Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending October 28, 2016 are as follows:

U.S. ITER FABRICATION (C. NEUMEYER):

Steady State Electric Network (SSEN):

Arrangement for the Transfer of the Battery Banks and LV Distribution Panels to the IO for Procurement; The Arrangement has been signed. A modification to the PA CAS relating to the IP distribution system is in process which will break out the battery and LV panels to allow these credits to be received separately from the UPS and DC distribution.

Power Transformers; Planning, logistics and shipping documents for the shipment of the Group 1 and 2 transformers from the Schneider Electric factory near Istanbul, Turkey have been received. French customs approval is in-process. Notification of ship date expected soon.

Reactive Power Compensators; Factory acceptance testing for the first lot of RPC units was held in Pringy, France from October 19 -22. Only minor punch list items were identified. It was anticipated that two lots could be completed but due to logistical problems within the allocated test area only one lot was tested. The second lot will be rescheduled.

Diagnostics:

Low Field Side Reflectometer (LFSR); A preliminary design review of the Virginia Diode Inc (VDI) upgrade of their D-band Source to a full send-and-receive bi-static reflectometer instrument to be used on the ITER LFS reflectometer was held. Very good progress was noted. Authority was granted to VDI by our subcontractor (GA/UCLA) to proceed with the upgrade implementation without further design reviews.

Motional Stark Effect (MSE); Nova Photonics has been working on the MSE Core View system optical ray trace. MSE-Core is located in EU DA Equatorial Port #1. The conceptual design was developed by a team at the IO several years ago. Major updates to the optical design were needed because of changes to the equatorial port shield module and diagnostic first wall designs. The MSE-core optics view spots along one of the adjacent heating neutral beams. The positioning of the heating beam had changes somewhat since the CDR design phase and the optical ray trace had to also be updated to account for this. Port integration space limits may cause a %30 reduction in light throughput compared to the CDR design. The MSE team is assessing the impact of this on MSE system time response and signal-to-noise levels.

Upper Port 11 and 14 Integration and DSM Engineering; Multiphysics analysis work on upper port 14 continues. Brian Linn and Jonathan Klabacha completed meshing and pre-processing of the Upper Port 14 ATTILA neutronics model. This will be the final preliminary design neutronics analysis for Upper Port 14. Yuhu Zhai completed a draft of a new Upper Port 14 Load Specification.

Equatorial Port 9 Integration and DSM Engineering; Allan Basile, Mike Messineo and Brian Linn visited ITER this week to discuss several important diagnostic port integration topics. The primary mission of the trip was to start discussions on a new Task Agreement between the US and ITER to support the generic design of the diagnostic ports Interspace (ISS) and Port Cell structures (PCS). Other meetings were held to discuss the status of the Port Plug common supply procurement, development of a new comprehensive System Requirements Document (SRD-55 V5) and the status of light weight DSM engineering work. Brian Linn held meetings on the use of Boron Carbide inside the port plugs for light weight shielding. Mike Messineo worked with the IO diagnostics CATIA team to check on the status of US ITER CATIA models and to get updates on generic structure models.

Toroidal Interferometer and Polarimeter (TIP); In order to reduce heat production on the TIP optical tables, the HeNe alignment laser will be located external to the tables and coupled into the optical system on the table via an optical fiber. This will also minimize the impact of HeNe replacement. Wenping Wang completed a series of optical-mechanical design and analysis iterations on the cooling of the TIP in-vacuum mirrors and the required equatorial port 9 cooling scheme to support TIP. There are twelve molybdenum TIP in vacuum mirrors but her work showed that only the four mirrors closest to the plasma require active water cooling to limit optical distortions. This helps to simplify the shield module design and fabrication.

NSTX-U (M. ONO):

Three NSTX(-U) Press Releases were chosen and posted to the APS-DPP Virtual Press Room for 2016. The first, “A Disappearing Feast: Mean Flows Remain Slim After Eating Eddies”, represents work by Ahmed Diallo and Tim Stoltzfus-Dueck, showing that the energy flow dynamics just prior to the L-H transition in NSTX is not consistent with those in the predator-prey model, with energy flowing from mean flow to turbulence in NSTX, rather than in the opposite direction as in the predator-prey model. Furthermore, the work shows that thermal energy fluctuations, which are not taken into account in the predator-prey model, are actually dominant. The second, “Launching Fusion Reactions Without a Central Magnet, or Solenoid” highlights the work of Fatima Ebrahimi, who performed resistive, 3D non-linear simulations to explore the plasmoid instability and its role in the production of non-inductive current through Co-Axial Helicity Injection. The third, “Steering a Fusion Plasma toward Stability”, highlights the work of Jack Berkery and Steve Sabbagh in developing a Disruption Forecasting Algorithm (DECAF), and in developing a reduced model for Resistive Wall Mode stability. The reduced model is implemented in DECAF and can robustly predict the destabilization of this mode, which can lead to a disruption. Early detection of the mode can trigger actuators that will enable active RWM stabilization.

