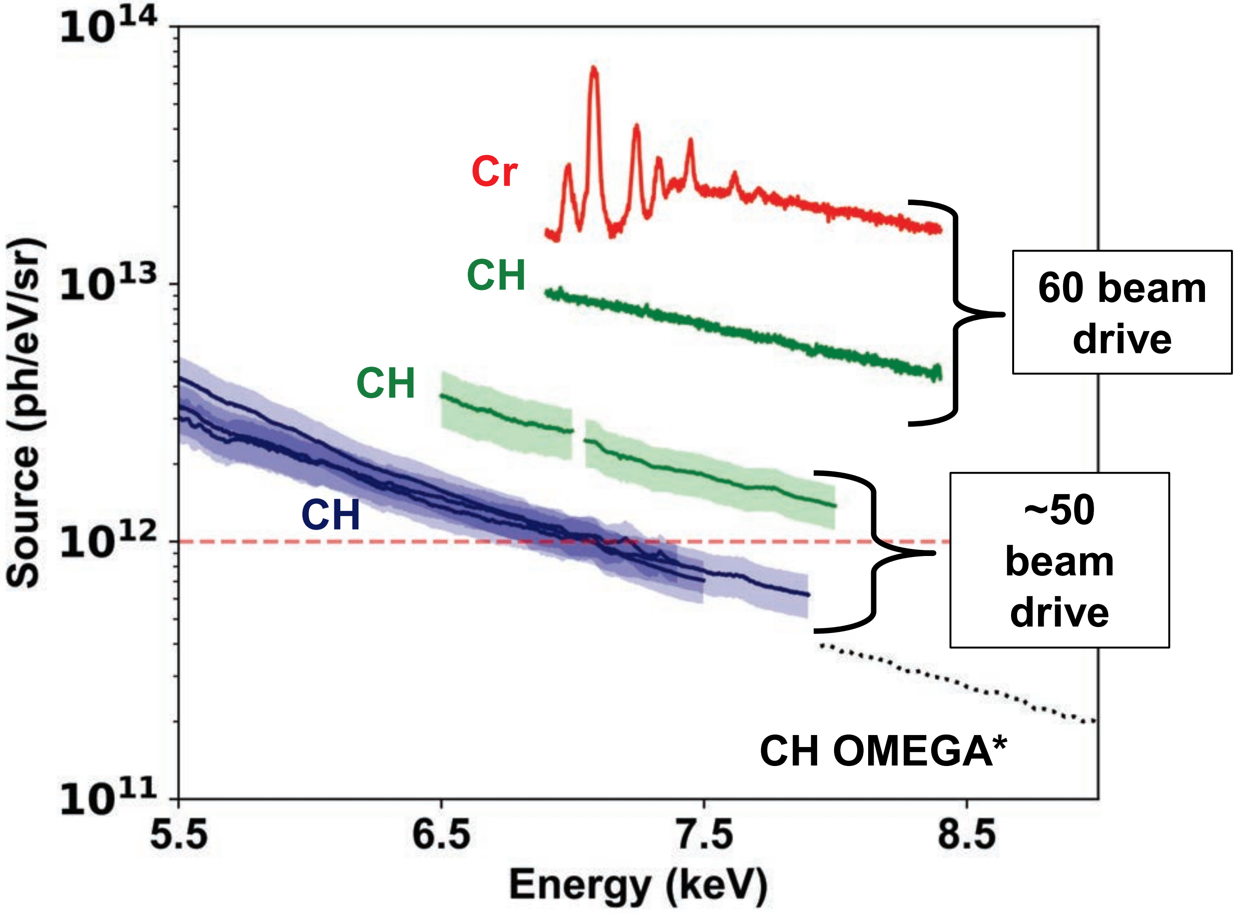
Characterization of the x-ray emission from spherical shells for x-ray absorption spectroscopy experiments on OMEGA-60



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*A. Do *et al.*, Rev. Sci. Instrum. 91, 086101 (2020)

We have characterized the performance of CH shell implosions, a common source for x-ray absorption spectroscopy (XAS) experiments*

- **XAS provides the temperature, density and complex chemistry of the probed material**
- **Implosion core emission is an ideal x-ray source for XAS, because it is bright, broadband, short duration and small**
- **The corona and afterglow emission stages can account for 25% of the total x-ray emission and can impact the spectral resolution due to source size broadening**
- **Improved illumination strategies and inner metal layers increase x-ray emission from CH shell implosions**

