ISSN 0915-633X

INTERNATIONAL ATOMIC ENERGY AGENCY

FIFTEENTH INTERNATIONAL CONFERENCE ON PLASMA PHYSICS AND CONTROLLED NUCLEAR FUSION RESEARCH

Seville, Spain, 26 September – 1 October 1994

IAEA-CN-60/A-2-III-5

NATIONAL INSTITUTE FOR FUSION SCIENCE

Study of Turbulence and Plasma Potential in JIPP T-IIU Tokamak

Y. Hamada, A. Nishizawa, Y. Kawasumi, K.N. Sato, H. Sakakita, R. Liang, K. Kawahata, A. Ejiri, K. Narihara, K. Sato, T. Seki, K. Toi, K. Itoh, H. Iguchi, A. Fujisawa, K. Adachi, S. Hidekuma, S. Hirokura, K. Ida, M. Kojima, J. Koog, R. Kumazawa, H. Kuramoto, T. Minami, I. Negi, S. Ohdachi, M. Sasao, T. Tsuzuki, J. Xu, I. Yamada, T. Watari

(Received - Aug. 24, 1994)

NIFS-301 Aug. 1994

RESEARCH REPORT
NIFS Series

NAGOYA, JAPAN

INTERNATIONAL ATOMIC ENERGY AGENCY

FIFTEENTH INTERNATIONAL CONFERENCE ON PLASMA PHYSICS AND CONTROLLED NUCLEAR FUSION RESEARCH

Seville, Spain, 26 September - 1 October 1994

IAEA-CN-60/A-2-III-5

Study of turbulence and plasma potential in JIPP T-IIU tokamak

Y. Hamada, A. Nishizawa, Y. Kawasumi, K.N. Sato, H. Sakakita, R. Liang, K. Kawahata, A. Ejiri, K. Narihara, K. Sato, T. Seki, K. Toi, K. Itoh, H. Iguchi, A. Fujisawa, K. Adachi, S. Hidekuma, S. Hirokura, K. Ida, M. Kojima, J. Koog, R. Kumazawa, H. Kuramoto, T. Minami, I. Negi[a)], S. Ohdachi, M. Sasao, T. Tsuzuki, J. Xu, I. Yamada, T. Watari

National Institute for Fusion Science, Nagoya, 464-01, Japan
a) Plasma Physics Laboratory, Kyoto University, Uji, Japan

Keywords: Potential, Turbulence, Tokamak, Pellet, Sawtooth

Abstract

By a novel use of 500 keV heavy ion beam probe (HIBP), the precise profile of plasma potential, fast changes of plasma potential in case of sawtooth and pellet injection, and the local characteristics of plasma turbulence are observed in a tokamak plasma.

1. Plasma turbulence

Compared with the conventional 2-points measurement in HIBP turbulence study, multiple-point measurement up to 13 points is performed. Because of the increase of the measurement points in turbulence study, we got a clear view of propagation of the turbulence in a tokamak plasma. Figure 1 shows correlation coefficient functions of detector signals, proportional to the local densities of various points of measurement (position 10 to 13 in order and about 5 mm separated poloidally each other) near the edge of an ohmically heated tokamak plasma. The correlation of the pair (p.11 and p.10) clearly shows that the main turbulence propagates in the electron-diamagnetic-drift direction and a small component propagates in the ion-diamagnetic-drift direction. The correlation of p.11 and p.12 has the same characteristics of propagation and indicates the consistency of the measurement. The correlation of p.11 and p.13 shows the decay of the correlation with distance and the larger propagation time. As the observation point goes deeper into the ohmic plasma, the component with ion diamagnetic drift direction decays and the observed turbulence propagates only in the electron diamagnetic drift direction. The change of the characteristics of the turbulence along the minor radius was recently found in TFTR using beam emission spectroscopy (BES).[1] Their result showed the turbulence propagating into the ion diamagnetic direction (ITG-mode) dominates in an inner region of the NBI-heated L-mode plasma. Our result shows the dominance of a pure electron drift wave in a linear ohmic confinement (LOC) plasmas, where BES measurement is not applicable due to the absence of the strong neutral beam. The negative values of the correlation coefficient functions at zero delay time in Fig. 1 can be considered to be a path integral effect[1] since the beam velocity is so high compared to the propagation velocity of the turbulence. If we analyze a correlation coefficient function with a careful treatment of the values at zero delay, we may be able to perform the turbulence analysis relatively free from a path integral effect.

