Appendix

At the plasma conditions presented here the electrons and the ions have different temperatures, and collisions between thermal particles and fast beam particles are considered. Therefore, the formulae for the Coulomb logarithm $L = \ln(\Lambda)$ applicable for collisions between species with different temperatures, as reported in Ref. [1] were used to calculate L:

$$L = L^{cl} + \ln\left(Z_1 Z_2 \frac{2\alpha c}{u}\right) - \frac{1}{2}$$

The classical Coulomb logarithm is:

$$L^{cl} = \ln\left(\frac{\lambda_D}{r_{min}}\right)$$

The charges of the colliding particles are Z_1 and Z_2, α is the fine-structure constant, u is the relative velocity, c is the velocity of light, λ_D is the species dependent Debye length and $r_{mim} = \frac{Z_1 Z_2 e^2}{4\pi\varepsilon_0 m u^2}$ is the minimum value of the impact parameter, and $m = \frac{m_1 m_2}{m_1 + m_2}$ is the reduced mass of the colliding particles.

The Debye length is given by:

$$\frac{1}{\lambda_D^2} = \frac{1}{\lambda_{Del}^2} + \sum_j \frac{1}{\lambda_{Dj}^2}$$

$$\lambda_{Dj} = \left(\frac{\epsilon_0}{c^2}\frac{T_j}{Z^2 n_j}\right)^{1/2}$$

The temperature and the number density of the species are T_j and n_j. The temperature of the projectile particles is derived from the relative velocity u, $T = \frac{mu^2}{3}$.

The Coulomb logarithm is calculated for collisions of the proton beam and the alpha particles with electrons, boron ions and protons. Figures A1 and A2 show the velocity dependent Coulomb logarithm for collisions of the proton beams and alpha particles during their slowing down in neutral plasma with temperature and density given in table 1. The stopping time of the proton beam and the alpha particle are sensitive to the Coulomb logarithm for collisions with electrons. A lower value of the Coulomb logarithm leads to higher stopping time for the proton beams as well as for the alpha particles.

