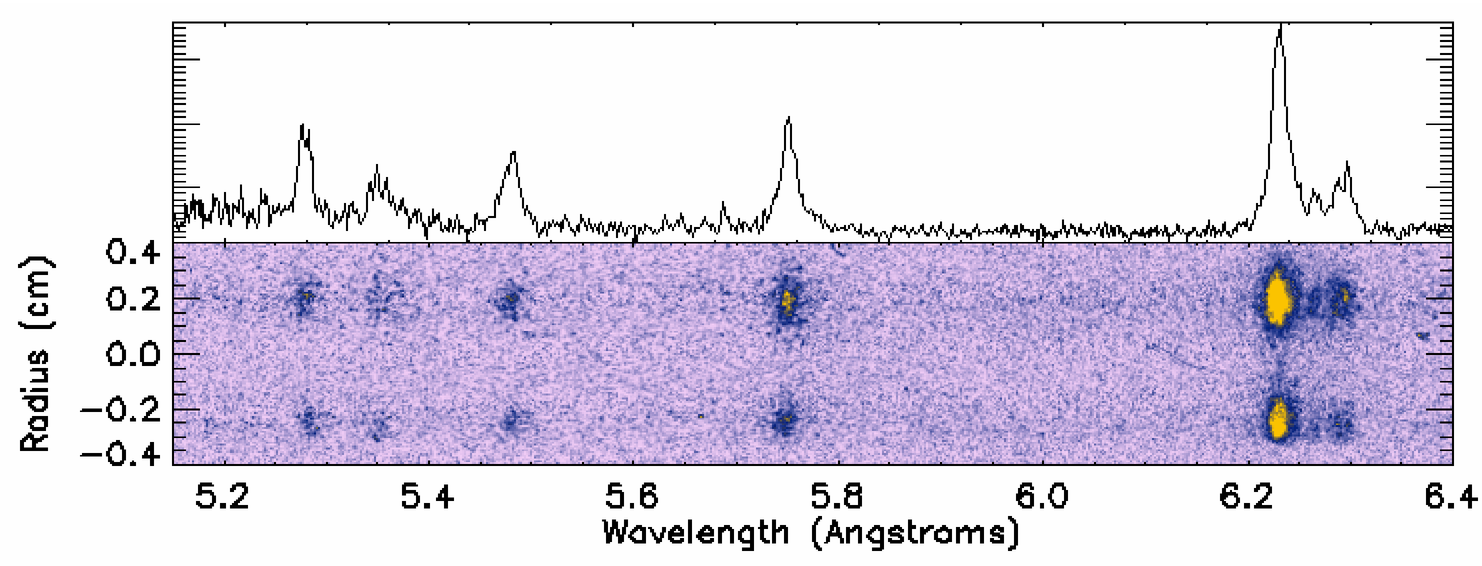
SAND2006-5575C

Si Emission Measurements of a Strong Radiating Shock in the Z-pinch Dynamic Hohlraum



Radiative Properties of Hot Dense Matter Workshop

September 11 – 15, 2006

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Sandia National Laboratories

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Acknowledgements

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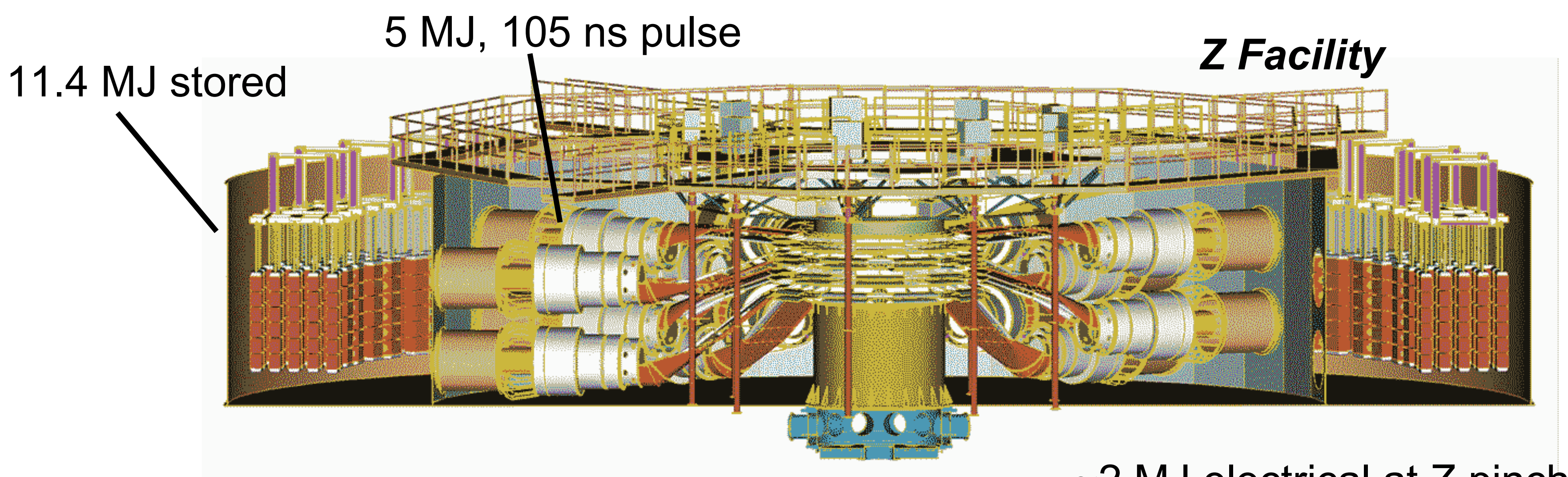
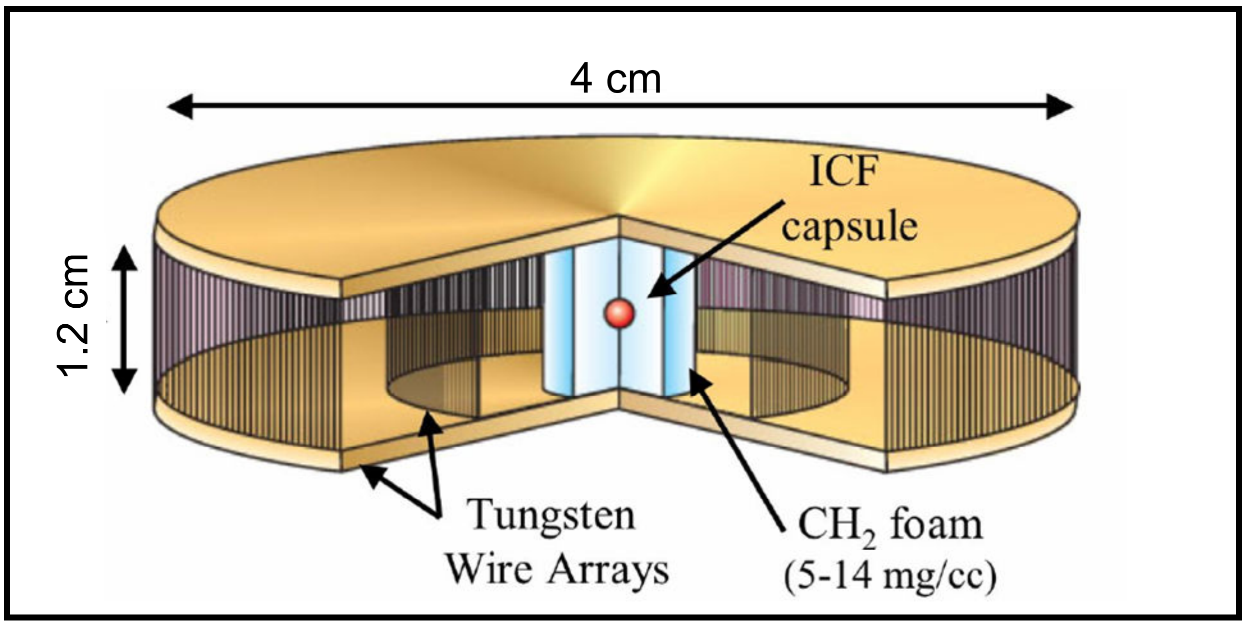
  Weizmann Institute of Science, Israel

- Igor Golovkin, Joe MacFarlane
  Prism Computational Sciences, Madison, WI

The Z-pinch dynamic hohlraum reaches internal temperatures >200 eV and peak axial power >10 TW.

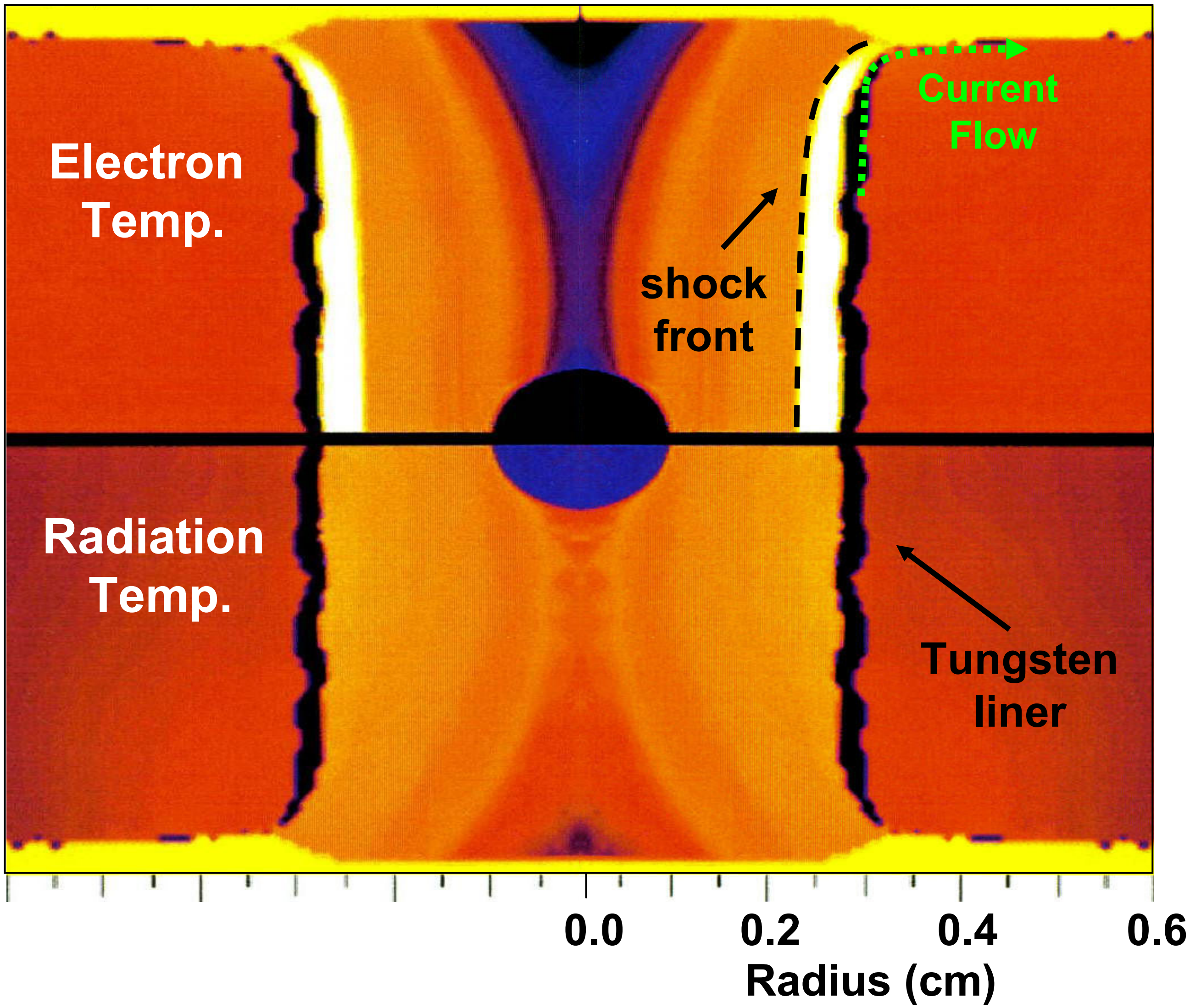




Total Radiated X-ray Energy	~ 0.8 MJ
Peak Axial Power	> 10 TW
Peak Internal Rad. Temp.	> 200 eV

The dynamic hohlraum is formed by an imploding tungsten liner, and heated by a strong radiating shock.

2-D RMHD Simulation



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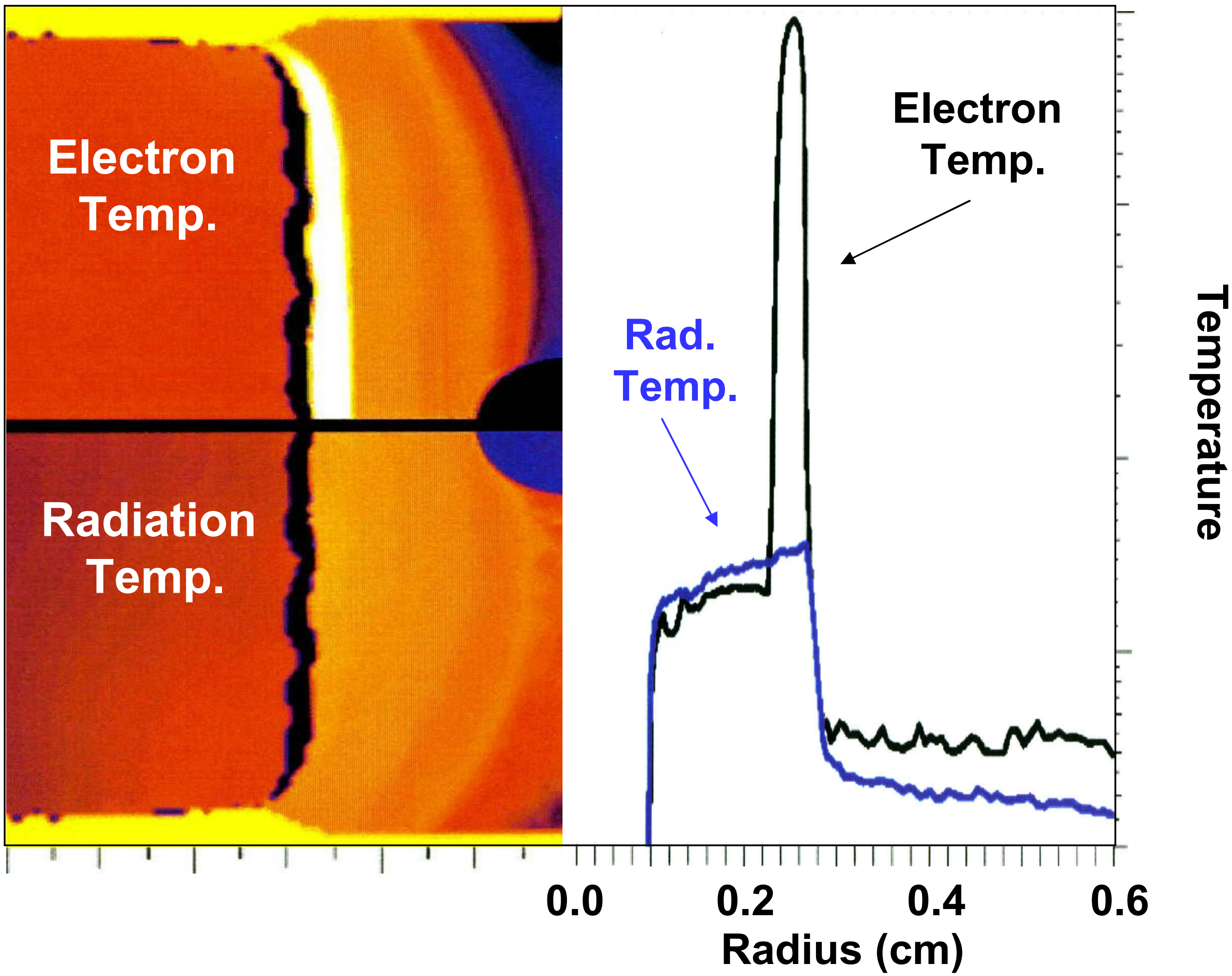
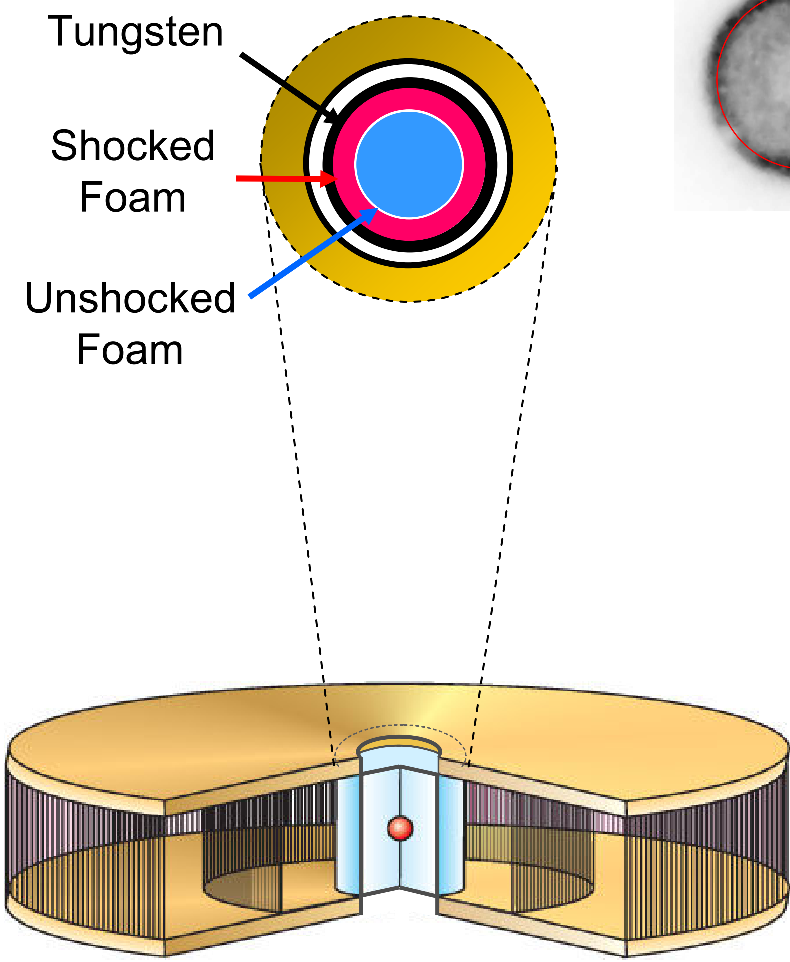
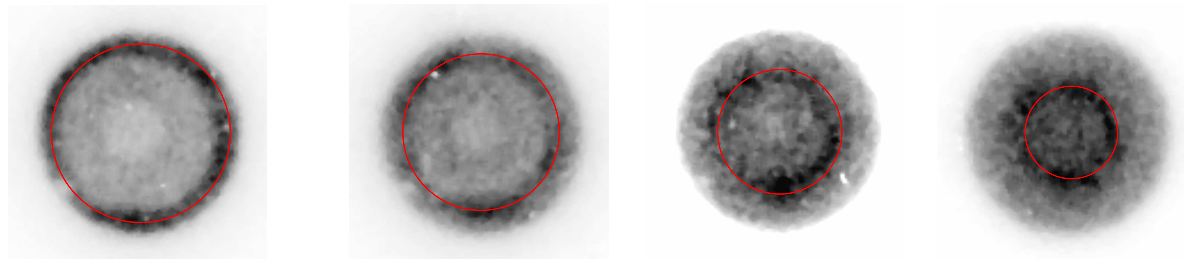
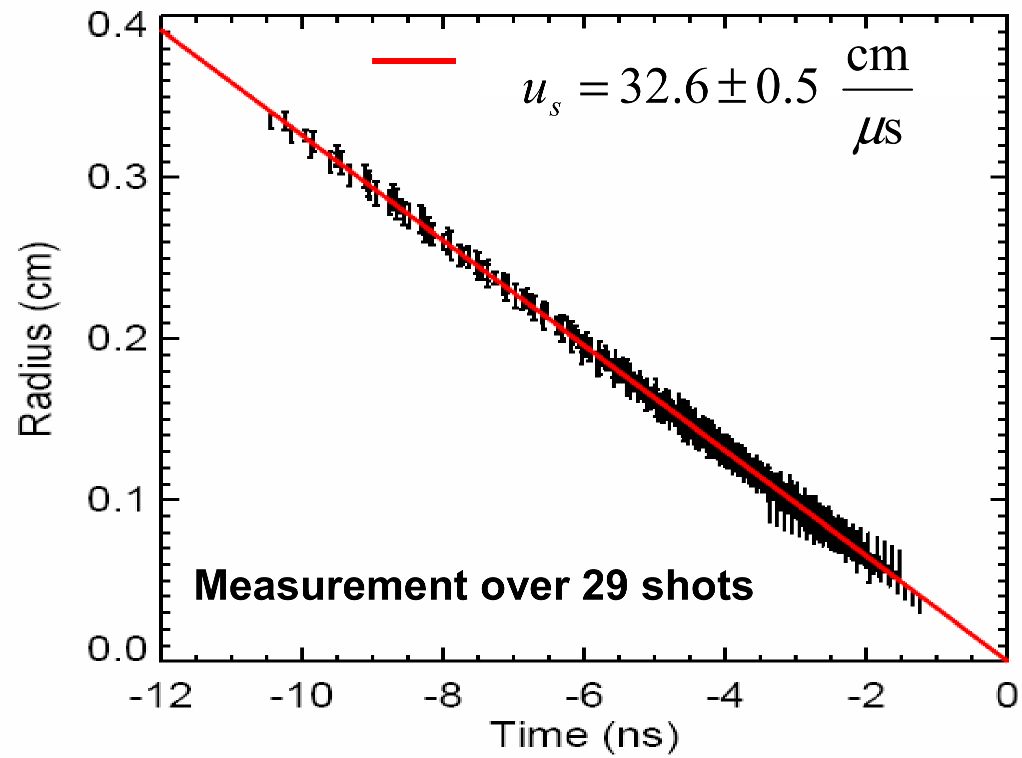


