

MEASUREMENTS OF BEAM PARTICLE LOSSES IN CHS

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1. Introduction

The behaviors of escaping fast ions have been studied extensively in tokamaks as reviewed in Ref. 1. Several physics mechanisms, such as the first-orbit loss [2], the stochastic ripple loss [3], the radial diffusion caused by small scale turbulence [4], the MHD induced loss [5], and the ICRF induced loss [6] have been investigated. On the other hand, a little work has been done in a helical device, which has a different magnetic field ripple structure [7].

Recently a scintillator-based lost particle probe (TFTR-type) has been installed on the Compact Helical System (CHS), a heliotron/torsatron type device ($R = 1$ m, $\langle a \rangle = 0.2$ m, $B_T = 2$ T, $l/m=2/8$), and a pitch angle and energy resolved measurement of neutral beam ions (40 keV protons) loss has started [8,9]. Distinct feature of the observation on CHS is that one group of the signal corresponds to the orbit loss of transition particles, i.e. particles near the passing/trapped boundary, and the other corresponds to those escaping from trapped region with higher pitch angles [10]. This lost particle probe together with magnetic probe array and soft X-ray detector array is also employed to study MHD modes which exhibit fishbone like burst behavior and induce resonant fast ion loss [11].

In the present paper are shown the results on the measurement of time-resolved behaviors of these particles using a nine channel array of photomultiplier tubes (PMT), during MHD activity was observed. A strong burst signals were measured on ions having a specific orbit.

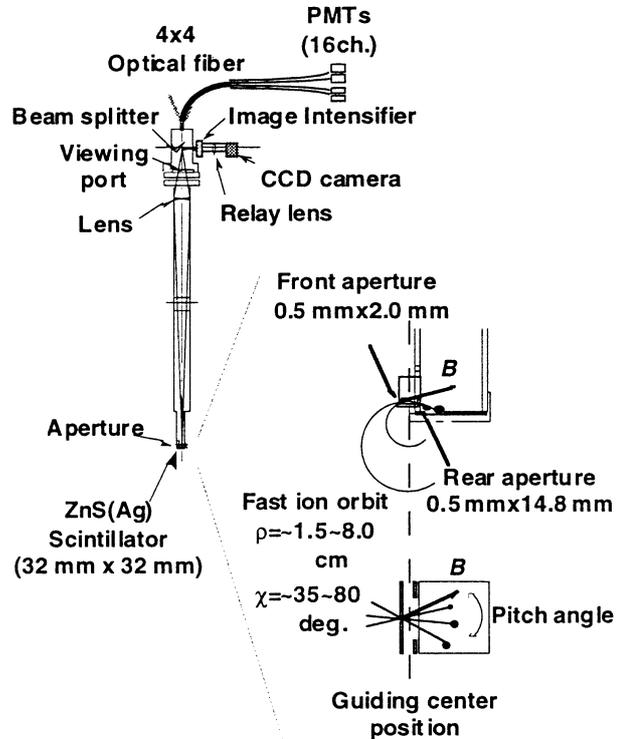


Fig. 1. Schematic view of the lost particle probe.

2. Experimental Setup

Figure 1 shows a schematic view of the probe designed for the measurement on CHS. The probe consists of a scintillator plate (ZnS(Ag), 32 mm \times 32 mm), a relay lens, a splitter

mirror, an Image-Intensified CCD camera and a nine channel array of photomultiplier tubes (PMT). The scintillator plate is fixed at the bottom inside end of a metal box, which has a pair of apertures. The aperture consists of a front aperture (0.5 mm height \times 2.0 mm width) which is on the surface of the metal box and a rear one (0.5 mm height \times 14.8 mm width) which is inside of the metal box. Fast ions whose gyroradii are comparable with approximately 40 keV protons are allowed to pass through the apertures.

The light distribution on the scintillator is detected by the CCD camera and the nine channel array of PMTs connected with optical fibers. The CCD signal is recorded by a video cassette recorder with sampling frequency of 30 Hz, and the signal of PMTs by CHS data acquisition system. The time-resolution of the PMT array is determined by the PMT response (20 kHz).

The array has been installed on the probe to detect lights on divided region on the scintillator as shown in Fig. 2. The position of each circle was determined by an in-situ calibration using a laser light transmitting from the output of the optical fibers, reversely onto the scintillator. The light spot sizes were about 10%-20% larger than that expected from the size of each fiber (\varnothing 1.5 mm) and the optics. This is probably due to the fact that the optical system is not perfectly focused, but the effect on the accuracy of our measurement is small.

The gyroradius/pitch-angle grid shown in Fig. 2 is obtained by a detector simulation code. In this code, a number of ions with a certain gyroradius and a certain pitch angle are launched from positions distributed across the front aperture, and the centroid of the distributions of strike points on the scintillator is computed.

