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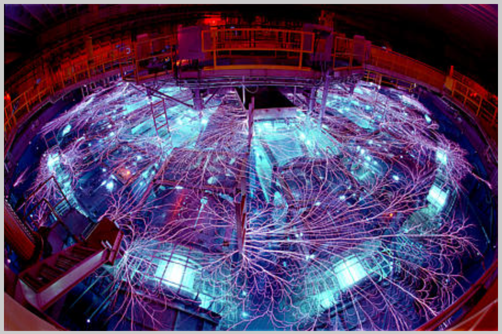

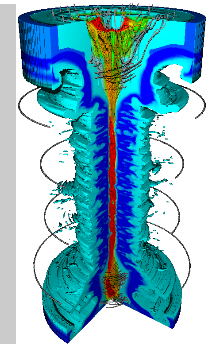

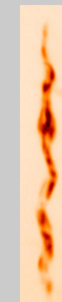

X-ray Imaging of MagLIF Experiments Using a Spherically Bent Crystal Optic.

E.C. Harding, M.R. Gomez, P.F. Knapp, S.B. Hansen, S. A. Slutz, A.B. Sefkow, M. Geissel, A.J. Harvey-Thompson, M. Schollmeier, K.J. Peterson, T.J. Awe, K.D. Hahn, P.F. Schmit, C.L. Ruiz, D.B. Sinars, C.A. Jennings, I.C. Smith, D.C. Rovang, G.A. Chandler, M.R. Martin, R.D. McBride, J.L. Porter, and G.A. Rochau

Sandia National Laboratories, Albuquerque, NM

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

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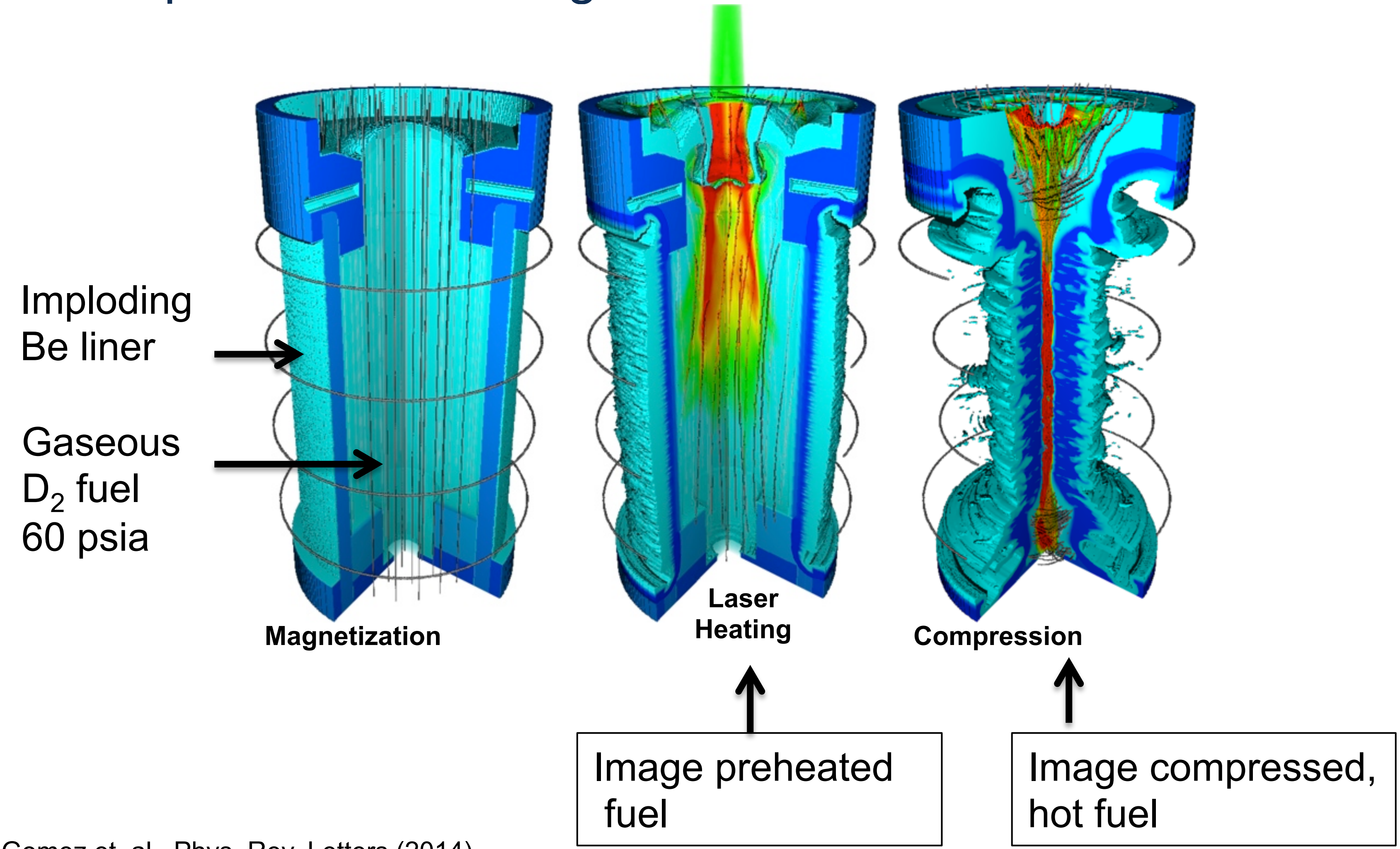
The development of the Magnetized Liner Inertial Fusion (MagLIF) concept has motivated the development of new diagnostics.[1]



[1]M.R. Gomez et. al., Phys. Rev. Letters (2014)
Graphic by C.A. Jennings

We use spherically bent crystal optics to image the x-ray, self-emission from our MagLIF targets.

