SAND2015-5906PE

Sandia National Laboratories

July, 2015

Diagnostics at the Z Facility: Current and Planned Diagnostic Capabilities

Chris Bourdon

Manager Imaging and Spectroscopy (1675)

(505) 845-8794; cjbourd@sandia.gov

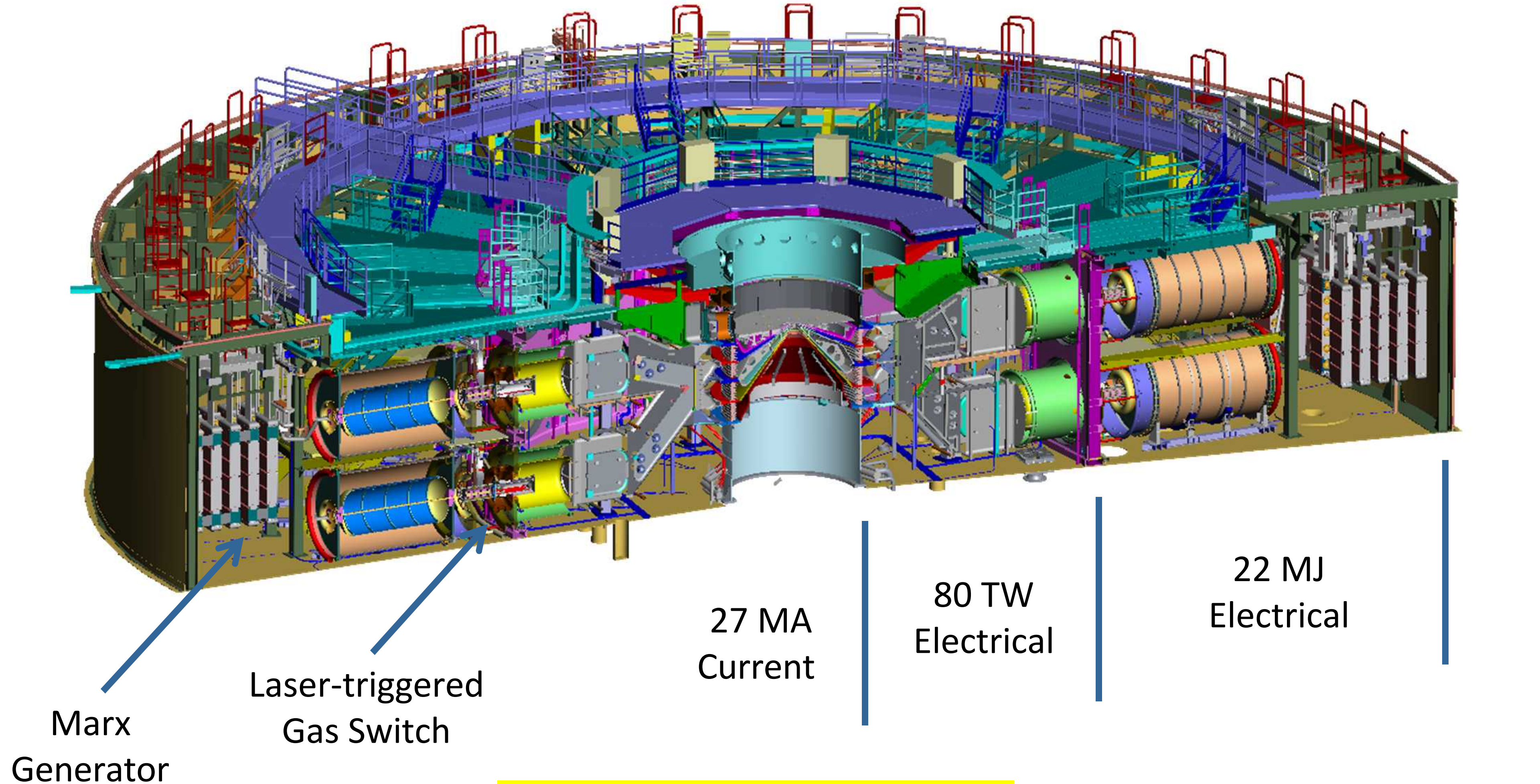
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories

Executive Summary

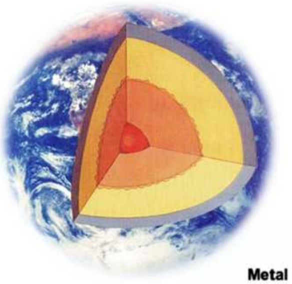
- Z is the world's premier pulsed power facility capable of accessing a broad range of the energy density phase-space
- The Z environment presents many challenges for fielding diagnostics, and developing new capabilities
- Experiments on Z support many different research areas with an emphasis on Dynamic Material Properties (DMP), Radiation Effects Sciences (RES), ICF, and Fundamental Science
- The roadmap for new capability development on Z acknowledges the resource trade space between diagnostics and other subsystems with an emphasis on new capabilities for DMP and ICF
- Many new capabilities have been commissioned in the last year:
  - TiGHER
  - Argon Imager
  - APE
  - CRITR-X
  - DAHX
  - TIPC
- Diagnostic Capabilities will continue to be developed to meet program needs; help welcomed

The Z facility at Sandia National Laboratories is the world's most powerful pulsed power machine.

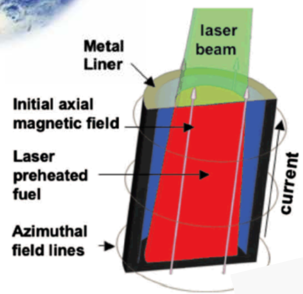


Operating Range: 11-27 MA

Z carries a broad portfolio of experiment campaigns with diverse requirements

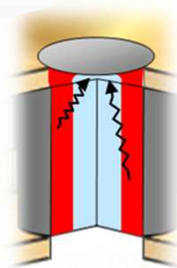


Dynamic Materials Properties (DMP)



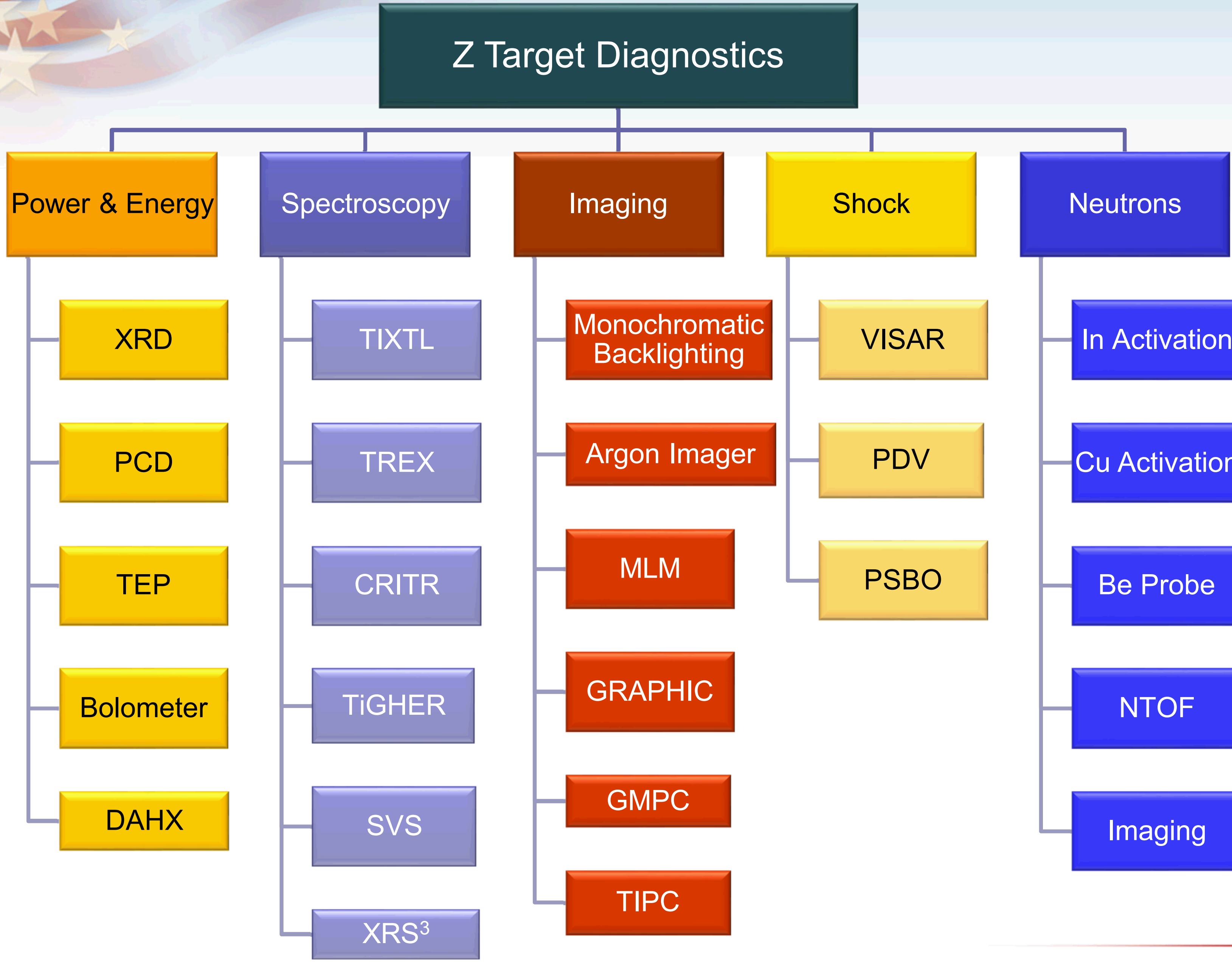
Inertial Confinement Fusion (ICF)

Radiation Effects Sciences (RES)



Secondary Assessment Technologies (SAT)

Fundamental Science (FS)

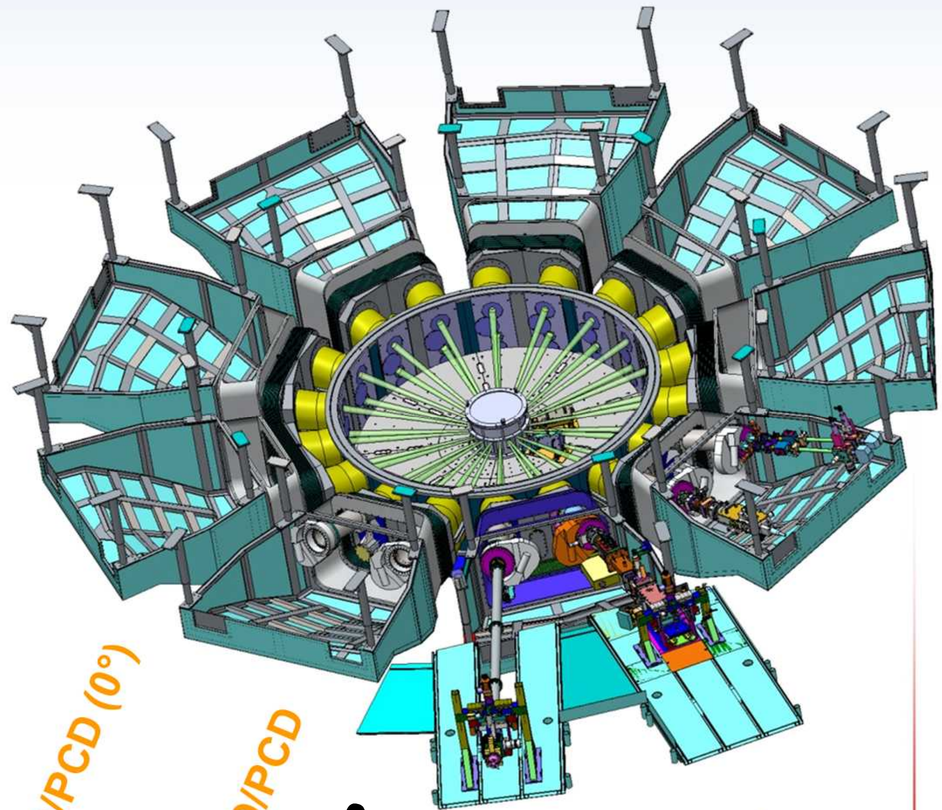


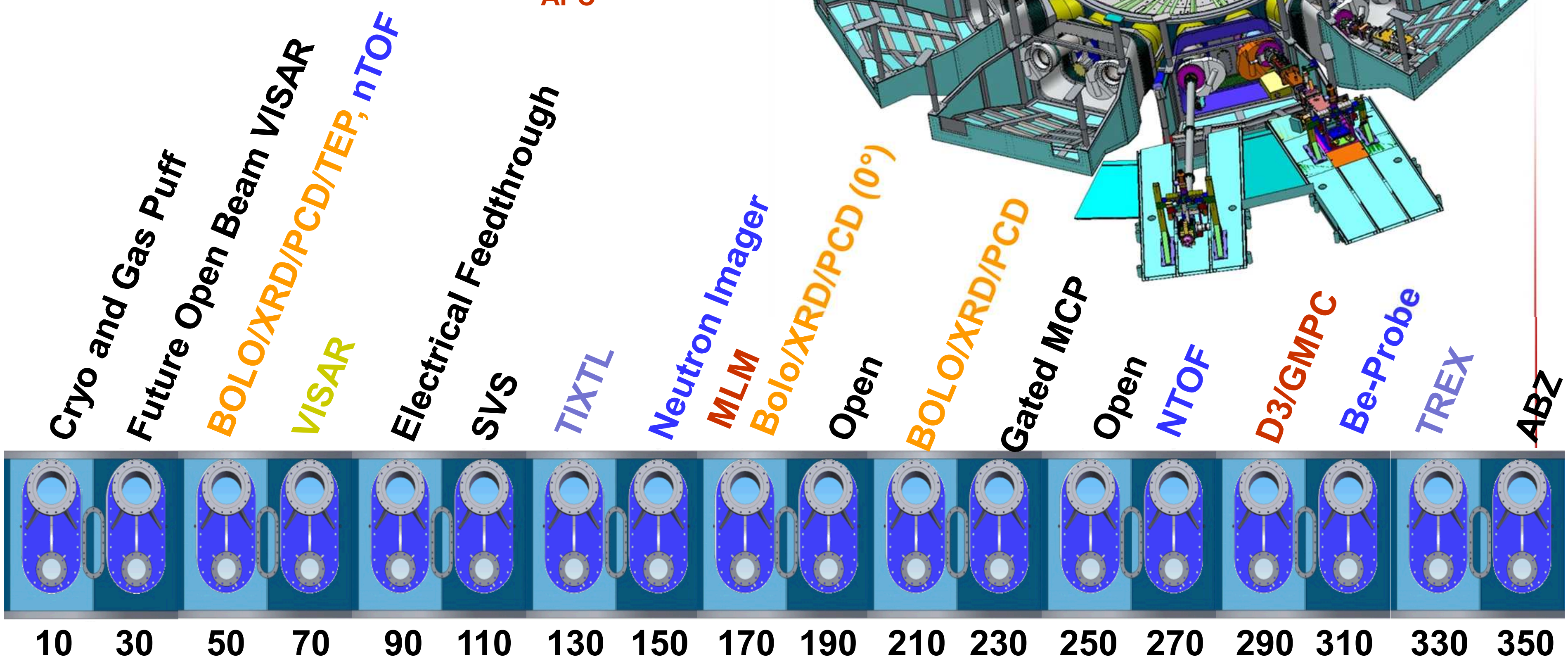
* Overview of of each diagnostic is available in the backup slides

Sandia National Laboratories

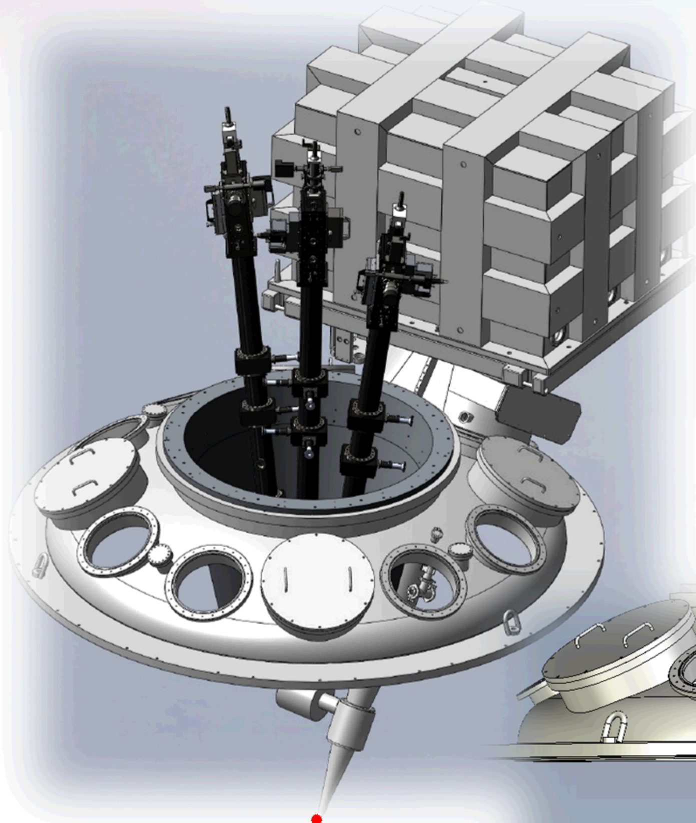
Radial LOS overview of the Z facility

- 18 Radial line of sights access ports at ~12º
- 18 line of sight access ports at ~0º
- Chamber diagnostics:
  - CRITR
  - TiGHER
  - SVS
  - DAHX
  - Neutron Activation(In and Cu)
  - VISAR
  - PSBO
  - Monochromatic Backlighter
  - TIPC
  - APE
  - APC

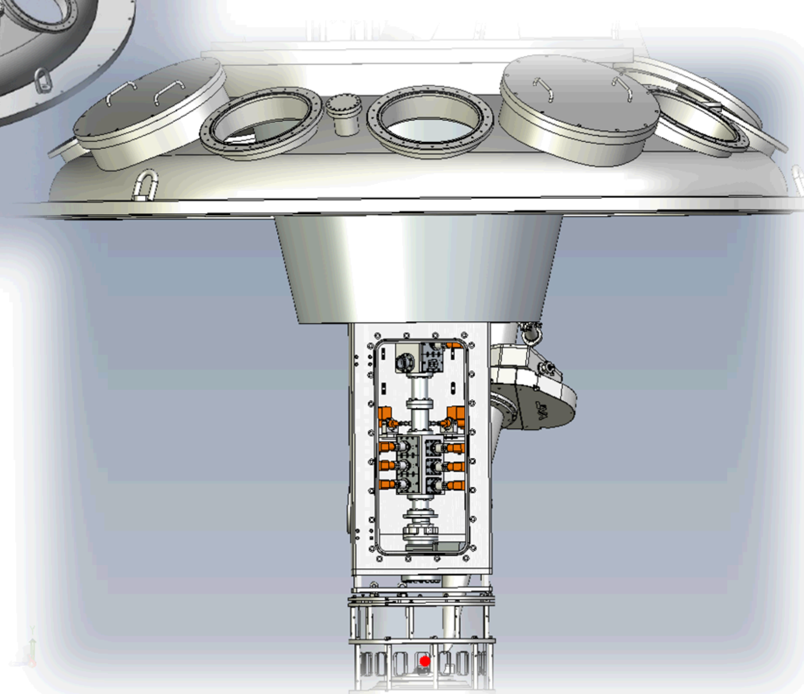




Axial LOS overview of the Z facility



- 3 Axial LOS:
  - –0°: PODD (ECP,CCP, MIP, GMPC)
  - – 9° E: PODD (ECP,CCP, MIP, GMPC)
  - –9° W: PODD (ECP,CCP, MIP, GMPC)