*D.A. Chin *et al.*, (in review) 2021

Collaborators

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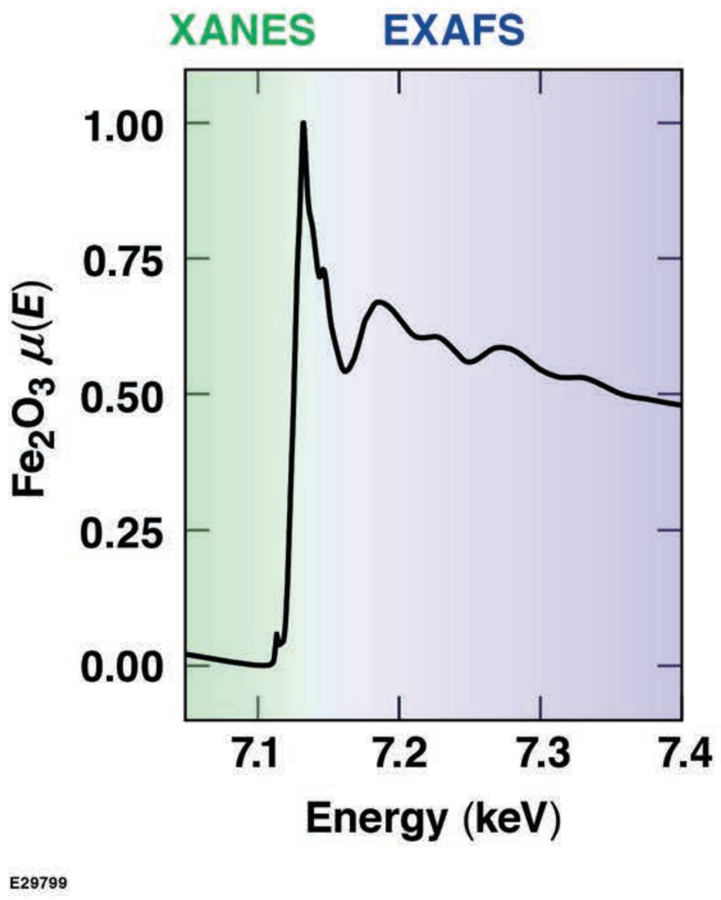
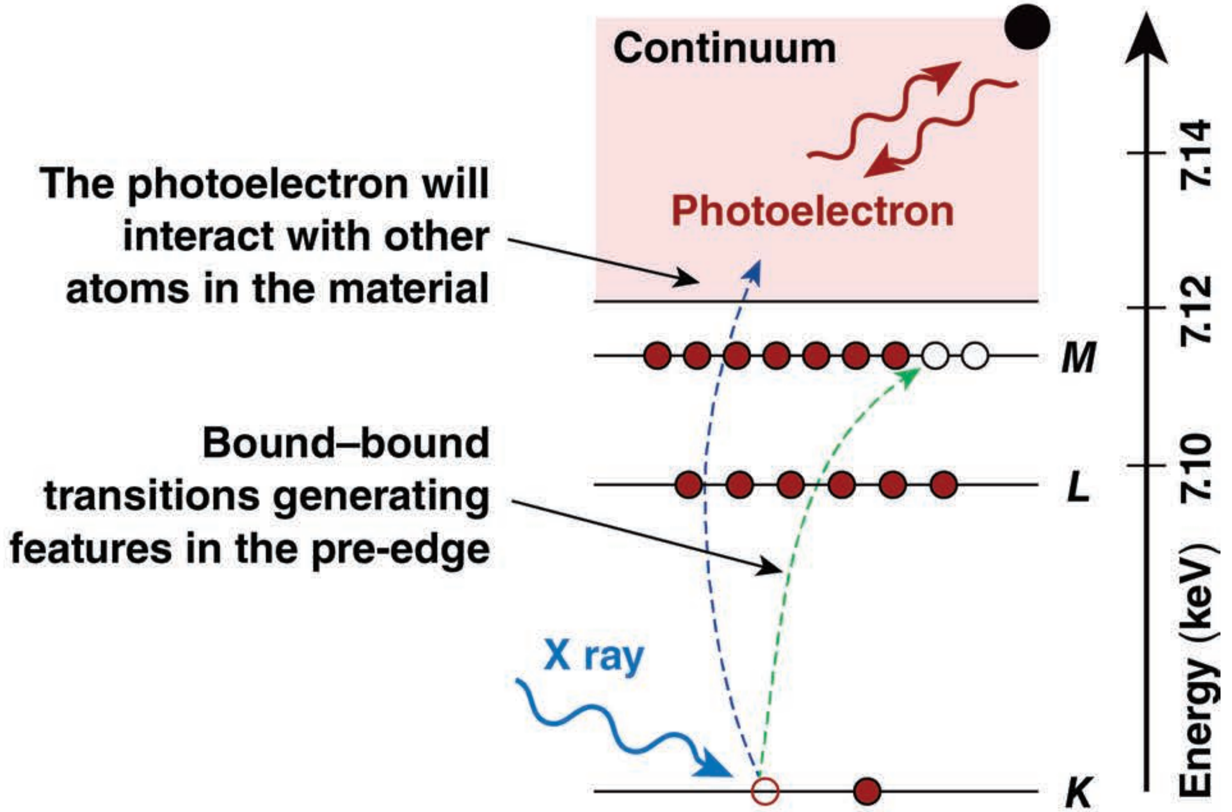
Spectral features near an x-ray absorption edge can be used to deduce the electronic density of states and atomic structure of matter





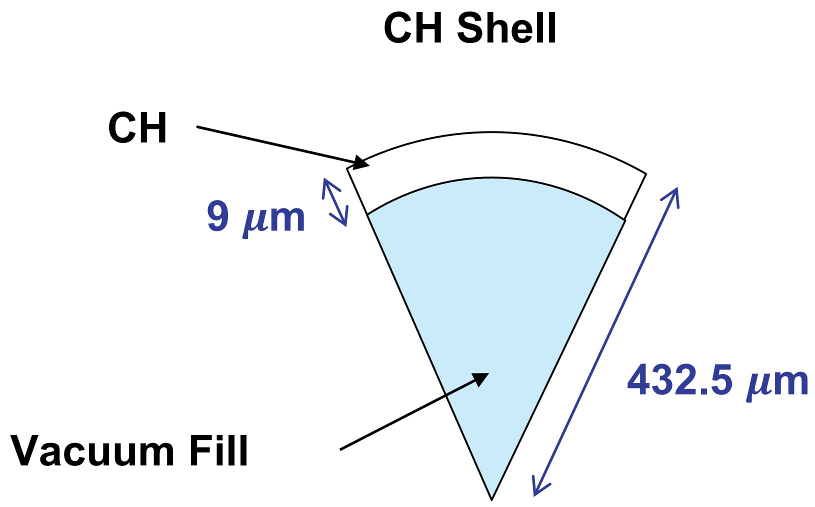
XANES: X-ray absorption near edge spectroscopy
EXAFS: Extended x-ray absorption fine structure

