Monthly Newsletter of the
U.S. Burning Plasma Organization
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Mission Statement

Advance the scientific understanding of burning plasmas and ensure the greatest benefit from a burning plasma experiment by coordinating relevant U.S. fusion research with broad community participation.

This newsletter provides a monthly update on U.S. Burning Plasma Organization activities. The USBPO operates under the auspices of the U.S. Department of Energy, Office of Fusion Energy Sciences (FES). All comments, including suggestions for content, may be sent to the Editor. Correspondence may also be submitted through the USBPO Website Feedback Form.

Become a member of the U.S. Burning Plasma Organization by signing up for a topical group.

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Director's Corner

C.M. Greenfield

Preparing for a National Academies study

As you may remember from last month's column, each of the US Burning Plasma Organization Topical Groups is collecting input from its membership to inform input from the USBPO to the upcoming National Academies study on "A Strategic Plan for U.S. Burning Plasma Research." We have been able to stretch out our deadline somewhat as the committee that will undertake this study is still being organized. However, we anticipate that we may have very limited time to prepare our input once they begin their work, since they will have an October 1 deadline for an interim report.

I would expect that most of you have very strong opinions that should be taken into account in preparing USBPO input for this study, so I urge you to respond to your Topical Group leaders and let them know what you think is important. Please see last month's column for more background on the study and what topics we are soliciting your input on.

The 9^{th} ITER International School

As I announced a few weeks ago, the 9^{th} ITER International School is being held on March 20-24 in Aix-en-Provence, France, with this year's topic being the physics of disruptions and their control. As we've done for previous instances of the IIS, the USBPO is providing eight scholarships for students and post-docs to attend. With the short lead-time, we had to do a very rapid selection process. The response was (to me) surprising, with considerably more deserving candidates than we could support. This left our selection committee (Eugenio Schuster of Lehigh University, Carlos Paz-Soldan of General Atomics, François Waelbroeck of the University of Texas) with a rather difficult challenge. Their selections are as follows:

> Post-Docs: Jayson Barr (ORAU), Jeff Herfindal (ORNL), and Jeff Parker (LLNL).
>
> Graduate Students: John Brooks (Columbia), Alex Tinguely (MIT), James Penna (University of Washington), Mitchell Clement (UCSD), and Max Hill (Georgia Tech).

Of course, the school is open to anybody who would like to attend, although unfortunately others will have to find their own funding to support their travel. More information can be found at http://iterschool.univ-amu.fr. Registration is open until March 7, and there is no registration fee and the organizers are providing housing.

I am also aware of at least three members of the US Burning Plasma community who will be participating as lecturers. They are Bob Granetz of MIT, Daisuke Shiraki of ORNL, and Francesco Volpe of Columbia.

Research Highlight

Integrated Scenarios Topical Group, Leaders: Francesca Poli and Francesca Turco

The DIII-D high β_p scenario and extrapolations to ITER steady-state operation

J. McClenaghan [1], A.M. Garofalo [1]

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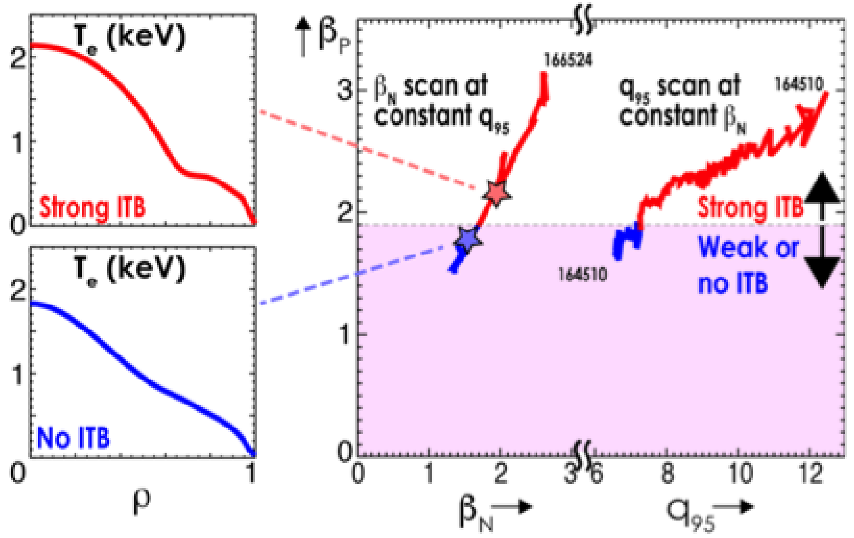

Figure 1: Top left: Radial profile of electron temperature with an ITB. Bottom left: Radial profile of electron temperature without an ITB. Right: As time evolves in the experiments, both normalized beta (β_N) scan and plasma current (q_{95}) scan show the same β_p threshold for ITB sustainment. (*Figure taken from in to Ding et al.* [2])

Tokamak operation at high β_p (thermal pressure over magnetic pressure produced by the plasma current) offers several important advantages for economically competitive power production in a nuclear fusion reactor: low probability of the plasma disrupting because of high safety factor (q), the majority of the plasma current is self-generated by the bootstrap effect reducing the need for external current drive, and the possibility of improved energy confinement due to equilibrium modification.

