Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending December 9, 2016 are as follows:

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

ITER Steady State Electrical Network (J. Dellas):

Power Transformers: The last two of the three shipping batches of the Group 1 and 2 transformers (that comprise shipping lots #1 and #2) have arrived at the ITER site. The first batch, which has already been delivered, includes the main bodies of the twelve oil-filled transformers. These last two batches include the accessories of the transformers (radiators, bushings, remaining oil, etc.).

Reactive Power Compensators: Manufacturing at the Schneider Pringy, France, factory is underway. The Factory Acceptance Testing (FAT) for the first two lots has been completed. The supplier is working on resolution of punch list items for the second lot. A contract amendment draft has been prepared which adjusts the VAT payments to the LSP pick-up milestones. UPS, DC Distribution; Regular coordination meetings for both contracts is ongoing to facilitate preparation of the Release for Manufacturing (RFM) documentation packages.

ITER Diagnostics (R. Feder):

Upper Wide Angle View VIS-IR Cameras (UWAVs): TNO continues Mirror cleaning R&D and has made good progress. Hydrogen (H2) sputtering rate (SR) observed to be ~3x lower than Helium (He) plasma SR. Initial composition evaluations suggest H2 sputtering produces re-deposition of Aluminum (Al) oxides and may result in non-uniform cleaning and lower SR. This effect may be less pronounced, or not occur, with He. It was suggested to try using Neon (Ne) gas.

Upper Port (UP) 11 and 14 Integration: Various Port integration interface sheets (IS), which describe functional and physical interfaces between 2 PBSs, have been reviewed and findings were reported to the ITER Organization's (IO) Technical Responsible Officer (TRO). Many of the IS sheets need revision. USITER will send the findings from each US System to the IO and will request that the ISs be placed under configuration control. This will reduce the risk of future design changes from various PBSs without our prior approval.

All Port Integrators from various Domestic Agencies (DA) including the US-DA participated in Port Integration Collaboration Team (PICT) meeting organized by the IO and held in China. Various concepts of Generic Electrical Feed-thru and Gas/Water Feed-thrus were presented. UP11/UP14 are planning to use feed-thrus developed by the KO-DA for Gas/Water and

Electrical Feed-thrus developed by the IO. KO-DA presented their design progress on the Gas/Water Feed-thru.

The integrated Upper Port 14 Preliminary Design Review (PDR) level baseline analysis model has been reviewed for consistency between the Nuclear Analysis and Electro-Magnetic (EM) Analysis. This is important for load transfer of structural integrity validation in preparation for the PDR Port Integrated Analysis.

Equatorial Port 09 (EP09) Integration and Diagnostic Shield Module (DSM) Engineering: A full collection of Interface Sheets relevant to EP09 integration was compiled this week with further review and comment of individual sheets still in work. Interface Sheets define and document working interfaces between all system pairings that must connect functionally, though they are developed by different DAs and organizations.

The final approved ITER construction design seismic Floor Response Spectra (FRS) was reviewed by the analysis team for the US ITER diagnostics system design and Port Plug Integration. Seismic load is the design driver for components attached in the Interspace, port cell structure, and the diagnostic building. A design by analysis plan for ex-vessel components of US system has been developed and will be reviewed together with IO next week.

The thermal-hydraulic analysis of the EP09 cartridge insert housing the TIP diagnostics in the Diagnostic Shielding Module 3 (DSM) (left looking from plasma center) is complete and resultant temperature distribution is reviewed for EP09 integration.

Toroidal Interferometer and Polarimeter (TIP): Preparations are nearly complete at General Atomics for the commissioning of a single channel prototype ITER TIP system on DIIID. Once manned access to the vessel is prohibited, it will be safe to align the lasers to the retroreflector mounted inside, and the system can be turned on and tuned up, in preparation for plasma operation.

