SAND2006-1649C

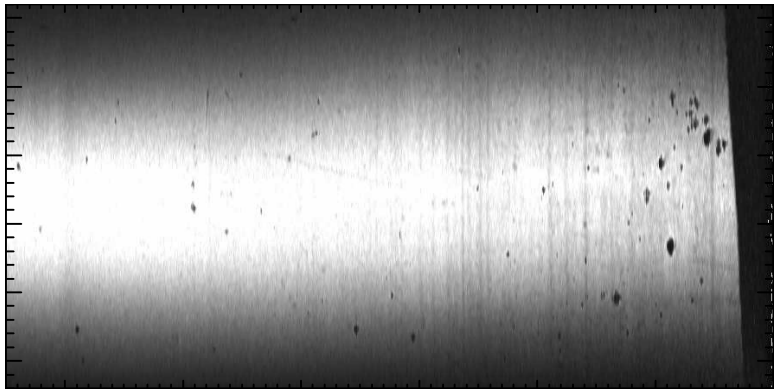
Opacity measurements at Z

High Energy Density Laboratory Atrophysics

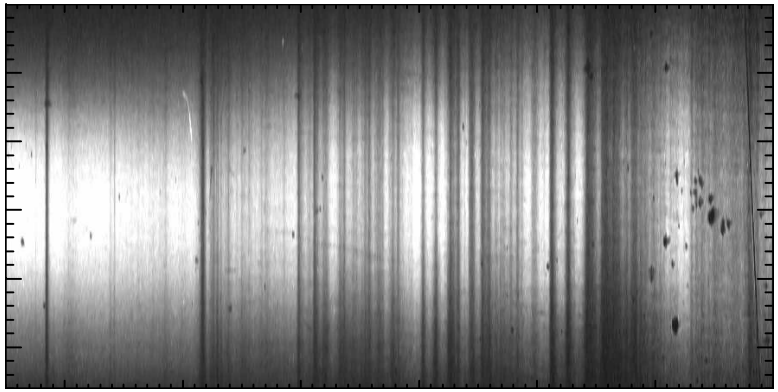
Houston, Texas

March 11, 2006

without Fe



with Fe + Mg



J. E. Bailey (jebaile@sandia.gov)

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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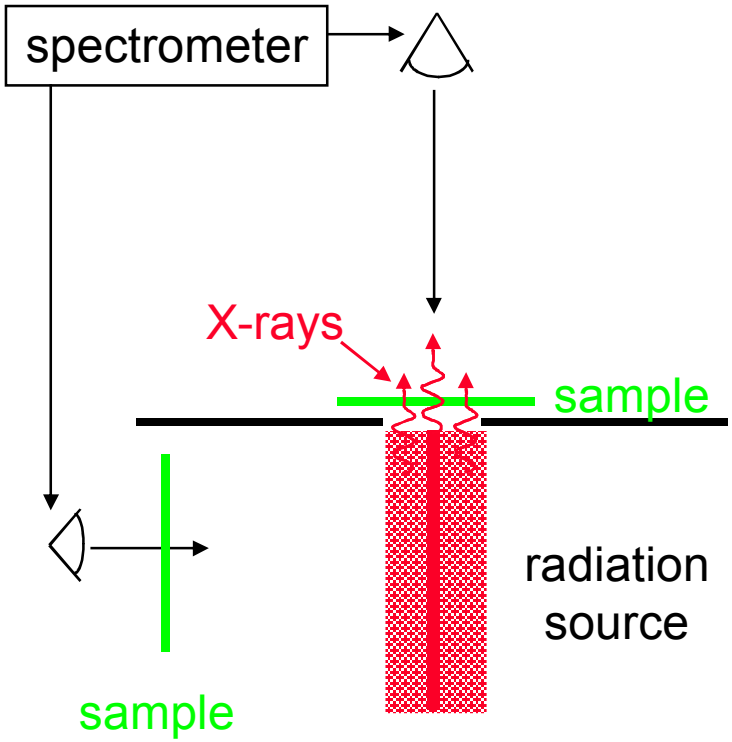
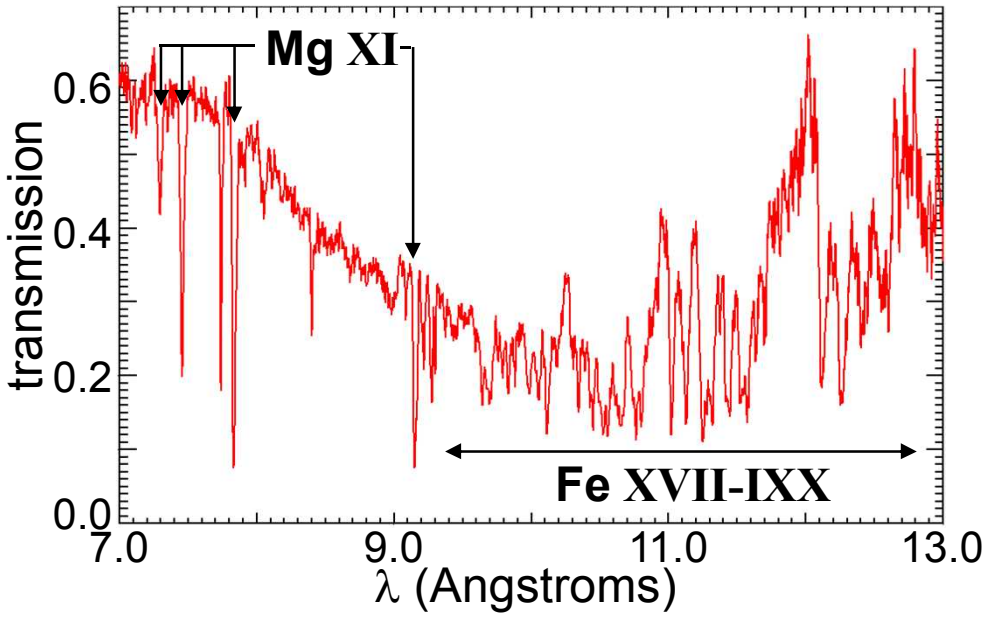
Z opacity experiments strengthen existing database and extend measurements beyond T ~ 150 eV



Fe + Mg transmission at
T_e ~ 160 eV, n_e ~ 10^{22} cm^{-3}



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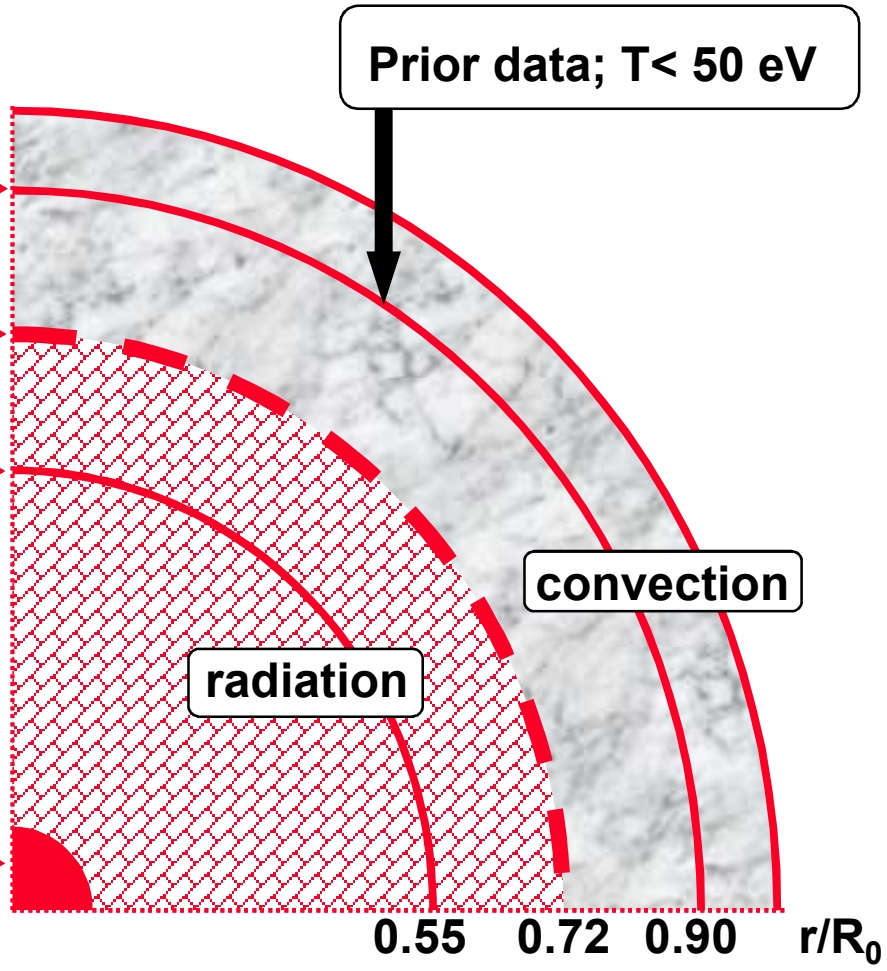
Laboratory opacity measurements at stellar interior conditions are not presently available

