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Scanning Parameter Space for NIF capsules in HYDRA

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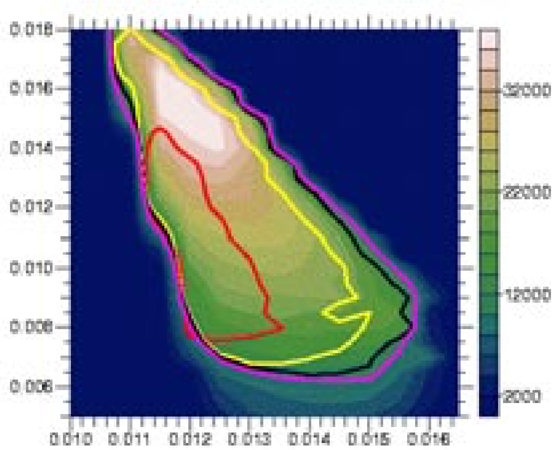
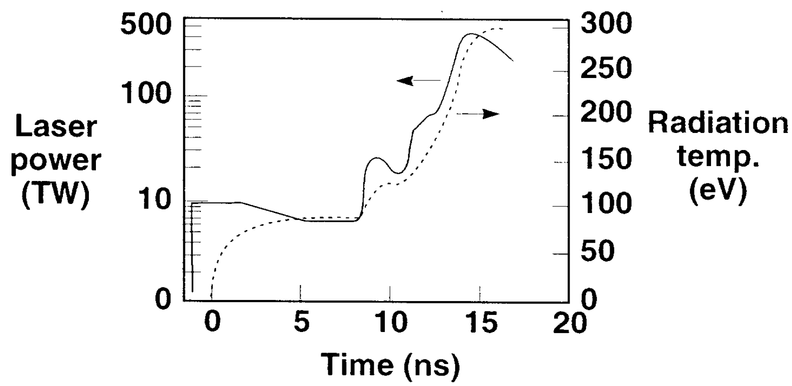
Summary

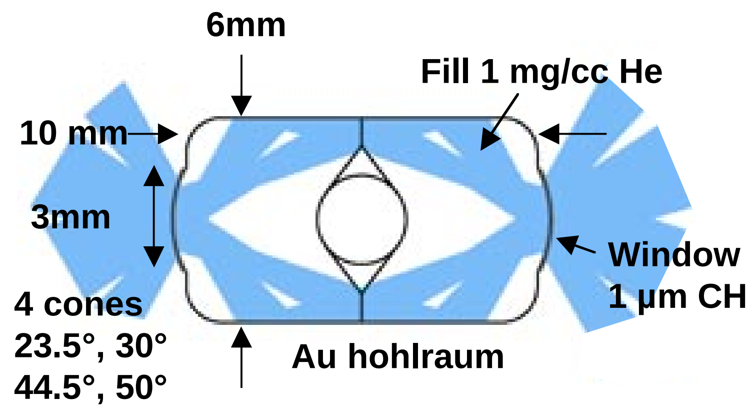


- We have implemented an automated pulse shaper for NIF capsules in HYDRA.
- We have developed the infrastructure to do scans using the automatic pulse shaper across any n-dimensions of capsule parameter space.
- Using this infrastructure, we have performed several scans examining parameters for uniformly doped Beryllium capsules.
- To coordinate more closely with the anticipated experimental shock timing strategy, we have started to develop an automated pulse shaper which uses planar geometry and liquid DD.

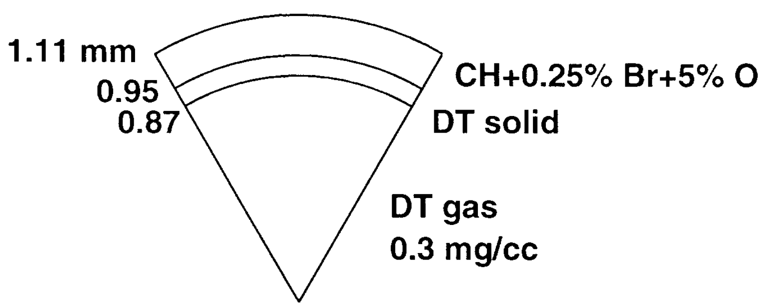
We are interested in choosing the optimum capsule for ignition experiments



There are at least eight critical values in pulse shaping, including timing, amplitudes and total flux



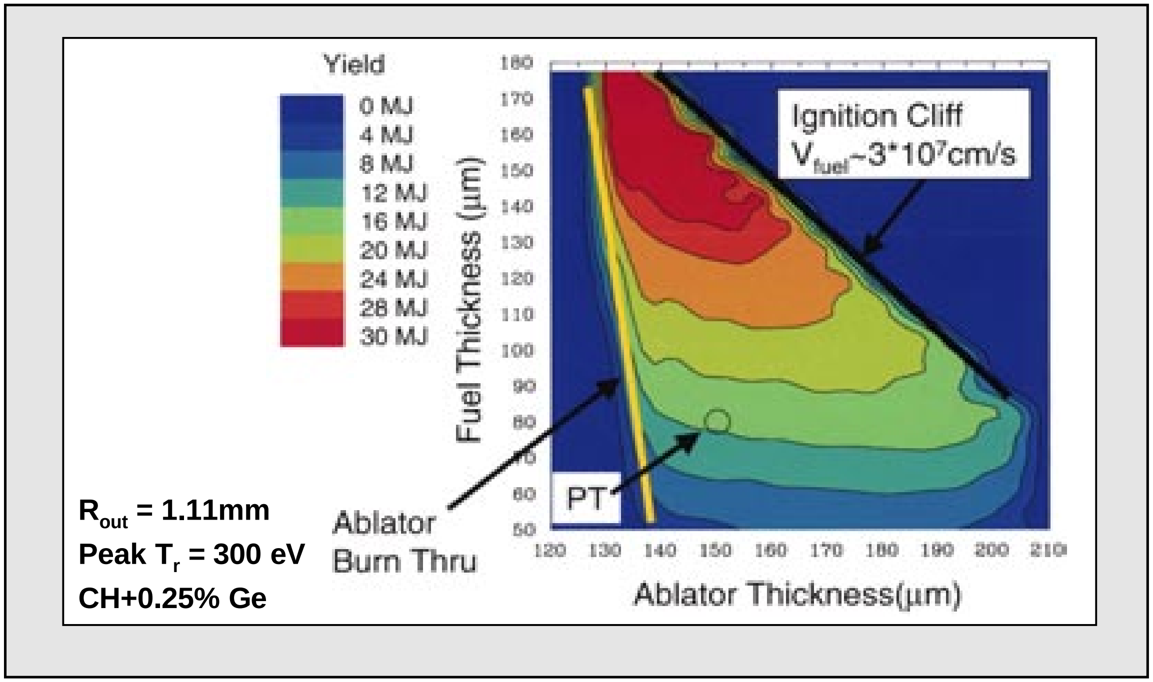
Hohlraum design can affect temperatures, spectrum, and many other variables

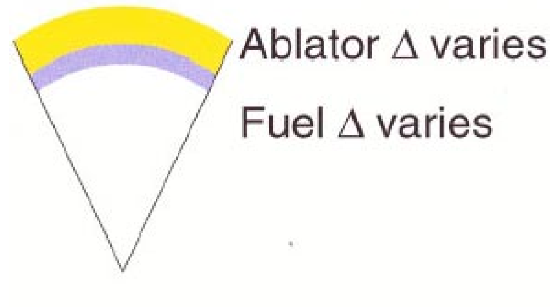


Capsules have different sizes, different materials, and different material thicknesses

There are many variables to choose from in capsule design!

Some scans of capsule parameter space have already been done





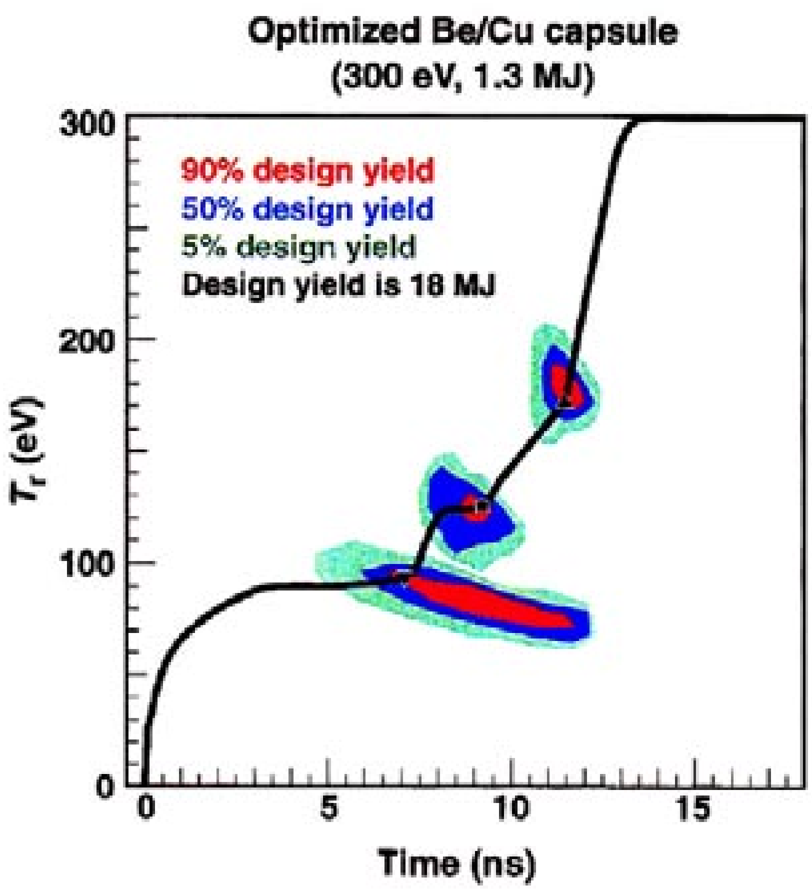
- **This contour map is made from a suite of ~500 1D capsule designs (5 µm spacing)**
- **Maps the space of performance according to 1D simulations**

We want to develop a better scanning ability

While the current scan technology has been useful, we would like the capability to:

- Scan using the code HYDRA
- Make changes to any input parameter without requiring significant change to the code
- Perform >2 dimensional scans, over parameters other than ablator or fuel thickness
- Use a pulse shaping technique more similar to anticipated experimental methods

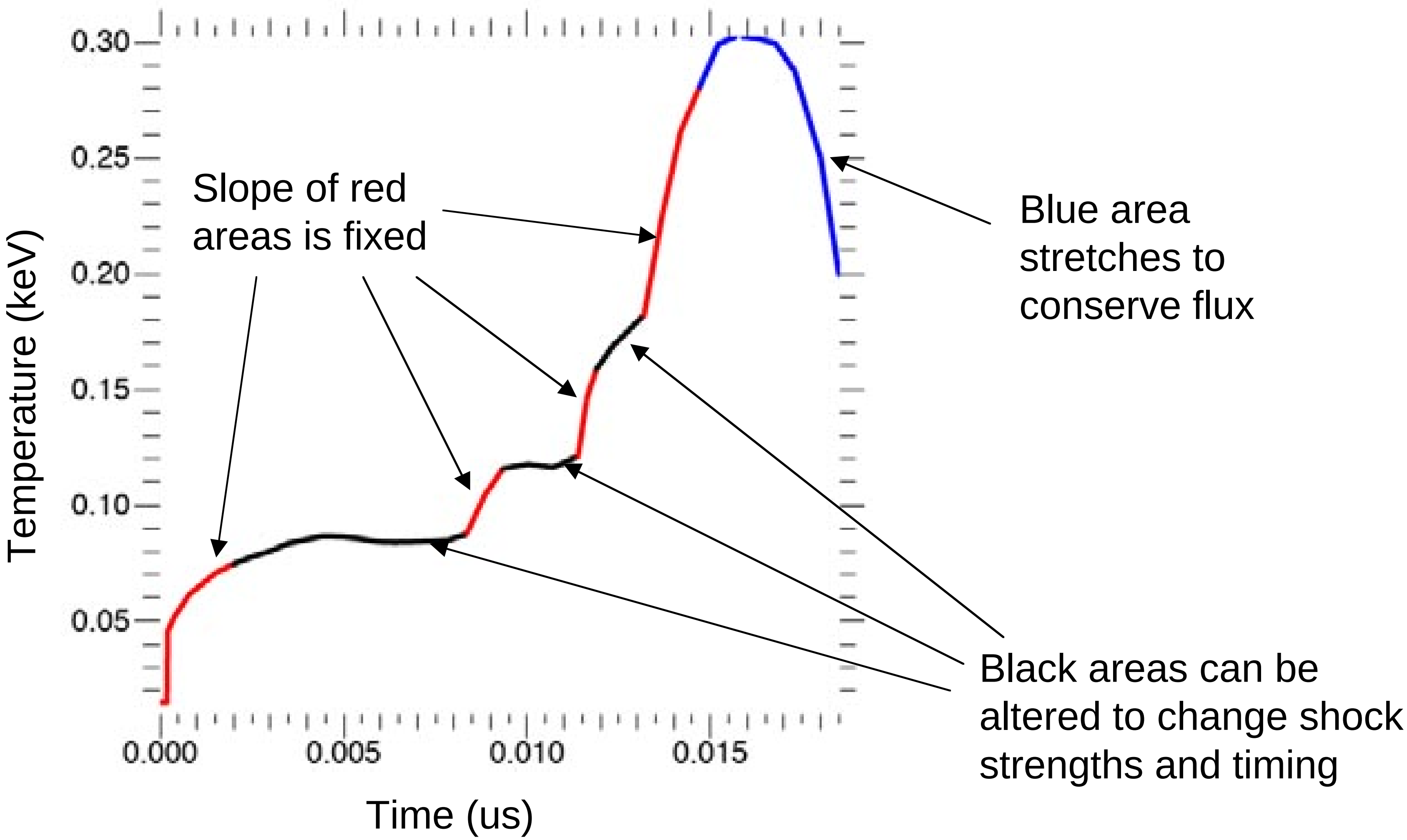
Capsules are very sensitive to the pulse shape



