§3. Study of the Burning Plasma Physics Issues in Helical Reactors

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Based on the inwardly shifted plasma of R=3.6 m in LHD (a=0.6 m, B_o=3 T), where the best confinement has been achieved so far, we have determined the FFHR reactor size using the LHD size scaling including the blanket thickness and machine weight. So far the Sudo density limit has been used without any improvement. If the density limit is higher than that as observed in LHD, the operational regime can be expanded significantly. In this report, the density limit is set to 1.5 times larger than the Sudo limit.

FFHR reactor with R=14 m and the pitch parameter γ=1.25 can have a blanket thickness of 0.9 m, which is less than the required value of 1.2 m for D-T blanket characteristics. However, adoption of γ=1.15 provides a blanket thickness of 1.2 m and enough minor radius. On the other hand, although an R=16 m reactor with γ=1.25 can have a blanket thickness of 1.2 m, the machine weight is too heavy. Therefore, we consider 14m reactor in this report.

When the density limit is determined by the Sudo scaling without any improvement (γ_{SUDO} =1), the confinement factor of γ_{ISS} =2.16 over ISS95 scaling (γ_{LHD}=1.35 over present LHD scaling) provides ignition. On the other hand, if the density limit is improved by 50 % (γ_{SUDO}=1.5), the confinement factor of γ_{ISS} =1.92 (γ_{LHD}=1.2) is enough for ignition.

In Fig. 1 is shown the temporal evolution of plasma parameters of FFHR with R=14 m, a=1.73 m, B_o=6 T, P_F=1.9 GW, γ_{SUDO}=1.5, γ_{ISS}=1.92 (γ_{LHD}=1.2) and η_α=90 %. When the external heating power of 80 MW is switched off at 150 s, ignition is reached. The peak density at the steady state is 2.67x10^{20} m^{-3}, the density limit is 10% over the operation density, temperature is 15.8 keV, average neutron wall loading is 1.5 MW/m^2. Beta is 3 % which is already achieved in LHD. As high energy alphas are assumed to be lost promptly by 10%, it should be confirmed in numerical simulation. As the density limit is 1.8 times larger than the Sudo scaling in the present LHD experiments, assumption of γ_{SUDO}=1.5 is reasonable.

In Fig.2 we have shown POPCON for ignition in this case. When the density limit is increased, the operating point can go down to the bottom of the ignition boundary with stable-unstable boundary. Therefore, the confinement factor can be reduced. When the density limit is decreased, the operating point goes up to the higher temperature side on the ignition boundary, requiring the larger confinement enhancement factor.

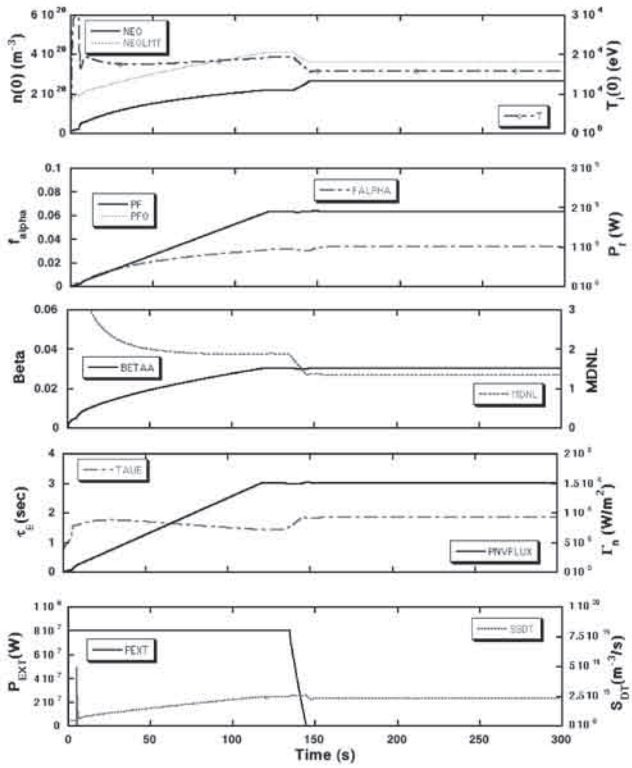

Fig. 1. The temporal evolution of the plasma parameters in FFHR (R=14 m).

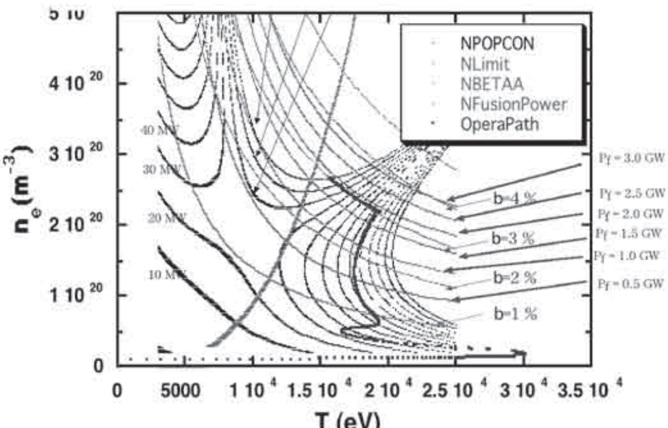

Fig. 2. POPCON diagram for FFHR (R=14 m) with the density limit of 1.5 over the Sudo scaling.