Big Science at a Small College: Fusion Experiments at the World's Largest Laser

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with

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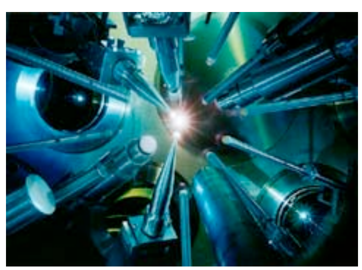
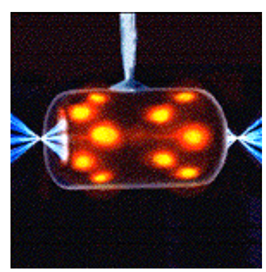
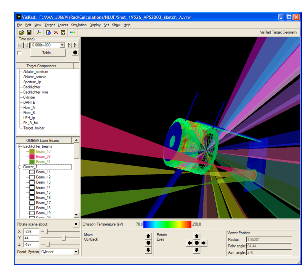






Outline

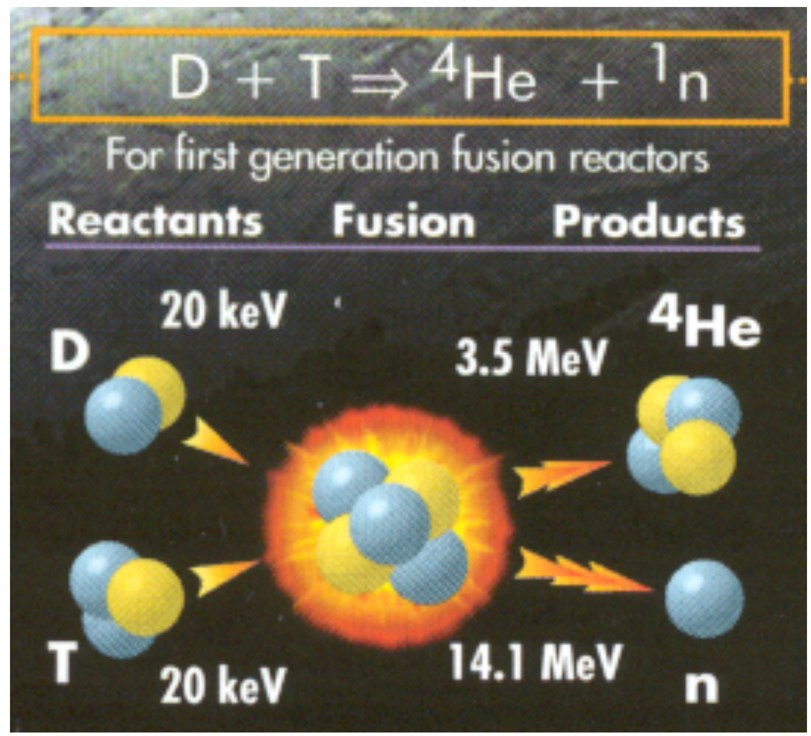
1. Fusion
    A. What is it?
    B. Laser/inertial confinement fusion
2. Our experiments
    A. Spectral measurement of X-ray burnthrough
    B. Doing experiments at the OMEGA laser (deferred to the end)
3. Spectroscopy
4. Modeling and Results

Fusion: combining two light atoms to create one heavier atom

Fusion releases tremendous amounts of energy, the ultimate source of which is the strong nuclear force, which binds neutrons and protons together in atomic nuclei.

The nuclear force is much stronger than the electromagnetic force, which is the source of energy in ordinary chemical reactions.

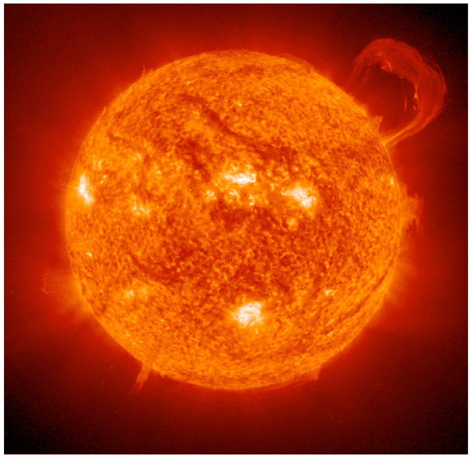
Reactions involving two isotopes of hydrogen (Deuterium and Tritium) – resulting in the creation of a helium nucleus and the release of energy – are the most powerful.



