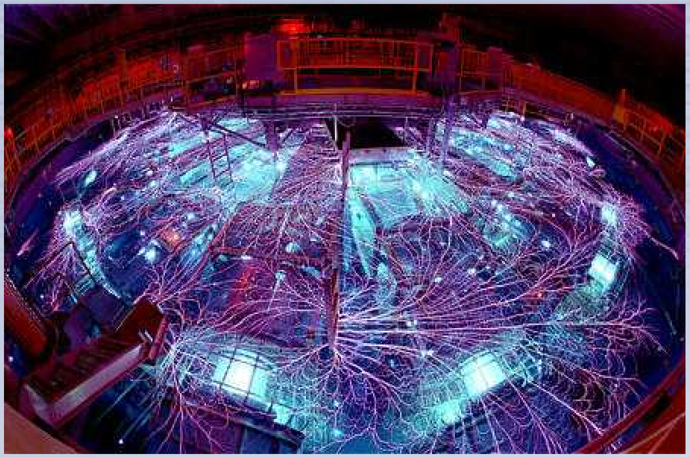
SAND2011-6891P

Science at Sandia National Laboratories' Z Pulsed Power Facility



UW-Madison

September 22, 2011

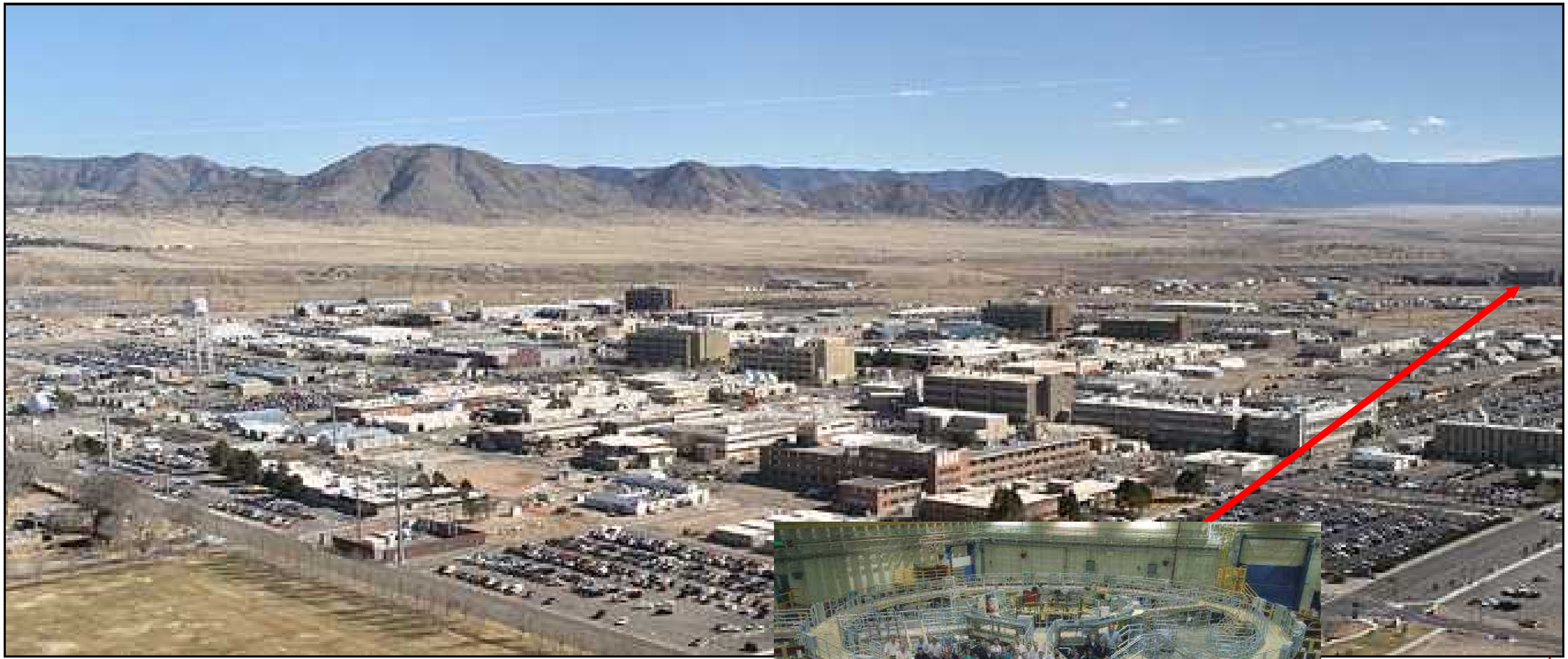
Amy Laspe

Sandia National Laboratories

Sandia National Laboratories

The Z Pulsed Power Facility is located at Sandia National Laboratories in Albuquerque, NM

Z Website: http://z.sandia.gov



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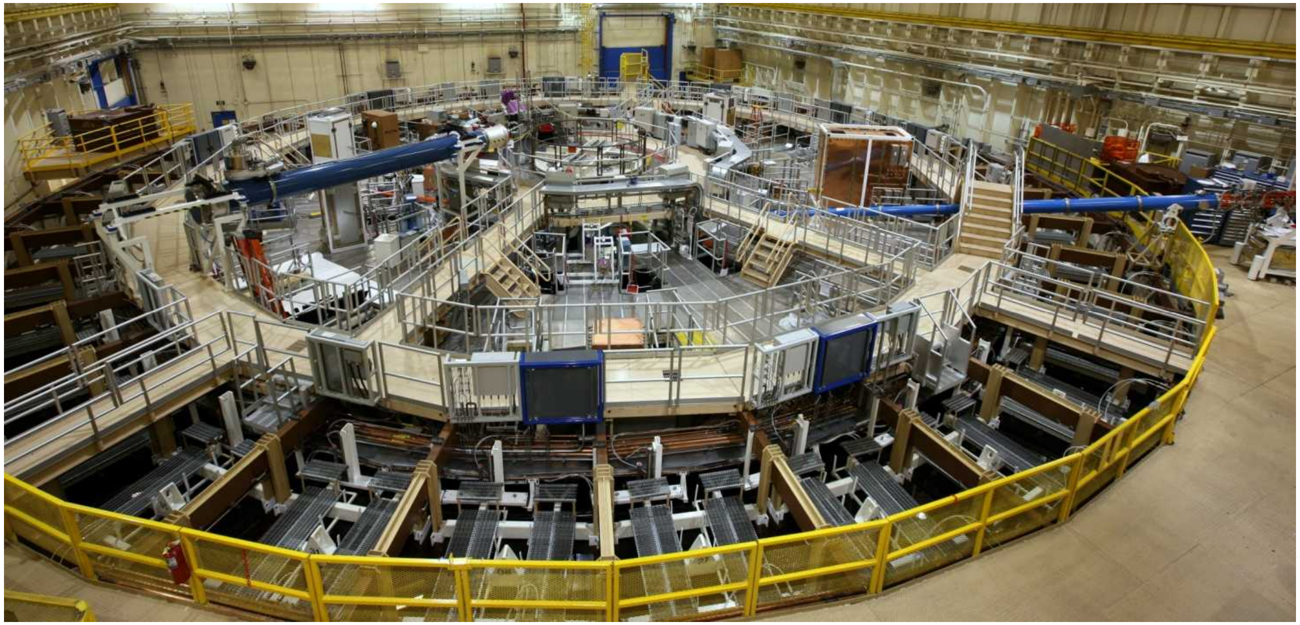
Z Basics

