Annual report of the ITPA Topical Group on Energetic Particle Physics

For the period Nov 2011 to Oct 2012

The EP Topical Group held two meetings (its 8^{th} and 9^{th}) during the reporting period – at National Institute for Fusion Science in Japan on March 7-9, 2012 and at the San Diego Marriott La Jolla Hotel in La Jolla in USA on October 15-17, 2012, immediately after the IAEA Fusion Energy Conference which was held on October 8-13.
Minutes of these meetings and viewgraphs presented are available at the ITPA website, therefore only a summary of the main results is given here.

In addition to JEX activities, the work of the group was concentrated mainly on the following topics:

- ***Benchmark effort for the linear codes of Alfvén eigenmode***
- ***Benchmark effort for the non-linear codes of Alfvén eigenmode***
- ***Evaluation of fast ion losses induced by 3D effects (ELM control coils) and MHD***
- ***Energetic particle diagnostics for ITER***
- ***Scope change***

Benchmark effort for the linear codes of Alfvén eigenmode
The linear n=6 TAE in a circular tokamak with a large aspect ratio of A=10 was originally prepared as the benchmark case to compare the linear phase of the non-linear code by A. Könis. Because this case is adoptable to a wide range of linear codes as well as nonlinear codes, many linear codes have also joined this benchmark study. As a results, 10 codes of MEGA, HMGC, GYGLES, LIGKA, EUTERPE, AE3D-K, CKA-EUTERPE, VENUS, CAS3D-K, TAEFL. The results are as follows;

- Overall agreement of the codes is satisfactory: (±20%) results with FLR effects and (±15%) without FLR effects
- This activity has led to code extentions and improvements
- This activity has established the starting point for non-linear benchmark /linear calculations of stability boundaries
- Following numerical problems addressed:
  - large obit size poses problems for allmost all codes
  - return policy for PIC codes
  - numerical damping for non-linear MHD

The result was presented by A. Könis in the IAEA Fusion Energy Conference prior to the ITPA meeting. The participants of this benchmark will make corrections/clarifications for the joint NF paper and will submit the results. This benchmark case for the linear stability is considered to be finished.
As a benchmark for realistic conditions, the plasma for a JET DT experiment was chosen. 8 codes of MEGA, LIGKA, MISHKA, KINX, VENUS, AE3D-K, TAEFL, HAGIS, CASTOR-K joined the activity. The physics of this case is considerably more complex than the previous benchmark with regard to various aspects: steep background gradients, slowing down alpha particle drive and NBI beam damping. Therefore, the validation with experimental results should be an important and valuable intermediate step on the way to an ITER benchmark case.
In parallel, as a first direct contribution to ITER, a benchmark for the ITER 9MA steady state scenario was established and first results were reported: depending on the safety factor profile

(two q=2 surfaces or q>2 throughout the whole plasma) not surprisingly different results concerning stability and most unstable mode numbers were reported so far (LIGKA, MEGA).
Plans for further work: Considering the first results for ITER, the details of the benchmark and the level of realism have to be rediscussed. At this point, the input of the ITER team in form of well established scenarios will be guiding this activity. Furthermore, the group will decide at the next meeting if another case based on a well diagnosed present-day experiment will be chosen as a joint modeling effort.

Benchmark effort for the non-linear codes of Alfvén eigenmode
It was found this activity needed several milestones in the activity in 2010. The first milestone was set to the benchmark of the linear stability of the mode. The benchmark case, described above, on an n=6 TAE mode was provided by A. Könies for this purpose. Good agreement was found among the nonlinear codes in spatial profile, frequency, and growth rate of the TAE mode. Resonant particle distributions in velocity space investigated with HMGC and MEGA were also in good agreement. Results concerning the nonlinear evolution of the n=6 TAE mode case were reported by HMGC, TAEFL, MEGA codes. The benchmark on saturation mechanism was proposed as the next step.
Plans for further work: The nonlinear evolution of the n=6 mode investigated with the nonlinear codes should be compared. The method to compare the non-linear physics will be developed. It is also considered that the nonlinear codes join the linear code benchmark for more realistic cases.