T(eV)	n_e (cm^{-3})	ρ (g/cc)
54	$1x10^{22}$	0.025
182	$9x10^{22}$	0.18
293	$4x10^{23}$	0.77
1360	$6x10^{25}$	157



Solar model : J.N. Bahcall et al, Rev. Mod. Phys. 54, 767 (1982)

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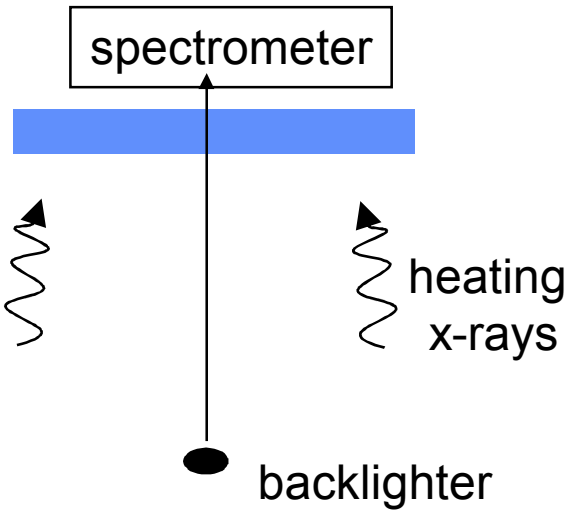
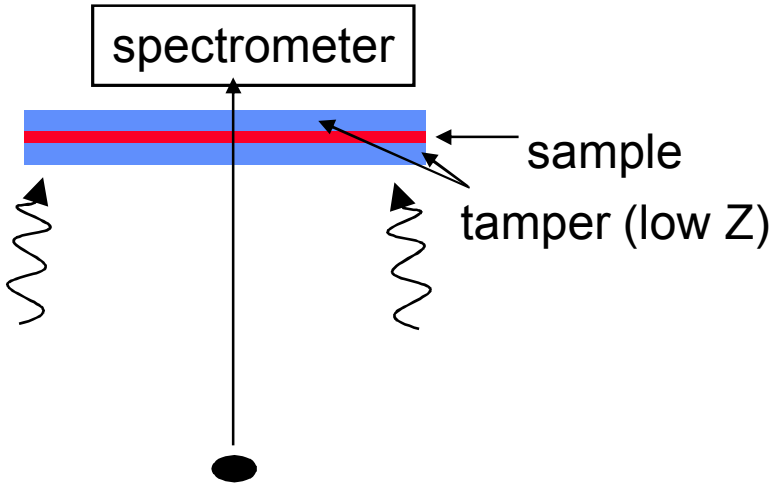
Mid-Z elements pose a challenge for opacity calculations

- Charge state distribution (spectroscopic accuracy)
- What transitions must be included?
- What approximations for configuration and transition grouping?
- What line broadening?
- How accurate are calculations of bound-free absorption?

Anatomy of an opacity experiment





Comparison of unattenuated and attenuated spectra determines transmission

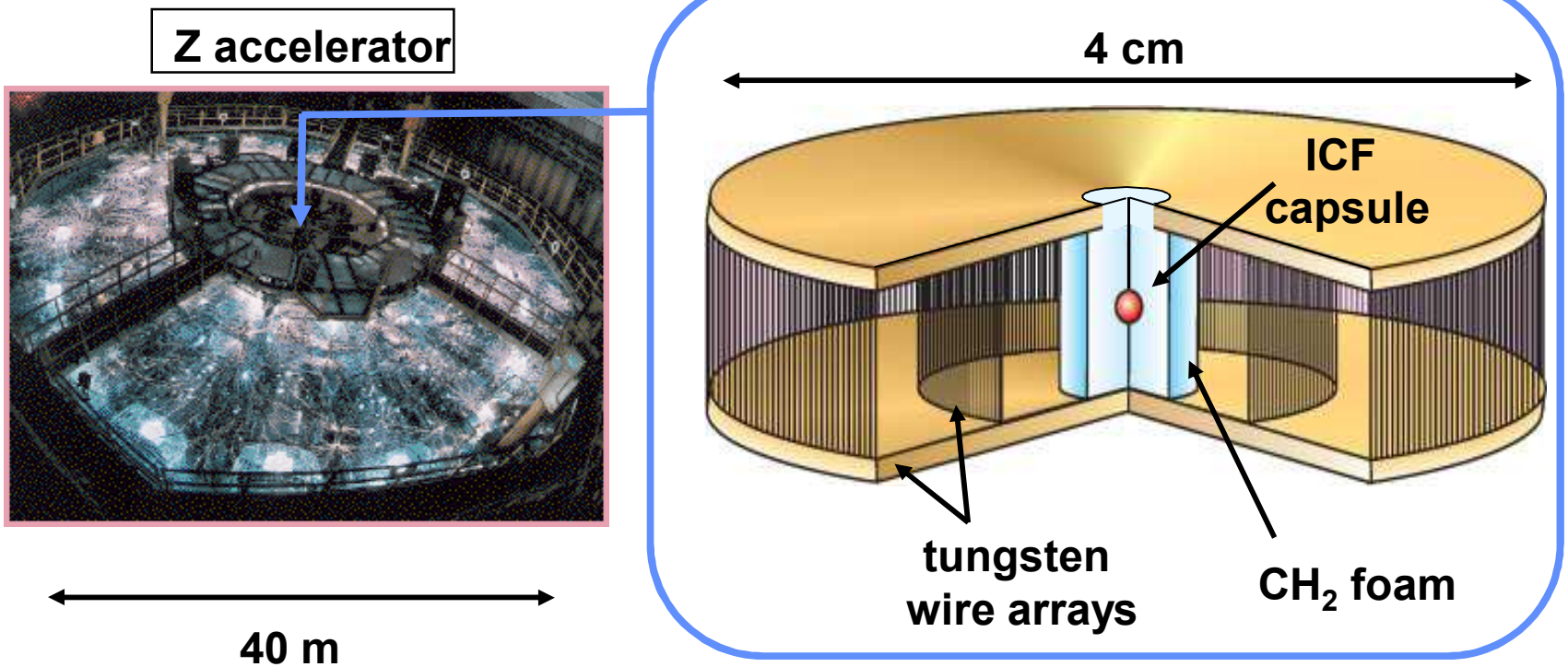
$T = \exp -\{\mu\rho x\}$

Desirable features of an opacity experiment

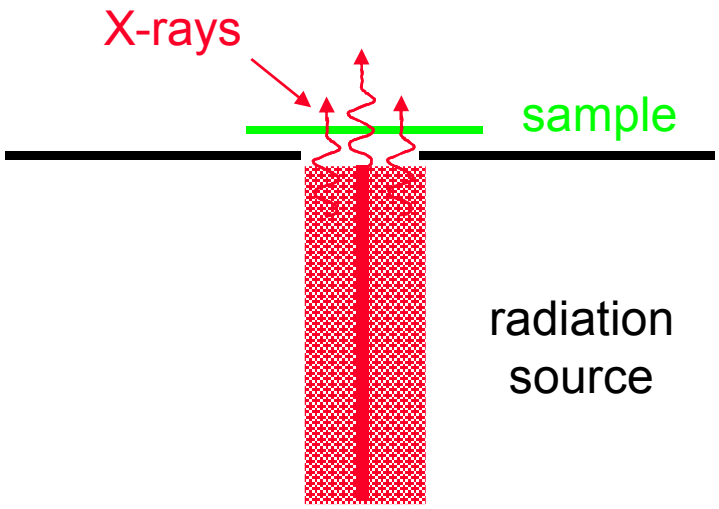
- Sample spatial uniformity (thin, large lateral size, thick tamper)
- Minimal temporal variations during probe time (backlight short compared to heating x-ray variation)
- Steady state (long duration heating x-rays)
- Temperature and density measurements (large wavelength range to enable simultaneous low Z and high Z measurements)