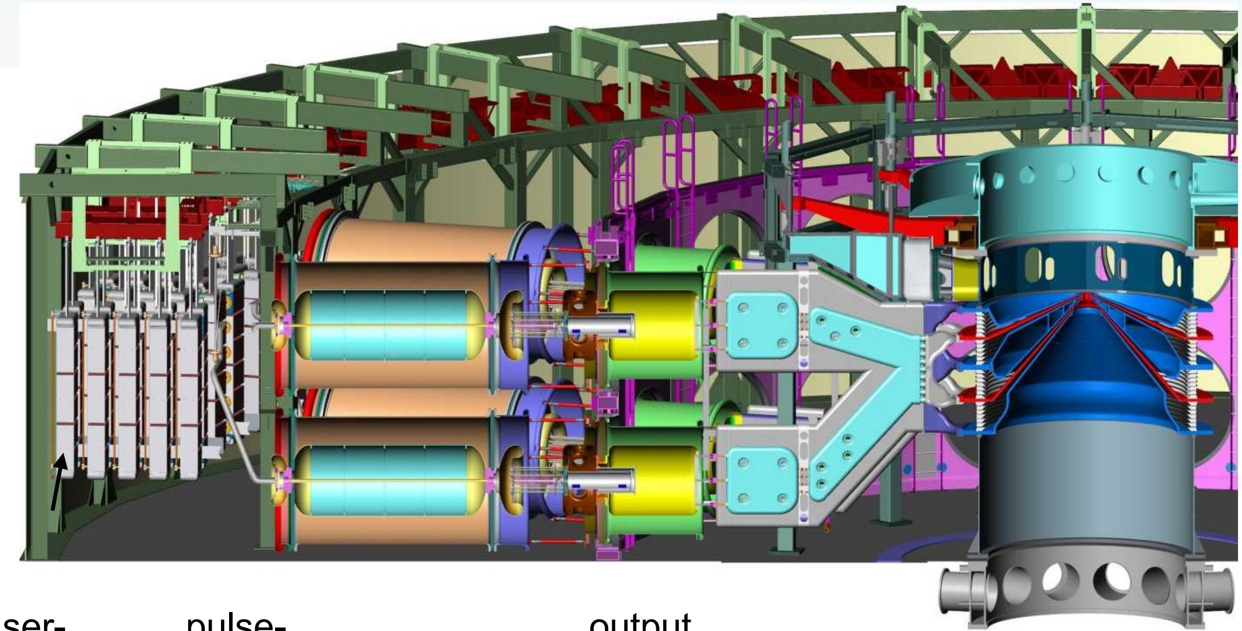
- Z is the most powerful and efficient laboratory radiation source
- Fires ~200 shots per year
- Uses 26 million amps
- Releases 350 TW of power
- Applications:
    - Equations of state: determine how materials will behave under extreme temperatures and pressures
    - Inertial confinement fusion (ICF)
    - Radiation effects

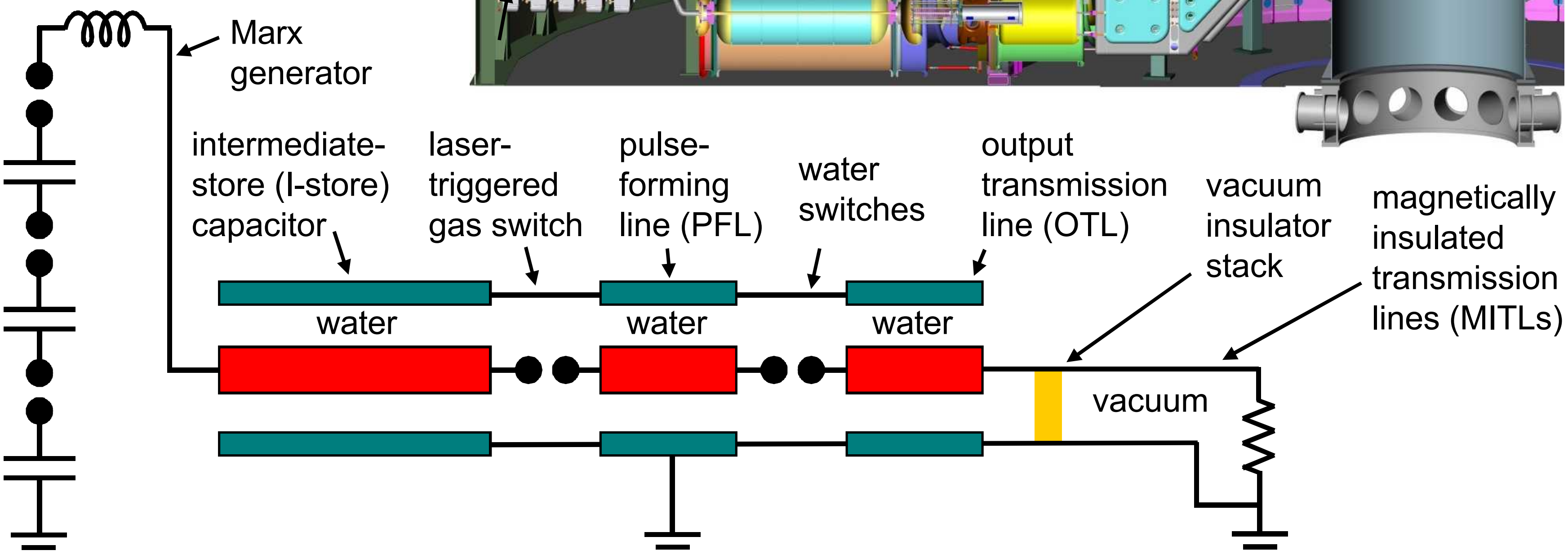


Each Z-accelerator module performs several stages of electrical-pulse compression

Marx voltage	stored energy
80 kV	19 MJ
85 kV	21 MJ
90 kV	23 MJ

The Marx generator is charged in 100 s, and discharged in 1 μs.



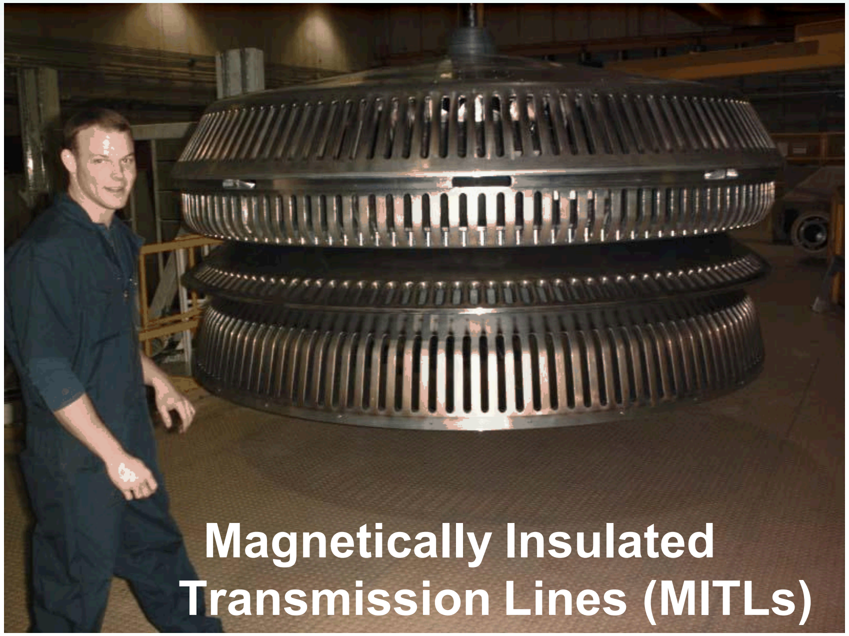


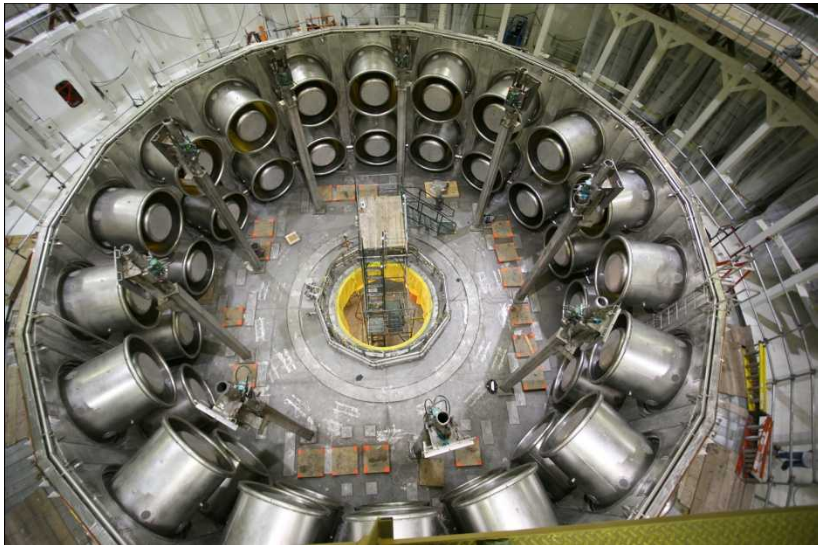
The I-store capacitor is charged in 1 μs, and discharged in 200 ns.