Electron Cyclotron Emission (ECE); PPPL is preparing for testing of the Piezo actuator in an unsteady magnetic field. Ramping of the field at a rate of up to 4 T/s will be performed using dummy load coil at NSTX site. The University of Texas group is focusing on hot source analysis model adding to the detailed design activities in advance of the molybdenum heater prototype arrival scheduled for mid-January. Design of waveguides is coordinated with IN-DA and neighboring TIP diagnostics

Core Imaging X-Ray Spectrometer (CIXS): A team of PPPL engineers and physicists traveled to Indiana University for neutron testing of an x-ray imaging detector. The detector is the key component of the CIXS system and needs to be able to withstand the ITER nuclear environment. The Neutron Radiation Effects Facility (NREF) facility (http://www.indiana.edu/~radeff/) at Indiana University provides a neutron spectrum and total fluence levels close to what will be present on ITER. The x-ray detector did not make it through the full test plan and the team thinks this is due to a failure in the read-out electronics and not the x-ray imaging pixel array. The team is now discussing ways to run another round of testing if a second detector can be procured.

NSTX-U RECOVERY PROJECT (R. HAWRYLUK):

The recovery project Responsible Engineer's focused on preparing for Design Verification and Validation Reviews. The first step of this process is preparing System Design Descriptions (SDDs) for the Design Validation Phase. Determining the resources required to develop draft SDDs and clarifying the scope of the SDDs was the focus of this effort. Various sources of information (databases, spreadsheets, and web sites) have been identified that will be beneficial for assessing the systems and components. These are being assembled for the upcoming reviews.

The NSTX-U center column is in its stand in the High Bay Area. Procedures for the centerstack casing lift and removal have been reviewed and approved, and a Pre-Job Briefing held. The lift is scheduled for this coming Tuesday. Preparations continue for the removals of the PF1A-L coil from the center column, and the lower ceramic break from the vacuum vessel. Hydrostatic testing of the PF1C coils has been successfully completed.

The Field Coil Power Conversion (FCPC) Test Stand is being prepared for magnetic testing of an ITER diagnostic Piezo Actuator during the week of December 12, and will then be reconfigured to support power testing of PF Inner Coils.

A meeting of the Fusion Facilities Operations Committee was held with remote participation by M. Foster (FES), J. King (FES), J. Irby (MIT), A. Kellman (GA), and C. Neumeyer, T. Stevenson, S. Gerhardt and A. von Halle of PPPL.

NSTX-U RESEARCH (J. MENARD):

Several NSTX-U researchers participated in the Max-Planck / Princeton Center for Plasma Physics held December 5-8 at the Princeton Center for Theoretical Science in Jadwin Hall at Princeton University. NSTX/NSTX-U-related contributions included: J. Menard: "Tearing and kink physics in NSTX and NSTX-U", C. Myers: "A multi-machine scaling of halo current duration and rotation", D. Pfefferle: "Vertical displacement events and reconnection", T. Stoltzfus-Dueck: "Parallel electron force balance and the L-H transition", and F. Ebrahimi: "3D plasmoid reconnection during CHI".

S. Kaye represented PPPL at the ITPA Coordinating Committee (CC) and IEA-CTP meetings held on December 6-8, at the ITER Headquarters in Cadarache, France. The CC meeting consisted of reports from ITPA Topical Group leaders, IO scientists and program descriptions of each of the Domestic Agency programs. Personnel exchanges and associated science topics were discussed at the IEA-CTP meeting.

Lucas Morton (an ORAU postdoc based at PPPL from General Atomics) gave a presentation to the NSTX-U MHD Stability Topical Science Group (MS-TSG) entitled "Aspect ratio dependence of tearing stability: comparing NSTX, NSTX-U, and DIII-D" and discussed tearing mode stability status and plans for the GA collaboration on NSTX-U. Z. Wang described recent "Progress in Resistive DCON Applications".

