STABILITY IN HIGH GAIN PLASMAS IN DIII–D*

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Recent experiments in DIII–D have focussed on raising the fusion gain in strongly-shaped plasmas. A factor of 3 increase over previously reported results [1] has been obtained by tailoring the pressure profile in H–mode plasmas. We report an increase in the fusion power gain in deuterium plasmas, to Q_{dd} = 0.0015. This was accomplished through control of the current profile in the target plasma prior to application of high power neutral beam heating, combined with control of the plasma pressure profile during the high power heating phase in strongly shaped plasmas. This value of Q_{dd} corresponds to an equivalent Q in a deuterium-tritium plasma, Q_{dt} = 0.32. Normalized to B^2R^2 these results are between 2 and 9 times larger than those achieved in other tokamaks. Higher values of BR represent both economic and technological obstacles to fusion power. These results offer the prospect of reduction in the size and field required for achieving higher gain approaching fusion ignition conditions in a plasma and support the viability of the concept of a smaller, economical tokamak reactor through tailoring the equilibrium profiles. In the course of these experiments we have achieved record stored energy, in excess of 4 MJ, increased the triple product to $n_d(0)T_i(0)\tau_E = 6.5 \times 10^{20}$ keV•s•m^{-3}, and neutron rates up to 2.4×10^{16} s^{-1}.

Improved core confinement with negative central shear (NCS) has been observed in both L–mode [2] and H–mode[3] DIII–D plasmas. However, L–mode NCS plasmas, with a pressure peaking typically of $p_0/\langle p\rangle \approx 4$ invariably disrupt at $\beta_N \leq 2.3$. This L–mode beta limit is consistent with ideal MHD stability limits which show an infernal mode type of n=1 instability. Broadening the pressure profile is predicted to enhance stability and result in a large increase in plasma reactivity for strongly shaped plasma cross sections. On the other hand, the broad pressure profiles typical of DIII–D H–mode plasmas result in too broad a deposition of the neutral beam power, reducing heating and fueling of the core. This also results in reduced fusion reactivity. Motivated by these observations we have performed experiments where the L-H transition timing is used strategically to moderate the peaking of the pressure profile. This controlled transition has led to record reactivity for DIII–D plasmas, with Q_{dd} reaching values comparable to those in the larger, higher magnetic field tokamaks.

The increase in achievable β and Q through a controlled L-H transition is shown in Fig. 1 where the evolution of an L–mode and an H–mode plasma are compared. Low power neutral

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beam injection (NBI) beginning at 0.3 s produces the NCS target. Small, controlled changes in plasma shape induce an H–mode transition in one case at 2.1 s, indicated by the edge pressure rise [Fig. 1(c)]. The L–mode case disrupts at about 2.25 s [Fig. 1(a)]. The H–mode plasma continues to increase its stored energy and fusion reaction rate until a stability limit is reached at β_N = 3.7. For this particular case Q_{dd} reached 0.0012. The high performance phase is terminated by an X-event, a global, β-limiting instability associated with the buildup of bootstrap-driven current density near the plasma edge, whereupon the plasma reverts to an ELMing H–mode.

During the experiment systematic variations were made in the target current profile. Though stability analysis of the results is incomplete at this time plasmas which evolved to a q profile with little shear in the central region at the time of peak reactivity performed better than those with substantial shear reversal. Stability analysis of these differences will be presented. Transport analysis indicates that ion thermal diffusivity is at less than standard neoclassical levels. A summary of results is in Fig.2 where we plot S_n vs P_{NBI}.

Experiments are underway to employ these techniques in plasmas having a shape like JET and results will be reported. Also, experiments to sustain this high performance by toggling between L– and H–mode (inner wall limited and double-null diverted) are planned.

[1] BURRELL, K.H., et al., Plasma Phys. and Contr. Nucl. Fusion Research 1994 (International Atomic Energy Agency, Vienna, 1995), Vol. I, p. 221.

[2] RICE, B.W., et al., to be published in Nucl. Fusion.

[3] STRAIT, E.J., et.al., Phys. Rev. Lett. **75**, 4421 (1995).

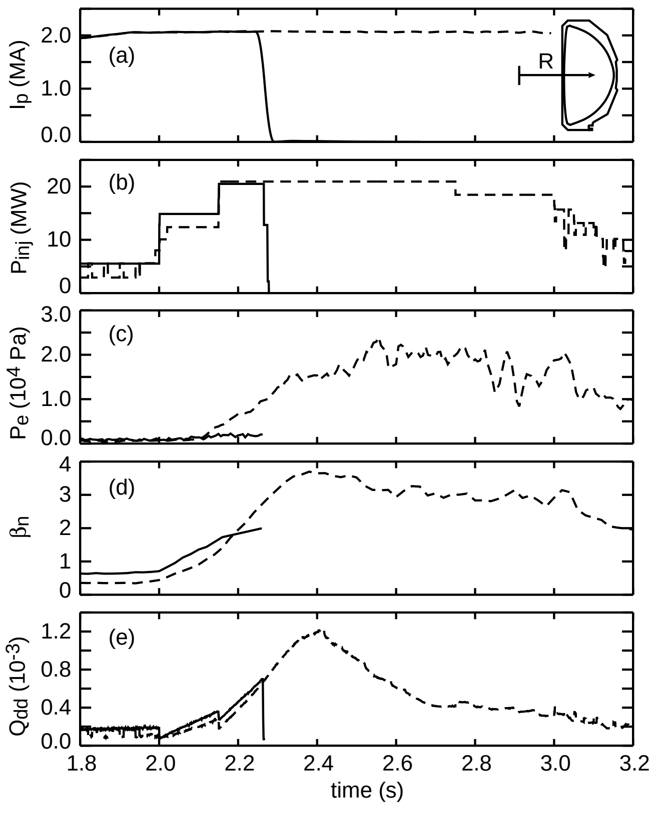

Fig. 1. Time evolution of two similar discharges 87887 which remains in L–mode (solid line) and disrupts and 87937 which makes a transition to H–mode (broken line). (a) Plasma current, (b) injected neutral beam power, (c) edge electron pressure, (d) β_N (= β a B_t/I_p) in units (% MA/m/T), (e) $Q_{dd} = P_{fusion}/P_{NB}$.

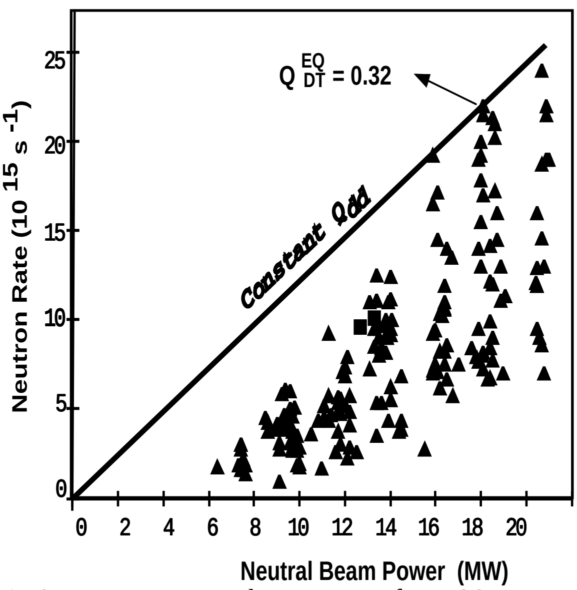

Fig 2. Neutron rate vs beam power for NCS target plasmas.