32nd EPS Conference on Plasma Phys. Tarragona, 27 June - 1 July 2005 ECA Vol.**29C**, P-5.067 (2005)

EXPERIMENTAL STUDIES of the ION COMPONENT BEHAVIOUR DURING DISRUPTIVE INSTABILITY in TOKAMAKS

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It is well known that the disruptive instability in plasma is accompanied by the acceleration of ions up to energies far exceeding the thermal energies [1-6].

To understand physical processes occurring during disruption, it is important to know the direction of ion acceleration, as well as the place and time at which the ions are accelerated. It was shown that in some devices the ions are accelerated along the toroidal magnetic field and in other ones the ions are accelerated across the toroidal magnetic field . It seems that ion acceleration in different devices is related to different mechanisms. The more full references on this problem one can find in [5].

The typical waveform of charge-exchange neutrals with energy of 2 keV ejected during disruption is presented in Fig.1. The plasma ion temperature in this case was 110 eV [5]. The zero time corresponds to the instant at which the loop voltage is maximal and the major disruption begins.

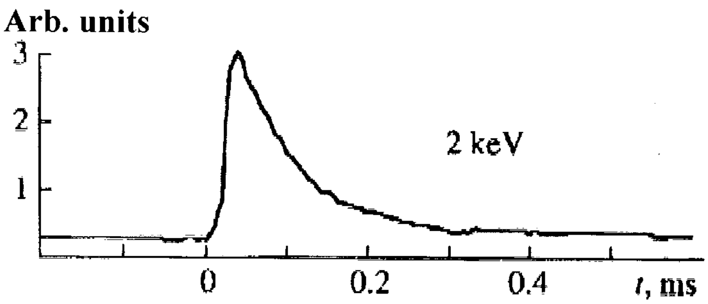

Fig.1.

In Fig.1 one can see that the signal increases during 20-30 μsec and after that it decays approximately at the rate given by the ion life time. It is need to stress that the waveforms of charge-exchange fluxes which escape along and across toroidal magnetic field are the same.

It is generally considered that there are two types of disruptions: major and minor ones. A minor disruption develops primarily at the plasma periphery, while a major disruption usually develops from a minor one and than spreads over the entire plasma column. The experiments were fulfilled when major disruptions or when minor one were exist. Analysis shows that during *minor* disruption the ions are mainly accelerated *along* the magnetic field, whereas during major disruption, they are mainly accelerated *across* the magnetic field. Fig.2 shows the waveforms of charge-exchange fluxes ejected along (curve 1) and across (curve 2) magnetic field. The some times when minor and major disruptions take place are marked in this figure. One can see that during minor disruption the ions are accelerated mainly along magnetic field and during major one the ions are accelerated predominantly across magnetic field.

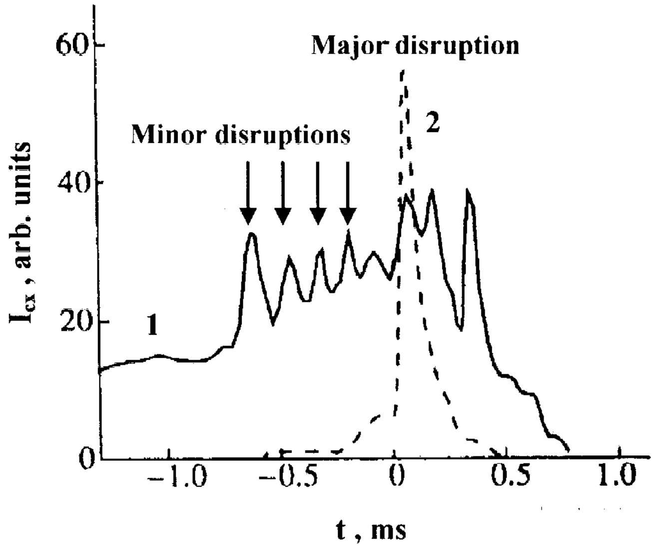

Fig.2.

In Fig.3 one can see the energy distribution of the plasma ions before the major disruption (curve 1) and ion distribution for perpendicular $E_\perp$ and parallel E_{II} energies (curves 3,4) during disruption (curve 3 and 4 refer to ions moving along the plasma current and in the opposite direction, respectively) [5]. One can see that the ion distribution function is Maxwellian before disruption, but has a pronounced high-energy tail afterwards, extending to a few keV. During a major disruption the ion temperature increases by a factor 1.5-2.

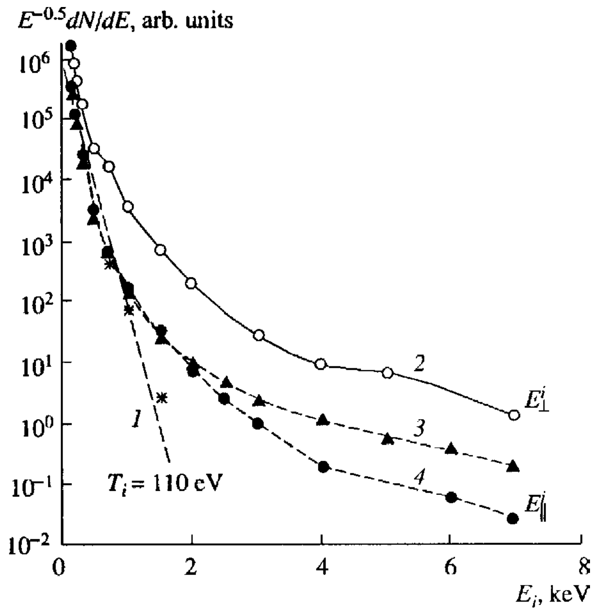

Fig.3.

