SAND2013-9737C

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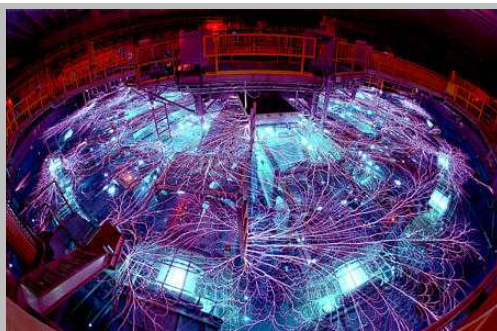

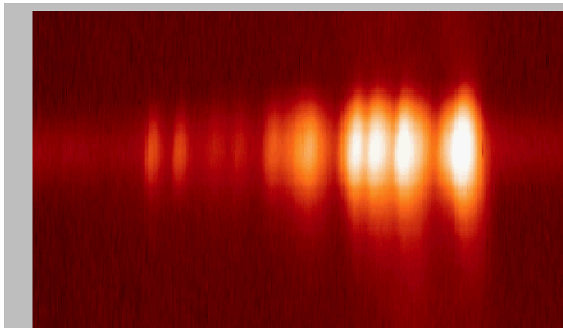

X-ray Thomson Scattering (XRTS) Development for Z

E.C. Harding[1], T. Ao[1], J.E. Bailey[1], D.B. Sinars[1], G.A. Rochau[1], S.B. Hansen[1], M.P. Desjarlais[1], L.P. Mix[1], M. Geissel[1], I.C. Smith[1], R.W. Lemke[1], G. Gregori[2]

[1]Sandia National Laboratories, Albuquerque, NM
[2]University of Oxford, Oxford, UK

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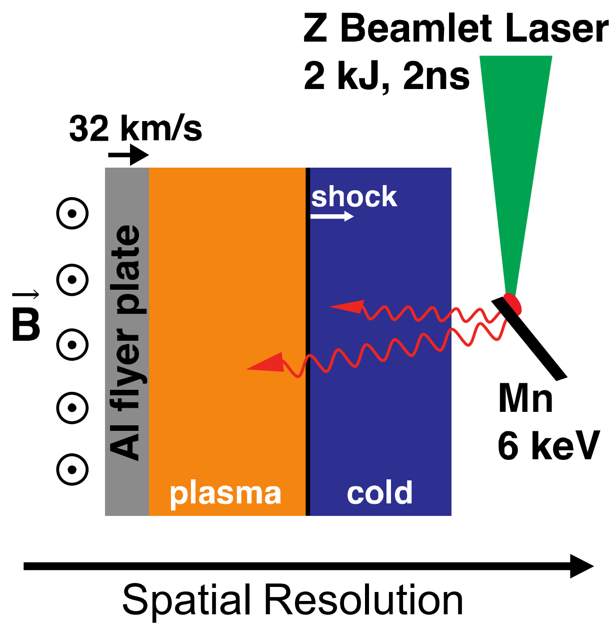
Why do XRTS on Z?

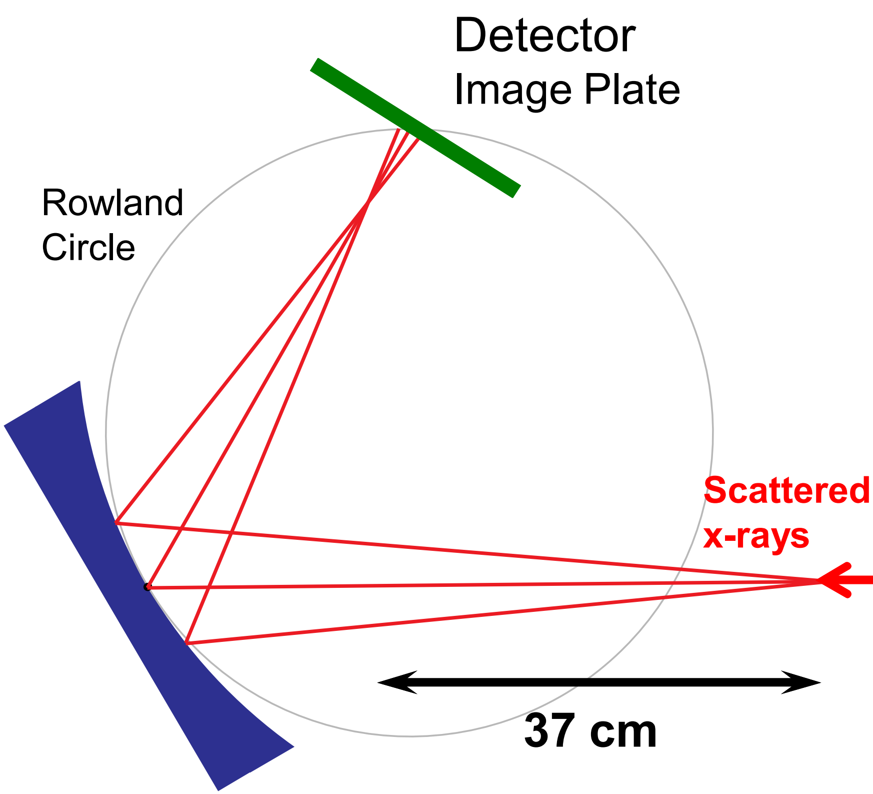
- Need to constrain EOS models with T_e measurements.
- Flyer plate driven targets offer some advantages:
  - Big targets (many mm sized)
  - Long lived steady shocks (90 ns in foam experiment)
  - No x-ray or hot-electron preheat

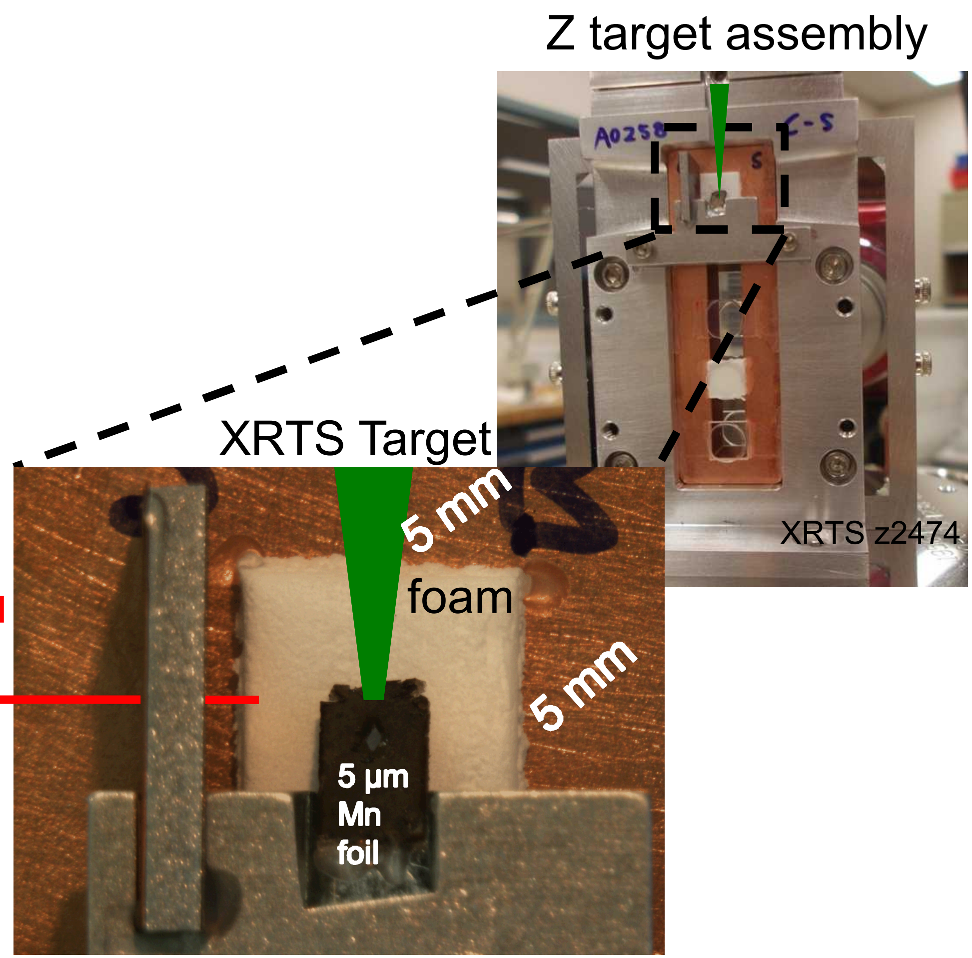


Warm Dense Matter on Z

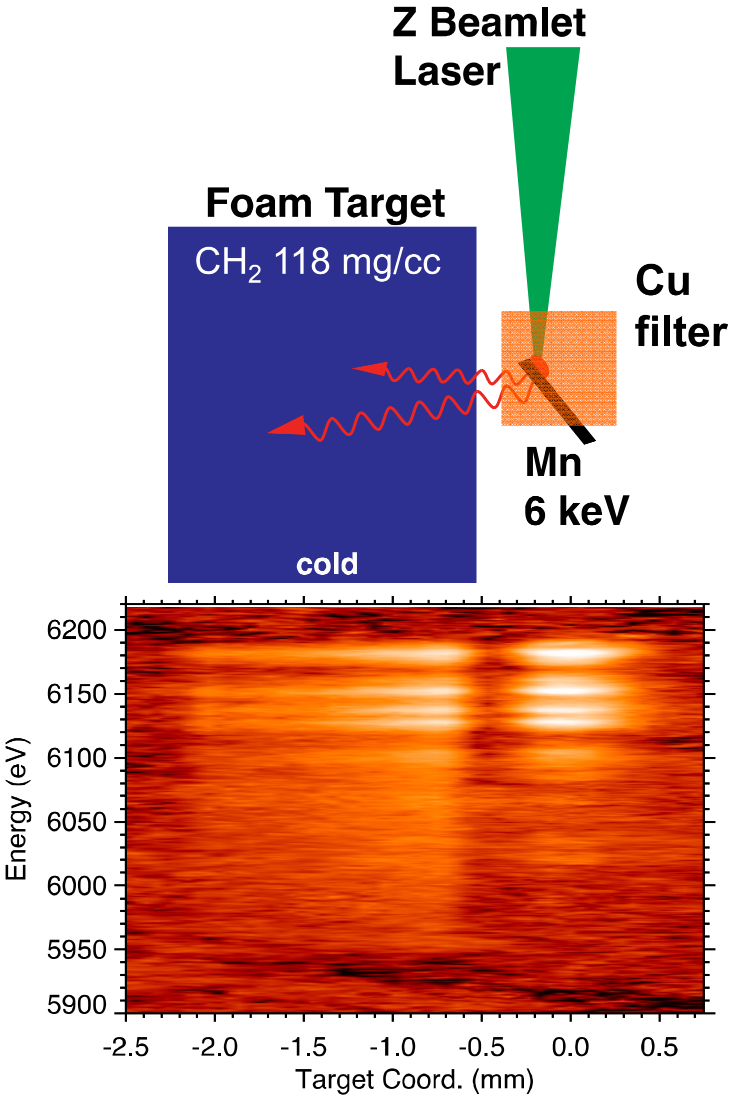
	CH_2 Foam	^{6}LiD	Be
T_e	7 eV	4 eV	3 eV
ρ	0.5 g/cc	2.55 g/cc	4.9 g/cc
P	1.1 Mbar	5 Mbar	9 Mbar
Zbar	0.6	0.6	2.0

A new spectrometer and target were developed to enable space-resolved XRTS measurements.

