysis and TRANSP tools for KSTAR within the OMFIT framework, accomplishments made through a recent collaboration between PPPL and KSTAR. These new predictive modeling and data analysis tools were well received and were considered a highlight of the conference.

Operations:

International PMI (R. Maingi):

R. Maingi (PPPL) and K. Tritz (JHU) visited EAST to collaborate on experiment analysis, paper preparation, and planning. Maingi also presented a seminar titled, "Real-time impurity injection for wall conditioning, ELM and H-mode pedestal control, and divertor exhaust enhancement." The talk covered recent impurity powder dropper results from all over the world.

A paper titled, "Real-time wall conditioning with lithium powder injection in long-pulse H mode plasmas in EAST with tungsten divertor" by Z. Sun (PPPL), et al, was published in *Nuclear Materials and Energy*. The paper highlights the role of the lithium powder dropper in achieving 100-second-long H-mode pulses in EAST.

International Long Pulse (F. Poli):

F. Poli visited Seoul National University on Feb. 25 and gave a seminar titled, "The challenges of integrated tokamak modeling and the path forward to a Whole Device Model." The talk reviewed the current status of integrated modeling for discharge prediction and noted outstanding gaps that need to be filled to develop a comprehensive model.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

S. Lazerson visited PPPL the week of Feb. 25 to complete preparatory tasks regarding a prototype fast-ion loss detector under development for W7-X. Lazerson and C. Freeman worked to test the data acquisition and logarithmic amplifier interface. Here data acquisition is accomplished with the use of a LabJack U6-Pro and a graphical user interface developed in Python with QT4. The logarithmic amplifiers designed and calibrated by Freeman performed well and the system was deemed ready for testing. The detector holder was also wired and inspected in this period. During his visit, Lazerson presented a talk to the NSTX-U/Magnetic Fusion Science Meeting entitled, “Energetic Particles in Wendelstein 7-X.” The talk covered initial results from NBI experiments conducted by Lazerson, plans for benchmarking the BEAMS3D code, and an overview of the prototype detector development. The talk was well received and engaged the audience.

System Design Collaborations

The Laboratory has compiled a draft report of its most recent work on S. Korea’s K-DEMO concept design study and submitted it to the project leader, S.-H. Hong of the National Fusion Research Institute (NFRI), for review. The work includes a detailed study of plasma current ramp-up in K-DEMO, examining the central solenoid and poloidal field coil currents and forces and checking against limits. Time-dependent simulations were performed using the Tokamak Simulation Code (TSC) to account for the time evolution of plasma properties such as the transition to a diverted configuration and rise in beta in the analysis. Also reported was a study of vertical launch electron cyclotron wave current drive, including scans over launcher position, frequency, and launched wave direction (varying both poloidal and toroidal angle). Both single-ray and finite beam-width analyses were performed. In terms of current drive efficiency, no advantage over near-midplance launch positions was found. Configuration studies continue to advance the optimization of in-vessel components for maintenance. The work was extended to investigate the handling and transport of the blanket sectors from their specified locations within the vacuum vessel out through the vertical ports and eventually to an exterior storage and maintenance facility. Looking beyond the tokamak itself, the study examined facility requirements such as the space requirements for storage and maintenance of removed components, transfer routes through the complex, and facilities for waste packaging, such as compaction, prior to off-site shipment. The report makes the information from these studies available to NFRI for use in their continued optimization of the design, but also advances the understanding of fusion reactor design

more generally. The work was performed by C. Kessel, D. Mikkelsen, T. Brown, and P. Titus.

THEORY (S. HUDSON)

M. Cole gave a talk at the Max Planck Princeton Center Workshop 2019 at Tokyo University titled, "Ion-scale microinstabilities in Wendelstein 7-X with XGC." The talk detailed ongoing developments of the XGC global gyrokinetic code to study stellarator geometry. A successful benchmark for linear ITG in the Wendelstein 7-X optimized stellarator was presented as well as preliminary results of linear simulations using experimentally derived Wendelstein 7-X equilibria and plasma profiles.

D. Stotler presented a paper at the 2018 PSI meeting titled, "Shadowing effects in simulated Alcator C-Mod gas puff imaging data," that has been published in *Nuclear Materials and Energy* and is now online (https://doi.org/10.1016/j.nme.2019.02.008). The paper describes the application of a synthetic gas puff imaging (GPI) diagnostic, constructed with the DEGAS 2 neutral transport code, to investigate the effect of turbulent plasma fluctuations on the GPI gas puff. For the turbulent XGC1 simulation used as the basis for the diagnostic, a significant "shadowing" effect was found, indicating that GPI would be unreliable as a turbulence diagnostic in this case.

W. W. Lee gave a theory seminar entitled, "Finite Larmor Radius effects at the high-confinement mode pedestal and the related force-free steady state." The talk is based on a recent manuscript, co-authored by R. White, that relates the previous calculations of the radial electric field at the high-confinement H-mode pedestal [PoP 23, 070705 (2016) and PoP 24, 081204 (2017)] with the actual magnetic fusion experimental measurements. The new pressure balance due to the ExB current, which is induced by the resulting radial electric field, was discussed. Its impact on the gyrokinetic MHD equations as well as their conservation properties in the force-free steady state was also discussed. The recent controversy on the H-mode physics was addressed.

J. Juno gave a presentation at the Max Planck Princeton Center Workshop 2019 at Tokyo University titled, "Discretizing the Vlasov-Maxwell system on a grid ... and applications." The talk presented a novel algorithm for the numerical solution of the Vlasov-Maxwell system of equations that uses high-order discontinuous Galerkin finite elements to discretize the system on a phase space grid. The resulting numerical method is robust and retains a number of important properties of the continuous system including conservation of mass and energy. The talk also discussed a number of discoveries concerning the computational implementation of the algorithm that bring the cost of directly discretizing the Vlasov-Maxwell system down tremendously and demonstrated

the utility of the solver on the study of basic plasma instabilities that yield new insight thanks to the high signal-to-noise ratio inherent in the continuum approach.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

SCIENCE EDUCATION (A. Zwicker):

On Feb. 22, PPPL hosted the 2019 NJ Regional Middle School Science Bowl. Approximately 100 middle schoolers participated in the *Jeopardy*-style quiz competition answering questions from all areas of STEM. Princeton Charter Middle School won first place and will represent New Jersey at Nationals in Washington, D.C. at the end of April.

On Feb. 23, PPPL hosted the 2019 NJ Regional High School Science Bowl. Approximately 100 high schoolers participated in the *Jeopardy*-style quiz competition answering questions from all areas of STEM. Ridge High School won first place and will represent New Jersey at Nationals in Washington, D.C. at the end of April.

The events were organized by D. Ortiz-Arias, Science Education Program Manager. Approximately 50 PPPL staff and Princeton University graduate students volunteered in a variety of roles during the two-day event. A HUGE thank you to all who were involved and helped!

COMMUNICATIONS (L. BERNARD)

The Office of Communications posted one press release to the PPPL website. It noted that Ridge High School and Princeton Charter School will go to Washington, D.C., for the National Science Bowl finals competition. The story was also posted to the *Newswise* press release distribution service.

This report is also available on the following web site:

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