Otto Asunta, Steven McNamara, and Adrian McFarland from Tokamak Energy, LLC in the UK visited PPPL during the week of December 5. They met with R. Majeski to discuss the use of lithium in tokamaks including benefits and pitfalls. They also received tours of LTX and information on LTX power supplies and new neutral beam injectors. A.Von Halle provided a tour of NSTX-U including the control room, test cell, and power supplies and provided information on NSTX-U grounding, boronization, neutral beam injection systems, and motor generators. Steve Sabbagh provided extensive information and assistance on NSTX-U EFIT and on usage and setup of EFIT for the ST40 device under construction at Tokamak Energy. Finally, S. Gerhardt and Dan Boyer provided information on the NSTX-U Plasma Control System.

M. Reinke (ORNL) visited the MIT Plasma Science and Fusion Center (PSFC) to work on calibrating the NSTX-U prototype IRVB diagnostic to enable quantitative interpretation of test data obtained on Alcator C-Mod during the September operational period.

S. Gerhardt led a meeting for NSTX-U researchers on December 7 to discuss the utility of the NSTX-U PF1B divertor coils for conventional/standard divertors, snowflake-minus/X-divertors, and coaxial helicity injection (CHI) and to address questions raised at the previous PF1B meeting.

J. Menard visited the MIT Plasma Science and Fusion Center (PSFC) on December 9 to discuss MIT/NSTX-U collaboration status and plans, and to give a research seminar entitled "Progress and plans for research on NSTX Upgrade".

ITER & TOKAMAKS (R. NAZIKIAN):

International (R. Maingi):

John Canik (ORNL), A. Diallo (PPPL), R. Lunsford (PPPL), R. Maingi (PPPL), D. Mansfield (PPPL), Tom Osborne (GA), and Kevin Tritz (JHU) started a two week visit to ASIPP to conduct lithium experiments on the EAST tokamak. The ASIPP contacts that facilitated the experiments included S. Zhen, J.S. Hu, G. Zuo, X. Gong, and G.S. Xu. ELMy H-mode discharges used lithium droppers with the goal of suppressing ELMs. One lithium dropper was used on the low field side of the plasma and one on the high field side. Strong ELM mitigation was observed, with a brief period of ELM suppression with simultaneous injection from both droppers. In addition, lithium granule injection experiments were used to trigger ELMs in H-mode plasmas. The efficacy of ELM pacing was assessed for three granule sizes with diameters 0.9 mm, 0.7 mm, and 0.5 mm.

R. Nazikian, J.-K. Park, and N.C. Logan gave a presentation titled "ELM Suppression in ASDEX-U, KSTAR, and Next Steps in 3D modeling," to the Office of Fusion Energy Science (OFES) on December 2. The presentation introduced recent accomplishments in the validation of 3D MHD (IPEC) calculations of the operational window for ELM suppression in KSTAR and the effect of plasma shape on ELM suppression in AUG. Plans were discussed for the predictive optimization of 3D fields in future experiments.

B. Ellis is working on a prototype steady state mirror for the KSTAR ECH launcher. This mirror uses a spiral stainless water cooling line that acts as a spring to allow for the required motion of the beam steering mirror. The prototype is expected to ship to KSTAR in the spring of 2017.

G. Taylor is currently visiting EAST to assess the operation of the fast wave system.

DIII-D (R. Nazikian):

M. Zarnstorff visited DIII-D this week to meet with the PPPL staff and with DIII-D program leaders.

D. Battaglia visited DIII-D to work with B. Grierson and the main ion CER team to install and run the XGC0 code aimed at calculating full orbit ion neoclassical effects in the plasma edge. This modeling capability will enable deeper understanding of the differences observed in the main ion and carbon impurity measurements in the outer mid plane on DIII-D.

This week A. Nagy held a quarterly PPPL team safety meeting at DIII-D. The discussion included an update on chits from the previous meeting, an overview of safety incident statistics and a discussion of hazard awareness with examples. Participants will follow up next week with a walk through of DIII-D work areas using PPPLs safety checklist.

