ISSN 0915-633X

NATIONAL INSTITUTE FOR FUSION SCIENCE

Thermal and Electric Oscillation Driven by Orbit Loss in Helical Systems

K. Itoh, H. Sanuki and S.-I. Itoh

(Received – Jan. 18, 1993)

NIFS-213

Mar. 1993

RESEARCH REPORT
NIFS Series

NAGOYA, JAPAN

Thermal and Electric Oscillation driven by Orbit Loss in Helical Systems

K. Itoh, H. Sanuki, S.-I. Itoh*

National Institute for Fusion Science, Nagoya 464-01, Japan

* Research Institute for Applied Mechanics, Kyushu University, Kasuga 816, Japan

Abstract

Coupled oscillation of the radial electric field, the heating power and the plasma temperature in helical systems is analysed. This oscillation is caused by the influence of the radial electric field on the direct loss of injected fast ions. The damped oscillations of the radial electric filed, temperature and fast-ion loss are predicted. Conditions for the mode and the dependence of the frequency are discussed.

keywords: radial electric field, direct orbit loss, oscillation, energy confinement time, slowing down time, torsatron/heliotron

PACS Index: 52.25.Fi, 52.55.Hc, 52.50.Gj

Recently the important role of the radial electric field on the confinement of the toroidal plasma is widely recognized. This is especially true for the plasmas in the toroidal helical devices such as torsatron/heliotron. This is because the trajectory of the helically trapped particles is strongly influenced by the radial potential difference which is of the order of the plasma temperature. Detailed work has been performed, specifying the magnetic configurations, on the motion of particles under the given electric field[1,2]. Recent progress has been focused on understanding the influence of the particle loss on the establishment of the radial electric field, including the analysis of the selfconsistent treatment of the radial electric field and the loss cone loss[3-5]. Majority of these selfconsistent analyses for helical plasmas, however, have been limited to the problems of the stationary solutions. The study on the dynamics, which is originated from the mutual influences between the loss cone loss and the electric field, has been studied associated with the H-mode physics in tokamaks[6], and requires further efforts. Oscillations of the loss of the fast ions has been reported on Heliotron-E device experimentally by Zushi and coworkers[7]. This phenomena, which we call the Zushi-oscillation, casts a strong motivation for the investigations. This is because the possible stationary operation is considered to be one of the main advantage of helical systems in proceeding to the future step of the fusion research.

In this article, we report the analytic study on the dynamics of the coupling between the radial electric field, plasma temperature, and loss cone loss in helical plasmas, and show the existence of the damped oscillations. The analysis is limited to the point model, simplifying the transport problems, in order to show the qualitative nature of the possible thermal and electric oscillations in helical plasmas.

We study the plasmas heated by the neutral beam injection with the injection energy W_b. The loss cone boundary is a functional of the potential profile. Owing to this relation, the heating power couples to the plasma potential. The heating power dictates the evolution of the plasma temperature. At the same time, the plasma temperature strongly influences the plasma potential. This closes a link, in helical plasmas, between the plasma temperature profile and radial electric field through the loss cone loss of injected fast ions. We, in the following, study the dynamics of this link of processes, showing the possible oscillations. (The plasma density is influential on the radial electric field as well. However, in order to keep the simplicity and clarity of the argument, we here neglect the coupling with the evolution of the density profile.)

The relation of the radial electric field and plasma temperature has been studied in helical systems. For the NBI heated plasmas, a simple formula,

$$E_r \simeq h_i T_i'/e + \delta E, \qquad (1)$$

works for the wide range of parameters[4], where the coefficient

h_i is the neoclassical coefficient (close to 3.5). The term δE is the contribution of the direct loss of fast ions. The expression for δE is given as[3,4]

$$\delta E \simeq -\Gamma_b \left[\partial \Gamma_i / \partial E_r\right]^{-1}, \qquad (2)$$

where Γ_b is the particle flux of fast ions, and Γ_i is that of the bulk ions. For the parameters of the plasma in present experiments, we have

$$\partial \Gamma_i / \partial E_r = e D_i n / T \qquad (3)$$

where D_i is the neoclassical ion diffusivity, n is the plasma density, and we take $T_i = T_e = T$ for the simplicity. Integrating δE, we have the contribution of the change δE to the potential difference, $\delta\phi$, as

