LA-UR-12-22271
Approved for public release; distribution is unlimited.

Title: The Defect Induced Mix Experiment (DIME) for NIF

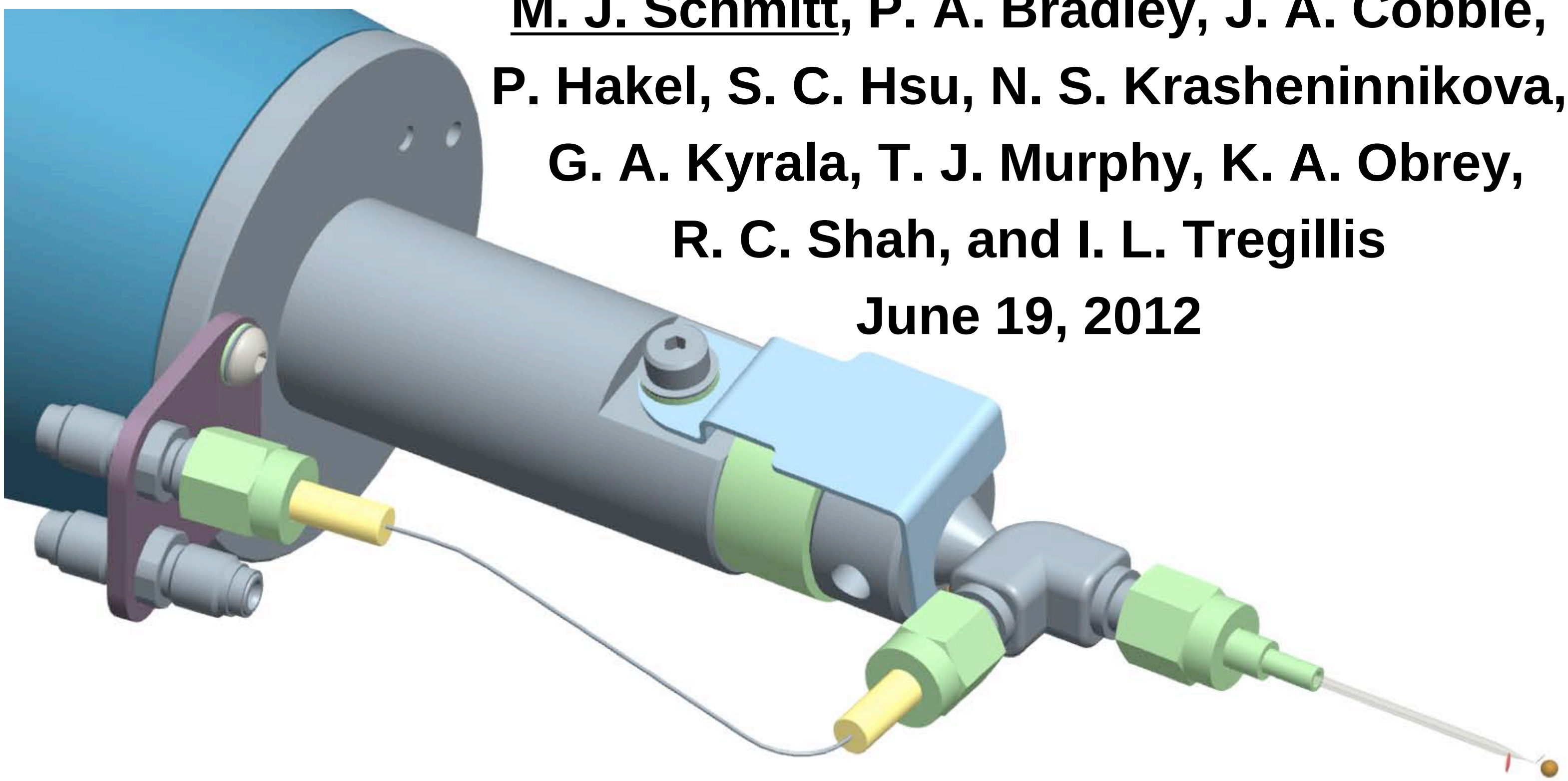
Author(s): Schmitt, Mark J
Bradley, Paul A
Cobble, James A
Hakel, Peter
Hsu, Scott C
Krasheninnikova, Natalia S
Kyrala, George A
Murphy, Thomas J
Obrey, Kimberly A
Shah, Rahul C
Tregillis, Ian L

Intended for: Presentation at the University of Rochester's Laboratory for Laser Energetics (LLE)on June 19th, 2012., 2012-06-19 (Rochester, New York, United States)

The Defect Induced Mix Experiment (DIME) for NIF

M. J. Schmitt, P. A. Bradley, J. A. Cobble, P. Hakel, S. C. Hsu, N. S. Krasheninnikova, G. A. Kyrala, T. J. Murphy, K. A. Obrey, R. C. Shah, and I. L. Tregillis

June 19, 2012



Abstract

The National Ignition Facility

LANL will perform two Defect Induced Mix Experiment (DIME) implosion campaigns on NIF in July and September, 2012. This presentation describes the goals for these shots and the experimental configuration and diagnostic set up to collect the appropriate data. The first two-shot campaign will focus on executing polar direct drive (PDD) implosions of plastic CH capsules filled with deuterium gas. Gas filling will be performed through a fill tube at target chamber center. A vanadium backligher foil will provide x-rays to radiograph the last half of the implosion to compare the implosion trajectory with modeling predictions. An equatorial groove in one of the capsules will be present to determine its effect on implosion dynamics. The second DIME campaign will commission and use a spectral imager (MMI) to examine the evolution of thin capsule layers doped with either Ge or Ga at 1.85%. Spectral line emission from these layers will quantify the mix width at the inner shell radius and near an equatorial groove feature.

Defect-Induced Mix Experiment (DIME-12A,B) Scope Overview

- **Purpose:**
  - *Use Polar Direct Drive (PDD) single-shell capsule platform to perform 2-D quantification of 4π and feature-induced perturbed shock mix in convergent ICF implosions*
- **Specific Deliverable of the DIME-12 campaign :**
  - *PQ Backlighter scheme (and MMI spectral imaging of mix w/o and w/ a groove defect)*
  - *Measure R vs t, bang time, and yield of the DIME capsule*
  - *Measure azimuthal symmetry of the implosion from self-emission near bangtime*
  - *Verify that defect has no gross effects on symmetry in equatorial view*
  - *Demonstrate direct-drive with fill tube assembly using all-CH capsule*
- **What would we do with results:**
  - *Verify symmetry and performance of the mix platform*
  - *Baseline yield for scaling to future DT shots with neutron imaging*
- **RI:** *Murphy/Kyrala* **Campaign ID:** *CMT ID: 521863*
- **Campaign Name:** *DIME_12_A* **Shot Name:** *DIME_12_A_s01 and s02* **Date:** *June 2012*
- **Major issues/Impacts:**
  - *First polar direct drive (PDD) D_2 fill at TCC; first area backlighter of PDD capsule*

Summary	Q3FY12	Q4FY12	Target Type	Exp Config	Notes:
DIME-12A		*2*	*C1,C2*	*Config 1*	*July, 2012*
DIME-12B		*3*	*C3,C4,C5*	*Config 2*	*Awaiting MMI*

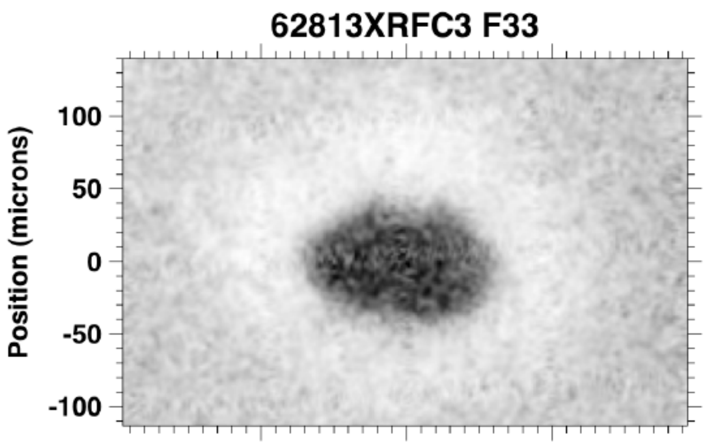
Experimental strategy

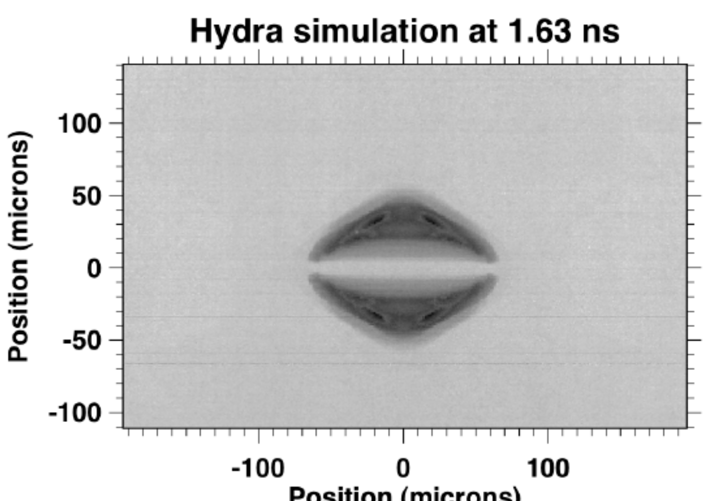
The National Ignition Facility

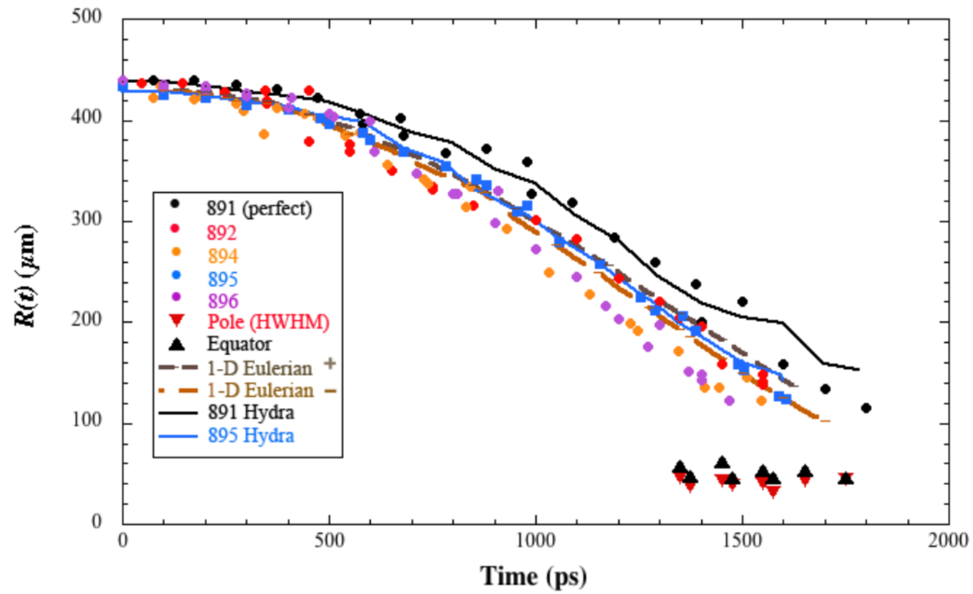
- DIME will investigate mix in convergent geometry in both uniform capsules (4π mix) and from features (defect-induced mix)
- For diagnostic access and to allow a sharply rising shock, LANL has chosen to utilize direct drive
- The NIF beam configuration supports Polar Direct Drive (PDD)
- To ensure that we are driving the capsule uniformly, we will backlight an implosion target to determine the uniformity of ablator at times when the capsule is ½ and ¼ of its original diameter, as well as near minimum radius
- We will measure the polar symmetry of the self-emission to confirm our ability to compensate for the backlighter beams
- We will measure yield to determine if neutron imaging would be feasible for a future DT experiment
- We will measure bang time to confirm our ability to model the implosion hydrodynamics

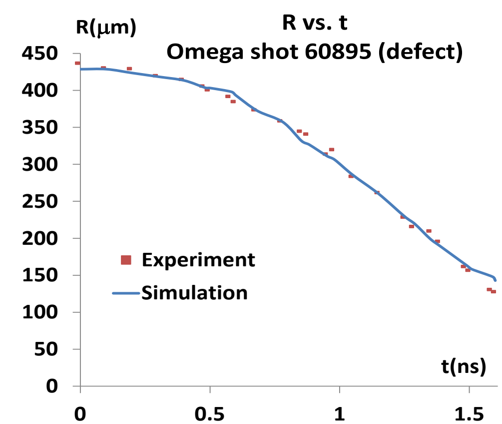
Los Alamos NATIONAL LABORATORY EST.1943

DIME-12A on NIF is a follow-on to on-going DIME experiments on Omega







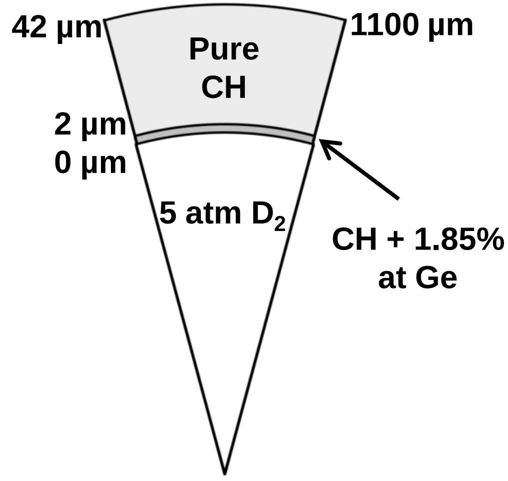


Images taken from manuscript "Asymmetric Directly Driven Capsule Implosions: Modeling andExperiments – a Requirement for the National Ignition Facility" by J.A. Cobble, et al., submitted for publication.

