Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending March 31, 2017 are as follows:

U.S. ITER FABRICATION (H. NEILSON):

ITER Steady State Electrical Network (J. Dellas):

Power Transformers: A draft contract amendment for the Site Support Services has been submitted to the supplier. Final inspection report from the supplier and signed contract amendment is pending.

Reactive Power Compensators: Manufacturing at the Schneider Pringy, France, factory is ongoing. Previously, Lot 3 did not pass the dielectric withstand test due to a faulty insulator. The corrected switch has been received back and a retest/inspection of the Lot 3 units has been arranged for April 4th and 5th. The RFS for the first two shipping lots has been approved. The planned shipping date of the first two lots was April 5, however, due to storage space availability issues at the IO site, the IO has requested to delay the shipment. The new ship date has been scheduled for April 19.

UPS, DC Distribution: The UPS contract was officially "Released for Manufacturing" on March 30. This is the final RFM to be issued for the US ITER SSEN procurements.

LV Distribution & Sub-distribution Panels: Arrangement has been signed which transfers to IO-CT the responsibility to procure, on behalf of US ITER, along with UPS and DC Distribution batteries. Full payment for the arrangement has been made to the ITER Organization. A single credit request of 2.16 KIUA for IP LV Distribution will be made upon delivery of the UPS and DC Distribution equipment.

ITER Diagnostics (R. Feder):

Upper Wide Angle View VIS-IR Cameras (UWAVS): Upper Wide Angle View VIS-IR Cameras (UWAVs): The Visible and InfraRed Back End Optical Chamber camera and filter design continues. The Instrumentation and control effort has also begun. We have discovered that there is a steep learning curve. Meetings continue to define the scope of work for each participant: GA, PPPL and Bertin.

Upper Port Plugs 11 & 14: Neutronics analysis report for UP14 is filled in IDM. This report will be used as a reference in the UP14 Load Spec document.

Toroidal Interferometer Polarimeter (TIP): While the IO Safety Department finds the tritium confinement strategy proposed by the TIP team likely to be satisfactory, they have requested that a calculation be performed to compute expected migration of gas from the port cell area into the relay tubes, against the pressure gradient.

NSTX-U RECOVERY PROJECT (R. HAWRYLUK):

The Design Verification and Validation Review (DVVR's) of the NSTX-U Vacuum and Fueling systems was held this week, and observation/suggestions (chits) are now being organized into corrective actions. This was the ninth of twelve. The external reviewers included Paul LaMarche (PU), Hatt Hansink (GA), Rui Viera (MIT), and Jim Irby (MIT).

A charge letter, preliminary agenda and Systems Design Description for the NSTX-U Bakeout System DVVR, scheduled for March 30, was distributed to the review team.

The assembled neutral beam ion source slated to be our first spare has successfully completed hydrostatic testing, and is expected to be ready for electrical insulation testing next week.

Regarding test cell work, initial machining of the Poloidal-CHERS diagnostic in-vessel passive plates has been completed, and fit-ups are in progress in preparation for completing modifications to the mounting structures. Installation and alignment of waveguides for the FIReTIPS diagnostic continues, and the removal of the Deposition Monitor and Dust Collector from the NSTX-U vessel has started. The bay H mid-plane port cover has been removed from the vessel to provide access for repair of a known leak on the neutral beam armor plates.

The lower guide bearing shoes of motor generator (MG#1) have been removed to allow for a full inspection of the shaft journal.

NSTX-U RESEARCH (J. MENARD):

The paper titled "Perturbative momentum transport in MAST L-mode plasmas" by W. Guttenfelder et al. was published in Nuclear Fusion. The paper is a result of a PPPL-CCFE collaborative experiment run during the NSTX Upgrade outage as part of an ITPA activity. It investigates the measurement and prediction of momentum pinch in MAST L-modes to complement previous experiments and analysis reported for NSTX.

O. Izacard (LLNL, in research assignment at PPPL) published the article entitled "Generalized fluid theory including non-Maxwellian kinetic effects" in the special issue of Journal of Plasma Physics 83 (2017) 595830201 for the N. Fisch symposium on Solved and Unsolved Problems in Plasma Physics. The main result of the proposed generalized fluid theory is the discovery of the origin of particle diffusion and heat conduction via the interpreted non-Maxwellian (called INMDF). The diffusion and conduction are due to the competition between a growing INMDF on short time scales due to spatial gradients and the thermalization toward the Maxwellian on longer time scales. The new non-Maxwellian fluid equations could initiate the next generation of fluid codes including kinetic effects and can be expanded to other scientific disciplines such as astrophysics, condensed matter or hydrodynamics.

S. Sabbagh attended the DIII-D Program Advisory Committee as a committee member.

ITER & TOKAMAKS (R. NAZIKIAN):

International:

R. Maingi held a bi-weekly conference call for the EAST PMI PI's. The PI's were debriefed on the EAST General Planning Meeting during this call. A follow-up call between ORNL and PPPL on pump plenum design calculations was held, as was a call to plan out impurity injection and transport experiments on EAST. Finally a call was held on using the EAST MAPES system for a test of the F depth markers for net erosion studies, led by MIT.

