Output Calculations for Laser Fusion Targets

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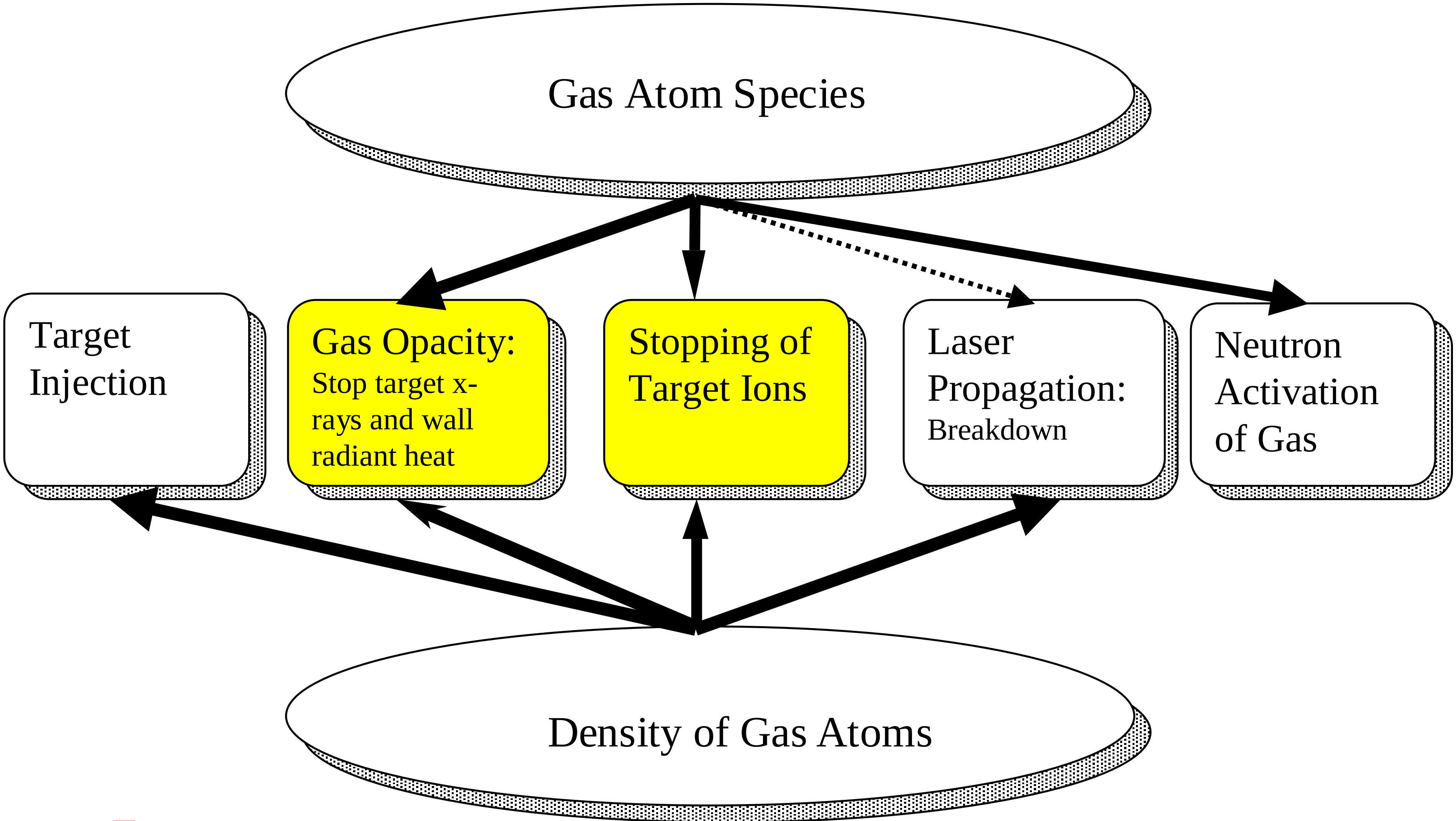
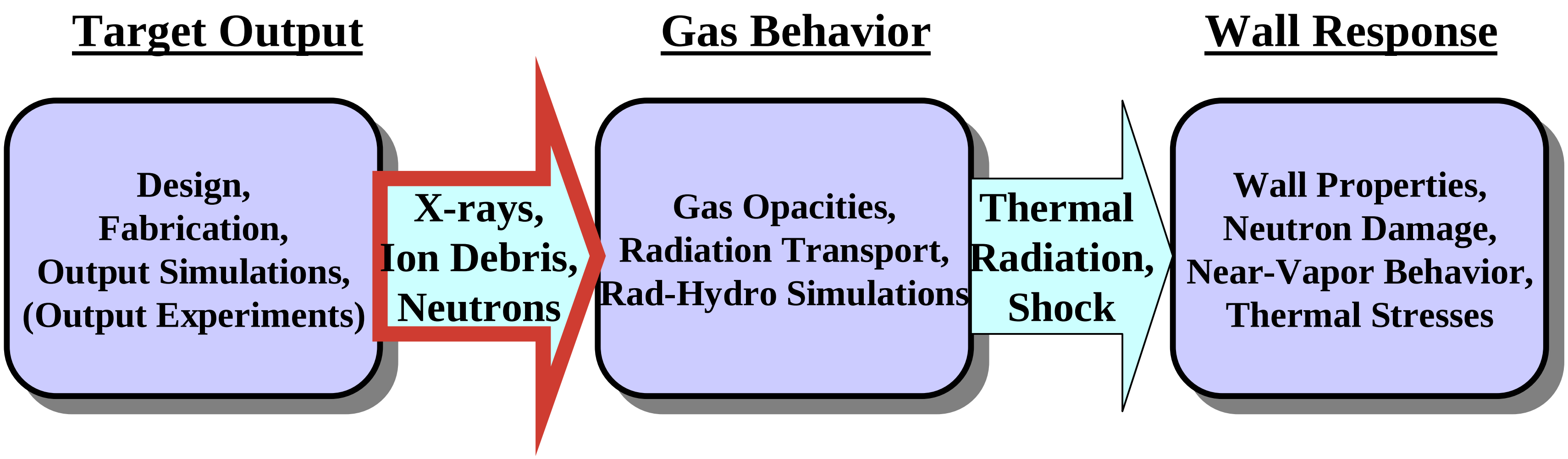
Variables Considered For Choosing the Cavity Gas Environment in SOMBRERO



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



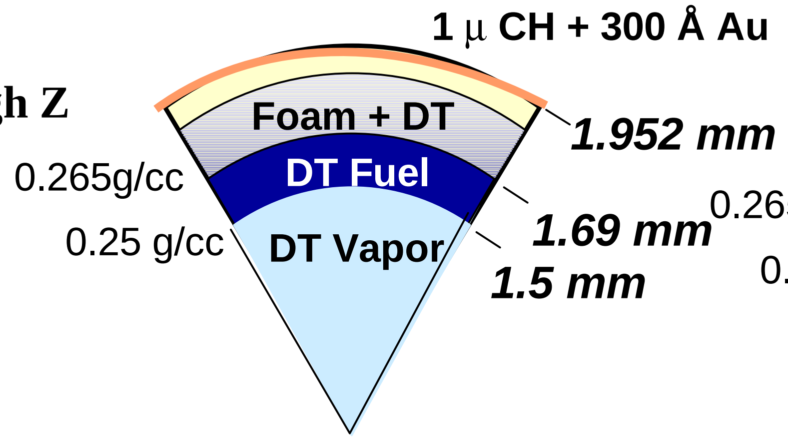
UW uses the BUCKY 1-D Radiation-Hydrodynamics Code to Simulate Target, Gas Behavior and Wall Response.

