Output Spectra from Direct Drive ICF Targets

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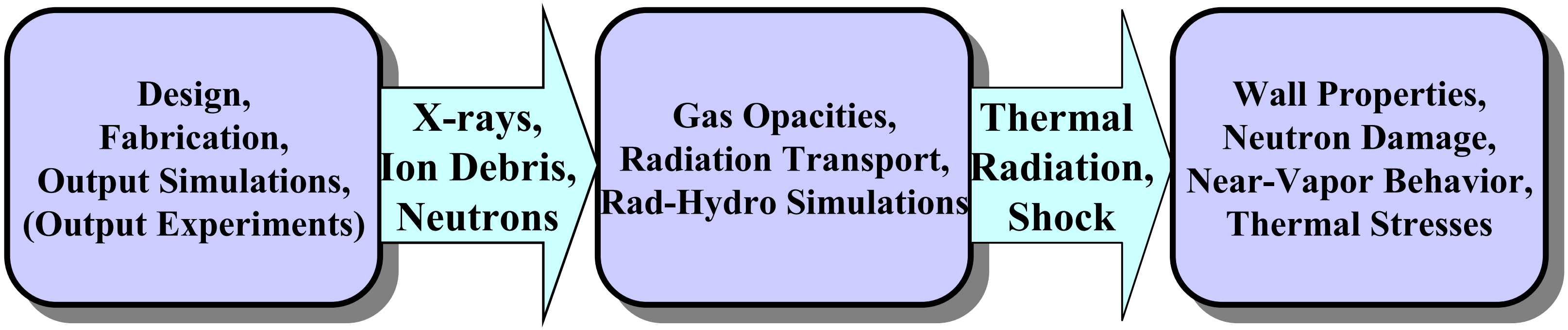
Chamber Physics Critical Issues Involve Target Output, Gas Behavior and First Wall Response

Target Output | **Gas Behavior** | **Wall Response**



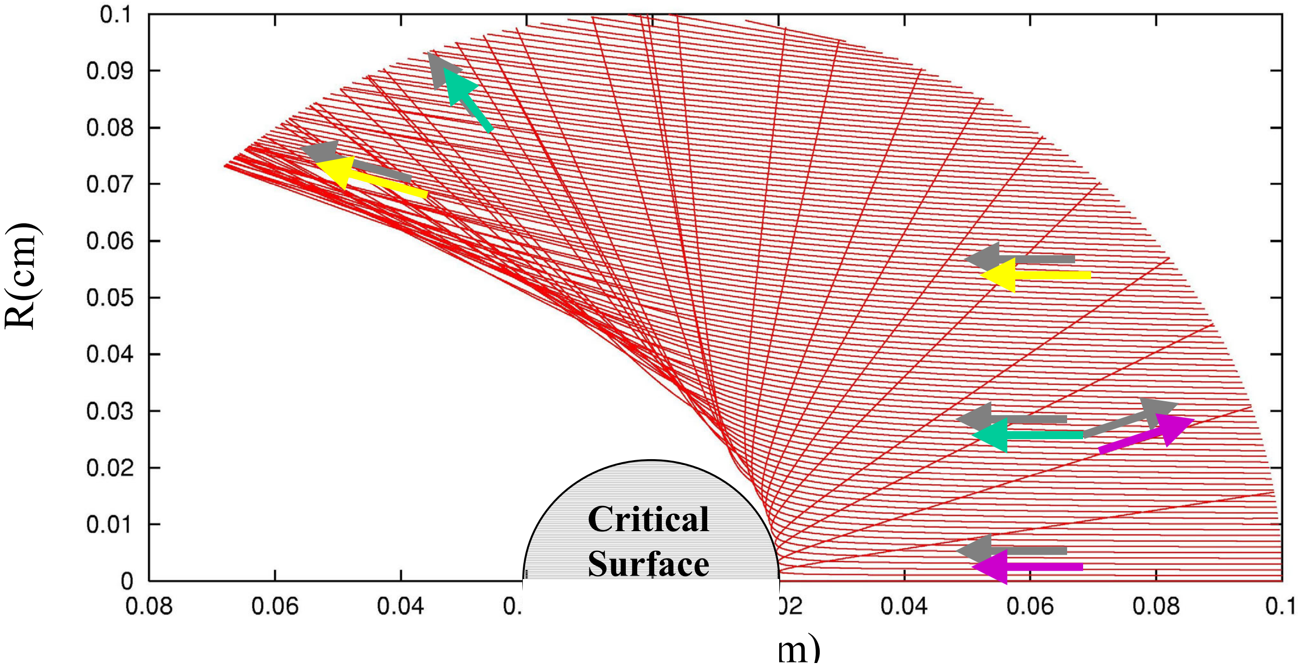
UW uses the BUCKY 1-D Radiation-Hydrodynamics Code to Simulate Target, Gas Behavior and Wall Response.

Question: How accurate are 1-D Output Calculations?

