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RECONSTRUCTION OF ION TEMPERATURE PROFILE IN T-10 TOKAMAK FROM ANALYSIS OF ENERGY-RESOLVED NEUTRAL-FLUX MEASUREMENTS

Yu.V.Gott, Yu.D.Pavlov

RRC "Kurchatov Institute", Moscow, Russia.

E-mail : gott@nfi.kiae.ru

At present time passive corpuscular diagnostics are widely used for plasma ion temperature determinations (see [1-2] for a review). In these methods the energy distribution in charge-exchange fluxes which escape from plasma along some chord are measured and plasma ion temperature is reconstructed. Numerous experiments have shown that measured with help of this diagnostic ion radial distribution is distorted. In the case when the measurements are fulfilled along different chords in the perpendicular to magnetic axis direction the maximal distortion is in such part of tokamak in which ion vertical drift is directed. Such distortion is explained by influence of the ions trapped in toroidal field ripples. In the tokamak part from which trapped in ripples ions are drifted the distortion is connected with ions which move along banana trajectories.

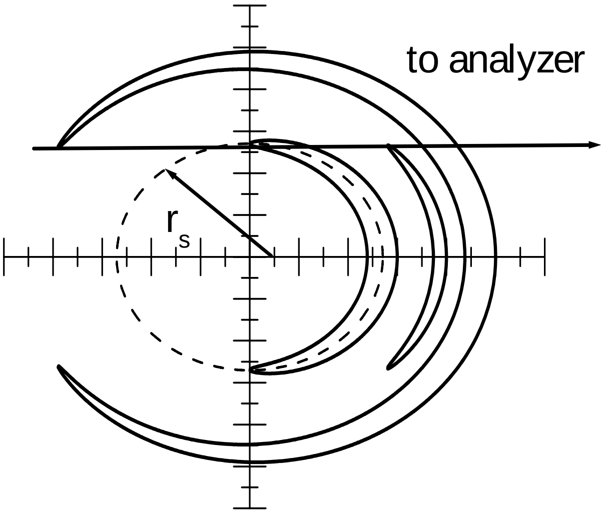

Fig.1

Due to tokamak design in charge-exchange (CX) particle analyzer can hit only particles with zero parallel to the magnetic field direction velocity. Such CX particles arise near banana tip. In Fig.1 one can see the sketch of experimental set up. From the figure one can see that into analyzer arrive particles which come to the tip from radius in which the density and temperature are greater than on magnetic surface with radius r_s (inner part of trajectory). Along the outer part of trajectory in the banana tip arrive particles from the radiuses where density and temperature are less that on r_s. Obtained such a way temperature is named as temperature on magnetic surface r_s.

For real ion temperature reconstruction it is necessary to find the ion distribution function in the banana tip. In Refs.[1,2] it was shown that this function can be found by guiding center averaging of local function

$$f = \frac{n(r)}{\left(2\pi T(r)\right)^{3/2}} \exp(-\frac{E}{T(r)}) \qquad (1)$$

This averaging is defined in terms of time integral along the particle guiding center path

$$< f >= \frac{1}{\tau} \oint f \frac{dl_{\parallel}}{|V_{\parallel}|} \approx \frac{r_s}{\tau} \oint f \frac{d\theta}{|V_{\parallel}|} \qquad (2)$$

where τ is period of particle excursion along trajectory, E is particle energy, T is temperature of particles, r is radial coordinate, θ is poloidal angle.

The CX particle flux reaching an analyzer is

$$\Phi(E) \sim \int \frac{n_0(r)}{\sqrt{E}} < f >< \sigma_{cx} V_i > e^{-L} dx \qquad (3)$$

the integration is fulfilled along the selected chord. Here $n_0(r)$ is the neutral atom density in point with coordinate r, $< \sigma_{cx} V_i >$ is CX rate coefficient averaged over a Maxwellian function of neutral atoms, V_i is ion velocity, e^{-L} is the probability for CX particle reach the analyzer. To measure $\Phi_{exp}(E)$ it is possible with help of Eq.(4) to find CX flux temperature and so the ion temperature of plasma.

$$T_{exp}(r_s) = -\left(\frac{d \ln \Phi_{exp}}{dE}\right), \qquad E>T_i(r_s) \qquad (4)$$

Plasma density and electron temperature radial distributions are measured by independent methods. For reconstruction plasma ion temperature distribution with help of experimental data (4) it is necessary to calculate CX neutrals flux using Eq.(3) for some distribution of $T_i(r)$, calculate radial distribution with help of Eq.(4) and compare result with experimental data. Taking the different distributions of $T_i(r)$ it is possible to obtain the minimal discrepancy between the modeled and experimental spectra.

