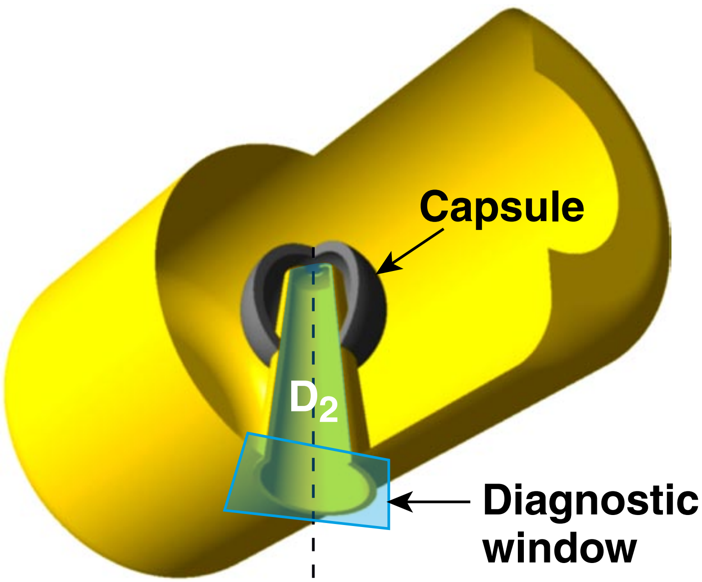
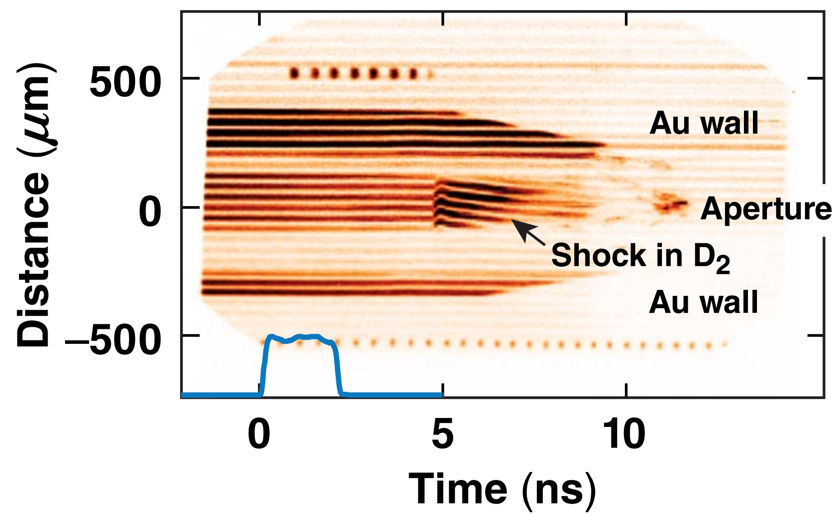
Demonstration of Shock-Timing Techniques for Ignition Targets

NIF Shock Timing Target



VISAR-2 shot 48881



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50th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Dallas, TX
17–21 November 2008

Summary

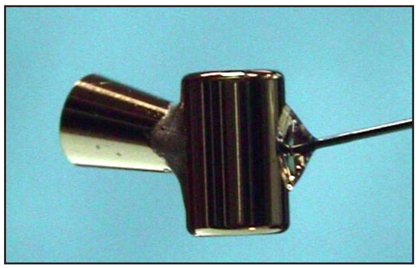
OMEGA experiments have demonstrated the technique for timing shock waves on the NIF

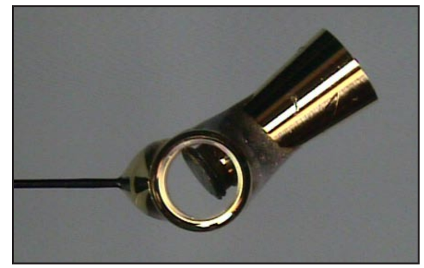
- Ignition targets use a precisely timed sequence of shocks to condition the capsule.
- These will be timed to ±50 ps using optical diagnostics in surrogate targets.
- Various issues associated with this technique were studied and resolved with OMEGA experiments.

Cryogenic hohlraum and direct-drive target experiments show this technique meets NIF requirements.

Collaborators

The success of these experiments is the result of collaboration of four laboratories





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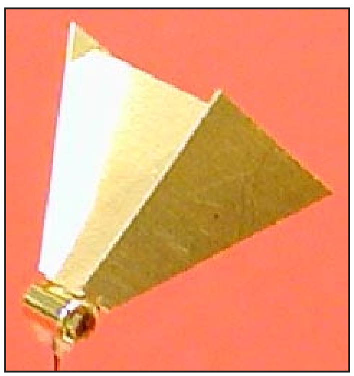

OMEGA Operations
OMEGA Target Fab
LLNL Shock Physics
SNL Target Fab
GA Target Fab

E16214a

Motivation

Ignition targets use precisely timed multiple shocks to approximate an isentropic compression

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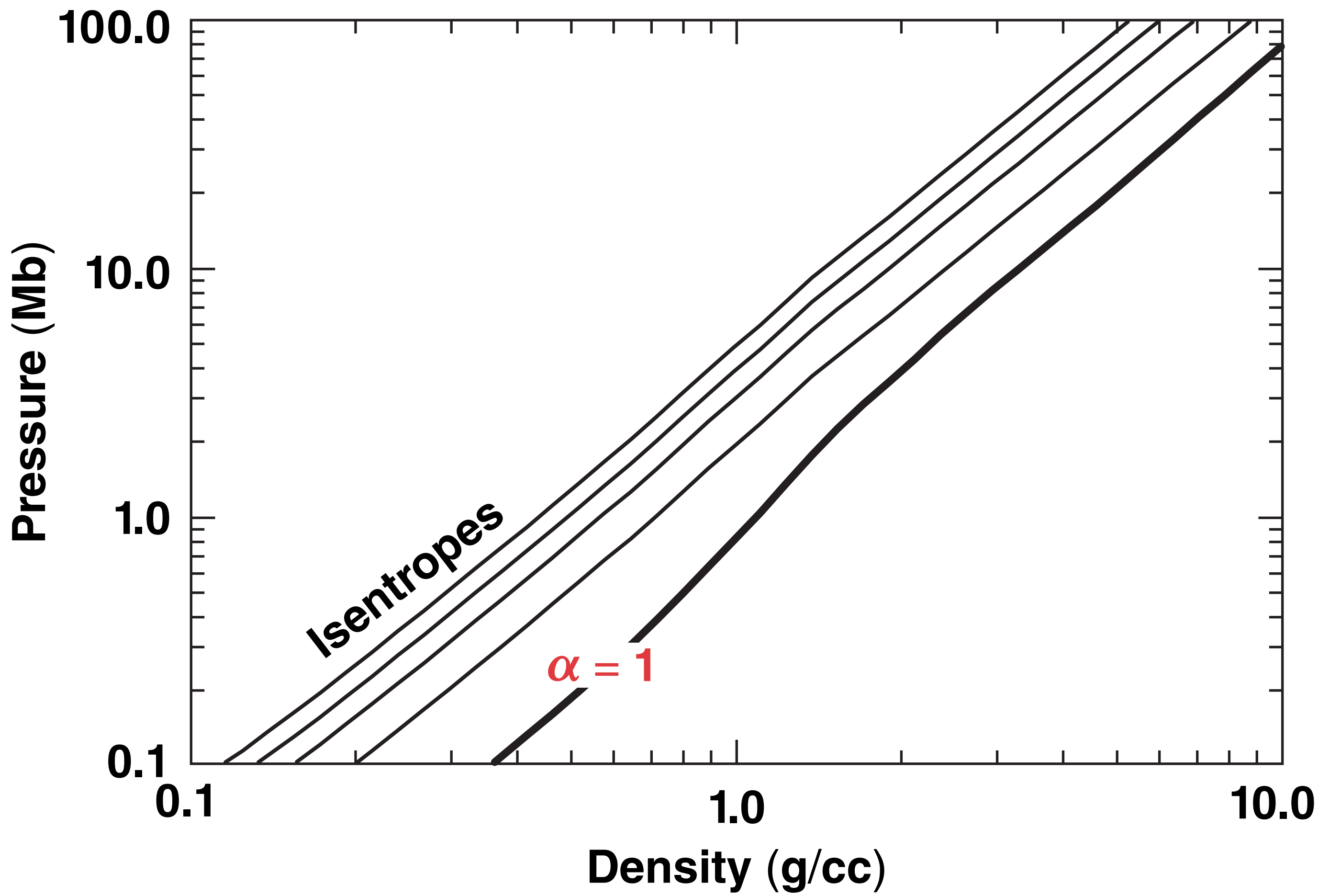
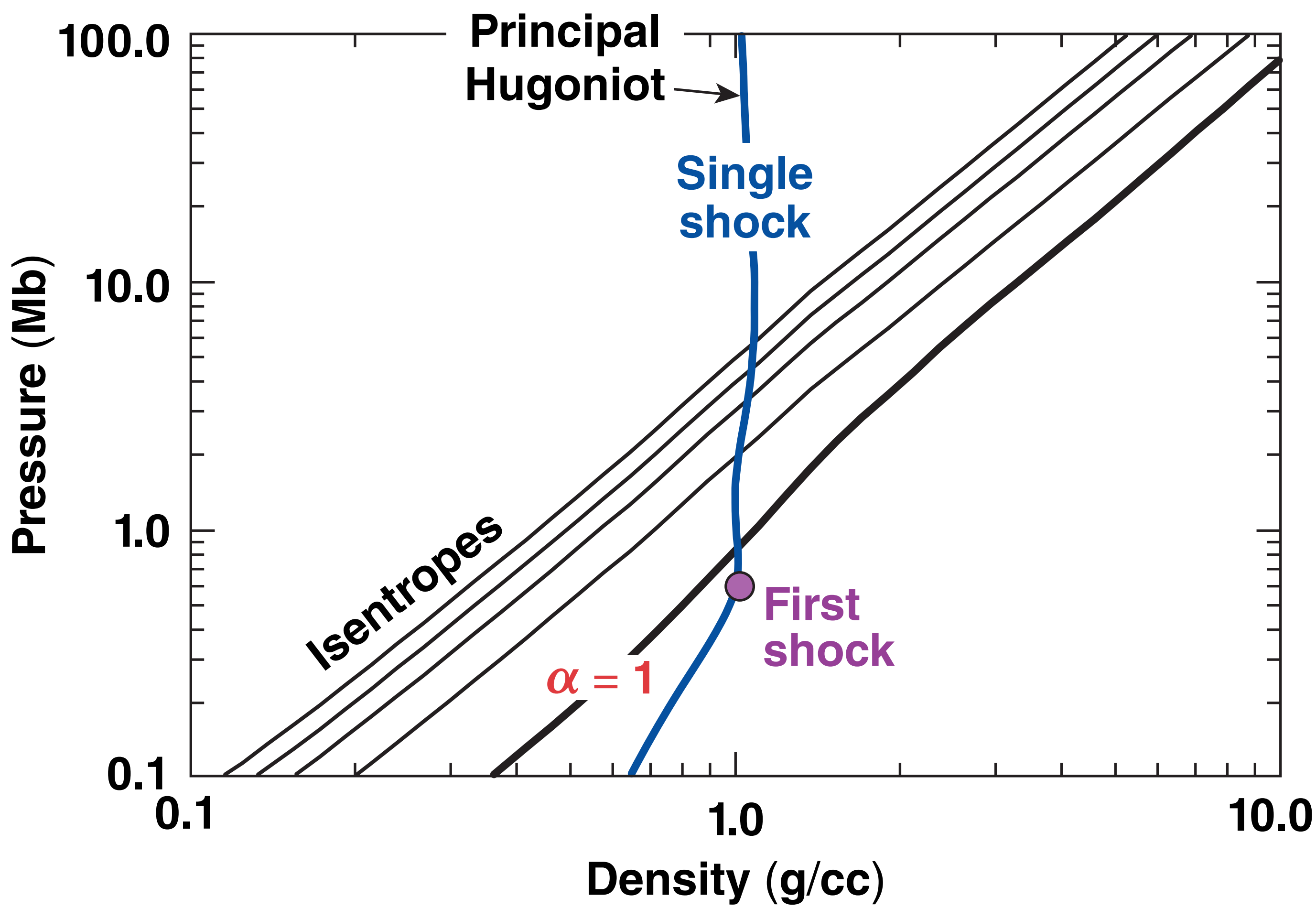


E17298

Motivation

Ignition targets use precisely timed multiple shocks to approximate an isentropic compression