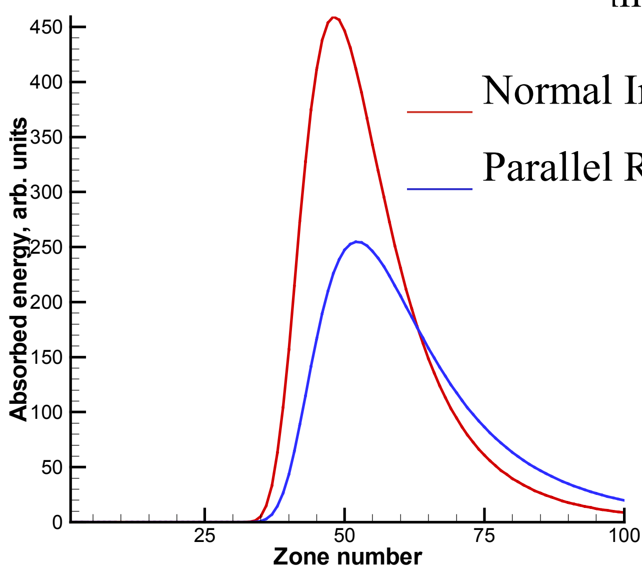
Outline

1. Laser Deposition
2. Burn Started from FAST-1D (NRL) Ignition Conditions
3. Ion Output
4. X-ray Output

New Laser Deposition Package for BUCKY Will Allow Us to Calculate Output Including Reflected Laser Light



- **Laser Rays** are refracted by electron density profile.
- In the example, $n_e(r) = n_c(r_c/r)^{1.5}$ where r_c=0.02 cm.
- Rays are initially parallel, but are refracted or absorbed by electrons.

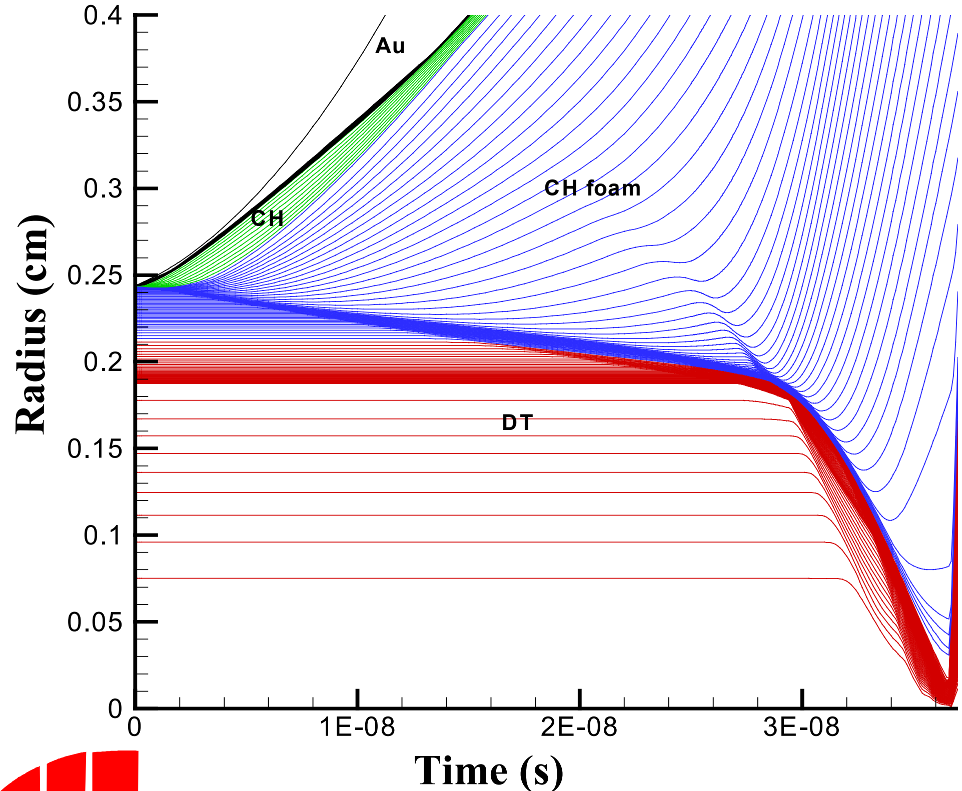


- Normally incident rays are absorbed more strongly because some parallel rays are refracted out of the plasma.
- Normally incident rays are absorbed nearer the critical surface, in a narrower region than parallel rays because of refraction.

