ISSN 0915-633X

INTERNATIONAL ATOMIC ENERGY AGENCY

FOURTEENTH INTERNATIONAL CONFERENCE ON PLASMA PHYSICS AND CONTROLLED NUCLEAR FUSION RESEARCH

Würzburg, Germany, 30 September – 7 October 1992

IAEA-CN-56/C-2-2

NATIONAL INSTITUTE FOR FUSION SCIENCE

MHD and Confinement Characteristics in the High-β Regime on the CHS Low-Aspect-Ratio Heliotron/Torsatron

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

(Received – Sep. 14, 1992)

NIFS-185 Sep. 1992

RESEARCH REPORT
NIFS Series

NAGOYA, JAPAN

INTERNATIONAL ATOMIC ENERGY AGENCY

FOURTEENTH INTERNATIONAL CONFERENCE ON PLASMA PHYSICS AND CONTROLLED NUCLEAR FUSION RESEARCH

Würzburg, Germany, 30 September – 7 October 1992

IAEA-CN-56/ C-2-2

MHD AND CONFINEMENT CHARACTERISTICS IN THE HIGH-β REGIME ON THE CHS LOW-ASPECT-RATIO HELIOTRON/TORSATRON

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§, I.YAMADA

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

* Plasma Science Center, Nagoya University, Nagoya 464-01, Japan

** Plasma Physics Laboratory, Kyoto University, Uji 611, Japan

† Oak Ridge National Laboratory, Oak Ridge, TN37831, USA

†† Kurchatov Institute, Moscow, Russia

§ Instituto Nacional de Pesquisas Espaciais, Sao Paulo, Brazil

MHD AND CONFINEMENT CHARACTERISTICS IN THE HIGH-β REGIME ON THE CHS LOW-ASPECT-RATIO HELIOTRON/TORSATRON

Abstract

The MHD and confinement characteristics associated with the finite-β effect have been investigated in the low-aspect-ratio heliotron/torsatron Compact Helical System (CHS). $\langle\beta\rangle$ values of 1.8% in the quasi-steady state and 1.9% in the transient phase have been realized and β_0 has reached 5.8%. The experimentally observed equilibrium characteristics are in good agreement with current 3-D analysis. Significant instabilities suppressing β value or terminating the discharges have not yet been observed in standard operation. This is supposed to be due to self-stabilization of the ideal interchange mode by spontaneously generated magnetic wells, which is a distinguishing feature of the low aspect ratio. Magnetic fluctuations with the frequency range less than 100 kHz have reached as much as 0.1% of the poloidal equilibrium field. The predominant modes are globally coherent with the low mode number and do not affect confinement. The scaling of β follows the prediction from LHD scaling. The thermal diffusivity depends on the local scale length of β, the characteristics of which is emphasized for the magnetic hill region. The present β value is limited by saturation of confinement with increasing density and degradation of confinement with increasing power rather than by MHD characteristics.

KEYWORDS: *Shafranov shift, resistive interchange mode*

1. INTRODUCTION

Toroidal helical systems (stellarator/heliotron/torsatron) have traditionally had large aspect ratios, as seen in a series of Wendelstein and Heliotron devices (for a review, see Ref.[1]). Recently, low-aspect-ratio helical systems have attracted much interest because of favourable MHD aspects as well as their potential use as reactors[2,3]. In this paper, we have investigated the characteristics of MHD equilibrium and stability, and the confinement properties associated with finite-β effects in a low-aspect-ratio heliotron/torsatron configuration, i.e. the Compact Helical System (CHS)[4] ($l/m = 2/8$, $R/a \sim 1$ m / 0.2 m). The CHS has an aspect ratio as low as 5, which is uniquely low for toroidal helical devices and induces strong breaking of helical symmetry. The Shafranov shift, Δ_{Sh}, is estimated for the low β case to be $\Delta_{Sh} = \beta_0 A_p a / \iota_a^2$. Since ι_a is approximately proportional to A_p, Δ_{Sh} is enhanced in a low-aspect-ratio configuration. The profile of ι which is opposite to that of the tokamak facilitates a large Shafranov shift ($\iota_0 \sim 0.3$ and $\iota_a \sim 1$ in CHS). Efficient generation of a magnetic well due to a large Shafranov shift tends to stabilize the interchange instability, but a large distortion of the magnetic surface structure might cause deterioration of confinement. The experimental results obtained here are of importance in demonstrating the advantage of a low-aspect-ratio configuration and clarifying the relevance of available 3-D theoretical models.