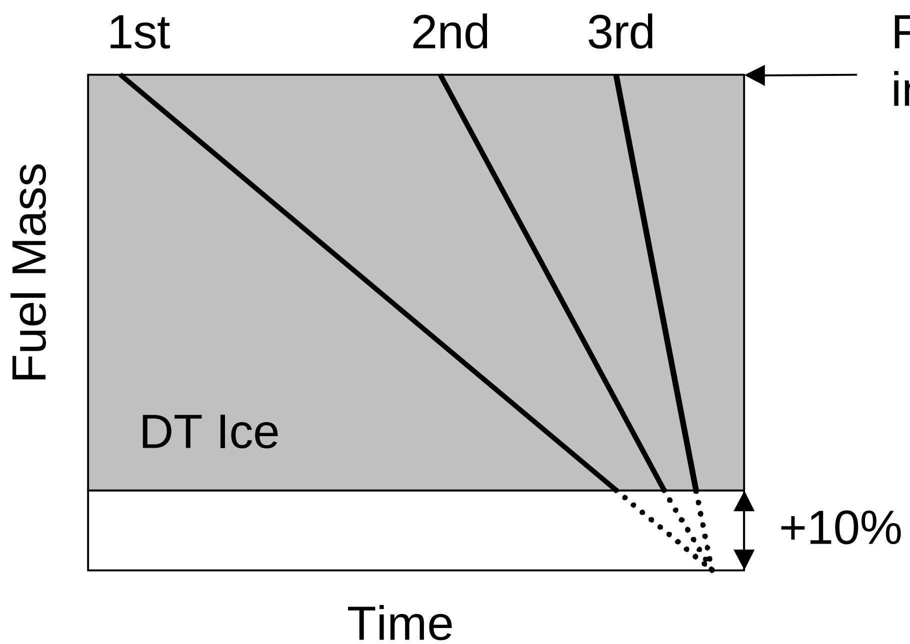
- The "banana plot" to the left shows that single shock shifts by as little as 100 picoseconds can be detrimental to capsule performance
- Shock strengths are not as vulnerable, as long as timing is changed accordingly.
- This diagram was produced by Dave Munro

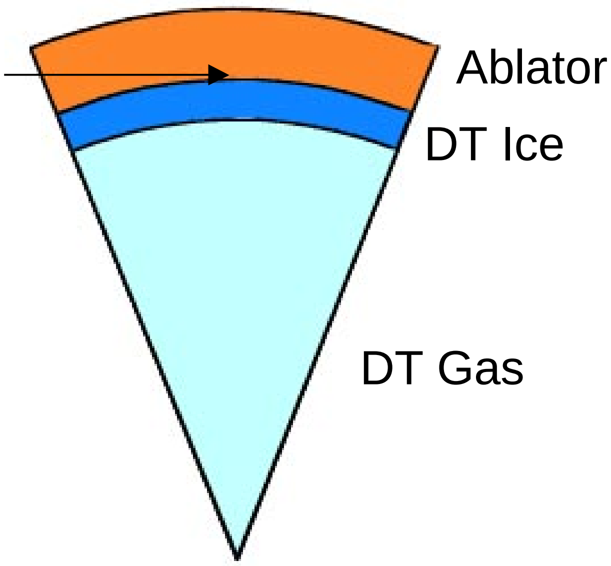
The first step is to develop an automated pulse shaper

Shock timing can be changed through modifying the radiation drive



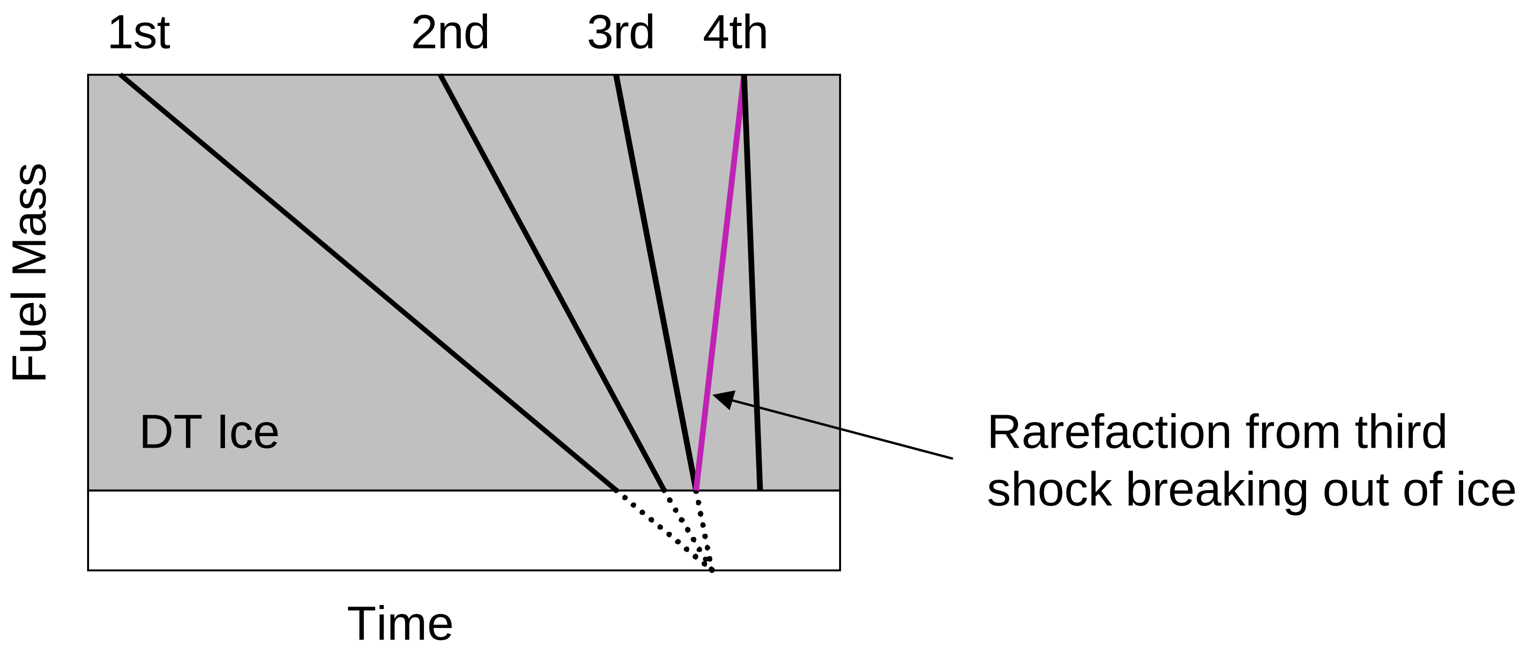
Shock timing is determined by Dave Munro's coalescence criterion





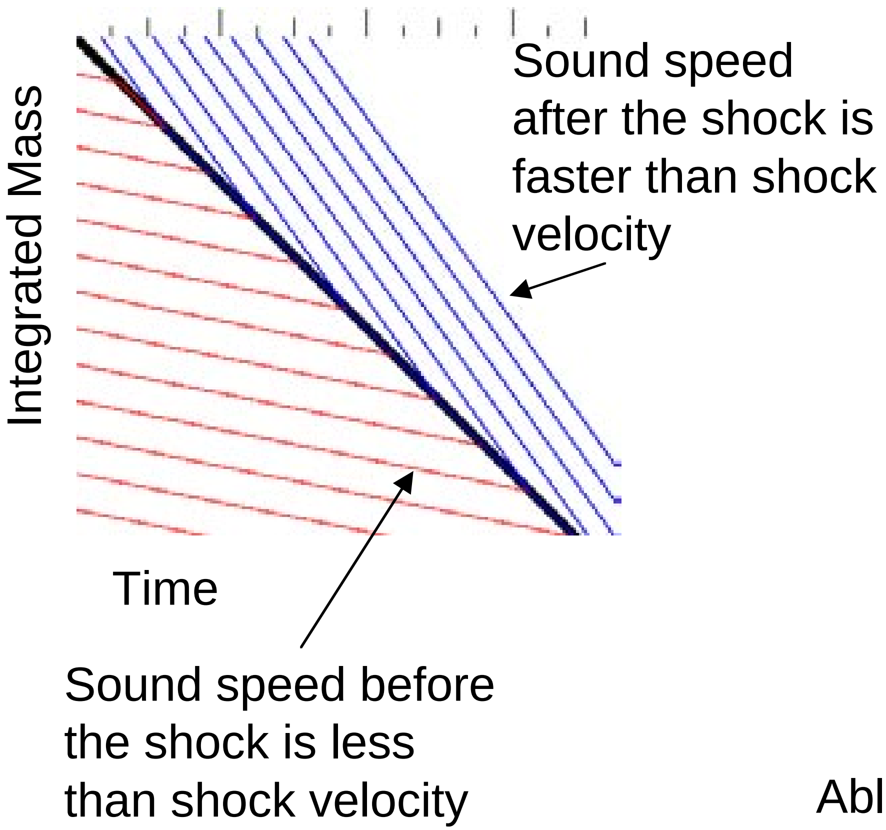
- The goal is to have the shocks "break out" in close succession, but not run into each other too early.
- Shock velocities are determined by pressures specified in advance
- Then, timing is found by working backwards from the coalescence depth, usually at 110% of fuel thickness

Fourth shock timing is done differently

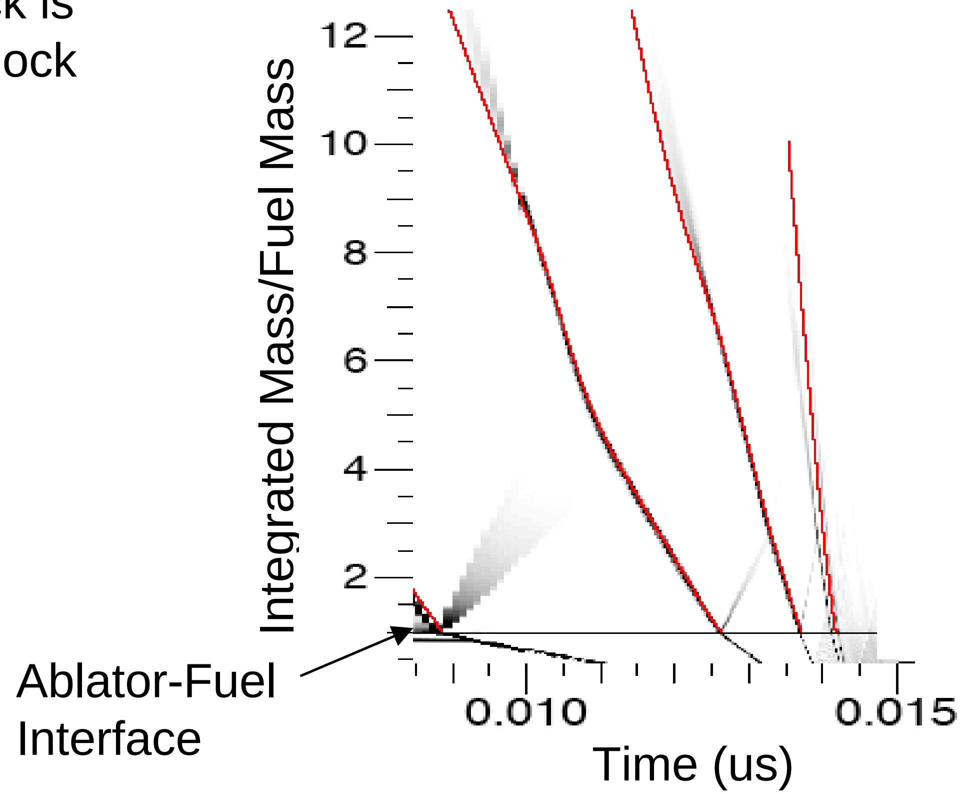


- A rarefaction is launched when the third shock breaks out of the fuel
- We want the fourth shock to cross the fuel interface at the same time as this rarefaction

