PRINCETON PLASMA PHYSICS LABORATORY

WEEKLY highlights

PPPL

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending October 24, 2014, are as follows:

FEATURED HIGHLIGHT:

The centerstack assembly has been successfully lifted into NSTX-U.

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

A two-day kickoff meeting of the full design team for the ITER Toroidal Interferometer/Polarimeter Diagnostic was held at General Atomics. Experts from PPPL, General Atomics, UCLA and Palomar Scientific discussed progress since the Conceptual Design Review and the near-term R&D plans. Tours were made of experimental areas where prototyping is planned.

In order to integrate systems into the upper port plugs, PPPL engineer A. Jariwala has organized meetings with designers of the Disruption Mitigation System and the Glow Discharge System, pointing out possible clashes and publicizing dates when interfaces need to be frozen.

NSTX (M. ONO):

S.A. Sabbagh and Young-Seok Park of Columbia University attended the IAEA Fusion Energy Conference in St. Petersburg, Russian Federation, held from October 13-18. S.A. Sabbagh gave two talks, three poster presentations, and aided in a fourth, representing PPPL. The first-authored talk was titled "Physical Characteristics of Neoclassical Toroidal Viscosity in Tokamaks for Rotation Control and the Evaluation of Plasma Response", and contained both NSTX and KSTAR data. The other presentations included "Overview of recent physics results from NSTX" by S. Kaye, et al., "Progress toward commissioning and plasma operation in NSTX-U" by M. Ono, et al., and supported Laila El-Guebaly of University of Wisconsin who presented "Configuration Studies for an ST-Based Fusion Nuclear Science Facility" by J.E. Menard, et al. Y.S. Park gave the presentation "Plasma Rotation Alteration by Non-axisymmetric Magnetic Fields, Resistive MHD Stability Analysis, and High Normalized Beta Plasmas Exceeding the Ideal Stability Limit in KSTAR", which included the recent achievement of reaching normalized beta of 4 transiently in KSTAR.

A year-long effort on quantification of 3D plasma response modeling in tokamaks, which has been targeted jointly among DIII-D, NSTX-U, C-Mod team in 2014, has been successfully completed with a comprehensive JRT14 report submitted to the Office of Fusion Energy Sciences. J.-K. Park, A. Reiman, S. Lazerson, Z. Wang, K. Kim (PPPL), S. Sabbagh, J. Berkerly (CU) performed various 3D code benchmark and applications to NSTX, NSTX-U and DIII-D, and led the studies of 3D kinetic effects, NTV (neoclassical toroidal viscosity) transport, including NTV optimization for NCC (non-axisymmetric control coils). J. Canik, J.-W. Ahn, J. Lore (ORNL) led the studies of heat flux splitting and detachment by 3D fields, and L. Delgado-Apraicio actively worked with C-Mod team and led layer physics experiments. The key NSTX-U group contributions are as follows. A range of 3D MHD codes, including linear to non-linear, ideal to two-fluids or hybrid-kinetic codes were tested and compared against various experimental data, as well as against each other complementing an ongoing theoretical initiative for the code benchmark. In many circumstances ideal MHD provided a good representation of 3D plasma response, but it was also found that (1) kinetic effects are important in high-beta (2) non-linear effects are significant in the edge of plasma, (3) non-linear and non-ideal effects may be associated with ELM suppression. Error field correction based on dominant single-mode picture from ideal MHD was again largely successful for lower n applications, but relatively not for higher n as non-resonant NTV braking can be substantial in other subdominant modes. The effects on transport by 3D fields were also actively studied. Various NTV codes were compared against each other and also experiments successfully, but internal 3D field structure or non-ideal response including drift-kinetic effects may be needed to account for modification of the mode structure by NTV effects. Ideal MHD modeling was also successful mostly for heat flux splitting and for divertor detachment when properly combined with realistic 3D transport modeling. Finally the island opening physics has been well explored by changing momentum injection by RF and observing locking and unlocking of islands.

Preparations for plasma operations in the NSTX-U configuration also continued. The Multi-pulse Thompson Scattering diagnostic (MPTS) Collection Optics Box has been set in place, and preparations are underway to complete alignments in early November. The RF transmission line re-installation is in progress, and the NSTX-U neutron detectors are being tested and then installed in their permanent locations in the test cell. A dynamic calibration of the neutron detectors will be performed in early November utilizing a neutron source run on a spatially calibrated track temporarily installed in the vacuum vessel.

