

# *NIF & Photon Science Directorate Overview and NIF Update*

NIF and JLF User Group Meeting  
2/9/2015

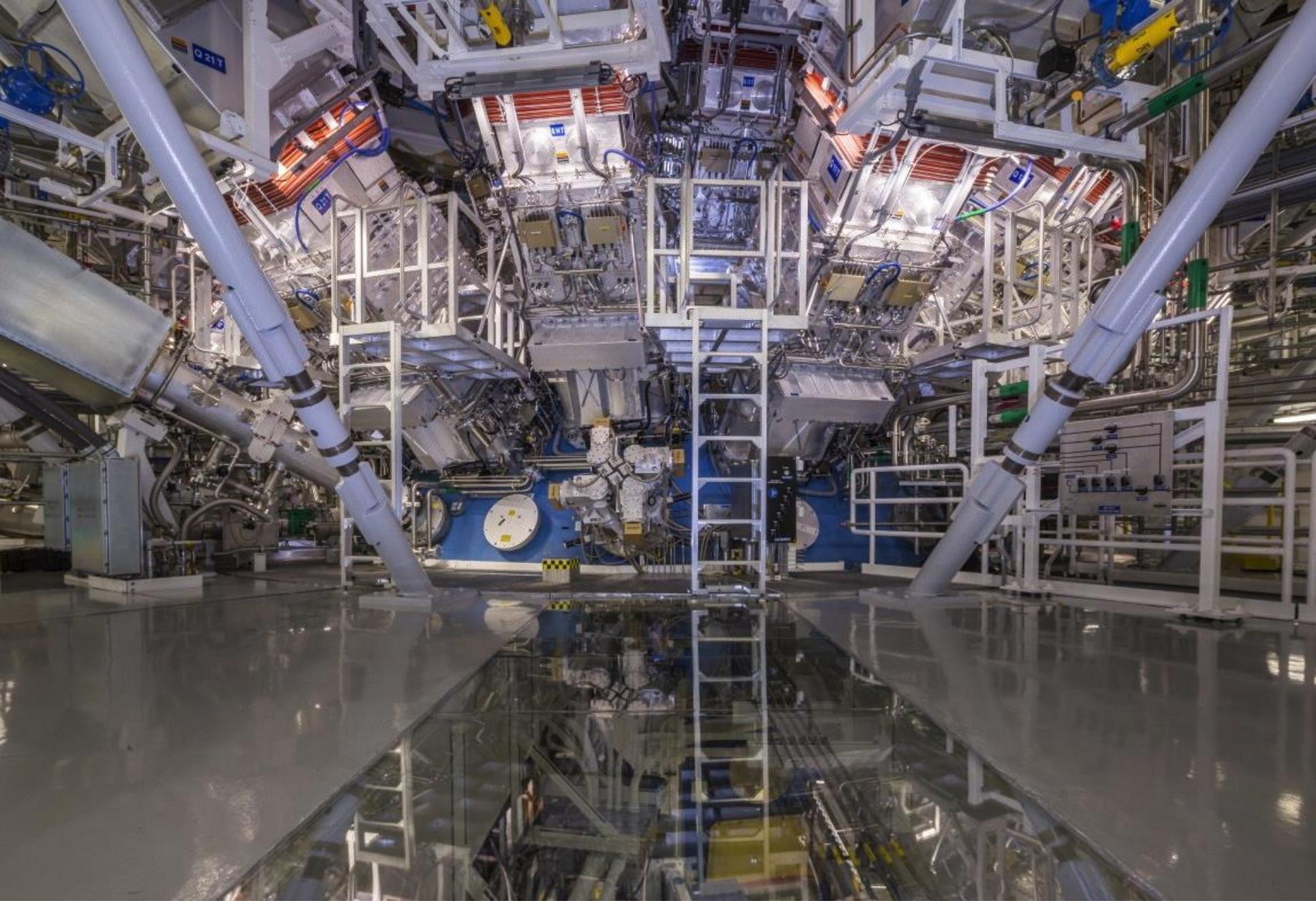
Mark Herrmann, NIF Director

 Lawrence Livermore  
National Laboratory



LLNL-PRES-667219

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



# LLNL has been delivering leading edge laser and optics solutions for over 40 years



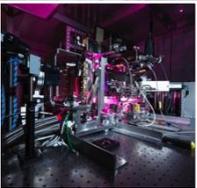
**T-REX**  
World's brightest  
laser gamma-ray  
source



**Heat Capacity  
Laser**  
World's highest  
average power  
solid state laser



**Mercury**  
World's highest  
average power  
10Hz laser



**DPAL**  
High Average  
Power



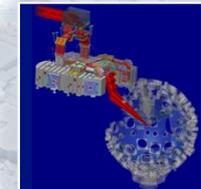
**Nova Petawatt**  
World's highest  
peak power laser



