

Overview of NIF X-Ray Spectroscopy Capabilities

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NIF & JLF User Groups Meeting

February 12, 2026

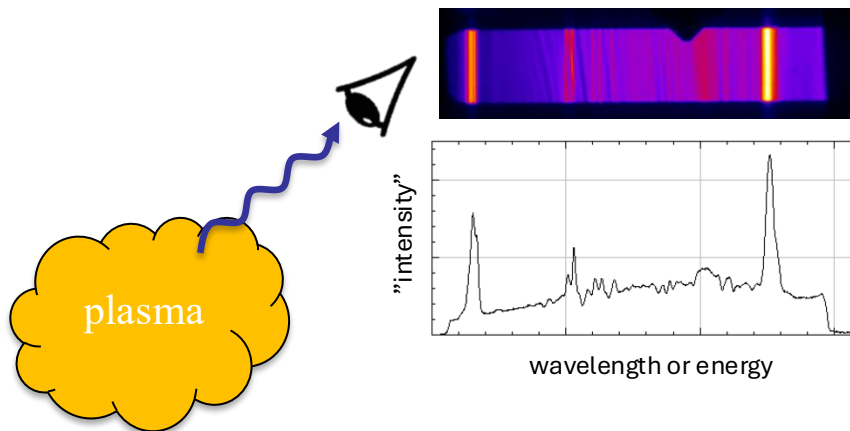


Plasma spectroscopy tries to understand what the number of photons registered at a specific wavelength can tell us about plasma properties

At HED conditions, all matter is ionized to some degree, and photons are a main observable

Complete source measurements include:

- **spectral contents (line position, width, shape)**
- **absolute intensity**
- **spatial distribution**
- **temporal behavior**

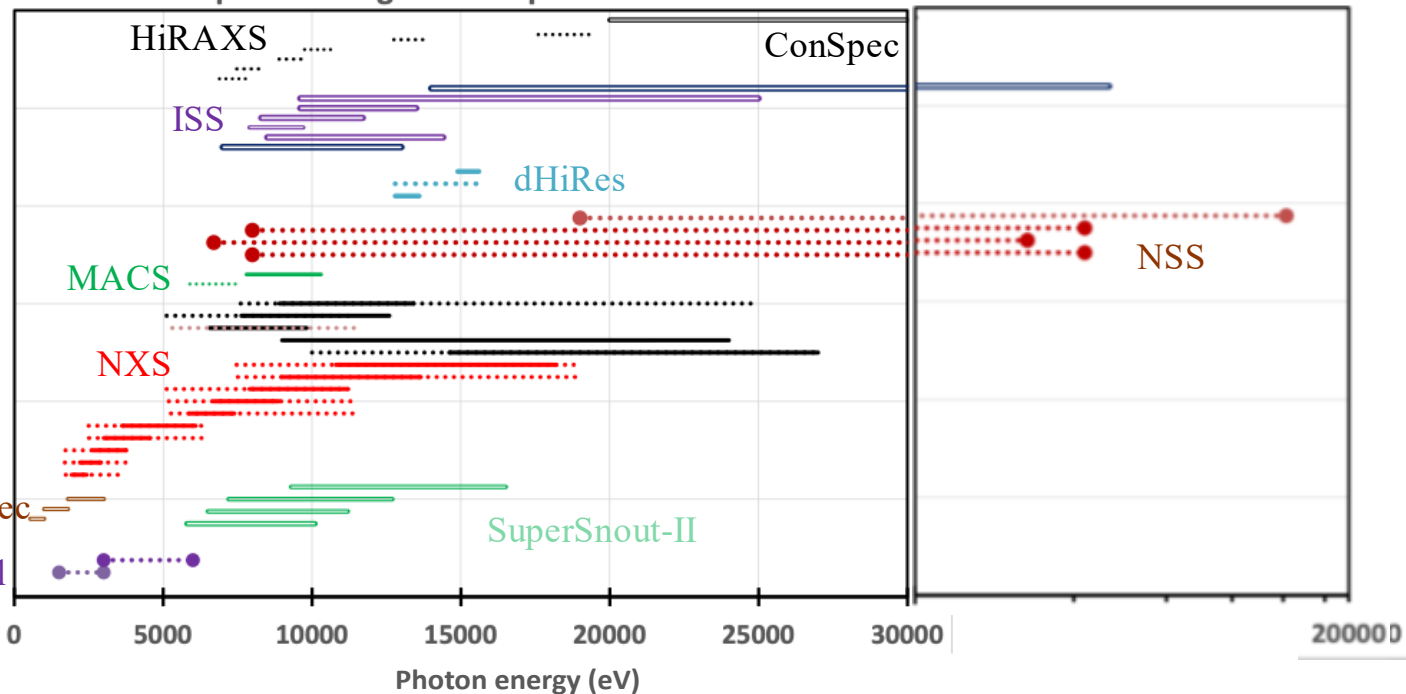


There are various techniques to resolve photon energy, but crystals allow eV-scale resolution for x-rays > 500 eV

At NIF, there are many spectrometers that offer different capabilities

Crystal-based!