$$-e\delta\phi \simeq \Delta_{layer}(T/D_i n)_a \Gamma_b \qquad (4)$$

where Δ_{layer} is the thickness of the layer where δE has a substantial contribution. Noting the relation that $\Gamma_b = P_{loss}/(4\pi^2 aRW_{loss})$, where P_{loss} is the loss power associated with the loss cone loss, a and R are minor and major radii, respectively, and W_{loss} is the typical energy of loss ions, we have

$$e\delta\Phi \simeq \frac{\Delta_{layer}}{4\pi^2 aRD_i n} \frac{T}{W_{loss}} P_{loss} \tag{5}$$

Summarizing Eqs.(1) and (5), the potential difference between the center and edge, Φ_0, is given as

$$e\Phi_0 = \{ -h_i T(0) - f_1 T_* \frac{T(a)}{W_{loss}} \frac{P_{loss}}{P_{in}} \} \tag{6}$$

The negative value of Φ indicates that E_r is negative, i.e., the static potential is lower at the axis. In Eq.(6), f_1 is a numerical coefficient defined by $a\Delta_{layer}n/2\tau_E D_i n(a)$, τ_E is the energy confinement time, n is the average density. The value T_* is the averaged temperature, which would be realized in the absence of the direct loss, given as

$$nT_* = \tau_E P_{in}/2\pi^2 a^2 R, \tag{7}$$

and P_{in} is the total injection power.

The loss cone boundary has been given in literatures[1,2]. Figure 1 illustrates the region of loss cone for the particles injected perpendicular to the magnetic field. In the case of the negative E_r, which we consider here, the loss cone region for the deeply trapped particles penetrates in the the core region for a particular energy range as $W_2 < W < W_1$ [2],

$$W_1 = \frac{e\{\Phi(a) - \Phi(r)\}}{\varepsilon_h(1-x^2) - \varepsilon_t(1+x)} \qquad (8\text{-}1)$$

and

$$W_2 = \frac{e\{\Phi(a) - \Phi(r)\}}{\varepsilon_h(1-x^2) + \varepsilon_t(1-x)} \qquad (8\text{-}2)$$

where ε_h and ε_t are the helical and toroidal magnetic ripple at the plasma edge, respectively, and $x = r/a$.

The energy range of the loss cone region at the magnetic axis, for present experimental parameters, lies between the injected energy and the bulk plasma temperature. (When the heating power is extremely high, the radial electric field would be so high that all the ions are trapped by the E×B rotation, and loss cone disappears for the injected fast ions.)

For the simplicity, we consider the case where the deposition of the fast ions are localized at the center with the specific injection angle of the helically trapped particles. (The extension for the case of the diffused deposition and for the case of the mixed injection angles is straightforward.) The boundary for the loss cone is given as $W_{loss} = W_1(0)$, i.e.,

$$W_{loss} = -e\Phi/(\varepsilon_h - \varepsilon_t) \qquad (9)$$

This relation holds for the general profile of the static potential for the case of $E_r<0$ [2]. When the condition $W_{loss}<W_b$

holds, as is the case of present experiments, the heating by the fast ions takes place during the slowing down process from the energy W_b to W_{loss}. Therefore the power which is used for the plasma heating, P_{heat}, is given as

$$P_{heat} = (1-W_{loss}/W_b)P_{in} \qquad (10)$$

The relation $P_{loss} + P_{heat} = P_{in}$ means the energy conservation relation. Figure 2 illustrates the relation of the heating power as the function of the plasma temperature.

Since the bulk plasma heating occurs through the slowing down process of fast ions, there is a time delay between the deposited power and the power transferred to bulk plasma. The time evolution of the power which causes the temporal change of the plasma temperature per unit volume, P, is simply modelled as

$$\partial P/\partial t = (P_{heat}/V_p - P)/\tau_{heat} \qquad (11)$$

where τ_{heat} is the typical slowing down time and V_p is the plasma volume.

The evolution of the plasma temperature is given by the energy transport equation

$$\partial T/\partial t = (P/n - T)/\tau_E. \qquad (12)$$

Equations (11) and (12) with equations (6), (9) and (10) constitute the set of basic equations.

