Ignition in NIF: Status & Plan

National Nuclear Security Administration

General Atomics

UR LLE

University of California
Lawrence Livermore National Laboratory

Los Alamos National Laboratory

Naval Research Laboratory

Sandia National Laboratories

Fusion Power Associates Annual Meeting

Bruce Warner
Deputy Associate Director, NIF Programs
Lawrence Livermore National Laboratory

October 11, 2005

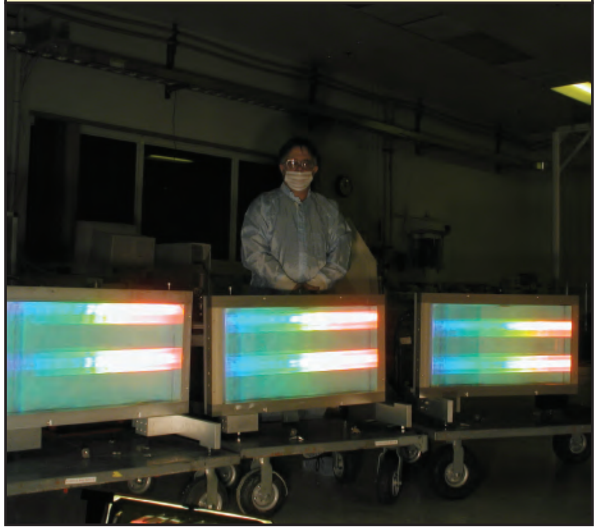
P9762

Agenda

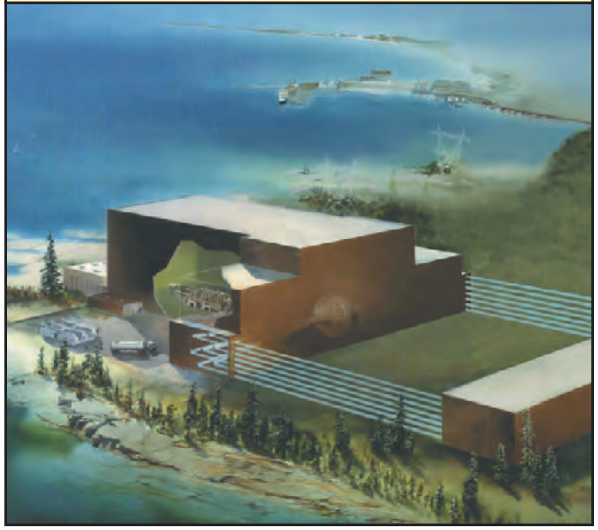
The National Ignition Facility

National Ignition Campaign

Short Pulse Lasers



High-Average-Power Laser

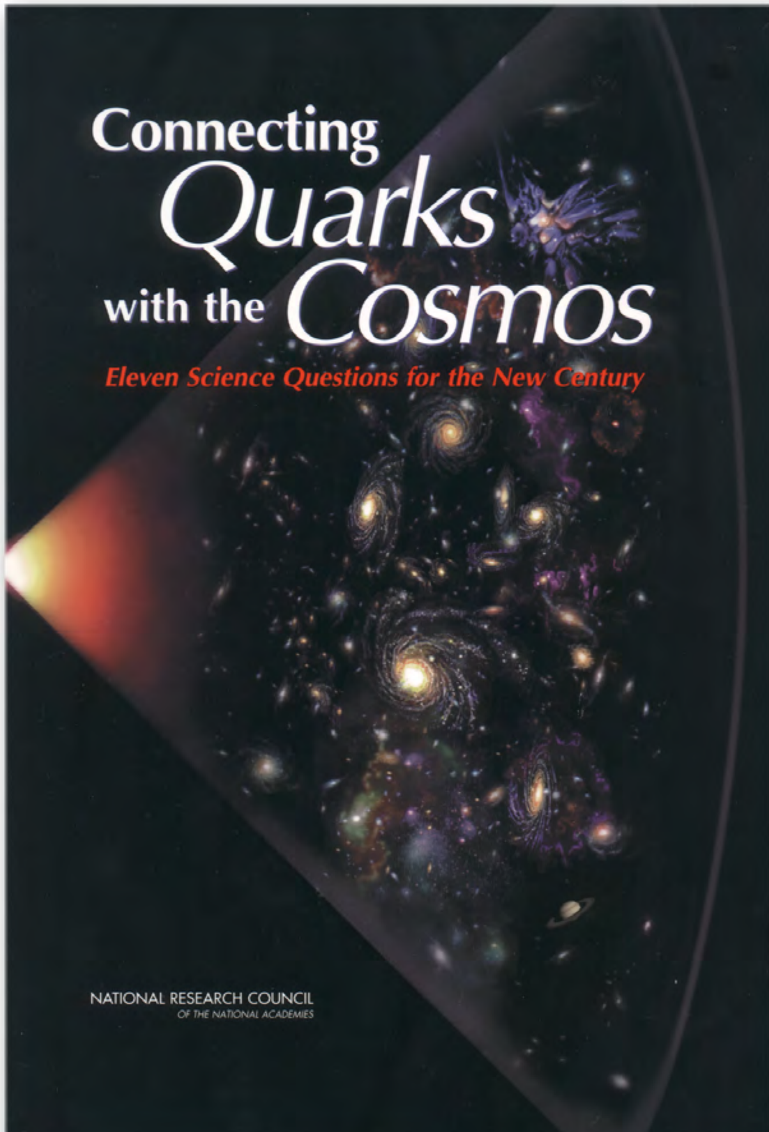


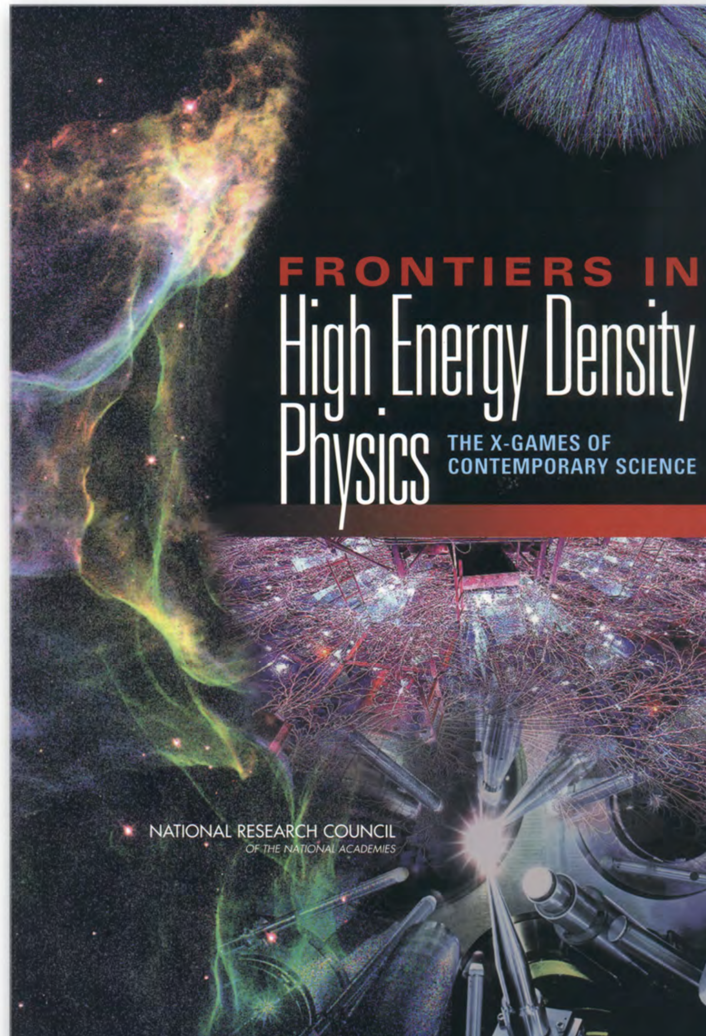
Stockpile Stewardship

NIF-0805-11197
01EIM/dj

P9516

Basic Science and Cosmology

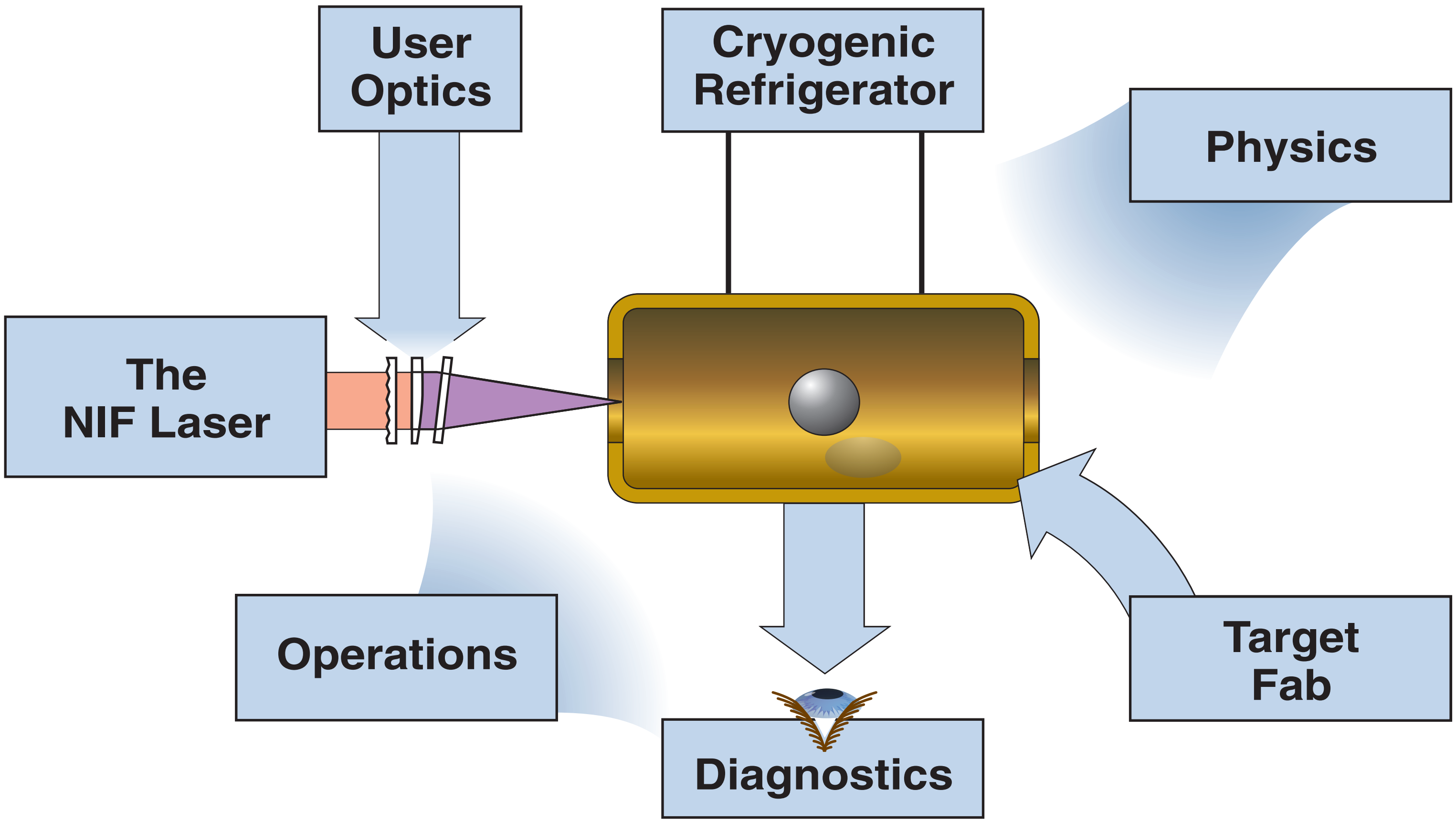





Fusion Energy
• Future energy source
• Transition to hydrogen economy
NIF-0702-05346rIFSA

Major elements of the National Ignition Campaign and point design

NIC
The National Ignition Campaign



- Our plan for 2009–2010 concentrates on systems integration and executing a credible ignition campaign
- NIC is a major transition in U.S. program planning

NIC Planning Status

NIC
The National Ignition Campaign

- Developed set of National Ignition Campaign objectives
- Agreed upon scope by participating sites (LLNL, LANL, LLE, SNL, GA)
- Developed self-consistent schedule with high-level milestones
- Preliminary budget allocation
- Developed a Campaign Execution Plan
- Structured organization for campaign execution