Characteristics can be used to find shocks

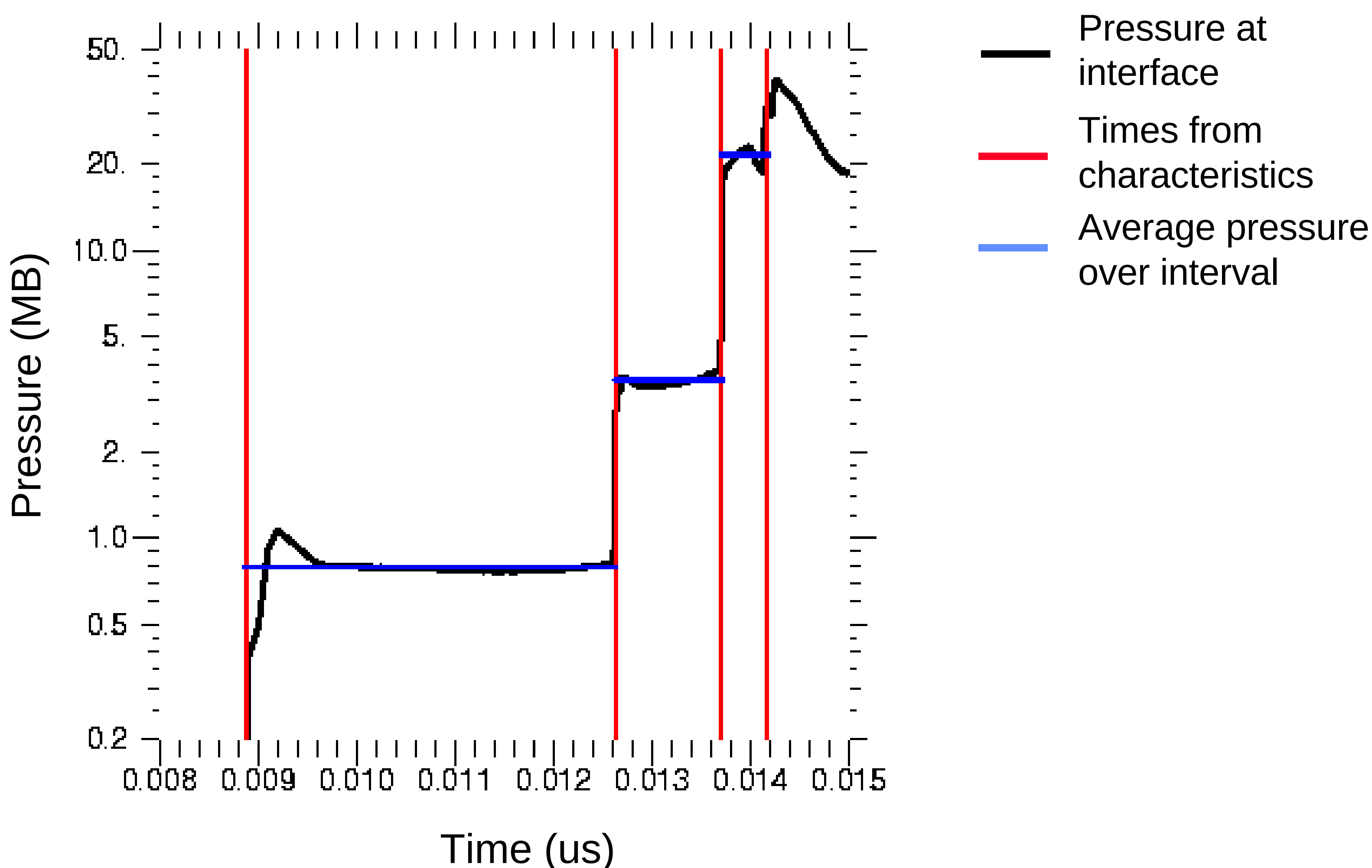


Log derivative of pressure;
Characteristics overlaid in red



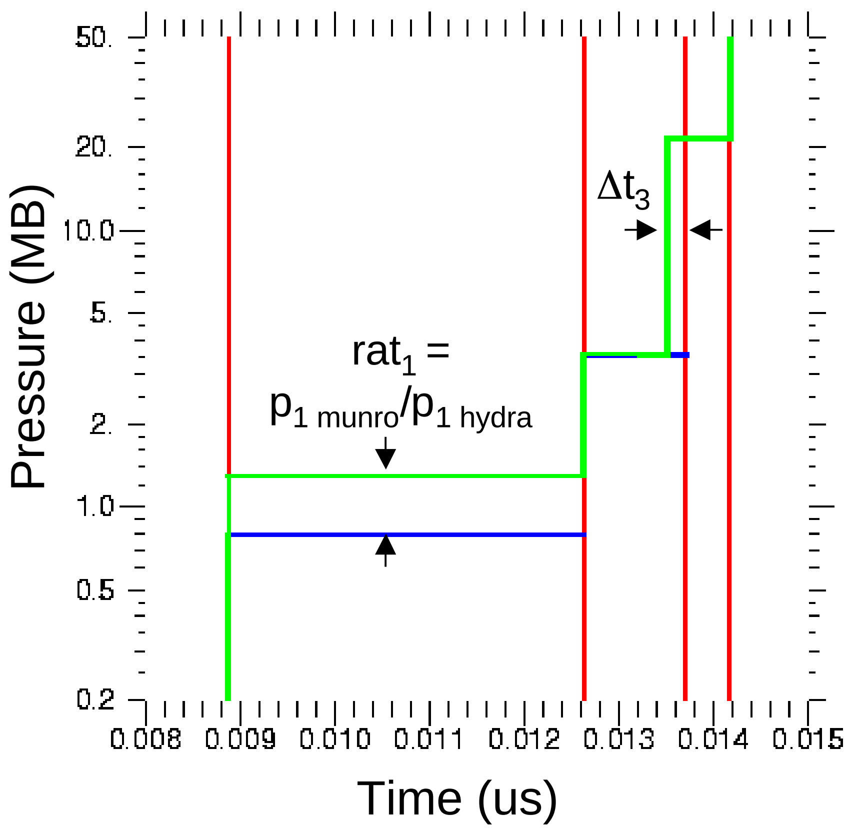
A postprocessor capable of tracking these characteristics was designed and implemented

The pressure profile at the fuel-ablator interface is then analyzed

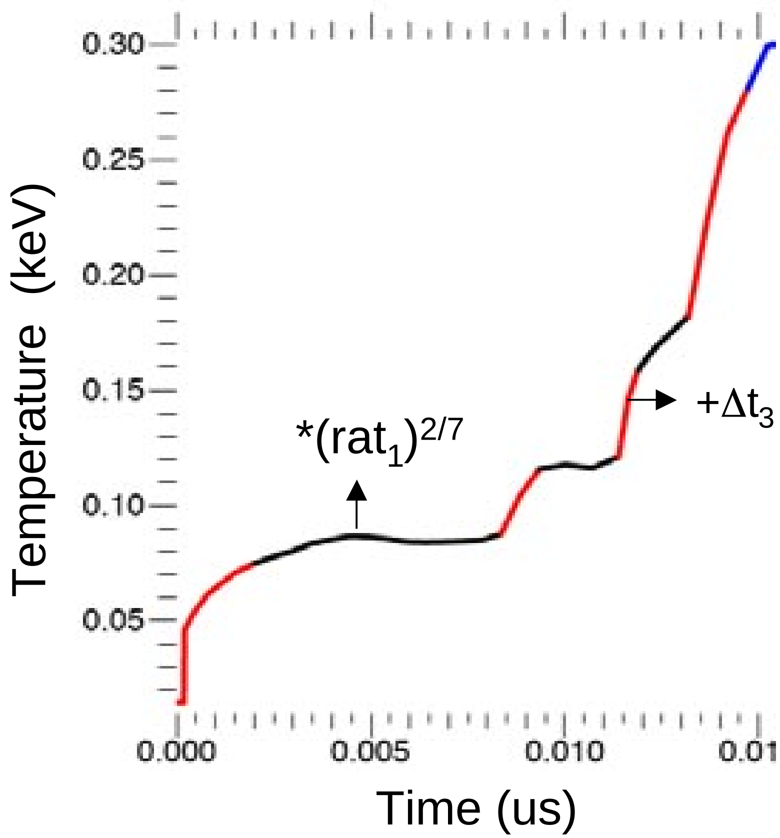


The pressure profile is compared with the Munro criteria and appropriate changes are made

Differences between the target pressure profile and actual profile are analyzed . . .

