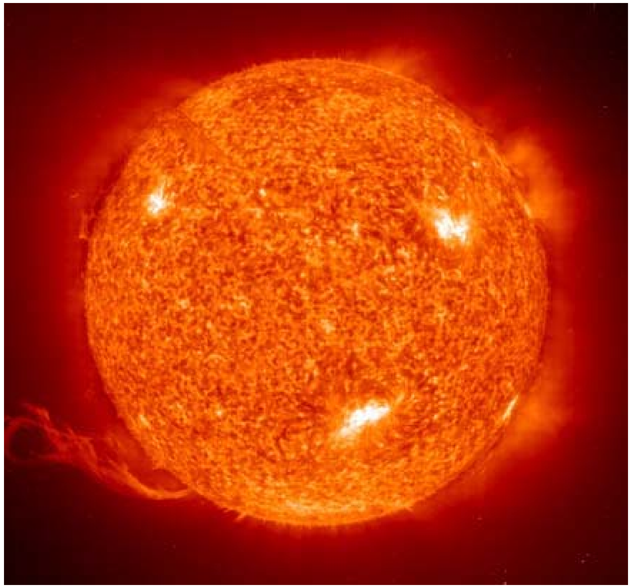
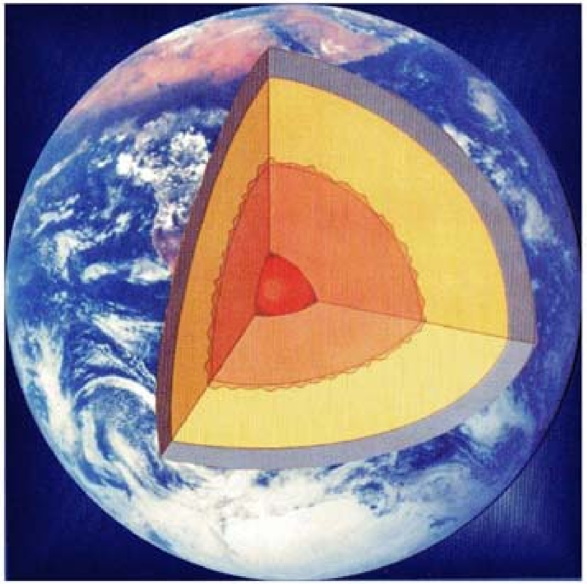
Pulsed-Power-Driven High Energy Density Physics and Inertial Confinement Fusion Research





M. Keith Matzen

American Physical Society, Division of Plasma Physics

Savannah, Georgia

November 15, 2004

National Nuclear Security Administration

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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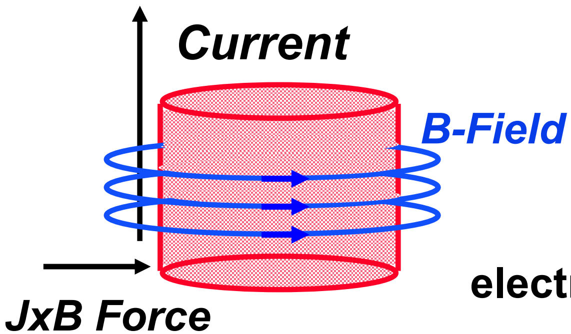
Magnetically-driven z-pinch implosions efficiently convert electrical energy into radiation



kinetic and electrical energy

↓

internal (shock heating)

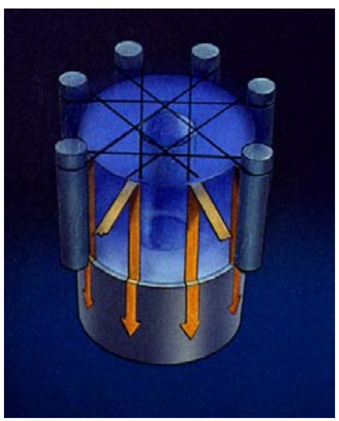
↓

x rays

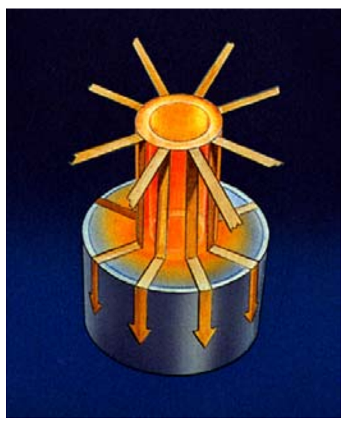
electrical energy

↓

kinetic energy



Initiation

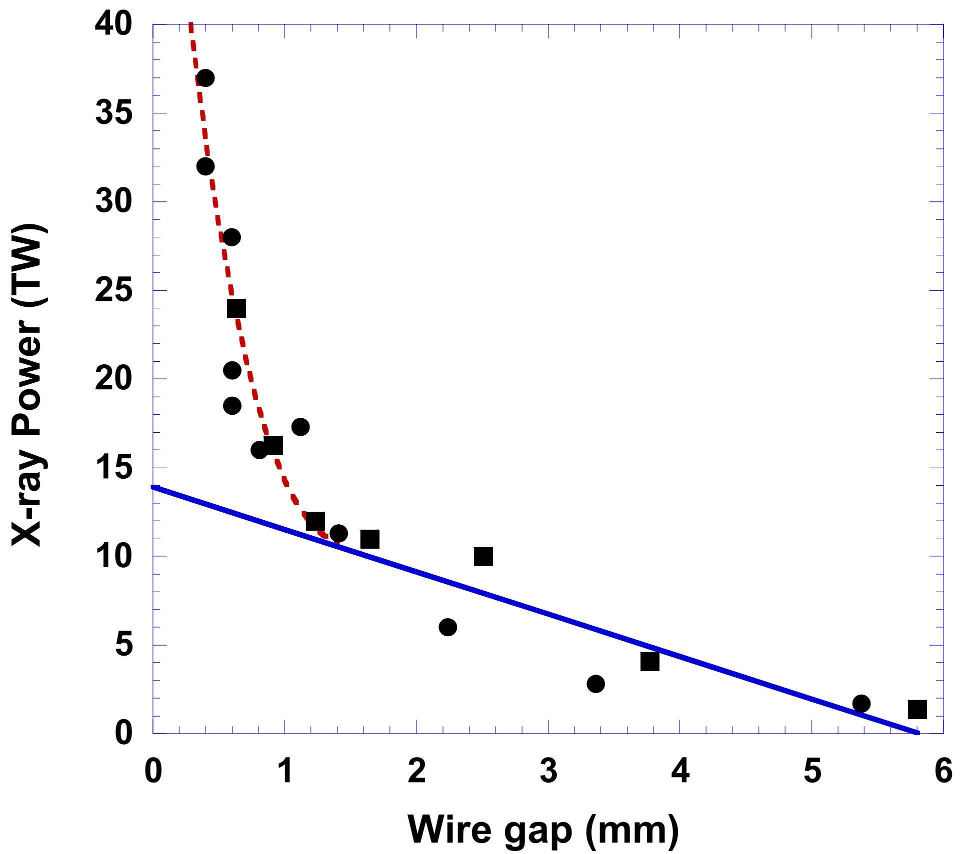


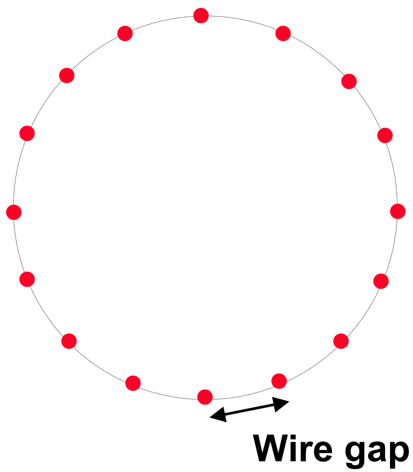
Implosion

Stagnation

- Z-pinch loads
  - Gas puffs
  - Foils
  - Low density foams
  - Low-number wire arrays
- Energy: x-ray ≈ 15% of stored electrical
- Power: x-ray ≈ electrical

Increasing the number of wires in a cylindrical array provided a breakthough in x-ray power



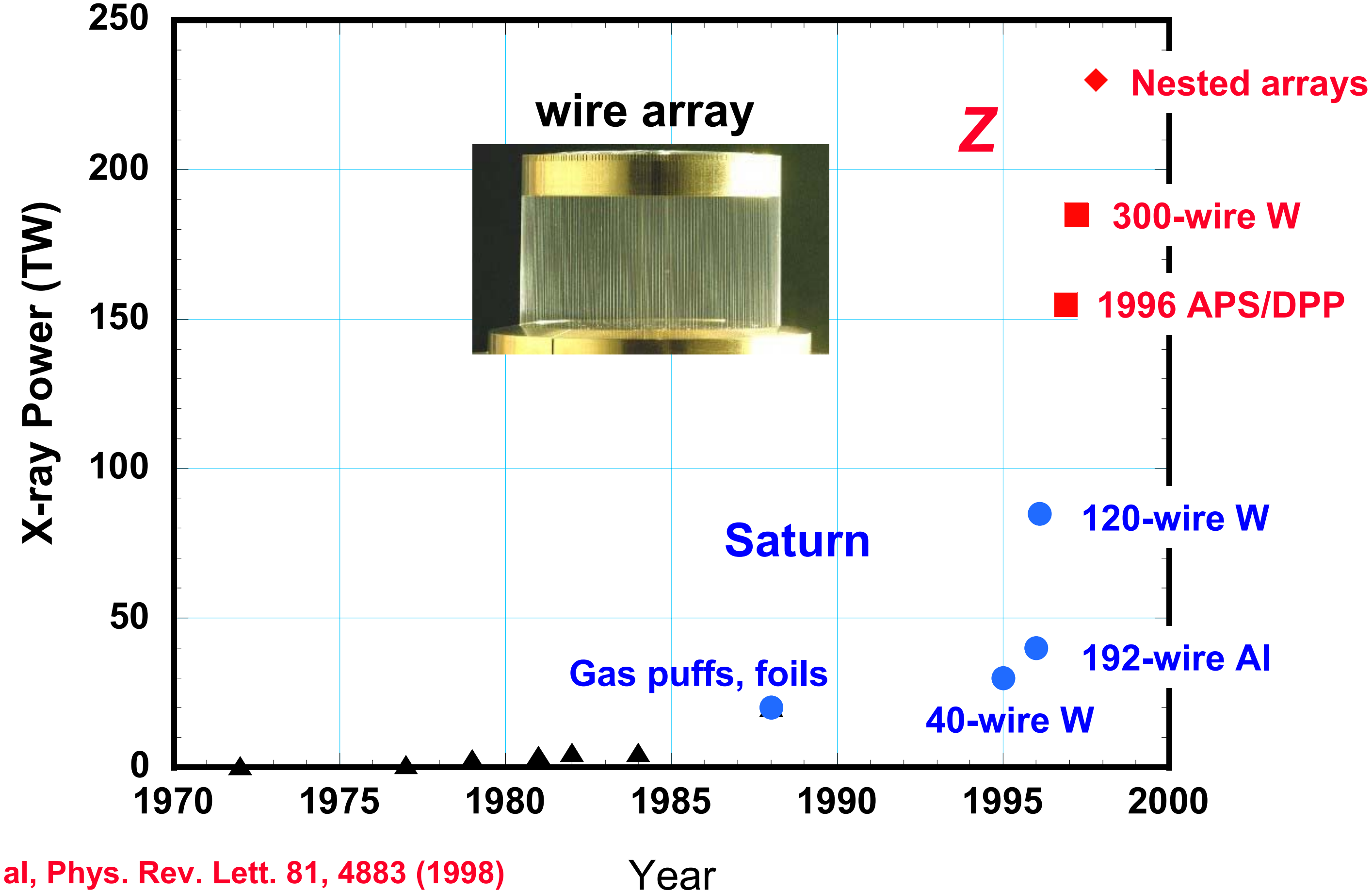


- **Al wire arrays**
  - **Fixed implosion time**
  - **Constant mass for given array diameter**
  - **Different array diameters**

T. W. L. Sanford, et al., Phys. Rev. Lett. 77, 5063 (1996)

The 20-MA Z facility quickly produced record x-ray powers with high-number wire arrays

The conversion of Sandia's Particle Beam Fusion Accelerator II (PBFA II) was completed in September 1996 (renamed Z)



C. Deeney et al, Phys. Rev. Lett. 81, 4883 (1998)
R.B. Spielman et al, Phys. Plasmas 5, 2105 (1998)
C. Deeney et al, Phys. Rev. E 56, 5945 (1997)

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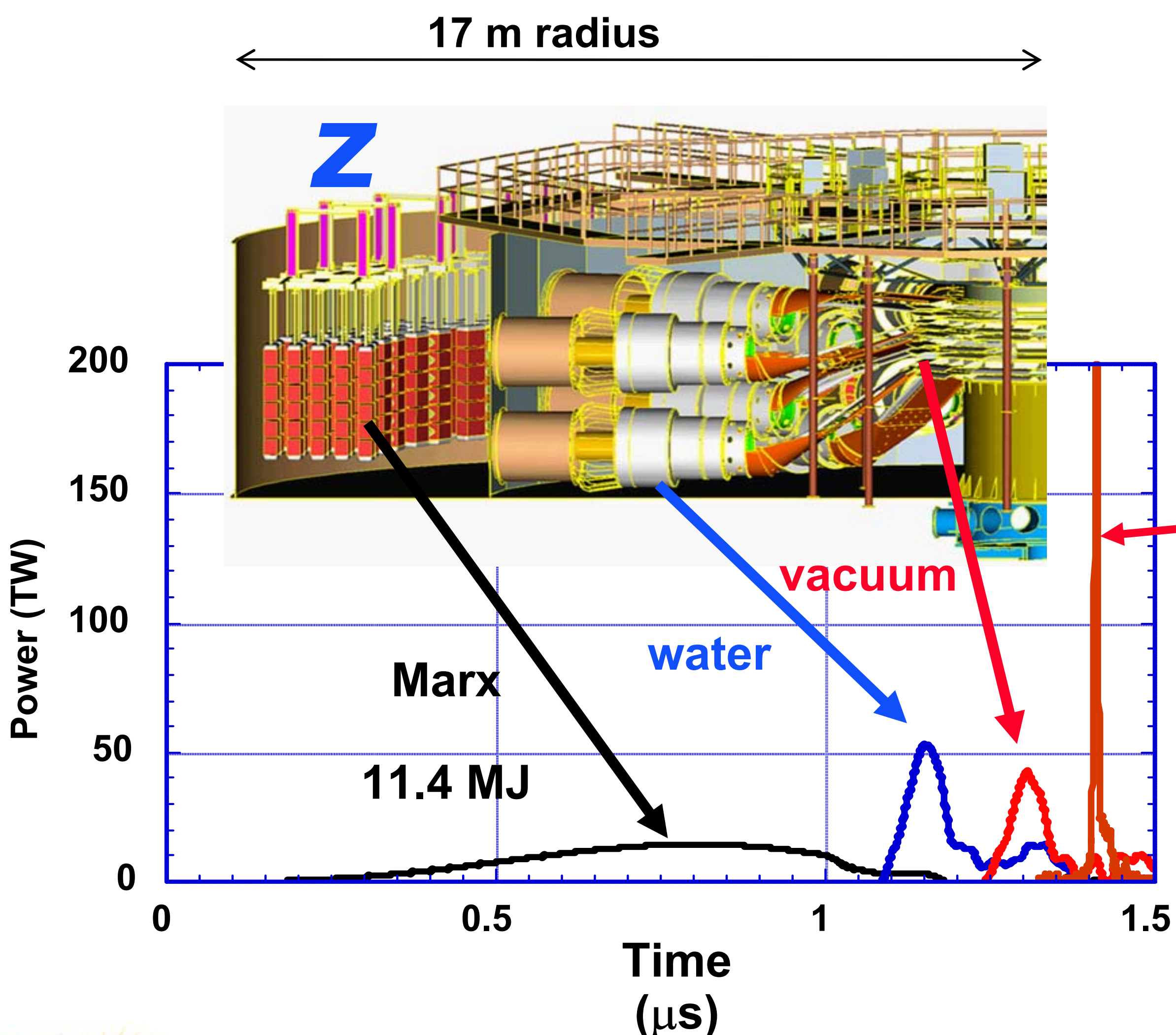
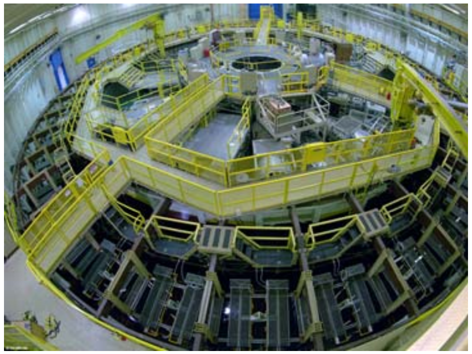
Pulsed-power provides compact, efficient, power amplification



x ray output
~1.6 MJ
~200 TW

Z (circa 1997)



<u>Electrical to x-ray energy</u>
Conversion efficiency ~ 15%

Efficiency ⇒ Low Cost

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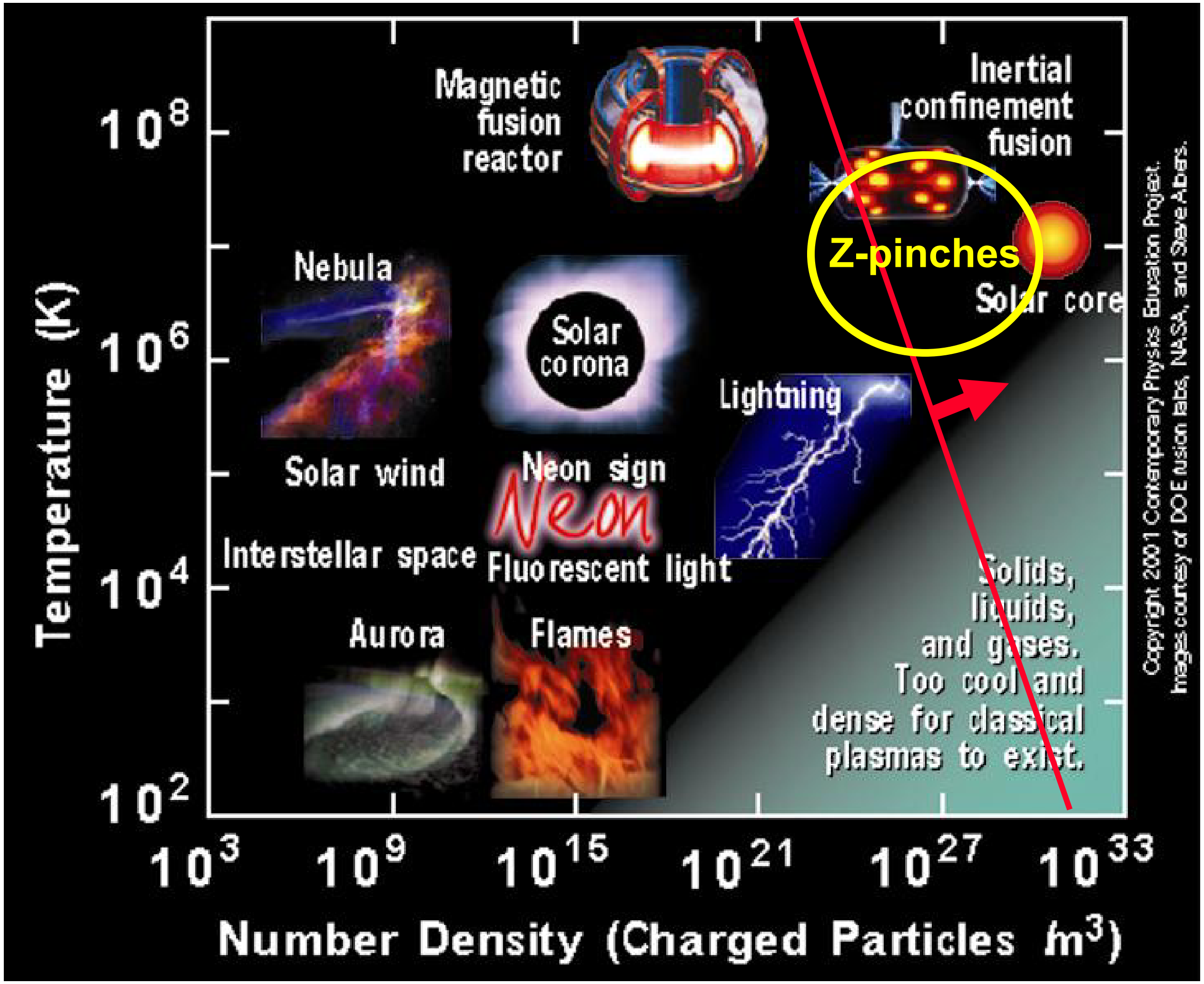
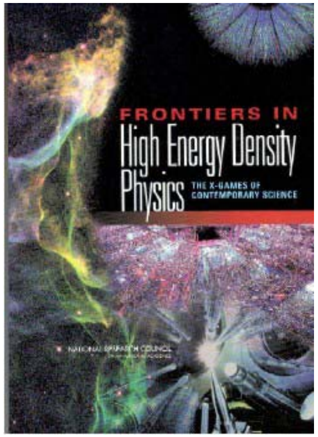
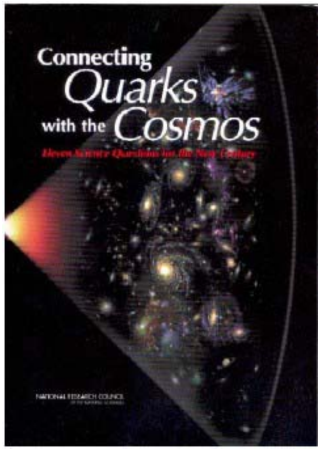
The *Z* pulsed power facility

[Movie of Z and wire array implosions]

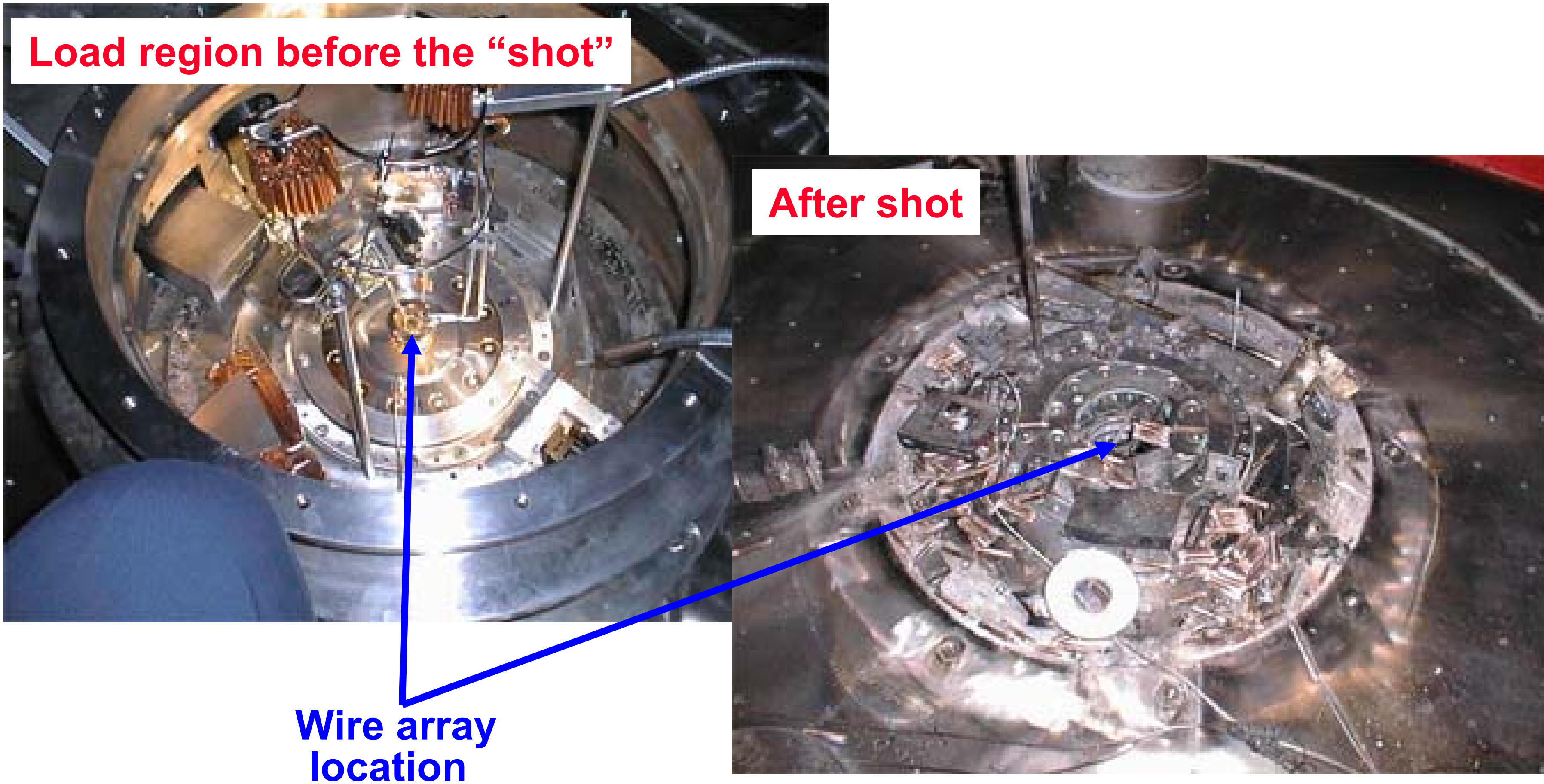
Regimes of high energy density are typically associated with energy density $\geq 10^5$ J/cm^3 = 1 Mbar





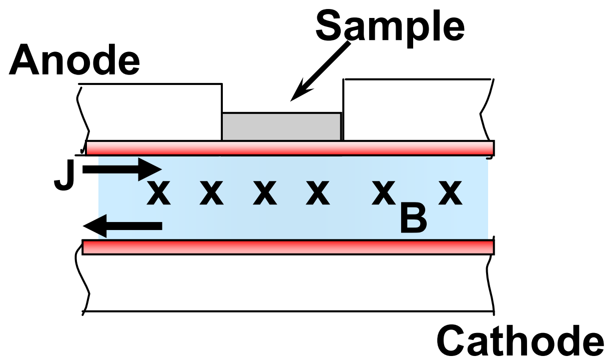


High energy density physics at the scale of the Z facility creates an exciting experimental environment



Energy equivalent of 2 lbs of high explosive released in few ns in volume of < 1 cc

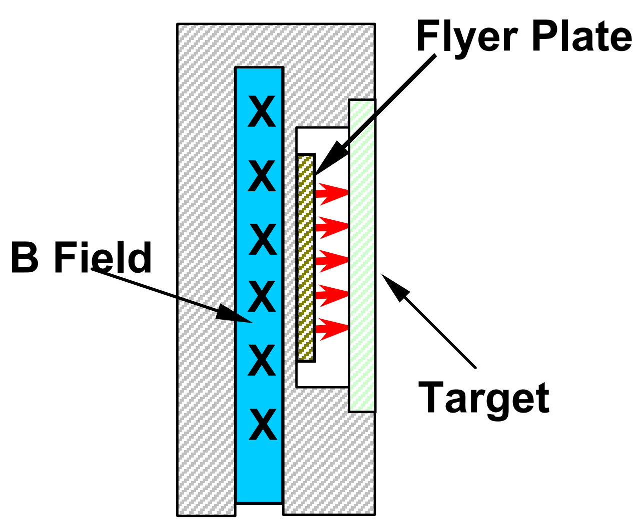
The magnetic pressure associated with high currents enable accurate EOS studies



Isentropic Compression Experiments (ICE)*

Magnetically produced Isentropic Compression Experiments (ICE) provide measurement of continuous compression curves
- previously unavailable at Mbar pressures
- presently capable of ~4 Mbar