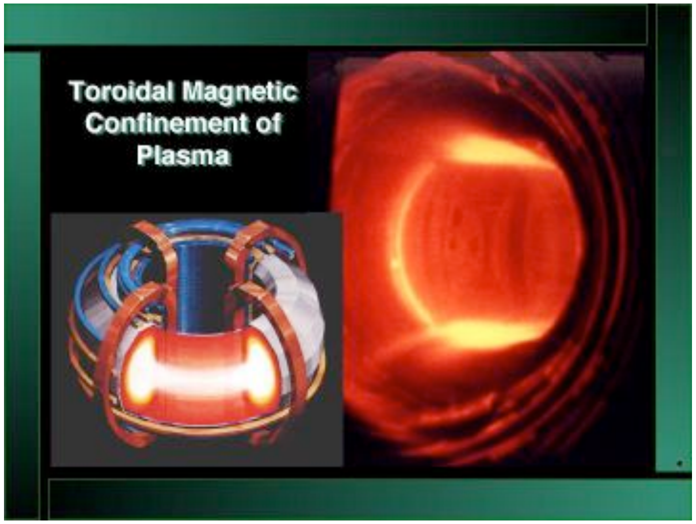
Combining two positively charged nuclei is tough…very high temperatures and/or densities are required to force the hydrogen nuclei together.

There are three methods for holding the hydrogen plasma together:

1. Gravitational confinement – as in stars.



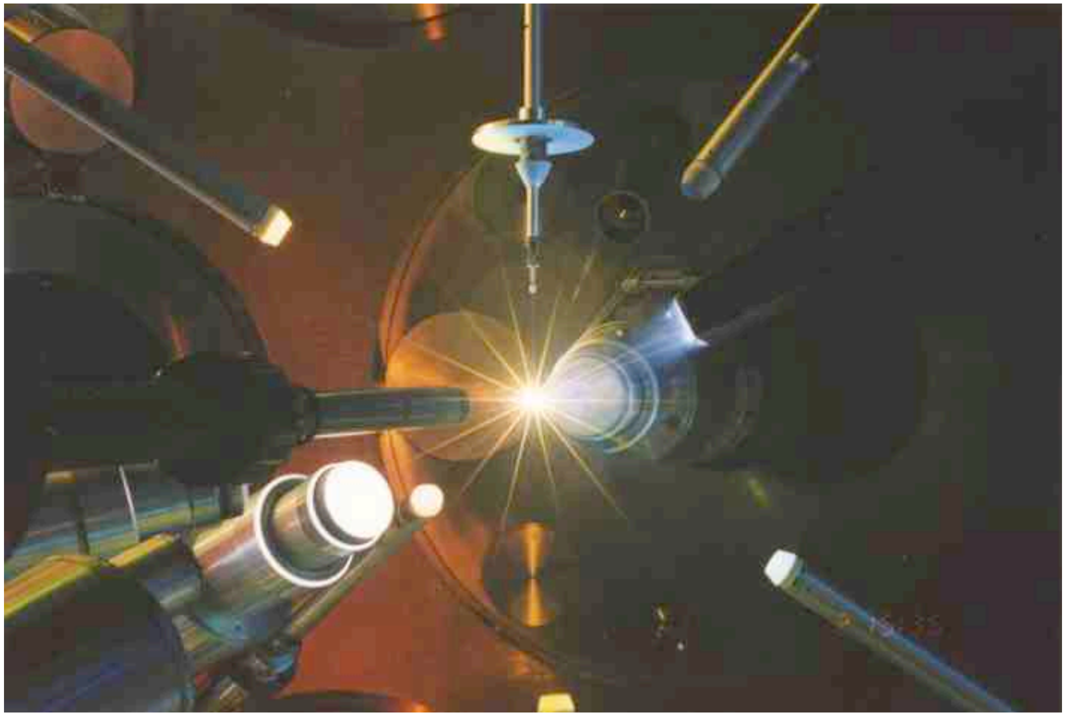
2. Magnetic confinement



3. Inertial confinement – heat and compress the hydrogen fuel with lasers or X-rays

The fuel's own mass and its inward-directed momentum keeps it held together…for a few nanoseconds (billionths of a second)

