PRINCETON PLASMA PHYSICS LABORATORY
WEEKLY highlights

PPPL
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending September 27, 2013, are as follows:

U.S. ITER FABRICATION (D. JOHNSON):

At an interface meeting for the ITER ECE system, the India domestic agency proposed a new arrangement at the vacuum boundary to facilitate the implementation of a fast shutter for protection against stray high power mm-wave radiation. PPPL engineers are investigating the feasibility of such a fast shutter, since this would be US scope.

D. Loesser met with IO diagnostic engineers in Cadarache to discuss various aspects of the Diagnostic First Wall (DFW), and to agree on a date for the Preliminary Design Review for this system. The date was set as December 9-10, the same week as the Final Design Review for the Generic Equatorial Port Plug Structure.

One of the issues under discussion for the DFW is the thickness of the plasma-facing stainless steel surface. If the surface is too thick, thermal fatigue will limit the lifetime. If it is too thin, there is concern that ablation or melting during the thermal flashes expected with massive gas injection for disruption mitigation may cause thinning that could lead to failure. A similar issue applies to some areas of the wall-mounted blankets that feature stainless steel plasma-facing surfaces set back to avoid plasma contact.

NSTX (M. ONO):

On September 23-24, S. Kaye (PPPL) participated in a review of the ITER Research Plan at the ITER IO in Cadarache, France. Also participating in the review were three other representatives from the U.S. as well as representatives from the EU, India, S. Korea, Japan and Russia. The objective of the review was to elicit comments and suggestions from the review panel on requirements and steps necessary to achieve the Q=10 goal of ITER. These comments would be incorporated into a presentation for the STAC meeting, which will be held in several weeks. The first day of the meeting was devoted to presentations by the ITER IO on the how it is envisioned that the present ITER Research Plan will be impacted by a number of diagnostic and facility capability delays and deferrals, as well as presentations on some of the critical ITER capabilities that need to be in place to achieve the Q=10 goal. These critical capabilities included the heating/current drive and diagnostic capabilities, the plasma control system, Disruption and ELM mitigation systems, effects of the tungsten divertor, and the tritium processing plant. The second day of the workshop involved the review committee to split into four working groups to address specific elements of the program (requirements and necessary steps to achieve the goals). For this exercise, the ITER IO asked us to assume that all delayed and deferred items would be

available before the non-nuclear phase. S. Kaye led the working group on the "Experimental program in nuclear phase towards Q=10 demonstration."

J. Menard (PPPL) visited the Culham Centre for Fusion Energy, UK on September 23-25 to collaborate on kinetic MHD modeling for NSTX and hold collaboration discussions with MAST researchers. J. Menard also toured several of the facilities of Tokamak Solutions, Inc.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

W. Solomon led a recent experiment on DIII-D to probe the upper density limit of ELM free QH-mode plasmas using strong deuterium gas puffing. A purpose of these experiments was to test whether the loss of QH-mode at high density corresponded with a crossing of the peeling-ballooning stability boundary. Profile and equilibrium analysis from the density ramps in these experiments has found that at constant beta_N, the height, width and gradient of the pedestal pressure all increase with the density, together with the calculated pedestal current. Qualitatively, this trend is expected to be destabilizing for the peeling-ballooning mode. Comparisons with ELITE and EPED calculations are planned.

The ECH Gyrotron 8 water manifold was delivered to General Atomics on September 16. Installation of valves, quick disconnects, pressure and temperature gauges is complete. This completed a PPPL program milestone for FY13 for the delivery of the fabricated and assembled manifold to DIII-D. The manifold will be moved into the ECH vault early next week.

C-Mod (S. Scott):

S. Scott (PPPL) gave a talk at the C-Mod weekly science meeting, "Relativistic electron runaway during impurity injections in LHCD plasmas". During a data-mining activity for LHCD plasmas with good measurements of current profiles by the MSE diagnostic, a shot from 2010 with unusual behavior was discovered. The shot (1101202020) was 5.4 Tesla, low current (430 kA), low density (nebar = 5.e19) with ~750 kW of lower-hybrid power. There were strong lower-hybrid driven currents in this shot, and the loop voltage decreased from its Ohmic value of 0.8 volts to about 0.1-0.2 volts during LHCD. About half-way through the 700ms period of LHCD, the plasma experienced a large influx of molybdenum, which generated intense radiative losses from the plasma core (3 MW/m^3), causing the central electron temperature decreased from ~3 keV to ~0.3 keV in 80 milliseconds, while the central density nearly doubled from 7 to 13 x 10^19 m^-3. But the plasma did not disrupt. Following the decrease in temperature, the loop voltage increased to somewhat above its Ohmic value, reaching ~1.3 volts. At the same time, we observed a large increase in hard x-ray emission and photo-neutron production. Similar behavior was observed in shot 1110329022 following a tungsten impurity injection. This is evidence that a population of relativistic runaway electrons was generated by the increased loop voltage following the impurity injection. The voltage at which the runaway population first appears is in excellent agreement with the value predicted from a database survey of the voltage needed for runaway generation, based on quiescent, flattop plasmas without LHCD (Granetz, ITPA MHD Meeting, La Jolla, CA, October 15-17, 2012). This behavior suggests that it may be possible to study the physics of runaway generation in a controlled way by deliberately injecting impurities

into a LHCD plasma, following a programmed step-down in plasma density.

