FLASH Simulations of 120 MJ Target Explosions in LIFE Reactor Chamber

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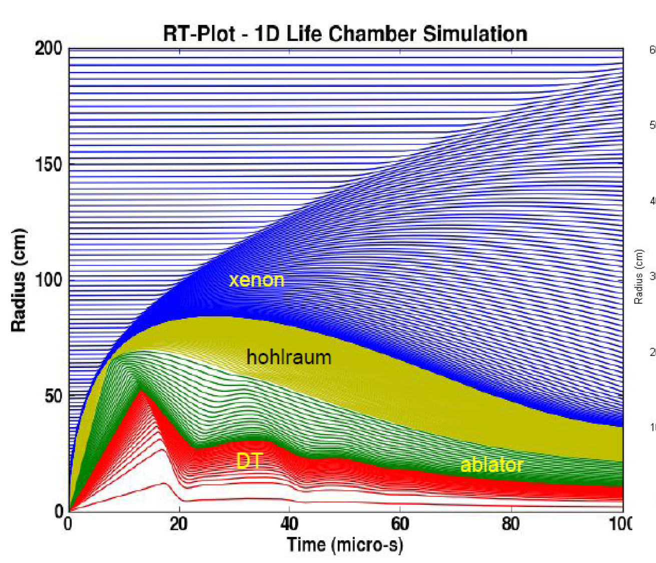
Simulations of the LIFE conceptual reactor design are performed using both the 1D BUCKY and 2D FLASH[a] radiation hydrodynamic codes. Points of interest include shock generation, plasma heating, hohlraum chamber material mixing and fluid instability development.

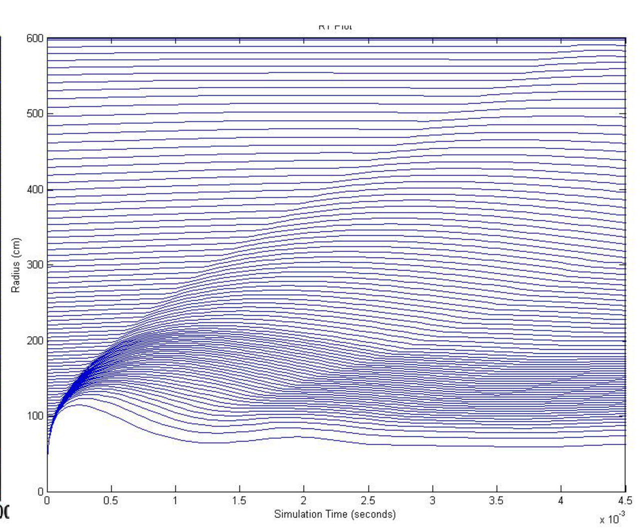
The LIFE reactor design consists of the following components[b]:
•12 m diameter chamber with steel first wall
•6 μg/cm^3 (~0.8 Torr) xenon chamber gas
•1 g lead hohlraum
•120 MJ indirect drive DT target yield
•~13 Hz repetition rate

Xe chamber gas response takes place on three time scales:
•Ignition, burn, and prompt x-ray emission; 10 ns
•Marshak wave propagation; 10-100's μs
•Blast wave propagation; 2-3 ms