E17298

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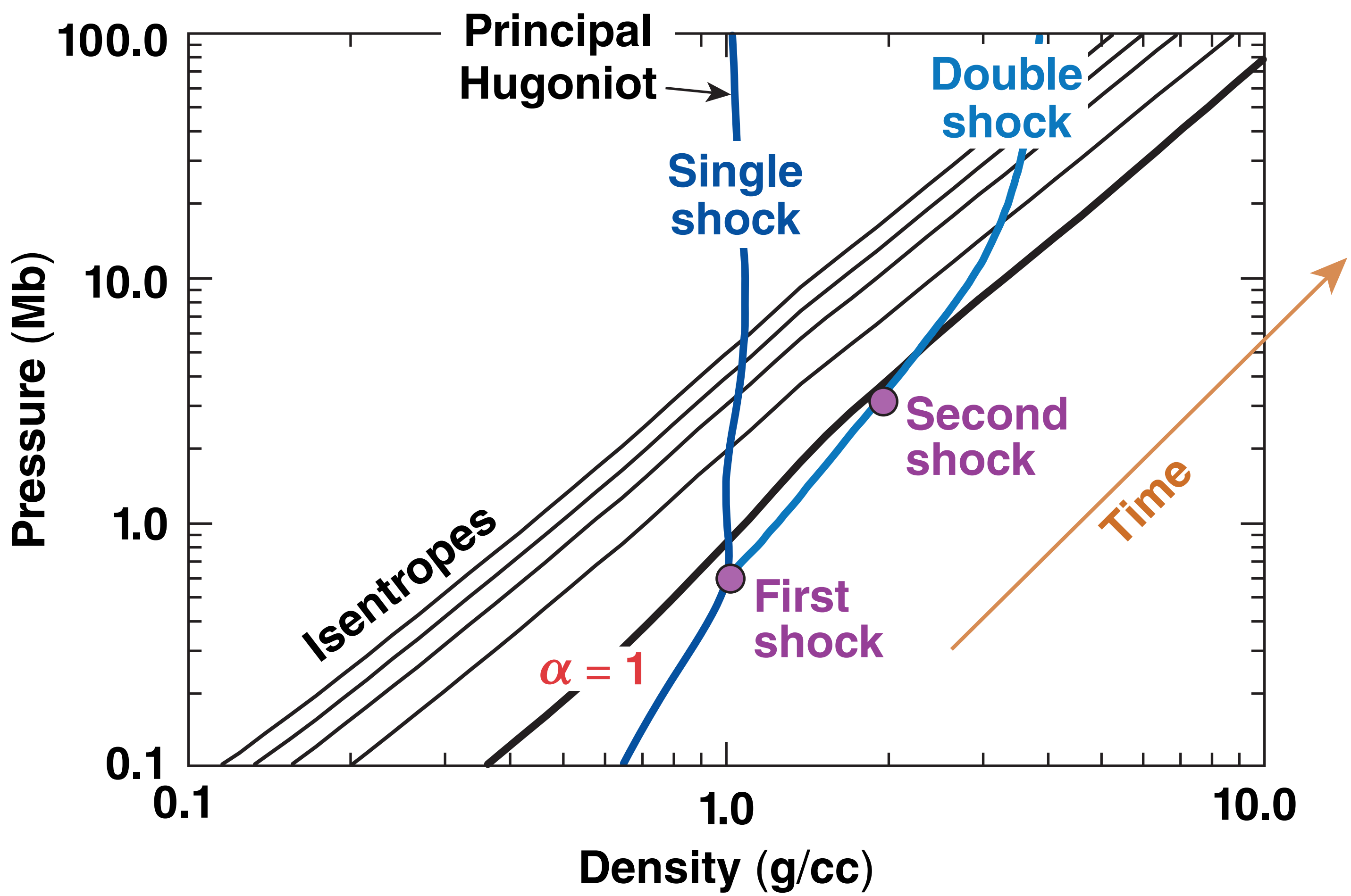

E17298

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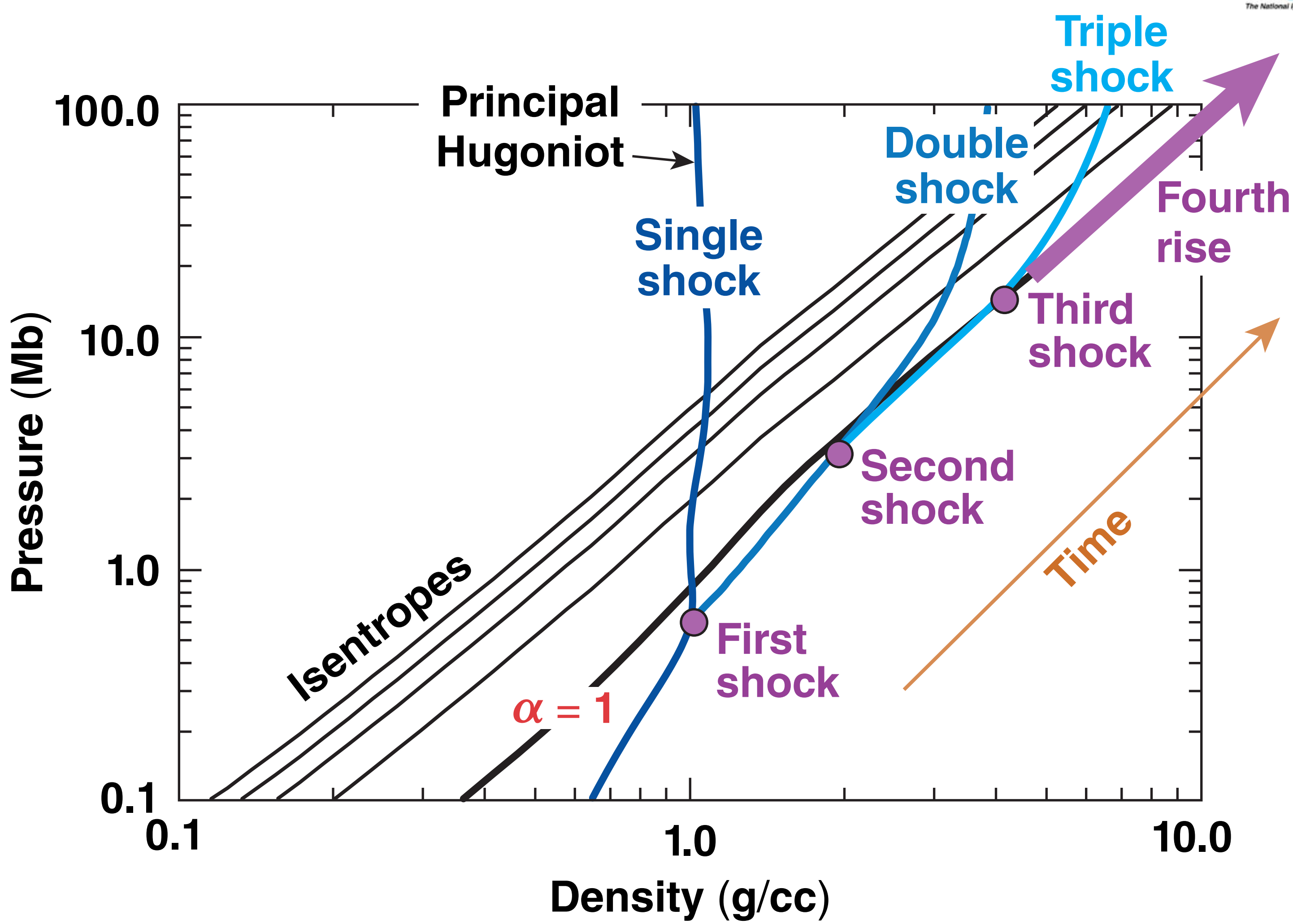

E17298

Motivation

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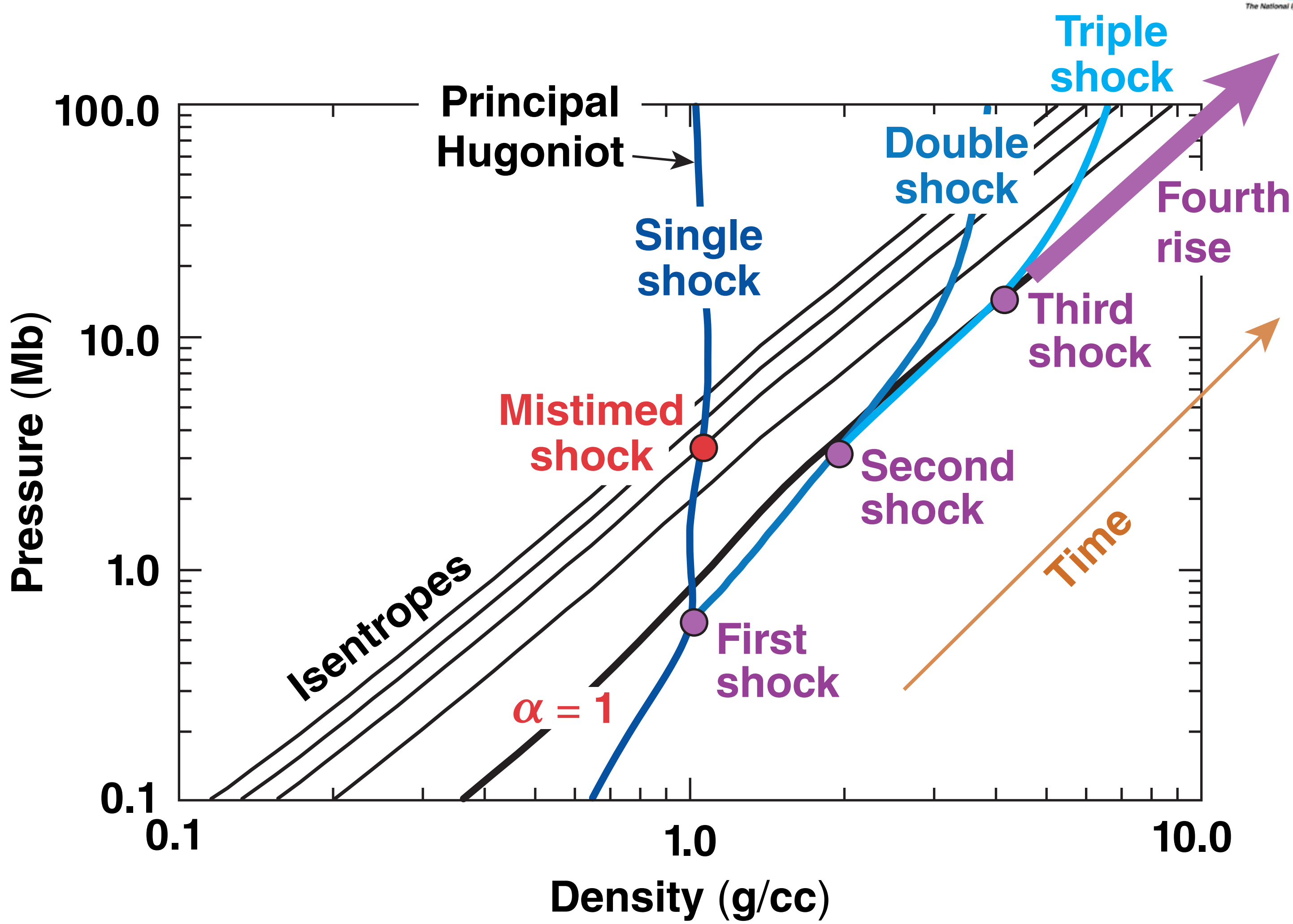