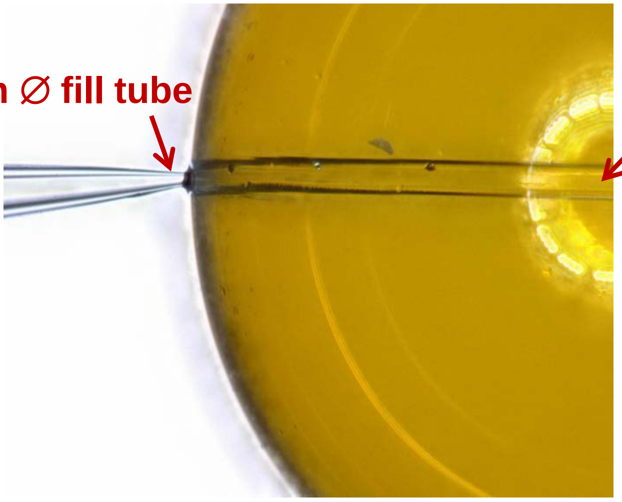
DIME-12A on NIF consists of two shots

The National Ignition Facility

Shot	CMT Shot ID	Goal	Target ID	DD Yield estimate
1	DIME_12_A_s01	PQ Backlighter Scheme	DIME-12A-C1	1.5×10^{12}
2	DIME_12_A_s02	Measure polar and azimuthal symmetry; determine R vs t; measure DD yield	DIME-12A-C2	2.0×10^{11}



DIME Capsule
DIME_12_A_C1 (no defect)
DIME_12_A_C2 (with defect)

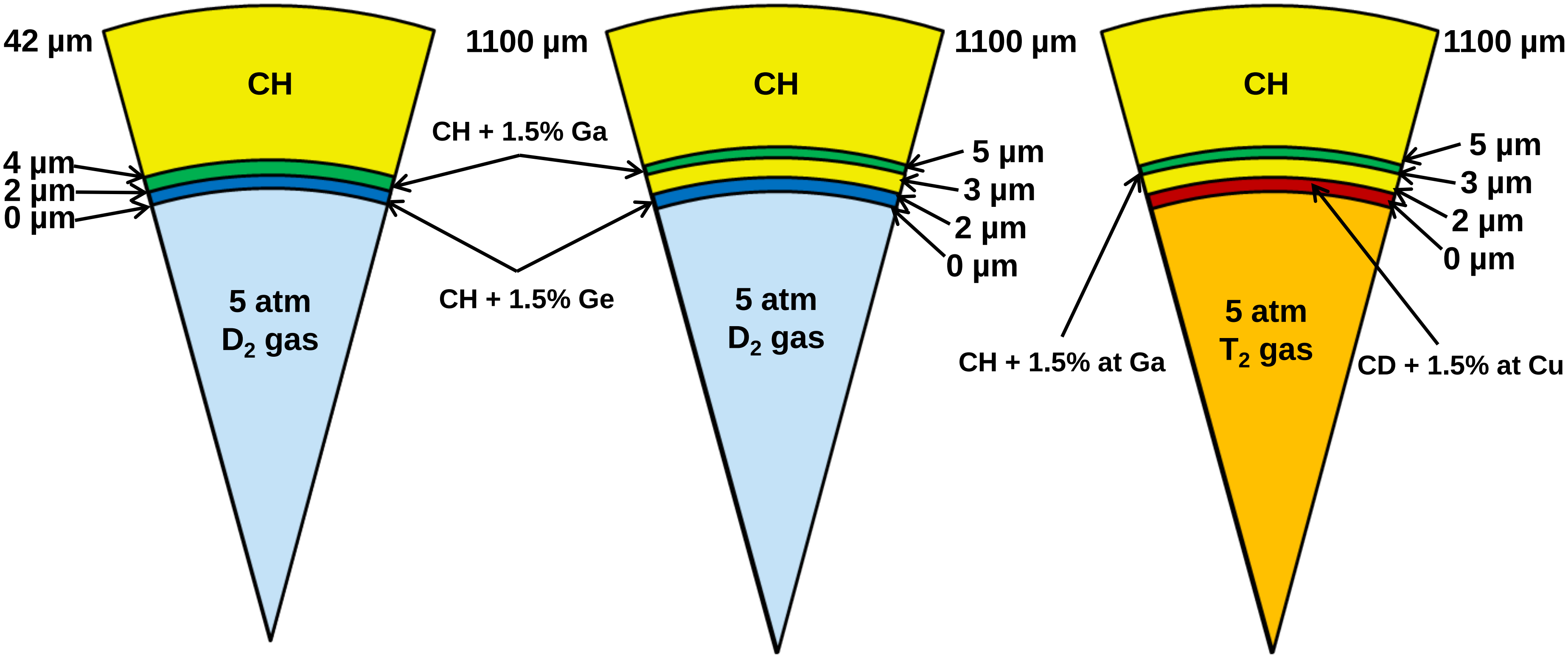


DIME Capsule with defect

Los Alamos NATIONAL LABORATORY EST.1943

DIME-12B & 13A,B,C targets are more complex

- Capsule types differ in dopant layer placement and defect



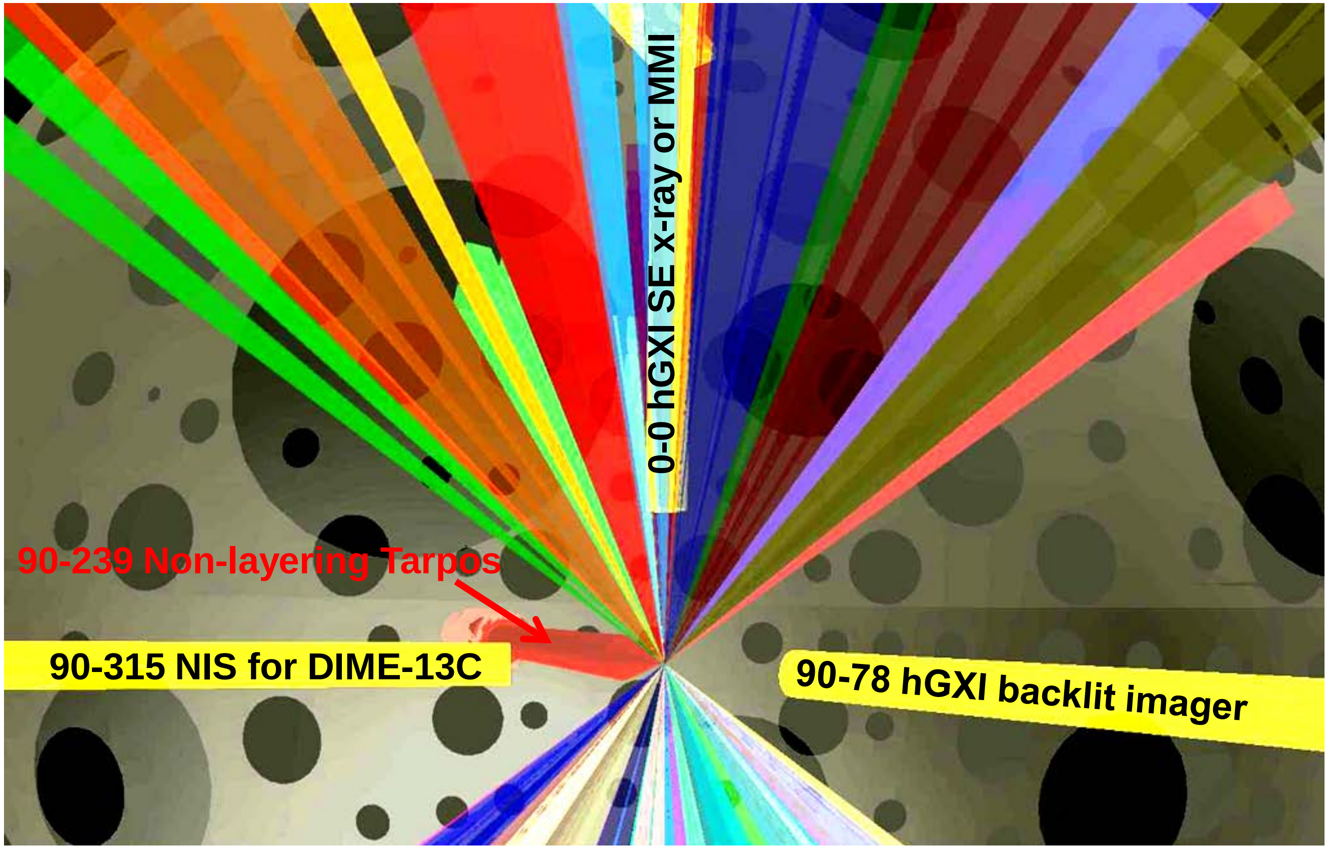
Dual dopant capsule	Modified dual dopant capsule	CD layered dual dopant capsule
DIME-13A-C1 (no defect)	DIME-13B,C-C3 (no defect)	DIME-13D-C5 (no defect)
DIME-13A-C2 (with defect)	DIME-13B,C-C4 (with defect)	DIME-13D-C6 (with defect)

- All capsules filled at TCC through a 30 µm diameter fill tube

DIME's first two FY12 shots will measure PDD implosion trajectory and symmetry of a fill tube mounted CH capsule

The National Ignition Facility

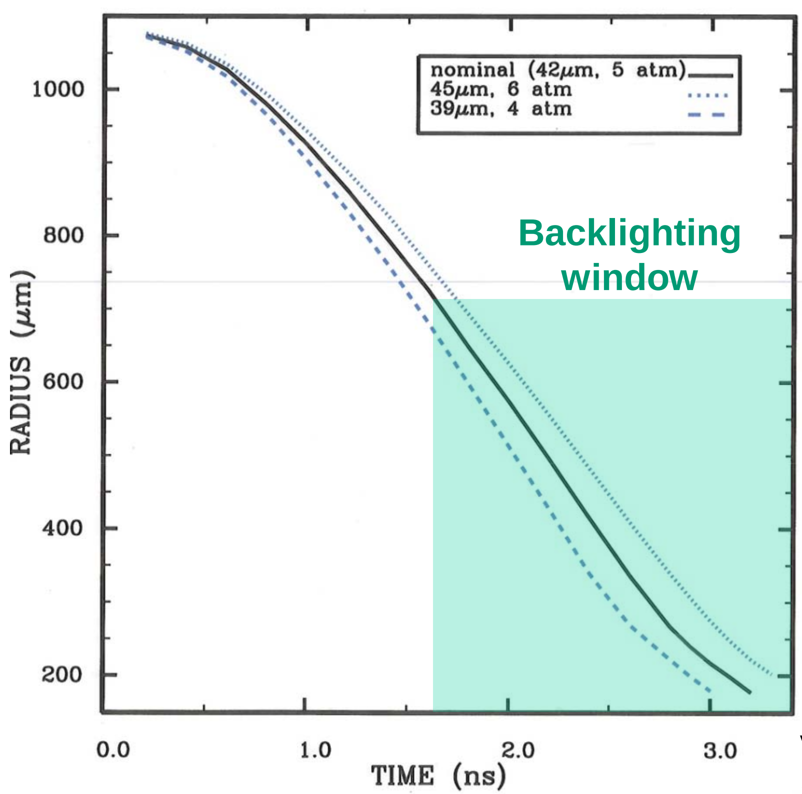
- Vanadium backlit x-ray images will be generated by an hGXI in the 90-78 DIM and self-emission x-ray imaging (MMI later) will be collected using an hGXI in the polar 0-0 DIM



- Targets are filled with D_2 using a fill tube mount
- The backlighter foil is mounted off the target mounting fill tube

Measurement of the implosion trajectory will focus on times between 1.65ns and bang time at 3.2ns

- The DIME-12A capsules (42µm thick, 2.2mm ∅ CH capsule, 5 atm D_2 gas fill through a 30 µm ∅ fill tube) will be PDD driven by ≤ 700 kJ in a 2.15ns FWHM square pulse



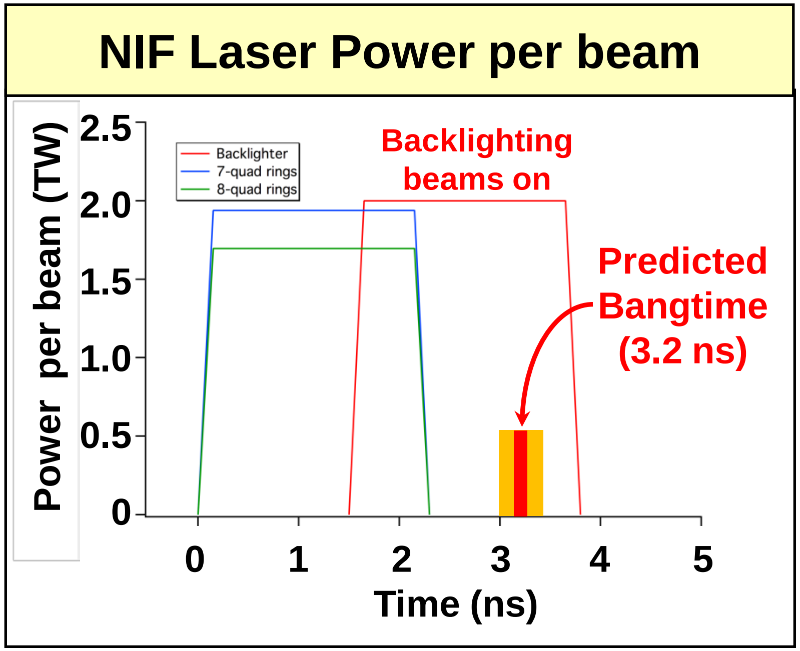
- Bang times of 3.2 ±0.2 ns are predicted
- Convergence ratio is ~ 6
- Expected $Y_n = 10^{11}$- $2x10^{12}$
- Nominal implosion trajectory (solid black line) and additional trajectories for slow and fast experimental conditions

Variations for blue lines are:
Shell thickness±3µm, P_{D_2}±1 atm, E_{laser} ∓ 5%

Backlighting needs

- <u>Image</u> backlighting of the capsule is needed to:
  1. Accurately determine the average radial trajectory of the shell
  2. Measure polar angle variations in the capsule shell radius from:
     a. laser drive variations
     b. equatorial features
     c. unintentional manufacturing defects (domes, dust, etc)

- A vanadium backlighting foil will be illuminated from 1.65 to 3.65 ns



Backlighting physics requirements

The National Ignition Facility

- Measure image-resolved capsule radius to ±20μm at ≤ 300ps intervals between t=1.65ns and bangtime with image contrast between 10 and 50%

  - Capsule implodes at ~300μm/ns, and framing camera images average over ~0.1ns yielding a systematic ~ 30μm motion blur

  - Hydra simulations predict ~ 4% polar angle variations in radius caused by variations in direct drive illumination (and about 1 % in the azimuthal direction) which translates to ≥ 20 μm variations in shell position when the 2.2mm ∅ shell has imploded half way.