The target chamber at the OMEGA laser

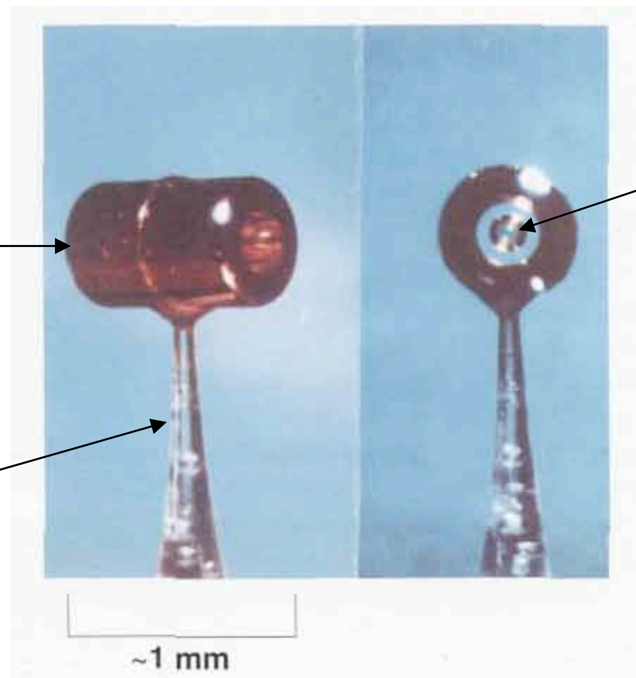


In our type of inertial confinement fusion experiments, laser energy is converted into X-rays inside a small gold cylinder, called a *hohlraum*.

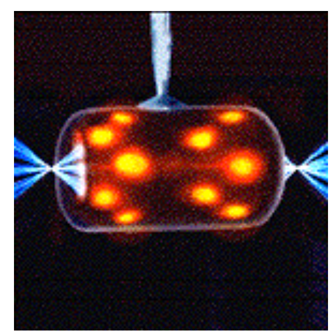
Recall, X-rays are light – just very, very energetic light. When all that laser energy is dumped into a small space, the space gets very hot and it radiates primarily X-rays.