Spectral Range of NIF Spectrometers

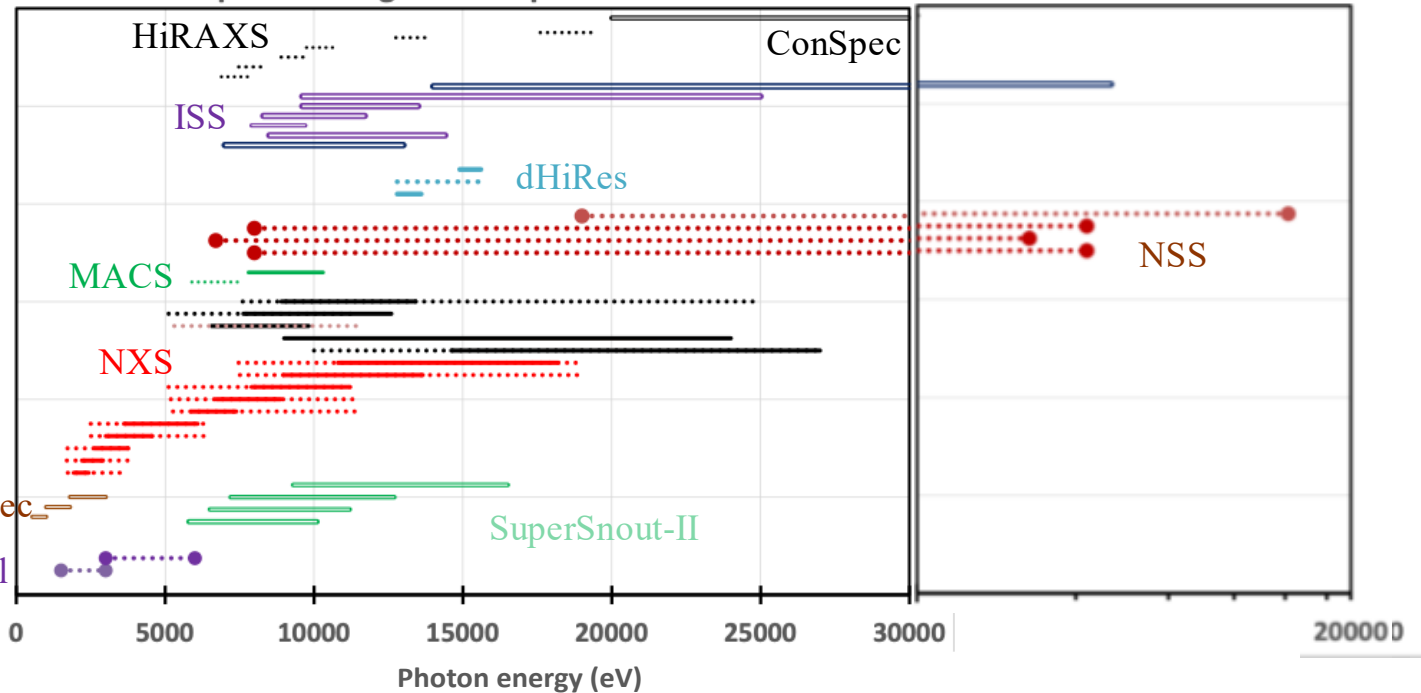


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Crystal-based!

Still a large spread of spectral resolving power

Spectral Range of NIF Spectrometers

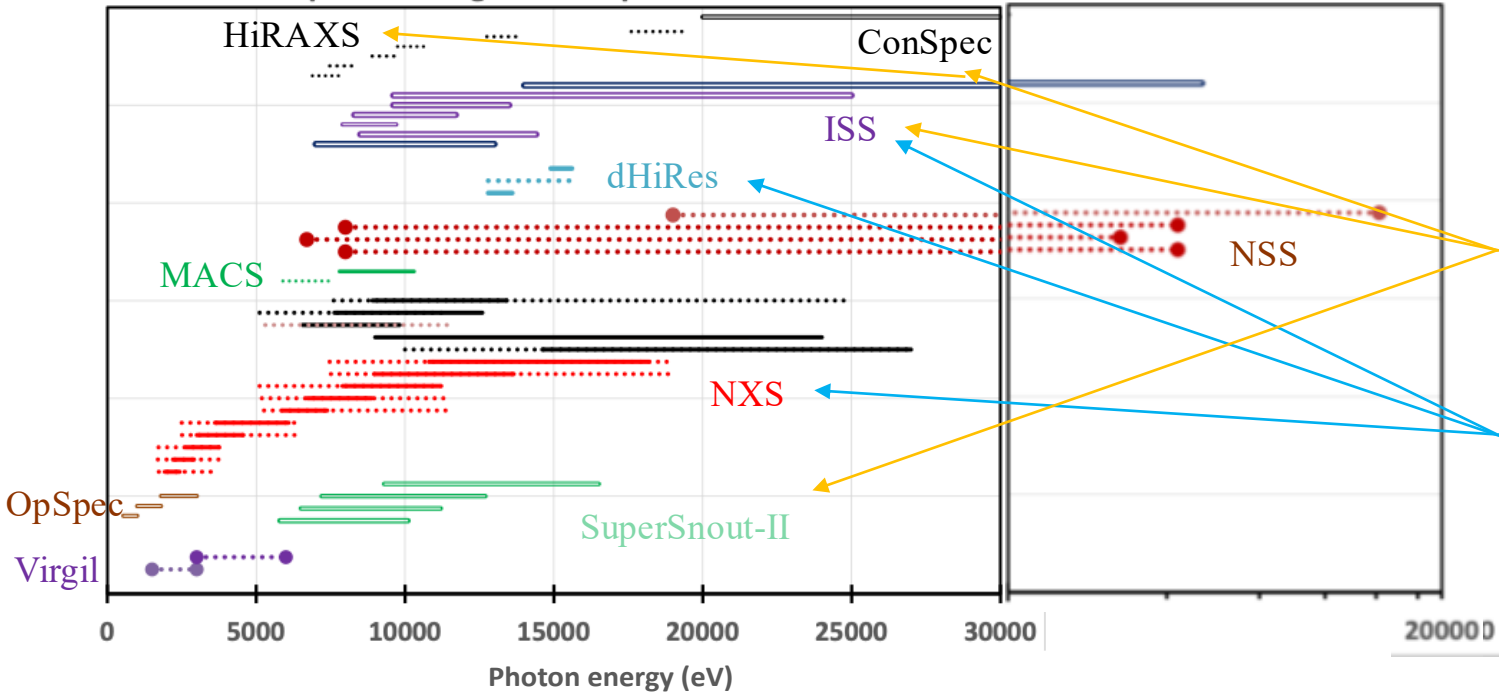


- spectral contents
- absolute intensity
- spatial distribution (apertures, crystal bend)
- temporal behavior (detector pairing)