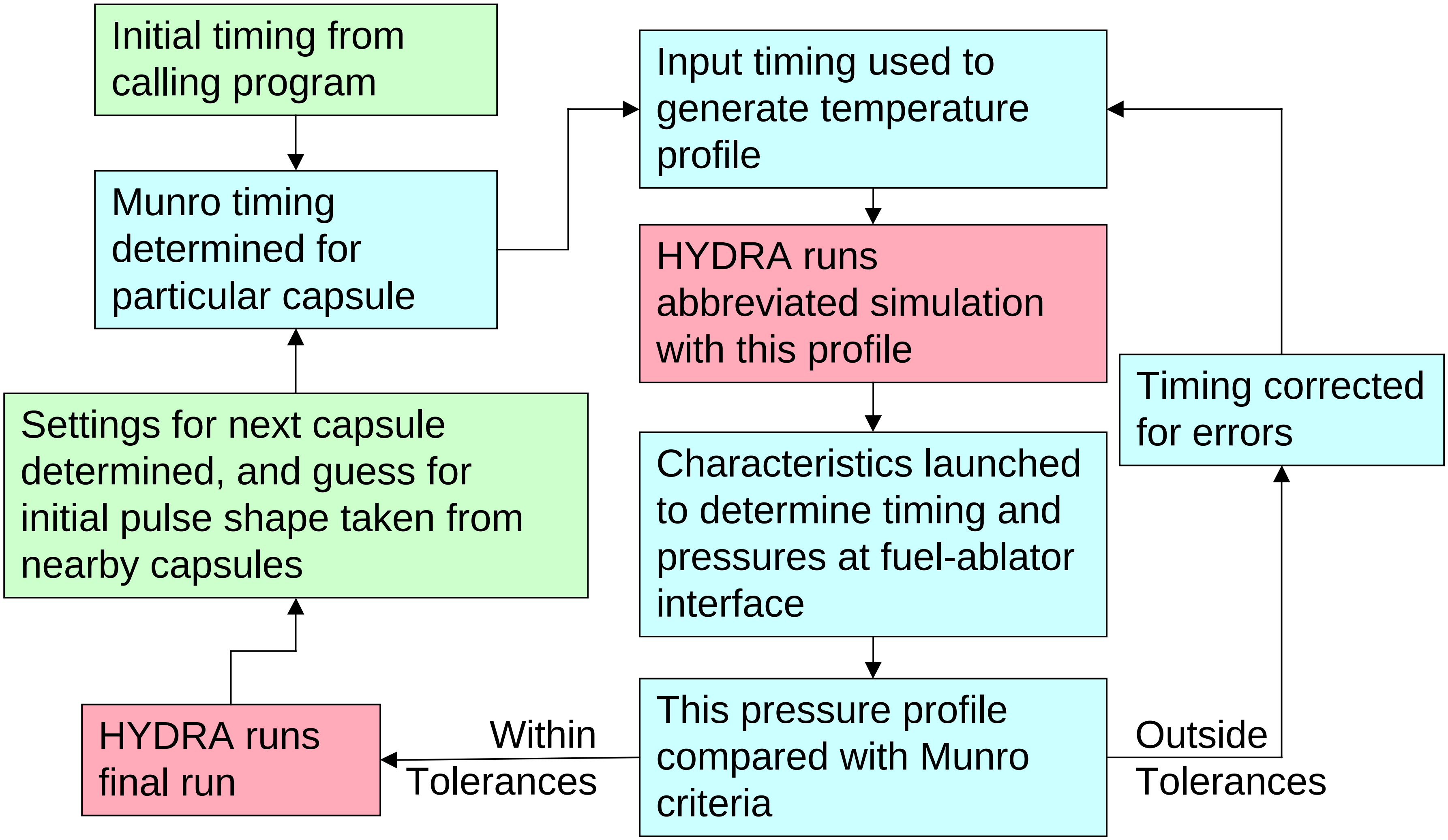


. . . and necessary changes are made to the radiation profile



Target pressures and timings

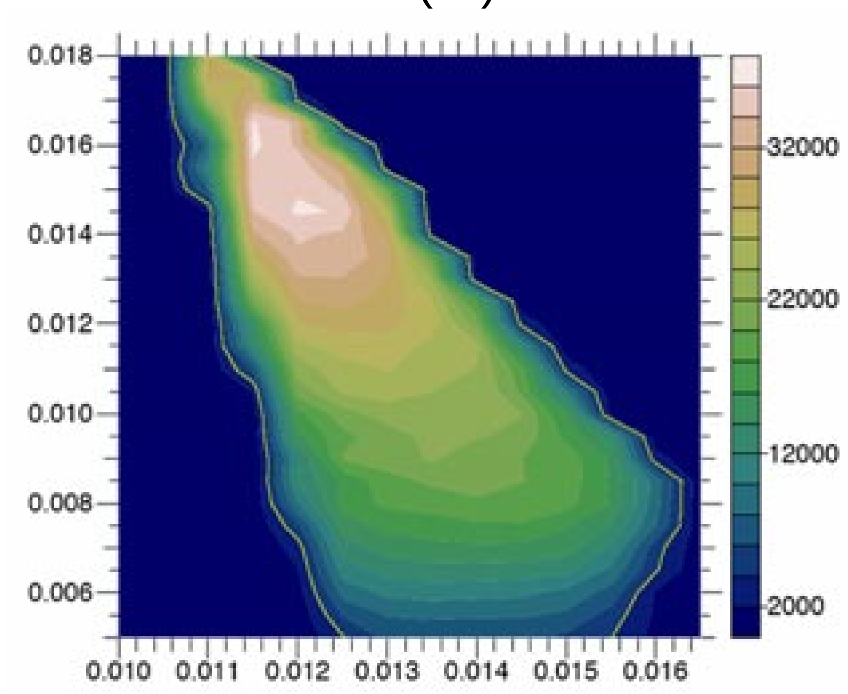
This process is iterated until a proper pulse shape is found



Our results show reasonable solutions for .9% Cu doped Be shell capsules

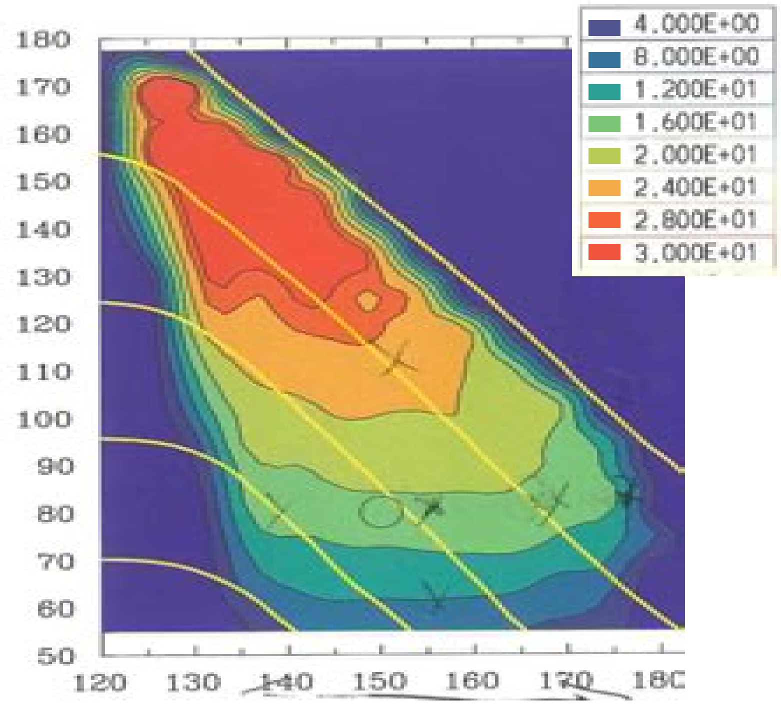
Yield (kJ)

Fuel Thickness (cm)



Ablator Thickness (cm)

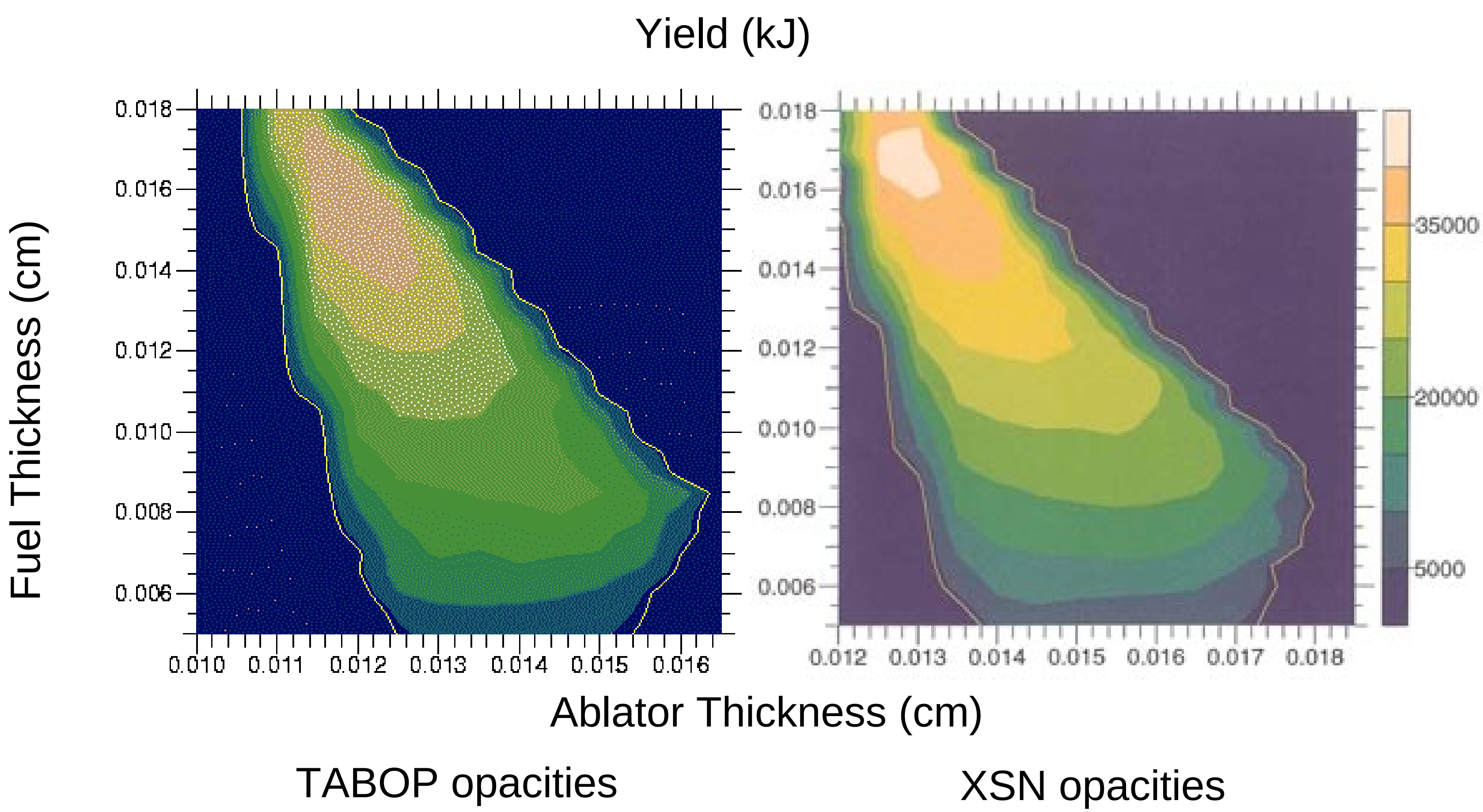
Yield (MJ)



Mark Herrmann's LASNEX Results for the same capsule

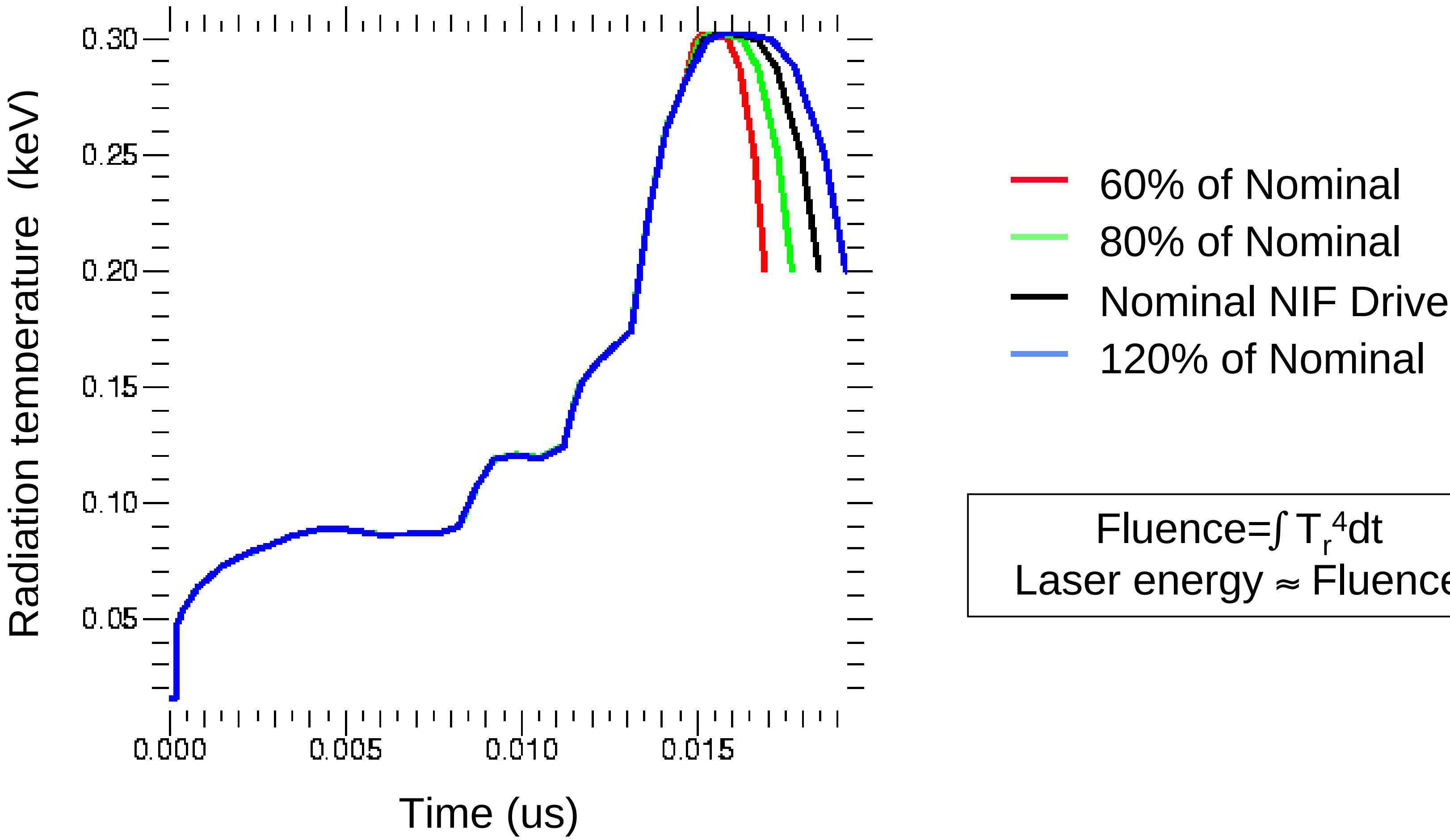
Note the ~20 um "shift" in Ablator Thickness.