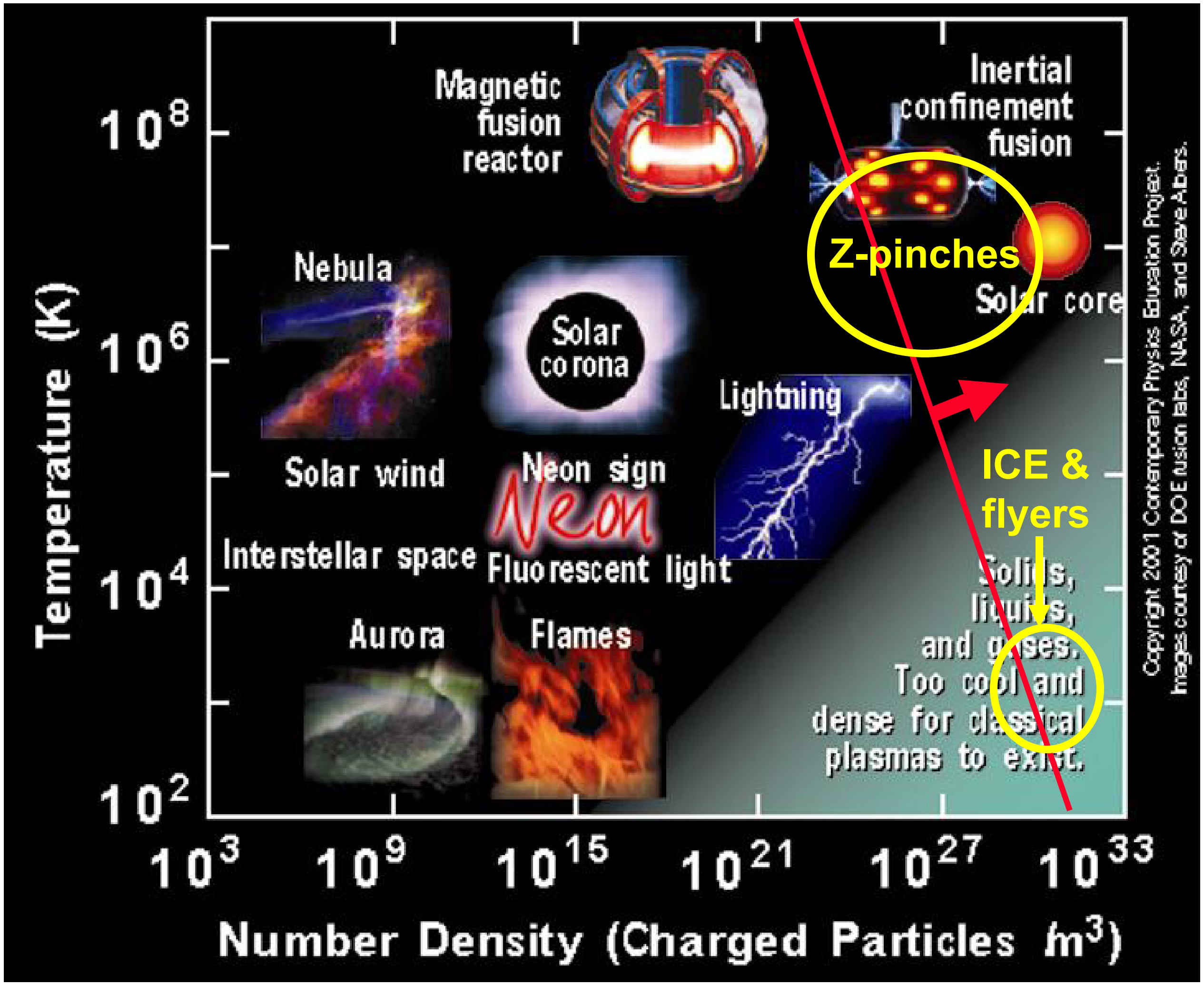
* Developed with LLNL

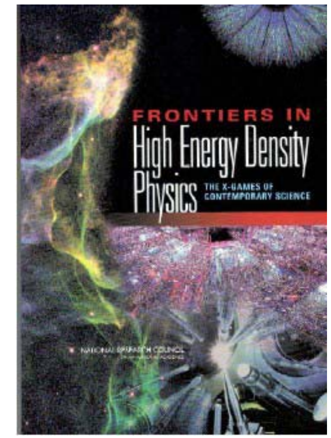


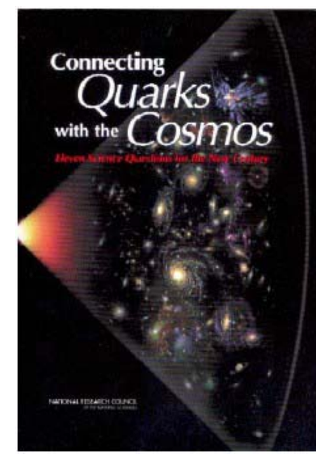
Magnetically launched flyer plates

Magnetically driven flyer plates for shock Hugoniot experiments at velocities to ~ 33 km/s
- exceeds gas gun velocities by ~ 4X and pressures by ~ 4-5X with comparable accuracy
- Presently capable of ~ 20 Mbar

Regimes of high energy density are typically associated with energy density ≥ 10^5 J/cm^3 = 1 Mbar







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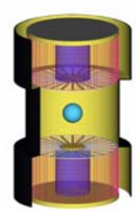
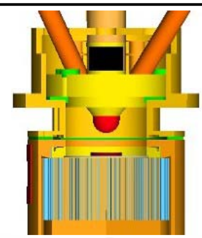
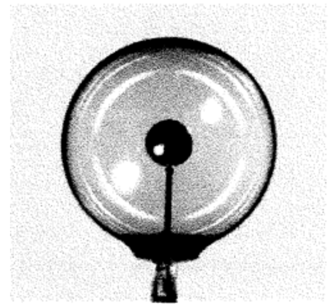
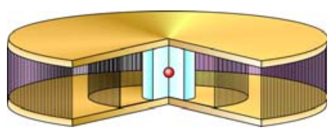
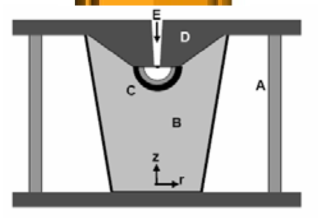
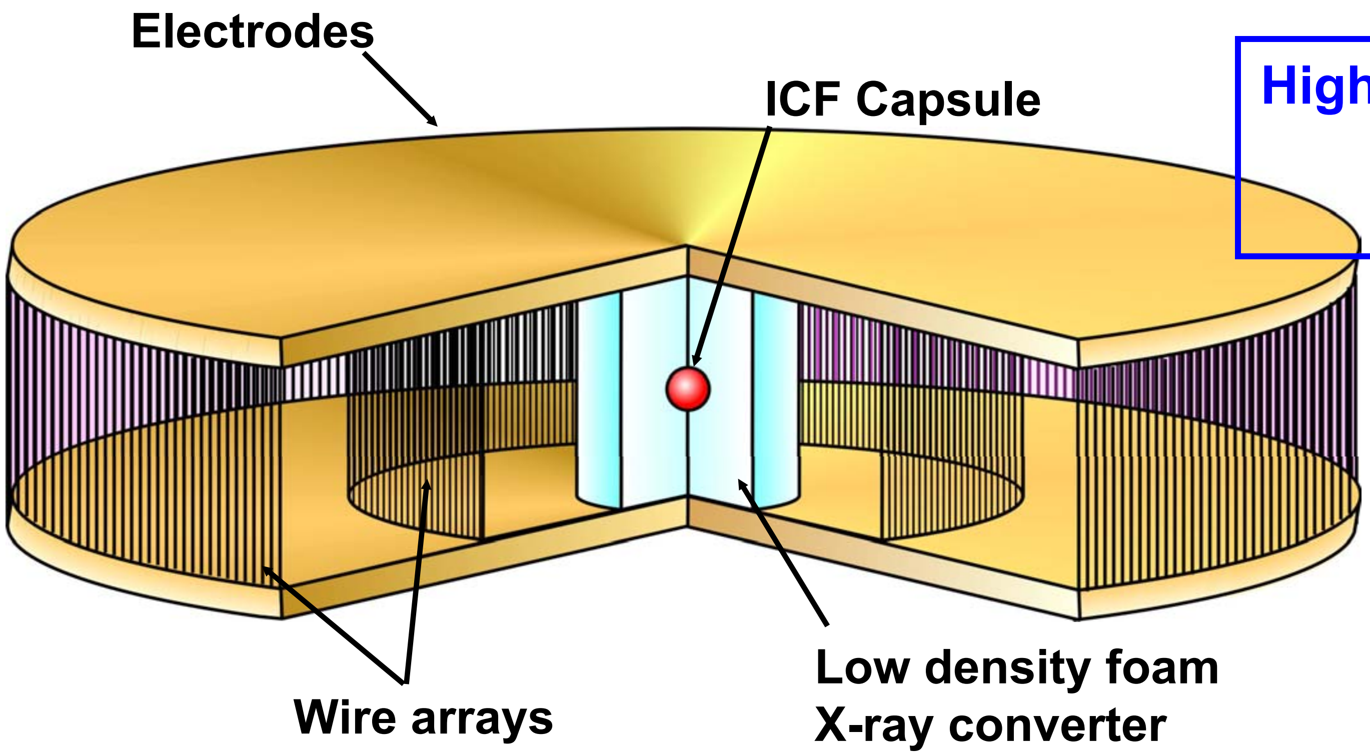
Outline

- Introduction
- Inertial Confinement Fusion
  - High temperature implosions
  - Symmetry of radiation drive
  - Fast ignition
- Radiation science
- Material properties
- Z-pinch physics/ALEGRA
- Ongoing capability enhancements
  - Z-Refurbishment
  - Z-Beamlet to high power (Z-Petawatt)
- Z-Pinch Inertial Fusion Energy

Pulsed-power drivers support a diverse research portfolio of ignition and high yield, high gain ICF options

	Driver	ICF Target		
		Cryogenic		Non-cryogenic
		Hot spot ignition	Fast ignition	Double shell
X-ray drive	Vacuum hohlraum			
	Dynamic hohlraum			

High temperature capsule implosions are performed in the “dynamic hohlraum” configuration



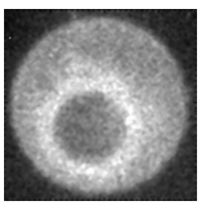
High yield design
54 MA
530 MJ

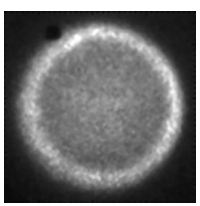
M. K. Matzen, T. W. Hussey, et al., internal Sandia reports (1980)
V.P Smirnoff, Plasma Phys. Controlled Fusion 33, 1697, (1991)
M. K. Matzen, Phys. Plasmas 4, 1519 (1997)
J.H. Brownell, R.L. Bowers, et al. Phys. Plasmas 5, 2071, (1998)
J. S. Lash et al., Proc. Inertial Fusion Sci. App. 99 (Paris: Elsevier) p 583 (2000)
T.A. Mehlhorn, Plasma Phys. Control. Fusion 45, 1–11 (2003)

Dramatic progress with dynamic hohlraums has enabled the first z-pinch driven hot dense capsule implosions

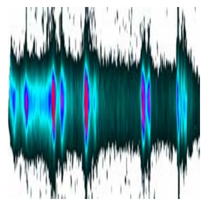
2000 — 2001 — 2002 — 2003 — 2004

dynamic hohlraum interior measurements

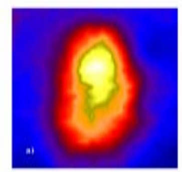




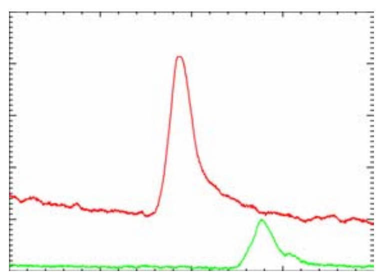
Ar spectra

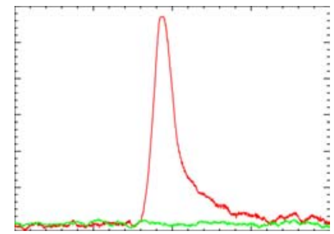


symmetry data



neutron measurements

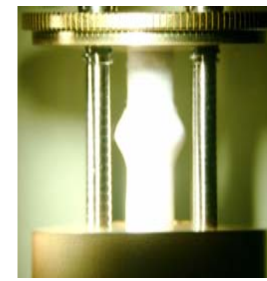




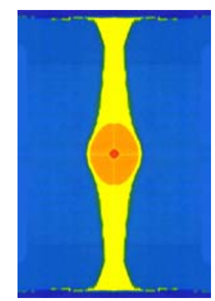
thermonuclear neutrons confirmed

40 kJ absorbed

ablator scaling experiments

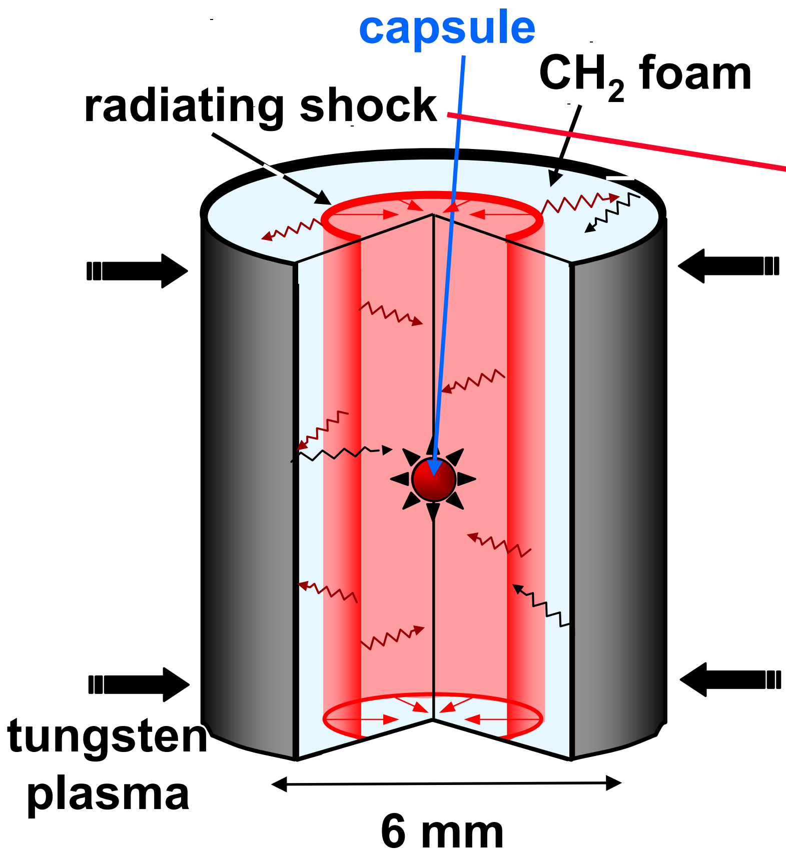


symmetry control

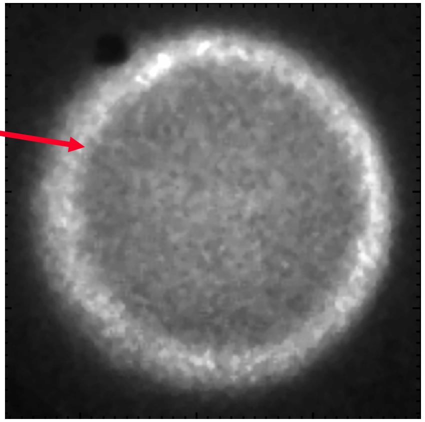


integrated 2D simulations

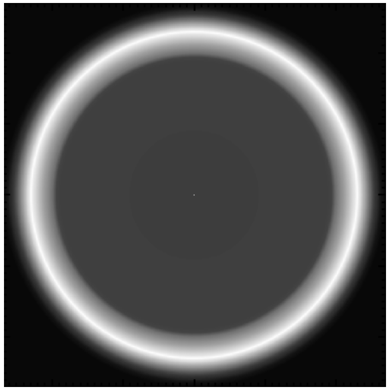
The primary radiation source is a thin radiating shock in the foam converter



Z670



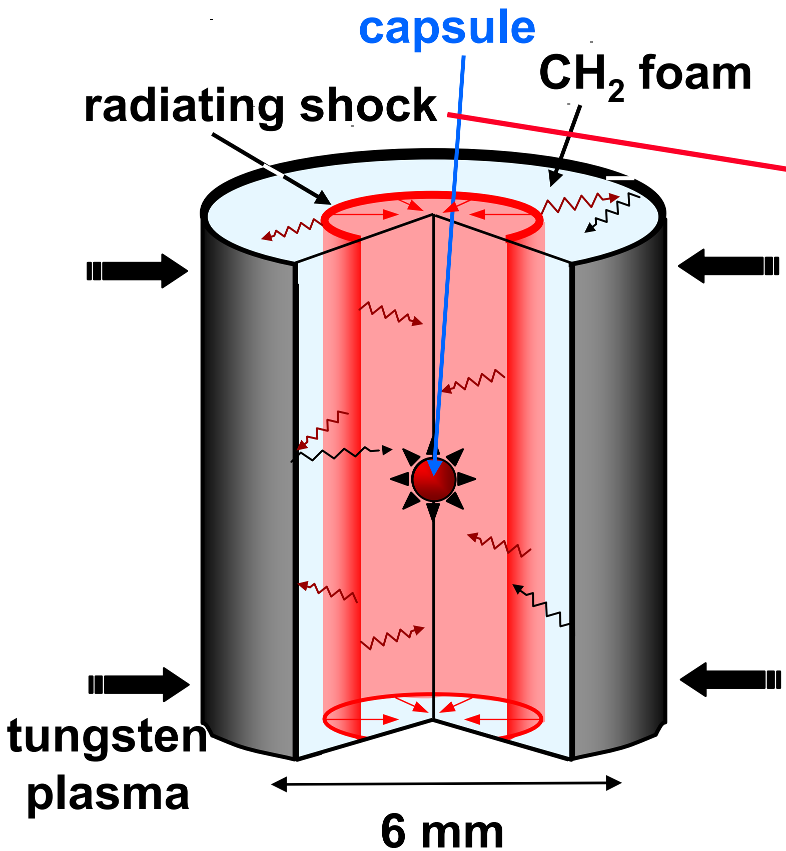
Simulated image

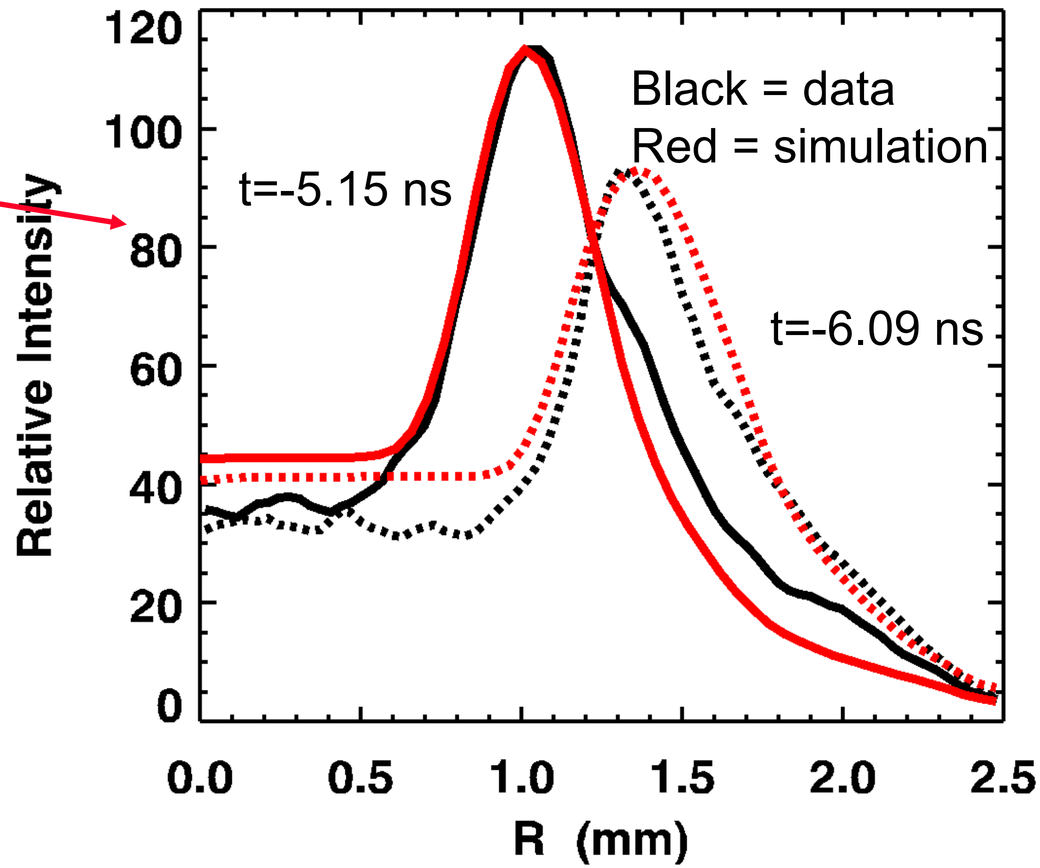


- **Measured annular shock width ~200 μm**
- **Shock is circular to within ± 1 - 4%**
- **No evidence of magnetic Rayleigh-Taylor imprint on shock**

J. E. Bailey, et al., Phys. Rev. Lett. 89, 095004 (2002)

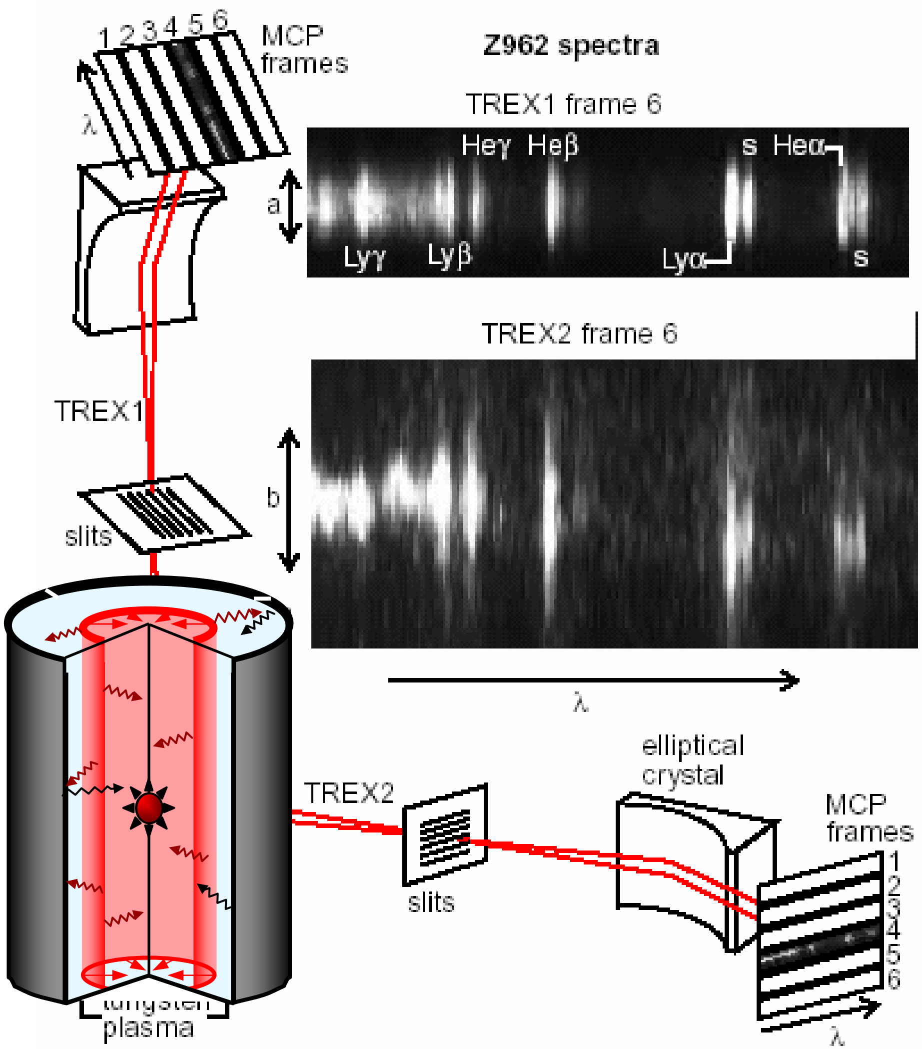
The primary radiation source is a thin radiating shock in the foam converter





R.W. Lemke, et al., Phys. Plasmas, to be published, (Jan 2005)

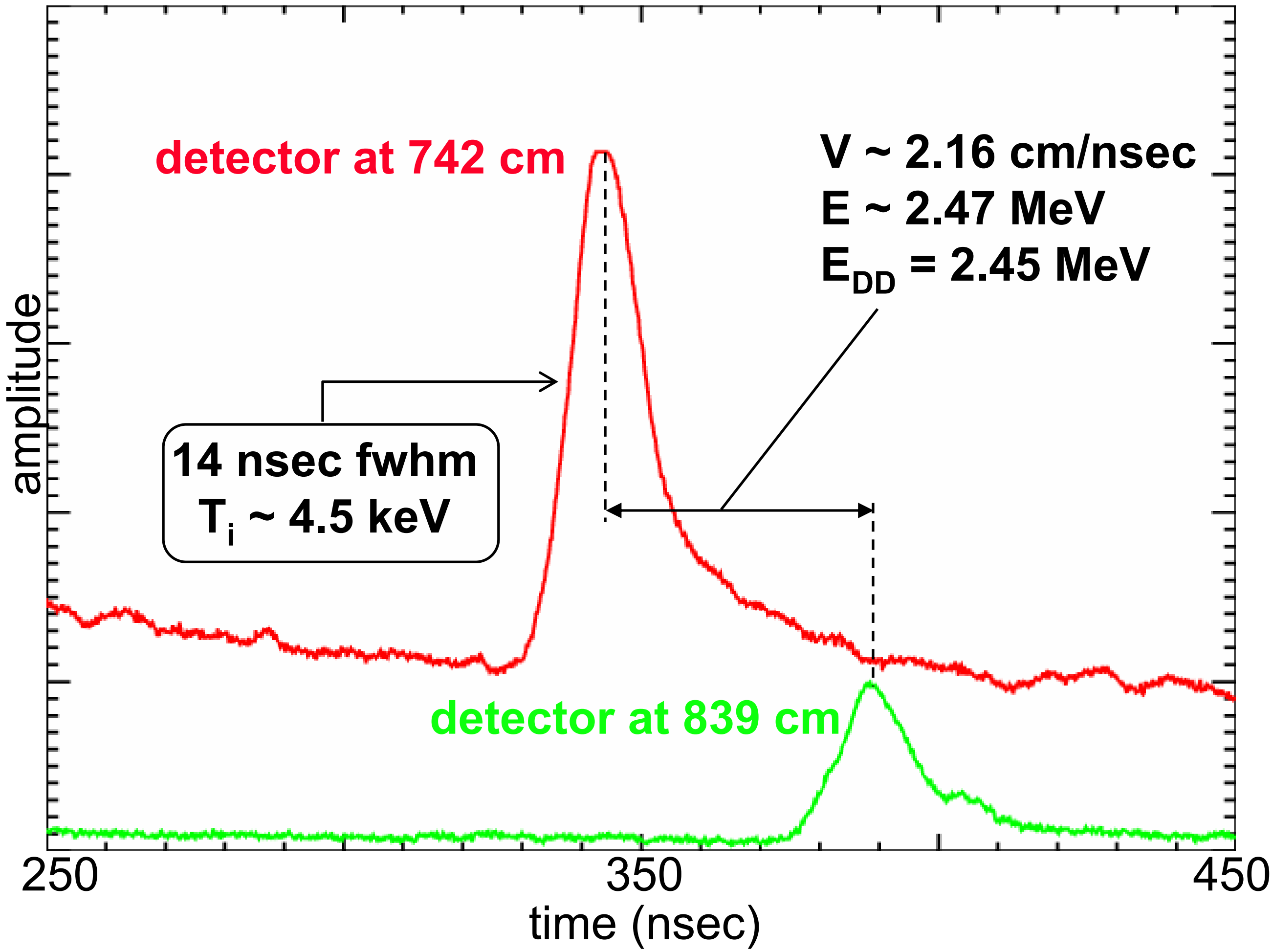
Orthogonal time- and space-resolving spectrometers can reconstruct 2-D electron density and temperature



The electron temperature and density deduced from the Argon K-shell spectra is 1 keV, 2x10^{23} cm^{-3}

J.E. Bailey et al., Phys. Rev. Lett. 92, 085002 (2004)

Neutron energy, yield, and isotropy are consistent with thermonuclear production mechanism



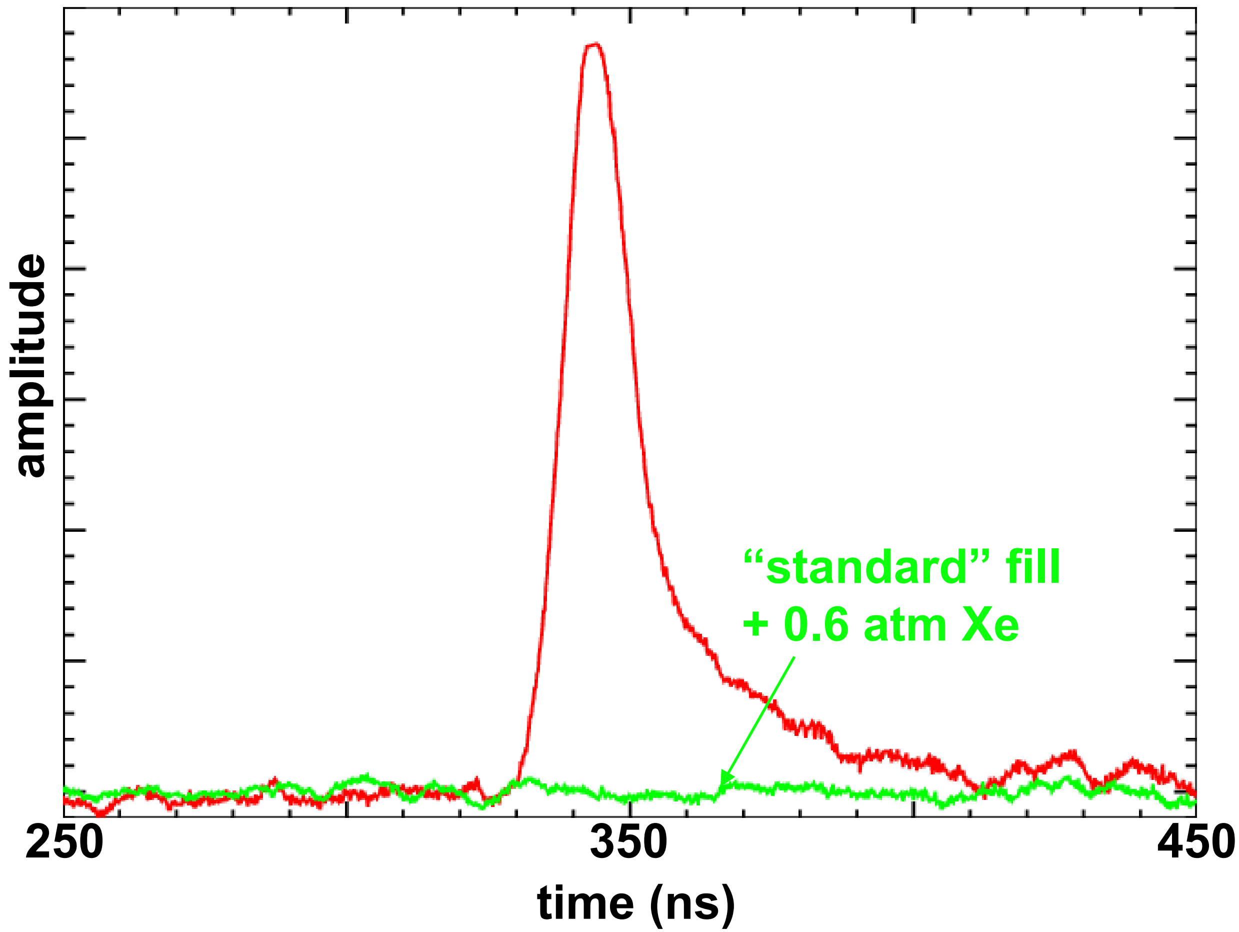
"standard" fill (20 atm D_2 + 0.085 atm Ar)