Gold "hohlraum" cylinder

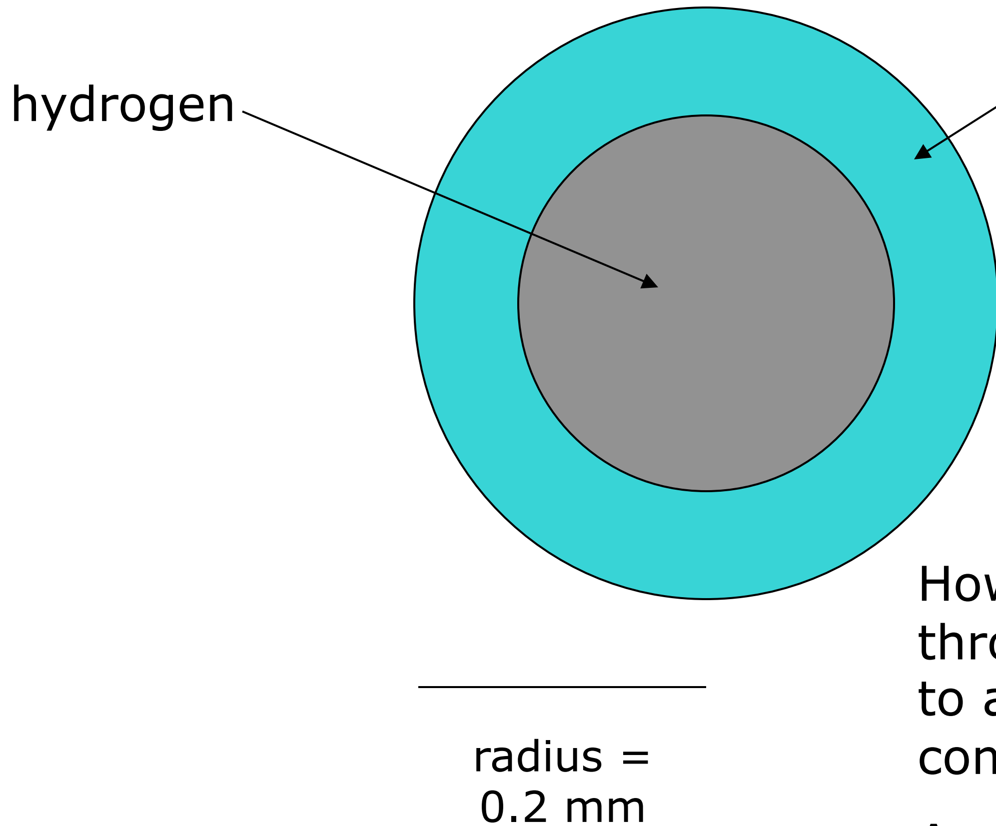
Stalk for holding the hohlraum



Spherical fuel capsule



Schematic of a hydrogen fuel capsule

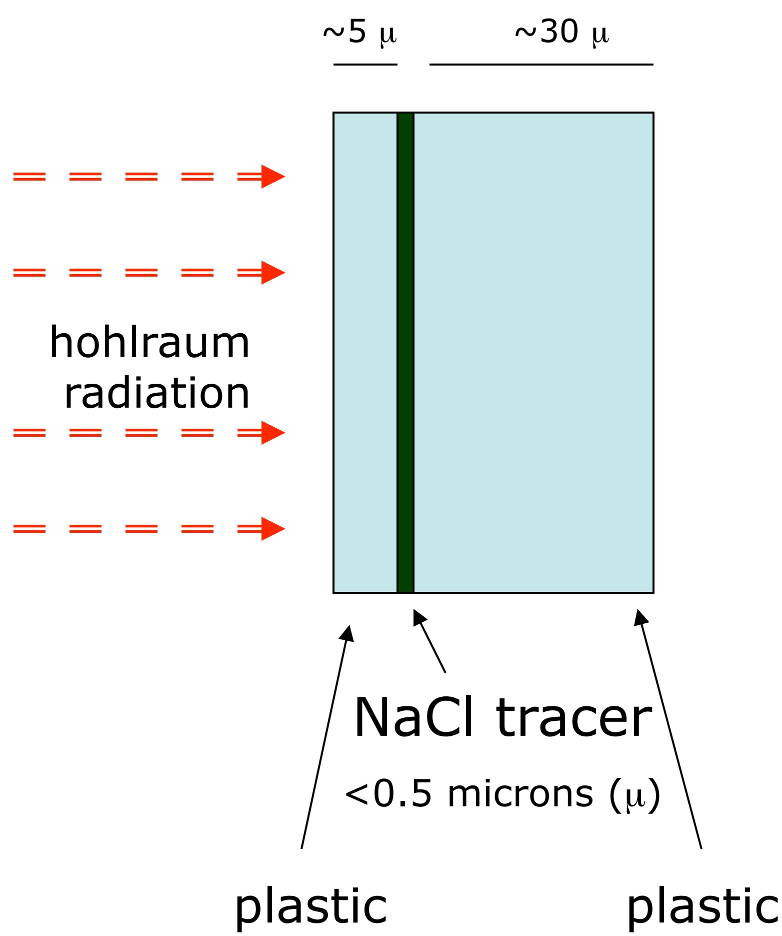


Plastic covering that absorbs X-rays, heats up, and compresses the hydrogen fuel to high densities and temperatures

How the X-rays “burn through” the plastic is crucial to achieving good compression of the fuel…

