Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending June 23, 2017, are as follows:

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

Steady State Electrical Network (J. Dellas):

The Power Transformers procurement continues to move toward completion, with all equipment deliveries having been completed several months ago. The final delivery report has been approved and transfer of warranty ownership and site support acknowledgment are in the final approval stages.

Final inspection reports and transfer of ownership documents for all of the Reactive Power Compensators have been received, and final delivery reports are in preparation.

Diagnostics (R. Feder):

Upper Port Wide Angle Viewing Cameras (UWAVs): The UWAVs systems provide primary machine protection views of the divertor and portions of the lower shield modules to detect hot spots and for operations views of the plasma. There are five UWAVs installations in five different upper port plugs. Significant progress has been made on the camera and filter design for the Back End Optical Chamber (BEOC). The BEOC optics transmits the optical signals into visible and infrared cameras. Recent discussions with Oak Ridge National Laboratory regarding the heat exchanger design clarified requirements for a key silicon carbide component, requiring further design adjustments before locking the design in preparation for a preliminary design review.

NSTX-U RESEARCH (J. MENARD):

NSTX-U researchers contributed to the FESAC TEC PMI sub-panel meeting with an oral presentation titled, "Slowly flowing and high temperature liquid metals as plasma-facing materials." The contribution detailed the potential advantages associated with liquid metal plasma-facing components especially the use of Li as a radiating impurity, even up to very high densities such as in the Li Vapor Box Divertor. M. Jaworski, R. Goldston, and M. Ono co-authored the contribution. M. Jaworski presented at the meeting held in Chicago. R. Majeski presented a talk, "Mitigation of scrape-off layer power flow with lithium plasma-facing surfaces," and E. Kolemen presented "Fast Flowing Liquid Metal Technology for Fusion Reactor Divertor." The meeting was organized and chaired by R. Maingi.

The paper “Effect of 3-D magnetic perturbations on divertor conditions and detachment in tokamak and stellarator,” by J-W. Ahn, et al. has been published in Plasma Physics and Controlled Fusion. This paper is a part of PPCF’s Special Issue Reviewing Divertor Plasma Detachment in Magnetic Fusion Devices. Recent data from two divertor tokamaks (NSTX and DIII-D) and a stellarator (LHD) have been presented, which include both experimental and simulation results for each device. Data from literature search for several other tokamaks and stellarators have also been compared. It is found that the effect of 3-D fields on the ratio of perpendicular to parallel transport is crucial to determine if the transition to detachment is facilitated or hampered by 3-D fields. Limiter tokamaks (TEXTOR and Tore Supra) and stellarators (LHD and W7-AS) can achieve enhanced perpendicular transport by 3-D fields and this leads to early detachment, i.e. transition at lower density. However, parallel transport is still dominant in divertor tokamaks (NSTX and DIII-D) even when 3-D fields and detachment facilitation is not observed. An EMC3-Eirene simulation for ITER H-mode plasmas shows the possibly important role of plasma response in the determination of perpendicular momentum loss that could lead to early detachment induced by 3-D fields.

The paper "Computation of Alfvén Eigenmode stability and saturation through a reduced fast ion transport model in the TRANSP tokamak transport code," by M. Podestà et al. has been published online in Plasma Physics and Controlled Fusion. The paper reports on recent work to explore the use of the fast ion "kick model" in TRANSP for predictive runs. A neutral beam heated NSTX discharge is used as reference to illustrate the potential of the model. Predictive capabilities for computing stability and saturation amplitude of Alfvénic instabilities are first assessed, based on given thermal plasma profiles only. Predictions are then compared to experimental results, and the interpretive capabilities of the model further discussed. The paper shows that the reduced "kick" model captures the main properties of the instabilities and associated effects on the fast ion population. Additional information from the actual experiment enables further tuning of the model's parameters to achieve a close match with measurements.

W. Guttenfelder and Y. Ren visited General Atomics the week of May 19-23 to prepare for two transport related DIII-D/NSTX-U campaign experiments scheduled to run in July. Draft shot plans were reviewed by the BPP-Transport group. Ren also worked with Dr. Y. Zhu of University of California-Davis on the ECEI diagnostic, particularly on how to improve noise shielding.