2. EXPERIMENTS AND DISCUSSIONS

The target plasmas have been produced by ECH (28 and 53 GHz) or ICRF (7.5 and 13 MHz) and heated by two balance injected neutral beams with a total power of 1.7 MW. The magnetic field has been operated in the range between 0.5 T and 1.6 T.

The procedure reconstructing a finite-β equilibrium from the experimental kinetic data of quasi-steady plasmas using the 3-D equilibrium code VMEC[5] has been established for the CHS experiments[6]. The description of finite-β equilibria is a prerequisite for MHD stability analysis as well as various transport analyses. The reconstructed equilibrium with anisotropic pressure due to a tangentially injected beam[7] is in good agreement with the experimental observations. Figure 1(a) shows a comparison of the Shafranov shift estimated from the reconstructed equilibrium with that from the ion temperature profile measured by 34 ch-charge-exchange-recombination spectroscopy with 7.5 mm spatial resolution[8]. The shift of the plasma outboard boundary derived from the VUV emission profile (350 Å~1700 Å) also indicates good correlation with the 3-D computation of the last closed flux surface (see Fig.1(b)). It should be noted that the quality of the discharge significantly affects the effective minor radius of the plasma; the discharges with lower temperature have smaller minor radius.

The maximum value of <β> including the beam pressure in the available profile database is 1.2% in the case of the vacuum magnetic axis position R_{ax} = 0.92 m, B_t = 0.5 T, $\bar{n}_e$ = 5.0 × 10^{19} m^{-3}, P_{abs} = 720 kW. On a single shot basis, the highest measured diamagnetic <β_{dia}> in quasi-steady state is 1.5% when R_{ax} = 0.92 m, B_t = 0.5 T, $\bar{n}_e$ = 5.4 × 10^{19} m^{-3} and P_{abs} = 770 kW. In the transient phase realized by a reheated mode [9], <β_{dia}> has reached 1.7% when R_{ax} = 0.95 m, B_t = 0.65 T, $\bar{n}_e$ = 5.7 × 10^{19} m^{-3} and P_{abs} = 820 kW. If we assume a reasonable parabolic profile, these shots have <β> of 1.8% and 1.9%, and β_0 of 5.4% and 5.8%, respectively; the last value corresponds to 80% of the conventional equilibrium β limit defined by the Shafranov shift reaching a value of half the minor radius.