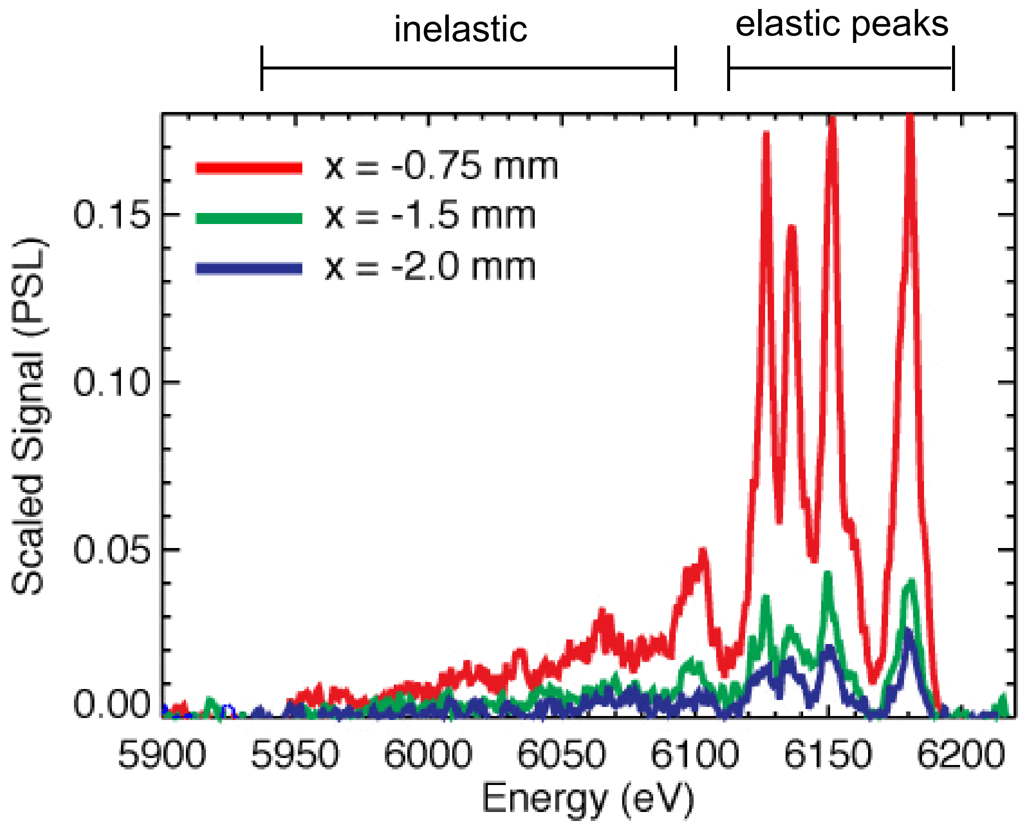




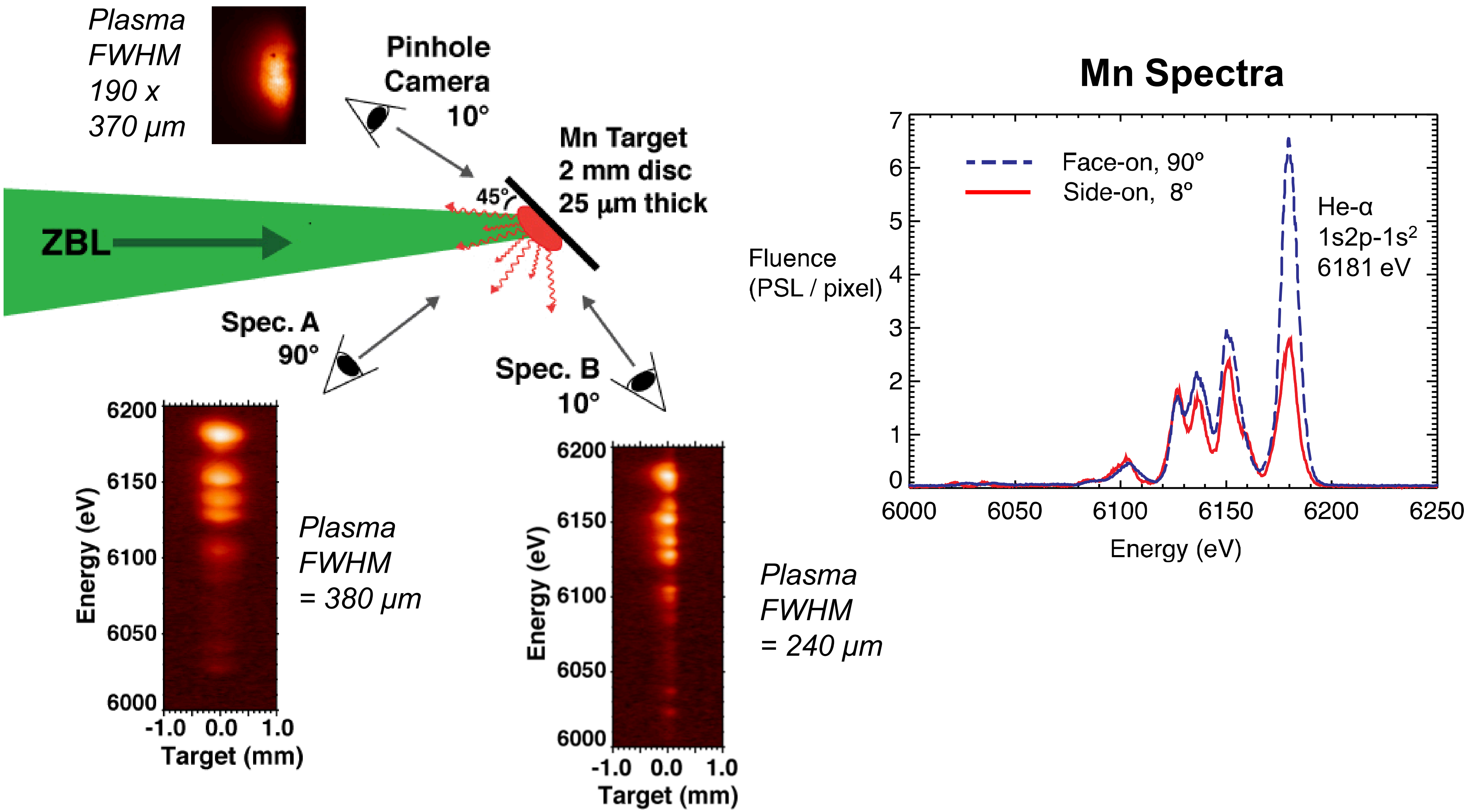
The first full integrated Z shot successfully observed space-resolved, x-ray scattering from unshocked foam.



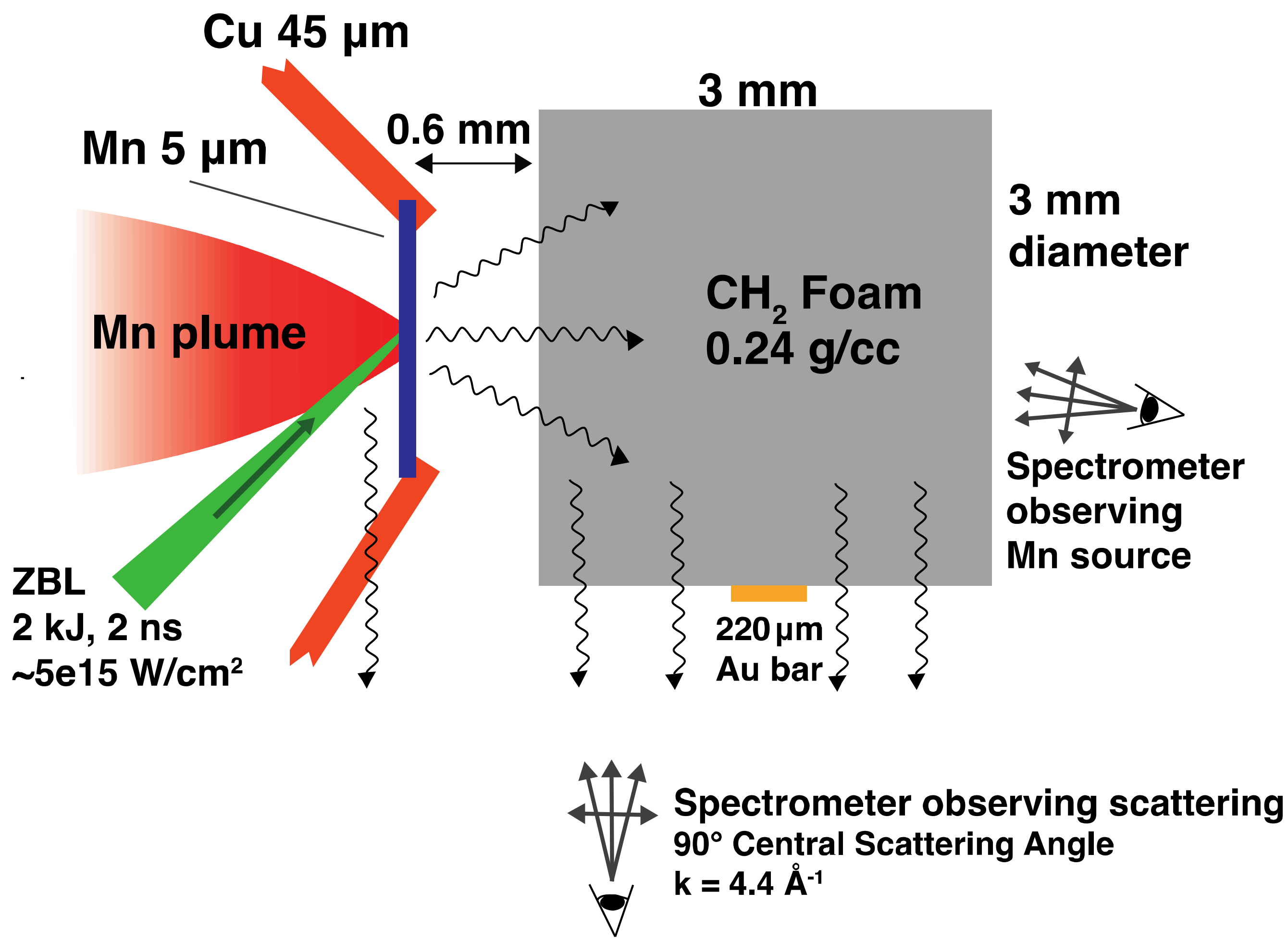
Lineouts show high-resolution elastic and inelastic scattering spectra.



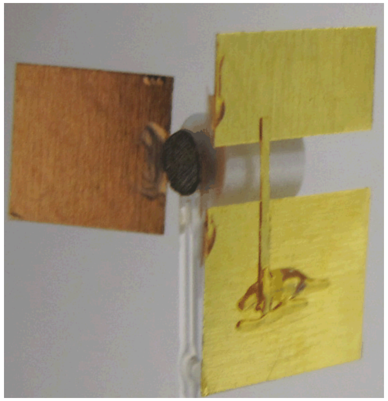
We have observed a variation in the shape and intensity of Dedicated Mn source experiments.



