Operational Experience at the National Ignition Facility

Canadian Workshop on Fusion Energy Science and Technology

October 18, 2015

Sandra Brereton
Deputy Principal Associate Director for Operations

LLNL-PRES-678259
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Lawrence Livermore National Laboratory

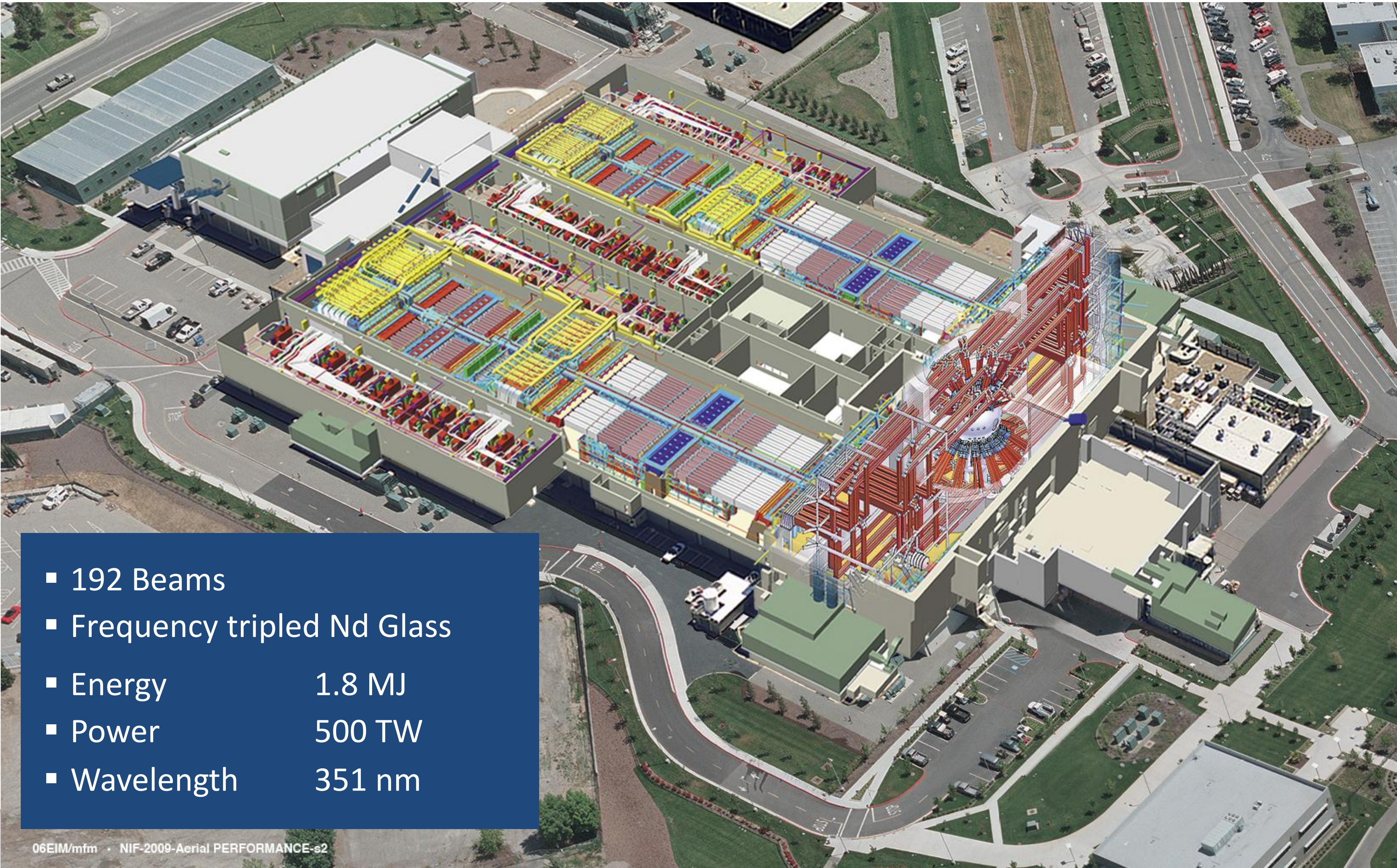

San Francisco
(45 mi.)
Lawrence Livermore National Laboratory
National Ignition Facility

The NIF is fully operational, now executing over 300 experiments per year

- **NIF is 70,000 square meters**
- **NIF concentrates all 192 laser beam energy into a mm^3**

▪ Matter temperature	$>10^8$ K
▪ Densities	$>10^3$ g/cm^3
▪ Pressures	$>10^{11}$ atm

NIF was designed and built to create ignition conditions

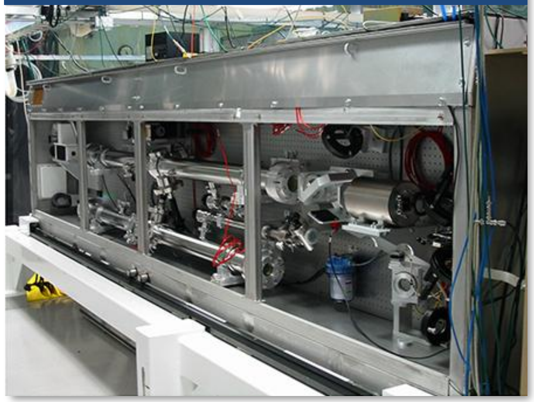


- 192 Beams
- Frequency tripled Nd Glass
- Energy 1.8 MJ
- Power 500 TW
- Wavelength 351 nm


00ABC/lh • NIF-0609-16540s2

6,206 line replaceable units (LRUs) were processed, assembled and installed in building NIF

Preamplifier Modules (48)

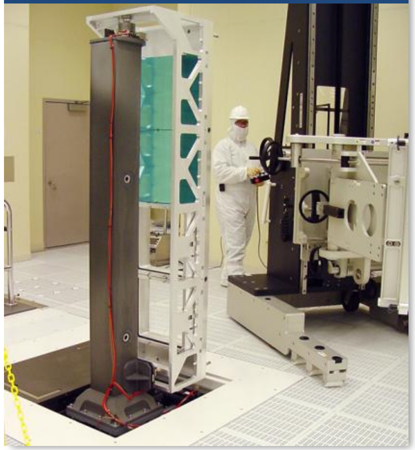


Laser Amplifiers (672)

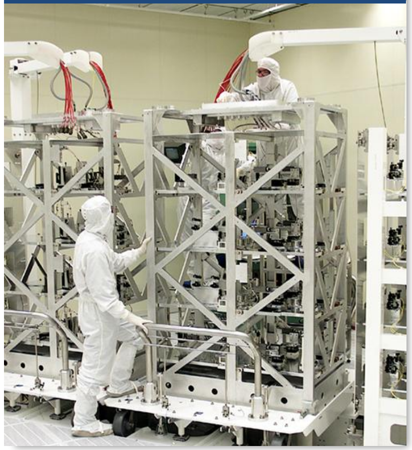
Final Optics Assemblies (960)

Laser Mirrors (656)

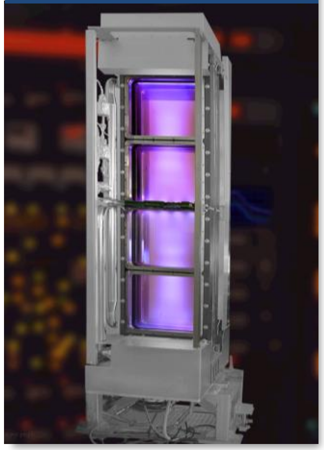
Spatial Filter Lenses (960)



Spatial Filter Towers (72)

