# Experimental design to understand the interaction of stellar radiation with molecular clouds

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## Abstract

Enhanced star formation triggered by local O and B type stars is an astrophysical problem of interest. O and B type stars are massive, hot stars that emit an enormous amount of radiation. This radiation acts to either compress or blow apart clumps of gas in the interstellar media. For example, in the optically thick limit, when the x-ray radiation in the gas clump has a short mean free path length the x-ray radiation is absorbed near the clump edge and compresses the clump. In the optically thin limit, when the mean free path is long, the radiation is absorbed throughout acting to heat the clump. This heating explodes the gas clump. Careful selection of parameters, such as foam density or source temperature, allow the experimental platform to access different hydrodynamic regimes. The stellar radiation source is mimicked by a laser irradiated thin gold foil. This will provide a source of thermal x-rays (around ~100 eV). The gas clump is mimicked by a low-density foam around 0.12 g/cc. Simulations were done using radiation hydrodynamics codes to tune the experimental parameters. The experiment will be carried out at the Omega laser facility on OMEGA 60.

## Motivation

- Universe filled with many sizes of main sequence stars
- O and B type are the most massive and thus the hottest.

| Star Type | Temperature (eV) | Source Intensity ($Wm^{-2}$) |
|---|---|---|
| O | 5.17-2.59 | $7.34 \times 10^{11} - 4.63 \times 10^{10}$ |
| B | 2.59-0.86 | $4.63 \times 10^{10} - 5.62 \times 10^{8}$ |
| Sun (G) | 0.50 | $6.43 \times 10^{7}$ |

Figure 1: The temperatures given above are from reference [2].

- Stars emit radiation close to a blackbody distribution
- The total flux emitted is given by the Stefan-Boltzmann law
  - $F_R = \sigma T^4$.

