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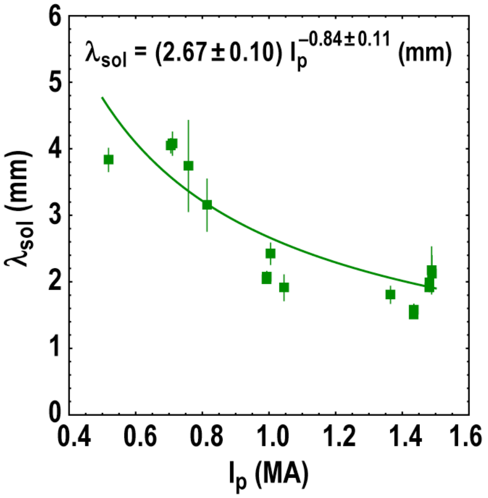

Fig. 1. SOL heat flux width versus I_p showing a strong inverse dependence.

DIII-D measurements indicate a systematic narrowing of the divertor heat flux width λ_q with plasma current in H-mode plasmas (Fig. 1) and significantly weaker dependence on other parameters. Comparisons of λ_q with upstream SOL profiles indicate a similar variation, consistent with expectations from flux-limited transport. The inverse dependence of λ_q on plasma current suggests that physics solutions for heat flux control may be more essential in next step devices such as ITER, FNSF, and DEMO to reduce the local heat flux below the maximum steady-state heat load sustainable by material surfaces of ~10 MW/m^2. We postulate that the dependence of the SOL heat flux width on plasma current results from a critical edge pressure gradient extablished by a kinetic ballooning mode.

We find that the heat flux profile in DIII-D is well fit by a two-parameter function [1] with one parameter (λ_{pvt}) characterizing the profile in the private flux region and the other (λ_{sol}) characterizing the SOL. The heat flux integral width (integral of the profile divided by its peak value) of this function is a weighted linear sum of these two parameters. The integral width scales inversely with I_p, and has weaker dependencies on other parameters such as the Greenwald fraction, f_{gw}, and the power through the separatrix, P_{sol}. However, λ_{sol} is found to have a much simpler scaling, depending only on I_p (or equivalently, the poloidal magnetic field B_p, since $B_p \sim I_p$) as shown in Fig. 1. These results are consistent with recent US [2] and EU [1] multi-machine scalings.

Using an upgraded Thomson scattering system, measurements of the upstream profiles with improved spatial and temporal resolution have been made to test models of parallel and radial heat transport in the SOL. An example of the data is shown in Fig. 2 which plots electron density, temperature, and pressure versus major radius at the midplane together with a fit to the data (blue line). The uncertainty in the location of the separatrix is indicated by the light-blue vertical band. A plot of the derived gradient scale length is also shown for each profile. Analysis of the profile gradient scale lengths reveals that the scaling of the divertor heat flux width is primarily due a

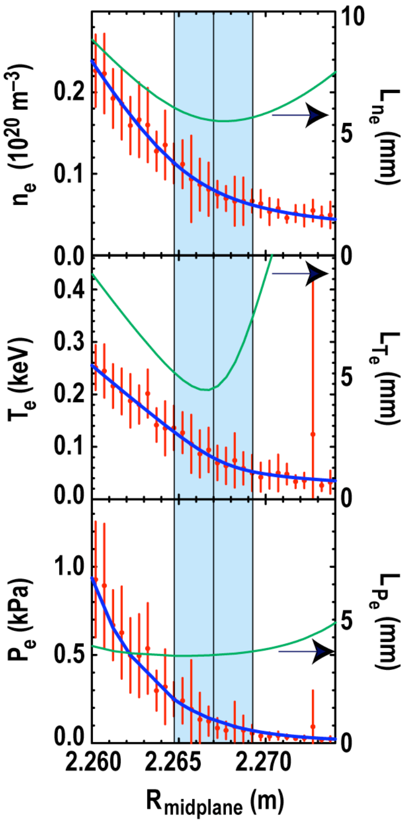

Fig. 2. Profiles of electron density, temperature, and pressure versus midplane major radius (note that the radial span is only 15 mm). A fit to the data is indicated by the blue line. The derived gradient scale length is plotted in green. The uncertainty in the location of the separatrix is indicated by the blue band.

narrowing of the SOL n_e profile width with increasing I_p, while the T_e width remains nearly constant. The scaling of the upstream SOL profiles is found to be consistent with a flux-limited parallel transport model at low collisionality. A Spitzer model is found to be in agreement at high collisionality where the model is expected to be more valid.

This strong dependence of λ_q on B_p suggests two possible physics mechanisms setting the heat flux width. In the first model, Goldston [3] posits that drifts carry particles across the separatrix and into the scrape-off layer with a typical penetration length on the order of the ion poloidal gyroradius. The DIII-D divertor heat flux scaling data is in very good agreement with the predictions of this heuristic model. In addition the Goldston model predicts the scaling of the divertor heat flux is driven by the width of the SOL density profile as observed in the DIII-D data.

An alternative model proposes that the SOL radial heat transport is driven by a critical edge pressure gradient, which when exceeded excites a Kinetic Ballooning Mode (KBM), rapidly increasing turbulent radial transport and limiting any further increase in the pressure gradient [4]. This model proposes that the critical gradient extends from the pedestal to a short distance outside the separatrix, thereby controlling the divertor heat flux width. Initial tests of this model have found the measured total pressure gradient at the separatrix scales with the expected pressure gradient limit, using the calculated ideal ballooning limit as a proxy for the KBM. This is demonstrated in Fig. 3 which plots the measured pressure gradient at the separatrix and the calculated ideal ballooning limit at the separatrix as a function of plasma current. The two are seen to scale in an almost identical manner.

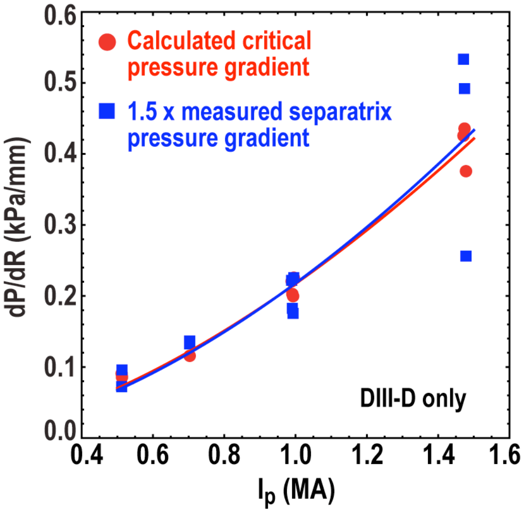

Fig. 3. Comparison of the calculated ideal ballooning critical pressure gradient and the measure separatrix pressure gradient versus I_p.

An additional density scan has been carried out from a low density attached state to a high density detached divertor state. The upstream profile scale lengths are again found to be related to the heat flux width for attached conditions. This suggests that the upstream profiles can be used to make inferences regarding radial SOL transport under detached conditions where the divertor heat flux profile is significantly altered due to radiative power losses.

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