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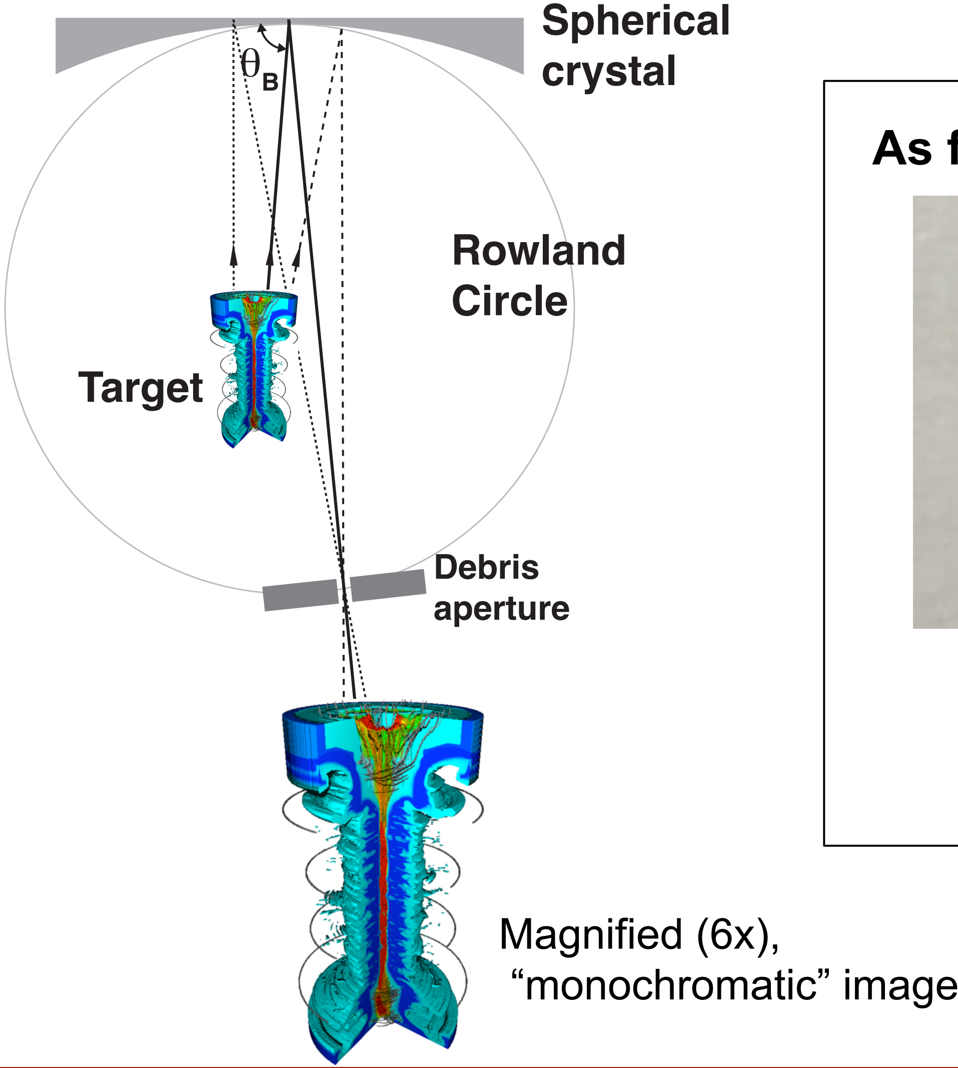
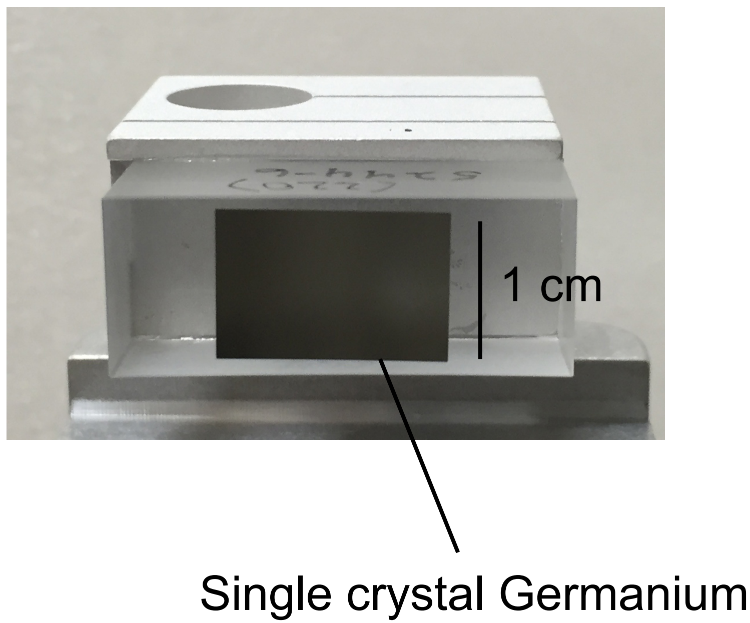
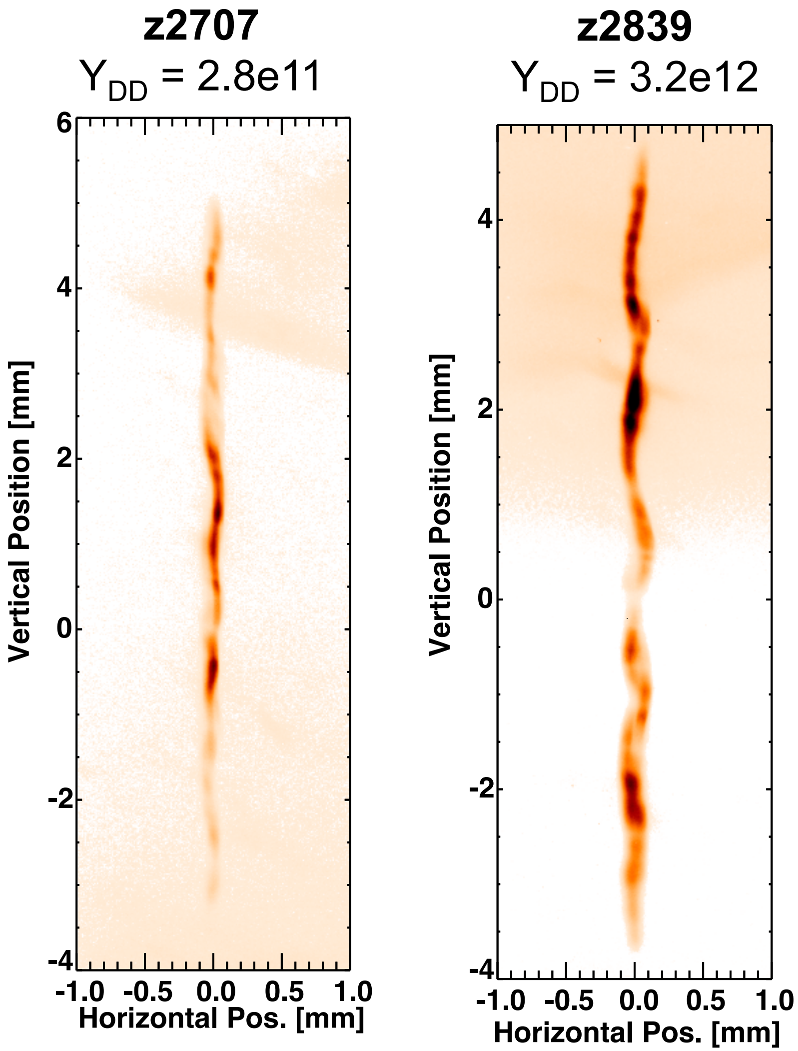
Diagnostic setup