The ion temperature is assumed to belong to a class of function as follows

$$T_i(r) = T_i(0)\left(1 - \left(\frac{r}{a}\right)^{\alpha}\right)^{\beta} \tag{5}$$

where α and β are parameters to be find and a is tokamak minor radius.

The experiments were fulfilled on T-10 tokamak. Experimental conditions were as follows: magnetic field value was equal to 2.4 T, plasma current was 300 kA, plasma density at $r/a = 0$ was $5\text{x}10^{13}$ cm^{-3}, maximal electron temperature was 1.3 keV, the deuterium plasma was used. The measurements were fulfilled in a tokamak part from which trapped in ripples ions are drifted. The analyzer with solid target [3] was used in this experiments. In Fig.2 the example of measured distribution function is presented.

In Fig.3 one can see the experimental data (triangles), reconstructed profiles (1, points) described by Eq.(5) with $\alpha = 4$ and $\beta = 2$.

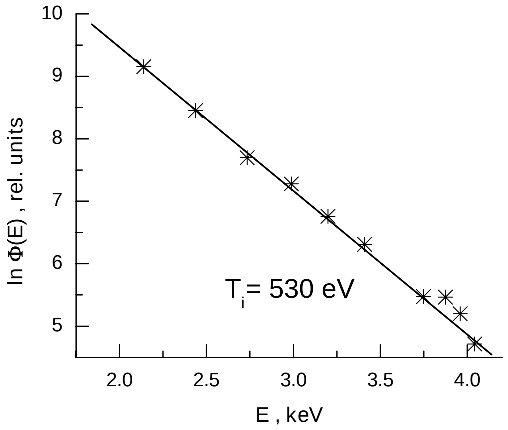

Fig.2

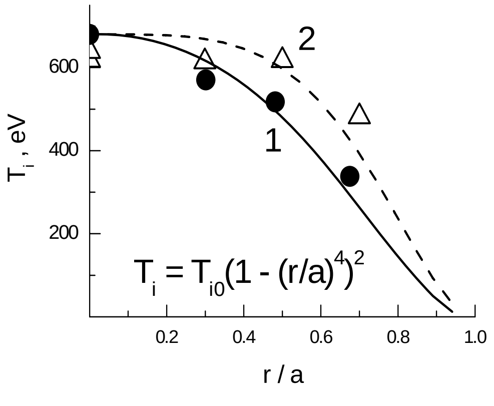

Fig.3

The comparison of restored value of plasma ion temperature distribution (points– 1) and calculated with help of code ASTRA [4] (curve 2) taking into account the Galeev-Sagdeev neoclassical ion transport coefficients is presented. It is possible to see from Fig.4 that these data are in good accordance.

CONCLUSIONS

1. To restore the radial distribution of ion temperature in tokamaks using the passive CX diagnostics one must take into account the "banana" effect.
2. The simulation with help of ASTRA code
3. This effect must be taken into account for CX data analysis in ITER [5].

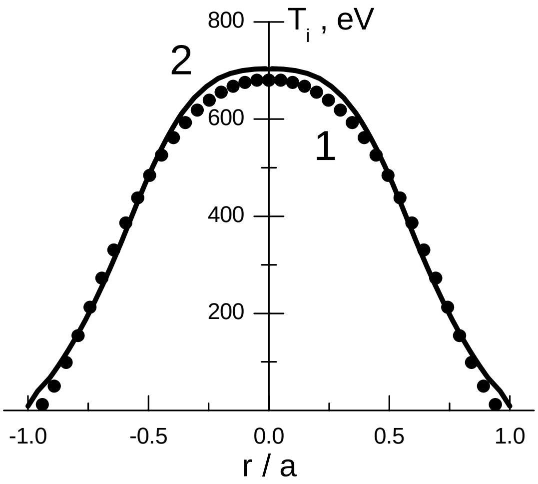

Fig.4

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1. Kovrizhnykh L.M. Fiz.Plazmy,1982,v. 8, p.1105.
2. Gott Yu.V. Plasma Physics Reports, 1995, v. 21, p. 621.
3. Gott Yu.V.,.Motlich A.G, Nuclear Instruments and Methods, v.155, p.443,1978.
4. Pereverzev G.V., Yushmanov P.N., Dnestrovsij A.Yu., et al. ASTRA (An Automatic system for transport analysis in a tokamak), Kurchatov Institute Report IAE-5358/6 (1992).
5. Afanasiev V.I., Kislyakov A.I., Kozlovski S.S., et al. Plasma devices and operations,v.12, p.209, 2004.