C. Myers traveled to DIII-D for the week of June 19 to lead a National Campaign experiment titled, "Impact of resonant versus non-resonant 3D fields on n=2 locking." PPPL co-authors on the experiment include N. Logan, J.-K. Park, N. Ferraro, S. Gerhardt, and J. Menard. The experiment is designed to expand the physics understanding of locked mode onset in the presence of applied n=2 fields. Over the course of the full run day (June 21), 35 successful plasmas were acquired on 38 attempts. Key parameter scans included the resonant spectral content of the applied n=2 fields as well as the toroidal field and the plasma density. One major product of the experiments is a series of five-point toroidal field scans in both ohmic and L-mode plasmas. These results will be used to inform the $n > 1$ error field correction strategy for ITER.

ITER & TOKAMAKS (R. NAZIKIAN):

International:

J.K. Park led two experimental sessions in KSTAR on the topic of RMP ELM suppression and magnetic braking. In one experiment, n=1 RMP ELM suppression was obtained for the first time using only off-midplane coils. The experiment was based on an IPEC model prediction that shows optimized edge resonant coupling with a 45 degree phase difference between the upper and lower coils. ELM suppression was also obtained at high beta for up to 20 seconds. The n=1 magnetic breaking experiment was also successful in showing that rotation breaking can be achieved without perturbing particle confinement when using optimized 3D magnetic fields.

DIII-D:

A. Ashourvan performed an analysis of low torque DIII-D discharges during which a radial sweep of X-point position was performed. Comparison between the theory prediction for intrinsic rotation by T. Stoltzfus-Dueck (PPPL) and the main-ion rotation shows good agreement. The observed modulations in the rotation velocity resulting from the X-point sweep are captured by the theory model with good accuracy.

C. Myers and N. Logan conducted an experiment on DIII-D to constrain major parametric dependencies of the n=2 error field locking threshold in an important step towards projecting accurate requirements to ITER. The experiment documented n=2 locking behavior as a function of the applied n=2 field spectrum, toroidal field strength and plasma density in both Ohmic and L-mode plasmas. Preliminary indications are that the n=2 locking threshold decreases with increasing toroidal field, although it is unclear at this time how this dependence is affected by the possibly toroidal field dependent intrinsic n=2 error field in DIII-D.

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ADVANCED PROJECTS (H. NEILSON):

Stellarators (D. Gates):

The Laboratory and the Max Planck Institute for Plasma Physics (IPP) have together made significant progress in improving capabilities for remote data access and remote participation in the Wendelstein 7-X (W7-X) experiment. Improvements in remote access to W7-X data archives, MDSPlus resources, and numerous online resources have been implemented by IPP and tested by PPPL staff. Now, the new capabilities are being tested by other U.S. partners, including Massachusetts Institute of Technology, Oak Ridge National Laboratory, and Auburn University. PPPL Networking Manager P. Henderson has tested a capability for secure cloud-based file sharing using NextCloud that would provide seamless file sharing for all collaborators, providing capabilities that previously were only available to on-site participants. PPPL network engineer S. Kampel arrived at the project site in Greifswald, Germany to begin a four-week visit in which he will collaborate on tasks required to implement a new 10 Gb/sec internet link for the

Greifswald site. It is expected that the combined improvements in functionality and speed will be available at all the U.S. partner sites by the start of plasma operation for the next W7-X campaign, OP1.2, which begins in August.

D. Gates, in his role as chair of the National Stellarator Coordinating Committee, organized submissions to the upcoming U.S. Magnetic Fusion Research Strategic Directions Workshop to be held in Madison, Wisconsin, July 24-28. In total, 11 white papers were submitted describing sections of the "Stellcon report."

S. Lazerson arrived in Greifswald, Germany as part of a two-year stay at the W7-X experiment. During this period he will act as the Scenario and Integration Task Force leader in conjunction with M. Hirsch. Additionally, he will continue his work on developing energetic particle diagnostics and simulations for stellarators. During the upcoming experimental campaign Lazerson will continue experiments to probe the existence of error fields in the device. These measurements will be used to develop scenarios for divertor heat load symmetrization.

N. Pablant, L. Delgado-Aparicio and L.Reusch (University of Wisconsin) traveled to the Dectris manufacturing facility in Baden, Switzerland, to characterize and calibrate two new Pilatus detectors. The Pilatus x-ray detectors are the enabling technology for the XICS spectrometer, and are installed on many machines including W7-X, NSTX, Alcator C-Mod, EAST and KSTAR. The main purpose of this trip was to calibrate two detectors to be used in a multi-energy configuration, which allows each pixel to be sensitive to a different energy range of x-rays. The x-ray group at PPPL developed the technique. These detectors will be installed at MST in Wisconsin and D-IIID at General Atomics, and eventually on NSTX-U. This trip also allowed us to talk with Dectris about our current and future needs for x-ray detection technology.