Recent high β_p experiments on DIII-D [1] and modeling of the results have demonstrated that energy confinement quality higher than standard H-mode ($H_{98} > 1$) is achieved and sustained thanks to a shift of the magnetic equilibria caused by the high β_p called the Shafranov shift. The scenario has been sustained with a high normalized plasma beta of $\beta_N \sim \beta_p \sim 3.8$, which reduces the requirement for externally driven current. This high energy confinement has also been found to be independent of the plasma rotation. This is particularly important for a fusion reactor which is expected to have low toroidal rotation because of the very large moment of inertia.

In the high β_p scenario, the improvement in confinement is associated with formation of radially localized steepening of the temperature and density gradients called an internal transport barrier (ITB). An example of an ITB in the electron temperature (T_e) can be seen on the left side of Figure 1. ITB formation and sustainment has been observed to have a threshold of $\beta_p \sim 2$, as can be seen in on the right side of Figure 1.

In ITER, the high β_p scenario could achieve the steady-state performance goal of fusion gain of $Q = 5$. Assuming the same level of confinement quality $H_{98} \sim 1.6$ observed in the DIII-D experiments, ITER steady-state would reach Q=5 with normalized beta $\beta_N = 2.9$, fraction of self-generated bootstrap current fraction $f_{bs} = 80\%$, and poloidal beta $\beta_p = 2.2$.

To verify if a confinement substantially higher than H-mode can be achieved in ITER without rotation, transport modeling has been carried out using the transport code TGYRO [3], which predicts the plasma profiles based on plasma the turbulence model TGLF [4]. Assuming a similar shape of the safety factor profile as the DIII-D experiments, the predicted profiles and energy confinement are significantly lower than what extrapolations from the scaling laws would predict with a fusion gain of only $Q = 2.2$. This can be seen in Figure 2, where the purple TGYRO predicted profiles are significantly lower than the scaled profiles and have no ITB. This is likely because TGYRO predicts that the ITB threshold is higher on ITER than it is on DIII-D.

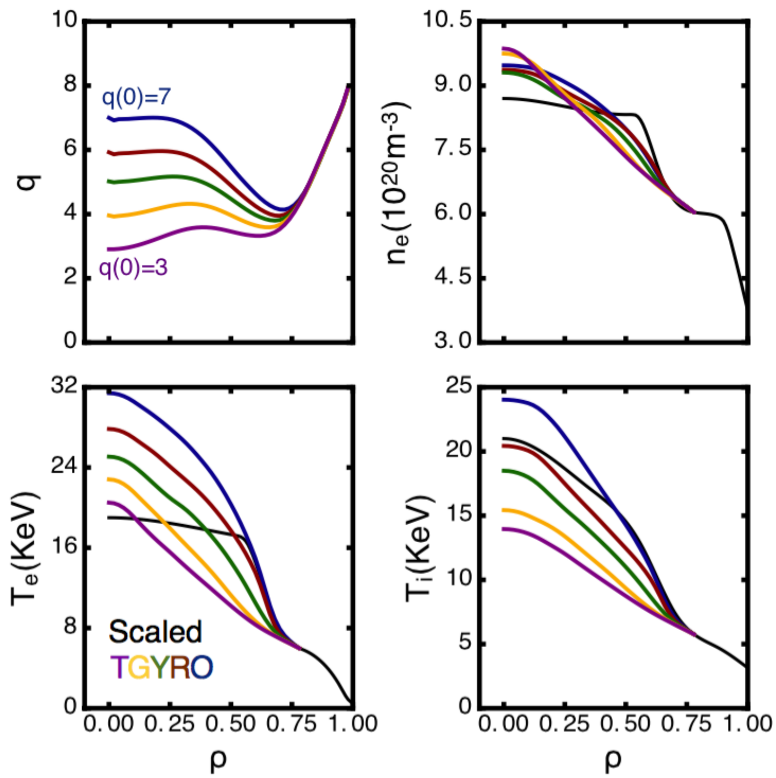

Figure 2: The safety factor q, electron density n_e, electron temperature T_e, and ion temperature T_i are plotted against radial coordinate ρ for the magnetic shear scan. The scaled ITER profiles are plotted in black, and the TGYRO predicted profiles are in color.

However, further investigations have shown that changing the shape of the q-profile strongly affects the TGYRO prediction of the total energy confinement. The on-axis safety factor is scanned from $q(\rho = 0) = 3 - 7$, which is shown in the top left panel of Figure 2. As $q(0)$ is increased, TGYRO begins to predict an ITB with the ion and electron temperatures significantly increasing.