  - Observed variations in excess of 20 μm will determine if there are incorrectly modeled hydrodynamics that need to be addressed

  - Simulations indicate that our equatorial defect induces perturbations far in excess of the above limitations

Measurement requirements for DIME-12A capsules are driven by implosion and defect evolution hydrodynamics

The National Ignition Facility

Early-time hydrodynamics around R_{50} (compression ratio of 2)

- Measure capsule symmetry-dependent capsule radius
  - Backlighter needs to provide $\leq$ 30 μm resolution at SNR $\geq$ 10
- Measure defect width expansion
  - Backlighter needs to measure ~100 μm defect width to ±30 μm

Mid-time hydrodynamics around R_{25} (compression ratio of 4)

- Measure capsule symmetry-dependent capsule radius
  - Backlighter needs to provide $\leq$ 30 μm resolution at SNR $\geq$ 8
- Measure defect width expansion
  - Backlighter needs to measure ~90 μm defect width to ±30 μm

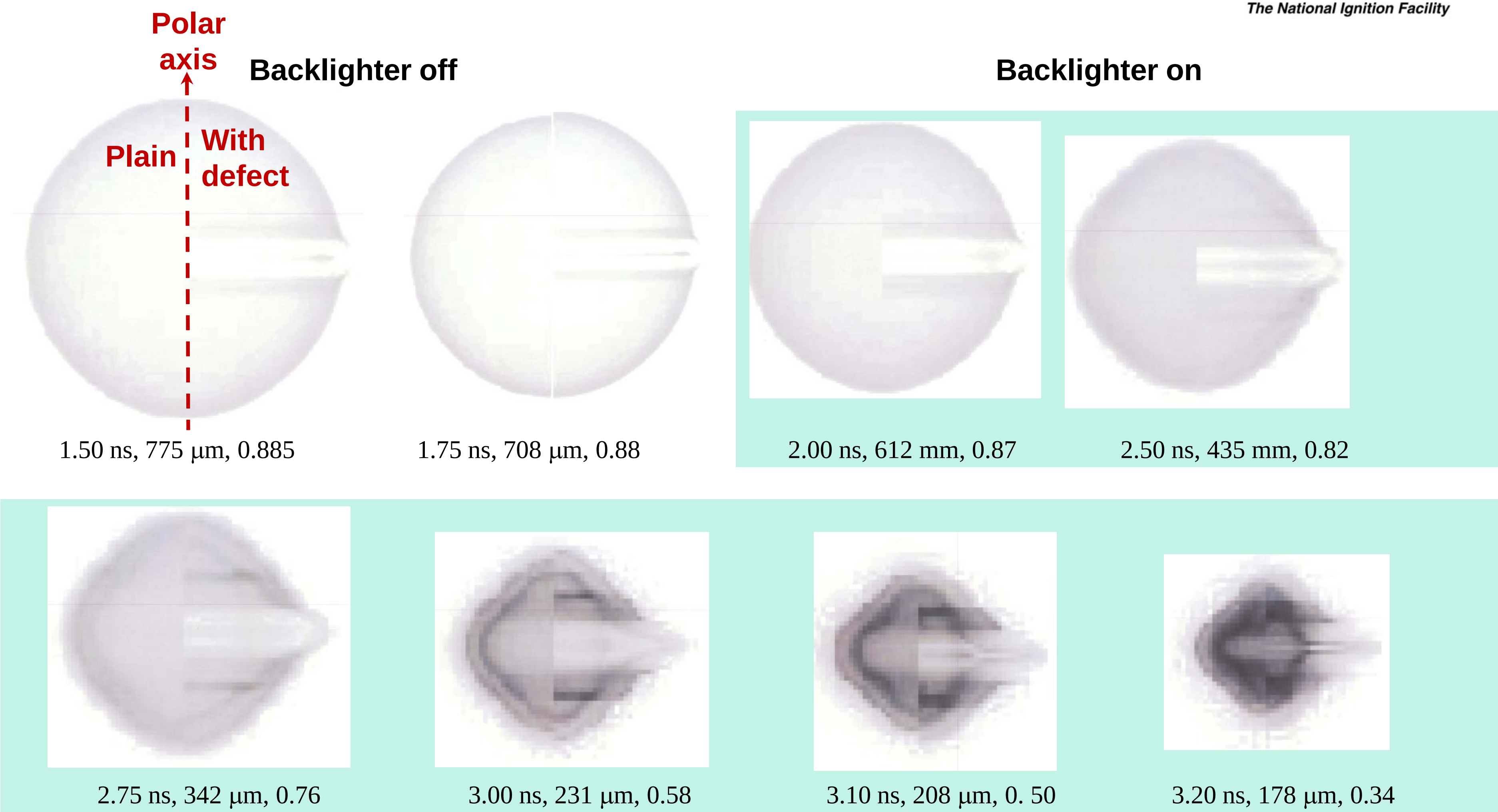
Bang-time hydrodynamics and yield around R_{min} (compression ratio of 6)

- Measure yield of capsules with and without defect
  - DD n-yield needs to be measured to an accuracy of ±40%
- Measure capsule symmetry-dependent capsule radius
  - Best effort measurement using backlighter and self-emission

Los Alamos NATIONAL LABORATORY EST.1943

Predicted DIME radiographs using a Cu backlighter clearly show equatorial blowout from the imposed feature

The National Ignition Facility



- **Simulation driven symmetrically**
- **Radiographs shown with 10 µm resolution**

<u>LEGEND</u>
time (ns), radius µm, contrast

Laser physics requirements

The National Ignition Facility

- Laser drive variations (P_2, P_4) must remain small enough not to dominate equatorial defect asymmetries

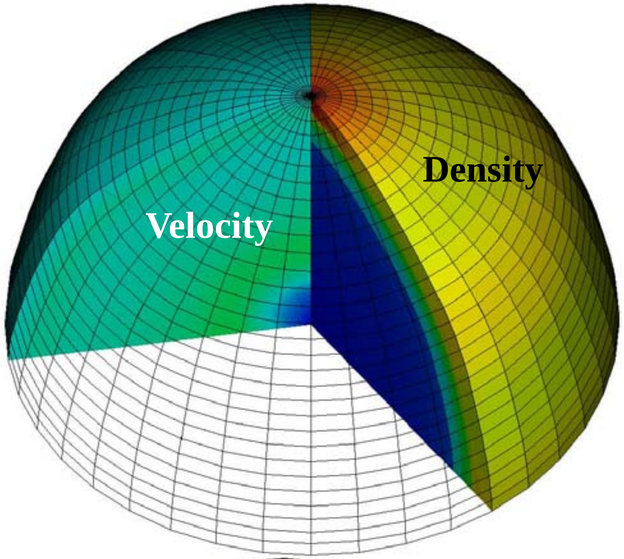
  - The remaining 7 quads in the two cones that will provide a quad each for backlighting must be increased in power by 8/7ths and repointed symmetrically around the capsule. Hydra simulations indicate an increase of less than 1% in the nominal blowby (9%). A 1% variation in laser absorption is well below the tolerance for the drive laser power

  - Hydra simulations in 2D, using nominal variations in laser beam and laser quad energy, show only small changes in capsule asymmetry (below the tolerances on the backlighter already discussed)

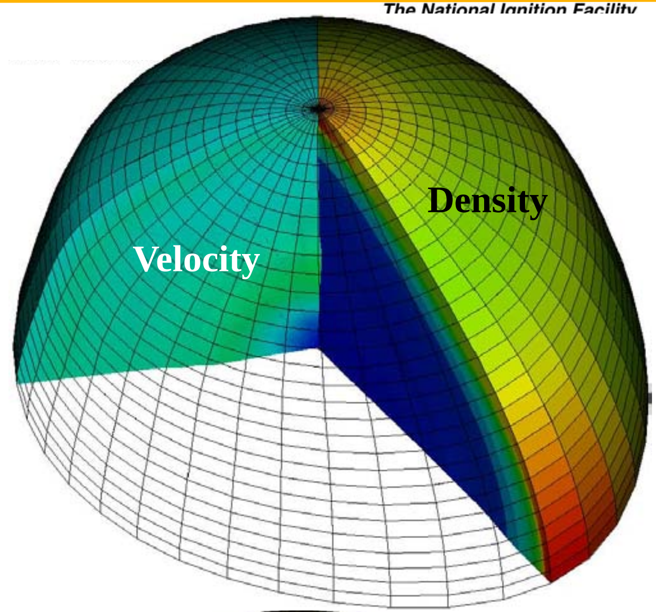
  - Hydra simulations to determine pointing angles to varying P_2 from what is observed will be available for subsequent shots

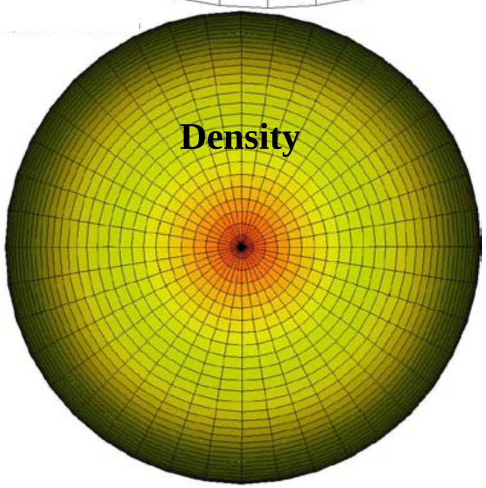
We have analyzed the effect of pulling a quad from each hemisphere for backlighting

t=2.9ns

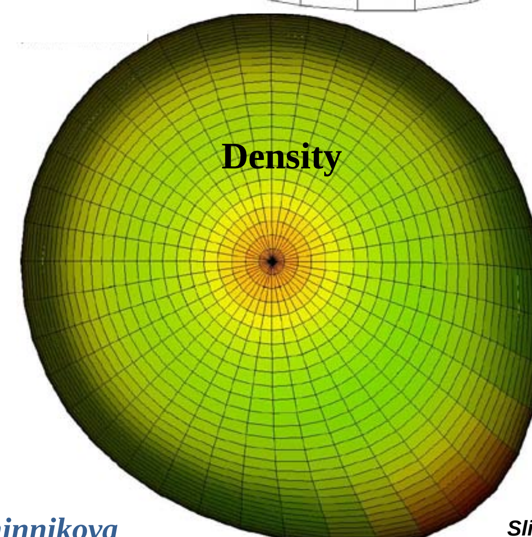


Pulling 50º quad and increasing energy to remaining quads leaves a large azimuthal asymmetry





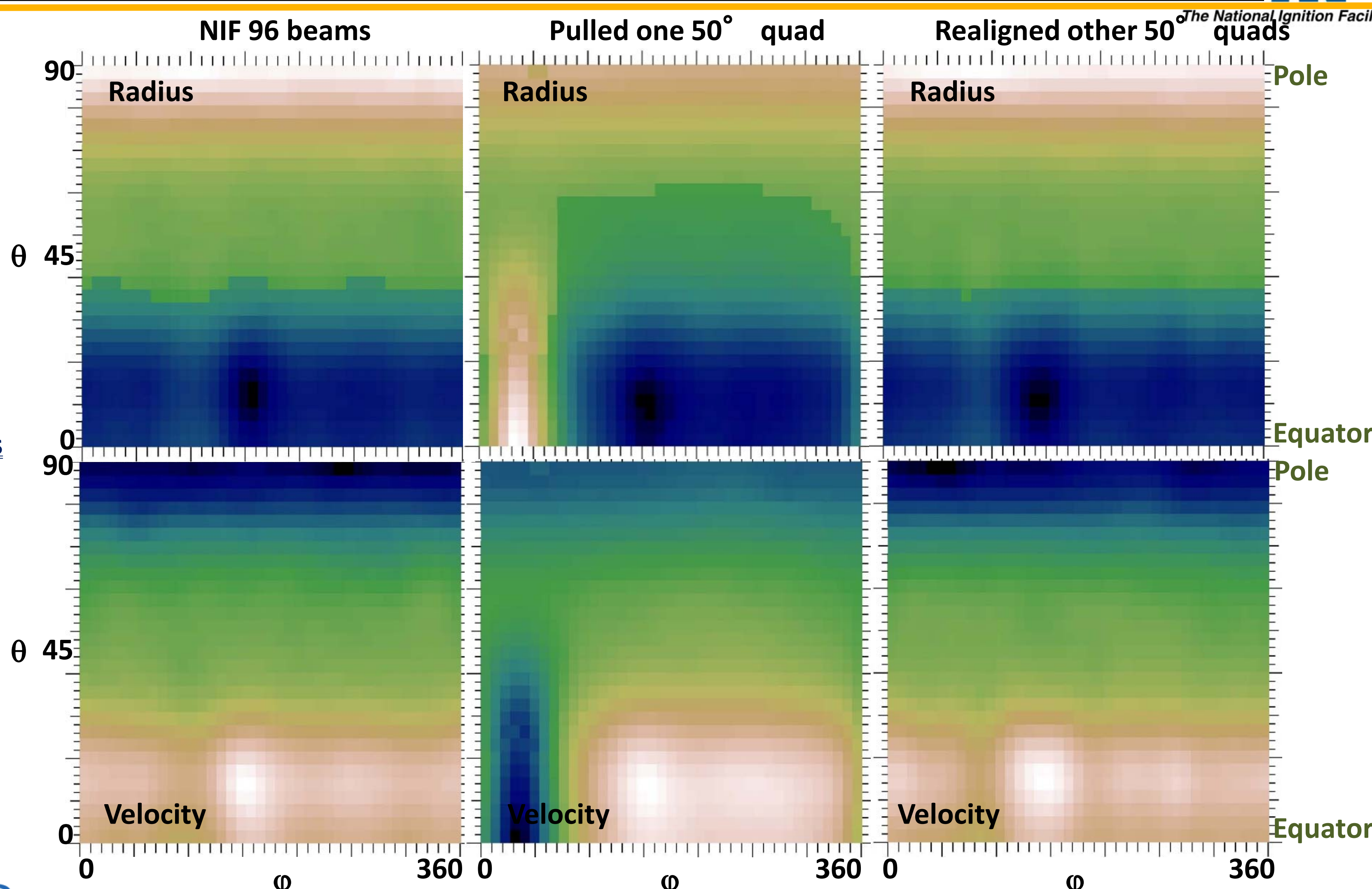
Yield reduction >70%



Re-pointing the remaining 7 quads restores symmetry and yield to within a few % of the nominal 1.5×10^{12} n

Simulation results courtesy of Natalia (Vinyard) Krasheninnikova

Skewing the beams in the effected cones to compensate for the missing quad restores symmetry and yield



