



CONTENTS

Director's Corner

Jim Van Dam

USBPO Topical Group Highlights

Nonlinear simulations of peeling-ballooning modes with anomalous electron viscosity and their role in edge-localized-mode plasma ejection

X.Q. Xu, M.V. Umansky,
B. Dudson, H.R. Wilson,
P.B. Snyder

Upcoming Burning Plasma-related Events

2011 Events

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

Remote Seminar about ITPA Meetings

On Tuesday, February 22, beginning at 12:00 noon Eastern Standard Time, the USBPO will sponsor a remote seminar to report about the recent meeting of the ITPA Transport and Confinement topical group and the activities of this topical group. In addition, there will be a report about the December meeting of the ITPA Coordinating Committee and the status of the Joint Experiments and Joint Activities. The speakers will be John Rice and Erol Oktay. The seminar is planned to last for about one hour. Connection information is provided below. Please mark it on your calendars.

Connection information for the USBPO seminar on Tuesday February 22 at 12:00 p.m. Eastern Standard Time, 9:00 a.m. Pacific Standard Time:

Two web-browser windows are needed to attend the seminar: one for video-plus-audio, and one for viewing the presentation slides.

1. Video and Audio (receive/listen only), using ESnet 'streaming':

Use a web browser to connect to:

<http://mcu1.es.net> or <http://198.129.252.171>

Mac users: FireFox recommended. Safari may have problems.

Sign-in name: <---- please type your name

Conference ID: 411411

Please do not enter a PIN number.

Streaming rate: choose QuickTime or Real Player.

Click "Stream this conference". If you see "invalid ID" then the conference has not yet started; try again in a few minutes.

2. Presentations, using ReadyTalk web conferencing:

To view the seminar slides, open another browser window and connect it to:

<http://esnet.readytalk.com>

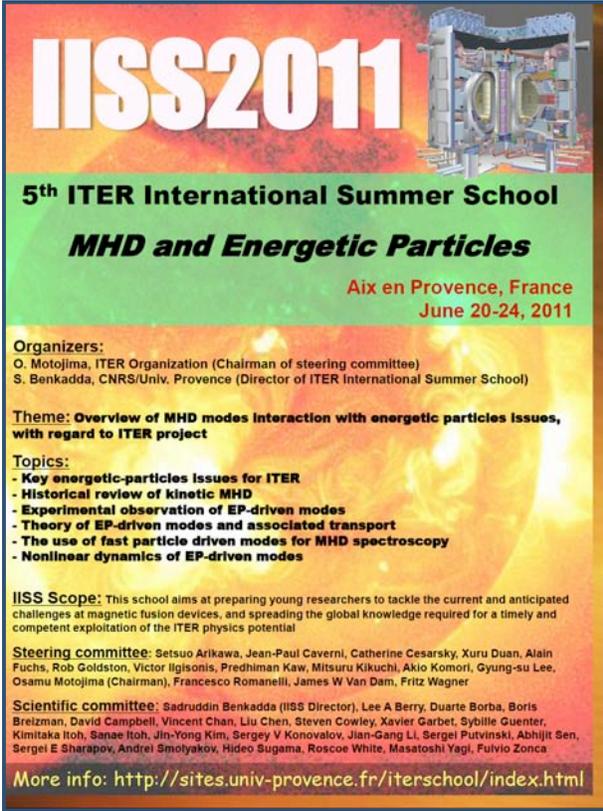
In the "Join a Meeting" window, type the Access Code of this seminar: 2705718 and click "Join".

NOTE: ReadyTalk Audio is *not* used for this seminar; please do not dial the telephone numbers displayed by ReadyTalk.

If you require alternate connection methods to attend this seminar then please send email to support@burningplasma.org or call Jim DeKock (608-263-8921).