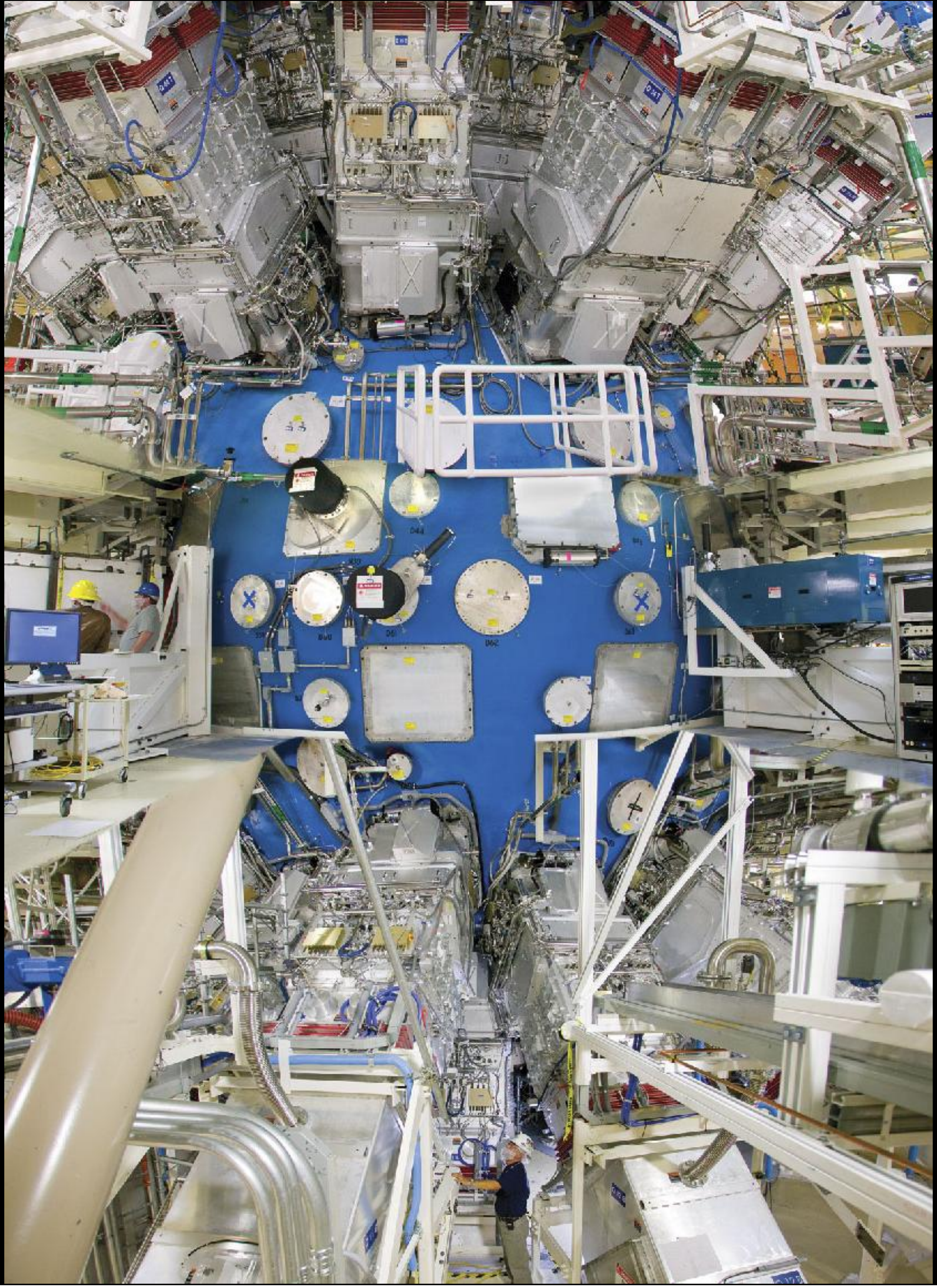


Plasma Electrode Pockels Cell (192)



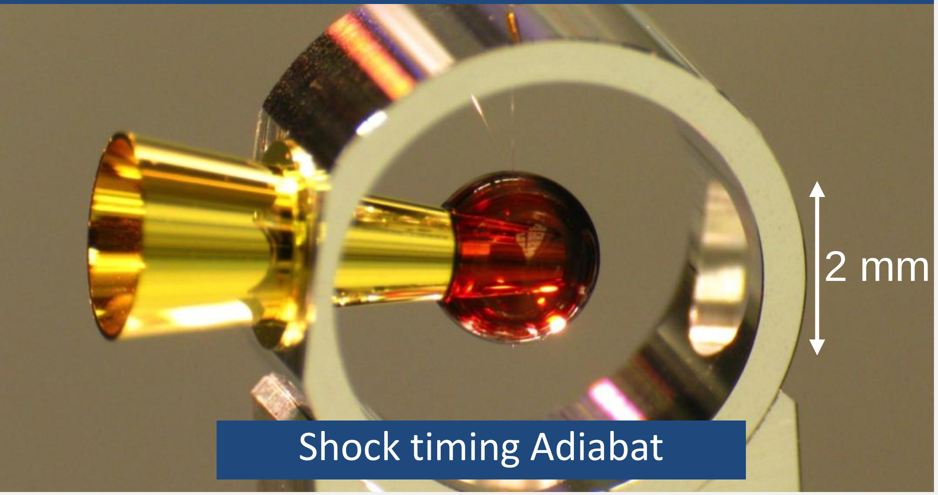
Flashlamps (1008)


3
AGV PRODUCTS



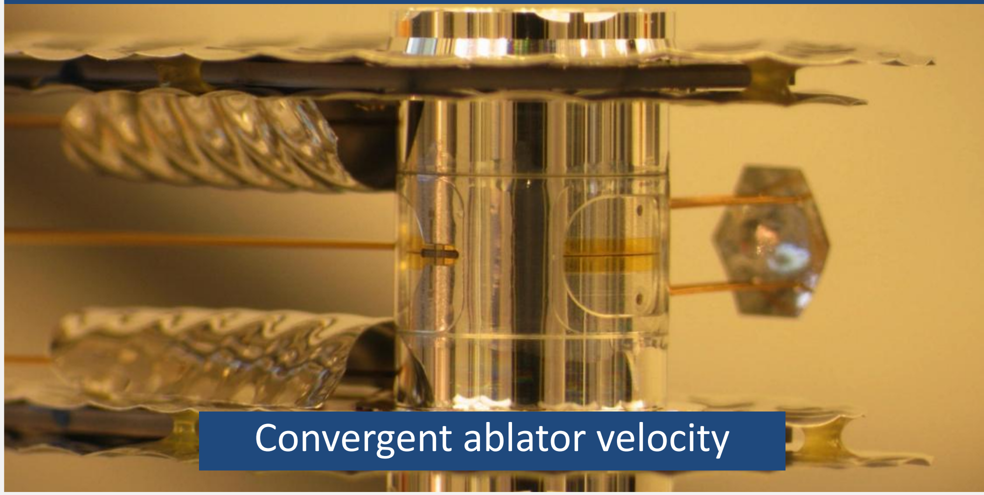
A wide range of targets and platforms are used to study target physics