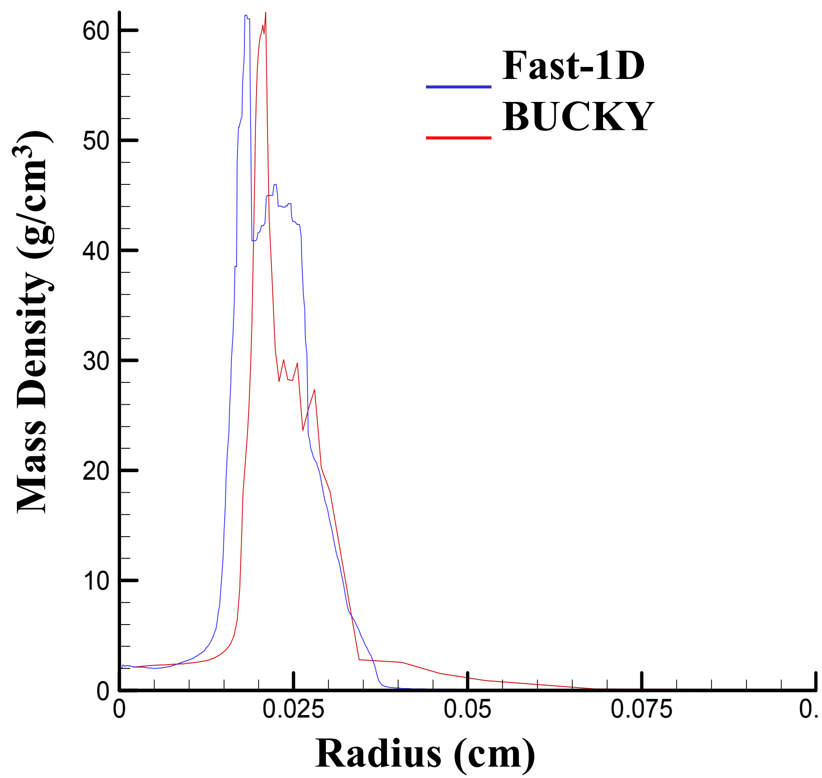
Implosion of High Yield Direct-Drive Laser Fusion Target with New BUCKY Laser Deposition Package

- Minor Differences Lead to Lower Yield.
- Peak mass density just before ignition is the same for FAST-1D and BUCKY, but density shape is a little different; the yield is 200 MJ versus 385 for Fast-1D.
- Need to use zooming consistent with NRL.

Implosion Yields 200 MJ



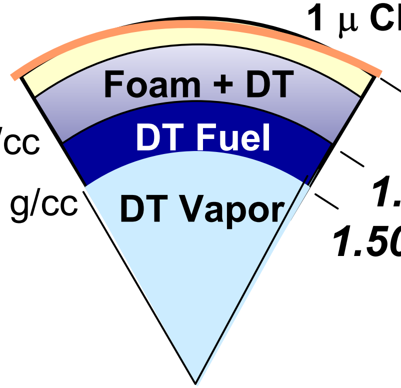
Mass Density Profiles Just Before Ignition



We Have Calculated Output from 2 NRL Targets Starting from NRL Supplied Ignition Conditions

Radiation Pre-Heated Direct-drive Laser Targets

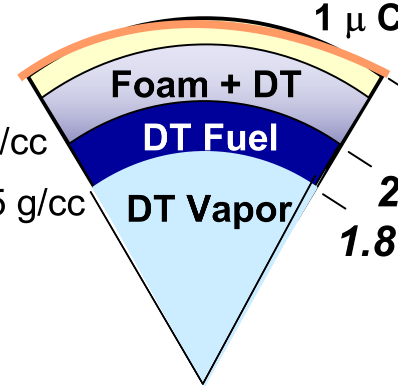
NRL (1999)
~165 MJ Yield



Laser Energy: 1.3 MJ
Laser Type: KrF
Gain: 150
Yield: 195 MJ

Energy Partitioning:
- 149.7 MJ neutrons (76.8%)
- 2.02 MJ x-rays (1.04%)
- 34.0 MJ hydrodynamic ions (17.4%)
- 1.06 MJ escaped fusion ions (0.54%)
- Error=2.3%

