§7. Core Plasma Design of the Compact Sub-Ignition Helical Fusion Reactor FFHR-c1

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A compact helical reactor named FFHR-c1 has been proposed as a helical type nuclear test machine in the 1st IAEA DEMO Programme Workshop [1]. FFHR-c1 is basically a large duplication of LHD with the scale factor of 10/3, *i.e.*, the helical coil major radius, R_c, of FFHR-c1 is 13.0 m. Two options with different magnetic field strength are under consideration for FFHR-c1. One is named FFHR-c1.0 with B_c = 4 T and the other is FFHR-c1.1 with B_c = 5.6 T, where B_c is the magnetic field strength at R_c, Typical machine parameters of FFHR-c1 are compared with those of LHD and FFHR-d1 [2,3] in Table 1.

To design the core plasma in FFHR-c1 using the Direct Profile Extrapolation (DPE) method [4,5], the effect of additional heating has been taken into consideration. The heating power in the reactor, $P_{reactor}$, in the DPE method has been modified to

$$P_{reactor} = P_\alpha - P_B + P_{aux} = C_{aux}\,(P_\alpha - P_B), \qquad (1)$$

where P_α, P_B, and P_{aux} is the alpha heating power, the Bremsstrahlung loss, and the auxiliary heating power, respectively. In Eq. (1), a factor C_{aux} is introduced to linearize the equation. Note that $P_{aux} = (1 - 1/C_{aux})\,P_{reactor}$. The confinement improvement factor, γ_{DPE}, used in the DPE method [5] has been modified to

$$\gamma_{DPE*} = ((1.0 - 0.35/C_{aux}) / (P_{dep}/P_{dep1})_{avg,exp})^{0.6}, \qquad (2)$$

where $(P_{dep}/P_{dep1})_{avg,exp}$ is the peaking factor of the heating profile in the experiment. Plasma parameters in FFHR-c1 are estimated by the modified DPE method as shown in Fig. 1. "*Q > 7*" with $P_{fusion} = 5\,P_\alpha \sim 1$ GW ($C_{aux} \sim 1.8$) and "*self-ignition*" with $P_{fusion} \sim 1.7$ GW (C_{aux} = 1) can be achieved in FFHR-c1.0 and c1.1, respectively.

1) http://advprojects.pppl.gov/Roadmapping/IAEADEMO
2) A. Sagara, et al., Fusion Eng. Des. **87** (2012) 594.
3) T. Goto, et al., Plasma Fusion Res. **7** (2012) 2405084.
4) J. Miyazawa, et al., Fusion Eng. Des. **86** (2011) 2879.
5) J. Miyazawa, et al., Nucl. Fusion **52** (2012) 123007.

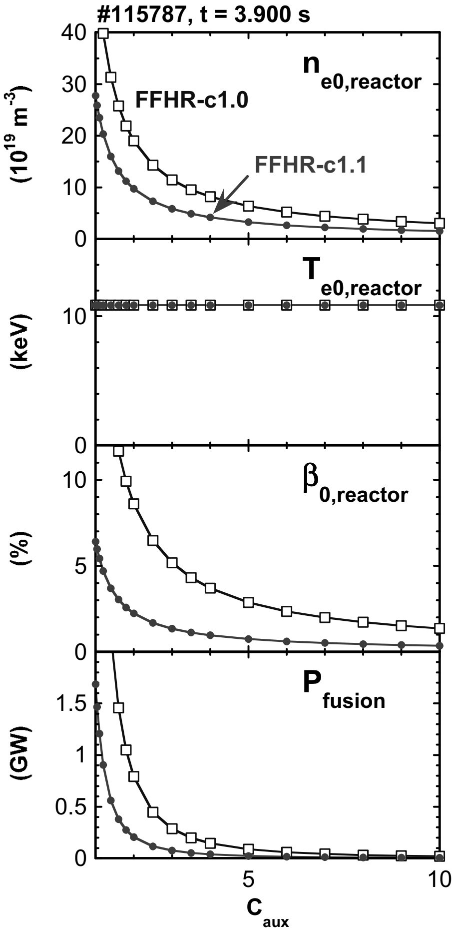

Fig. 1. Plasma parameters estimated by the modified DPE method. (a) the central electron density, (b), the central electron temperature, (c) the central beta, and (d) the fusion output, in FFHR-c1.0 (open squares) and c1.1 (closed circles), are plotted with respect to C_{aux}.

Table 1. Typical machine parameters in LHD, FFHR-c1.0, FFHR-c1.1, and FFHR-d1. The maximum duration time in FFHR-c1.1 is limited to a half year since the neutron shields is expected to be 5/6 times thinner than in FFHR-d1.

	LHD	FFHR-c1.0	FFHR-c1.1	FFHR-d1
R_c *Helical coil major radius*	3.9 m	13.0 m	←	15.6 m
V_p *Plasma volume*	~30 m^3	~1,000 m^3	←	~2,000 m^3
B_c *Magnetic field strength at R_c*	~2.5 T	4.0 T	5.6 T	4.7 T
W_{mag} *Magnetic stored energy*	~1 GJ	~68 GJ	~126 GJ	~160 GJ
P_{aux} (τ_{aux}) *Auxiliary heating power (heating time)*	30 MW (2 s)	140 MW (1 year)	50 MW (1 hour)	50 MW (1 hour)
P_{fusion} *Fusion output*	–	~1 GW	~2 GW	~3 GW
$\tau_{duration}$ *Maximum duration time of a shot*	1 hour	1 year	6 month	1 year
Φ_n *Maximum neutron fluence per shot*	–	~8 dpa (~0.8 MW/m^2 × 1 year)	~8 dpa (~1.5 MW/m^2 × 6 month)	~15 dpa (~1.5 MW/m^2 × 1 year)