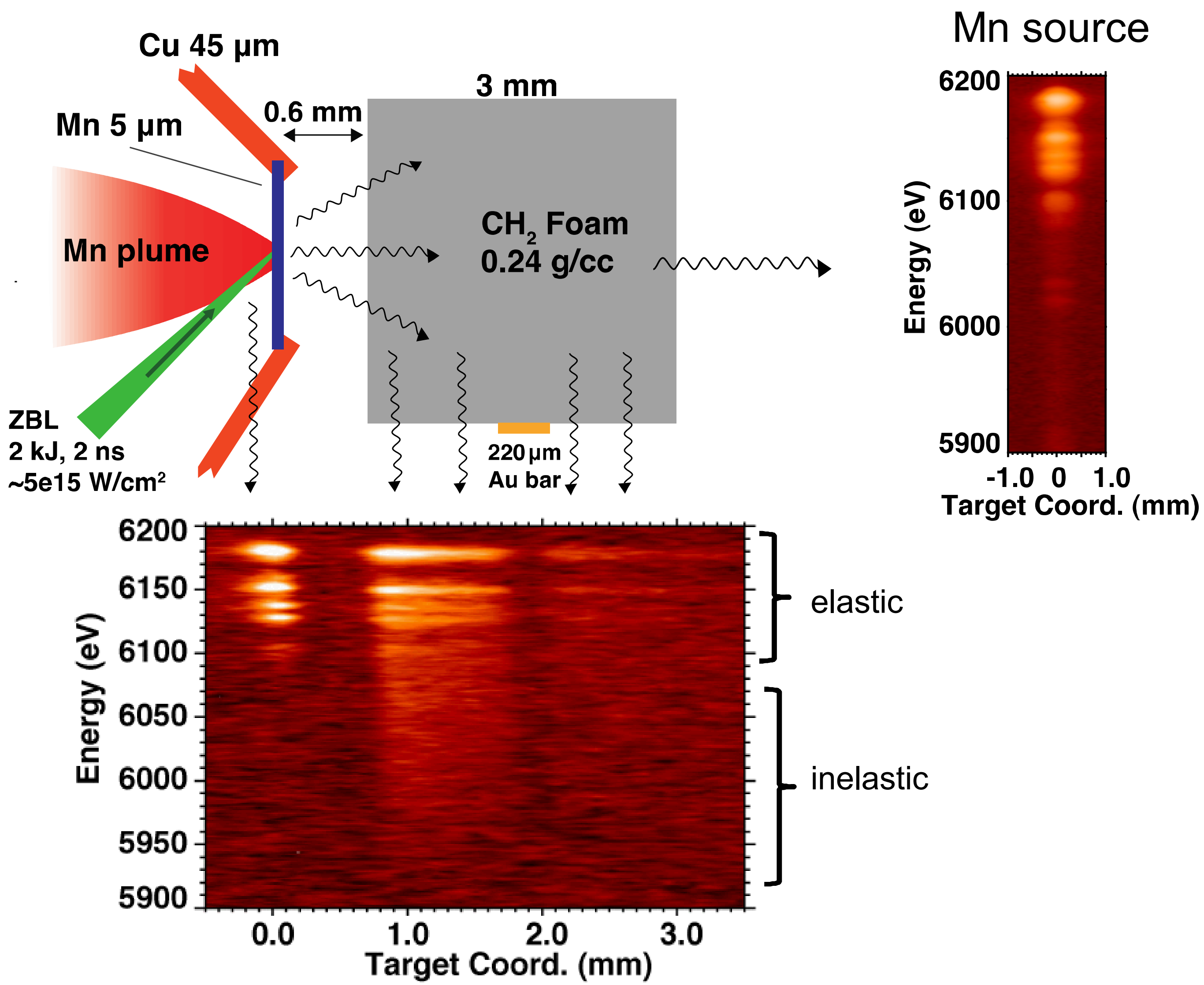
A laser only target was tested with two identical spectrometers that observed the scattering and the source as witnessed by the foam.



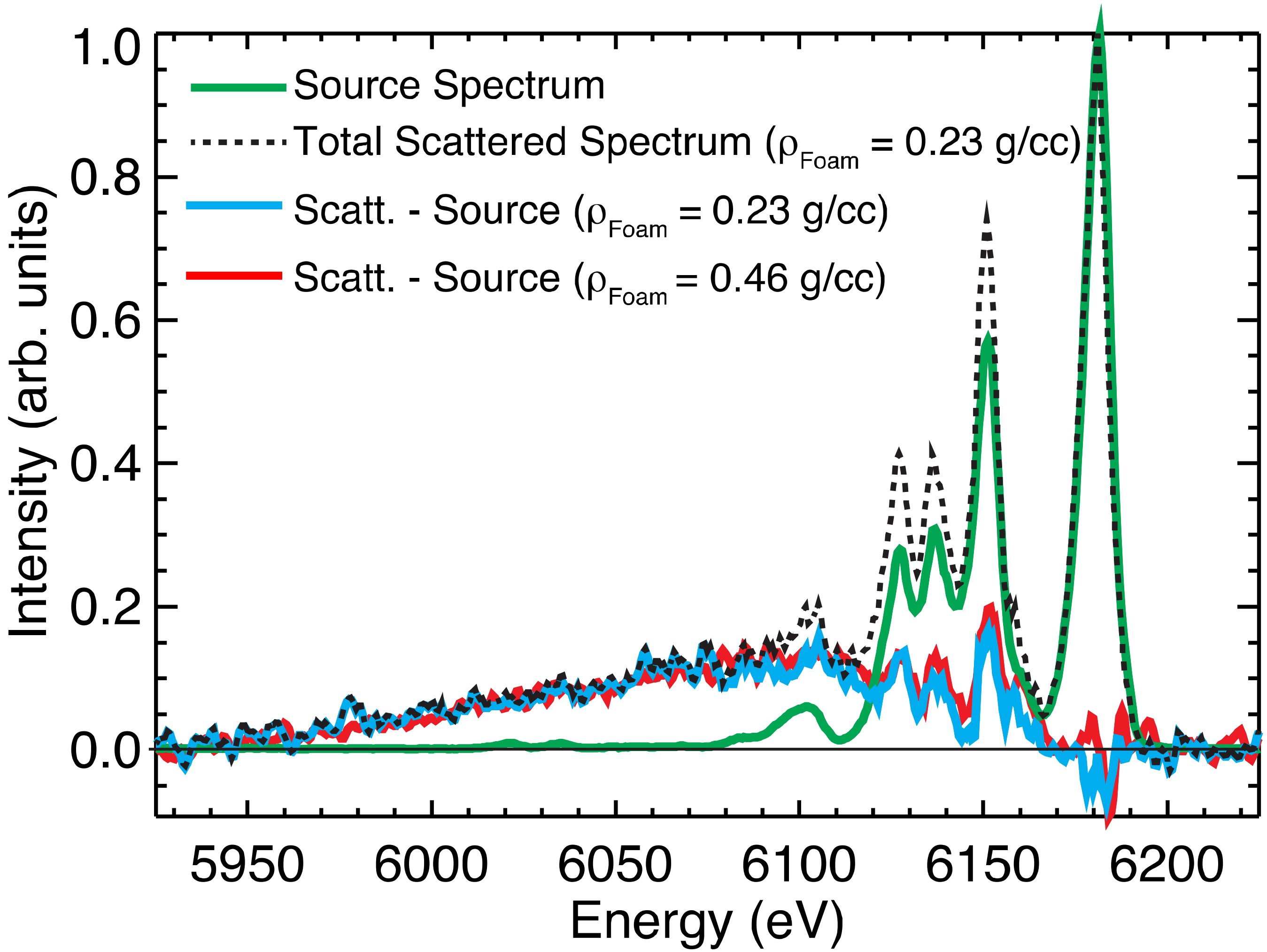
Target Photo



Foam experiments observed detailed scattering and source spectra in the same shot.



The inelastic scattering is isolated by subtracting the source spectrum from the total scattered spectrum.



The relative line intensities of the scattered spectrum depend on the binding energies of the Carbon 2p electrons.

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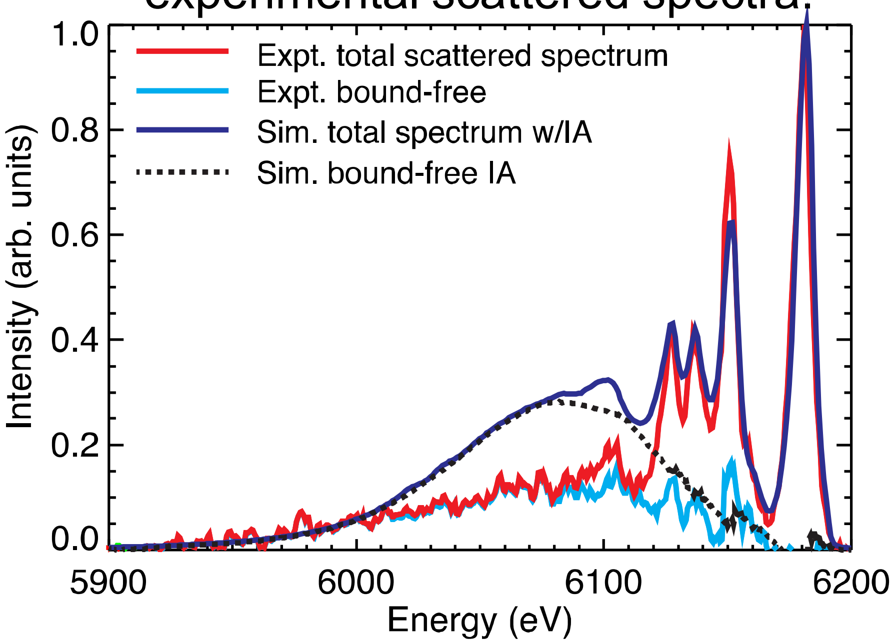
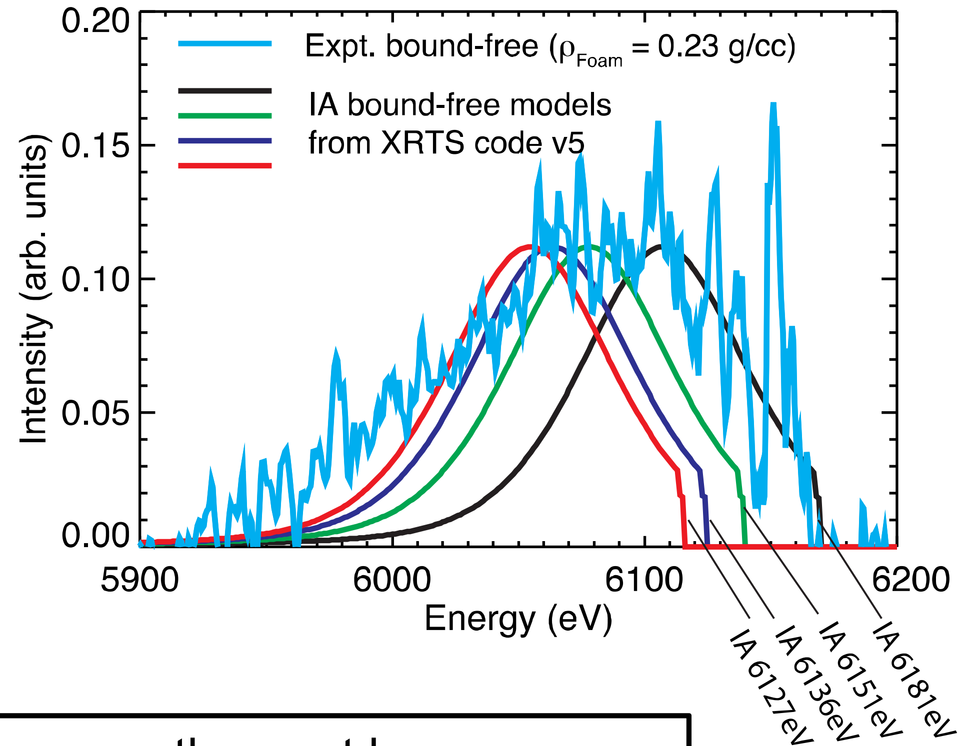
Comparison of simulated and experimental scattered spectra.