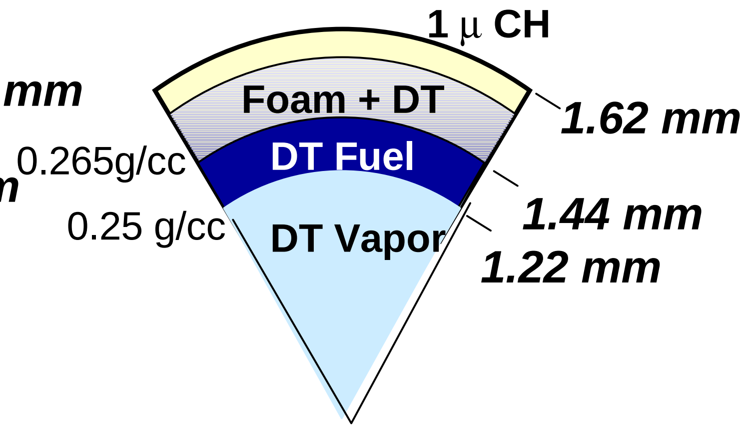
BUCKY is a Flexible 1-D Lagrangian Radiation-Hydrodynamics Code

- 1-D Lagrangian MHD (spherical, cylindrical or slab).
- Thermal conduction with diffusion.
- Applied electrical current with magnetic field and pressure calculation.
- Radiation transport with multi-group flux-limited diffusion, method of short characteristics, and variable Eddington.
- Non-LTE CRE line transport.
- Opacities and equations of state from EOSOPA or SESAME.
- Equilibrium electrical conductivities
- Thermonuclear burn (DT,DD,DHe^3) with in-flight reactions.
- Fusion product transport; time-dependent charged particle tracking, neutron energy deposition.
- Applied energy sources: time and energy dependent ions, electrons, x-rays and lasers.
- Moderate energy density physics: melting, vaporization, and thermal conduction in solids and liquids.
- Benchmarking: x-ray burn-through and shock experiments on Nova and Omega, x-ray vaporization, RHEPP melting and vaporization, PBFA-II K_α emission, …
- Platforms: UNIX, PC, MAC

Direct and Indirect Drive Targets Under Consideration Have Different Output

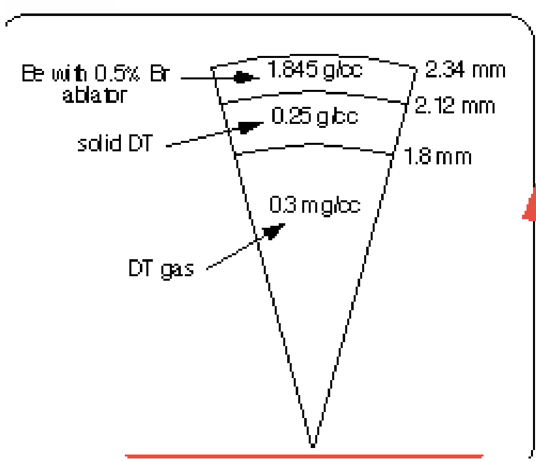
NRL Direct-drive Laser Targets May Contain High Z

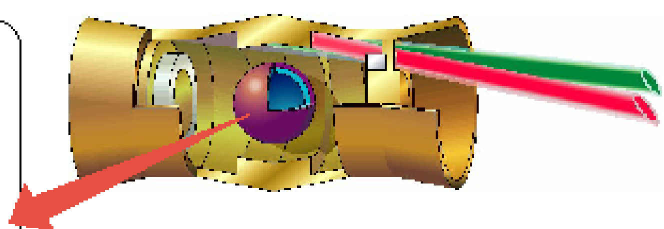




Indirect-drive HIF and Z-pinch Targets Have High-Z Hohlraums

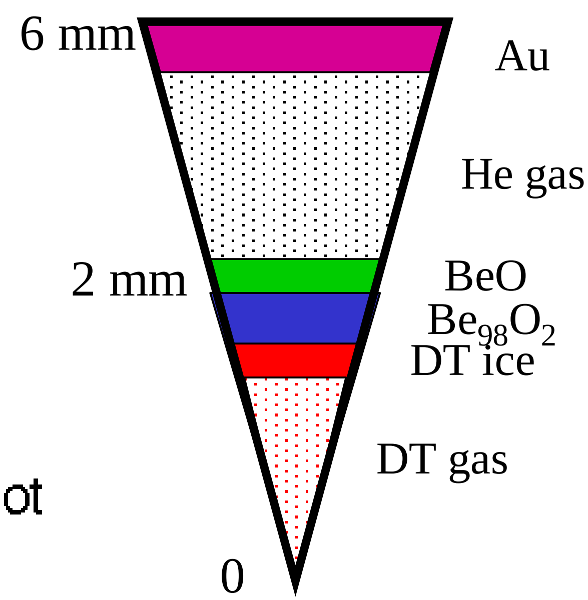
LLNL/LBNL HIF Target





Ion beam characteristics:
- 3.5 GeV Pb^+ ions
- 3.3 MJ input energy
- 1.7 mm effective radius spot

X-1 Target

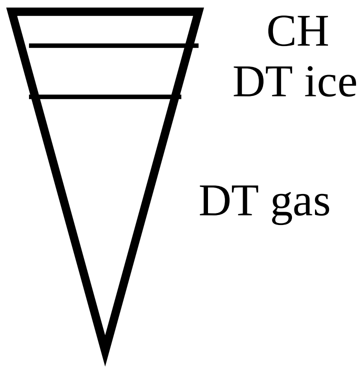


Original SOMBRERO Study Operated Under Substantially Different Target Assumptions Than Are Currently Used

	T_{min} (K)	ΔT Allowed (K)	Target Reflect-ivity	Wall Emis-sivity	Flight Length (m)	Flight Time (ms)	Gas	Density (Torr)	Output Spectra	Yield (MJ)
SOMBRERO (1991)	4	14	0 (no Au)	1.0	6.5	16.3	Xe	.5	given	400
SOMBRERO (2000)	18	0.5 – 1.7	.99	.8	< 2	< 5	Xe - Kr	< 0.5	given	400
NRL Target	18	0.5 – 1.7	.2	.8	2 – 6.5	5 – 16.3	Xe	?	Calc.	160

Direct-Drive Target Output is Dominated by Neutrons and Energetic Ablator Ions

SOMBRERO Target



Debris Ions

94 keV D -	5.81 MJ
141 keV T -	8.72 MJ
138 keV H -	9.24 MJ
188 keV He -	4.49 MJ
1600 keV C -	55.24 MJ
Total -	83.24 MJ per shot