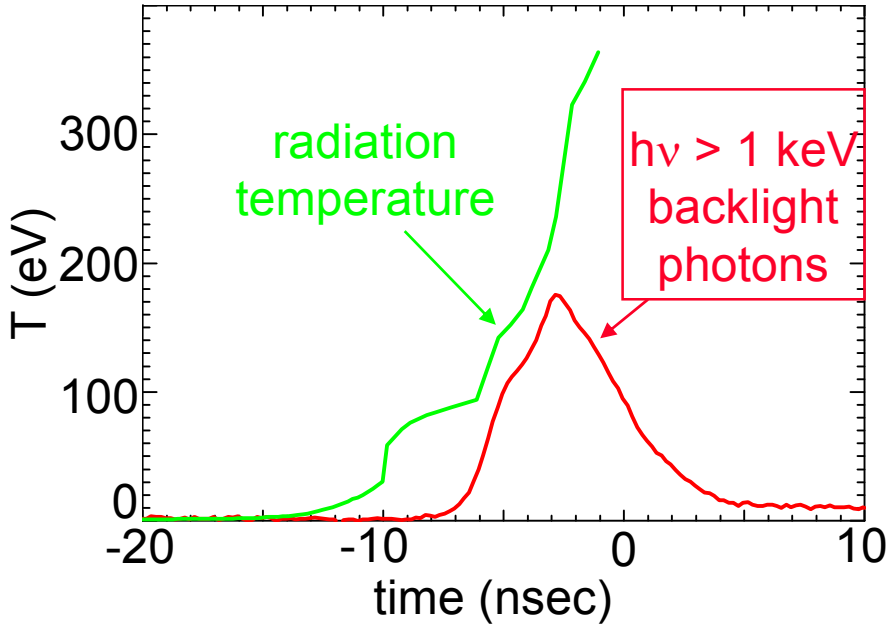
Characteristics of Z x-ray source can promote quality measurements

Opacity experiments can exploit the intense radiation provided by the Z accelerator



The radiation source heats and backlights the sample





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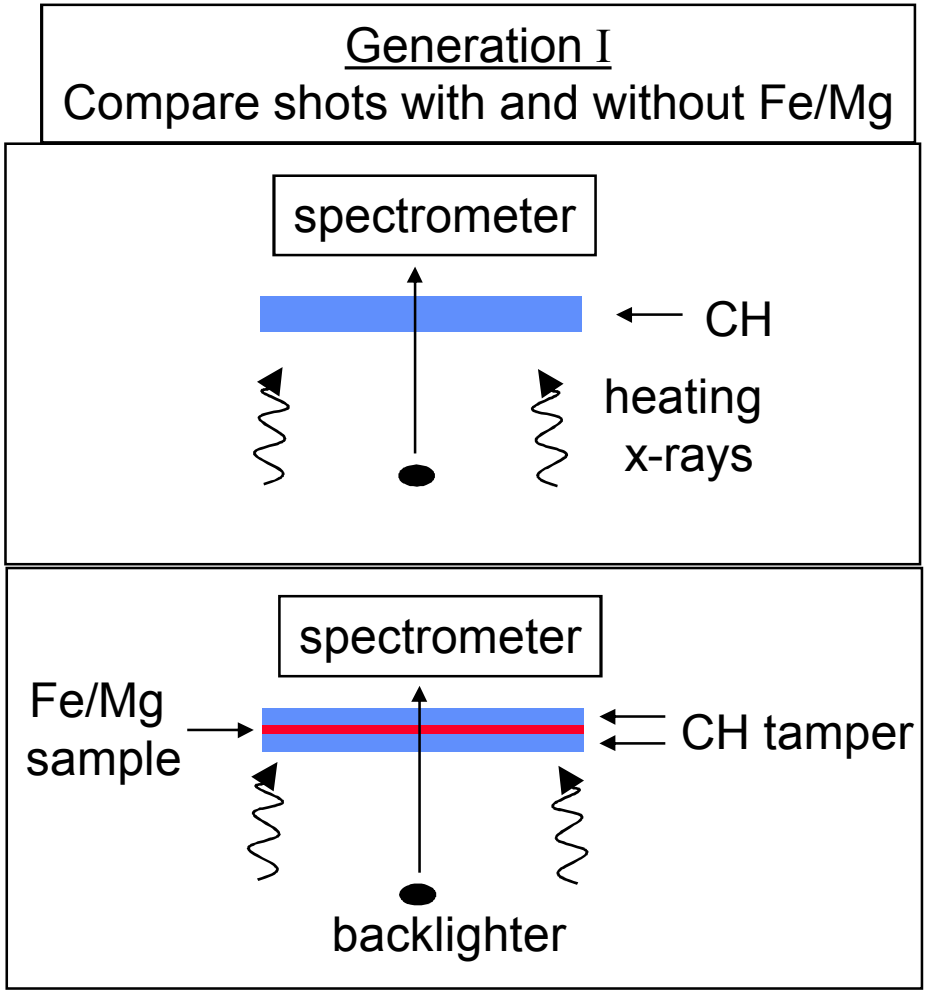
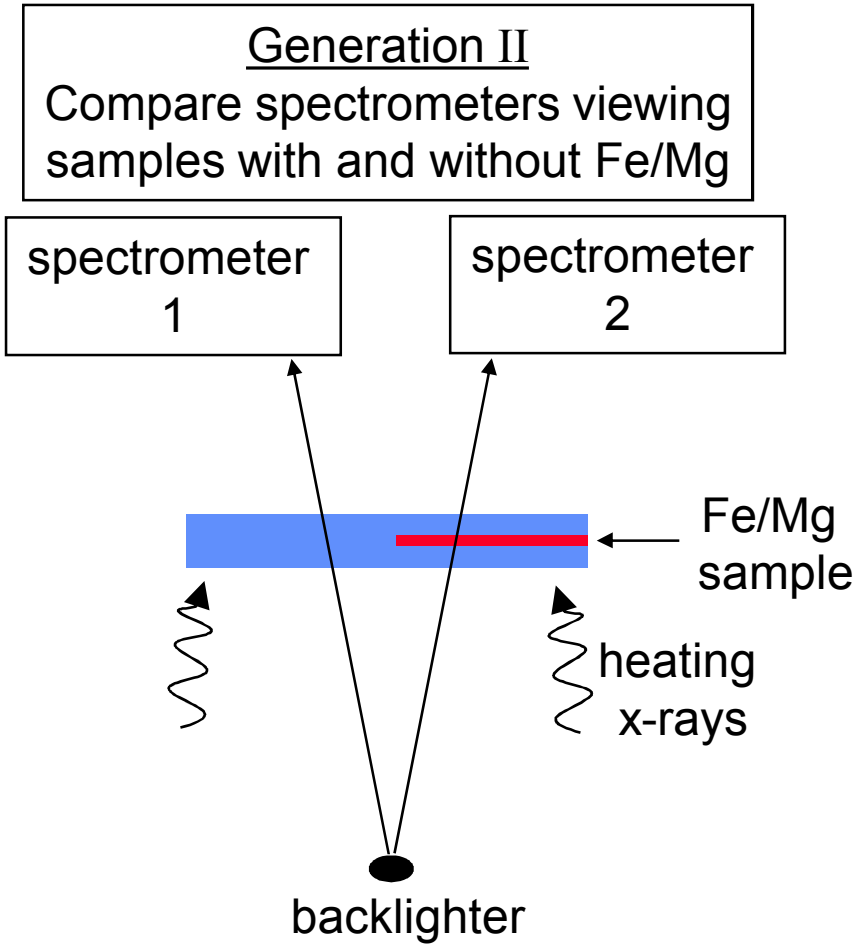
Two types of opacity measurements have been performed





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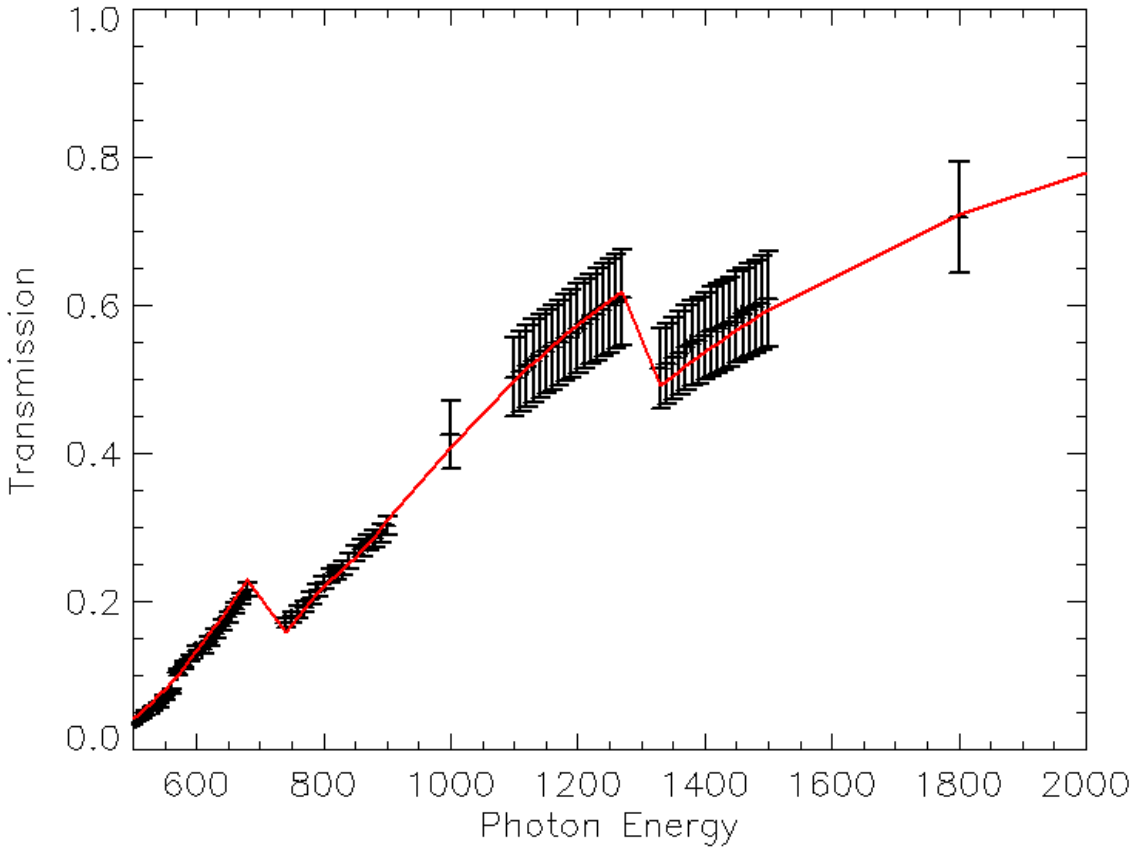
Recent experiments used samples characterized with synchrotron x-ray transmission measurements