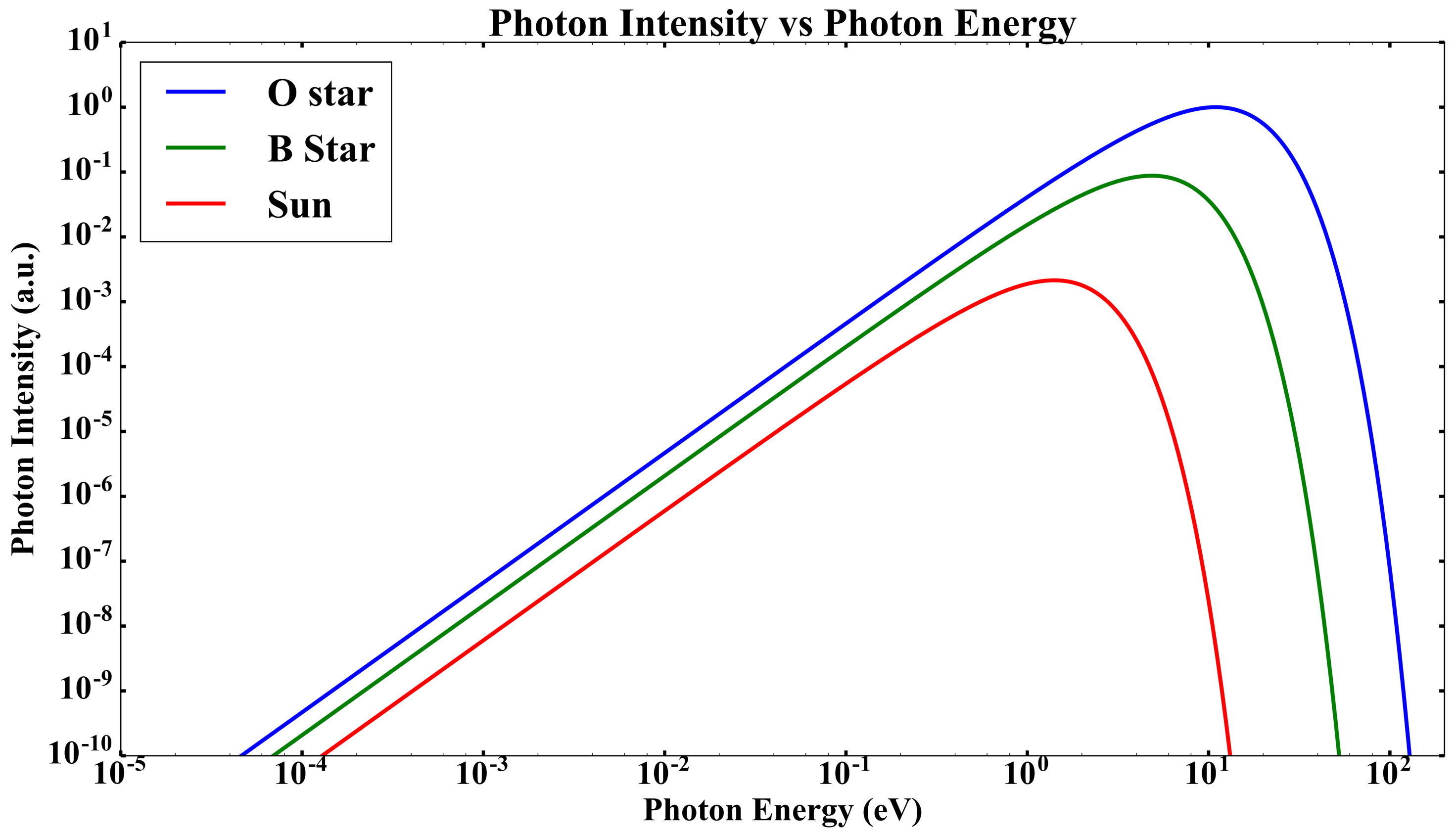



Figure 2: The image above shows photon distributions for O, B, and G type stars.

- O and B type stars increase stellar formation rates
- Clumps of gas in HII regions interact with the radiation
- Important gas clump parameters:
  - Density
  - Composition
  - Radiation Flux
- Radiation Mean Free Path=$5 \times 10^{-7} \rho^{-\frac{8}{7}} T_{eV}^{2}$ (See source [1])
- Two interaction limits:
  - Optically thin: Radiation absorbed throughout clump. Explodes the clump.
  - Optically thick: Radiation absorbed in the gas clump edge. Compresses the clump.

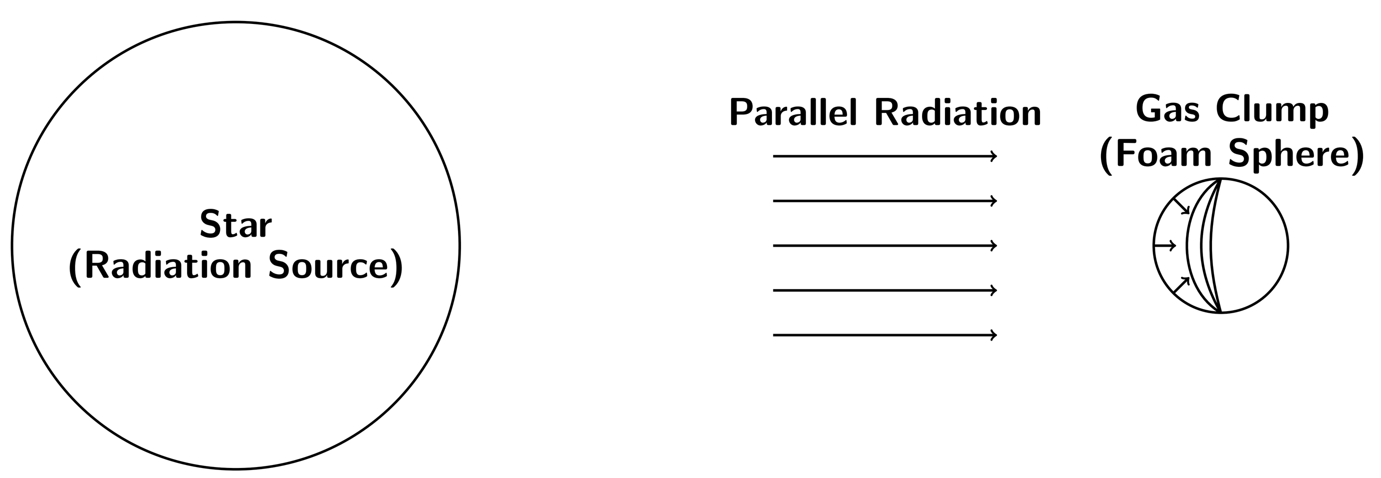



Figure 3: The compression case is shown. The arrows in the gas clump indicate the compression.