ITER & TOKAMAKS (R. HAWRYLUK):

PPPL researchers actively participated in the ITPA meetings.

PPPL researchers presented four talks at the ITPA Pedestal and Edge Physics Meeting in Cadarache, France from October 20-22: R. Nazikian "Recent results from n=2 ELM suppression experiments in DIII-D"; R. Maingi "DIII-D edge stability changes with lithium injection"; B. Grierson "Z_{eff} profile and impurity density determination in DIII-D"; and C.S. Chang "Gyrokinetic simulation of Divertor heat-load width under neoclassical and blobby turbulence

dynamics". The ITPA Pedestal and Edge Physics meeting was chaired by R. Maingi.

C.S. Chang participated in the ITPA-Turbulence and Confinement meeting as well as the Pedestal and Edge Meeting. In addition to the talk noted above, he gave presentations on: XGC1 simulations for the DIII-D transport shortfall case, Turbulent neoclassical momentum source in the edge plasma and Neutral particle effect on plasma turbulence.

W. Guttenfelder participated in the ITPA- turbulence and confinement meeting and gave an NSTX talk on behalf Yang Ren entitled "Experimental observations of nonlocal electron thermal transport in NSTX RF-heated L-mode".

C. Kessel and F. Poli attended the ITPA-IOS meeting. Kessel reported on the ITPA joint activity he is leading on entry to burn. This was also a paper at the IAEA-FEC conference. He did discuss issues with impurity content and radiation, with L-H transition in low power scenarios, ramp-down, energy confinement, particle screening. Kessel also reported on the joint activity on particle transport. He has prepared a reference case for the baseline scenario that modelers will use in time-dependent simulations on different platforms to compare particle transport models, define uncertainty ranges in the simulations and define specific issues that need to be further addressed, both in simulations and in experiments.

F. Poli reported on an action on pedestal boundary conditions for ITER scenarios.
She has coordinated the collection of EPED1 calculations in a lookup table that will be used by modelers in ITER simulations. The calculations have been compared with parametrizations that can be easily pugged-in in time-dependent simulations.

R. Goldston attended the Divertor and Srape-Off Layer ITPA meeting in Prague, Czechoslovakia on October 20-23. He made a presentation on "Numerical Studies of the 'Eich Fit Function' for Divertor Heat Flux"

Mario Podesta attended the ITPA- Energetic Particle meeting and gave a talk entitled "Development of reduced models for energetic particle transport in Integrated Simulations".

M. Okabayashi attended the ITPA-MHD meeting and gave a talk entitled "Further study of NTM control with feedback- Avoidance of Tearing Mode Locking and Disruption with Electro-Magnetic Torque Introduced by Feedback-based Mode Rotation Control in DIII-D and RFX-mod."

In response to the ITER Management Assessment, the ITER Director General set up an External Management Advisory Board to provide him input on management issues. The EMAB met on the October 20-21 at the ITER Organization Headquarters. The attending members were R. Hawryluk, M. Tendler, Y. Wan and J. Jacquinot. Jacquinot chaired the meeting.

DIII-D (R. Nazikian):

E. Kolemen presented a talk at the IAEA meeting covering various aspects of plasma control, including control of the snowflake configuration, detachment control, and burn control using RMP fields. He also put up a poster for R. Hawryluk on burn control. Mickey Wade presented a talk for R. Nazikian describing new understanding of the role of resonant penetration for RMP

ELM suppression.

Work continues on the Lithium Granular Injector for experiments at DIII-D. The TIV, bellows, and the support stand were successfully installed/leak checked. All vacuum cable interfaces were installed, along with the control interfaces. Progress continues with the neutral beam pole shield manufacturing and remains on schedule.

International (J. Hosea):

N. Bertelli, G. Taylor and J. Hosea collaborated on KSTAR from October 9-15 and performed two XPs on NTM stabilization and ICRF heating. The NTM was observed but no clear effect of the ECH on the NTM was found. This work will continue later in this KSTAR run to assure that the ECH deposition location is at the NTM location. The ICRF was observed to heat in both the L-mode and H-mode. Approximately 360 kW of the 600 kW applied ICRF power was deposited in the H-mode case. S. Wang and others are investigating the loss in the antenna under vacuum conditions to determine if Ohmic antenna losses account for much of the lost power.

R. Maingi presented a seminar at ASDEX-Upgrade titled "The effect of Lithium on DIII-D, NSTX, and EAST". The talk was well received, and in preparation for a Lithium injection collaboration in 2015 in ASDEX-Upgrade.