$Y_N = 2.9 \pm 1.6 \times 10^{10}$ (record DD yield from X-ray drive)

1D prediction: $Y_N \sim 6 \times 10^{10}$

C.L. Ruiz et al., Phys. Rev. Lett. 93, 015001 (2004)

Xe fill gas quenches the implosion, substantiating the thermonuclear origin of the neutrons



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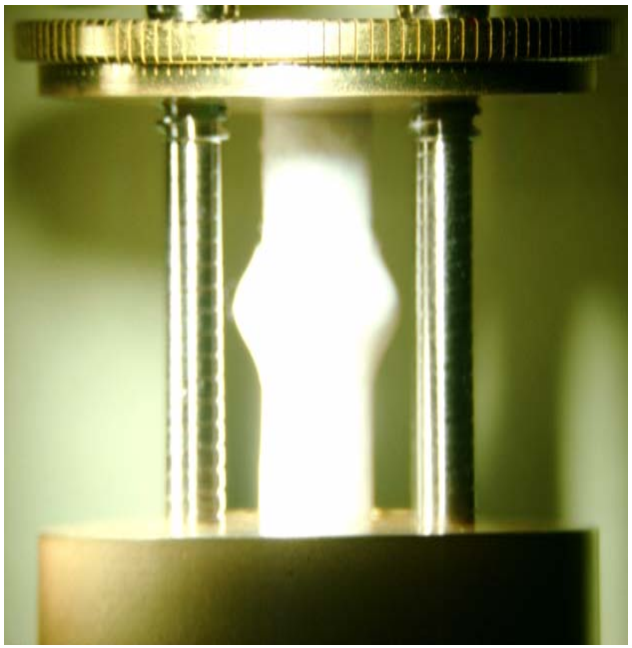
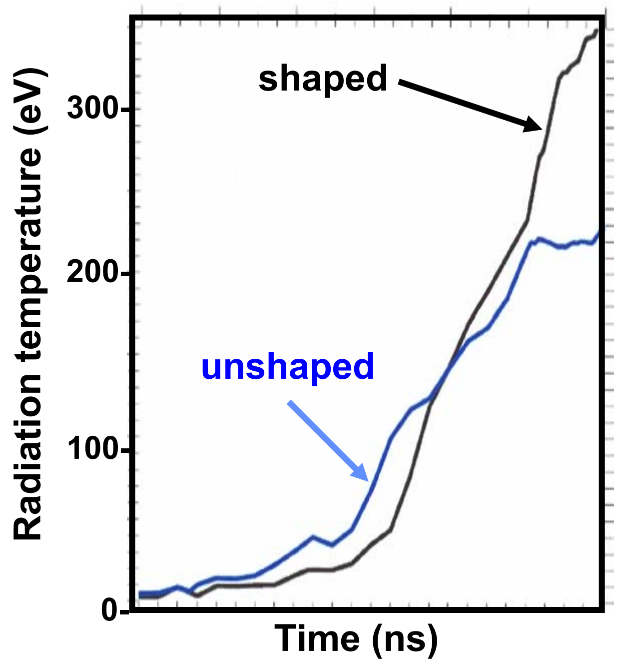
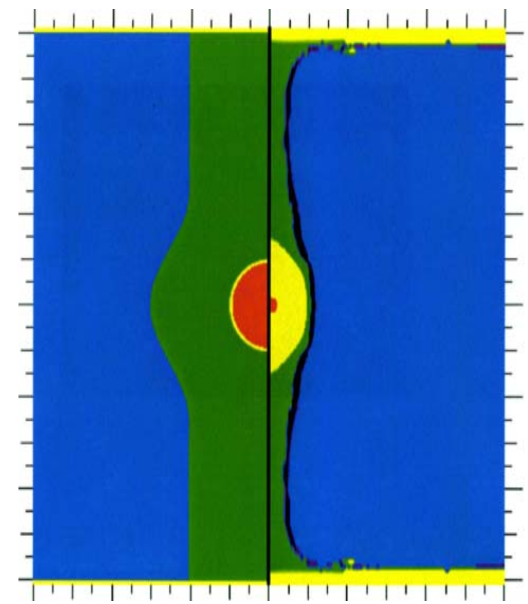
Sophisticated simulations, target fabrication, and diagnostics are required to improve symmetry

•2D integrated LASNEX simulations: a shaped convertor improves the radiation symmetry, drive temperature, and neutron yield

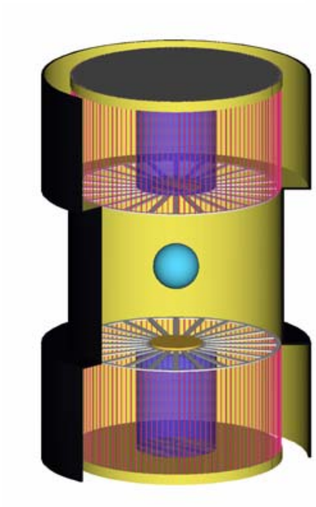






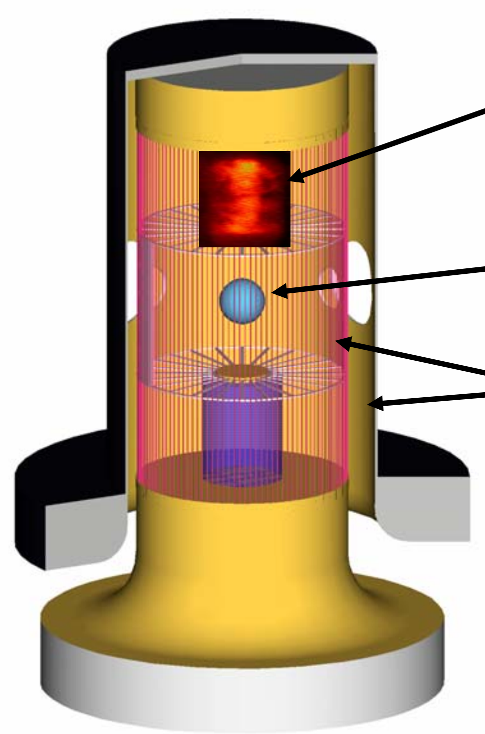
	Simulation	Experiment	Ratio
Unshaped foam	1.2×10^{11}	$.42 \pm .13 \times 10^{11}$	.35
Shaped foam	5×10^{11}	$1.7 \pm .5 \times 10^{11}$	.34

The Double-Ended Hohlraum (DEH) configuration is an excellent testbed for radiation symmetry studies



two-sided power feed

Two 63 MA pinches
380 MJ yield



single-sided power feed on Z

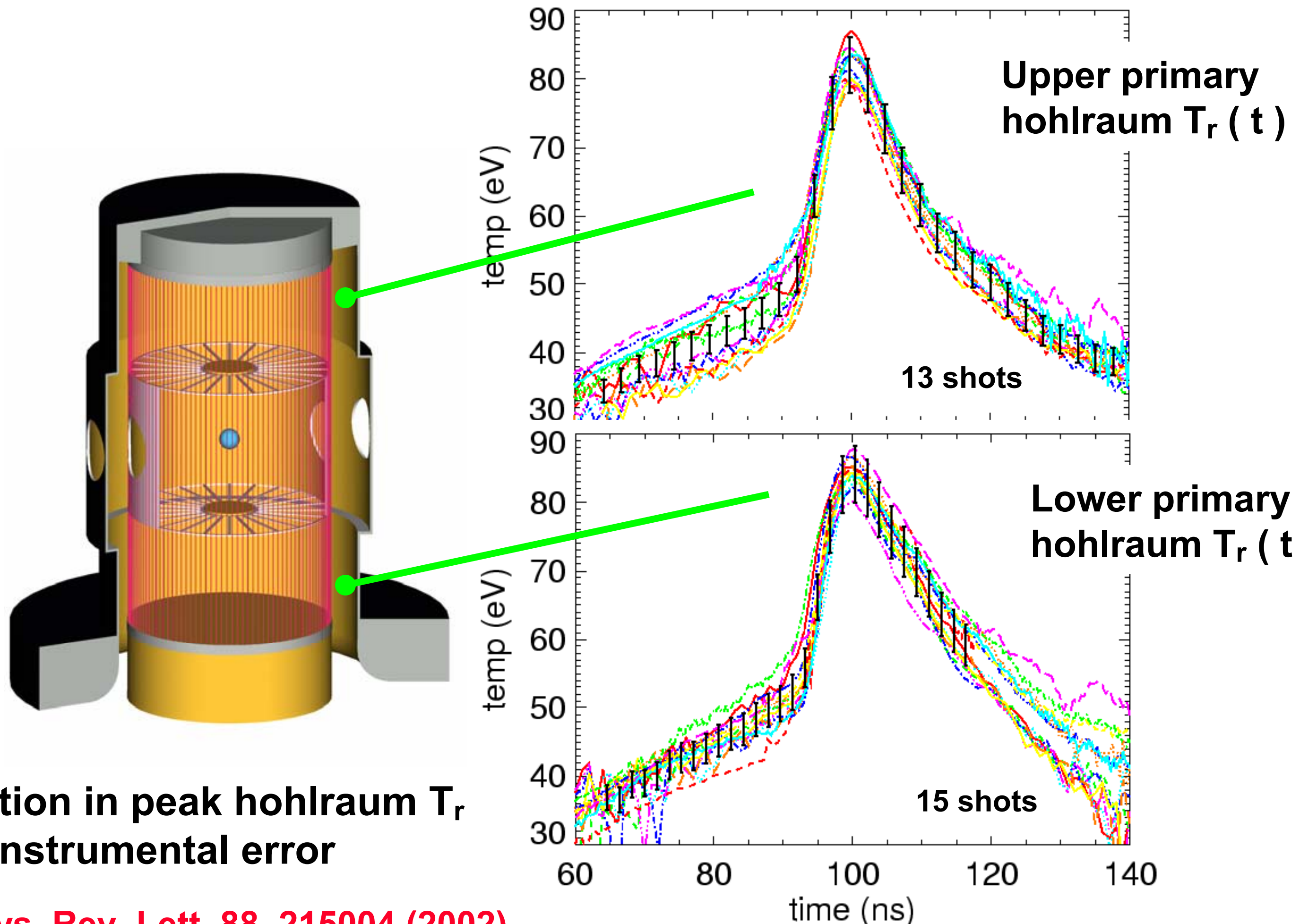
J. Hammer et al., Phys. Plasmas 6, 2129 (1999)

M. Cuneo et al., Phys. Plasmas 8, 2257 (2001)

D. Hanson et al., Phys. Plasmas 9, 2173 (2002)

Radiation symmetry experiments have been enabled by the development of a single-sided power feed, double-pinch load for Z

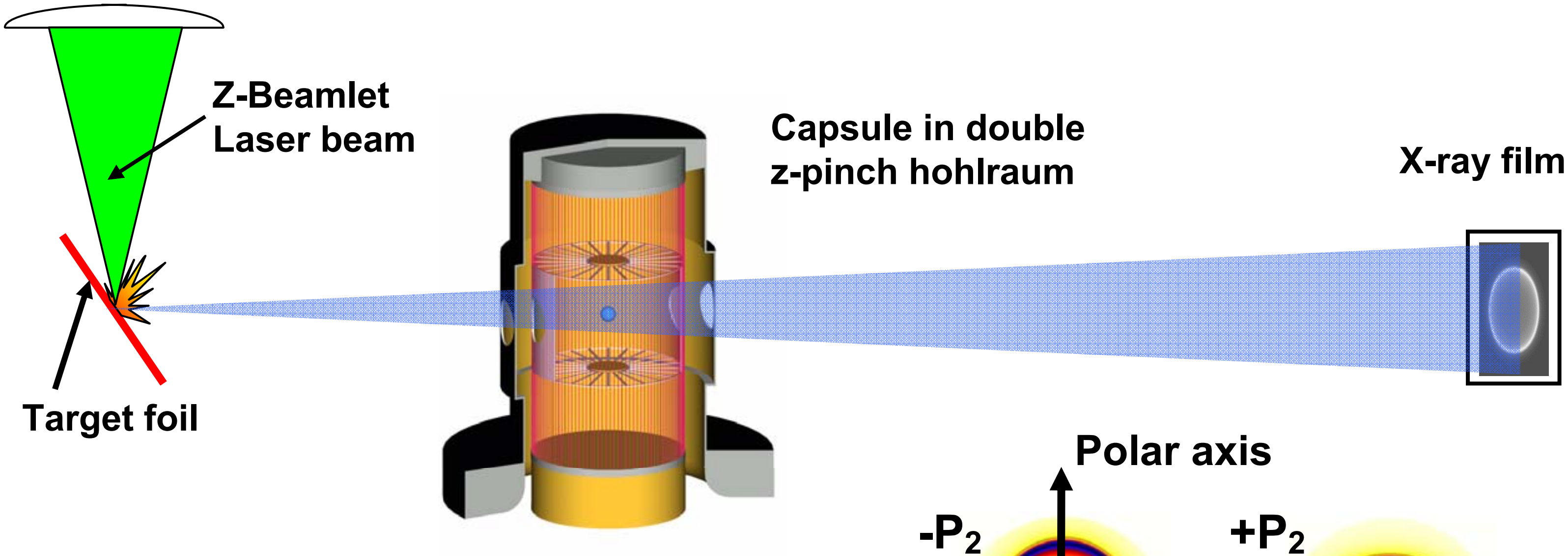
Wire array hardware



Shot-to-shot variation in peak hohlraum T_r is less than ± 5% instrumental error

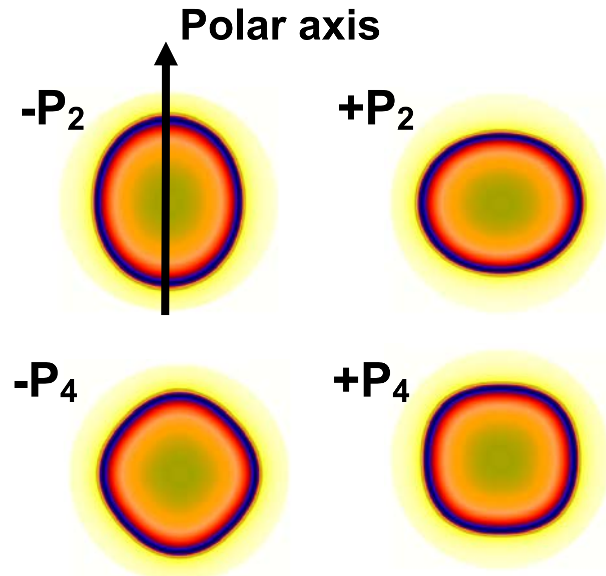
M. E. Cuneo et al., Phys. Rev. Lett. 88, 215004 (2002)

We diagnose radiation asymmetry on Z with x-ray point-projection backlighting of an imploding capsule



Capsule drive asymmetry expressed in terms of low-order Legendre modes P_ℓ

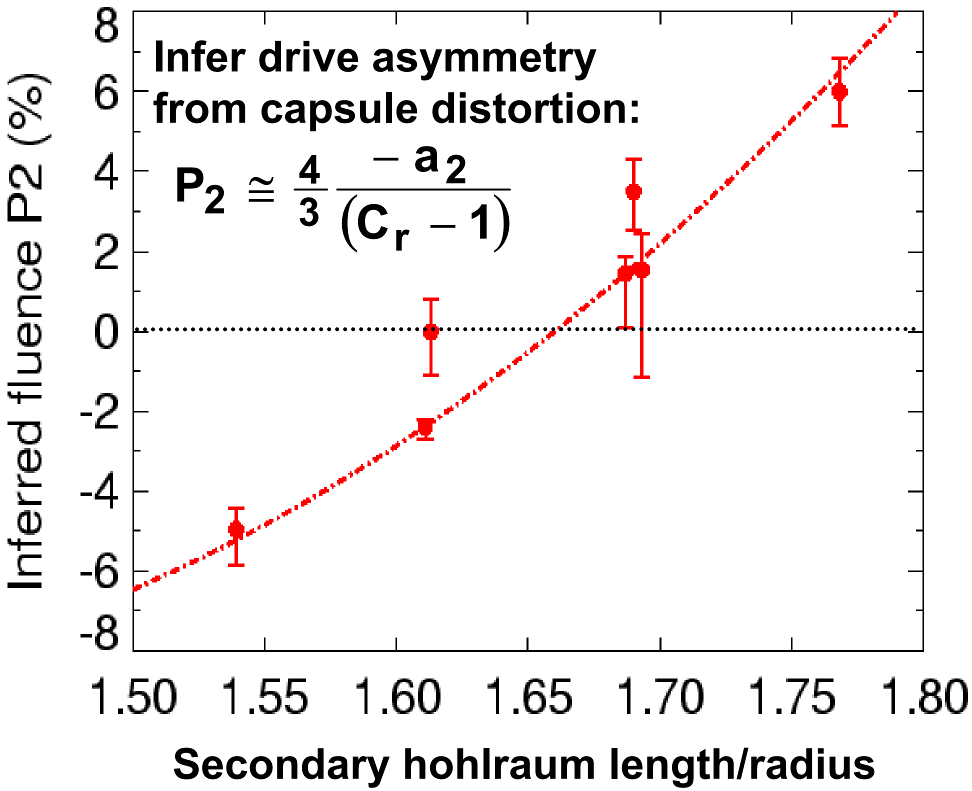
Example in-flight backlit images of capsules driven by dominant modes:



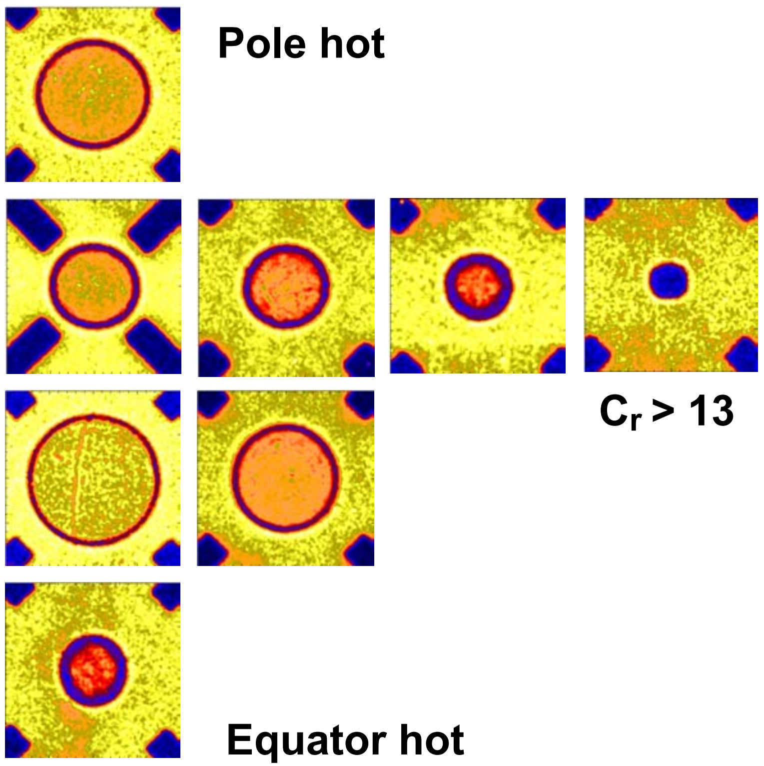
G. R. Bennett et al., Rev. Sci. Instr. 72, 657 (2001)
G. R. Bennett et al., Phys. Rev. Lett. 89, 245002 (2002)

Experiments with 2-mm capsules demonstrate the ability to zero out the P_2 asymmetry and $C_r > 13$

R. A. Vesey et al., Phys. Plasmas 10, 1854 (2003)
G. R. Bennett et al., Phys. Plasmas 10, 3717 (2003)

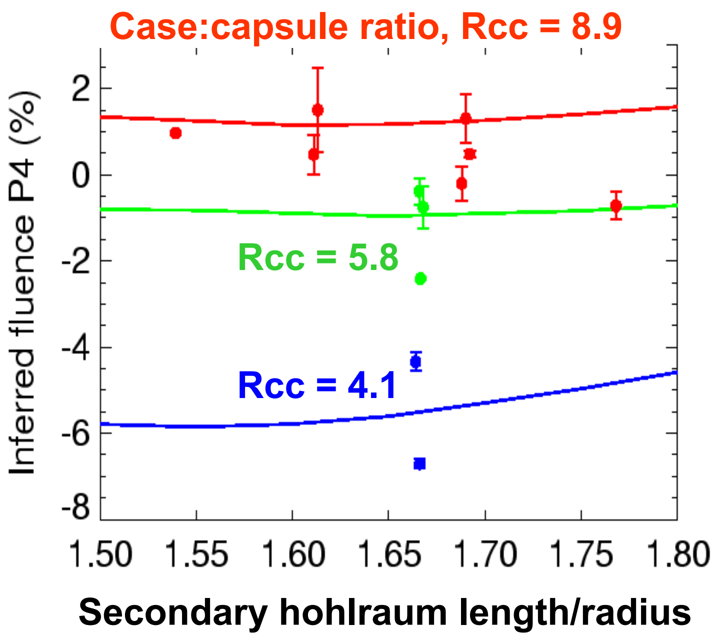


Experimental 6.7 keV x-ray backlit images

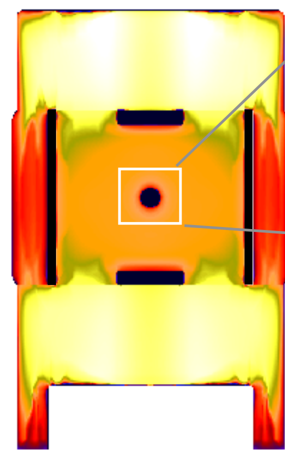


Symmetry experiments on Z provide a range of data to validate hohlraum simulations

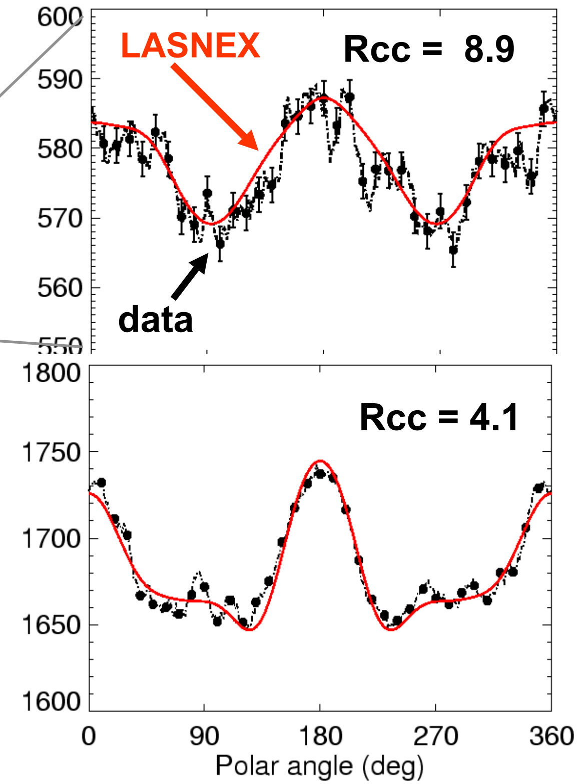
P_4 vs. length and capsule size compared to viewfactor calculations



2D LASNEX Radiation-MHD



Backlit capsule distortion vs. angle



Viewfactor and 2D LASNEX simulations are complementary tools for design and interpretation of experiments on Z and beyond

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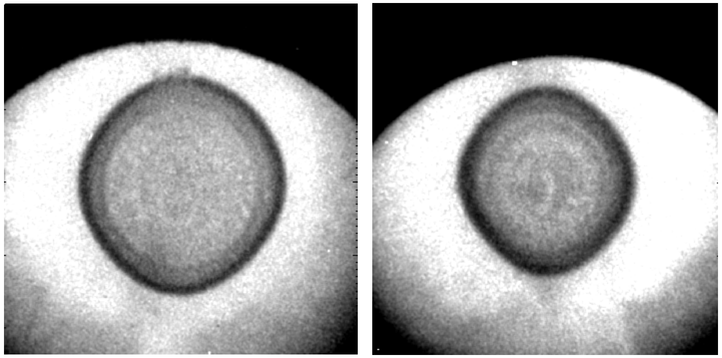
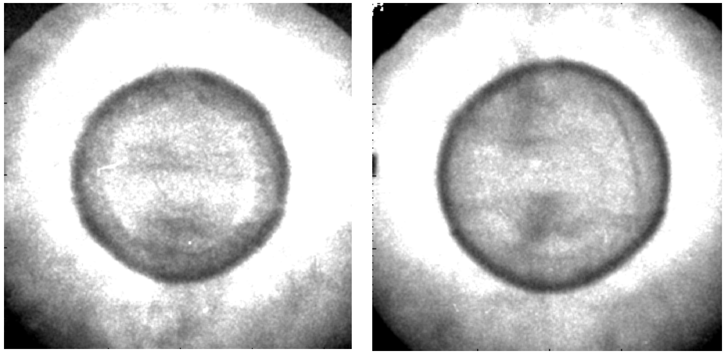
Larger 4.7-mm diameter capsules test symmetry control at relevant case-to-capsule ratios of ~ 4

- Measured P4 for small case to capsule ratios are all negative, ranging from -3% to -8%
- D. Callahan (LLNL) designed experiments to validate removal of early time radiation asymmetry by angle-dependent shims (Nucl. Inst. Meth. A, 2004)
- A. Nikroo (GA) developed the angle-dependent shim overcoating technique

Unshimmed capsules



Shimmed capsules



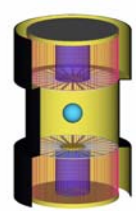
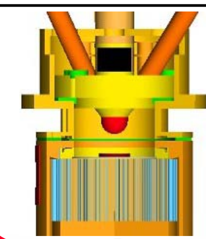
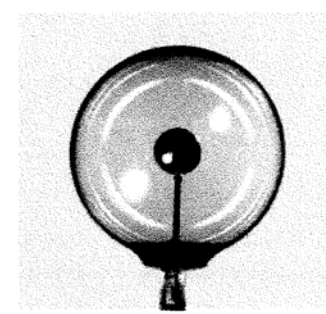
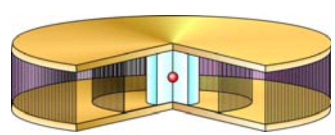
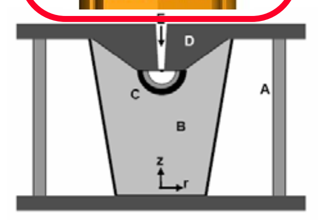
Inferred drive asymmetry

Unshimmed: P_2 = - 4 %, P_4 = - 6-8 %

Shimmed: P_2 = + 5-6 %, P_4 = - 3-4 %

This technique is relevant to heavy-ion fusion, z-pinch fusion, and NIF

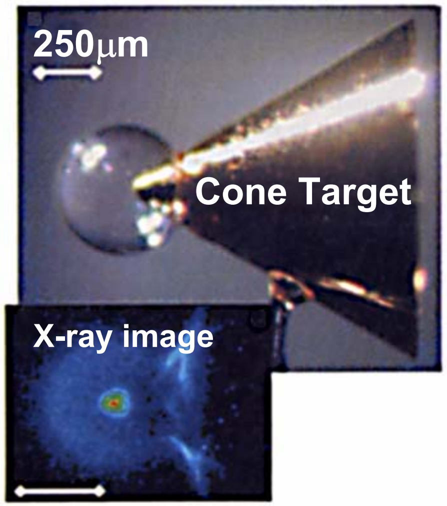
Pulsed-power drivers support a diverse research portfolio of ignition and high yield, high gain ICF options