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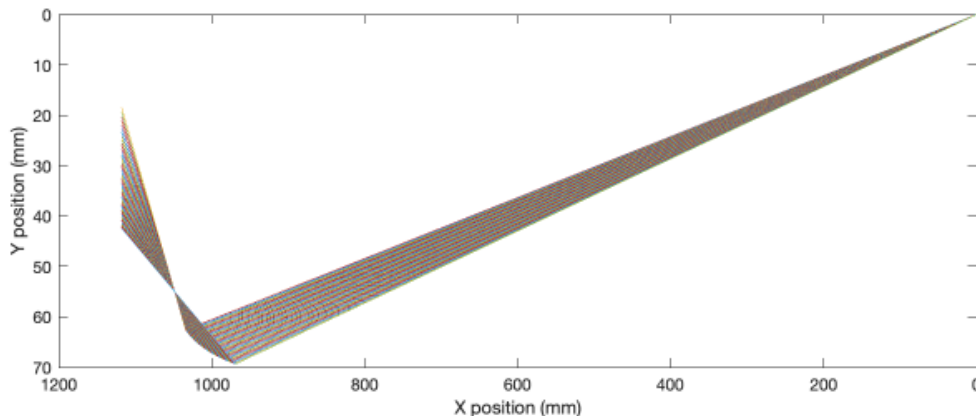
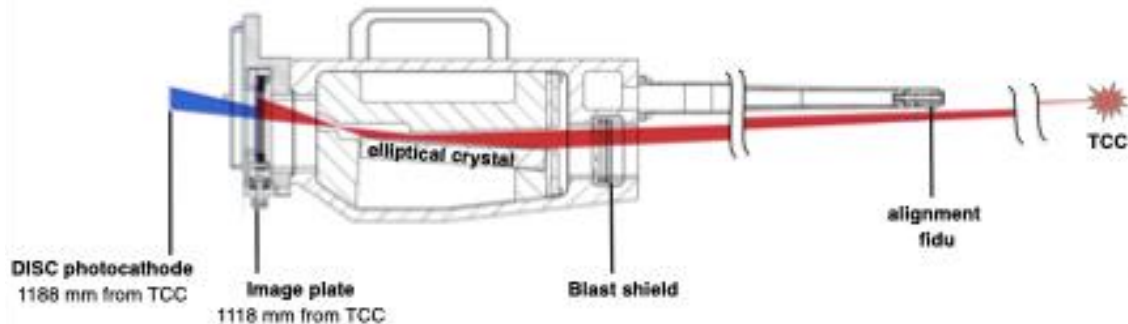
Crystal-based! → Still a large spread of spectral resolving power

Spectral Range of NIF Spectrometers



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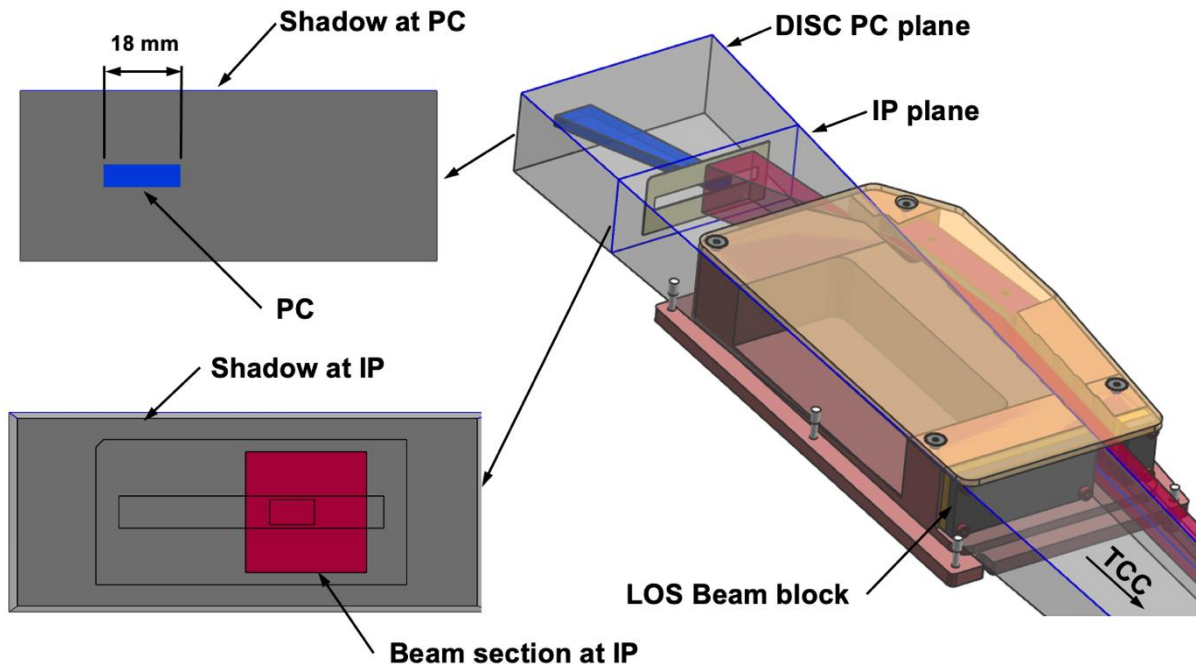
NXS: “NIF X-ray Spectrometer” is a DIM-mounted diagnostic that collects time-integrated and time-resolved x-ray spectra



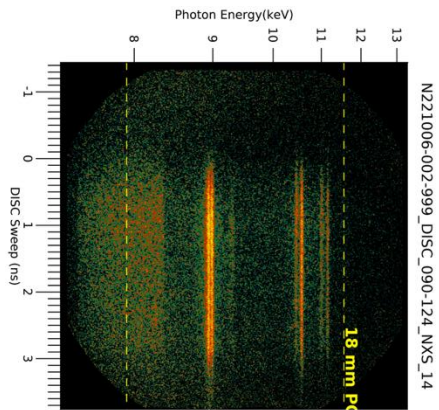
Note: axes not equal

Specifications	
Crystal Geometry	Singly-Curved Elliptical Bragg Crystal 17 interchangeable configurations
Crystal material(s)	KAP, RbAP, PET, Quartz, Si
NIF port location(s)	00-00, 90-78, 90-124, 90-315
Data Collection	Image Plates and DISC
Spectral resolution	25 – 100+ eV, crystal & energy dependent

Streaked spectrum can be calibrated in-situ against time-integrated spectrum recorded on an image plate



