Annual Report on the Activities of the ITPA Confinement Database and Modelling Topical Group
June 2007 – June 2008

Prepared for the CDBM Topical Group by W.A. Houlberg

I. Organization of the ITPA Confinement Database and Modelling Topical Group

The activities of the Confinement Database and Modelling Topical Group (CDBM TG) are supported by a diverse group of active participants. There have been no changes in the official representatives since last year's report (see table). The CDBM TG is broken down into four Working Groups to organize working sessions and facilitate discussion for the bi-annual meetings. K. Thomson coordinates the Global Database Working Group (GDB WG), W. Houlberg coordinates the modelling applications (Transport Modelling WG), H. Weisen coordinates the Particle Transport WG, and P. Strand coordinates the integrated model development WG (IMAGE WG).

China	EU	India	ITER-IT
Z. Cui Z. Gao Y. Shi C. Yu J. Zhang	C. Hidalgo (Stellarator) F. Imbeaux D.C. McDonald F. Ryter	I. Bandyopadhyaya P. Chattopadhyaya R. Srinivasan R. Singh	A.R. Polevoi (Co-chair)
Japan	**RF**	**Korea**	**US**
Y. Ogawa H. Takenaga T. Takizuka M. Yagi H. Yamada	A. Chudnovskiy Yu.N. Dnestrovskiy V.M. Leonov	C.B. Kim J.M. Park S.H. Seo	R.V. Budny J.C. DeBoo W.A. Houlberg (Chair) S.M. Kaye J.A. Snipes

The most notable of the many active participants in CBDM activities are the managers of our databases, who have spent considerable effort in maintaining and extending these valuable resources.

International Global H-mode Confinement Database

Functionality:	Analysis of global confinement in H–mode plasmas	
Manager:	K. Thomsen	EFDA CSU, thomsek@ipp.mpg.de
Location/website:	IPP Garching	http://efdasql.ipp.mpg.de/igd/

International Global L-mode Confinement Database

Functionality:	Analysis of global confinement in L–mode plasmas	
Manager:	F. Imbeaux	CEA Cadarache, imbeaux@drfc.cad.cea.fr
Location/website:	CEA Cadarache	http://www-itpa0d.cea.fr

International H-mode Power Threshold Database

Functionality:	Analysis of the L-H and H-L transition thresholds	
Manager:	Y. Martin	CRPP/EPFL Lausanne, yves.martin@epfl.ch
Location/website:	IPP Garching	http://efdasql.ipp.mpg.de/igd/

International Profile Database

Functionality:	Analysis of local transport and model testing	
Manager:	C. Roach	UKAEA Culham, colin.m.roach@ukaea.org.uk
Software Manager:	T. Fredian	MIT, twf@psfc.mit.edu
Location/website:	UKAEA Culham	http://tokamak-profiledb.ukaea.org.uk/

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The managers of the Global H-mode Confinement and the H-mode Power Threshold DB have had changes in their job positions that will prevent them from continuing as DB managers. This led to a discussion at the Spring 2008 meeting of the future of the databases under the new organization of the Transport & Confinement Topical Group that merges the Confinement Database & Modelling and Transport Physics Topical Groups. It was decided that it was time to discontinue active development of the Global H-mode and Global L-mode Confinement Databases, but that these should be safely archived for potential future use. There are many reasons for discontinuing development at this time. Regarding ITER needs, many of the major parameters used to characterize global energy confinement are machine parameters such as size and toroidal field that played a strong role in the design, but will have very restricted variations in the ITER research program. Furthermore, it was felt that the experimental programme with its advanced diagnostics, and supported by theory and modelling, could more productively focus on the local transport issues that have a major impact on present experiments as well as planning for ITER operation. These issues include barrier formation and sustainment, localized heating and current drive for control, intrinsic rotation and its relationship to barrier physics, etc. Although turbulence theory and modelling have made significant progress over the past decade, there is still potential for major improvements in understanding the fundamental transport process that would facilitate the planning of the ITER experimental program as well as providing a more solid basis for projections to DEMO.

The issue remains as to how to safely archive the inactive DBs as well as to ensure the sustained development of all the ITPA DBs as managers change. With the new sponsorship of the ITPA under ITER and now that ITER is an official project, it was felt that there should be discussion of shared responsibility between ITER and ITPA. For example, ITER could be the host for the DBs and associated analysis tools (hardware, software and system management), while the ITPA takes responsibility for the technical aspects (selection of data, analysis, publishing results). This arrangement would be similar to the plan that was developed during the EDA, but was discontinued due to lack of resources within the ITER central team. Discussions between the IO and ITPA CC should address and resolve this issue.

Related to the discussion of shared responsibility for the DBs is the archival of all ITPA documents and communications: meeting and annual reports, publications, plans for meetings, mailing lists, etc. It may be possible for ITER to take over the responsibility for the effort begun at the Garching JWS by Marc Maraschek. This would improve the communication between the IO, ITPA and the broader community. However, more discussion of this shared responsibility needs to take place between the IO and ITPA CC.