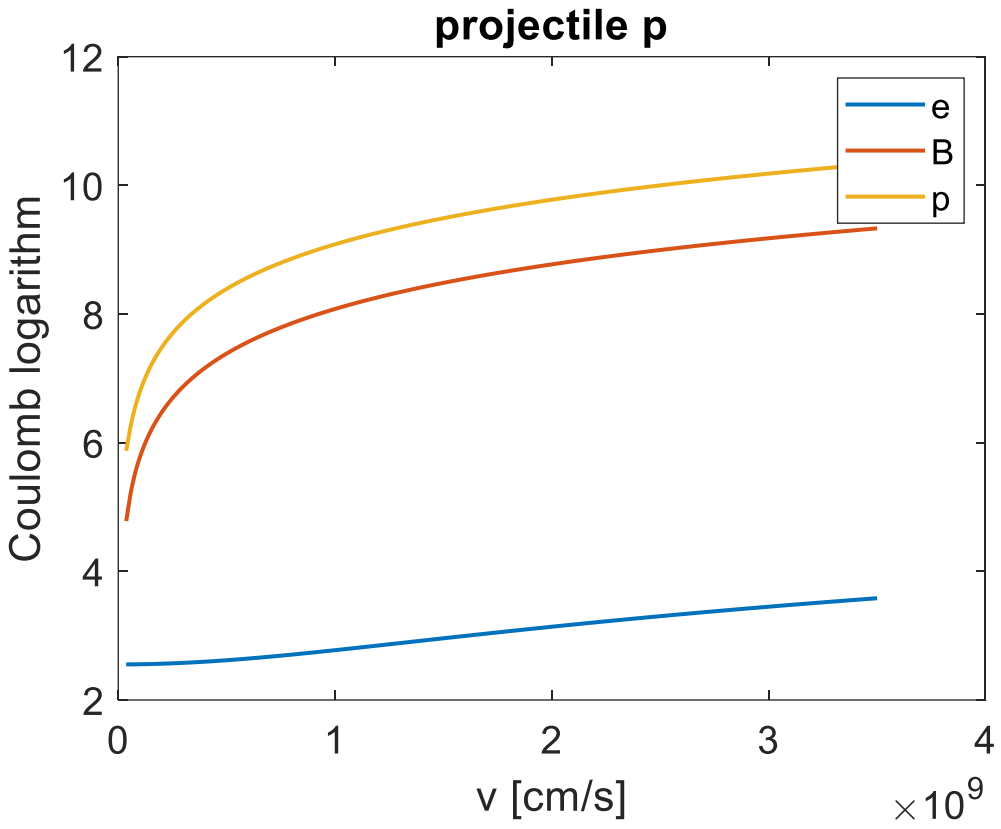

Figure A1: The Coulomb logarithm as function of the proton beam velocity for neutral plasma conditions in table 1.

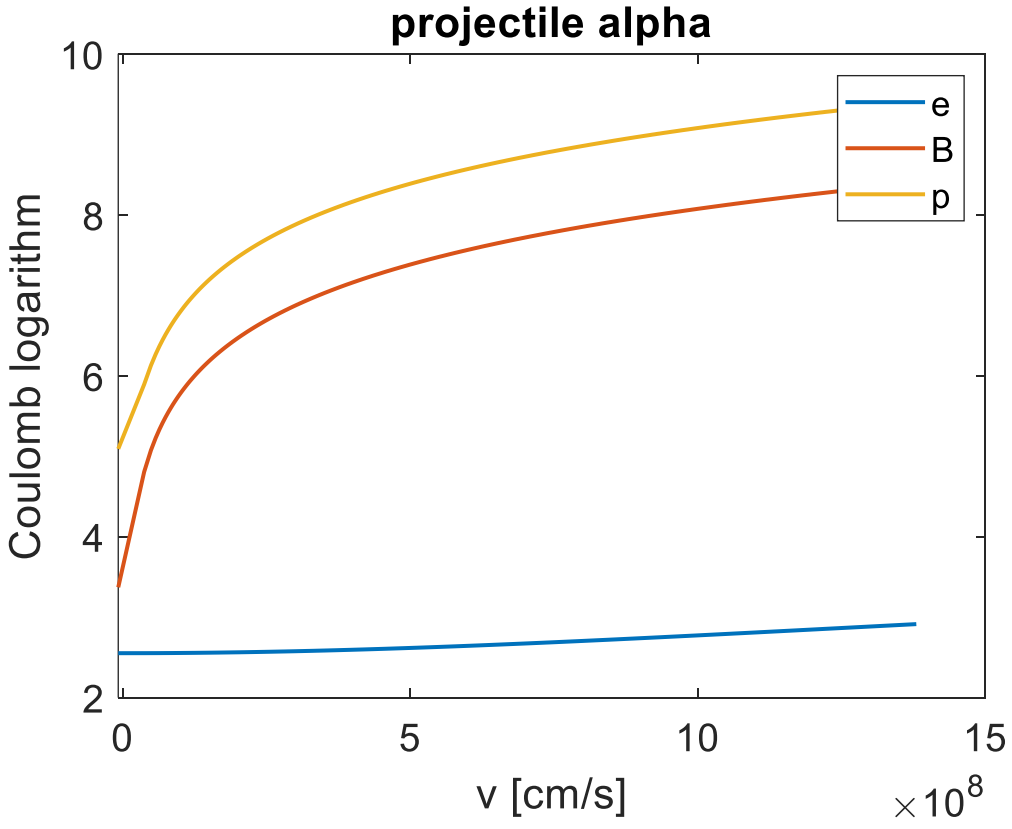

Figure A2: The Coulomb logarithm as function of the alpha particle velocity for neutral plasma conditions in table 1.

References

[1] M. Honda, *Coulomb Logarithm Formulae for Collisions between Species with Different Temperatures*, Jpn. J. Appl. Phys. **52**, 108002 (2013).