As fielded, spherically bent crystal



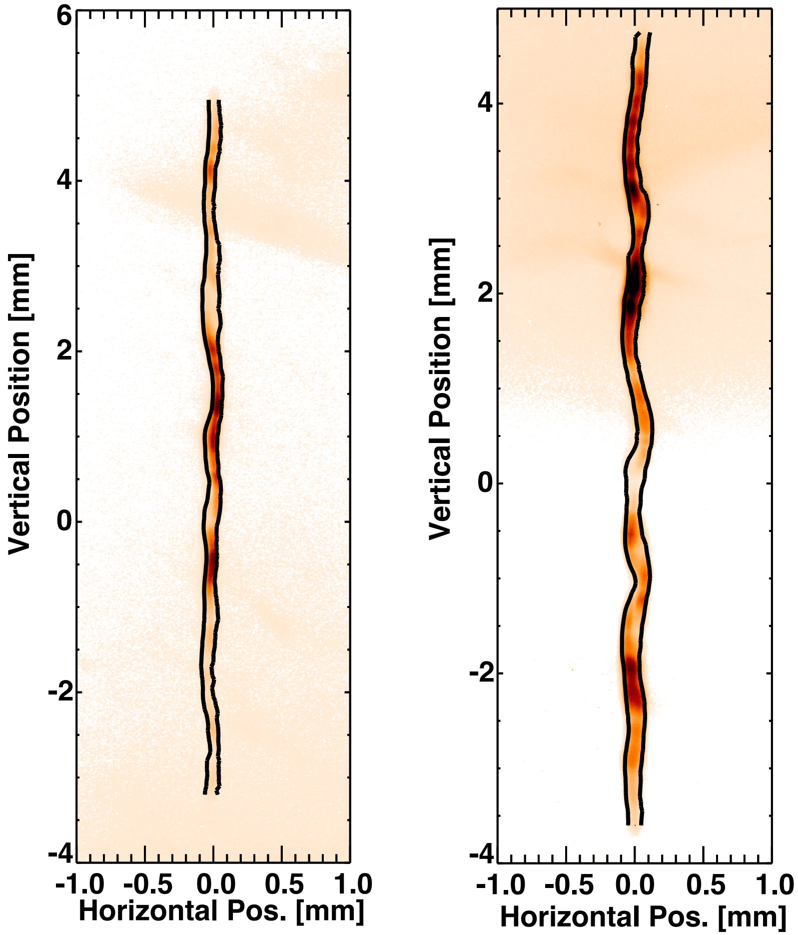
The crystal imager images the continuum emission generated by the compressed deuterium fuel at stagnation.



- These time-integrated images are primarily a superposition of 6.2 and 9.4 keV x-rays imaged by n=2 and n=3 Bragg reflections.
- The emission column is narrow and extends over many mm in the vertical direction. The emission undergoes large variations in intensity.

The average emission diameter appears to increase for shots with higher DD neutron yields.* Variations in the axial emission intensity still require an explanation.

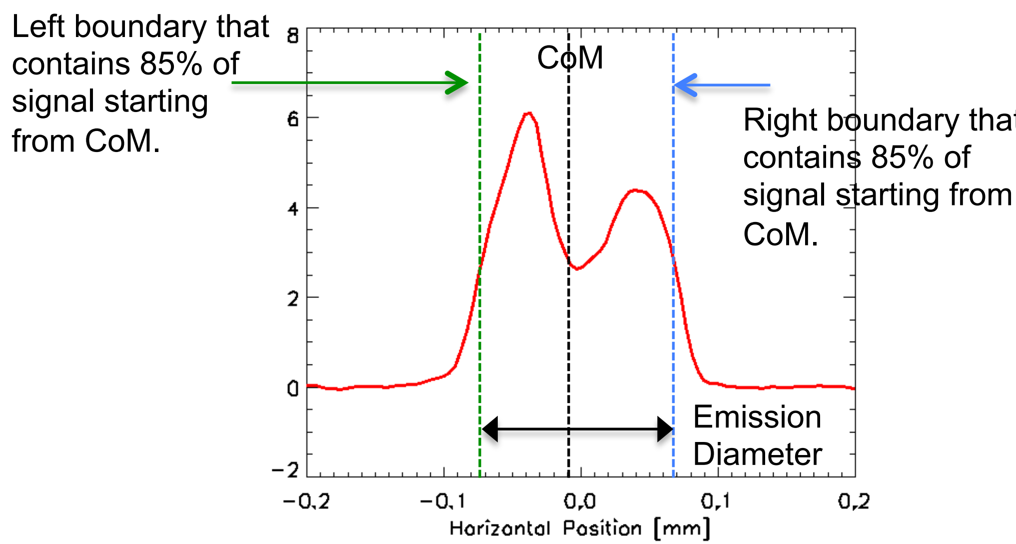
z2707 Y_{DD} = 2.8e11 | **z2839** Y_{DD} = 3.2e12