International X-ray Absorption Society, Fe2O3 Data, https://xaslib.xrayabsorption.org

M. Newville, Rev. Min. Geo. 78, 33 (2014).

Precision XAS requires bright, broadband, short duration and small x-ray sources

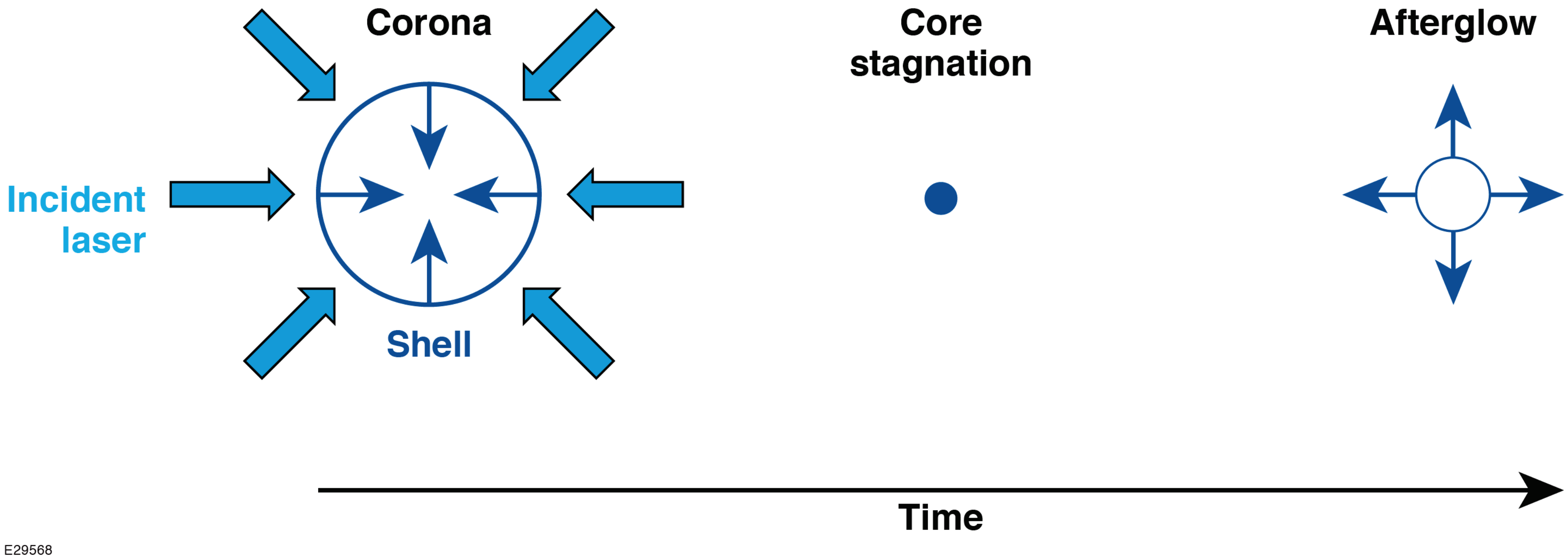
- Multiple different implosion shells have been studied to determine the optimal target design[*,**,†]
- Recent XAS experiments used CH shells with a vacuum fill[‡]



This work will focus on 9 μm thick CH shells with an 865 μm outer diameter and a vacuum fill

[*] B. Yaakobi *et al.*, J. Opt. Soc. Am. B 20, 238 (2003)
[**] F. Coppari *et al.*, Rev. Sci. Instrum. 88, 83907 (2017)
[†] A. Krygier *et al.*, Rev. Sci. Instrum. 89,10F114 (2018)
[‡] Y. Ping *et al.*, Phys. Rev. Lett. 111, 065501 (2013).