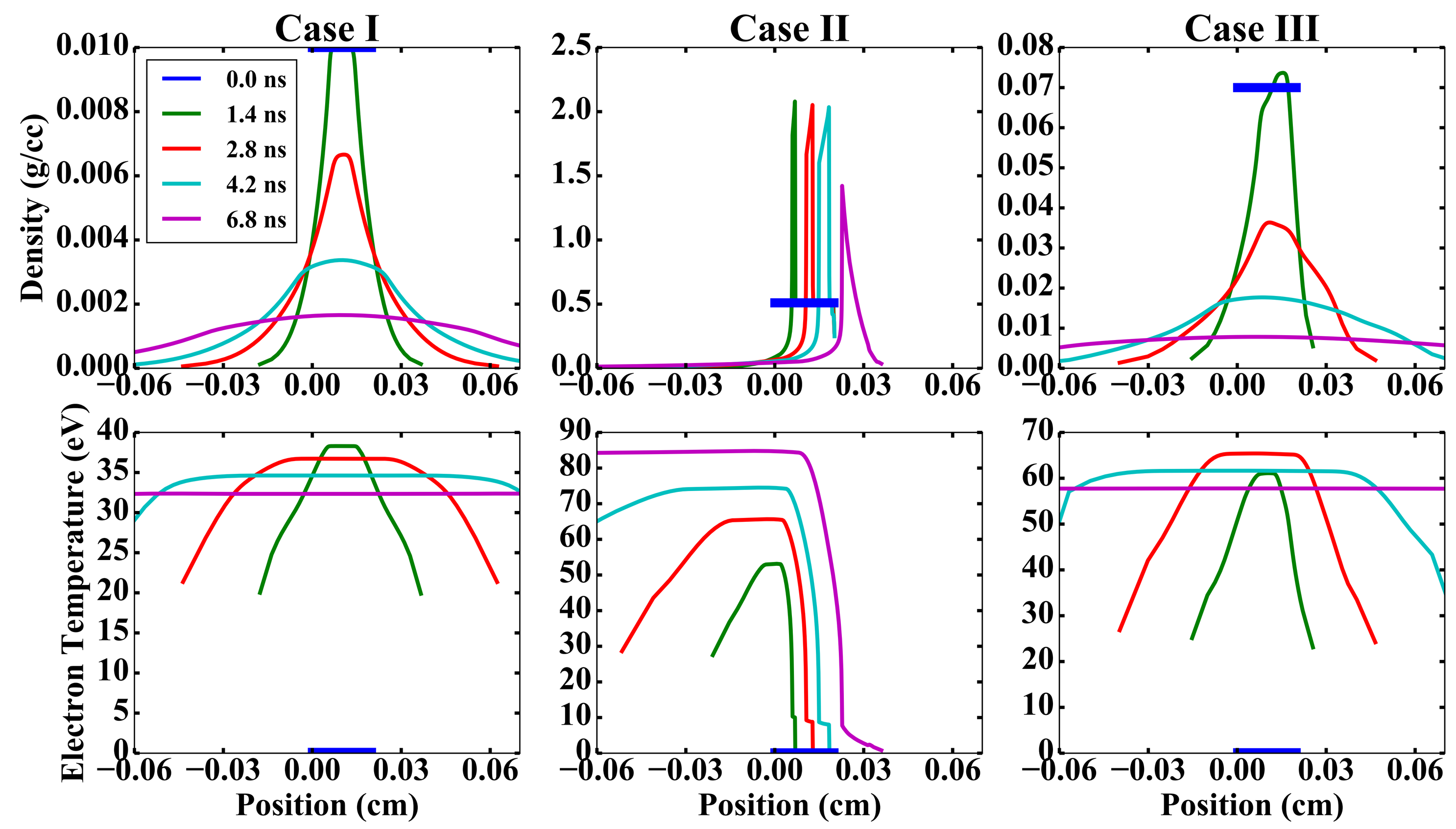
## Experimental Target Parameters

- Develop an experimental platform to diagnose targets
  - Use a thin gold foil as the radiation source (star)
  - Use a foam sphere as the gas clump

| | |
|---|---|
| Foam diameter | 50 – 400$\mu$m |
| Foam Density | 10-1000mg/cc |
| Foam Material | Polystyrene |
| Source to foam length | ~1 mm |
| Source Temperature | 75-125 eV |