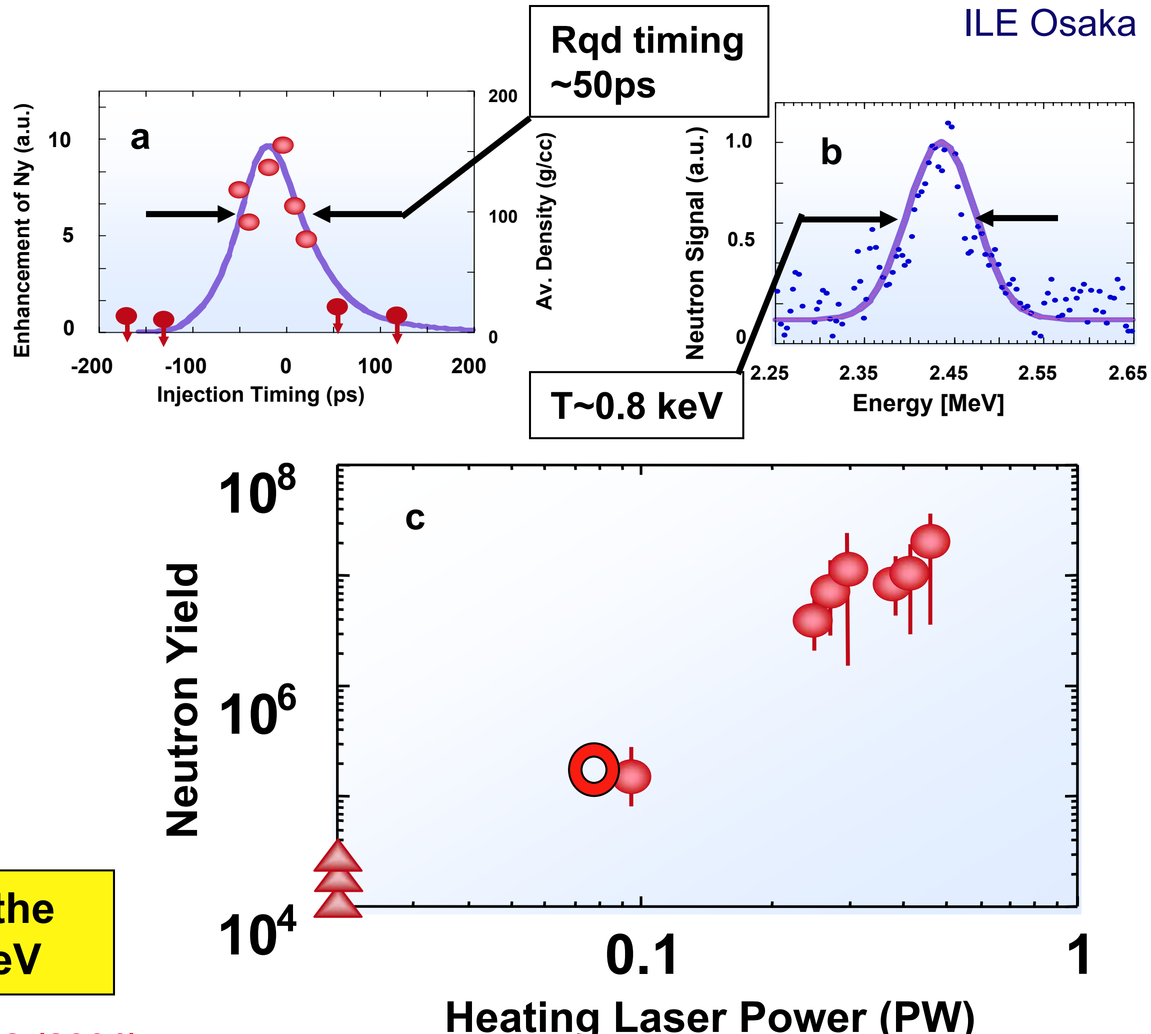
Driver		ICF Target: Cryogenic – Hot spot ignition	ICF Target: Cryogenic – Fast ignition	ICF Target: Non-cryogenic – Double shell
X-ray drive	Vacuum hohlraum			
	Dynamic hohlraum			

Integrated experiments at ILE show efficient heating

ILE Osaka

- Nine drive beams, 2.5 kJ
- 1/2 PW ignition beam
- Deuterated plastic target





300 J short pulse doubled the core plasma temp to 0.8 keV

R. Kodama, et al., Nature 412, 798 (2001).

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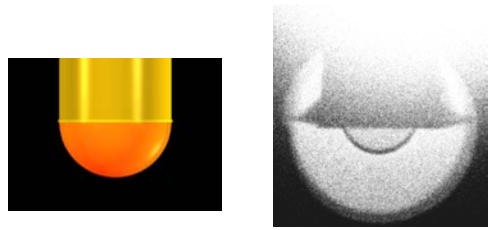
Hemispherical implosions are being developed on Z for fast ignition fuel assembly

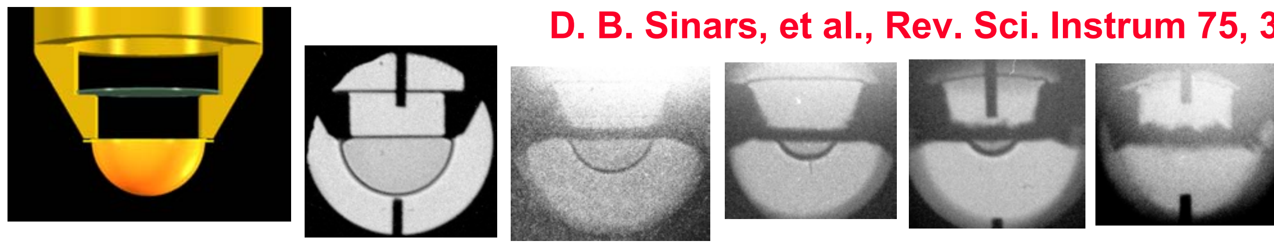
ϕ2.0mm, 60μm thk GDP hemi-shell on flat gold surface



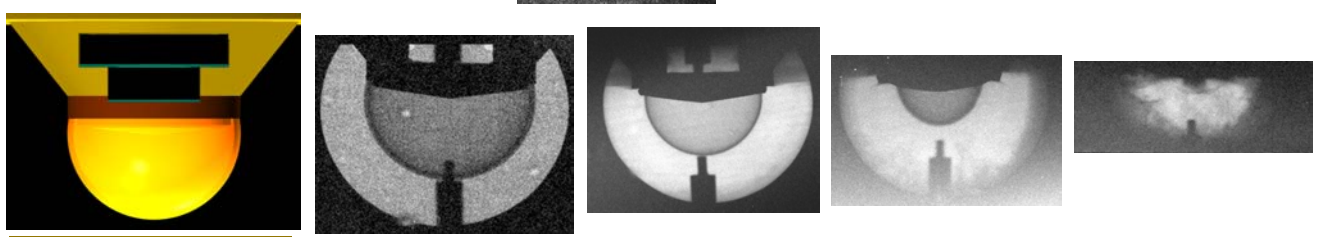
Capsule images obtained with ZBL point-projection backlighting and 6.151 keV monochromatic crystal imaging

D. B. Sinars, et al., Rev. Sci. Instrum 75, 3672 (2004)

ϕ2.0mm, 60μm thk GDP hemi-shell on 30μm thk gold disc



ϕ3.0mm, 110μm thk GDP hemi-shell on 8 deg surface



ϕ3.0mm, 110μm thk GDP hemi-shell on 12 deg surface

R. A. Vesey, et al., Phys. Plasmas, (2003).
D. L. Hanson, et al., Proc. IFSA 2003.
R. A. Vesey, et al., submitted to FS&T (2004).

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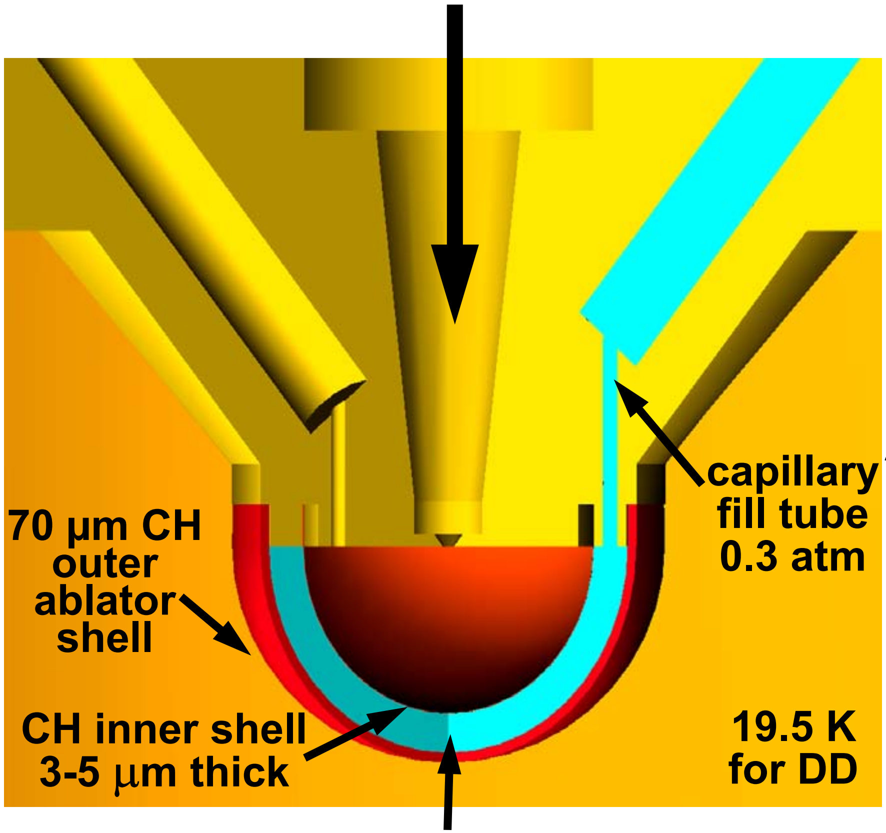
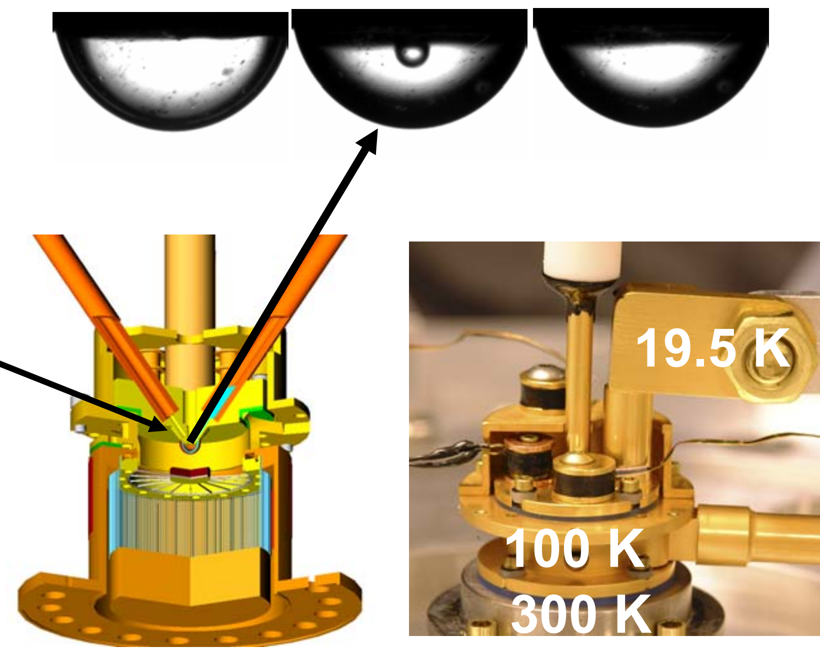
Hemispherical capsule provides a uniquely convenient mount for a cryogenic liquid fuel target



Successful test of condensation of liquid D_2 in outer ablator shell at 19.5 K

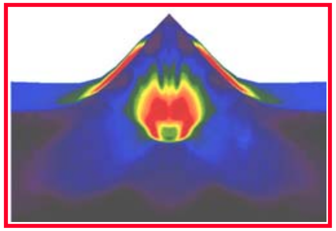


M. Knudson, D. L. Hanson, et al., Phys. Rev. Lett., (2001).
D. L. Hanson, et al., submitted to FS&T (2004).

First Z experiments planned for March 2005

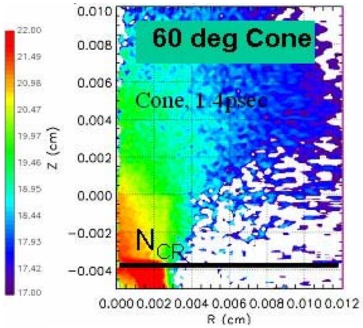
Fast ignition experiments for Z are being designed with analytic models and multidimensional simulations

- 2D MHD simulations show cryogenic liquid fuel can be compressed to high density
  - ρ_{max} ~ 300 g/cc; ρz ~ 2 g/cm^2



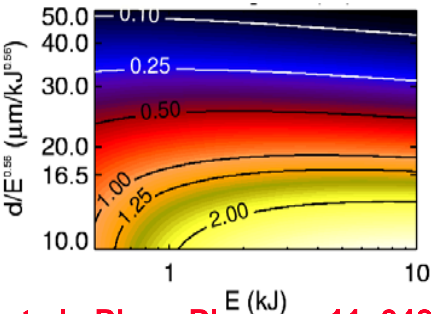
R. A. Vesey, et al., submitted to FS&T (2004).

- LSP (3D hybrid PIC code) simulates high energy, high power laser matter interactions
  - Benchmarked with GEKKO/PW data



R. B. Campbell, et al., submitted to Phys.Rev.Lett. (2004).

- Analytic models have been developed to assess $E_{fusion}/E_{deposited}$



S. A. Slutz, et al., Phys. Plasmas 11, 3483 (2004).

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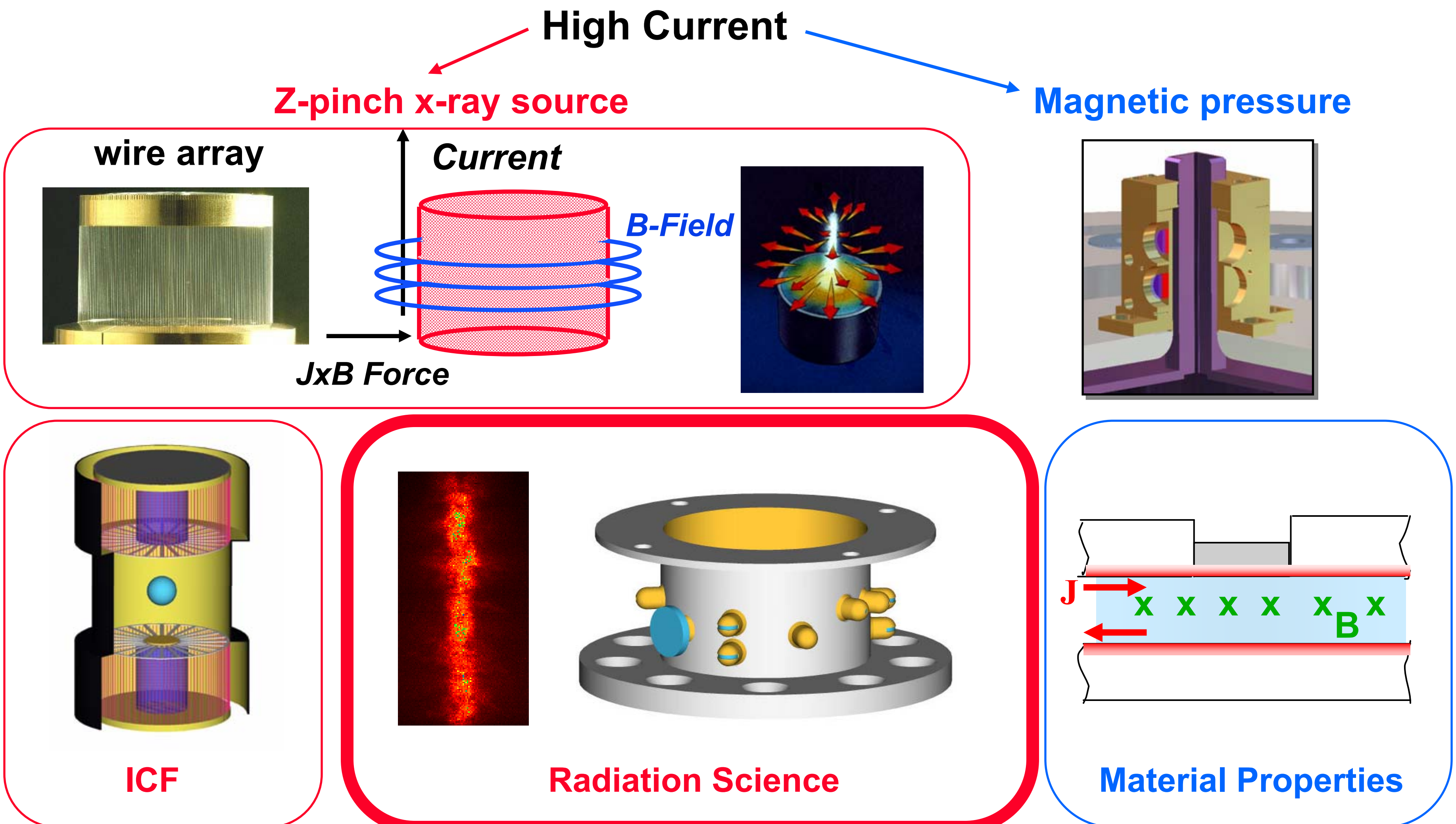
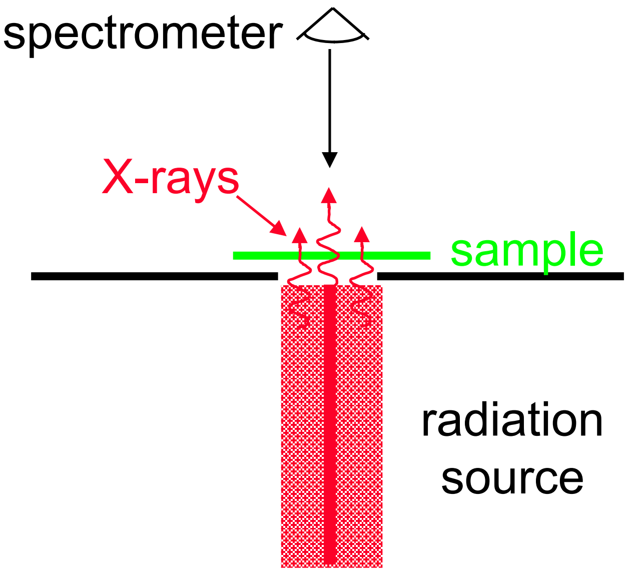
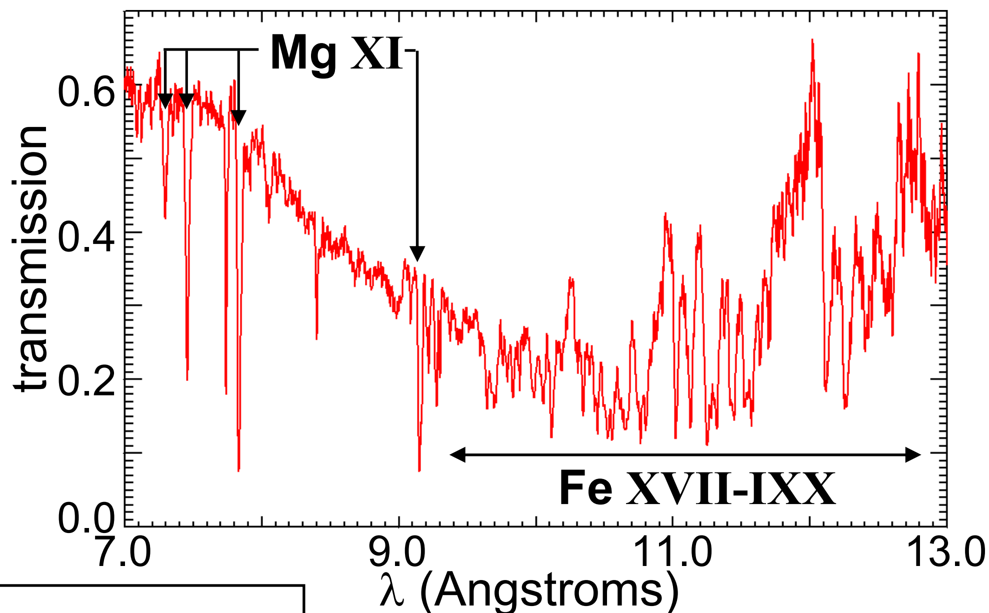
High current pulsed power accelerators drive many different load configurations



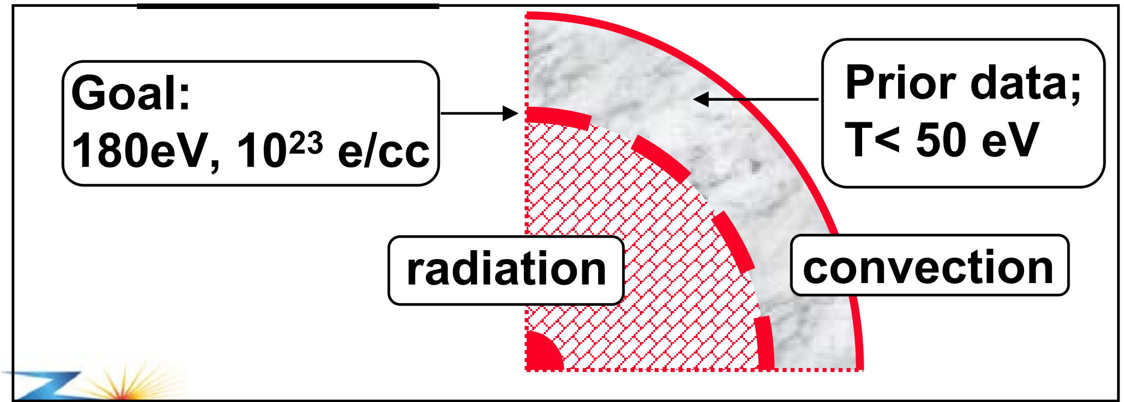
Z experiments extend laboratory opacity measurements beyond T ~ 150 eV for the first time



Fe + Mg transmission at
T_e ~ 160 eV, n_e ~ 10^{22} cm^{-3}



Solar Model



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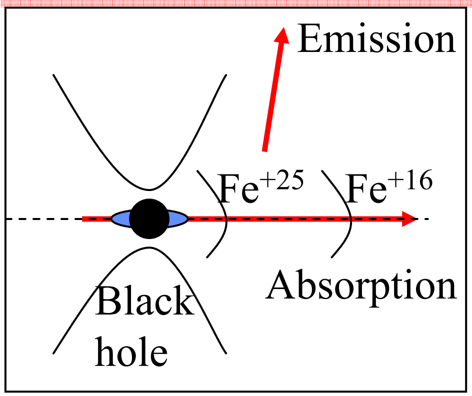
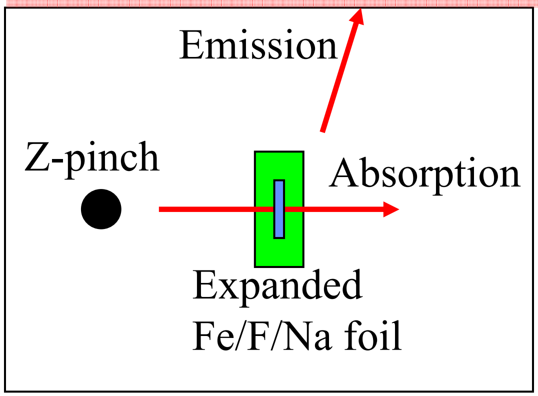
Plasmas in Photoionization Equilibrium include neutron star and black hole accretion disks and, now, tamped Fe:NaF foils illuminated by Z-pinch X-rays

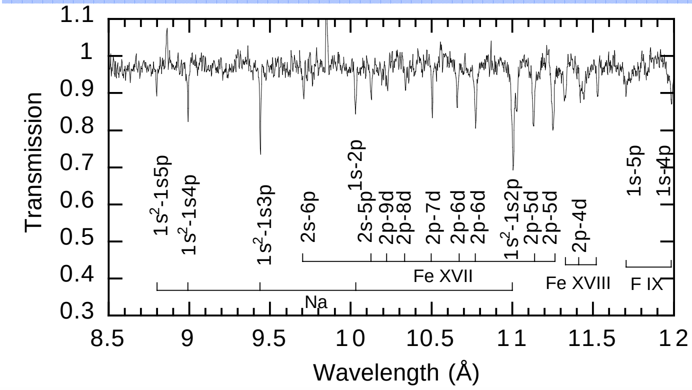
An Active Galaxy's Nucleus



Experiments at Sandia Z Facility



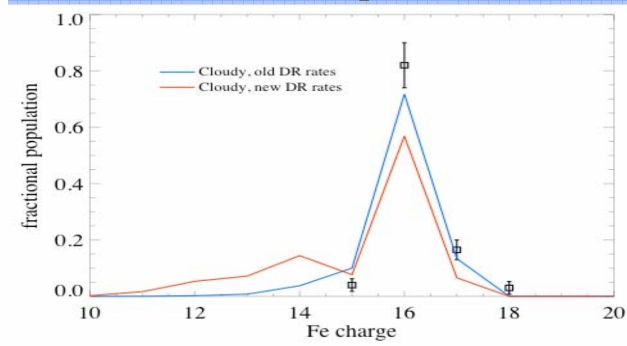
Absorption spectra indicate L-shell Fe(+16), K-shell Na(+9) and F(+8) were produced



Scaling these plasmas into the laboratory requires the photoionizing X-ray flux (Γ_{rad}) be dominant over collisional ionization (~N_e):

Astrophysical Plasma		***Experiment***
$N_{Fe}L = 10^{17}$ cm^{-2}	*(match absorption)*	$N_{Fe}L = 10^{17}$ cm^{-2}
$N_e = 10^2$ cm^{-3}	*(equilibrium, no 3-body)*	$N_e = 10^{19}$ cm^{-3} *(few ns)*
$\xi_{ion}\mu\Gamma_{rad}/N_e = 1\text{–}1000$	*(photoionization)*	$\xi_{ion}\mu\Gamma_{rad}/N_e = 20$

Charge state distribution for iron: Cloudy 1-D simulation vs. experimental result

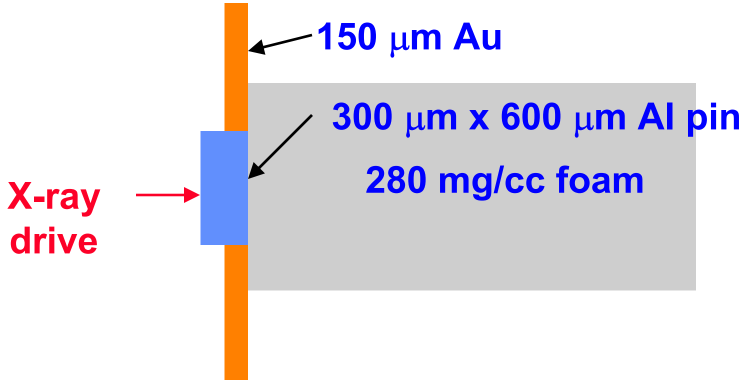


See e.g. ***Phys. Rev. Lett. 93***, *055002 (2004)* by M.E. Foord, R.F. Heeter, et al., (an LLNL – Sandia – Queen's Univ. Belfast – Oxford University Collaboration).