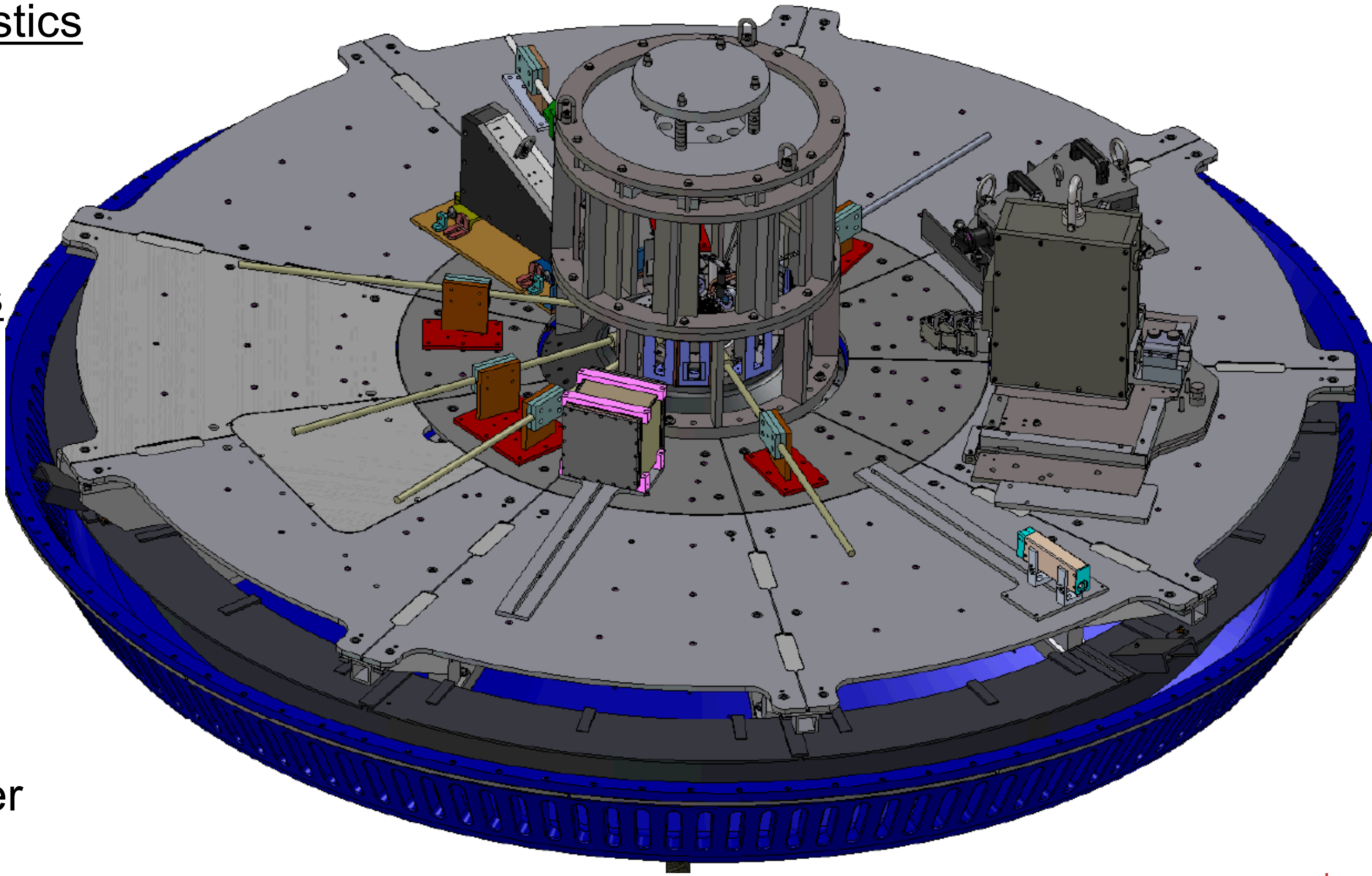
- 1 Close-Proximity LOS:
  - –0°: GRAPHIC, PODD, GMPC

In-chamber diagnostics provide opportunities for improved access and sensitivity

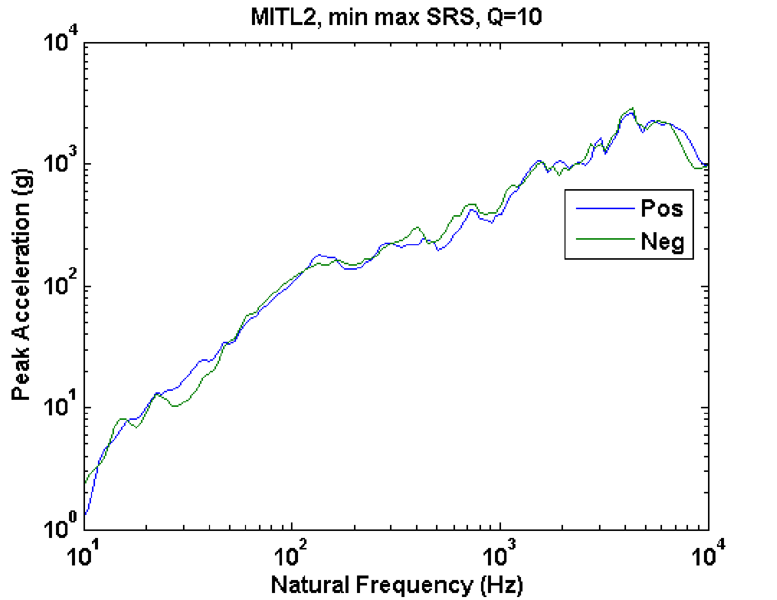
<u>Fiber-Based Diagnostics</u>
- VISAR
- PDV
- SVS

<u>X-ray Spectrometers</u>
- CRITR-AR
- CRITR-RR
- XRS3
- TiGHER
- DAHX

<u>X-ray Imagers</u>
- Monochromatic Crystal Backlighter
- Spherical Imager
- TIPC
- APC
- APE

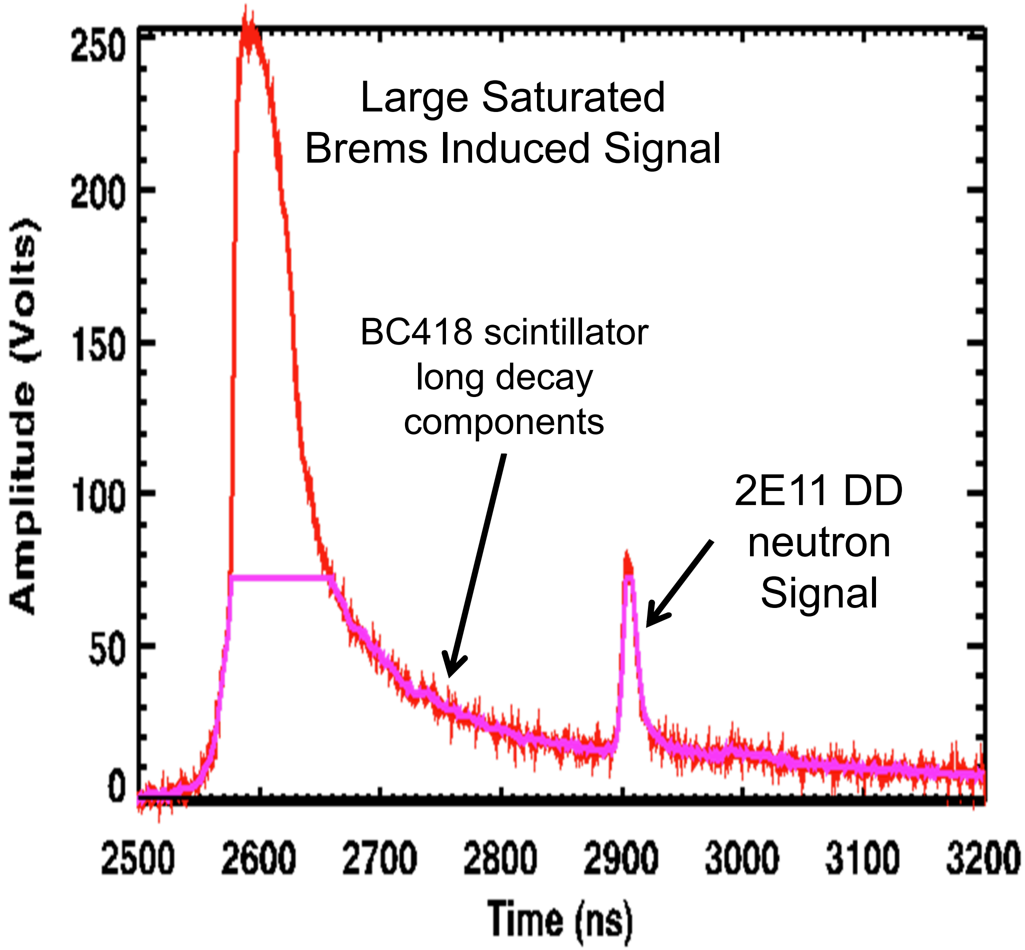


Shock and debris pose major challenges



The Bremsstrahlung background on Z saturates nTOF instrumentation requiring long fielding distances and significant line-of-sight shielding.

Example nTOF data on Z



Bremsstrahlung background source:

- Originates from power-flow and late-time z-pinch instabilities
- End-point energy > 10 MeV
- Highly variable depending on electrical load design

To mitigate background effects:

- 4" lead shielding
- Collimation
- Fast Mesh PMT's (NSTec) with a large linear current and fast recovery

*Figure courtesy G. Chandler, SNL

Diagnostic Operation on Z is heavily influenced by the unique Z environment

- Target chamber must be vented in-between every shot
  - Removal of all in-chamber and axial diagnostics every shot
- Debris environment requires inspection of diagnostic components between each shot
  - Venting of most fixed diagnostics every shot
- Shock environment and replacement of load hardware requires re-alignment of diagnostics every shot
- X-ray Background requires heavy, 4-pi shielding (Typically 1” Tungsten)
- EMP environment requires carefully shielded cables and RF enclosures for all active electronics
  - CCD cameras are challenging to properly shield and operate

Something doesn’t have to be a brand new technology to be valuable on Z. Implementing a proven technology in a new, harsh environment is every bit as challenging.

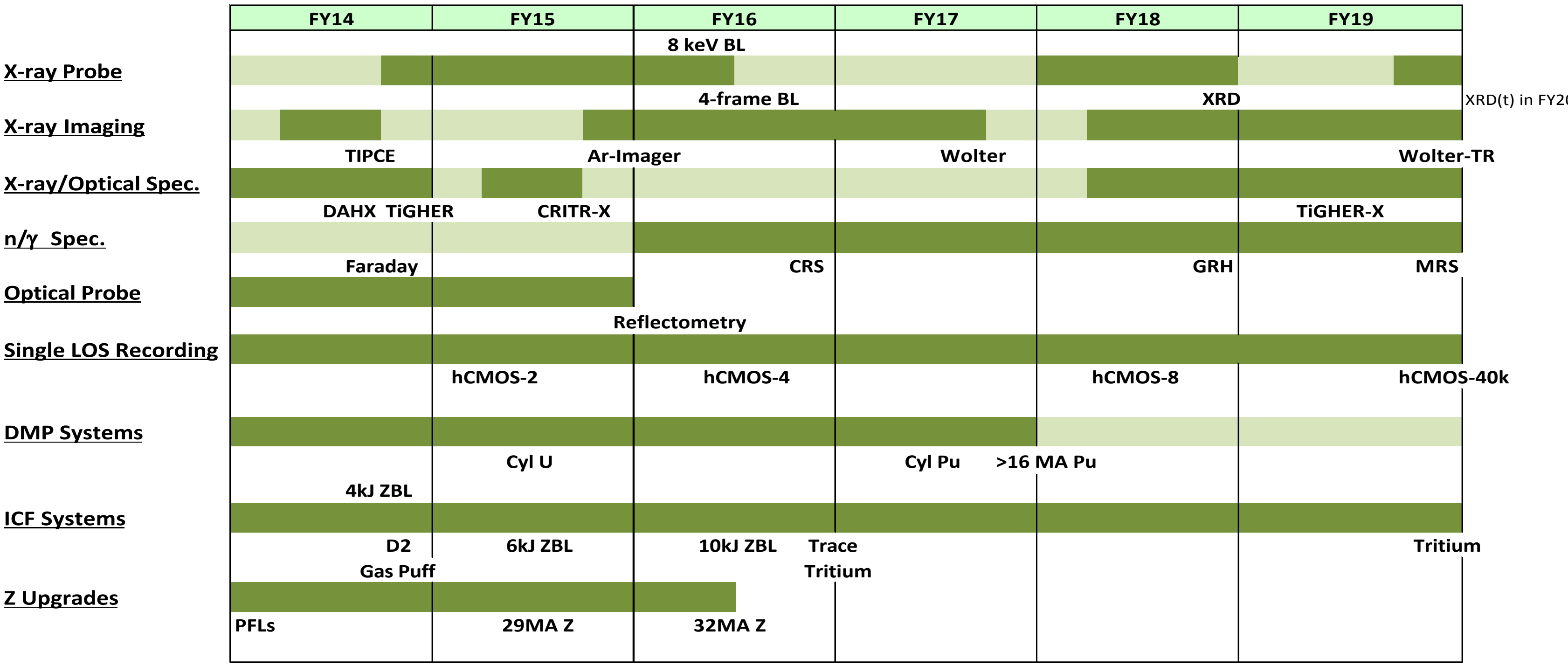
Sandia National Laboratories

Capabilities under Development

- Development Plan tied to:
  - National ICF/HED diagnostics plan
  - ICF, RES and DMP 5-year plans
  - Facility and Z capabilities and infrastructure plans
- Integrates all diagnostic development opportunities across Z community
- Seeks to take advantage of development of new technologies

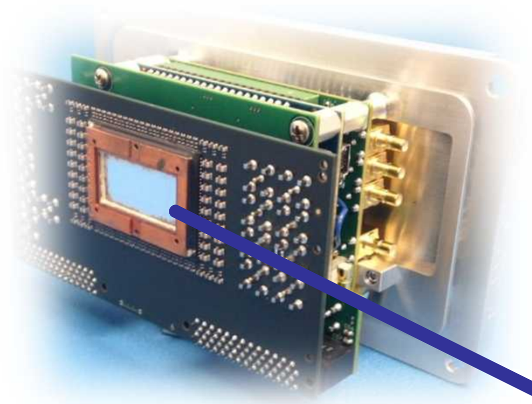
Capabilities not captured on the roadmap:

- Time-Gated spherically-bent crystal spectrometer
- On-Axis time-integrated differential pinhole imaging
- ……



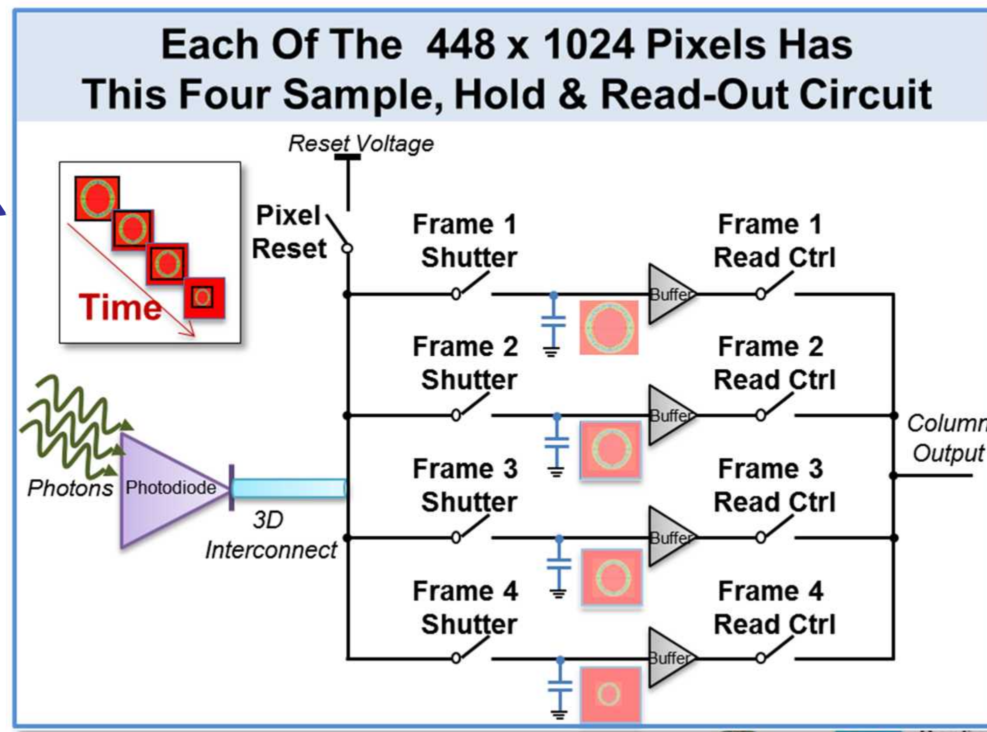
We've developed a high speed CMOS camera for multi-frame imaging, backlighting, and spectroscopy

hybrid CMOS camera



- Up to 4 frames of data on a single line-of-sight
- 1.5 ns minimum gate time
- 448x1024 pixel array
- 25 um x 25 um per pixel
- Sensitive to visible light and 0.7-6 keV x-rays

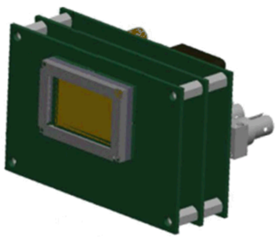
designed and built in collaboration with the MESA facility



hCMOS imaging is key to the national diagnostic strategy and will transform capability across ICF and the Science Campaigns