2. Fast potential change in tokamak plasmas

Although physics of a quasi-steady potential formation in tokamak plasmas are not still well understood, we found a few cases of fast potential changes in tokamak plasmas and put explanations on these phenomena. One case is at a sawtooth clash. A sawtooth oscillation in the center of a tokamak plasma column is characterized by a rapid energy loss from a hot core region. For the first time it is found that a barrier potential (ambipolar potential), which is common in the open-ended plasma device, is formed in the tokamak at a sawtooth clash. During the sawteeth enlarged by the IBW heating, the potential in the center of the plasma shows a sharp rise associated with the decay of ECE temperature as shown in Fig. 2. Its rise only occurs inside the sawtooth inversion layer. Outside the inversion layer, the change is negative. The polarity and magnitude of these changes is consistent with the formation of a barrier potential due to the interaction of hot and cold plasmas at the decay phase of the sawtooth.

A large and fast negative change of a space potential in a tokamak plasma is observed as shown in Fig. 3, when a hydrogen pellet is injected towards the center of a tokamak plasma. Since the analyzer has two-staged optical traps to suppress the effect of UV radiation from the plasma, the intense radiation at a pellet injection has a negligible effect on a potential measurement of Fig. 3. Accordingly, the principal error in a fast measurement of a space potential by HIBP at a pellet injection, may be due to a fast deflection of the beam due to the change of a profile of plasma current. This error is found to be small from the measurements under different entrance angles of the secondary beams to a parallel-plate analyzer by rotating the analyzer toroidally. The change of the potential may be due to the cooling of hot ions by a cold blob of a pellet. When high-temperature ions hit a cold and very high-density blob, the ions are cooled down and the Larmor radii of the ions get smaller. Then the ions can not go back to the initial magnetic surfaces. This means that the inner part becomes electron-rich and negatively charged by a potential of a few times an ion temperature. This explanation is consistent with the experimental results in terms of polarity and magnitude. It may be very similar to the formation of a negative plasma potential at the plasma surface due to the ion loss to a limiter or divertor plates. In both cases ions can not go back to the initial magnetic surfaces.

3. Potential profile

By a novel use of simultaneous fast toroidal and slow poloidal sweeps in the heavy ion beam probe, potential profiles in JIPP T-IIU tokamak plasma are measured at the rate of 120 profiles per second.[2] So far the plasma potential profiles in other tokamaks have been measured using 10 or 20 discharges on shot-to-shot basis. By this novel method, it becomes possible to perform a detailed study of potential profiles in tokamak plasmas under ohmic, NBI and IBW heating. Main results are a) the depth of a plasma potential at the center increases drastically as an average plasma density and confinement time increase in a linear ohmic confinement (LOC) regime. b) Its depth is a few times the ion temperature and the accurate dependence on the ion temperature is hard to get because the additional heatings always induce a density rise in our plasmas. c)

Different types of a potential profile are observed, one with a large region of positive potential and one without it.

The authors would like to thank to Director-general A. Iiyoshi and professors M. Fujiwara and K. Matsuoka for their continuous encouragement.

