Opportunities on NIF as a User Facility

Fusion Power Associates Meeting

Mark Herrmann
NIF Director
Thanks to the NIF team

December 16, 2015

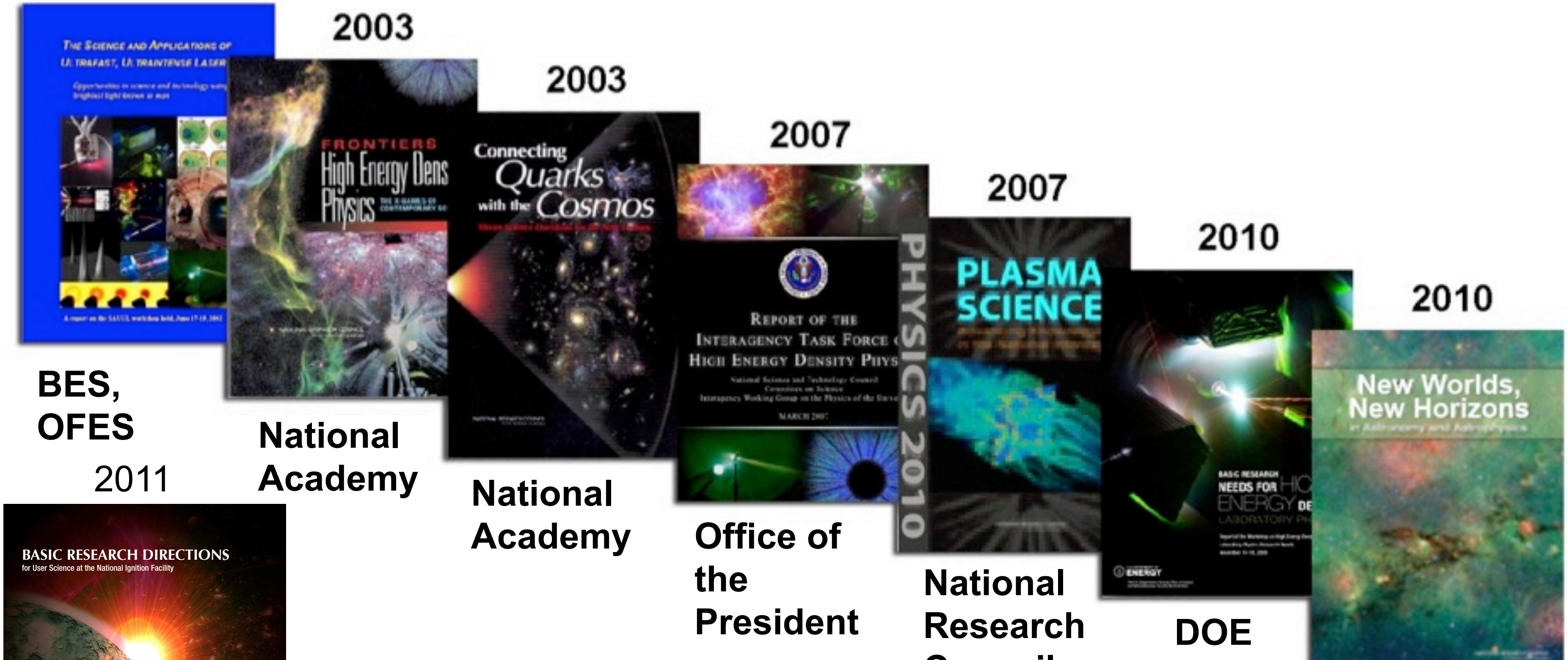
LLNL-PRES-XXXXXX
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Lawrence Livermore National Laboratory

It’s an exciting time in the field of High Energy Density Science and on the National Ignition Facility

- Amazing capabilities have been developed over the past decade to perform fascinating science on the boundary of what is possible.
- HED Scientists are exploiting these capabilities and delivering fabulous science. The work is being well received by the broader scientific community.
- “Discovery Science” time on NIF is allocated via a competitive process and plays an important role in enabling innovation and addressing the most fundamental questions facing the field of high energy density science
- Diagnostics also provide an important avenue for users to collaborate on NIF. The Advanced Radiographic Capability is now operational on NIF and opens up multiple opportunities to study high energy density science.

A number of studies of high energy density science were performed in the "2000's"



2002 — BES, OFES

2003 — National Academy

2003 — National Academy

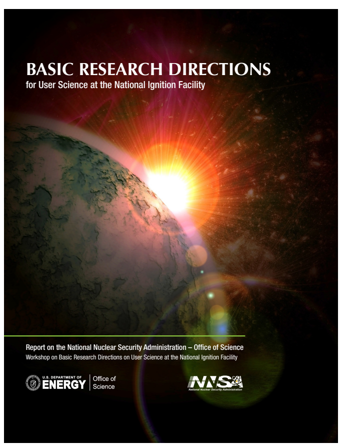
2007 — Office of the President

2007 — National Research Council

2010 — DOE

2010 — Decadal survey in Astronomy & Astrophysics

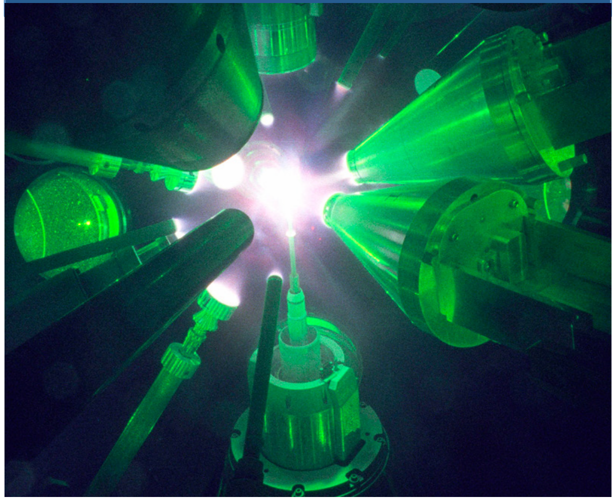
2011



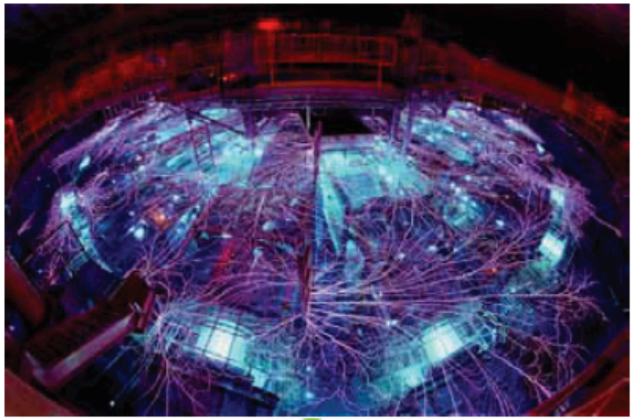
DOE & NNSA

At the same time, significant construction and upgrades were being performed on world class capabilities for creating and studying high energy density science

Omega and Omega EP Laser Facilities



Z Pulsed Power Facility



National Ignition Facility

LCLS

HED scientists are exploiting these capabilities to push the scientific boundaries

LETTER

doi:10.1038/nature14048

A higher-than-predicted measurement of iron opacity at solar interior temperatures