G. Ferland's code Cloudy (b. 1978) is now used in over 70 astro publications/year

The new laboratory data are now being used to benchmark models which have been developed by X-ray astrophysicists for over 25 years, as well as HED plasma codes

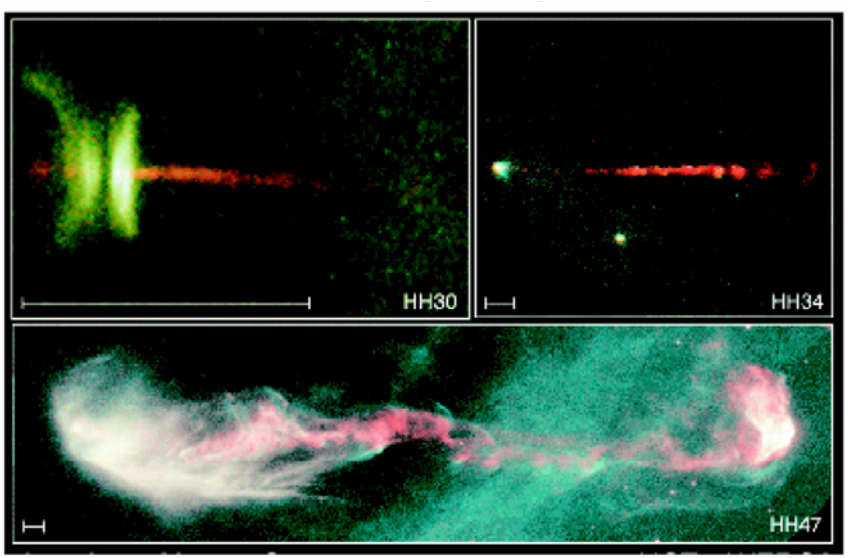
In addition to astrophysical relevance and basic science, jet data can help benchmark various radiation-hydrodynamics codes used in HEDP/ICF



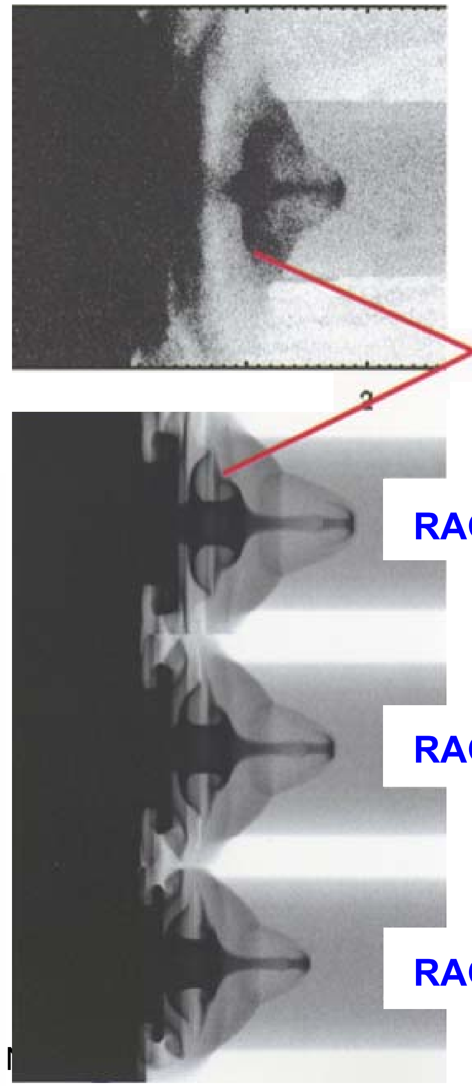
Z jet experiments have been designed with Los Alamos' RAGE code

(Radiation Adaptive Grid Eulerian)

Jets from young stars



10 μm resolution over 4x20 mm image



Structure behind jet is due to shearing between Al pin and Au washer that RAGE is not doing correctly

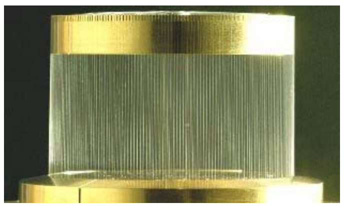
[Bennett *et al*. EP1.015]

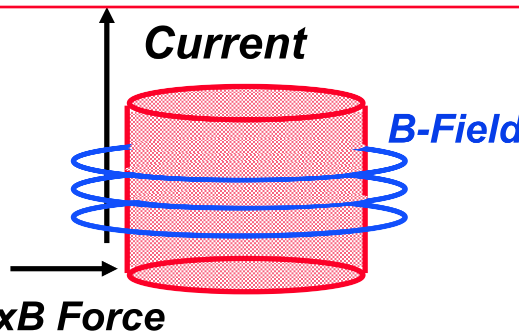
High current pulsed power accelerators drive many different load configurations

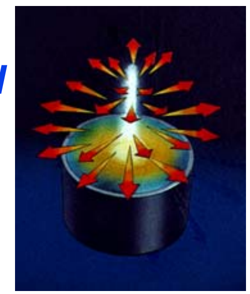
High Current

Z-pinch x-ray source

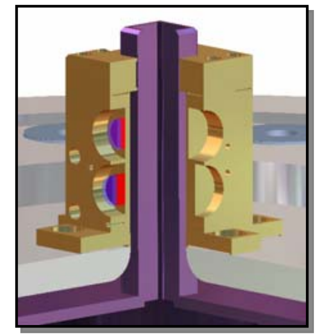
wire array

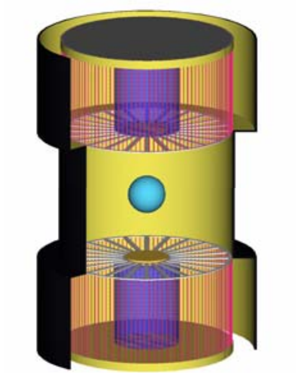




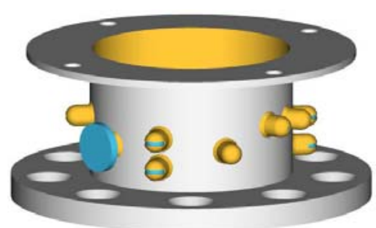


Magnetic pressure

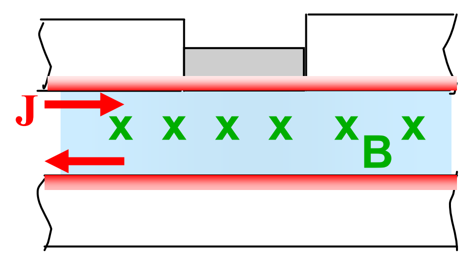




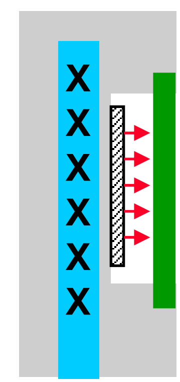
ICF



Radiation Science

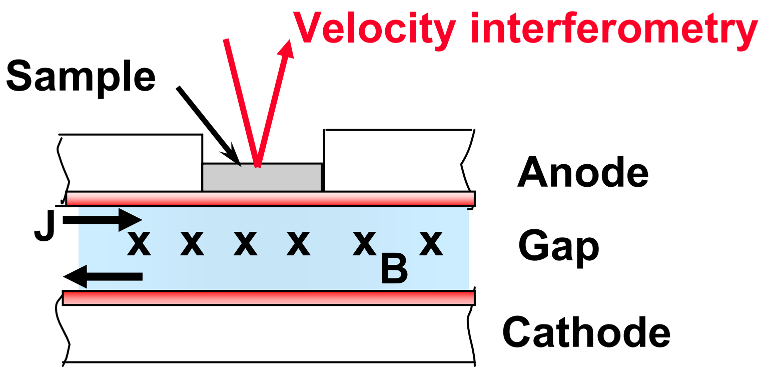


Isentropic Compression



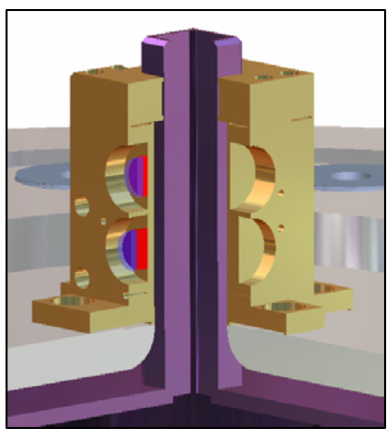
Flyer Plate

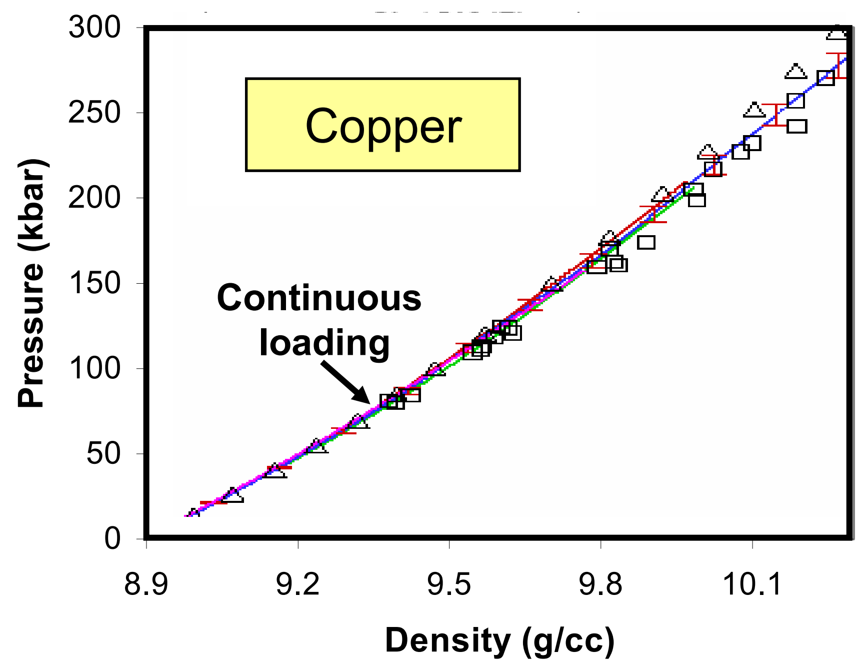
The (quasi) isentropic loading technique is providing new opportunities for material property studies



$$B = \mu_0 J$$

$$P = B^2 / 2\mu_0$$





- Shockless loading for 200-300 ns
- Multiple experiments/shot (4-12)
- Identical loading (A-B comparison)
- Versatile (simultaneous Lo/Hi T)

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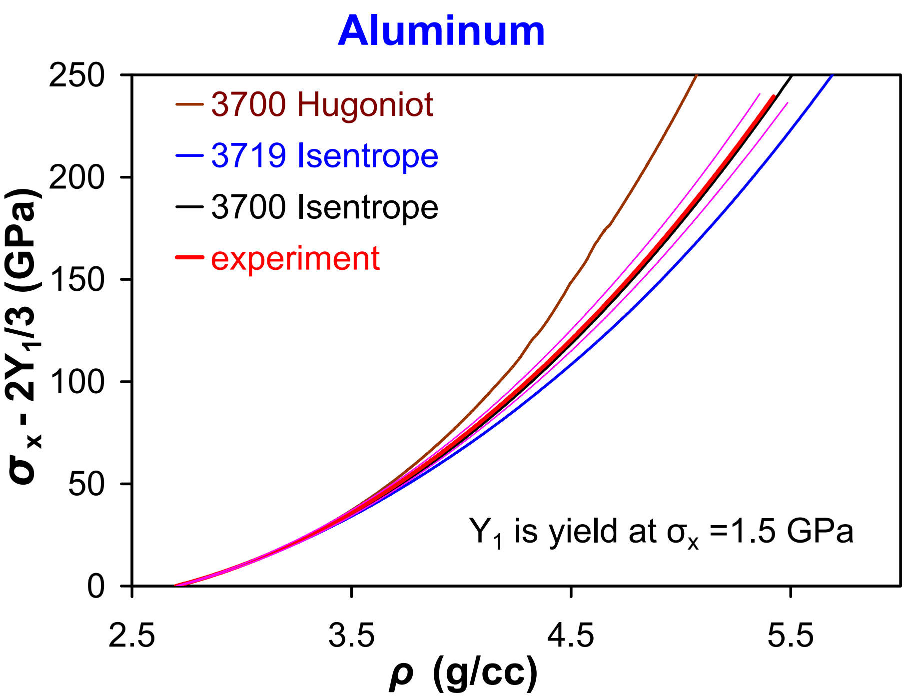
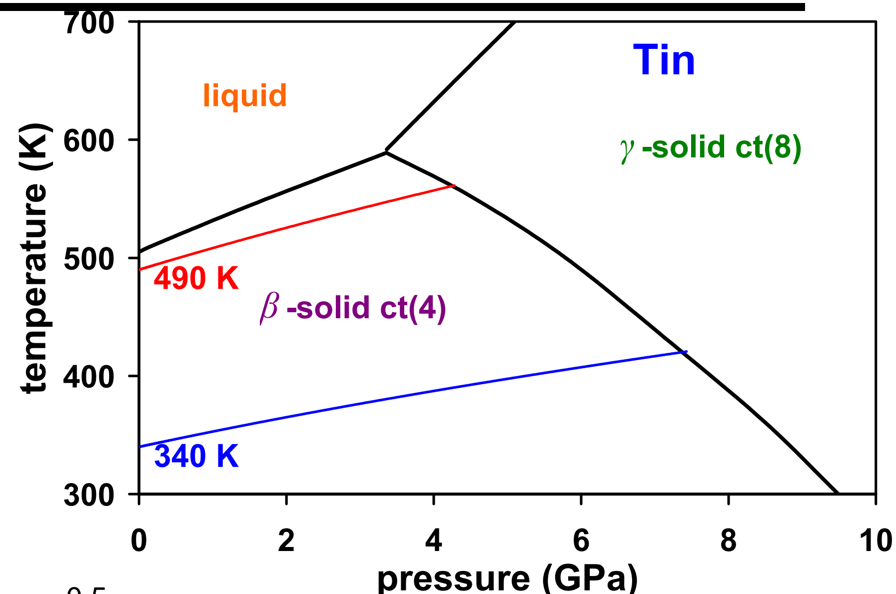
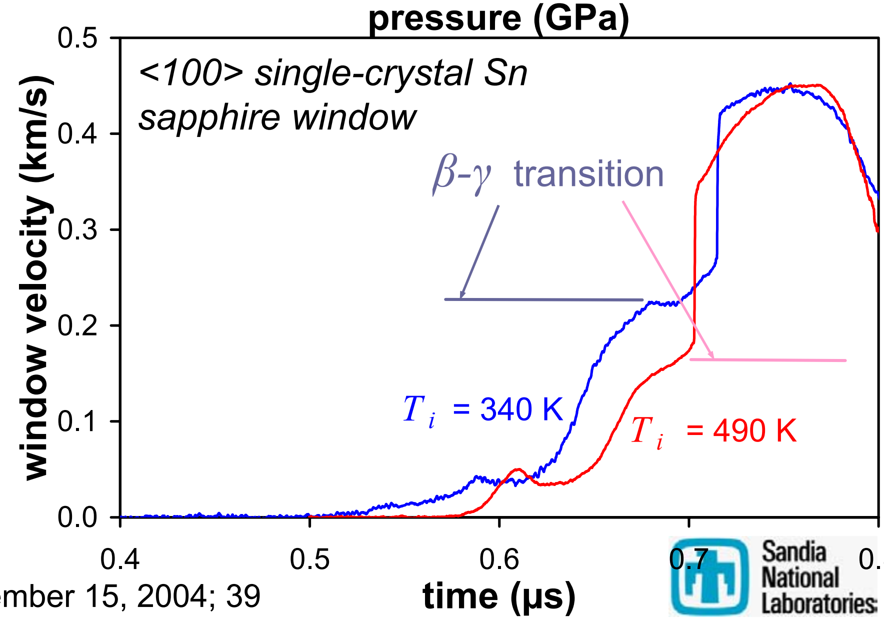
We have measured an isentrope to 2.5 Mbar for Al, and have demonstrated the measurement of a phase boundary

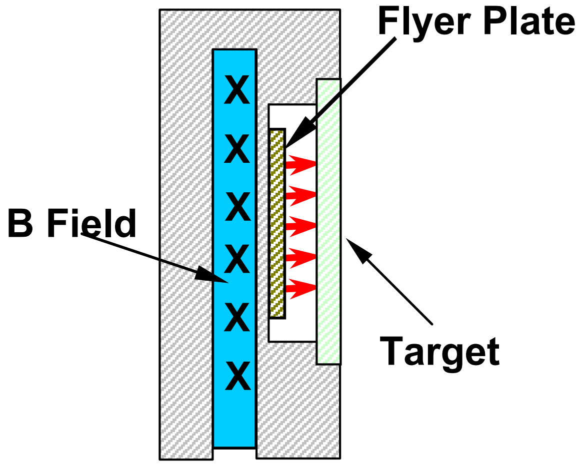


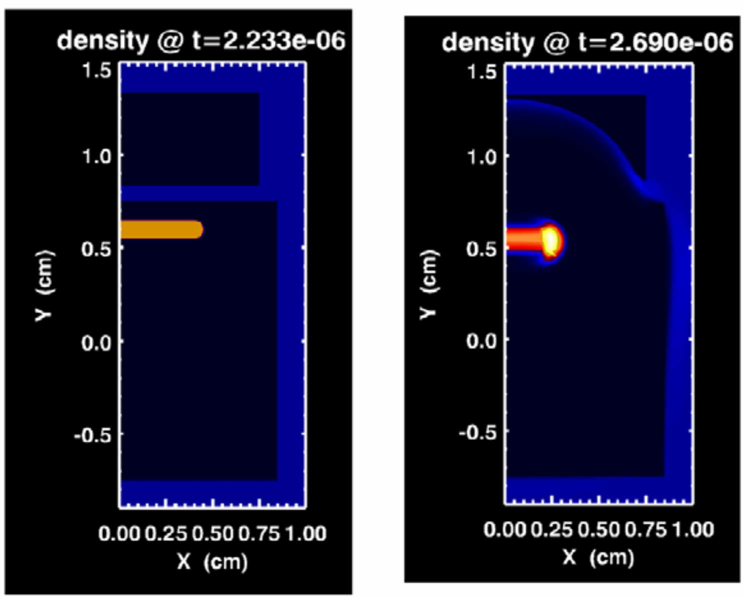
J. P. Davis [EI2.004]



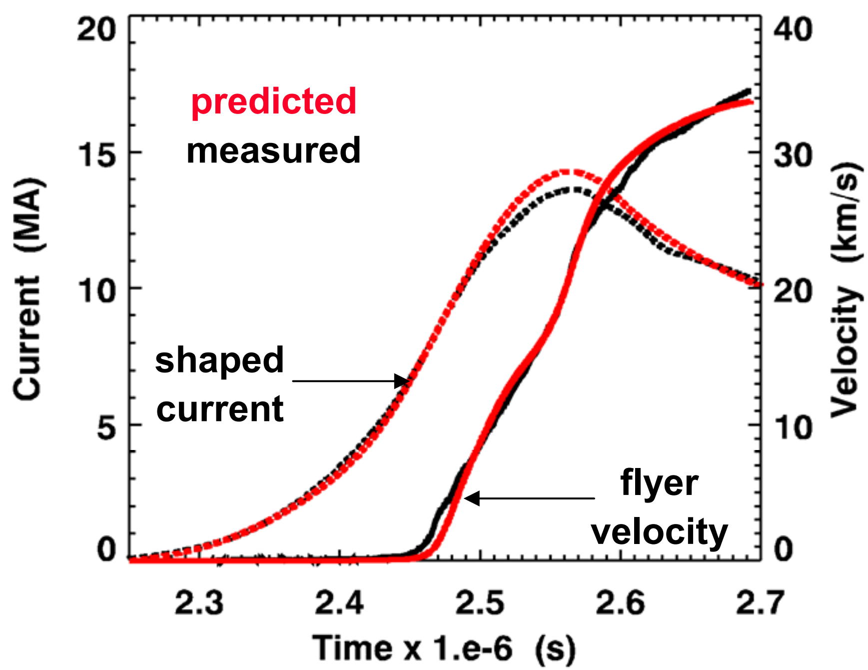


Achieving high flyer plate velocities is the result of close coupling between simulations and experiments





Flyer plate accelerated to 33 km/s



Max(B) ~ 11 MG; Max($B^2/8\pi$) ~ 4.9 Mbar

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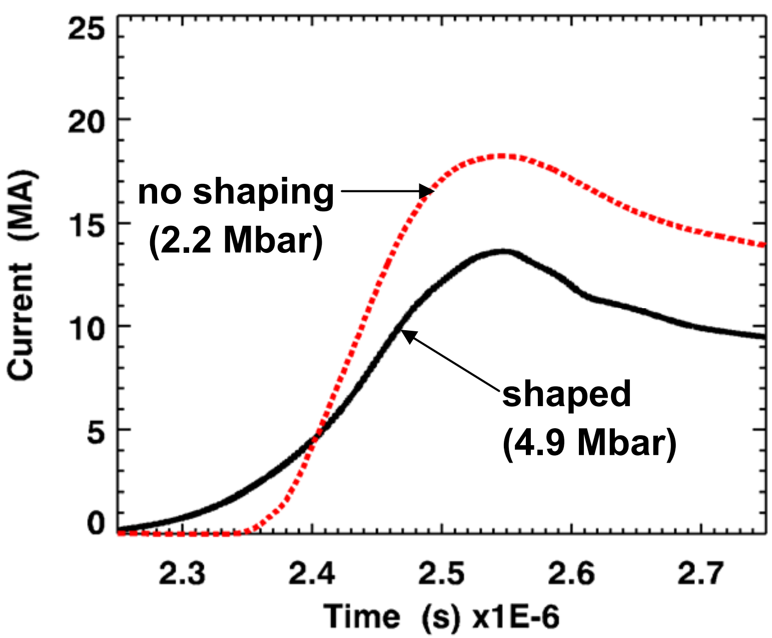
Peak velocity of flyer useful for EOS experiments increased by factor of ~1.7 via pulse shaping

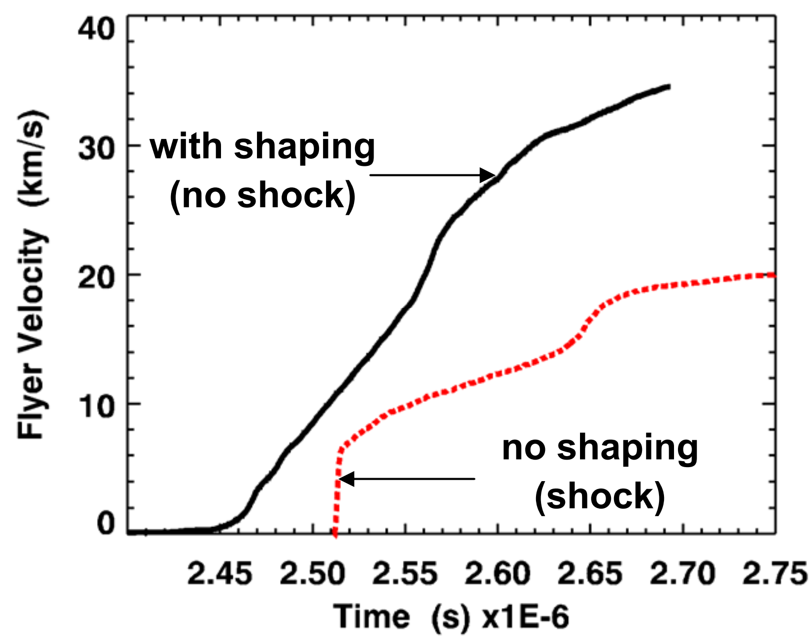
- **Shaping the current pulse enabled:**
  - Deuterium EOS to 1.4 Mbar
  - High-Z Hugoniot expts to > 20 Mbar
  - Al strength measurements to 2.4 Mbar
    - J. P. Davis [EI2.004]

A fraction of flyer remains at solid density for accurate EOS measurements

Measured drive current

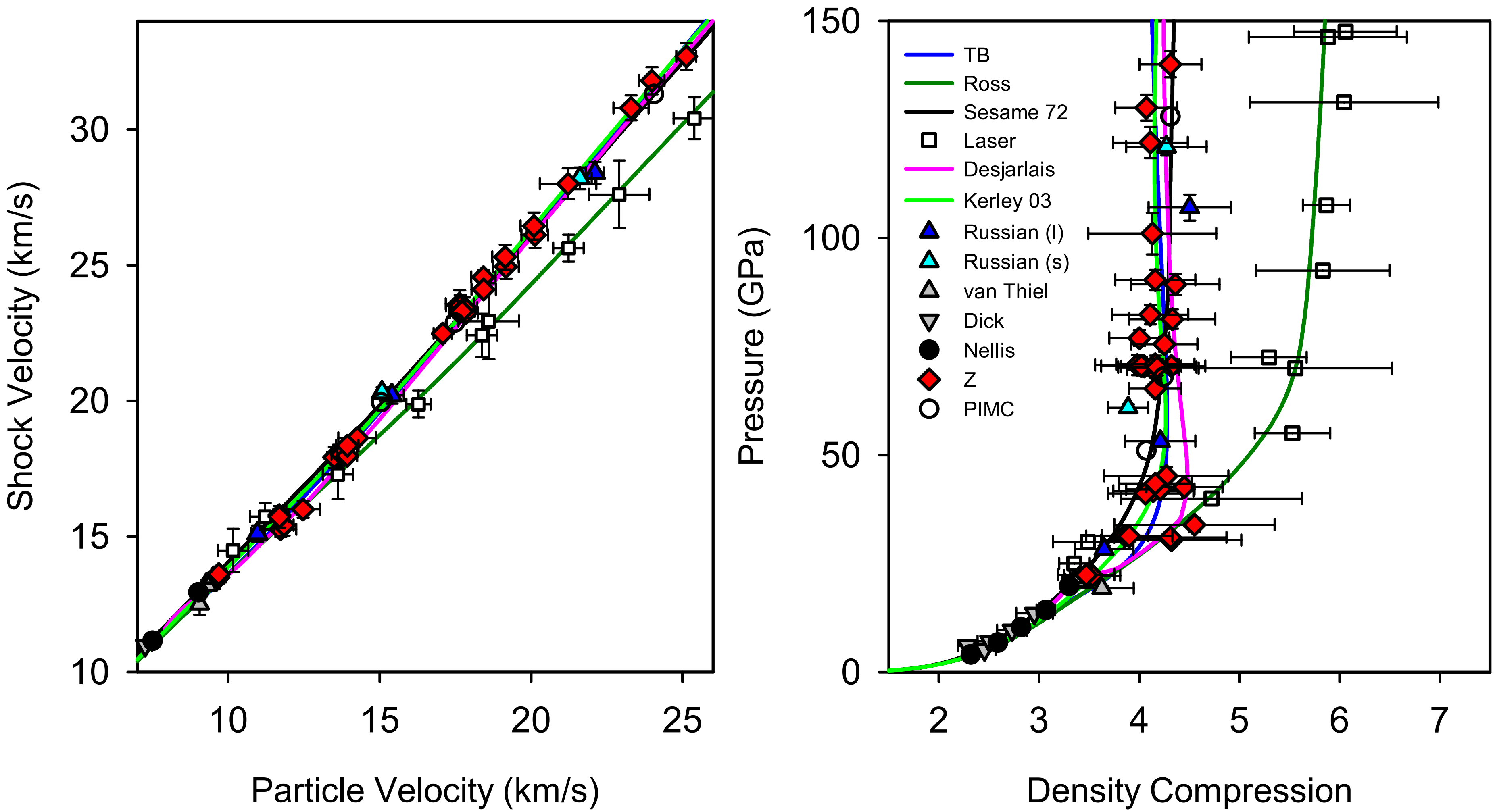


Measured flyer velocity 850 µm Al



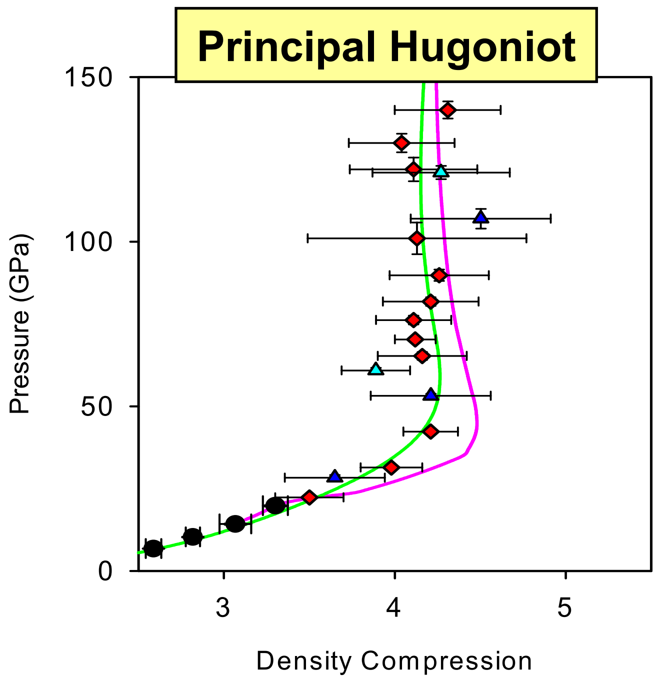
National Laboratories

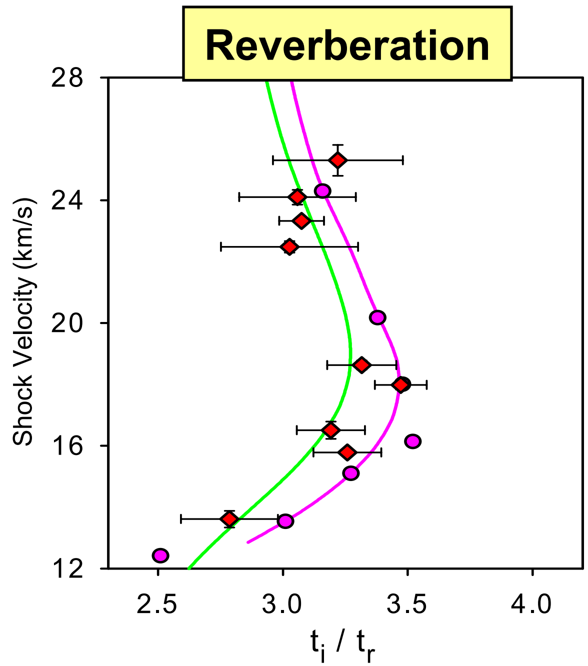
Data to 1.4 Mbar obtained on liquid D_2 helps resolve discrepancy in high-pressure response