Preparations for the removal of the NSTX-U Centerstack continued this past week with work outside the vessel. Work also continued on the recommissioning of the coil winding facility this

week with the reassembly of the oven, and the preparations for a heat run. Good progress was made on neutral beam #2 calorimeter maintenance with the replacement and testing of the calorimeter "Vee" (beam target) guide bearings.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

B. Grierson presented an Oral presentation at the IAEA FEC in Kyoto, Japan on recent progress in intrinsic rotation studies and extrapolation to ITER. Through a joint experiment between DIII-D and JET, the scaling of intrinsic torque with dimensionless gyro-radius (rho*) has revealed a dependency with a negative exponent, which extrapolates to a larger intrinsic torque in ITER than present experiments. This scaling produces an expected intrinsic torque of approximately 45 Nm, which is comparable to the NBI torque (33 Nm), and angular rotation near 12 kRad/s. While the overall rotation is important for stability, the rotation shear is important to improve confinement, and global nonlinear GTS simulates have shown that intrinsic rotation profiles can be computed from first principles. Specifically, the occurrence of an intrinsic rotation "reversal" has been well captured by the gyrokintiec simulations of the turbulent residual stress. Further details of both results will be presented at the APS-DPP meeting in San Jose by C. Chrystal (GA) and W.X. Wang (PPPL).

B. Grierson attended the ITPA Transport and Confinement meeting in Naka, Japan and delivered two presentations. The first presentation was on DIII-D and multi-machine scaling of the plasma intrinsic torque with normalized minor radius, rho*, as well as the application of the scaling results and quasi-linear modeling of the performance impact for ITER. The second presentation displayed a general database creator toolkit implement in OMFIT, which provides access to MDS+ time histories, as well as 1D plasma profiles, EFIT variables, and TRANSP runs. Databases are easily created and visualized for more sophisticated analysis such as fitting dependencies and regressions.

Three presentations were given by PPPL scientists on DIII-D at the ITPA pedestal meeting in Naka following the IAEA. First ELM suppression in AUG in a DIII-D joint experiment was presented by Raffi Nazikian. Lithium ELM pacing results on DIII-D was presented by Alessandro Bortolon. First results with XGCa on RMP effects in DIII-D was presented by Robert Hager.

This week Alex Nagy, NB210 Off-Axis Neutral Beam (OANB) Lead Engineer, has released a completed and approved heat load document from DIII-D to PPPL engineering. PPPL will design and fabricate the new collimator for installation into the OANB exit collimator starting September 2017. This NB will use a focused source to fit through the vessel port.

C-Mod (l. Delgado-Aparicio)

Luis F. Delgado-Aparicio attended the IAEA Fusion Energy Conference in Kyoto, Japan. Luis showed his latest results from C-Mod on Locked-mode avoidance and recovery without external momentum input using Ion Cyclotron Resonance Heating (ICRH). New observations of the formation and dynamics of error-field- induced locked- modes at ITER toroidal fields, without fueling and external momentum input have recently been carried out on Alcator C-Mod. Delay

of the mode onset and recovery from pre-existing locked-modes has been successfully obtained at low-density (ne/nG~0.1-0.2) using Ion Cyclotron Resonance Heating (ICRH). The use of external heating concomitant with the n=1 error-field ramp- up resulted in a delay of the mode-onset avoiding the density pump-out and achieving high-confinement "H-modes." Heating the low-density plasma after the mode-onset was not conducive to an L→H transition but resulted in unlocking the plasma without external torque and obtaining co/counter-current flows at the edge/core. This simple heating technique could provide an important actuator to circumvent error-field-induced locked-mode disruptions in tokamak plasmas. These results will be submitted for a Nuclear Fusion paper. There is interest in our community to test this technique in larger machines like KSTAR (Korea), ASDEX (Germany) and JET (UK).

International Collaborations and ITER: (R. Maingi)

R. Maingi chaired the Pedestal and Edge Physics (PEP) topical group, which met in Naka, October 24 – October 26. In addition to ongoing joint research activities, there were three joint sessions of note: one with divSOL (impurities and ELM heat flux), one with transport and confinement (I-mode), and one with IOS (reduced pedestal models). A notable highlight was the tour of JT-60SA, which is making excellent progress, and is on schedule for first plasma in 2019.

