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INVESTIGATION OF DIFFERENT PLASMA COMPONENTS CONFINEMENT AND TURBULENCE CHARACTERISTICS IN T-10 TOKAMAK

V.A. Vershkov[1], D.A. Shelukhin[1], S.V. Krylov[1], A.Yu. Novikov[1], Yu.D. Pavlov[1], V.M. Timokhin[2], V.A. Skokov[2]

[1]NFI RRC "Kurchatov Institute", Moscow, RF, vershkov@nfi.kiae.ru
[2]St.-Petersburg State Polytechnic University, St.-Petersburg, RF

Comparison of different plasma component transport can be the important tool for characterization of plasma turbulence conditions. The confinement of the plasma, highly charged impurities, energy and turbulence characteristics were investigated at different plasma densities in OH and ECRH regimes. In the case of neoclassical plasma the different plasma ions should have different confinement times, in contrast to the conditions of strong drift long wave turbulence, where the transport should be the same for all plasma ions [1]. Thus the equal confinement of impurities and main plasma ions may evidence in favor of the strong turbulence plasma condition. From other hand the longer impurity confinement due to the neoclassical accumulation will show that anomalous turbulent transport is smaller then neoclassical one. At the same time, the development of the short-wave turbulence at the electron Larmour scale could result in the additional losses of the electrons and their lower confinement with respect to ions. The measurements of the plasma potential in T-10 with HIBP [2] showed that in OH and, even in ECRH discharges, core plasma potential is negative, which evidences that ion diffusivity is higher, then electrons. In this case the plasma diffusion should be determined by the ion component. Thus, the comparison of the different plasma species confinement may be informative about turbulence types and its level. Simultaneous investigations of the plasma transport and the turbulence characteristics enable to propose the hypothesis to explain the confinement rise with the density.

The transport of high Z ions was studied using KCl, Ti pellets and fast argon gas injections. The impurities were added by the pneumatic injector. Their confinement was analyzed by means of X-ray crystal monochromator RM-2 [3]. It was able to record the brightness of the He or H-like argon, potassium or titanium lines simultaneously along the 48 chords with the time resolution of 10 μs. The emission of each line was observed in a series of the reproducible discharges. The dynamic variation of He and H-like impurity ions after injection was modeled with the special code. Main plasma confinement was investigated, using short D_2 gas puff. The dynamic evolution of the local density was done with the Abel inversion of the 16 channels mm-wave and infra-red laser interferometer. The energy confinement time was estimated from the total heating power and total energy in plasma. Turbulence characteristics were measured by correlation reflectometer (CR) [4], from top of the plasma torus.

The confinement times were obtained by the observing of the decay time for the non-recycling impurities as K and Ti. For the cases of nearly 100% recycling Ar impurity and plasma density, the confinement times were determined from the rate of the approaching of the stationary level. The computer simulations proved that both approaches give the same values of the confinement time for the equal diffusion and pinch velocities. Moreover, in such approach the confinement times are determined during the last phase of the injection, when plasma parameters already return to the stationary values and the perturbations are negligible. It should be noted that during 10 – 15 ms after injection plasma parameters and the turbulence were significantly perturbed and the features of so-called non-local diffusion were seen. But this phenomenon is out of scope of the paper.

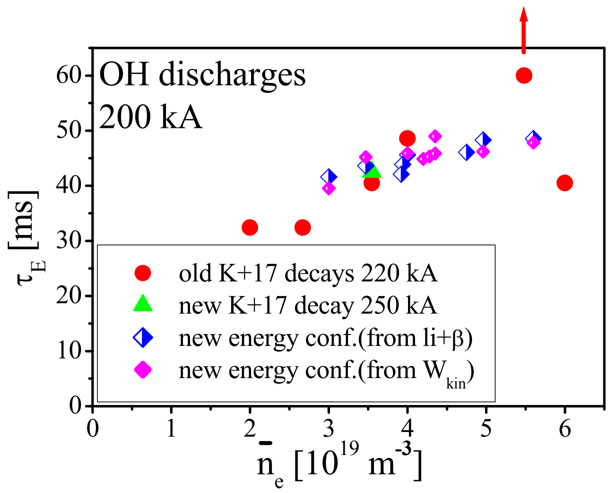

Fig.1 Confinement vs. density for OH discharges.

The dependence of the impurity confinement on plasma density in OH regimes has been investigated in T-10 previously [5]. These results are shown in Fig. 1 together with the new impurity and energy confinement data. The discharge conditions were Ip=200 kA and Bt=2.3 T. It is clearly seen that impurity and energy confinement are equal each other. Moreover, both data reveal the well known feature. The confinement rises with density up to 0.5 of the Greenwald limit and after that saturate. Recent results of impurity confinement agree well with the old one. The impurity confinement are equal to the energy with the exception of high densities region, where a great scatter of the data from 40 to 240 ms was observed. In order not to increase the scale, only one such discharge is plotted Fig. 1 and the vertical arrow show the trend. The analysis of discharges with high impurity confinement reveals the fact that accumulation occurs in a dirty plasma, where sawteeth activity is suppressed and neoclassical impurity accumulation takes place mainly in the plasma centre. This proves well-known phenomenon that plasma transport near the axis is near to neoclassical. At the same time in the clean conditions sawtooth activity is sustained and the lowest confinement of 40 ms. is observed. It reveals the fact that the gradient zone of the

