§3. Development of Direct Profile Extrapolation Method

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A new method to extrapolate the radial profiles of temperature and density in present devices to a fusion reactor has been developed and named "DPE (Direct Profile Extrapolation)" method.[1)] In traditional fusion reactor design activities, radial profiles have been assumed to be, for example, parabolic, while using zero-dimensional energy confinement scalings to determine the absolute values.[2,3)] In the DPE method, radial profiles of temperature and density obtained in the experiment are directly extrapolated to the reactor condition assuming gyro-Bohm type parameter dependence. As was reported in Ref. 4, the gyro-Bohm type parameter dependence is observed not only in the global energy confinement time, but also in the local pressure in LHD. Enhancement factors of the density, f_n, the plasma beta, f_β, the energy confinement, γ, and the magnetic field strength, f_B, are also assumed to determine how large heating power, $P_{reactor}$, and the plasma size, $a_{reactor}$ and $R_{reactor}$, will be needed in the reactor.

Example profiles extrapolated from LHD to the reactor condition without auxiliary heating, *i.e.*, self-ignition, are shown in Fig. 1, where $f_n = 2$, $f_\beta = 5$, $\gamma = 1.3$, and $f_B = 1.85$ are assumed. Typical profiles assumed in the FFHR-2m2 design (solid lines in Fig. 1) are well reproduced by using these enhancement factors. Assuming the self-ignition condition, $P_{reactor}$, $a_{reactor}$, and $R_{reactor}$, are determined as a function of f_n, f_β, γ, and f_B. In Fig. 2, $R_{reactor}$ is plotted with respect to the magnetic field strength on the magnetic axis in the reactor, $B_{reactor}$, to show the design window of a self-ignited fusion reactor. If $B_{reactor}$ = 10 T, and $f_n = f_\beta = \gamma = 1.0$, for example, then $R_{reactor}$ should be larger than ~17 m, to achieve the self-ignition condition. And if f_n is increased to 2, then the minimum $R_{reactor}$ is reduced to ~13 m. The lower envelope of the design window with various f_n has a form of

$$R_{reactor} = C_{exp}\ \gamma^{-5/6}\ f_\beta^{-1/3}\ B_{reactor}^{-4/3}, \qquad (1)$$

where C_{exp} is a factor depending on the used profiles. The smaller C_{exp} is favorable to decrease the device size and the magnetic field in the reactor. Enhancement in the confinement and/or the plasma beta is also favorable. As was shown in Fig.1, the FFHR-2m2 design of $R_{reactor}$ = 15.7 m and $B_{reactor}$ = 5.1 T is within the design window if f_n = 2, f_β = 5, and γ = 1.3 are assumed.

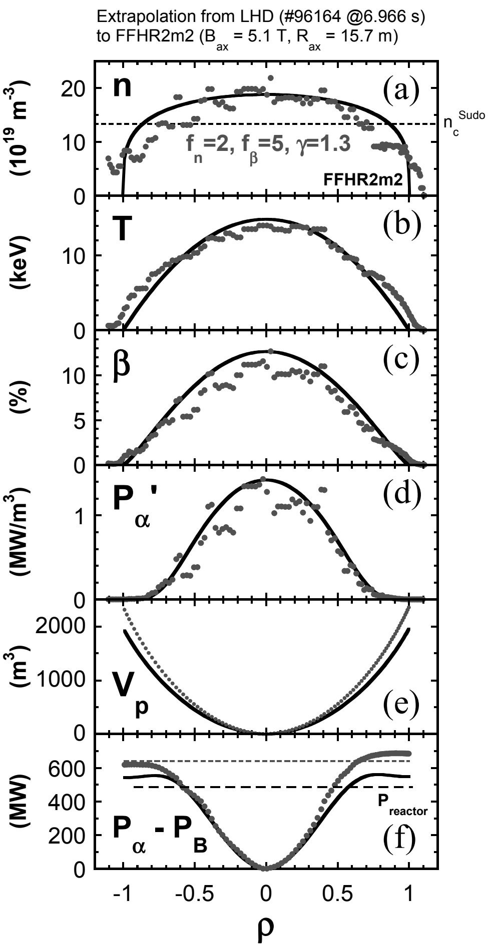

Fig. 1. Radial profiles in a self-igniting helical reactor extrapolated from typical radial profiles in LHD. Solid lines are the profiles assumed in the design of FFHR-2m2.

1) J. Miyazawa, et al., submitted to Fusion Eng. Des.
2) A. Sagara, et al., Fusion Eng. Des. **83** (2008) 1690.
3) O. Mitarai, et al., Nucl. Fusion **47** (2007) 1411.
4) J. Miyazawa, et al., J. Plasma Fusion Res. SERIES, Vol. 9 (2010) 94.

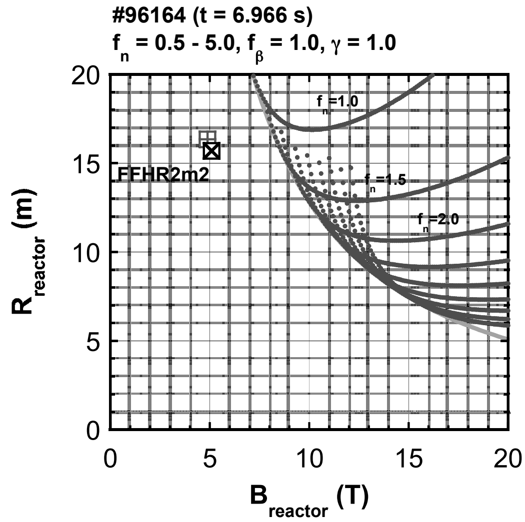

Fig. 2. Example of the reactor design window derived from radial profiles of #96164 (t = 6.966 s). Plasma major radius is plotted as a function of the magnetic field strength.