We take the normalized form $\hat{T} = T/W_b$, $\hat{P} = \tau_E P/nW_b$, and $\tau = t/\tau_E$. Equations (6) and (9)-(12) are rewritten as

$$\partial\hat{T}/\partial\tau = \hat{P} - \hat{T} \tag{13-1}$$

$$\partial\hat{P}/\partial\tau = \sigma\{[1-C\hat{T}-C_1\hat{P}_{in}\hat{T}(a)]\hat{P}_{in} - \hat{P}\} \tag{13-2}$$

where $\sigma = \tau_E/\tau_{heat}$, $\hat{P}_{in}=\tau_E P_{in}/nV_p W_b$, $\hat{T}(a)=T(a)/W_b$, and C and C_1 are coefficients defined as

$$C = h_i \frac{T(0)}{T} \frac{1}{\varepsilon_h - \varepsilon_t} \tag{14}$$

and $C_1 = Cf_1/h_i$. For the torsatron/ heliotron configuration, such as Heliotron E and CHS, the term in Eq.(6), which is in proportion to f_1, has only a small contribution. We therefore neglect this term here.

Under the condition of our interest corresponding to the experimental conditions, which is shown in Fig.1, the equation (13) has one fixed point. The stationary solution is given as

$$\hat{T} = \hat{P} = \hat{P}_0 \equiv \hat{P}_{in}/(1+C\hat{P}_{in}) \tag{15}$$

The stability of the trajectory near this fixed point is studied by expanding $\hat{T}$ and $\hat{P}$ near $\hat{P}_0$ as $\hat{T} = \hat{P}_0 + x$ and $\hat{P} = \hat{P}_0 + y$. The linearized equation is given as

$$\begin{pmatrix} \partial x/\partial \tau \\ \\ \partial y/\partial \tau \end{pmatrix} = \begin{pmatrix} -1 & 1 \\ \\ -\sigma C\hat{P}_0 & -\sigma \end{pmatrix} \begin{pmatrix} x \\ \\ y \end{pmatrix} \tag{16}$$

by assuming that T(r) profile is fixed. Writing the time dependence as $(x, y) \sim (x_0, y_0)\exp(\lambda\tau)$, we have

$$\lambda = -(1+\sigma)/2 \pm \sqrt{(1-\sigma)^2/4-\sigma C\hat{P}_{in}} \tag{17}$$

This result shows that the oscillation around the stationary solution is possible if the condition

$$4\sigma C\hat{P}_{in} > (1-\sigma)^2 \tag{18}$$

is satisfied. This relation is more easily satisfied for the case that the slowing down time is close to the energy confinement time, $\sigma \simeq 1$, or the case of large C (i.e., ε_t is closer to ε_h). Since the real part of the eigenvalue λ is always negative, the oscillation is a damped oscillation. The oscillation is more clearly seen if $|Im\,\lambda| > |Re\lambda|$, or

$$C\hat{P}_{in} > 1 \tag{19}$$

In this case, the oscillation frequency, $|Im\,\lambda/\tau_E|$, is approximately proportional to $\sqrt{P_{in}/\tau_{heat}}$. If. Eq.(19) is not satisfied, the damping rate is comparable to or larger than the oscillation frequency, and the oscillation would not be observed.

From Eq.(18), we see that the oscillation is possible only if τ_E and τ_{heat} is finite. The oscillation requires the relaxations both in the real space and the velocity space.

The ratio between the amplitudes of oscillation of the temperature and the heating power can be also obtained. From Eq.(6), we see that the potential difference is $h_i T(0)/T$ times larger than the variation of the average temperature. This is also the case for the heating power. Substituting the eigenvalue Eq.(17) in to Eq.(16), we have the ratio between y and x, i.e., y_0/x_0, is given by

$$y_0/x_0 = (\sigma-1)/2 \pm \sqrt{(1-\sigma)^2/4-\sigma C\hat{P}_{in}} \qquad (20)$$

For the case that the oscillation can be observed, i.e., Eq.(19) holds and $\sigma \approx 1$, y is larger than x. This implies that the variation of the ion loss is more prominent than the change of the temperature.