II. High Priority Research Areas

The High Priority Research areas for 2007-2008 were all continued from 2006-2007:

- **HP-1:** Resolve the differences in β scaling in H-mode confinement
- **HP-2:** Develop a reference set of ITER scenarios for standard H-mode, steady-state, and hybrid operation and submit cases from various transport code simulations to the Profile DB
- **HP-3:** Resolve which is the most significant confinement parameter, ν^* or n/n_G
- **HP-4:** Understand the aspect ratio dependence of the L-H power threshold
- **HP-5:** Understand the collisionality dependence of density peaking
- **HP-6:** Develop common technologies for integrated modelling, e.g. frameworks, code interfaces, data structures
- **HP-**7: Re-examine L-H power threshold at low density

Under the new Transport and Confinement TG, these HP Research areas will be changed. Initial discussion was held at the Spring 2008 meeting, but the establishment of new priorities will be the responsibility of the new leaders.

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III. International Collaboration Under IEA Agreements

Summary reports for 2007 and proposals for 2008 were submitted at the 6th IEA/ITPA workshop on 'Implementation of the ITPA Coordinated Research Recommendations' in December 2007. Progress on them was also reviewed at the 14th CDBM meeting in Oak Ridge, TN USA, 22-25 April 2008. Here we summarize the progress since the last annual report.

The key areas of focus are (i) global energy confinement scaling with beta **CDB-2**, with collisionality **CDB-4**, aspect ratio **CDB-6**, and ρ^* **CDB-8,** (ii) density peaking as a function of collisionality **CDB-9**, and (iii) the H-mode power threshold and confinement just subsequent to the transition at low density **CDB-10**, scaling of the low density limit **CDB-11**, and as a function of ioiic species (H, D, He) **CDB-12**. The latter two are new in 2008.

CDB-2: Beta scaling

There are a range of trends from β independence to strong β degradation across studies on JET, DIII-D, JT-60U, AUG, NSTX. The difference in β scaling seems to be associated with shape (triangularity) and edge (pedestal) behaviour. Theory and modelling show that core transport should be ~β-independent for experiments, but different pedestal behaviour could be accounted for by peeling-ballooning mode theory. Future work should focus on increased analysis of pedestal effects in existing experiments and consider 2-term scalings with more realistic pedestal models.

CDB-4: Scaling with collisionality and Greenwald fraction

Previous experiments matching JET and DIII-D indicate that ν^* is a better scaling parameter for confinement than n/n_G but the error bars are larger than the expected difference in scaling between these two devices. Initial comparisons between JET and C-Mod also indicated that □* is a better scaling parameter, but they were taken at a single C-Mod condition. The latest JET results indicate a saturation of confinement at the lowest collisionality. Planned experiments on C-Mod intend to match JET and scan collisionality to determine if ν^* remains the best scaling parameter for transport across a range of collisionalities.

CDB-6: Aspect Ratio Scaling

MAST expanded the H-mode operating space up to 1.2 MA in a DND configuration with powers up to 3.2 MW. A weaker than linear current dependence, and strong toroidal field dependence of total stored energy was found. Rotation data from NSTX was compiled for observations in the H-mode database. It was found that core confinement times are not well ordered by either $\omega(0)$ or $\omega(r/a=0.5)$. There appears to be little to be gained by studying this parameter, but there remains a need to assess the dependence on local ω'.

CDB-8: r* scaling at high and low beta

JET and C-Mod, which lie at the extremes of ρ^*, will perform the low β experiments first. JET has made some successful test shots. C-Mod has also performed test shots, but was not able to reach the required density. With the divertor cryopump operational, it is hoped that experiments can be scheduled for 2008. The program will then move on to the AUG and DIII-D machines. The high β part of the ρ^* scan will be a hybrid scenario, and is still deferred until JET auxiliary power is increased and the 'hybrid' scenario is more firmly established.

CDB-9: Density peaking dependence on collisionality

There are 4 devices (JET, AUG, C-MOD, JT-60U) reporting very similar behaviour of peaking increasing as collisionality decreases in H-mode. The emphasis has now shifted to identifying other, less obvious dependencies and understanding behaviour in devices and confinement modes that appear to deviate from these observations. Impurity behaviour, especially He, needs to be systematically documented.

CDB-10: L-H threshold power at low density
The threshold power has been seen to have a minimum value at low density in many tokamaks including AUG, C-Mod, DIII-D, JET and JT-60U, but the physics and scaling of the minimum threshold and the density at which it occurs is not clear and thus projections to ITER are uncertain. Joint experiments are expected to focus on density scans to study the physics and parametric dependence of the minimum threshold and density at which it occurs.

CDB-11: Scaling of the low density limit to the H-mode threshold in H & D plasmas
At intermediate to high densities in D plasmas, the H-mode threshold increases gradually with increasing density. At low densities, however, there is a sudden increase in the power required to achieve H-mode that can be two to three times the nominal threshold scaling. On ASDEX-Upgrade, DIII-D, JET, and JT-60U D plasmas, the density below which the H-mode threshold power increases sharply is around 0.25×10^{20} m^{-3}. On Alcator C-Mod, however, which operates at the ITER toroidal field, this low density limit occurs at between 0.8 and 1×10^{20} m^{-3}. ITER intends to operate at an L-mode target density of 0.5×10^{20} m^{-3}. So, it is imperative to know how this low density limit scales with plasma parameters, and with plasma species (H and D). C-Mod performed some initial experiments with D plasmas in 2007 to see if the low density limit scales with plasma current and no dependence was found. This indicates that the limit does not depend on the Greenwald density limit.