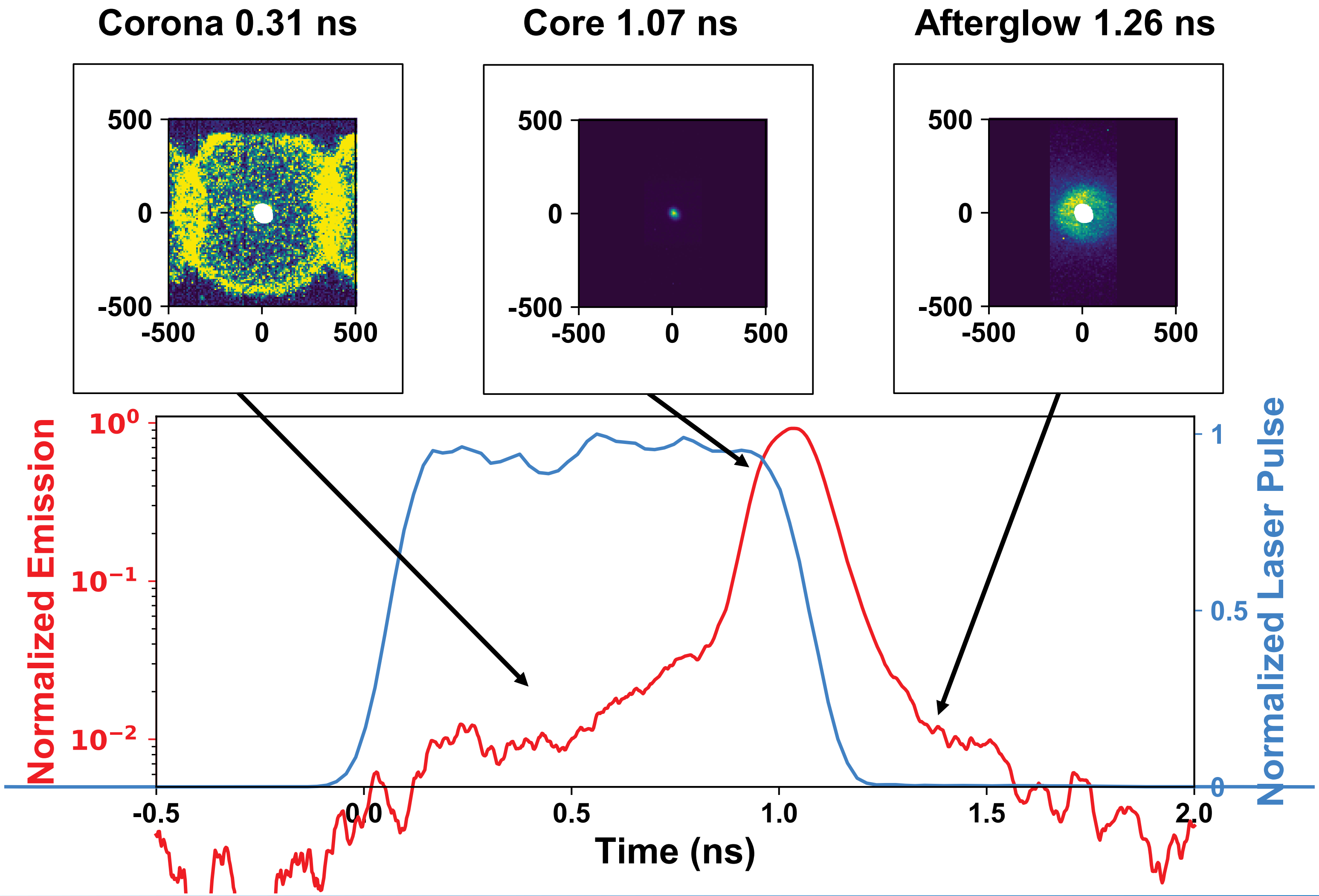
The corona and afterglow emission stages can be sizeable contributors (~25%) to the x-ray emission from an implosion



The larger source size can degrade spectral resolution and must be accounted for

Time resolved imaging and spectroscopy measured the x-ray emission stages

Time Resolved Images



Color scale adjusted for visibility

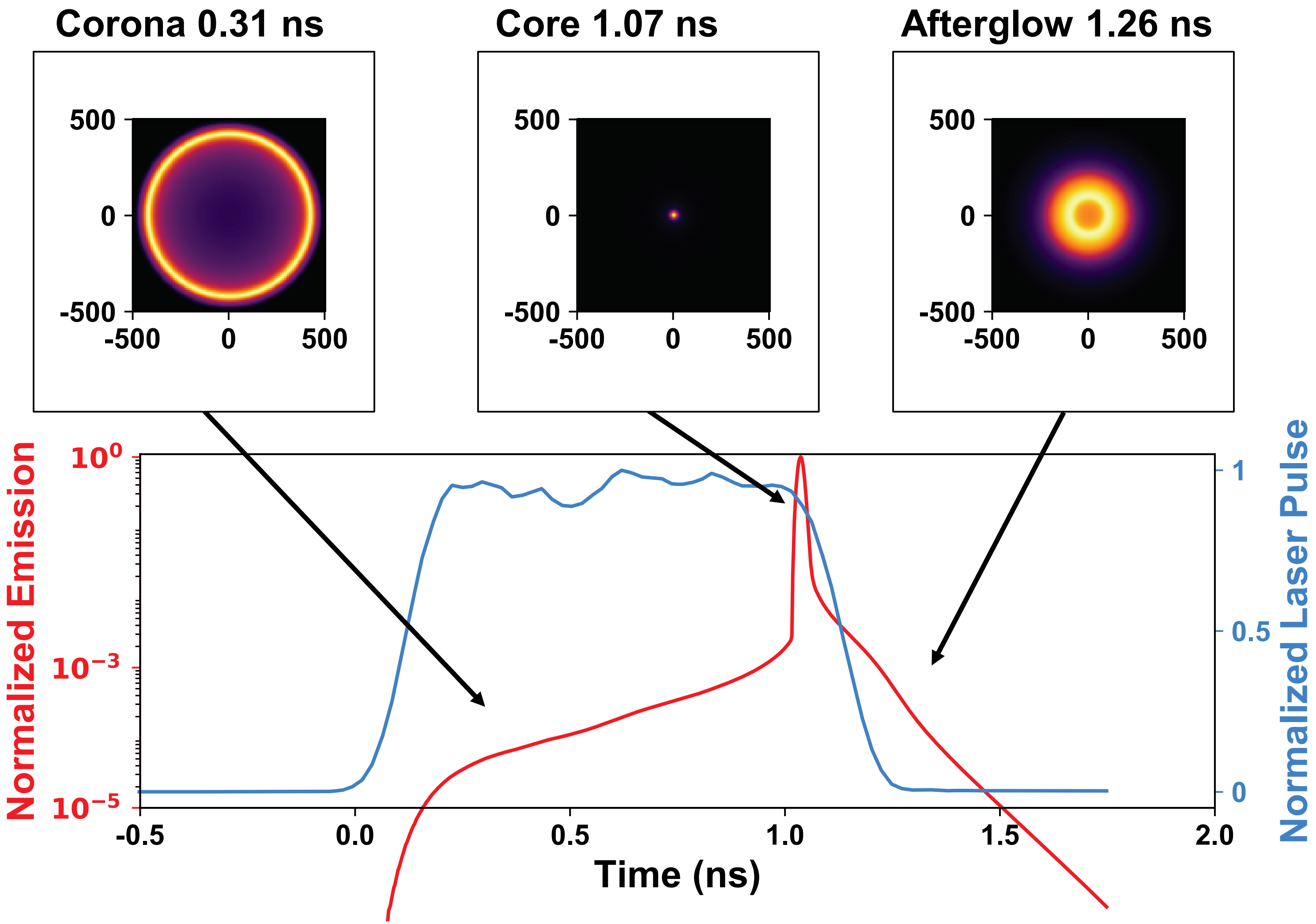
Measured x-ray emission between 7 and 8 keV