Keyhole



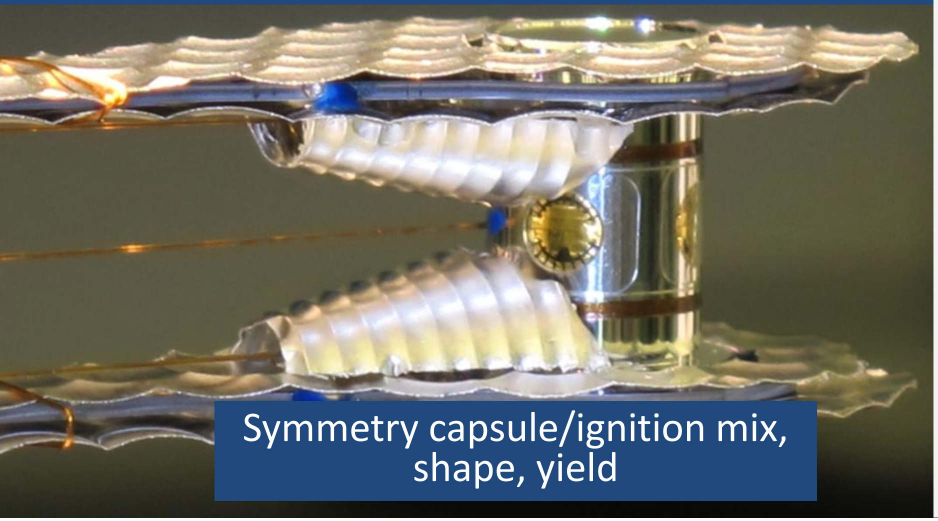
Shock timing Adiabat

Con A



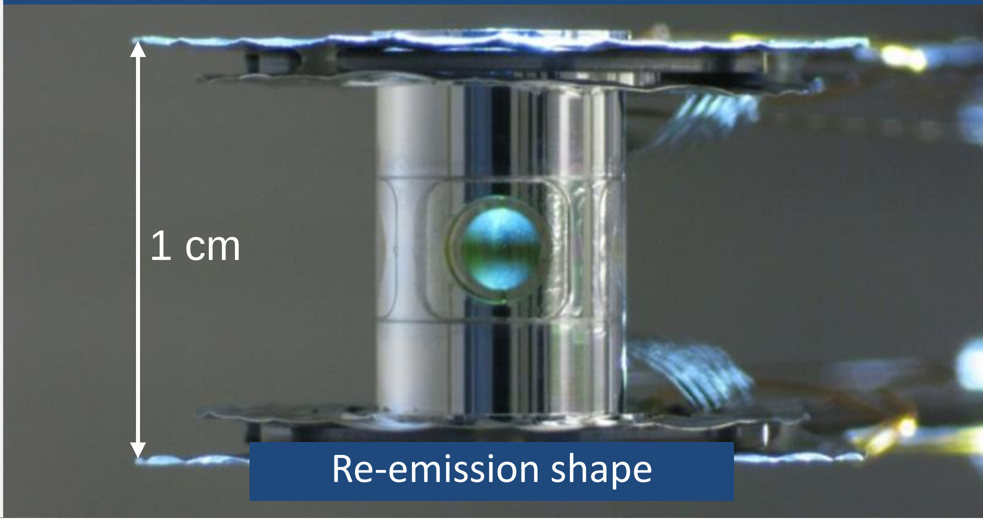
Convergent ablator velocity

Symcap/ignition



Symmetry capsule/ignition mix, shape, yield

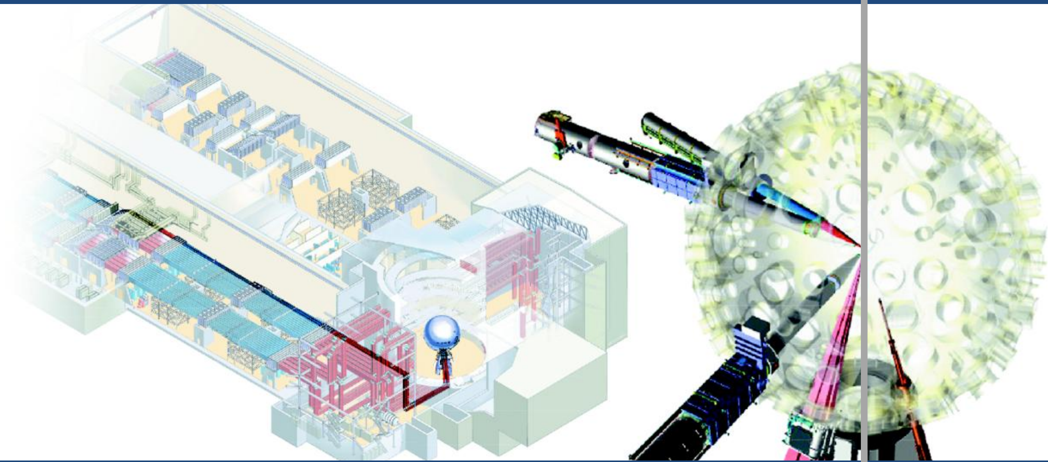
Re-emit



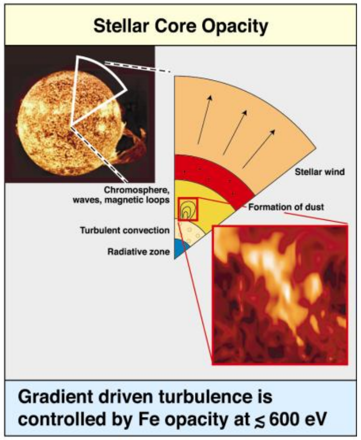
Re-emission shape

NIF can access unprecedented high energy density regimes

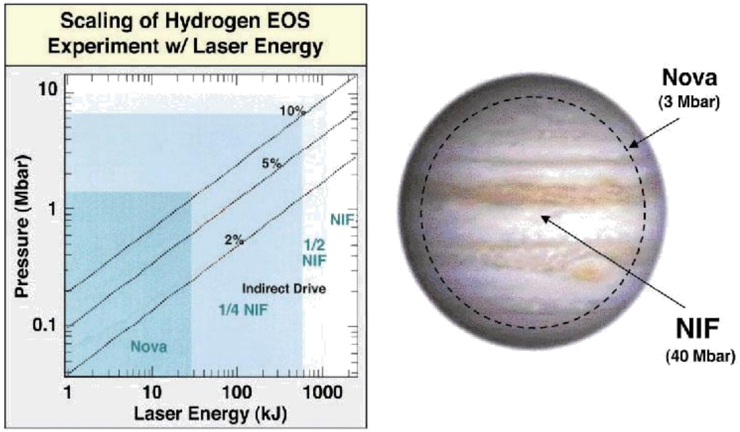
NIF is capable of achieving Ignition, and will create a Flux of Neutrons



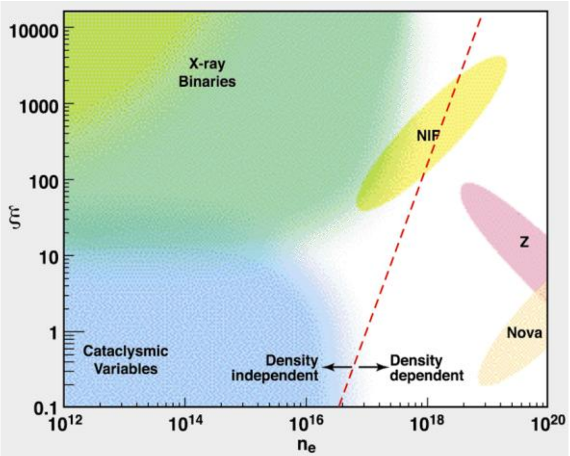
NIF Will Create Thermal Plasmas at the Conditions of Stellar Interiors



NIF Will Drive Targets to Pressures Found at the Center of Jupiter



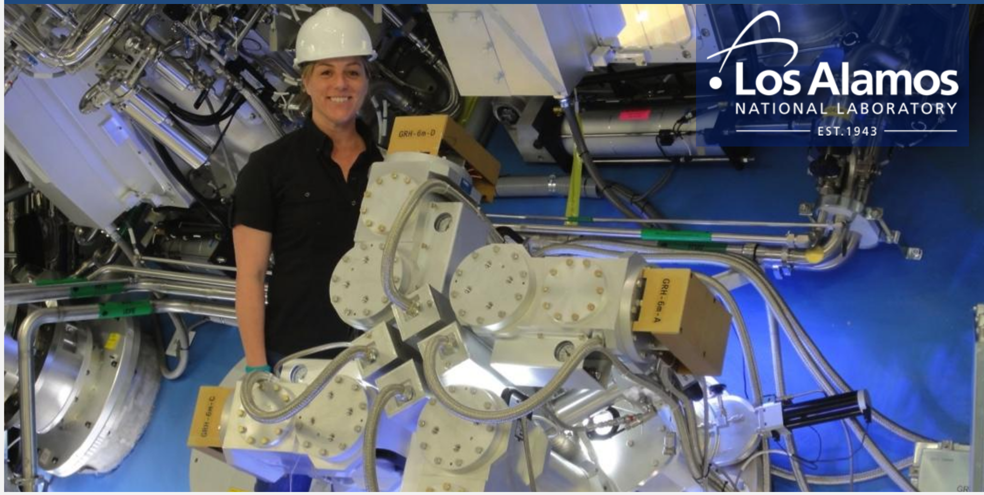
NIF Will Produce Enough X-Ray Flux to Simulate Conditions in an Accretion Disk