Special measurements performed in [6] showed that, during the major disruption, the ions are accelerated near the rational magnetic surfaces *q=1* and *q=2*. As example in Fig. 4 it is shown the typical distributions of fluxes of 700-eV charge-exchange neutrals ejected from the plasma along different chords and measured 160 μsec before the major disruption (curve 1) and 25 μsec after it (curve 3). The curves in this figure are normalized to the corresponding flux intensities at z=0. Unfortunately, because of technical problems, we could not measure neutral fluxes immediately at the instant of disruption. It can be seen that these distributions are nonmonotonic and have pronounced maxima near the chords corresponding to $z \approx \pm 20\,\text{mm}$ and $z \approx \pm 70\,\text{mm}$ from the plasma axis.. The calculations show that the position $z \approx \pm 20\,\text{mm}$ corresponds $q = 1$ and the position $z \approx \pm 70\,\text{mm}$ corresponds $q = 2$. The arrows near the experimental points mean that the correspondent signal amplitudes far exceed the values indicated in the figure. Sometimes during the plasma discharge we have several major disruptions. Results from similar chord measurements during the second major disruption are presented in Fig.5. In contrast to the first major one, this distribution has no pronounced peaks in the central region of the plasma column. Probably, after the first major disruption, the current density is redistributed so that the safety factor near the plasma axis becomes greater than unity.

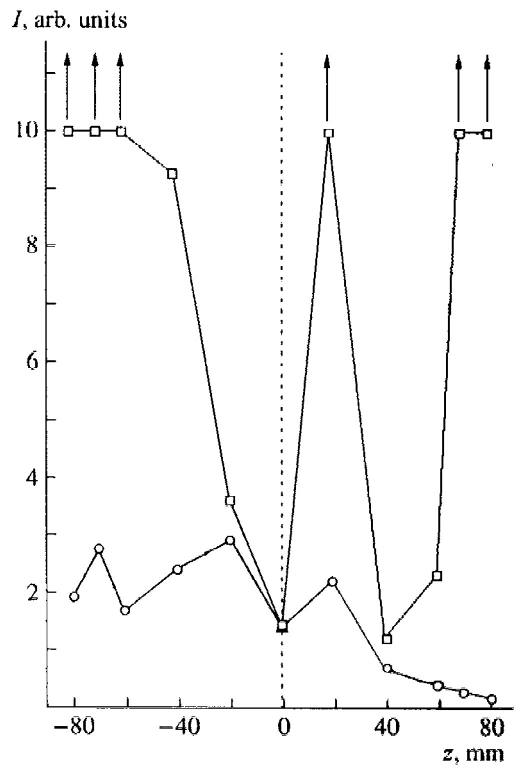

Fig.4.

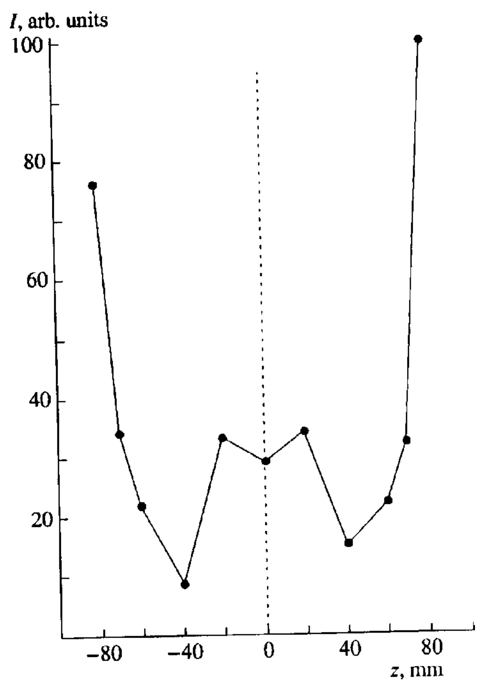

Fig.5.

The physical origin of these phenomena can be explained as follows. During disruption the substantial toroidal electric field must be induced. This electric field produces the runaway ions. The induced electric field is in direction of the plasma current near the center (where the current drops during disruption) but negative at the inboard edge (where the current rises). So we can see that ions are accelerated in current direction and in opposite one (Fig.3). Evidently such situation we have during minor and major disruptions.

During the major disruption it is possible to see that the ions are accelerated across the magnetic field. Such acceleration can take place if during disruption some ion-cyclotron instability is exited. The mechanism for the onset of this instability may be as follows: electrons near rational surfaces are accelerated during the disruption. When the velocity of these electrons exceeds a certain value, an ion-cyclotron instability develops. So we can approve that during the minor disruption the velocities of the runaway electrons are insufficient for instability excitation and the ions are accelerated mainly along the magnetic field in the co- and contr- directions. During the major disruption the runaway electrons develop ion-cyclotron instability and ions are accelerated along and across magnetic field.

To great regret the characteristics of this instability now are unknown.

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