Reference

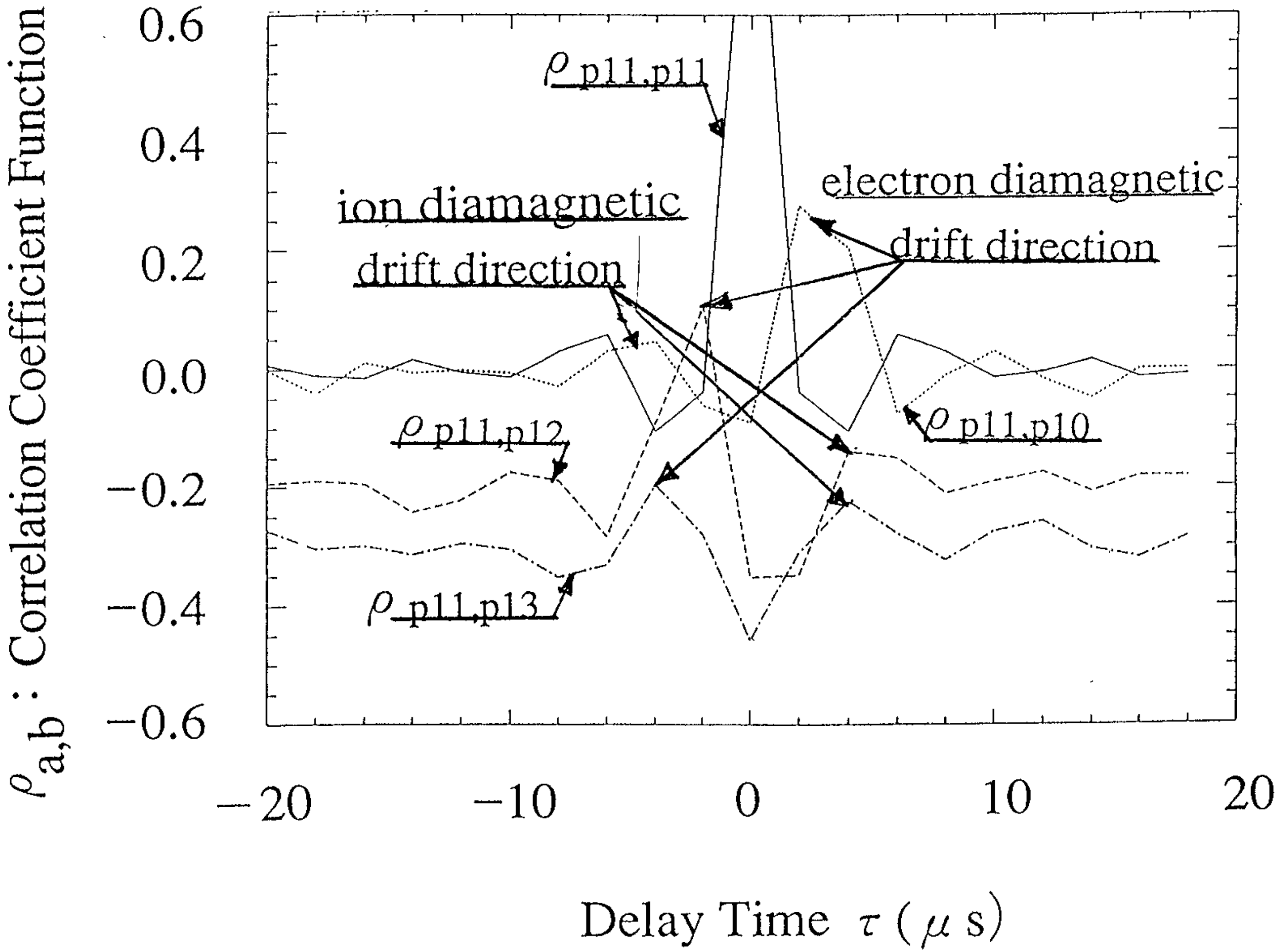
1)Fonck, R., et al., Phys. Rev. Lett., 70 (1993) 3736.

2)Hamada, Y., et al., to be published in Plasma Physics and Controlled Nuclear Fusion.

Fig. 1. Correlation coefficient functions of multiple measurement points in HIBP. The intensities of secondary current, proportional to the local plasma density are analyzed. Points of measurements are located around $r/a_p = 0.9$. Poloidal separation is about 2 mm between each point of measurement.

