eNews

May 24, 2011 (Issue 55)

CONTENTS

Dear Burning Plasma Aficionados:
This newsletter provides a short update on U.S. Burning Plasma Organization activities. E-News is also available online. Comments on articles in the newsletter may be sent to the Editor (Tom Rognlien) or Assistant Editor (Rita Wilkinson). Thank you for your interest in Burning Plasma research in the U.S.!

Director's Corner by Jim Van Dam

USBPO Web Seminar

The third USBPO web seminar was held Tuesday, May 24, from 12:00 noon to 1:00 p.m. (Eastern Time). The purpose for these seminars is to disseminate information to the US fusion community about developments at recent meetings of the ITPA Topical Groups, and to provide an opportunity for community feedback and input. The topical groups and the speakers for the May 24 seminar were:

- *Energetic Particle Physics* — Raffi Nazikian
- *Pedestal and Edge Physics* — Phil Snyder

Annual USBPO Council Election

It's time for the annual election of new members for the USBPO Council. The twelve members of the USBPO Council serve staggered three-year terms. Every year around this time, four members rotate off. An election is held to replace two of the members, with the other two being appointed.

The Council's Nomination Committee—which consists of Lee Berry (chair), Dylan Brennan, Mike Mauel, Cynthia Phillips, John Rice, and Mike Ulrickson—had earlier sent messages to the entire USBPO membership, asking for recommendations for qualified candidates. Using the many good responses from the membership, the Committee has now proposed a slate of six candidates, approved by the Council. An announcement with voting instructions was sent out to BPO members by Mike Mauel on Friday, May 20. Review this email from Mike, and be sure to vote.

You might also take this opportunity to check your membership status, since only regular members of the USBPO may vote in this election. Membership is obtained by signing up for one or more Topical

Groups via the USBPO web site. If you are uncertain about your membership status or your email address has changed, please contact our Communications Coordinator, Jim DeKock.

USBPO Activities at APS-DPP Meeting

In 2010, for the third year in a row, the schedule for the APS Division of Plasma Physics Annual Meeting included a contributed oral session on "Research in Support of ITER." In fact, there was so much interest that this turned into two sessions (ITER I and ITER II), with a total of 20 talks from the US, Europe, and Japan. These ITER contributed oral sessions have become quite popular and were well attended last year despite their Thursday and Friday placement on the agenda.

Following up on last year's success, the US Burning Plasma Organization is organizing a similar session for the 53rd Annual Meeting of the Division of Plasma Physics, which will take place in Salt Lake City, Utah, on November 14-18. As was the case last year, we are looking for talks about research done to address ITER issues. These talks are 10 minutes in duration, followed by a two-minute discussion period. We hope to have broad participation once again, so we can highlight the breadth of this work and the institutions performing it. Chuck Greenfield and Mike Mauel have agreed to organize this contributed oral session.

If you or somebody from your institution is interested in making a presentation in this session, please send the title and the author's contact information to Chuck Greenfield and Mike Mauel as soon as possible (and no later than June 30). Also, the abstract itself should be submitted via the conference website no later than 5:00 PM Eastern Daylight Time on July 15. Please indicate "Research in Support of ITER" in the placement requests box for the abstract. The DPP Program Committee may place abstracts that are not selected for the ITER session into other sessions.

As in previous years, the USBPO also plans to organize an evening ITER Town Meeting at the 2011 APS-DPP Meeting. More details will be forthcoming as speakers are lined up.

STAC-10 Meeting

The Science and Technology Advisory Committee (STAC) of the ITER Council held its tenth meeting recently, May 9-11, in Cadarache, France. The delegation from the US consisted of Steve Eckstrand (replacing Erol Oktay, recently retired), Rob Goldston, Stan Milora, Tony Taylor, and myself.

The Council at its November 2010 meeting (IC-7) had formulated a set of charges for STAC-10 to address. This original set of charges had six items:

1) Review the Additional Direct Investments not yet included in the ITER Baseline to assess the priority of the various items from the scientific and technical point of view;
2) Provide technical analysis of additional cost-saving measures proposed by the IO;
3) Evaluate the definition of ITER baseline scenarios and, in particular, the capability of the H&CD, Diagnostics and Control systems to satisfy the requirements for advanced operating modes such as hybrid and steady-state operation;
4) Evaluate the progress on Design and R&D for the ITER radiofrequency heating systems and the status of risk mitigation measures;
5) Evaluate the project's approach to mitigating the major effects of plasma disruptions and comment on the opportunities for supporting disruption R&D in the fusion programme;
6) As standing items of the STAC meeting, review the progress on some key open STAC issues such as diagnostic risk assessment and performance specification, the design and R&D of in-vessel coils, and options to minimize the time between first plasma and DT operation.

