Annual Report of ITPA Topical Group on MHD

For the period July 2007 to June 2008

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Executive Summary

The MHD Topical Group held two meetings (its 10th and 11th) during the reporting period – at IPP-Garching, from 10th-12th October 2007, and at Naka (JAEA site) from 25th -29th February 2008. The meeting in Garching, followed on from an IAEA TM on Energetic Particles in Klosters Seeon, and about ½ the participants at the ITPA meeting joined from the IAEA meeting. The meeting in Naka was held in conjunction with the US-Japan Workshop on MHD, and an IEA workshop (W68) on ELM/RWM control (some of the ITPA meeting was held in parallel sessions to the other workshops).

At both MHD Topical Group meetings there was discussion of progress on high priority areas and on joint IEA/ITPA co-ordinated experiments. Another major focus of both meetings was on key areas arising out of the ITER Design Review (RWM/ELM control coils, vertical control and disruption related issues).

In the high priority areas there has been good progress in most areas, including:- improved understanding of RWM damping; quantitative assessments of RWM feedback coil options for ITER; understanding of the requirements and constraints on massive gas injection disruption mitigation for ITER; intermediate-n TAE damping measurements (in C-Mod, JET and MAST); and on the effects of flow shear on NTM stability.

The next meeting of the MHD Stability Topical Group and the new Energetic Particle Topical Group is planned to be at CRPP Lausanne from 20th-22nd October 2008, at the same time as the SSO Group. These TG meetings are planned on these dates to take advantage, from a travel viewpoint, of the IAEA Fusion Energy Conference which will be held the preceding week in Geneva.

Contents

1. Meetings and reports

A full summary of the 10th and 11th meetings of the ITPA MHD Topical Group, and viewgraphs presented, are available at the ITPA website, and only a shortened summary is given here. Also a summary of results on IEA/ITPA co-ordinated experiments was presented at the November 2007 planning meeting for these experiments (at JET, UK) and will not be repeated here.

1.1 Report on the 10th Meeting of ITPA Topical Group on MHD, IPP-Garching

The 10th meeting of the ITPA Topical Group on MHD was held at IPP, Garching, Germany from 10th-12th October 2007. The meeting was kindly hosted by the Max Planck Institute for Plasma Physics. At the Topical Group meeting there were 40 participants (3 from the ITER Organisation, 7 from Japan, 14 from the EU, 1 from India, 2 from Russia and 13 from the US). The meeting followed the IAEA TM on Energetic Particles in Klosters Seeon, and about ½ the participants at the ITPA meeting joined from the IAEA meeting.

The meeting covered a wide variety of topics, many of which related to the High Priority Research areas in MHD for 2007-2008. The 2 key foci of the meeting were a discussion of MHD issues related to the ITER Design Review (principally vertical stability, disruptions and ELM/RWM control coils) and a 2/3rd of a day session on fast particle issues for ITER. A discussion session on key ITER MHD issues was held with David Campbell who was an attendee of the meeting. The meeting also discussed progress on, and the future of, the IEA-ITPA Joint Experiments related to MHD.

Discussion of ITER Design Review

David Campbell and Abhijit Sen discussed the issues arising from the studies by Working Group 1 (WG1) of the ITER Design Review in the MHD area. Some of these were encapsulated as Design Change Requests (DCRs) relating to improved vertical control through an increase in the voltage capability in the existing VS circuit (VS1) to ±9kV and that elements of the central solenoid be used to form a second VS circuit, studies of requirements for RMP Coils and for a Disruption Mitigation System.

As reported at the previous meeting at full current (I_p=15MA) the reliable operating window in l_i is limited by vertical stability. Data shown at the 2007 IPP-Garching meeting from Alcator C-Mod showed during current rampdown their plasmas enter the unstable l_i domain for ITER. It is possible that careful discharge programming in ITER could lower the current and elongation in such a way to remain vertically stable but it is highly desirable to improve the vertical stability margin

There are significant implications on the pumping systems of the ITER Disruption Mitigation system if massive Gas Injection is used. The densities required for mitigation/runaway suppression in ITER are fairly well quantified (though the degree of conservatism in the estimates should be reviewed). Less clear is the preferred gas mixtures and toroidal symmetry requirements (i.e. how many valves are needed). It is clear the valves should be as close to the plasma as engineering constraints allow.

