# DSOL-28 Narrow heat flux widths and divertor power dissipation

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| **TG priority:** High | **Start date:** 2013 | **Status:**  On-going | **Personnel exchange:**   |
| **IO priority:**   | **End date:** 2016 | **Motivation:** Physics Basis |

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| **Device** | **Contact** | **2016 TGRequest** | **Activity (from JEX/JA spreadsheet)** |
| **2013** | **2014** | **2015** | **2016** |
| AUG  | T. Eich | Desirable | Committed | Committed | Committed |   |
| NSTX-U  | R. Maingi | Desirable |   | Considering |   |   |
| DIII-D  | A. W. Leonard | Desirable | Committed | Analysis | Analysis |   |
| C-Mod  | B. LaBombard | Desirable | Analysis | Analysis | Analysis |   |
| ITER  | R. A. Pitts | Desirable |   |   |   |   |
| TCV | H. Reimerdes | Desirable | Considering | Analysis | Committed |   |
| JET | A. Scarabosio | Desirable | Committed | Committed | Committed |   |

**Results for 2015**

* AUG: Large 2015 L-mode campaign confirms previous results on outer target q (about twice as H-mode scaling but similar parametric dependence) and in contrast to the H-mode a dependence on ne is found. Only weak correlation with mass number of the main ions emerges from the data. New measurements at the inner target show an even stronger increase of q,inner with ne with q,inner<q,outer at lower ne and q,inner>q,outer at larger ne but still below inner target power detachment [1]. As in previous study the divertor broadening S strongly increase for target Te below 30eV and interpreted as resulting mainly from changes in the parallel electron conductivity. In contrast with the phenomenology of q, new experiments show almost twice as large S for Hydrogen plasmas and always smaller S at the inboard side compared to outboard side.

With the upgraded AUG Thomson scattering system it found that in H-mode Te has the same main parametric dependence as the q scaling from Eich et al. (PRL 2011) and a good much is found on the absolute values by using the simple, purely conductive, two-point model relationshipq=2/7Te [2]. Similarly to DIID, this result confirms the possibility of inferring q from target IR data and provide perhaps surprisingly simple picture of the parallel heat transport in the considered regime. In the detached H-modes, not accessible to divertor IR data, the near SOLTe andne are observed to double, implying a large profile broadening. This only happens when the divertor is completely detached and when the effective collisionality is above a critical value similarly as observed also in L-mode plasmas.

[1] B. Sieglin et al., submitted to Plasma physics and controlled Fusion

[2] H. J. Sun et al, Plasma Phys. Control Fusion 57 (2015) 125011 (11p)

**Plans for 2016**

* Analysis of TCV experiments on divertor heat fluxes with negative triangularity plasmas (end 2015 campaign)
* Further JET plasma on vertical target (if new IR optical system will allow good resolution at the vertical target)
* Experiments on q and S in AUG Helium H-mode plasmas
* Study of q increase prior power detachment at AUG for L-mode plasmas
* Further analysis of in/out divertor asymmetry seen at AUG

Due to lack of manpower no AUG upper divertor modelling during 2015. In 2016 a new PhD will model heat fluxes at upper divertor for AUG L-mode plasma and compare with experimental results (see 2104 results)

