Velocity Dependence of Energy Loss of Iron Ions in Dense Helium Plasma

J. Hasegawa, N. Yokoya, Y. Kobayashi, M. Yoshida, M. Kojima, T. Sasaki, M. Ogawa
Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology, Japan

To investigate interaction processes between fast heavy ions and dense plasma, which is essential for target design of heavy ion fusion, we have measured the energy loss of heavy ions in a helium plasma [1,2].

The plasma target was produced in a 30-mm-diameter quartz tube by z-pinch discharge with a peak current of 70 kA after 2 μs from the ignition. Stark broadening of HeII P_α line (468.6 nm) showed that the electron density reached 8×10^{18} cm^{-3} after about 1 μs. The plasma target length was estimated to be 15.5 cm from an electron density profile in the beam axis. Thus, the line density of the target exceeded 10^{20} cm^{-2}. Under a LTE assumption the line intensity ratio of HeII P_α and HeI 1s2p-1s3d (567.7 nm) indicated the electron temperature was about 6 eV at the peak density.

For interaction experiments we used ^{56}Fe beams with an energy of 4.3 MeV/u or 6 MeV/u from HIMAC at NIRS. The projectile ions entered the plasma target through a 1-mm-diameter aperture and interacted with a pinched plasma column. After exiting from the target, the ions were focused by a quadrupole doublet and detected by a micro-channel-plate detector at 3 m downstream from the target. From a delay in the arrival time at the detector, we extracted the energy loss of the ions in the target.

Fig. 1 plots the energy loss of 6-MeV/u ^{56}Fe ions as a function of time. The energy loss increases with increasing electron density and reaches a maximum of 65 MeV at the peak density. Note that the observed energy losses were independent of the initial charge state of the projectile ions, which indicates that the plasma target was thick enough for the charge state distribution of the projectile to reach its equilibrium immediately after beam injection into the plasma. Numerical calculations of charge state evolution of the projectile in the plasma also supported the experimental result.

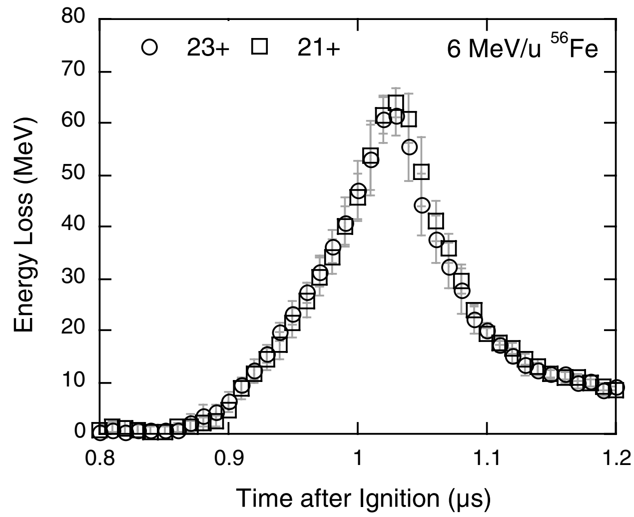

Fig. 1. Time evolution of energy loss of 6 MeV/u ^{56}Fe ions in a z-pinch helium plasma.

The dependences of the energy loss of 4.3-MeV/u and 6-MeV/u ^{56}Fe ions on the target electron density were shown in Fig. 2 and Fig. 3, respectively. Theoretical predictions of the energy loss were also plotted as a function of electron density. When the plasma density was relatively low, the theoretical values well reproduced the experimental results for both injection energies. As the electron density increases, the discrepancy between the theory and the experiment becomes large. This tendency is more remarkable at an injection energy of 6 MeV/u. One possible explanation for these results is that density effects, such as ladder-like excitation and ionization of the projectile, become significant at higher density, whereas the theoretical value does not take into account any density effect. By using a more sophisticated theoretical model including such effects, the discrepancies were expected to become small.

Reference

[1] J. Hasegawa, *et al*, Nucl. Instr. Meth. A **464**, 237 (2001).

[2] M. Ogawa, *et al*, Acta Physica Polonica B **32**, 945 (2001).

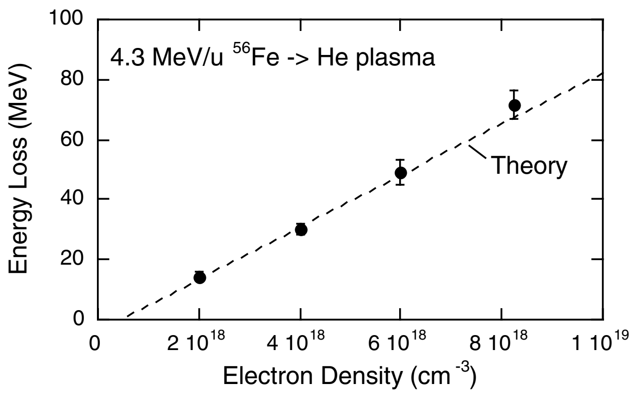

Fig. 2. Dependence of energy loss of 4.3-MeV/u ^{56}Fe ions on electron density of the helium plasma target.

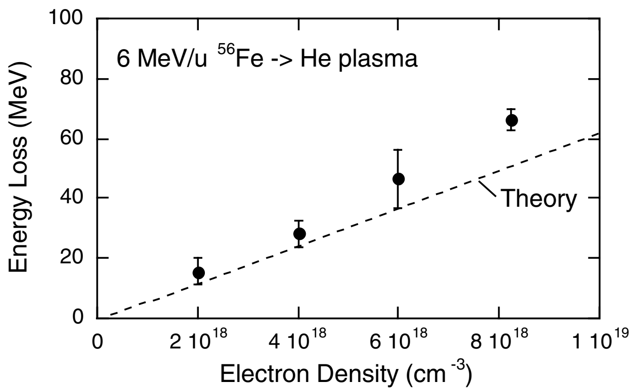

Fig. 3. Dependence of energy loss of 6 MeV/u ^{56}Fe ions on electron density of the helium plasma target.