Approved by NNSA and is now operational

NIF Project and Ignition Campaign Integration Schedule

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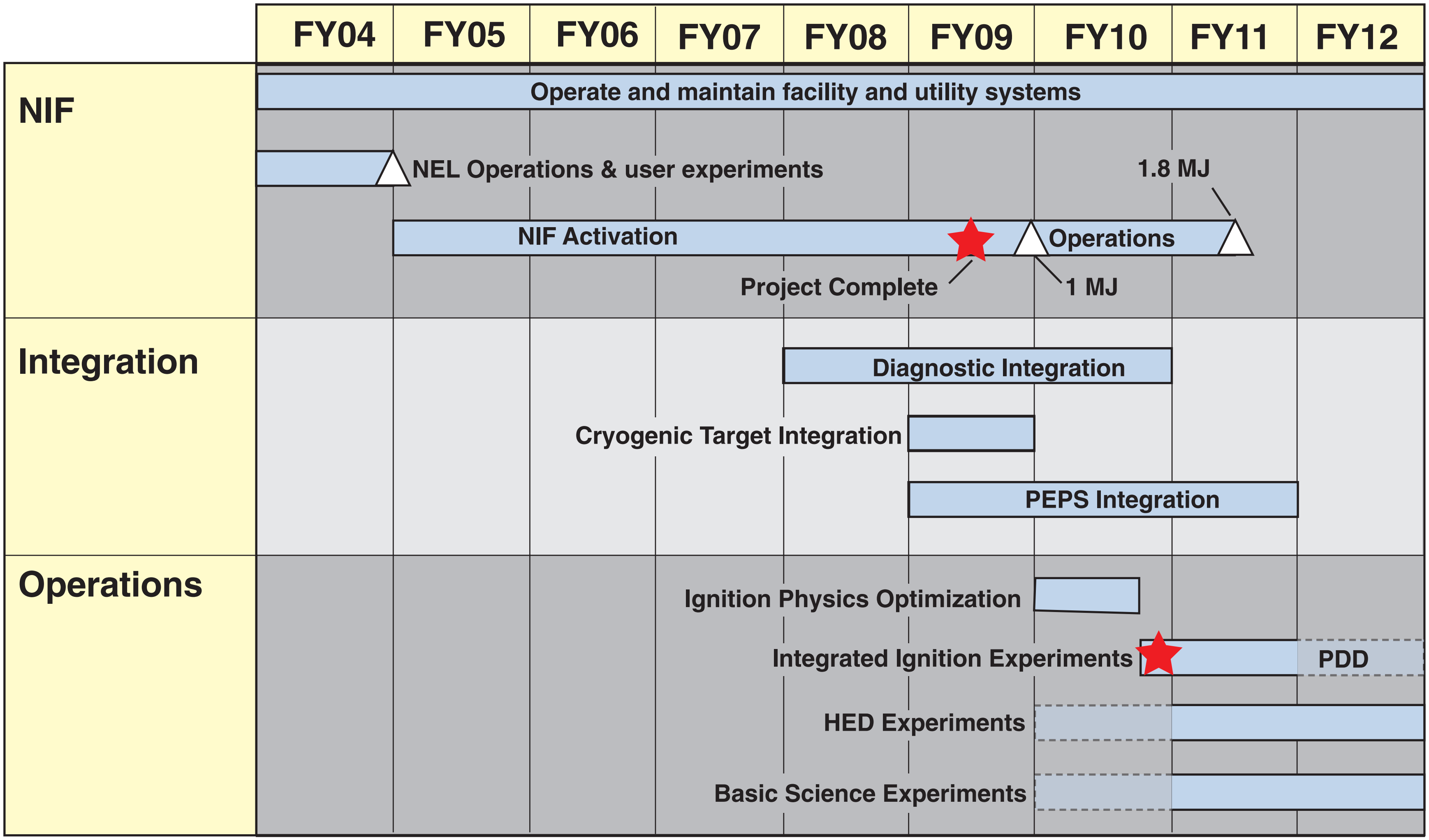
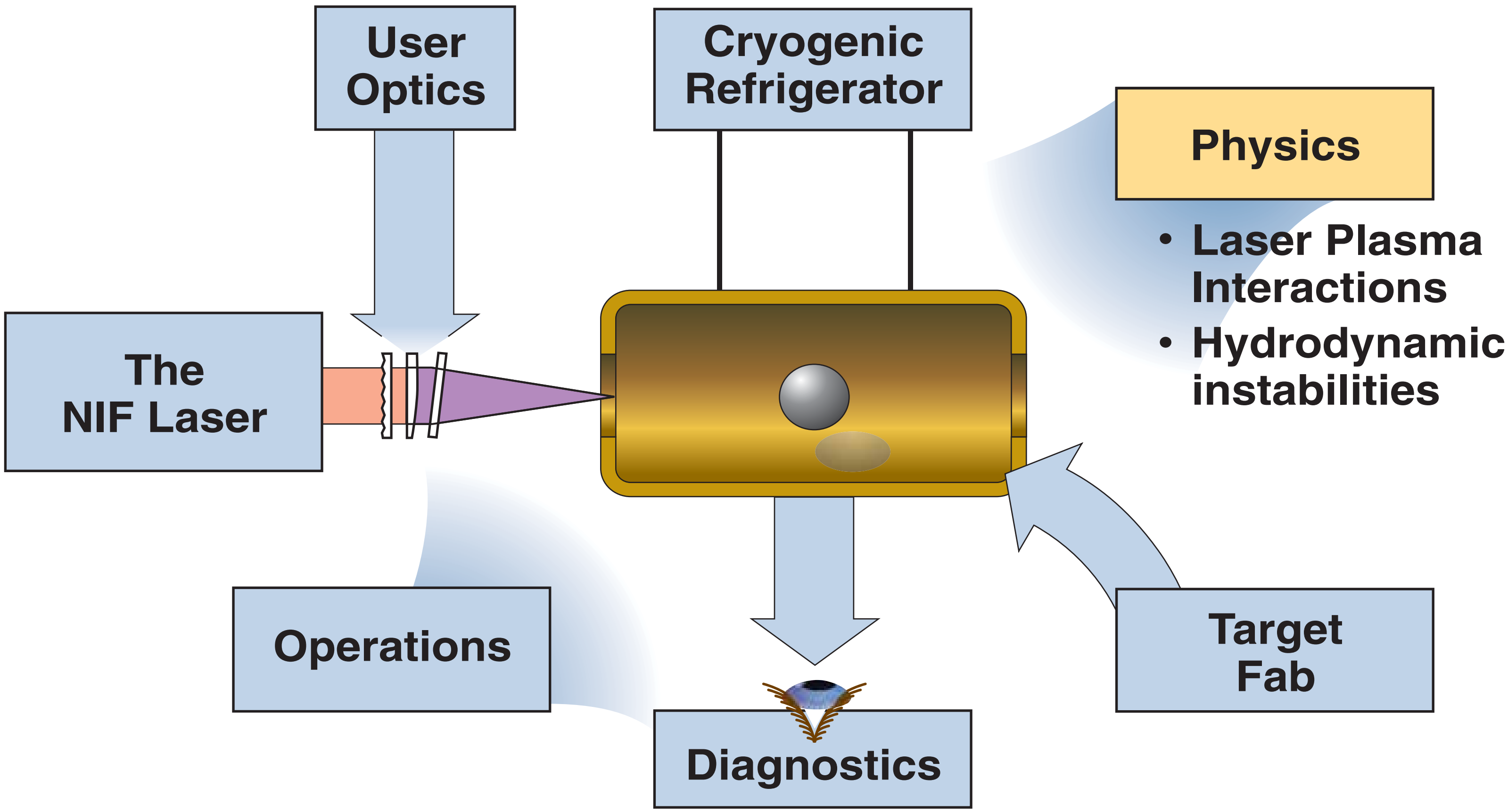


Major elements of the National Ignition Campaign and point design

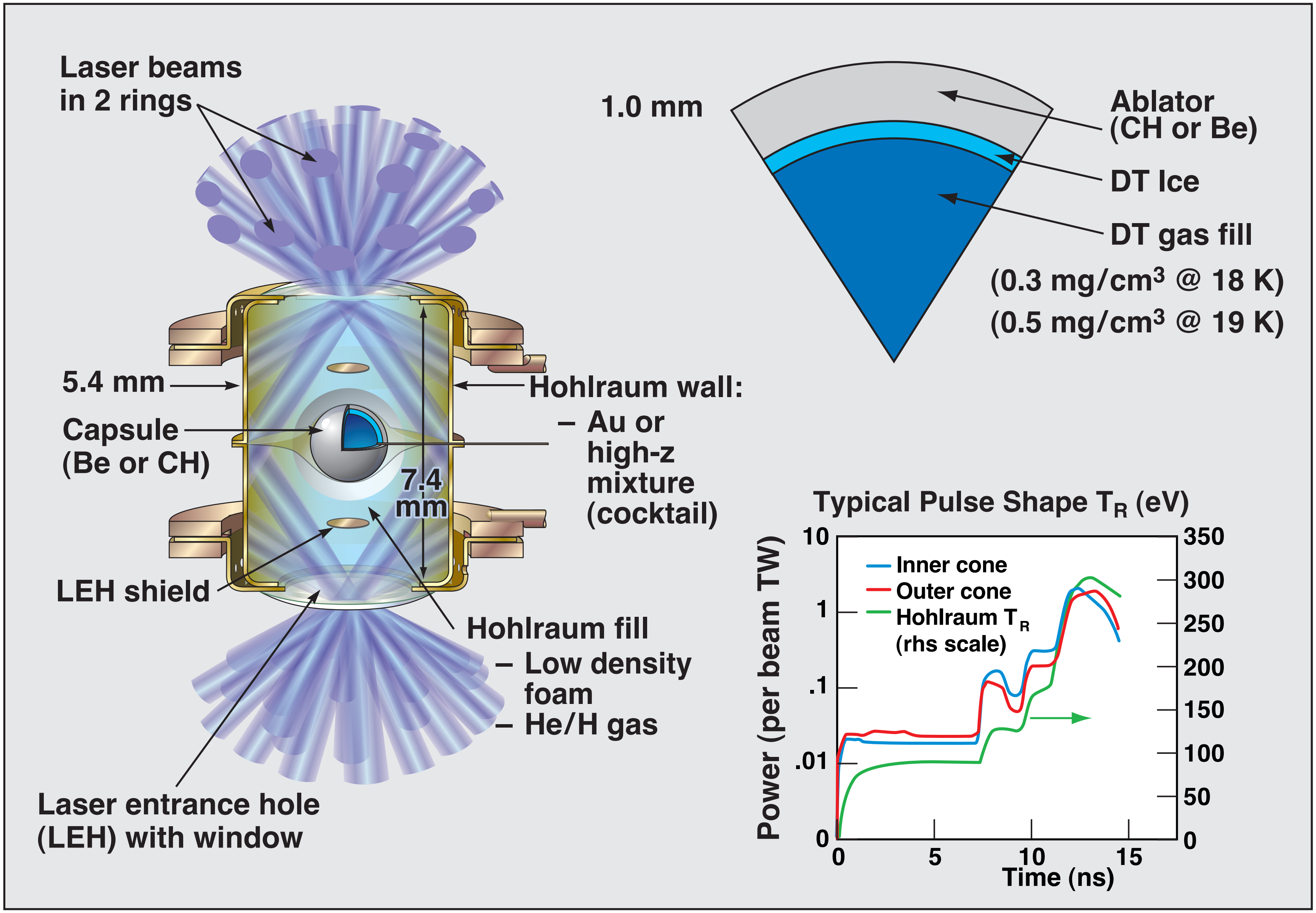
NIC
The National Ignition Campaign



We have developed new high performance target designs

NIF Indirect Drive target schematic

The National Ignition Facility



Improvements in ignition point designs have reduced laser energy estimates from 1.8 MJ to ~1 MJ

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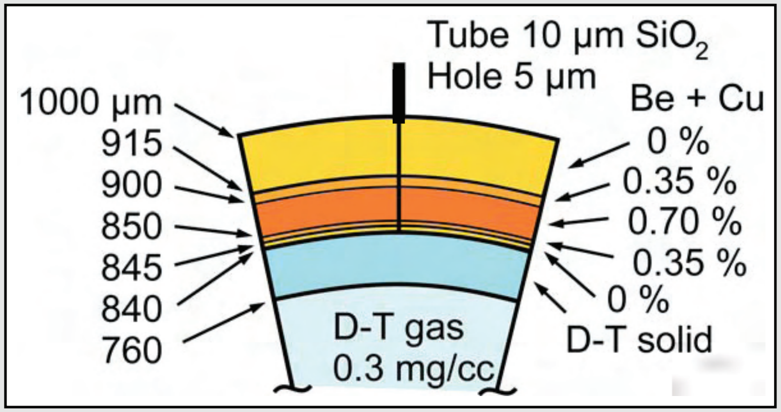
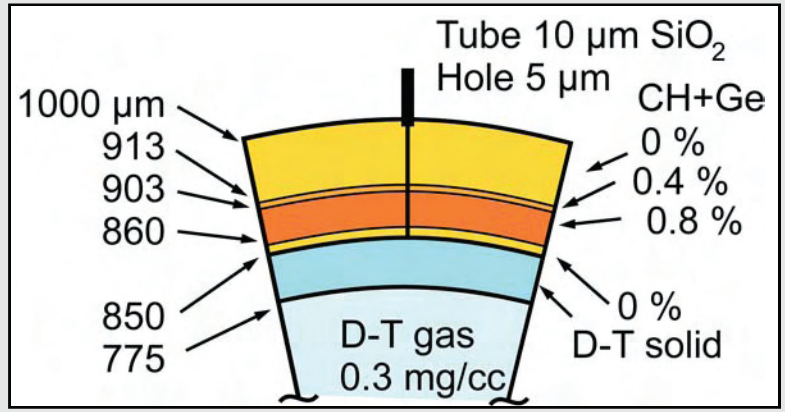
Be Capsule



CH Capsule



	Be Capsule	CH Capsule
Yield	13 MJ	10.4 MJ
Eabs	139 kJ	107 kJ
Implosion velocity	3.70×10^7 cm/s	3.86×10^7 cm/s
Fuel mass	0.161 mg	0.156 mg
Ablator mass	3.19 mg	1.76 mg