In summary, the analytic theory of the thermal and electric oscillation in helical plasma is developed. The existence of the coupled oscillations of (T, E_r, W_{loss}, P_{heat}), caused by the coupling of the loss cone loss with the radial electric field, is predicted. This newly predicted coupled oscillation is found to be stable. This suggests that the oscillations appear as the postcursor to the sudden and large amplitude change of temperature change (such as the internal disruption). This is consistent with what Zushi and coworkers have observed on

Heliotron E. It is also noted, from Eq.(20), that the temporal variation is more prominent for the loss cone loss than for the plasma temperature. This explains one of the characteristics of the observed Zushi-oscillation, that the oscillation is prominent in the loss of energetic ions. The dependence of the oscillation frequency is derived, which is different from those in the conventional relaxation process of the pressure driven modes. If the relations $\tau_{heat} \propto T^{1.5}$ and $T \propto P_{in}{}^{\mu}$ hold, then the frequency is proportional to $P_{in}{}^{1/2-3\mu/4}$. The frequency is higher for higher heating power in the L-mode plasmas.

When heating power is extremely high so that $W_b < W_2$ holds, or

$$\frac{\tau_E P_{in}}{n V_p W_b} > \frac{1}{C} \frac{\varepsilon_h + \varepsilon_t}{\varepsilon_h - \varepsilon_t} \qquad (21)$$

the radial electric field would be so high that all the injected ions are trapped by the E×B rotation, and loss cone disappears for the fast ions. The extrapolation of this theory to the general injection angle would be straight forward. The variety in phenomena would be expected.

This oscillation requires both the time delays, i.e., real and velocity space diffusion. The analysis in this note is limited to the point model, which simplifies the diffusion process much. The study including the radial profiles, which would be necessary for the quantitative comparison with the Zushi-oscillation, is left for the future study.

One of the authors (KI) acknowledges discussion with Dr. H. Zushi. This work is partly supported by the Grant-in-Aid for Scientific Research of MoE Japan.

References

[1] For a review, K. Miyamoto: Nucl. Fusion **18** (1978) 243.
See also H. E. Mynick, W. N. G. Hitchon, Nucl. Fusion **23** (1983) 1053
R. H. Fowler, J. A. Rome, J. F. Lyon: Phys. Fluids **28** (1985) 338.

[2] K. Itoh, S.-I. Itoh, A. Fukuyama, K. Hanatani: Nucl. Fusion **29** (1989) 1851
K. Itoh, H. Sanuki, J. Todoroki, T. Kamimura, S.-I. Itoh, A. Fukuyama, K. Hanatani: Phys. Fluids **B3** 81991) 1296

[3] K. Itoh, H. Sanuki, S.-I. Itoh: Nucl. Fusion **32** (1992) 1047.

[4] H. Sanuki, K. Itoh, K. Ida, S.-I. Itoh: J. Phys. Soc. Jpn. **60** (1991) 3698, J. Phys. Soc. Jpn. **62** (1993) in press.

[5] K. Itoh, S.-I. Itoh, H. Sanuki, A. Fukuyama: Comment. Plasma Phys. Cont. Fusion **14** (1992) 343.

[6] S.-I. Itoh, K. Itoh, A. Fukuyama, Y. Miura, JFT-2M Group: Phys. Rev. Lett. **67** (1991) 2485.

[7] H. Zushi, et al.: in Proceedings of ***14th International Conf. Plasma Phys. Controlled Nucl. Fusion Research*** (Wurzburg, 1992, IAEA) paper C-4-1.

Figure Captions

Fig. 1 Loss cone region of the perpendicularly injected fast ions in torsatron/heliotron configuration. The initial energy W_b and the energy at the loss boundaries, W_1 and W_2, are also noted.

Fig. 2 Heating efficiency, P_{heat}/P_{in}, and the normalized loss power of the energy transport, $nTV_p/\tau_E P_{in}$ (dashed line), are plotted as a function of the temperature for the perpendicular injection. The crossing of two lines gives the stationary solution. When the temperature is very high and $W_2(0) > W_b$ holds, then the injected fast ions are confined by the E×B rotation, and the heating efficiency increases again.

