EFDA WORKPROGRAMME 2010

Call for Participation

(Part of the EFDA WP, MHD TG)

Activities under MHD

Deadline for Responses: 20th November 2009

Topical Group Chair: Piero Martin

Topical Group Vice-Chairs: Rudi Koslowski, Emmanuel Joffrin

EFDA CSU contact person: Duarte Borba

This Call for Participation aims to implement the EFDA Work Programme for 2010 on MHD under Task Agreements as foreseen in the new EFDA Art. 5

Introduction

At its meeting in Prague on 12 March 2009, the EFDA Steering Committee approved elements of the EFDA 2010 Work Programme, among which the MHD programme. This includes the preparation and execution of experiments performed in the Associations and the subsequent coordinated analysis of experimental data.

Task Agreement WP10-MHD-01: Fast Particles Physics - Experiments on fast particle instabilities - Assessment of ITER needs and feasibility studies
Task Agreement WP10-MHD-02: Disruptions - Runaway electrons - Electromagnetic forces - Mitigation and avoidance
Task Agreement WP10-MHD-03: Sawtooth and Tearing Modes (NTMs), Edge Localised Modes (ELMs) and Stability at high Beta (RWMs) - Sawtooth and Tearing Modes - Edge Localised Modes - Stability at high Beta

1. Fast Particles Physics :

Task Agreement WP10-MHD-01:

Fast Particles Physics

1.1 Introduction

Fast particles interact with MHD waves for on one hand they may drive or stabilize MHD instabilities (destabilization of Toroidal Alfven Eigenmodes or Energetic Particles Modes and stabilization of sawtooth are just two examples), and on the other hand MHD instabilities affect confinement of fast particles. In ITER, for instance, the alpha-particle partial pressure may be significant enough to induce collective instabilities leading to energy confinement degradation and first wall damage due high alpha particle fluxes. Therefore, understanding the physics of these fast particles (in particular in presence of a significant population of them) and in general of fast ions is one of the key issues for controlling burning plasmas.

On present-day machines there is an urgent need to understand the mechanisms of fast ion transport (this has clear consequences for example on NBI heating and current drive efficiency) and the nonlinear behaviour of multiple Alfven modes since they may be also destabilised in ITER.

The key gap is in understanding the wave interaction with the fast ions by measuring the distributions that drive instabilities and observing changes in distribution due to instabilities. New diagnostic capability on devices that access the relevant regimes is needed. In addition it is urgent to assess whether ITER is sufficiently equipped to address these issues, considering in particular the capability for TAE probing via antennae, and gamma ray imaging.

1.2 Objectives

- Exploit the enhanced capabilities of confined fast particles diagnostics implemented and to be implemented following the feasibility studies launched in 2008 and 2009, in order to study the interaction with the fast ions by measuring the distributions that drive the instabilities, and observing changes in distribution due to instabilities. Analysis of fast particles and escaping fast ions data, comparisons with modelling.

- Improve confidence in predicting the fast particle stability boundaries in ITER (intermediate n).
- Improve theoretical understanding and develop/extend nonlinear models for the evolution of multiple instabilities and related fast particle transport and losses.
- Assess whether ITER is sufficiently equipped to address the interaction of Alfven waves with fast ions, considering in particular the capability for TAE probing via antennae, and gamma ray imaging.

1.3 Work Description and Breakdown

Work Breakdown

WP10-MHD-01-01

Experiments on fast particle instabilities

Co-ordinated experiments on fast particle instabilities exploiting the enhanced capabilities of confined fast particles diagnostics

WP10-MHD-01-02

Assessment of ITER needs and feasibility studies

Assessment of ITER needs and feasibility for a TAE antenna and/or gamma ray imaging

JET related activities

JET related activities are implemented under EFDA Art.6. However some JET activities can be mentioned for information in this TA when they closely related to the activity implemented under Art.5. JET data collected under the JET part of the EFDA WP can be brought together with other data under this TA when relevant for the progress of the work or used in multi- machine modelling activities under Art.5.