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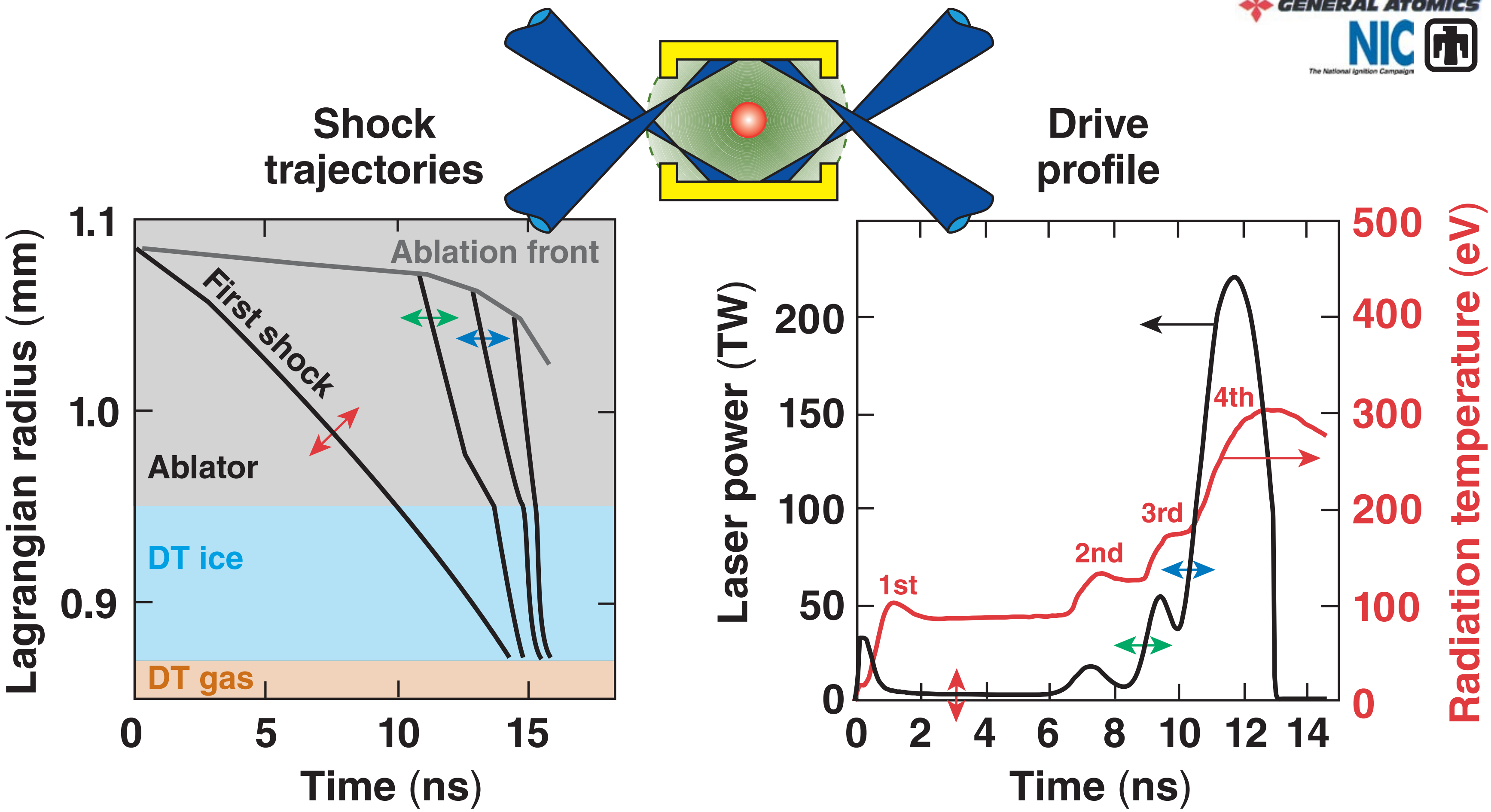
Approach

Tuning experiments will adjust the drive to produce optimal timing: a tight sequence of shock arrivals



- First three shocks ±50 ps
- Fourth shock ±100 ps

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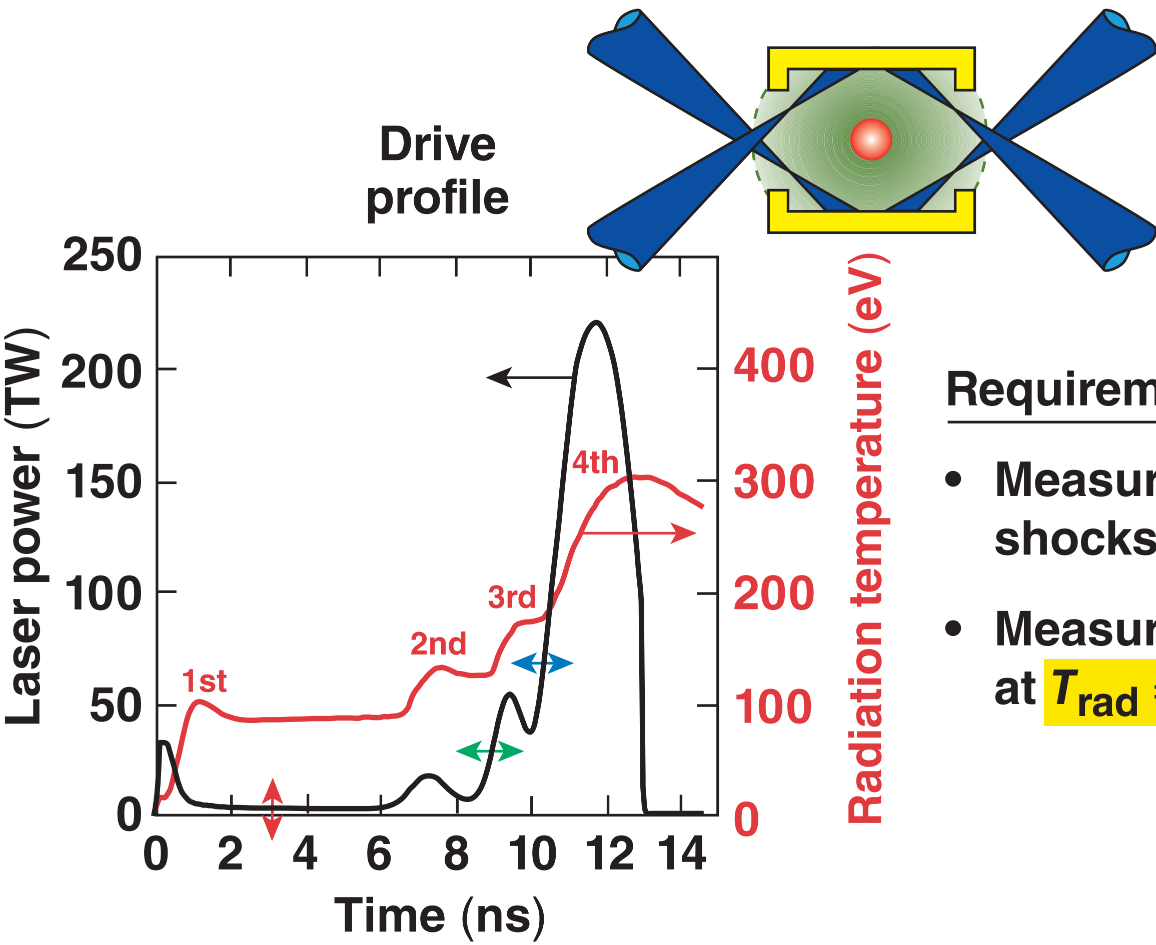
Requirements

Tuning experiments will adjust the drive to produce optimal timing: a tight sequence of shock arrivals



Requirements

- Measure velocity and timing of shocks 1 to 3 at T_{rad} = 165 eV
- Measure timing of fourth rise at T_{rad} = 250 eV

Meet these requirements with separate target types and campaigns.

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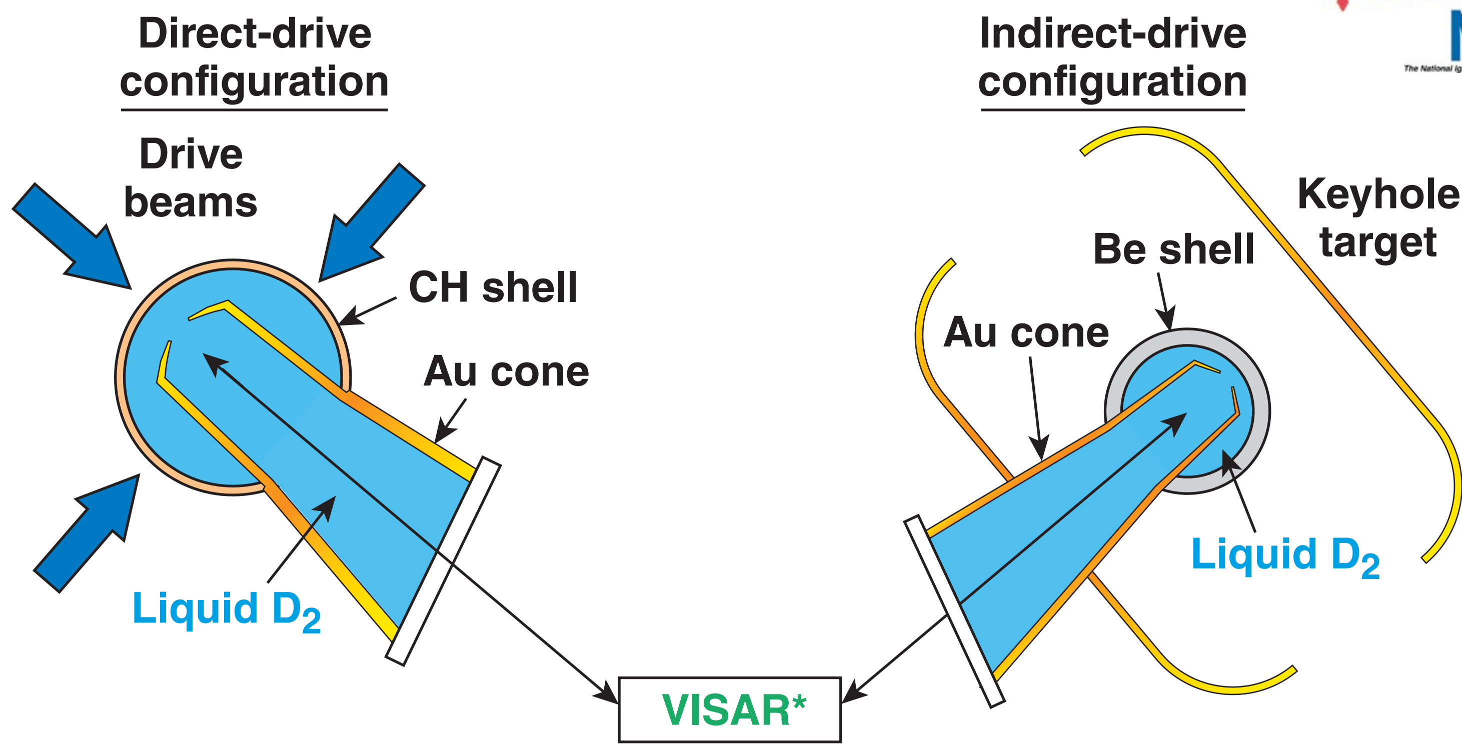
Surrogate Targets

Shock-timing measurements in direct- and indirect-drive targets use re-entrant cones



Capsules IET	FY09				FY10											
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
NIF tuning experiments																
Tuning of shock 1-3 timing (LLE, LLNL, SNL)					NIF	NIF			NIF				NIF			
	Experimental readiness review of shocks 1–3 timing					Qualify shocks 1–3 timing technique				Specify shocks 1–3 launch time and laser step strength for 1st ignition attempt						