The PPPL supplied Neutral Beam Local Control System 8 installation is now complete, including high voltage commissioning. System crowbar trips due to ground system noise were resolved. Start up of the Neutral Beam source will be attempted next week. This represents a significant milestone towards eventually replacing all the aging power supply controllers for the DIII-D neutral beams.

ADVANCED PROJECTS (H. NEILSON):

Stellarators (D. Gates):

In the Wendelstein 7-X divertor scraper project, bakeout of the graphite tiles was completed by the supplier Solar Atmospheres of Eastern PA, the final step in the manufacture of the two scraper units. The bakeout operation was performed in a clean vacuum environment, confirmed by surface analysis of sample coupons that were baked along with the tiles. The tiles have been returned to PPPL and are currently being crated, together with all of the remaining scraper components, in preparation for shipment to the Greifswald, Germany project site.

S. Lazerson traveled to IPP-HGW to participate in the first W7-X Energetic Particle Workshop. At this meeting Lazerson presented his work plan for a new low profile Faraday-cup fast ion loss detector and progress on benchmarking the BEAMS3D energetic particle code against the ASCOT and VENUS-LEVIS codes. Additionally, Lazerson led a discussion with key member of the W7-X Scenario and Integrations Task Force (of which he is one of two leaders). This visit highlights the continuing collaboration with the W7-X team.

S. Lazerson was interviewed by BBC Radio Scotland, BBC Radio 5 London, and BBC Radio World Service regarding his recent participation in the first experimental campaign on W7-X. A

recent Nature Communications article "Confirmation of the topology of the Wendelstein 7-X magnetic field to better than 1:100,000," of which Lazerson is a co-author, motivated these interviews. In the interview, Lazerson spoke of how W7-X fits into the world fusion energy roadmap and the overall value fusion energy plays should a power plant be deemed feasible. (Link to edited interview http://bbc.in/2g9rX4s)

THEORY (A. BHATTACHARJEE):

A paper titled "Generalized Kapchinskij-Vladimirskij Distribution and Beam Matrix for Phase-Space Manipulations of High-Intensity Beams," by Moses Chung, Hong Qin, Ronald C. Davidson, Lars Groening, and Chen Xiao, was published in Physical Review Letters [Phys. Rev. Lett. 117, 224801 (2016), https://doi.org/10.1103/PhysRevLett.117.224801].This paper reports on the most recent advances in developing a modern theoretical framework for high-intensity, charged-particle beam dynamics in strongly coupled lattices, called generalized Courant-Snyder theory and generalized Kapchinskij-Vladimirskij distribution which has been developed by the authors in a recent series of Physical Review Letters [Phys. Rev. Lett. 111, 104801 (2013) https://doi.org/10.1103/PhysRevLett.111.104801], [Phys. Rev. Lett. 110, 064803 (2013) https://doi.org/10.1103/PhysRevLett.110.064803], [Phys. Rev. Lett. 103, 224802 (2009). https://doi.org/10.1103/PhysRevLett.103.224802]. In addition to being an elegant theoretical model, it is an effective tool in the design of coupled, focusing lattices for manipulating high-intensity, charged-particle beams, and has been applied to study the beam matrix for the Emittance Transfer Experiment at the GSI Helmholtzzentrum für Schwerionenforschung, GmbH.

Many staff from the Theory Department attended the "Meeting of the Max-Planck/Princeton Center for Plasma Physics", December 5-8, in the Princeton Center for Theoretical Science in Princeton University. After an introduction by Prof. Stewart Prager of Princeton University/PPPL and Professor S. Günter, of the Max Planck Institute, presentations, and discussions, were given on a wide range of topics, including cosmic rays, magnetic reconnection, magnetorotational instabilities, turbulence, energetic particles and dynamos. Presentations given by the Theory Staff include: Dr. A. Hakim, E.L. Shi & G. Hammett, titled "Turbulence research with Gkeyll: next steps"; Dr. T. Stoltzfus-Dueck, titled "Parallel electron force balance and the L-H transition"; Dr. I. Krebs, titled "Self-sustaining sawtooth-free tokamak plasma states in 3D, non-linear MHD simulations"; Dr. W. Fox, titled "Experimental verification of the role of electron pressure in magnetic reconnection with a guide field"; Dr. F. Ebrahimi and Dr. V. Igochine, titled "3D plasmoid reconnection during CHI"; Dr. L. Comisso, titled "General theory of the plasmoid instability"; Dr. M. Kunz, titled "Turbulence in kinetic MRI"; Professor A. Bhattacharjee, titled "Generation of large-scale magnetic fields by small-scale Dynamo", and Dr. P. Bhat titled "Dynamo in MRI flows".