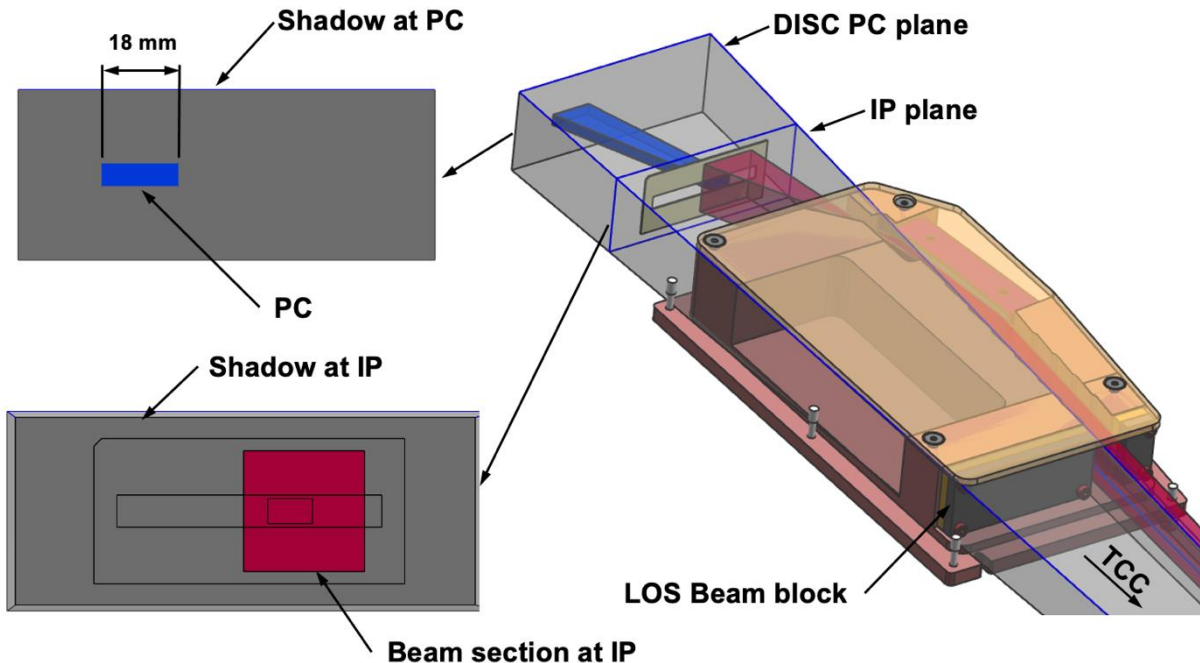
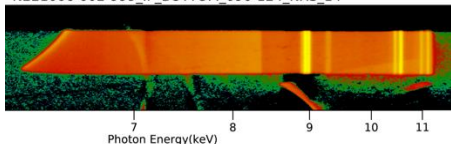
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N221006-002-999_IP_TOP_090-124_NXS_14

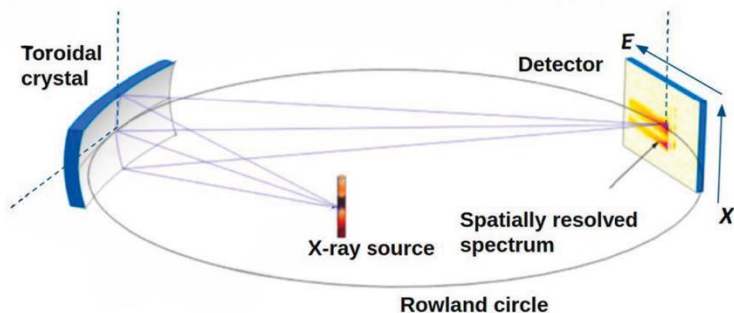


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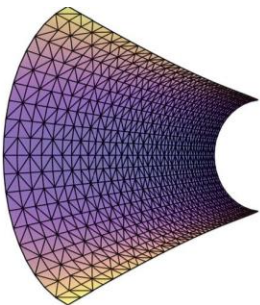


HiRAXS: “High Resolution Absorption X-ray Spectrometer” was developed for high resolution and high throughput; it’s aka the EXAFS spectrometer

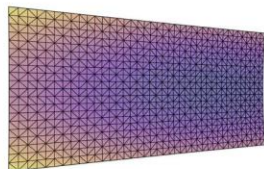
S. Stoupin et al, Rev. Sci. Instrum. 92, 053102 (2021)



VR Spiral



Large for visualization



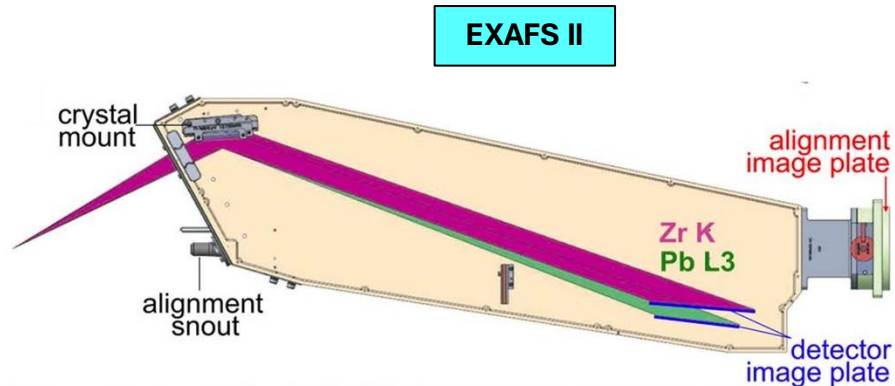
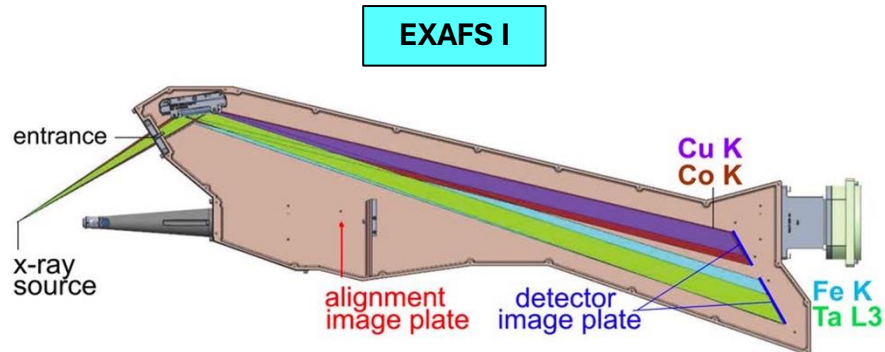
Actual shape