Fig. 1

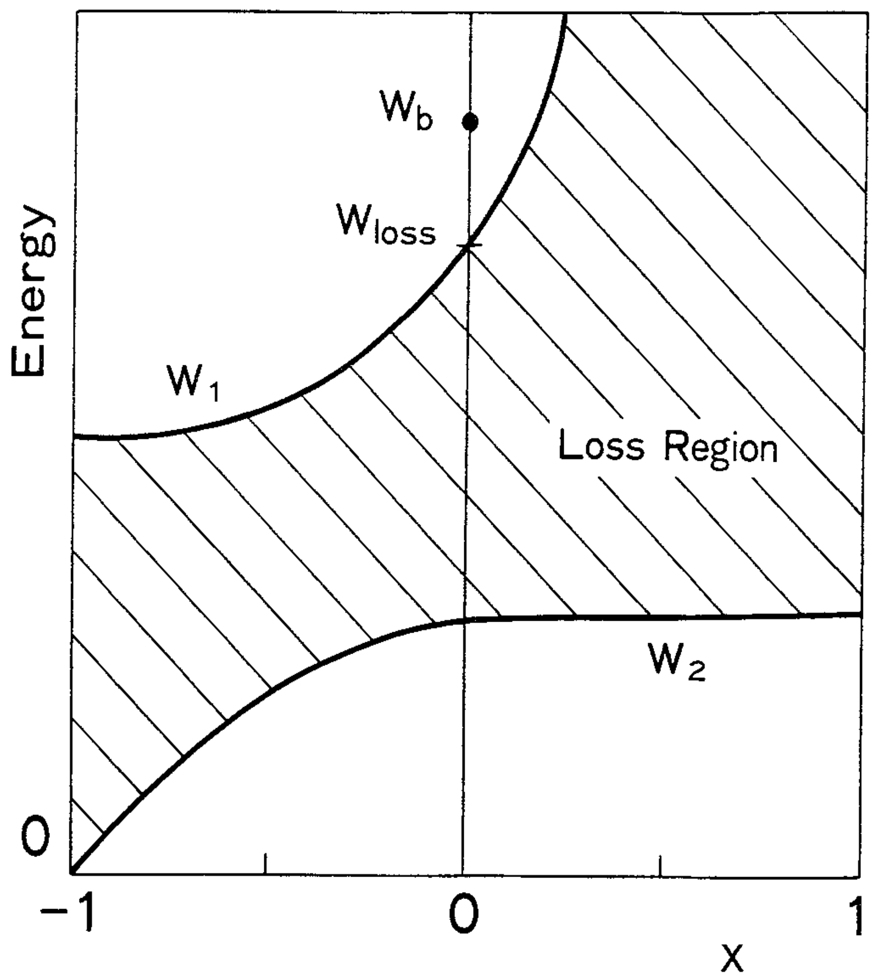
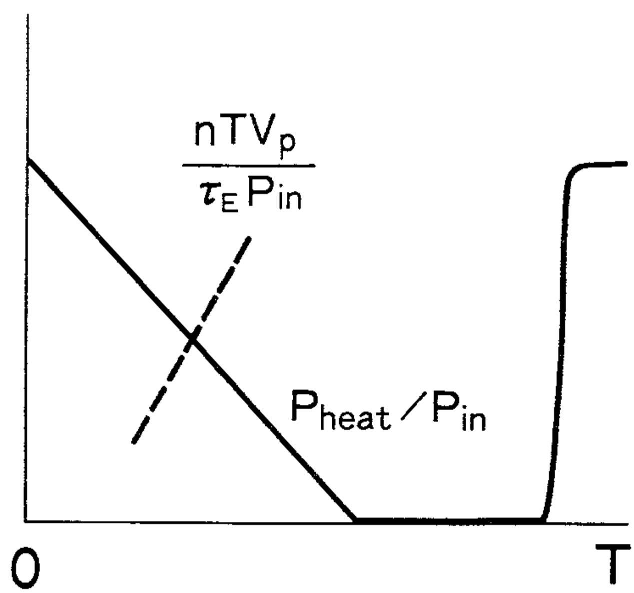


Fig. 2



Recent Issues of NIFS Series

NIFS-170 H. Sugama, M. Okamoto and M. Wakatani, *K- ε Model of Anomalous Transport in Resistive Interchange Turbulence* ; Sep, 1992

NIFS-171 H. Sugama, M. Okamoto and M. Wakatani, *Vlasov Equation in the Stochastic Magnetic Field* ; Sep. 1992