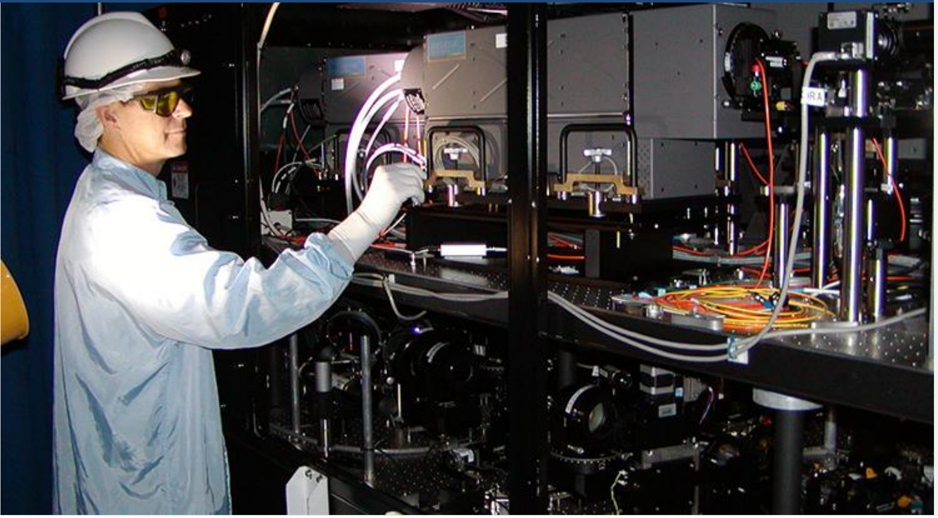
NIF has a suite of over 50 target diagnostics

Dante

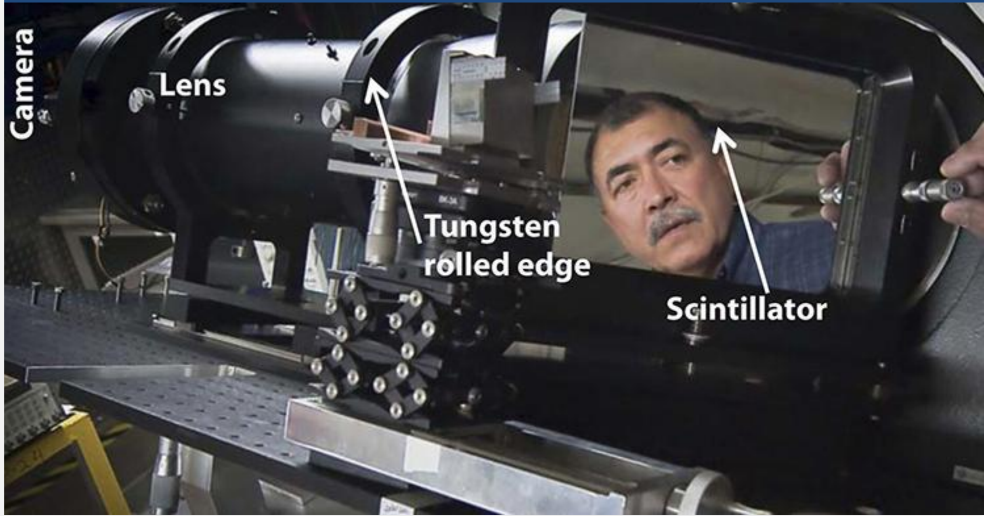
Gamma Reaction History



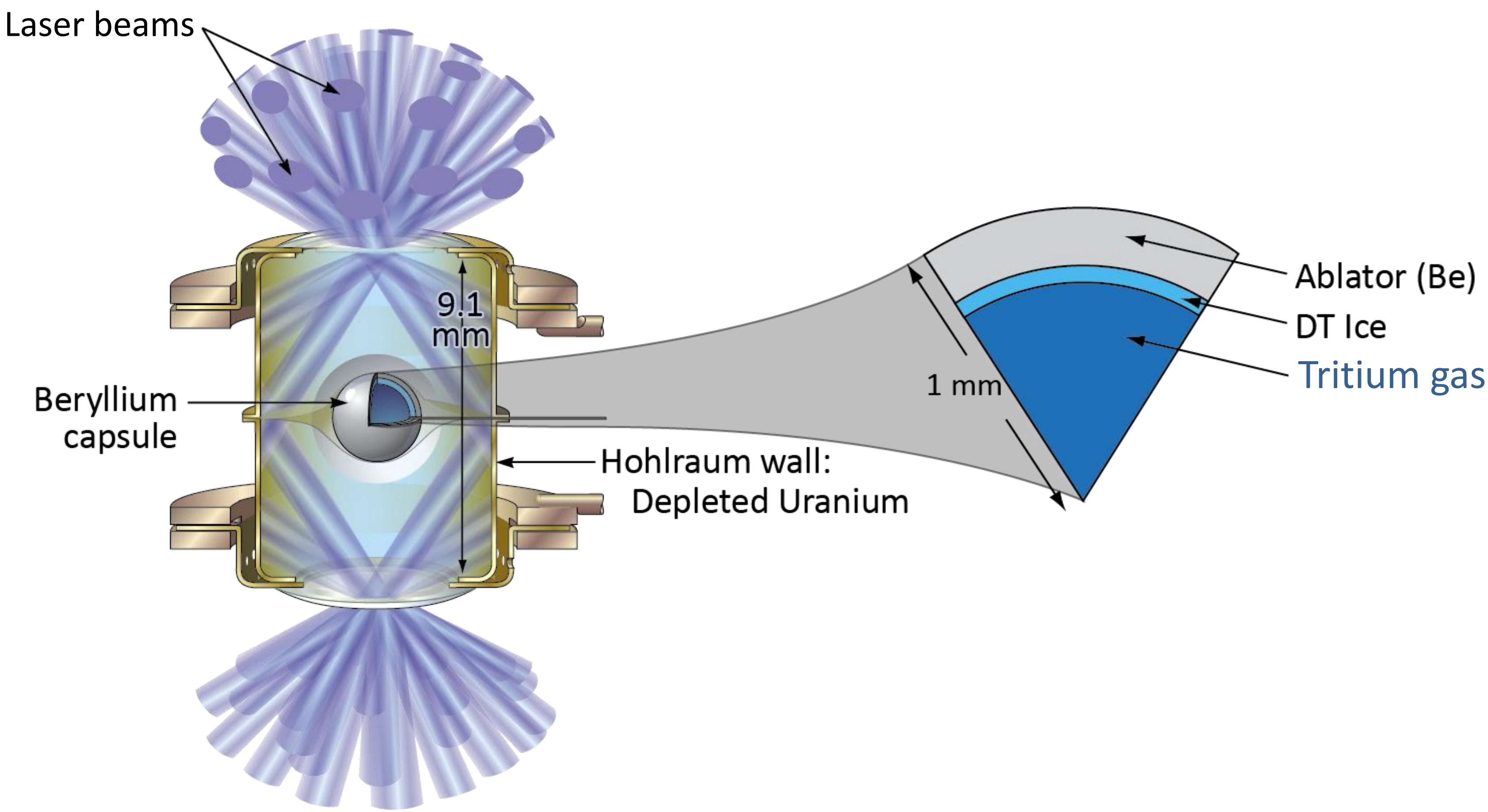
VISAR



Neutron Imager

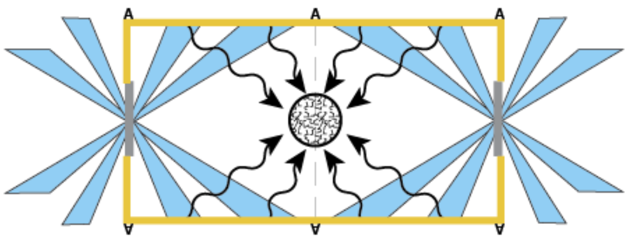


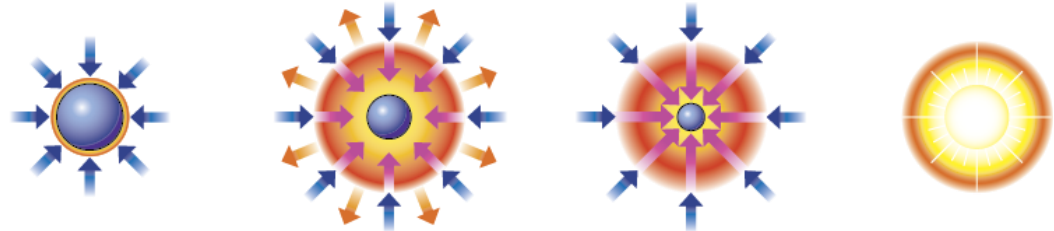
Ignition Point Design



Indirect Drive

Laser energy Blowoff Inward transported thermal energy





X-ray generation

Laser beams rapidly heat the inside surface of the hohlraum surrounding the capsule with a uniform field of x rays

