L-06 AAPPS-DPP2019

3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Escape of α-particle from hot-spot for inertial confinement fusion

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Escape of α-particles from a burning or an ignited burning deuterium-tritium (DT) hot-spot with temperature up to more than tens keV is very important in inertial confinement fusion, which can significantly influence not only the hot-spot dynamics but also the energy gain.

In the present work, we study the α-particle escape from an burning DT hot-spot with temperatures up to more than tens keV by considering modifications of the α-particle stopping by both DT ions and electrons with their Maxwellian average stopping weights, the relativity effect on electron distribution, and the modified Coulomb logarithm of the DT-α collisions. From our studies, it is shown that: (1) the deceleration is mainly induced by the electrons for a newborn α-particle at T≤50keV, while it is fully dominated by the DT ions for a seriously decelerated α particle or at T >50 keV; (2) the relativity effect can remarkably decreases the α-particle stopping induced by electrons at a high temperature, such as it can decrease by 28% at 100 keV; (3) the modified Coulomb logarithm can be as much as 1.6 times of the ones in traditional model. We gave a fitted expression with consistent geometric treatment, to calculate the α-particle escape factor, which can be applied to the burning hot-spot of 1 to 150 keV and 0.04 to 3 g/cm^2 with an accuracy within ± 0.02. This expression can be used to estimate the α-particle escape factor for a DT hot-spot with a uniform density and a uniform temperature and with the same temperature for the DT ions and the electrons. However, with integration, presented methods can provide a more reliable escape factor for the hot-spot whose plasma status is time and space dependent.

We further discussed the α-particle escape-effect on the hot-spot dynamics by comparing the calculation results with α-particle escape factors from different models. As a result, the hot-spot dynamics of a burning fuel is strongly connected with the escape of α-particles. The escape factor of α-particles from our model is larger than previously published results, which can lead to a lower self-heating, a lower temperature, a lower pressure, and thus leads to a lower energy gain. The escape of α-particles may fail the ignition for parameters near the ignition condition. However, for a violent burning with high temperature (≲64 keV), the α-particle escape can increase the fusion energy gain.

References

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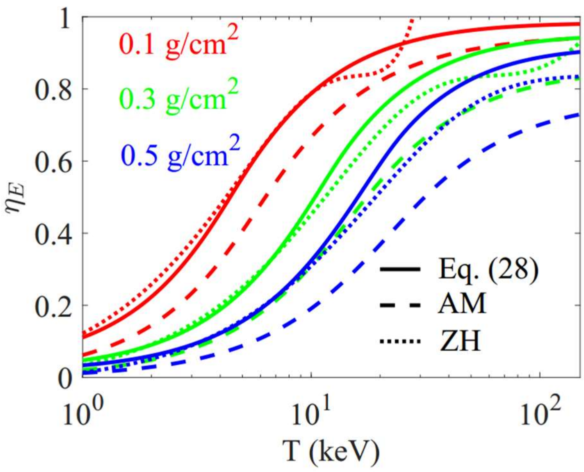

Figure 1. Comparisons among α-particle escape factors from present model (solid line), the traditional model (dashed line, S. Atzeni and J. Meyer-ter-Vehn) and the very recent model (dotted line, A. B. Zylstra and O. A. Hurricane) for a burning hot-spot with temperature T varying from 1 to 100 keV at area density ρR = 0.1 g/cm^2 (red), 0.3 g/cm^2 (green) and 0.5 g/cm^2 (blue).