Quantum Effects on Nuclear Fusion in Plasma Target Irrigated by Energetic Ion Beam

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We need very high temperature or large size reactor in order to obtain net thermonuclear fusion energy gain, especially for typical nuclear fusion reactions besides deuterium-tritium reaction. Are there some new novel fusion schemes to obtain net energy gain with the lower ignition temperature and compact reactor? Recently, it becomes increasingly attractive to use intense energetic ion beams irrigating high density plasma target so as to generate nuclear fusion, which is called as Beam-Target Fusion Reaction.

When the plasma density is so high that its electron Fermi energy level is higher than its thermal kinetic energy, quantum effects appear and beam-plasma interactions show behavior different from the classical cases. We have derived the quantum kinetic equations based on the time-dependent Kohn-Sham equation [1,2], and developed a quantum kinetic code solving Wigner-Poisson equations[3].

As an example, we have made numerical simulations including quantum effects for the proton-boron (p-^{11}B) reaction [4]. The fusion yield of p-^{11}B reactions is closely related to proton beam parameters and boron target conditions such as density, temperature, and ingredients. Quantum degeneracy effect will increase fusion yields by reducing the stopping power of injected protons. A new scheme for beam-target p-^{11}B fusions via injecting a MeV proton beam into a highly compressed quantum degenerated boron target is proposed. Our simulation results show that for densities ranging from 10^3 to 10^4 times the density of solid boron, contributions of bound and free electrons to the stopping power of protons can be dramatically reduced respectively. We can obtain net energy gain when the density of boron target is higher than 2.15×10^4 times the density of solid boron, and the kinetic energy of injected protons is 0.8 MeV.

References

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