Update on High Energy Density Physics and Related Research at NNSA

National Nuclear Security Administration

Presented to:
The National Academy of Sciences
Board on Physics and Astronomy

Presented by:
Dr. Allan A. Hauer
Chief Scientist, Stockpile Stewardship Office
April 29, 2010

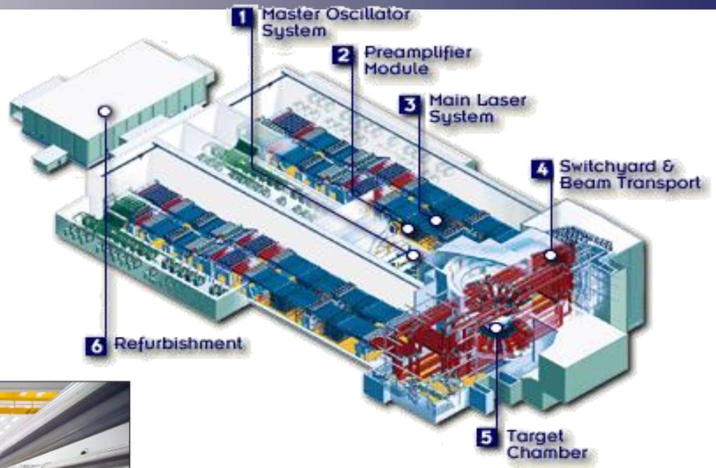
NNSA HED Highlights - Outline

- An impressive tandem increases in experimental and computational power are producing outstanding advances.
- NNSA continues to be an important sponsor and steward of High Energy Density (HED) Physics
  - Academic outreach programs continue to be highly successful.
- Important advances in HED diagnostic development are opening up new research paths.
- The NAS study of Inertial Fusion Energy has begun.
- First ignition experiments will be a key milestone for basic science as well as weapons science.
- Capabilities that were assembled in the pursuit of ignition also have important applications in HED, dynamic materials science and other fields

NNSA sponsors a broad spectrum of High Energy Density Plasma Activities

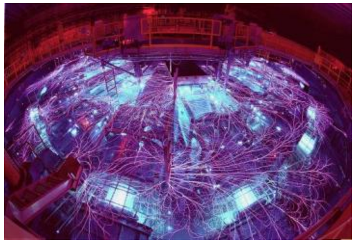
- The pursuit of ignition at the National Ignition Facility remains the largest experimental activity in NNSA Defense Programs.
  - A major effort in diagnostic development is part of this effort
- Other High Energy Density Plasma experiments are also a major emphasis
  - Materials under extreme conditions
  - Atomic physics in dense plasma conditions
- The NNSA Academic outreach program has had major successes.
  - One project was the recipient of the Schawlow Prize
  - 2 of the sponsored simulation efforts have received the Gordon Bell Award
  - Bridgman Award for High Pressure Science
  - Academic participants have contributed major diagnostic and theoretical tools for NNSA programs

Important advances in experimental and computational power have occurred.

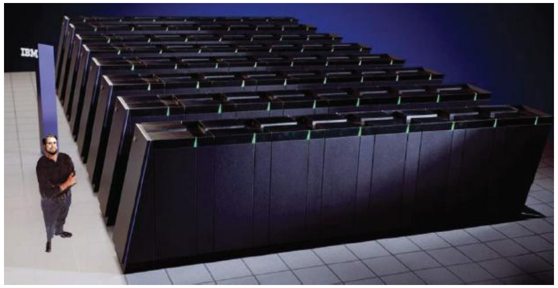


- **National Ignition Facility (NIF)**
  - Only access to burning plasma conditions
  - Important mission experiments have already been performed

- **Omega EP**
  - Sophisticated high irradiance capabilities
  - Important venue for advanced fusion research



- **Z Machine**
  - Key venue for materials science measurements
  - outstanding new results at 4 Mbar.



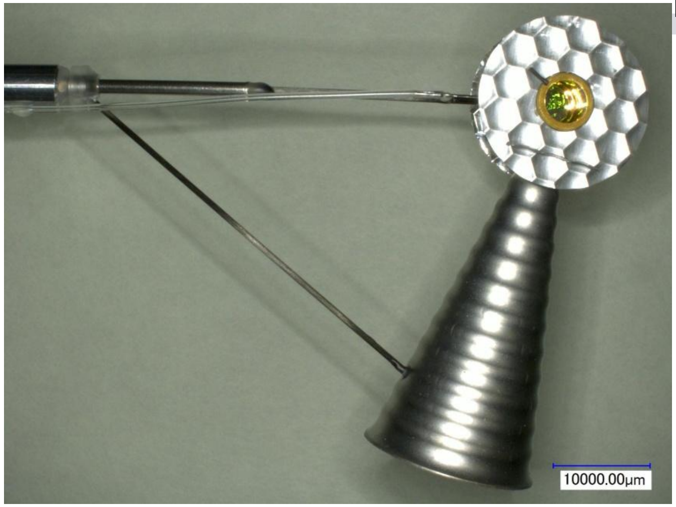
- **Enormous increase in computational power**
  - Peta-flop performance utilized for important developments in plasma science
  - 20 PF in 2012

The achievement of igniting conditions will open new frontiers in plasma research

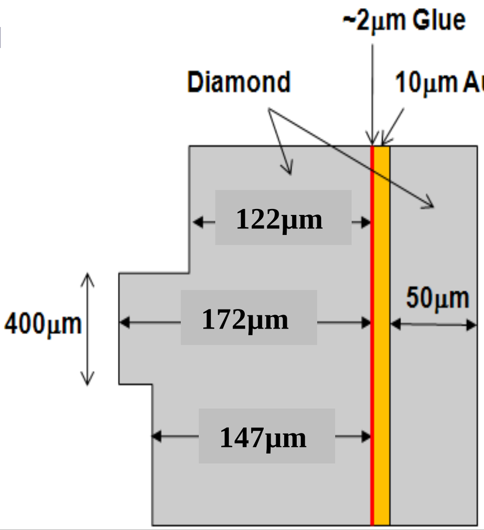
- Plasma temperatures > 20 keV ; compressed densities > 1000 gm / cm^2 ; pressures ~ 1 Tbar
- Performing detailed measurements under igniting conditions will present a considerable diagnostic challenge.
- The high performance implosions and high temperature hohlraums needed for ignition can also be employed in a variety of non-ignition basic science investigations.
  - Planetary and astro- physics
  - Materials under extreme conditions

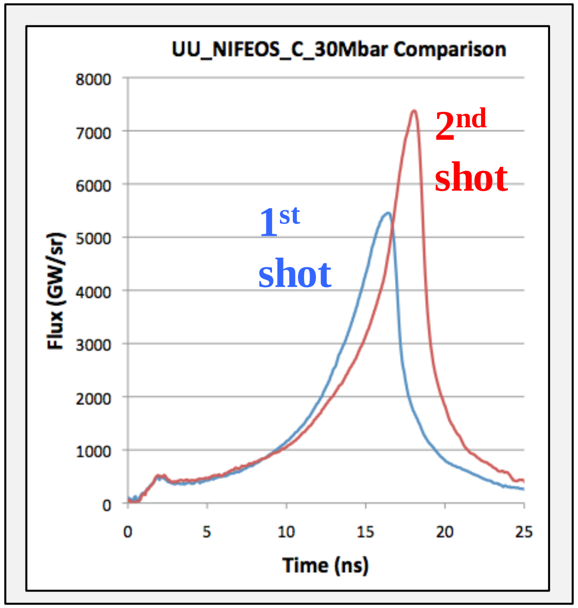
The extraordinary capabilities at NIF are also being applied to variety of non- ignition experiments

NIF was used to "quasi-isentropically" compress carbon to 30 Million atmospheres pressure

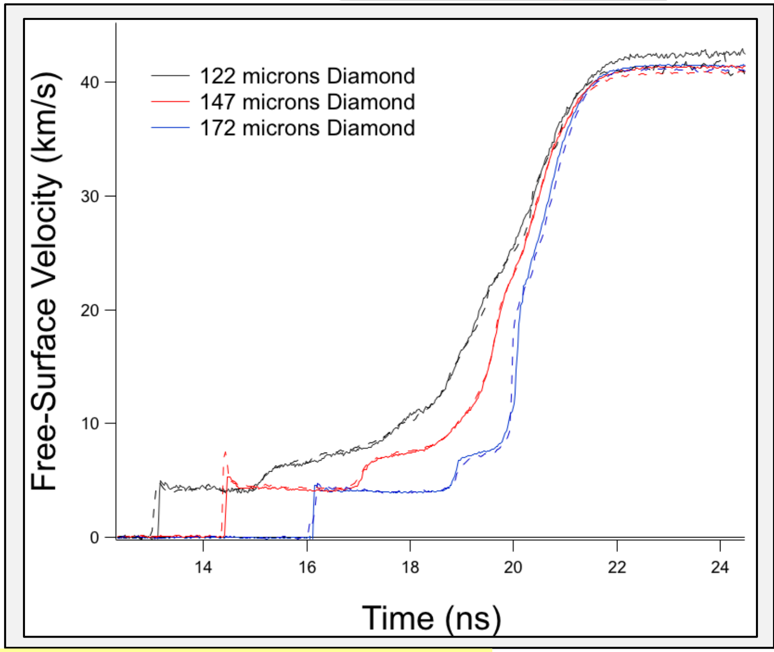


Gas-filled, room-temperature, stepped target mounted on side of Hohlraum with VISAR cone.



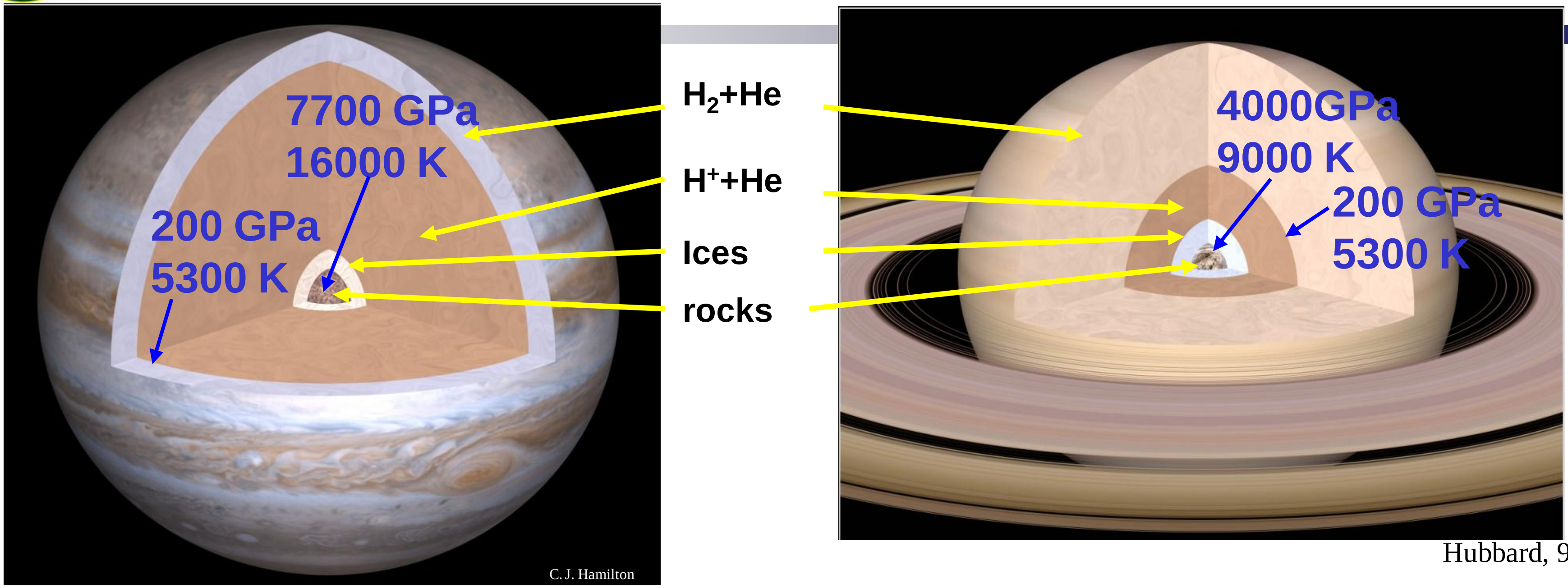


<= flux history for 2 NIF Diamond ramp experiments. 1st experiment (blue) shocked up due to physics understanding. Models and pulseshape were adjusted, NIF delivered ~ exactly what was asked for=>**Diamond was ramp compressed to 25-30 Mbar**



Raymond Jeanloz UCB, Tom Duffy Princeton, Ray Smith, Jon Eggert, Peter Celliers, Matt Cowan, Gilbert Collins

Emerging capabilities address fundamental questions in planetary and condensed matter physics



Hubbard, 98

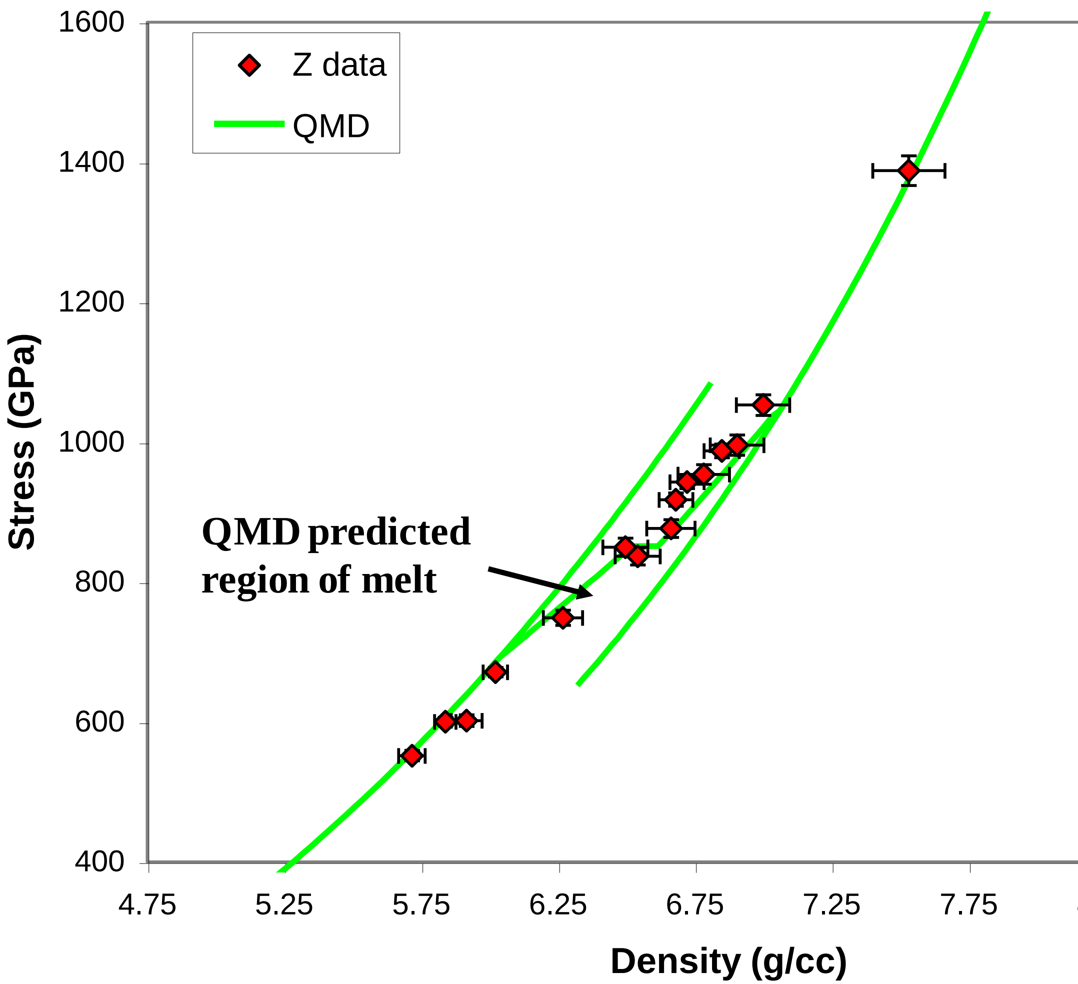
- **FOR EXAMPLE:**
- **Jupiter: luminosity data + EOS models + evolutionary=>calculated age = 4.7 GYr Age of our solar system = 4.6 Gyr**
- **Saturn: Using the same models + luminosity data from Saturn, it "looks" to be only 2.1 GYr old!**
  - **The difference may be due to inhomogeneous mixing of He/H!**

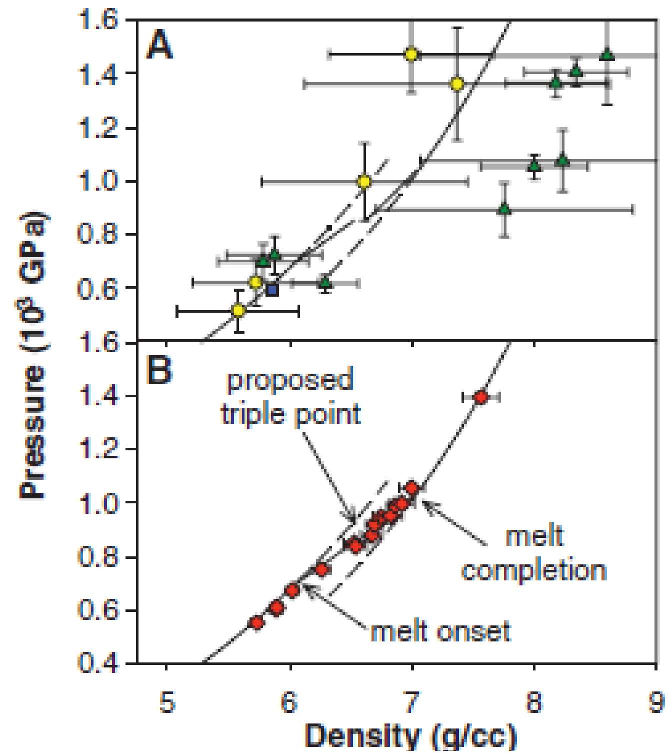
NIF allows access most of these states for the first time

Precision measurements on *Z* quantified properties of Be & diamond for the National Ignition Campaign

- **Z data obtained in 1 week**
- **Measurements on Z have an accuracy of ≤ 1%**

Stress versus density for diamond





Science AAAS

Shock-Wave Exploration of the High-Pressure Phases of Carbon
M. D. Knudson, *et al.*
Science **322**, 1822 (2008);
DOI: 10.1126/science.1165278

Molecular Dynamics has been the unifying paradigm for much of the advanced computational work

Large-scale Molecular Dynamics of Dense Plasmas: The Cimarron Project

Frank R. Graziani[a], Victor S. Batista[c], Lorin X. Benedict[a], John I. Castor[a], Hui Chen[a], Sophia N. Chen[a], Chris A. Fichtl[b], James N. Glosli[a], Paul E. Grabowski[b], Alexander T. Graf[a], Stefan P. Hau-Riege[a], Andrew U. Hazi[a], Saad A. Khairallah[a], Liam Krauss[a], A. Bruce Langdon[a], Richard A. London[a], Andreas Markmann[c], Michael S. Murillo[b], David F. Richards[a], Howard A. Scott[a], Ronnie Shepherd[a], Liam G. Stanton[a], Michael P. Surh[a], Jon C. Weisheit[d], Heather D. Whitley[a]

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[b]*Computational Physics Group, Los Alamos National Laboratory, Los Alamos, NM 87545*
[c]*Department of Chemistry, Yale University, New Haven, CT 06520-8107*
[d]*Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA 15260-8709*