J. E. Bailey[1], T. Nagayama[1], G. P. Loisel[1], G. A. Rochau[1], C. Blancard[2], J. Colgan[3], Ph. Cosse[2], G. Faussurier[2], C. J. Fontes[3], F. Gilleron[2], I. Golovkin[4], S. B. Hansen[1], C. A. Iglesias[5], D. P. Kilcrease[3], J. J. MacFarlane[4], R. C. Mancini[6], S. N. Nahar[7], C. Orban[7], J.-C. Pain[2], A. K. Pradhan[7], M. Sherrill[3] & B. G. Wilson[5]

nature physics LETTERS
PUBLISHED ONLINE: 19 JANUARY 2015 | DOI: 10.1038/NPHYS3178

Observation of magnetic field generation via the Weibel instability in interpenetrating plasma flows

C. M. Huntington[1*], F. Fiuza[1], J. S. Ross[1], A. B. Zylstra[2], R. P. Drake[3], D. H. Froula[4], G. Gregori[5], N. L. Kugland[6], C. C. Kuranz[3], M. C. Levy[1], C. K. Li[2], J. Meinecke[5], T. Morita[7], R. Petrasso[2], C. Plechaty[1], B. A. Remington[1], D. D. Ryutov[1], Y. Sakawa[7], A. Spitkovsky[8], H. Takabe[7] and H.-S. Park[1]

nature geoscience LETTERS
PUBLISHED ONLINE: 2 MARCH 2015 | DOI: 10.1038/NGEO2369

Impact vaporization of planetesimal cores in the late stages of planet formation

Richard G. Kraus[1,2*], Seth Root[3], Raymond W. Lemke[4], Sarah T. Stewart[1,5], Stein B. Jacobsen[1] and Thomas R. Mattsson[4]

nature COMMUNICATIONS

ARTICLE

Received 6 May 2014 | Accepted 2 Jan 2015 | Published 4 Feb 2015 DOI: 10.1038/ncomms7190

A laboratory study of asymmetric magnetic reconnection in strongly driven plasmas

M.J. Rosenberg[1], C.K. Li[1], W. Fox[2], I. Igumenshchev[3], F.H. Séguin[1], R.P.J. Town[4], J.A. Frenje[1], C. Stoeckl[3], V. Glebov[3] & R.D. Petrasso[1]

Science AAAS

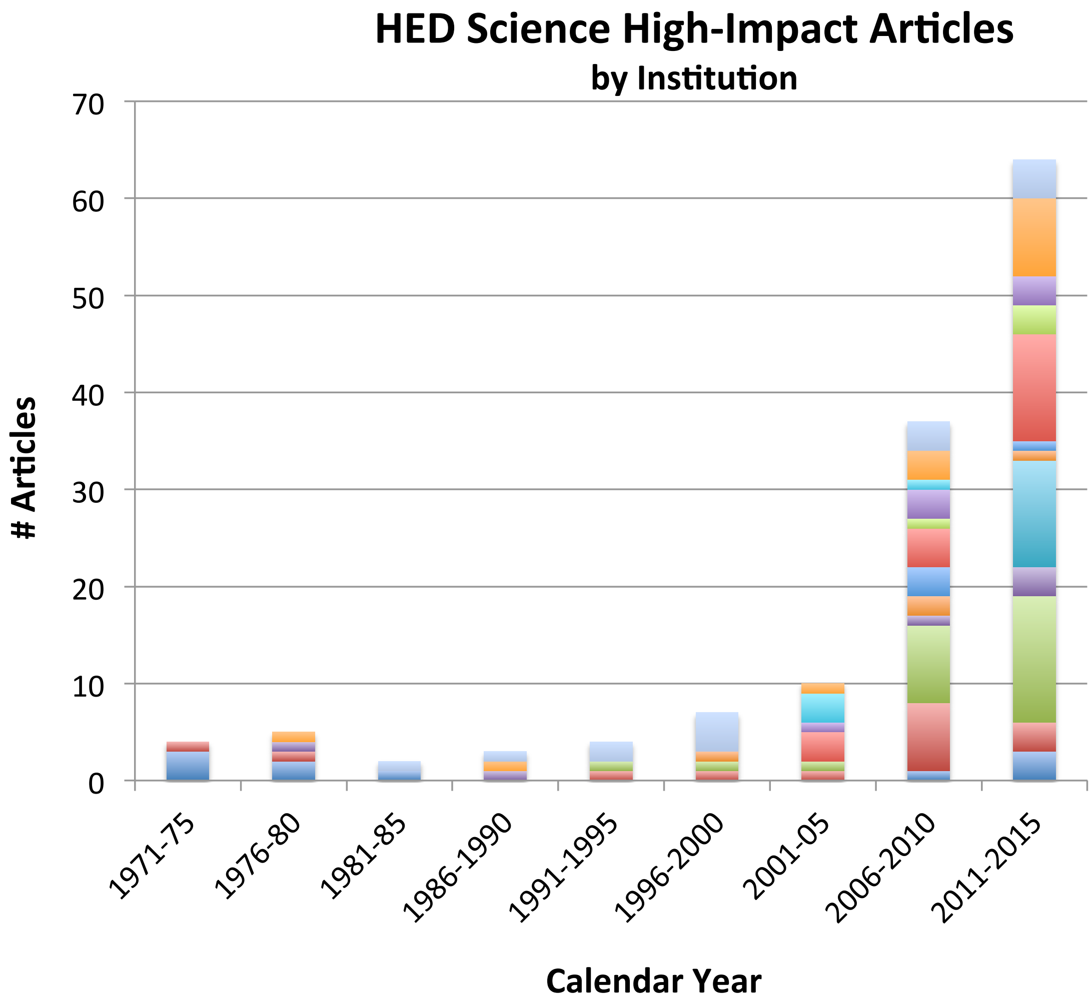
Direct observation of an abrupt insulator-to-metal transition in dense liquid deuterium
M. D. Knudson *et al.*
Science **348**, 1455 (2015);
DOI: 10.1126/science.aaa7471

ARTICLES
PUBLISHED ONLINE: 23 MARCH 2015 | DOI: 10.1038/NPHOTON.2015.41
nature photonics

Ultrabright X-ray laser scattering for dynamic warm dense matter physics

L. B. Fletcher[1,2*], H. J. Lee[1], T. Döppner[3], E. Galtier[1], B. Nagler[1], P. Heimann[1], C. Fortmann[4], S. LePape[3], T. Ma[3], M. Millot[2,3], A. Pak[3], D. Turnbull[3], D. A. Chapman[5,6], D. O. Gericke[6], J. Vorberger[7], T. White[8], G. Gregori[8], M. Wei[9], B. Barbrel[2], R. W. Falcone[2], C.-C. Kao[1], H. Nuhn[1], J. Welch[1], U. Zastrau[1,10], P. Neumayer[11], J. B. Hastings[1] and S. H. Glenzer[1*]

