Scaling of the H-Mode Pedestal and ELM Characteristics with Gyro-Radius on the JET and DIII-D Tokamaks

DIII-D

by T.H. Osborne and M.N.A. Beurskens

with

L. Horton, L. Frassinetti, R. Groebner, A. Leonard, P. Lomas, I. Nunes, S. Saarelma, P. Snyder, I. Balboa, B. Bray, K. Crombé, J. Flanagan, C. Giroud, E. Giovannozzi, M. Kempenaars, N. Kohen, A. Loarte, J. Lönnroth, E. de la Luna, G. Maddison, C. Maggi, D. McDonard, G. McKee, P. Pasqualotto, G. Saibene, R. Sartori, E. Solano, W. Suttrop, E. Wolfrum, M. Walsh, Z. Yan, L. Zabeo, D. Zarzoso and the JET-EFDA, DIII-D, and AUG teams

Presented at

Fifty First APS Meeting of the Division of Plasma Physics Atlanta, Georgia November 2–6, 2009 <image>



JET



Goals of the Experiments

- Determine the scaling of the edge transport barrier (ETB) width, w/a, and ELM size with normalized gyro radius, $\rho_* = \rho/a$.
 - Since $\rho_*^{\text{ITER}} < \text{current tokamaks } (\rho_*^{\text{ITER}} / \rho_*^{\text{JET}} < 0.5) \Rightarrow w/a \propto \rho_*^X, X > 0 \text{ is undesirable for ITER } (Q~T^{\text{PED}})$
 - X>0 suggested by some theoretical arguments and experiments: V_{ExB} turbulence suppression: $\gamma_{DW} \sim c_s / a = (V_{ExB})' \Longrightarrow w / a \sim \rho_*^{1/2}$
 - Vary ρ_* keeping β , υ_* , q, T_e/T_i , M, plasma shape fixed $\Rightarrow \rho_* \propto (aB^{4/5})^{-5/6}$

Examine the role of the edge particle source in ETB structure and ELMs

- With all pedestal dimensionless parameters matched "plasma physics" $\Rightarrow w \propto a$ neutral source $\Rightarrow w = \lambda_n \propto 1/n \propto a^2$





${\rho_*}^{\text{PED}}$ Scans Carried Out in Both High and Low Triangularity Shapes



• Shapes normalized to major radius, R





Both n_e and T_e Widths are Relatively Unchanged Over the Factor of 4 Range of ρ_{\ast}



Comparison with EPED1 Model (Snyder^[1] TP8.00018) Suggests a Residual Inverse ρ_{*} Dependence



T_e Profiles Match with all Dimensionless Parameters Matched but n_e Profiles Suggest Particle Source Effect



- At dimensionless parameter match
 - T_e profiles matched
 - n_e profile in DIII-D discharge is shifted outward relative to T_e profile



- Top of n_e pedestal shifts inward as MFP, $\lambda_n/a \propto 1/(an_e)$, increases on D3D
- Trends offset at different δ on D3D
- JET has larger normalized shift and no obvious n_e dependence



Variation in n_e Profile Shift with δ and Tokamak Suggests Variation in Poloidal Distribution of Neutral Source



ELM Losses Increase Strongly with $\rho_{*}\,$ on DIII-D but not on JET



NATIONAL FUSION FACILITY

- ELM losses increase strongly with ρ_{*} on DIII-D
- Losses match at identity point but trend with ρ_{*} weakly reverses in JET
- ELM loss at high ρ_{*} on DIII-D exceed value expected from υ_{*} scaling
- Large ELM loss at high
 ρ* on DIII-D are
 correlated with
 increased ELM depth
 and duration



High Edge p' Region and PB Eigenmode are Wider Due to Density Profile Shift at High ρ_* but Change is Modest Compared to ELM Size Increase





- The n_e profile shift, possibly related to λ_n effects, results in narrowing of width of the high p' region at small ρ_* (high n_e)
- A modest increase in PB eigenmode width is associated with expansion of high p' region



Summary Conclusion

- $w_{Te} \propto a$ at matched dimensionless pedestal parameters \Rightarrow plasma physics and not neutrals set w_{Te}
- Outward shift of n_e profile at high n_e (small ρ_*) consistent with particle source affect on n_e profile
 - Fitting JET results into this picture requires main chamber dominated particle source in JET
- w_{Te} and w_{ne} weakly decreasing through a factor of 4 variation in ρ_* : $w_{Te}(\psi_N) \propto \rho_*^{-0.17}$, $w_{ne}(\psi_N) \propto \rho_*^{-0.10}$
 - Combining a β^{PED} scan with the ρ_* scan recovers the EPED1 $(\beta_P^{PED})^{0.5}$ scaling but suggests a residual ρ_* dependence: $w_{Te} \propto (\beta_P^{PED})^{0.5} \rho_*^{-0.25}$
- ELM energy loss increases strongly with ρ_{*} on DIII-D but is weakly decreasing with ρ_{*} on JET
 - Large losses at high ρ_* on DIII-D > 2× Loarte v_{*} scaling
 - ELM size and ELM depth correlated with PB eigenmode width but change in PB width is small compared to ELM size change