The PFL is charged in 200 ns, and discharged in 100 ns.

The pulse is delivered to a physics package, which is the load of the accelerator circuit.

Some of the Components of Z





Pulse forming section of Z during refurbishment

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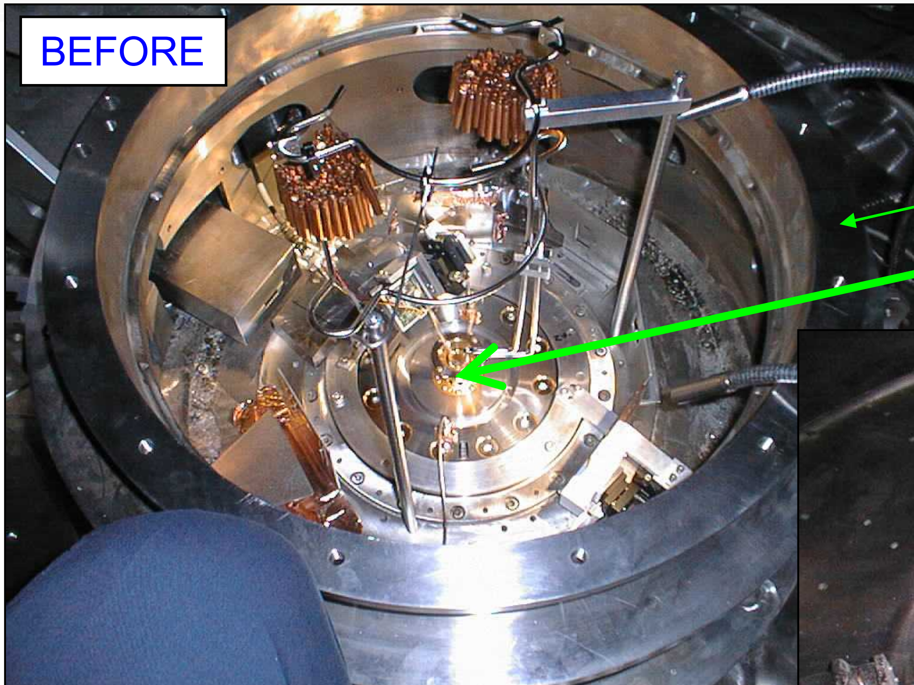
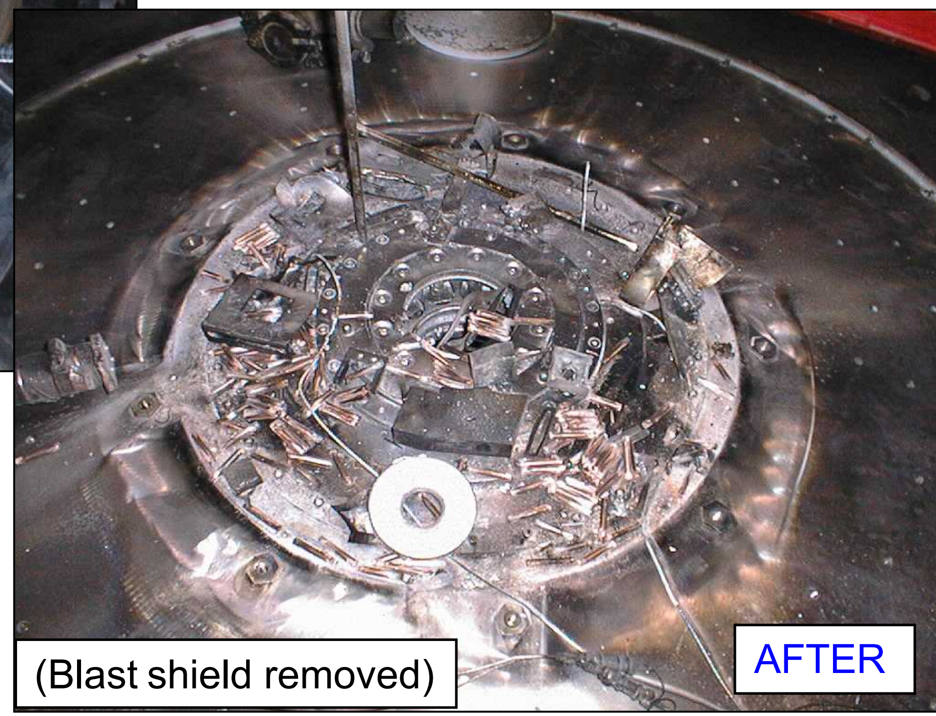
The enormous magnetic and radiation pressures destroy the load hardware on each shot



Equivalent to 2 lbs high explosive released in a few ns in <1 cc volume!

Blast shield

Wire array



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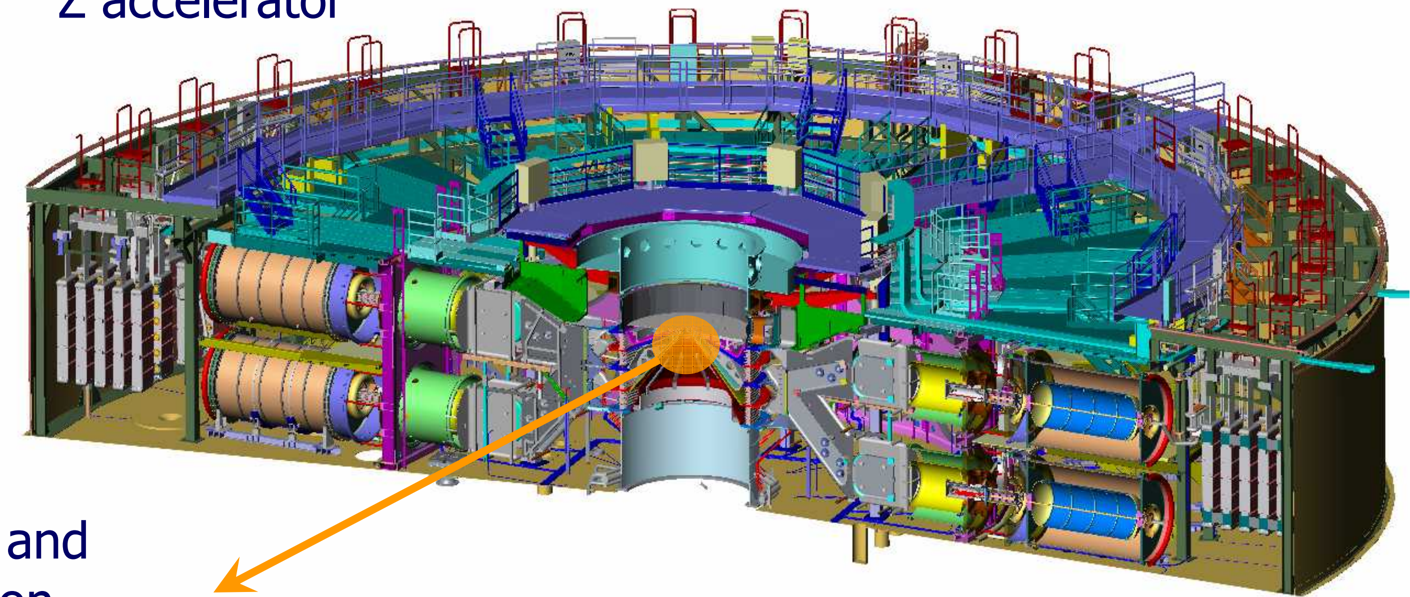
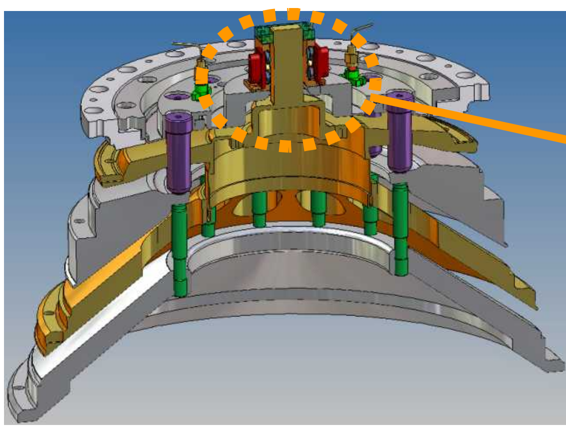
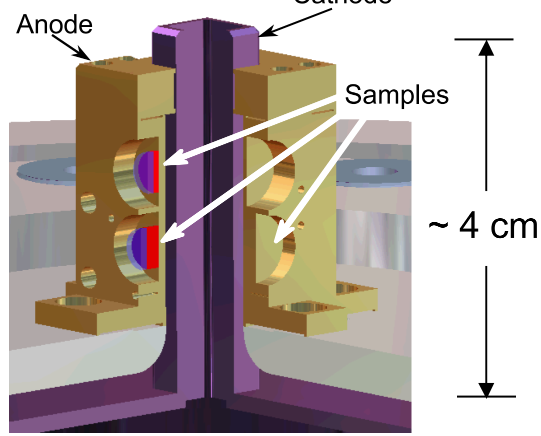
High Energy Density Physics experiments are mounted at the center of the Z accelerator