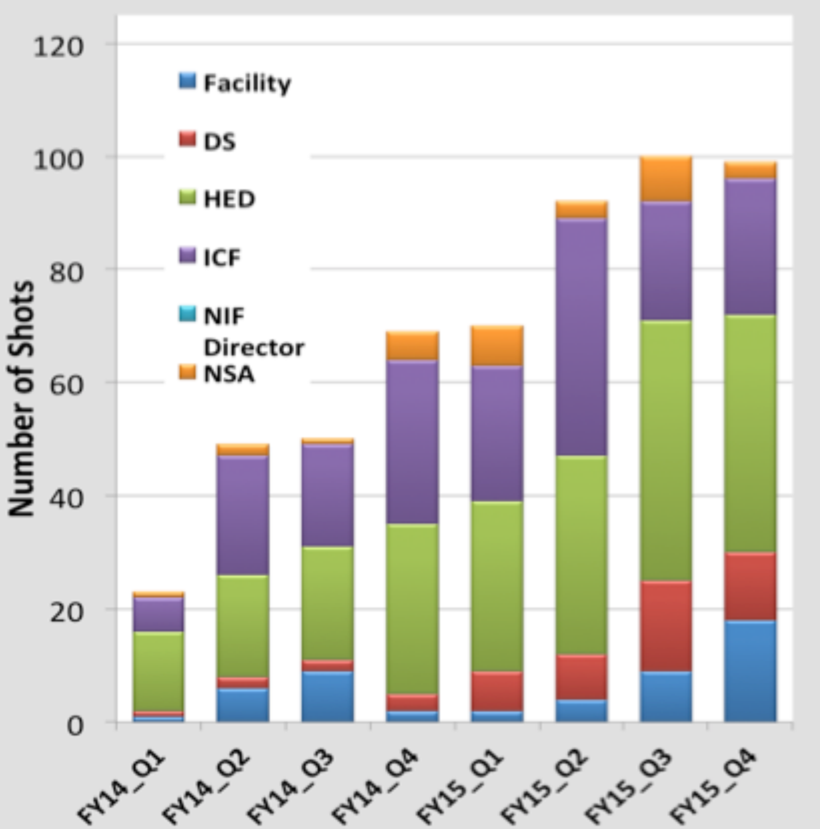
The HED Science community is delivering on the promise that was identified in the 2000's



Impact factor > 10, e.g. Nature, Science, etc., does not include PRL's
Courtesy of Rulon Lindford)

We are significantly increasing the scientific productivity of the NIF

Target shots by quarter and shot rate

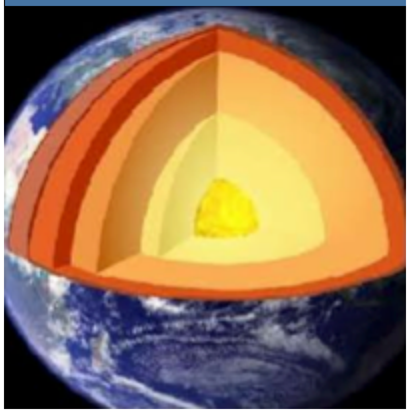


- We increased the number of experiments from 191 in FY14 to 356 in FY15 with fixed funding
- More experiments enable a faster rate of learning, more exploration, and more users on the facility
- User satisfaction has remained high (>90%) as the number of shots has increased
- We have brought several new diagnostics on line and deployed new experimental capabilities enabling new measurements
- Number of publications per year with NIF data is rapidly increasing

Lawrence Livermore National Laboratory
Sandia National Laboratories
UR LLE
Los Alamos NATIONAL LABORATORY EST.1943
GENERAL ATOMICS

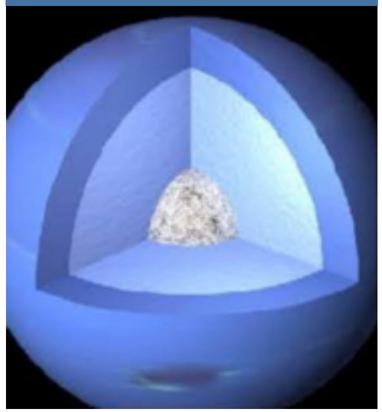
NIF allocates a small fraction (~8%) of the facility's time to "Discovery Science"

C, Fe EOS at planetary interior pressures



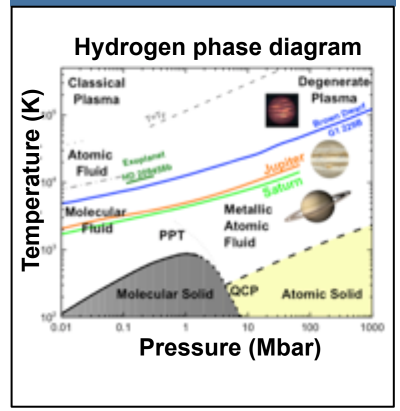
Duffy (Princeton), Jeanloz (UCB)

High pressure phases of carbon



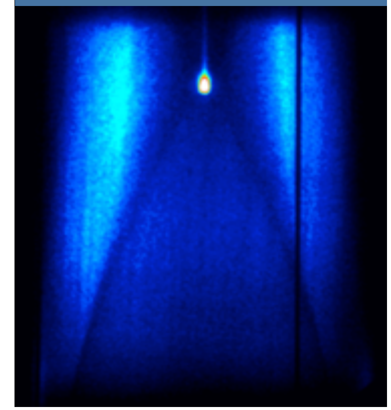
Wark (Oxford)

High pressure hydrogen properties



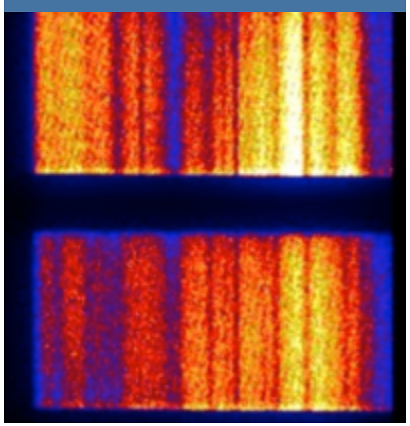
Jeanloz (UCB), Hemley (CIW)

CH and carbon at near Gbar pressures



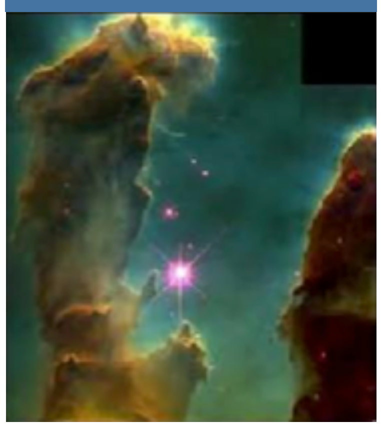
Falcone (UCB), Neumayer (GSI)

Planar ablation front Rayleigh-Taylor growth



Casner (CEA)

Molecular cloud radiative dynamics

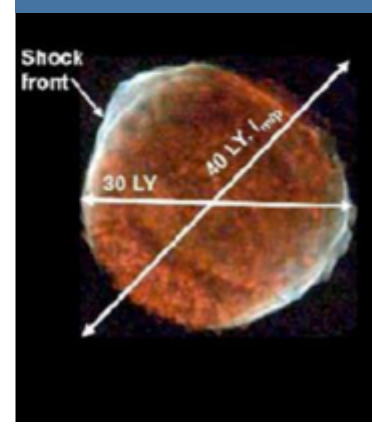


Kane (LLNL), Pound (Maryland)

Supernova explosion rad. hydrodynamics

Kuranz, Drake (Mich)