The radiating shock was first evidenced by 2-D broadband x-ray images.

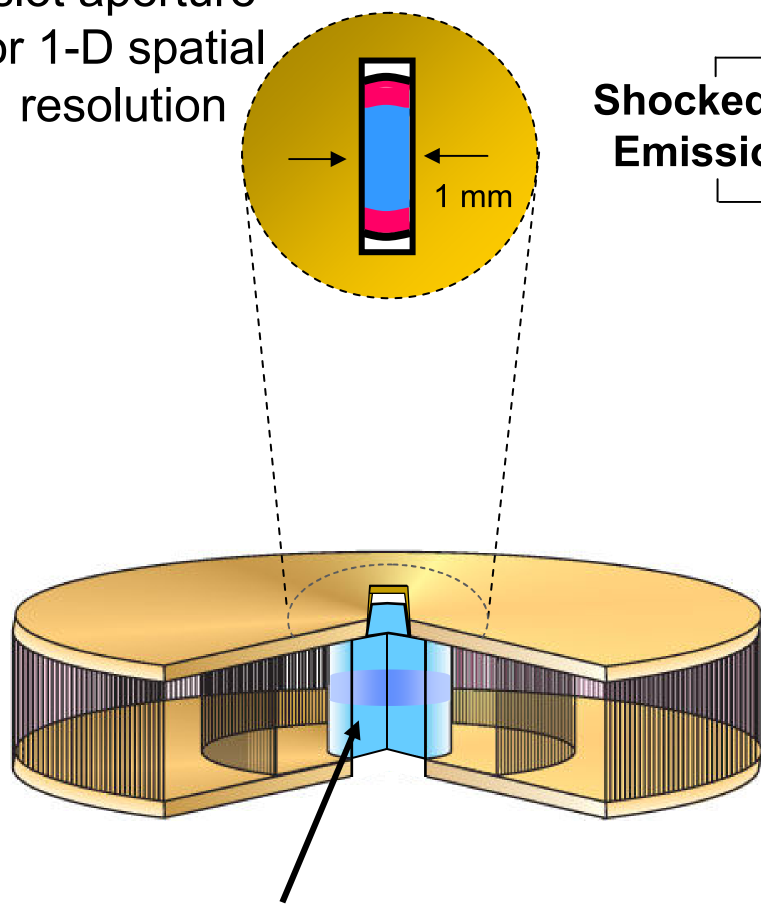






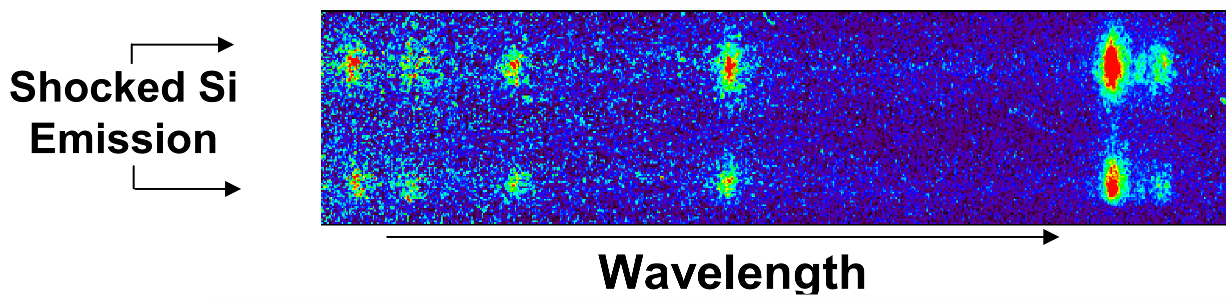
Si emission spectroscopy has been used to probe the local conditions of the DH source shock.

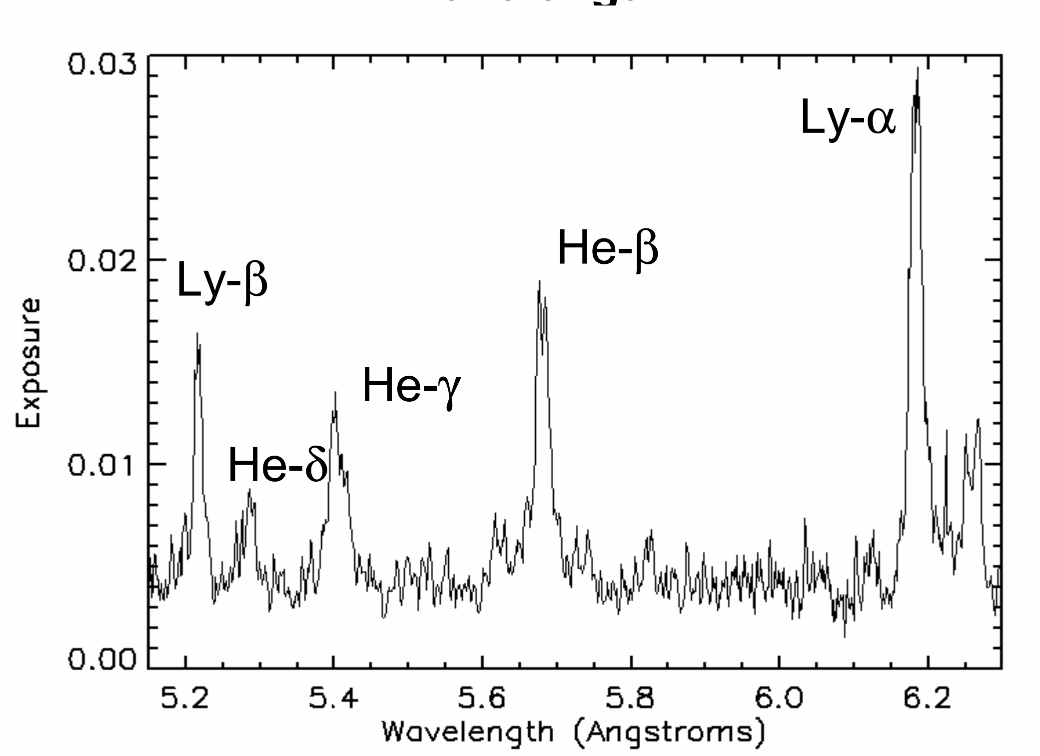
slot aperture for 1-D spatial resolution



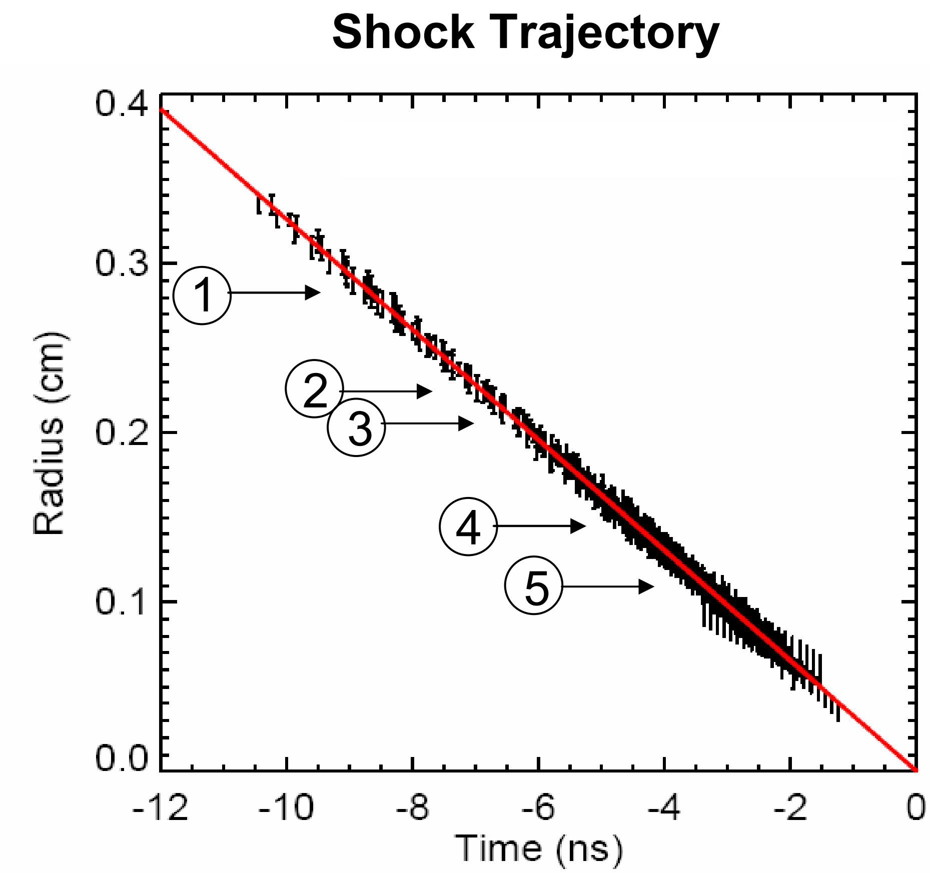
central 3mm height of the 15 mg/cc CH_2 foam is doped with 2.5% Si_2O_3

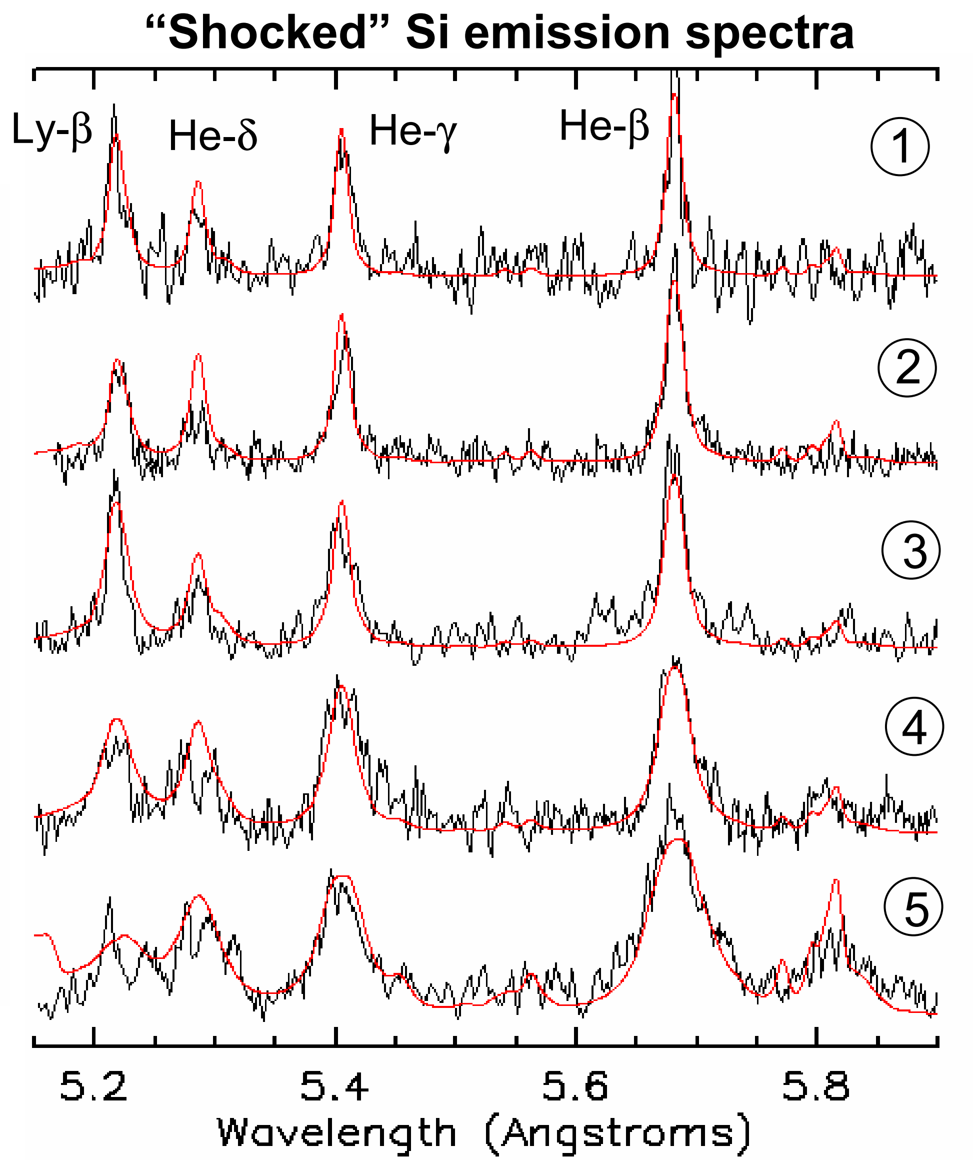
Time- and 1-D Space-Resolved Si Spectra





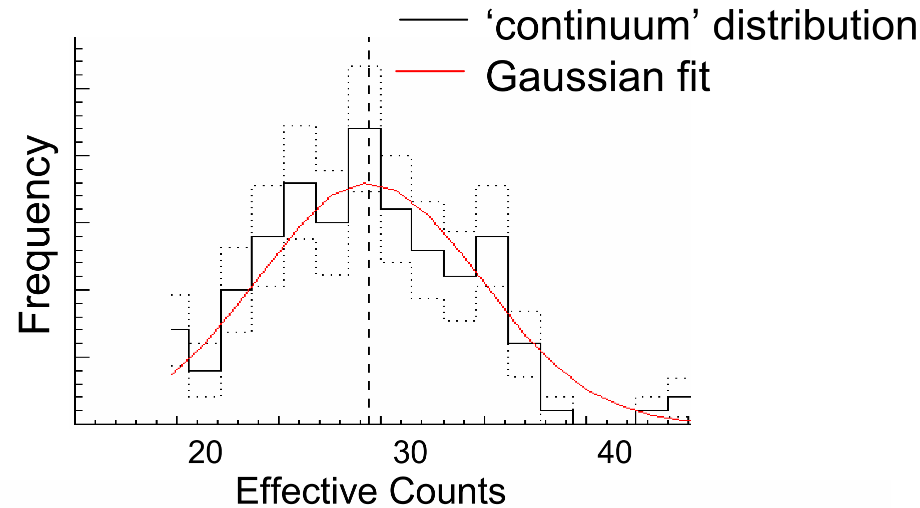
Si emission from the shocked DH foam has been recorded for shock radii from 1.1 – 2.8 mm.