Subsequently, the Chair of the ITER Council, with agreement from the STAC Chair, had withdrawn Charge #1, because the Management Advisory Committee, at its Extraordinary Meeting in January 2011, proposed guidelines for dealing with the Additional Direct Investment (ADI) items that are not yet included in the ITER Baseline.

The other two changes to the agenda for the STAC-10 meeting were the addition of (1) a report about the new physics R&D results on ELM suppression with RMP coils on ASDEX Upgrade and (2) a report about the recent conductor test results for the Central Solenoid and Toroidal Field coils.

Top management and senior scientific leaders from the ITER Organization presented nine talks to the STAC concerning the five charge questions and the additional items of business. The STAC members divided into five groups to write draft sections of the report. The STAC then discussed the entire report in plenary session, before briefing ITER management at the end of the third day of the meeting. The final version of the report was completed the following week via email. The STAC-10 report will be submitted to the eighth meeting of the ITER Council, to be held in Aomori, Japan, June 14-15, 2011.

The *ITER Newsline* has published an article about the STAC-10 meeting. Below are some photographs at the ITER construction site. The STAC members were given a tour on the morning of the second day of their meeting.

STAC-10 members posing in front of the future ITER Headquarters Building, now under construction.
(photo courtesy of ITER)

Poloidal Field Coil Winding Building, under construction
(photo courtesy of ITER)

ITER Headquarters Building, under construction.
(photo courtesy of ITER)

Fusion and High Performance Computing

Two USBPO scientists recently presented talks about fusion and high performance computing at the 41st HPC User Forum meeting, held April 5-7, 2011, in Houston, Texas. Dylan Brennan, Deputy Leader of the USBPO Modeling and Simulation Topical Group, gave a talk on "Fusion Research and High Performance Computing." Lee Berry, a member of the USBPO Council, gave a talk on "Magnetic Fusion Simulation: The Problem, The Successes, The Challenges." The HPC User Forum was established in 1999 to promote the health of the global HPC community and address issues of common concern to users. The Forum has grown to 150 members; it is directed by a volunteer steering committee of users from government, industry, and academia, and operated for the users by industry analyst firm IDC. The talks by Brennan and Berry are both posted on the Reference Files page of the USBPO web site. You can also find the talks posted at the HPC Forum web site.

Later the same week, the 2011 US Transport Task Force Meeting in San Diego, California, Dylan Brennan organized a special session of talks about the Fusion Simulation Project. The speakers and their titles are listed on the TTF agenda. This series of excellent talks about the mission, structure, and science of the Fusion Simulation Project was well attended and well received.

As already reported in last month's issue of *eNews*, ITER will hold an Integrated Modeling Technology Workshop June 8-10 in Cadarache, France. The organizers are Wayne Houlberg and Frederic Imbeaux of the ITER Organization.

Fusion Miscellany

Pat Boone, well-known crooner of yesteryear, has written a column in *World Net Daily* that advocates for fusion energy. His commentary is entitled "Fusion: Our 1st, Best, and Only Hope".

Bull Supercomputer has been selected to provide, maintain, and operate the supercomputer for the International Fusion Energy Research Center at Rokkasho, Japan. This is part of the European-Japanese Broader Approach agreement. The computer will become available in January 2012. Peak performance will be 1.3 petaflops.

Neil Calder, former Head of Communication for the ITER Organization and now Senior Advisor in Communication at the brand-new Okinawa Institute of Science and Technology in Japan, has written an interesting article in the March issue of *Physics Today* about the importance of strategic communication for science. His article entitled "What's It For?" is about how to communicate science in non-technical ways so as to be understandable by a broad audience.

The European Fusion Development Agreement (EFDA) organization has announced the publication of a new quarterly online newsletter called *Fusion in Europe*. The first issue can be viewed here.

Students, Arise!

Once again we would remind students that they are eligible—and indeed welcomed—to join the US Burning Plasma Organization. Go to the USBPO web page and click on Topical Groups under Sign Up. It's painless. Be involved! Be informed! You are the "ITER Generation."

USBPO Topical Group Highlights

(Editors note: The BPO Energetic Particles Topical Group works to facilitate U.S. efforts to understand the behavior of energetic particles via improved measurements and computational models for existing and future magnetic fusion devices [leaders are Don Spong and Eric Fredrickson]. This month's Research Highlight by Eric Fredrickson et al., summarizes recent measurements and modeling of Alfvén wave instabilities and their effect on fast-ion confinement in NSTX. BPO members are welcome to propose future Research Highlight articles to the editor.)