CDB-12: H-mode transition and confinement dependence on ionic species
This proposal call for joint experiments to determine the H-mode threshold power and energy confinement in H, D and He plasmas as a function of different plasma parameters, plasma configurations and auxiliary heating methods. The new experiments will primarily be with H and He plasmas, which will then be compared with data already obtained in similar discharges with D plasmas. The primary parameter scans (for all devices) will be of the target plasma density, plasma current and toroidal field. The auxiliary heating methods will be: for DIII-D, H-NBI into H plasmas, He-NBI into He plasmas, D-NBI into D plasmas, plus ECH; for ASDEX Upgrade, H-NBI into H plasmas, H-NBI into He plasmas and D-NBI into D plasmas, plus ECH and ICRH; for JET, H-NBI into H plasmas, He-NBI into He plasmas and D-NBI into D plasmas, plus ICRH.

IV. Publications

Two publications have been submitted to journals: one documents the analysis of new data on power requirements to access the H-mode, and the other documents the Profile Database – its content, access and supporting analysis tools – that allows for a new release (PR08) of the data to the public.

Y.R. Martin, T. Takizuka and ITPA CDBM H-mode Threshold Database Working Group, ‘Power requirement for accessing the H-mode in ITER,’ submitted to *J. Phys.: Conf. Series*.

Abstract: The input power requirements for accessing H-mode at low density and maintaining it during the density ramp in ITER is addressed by statistical means applied to the international H-mode threshold power database. Following the recent addition of new data, the improvement of existing data and the improvement of selection criteria, a revised scaling law that describes the threshold power required to obtain an L-mode to H-mode transition is presented. Predictions for ITER give a threshold power of ~52MW in a deuterium plasma at a line average density $n_e = 0.5\times10^{20}$m^{-3}. At the nominal ITER H-mode density, $n_e = 1.0\times10^{20}$m^{-3}, the threshold power required is ~86MW. Detailed analysis of data from individual devices suggests that the density dependence of the threshold power might increase with the plasma size and the magnetic field. On the other hand, the density at which the threshold power is minimal is found to decrease with the plasma size and increase with magnetic field. The influence of these effects on the accessibility of the H-mode regime in ITER plasmas is discussed. Analyses of the confinement database show that, in present day devices, H-modes are generally maintained with powers exceeding the threshold power by a

factor larger than 1.5, and that, on the other hand, good confinement can be obtained close to the threshold power although rarely demonstrated.

C.M. Roach, M. Walters, R.V. Budny, F. Imbeaux, T.W. Fredian, M. Greenwald, J.A. Stillerman, D.A. Alexander, J. Carlsson, J.R. Cary F. Ryter, J. Stober, P. Gohil, C. Greenfield, M. Murakami, G. Bracco, B. Esposito, M. Romanelli, V. Parail, P. Stubberfield, I. Voitsekhovitch, C. Brickley, A.R. Field, Y. Sakamoto, T. Fujita, T. Fukuda, N. Hayashi, G.M.D. Hogeweij, A. Chudnovskiy, N.A. Kinerva, C.E. Kessel, T. Aniel, G.T. Hoang, J. Ongena, E.J. Doyle, W.A. Houlberg, A.R. Polevoi, ITPA Confinement Database and Modelling Topical Group and ITPA Transport Physics Topical Group, The 2008 Public Release of the International Multi-tokamak Confinement Profile Database,' submitted to Nucl. Fusion.

Abstract: This paper documents the public release PR08 of the International Tokamak Physics Activity (ITPA) profile database, which should be of particular interest to the magnetic confinement fusion community. Data from a wide variety of interesting discharges from many of the world's leading tokamak experiments are now made available in PR08, which also includes predictive simulations of an initial set of operating scenarios for ITER. In this paper we describe the discharges that have been included and the tools that are available to the reader who is interested in accessing and working with the data. In addition, we review physics analyses that have already made use of the profile database discharges. Public access to PR08 data is unconditional, but this paper should be cited by any publication that makes use of PR08 data.

V. Meetings

Meetings held in 2007-2008

The 13th Topical Group Meeting was held 1-3 October, 2007 in Naka, Japan, with H. Takenaga as the local organizer and JAERI-Naka as host. It was held jointly with the Transport Physics and Pedestal &Edge Physics Topical Groups.

The 14th Topical Group Meeting was held 22-25 April in Oak Ridge, TN, USA, with D.B. Batchelor as the local organizer and the Oak Ridge National Laboratory as host. It was held jointly with the Transport Physics Topical Group and all sessions were combined to facilitate transition to the he new organization where these two groups will be combined into the Transport & Confinement Topical Group.

Future meetings

The first meeting of the Transport & Confinement Topical Group (merger of the CDBM and TP TGs) will be held in Milan after the IAEA FEC 2008 meeting in Geneva, hosted jointly by IFP (Paula Mantica) and the University of Milan. It will be held jointly with the Pedestal & Edge Physics Topical Group.

VI. Summary of the 13th ITPA CDBM TG Naka, Japan

Introduction

The 13th meeting of the ITPA Topical Group on Confinement Databases and Modelling (CDBM) Topical Group was held in Naka, Japan, 1-3 October 2007, jointly with the Transport Physics (TP) and Pedestal and Edge Physics (PEP) TGs. It was hosted by JAEA-Naka, with H. Takenaga, Y. Sakamoto, N. Oyama as the local organization committee. There were about 65 participants for the combined meetings. A joint session between all three TGs covered various aspects of plasma toroidal rotation – rotation transport observations and theory, its effects on the L-H transition and pedestal characteristics, ITER rotation issues, and projections of rotation to ITER. Another three-way joint session addressed tearing modes and NBI injection in ITER. A joint session with the TP TG addressed progress on the ITPA Profile Database (PDB), the Nuclear Fusion paper being prepared for release of the PDB, and plans for an IAEA FEC 2008 paper. Other joint sessions with the TP TG addressed the scaling of energy confinement with beta and particle transport. In the latter session, the Particle Transport Working Group discussed density peaking at low collisionality and it effects on impurities. Joint sessions with the PEP TG covered the H-mode pedestal and power threshold databases and modelling of the pedestal. Working sessions for the CDBM TG covered progress and plans on joint experiments, the L-mode, H-mode, and L-H power threshold databases, and ITER modelling.