ADVANCED PROJECTS (D. GATES):

Key decisions were taken in this week's TDU Scraper Element project meeting. The Laboratory is participating in this ORNL-led project as part of its collaboration with the Wendelstein 7-X (W7-X) program at Germany's Max Planck Institute for Plasma Physics (IPP). When installed, the Scraper Element will become a focus for U.S. edge physics research on W7-X. This week, the armor material selection decision was completed, based to a major extent on PPPL's thermal-mechanical analysis, which showed that a graphite material that is used in other W7-X components would satisfy scraper element performance requirements. The choice of a material that is already known to satisfy W7-X compatibility requirements is advantageous in avoiding the cost and risk of qualifying a material that is new to the project. The remaining open issue was to determine what, if anything, would be required beyond the analysis being performed by PPPL and the attachment concept test being conducted by ORNL, to qualify the design. After reviewing a number of bench-testing options suggested by PPPL, it was determined by IPP that a high heat-flux test in IPP's GLADIS facility would be needed prior to installation in W7-X, in order to demonstrate the mechanical integrity of the structure under thermal load. Test samples for this test will be fabricated by PPPL as one of its project responsibilities, and the tests will be carried out by IPP. With these decisions having been taken, the project will continue to move toward a preliminary design review in January 2015, and establishment of a project baseline thereafter.

THEORY (A. BHATTACHARJEE):

A paper entitled "Comment on "Formation of Phase Space Holes and Clumps"" by I. Y. Dodin was published in Physical Review Letters [Phys. Rev. Lett.113, 179501 (2014)]. The work

comments on a recent study by M. K. Lilley and R. M. Nyqvist regarding the linear collisionless instability of energetic-particle distributions with a plateau. The paper by I. Y. Dodin points out that the authors overlooked important applicability conditions for the dispersion relation reported in their original paper. Specifically, dispersive properties of plasma cannot be calculated reliably using the Landau rule if the background distribution is modeled as abrupt, for the analytic continuation of such a distribution to the complex-velocity plane is not well defined. A more detailed calculation shows that, at least at weak dissipation, the instability of the plateau is the standard bump-on-tail instability (BTI) and has its rate continuing analytically to that of the plateauless BTI.

A poster by N.N. Gorelenkov et al was presented at the IAEA held in St. Petersburg, Russia, October 13-17. In this work, two techniques were presented which are able to relax the fast ion profiles in fusion burning plasmas. The first one is the critical gradient model (CGM) where marginally unstable (or critical) gradient of fast ion pressure is prescribed by unstable AEs in the presence of fixed thermal plasma damping. Critical gradient allows to reconstruct the fast ion pressure profile and compute fast ion losses. The second hybrid technique evaluates dynamically AE growth rates during the evolution of the system. Both methods are relatively fast ways to predict the fast ion profiles in burning plasmas and can be used for predictive modeling of future fusion devices.

Zhixin Lu, a long-time collaborator from UCSD, presented on effects of q-profile structure on intrinsic torque reversals, the subject of his upcoming APS invited talk. In more detail: Changes in rotation have been observed in LHCD experiments. From these observations, reversals in intrinsic torque have been inferred. This work identifies a new mechanism for intrinsic torque reversal linked to magnetic shear. Gyrokinetic simulations demonstrate that as compared to the normal magnetic shear case, the intrinsic torque reverses, when the magnetic shear is lower than a critical value. Analysis shows that the reversal occurs due to the dominance of a new symmetry breaking mechanism in the intensity-gradient induced residual stress. This mechanism is a consequence of ballooning structure at weak magnetic shear, related to the synergy of toroidal coupling and intensity gradient. Gyrokinetic simulation shows that for collisionless trapped electron modes (CTEM) and ion temperature gradient (ITG) modes, this critical magnetic shear is 0.3 and 1.3 respectively. The value of the critical magnetic shear is consistent with results from the Alcator C-Mod LHCD experiments, for which the magnetic shear is positive in the whole plasma column and the critical magnetic shear for torque reversal is 0.2~0.3.