Fig. 2. Typical potential behaviors in IBW heated sawtooth crash inside the sawtooth inversion layer measured by HIBP. The potential is measured by ND (normalized difference of upper and lower detector currents, proportional to the change of plasma potential). The conversion ratio from ND to potential is 1037 V/ND

Fig. 3. ND during the sweep across the plasma. The point of measurement is swept slowly from about the plasma center to the surface. A pellet is injected in this case when the point of measurement is about $r/a_p = 0.2$.



ρ p11,p11
ρ p11,p10
ρ p11,p12
ρ p11,p13
ion diamagnetic drift direction
electron diamagnetic drift direction
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
ρ a,b : Correlation Coefficient Function
−20
−10
0
10
20
Delay Time τ (μ s)

Fig. 1

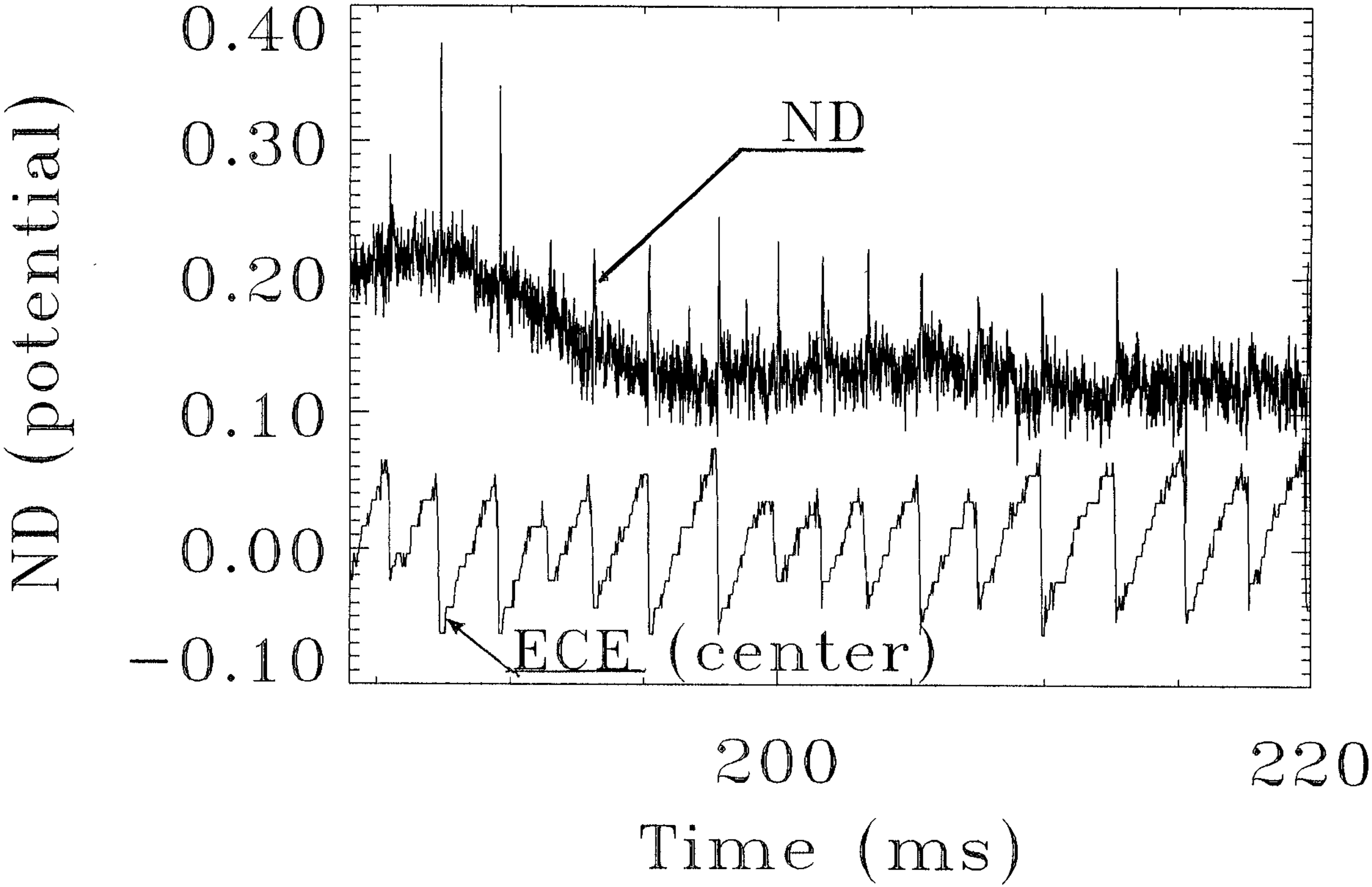
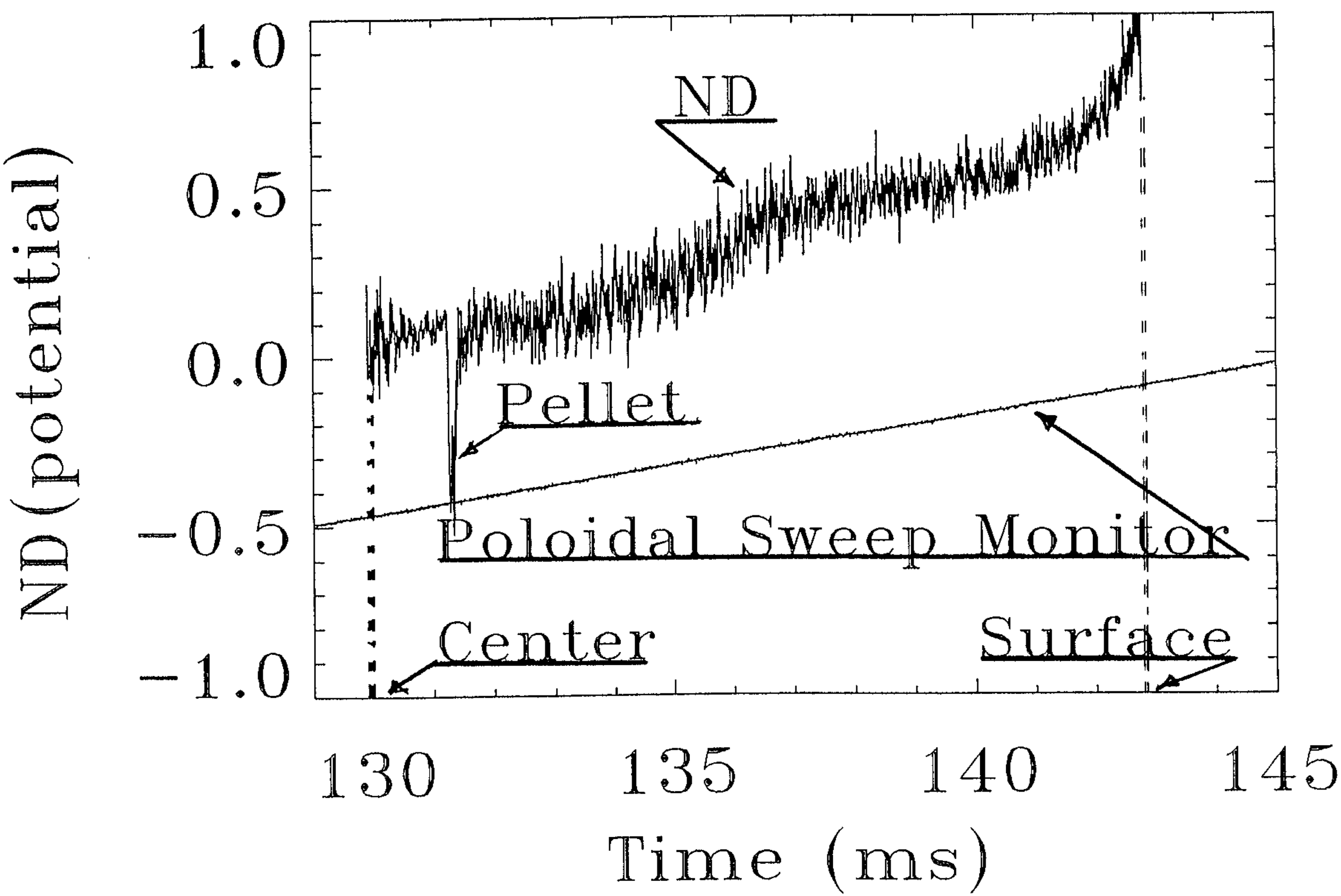

