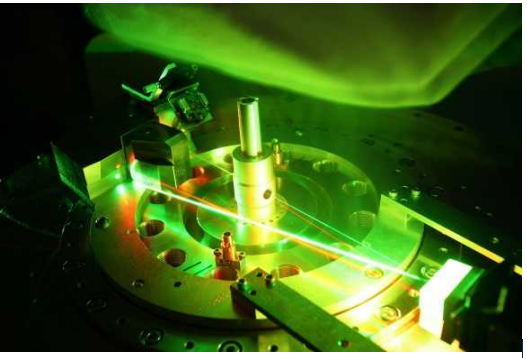
SAND2015-10853C



The Z-Backlighter Laser Facility at Sandia National Laboratories

Marius S. Schollmeier

International Meeting on Laser-Driven Radiation Sources for Nuclear Applications (LDRS2015)

George Washington University, Washington, DC

December 13 – 15, 2015

Sandia National Laboratories

Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Sandia National Laboratories

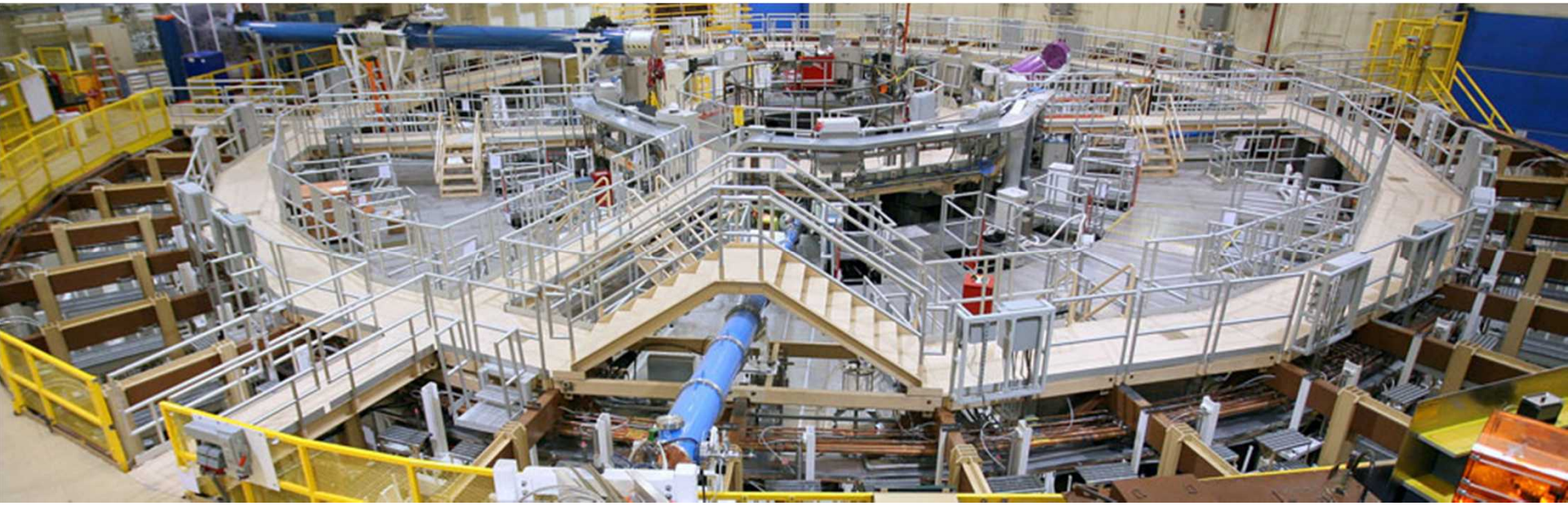
- Federally funded research and development center; government-owned, contractor operated
- Principal sites at Albuquerque, NM and Livermore, CA
- Regular employees: 10,540; total laboratory expenditures (FY14): $2,686,329,000
- 7 research foundations:
  - Bioscience
  - Computing and Information Sciences
  - Engineering Sciences
  - Geoscience
  - Materials Sciences
  - Nanodevices and Microsystems
  - *Radiation Effects and High Energy Density Science*

High Energy Density Science on

"Science from Earth's Core to Black Holes"*

- **Inertial Confinement Fusion and Magnetized Liner Inertial Fusion (MagLIF)**
- **Dynamic Material Compression and EOS studies**
- **Z Astrophysical Plasma Properties**
- **Radiation Effects Sciences**

- **33 m diameter, 1 shot per day, ≈150 shots per year**
- **11-27 MA, 80 TW electrical power**
- **Up to 300 TW/2.5 MJ of x-rays**



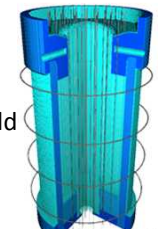
*http://www.sandia.gov/z-machine

The Z-Backlighter Facility supports 3 key research areas at Z

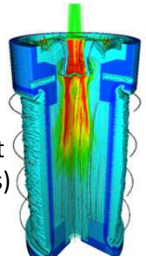
Sandia National Laboratories

Preheating a Magnetized Liner Inertial Fusion (MagLIF) target

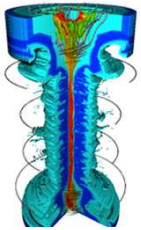
Magnetization with external B-Field (ABZ, 10-30 T)

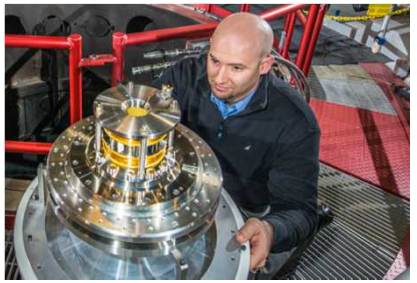


Laser heating with Z-Beamlet (2-6 kJ @ 2-6 ns)