PLASMA SCIENCE AND TECHNOLOGY (P. EFTHIMION):

The PS&T Department seminar this week entitled "Study of collisionless heating and transient electric field phenomena in capacitively coupled plasma discharges" was presented by Dr. Sarveshwar Sharma from Institute for Plasma Research, Gujarat, India. The abstracts reads "Collisionless or stochastic heating is an important phenomenon in low-pressure radio-frequency capacitively coupled plasma (RF-CCP) discharges. This heating is usually understood to originate in a stochastic interaction between electrons and the nonlinear electric fields inside sheath region. We have studied the dependence of stochastic heating on various discharge parameters by scaling of these parameters with the help of semi-infinite particle-in-cell[5] (PIC) simulation in current driven argon discharges. The existing analytical models[1,2,3] are benchmarked with simulation results. New physical effects appear (such as field reversal,

electron trapping, reflection of ions, etc.) and the simulation results deviate from existing analytical models for higher values of current density amplitude J_0. We have also studied the analytical prediction of the presence of transient electric field regions between the bulk plasma and sheath edge in RF-CCP discharges has been reported by *Kaganovich*[4]. Semi-infinite PIC simulation technique is used to verify the theoretical prediction for the existence of transient electric field in the linear regime; it is shown that the PIC simulation results are in good agreement with the results predicted by analytical model in this regime. It is also demonstrated that the linear theory overestimates the transient electric field as one moves from linear to weakly nonlinear regime. The effect of applied RF current density and electron temperature on evolution of transition field and phase mixing regime has been explored.

1. M. A. Lieberman, *IEEE Trans. Plasma Sci.* 16, 638 (1988).
2. M. M. Turner, *Phys. Rev. Lett.* 75, 1312 (1995).
3. Igor D. Kaganovich, Oleg V. Polomarov, and Constantine E. Theodosiou, *IEEE Trans. Plasma Sci.* 34, 696 (2006).
4. I. D. Kaganovich, *Phys. Rev. Lett*. 89, 265006 (2002).
5. G. Gozadinos, D. Vender, and M. M. Turner, *J. Comput. Phys.* 172, 348 (2001)."

ENGINEERING AND INFRASTRUCTURE (M. WILLIAMS):

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

Construction: New shields were installed on the PF1A coils and the microtherm on the centerstack was re-established with one layer and an overwrap of silica fabric. The casing was installed over the centerstack and the upper PF1A coil was installed over the centerstack bundle and inside the casing. The full centerstack assembly was weighed and was found to be 29,780 pounds. The centerstack assembly has been successfully lifted into NSTX. Work continues on the PF cooling water flow switches. The TF lead extension additional machining has been started.

CS Upgrade: Construction crews completed the installation of the CS Casing, PF1A and installation of the CS assembly into the vacuum vessel. Insulation of the OH Buss connection was completed. Installation of the insulation on the PF buss bars commenced in the CS winding area.

NBI Upgrade: Platform support column installation has been completed and subsequent measurements made to update drawings for fabrication of crossbeams and walkways. Services work continues on turbo vacuum piping. The HVE pumpdown and leakcheck is in progress prior to SF6 fills. Additional switchyard, surge room, and mod/reg work was completed in anticipation of Accel reactivation and the NB fixed frequency breaker SB10 was racked in for operations by AC Power. Kirk key interlock test procedures are in progress. Controls work continues with installation of cable, trays, and terminations. Ion source wiring has started on all three sources. Cryogenics maintenance and repairs in preparation for operations continues. The shield wall drawing development continued. Development of NB procedures continues.

Digital Coil Protection System: Development of the real world PTP continued and dry run tests have been performed. DCPS software preoperational test procedures and bug investigations continued. Investigatory work continued with Concurrent support. Development of a DCPS

System Design Description and Reliability Assessment continues per requirements. FMEA details were edited per current design and plans. Updates to the autotester to support testing and operations were completed.

BUSINESS OPERATIONS (K. FISCHER):

DOE approved a work for others agreement with Princeton University entitled "Coherent Structures in Plasmas Relevant to Electric Propulsion". The Principal Investigator is I. Kaganovich and the budget is $315,000.

INFORMATION TECHNOLOGY (A. KELLEY):

E. Feibush presented two mini-courses, Python Programming Techniques and Python Numpy Programming, sponsored by the Princeton University Institute for Computational Science and Engineering (PiCSciE). The hands-on programming sessions emphasized the elements and features of Python and how it can be used for efficient array computations in a scientific workflow. Topics included plotting data and using Latex syntax to format labels and equations in the graphs. Tools and techniques were demonstrated so attendees learned how to continue progressing with Python on their own. Researchers from a total of 20 different departments attended the two sessions. PPPL interns Zachary Kaplan and Bum Shik Kim served as teaching assistants for the programming exercises.

PUBLICATIONS:

Dodin, I.Y., "Comment on "Formation of Phase Space Holes and Clumps," Physical Review Letters 113, 179501 (2014)

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