E15221c

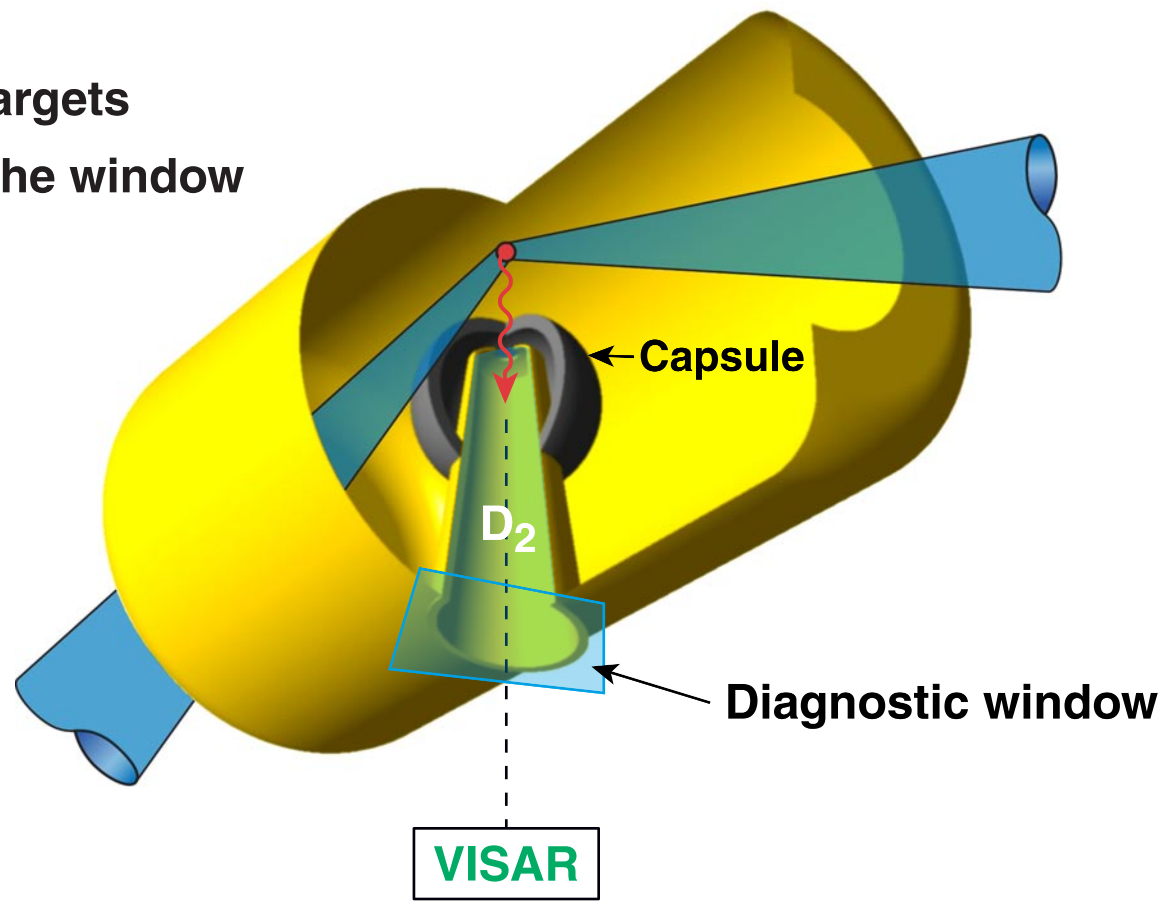
*Velocity Interferometer System for Any Reflector

Various issues were resolved to demonstrate the shock-timing technique for NIF

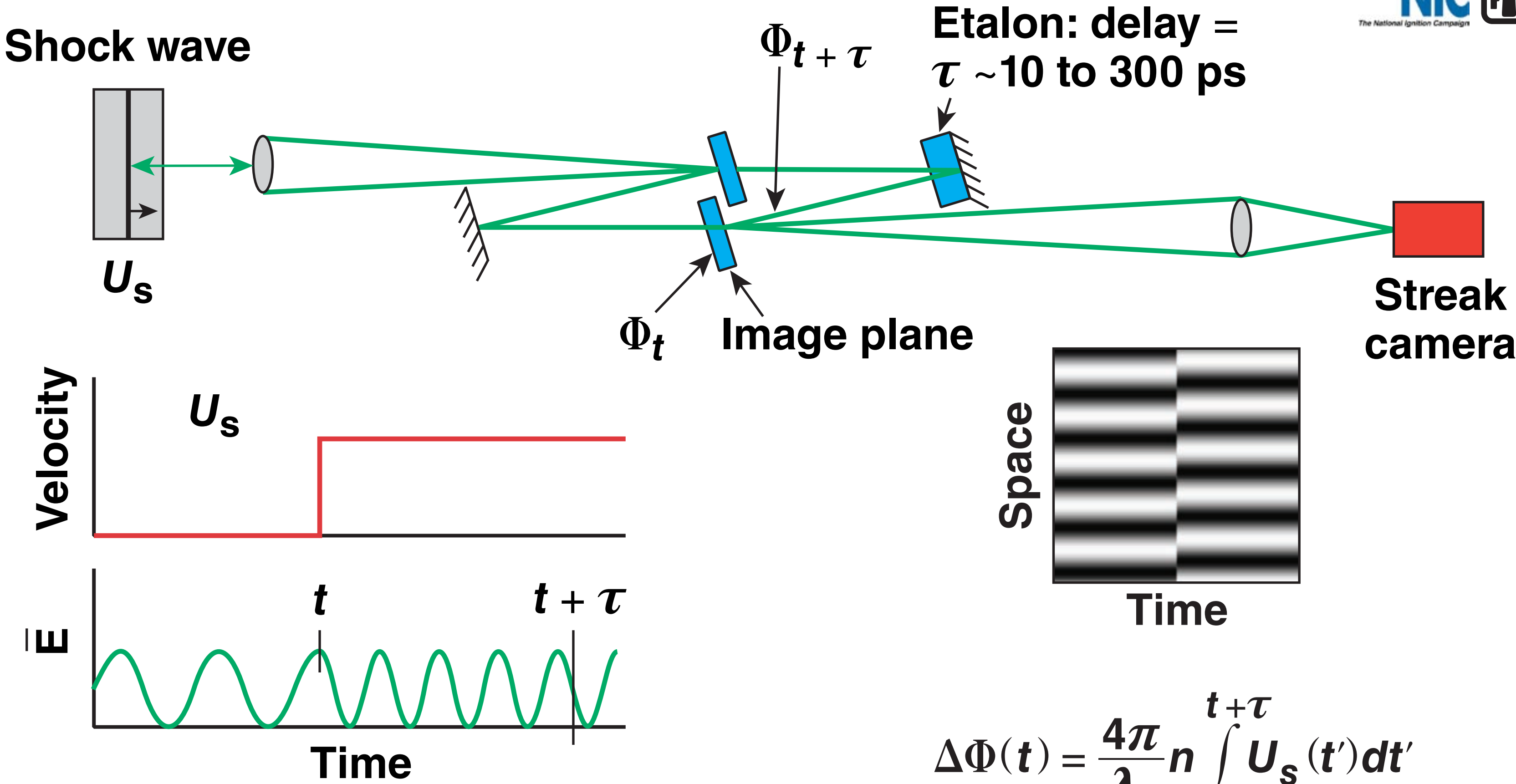
Hard x rays from laser spots can blank diagnostic window

Issues

- Surrogacy to ignition targets
- Ionization blanking of the window
- Secondary hohlraum
- Effect of D_2 column
- Convergence effects



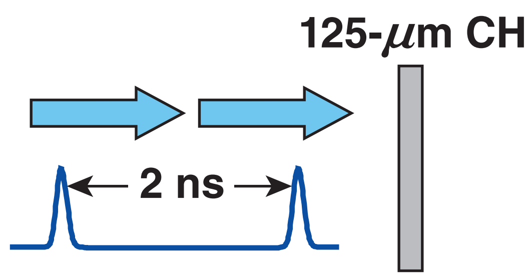
The velocity interferometer system for any reflector (VISAR) detects Doppler shifts to measure velocity

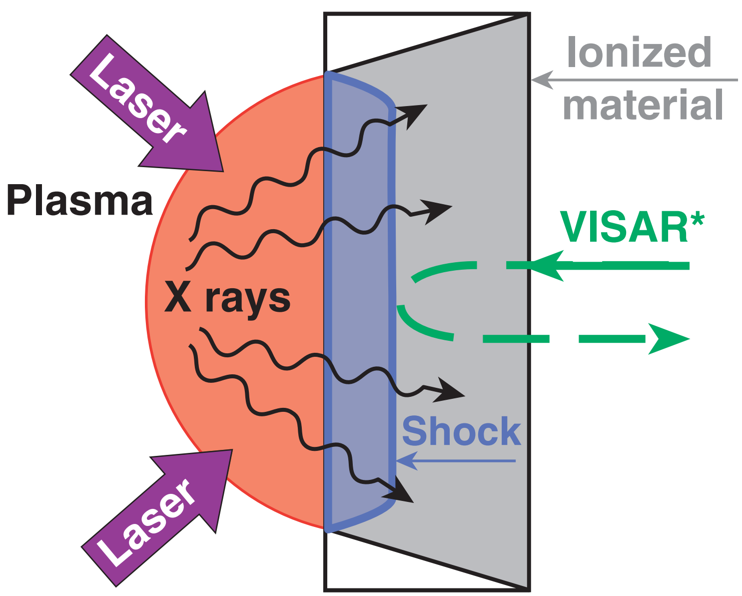


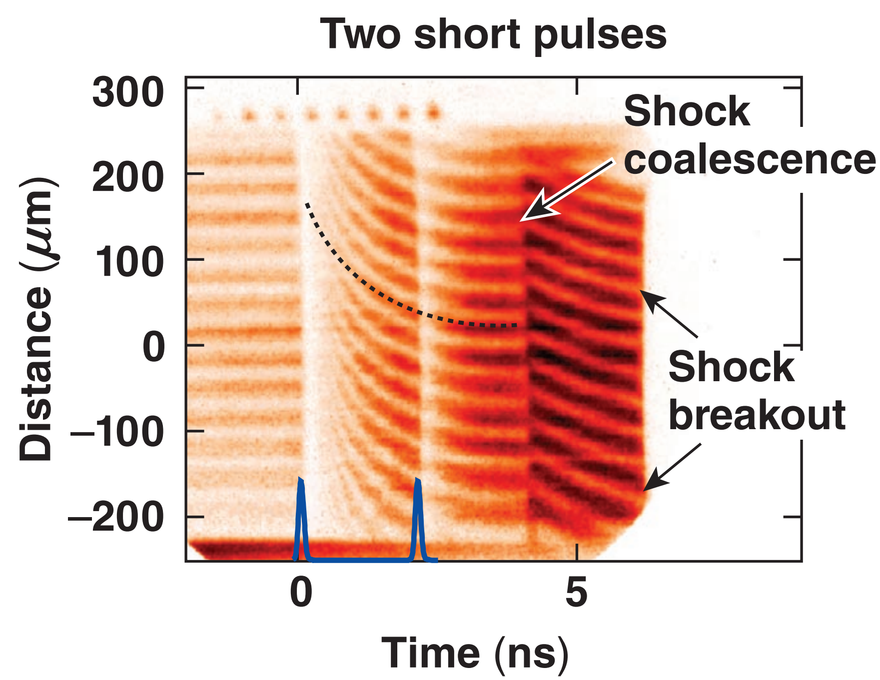
$$\Delta\Phi(t) = \frac{4\pi}{\lambda_0} n \int_t^{t+\tau} U_s(t')dt'$$

VISAR has time resolution <30 ps and a velocity precision of ~1%.

Shock velocities are readily measured in transparent targets but "blanking" can be a problem



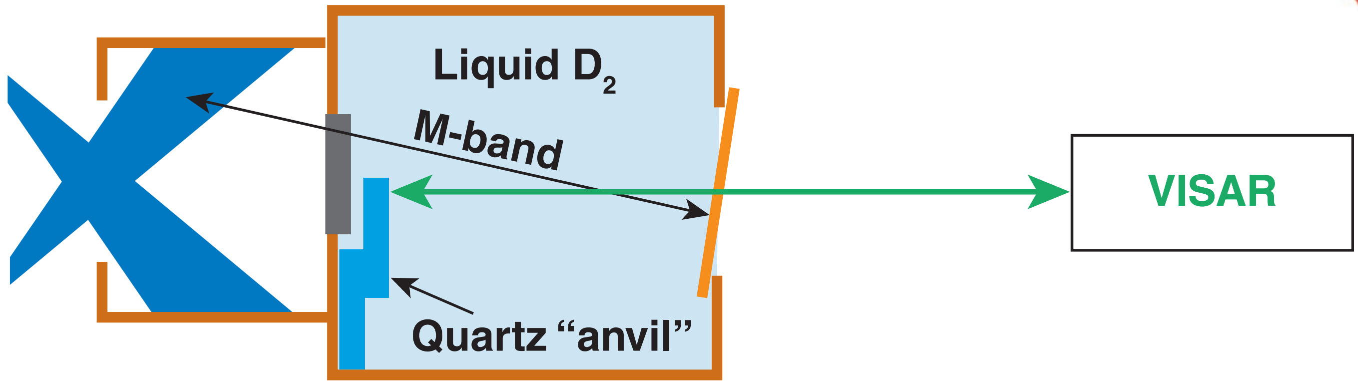


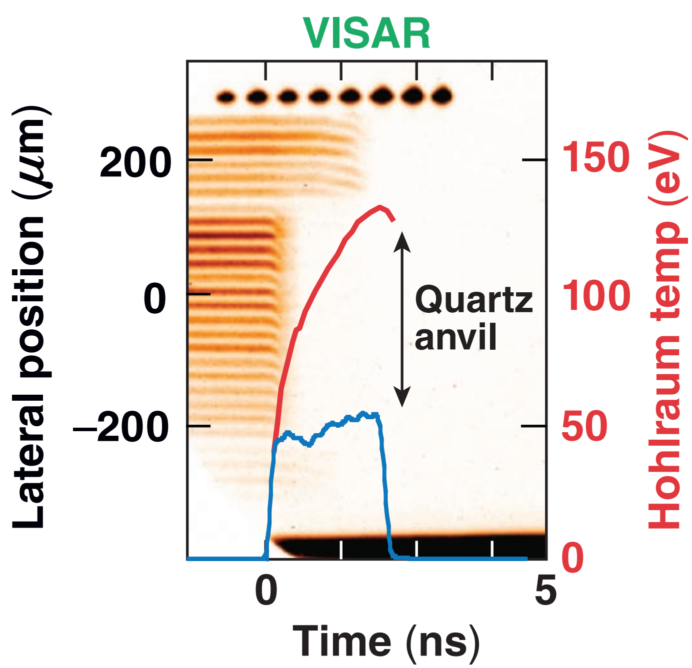


E15223c

*Velocity Interferometer System for Any Reflector

Halfraum experiments were used to select window material and optimize target design