 **Results for 2014**

* SOLPS simulations carried out using four different divertor geometry configurations have been used to show the effect of a step by step evolution from a open-type divertor (ex. AUG divI or JET tile-5 configuration) to a closed one (ex. AUG divIIb) in the heat flux profile parameters in the outer divertor. As expected, closer divertor geometries strongly increase the neutral density near the separatrix due mainly by the different orientation of the target tile. It increases the Te drop along the flux tubes, via enhancing the neutral and impurity radiation and pressure conservation, and, consequently, leads to stronger dependences of q and S on the upstream plasma parameters. In closed divertors, q and S increase up to a factor of 3 and 4 respectively with respect to the very low density case (with target Te>40eV). In open divertor q is rather insensitive to the upstream density in the typical range of AUG L-mode plasmas whilst the increase of S is strongly reduced. Additionally, a strong link has been established between S and target Te, which seems to be sufficient to order S data for different cases (different geometry, suppression of sputtering, different connection length, etc). SOLPS predicts that scenarios with Te>10eV and S/fx >1mm are not possible.
* JET: M13-13 experiments, aiming at comparing horizontal and vertical target configurations and validate simulation results, did not provide sufficiently high quality IR due to technical limitations of the system. LP data show, however, no large differences in target Te and power spreading S for vertical and horizontal configurations suggesting lower tightness for neutrals than expect from simulations.
* AUG: The heat flux onto both the outer and inner upper divertor plates was measured using a fast 2D IR camera in AUG. Goal of this is the experimental investigation of the influence of the toroidal magnetic field direction on the heat transport in the scrape-off layer. For the divertor broadening S no dependence on the toroidal magnetic field direction is observed. Overall the values for the inner divertor target are around 20 % larger compared to the values for outer divertor target if the magnetic geometry is taken into account. The exponential power fall-off length lambda\_q on the outer divertor target with ion grad B drift towards the active X-point is described with the commonly agreed empirical scaling laws. The values for the inner divertor target are smaller compared to the values for the outer divertor target. The ratio between inner and outer power fall-off length is dependent on the toroidal magnetic field direction. With the ion grad B drift towards the upper X-point the ratio between inner and outer power fall-off length is around 1:2.3, for reversed toroidal magnetic field around 1:1.2.
* DIID: simple 2-point model conductive q=2/7Te is well supported by Thomson Scattering (TS) data in attached conditions. Discrepancy in detached plasmas suggests some level of upstream-divertor target decoupling. Density and power dependence are weak as in multi-machine database and consistent with SOLPS open divertor results.

**Plans for 2015**

* Experiment on S and divertor power dissipation on TCV and JET (depending on IR system improvement)
* Further modeling with SOLPS(5.0 and/or ITER version) in particular of upper divertor plasmas at AUG
* Analysis of the relationship between upstream and target temperature, density and power decay lengths. Improved AUG TS provides now high quality SOL data suitable for this task. AUG q and S data shall become available for H and He plasmas from late 2014 experiments.

**Purpose:** The new experiments proposed here are designed to determine the required conditions for partial detachment as a function of q|| and possible limits to q and/or upstream density associated with the MHD stability of the SOL.

**Background:** A multi-machine scaling study involving 6 tokamaks, including the ST devices MAST and NSTX, and conducted under the auspices of the ITPA, has yielded a scaling of the inter-ELM H-mode near-SOL characteristic heat flux widths, which extrapolates to q,ITER ~1 mm [1] for the ITER baseline inductive scenario. Both a heuristic drift based model [2] and a model based on EPED calculations [3] fit the experimental finding both in absolute magnitude and scaling; the former yields q,ITER ~1 mm, the latter a pressure scale length ~5 mm. An extremely narrow q,ITER as in [1,2] implies very high upstream parallel heat fluxes, q|| which may be challenging to dissipate in the ITER divertor (technology imposes q⊥ ≤ 10 MWm-2 on the targets) whilst maintaining a reasonable H-mode operational window. Indeed, both new experimental scaling results on radiated power, PRAD [4] and ITER plasma boundary simulations [5] suggest that high SOL density will be necessary at the outer midplane and at the divertor strike points to provide the required PRAD. It is not clear that these conditions will be compatible with H-mode confinement. The DivSOL scaling has so far concentrated on strongly attached divertor plasmas, to allow the best possible measurement of q from divertor thermography, but must now be extended to more directly ITER-relevant dissipative divertor conditions.

**References:** [1] T. Eich et al., 24th IAEA FEC, San Diego, USA, 8-13/10/2012; [2] R. G. Goldston, Nucl. Fusion **52** (2012) 013009; [3] P. Snyder et al, presentation to joint DivSOL/Pedestal session at ITPA, San Diego 2012; [4] A. Kallenbach et al., 24th IAEA FEC, San Diego, USA, 8-13/10/2012; [5] A. S. Kukushkin et al., 20th PSI Conf., Aachen, Germany, 21-25/05/2012