The space shifts depending on opacities



This 20 um shift is due to differences in opacities

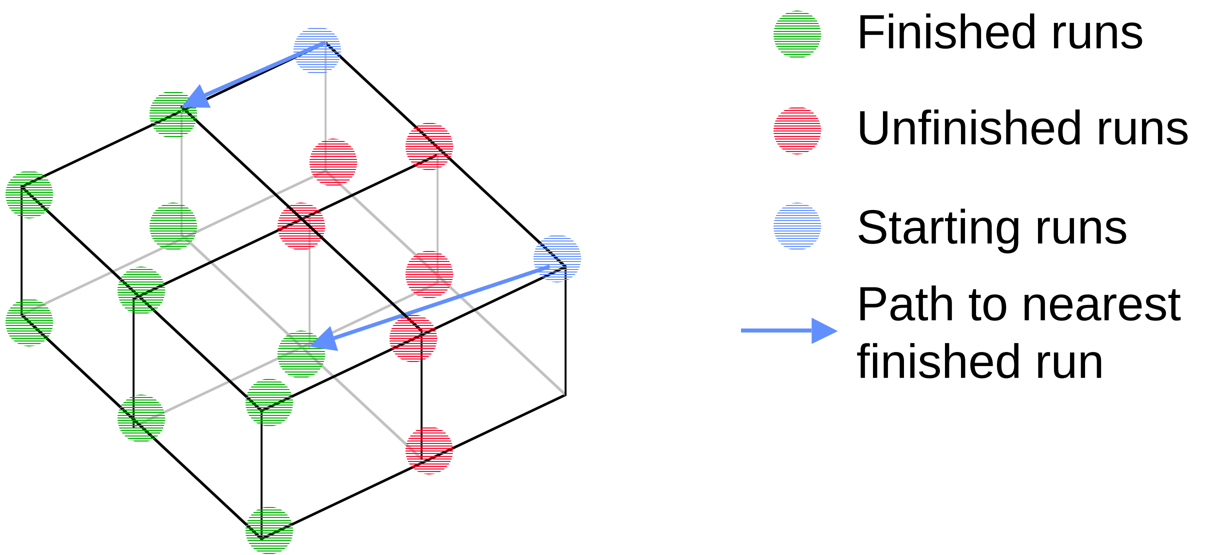
Changes in total fluence can have an important effect on the ability of the capsule to burn



Fluence= $\int T_r^4 dt$

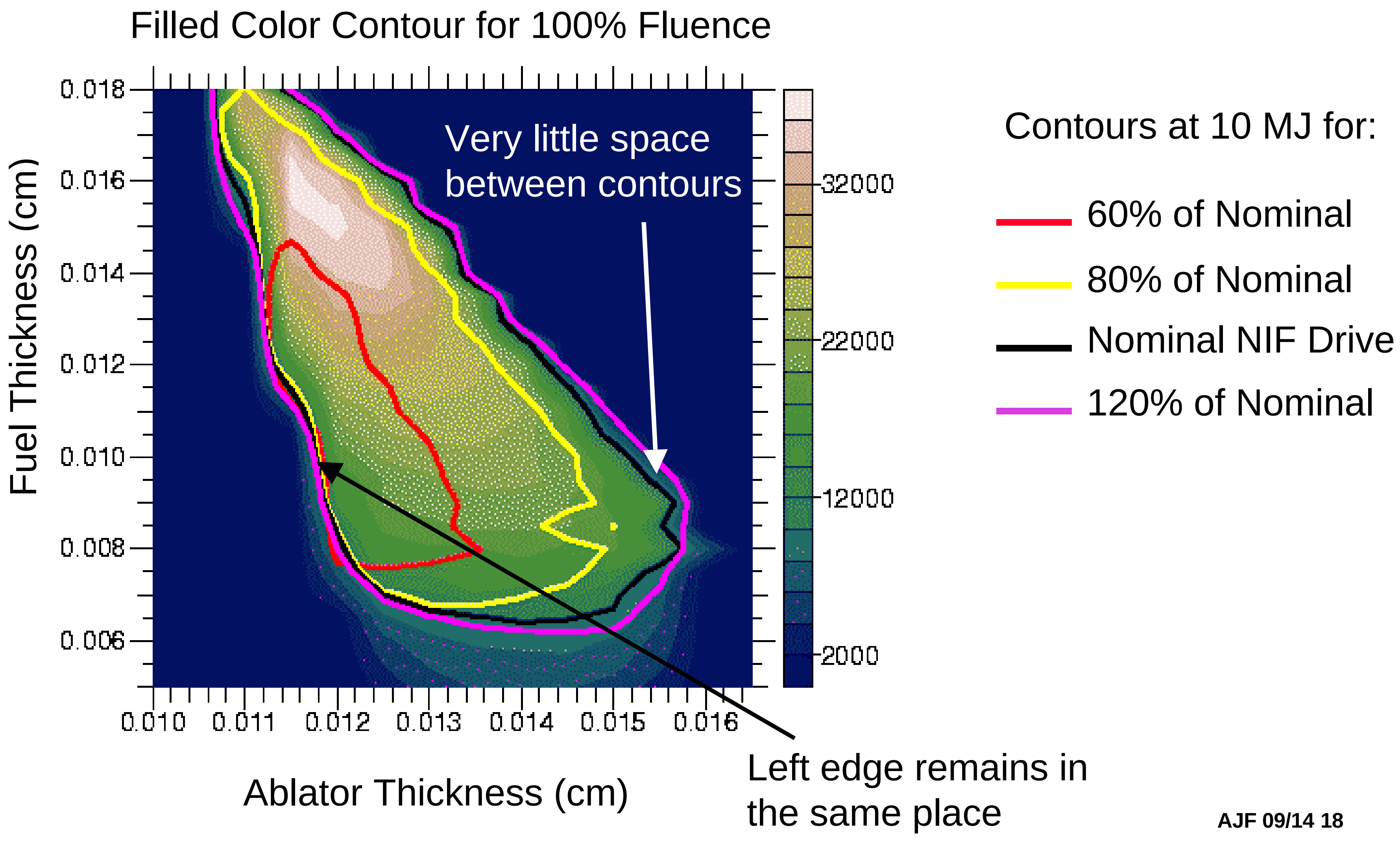
Laser energy ≈ Fluence

Starting runs use the timing from the nearest finished run in n-dimensional space

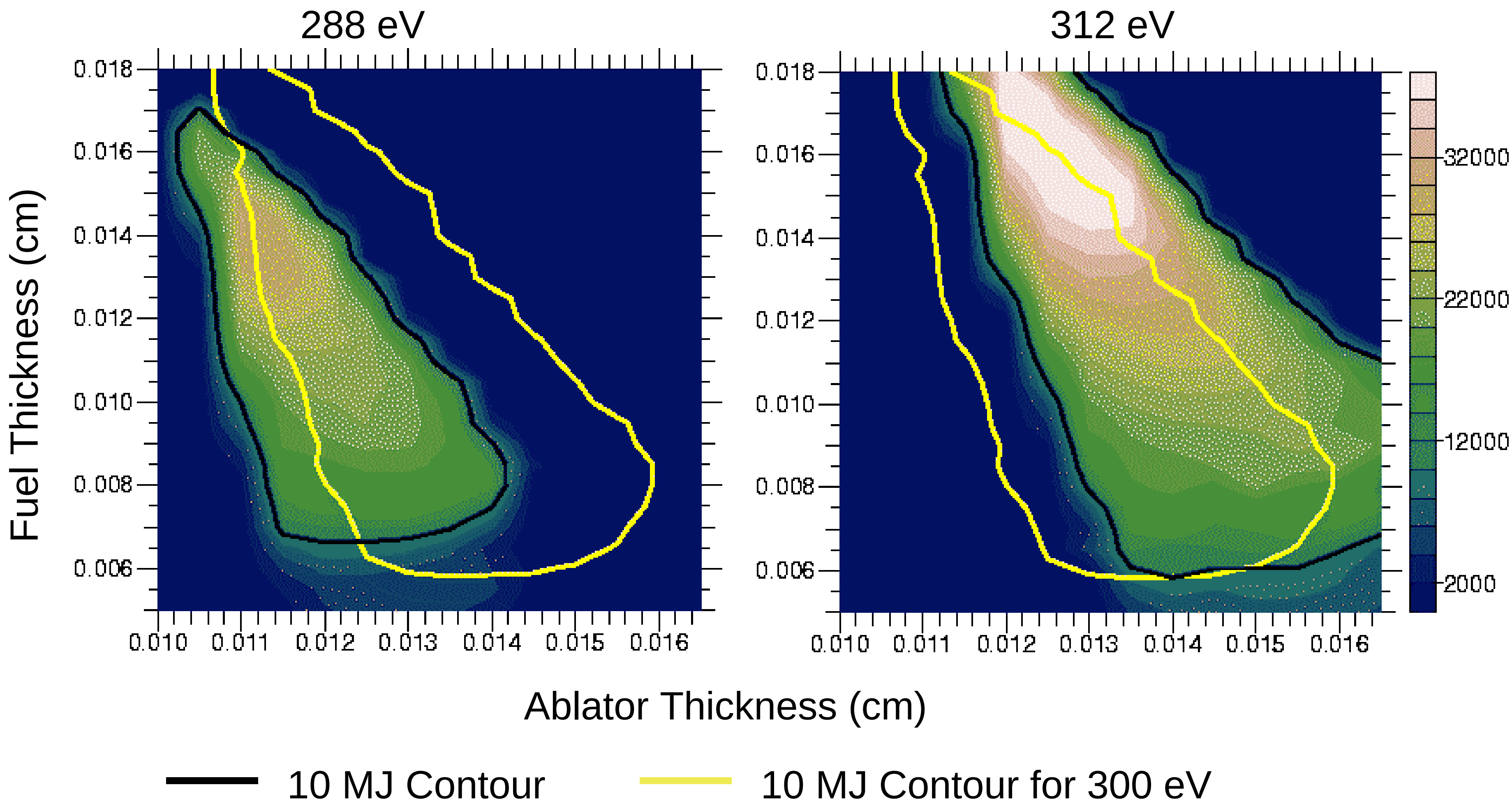


Scanning over n-dimensions is much more efficient than repeating 2D scans

While raising the fluence produces few benefits, reducing the fluence can impact performance