An issue of high importance that was discussed at the 2007 IPP-Garching meeting was the horizontal asymmetric VDE forces on the vessel during a disruption. JET has the best data on this and application of the model, developed to explain the JET data, to ITER would imply unacceptably large horizontal forces. An E-mail sent by Sugihara-san several weeks before the meeting, and presentations at the meeting, clarified the data available from other tokamaks – in C-Mod and JT-60U there is no data on this issue, DIII-D has a very rigid vessel and vessel displacements that are measured yield no information on the size of the forces, the best data (other than JET) is from AUG where the maximum radial displacement is ~ 0.25 mm and corresponds to a statically applied force of 18kN. This force is smaller than would be predicted by the JET model – further results on this issue were reported at the February 2008 MHD TG meeting (see below).

Sessions on Energetic Particles

3 sessions on energetic particles were held at the 2007 IPP-Garching TG meeting:-

1. Linear stability of fast particle instabilities (Led by A Fasoli)
2. Nonlinear stability of fast particle instabilities (Led by R Nazikian)
3. Fast ion diagnostics requirements for ITER (Led by B Heidbrink)

The overall conclusions of the 3 sessions were summarised by Professor Toi.

The aim of these sessions was to establish what are the outstanding issues in the energetic particle area for ITER and the primary conclusions were:-

- Develop an experimental benchmark case probably based on a well documented DIII-D case for comparison of code predictions on linear stability.
- Develop a new experimental case as joint experiment (see MDC-11 below) to provide a nonlinear benchmark case of fast ion losses.
- Consult the ITPA Diagnostics Topical Group on fast ion diagnostics

1.2 Report on the 11th Meeting of the ITPA Topical Group on MHD, Naka, Japan

The 11th meeting of the ITPA Topical Group on MHD was held at Naka Japan from 25th – 29th February 2008. The meeting was kindly hosted by the Japan Atomic Energy Agency. The meeting was held in conjunction with the US-Japan Workshop on MHD, and an IEA workshop (W68) on ELM/RWM control (some of the ITPA meeting was held in parallel sessions to the other workshops). At these meetings there were 61 participants (4 from the ITER IO, 31 from Japan, 11 from the EU, 1 from India, 2 from Korea, 3 from Russia and 9 from the US).

The meeting covered a wide variety of topics, many of which are related to the High Priority Research areas in MHD for 2007-2008. From the ITPA perspective the key foci of the meeting were discussions of MHD issues related to the ITER Design Review - principally vertical stability, disruptions (mitigation and loads) and ELM/RWM control coils. The meeting also discussed progress on the IEA-ITPA Joint Experiments related to MHD and high priority research areas for 2008/9.

Discussion of ITER Design Review Issues

ELM Control Coils

The primary options for ELM mitigation are pellet pacing and resonant magnetic perturbation (RMP) coils. A range of RMP coil options have been examined:

- A single row of mid-plane coils possibly combined with upper-port plug coils
- Two rows of coils in between the 2 vessel walls represented a good physics solution, but was rejected for other reasons

The favoured solution at the time of the meeting was the blanket vessel interface (BVI) coils mounted between the blanket and vessel. A mid-plane row of 9 coils, with 2 more rows of 9 coils above and below the midplane was envisaged at the time of the meeting.

It is found that the upper port plugs do not provide a significant benefit in terms of ELM control and that the non-resonant braking associated with the equatorial coils is substantially higher than from the BVI coils. Also the only fully successful coil configuration, to date, for complete ELM suppression has been the DIII-D I-coils (two rows of off mid-plane coils). Thus given these considerations the best option for ELM control seems to be the BVI coils. If included the blanket-vessel-interface coils might also be used for vertical control and RWM control.