NRL (2001)
~400 MJ Yield

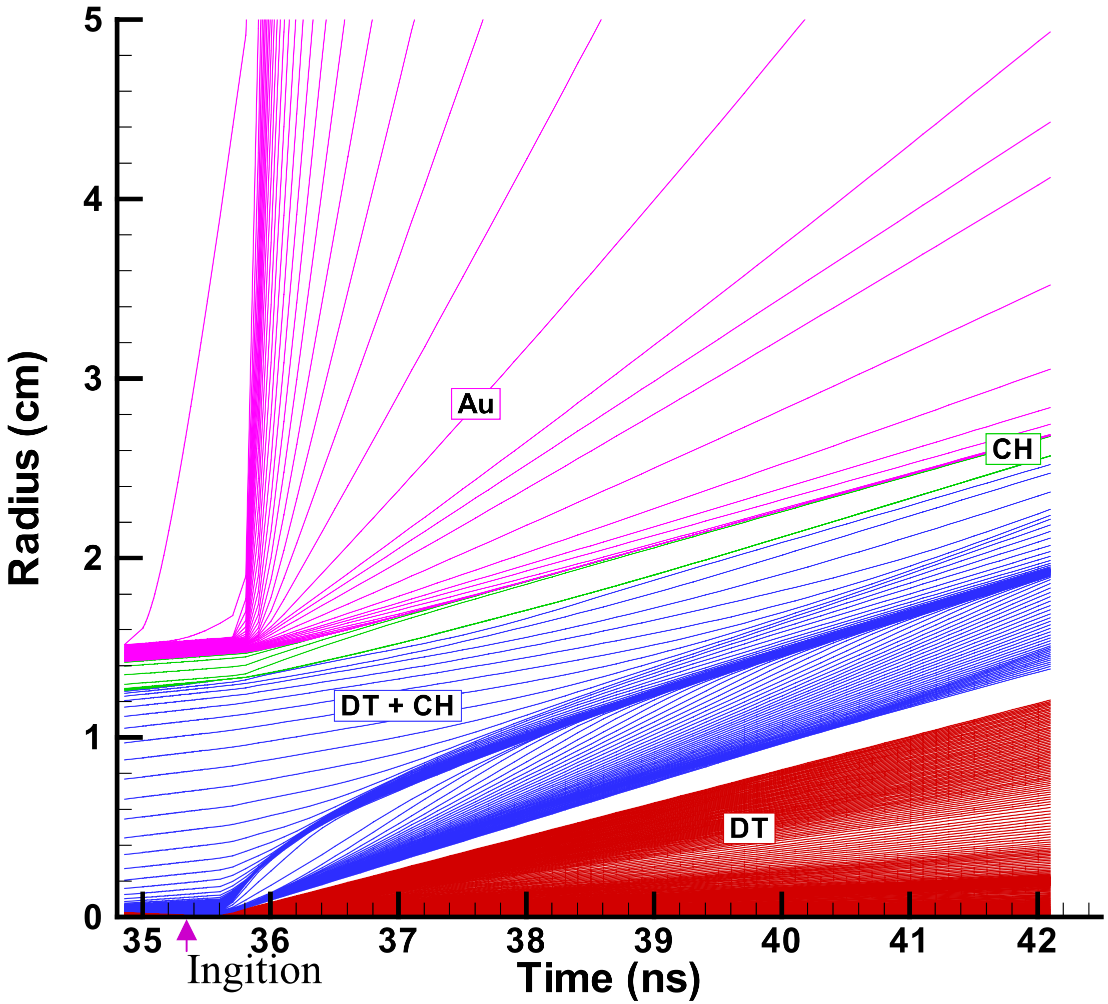


Laser Energy: 2.5 MJ
Laser Type: KrF
Gain: 175
Yield: 437 MJ

Energy Partitioning:
- 303.3 MJ neutrons (69.4%)
- 2.67 MJ x-rays (0.61%)
- 119.8 MJ hydrodynamic ions (27.4%)
- 12.6 MJ escaped fusion ions (2.89%)
- Error = 0.3%

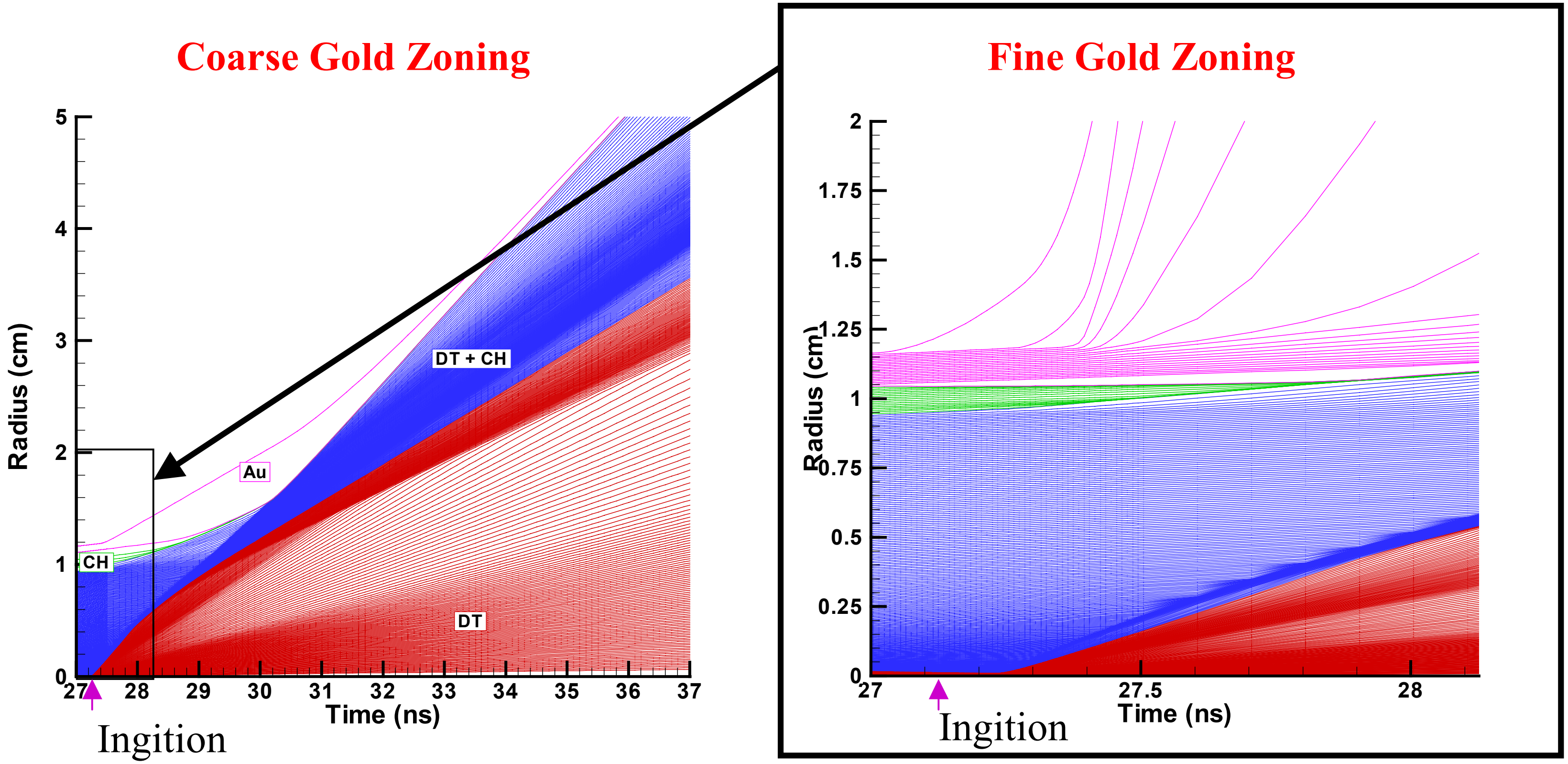
Burn and Explosion of High Yield NRL Radiation Smoothed Direct-Drive Laser Fusion Target