Collisionless astrophysical shocks

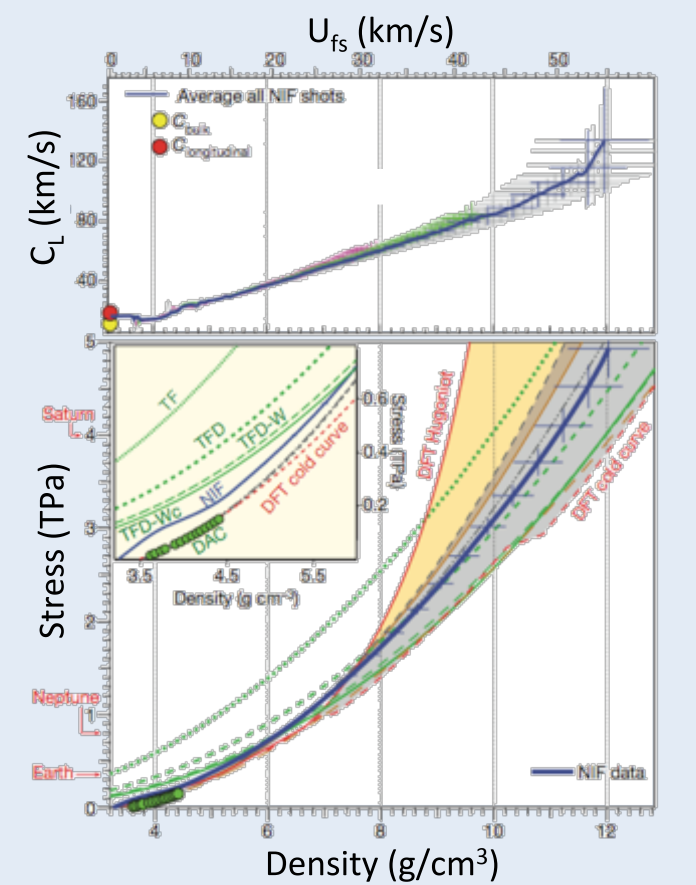


Sakawa (Osaka), Takabe (HZDR)

Discovery Science had 44 target shots in FY15 versus 26 DS shots total in FY10-FY14

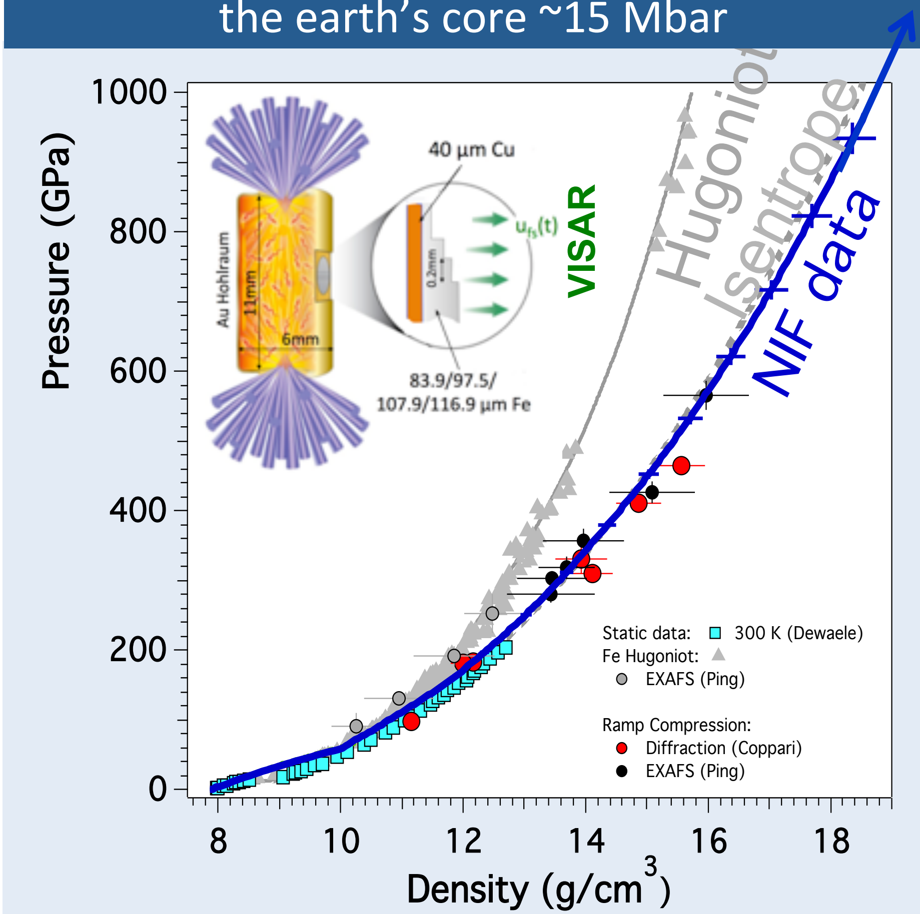
The EOS of carbon and iron were studied under ramp compression

Diamond ramp-compressed to 50 Mbar



"Ramp compression of diamond to five terapascals",
R. F. Smith, R. Jeanloz, T.S. Duffy et al., Nature 511, 330 (2014)

Iron ramp-compressed to 4X the pressure of the earth's core ~15 Mbar

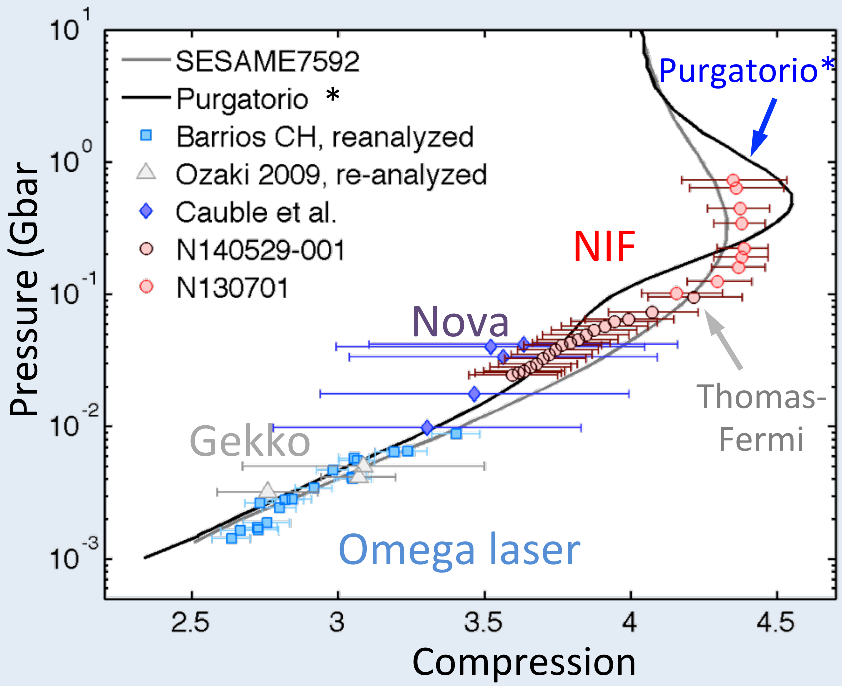


Preliminary analysis

Berkeley UNIVERSITY OF CALIFORNIA · PRINCETON UNIVERSITY

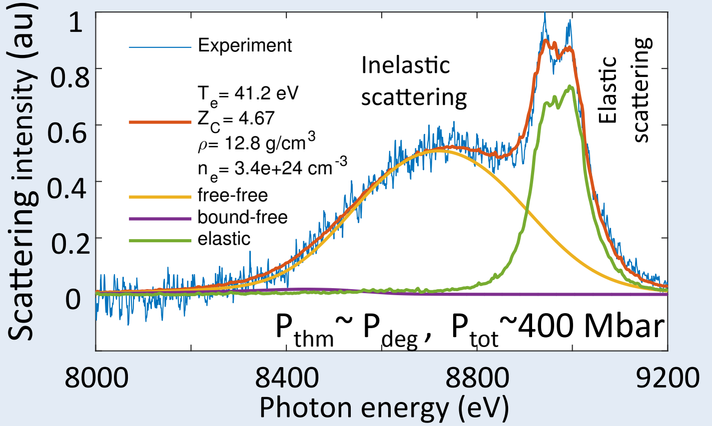
The EOS of CH at near-Gbar pressures is measured using a spherically converging shock