Scholarships for 2011 ITER Summer School

The 5th ITER International Summer School will be held in Aix en Provence, France, during June 20-24, 2011. The theme of this year's Summer School will be "MHD and Energetic Particles." These Schools are primarily designed for graduate students, postdocs, and young



IIS2011

5th ITER International Summer School
MHD and Energetic Particles

Aix en Provence, France
June 20-24, 2011

Organizers:
O. Motojima, ITER Organization (Chairman of steering committee)
S. Benkadda, CNRS/Univ. Provence (Director of ITER International Summer School)

Theme: Overview of MHD modes interaction with energetic particles issues, with regard to ITER project

Topics:
- Key energetic-particles issues for ITER
- Historical review of kinetic MHD
- Experimental observation of EP-driven modes
- Theory of EP-driven modes and associated transport
- The use of fast particle driven modes for MHD spectroscopy
- Nonlinear dynamics of EP-driven modes

IIS Scope: This school aims at preparing young researchers to tackle the current and anticipated challenges at magnetic fusion devices, and spreading the global knowledge required for a timely and competent exploitation of the ITER physics potential

Steering committee: Setsuo Arikawa, Jean-Paul Caverni, Catherine Cesarsky, Xuru Duan, Alain Fuchs, Rob Goldston, Victor Ilgisonis, Predhiman Kaw, Mitsuru Kikuchi, Akio Komori, Gyung-su Lee, Osamu Motojima (Chairman), Francesco Romanelli, James W Van Dam, Fritz Wagner

Scientific committee: Sadrudin Benkadda (IIS Director), Lee A Berry, Duarte Borba, Boris Breizman, David Campbell, Vincent Chan, Liu Chen, Steven Cowley, Xavier Garbet, Sybille Guenter, Kimataka Itoh, Sanae Itoh, Jin-Yong Kim, Sergey V Kononov, Jian-Gang Li, Sergei Putvinski, Abhijit Sen, Sergei E Sharapov, Andrei Smolyakov, Hideo Sugama, Roscoe White, Masatoshi Yagi, Fulvio Zonca

More info: <http://sites.univ-provence.fr/iterschool/index.html>

researchers. If you are interested in attending, please go to the [School's web site](#) and register. According to the web site, the registration deadline is February 25, but I was informed that this is to be extended to April 1.

The USBPO will make available eight scholarships for US participants to this year's ITER Summer School. "US participants" must be US citizens working at US institutions. The scholarships will cover round-trip airfare, registration fee, and six nights of student housing, which are the three items that constitute the bulk of the expenses. Participants' home institutions are encouraged to supplement the scholarships to cover other travel-related expenses. Please send applications to [Prof. Michael Mauel](#), chair of the USBPO Council. In each application, please include (1) a vita, (2) a list of publications, (3) a statement about the reasons why your participation at this School would be beneficial, and (4) a letter of reference from a senior scientist who is knowledgeable about you. Please submit applications for scholarships by March 23.

Retirement News

At the December meeting of the ITPA Coordinating Committee, the Committee members paid tribute to Dr. Erol Oktay of the U.S. Department of Energy (DOE), who announced that he is retiring after a career of 40 years in fusion research, of which 36 years were spent working in the DOE Fusion Energy Sciences program. For many of these years, Dr. Oktay was deeply involved in promoting international collaborations in fusion. For the last five years, he served as Acting Director of the ITER and International Division of the Office of Fusion Energy Sciences at DOE. He was a member of the US delegation to the meetings of the Science and Technology Advisory Committee of the ITER Council. He has been the program manager for the DIII-D National Fusion Facility. And, very importantly, at DOE, he has been the lead person for the USBPO, in which capacity he has attended biweekly Research Committee meetings, biweekly Executive Committee meetings, and quarterly USBPO Council meetings. It would be difficult to

list all the ways in which he has nurtured the activities of the USBPO. I interacted with Erol frequently and was always amazed at the workload he carried. Most impressive and appreciated has been his genuine passion for fusion. On behalf of the US Burning Plasma Organization, I express sincere appreciation to him and best wishes for a pleasant retirement. Erol, we'll miss you!



*The ITPA Coordinating Committee congratulated Dr. Erol Oktay at its December 2010 meeting
(photograph courtesy of ITER)*

Upcoming ITPA Meetings

Proposals for five of the seven Spring 2011 ITPA Topical Group meetings are now posted on the [USBPO web site](#). If you have any contributions to the topical areas and/or wish to attend any of these meetings, please contact the respective US Coordinator and/or Deputy Coordinator. For reference, here are their names:

ITPA Topical Group	US Coordinator	US Deputy Coordinator
Diagnostics	Rejean Boivin	Jim Terry
Energetic Particles	Raffi Nazikian	Boris Breizman
Integrated Operation Scenarios	Chuck Kessel	Tim Luce
MHD Stability	Ted Strait	Bob Granetz
Pedestal	Phil Snyder	Rajesh Maingi
SOL and Divertor	Bruce Lipschultz	Tony Leonard
Transport and Confinement	Stan Kaye	George McKee