Atmosphere formation

X rays rapidly heat the surface of the fusion capsule forming a surrounding plasma envelope

Compression

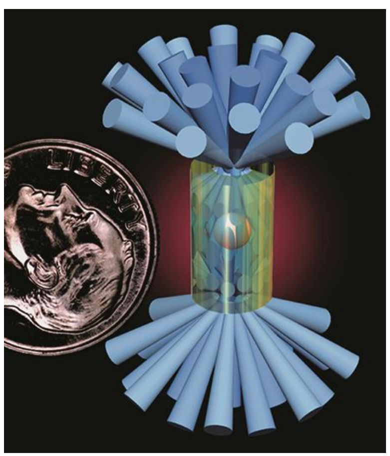
Fuel is compressed by the rocket-like blowoff of the hot surface material

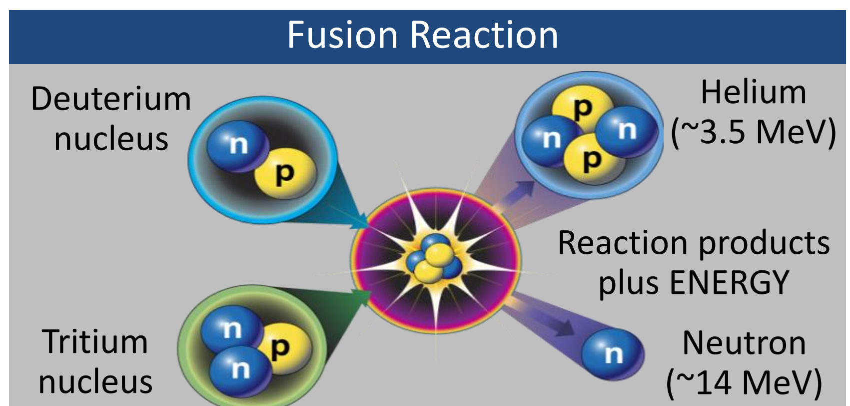
Ignition

During the final part of the laser pulse, the fuel core reaches 20 times the density of lead and ignites at 100,000,000 K

Burn

Thermonuclear burn spreads rapidly through the compressed fuel, yielding many times the input energy





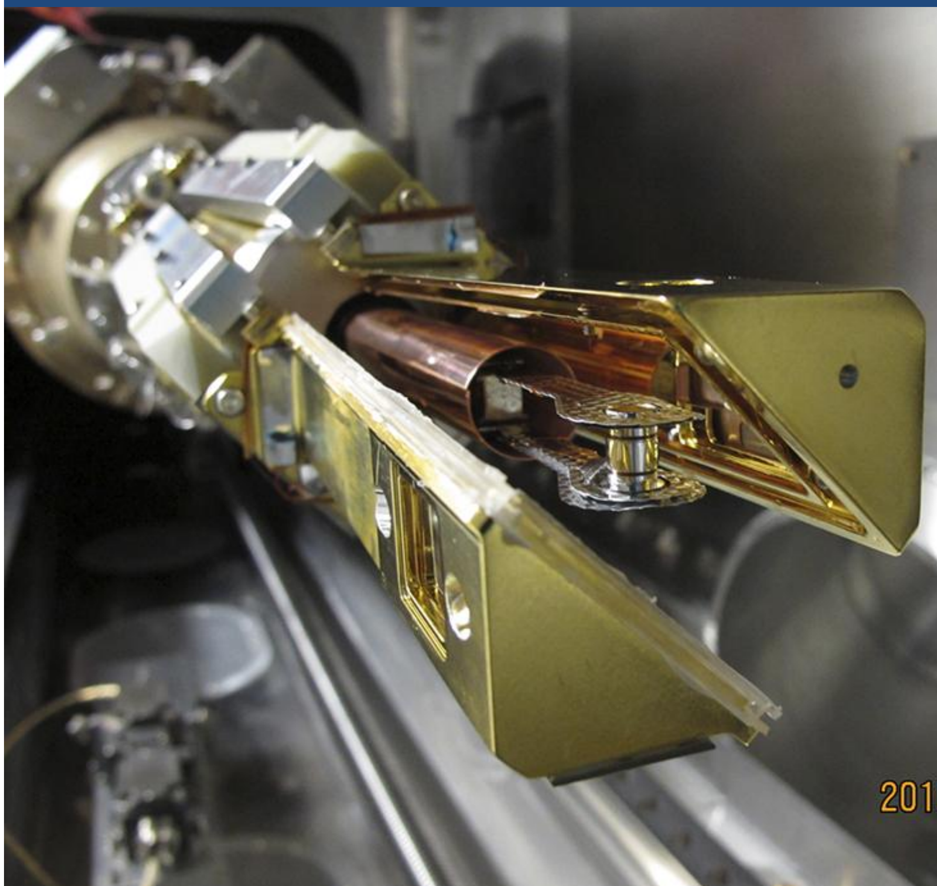
NIF Fun Facts

- NIF targets are shot one at a time
  - 2/day to 1/wk
- NIF laser pulse: ~ 20 nsec
  - Laser operates small fraction of the time, < 10 μsec/yr
- Tritium is used as fusion fuel in NIF capsules
  - ~ 10 Ci (1 mg/shot), elemental
  - Quantity compares to commercially available items
- Uranium is used in the hohlraum, to create x-rays for heating
  - ~ 40 mg DU per target
- Yield up to 7.1e18 neutrons/shot (20 MJ fusion energy)
  - ~ 1e10 MW for a couple of nsec
  - Gain ~ 10

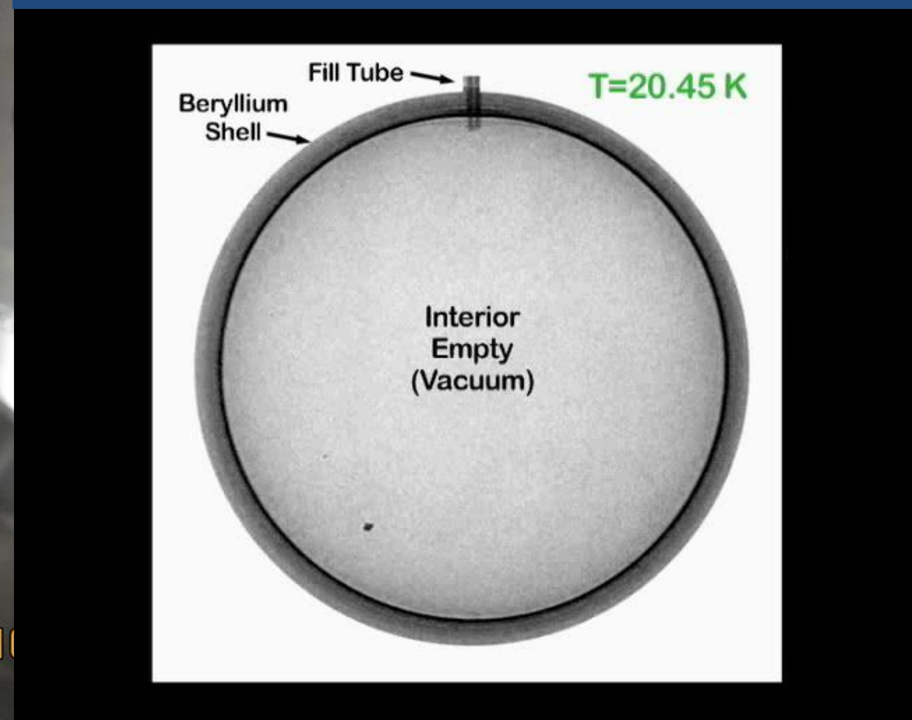
- Operations to date
  - As many as 10 targets shot in a week
  - Tritium throughput ~ 2000, - 4,000 Ci/yr
  - Stack release < 10 Ci/yr
  - Yield up to 1e16 neutrons/shot (~ 30 kJ)