Z accelerator

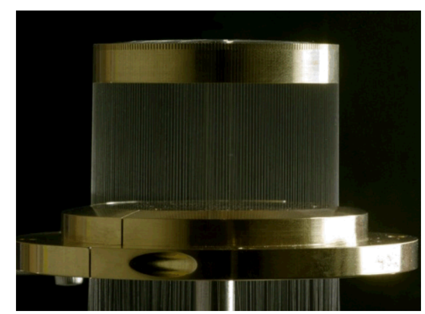


Convolute and load region





Material property experiment



Wire array experiment

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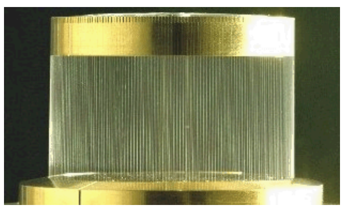
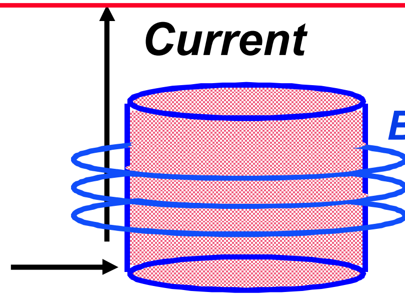
We can use high currents to push plasmas in different ways for different applications

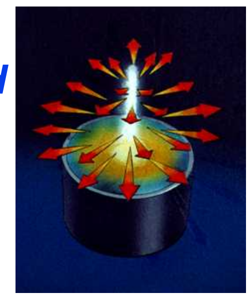
High Current

Cylindrical magnetic pressure

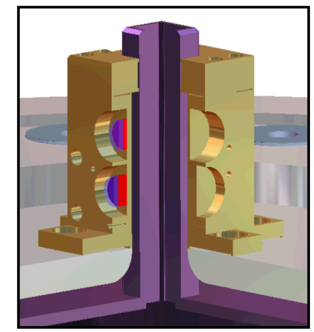
wire array



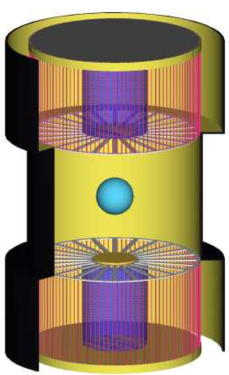


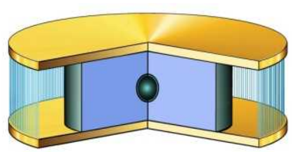


Planar magnetic pressure

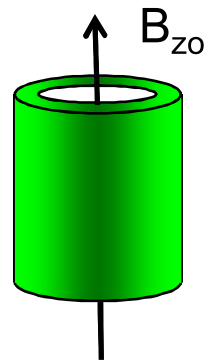


Inertial Confinement Fusion (ICF)



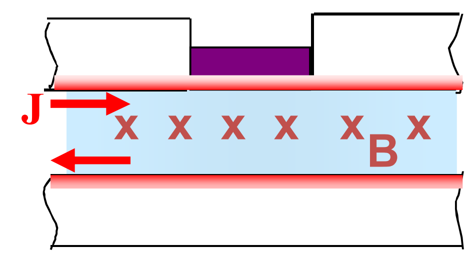


Indirect



Direct (MTF)

Material Properties



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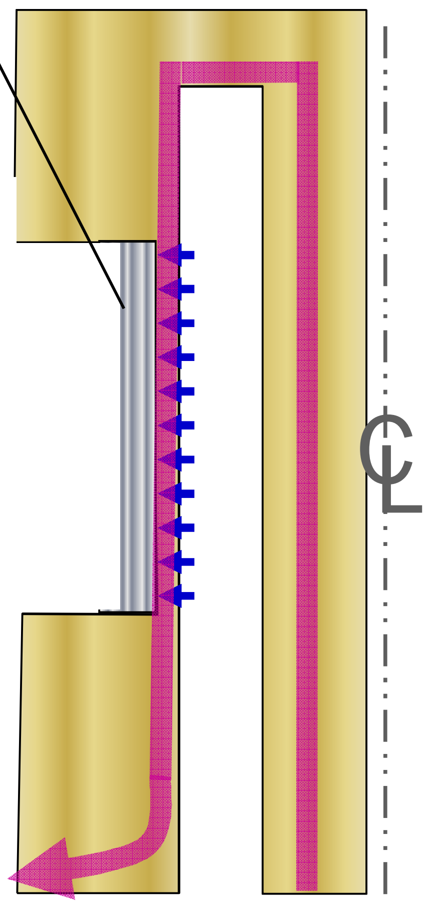
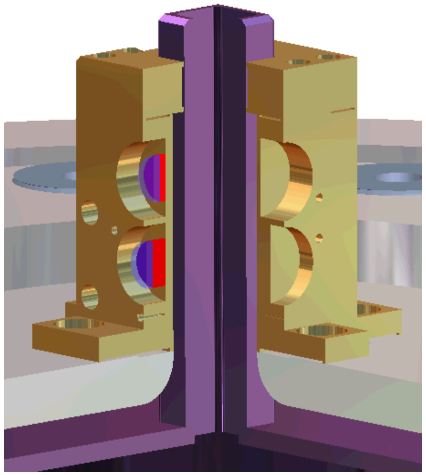
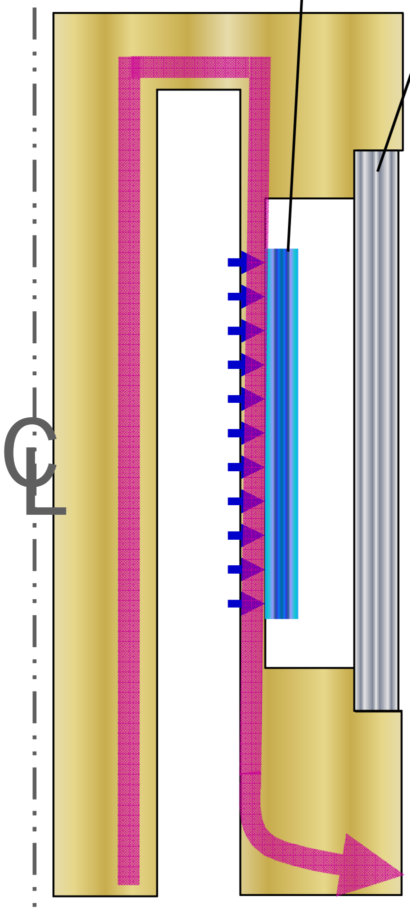
Isentropic compression and shock wave experiments are both possible on Z