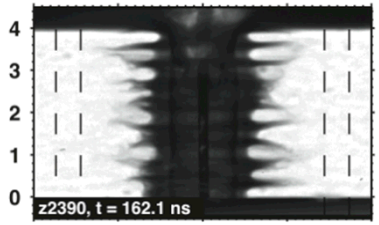


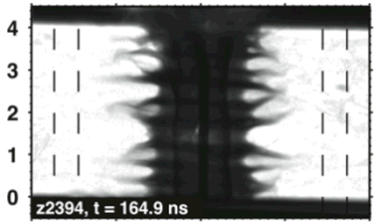
Compression with Z

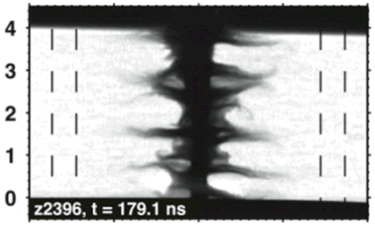


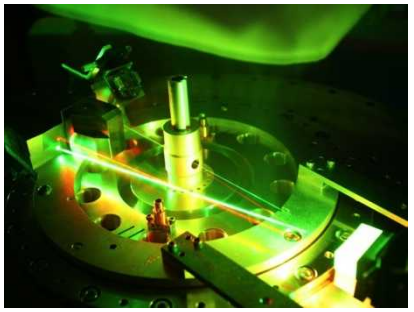


Driving 1.8 and 6.2 keV x-ray backlighters for x-ray radiography of imploding liners or wire arrays

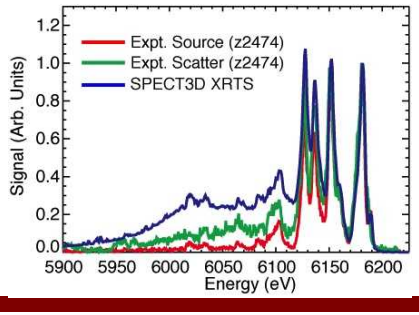


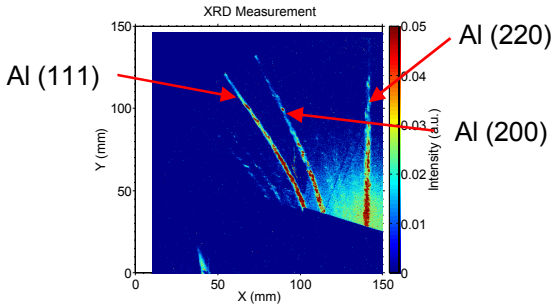


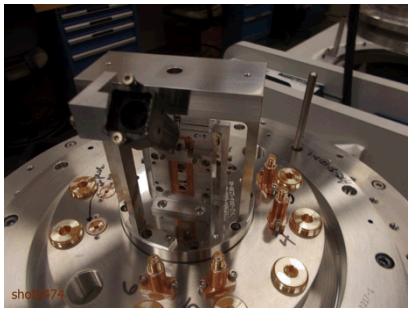




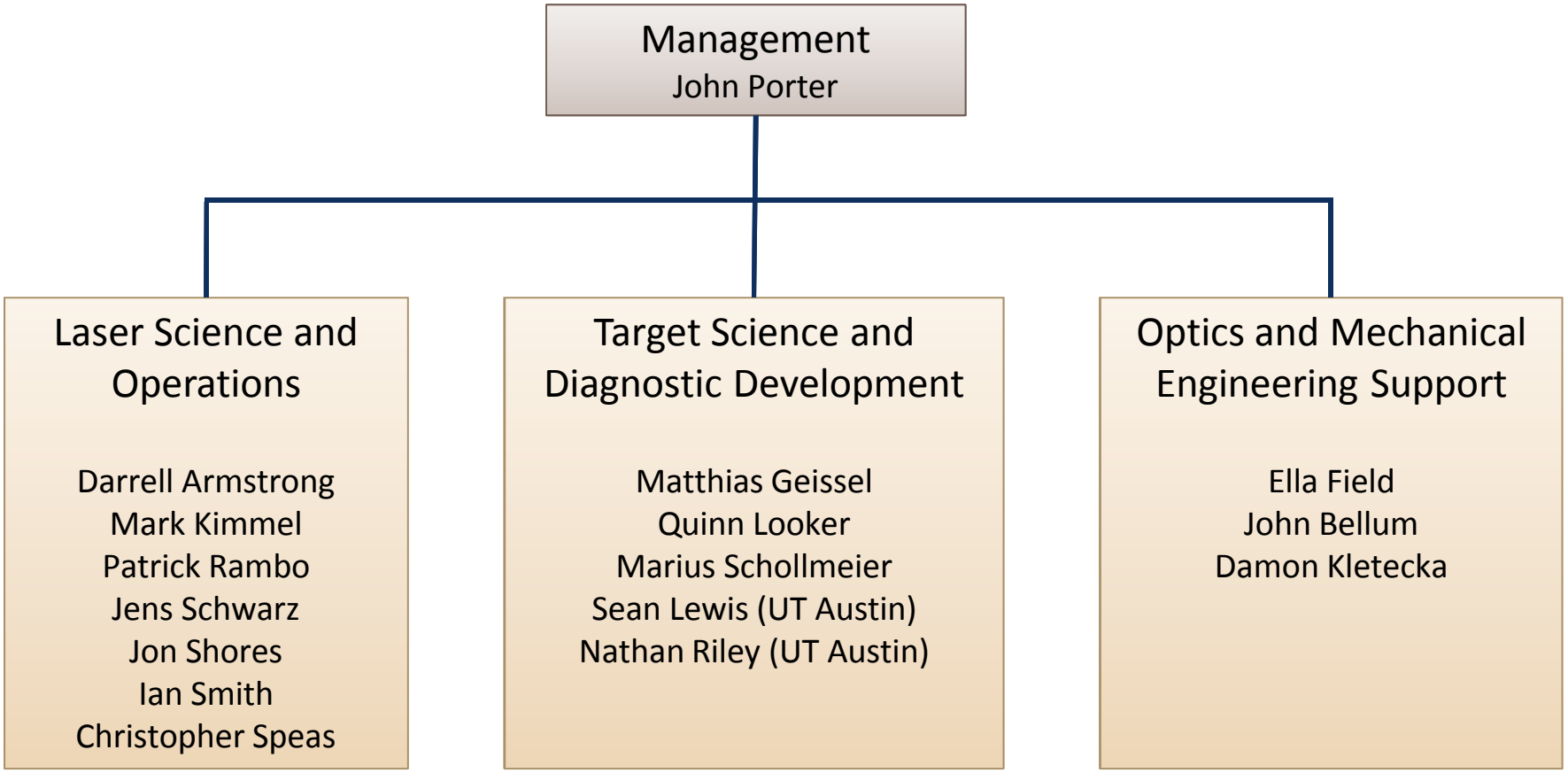
Generating x-ray sources for x-ray scattering and diffraction on dynamically compressed matter