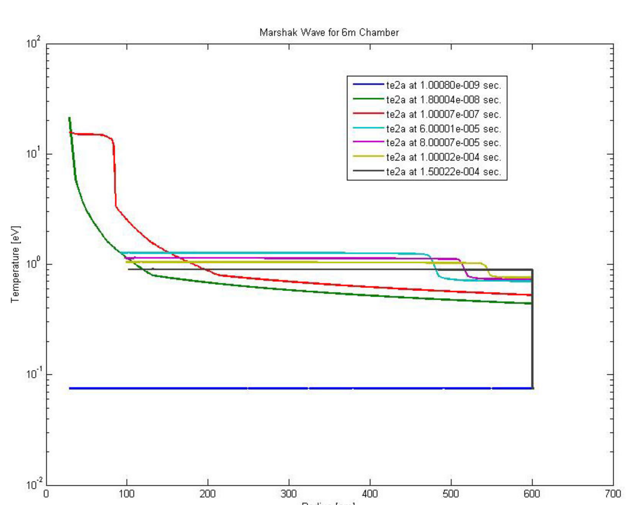
1D Results



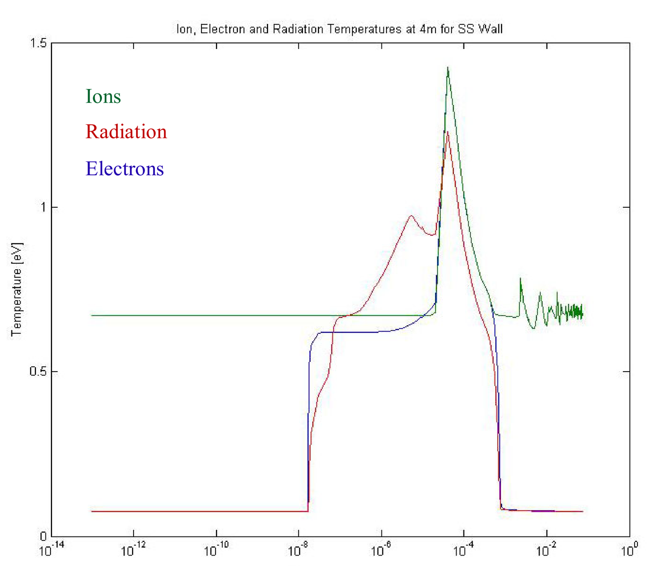
Cooper simulation of a full hohlraum explosion.



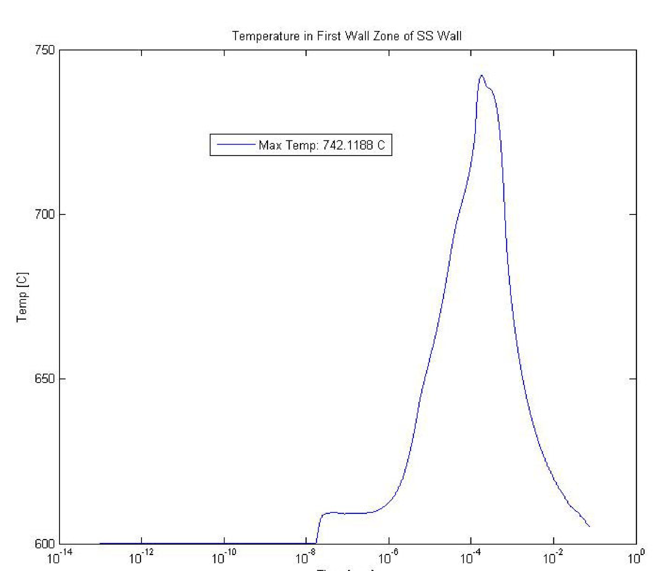
BUCKY simulation of 120 MJ target explosion.



Marshak wave position for a 6m reactor chamber. Wave arrives at the wall between 100 -150μs

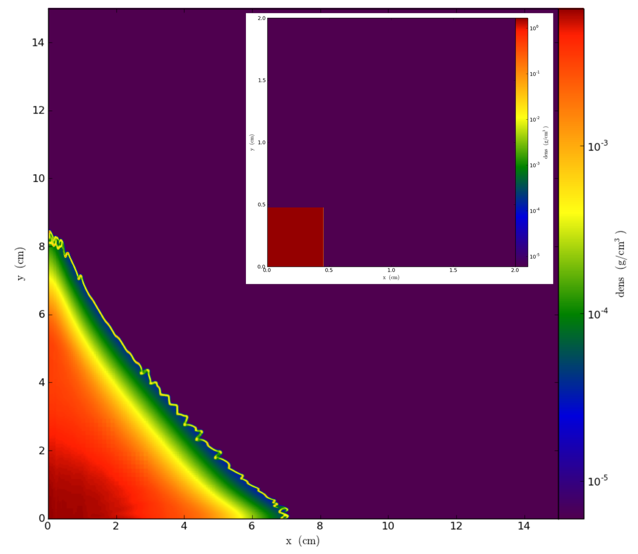


Temperature response at 4m from chamber center. Note the electrons coupling and then decoupling from the ions

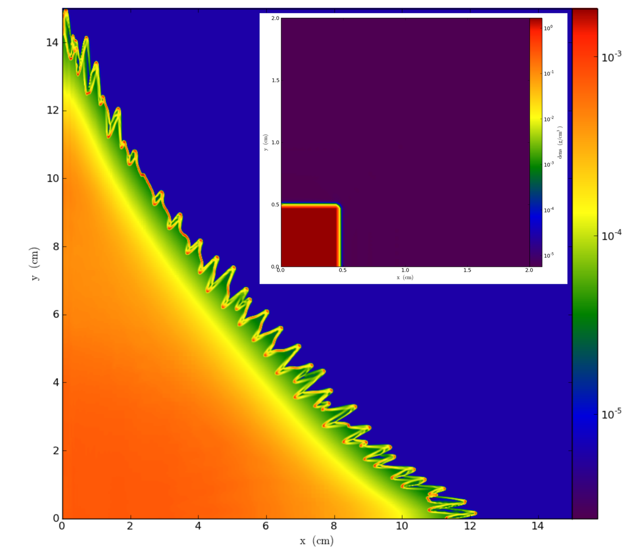


First wall surface temperature rise. Note the maximum corresponds to arrival of Marshak wave.