Measuring and modeling fast ion transport during Alfvénic avalanche events*

E. D. Fredrickson, N. Gorelenkov, E. Belova, B. LeBlanc, R. E. Bell, M. Podesta (Princeton Plasma Physics Laboratory); *N. A. Crocker, S. Kubota* (University of California, Los Angeles); *and H. Yuh, F. Levinton* (Nova Photonics)

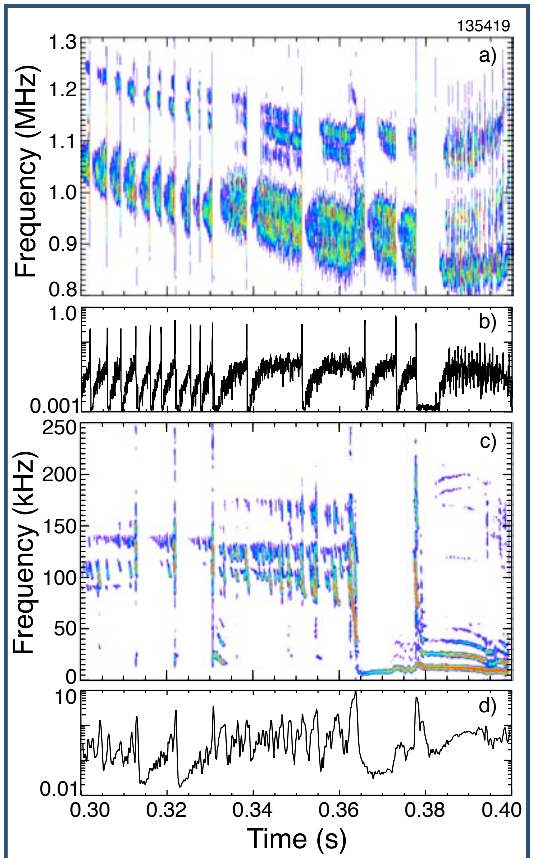

Fig. 1. NSTX data of a) spectrogram showing GAE modes, b) rms magnetic fluctuations 0.8 MHz<freq<1.3 MHz, c) spectrogram showing TAE and low frequency kink activity, d) rms magnetic fluctuations from 30 kHz<freq< 200 kHz.

A super-Alfvénic fast-ion population, such as the fusion-produced alpha particles in ITER, can excite instabilities extending from low-frequency Energetic Particle Modes (EPMs) at tens of kHz, through Toroidal Alfvén Eigenmodes (TAE) with frequencies in the range of $V_{Alfvén}/(4\pi qR)$, to high-frequency Global and Compressional Alfvén Eigenmodes (GAE and CAE) in the ion cyclotron frequency (ω_{ci}) range from roughly $0.1\omega_{ci}$ to $0.7\omega_{ci}$. Instabilities excited by fast ions can exhibit complex non-linear behavior, including strong growth which onsets above an amplitude threshold when resonance regions in the fast ion phase space for different modes, or even the multiple resonance regions that may be present for a single mode, start to overlap, resulting in strong fast ion transport [1]. In neutral beam-heated NSTX plasmas, the GAE and CAE are excited through a Doppler-shifted ion cyclotron resonance with beam ions traveling faster than the Alfvén velocity, and thus may also be present in ITER, excited by the fusion alpha particles that also will be moving faster than the Alfvén velocity.

Single modes create one or more resonant fast-particle phase space "islands" in the 6-dimensional space describing the fast ion population, f(r,v), where an island is the region where fast ions have become trapped in the wave field. As the mode amplitude increases, the size of the resonant "island" increases. With multiple resonances, islands close together can overlap, creating a larger, stochastic region, which greatly enhances fast-ion redistribution, that is, avalanches. While single, low amplitude TAEs cause negligible fast ion transport in NSTX, multiple, strongly interacting modes as in an "avalanche event" can cause substantial fast ion loss. In a similar manner, interaction of multiple modes on ITER could redistribute or cause the loss of fusion alpha particles.

The avalanching behavior has been seen on NSTX for two classes of Alfvénic modes. Figure 1 shows examples of (a,b) GAE avalanches at frequencies near 1 MHz, and (c,d) avalanching of the lower frequency TAE. Strong drops in the fusion neutron rate, indicating losses of super-thermal ions, are seen at the TAE avalanches. Direct losses of fast ions have not been observed with the GAE avalanches, but fast ion redistribution is inferred, as in this example where the GAE avalanches appear to trigger TAE avalanches.