Improve Performance

- Cocktail hohlraums
- Laser entrance hole shields
- SSD, Polarization smoothing

Improved Operability

- Fill tubes for warm transport

1997 1.7 MJ ignition point design

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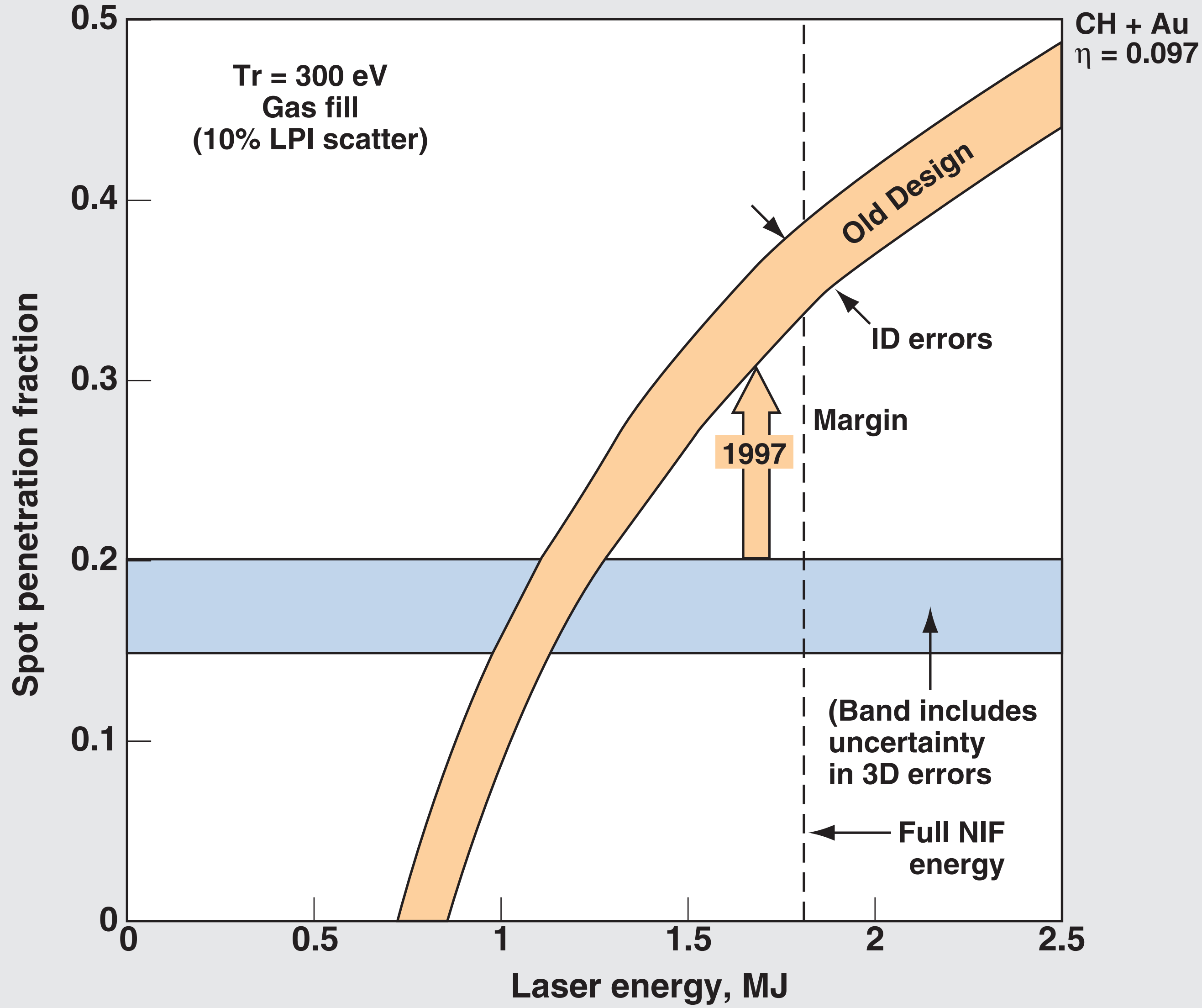

The current 1 MJ designs is comparable to the 1997 design at 1.7 MJ

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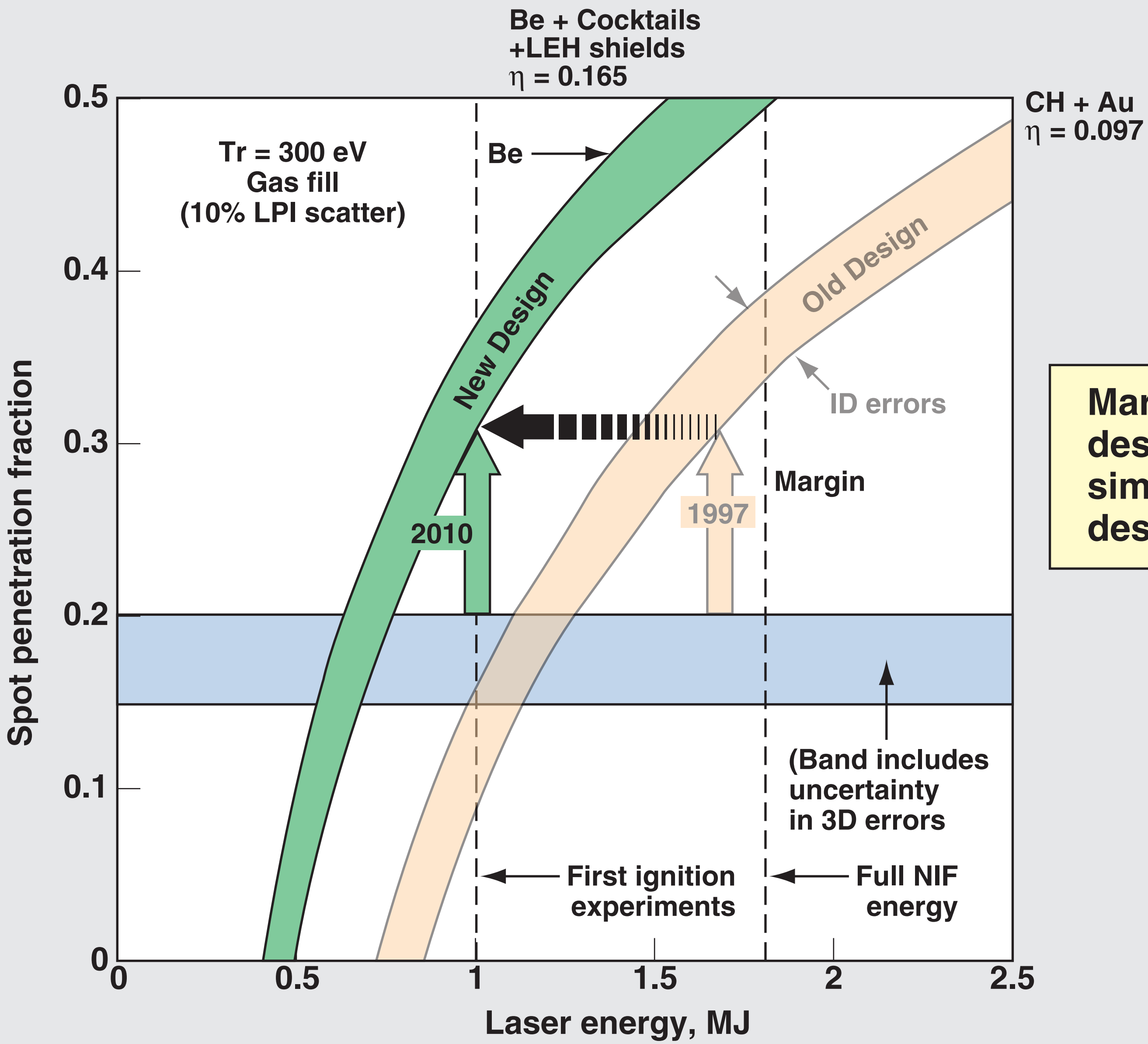

Margin of current designs at 1 MJ is similar to original designs at 1.7 MJ

1.8 MJ operation will result in high yield

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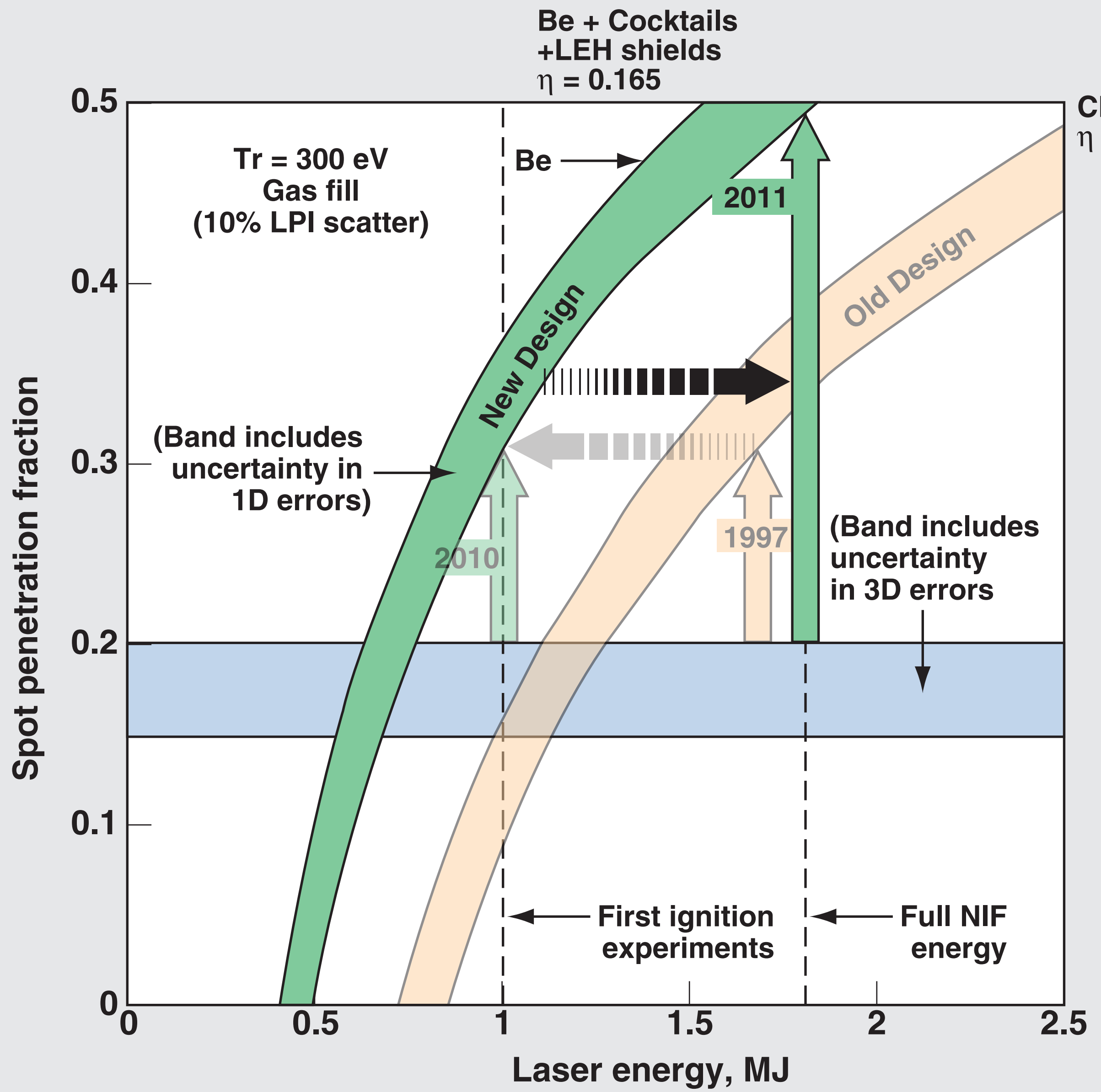

Margin of current designs at 1 MJ is similar to original designs at 1.7 MJ

Margin of current design at 1.8 MJ is much greater than ever before

We have demonstrated target fabrication at the component level

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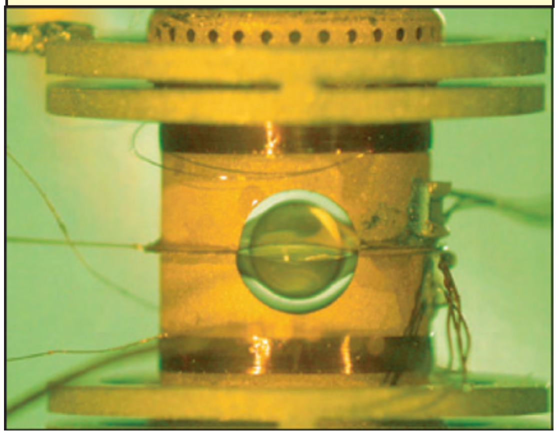
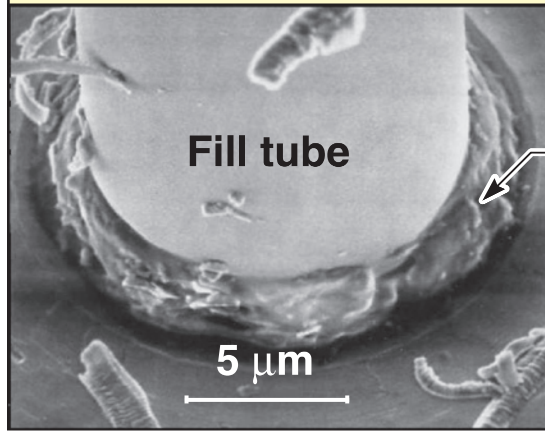
Cryogenic hohlraum

