Three Dimensional Transport Analysis for ELM Control Experiments in ITER Similar Shape Plasmas at Low Collisionality in DIII-D*

O. Schmitz[1], M.A. Jakubowski[1,2], T.E. Evans[3], M.E. Fenstermacher[4], H. Frerichs[1], M. Groth[4], I. Joseph[5], C.J. Lasnier[4], R.A. Moyer[5], M.J. Schaffer[3], B. Unterberg[1], J.G. Watkins[6], W.P. West[3], S.S. Abdullaev[1], J.A. Boedo[5], K.H. Burrell[3], K.H. Finken[1], P. Gohil[3], Y. Feng[2], M. Lehnen[1], T.H. Osborne[3], D. Reiter[1], A.M. Runov[2], U. Samm[1], R. Schneider[2], M. Tokar[1], Z. Unterberg[7], R. Wolf[2], and the DIII-D and TEXTOR Teams

[1]*Institut für Energieforschung-Plasmaphysik, Jülich, Germany*
[2]*Max Planck Institut für Plasmaphysik, IPP-EURATOM Association, Greifswald, Germany*
[3]*General Atomics, P.O. Box. 85608, San Diego, California 92186-5608 USA*
[4]*Lawrence Livermore National Laboratory, Livermore, Califonria USA*
[5]*University of California-San Diego, La Jolla, California USA*
[6]*Sandia National Laboratory, Albuquerque, New Mexico USA*
[7]*Oak Ridge Institute for Science Education, Oak Ridge, Tennessee USA*

The mitigation of large type-I edge localized modes (ELMs) and of the associated transient heat ejection is important to maintain a long term integrity of the ITER first wall. At the DIII-D tokamak, application of resonant magnetic perturbation (RMP) was pioneered as a tool to control the edge transport and hereby the ELM characteristics [1]. In this contribution we present recent results from experiments with ITER similar shape plasmas in high average triangularity ($\overline{\delta}$ = 0.56) at low ITER similar collisionality ($\nu_e^* \leq 0.2$). Here complete ELM suppression was achieved robustly at an edge safety factor $q_{95} \sim 3.5$ in a resonance window of $\Delta q_{95} \sim 0.1$ determined by the perturbation spectrum applied. Optimizing this RMP spectrum leads to an extension of Δq_{95} by a factor of 3 – 5 proving that the design of an RMP coil set for ITER needs to be flexible. The ELM suppression is achieved through a reduction of the pedestal pressure gradient below the stability limit for peeling ballooning modes mainly by a decrease in pedestal density while electron and ion temperature slightly increase.

The modified transport characteristics in the perturbed, three dimensional (3D) magnetic field structure is analyzed by comparison of experimental and numerical results from TEXTOR-DED and DIII-D. Hereto modeling of the 3D magnetic topology and transport modeling with the E3D thermal transport code and with the plasma and neutral transport code EMC3/EIRENE is used. This analysis suggests for DIII-D three transport domains along normalized toroidal flux Ψ_N: resonant magnetic island chains in $0.8 < \Psi_N < 0.95$ and a highly stochastic volume close at the separatrix in $0.95 < \Psi_N < 0.99$ shall lead to an enhanced radial transport. The last step towards the divertor target is eventually performed along open magnetic field lines which end on the divertor target in a striated, non-axisymmetric pattern of the perturbed separatrix. These open field lines have a connection length $L_c \leq 500$ m which is in the order of the thermal correlation length $L_t \simeq 200 - 400$ m and small compared to the electron mean free path $\lambda_e \sim 10^3 - 10^4$ m. As they penetrate as deep as $0.8 \leq \Psi_N \leq 1.0$ into the stochastic boundary, large parallel heat conduction and therefore a strong imprint of the striated separatrix topology in the target heat flux was seen at TEXTOR-DED and was expected for DIII-D also.

However, the divertor particle and heat fluxes measured at DIII-D show during complete ELM suppression only a weak heat transport along these open field lines but instead a strong

*Work supported by the U.S. Department of Energy under DE-FG02-04ER54758, DE-FC02-04ER54698, DE-AC05-000R22725, and DE-FG02-95ER54309.

parallel particle flux. Therefore the stochastic domain is thermally not connected to the target while the parallel particle fluxes yield to a strong particle loss from the outer pedestal region. In contrast, an increase of the heat flux along the open field lines was observed for (a) interaction of the RMP with ELM filaments and (b) during pellet injection. Here the pedestal region gets thermally connected to the divertor target by an enhanced radial heat transport and accordingly strike point splitting is observed in both, particle and heat flux. Such enhanced radial heat transport – which was originally anticipated to be dominant for transport in a stochastic magnetic boundary – is not apparent during ELM suppression. To explain these paradox experimental observations two mechanisms are discussed here: a limitation of the parallel heat conduction [2] and a screening of the external RMP field by plasma rotation [3].

[1] T. Evans et al., Nucl. Fusion **48**, 024002 (2008).

[2] M. Tokar et al., Phys. Rev. Lett. **98**, 095001 (2007).

[3] A. Cole, R. Fitzpatrick et al., Phys. Plasmas **13**, 32503 (2006).