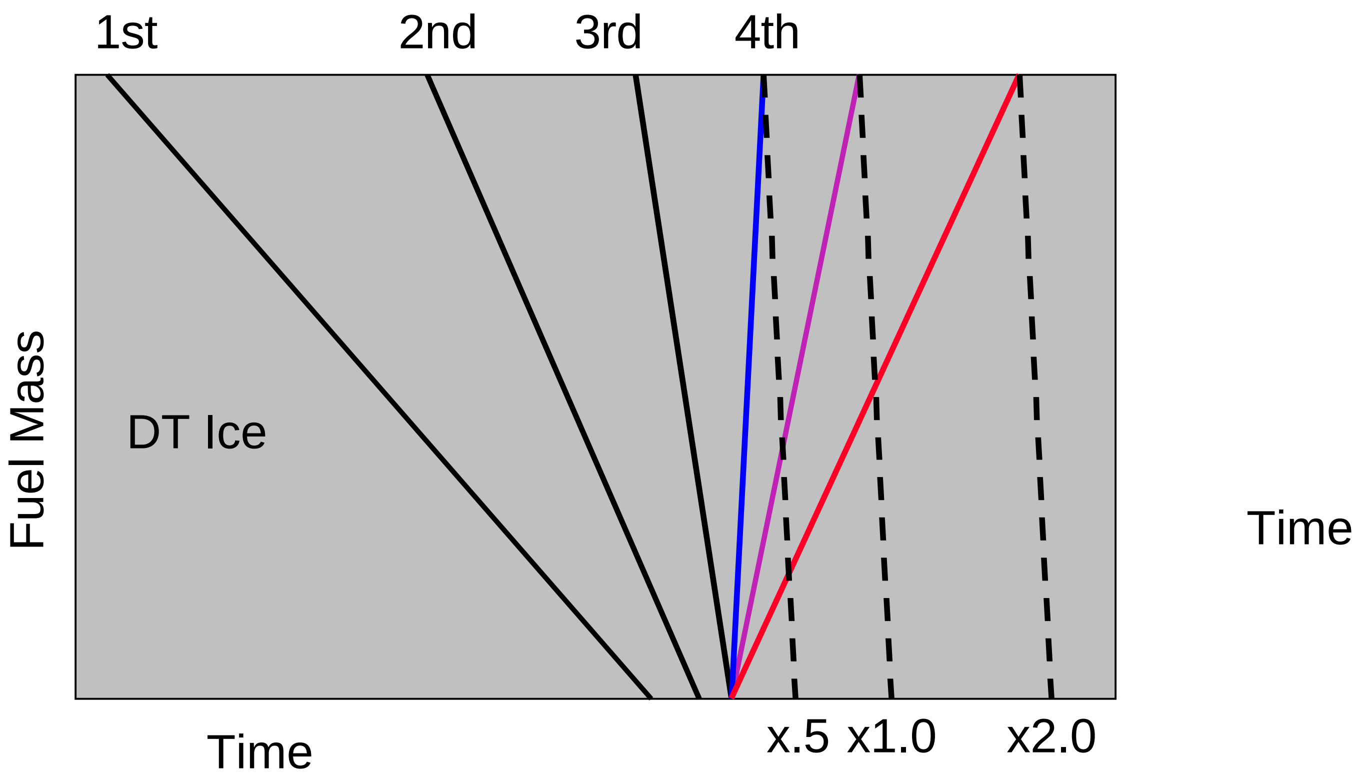


We also found that peak radiation temperature has an impact on the design space

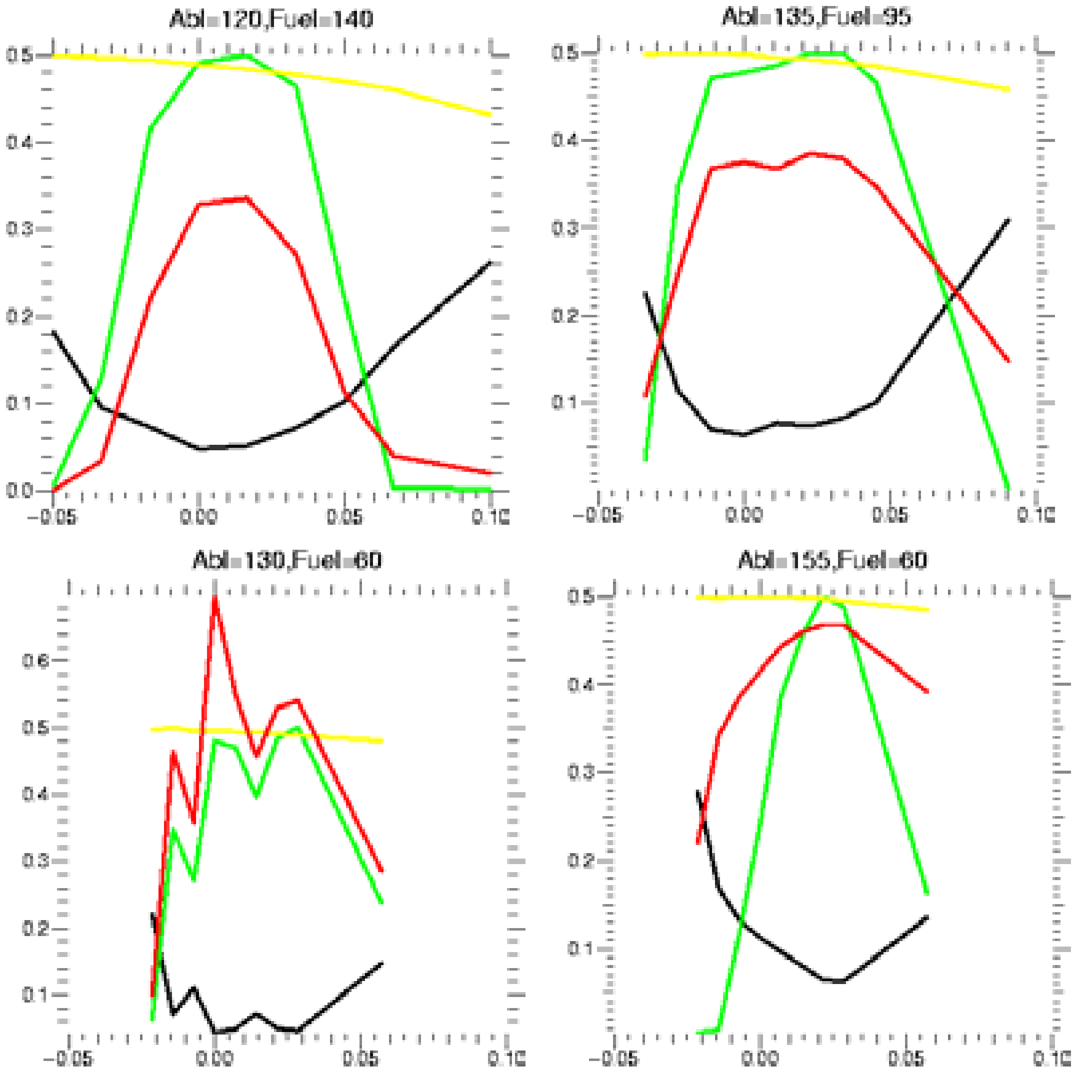


Total flux is the same as the 300 eV capsule

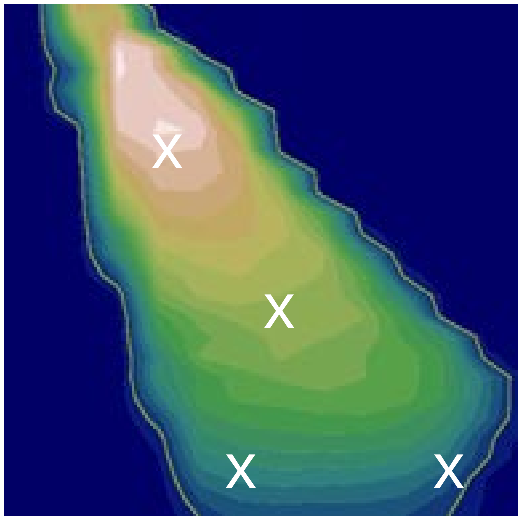
To better understand fourth shock timing, we conducted a scan over the fourth shock space



Scanning over fourth shock timing show some improvements can be made



Fourth shock time shift (10 ns)