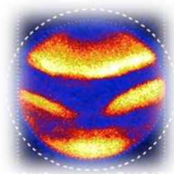
FY14	FY15	FY16	FY17	FY18	FY19
◆	◆	◆	◆		◆
2 Frame 1.5ns	2 Frame 1.5ns, Interlacing	4 Frame 1.5ns	8 Frame 1ns		8 Frame 1ns, Interlacing

Key Direct Sensor Applications

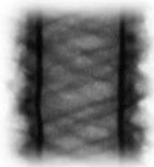


1-2 ns

LEH imaging (Z & NIF)

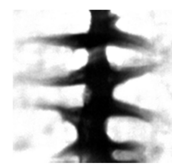


6 keV Backlighting

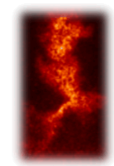


Opacity (Z & NIF)

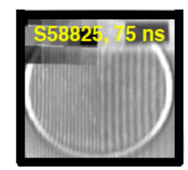
8-10 keV Backlighting



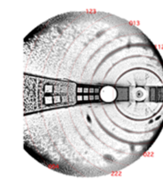
17-22 keV Imaging



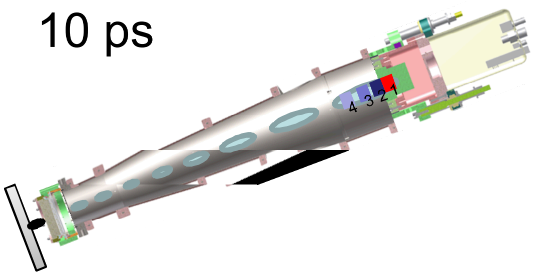
Strength (NIF)



Diffraction (Z & NIF)

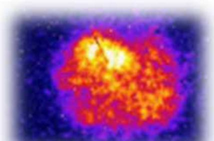


10 ps

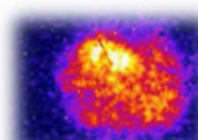


Key Pulse-Dilation Applications

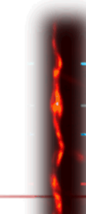
Hot Spot Imaging (NIF)



Hot Spot $T_e(r)$ (NIF)



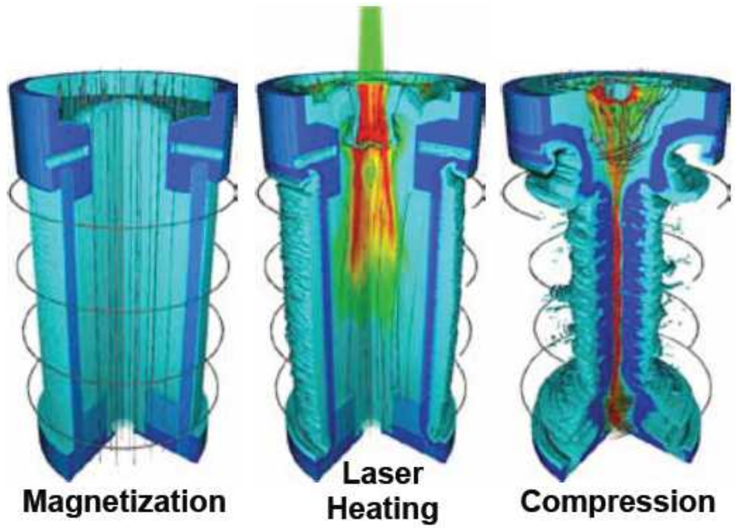
MagLIF Stagnation



Sandia National Laboratories

Diagnosing plasma preconditioning and stagnation conditions

MAGLIF Concept

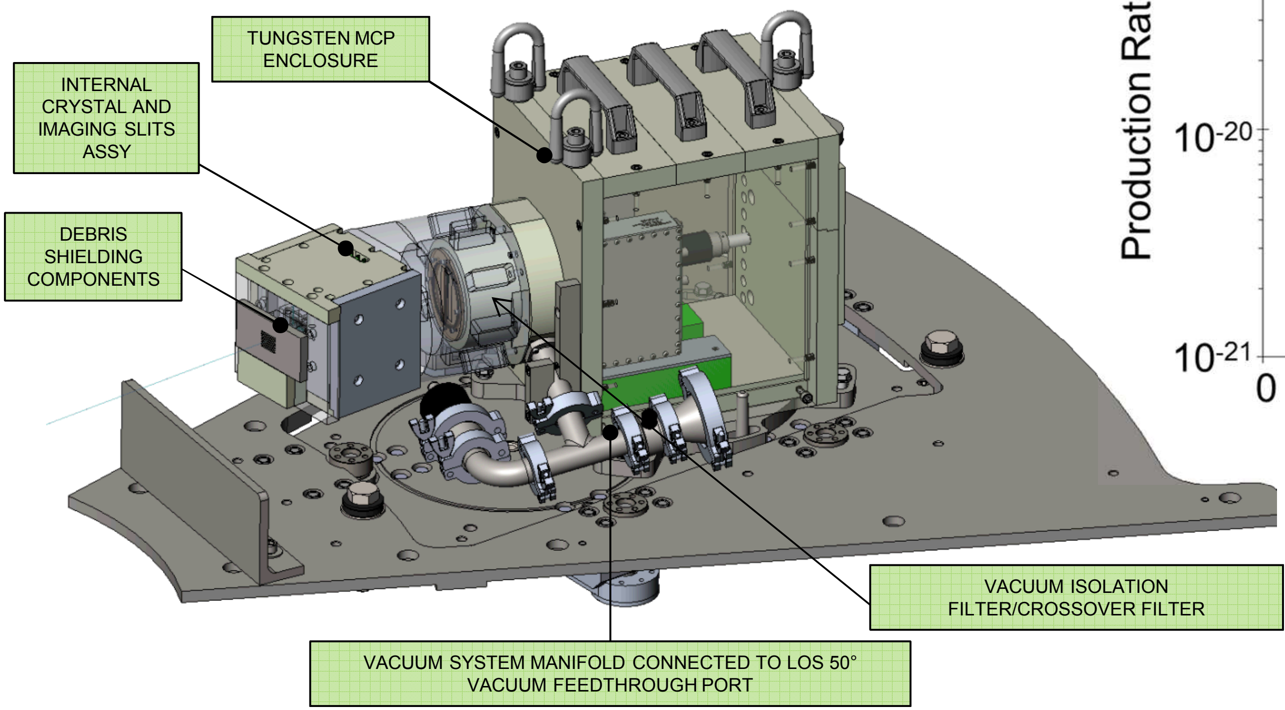


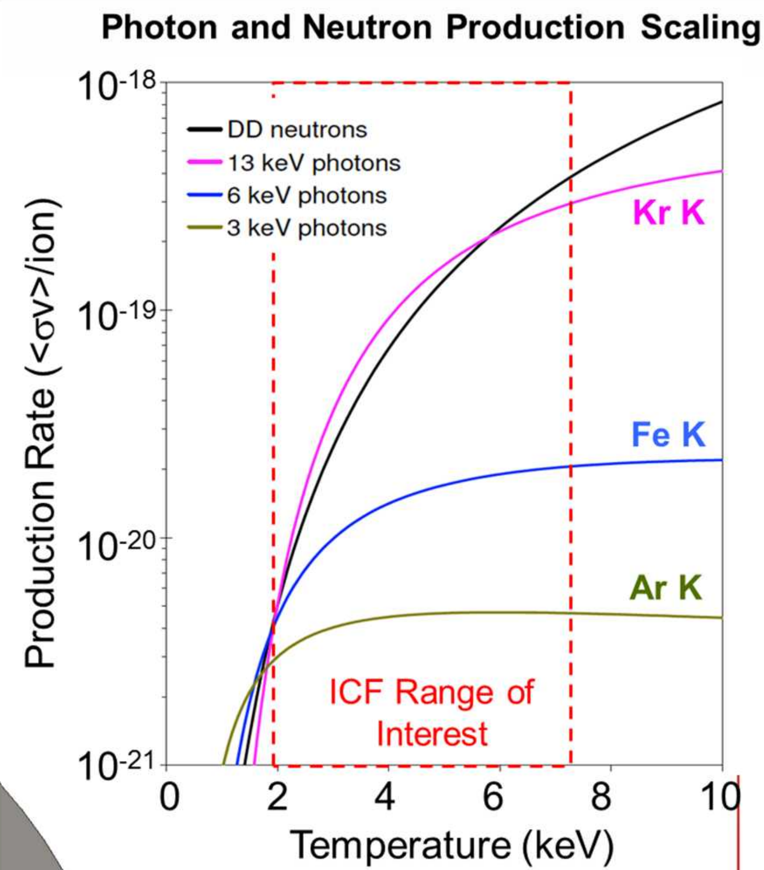
- Key target design elements
  - Magnetization
  - Laser heating
  - Liner compression

- Emerging diagnostic needs:
  - Diagnosing effectiveness of laser pre-heat
  - High-resolution imaging of stagnation column
  - Surrogates for neutron production

The Time Gated High Energy Radiation (TiGHER) spectrometer is commissioned October 2014.

- Cauchois Crystal spectrometer
- 8-frame MCP detector
- Quartz 1011, Mag 0.8x, 0.5x
- 4π Tungsten shielding enclosure
- Kr K-shell emission as a surrogate for DD neutron production





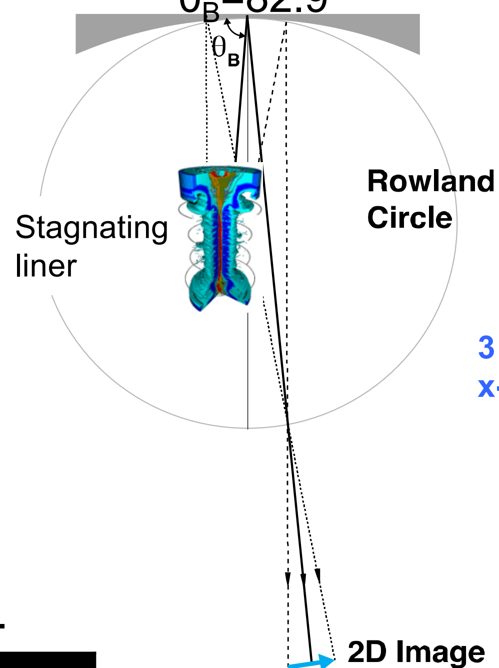
Sandia National Laboratories

Argon Imager

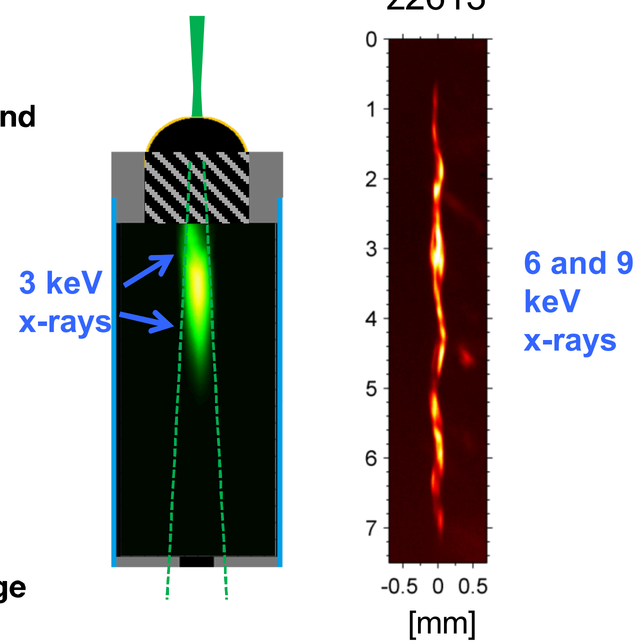
Time integrated, self-emission imaging has provided valuable data for MagLIF and is now being extended to other targets on Z.

Advantages of crystal imaging

1) high sensitivity
2) narrow bandwidth
3) 0° line-of-sight
4) large field-of-view



Self-emission images from MagLIF targets on Z



The analysis is complicated by higher order crystal reflections.

Reflection Plane	Energy (keV)	Thru*
Ge (220)	3.1	Ω_o
Ge (440)	6.2	$2.0*\Omega_o$
Ge (660)	9.4	$2.4*\Omega_o$
Ge (880)	12.5	$0.4*\Omega_o$

*Includes filters

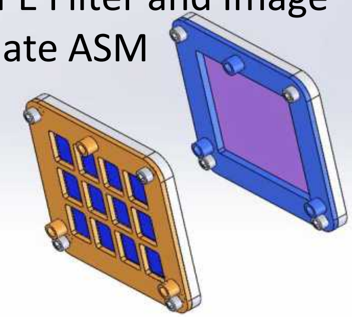
- Management POC: Chris Bourdon
- Responsible Scientist: Eric Harding

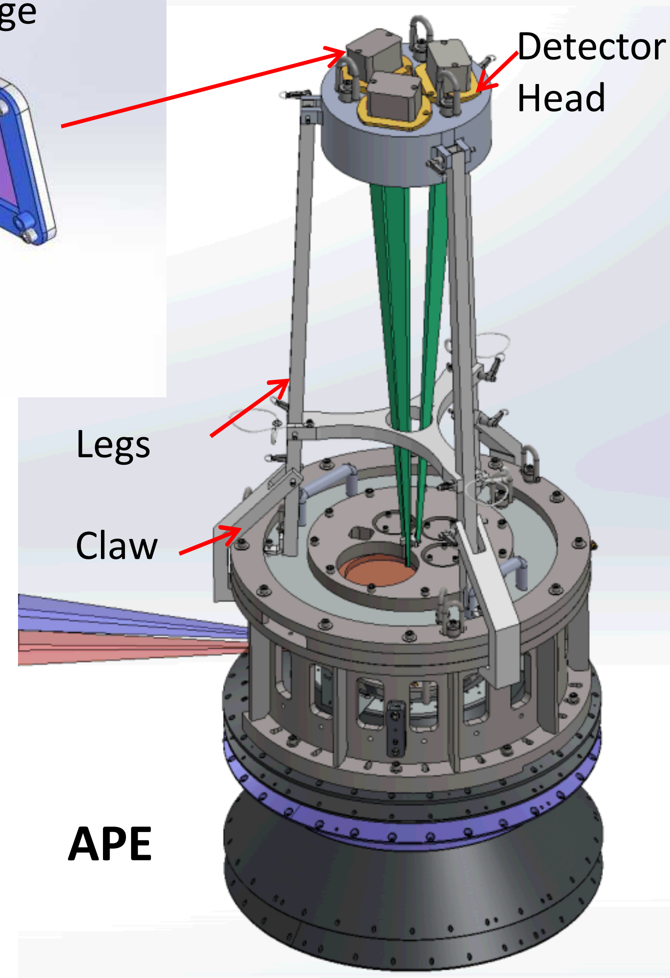
Graphics from Matt Gomez's APS-DPP invited talk (2014)

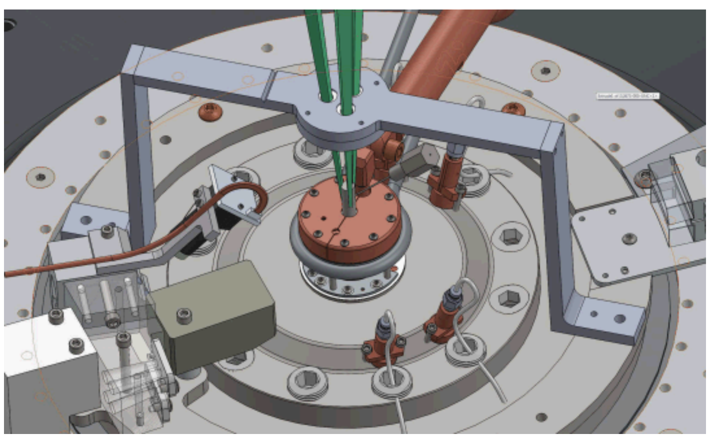
Axial Pinhole ImagEr (APE) Developed and Fielded in FY15

- Employs 1-micron pinhole arrays installed 10 cm from load
- 3 sets of 12 differentially-filtered data packets collected at head
- Time-integrated, resolution of ~12 μm, magnification ~10
- First in-chamber on-axis diagnostic deployed on Z
- 6 months from concept to fielding

APE Filter and Image Plate ASM



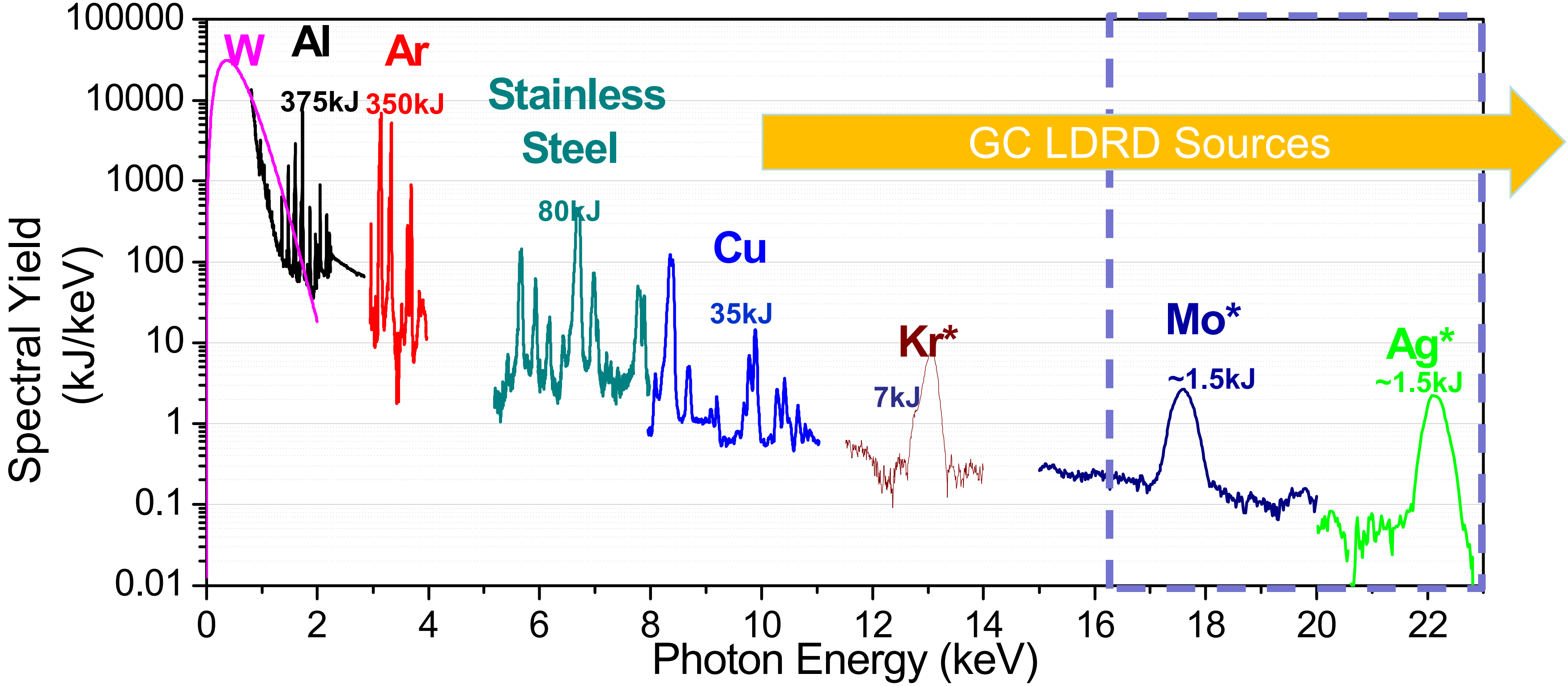




APE pinhole arrays: 3 arrays held in bridge 10 cm above load, inside of blast shield