Big Physics Symposium

Recently I was invited to give a talk with the title “An Overview of ITER and US Efforts” at a meeting, called Big Physics Symposium, held February 7 in Paris, France. The focus of the meeting was on control, diagnostic, and measurement for physics systems and experiments. There were five talks about plasma control systems and remote handling for tokamaks, including a keynote address by Dr. Dhiraj Bora, ITER Deputy Director-General for the CODAC Directorate. In addition, there were four talks about large particle accelerators, specifically at CERN, a talk about the European EISCAT facility for radar studies of the atmosphere and

ionosphere, and specialized talks about control instrumentation and software. My talk is posted on the USBPO web site, Reference Files page.

USBPO Topical Group Highlights

(Editors note: The BPO Pedestal and Scrape-Off Layer Topical Group works to facilitate U.S. efforts to understand the boundary region of existing and future magnetic fusion devices via experiments and simulations (leaders are Tom Rognlien and Tony Leonard). This month's Research Highlight by Xueqiao Xu et al. summarizes ongoing work to simulate nonlinear ELM dynamics including the radial ejection of pedestal plasma.)

Nonlinear simulations of peeling-ballooning modes with anomalous electron viscosity and their role in edge-localized-mode plasma ejection

X.Q. Xu, M.V. Umansky (Lawrence Livermore National Laboratory); B. Dudson, H.R. Wilson (University of York, UK); P.B. Snyder (General Atomics)

The edge-localized modes (ELMs) are quasi-periodic relaxations of the high-pressure edge pedestal during high confinement H-mode operation that are observed routinely in tokamaks [1]. The resulting hot plasma ejection could potentially damage the ITER divertor plates and first wall, as well as reduce energy confinement. Consequently, one of the ITER "urgent tasks" is to assess the effect of ELMs on the plasma confinement and the associated energy loss and fluxes to plasma-facing components (PFCs).

Through the development of the theory of peeling-ballooning (P-B) modes and their numerical implementation in codes such as ELITE [2,3], a robust prediction of edge MHD stability limits is available for existing and future tokamaks. It has been found that large ELMs are triggered, and pedestal height is constrained, by ideal peeling-ballooning stability. peeling-ballooning modes are ideal MHD modes, which are driven by a combination of steep edge pressure gradients (ballooning) and bootstrap current in the pedestal. Onset of each ELM (type-I) is consistently found to correlate with crossing of the ideal peeling-ballooning stability boundary [4]; i.e., peeling-ballooning theory successfully describes the trigger of the ELM. However the nonlinear dynamics, and, in particular, the physics of the ELM energy loss and pedestal dynamics after the onset of each ELM (type-I) remain uncertain.

Nonlinear ELM simulations become computationally difficult because the ratio of the Alfvén wave transit time to the resistive diffusion time (the Lundquist number, S) is very large. In this parameter regime, very fine spatial resolution is needed to resolve the narrow current sheets and/or narrowing plasma fingers arising from the explosive ideal MHD instabilities predicted from nonlinear ballooning theory [5,6]. These very fine structures lead to dramatic reduction of the simulation time step at the early nonlinear stage of ELM evolution [6]. Similar problems appear in other fields, such as magnetospheric substorms, solar and stellar flares, and sawtooth crashes in tokamaks. A common practice is to use an anomalous resistivity and/or ion viscosity to complete nonlinear ELM simulations, which also leads to significantly different linear growth rates and instability thresholds. Furthermore, in nonlinear resistive MHD simulations, the pedestal pressure collapses deep into the plasma core, which yields much larger ELM sizes than observed experimentally.

In a recent paper published in *Physical Review Letters* [7], we describe nonlinear simulations of plasma edge pedestal collapse in the tokamak configuration using a three-field model (pressure, electrostatic potential, and magnetic vector potential), as illustrated in Fig. 1. The simulations are carried out in the BOUT++ two-fluid framework [8], which allows studies of nonlinear dynamics of ELMs with extensions beyond ideal MHD physics. The nonlinear

simulations show that the peeling-ballooning modes trigger magnetic reconnection, which drives the collapse of the pedestal pressure. Anomalous electron viscosity, which appears as a hyper-resistivity term for the parallel magnetic vector potential, is found to limit the radial spreading of ELMs by facilitating magnetic reconnection.