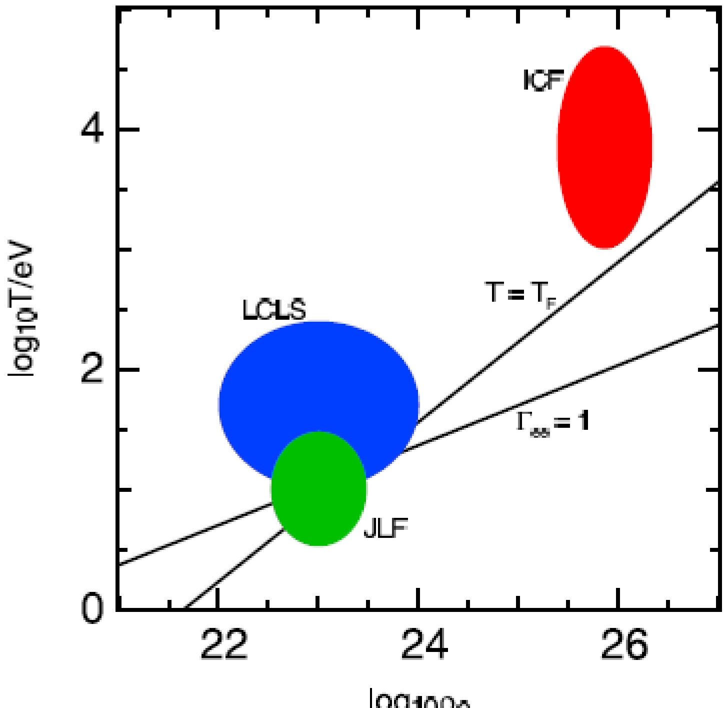
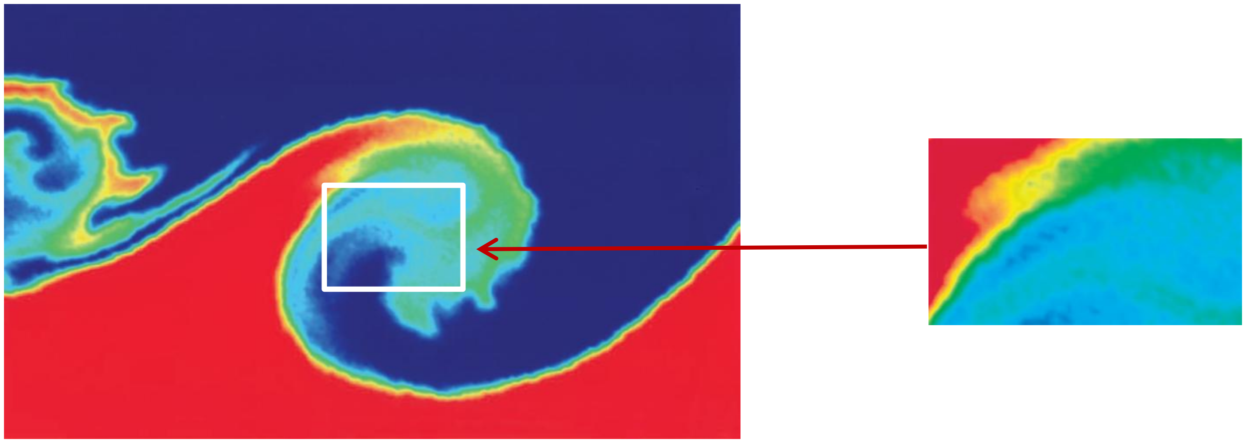


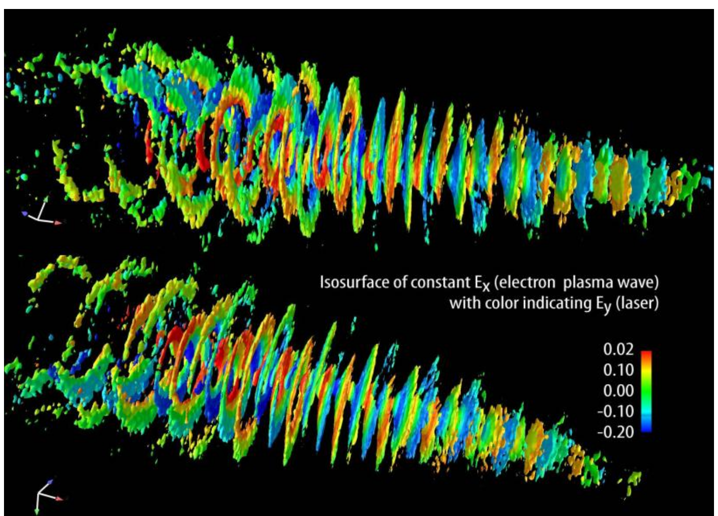
Figure 1: The various domains of non-degenerate *vs.* degenerate matter, and weak *vs.* strong plasma coupling in ρ_e, T space are compared with the prevalent conditions in ICF, LCLS and JLF plasmas. Abscissa: electron density ρ_e in electrons/cm^3; ordinate: temperature T in eV.

NNSA sponsored simulations are coupled with forefront experiments and have received wide recognition

Gordon Bell Award winners



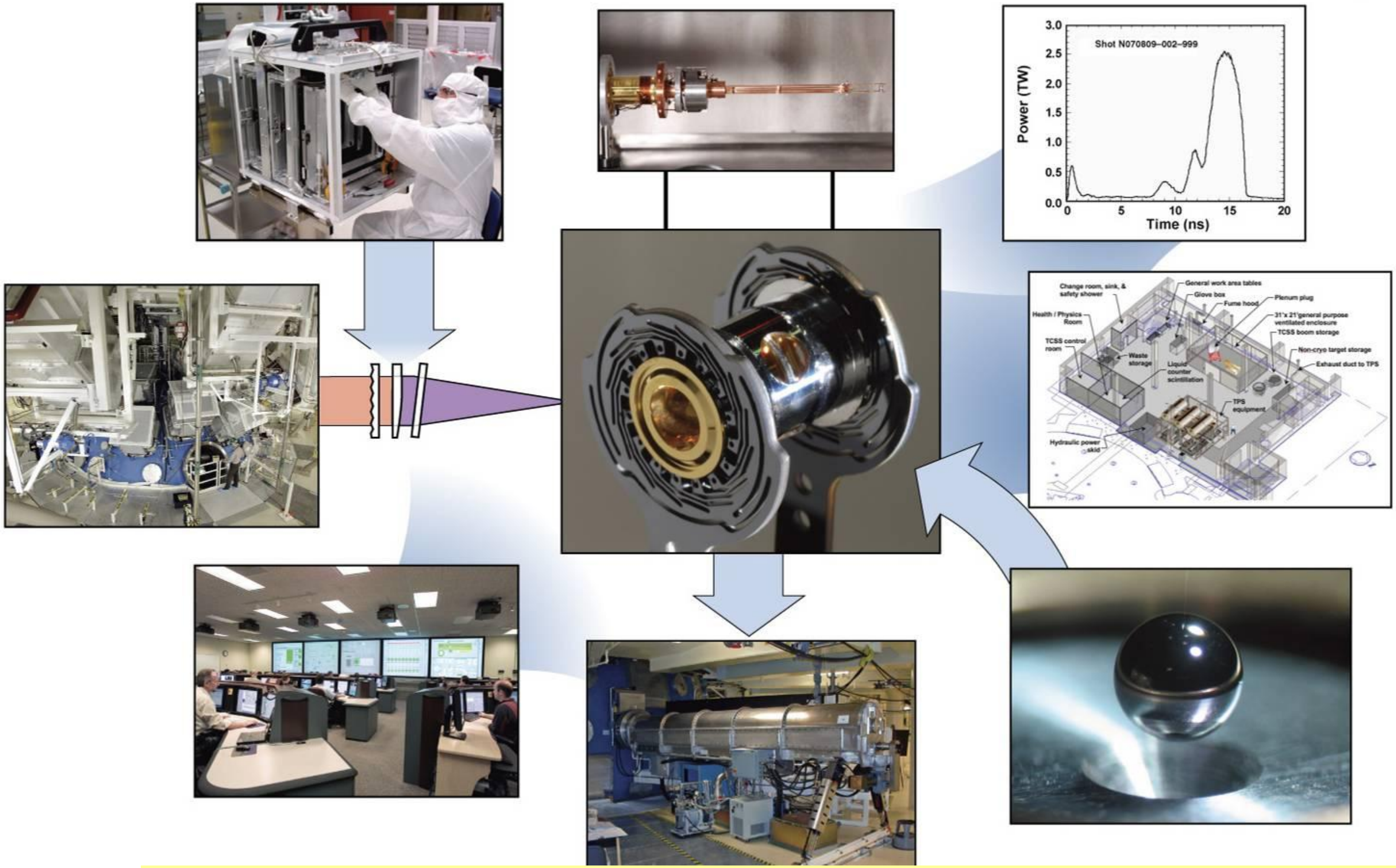
First simulation of Kelvin-Helmholtz instability in molten metals



VPIC simulation of high intensity Laser-matter interaction

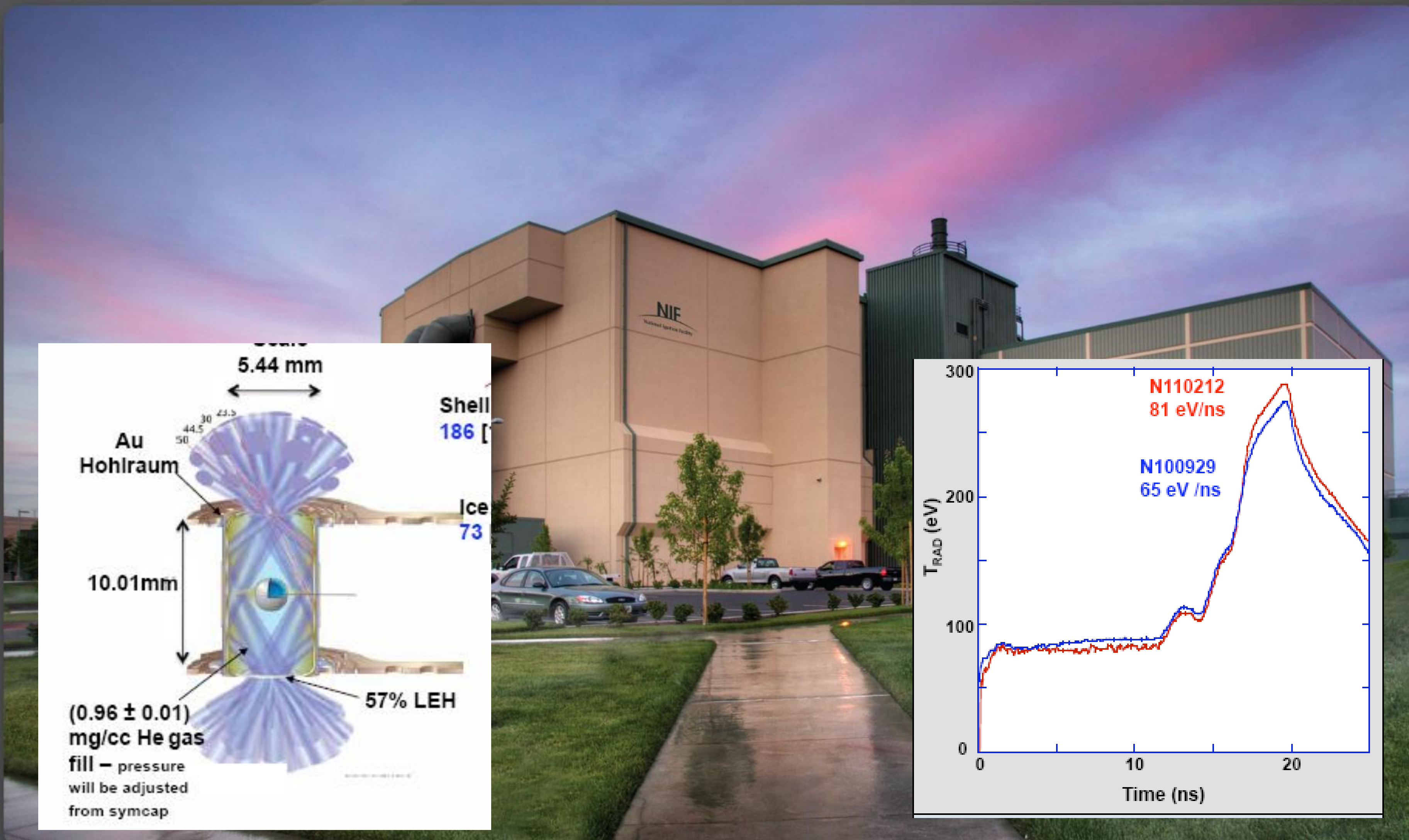
- important component of ignition-level experiments

Ignition will be the start of a new scientific era for NNSA and the Nation

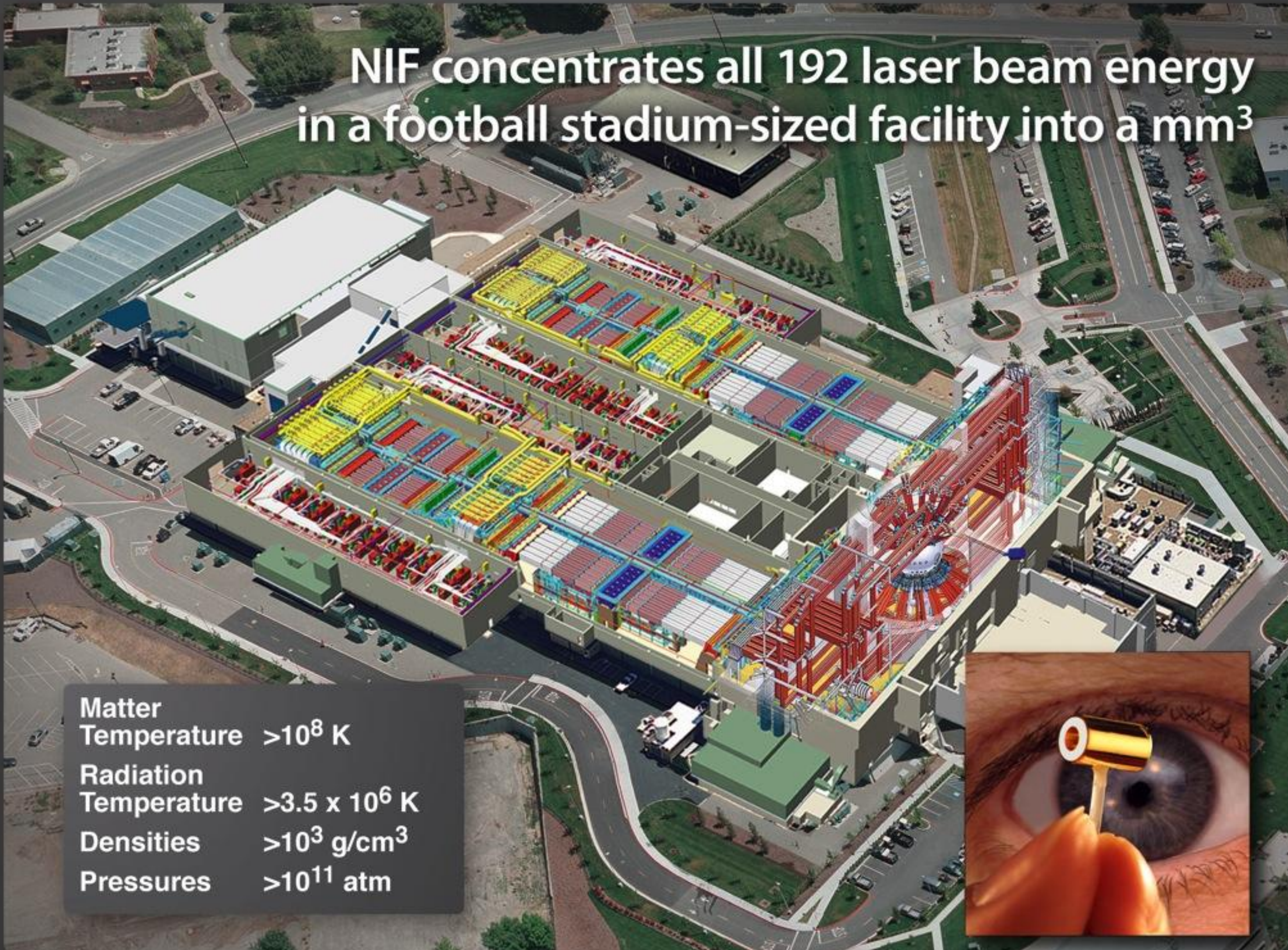


Ignition on NIF will be a defining moment for inertial confinement fusion energy

NIF is operational and performing a wide variety of Experiments in addition to those focused on ignition

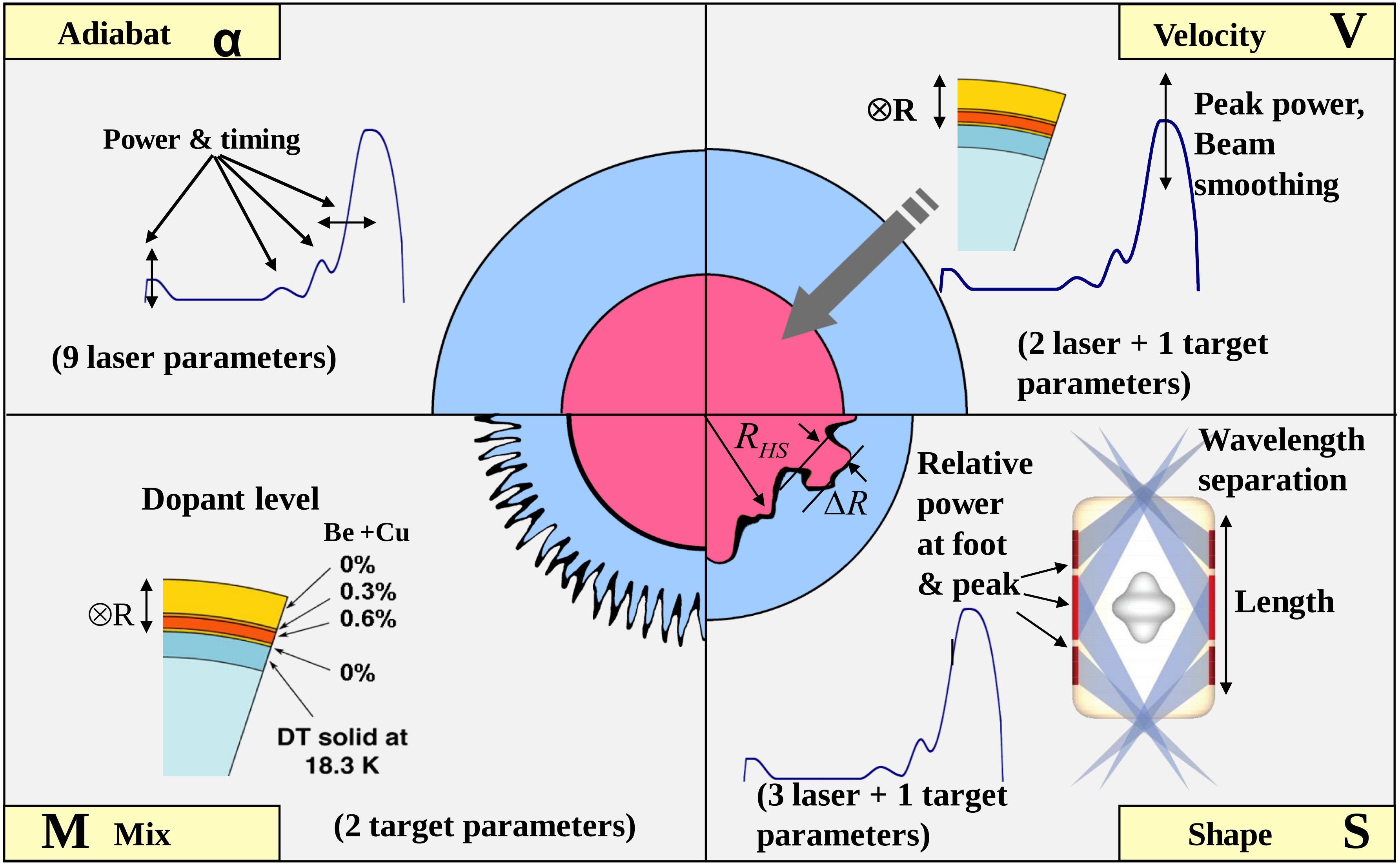


NIF concentrates all 192 laser beam energy in a football stadium-sized facility into a mm^3