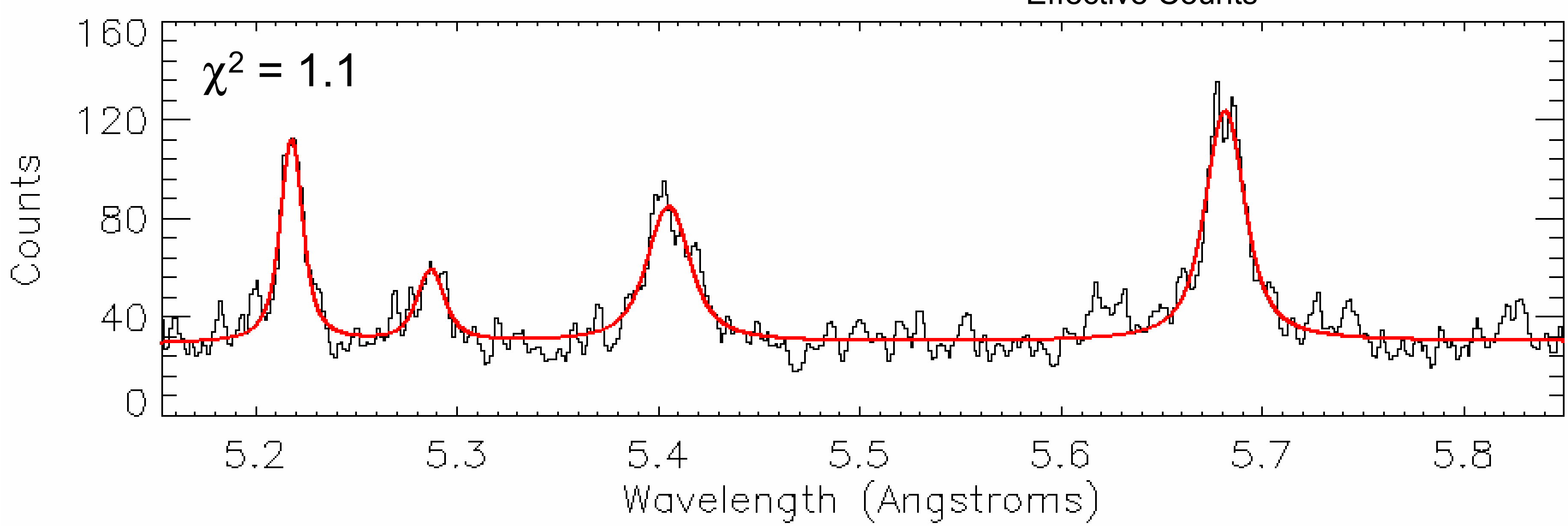




"Noisy" data requires a careful statistical analysis to determine line-widths and line-strengths with error bars.

- Determine frequency distribution of the data continuum and assume Poisson statistics to get weights.
- Perform a least-squares fit to the spectra using ROBFIT[1]
  - assume Voigt line profiles (η = 1)
  - simultaneously fit background and emission lines

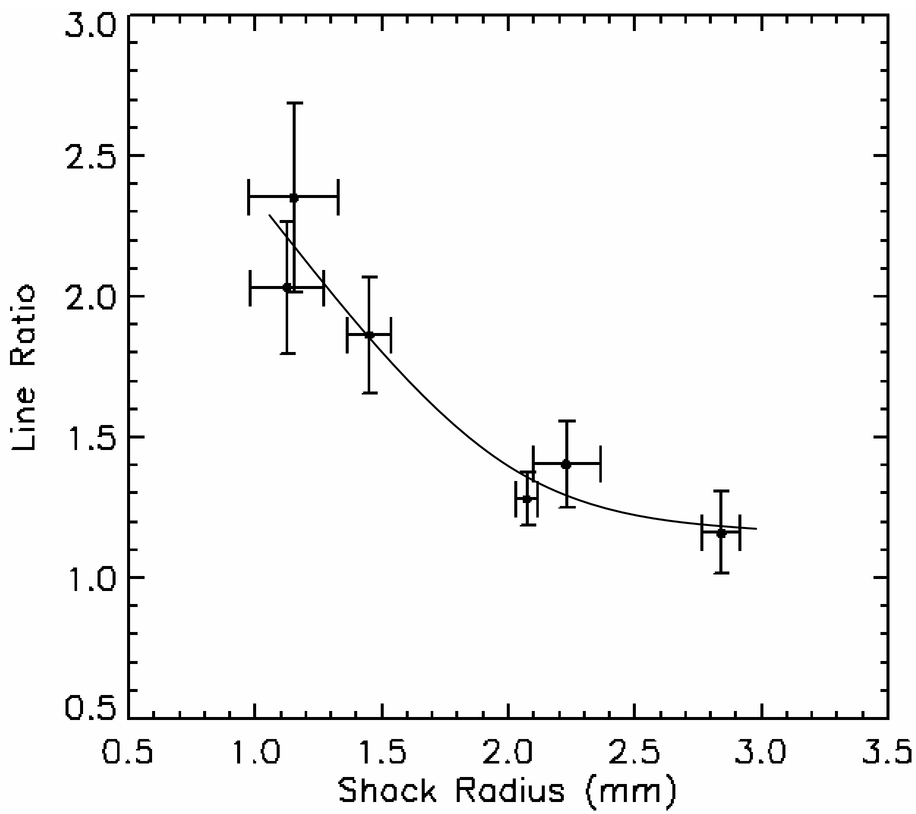




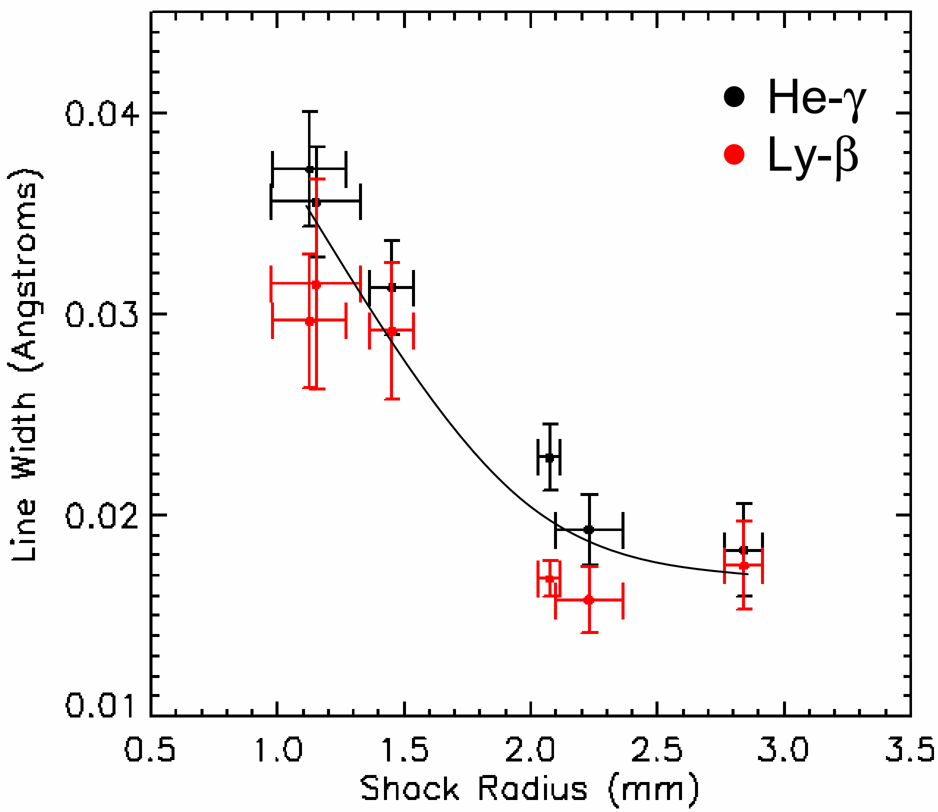
[1]R.L. Coldwell and G.J. Bamford, *The Theory and Operation of Spectral Analysis using ROBFIT*, (AIP, 1991).

The ROBFIT analysis shows He / H line ratios and line widths that increase with decreasing radius.

He-γ / Ly-β Ratio



Line Widths

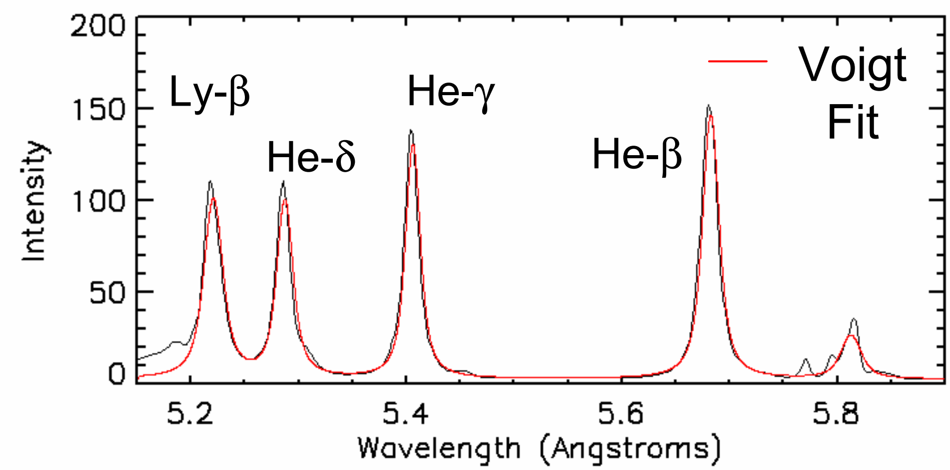


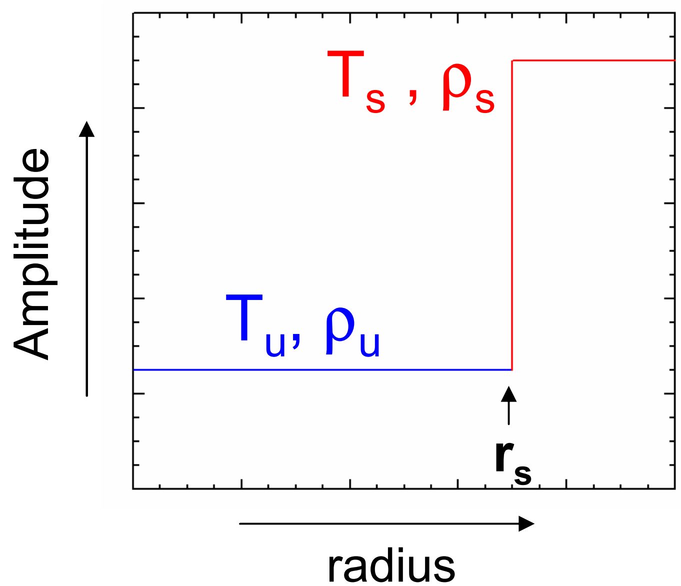
Shock conditions are determined from a 2-D model with non-LTE population kinetics and non-local radiation.

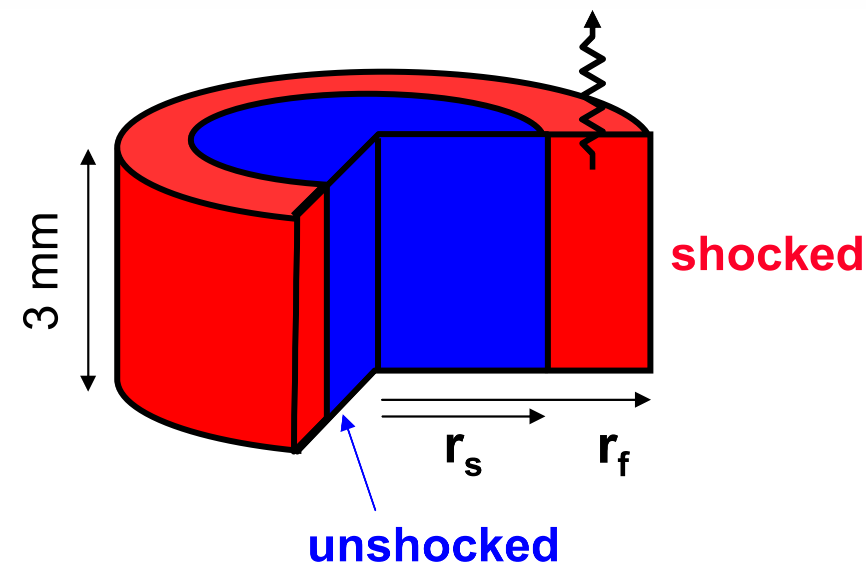
SPECT3D modeling

- **C-R radiation transport**
- **Non-LTE population kinetics**
- **>4000 atomic level transitions**
- **Fix T_u , ρ_u -- vary T_s , ρ_s**
- **Fit each simulated spectra with ROBFIT**
- **Tabulate line ratios / widths vs. T_s, ρ_s**

Simulated Si Emission Spectrum

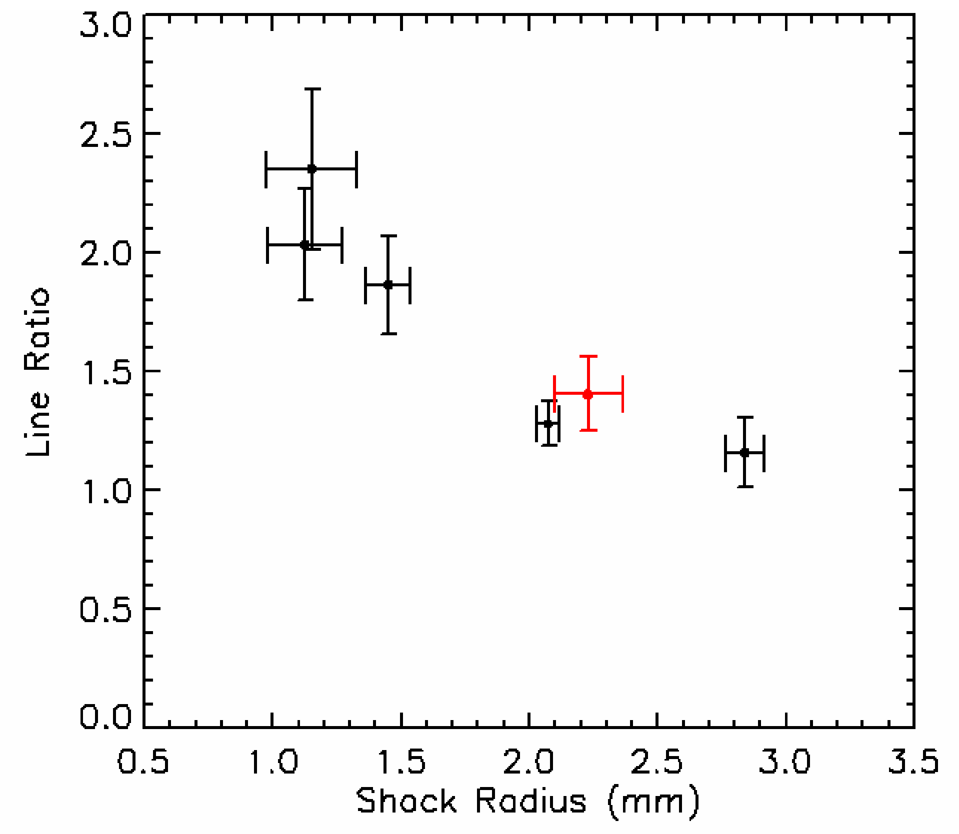




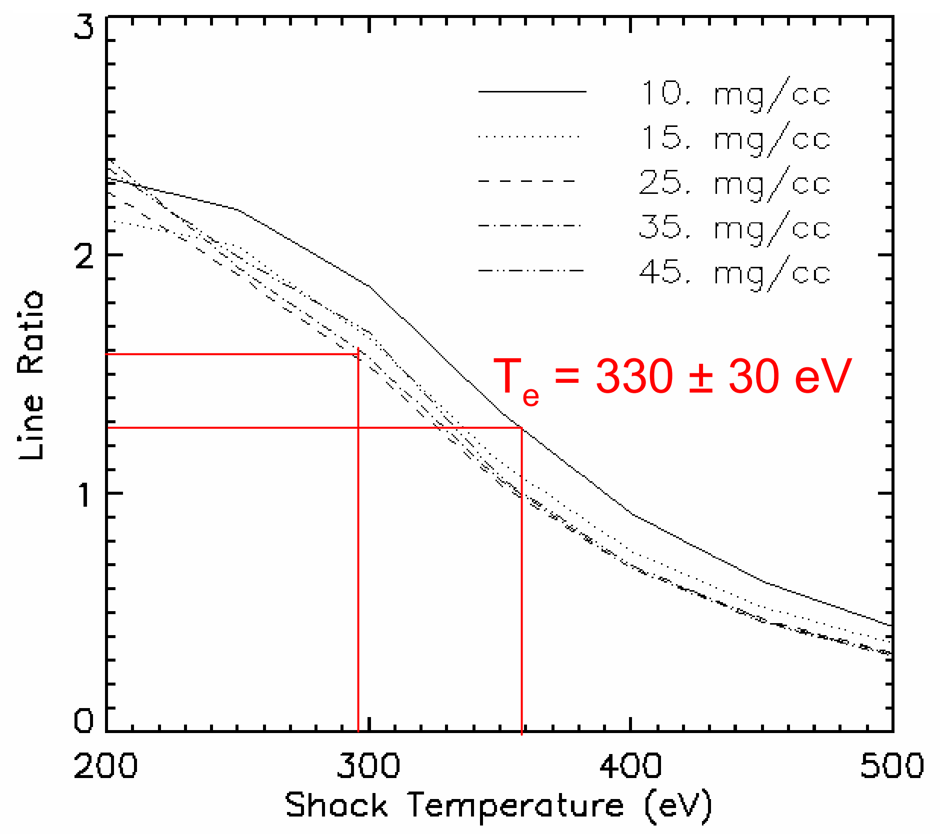


The shock temperature is determined from the He-like to H-like line ratios.