Vertical Control

At $l_i(3)=1.2$ the maximum level of controllable perturbation ~2cm, ($\Delta Z_{max}/a \sim 1\%$) with the present vertical control system. The options under study for enhancing vertical control at the time of the Naka meeting were:-

- Second VS circuit (VS2) utilizing CS modules CS2U and CS2L with 6kV allows increase of max(Z_0) by about 50%.
- Increase of voltage in the main VS circuit (VS1) from 6kV to 9kV increases max(Z_0) additionally by about 50% - this option remained under study because under fault conditions potentially very high voltages might be applied to the PF coils
- Use of the proposed internal BVI ELM control coils (powered as n=0)
- Additional passive stabilizers

Studies under the US-BPO, and in the EU, show use of BVI-type coils increases the stability margin considerably (giving a maximum controllable displacement $\Delta Z_{max}/a > 50\%$). The passive stabilisers increase the stability margin to $\Delta Z_{max}/a > 4\text{-}5\%$, but induced currents during fast transients in the passive stabilisers severely compromise the ability to reconstruct equilibria (due to the effect on measured magnetic signals).

Disruption Loads

<u>Sideways force</u>

As mentioned in the report on the 2007 Garching TG meeting the observed horizontal loads in JET, if extrapolated in a ‘simple’ manner to ITER would significantly exceed the design limit. Three candidate models have been examined in an attempt to understand this issue and its extrapolation to ITER (i) A Sink and Source model; (ii) A Wetted Area kink mode model and (iii) Asymmetry of vertical halo current due to radial shift.

For the Sink and Source model a detailed EM model of the ITER vessel has been developed by the Efremov Institute and this indicates a 40MN sideways force in ITER. A simple estimate with the Wetted Area model shows a sideways force of ~20MN. Further comparison of the models with experiments is necessary and an understanding of underlying physics is important to identify the reaction force.

<u>Vertical force</u>

Here the basic physics is comparatively clear. The force from halo currents calculated by DINA and DIII-D models is similar (80-85 MN). This translates to a maximum load on each support leg of ITER of ~28MN, which is just below the design limit - indicating the importance of minimising the uncertainty in halo current predictions.

2. High Priority Research Areas

Area	Progress Reported at ITPA Meeting
Continue development of the disruption DB to include pre-disruptive energy loss and halo current data.	It remains to include in the disruption database new variables to quantify halo fractions and pre-disruptive energy losses – it is planned to progress this as a matter of urgency. Analysis of MGI induced disruptions on DIII-D indicate they approach the fastest natural disruption rate of $1.7 ms/m^2$ – one consequence of faster Ip-quench is that this raises the densities to avoid avalanche electrons. In the disruption database it is found that DIII-D experiences significantly faster current quenches than the other conventional aspect ratio tokamaks. Taking the plasma as a lumped circuit type model the quench rate time is $\propto$ L (the external inductance). Though studies in JT-60U also indicate the importance of considering the dL/dt term to get quantitative agreement on quench rates. In all but DIII-D the external inductance is determined by the plasma-vacuum vessel inductance. Whereas the relatively short time constant of the DIII-D vessel makes the plasma to PF set inductance an important feature. If this explanation is correct then it appears the current quench limit for ITER is appropriate (i.e. the external inductance on ITER is roughly the same fraction of the total as in DIII-D). Numerical models should be developed to confirm this.
Develop ITER applicable disruption mitigation techniques, with particular emphasis of runaway avoidance, and understand influence of MHD on impurity penetration under massive gas injection. Validate 2 and 3-D codes, in particular MHD and radiation models, on gas injection. Develop reliable disruption prediction methods.	Present experiments show best results with H2, D2 or He (possibly mixed with small amounts of higher-Z gases , few %) - high fractions of high-Z gases give lower assimilated fractions and seem to cause runaway generation. Assuming 20% assimilation, an injected gas quantity of up to 5×10^5 Pa-m^3 is needed in ITER to avoid secondary runaway generation. The pumping requirements for these large quantities of gas are problematic. An injection duration of ≤ 10 ms is needed with a rise time (to 90% flow) of ≤ 3 ms (≤ 1 ms desirable) and a propagation time of ≤ 3 ms (i.e. ≤ 3 m to plasma) and ≤ 1 ms is desirable. In DIII-D experiments using the MEDUSA MGI system with H2 and He have demonstrated the efficacy of 'highflow' + 'fast-rise' MGI; with an assimilation fraction of f_{assim} ~35% but only reaching a small fraction of the no-avalanche requirement f_{RB} = ~0.08 with He (f_{RB} = 0.07 with Ne and Ar). A new concept for a fast valve, located in the vessel close to the plasma and actuated by air pressure has been developed for ASDEX Upgrade. The in-vessel valve shows better mitigation performance with respect to the older EM valve in terms of:

Area	Progress Reported at ITPA Meeting
	▪ Extremely fast response of the plasma - start of a fast current quench within 1 ms from trigger ▪ High plasma cooling efficiency -> large radiated power, fast current quench and small vertical forces; ▪ High refuelling efficiency ($\Delta N_e/N$~ 25-50 % of injected atoms) independent of the type of gas injected, implying suppression of the avalanche of the primary source in ITER.
Study NTMs in Hybrid Scenarios, the effect of plasma rotation, validate ECCD control models against data (including modulation) and specify diagnostics for NTM detection.	ITER document, DDD 5.2 (Detailed Design Document : EC system) states a modulation frequency of 1kHz is needed for the ECCD system. This is based on a former study of power supply modulation, not on NTM physics requirements. The likely rotation in ITER is still subject to considerable uncertainty with estimates in the range 1-8KHz for the 3/2 NTM (and more than 2 times smaller for the 2/1 NTM). The ITPA meeting concluded that while the large uncertainty in rotation rates prohibits a definite conclusion, that an extension of the ECRH modulation capacity to 5kHz is desirable and that there is high probability this will allow control of the most dangerous 2/1 NTM. There is strong experimental evidence for toroidal shear flow induced modification of the NTM threshold β and saturated island size, for the 3/2 (in sawtoothing and hybrid plasmas) and 2/1 NTMs. The main effect appears to arise from a change in the tearing mode stability parameter, Δ'. A heuristic model and empirical fitting gives linear scaling of Δ' with flow gradient and preliminary investigations with the resistive MHD code NEAR, and Newcomb equation analysis, supports this scaling for classical tearing modes - it is necessary to extend the analysis to NTMs.
For RWMs understand mode damping particularly at low rotation. Continue benchmark tests of theory models for RWM feedback and experimentally study feedback control at low rotation. Study coil systems for RWM control in ITER and specify diagnostics.	In JT-60U to sustain high-β_N above the no-wall limit active plasma rotation control has been attempted. However, an n=1 bursting mode caused rotation damping and an RWM appeared. Strong plasma rotation braking due to the RWM was observed after its onset and this seems to occur first near q=2. Active diagnostics for sensing RWM stability, using external coils, have been installed in JT-60U. In DIII-D in the rotationally-stabilized regime transient events can excite the RWM to grow up to 10-30 gauss level within 100-200 microsec. This process is observed to occur with ELMs and fishbones providing the transient disturbances. After each event a persistent level of RFA remains – this can be reduced (particularly in the ELM case) by active feedback. These results suggest a continued focus on reducing the residual error field is important. Also the results suggest the

