33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-4.093 (2006)

ION HEATING IN the T-10 TOKAMAK DURING PELLET INJECTION AND ECRH

Yu.V.Gott, A.A.Borschagovskii, E.P. Gorbunov, M.M.Dremin, O.B.Ishevskii, A.Ja.Kislov, S.V. Krilov, V.V.Matveev, Yu.D.Pavlov, V.V.Prut, I.N.Roj, D.V.Rizakov, V.M.Trukhin, F.M.Khramenkov, V.V.Chistjakov

RRC "Kurchatov Institute", Moscow, Russia

The results of ion temperature behavior in T-10 tokamak during synchronous pellet injection and ECRH are described.

The ion temperature measurements were fulfilled with help of Solid Target Charge-Exchange Particle Analyzer (STA) [1] and using the intensity of neutron radiation. In Fig.1 one can see the time behavior of the ion temperature in the plasma center measured by STA (points) and with help of neutron radiation (curve) in the ohmic discharge. It is possible to see that the ion temperature measured by both method is the same. Maximal plasma density in this case was ~ 7.6x10^{13} cm^{-3}, plasma current was ~ 300 kA and the magnetic field value was 2.4 T.

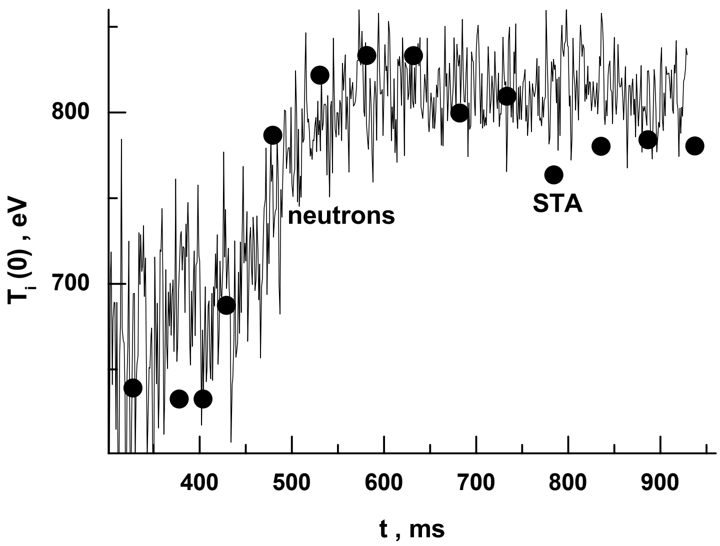
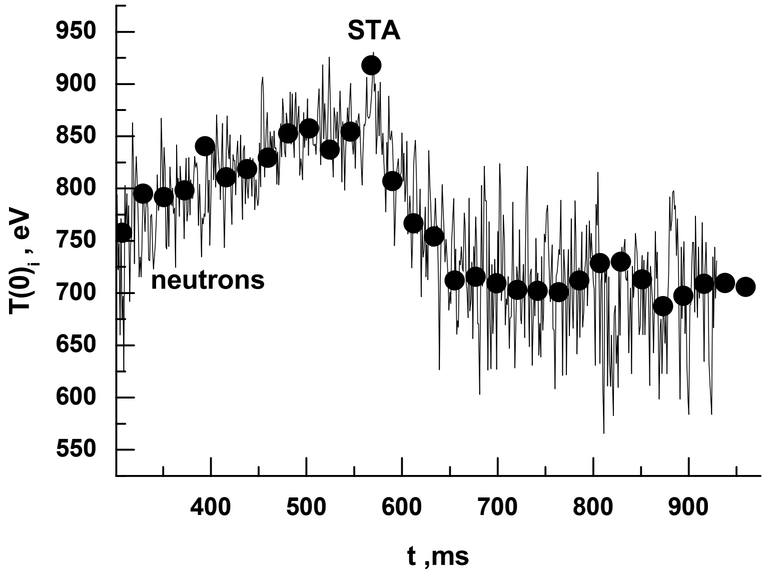


Fig.1.