System Studies (C. Kessel):

PPPL held a conference call with the Korean DEMO team at NFRI where C. Kessel presented time dependent discharge simulations for the K-DEMO design, examining the pedestal, plasma density, impurities, empirical and theory based energy transport models, and incorporating the heating and current drive assessments made by D. Mikkelsen. The post-shutdown nuclear dose rates were reported for the K-DEMO design, focusing on the port region and incorporating a labyrinth to suppress neutron streaming. They were able to reach the required dose levels with material choices and 2-step shaping in the port region. The statement of work for the next K-DEMO contract were briefly reviewed, and a final report will be prepared for NFRI on this years activities which includes facility layout, helicon modeling, and the time-dependent plasma simulations.

THEORY (A. BHATTACHARJEE):

S. Hudson was invited to visit the University of Leiden, Netherlands, June 19 – 21, to serve on the Review Panel for the Doctoral Defense of Christoper Smiet, who defended his dissertation titled "Knots in Plasmas." On June 19, Dr. Hudson attended the International Leiden Symposium on Plasma Physics and presented an invited talk titled, "Cantori, chaotic coordinates and temperature gradients in chaotic magnetic fields." The abstract was: "Using a simple, anisotropic-diffusion model of heat transport for illustration, this paper [S.R. Hudson & J.

Breslau, Phys. Rev. Lett. 100, 095001 (2008)] will show that chaotic fields (without invariant surfaces) can support significant temperature gradients, despite the fact that invariant surfaces may be destroyed by applied error fields. The remnants of the irrational flux surfaces, the cantori, present extremely effective partial-barriers to field-line transport, and thus present effective barriers to any transport process that is dominantly parallel to the field. We extend the concept of magnetic coordinates to chaotic fields by a construction of nearly invariant surfaces known as ghost surfaces, and show that the temperature, generally a function of three-dimensional space, takes the simple form $T(s)$, where s labels the chaotic-coordinate surfaces."

On June 19, D. Pfefferlé was invited to present a colloquium at the University of Western Australia titled, "A hitchhiker's guide to the Boltzmann equation." The Boltzmann equation is a rich and fascinating equation describing non-equilibrium phenomena in various complex systems. Applied to the specific case of multi-species plasmas (coupled to Maxwell's equations), it becomes a particularly challenging 6D non-linear integro-differential equation. In this talk, Pfefferlé gave context to the two "sides" of the Maxwell-Boltzmann equation: the left-hand side (or Vlasov term) relates to the dissipation-less (Hamiltonian) dynamics, while the right-hand side embodies the statistical reorganization of phase-space due to binary Coulomb collisions. A particularly convenient aspect of the left-hand side in the presence of strong magnetic fields is that the dynamics can be reduced from the full orbit to the so-called guiding-centre motion, thereby facilitating the study of certain collisionless transport processes. The phenomenon of bounce tip stochastisation in the ripple field of a tokamak is shown as an example. Such "guiding-centre" reduction of the collision operator on the right-hand side of the Boltzmann equation remains however an open problem, where a proper treatment is required to derive consistent fluid equations. A few ideas are exposed for the case of the Landau collision operator.

On June 22, A. Hakim gave a theory seminar on "Continuum kinetic schemes for Vlasov-Maxwell equations, with applications to laboratory and space plasmas." Increasingly accurate laboratory experiments and satellite observations have led to a "golden age" in plasma physics. Detailed kinetic features, including distribution functions, can now be measured in-situ, putting severe strain on theory and modeling to explain the experiments/observations. The Particle-In-Cell (PIC) method remains a powerful and widely used tool to study such kinetic physics numerically. Recently, complementing the PIC approach, significant progress has been made in discretizing the Vlasov equation directly, treating it as a partial differential equation (PDE) in 6D phase-space. In this talk, Hakim presented a high-order discontinuous Galerkin (DG) algorithm to solve the Vlasov equation. This continuum scheme leads to noise-free solutions and, with the use of specially optimized computational kernels, can be very efficient, in particular, for problems in which the structure of distribution functions and its higher-moments are required. In addition, with a proper choice of basis functions and numerical fluxes, the scheme conserves energy exactly, while conserving momentum to a high degree of accuracy. Applications of the scheme to (a) kinetic saturation mechanism of Wiebel-like instability, and (b) turbulence in the solar wind are presented. We demonstrate a new and novel mechanism for the nonlinear saturation of the Wiebel instability that comes about from a balance between filamentation and a secondary electrostatic two-stream instability. We use 5D simulations of turbulent plasmas to study detailed kinetic physics of magnetized turbulence, showing that the solution contains remarkable amount of detail in the distribution function, leading to new and novel insights the nature of kinetic wave-particle exchange in turbulent plasmas.