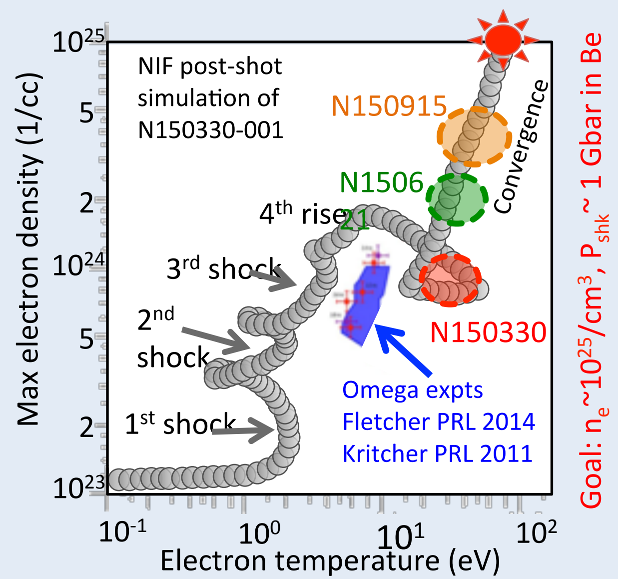
Absolute shock Hugoniot measurements of plastic equation of state



NIF data suggests that carbon K-shell ionization starts at ~60 Mbar (T_e ~ 35 eV)

[Courtesy of Tilo Doeppner, Roger Falcone, Paul Neumayer]

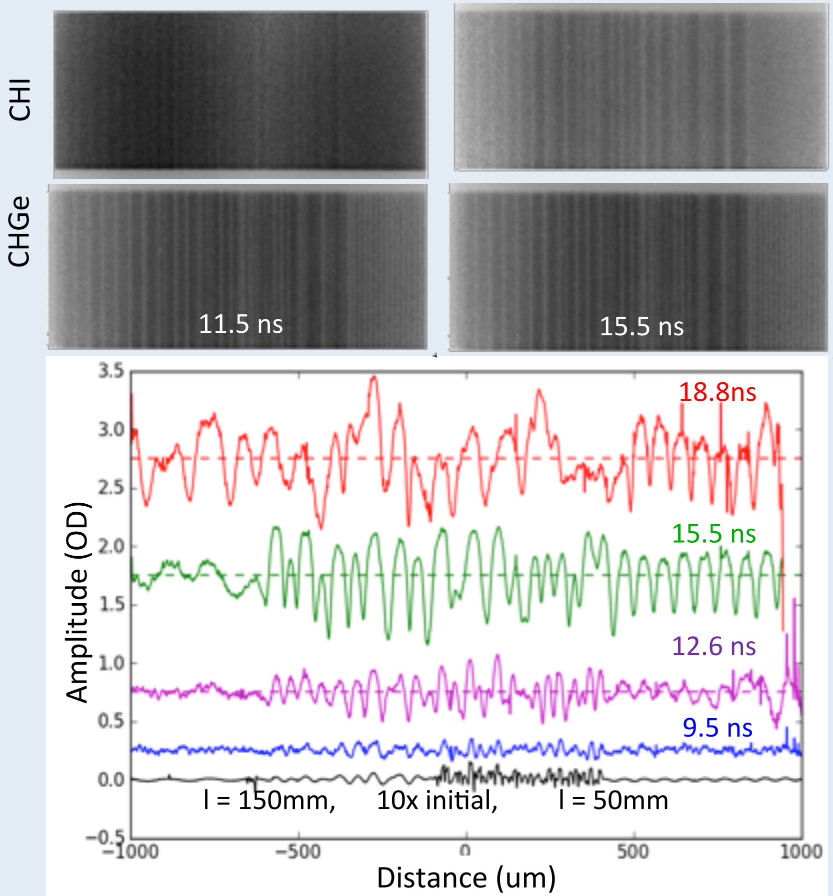




Berkeley UNIVERSITY OF CALIFORNIA

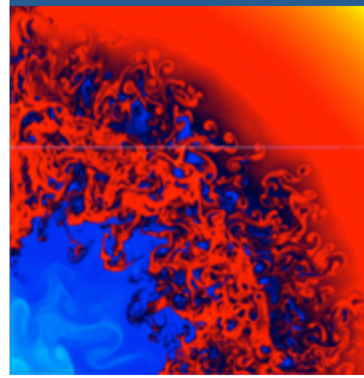
Non-linear radiative hydrodynamics for ablation front RT, scaled supernova RT, and molecular cloud dynamics are being measured on NIF

Ablation front RT

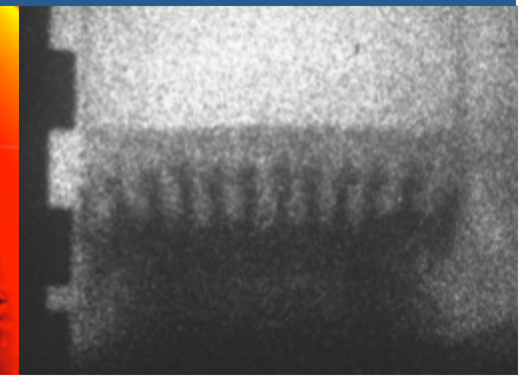


[D.A. Martinez et al (2015)]

Supernova RT (self-generated radiation)

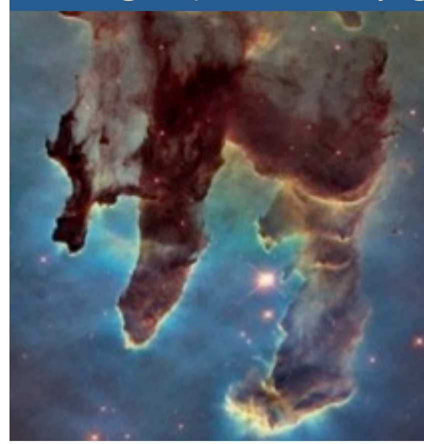


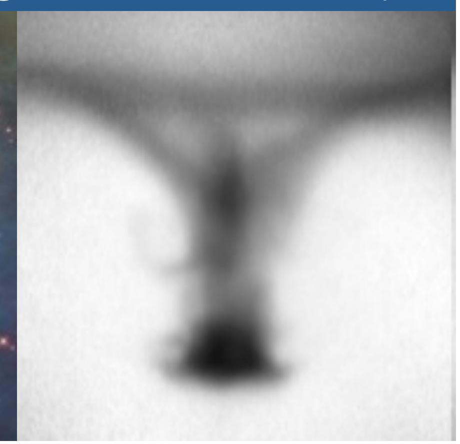
[C. Kuranz]



