OMEGA shot rate allows innovative diagnostics and targets to be developed, opening new areas of science

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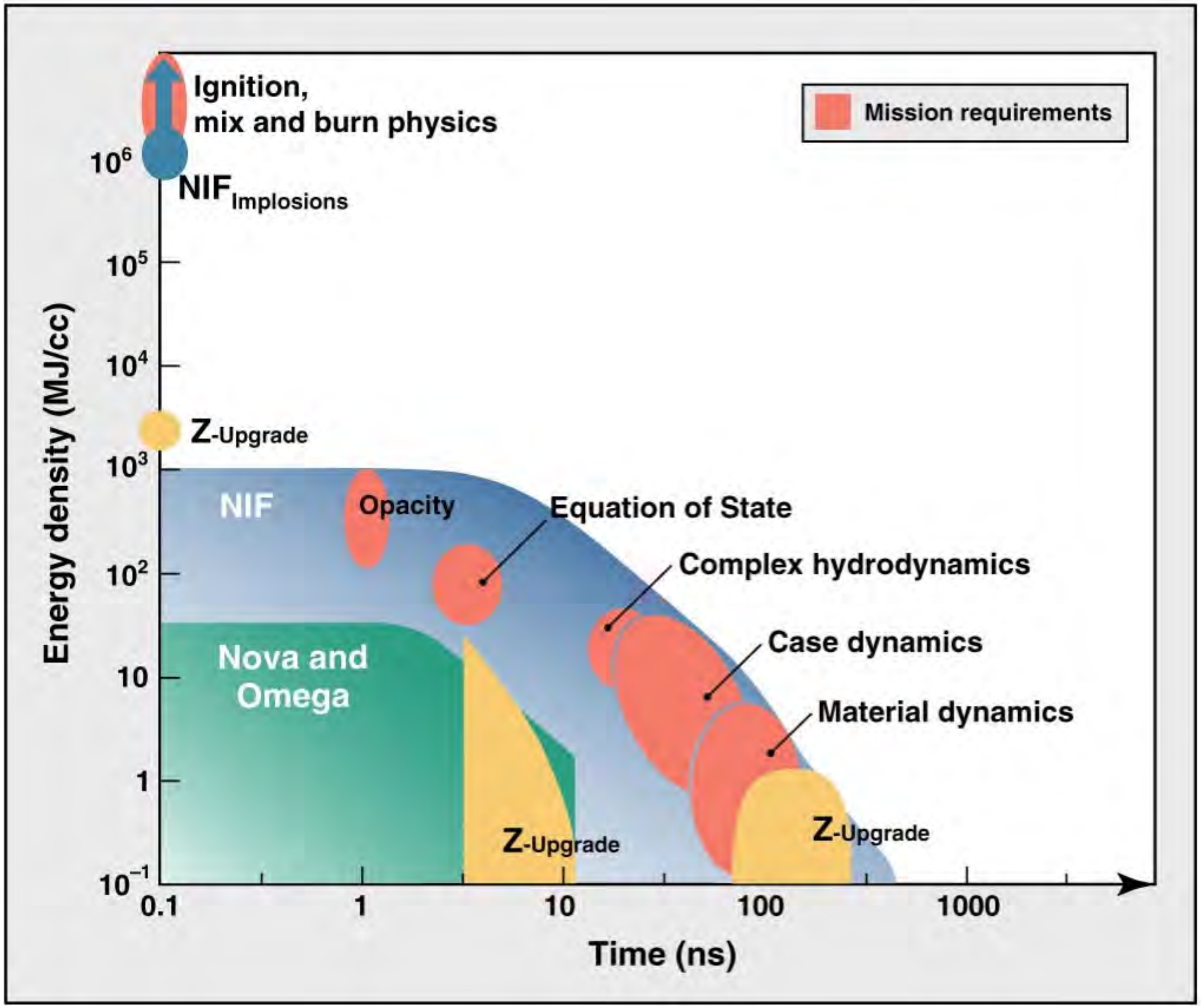
NIF Diagnostics.

OLAG, April 28, 2010

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

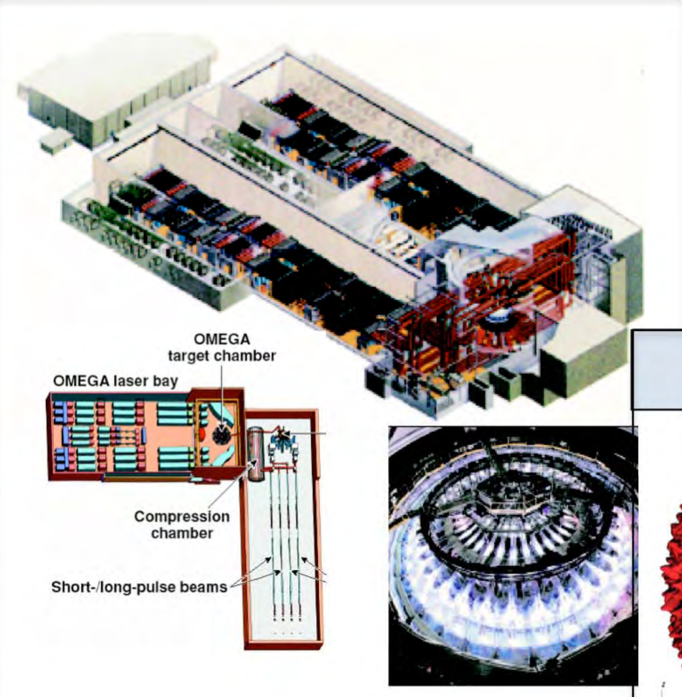
NIF opens new windows in HED science



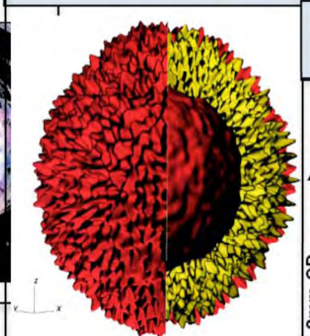
As well an important role for OMEGA is to develop techniques / diagnostics for NIF

Advances in High Energy Density Physics Require:

Drivers

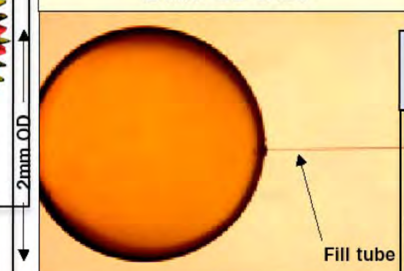


Theory



Targets

6 µm OD fill tube in
2 mm OD shell



Diagnostics

Given a driver innovation in targets and diagnostics drive new science

The HED diagnostic effort on NIF is international

LLNL
- FABS,NBI
- Dante I & II
- Visar
- SXD
- HEXRI
- RadChem1
- hGXI
- ARIANE
- DIXI

NSTec
- Calibration

LBNL
- Calibration
- Rad. Chem.

LLE
- NToF
- 4ω fidu system
- MRS, NADS
- SPBT

AWE
- FFLEX

MIT
- MRS
- WRF

LANL
- GXD
- γ burn
- Rad. Chem. II
- n imaging

SNL
- X-ray burn
- DISC
- NAD
- Xtal imager

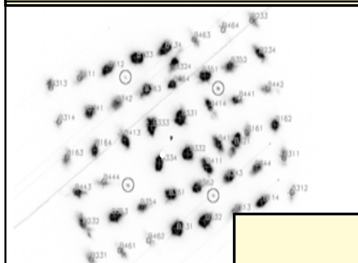
Duke
- Calib.

CEA
- N imaging

We also work with MFE- High Temperature Plasma Diagnostic Conference, Wildwood NJ , May 16-20

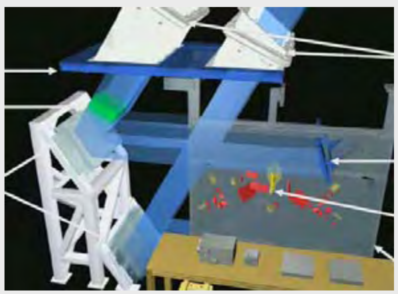
Most of the NIF diagnostics were developed on Nova or OMEGA