Ignition Shots use cryo-layered targets

Target before the shot

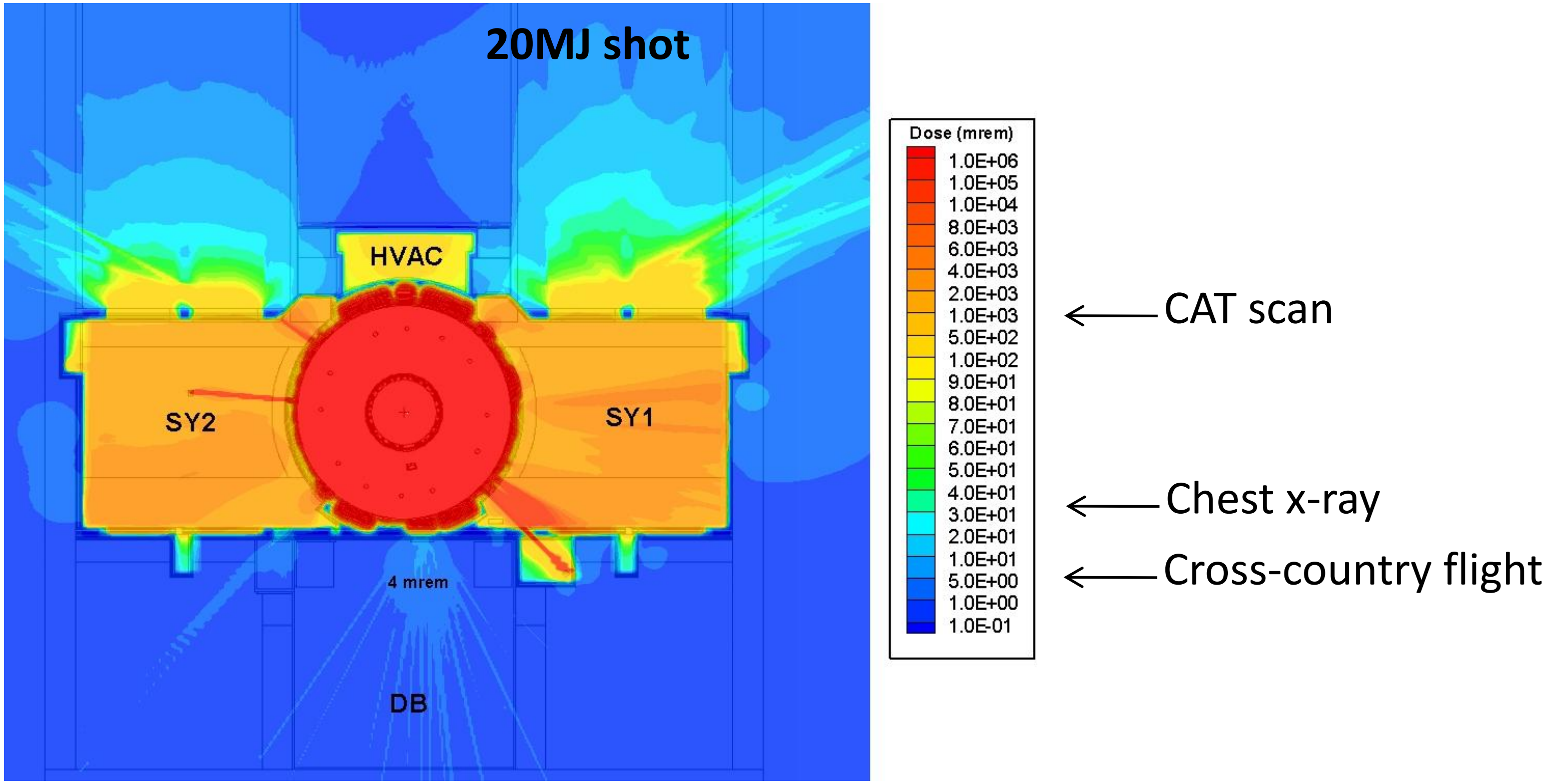


Layer formation



X-ray phase contrast imaging has sufficient accuracy for ice characterization

Neutron-producing shots can result in high radiation fields in some locations at the instant of the shot

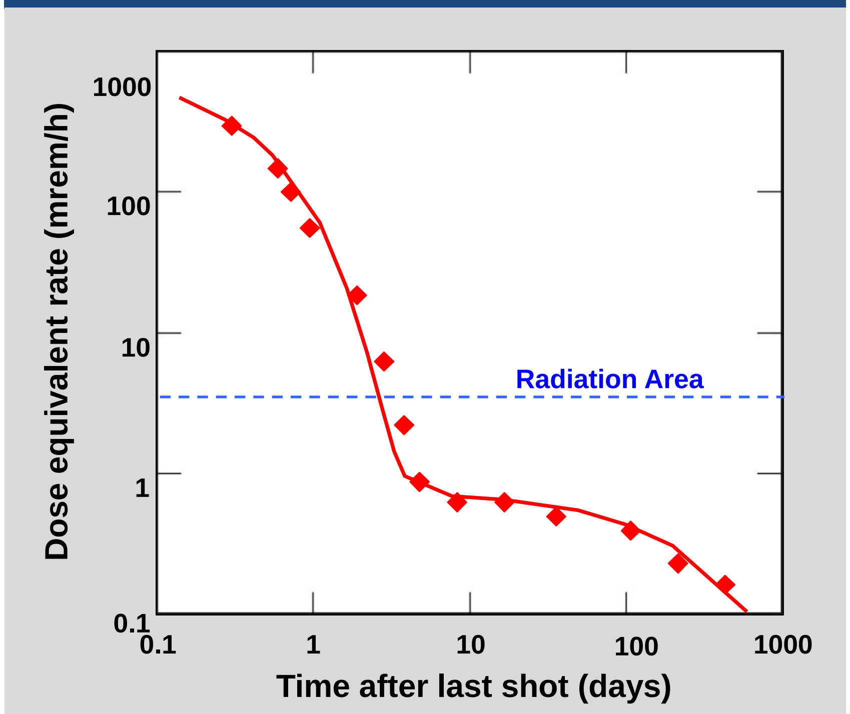


- Extreme hazard in TB during high yield shots
- Sweeps conducted to keep people out of affected areas
- Occupied areas <~5mrem (dark blue)

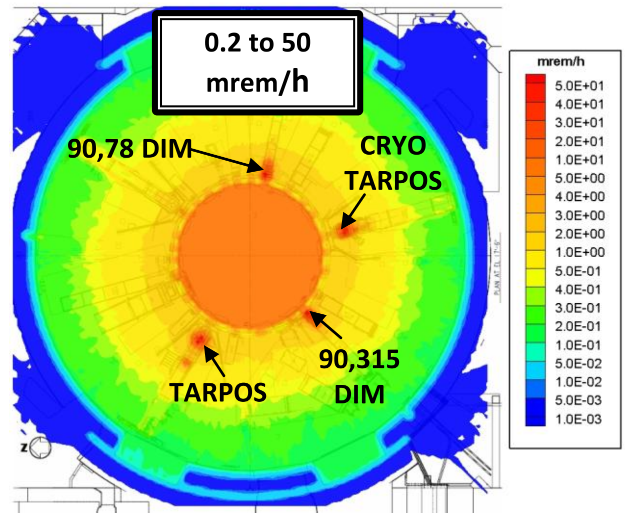
Sweeps & shield walls and doors mitigate the prompt radiation hazard

A residual radiation field exists in the TB after neutron producing shots: some material becomes activated

Dose rate vs. time near the debris shields (20 MJ shot)