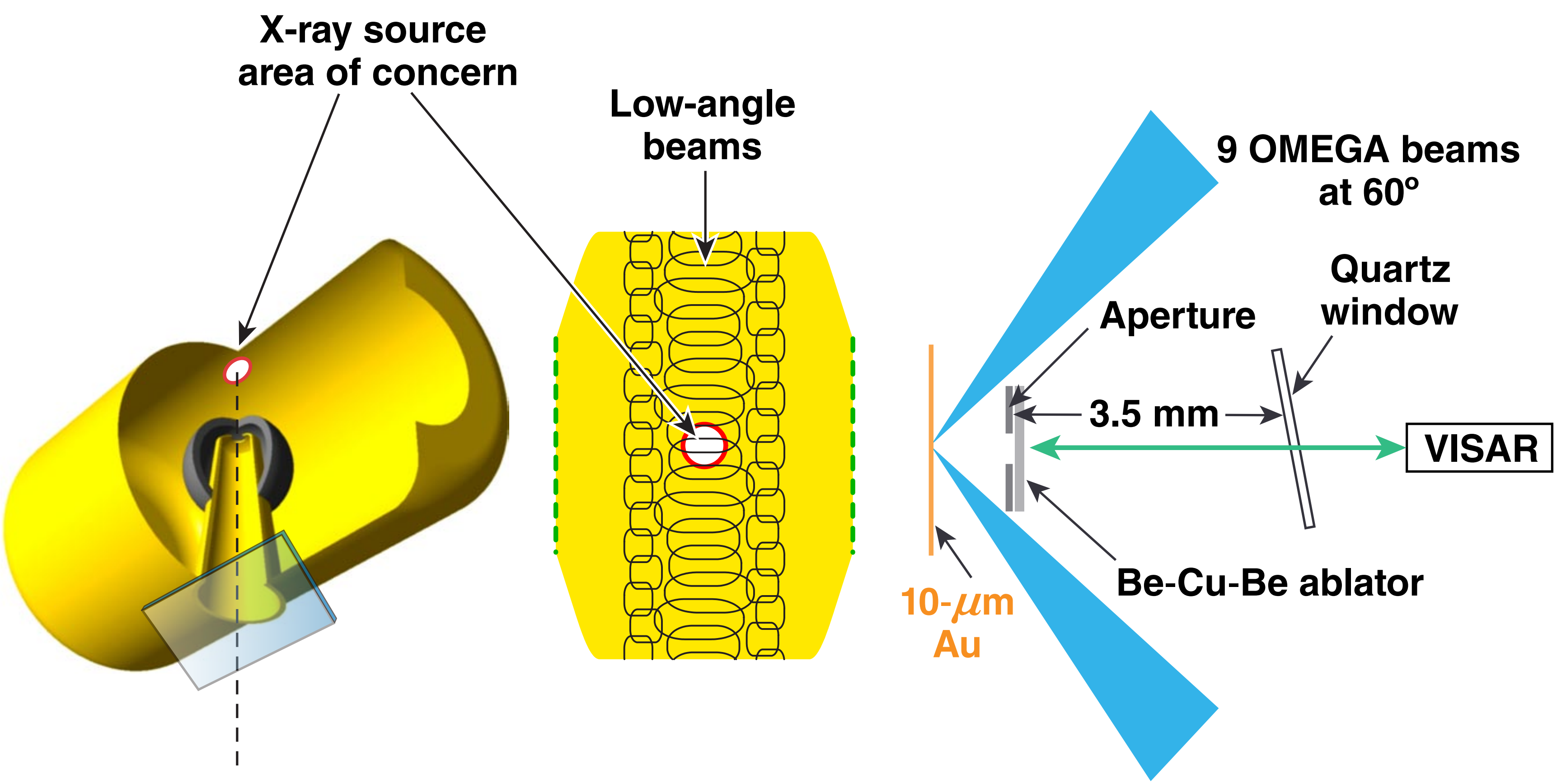


Developments

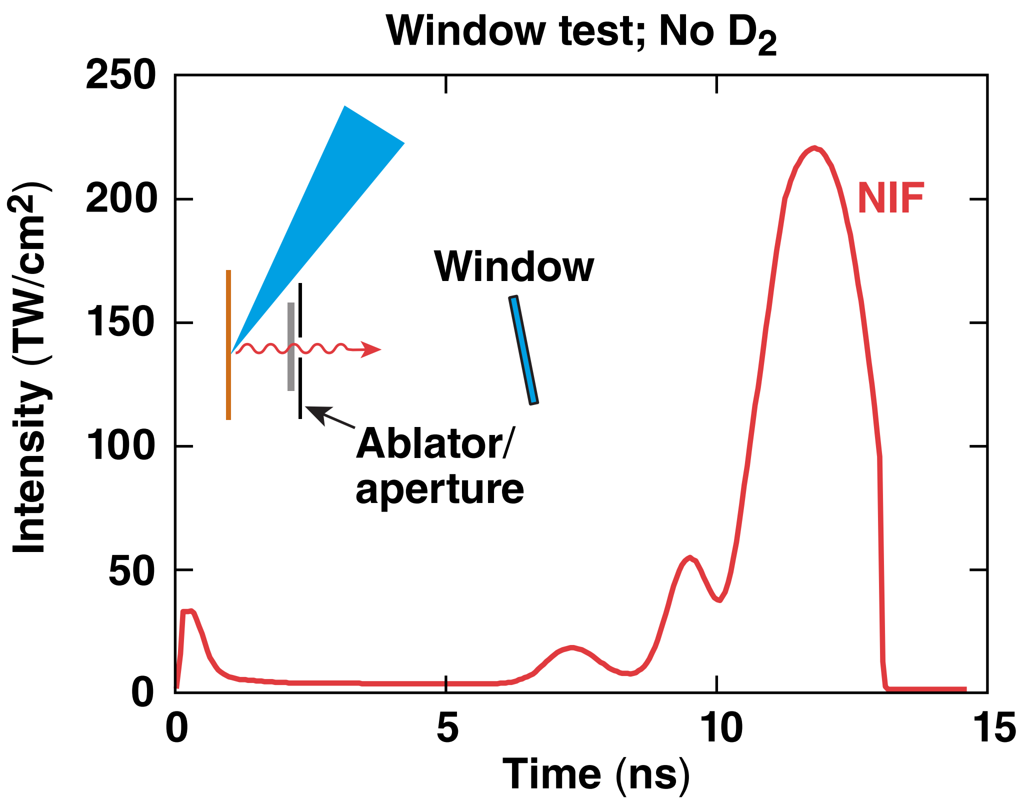
- Quartz windows
  - high band gap
  - optical quality
  - strong/resilient
- Pellicle as spatial fiducial
- Small aperture; large distance to window

E14173b

Open line-of-sight targets mimic the effect of NIF laser spots in keyhole targets



Stacked-pulse experiments show that neither instantaneous nor integrated flux is expected to be problematic



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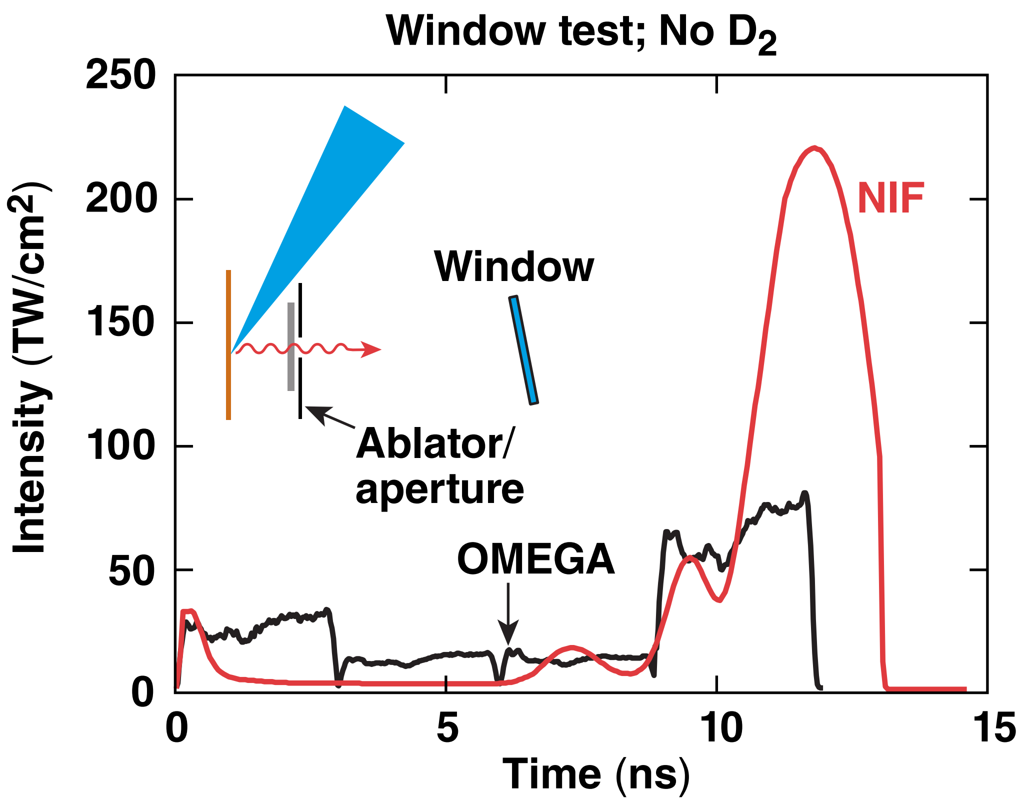
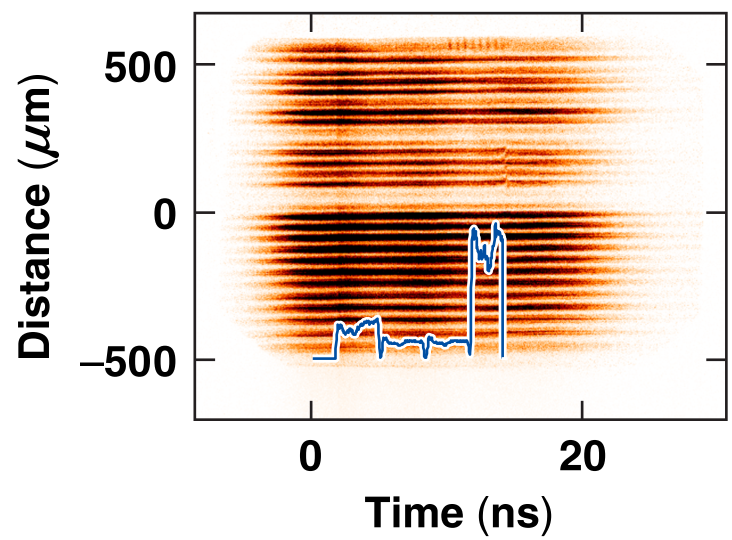
E15116c

Stacked-pulse experiments show that neither instantaneous nor integrated flux is expected to be problematic