Poloidal field flexibility in CHS enables external control of the magnetic well and shear by changing the magnetic axis position. In a significantly inward shifted configuration, i.e R_{ax} = 0.89 m, where the magnetic hill is increased, sawtooth phenomena in the core region (ρ~0.25) accompanying magnetic fluctuation with resonant m/n = 3/1 mode have sometimes been observed by soft X-ray diagnostics. In other experimental magnetic configurations, self-stabilization of the ideal interchange mode due to spontaneously generated magnetic well enables a Mercier stable discharge towards the equilibrium β limit. Strong instabilities invoking major disruption and sawtooth oscillation have not been observed experimentally except for the case of R_{ax} = 0.89 m. However, since the magnetic hill cannot be excluded in the peripheral region, the resistive interchange mode is destabilized, even for low β[10].A magnetic fluctuation of a level of up to 0.1% of the poloidal equilibrium magnetic field at the surface has been observed experimentally. The dominant component has a globally coherent structure with $m \leq 4$ and $n \leq 3$, with its resonance in the magnetic hill region. These modes usually rotate in the ion diamagnetic direction and are not synchronized with the bulk plasma rotation estimated from the Doppler shift of impurity line emission. The characteristics of magnetic fluctuation depend on the pressure profile. Figure 2(a) shows the pressure profiles in the intermediate region for different discharges with $R_{ax} = 0.89$ m and $B_t = 0.95$ T. Periodic bursts of the coherent $m/n = 2/1$ mode have been detected for the lowest pressure case (see Fig.2(b)). No events correlating with these bursts have been observed in soft X-ray and fast ion loss. In spite of the appearance of the instability, the pressure gradient around $\iota = 1/2$ can be increased by increasing density and/or power. This suggests that the coherent instability with low mode number does not limit local confinement. With increasing pressure, the ensemble averaged fluctuation continued increasing but the coherent component was suppressed. Also the burst of $m/n = 2/1$ mode became less distinct and the power spectrum of the magnetic fluctuation changed into a $1/f$ like shape. In the highest pressure case, an $m/n = 1$ mode emerged instead of the $m/n = 2/1$ mode.

Confinement scaling can easily be rewritten for β scaling. When we apply the LHD scaling[11], we get $\beta\ (\%) = 1.44 P_{abs}^{0.42}\ \bar{n}_e^{0.69} B_t^{-1.16} R^{-0.25}$, where P_{abs}, $\bar{n}_e$, B_t and R are in MW,10^{20}m^{-3},T and m units, respectively. The experimental data based on diamagnetic measurements follow this scaling well in the realized range with $\langle\beta_{dia}\rangle \leq 1.5\%$ (see Fig.3(a)). A small decline in the higher β region corresponds to high density discharges. Since the dependence of β on B_t is not degraded down to 0.5 T operation, the trend of degradation in the high-β regime is supposed to be due to confinement saturation with increasing density or power, and not with an MHD effect related to the increase of β. Improvement of confinement by inward shifted configuration[12], which is unfavourable to the interchange mode, could be realized in high-β oriented discharges down to 0.5 T.

Although the global mode destabilized in the magnetic hill region does not seem to degrade the confinement in CHS, it is probable that the resistive interchange mode with microscopic scale dominates transport [13]. If anomalous transport in CHS plasmas is related to resistive interchange mode, the thermal diffusivity χ should show a dependence on the pressure gradient and change its characteristics in the magnetic well region. To distinguish these features, χ_e and χ_i derived from the power balance for discharges in the profile database are normalized by $T_e^{3/2} B_t^{-2}$ and shown as a function of the local scale length of β, L_β, in Fig.2(b). Strong coincidence of χ_e and χ_i has been observed, which is a common feature of the microinstability. The normalized χ is a decreasing function of L_β, and the dependence appears to be enhanced in the magnetic hill region ($\propto L_\beta^{0.8}$ in the hill region and $\propto L_\beta^{0.3}$ in the well region).

ACKNOWLEDGEMENTS

Useful discussions with Dr.K.Itoh and colleagues in the torus experiment group as well as continuing encouragement by Director-genral A.Iiyoshi are greatly appreciated by the authors.