In Fig.2 the time behavior of the maximal value of plasma ion temperature during Electron Cyclotron Resonance Heating (ECRH) is presented. The heating pulse starts at

550 ms. Fig.2 shows that in the moment when ECRH starts the ion temperature ***decreases***.



F*ig.2*

The explanation of this effect is as follows. During ECRH the electron temperature ***increases*** and the cross-section of heat transport from electrons to ions decreases and ions ***cools*** with the energy confinement time.

The ion temperature behavior after injection of one deuterium pellet of 0.01 cm^{-3} volume is shown in Fig.3. One can see that after pellet injection the ion temperature decrease in time less than 1 ms, and after that it is restored with plasma energy confinement time. In the ohmic stage of discharge the ion temperature measured with help of both methods is the same, but after pellet injection the ion temperature measured with help of neutrons usually less than one measured by STA. Seemingly it can be explained by the changing of plasma density radial distribution during pellet injection. The intensity of

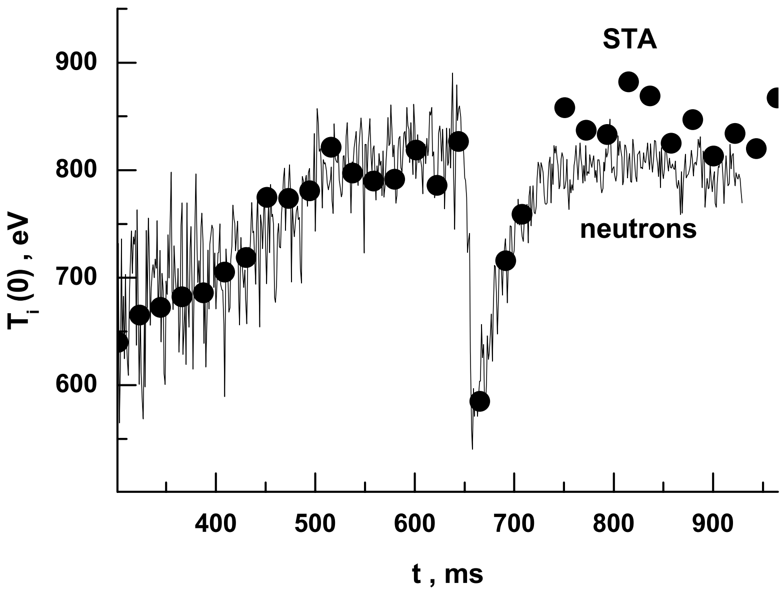


Fig.3.

neutron radiation on the plasma density radial distribution strongly depends on this distribution ($\sim n^2(r)$). The fast decrease of the ion temperature can be explained as follows. When pellet evaporates the big value of cold neutral atoms are injected in plasma . Due charge-exchange process some fast plasma ions are change on cold ions. The additional amount of cold ions is added from cold atom ionized by plasma electrons. Ionization and charge-exchange times are about several microseconds. After finishing of these processes the plasma electrons start to heat ions.

Synchronous with pellet injection the ECRH took place. The electron temperature was measured with help of semiconductor spectrometer (SXR) and second harmonic electron cyclotron emission (ECE). The results are presented in Fig.4. From this figure it is possible to see that during pellet injection electron temperature decrease during short time and after that starts to increase in the time which is compared to energy confinement one. Such behavior is connected with electron energy losses on atom ionization and excitation and ECR heating.