=15.68 J/cm^2 on SOMBRERO Wall

Neutrons

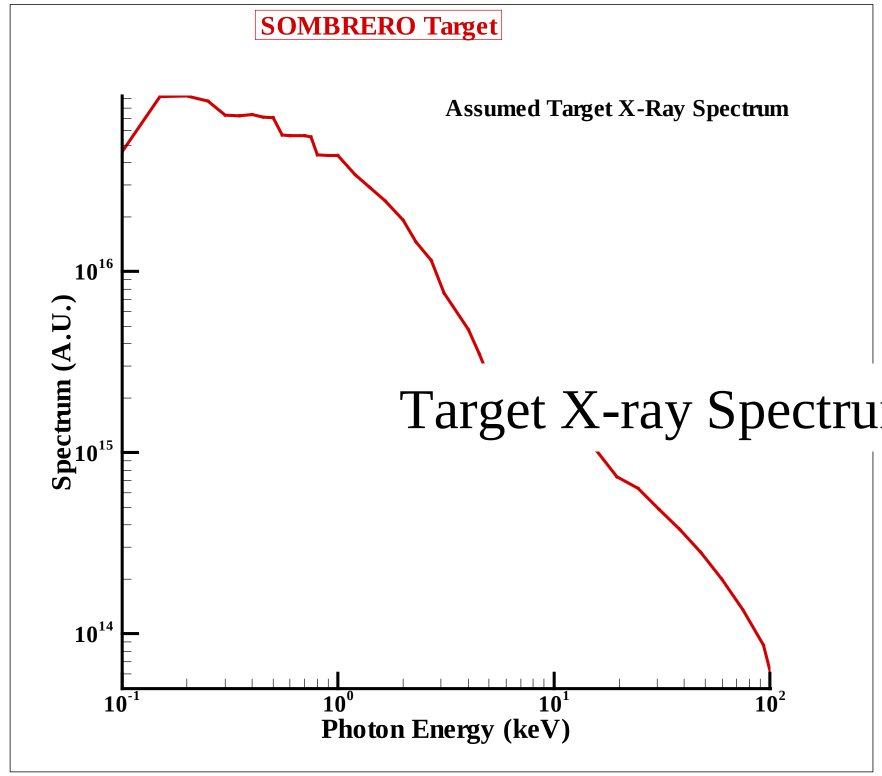
317 MJ per shot

=59.7 J/cm^2 on SOMBRERO Wall

X-Rays

22.41 MJ per shot

=4.22 J/cm^2 on SOMBRERO Wall

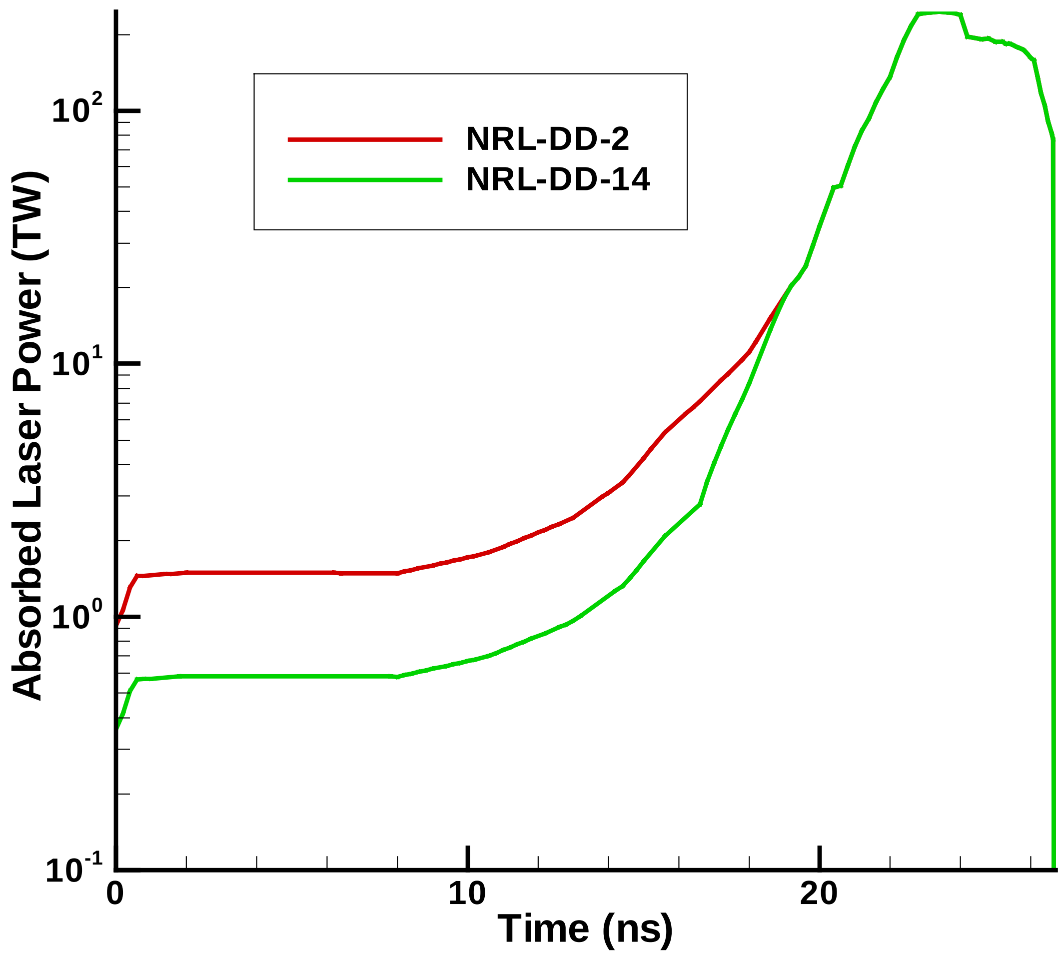


Z Experiments in Progress (6/15-6/21)

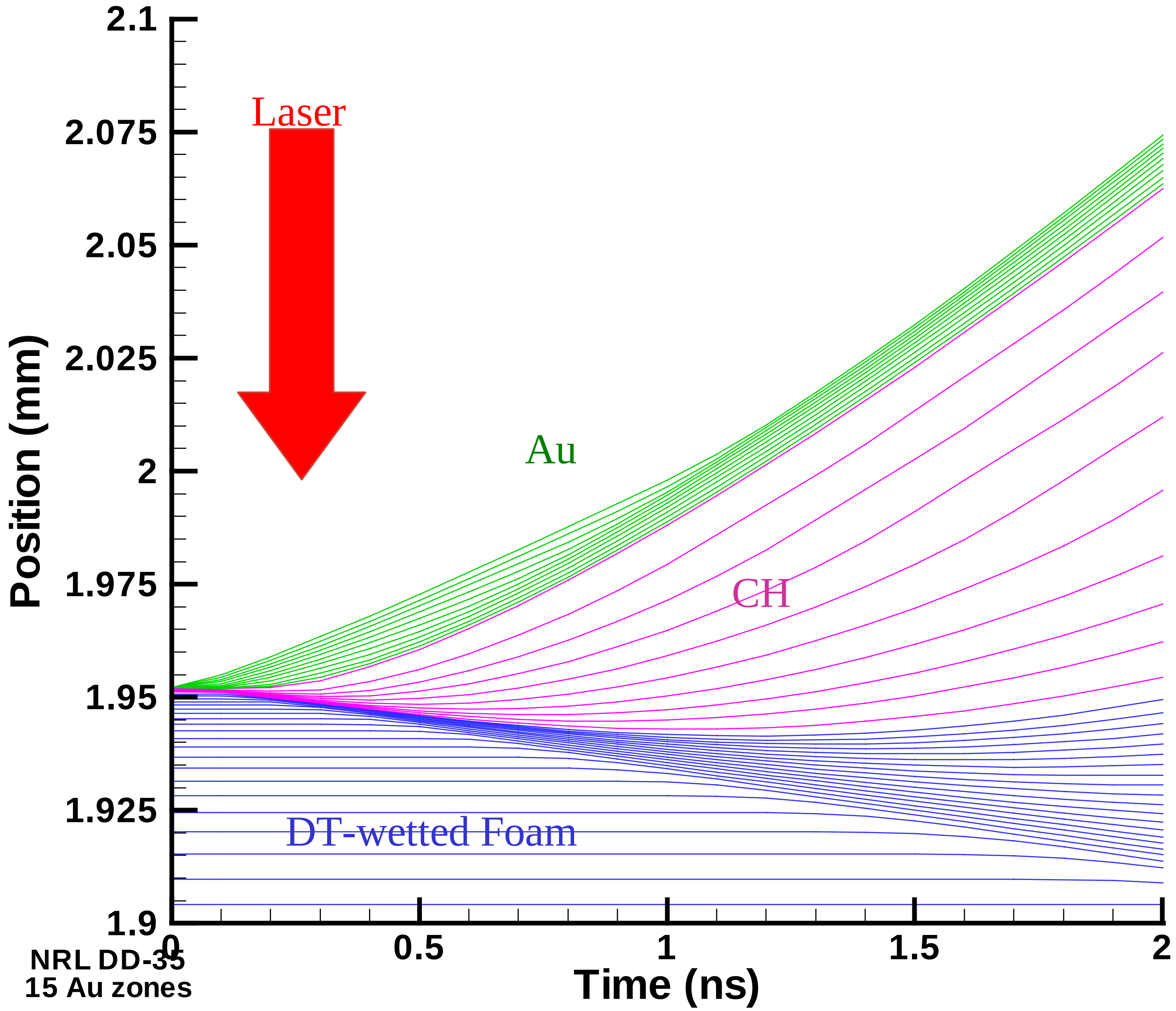
Explosion of a thin plastic foil with Z-pinch x-rays (to simulate the explosion of an ablator) and a measurement of ion energies