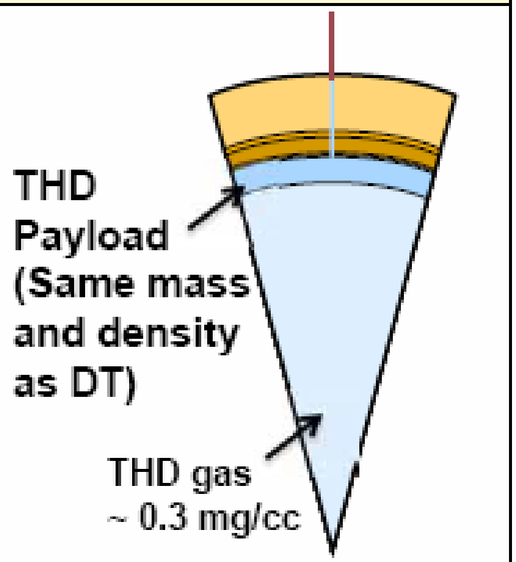
Matter Temperature	$>10^8$ K
Radiation Temperature	$>3.5 \times 10^6$ K
Densities	$>10^3$ g/cm^3
Pressures	$>10^{11}$ atm

To reach ignition conditions 4 key physical phenomena must be carefully tuned



Layered cryogenic implosion experiments have begun

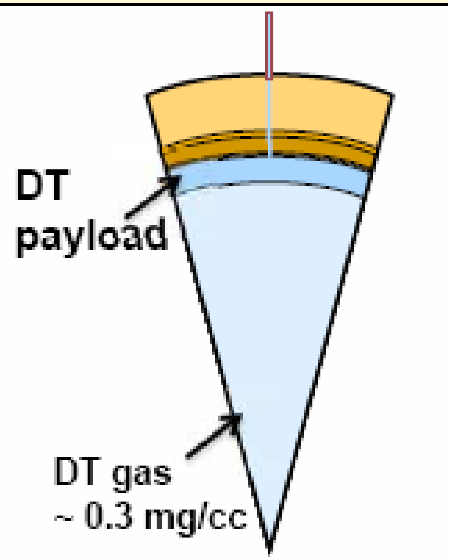
THD



Y ~ 10^{14}-10^{16}

Convergence ratio ~ 40

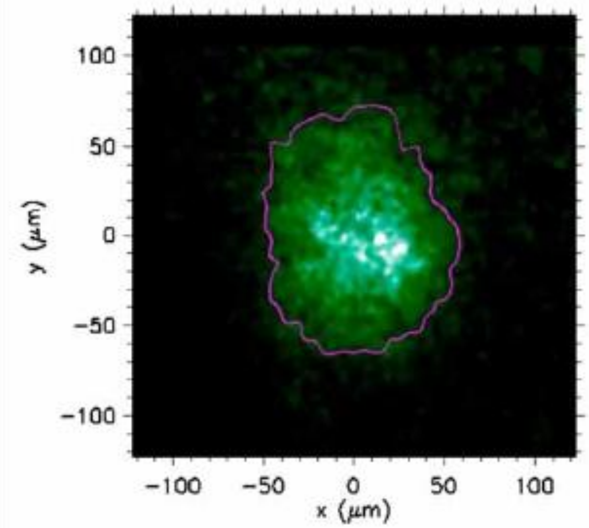
DT



Y ~ 10^{16}-10^{19}

Convergence ratio ~ 30

THD implosion are compressed to P_0 = 42 μm with a slight prolate shape

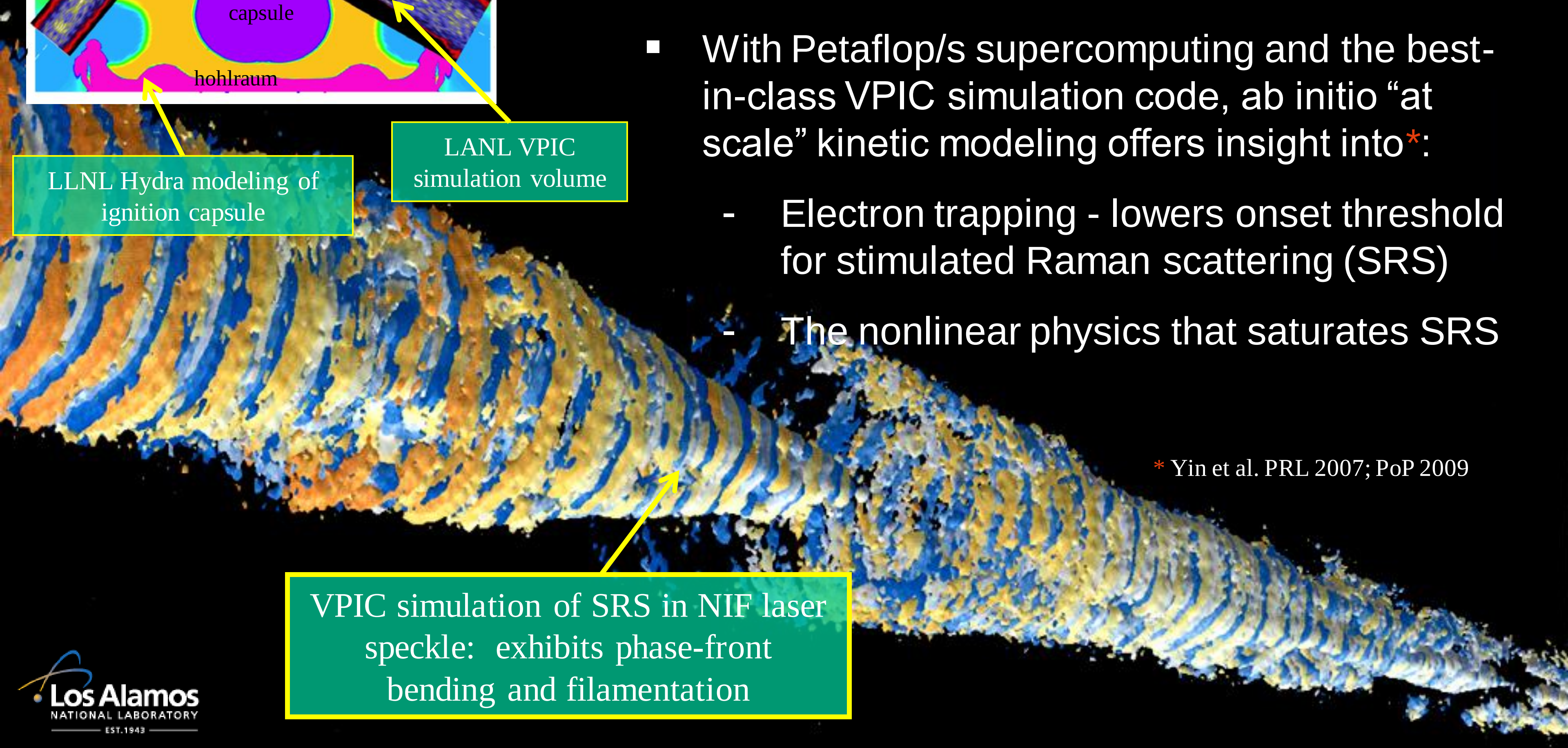


Optimizing shape and P_0 is expected to increase DT yield in THD implosions

Deuterium poor (THD) layered implosions are
Used for preliminary experiments

X-ray image of the implosion of a THD capsule
by 1.3 MJ of NIF laser energy

Recent advances in laser-plasma interaction science required Petaflop-scale simulations



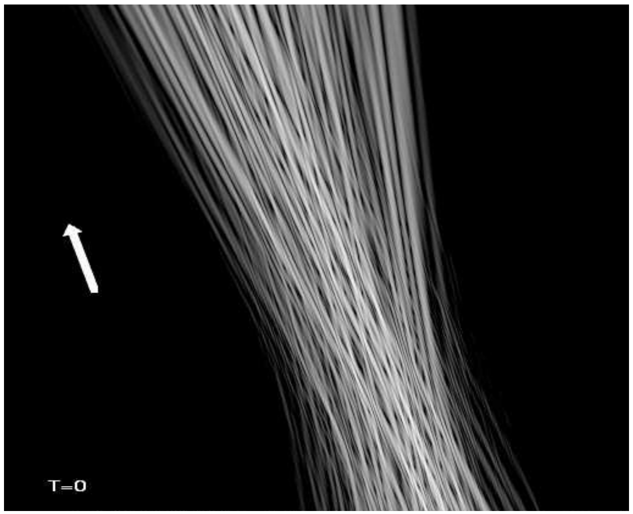
- Laser-plasma interaction (LPI) is a source of uncertainty in inertial confinement fusion experiments – LPI scatters laser beams & makes hot e^- that preheat capsule
- With Petaflop/s supercomputing and the best-in-class VPIC simulation code, ab initio "at scale" kinetic modeling offers insight into*:
  - Electron trapping - lowers onset threshold for stimulated Raman scattering (SRS)
  - The nonlinear physics that saturates SRS

* Yin et al. PRL 2007; PoP 2009

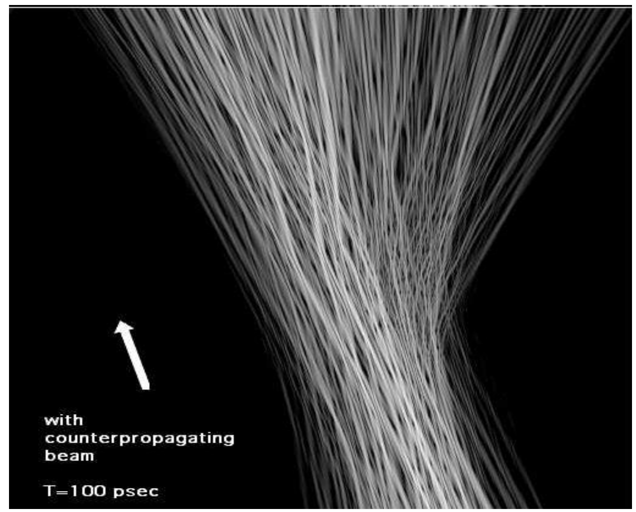
Basic plasma research in HED laser plasmas remains essential to ICF success

National Nuclear Security Administration

$I < I_{thr}$, single-beam simulation
No filamentation

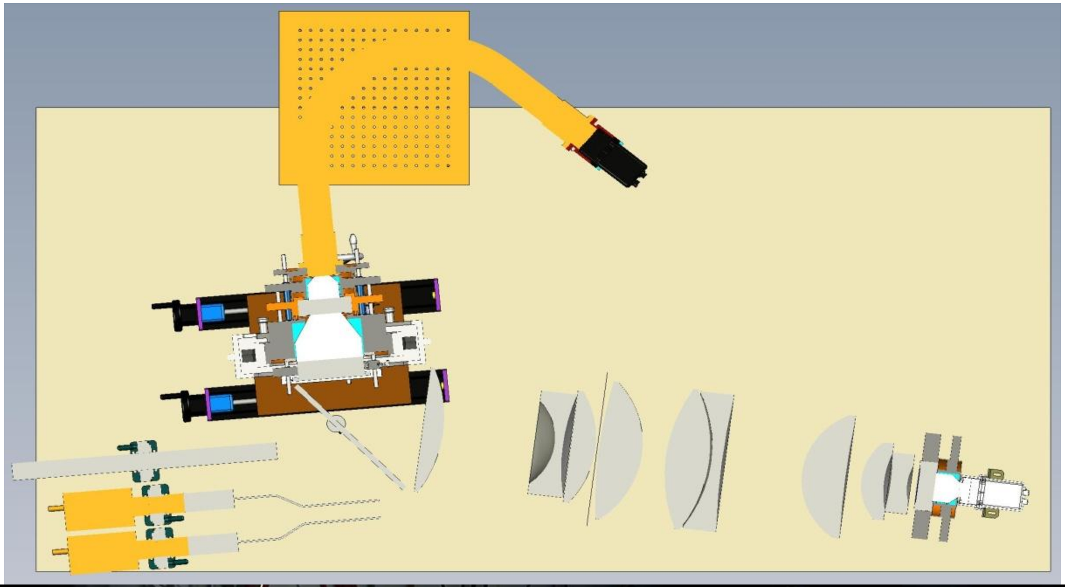


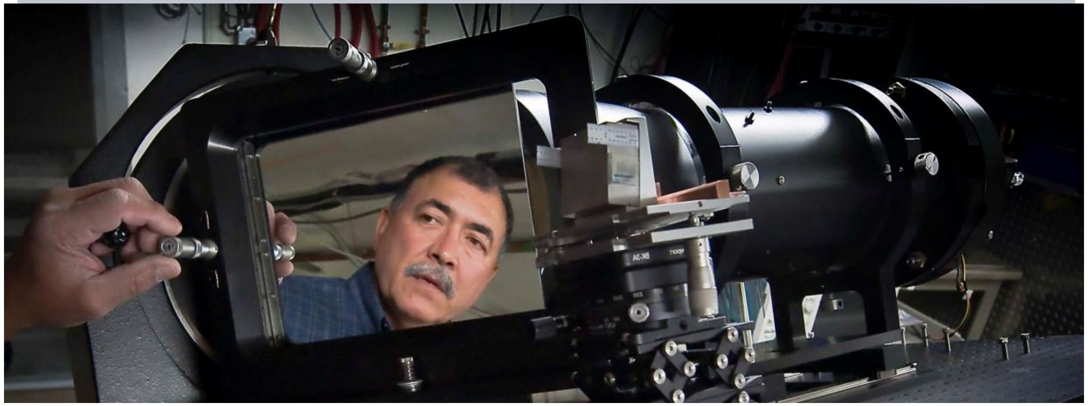
$I < I_{thr}$, non-resonant, lower amplitude
counter propagating beam seeds enhanced scatter



- **Filamentation strongly affects the initiation and evolution of SRS and SBS backscatter as well as beam pointing.**
- **Simulations such as these are used to tune parameters in ICF target designs**

Important advances in ignition diagnostics have occurred



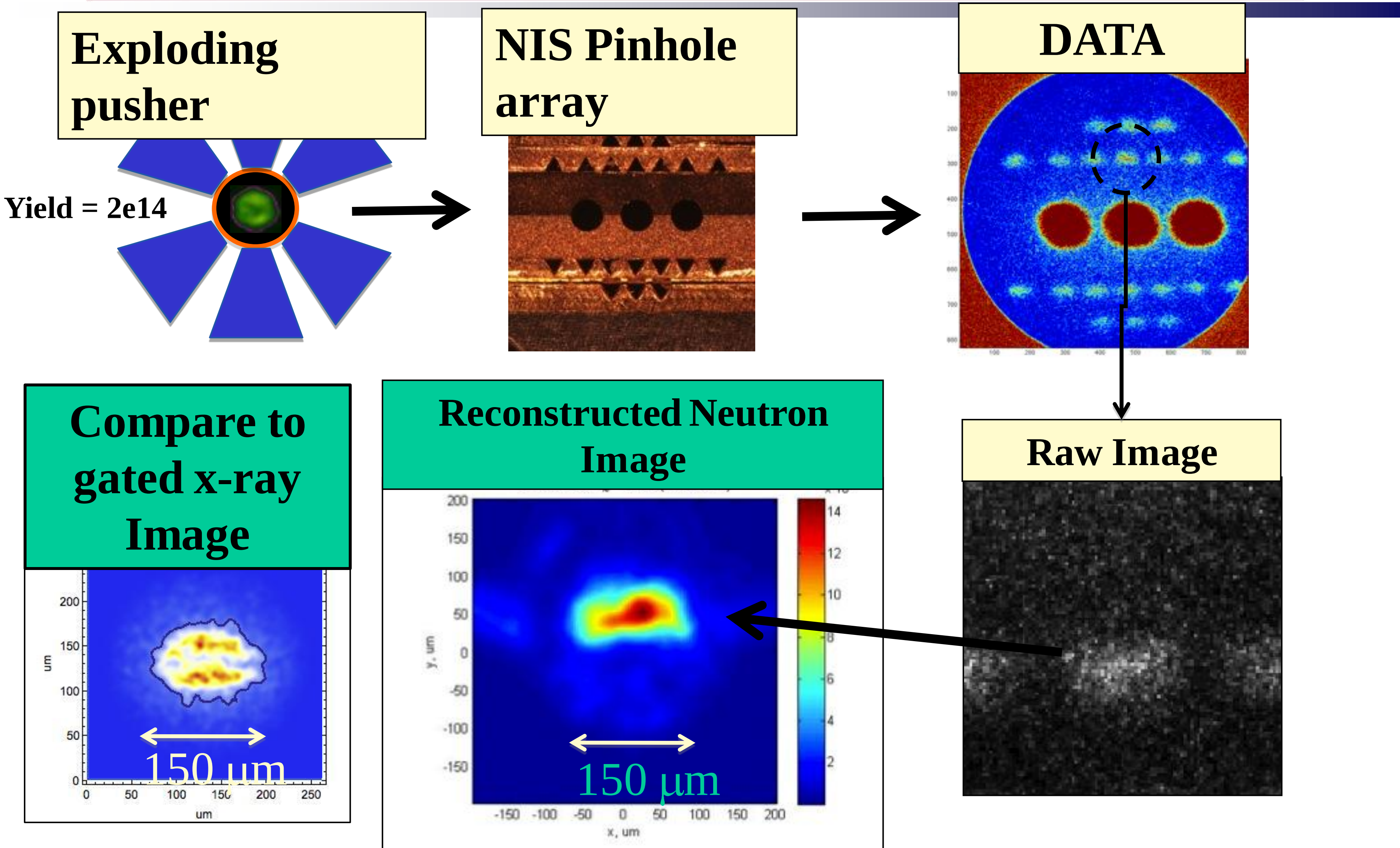


Los Alamos NIF Neutron imager is tested and calibrated on Omega .

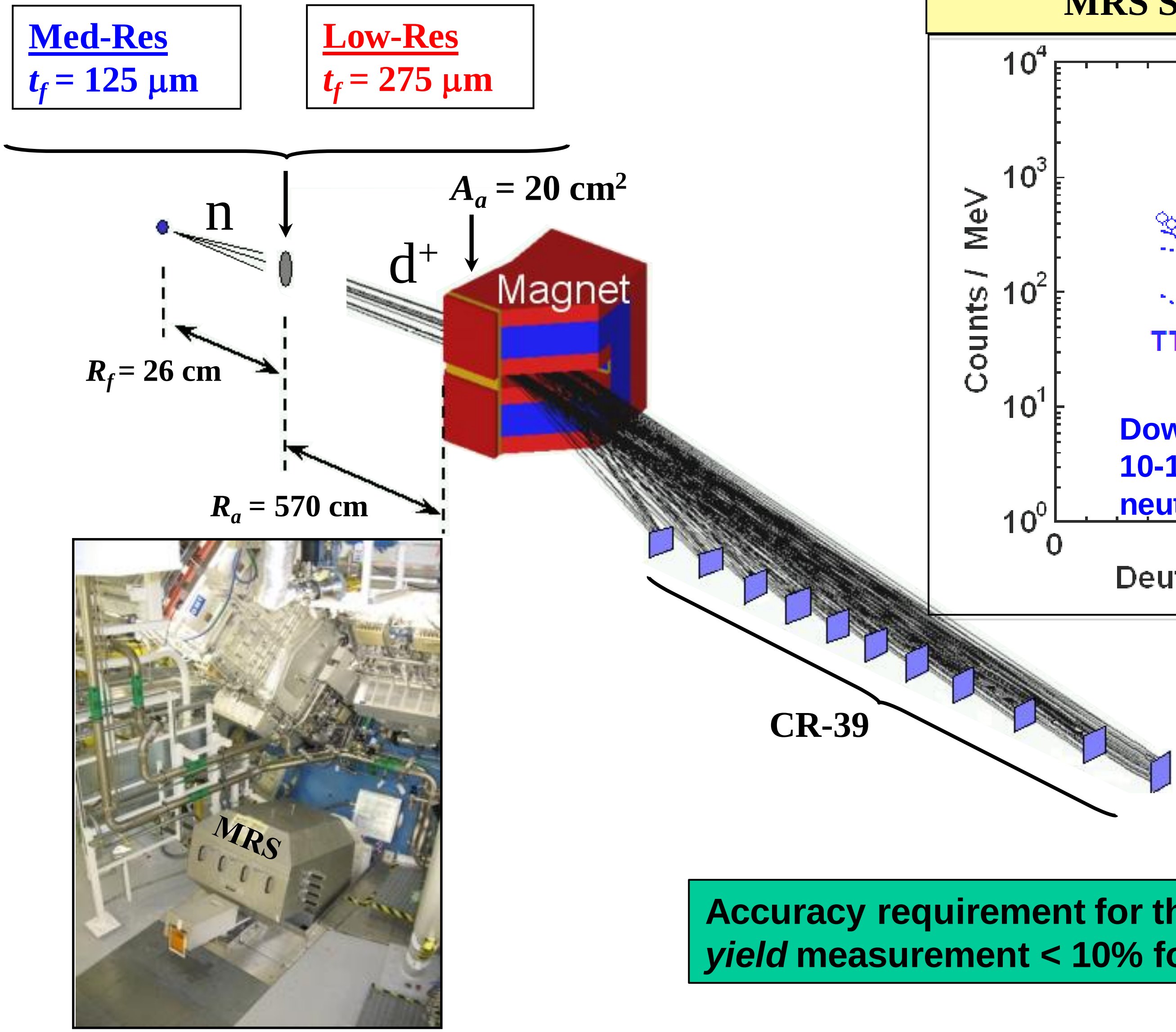
2 axis / 2 image system will allow simultaneous primary(14-MeV) and downscattered (10-12 MeV) imaging.