REFERENCES

[1] CARRERAS,B.A., et al., Nucl.Fusion **28** (1988) 1613.
[2] SHAFRANOV,V.D., Phys. Fluids **26** (1983) 357.
[3] CARRERAS,B.A., et al., Nucl. Fusion **28** (1988) 1195.
[4] MATSUOKA,K. et al., in *Plasma Physics and Controlled Nuclear Fusion Research, 1988* (Proc.12th IAEA Int. Conf.,Nice, 1988) , Vol. 2, IAEA, Vienna (1989) 411.
[5] HIRSHMAN, S.P., Comput. Phys. Commun. **43** (1986) 143.
[6] YAMADA,H. et al., in *Controlled Fusion and Plasma Physics* (Proc. 18th Europ. Conf. Berlin, Part II (1991) 137.
[7] YAMADA,H., et al., Nucl. Fusion **31** (1992) 25.
[8] IDA, K., HIDEKUMA, S., Rev. Sci. Instrum. **60** (1989) 876.
[9] MORITA, S., et al., IAEA-CN-56/C-2-5, this conference.
[10] HARRIS,J.H., et al., Phys. Rev. Lett. **63** (1989) 1249.
[11] SUDO, S., et al., Nucl. Fusion **30** (1990) 11.
[12] KANEKO,O., et al., in *Plasma Physics and Controlled Nuclear Fusion Research, 1990* (Proc.13th IAEA Int. Conf. Washington, 1990), Vol.2, IAEA, Vienna (1991) 473.
[13] see e.g. CARRERAS,B.A., et al., Phys. Fluids **30** (1987) 1388; SUGAMA,H., WAKATANI,M., J. Phys .Soc. Jpn. **57** (1988) 2010; ITOH,K., et al., Phys. Rev.Lett. **69** (1992) 1050.

FIGURE CAPTIONS

FIG.1 Equilibrium characteristics. (a) Comparison of Shafranov shift of the reconstructed equilibrium from experimental data, $\Delta_{Sh}{}^{cmp}$ with that from the peak position of T_i, $\Delta_{Sh}{}^{exp}$ at the vertically elongated cross section (ϕ=0). The data are normalized by the radius on the shorter axis; a_s. The top abscissa is the toroidally averaged value of Shafranov shift. The database covers R_{ax} = 0.89 ~ 1.02 m, B_t = 0.5 ~ 1.6 T, $\bar{n}_e$ = (0.8~5.5) × 10^{19} m^{-3}, P_{abs} = 190 ~ 760 kW and <β> = 0.15 ~ 1.2%. (b) Shift of the outboard boundary derived from the emission profile of VUV compared with that of the last closed flux surface given by the 3-D computation.

FIG.2 Instability characteristics. (a) Electron kinetic pressure profile measured by Thomson scattering. The $\bar{n}_e$, P_{abs}, and <β_{dia}> are Case1: 1.0 × 10^{19} m^{-3}, 180 kW and 0.16%, Case2: 2.5 × 10^{19} m^{-3}, 480 kW and 0.40%, Case3: 4.3 × 10^{19} m^{-3}, 740 kW and 0.57%, Case4: 5.3×10^{19} m^{-3}, 970 kW and 0.74 %, respectively. Arrows show the location of ι =1/2. (b) Observed magnetic fluctuations with the frequency band between 3kHz and 100kHz.

FIG.3 Confinement characteristics. (a) Comparison of experimental <β_{dia}> based for quasi steady plasma with the scaling derived from the LHD scaling. Closed symbols are for $B_t \leq 0.6$ T. The database covers R_{ax} = 0.89 ~ 1.02 m, B_t = 0.5 ~ 1.6 T, $\bar{n}_e$ = (0.6~7.1) × 10^{19} m^{-3}, P_{abs} = 160 ~ 950 kW. Symbols are plotted for different density regions with reference to the empirical critical density limit on helical devices [11]; $n_c = 0.25 P_{abs}{}^{0.5} B_t{}^{0.5} a^{-1} R^{-0.5}$. (b) Thermal diffusivity as a function of the local scale length of β. The database is the same as described in Fig.1(a).