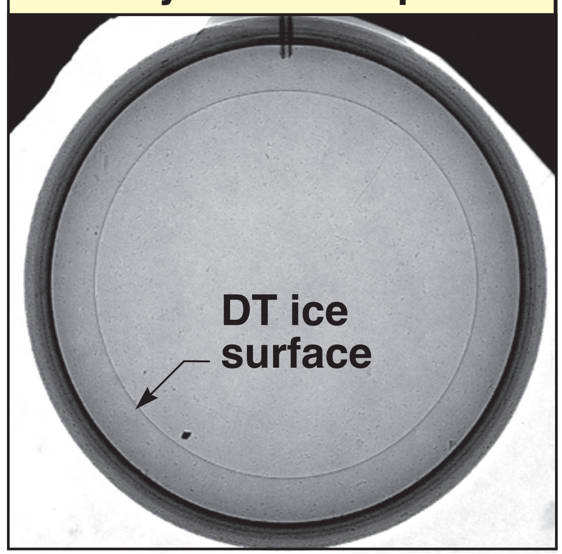


Micro-machined fill tube



Polished Be capsule

DT layer in Be capsule



Radiography quantifies Cu concentration and layer location in NIF beryllium capsules

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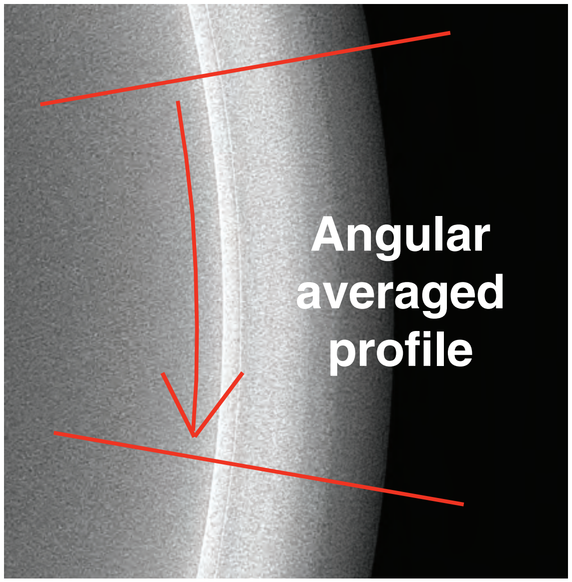
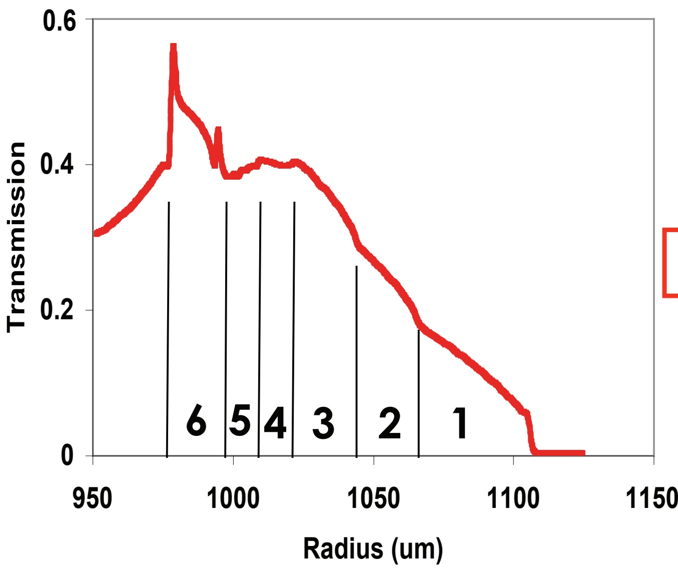


- Dopant concentration is determine from fitting a physics-based model
  - — X-ray source spectrum, material properties, and film response comrise the madel
- Geometrical corrections give precise interface locations
  - — Input magnification, x-ray refraction, lens destortion

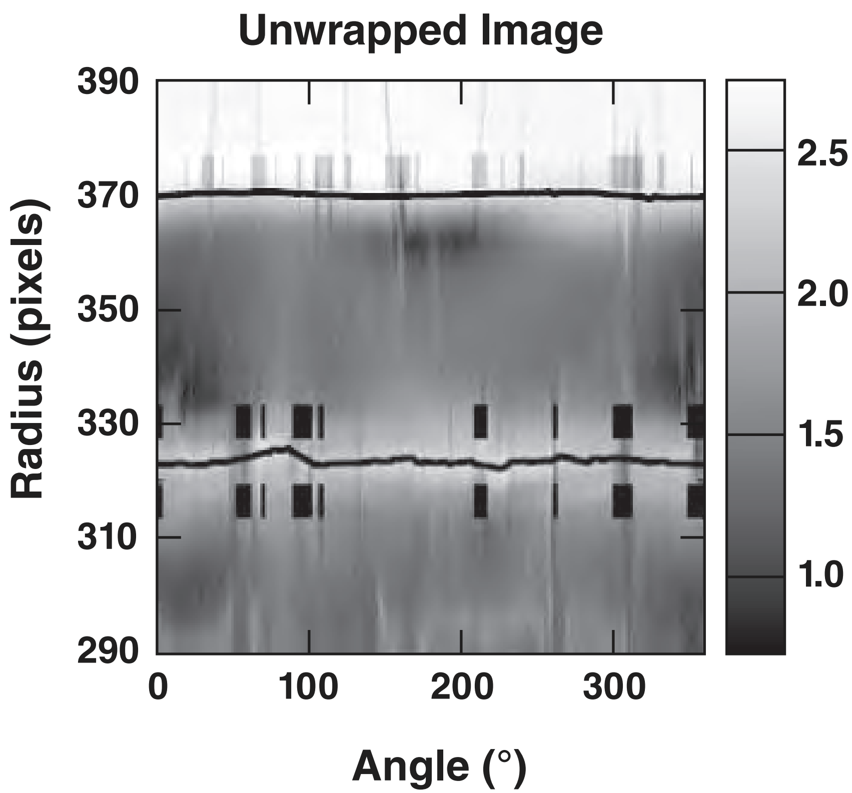


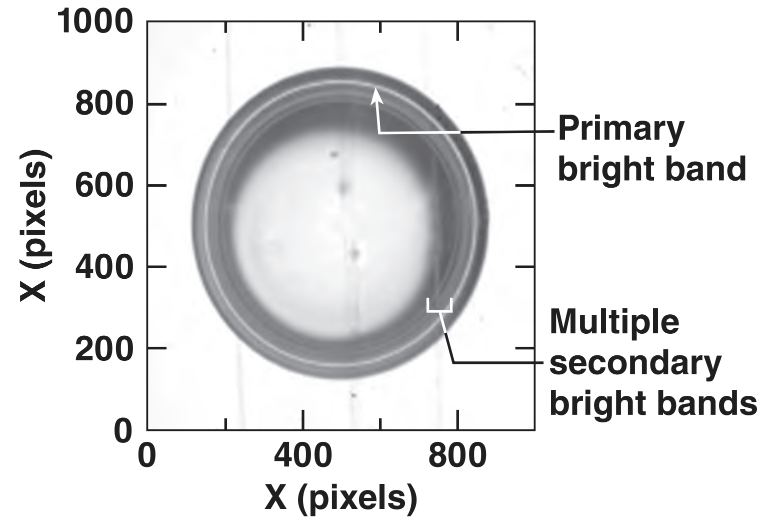
Layer	Cu dopant σ~0.1xvalue	Layer thickness σ~0.2 um
1	0.00%	40.0 um
2	0.17%	21.7 um
3	0.33%	22.0 um
4	0.16%	12.8 um
5	0.00%	15.9 um
6	Plastic	15.0 um

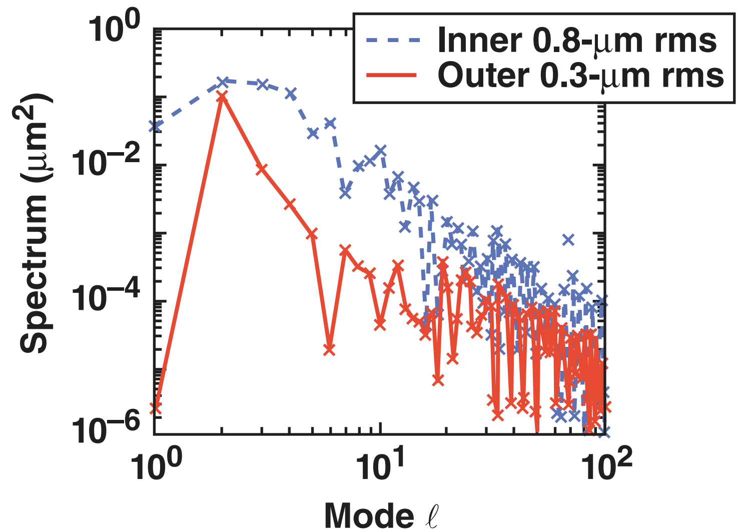
GENERAL ATOMICS

The best layer to date is 1.2-μm rms (all modes) with the best regions below 1.0-μm rms

- 24 shadowgraphic views of "x" and "y"







Multilayer Au-Ucocktail hohlraums have been fabricated for OMEGA experiments

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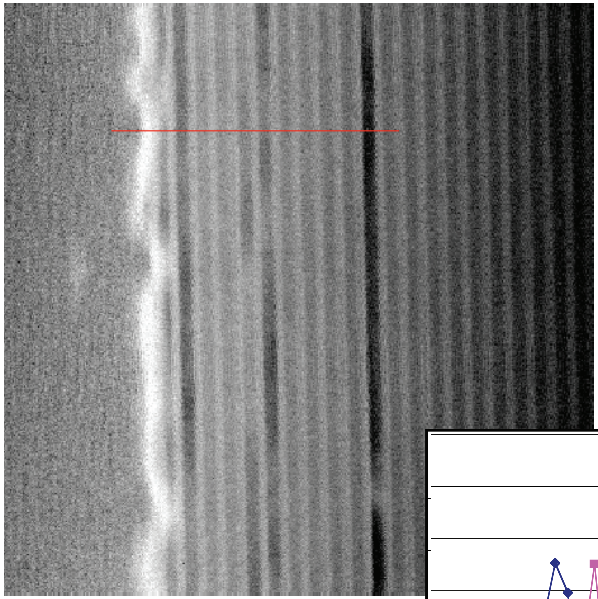
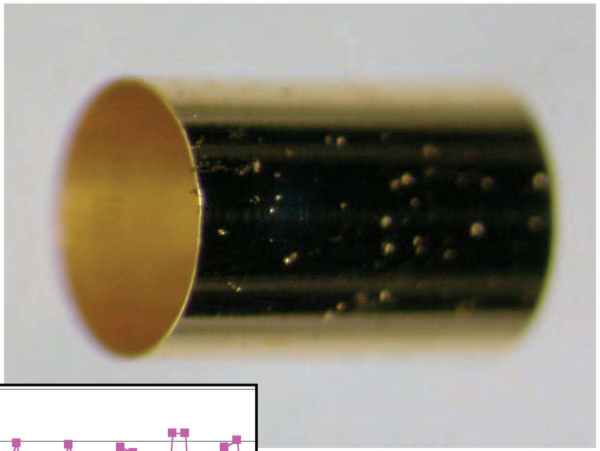
SEM Image

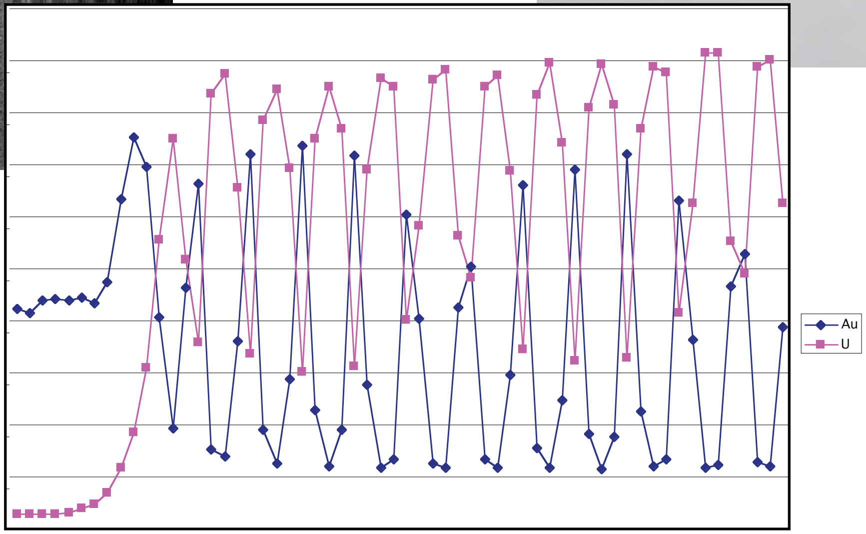


Gold overcoating stabilizes the cocktail against destructive oxidation



20 nm Au layers alternating with 10 nm U

EDX analysis of layers



Developments for NIF scale ignition hohlraums are underway

GENERAL ATOMICS

Recent cocktail hohlraums demonstrate expected soft x-ray flux increase over gold hohlraums

