Analysis of 4^+ carbon projectiles energy loss passing through carbon plasma experiment within LIGHT project at GSI

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Introduction

In this work, we analyze the energy loss of 4^+ carbon projectiles at an energy of 0.6 MeV/u as they pass through a carbon plasma of the experiment to be carried out at GSI within the LIGHT (Laser Ion Generation, Handing and Transport) project. In this experiment, the aim is to measure the energy loss of carbon ions as they pass through a laser-generated carbon plasma. Based on these experimental conditions, plasma simulations will be carried out using the hydrodynamic simulation codes, which will provide us with the theoretical data of the plasma state to estimate its stopping power and therefore find the energy loss of the ion beam passing through it.

The estimation of the energy loss of an ionic projectile in a plasma has a quadratic dependence on the charge state of the projectile, therefore a correct estimation of the instantaneous charge state of the projectile is of great importance. For this purpose, we will use our successful model that uses rate equations based cross sections that describe all the processes of losses and electronic captures that the projectile undergoes in its interaction with the plasma, which we have already defined in [1, 2]. In addition to this charge state model, we will use for comparison the semiempirical models of Kreussler [3] and Guskov [4].

For the calculation of the stopping power due to plasma free electrons we will use the T-Matrix model as described in [1, 2], while for the calculation of the stopping power due to plasma bound electrons, we will use PLASTOP [8]. Finally, the interaction of the projectile with the plasma will be treated in detail, since the plasma parameters are not constant along the projectile trajectory, causing instantaneous variations in the charge state of the projectile, which directly affects the stopping power and the resulting energy loss. By considering the changing stopping power experienced by the projectile, the energy of the projectile is updated, which in turn affects all the above parameters.

Experimental set-up

LIGHT provides ion pulse lengths of around 1 ns lower than the 5.5 ns of previous experiments, which improves the temporal uncertainty when measuring the energy loss. The plasma will be generated by using two frequency-doubled laser beams from the ns-Laser (nhelix) with a configuration of E = 2 x 30 J, τ=7 ns, λ=532 mm and I = 4.6E11 W/cm^2 incident on both sides of the 105 µm/cm^2 thin carbon foil. On the other hand, a carbon ion beam of 1.23 ns FWHM and 8.4 mm focal spot will be generated using the PHELIX laser with a configuration of E = 30 – 40 J, τ= 650 fs, λ=1053 nm, d_t=3.5 µm and I > 1E19 W/cm^2. The outline is shown in Figure 1.

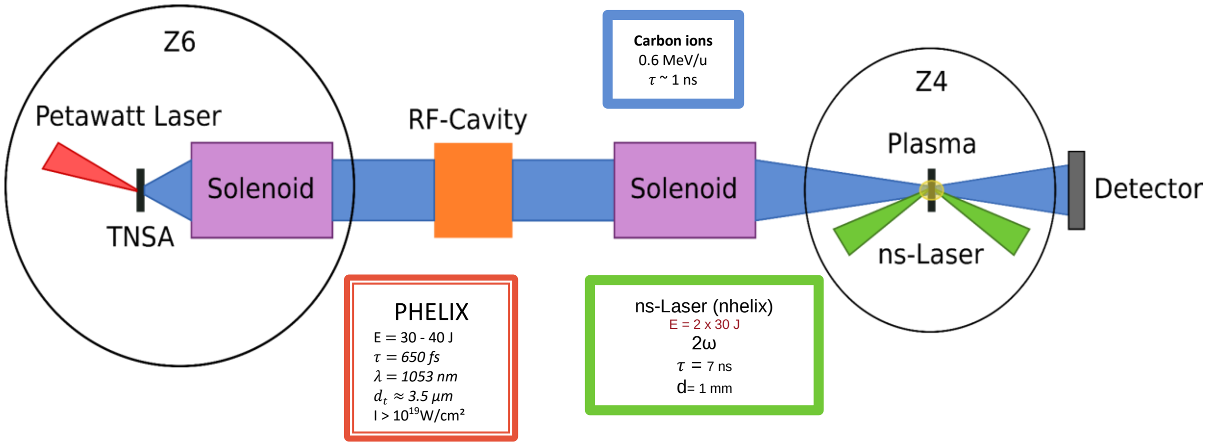

Figure 1: Experimental set-up.

Theoretical model

a) Cross sections

The charge state of the projectile on its path through the plasma is a fundamental parameter for the calculation of stopping power, because it has a quadratic dependence with this parameter. The charge state depends on the number of electrons bound and is therefore affected by the processes of ionization and electronic capture. The ionization and recombination cross sections quantify the probability of each this process [5, 6, 7, 8]. The resulting charge state is compared with Kreussler [3] and Guskov [4] models in Figure 2.