**AVLIS**  
World's highest  
average power  
tunable laser



**HAPLS**  
High average  
power petawatt  
laser under  
construction



**ARC**  
World's highest  
energy PW  
system



**NIF**  
World's most  
energetic laser



# NIF&PS continues to push on the leading edge of photon sciences and applications

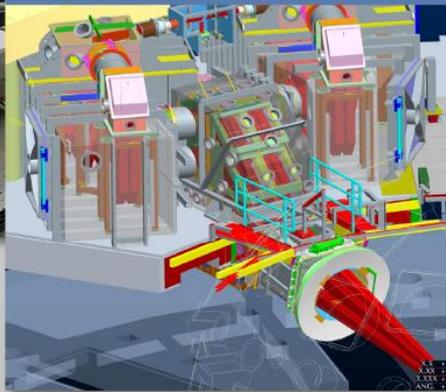
DPAL

Average Power:  
kW to MW



ARC, HAPLS

Peak Power:  
Petawatts to Exawatts



Compton Source

Photon Energy:  
keV to MeV



NIF

Energy:  
kJ to MJ

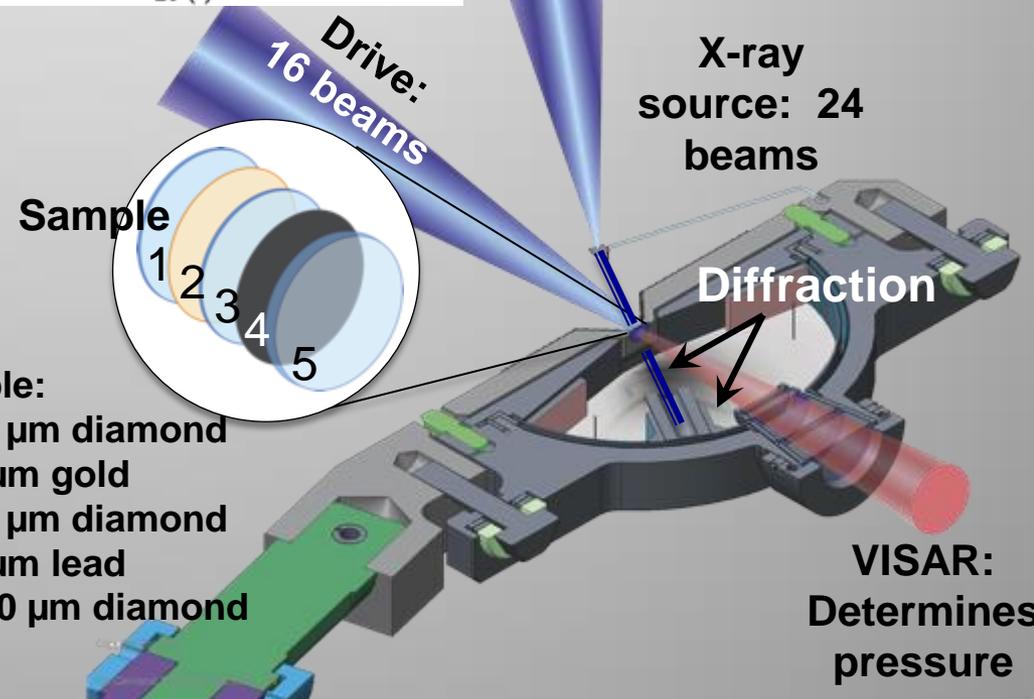
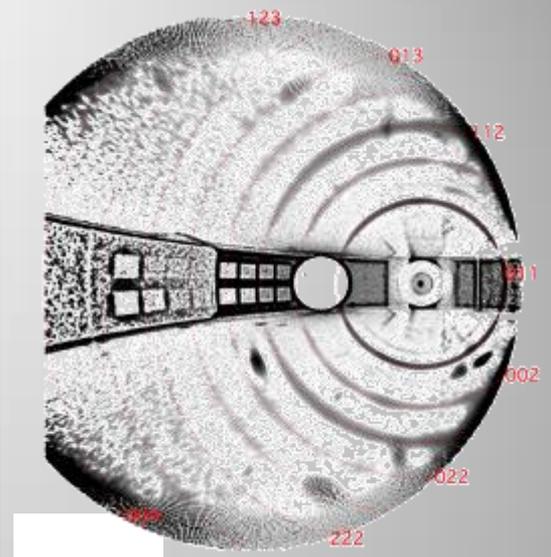
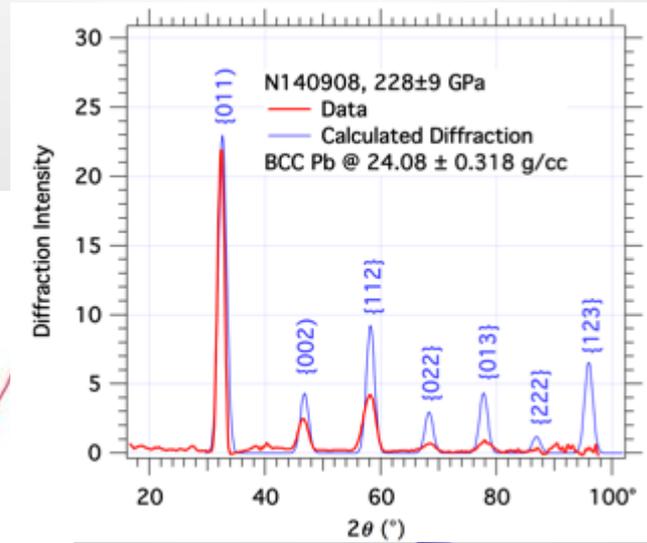
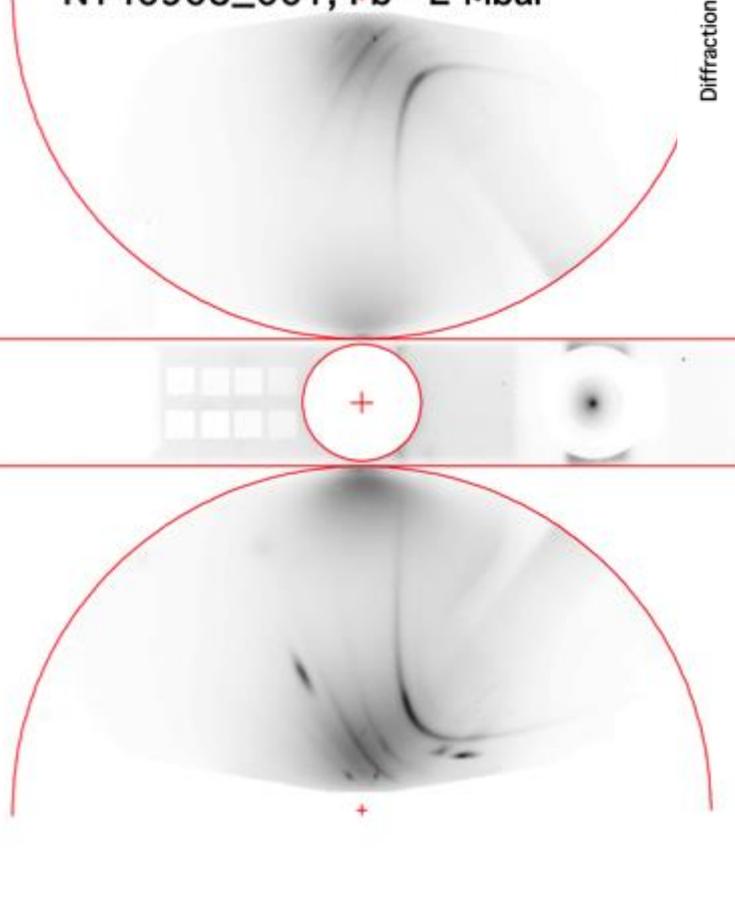


# **It is an exciting time at the National Ignition Facility; We are building a strong foundation for NIF's long future supporting the field of High Energy Density Science**

- **Exciting scientific results are being obtained on the facility nearly every day**
- **We have significantly increased the shot rate, enabling**
  - **A faster rate of learning by users**
  - **Stronger support for both the Discovery Science and National Security Applications**
  - **We are on track for the challenging goal of 300 shots in FY15**
- **We have completed our first new call for Discovery Science experiments in more than 4 years**
- **A National Diagnostic Plan is being developed that is focused on transformative diagnostics for HED facilities**
- **We have an ambitious goal of 400 shots in FY16. This goal will challenge the facility, target fabrication, optics, and the users.**
- **We want your feedback to make NIF better for our users!**

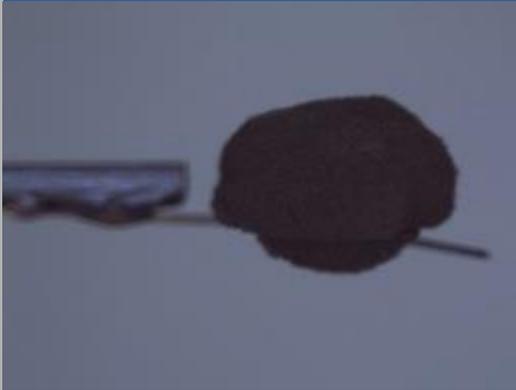
# Excellent diffraction data has been obtained on multiple materials, including lead