Z source activities GC LDRD

- Thermal K-shell
  - He-like and H-like lines
  - Need to ionize to the K-shell
- Non-thermal K-shell
  - Cold K-lines
  - Need hot electrons/photons
  - Don't need to ionize bulk plasma



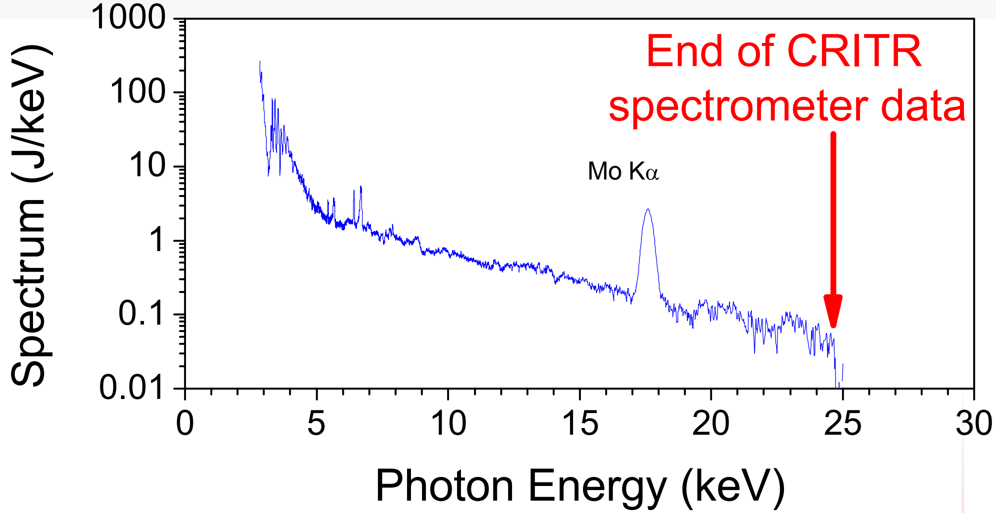
* Presented at HEART conference, 2015 by Christine Coverdale

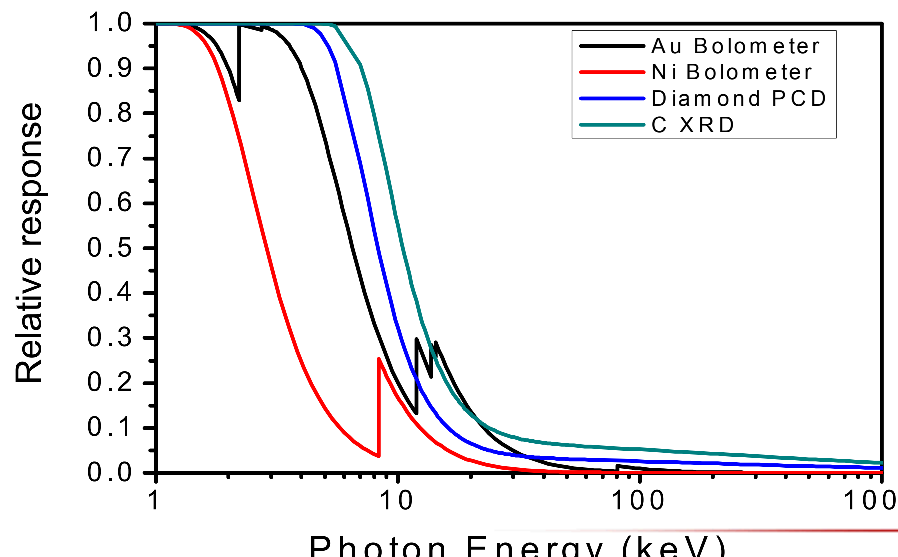
Standard Z diagnostics are limited for energies >15 keV

- Typical diagnostics on Z very well suited to diagnosing 1-15 keV x-ray sources

- For sources >25 keV, the existing diagnostics are less suitable
  - End of spectral range of the highest photon energy spectrometer is 20-25 keV
  - Diamond PCD absorption drops below 5%

- Diagnostics are not calibrated for high photon energies



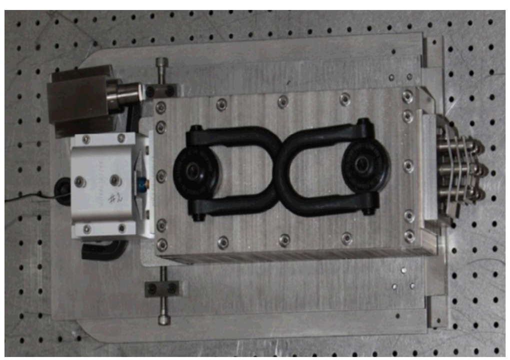


* Presented at HEART conference, 2015 by Christine Coverdale

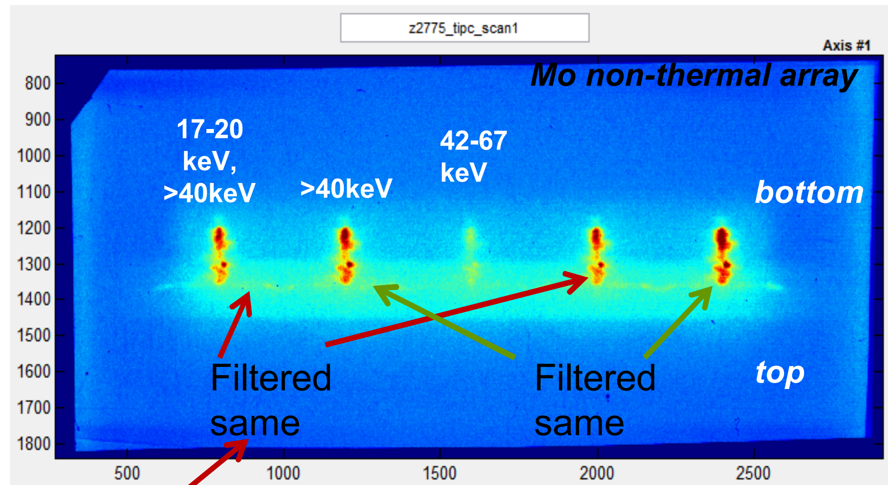
Time Integrated Pinhole Camera(TIPC)

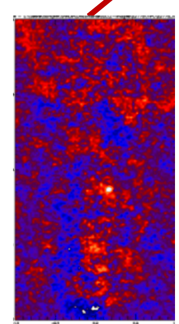
Features and Requirements

- Time integrated pinhole images
  - Image plate
- Spectral Differentiation 20-100 keV
  - Filters include: Ti, Mo, Ag, Ta, W, Au, Pb, U
- Axial field of view = 2cm
- Radial field of view = 1cm
- Up to 5 images at a time
- Fielded in-chamber 17" from center axis
- Conical (1degree) and straight pinholes

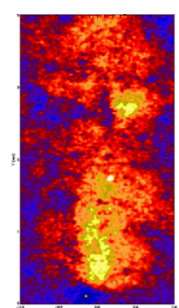


- Data illustrates consistency of images, spatial location of hard emissions, and provides images in relevant photon energy bands





Subtracting images that are filtered the same



Subtracting different filtered images to get 17-20 keV window

- Commissioned in 2014

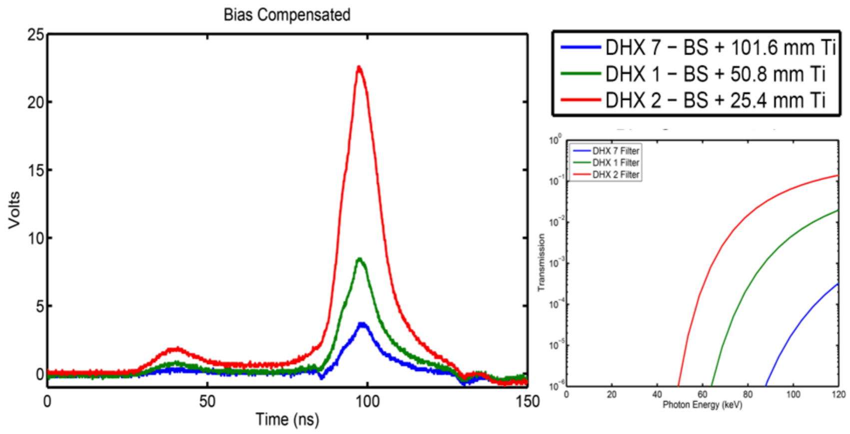
* Presented at HEART conference, 2015 by Christine Coverdale

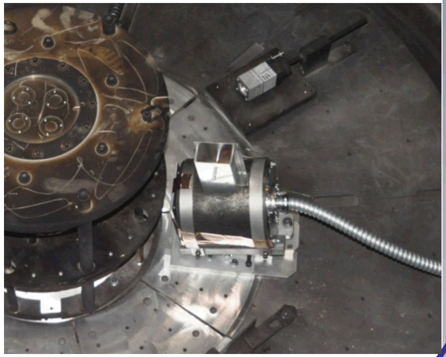
Differential Absorption Hard X-Ray (DAHX) Detector

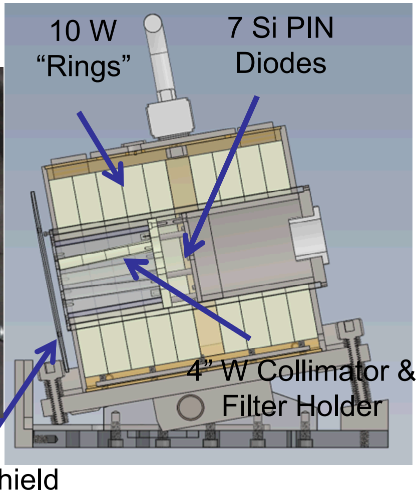
Features and Requirements

- Measures time-resolved spectral output of x-rays >20 keV, with coarse spectral resolution provided by filter variation.
- Consists of an array of 7 Si PIN didoes within a tungsten housing, located behind a ¼” aluminum blast shield and collimating (focusing) filter holder.
- Temporal Resolution: ~1 ns
- Spectral Range: 20 keV – 100 keV
- Spectral Resolution: Set by filter selection (~5 keV+)

¼” Al Blast Shield (BS) with varying Ti Filters



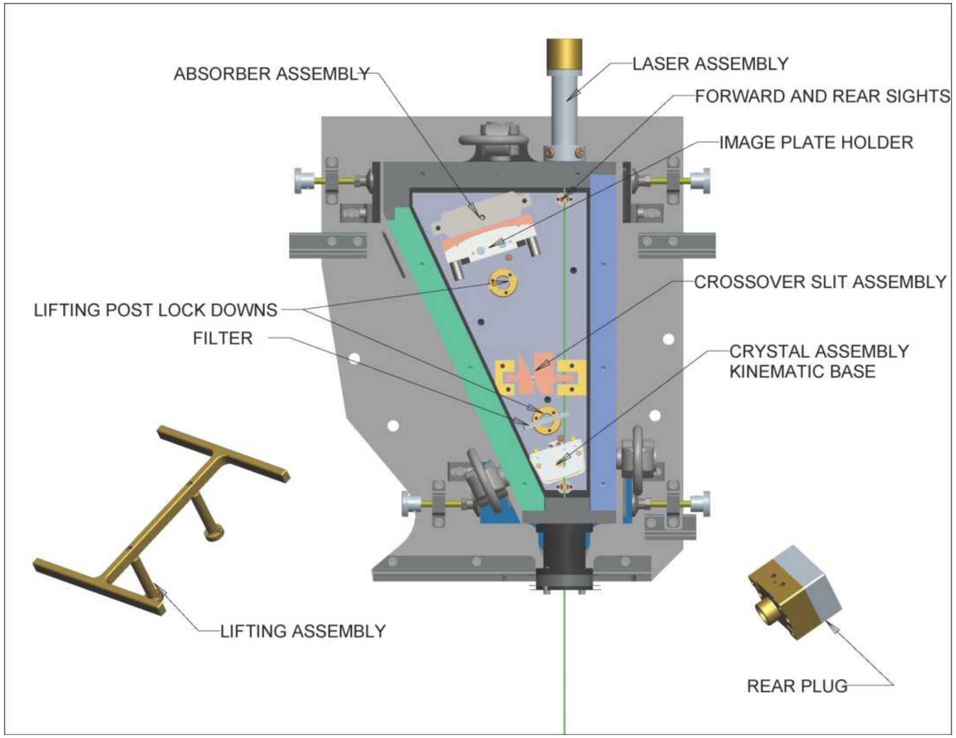




* Presented at HEART conference, 2015 by Christine Coverdale

CRITR-X extends existing CRITR capability to harder x-rays

- New baseplate for existing CRITR housing and components to provide absolutely calibrated spectrometer design
  - Complete system calibration at NIST
  - CRITR-X



Designed by Artep (J. Seely)

Three interchangeable crystals cover the 6.7 – 86 keV range with >200 resolving power

Crystal	Quartz Cut 2d (mm)	Emin (keV)	Emax (keV)	Rel. efficiency
(101)	0.6684	6.7	21.0	100
(203)	0.2750	16.3	51.0	40
(502)	0.1624	28.0	86.0	13

Staged development across multiple projects

- design funded by D. Ampleford LDRD
- Construction and fielding of prototype (GC LDRD)
- Fabrication and fielding of additional units (Z Program)

* Presented at HEART conference, 2015 by Christine Coverdale

Many opportunities for diagnostic development on Z

- Collaboration on a program-driven diagnostic need
  - Connection to Z diagnostics roadmap or national ICF diagnostics roadmap
  - Modeling of diagnostic performance
  - Shielding, debris mitigation
  - Relevant detector development
  - Detector performance and/or calibration
- Ride-along test and evaluation
  - Ride-along acceptance and coordination managed through C. Bourdon
  - Must meet facility safety standards and not interfere with primary science objectives
  - Coordinated with Shot PI

Executive Summary

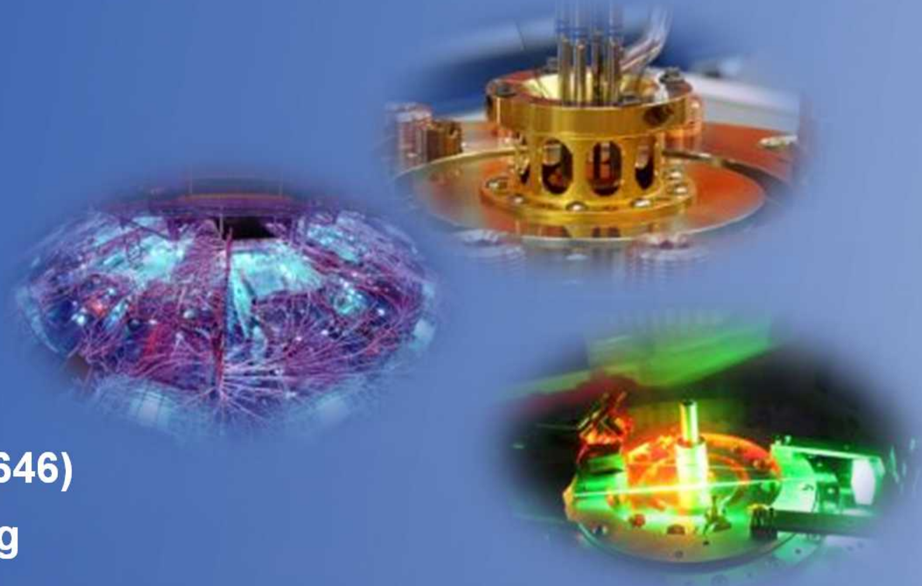
- Z is the world's premier pulsed power facility capable of accessing a broad range of the energy density phase-space
- The Z environment presents many challenges for fielding diagnostics, and developing new capabilities
- Experiments on Z support many different research areas with an emphasis on Dynamic Material Properties (DMP), Radiation Effects Sciences (RES), ICF, and Fundamental Science
- The roadmap for new capability development on Z acknowledges the resource trade space between diagnostics and other subsystems with an emphasis on new capabilities for DMP and ICF
- Many new capabilities have been commissioned in the last year:
  - TiGHER
  - Argon Imager
  - APE
  - CRITR-X
  - DAHX
  - TIPC
- Diagnostic Capabilities will continue to be developed to meet program needs; help welcomed

Backups

Sandia National Laboratories

August, 2014

Diagnostics at the Z Facility: Current Capabilities



Chris Bourdon, Imaging and Spectroscopy (1675)

