3 - 24 Energy Loss of Protons Beam with Different Energies in Hydrogen Plasma

Chen Yanhong, Cheng Rui, Wang Yuyu, Zhou Xianming, Lei Yu, Zhang Min, Ma Xinwen and Xiao Guoqing

The interaction of ion beam with matter has always been a classical point of atomic and nuclear physics[1]. However there still need deeper understanding of physical processes in theory. In this paper the energy loss of protons beam with different energies in hydrogen plasma target was introduced and compared with the theoretical predictions by applying the Bethe theory.

In Bethe theory the stopping power can be written as:

$$-\frac{\mathrm{d}E}{\mathrm{d}x}=\frac{4\pi e^4 Z_{\mathrm{eff}}^2}{m_{\mathrm{e}}v_{\mathrm{p}}^2}\left[\sum_k n_{\mathrm{be}}L_{\mathrm{be}}+G\left(\frac{v_{\mathrm{p}}}{v_{\mathrm{th}}}\right)n_{\mathrm{fe}}L_{\mathrm{fe}}\right]$$

where e is the electron charge, Z_{eff} is the effective charge of beam ions, m_e is the electron mass, V_{p} is the projectile velocity, n_{be} is the density of bound electron, n_{fe} is the density of free electron, L_{be} is the Coulomb logarithm for bound electron and L_{fe} is the Coulomb logarithm of free electron, v_{th} is the average thermal velocity, G is the Chandrasekhar function[2]. The Coulomb logarithm can be expressed as

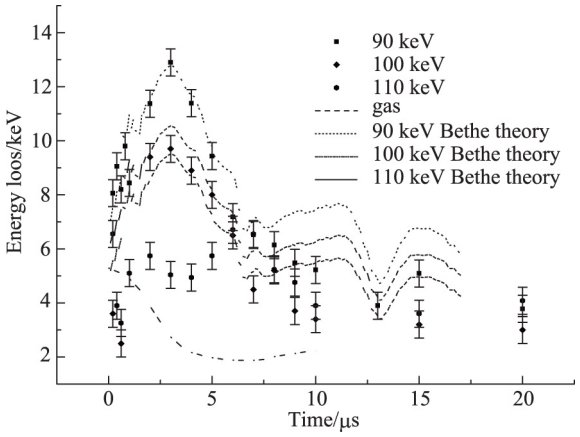

Fig. 1 Comparison of experiment data of energy loss of protons beam with different energies in hydrogen plasma target and Bethe theory

$$L_{\mathrm{be}}=\ln\left(\frac{2m_{\mathrm{e}}v_{\mathrm{p}}^2}{I_{\mathrm{k}}}\right),\ L_{\mathrm{fe}}=\ln\left(\frac{2m_{\mathrm{e}}v_{\mathrm{p}}^2}{\hbar\omega_{\mathrm{p}}}\right)$$

where the I_k represents excitation energy of bound electron and ω_{p} represents the plasma frequency.

Fig. 1 presents the experimental data of energy loss of protons beam with different energies in hydrogen plasma target and the calculation of Bethe theory. It is seen that the Bethe theory is basically in agreement with experiment data. The energy loss decreases with the increase of incident energies. The term velocity of projectile is in the denominator of the expression of Bethe theory. The cross section of condition of proton with bound electrons are less than that of free electrons. The theoretical calculation shows that the free electrons make a considerable contribution to the energy loss for the interaction of proton with the hydrogen plasma.

References

[1] H. Bethe, Ann. Phys. (Leipzig), 397(1930)325.

[2] A. P. Kuznetsov, O. A. Byalkovskii, R. O. Gavrilin, Plasma Phys. Rep., 39(2013)248.