Specifications	
Crystal Geometry	Doubly-Curved Bragg Crystal Toroidal and Variable-Radii Spiral 6 configurations for two snouts
Crystal material(s)	Ge, Si
NIF port location(s)	90-124, 90-348
Data Collection	Image Plates
Spectral resolution	3-9 eV, crystal & source size dependent
Spatial Mag	2X-3X, config dependent

N. A. Pablant et al, Rev. Sci. Instrum. 92, 093904 (2021)

Two versions of the spectrometer hardware exist for the different crystal geometries; both include imaging pinholes for alignment verification

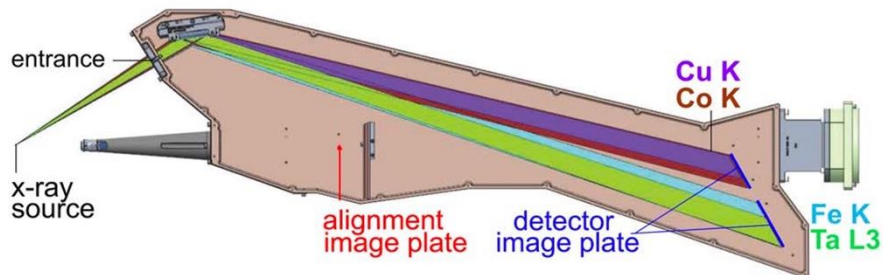
H. Sio et al, Rev. Sci. Instrum. 95, 103523 (2024)



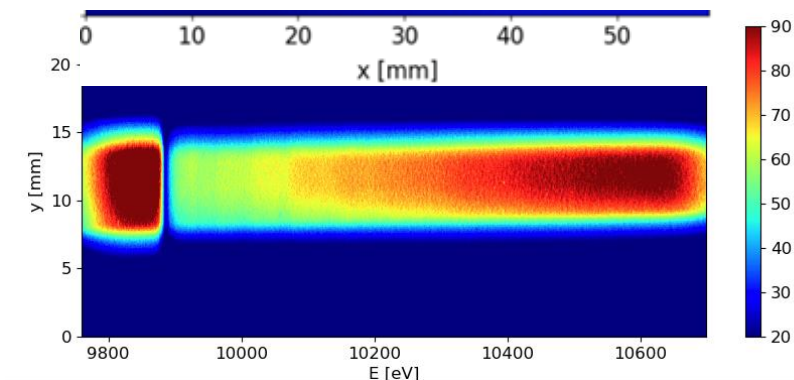
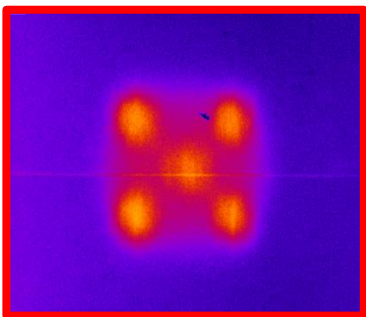
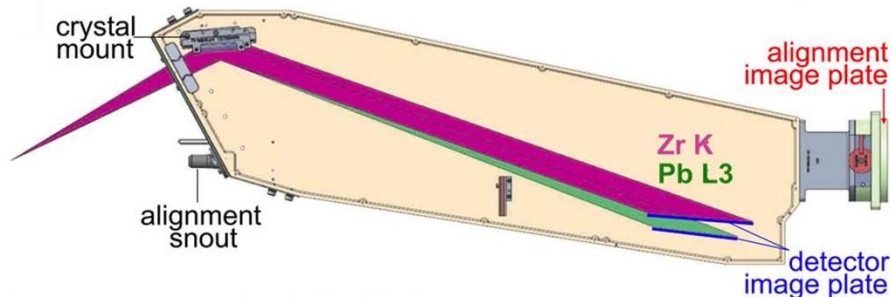
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EXAFS I

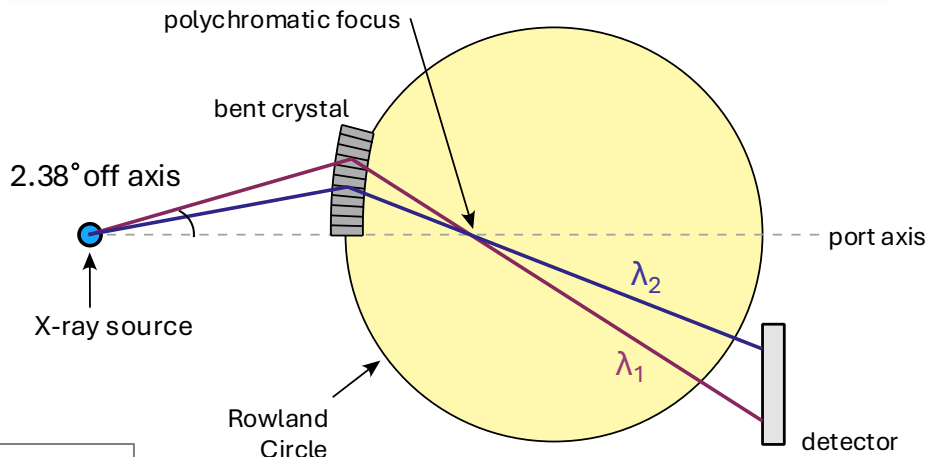
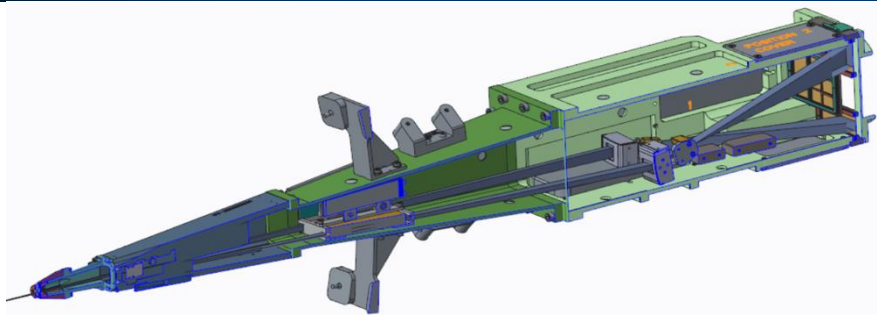