Image Units: μm

Lilac simulations were used to construct models for each of the three x-ray emission stages

Simulated Time Resolved Images

Simulated x-ray emission between 7 and 8 keV



Color scale adjusted for visibility

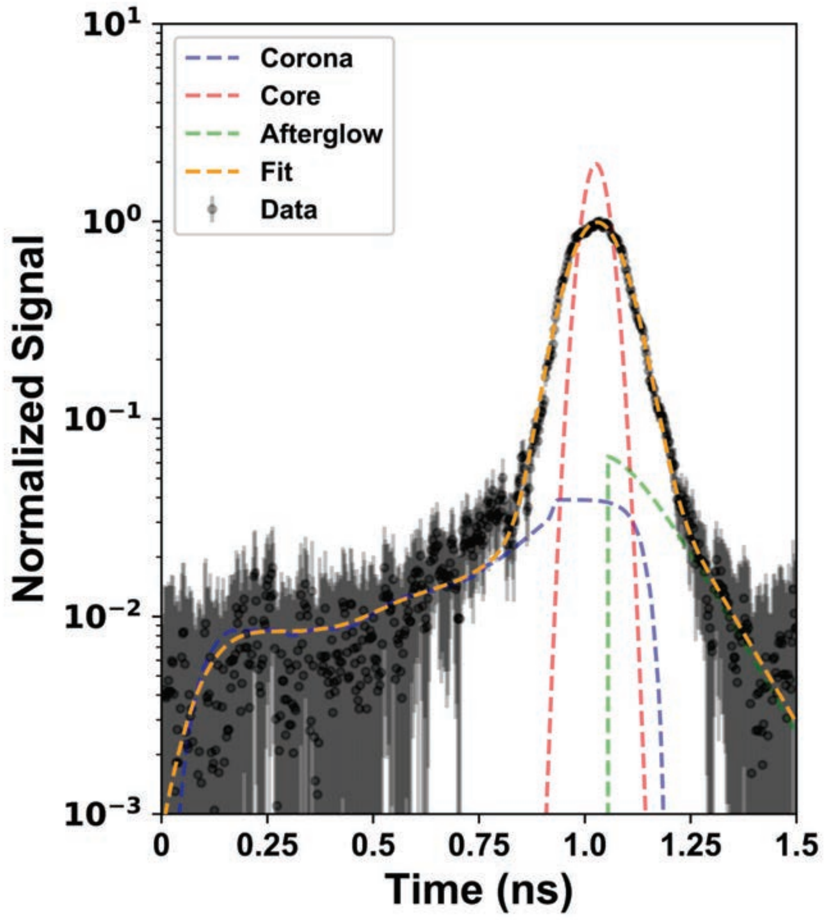
Image Units: μm

J. Delattrez *et al.*, Phys. Rev. A 36, 3926 (1987)

Models were applied to each stage and fit to the data to characterize the fraction of the signal in each stage

- An 8 parameter model was developed to characterize the fraction of the signal in each stage
- The model was verified using the hydrodynamic simulation and then fit to the data

