PRINCETON PLASMA PHYSICS LABORATORY
WEEKLY highlights

PPPL
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending November 20, 2015 are as follows:

FEATURED HIGHLIGHT (M. ONO):

R. Goldston (PPPL) has won the 2015 "Nuclear Fusion Journal" award for his 2012 paper on the "Heuristic drift-based model of the power scrape-off width in low-gas-puff H-mode tokamaks," Nuclear Fusion 52 (2012) 013009. His model predicts that this width should be 2a/R *rho_p. In 2011, when the paper was written, initial experimental results were roughly consistent with this model. Many more measurements and careful analysis by NSTX, C-MOD, DIII-D, ASDEX-U and JET teams have found results surprisingly close to this model. Even inner-wall limited plasmas seem to have a similar near-plasma high-heat flux feature. It is on the basis of this model that the NSTX department projects that NSTX-U will be a very effective device for studying PMI physics, for it will have a high heat flux.

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

Steady State Electric Network (SSEN):

Subcontract for the Reactive Power Compensators procurement was awarded to Schneider Electric USA (factory in Pringy, France).

All Release for Manufacturing (RFM) submittals for the Power Transformers have been approved by ITER. Terms of a contract amendment covering changes that have come about during the RFM design review process is being negotiated.

Diagnostics:

Upper Port Wide Angle View Visable-IR Camera (UPP WAVs): M. Smith attended a three-day technical workshop at General Atomics in San Diego, California, which included all team members. Roger Reichle from IO attended remotely on the first day. Everything was discussed related to the UWAVs project: cost and schedule, design, R&D, P&ID, etc.

Diagnostic RGA (DRGA): Preliminary testing of low-fringing-fields-sensitivity study on the Ion-Trap mass-spec has begun. The testing setup has not been optimized yet, but preliminary data indicates that the sensitivity may, in fact, be HIGHER, than for a quadrupole mass-spec, at least based on available literature. This preliminary finding is counter-intuitive and will be further investigated.

Equatorial Port 9 Integration: The EP09 integration team participated in the ITER Port Integrator Coordination Team (PICT) event on November 16. Sessions focusing on port DSMs allowed for the opportunity to share new DSM redesign intentions with the IO and all the DAs. A variety of solutions for engineering problems shared by all DAs were presented. Also this week, the US port integration team here at PPPL outlined presentation plans for the December window PDR event at ITER.

Toroidal Interferometer and Polarimeter (TIP): Recent work on the laboratory prototype TIP system at General Atomics has focused on noise reduction. The causes of several noise sources were identified and eliminated. This work is being documented in a report. The interferometer performance is now thought to be near the noise floor, while additional work is needed to eliminate remaining sources of noise and drift in the polarimeter. Once this has been achieved for the short path length configuration confined to the optical table, the beams will be sent down the full-scale prototype relay system to study the effects of the much longer path length and the real-time alignment system.

NSTX (M. ONO):

NSTX-U physicists attended the Annual APS-DPP meeting held in Savannah, Georgia on November 16 – 20. There were two NSTX/NSTX-U related invited talks: "Phase space effects on fast ion transport modeling in tokamaks" by M. Podesta (PPPL) and "Torque-consistent 3D force balance and optimization of non-resonant fields in tokamaks" by J-K. Park. In addition, there were six NSTX/NSTX-U related oral contributed talks and 56 contributed posters.

A tutorial entitled "The snowflake divertor" by D. D. Ryutov (Lawrence Livermore National Laboratory) and V. A. Soukhanovskii (Lawrence Livermore National Laboratory) has been published in Physics of Plasmas 22, 110901 (2015) http://dx.doi.org/10.1063/1.4935115. The paper provides a comprehensive review of the snowflake divertor magnetic configuration—its theory, main magnetic and plasma properties, and experimental results obtained with the snowflake divertor configuration on several tokamaks, including NSTX, to date.

An extensive review paper by K.C. Shaing (National Cheng Kung University, Taiwan), K. Ida (NIFS, Japan), and S.A. Sabbagh (Columbia University) entitled "Neoclassical plasma viscosity and transport processes in non-axisymmetric tori" has been recently published in Nuclear Fusion 55 (2015) 125001 (http://stacks.iop.org/0029-5515/55/125001). The paper reviews substantial work on neoclassical transport processes, especially neoclassical toroidal viscosity (NTV) published in ~10 papers by Shaing through the period 2000 ~ 2010. Foundational NTV experimental work on stellarators and tokamaks is also contained in the review.

NSTX-U Operations activities were curtailed on Tuesday through Thursday this past week so staff could attend DOE Conduct of Operation Training. Diagnostic installation activities continued during this time, and vacuum leak checking and the sealing of vacuum leaks in the upper and lower umbrellas was successfully completed. Field Coil power testing per the Integrated System Test Procedure resumed at the end of the week.