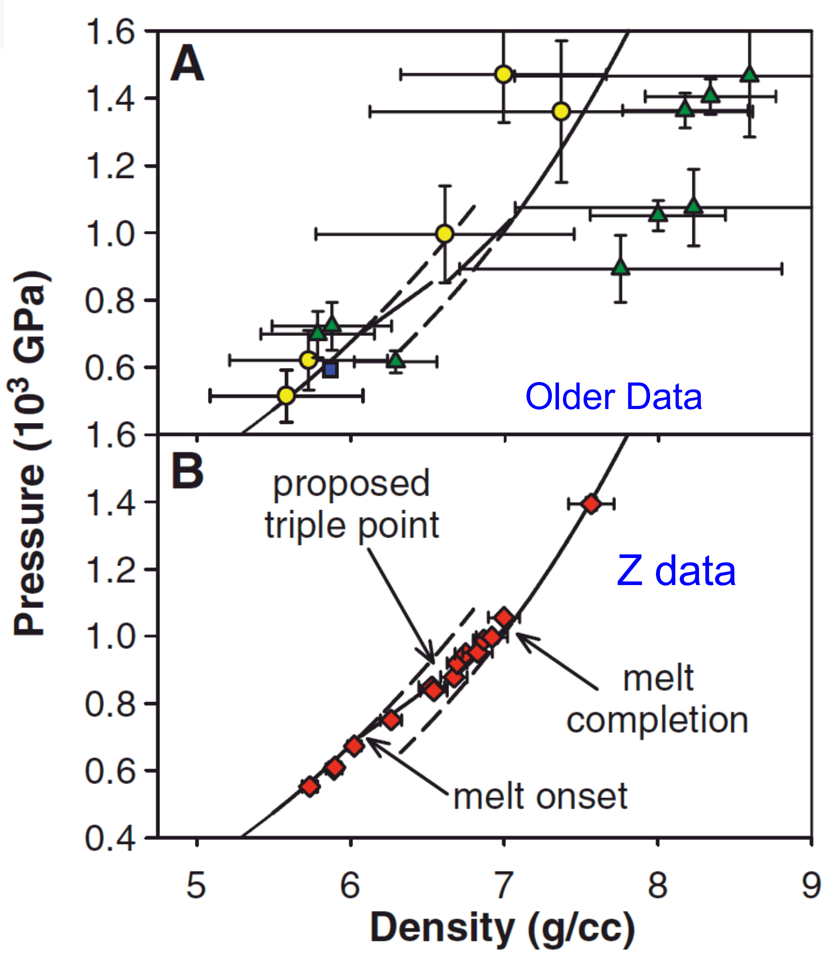
Isentropic Compression Experiments:
gradual pressure rise in sample

Shock Hugoniot Experiments:
shock wave in sample on impact

Experiments on Z have determined the shock melting of diamond with unprecedented accuracy

At what shock pressure does diamond melt?

Accuracy of shock impact experiments on Z allowed for quantitative comparison with Quantum Molecular Dynamics (QMD) predictions



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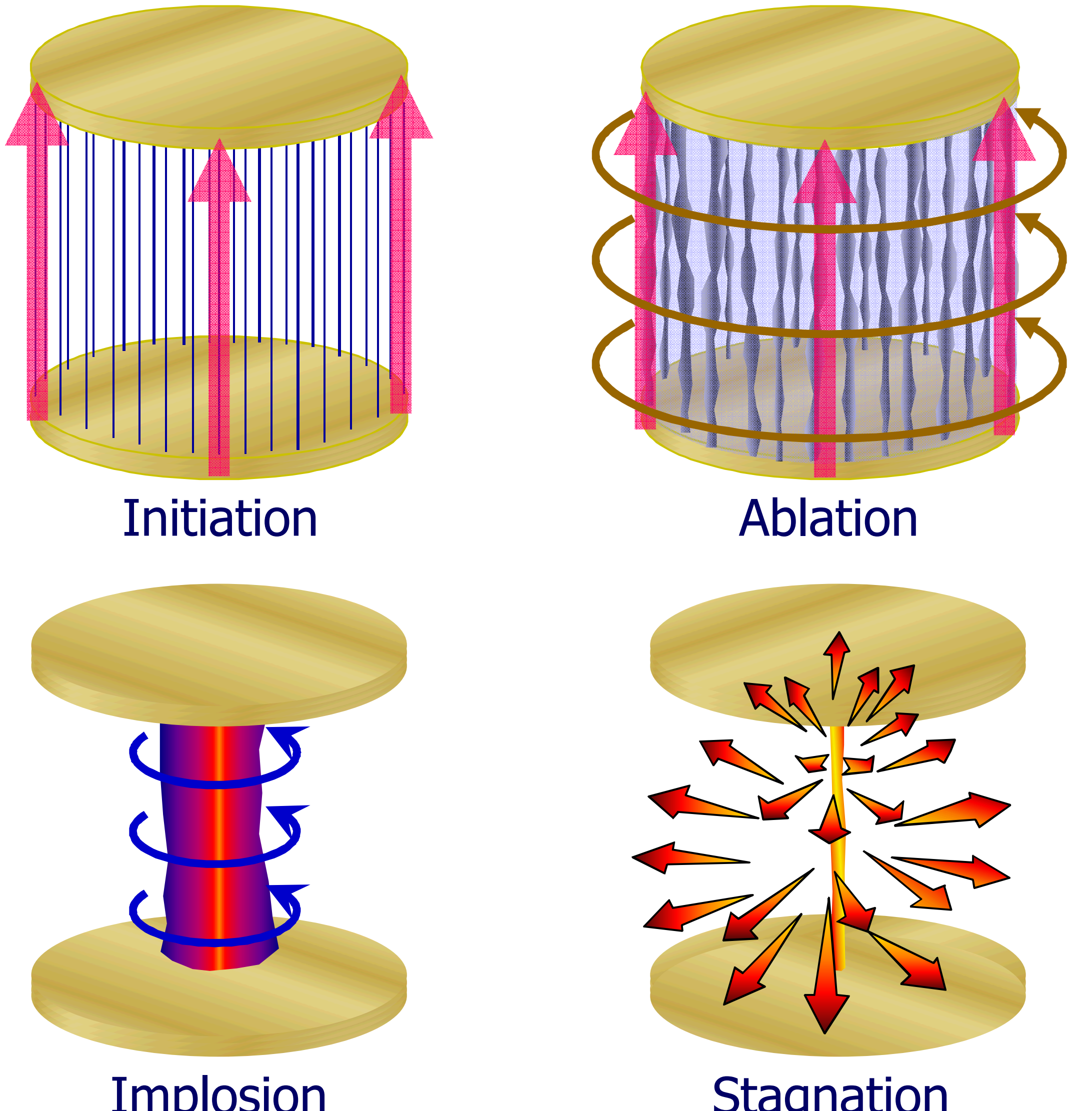
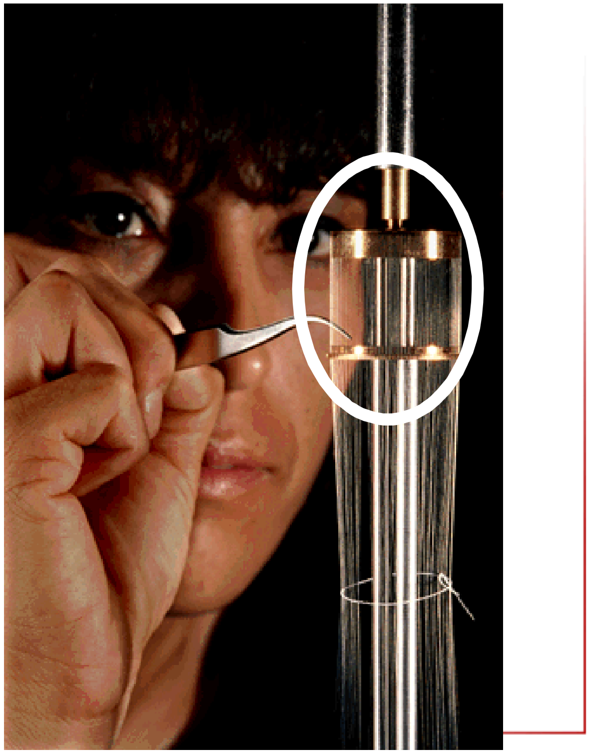
Magnetically-driven z-pinch implosions efficiently convert electrical energy into radiation