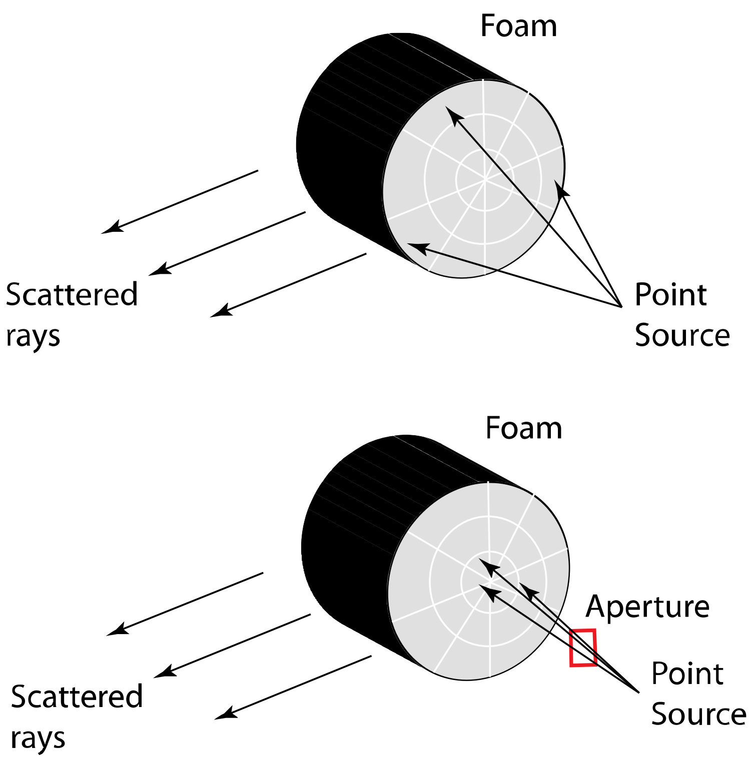
Each spectral line begins to contribute to the bound free spectrum the Carbon $2p^2$ binding energy is exceed.



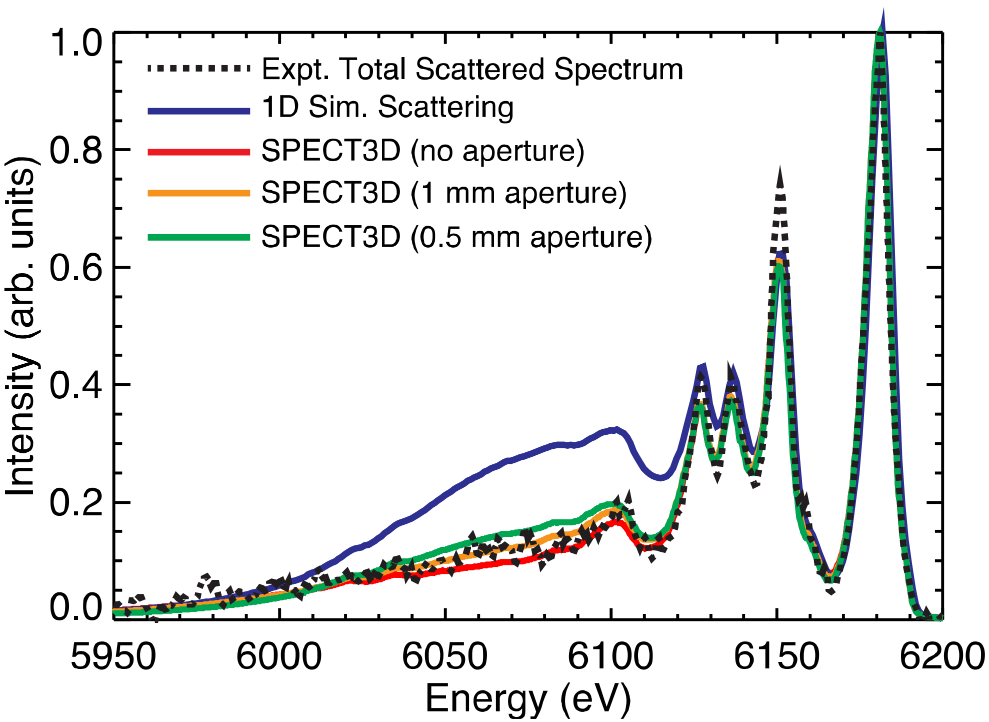
With no input aperture multiple x-ray paths must be considered

The XRTS code was add to SPECT3D in order to model scattering from 3D, non-homogenous plasmas.

SPECT3D Geometry



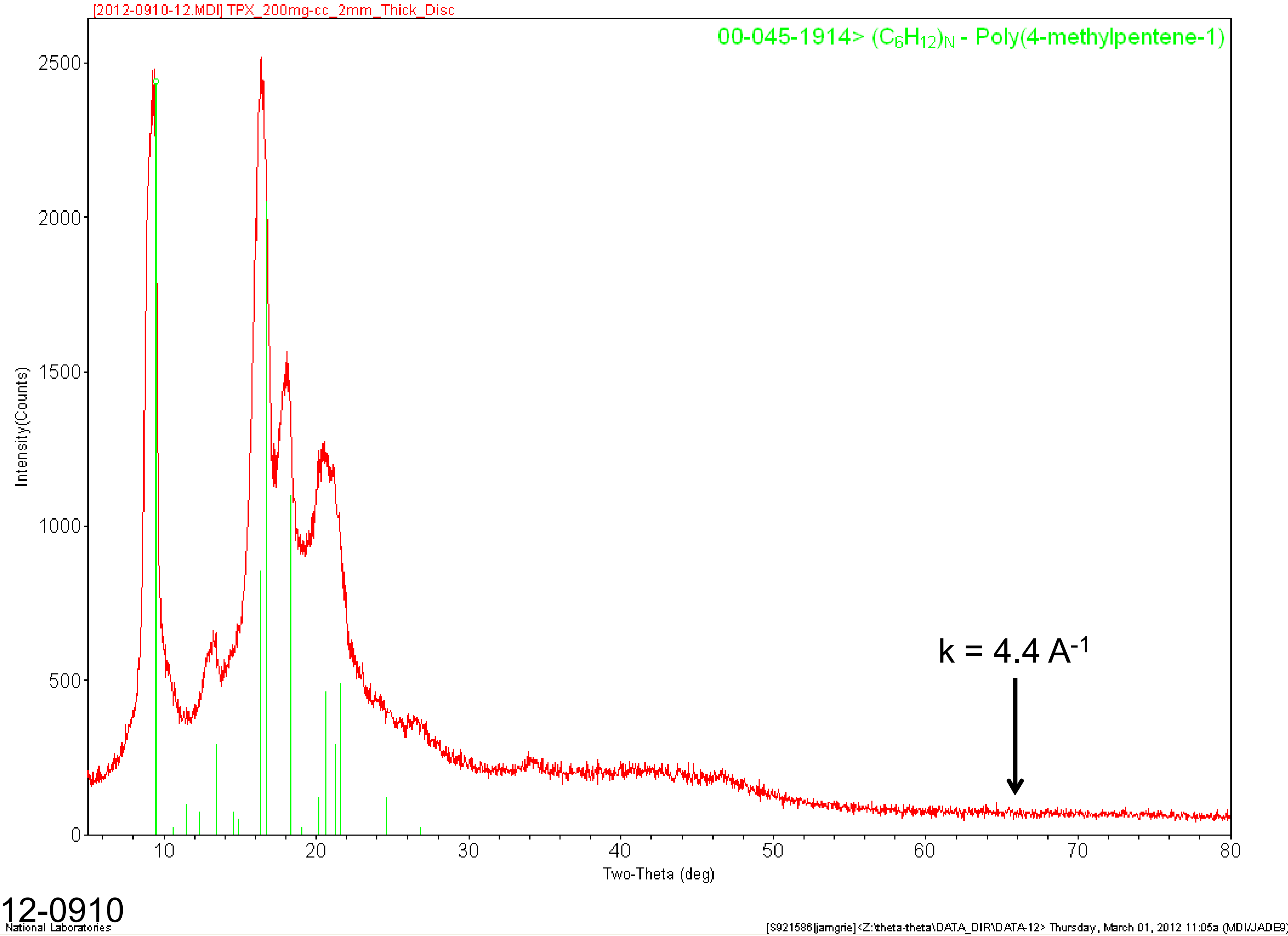
Comparison of SPECT3D simulated scattering and experiment.



SPECT3D simulated scattering fits data well with S_{ii} = 1.5. However, the relative line intensities are not reproduced.

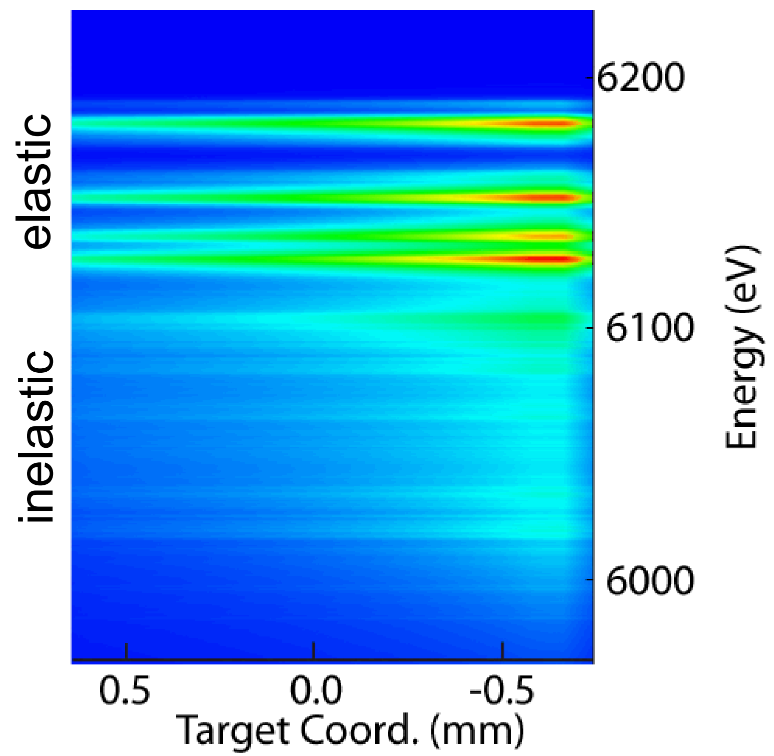
Summary

Sample Name: **TPX 200mg/cc 2mm Thick Disc** identified as Poly(4-methylpentene-1)

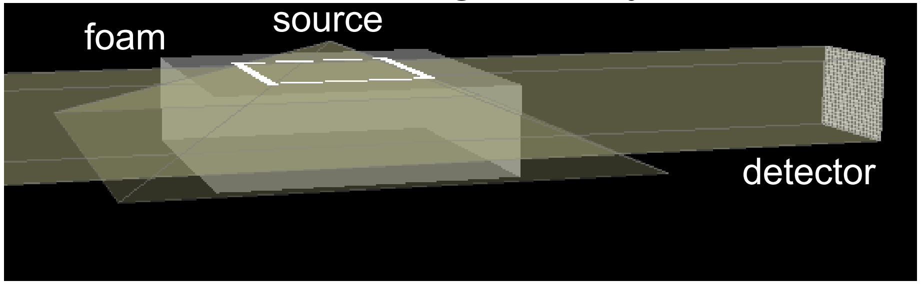


Gregori's XRTS code was add to SPECT3D in order to model scattering from 3D, non-homogenous plasmas[1].