International Collaborations (R. Hawryluk):

R. Hawryluk, S. Jardin and M. Zarnstorff participated in the Fachbeirat meeting in Garching, Germany, which reviewed the progress by the Institut fur Plasmaphysik (IPP). R. Hawryluk chaired this meeting composed of international experts and gave a preliminary oral report to the Max Planck Society Vice-President.

ADVANCED PROJECTS (H. NEILSON):

In the Laboratory's collaboration with the Wendelstein 7-X project at Max Planck Institute for Plasma Physics, it was reported that the five U.S.-supplied trim coil power supply units arrived at the project site in Greifswald, Germany. With the accomplishment of this milestone, the Laboratory achieved the FY13 Notable Outcome, "Complete manufacture and delivery to the Wendelstein 7-X site of the entire trim coil system and the power supplies." The last coil was delivered earlier this year and four of the five coils are already installed on the W7-X device. The Laboratory will support installation and commissioning of the power supplies in FY14.

H. Neilson met with faculty, staff, and students at the University of Science and Technology of China (USTC) in Hefei, China for discussions on fusion research and various collaboration topics. Design of two options (one based on superconducting and one based on copper magnets) for the Chinese Fusion Engineering Test Reactor (CFETR) continues on pace to deliver a report to the Ministry of Science and Technology by the end of 2014. The mission has been established and multiple options for the blankets and for the divertor configuration are being studied. A collaborative reactor design study has been proposed in the framework of USTC's Collaborative Innovation Center for Advanced Fusion Energy and Plasma Science, in which USTC and PPPL are partners along with other institutions. The study would examine the maintenance and reconfigurability of in-vessel components in a superconducting device such as CFETR, where such components are being exposed to a real fusion environment for the first time. During the visit, Neilson presented a seminar, "Comparing Options for Next-Step Fusion Nuclear Facilities."

THEORY (A. BHATTACHARJEE):

Drs. N.N. Gorelenkov and G.Y. Fu attended the IAEA technical committee meeting on energetic particles in fusion research held in Beijing, China, September 17-21. Dr. N.N. Gorelenkov gave an oral talk on " Critical Gradient Model for AE Fast Ion Relaxation and its validation against the DIII-D experiments" whereas Dr. G.Y. Fu presented an invited talk "Linear Stability and Nonlinear Dynamics of n=1 Fishbone in NSTX reversed shear plasmas".

Few key presentations of the meeting were devoted to the models to describe the fast ion profiles and their relaxation in tokamak plasmas. The experiments were performed and documented on DIII-D, which demonstrated stiff fast ion profiles in the presence of alfvenic instabilities driven by beam ions. Two theories developed independently supported these observations. One of them

is developed at PPPL by Drs. N.N. Gorelenkov and K. Ghantous and is relatively approximate. It shows the surprising agreement with experimental measurements. The theory is based on well-validated linear stability computations of alfvenic instabilities and is able to predict fast ion beta profile, compute their losses and neutron signal drops. The later was used to compare the predictions of the model with the experiments. Applications of the model for planned burning plasma experiments were argued to be the motivations for future validations. Another theory on this subject was developed at General Atomics and was presented using the code GYRO and is complementary to the critical gradient model of PPPL.

Dr. W. Tang visited the Keldysh Institute of Applied Mathematics (KIAM) in Moscow, Russia and presented an invited talk on "Theoretical Basis and Algorithms for Advanced HPC Fusion Simulations" on September 26. As the US PI for the G8-sponsored Nuclear Fusion Simulations @ Extreme Scale (NuFuSe) project, which is supported by the NSF, he was hosted by the Russian PI for this G8 project, Academician Boris Chetverushkin – the KIAM director and a distinguished member of the Praesidum of Russia's National Academy of Science (RAS) – to engage in timely strategic planning/future collaborative discussions.