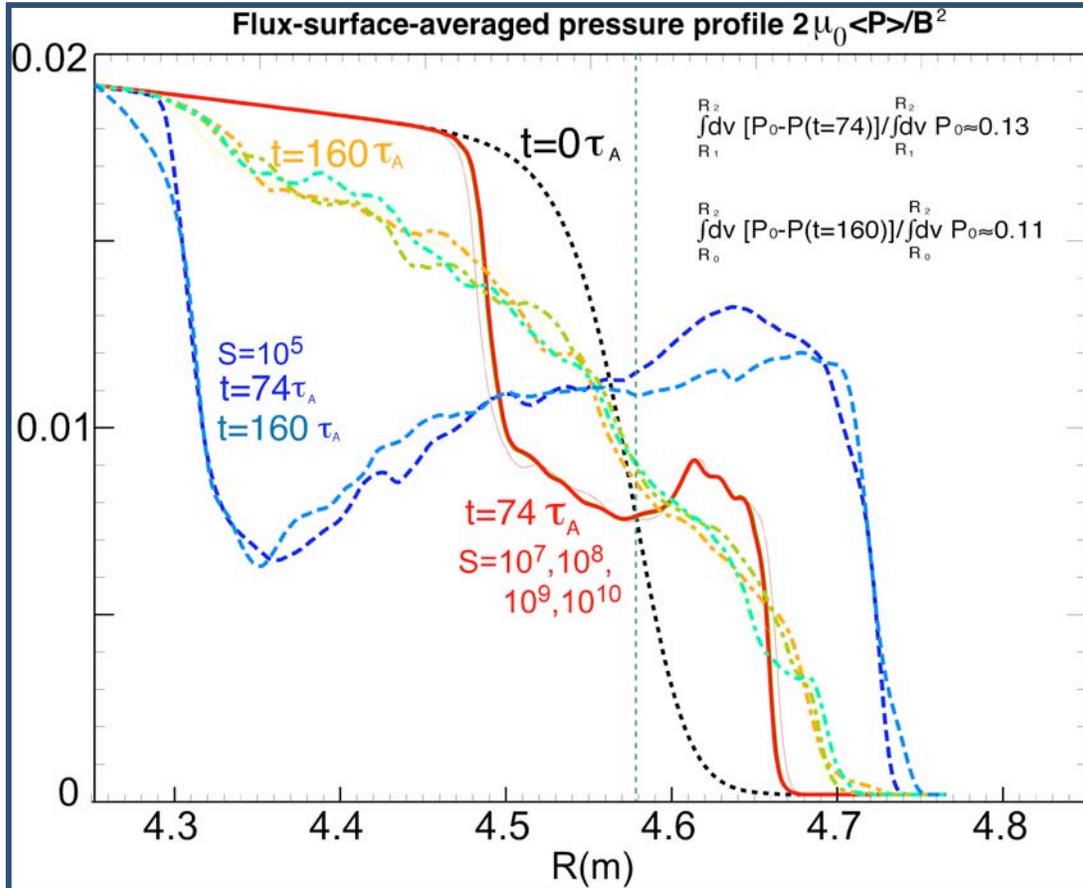


Fig. 1. Radial pressure profiles at several different Lundquist numbers S and time slices. Open magnetic field line plasma loss occurs for $R > 4.58$. From Ref. 7.

For typical pedestal plasma parameters, $S \approx 10^8 - 10^{10}$, the growth rate of the peeling-ballooning mode is $\gamma_{PB} \approx 0.1\omega_A$ (with ω_A the Alfvén frequency), and the width of the resistive current sheet is $\Delta_J \approx R(\omega_A/\gamma_{PB}/S)^{1/2} \sim 10-100$ microns (with R the major radius), which is comparable to the electron Larmor radius. In the absence of the hyper-resistivity, the simulation time-step collapses as the radial scale-length of the current sheet approaches the radial grid spacing Δ_x for typical resistive MHD simulations $L_p \gg \Delta_q \gg \Delta_x \gg \rho_i \sim \delta_i \sim \delta_e \gg \Delta_J > \rho_e$. Here L_p is the pedestal width, Δ_q is the rational surface spacing, δ_i and δ_e are the ion and electron skin depths, and ρ_i and ρ_e are the ion and electron Larmor radii. With the hyper-resistivity η_H (or anomalous electron viscosity), the width of the hyper-resistive current sheet is $\Delta_H \approx R(\omega_A/\gamma_{PB}/S_H)^{1/4}$. Here $S_H = \mu_0 R_0^3 v_A / \eta_H$ is defined as the hyper-Lundquist number. The hyper-resistivity could arise, for example, from small-scale electron turbulence in the H-mode pedestal [9]. Under the assumption that the electron viscosity is comparable to the anomalous electron thermal diffusivity, we have $S_H = 10^{12}$; hence $L_p \gg \Delta_q \gg \Delta_H > \Delta_x$.