The $\beta_p = 2.2$ scenario is more sensitive to magnetic shear stabilization than a more typical ITER steady-state scenario with higher plasma current $I_p = 9$ MA and lower $\beta_p = 1.5$. Figure 3 shows the fusion gain for the $q(0)$ scan for both $\beta_p = 2.2$ and the $\beta_p = 1.5$ scenarios. The $\beta_p = 2.2$ scenario is predicted to achieve $Q = 5$ if $q(0) = 7$ can be sustained, where the $\beta_N = 1.5$ scenario is predicted to only have $Q = 2.9$.

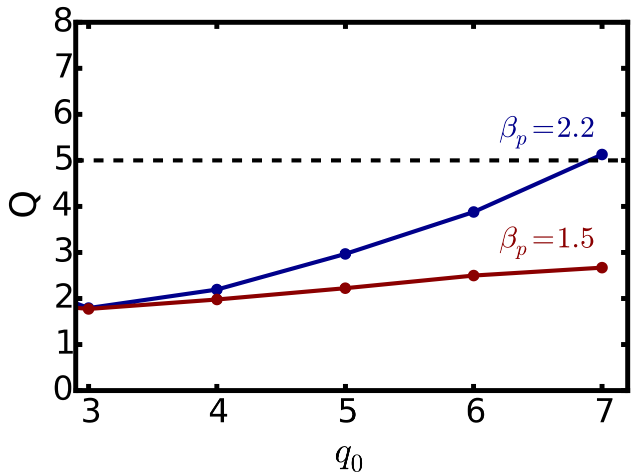

Figure 3: The TGYRO predicted fusion gain Q is plotted versus on-axis safety factor q_0.

In the high β_p scenario on DIII-D, the threshold for ITB formation is $\beta_p \approx 2$. In ITER, the $\beta_p = 1.5$ scenario is far away from an ITB threshold driven by Shafranov shift. As a result, the fusion gain and confinement are not significantly enhanced by the changes to the q-profile. The higher $\beta_p = 2.2$ scenario is closer a Shafranov shift-driven ITB threshold. Thus additional turbulence suppression by raising the on-axis safety factor enhances the confinement and fusion gain. Transport calculations with self-consistent current profile evolution are ongoing to determine if the reversed shear profile can be achieved in ITER with the expected current drive tools.

Acknowledgements

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References

[1] A.M. Garofalo, et al., *Nucl. Fus.* **55** (2015) 123025.
[2] S. Ding, et al.,*Phys. of Plasmas* **Submitted** (2017).
[3] J. Candy, et al., *Phys. of Plasmas* **16** (2009) 060704.
[4] G.M. Staebler, et al., *Phys. of Plasmas* **14** (2007) 055909.

Schedule of Burning Plasma Events

USBPO Public Calendar: View Online or Subscribe

2017

March 22-24, ITPA MHD Topical group meeting, Southwestern Institute of Physics (SWIP), Chengdu, China

April 3-6, ITPA IOS Topical group meeting, ITER Headquarters, Cadarache, France

April 18-20 31^{st} meeting of ITPA PEP Topical group, York, UK

April 18-21, 2^{nd} European Conference on Plasma Diagnostics (ECPD), Bordeaux, France

April 25-28, EU-US Transport Taskforce Meeting (TTF), Williamsburg, Virginia

April 26-28, ITPA EP topical group meeting, Sevilla, Spain

May 1-3, Sherwood Fusion Theory meeting, Annapolis, MD, USA

May 1-3, ITPA TC Topical group meeting, Princeton, USA

May 8-12, ITPA DIAG topical group, Chengdu, China

May 21-25, 44^{th} International Conference on Plasma Science (ICOPS), Atlantic City, New Jersey

May 30 - June 2, ITPA Divertor Scrape-Off (DSOL) Meeting, York, UK

June 4-8, 27^{th} IEEE Symposium on Fusion Engineering (SOFE2017), Shanghai, China

June 26-30, 44^{th} EPS Conference on Plasma Physics, Belfast, Northern Ireland

September 5-8, 2nd Asia-Pacific Symposium on Tritium Science (APSOT-2), Livermore Valley, California, USA

September 11-13, ITPA EP topical group meeting, Princeton, USA

September 18-20, ITPA PEP topical group meeting, Helsinki, Finland

September 18-20, ITPA TC topical group meeting, Helsinki, Finland

September 18-22, 1^{st} Asia-Paficic Conference on PLasma Physics (AAPPS-DPP), Chengdu, China

September 27-29, Plasma Edge Theory in Fusion Devices (PET16), Marseille, France

October 9-12, ITPA IOS Topical group meeting, Lisbon, Portugal

October 23-27, 59^{th} Annual Meeting of the APS Division on Plasma Physics, Milwaukee, Wisconsin

December 5-7, ITPA Coordinating Committee, ITER Headquarters, Cadarache, France

2018

June 24-28, 2018 IEEE International Conference on Plasma Science (ICOPS), Denver, Colorado, USA

2019 — JET DT-campaign — JT60-SA First Plasma —