[A. Miles, Ap.J. 696, 498 (2009)]

Eagle (externally-generated radiation)

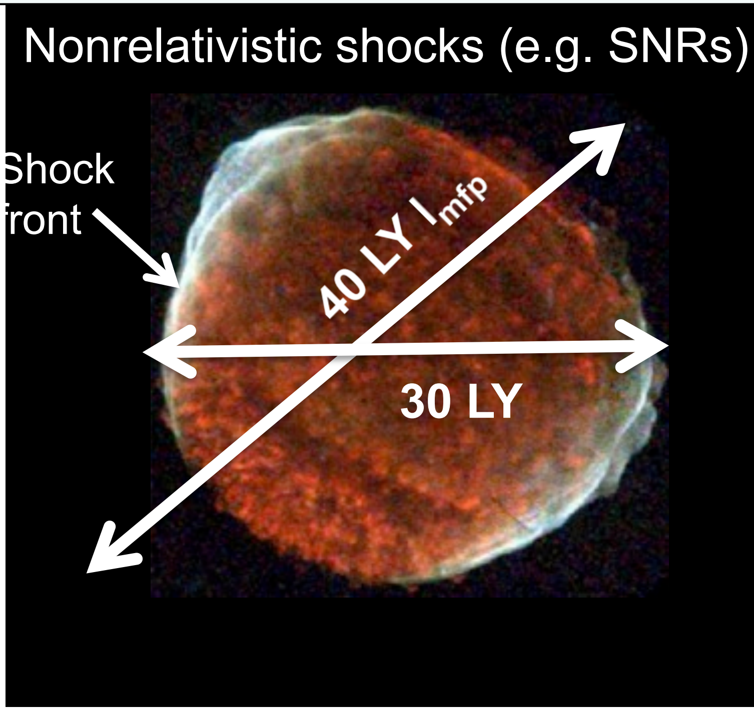




[J.O. Kane, D.A. Martinez]

The collisionless shock collaboration on NIF shows how large, diverse collaborations can arise to work on these fascinating problems

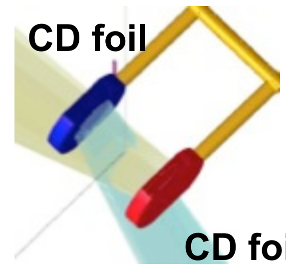
Collisionless shocks are ubiquitous in universe; Weibel instabilities can generate magnetic fields to form these shocks

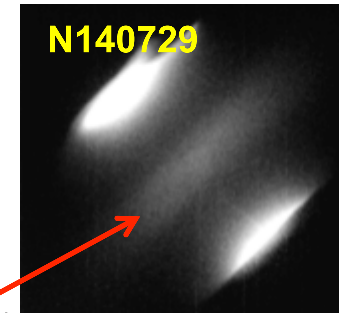


[J.S. Ross, invited talk, Mon. pm, CM9.002]

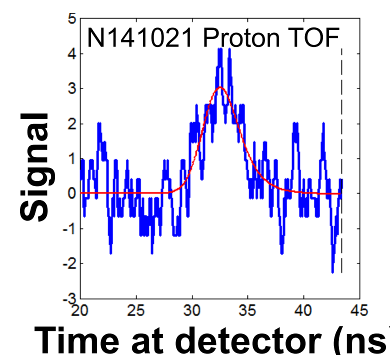
[Courtesy of Hye-Sook Park (2015);
C.M. Huntington, Nat. Phys. (2015)]

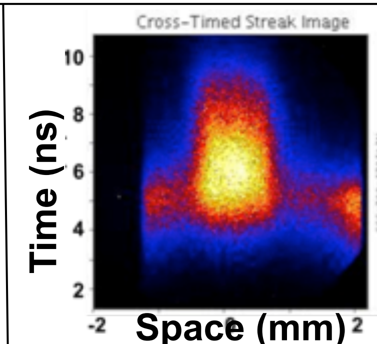
Experiments with CD-CD targets observed x-rays, neutrons and protons from the central shock-forming region





X-ray brightening from self-emission of hot plasmas

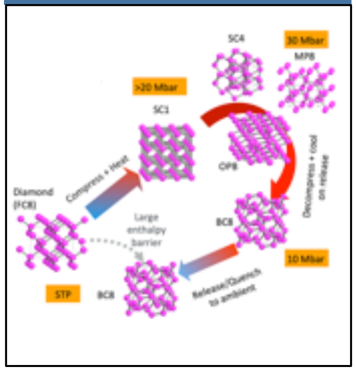




OSAKA UNIVERSITY · UNIVERSITY OF OXFORD · Lawrence Livermore National Laboratory · PRINCETON UNIVERSITY · MIT PSFC · UR LLE · UNIVERSITY OF MICHIGAN · THE UNIVERSITY OF CHICAGO · THE UNIVERSITY of York · RICE

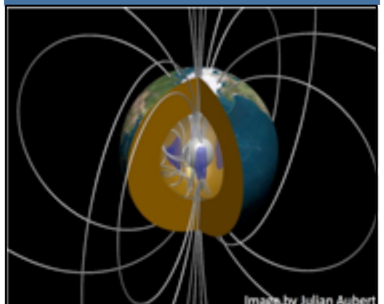
We are starting nine new NIF-DS experiments in FY16; first shots in Q_1 (Dec.)

Metastability of dynamically compressed C



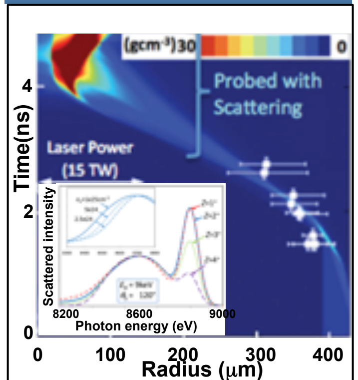
Wark (Oxford)

Iron melt curve, magnetospheres, and habitable Super Earths



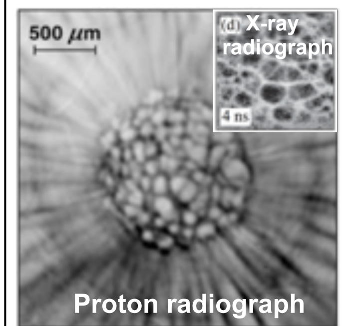
Hemley (CIW), Stewart (UCD)

Pressure ionization at extreme densities



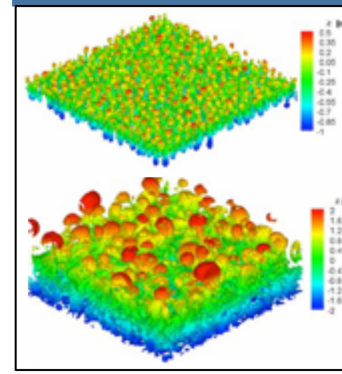
Neumayer(GSI), Falcone(UCB)