Future testing of NI will likely involve polar direct drive capsules thus advancing both basic science and diagnostic development

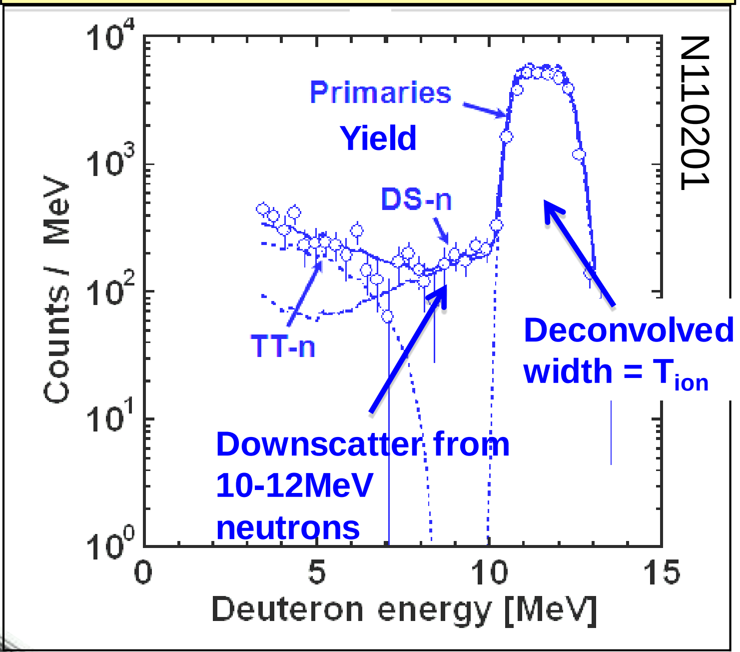
Neutron Imaging system has begun performance qualification shots



The MRS has been designed and implemented for simultaneous measurements of ρR, Y_{1n} and T_{ion}



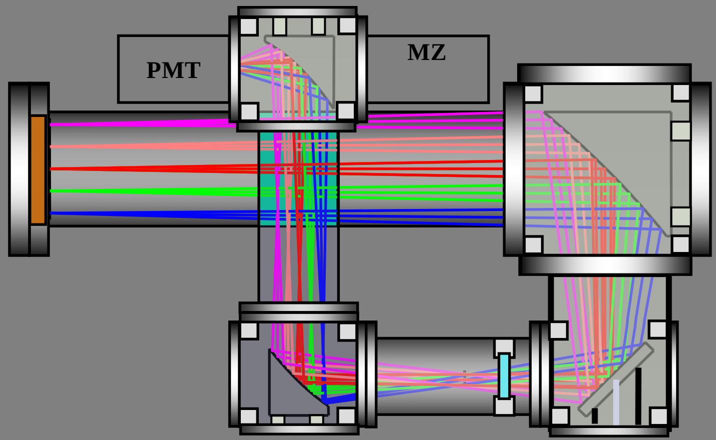
MRS Spectrum THD-3



Accuracy requirement for the MRS absolute *yield* measurement < 10% for $Y_{1n} > 10^{14}$

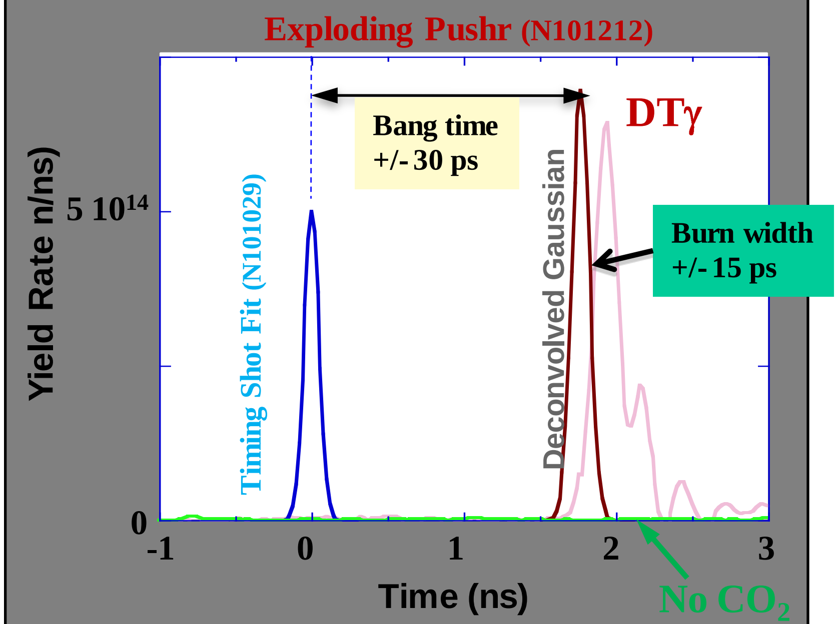
Bangtime: Gamma Reaction History (GRH) routinely measuring Bang Time (w/in 30 ps) and Burn Width (w/in 15 ps)

GRH-6m at (64,20)



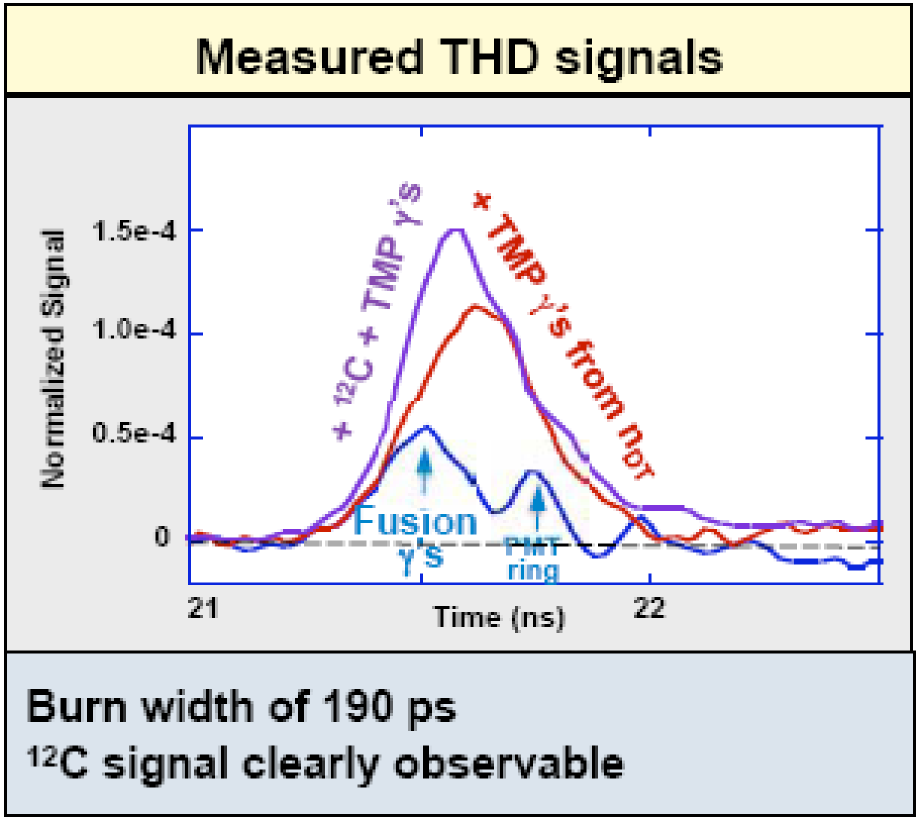
- 4 Gas Cherenkov cells
- Detectors installed with Ultra-fast MCP PMTs and optical Mach Zehnders

DT exploding pusher Data



- Bangtime agrees with Ntof_BT data to within 100 ps
- Energy threshold of each cell set by gas pressure /composition
- 3-10MeV GRH will be fielded on DT implosions for yield and 4.4MeV carbon γ (ablator density measurement)

THD Gamma-ray spectrum has been measured providing total yield, nuclear bang time burn width



- 10 MeV Fusion Gammas
- 5 MeV also includes neutron-induced rays off Thermomechanical Package (TMP)
- tracks fusion gammas until neutrons reach TMP (~100 ps delay)
- 3 MeV also includes 4.44 MeV 12C(n,n') γ -rays

Modest resources are also devoted to alternate fusion methods

As part of Fast Ignition Research-

Proton probing

of a high intensity

channeling On the

Omega laser

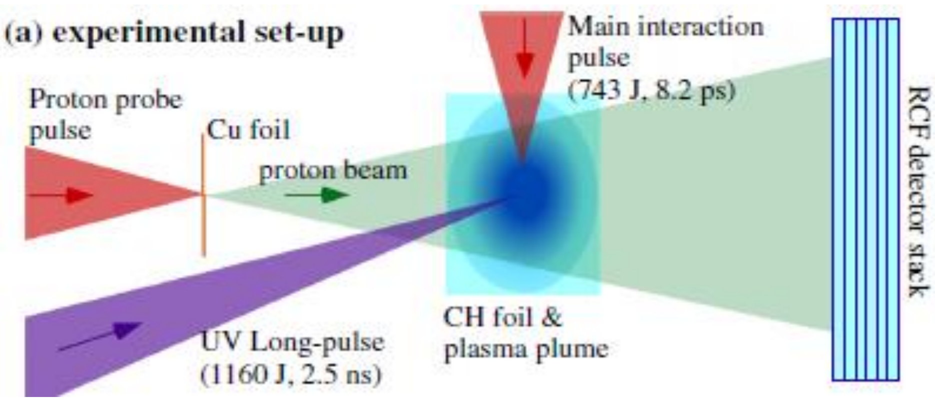
University of Michigan (P.I. L. Willingale**)**

High-Power, Kilojoule Class Laser Channeling in Millimeter-Scale Underdense Plasma

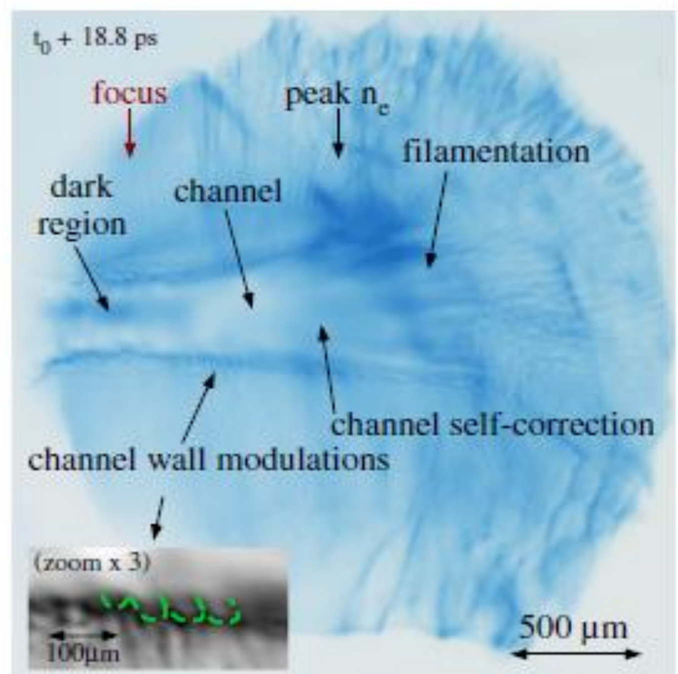
L. Willingale,[1] P. M. Nilson,[2] A. G. R. Thomas,[1] J. Cobble,[3] R. S. Craxton,[2] A. Maksimchuk,[1] P. A. Norreys,[4] T. C. Sangster,[2] R. H. H. Scott,[4] C. Stoeckl,[2] C. Zulick,[1] and K. Krushelnick[1]

[1]*Center for Ultrafast Optical Science, University of Michigan, 2200 Bonisteel Boulevard, Ann Arbor, Michigan 48109, USA*
[2]*University of Rochester-Laboratory for Laser Energetics, Rochester, New York 14623, USA*
[3]*Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*
[4]*STFC, Rutherford Appleton Laboratory, Central Laser Facility, Oxfordshire, OX11 0QX, UK*

(Received 10 December 2010; published 10 March 2011)



NLUF experiment



NNSA sponsors a variety of academic outreach programs spanning both experiment and computation

- Graduate Fellowships
  - 35 Students in experimental and theoretical pursuits
- *Competitively* awarded individual and small group grants
  - 57 Awards
- Competitive awards to moderate size centers ($750K -$3.0M)
  - 14 Centers ranging from materials science, plasma diagnostics, computational science and other activities

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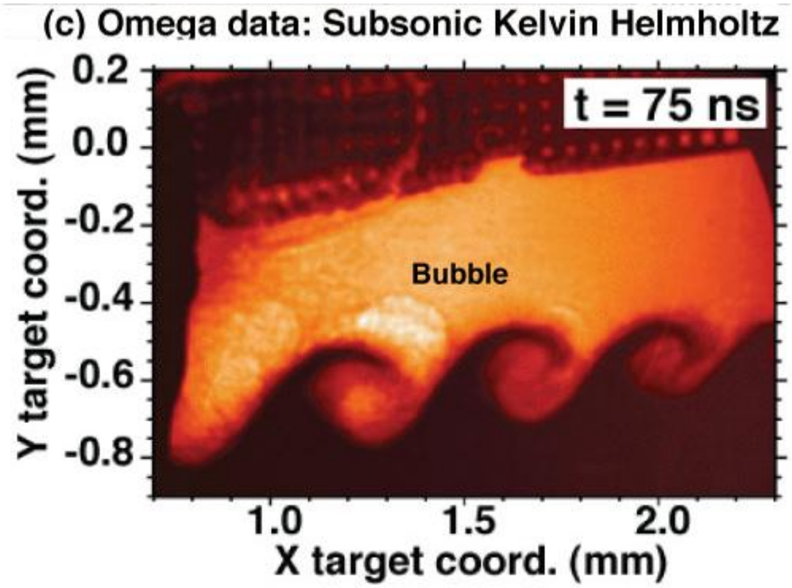
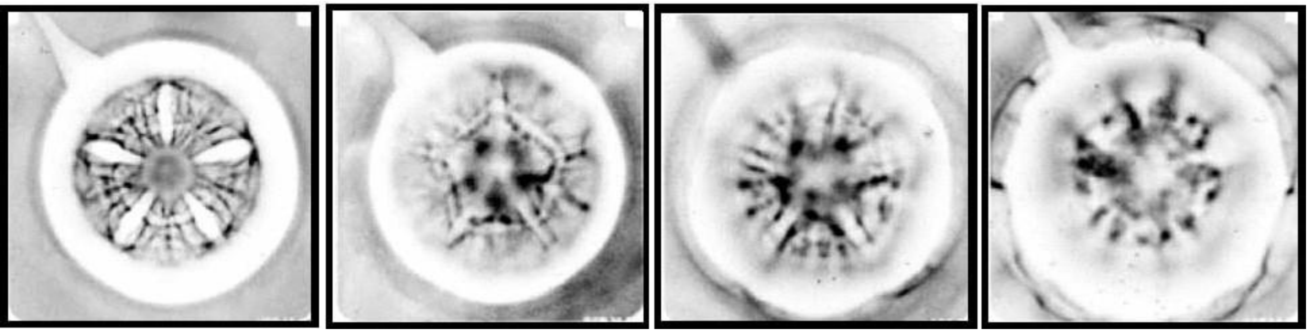
NNSA sponsors a variety of academic outreach programs spanning both experiment and computation - examples



Kelvin Helmholtz instability - blast wave in carbon foam radiographed at the Omega Laser

U. Michigan - Center for Laboratory Astrophysics



- **Proton radiographs of laser driven implosions at the Omega laser**

  the M.I.T Center for Particle Plasma Diagnostics

Recent graduates from NNSA Academic Programs are now staff members at various national laboratories

Dr. Eric Harding
Sandia Nat. Labs.

Dr. Seth Root
Sandia Nat. Labs.

Dr. Nenad Velisavljevi
Los Alamos Nat. Lab.

Dr. Amy Cooper
Lawrence Livermore Nat. Lab.

NNSA / Office of Science Collaboration in HED Basic Science

Joint sponsorship of Workshop: Basic Research Directions at the National Ignition Facility –May 2011

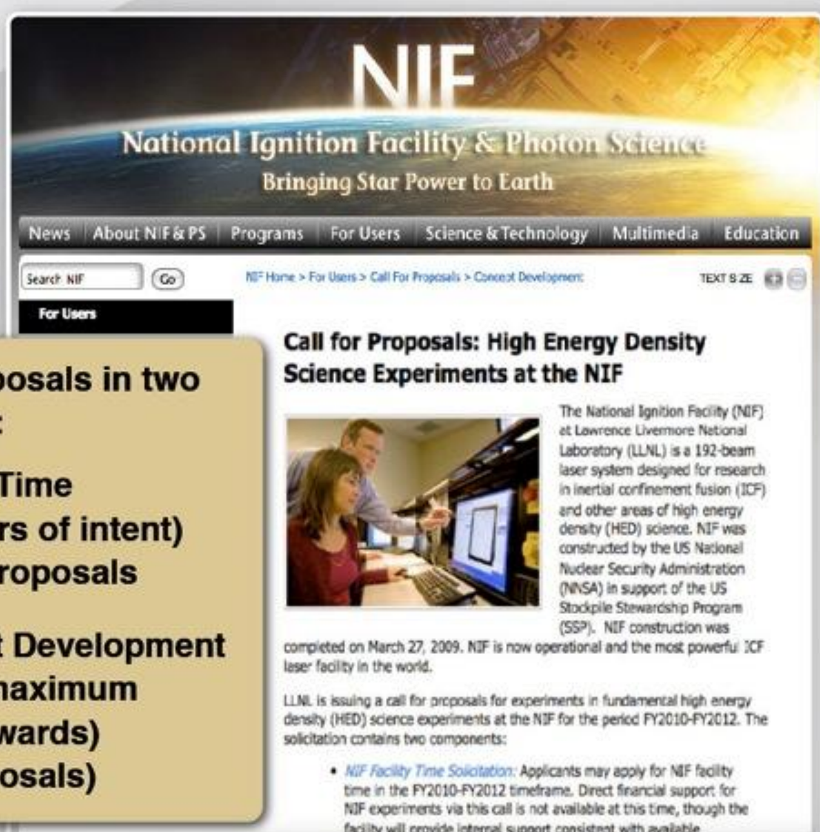
- **Goals:**
  - **Inform broad science communities about capabilities at NIF and other HEDP platforms.**
  - **Solicit input in identifying and prioritizing research connected to the Office of Science that could benefit from utilization of these facilities.**
  - **Discussion of facility access, use and support modes**
  - **Identify potential high impact experiments**
- **Outcomes**
  - **Summarize current state of research in relevant fields**
  - **Define preferred governance and access process**
  - **Define a set of potential "Grand Challenges" for NIF**

NNSA / Office of Science Collaboration in HED Basic Science

Joint sponsorship of Workshop: Basic Research Directions at the National Ignition Facility –May 2011

- **Tri-Chairs:**
  - **John Sarrao (Los Alamos), Mike Wiescher (Notre Dame), Kim Budil (Livermore)**
- **Organizing Committee:**
  - **Paul Drake, Roger Falcone, Rus Hemley, Bill Goldstein, Chan Joshi, Margaret Murnane, Richard Petrasso, Alan Wootton**
- **Office of Science/NNSA staff:**
  - **Jim Glownia, Mike Kreisler**

The response (86 submissions) to our first call for proposals on fundamentsal High Energy Density science at the NIF has been outstanding


NIF
National Ignition Facility & Photon Science
Bringing Star Power to Earth
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Search NIF | Go
NIF Home > For Users > Call For Proposals > Concept Development
TEXT SIZE
For Users

Call for Proposals: High Energy Density Science Experiments at the NIF

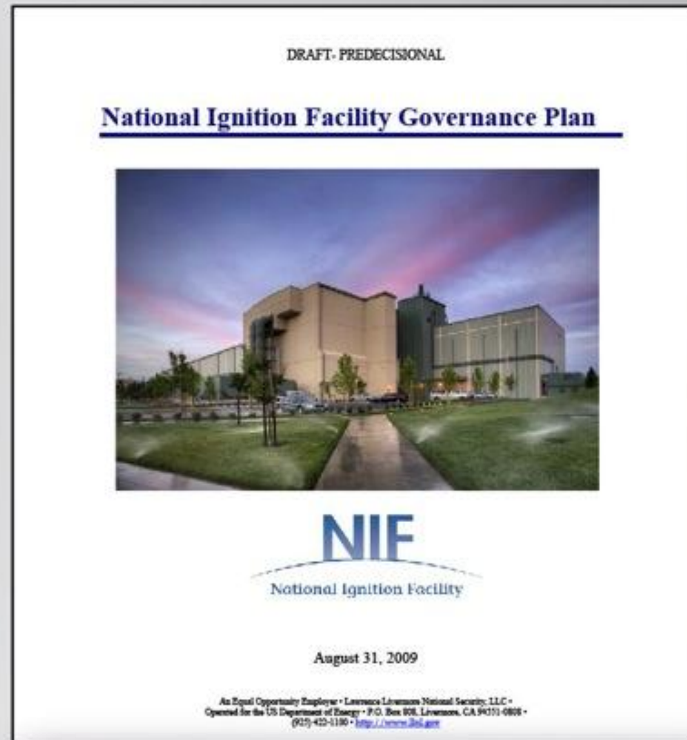
The National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL) is a 192-beam laser system designed for research in inertial confinement fusion (ICF) and other areas of high energy density (HED) science. NIF was constructed by the US National Nuclear Security Administration (NNSA) in support of the US Stockpile Stewardship Program (SSP). NIF construction was completed on March 27, 2009. NIF is now operational and the most powerful ICF laser facility in the world.