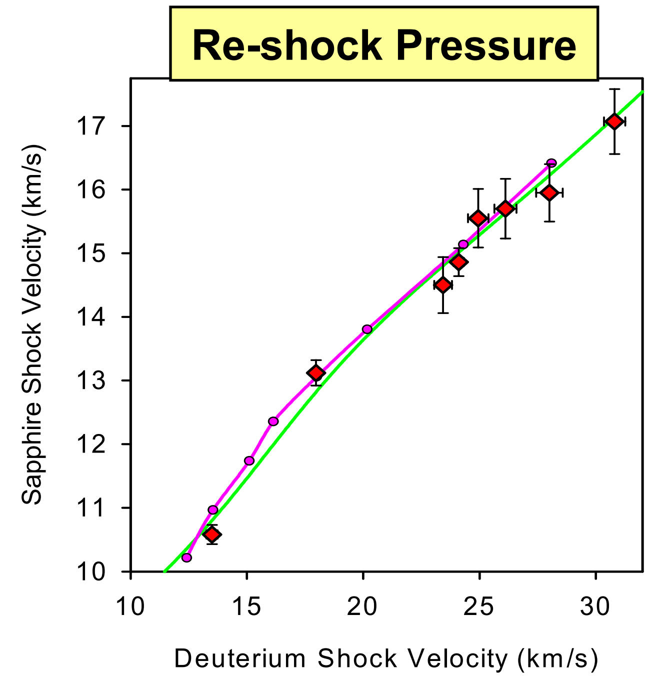


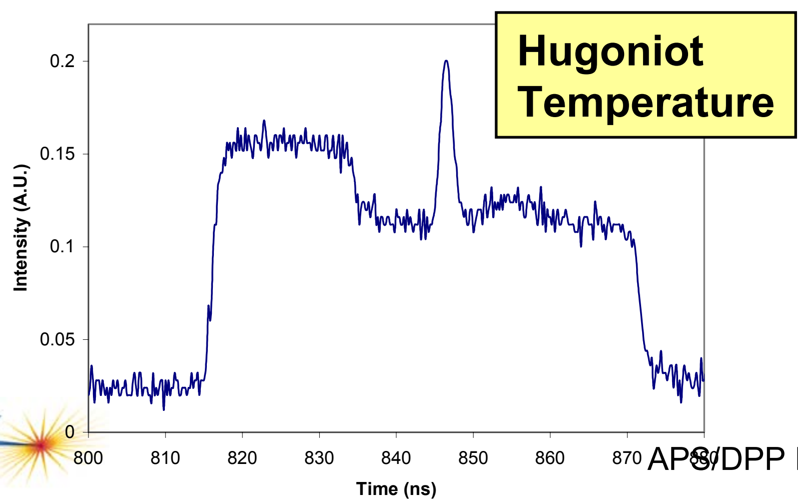
M.D. Knudson, et al., Phys. Rev. Lett. 87, 225501 (2001); Phys. Rev. B 69, 144209 (2004)

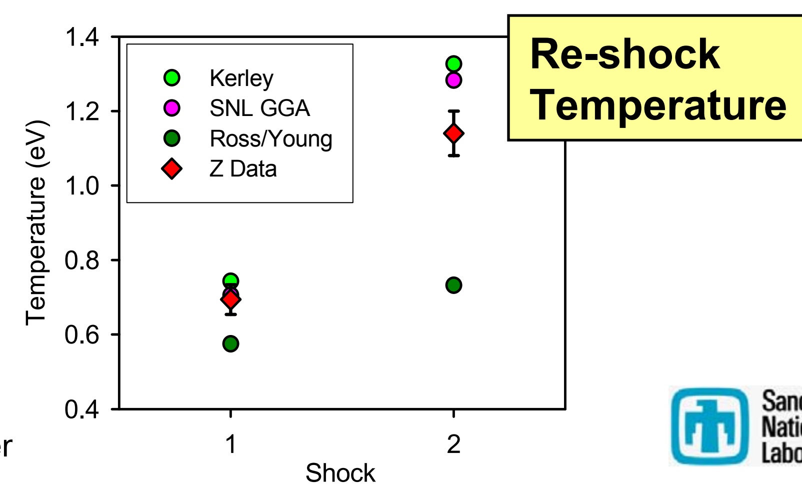
Independent, self-consistent measurements for D_2 are in agreement with *ab-initio* models to 1.4 Mbar







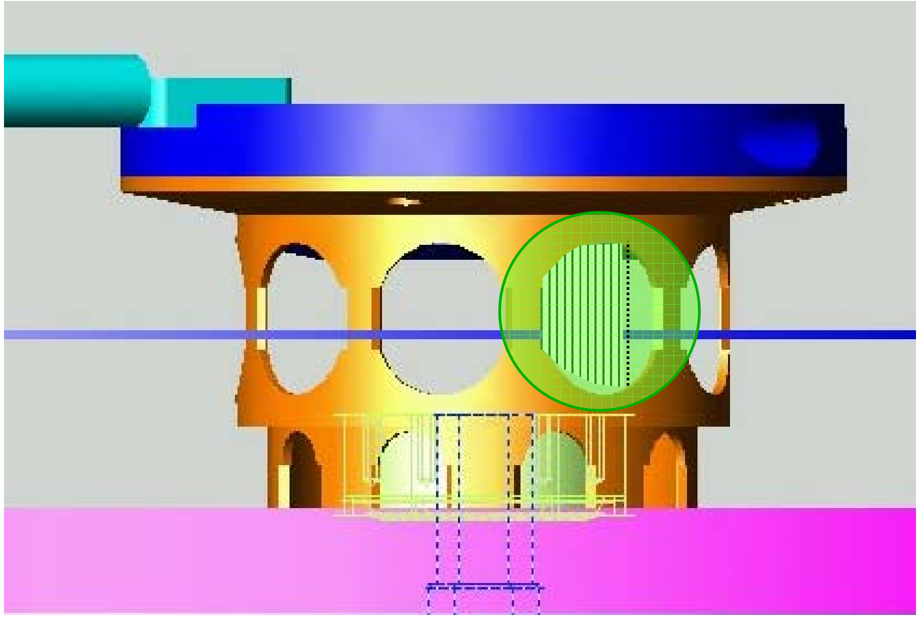




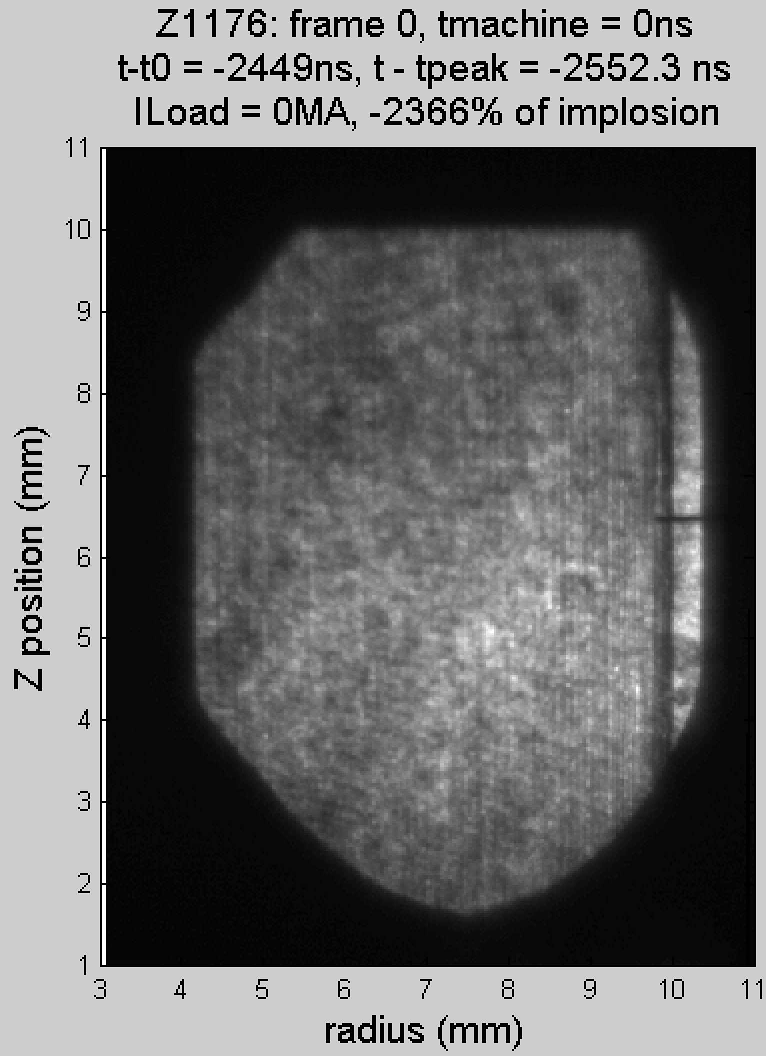
Outline

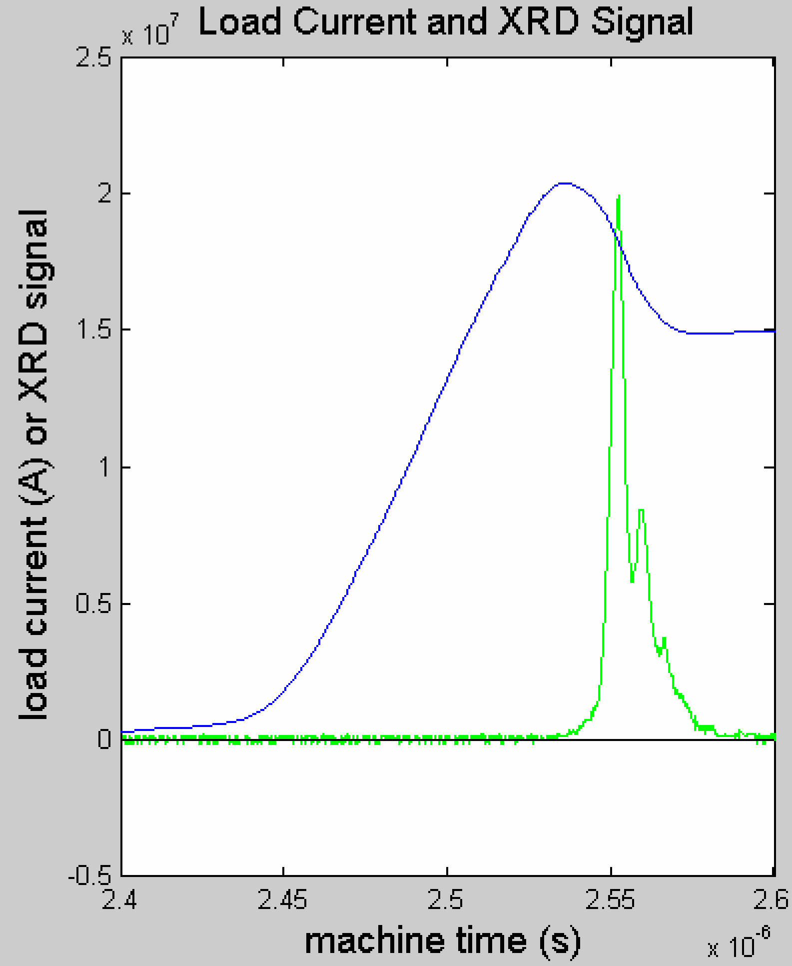
- Introduction
- Inertial Confinement Fusion
  - High temperature implosions
  - Symmetry of radiation drive
  - Fast ignition
- Radiation science
- Material properties
- Z-pinch physics/ALEGRA
- Ongoing capability enhancements
  - Z-Refurbishment
  - Z-Beamlet to high power (Z-Petawatt)
- Z-Pinch Inertial Fusion Energy

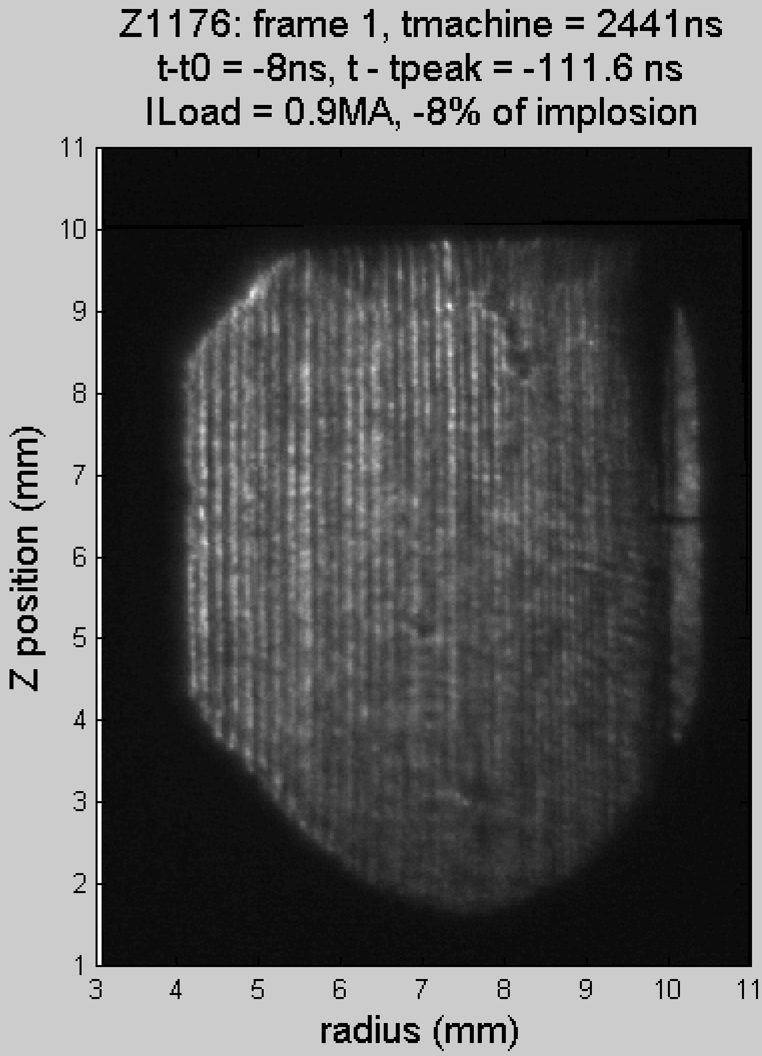
A set of six laser shadowgraphs, registered in both space and time, provides a great basis for insight into the dynamics of wire array implosions on Z



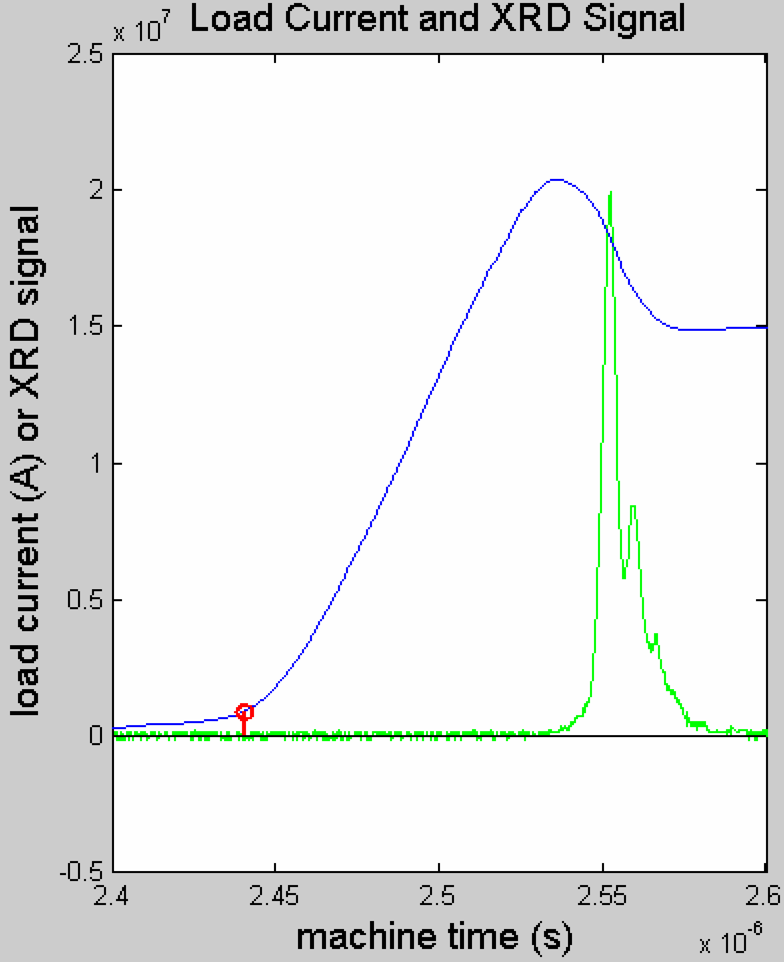
Material: W
Array Diameter: 20 mm, 300 wires
Array Height: 10 mm
Wire Φ: 11.5 μm
Array Mass: 6 mg


Z1176: frame 0, tmachine = 0ns
t-t0 = -2449ns, t - tpeak = -2552.3 ns
ILoad = 0MA, -2366% of implosion
Z position (mm)
radius (mm)

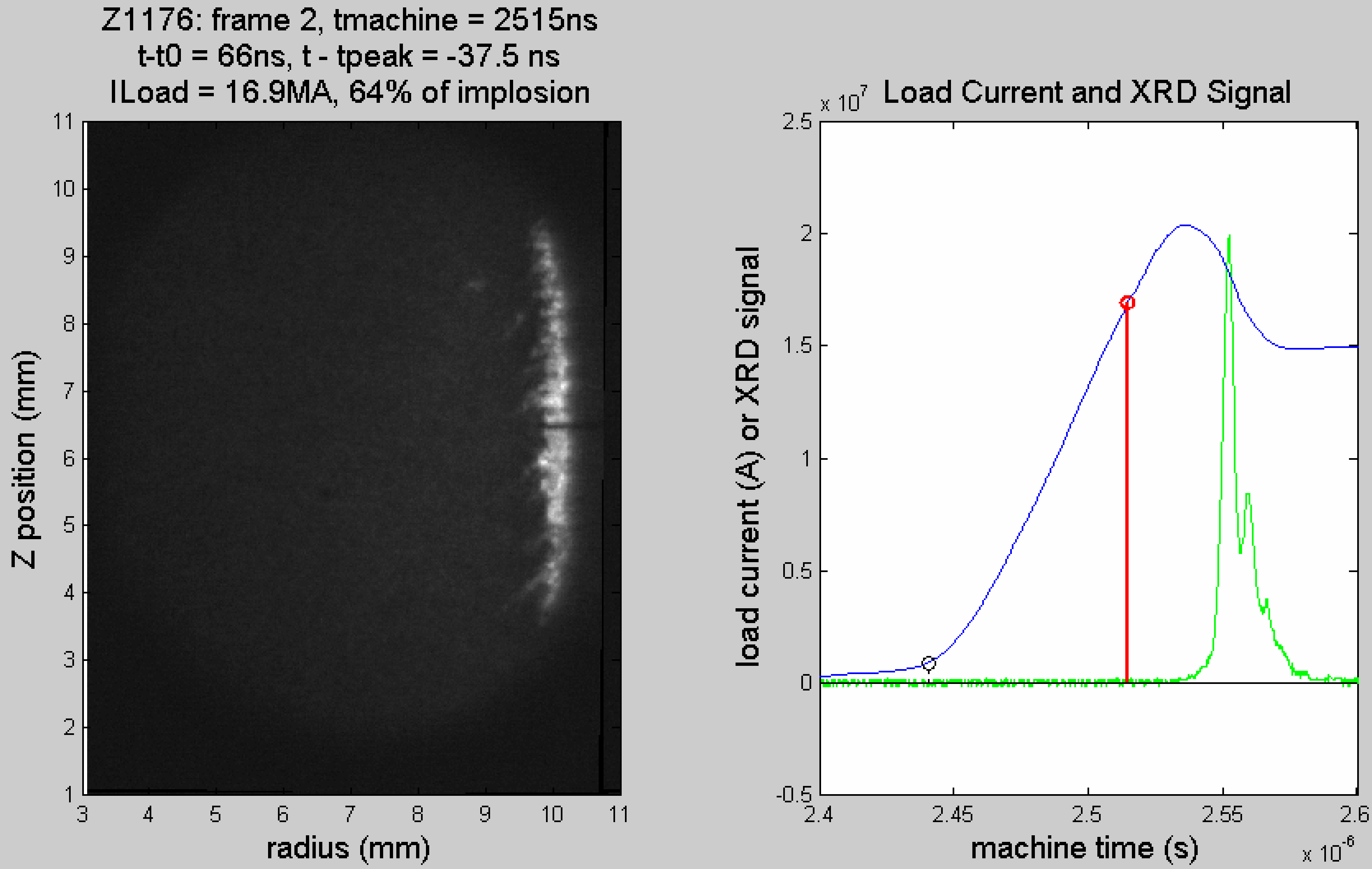

Load Current and XRD Signal
x 10^7
load current (A) or XRD signal
machine time (s)
x 10^-6



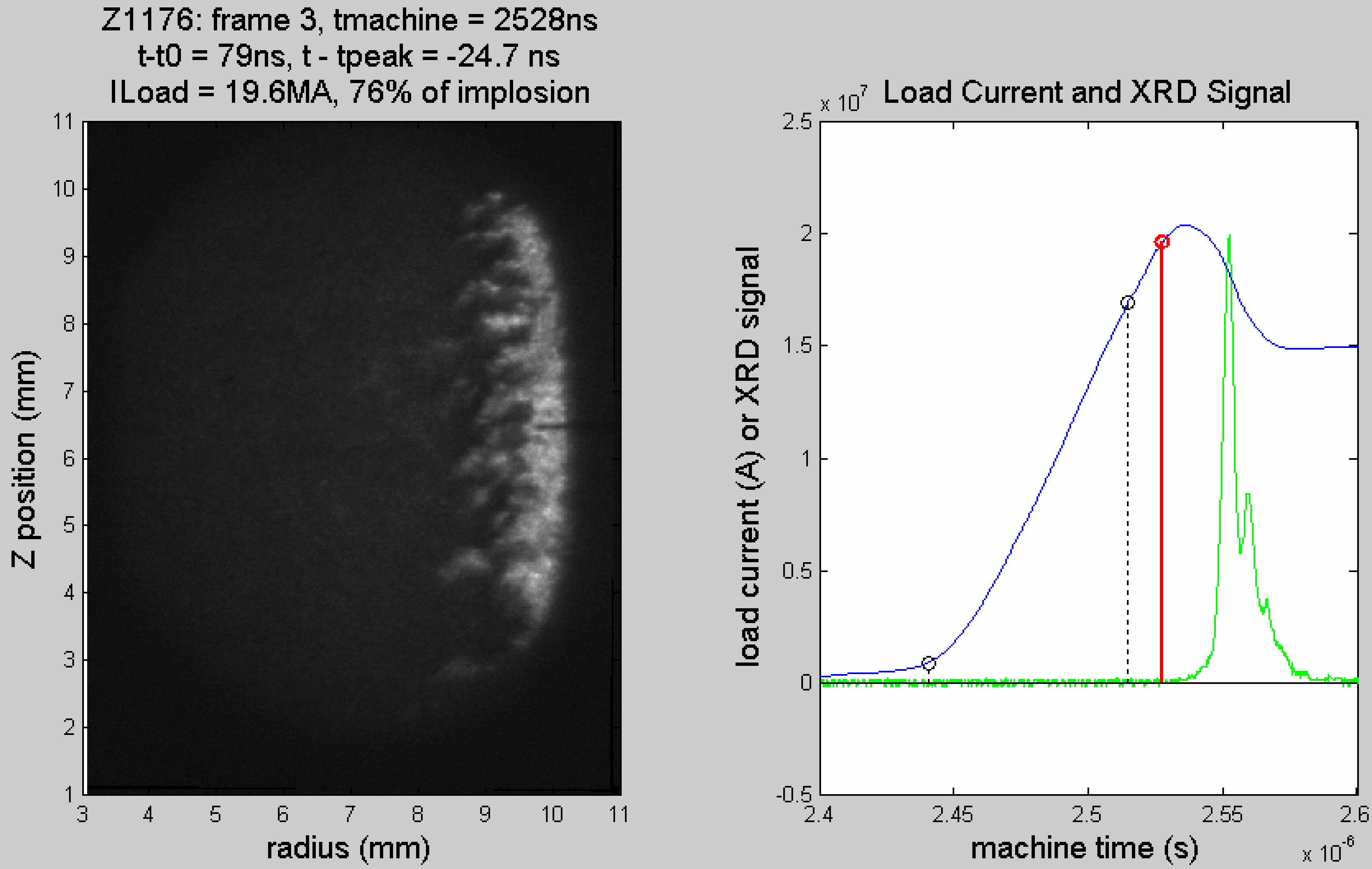
Z1176: frame 1, tmachine = 2441ns
t-t0 = -8ns, t - tpeak = -111.6 ns
ILoad = 0.9MA, -8% of implosion
Z position (mm)
radius (mm)

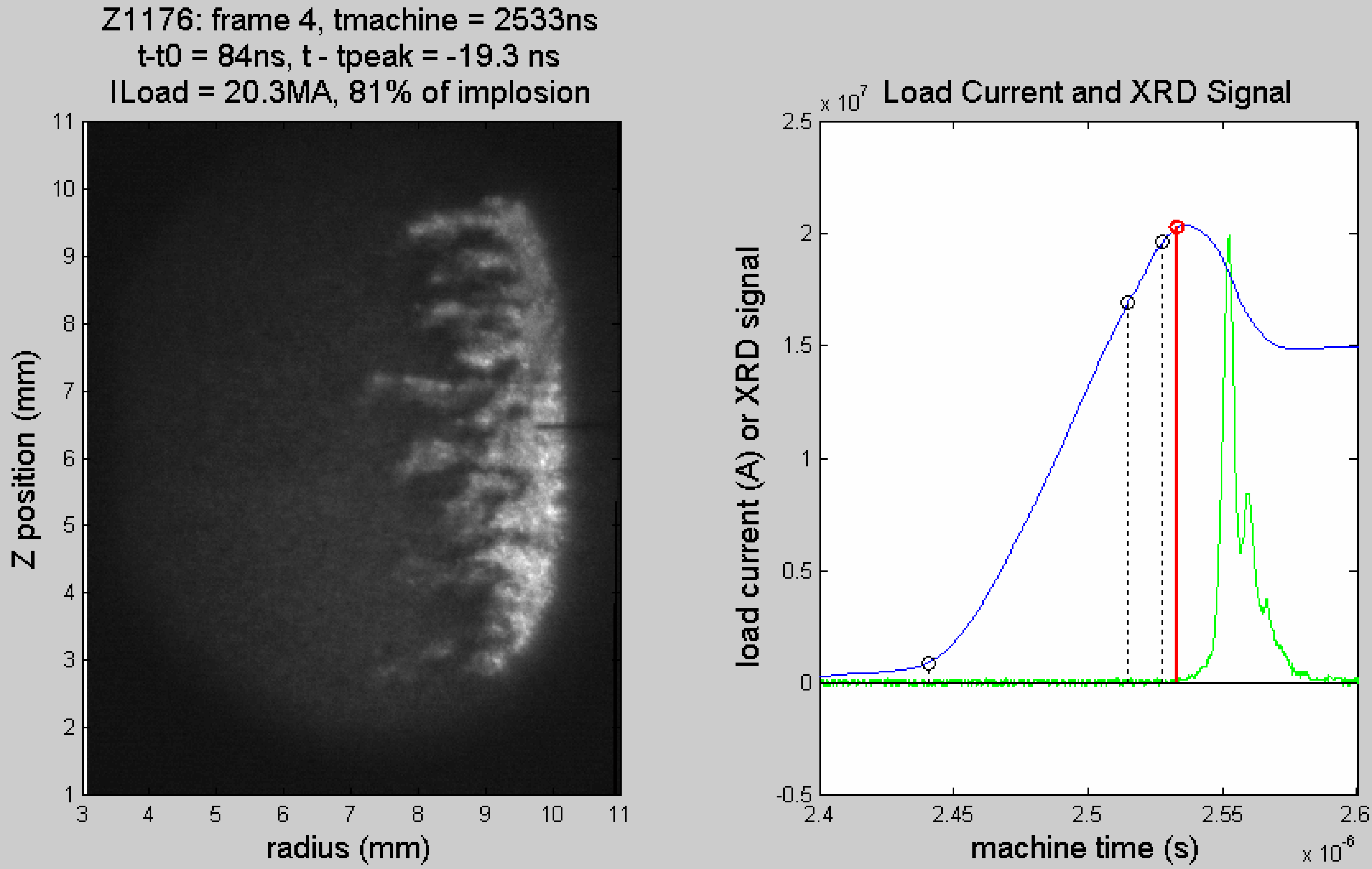


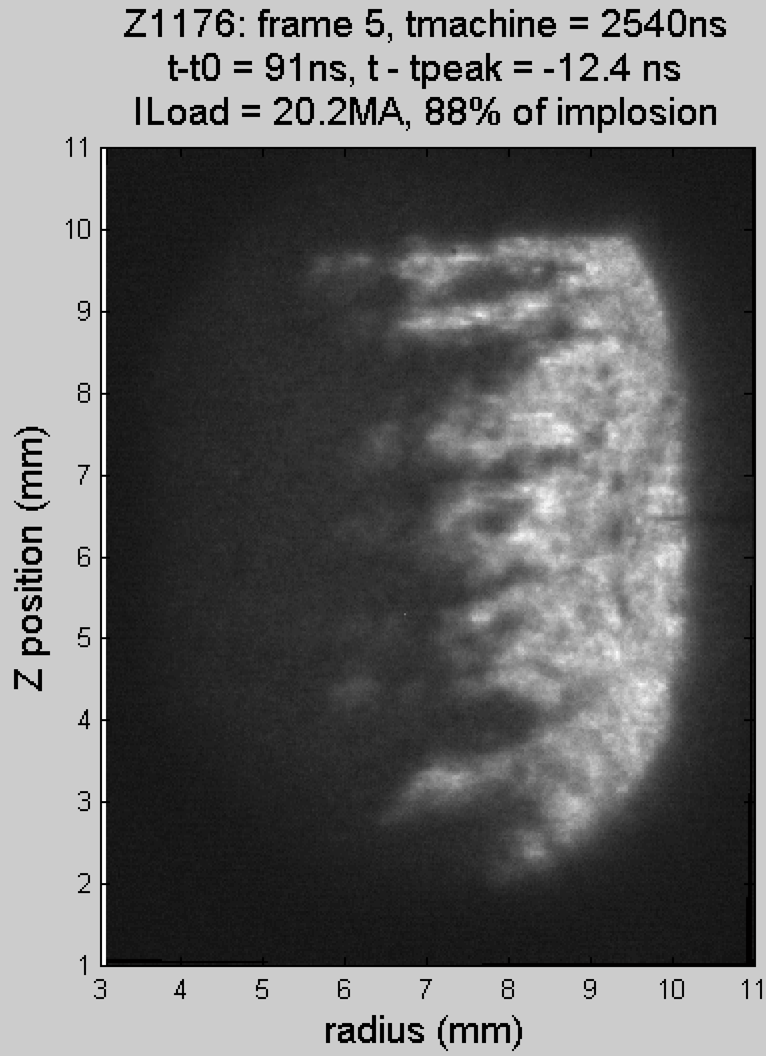
Load Current and XRD Signal
x 10^7
load current (A) or XRD signal
machine time (s)
x 10^-6