Area	Progress Reported at ITPA Meeting
	repetition time of the ELM or fishbone is an important parameter to consider in designing RWM feedback systems. It is found in DIII-D that low-torque, low-rotation plasmas often develop tearing modes near the RWM stability threshold, raising the question of whether non-rotating "RWMs" in these plasmas are also tearing modes? The MARS-F code has been extended to allow the kinetic RWM stabilisation terms to be included non-perturbatively. It is found that the ideal kink eigenmode structure is modified by the RW, and further modified by drift kinetic resonances. Prediction of the RWM stability may depend on whether a perturbative or non-perturbative approach is used. Whilst a perturbative approach does predict full stabilisation of RWM in DIII-D & ITER, the non-perturbative approach seems to find less stabilisation. Extensive development of 3D codes, including detailed wall structures, to allow RWM simulations are well advanced. The MARS-F and CARIDDI codes have been coupled to study RWM stability and control, where 3D effects of conducting structures are important. The code has been used in various applications, such as tokamaks and RFPs. It is found that detailed modelling of the wall structures (e.g. holes, tubular extensions, etc.) in ITER is very important to predict the RWM stability and control. Equivalently the 3D MHD codes VMEC (equilibrium code), CAS3D (3D ideal MHD stability) and STARWALL (3D, with realistic resistive wall structures) codes are being used at IPP-Garching for RWM studies. Benchmarking between MARS, VALEN, STARWALL and KINX continues. Using the new smoothed boundary equilibria reasonable agreement is found on the growth rates. However there remain discrepancies in the transfer function at high beta under feedback control (notably between VALEN and MARS-F). A possible explanation for this is that VALEN represents the instability as a single mode whereas the other codes have a general representation – a new multi-mode version of VALEN is nearing completion and will be applied to analysing the transfer function for comparison with MARS.
Quantify effects of non-resonant error fields, specify multi-mode error correction requirements and error field thresholds at high β.	A comparison experiment, using n=2 magnetic braking, between JET and C-Mod has commenced. The experiment is based on matched n=2 applied error field spectra in the 2 machines. In JET plasmas braking of up to ~50% has been observed due to the n=2 field. In C-Mod the braking, if any, was in the noise. This is however consistent with the theoretically scaled braking effect from

Area	Progress Reported at ITPA Meeting
	JET. Also during 2007 MAST data on magnetic braking from n=2 applied fields was obtained – like C-Mod the braking effect was small and analysis to compare with theory is ongoing.
Understand intermediate-n AEs and Energetic Particle Modes ; redistribution of fast particles from AEs; and perform theory-data comparisons on damping and stability.	As previously reported the computed fast ion transport using the measured AE eigenfunction amplitudes for a DIII-D discharge is much too small when compared with measurements. Recent analysis suggests this may be due to:- • The use of time-stationary eigenfunctions whereas analytical estimates indicate that "bucket" transport by frequency-sweeping RSAEs could be important. (New calculations are in progress.) • While there are no regular low-frequency MHD modes, there is discernable activity in this band – making these modes a definite candidate for appreciable transport. In C-Mod experiments and comparison of intermediate-*n* damping data with theory are at a fairly mature stage. During 2007 two dedicated sessions were run with ICRF heating to examine stability in the presence of a fast ion tail. Additionally there are now 10 toroidal positions of poloidal field pick-up coils to improve the *n*-number determination. In JET: large amounts of data have been taken. Analysis has started and initial difficulties are with mode number separation/identification (multiple *n*'s) – a new algorithm for mode number identification has been developed. First results from three antennas in MAST indicate damping in the range $4\% < \lvert\gamma/\omega\rvert < 20\%$, with *n* numbers not yet determined. And JT-60U has recently installed two antennas capable of exciting $n \leq 20$ and first results are expected soon.

3. Proposed high priority research areas for 2008/9

The following High Priority Research areas are proposed for the MHD Stability TG for 2008/9:-

- Assess vertical stabilisation options for ITER, based on data on presently controllable vertical displacements and n=0 noise, and specify diagnostic requirements.
- Develop ITER applicable disruption mitigation techniques. For massive gas injection, understand optimal gas mixtures, their assimilation properties and the influence of MHD on impurity penetration to the core. Study the ability to suppress secondary runaways. Develop reliable disruption prediction methods and understand diagnostic requirements.
- Continue development of the disruption DB to include pre-disruptive energy loss and halo current data.
- Study NTMs in Hybrid Scenarios, the effect of plasma rotation, validate ECCD control models against data (including modulation) and specify diagnostics for NTM detection.
- For RWMs understand mode damping particularly at low rotation. Continue benchmark tests of theory models for RWM feedback and experimentally study feedback control at low rotation. Study coil systems for RWM control in ITER and specify diagnostics.
- Quantify effects of non-resonant error fields, specify multi-mode error correction requirements and error field thresholds at high ß.