The radial pressure profiles at the outer mid-plane at several different time slices and different Lundquist numbers are shown in Fig. 1. It is clearly shown at late times that the ELM causes the pedestal pressure to collapse deeply inside the core plasma at low Lundquist

number ($S = 10^5$). It is also shown that for high Lundquist number there are two distinct processes in the evolution of pressure profiles: a fast collapse greatly flattening the pressure profile near the peak pressure gradient on the order of tens of Alfvén times after the onset of nonlinear peeling-ballooning mode, $t = 74\omega_A$, and a subsequent slow buildup of pressure gradient. We can characterize the fast collapse as a magnetic reconnection (triggered by peeling-ballooning modes) \rightarrow magnetic island formation \rightarrow bursting process, and a slow buildup as a turbulence transport process. The radial-poloidal pressure profiles clearly show the characteristics of the ballooning mode. As is well known from linear instability analysis, ϕ and A_{\parallel} have ballooning parity for the peeling-ballooning mode. In the nonlinear stage, however, a tearing parity component appears due to the nonlinear mode coupling, which facilitates magnetic reconnection and island formation.

Defining the ELM size as the ratio of the ELM energy loss to the pedestal stored energy, the ELM size is calculated from each nonlinear simulation. The ELM size scaling vs. classical

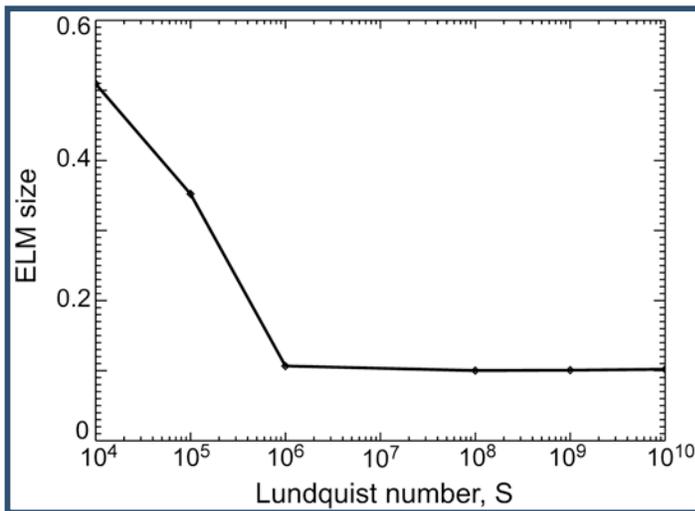


Fig. 2. Simulation ELM size vs Lundquist number S with $S_H = 10^{12}$ showing reduction to a minimum size; the experimental range for S is $10^6 - 10^{10}$.

region). With a fixed hyper-Lundquist number $S_H = 10^{12}$, when $S > S_c = (S_H \omega_A / \gamma_{PB}) > 10^6$, the ELM size is insensitive to the resistivity, which is relevant to today's modestly sized tokamaks and ITER.

This work was performed for U.S. DOE by LLNL under Contract DE-AC52-07NA27344, grants DE-FG03-95ER54309 at general Atomics, and by the UK Engineering and Physical Sciences Research Council under grant EP/H012605/1 and the Euro. Commun. under the contract of Association between EURATOM and CCFE.

