§3. Fast Potential Change Measured by HIBP at Sawtooth Oscillations

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The periodic crashes of the central electron temperature called sawtooth oscillations are a common feature of the tokamak plasmas. We observed for the first time by a heavy ion beam probe that the fast change of the electrostatic potential is induced at the crash. Figure 1 shows trajectories of 450 kV thallium beams at 3 Tesla toroidal field and points of measurement (sample volume) conducted in this experiment, well inside (A), near (B) and outside (C) of the inversion radius of the sawtooth and sample volumes of the ECE measurements. Very sharp positive changes are observed when the sample volume is at the position A well inside the inversion layer of ECE and soft x-ray . At B, the mixture of positive and negative potential pulse are observed at C. Figure 2 shows how the rapid plasma motion at the crash depends on the polarity of the potential change at the sample volume B. If the core moves towards the point of measurement at the crash, the positive change is observed. When the movement is inwards, the negative potential is observed.

The fast MHD movement is considered to be derived from E/B motionthrough v_{perp}= ExB/B^2 where E=-gradΦ_{MHD}. In a sawtooth crash, the theories predict thepotential which causes rather uniform shift inside the q=1 surface. The maximum MHD potential Φ_{MHD} occurs near the inversion radius and may be estimated by the $\Phi_{MHD} = v_{perp} \times B_t \times r_{inv}$. At the fast adiabatic motion just before the crash at Fig.2b, the estimated maximum potential is Φ_{MHD} = ~100eV. The experimentally observed potential at the adiabatic shift is in rough agreement in magnitude and polarity although it is complicated because of the n=1/m=1 oscillation. In case of Fig.2a, the adiabatic shift is slow and the observed potential is small in accordance with Φ_{MHD}. The observed potential reaches, however, its peak where the crash is completed and there is presumably no MHD motion. In addition, the predicted MHD potential near the magnetic axis may be small and change its polarity depending on the direction of the fast movement in contradiction with the observed behaviour at A. Accordingly, we conclude that observed fast changes of a potential are the mixtures of a MHD potential Φ_{MHD} and a transient ambipolar potential along the magnetic line of force (barrier potential), caused by the mixing of a hot core inside the q=1 surface with a cold plasma through the reconnection or enhanced ergodicity at the crash. The fast change of the potential can be interpretated by the interaction of hot and cold plasmas at the sawtooth. The electrons of the hotter plasma travel faster through the destroyed magnetic surfaces and enter the region of region of cold plasma, producing the potential. The hotter region will become positive and cold region will be negative in accordance with the experiment. The amplitude of the change of the potential is about 100-200 V and is approximately the same with change of the electron temperature measured by the YAG Thomson scattering.

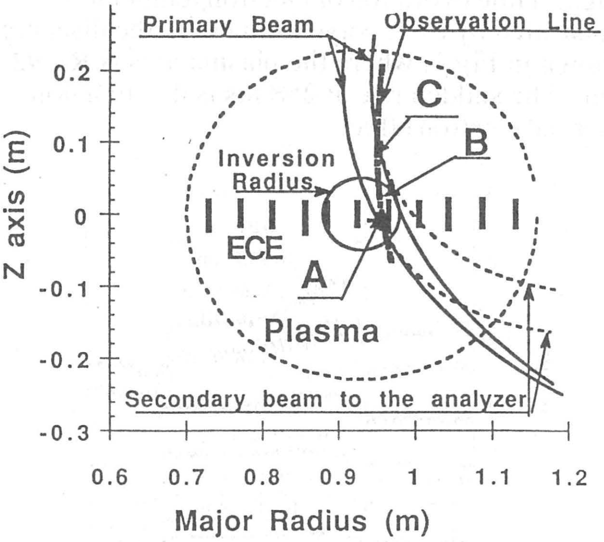

Fig 1. Trajectories of primary and secondary beam detected by the analyzer, and position of sample volume where measurements are conducted.

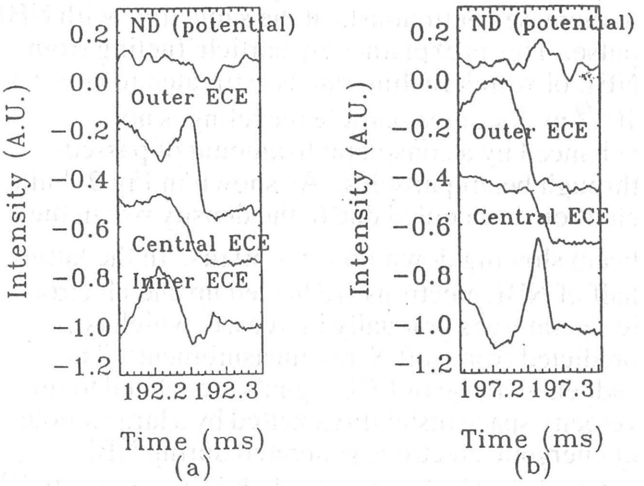

Fig. 2. Typical change of ND (the difference of to the upper and lower detector currents, normalized by the sum) at various postion of sample volume in sawtooth clashes. The conversion from ND to the plasma potential is about 1 kV/1.0ND.