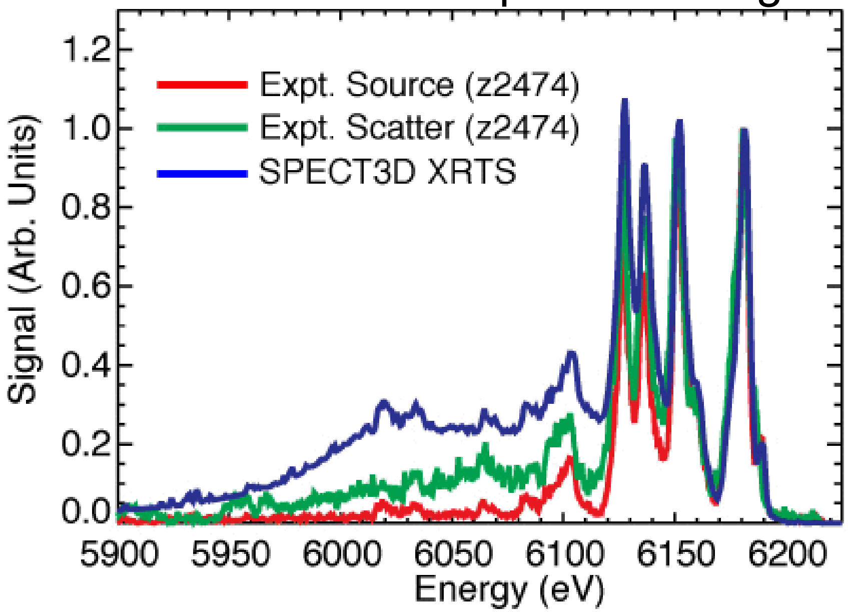
Simulated Scattering Spectra



SPECT3D geometry



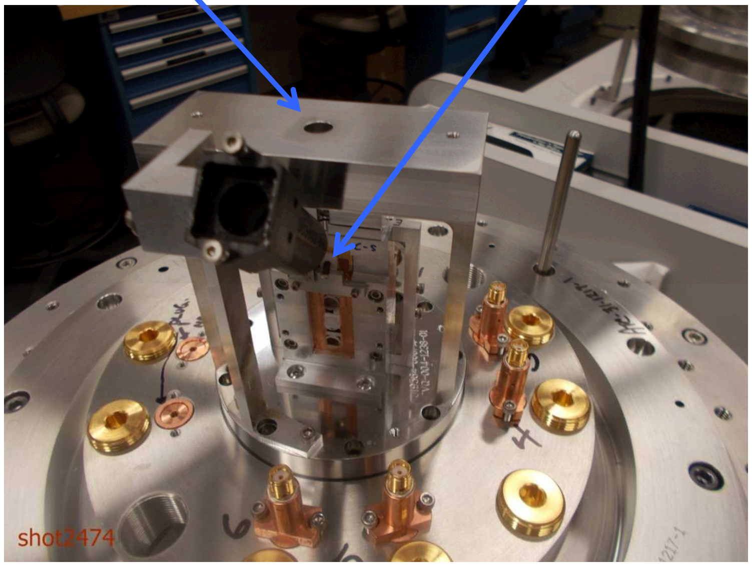
Simulated vs. Expt. Scattering

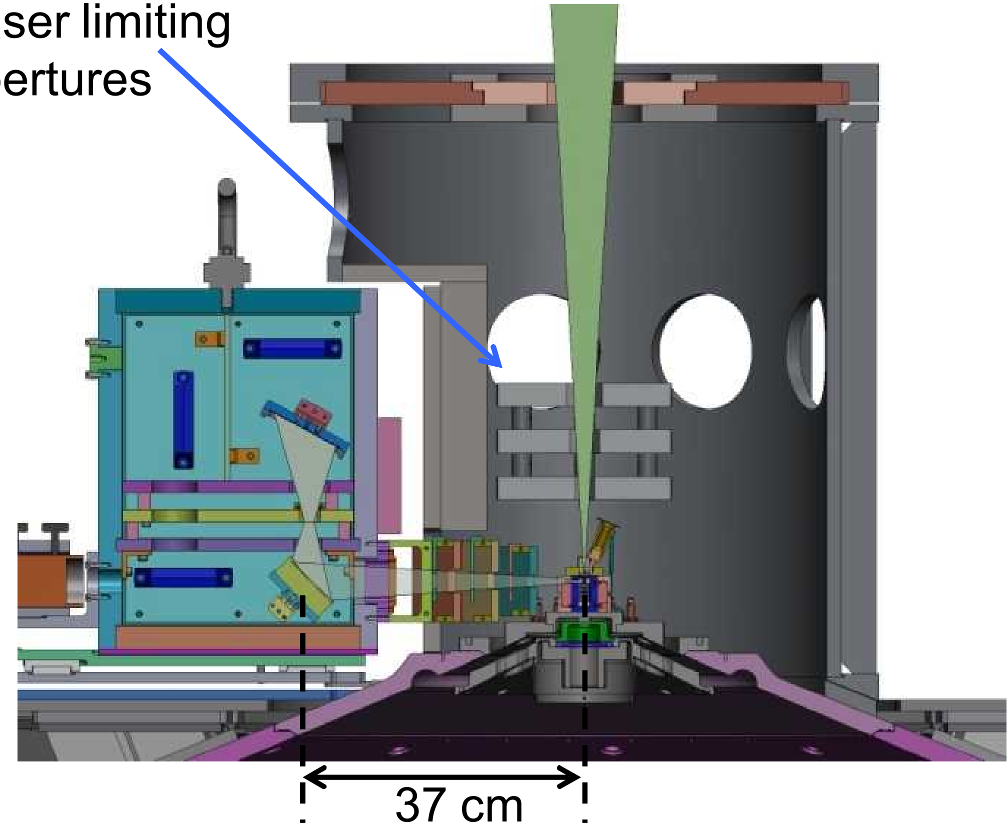


[1]Igor Golovkin *et. al.*, JQSRT *(submitted)*

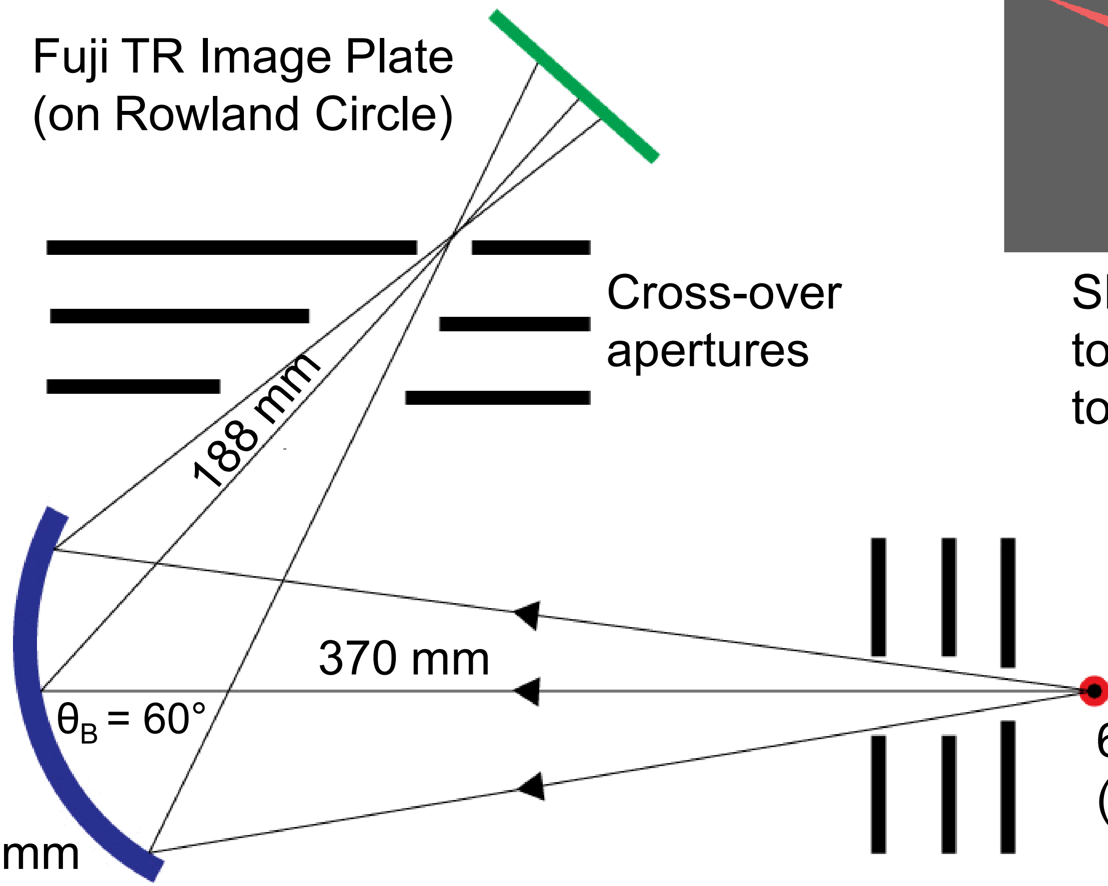
Limiting apertures were designed to protect both the crystal and laser focusing optics.

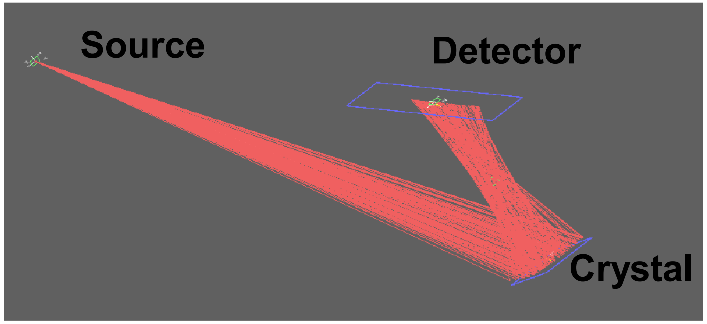
- Engineering design of apertures informed by NASA micro-meteorite data from impacts on glass





The spectrometer point design uses a spherical Ge 422 crystal (R = 216 mm) and has a spatial magnification = 0.5x.