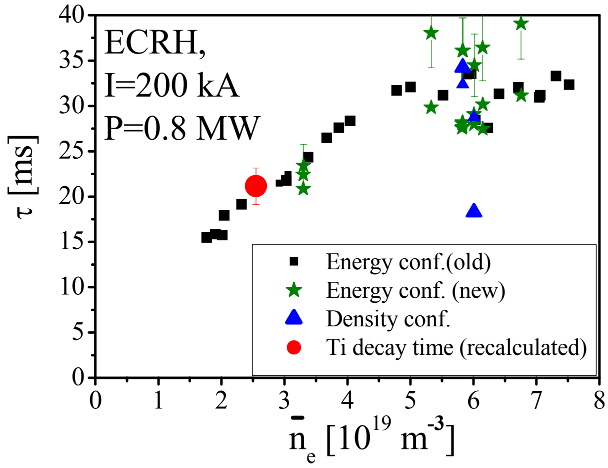

Fig.2 Confinement vs. density for ECRH 200 kA discharges.

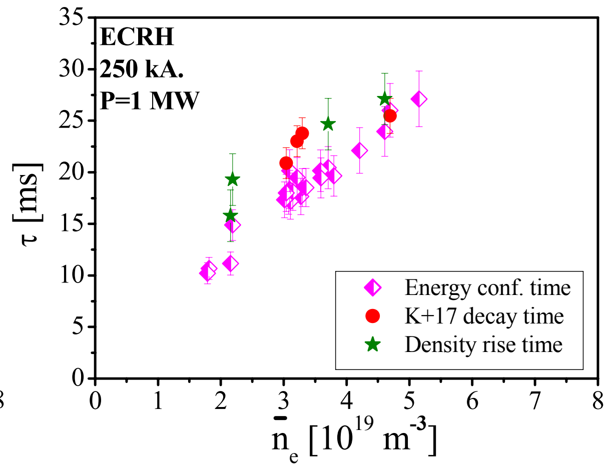

Fig.3 Confinement vs. density for ECRH 250 kA discharges.

discharge is highly anomalous. The coincidence of the impurity and energy confinement times is the evidence that plasma transport in OH is dominated by the strong long-wave drift turbulence like ITG or TEM.

The dependence of different plasma species confinement versus average density in ECRH is plotted in Fig.2. The discharge conditions were Ip=200 kA and Bt=2.3-2.5 T and central ECRH power 0.8-1 MW. The points of the Ti and plasma confinement are plotted together with the energy confinement in the previous [6] and new experiments. One can see that although the values are greatly reduced with respect to OH case, the qualitative density dependence is similar and, again, the plasma and impurity confinements are close. The relation between impurity and plasma confinement with energy is illustrated with additional data in Fig.3. The discharge conditions were Ip=250 kA and Bt=2.4 T and central ECRH power 1 MW. The linear rise of the confinement of all species is clearly seen at low densities. Although the values of impurity and plasma confinement are close each other, their values seems 20-30% higher, then the energy. The coincidence of the impurity and plasma confinement may point out that all ions have the same diffusivity and it exceeds that of the electrons. The lower energy confinement (determined mainly by electrons) with respect to ions may be regarded as the appearance of the additional loss channel in electron component. This may be caused by destabilization of the short drift waves at the electron larmour scale.

The dependence of the Ti and energy confinement on the heating power in OH and the central ECRH is shown in Fig.4. The discharge conditions were Ip=200 kA, Bt=2.3 T and average density Ne about 3×10^{19} m^{-3}. The central ECRH power varied from 0.4 to1.4 MW. The dashed line presents the ITER “L” mode scaling [7]. It is seen that the energy confinement decreases with power in good agreement with the scaling. The Ti confinement also degraded, but to less extend. As can be seen, Ti confinement at highest power about 20-

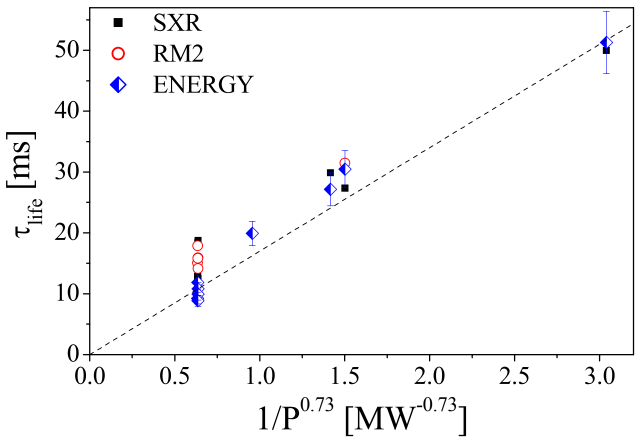

Fig.4 Ti impurity life time dependence from total ECRH power in discharge.

30 % higher, then energy. This support the data of the Fig.3 and may point out additional electron losses at high ECRH power.

Reflectometry measurements of the characteristics of the density fluctuations were made with the T-10 correlation reflectometry and the results can be found in [4]. The measurements were made at a half of minor radius and show that long wavelength turbulence replaced by shorter one, while density increases up to half of the Greenwald density. This transition of the turbulence mean wavelength was completed at the half of the Greenwald density. So the turbulence wavelength became constant at higher densities. The confinement of all plasma particles and energy are equal in OH plasma and exhibit the linear rise at low densities with the following saturation. These results strongly support that in OH plasma transport is dominated by the electrostatic drift convection, caused possibly by ITG and TEM instabilities. The other important factor is the strong decrease of the Te/Ti ratio with the increase of density. This can also cause the rise of confinement.

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