- •Start from plasma conditions just before ignition from Denis Colombant.
- •BUCKY specifically includes Compton scattering in opacities.
- •BUCKY predicts 430 MJ of yield compared with 385 MJ from FAST-1D.
- •Burn radiation "explodes" Au shell.



Burn and Explosion of 165 MJ Yield NRL Radiation Smoothed Direct-Drive Laser Fusion Target

- Start from plasma conditions just before ignition from Andy Schmitt
- BUCKY specifically includes Compton scattering in opacities.
- BUCKY predicts 195 MJ of yield compared with 165 MJ from FAST-1D.
- Passage of Burn radiation through Au shell depends on details of Gold Plasma (see course versus fine Au zoning).



Explosion of Gold Shell in 400 MJ Target is Explained by Absorption of Target X-rays

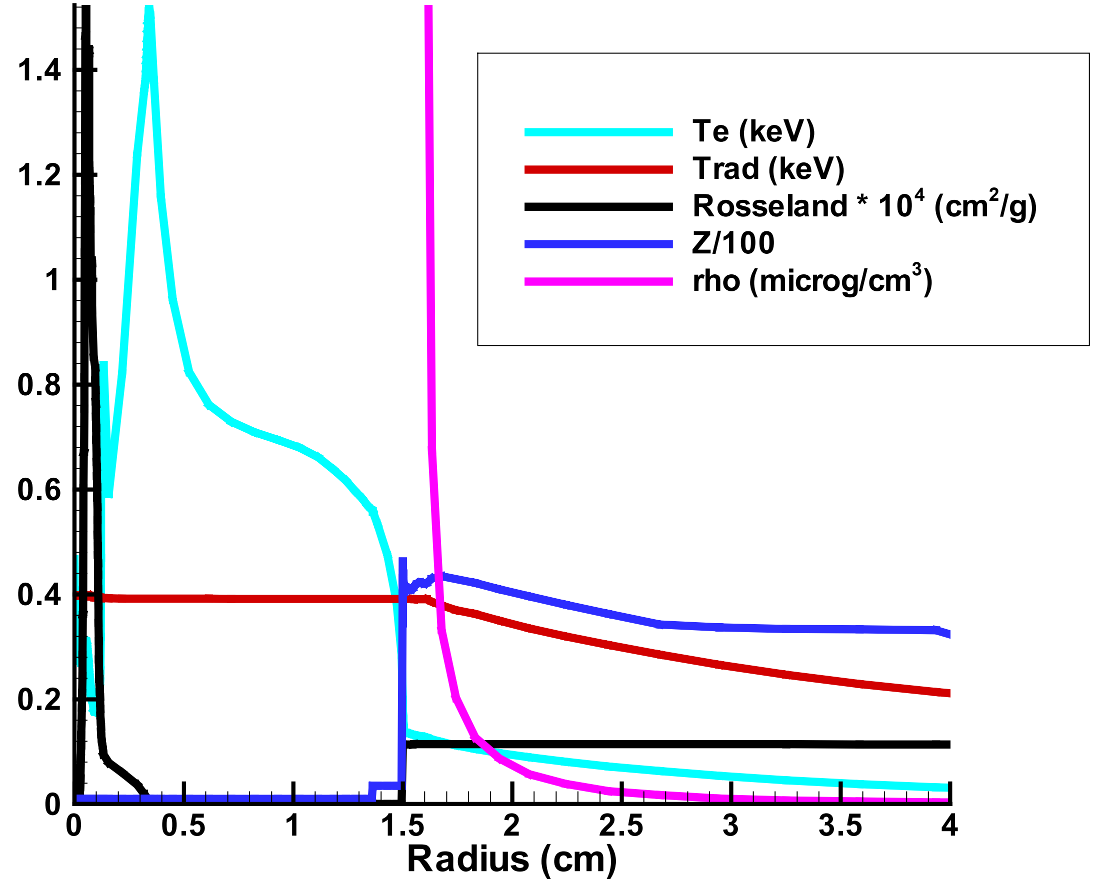
•Gold begins to explode at 36 ns.