Simulation results courtesy of Natalia Krasheninnikova

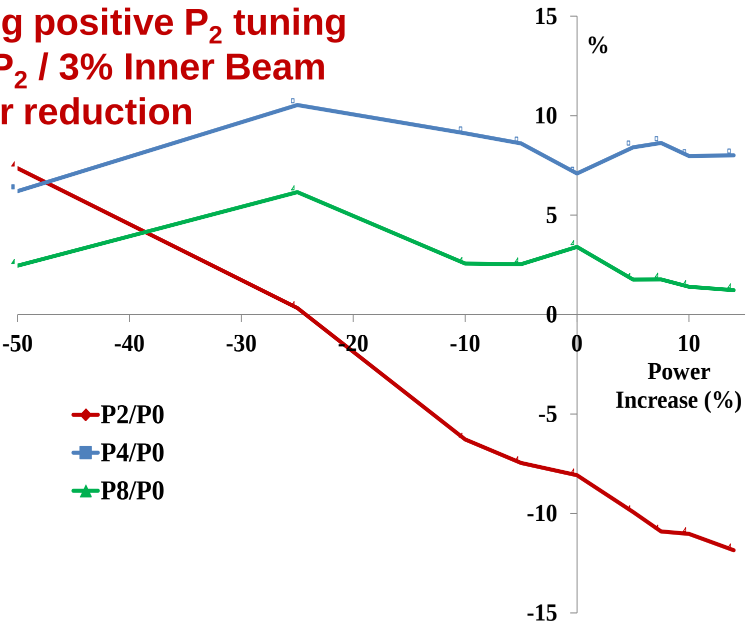
Hydra calculations indicate that we can use laser cone energy to compensate for P_2 asymmetry at R_{25}

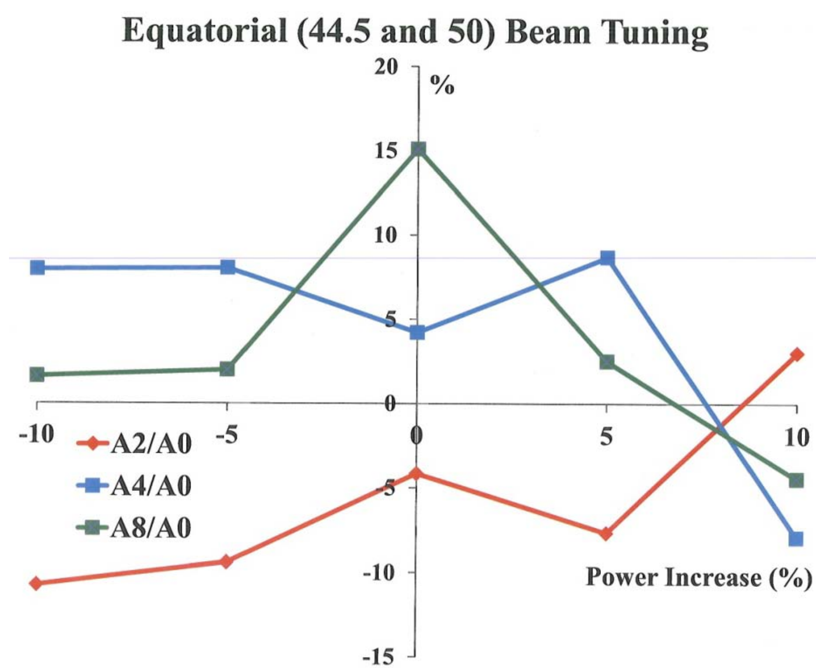
The National Ignition Facility

- Reducing the inner cone power will swing P_2 if oblate asymmetry at R_{25} is an issue

- Reduction of the 23º/30º cones provides +15% tuning of P_2 at R_{25}

Strong positive P_2 tuning
+1% P_2 / 3% Inner Beam power reduction





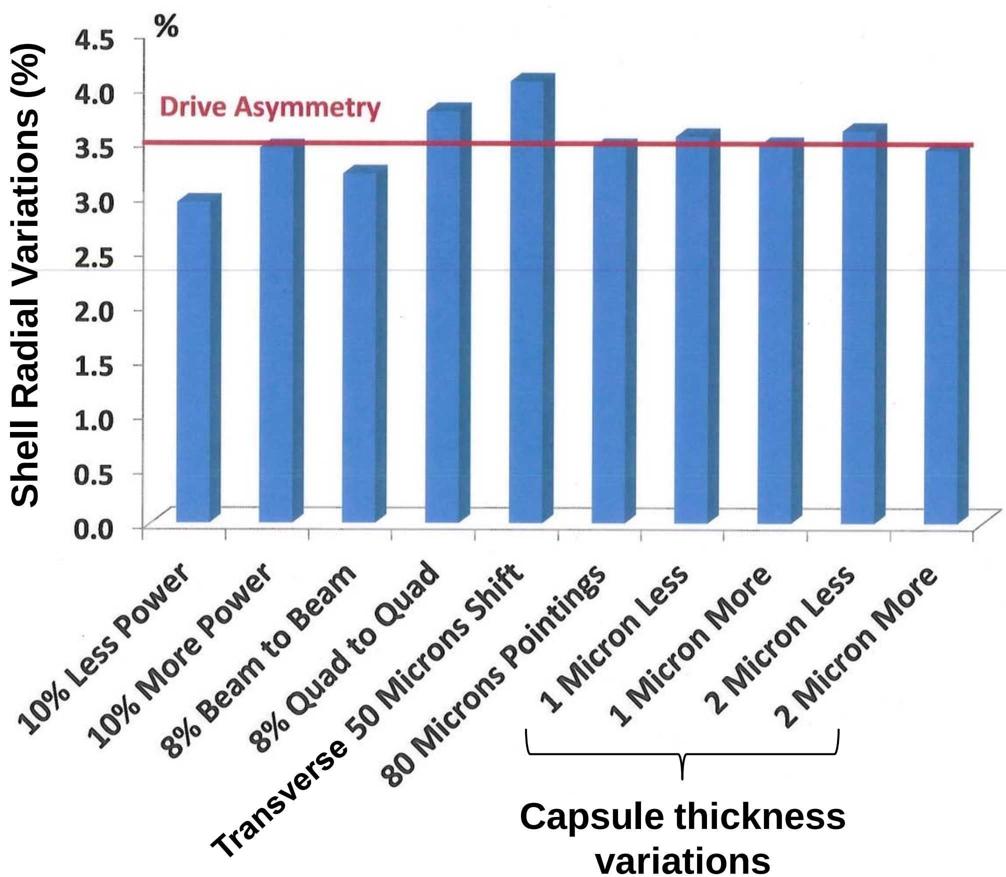
- Increasing the outer cones is limited by NIF's ~2 TW peak power per beam

Los Alamos NATIONAL LABORATORY EST.1943

Shell radius perturbations from laser and capsule thickness variations are small

The National Ignition Facility

Sensitivity studies using Hydra indicate that the nominal NIF laser variations result in variations in <u>shell radius</u> that are small compared to the nominal PDD polar angle asymmetry variations and equatorial defect perturbations

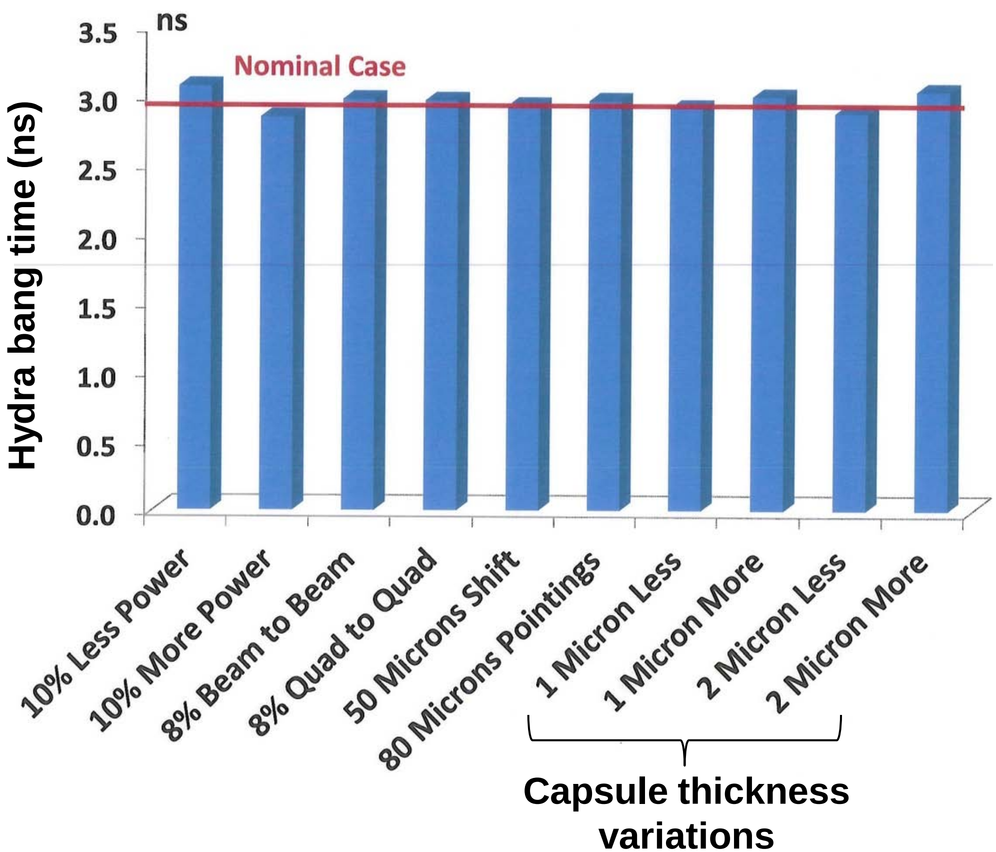


Los Alamos NATIONAL LABORATORY EST. 1943

Bang time variations of 200ps are well within our diagnostic collection window

The National Ignition Facility

Sensitivity studies using Hydra indicate that the nominal NIF laser variations result in bang time variations that are small compared to our diagnostic collection window



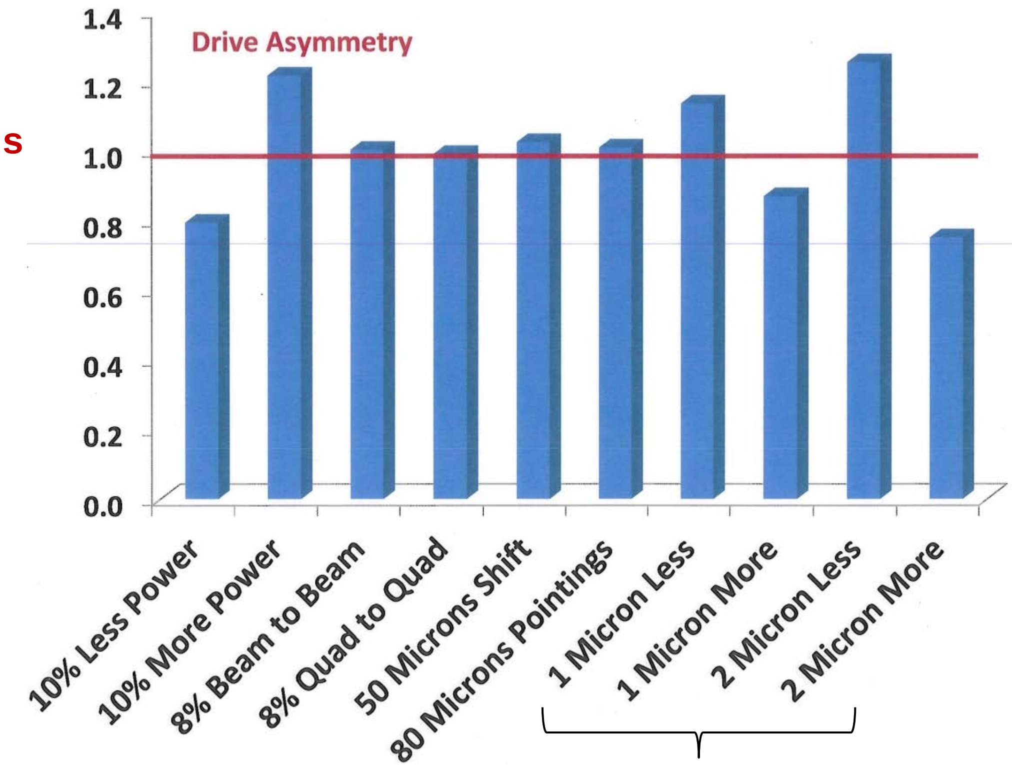
Los Alamos NATIONAL LABORATORY EST. 1943

Nuclear yield variations will be dominated by variations in total laser power and shell thickness

The National Ignition Facility

- Sensitivity studies using Hydra indicate that the nominal NIF laser variations result in ±20% variations in DD yield

Nominal yield is 1.5×10^{12}

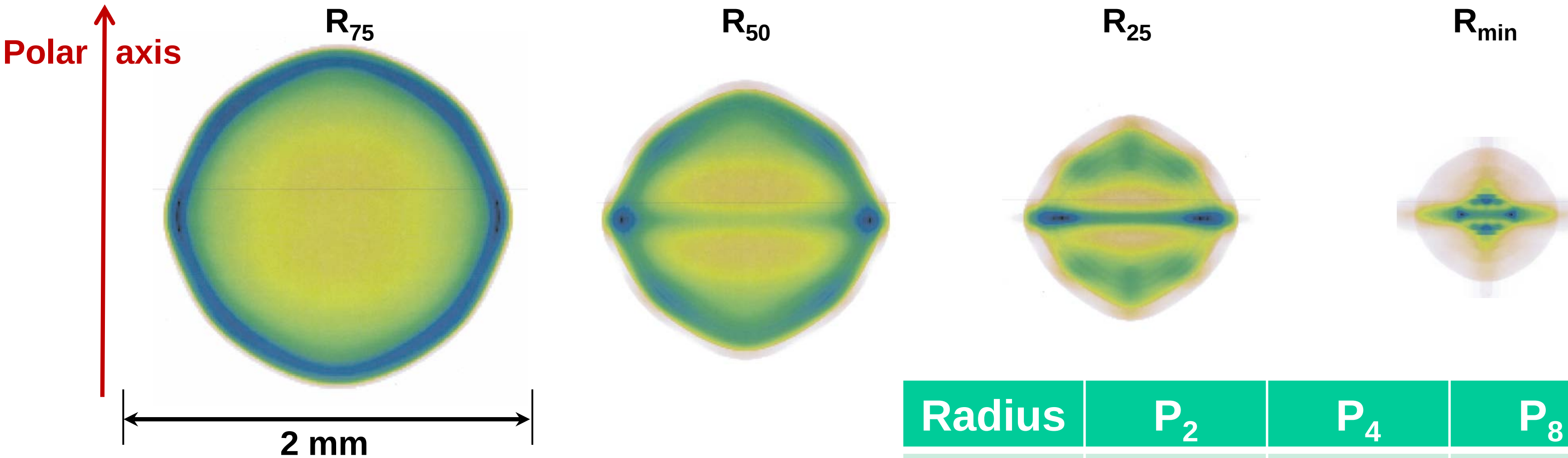


Capsule thickness variations

Los Alamos NATIONAL LABORATORY EST. 1943

Polar Direct Drive imposes significant asymmetry on the capsule late in the implosion