Here, the gyroradius centroid is given by $\rho = (2mE)^{0.5}/qB$ and the pitch angle is $\chi = \arccos(v_{\parallel}/v)$. Calculated distributions of mono-energy ions of 10, 25 and 40 keV, with $\chi = 43^\circ$, are

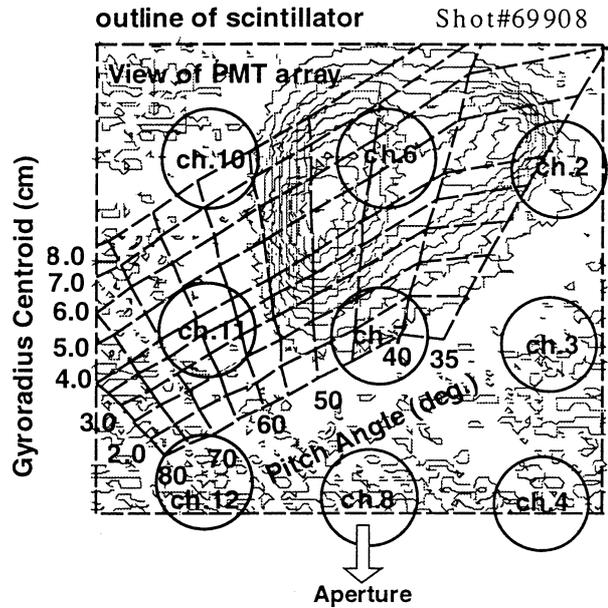


Fig. 2. View of the PMT array on the scintillator with the calculated grid.

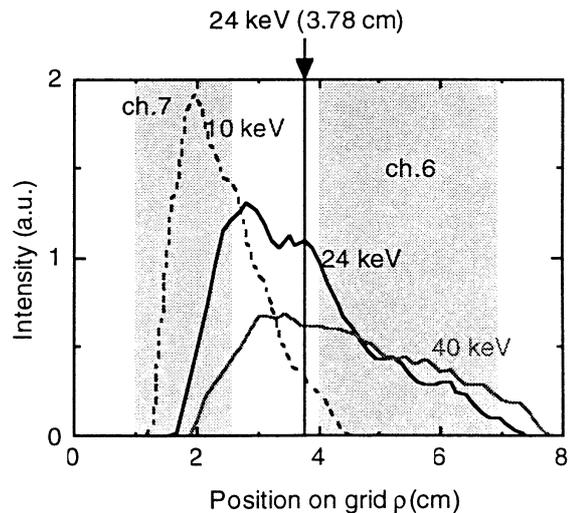


Fig. 3. Calculated distribution of mono-energy ions on the scintillator.

shown in Fig. 3. The energy resolution is mostly deteriorated by this spread and should be convoluted. On the other hand, the geometrical pitch angle resolution is very small, and its overall resolution (about 2 degrees) is determined by the depth of the focus of the optics and the accuracy of the calibration.

3. Results and Discussions

Measurements with the array were applied to a plasma when the MHD activity was observed. Figure 4 shows time evolutions of fast ion loss for several channels of the array. The vacuum magnetic axis position R_{ax} , the toroidal field strength B_T and the line averaged electron density n_e were 99.5 cm, 0.88 T and $6 \times 10^{12} \text{ cm}^{-3}$, respectively. The signal level of each channel in Fig. 4 is corrected for its relative amplification factors of PMT's.

Spikes synchronizing with magnetic fluctuation due to MHD activity are seen in the signals, especially on ch.6 and ch.7. Two group of spikes are observed, one during the period from 70 ms to 110 ms and the other from 115 ms to 130 ms. In the former, a burst of 50 kHz is observed on the magnetic probe, while that of 100 kHz is observed in the latter. The toroidal array of the magnetic probes indicates that the toroidal mode number of the former mode n is 2. Although spikes in ch. 7 are standing out, the ratio of the amplitude of these spikes in ch. 7 to that in ch. 6 is 1:2, while the ratio is 1: 10 for the quiescent portion of the loss signal. The latter ratio corresponds to the distribution of the protons with the energy loss of near its initial energy (38 keV) and the ratio of spikes is corresponding to lower energy protons. If we assume that these spikes consist of mono-energetic ions, the ratio of 1:2 can be