ITER & TOKAMAKS (R. HAWRYLUK):

R. Maingi summarized the PMI community workshop report in a town hall meeting at APS.

DIII-D (R. Nazikian):

W. Solomon presented an invited talk at the APS meeting, describing a high pedestal regime, dubbed Super H-mode, which has been theoretically predicted and experimentally realized on DIII-D. The new regime allows the thermal energy confinement time to continue to increase with density, up to high normalized density where ITER and reactors are expected to operate. This is in contrast to standard H-mode where confinement is often observed to degrade at high density. The talk also described the potential benefits of exploiting a Super H-mode pedestal on ITER and future power plant designs.

N. Logan presented as an invited speaker at the 2015 American Physical Society meeting. His talk, entitled "Observation, Identification, and Impact of Multi-Modal Plasma Responses to Applied Magnetic Perturbations," highlighted a new understanding of the magnetic diagnostics that can directly relate the observed multi-modal behavior to the resonant current drive thought to be important for suppressing Edge Localized Modes. A previously unused property of the plasma, the reluctance, provides the basis with which this connection can be made experimentally. His talk introduced the application of this plasma property, its connection to the magnetic measurements, and connections to previous performance metrics.

B. Tobias presented an invited manuscript describing the mutual coupling of tearing instabilities and the resulting phase-locked rotation profiles observed on DIII-D. The flattening, even reversal of fluid rotation across the core plasma has consequences for the local and global stability of the discharge. It also impacts transport in other channels. Discharges that do not conform to the predictions of resistive, single-fluid MHD theory belie the importance of neoclassical effects, opening rich new avenues of research with respect to the dynamics of tokamak disruptions.

L. Cui presented an invited talk on her PhD study, the observation of a transport bifurcation that occurs by the spontaneous self-organization of a simple drift-wave system. As the magnetic field is increased above a threshold (=1200G), a global transition has been seen in steepening of mean density and ion pressure profiles, strong EXB shearing, reduction of turbulence and improved turbulent radial particle transport. The total Reynolds work sharply increase above threshold that correlates with the sharp increasing of density steepness, which suggests the Reynolds stress-driven flow plays an essential role in density steepening and transport bifurcation. Several interesting phenomena related to the transport bifurcation are also reported: the local inward particle flux, the co-existence of ion and electron feature, and the self-sustained axial flow.

S. Haskey gave an invited talk at APS based on his thesis work on low frequency Alfven eigenmodes in the H-1 helical axis stellarator (HELIAC) at the Australian National University. The talk included modeling which showed that despite the low-beta in H-1, the strong geodesic curvature allows for significant low frequency gap structure in the Alfven continuum. Further modelling showed that low frequency global BAE type modes exist in these gaps. A unique tri-axis helical Mirnov array and a high frequency synchronous imaging technique were developed in order to validate the nature of these modes. The data from these diagnostics confirm that these modes are most likely BAEs, providing experimental validation that these modes can exist in a

low-beta stellarator.

A. Nagy, lead engineer on the high power helicon system installation at DIII-D, held a kick off meeting outlining the team tasks and goals. The ~20 member team is charged with developing and operating a high power Helicon launcher that will handle megawatt pulses at 476 MHz for up to 10 seconds. The system includes a high voltage power supply operating a 1.2 MW klyston provided by SLAC. The RF waves are routed through existing 9" coaxial transmission line to a switching/splitter network at the vessel. The traveling wave antenna is expected to drive ~60 kA of off-axis plasma current. The high power antenna design, fabrication, and installation will proceed with a vessel installation in the summer of 2016.

C-Mod (C. Kessel):

C. Kessel presented a poster on the He ELMy H-mode experiment at the APS-DPP meeting in Savannah, Georgia. This is a joint experiment in the ITPA Integrated Operating Scenarios group to understand what can be expected for He discharges to prototype DD and DT experiments before activating the tokamak in ITER. On C-Mod the He ELMy discharges are being compared to D ELMy discharges from 2009, 2010, and 2012. Overall, similar plasma parameters can be accessed, including ELM frequency, electron pedestal pressure, and ELM regimes, while the He plasma stored energy is 80-90% of the best D case, and they require roughly 25% higher Pnet/Pthreshold to sustain the H-mode. Analysis and interpretation is continuing.

ADVANCED PROJECTS (H. NEILSON):

Several papers on the Department's 3D physics and reactor collaborations were presented at the Annual APS Division of Plasma Physics (DPP) meeting in Savannah, Georgia. D. Gates gave an invited talk entitled "The tokamak density limit: a thermo-resistive disruption mechanism." The talk summarized recent work by Gates and collaborators that have proposed a theory for the tokamak density limit scaling commonly referred to as the Greenwald limit. The discoveries reported in the talk were selected for inclusion as one of the APS-DPP annual press releases.