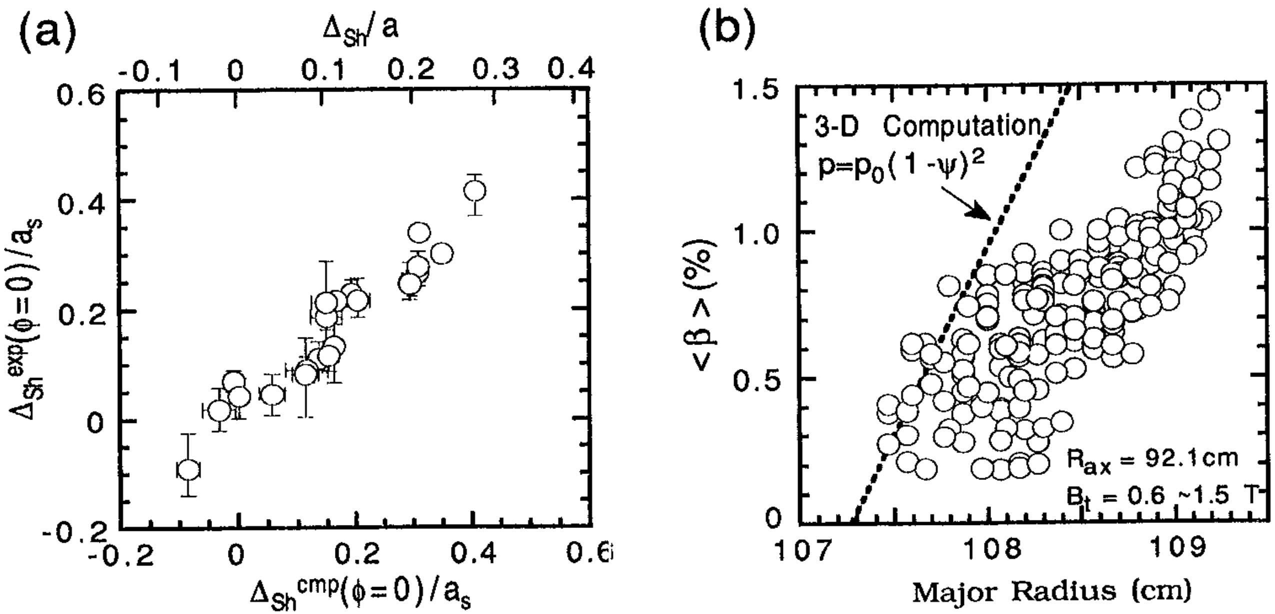
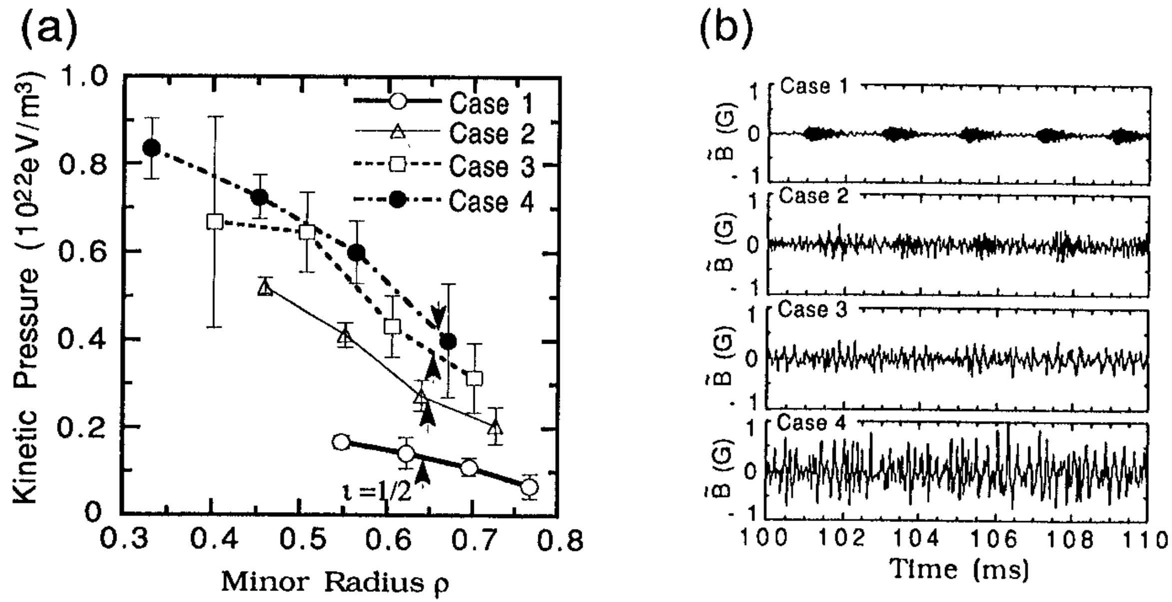