International Collaborations Under the ITPA/IEA

On CDB-2 "Confinement scaling in ELMy H-modes: Beta degradation," NSTX experiments have found no beta degradation in highly shaped plasmas, but strong degradation in more weakly shaped plasmas. Preliminary analysis of new DIII-D beta scan experiments with fixed ρ^* and ν^* indicated a moderate beta degradation in all cases. However, the experimental technique is not viewed to be as clean as in previous DIII-D scans and it is not clear how much weight can be placed on the results. Preliminary results of a new experiment performed at JET For CDB-4 "Collisionality scan for core and edge transport" indicate a non-power law scaling of confinement with collisionality. MAST has made a significant contribution CDB-6 "Improving the condition of global DBs: low aspect ratio" by increasing the parameter space of their H-mode data to currents of 1.2MA and powers of 3.2MW. NSTX has collected toroidal rotation data for its existing shots, but has found no clear dependence of confinement on rotation. For CDB-9 "Density profiles at low collisionality", recent questions over the consistency of the JET density data have been resolved and a negative dependence of density peaking on collisionality is now observed when density is measured by interferometry or Thomson scattering. The L-H threshold experiments CDB-10 and CDB-11 were left to the L-H threshold session and are summarised in this section of the minutes.

Global L-mode Confinement DB

Progress on the ongoing task of cleaning up some data (WMHD and WDIA) was reviewed. The Database managers (CEA) could retrieve the original data from archive versions of the DB. It is proposed to use these archives to replace the present data (apparently corrupted). D3D, DIII, and CMOD have validated this approach by looking to their original submissions. The solution remains to be confirmed by data providers of ASDEX, JET, FTU, PDX and PBXM (ongoing). The other machines (TEXTOR, TSUPRA, TFTR, T10) were not affected by the data corruption. Scalings are not affected since they do not use these variables.

Global H-mode Confinement DB

K. Thomsen reported that a new preliminary version DB4v5 had been created. This version included new data from AUG, DIII-D, JT-60U and NSTX. All hybrid data have been marked with the variable HYBRID (= YES, IH or HYBRID). The new rotation variables as defined by S. Kaye had been inserted but data for these quantities had not yet been received. However DIII-D had provided data for the old rotation variables in the database. A web page with a new list of variables and access to different formats of the DB4v5 database has been created.

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J.C. DeBoo presented a summary of the Hybrid experiments on DIII-D during the 2007 campaign. The Hybrid research areas for 2007 included a continuation of low rotation studies during which simultaneous feedback control of β_N and toroidal rotation was developed for the first time in hybrid plasmas and low rotation hybrid plasmas were sustained near the threshold for mode locking. The dependence of the hybrid performance on the electron to ion temperature ratio was investigated. A significant increase in long wavelength turbulence along with modest increases in heat and momentum transport was measured when 2.4 MW of ECH was used to increase Te/Ti at fixed rotation. The NTM suppression studies revealed that suppressing the 3/2 NTM using ECCD at the q = 1.5 surface did not significantly affect the low rotation locking threshold. Finally the suppression of ELMs with Resonant Magnetic Perturbations (RMP) from the I-coil was achieved for the first time in hybrid plasmas.

Finally a list of actions for the next meeting was agreed upon.

L-H Power Threshold DB

New data from JFT-2M and CHS have been included in the threshold database and modifications in the Alcator C-Mod dataset were uploaded. A new version, IGDBTH4v7, of the database was then released. A recommended scaling was presented at the IAEA H-mode workshop: $P_{thresh} = 0.049\ n^{\mathbf{0.717}+/-0.035}\ B^{\mathbf{0.803}+/-0.032}\ S^{\mathbf{0.941}+/-0.019}$. This scaling was estimated from ITER like data from 5 tokamaks. Predictions for ITER then give a threshold power of 52MW at low density (0.5 x $10^{20}m^{-3}$) DD plasmas and 86MW at high density (1.0 x $10^{20}m^{-3}$). In DIII-D it was noted that the confinement time drops soon after the L-H transition giving an H factor of 0.4~0.8. New DIII-D results on L-H transitions obtained by changing the NBI torque without changing the injected power showed that the threshold power increases with the torque. The paper presented at the IAEA H-mode workshop included the recommended scaling, the possible influence of the plasma size on the density dependence of the threshold power, the influence of the plasma size and the magnetic field on the plasma density at which the threshold power is minimum, the power ratio (P_{tot}/P_{thresh}) at which devices usually operate for confinement studies and finally on the possibility to obtain good confinement with P_{tot} close to the threshold power. Actions include finalising the IAEA H-mode workshop paper, adding new NSTX data in the database and analysing the effect of the aspect ratio. A new Joint Experiment dealing with the hysteresis in the L-H and H-L transitions as well as the type of confinement obtained when the total power is close to the threshold power was proposed.