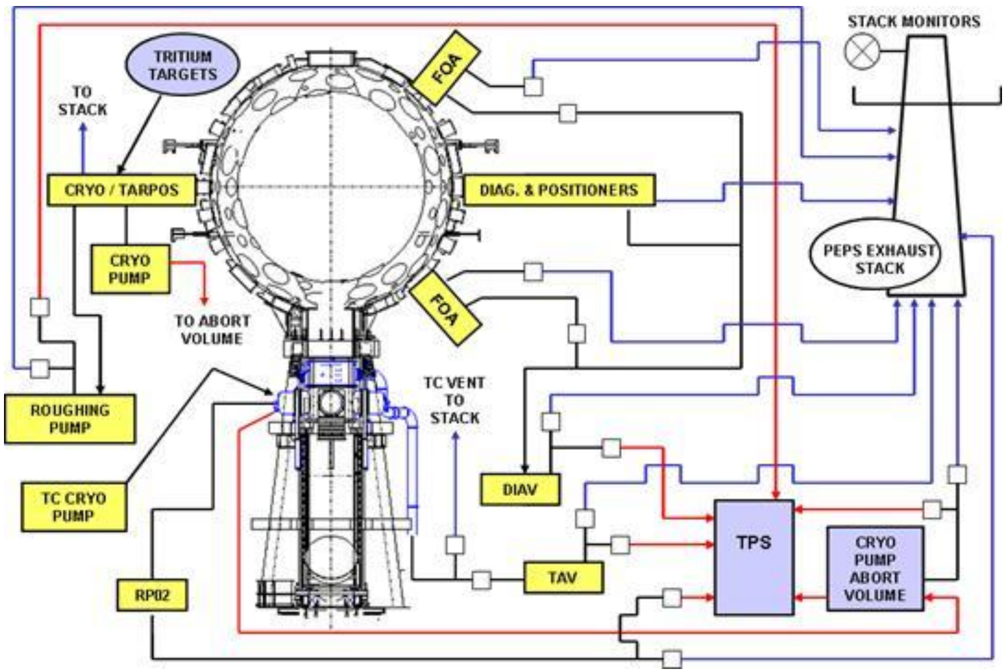


- Controls:
  - Stayout time after shots
  - TB entry tightly controlled
  - Work carefully planned to minimize dose incurred while in the target bay
  - Individual and collective dose closely monitored



NIF Goal is ALARA – As Low As Reasonably Achievable

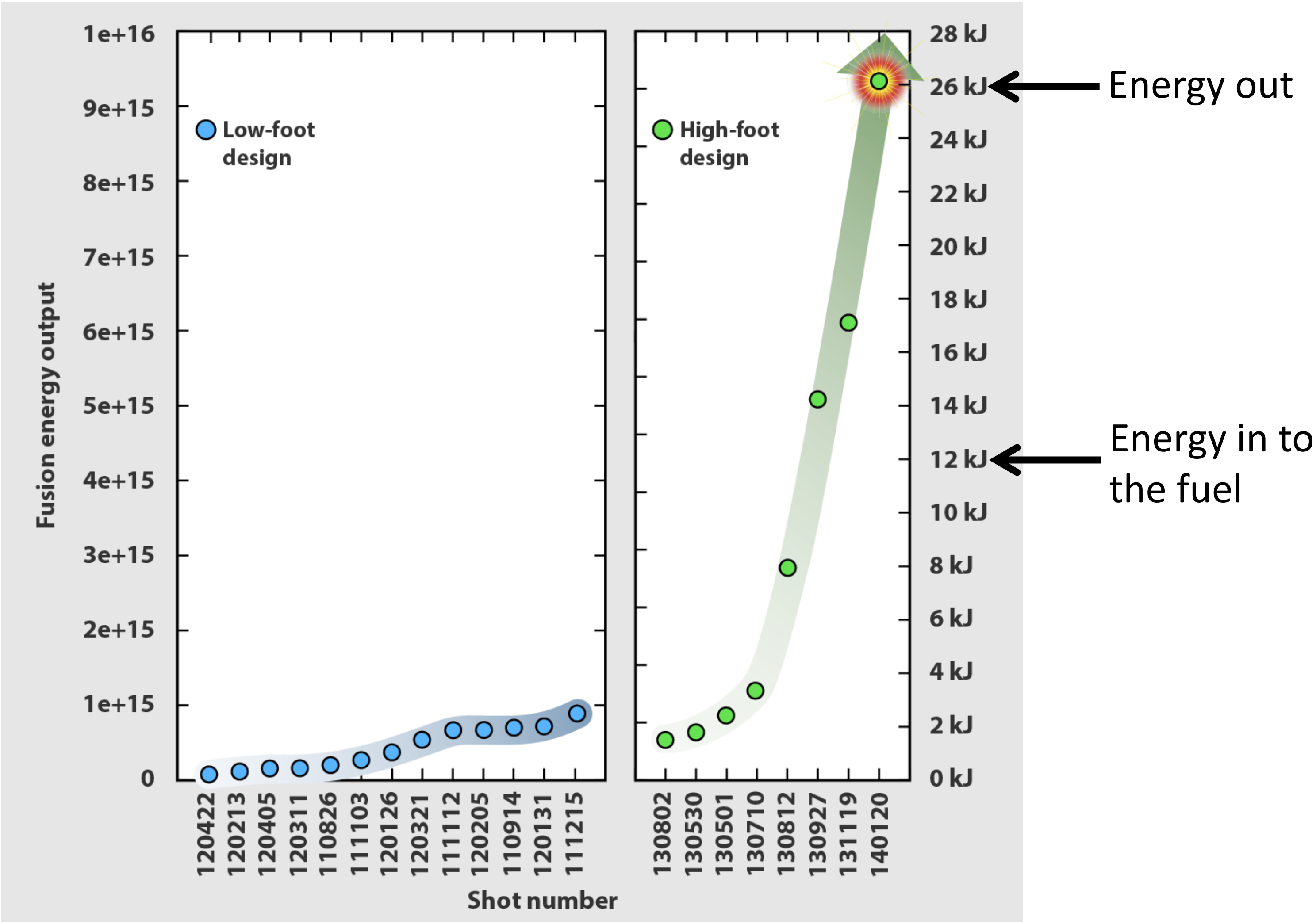
The interior of the target chamber, entrant items and attached systems become contaminated



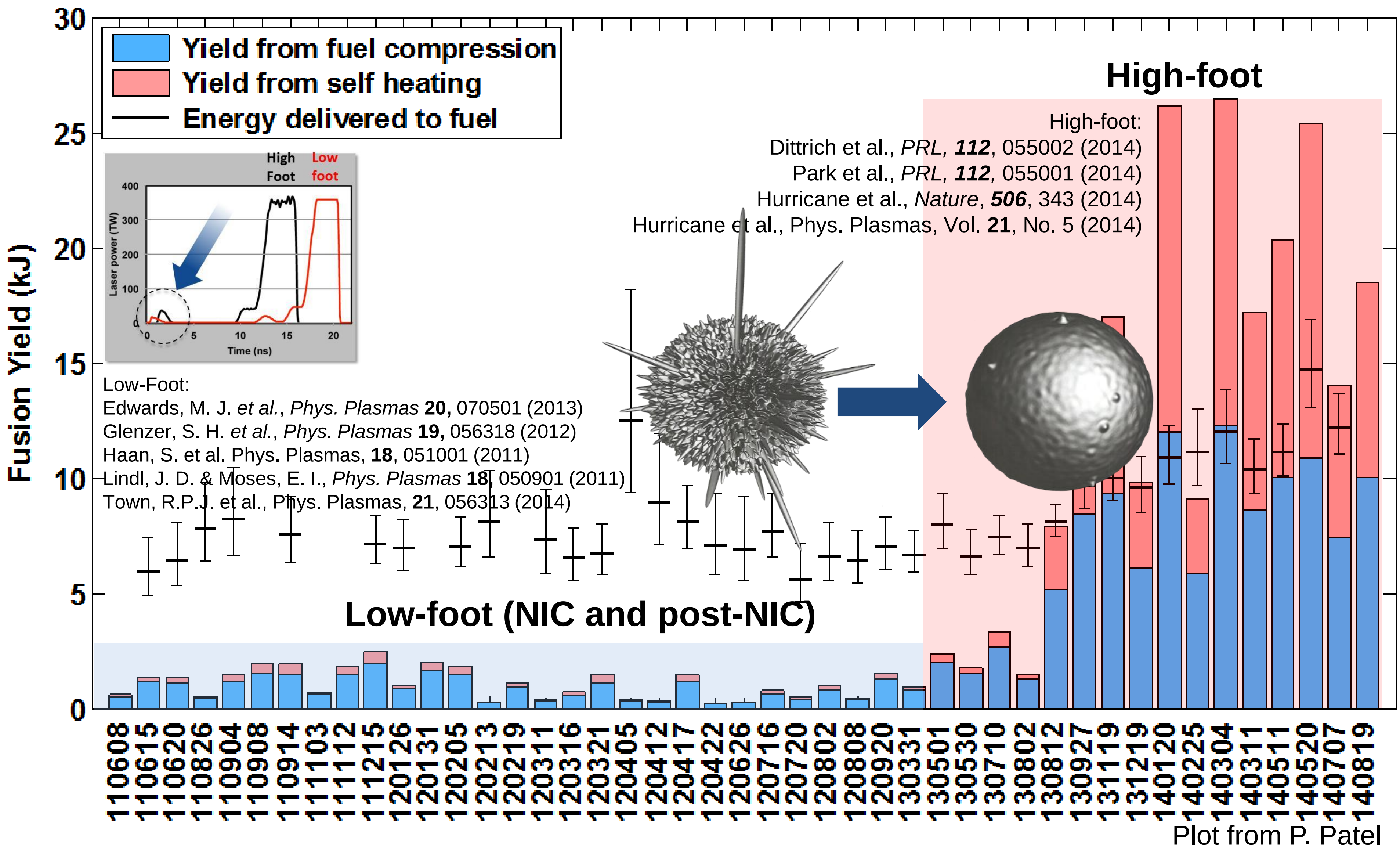
- Tritium, activation products, and small amounts of fission products will be present on exposed surfaces
- Contaminated volumes are accessed regularly
- Standard contamination control practices are applied:
  - — Confinement/ventilation
  - — PPE, draping
  - — Contamination areas
  - — Monitoring