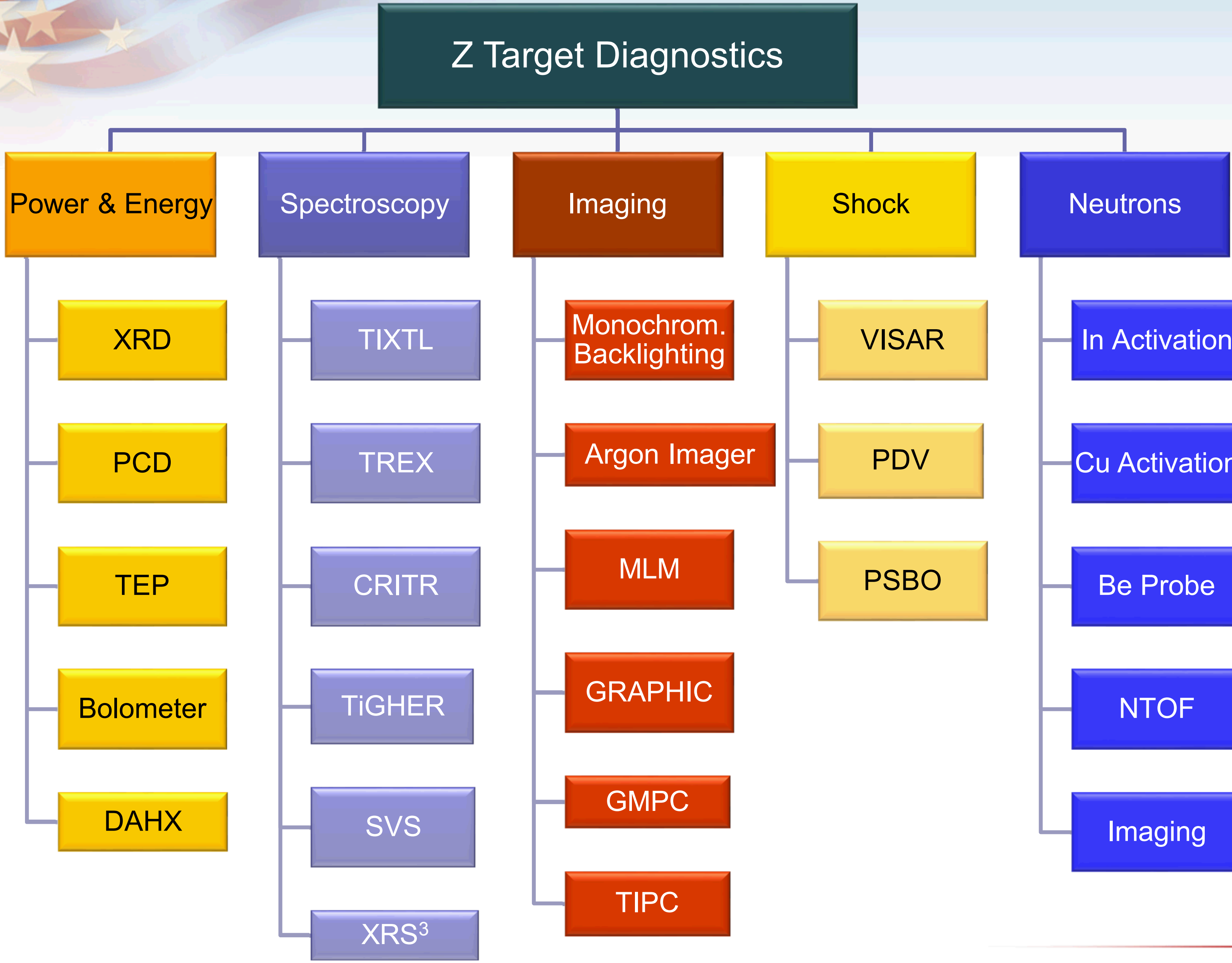
Brent Jones, Neutron Diagnostics (1678)

John Benage, Dynamic Material Properties (1646)

John Porter, Laser operations and engineering (1682)

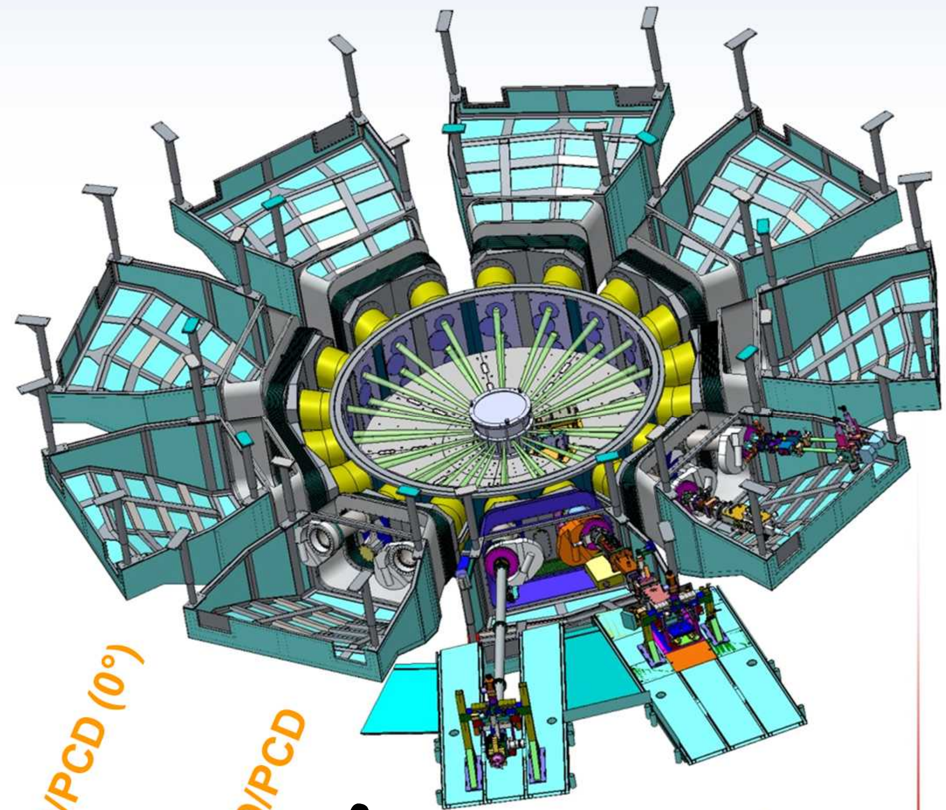
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

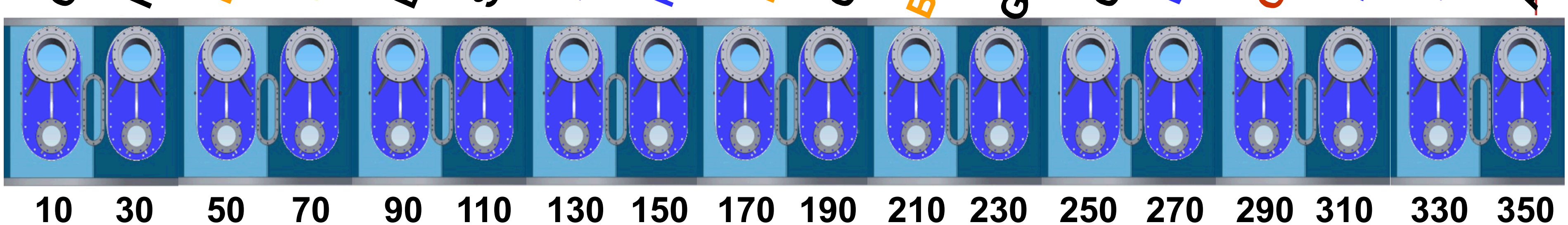
Sandia National Laboratories


Z Target Diagnostics
Power & Energy
XRD
PCD
TEP
Bolometer
DAHX
Spectroscopy
TIXTL
TREX
CRITR
TiGHER
SVS
XRS3
Imaging
Monochrom. Backlighting
Argon Imager
MLM
GRAPHIC
GMPC
TIPC
Shock
VISAR
PDV
PSBO
Neutrons
In Activation
Cu Activation
Be Probe
NTOF
Imaging

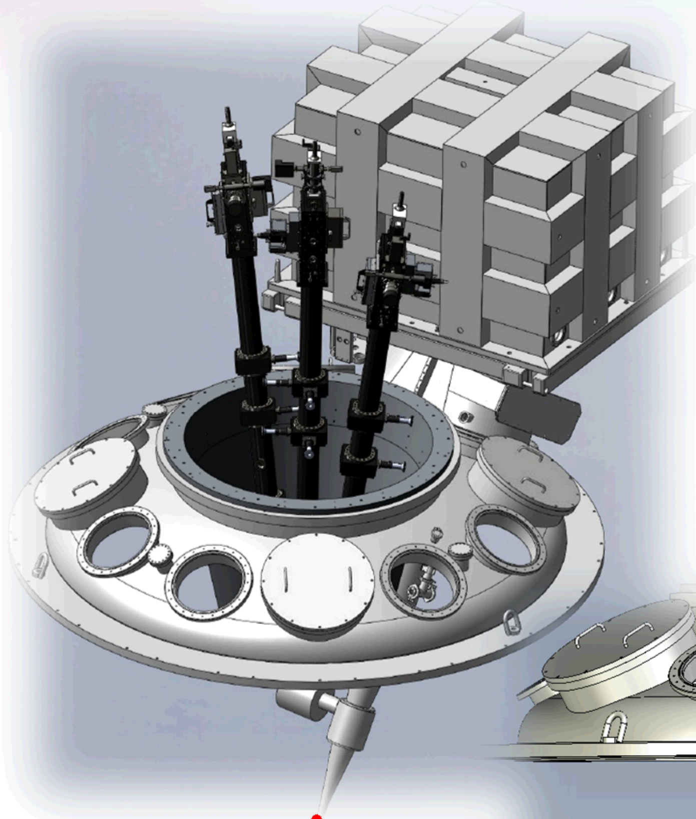
Radial LOS overview of the Z facility

- 18 Radial line of sights access ports at ~12º
- 18 line of sight access ports at ~0º
- Chamber diagnostics:
  - CRITR
  - TiGHER
  - SVS
  - DAHX
  - Neutron Activation (In and Cu)
  - VISAR
  - PSBO
  - Monochromatic Backlighter
  - TIPC

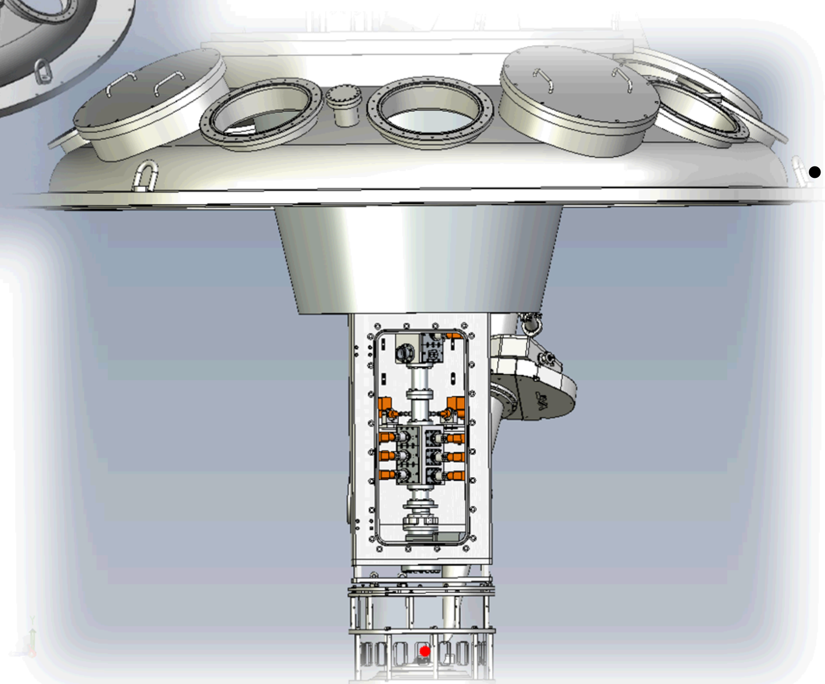




Axial LOS overview of the Z facility



- 3 Axial LOS:
  - –0°: PODD (ECP,CCP, MIP, GMPC)
  - – 9° E: PODD (ECP,CCP, MIP, GMPC)
  - –9° W: PODD (ECP,CCP, MIP, GMPC)



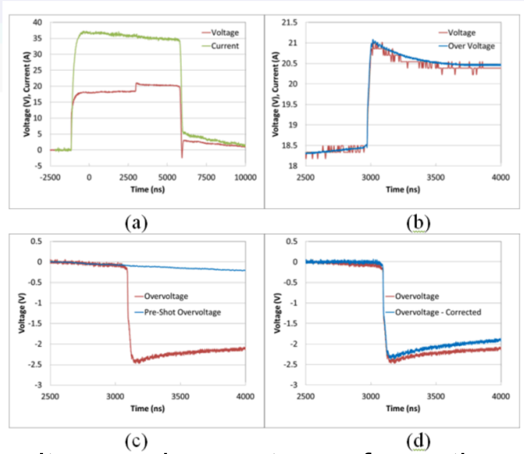
- 1 Close-Proximity LOS:
  - –0°: GRAPHIC, PODD, GMPC

Sandia National Laboratories

Bolometers

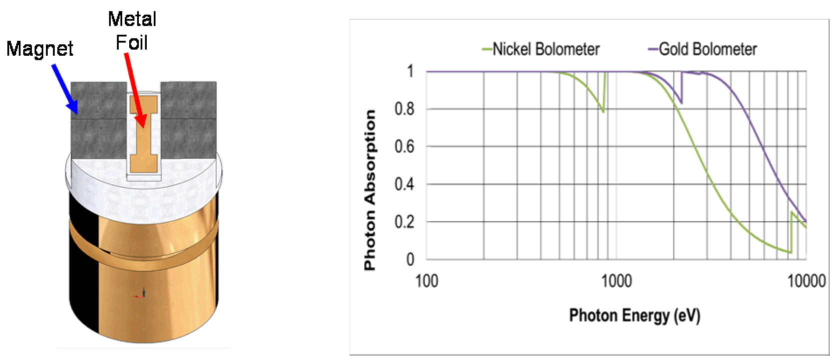
Features and Requirements

- Measures absolute x-ray fluence in a spectral band determined by the transmission of a filter and the sensitivity of the nickel or gold bolometer.
- Use in conjunction with the TEP (Nickel) or PCD (Gold) to obtain an x-ray power.
- **Spectral range**: Nickel < 2 keV; Gold < ~5keV
- **Measurement accuracy**: ±20%



(a) Typical voltage and current waveforms through a nickel bolometer (b) Voltages are split into two digitizers to increase dynamic range (c) pre-shot and downline overvoltage signal (d) corrected downline overvoltage signal

- **Fielding Locations:** LOS 50 – 12.0° (3x), LOS 170 – 0° (1x), LOS 210 – 12.0° (1x)
- **Calibration Requirements:** Characterization of the bolometer dependent on intrinsic material properties and detector physical dimensions.
- **Management POC:** Michael Jones
- **Responsible Scientist:** Robert Hohlfelder

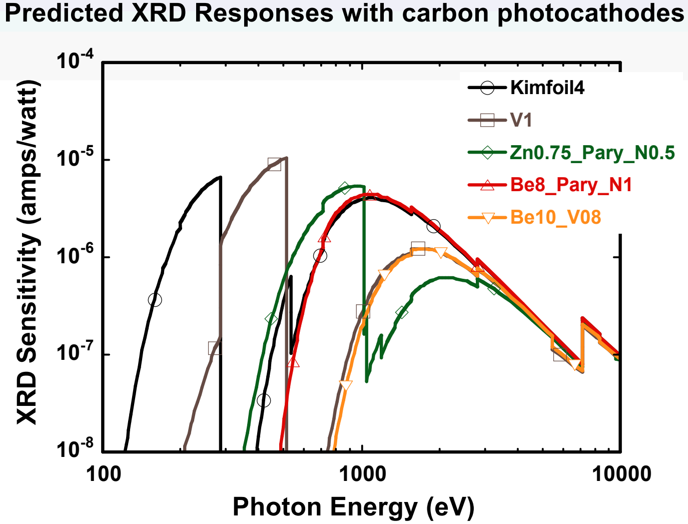


Bolometer detector showing the metal element and magnet placement (b) Photon absorption in 1um Nickel and 1um Gold thin films.

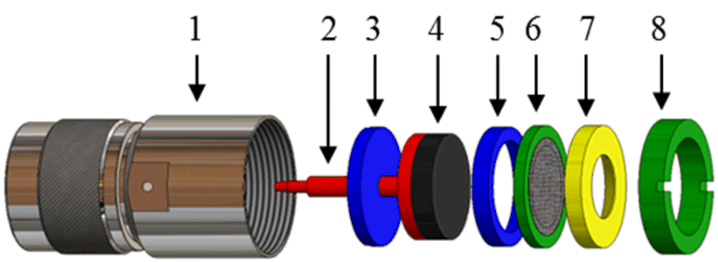
X-ray Diodes (XRDs)

Features and Requirements

- Measures absolute x-ray flux in a spectral band determined by the transmission of a filter and the sensitivity of a carbon cathode.
- 5 filtered channels
- **Spectral range:** ~200 eV – 2500 eV
- **Measurement accuracy**: ~± 20% over the spectrally weighted integral per channel



- **Fielding Locations:** LOS 50 – 11.6° (5x), LOS170 – 0° (2x), LOS 210 – 12° (4x), Top Axial Package (2x)
- **Calibration Requirements:** XRD sensitivities and filter transmissions known to: ±20%. Measured at the National Synchrotron Light Source (NSLS) Beam-lines:
  - U3C: 50 eV - 1000 eV
  - X8A: 1 keV - 5.9 keV
  - Must request to use calibrated filters or carbon photocathodes
- **Management POC:** Michael Jones
- **Responsible Scientist:** Robert Hohlfelder



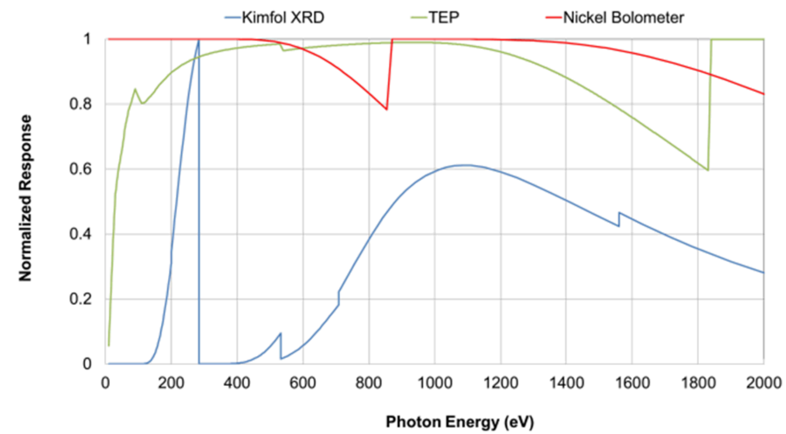
Exploded view of the XRD. 1) N connector body, 2) gold plated or nickel stalk, 3) Teflon insulator, 4) vitreous carbon photocathode, 5) Teflon insulator, 6) nickel anode mesh, 7) limiting aperture, 8) locking ring.

Total Energy & Power (TEP)

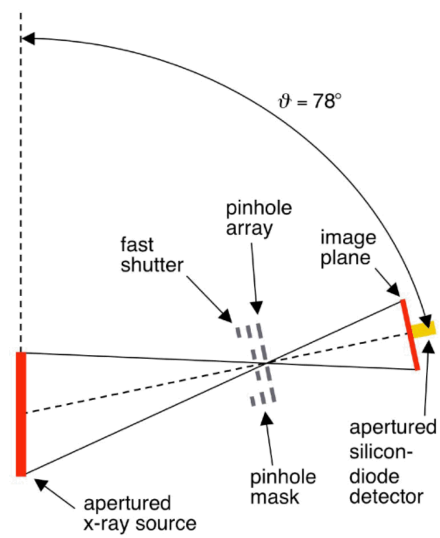
Features and Requirements

- Measures absolute x-ray flux over a broad spectral band determined by the relative sensitivity of a silicon diode and the absolute sensitivity of a bolometer.
- 2 identical channels
- **Spectral range**: ~100 eV – 2500 eV
- **Measurement accuracy**: ~± 30%.