References

- [1] M. Keilhacker, G. Becker, and K. Bernhardt *et al.*, Plasma Phys. Controlled Fusion 26, 49 (1984).
- [2] H.R. Wilson *et al.*, Phys. Plasmas **9**, 1277 (2002).
- [3] P.B. Snyder *et al.*, Phys. Plasmas **9**, 2037 (2002).
- [4] P.B. Snyder *et al.*, Nucl. Fusion **49**, 085035 (2009).
- [5] H.R. Wilson and S.C. Cowley, Phys. Rev. Lett. **92**, 175006 (2004).
- [6] P.B. Snyder *et al.*, Phys. Plasmas **12**, 056115 (2005).
- [7] X.Q. Xu, B. Dudson, P.B. Snyder, M.V. Umansky, and H.R. Wilson, Phys. Rev. Lett. **105**, 175005 (2010).

- [8] B.D. Dudson, H.R. Wilson, M.V. Umansky, X.Q. Xu, and P.B. Snyder, *Comput. Phys. Commun.* **180**, 1467 (2009).
[9] H. Biglari and P.H. Diamond, *Phys. Fluids* **B 5**, 3838 (1993).

Announcements

Submit BPO-related announcements for next month's eNews to [Tom Rognlien](#).

Upcoming Burning Plasma Events

2011 Events

March 1-4, 2011 **UPDATED** send title of talk to senabhijit@gmail.com

[ITPA MHD Topical Group Meeting](#)

Ahmedabad, INDIA

March 7-8, 2011

[Fusion Energy Science Advisory Committee](#) (FESAC)

Bethesda, Maryland, USA

March 30 - April 1, 2011

[20th ITPA Pedestal and Edge Topical Group Meeting](#)

Cambridge, Massachusetts, USA

April 4-5, 2011

ITPA Transport & Confinement Topical Group Meeting

San Diego, California USA

April 5, 2011 **NEW** abstract deadline: **March 4, 2011** send to: snyder@fusion.gat.com

Edge Coordinating Committee Workshop on RMP

San Diego, California USA

April 6-9, 2011 abstract deadline: **Feb. 18, 2011**

[Joint US-EU Transport Task Force \(TTF\) Workshop](#)

San Diego, California USA

April 11-13, 2011

ITPA Energetic Particles Topical Group Meeting

Frascati, ITALY

April 11-14, 2011

ITPA Integrated Operation Scenarios Topical Group Meeting

JET, Culham, UNITED KINGDOM

April 11-14, 2011 abstract deadline: **closed**

[Workshop on Stochasticity in Fusion Plasmas \(SFP 2011\)](#)

Jülich, Germany

April 20-22, 2011 **NEW** abstracts due: **Feb. 28, 2011** send to: marian1@llnl.gov

[2011 IEA Fusion Modeling Workshop on Materials](#)

Lawrence Livermore National Laboratory, Livermore, CA

May 2-4, 2011

[2011 International Sherwood Fusion Theory Conference](#)

Austin, TX USA

May 9-13, 2011

[13th International Workshop on Plasma-Facing Materials and Components for Fusion Applications \(PFMC-13\) and 1st International Conference on Fusion Energy Materials Science \(FEMaS-1\)](#)

Rosenheim, Germany

May 15-19, 2011

[15th International Conference on Emerging Nuclear Energy Systems \(ICENES\)](#)

San Francisco, CA USA

May 16-19, 2011

ITPA SOL and Divertor Topical Group Meeting

Helsinki, FINLAND

May 23-26, 2011

ITPA Diagnostics Topical Group Meeting

FOM, NETHERLANDS

June 1-3, 2011

19th Topical Conference on Radio Frequency Power in Plasmas (CK Phillips and JR Wilson PPPL)

Newport, RI USA

June 20-24, 2011

[ITER International Summer School on MHD and Energetic Particles](#)

Aix en Provence, FRANCE

June 26-30, 2011 abstract deadline: March 1, 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

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 19-21, 2011

Plasma Edge Theory Meeting

South Lake Tahoe, CA USA

October 5-7, 2011

ITPA Transport & Confinement Topical Group Meeting

Cadarache, FRANCE

October 5-7, 2011

ITPA Pedestal and Edge Topical Group Meeting

York, UNITED KINGDOM

Oct 16-21, 2011

[15th International Conference on Fusion Reactor Materials \(ICFRM-15\)](#)

Charleston, SC USA

October 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

December 2011 or January 2012

ITPA Divertor and SOL (PSI Selection Committee) Topical Group Meeting

Jülich, GERMANY

December 12-15, 2011

ITPA CC & CTP-ITPA Joint Experiments Meeting

Cadarache, FRANCE

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.