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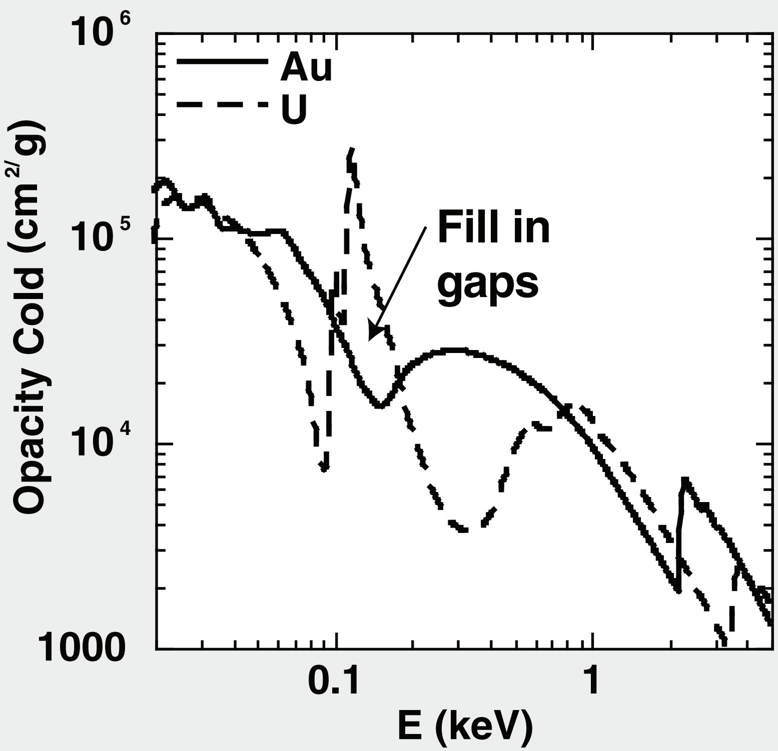
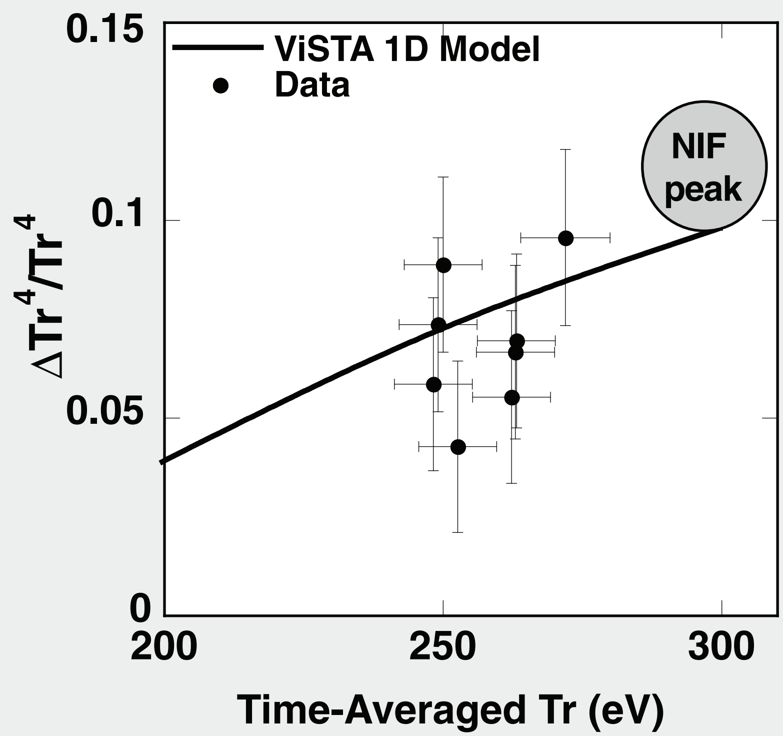
Use mixture of materials to increase Rosseland mean opacity*



$Au_{0.2}U_{0.6}Dy_{0.2}$ vs Au

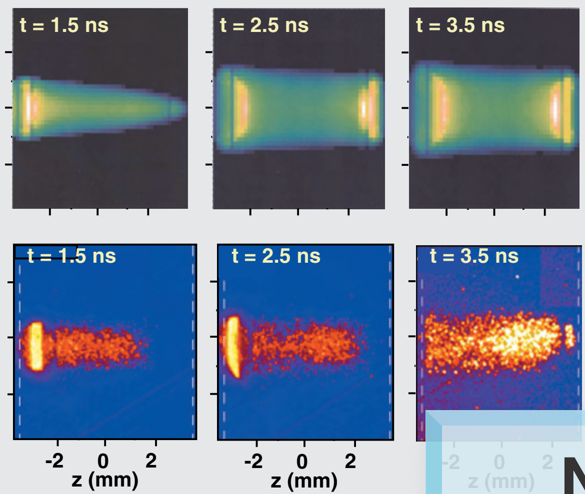


J. Schein (This Session)

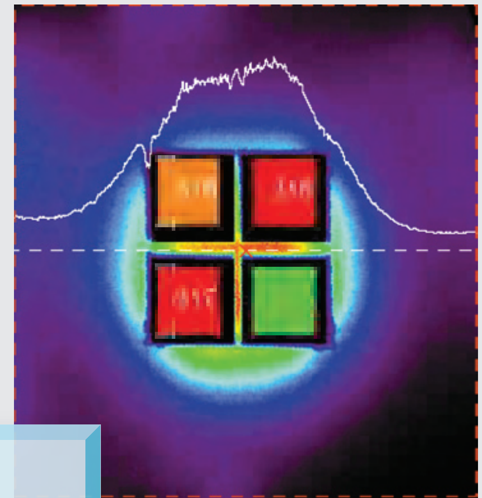
Future shots will test Tr scaling and measure burnthrough brightness ~1/κ (w SNL, G. Rochau, R. Olson)

*H. Nishimura, T. Endo, H. Shiraga, Y. Kato, and S. Nakai, Appl. Phys. Lett. 62 (12), 1344 (1993).

LPI

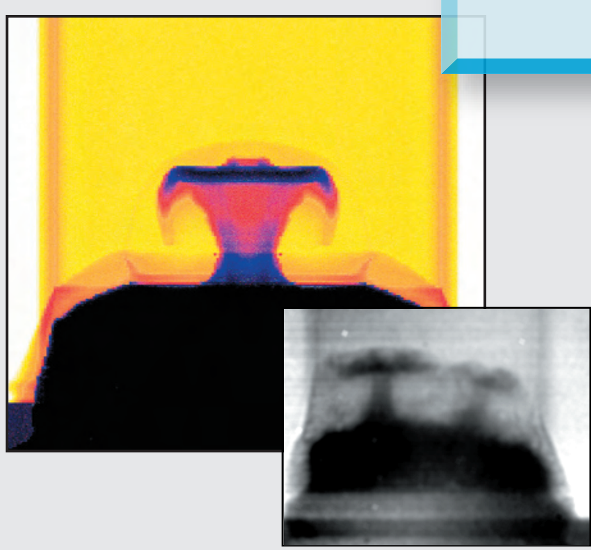


Hohlraums

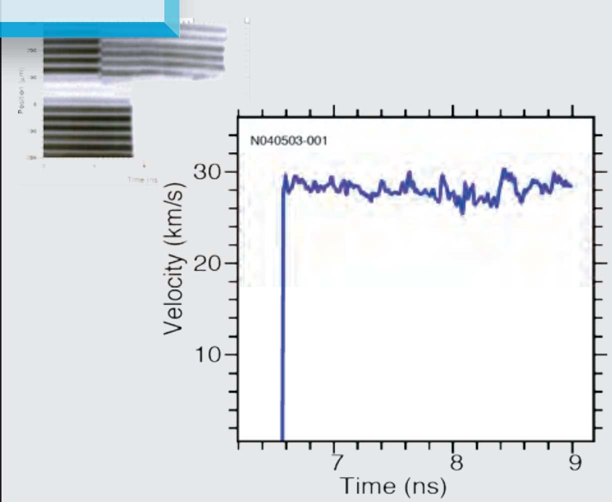


NEL performed four user target experimental campaigns

Hydro



EOS



O. Landen – Tu02.3
B. Blue – M02.1
D. Hinkel – M03.2
J. Fernandez – Tu07.1

The first LPI experiments on NIF have demonstrated propagation in NIF ignition scale plasmas

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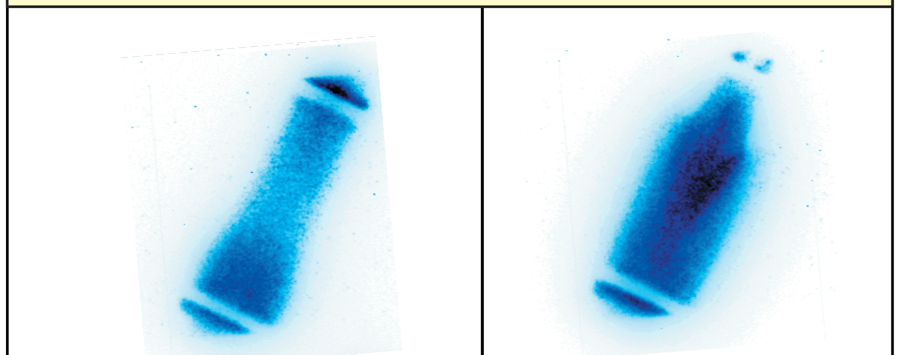
Target

- 2.5×10^{15} W/cm^2
- 16 kJ in 3.5 ns
- 3ω

Polarization Smoothing

3 - 5 keV x-ray images at 3 ns

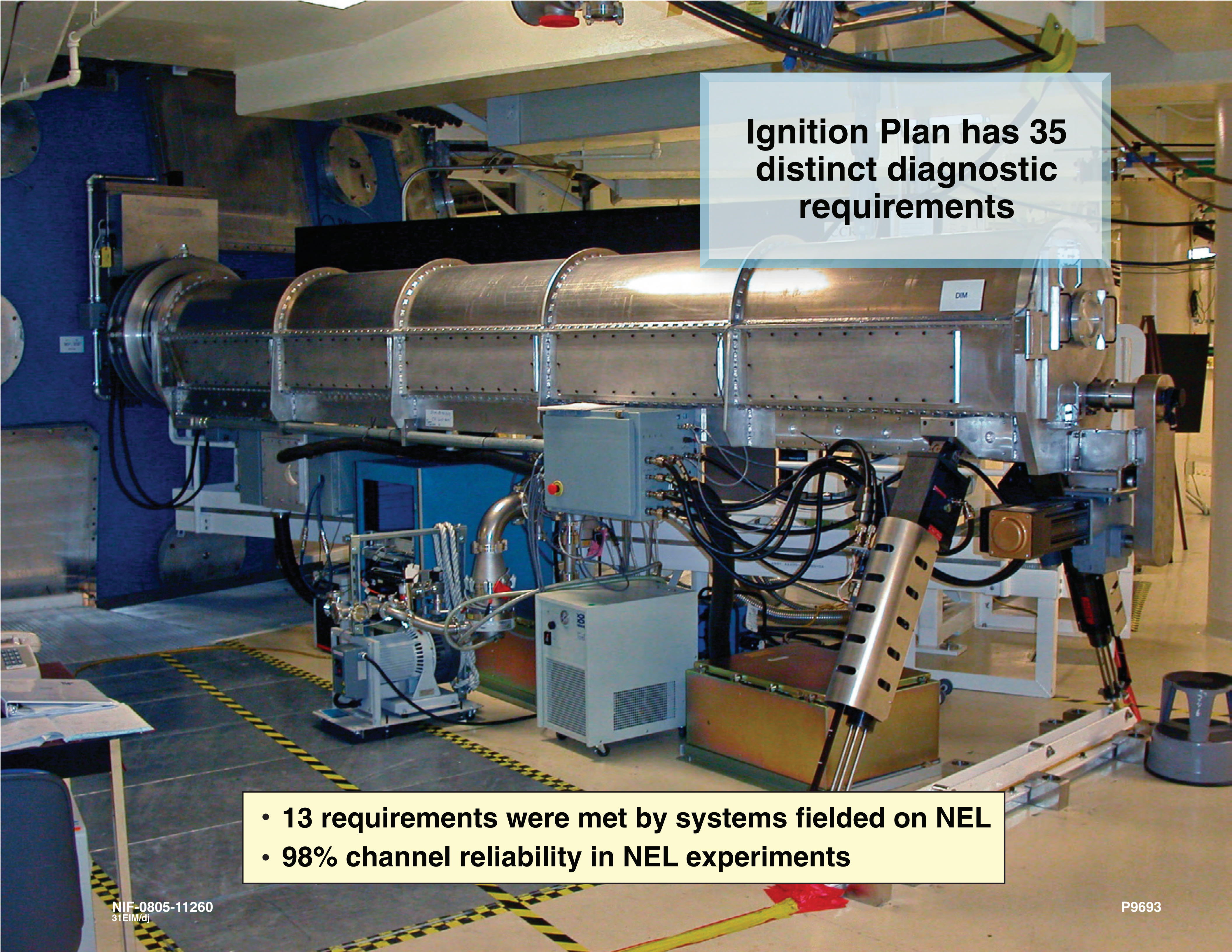


Phaseplate , SSD, and Polarization wedges	Phase-plate only (filaments)