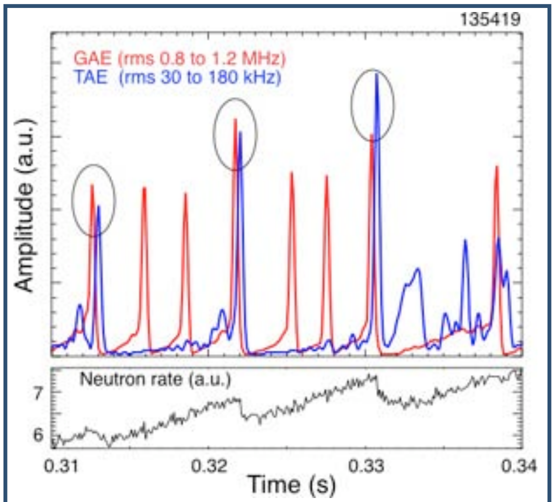

Fig. 2. RMS fluctuation levels in GAE frequency band (red) and TAE frequency band (blue). Relative fluctiation amplitude between red/blue curves is arbitrary; shown for timing only.

Figures 1a and 1b show a spectrogram of the GAE activity and the rms fluctuation level over the frequency range from 0.8 MHz to 1.3 MHz, respectively. The modes are seen to grow slowly for several milliseconds (ms), then very quickly for a brief period (the spikes seen in Fig. 1b, or Fig. 2), followed by a quiescent period, and finally the cycle starts again. Figures 1c and 1d show similar concurrent spectrograms depicting TAE avalanches and their rms mode evolution, as described in a previous publication [2].

The strong, periodic bursts of GAE activity shown in Fig. 1 have all of the characteristics of avalanching behavior. Abrupt decreases in the neutron rate are not observed with the GAE avalanches; however, the GAE-quiescent period following each strong burst is consistent with a fast-ion redistribution that reduces the free energy available to drive the modes. Further evidence of fast ion redistribution is shown in Fig. 2, where the rms fluctuation level for GAE (red) and TAE (blue) are shown. The three TAE avalanche events in this time range are seen as spikes in the blue curve. Each of the three TAE avalanches has a GAE avalanche several hundred microseconds earlier, although not every GAE avalanche triggers a corresponding TAE avalanche. The timing suggests that the redistribution of fast ions from the GAE avalanche provided some of the impetus to trigger the TAE avalanche [3].

The transport of fast ions resulting from strongly non-linear Toroidal Alfvén Eigenmode avalanches in NSTX has been simulated with the NOVA ideal magnetohydrodynamic code to calculate the eigenmodes and with the ORBIT code to model fast ion transport. A multi-channel reflectometer and the toroidal Mirnov coil arrays are used to measure the toroidal mode numbers, internal mode structure, and frequency, to validate the NOVA calculations of the eigenmodes. Doppler corrections to the continuum were needed to find good agreement. The NOVA eigenfunctions, scaled with the experimental amplitude and frequency evolution, are used in the ORBIT code to simulate redistribution and loss of the fast ions during the final 1 ms burst of the TAE avalanche cycle.

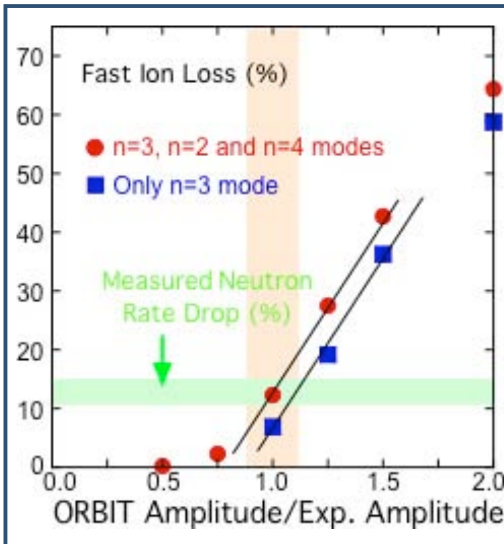

Fig. 3. Fast ion loss fraction as mode amplitudes are scaled about the NSTX experimental value.

The simulated losses exhibit a strong, non-linear onset with mode amplitude, consistent with the avalanche model. Good quantitative agreement has been found with fast ion losses as inferred from fast neutron rate measurements and also with the energy dependence of losses measured with the neutral particle analyzer (NPA) diagnostic, which samples the ion loss distribution via edge charge-exchange neutrals. These results are also being compared to non-linear M3D-K simulations. The unperturbed fast ion distribution is calculated with the TRANSP Monte Carlo beam deposition code and used as input to ORBIT. The ORBIT simulations show the onset of strong, non-linear losses at a mode amplitude that is 20% lower than the experimental value (Fig. 3).