Laser IPT



• **4 target chamber diagnostics**

Energetics IPT



F

c

Energetics diagnost
NEL-recommissione

• **9 diagnostics**

Capsule IPT

Gated
X-ray
Detect

Capsule diagnostics, developed on OMEGA, used NEL

• **4 diagnostics**

• **19 diagnostics**

Ignition IPT

UGT experience, development on OMEGA

Installing 39 NIF Diagnostics up to 2011, most of them developed/tested on OMEGA

NIC

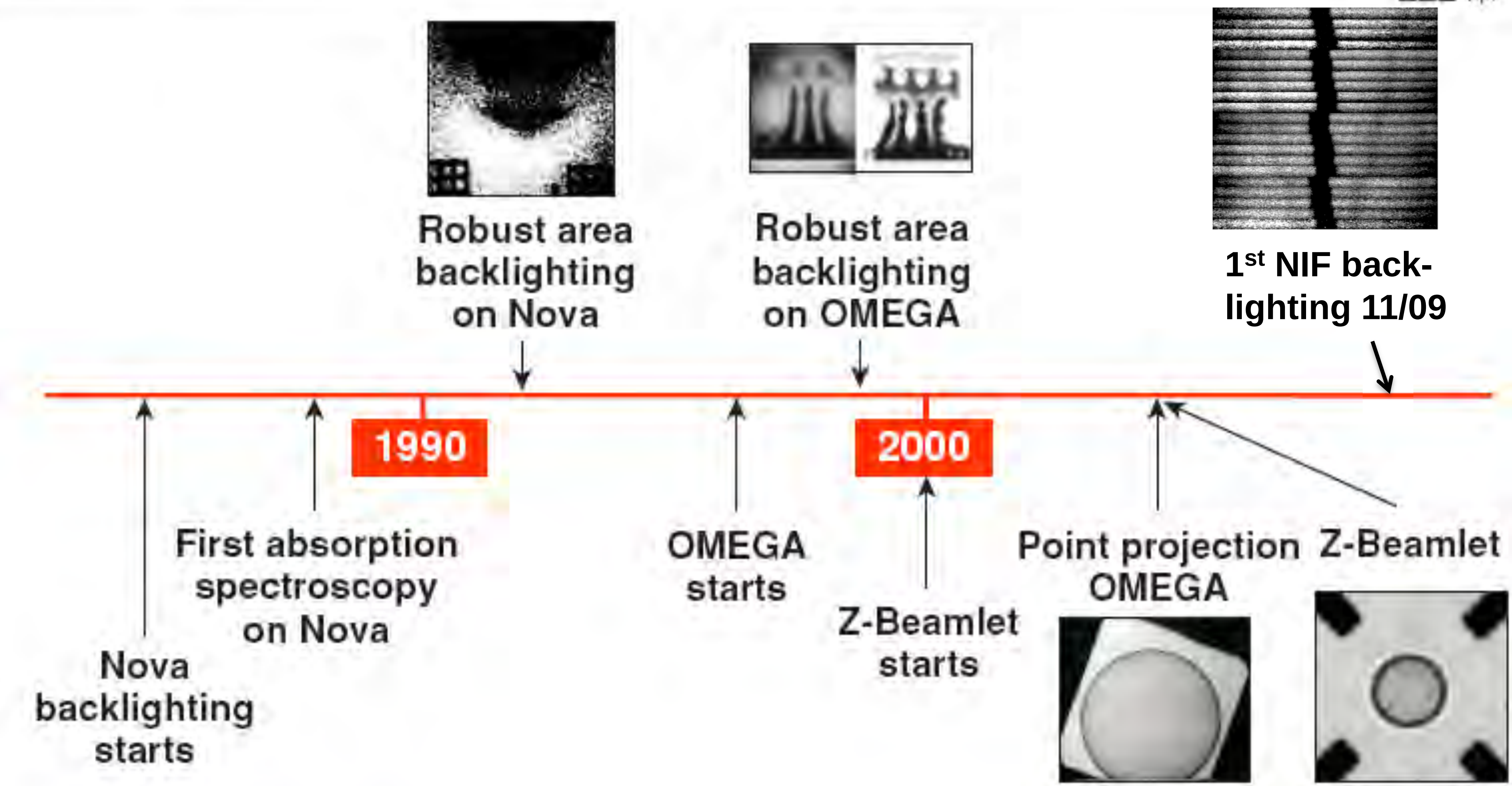
Diagnostic	Acronym	Purpose and Function	Works
Static x-ray imager	SXI(upper) SXI (lower)	Provides time integrated images of low energy (3-7 keV) x-ray emission and is used to survey hohlraum experiments and pointing of laser beams	2009
Streaked X-ray Detectors	SXD1 SXD2	Measures with continuous time resolution x-ray emission from the targets and used to synchronize the arrival time of laser beams on targets	2009
Broad-band, time-resolved x-ray spectrometer	DANTE 1 DANTE 2	Measures the soft x-ray flux vs time and primarily used to determine the radiation temperature in the hohlraum	2009
Full Aperture Backscatter Station	FABS 31B-in FABS 36B-out	Light backscattering stations that measure the angular, temporal and spectrally resolved light backscattered into the focus lenses. One quad of beams on the inner cone 31B and one quad. on the outer cone 36B	2009
Near Backscatter Imager	NBI 31B-in NBI 36B-out	Light backscattering stations that measure the angular,temporal andspectrally resolved light backscattered near the focus lenses. One quad of beams on the inner cone 31B and one quad on the outer cone 36B	2009
Filter Fluorescer Diagnostic	FFLEX	Measures hard x-rays bands (10 keV to 400 keV) with time resolution on some channels from which the hot electron fraction can be inferred	2009
Time-Gated X-ray Detectors	GXD1 GXD2	Images x-rays with time resolution of 60 micron	
Thomson Scattering	TS	4ω Thomson scattering f temperature	
Velocity Interferometer For Any Reflector	VISAR	Measures the shock velo in the NIC ignition pulse	
VISAR/Streaked Optical Pyrometer	VISAR/SOP	Measures the timing of t	
DIM insertable Streak camera	DISC	Hardened x-ray streak c	
4ω fiducial	4ω Fidu	4 w fiducial for x-ray str	

Diagnostic	Acronym	Purpose and Function	Operational
Electromagnetic Power	EMP	Measures electromagnetic frequency spectrum in the target chamber	2009
Wedge Range Filter	WRF	Measures the energy of charged particle products (protons)	2009
Gamma Reaction History	GRH	Measures γ spectrum and time history. Used for bang time, burn hostory	2010
Hardened X-ray Imager	h-GXI	Measures spatially and temporally resolved x-ray emission from a imploding core containing THD fuel to determine core temperature and shape	2010
Hot spot x-ray Spectrometer	HSXRS	Measures x-ray emission from ablator dopants mixing into the hot core.	2009
X-ray Pinhole Camera	xPHC	Measures static x-ray images of implosions	2010
Neutron Time-Of-Flight	NTOF4.5- 4of	Four NTOFs located 4.5 m from TCC used to measure neutron yield, ion temperature, neutron bang time, γ history	2009
Neutron Time-Of-Flight	NTOF20- 2 of	Two NTOFs located 20 m from TCC used to measure neutron yield, ion temperature, and areal density (ρr).	2010
Magnetic Recoil Spectometer	MRS	Measures the absolute neutron spectrum between 6 and 30 MeV from which ion temperature, areal density (ρr), and neutron yield can be directly inferred	2010
Neutron Imaging	NI	Measures static neutron images of primary (14 MeV) and downscattered neutrons from a burning DT capsule to assess hot spot size and fuel asymmetry and from the downscattered fraction, the cold fuel areal density (ρr_{shell}).	2011
High Enegy X-ray Imager	HEXRI	In combination with ARC, measures spatially resolved x-ray scattering images of the cold fuel from which cold fuel areal density (ρr_{shell}) can be inferred	2011
Neutron Activation Detector	NAD	Measures the integrated neutron flux by activation of witness foils	2009
Advanced Radiographic Capability	ARC1	Advanced radiographic capability using ARC the short pulse laser to produce an x-ray blacklighting source to radiograpically image imploding capsule	2011
Radiochemical Diagnostic	RadChem-gas	Uses radiochemical separations and nuclear counting methods to measure neutron activation products produced from tracers embedded in the ablator shell of the target with gas sample collection	2011
Radiochemical Diagnostic	RadChem-solid	Uses radiochemical separations and nuclear counting methods to measure charged particle activation produced from tracers embedded in the ablator shell of the target with solid sample collection	
Dilation x-ray imager	DIXI	10 psec x-ray imager	2011

Installed

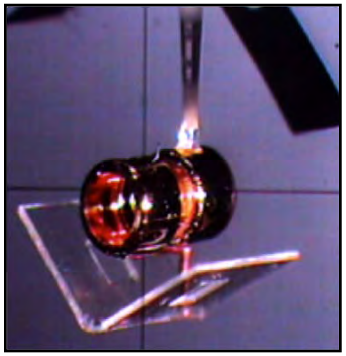
And there will be more

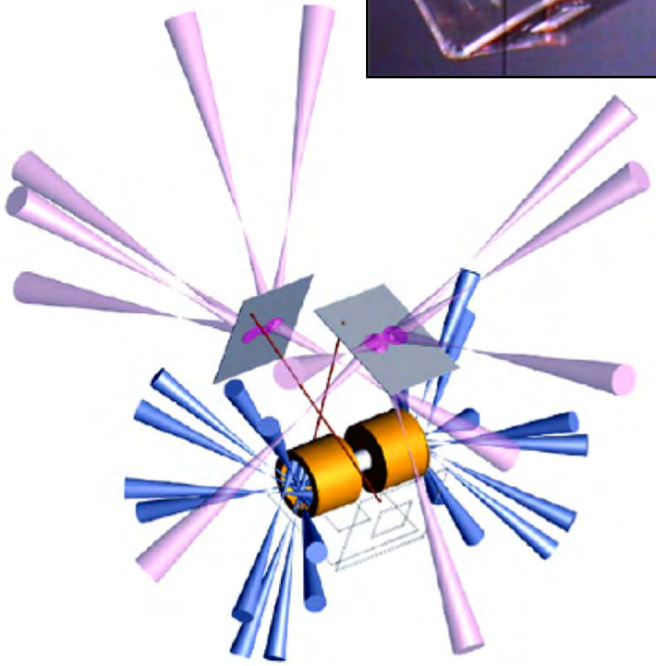
The technology for backlighting of laser plasmas takes time and shots to develop

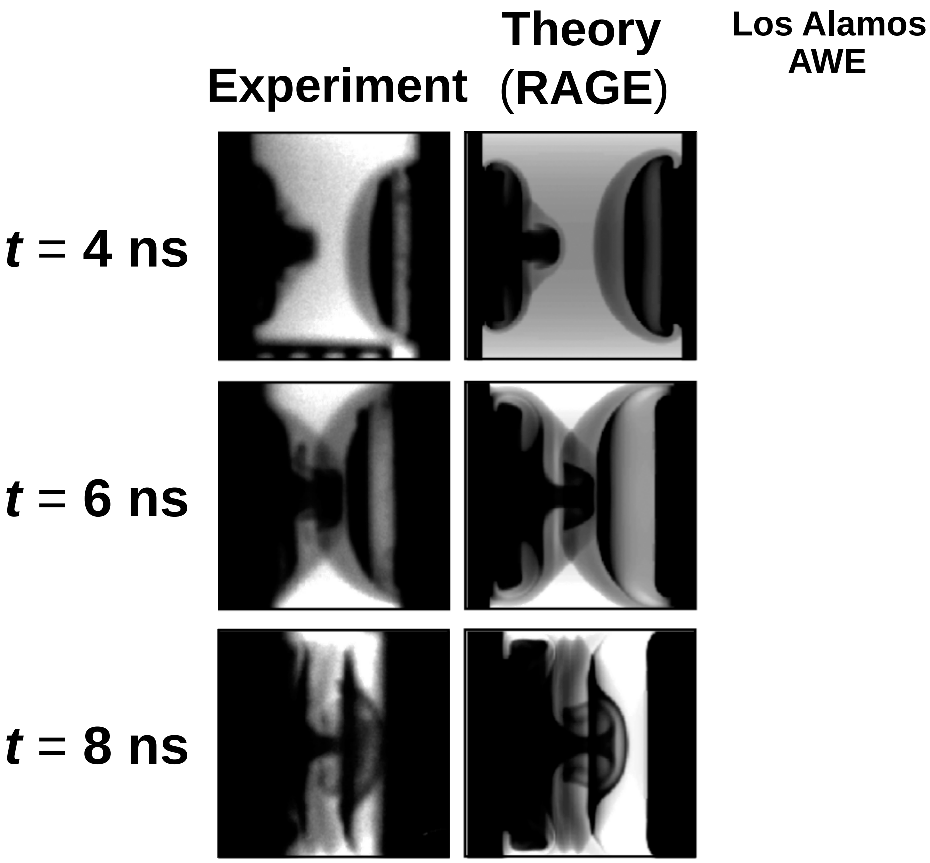


Point projection backlighting with thermal x rays is not yet routinely used; hard x-ray backlighting will have new problems.