S. Lazerson and N. Pablant reported on work performed under the Laboratory's collaboration in Germany's Wendelstein 7-X (W7-X) stellarator project. Lazerson's paper, "Modeling and analysis of flux surface mapping experiments on W7-X," reported on comparisons between predictions and the first experimental data from W7-X, including studies of the influence of applied low-order perturbations on the W7-X magnetic configuration. The U.S.-supplied trim coils were used to generate these perturbations, marking the first use of this equipment in a W7-X experiment. Pablant's paper, "Expected Performance from the X-ray Imaging Crystal Spectrometer on the W7-X Stellarator," reported on a U.S.-supplied diagnostic that is now ready for W7-X plasma operation, as well as analysis techniques that will be use to infer plasma transport properties based on the data.

Work performed as part of a collaboration with South Korea's National Fusion Research Institute was reported by D. Mikkelsen in "Survey of heating and current drive for K-DEMO." The paper reports on simulations of heating and current drive performance of neutral beams and a range of radiofrequency wave launchers for plasma conditions expected in the K-DEMO facility, now being studied as a next step in South Korea's fusion program. The results

will be used as input to the design of an optimum configuration of heating and current drive technologies for K-DEMO.

THEORY (A. BHATTACHARJEE):

Researchers from the PPPL Theory Department attended the Annual Meeting of APS Division of Plasma Physics in Savannah, Georgia from November 16-20. A. Bhattacharjee presented an invited tutorial titled "Recent developments in reconnection theory: the plasmoid Instability, self-generated turbulence, and implications for laboratory and space plasmas." Other members of the department also presented invited talks: N. Ferraro presented "Free-boundary 3D equilibria and resistive wall instabilities with extended-mhd," S. Jardin presented "Magnetic self-organization in tokamaks," and I. Kaganovich presented "Acceleration of plasma electrons by intense nonrelativistic ion and electron beams propagating in background plasma due to two-stream instability." There were contributed talks given by I. Barth, V. Duarte, F. Ebrahimi, and W. Fox. Posters were presented by D. Brennan, R.M. Churchill, I. Dodin, N. Gorelenkov, A. Hakim, S. Ku, W.W. Lee, M. Lingham, M. Parsons, D. Pfefferle, A. Reiman, D. Stotler, T. Stoltzfus-Dueck, and W. Wang.

PLASMA SCIENCE AND TECHNOLOGY (P. EFTHIMION):

PPPL hosted the Workshop on Magnetic Fields in Laboratory High Energy Density Plasmas (LaB) at Jadwin Hall at Princeton University on November 11 – November 13 with support by Princeton Center for Theoretical Science. The main organizers were W. Fox, L. Gao, and H. Ji; other PPPL physicists (P. Efthimion, K. Hill, A. Bhattacharjee, I. Kaganovich et al.) have actively participated in organizing and discussions. The "LaB" workshop series aims at bringing together, in a trans-disciplinary forum, scientists interested in the emerging areas of coupling laboratory high-energy-density (HED) plasmas and external and internal intense magnetic fields in varied domains, including plasma astrophysics, inertial fusion, and particle acceleration. Magnetic fields have been widely recognized to have profound effects in these areas, but specific progress is hindered by limited theoretical understanding and diagnostics capabilities. The main aim of such a forum is to serve as an exchange of ideas, discussion of theoretical and experimental work that has been done, and to explore potential new collaborations in these critical areas. During the LaB meeting at Princeton, scientists from around the world gave 42 presentations covering almost all areas of magnetic field effects in the HED plasmas. Extensive discussions took place on the following sessions: (1) Applications of B field to ICF, (2) Generation and dynamics of B fields, (3) Measuring B fields, (4) Magnetic reconnection, (5) Shocks, (6) Plasma Dynamos, and (7) Jets and magnetized disks.

BUSINESS OPERATIONS (K. FISCHER):

Budget Office:

PPPL submitted six proposals to DOE in response to the Early Career Research Program Announcement LAB 15-1386. The Principal Investigators for the six proposals are D. Battaglia,

I. Dodin, N. Ferraro, W. Fox, A. Hakim, and F. Poli. The requested budget for each proposal is $2.5 million over a five-year period.

PPPL submitted a Project Data Sheet for a new Laboratory Directed Research and Development (LDRD) project to the DOE for concurrence. The project is titled "Stellarator Core Designs for a Net-Energy Breakeven (Qeng = 1) Fusion Plant." Including the budget request for this project, the total budget allocated to LDRD projects in FY16 is $2.9M against the $3.0M LDRD funding ceiling approved by DOE.

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