Measured
He-γ / Ly-β Line Ratios



Calculated He-γ / Ly-β
Line Ratios vs. Shock Temperature



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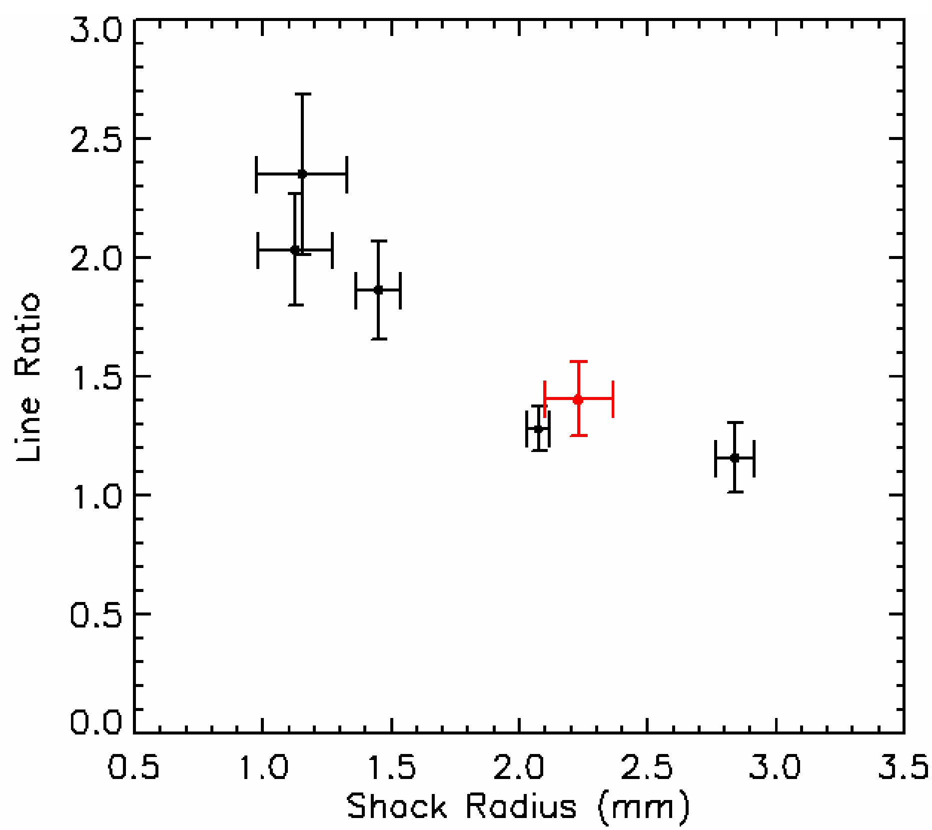
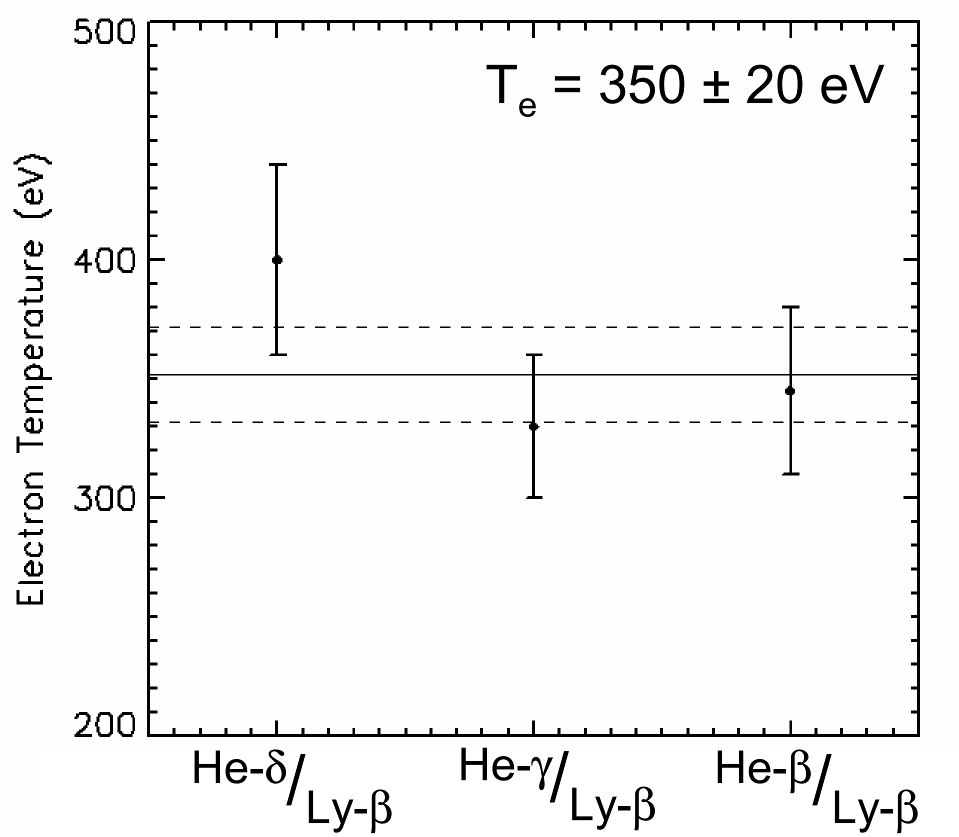
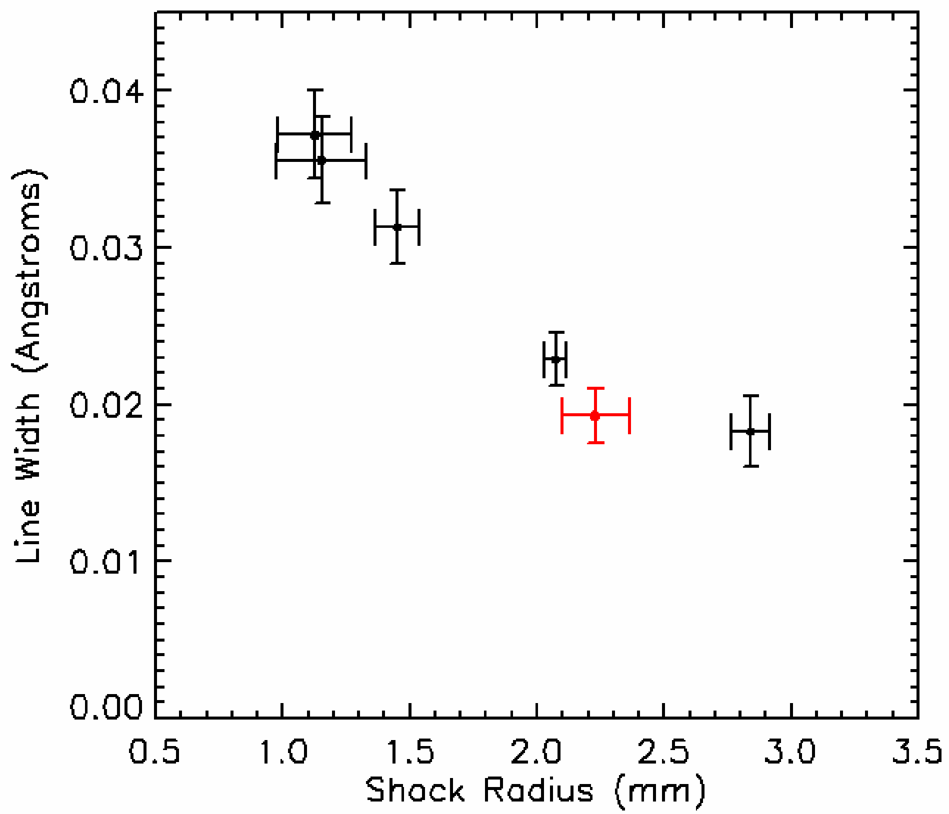


Temperatures Inferred from
Calculated Line Ratios at r_s = 2.2 mm

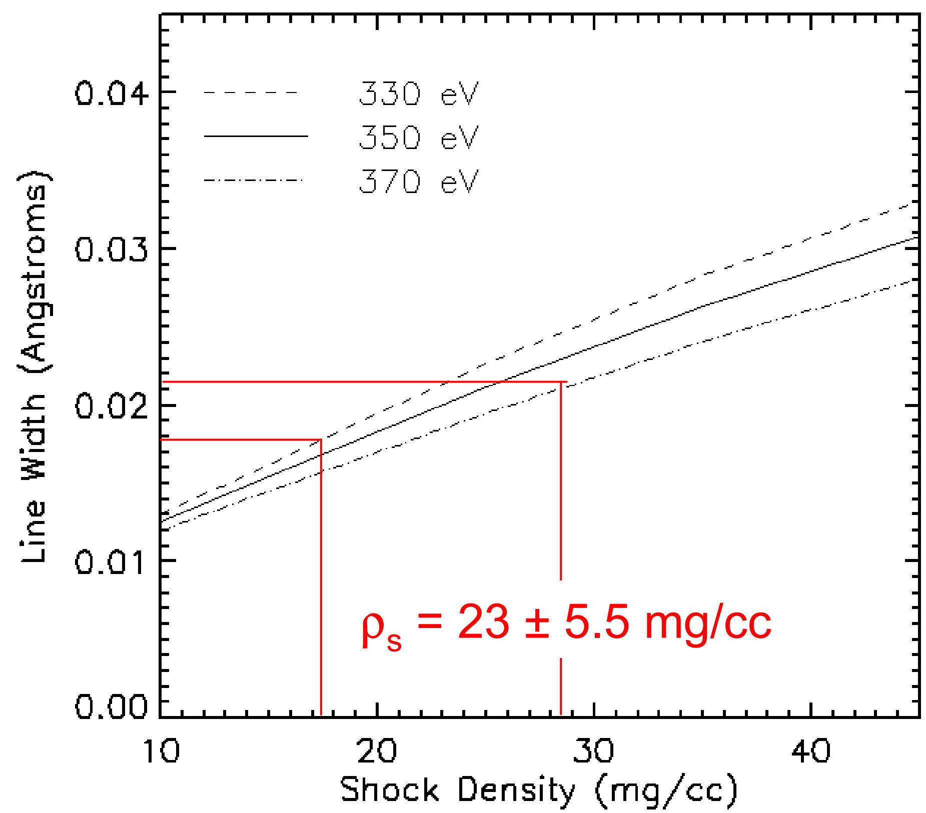


Once the temperature is known, the shock density is determined from the opacity & stark broadened line widths.

Measured
He-γ Line Widths



Calculated He-γ Line
Width vs. Shock Density



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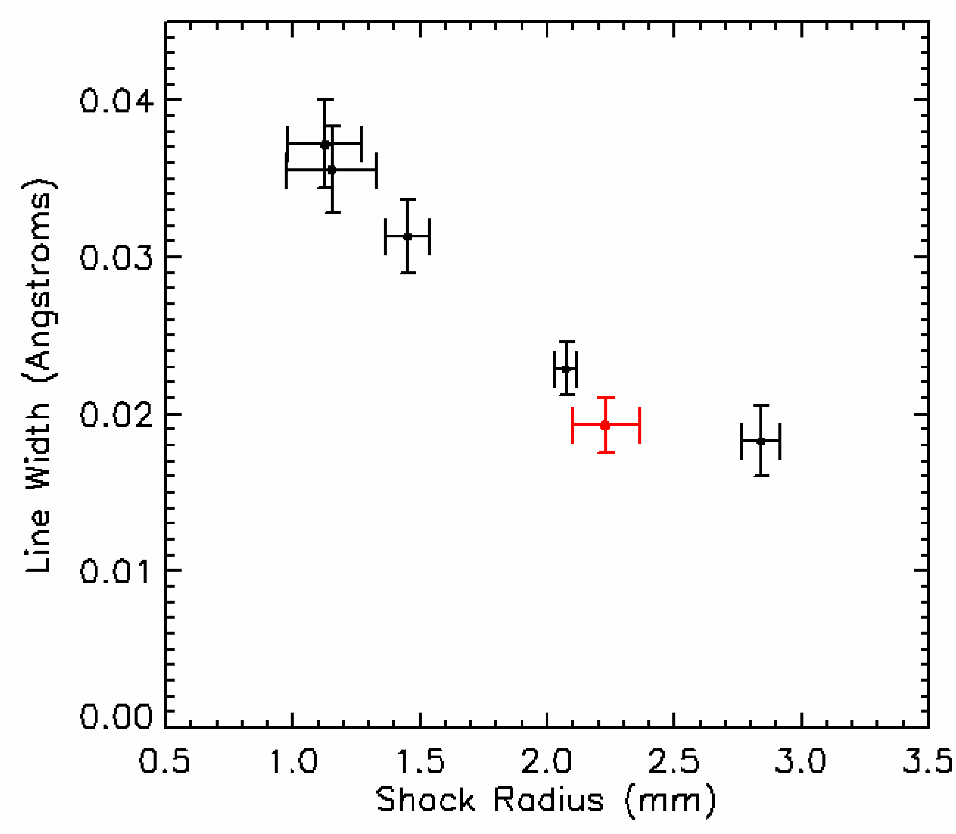
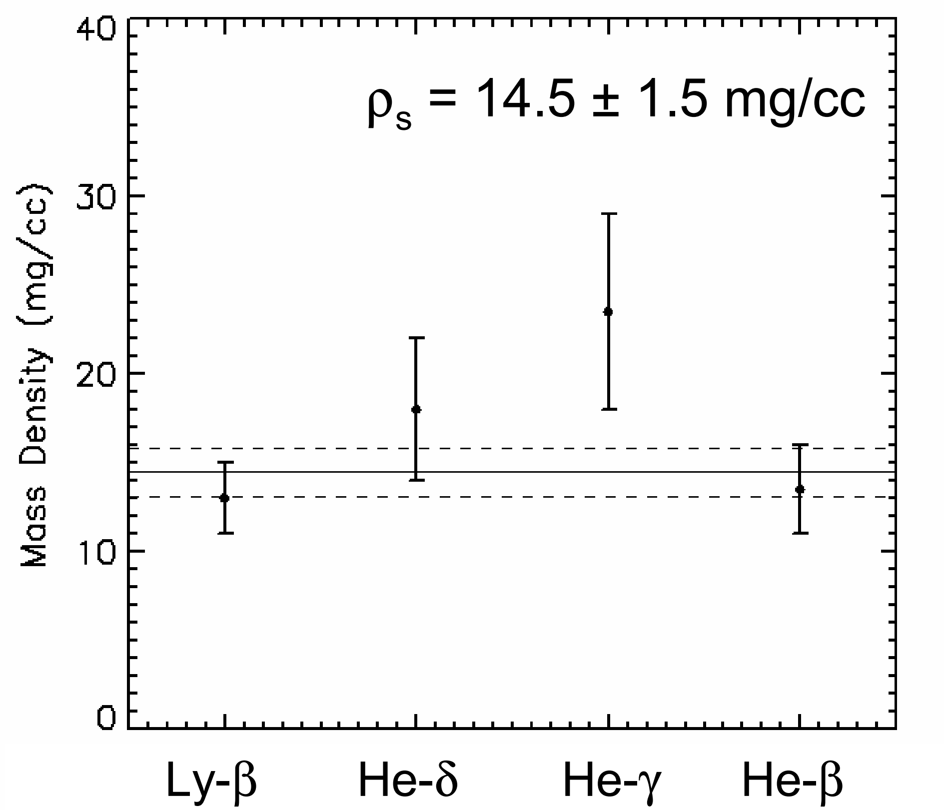
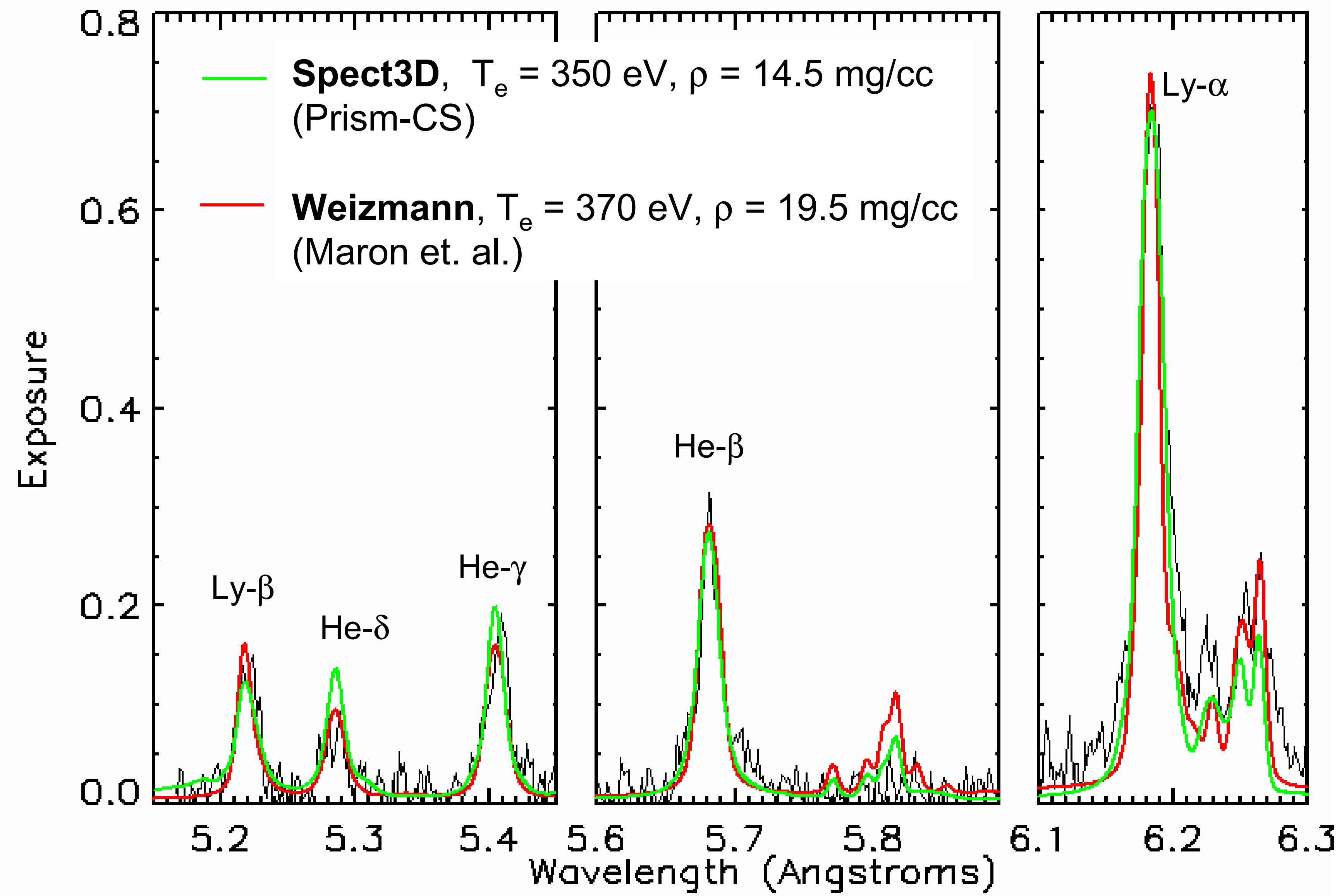
Measured
He-γ Line Widths