Complex multi-target area back-lighter assemblies are routinely fielded on OMEGA

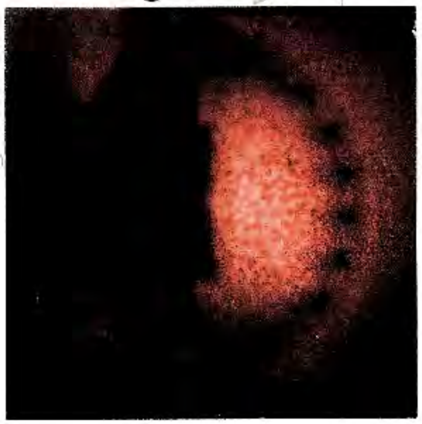






A wide range of hydrodynamic experiments have been performed on OMEGA for both stockpile stewardship and astrophysics

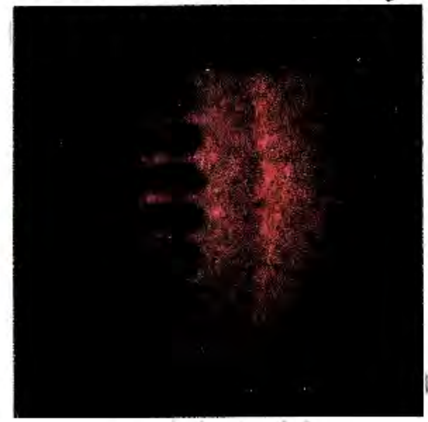
Instability at a spherically divergent interface



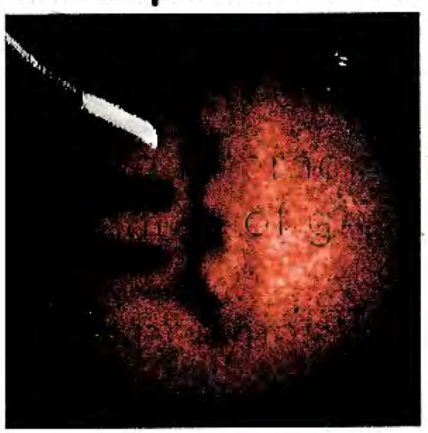
2D numerical simulation of supernova SN1987A

Muller, Fryxell, and Arnett, Astron. Astrophys. 251 (1991)

2D vs. 3D instability



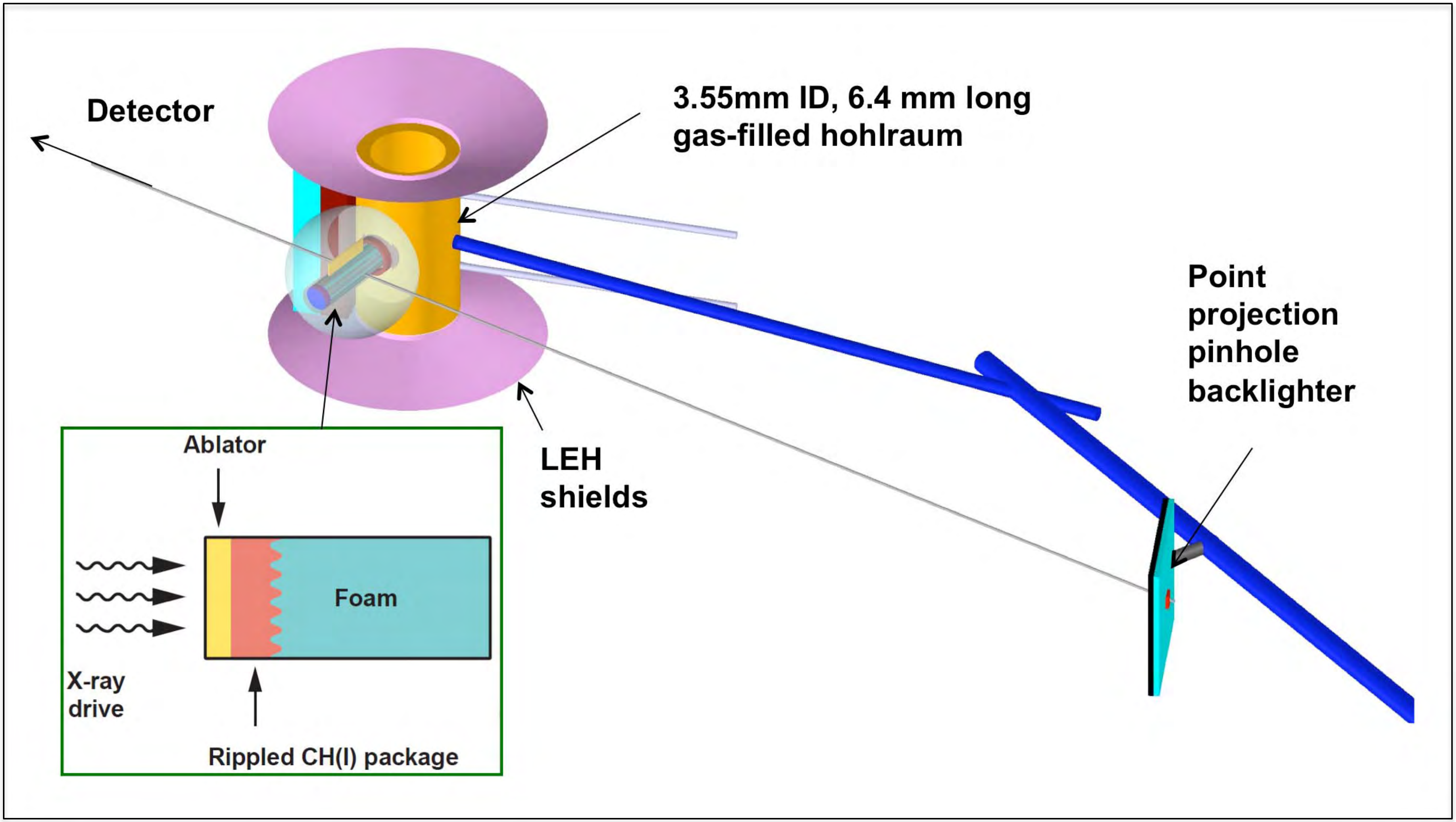
Coupled instability at multiple interfaces



Multi-mode instability

Radiographic images from recent experiments on Omega studying mixing in supernova explosions

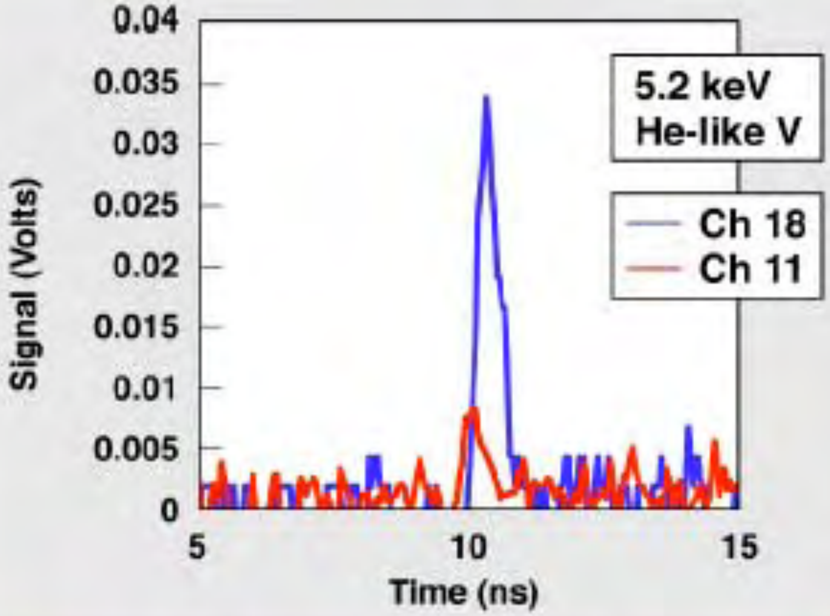
U of M: Supernova Radiatively Reduced Hydrodynamic Growth Experiment on NIF based on OMEGA experience



Possible because of technique development with OMEGA shots

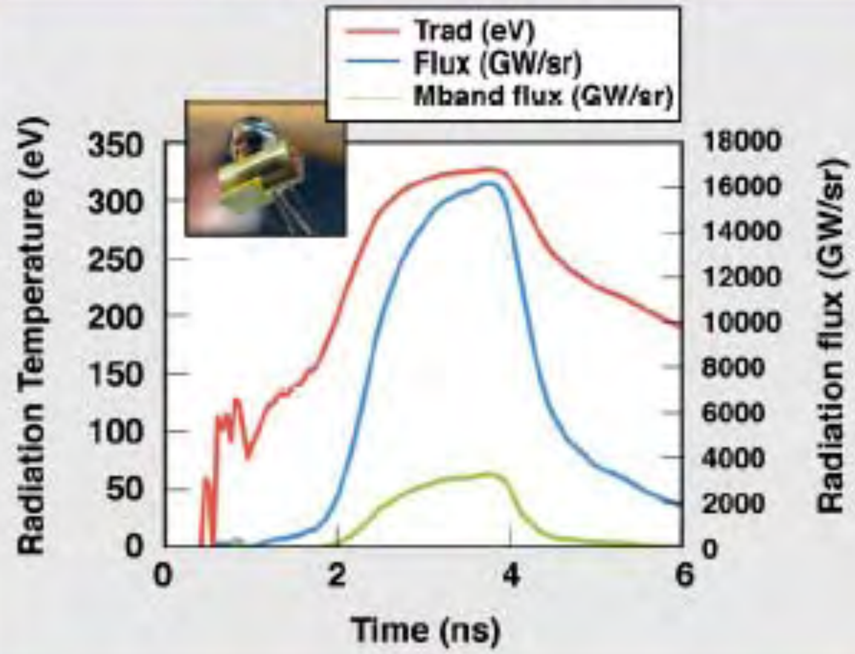
The first university experiments at NIF have been conducted (C. Kuranz et al., University of Michigan)