N140908\_001, Pb ~2 Mbar

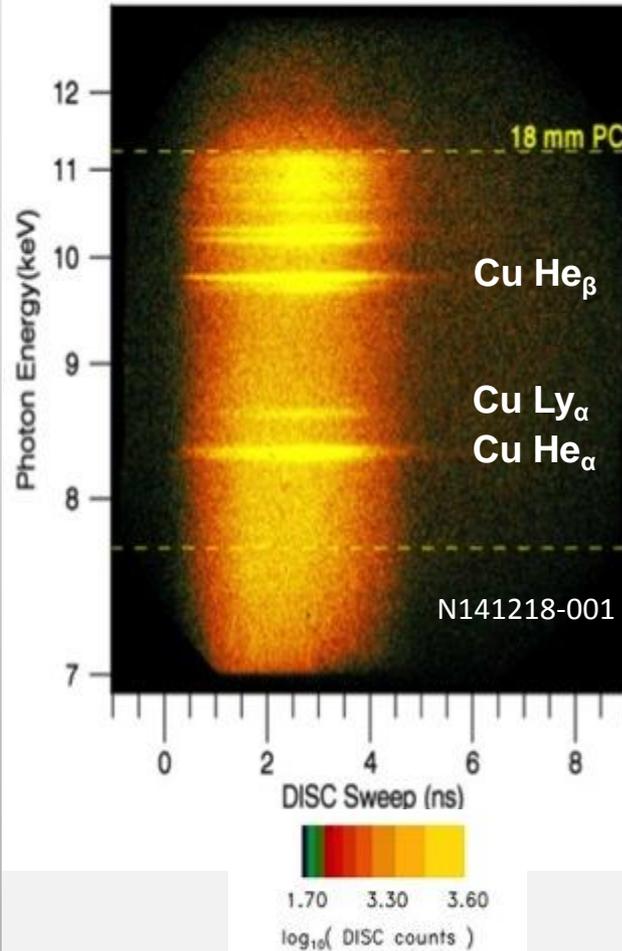


# We recently performed 5 shots in two days developing bright x-ray sources

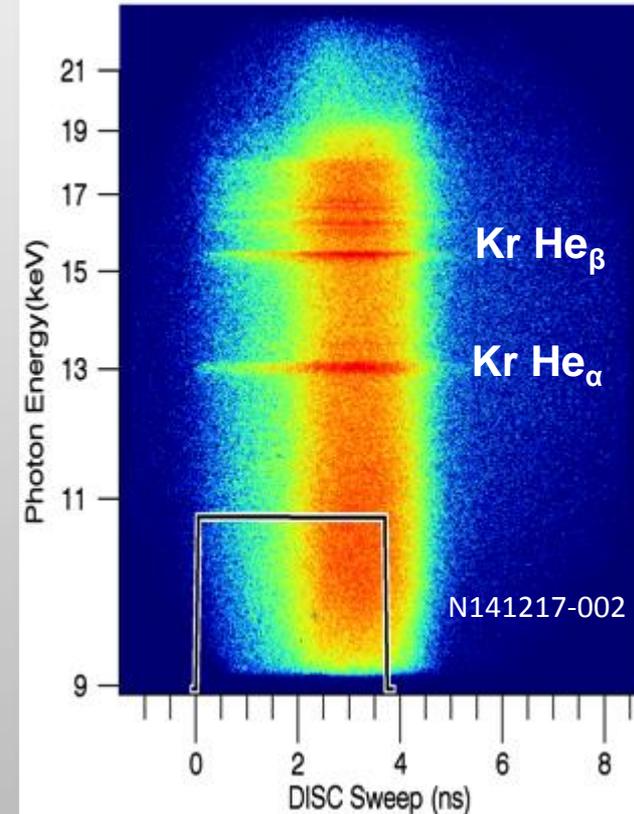
## Copper Metal Foam



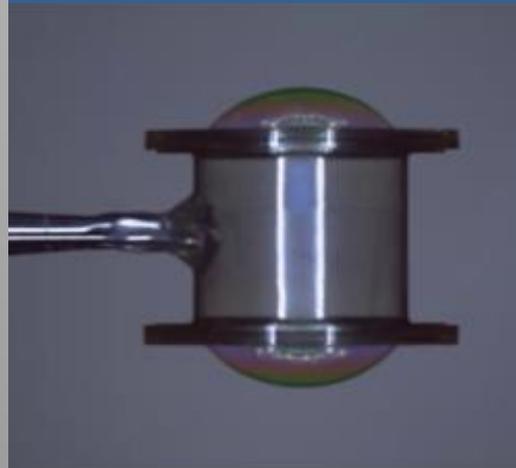
## Copper Metal Foam



## Kr gas pipe



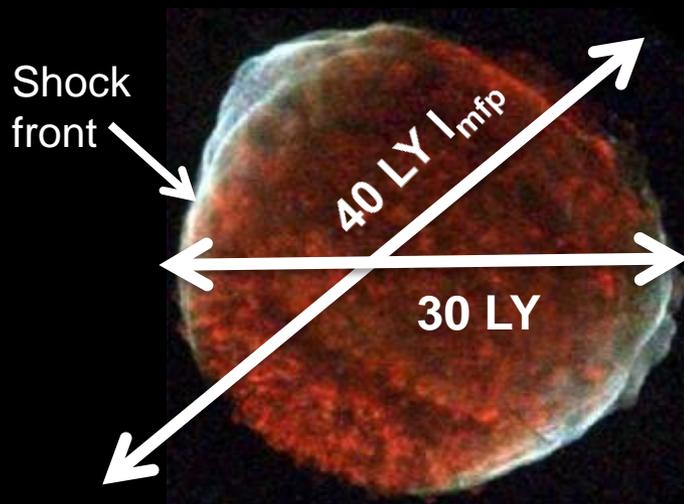
## Kr gas pipe



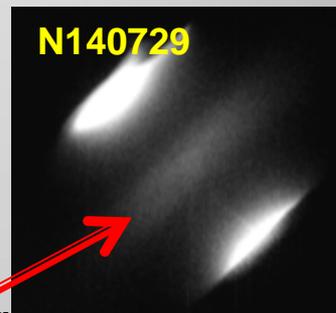
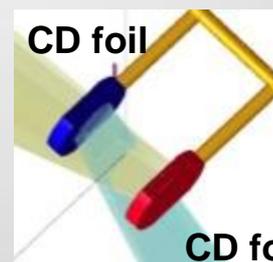
We performed our first collisionless shock experiments for the Discovery Science program, including 3 shots in 26 hours, building on techniques developed at Omega

Collisionless shocks are ubiquitous in universe; Weibel instabilities can generate magnetic fields to form these shocks

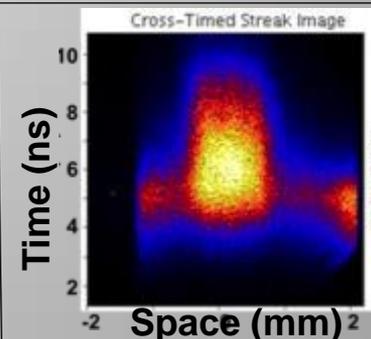
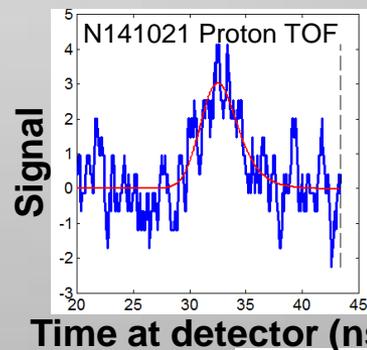
Nonrelativistic shocks (e.g. SNRs)



Experiments with CD-CD targets observed x-rays, neutrons and protons from the central shock-forming region



