Pedestal Group Annual Report 2010

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1. Introduction

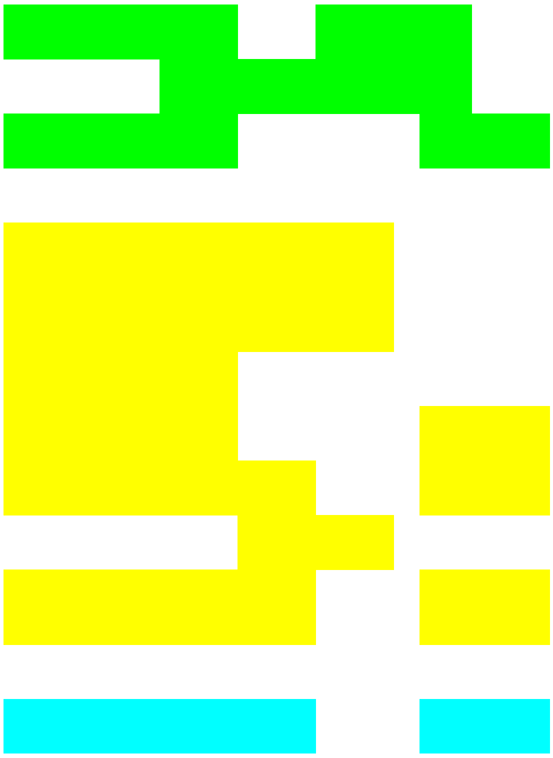
The ITPA Pedestal group has enjoyed another very active year, with substantial progress being made in a wide range of important issues for fusion, and ITER in particular. This is reflected in the large number of publications in refereed journals during 2009/10, with a total of 24 related to the activities of the ITPA pedestal group. We have held two meetings during the year: a joint meeting with the Transport and Confinement Group at Princeton Plasma Physics Laboratory in September, 2009 and another at JAEA, Naka in April 2010. Eruptions from the Icelandic volcano meant that many of our colleagues were unable to travel to the Naka meeting but it was nevertheless very productive, with extensive use being made of videoconference facilities. This report gives an overview of the group's activities over the past year. The following section describes the work related to the PEP joint experiments and the database development activity. In Section 3 we review the progress made towards the ITER urgent issues, before closing in Section 4 with a summary of future meetings.

2. Joint Experiments and database activity

The full summary report for each of the experiments is provided on the ITER portal at https://portal.iter.org/departments/FST/ITPA/CC/IEAITPA/default.aspx?InstanceID=8, so we refer the interested reader to that report. One of the main motivations for the joint meeting with the Transport and Confinement group in Princeton was to identify a research programme to advance our understanding of the LH transition for ITER. Three new joint experiments were proposed as a consequence (PEPs 26-28). Four other joint experiments were closed during the year, having achieved their aims: PEPs 14-17 and 20.

Turning to the database activity, the main development here is the definition of the structure of the new LH transition database, that is being developed as a joint project between the Pedestal Group and the Transport and Confinement group. The activity is led by Jerry Hughes of MIT. Access to the International Global Threshold DataBase (IGDBTH), used for many years to derive empirical scaling laws for the H-mode power threshold, is being made available from MIT beginning in the fall of 2010. The database schema will be largely consistent with prior implementations, and access will be granted to ITPA and IO members who request it. In the near future, the group will also implement a new database, which will allow the archiving of edge profile information for the study of H-mode thresholds in local parameters. Several devices are expected to populate this database with an initial set of data taken from experiments with density scans on individual devices.

3. Urgent R&D issues for ITER



Motivation:
It is extremely likely that control of Type I ELMs will be necessary for ITER to meet its objectives fully. Coils to provide resonant magnetic perturbations (RMPs) are presently the only tool available known to suppress the ELMs in such high performance regimes. However, ELM suppression has only been proven on DIII-D to date and the physics remains uncertain. RMP ELM control also has the potential to mitigate ELM impulsive energy sufficiently for ITER requirements by pacemaking. The work plan presented here aims to improve our understanding, and so reduce uncertainties in ELM control scenarios for ITER, quantifying the conditions and requirements for suppression, mitigation and pacemaking.