Z-Backlighter Facility Organization



12 full-time employees & 2 grad students to support
3 laser systems, Z shots and 5 target chambers!

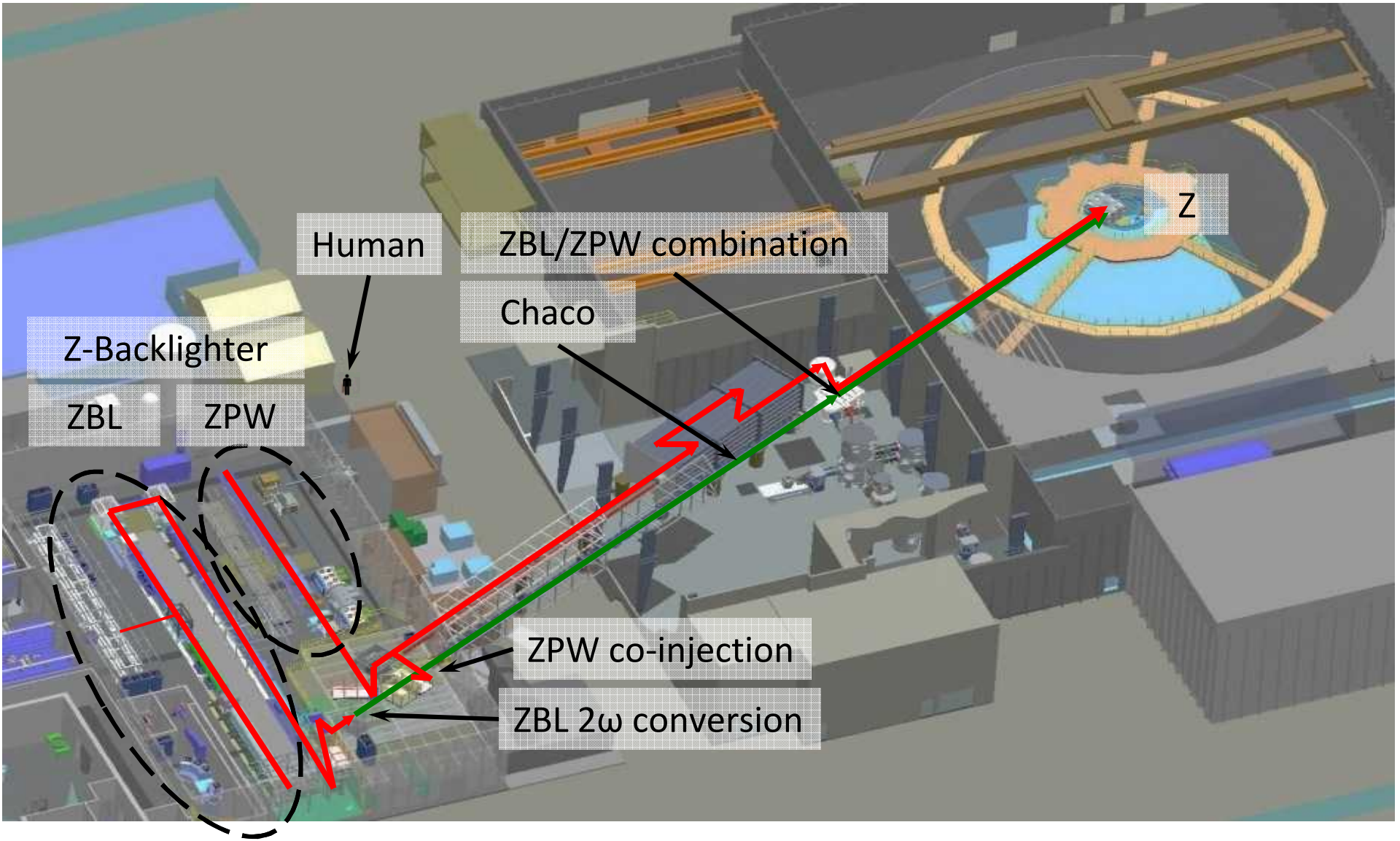
Z-Backlighter Facility Overview

Sandia National Laboratories

Z Backlighter

	Z Beamlet	Z Petawatt	Chaco
λ (nm)	527	1054 / 527	1064 (532)
pulse duration	0.3-8 ns, typ. 2 ns	500 fs – 10 ps/ 2 ns	300 ps – 10 ns
typ. spot size (μm FWHM)	75	6 / ?	20
E_{max} (J)	4500	100 (200TW) / 500 (ZPW) / 800 (co-inj.)	50 (25)
I (W/cm^2)	~ 10^{17}	~10^{20} / ~10^{16}	~ 10^{16}
Shot Intervals (minutes)	180	180	20
'Special feature'	2 pulse Multi-Frame-Backlighter or single pulse	OPCPA for shortpulse operation or narrowband co-injection into ZBL	8-10 ns option: 1w and >100J, picket-fence pulses