X-ray brightening from self-emission of hot plasmas

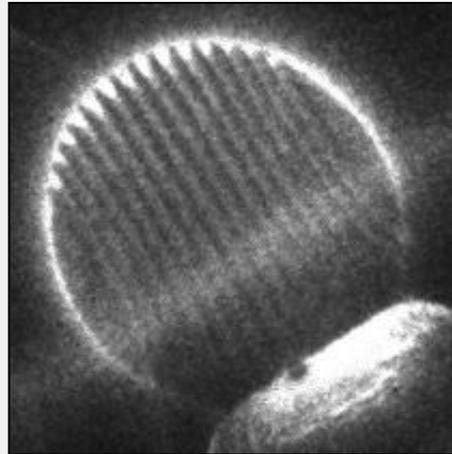


# We've performed a number of firsts on NIF for the National ICF program with our sister laboratories

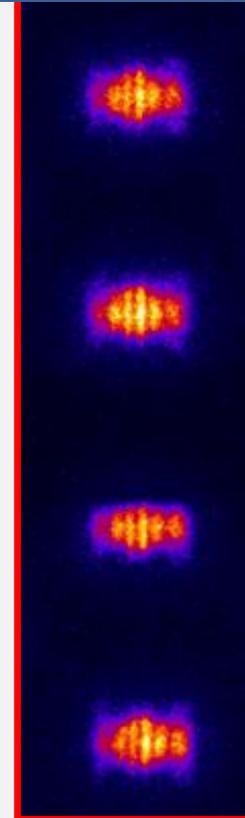
First Be Capsule on NIF



First Polar Direct Drive Hydro Growth Experiments on NIF



First Self-Backlit Deceleration Phase RT Growth Experiments on NIF



# We successfully obtained x-ray images of a DT layered diamond capsule with ~10ps temporal resolution

~BT-60ps

~BT

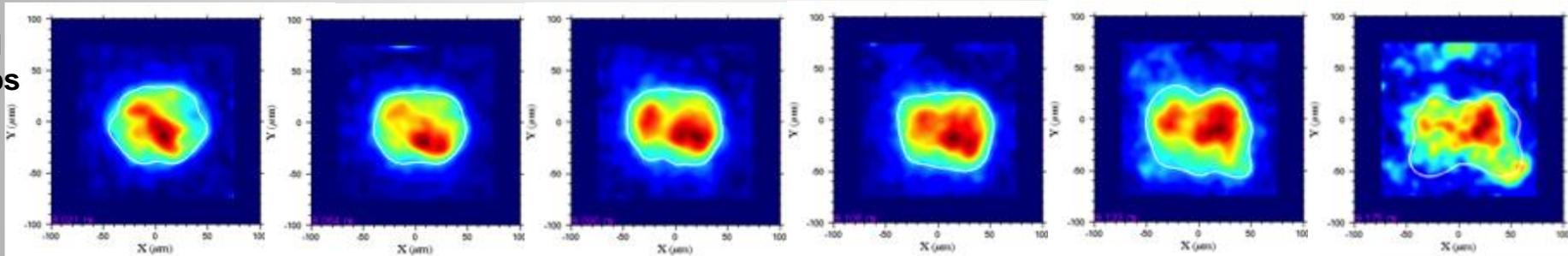
~20 ps

~40 ps

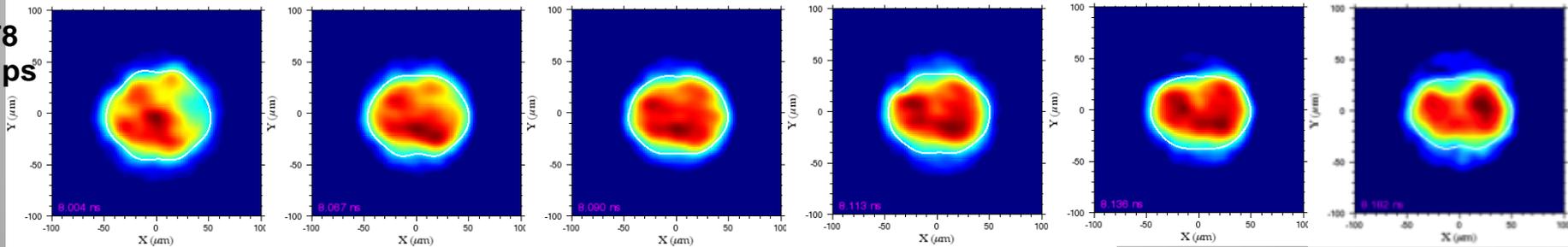
~60 ps

~100 ps

DIXI  
10 ps

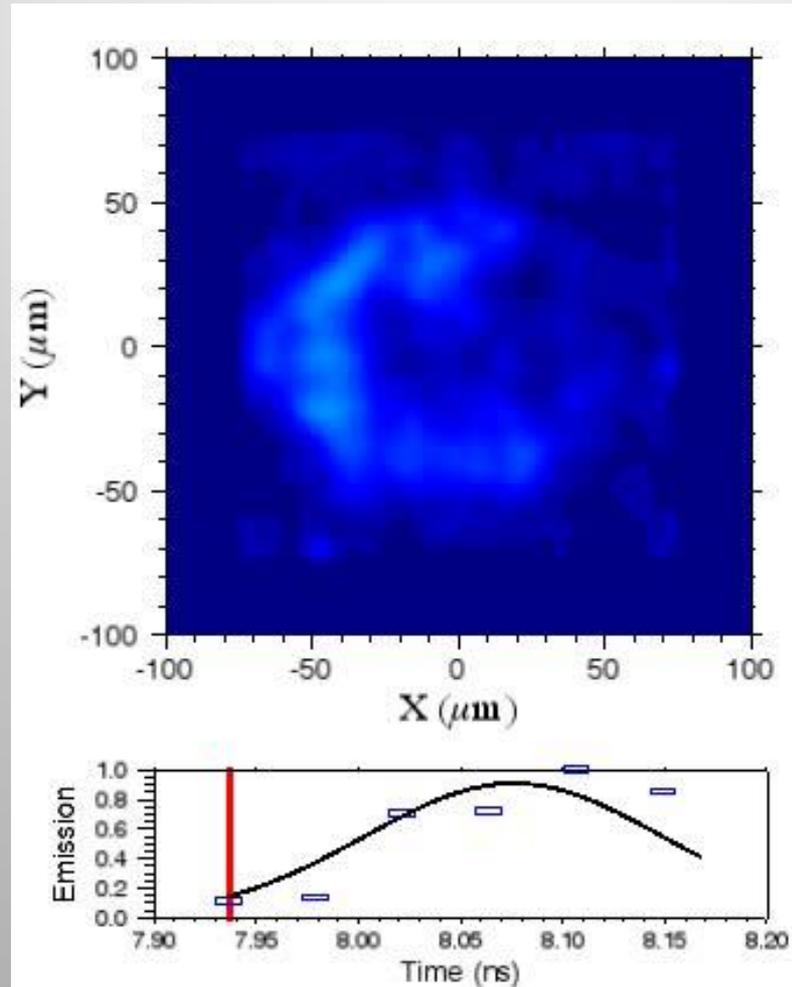


90/78  
100 ps



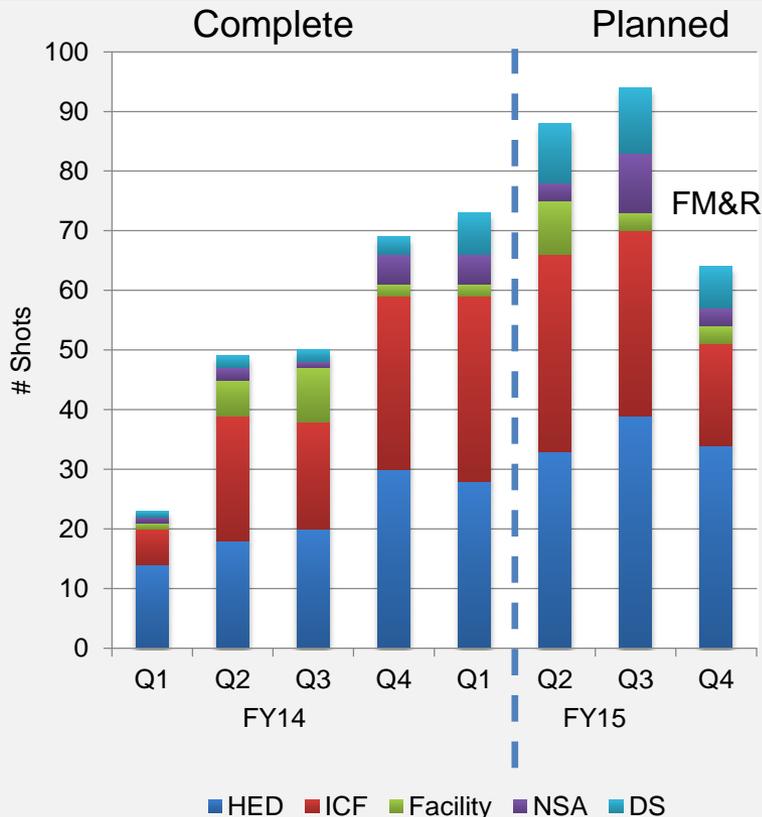
Preliminary analysis  
90/78 by Art Pak  
DIXI by S. Nagel and S. Khan

We successfully obtained x-ray images of a DT layered diamond capsule with  $\sim 10$ ps temporal resolution



# Shot-rate improvements are already benefitting NIF's users

## Shot rate increasing



## Recent shot-rate highlights

- We completed FY14 with 191 shots, significantly more than the 150 that were planned.
- We completed 100 target shots in the first 4 months of FY15!
- The enhanced shot rate has enabled significantly more experiments for Discovery Science and National Security Applications
- We continue to work to shorten the time between shots and make more efficient use of facility time

**Our stretch goal is 300 shots in FY15 and 400 shots in FY16 with fixed budgets**

# The Discovery Science Program(DS) on NIF is critical for the health of our work in high energy density (HED) science

- **We are committed to stewarding the field of HED Science. Doing so**
  - Enables a safe, secure, and effective stockpile without nuclear testing
  - Provides a visible manifestation of the credibility of our deterrent
  - Ensures we are aware of what is possible to avoid technological surprise
- **DS plays a key role in our strategy for stewarding HED Science. It enables**
  - Collaboration with leading scientists across the nation and the world to solve grand-challenge problems
  - Engagement of our scientific staff in publishable research with broad impact and importance for the general scientific community
  - Development of new innovative research methods and experimental platforms
  - Training of future generations of scientists knowledgeable about HED
  - Relationships for recruiting the very best to LLNL and/or other NNSA labs
  - A broader constituency of users for the NIF
  - A richer national scientific enterprise



# The high-pressure properties of carbon team from Princeton, UC Berkeley, and LLNL, has generated the 1<sup>st</sup> NIF DS paper



Ray Smith  
LLNL



Jon Eggert  
LLNL



Juergen Biener  
LLNL



Alex Hamza  
LLNL



Peter Celliers  
LLNL



Rob Rudd  
LLNL



Lorin Benedict  
LLNL



Tom Duffy  
Princeton Univ.