ND
ECE (center)
ND (potential)
0.40
0.30
0.20
0.10
0.00
−0.10
200
220
Time (ms)

Fig. 2


ND
Pellet
Poloidal Sweep Monitor
Center
Surface
1.0
0.5
0.0
−0.5
−1.0
130
135
140
145
ND (potential)
Time (ms)
Fig. 3

Recent Issues of NIFS Series

NIFS-258 K. Yamazaki, H. Kaneko, S. Yamaguchi, K.Y. Watanabe, Y.Taniguchi, O.Motojima, LHD Group,
Design of Central Control System for Large Helical Device (LHD); Nov. 1993

NIFS-259 S. Yamada, T. Mito, A. Nishimura, K. Takahata, S. Satoh, J. Yamamoto, H. Yamamura, K. Masuda, S. Kashihara, K. Fukusada, E. Tada,
Reduction of Hydrocarbon Impurities in 200L/H Helium Liquefier-Refrigerator System; Nov. 1993

NIFS-260 B.V.Kuteev,
Pellet Ablation in Large Helical Device; Nov. 1993

NIFS-261 K. Yamazaki,
Proposal of "MODULAR HELIOTRON': Advanced Modular Helical System Compatible with Closed Helical Divertor; Nov. 1993

NIFS-262 V.D.Pustovitov,
Some Theoretical Problems of Magnetic Diagnostics in Tokamaks and Stellarators; Dec. 1993

NIFS-263 A. Fujisawa, H. Iguchi, Y. Hamada
A Study of Non-Ideal Focus Properties of 30° Parallel Plate Energy Analyzers; Dec. 1993

NIFS-264 K. Masai,
Nonequilibria in Thermal Emission from Supernova Remnants; Dec. 1993

NIFS-265 K. Masai, K. Nomoto,
X-Ray Enhancement of SN 1987A Due to Interaction with its Ring-like Nebula; Dec. 1993

NIFS-266 J. Uramoto
A Research of Possibility for Negative Muon Production by a Low Energy Electron Beam Accompanying Ion Beam; Dec. 1993

NIFS-267 H. Iguchi, K. Ida, H. Yamada, K. Itoh, S.-I. Itoh, K. Matsuoka, S. Okamura, H. Sanuki, I. Yamada, H. Takenaga, K. Uchino, K. Muraoka,
The Effect of Magnetic Field Configuration on Particle Pinch Velocity in Compact Helical System (CHS); Jan. 1994

NIFS-268 T. Shikama, C. Namba, M. Kosuda, Y. Maeda,
Development of High Time-Resolution Laser Flash Equipment for Thermal Diffusivity Measurements Usting Miniature-Size Specimens; Jan. 1994

NIFS-269 T. Hayashi, T. Sato, P. Merkel, J. Nührenberg, U. Schwenn,
Formation and 'Self-Healing' of Magnetic Islands in Finite-β Helias Equilibria; Jan. 1994

NIFS-270 S. Murakami, M. Okamoto, N. Nakajima, T. Mutoh,
Efficiencies of the ICRF Minority Heating in the CHS and LHD Plasmas; Jan. 1994

NIFS-271 Y. Nejoh, H. Sanuki,
Large Amplitude Langmuir and Ion-Acoustic Waves in a Relativistic Two-Fluid Plasma; Feb. 1994

NIFS-272 A. Fujisawa, H. Iguchi, A. Taniike, M. Sasao, Y. Hamada,
A 6MeV Heavy Ion Beam Probe for the Large Helical Device; Feb. 1994