DIII-D:

H. Neilson chaired the 2017 meeting of the DIII-D Program Advisory Committee, held 28-30 March at General Atomics in San Diego. The committee responded to charges related to DIII-D's five-year planning process, addressing research and facility upgrade plans in the areas of burning plasma core, boundary solutions, and core-edge integration. A debrief of the committee's conclusions was presented to the DIII-D and DOE Fusion Energy Sciences staff on 30 march. A written report is in preparation.

The article "Mitigation of divertor heat flux by high-frequency ELM pacing with non-fuel pellet injection in DIII-D," by A. Bortolon et al. has been published in Nuclear Materials and Energy. The article reports analysis of ELM pacing by injection of Li granules in DIII-D, including injection in ITER-baseline plasmas. The results show that paced ELM in some conditions can show a broad distribution of ELM peak flux. This is despite the fact that the ELMs are well paced. This broad distribution limits the quality of ELM mitigation by ELM pacing. Striations in the far SOL are documented in the visible and IR. These are correlated with granule ablation events and suggest energy and particle losses associated with the magnetic perturbations induced by the granule injection.

B. Grierson held a videoconference between GA and PPPL on the neutral beam calorimeter design. The meeting focused on validating copper melt curves calculated by PPPL engineers to be used in the calorimeter design. A DIII-D database of calorimeter pulses for a range of heat flux and beam duration were used to assess the proximity to the theoretical melt point for copper. It was found that the calorimeters with no indication of melting were operated below the theoretical melt point. One set of beam lines, for which the calorimeters do show melting, was found to operate above the melt point on one occasion, coinciding with the date that issues with the calorimeter were detected. This validation of the copper melt curves allows the calorimeter design to proceed with confidence.

M. Knolker is participating in multi week collaboration with scientists from ASDEX-U to measure divertor surface layers on DIII-D tiles and discuss IR measurement methods. The goal of this research is to standardize ELM measurements and work on the latest Eich model for assessing ELM energy densities.

This week A. Nagy held a design review for the NB Local Control System (LCS) 5 and 6 configuration. A new configuration is needed due to the noise and ground loop issues found in the first system LCS8. The new system uses extensive noise suppression and fiber optic communication to the satellite power supply systems. This approach was found to resolve issues with LCS 8.

ADVANCED PROJECTS (H. NEILSON):

Stellarators (D. Gates):

S. Lazerson and N. Pablant attended the W7-X OP1.2a run planning workshop at the Max Planck Institut für Plasmaphysik, which was held in Greifswald Germany from March 27 – 31.This workshop, focused on preparations for the upcoming experimental campaign on the device, which will now begin divertor operation for pulse lengths up to 10s. Lazerson presented an overview of Task Force IV, Scenarios and Integration, serving in his role as a Task Force leader. Discussions focused on prioritization of magnetic configurations and heating scenarios for this first campaign.

R. Miller and D. Loesser assisted IPP W7-X technician staff with the re-assembly and trial installation of the TDU-SE components into a W7-X vacuum vessel mock-up and than afterward performed a trial insertion into the actual W7-X vessel. All the test and assembly efforts were successful. The final installation into W7-X is expected later this year.

THEORY (A. BHATTACHARJEE):

On March 30, Botsz Huang (Sokendai, The Graduate University for Advanced Studies, Toki, Japan) presented a theory seminar on Improved Neoclassical Transport Simulation for Helical Plasmas. This work contains the following studies: (1) benchmark of the neoclassical transport models and clarify the impact of their approximations among drift-kinetic equations in helical plasmas. (2) apply the local models for a quantitative evaluation of bootstrap current in FFHR-d1 DEMO. In the part 1, this work reports that the benchmarks of the neoclassical transport codes based on the several local drift-kinetic models. The drift-kinetic models are zero-orbit-width (ZOW), zero-magnetic-drift (ZMD), DKES-like, and global, as classified in [Matsuoka et al., Phys. Plasmas 22, 072511 (2015)]. The magnetic geometries of HSX, LHD, and W7-X are employed. It is found that the assumption of $E \times B$ incompressibility causes discrepancy of neoclassical radial flux and parallel flow among the models when $E \times B$ is sufficiently large compared to the magnetic drift velocities. For example, $Mp \leq 0.4$ where Mp is the poloidal Mach number. On the other hand, when $E \times B$ and the magnetic drift velocities are comparable, the tangential magnetic drift plays a role in suppressing the unphysical peaking of neoclassical radial-fluxes in the other local models at $Er \simeq 0$. In low collisional frequency plasmas, the tangential drift suppress such unphysical behavior in the radial transport well. This work demonstrates that the ZOW model not only mitigates the unphysical behavior but also implements evaluation of bootstrap current in LHD with the low computation cost compared to the global model. In the part 2, the impact of the parallel momentum conservation on the boot-strap current among the ZOW, DKES, and PENTA models are demonstrated. The ZOW model is extended to include the ion parallel mean flow effect on the electron-ion parallel friction. The

DKES model employs the pitch-angle-scattering as the collision operator. The PENTA code employs the Sugama-Nishimura method to correct the momentum balance of DKES results. Therefore, the ZOW model and PENTA codes both conserve the parallel momentum in like-species collisions and include the electron-ion parallel frictions. The work shows that the ZOW and the PENTA code agree with each other well on the calculations of the bootstrap current. Then, this verifies the reliability of the bootstrap current calculation with the ZOW model and the PENTA code for FFHR-d1 DEMO.