- Legendre mode fits (at the 17% contour) have been performed using simulated radiographs (Cu He$_\alpha$ at 8.3 - 8.4 keV) in the equatorial plane from post-processed Hydra simulations

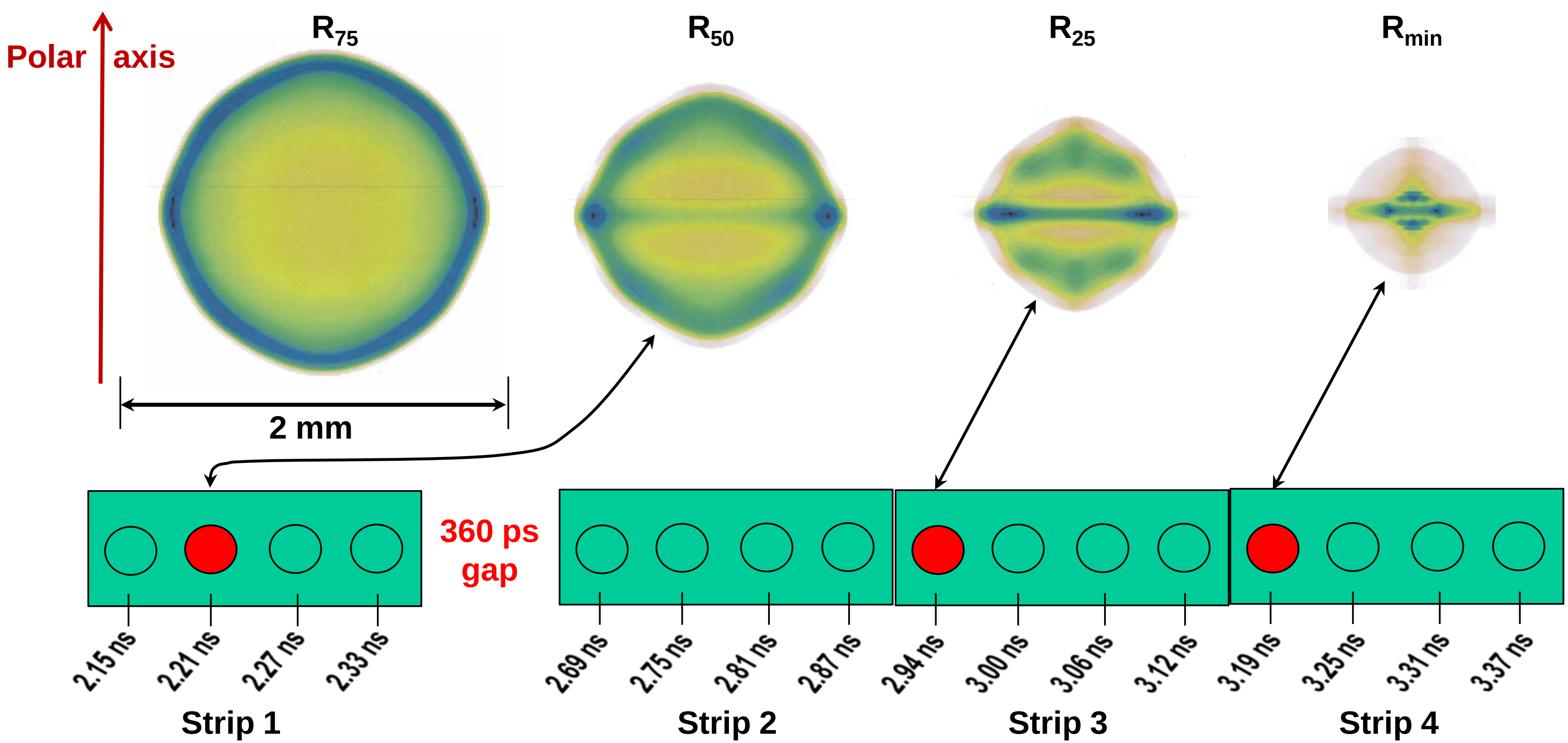


Radius	P_2	P_4	P_8
R_{75}	-1.4%	2.8%	1.7%
R_{50}	-1.0%	5.7%	3.2%
R_{25}	-1.6%	8.6%	12%
R_{min}	-9.9%	52%	34%

- PDD induces large P_4 and P_8 drive asymmetries near bang time

Backlighter hGXI strips are timed to capture images of the capsule from R_{50} through bang time

- 1 mm ∅ backlighter spot will be just large enough at R_{50}
- Other images add redundancy and cover timing uncertainties



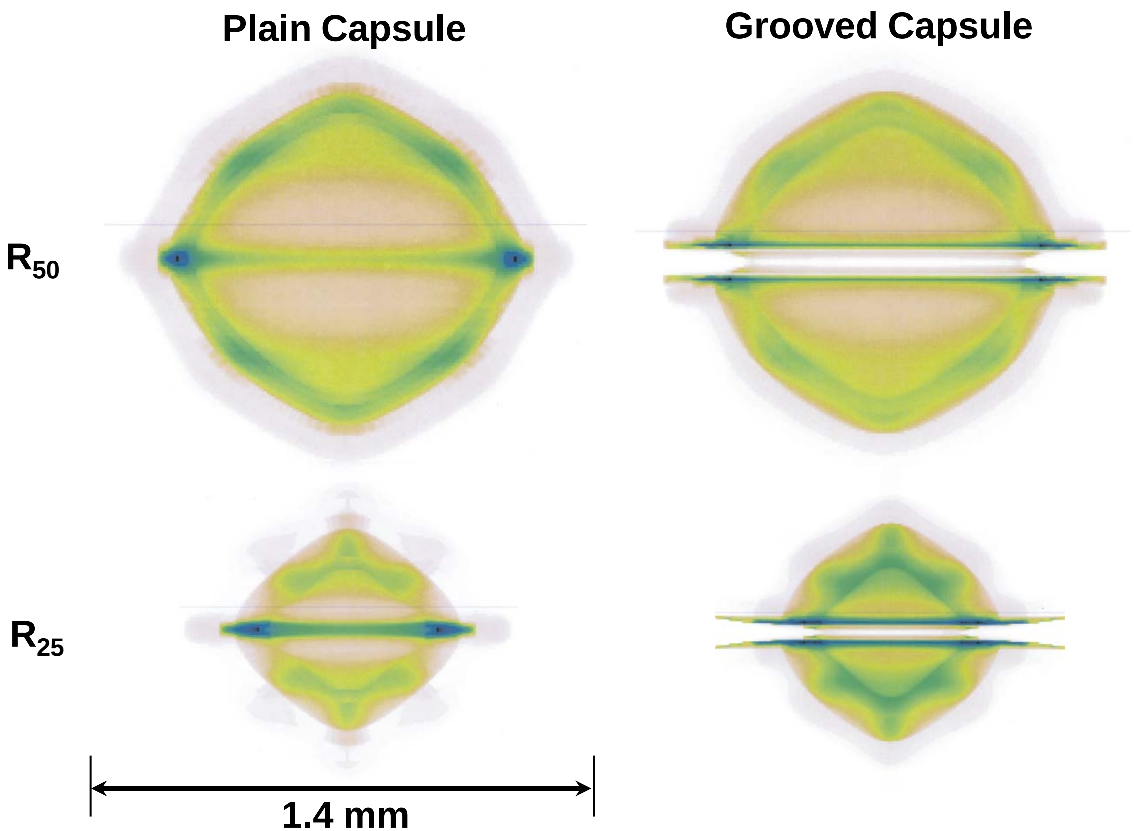
The National Ignition Facility

Los Alamos NATIONAL LABORATORY EST. 1943

Differences between DIME capsules with and without defects will be clearly visible

The National Ignition Facility

- Hydra predicts our equatorial feature will produce clearly discernible x-ray backlit radiograph differences

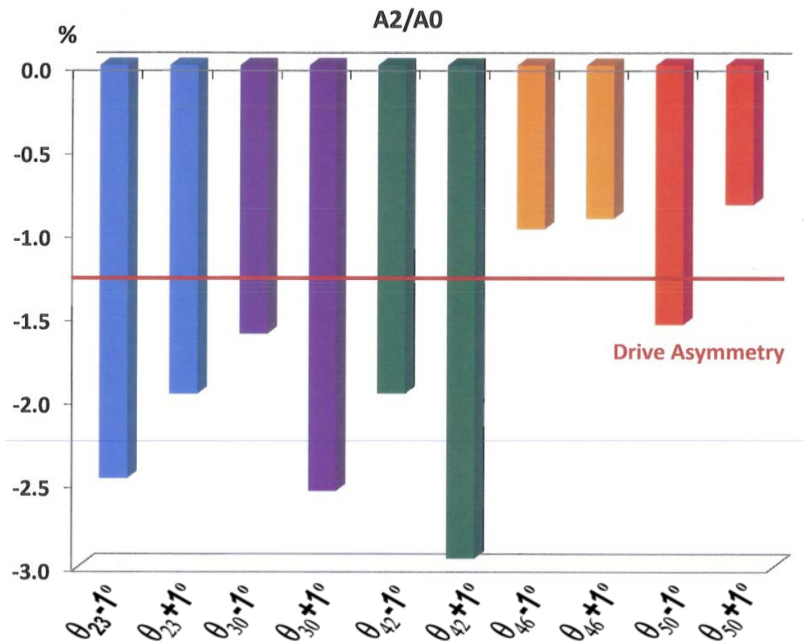


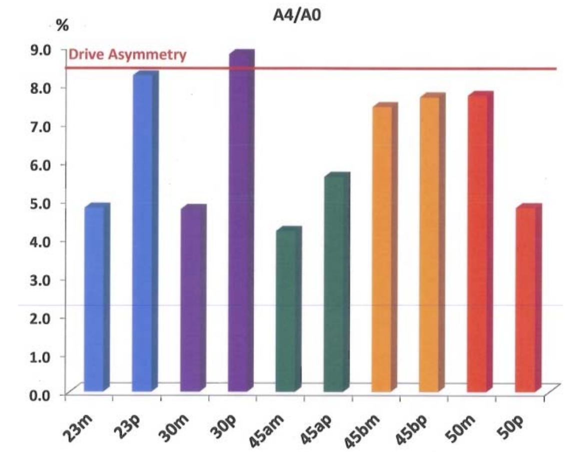
Beam pointing on the capsule can also be used to modify P2 and higher mode asymmetries at R_{25}

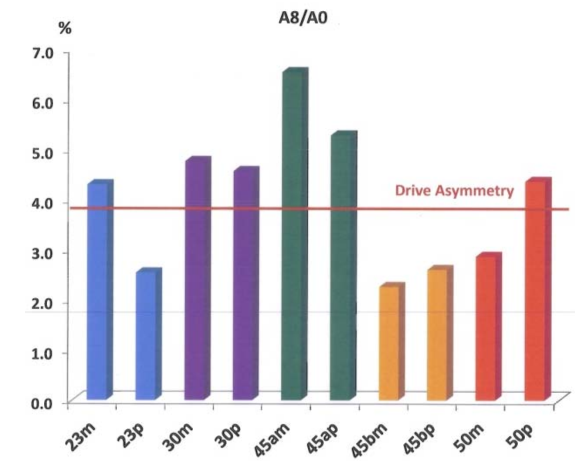
The National Ignition Facility

- Far outer cones can be used to swing P2 in the positive direction

- 1 Degree corresponds to a 17 μm shift on the capsule surface







Los Alamos NATIONAL LABORATORY EST.1943

Target Physics Requirements

The National Ignition Facility

- **The target must provide a reproducible platform from which 4π mix uniformity and increased mix from defects can be deduced (in future experiments)**
  - **Target shell thickness must be known to within <0.5 μm to keep the shot-to-shot yield variation to less than 10%**
  - **Target fill gas (D_2) pressure at shot time must be known to within ± 0.1 atm to keep its effect on yield to less than ± 5%. (Capsule evacuated of air prior to D_2 fill) (dY/dP = 36%/atm with mix)**
  - **Capsule positioning to the NIF spec of 30 μm from TCC will keep changes in capsule asymmetry to less than 5% (at $R=R_0/2$) of the nominal 4% PDD induced asymmetry and yield variations to less than 5%**

Los Alamos NATIONAL LABORATORY EST. 1943

Capsule Fill Pressure Requirements

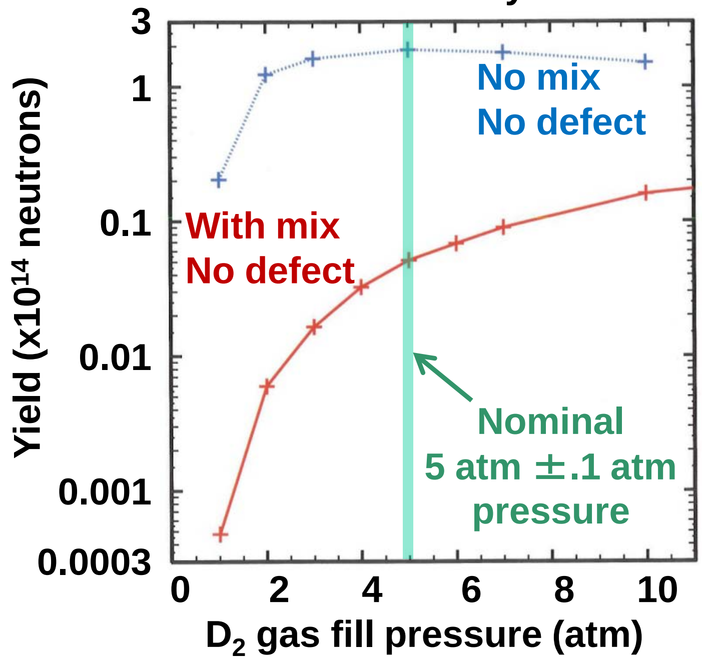
The National Ignition Facility

- Performance of the DIME capsules (42 μm thick, 2.2 mm ∅ CH, 5 atm D_2 gas fill, PDD laser drive at 700kJ changes significantly when mix is included in the simulations

- When mix is included, the yield becomes more sensitive to fill gas pressure
(dY/dP = 36%/atm)