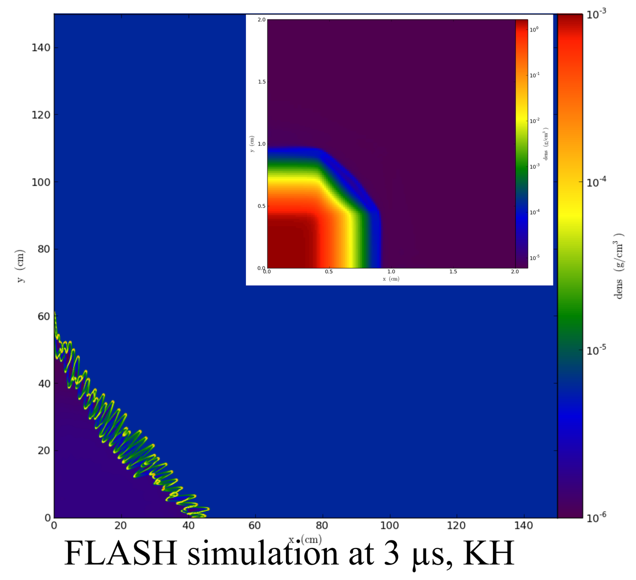
2D Results



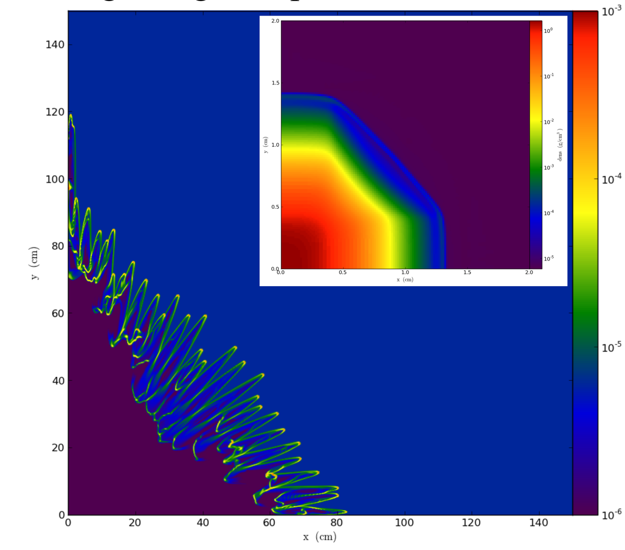
FLASH simulation at 0.2 μs, KH instabilities beginning to develop. Inset shows target initial condition



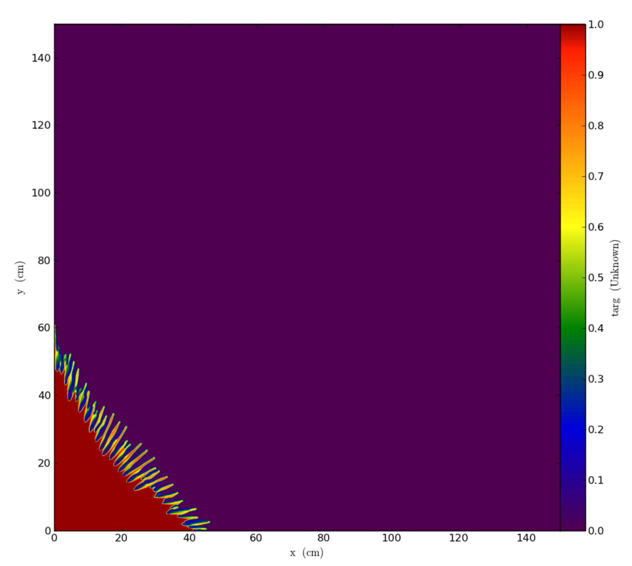
FLASH simulation at 0.4 μs, KH instabilities growing with outward expansion. Inset shows target at 1ns beginning to expand



