AAPPS-DPP 2018 Plenary speaker Name: Prof. Yasushi Todo
Affiliation: National Institute of Fusion Science, NINS

Rationale: The candidate is a specialist of kinetic-MHD hybrid simulation of energetic particle driven MHD instabilities. The candidate has recently developed a new simulation technique for the energetic particle distribution formation process coupled with MHD equations, neutral beam injection (=particle source), and collisions for the long (=collisional) time scale. The simulation has been successfully validated on tokamak (DIII-D, JT-60U, TFTR) and stellarator/heliotron (LHD) experiments for various time evolution of MHD instabilities (steady, bursting, frequency chirping), fast ion pressure profile, and electron temperature fluctuations (amplitude and spatial profile) brought about by the MHD instabilities. The candidate will show plenty of simulation and experiment results of energetic particle driven instabilities in fusion plasmas, and give a tutorial talk on basic aspects of energetic particle physics such as inverse Landau damping, wave-particle trapping, resonance overlap of multiple waves and the emergence of stochasticity, and spontaneous formation of hole-clump structure (=BGK type structure) in energetic particle phase space and the associated frequency chirping.

Talk Title: Energetic particle physics in fusion plasmas through computer simulation

Short abstract: Plasmas, both laboratory fusion plasmas and space/astrophysical plasmas, often contain energetic (=suprathermal) particles in addition to thermal ions and electrons. An overview of energetic particles in fusion plasmas is presented in this talk to explain why energetic particles are important and scientifically interesting from the viewpoint of wave-particle interaction.

Nuclear fusion is a safe and environmentally friendly energy source in the next generation. Fusion reactors based on magnetically confined plasmas will harness the fusion reaction of deuterium and tritium in high temperature plasmas. Alpha particles born from the deuterium and tritium reaction with birth energy 3.5MeV are expected to heat the plasma to maintain the high temperature. This type of high temperature plasma that is self-sustained by the fusion reaction is called “burning plasma”. Alfvén eigenmodes (AEs) are magnetohydrodynamics (MHD) oscillations of the magnetically confined plasmas. The speed of alpha particle with energy 3.5MeV exceeds the phase velocities of Alfvén wave and slow magnetosonic wave. The alpha particles can resonate with AEs in the collisional slowing-down process, and may destabilize and amplify the AEs. The alpha particle transport by the amplified AEs flattens the alpha particle spatial profile and leads to alpha particle losses. This will reduce the alpha particle heating efficiency and deteriorate the fusion reactor performance. Alpha particle driven AEs are one of the major concerns of burning plasmas. This motivates the extensive studies of the interactions between energetic particles and AEs using fast ions generated by the neutral beam injection (NBI) and ion-cyclotron-range-of-frequency (ICRF) wave heating in tokamak and stellarator/heliotron plasmas.

A tutorial talk will be given on basic aspects of energetic particle physics such as inverse Landau damping, wave-particle trapping, resonance overlap of multiple waves, and spontaneous formation of hole-clump structure (=BGK type structure) in energetic particle phase space and the associated frequency chirping. The energetic particle driven instabilities are saturated by wave-particle trapping, but the resonance overlap among multiple AEs with large amplitude will generate stochasticity and liberate a large amount of energy. This significantly enhances the AE amplitude and energetic particle transport. Recent computer simulations that reproduced the spatial profile and amplitude of AEs and energetic particle transport measured in the experiments will be presented [1-5].

List of related published papers

[1] Y. Todo *et al.*, Phys. Plasmas **24** (2017) 081203.
[2] Y. Todo, New J. Phys. **18** (2016) 115005.
[3] Y. Todo *et al.*, Nucl. Fusion **56** (2016) 112008.
[4] Y. Todo *et al.*, Nucl. Fusion **55** (2015) 073020.
[5] Y. Todo *et al.*, Nucl. Fusion **54** (2014) 104012.