Annual report of the ITPA Topical Group on Energetic Particle Physics

For the period June 2009 to July 2010

The EP Topical Group held two meetings (its 3rd and 4th) during the reporting period – in Kiev – right after the IAEA TCM on energetic particles – September 24-25 and at IPP Garching April 26-28, 2009.
Minutes of these meetings and viewgraphs presented are available at the ITPA website, therefore only a summary of the main results is given here.

The work of the group concentrated mainly on the following topics:

Fast ion losses and the resulting heat loads to the walls induced by 3d effects (magnetic field ripple, TBMs, ELM control coils)
Damping and drive of fast particle driven instabilities
Influence of background turbulence on fast particles

Fast ion losses and the resulting heat loads to the walls induced by 3d effects (magnetic field ripple, TBMs, magnetic islands, ELM control coils):
In 2009 several codes that follow drift particle orbits in three-dimensional magnetic field configurations had been benchmarked and applied to the effect of TBMs (with and without ferritic inserts). It had been found that the ferritic inserts reduce the fast ion losses significantly and thus lead to acceptable heat loads to the ITER walls.
On of the main efforts in 2010 was the application of the codes to the effect of the DIII-D TBM mock-up coils. As in the experiment, fast ion losses associated with strongly localized heat loads have been observed. The calculated heat loads are however still smaller than the heat loads needed to explain the observed temperature increase. Thus, a refined analysis (e.g., longer simulation times, better spatial resolution) is required to resolve this discrepancy. A joint effort with several codes is ongoing. The results will be reported at the forthcoming

non-linear codes. The results of the fast ion losses due to three dimensional field perturbations will be summarized in an **ITPA-EP group paper at the forthcoming IAEA-FEC** in Daejon: “3D Effect of Ferromagnetic Materials on Alpha Particle Power Loads on First Wall Structures and Equilibrium on ITER” (submitted by : K. Shinohara).

TAE damping rates:

A reliable prediction of the occurrence of **fast particle driven instabilities** in ITER requires a detailed investigation of damping and drive of these modes. As a first step in this direction, a common benchmark effort was initiated in 2009. As a basis for this benchmark exercise a well diagnosed JET discharges with measured damping rates has been used.

The benchmark exercise has been performed for n=3 TAE modes with an impressive agreement of the code results. Both, frequency and structure of the TAE modes agree very well between the codes. As expected, the damping rates were larger for the fully gyrokinetic code (LIGKA) as it is best suited to correctly deal with the radiative damping (a finite Lamor radius effect). Nevertheless, also the MHD-hybrid codes (CASTOR-K, NOVA-K) are able to provide reasonable damping rates (agreement within a factor of 2), which is much better than discussed earlier in literature. The damping rates provided by the codes are still smaller than the measured ones (LIGKA: a factor of 2 smaller), but this is within the experimental error bars as the damping rates are very sensitive to the exact density and q-profiles at the plasma edge. The increase in damping rates with plasma shaping (elongation) as measured in the JET experiment could be well reproduced.

The code benchmark exercise provided additional insight to the possibility of measuring the damping rates by external antennas: It had been proposed for ITER to monitor the damping rates of the least unstable TAE modes and take adequate measures once the damping rates become too low, even before the modes are driven unstable. In the benchmark exercise it has been found that external antennas do not always couple to the least unstable modes. They preferentially couple to modes that extend to the plasma edge (those for which the TAE gap is open). Even for low-n modes these are not always the most unstable modes. For ITER medium-n modes (n~10) are expected to be most unstable. Thos modes are more localized in radius and are thus not expected to extend towards the plasma edge. It is thus very unlikely that a monitoring of the TAE damping rate in ITER is a reasonable measure to counteract fast ion driven instabilities. The results of the benchmark exercise and comparison with measured damping rates will be published in an **ITPA-EP group paper at the forthcoming IAEA-FEC** in Daejon: The Influence of Plasma Shaping Effects on the Damping of Toroidal Alfvén Eigenmodes (submitted by: S. Günter).

Plans for further work: For the near future it is planned to go to higher toroidal mode numbers as is relevant for ITER. Besides the damping rates, it is planned to perform a benchmark exercise for the drive (linear growth rates) of TAE modes. After a successful code benchmark a medium term goal is the calculation of ITER equilibria with marginal fast particle distributions functions as such distribution functions are expected to result after saturation of fast particle driven instabilities. Such distribution functions can then be used to simulate fast ion losses due to three-dimensional effects as discussed above. To improve the predictions for possibilities of MHD spectroscopy, a better antenna model should be developed an included in the relevant codes.

Fast ion redistribution due to energetic particle driven instabilities (non-linear effects):

A benchmark case for non-linear simulations was agreed on, and several codes participated in the benchmark exercise. The results of this exercise was however not satisfying. All codes found an energetic particle mode unstable for large drive, but not the TAE mode which was found in some simulations to be unstable for smaller fast particle drive. It was decided to modify the benchmark case such that the non-linear simulations (in their linear phase) can be