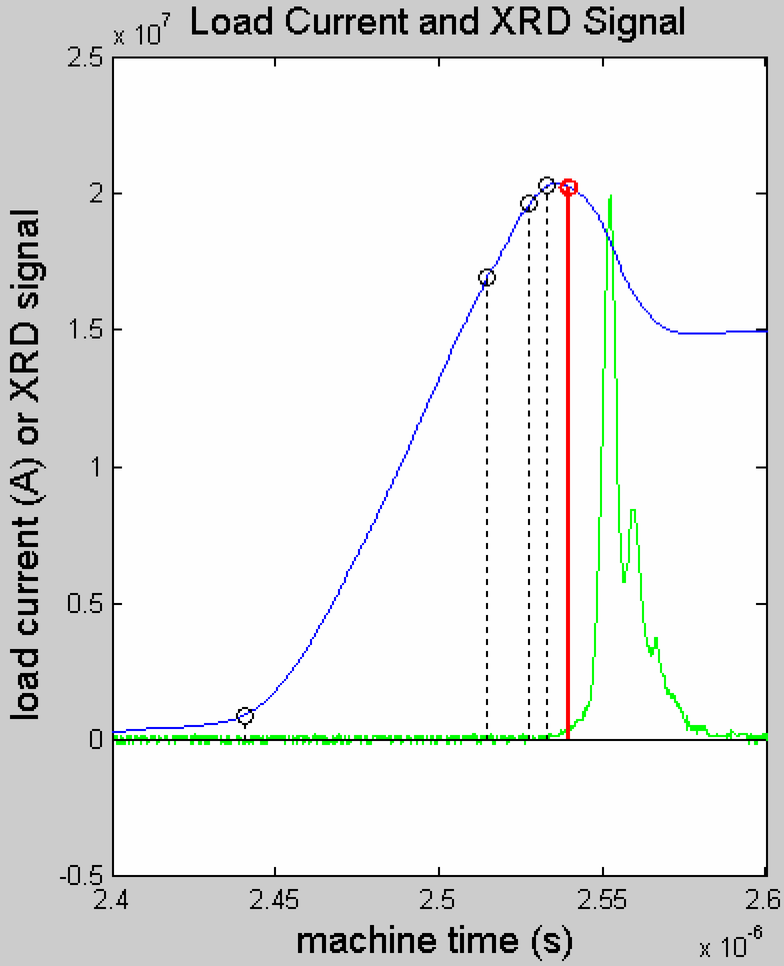
Z1176: frame 2, tmachine = 2515ns
t-t0 = 66ns, t - tpeak = -37.5 ns
ILoad = 16.9MA, 64% of implosion
Z position (mm)
radius (mm)
11
10
9
8
7
6
5
4
3
2
1
3
4
5
6
7
8
9
10
11
x 10^7
Load Current and XRD Signal
load current (A) or XRD signal
machine time (s)
x 10^-6
2.5
2
1.5
1
0.5
0
-0.5
2.4
2.45
2.5
2.55
2.6


Z1176: frame 3, tmachine = 2528ns
t-t0 = 79ns, t - tpeak = -24.7 ns
ILoad = 19.6MA, 76% of implosion
Z position (mm)
radius (mm)
Load Current and XRD Signal
x 10^7
load current (A) or XRD signal
machine time (s)
x 10^-6

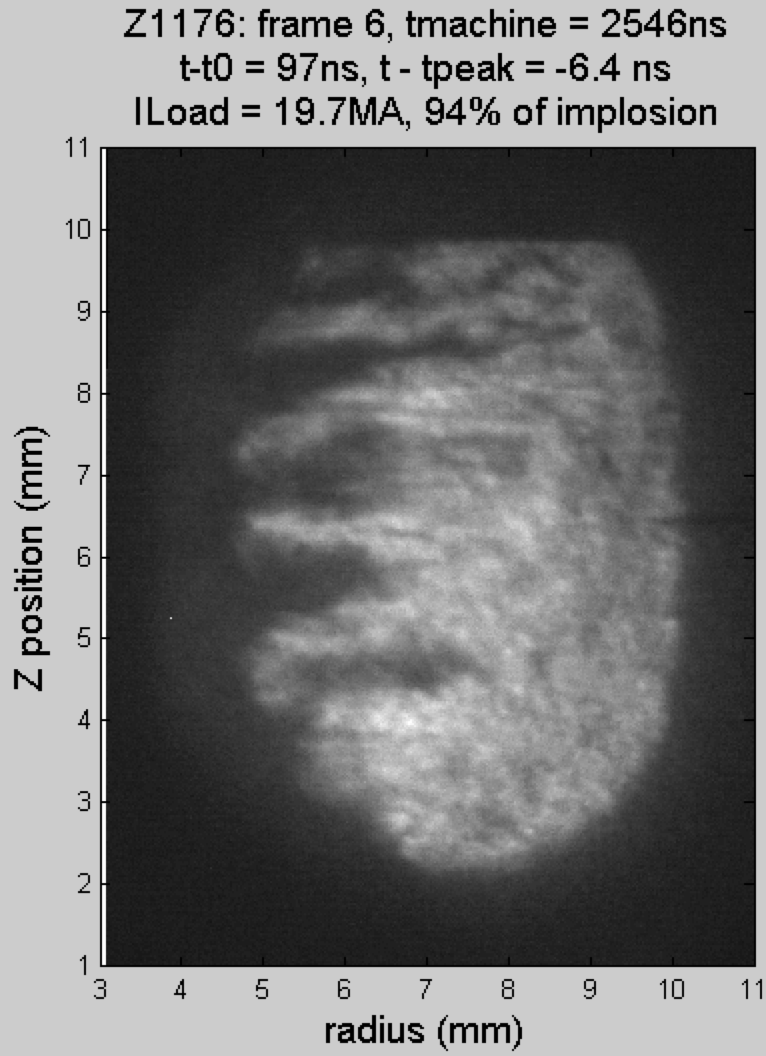

Z1176: frame 4, tmachine = 2533ns
t-t0 = 84ns, t - tpeak = -19.3 ns
ILoad = 20.3MA, 81% of implosion
Z position (mm)
radius (mm)
Load Current and XRD Signal
x 10^7
load current (A) or XRD signal
machine time (s)
x 10^-6



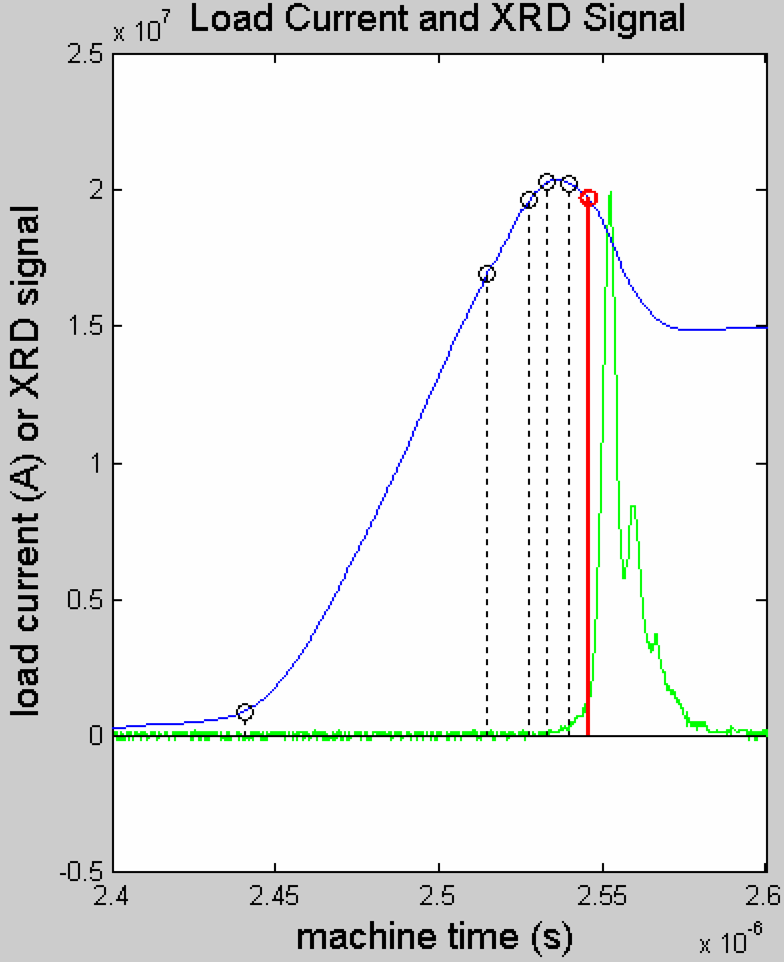
Z1176: frame 5, tmachine = 2540ns
t-t0 = 91ns, t - tpeak = -12.4 ns
ILoad = 20.2MA, 88% of implosion
Z position (mm)
radius (mm)



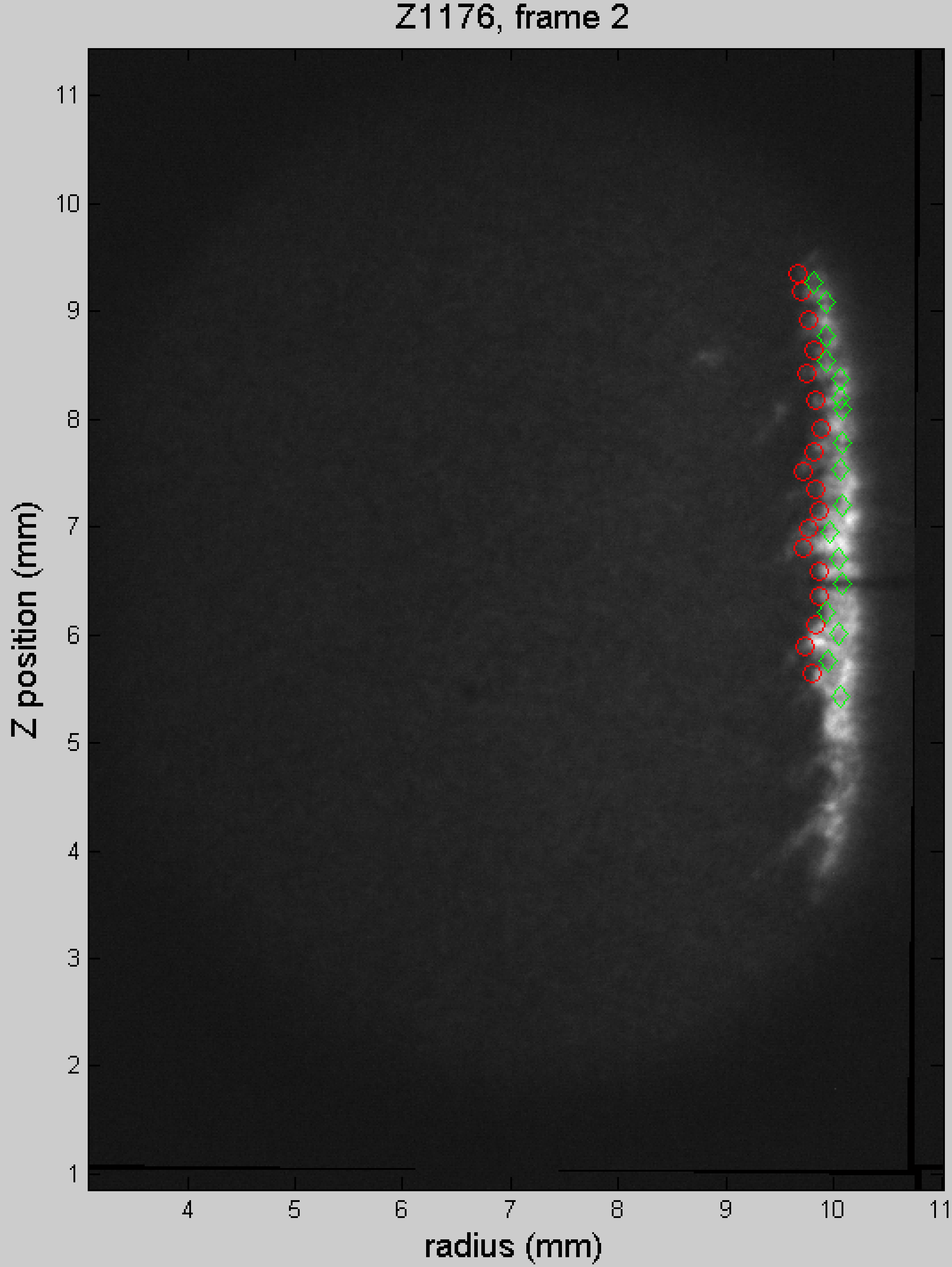
Load Current and XRD Signal
x 10^7
load current (A) or XRD signal
machine time (s)
x 10^-6

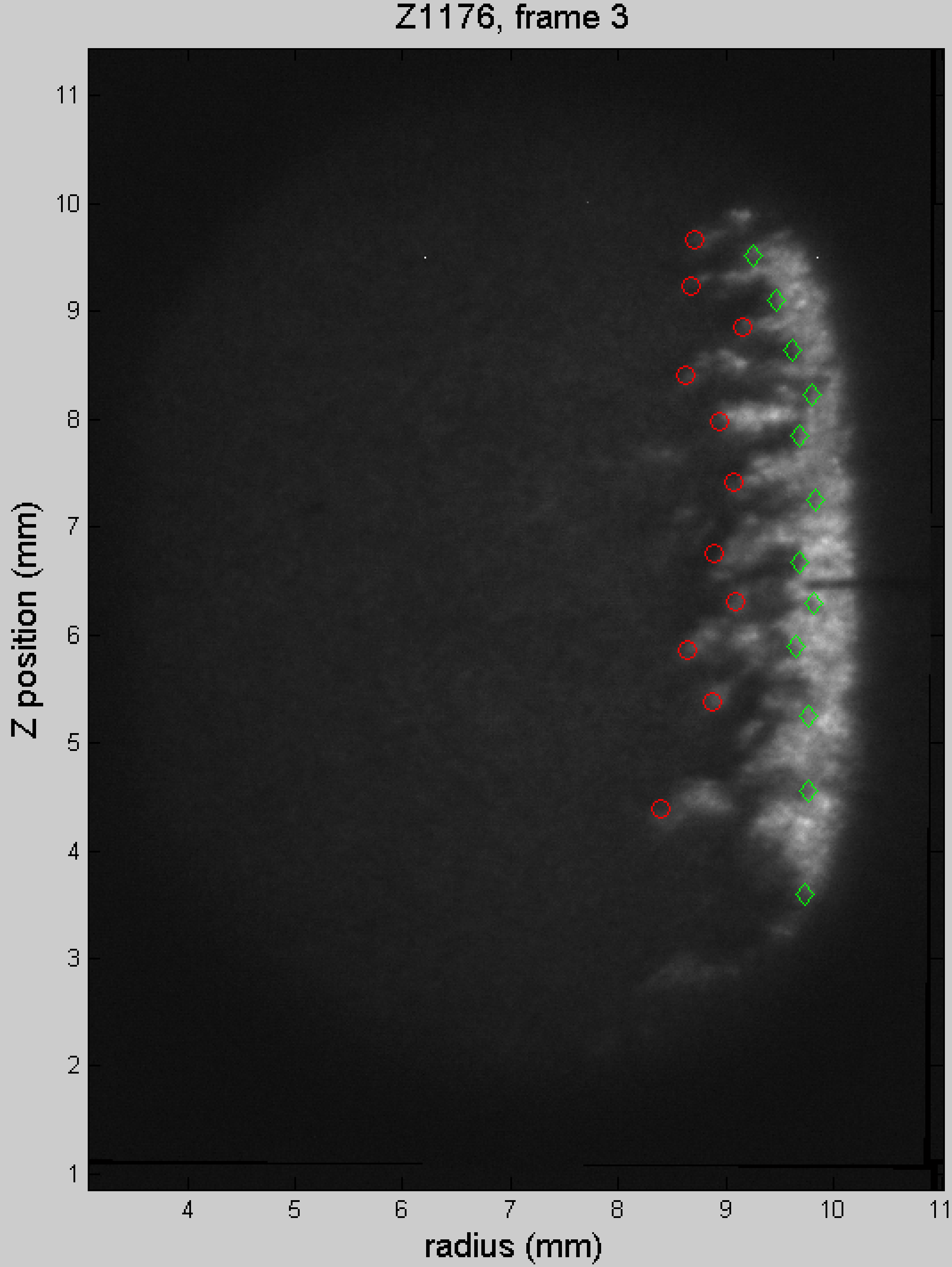


Z1176: frame 6, tmachine = 2546ns
t-t0 = 97ns, t - tpeak = -6.4 ns
ILoad = 19.7MA, 94% of implosion
Z position (mm)
radius (mm)

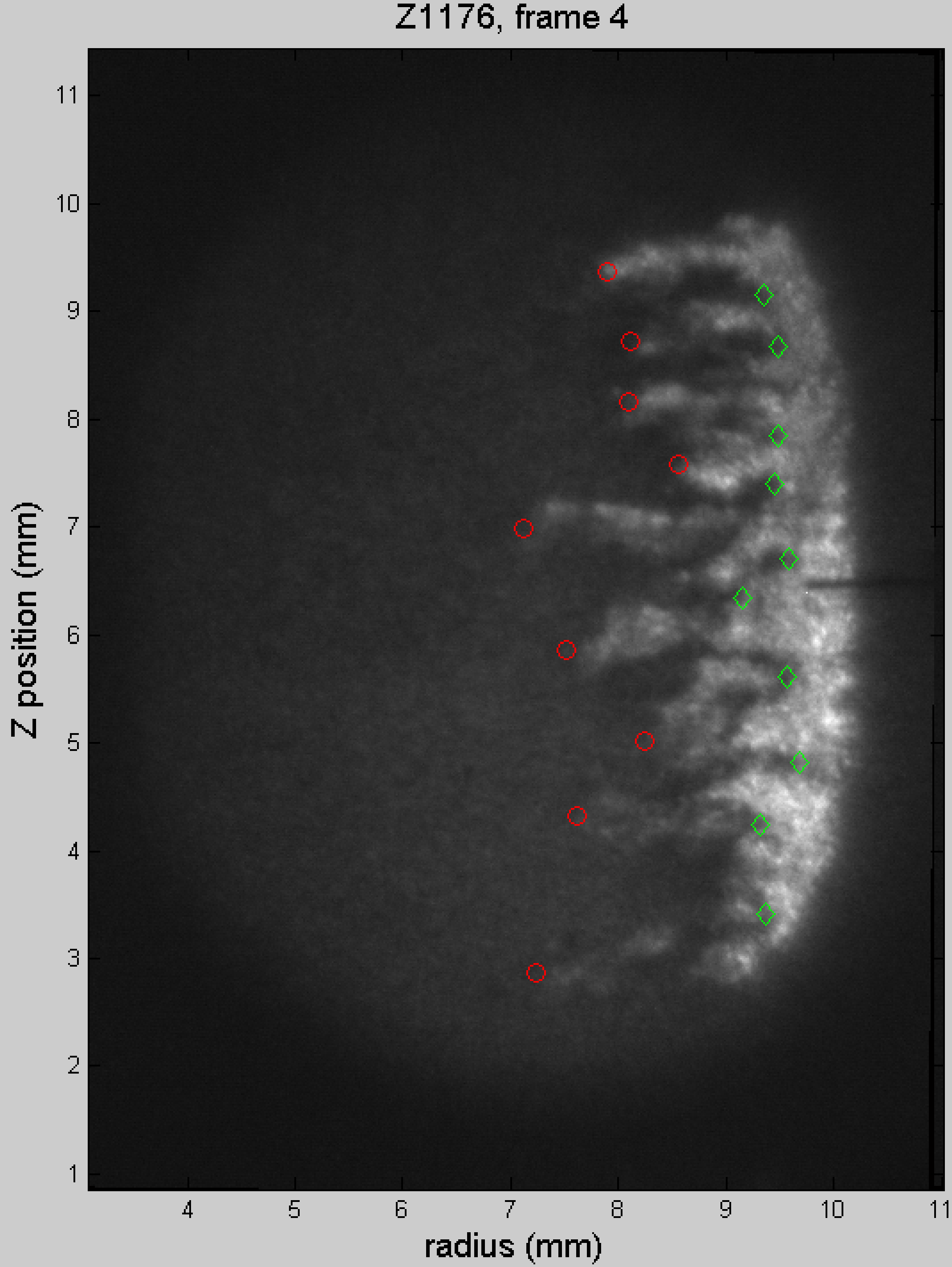


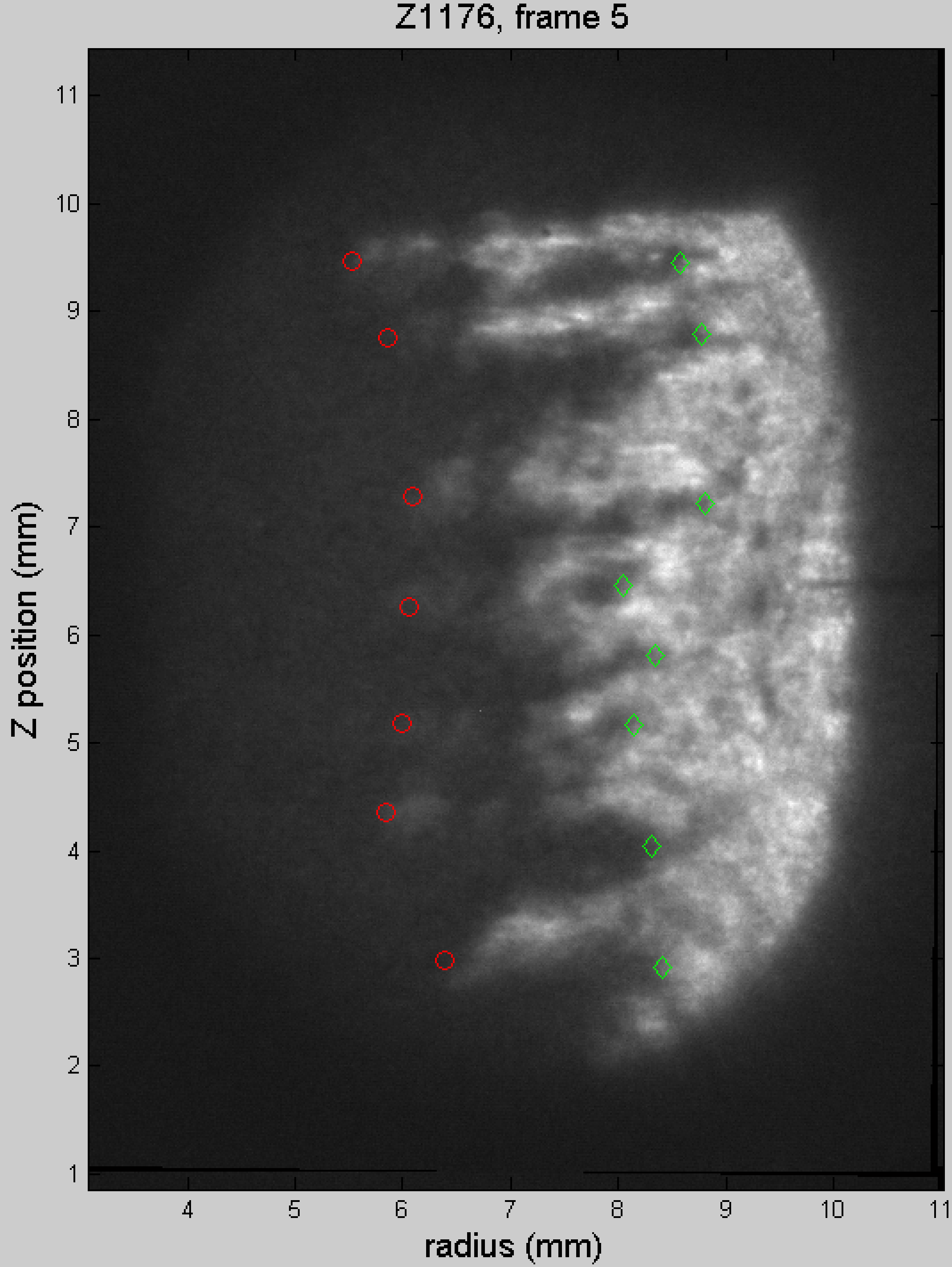
Load Current and XRD Signal
x 10^7
load current (A) or XRD signal
machine time (s)
x 10^-6


Z1176, frame 2
Z position (mm)
radius (mm)
1
2
3
4
5
6
7
8
9
10
11
4
5
6
7
8
9
10
11



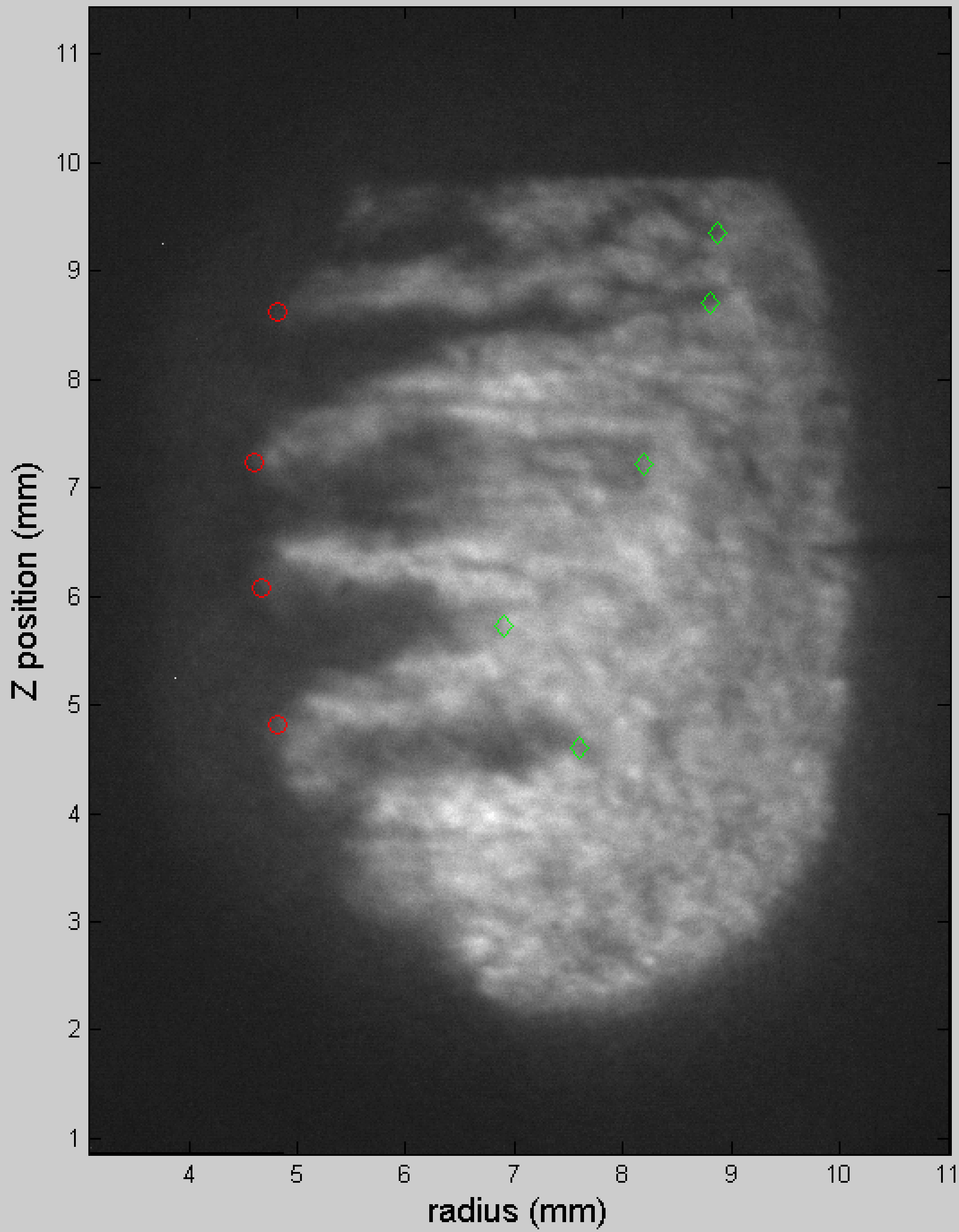
Z1176, frame 3
Z position (mm)
11
10
9
8
7
6
5
4
3
2
1
radius (mm)
4
5
6
7
8
9
10
11


Z1176, frame 4
Z position (mm)
radius (mm)
1
2
3
4
5
6
7
8
9
10
11
4
5
6
7
8
9
10
11

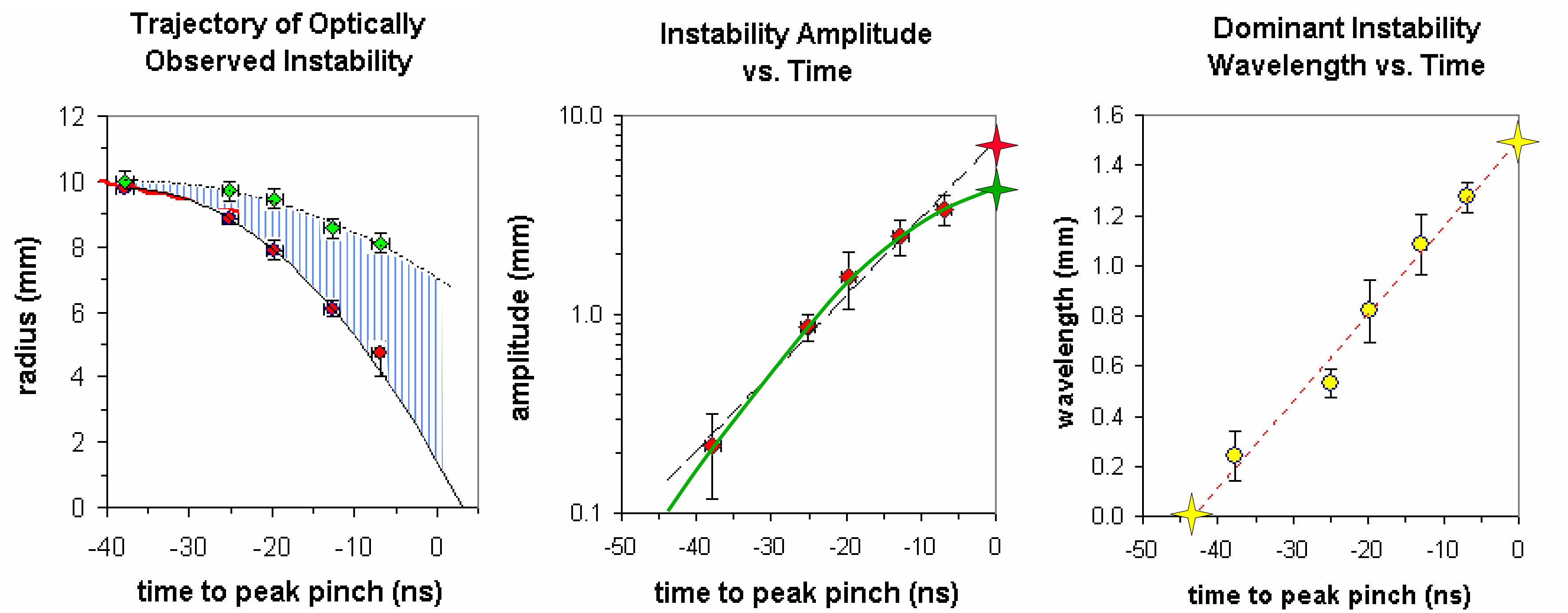


Z1176, frame 5
Z position (mm)
radius (mm)
11
10
9
8
7
6
5
4
3
2
1
4
5
6
7
8
9
10
11

Z1176, frame 6



Analysis of the growth of the magnetic Instability during the implosion phase



Trajectory of inner boundary can be fit to constant acceleration, $a = 1.18 \times 10^{13}$ m s^{-2}

Amplitude grows approximately exponentially with time, reaching ~6-7 mm at peak.