NIFS-172 N. Nakajima, M. Okamoto and M. Fujiwara, *Physical Mechanism of E_ψ-Driven Current in Asymmetric Toroidal Systems* ; Sep.1992

NIFS-173 N. Nakajima, J. Todoroki and M. Okamoto, *On Relation between Hamada and Boozer Magnetic Coordinate System* ; Sep. 1992

NIFS-174 K. Ichiguchi, N. Nakajima, M. Okamoto, Y. Nakamura and M. Wakatani, *Effects of Net Toroidal Current on Mercier Criterion in the Large Helical Device* ; Sep. 1992

NIFS-175 S. -I. Itoh, K. Itoh and A. Fukuyama, *Modelling of ELMs and Dynamic Responses of the H-Mode* ; Sep. 1992

NIFS-176 K. Itoh, S.-I. Itoh, A. Fukuyama, H. Sanuki, K. Ichiguchi and J. Todoroki, *Improved Models of β-Limit, Anomalous Transport and Radial Electric Field with Loss Cone Loss in Heliotron / Torsatron* ; Sep. 1992

NIFS-177 N. Ohyabu, K. Yamazaki, I. Katanuma, H. Ji, T. Watanabe, K. Watanabe, H. Akao, K. Akaishi, T. Ono, H. Kaneko, T. Kawamura, Y. Kubota, N. Noda, A. Sagara, O. Motojima, M. Fujiwara and A. Iiyoshi, *Design Study of LHD Helical Divertor and High Temperature Divertor Plasma Operation* ; Sep. 1992

NIFS-178 H. Sanuki, K. Itoh and S.-I. Itoh, *Selfconsistent Analysis of Radial Electric Field and Fast Ion Losses in CHS Torsatron / Heliotron* ; Sep. 1992

NIFS-179 K. Toi, S. Morita, K. Kawahata, K. Ida, T. Watari, R. Kumazawa, A. Ando, Y. Oka, K. Ohkubo, Y. Hamada, K. Adati, R. Akiyama, S. Hidekuma, S. Hirokura, O. Kaneko, T. Kawamoto, Y. Kawasumi, M. Kojima, T. Kuroda, K. Masai, K. Narihara, Y. Ogawa, S. Okajima, M. Sakamoto, M. Sasao, K. Sato, K. N. Sato, T. Seki, F. Shimpo, S. Tanahashi, Y. Taniguchi, T. Tsuzuki, *New Features of L-H Transition in Limiter H-Modes of JIPP T-IIU* ; Sep. 1992

NIFS-180 H. Momota, Y. Tomita, A. Ishida, Y. Kohzaki, M. Ohnishi, S. Ohi, Y. Nakao and M. Nishikawa, *D-^{3}He Fueled FRC Reactor "Artemis-L"*

; Sep. 1992

NIFS-181 T. Watari, R. Kumazawa, T. Seki, Y. Yasaka, A. Ando, Y. Oka,O. Kaneko, K. Adati, R. Akiyama, Y. Hamada, S. Hidekuma, S. Hirokura, K. Ida, K. Kawahata, T. Kawamoto, Y. Kawasumi, S. Kitagawa, M. Kojima, T. Kuroda, K. Masai, S. Morita, K. Narihara, Y. Ogawa, K. Ohkubo, S. Okajima, T. Ozaki, M. Sakamoto, M. Sasao, K. Sato, K. N. Sato, F.Shimpo, H. Takahashi, S. Tanahasi, Y. Taniguchi, K. Toi, T. Tsuzuki and M. Ono, *The New Features of Ion Bernstein Wave Heating in JIPP T-IIU Tokamak* ;Sep, 1992

NIFS-182 K. Itoh, H. Sanuki and S.-I. Itoh, *Effect of Alpha Particles on Radial Electric Field Structure in Torsatron / Heliotron Reactor*; Sep. 1992

NIFS-183 S. Morimoto, M. Sato, H. Yamada, H. Ji, S. Okamura, S. Kubo, O. Motojima, M. Murakami, T. C. Jernigan, T. S. Bigelow, A. C. England, R. S. Isler, J. F. Lyon, C. H. Ma, D. A. Rasmussen, C. R. Schaich, J. B. Wilgen and J. L. Yarber, *Long Pulse Discharges Sustained by Second Harmonic Electron Cyclotron Heating Using a* $35GH_Z$ *Gyrotron in the Advanced Toroidal Facility*; Sep. 1992