And for the Energetic Particle TG the proposed 2008/9 High Priority Research areas are:-

- Measure damping rates of Alfvén waves (together with reliable mode identification: eigenfunction, frequency etc) and compare with theory
- Define benchmark test cases for fast particle stability codes
- Develop relevant diagnostics and make recommendations for ITER diagnostics
- Compare theoretical predictions with measurements of fast ion losses caused by magnetic field ripple and error fields in present day devices
- Predict the power loads to the ITER first wall caused by error fields, ferritic inserts, test blanket modules and perturbation fields (ELM mitigation coils)

4. Proposed Scope and Tasks for the MHD Stability and Energetic Particle TGs

Scope and Tasks for the ITPA Topical Group on MHD Stability

Scope

The general scope of the ITPA Topical Group on MHD is to provide the experimental and theoretical basis and recommendations for both conventional and advanced tokamak scenarios on next step burning fusion devices in the field of

- ß limiting MHD instabilities and their active control
- disruptions (physics, prediction, avoidance and mitigation), and the connected halo currents, forces and heat loads
- plasma magnetic control (current, position, shape, error fields).

In these fields the group shall co-ordinate collaborative research activities among international fusion research establishments, including experiments to be conducted, analysis of results, modelling and comparison with theory. The group shall also direct the application of the present understanding to modelling and assessment of ITER plasmas.
Predictions to burning plasma experiments require the construction, extension and analysis of a disruption database, and contributions to other databases.
In addition, research priorities for Physics R&D in support of burning plasma experiments have to be identified and formulated and to be endorsed by the ITPA Coordinating Committee.
Based on these activities, the TG shall recommend physics guidelines and methodologies for physics and technical design of burning plasma experiments.
Publications and presentations on the activities of the TG to fusion journals and international conferences will be promoted.

Tasks
The Topical Group, on the basis of experimental and theoretical studies, should provide input in the field of the three main subjects.

MHD instabilities and their control
- limits imposed on plasma parameters, especially ß, by MHD instabilities in both conventional and advanced tokamak operation (NTMs, external kinks, RWMs),
- active control of MHD instabilities via pressure and current profile control,
- active control of MHD instabilities via conducting structures and additional coils,
- interaction of MHD modes with plasma rotation, error fields and TF ripple,
- diagnostic issues related to measurement and control of MHD instabilities

Disruptions and their mitigation
- disruption characterisation, (e.g. thermal and current quench times, halo currents, production and quenching of runaway electrons) and its projection to the future machines,
- validation of theoretical models used in disruption studies, namely disruption prediction, avoidance, and mitigation,
- extension of the existing disruption database, especially towards $q\approx3$ discharges, quench time scales and halo current asymmetries,
- tools and recommendations for disruption prediction, avoidance, and mitigation (both for heat loads and forces to achieve reliable machine protection),
- assessment of disruption mitigation by techniques including pellets and strong gas puffs,
- avoidance and mitigation of runaway electron production during current decay
- scenarios of emergency plasma termination (fast shut-down).
- diagnostic issues related to prediction, avoidance, and mitigation of disruptions

Plasma magnetic control
- recommendations on the reactor relevant conventional and advanced tokamak scenarios,
- plasma scenario and machine sequencing requirements to get the plasma target parameters and to avoid disruption,
- feedback and feedforward control of plasma current, position and shape by axisymmetrical poloidal fields,
- control and reduction of error fields,
- experimental validation of theoretical models used for magnetic control simulations,
- diagnostic issues related with magnetic control

- development, tests and recommendation on magnetic control used in Plasma Control Simulators[1].