Backlighter development
October 27, 2009



Conversion efficiency of ~0.4% measured in both channels—agrees with expectation

Drive development
November 24, 2009

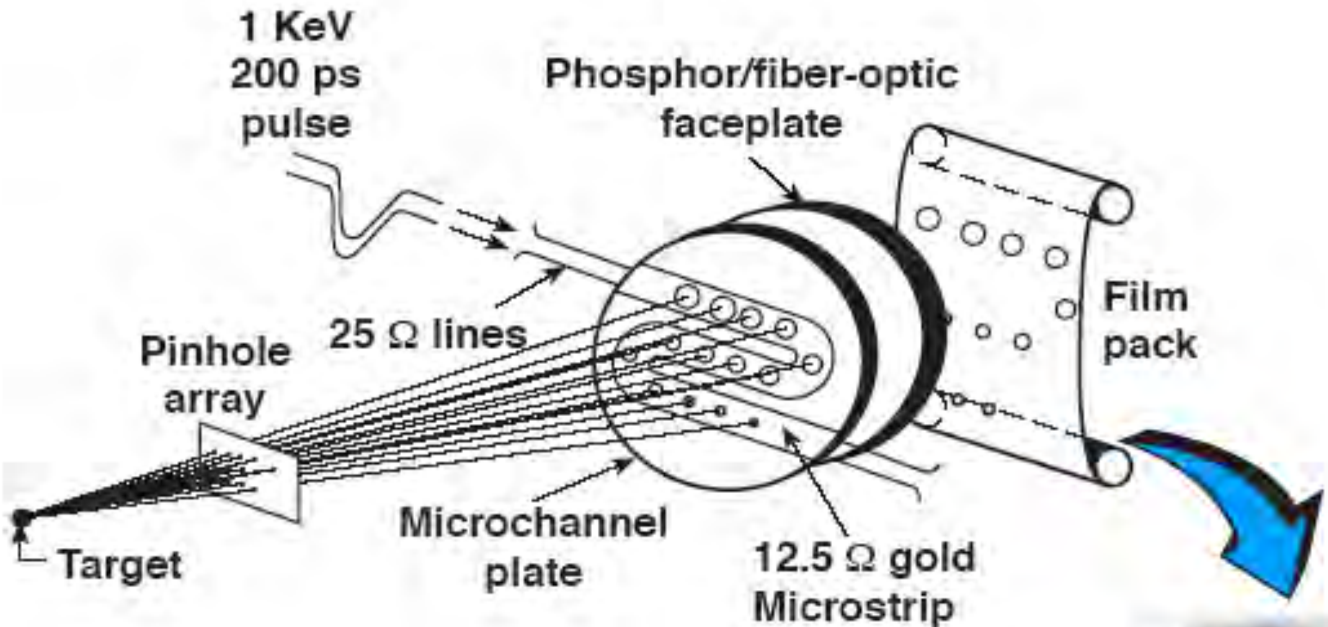


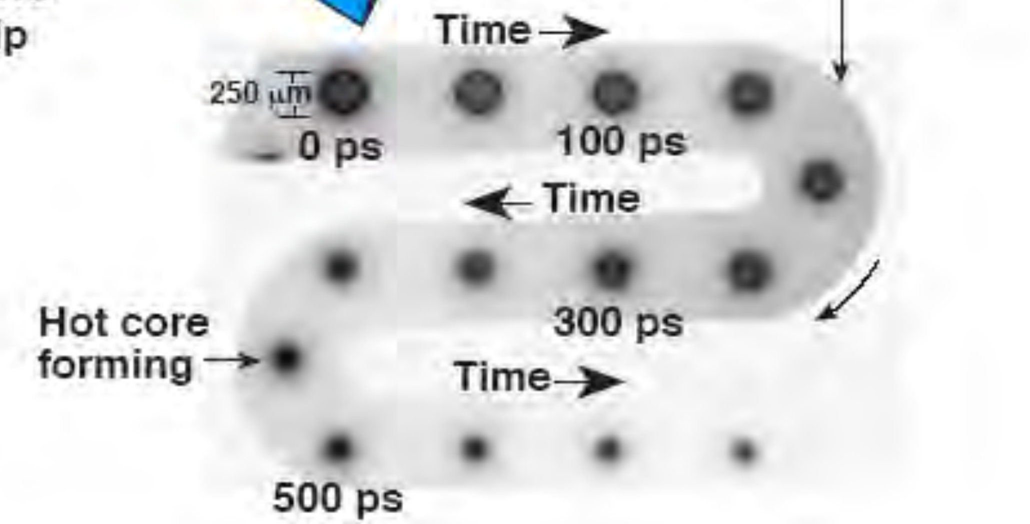
Highest drive ever measured in gas-filled hohlraum

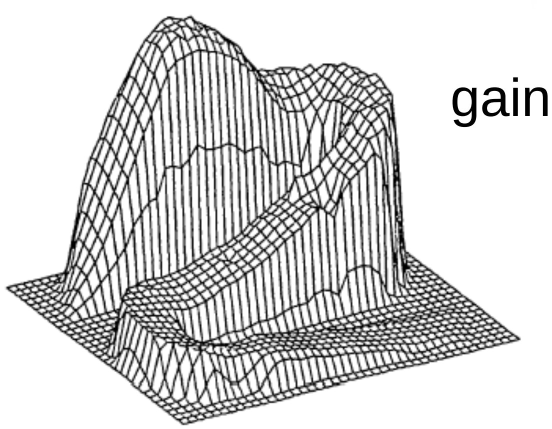
The serpentine geometry allows a 14-frame sequence of images of an imploding capsule to be recorded over about 700 ps

UR LLE

Los Alamos







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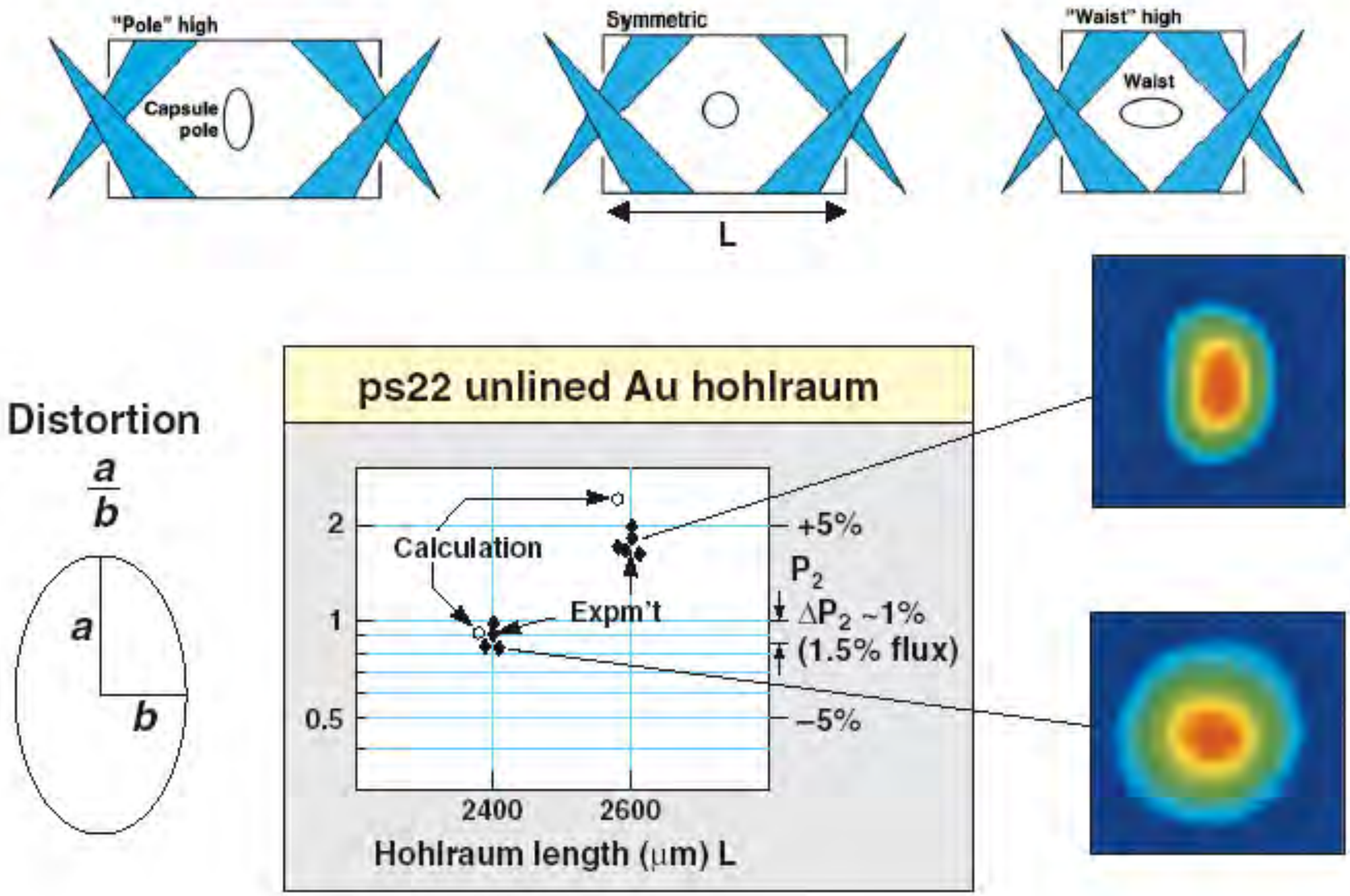
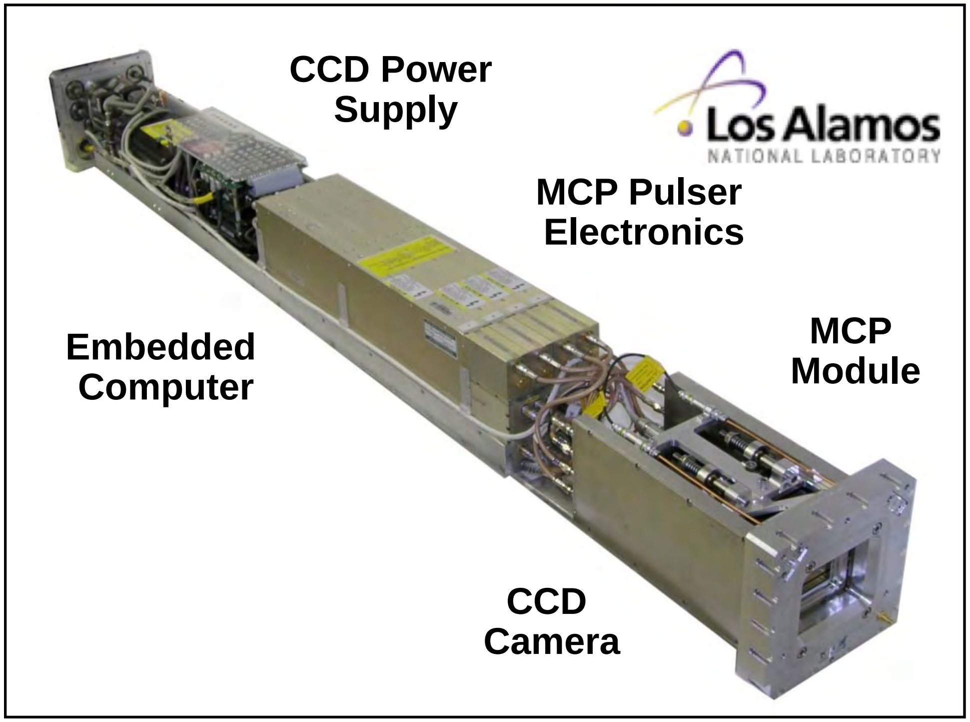
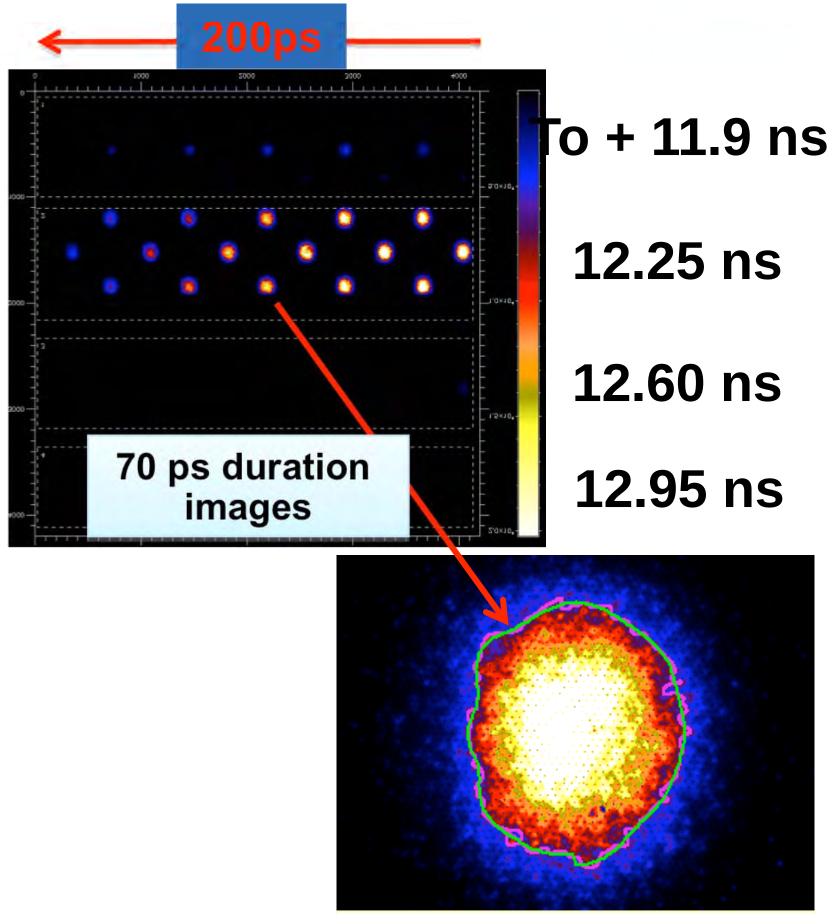
On Nova gated x-ray imaging demonstrated control of symmetry by changing beam pointing