•Gold opacity to 400 eV is much higher than other parts of corona.

•Radiation is attenuated in Gold

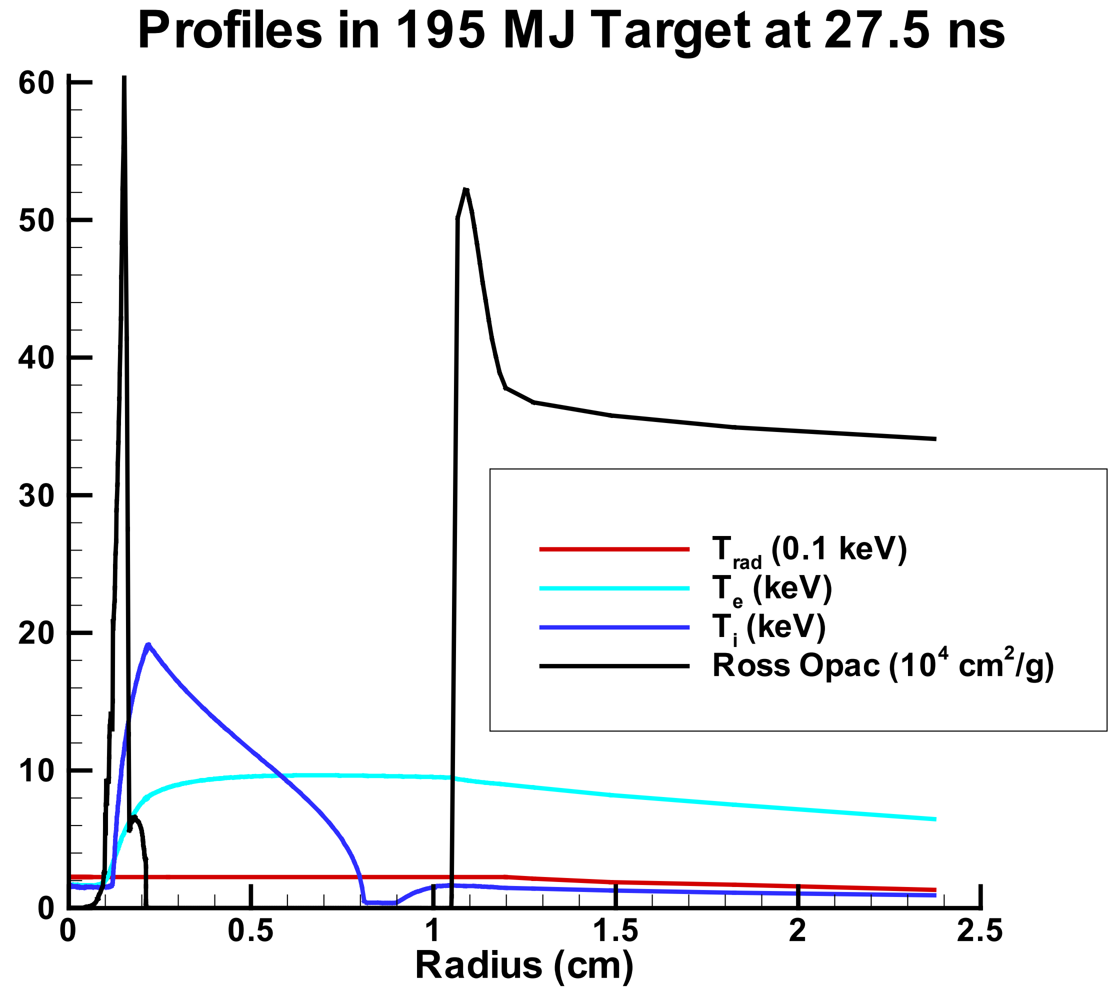
•100 eV electron temperature in gold leads to charge state of 40-45.

Profiles im 400 MJ Target at 36 ns



Explosion of Gold Shell in 195 MJ Target is Explained by Absorption of Target X-rays