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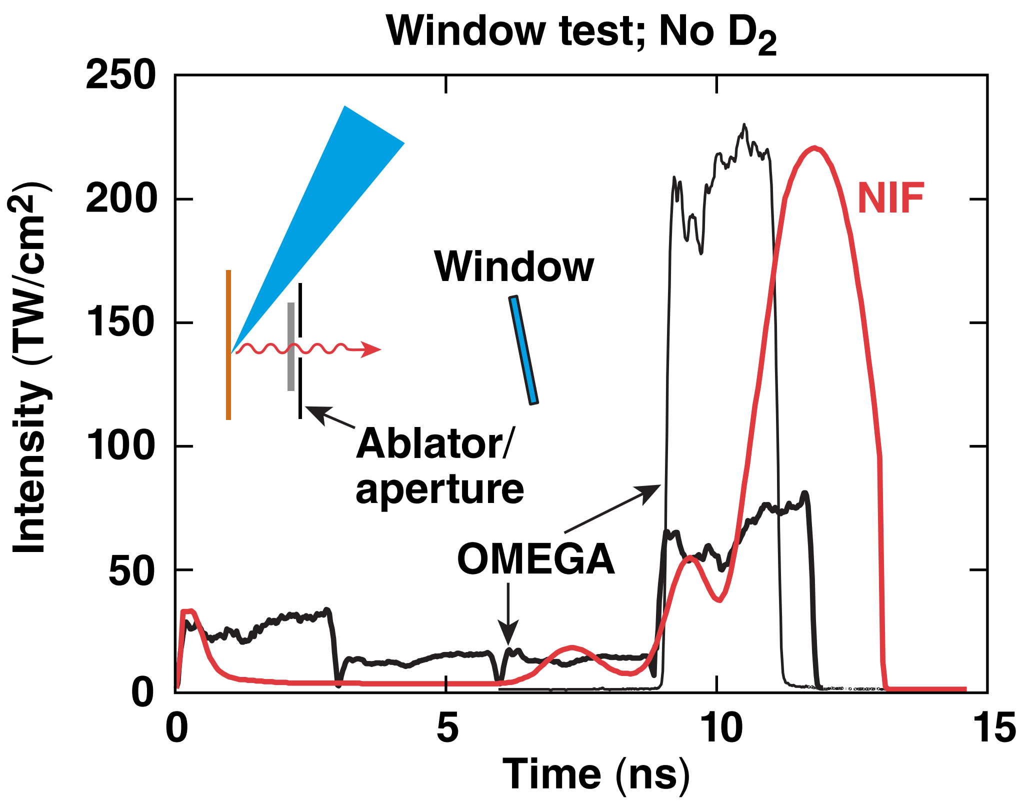

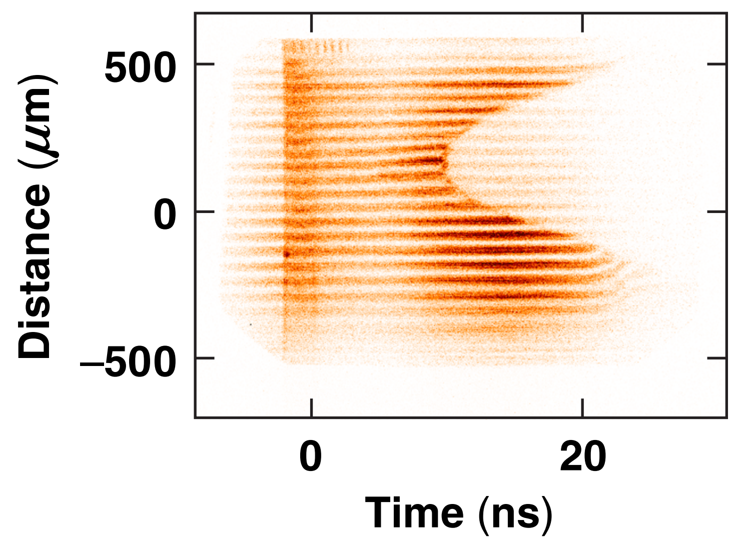

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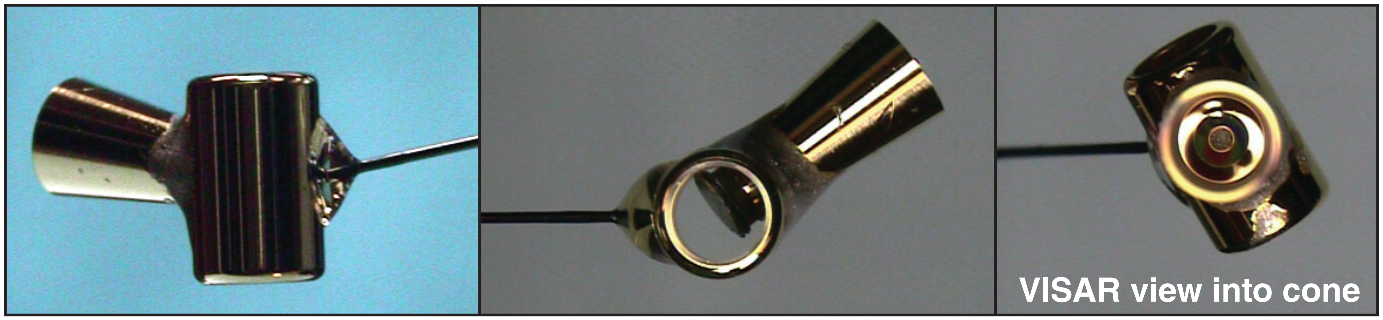
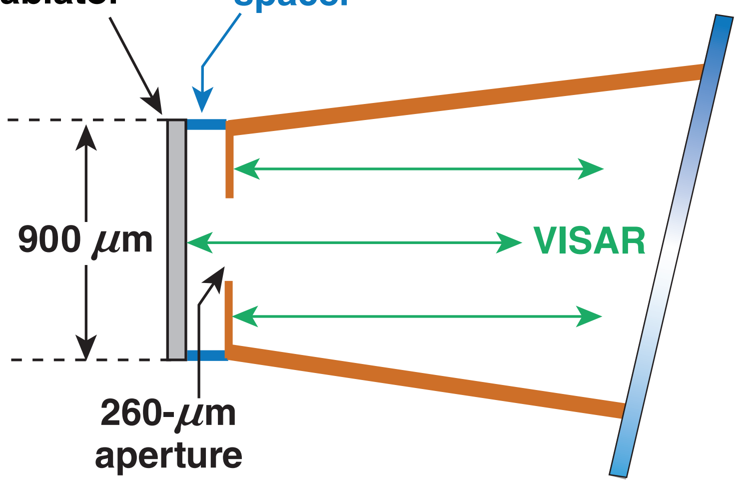
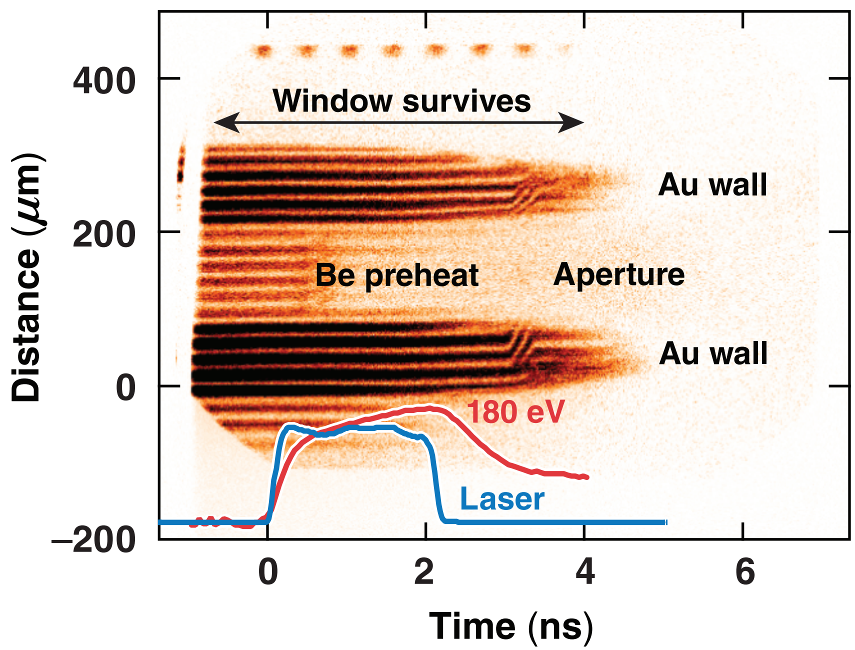
Warm hohlraum experiments with NIF-sized re-entrant cones demonstrate success at T_{rad} = 180 eV