Bucky Target Implosion and Burn Calculations used to Study Target Output

- Bucky does not have zooming or detailed LPI, so laser deposition will not agree with codes that do: need to increase contrast between foot and main pulse.
- Laser deposition comes from Andy Schmitt's calculation.
- Pulse shape is then adjusted to get best implosion.
- Sensitivity of output spectra and partitioning to target yield is studied by adding energy to core.

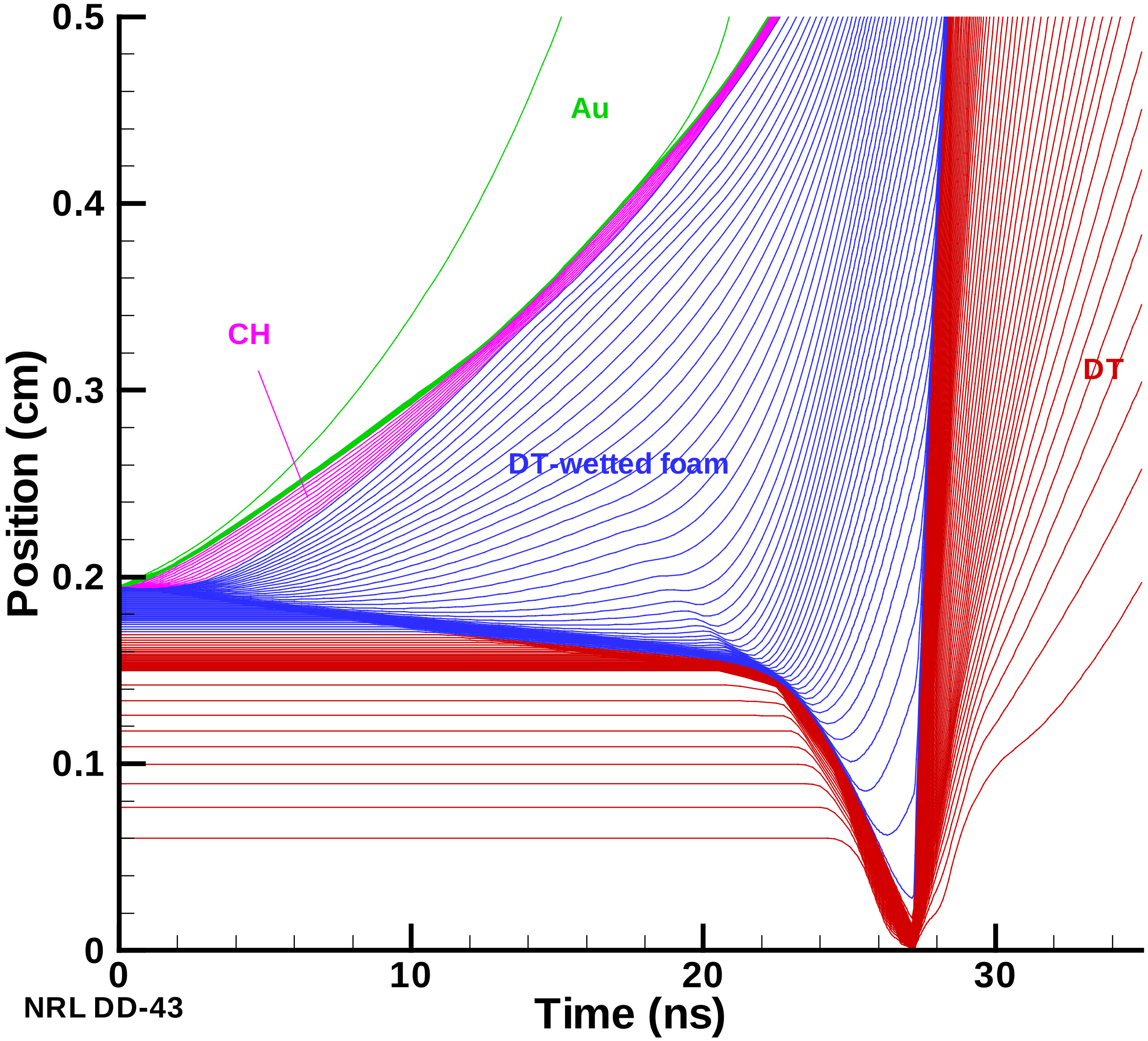


Laser Quickly Burns though 300 Å Au and 1 μ Plastic and Launches a Shock in DT-wetted Foam



With 1.4 Times Laser Pulse NRL-DD-14, Target Implodes and Ignites at 27.3 ns, giving 115 MJ of Yield

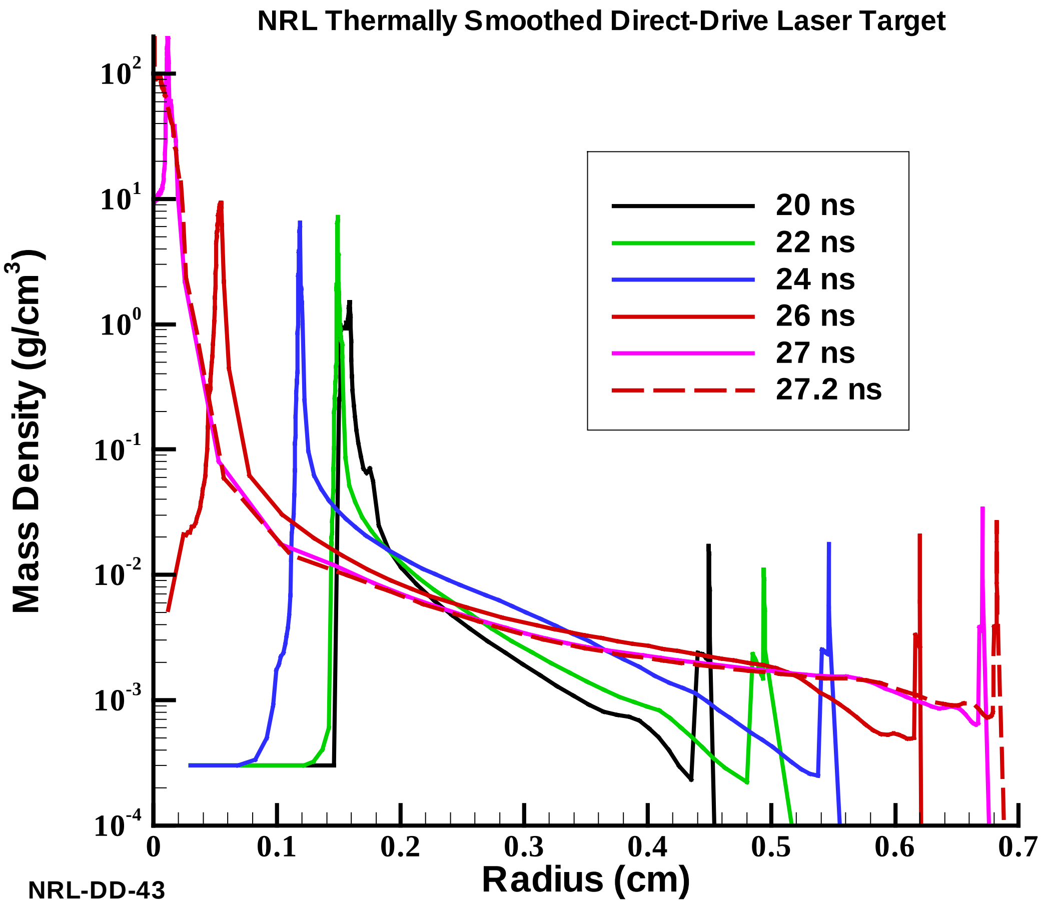
- 22% of DT ice is burned; NRL and LLNL get about 32 %, though peak ρR (LLNL) and bang time (NRL) do agree.
- BUCKY does not have zooming, so we’ve had to re-design laser pulse shape.
- Very little DT in wetted foam is burned.
- BUCKY burn fraction would be improved with further tuning.
- Target expands at a few x 10^8 cm/s and radiates.