(a)
Δ_Sh/a
-0.1
0
0.1
0.2
0.3
0.4
0.6
0.4
0.2
0
-0.2
Δ_Sh^exp(φ=0)/a_s
-0.2
0
0.2
0.4
0.6
Δ_Sh^cmp(φ=0)/a_s
(b)
1.5
1.0
0.5
0
<β> (%)
3-D Computation
p=p_0(1-ψ)^2
R_ax = 92.1cm
B_t = 0.6 ~1.5 T
107
108
109
Major Radius (cm)

Fig.1



(a)
Kinetic Pressure (10^{22}eV/m^3)
1.0
0.8
0.6
0.4
0.2
0
0.3
0.4
0.5
0.6
0.7
0.8
Minor Radius ρ
Case 1
Case 2
Case 3
Case 4
ι =1/2
(b)
Case 1
Case 2
Case 3
Case 4
$\tilde{B}$ (G)
1
0
-1
100
102
104
106
108
110
Time (ms)

Fig.2

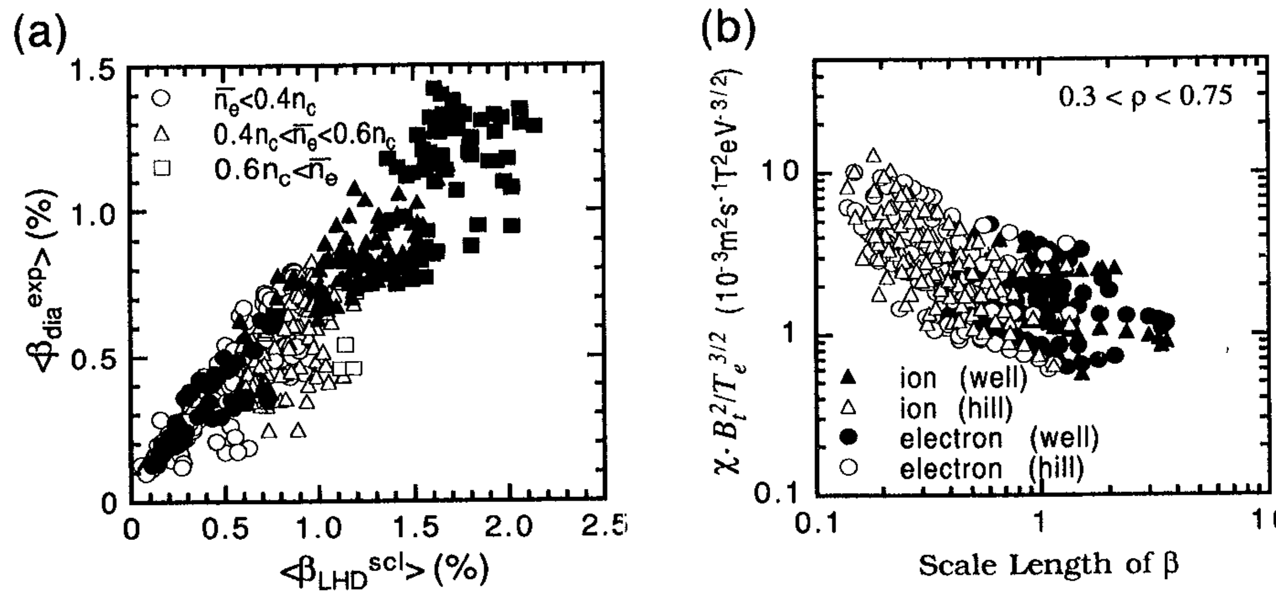

(a)
(b)
$\bar{n}_e$<0.4n_c
0.4n_c<$\bar{n}_e$<0.6n_c
0.6n_c<$\bar{n}_e$
<β$_{dia}$^{exp}> (%)
<β$_{LHD}$^{scl}> (%)
0.3 < ρ < 0.75
ion (well)
ion (hill)
electron (well)
electron (hill)
$\chi \cdot B_t^2/T_e^{3/2}$ ($10^{-3}m^2s^{-1}T^2eV^{-3/2}$)
Scale Length of β

Fig.3

Recent Issues of NIFS Series

NIFS-140 K. Itoh, S. -I. Itoh and A. Fukuyama, *Theory of Anomalous Transport in Toroidal Helical Plasmas;* Mar. 1992

NIFS-141 Y. Kondoh, *Internal Structures of Self-Organized Relaxed States and Self-Similar Decay Phase;* Mar. 1992

NIFS-142 U. Furukane, K. Sato, K. Takiyama and T. Oda, *Recombining Processes in a Cooling Plasma by Mixing of Initially Heated Gas*; Mar. 1992

NIFS-143 Y. Hamada, K. Masai, Y. Kawasumi, H. Iguchi, A. Fijisawa and JIPP T-IIU Group, *New Method of Error Elimination in Potential Profile Measurement of Tokamak Plasmas by High Voltage Heavy Ion Beam Probes;* Apr. 1992

NIFS-144 N. Ohyabu, N. Noda, Hantao Ji, H. Akao, K. Akaishi, T. Ono, H. Kaneko, T. Kawamura, Y. Kubota, S. Morimoto. A. Sagara, T. Watanabe, K. Yamazaki and O. Motojima, *Helical Divertor in the Large Helical Device;* May 1992