Jue Wang  
Princeton Univ.



Raymond Jeanloz  
UC Berkeley



Reed Patterson  
LLNL



Gilbert Collins  
LLNL



Dave Braun  
LLNL



Tom Braun  
LLNL

# nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

# INSIDE JUPITER

THE GIANT PLANET'S INTERIOR REPLICATED AT THE  
US NATIONAL IGNITION FACILITY

PAGES 294 & 330

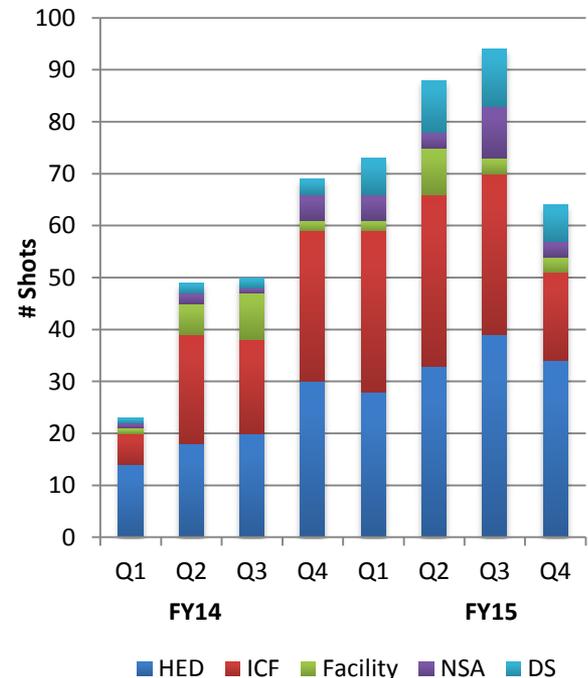
[R. F. Smith, J. H. Eggert, R. Jeanloz, T. S. Duffy, D. G. Braun, J. R. Patterson, R. E. Rudd, J. Biener, A. E. Lazicki, A. V. Hamza, J. Wang, T. Braun, L. X. Benedict, P. M. Celliers, and G. W. Collins, Nature 511, 330 (2014)]



# There are opportunities for increasing partnerships on our HED facilities

- In many ways, Z and NIF are like some Office of Science high-energy physics facilities:
  - Single end-station
  - Heroic efforts to execute experiments
  - Multimillion dollar diagnostics with ~100 contributors
- However, we have a unique challenge not constraining for most Office of Science facilities – *an applied mission!*
- We have a vibrant existing program in non-laboratory funded work in HED science
  - SSAA, SSGF, NLUF, various summer schools
- We are increasing partnerships with nuclear threat science communities and we are pursuing an agreement with OFES
- We are interested in supporting a partnership vice ownership model
  - Do our interests align?
- Deployment of "ownership" user-models are commensurate with our other priorities. We recognize a need to:
  - Develop target design-constrained catalog of arbitrary sources
  - Improve access to facilities (efficient operations)
  - Establish an NLUF-like program to fund non-laboratory PIs

- The “120-Day Study” forms the backbone of our shot-rate improvement effort
  - Includes ~ 80 specific actions
    - About half completed in FY14
    - Remainder planned for FY15 and FY16



**The key to enabling partnerships is increased operational efficiency at NIF and pursuit of dedicated materials science platforms**

# Based on the NIF User Group recommendation and the Discovery Science(DS) Technical Review Committee recommendation, we have significantly enhanced the time devoted to DS

- We have allocated 18 days of NIF time to Discovery Science in FY15. The goal is, to the extent possible, to close out the initial round of Discovery Science projects (from 2010!).
- So far in FY15, we have performed 11 DS shots more than all of FY14 (8 DS shots). Current plan is ~40 shots.
- Our intention is to go to annual solicitations and allocate ~ 18 days per year.
- We have performed the solicitation for FY16. The call resulted in 50 Letters of Intent and 42 proposals.
- A review of the 42 proposals (including 25 minute oral presentation by the team) took place on 11/11-11/12.
- We have awarded 3 days each to 9 proposals.
- We have named Bruce Remington the Program Leader for Discovery Science

# There are 8 active projects that comprise the existing program of dedicated Discovery Science shots on NIF

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## A. EOS/Materials Science

1. Carbon and Iron Equation of State (Tom Duffy, Princeton; Ray Smith, LLNL)
2. Novel Phases of Compressed Diamond (Justin Wark, Oxford; Amy Lazicki, Jon Eggert, LLNL)
3. Hydrogen at Ultra High Pressures (Raymond Jeanloz, UC Berkeley, Russ Hemley, Carnegie Institution of Washington; Marius Millot, Peter Celliers, LLNL)
4. **Gbar Equation of State** (Roger Falcone, UC Berkeley, Paul Neumayer, GSI Darmstadt; Tilo Doeppner, Damian Swift, Andrea Kritcher, LLNL)

## B. Hydrodynamics

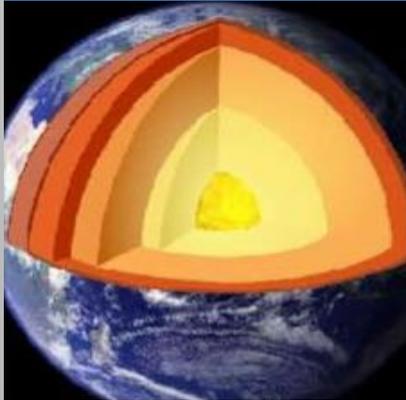
5. **Ablative Rayleigh-Taylor Instability** (Alexis Casner, CEA, France; David Martinez, LLNL)
6. Eagle Nebula Experiment (Jave Kane, David Martinez, LLNL)
7. **Supernova Hydrodynamics: The Effects of a Radiative Shock on Hydrodynamic Instabilities** (Carolyn Kuranz, Univ. of Michigan; Hye-Sook Park, LLNL)

## C. Plasma Physics

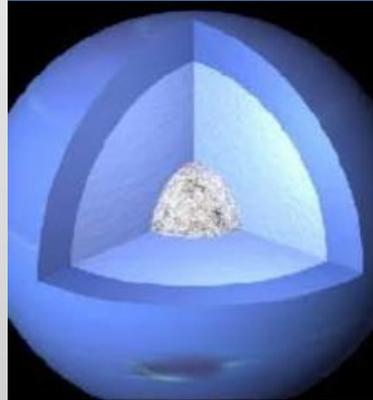
8. **Astrophysical collisionless shocks** (Youichi Sakawa, Osaka; Gianluca Gregori, Oxford; Steve Ross, Hye-Sook Park, LLNL)

# A wide variety of NIF-DS experiments are underway this year and each is aiming to reach a first science result by the end of FY15