Direct-drive hydrodynamics



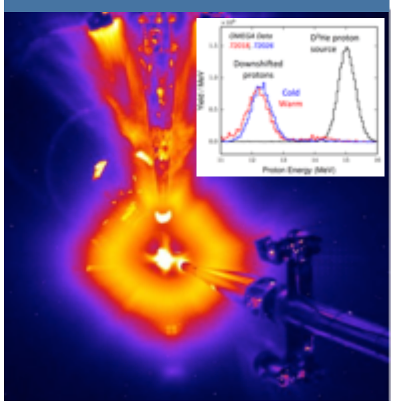
Casner(CEA),

Asymptotic self-similar instabilities



Shvarts(Israel), Drake(Mich)

Charged particle stopping powers

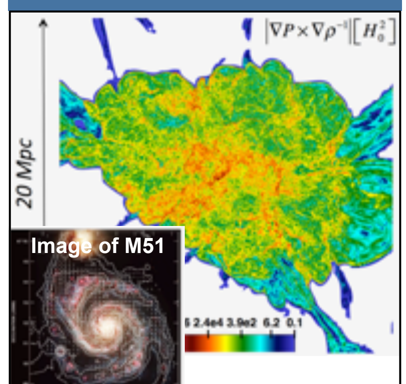


Zylstra (LANL), C.K.Li (MIT)

Stellar and Big Bang nucleosynthesis

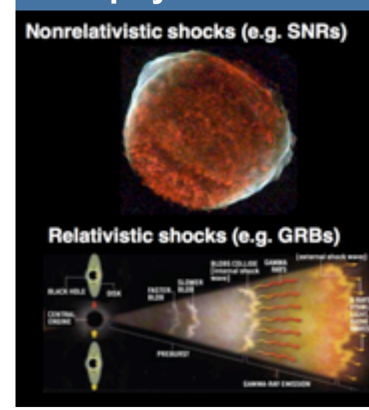
Gatu-Johnson (MIT)

Turbulent dynamo B field amplification



Gregori (Oxford), Lamb (Chicago)

Collisionless astrophysical shocks

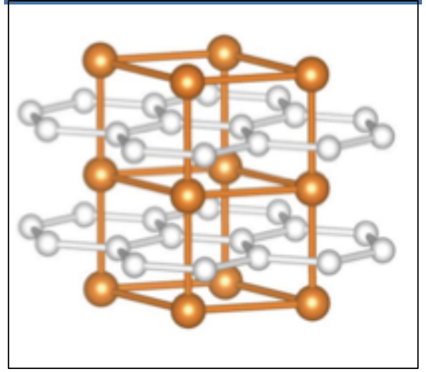


Sakawa(Osaka), Spitkovsky(Princeton)

A total of 22 DS proposals were received for the FY17-18 DS round. All were of very high quality; below are the 8 approved proposals.

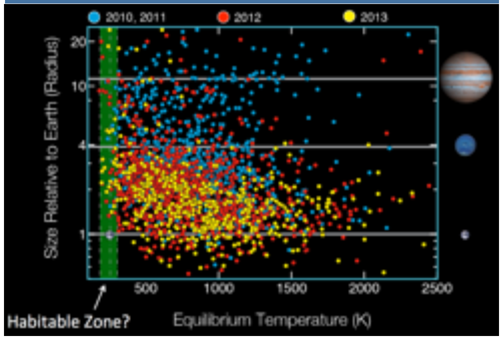
McMahon U. Edinburgh: Mg electrides

Mg at extreme densities



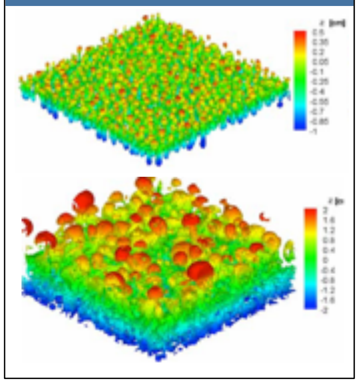
Hemley, CIW: TarDIS_FeMelt

Iron melt curve, magnetospheres, and habitable exoplanets



Shvarts, NRNC/U. Michigan: nonlinear hydro

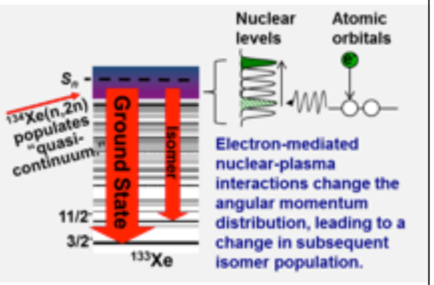
Asymptotic self-similar instabilities



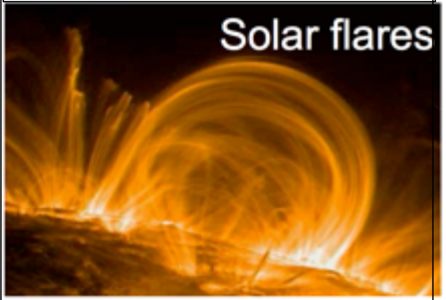
Pound, U Maryland: Eagle Nebula

Molecular cloud radiative dynamics

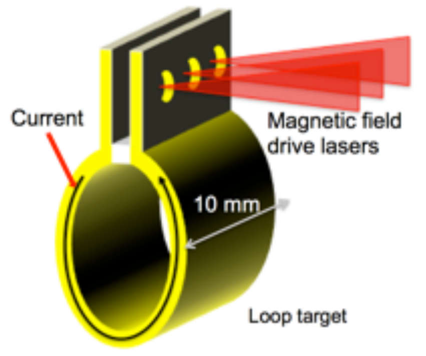
Berzak-Hopkins, LLNL: nuclear reactions in plasma



Fox, Princeton: Magnetic reconnection

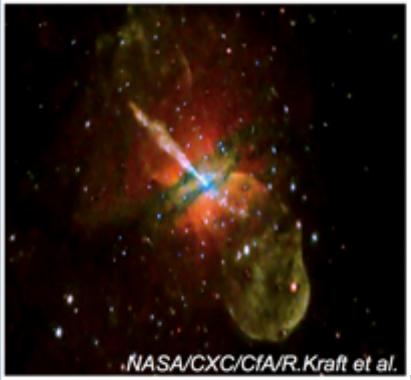


Pollock, LLNL: laser-driven B field generation



Chen, LLNL: hot e$^-$, e$^+$ in ARC driven samples

Rel. e-e+ plasmas present only in astro. events



VIRGIL

NIF x-ray spectrometer (NXS)

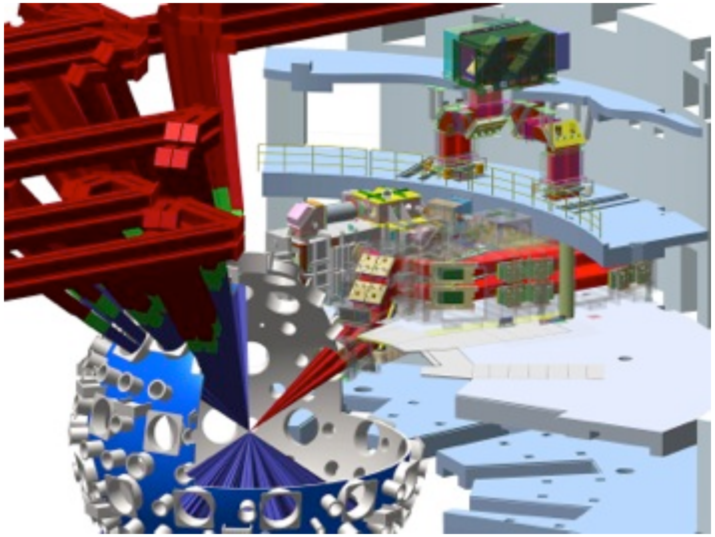
DIXI

Magnetic proton time of flight (M-pTOF)