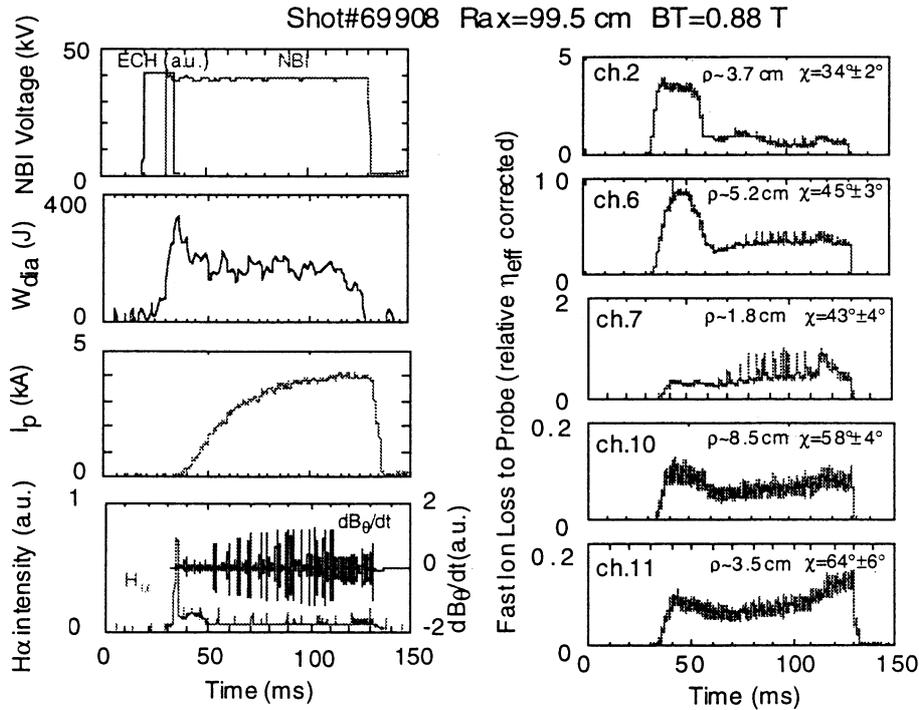


Fig. 4. Time evolutions of fast ion loss for several channels of the PMT array.

explained with $24\text{keV}_{-4\text{keV}}^{+10\text{keV}}$ protons, as shown in Fig. 3. The pitch angles of these channels are about 37 - 48 degrees.

In order to understand these resonant particles, a full gyro-orbit calculation was performed using codes which are recently developed for fast ions in a helical system [8,9], one of which is based on the code used for fusion products in tokamaks [1,2]. Figure 5 shows orbits of particles starting from the detector position, time-reversely into a plasma, with $E=25\text{ keV}/\chi=43\text{ deg.}$ (A), $E=25.5\text{ keV}/\chi=42.8\text{ deg.}$ (B), $E=25\text{ keV}/\chi=42.7\text{ deg.}$ (C), and $E=27.2\text{ keV}/\chi=43\text{ deg.}$ (D). The particle in Fig. 5(A) is trapped but a small energy increase or a small pitch angle decrease changes its orbit into passing. This shows that the transition particles resonate with MHD activities. The average toroidal rotation speed of this particle is about 10^5 m/set , about 4 times larger than the toroidal rotation speed of MHD perturbation. Further works will be done to reveal the conditions and resonance mechanism.

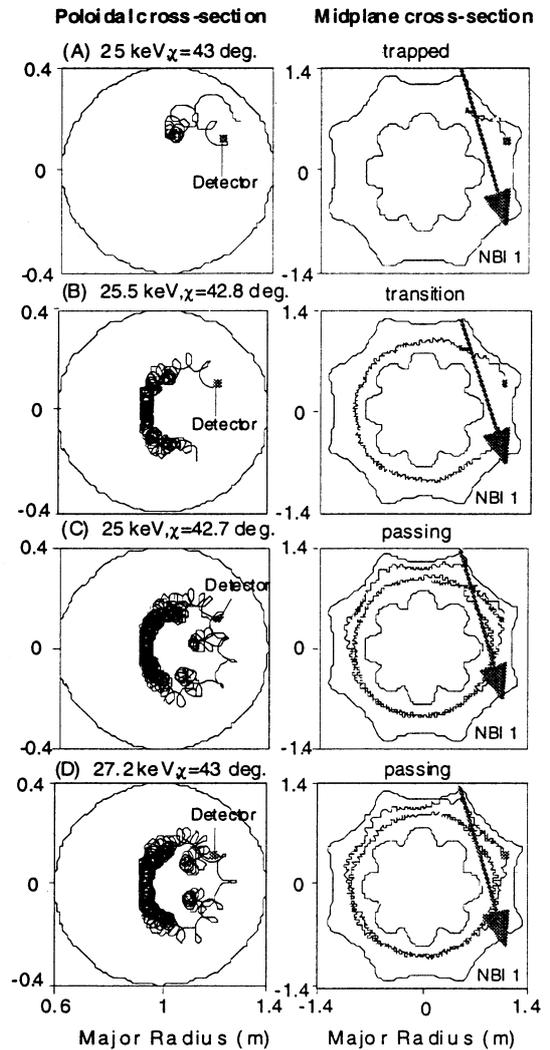


Fig. 5. Orbits of particles near MHD resonance.

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