

Ignitor Physics Assessment and Confinement Projections

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Ignitor [1] is a high field ($B_T = 13$ T, $I_p = 11$ MA) tokamak reactor design that offers the possibility of producing ignition in a pulsed D-T discharge. The standard dimensionless parameters are similar to those of the conventional large volume, low field tokamak reactors. The main qualitative differences are that the small dimensions ($R/a = 1.32$ m/.47 m, $\kappa = 1.8$) and high toroidal field allow access to more than ten times the standard tokamak density. This increases the nuclear reaction rate at the Greenwald density limit to very high values. As a consequence Coppi *et al.* [2] predict that the system will achieve ignition in a relatively low temperature and low plasma pressure (toroidal $\beta_T \lesssim 1\%$) that makes the design have a wider margin of stability against MHD modes and sawteeth than the conventional design. The key issue remains, however, whether the anomalous thermal transport is sufficiently weak to allow the plasma to reach ignition. Here we carry out both analytic studies and transport code simulations of the system with state of art formulas for the plasma thermal diffusivities to make predictions for the system's performance. We compare these turbulence theory-based predictions with the standard database derived scaling law's predictions that were a principal product of the ITER physics studies [3]. We also use statistical techniques to attempt to assess the uncertainties with the extrapolations from the historical database with mean parameters bounded by 4 T, 1 MA to the 13 T, 11 MA regime of Ignitor. This engineering parameter, and the plasma density, are two to three sigma out in the distributions from the mean values in the historical confinement database.

Briefly, the Ignitor confinement requires [1] is $n_0\tau_E \sim 4 \times 10^{20} \text{ m}^{-3} \text{ s}$ for well-peaked density profiles and the central plasma temperature of 10 – 12 KeV. Central densities $n_0 \sim 10^{21} \text{ m}^{-3}$ are below the Greenwald density limit and should be achievable. Thus, the energy confinement time needed to reach the desired performance is $\tau_E \sim 0.4$ s. This time is long compared with the alpha particle slowing down time, $\tau_\alpha \sim 0.07$ s, and short compared with the discharge pulse length $\Delta t_p \sim 10$ s. Critical issues discussed are the maintenance of a peaked density profile and the possible need for an H factor between 1.2 to 1.5 for ignition over the ITER97 P confinement time [3].

The transport simulations are carried out with BALDUR including a complete range of physical processes [4] and also with a new, idealized physics code called TBD (transport barrier dynamics [5]) that is designed to study the feedback loops between the turbulence, the plasma gradients and the sheared mass flows. BALDUR has been used to model the transport barriers in the two OS JET discharges designated for community study and for a NCS discharge in DIID with good success [6]. Thus, the code is capable of describing the H confinement improvement factor that is expected in weak central magnetic shear experiments. The neoclassical friction-flow relations used to calculate the mass flow velocities have been benchmarked with matched RS/ERS

discharges in TFTR [7].

One main asset of the Ignitor design is the increased safety margin against MHD instabilities. The relatively low values of the plasma beta parameter and relatively large values of the safety factor needed at ignition guarantee this. Thus, Ignitor is designed to operate well below the stability thresholds for ballooning modes and for neoclassical tearing modes. Thus, the incidence of disruptions in Ignitor can be expected to be low. A quantitative assessment of MHD stability will be presented from recent theoretical results.

For the internal kink modes [8], leading to the well-known sawtooth internal relaxation oscillations and fishbone oscillations, we note that the transient nature approach to ignition is such that the q profile develops a $q = 1$ surface only well into the current flat top, after ignition is reached. In this way, the $q = 1$ radius, which measures the extent of the central plasma region affected by sawteeth, should remain small. Thus, if sawteeth appear at all, their effect should cause only a minor redistribution of the plasma core properties. Further analysis of the evolution of the current density profile and of the sawtooth trigger condition will be reported. Fishbone oscillations, and other energetic particle modes, that can be expected after sufficient alpha particle density build-up will also be surveyed.

Acknowledgments

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