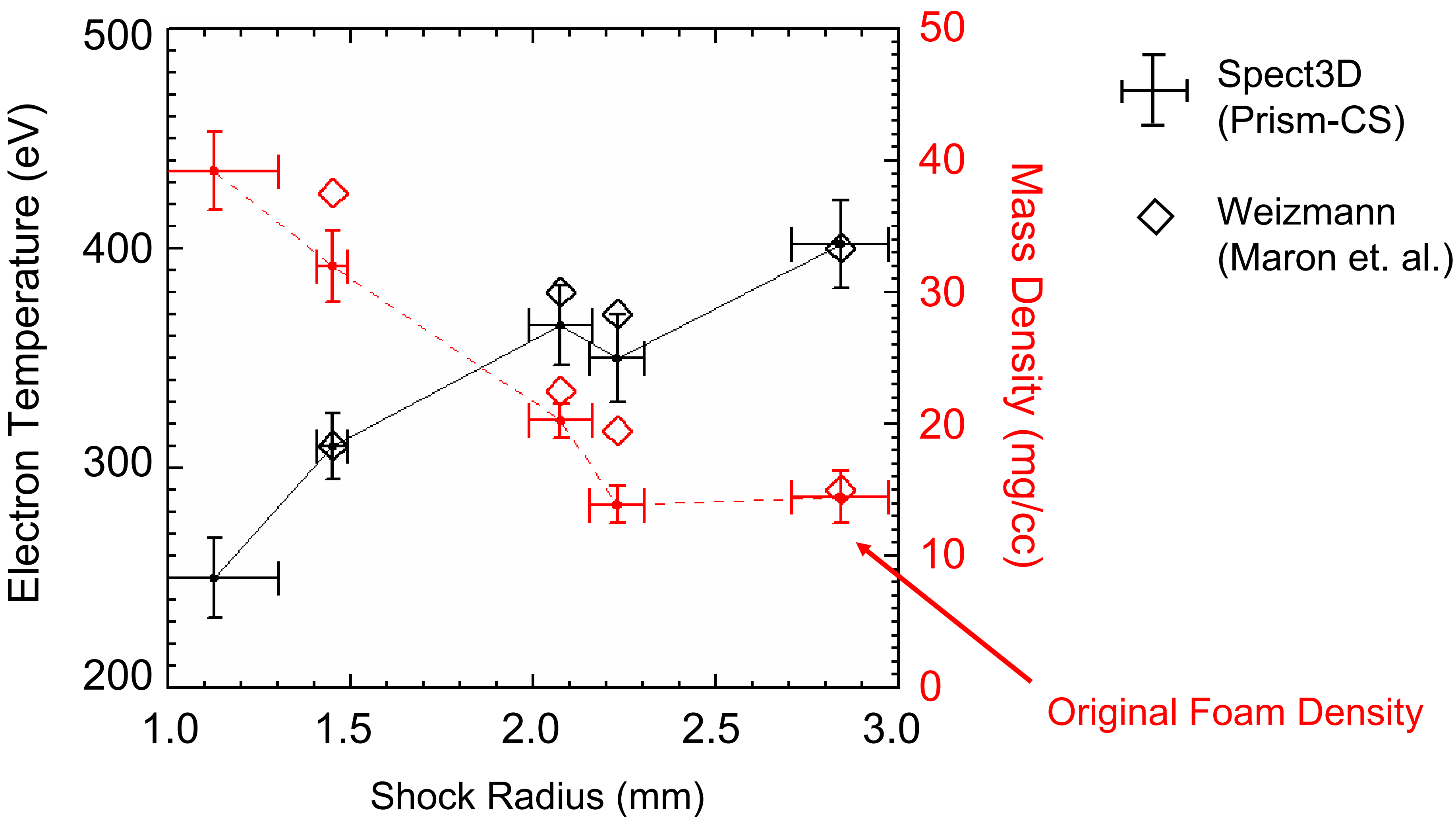
Densities Inferred from Calculated
Line Widths at r_s = 2.2 mm



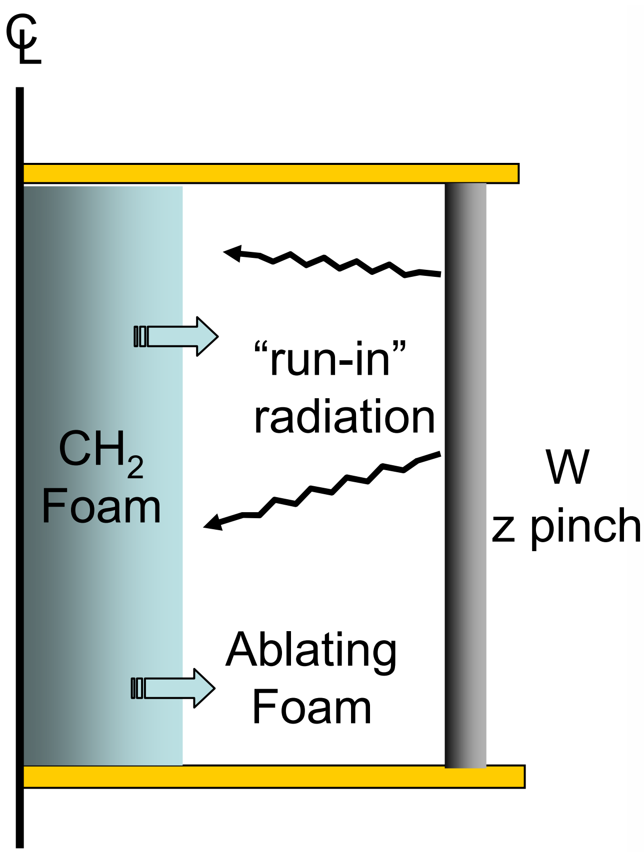
The 'Best-Fit' plasma conditions are then tested for consistency across the measured range.

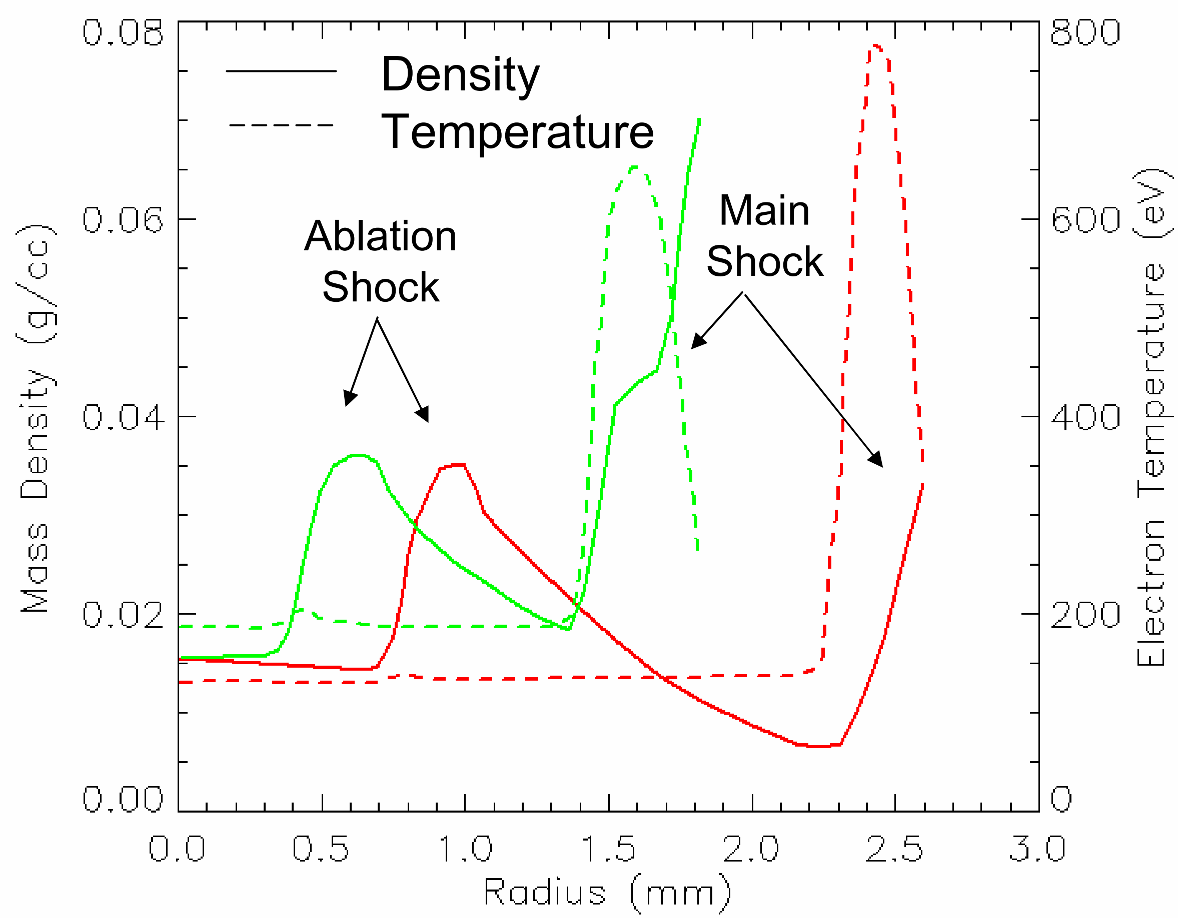


The measured shock temperature decreases and the shock density increases with decreasing shock radius.



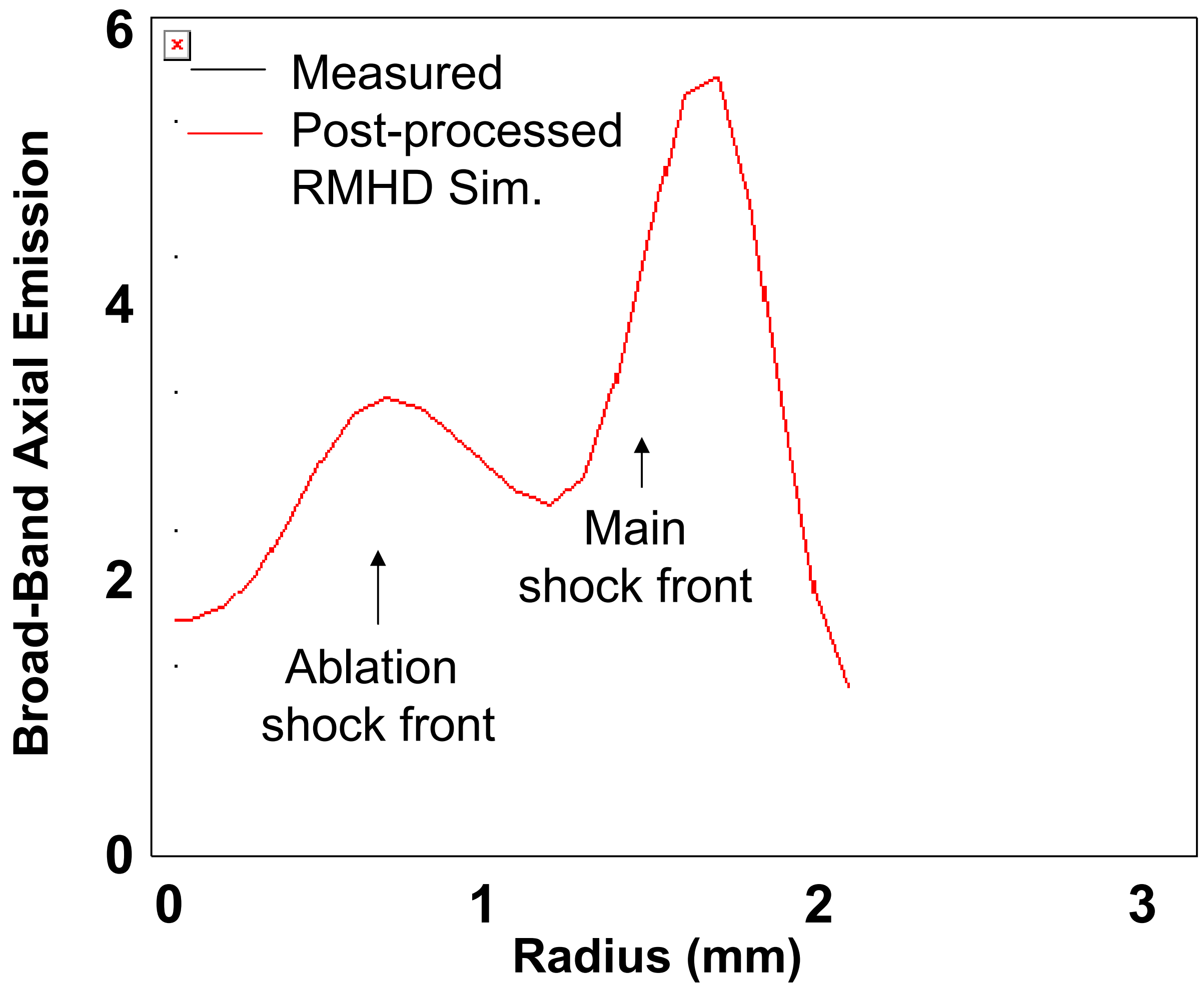
2-D RMHD calculations predict the existence of an ablatively driven shock ahead of the main compression shock.





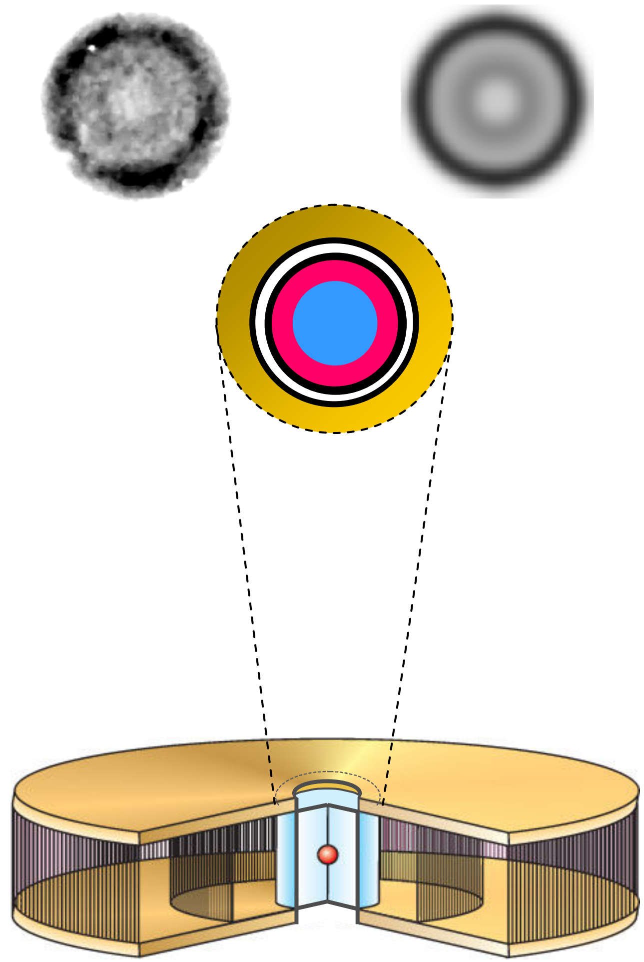
2-D shock emission data support the presence of an ablatively driven shock ahead of the main shock.

Azimuthally Averaged Radial Lineout of Shock Emission at $h\nu \sim$ 200-300eV



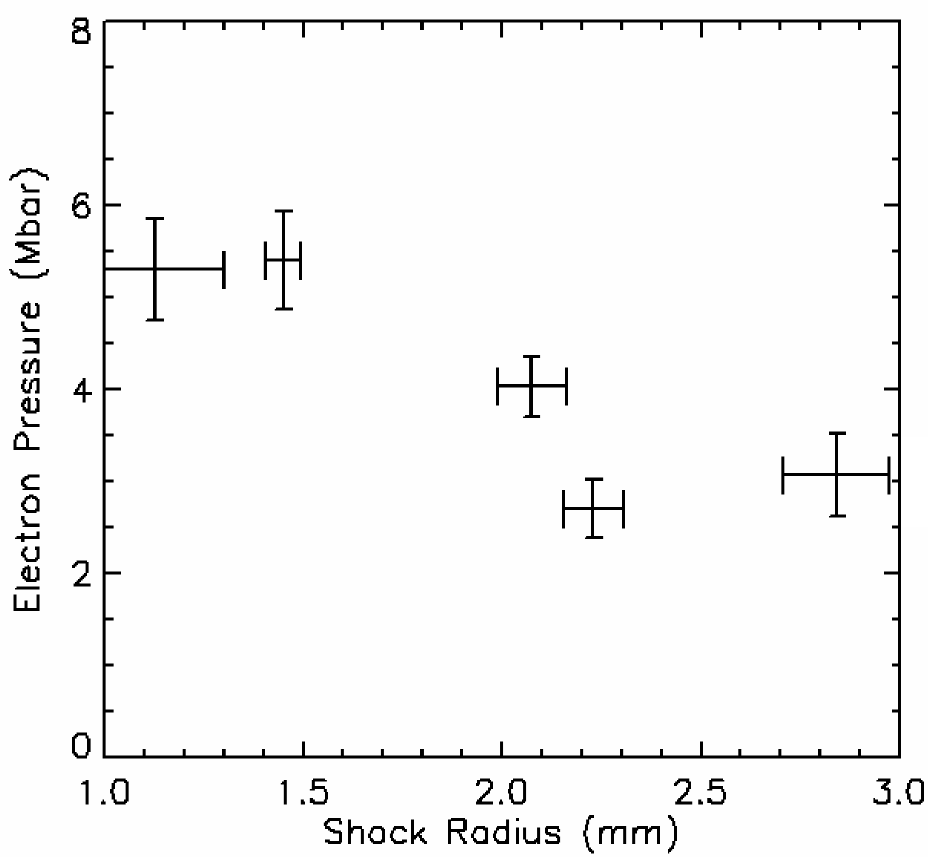
Measured Image

Post-Processed Image

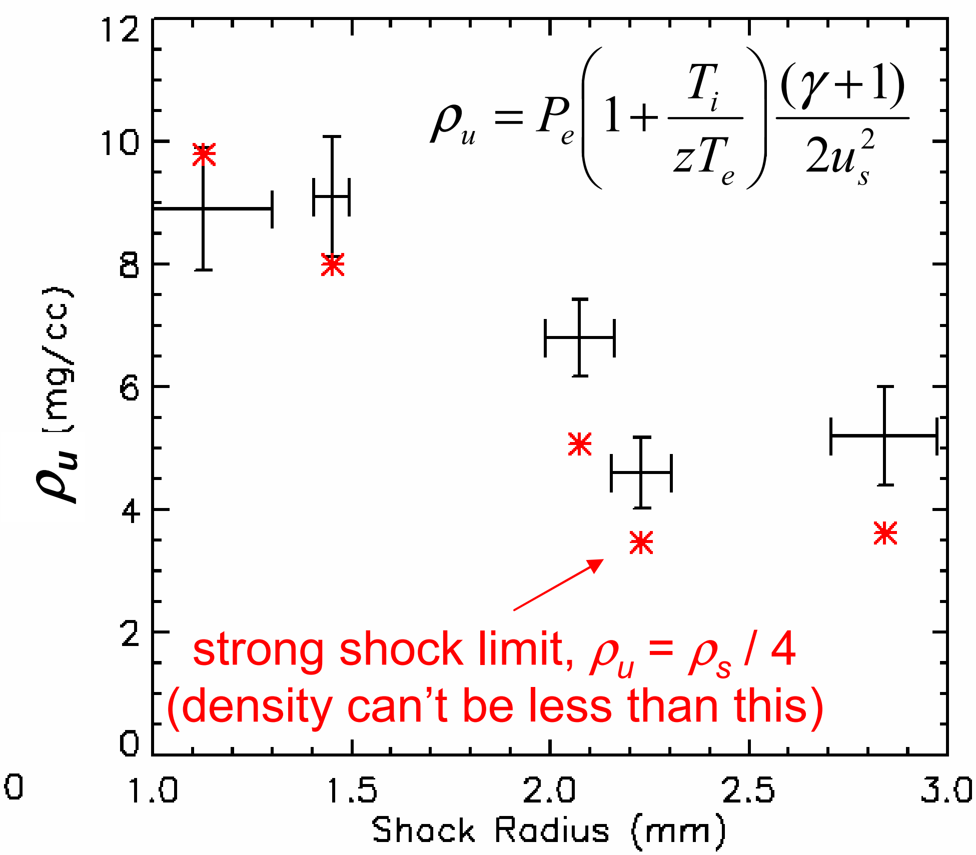


The electron pressure and shock velocity provide a LOWER BOUND on the density ahead of the main shock front.