Propagation improvement consistent with modeling and increase in filamentation threshold with improved beam smoothing (I.e. less power/speckle)

S. Glenzer (10186)
E. Dewald (This Session)

Ignition Plan has 35 distinct diagnostic requirements



- 13 requirements were met by systems fielded on NEL
- 98% channel reliability in NEL experiments

NIF Cryogenic Target System

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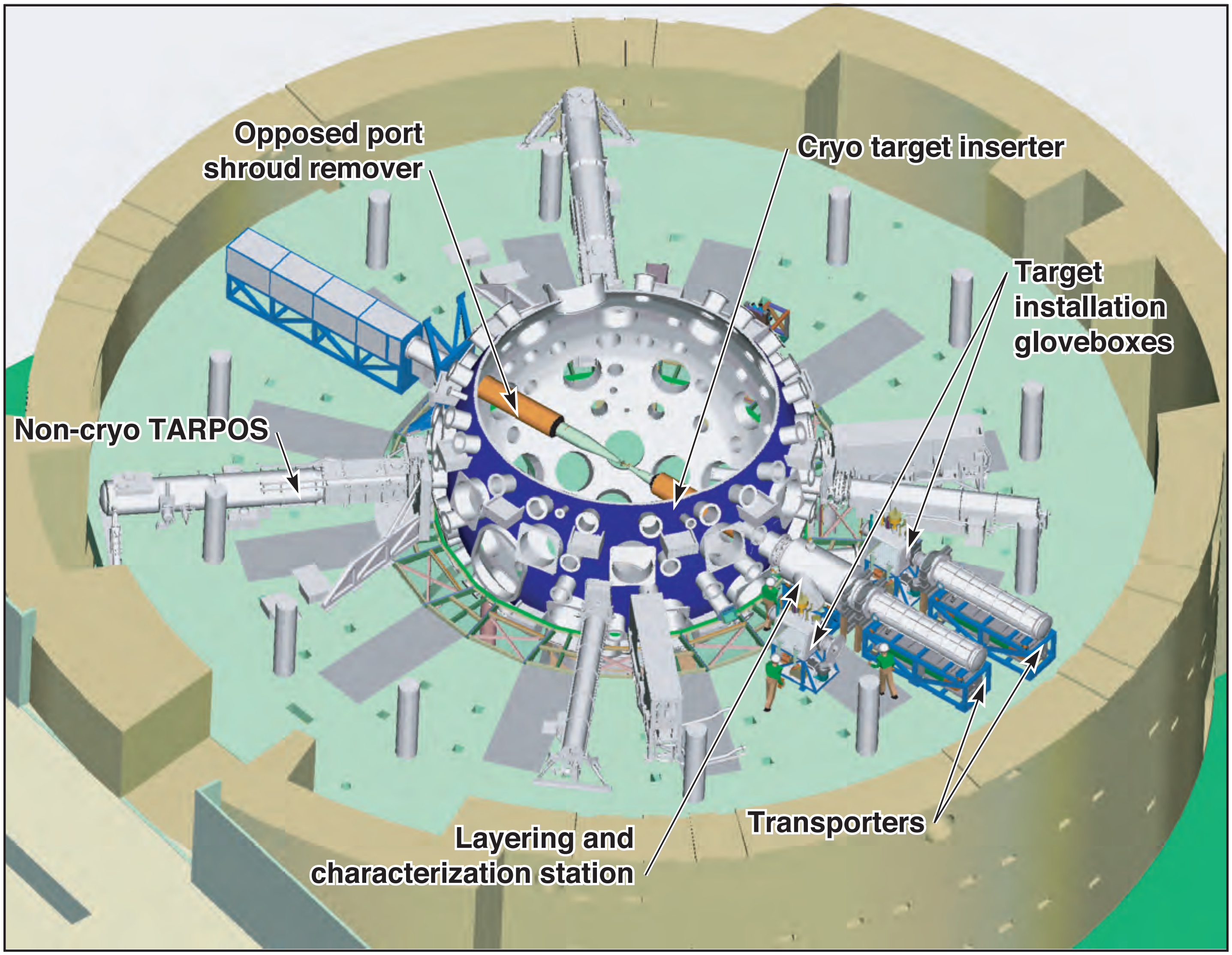

NCTS adapts OMEGA cryo target experience

Ignition 2010 Experimental Plan

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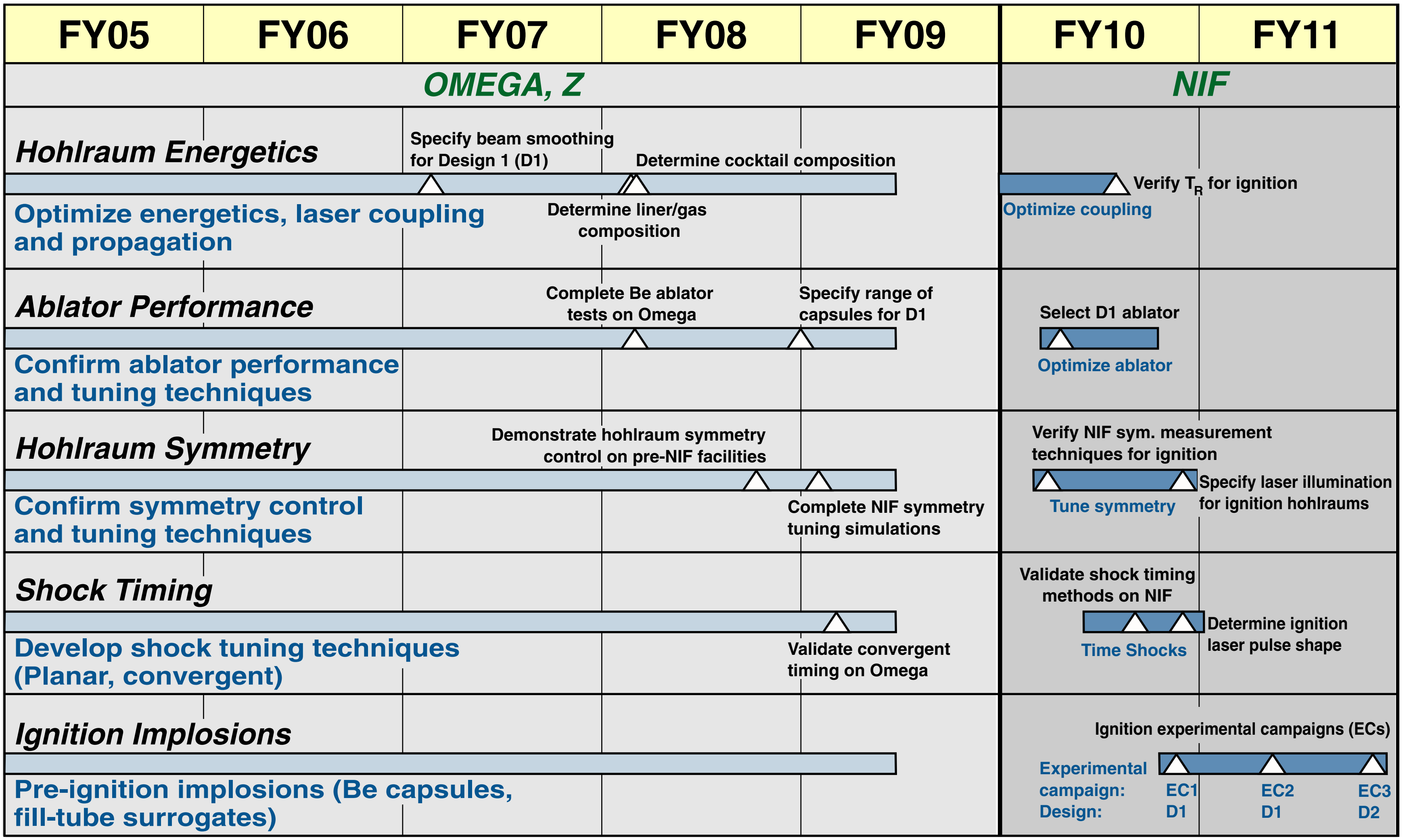

Experiments on other facilities will further optimize and validate ignition target designs before 2010

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	Energetics	Laser Plasma Interactions	Symmetry	Ablator Physics	Shock Timing	Implosions
OMEGA	✓	✓	✓	✓	✓	✓
Z/ZR			✓	✓		
Trident		✓		✓		
LIL	✓	✓				

NIC: All the elements to succeed at ignition are in place

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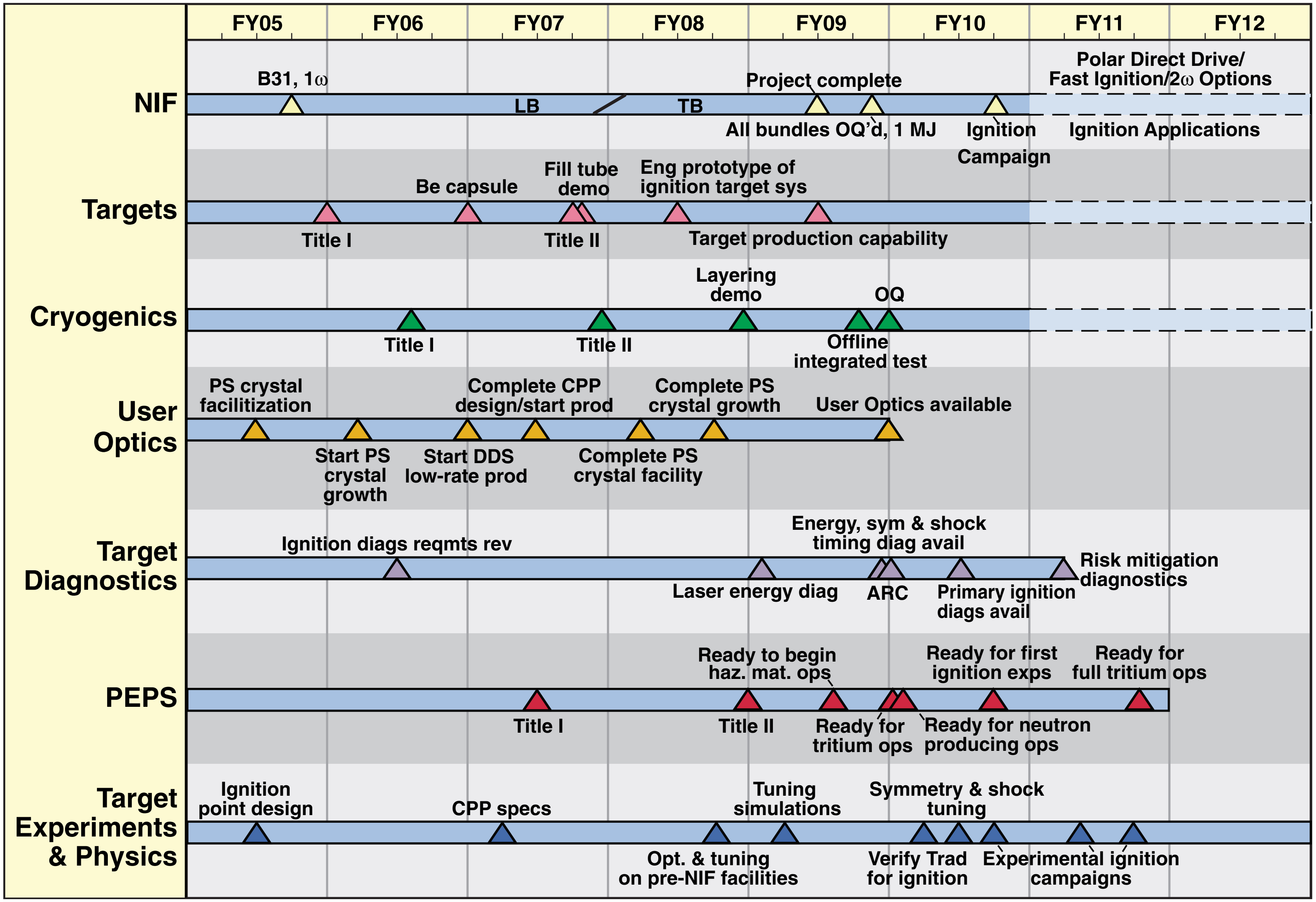

We have a balanced risk strategy to meet the 2010 goal for a credible ignition campaign

NIC: Visions of yesterday become reality of today

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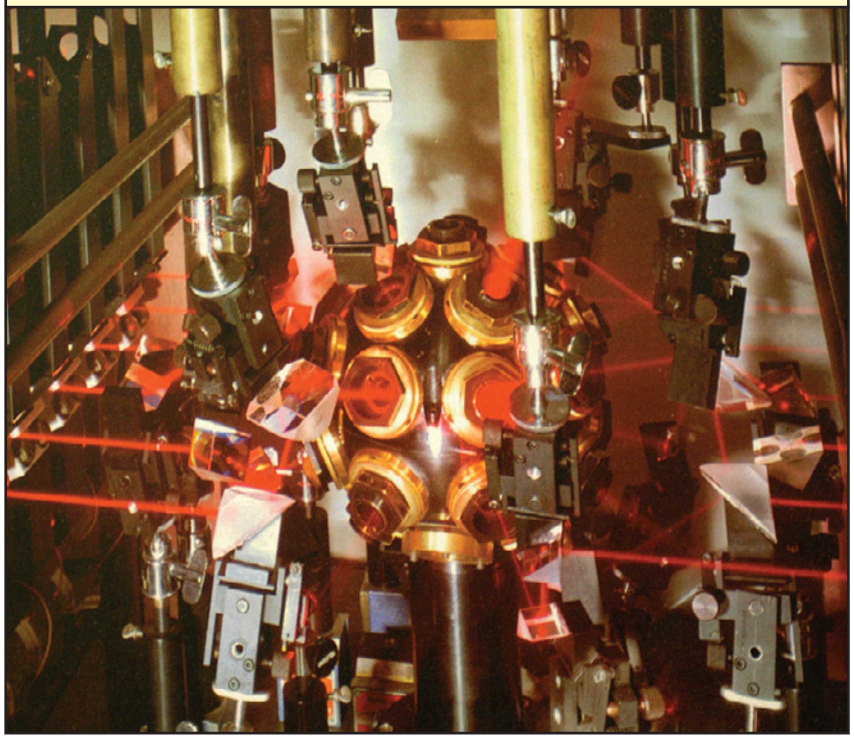
1960 – Invention of Laser	2010 – Goal of Ignition
	