Z-Backlighter Facility Overview



Z-Beamlet Basics

Sandia National Laboratories

- The Z-Beamlet Laser (ZBL) was the LLNL NIF prototype (1992-1998)

- Now at Sandia and used for Z experiments
  - 1st shots into Target Chamber: Mar 2001
  - 1st active Z radiographs: Jun 2001

- Parameters:
  - Up to 6 kJ @ 1053 nm, , 31 x 31 cm^2 beam
  - Up to 4 kJ @ 527 nm, 31 x 31 cm^2 beam

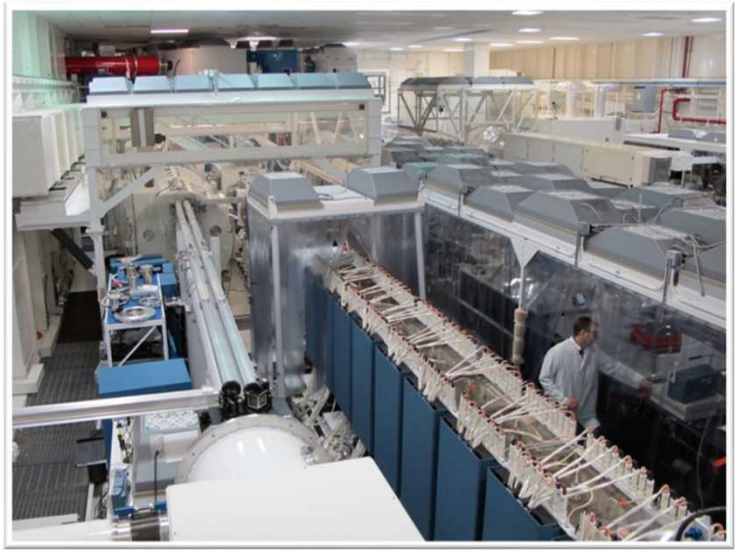
  - 3 shots per day
  - 0.3 – 4 ns pulse length
  - $I \approx 10^{17}$ W/cm^2

  - 4 target chambers + Z
  - Adaptive optics & phase modulation systems
  - Lens & phase plates for focusing

