Neoclassical Tearing Modes and Fast Ions Confinement in ASDEX Upgrade

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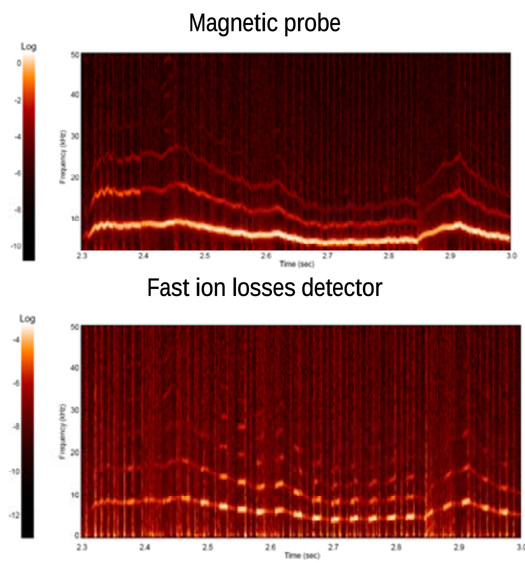
One of the critical aspects for the ITER relevant fusion research is fast particle physics. Fast particles can in fact drive MHD instabilities, but also their confinement is affected by MHD modes.

In this paper we present new experimental results, coming from the present 2006 ASDEX Upgrade (AUG) experimental campaign, on the role of NTMs in causing fast ion losses. A theoretical interpretation is suggested. While the NTM impact on the global confinement is rather well established, less is known on how they influence energetic particles. The latter effect may not be less important than the former, in particular to fully assess the performance of regimes with low amplitude NTMs; they might have negligible effects on thermal confinement, but not on fast particles. This might influence for example NBI heating and current drive and, in ITER, also the confinement of fast particles.

AUG has unique capabilities: its heating system, with 20 MW of NBI at 60/100 keV, 6 MW of ICRH and 2 MW of ECRH, allows for a variety of scenarios, where the behavior of fast ion population can be finely tuned and decoupled from the bulk plasma environment. A new detector (FILD) provides energy and pitch-angle resolved measurements of fast ion losses, with a bandwidth of 1 MHz. The 148 channels tomography, with the same bandwidth, provides crucial elements for the reconstruction of eigenfunctions.



Fast particle losses are recorded in presence of both 2/1 and 3/2 NTMs. These particles – of NBI origin - are mostly passing, and there are lost basically with the energy that they had at their birthplace, i.e. the NBI energy. Their transit frequency (~ 200 kHz) is higher than the mode frequency (~ 5 kHz for 2/1, ~15 kHz for 3/2). We observed a good coincidence between the frequency and phase of the mode and those of the losses and a strong correlation between the NTM amplitude and the amount of particle losses. An example is shown in the figure, which reports the Fourier spectrogram vs. time for a magnetic pick-up probe and for one of the FILD channels for a time lag where a 2/1 mode and its harmonics are present. Signatures of losses correlated with the mode are evident. Dedicated experiments, where the NTM has been artificially reduced by means of ECCD stabilization, will also be discussed.

An experiment with NBI amplitude modulated in time (i.e. with a modulated fast ion source, as that shown in the figure) gives information on the time scales of the losses: a fraction of particles are lost within times corresponding to a few toroidal transit periods (5 µs for 100 keV deuterons), but there is also evidence of slower losses (which seem to be more evident with small 3/2 amplitudes). This has been interpreted as a result of orbit stochasticity (Mynick, Phys. Fluids B **5**, 1471-1993): small magnetic perturbations, which do not cause significant ergodicity of magnetic field lines, can nevertheless result in drift islands in the fast particle's phase space, because of the coupling between the fast particles guiding center motion in the perturbed magnetic field and that due to the drifts, which have mainly a 1/0 character. These islands in the orbit space can overlap and originate stochastic motion of energetic particles. Simulations of this mechanism performed with the Hamiltonian guiding center code ORBIT code give results, which are consistent with experimental data and contribute to their explanation.