Effect of isotope mass on transport and confinement: overview of theoretical interpretations and current status of modelling

Y. Camenen

CNRS, Aix-Marseille Univ., PIIM UMR7345, Marseille, France

Experimentally, the beneficial impact of the isotope mass on the energy confinement time is well established. Explaining this isotope dependence, however, remains a challenge. The purpose of this talk is to review the existing interpretations and summarize the current understanding of this research from a theoretical perspective. The experimental observations will be reviewed in a companion talk by C. Maggi.

Turbulent transport is a natural candidate to explain a change in energy confinement. Its isotope dependence will therefore be discussed in the first part of the talk. In its simplest limit, the gyrokinetic equation implies a turbulent diffusivity proportional to the square root of the isotope mass, $\chi \propto \sqrt{m}$. This is the mass dependence of the gyro-Bohm scaling. It implies a deterioration of confinement with the isotope mass opposite to what is observed experimentally. A number of mechanisms can alter the gyro-Bohm scaling of turbulent transport. For instance, the kinetic electron response, zonal flows, collisions, $E \times B$ shearing or avalanches. These mechanisms will be described and their impact on the isotope scaling of transport quantified, showing that a much weaker dependence, sometimes reversed, on the isotope mass can be obtained.

The link between turbulent transport and confinement time is not as straightforward as it sounds. For stiff transport, the role of the boundary condition can be amplified and dominate the isotope dependence of transport. Other indirect effects, like a change in the equipartition power due to the isotope mass combined with stiff transport can also lead to an isotope scaling of confinement different from that of transport. These aspects will be discussed in the second part of the talk.