Resources

Baseline Support: manpower 3 ppy

1.4 Scientific and Technical Reports

Progress reports

At the end of each calendar year, during the Topical Group annual meeting, the Task Coordinator shall present a report on activities under the Task Agreement to the EFDA Leader for his approval. These reports shall integrate the progress made by each Association on each activity, and they shall indicate the level of achievement of the objectives, the situation of the activities, the allocation of resources and recommendations for the next year when applicable. The EURATOM financial contribution will be made through the usual procedures for baseline support through the Contract of Association.

Report of achievements under Priority Support

Achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report (and intermediate reports marking substantial progress in the achievement of deliverables, if the EFDA Leader so requests) shall be prepared by the Task Coordinator and submitted to the EFDA Leader. Each participating Association will have to report in one subsection on the degree to which the deliverables of their Task have been achieved, and shall include a breakdown of expenditure. The Task Coordinator will collect the individual subsections into the final report for Priority Support activities addressing the milestones. The EURATOM financial contribution will be made after approval by the EFDA Leader of these reports.

Milestones and Deliverables

Milestones:

- Mid 2010 Activity Meetings: Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2009 and early 2010.
- End second trimester 2010 Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.
- December 2010 Final report sent to EFDA-CSU.

Deliverables:

- Co-ordinated experiments on fast particle instabilities exploiting the enhanced capabilities of confined fast particles diagnostics, performed in collaboration with the diagnostics topical group.
- Data analysis of confined fast particles and escaping fast ions, comparisons with modelling using orbits following codes.
- Investigation of Alfven eigenmodes stability in well diagnosed cases for modelling fast particle instabilities
- Report on assessment of ITER needs and feasibility for a TAE antenna and/or gamma ray imaging.

2. Disruptions:

Task Agreement WP10-MHD-02:
Disruptions

2.1 Introduction

Unmitigated disruptions represent an intolerable risk for ITER and should be avoided by a reliable control of the plasma discharge. However the understanding of how to predict and avoid such events is at a rudimentary level since extensive development of avoidance and control techniques has not been envisaged on existing devices. In addition, an extrapolation of the effects of a disruption from existing devices to ITER is affected by uncertainties which must be reduced to guarantee the integrity of the machine. Significant progress is required in the area of understating runaway electron beams and electro-magnetic forces caused by disruptions and the development of mitigation and avoidance techniques.

2.2 Objectives

Runaway electrons

- New diagnostic methods to measure the runaway electrons: in 2010 feasibility studies to prove the potential of methods measuring Cerenkov radiation, synchrotron radiation and X-ray emission will be conducted. These could lead to proposals for implementation in 2011.
- Development of robust disruption prediction methods, including the development and maximum applicability for a major cross-cutting 3d non-linear resistive MHD code initiative.
- Step-wise development towards full runaway code, capturing threshold, plasma profile evolution, runaway beam properties, action of mitigators, 3d dynamics and beam stability.

(i) Integration of primary and secondary generation mechanisms in 2d runaway code, with ITER relevant parameter scan predictions
(ii) Capability to model runaway onset and early development in context of evolving plasma conditions (eg rising loop voltage, changing profiles and shape).

(iii) Output of runaway energy spectra at realistic plasma parameters.
(iv) Initial development of outline 3d runaway beam evolution – skeletal framework to which full physics and inputs from other processes to be added later.

Electromagnetic forces

- Perform better measurements in present machines of the forces induced by disruptions, particularly on the in vessel components (benchmarking FEM codes), and halo currents (toroidal asymmetries). Comparison between different types of measurement techniques.
- When necessary and justified, upgrade the diagnostic capability in present machines both in terms of spatial coverage and time resolution.
- Improvements of the diagnostics for the impurity influxes, including fast bolometry, spectroscopy and imaging.
- Development of a full model of the VDE integrating 3d plasma distortion, vessel response and halo width models.

Mitigation and avoidance

- Further development of control systems (routine safe operation, avoidance of events and safe plasma landing in off-normal conditions).
- Investigation and understanding of active termination systems such as Massive Gas Injection (MGI), with other novel techniques considered or combined (e.g. jets, pellets, RMPs, influence of impurities), including appropriate diagnosis.