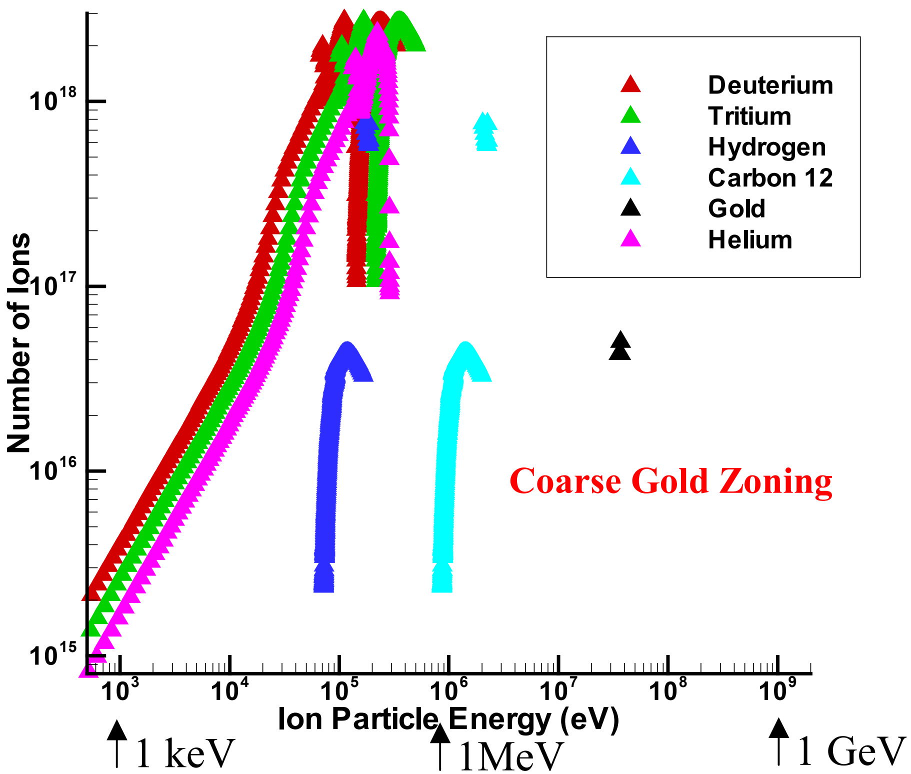
- •Gold begins to explode at 27.5 ns.
- •Gold opacity to 2 keV is much higher than other parts of corona.
- •Radiation is attenuated in Gold



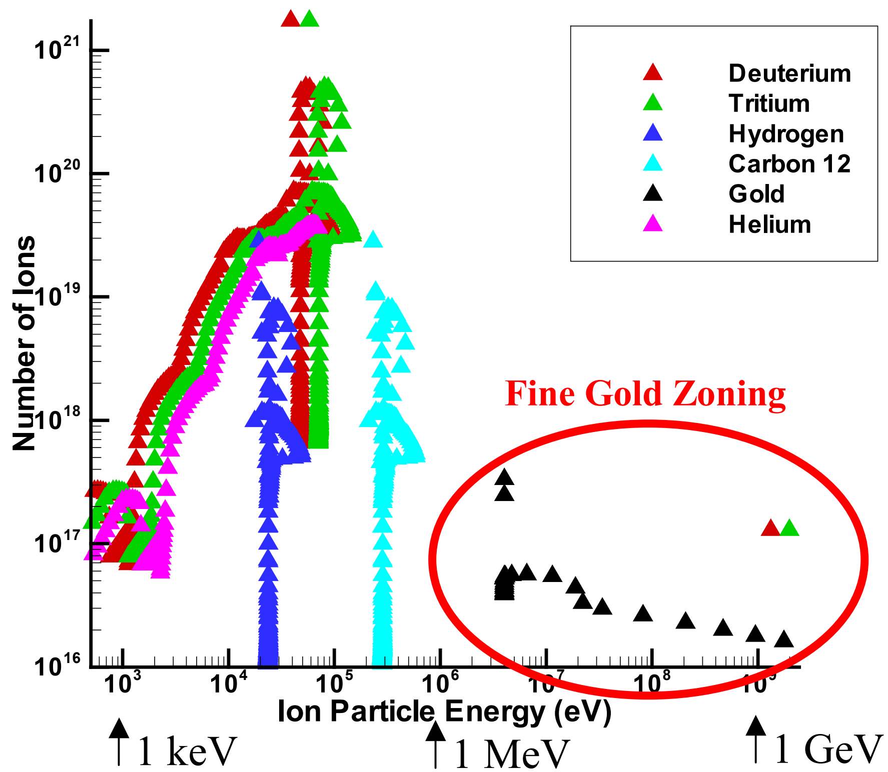
1-D Finely-Zoned BUCKY Runs for Gold-Coated Direct-Drive Targets Predict High Energy Gold Ions

- The particle energy of each species in each zone is then calculated as $mv^2/2$ on the final time step of the BUCKY run. This time is late enough that the ion energies are unchanging. The numbers of ions of each species in each zone are plotted against ion energy.
- The spectra from direct fusion product D, T, H, He^3, and He^4 are calculated by BUCKY but they are not a significant part of the threat.