LLNL is issuing a call for proposals for experiments in fundamental high energy density (HED) science experiments at the NIF for the period FY2010-FY2012. The solicitation contains two components:

- *NIF Facility Time Solicitation:* Applicants may apply for NIF facility time in the FY2010-FY2012 timeframe. Direct financial support for NIF experiments via this call is not available at this time, though the facility will provide internal support consistent with available

Call for Proposals in two major areas:

- Facility Time
  (44 letters of intent)
  40 full proposals
- Concept Development
  ($100k maximum
  1 year awards)
  (42 proposals)


DRAFT- PREDECISIONAL

National Ignition Facility Governance Plan

NIF
National Ignition Facility

August 31, 2009

To learn more visit us on the web at:
http://lasers.llnl.gov/for_users

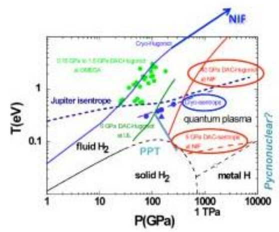
Proposed NIF experiments will be reviewed by an advisory committee chaired by Dr. Robert Rosner

Recent call for proposals for "Science on NIF"

- **LLNL/NIF 'Science on NIF' call for proposals - early FY10**
- **40 proposals received**
- **Reviewed by external committee**
  - ***Robert Rosner, Chicago (Chair)***
  - **David Arnett, Arizona**
  - **Riccardo Betti, Rochester**
  - **Roger Blandford, Stanford**
  - **Nathaniel Fisch, Princeton**
  - **Ramon Leeper, Sandia**
  - **Christopher McKee, Berkeley**
  - **Mordecai Rosen, Livermore**
  - **John Sarrao, Los Alamos**
  - **Hideaki Takabe, Osaka Univ.**
  - **Justin Wark, Oxford**
  - **Choong-Shik Yoo, Washington State**

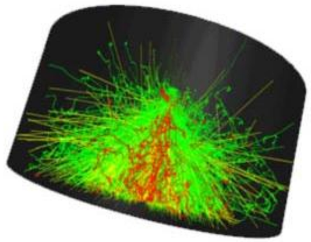
Selected proposals span an exciting spectrum of scientific questions

Observing new states of matter (H)



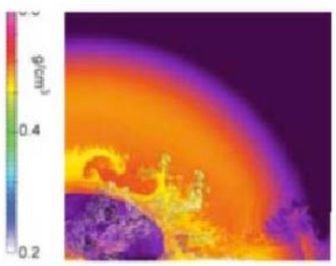
Berkeley, CEA, Carnegie Inst. UR/LLE, LLNL

Understanding the most energetic events in the universe



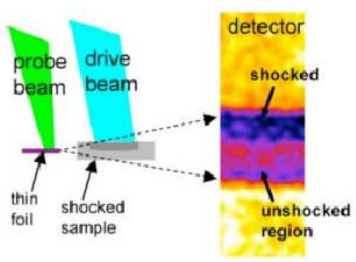
LLNL, UR/LLE, Osaka, Stanford

How do supernovae explode?



Florida State, Michigan, Arizona, Texas, LLNL

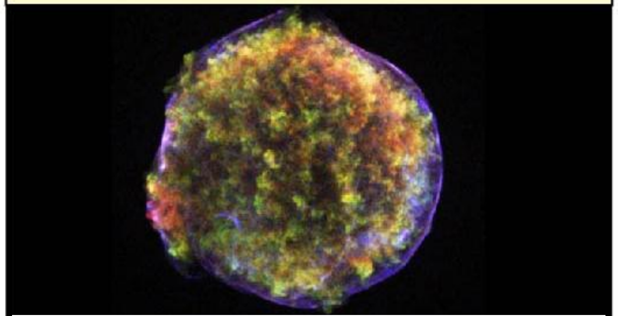
Probing the highest energy density states on Earth



GSI, Berkeley, Jena, Rostock, SLAC, Carnegie Inst., Imperial College, LLNL

Selected proposals span an exciting spectrum of scientific questions

Origin of ultra-high energy cosmic rays

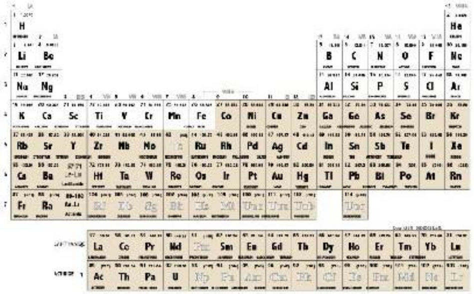


Osaka, Oxford, LLNL, Princeton, Ecole Polytechnique, York, ETH Zurich, UCLA, Aoyama Gakuin, Tokyo, Kansas, Rice

Large-scale behavior of matter in the universe

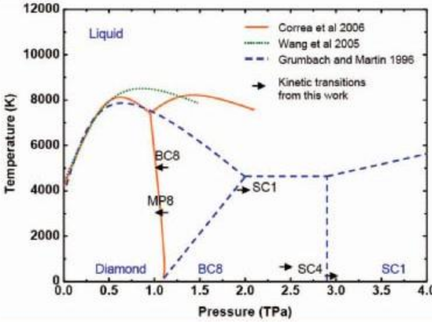
CEA, LLNL, IRPHE, AWE

Synthesis of elements heavier than iron



LLNL, Ohio U. , Oslo

Novel phases of compressed diamond

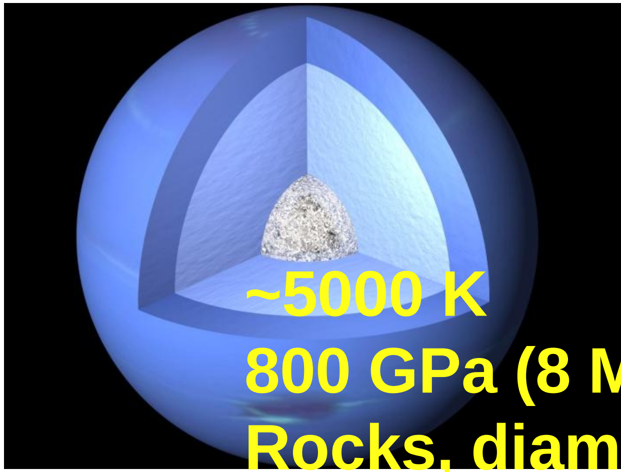


LLNL, Oxford, NRC Canada, Washington St. AWE, Osaka, UR/LLE

X-ray diffraction studies of dynamically compressed diamond

PI : J. Eggert (LLNL)

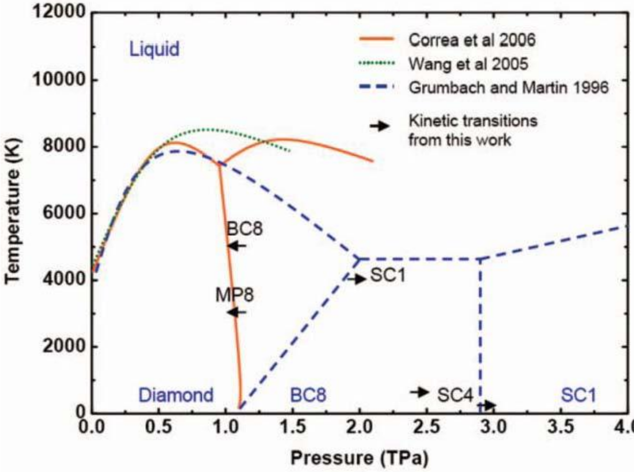
Collaborators: J. Wark, A. Higginbotham, M. Suggit, G. Mogni (Oxford Univ.); D. Klug, Y. Yao (NRC Canada); C.S. Yoo (Wash. State Univ.); N. Park (AWE); K. Shigemori, K. Shimizu (Osaka); T. Boehly (UR/LLE); R. Rygg, J. Hawreliak, D. Kalantar, D. Hicks, P. Celliers, H.S. Park, G. Collins, B. Remington (LLNL)



Scientific Objective:

(1) Develop the x-ray diffraction technique at NIF; extend pressures beyond 5 MBar (previosuly examined at Omega)

(2) Perform x-ray diffraction studies at NIF in steps from 5 to 30 Mbar; map the phase diagram of compressed diamond; test recent first principles simulations; attempt to create and recover the BC8 phase.



Experiment Description:

(1) Experiment will use the ramp compression hohlraum platform developed at NIF.

(2) Three possible configurations for x-ray diffraction will be tested.

Pair plasma creation using the National Ignition Facility

PI: H. Chen (LLNL)

Collaborators: R. Tommasini, S. Wilks, C. Chen, P. Beiersdorfer (LLNL); D. Meyerhofer (UR/LLE); H. Takabe (Osaka); J. Sheppard, T. Raubenheimer (Stanford)

Scientific Objective:

(1) Produce pure electron-positron pair plasmas at NIF and conduct preliminary scaling studies

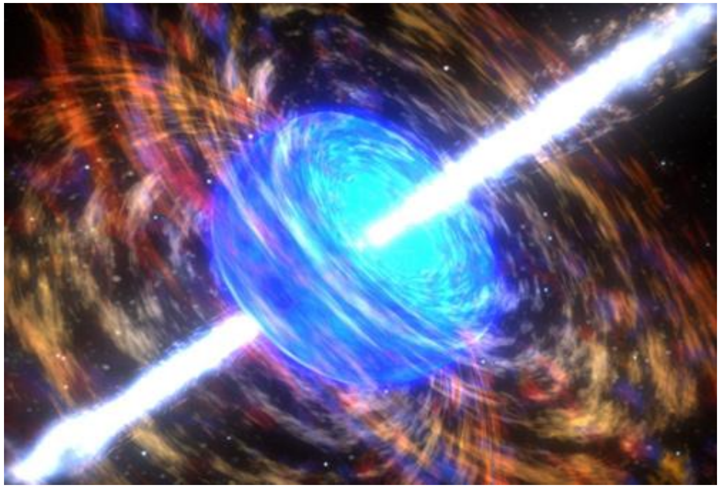
(2) Perform initial pair jet/plasma interaction experiments

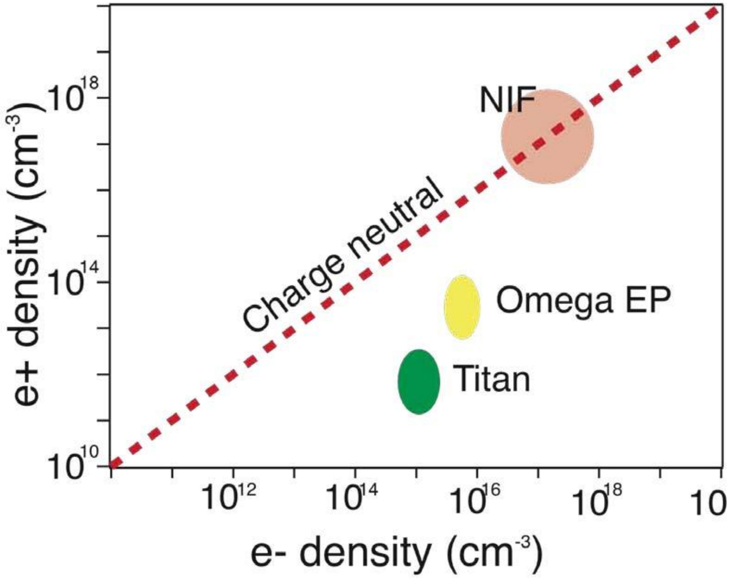
Experiment Description:

(1) Create initial pair plasma via ARC beam @10 psec, 300-800 J interaction w/ Au target (reference previous Titan/Omega EP data)

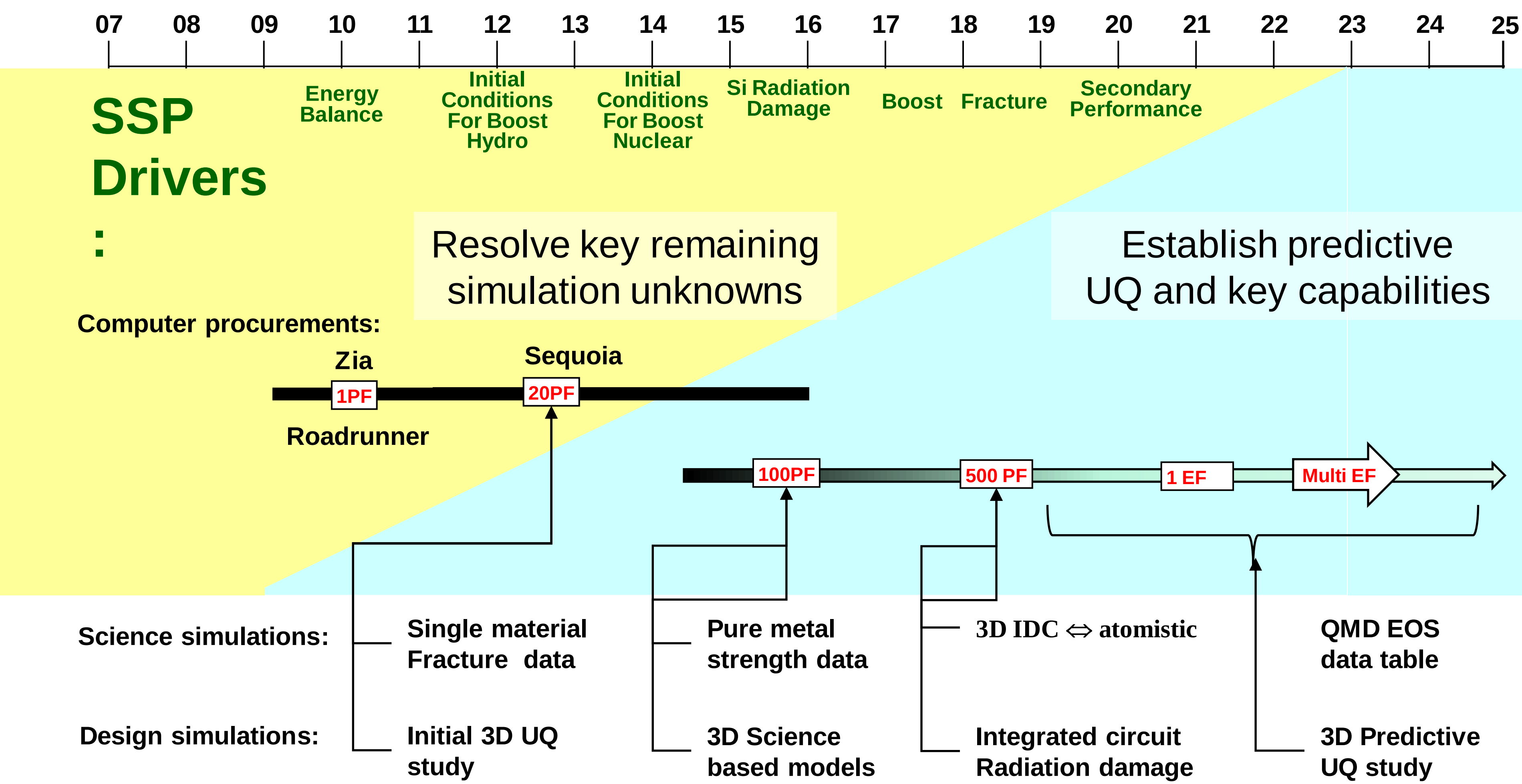
(2) Study scaling of pair plasma production with laser energy; examine shaped target to optimize pair plasma density

(3) Examine pair jet/plasma interaction with shaped target





SSP requirements are driving advanced physical understanding, which will require Exascale to establish predictive 3D UQ



By 2022, ASC should provide a simulation capability for the SSP to support the Stockpile with confidence using QMU methodologies exploiting predictive UQ capabilities

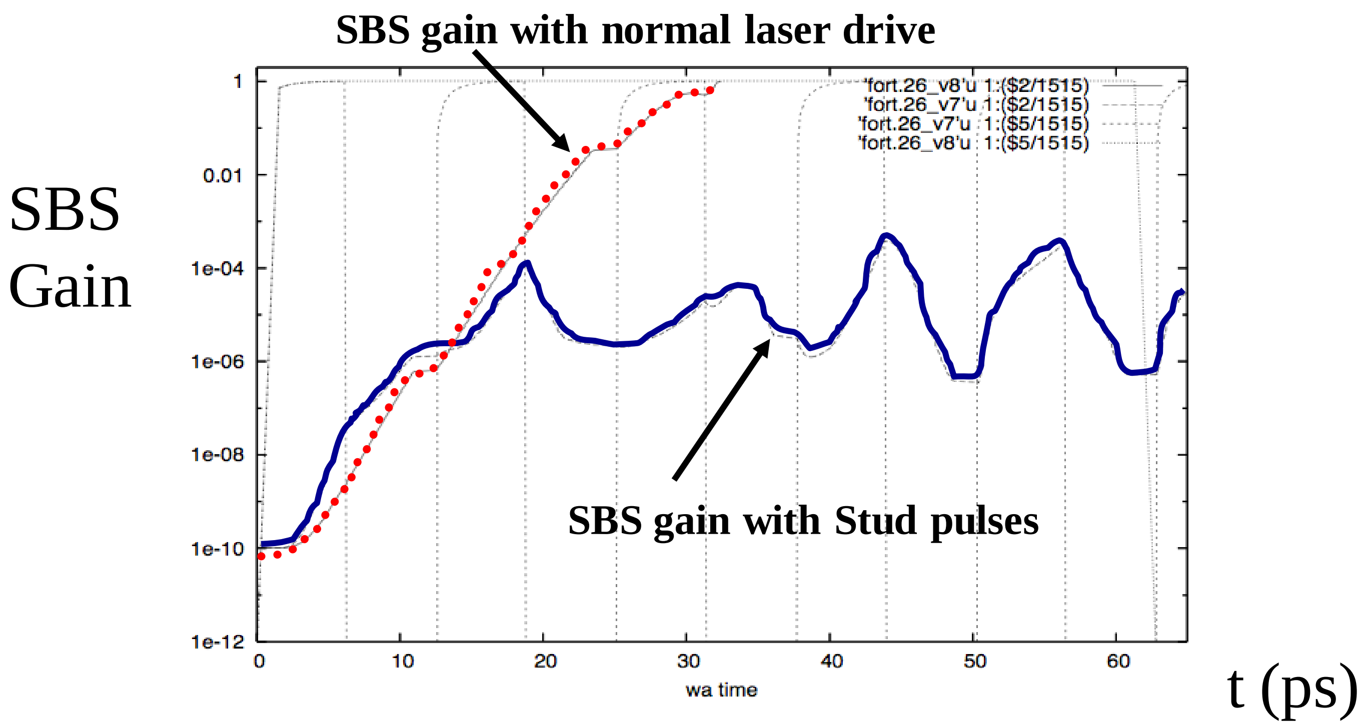
NNSA Highlights - Outline

- An impressive tandem increase in experimental and computational power is producing outstanding advances.
- NNSA continues to be an important sponsor and steward of High Energy Density (HED) Physics
  - Academic outreach programs continue to be highly successful.
- Important advances in HED / Plasma diagnostic development are opening up new research paths.
- The NAS study of Inertial Fusion Energy has begun.
- First ignition experiments will be a key milestone for basic plasma science as well as weapons science.
- Capabilities that were assembled in the pursuit of ignition also have important applications in HED, dynamic materials science and other fields

Backups

Innovative plasma research may enable greatly enhanced laser drive conditions

- **STUD pulses**: *Spike Trains of Uneven Duration and Delay superimposed on the main laser drive.*
- Suppression of Laser-plasma instabilities may enable the use of green 2 ω Nd laser light which can be produced at much higher energy
- May provide a method for controlling cross beam energy transfer.