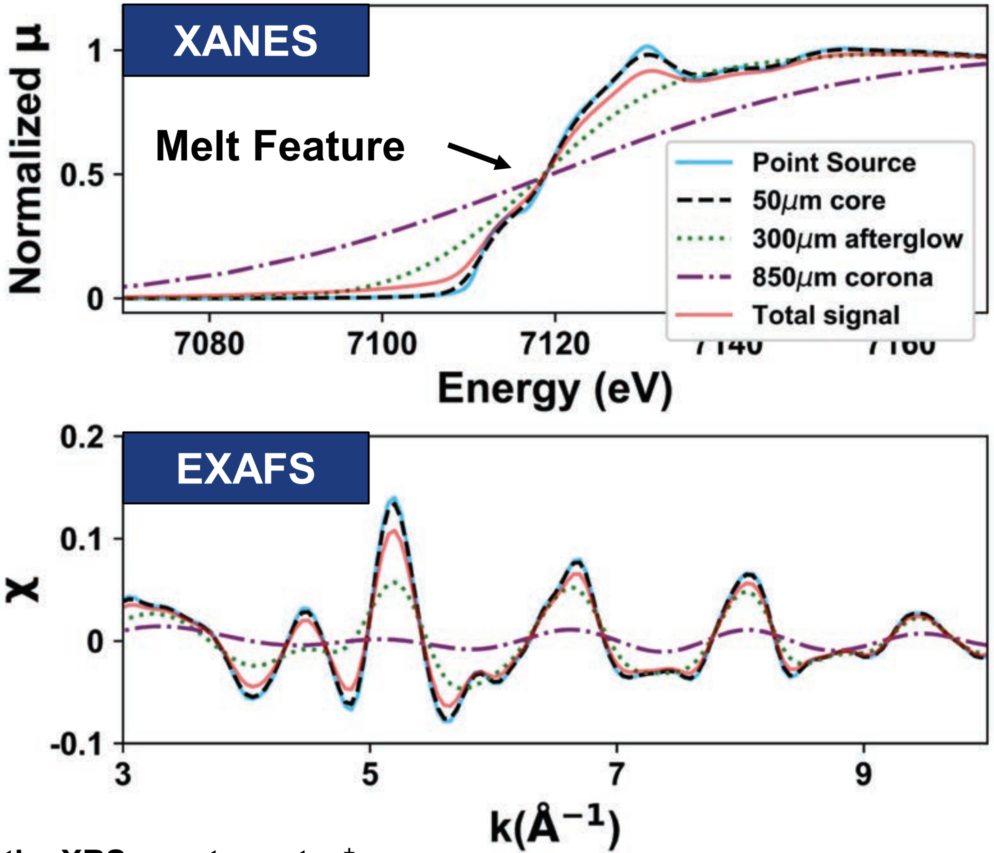
	Corona	Core	Afterglow
Signal Fraction	$12^{+2}_{-2}\%$	$76^{+7}_{-9}\%$	$12^{+7}_{-6}\%$



J. Salvatier *et al.*, Peer J Computer Science 2, e55 (2016)

The source broadening from each stage was calculated and used to simulate the absorption spectrum of iron

A point source spectrum was degraded using the spectral resolution corresponding to each stage†



The additional broadening terms prevent the ability to use XANES to determine the iron melting*

The additional broadening terms decrease the Debye-Waller Factor by 5 – 10%**

†Assuming the XRS spectrometer‡

‡ Y. Ping *et al.*, Phys. Rev. Lett. 111, 065501 (2013).

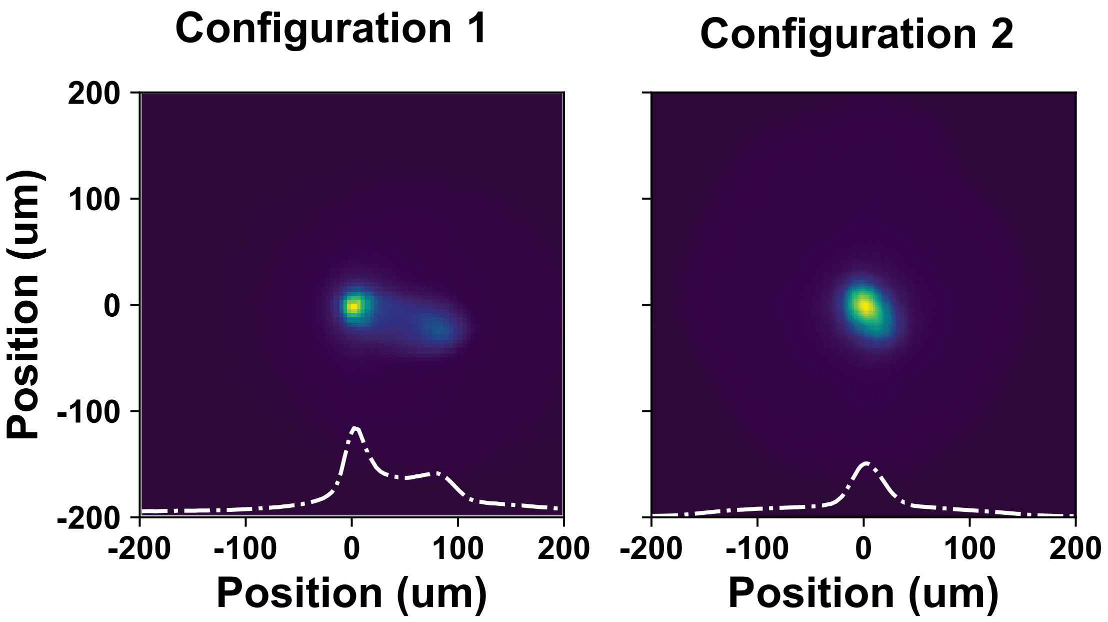
*M. Harmand *et al.*, Phys. Rev. B 92, 024108 (2015)

**E. Sevillano *et al.*, Phys. Rev. B 20, 4908 (1979)

By repointing the drive beams to more symmetrically illuminate the shell, we increased the symmetry of the core stagnation

- In XAS experiments, five beams are used to drive the XAS target while the remaining beams illuminate the CH shell