- Our equatorial defect (80μm wide x 10 μm deep) will reduce the yield by an additional factor of 5-10

Calculated 1-D yields



- Plain capsule expected yield = 1.5×10^{12}

- Defect capsule expected yield = 2×10^{11}

- Using de-rating factors from Omega DIME shots and NIF exploding pusher experiments, yields in the 1×10^{11} – 2×10^{12} are expected for these D_2 shots

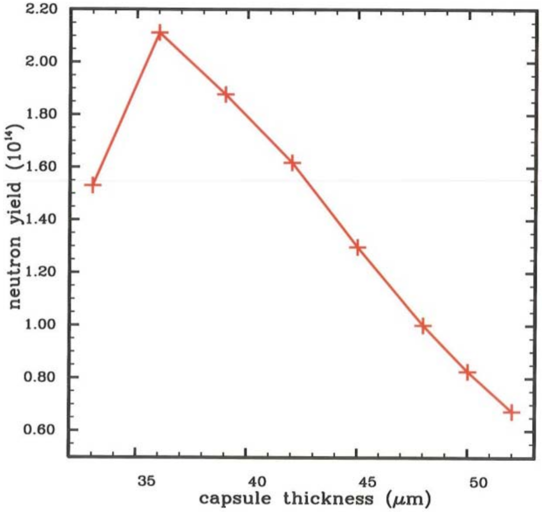
Los Alamos NATIONAL LABORATORY EST. 1943

Capsule Physics Requirements

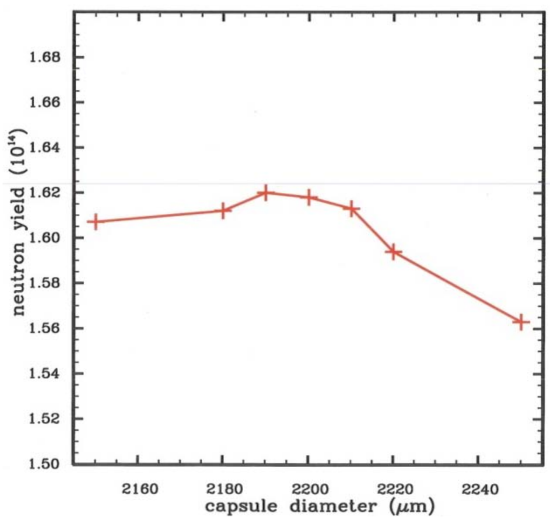
- **Capsule shell tolerances at shot time are:**

Shell thickness:	**Nominal (42 μm) ± 0.5 μm**
Shell diameter:	**Nominal (2.2 mm) ± 20 μm**
Ge dopant:	**Nominal (1.5%) ± 0.1%**
Ge layer thickness:	**Nominal (2 μm) ± 0.1 μm**

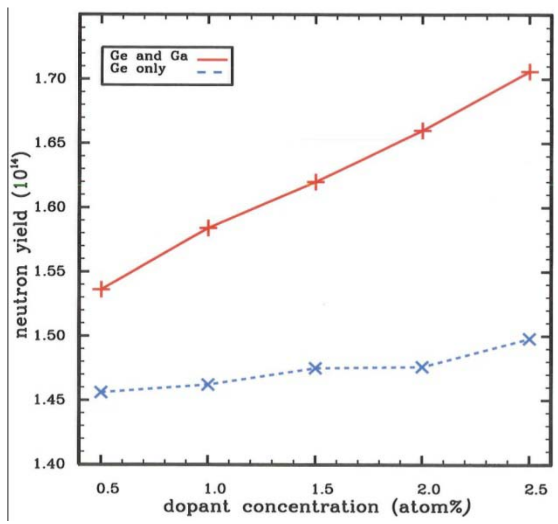
Yield vs Shell thickness



Yield vs Shell diameter



Yield vs Dopant atom %



- **These results do not include mix**

Follow on experiments will measure mix

The National Ignition Facility

- **MMI spectral imaging of single and dual doped CH capsules for mix layer assessment**

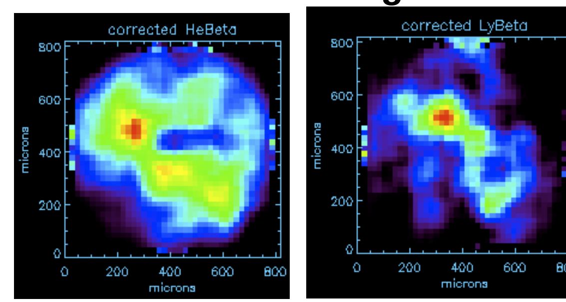
- **Areal image backlighting to determine r(t)**
(Note: A flat field shot would be useful to set the gains for these shots)

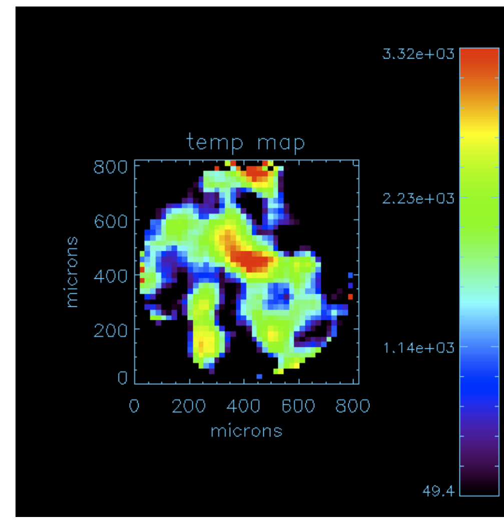
- **Initial PDD symmetry measurements using equatorial backlighting and polar view self-emission**

- **D_2 fill at TCC of PDD CH capsules**

- **Defect capsule imaging**

Ω-MMI images





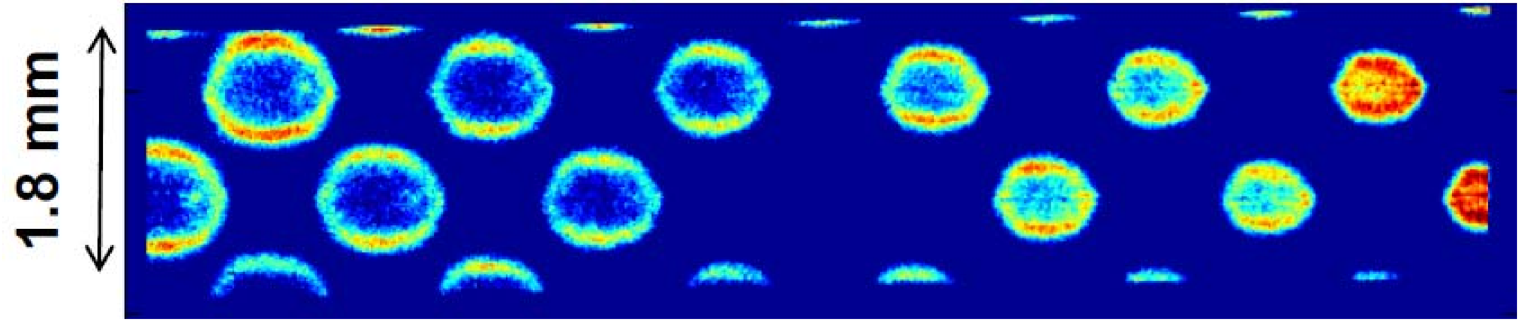
DIME in FY12-13 will focus on PDD symmetry-dependent mix and moving burn into the mix region for validation of mix/burn models

We have examined existing NIF PDD data to provide confidence on our symmetry predictions at R_{25}

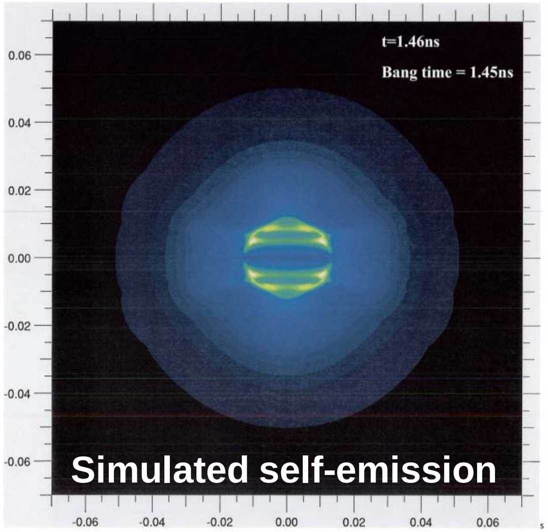
The National Ignition Facility

- Recent NIF direct drive shot showed **P2/P0~-20%** symmetry at ~ ¼ radius (enable by reduction of Kapton from 2500 microns to 150 microns)

NIF shot N120328 with 150µm Kapton, D. T. Michel, S. LePape, A. Shvydky, D. H. Froula



Hydra simulation of this 130kJ, 1.56mm∅, 4.4 µm thick glass capsule with 10 atm DT gas produces a similar asymmetric result at a simulated bang time of 1.45ns



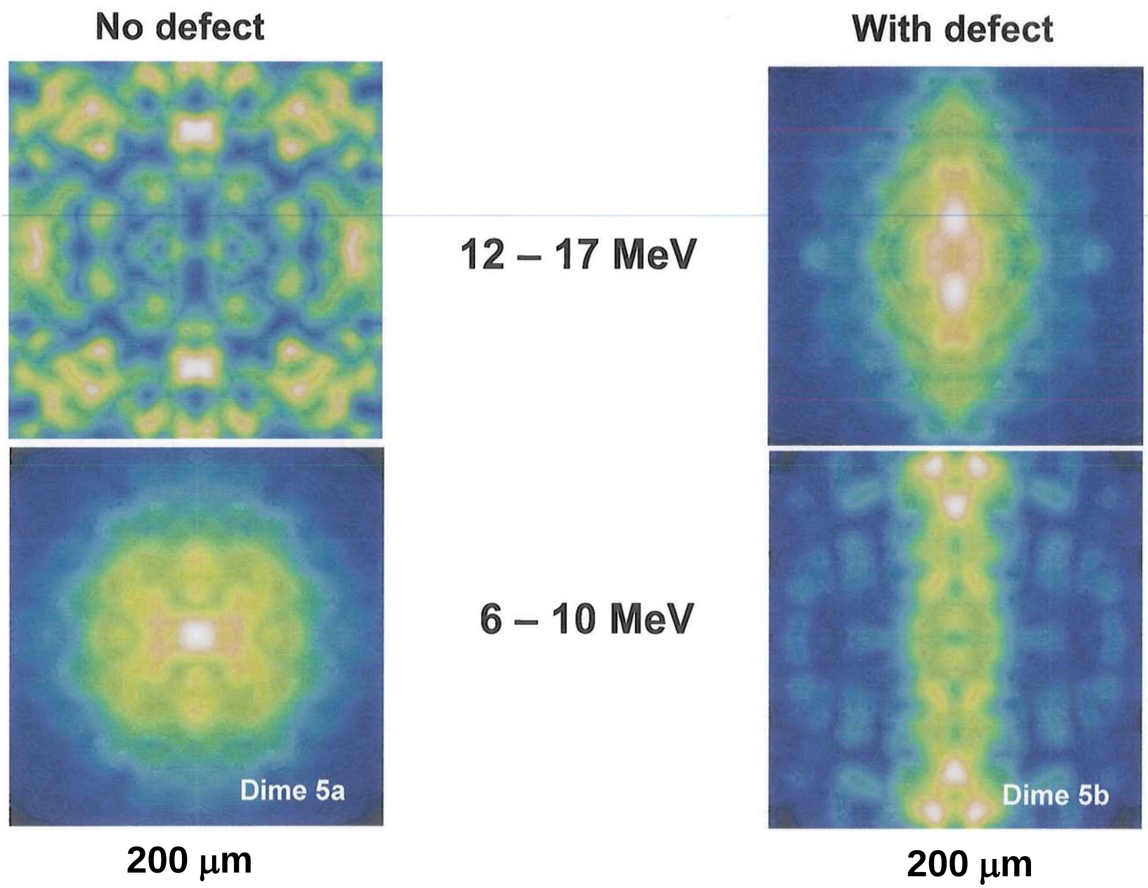
Simulated Legendre
<u>mode amplitudes</u>
P2/P0 = -19%
P4/P0 = 17%
P6/P0 = 15%
P8/P0 = -22%
(updating to 10atm)

Los Alamos NATIONAL LABORATORY EST.1943

We are currently in the design phase for our late FY13 CD-T_2 NIF shots

The National Ignition Facility

- **Simulations being conducted with both Eulerian and Lagrangian codes**



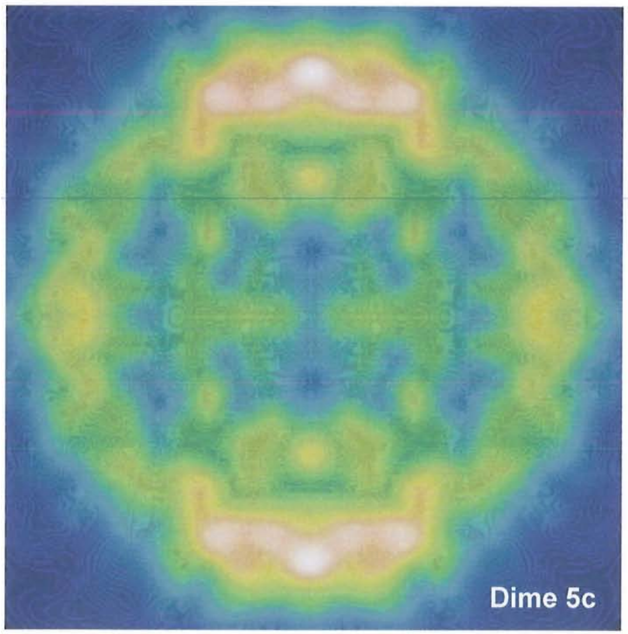
Los Alamos NATIONAL LABORATORY EST. 1943