The NIF Gated X-ray Detectors (GXD) are smart versions of detectors developed on OMEGA and Nova





P0 = 100 µm
P2/P0 = 0.089+/-.008
P4/P0 = 0.037+/-0.10

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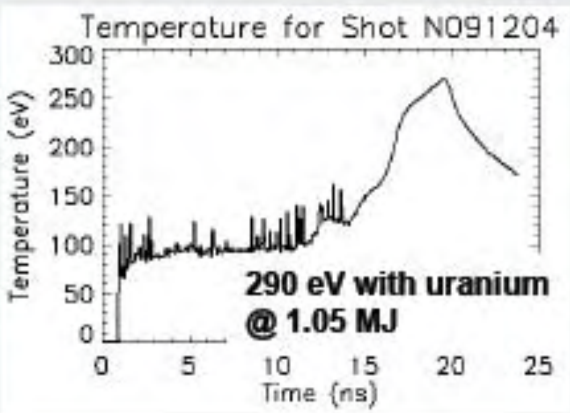
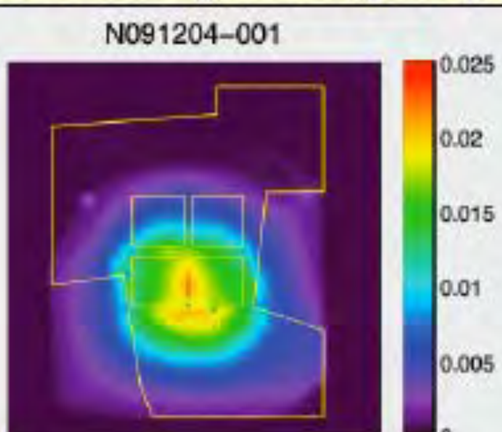
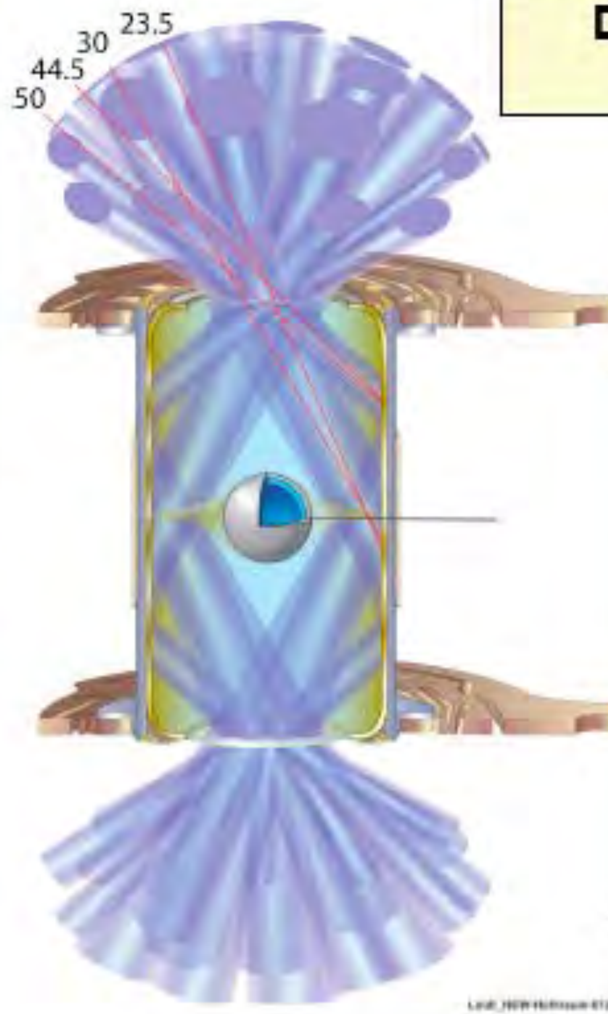
We have successfully commissioned ignition-scale hohlraums at 290eV

Drive needed for ignition



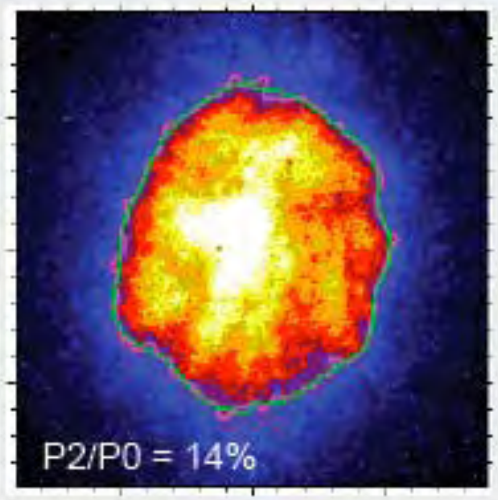
LPI low enough to meet drive and symmetry req.





Data from Dec 4th, 2009
1.05 MJ implosion

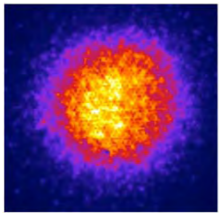
Tunable Symmetry

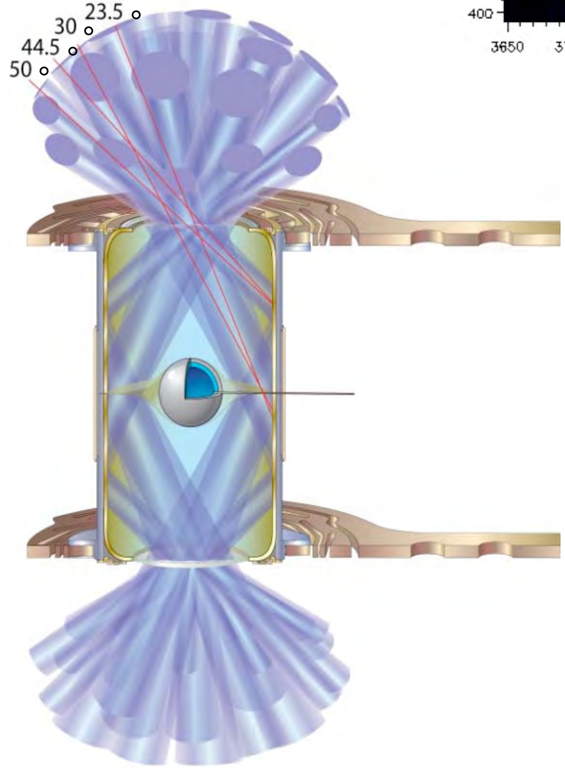


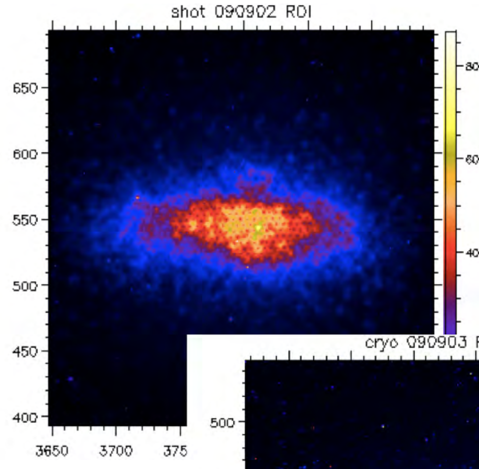
We are ready to commission the capsule

NIF gated x-ray imagers allow drive symmetry to be tuned by measuring the shape of the imploded targets