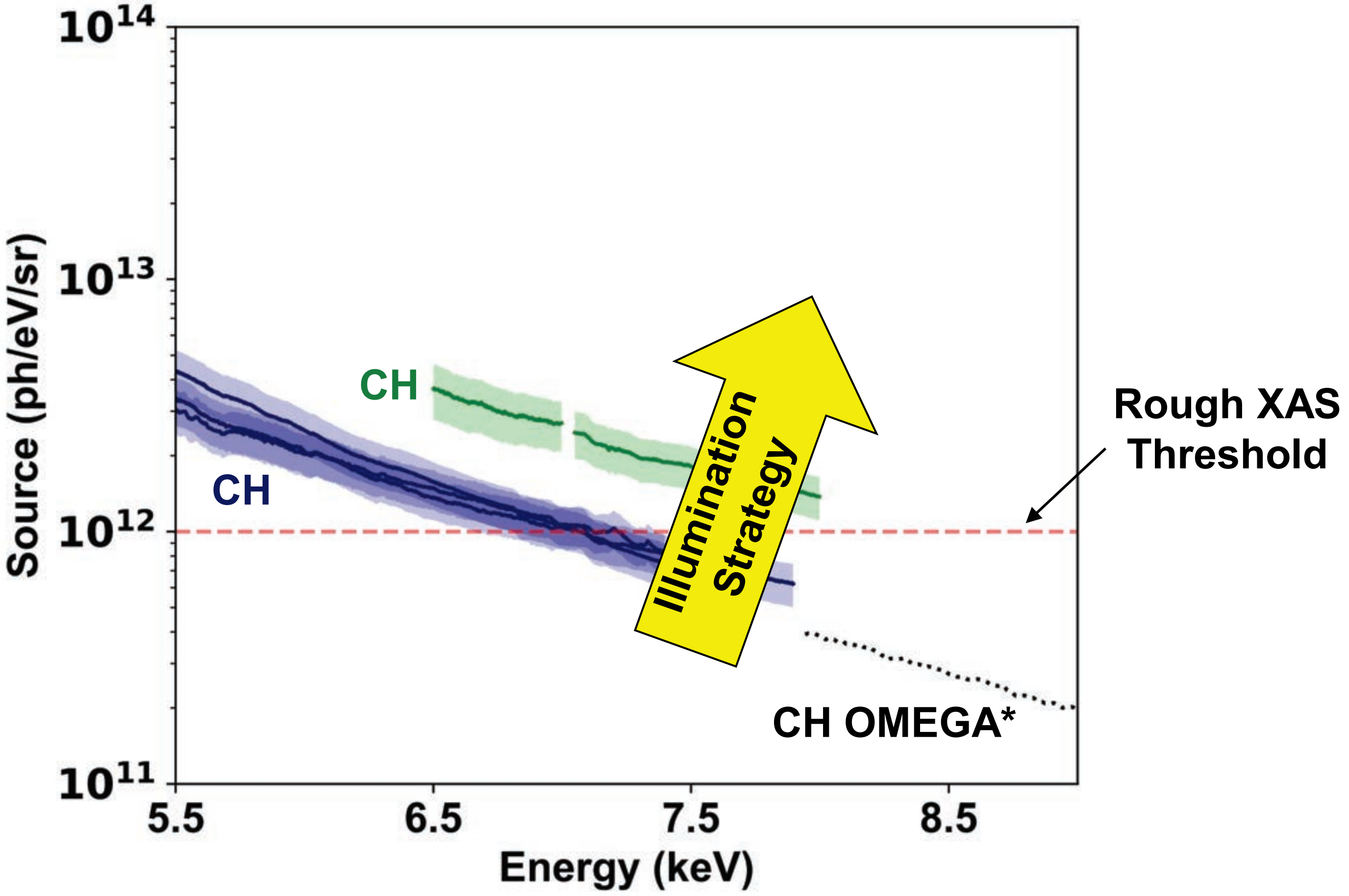
- The drive beams were repointed in configuration 2 resulting in a 4x decrease in the variation of the absorbed laser intensity



R. S. Craxton and R. L. McCrory, J. Appl. Phys. 56, 109 (1984)
R.S. Craxton *et al.*, Phys. Plasmas 12, 056304 (2005)

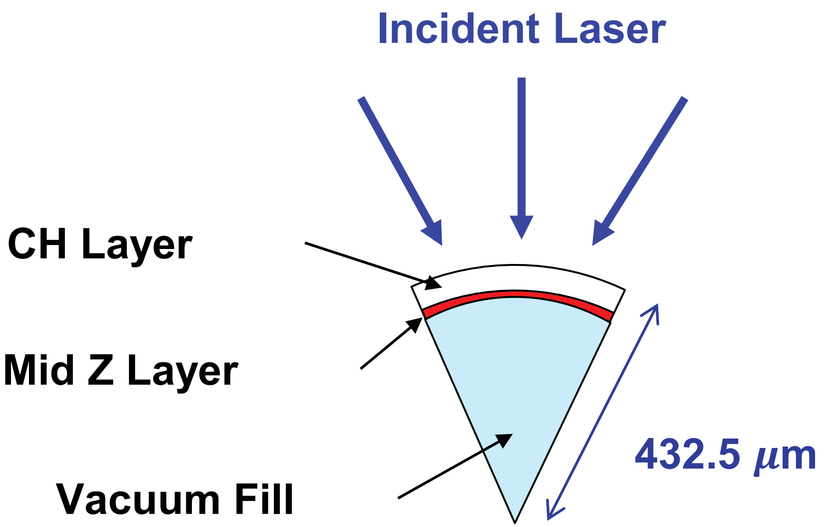
An improved target illumination strategy resulted in a factor of two increase in the x-ray emission