2.3 Work Description and Breakdown

Work Breakdown

WP10-MHD-02-01

Runaway electrons

Development of new diagnostic methods to measure the runaway electrons, tests effect of Resonant Magnetic Perturbations on runway dynamics, improve infra-red imaging capability and development full runaway code.

WP10-MHD-02-02

Electromagnetic forces

Installation of the necessary additional detectors to perform better measurements, develop code as a flexible and accessible tool with a 2d model of VDE, further exploitation and optimisation of the diagnostics for the impurity influxes, development of JOREK code for disruption application and Integrated code package comprising 3d core plasma dynamic and 3d wall response.

WP10-MHD-02-03

Mitigation and avoidance

Co-ordinated Disruption mitigation experiments and develop control systems and active disruption initiation tools.

JET related activities

JET related activities are implemented under EFDA Art.6. However some JET activities can be mentioned for information in this TA when they closely related to the activity implemented under Art.5. JET data collected under the JET part of the EFDA WP can be brought together with other data under this TA when relevant for the progress of the work or used in multi- machine modelling activities under Art.5.

Resources

Baseline Support: manpower**5 ppy**

Priority Support: manpower **2 ppy**, **170** keuro of hardware, as follows:

- Hardware: diagnostics for improved measurements of runway electron beam and impurity dynamics, halo currents and vessel forces.
- Software developments for non-linear MHD studies as specified above;
- Support for co-ordinated experiments.

2.4 Scientific and Technical Reports

Progress reports

At the end of each calendar year, during the Topical Group annual meeting, the Task Coordinator shall present a report on activities under the Task Agreement to the EFDA Leader for his approval. These reports shall integrate the progress made by each Association on each activity, and they shall indicate the level of achievement of the objectives, the situation of the activities, the allocation of resources and recommendations for the next year when applicable. The EURATOM financial contribution will be made through the usual procedures for baseline support through the Contract of Association.

Report of achievements under Priority Support

Achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report (and intermediate reports marking substantial progress in the achievement of deliverables, if the EFDA Leader so requests) shall be prepared by the Task Coordinator and submitted to the EFDA Leader. Each participating Association will have to report in one subsection on the degree to which the deliverables of their Task have been achieved, and shall include a breakdown of expenditure. The Task Coordinator will collect the individual subsections into the final report for Priority Support activities addressing the milestones. The EURATOM financial contribution will be made after approval by the EFDA Leader of these reports.

Milestones and Deliverables

Milestones:

- Mid 2010 Activity Meetings: Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2009 and early 2010.
- End second trimester 2010 Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.
- December 2010 Final report sent to EFDA-CSU.

Deliverables:

Runaway electrons

- Feasibility studies and proof of principle experiments (2010) for the development of new diagnostic methods to measure the runaway electrons properties in view of possible implementation and further exploitation in 2011 and 2012 aiming at measurements of runaway threshold, spectrum, localised heating and if possible beam evolution dynamics.
- Tests of new novel techniques such as Resonant Magnetic Perturbations effect on runway dynamics (2010).
- Improving infra-red imaging capability to diagnose thermal quench and runaway heat loads, performed in collaboration with the diagnostics topical group see VI.1.2: Diagnostics for protection of plasma facing components.
- Step-wise development towards full runaway code, capturing threshold, plasma profile evolution, runaway beam properties, action of mitigators, 3d dynamics and beam stability (multi-year project going beyond 2011).