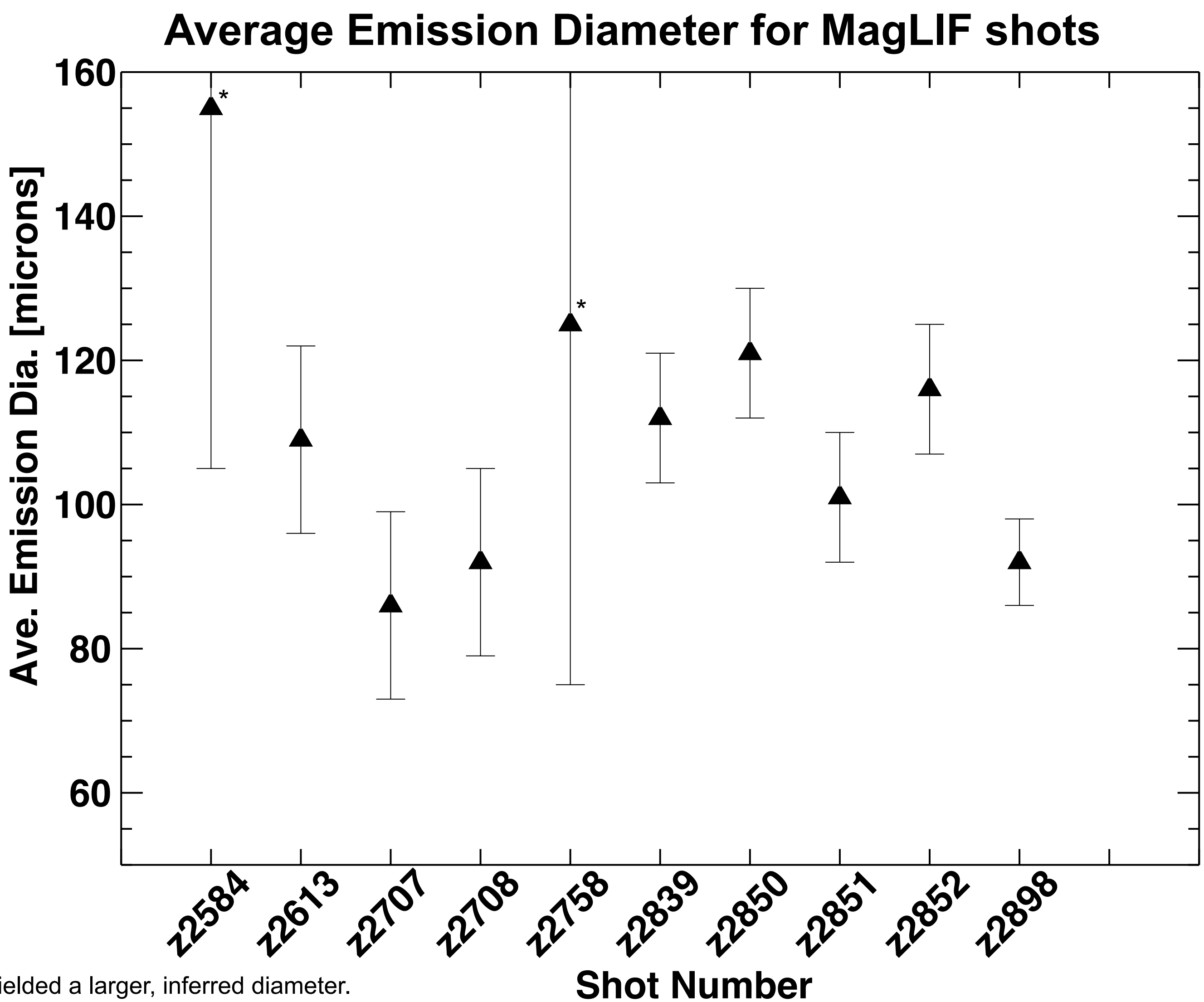
Steps for Defining Intensity Contour

1) Take a series of horizontal lineouts
2) Fit and subtract background
3) Find the center of mass (CoM) of each lineout
4) Integrate from CoM to a position that contains 85% of the total signal.