And we’d like a way of measuring the speed of this burn-through

We study the interaction of the X-ray radiation field with the plastic capsule cover in a *flat* sample of plastic, to keep things simple(r)



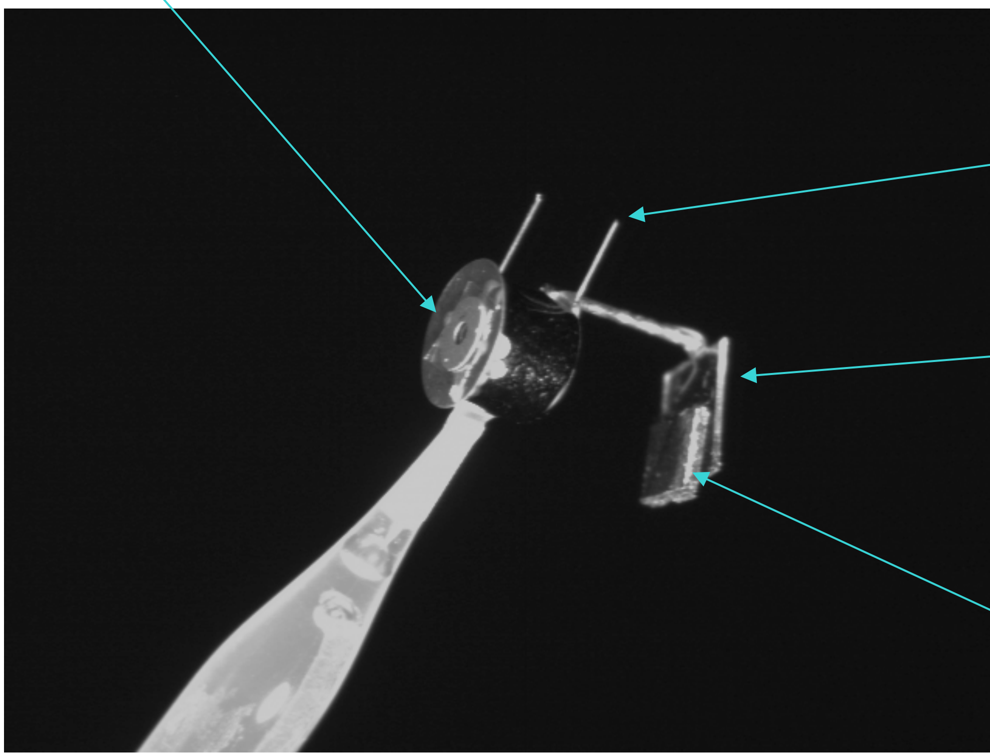
Thin "tracer" layers are embedded at known depth in a plastic sample;

We then look for the spectroscopic signal of the chlorine in the tracer;

That tells us when the radiation has reached the depth of the tracer.