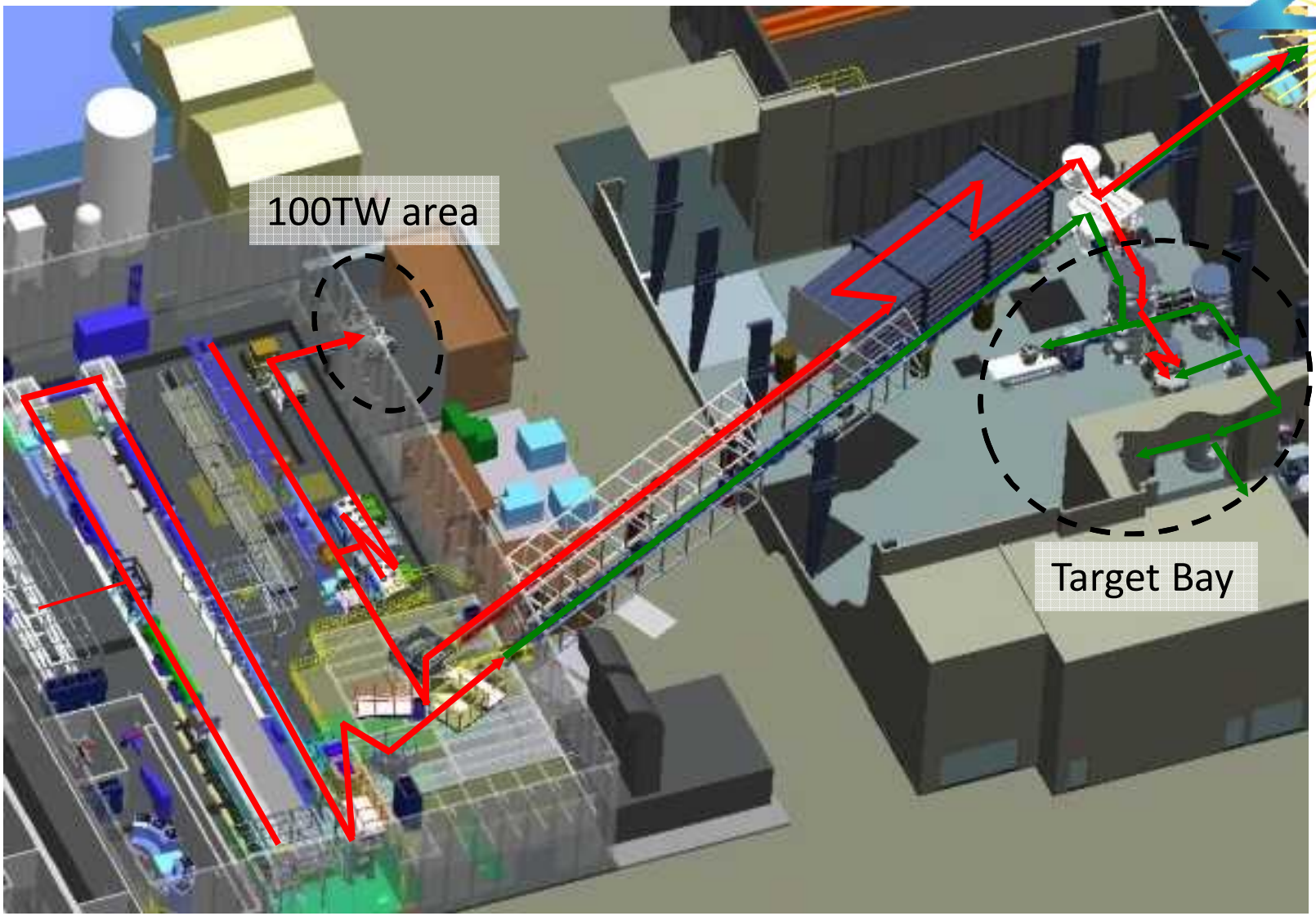
Z-Petawatt Basics

Sandia National Laboratories

- Shortpulse, 1ω operation
  - High-field physics (particle acceleration/γ-rays)
  - >10 keV x-ray generation
- Co-injection into ZBL and 2ω operation
  - Additional energy for ZBL pulse
  - Flexible prepulse for MagLIF/radiography
- Parameters:
  - Up to 500 J @ 1053nm, 500 fs, 41 x 41 cm^2
  - Up to 100 J @ 1053nm, 500 fs, 100 TW, 8” round
  - Up to 500 J @ 527nm, 2 ns, sub-aperture
  - 3 shots per day
  - Pulse length: 0.5 - 100 ps @ 1ω, 2 ns @ 2ω
  - $I = 2 \times 10^{20}$ W/cm^2 @ 1ω
  - 2 target chambers + Z
  - Off-axis parabola or lens focusing
  - 2 kJ full aperture upgrade: on-going



Z-Petawatt/Z-Beamlet target areas

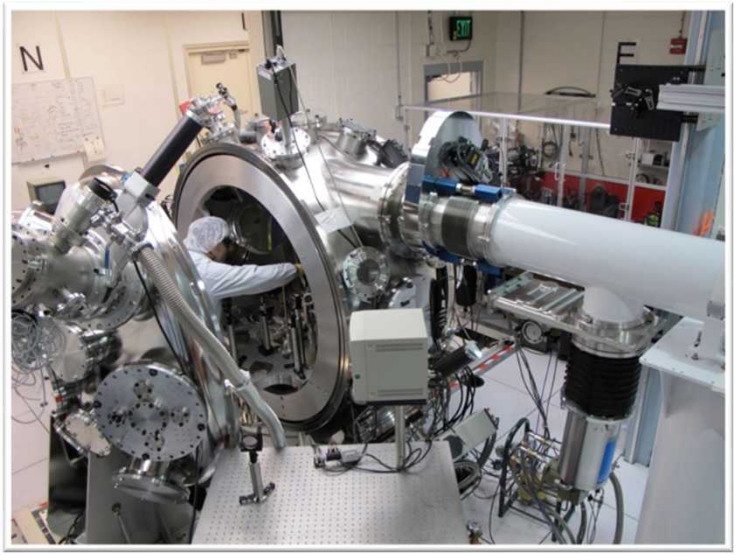


“100TW” Capabilities

Sandia National Laboratories

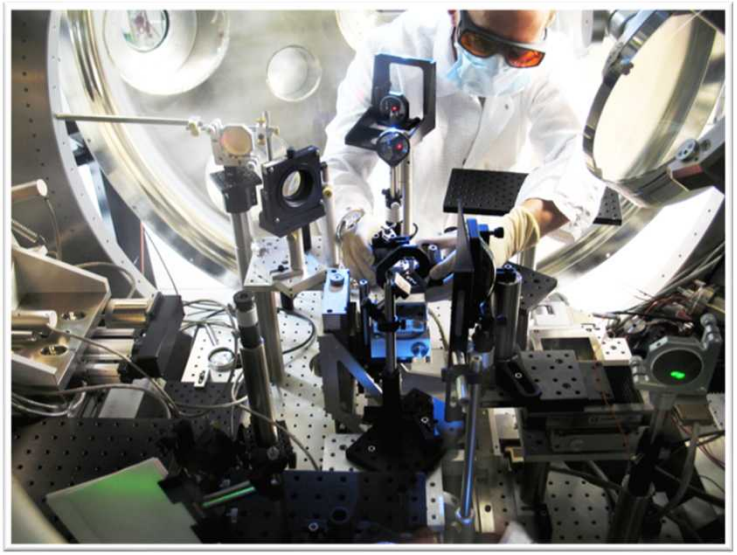
High-field experimental area:

- **100 J in 500 fs (250 TW), I = 2 × 10^{20} W/cm^2**
- **Target chamber:**
  - **ca. 75 cm diameter**
  - **2 half-domes on rails allow full access to interior**