Model Development and ITER Applications

G. Bateman summarized progress in the CPES project for simulating plasma edge physics, which uses the kinetic XGC0 code as a kernel. The TEQ direct equilibrium solver, the ideal MHD linear stability code ELITE, and M3D and NIMROD codes (for non-linear evolution of ELM crashes) are all coupled to XGC0 through the Kepler workflow. P. Snyder reviewed progress in understanding the pedestal power dependence and the predictions of pedestal height for ITER. The pedestal height shows a general increase with power in uncontrolled database studies. Different cases can be understood via peeling-ballooning stability studies: in power-independent cases, the stability limit is generally independent of the Shafranov shift, but in power-dependent cases, the stability limit increases with Shafranov shift. A study suggests that a pedestal width dependent only on global parameters (e.g. global pressure, β, β_p, β_N or T) is

NOT consistent with observations, but a pedestal width dependence on local pedestal parameters (e.g. ρ_{ped}, $\rho_{\theta ped}$, β_{ped}, β_{Nped} or T_{ped}) is consistent with observations.

There were several reports of work performed in support of the ITER Design Review. D. McDonald reported on ITER 0-D sensitivity analyses for Scenario 2 (inductive operation) using the GTBURN and HELIOS codes. The two codes yield comparable results for the ITER reference scenario, 10% reduced field, increased current, and improved confinement. An ITER Scenario Modelling Working Group (lead by V. Parail) was recently established within the EU ITM TF. At the first session in July, three 1.5-D codes (ASTRA, CRONOS and JETTO) were benchmarked against each other, with good agreement between the codes when they all used the same power deposition and radiated power. N. Hayashi reported on TOPICS simulations for an ITER sensitivity study that included reduction of the toroidal field by 10% and variation of the plasma current by ±10%. Scenarios 1-3 and 5 have been completed and scenario 4 was still in progress. Future plans include varying the elongation and control of the heating a CD to recover baseline performance. R. Budny reported on PTRANSP simulations of ITER scenarios: the consequences of: variations in H-mode performance; NNBI steering, sawteeth, rotation; reduction of B_t by 20%; and reducing beam energy below 1 MeV. GLF23 was used to model the confinement and damping of NBI torque.

W. Houlberg gave a brief report on the status of plans to operate ITPA under the auspices of ITER, and the plans to improve coordination of integrated modelling (IM) between ITER and the parties. The IM effort will consist of two primary components: scenario development and evaluation, and the longer-term development of an advanced suite of integrated modelling codes.

Joint CDBM/TP papers and Profile DB

A joint CDBM/TP group paper for IAEA 2008 was proposed by J. Kinsey, contyaining: i) 1-D transport modelling comparing the new TGLF model with experimental data and results from GLF23 / Weiland model, and linear and non-linear gyro-kinetic calculations. The idea is to focus on the impact of rotation in hybrid discharges. A public release of the unified ITB + Profile DB was targeted for the beginning of 2008. Most data providers have already provided the descriptions of the new discharges, as well as the translation to the new agreed variable set. However, 20 discharges from DIII-D, 79 discharges from TFTR, and some ITER scenarios from ASTRA are still missing. It has been decided that those contributions should be submitted before the end of 2007, otherwise they will not be included in the Public Release. A draft NF paper to accompany this public release has been posted on the PDB website and is nearing completion.

IMAGE WG

The IMAGE WG was established under the ITPA CDBM umbrella to provide a venue for discussions between the different Integrated Modelling (IM) projects and activities in the ITER parties. The scope of the IMAGE WG was elaborated at the first meeting in Lausanne and the initial focus areas were agreed according to the following list of topics: Standardization of data structures and code interfaces, machine descriptions, V&V metrics and standardized methodologies and transport solvers. Following an action proposed at the Lausanne meeting in May a first week-long meeting hosted by ITER in Cadarache was held in early September that focussed on data structures and code interfaces. The work on transport solvers was expected to start at the Naka meeting but this discussion was delayed as an IMAGE venture although activities are maintained in the partners' work programmes. As Naka IMAGE meeting was held fairly shortly after the ITER session on data structures only a smaller IMAGE session was needed to report on the outcome of the ITER IM meeting (W. Houlberg), and provide updates on the status of the IM projects through presentations by M. Yagi (JA), S. Konovalov (RF), P. Strand (EU) and G. Bateman (US).

Particle Transport WG

This session covered three topics: impurity profiles under conditions of peaked density profiles, density peaking in low aspect ratio plasmas, gyro-kinetic simulations of peaked density profiles to help discover the physics basis of density peaking. C. Giroud reported some first results from the analysis of impurity transport experiments from the 2006-2007 JET database. A wide dataset of He, Ar, Ne, Ni has been collected, but some discharges could not be analyzed because of changing conditions or MHD activity. L-mode and H-mode exhibit similar impurity peaking, which increases with Z. A comparison of Hybrid and H-mode cases showed the same peaking from C to Ar. Ni transport analysis is to be extended and He transport analysis started. Future plans also include beta and ν_{eff} scaling, and systematic comparison with theoretical models. H. Takenaga reported on impurity transport in JT-60U ELMy H-mode plasmas. Carbon density profiles are flatter than the electron density profiles in H-mode plasmas, but there is no clear change in the C density profiles with varying plasma density or collisionality: the C density profile does not peak with reduced collisionality as the electron density profile peaks. Peaking of the C and electron density profiles both increase as the toroidal rotation shifts from co- to counter, but the C peaking dependence is much weaker. The central C density is higher with low central fuelling and electron heating. The Ar density profiles are similar to the electron density profiles. Tungsten radiation from the core increased with ctr-rotation electron density peaking, but the W source was not evaluated.