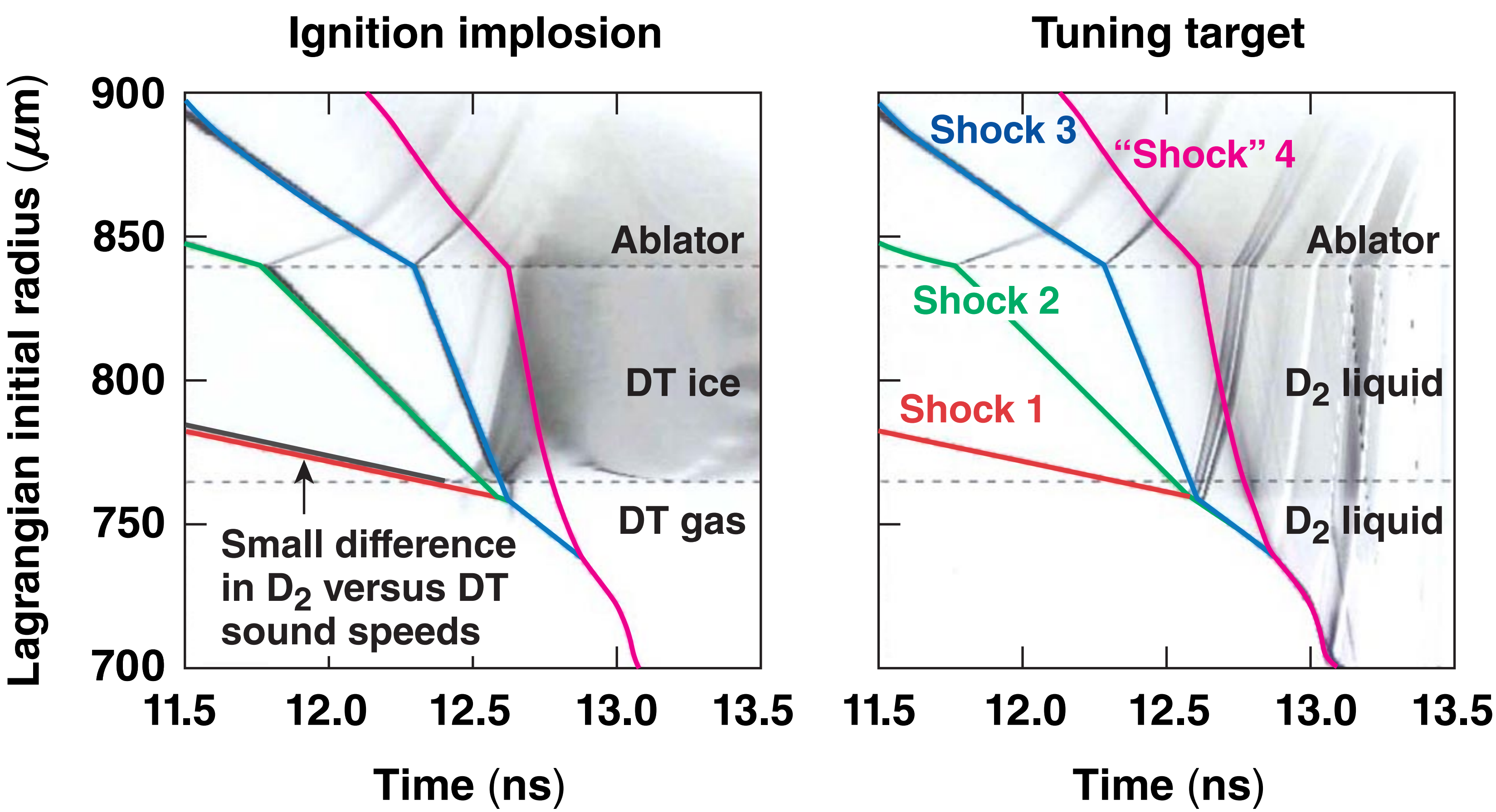


Window test at T_{rad} = 180 eV without D_2



E16213b

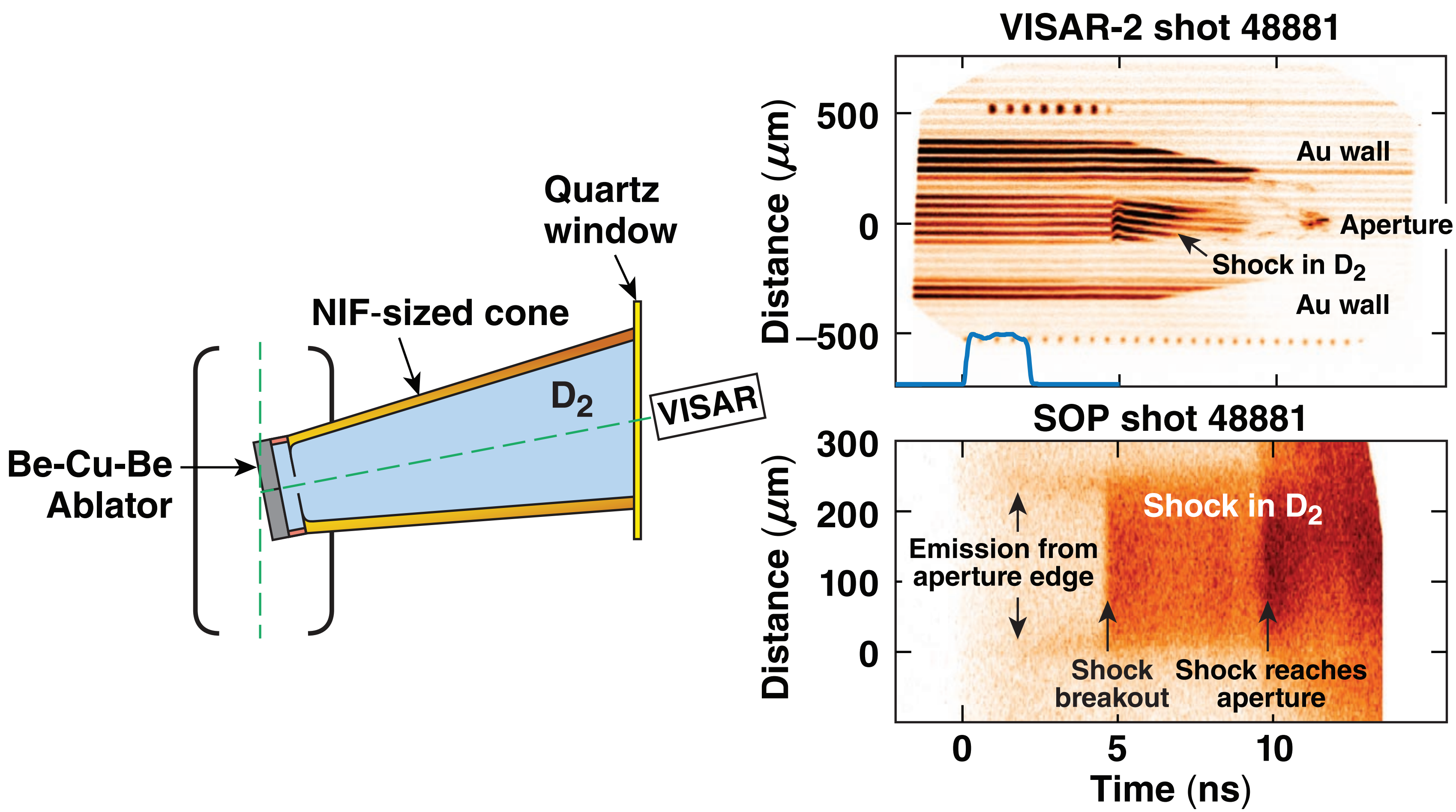
Liquid D_2 tuning experiments are good surrogates for ignition designs



D_2 to DT corrections are known and minor.

VISAR measurements were made in targets filled with liquid deuterium and driven at 135 eV

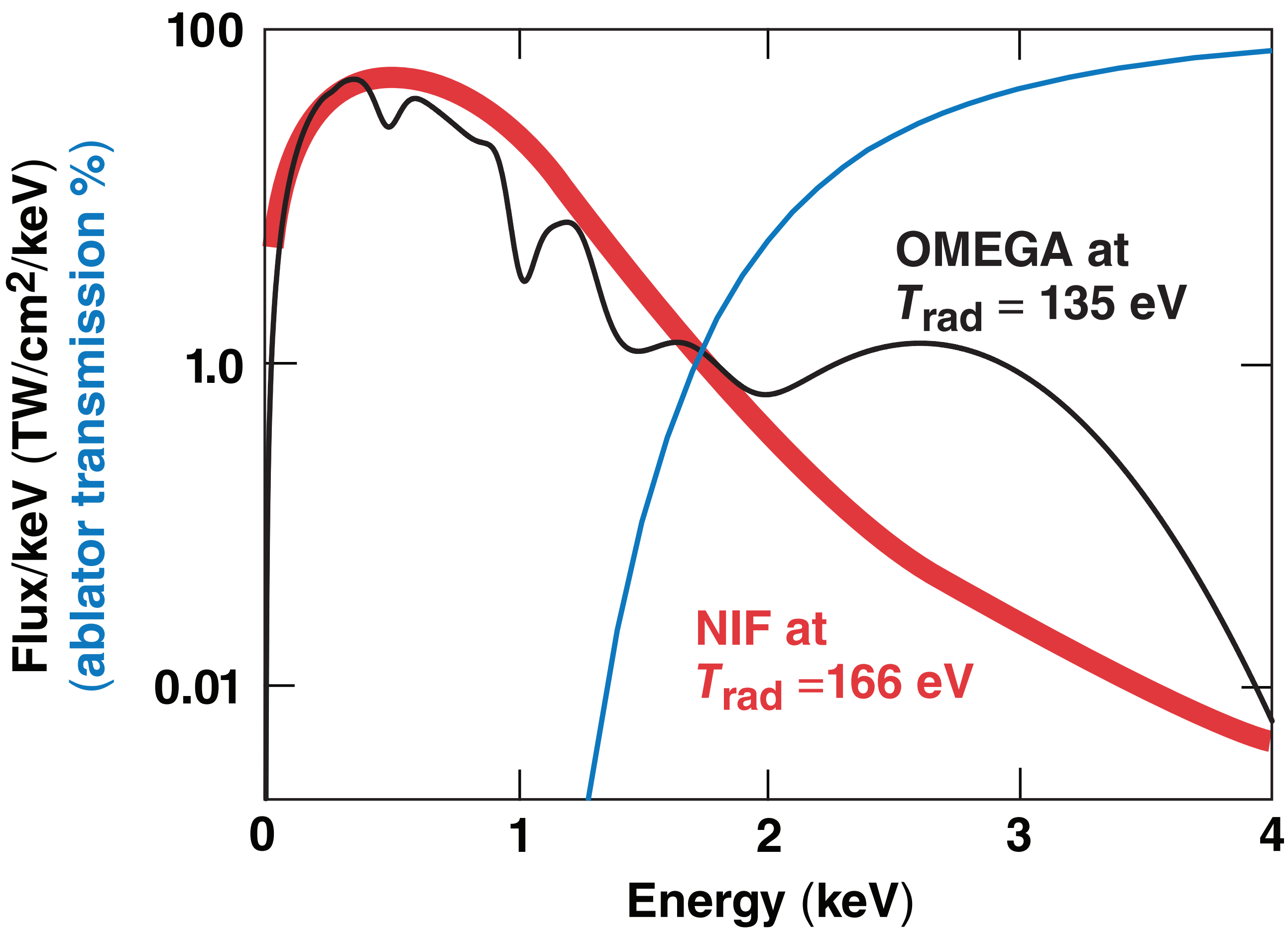
VISAR and self-emission data show identical features



E16219b

This meets NIF shock timing requirements.

OMEGA hohlraums produce “hard” x-ray fluxes that exceed those expected on the NIF

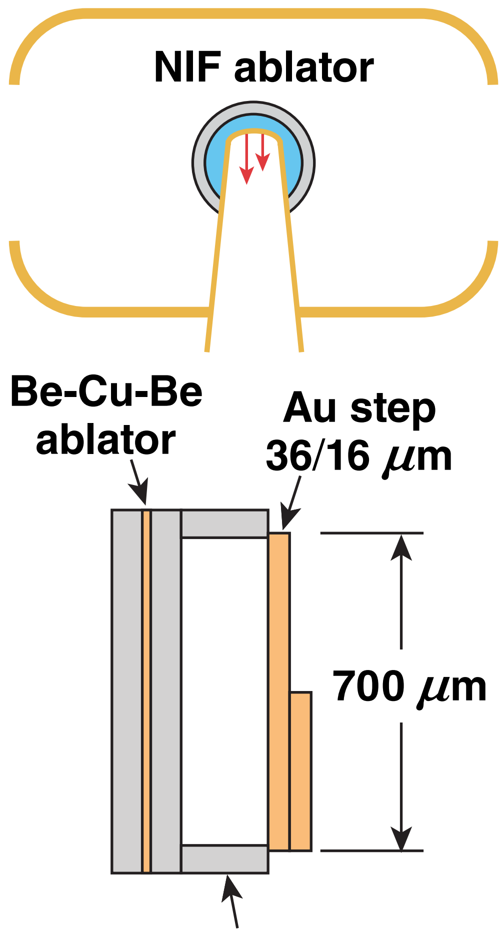


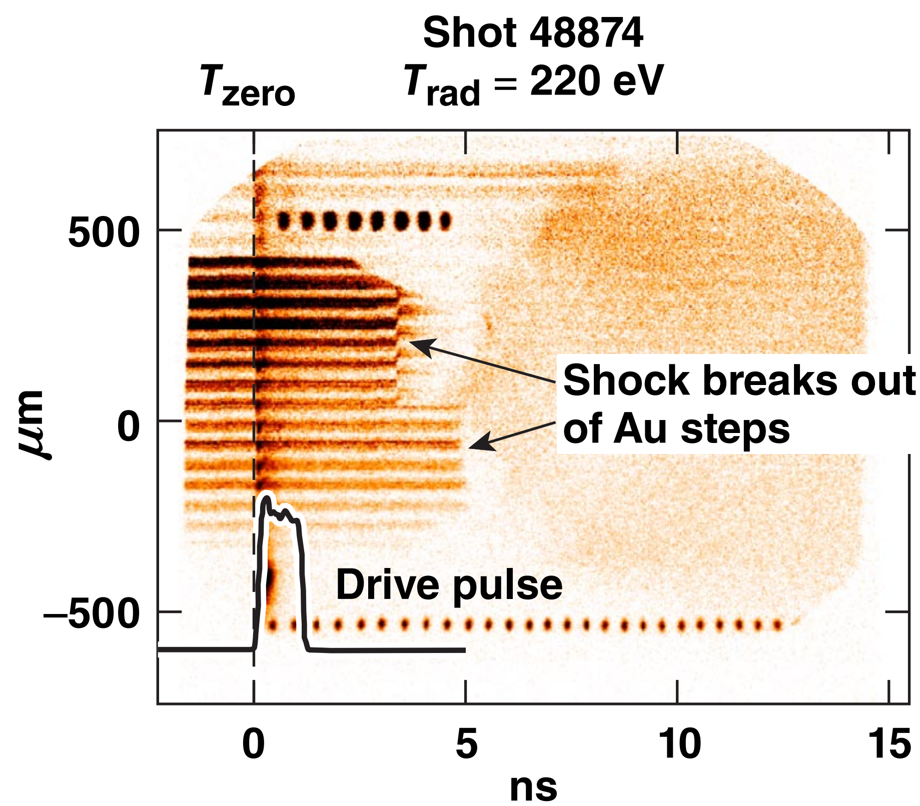
OMEGA-scale hohlraums have higher laser-spot intensities than the NIF.