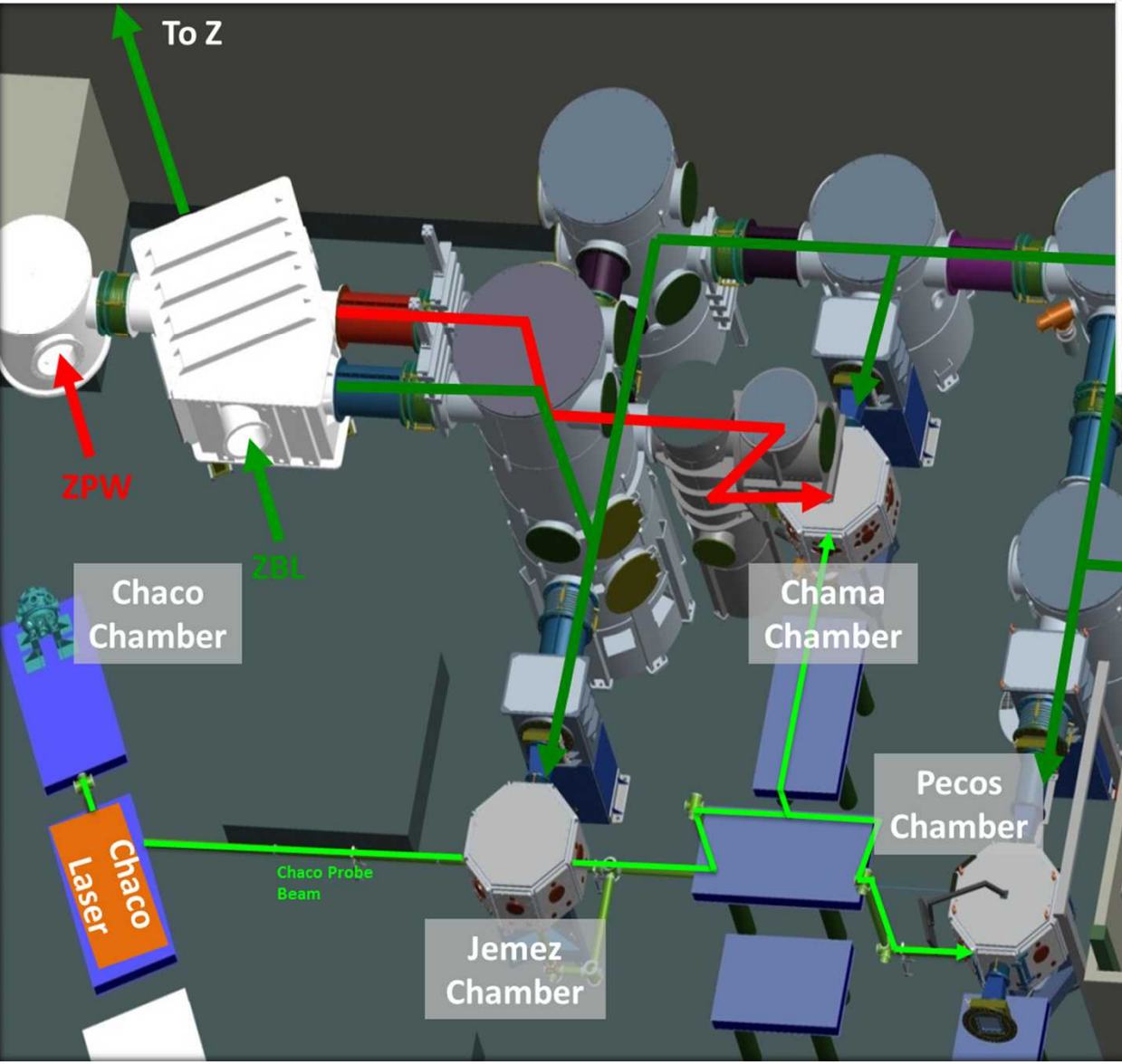
Experimental efforts have included:

- **Proton acceleration up to 65MeV**
- **Proton radiography**
- **K_α line source optimization up to 25 keV**
- **K_α bent crystal imager development up to 16 keV**
- **Bremsstrahlung radiography up to 500 keV**



The Target Bay

Sandia National Laboratories



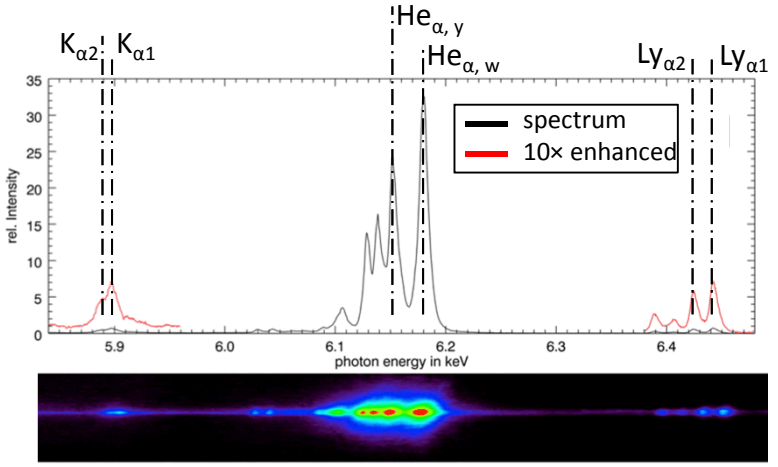
Chama Chamber and beam transport

Pecos Chamber

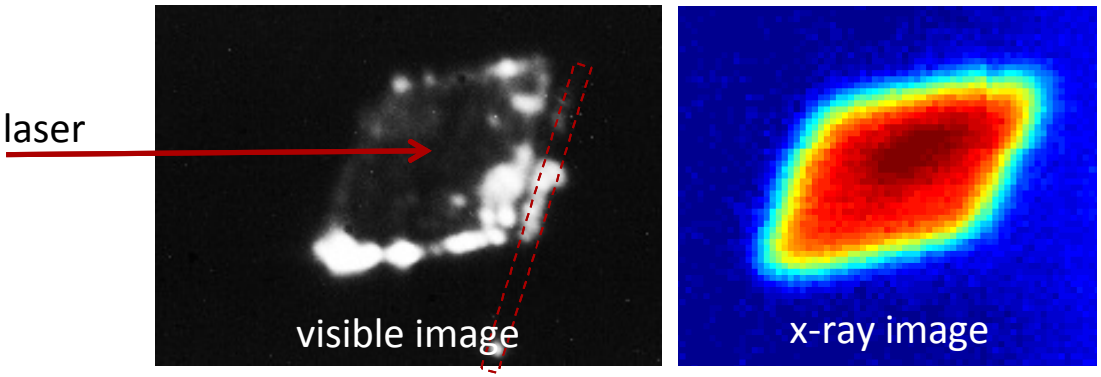
Laser-driven radiation sources: X-rays

Key parameters:

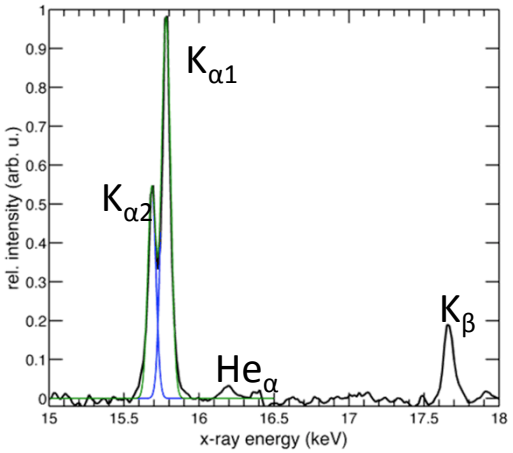
- **Up to 10 keV x-rays with Z-Beamlet:**
  - **He_α line emission from ions in hot plasma**
  - **≈10^{16} photons in 1-4 ns pulse**



- **Up to 25 keV x-rays with Z-Petawatt:**
  - **K_α line emission from cold atoms in dense matter**
  - **≈10^{14} photons in 0.5-100 ps pulse**



ZPW: 1 ps, 100 J, I = 10^{20} W/cm^2
Zirconium, E = 15.7 keV

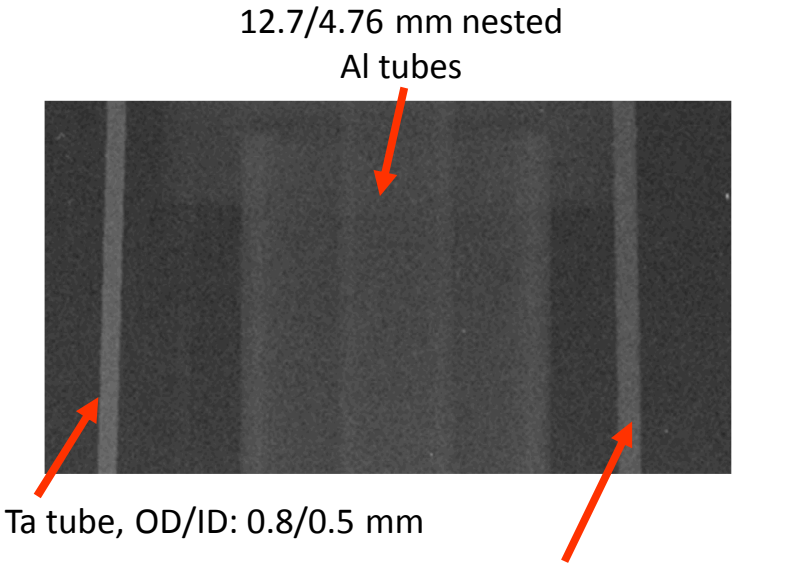


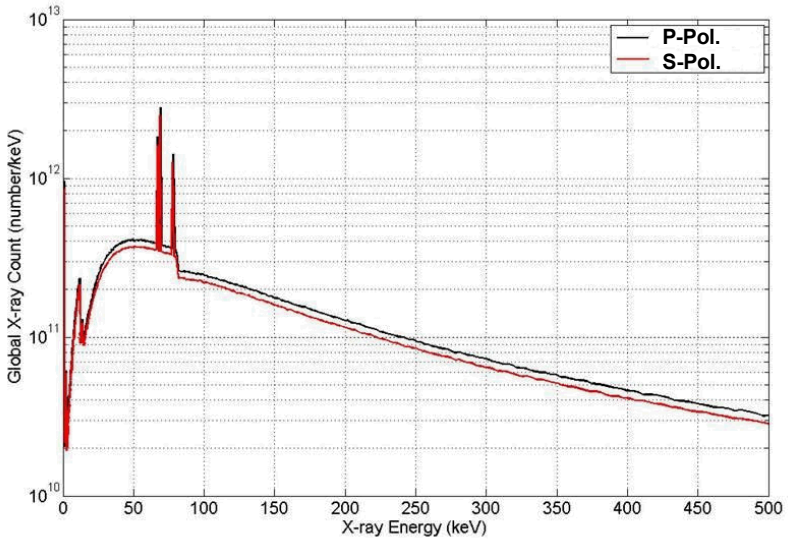
Laser-driven radiation sources: High-energy Bremsstrahlung photons

Sandia National Laboratories

Key parameters [1]:

- **High-intensity irradiation of Au targets leads to >500 keV Bremsstrahlung x-rays**
- **Radiation dose ≈100-300 mrad @ 1 meter**
- **2% spatial x-ray dose uniformity over several centimeters.**
- **Penetration power:**
  - **Tungsten: 0.5 g/cm^2 maximum**
  - **Copper: 8.0 g/cm^2 maximum**
  - **Aluminum: >10 g/cm^2 maximum**