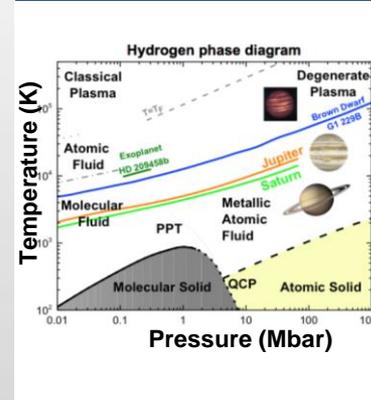
C, Fe EOS at planetary interior pressures



High pressure phases of carbon



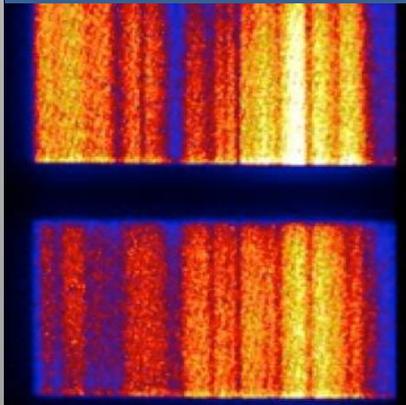
High pressure hydrogen properties



CH and carbon at near Gbar pressures



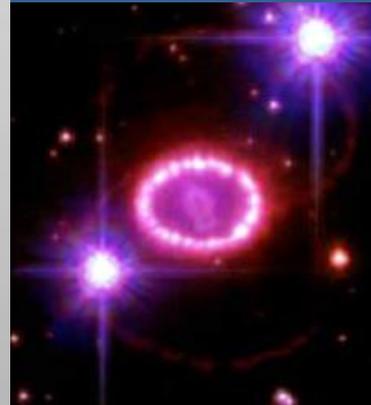
Planar ablation front Rayleigh-Taylor growth



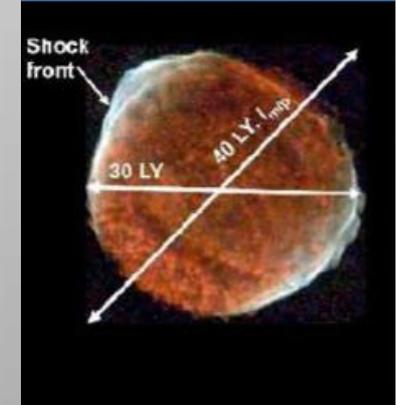
Molecular cloud radiative dynamics



Supernova explosion rad. hydrodynamics



Collisionless astrophysical shocks



## The DS Technical Review Committee met in November to rank proposals for time in FY16

Dr. Riccardo Betti	University of Rochester
Dr. Nathaniel Fisch	Princeton University
Dr. Richard Firestone	Lawrence Berkeley National Laboratory
Dr. Siegfried Glenzer	SLAC
Dr. Denise Hinkel	Lawrence Livermore National Laboratory
Dr. Ramon Leeper	Sandia National Laboratory
Dr. Christopher McKee (chair)	University of California, Berkeley
Dr. Mordecai Rosen	Lawrence Livermore National Laboratory
Dr. John Sarrao (co-chair)	Los Alamos National Laboratory
Dr. Choong-Shik Yoo	Washington State University



- **42 full proposals** were received in September 2014. All 42 proposals were reviewed in Nov. 2014 by the McKee DS-TRC committee
- **9 proposals were accepted with ~ 3 days of facility time per proposal** (since this is the first year we allocated time 1.5 years of time)
- **Scheduling of the FY16 DS experiments** will begin in the spring as part of the normal NIF scheduling process.
- **The NIF DS TRC will convene** for a status update in April 2015, after which another call for proposals will be issued.

# Proposals were submitted in five scientific areas for three different type of awards

## Proposal types

- Data Acquisition: Facility time provided with high confidence of obtaining data on existing platforms
- Platform Development: Facility time provided to develop new experimental capabilities of broad interest to the community
- New Proposal Development: Establish partnership with scientific and/or technical staff to refine scientific concepts
- **5 Data Acquisition and 4 Platform Development proposals were awarded time; 1 New proposal development was also accepted**

Award Type	Total
Data acquisition	19
New proposal development	3
Platform Development	20
Grand Total	42

Science Area	Total
Astro	9
Hydro	6
Materials	13
Nuclear	9
Plasma	5
Grand Total	42



# We have accepted 9 new NIF Discovery Science proposals for FY16

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## A. EOS/Materials Science

1. **Release and metastability of dynamically compressed carbon**(Justin Wark, Matt Suggit, Univ. Oxford; Andrew Higginbotham, Univ. York; Amy Jenei, Jon Eggert, LLNL)
2. **The iron melting curve and magnetospheres of habitable super Earths** (Russ Hemley, Carnegie Institution of Washington (CIW); Lars Stixrude, Univ. College London (UCL), Ron Cohen, (CIW, UCL); Sarah Stewart, UC Davis; Dayne Fratanduno, Jon Eggert, LLNL)
3. Pressure ionization at extreme densities (Paul Neumayer, GSI Darmstadt; Roger Falcone, Dominik Kraus, UCB; R. Redmer, U. Rostock, Germany; D. Gericke, U. Warwick, UK; D. Champman, AWE, UK; Tilo Doepfner, Benjamin Bachmann, LLNL)

## B. Hydrodynamics

4. **Asymptotic self-similar evolution of RT and RM instabilities** (Dov Shvarts, Yoni Elbaz, NRCN, Israel; M. Fraenkel, A. Zigler, SNRC, Israel; C. Kuranz, R.P. Drake, U. Mich.; Alex Casner, CEA, France; Channing Huntington, Tammy Ma, Steve MacLaren, Kumar Raman, LLNL )
5. Long duration, planar, direct-drive platform development (Alex Casner, CEA, France; Igor Igumenshchev, LLE; R.P. Drake, U. Mich.; T. Plewa, FSU; L. Gao, PPPL; X. Ribeyre, Univ. Bordeaux, France; D. Shvarts, G. Malamud, NRCN and Ben-Gurion Univ., Israel; Vladimir Smalyuk and David Martinez, LLNL)

# We have accepted 9 new NIF Discovery Science proposals for FY16

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## C. Plasma Astrophysics Physics

6. Generation of collisionless shocks and magnetic fields (Youichi Sakawa, H. Takabe, Osaka U., Japan; T. Morita, Kyushu U., Japan; Gianluca Gregori, Oxford; G. Gregori, U. Oxford, UK; D. Froula, LLE; R. Petrasso, MIT; A. Spitkovsky, Princeton U.; M. Koenig, Ecole Polytechnique, France; D. Lamb, U. Chicago; Frederico Fiuza, Kavli Institute, Stanford; Hye-Sook Park, Steve Ross, Dmitri Ryutov, LLNL)
7. **Primordial magnetogenesis and turbulent amplification** (Gianluca Gregori, U. Oxford, UK; D. Lamb, U. Chicago; Y. Sakawa, Osaka Univ., Japan; D. Froula, LLE; M. Koenig, Ecole Polytechnique, France; A. Casner, CEA, France; R. Petrasso, MIT; F. Miniati, ETH, Switzerland; B. Reville, Queen's Univ., UK; D. Ryu, UNIST, Korea, A. Spitkovsky, Princeton Univ.; Hye-Sook Park, Steve Ross, LLNL)

## D. Nuclear Physics

8. **Stellar and Big Bang nucleosynthesis** (Maria Gatu-Johnson, MIT; Carl Brune, Ohio Univ.; Hans Herrmann, LANL; Andrew Bacher, Indiana Univ.; Dan Casey, Dan Sayre, LLNL)
9. **Charged particle stopping powers in dense degenerate plasmas** (Alex Zylstra, Chikang Li, Johan Frenje, MIT; Paul Grabowski, UC Irvine; Ryan Rygg, Jesse Pino, Frank Graziani, LLNL)

# A National Diagnostic Plan is being developed to accelerate the development of transformational diagnostics for all 3 HED Facilities