Working Group:

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Wolfgang Suttrop	Andrew Kirk
Todd Evans	Oliver Schmitz
Pavel Cahyna	CS Chang
Alberto Loarte	John Canik
Wayne Solomon	Andrea Garofalo

Objectives:
The objectives for this working group remain largely as originally defined. There is, however, one additional objective, inserted as 1.7, to explore the impact of modulated RMPs on ELMs.

1.1 Reproduce ELM suppression with RMPs on at least one tokamak other than DIII-D.
1.2 Identify the criteria for ELM suppression from experimental data and theoretical models.
1.3 Quantify the impact of ELM suppression by RMPs on the pedestal pressure and core confinement and develop/validate theoretical models
1.4 Quantify the power loading on the walls and divertor with RMP-suppressed ELMs; make recommendations on any requirement for rotating RMPs
1.5 Explore the capability to suppress or mitigate ELMs during the current ramp phase (ie close to the L-H transition threshold, and with q95 varying with time).
1.6 Demonstrate ELM control with ITER-like pellet fuelling
1.7 Demonstrate the ability of modulated RMP fields to mitigate ELM impulsive energy by the factor needed to meet ITER requirements
1.8 Model the performance of the ITER ELM control coil set, and propose changes to the design as appropriate. This is likely to require further developments in modelling the plasma response, which is very challenging.

Capability:
A large number of tokamaks have coils suitable for ELM control, including DIII-D, MAST, NSTX and JET. Of these, only DIII-D and MAST have internal coils off the mid-plane, as planned for ITER, and therefore these have a particularly key role to play in this area. In addition, ASDEX Upgrade will have a reduced set (2 rows x 4 coils) of ITER-relevant internal RMP coils from late-2010 to early-2011, and a full set (3 rows x 8 coils) from early 2012, that should provide important input on the required time-scale. A number of codes exist that can calculate the vacuum response to the RMPs. Fluid codes (eg M3D, JOREK, BOUT++) and kinetic codes (e.g. XGC0, XGC1) also exist that can analyze the effects of the plasma response.

Work plan, time-scales and assumptions
Figure 1 shows the present work plan and time scales for the tasks related to ELM control by RMP coils. The original work plan was based on a number of assumptions, but is adjusted as assumptions are proven or falsified. These original assumptions were:

1. The *complete* suppression of ELMs on DIII-D by RMPs, while not on JET, for example, is because the DIII-D coils are off the mid-plane, as presently designed for ITER. Thus only MAST

the next two years are AUG, DIII-D and JET. JET provides a unique tool for pellet pace-making demonstrations as it is the only device large enough such that the fuelling of the pellets will not be the dominant effect. This package of work will also strive to develop a physics understanding of the mechanism by which pellets trigger ELMs, thus helping to minimise uncertainty in extrapolating the technique to ITER. A high frequency pellet injector is probably not required for this physics study and a number of other tokamaks can contribute to this work.

Working Group:

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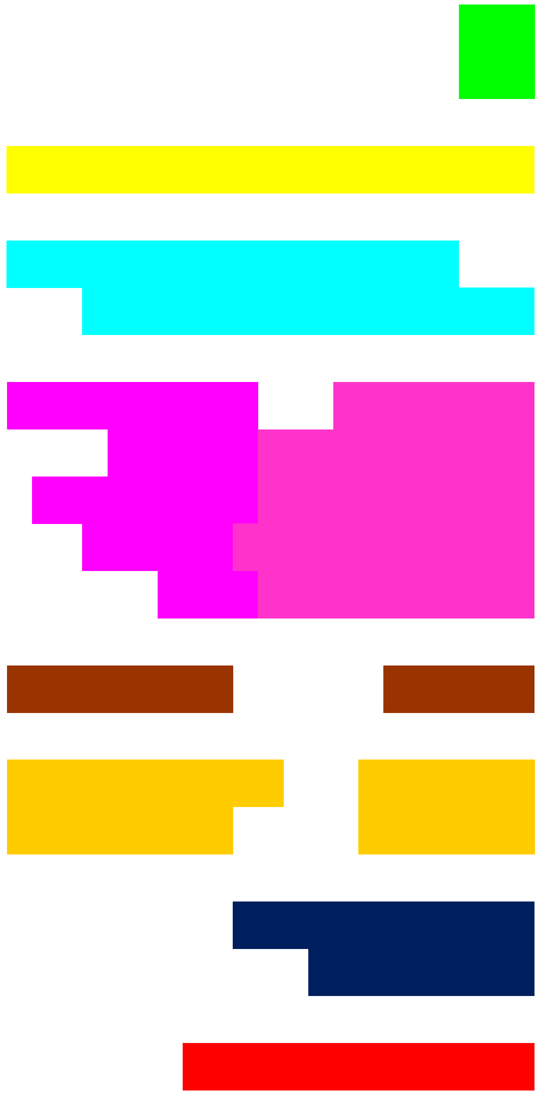
Objective Task