Electromagnetic forces

- Installation of the necessary additional detectors to perform better measurements in present machines of the forces induced by disruptions, particularly on the in vessel components (2010), for further exploitation in (2011 and 2012), aiming at complete the validation of DINA with experimental tests and execute necessary model development to validate the predictions for ITER.
- Develop a DINA replacement code as a flexible and accessible tool with a 2d model of VDE, machine portable, including image currents (multi-year project going beyond 2011), in collaboration with ITM Task Force see V.1.
- Further exploitation and optimisation of the diagnostics for the impurity influxes, including fast bolometry, spectroscopy and imaging (2010), aiming at measurements of impurity influxes during disruptions for the reconstruction of the evolution of the various processes, including a more reliable code that model plasma shape evolution from available diagnostics during the VDE and/or quench phases, as input to other code initiatives (2010).
- Development of JOREK code for disruption application: 3d MHD and tearing predictions as disruption process progresses (2010).
- Integrated code package comprising 3d core plasma dynamic (e.g. M3D, JOREK) and 3d wall response (CARIDDI) (multi-year project going beyond 2011), in

collaboration with ITM Task Force see V.1. Modelled test cases showing impact on stability, asymmetry and evolution of process.

Mitigation and avoidance

- Co-ordinated Disruption mitigation experiments in collaboration with the Plasma Wall interaction Task Force. Dedicated active mitigation work is coordinated under the PWI task force. The focus of the MHD topical group is on understanding the processes involved through additional experimental studies that look at the mitigation action directly or underlying processes, in this case through specific experiments.
- Control system changes and active disruption initiation tools implemented on one or more devices to allow it access new disruption study capability, aiming at demonstrating reduced disruption incidence and severity.

3. Sawtooth, NTMs, ELMs and RWMs:

Task Agreement WP10-MHD-03:
Sawtooth and Tearing Modes (NTMs), Edge Localised Modes (ELMs) and Stability at high Beta (RWMs)

3.1 Introduction

Sawtooth and NTMs

The emphasis of the sawtooth physics studies is on diagnosis and interpretation of the sawtooth crash, its consequent impact on plasma profiles, fast particles, the overall cycle; and understanding inter-relation with other events such as NTMs and ELMs. Control in ITER will be required to avoid long sawtooth periods in the standard ELMy H-mode scenario caused by the strong stabilisation effect of alpha particles and fast ions generated by the auxiliary heating systems. Sawtooth control has been demonstrated in several devices using a range of techniques (ECCD, ICCD, off axis NBI, profile modification, etc). At present, the ITER scaling foresees the destabilisation of NTMs at modest values of beta normalised, but uncertainties exist regarding the role of rotation, of ion polarization current and other small island physics effects. ECCD control is a key priority for ITER, particularly for the 2/1 NTM.

ELMs

The onset of large ELMs is broadly accepted to be usually associated with the triggering of peeling-ballooning modes, and codes can predict the threshold and the structure of these instabilities, including many of the key parameter dependencies, with considerable precision. However, there are important physics aspects that need further investigation. Crucial questions include the need to develop ELM mitigations strategies to achieve an ELM frequency increase of the order of 10 times when compared to unmitigated ELM frequencies, as required on ITER.

RWMs

The role RWM destabilization has been investigated in several tokamaks. In particular, non-resonant magnetic error field components have a strong effect on the plasma flow, and therefore on the RWM stabilization mechanism, through their role in damping the toroidal flow by a neoclassical viscous torque mechanism. Predictions on Neoclassical Toroidal Viscosity (NTV) for ITER have high priority and high urgency, because of their implications on ELM RMP coil designs.

3.2 Objectives

- Increase the focus on theoretical/numerical efforts to model and interpret Sawtooth and tearing mode physics, the non-linear MHD evolution of instabilities including ELMs, transport in 3d fields, and control algorithms.
- Bring in more refined physics models, including realistic 3D wall, 3D equilibrium fields and kinetic effects, in particular for beta-limiting instabilities.
- Study the influence of 3D magnetic fields in the plasma (ELM control in relation to magnetic braking, locked modes, neoclassical modes and RWMs) and interaction with field errors.
- Promote collaborative experiments on the aforementioned cross-cutting initiatives.

3.3 Work Description and Breakdown

Work Breakdown

WP10-MHD-03-01

NTMs

Test physics through 3D non-linear code development and study non-linear interaction between modes and with external perturbations.

WP10-MHD-03-02

ELMs

Nonlinear code development and more refined modelling using upgraded Edge Current diagnostics; study the physics of Resonant Magnetic Perturbations, develop practical application of control tools and integration into scenarios.