E16229a

Windowless targets will make it possible to time the fourth rise (compression wave) at >220 eV

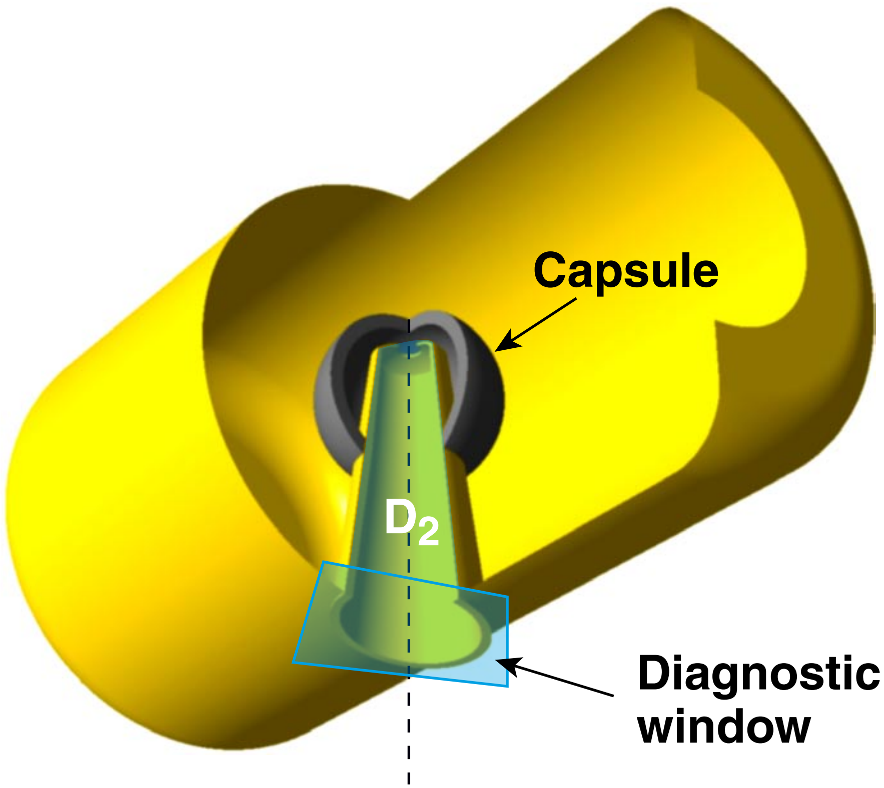
Geometry for "shock 4"





E17245a

Various issues were investigated to demonstrate the shock-timing technique



Issues

- Surrogacy to ignition targets ✔
- Ionization blanking of window ✔
- Secondary hohlraum ✔
- Effect of D_2 column ✔
- Convergence effects

The timing of multiple convergent shocks is studied using directly driven spheres with re-entrant cones

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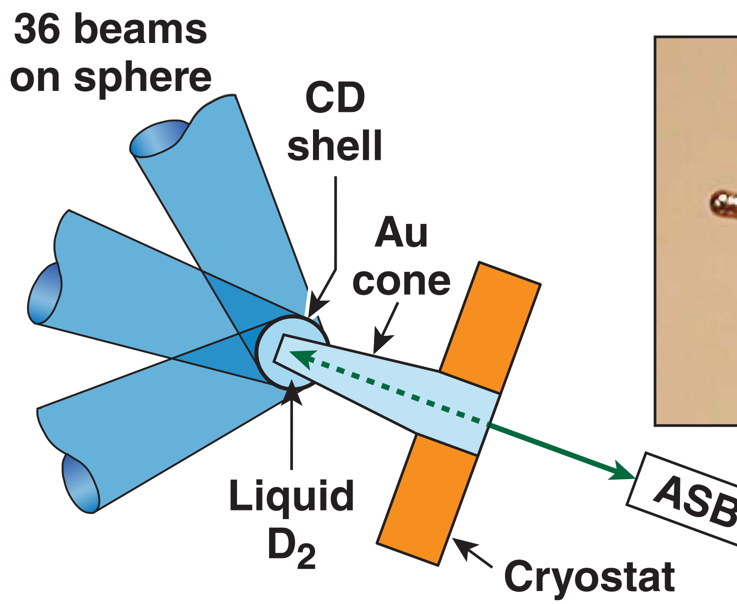
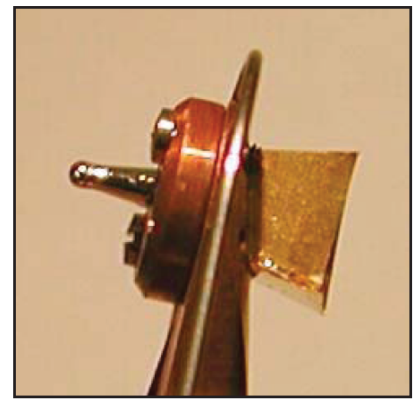
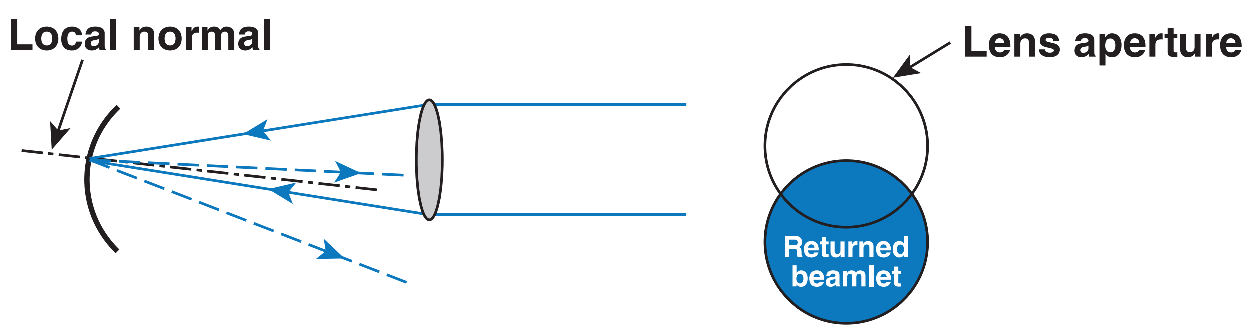
- Cannot produce multiple shocks and the requisite radiation temperature in hohlraums on OMEGA



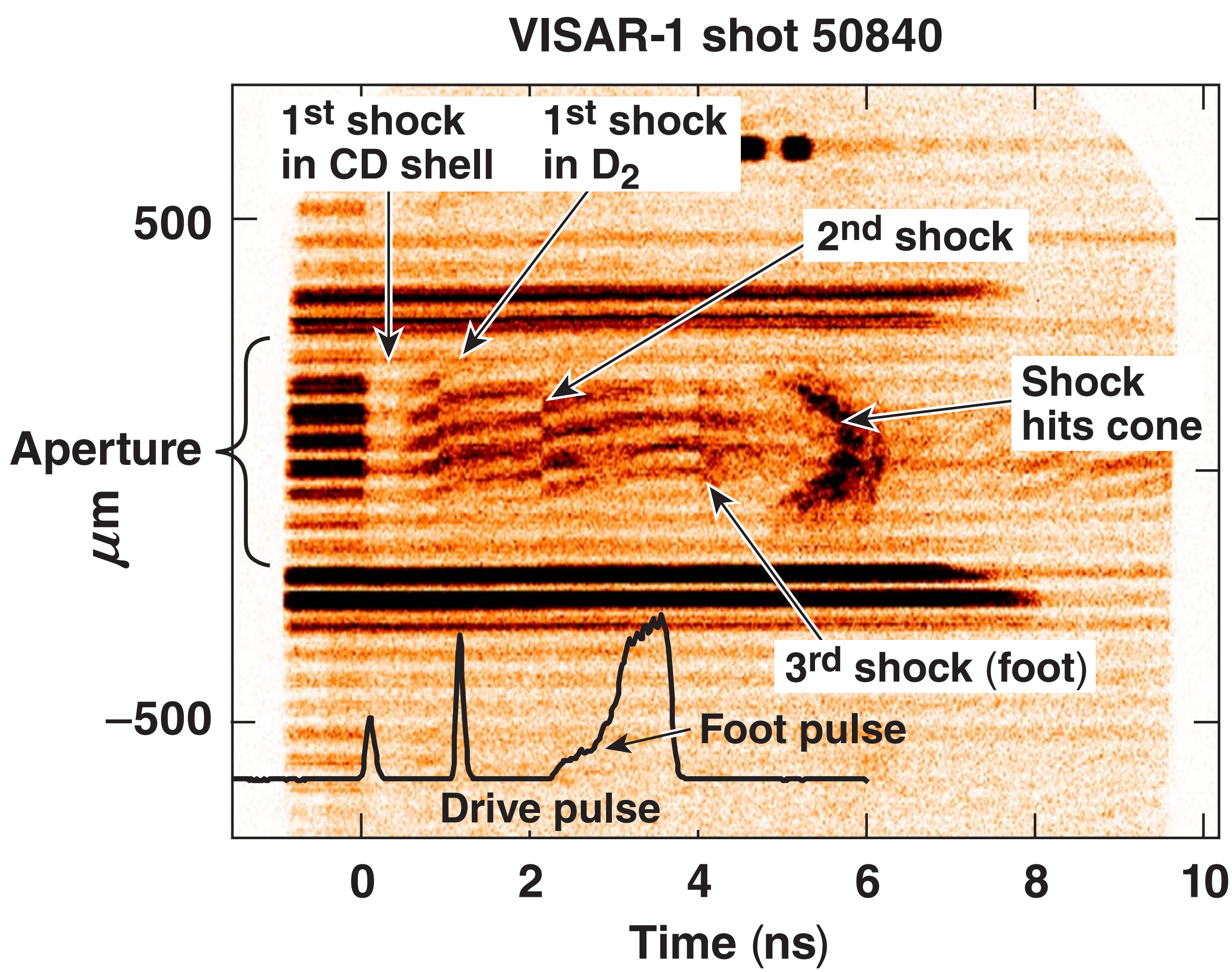




E16636a

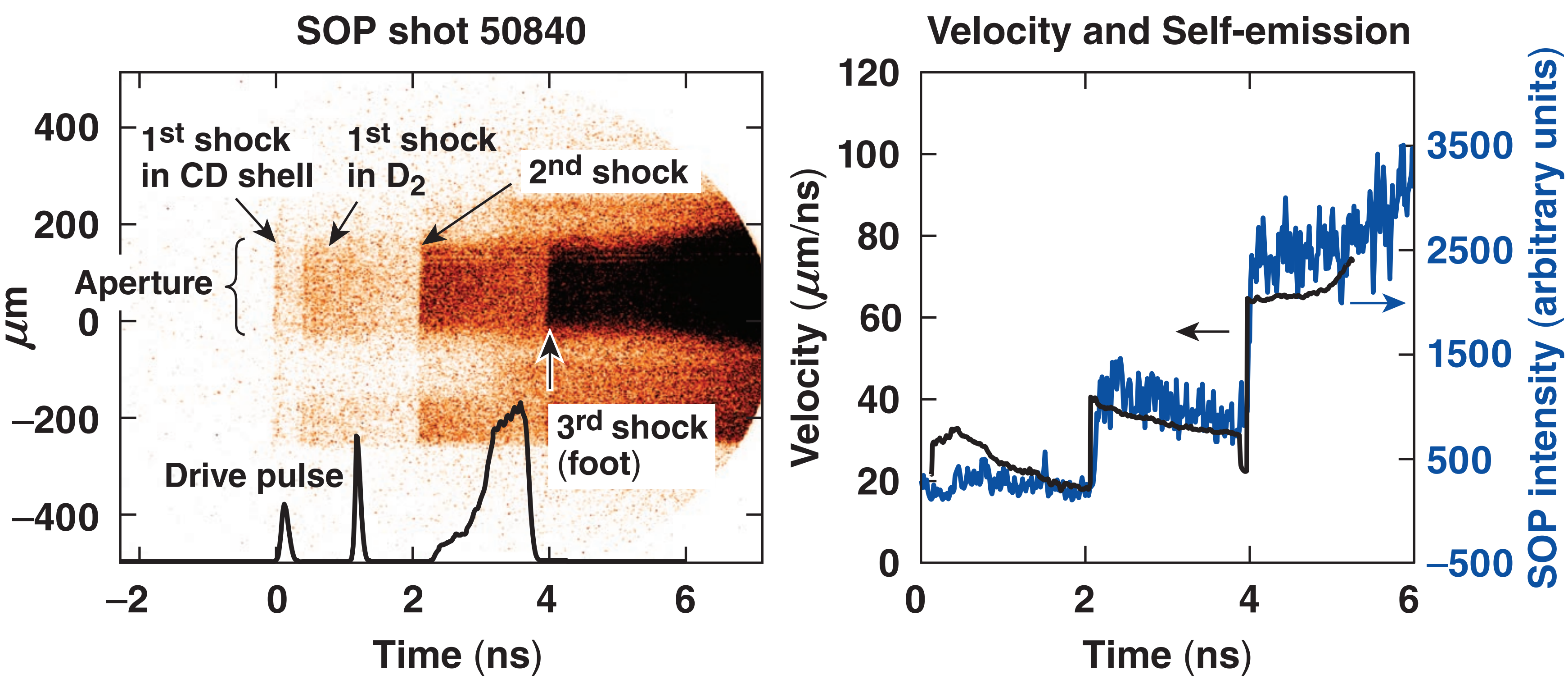
Three spherically convergent shocks were observed in directly-driven cryogenic spherical targets

VISAR-1 shot 50840



U816a

The temporal features in self-emission data confirm shock-timing observed in VISAR data



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