- Better measurements are needed to make more rapid progress in both ICF and HED research
- Transformational diagnostics will have applicability across all three HED facilities and will require large investments, making national coordination advantageous and essential
- Investments in diagnostics should be front loaded to obtain maximum return
- Yearly workshops and national coordination committee have been very effective in moving this effort forward



## Developing a National Diagnostic Plan

Joe Kilkenny, Greg Rochau, Craig Sangster, Steve Batha, Ray Leeper, Perry Bell, Mike Campbell, Johann Frenje, Warren Hsing, Bob Kauffman, Jim Knauer, Jeff Koch, Doug Larson, John Moody, Rich Petrasso

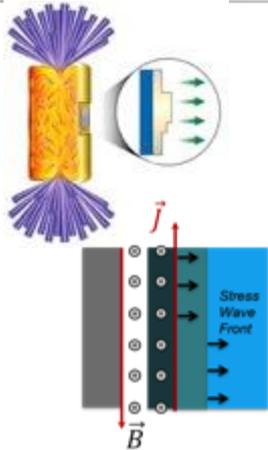
U.S. DEPARTMENT OF ENERGY NNSA

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# 'Transformational' diagnostics are at the resonance between the most compelling needs and the most promising technologies

## High Pressure Materials



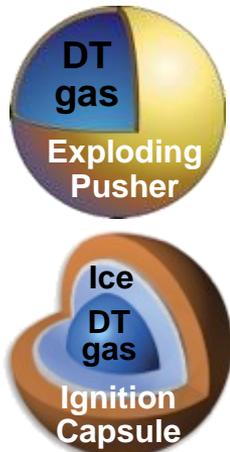
Phase and structure  
**Time-dependent X-ray diffraction**  
Strength  
**Multi-layer Wolter**

## Complex Hydrodynamics



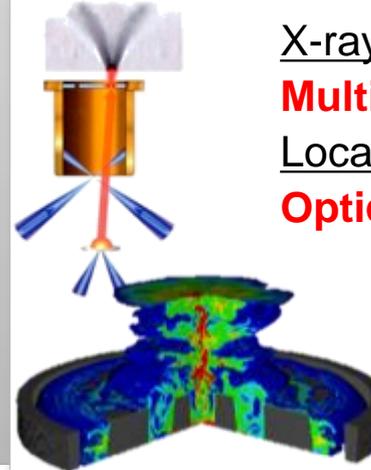
Meso-scale Hydro Instabilities  
**Multi-layer Wolter**  
Mix Fraction  
**Time-Resolved  $\gamma$  Spect**

## Ignition Applications and Burn



Time-resolved Burn  
-vs. Energy  
**Time-Resolved  $n/\gamma$  Spect.**  
-vs. Space  
**3-D  $n/\gamma$  Imaging**  
-Equilibration  
**High-Res X-ray Spect.**

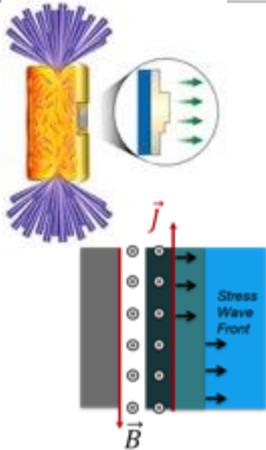
## Radiation Transport, Opacity, & Effects



X-ray Source Formation  
**Multi-layer Wolter**  
Localized Te/ne  
**Optical TS**

# 'Transformational' diagnostics are at the resonance between the most compelling needs and the most promising technologies

## High Pressure Materials



Phase and structure  
**Time-dependent X-ray diffraction**  
 Strength  
**Multi-layer Wolter**

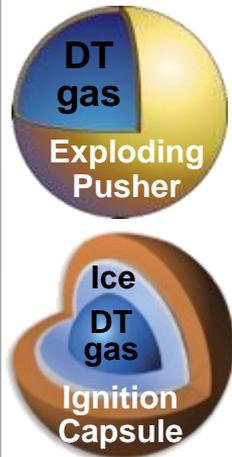
## Complex Hydrodynamics



Meso-scale Hydro Instabilities  
**Multi-layer Wolter**  
Mix Fraction  
**Time-Resolved  $\gamma$  Spect**

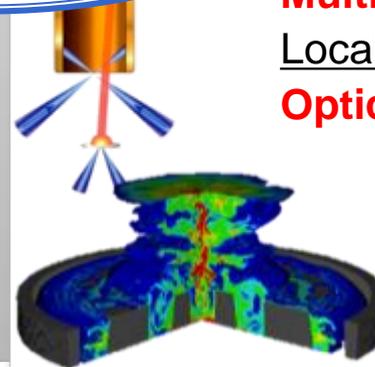
**High Res, Many-Frame SLOS Gating**  
Hohlraum Character.  
**Optical TS**

## Ignition Application



Time-resolved  
 -vs. Energy  
**Time-Resolved  $n/\gamma$  Spect.**  
 -vs. Space  
**3-D  $n/\gamma$  Imaging**  
 -Equilibration  
**High-Res X-ray Spect.**

## Support, Opacity, & Effects



X-ray Source Formation  
**Multi-layer Wolter**  
Localized Te/ne  
**Optical TS**

# We are requesting input on new capabilities for the facility

- **NIF's funding includes a dedicated funding line for Diagnostics, Cryogenics, and Experimental Support for developing new capabilities needed to support both current and future users**
- **We apply this funding to four areas to make NIF more capable for ICF and HED research**
  - Diagnostics (further broken down into the categories below)
    - Transformative capability
    - Broad or significant new capability
    - Minor, but important new diagnostic capability
  - Facility Infrastructure
  - New Laser Capabilities
  - Cryogenic Target Capabilities
- **To enhance the transparency of how these funds are allocated we will**
  - Issue call for new capabilities
  - Estimate costs and based on feedback from community develop a prioritized list
  - NIF Director will solicit input from HED and ICF Councils
  - Special attention paid to multi-year and large efforts

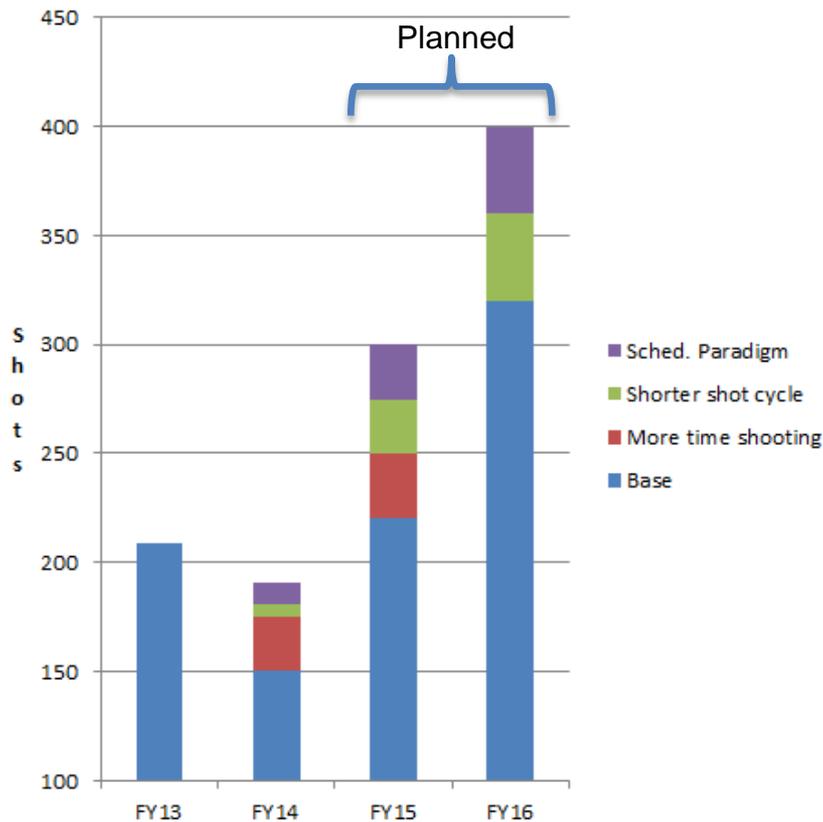
# We have a challenging goal of 400 shots in FY16