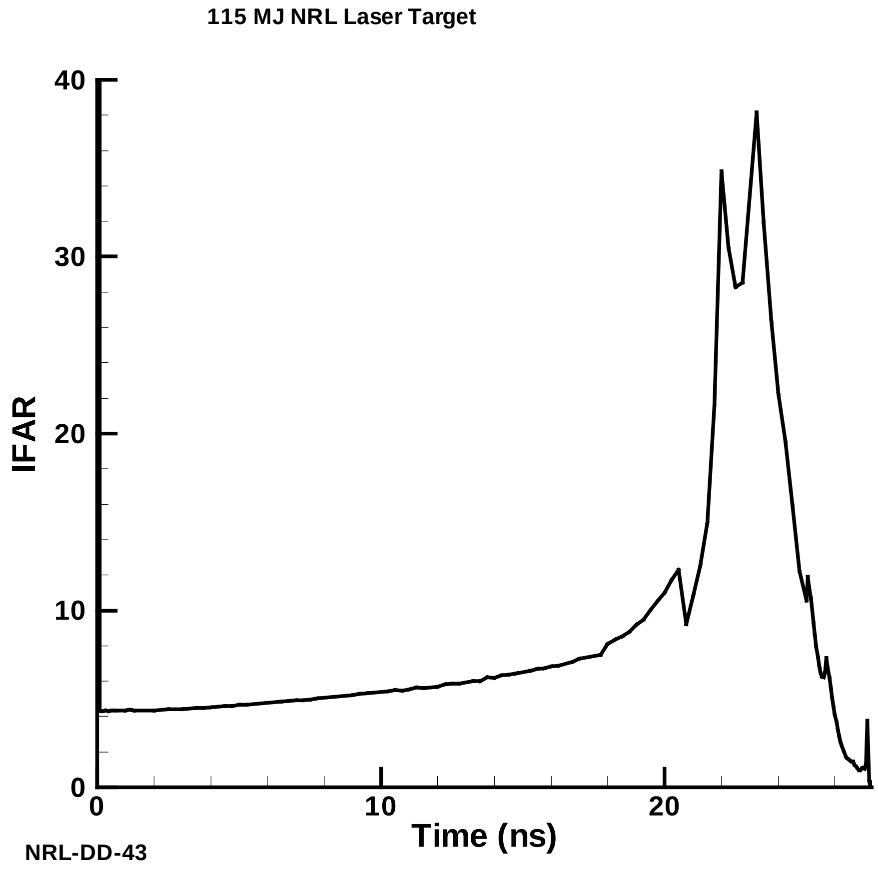


Implosion Keeps In-Flight Aspect Ratio Less than 40; Convergence Ratio is About 9

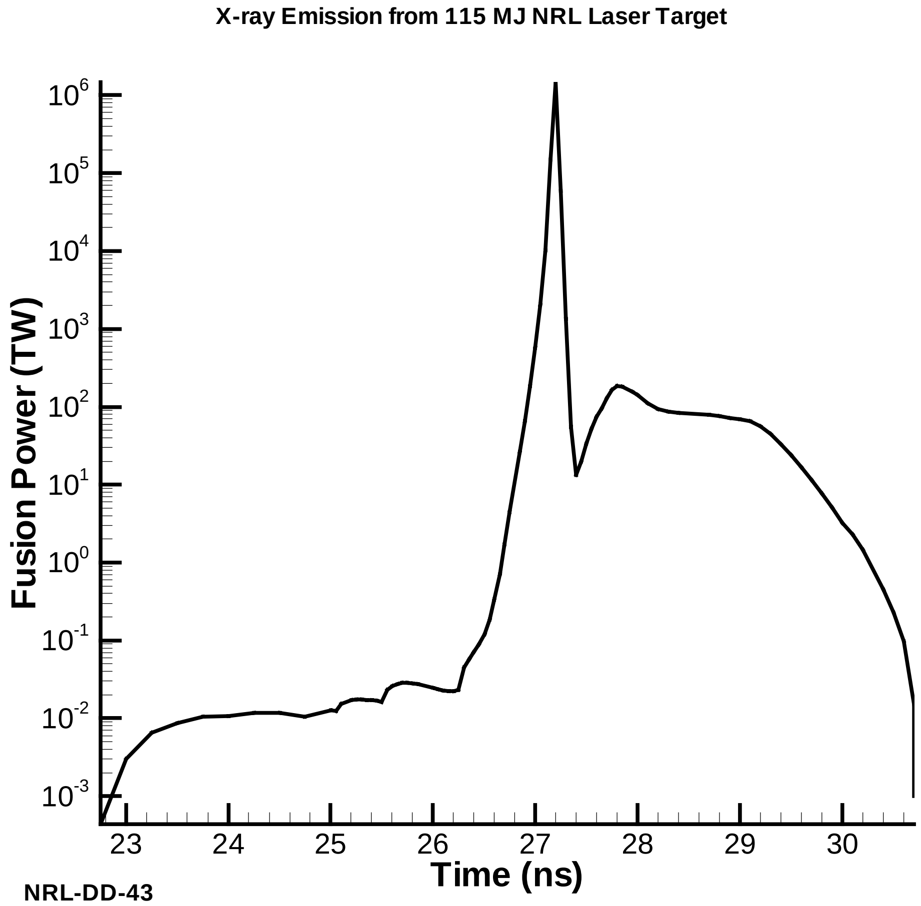
Convergence Ratio = $R_{fuel-initial}/R_{fuel-final}$