Ion Spectrum for 195 MJ Yield NRL Target



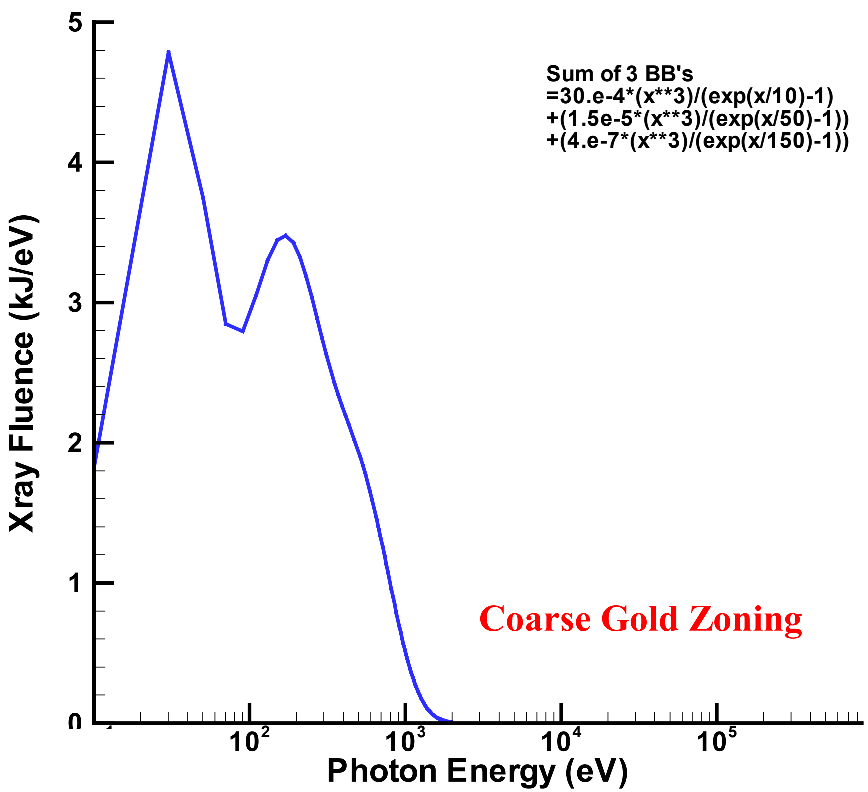
Ion Spectrum for 437 MJ Yield NRL Target



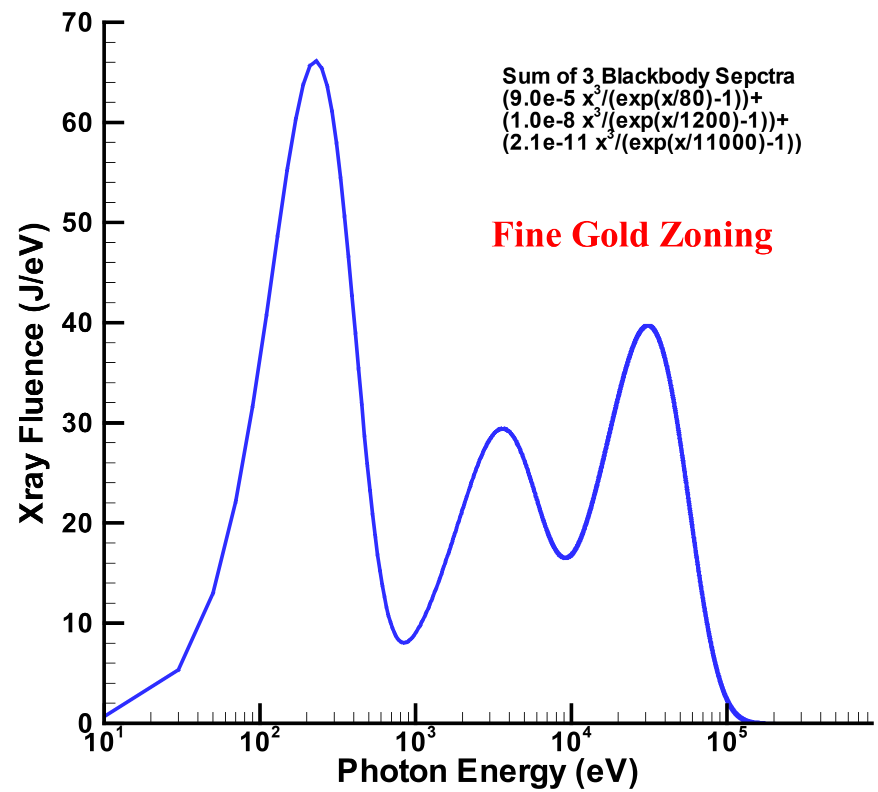
1-D Finely-Zoned BUCKY Runs for Gold-Coated Direct-Drive Targets Predict Attenuation of Sub-keV X-rays

- Finely-zoned calculations predict the heating of Au layers to the point where they are well-ionized to absorb sub-keV radiation from burn.
- A coarsely-zoned calculation does not attain sufficient opacity and sub-keV radiation passes through the Au layer.

X-ray Spectrum for 195 MJ Yield NRL Target



X-ray Spectrum for 437 MJ Yield NRL Target



CONCLUSION: Let's Get it Right

1. **Ion and X-ray Spectra are very different for various calculations.**
2. **Plasma dynamics and opacity of Gold seems to be playing a big role.**
3. **Can we believe gold opacities?: LTE versus non-LTE.**
4. **All known direct-drive output calculations today are 1-D. We believe that the gold layer may be hydro-dynamically unstable and will have plasma conditions (and opacity) different than modeled in 1-D.**
5. **What can we do?**
   a. ***More calculations by the next meeting (we only have a few tries at 400 MJ) --- sensitivity versus opacity (Compton Scattering???).***
   b. ***Develop non-LTE Gold opacities.***
   c. ***Are there experiments we can do today?***
   d. ***Wait for NIF to ignite direct-drive targets?***