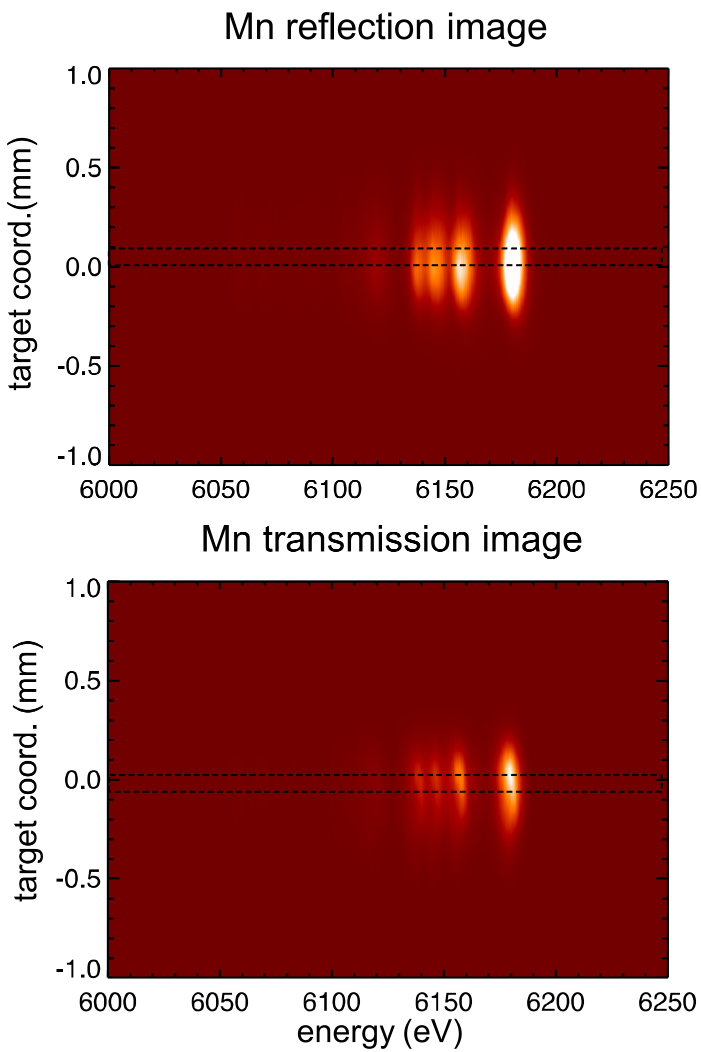


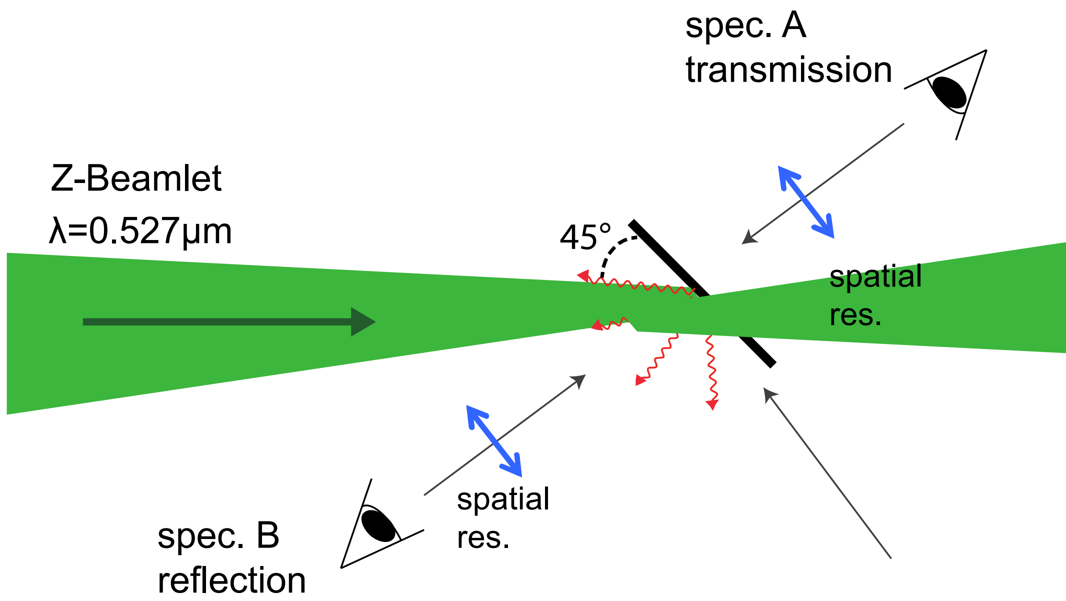
SHADOW ray tracing used to determine alignment tolerance and PSF.

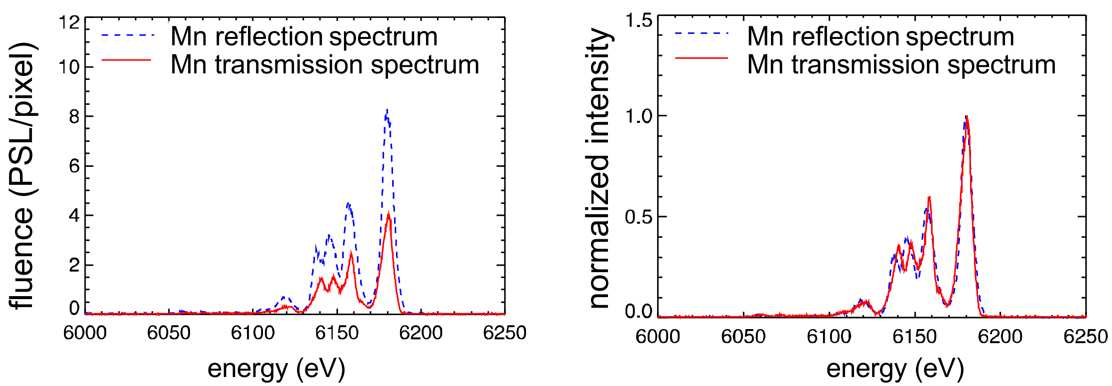
Standoff: +/- 2 mm
Vertical: +/- 1 mm
PSF = 10 μm (w/o IP)

Reflection and transmission spectra

- Spectra similar but transmitted x-rays attenuated by 50% compared to reflected x-rays



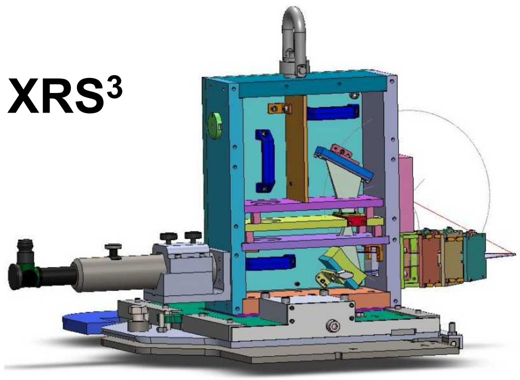




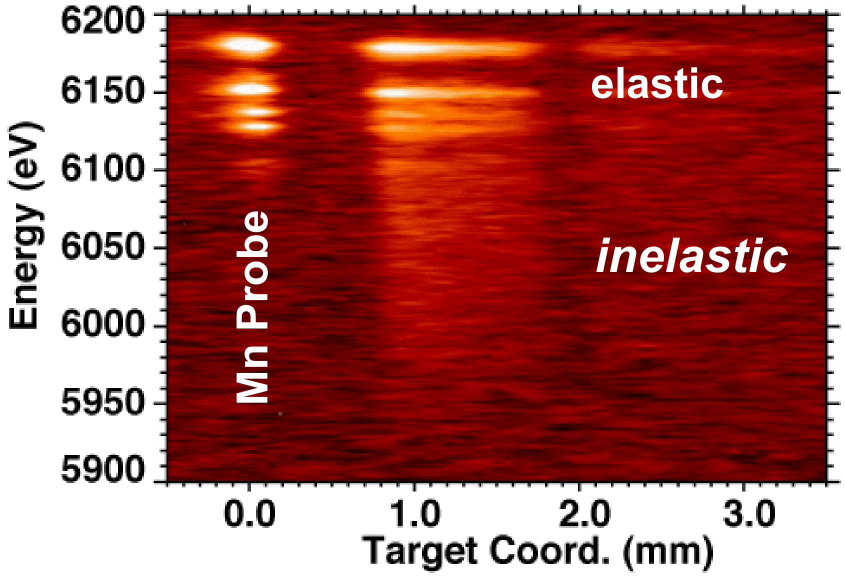
Summary: We have used a spherical spectrometer to record spatially resolved XRTS spectra.

- Goal: XRTS with spatial resolution on the Z machine
- We are using spherically bent Ge 422 crystals
- We are characterizing the probe plasma to improve its effectiveness for XRTS

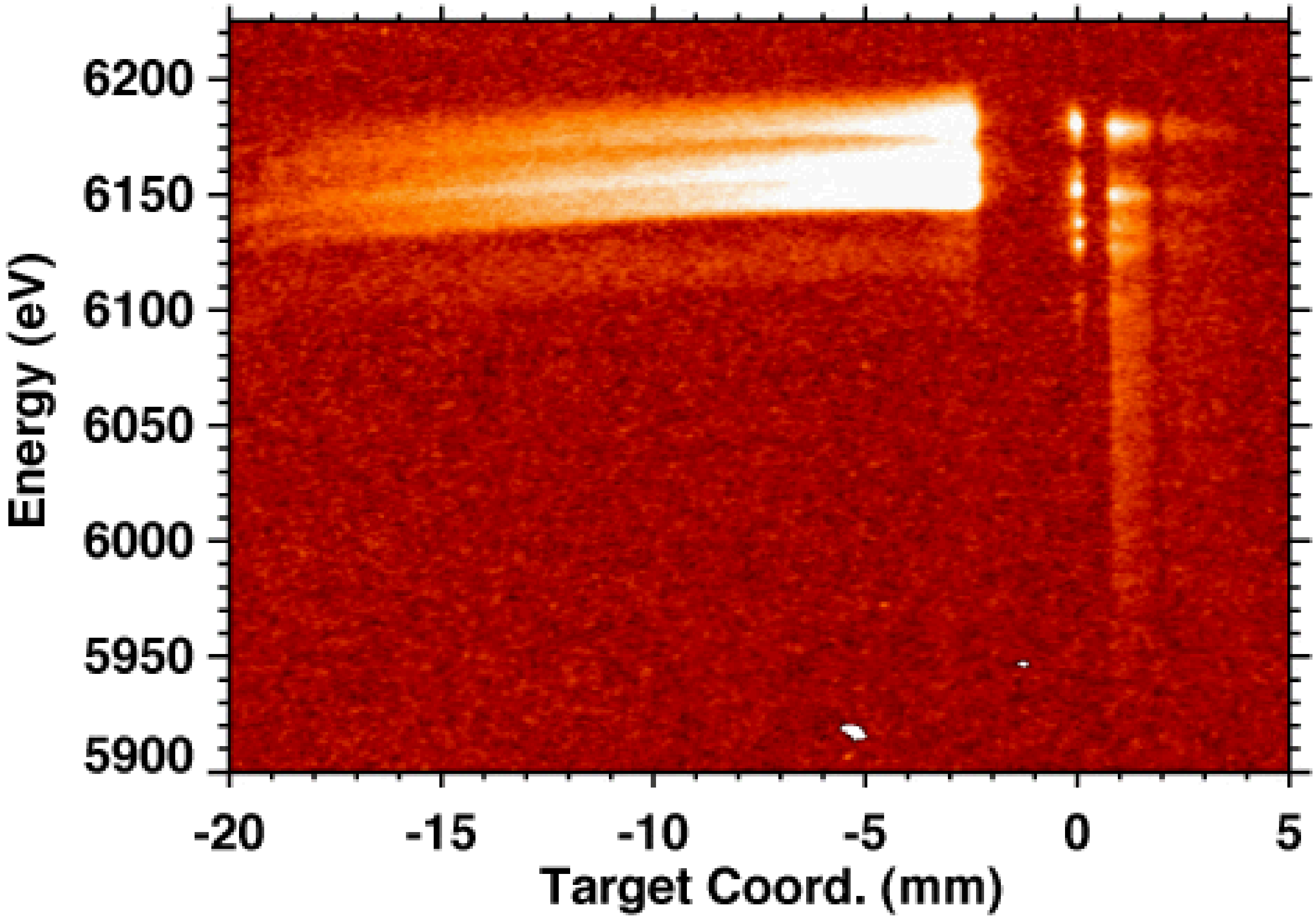
XRS^3



Spatially resolved XRTS data



Full Scattering Data Image

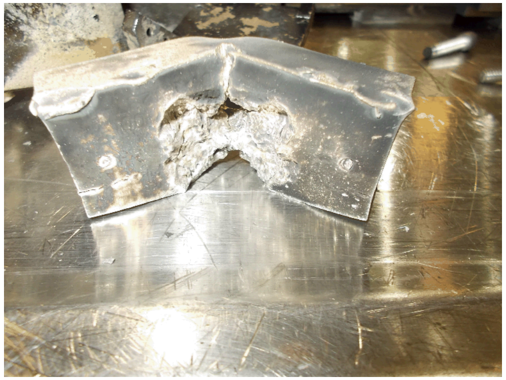


Debris damage continues to surprise us, but mitigation has been successful.