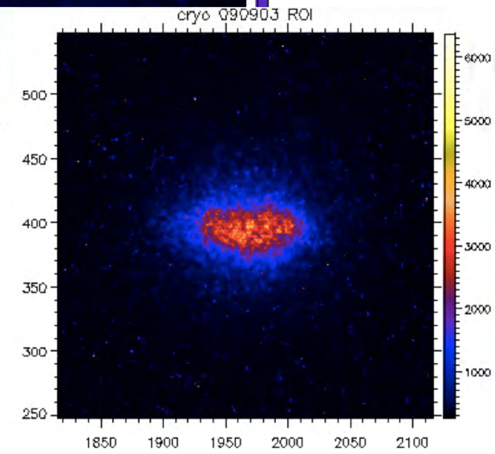
Core shape: Gated x-ray imager



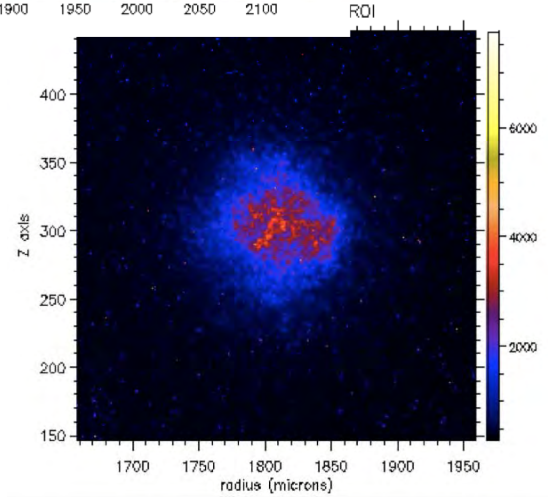




Oblate
(P_2 =-0.6, P_4 = 0.4)



Less oblate
(P_2 =-0.36
P_4 =0.14) to

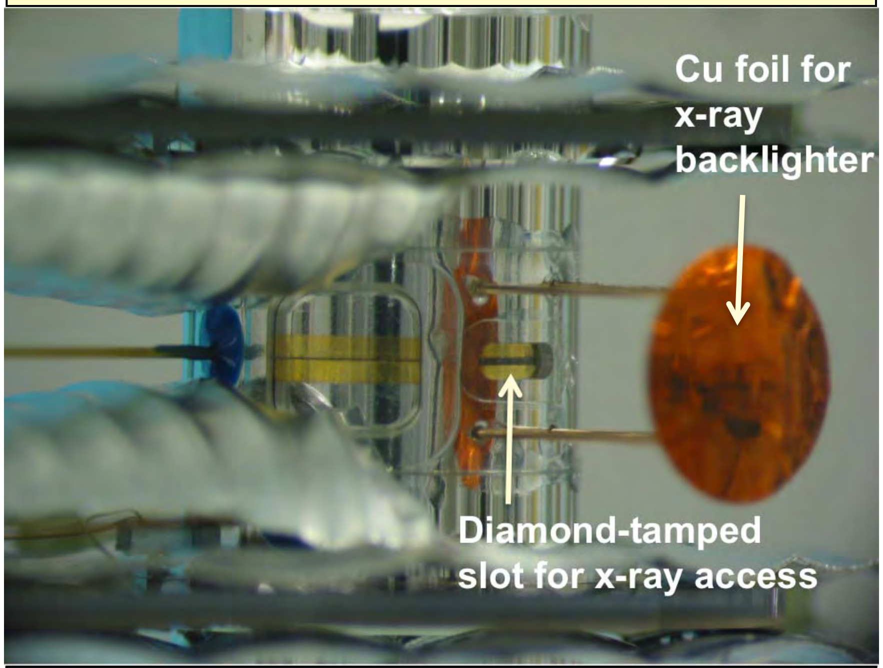


~Round
(P_2 =-0.04
P_4 =0.13)

Success of GXD due to OMEGA development

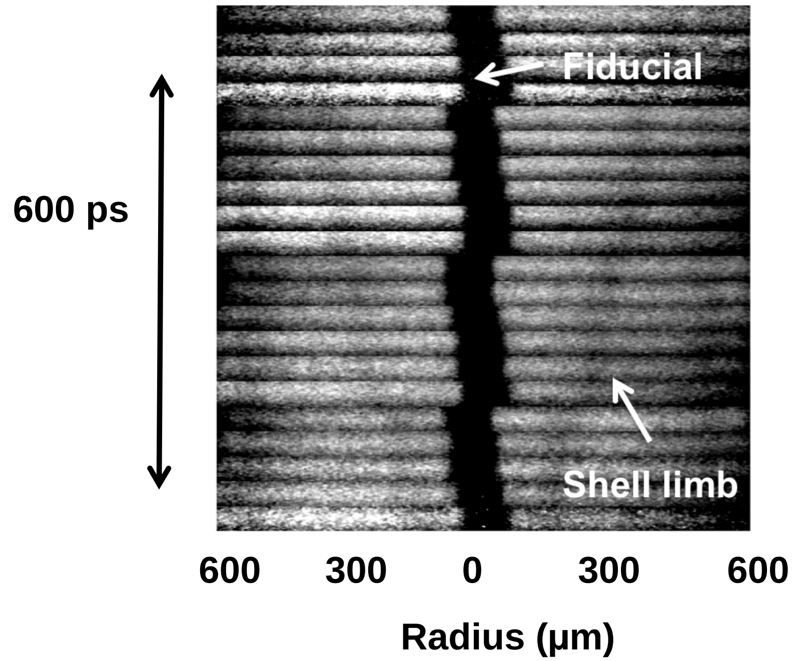
First NIF backlit in-flight capsule experiment was performed on Scale 4.6 mm, 660 kJ hohlraum drive

4.6 mm Hohlraum + Backlighter



134 µm-thick CH(Ge) capsule

Compilation of 1D-resolved 70 ps gated 8 keV radiographs



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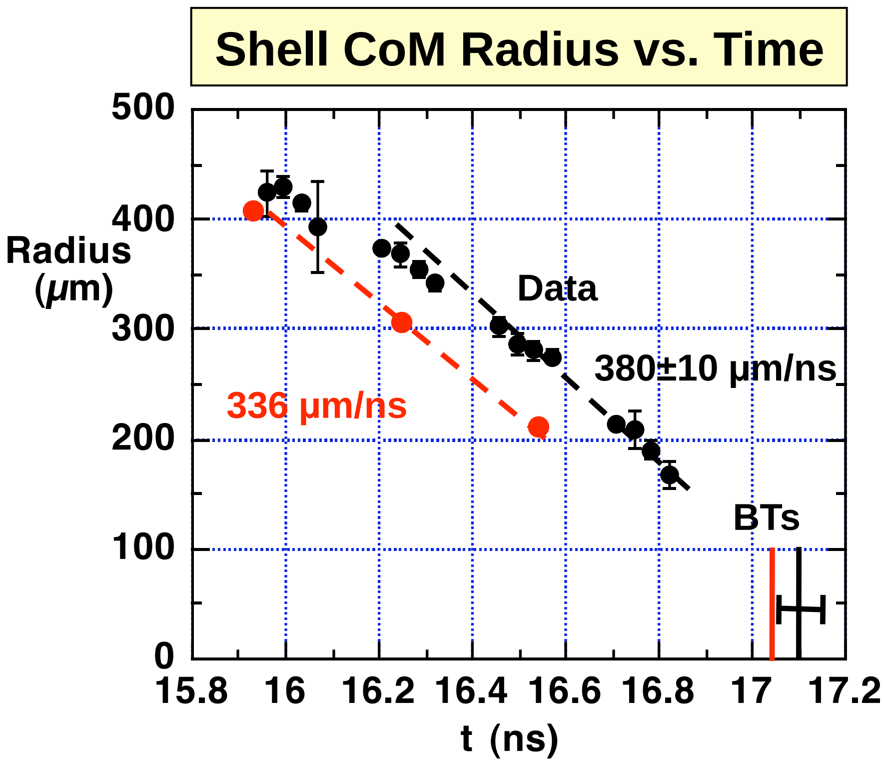
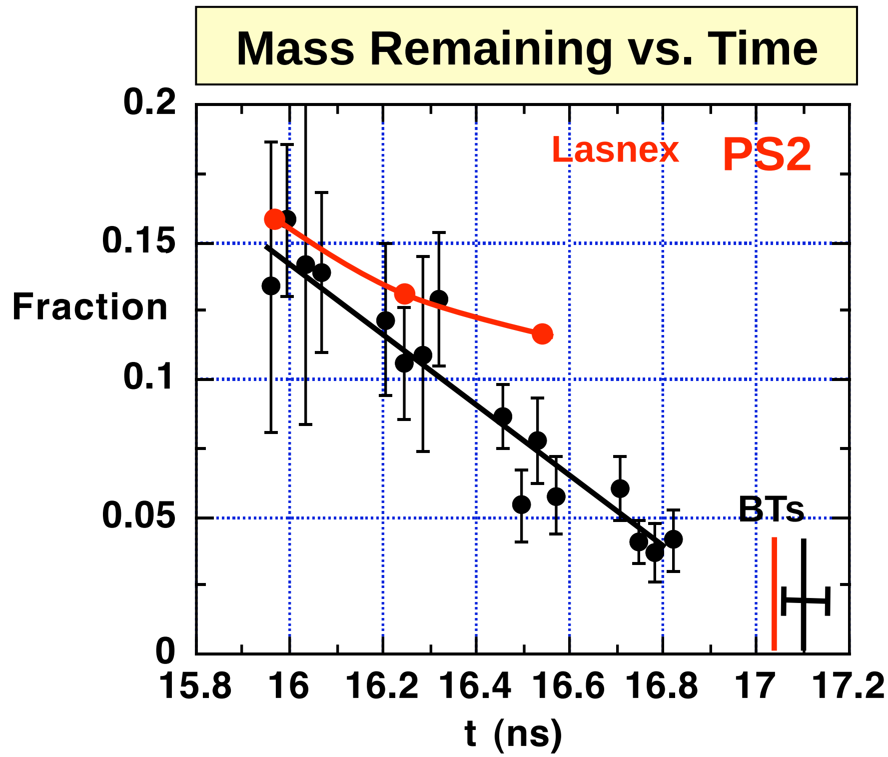
Simulations that match measured peak drive calculate 12% mass fraction vs 4% measured