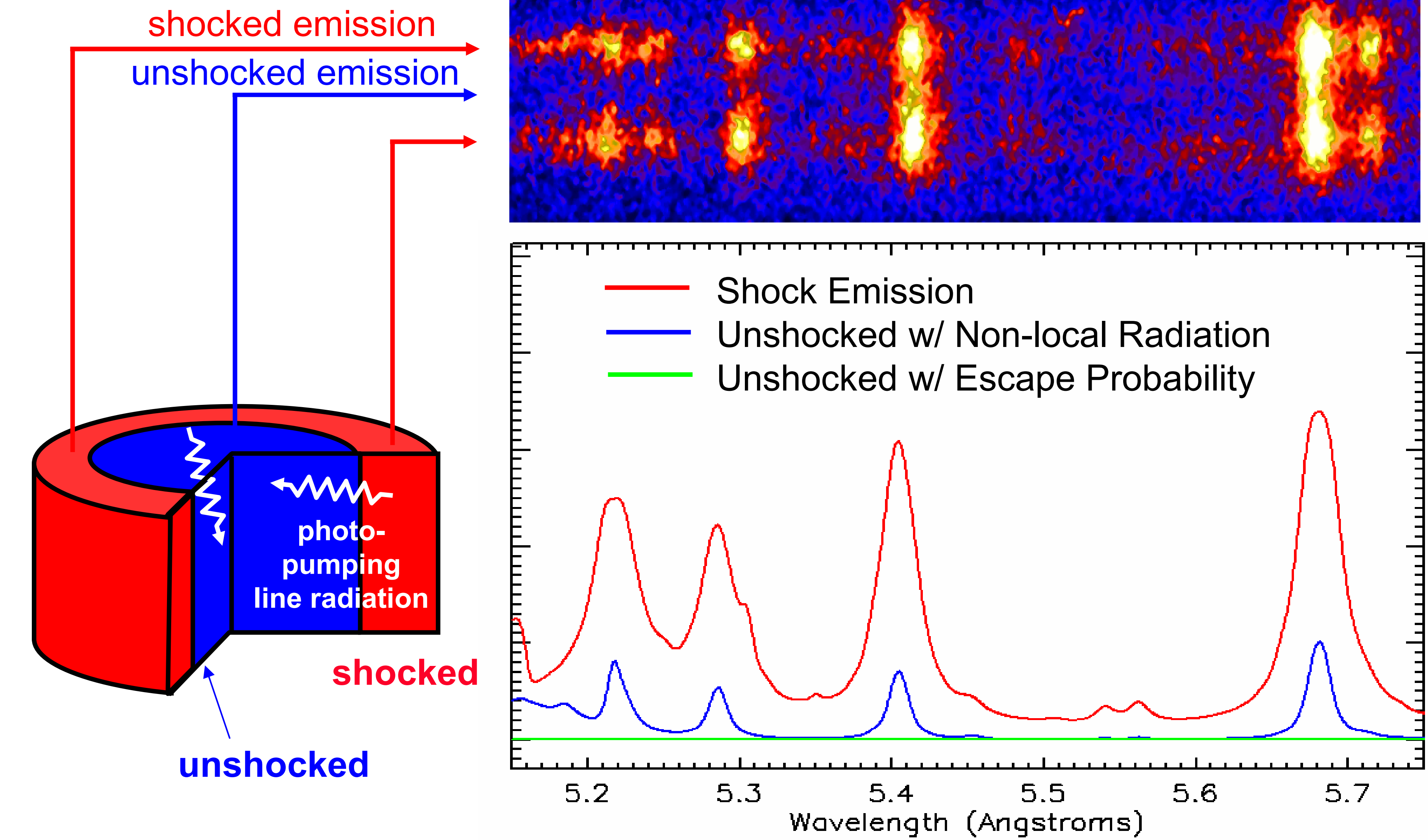
Electron Pressure Behind Main Shock (determined from Si measurements)



Density Ahead of Main Shock Front Assuming $T_i = T_e$

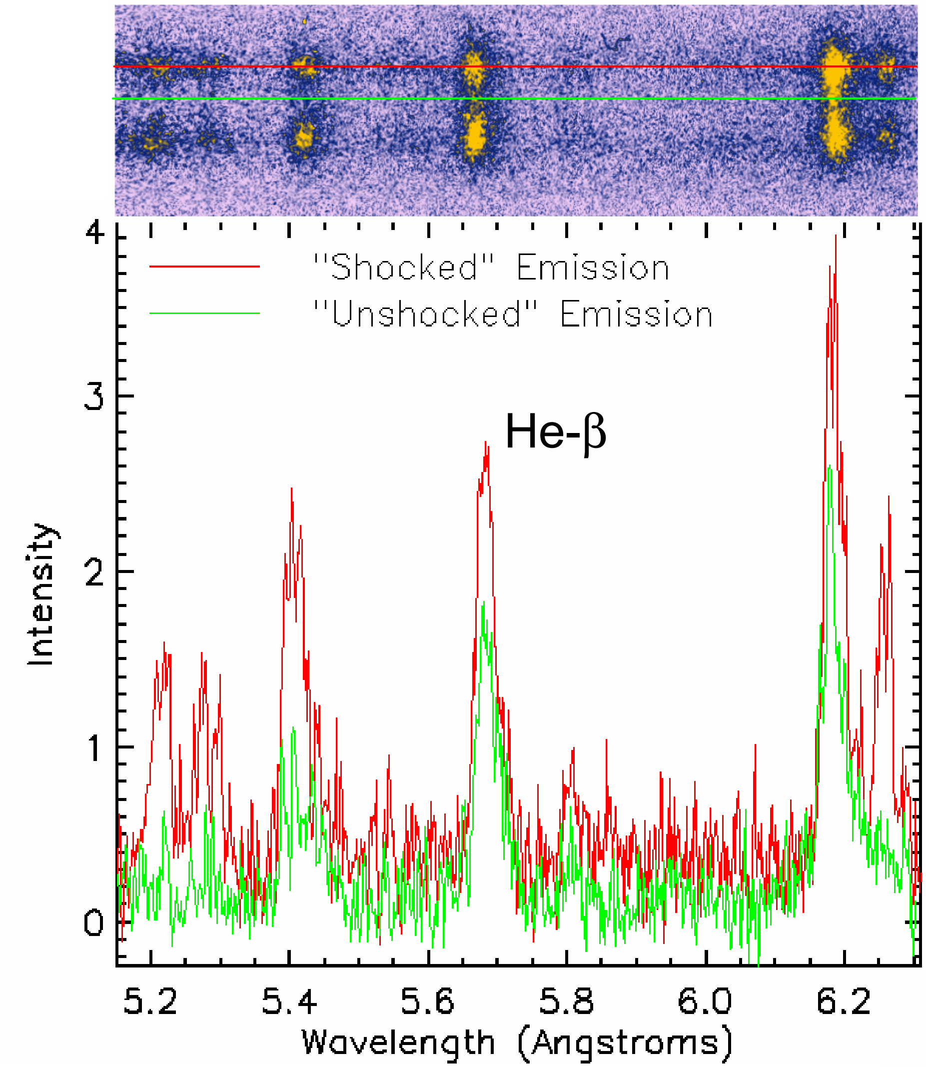


At late times (r_s < 1.5 mm), photo-pumped line emission can be used to determine conditions ahead of the shock.

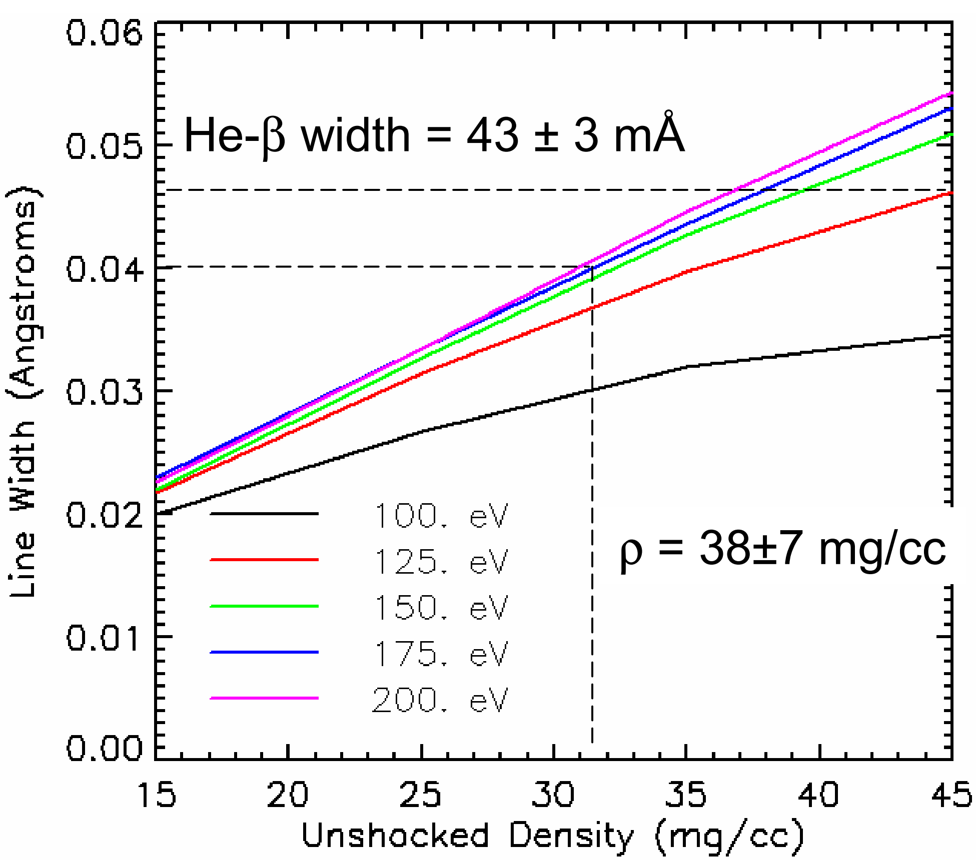


At r_s ~ 1.5 mm, the measured emission ahead of the main shock indicates a colder plasma of similar density.

Measured Si Emission Spectrum



Spect3D Simulation of Photo-Pumped
<u>He-β Line Width vs. Density</u>
at T_s = 310eV, ρ_s = 32 mg/cc



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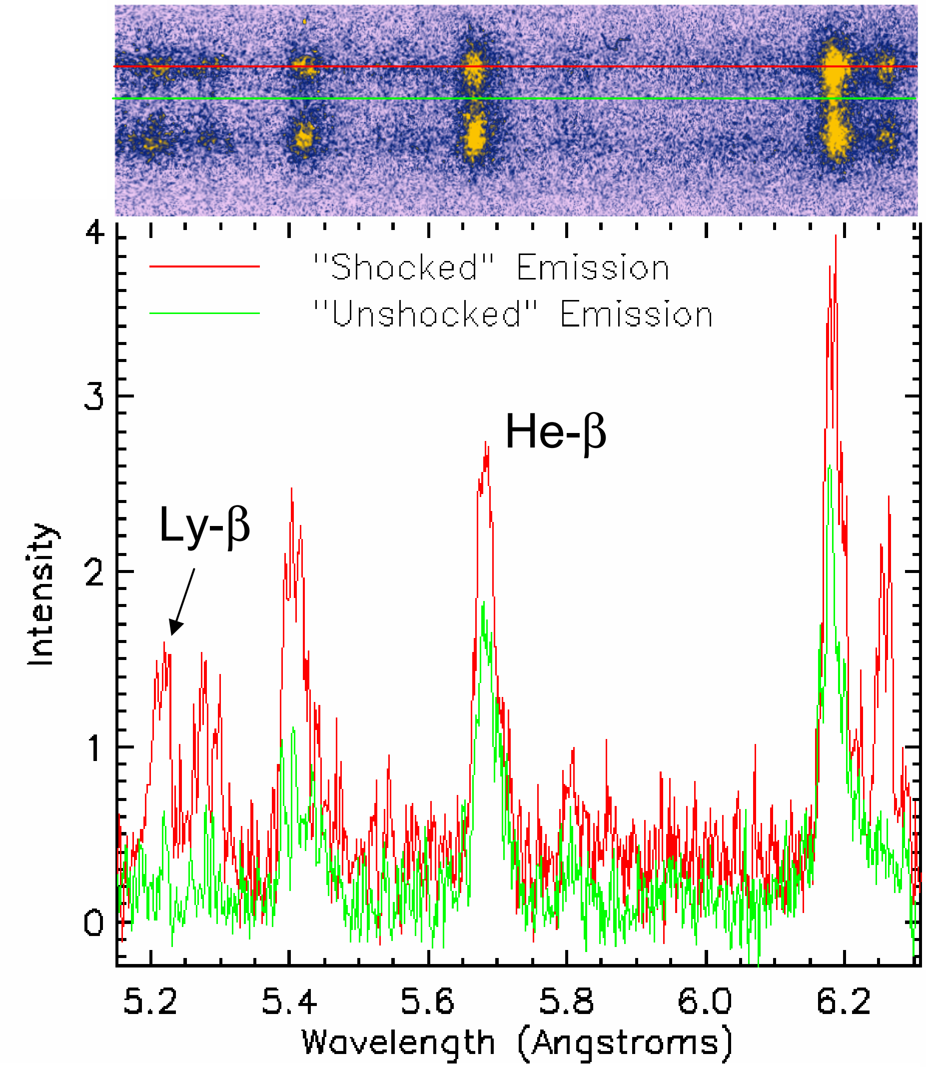
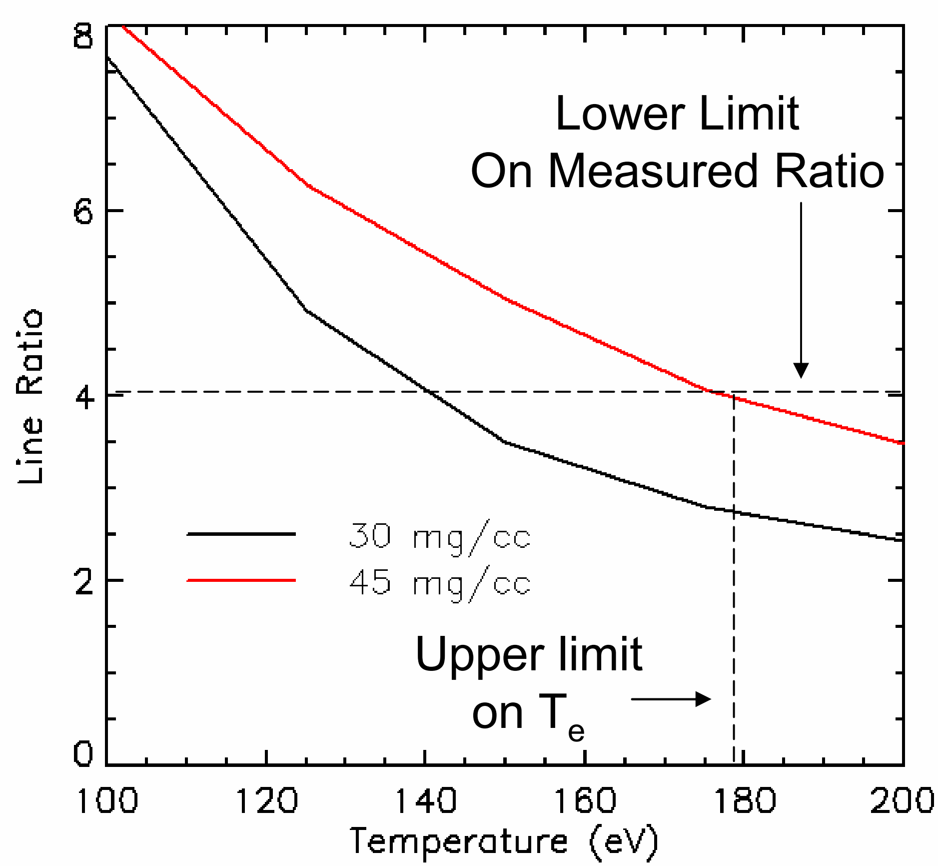
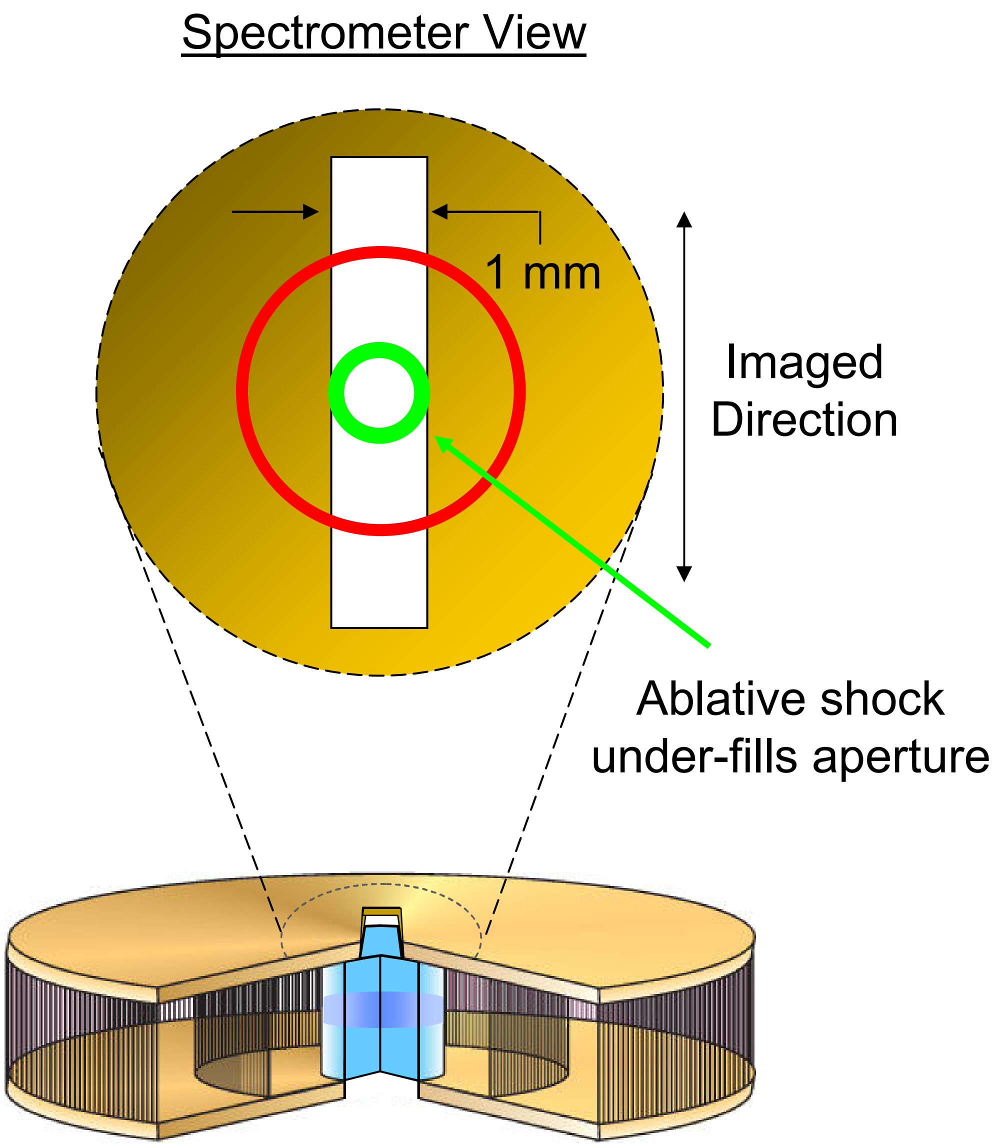
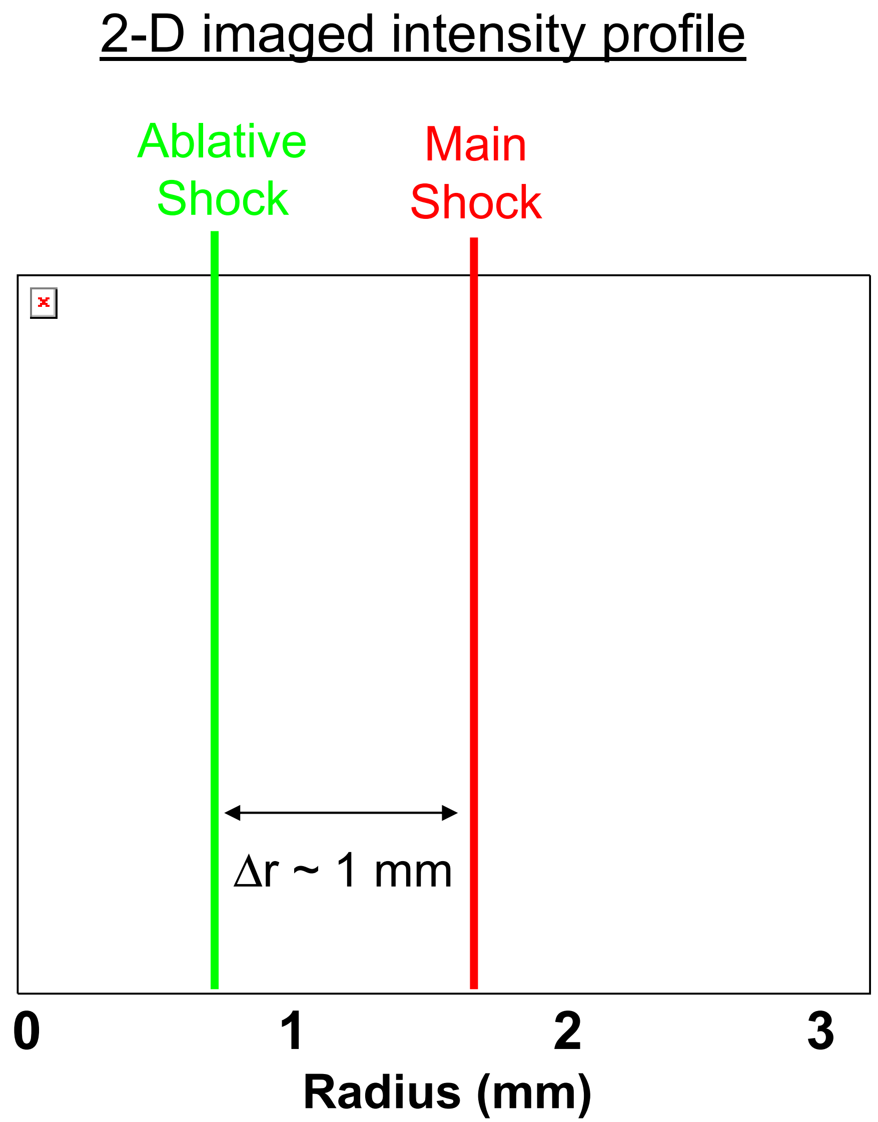