NIFS-184 S. Okamura, K. Hanatani, K. Nishimura, R. Akiyama, T. Amano, H. Arimoto, M. Fujiwara, M. Hosokawa, K. Ida, H. Idei, H. Iguchi, O. Kaneko, T. Kawamoto, S. Kubo, R. Kumazawa, K. Matsuoka, S. Morita, O. Motojima, T. Mutoh, N. Nakajima, N. Noda, M. Okamoto, T. Ozaki, A. Sagara, S. Sakakibara, H. Sanuki, T. Seki, T. Shoji, F. Shimbo, C. Takahashi, Y. Takeiri, Y. Takita, K. Toi, K. Tsumori, M. Ueda, T. Watari, H. Yamada and I. Yamada, *Heating Experiments Using Neutral Beams with Variable Injection Angle and ICRF Waves in CHS* ; Sep. 1992

NIFS-185 H. Yamada, S. Morita, K. Ida, S. Okamura, H. Iguchi, S. Sakakibara, K. Nishimura, R. Akiyama, H. Arimoto, M. Fujiwara, K. Hanatani, S. P. Hirshman, K. Ichiguchi, H. Idei, O. Kaneko, T. Kawamoto, S. Kubo, D. K. Lee, K. Matsuoka, O, Motojima, T. Ozaki, V. D. Pustovitov, A. Sagara, H. Sanuki, T. Shoji, C. Takahashi, Y. Takeiri, Y. Takita, S. Tanahashi, J. Todoroki, K. Toi, K. Tsumori, M. Ueda and I. Yamada, *MHD and Confinement Characteristics in the High-*β *Regime on the CHS Low-Aspect-Ratio Heliotron / Torsatron* ; Sep. 1992

NIFS-186 S. Morita, H. Yamada, H. Iguchi, K. Adati, R. Akiyama, H. Arimoto, M. Fujiwara, Y. Hamada, K. Ida, H. Idei, O. Kaneko, K. Kawahata, T. Kawamoto, S. Kubo, R. Kumazawa, K. Matsuoka, T. Morisaki, K. Nishimura, S. Okamura, T. Ozaki, T. Seki, M. Sakurai, S, Sakakibara, A. Sagara, C. Takahashi, Y. Takeiri, H. Takenaga, Y. Takita, K. Toi, K. Tsumori, K. Uchino, M. Ueda, T. Watari, I. Yamada, *A Role of Neutral Hydrogen in CHS Plasmas with Reheat and Collapse and Comparison with JIPP T-IIU Tokamak Plasmas* ; Sep. 1992

NIFS-187 K. Ioth, S.-I. Itoh, A. Fukuyama, M. Yagi and M. Azumi, *Model of the L-Mode Confinement in Tokamaks* ; Sep. 1992

NIFS-188 K. Itoh, A. Fukuyama and S.-I. Itoh, *Beta-Limiting Phenomena in High-Aspect-Ratio Toroidal Helical Plasmas*; Oct. 1992

NIFS-189 K. Itoh, S. -I. Itoh and A. Fukuyama, *Cross Field Ion Motion at Sawtooth Crash* ; Oct. 1992

NIFS-190 N. Noda, Y. Kubota, A. Sagara, N. Ohyabu, K. Akaishi, H. Ji, O. Motojima, M. Hashiba, I. Fujita, T. Hino, T. Yamashina, T. Matsuda, T. Sogabe, T. Matsumoto, K. Kuroda, S. Yamazaki, H. Ise, J. Adachi and T. Suzuki, *Design Study on Divertor Plates of Large Helical Device (LHD)* ; Oct. 1992

NIFS-191 Y. Kondoh, Y. Hosaka and K. Ishii, *Kernel Optimum Nearly-Analytical Discretization (KOND) Algorithm Applied to Parabolic and Hyperbolic Equations* : Oct. 1992

NIFS-192 K. Itoh, M. Yagi, S.-I. Itoh, A. Fukuyama and M. Azumi, *L-Mode Confinement Model Based on Transport-MHD Theory in Tokamaks* ; Oct. 1992