Fast ion losses induced by 3D effects (TBMs, ELM control coils) and MHD
The assessment of the effect of the 3D effects and MHD using codes that follow drift particle orbits in three-dimensional magnetic field configurations has been one of our main activities.
An investigation of the effect of the ELM mitigation coils on the fast ion loss has been carried out for the wide range of ELM coil configurations and operation scenarios by ASCOT, F3D-OFMC, DRIFT codes. The magnetic field in the calculation is a vacuum field without considering the plasma response. New results confirmed one of the conclusions reported by F3D-OFMC last year. Namely, the enhanced transport of fast ions was observed when the ELM coil configuration is optimized for the ELM mitigation. This result arouses a concern about the future calculations using the background field in which the plasma response is taken into account. It is expected that the background filed will not be “optimized“ when the input for the field calculation is the optimzed coil configuration which was desinged using a vacuum field. Such background field would not be the optimized field for the ELM mitigation, then would not induce the fast ion loss. Thus, the fast ion confinement study using the “false optimized“ background field would mislead the understanding of the field for the ELM mitigation. E.g. it might lead to the following wrong messange that “the field which takes the plasma response into account does not degrade the fast ion confinement“. We recommend the IO should provide us the “optimized“ background field in order appropriately to evalulate the effect on fast ion confinement of the magnetic filed for the “ELM mitigation”
.
The simulation under perturbations by MHD activity, energetic particle driven modes and plasma turbulence besides the 3d effects of the equilibrium fields is an important topic. ASCOT has been upgraded to include perturbation due to NTM and TAE. and applied to fusion alpha redistribution in ITER.
Plans for further work: The effect of field perturbation by ELM coil will be assessed continusly. We want to have the appropriate magnetic field which considers the plasma response and still is optimized for the ELM mitigation. The assessment of the effect of perturbations by MHD activity will be continued. A long-term goal is to include fast ion redistribution caused by energetic particle driven modes as calculated by non-linear codes.

Energetic particle diagnostics for ITER

It is considered that one of the important topic in Work Program is "Development of diagnostics for escaping α-particles". However, we have recognized that the concrete diagnostic for the loss fast ion is not assigned. No fast-ion loss detector is currently enabled in ITER. This is a serious problem. Any diagnostics which make the research on the loss ion possible would not be prepared in ITER unless the EP TG would work on the IO about the necessity of this diagnostics. The point of the discussion was to assess if the importance of having a FILD system in ITER outweighs its significant integration issues. We attached the note as an appendix of the minutes of the 8th meeting to propose the IO to consider the installation of the FILD.

Scope change

The topic of the runaway electron was in the scope of the EP TG. However, the reports in this topic were a few in the EP TG. On the other hand, the disruption is handled in the MHD TG and the most of experimentalists carry out the experiments on the runaway electron as a part of his/her disruption study. Thus, the results on the runaway electron were actively reported in the MHD TG, not in the EP TG. It was difficult to enhance the activity on the runway electron in the EP TG in this situation. It was considered to be natural for the MHD TG rather than the EP TG to handle this topic. We discussed the handling of the topic of the runaway electron. It was decided to move the topic of runaway electrons from the scope of the EP TG so that it is now handled by the MHD TG which the majority of active researchers in this field attend. This scope change has been approved by both TGs in the joint session in ITPA meeting held in San Diego. EP TG will try to contribute on this topic by our knowledge, having joint TG meeting as possible.