COMPUTATIONAL PLASMA PHYSICS GROUP (S. JARDIN):

The Hamiltonian guiding center code ORBIT went through a major performance upgrade this summer thanks to the work of Princeton University undergraduate student Ante Qu, who was the recipient of a DOE OFES National Undergraduate Fellowship. The summer internship project, under the supervision of CPPG S. Ethier and E. Feibush, consisted in the parallelization of the ORBIT code for multi-threaded architectures, such current multi-core CPUs and high performance Graphical Processing Units (GPUs). By using the OpenMP directive-based approach on CPU, and CUDA-Fortran GPU extensions for GPU. The upgraded ORBIT code was able to reach a 53X speedup improvement on the latest Nvidia GPU compared to its traditional single-core speed. The OpenMP multi-threaded version, which takes advantage of shared memory parallelism on current multi-core CPUs, was shown to achieve more than 20X speedup on a 32-core CPU. These impressive results were achieved without any modifications to the main parts of the code that users interact with. Only the compute-intensive core of the code was modified, minimizing the impact on the users.

ENGINEERING AND INFRASTRUCTURE (M. WILLIAMS):

NSTX Upgrade (R. Strykowsky, E. Perry, L. Dudek, T. Stevenson):

Management: Plans are being finalized for the Lehman review, which will take place next week, October 2-3.

NSTXU Construction: Permanent shims for the upper TF supports have been installed in bays G through A and the upper scaffold in these bays has been removed so other installations can proceed. Installation of the bay L ports is in progress. Cable trays under the neutral beam boxes have been completed. Permanent AC power has been restored to the category 1 and 2 racks as well as to the convenience outlets and under platform lighting. Re-installation of port covers has been started where installation procedures exist. The PF4/5 support work continues. The Bus bar

fabrication continues in the Tech Shop.

NBI Upgrade: Decon of the TTC East wall for cable tray installation continues. Work on cryo valves on the south wall and BL is complete and awaits wiring for control. The calorimeter stand was deconned, surveyed, and moved out the TTC to the Rad Waste Facility. The DI water system subcontract awaits flanges in the NTC; flange installation is in progress. The Ion Source and Ion Dump DI H2O Pump procurement continues. Vacuum system installation detailed drawings are in progress and a package is being developed for installation. BL2 alignment of 90-inch flange, OMA scrapers, and source platform rails continues. The power system cable and tray subcontract mobilization continues; fieldwork has started. Scanning for wall and ceiling mounts has started. Cable tray supports have been delivered. The drilling template fabrication is complete. The NBI duct rectangular spool piece was leakchecked successfully. Thermocouple fabrication for the armor tiles continues. Final welding of t-bar studs is imminent. Controls tray installation in the NTC has resumed around and under the beamlines. Management preparations for the upcoming Office of Science review scheduled for early October.

CS Upgrade: The requisition for the procurement of the TF Lead Extensions has been generated. The procedures for the OH Winding and Aquapour installation are in review. The CHI ring buss bars have been formed in the Tech Shop. The installation of the OH Winding station in the CS Coil Shop is in progress and approximately 90% complete. The final step of the installation, winder alignment, is underway. The VPI of the TF bundle was completed over the weekend and cooled sufficiently on September 26 to allow the removal of the mold covers. The mold cover is in the process of being removed and the bundle will be removed from the mold early next week. The PF1B coil mandrel has been welded at the machinist vendor and is on schedule to arrive at Everson next week. The Centerstack tilting fixture was load tested and mounted in the CS winding area.

OFFICE OF COMMUNICATIONS: (K. MACPHERSON):

B. Quirke, the Director of Communications for the DOE Chicago office, visited the Office of Communications from September 24-26, hosted by K. MacPherson.

PUBLICATIONS:

The paper "Overview of physics results from the conclusive operation of the National Spherical Torus Experiment" by S.A. Sabbagh (Columbia University), and the NSTX Team is now published in Nuclear Fusion (Nucl. Fusion 53 (2003) 104007, http://stacks.iop.org/0029-5515/53/104007). This paper summaries NSTX results obtained before the upgrade outage with broad scope (including transport and stability physics at reduced collisionality, H-mode pedestal physics, effects of lithium wall conditioning, macroscopic stability and control at high betaN (incl. kinetic RWM stability and control), disruption prediction and characteristics, energetic particles, modes and 3D field effects, heat flux mitigation (incl. snowflake divertor), L-H power threshold, non-inductive current results and operational scenarios for NSTX-U) and with suitable references to the more detailed material. (NSTX)
Several papers reporting Advanced Projects work were published in a special issue of Fusion Science and Technology, Proceedings of the ANS Topical Meeting on the Technology of Fusion

Energy (TOFE). The papers are: “The Evaluation of the Heat Loading from Steady, Transient and Off-Normal Conditions in ARIES Power Plants,” by C. Kessel, *et al.*; “Mission and Readiness Assessment for Fusion Nuclear Facilities,” by G. H. Neilson, *et al.*; “Comparison of Options for a Pilot Plant Fusion Nuclear Mission," by T. Brown, *et al.*; and “TF Inner Leg Space Allocation for Pilot Plant Design Studies,” by P. Titus, *et al.*

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