Effects of Target Material on Angular Distribution for Ultra Intense Laser Solid Interactions in Space Propulsion

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INTRODUCTION

With the further development of technological opportunities, high energy physics is a strong milestone in this era. Nowadays, space-propulsion have become increasingly popular thanks to new particle accelerator mechanisms . There are, however, some blur topics on how that mechanism works, and the parameters affecting the mechanisms are still unknown.

In this project, **the angle distributions for different materials used as target in Target Normal Sheath Acceleration mechanism is inspected** to figure out how energy is changed with respect to material type.

BACKGROUND & METHODS

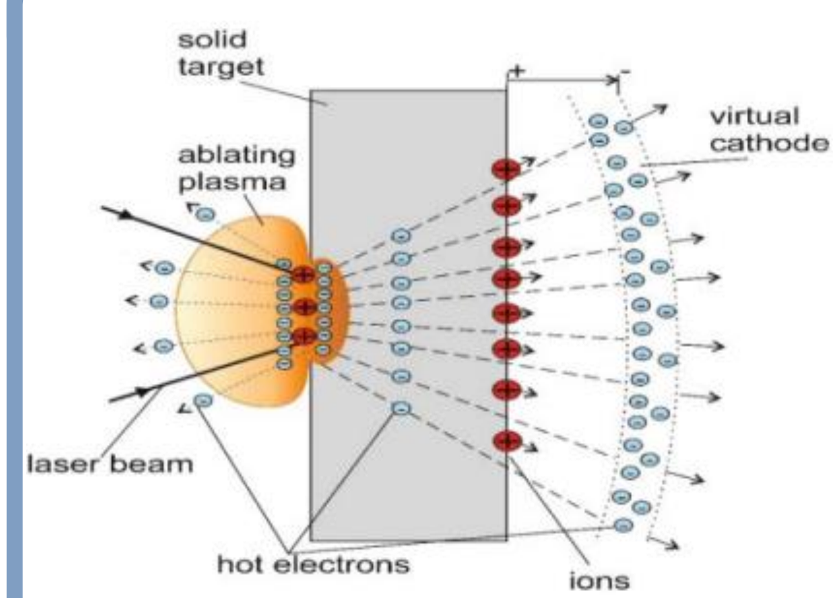

Figure 1. TNSA mechanism schematics.

In the selected mechanism, a metal **target emits electrons** from itself when an **ultra-intense laser** beam hit the surface of the target. These electrons are then used to **generate an electric field**, which accelerates the ions to relativistic speeds. The **resulting thrust** can be used to propel a spacecraft through space.

The **Particle in Cell** (PIC) **technique** is used by the simulation code for plasma physics. This approach uses **smaller-sized pseudo-particles** to represent groups of actual particles, and it uses **a finite difference time domain** methodology to compute the fields produced by the motion of these pseudo-particles on **a grid with a set spatial resolution**.

There are set of equations used in PIC method:

Maxwell's Equations:

$$\nabla \vec{E} = 4\pi\rho \qquad \text{Eq. (1)}$$

$$\nabla \vec{B} = 0 \qquad \text{Eq. (2)}$$

$$c\nabla \times \vec{E} = -\partial\vec{B}/\partial t \qquad \text{Eq. (3)}$$

$$c\nabla \times \vec{B} = 4\pi\vec{J} + \partial\vec{E}/\partial t \qquad \text{Eq. (4)}$$

Lorentz's Force Equation:

$$d\vec{p}/dt = q(\vec{E} + \vec{v} \times \vec{B}/c) \qquad \text{Eq. (5)}$$

Continuity Equation:

$$\nabla\vec{J} + \partial\vec{\rho}/\partial t = 0 \qquad \text{Eq. (6)}$$

Table 1. Material types used in EPOCH 2D.

No	Material Type
1	Plastic (CH)
2	Aluminum (Al)
3	Ferrite (Fe)
4	Solid Hydrogen (H)
5	Lithium (Li)

Table 2. Properties of input.deck block in EPOCH 2D

Simulation Parameters	
Number of cell	100 x 1000 cell
Dimensions	15 μm x 100 μm
λ_laser	0.80 μm
t_laser	0.25 fs
n_critical	1.7 x 10^{21} cm^{-3}
t_simulation	500 fs

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor **Prof. Dr. Melahat Bilge Demirköz** for providing me to perform this project, and to thank my co-advisor **Assoc. Prof. Özgür Culfa** for giving me their time and effort.

RESULTS & DISCUSSIONS

Although the laser is ultra-intense and has significantly small pulse, it does not directly affect the atom to create the electric field and the accelerated electrons. Thus, a **thin layer of hydrogen** is **added to each material** used in EPOCH 2D PIC simulations.