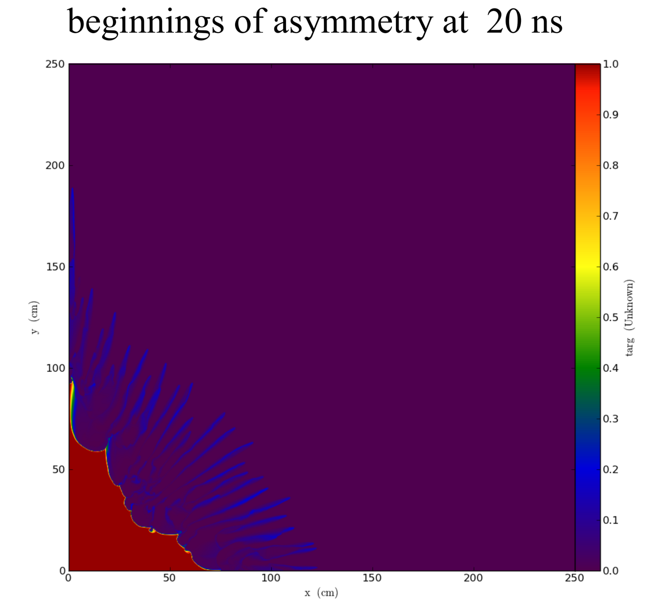
FLASH simulation at 3 μs, KH instabilities beginning to flip RT instabilities. Inset shows diamond shaped expansion at 10 ns



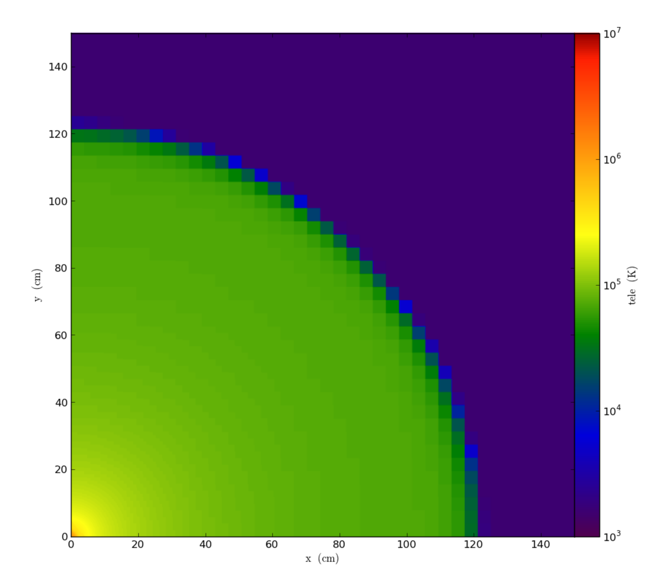
FLASH simulation at 10 μs, RT instabilities have grown as target material continues to expand. Inset shows beginnings of asymmetry at 20 ns



Material mixing at 3 μs.



Material mixing at 30 μs



Marshak wave expansion in FLASH at 0.1 μs

FLASH simulations were preformed with following parameters:
•3T Eulerian hydrodynamics using 3rd order Piecewise-Parabolic Method (PPM).
•Grey flux-limited radiation diffusion using implicit coupling using an algorithm based on the RAGE code[c].
•Cylindrical shaped starting material (see figure insets)
•IONMIX EoS and Opacity
- Only Xe data used, target treated at Pb density
- Grey opacities used

•AMR started at level 15 maximum refinement, relaxed to 9 maximum at 2 μs.

Discussion

•2D Simulations indicate initial asymmetric expansion due to edge effects from cylindrical initial geometry.
•This expansion leads to shears along the edge that initiate Kelvin-Helmholtz instabilities.
•Initial KH instabilities lead to Rayleigh-Taylor instabilities as target material expands into chamber, decelerates and becomes less dense.

Current Status

•2D FLASH simulations show good agreement with 1D BUCKY and Cooper hydro results.
•Multigroup vs. Grey opacity approximation influences Marshak wave speed.

Future Work

•Add in Pb EoS and opacity data to model target.
•Add in multigroup opacity functionality.
•Perturb initial target surface to study effect on instability growth.
•Study influence of target motion relative to chamber gas.

- [a] Fryxell, B., Olson, K. *et al.*,FLASH: An Adaptive Mesh Hydrodynamics Code for Modeling Astrophysical Thermonuclear Flashes, *Astro. Journal Sup. Series.*, **131**, 273 (2000)
- [b] Moses, E.I., Ignition on the National Ignition Facility: a path towards inertial fusion energy, *Nucl. Fusion* **49** 104022 (2009)
- [c] Gitting, M., Weaver, R. *et al.*, The RAGE radiation-hydrodynamics code, Computational Science & Discovery, **1**, 015005 (2008)

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