A paper titled "Magnetorotational Turbulence and Dynamo in a Collisionless Plasma" authored by Matthew W. Kunz, James M. Stone and Eliot Quataert, has been published [Phys. Rev. Lett. 117, 235101 (2016), https://doi.org/10.1103/PhysRevLett.117.235101]. This paper, which was highlighted by the Editors of Physical Review Letters, presents results from the first three-dimensional (3D) kinetic, numerical simulation of magnetorotational turbulence and dynamo, using the local shearing-box model of a collisionless accretion disk. The paper reports that the kinetic magnetorotational instability grows from a subthermal magnetic field having zero net

flux over the computational domain to generate self-sustained turbulence and outward angular-momentum transport. Significant Maxwell and Reynolds stresses are accompanied by comparable viscous stresses produced by field-aligned ion pressure anisotropy, which is regulated primarily by the mirror and ion-cyclotron instabilities through particle trapping and pitch-angle scattering. The latter endow the plasma with an effective viscosity that is biased with respect to the magnetic-field direction and spatio-temporally variable. Energy spectra suggest an Alfvén-wave cascade as large scales and a kinetic-Alfvén-wave cascade at small scales, with strong small-scale density fluctuations and weak non-axisymmetric density waves. Ions undergo non-thermal particle acceleration, their distribution accurately described by a kappa distribution. These results have implications for the properties of low-collisionality accretion flows, such as that near the black at the Galactic center.

Computational Plasma Physics Group (S. Jardin):

X. Yuan has developed an impurity density prediction capability using ADAS database in PT_SOLVER, and this capability has been tested and committed to the xshare version of TRANSP. This new capability in TRANSP uses ADAS database to predict the line radiation and bremsstrahlung radiation, which in turn are used in the temperature prediction as source terms. The impurity density prediction in PT_SOLVER solves the particle conservation equation for individual impurity elements, the TGLF and NEO code are used to calculate the turbulent and neoclassical transport fluxes. Coronal equilibrium is assumed, the ADAS ionization and recombination coefficients are used to calculate the density profiles for individual charge states. Initial tests show that the new capability can self-consistently predict the power radiation loss, electron and ion temperature, angular momentum, and impurity density at the same time. The next step will be focus on the benchmarking the prediction against existing experimental data.

The TRANSP development group has worked with the ITER IMAS group and successfully tested submission of jobs from the ITER site. The first ITER job has been submitted to the PPPL cluster thru the Fusiongrid using the Open Source Grid Certificate. Tests will continue over the next weeks to complete and demonstrate the entire workflow of preparation, submission and storage of simulations in the IDS (ITER Data Structure).

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER):

Communications (L. Bernard):

J. Greenwald reported and wrote a feature about a paper on magnetic reconnection published by M. Yamada and E. Zweibel of the University of Wisconsin in Britain's Proceedings of the Royal Society A. Greenwald also arranged a BBC Radio Live interview with physicist S. Lazerson about a Nature Communications paper on the Wendelstein 7-X magnetic field, which led to subsequent interviews on BBC Scotland and BBC World, and the NY Post. Greenwald's PPPL article that gave rise to the interviews was published in the U.S., England, Spain, Mexico,

Hungary and Germany. An earlier feature by Greenwald on L. Comisso's plasma instability paper in Physics of Plasmas was reported on by 15 publications, including Forbes and Wired magazines.

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