NIFS-193 T. Watari, *Review of Japanese Results on Heating and Current Drive* ; Oct. 1992

NIFS-194 Y. Kondoh, *Eigenfunction for Dissipative Dynamics Operator and Attractor of Dissipative Structure* ; Oct. 1992

NIFS-195 T. Watanabe, H. Oya, K. Watanabe and T. Sato, *Comprehensive Simulation Study on Local and Global Development of Auroral Arcs and Field-Aligned Potentials* ; Oct. 1992

NIFS-196 T. Mori, K. Akaishi, Y. Kubota, O. Motojima, M. Mushiaki, Y. Funato and Y. Hanaoka, *Pumping Experiment of Water on B and* LaB_6 *Films with Electron Beam Evaporator* ; Oct., 1992

NIFS-197 T. Kato and K. Masai, *X-ray Spectra from Hinotori Satellite and Suprathermal Electrons* ; Oct. 1992

NIFS-198 K. Toi, S. Okamura, H. Iguchi, H. Yamada, S. Morita, S. Sakakibara, K. Ida, K. Nishimura, K. Matsuoka, R. Akiyama, H. Arimoto, M. Fujiwara, M. Hosokawa, H. Idei, O. Kaneko, S. Kubo, A. Sagara, C. Takahashi, Y. Takeiri, Y. Takita, K. Tsumori, I. Yamada and H. Zushi, *Formation of H-mode Like Transport Barrier in the CHS Heliotron / Torsatron* ; Oct. 1992

NIFS-199 M. Tanaka, *A Kinetic Simulation of Low-Frequency Electromagnetic Phenomena in Inhomogeneous Plasmas of Three-Dimensions* ; Nov. 1992

NIFS-200 K. Itoh, S.-I. Itoh, H. Sanuki and A. Fukuyama, *Roles of Electric Field on Toroidal Magnetic Confinement*, Nov. 1992

NIFS-201 G. Gnudi and T. Hatori, *Hamiltonian for the Toroidal Helical Magnetic Field Lines in the Vacuum*; Nov. 1992

NIFS-202 K. Itoh, S.-I. Itoh and A. Fukuyama, *Physics of Transport Phenomena in Magnetic Confinement Plasmas*; Dec. 1992

NIFS-203 Y. Hamada, Y. Kawasumi, H. Iguchi, A. Fujisawa, Y. Abe and M. Takahashi, *Mesh Effect in a Parallel Plate Analyzer*; Dec. 1992

NIFS-204 T. Okada and H. Tazawa, *Two-Stream Instability for a Light Ion Beam -Plasma System with External Magnetic Field;* Dec. 1992

NIFS-205 M. Osakabe, S. Itoh, Y. Gotoh, M. Sasao and J. Fujita, *A Compact Neutron Counter Telescope with Thick Radiator (Cotetra) for Fusion Experiment*; Jan. 1993

NIFS-206 T. Yabe and F. Xiao, *Tracking Sharp Interface of Two Fluids by the CIP (Cubic-Interpolated Propagation) Scheme*, Jan. 1993

NIFS-207 A. Kageyama, K. Watanabe and T. Sato, *Simulation Study of MHD Dynamo : Convection in a Rotating Spherical Shell*; Feb. 1993

NIFS-208 M. Okamoto and S. Murakami, *Plasma Heating in Toroidal Systems*; Feb. 1993

NIFS-209 K. Masai, *Density Dependence of Line Intensities and Application to Plasma Diagnostics*; Feb. 1993

NIFS-210 K. Ohkubo, M. Hosokawa, S. Kubo, M. Sato, Y. Takita and T. Kuroda, *R&D of Transmission Lines for ECH System* ; Feb. 1993

NIFS-211 A. A. Shishkin, K. Y. Watanabe, K. Yamazaki, O. Motojima, D. L. Grekov, M. S. Smirnova and A. V. Zolotukhin, *Some Features of Particle Orbit Behavior in LHD Configurations*; Mar. 1993

NIFS-212 Y. Kondoh, Y. Hosaka and J.-L. Liang, *Demonstration for Novel Self-organization Theory by Three-Dimensional Magnetohydrodynamic Simulation*; Mar. 1993