Example Horizontal Lineout with Double Peak

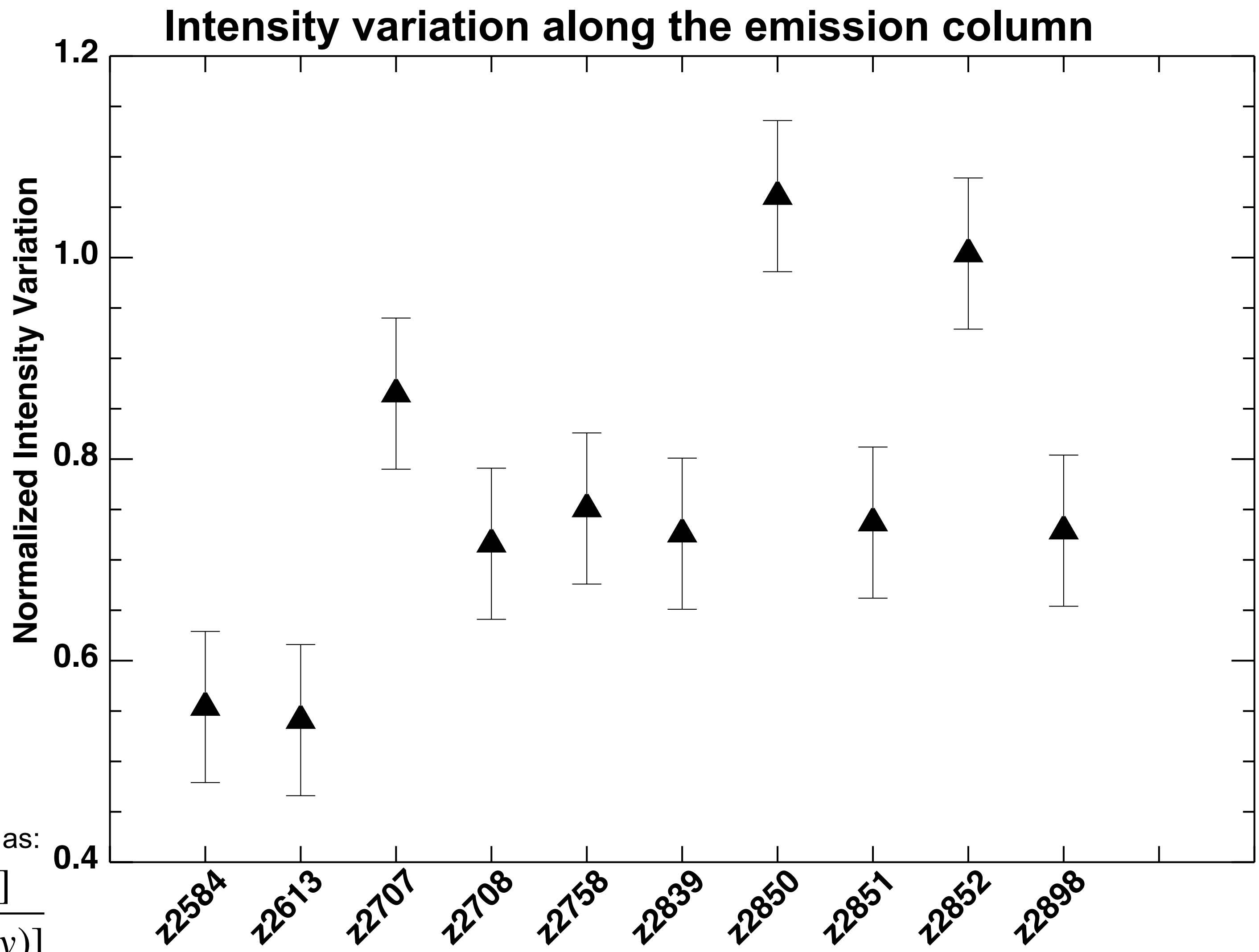


The average emission diameter is around 110 microns. Some shot-to-shot variations are significant.



*Poor radial focusing yielded a larger, inferred diameter.
Error bars attempt to capture the uncertainty, but offset should be systematic.

The emission variation along the axial dimension are large compared to the column average. Does this variation relate to the stability/uniformity the implosion?



*Variations defined as:

$$I_{\text{var}} = \frac{\sigma[I(y)]}{Mean[I(y)]}$$

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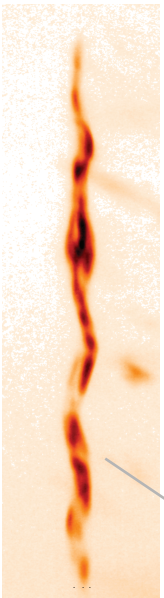

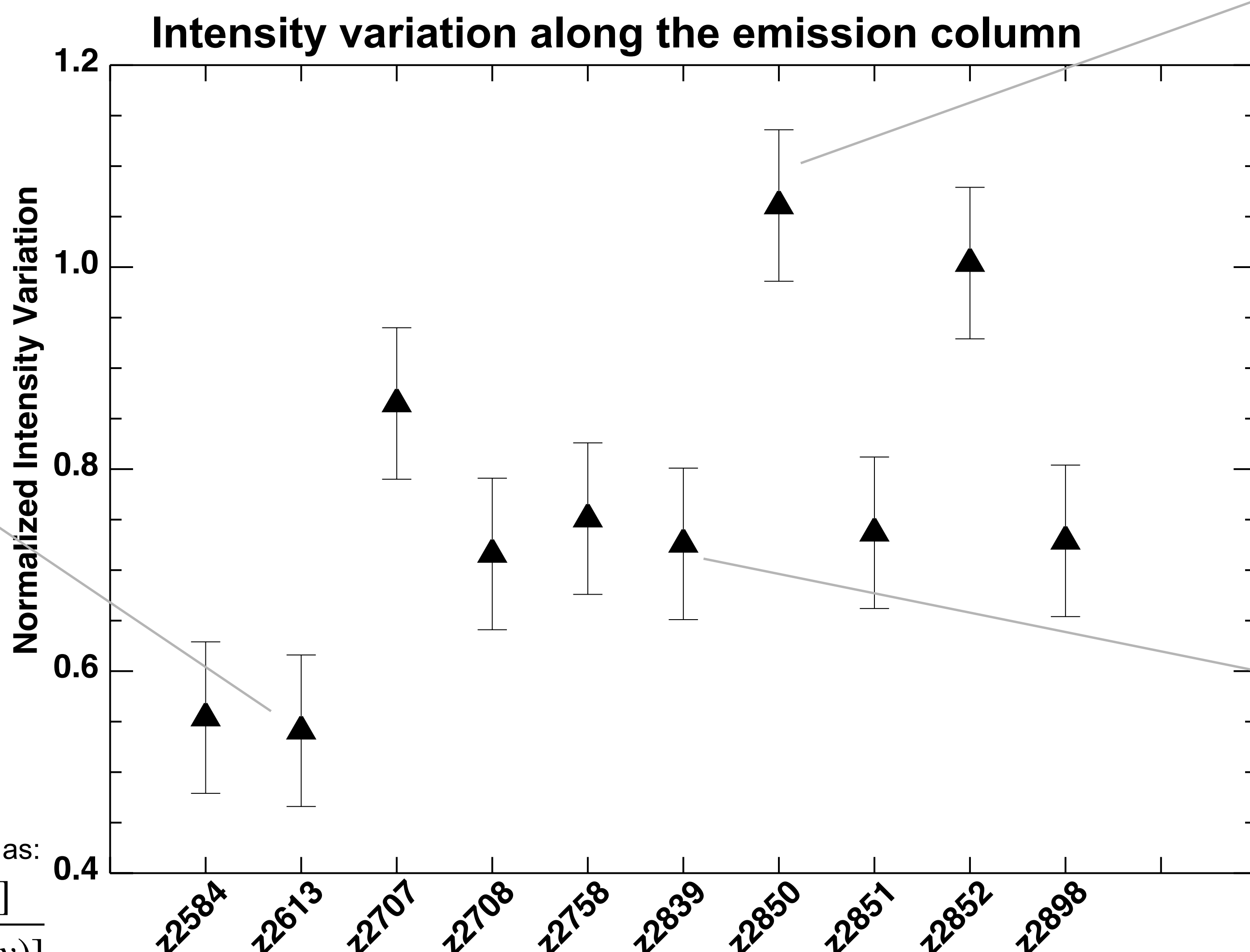

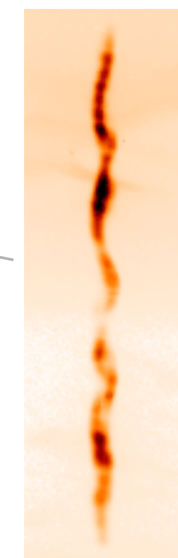

*Variations defined as:

$$I_{\text{var}} = \frac{\sigma[I(y)]}{Mean[I(y)]}$$

The emission structure does not appear to be reproducible but DD yields are similar for nearly identical targets. Is this related to mix and/or stability?