The good agreement between the experimental data and the losses simulated with ORBIT confirm that strongly non-linear physics plays an important role in the fast ion loss events seen on NSTX. Further, the basic physics of mode growth, saturation, and fast ion losses predicted by the avalanche model seem to agree very well with the experimental observations. The simulations shown here, however, are semi-empirical in that the experimentally measured modes and mode amplitude evolutions are needed to scale the linear eigenmodes found by NOVA. The next step in developing a predictive capability for fast ion losses is to develop fully self-consistent, non-linear codes that can model the avalanching physics.

REFERENCES

[1] H. L. Berk, B. N. Briezman, and M. Pekker, Phys. Plasmas **2**, 3007 (1995).
[2] E. D. Fredrickson, N. A. Crocker, R. E. Bell, *et al*., Phys. Plasmas **16**, 122505 (2009).
[3] E. D. Fredrickson, N. N. Gorelenkov, E. Belova, *et al.,* 23rd IAEA Fusion Energy Conference, 11-16 October 2010, Daejeon, Republic of Korea, EXW/P7-06.

*Work supported by U.S. DOE contracts DE-AC02-09CH11466, DE-FG03-99ER54527, DE-FG02-06ER54867, and DE-FG02-99ER54527.

ITPA Reports

Summary of the 6th Meeting of the ITPA Integrated Operations Scenarios Topical Group, Culham, United Kingdom

C. Kessel (Princeton Plasma Physics Laboratory)

The ITPA Integrated Operations Scenarios (IOS) meeting was held April 11-14, 2011, at Culham. The meeting began with a welcome from M. Watkins, and logistics from G. Sips (deputy chair) and S. Ide (chair). S. Ide reported on the ITPA Coordinating Committee meeting, which is combined with the IEA meeting on the cooperation of tokamak programs. The IOS joint experiments were largely accepted, with the exception of the simulated burn-control proposal. What used to be the large tokamak agreement is turning into the US, EU, Japan, and Korea tokamak agreement. New ITPA chairs will be determined by the next meeting or soon after.

J. Snipes reported on ITER developments primarily for the ITER Science and Technology Advisory Committee (STAC) review, including testing of super-conducting center stack (CS) and poloidal field (PF) coils, internal control coils, diagnostics, acceleration of first DT operation, possible downgrading of the neutral beam (NB) energy to 850 keV, toroidal magnetic field ripple from the ferritic inserts, and optimization of midplane Electron Cyclotron (EC) wave launchers. He also covered control of ITER operational scenarios as a new area where participation by the IOS group would be very helpful. This work includes testing of ITER control algorithms on present tokamaks, the reliability of magnetic diagnostics for long times and in a radiation environment, steady-state scenarios for 3000 s with q-minimum (magnetic safety factor) and loop voltage control, transport control with toroidal rotation, internal transport barriers (ITBs) and impurities, divertor heat-load control at lower densities, event handling, and impurities for radiation.

Reports were given on experimental results for various devices: ASDEX-Upgrade (AUG) reported resonant-magnetic-perturbation coil results for ELM modification; Frascati Tokamak Upgrade (FTU) reported the development of an EC refractometer; JT-60SU reported work to understand the hybrid operating mode in the absence of neoclassical tearing modes (NTMs); Tore Supra reported further progress with the PAM lower-hybrid (LH) wave launcher; Alcator C-Mod reported discharge-current ramp down, electron temperature ITBs, and I-mode confinement; JET reported that impurity seeding caused type-III ELMs when injected into type-I ELMing discharges; the Korean KSTAR tokamak reported their first H-modes; and some data and interpretation of tearing modes in DIII-D was presented.

The status of the various IOS Joint Experiments (JE) were reported as follows:

IOS 1.1: <u>Baseline ITER 15 MA scenario demonstrations</u>

AUG reported 4 s discharges that were MHD stable.
C-Mod reported 1 s flattops with $\beta \geq 1.5$, where tearing modes were present.

IOS 1.2: Impurity seeding effects
Several devices have related data, which needs further integration into ITER demo discharges, and machine comparisons.

IOS 2.3: EC X-mode 2nd harmonic breakdown
Examining closure of this Joint Experiment or possible extensions.

IOS 3.1: Beta-limit in advanced tokamak (AT) discharges
Close and write paper; wait for AUG data.

IOS 3.2: Access conditions to steady-state (SS) discharges
How to define a good target discharge—normalize plasma beta (β_N), non-inductive current fraction (f_{NI}), etc.
Identifying the initial conditions that provide the best sustained discharges.