2.1



Objectives:

2.1 Achieve a frequency of pellet-triggered ELMs that is greater than ten times the natural ELM frequency with minimal density rise in an ITER-relevant scenario (e.g. shape, *q*, etc).

2.2

depth required for a pellet to trigger an ELM. This is also expected from MHD modelling. This threshold was reached in the baseline scenario for a D particle content of 1-3 10^{19}, corresponding to a pellet penetration close to the pedestal top. Consistent with this, experiments on AUG found that low field side pellets must penetrate close to the pedestal top in order to trigger an ELM.

New experiments this year on DIII-D show significant promise for the technique, demonstrating pacemaking with a five-fold increase in ELM frequency, with negligible additional fuelling. A moderate decrease in confinement of ~10% was experienced. Like JET, the experiments indicate a single filament is formed from the pellet ablation plasmoid. The higher spatial resolution of the camera system on DIII-D showed that the filament forms in front of the LFS pellet. This is interpreted as a steepening pressure amplitude fixed. The analysis of JT-60U data will help to separate the effects of ripple amplitude and toroidal rotation. JT-60U data on the non-uniform TF ripple amplitude associated with ferritic steel tiles can also contribute to our understanding of the impact of local ripple due to TBMs in ITER. Additional data supporting the tasks of this working group can be obtained from a single machine by using radial displacements of the plasma to vary the ripple. A new capability this year has been provided by the tritium breeding blanket module (TBM) mock-up coil installed on DIII-D to allow the study of a toroidally localised source of ripple, as will be produced by the TBMs that will be installed on ITER.

Work plan and time-scales

Figure 3 shows the work plan and time scales. The target date for input to the ITER Organisation on the

Objectives:

4.1 Explore whether the pressure pedestal height and width depend on the heating source, quantify any differences and interpret in terms of emerging models for pedestal height

4.2 Explore whether the density pedestal properties depend on heating source (e.g. through modified

pedestal pressure. A set of different JET experiments shows the same trend, but with H=1 achieved for P_{loss} $_{th}$, while in other JET experiments H=1 is reached only when P_{loss} $_{th}$ because for lower powers the H-mode is not stationary. The ASDEX-U analyses also show that the evolution of the H-mode after the L-H transition depends on plasma parameters such as heating ramp rate, n_e, q_{95}. NSTX finds that H=1 is achievable with loss power equal to the measured threshold power in ELM free discharges, although the conditions to achieve this are not clear. Both ASDEX-U and JET do not find any correlation between H and P_{loss}/P_{th} from database information. These results indicate that:

i) the analysis of H vs P_{loss}/P_{th} depend on two scaling predictions that have associated error bars and that do not include all the experimentally observed trends, such as the well known dependencies of H on density and triangularity. Therefore this analysis can only highlight trends for specific situations in which discharge parameters, such as shape, I_p, B_t, density, are not varied and where, ideally, P_{th} is the measured threshold (including P_{th} density dependence) in those

Related Joint Experiments

PEP-2	*Pedestal gradients and ELM energy losses in dimensionally similar discharges and their dimensionless scaling* (JET, DIII-D and ASDEX Upgrade)
PEP-26	*Critical edge parameters for achieving L-H transition* (C-Mod, AUG, DIII-D, MAST, NSTX)
PEP-27	*Pedestal profile evolution following L-H transition* (C-Mod, AUG, DIII-D, MAST, NSTX)
PEP-28	*Physics of H-mode access with different X-point height* (AUG, DIII-D, C-Mod, JET, MAST, NSTX, TCV)

4. Future meetings

The next ITPA Pedestal Group meeting will be held in Seoul, S Korea 18-20 October, 2010. Following