Ignition by 2010
Golden Anniversary of the invention of the laser and the ICF concept

Agenda

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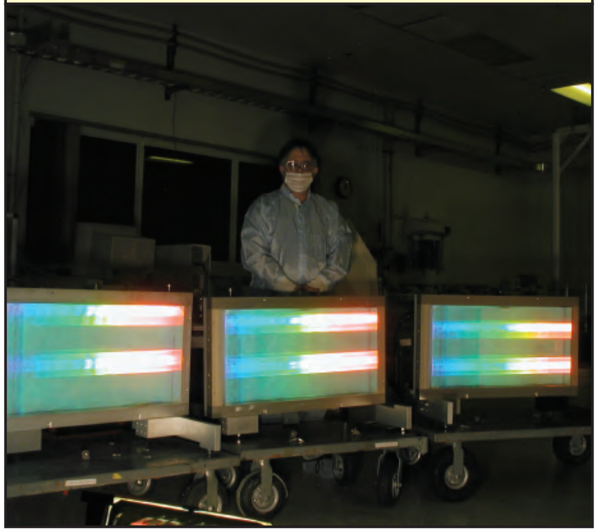
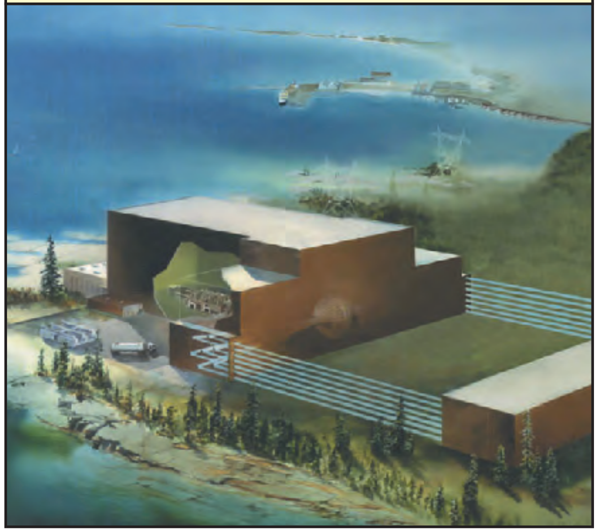
Short Pulse Lasers

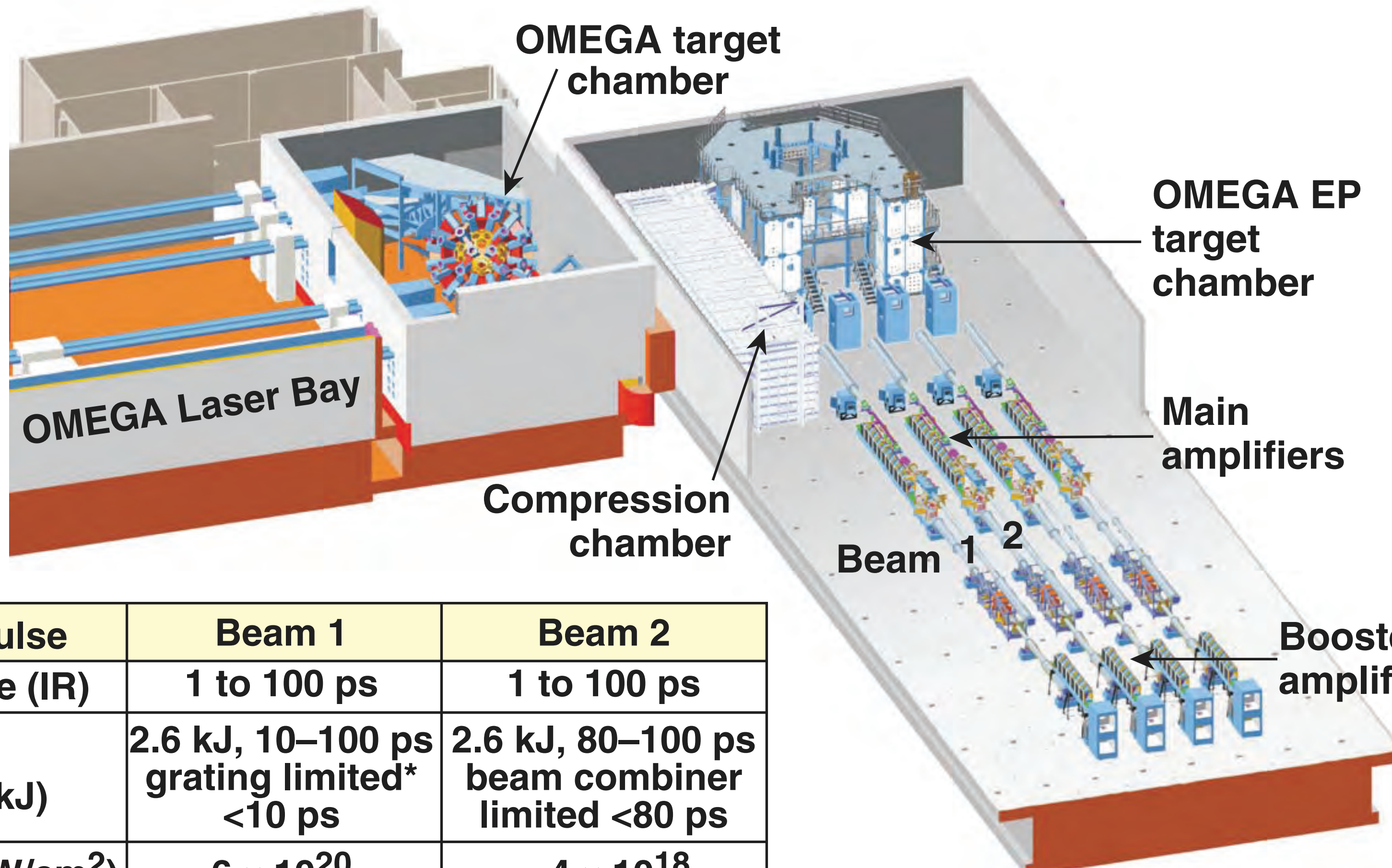


High-Average-Power Laser



Short-pulse OMEGA EP beams can be directed either to OMEGA or new EP target chamber

UR LLE



Short pulse	Beam 1	Beam 2
Short pulse (IR)	1 to 100 ps	1 to 100 ps
IR energy on target (kJ)	2.6 kJ, 10–100 ps grating limited* <10 ps	2.6 kJ, 80–100 ps beam combiner limited <80 ps
Intensity (W/cm^2)	6×10^{20}	$\sim 4 \times 10^{18}$
Focusing (diam)	> 80% in 20 μm	> 80% in 40 μm

* Grating damage threshold is 2.9 J/cm^2 (beam normal).

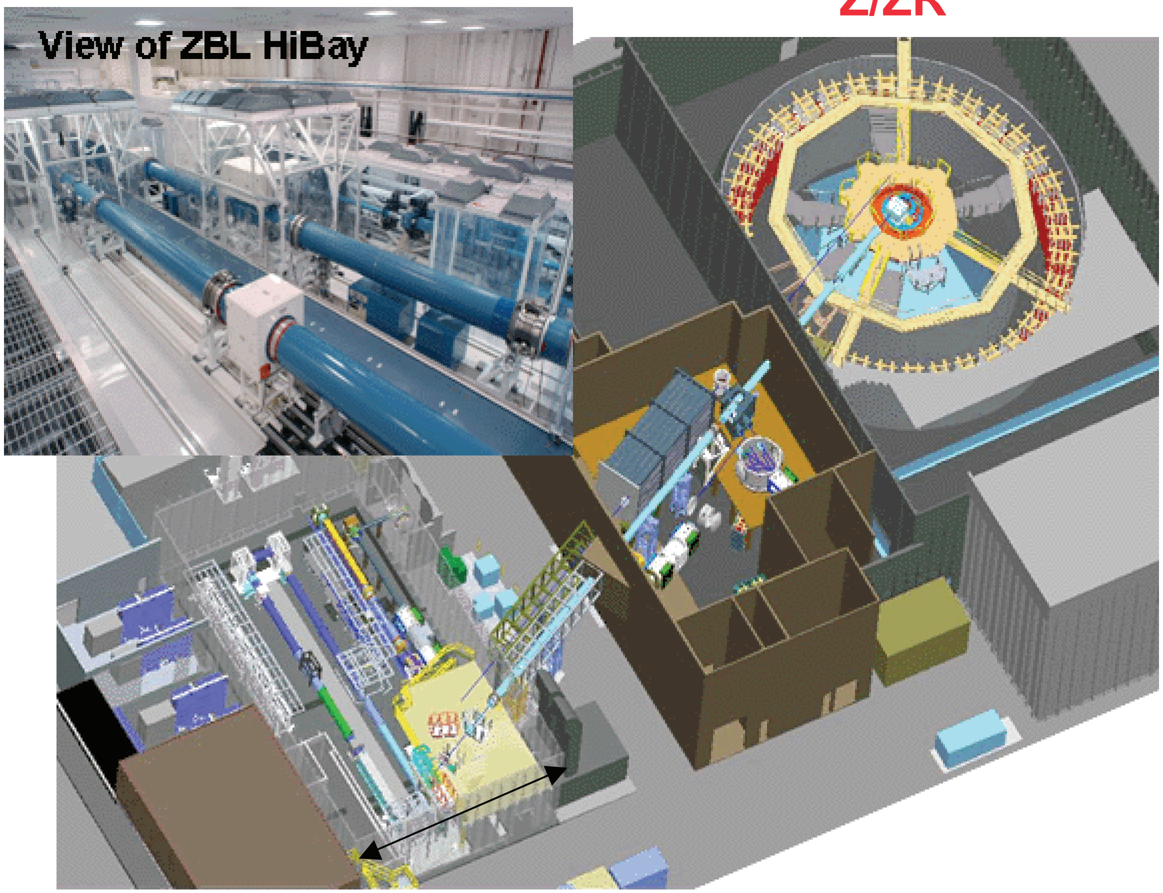
J. H. Kelly ThF1.3
J. D. Zuegel poster
J. Bromage poster
B. E. Kruschwitz poster

G5546y

OMEGA EP will be completed in FY07

The Z-Petawatt Laser System will provide new capability for radiography and fast ignition research

Z/ZR



Z-Beamlet Laser

- Currently, the terawatt-class Z-Beamlet Laser (ZBL) creates a backlighting x-ray source in the 1-10 keV range on Z
- A petawatt-class enhancement, referred to as the Z-Petawatt (ZPW), is being constructed for:
  - New radiography options (X-ray radiography in the 10-100 keV range; Proton radiography)
  - Fast Ignitor fusion research on Z/ZR
- The 2 kJ/1 ps system will begin operation in 2007

*See Rambo *et al* (IFSA Poster G31)

