§4. Getting High-Beta Data with Peaked Density Profile for Extrapolation to FFHR-d1 II

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In the helical fusion reactor FFHR-d1, a pair of poloidal coils that is called the IS (Inner Shaping) coils in LHD is omitted to enlarge the port size for maintenance [1,2]. This situation can be simulated in LHD by reducing the coil current in the IS coils to zero. Then, the averaged plasma cross-section, which is basically adjusted to form a circle in normal configurations of B_Q = 100 %, where B_Q denotes the percentage of cancellation of the quadrupole components, becomes vertically elongated and B_Q becomes smaller than 100 %. On the other hand, the high aspect ratio configuration with γ_c = 1.20, where γ_c is the pitch of helical coils, has been shown to be effective for Shafranov shift mitigation in the reactor condition [3]. Although vertical elongation of normal aspect ratio plasmas of γ_c = 1.254 has been already performed in LHD [4], vertical elongation of high aspect ratio plasmas of γ_c = 1.20 has not yet been tried until the 17th campaign in FY2013.

Experiments with the IS coil current ~ 0 has been performed in the inward-shifted high aspect ratio configurations of R_{ax} = 3.55 m and 3.60 m, where R_{ax} is the major radius of the magnetic axis in vacuum, and γ_c = 1.20, for the first time in the 17th campaign. Corresponding B_Q is 91 % in R_{ax} = 3.55 m, and 82 % in R_{ax} = 3.60 m, respectively. The central beta, β_0, obtained in the configuration of R_{ax} = 3.55 m, γ_c = 1.20, B_Q = 91 %, and B_0 = 1.45 T, where B_0 is the magnetic field strength at R_{ax} in vacuum, is shown with respect to the central electron density, n_{e0}, and compared with that obtained in the configuration of R_{ax} = 3.55 m, γ_c = 1.20, B_Q = 100 %, and B_0 = 1.0 T, in Fig. 1(a). Since B_0 was 1.45 T in the case of B_Q = 91 %, achieved β_0 is smaller than those in the case of B_Q = 100 % where B_0 = 1.0 T. Furthermore, applied heating power was limited in the case of B_Q = 91 %, since this was the first trial of this configuration.

Using these data, the performance of the fusion reactor core plasma can be expected. In Figs. 1(b), 1(c), and 1(d), shown are the fusion power, P_{fusion}, the auxiliary heating power, P_{aux}, and the Q-value = P_{fusion} / P_{aux}, expected in FFHR-d1B [2], respectively. These were obtained by using the Direct Profile Extrapolation (DPE) method [5]. The beta in the reactor was assumed to be the same as that in the experiment. In Fig. 2, depicted is the Q-value as a function of β_0 for the two configurations. As seen in Fig. 2, the Q-values in these two configurations similarly increase with β_0^2. Although the Q-value in the B_Q = 91 % configuration is not large enough at this moment, it can be increased further by increasing β_0 by reducing B_0 and/or increasing the heating power.

1) A. Sagara, et al., Fusion Eng. Des. **87** (2012) 594.
2) A. Sagara, et al., to appear in Fusion Eng. Des.
3) J. Miyazawa, et al., Nucl. Fusion **54** (2014) 043010.
4) J. Miyazawa, et al., Plasma Fusion Res. **3** (2008) S1047.
5) J. Miyazawa, et al., Fusion Eng. Des. **86** (2011) 2879.

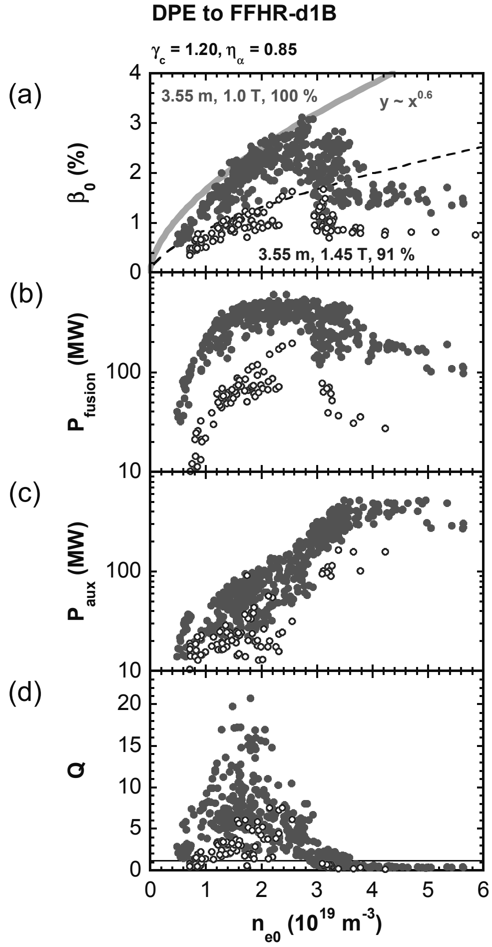

Fig. 1. Comparison of vertically elongated plasmas (open circles) and circular plasmas (closed circles) in the high aspect ratio configuration of γ_c = 1.20, where (a) the central beta, β_0, (b) the fusion power, P_{fusion}, (c) the auxiliary heating power, P_{aux}, and (d) the Q-value defined by P_{fusion} / P_{aux}, obtained by extrapolating the experimental data to FFHR-d1B using the DPE method are shown from top to bottom. The abscissa is the central electron density, n_{e0}, in the experiment.

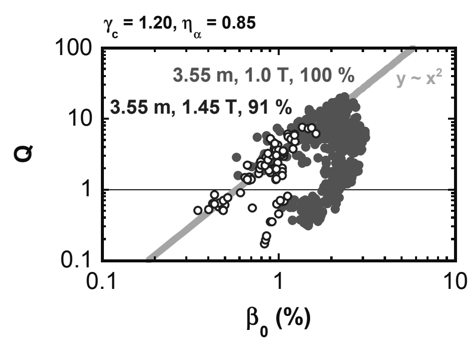

Fig. 2. The Q-value expected in FFHR-d1B as a function of the central beta, β_0.