Enhancement of nuclear reactions via the kinetic Weibel instability in plasmas

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Abstract: In astrophysics, nuclear reactions take place mostly in the plasma environment, such as the primordial universe, stars and interstellar mediums. However, so far, most of our knowledge of nuclear reactions are from the experiments on conventional particle accelerators, with no plasma effects taken into account. With the rapid progresses of high-power laser facilities, laser-plasma has been regarded as a unique platform for researching nuclear reactions in plasmas. Some colliding laser-produced plasmas experiments have been performed on different laser facilities, and give us strong hints that nuclear reactions in plasmas can be modulated significantly by the self-generated electromagnetic fields and the collective motion of plasma. However, no self-consistent theory or simulation has been given to explain how the kinetic effects influence the nuclear reactions in plasmas.

With the implement of nuclear reactions module in particle-in-cell code, we systematically show that, the kinetic Weibel instability occurring in colliding plasma results in significant enhancement of nuclear reactions. Specifically, the self-generated magnetic fields deflect ion motions to different angles, decreasing the relative velocity and converting plasma kinetic energy to thermal energy. For reactions with sharp resonance peak in the cross-section, like $t(d,n)\alpha$ or ${}^{12}_{6}C(\mathrm{p},\gamma){}^{13}_{7}N$, the enhancement of reaction yield could reach up to several times even orders of magnitudes, which is a meaningful result and deserves more attention and further research.

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