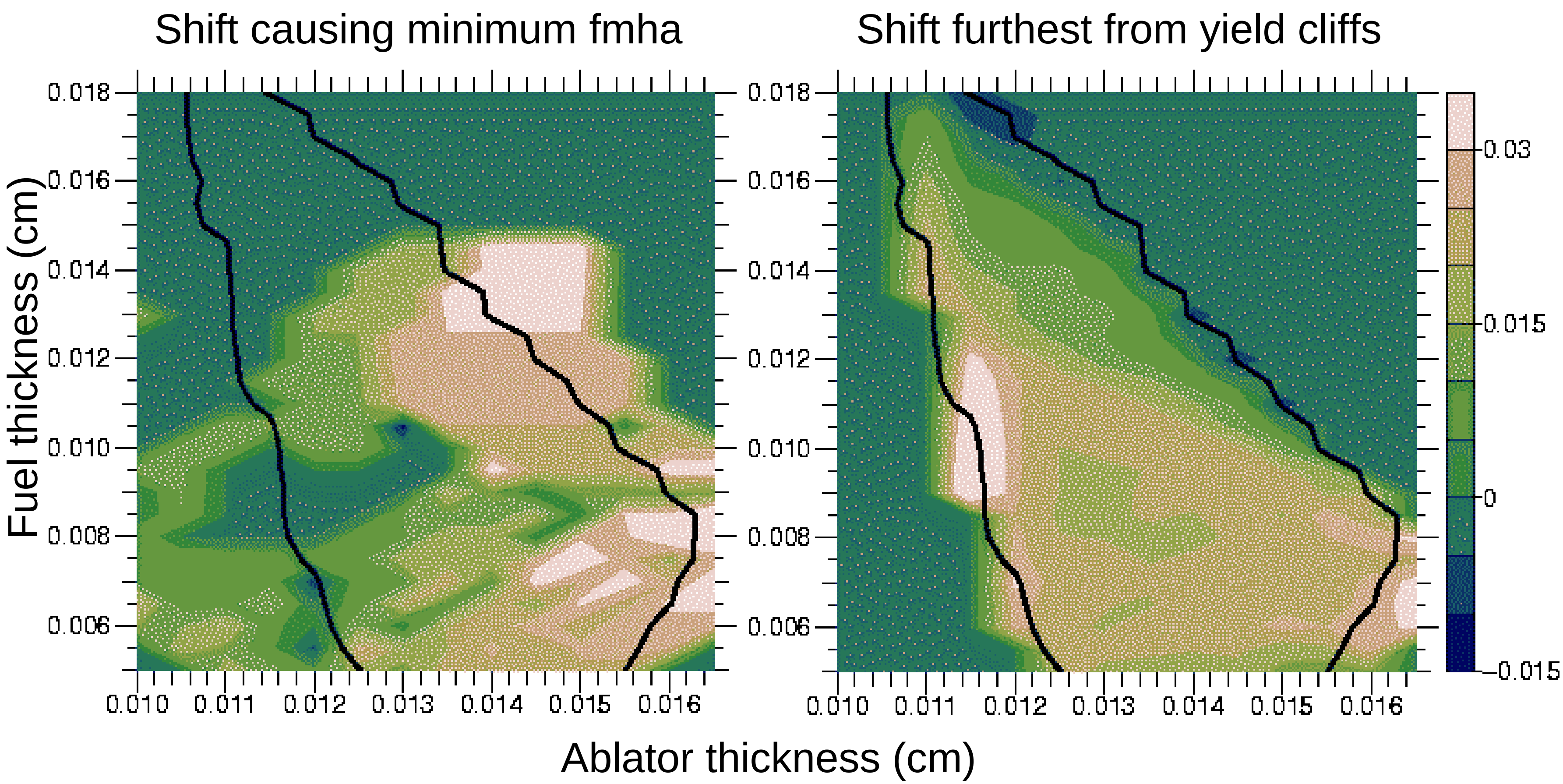
Normalized velocity

Normalized yield

Margin

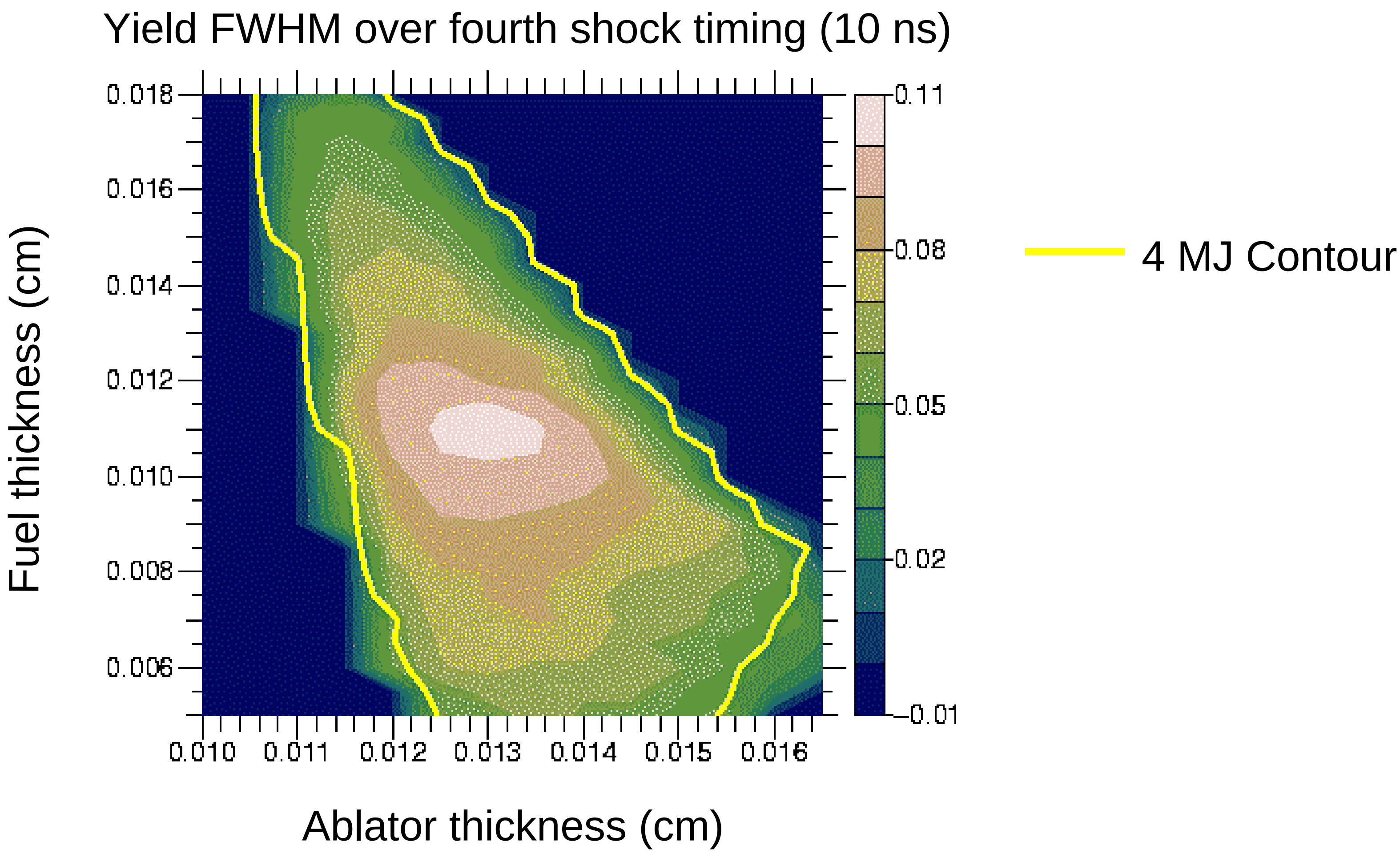
FMHA

We can find the optimum fourth shock timing over the interesting space

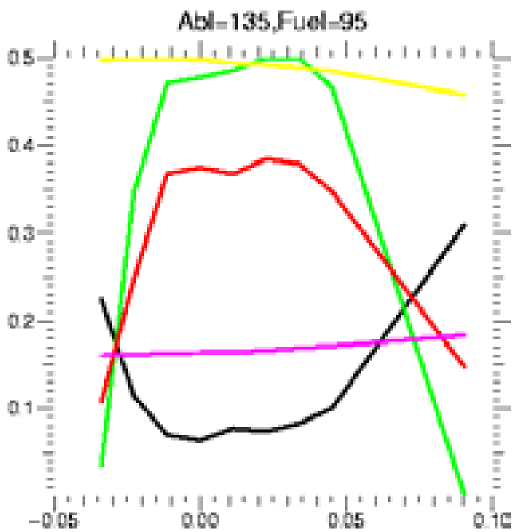


While the methods differ, and vary over the space, an optimum shift for the most interesting area is about 200 ps

Tolerance to changes in the fourth shock timing is best in the center of the space



The fourth shock timing is not the only thing changing when the target time is moved

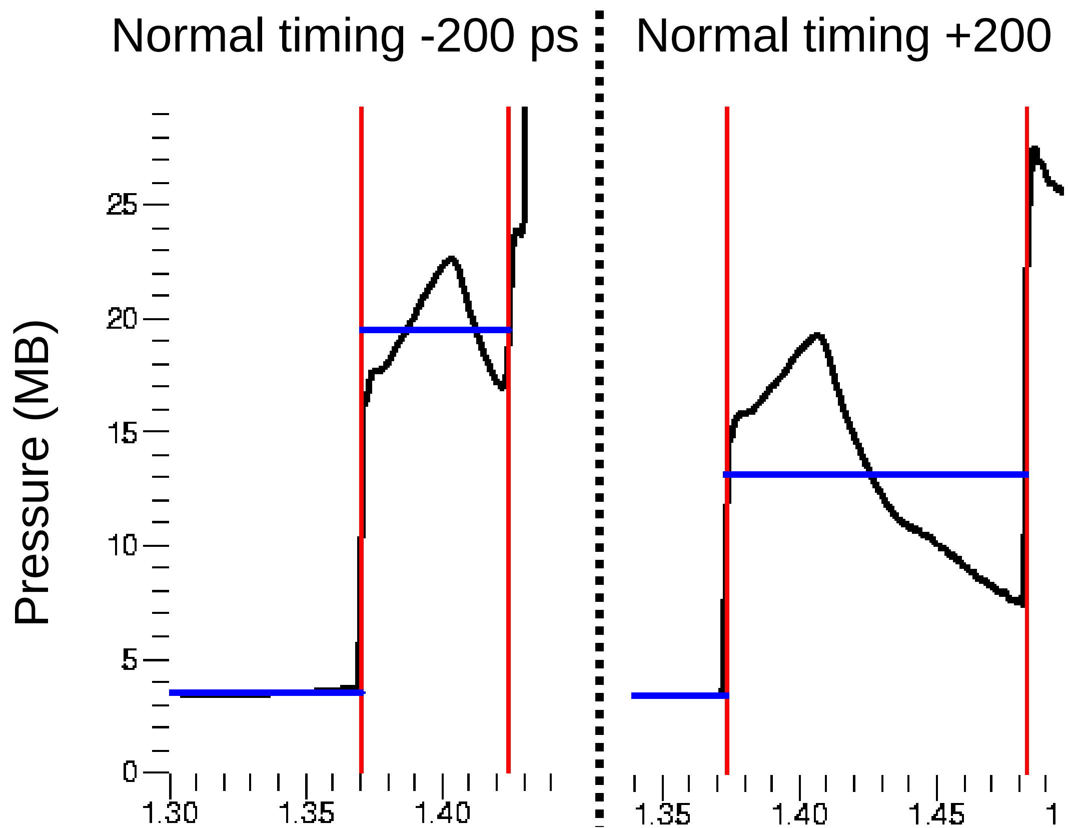


Fourth shock time shift (10 ns)

Third shock launch temperature

Pressure profile for third shock at fuel-ablator interface

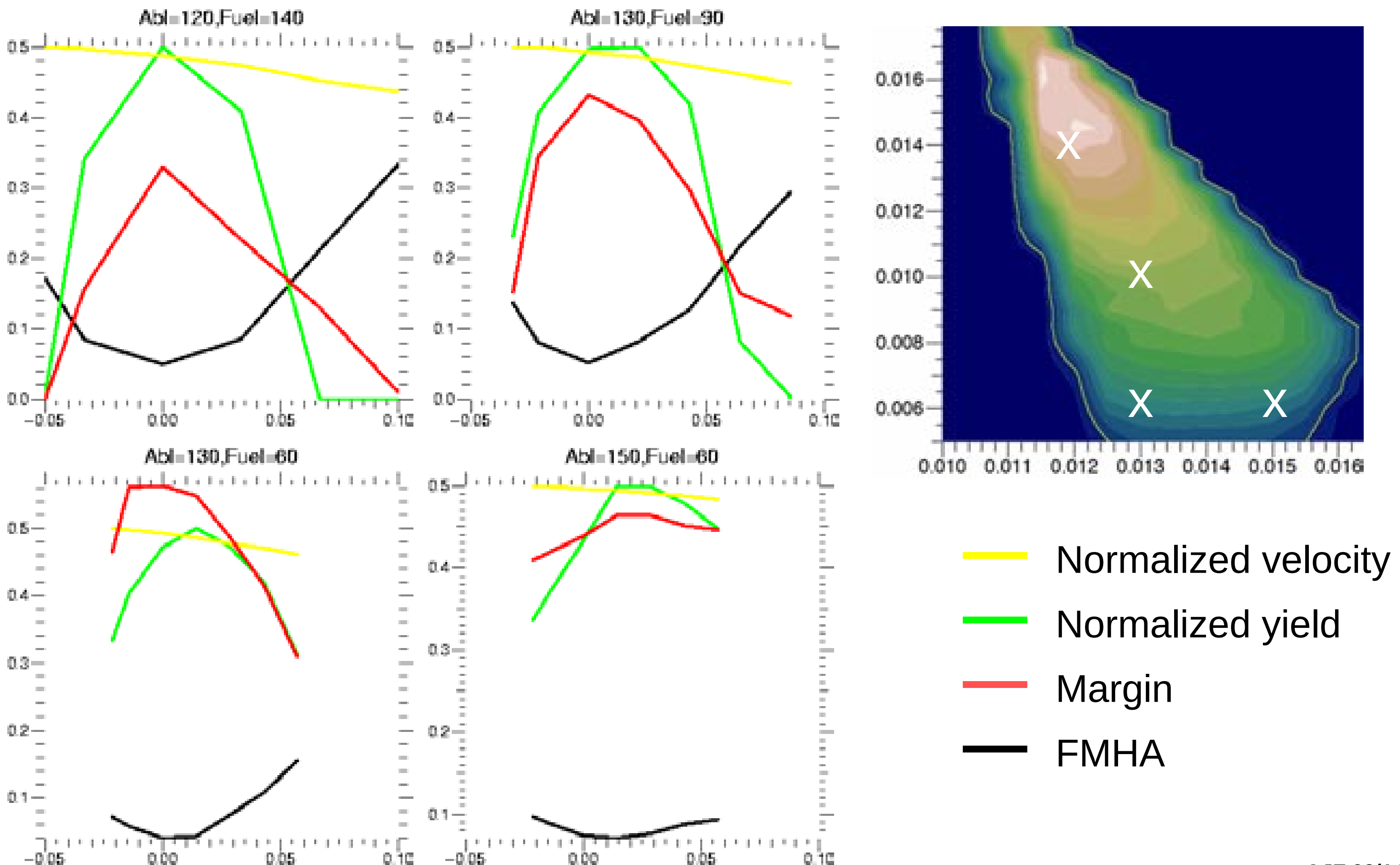
Fourth shock timing:



Time (10 ns)

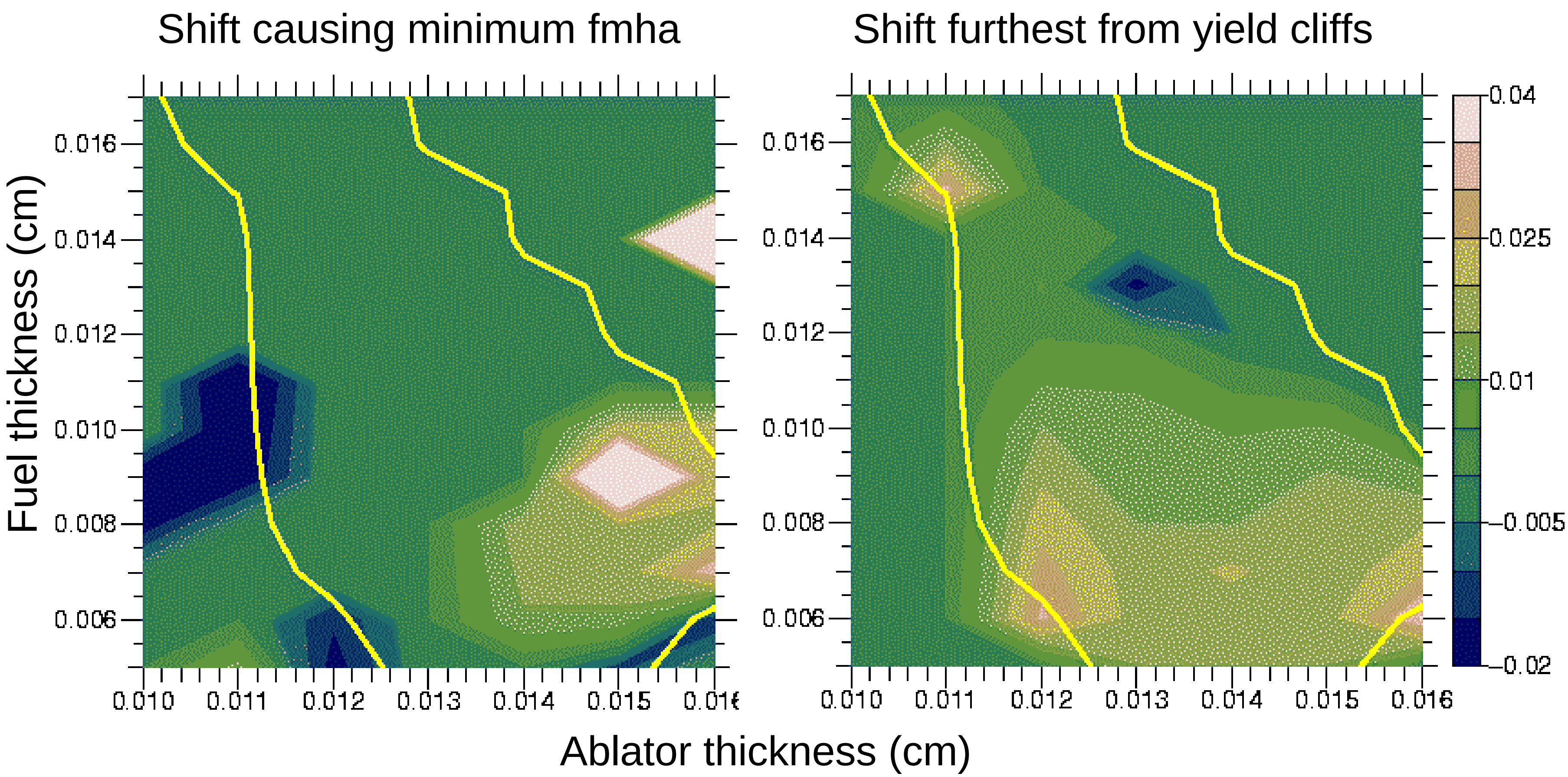
In response to this apparent DECREASE in amplitude, the pulse shaper INCREASES the third shock temperature