I. Dodin (PPPL) and Alexey Arefiev (U. Texas-Austin) published a paper "Parametric decay of plasma waves near the upper-hybrid resonance" [Phys. Plasmas 24, 032119 (2017), that describes an instability of an intense X wave with respect to a parametric decay into an electron Bernstein wave and a lower-hybrid wave. The proposed theory extends to the high-intensity regime, where the instability rate ceases to be a linear function of the incident-wave amplitude. An explicit formula for this rate is derived and expressed in terms of cold-plasma parameters. Theory predictions are in reasonable agreement with the results of the particle-in-cell simulations presented in a separate publication.

Paul Messina, Head of the DOE Exascale Computing Project (ECP), visited PPPL on March 29 and March 30. Members of the Theory Department made short presentations on the following topics: A. Bhattacharjee, "Introduction to our ECP Whole Device Model project, its importance to FES and the fusion community, synergies with SciDAC, PPPL flagship computing"; C.-S. Chang, "Boundary Physics and the XGC code"; S. Jardin, "Macroscopic stability and the M3D-C1 code"; I. Kaganovich, "Plasma-Material Interaction Simulations"; G. Hammett, "New Algorithms"; W. Tang, "Machine Learning Methods for Disruption Prediction"; A. Bhattacharjee, "High-Energy-Density-Physics and Space Weather Connections".

Computational Plasma Physics Group (S. Kaye, S. Jardin):

In an effort to speed up PT_SOLVER execution in TRANSP, the Interpolated Differential Operator (IDO) scheme has been implemented in PT_SOLVER by X. Yuan. The IDO scheme solves the particle density, electron and ion energy, and angular momentum equations and their associated derivative equations at the simultaneously. The high order derivatives required by the IDO discretization equations are calculated by using spline curve reconstruction method and fourth order compact scheme. The backward Euler method is used to advance the transport equation implicitly. Initial tests with limited TFTR, D3D and ITER cases show that the new IDO scheme converges to similar results as the existing PT_SOLVER using the TGLF and Chang-Hilton models, but with improved robustness. This new IDO algorithm in PT_SOLVER has similar namelist inputs, with only one different switch. The algorithm will be available for beta testing soon.

Two CPPG student interns, Matthew Parsons and Ante Qu, have recently been awarded National Science Foundation Graduate Research Fellowships. Both students were in the Department Of Energy Science Undergraduate Laboratory Internship (SULI) program at PPPL and mentored by Stephane Ethier and Eliot Feibush. Ante Qu is now in the Ph.D. program at Stanford in computer science, with a strong interest in computer graphics and scientific visualization. Matthew Parsons is currently at ITER on his Fulbright scholarship, to be followed by Ph.D. studies at the University of Illinois.

PLASMA SCIENCE & TECHNOLOGY (P. EFTHIMION):

W. Fox, F. Sciortino, A. v. Stechow, J. Jara-Almonte, J. Yoo, H. Ji, and M. Yamada published a paper "Experimental Verification of the Role of Electron Pressure in Fast Magnetic Reconnection with a Guide Field" has been published in Physical Review Letters. [PRL 118, 125002 (2017)], The work, conducted at the MRX experiment, reports detailed laboratory observations of the structure of a reconnection current sheet in a two-fluid plasma regime with a guide magnetic field. We observe and quantitatively analyze the quadrupolar electron pressure variation in the ion-diffusion region, as originally predicted by extended magnetohydrodynamics simulations. The projection of the electron pressure gradient parallel to the magnetic field contributes significantly to balancing the parallel electric field, and the resulting cross-field electron jets in the reconnection layer are diamagnetic in origin. These results demonstrate how parallel and perpendicular force balance are coupled in guide field reconnection and confirm basic theoretical models of the importance of electron pressure gradients for obtaining fast magnetic reconnection. The work was a collaborative effort through the Max-Planck Princeton Center for Plasma Physics involving researchers from the MRX group at PPPL and IPP Greifswald.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER):

Science Education (A. Zwicker):

On March 23, the Annual Young Women's Conference in STEM was held. The event took place on Princeton University's main campus and over 600 young women in grades 7-10 attended, representing over 60 different schools. Seventy-five exhibitors representing over 30 different institutions, including, PPPL, Princeton University and the Federal Bureau of Investigations Evidence Response Team, were present to showcase the various fields of STEM they currently work on. K. Wagner led three Chemistry Shows and Dr. Jyoti Sharma, Chairperson of Women in Engineering IEEE, and Dr. V. Riccardo, Head of PPPL's Engineering Department, were the break-out session speakers through out the day. Dr. Aprille Ericsson, of NASA Goddard Space Flight Center, was the keynote speaker at the event.

This report is also available on the following web site:
http://www.pppl.gov/publication-type/weekly-highlights