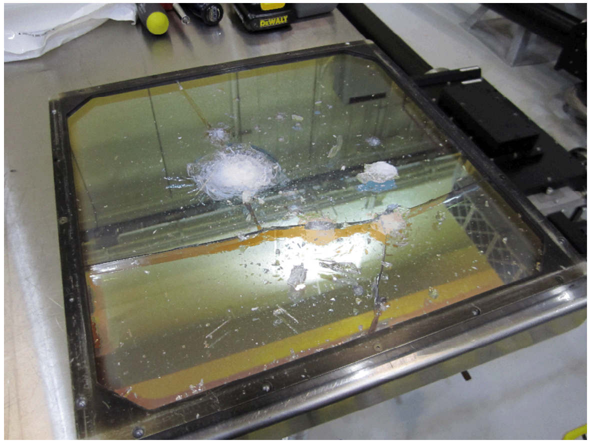
Inside spectrometer after first shot

Crystal does not survive

Aperture block successfully mitigated axial debris



Laser debris shield damaged but not compromised



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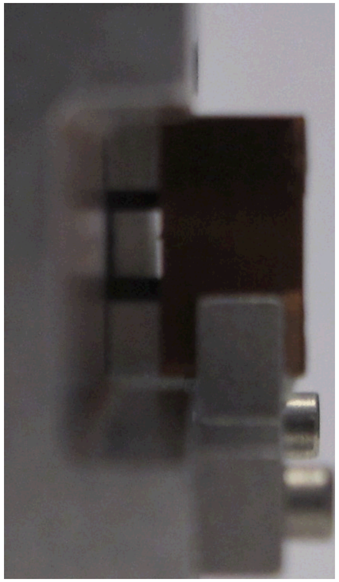
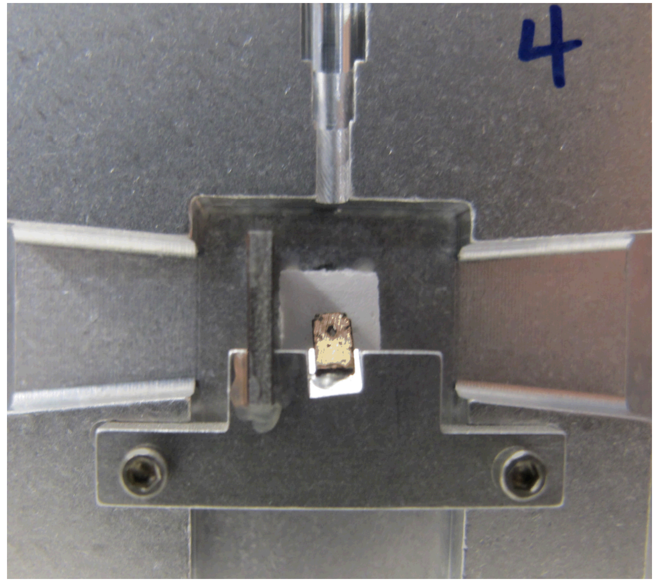
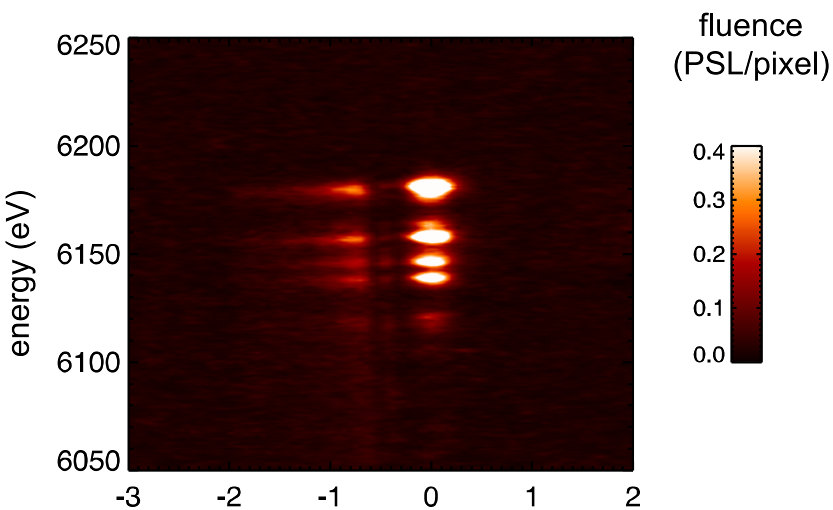


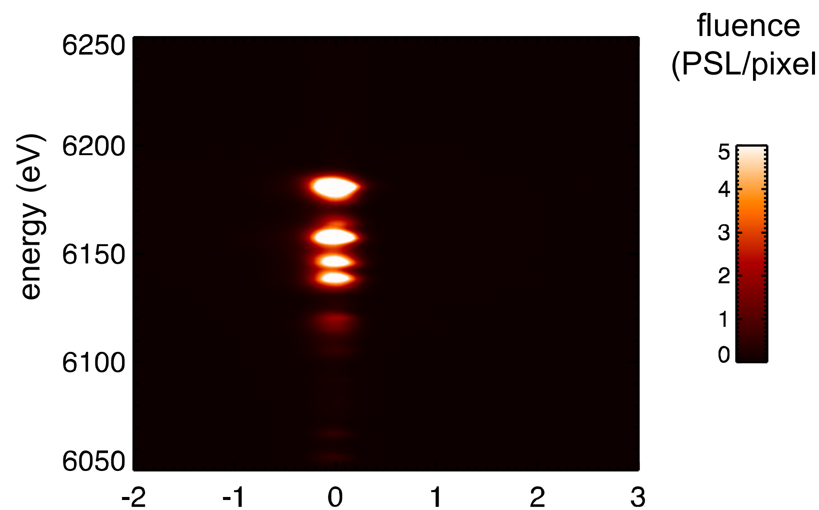
Spec. A (90° view)



ZBL (0° view)

Spec. B (-90° view)





The V He-β spectra also show differences between the two viewing angles.

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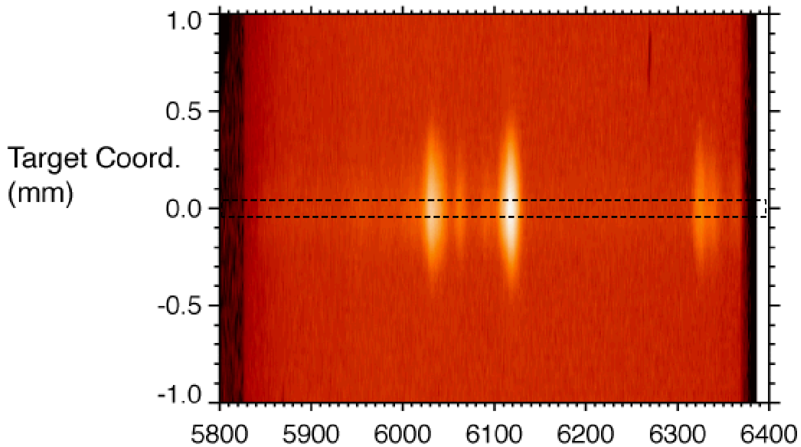
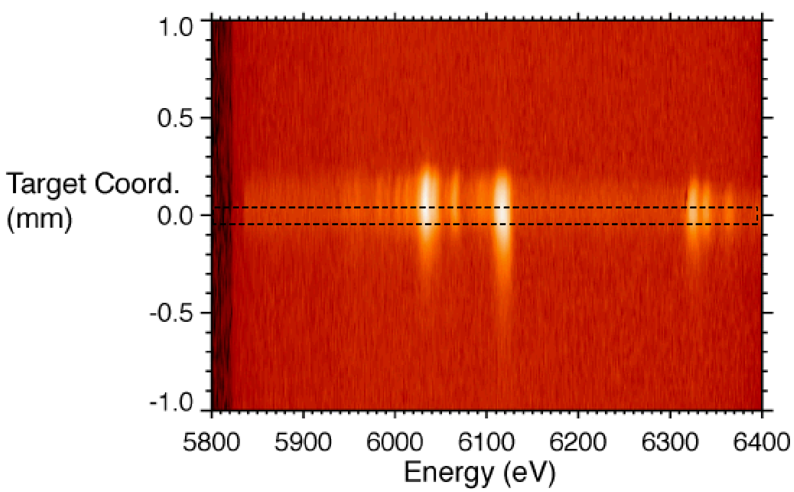
V Face-on Image

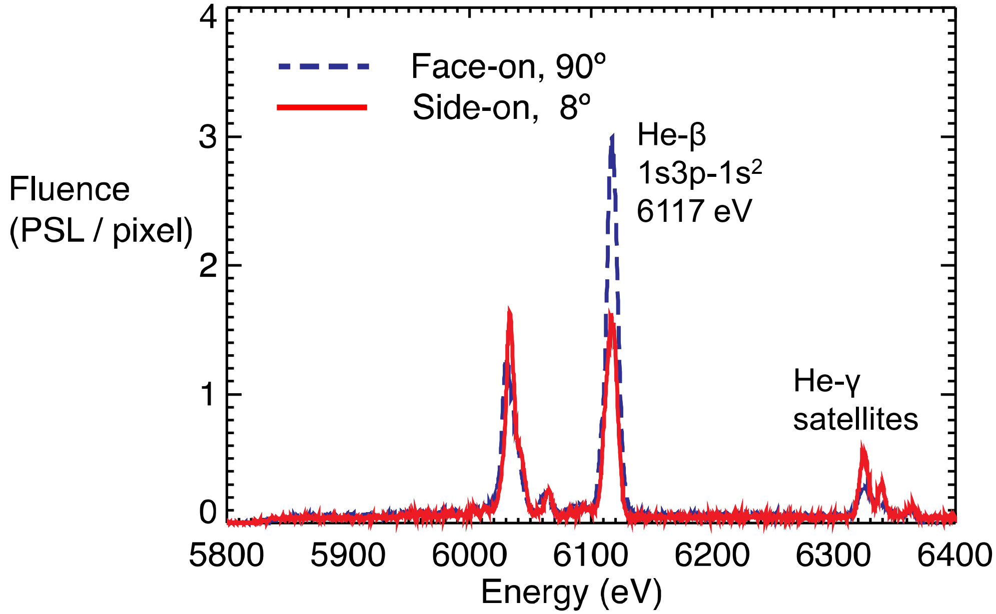


V Side-on Image



V Spectra

Lineout width = 0.1 mm, centered at y = 0 mm



Spatial Information from vertical lineouts

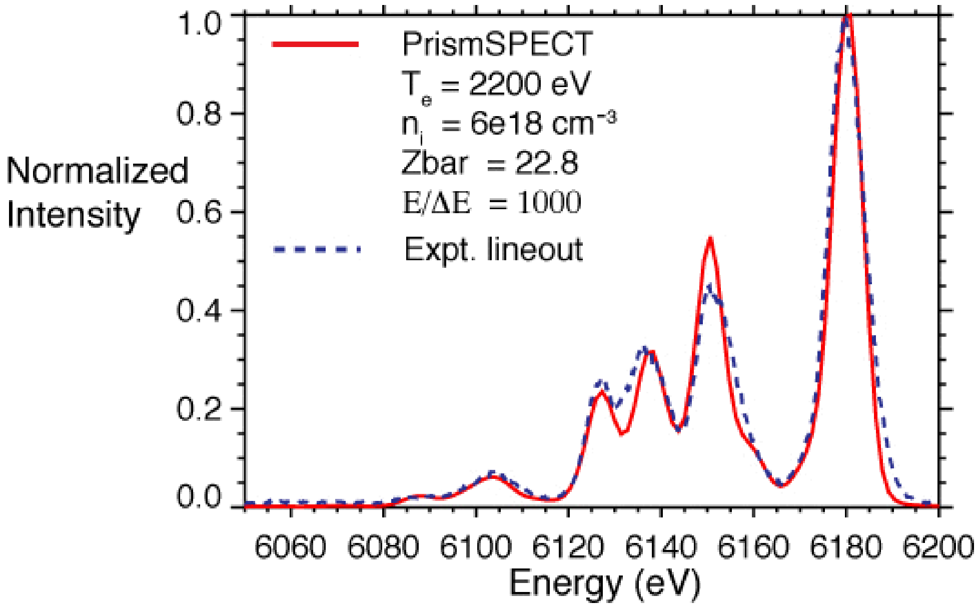
Face-on FWHM: 310 μm @ 6117 eV

Side-on FWHM: 230 μm @ 6117 eV

PrismSPECT NLTE simulations of Mn at T_e = 2.2 keV and n_i = 6 x 10^{18} cm^{-3} show good agreement with the Face-on spectrum.