ITPA Topical Group Publication list 2012

Group	Year	list
EP	2012	**Presentations at the 2012 IAEA Fusion Energy Conference, San Diego** A. Koenis et al., Benchmark of Gyrokinetic, Kinetic MHD and Gyrofluid Codes for the Linear Calculation of Fast Particle Driven TAE Dynamics, ITR/P1–34 E D Fredrickson et al., Fast-ion Energy Loss during TAE Avalanches in the National Spherical Torus Experiment, EX/P6–05 G. Kramer et al., Observation of Localized Fast-Ion Induced Heat Loads in Test Blanket Module Simulation Experiments on DIII–D, ITR/P1–32 M. Garcia-Munoz et al., Fast-ion Redistribution and Loss due to Edge Perturbations in the ASDEX Upgrade, DIII–D and KSTAR Tokamaks, EX/P6–03 S.E. Sharapov et al., Energetic Particle Instabilities in Fusion Plasmas, OV/4-3 T. Kurki-Suonio et al., Fast Ion Power Loads on ITER First Wall Structures in the Presence of ELM-mitigation Coils and MHD Modes, ITR/P1–33 T. Oikawa et al., Effects of ELM Control Coil on Fast Ion Con- finement in ITER H–mode Scenarios, ITR/P1–35 **Publications in peer-reviewed journals** A. Bovet et al., Investigation of fast ion transport in TORPEX, Nuclear Fusion 52, 094017 (2012)

D.A. Spong et al., Verification and validation of linear gyrokinetic simulation of Alfven eigen-modes in the DIII-D tokamak, Phys. Plasmas 19 082511 (2012)

D S Darrow et al., Stochastic orbit loss of neutral beam ions from NSTX due to toroidal Alfven eigenmode avalanches, Nucl. Fusion 53 013009 (2013)

D.Testa, et al., Plasma Isotopic Effect on the Damping Rate of Toroidal Alfvén Eigenmodes with Intermediate Toroidal Mode Numbers, Nuclear Fusion 52 094006 (2012)

D.Testa, M.Albergante, A phenomenological explanation for the anomalous ion heating observed in the JET alpha heating experiment of 1997, Nuclear Fusion 52 083010 (2012)

D.Testa, M.Albergante, Evidence for a new path to the self-sustainment of thermonuclear fusion in magnetically confined plasmas, EurophysicsLetters 97 35003 (2012)

E D Fredrickson et al., Observation of global alfven eigenmode avalanche events on the National Spherical Torus Experiment, Nucl. Fusion 52 043001 (2012)

E D Fredrickson et al., Fast-ion energy loss during TAE avalanches in the National Spherical Torus Experiment, Nucl. Fusion 53 013006 (2013)

K. Ghantous et al., 1.5D quasilinear model and its application on beams interacting with Alfven eigenmodes in DIII-D, Phys. Plasmas 19 092511 (2012)

K. Gustafson et al., Suprathermal ion transport in simple magnetized torus configurations, Physics of Plasmas 19, 062306 (2012)

K. Gustafson et al., Nondiffusive Suprathermal Ion Transport in Simple Magnetized Toroidal Plasmas, Physical Review Letters 108 (2012)

K. Shinohara et al., Effects of rippled fields due to ferritic inserts and ELM mitigation coils on energetic ion losses in a 15MA inductive scenario in ITER, Nuclear Fusion 52, 094008(2012)

K.Tani et al., Effects of ELM mitigation coils on energetic particle confinement in ITER steady-state operation, Nuclear Fusion 52 013012 (2012)

M.A. Van Zeeland et al., Alfven eigenmode stability and fast ion loss in DIII-D and ITER reversed shear plasmas, Nucl. Fusion 52 094023 (2012)

M. Podestà et al., Study of chirping TAEs on the National Spherical Torus Experiment, Nucl. Fusion 52 094001 (2012)

R.B. White, Commun. Nonlinear Sci. Numer. Simul. 17 2200 (2012)

S. Zhou et al., Thermal plasma and fast ion transport in electrostatic turbulence in the large plasma device, Phys. Plasmas 19 055904 (2012)

W. W. Heidbrink, et al., Measurements of interactions between waves and energetic ions in basic plasma experiments, Plasma Physics and Controlled Fusion 54 124007 (2012)