Spectral Response of TEP vs. XRD vs. Ni Bolometer



- **Fielding Locations:** LOS 50 – 12.0° (2x),
- **Calibration Requirements:** None. Used in conjunction with the Nickel bolometers. Only pulse shape of the TEP is used.
- **Management POC:** Michael Jones
- **Responsible Scientist:** Robert Hohlfelder



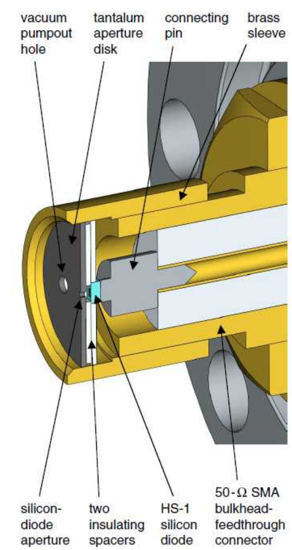
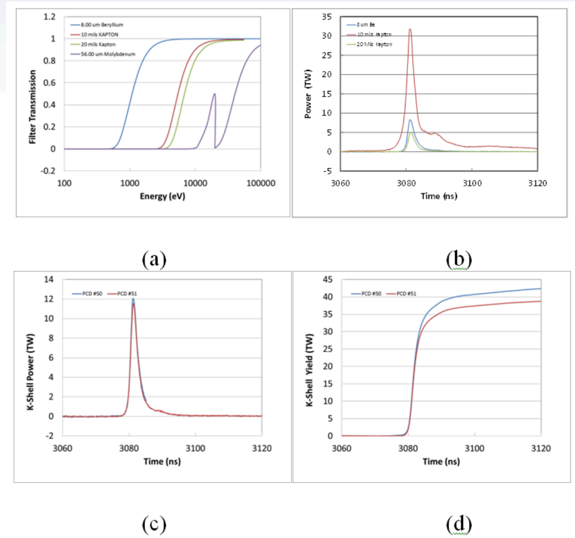


Photo Conducting Diamonds (PCDs)

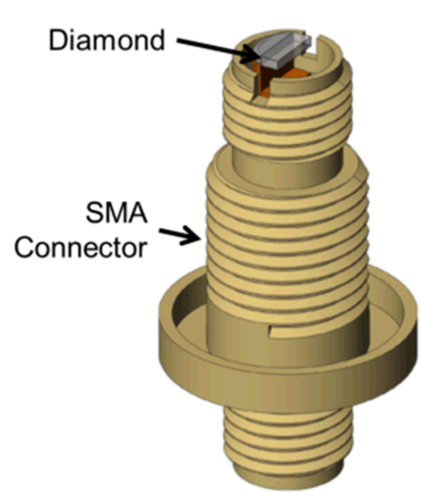
Features and Requirements

- Measures absolute x-ray flux in a spectral band determined by the transmission of a filter and the sensitivity of a photo conducting diamond.
- > 10 channels
- **Spectral range**: ~1000 eV – 10000 eV
- **Measurement accuracy**: ~± 30%



(a) Typical filter set used on PCDs during stainless steel wire array experiments, (b) measured power (c) k-shell power (d) k-shell yield.

- **Fielding Locations:** LOS 50 – 12.0° (6x), LOS 50 – 11.6° (5x), LOS 170 – 0° (6x), LOS 210 – 12.0° (4x), Top Axial Package (2x)
- **Management POC:** Michael Jones
- **Responsible Scientist:** Robert Hohlfelder



PCD element used at Z

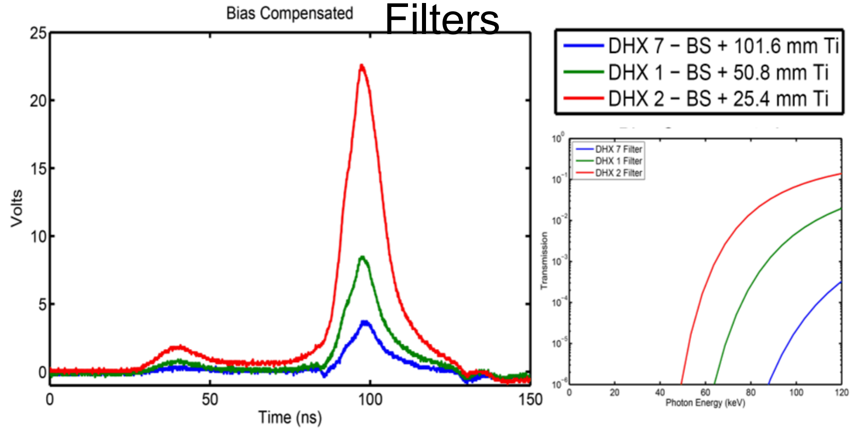
Sandia National Laboratories

Differential Absorption Hard X-Ray (DAHX) Detector

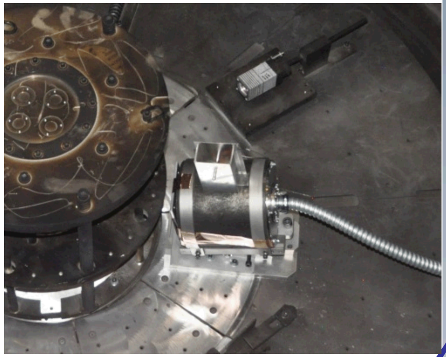
Features and Requirements

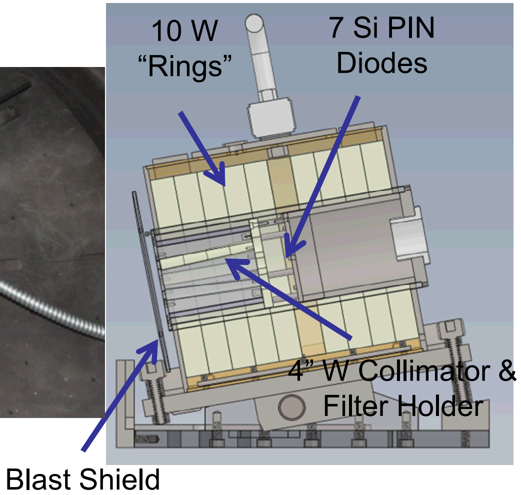
- Measures time-resolved spectral output of x-rays >20 keV, with coarse spectral resolution provided by filter variation.
- Consists of an array of 7 Si PIN didoes within a tungsten housing, located behind a ¼” aluminum blast shield and collimating (focusing) filter holder.
- Temporal Resolution: ~1 ns
- Spectral Range: 20 keV – 100 keV
- Spectral Resolution: Set by filter selection (~5 keV+)

¼” Al Blast Shield (BS) with varying Ti Filters



Management POC: Chris Bourdon
Responsible Scientist: Kate Bell



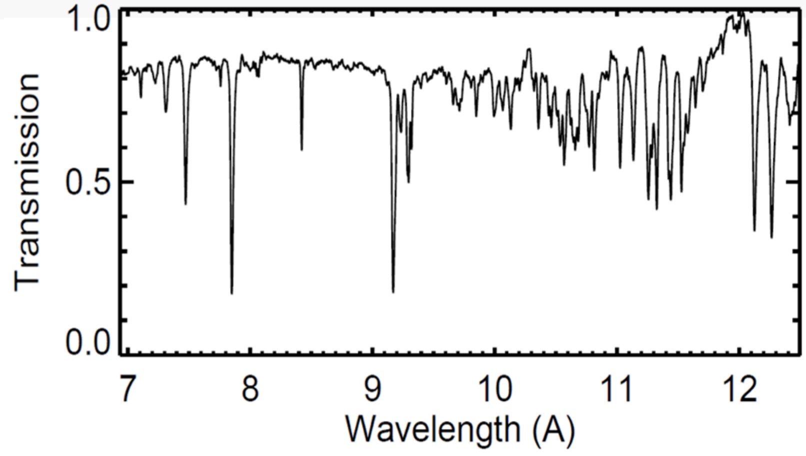


Time Integrated Crystal Spectrometers (TIXTL/PODD CCP)

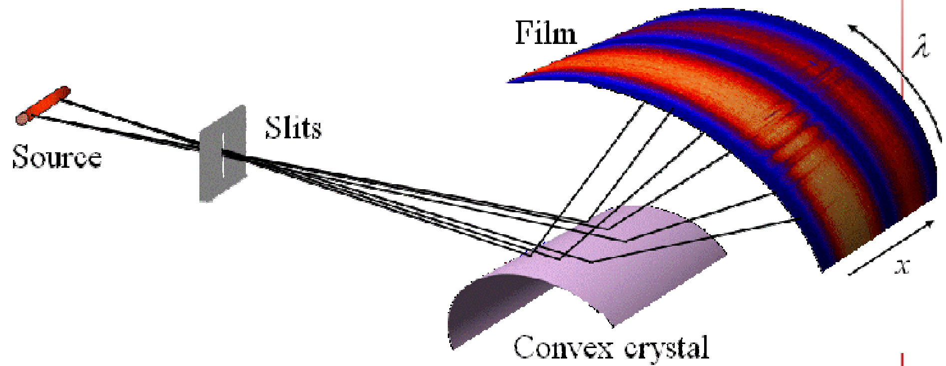
Features and Requirements

- Measures 1-D space-resolved x-ray spectra using a slit optic imaged onto a convex Bragg crystal and recorded on x-ray film or image plate
- Spectral Range: 2 –16 Å (select configs of $\Delta\lambda$<10 Å)
- Spectral Resolution: $\lambda/\delta\lambda$ > 800
- Spatial Resolution: >50 μm
- Required measurement accuracy: < ± 20% relative efficiency vs. λ; ~±10% spectral resolution

Mg/Fe Absorption Spectrum



Management POC: Chris Bourdon
Responsible Scientist: Greg Dunham

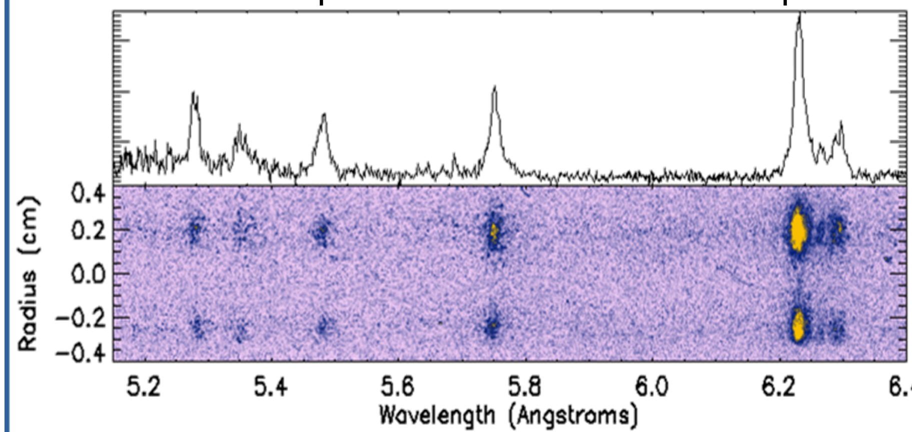


Time Resolved Elliptical Crystal Spectrometers (TREX/PODD ECP)

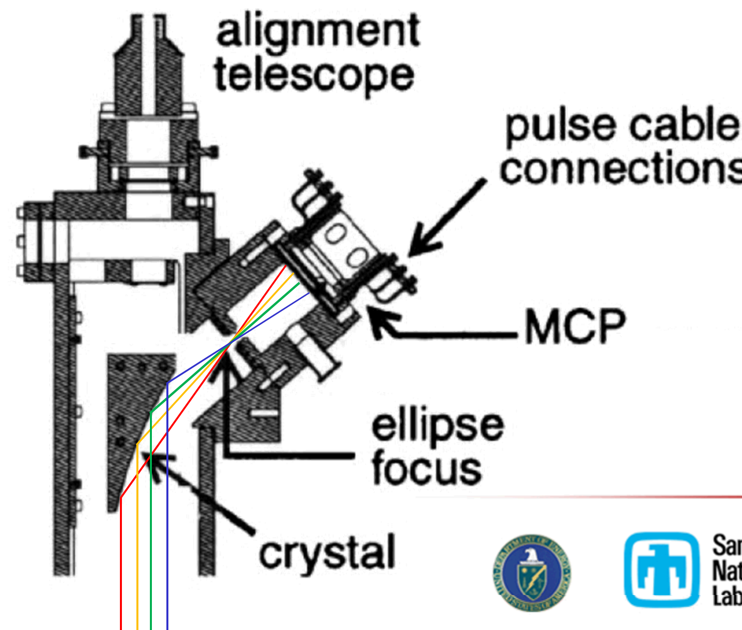
Features and Requirements

- Measures time- and 1-D space-resolved x-ray spectra using a slit optic imaged onto an elliptical Bragg crystal and recorded on MCP.
- Spectral Range: ~1.2–10 Å (select configs of $\Delta\lambda$<2 Å)
- Spectral Resolution: $\lambda/\delta\lambda$ > 800
- Spatial Resolution: >50 μm
- Temporal Resolution: ≥100 ps
- Required measurement accuracy: < ± 20% relative efficiency vs. λ; ~±10% spectral resolution

Time- and space-resolved Si emission spectra



Management POC: Chris Bourdon
Responsible Scientist: Greg Dunham



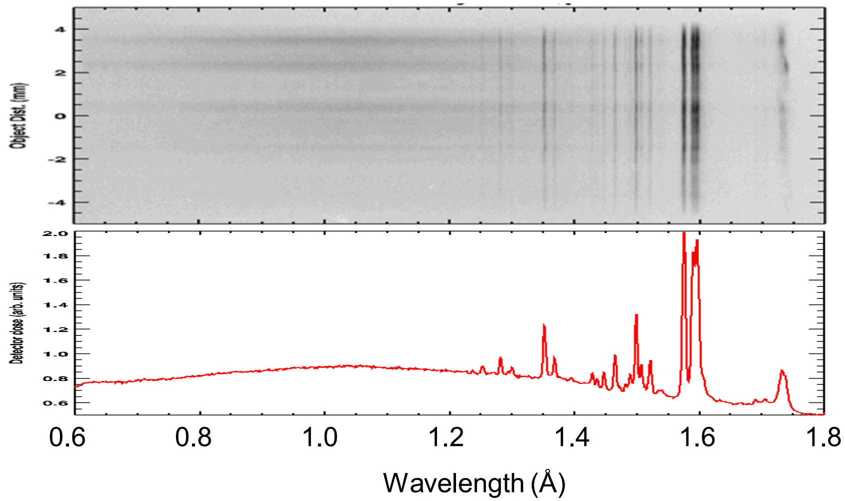
Sandia National Laboratories

Compact, Removable, In-chamber Transmission (CRITR) spectrometer

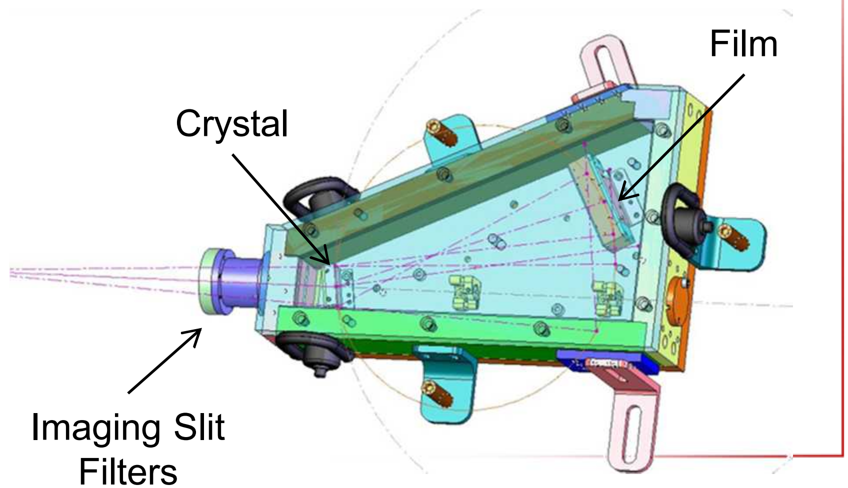
Features and Requirements

- Measures high energy, 1-D space-resolved x-ray spectra using a slit optic imaged onto a Quartz crystal in transmission and recorded on IP.
- Spectral Range: 0.5-1.8 Å (7-25 keV)
- Spectral Resolution: $\lambda/\delta\lambda$ > 1000
- Spatial Resolution: >50 μm
- Required measurement accuracy: < ± 20% relative efficiency vs. λ; ~±10% spectral resolution

Space-resolved stainless steel emission spectra



Management POC: Chris Bourdon
Responsible Scientist: Armon McPherson

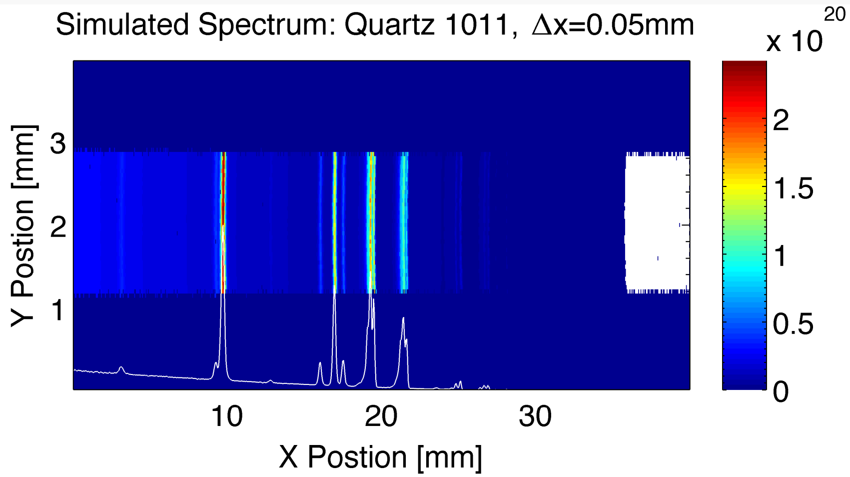


Sandia National Laboratories

Time-Gated High-Energy Spectrometer (TiGHER)