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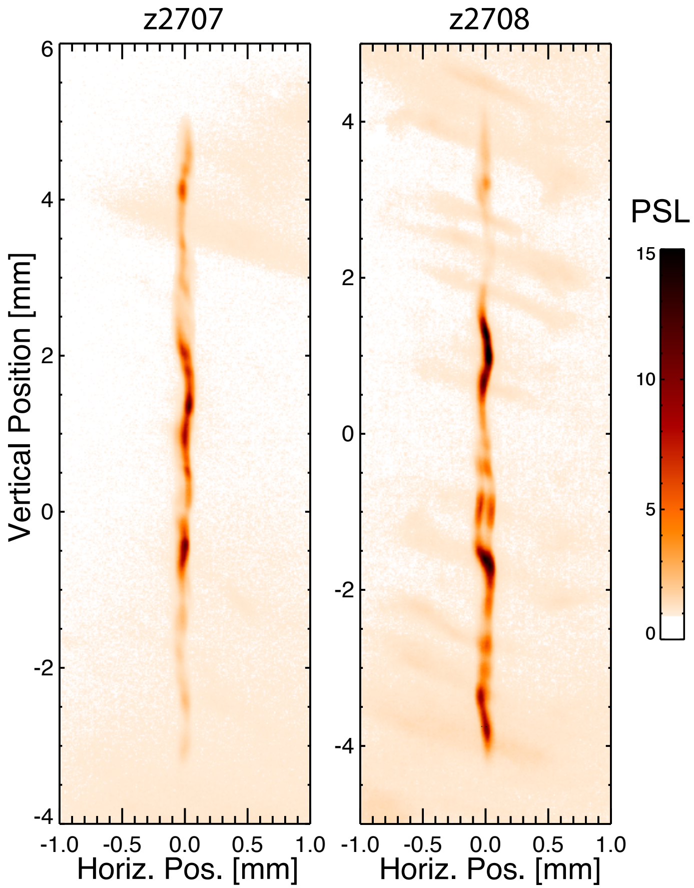
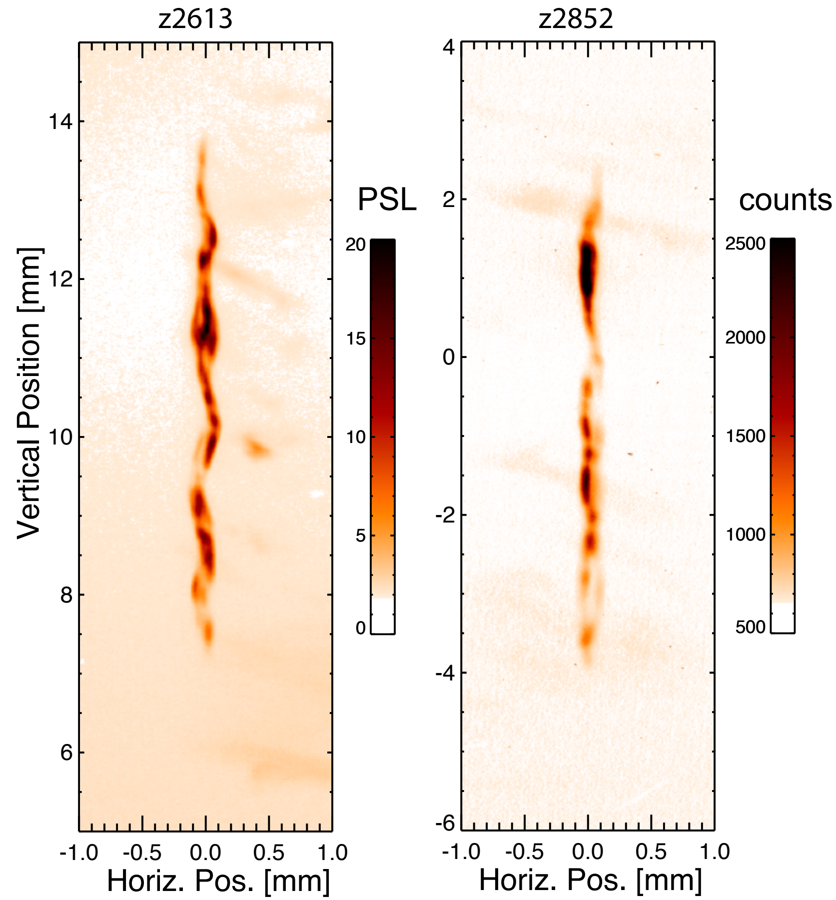
Y_{dd} = 2.8e11
I_{var} = 0.87
I_{ave}= 2.1 PSL

Y_{dd} = 1.8e11
I_{var} = 0.716
I_{ave}= 5.0 PSL



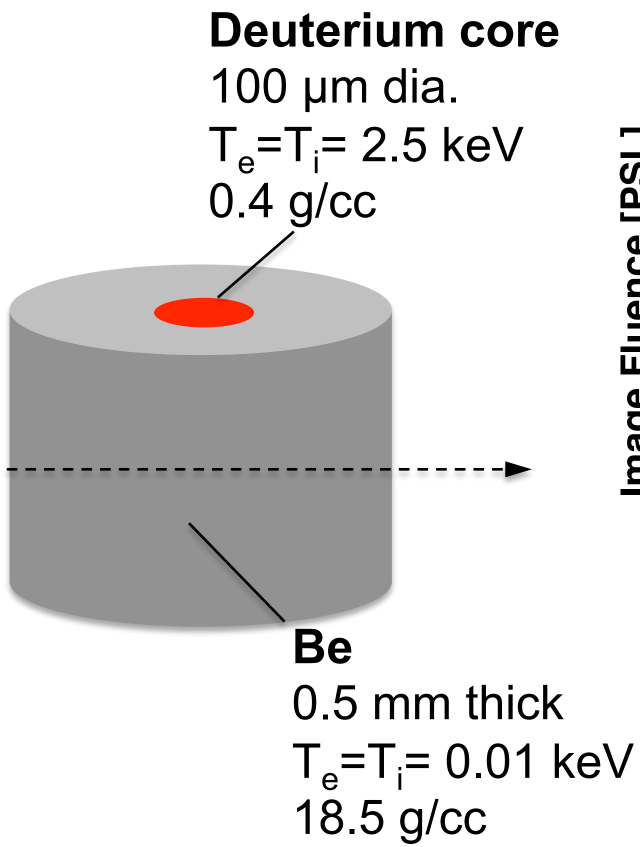
Y_{dd} = 1.1e12
I_{var} = 0.541
I_{ave}= 5.3 PSL