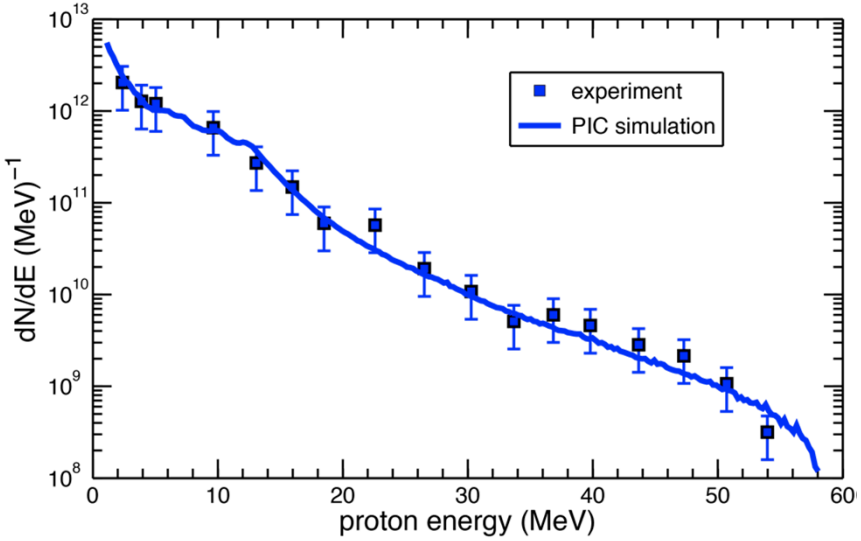


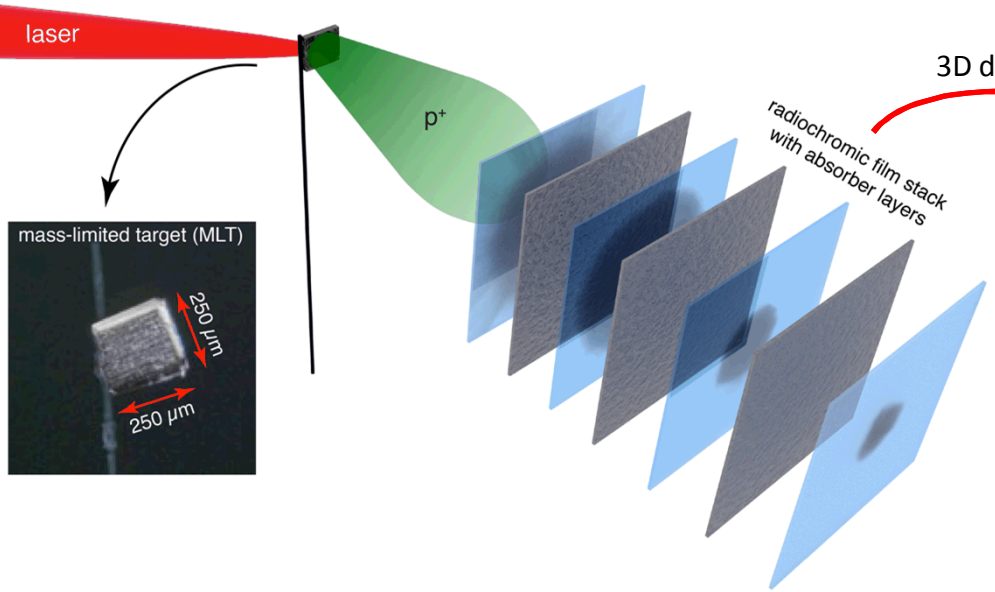
[1] T. Webb *et al.*, ICOPS 2011, Session IO6A

Laser-driven radiation sources: Protons

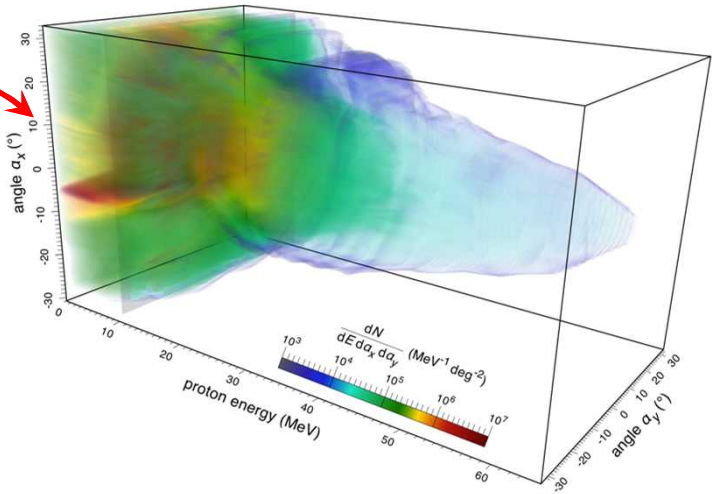
Key parameters [1]:

- **Thermal spectrum**
- **Sharp cutoff, up to 65 MeV**
- **≈10^{13} protons total**
- **Divergent beam up to ±30°**
- **Beam parameters depend on temporal laser pulse profile**





3D data unfolding



[1] MS *et al.,* Phys. Plasmas 22, 043116 (2015)

Summary: The Z-Backlighter Facility

Sandia National Laboratories

Supports 3 key research areas at Z:

- Laser heating a MagLIF target
- Driving 1.8 and 6.2 keV x-ray backlighters for radiography of imploding liners or wire arrays
- Generating sources for x-ray scattering or diffraction on dynamically compressed matter

3 laser systems:

- Z-Beamlet: kJ, ns, 2ω, ≈10^{17} W/cm^2
- Z-Petawatt: sub-kJ, ps, 1ω, 10^{20} W/cm^2 or sub-kJ, ns, 2ω
- Chaco: <100 J, ns, 2ω, ≈10^{16} W/cm^2

6 target chambers + Z:

- 100 TW
- 3 x 1.6 m Octagons
- 2 x 50-cm-class Spheres

Laser-driven radiation sources:

- X-ray He_α and K_α line radiation up to 25 keV
- Bremsstrahlung x-rays up to 500 keV
- Protons up to 65 MeV