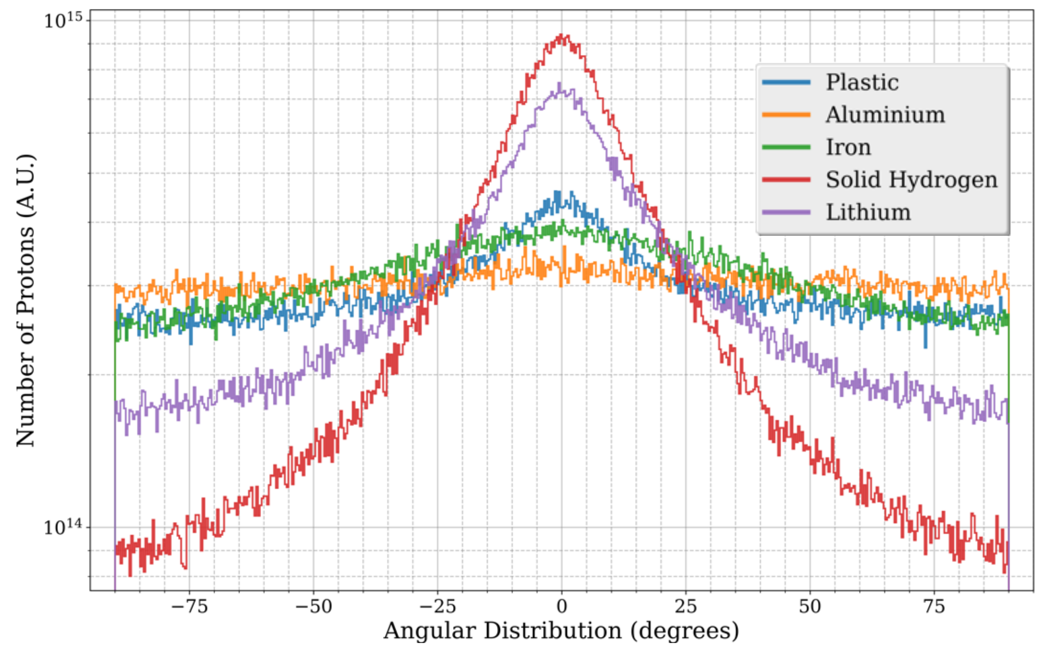

Figure 2. The distribution of number of particles in angle range between -90 and 90 in degrees

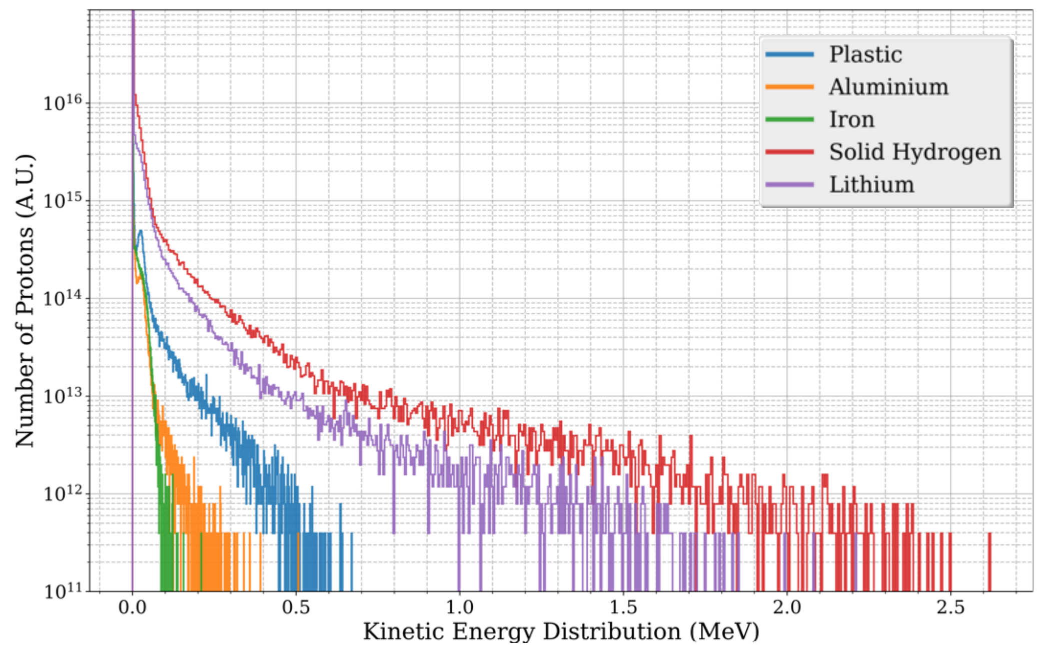

Figure 3. The distribution of number of particles in energy scale at the simulation time of 500 fs

Overall, we unexpectedly obtained **lower kinetic energy** values for the elements of aluminum and iron. This shows that the **incoming laser** beam is **reflected back** because it cannot **pass through** the **1 micron** target layer. With these energy values, unfortunately, we cannot progress in space propulsion yet. But developments always continue, and we are being close enough to breakthrough.

CONCLUSION

- **Linearly polarized laser** offers TNSA acceleration mechanisms for the particle acceleration.
- Protons have scattering on the x and y direction **causing electric field generation on both axis.**
- **Decreasing the atom number** gives more **sharp impulse distribution** on angle characteristic.
- Kinetic energy distribution of atoms with lower atom numbers are also better than **those having much higher scattering angles.**

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