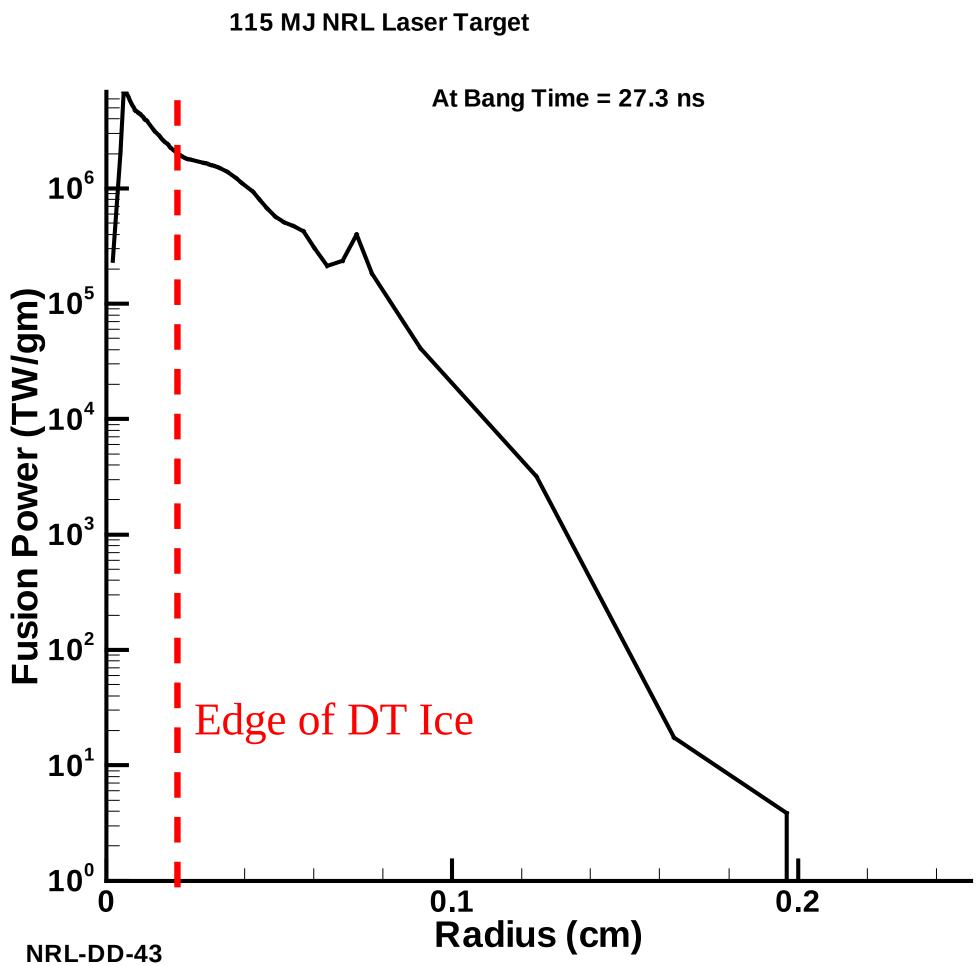
IFAR = $R(t)/\Delta R$





Most of Burn is in Cryogenic DT Ice and Takes Place in < 50 ps

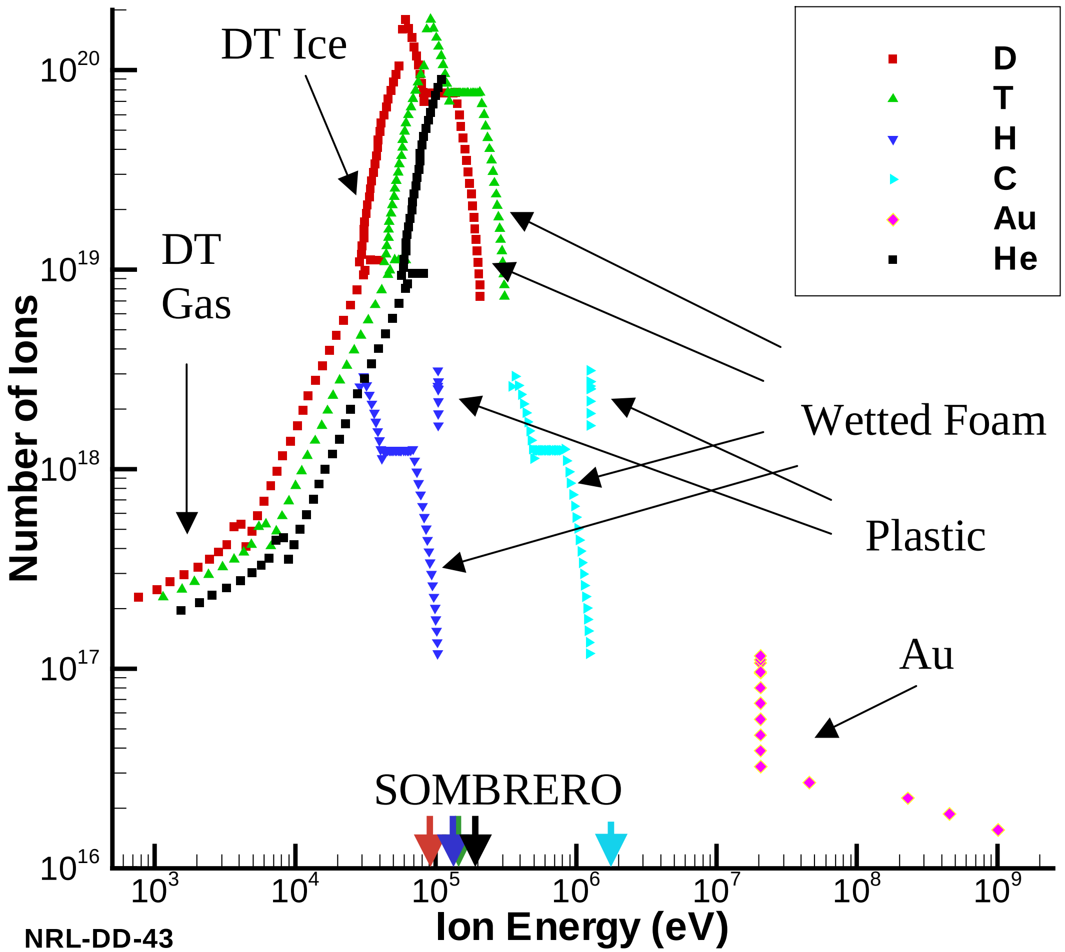




Ion Spectrum for UW Best Burn

- Ion Spectrum is calculated from the velocity of each zone in the final time step of the BUCKY.
- The particle energy of each species in each zone is then calculated as $mv^2/2$.
- 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 are not shown in the figure (their numbers are low).
- Regions of origin are shown.
- In chamber calculations, these ions are assumed to be launched over 10 ns from the center of the chamber.

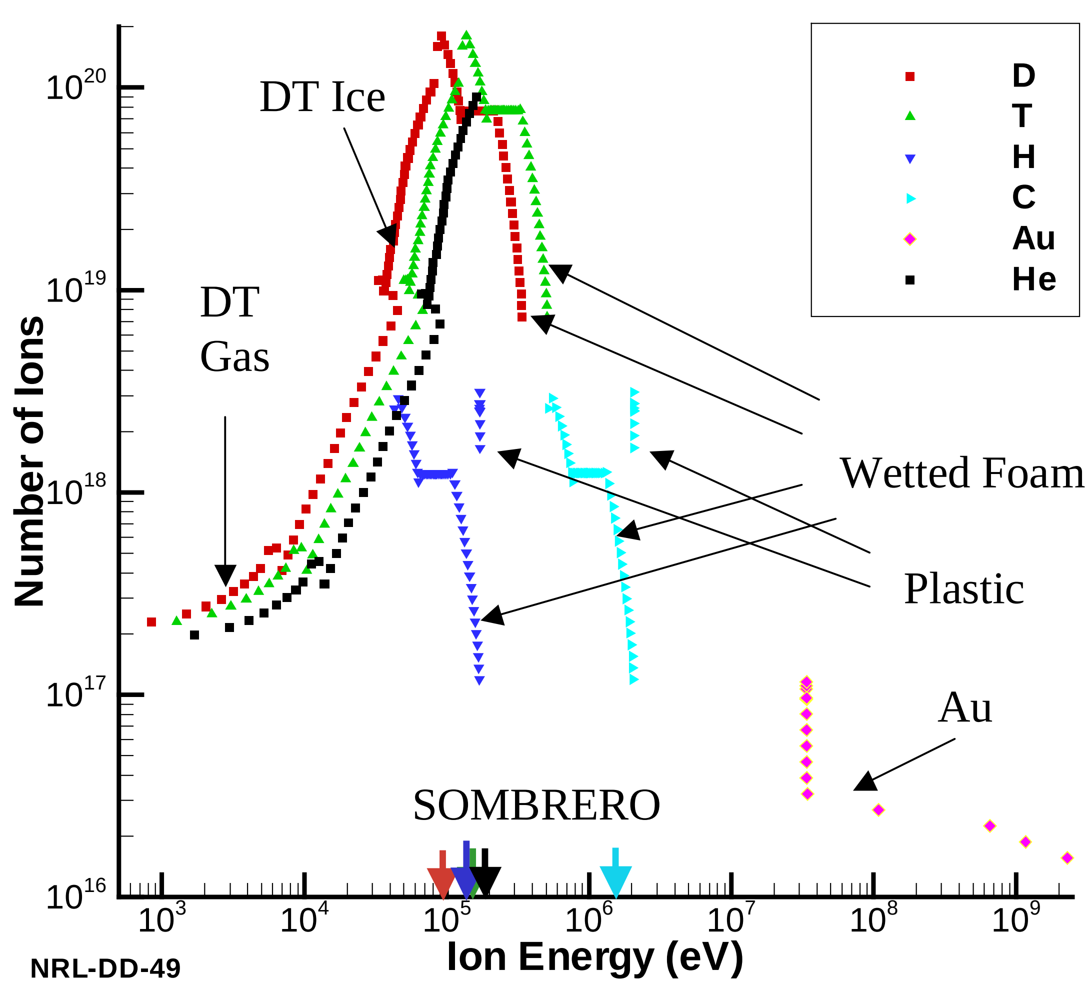
Ion Spectrum from 115 MJ NRL Laser Target