NIFS-273 Y. Hamada, A. Nishizawa, Y. Kawasumi, K. Narihara, K. Sato, T. Seki, K. Toi, H. Iguchi, A. Fujisawa, K. Adachi, A. Ejiri, S. Hidekuma, S. Hirokura, K. Ida, J. Koong, K. Kawahata, M. Kojima, R. Kumazawa, H. Kuramoto, R. Liang, H. Sakakita, M. Sasao, K. N. Sato, T. Tsuzuki, J. Xu, I. Yamada, T. Watari, I. Negi,
Measurement of Profiles of the Space Potential in JIPP T-IIU Tokamak Plasmas by Slow Poloidal and Fast Toroidal Sweeps of a Heavy Ion Beam; Feb. 1994

NIFS-274 M. Tanaka,
A Mechanism of Collisionless Magnetic Reconnection; Mar. 1994

NIFS-275 A. Fukuyama, K. Itoh, S.-I. Itoh, M. Yagi and M. Azumi,
Isotope Effect on Confinement in DT Plasmas; Mar. 1994

NIFS-276 R.V. Reddy, K. Watanabe, T. Sato and T.H. Watanabe,
Impulsive Alfven Coupling between the Magnetosphere and Ionosphere; Apr.1994

NIFS-277 J. Uramoto,
A Possibility of π^- Meson Production by a Low Energy Electron Bunch and Positive Ion Bunch; Apr. 1994

NIFS-278 K. Itoh, S.-I. Itoh, A. Fukuyama, M. Yagi and M. Azumi,
Self-sustained Turbulence and L-mode Confinement in Toroidal Plasmas II; Apr. 1994

NIFS-279 K. Yamazaki and K.Y.Watanabe,
New Modular Heliotron System Compatible with Closed Helical Divertor and Good Plasma Confinement; Apr. 1994

NIFS-280 S. Okamura, K. Matsuoka, K. Nishimura, K. Tsumori, R. Akiyama, S. Sakakibara, H. Yamada, S. Morita, T. Morisaki,. N. Nakajima, K. Tanaka, J. Xu, K. Ida, H. Iguchi, A. Lazaros, T. Ozaki, H. Arimoto, A. Ejiri, M. Fujiwara, H. Idei. O. Kaneko, K. Kawahata, T. Kawamoto, A. Komori, S. Kubo, O. Motojima, V.D. Pustovitov, C. Takahashi, K. Toi and I. Yamada,
High-Beta Discharges with Neutral Beam Injection in CHS; Apr. 1994

NIFS-281 K. Kamada, H. Kinoshita and H. Takahashi,
Anomalous Heat Evolution of Deuteron Implanted Al on Electron Bombardment ; May 1994

NIFS-282 H. Takamaru, T. Sato, K. Watanabe and R. Horiuchi,
Super Ion Acoustic Double Layer; May 1994

NIFS-283 O.Mitarai and S. Sudo
Ignition Characteristics in D-T Helical Reactors; June 1994

NIFS-284 R. Horiuchi and T. Sato,
Particle Simulation Study of Driven Magnetic Reconnection in a Collisionless Plasma; June 1994

NIFS-285 K.Y. Watanabe, N. Nakajima, M. Okamoto, K. Yamazaki, Y. Nakamura, M. Wakatani,
Effect of Collisionality and Radial Electric Field on Bootstrap Current in LHD (Large Helical Device); June 1994

NIFS-286 H. Sanuki, K. Itoh, J. Todoroki, K. Ida, H. Idei, H. Iguchi and H. Yamada,
Theoretical and Experimental Studies on Electric Field and Confinement in Helical Systems; June 1994

NIFS-287 K. Itoh and S-I. Itoh,
Influence of the Wall Material on the H-mode Performance; June 1994

NIFS-288 K. Itoh, A. Fukuyama, S.-I. Itoh, M. Yagi and M. Azumi
Self-Sustained Magnetic Braiding in Toroidal Plasmas: July 1994

NIFS-289 Y. Nejoh,
Relativistic Effects on Large Amplitude Nonlinear Langmuir Waves in a Two-Fluid Plasma; July 1994