- **The transmission as a function of photon energy measures areal density of individual sample constituents**

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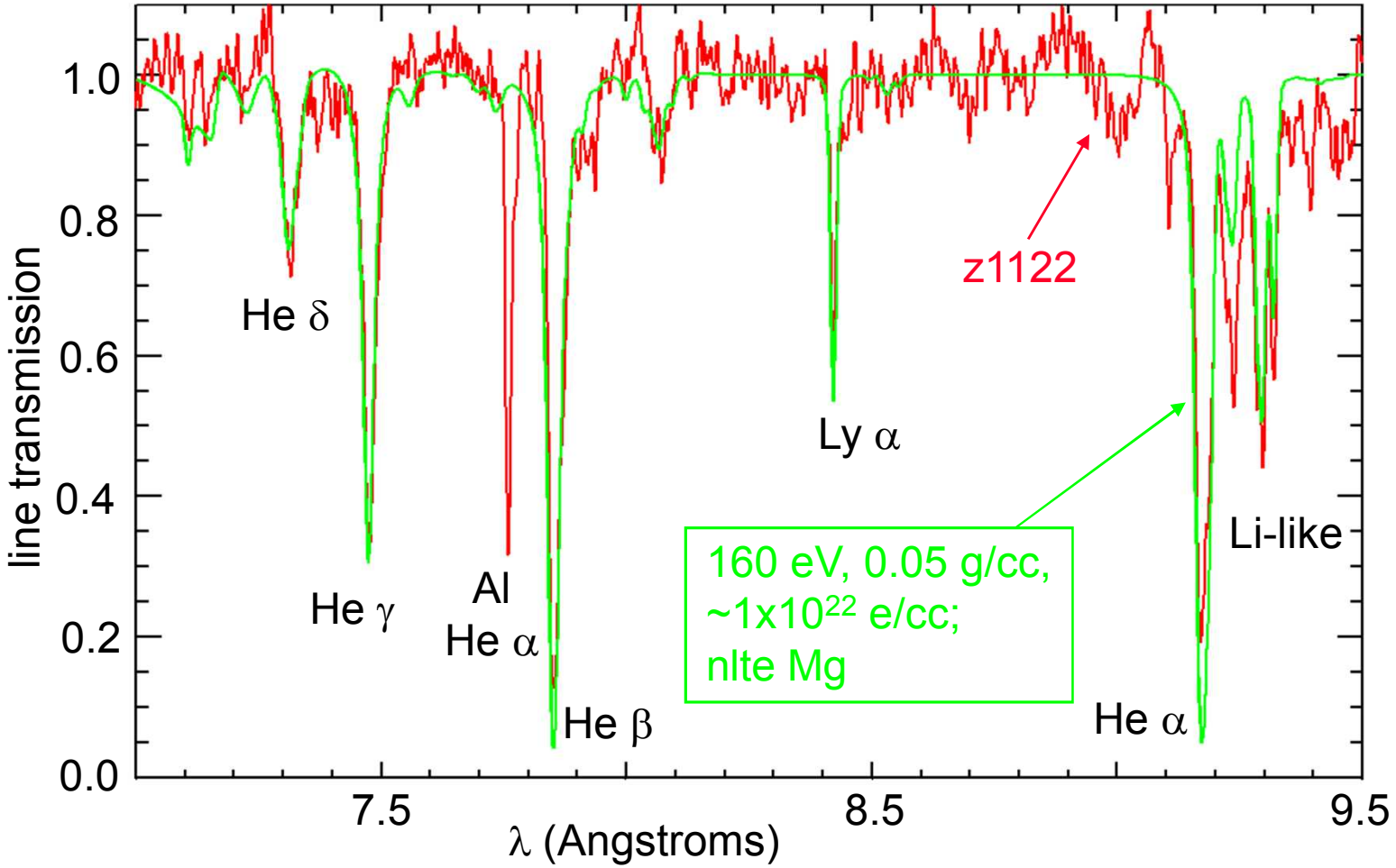
The sample conditions are diagnosed from Mg absorption spectra



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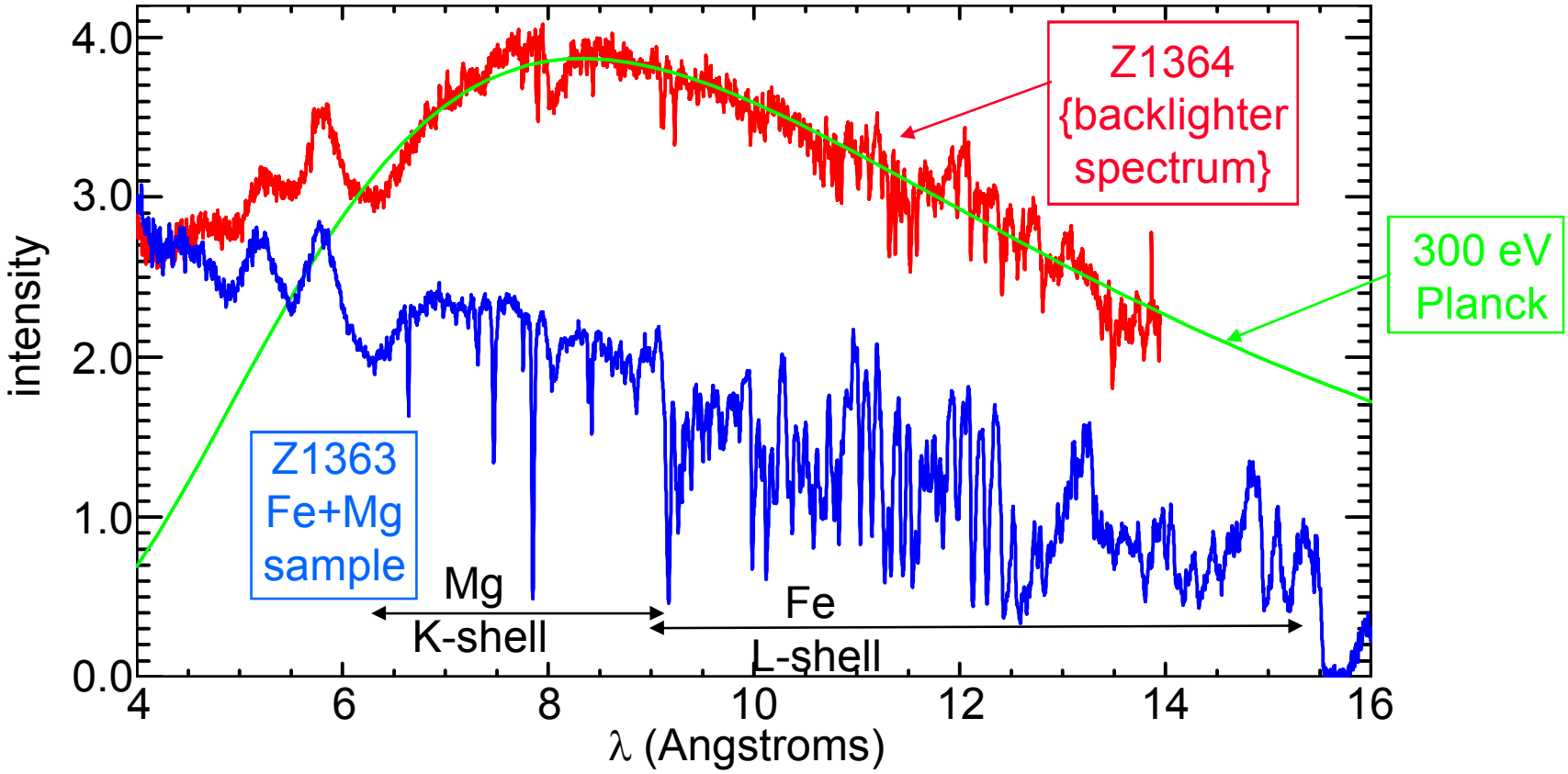
Experiments with and without Fe enable determination of the Fe transmission