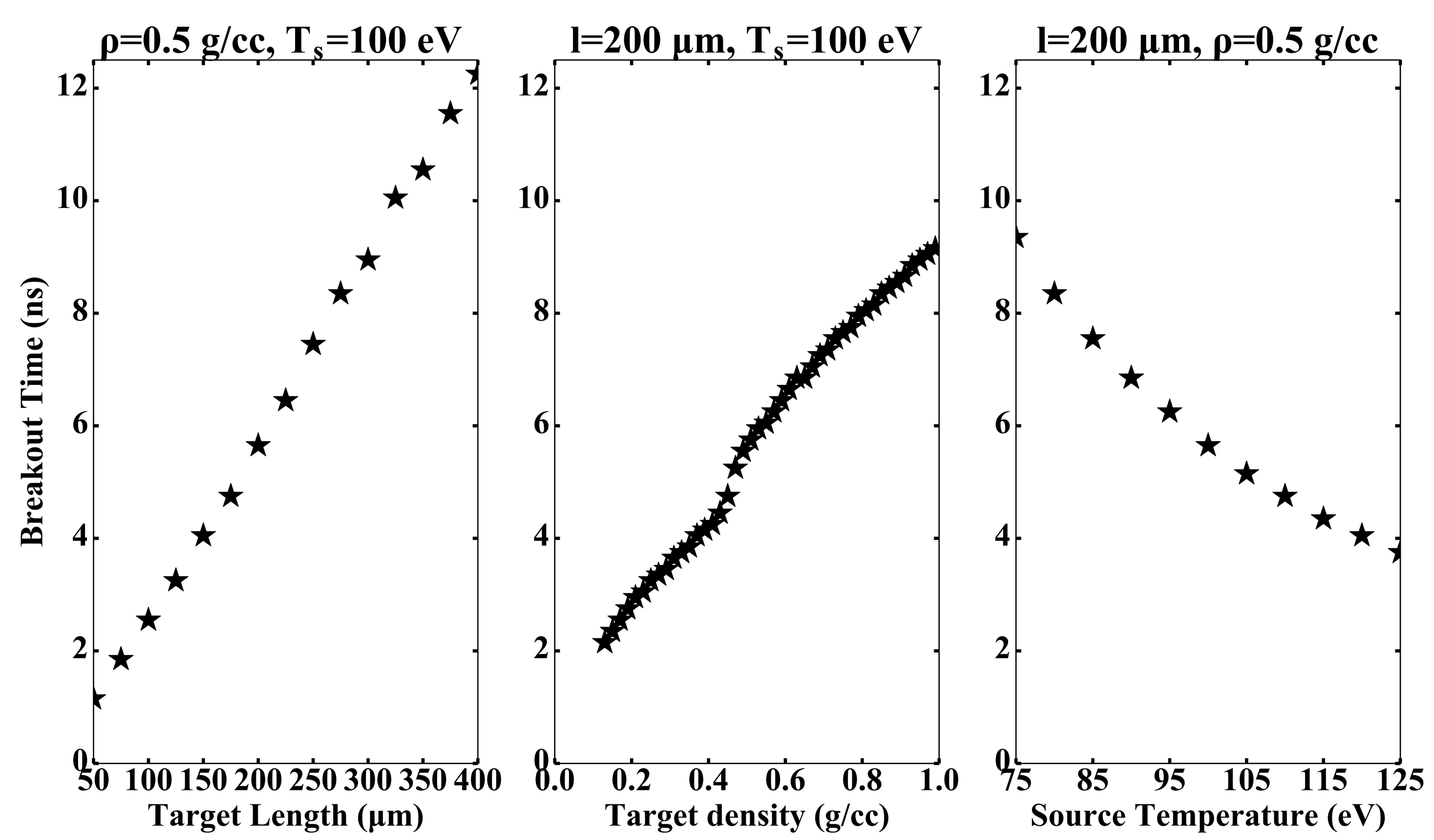
## Simulation predictions depend on radiation mean free path

- HYADES a one dimensional radiation hydrodynamics code
- Three cases seen in simulation:
  - Case I: Immediate explosion of the target
  - Case II: Shocks driven through target.
  - Case III: Shocks driven into target with target explosion.