NIFS-290 N. Ohyabu, A. Komori, K. Akaishi, N. Inoue, Y. Kubota, A.I. Livshit, N. Noda, A. Sagara, H. Suzuki, T. Watanabe, O. Motojima, M. Fujiwara, A. Iiyoshi,
Innovative Divertor Concepts for LHD; July 1994

NIFS-291 H. Idei, K. Ida, H. Sanuki, S. Kubo, H. Yamada, H. Iguchi, S. Morita, S. Okamura, R. Akiyama, H. Arimoto, K. Matsuoka, K. Nishimura,

K. Ohkubo, C. Takahashi, Y. Takita, K. Toi, K. Tsumori and I. Yamada,
Formation of Positive Radial Electric Field by Electron Cyclotron Heating in Compact Helical System; July 1994

NIFS-292 N. Noda, A. Sagara, H. Yamada, Y. Kubota, N. Inoue, K. Akaishi, O. Motojima, K. Iwamoto, M. Hashiba, I. Fujita, T. Hino, T. Yamashina, K. Okazaki, J. Rice, M. Yamage, H. Toyoda and H. Sugai,
Boronization Study for Application to Large Helical Device; July 1994

NIFS-293 Y. Ueda, T. Tanabe, V. Philipps, L. Könen, A. Pospieszczyk, U. Samm, B. Schweer, B. Unterberg, M. Wada, N. Hawkes and N. Noda,
Effects of Impurities Released from High Z Test Limiter on Plasma Performance in TEXTOR; July. 1994

NIFS-294 K. Akaishi, Y. Kubota, K. Ezaki and O. Motojima,
Experimental Study on Scaling Law of Outgassing Rate with A Pumping Parameter, Aug. 1994

NIFS-295 S. Bazdenkov, T. Sato, R. Horiuchi, K. Watanabe
Magnetic Mirror Effect as a Trigger of Collisionless Magnetic Reconnection, Aug. 1994

NIFS-296 K. Itoh, M. Yagi, S.-I. Itoh, A. Fukuyama, H. Sanuki, M. Azumi
Anomalous Transport Theory for Toroidal Helical Plasmas, Aug. 1994

NIFS-297 J. Yamamoto, O. Motojima, T. Mito, K. Takahata, N. Yanagi, S. Yamada, H. Chikaraishi, S. Imagawa, A. Iwamoto, H. Kaneko, A. Nishimura, S. Satoh, T. Satow, H. Tamura, S. Yamaguchi, K. Yamazaki, M. Fujiwara, A. Iiyoshi and LHD group,
New Evaluation Method of Superconductor Characteristics for Realizing the Large Helical Device; Aug. 1994

NIFS-298 A. Komori, N. Ohyabu, T. Watanabe, H. Suzuki, A. Sagara, N. Noda, K. Akaishi, N. Inoue, Y. Kubota, O Motojima, M. Fujiwara and A. Iiyoshi,
Local Island Divertor Concept for LHD; Aug. 1994

NIFS-299 K. Toi, T. Morisaki, S. Sakakibara, A. Ejiri, H. Yamada, S. Morita, K. Tanaka, N. Nakjima, S. Okamura, H. Iguchi, K. Ida, K. Tsumori, S. Ohdachi, K. Nishimura, K. Matsuoka, J. Xu, I. Yamada, T. Minami, K. Narihara, R. Akiyama, A. Ando, H. Arimoto, A. Fujisawa, M. Fujiwara, H. Idei, O. Kaneko, K. Kawahata, A. Komori, S. Kubo, R. Kumazawa, T. Ozaki, A. Sagara, C. Takahashi, Y. Takita and T. Watari
Impact of Rotational-Transform Profile Control on Plasma Confinement and Stability in CHS; Aug. 1994

NIFS-300 H. Sugama and W. Horton,
Dynamical Model of Pressure-Gradient-Driven Turbulence and Shear Flow Generation in L-H Transition; Aug. 1994