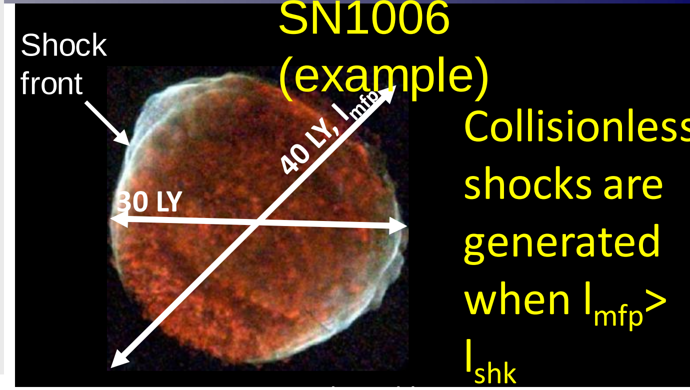
Stimulated Brillouin gain with and without stud pulses superimposed on the main laser drive pulse

Astrophysical collisionless shock generation on NIF

PI : Y. Sakawa (Osaka Univ) / G. Gregori (Oxford Univ)

Collaborators: A. Bell, A. Diziere, L. Gargate, S. Glenzer, C. Gregory, M. Hoshino, T. Ide, T. Kato, R. Kodama, M. Koenig, Y. Kuramitsu, E. Liang, M. Medvedev, F. Miniati, T. Morita, C. Niemann, H. Park, A. Ravasio, B. Remington, D. Ryutov, Y. Sentoku, A. Spitkovsky, H. Takabe, N. Woolsey, R. Yamazaki

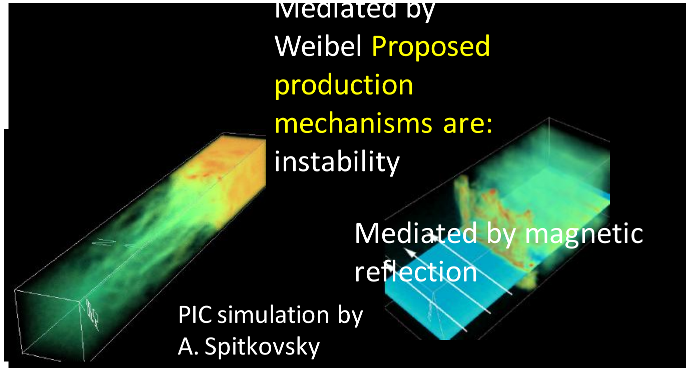
Institutions: Osaka, Oxford, LLNL, Princeton, Ecole Polytechnique, York, ETH Zurich, UCLA, Aoyama Gakuin, Tokyo U., Kansas, Rice



Scientific Objective:

(1) To study the generation of high Mach-number non-relativistic collisionless shocks relevant to SNRs and protostellar jets

(2) To study the formation of self-generated magnetic fields from the Weibel instability and cosmic ray acceleration



Experiment Description:

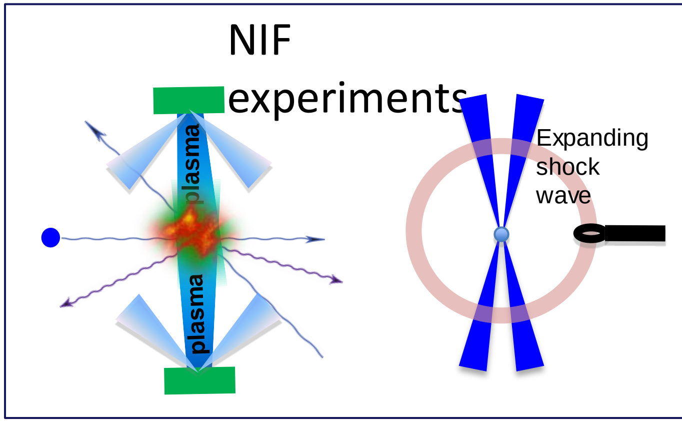
(1) Irradiate the inner-surface of low-Z foils to create high velocity counter-streaming plasmas

(2) Create expanding shocks in the gas-filled NIF chamber

(3) 200 kJ – 1 MJ, all 192 beams, 1ns, 20 ns, square pulses

(3) The plasma states and magnetic fields will be measured by Thomson scattering, interferometry, proton radiography, induction coils, electron spectrometer, gated imagers

(4) FY12 – 6 shots to test diagnostic capabilities and measure plasma states; FY13, FY14 – 6 shots/year for science return

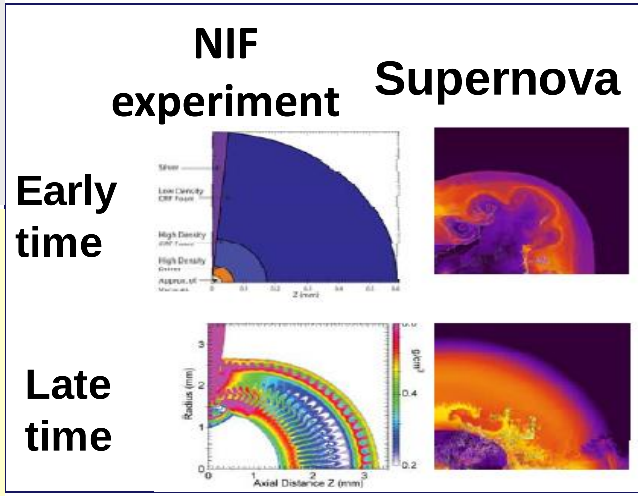


Diverging Supernova Explosion Experiments on NIF

PI :T. Plewa (Florida State Univ.)

Collaborators: P. Drake, C. Kuranz, M. Grosskopf (U. Michigan); W. Arnett (U. Arizona), C. Wheeler (U. Texas), A. Miles, H. Park, B . Remington (LLNL)

Scientific Objective: Develop understanding of extensive Rayleigh-Taylor mixing in exploding massive stars. Data will give physics insights of inter-shell penetration outwards to surface via turbulent mixing, shell breakouts, growth of secondary instabilities, and vorticity-enhanced mixing.



Experiment Description:

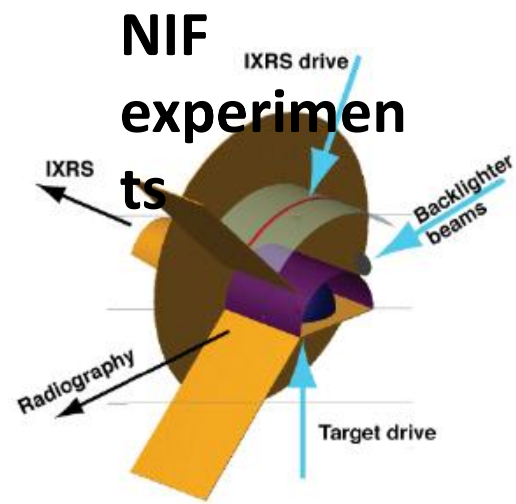
(1) Targets: Layers of ablator, high-Z (Cu) components, mid density foam, low density foam layers to scale the SN1987A

(2) Drive: up to 200 kJ, 3 ns; Imaging x-ray scattering (IXRS) up to 600 kJ, 1.2 ns; Backlighter, up to 10 kJ, 1 ns

(3) Imaging x-ray scattering (IXRS) will probe dynamic features diverging explosion; in addition, point projection radiography will be employed

(4) FY12: 5 shots to demonstrate diagnostic capability

(5) FY13, FY14: 4-8 shots/year; 2 interface patterns, imaging at 2 delay times, symmetric vs asymmetric explosions



Rayleigh-Taylor Instability (RTI) Collaboration

PI's : A. Casner (CEA), A. Cooper (LLNL)

Collaborators: L. Masse, G. Huser, J.P. Jadaud, F. Girard, O. Poujade, D. Galmiche, S. Liberatore, P. Loiseau, L. Jacquet, L. Videau (CEA); V. Smalyuk, B. Remington, S. Maclaren, J. Kane, D. Ryutov, M. Foord, J. Hayes, K. Raman (LLNL); P. Clavin (IRPHE); A. Moore, R. Williams (AWE); M. Pound

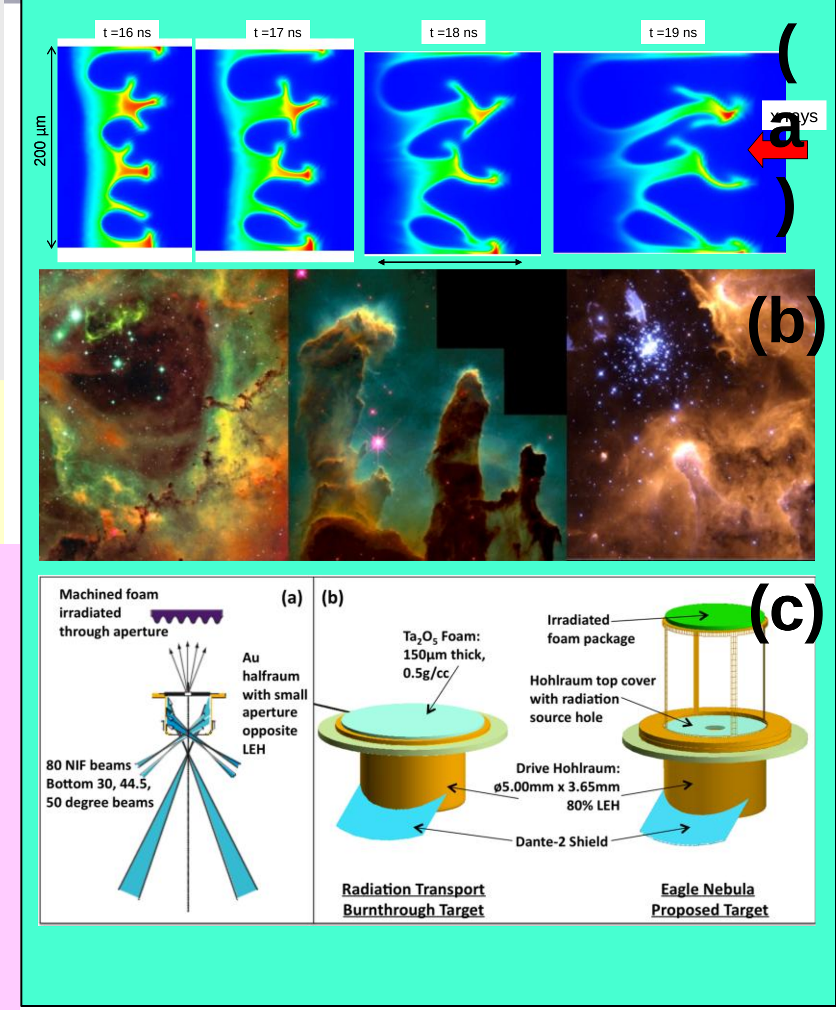
Scientific Objective: Study ablative Rayleigh-Taylor instability and the effect of directional radiation in the deeply non-linear regime

Experiment Description:

a) **Side-on, post-processed images illustrating the ablative, bubble-merger regime; initial 2D multimode perturbations with amplitude of 1 µm.**

b) **Examples of astronomical pillars (Eagle Nebula in center), structures which may be explained with directional radiation effects on RTI.**

c) **Sample experiment configuration: the collaboration will build from an established programmatic platform to drive ablative or directional RTI.**



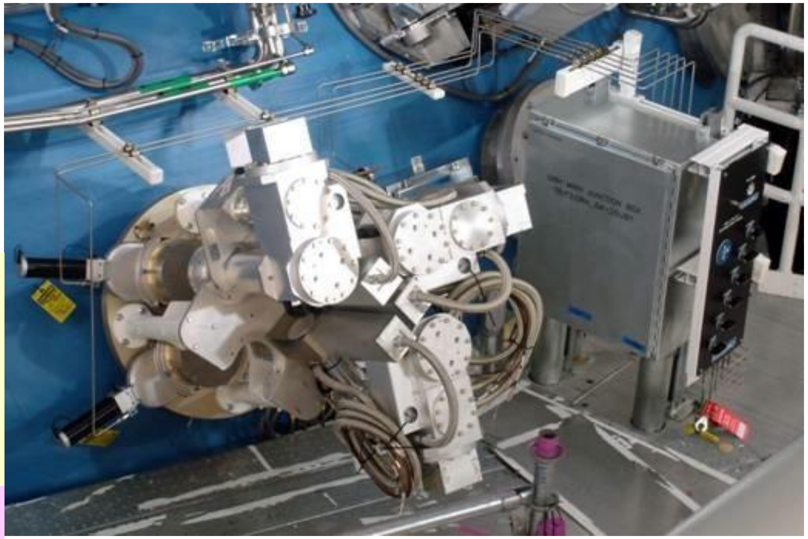
Measuring the astrophysically-relevant low energy neutron spectrum using GRH in NIF capsules

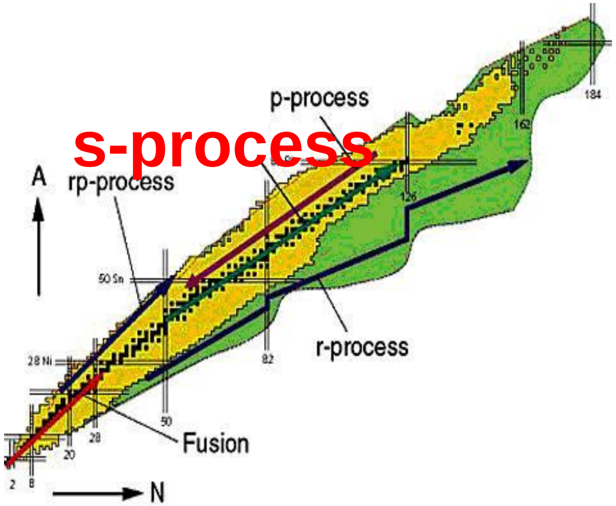
PI : L. Bernstein (LLNL)

Collaborators: H. Herrmann, W. Stoeffl, N. Hoffman, C. Cerjan, J.A. Caggiano, C. Brune, D.H.G. Schneider, S. Siem, A. Görgen

Scientific Objective: Develop a capability to measure the low-energy (E_n<200 keV) neutron spectrum responsible for the formation of most of the elements above Fe (Z=26).

Experiment Description: We will use GRH to observe "late-time" (≥ 250 ps) gamma-rays from neutron capture on the gold in the hohlraum and an additional external diagnostic band. This information is needed to allow for the measurement of the "stellar thermal" component of the NIF neutron spectrum needed for astrophysical nucleosynthesis studies.

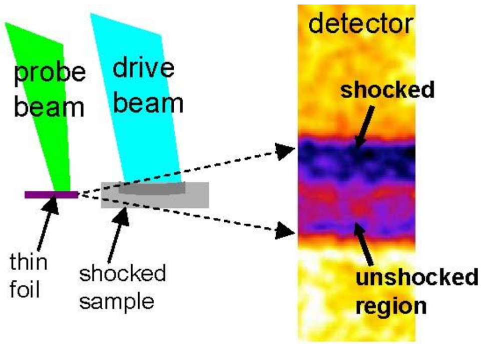




Generation of characterization of highly compressed matter

PI : P. Neumayer (GSI), R. Falcone (UC Berkeley)

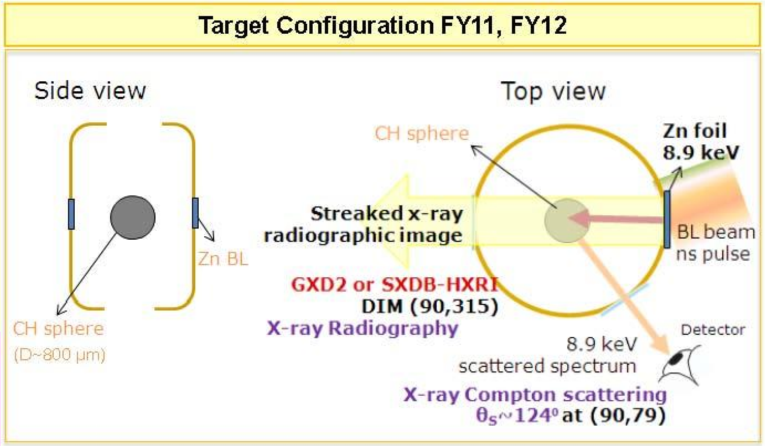
Collaborators: R. Redmer (Rostock); E. Forster (Jena); P. Davis (UC Berkeley); H. Lee, G. Hays (SLAC/LCLS); R. Hemley (Carnegie Institution); S. Rose (Imperial College); S. Glenzer, P. Celliers, J. Eggert, D. Milathianaki, S. LePape, T. Doppner, C. Fortmann, A. Kritcher, J. Hawreliak (LLNL)



Scientific Objective:

(1) Test first principle DFT-MD calculations of EOS and other properties of warm dense matter via shock compressed matter expts. diagnosed with x-ray Thomson scattering

(2) Determine absolute equation of state and pressure-induced ionization for 10-1000 TPa regimes to understand and model material under shock loading



Experiment Description:

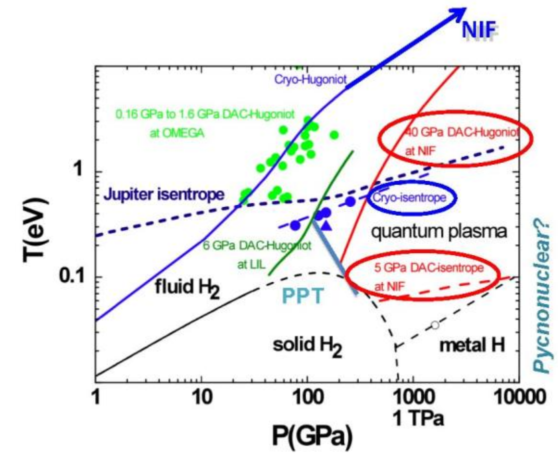
(1) Planar geometry experiments will use multi-shock compression

(2) High pressures to be obtained in convergent geometries

Measurements of properties of hydrogen and methane at ultra-high pressures

PI : R. Jeanloz (UC Berkeley)/P. Loubeyre (CEA); R. Hemley (Carnegie Institution)

