§24. Ignition Analysis for D Plasma with Non-Maxwellian ^{3}He Minority in Fusion Reactors

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One of the possible techniques to decrease neutron load on plasma facing components and superconducting coils in fusion reactors is to use fuel cycle based on D-^{3}He reaction as alternative to D-T. Taking into account that the thermal reactivity of D-^{3}He is much lower than that of D-T, new approach such as ICRF catalyzed fusion should be developed. As far as the reactivity itself depends on the distribution functions of fusion reagents, the main idea of this technique is to modify reagent distribution function in order to achieve favorable reaction rate for nuclear fusion energy production. The effect of transformation from the Maxwellian to non-Maxwellian plasma is essential for reactor aspects studies both in tokamaks and heliotrons.

We demonstrate the possibility to increase the averaged reactivity by modification of distribution function of ^{3}He minority due to ^{3}He selective ICRF heating. This study is done by means of numerical code, based on test-particle approach.[1,2] A simple model for ICRF heating is included in code as well.[3]

The energy from the RF heating is deposited in the perpendicular velocity of the test-particles. Hence the distribution function of ^{3}He is modified to anisotropic shape with an elongated tail in the $v_\perp$ direction. The further elongation is prevented by collisions of test-species with background plasma. The energy from the test-particles transfers to the background species and spreads in the pitch-space. This is called the gyro-relaxation effect. As an example, in Fig. 1 the distribution function of ^{3}He ions in ($v_\parallel$, $v_\perp$) velocity space under F_{RF}=50 MHz heating at t=0.3 s is demonstrated.

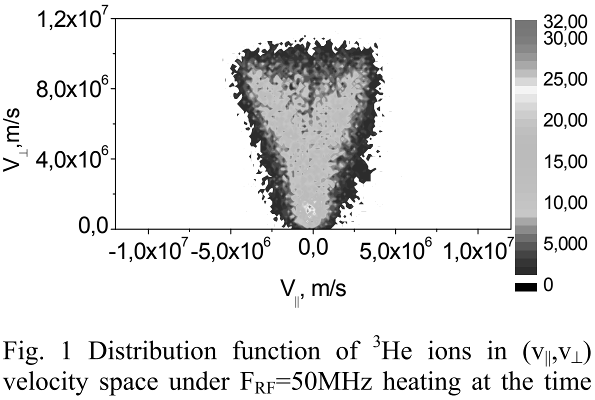

Fig. 1 Distribution function of ^{3}He ions in ($v_\parallel$,$v_\perp$) velocity space under F_{RF}=50MHz heating at the time slice t=0.3 s.

The size and the shape of the energetic tail depend on the heating efficiency, particle losses and energy transfer from the energetic fraction to the background plasma.

In Fig. 2 the evolution of reactivity rates $^3He(d,p)\alpha$ for non-Maxwellian ^{3}He distribution function under F_{RF}=50 MHz heating (red) and F_{RF}=51 MHz heating (blue) is displayed. In both cases deuterium ions are Maxwellian distributed with the temperature 15 keV. With the green curve the reactivity related to the case when both components deuterium and ^{3}He have Maxwellian distributions with the background temperature 15 keV is displayed. The plasma parameters used in this calculation are the following: major radius 6.2 m, minor plasma radius 2 m, deuterium density 5×10^{19} m^{-3}, electron density 6×10^{19} m^{-3}, plasma temperature 15 keV, on-axis magnetic field 5.3 T, RF electric field amplitude 12 kV/m. Throughout our study ^{3}He is considered as minority fraction.

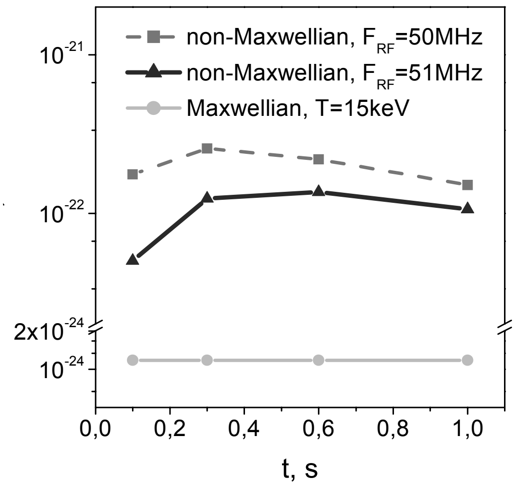

Fig. 2 Reactivity rates $^3He(d,p)\alpha$ for non-Maxwellian ^{3}He distribution function under F_{RF}=50MHz heating (red) and F_{RF}=51MHz heating (blue). The case when deuterium and ^{3}He have Maxwellian distributions with the background temperature 15keV is displayed in green.

The reactivity depends on the relative velocity of the interacting particles.[4] When we increase the energetic tail for one reacting specie (^{3}He) we increase the relative velocity and hence the reactivity by itself. The non-Maxwellian shape of the ^{3}He distribution function plays the key role for reactivity enhancement. It is calculated that the formation of the energetic tail gives rise to the reactivity increase of factor of 100 for both heating scenarios in the considered fusion plasma. The increase of reactivity rate is an important issue for the performance of fusion reactors, which needs further detailed studies.

1) O.A. Shyshkin et al, Nucl. Fusion **47** (2007).
2) A.H. Boozer and Gioietta Kuo-Petravic, Phys.Fluids, **24** (1981).
3) S. Murakami et al, Nucl. Fusion 46 (2006) S425-S432.
4) H.-S. Bosch and G.M. Hale, Nucl. Fusion **32** (1992)