- The difference between z1363 &z1364 is the Fe+Mg transmission
- Assuming shot to shot reproducibility

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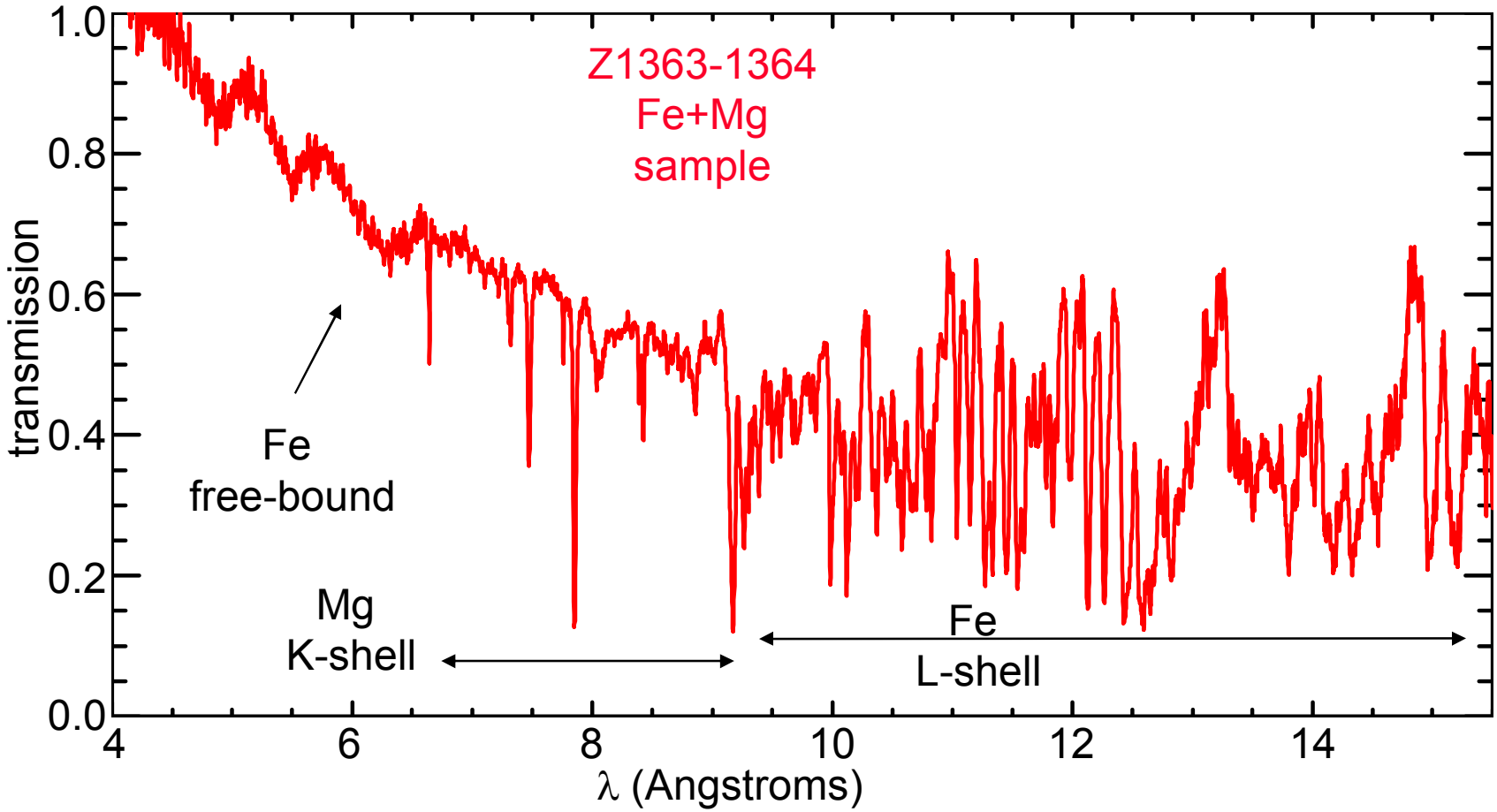
The dynamic hohlarum backlighter measures transmission over a very broad λ range



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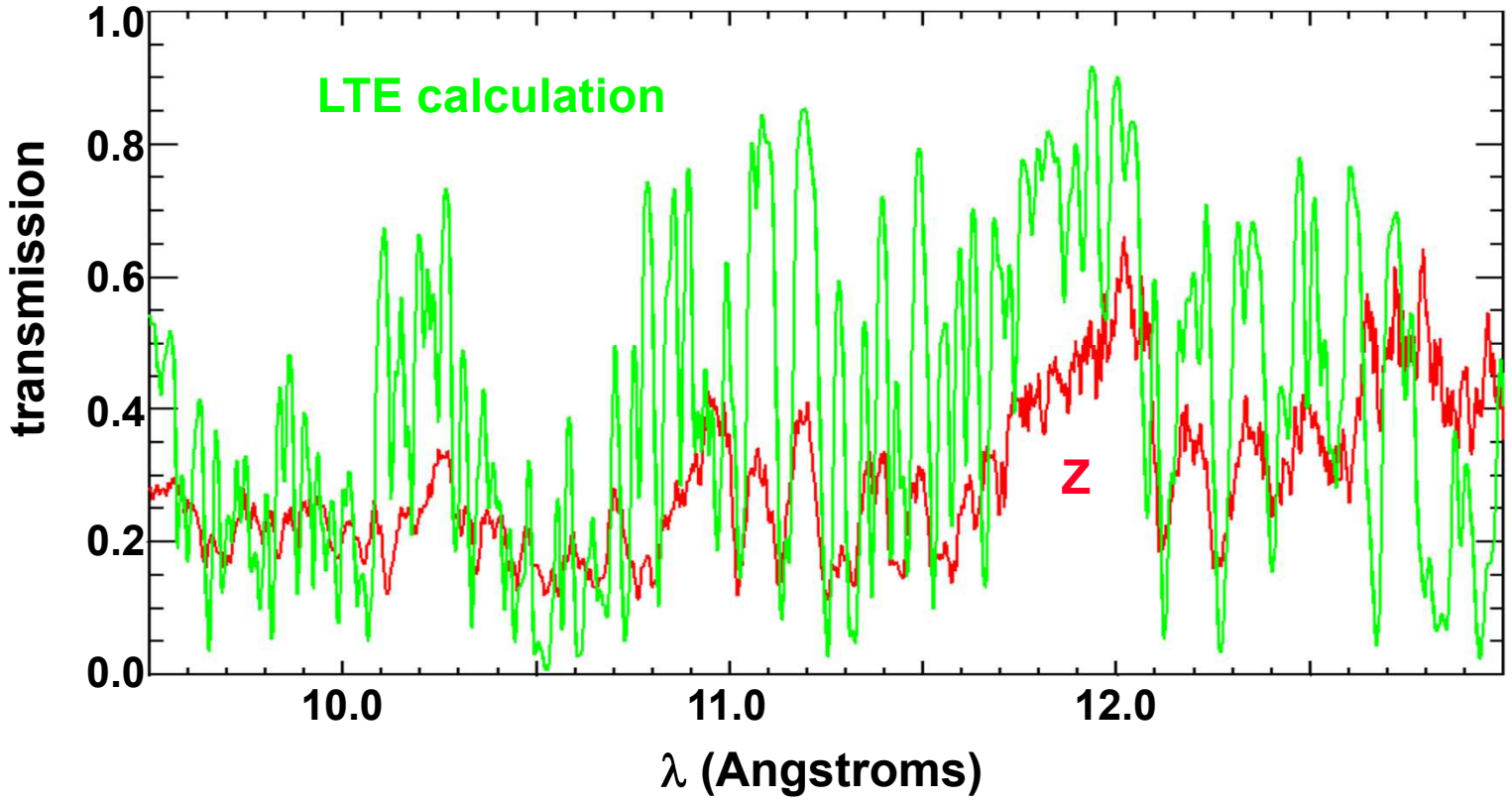
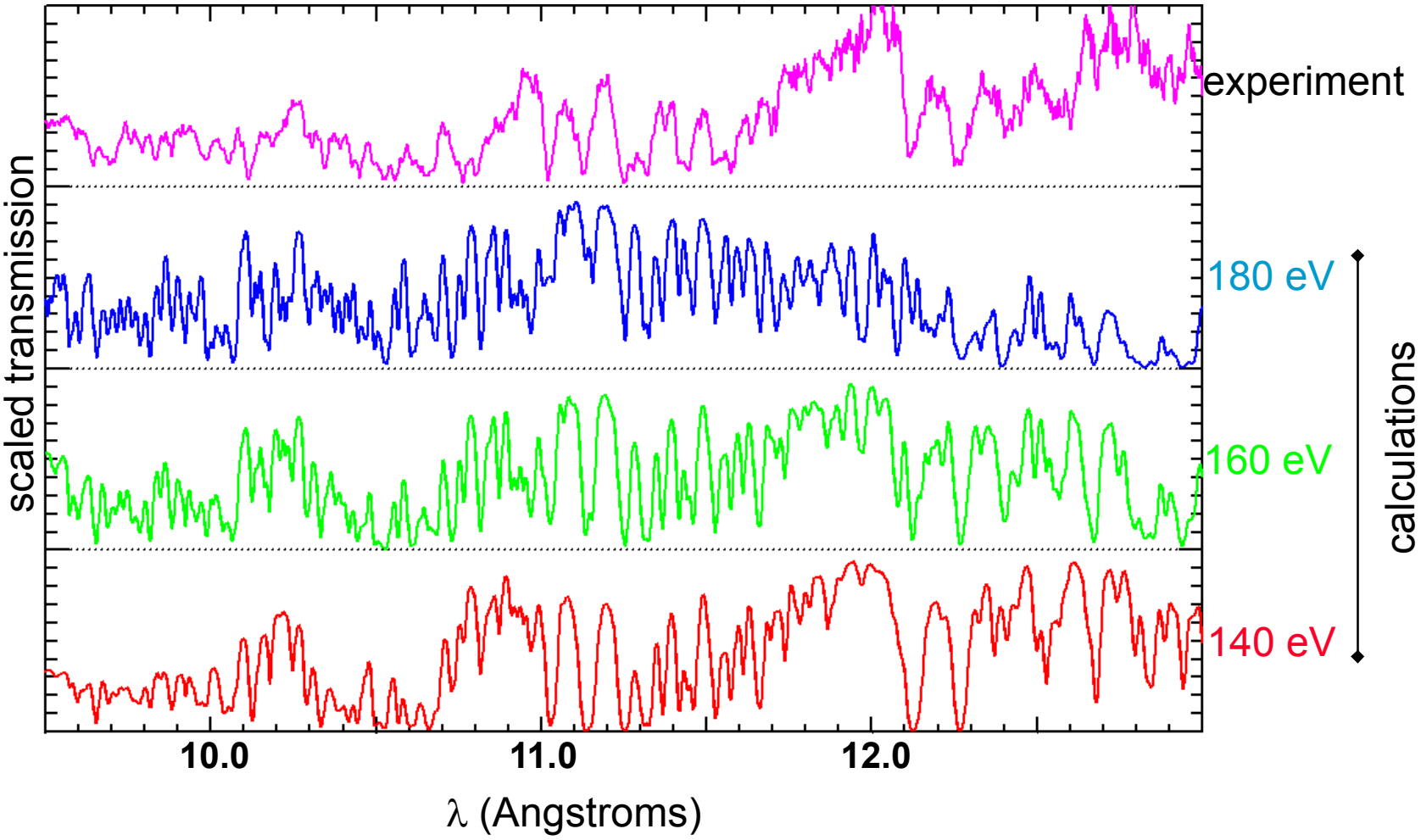
PRISMSPECT calculations exhibit respectable agreement with Fe transmission