Data versus post simulations that match measured peak drive to <7%

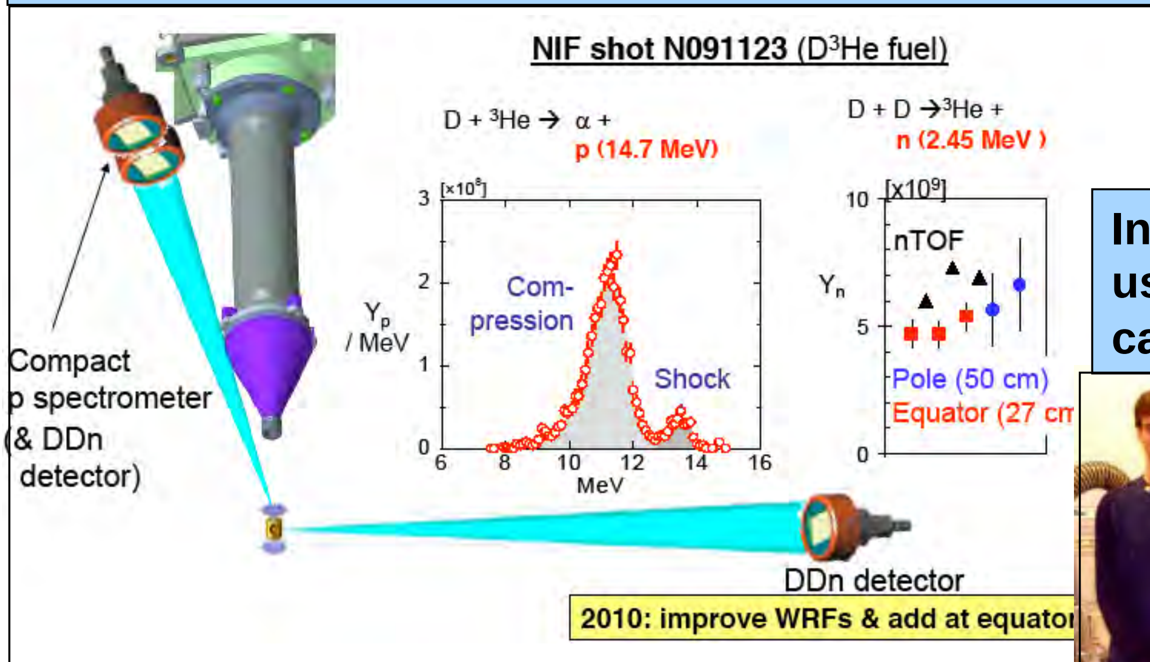




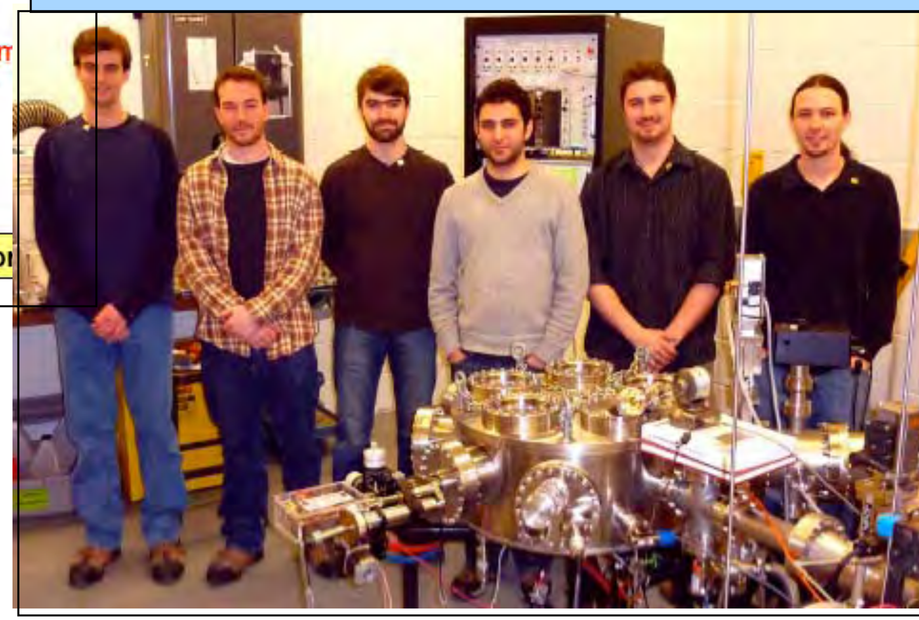
First backlit shell reached ignition design 380 μm/ns

The Wedge Range Filter (WRF) were used on NIF fall 2009 after major OMEGA/MIT development

NIF WRF proton spectrometer used in 2009, improvements for 2010



In NIF 2009 campaign, MIT students used their accelerator 16 hr/day for calibration

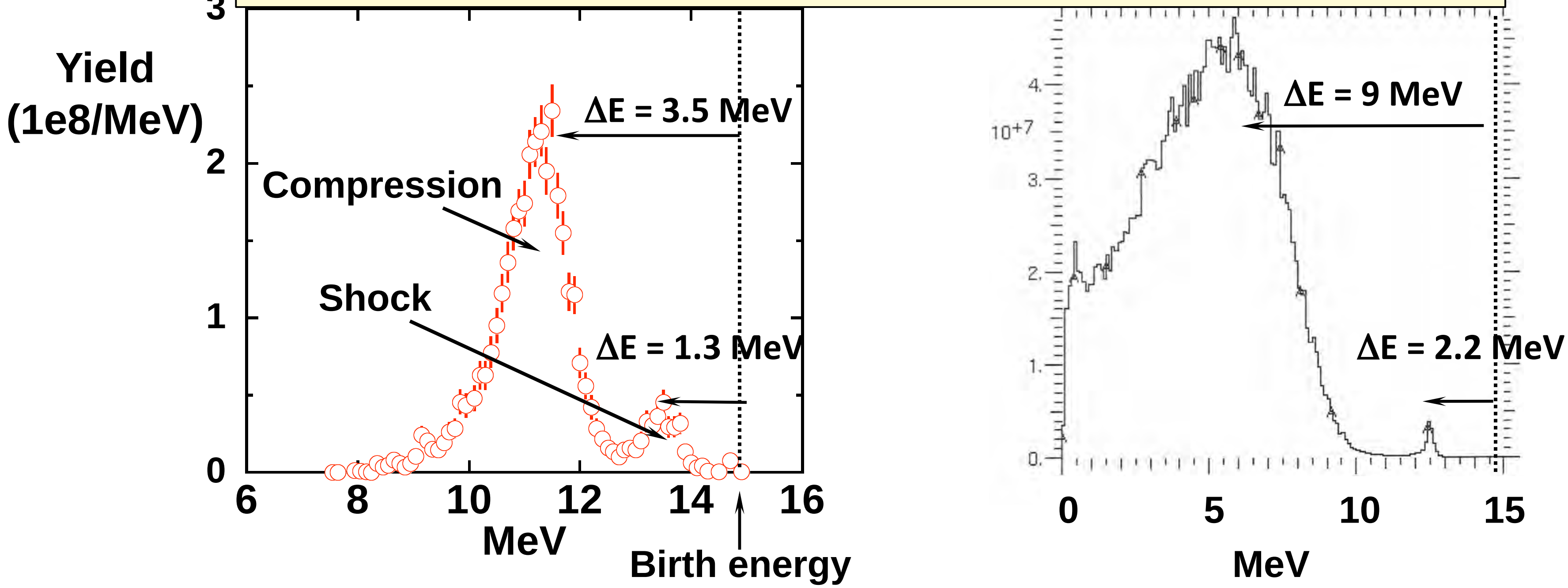


NIC

Inferred ρr from energy downshift of the escaping D^3He protons is also less than predicted

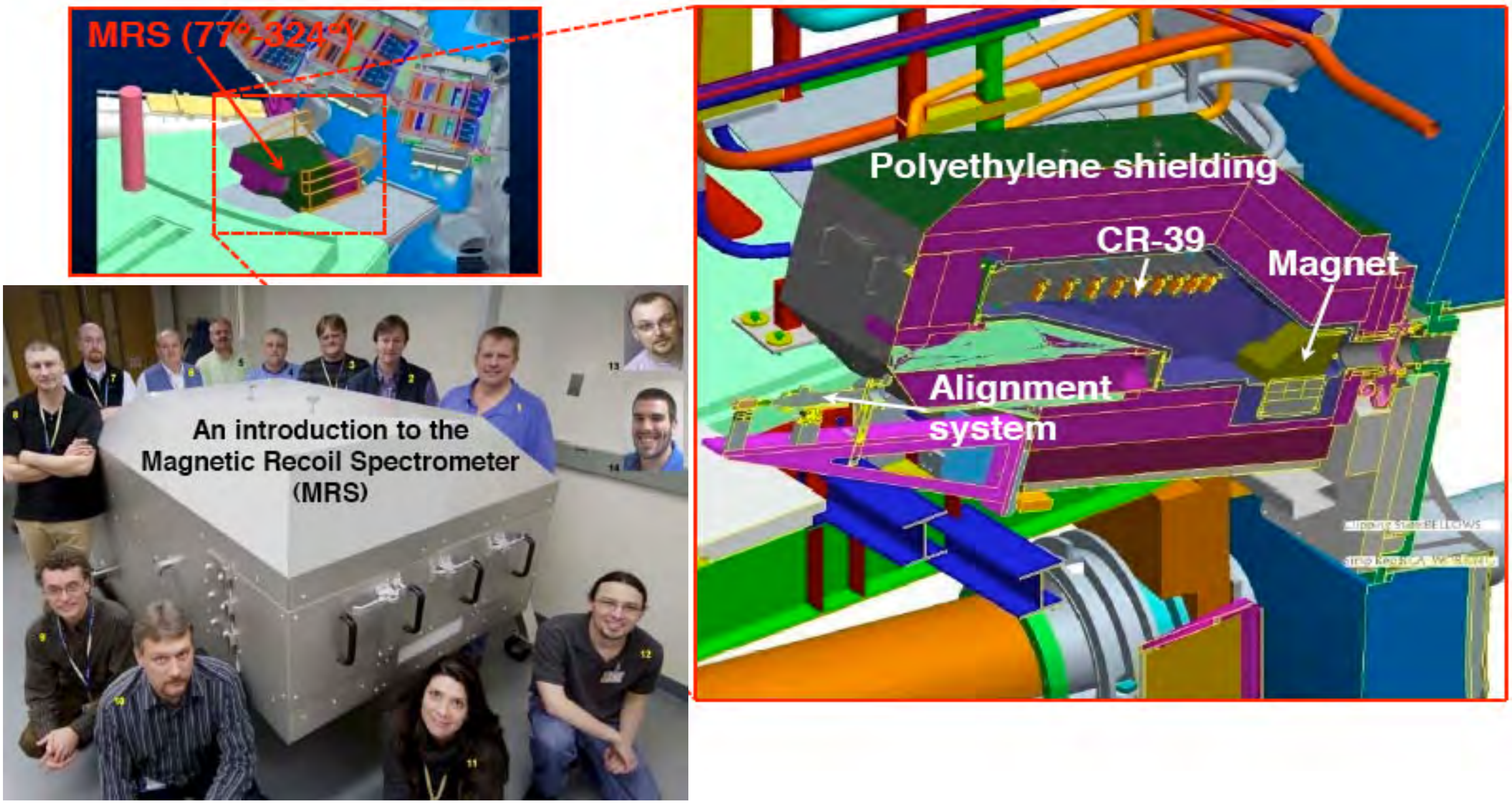
D + ^{3}He → ^{4}He + p (14.7 MeV)