Y_{dd} = 2.0e12
I_{var} = 1.0
I_{ave} = 528 counts

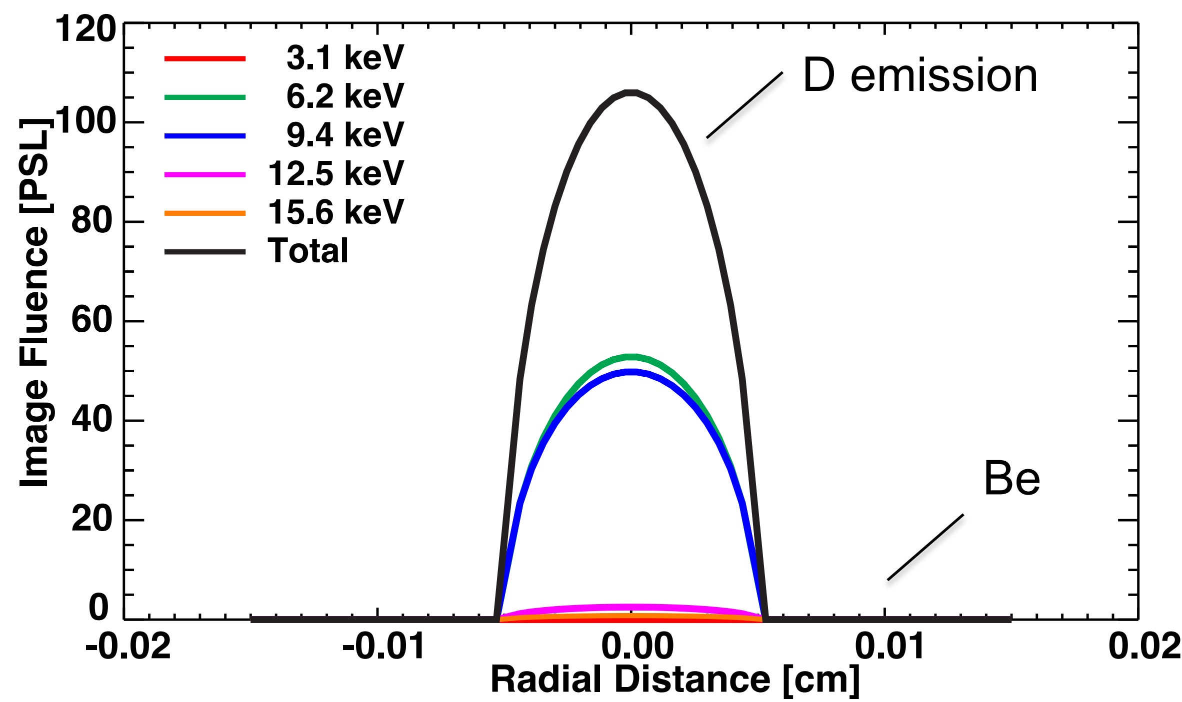


Simple SPECT3D* simulations indicate the stagnation images are primarily a superposition of 6.2 and 9.4 keV emission.

SPECT3D setup



Radial emission profiles from SPECT3D



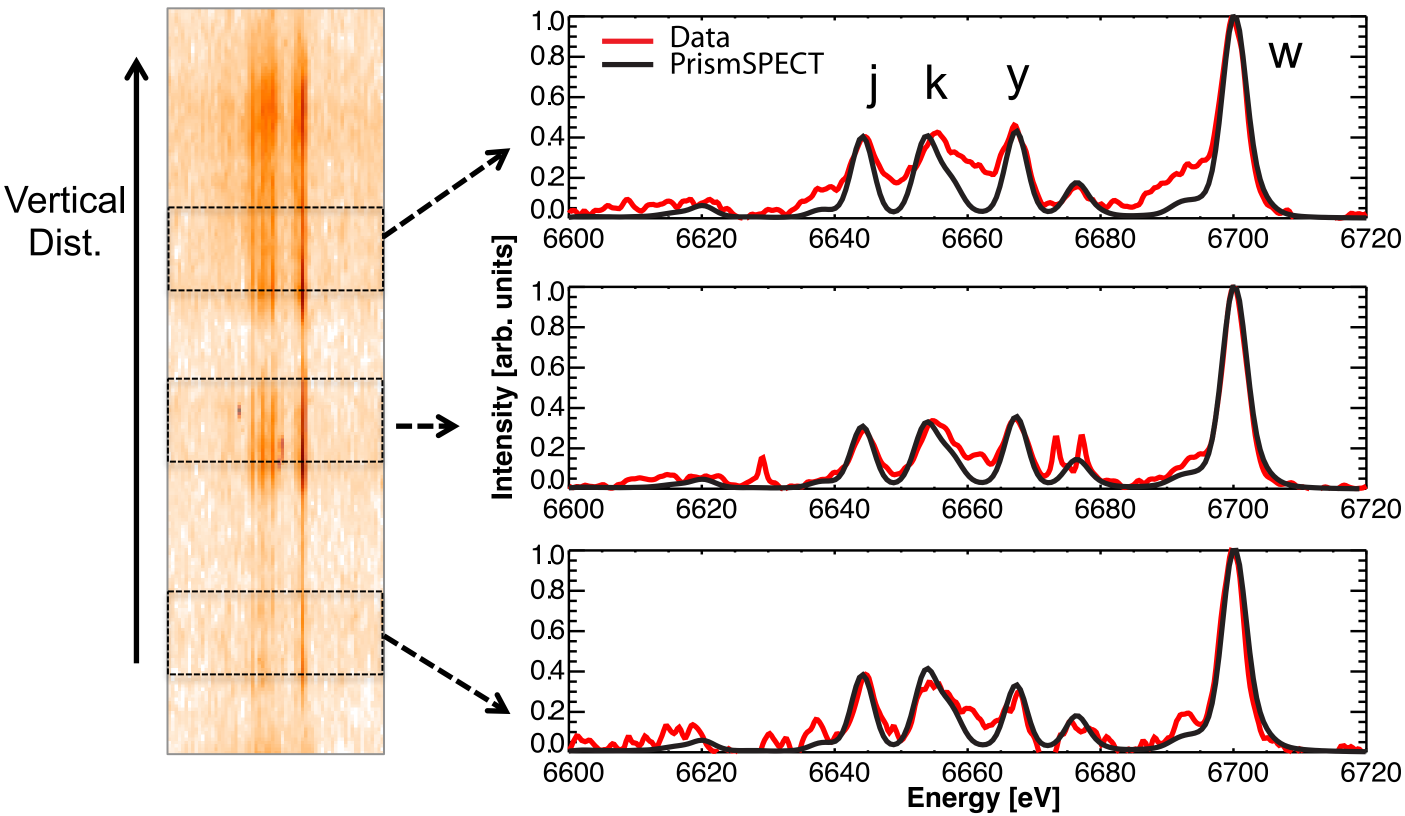
Because the 6.2 keV contribution is significantly affected by the Be opacity the emission variations maybe stability related.