S. Kaye reported on initial analysis of a new database for MAST and NSTX density profile peaking studies. The peaking is somewhat stronger in the low A machines than in higher A machines at the same effective collsionality. There are also some differences between the low A machines: While MAST data shows a dependence of the peaking on the current profile, NSTX does not. M. Valovic reported that pellet deposition profiles on MAST confirm the presence of the ∇B-drift effect. The pellet deposition creates a zone with distinct gradients – positive ∇n and doubled $\nabla T < 0$ - which provide a favourable inward diffusion and a new boundary for core confinement according to turbulence codes. The retention time for the particles introduced by the pellet correlates with the state of the edge transport barrier and deposition radius. Extrapolation to ITER conditions yields $\tau_{pel} / \tau_E \sim 0.2$, i.e. ~70% of the designed throughput.

D. Mikkelsen reported on GYRO simulations of peaked density plasmas in C-Mod. Usually EDA H-mode plasmas in C-Mod have a very flat density profile, but operation with JFT-2M shape produced low-density H-mode plasmas with strong density peaking, which is a surprising result because the density profile is never peaked at higher densities. The peaking factor and collisionality are similar to AUG & JET, which breaks the co-linearity of several parameters. GYRO simulations point to differences in the T_e and T_i profiles in C-Mod. Is collisionality, per se, the important controlling parameter? Fast ion dilution also scales similarly to collisionality, and this might be shutting off the ITG turbulence via fast-ion dilution in NBI shots. The proposed C-Mod mechanism (low electron-ion energy exchange and relaxed T_i profile gradients) may not work for ITER and beyond where the temperatures are better coupled. The reality of the new T_i profile shapes in C-Mod still need to be confirmed, followed by simulations based on the full measured T_i profile.

Joint CDBM/PEP/TP sessions on toroidal rotation, tearing modes, and NBI on ITER
Rotation is governed by both intrinsic properties and by application of external torque. The question is whether it can be controlled in reactors, particularly in ITER where the applied neutral beam torque is low. As ITER proceeds from its basic operation through the more advanced hybrid and steady-state operating phases, the potential needs for rotation control increase – rotation is known to influence the core and pedestal confinement, ELMs and resistive walls modes – and the more advanced operating regimes will be successful only if the best confinement characteristics can be assured. The core and pedestal intrinsic (spontaneous) rotation properties have to be distinguished from the response of the core to applied toroidal torque. Recent results from several experiments indicate the intrinsic rotation will likely be very strong for ITER, while the incremental rotation from NBI will likely be low. However, the rotational shear may be more strongly affected by NBI, depending on the strength of the velocity pinching of both the intrinsic rotation and response to the applied torque. There is presently very strong experimental, theory and modelling efforts addressing rotation that will undoubtedly lead to rapid progress in basic understanding of toroidal rotation and its projections to ITER conditions.

VIII. Summary of the 14th ITPA CDBM TG Meeting, Oak Ridge, TN

Introduction
The 14th meetings of the ITPA Confinement Databases and Modelling (CDBM) and Transport Physics Topical Groups were held in Oak Ridge, TN, 22-25 April 2008 with 28 participants. All sessions were held jointly as a prelude to the merger of the two groups.

International collaborations under the ITPA/IEA
On CDB-9 (density profiles at low collisionality), He plasmas in AUG and JET show the same peaking with reduced collisionality as shown earlier for D plasmas in AUG, JET and C-Mod. GS2 modelling of the JET database finds a collisionality dependence of the predicted peaking in agreement with the experimental behaviour. On CDB-11 (scaling of the low density limit of the H-mode threshold), C-Mod, scans at 5.4T found that the low density limit remained n_e=8-10x$10^{19}m^{-3}$ independent of the plasma current, and that the low density limit does not depend on n/n_G. A scan at 2.2T found that the low density limit dropped to about n_e=4x$10^{19}m^{-3}$, which is still somewhat higher than the low density limit observed on AUG, DIII-D, JET, and JT-60U (n_e=2.5x$10^{19}m^{-3}$).