- The main features are well reproduced
- The calculated transmission has “windows” between the lines

The data enables tests of the calculated charge state distribution



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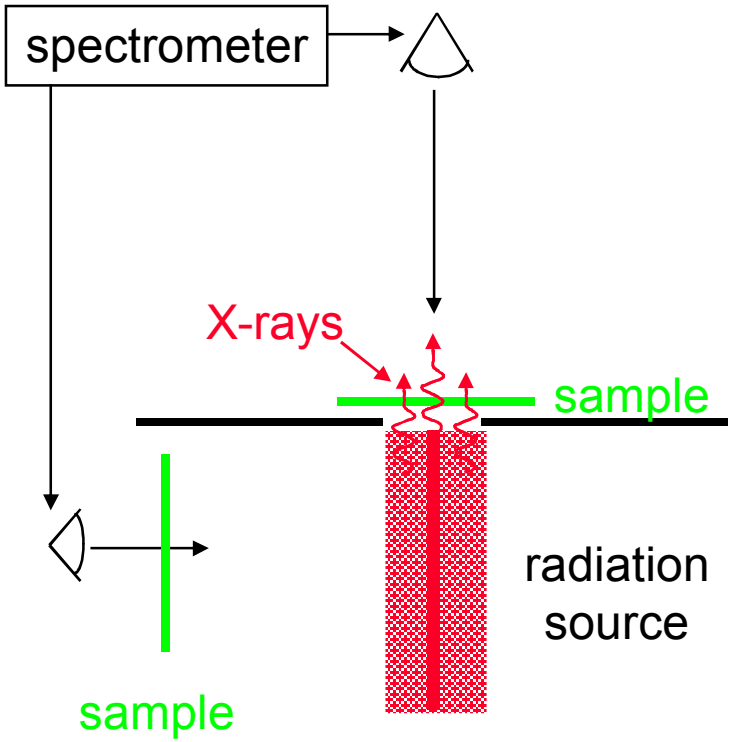
goals for future work

- Model comparisons, feature identification
- Measure transmission with multiple Fe thickness on a single shot
- Extend to shorter and longer wavelengths
- Optimize tamping and sample design with benchmarked rad-hydro simulations
- Extend to higher densities and temperatures (ZR)

Z opacity experiments strengthen existing database and extend measurements beyond T ~ 150 eV



Fe + Mg transmission at
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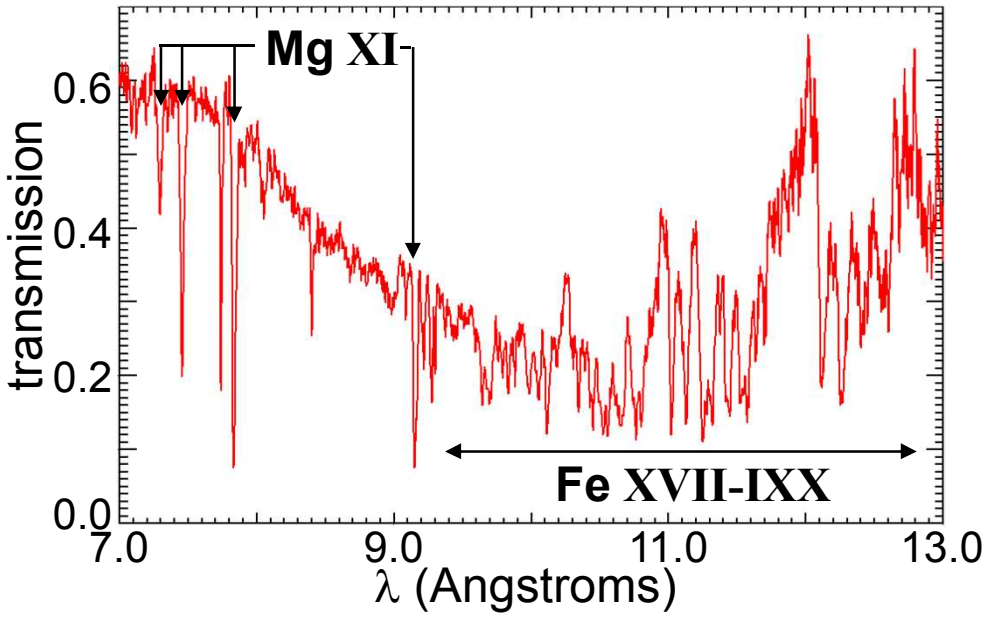