On Z:

- Energy: x-ray
  ≈10% of stored electrical
- Power: x-ray
  ≈3 times electrical



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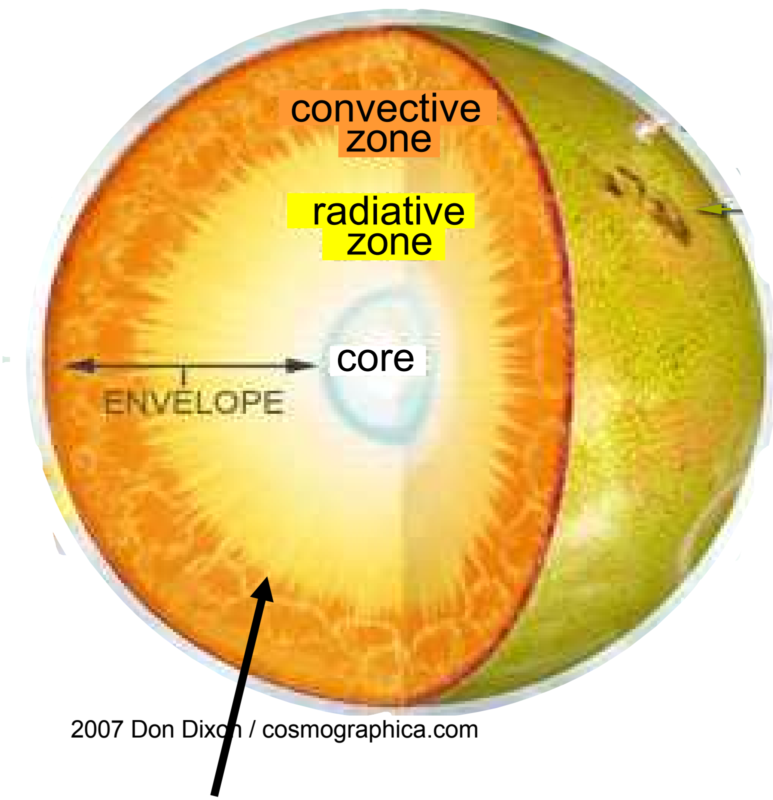
Z experiments test opacity models that are crucial for stellar interior physics



Solar convective zone boundary
T_e = 193 eV, n_e = 1 x 10^{23} cm^{-3}

Predictions of solar structure do not agree with observations

Solar structure depends on opacities that have never been measured

<u>Challenge: create and diagnose stellar interior conditions on earth</u>

High T enables first studies of transitions important in stellar interiors

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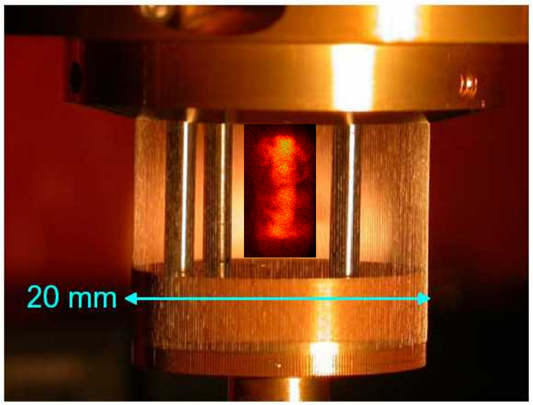
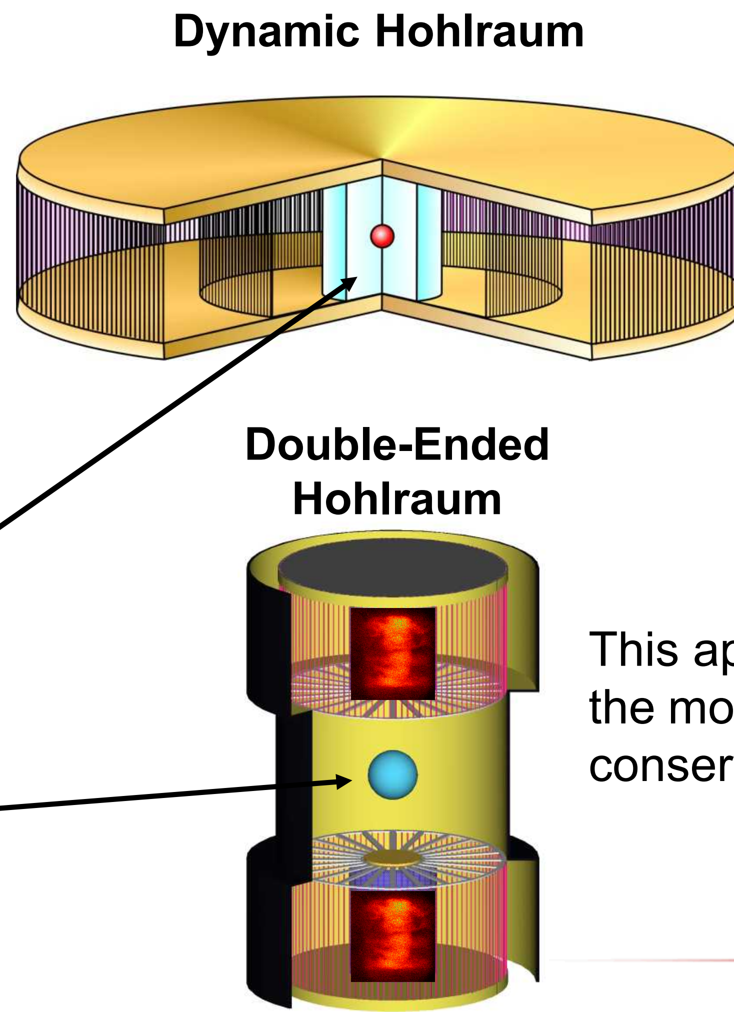
How can we use this efficient x-ray source to do ICF?



Where do we put the capsule?

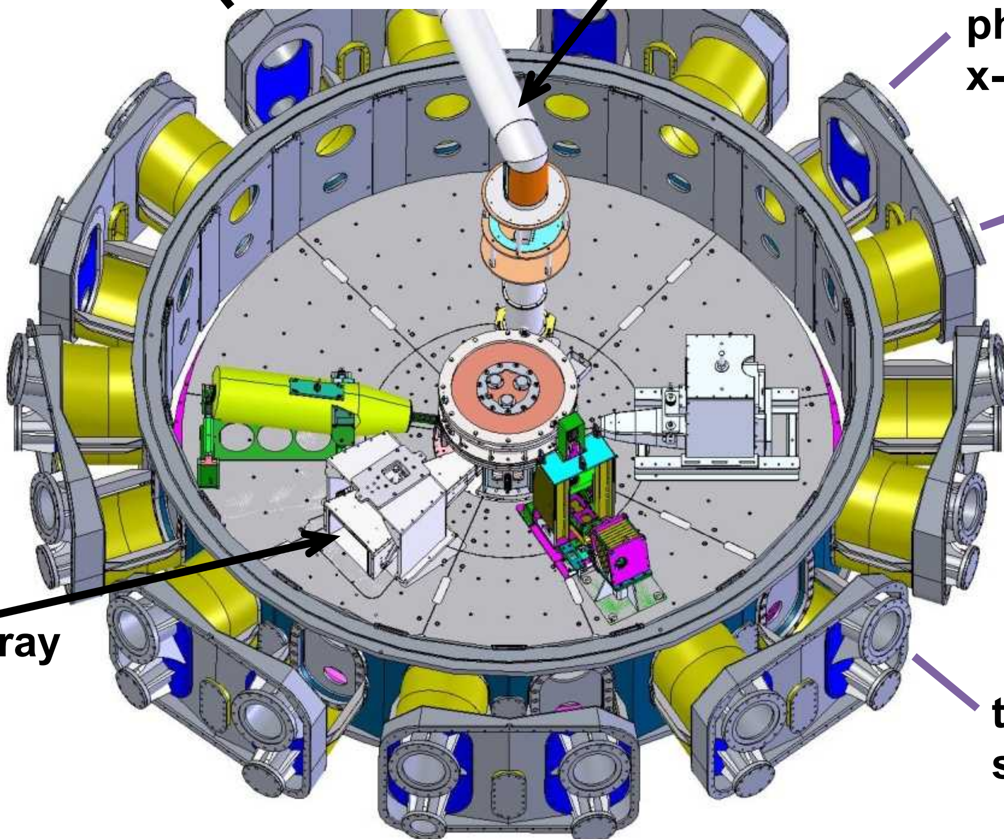
We want high intensity (high Tr) for high ablation pressure
-> let the capsule see the pinch