IOS 4.1: Access to hybrid discharges
Working on classifying ramp up to hybrids that uses histograms to identify trends in several parameters. There appear to be few correlations apart from magnetic safety factor q(0) > 1 and possibly total NB energy injected.
Possibly the transition from current ramp up to flat top is more important than ramp up; DIII-D and JET are primary contributors, AUG has database too.

IOS 4.2: The normalized gyroradius ($\rho*$) dependence on transport/stability of hybrid
IAEA paper, progress reported, add AUG.

IOS 5.2: Ion cyclotron radio frequency (ICRF) coupling to the plasma
IAEA paper, primary focus is gas injection, further reports at the next meeting.

IOS 5.3: LH current drive at high density
Separate devices reporting varying experience with density. Need to assemble data and determine Joint Experiments that can be tried on all devices with Lower Hybrid.

IOS 6.1: Plasma profile control
Appears to have completed the open-loop model building aspect of the Joint Experiment, but still needs closed-loop tests of the related controller behavior.
Considering closing this Joint Experiment and opening another on the closed loop application.

IOS 6.2: Internal inductance (li) control
Close this Joint Experiment, no activity.

IOS 6.3: DT burn control
This Joint Experiment was rejected by the Coordinating Committee because there are no devices taking this on; discussions ensued on how to proceed.

Presentations were given in the area of modeling using the integrated plasma simulator from the SWIM SciDAC project, EU ITER scenario modeling, SS scenario modeling, EC launcher variations, plasma control, the hybrid mode on JET, ramp up comparison between DIII-D and JET, using the TGLF package in ramp up modeling, dimensionless physics parameters for pedestal scaling, and ITER zero-dimensional (0D) analysis of steady-state operating space.

The effort of providing modeling through Joint Activities (JA), similar to joint experiments, is continuing. The following series of Joint Activities were presented for ongoing discussions.

JA 1.0: modeling of ITER-like experiments
JA 2.0: ramp down ITER scenarios
JA 3.0: hybrid benchmark
JA 4.0: SS benchmark
JA 5.0: hybrid and SS access
JA 6.0: ICRF modeling
JA 7.0: SS exploration
JA 8.0: burn control
JA 9.0: 0D operating space
JA 10.0: operation in non-activation phases

Proposals for IAEA papers are needed by the next meeting. Specific reporting tasks for the Joint Experiments and Joint Activities were identified. The next meeting of the ITPA-IOS group is Oct 18, 2011, in Kyoto, Japan.

Summary of the 6th Meeting of the ITPA Energetic Particles Topical Group, Frascati, Italy

Raffi Nazikian (Princeton Plasma Physics Laboratory)*

The sixth ITPA topical group meeting on energetic particles (EP) took place on April 11-13, 2011 in Frascati, Italy. The meeting was hosted by the Association Euratom ENEA, with Sergio Briguglio as the local organizer. There were 25 participants, including 16 from the European Union, 1 from the Russian Federation, 3 from Japan, 2 from Korea, and 4 from the US. Presentations spanned a range of topics from progress on joint experiments to code benchmarks and discussions on ITER design issues.

Participants were shown photographs of the latest developments at the ITER construction site. The large excavation for the ITER tokamak building and the fabrication of the coil winding facility demonstrated the impressive scale of the project and underscored the importance of the ITPA working groups in helping to support ITER design decisions.

Updates were presented on the feasibility of measurements for confined and lost alpha particles in ITER. For collective Thomson scattering (CTS), analysis indicates the optimal source frequency is 60 GHz in order to avoid background noise due to emission at the fundamental electron cyclotron frequency. Various scattering geometries are being considered for their sensitivity to different regions of the confined alpha particle distribution function. A feasibility study was also presented on the measurement of lost alpha particles in ITER. A design for a reciprocating probe was presented, and the trade off between thermal heat loads and the phase space of detectable lost alphas was discussed. These design studies will continue.

An important activity of the ITPA is the planning and execution of joint experiments and analysis aimed at addressing ITER design and operational issues. The EP group currently has several active research tasks that were reported on during the meeting. These tasks are: (i) fast ion loss and redistribution by localized Alfvén eigenmodes, (ii) beam ion loss due to edge localized magnetic perturbations, (iii) fast ion transport by small scale turbulence, and (iv) linear stability benchmark study for gyrokinetic and hybrid MHD simulation codes.