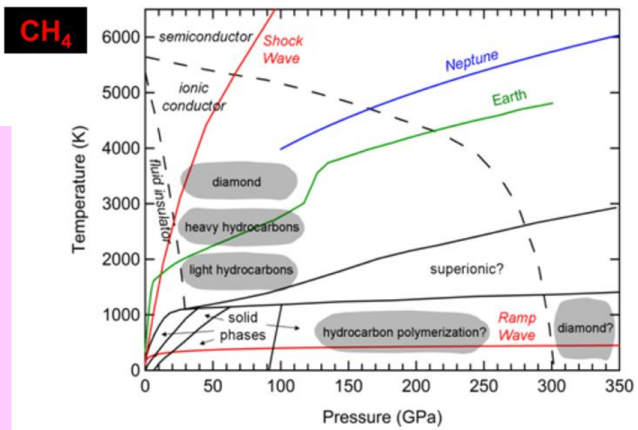
Collaborators: S. Brygoo (CEA); A. Goncharov, A. Dalton, S. McWilliams (Carnegie); D. Fratanduono (UR/LLE); J. Eggert, R. Rygg, R. Smith, R. Collins (LLNL)



Scientific Objective:

(1) Provide data used to test planetary evolution models relevant to extrasolar planets

(2) Determine absolute equation of state and pressure-induced ionization for 10-1000 TPa regimes to understand and model material under shock loading



Experiment Description:

(1) Using mini-DAC and indirect drive configurations, test predictions for plasma phase transitions; provide highest pressure H shock data ever collected; ultra-high pressure melt curve; look for Wigner crystal state

(2) Using ramp compression platform under development at NIF, determine optical-electronic properties and phase diagrams of hydrogen and methane at high densities and low temperatures

The pursuit of ignition will dominate the agenda at NIF through 2012

- **3 major series of ignition experiments are planned for 2010-2012.**
  - The plan is to transition to development of an "ignition weapons physics platform"
  - **This "platform" development shares many common goals with energy research**
    - **Robust operation, moderate to high gain**

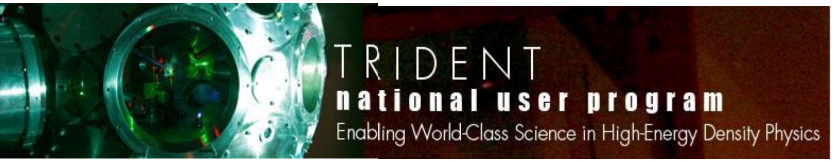
- **The diagnostic suite will be rapidly evolving during this period.**
  - Installation of Neutron imaging began in 2010
  - Several beam lines of the ARC backlighting system will be available in 2012.
  - Detailed burn history measurements were begun in 2010
  - **Diagnostics that may be unique to the energy mission should be under consideration now.**

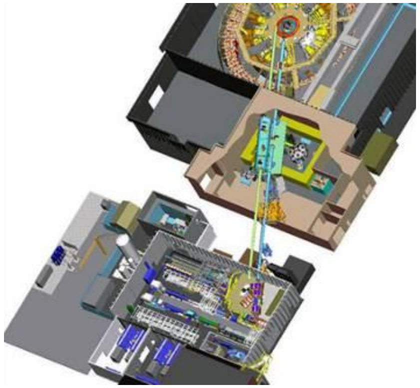
The schedule for the first ignition attempts is somewhat behind the projection presented at the '09 FPA meeting

NNSA relies on intermediate scale plasma science facilities for basic science support

Examples of intermediate size plasma facilities:

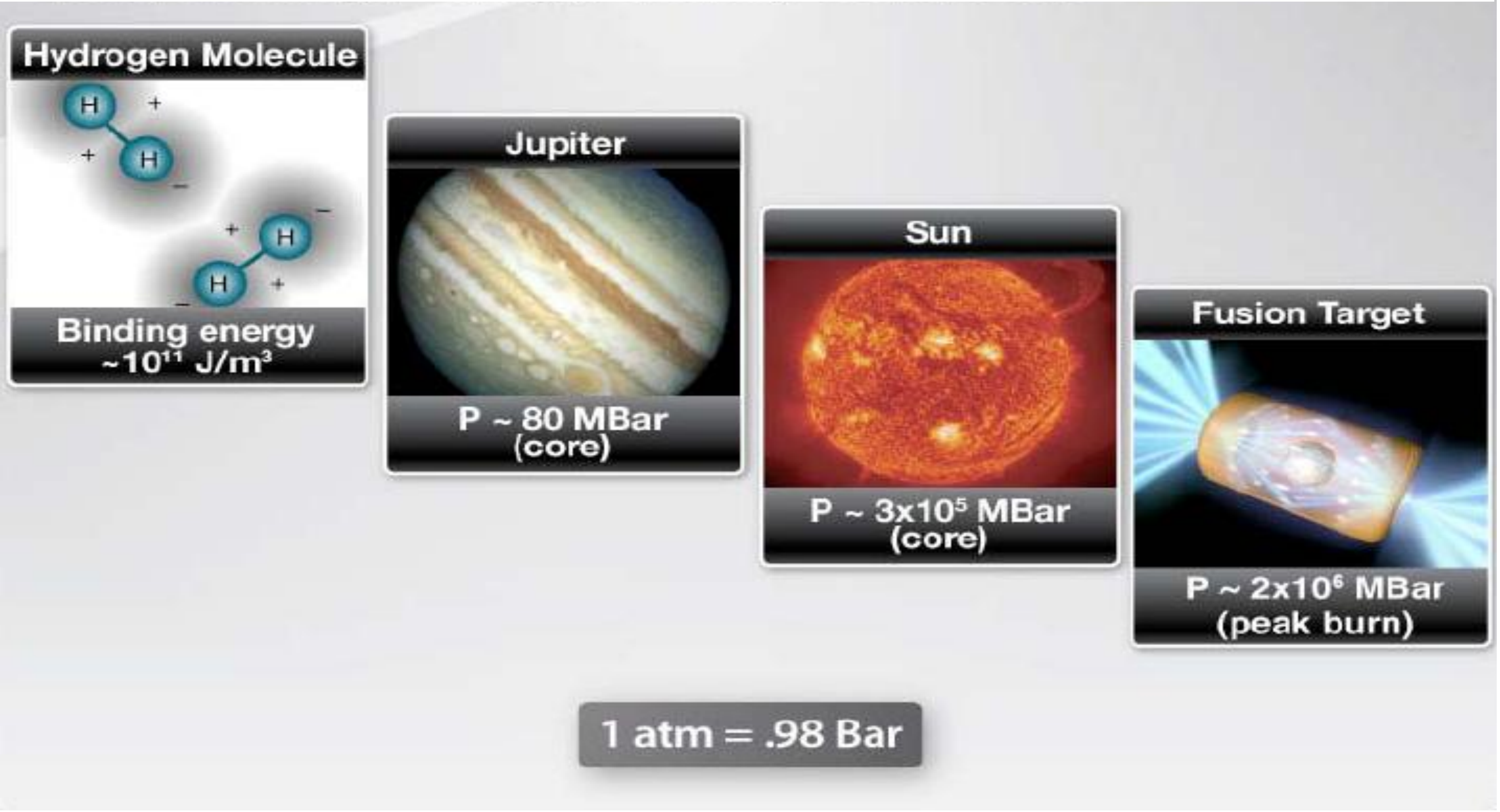
- **Jupiter at LLNL (lasers): support of NIC and NIF; mission; users**
- **Trident at LANL (laser): support of NIF and NIC; mission; users**
- **Texas Petawatt at UTX (laser): discovery-driven research; users**
- **Z-Beamlet / Z Petawatt at SNL (laser): diagnostic for ZR; users**
- **Nevada Terawatt at UNR: pulsed power**



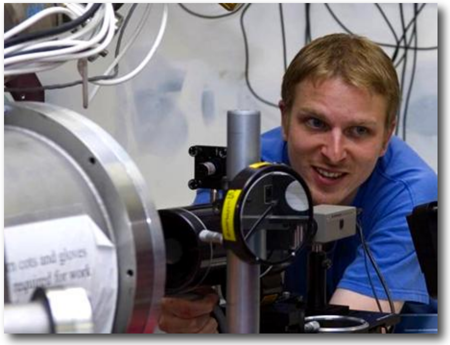


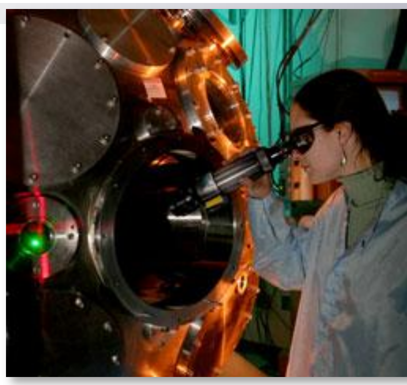
Intermediate-size plasma facilities provide both direct and indirect mission support, and we are encouraging user access at our intermediate facilities

NIF will provide unprecedented capabilities to study matter at high-energy density conditions



The unique laser capabilities and extensive diagnostic suite enable cutting edge research at Trident

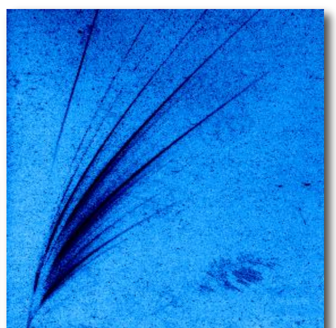




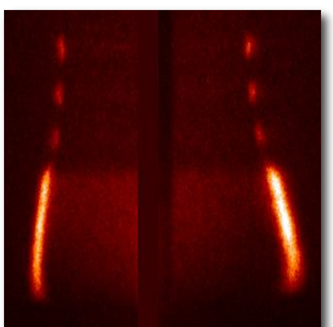
Scope of Research on Trident:

- Relativistic Laser-Matter Interactions
- Fast Ignition Science
- Novel Laser-driven accelerators
- Novel X-ray source development
- Inertial Fusion Science & HEDP
- Fundamental laser-plasma research
- High-strain-rate Dynamic Materials

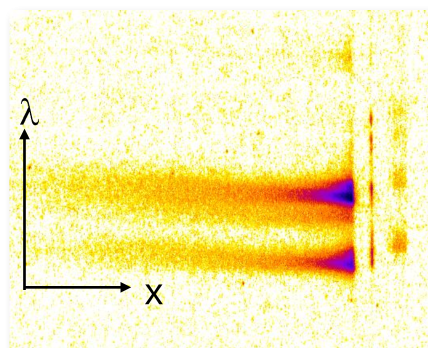
laser-accelerated ion spectra



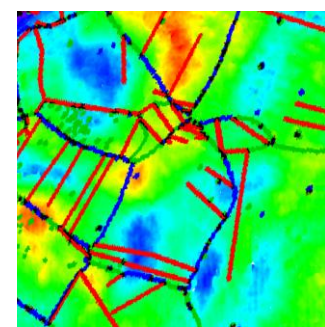
streaked UV Thomson scatter



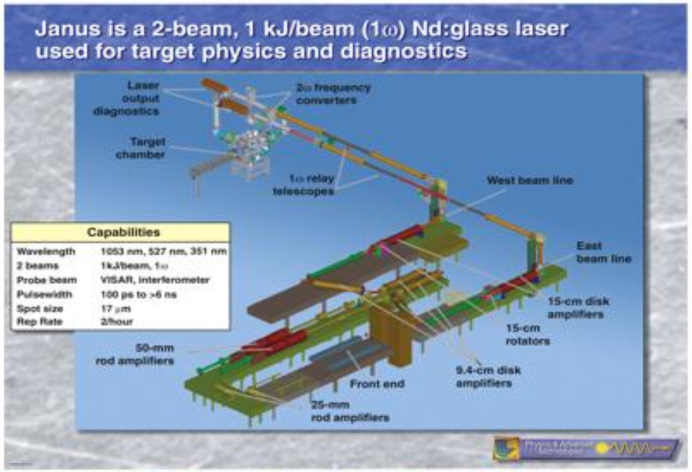
imaging x-ray Thomson scatter

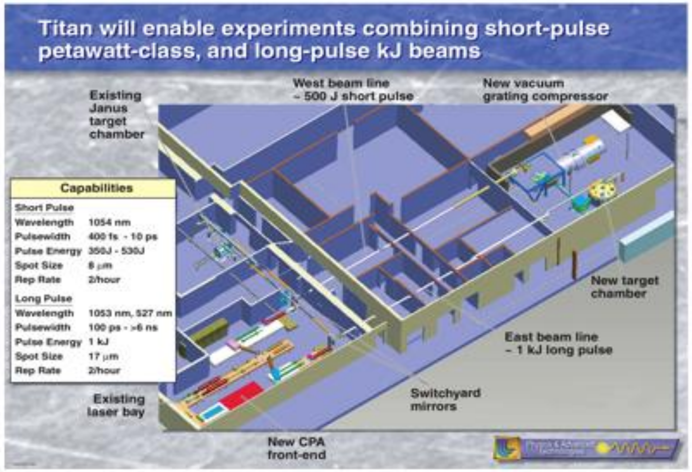


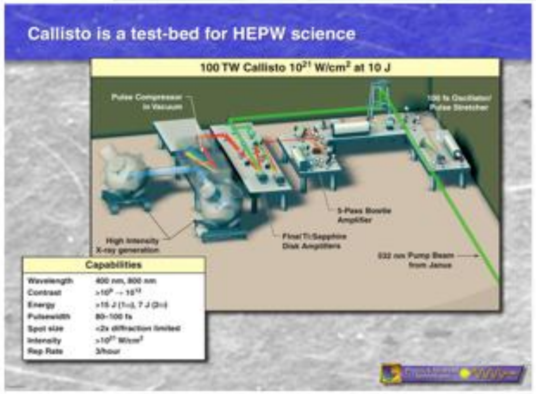
transient imaging displacement interferometry

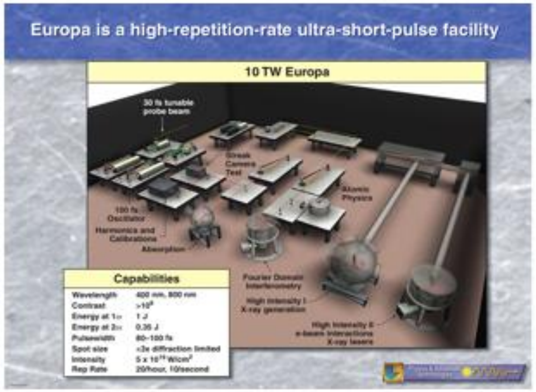


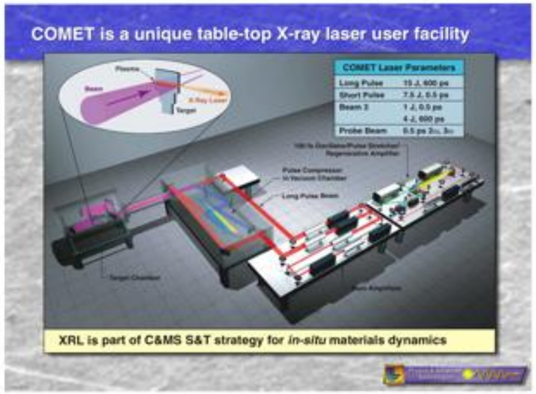
Jupiter is a unique multi-platform user facility for high energy-density physics











• Fusion Research • Material Science
• HED Laser Plasma Physics

The expansion of HED Laboratory Plasma Science continues

- **There has been active work in Laboratory astrophysical experiments**
  - One experiment contributed to Hubble planning
  - A center for Lab Astrophysics has been established as part of the Joint HEDLP Program.

- **Discovery driven, high energy density plasma science**

  This is specifically supported by NNSA through: the HEDLP joint program, User Facilities (including NLUF), LDRD, University programs, workshops and individual contracts.

- **Intermediate –scale plasma science**

  NNSA continues to develop its intermediate scale User Facilities, where peer-reviewed academic use for discovery-driven science is growing

- **Cross-cutting research**

  NNSA is growing its collaborative partnerships with other agencies, institutions, and individuals through WFO, LDRD, User Facilities, and University programs. This is an effective method to optimize cross-cutting research

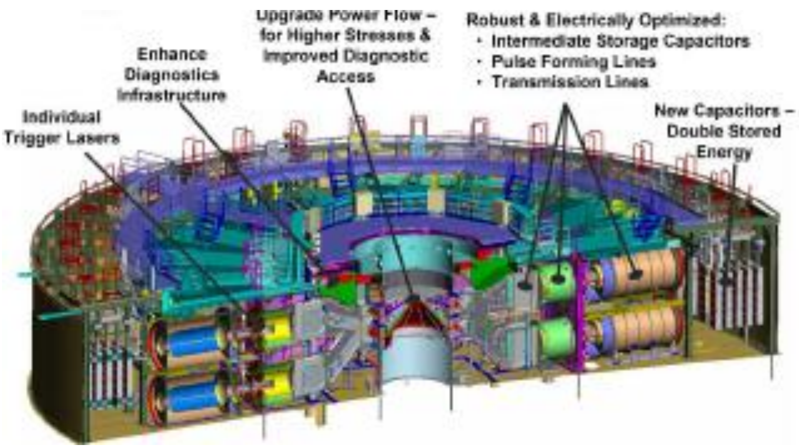
User Facilities and Shared National Resources – an important component of the future of NNSA facilities

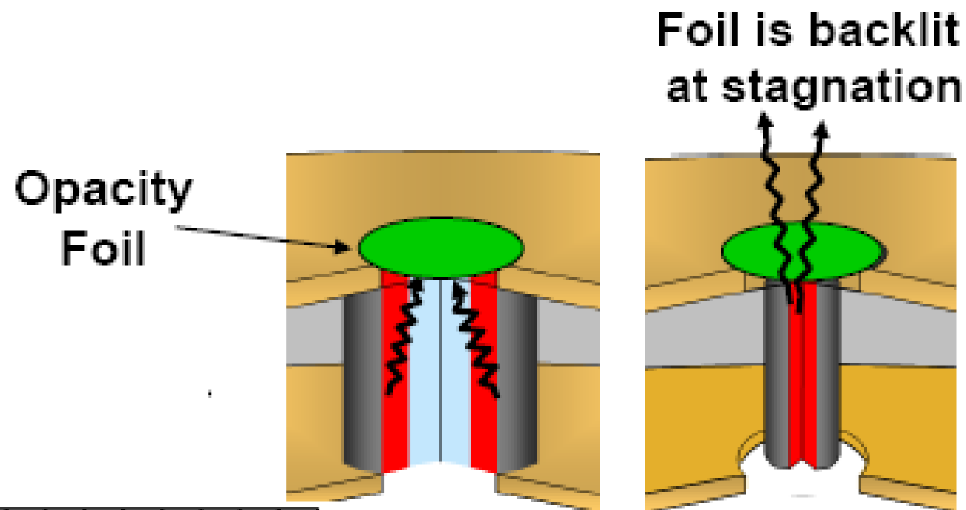
- **Strengthening the HED science base** is an essential part of the NNSA mission and a responsibility to the nation.
- **15% of facility time** devoted to basic science is a goal.
- **Mission oriented work** will still dominate the agenda for the foreseeable future.
- **Uniform policies and procedures** will give a clear picture to the international science community and to our sponsors
- A broader constituency for our facilities is attractive to substantial segments of **congress**.