We need high uniformity (~1%) in x-rays the capsule sees for symmetry
-> hide the capsule from the pinch



This approach is the most conservative

There are many diagnostics and experimental systems available for each shot



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The Z facility has an extensive suite of x-ray diagnostics

X-ray Power and Energy

Filtered X-ray Diodes (XRDs)………………. < 4 keV Power
Photo-Conducting Diamonds (PCDs)………. > 1 keV Power
Silicon Diodes (TEP)…………………………. Broad-band Power
Bolometers………………………….............. Broad-band Energy

X-ray Spectroscopy

Elliptically Curved Crystals……………………0.7-10 keV Time-gated
Convex Curved Crystals…………………….. 0.7-10 keV Time-integrated
Spherically Curved Crystals…………………. 0.7-10 keV Time-integrated
Transmission Crystals…………………………> 10 keV Time-integrated

X-ray Imaging

Filtered Pinhole Cameras……………………..> 0.7 keV Time-gated
Multi-layer Mirror Pinhole Cameras…………0.277±0.003 keV Time-gated

X-ray Backlighting

Point-projection……………………………….two-frame @ ~1kJ ea.
1 or 2-color Monochromatic Imaging.............two-frame @ ~1kJ ea.

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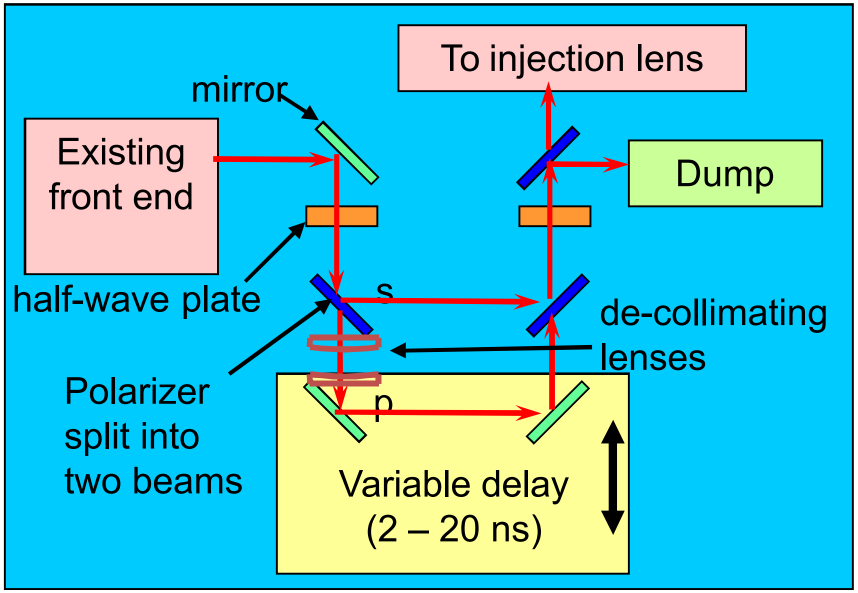
Z-Beamlet enables 2 x-ray backlighting images to be acquired on a single Z shot

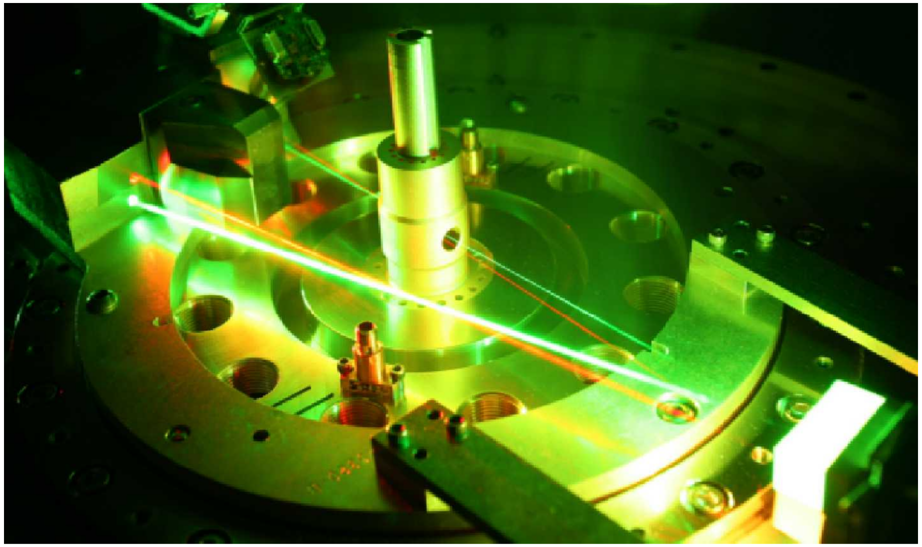
Modifications of Z-Beamlet laser

- The output from the front end is split into two beams.
- A 2-20 nsec time delay introduced between the 2 beams.
- The beams are injected into the main cavity amplifiers with a 1.3 mrad angular separation.



Modifications of backlighter detector

- The 2 beams are focused onto foil targets and are imaged by 2 spherically bent crystals at 1.865 keV or 6.151 keV onto 2 image plate detectors.