Spect3D Simulation of Photo-Pumped
<u>He-β / Ly-β Line Ratio vs. Temperature</u>
at T_s = 310eV, ρ_s = 32 mg/cc

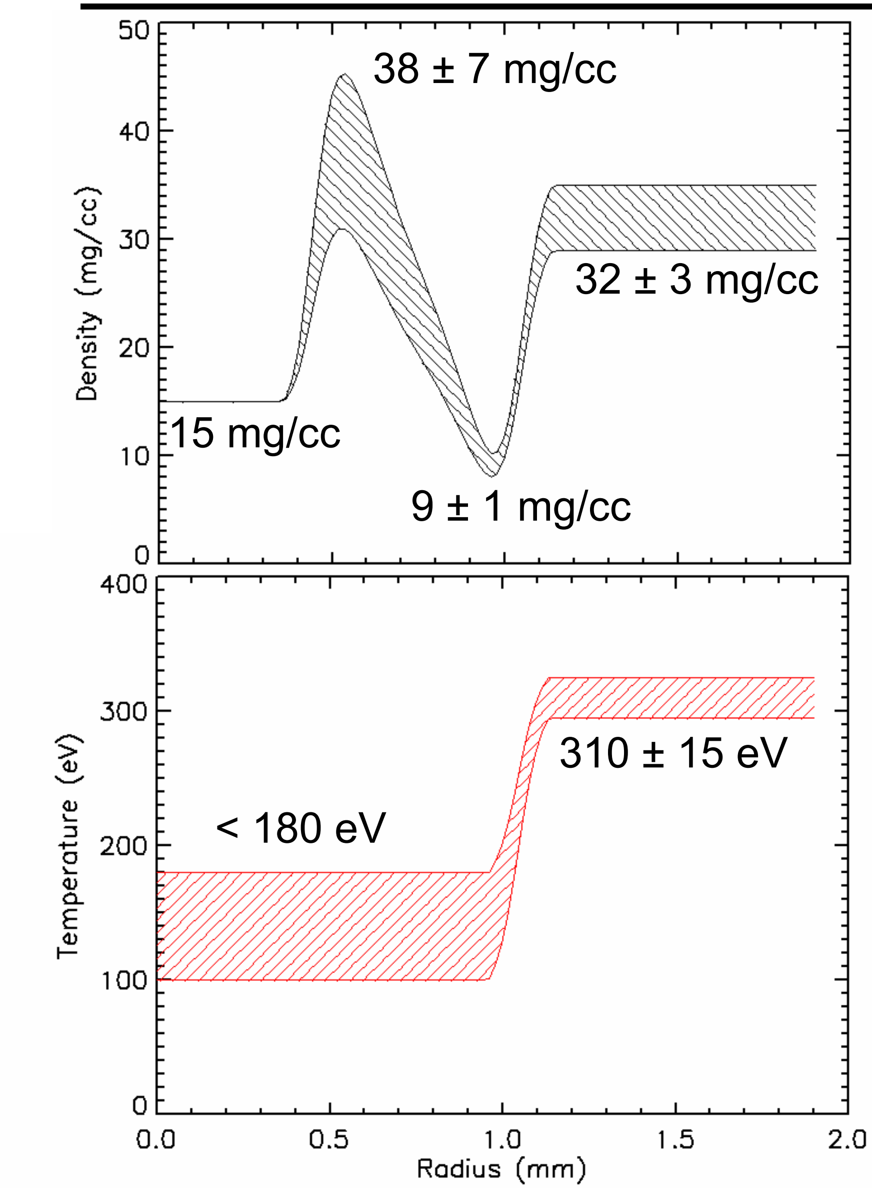


At r_s < 1.5 mm, Si emission ahead of the main shock is likely dominated by ablatively shocked plasma.

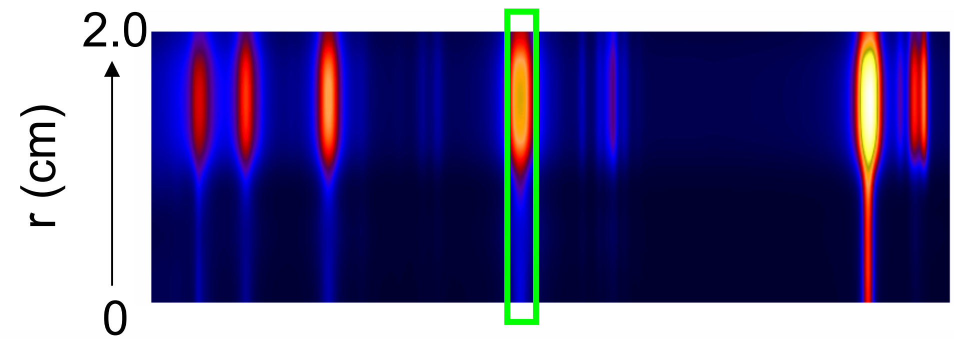


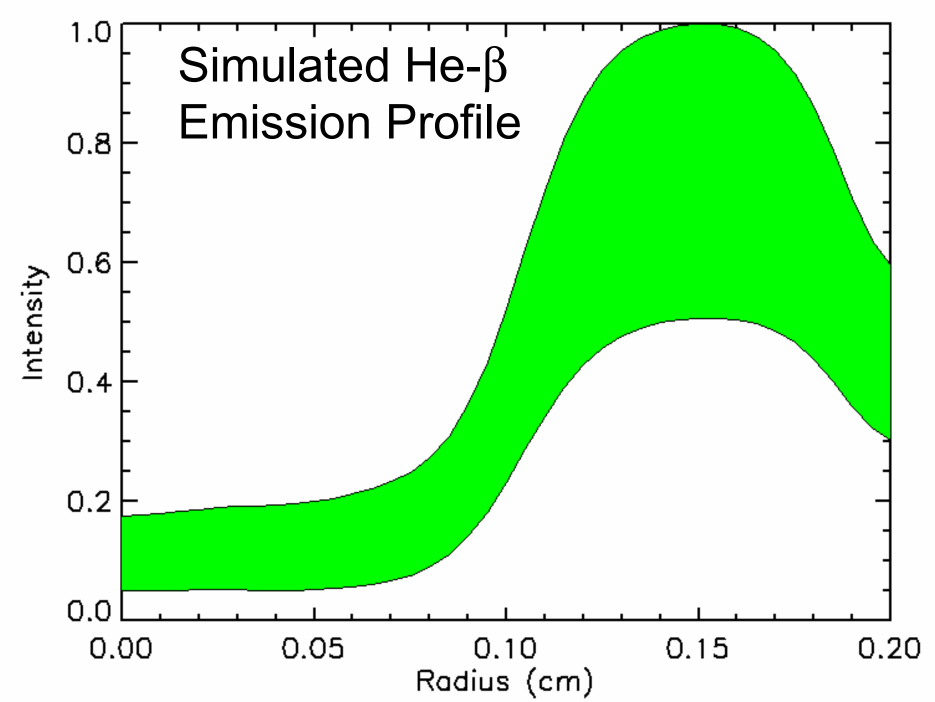


All inferred quantities can be used to create density and temperature profiles to simulate the spatial emission distribution.



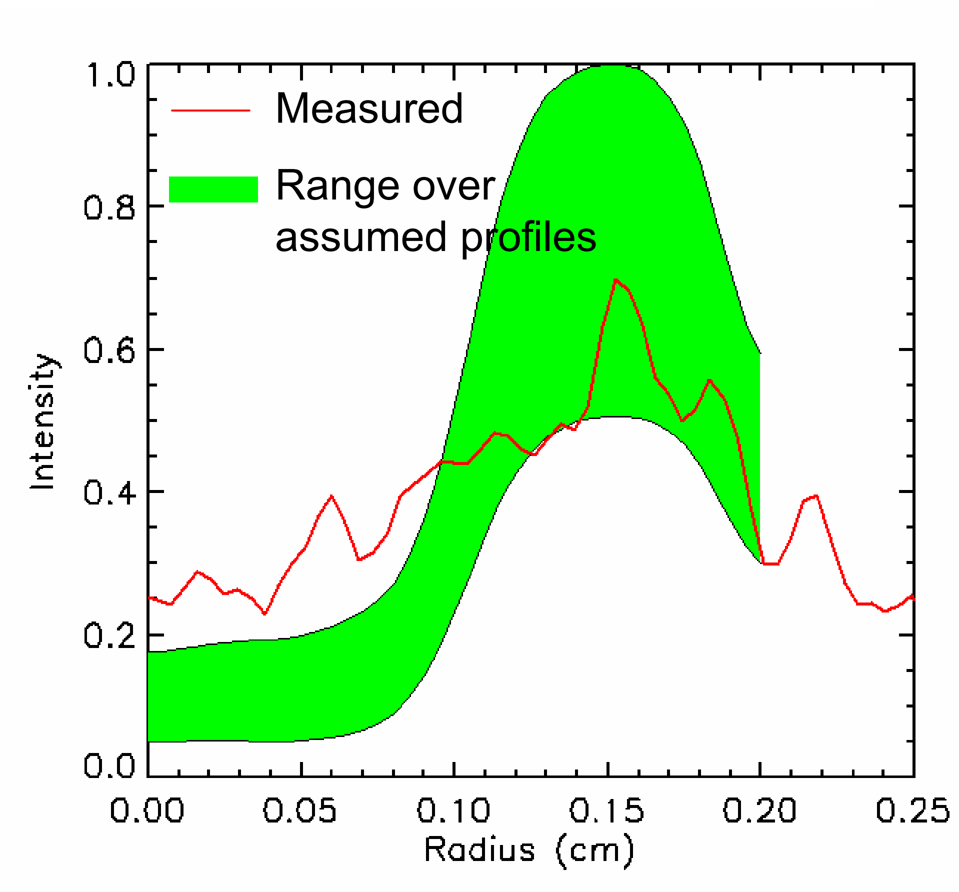
Simulated Spectral Axial Emission convolved with a 300μm Gaussian



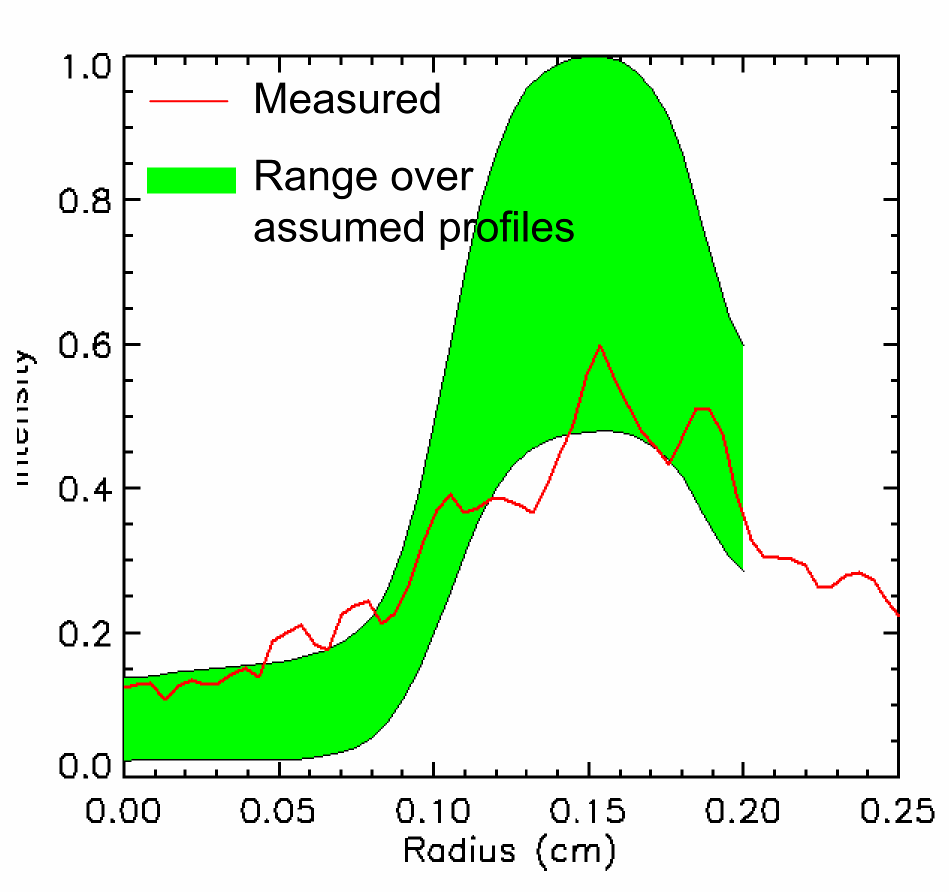


The photo-pumping efficiency is slightly under-predicted for the He-β line, but in fair agreement for the He-γ.