Ion Spectrum for UW Adjusted Burn

- Adjusted Burn has 140 MJ of burn plus an extra 20 MJ in the core plasma.
- Since 30% of the fusion yield leaves the target as non-neutronic, x-ray and ion spectra are equivalent to a 200 MJ yield.
- SOMBRERO ion energies (one energy for each species) are shown for reference.
- Naturally, ion energies are higher in adjusted burn case (i.e. Au is 50 % more energetic)
- Extremely high energies of a few Au ions do not agree with LLNL calculations (molecular flow?).

Ion Spectrum from 160 MJ NRL Laser Target



Gold Ions are at a Charge State Between 10 and 25; Other Ions are Full Stripped

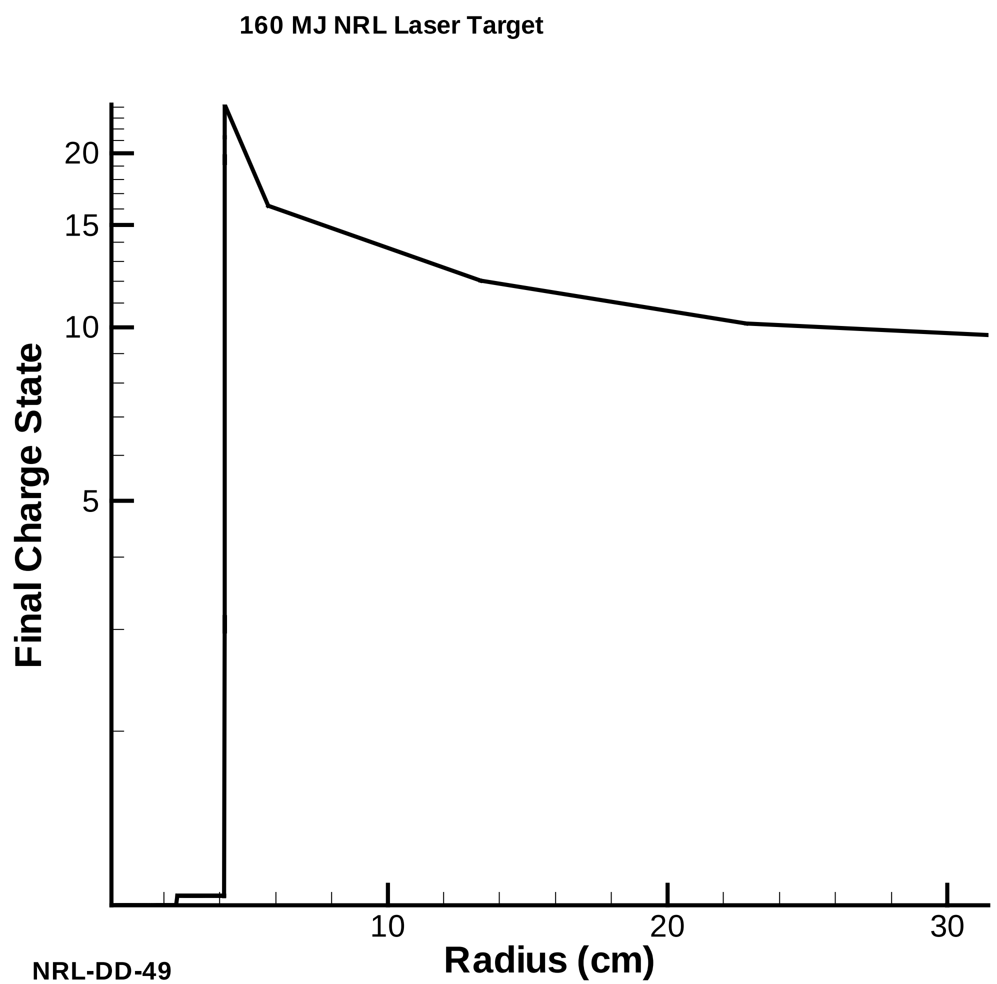
•Charge State of debris ions is important to deposition in Chamber Gas.

•At launch time (end of target explosion simulation), charge state is taken from data tables in temperature and density.

•The tables are calculated by the EOSOPA code in a Saha LTE method.

•The free electrons are assumed to move with the ions (quasi-neutrality).

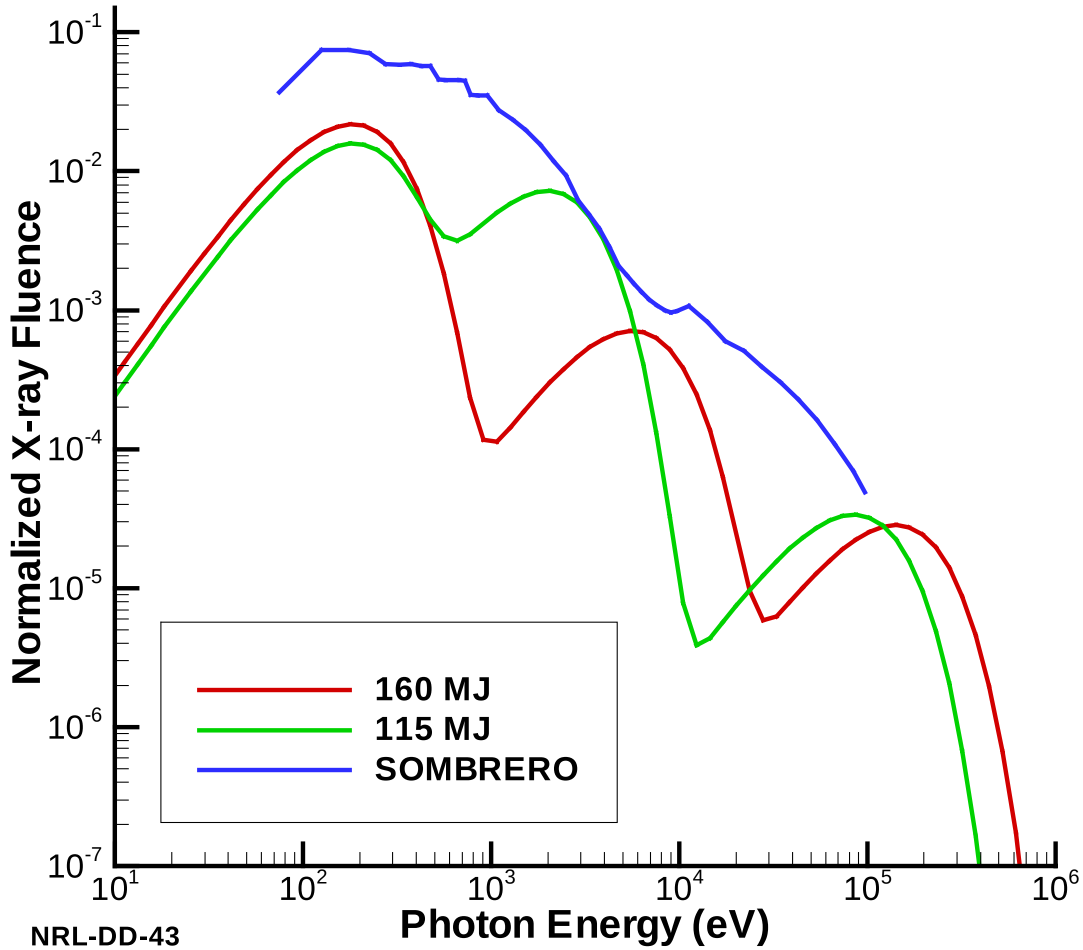
•When greatly expanded, the target remnants are probably in Coronal Equilibrium.