D. Stotler participated in the IAEA Research Coordination Meeting on "Data for Atomic Process of Neutral Beams in Fusion Plasmas," held June 19-21 in Vienna, Austria. Stotler's presentation was entitled, "Neutral beam analysis codes used on NSTX-U and DIII-D" and laid out the plans for his team's contributions to the coordinated research project over the next three years. Other members of this team include the project's secondary scientific investigator, B. Grierson, as well as M. Gorelenkova, D. Liu (University of California - Irvine), B. Heidbrink (University of California - Irvine), F. Levinton (Nova Photonics), H. Yuh (Nova Photonics), and R. Bell.

L. Comisso presented a Research and Review Seminar on June 23 titled, "Plasmoid instability as a tearing instability in time-evolving current sheets." The plasmoid instability has had a transformative effect in our understanding of magnetic reconnection in a multitude of systems. By preventing the formation of highly elongated reconnection layers, it has proven to be crucial in enabling the rapid energy conversion rates that are characteristic of many plasma phenomena. In the well-known Sweet-Parker current sheets, the growth of the plasmoid instability occurs at a rate that is proportional to the Lundquist number (S) raised to a positive exponent. For this reason, in large-S systems, Sweet-Parker current sheets cannot be attained as current layers are linearly unstable and undergo disruption before the Sweet-Parker state is attained. Here, we present a quantitative theory of the plasmoid instability in time evolving current sheets based on a principle of least time [L. Comisso, M. Lingam *et al.*, Phys. Plasmas 23, 100702 (2016)]. We obtain analytical expressions for the growth rate, number of plasmoids, plasmoid width, current sheet aspect ratio and onset time for fast reconnection. They are shown to depend on the Lundquist number, the magnetic Prandtl number, the noise of the system, the characteristic rate of current sheet evolution, as well as the thinning process [L. Comisso, M. Lingam *et al.*, to be submitted (2017)]. We validate the obtained analytical scaling relations by comparing them against the full numerical solutions of the principle of least time. Furthermore, we show that the plasmoid instability comprises of a relatively long period of quiescence followed by rapid growth over a shorter timescale**.**

ENGINEERING & INFRASTRUCTURE (V. RICCARDO):

Collaborations: CDR for the GA DIII-D NB Absolute Collimator was carried out.

Fabrication: Held meeting with NSTXU engineering personnel to review the plan to bring Pressure Systems in compliance with ES-MECH-015.

In the CS Coil Winding area 4 Soft Wall Clean room module frames were assembled. The new units fit well into the area and in addition to providing a clean environment for the winding operation provide better lighting to the area.

Document Management System: Polled main campus users for their experience with OnBase software.

BUSINESS OPERATIONS (K. FISCHER):

The RFQ for the furniture procurement for LSB annex as part of the IOI project has been issued. Proposals are due June 30.

ENVIRONMENT, SAFETY, & HEALTH (J. LEVINE):

The FY17 spares inventory for commodities 9601 (D-Site Infrastructure), 9602 (C-Site Infrastructure), and 9603 (Maintenance) was completed with excellent results. The report has been submitted to DOE.

A management safety walkthrough of the RF Building first Floor and courtyard was held on June 22.

Hazard awareness training was provided to about 30 summer students on June 23.

DIRECTOR'S OFFICE (S. ZELICK):

Patricia Hoffman, the Acting Under Secretary for the Department Of Energy (DOE) Office of Science, and the Assistant Secretary for the DOE Office of Electricity and Energy Reliability visited PPPL on June 21 and toured the NSTX-U Facility.

Site Protection (F. White):

Engine 66 responded to Princeton for four mutual aid assignments.

Ambulance 66 responded to Plainsboro for two mutual aid assignments.

Members of the Site Protection Division and the Emergency Services Unit continued candidate interviews for the Emergency Services Officer position.

B Platoon and A Platoon completed their annual Physical Agility Test.

On June 19, SPD provided safety and security training to the new summer interns at PPPL.

On June 20, on behalf of PPPL, SPD participated in the DOE Operation Eagle Horizon and responded to one exercise inject as well as acknowledging operations continuity messaging.

SPD conducted a limited Emergency Response Organization (ERO) PTENS test.

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