In our experiments, we put the flat plastic capsule material on the outside of a half-hohlraum and measure the spectroscopic signal from the tracer

plastic sample

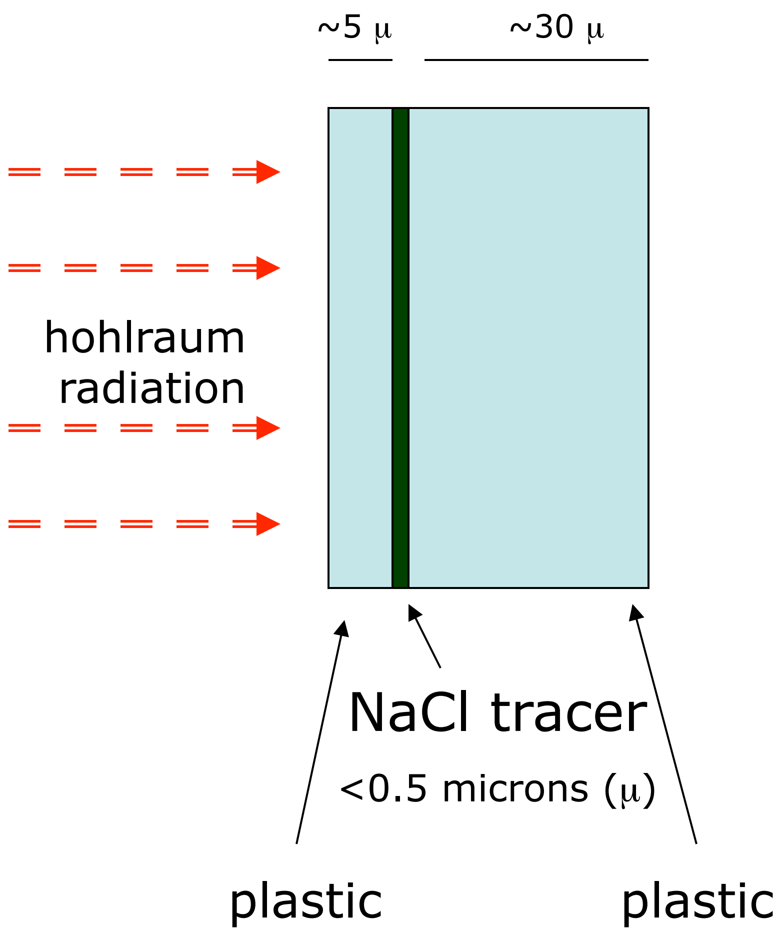


positioning wires

Pb-doped plastic mount

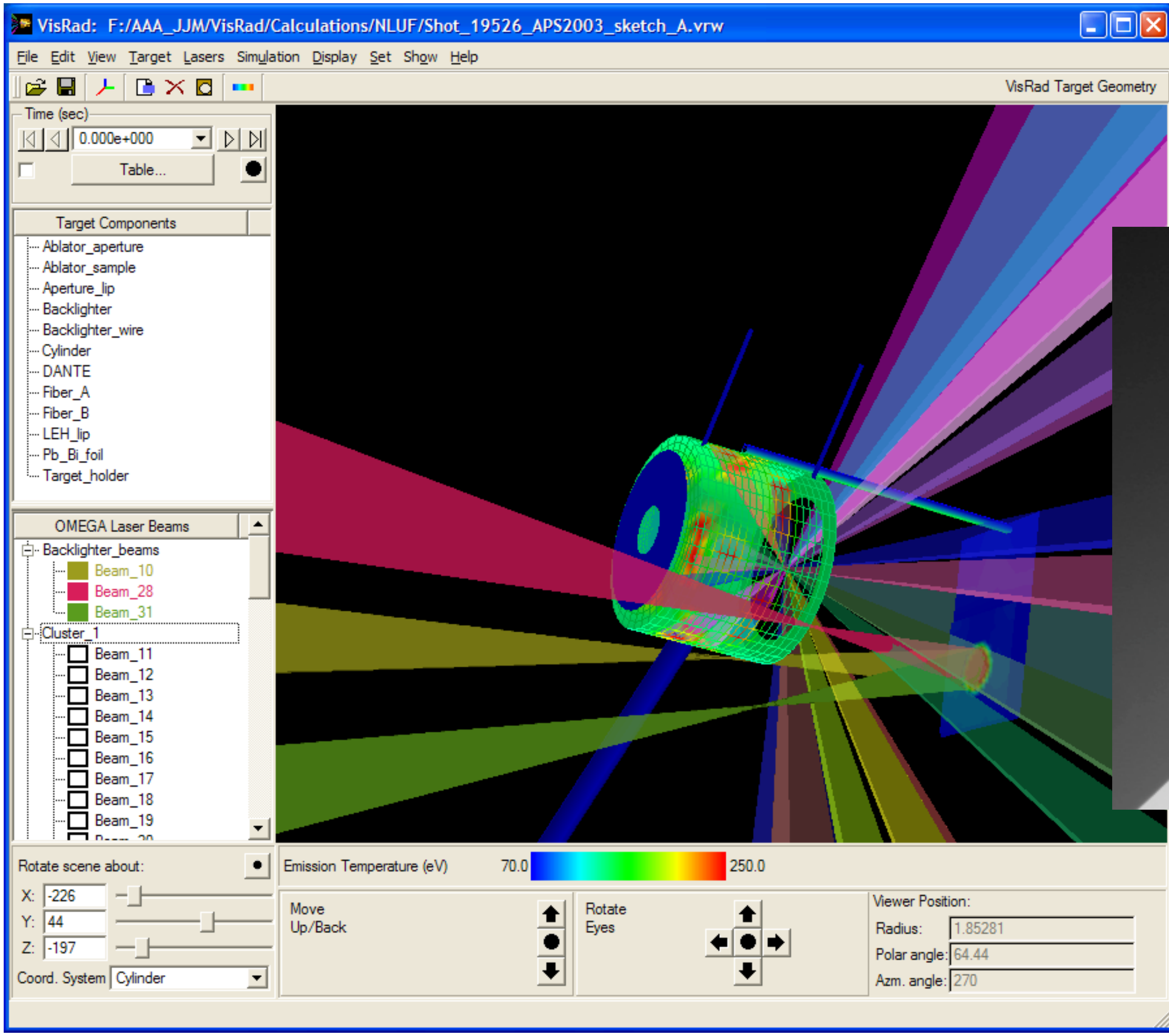
Bi/Pb backligher foil

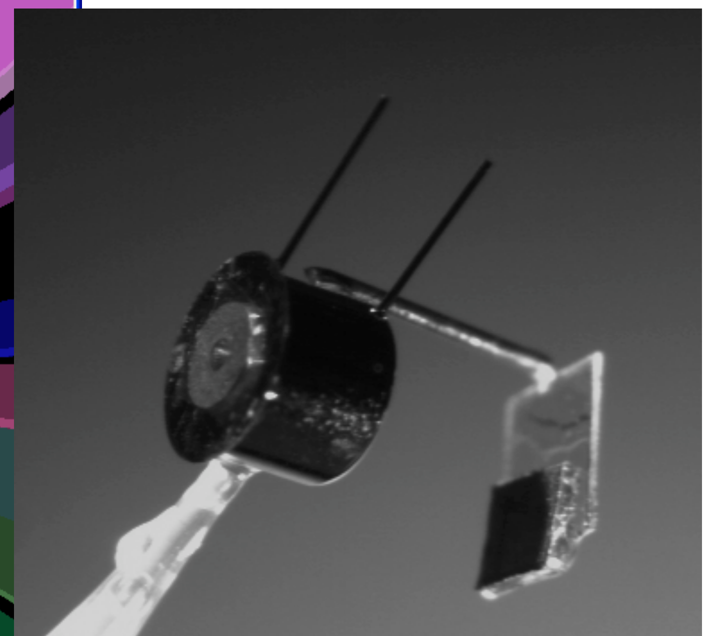
Once again, the measurement in our experiment is the time it takes for the radiation wave (and associated heating) to reach the depth of the chlorine-bearing tracer layer



