Isotope effects on turbulent transport and confinement in helical and tokamak plasmas: theory and experiment

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Impacts of the hydrogen isotope ion mass on the energy confinement, which are observed in earlier tokamak and helical plasma experiments, have been a long-standing issue in plasma and fusion research, despite its broad interests and importance. One of the scientific goals in new deuterium plasma experiments in Large Helical Device (LHD) is to explore such "*isotope effects*" on transport and confinement.

In this talk, we present a recent progress in gyrokinetic turbulence simulation studies and the related experiments in LHD. Gyrokinetic Vlasov simulations of trapped-electron-mode (TEM) and ion-temperature-gradient (ITG) driven turbulence in LHD plasmas with hydrogen isotope ions and real-mass kinetic electrons are carried out. It has been clarified that combined effects of the collisional TEM stabilization by the isotope ions and the associated increase of the steady zonal flows at the near-marginal linear stability lead to the transport reduction [1, 2], which is distinct from the ion mass dependence in the conventional gyro-Bohm scaling. On the other hand, the gyro-Bohm like dependence is found for the ITG case without the effect of poloidal rotations by equilibrium radial electric fields. The universal nature of the isotope effects on the TEM-driven turbulence and zonal flows is theoretically verified also for tokamak plasmas. In addition, by using PCI and HIBP/CXS measurements in LHD, TEM-like fluctuations propagating to the electron diamagnetic direction have been identified in high-Te/Ti deuterium and hydrogen experiments with ECRH. A moderate isotope mass dependence in the global energy confinement is also found.

[1] M. Nakata, M. Nunami *et al*., Physical Review Letters **118,** 165002 (2017)

[2] M. Nakata, M. Nunami *et al*., Plasma Physics and Controlled Fusion **58,** 074008 (2016)