# FLUCTUATION SUPPRESSION DURING CONFINEMENT POTENTIAL FORMATION IN GAMMA 10

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*The suppression of the potential fluctuation was clearly observed by a gold neutral beam probe (GNBP) during the higher potentials and positive electric fields driven by electron cyclotron heating. The particle flux evaluated from the phase difference between the potential and density fluctuations measured by GNBP showed the radial outward flux and correlates with the decrease in the stored energy. When flux is suppressed by the potential formation, the quick plasma stored energy increase is observed.*

## I. INTRODUCTION

In the tandem mirror GAMMA 10, an electrostatic potential for improving an axial confinement is created by applying electron cyclotron resonance heating (ECH) in the end mirrors (plug/barrier cells).[1-6] The drift-wave mode arises due to the existence of a density gradient. The radial electric field *E* due to the potential causes an *E*×*B* plasma rotation in the direction of the ion diamagnetic drift velocity, which may enhance instabilities such as rotational flute and drift wave modes, and degrade radial confinement. While present studies show that the low frequency fluctuations suppression on the density and the potential during the formation of axial confinement potential during plug-ECH (P-ECH).[1-3,4-6] The former works by Sanuki[7] and Chaudhry et al.[8] discussed the effects of ambipolar potential on the stability of drift waves. The stability is considered to be due to the ion Landau damping caused from the velocity shear effect of the *E*×*B* drift.[9-12] In GAMMA 10, there is a good potential measurement system that is a gold neutral beam probe system (GNBP).[4,6,13] We can observe the density and potential fluctuations when the axial confinement potential produced by the application of P-ECH in single plasma shot. We tried to obtain the two radial positions' potentials and their fluctuations in single plasma shot with applying the rectangular wave at the vertical beam deflector electrode. Then we successfully obtained the potentials and their fluctuations of two radial positions in single plasma shot. Then we obtained the radial electric field profile. We observed the suppressions of density and potential fluctuations by the potential formation during P-ECH by using the GNBP. We can study more detail about the suppression mechanisms of drift type fluctuation during the formation of confinement potential produced by P-ECH.

In this paper, we show the relationships between the suppression of potential fluctuation of drift type and the potential and electric field radial profiles. Moreover, we show the particle flux related value obtained by using the phase differences between the electron density fluctuation and the potential fluctuation.

## II. EXPERIMENTAL APPARATUS

In the GAMMA 10 tandem mirror, the plasma confinement is improved by not only a magnetic mirror configuration but also high potentials at both end regions[1-6]. The main plasma is produced and heated by ion cyclotron range of frequency waves. The potentials are produced by the P- and barrier-ECH (P/B-ECH) at the plug/barrier region. The typical electron density, electron and ion temperatures are about $2 \times 10^{12}$ cm$^{-3}$, 0.1 keV and 5 keV, respectively. We measured the potential and its fluctuation by using GNBP in the central cell. The GNBP consists of a beam source and a beam detector with an electrostatic energy analyzer. Analyzed beam position and beam current in the energy analyzer correspond to the potential and the relative density, respectively. By sweeping the beam trajectory, the system can measure radial profiles of the potential and relative density, and their fluctuations, simultaneously.

## III. POTENTIAL FLUCTUATION

The radial potential and electric field profiles have been measured by applying the rectangular wave on the deflector electrodes of the GNBP system in order to measure the plasma potentials at two positions in a single plasma shot.

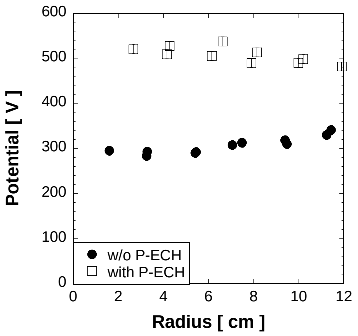

Fig. 1. Radial potential profiles without and with P-ECH.

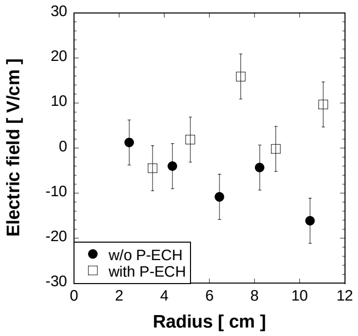

Fig. 2. Radial electric field profiles with and without P-ECH.

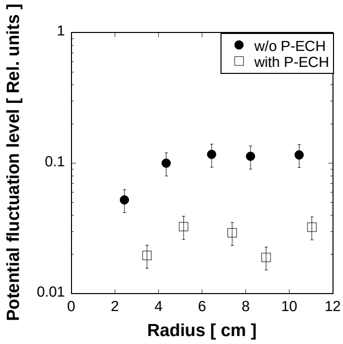

Fig. 3. Radial potential fluctuation levels measured by GNBP. Closed circles and open squares show those without and with P-ECH, respectively.