Measured	Expected
Total <ρr> ~ ΔE = 110 ± 5 mg/cm^2	260 mg/cm^2
Shock <ρr> = 41 ± 5 mg/cm^2	65 mg/cm^2



◆Similar trend for proton spectrum increases confidence in radiography result
◆Next step is confirming sensitivity to initial capsule thickness as we did at OMEGA

The NIF magnetic recoil was developed on OMEGA by MIT and LLE



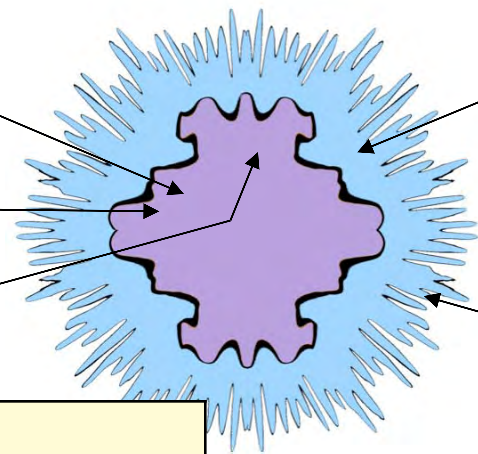
Summary

• Advances in HED requires innovative targets

• New diagnostics require a significant number of development shots

• OMEGA is playing a major role in development of NIF diagnostics

Diagnostics can be categorized by the attributes of the implosion they measure

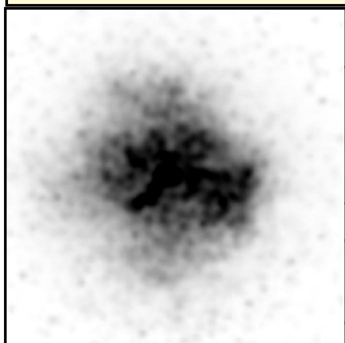


Hot Spot		
T_{HS}	4.5 keV	NTOF, hGXI
ρR_{HS}	0.2 g/cm^2	hGXI,ARC
$\langle R_{HS} \rangle$	25µm	hGXI,NI
Y_n	10^{14}	NToF, NAD, MRS
$t_{burn,bang}$	100 ps, ~20ns	hGXI, SPBT, GRH, NToF4.BT
mix	30%	hGXI, HEXRS

Cold Fuel		
$\langle \rho R \rangle$	> 1.7 g/cm^2	NToF, MRS, RAD-CHEM, ARC, NI, GRH
$\Delta \rho R(\theta)$	< 0.4 g/cm^2	ARC, NI
$\Delta R_{mix}/\Delta R_{shell}$	< 0.25	hGXI, RADCHEM

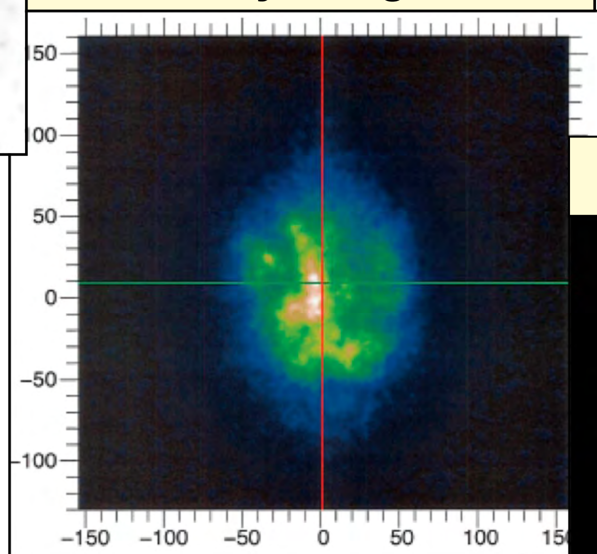
Gated x-ray imaging measures mix, presumably seeded by surface perturbations

N090904
X-ray Image



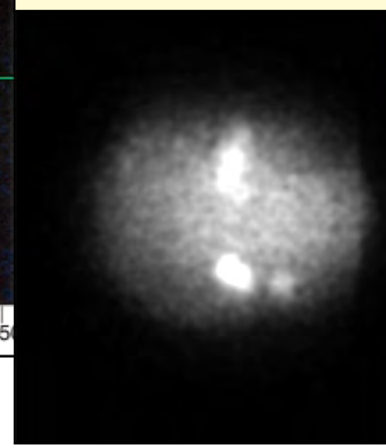
Good implosion

N091204 Gated
X-ray Image



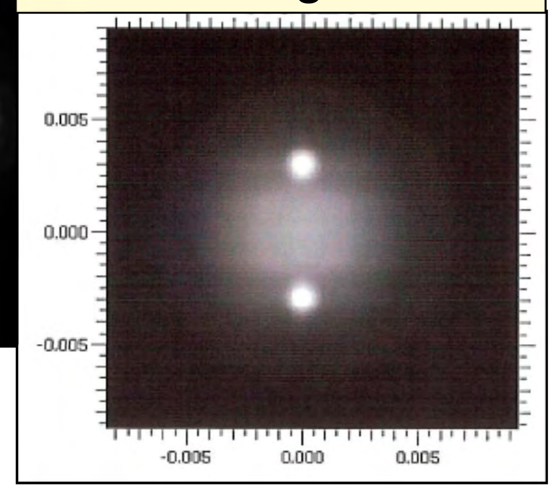
Bad implosion

N091118



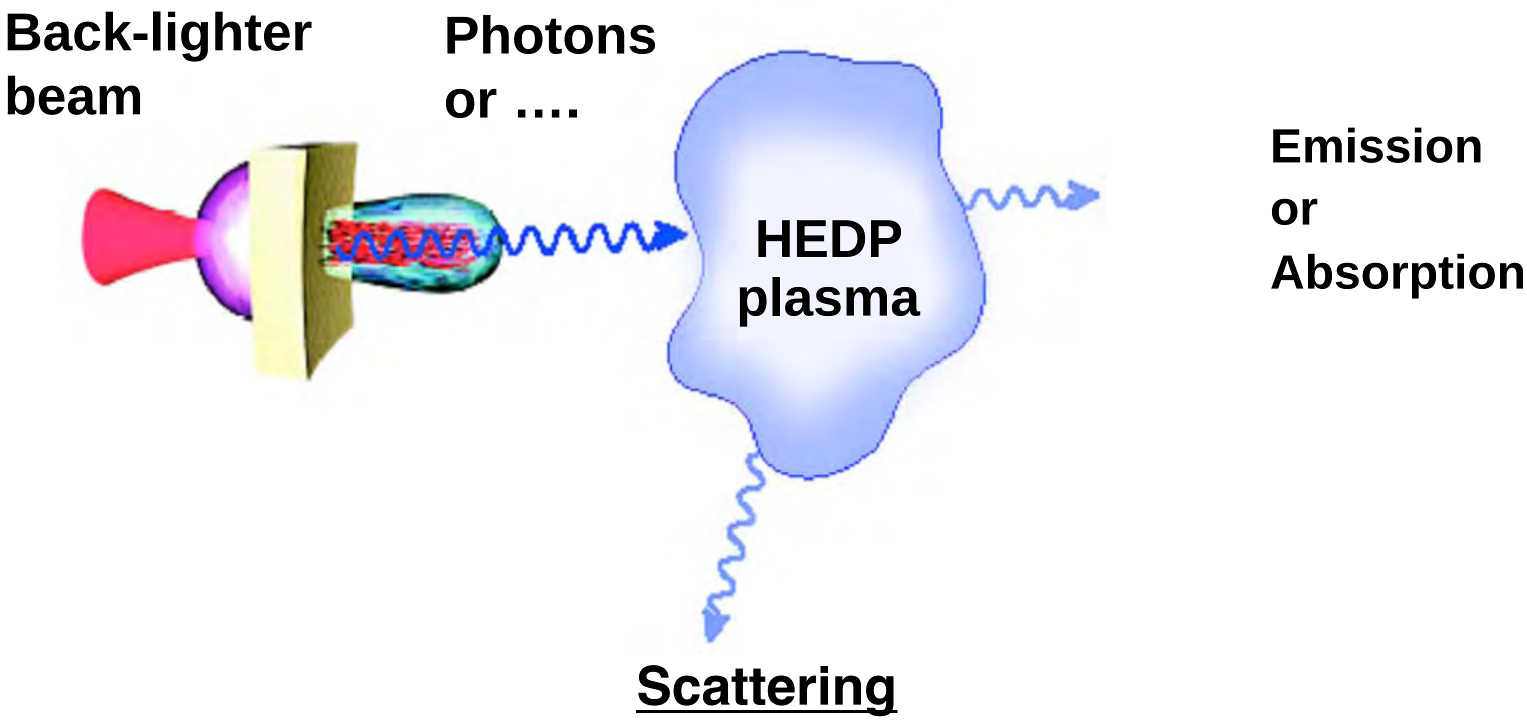
Ugly implosion
&
ugly simulation

Simulated X-ray
Image



Ignition tuning will use n hardened gated imager to monitor mix

Diagnostics work in emission, absorption or scattering



Probing techniques on large ICF facilities take time and shots to develop