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PROGRESS TOWARDS A PREDICTIVE MODEL FOR PREDICTIVE PEDESTAL HEIGHT IN DIII-D

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Progress Towards a Predictive Model for Pedestal Height in DIII-D Ex-C

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A new theoretical model predicts the observed pedestal height for a range of conditions in DIII-D. The predictions from this model have matched the experimental measurements in an experiment where the pedestal height was varied over more than an order of magnitude. This model uses the peeling-ballooning MHD model [1] as a constraint on the total pressure gradient and an empirical scaling for the pressure width Δ_p= 0.08 $\beta_{p,ped}^{1/2}$ [2,3], where the width is measured in normalized psi. Recent experimental measurements, made with highly resolved pedestal profiles, provide strong support for this width scaling. In addition, recent studies have revealed that a simultaneous increase of pedestal width and height occurs during pedestal evolution in ELM-free H-mode and during the recovery from an ELM. These width studies provide tests of several theoretical pedestal models. These tests include qualitative tests of a neutral penetration model [4], time-dependent barrier-expansion models [5-6], and the new XGC neoclassical model for density width [7].

The new pedestal height model is built upon previous work, which showed that the peeling-ballooning constraint provided good predictions of the pedestal height in DIII-D, when the measured pedestal width was used as an input [1]. In the new version of the model, the pedestal width is taken from the empirical scaling Δ_p = 0.08 $\beta_{p,ped}^{1/2}$, where the constant of proportionality is obtained from a fit to experimental data. This model has correctly predicted the height of the pedestal achieved just before an ELM crash in scans of plasma current, toroidal field and triangularity, which varied the pedestal height by more than an order of magnitude, as shown in Fig. 1(a). Recent experiments, which produced high quality pedestal profiles, show that this width scaling is a good description of a wide range of DIII-D data [3]. As shown in Fig. 1(b), for example, a pedestal width scaling with $\beta_{p,ped}^{1/2}$ is required in order to obtain consistency of the peeling-ballooning MHD limit for the pressure with the observed pedestal height. A constant width assumption is not consistent with the data.

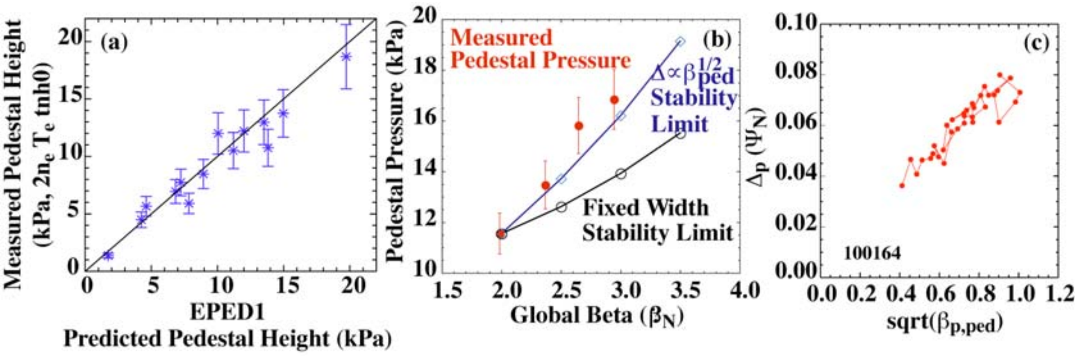

Fig. 1. (a) Predicted pedestal height agrees well with measured pedestal height over more than an order of magnitude. (b) Pedestal stability analysis (blue line), based on the assumption that pedestal pressure width scales with $\beta_{ped}^{1/2}$, provides much better agreement with measured pedestal height than does assumption that pedestal width is constant (black line). (c) During pedestal build-up in ELM-free H-mode, pedestal width shows approximately scaling Δ_p = 0.08 $\beta_{p,ped}^{1/2}$, the same scaling as used in the predictive pedestal height model.

In addition, recent measurements reveal that the pedestal width and height both increase with time during the pedestal buildup after an L-H transition and during the pedestal recovery after an ELM. That is, the electron pressure width and electron pressure pedestal height increase in time during the ELM-free phase. The increase in pedestal pressure height is due to increases in the heights for the T_i, T_e, and n_e pedestals. Preliminary analysis [Fig. 1(c)], shows that the relationship $\Delta_p = 0.08\,\beta_{p,ped}^{1/2}$ also holds during this pedestal buildup. Thus, the width scaling which has been observed at the ELM crash may be a consequence of transport physics of the pedestal prior to the crash.

The expansion of the pedestal allows for tests of several pedestal models. The increase of Δ_{ne} as the pedestal density $n_{e,ped}$ increases contradicts an analytic neutrals model, which predicts that Δ_{ne} should decrease as $n_{e,ped}$ increases [4]. Calculations with a 1D kinetic neutrals model show that deeper penetration of charge exchange neutrals as $T_{i,ped}$ increases (during the pedestal expansion) cannot explain these observations [8]. These results strongly indicate that transport effects, perhaps an inward particle pinch, must be invoked to explain the density pedestal expansion. Previously, the neutrals model has successfully described the decrease of Δ_{ne} with increasing $n_{e,ped}$, observed in rapidly ELMing discharges in DIII-D [4]. The new results presented here indicate that the neutrals model cannot explain the dynamic behavior of the pedestal within an ELM cycle. A more complete model of Δ_{ne} in ELMing discharges would need to include the pedestal growth between ELMs and the destruction at an ELM, as well as neutral effects.

Time-dependent theoretical models, based on *E*x*B* shear suppression of turbulence in the pedestal, qualitatively predict the observed expansion of the n_e and p_e barriers [5,6]. In these models, ∇p is assumed to be the dominant term that balances the radial electric field E_r. As a result, the pedestal barrier will self-consistently expand into the plasma as heat flows from the plasma core into the pedestal. These results imply that the observed barrier expansion might be a natural result of *E*x*B* shear suppression physics.

Other models have been tested. For example, a neoclassical pedestal model, based on a numerical orbit-following code in realistic geometry, predicts the ion toroidal gyroradius ρ_i scaling $\Delta_{ni} \sim \propto T_i^{1/2}/B_T$ [7]. This prediction is consistent with experimental relationships observed between Δ_{ne} and $T_i^{1/2}$ during the pedestal buildup in ELM-free H-mode in DIII-D. Scaling with B_T is not well studied. Although this ρ_i scaling has been observed during the temporal expansion of the density barrier, pedestal widths observed just before an ELM crash do not exhibit a ρ_i scaling in DIII-D. Finally, comparisons have been initiated between the ExB shearing rate and the linear growth rates for gyrokinetic modes in the pedestal, as computed with the TGLF transport model [9]. Initial results show that the ExB shearing rate is of about the right magnitude to suppress long wavelength modes, that are thought to be responsible for transport at the plasma edge.

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