Drive energies ≤1 MJ are being considered to optimize yield for NIS imaging

The National Ignition Facility

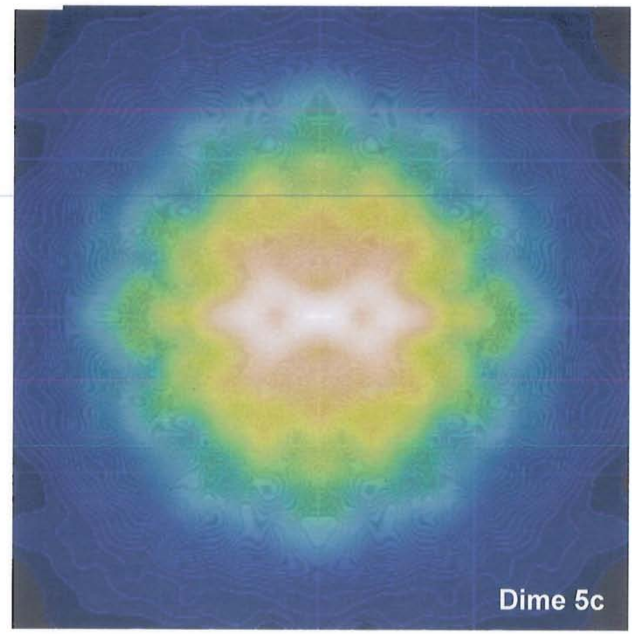
700kJ drive

12 – 17 MeV



$n=1.2x10^{13}$

6 – 10 MeV



$n=1.4x10^{13}$

Neutron field of view:
200 µm x 200 µm

Los Alamos NATIONAL LABORATORY EST.1943

Laser Configuration

The National Ignition Facility

Laser Parameter	Value	Tolerance
1) Energy range per beam	High: 4.17 kJ Low: 3.65 kJ BL: 4.3 kJ	± 0.3 kJ rms
Quads needed	48	Can lose 1 quad, NOT BL or 50 or 135 cone
2) Pulse length	2.15 ns FWHM	±100 ps
3) Pulse shape	LPOM_SQUARE pulse shape	Nominal
4) PB - Provide expected 2ns power balance as a function of time	Nominal	
5) SSD bandwidth	45 GHz	
6) CPP design	Current NIF configuration	
7) Pulse delays	Q16T and Q12B: 1.5 ns	±100 ps
8) 2-color wavelength offset	Current values	
9) Beam pointing	Details in CMT	100 μm RMS
10) Beam focus	Details in CMT	+/- 2 mm

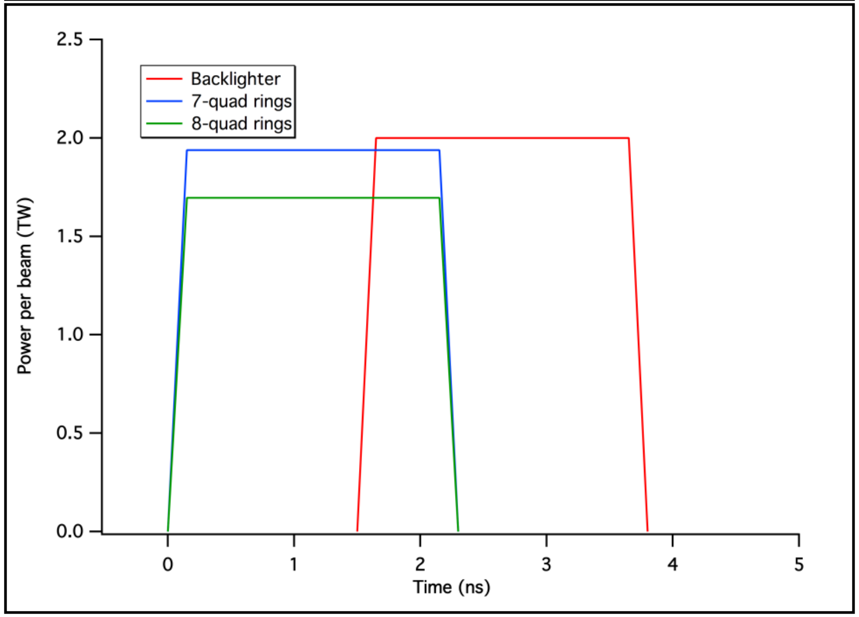
Total Energy Requested: 734.4 kJ
Drive energy: 700 kJ
Backlighter energy:34.4 kJ

Los Alamos NATIONAL LABORATORY EST.1943

Pulse shape

NIF — The National Ignition Facility

NIF Laser Power per beam



- Quads Q16T and Q12B will be used for backlighting at 4.3 kJ/beam in a 2.0 ns flat top LPOM-square pulse, delayed 1.5 ns relative to drive beams
- Other beams in the 50° and 135.5° cones operate at 4.17 kJ/beam
- All other quads operate at 3.65 kJ/beam

LPOM_SQUARE_2.15 pulse has 150 ps rise and fall, 2 ns flat top

Los Alamos NATIONAL LABORATORY EST. 1943

Beam rules of engagement

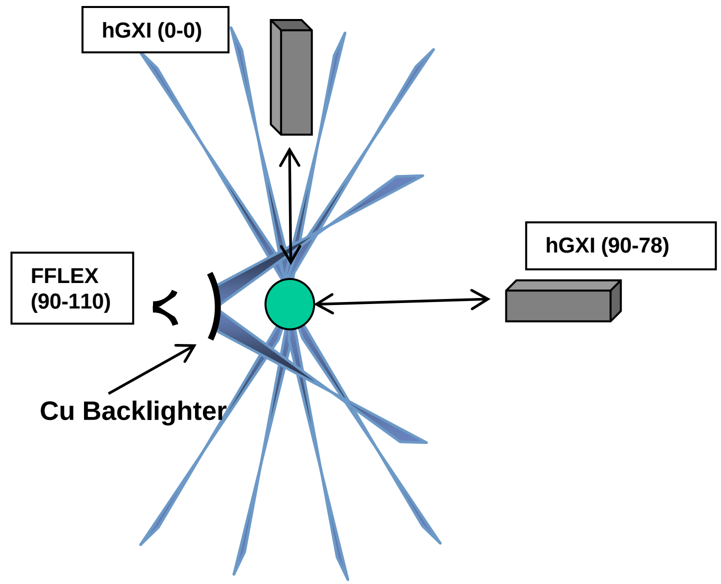
The National Ignition Facility

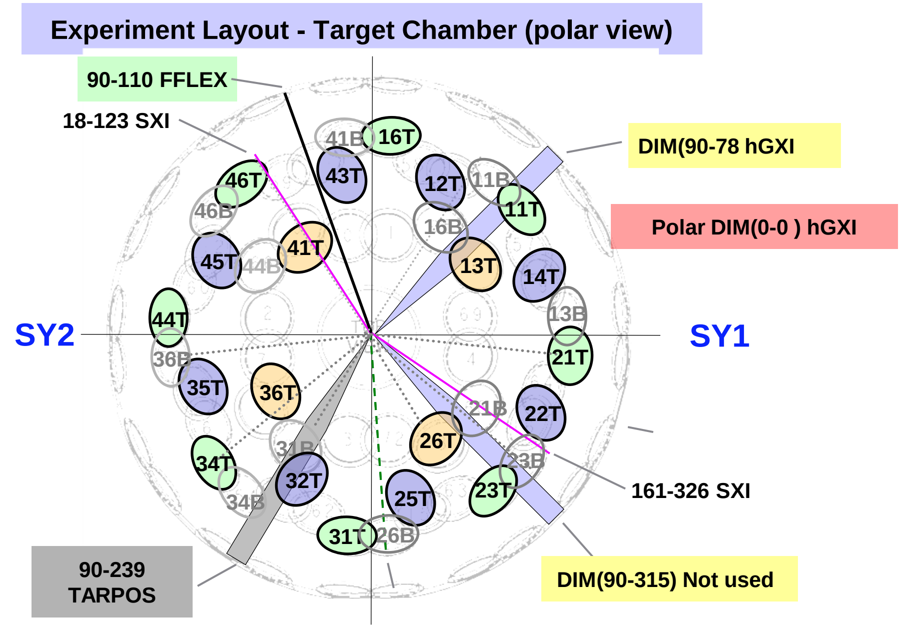
Beam Availability for DIME-12A

	Beams	Rule	Justification
Priority 1	**16T, 12B**	The beams belonging to these quads must be on the shot	Backlighter quads are required for sufficient signal
	11T, 21T, 31T, 44T, 23T, 34T, 46T, 22B, 32B, 43B, 14B, 25B, 35B, 45B	The beams belonging to these quads must be on the shot	Loss of beams from cones that BL were pulled from would induce too much asymmetry
Priority 1A	**All other quads**	Up to 1 quad in this group may not be available for the shot	Calculations show the asymmetry due to loss of one quad; images with one quad lost could still be used to compare to simulations
Priority 2			
Priority 3			
Total	All quads together	**A maximum of 1 quad may be unavailable**	Shot is still useful with 45 drive quads

Los Alamos NATIONAL LABORATORY EST. 1943

Diagnostic summary





hGXIs operate in hGXI4-H-1000-12.7-4X config

Diag	DIM	Priority	Type	Calib/Chara
nToF 4.5 DD	64-309, 64-330	1 2	3	Pre-shot
nToF 20	90-174	1	3	Pre-shot
NAD-DIM (In)	0-0	2	3	Pre-shot
SPBT		2	3	Pre-shot

Diag	DIM	Priority	Type	Calib/Chara
hGXI	0-0	1	3	Pre-shot
hGXI	90-78	1	3	Pre-shot
FFLEX	Fixed	2	3	Pre-shot
FABS/NBI	Fixed	1	3	Pre-shot
SXI	U, L	2	3	Pre-shot

Summary: We will obtain information from the DIME-12A shots needed to perform our mix experiments on NIF

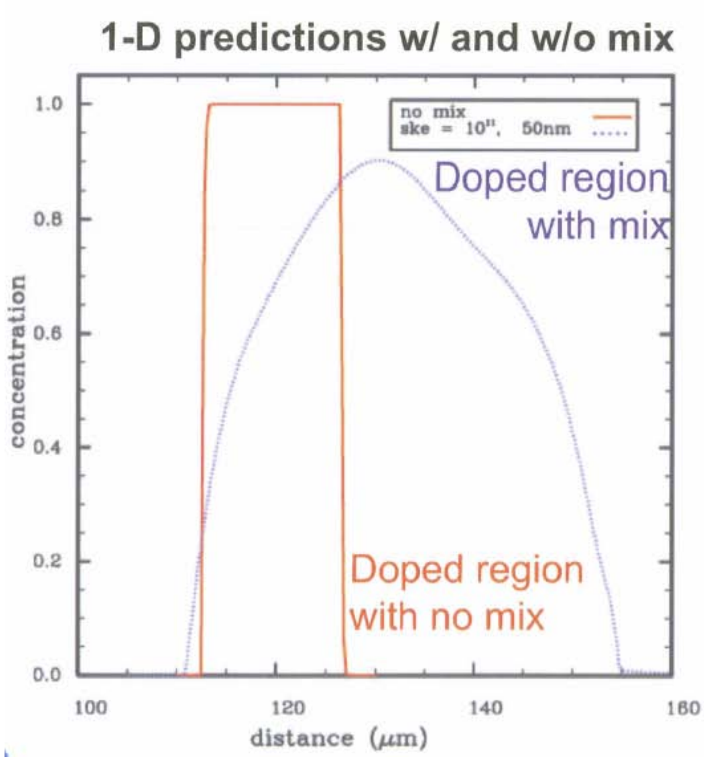
The National Ignition Facility

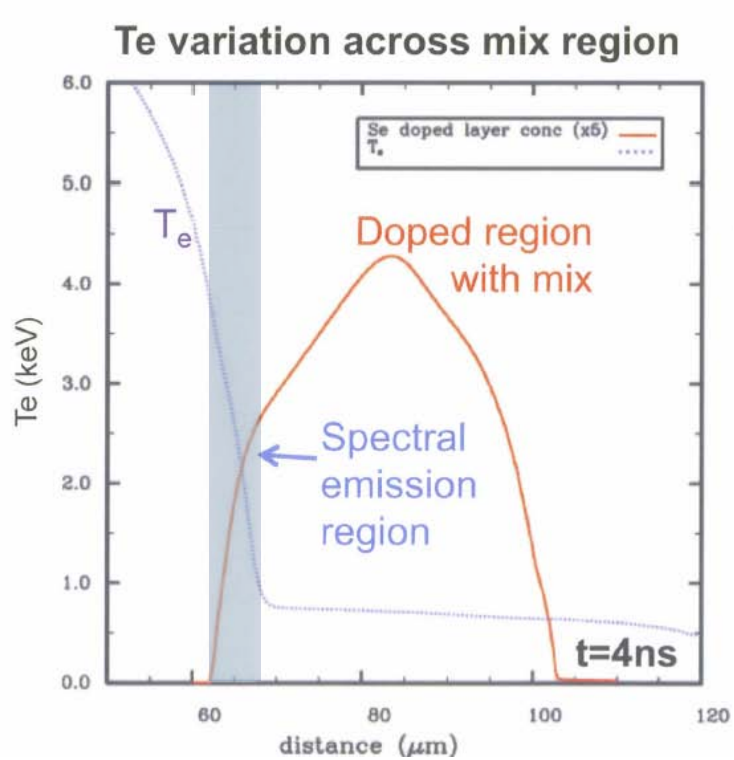
- Symmetry
  - Will measure P_2/P_0 from backlit imaging
  - Will measure M_4/M_0 from self-emission of imploded core
- Bang time
  - Expect to get bang time from multiple sources including:
    - Timing of images on hGXIs
    - South pole bang time detector
    - nToF bang time detector
- Yield
  - Neutron yield will be measured from nToF 4.5 DD and from NAD-DIM (In)

Los Alamos NATIONAL LABORATORY EST. 1943

Simulations with BHR mix have been performed to assess its effects on MMI spectra

- BHR predicts 10's of micron mix widths in no-defect regions (4π mix)
- Mix drives the doped shell material into the hot gas where dopants spectrally emit
- Mix width determined by deepest dopant layer that "uniformly" emits

