(1) Study of Deuterium Experiment Program in LHD

To achieve the higher performance plasma and to confirm technical advantages of LHD for designing the future economical steady state helical type reactor, the National Institute for Fusion Science (NIFS) had been making preparation for an experiment program using deuterium. On March in 2013, NIFS signed the Agreement for Environmental Conservation with local government bodies which include Toki-city, Tajimi-city, Mizunami-city and Gifu-prefecture. They also signed the agreement of operation of deuterium experiment of LHD.

These agreements are the achievement from the long and enormous efforts of mutual understanding with local government bodies and public relations activities. In 2007, the Safety Assessment Committee of NIFS Deuterium Experiment consisting of outside members only issued a first report which evaluated The Measures for Safety of LHD Deuterium Experiment was considered reasonable and proper. On March 11th, 2011, the Great East Japan Earthquake and the Fukushima No.1 nuclear power plant accident were happened. After the nuclear accident, the Safety Assessment Committee revalued the reexamined Measures for Safety of LHD Deuterium Experiment and reported the reexamined measures are reasonable and proper in Feb. 2012 again.

Recent LHD achievements of high ion temperature, high beta and very high density plasma and steady state operation show the realistic design base for economical helical fusion reactor. The extensive study of the deuterium experiment program has been conducted by incorporating a wide range of views from the university researchers through workshops and coordination research.

A major issue of the deuterium experiment is to build up the more reliable model which foresees future reactor design using the heliotron configuration. In the design data base, the definition of mass-dependency (isotope effect) with high accuracy is the most important physics issues. As a result of recent progress of high performance plasma experiments such as the high ion temperature mode plasma with impurity hall and the super dense core plasma with internal density barrier, deliberating future experiment program is greatly significant.

During the fiscal year of 2012, we have examined the impact of deuterium experiment on LHD by using tokamak experimental database. In tokamak plasmas, the favorable effect of mass can be found both in the L-mode (ITER89-P) and H-mode (IPB98(y,2)) scaling and the energy confinement time was scaled with $M^{0.5}$ and $M^{0.19}$, respectively, where M is the mass number of the plasma as shown below[1]:

$$\tau_E^{ITER89\text{-}P} = 4.8\times10^{-2}\, I^{0.85} B^{0.2} P^{-0.5} (n_e/10^{20})^{0.1} M^{0.5} R^{1.5} \varepsilon^{0.3} \kappa_a^{0.5}$$

$$\tau_E^{IPB98(y,2)} = 1.45\times10^{-1}\, I^{0.93} B^{0.15} P^{-0.69} (n_e/10^{20})^{0.41} M^{0.19} R^{1.97} \varepsilon^{0.58} \kappa_a^{0.78}$$

On the other hand, it is theoretically suggested that the effect of the isotope on the confinement could appear through ρ^* of Gyro-Bohm scaling. Thus, it is expected that the confinement time would be scaled as $M^{-0.5}$, which contradicts the empirical scaling laws. Detailed comparison of Deuterium and Hydrogen H-mode plasmas can be found in ref. [2], where the result is consistent to the IPB98(y,2) scaling. In ref. [2], it is pointed out the independent treatment of isotope effect from the ρ^* is necessary and it is still a remaining issue even in tokamak devices. To obtain conclusive understanding of confinement properties of plasmas, it has been demanded to establish unified law both in tokamak and helical devices. In that sense, the Deuterium experiment of LHD will provide us important information for the understanding of plasma physics.

We would like to note again that we can start specific program for LHD deuterium experiment by concluding agreement by the local governments on March 28th of 2013.

1) ITER Physics expert group, et.al., Nucl. Fusion **39**(1999)p.2175

2) Urano, H., et.al., Nucl. Fusion **52** (2012) 114021.

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