He-β intensity profile

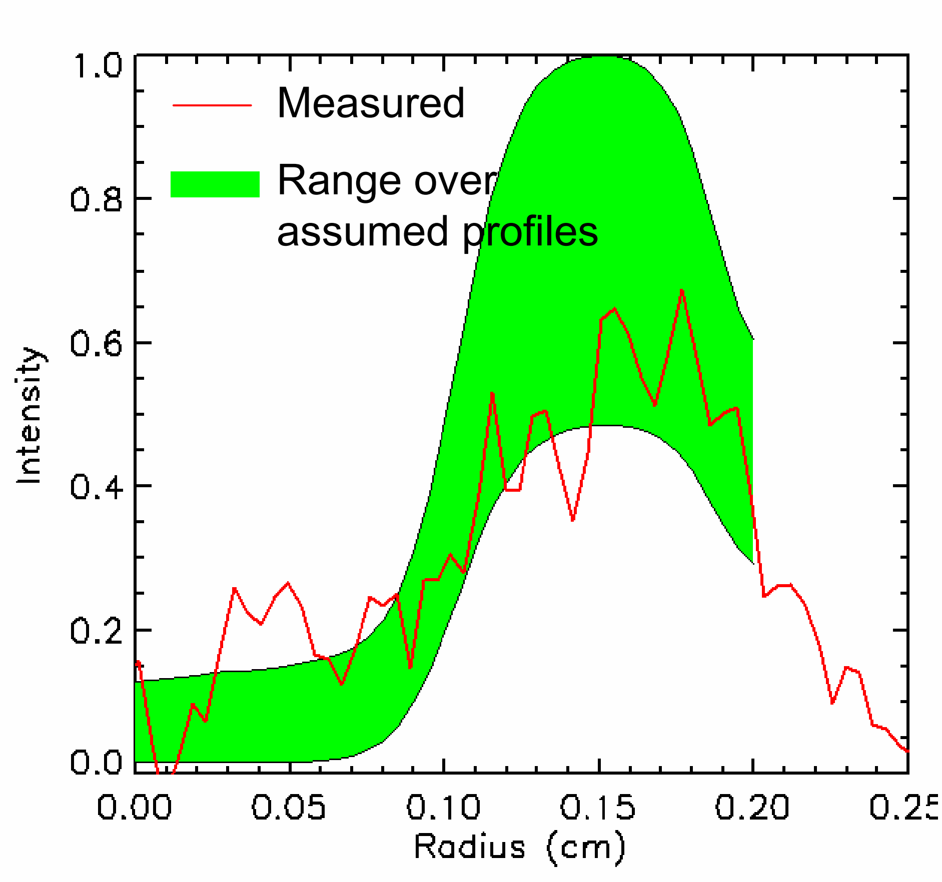


He-γ intensity profile

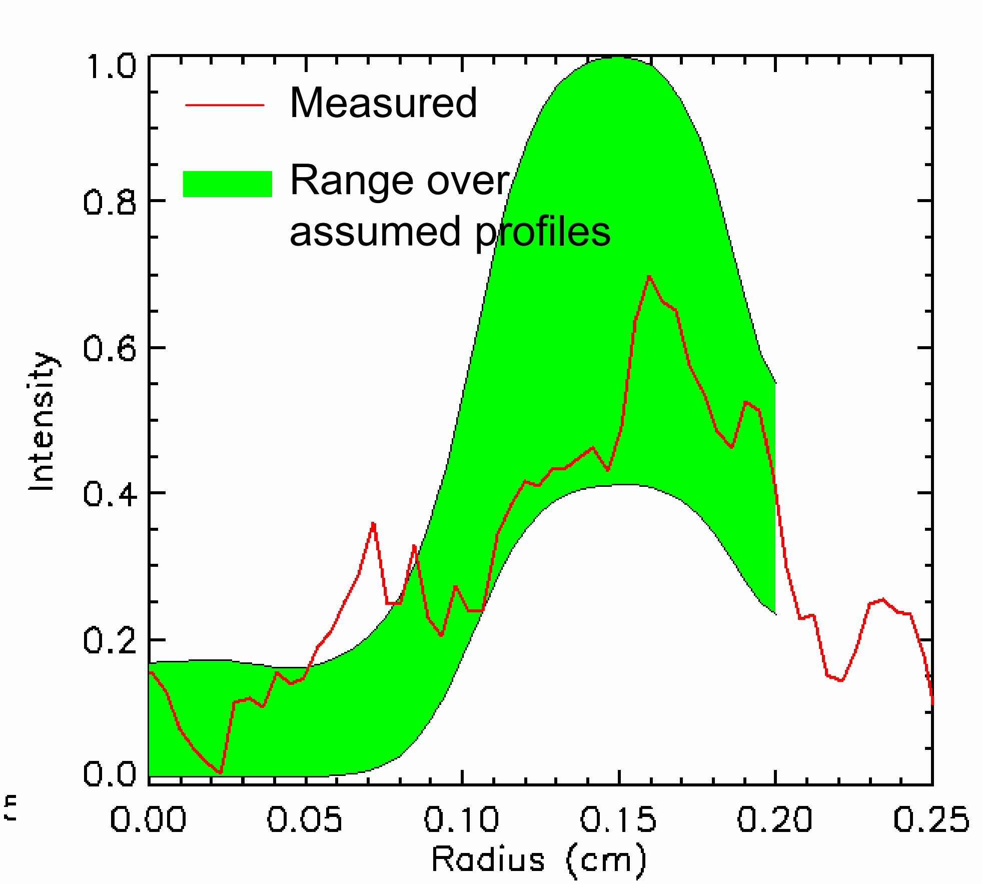


The photo-pumping efficiency is in fair agreement for both the He-δ and the Ly-β.

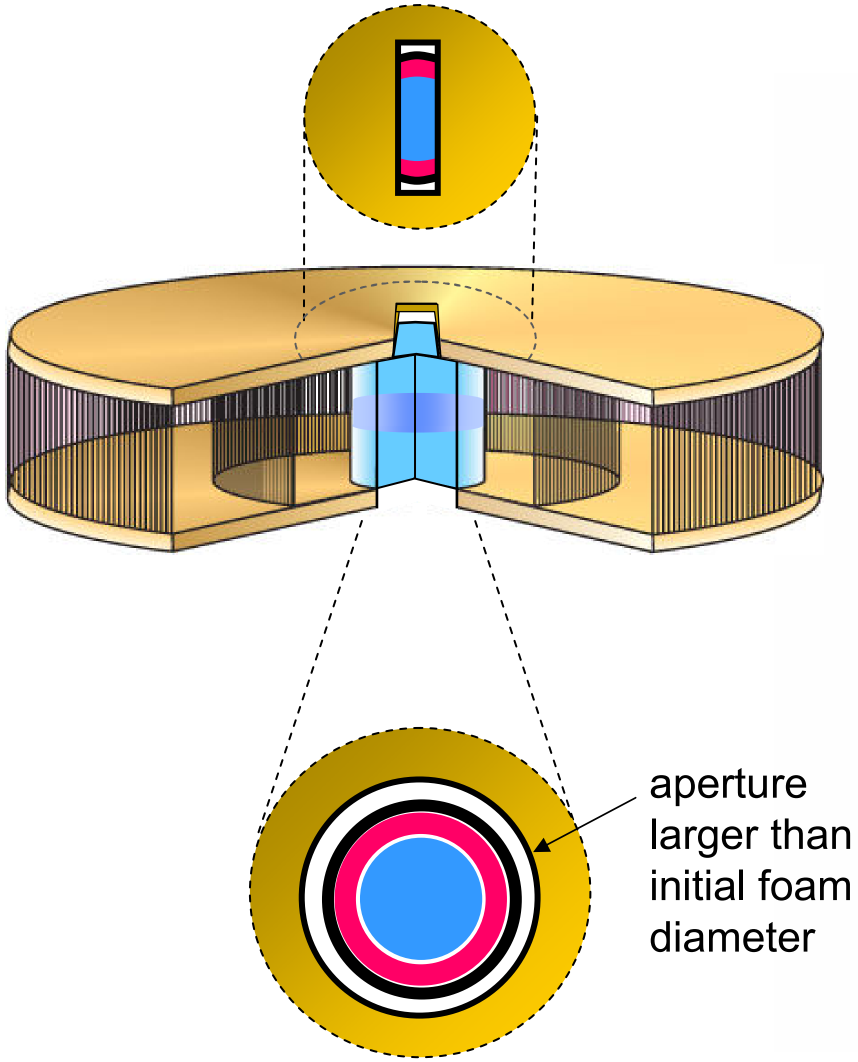
He-δ intensity profile

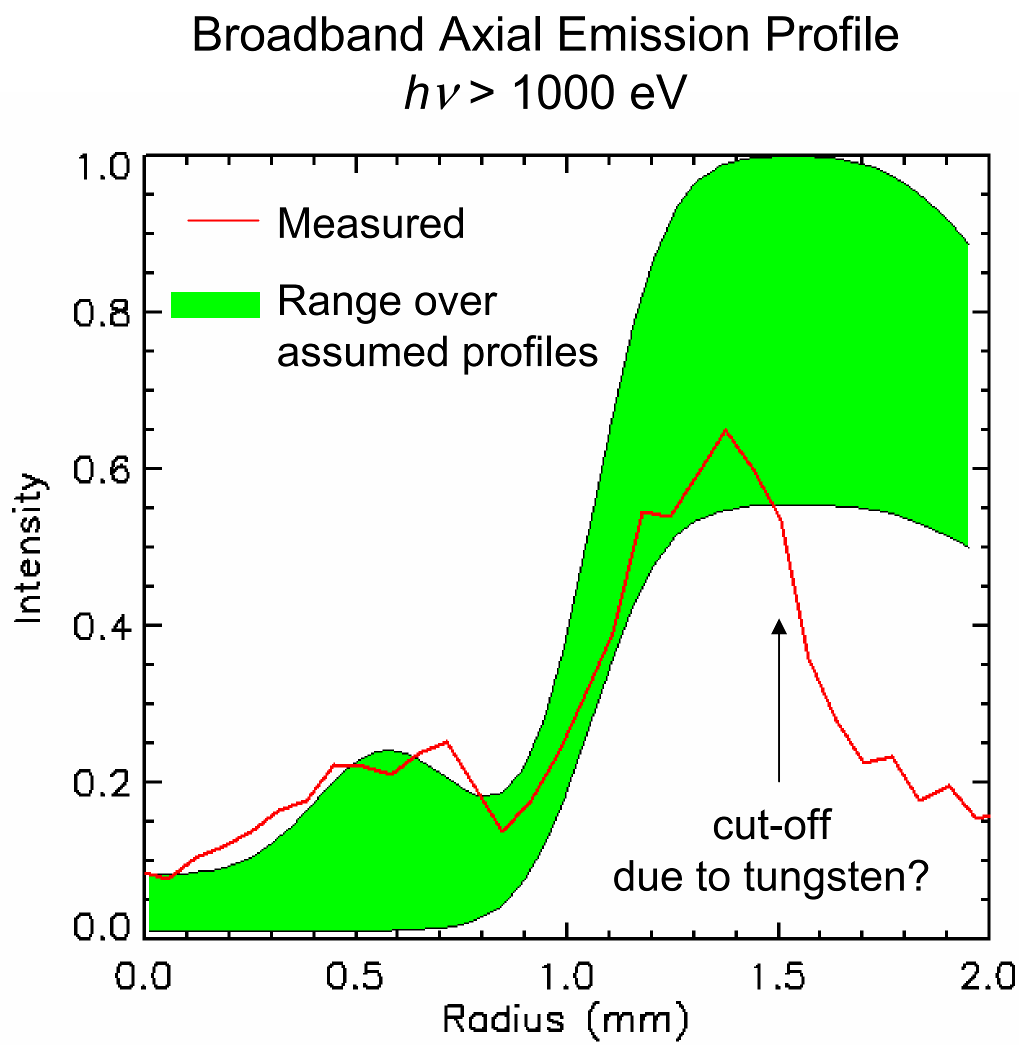


Ly-β intensity profile



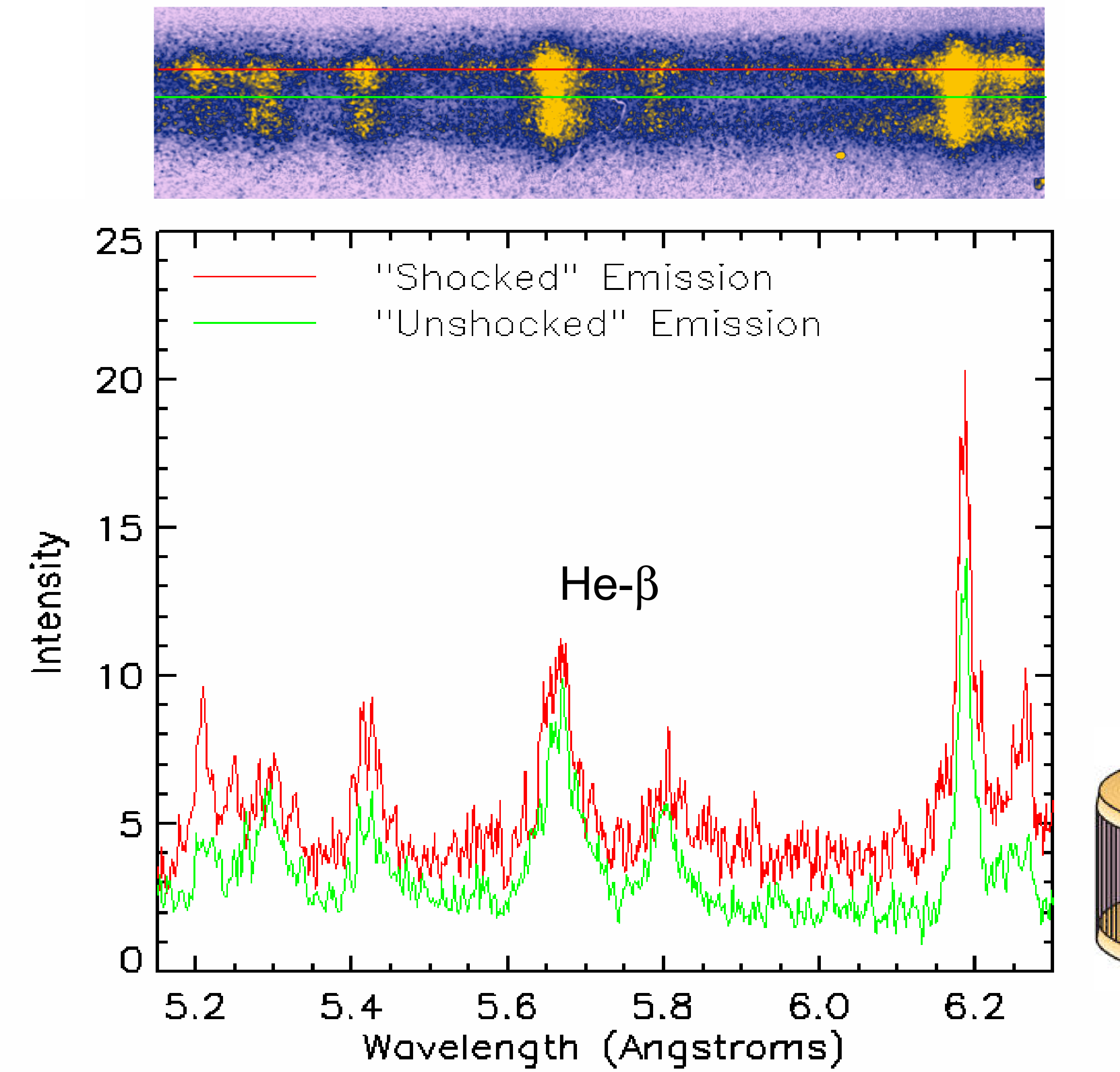
The broadband emission profile from x-ray pinhole camera data is in good agreement up to the emission peak.

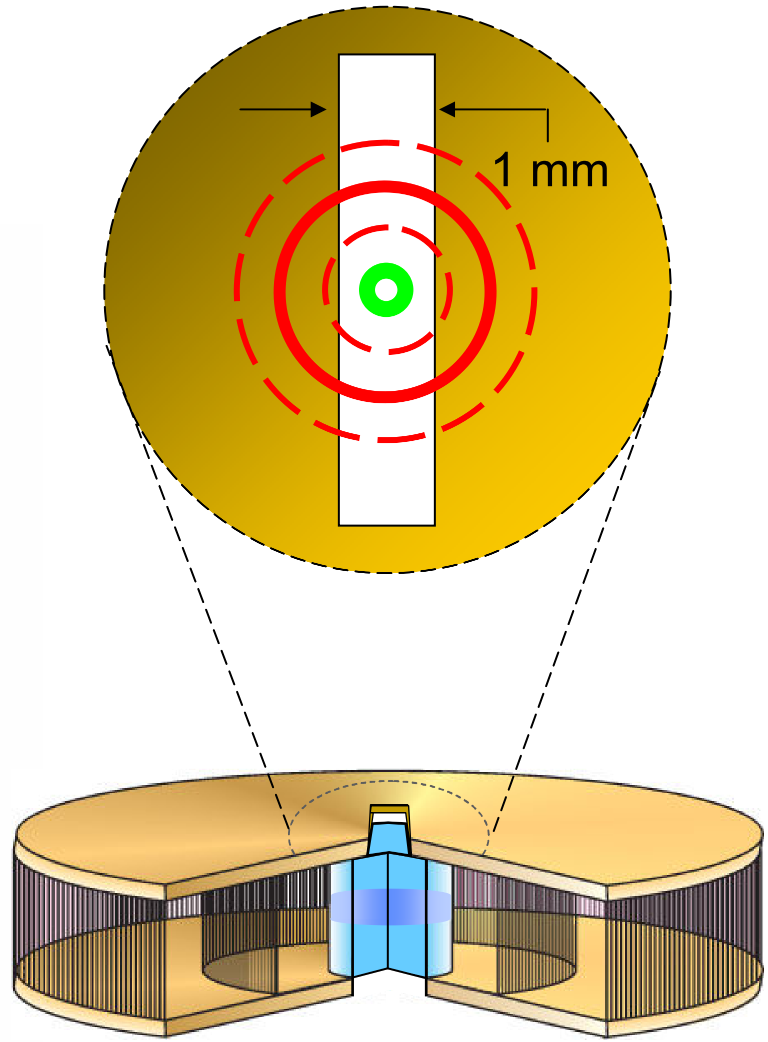




At r_s ~ 1.1 mm, the spectra are nearly homogeneous across the measured geometry.

Measured Si Emission Spectrum





Summary

- A strong radiating shock is the source of thermal energy for the Z-pinch Dynamic Hohlraum.

- The temperature and density of this shock have been measured through the interpretation of time- and space-resolved Si emission spectra from Si atoms doped across the central 3 mm height of the 12 mm tall DH.

- These measurements indicate a shock temperature decreasing from 400 - 250 eV, a shock density increasing from 15 - 40 mg/cc, and a shock pressure increasing from 4 – 8 Mbar.

- Once the main shock conditions are determined, interpretation of the photo-pumped Si emission spectra ahead of the main shock provides information on the density and temperature of the ablative shock.

- The measured conditions from both shocks can be used to infer the radial profile of the temperature and density conditions in the interior of the DH.