Shifting the fourth shock without modifying the third yields similar results



Fourth shock time shift (10 ns)

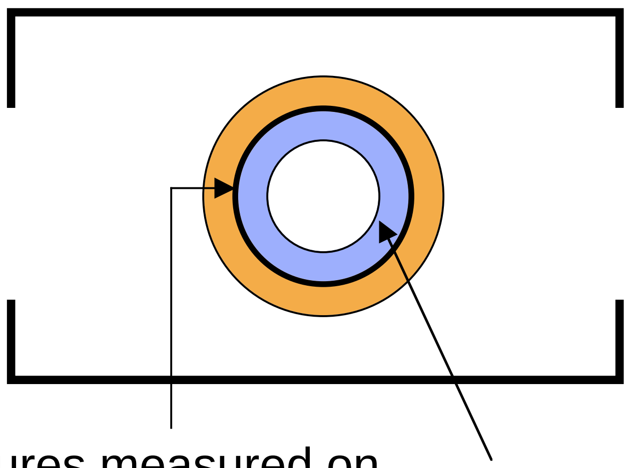
We can do the same optimum finding on the new space



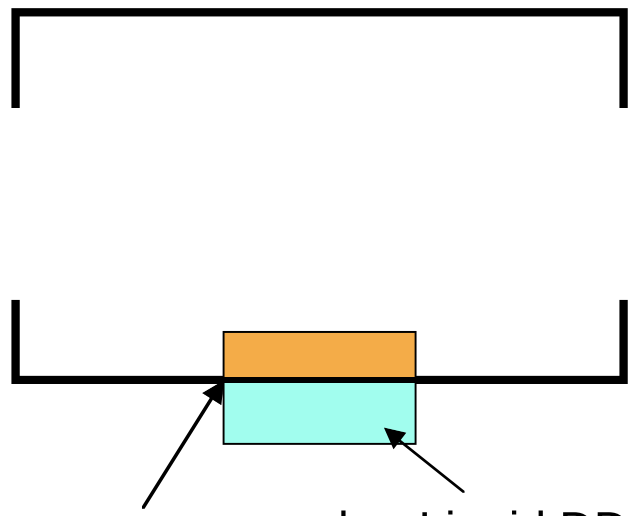
Again we find a shift of 100-200 ps to be optimum in the most interesting region

While tuning in spherical geometry is nice, experimental tuning is done in planar geometry

“Spherical Tuning”



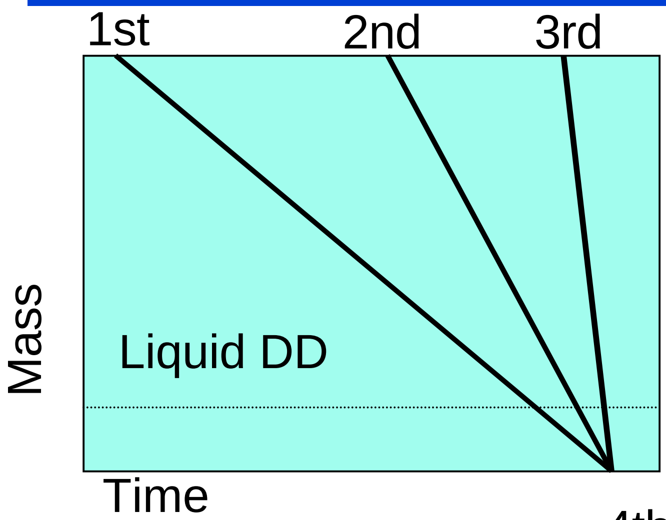
Experimental Tuning



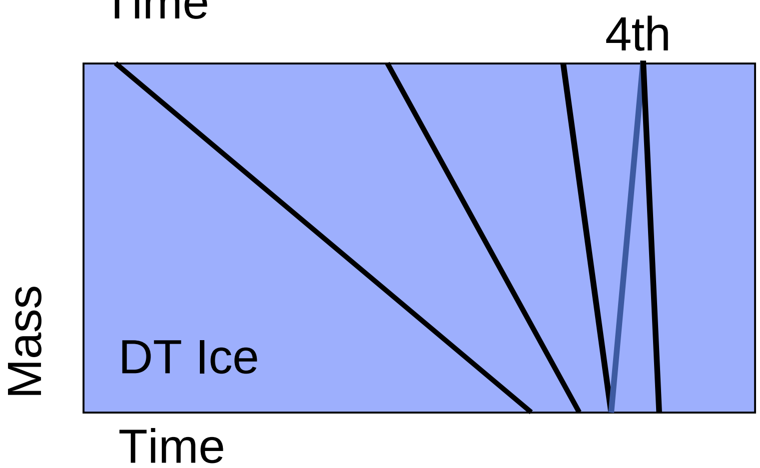
Dave Munro has shown that the same drive that leads to the proper coalescence depth in liquid DD in a planar geometry provides a good pulse shape for spherical capsules using DT ice.

How can we implement this pulse shaping technique?

Pulse shaping using a planar geometry is a two stage process



First, the first three shocks are tuned to get the proper convergence depth in the planar geometry with liquid DD



Then, the first three shocks are fixed and the fourth shock is timed in a spherical geometry with DT Ice.

While the shock velocities should be the same in both cases, the pressure at the interface is different due to the different material properties

This process, however, does not yield desired results.

Target DT Pressure: 0.8 MB

↓ QEOS

Shock velocity: 0.0205 cm/(10 ns)

↓ QEOS

Equivalent DD Pressure: 0.527 MB

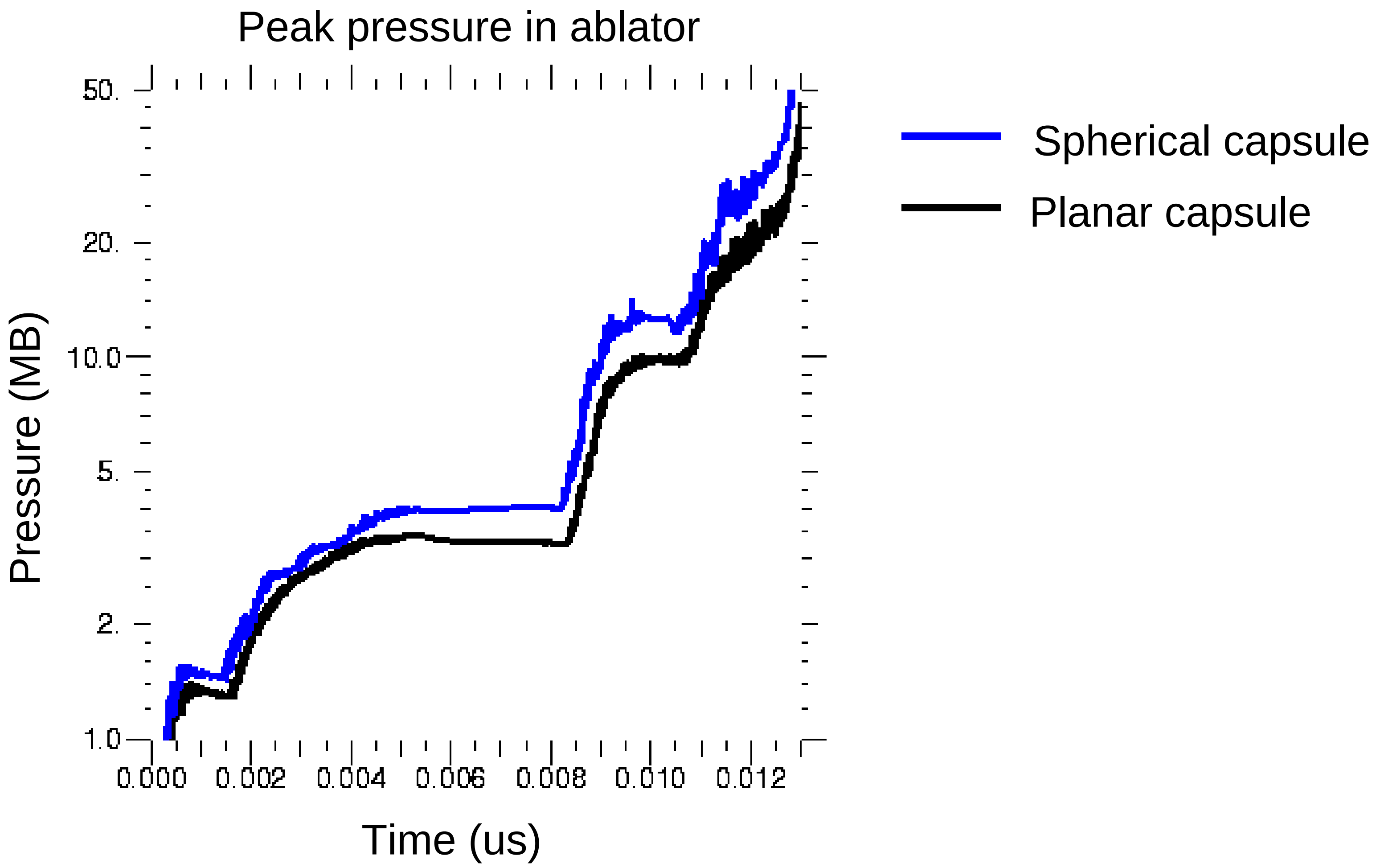
↓ Tuning in planar geometry with DD

Necessary shock radiation temperature: 86 eV

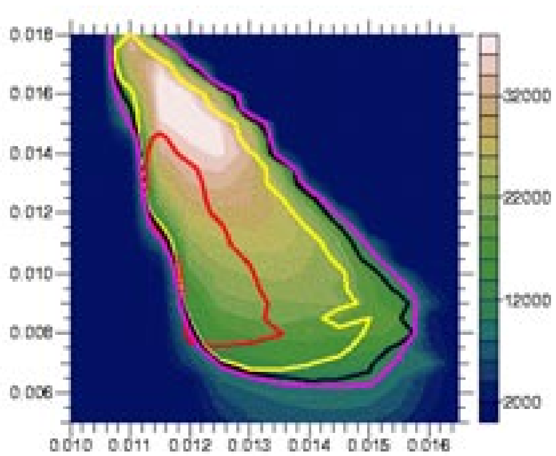
↓ HYDRA in spherical geometry with DT

Actual DT Pressure: **0.95 MB**

The culprit is the difference between planar and spherical ablation



Summary



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Further Work

- Work on solutions to pulse-shaping in planar geometry
- Using this pulse shaper, complete scans over other pulse-shaping parameters.
- Implement the ability to use 2D decks to determine robustness of capsules.
- Make scanning apparatus and pulse shaper completely compatible with graded dopants.