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The Advanced Tokamak Path to a Compact Fusion Pilot Plant

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The Advanced Tokamak concept represents a virtuous approach for a fusion reactor, combining improved confinement and stability with reduced heat flux and disruption severity, and the potential for fully stationary "always on"steady state operation to ease engineering and stability challenges. Self-consistent, integrated 1.5D simulations project new paths to a compact fusion pilot plant based on this approach that could demonstrate net electricity production and conduct long pulse nuclear testing. The concept benefits from a combination of strong shaping, broad profiles and high beta operation, to reduce turbulent transport, raise pedestals, and raise or remove various global MHD and energetic particle drive instability limits. This leads to configurations where the plasma becomes self-driven by bootstrap currents that naturally align to the required profiles.

The physics-based approach deployed here leads to new insights and understanding of reactor optimization. Studies utilize a new integrated 1.5D core-edge approach for whole device modeling to predict plasma performance, by self-consistently applying the latest transport, pedestal, equilibrium, stability and current drive physics models to converge fully non-inductive stationary solutions without any significant free parameters. This contrasts with previous "systems code"approaches, where parameters are simply set to desired values based on plausible arguments.

Studies highlight the critical levering roles of density, toroidal field and beta in increasing fusion performance, while raising stability and enabling increased heat dissipation at higher density. The resulting increased confinement and bootstrap fraction reduces heating and current drive demands as a fraction of fusion power, and thus enables configurations with high net electricity at reduced size and current. Solutions are found with ˜200MW net electricity at the 4m major radius scale and 6-7T. Heat loads are mitigatable with reasonable levels of core and divertor radiators, and good H mode access maintained. Auxiliary current drive is projected from neutral beam and ultra-high harmonic (helicon) fast wave, though other advanced current drive approaches presently being developed also have potential, and may be more desirable.

Low recirculating power and a double null configuration leads to a divertor heat flux challenge comparable to ITER, though reactor solutions may need to increase dissipation further. Strong H-mode access (factor >2 margin over the L-H transition scaling) and ITER-like heat fluxes are maintained with ˜20-60% core radiation. Neutron wall loadings appear tolerable but suitable for a nuclear testing mission. The approach would benefit from high temperature superconductors, the higher fields of which increase performance margins, while their potential for demountability would facilitate a nuclear testing mission. An advanced load sharing and reactive bucking approach in the machine centerpost region provides improved mechanical stress handling.

As with all power plant concepts, the work identifies some significant plasma and technology research challenges, though the inherent advantages of the approach discussed here have the potential to offer a more stable path to a power plant in the near term, and ease challenges placed on technology components. This presentation will explain the underlying physics benefits, their experimental validation and the projection to compact solutions for a fusion pilot plant.

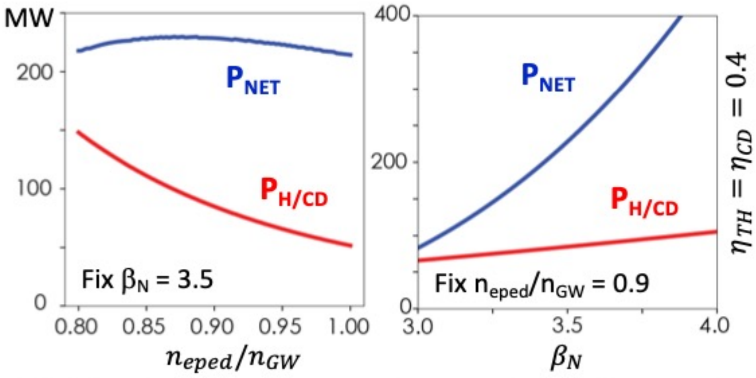

Figure: Projected dependencies of net electric performance and required heating and current drive power for a 4m, 7T, net electric fusion pilot plant based on the advanced tokamak approach.

Figure 1: Caption

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