EXAFS II



RS: Stan Stoupin
(stoupin1@llnl.gov)

ISS: “Imaging and Spectroscopy Snout” supports multiple measurements along pole, with a lot of options for spectral data



not to scale

Specifications	
Crystal Geometry	Singly-Curved Cylindrical Transmission Crystal Many configurations for two snouts
Crystal material(s)	Quartz, Si
NIF port location(s)	00-00
Data Collection	Image Plates and HGXD or DISC
Spectral resolution	~10-30 eV, channel, energy & source size dependent
Spatial Mag	2X or 12X, snout dependent
Addl capability	Supports NIS-NP and P-DIXI

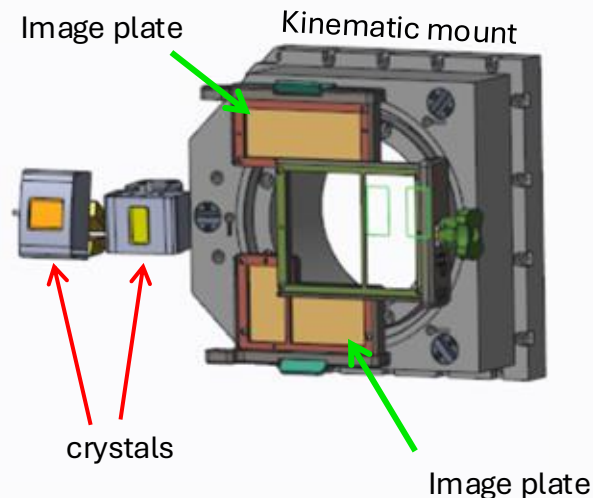
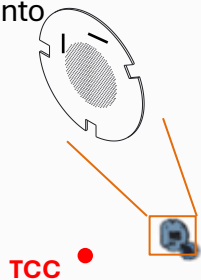
ISS was intended to be “Swiss army knife of diagnostics” spectrometers

ISS supports neutron imaging (NIS-NP) and x-ray imaging (52x P-DIXI and optionally 11-12x on HGXD & IP)

Configurations:

- Two time-integrated, 1D spatially-resolved x-ray spectra (always)

50 μm slits
machined into
substrate

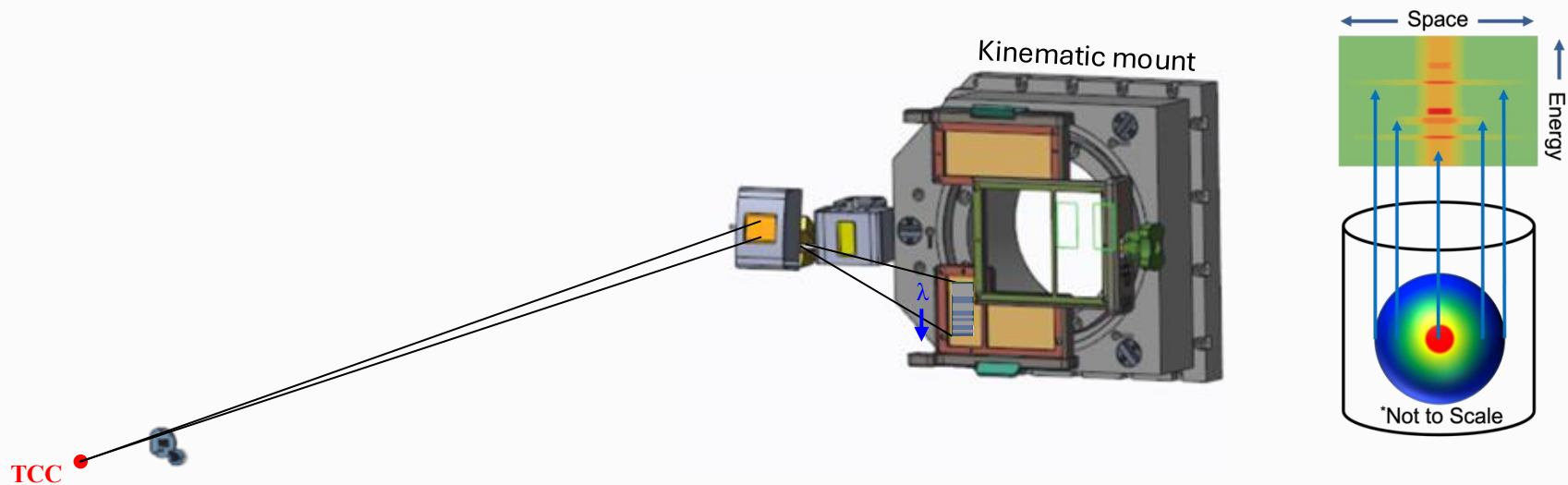


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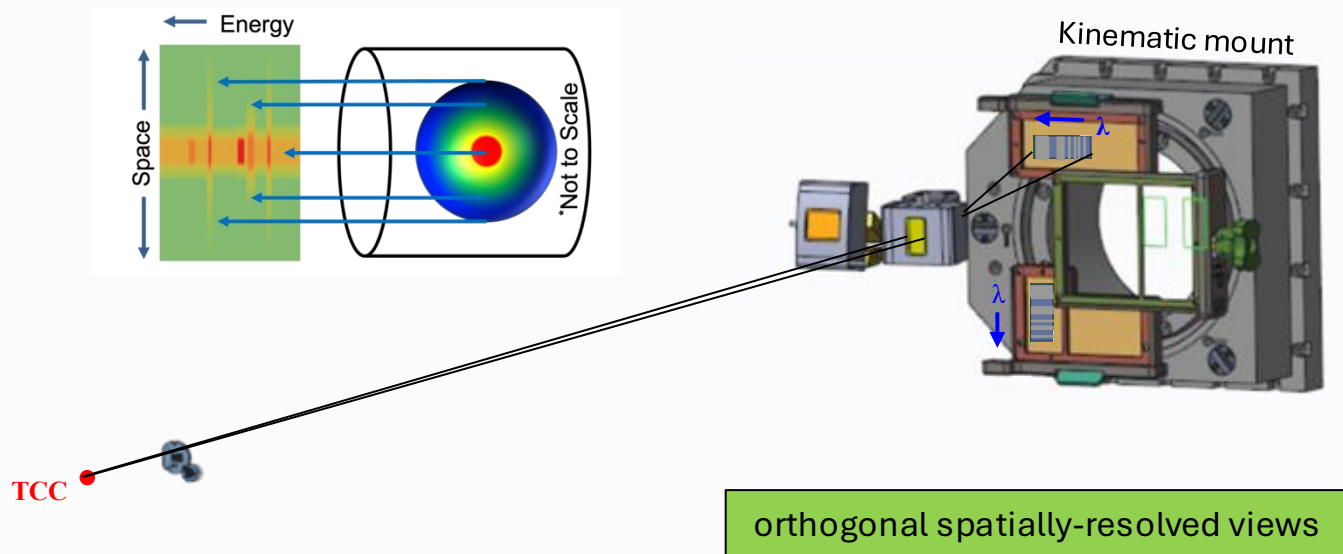