Wavelength grows linearly with time.
$t_o = -42.5$ ns
$\lambda(t=0) = 1.5$ mm

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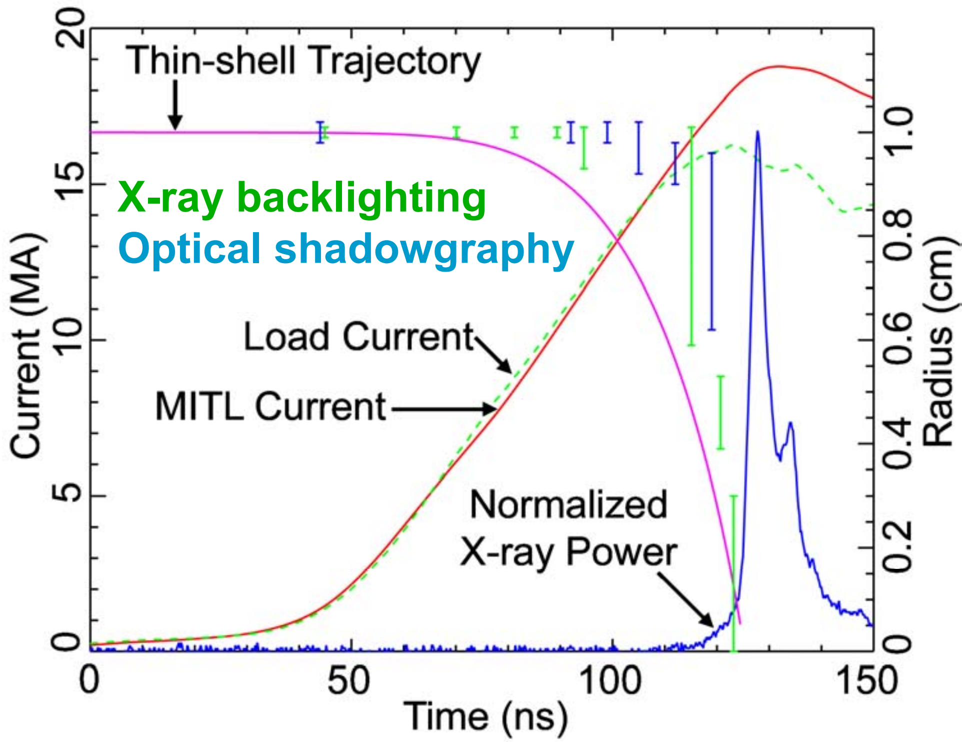
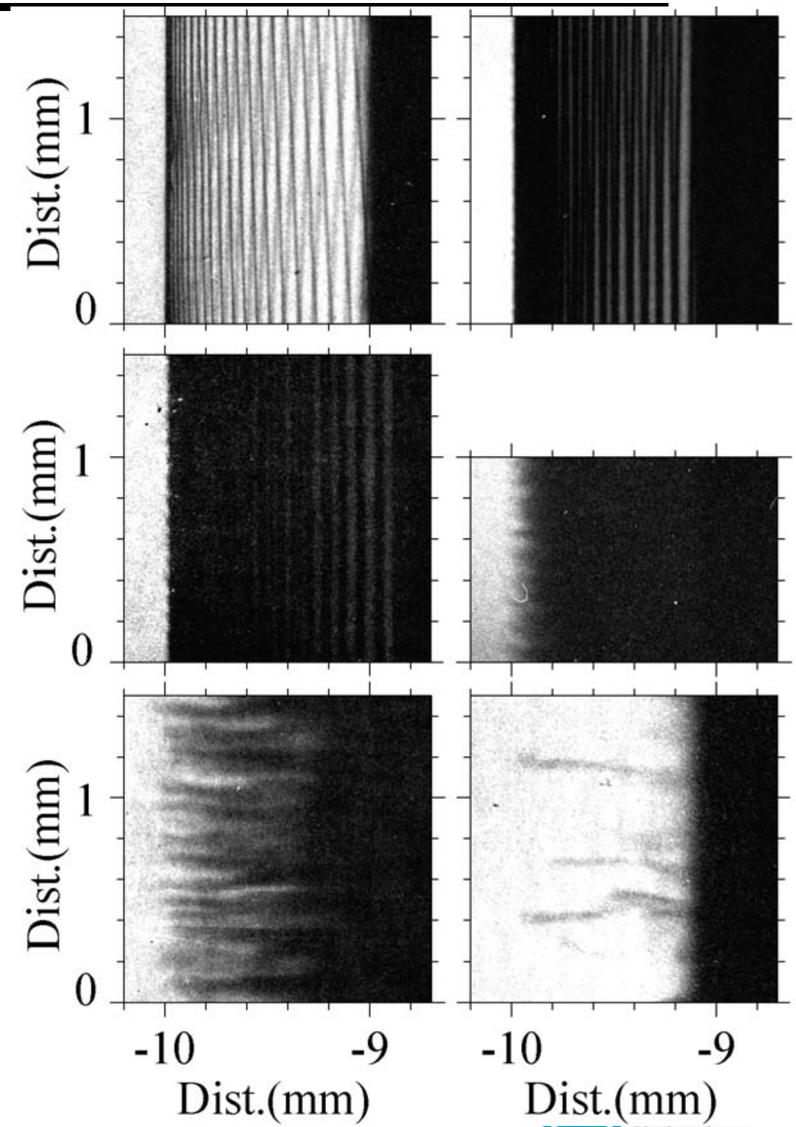
We are using x-ray backlighting to measure the mass profile and instability growth during wire-array implosions

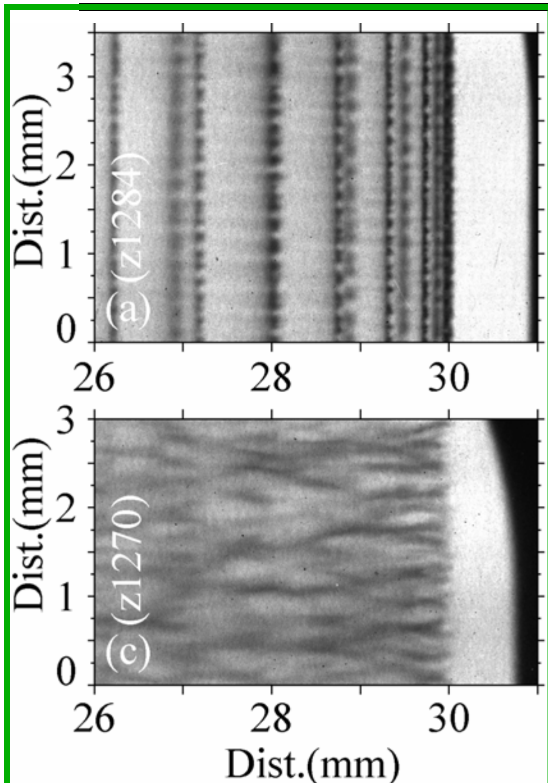




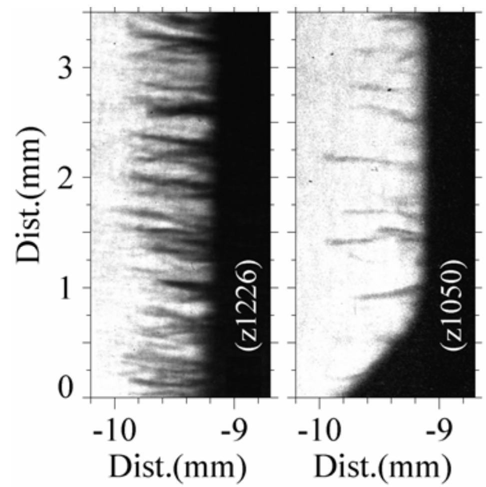
Correlated instabilities and axially non-uniform breakup of wires contribute to the creation of trailing mass and limit peak radiation powers

D.B. Sinars *et al.*, Phys. Rev. Lett. 93, 145002 (2004).

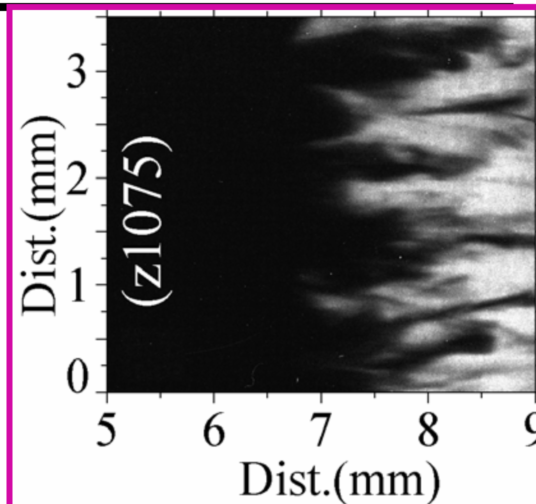
A wide range of z-pinch implosion phenomena are now being studied in detail



Wire breakup and development of correlated instabilities

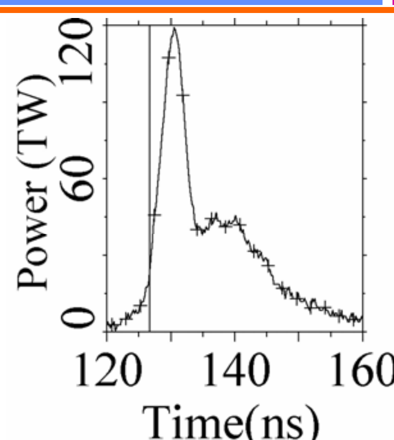


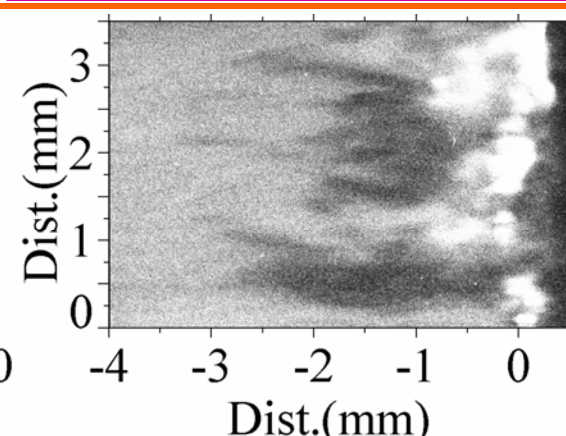
Trailing mass caused by non-uniform wire breakup



Evolution of axial instabilities

Mass profile near the axis

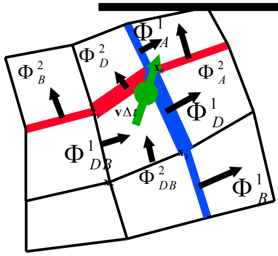




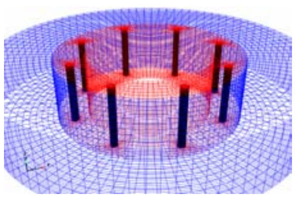
D.B. Sinars *et al.*, EI2.002

National Laboratories

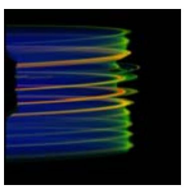
The ALEGRA-HEDP predictive design and analysis capability enables effective use of *Z*



Algorithms

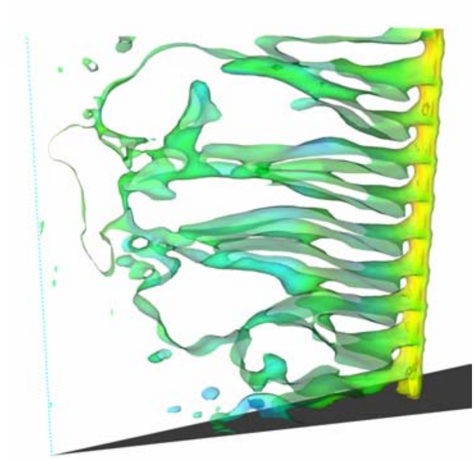


Meshing

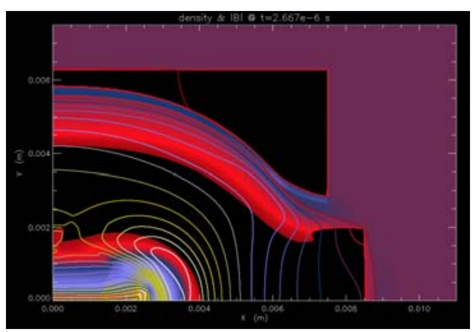


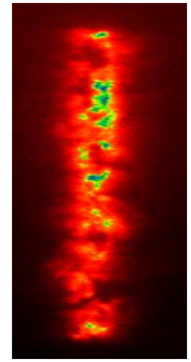
Visualization

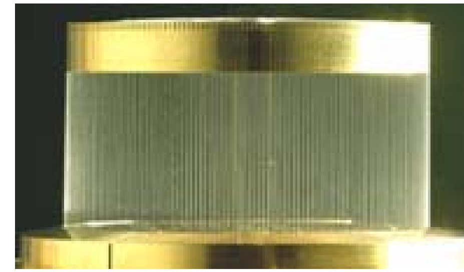
Platforms



ALEGRA-HEDP

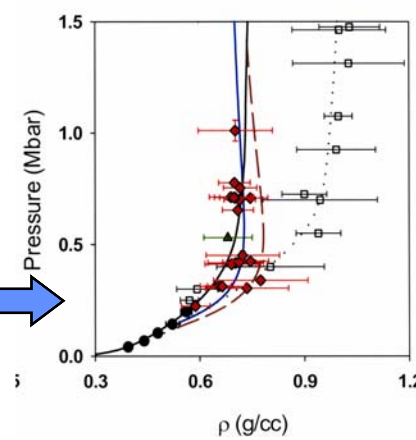


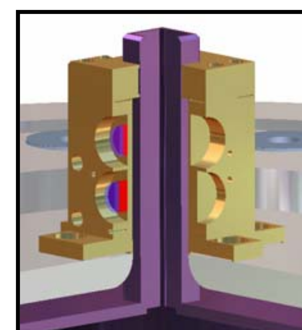




Z-pinches as x-ray sources

Magnetic flyers for EOS





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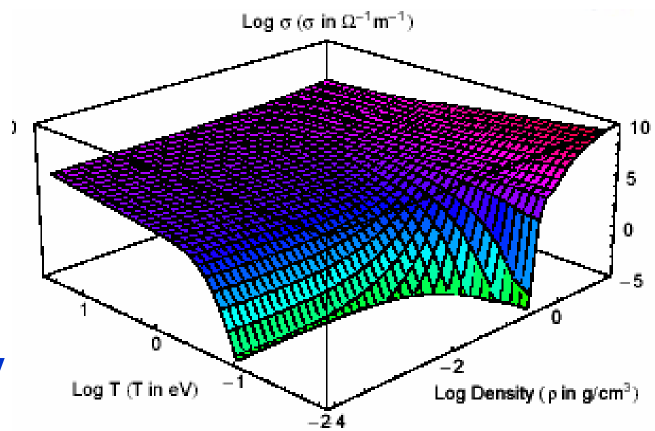
Accurate material models are necessary for quantitative/predictive simulations

Material properties span > 10 orders of magnitude!

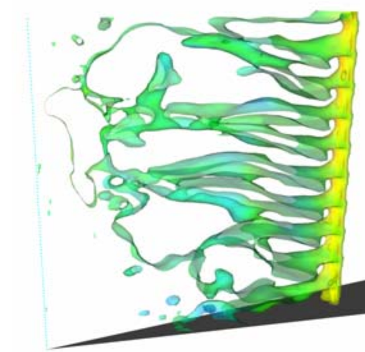
EOS

Opacity

Conductivity



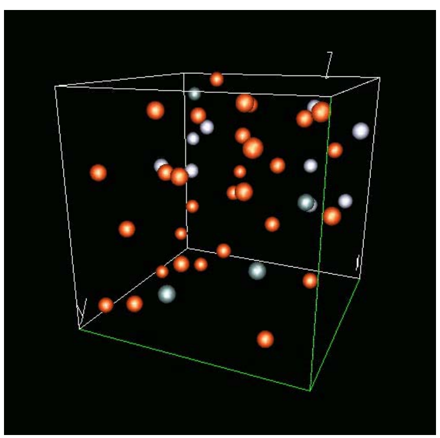
Mesoscopic level



System level

Wire-array experiments

ICF targets



Atomistic level

Density Functional Theory

Atomistic dynamics

Quantum Mechanics

No adjustable parameters

M Desjarlais
Invited talk
EI2.005

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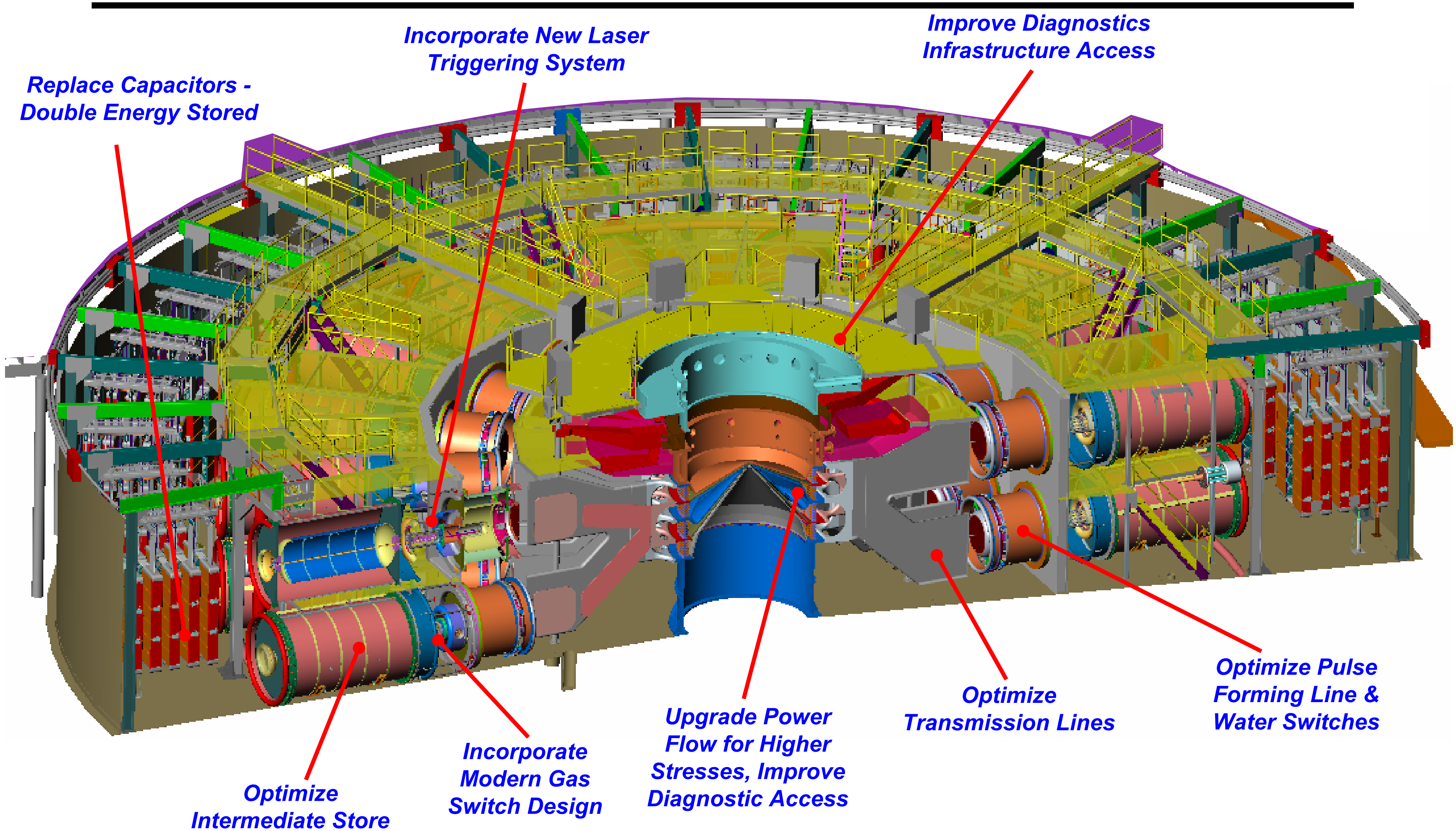
ALEGRA-HEDP 3D 8-wire z-pinch implosion calculation

[Movie of 3D 8-wire array calculation]

ALEGRA-HEDP 30-wire 2D MHD with IMC radiation and 9-slot return current structure

[Movie of 2D r-theta 30-wire array calculation]

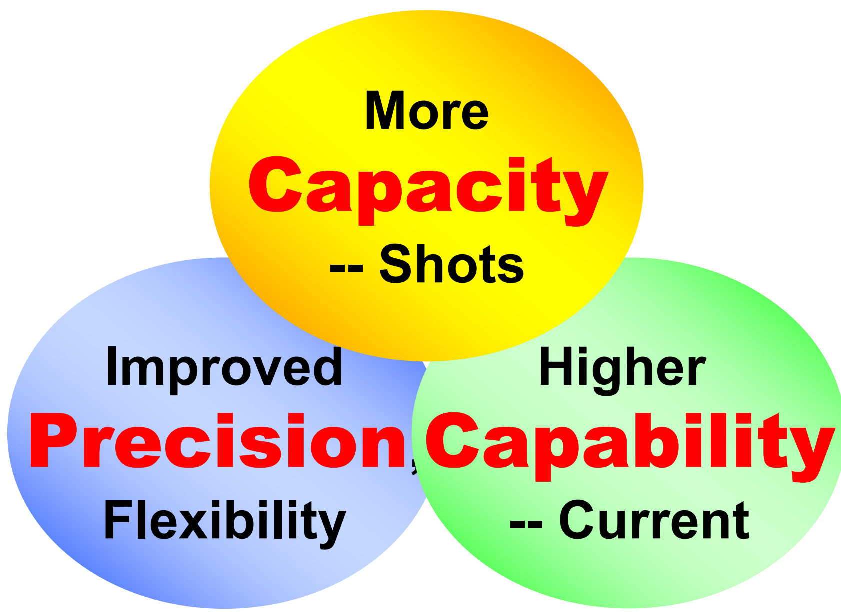
ZR - Refurbishing the Z pulsed power facility



TEC = $61,710k; FY07 completion

Z-Refurbishment Project Objectives

- **Extend lifetime and utility of the Z pulsed power facility**
  - Increase **shot capacity** to meet demands
  - Increase **precision** for high quality data for code validation
  - Increase **current capability** to meet future temperature, x-ray power and energy, and equation of state requirements



Higher current will provide increased capability

Capability	Z today	After Refurbishment
Peak load current reproducibility	± 5 %	± 2 %
Pulse shaping flexibility	Minimal	Significant Variability
Peak Current	18 MA	26 MA
Power Radiated (Nested Arrays)	230 TW	350 TW
Energy Radiated (Single Array)	1.6 MJ	2.7 MJ

Increased capability will be applied to:

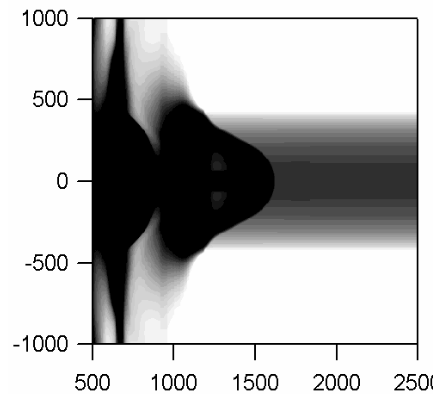
- Hot spot Inertial Confinement Fusion
- Fast ignition
- Radiation hydrodynamics
- Opacity
- Material response to radiation fluence
- Dynamic material properties

The Z-Beamlet laser is being upgraded to provide a high energy PW laser for use on Sandia's Z facility

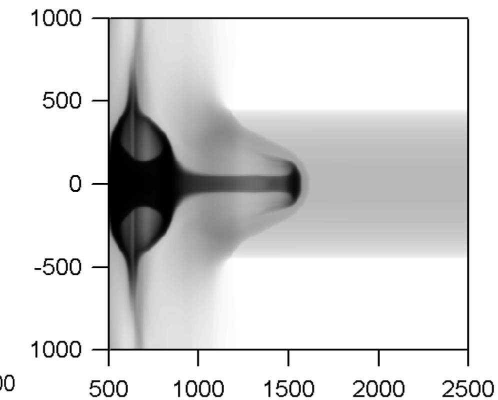
- **The Z-Beamlet laser is being upgraded to provide a 2-4 kJ, 1-10 psec short pulse laser**
  - **high energy radiography**
  - **fast ignition experiments**
  - **ultra-intense short pulse HED science**

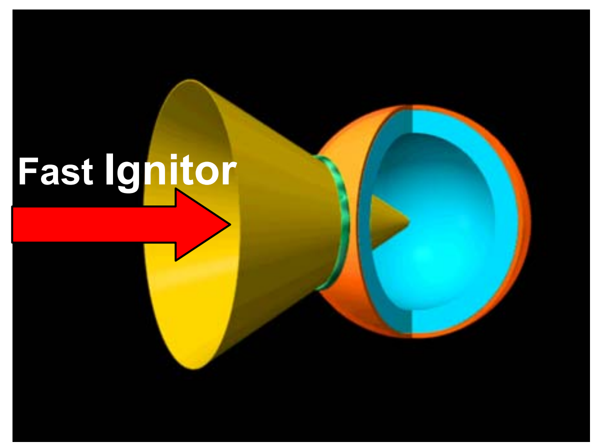
Z-Beamlet multikilojoule laser facility

6 keV radiograph presently available



20 keV radiograph available with an HEPW laser system





Pulsed power facilities are versatile platforms for HEDP and ICF science