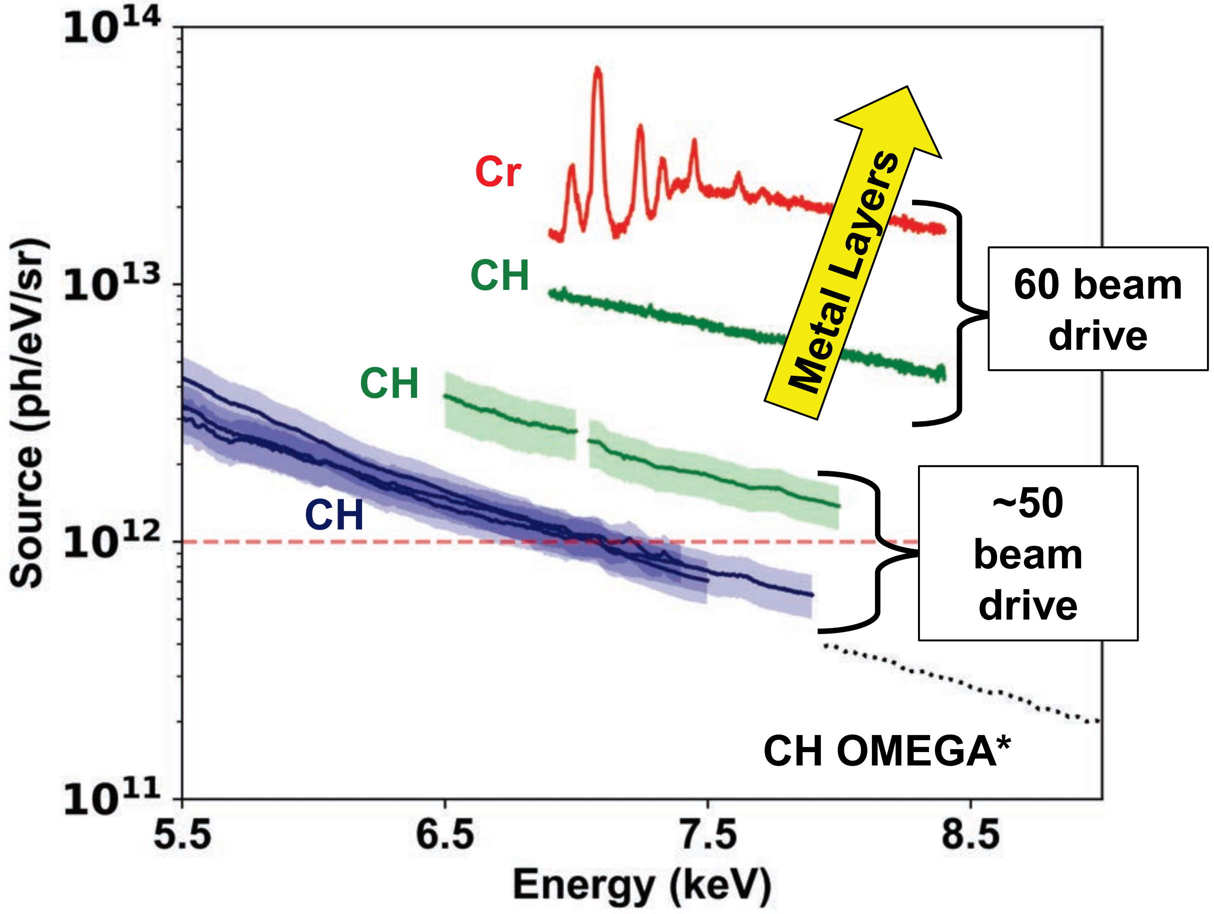
The target illumination strategy was improved by changing the laser phase plates and repointing the target drive beams



*A. Do *et al.*, Rev. Sci. Instrum. 91, 086101 (2020)

Preliminary results indicate metal layers can further increase the total x-ray emission





Experiments are scheduled to characterize the spatial and temporal profile of the metal layer shells

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Future experiments are planned to characterize the spatial and temporal x-ray emission profile of the metal layered shells for XAS experimental use

Backup

An 8 parameter model was used to fit the x-ray emission and constrain the three emission stages

- **Corona Emission:**

$$J_{corona}(t; A_1, B_1) = \frac{A_1}{\sqrt{\tau}} e^{-\frac{1}{\tau}} \text{ and } \tau = B_1 \left(\frac{p(t)}{r_{crit}(t)}\right)^{\frac{2}{3}}$$

- **Core Emission:**

$$J_{core}(t; A_2, \mu_2, \sigma_2) = A_2 e^{-\frac{1}{2}\left(\frac{(t-\mu_2)}{\sigma_2}\right)^2}$$

- **Afterglow Emission:**

$$J_{afterglow}(t; A_3, v_3, t_3) = \begin{cases} 0 & t < t_3 \\ A_3 \eta_e^2 & t \geq t\_3 \end{cases} \text{ and } \eta_e = \frac{1}{\left(50 + v_3 (t - t_3)^{\frac{3}{2}}\right)^3}$$

- **Total Emission:**

$$J_{model} = J_{corona} + J_{core} + J_{afterglow}$$