On the physics of isotope effect, operational limits and Zonal Flows in the TJ-II stellarator

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In this work is reported the first experimental evidence of the effect of isotope mass on the radial width of Zonal Flow-like fluctuations in fusion plasmas. In addition, the influence of density limit scenarios on the amplitude of Zonal Flows is discussed.

The mechanism governing the influence of the ion mass on plasma transport is still one of the main scientific conundrums facing the magnetic fusion community after more than twenty years of intense research. On the other hand, density limit is manifested in tokamaks, stellarators and RFPs. In stellarator the density limit is related to radiation collapse whereas in tokamaks edge transport can play an important role.

Electron cyclotron resonance heating (ECRH) (two gyrotrons, 53.2 GHz, P ≈ 240 kW each, suitable for X2 heating in B = 1 T) and neutral beam injection (NBI) heating (two H_0 injectors, E ≈30 kV, P ≈ 500 kW each) plasmas have been investigated in Hydrogen (H) and Deuterium (D) dominated plasmas in TJ-II. Pure NBI plasmas in TJ-II with lithium-coated walls allows to investigate the influence of magnetic fields [B = 0.7 – 1 T] in the density limit. A dual system of multi-probes arrays, placed at two different toroidal and poloidal locations, is used to characterize the spatial profile of long distant cross-correlation (LRC) in floating potential fluctuations in the TJ-II plasma edge [rho ≈ 0.8 – 1].

In ECRH plasmas the LRC radial structure could not be fully explored due to the limited edge plasma region accessible to the dual probe system. Within experimental uncertainties, both the amplitude and radial width of LRC are comparable in H and D plasmas with a slight but systematic increase in the amplitude of LRC in D as compared to H scenarios. The case of NBI plasmas is different. Although the maximum amplitude of LRC is similar in H and D scenarios, its radial position is shifted radially inwards (in the range of 0.5 cm) in the case of D plasmas with respect to pure H plasmas. Furthermore, the radial size of the LRC is of about 1.5 times larger in D than in H plasmas, which is comparable to the ratio of ion Larmor radius (D vs H) in NBI plasmas.The amplitude of LRC is reduced approaching the density limit together with a reduction in radial electric fields and turbulence levels. Results point to the role of collisionality, mean E × B flows and level of turbulence on the amplitude of zonal flows in the proximity of the density limit.