Significant progress has taken place in understanding Alfvén eigenmode-induced redistribution and loss of fast ions. New measurement capabilities on multiple devices and advances in analysis methods are enabling quantitative understanding of the redistribution and loss of fast ions induced by a wide range of Alfvénic mode activity. Extensive diagnostic upgrades on both DIII-D and ASDEX-Upgrade (AUG) have lead to similar measurement capability on both facilities for the internal structure of Alfvén eigenmodes and for the confined and lost fast ion population. A drop in neutron emission is observed on both machines when multiple Alfvén eigenmodes are excited by beam ions in the early phase of the discharge. Similar Alfvén eigenmode activity is observed on electron cyclotron emission (ECE) imaging and fast ion scintillator detectors. Internal fast ion redistribution is also observed on the Fast Ion D-alpha (FIDA) measurements in both devices. The next step in this joint study is to apply ion orbit analysis using measured internal mode amplitudes in order to model the measured losses and beam ion redistribution.

Fast ion loss events on NSTX resulting in a 10% to 20% drop in the neutron emission due to toroidal Alfvén eigenmode (TAE) avalanches have been well modeled with the use of the NOVA and ORBIT codes. The ORBIT (guiding center) analysis uses the eigenmodes calculated by NOVA that fit the experimentally measured radial mode structure and amplitude. Large amplitude, multiple mode bursts above a threshold in amplitude are found to induce very large beam ion losses. This amplitude threshold was found to be in very good agreement with the experimentally measured amplitude. Future work will involve more detailed measurements of the characteristics of the lost fast ions for comparison with modeling, and extension of the modeling to self-consistent codes to predict the mode growth and saturation as well as multi-mode interactions.

Results were also presented on the recent analysis of Tornado modes (viz., TAEs inside q=1, where q is the magnetic safety factor) on JET. Gamma ray camera measurements clearly indicate redistribution of energetic ions during the mode activity prior to the giant sawtooth crash. Exciting observations developments are also expected in the near future for MAST with the development of a 2-D Beam Emission Spectroscopy (BES) system and a neutron camera for imaging the neutron emission profile. Recent results were also presented from the LHD stellarator showing a rich variety of intense bursting and frequency chirping behavior for modes driven by neutral-beam-produced ions. Correlating this mode activity to the measurement of redistribution and loss of beam ions is an important area of ongoing research.

Beam ion loss due to edge localized magnetic perturbations is an important area of activity motivated by concerns regarding the effect of the Test Blanket Module (TBM) and resonant magnetic perturbations (RMP) on fast ion confinement in ITER. Benchmark analysis was carried out on results from the TBM mock-up experiments performed on DIII-D. Broad agreement was found between the OFMC, SPIRAL, and ASCOT codes on the temperature increase observed on TBM carbon tiles based on beam ion loss calculations using vacuum magnetic fields. However, good agreement was not found for the case of losses calculated using a self-consistent VMEC 3-D magnetic equilibrium. This difference is likely related to currently existing computational limits on the toroidal resolution available in the 3D equilibrium calculation. Future analysis will be performed once additional data is obtained on the spatial pattern of the heat deposition on TBM carbon tiles later in the year.

Recent calculations showing 5-13% of 1 MeV beam ion loss in ITER due to RMP fields for ELM control has spurred new analysis of beam ion losses in existing experiments such as DIII-D, AUG, and LHD. ASCOT analysis was presented on beam ion losses due to the RMP coils on AUG, and new analysis is underway to quantify the losses induced by similar coils on DIII-D. An important question in these studies is whether the enhanced losses due to RMP coils can be detected using thermal imaging of the carbon tiles near the TBM mock-up in DIII-D or on particle loss detectors. LHD is planning to study beam ion loss with resonant n=1 toroidal perturbations in the plasma edge using the local island divertor coils.

Just as externally applied magnetic fields can induce fast ion loss, so can fields induced by MHD activity such as edge localized modes (ELMs). Indeed, recent results from AUG demonstrate that peak fast ion losses during ELMs can exceed the background prompt loss rate by over an order of magnitude. On LHD, large-amplitude ELMs induced strong losses of beam ions in the large radius (3.9 m) configuration where co-beam ion orbits are strongly shifted in the outboard direction. This is an evolving area of research that will conducted over a number of facilities in the coming year to better understand the role of ELMs on fast ion confinement.

Microturbulence-induced fast ion loss has been a recent focus of attention based on calculations showing that enhanced redistribution should occur in present experiments when the beam ion energy is within a factor of ten of the thermal ion temperature. Results were presented from previous TFTR experiments demonstrating a consistent overestimation of the neutron emission based on the TRANSP code analysis at low toroidal field, but good agreement for low E_{beam}/Ti at high field where microturbulence-induced transport is expected. More recent analysis of DIII-D results demonstrates a fast ion confinement anomaly that scales with the beam ion energy normalized to ion temperature, consistent with expectations for electrostatic microturbulence-induced transport. Based on results from AUG and DIII-D analyses, it is expected that significant microturbulence effects should occur in ITER for alpha particles and beam ions below 300 keV. This energy range is where ash removal is needed so that the effect of microturbulence is expected to be beneficial for removal of nearly thermalized alpha particles.

