Energetic ions in a plasma of compact tokamak: role of the magnetic field in EI confinement

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Energetic ions (EI) play important role in high temperature plasma physics, since, firstly, the most effective heating methods (NBI, ICRH) are based on EI beams generation and its subsequent thermalisation accompanied by their energy transfer to target plasma; secondly, EI are produced in fusion reactions and thus provide plasma self-heating. Therefore, optimization of EI confinement is one of major priorities in physics of magnetic confinement and nuclear fusion.

Interest in EI confinement studies is further increased in view of plans of construction of compact neutron sources based on magnetic nuclear fusion concept. Increase of toroidal magnetic field and plasma current is natural and seemingly the only way to enhance EI confinement in compact fusion devices. Three spherical tokamaks – NSTX (Princeton), MAST (Culham) and Globus-M (Ioffe Institute) – began this way. In order to explore effect of Bt and Ip on plasma parameters and EI confinement the experiments with increased toroidal field and plasma current have been performed recently in the TUMAN-3M tokamak. Possibility to increase magnetic field and plasma current was provided with modernization of the toroidal field coils (TC) power supply [1]. Bt in the phase of NBI heating was increased by 30-40% up to 1 T – design magnitude of magnetic field in tokamaks NSTX and Globus-M (field in MAST will be a bit smaller 0,84 T). Plasma current was increased up to 190 kA.

Most sensitive method to observe behavior of EI is detection of total rate of neutrons, generated in fusion reactions. High sensitivity of the method is a result of strong dependence of fusion reaction crossection on relative velocity of interacting ions. In our case 2,45 MeV neutrons produced in DD reaction of EI, arising due to ionization of NBI particles, with target ions. As a result of study of neutron rate In behavior at various magnetic fields, plasma current and densities the dependencies of In on Bt, Ip and n\_e have been established [2]. 2-fold increase of DD neutron rate has been found with increased Bt and Ip. Data base of neutron rate measurements allowed to derive scaling of In on “engineering” plasma parameters:

In ∝ (n^0,36)×(Ip^2,63)×(q\_cyl^1,29)×(E\_b0^4,67).

In the experimental run in plasmas with various horizontal displacements 20% increase in the neutron rate and 2-fold increase in the high energy charge-exchange atom fluxes were found with small plasma shift of 1 cm towards high field side (note minor radius of TUMAN-3M plasma is 22 cm). Analysis of obtained data has shown that major reason of observed increases in the fluxes is a growth of amount of EI [3]. Ion temperature measurement revealed Ti(0) rise from 250 to 350 eV, which is in line with EI amount increase with inward horizontal displacement. Enhancement of capture of EI produced by NB ionization in the inwardly shifted plasma was confirmed by numerical simulation of EI trajectories [4].

References

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