*SPECT3D is a collisional-radiative spectral analysis code produced by Prism Computational Sciences, Inc.

The high-resolution Fe spectra enable a measurement of T_e and n_e by fitting simulated spectra to the measured satellite (j,k), intercombination (y) and resonance (w) lines.

z2839 Spectral Image

Experimental spectra fitted with PrismSPECT simulations using E/ΔE = 3000.



<u>Inferred values</u>

T_e = 1.5 keV
n_e = 1.2e23 cm^{-3}

T_e = 1.6 keV
n_e = 1.7e23 cm^{-3}

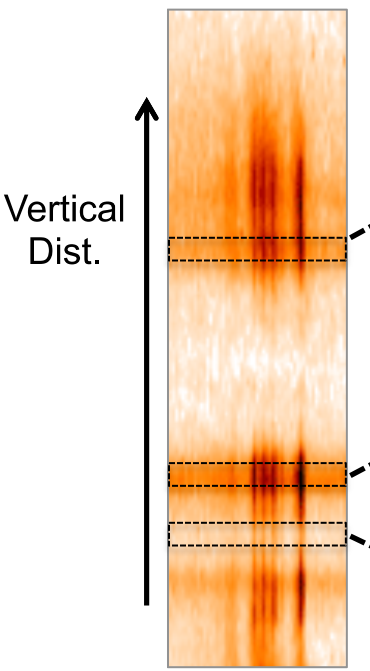
T_e = 1.4 keV
n_e = 2.0e23 cm^{-3}

Here the regions of bright Fe emission are lower density suggesting the increased brightness may be related to an elevated fraction of Fe mix.

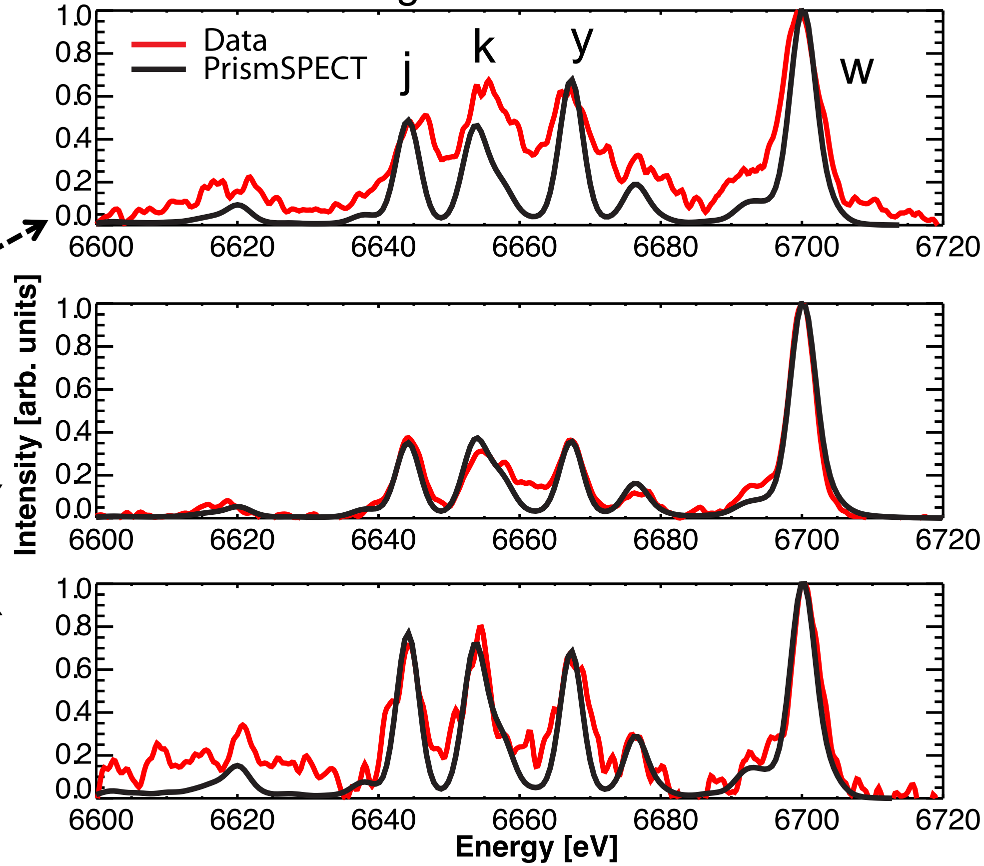
Fitting reveals similar T_e and n_e values in z2850, but now the dimmer regions are less dense.

z2850

Spectral Image



Experimental spectra fitted with PrismSPECT simulations using E/ΔE = 3000.



Inferred values

T_e = 1.6 keV *
n_e = 2.9e22 cm^{-3}
Fitting accuracy maybe compromised by source broadening.

T_e = 1.5 keV
n_e = 1.7e23 cm^{-3}

6x density difference

T_e = 1.3 keV
n_e = 2.9e22 cm^{-3}

The large variation in n_e for two adjacent regions suggest that the compression uniformity may need improvement.

Concluding Remarks:

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- The average emission diameter is around 110 microns. This diameter includes 85% of the total signal. Emission length is 5-8 mm.
- The emission varies by more than 50% of the average emission value.
- We don't know what causes these large variations in emission.
  - Local pinching that increases T_e and n_e
  - Variation in the liner (i.e., pusher) opacity. May be correlated with T_e and n_e
  - Non-uniform mix distribution