§3. Study on the Dependence of the Ion to Electron Energy Confinement Time Ratio during Ignition in FFHR

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Ignition analysis of FFHR reactor has been based on the one fluid equation with equal ion and electron temperatures so far $^{(1)-(3)}$. Although this is a good approximation in the high-density operation, it may not be in low-density and high temperature regime. Purpose of this research is to study how the ion and electron confinement time ratio affects the ignition access in FFHR. ECRH alone, NBI and alpha heating on the electron and ion heating are taken into account to study more realistic situations. Further more, the high-density operation is also studied using the electron and ion confinement time ratio to justify its approximation.

In this annual report, we describe the ECRH heating effect on the low-density and high temperature ignition regime.

2. Ignition to the low-density and high temperature regime by ECRH alone

In Fig. 1 is shown the temporal evolution of low-density operation in FFHR with the R=15.7m, a_{eff}=2.5m and B_o=4.5 T by ECRH heating alone in the case of τ_{Ei}/τ_{Ee}=2. The fusion power of P_f=3.0 GW, the confinement factor over ISS95 scaling of γ_{ISS}=1.92, $\tau_p{}^*/\tau_E$=3, $\tau_\alpha{}^*/\tau_E$=4, and alpha heating efficiency of η_α=98 % have been used. The density and the temperature profiles are assumed to be parabolic.

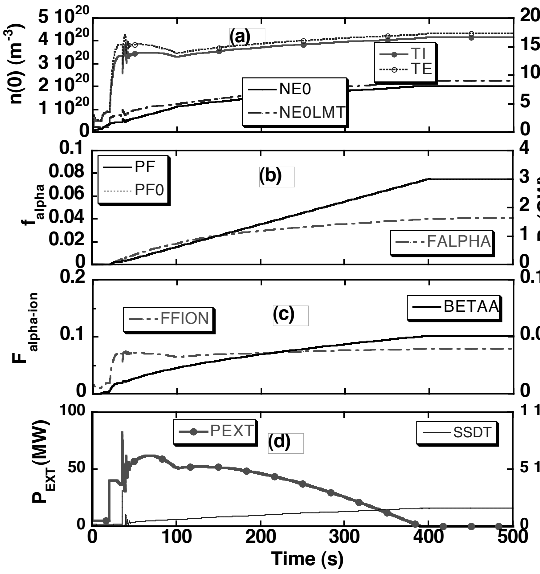

Fig. 1. Temporal evolution of the plasma parameters to thermally stable ignition regime with different energy confinement time in FFHR with 15.7 m. (a) Peak ion and electron temperature, peak density and density limit, (b) alpha ash fraction, fusion power and its set value, (c) alpha heating fraction to ions and beta value, and (d) D-T fueling rate and the with feedback controlled heating power of ECRH.

The 100 % of the heating power is transferred to electron, and then goes to ions due to electron- ion coupling. Therefore, as shown in Fig. 1, the electron temperature is slightly higher (T_i/T_e~0.98), and alpha-heating power to the ion fraction is 8.5% in this case. The ECRH heating power of ~60 MW is needed to reach ignition, and then reduced to zero at 400 s automatically, leading to ignition. In the case of one power balance equation with equal ion and electron temperature, the heating power is ~40 MW and reduced to zero at 300s. Therefore it is slightly worse, but it is still possible to reach ignition.

In Fig.2 is shown the dependence of the ignition capability on the ion to electron confinement time ratio τ_{Ei}/τ_{Ee} for three cases of alpha heating fraction to ions. Regime above the bold solid horizontal line at T_i/T_e =0.95 shows the ignition, indicating the hot-ion mode is better for ignition, and hot-electron mode is less favorable for ignition. For 100% electron heating from alpha heating, the ion to electron confinement time ratio should be larger than 3 to reach ignition.

It is interesting to note that the ion to electron temperature ratio T_i/T_e is less than 1.05 when the ion to electron confinement time ratio is as large as τ_{Ei}/τ_{Ee} =10 and energy transfer fraction to ion from alpha heating of 0.2. It is therefore important to increase the alpha-heating fraction to ions to obtain the hot ion mode.

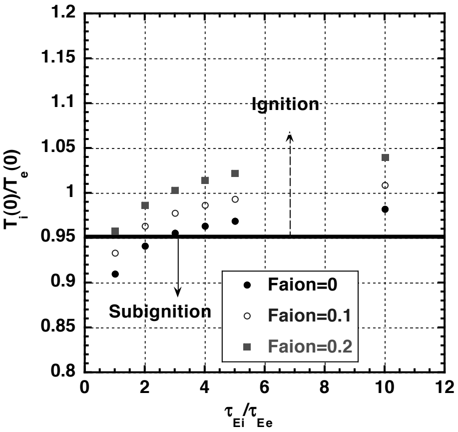

Fig. 2. Dependence of the ignition access on the ion to electron energy confinement time ratio τ_{Ei}/τ_{Ee} for three cases of the ion energy transfer fraction from alpha heating.

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