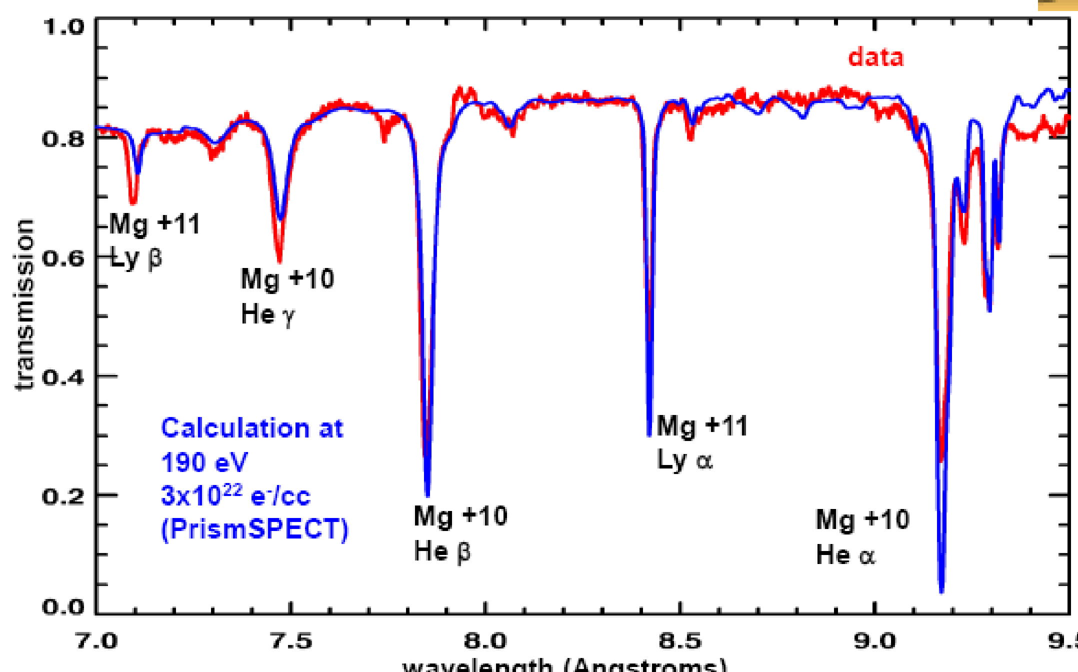
Carefully addressing the needs of the mission-oriented agendas while promoting a level of peer review that will grow to be consistent with Office of Science standards

Backups

The Z Machine has been used for a variety of materials and astrophysics studies







Recent Z experiments reach the temperature at the solar convection zone boundary

NNSA supports HED facilities of varying scale

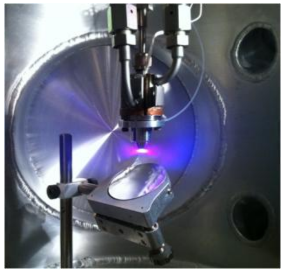
- Large facilities – NIF, OMEGA, Z
  - Most extreme conditions, complex experimental setups, large operations crews, few hands-on opportunities
- Intermediate Scale – Trident, Jupiter, Zebra, …
  - Modest operations crew, hands-on opportunities
- University Scale – Texas Petawatt, OSU high rep. rate, …
  - Small operations crew, serve as a basic training ground for new students, many hands-on opportunities

In many cases, experiments will progress from small to intermediate to large scale facilities

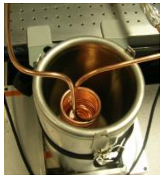
Smaller scale work will also continue to play a role in IFE

The Texas PW Center had two major experimental successes on in the past year

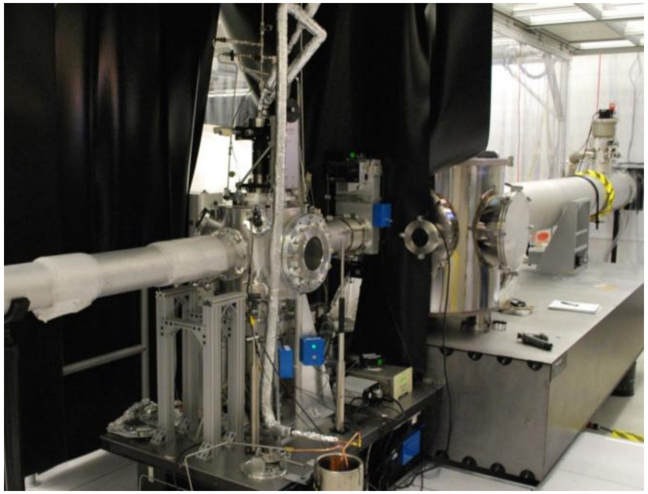
Target area of the TPW for the cluster fusion experiment



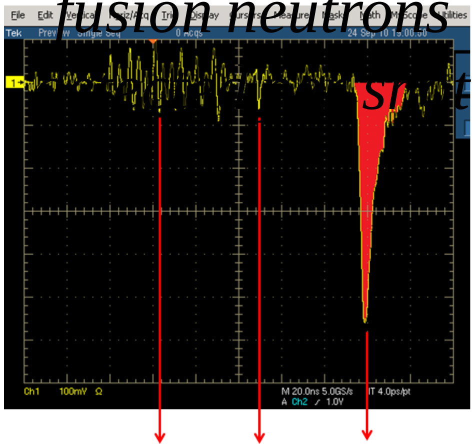
Deuterium plasma



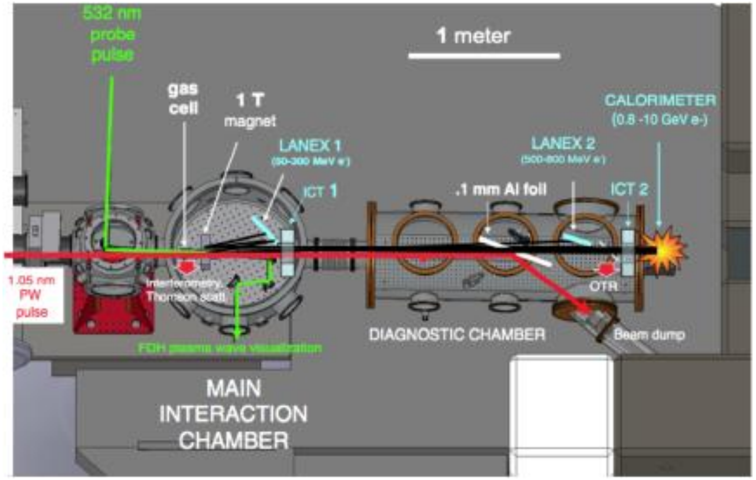
LN2 cooling line



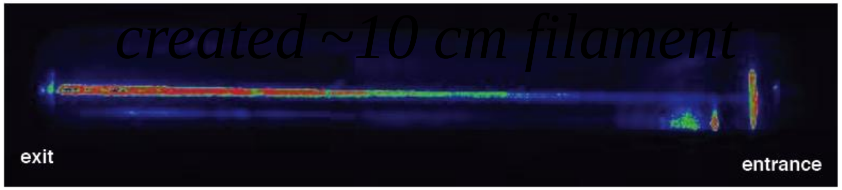
Up to 2 x 10^7 DD fusion neutrons



EMP X-ray neutron



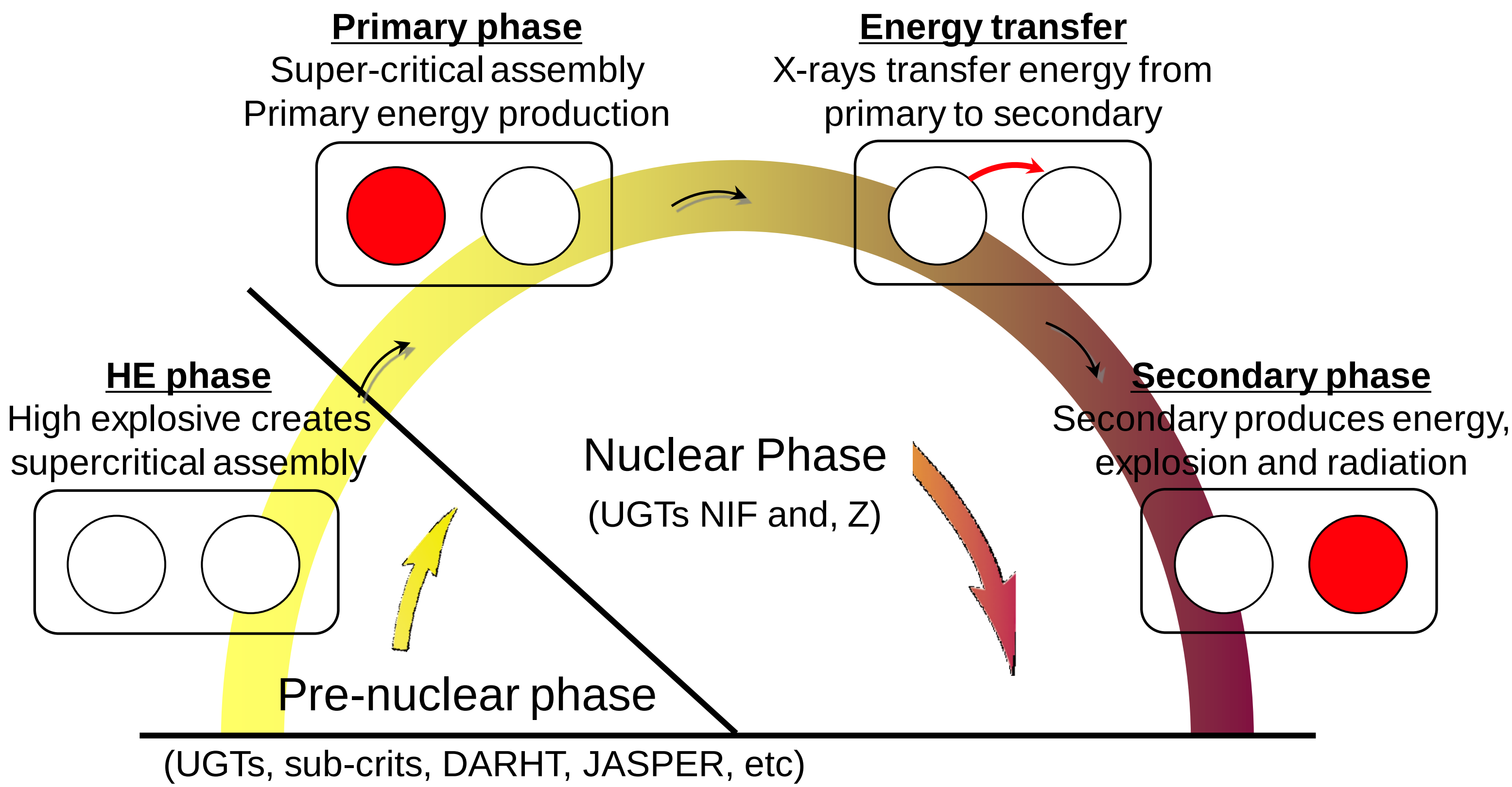
Self injection of plasma electrons observed in TPW-created ~10 cm filament



10 cm plasma wakefield filament image

After the explosive phase, weapons rapidly evolve into the HED and plasma regimes

Relevant laboratory expts. are performed throughout the HED phase

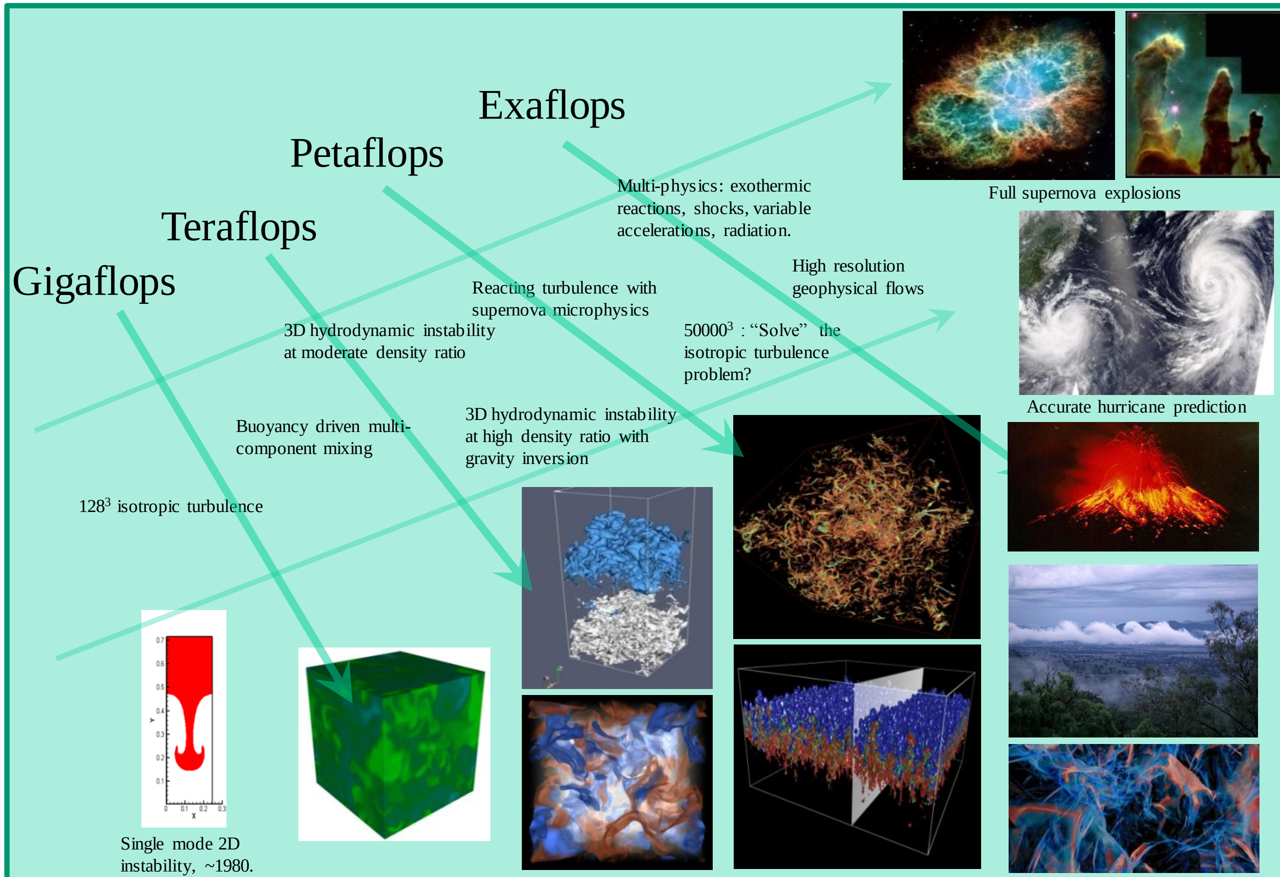


Weapons operation proceeds ***through the conditions of planetary interiors, to stellar interiors***

Exascale for Energy: Accurate Turbulence Simulations

After decades of research, turbulence and turbulent mixing still remain unsolved problems in physics; this due in part to the very large range of spatio-temporal, dynamically relevant scales.

Large scale computing is expected to bring a number of breakthroughs in science. One of the areas most likely to benefit is fluid turbulence, where very large scale computations can bring the insight and indicate the appropriate modeling approaches for the routine coarse mesh calculations needed in applications.



The road to Exascale will enable accurate turbulence simulations which will dramatically increase the predictability of complex practical flow and, thus, will directly impact the US competiveness, economy, and policy landscape.

Exascale for Energy: Accurate Turbulence Simulations

Exaflops

Petaflops

Teraflops

Gigaflops

Multi-physics: exothermic reactions, shocks, variable accelerations, radiation.

High resolution geophysical flows

Reacting turbulence with supernova microphysics

3D hydrodynamic instability at moderate density ratio

50000^3 : "Solve" the isotropic turbulence problem?

Buoyancy driven multi-component mixing

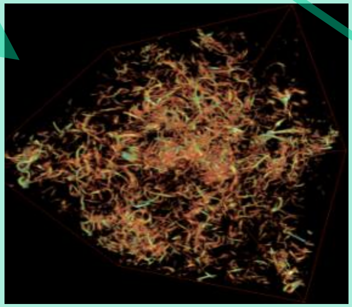
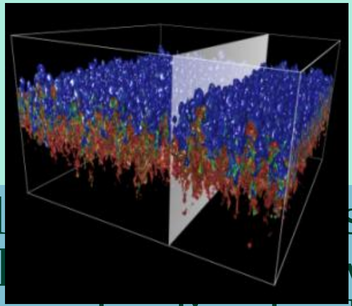
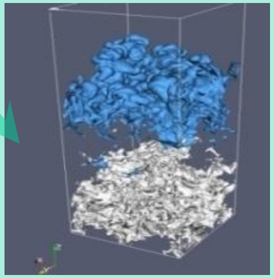
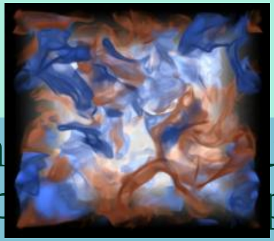
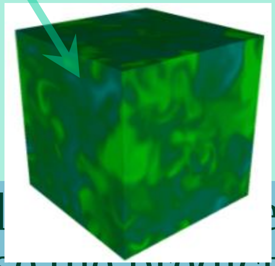
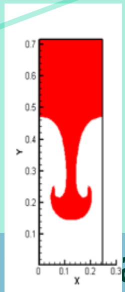
3D hydrodynamic instability at high density ratio with gravity inversion

128^3 isotropic turbulence


Full supernova explosions

Accurate hurricane prediction



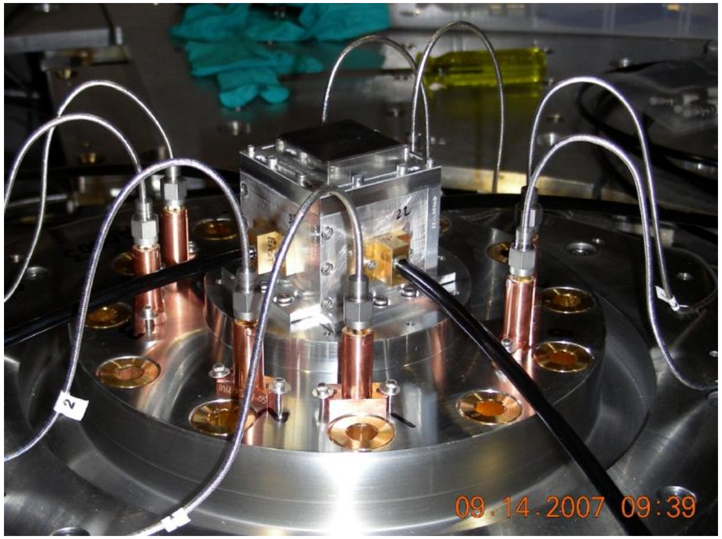








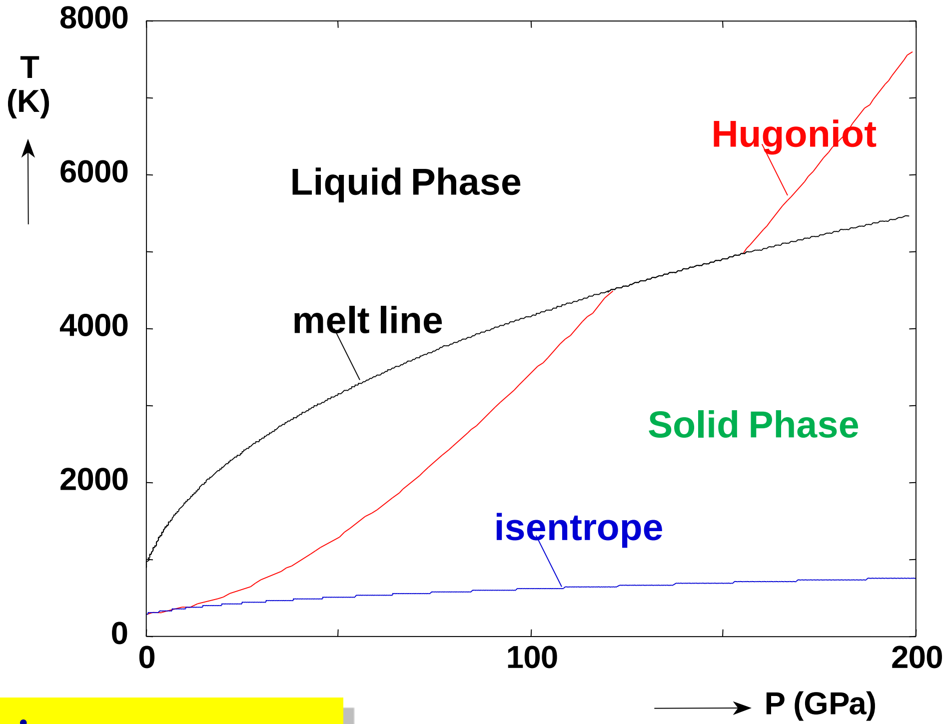
Single mode 2D instability, ~1980.

The road ... ascal ... e a ... ul ... s v
dramatically increase the predictab ... pl ... w a
directly impact the US competitiveness, economy, and policy landscape.

Magnetically-driven isentropic compression (ICE) on Z provides high quality dynamic material property data

- **Quasi-Isentropic Compression (ICE) on Z**
  - Multi-megabar
  - Centimeter sized samples millimeters thick
  - Ramp durations that are reasonable to approximate isentropic compression based on theoretical investigations





ICE measurements can be done in a containment system