Scope and Tasks for the ITPA Topical Group on Energetic Particle Physics

The general scope of the ITPA Topical Group on Energetic Particle Physics is to tackle the qualitatively new physics element of ITER: dominating α–particle heating. The group shall provide the experimental basis and the theoretical knowledge to give recommendation for both the conventional and advanced scenarios in ITER in the fields of :

- energetic particle driven instabilities (Alfvén waves and energetic particle modes) and their consequences for plasma heating and the first wall material
- effects of non-axisymmetric magnetic fields such as field ripple, error/perturbation fields
- interaction of fast ions with background MHD (to be coordinated with MHD?)
- NBI heating and current drive (to be coordinated with SSO)
- runaway electrons (to be coordinated with MHD)

ITER itself will not mark the last stage in the development of fusion heating, and a comprehensive ab-initio understanding of fast particle results on this device will be a necessary prerequisite for bridging the gap to DEMO. The group shall therefore co-ordinate collaborative research activities in existing experimental devices, but in particular also encourage a close collaboration between theory and experiment. In addition, the ITPA topical group shall identify the diagnostic requirements for ITER, needed to extrapolate towards reactor relevant conditions ($Q > 50$).
Publications and presentations on the activities of the TG to fusion journals and international conferences will be promoted.

Tasks
The Topical Group, on the basis of experimental and theoretical studies, should provide input in the field of the following main subjects.

Destabilisation of Alfvén waves and Energetic Particle Modes (EPMs)

- measurements of damping rates of Alfvén waves (together with reliable mode identification: eigenfunction, frequency etc) and comparison with theory
- investigation of the drive of different kinds of Alfvén waves (TAEs, BAEs, RSAEs,...) and EPMs depending on the fast ion distribution function (energy and pitch angle)
- measurements of the influence of fast particle driven instabilities on the fast ion distribution function, expulsion of fast ions, comparison between experiments and state of the art non-linear theory/codes
- definition of benchmark test cases for fast particle stability codes
- development of relevant diagnostics, recommendations for ITER diagnostics
- Prediction of the role of fast particle driven modes in ITER conventional and steady state scenarios, including the power load on the first wall caused by the fast particle loss; recommendations for operation.

[1] Taking into account high cost of ITER equipment and cost of the tokamak discharge, all experiments should be at first simulated and proper optimised with “user friendly” numerical codes, Plasma Control Simulators. Activity on the PCS includes development of “user-friendly” codes, their validation in experiments, improvement of the codes and simulation of ITER discharges with the feedforward and feedback plasma control. Methodology of the codes adaptation to the experimental results should be developed.

Effect of non-axisymmetric magnetic fields

- comparison between theoretical predictions and measurements of fast ion losses caused by magnetic field ripple and error fields in present day devices
- prediction of the power loads to the first ITER wall caused by error fields, ferritic inserts, test blanket modules and perturbation fields (ELM mitigation coils)

Interaction of fast ions with background MHD

- investigation of the interaction of background MHD and fast particle confinement in present day devices, comparison with theory
- prediction of the influence of NTMs and possible synergistic effects with field ripple/error fields on fast particle confinement in ITER
- influence of fast ions on sawtooth stability, development of control tools for ITER

Runaway electrons

- study of generation of runaway electrons by disruptions in present day devices, comparison with theory
- development of mitigation/control tools for ITER

NBI heating and current drive

- investigation of localisation of NBI heating and current drive
- prediction of the role of NBI current drive on current profile control in ITER

5. Future Meetings

The next meeting of the MHD Stability Topical Group and the new Energetic Particle Topical Group is planned to be at CRPP Lausanne from 20^{th}-22^{nd} October 2008, at the same time as the SSO Group. These TG meetings are planned on these dates to take advantage, from a travel viewpoint, of the IAEA Fusion Energy Conference which will be held the preceding week in Geneva. The location of meeting in early 2009 is not yet decided – it is noted that the MHD TG has never met in Korea or India.