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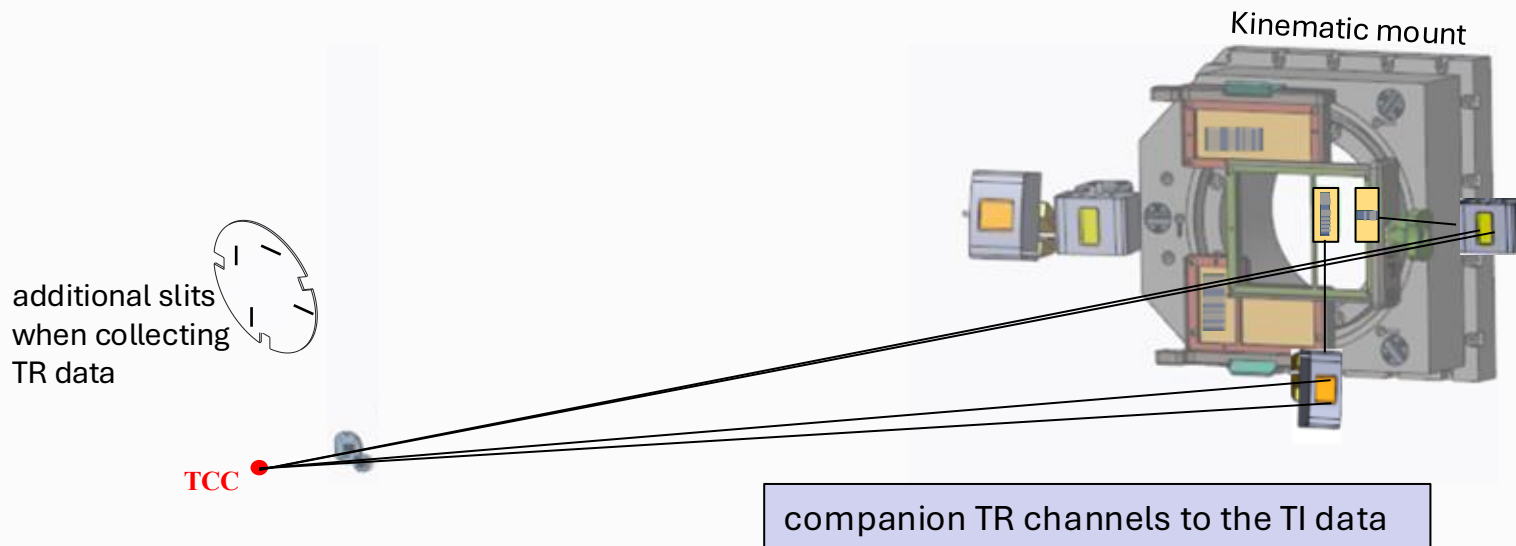


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Configurations:

- Two time-integrated, 1D spatially-resolved x-ray spectra (always)
- Two time-gated, 1D spatially-resolved x-ray spectra (optional)




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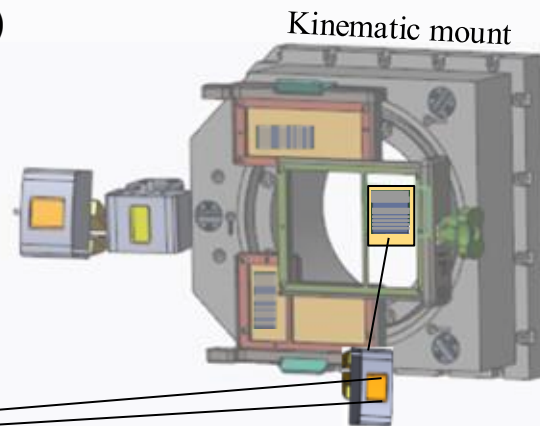
Configurations:

- Two time-integrated, 1D spatially-resolved x-ray spectra (always)
- Two time-gated, 1D spatially-resolved x-ray spectra (optional)
- Time-resolved x-ray spectra with streak camera (optional)

additional slits
when collecting
TR data



TCC



ISS was intended to be “Swiss army knife of diagnostics” spectrometers

ISS supports neutron imaging (NIS-NP) and x-ray imaging (52x P-DIXI and optionally 11-12x on HGXD & IP)

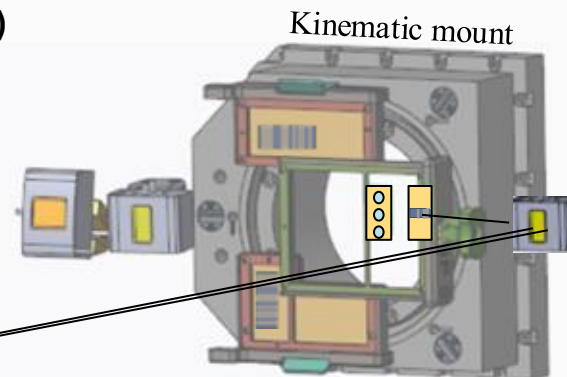
Configurations:

- Two time-integrated, 1D spatially-resolved x-ray spectra (always)
- Two time-gated, 1D spatially-resolved x-ray spectra (optional)
- Time-resolved x-ray spectra with streak camera (optional)
- One time-gated, 1D spatially-resolved x-ray spectrum + time-gated 2D pinhole imaging (optional)

additional slits
when collecting
TR data



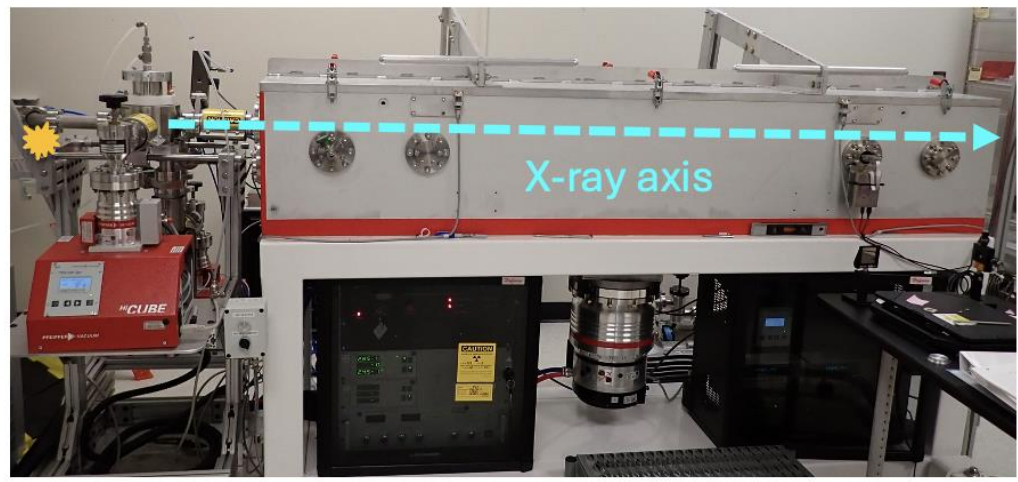
TCC

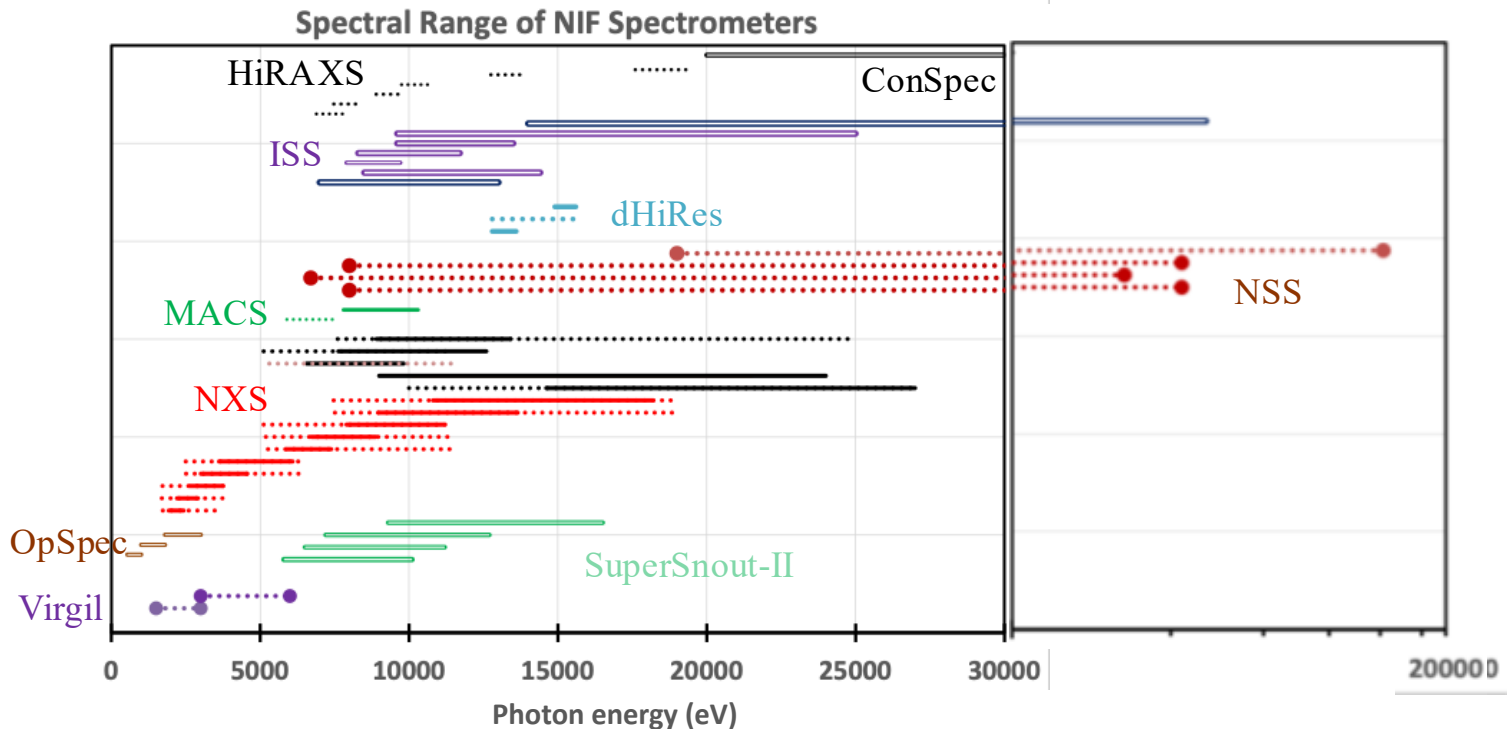
SCS: "Spectrometer Calibration Station" was developed at LLNL to absolutely calibrate NIF spectrometers in their fielded configuration

- Work needed before going on NIF!**
- Optical alignment
 - Crystal evaluation (quality)
 - Bandwidth characterization (ΔE)
 - Crystal dispersion (E vs x)
 - Spectral resolution ($\lambda/\delta\lambda$)
 - Source displacement and insertion error evaluation
 - Absolute throughput measurement

Ratio of signals yields crystal response, which is fed into instrument response :



NIF has a variety of x-ray spectrometers; we continue to push towards collecting spectral data with spatial and temporal information



Reach out with questions re: diagnostics or calibration
Christine.Mariscal@ga.com