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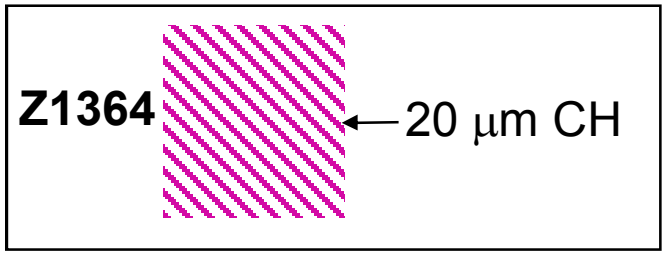
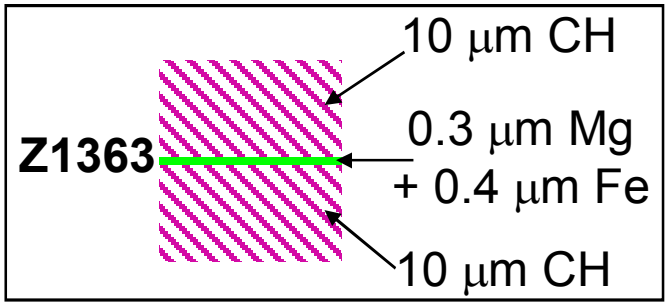
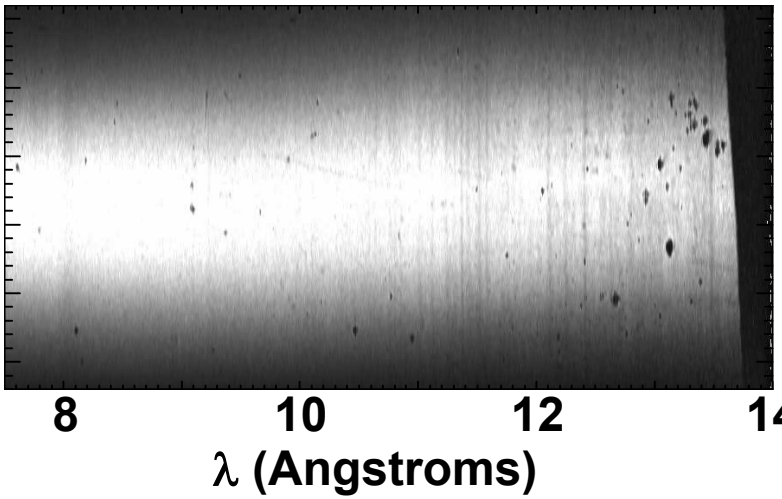
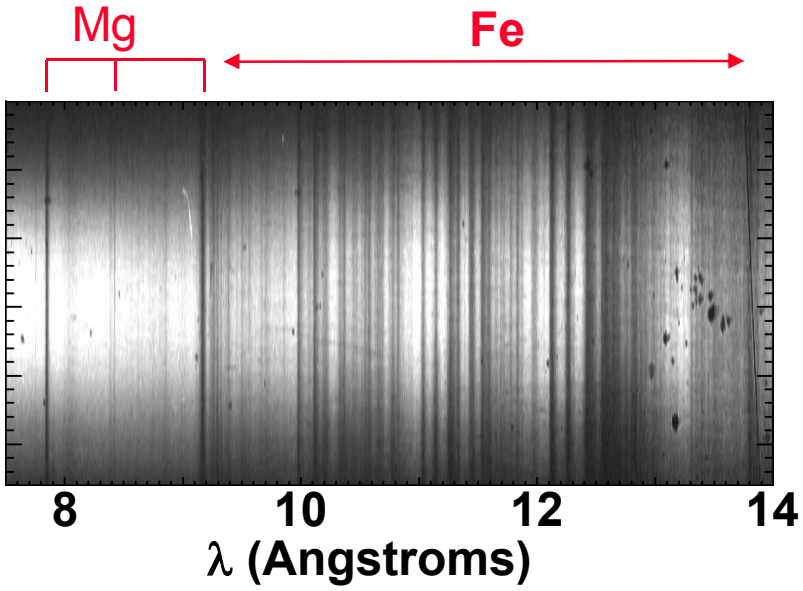
L-shell Fe absorption features have been successfully recorded









One pair of Z experiments determines the Fe + Mg transmission

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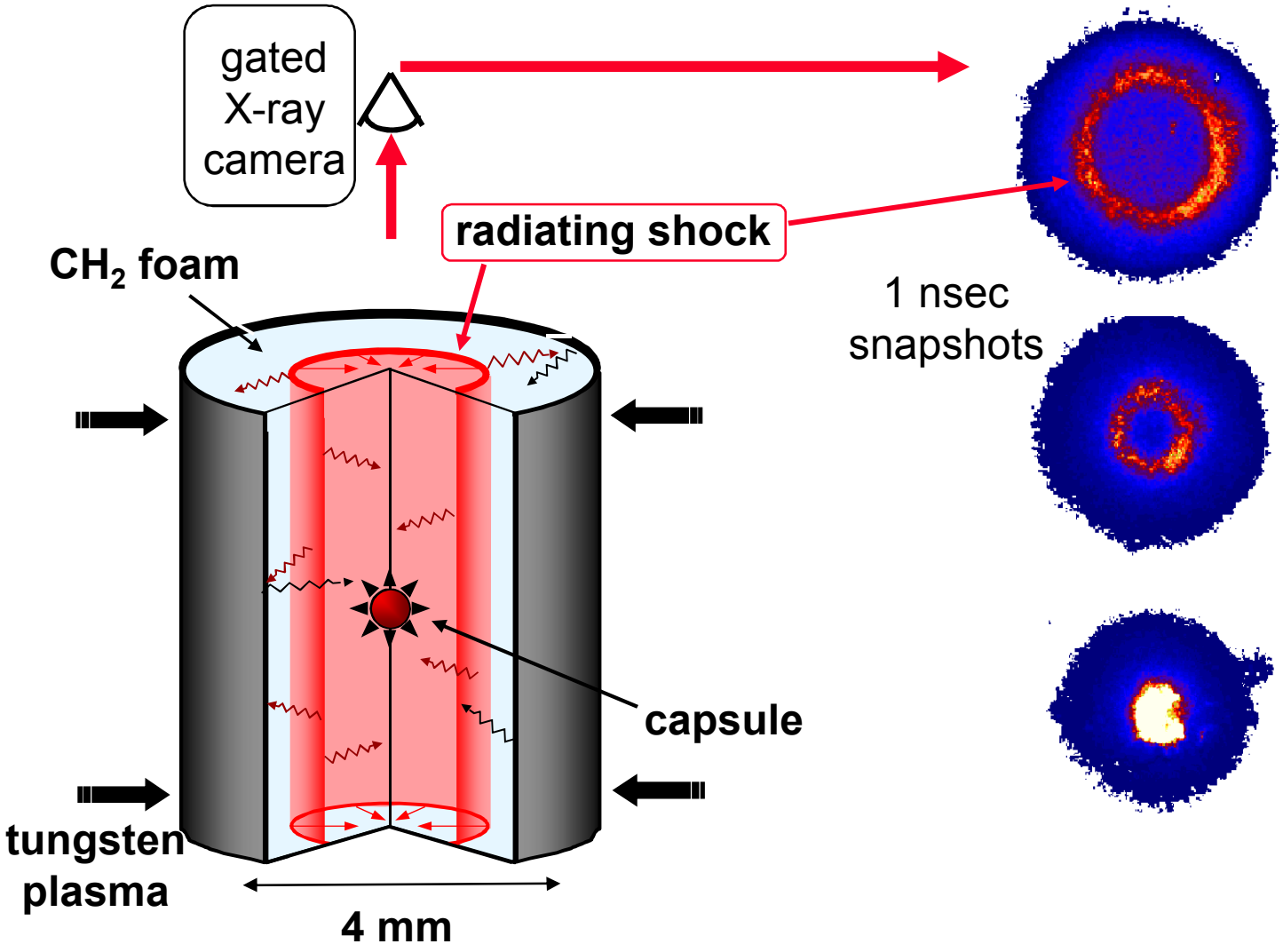
Dynamic hohlraum radiation source is created by accelerating a tungsten plasma onto a low Z foam