- NIF is significantly oversubscribed for all its programs
- More shots enable:
  - Shorter iteration time between experiments
  - Broader survey of a very large parameter space
  - Exploration of new ideas and new concepts
  - More stockpile stewards on the facility
- Supporting a higher shot rate, with fixed resources, is a challenge for
  - Facility operations
  - Target Fabrications
  - Optics usage (depending on the laser energy mix of the shots)
  - Programs
  - Budget
- We are working hard to meet this challenge

An important strategic question for NIF is the shot rate goal for FY17 and beyond

# Shot-rate improvements are primarily in three categories

## Elements of Shot-Rate Improvement

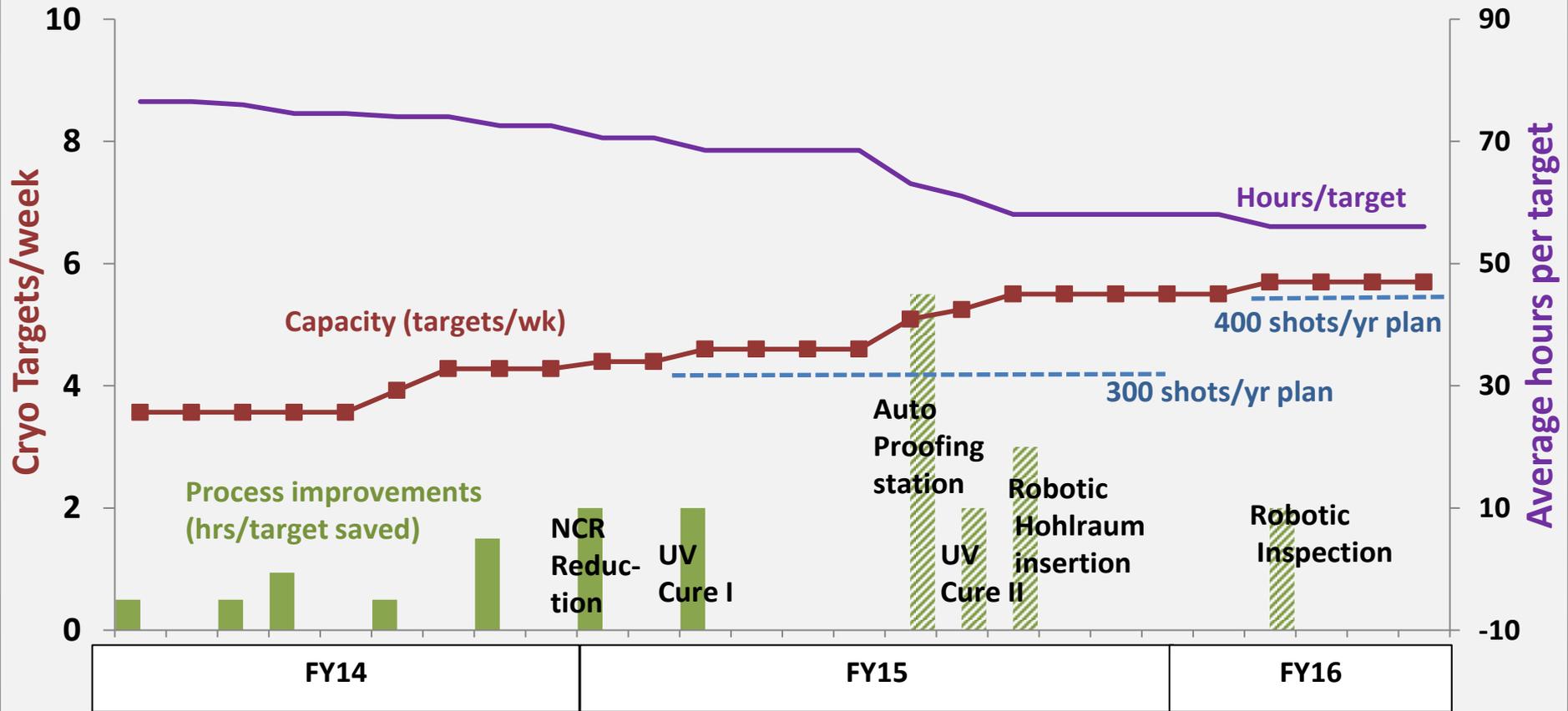


- **Spend more time shooting**
  - 24/5 operation each week
  - Shorter, more focused maintenance periods
- **Reduce the average duration of the shot cycle**
  - Process improvements
  - Engineered (equipment) improvements
- **Schedule experiments more efficiently in the facility**
  - “Train schedule” groups shots with common configuration
  - Limit flexibility in special configs
  - Scripted shot series (mini-campaigns)
  - Sub-scale and reduced optics usage

We're building the shot plan to generate margin against these goals

# We are making process improvements to meet the shot demand for targets

## Cryo Target Production Plan



# Challenges remain going forward

- **There is a fierce competition for resources within NNSA as there is far more work to be done than money available and many stakeholders (NNSA, DOE, DOD, Congress)**
- **At least some in Congress/Administration are still advocating for full cost recovery for academic experiments on NIF**
- **Funding opportunities for successful PI's are very limited, this is a long term concern for growing a vibrant user base.**
- **Our funding model constrains our Discovery Science Program**
  - **NNSA does not allocate any additional money or set aside money for our DS Program**
  - **We can support DS activities that meet NNSA's partnership model: Shot time, targets, limited new/modified diagnostics, liason scientist time**
  - **Proposals that require major investment or significant development are severely constrained by the current funding model**
- **Out year budgets (FY16-) are very uncertain due to the national political climate**

**We can partially address these challenges by performing stunning science and broadly communicating the work**

## We are very interested in your feedback!

- Are we doing the best science we can, within current constraints?
- What are the most promising directions for NIF to move in scientifically?
- What science aren't we doing that we should be trying to encourage?
- If funding was available, what investments would have the biggest impact on the Discovery Science we can do?
- How do we enhance our communication about the quality of science being performed on the NIF?
- What can we do better?

Please email me at [herrmann9@llnl.gov](mailto:herrmann9@llnl.gov) or the NIF user office at [nifuseroffice@llnl.gov](mailto:nifuseroffice@llnl.gov) with any questions, concerns, or suggestions

# **It is an exciting time at the National Ignition Facility; We are building a strong foundation for NIF's long future supporting the field of High Energy Density Science**

- **Exciting scientific results are being obtained on the facility nearly every day**
- **We have significantly increased the shot rate, enabling**
  - **A faster rate of learning by users**
  - **Stronger support for both the Discovery Science and National Security Applications**
  - **We are on track for the challenging goal of 300 shots in FY15**
- **We have completed our first new call for Discovery Science experiments in more than 4 years**
- **A National Diagnostic Plan is being developed that is focused on transformative diagnostics for HED facilities**
- **We have an ambitious goal of 400 shots in FY16. This goal will challenge the facility, target fabrication, optics, and the users.**
- **We want your feedback to make NIF better for our users!**



# Key April 2014 Recommendations-I

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The Committee's principal recommendation is that the first round of NIF fundamental-science shots from the 2010 call should be completed by the end of FY2015 and that a new call for proposals for projects starting in FY2016 should be issued as soon as possible.

The Committee recognizes that this strategy might negatively impact the research plans of some of the existing groups, but it believes that the benefits of the resulting opportunities for new projects far exceeds this impact.

# Key April 2014 Recommendations-II

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It is essential to the development of a vigorous user community that subsequent calls for proposals be issued annually.

The Committee endorses the NIF Users' Group recommendation that a minimum of 35 shots per year be devoted to fundamental science.

A minimum of 16.5 shot-days should be devoted to fundamental science in both FY16 and FY17; thereafter, the minimum should increase to 18 shot-days per year. For a typical program of three shot-days spread over two years, this would enable six new programs to be selected annually beginning in FY17.