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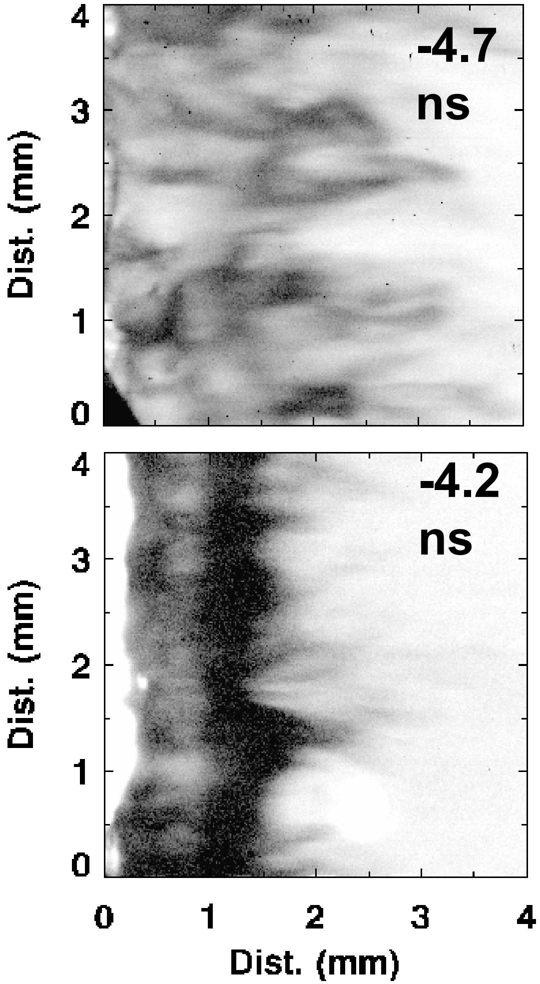
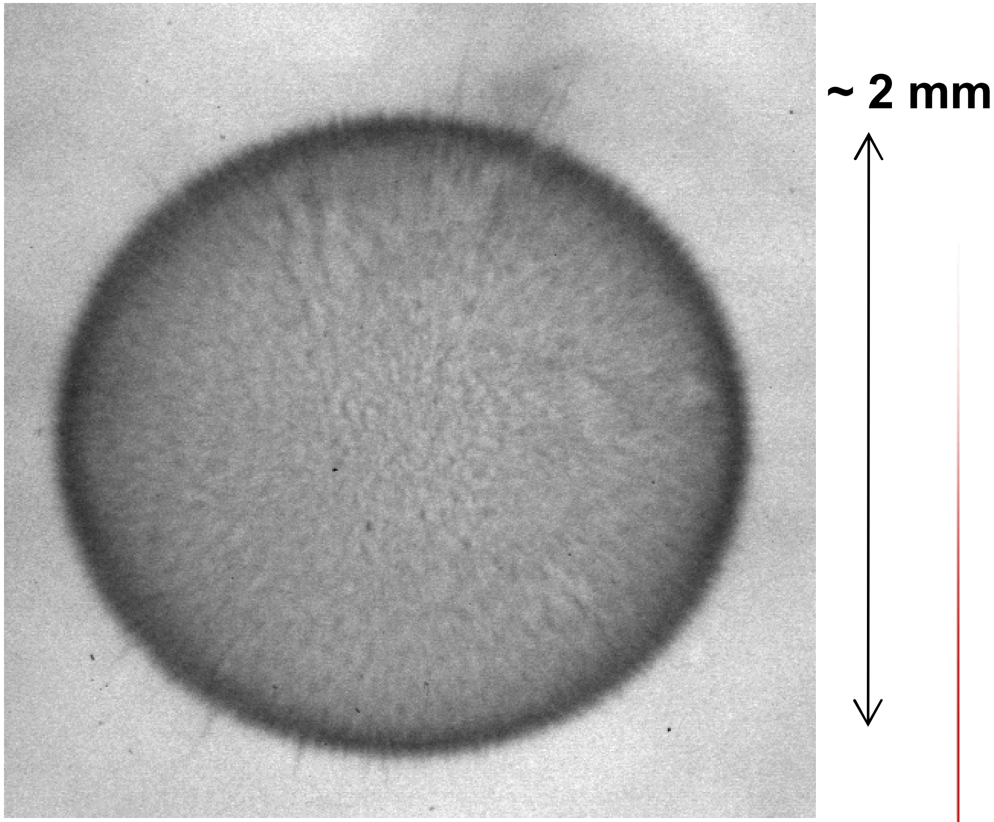
Two-frame, high resolution x-ray backlighting is an important diagnostic now in routine use on Z

Z-pinch implosion



6.151 keV x-ray radiograph of imploding capsule (C_r = 1.7)



Backlighter developed by: D. B. Sinars, G. R. Bennett

Experiments by Cuneo et al

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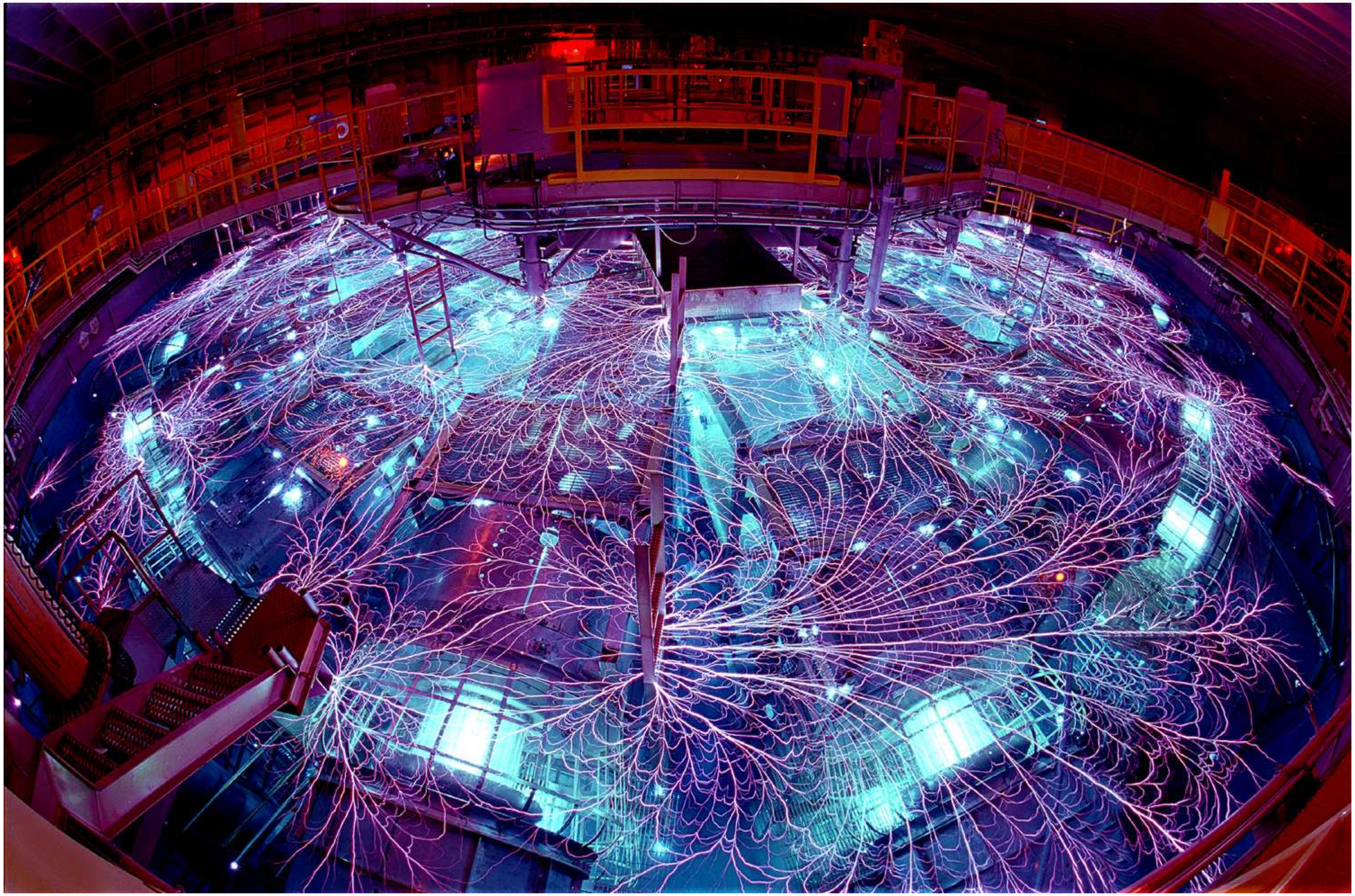
Questions?



Many people contributed to this talk

Thanks to:

D. Ampleford, B. Atherton, J. Bailey, G. Bennett, G. Cooper, C. Coverdale, M. Cuneo, M. Desjarlais, A. Edens, M. Geissel, D. Hanson, D. Headley, M. Herrmann, C. Jennings, B. Jones, M. Jones, M. Knudson, K. LeChien, R. Leeper, G. Leifeste, R. Lemke, F. Long, M. Lopez, K. Matzen, T. Mehlhorn, R. McBride, R. McKee, A. McPherson, T. Nash, K. Peterson, J. Porter, P. Rambo, G. Rochau, G. Robertson, D. Rovang, C. Ruiz, D. Sandoval, M. Savage, J. Schwarz, A. Sefkow, D. Sinars, S. Slutz, I. Smith, K. Struve, W. Stygar, R. Thomas, P. VanDevender, R. Vesey, E. Waisman, and the Z and Z-Beamlet operations teams