NIFS-145 K. Ohkubo and K. Matsumoto, *Coupling to the Lower Hybrid Waves with the Multijunction Grill*; May 1992

NIFS-146 K. Itoh, S. -I.Itoh, A. Fukuyama, S. Tsuji and Allan J. Lichtenberg, *A Model of Major Disruption in Tokamaks*; May 1992

NIFS-147 S. Sasaki, S. Takamura, M. Ueda, H. Iguchi, J. Fujita and K. Kadota, *Edge Plasma Density Reconstruction for Fast Monoenergetic Lithium Beam Probing*; May 1992

NIFS-148 N. Nakajima, C. Z. Cheng and M. Okamoto, *High-n Helicity-induced Shear Alfvén Eigenmodes*; May 1992

NIFS-149 A. Ando, Y. Takeiri, O. Kaneko, Y. Oka, M. Wada, and T. Kuroda, *Production of Negative Hydrogen Ions in a Large Multicusp Ion Source with Double-Magnetic Filter Configuration*; May 1992

NIFS-150 N. Nakajima and M. Okamoto, *Effects of Fast Ions and an External Inductive Electric Field on the Neoclassical Parallel Flow, Current, and Rotation in General Toroidal Systems*; May 1992

NIFS-151 Y. Takeiri, A. Ando, O. Kaneko, Y. Oka and T. Kuroda, *Negative Ion Extraction Characteristics of a Large Negative Ion Source with Double-Magnetic Filter Configuration*; May 1992

NIFS-152 T. Tanabe, N. Noda and H. Nakamura, *Review of High Z Materials for PSI Applications* ; Jun. 1992

NIFS-153 Sergey V. Bazdenkov and T. Sato, *On a Ballistic Method for Double Layer Regeneration in a Vlasov-Poisson Plasma*; Jun. 1992

NIFS-154 J. Todoroki, *On the Lagrangian of the Linearized MHD Equations*; Jun. 1992

NIFS-155 K. Sato, H. Katayama and F. Miyawaki, *Electrostatic Potential in a Collisionless Plasma Flow Along Open Magnetic Field Lines;* Jun. 1992