Mn PrismSPECT model and Experiment

Intensity normalized to He-α Res. line.



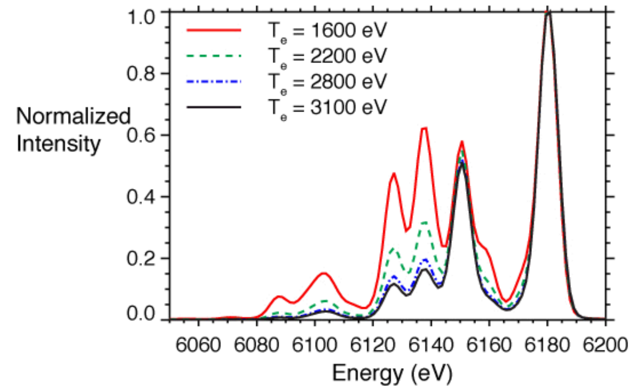
PrismSPECT indicates that our spectrometer has E/ΔE =1000.

PrismSPECT gives n_e = 1.4e20 cm^{-3} which is 30x lower than n_{cr} (4e21 cm^{-3}).

Mn Li-sat. to He-α ratio provides T_e measurement

Plasma slab 200 μm thick, n_i = 6e18 cm^{-3}

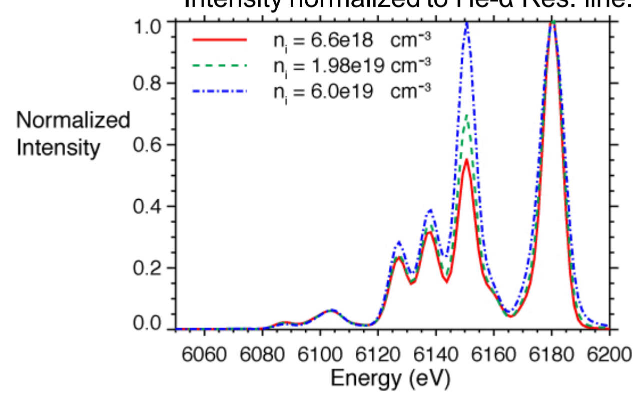
Intensity normalized to He-α Res. line.



Mn Inter. Comb. line to He-α ratio provides n_i measurement

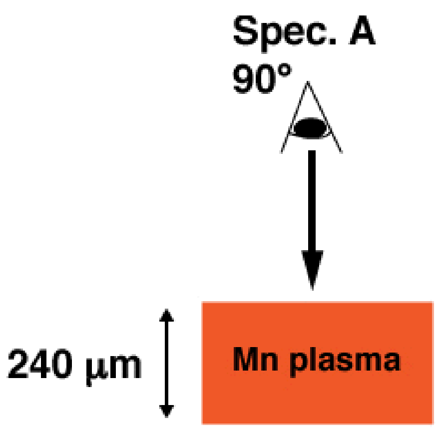
Plasma slab 200 μm thick, T_e = 2.2 keV

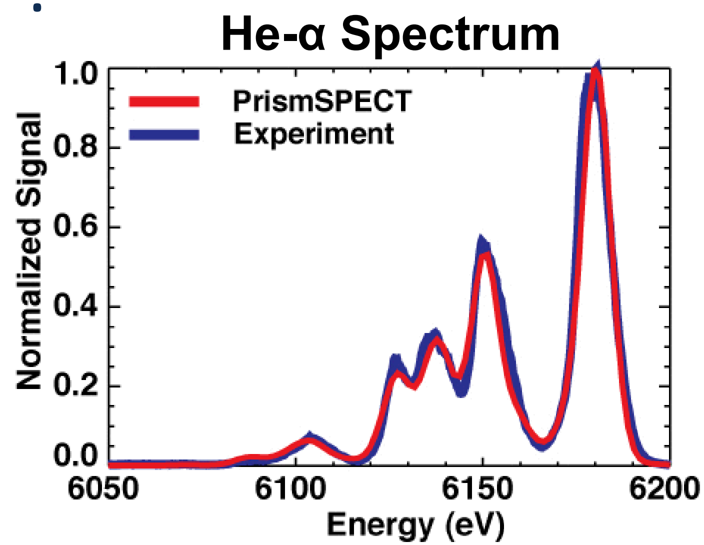
Intensity normalized to He-α Res. line.

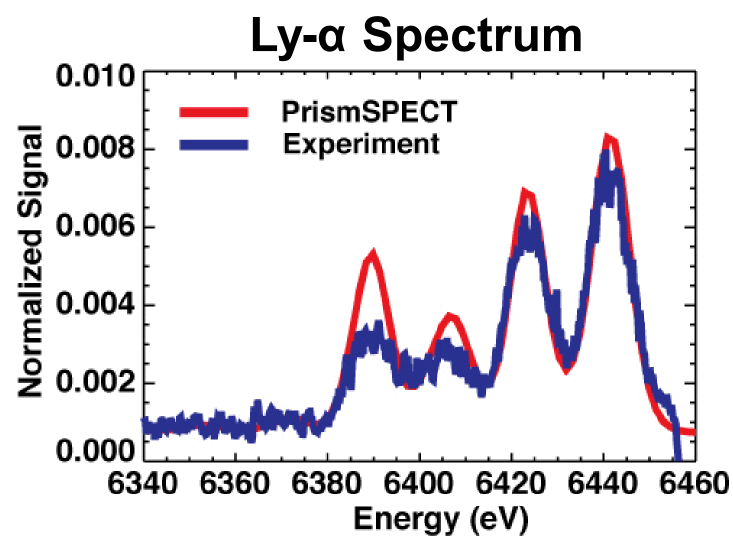


Assuming a uniform slab geometry PrismSPECT* simulations best fit the experimental spectrum for T_e = 2.2 keV and n_i = 6e18 cm^{-3}.

Mn PrismSPECT Model
nLTE
1D Slab
240 μm thick
T_e = 2.2 keV
n_i = 6e18 cm^{-3}



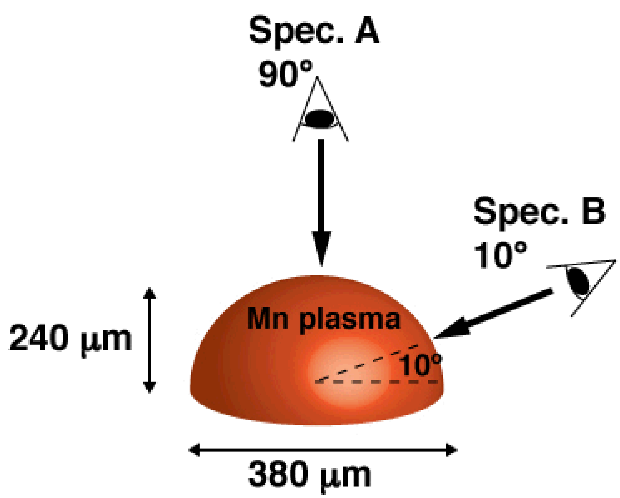


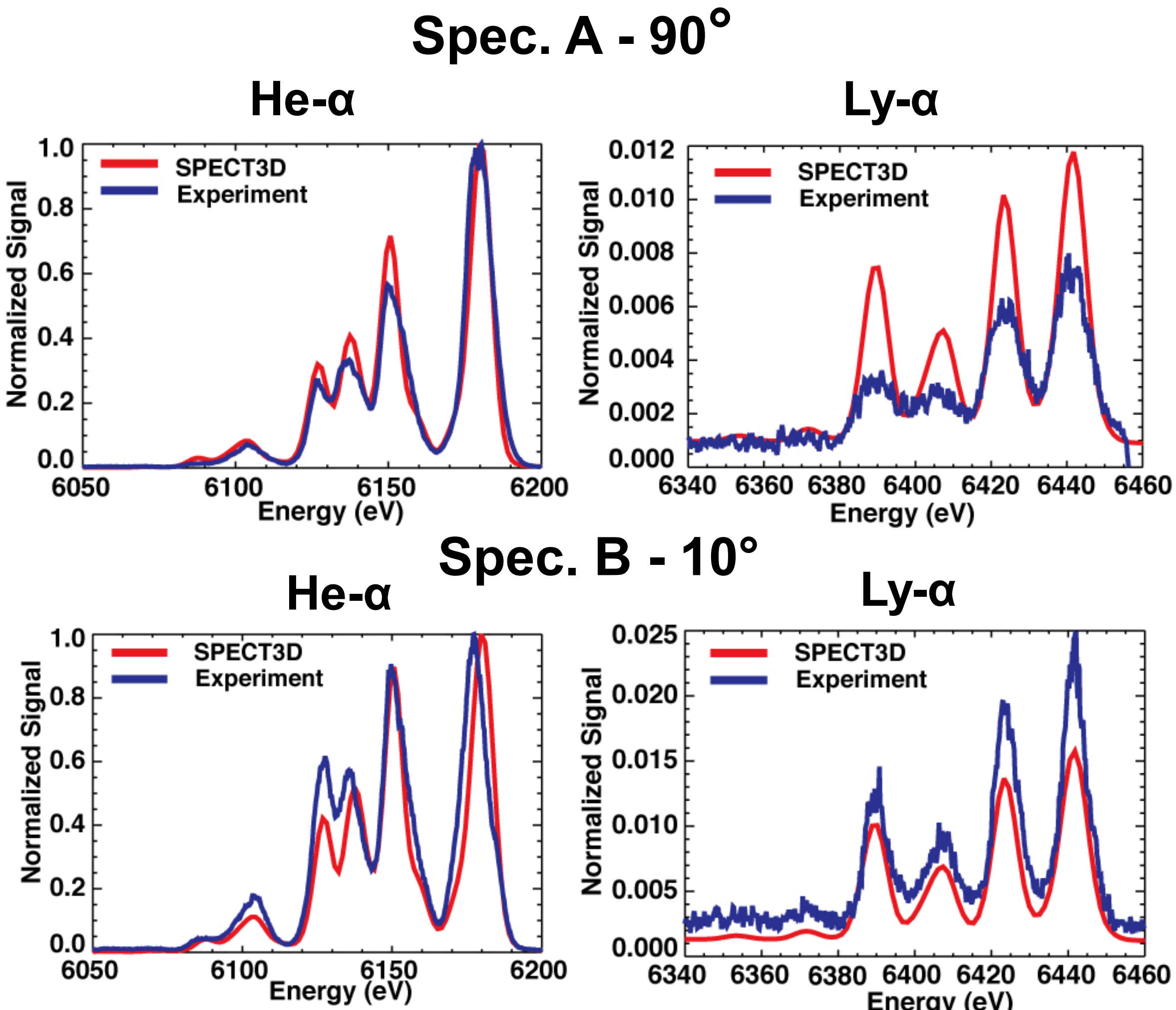


*PrismSPECT is a collisional-radiative spectral analysis code produced by Prism Computational Sciences, Inc.

SPECT3D* was used to simulate the spatially resolved spectra from the two spectrometer viewing angles.

Mn SPECT3D Model
3D Ellipsoid Shape
nLTE
T_e = 2.2 keV
n_i = 6e18 cm^{-3}





*Spect3D is a collisional-radiative spectral analysis code produced by Prism Computational Sciences, Inc.