We measure this **spectroscopically**…

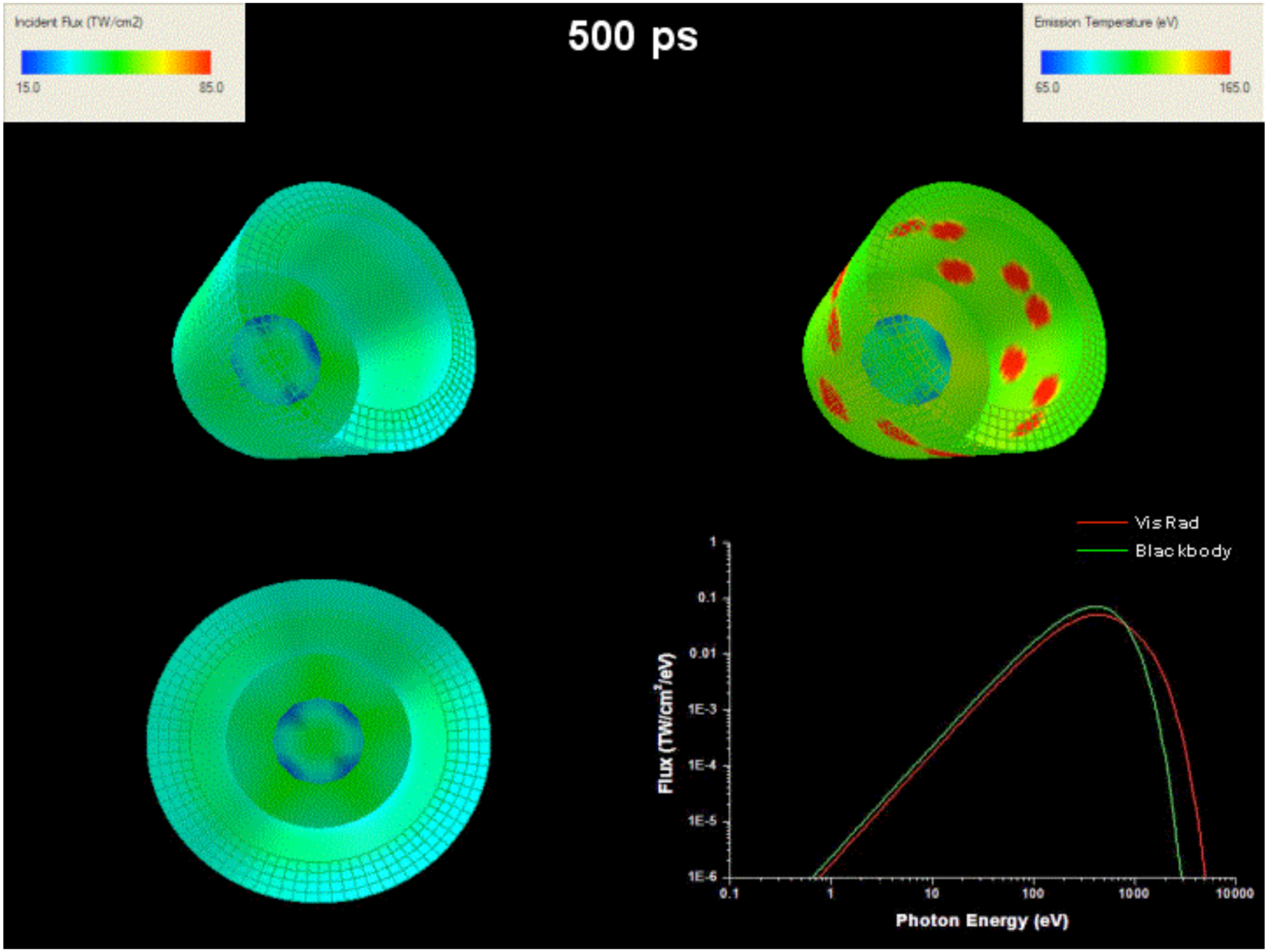
Every aspect of the experiment has to be modeled – laser heating of hohlraum and backlighter foil on left





Note: laser beams onto backlighter foil creates X-ray source that illuminates the plastic sample – this is the signal we measure