On TP-3.1 (transport dependence on T_i/T_e in hybrid and steady-state plasmas), JT-60U found that 2nd harmonic X-mode ECH flattened the density profile and reduced toroidal rotation. The decrease in confinement correlates with an increase in low-k turbulence (BES data). On TP-3.2 (transport dependence on T_i/T_e in L-mode plasmas), TEXTOR found that the addition of either ECH or ICRH leads to a saturation in total plasma energy that is consistent with a $P^{-2/3}$ degradation of energy confinement in L-mode, but the electron and ion energy contents scale differently with ECH and ICRH. On TP-4 (transport dependence of high performance operation on low momentum input), JT-60U changed the NB momentum input from co- to counter in order to compare the effects of ECH and rotation. When the NB momentum input was changed, T_i decreased inside the ITB, but the ITB structure was maintained. The effect of ECH does not seem to be explained by the change in toroidal rotation. On TP-5 (QH and QDB plasmas), DIII-D obtained QH-mode with balanced beams and slightly positive D_{rsep} (i.e. upward biased double-null), with no MHD activity (no EHOs or broadband MHD), with dominant co-NBI and reversed I_p (1 shot), and also during co-NBI with normal I_p. On TP-6.1 (spontaneous rotation with no external momentum input), rigid body rotation (i.e. flat radial profile) is observed in TEXTOR using reflectrometry measurements of turbulence. Application of ICRH in co-NBI plasmas drives the rotation negative, which is consistent with fast ion losses driven by the ICRH. Application of LH in C-Mod reverses the direction of the Ohmic rotation, which evolves on the same timescale as the current evolution (i.e. much slower than the energy confinement). In a scan over $n_{||}$, a correlation between changes in rotation and l_i was observed. On TP-6.3 (NBI driven momentum transport), DIII-D observed that there was a significant difference in edge turbulence and flows between co-NBI and balanced. Edge turbulence flow reversed during the torque scan. On TP-7 (measurement of ITG/TEM line splitting and comparison with codes), comparisons were made between ECH and NBI plasmas in DIII-D. TGLF analysis confirmed TEM dominance for r/a=0.5 with ECH, and ITG dominance with NBI. No obvious shift in the turbulent frequency spectra associated with ITG or TEM was observed, but this may have been because the TGLF-calculated mode frequency at the measured k_θ was a factor of >10 smaller than the Doppler shift due to E_r. Analysis of T-10 data shows that the turbulence has a very complicated structure with contributions from broadband, low and high frequency quasi-coherent oscillations, and stochastic low frequency fluctuations. These can be interpreted as signatures of ITG and TEM modes, which respond to changes in density in both Ohmic and ECH plasmas. On TP-8.4 (T-10/TEXTOR/HL-2A ITB similarity experiments), TEXTOR analysis showed that heat pulses propagate around islands through the x-point, while transport inside an island is similar to the bulk plasma. HL-2A sees a similar stair-step response to the location of ECH as TEXTOR.

There are far too many joint experiments for the combined group to carry forward. These should be reviewed at the Milan meeting to in light of progress and attention to issues identified in the ITER Research Plan.

<u>Databases</u>
The paper on the H-mode Threshold Database based on the IAEA H-mode workshop has been completed, revised based on the reviewers' comments, and will be sent to the journal by 15 May. Analysis of the relatively few H and He cases in the DB show that the threshold for He is a factor of ~1.3 higher than D, while H is a factor of ~1.6 higher than D. Decisions need to be made on whether new data should be added, and a new DB Manager appointed (Y. Martin has assumed new responsibilities that will preclude continuing as DB Manager). G. Wang reported that on DIII-D the power was ramped down by a factor of two in a simulation of an ITER Scenario discharge. The plasma went from ELMy to ELM-free operation, a density increase, and finally an H-L transition. Analysis of the DIII-D data in the threshold DB shows no clear trend in the $H_{98(y,2)}$ confinement factor over the range $0.5<P_L/P_{thr}<0.7$.

200 new data points from 190 JET shots in the 2006-2007 campaigns have been added to the Global H-mode Confinement DB. The majority of the shots were from Hybrid discharges, ripple studies, high current and high triangularity discharges, or dimensionless confinement studies. K. Thomsen has assumed other duties and will be unable to continue as DB Manager. The possibility of suspending further development of the DB was discussed, with most appearing to favour that option and moving more aggressively on more detailed local analysis of transport and confinement under the new ITPA organization.

The corruptions of JET, FTU and DIII WDIA and WMHD values that occurred between v0.8 and v0.9 of the Global L-Mode Confinement DB are being repaired. There are no regression or physics studies in progress with the DB, so its future needs to be discussed. As with the H-mode DB, suspension of further development was favoured.

The draft NF paper on the new release of the Profile DB (PR08) has been circulated among the authors. The tokamak-profiledb server OS has been upgraded and is fully operational. The ntcdata server is also working but needs to be made more robust and integrated with the website.

Species dependence of transport and confinement

The species dependence of confinement has been studied most extensively in JET. The L-H transition power in ^{4}He was 1.4±0.1 times that in D plasmas. Type I and III ELMs showed similar parametric dependence. Confinement in ^{4}He was 0.68±0.08 that D, scaling as $Z^{-0.7\pm0.08}$. L-H power transition threshold studies in H/D/D-T/T plasmas showed that the threshold scaled as 1/M. The Type I-III ELM boundary followed the M scaling, although there was very little Type I data. The edge electron temperature scaled as $1/M^{0.5}$, there was limited ion pedestal data and no rotation data. Confinement showed a weak negative M scaling and there was a strong correlation between the total thermal energy and the pedestal energy, although the pedestal energy showed a stronger M dependence. Diagnostics were insufficient to distinguish pedestal widths/gradients. The basis for projecting both H and ^{4}He to ITER operation is still very limited. In ASDEX Upgrade there have not been any dedicated ^{4}He L-H threshold studies, but several ^{4}He campaigns have been conducted over a period of 10 years. The threshold power in He is ~1.33 the power in D, which is comparable to the 1.42 observed in JET. The threshold power in H is ~1.8 that in D, which is in rough agreement with 1/M scaling. The confinement in He plasmas is comparable to H plasmas, ~0.76 times that in D plasmas. Future ^{4}He studies are envisioned for autumn 2008 or mid 2009. These will uniquely address He plasmas in a W device with more attention to plasma conditions and analysis. There have been no systematic studies of the H-mode power threshold for H or He plasmas in DIII-D. Nevertheless, studies of individual cases show the threshold in He is higher than the L-H transition scaling for D. Similar case comparisons show that the threshold in H plasmas is much greater than the scaling for D plasmas. Confinement in He discharges is also low compared to the IPB98y2 scaling expression for H-mode. An experimental campaign of three or more days in Jul 2008 is scheduled for H and/or He plasmas. Observations of density peaking in He plasmas have been made on several devices. The He edge neutrals penetrate much less than H edge neutrals because the ratio of CX to ionization rate coefficients about one order of magnitude smaller in He. Despite this, no significant difference in the density profiles is observed between pairs of similar D and He plasmas in TCV, JET, AUG, and JT-60U, in both L- and H- mode. This result provides further confirmation that neutral penetration (particle source / NBI fuelling) is NOT the main ingredient leading to peaked density profiles.