Features

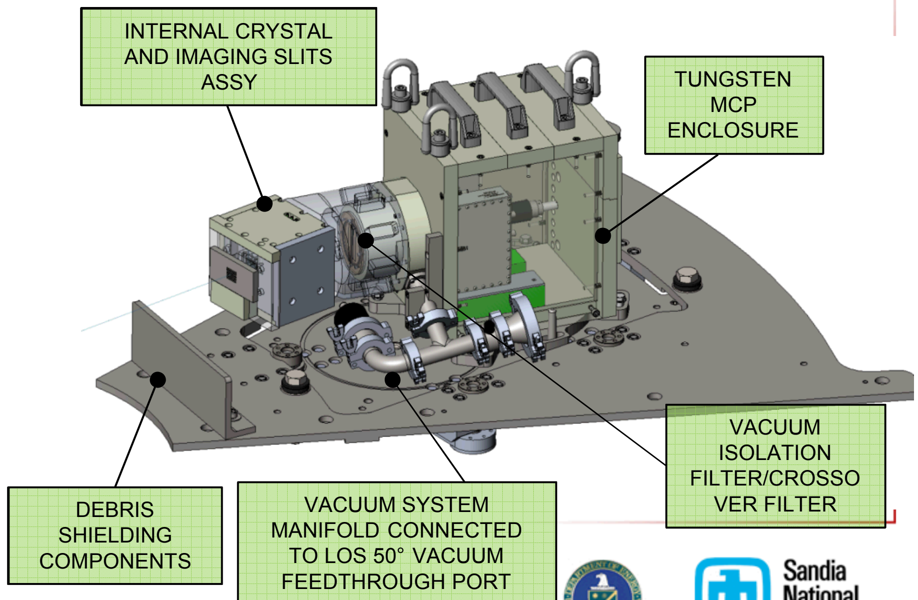
- TiGHER is an in-chamber axially-resolved spectrometer
- Uses cylindrically-bent Quartz 1011 crystal in transmission to resolve X-Ray spectra
- Can be fielded at LOS 90
- Will be commissioned in September 2014



Spectrometer Specifications

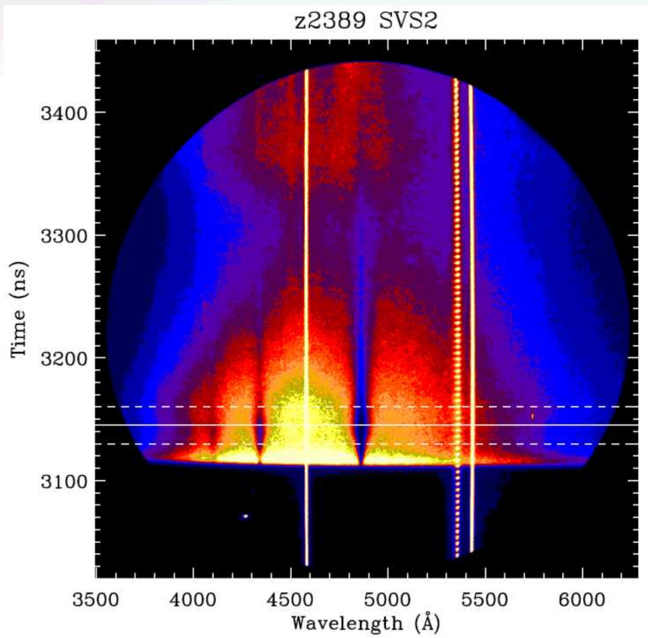
- Spectral range of 8-25 keV (0.5-1.55 Angstroms)
- Spectral Resolution $\lambda/\Delta\lambda$~700
- Spatial resolution ~100µm
- Magnification of 0.8 or 0.5x
- 8 frames, 250 ps gate width

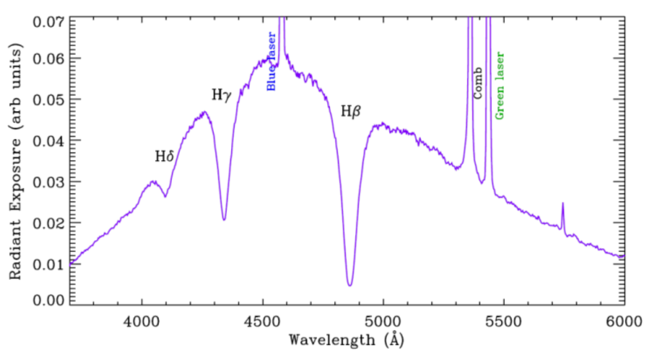
- **Management POC:** Chris Bourdon
- **Responsible Scientist:** Pat Knapp



Sandia National Laboratories

Streaked Visible Spectroscopy (SVS)





Features and Requirements

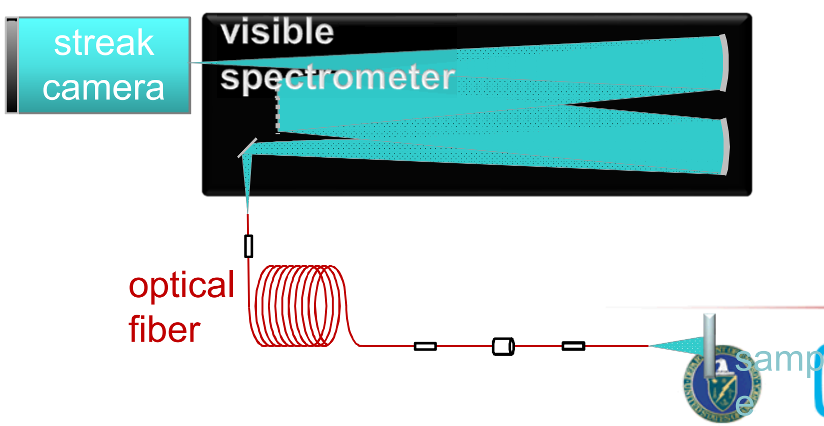
- Measures time-resolved visible spectra using a f=1m grating spectrometer and streak camera with an optical fiber couple to the target.
- Spectral Range: 350-800 nm
- Spatial Resolution: Single point or spatially averaged area, depending on target optics.

Applications

- Streaked pyrometry for temperature determination.
- Lineshape measurement of dopants for density, temperature and magnetic field measurements.

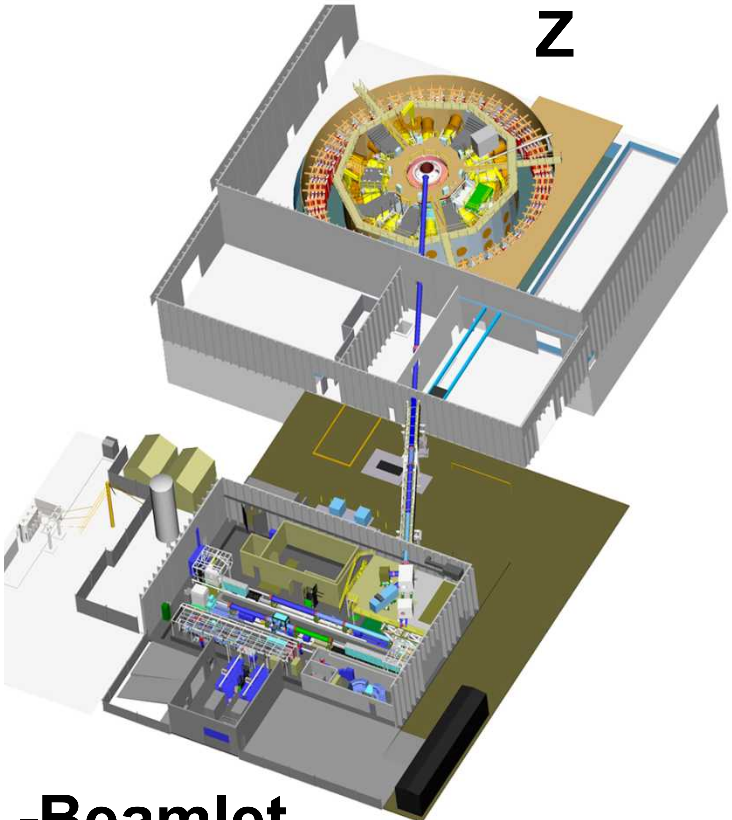
Contacts

Management POC: Chris Bourdon
Responsible Scientist: David Bliss



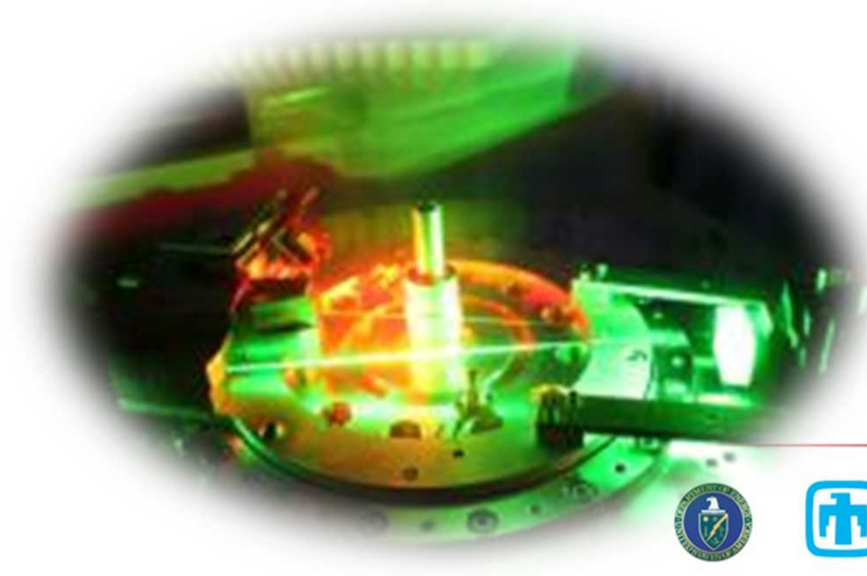
Sandia National Laboratories

X-ray Backlighting on Z



Z -Beamlet

- ~2 kJ at 2ω in up to a four-post picket at ≤ 2 TW peak power.
- > 80% of the 2ω energy into a focal spot of 50-μm-diam
- 1 or 2-frame Monochromatic Radiography
  - -1.865 keV
  - -6.151 keV
- 2-color Monochromatic Radiography
  - -1.865 and 6.151 keV



- Management POC: John Porter
- Responsible Scientist: Ian Smith

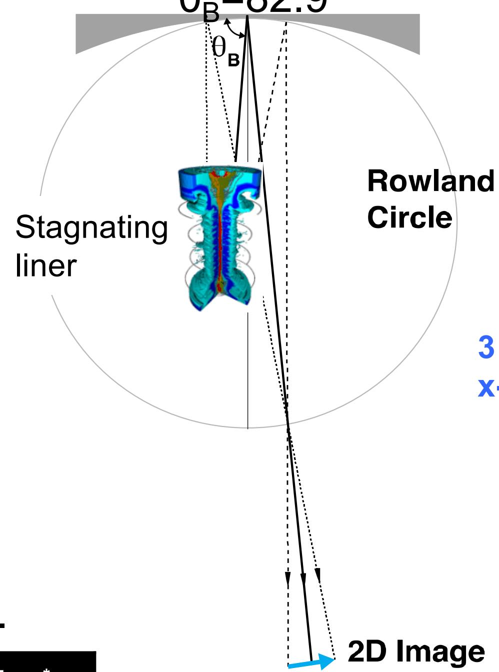
Sandia National Laboratories

Argon Imager

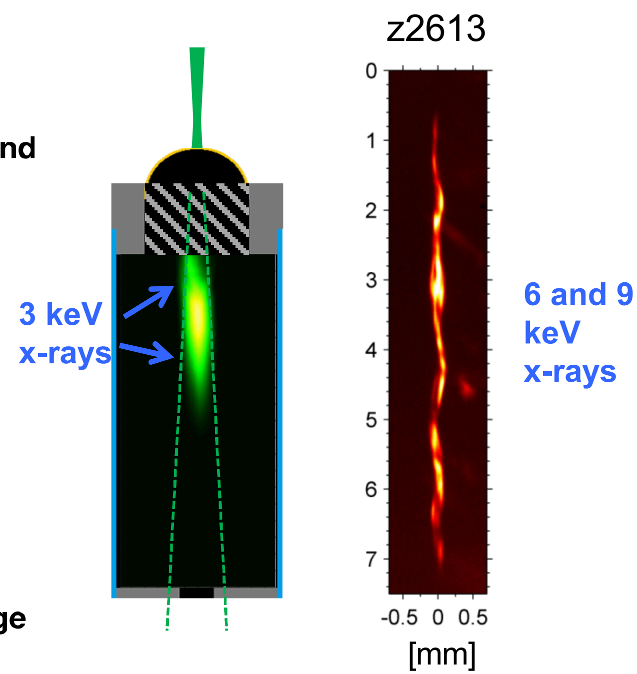
Time integrated, self-emission imaging has provided valuable data for MagLIF and is now being extended to other targets on Z.

Advantages of crystal imaging

1) high sensitivity
2) narrow bandwidth
3) 0° line-of-sight
4) large field-of-view



Self-emission images from MagLIF targets on Z



The analysis is complicated by higher order crystal reflections.

Reflection Plane	Energy (keV)	Thru*
Ge (220)	3.1	Ω_o
Ge (440)	6.2	$2.0*\Omega_o$
Ge (660)	9.4	$2.4*\Omega_o$
Ge (880)	12.5	$0.4*\Omega_o$

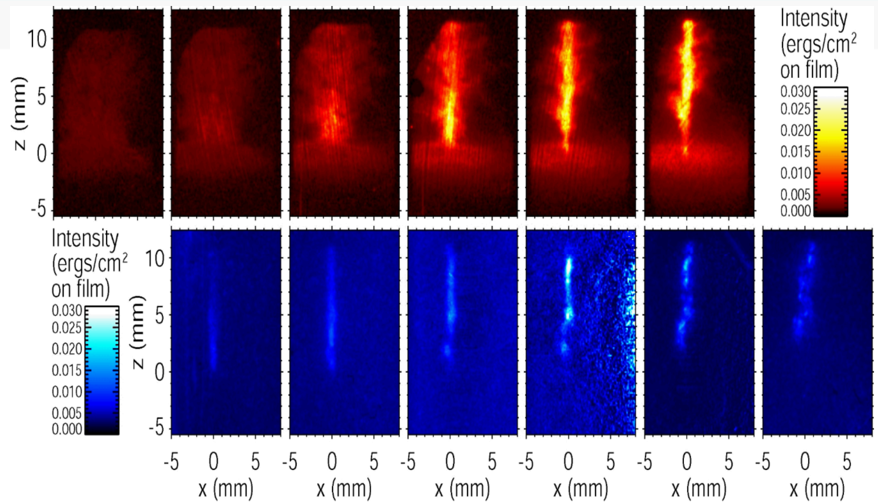
*Includes filters

- Management POC: Chris Bourdon
- Responsible Scientist: Eric Harding

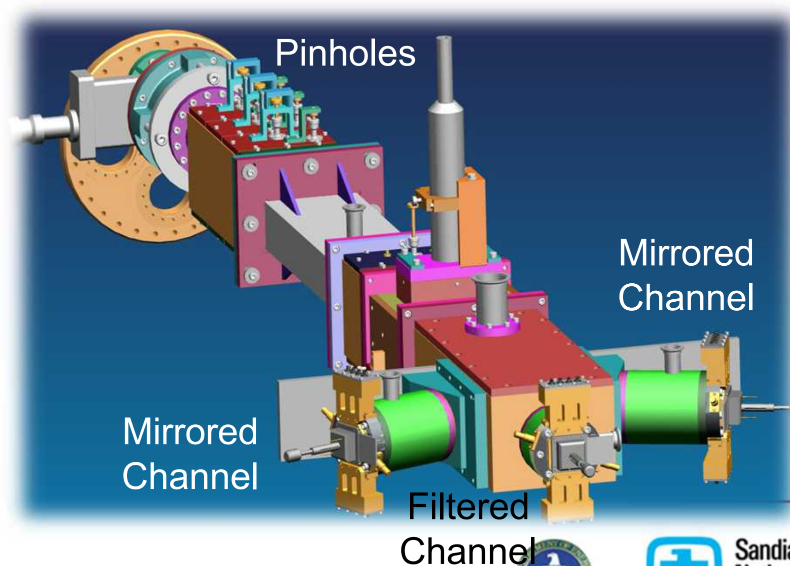
Multi-Layer Mirror (MLM) Pinhole Camera (PODD MIP)

Features and Requirements

- Measures time- and space-resolved monochromatic and broadband images using a pinhole optic imaged (onto a flat multilayer mirror) and recorded on MCP.
- Monochromatic Energies: 277±3 eV, 528±5 eV
- Spatial Res: >50 μm (filtered), > 300 μm (mirrored)
- Temporal Resolution: ≥250 ps
- Number of Frames: 8 (filtered), 16 (mirrored)
- Required meas. accuracy: < ± 20% relative intensity



- Management POC: Chris Bourdon
- Responsible Scientist: Ming Wu

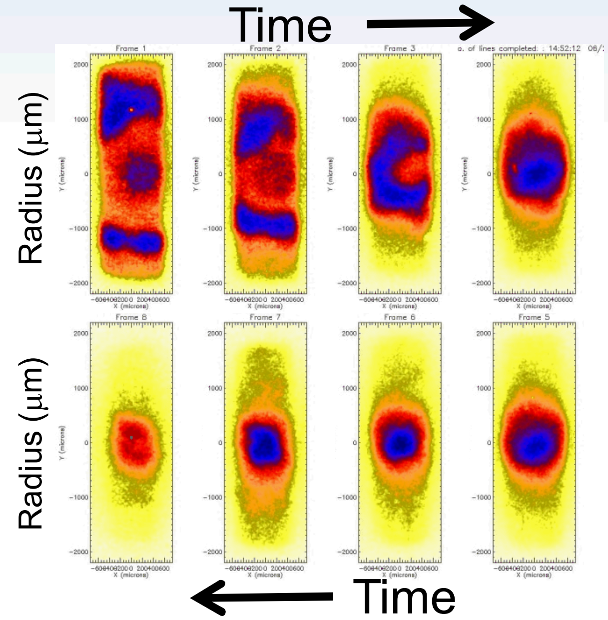


Sandia National Laboratories

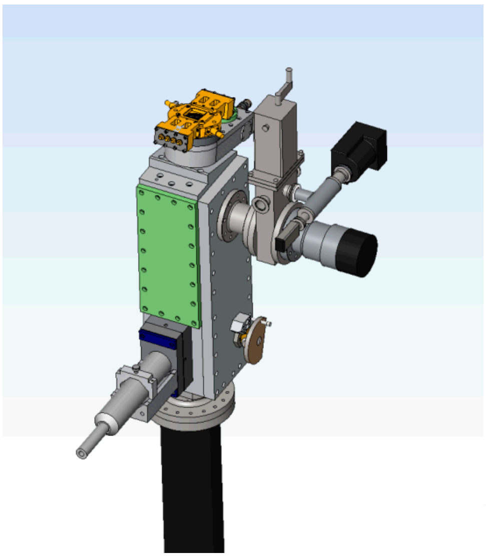
Glancing Mirror Pinhole Camera (GMPC)

Features and Requirements

- May be fielded on axial package at 0^o or on LOS 290 12^o port.
  - Axial Field Of View: = 4.5mm
  - Radial field-of-view:
- Spatial Resolution: 100 and 200 micron pinholes
- 8 time-resolved pinhole images, with 100 ps or longer gate times
- May be fielded as either filtered pinhole camera or as glancing mirror pinhole camera with gold 2.5^o wedge installed.