WP10-MHD-03-03

RWMs

Enhancement of numerical codes, application of enhanced computational models to ITER, study Error field effects on Neoclassical Toroidal Viscosity and the effect of 3d plasma shaping, study tearing modes an error field effects close to RWM limit and interaction with ideal MHD.

JET related activities

JET related activities are implemented under EFDA Art.6. However some JET activities can be mentioned for information in this TA when they closely related to the activity implemented under Art.5. JET data collected under the JET part of the EFDA WP can be brought together with other data under this TA when relevant for the progress of the work or used in multi- machine modelling activities under Art.5.

Resources

Baseline Support: manpower **26 ppy**
Priority Support: manpower **2 ppy**, as follows:

- Specific software developments for linear/non-linear MHD studies including 3D geometry and kinetic effects and control as specified above; and
- Co-ordinated experiments on mitigation and control of MHD instabilities, and in general on cross-cutting initiatives.

3.4 Scientific and Technical Reports

Progress reports

At the end of each calendar year, during the Topical Group annual meeting, the Task Coordinator shall present a report on activities under the Task Agreement to the EFDA Leader for his approval. These reports shall integrate the progress made by each Association on each activity, and they shall indicate the level of achievement of the objectives, the situation of the activities, the allocation of resources and recommendations for the next year when applicable. The EURATOM financial contribution will be made through the usual procedures for baseline support through the Contract of Association.

Report of achievements under Priority Support

Achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report (and intermediate reports marking substantial progress in the achievement of deliverables, if the EFDA Leader so requests) shall be prepared by the Task Coordinator and submitted to the EFDA Leader. Each participating Association will have to report in one subsection on the degree to which the deliverables of their Task have been achieved, and shall include a breakdown of expenditure. The Task Coordinator will collect the individual subsections into the final report for Priority Support activities addressing the milestones. The EURATOM financial contribution will be made after approval by the EFDA Leader of these reports.

Milestones and Deliverables

Milestones:

- Mid 2010 Activity Meetings: Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2009 and early 2010.
- End second trimester 2010 Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.
- December 2010 Final report sent to EFDA-CSU.

Deliverables:

- Perform co-ordinated experiments on the influence of 3D magnetic field perturbations in the plasma, with applications to ELMs, NTMs, RWMs, in terms of resonant, sideband and non-resonant components and the effect on other instabilities such as locked modes, through changes in the rotation profile, in synergy with theoretical modelling efforts.

Sawtooth and NTMs

- Test physics through 3D non-linear code development, modelling and comparison to data, including the threshold and triggering physics and performance limit scaling.
- Study non-linear interaction between modes and with external perturbations, in particular with the aim of extracting basic information to be used in other areas.

ELMs

- Nonlinear code development and more refined modelling using upgraded Edge Current diagnostics in close collaboration with the Transport Topical Group, including non-linear evolution, structure and impact of the ELM, and maximum applicability for major cross-cutting 3d non-linear resistive MHD code developments such as JOREX.
- Study the physics of Resonant Magnetic Perturbations, in particular, transport in stochastic magnetic field and effect of plasma flow on error field penetration/magnetic topology.
- Develop practical application of control tools and integration into scenarios, including clear non-linear model predictions of ELM evolution, contrasted against key regimes of unmitigated and mitigated type I ELMs in EU devices.

RWMs

- Enhancement of numerical codes (e.g. addition of rotation and kinetic damping to RWM analysis, multimodal n=0 + n>0 modelling, fast techniques and their parallelization for dealing with huge computational models see V-2: HPC-FF work programme, inclusion of iron in the wall, development of innovative RWM feedback control schemes).
- Application of enhanced computational models to ITER (e.g. effect of rotation and damping on RWM growth rates, evaluate the impact of rotation and damping on active RWM feedback control requirements, application to ITER of control schemes validated experimentally, ferromagnetic inserts....).
- Study Error field effects on Neoclassical Toroidal Viscosity and the effect of 3d plasma shaping

- Study tearing modes an error field effects close to RWM limit and interaction with ideal MHD.