Overview of the Pegasus Non-Solenoidal Startup Research Program

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Research on the ultra-low aspect ratio $A \sim 1.2$ Pegasus spherical tokamak is targeted to develop the physics understanding of optimal non-solenoidal tokamak startup and its supporting technology. Recent experimental campaigns focus on studies of non-solenoidal startup via Local Helicity Injection (LHI) using a new set of compact, high-power helicity injectors adjacent to the plasma edge in the high-field-side (HFS), lower divertor region. This injector geometry produces and sustains plasmas with minimal inductive drive from poloidal field induction and dynamic shaping, complementing earlier studies with sources near the outboard midplane on the low-field-side (LFS) that maximized those effects. Plasmas with $I_p \leq 200$ kA, $\Delta t_{pulse} \sim 20$ ms and $0.1 < B_T/B_{T,max} \leq 1$ (0.015 T $< B_{T0} < 0.15$ T) are produced with the HFS system to date, sustained by two injectors with $V_{inj} \sim 1.5$ kV, $I_{inj} \sim 8$ kA, and $A_{inj} = 4$ cm^2. Technical improvements to the injectors, rail limiters, divertor structures, and active cathode spot suppression circuitry minimize plasma-material interactions and improve reliable access to this operational space. As with outboard LHI, these plasmas feature anomalous, reconnection-driven ion heating, with $T_i \geq T_e$ [1] and large-amplitude MHD activity driven by the injectors. However, during HFS injection measured MHD fluctuations can abruptly decrease by over an order of magnitude without loss of LHI drive. Such reductions result in improved particle confinement and suggest additional physics underlies the current drive mechanism. The HFS LHI system also facilitates unique tests of MHD stability. The high normalized current ($I_N \sim \frac{I_p}{aB_T} \geq 10$), reconnection ion heating, and low-ℓ_i driven by LHI, combined with the favorable stability of near-unity A ST geometry allows access to record values of β_t and high β_N without wall stabilization [2]. Kinetically-constrained equilibrium reconstructions indicate $\beta_t \sim 100\%$ is obtained in 100 kA LHI discharges, with the highest-performing discharges terminating disruptively at the ideal no-wall limit. These high-β_t plasmas feature a minimum $|B|$ well spanning ~50% of the plasma volume.

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[1] M.G. Burke *et al.*, Nuclear Fusion 57 (2017) 076010
[2] D.J. Schlossberg *et al.*, Physical Review Letters (2017) *In Press*