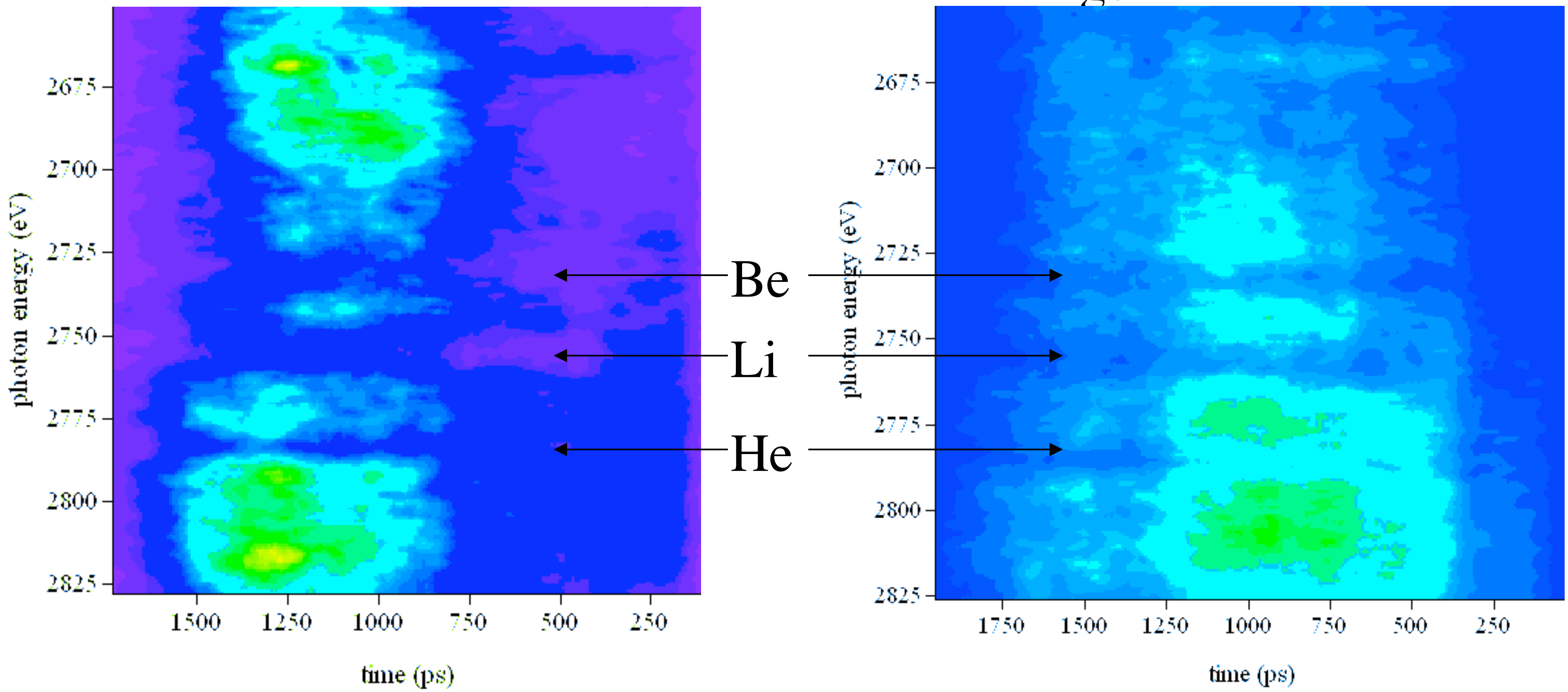
Simulations of the hohlraum filling up with X-ray radiation – note the hot spots where the lasers hit the hohlraum



Simulations by Dave Conners ('03)

“plain” plastic

plastic with a little germanium in it



These are our data – time-dependent absorption spectra… we see the chlorine spectral signals turn on a few 100 picoseconds (trillionths of a second) after the lasers heat the hohlraum

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Figure 8. Nova laser bay.

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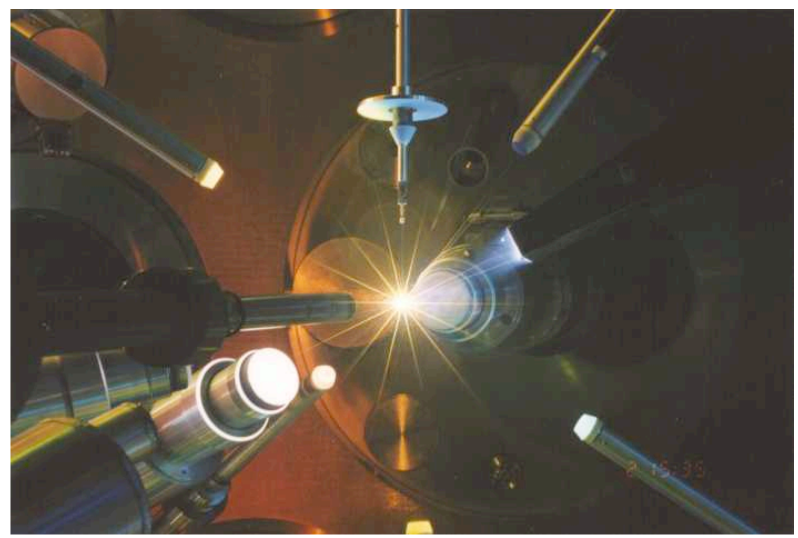
Figure 9. Nova target chamber.

people



What's it like to do experiments at the OMEGA laser?

The OMEGA laser facility is run in a business-like manner

Publicity shots – lobby (left) and control room (right)

Conclusions: big science can be done “at” a small college

…commercial fusion power is a long way off

…spectroscopy is cool