Advanced Radiographic Capability is being developed for NIF

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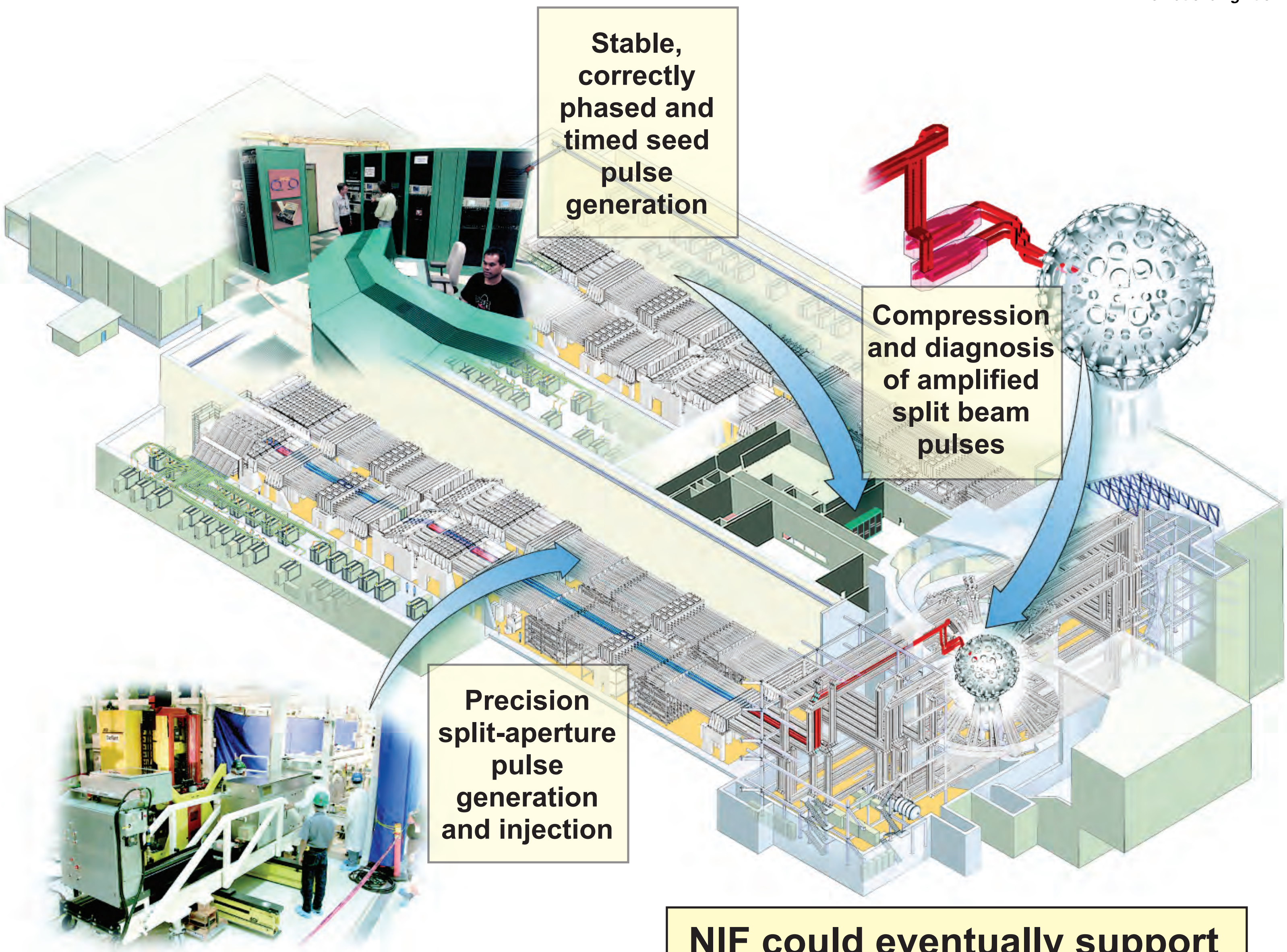

NIF could eventually support fast ignition capability

NRL "Electra" 5 Hz Krypton Fluoride Amplifier

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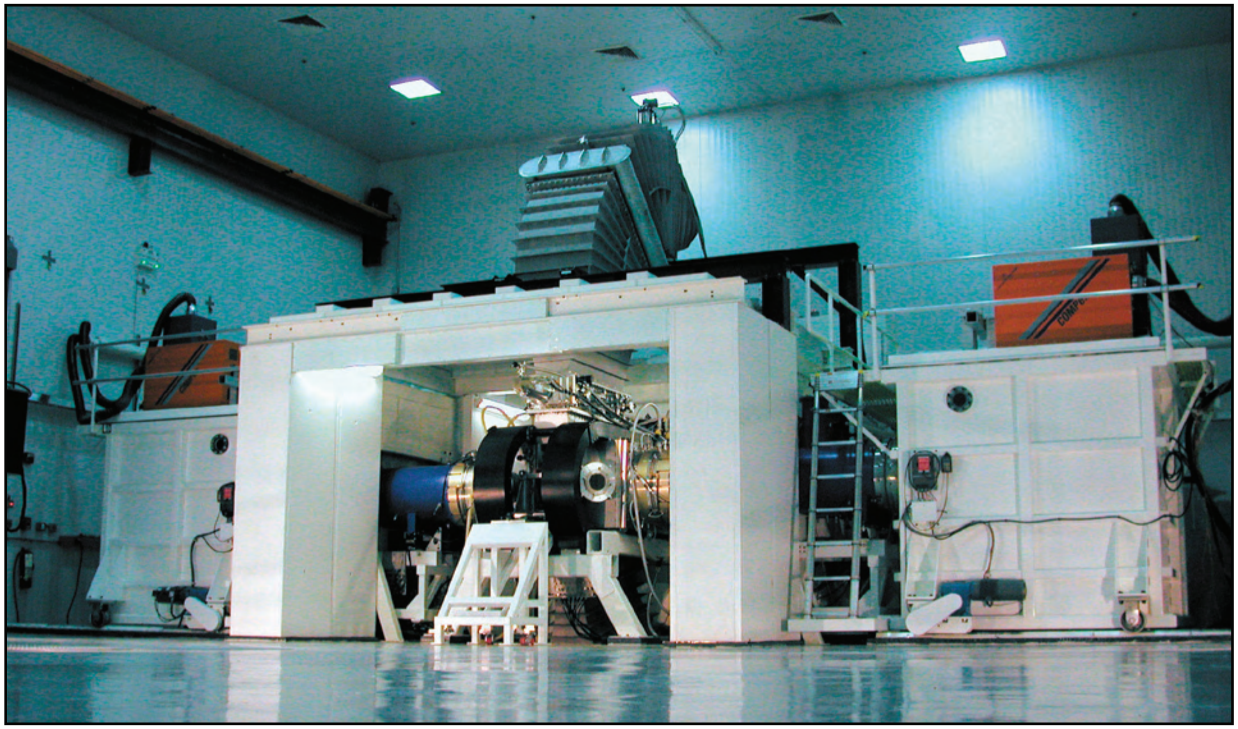
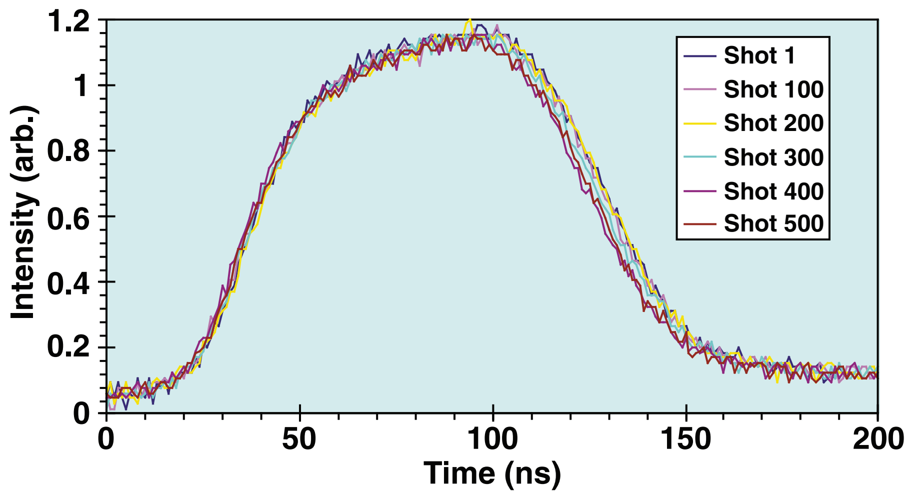
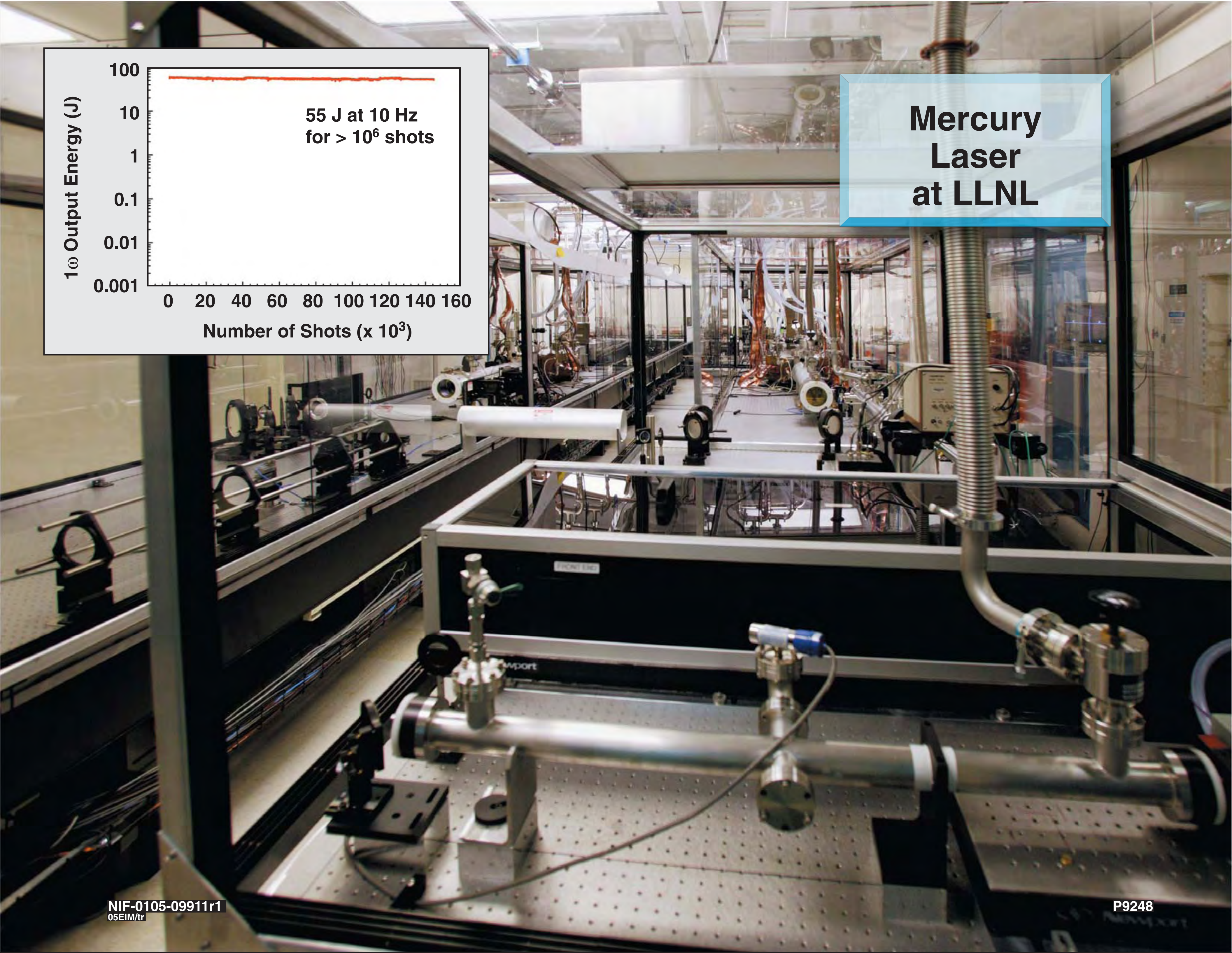


500 overlapped shots
400J @ 5 Hz
Laser Output (oscillator mode)




100
10
1
0.1
0.01
0.001
1ω Output Energy (J)
55 J at 10 Hz
for > 10⁶ shots
0 20 40 60 80 100 120 140 160
Number of Shots (x 10³)
Mercury
Laser
at LLNL
NIF-0105-09911r1
05EIM/tr
P9248

Agenda

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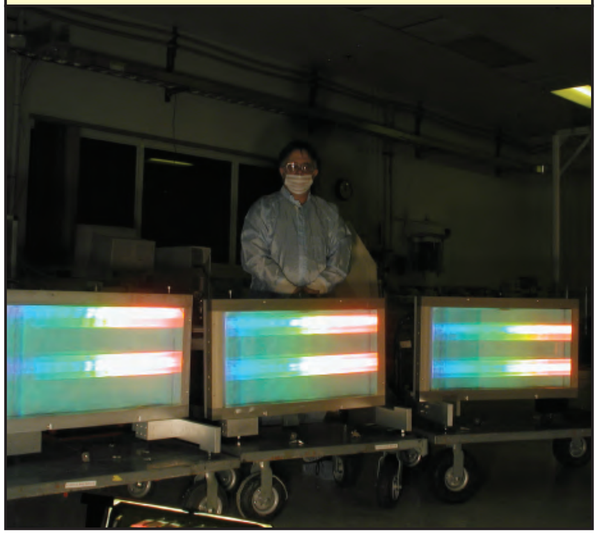
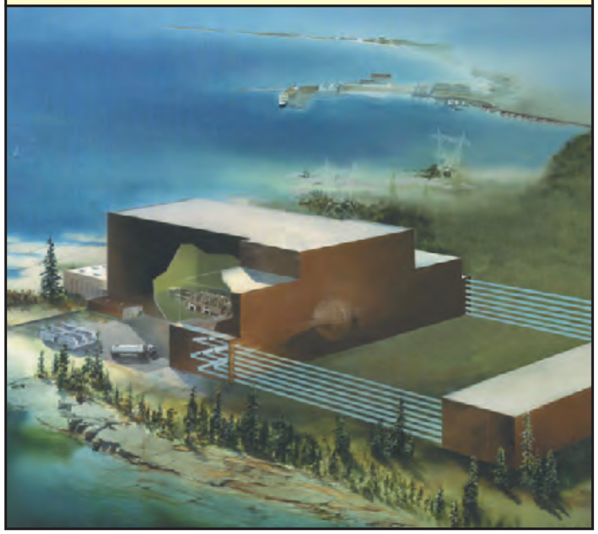
Short Pulse Lasers



High-Average-Power Laser



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FACILITY


Oct ’03