X-ray Spectra from Targets is Changed by High Z Components

- •X-ray spectra are converted to sums of 3 black-body spectra.
- •Time-dependant spectra are in Gaussian pulses with 1 ns half-widths and are used in chamber simulations.
- • Time-integrated fluences are shown for Best UW calculation, adjusted yield, and SOMBRERO.
- •The presence of Au in the NRL targets adds emission in spectral region above a few keV.
- •At higher yield the Au is more important.

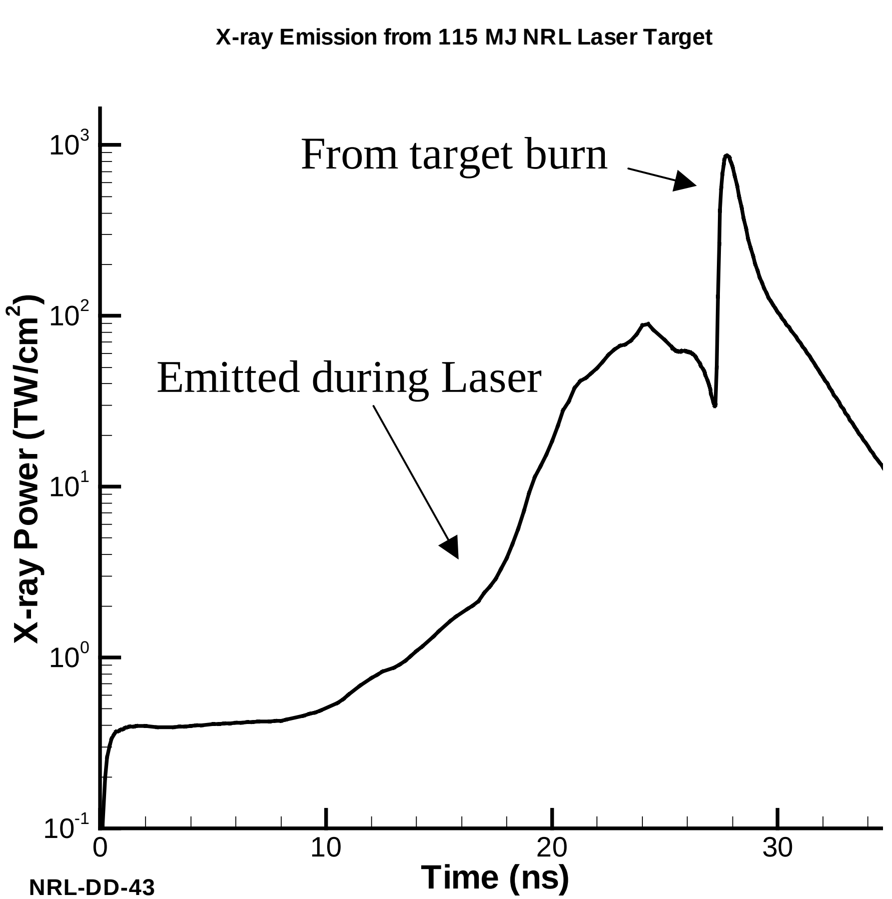
X-ray Spectrum from 115 MJ and 160 MJ NRL and SOMBRERO Laser Targets



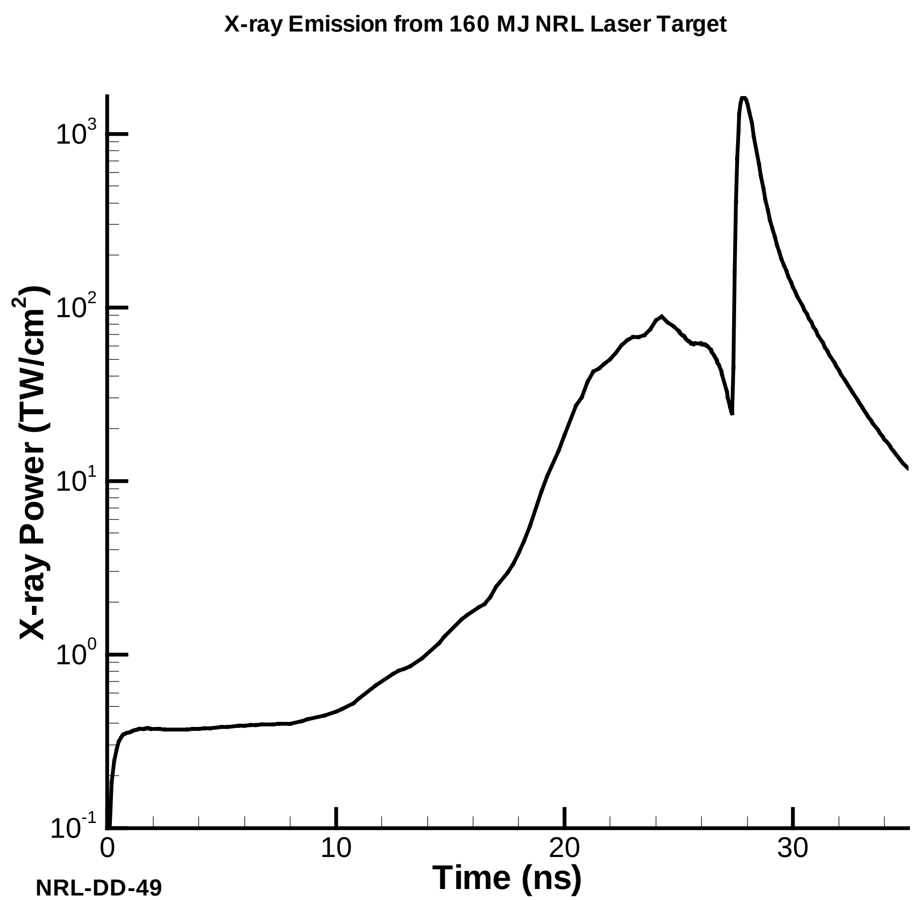
NRL-DD-43
NRL-DD-49

X-ray Power Emitted from Target is Mostly from Target Explosion in 1 ns Burst, but Laser History is Apparent

UW Best



Adjusted Yield



X-ray and Ion Debris Yield Partitioning Not A strong Function of Total Yield

	DD-43	DD-49
Laser Energy (MJ)	1.6	1.6
Fusion Yield (MJ)	115.7	139.7
Added Energy (MJ)	0	20
X-Ray Yield (MJ)	1.66 (8%)	2.33 (7.3%)
Debris Yield (MJ)	19.0 (92%)	29.7 (92.7%)
Total Non-Neutronic Yield (MJ)	20.66	32.0