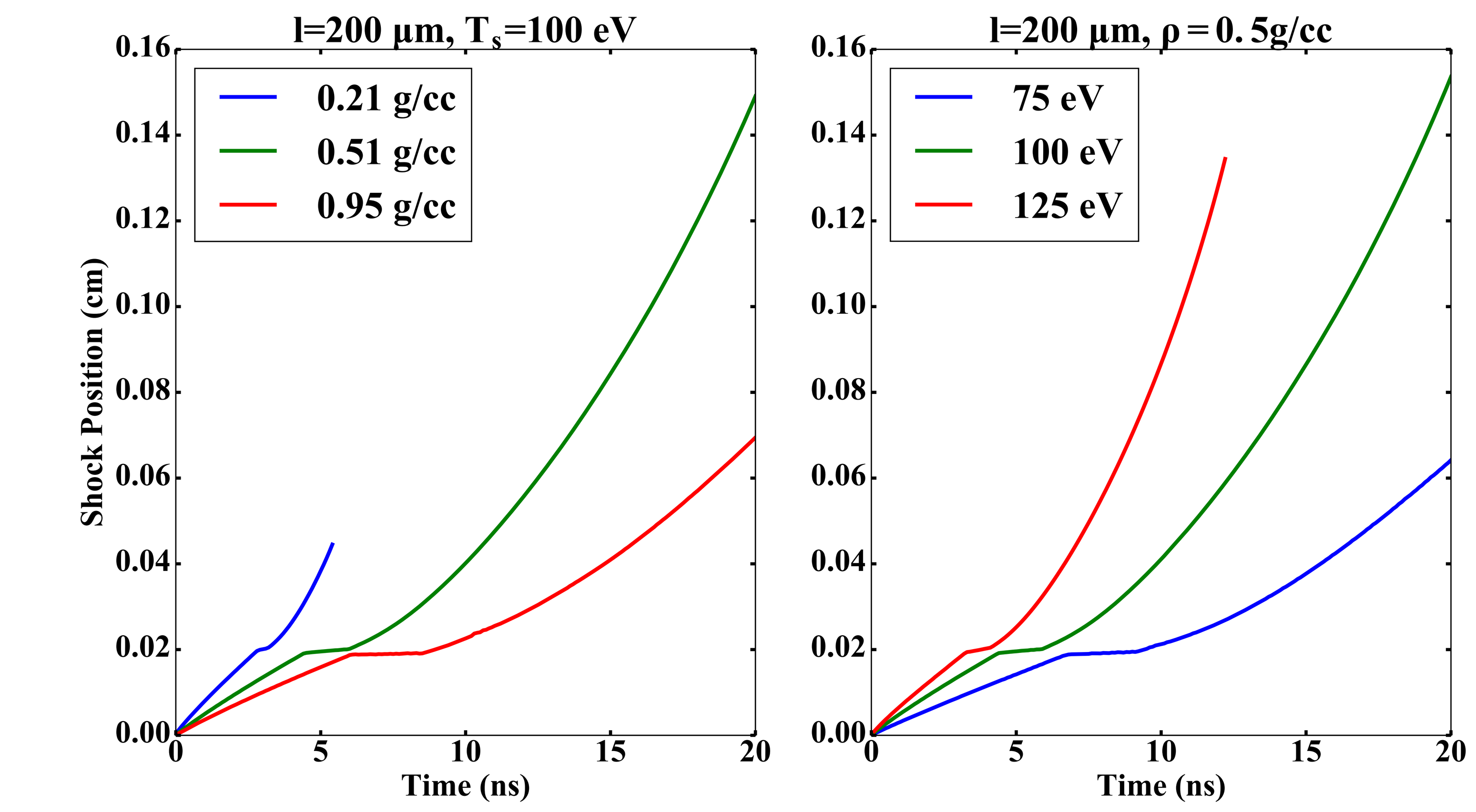

- Simulation parameters
  - 100 eV radiation source, 1 ns duration
  - Case I: Density= 0.01g/cc, length= 200$\mu$m
  - Case II: Density=0.51 g/cc, length= 200$\mu$m
  - Case III: Density=0.07 g/cc, length= 200$\mu$m
- Case type dependent on optical depth