The 17 ITPA topical group meeting was held in Kyoto University, Japan from October 24 – 26 following IAEA FEC conference. The meeting discussed several topics of broader interests including several joint experiments: impact of ECH on AE activity, transport problem of thermal plasma and EPs in steady-state scenarios, assessment of ICE for diagnosing lost and barely confined fast ions. Several presentations on the research on those topics were also given. Among them are the reports on the successful conclusion of ECH excitation of AEs on DIII-D machine which unambiguously showed that AEs are stabilized by applying significant power of ECH > 2.5MW. An explanation of this was given in terms of the GAM frequency dependence on the thermal electron temperature. Another important topic is the potential ICE application as a diagnostic of fusion products in the burning plasma conditions. Even though this technique seems to be not clearly formulated several conclusions can be made even now. ICE is expected in experiments at low field side if fast ions are present there. ICE intensity should correlate with the fast ion population at that location. The spectrum of ICE should be sensitive to the details of fast ion distribution function, which is currently the subject of the research.

Francesca Poli attended the ITPA-IOS meeting in Naka, Japan, October 24-27. The meeting was held with joint sessions with the T&C and Pedestal-ELM topic groups. Discussion during the joint meeting involved the adoption of IMAS for sharing experimental and modeling databases and topics of interest for integrated scenario modeling, like particle transport, transport during the ramp-up phase, modeling of ramp-down for ITER, use of neural networks for fast transport predictions and how to include pedestal predictions in ITER time-dependent simulations.

ADVANCED PROJECTS (H. NEILSON):

The Laboratory hosted the quarterly U.S. Wendelstein 7-X Management (W7-X) meeting, with representatives from DOE Fusion Energy Sciences and Massachusetts Institute of Technology (MIT) participating remotely. The meeting featured status reports on several projects that will

enhance the U.S. team capabilities for the next W7-X operating campaign, known as OP-1.2. E. Edlund and M. Porkolab of MIT reported progress in the preparation of a phase contrast imaging diagnostic, which will be used to detect turbulent fluctuations in the W7-X plasma over a broad range of spatial and temporal scales. J. Terry of MIT reported on a fast imaging diagnostic which will be used to study fluctuations and plasma structure in the edge and near island-divertor region, providing data critical for the understanding of boundary plasma physics and heat exhaust control in W7-X. Laboratory staff reported on the plans for completing the final steps in the fabrication of two TDU divertor scrapers, an instrumented plasma-facing component that will be used to test understanding of power and particle flows in the W7-X edge plasma.

This week D. Gates served on the thesis committee of Ph.D. student Rene Reimer from Ernst-Moritz-Arndt-Universität in Greifswald, Germany. The thesis was aimed at measuring the absolute value of the magnetic field in a toroidal plasma using the Motional Stark Effect (MSE) but also involved calculation of the Zeeman effect as a correction. A formal report was submitted grading the thesis.

THEORY (A. BHATTACHARJEE):

On October 28, Cesare Tronci (University of Surrey, UK) presented a theory seminar on modeling efforts in hybrid kinetic-MHD and fully kinetic theories; Over the decades, multi-scale modeling efforts have resorted to powerful methods, such as asymptotic/perturbative expansions and/or averaging techniques. As a result of these procedures, finer scale terms are typically discarded in the fundamental equations of motion. Although this process has led to well consolidated plasma models, consistency issues may emerge in certain cases especially concerning the energy balance. This may lead to the presence of spurious instabilities that are produced by nonphysical energy sources. The talk proposes alternative techniques based on classical mechanics and its underlying geometric principles. Inspired by Littlejohn's guiding-center theory, the main idea is to apply physical approximations to the action principle (or the Hamiltonian structure) underlying the fundamental system, rather than operating directly on its equations of motion. Here, I will show how this method provides new energy-conserving variants of hybrid kinetic-MHD models, which suppress the spurious instabilities emerging in previous non-conservative schemes. Also, this method allows for quasi-neutral approximations of fully kinetic Vlasov theories, thereby neglecting both radiation and Langmuir oscillations.

S. Hudson visited collaborators at the University of Tokyo on October 24 - 25. He gave a seminar about recent work on transport in chaotic fields and so-called “ghost surfaces,” on magnetic confinement devices in the shape of a knot which are called “knotatrons,” and recent calculations with the Stepped Pressure Equilibrium Code SPEC. He met with Professor Yoshida and Dr. Abdelhamid and discussed how Hall effects may resolve singularities in stepped-pressure equilibria.

N. Gorelenkov attended the ITPA meeting in Kyoto University on October 24 - 25, and presented a talk titled “Revisiting damping of CAEs for ICE problem” with co-author E. Belova. S. Jardin also attended, and presented a talk titled “3D Modeling of NSTX Vertical Displacement Events with M3D-C1”.

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

On October 22, PPPL hosted over 250 Boy Scouts and 50 volunteers for the second Science & Technology Meir Badge Fair. Scouts could choose from 15 different STEM merit badges ranging from Chemistry and Drafting to Fire Safety, Robotics and Surveying. Classes were led by teams composed of BSA volunteer merit badge counselors and subject matter experts from PPPL, Princeton University, and other organizations. The event was jointly organized by PPPL and the Washington Crossing Council, Boy Scouts of America.

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