Major progress was demonstrated on the linear benchmark analysis for hybrid and gyrokinetic simulation codes for Alfvén eigenmodes. In order to facilitate the benchmark analysis, a large aspect ratio (A=10) circular cross section plasma was selected with a localized n=6 TAE. Comparison between all codes (LIGKA, GYGLES, MEGA, CAS3D, AE3D, TAEFL, HMGC, AE3D-K, CKA) demonstrated good agreement on the mode frequency and mode structure. Stability was calculated as a function of the fast ion temperature with a Maxwellian distribution. Very good agreement was found between most codes for fast ion drive with finite orbit width (FOW) effects and without finite Larmor radius (FLR) effects. For the case with both FOW and FLR effects, the fast-ion drives calculated by the hybrid codes are somewhat higher than those obtained by the gyrokinetic codes. The next step in the linear benchmark study is to focus on one of the ITER operational scenarios and to identify a core-localized TAE with intermediate toroidal mode numbers. Such a case will be identified and discussed at the next ITPA meeting.

Considerable discussion took place on the future of the code benchmark study. In particular, it was recognized that a nonlinear benchmark study should be initiated, building on the success of the linear benchmark study. Identification of a suitable nonlinear benchmark case will require continued discussion at the next ITPA meeting.

The next ITPA-EP meeting will take place on Sept. 12-13, 2011, following the IAEA Technical Meeting on Energetic Particles, both in Austin, TX.

*Also contributing to this summary are E. Fredrickson and G. Fu of PPPL, and D. Spong of ORNL.

Announcements

Submit BPO-related announcements for next month's eNews to Tom Rognlien.

Upcoming Burning Plasma Events

2011 Events

May 23-26, 2011
ITPA Diagnostics Topical Group Meeting
FOM, NETHERLANDS

Jun 1-3, 2011
19th Topical Conference on Radio Frequency Power in Plasmas (CK Phillips and JR Wilson PPPL)
Newport, RI USA

Jun 20-24, 2011
ITER International Summer School on MHD and Energetic Particles
Aix en Provence, FRANCE

Jun 26-30, 2011
38th IEEE International Conference on Plasma Science (ICOPS) and the 24th Symposium on Fusion Engineering (SOFE)
Chicago, IL USA

Jun 27-Jul 1, 2011
38th European Physical Society Conference on Plasma Physics
Strasbourg, FR EPS

Fall 2011
ITPA Diagnostics Topical Group Meeting
CHINA

Sep 5-7, 2011
IAEA Technical Meeting on Theory of Plasma Instabilities
Austin, TX USA

Sep 8-10, 2011
IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems
Austin, Texas USA

Sep 12-13, 2011
7th Meeting of the ITPA Energetic Particles Topical Group
Austin, Texas USA

TBA---tentatively scheduled
ITPA MHD Topical Group Meeting
Padova, ITALY

Sep 11-16, 2011
10th International Symposium on Fusion Nuclear Technology
Portland, Oregon USA

Sep 14-16, 2011 NEW
BOUT++ Workshop
LLNL, Livermore, California USA

Sep 19-21, 2011
13th International Workshop on Plasma Edge Theory in Fusion Devices
South Lake Tahoe, California USA

Oct 5-7, 2011
ITPA Transport & Confinement Topical Group Meeting
Cadarache, FRANCE

Oct 5-7, 2011
ITPA Pedestal and Edge Topical Group Meeting
York, UK

Oct 10-12, 2011
13th International Workshop on H-mode Physics and Transport Barriers
Oxford, UK

Oct 16-21, 2011
15th International Conference on Fusion Reactor Materials (ICFRM-15)
Charleston, SC USA

Oct 18-21, 2011
ITPA Integrated Operational Scenarios Topical Group
Kyoto University, JAPAN

Nov 14-18, 2011
53rd APS Division of Plasma Physics Annual Meeting
Salt Lake City, Utah USA

Dec 12-15, 2011
ITPA CC & CTP-ITPA Joint Experiments Meeting
Cadarache, FRANCE

Dec 2011 or Jan 2012
ITPA Divertor and SOL (PSI Selection Committee) Topical Group Meeting
Jüelich, GERMANY

Directories of Other Plasma Events

IEEE Directory of Plasma Conferences
Fusion Ignition Research Experiment (FIRE) Physics Meetings

Please contact the administrator with additions and corrections.