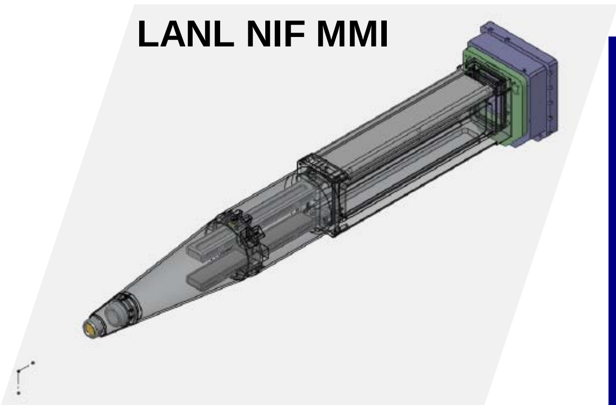


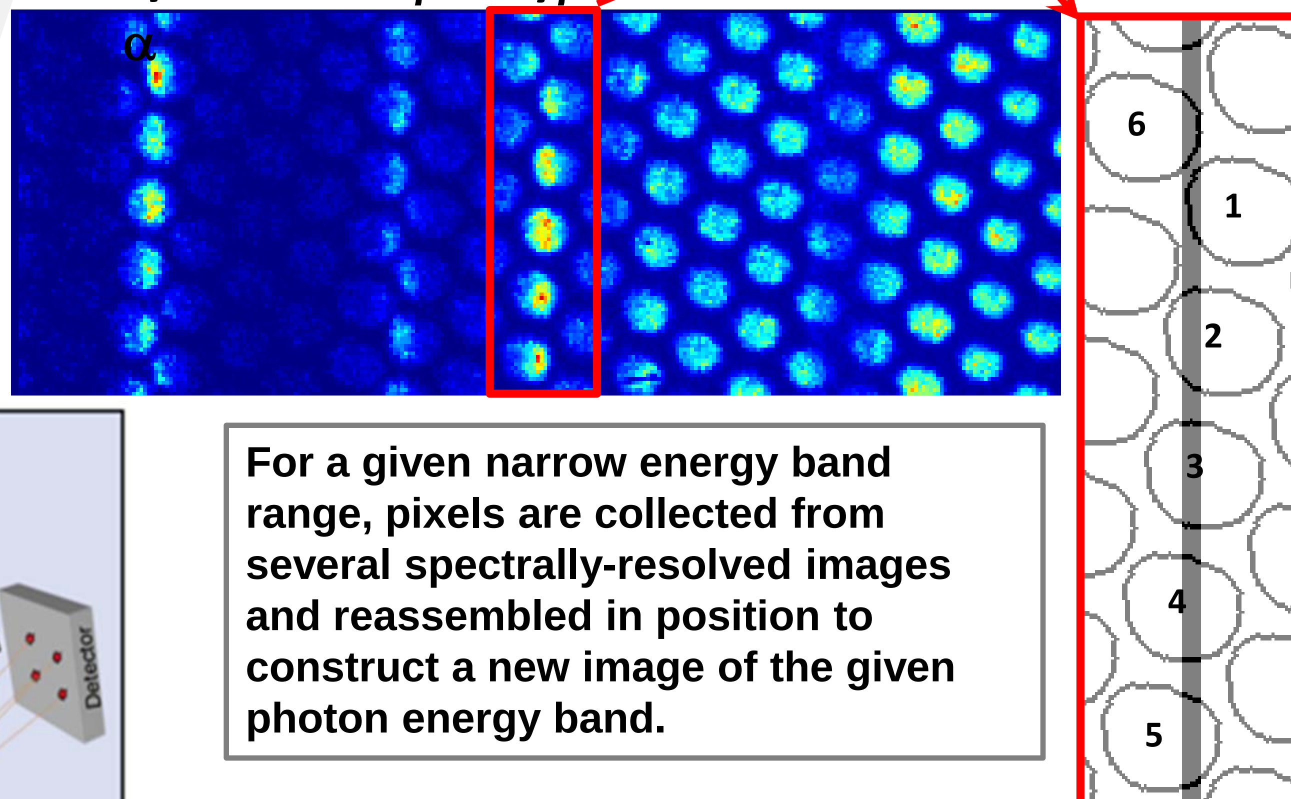


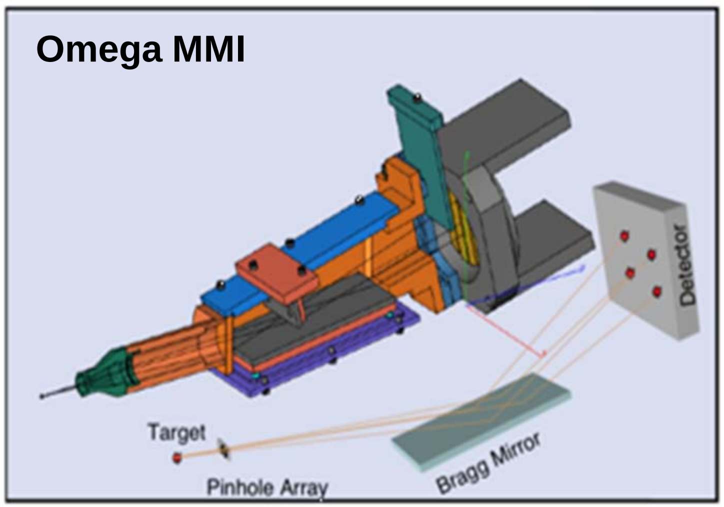
Simulations courtesy of Paul Bradley

Los Alamos NATIONAL LABORATORY EST.1943

LANL is building an MMI "snout" for the FY12 NIF DIME Campaign to collect spectrally resolve images from 8-13keV







For a given narrow energy band range, pixels are collected from several spectrally-resolved images and reassembled in position to construct a new image of the given photon energy band.

R. Tommasini, J. Koch, N. Izumi, L. Welser, R. Mancini, J. Delettrez, S. Regan and V. Smalyuk, Rev. Sci. Instrum. 77, 10E303 (2006)

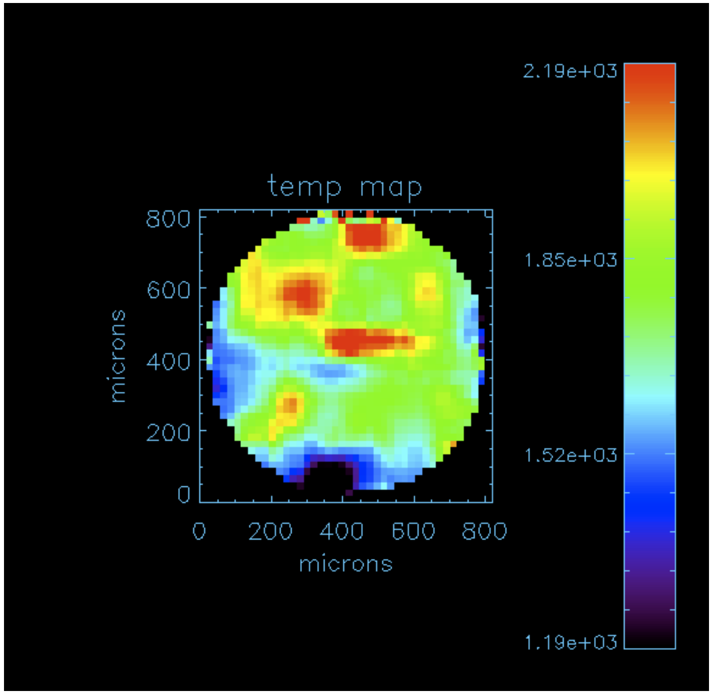
T. Nagayama, R. Mancini, R. Florido, R. Tommasini, J. Koch, J. Delettrez, S. Regan, V. Smalyuk, L. Welser, and I. Golovkin, Rev. Sci. Instrum. 79, 10E921 (2008)

T. Nagayama, R.C. Mancini, R. Florido, R. Tommasini et al, J. Applied Physics (submitted for publication)

DIME prepared for NIF by demonstrated its PDD mix platform on Omega including MMI imaging of mid-Z doped layers, defects and fill tubes

•Omega MMI data is being used to estimate temperatures in the capsule and has revealed pentagonal laser imprinting of mix in the imploded core

Temperature map derived from Ti dopant line ratios



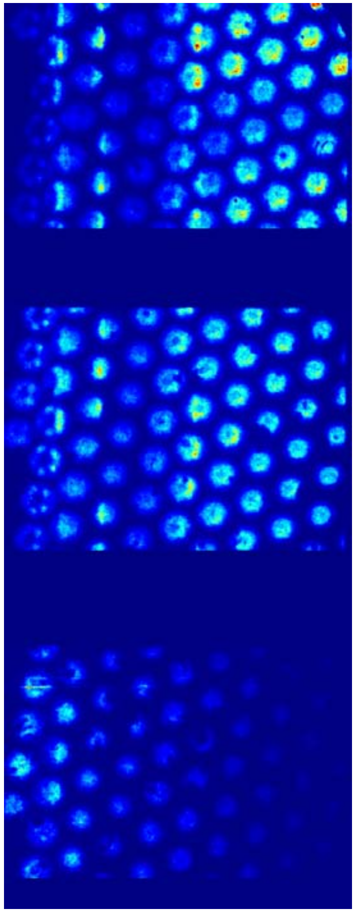
DIME Omega polar MMI Data

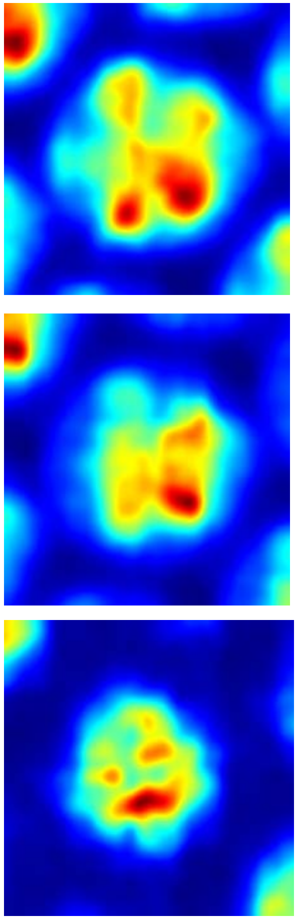
Post-processed Heα images

Frame 1

Frame 2

Frame 3





Postprocessed images courtesy of Rahul Shah, LANL, and Roberto Mancini (and his UNR Analysis Team)

DIME Summary

The National Ignition Facility

- The DIME campaign will measure defect-hydro-burn effects on NIF

- DIME has demonstrated keys aspects of these experiments on Omega
  - ✓ Capsules with and without defects have been shot
  - ✓ Capsules shot using PDD geometry with good symmetry
  - ✓ Capsules with 2 different doped layers shot and MMI spectra recorded
  - ✓ Capsules with fill tubes shot showing perturbation is tolerable

- LANL NIF shots will use backlighting and MMI diagnostics
  - \- LANL design for a Ge-Ga MMI being built
  - \- Working with UNR on MMI data reduction
  - ✓First set of GA built targets now at LLNL

- LANL cross code analysis of PDD implosions useful for ICF code validation
  - ✓ 3-D Hydra calculations already have assessed current laser drive symmetry
  - ✓ LANL MMI simulator now being used on rad-hydro results
  - \- Experiments will validate BHR mix model for convergent implosions

- FY12 DIME shots lead to D_2 tuning shots and CD-T_2 mix/burn shots in FY13

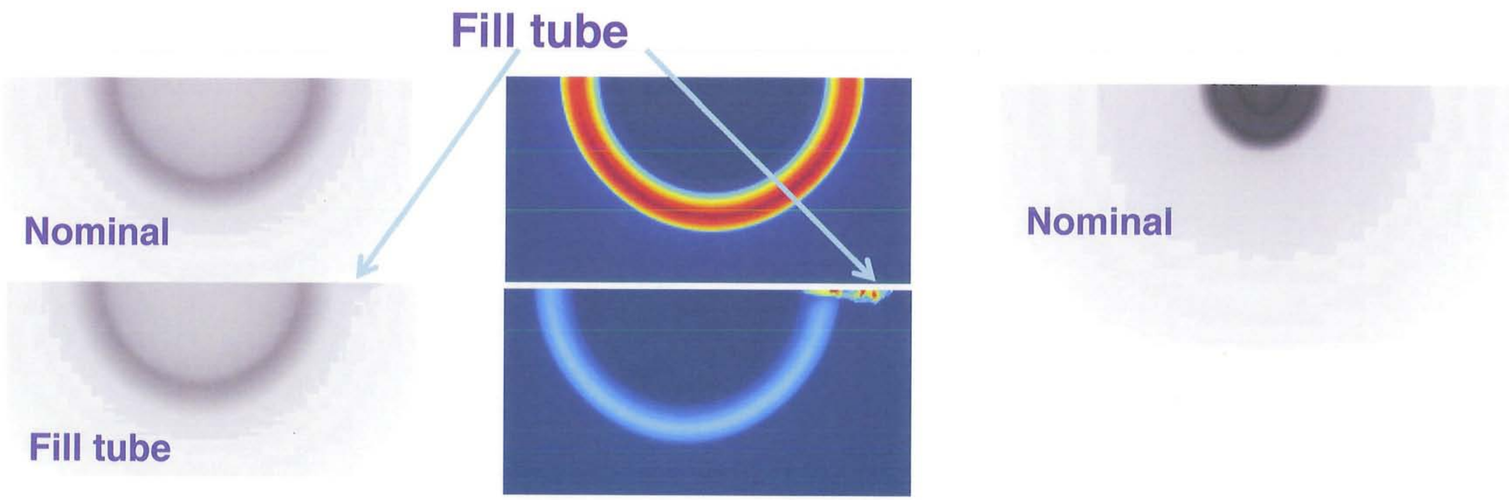
Los Alamos NATIONAL LABORATORY EST.1943

BACKUP Slides

We are modeling the fill tube for its effects

The National Ignition Facility

The fill tube has only a small effect near the equator



At 1.18 ns,
V backlighter image
and density plots
Interior of radiograph at 680 μm

At 2.10 ns,
V backlighter image
Dark features at 270 and 170 μm

Los Alamos NATIONAL LABORATORY EST.1943

Capsule P_2 can estimated from its major and minor radii

The National Ignition Facility

For a capsule with only a P_2 asymmetry component, its radius is given by

$$r(\theta) = A_0 P_0(\cos\theta) + A_2 P_2(\cos\theta)$$
$$= A_0 + A_2\left[\frac{3}{2}\cos^2\theta - 1/2\right]$$

Legendre Polynomials

$$P_0(\cos\theta) = 1$$
$$P_2(\cos\theta) = \frac{3}{2}\cos^2\theta - \frac{1}{2}$$

The polar and equatorial radii are

$$r_p = r(0) = A_0 + A_2\left[\frac{3}{2} - \frac{1}{2}\right] = A_0 + A_2$$
$$r_e = r(90^\circ) = A_0 + \frac{1}{2}A_2$$

The Legendre amplitudes can be expressed in terms of these radii as

$$A_2 = \frac{2}{3}\left(r_p - r_e\right)$$
$$A_0 = \left(r_p + 2r_e\right)/3$$

such that the fractional A_2 can be expressed

$$\frac{A_2}{A_0} = \frac{r_p/r_e - 1}{r_p/2r_e + 1}$$

yielding A_2/A_0 values of 0.5 and -0.4 for r_p/r_e ratios of 2 and ½, respectively

Los Alamos NATIONAL LABORATORY EST. 1943