The temporal evolutions of the potential were measured by GNBP with P-ECH power of 250 kW. The central potential quickly increased during the P-ECH period. Potential and electric field radial profiles were observed without and with P-ECH. In Fig. 1 and Fig. 2, we show the radial potential and electric field profiles, respectively. In those figures, closed circles and open squares show them without and with P-ECH periods, respectively. Before application of P-ECH, the radial potential profile had a profile in which the plasma center (R~0 cm) had a lower potential than that at R~12 cm. With the application of P-ECH, however, the radial potential profile had a higher potential at the plasma center (R~0 cm) than that at R~12 cm. The potential fluctuation with frequency of about 10 kHz was observed and it corresponds to the diamagnetic drift-type fluctuations. Figure 3 shows the radial profile of potential fluctuation peaks at a frequency from 8 kHz to 12 kHz. In this figure, the closed circles and the open squares show the potential fluctuation peaks without and with P-ECH, respectively. Potential fluctuation suppression with the application of P-ECH was clearly observed at each radial position. In Fig. 4 and Fig. 5, the relationship between the potential and electric field strength and the potential fluctuations are shown, respectively. Then the potential fluctuations are smaller at the larger potential

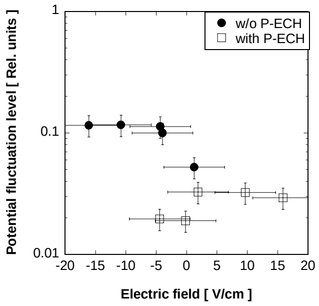

Fig. 5. Relation between the electric fields and fluctuation levels.

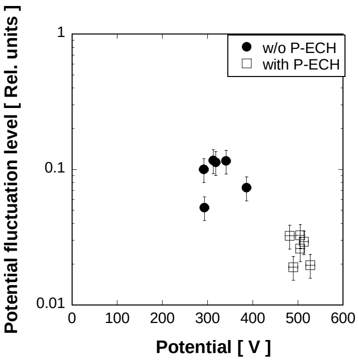

Fig. 4. Relation between the potential and fluctuation levels.

formation. Moreover, the potential fluctuations at the negative electric field region are larger than those at the positive electric fields region. Then the drift-type fluctuations are suppressed by the potential formation and positive electric field formation on the central cell. During the periods without P-ECH, the negative electric fields have enhancement of diamagnetic drift. While during the periods with P-ECH, the positive electric fields suppress the diamagnetic drift. The fluctuation suppressions by the higher potentials and positive electric fields are clearly observed.

## IV. PARTICLE FLUX ANALYSIS

The particle flux was evaluated from the fluctuations of the potential and the density and their phase difference measured by GNBP. In GAMMA 10, the azimuthally propagating electrostatic fluctuations are observed. Radial particle flux for experimental investigation is derived as

$$\Gamma_p \approx \frac{2}{B}\int_0^\infty k_\theta \left|\gamma_{n\phi}\right|\left|\tilde{n}\right|\tilde{\phi}\,\sin\alpha_{n\phi}\,d\omega \quad , \qquad (1)$$

where $k_\theta$, $\gamma_{n\phi}$, $\tilde{n}$, $\tilde{\phi}$ and $\alpha_{n\phi}$ indicate the wave number, the coherence between the density and the potential fluctuations, the density and the potential fluctuations, and the phase difference between the density and the potential fluctuations, respectively. We observed the frequencies of about 8 to 12 kHz in the potential and density fluctuations which correspond to the drift-type fluctuations. Figure 6 shows the temporal evolution of diamagnetism and particle flux related value obtained by the potential and density fluctuations at r~6 cm. The B- and P-ECH were applied from 150 to 190 ms and 155 to 175 ms, respectively, in order to produce the axial confining potential. A good correlation between the diamagnetism and flux is obtained. The particle flux increases at the edge region during the period without P-ECH. This tells us the source of the anomalous radial transport is the potential and density fluctuations and the fluctuations decrease the plasma stored energy. Moreover, Fig. 6 shows that suppression of particle flux also suppressed with application of P-ECH and the stored energy quickly increased.

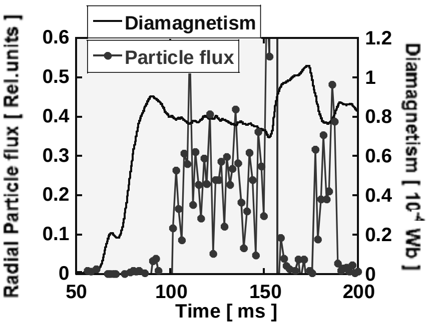

Fig.6: Temporal evolutions of the radial particle flux related value and diamagnetism.

## V. SUMMARY

We studied the suppression of the density and potential fluctuations by applying P-ECH in the GAMMA 10 tandem mirror. The higher potential and positive electric field formation in the central cell stabilizes the drift-type fluctuations. The correlation between the radial particle flux deduced from the phase differences of the density and potential fluctuations and stored energy is also studied by using GNBP. It is found that the radial anomalous transport induced by the drift-type fluctuations causes the reduction of the plasma stored energy. These results indicate the possibility of the suppression of the anomalous transport by the potential formation with ECH.

## ACKNOWLEDGMENTS

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