Rotation

H. Takenaga reported that as toroidal rotation increases in the co-direction in JT-60U, the pedestal pressure increases, which then increases the energy content due to stiffness in the core of standard H-mode plasmas. In an analysis of tokamaks based on 3D equilibria, D. Spong showed that finite beta amplifies the ripple through diamagnetic currents. E_r and toroidal rotation drive were found to be stronger at lower effective ripple. Simulations of momentum transport in tokamaks reported by G. Bateman showed that increasing the E×B shear has a dramatic effect on the GLF23 transport threshold, but much less effect on the Weiland model. In the Weiland model, the diffusivity suppression is due to magnetic shear effects, and not because of E×B shear. The relative sensitivity to E×B shear leads to the result that GLF23 over predicts toroidal rotation in comparison with the Weiland model. J. Weiland concluded in a report on simulations of spontaneous rotation that magnetic curvature effects increase both the diagonal (outward) flux and the convective (inward) flux.

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Particle transport, confinement and transport properties

D. Mikkelsen reported on GYRO simulations of a peaked density H-mode plasma in C-Mod. The simulations show a null particle flux at the observed density gradient, and reducing the gradient produces an inward flux. The essential ingredient appears to be the low ITG drive from a larger R/L_{Ti}. L. Baylor presented initial results of pellet dropper experiments on DIII-D that were designed to examine ELM triggering with small LFS pellets. In Ohmic L-mode plasmas, the 10 m/s pellets travel in a vertical path and are observed in the divertor D_α signals and edge interferometer. In H-mode plasmas the pellets are observed to skip along the surface, being swept toroidally by a rocket effect, and do not penetrate inside the separatrix. The largest of the 1mm pellets appear to coincide with ELMs. Pellet fuelling during RMP also leads to ELMs, which may in part be due to increased density. In lower density cases with fewer pellets, only a few ELMs are triggered. Future plans are to test pellet size and speed required to trigger ELMs and study their properties, participate in pellet pacing experiments, and possible upgrade the injector to use high frequency pellets with a similar guide tube to ITER.

Model development and ITER applications

V. Mukhovatov emphasized the sensitivity of the current profile evolution in ITER start-up and ramp-down to the transport model. J. Callen concluded from 18 tests in 7 axisymmetric resistive, current-carrying toroidal plasmas of the paleoclassical model that minimum χ_e is likely to be set by χ_{pce} when $T_e<T_e^{crit}{}_e\sim B^{2/3}a^{1/2}$ keV (~3.5-5 keV in ITER). F. Imbeaux summarized the effort to simulate ITER current ramp-up under the EU ITM ITER Scenario group. E. Doyle reported on DIII-D demonstrations of ITER operation scenarios, and N. Hayashi summarized the status of TOPICS modelling of ITER scenarios. A. Polevoi assessed plasma parameters for the low activation phases (H/He and D) of ITER operation. Heating and CD system commissioning is foreseen in He and D plasmas at half field, half current as well as full field, full current. R. Budny summarized predictions of ITER H-mode and Hybrid plasma performance using PTRANSP, and F. Imbeaux reported on CRONOS modelling of ITB evolution and control in an ITER steady-state scenario. Y. Sakamoto summarized the observations of ITB dynamics in JT-60U reversed shear plasmas. With balanced NBI the ITB is very wide, its foot is located near q_{min}, the steep T_i gradient region expands while keeping its gradient, and there is no significant difference in $V_T(r)$ during the expansion phase. With co-injection, slow changes in T_i and V_T were observed before the transition. At the transition T_i increased rapidly, and the ITB foot could be located in the positive shear region. P. Strand presented a status report on the EU ITM Task Force and EUFORIA projects, and W. Houlberg reviewed the status of plans for ITER Integrated Modelling.

Proposed High Priority Research areas for 2008-09

Following discussion in several of the sessions, E. Doyle drafted a list of proposed High Priority Research areas for the Transport and Confinement TG:

- Develop an improved characterization of the L-H transition threshold: toroidal field, density, rotation and species dependence of the power threshold in ITER-like geometry
- Particle and impurity transport: define parametric dependences of density peaking over a range of conditions; examine correlations between impurity and main ion density profiles
- Electron transport: resolve role and importance of ETG vs coupled ITG/TEM/ETG, vs other possibilities in governing electron transport; improve demonstration and modeling of reduced transport regimes with dominant electron heating
- Ion thermal transport: verify and validate theory-based transport models (but this applies to all!); increase tests/model validity to plasmas with ITBs and other enhanced confinement regimes
- Momentum transport and plasma rotation: improve characterizion of rotation sources, transport mechanisms and effects on confinement and barrier formation, especially with regard to intrinsic rotation