Contamination Control practices are widely applied

Performance on NIF to date has shown progress towards ignition



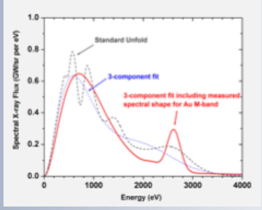
Performance on NIF to date has shown progress towards ignition



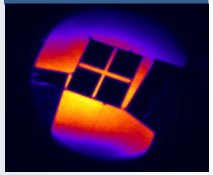
Need for focused physics experiments: previous diagnostic set not adequate to completely understand performance

Hohlraum performance

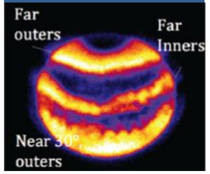
Spectrum



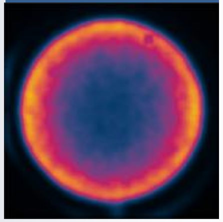
Backscatter

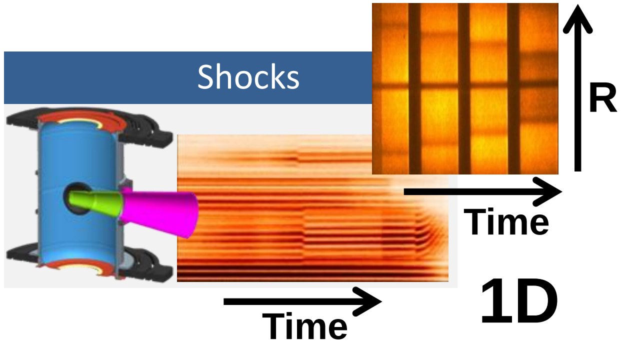


LEH size

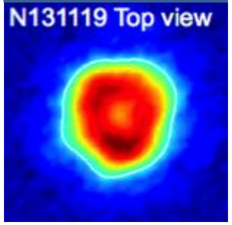


Picket drive symmetry



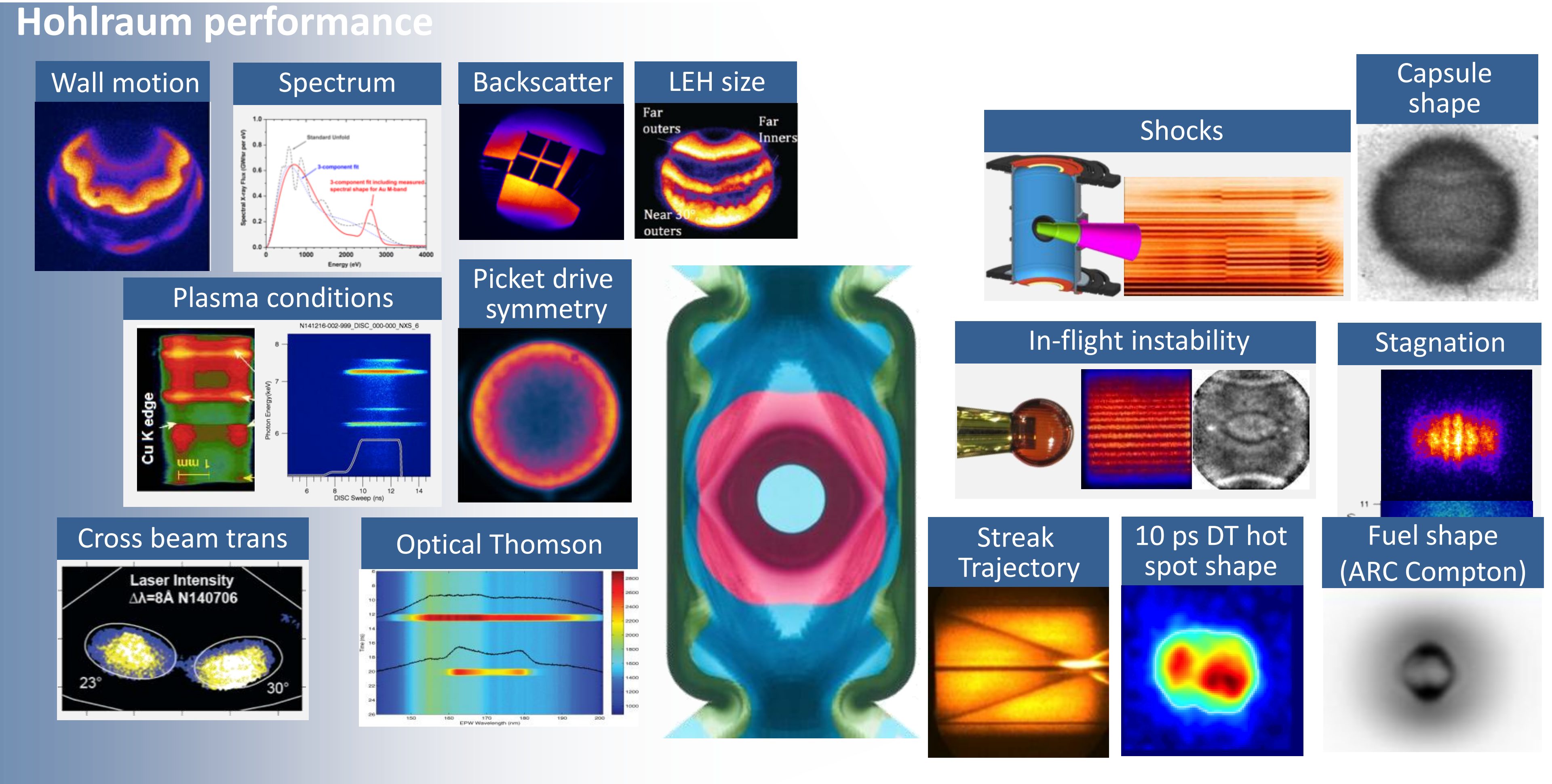


DT hot spot shape



3D

We have greatly expanded our platforms and diagnostics for ICF



Transformational and foundational diagnostics now being coordinated nationally in diagnostics working group

It is an exciting time at the National Ignition Facility

- Meaningful scientific results are being obtained on the facility every day
- We have significantly increased the shot rate, enabling
  - A faster rate of learning
  - Stronger support for users in addition to NNSA
- We met the challenging goal of 300 shots in FY15 six weeks early
  - We have an ambitious goal of 400 shots in FY16; this goal will challenge the facility, target fabrication, optics, and the users
- Future Focus
  - More experiments
  - New and better diagnostics
  - Improved laser: higher laser energy, more robust optics, more pulse shaping options
  - New and better targets and increased agility/shorter lead-time to field, magnetic target capability
- Experimental Focus
  - Ignition, critical stockpile stewardship issues, discovery science

We are building a strong foundation for NIF's long future supporting the field of High Energy Density Science and Inertial Confinement Fusion

Lawrence Livermore
National Laboratory