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Prompt Loss Characteristics of Energetic Particles in the KSTAR Negative Triangularity Plasma

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The discovery that negative-triangularity (NT) plasma can achieve fusion reactor-grade performance in the absence of Edge Localized Modes (ELMs) [1] has sparked widespread research interest in NT plasma physics globally. This research has catalyzed active investigations into fusion reactor design [2,3]. Considering the potential of ELM-free high-performance NT plasma as a base operational scenario for future fusion reactors, NT plasma experiments and simulation studies have been being undertaken utilizing KSTAR. In the experimental endeavors, a plasma with the triangularity (δ) of -0.2 and the elongation (κ) of 1.4 at the last closed flux surface (LCFS) was achieved for the first time in 2022. This year, an NT reference limited plasma with δ = -0.3 and κ = 1.7 at the LCFS is to be achieved in KSTAR, whose control scheme will be verified by TokSys beforehand. The simulation efforts focus on modeling transport of energetic particles and impurity gases, and radiation power loss in NT plasma, employing codes such as NuBDeC, Hermes-3/BOUT++, etc.

In this presentation, we will discuss the methods and results of a simulation study using the NuBDeC code [4] to characterize the prompt loss of energetic neutral beams injected from the two KSTAR neutral beam injection (NBI) machines, NB1 and NB2, into the KSTAR NT reference plasma through comparison with a positive-triangularity (PT) counterpart. Figure 1 illustrates that the loss in the NT configuration was substantially larger than in the PT configuration, by about 5 - 60 times, depending on the beam. However, the prompt loss of energetic particles over the surfaces of the plasma facing components (PFC) tended to be directed to lower X points and then to divertor (potentially wider in the case of NT) target regions for both configurations. Among the six beams injected from the two NBI machines, only NB1-B, which is horizontally aimed at the magnetic axis or the innermost core, did not result in any prompt loss of the deposited particles in either plasma configuration. This was speculated to be because no beam particles were deposited at the edge of the plasma. The implications of these results and other details will be discussed in the presentation. If available, experimental data will also be presented to validate the simulation results.

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References

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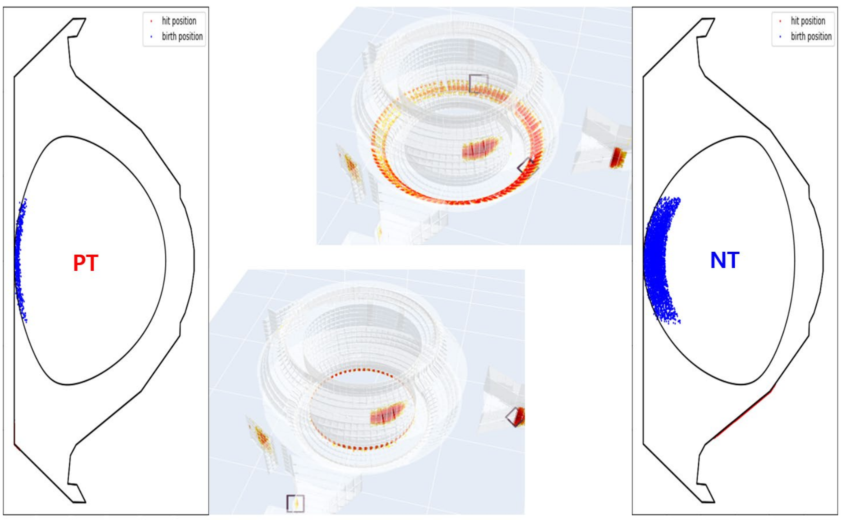

Figure 1. Beam particle deposition and prompt loss aspects for the NT reference plasma and a PT counterpart in KSTAR: The center images show 3-D visualizations of the heat load on the PFC for the NT reference plasma (right) and the PT counterpart (left). The blue dots represent the locations where prompt loss particles are deposited.