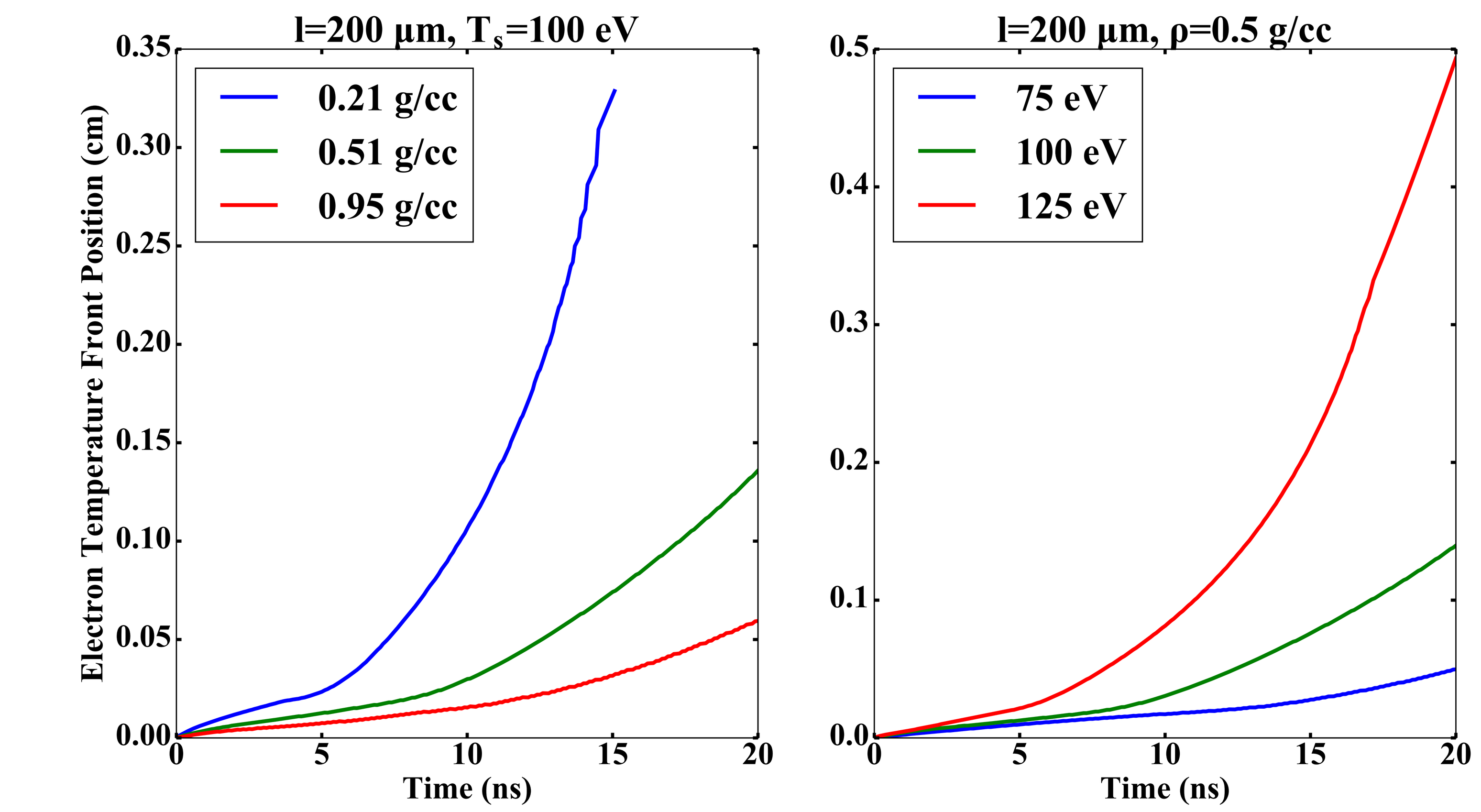
## Target Parameter Effects on Shock Breakout Times




- Break out time = time for shock to exit the target
- Break out time increases with density, and length
- Breakout time decreases with radiation flux

## Evolution of Front Positions in Time




- Front speeds strongly depend on foam density and radiation source temperature.

## Results and Conclusions

- The optical depth of the target determines target interaction.
  - The largest optical depth allows for photons to heat the entire target.
  - The smallest optical depth drives a shock through the target.
- At constant density:
  - Length changes the breakout time
  - Radiation temperature determines the front speed
- At constant source temperature:
  - Length changes the breakout time
  - Density determines the front speed

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## References

1. Drake, R. P. 2010, High-Energy-Density Physics (Springer)
2. http://hyperphysics.phy-astr.gsu.edu/hbase/starlog/staspe.html