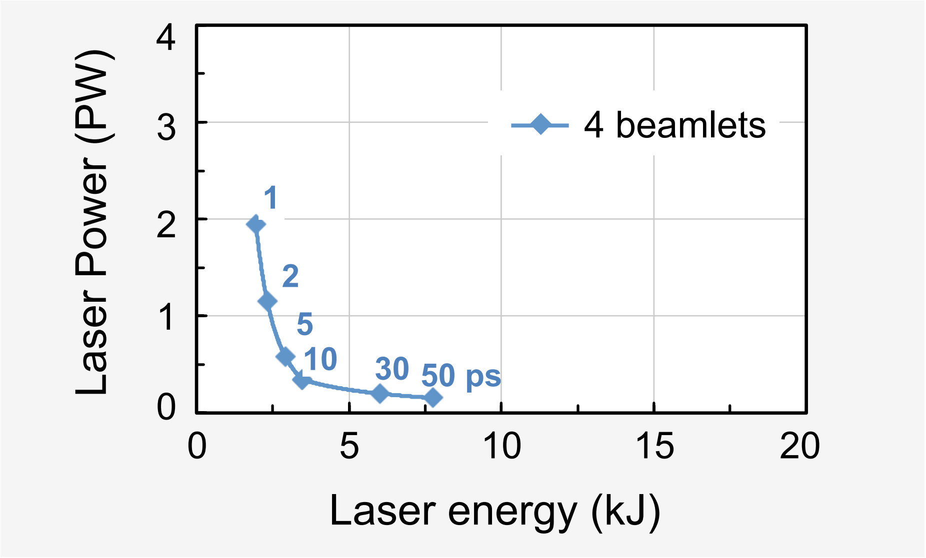
Several transformative diagnostic capabilities will be developed over the next several years for NIF, Omega, and Z as part of the National Diagnostics Initiative

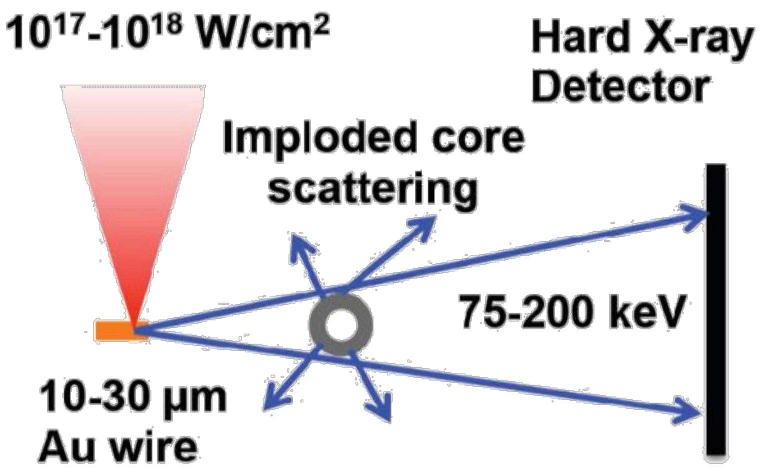
Transformative diagnostic	Institutions	New capability-program
Single LOS imaging (h-CMOS, dilation)	SNL,GA, LLNL,LLE, AWE	Many measurements on one shot for all missions. Short gating capability for implosions measure shape change during the stagnation process.
Optical Thomson Scattering (OTS)	LLE, LLNL, LANL, NRL	Hohlraum ne, Te, Ti, Z-All: Radiation channel flow: discovery science
3D n/gamma imaging (NIS)	LANL, LLNL	3D shape of burn
Gamma spectroscopy (GCD)	LANL, AWE, GA,LLNL	Burn duration, mix
Time resolved n spectrum (MRS-t)	MIT LLNL, GA, LLE	Alpha heating diagnostic - burn
Hi Res. X-ray spect. (HiRes)	LLNL,LLE,PPL, NSTec, SNL	T warm compressed hi Z-strength: density of burning plasmas
Hard x-ray imaging (Wolter)	SNL, LLNL	Higher areal density backlighting for strength, complex hydro. Time & space resolved T of burning plasmas.
Time resolved diffraction TARDIS-t	SNL, LLNL	Material phase change versus time for strength & discovery science

The Advanced Radiographic Capability is now online for program use with its initial 30 ps, ~ 4 kJ capability



ARC entering the NIF chamber





It's an exciting time in the field of High Energy Density Science and on the National Ignition Facility

- Amazing capabilities have been developed over the past decade to perform fascinating science on the boundary of what is possible.
- HED Scientists are exploiting these capabilities and delivering fabulous science. The work is being well received by the broader scientific community.
- "Discovery Science" time on NIF is allocated via a competitive process and plays an important role in enabling innovation and addressing the most fundamental questions facing the field of high energy density science
- Diagnostics also provide an important avenue for users to collaborate on NIF. The Advanced Radiographic Capability is now operational on NIF and opens up multiple opportunities to study high energy density science.


OSAKA UNIVERSITY
Sandia National Laboratories
Los Alamos NATIONAL LABORATORY EST. 1943
UNIVERSITY OF OXFORD
UNIVERSITY of York
RICE
UC DAVIS UNIVERSITY OF CALIFORNIA
UNIVERSITY OF NEVADA RENO 1874
PRINCETON UNIVERSITY
THE UNIVERSITY OF CHICAGO
UR LLE
AWE
UNIVERSITY OF MICHIGAN
MIT PSFC
ETH
CARNEGIE INSTITUTION OF WASHINGTON 1902
GENERAL ATOMICS
cea
GSI
Massachusetts Institute of Technology
Ben-Gurion University of the Negev
ULSAN NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY UNIST
Universität Rostock Traditio et Innovatio
Lawrence Livermore National Laboratory
INDIANA UNIVERSITY OFFICE OF THE VICE PRESIDENT FOR ENGAGEMENT
National Security Technologies LLC Vision • Service • Partnership
Queen's UNIVERSITY
Berkeley UNIVERSITY OF CALIFORNIA
KYUSHU UNIVERSITY
ÉCOLE POLYTECHNIQUE UNIVERSITÉ PARIS-SACLAY
UCL
OHIO UNIVERSITY
NNSA National Nuclear Security Administration
PRINCETON UNIVERSITY

Discovery Science Technical Review met in October 2015 to rank proposal for time in FY17

Dr. Riccardo Betti	Laboratory for Laser Energetics, Univ. of Rochester
Dr. Richard Firestone	Lawrence Berkeley National Laboratory
Prof. Nathaniel Fisch	Princeton University
Dr. Siegried Glenzer	SLAC
Dr. Denise Hinkel	Lawrence Livermore National Laboratory
Prof. Karl Krushelnick	University of Michigan
Dr. Ramon Leeper	Los Alamos National Laboratory
Dr. Mordy Rosen	Lawrence Livermore National Laboratory
Dr. John Sarrao (Chair)	Los Alamos National Laboratory
Prof. Sarah Stewart	U.C. Davis

- 34 Abstracts were received in July 2015.
- 22 full proposals were reviewed in October by the DS TRC committee
- 8 proposals were accepted for a total of 18 shot days.