§1. Global Confinement Analysis of NBI Heated Plasmas

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An analysis of global energy confinement times has progressed in the expanded operational regimes from the condition of the 2nd experimental campaign. In particular, a high magnetic-field close to 3 T and the inward shifted configuration characterized by the magnetic axis position R_{ax}=3.6m have been highlighted in the 3rd experimental campaign in 1999. Here NBI heated plasmas have been studied. Parameter regimes studied here cover B of 0.75-2.9 T, line averaged densities $\bar{n}_e$ of 0.8–7.0×10^{19} m^{-3} and heating power of NBI P_{abs} of 0.7-4.2 MW.

When the LHD data is compared with the medium-sized heliotron /torsatrons (MHT) which have a common physical basis, the improvement factor reaches 2 for the standard configuration with magnetic axis R_{ax} = 3.75 m. Here the scaling from MHT is expressed as follows;

$$\tau_E^{HTS} = 0.040 \times a^{2.06} R^{0.74} P_{abs}^{-0.63} \bar{n}_e^{-0.53} B^{0.80} \iota_{2/3}^{0.39} .$$

This improvement had been examined in the 2nd experimental campaign and found to be attributed to the formation of an edge pedestal which has not been observed in MHT. These characteristics have been maintained in the 3rd experimental campaign with the different operational condition of divertor material (carbon) and a high magnetic field. When the core inside ρ=0.9 is considered, analysis of LHD data with R_{ax} of 3.75 m and MHT indicates that the energy confinement can be scaled with the following reasonable scaling, which is almost dimensionally correct, (see Fig. 1);

$$\tau_E^{scl} = 0.059 \times a_{0.9}^{2.24} R^{0.67} P_{abs}^{-0.63} \bar{n}_e^{-0.54} B^{0.81} \iota_{2/3}^{0.47}$$

$$\propto \tau_B \rho^{*-0.53} \beta^{-0.33} \nu^{*0.07} A_p^{0.1} \iota_{2/3}^{1.36} a^{0.05} ,$$

where P_{abs} and $\bar{n}_e$ are in units of MW and $10^{19}m^{-3}$, respectively. This means that the core confinement in both LHD and MHT lies between the Bohm and gyro-Bohm scalings. The inward shifted configuration with R_{ax}=3.6m shows significant further enhancement in energy confinement times. The improvement factor compared with the scaling form MHT has exceeded 3 (see Fig.2). The H factor from ITER89P reaches 2.4 in the case with R_{ax}=3.6m when the rotational transform is translated into toroidal currents. The argument considering the core part, which has been successful for the case with R_{ax}=3.75m breaks down when the entire data set that includes the inward shifted configuration case with R_{ax} = 3.6 m is processed. This simple procedure yields a scaling expression with strange size dependence which is not dimensionally correct. While the components of the pedestal pressure of R_{ax} = 3.6 m and R_{ax} = 3.75 m cases are similar, the core component is larger for the R_{ax} = 3.6 m case by a factor of 1.6 (see also Fig.1). Although this configuration is unfavorable for the MHD interchange mode, the enhanced confinement is not deteriorated beyond <β> =2%.

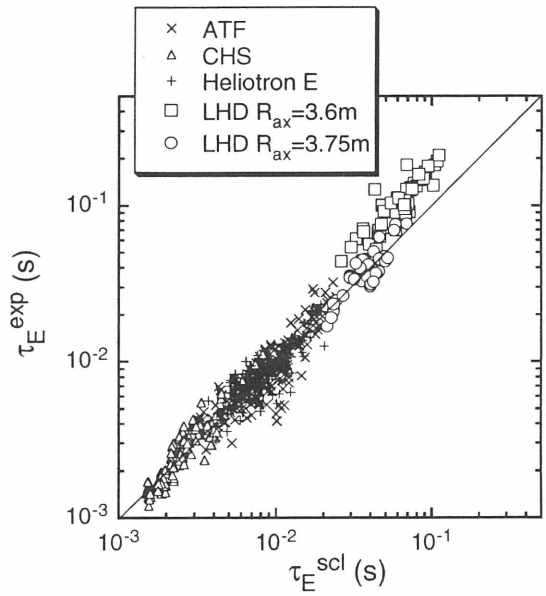

Fig.1 Comparison of experimental energy confinement times (core part of ρ < 0.9) with the scaling derived from data of the medium-sized heliotron / toratrons and LHD with R_{ax}=3.75 m.

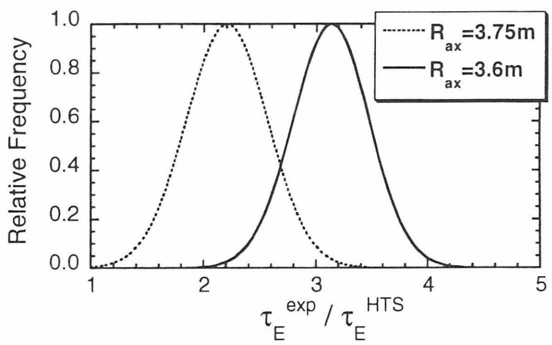

Fig.2 Relative frequency of experimental data as a function of a confinement enhancement factor to the scaling from the medium sized heliotron/torsatrons.