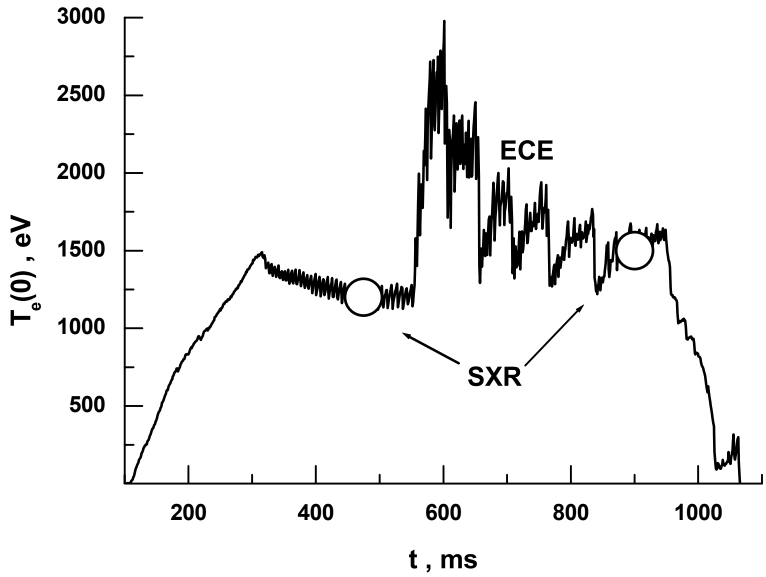


Fig.4

It is known, that in the steady-state ion temperature are connected with electron temperature as

$$T_i = \frac{T_e}{1 + \tau_B / \tau_E} \qquad (1)$$

where

$$\tau_B = 4.4 \cdot 10^{-2} A_i \frac{T_e^{3/2}(\text{keV})}{n_{13}} \qquad (2)$$

is the electron-ion energy change time, τ_E - is the energy confinement time and A_i is plasma ions atomic number.

In Fig.5 the temperature measured by STA (points) and one measured with help of neutron radiation (curve) are compared. In this impulse five pellets were injected. It is seen that after injection of fifth pellet the "neutron" temperature is distinctly less than "STA" temperature. Due to the fact that the temporal resolution of neutron measurements (~ 1-2 ms) is much better than one of STA measurements (20 ms) the moments of measured drop of temperature are not always coincide. The plasma density after injections of fifth pellet is about 1.05×10^{14} cm^{-3}.

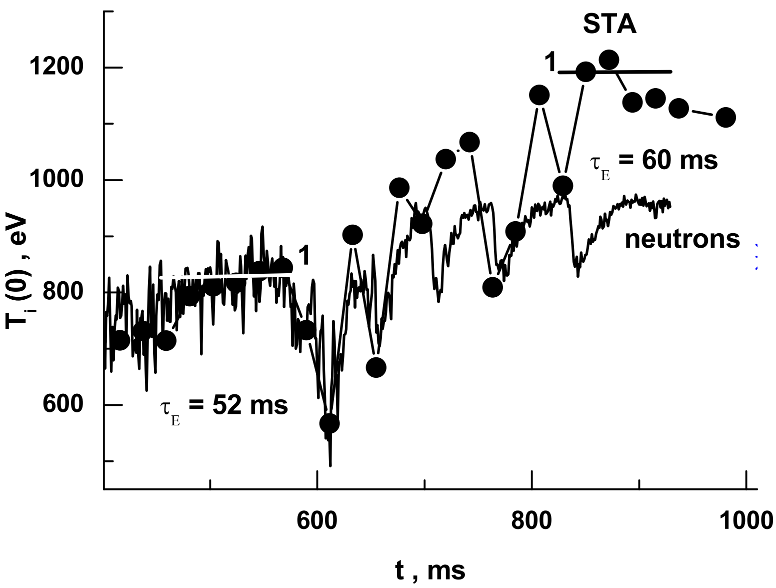


Fig.5

The maximal ion temperature found with help of expression (2) is 800 eV for ohmic part of discharge and 1200 eV after injection of fifth pellet (lines 1 in Fig.5.) . These values are the same as measured by STA. The full plasma energy calculated with help of obtained data at 900 ms is 57 kJoule and experimentally found one is 57.4 kJoule.

So it is possible to insist that synchronous increasing the plasma density with help of pellet injection and heating electrons with help of ECRH give possibility to effectively heat the plasma ion component.

1. Yu.V.Gott, A.G.Motlich, Comparative Characteristics of Atomic Particle Stripping Analysers With Solid and Gaseous Targets, Nuclear Instruments and Methods, v.155, p.443-447, 1978.