NIFS-156 O.J.W.F.Kardaun, J.W.P.F.Kardaun, S.-I. Itoh and K. Itoh, *Discriminant Analysis of Plasma Fusion Data*; Jun. 1992

NIFS-157 K. Itoh, S.-I. Itoh, A. Fukuyama and S. Tsuji, *Critical Issues and Experimental Examination on Sawtooth and Disruption Physics*; Jun. 1992

NIFS-158 K. Itoh and S.-I. Itoh, *Transition to H-Mode by Energetic Electrons*; July 1992

NIFS-159 K. Itoh, S.-I. Itoh and A. Fukuyama, *Steady State Tokamak Sustained by Bootstrap Current Without Seed Current*; July 1992

NIFS-160 H. Sanuki, K. Itoh and S.-I. Itoh, *Effects of Nonclassical Ion Losses on Radial Electric Field in CHS Torsatron/Heliotron*; July 1992

NIFS-161 O. Motojima, K. Akaishi, K. Fujii, S. Fujiwaka, S. Imagawa, H. Ji, H. Kaneko, S. Kitagawa, Y. Kubota, K. Matsuoka, T. Mito, S. Morimoto, A. Nishimura, K. Nishimura, N. Noda, I. Ohtake, N. Ohyabu, S. Okamura, A. Sagara, M. Sakamoto, S. Satoh, T. Satow, K. Takahata, H. Tamura, S. Tanahashi, T. Tsuzuki, S. Yamada, H. Yamada, K. Yamazaki, N. Yanagi, H. Yonezu, J. Yamamoto, M. Fujiwara and A. Iiyoshi, *Physics and Engineering Design Studies on Large Helical Device*; Aug. 1992

NIFS-162 V. D. Pustovitov, *Refined Theory of Diamagnetic Effect in Stellarators;* Aug. 1992

NIFS-163 K. Itoh, *A Review on Application of MHD Theory to Plasma Boundary Problems in Tokamaks*; Aug. 1992

NIFS-164 Y.Kondoh and T.Sato, *Thought Analysis on Self-Organization Theories of MHD Plasma*; Aug. 1992

NIFS-165 T. Seki, R. Kumazawa, T. Watari, M. Ono, Y. Yasaka, F. Shimpo, A. Ando, O. Kaneko, Y. Oka, K. Adati, R. Akiyama, Y. Hamada,

S. Hidekuma, S. Hirokura, K. Ida, A. Karita, K. Kawahata, Y. Kawasumi, Y. Kitoh, T. Kohmoto, M. Kojima, K. Masai, S. Morita, K. Narihara, Y. Ogawa, K. Ohkubo, S. Okajima, T. Ozaki, M. Sakamoto, M. Sasao, K. Sato, K. N. Sato, H. Takahashi, Y. Taniguchi, K. Toi and T. Tsuzuki, *High Frequency Ion Bernstein Wave Heating Experiment on JIPP T-IIU Tokamak*; Aug. 1992

NIFS-166 Vo Hong Anh and Nguyen Tien Dung, *A Synergetic Treatment of the Vortices Behaviour of a Plasma with Viscosity*; Sep. 1992

NIFS-167 K. Watanabe and T. Sato, *A Triggering Mechanism of Fast Crash in Sawtooth Oscillation*; Sep. 1992

NIFS-168 T. Hayashi, T. Sato, W. Lotz, P. Merkel, J. Nührenberg, U. Schwenn and E. Strumberger, *3D MHD Study of Helias and Heliotron;* Sep. 1992

NIFS-169 N. Nakajima, K. Ichiguchi, K. Watanabe, H. Sugama, M. Okamoto, M. Wakatani, Y. Nakamura and C. Z. Cheng, *Neoclassical Current and Related MHD Stability, Gap Modes, and Radial Electric Field Effects in Heliotron and Torsatron Plasmas;* Sep. 1992

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-^3He 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. Saki, 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