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The High-β_N Hybrid Scenario for ITER and FNSF Steady-State Mission[1]

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New experiments on DIII-D have demonstrated the steady-state potential of the hybrid scenario, with 1 MA of plasma current driven fully noninductively and β_N up to 3.7 sustained for $\sim$3 s ($\sim$1 current diffusion time, τ_R, in DIII-D), providing the basis for an attractive option for steady-state operation in ITER and FNSF. Excellent confinement is achieved ($H_{98y2} \sim 1.6$) without performance limiting tearing modes. The usual Advanced Tokamak (AT) approach relies on a large fraction of off-axis current drive and careful current drive alignment to reach $q_{min} > 2$ and high bootstrap current (>70%). In contrast, the hybrid regime overcomes the need for off-axis current drive efficiency, taking advantage of the poloidal magnetic flux pumping, believed to be the result of a saturated 3/2 tearing mode, to produce a self-organized current density profile. This allows for efficient current drive close to the axis, without deleterious sawtooth instabilities. In these new experiments, the edge surface loop voltage is driven down to zero for >1 τ_R when the poloidal β is increased above 1.9 by utilizing 3.15 MW of electron cyclotron current drive at a plasma current of 1.0 MA and density of $\sim 4\times10^{19}\,\mathrm{m}^{-3}$. Stationary operation of hybrid plasmas with all on-axis current drive is sustained at pressures slightly above the ideal no-wall limit, while the calculated ideal with-wall MHD limit is $\beta_N \sim$ 4-4.5. For the first time, off-axis NBI power has been used to broaden the pressure and current profiles in this scenario, seeking to take advantage of higher predicted kink stability limits and lower values of tearing stability index Δ', as calculated by the DCON and PEST3 codes. Preliminary results based on measured profiles predict ideal limits at $\beta_N > 4.5$. With collisionality and edge safety factor values comparable to those envisioned for ITER and FNSF, the high-β_N hybrid represents an attractive high performance option for the steady-state missions of these devices,

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