- Management POC: Chris Bourdon
- Responsible Scientist: Greg Dunham

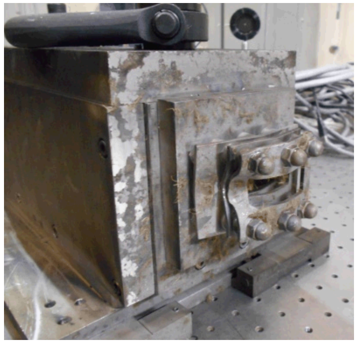


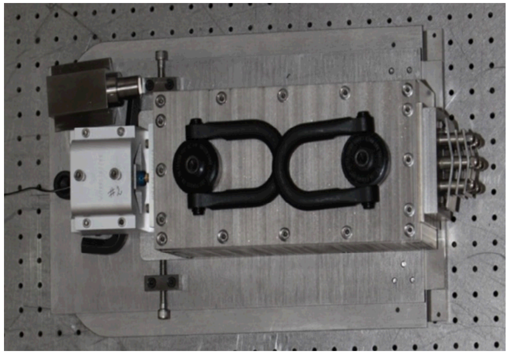
Sandia National Laboratories

Time Integrated Pinhole Camera(TIPC)

Features and Requirements

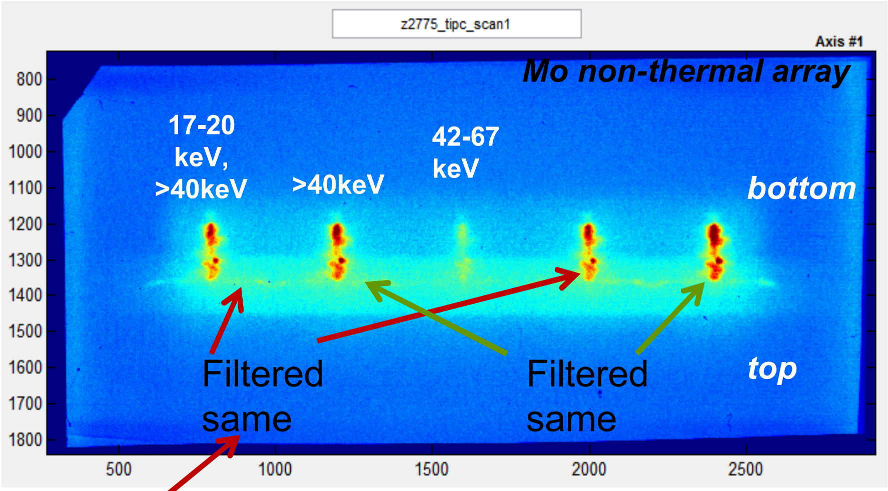
- Time integrated pinhole images
  - Image plate
- Spectral Differentiation 20-100 keV
  - Filters include: Ti, Mo, Ag, Ta, W, Au, Pb, U
- Axial field of view = 2cm
- Radial field of view = 1cm
- Up to 5 images at a time
- Fielded in-chamber 17” from center axis
- Conical (1degree) and straight pinholes

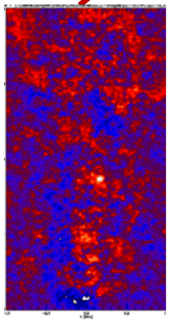




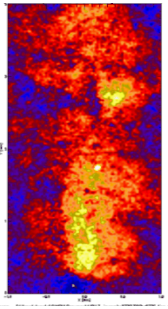
- Management POC: Chris Bourdon
- Responsible Scientist: Armon McPherson

- Data illustrates consistency of images, spatial location of hard emissions, and provides images in relevant photon energy bands





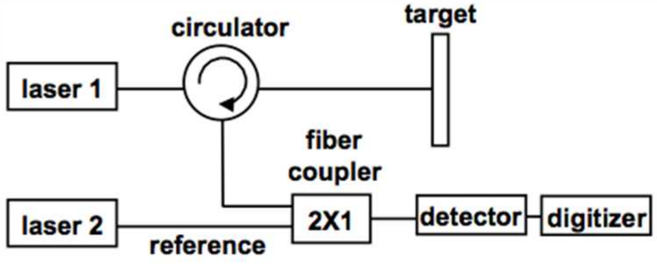
Subtracting images that are filtered the same



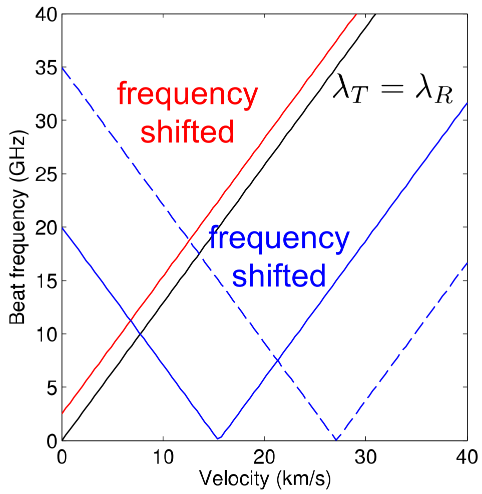
Subtracting different filtered images to get 17-20 keV window

PDV (Photonic Doppler Velocimetry)

- Fiber-based interferometer
  - Telecommunications hardware (1550 nm)
    - Single-mode fiber
  - Fiber laser illuminates target
  - Circulator separates reflected light
  - Target light (T) mixed with reference (R) laser
- Velocity represented by beat frequency
  - 1.29 GHz per 1 km/s velocity change
  - Base value depends on reference wavelength
    - Red: frequency always increases with velocity
    - Blue: initially decreases with frequency
- Bandwidth defines velocity range
  - 25 GHz digitizer
    - 19.4 km/s (one way)
    - 38.8 km/s with DC "bounce"
  - Measurements can be interleaved for greater coverage (0 to 45 km/s demonstrated)



$$B = \left| \frac{2v}{\lambda_T} + c_0 \left(\frac{1}{\lambda_T} - \frac{1}{\lambda_R} \right) \right|$$

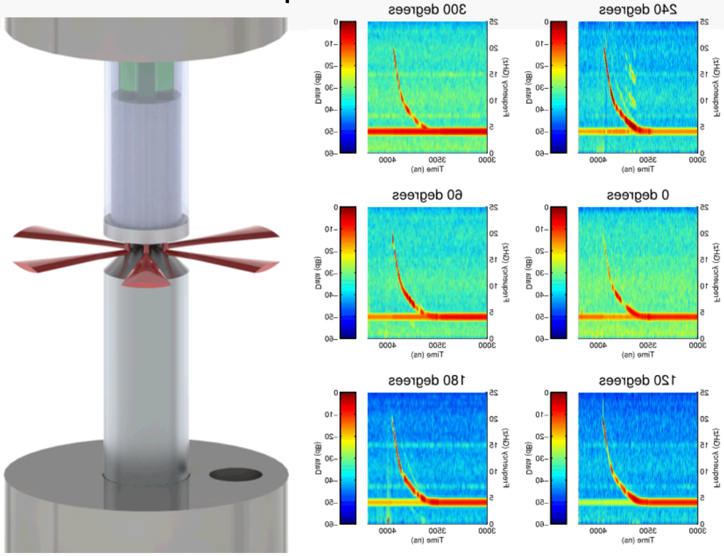


- Management POC: John Benage
- Responsible Scientist: Dan Dolan

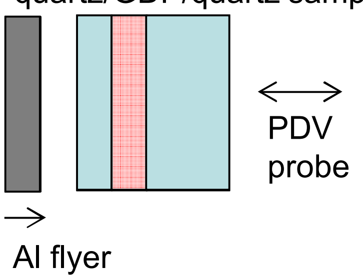
PDV capabilities

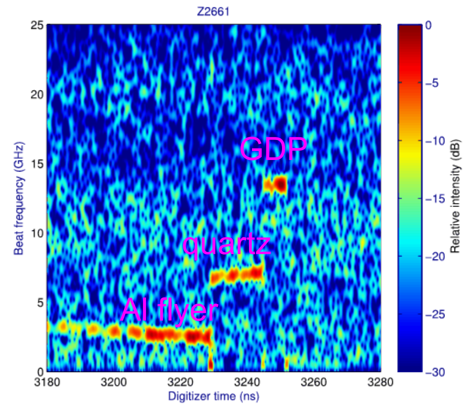
- Performance
  - Event timing
    - <<100 ps between measurements
    - ~200 ps to machine time
  - Rise time related to velocity uncertainty
    - Example: 80 GS/s, 10% signal noise
    - 1 ns data analysis blocks ➔ 7 m/s noise
  - Works on diffuse or specular surfaces*
    - *specular surfaces may require careful probe alignment
- Configurations
  - Six points inside cylindrical loads
    - Hollow or liquid-filled liners
  - One probe per sample in planar loads
  - Up to eight probes per measurement

Ta liner implosion



quartz/GDP/quartz sample





- Management POC: John Benage
- Responsible Scientist: Dan Dolan

Activation Samples

For deuterium fuel experiments on Z, neutron yields are measured based on neutron activation of select materials.

- **Primary DD yield**
  - **Indium***

    $^{115}In(n,n')^{115m}In$
    336-keV threshold
    4.5-hr half-life

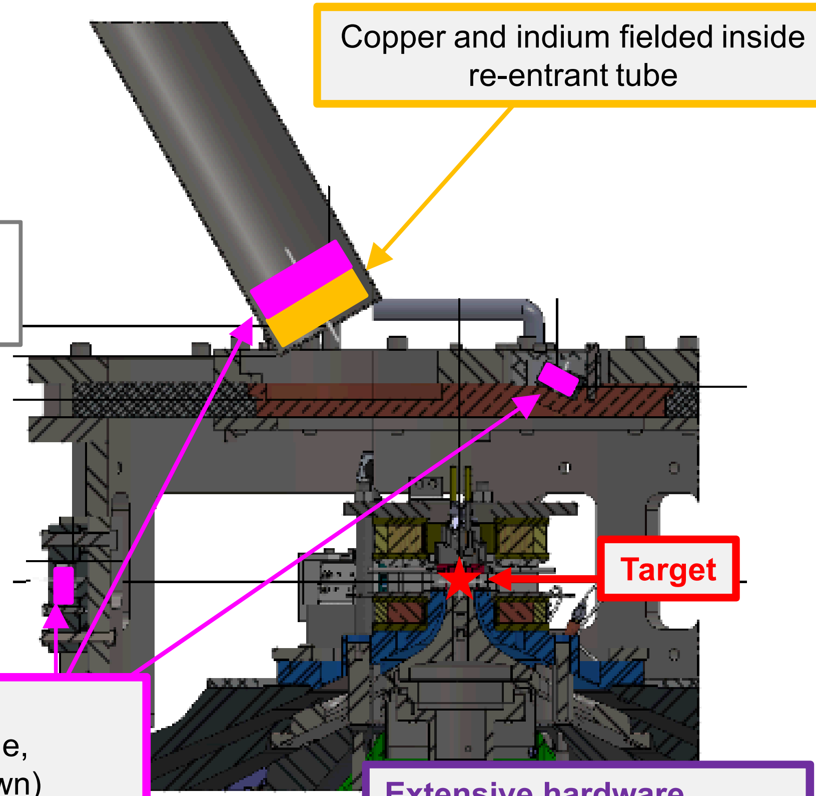
  - **Beryllium detector***

    $^{9}Be(n,\alpha)^{6}He(\beta-)$
    670-keV threshold
    0.8-sec half-life

- **Secondary DT yield**
  - **Copper ***

    $^{63}Cu(n,2n)^{62}Cu(\beta+)$
    11-MeV threshold
    9.7-min half-life

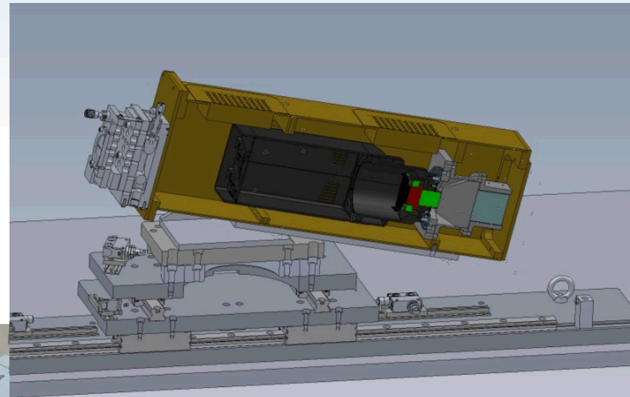
*Absolutely calibrated at Sandia's Ion Beam Laboratory.

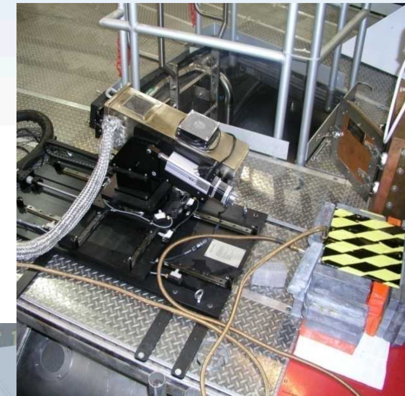


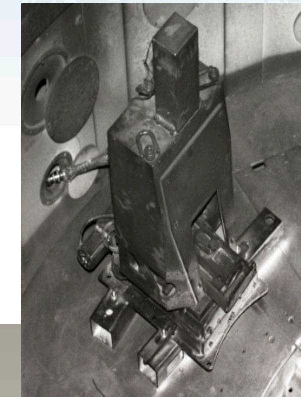
Neutron scattering from extensive hardware near target contributes > 30% to induced activity for most activation diagnostics on Z.

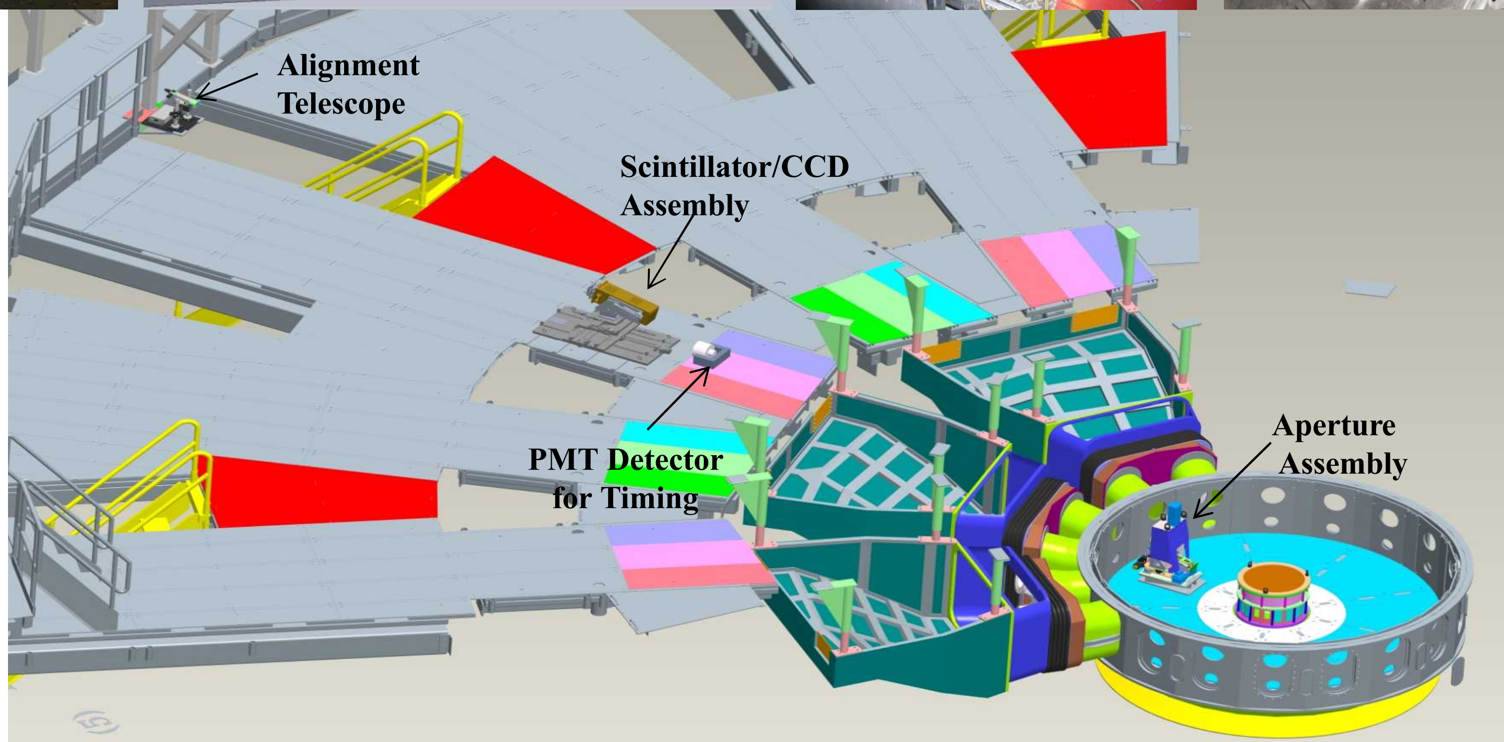
- Management POC: Brent Jones
- Responsible Scientist: Kelly Hahn

Neutron Imaging









Both 1D and 2D Apertures Are Available

1D Aperture Is 204 Microns By 1 cm.
2D Aperture Is 152 Micron.
Overall Length Of Aperture Is 15 Inches.
Aperture Straight Section Is 1.8 cm.
Material Is Tungsten.

Resolution For Either Is Slightly Less Than 300 Microns.

Imaging Scintillator Is 2 Inch Cube That Has 250 Micron Pixels.

- Management POC: Chris Bourdon
- Responsible Scientist: Armon McPherson

Sandia National Laboratories

Capabilities under Development

- Development Plan tied to:
  - National ICF/HED diagnostics plan
  - ICF, RES and DMP 5-year plans
  - Facility and Z capabilities and infrastructure plans
- Integrates all diagnostic development opportunities across Z community
- Seeks to take advantage of development of new technologies

Capabilities not captured on the roadmap:

- Time-Gated spherically-bent crystal spectrometer
- On-Axis time-integrated differential pinhole imaging
- ……