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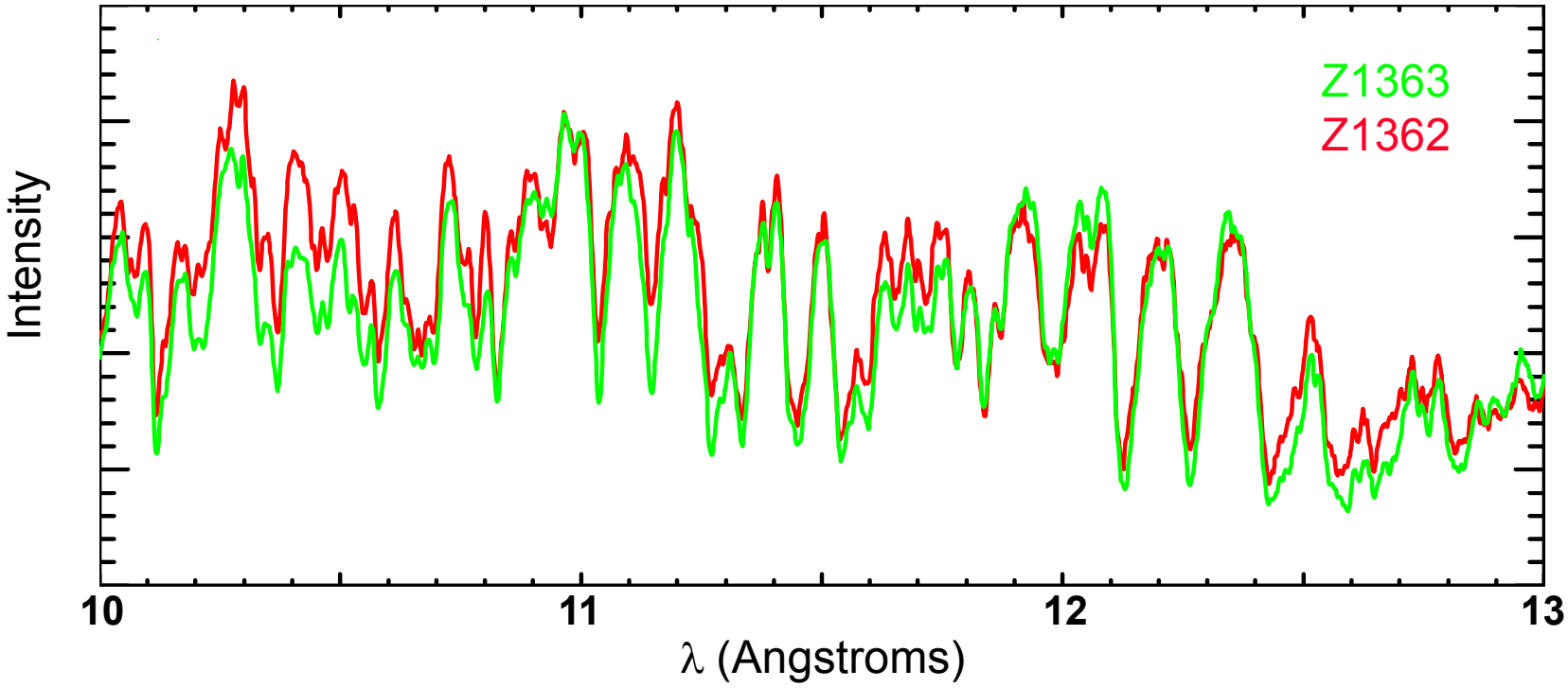
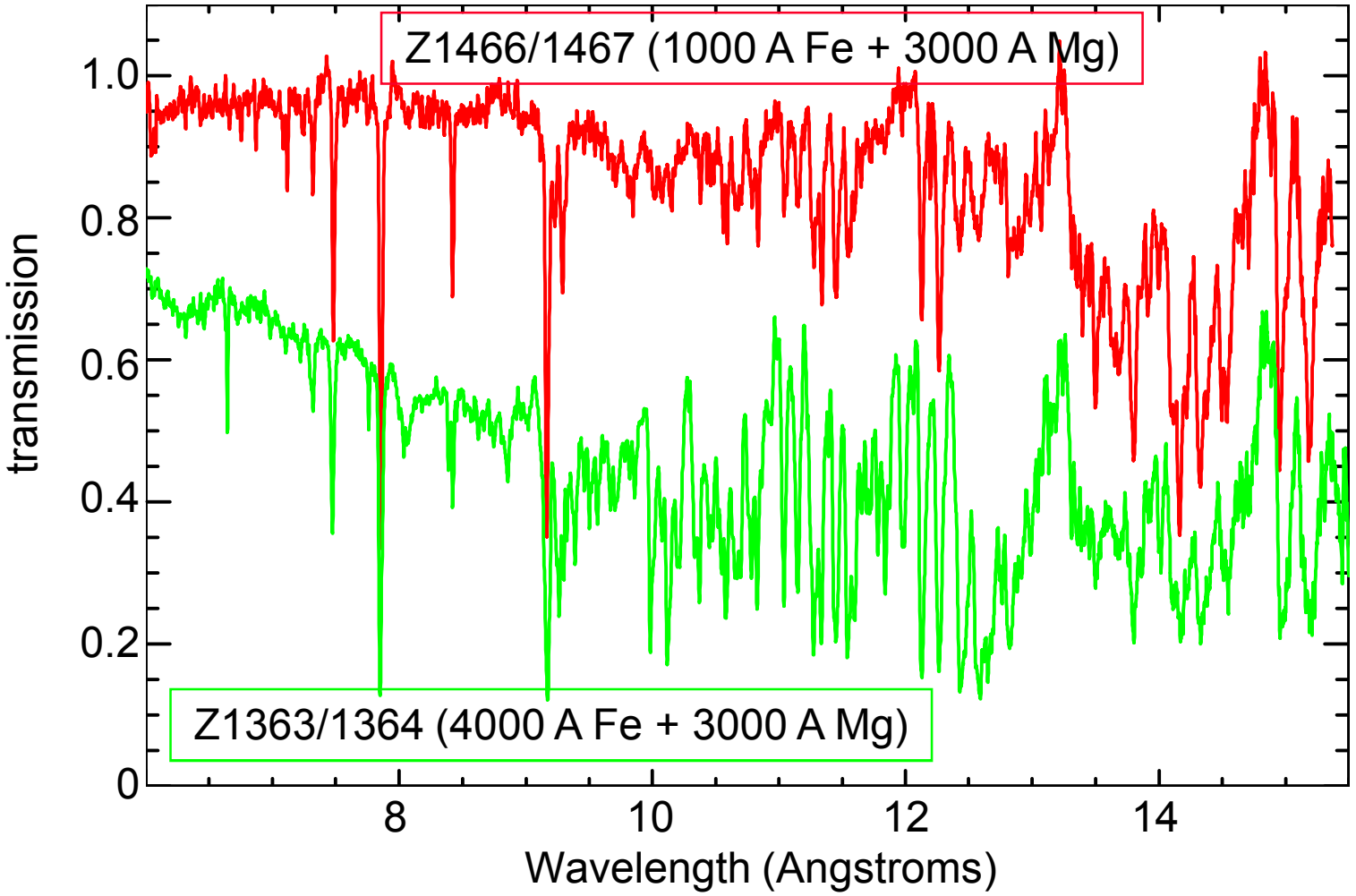
The shot to shot reproducibility is good, if conditions are carefully controlled

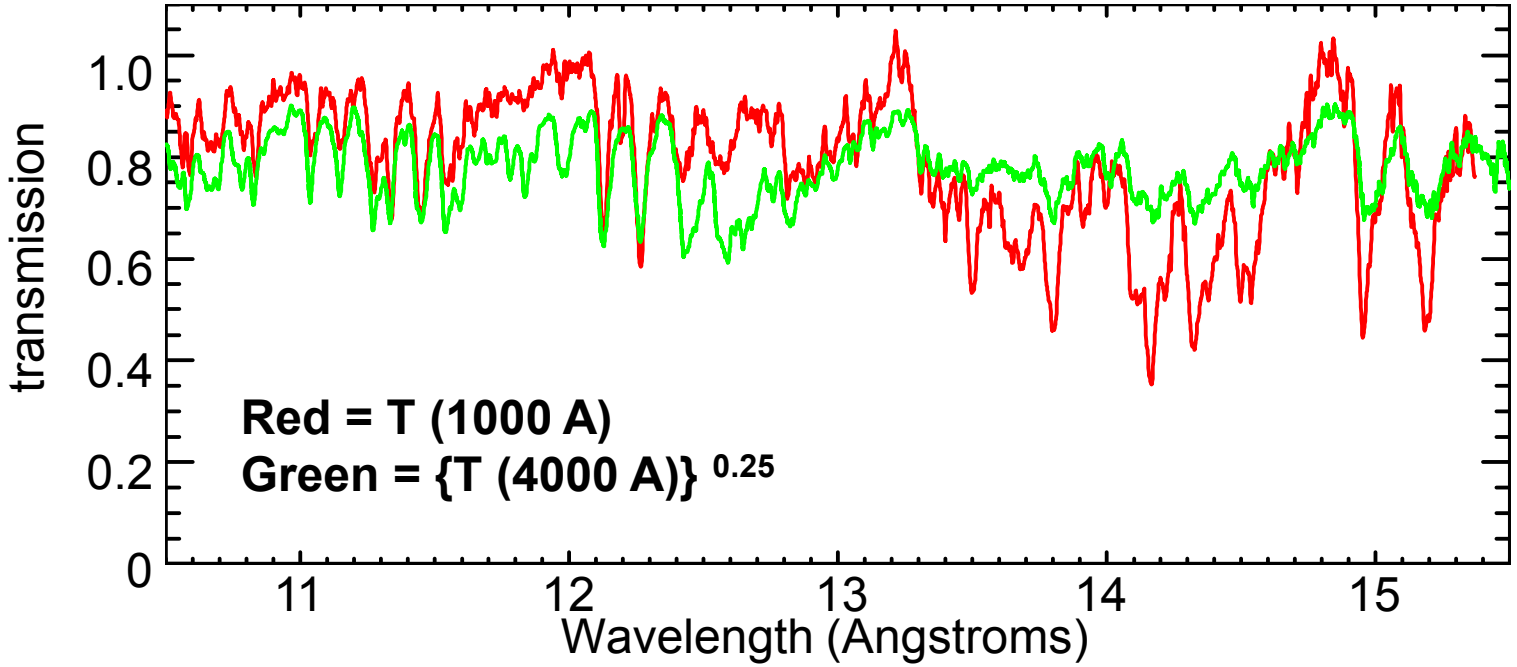


- Both experiments used 10 μm CH | 0.3 μm Mg + 0.4 μm Fe | 10 μm CH sample
- No scaling was applied for this comparison
- Reproducibility is approximately 10% or better over this wavelength range

Transmission for two Fe thicknesses under similar T_e and n_e conditions has been measured



The transmission data scales with the thickness approximately as expected



- Significant portions of the spectrum scales with { T } ^{x}, with x=thickness
- This supports method robustness - correct areal density, negligible self emission, correct film response, correct background subtraction
- Residual differences due to line saturation, possibly different Te, ne

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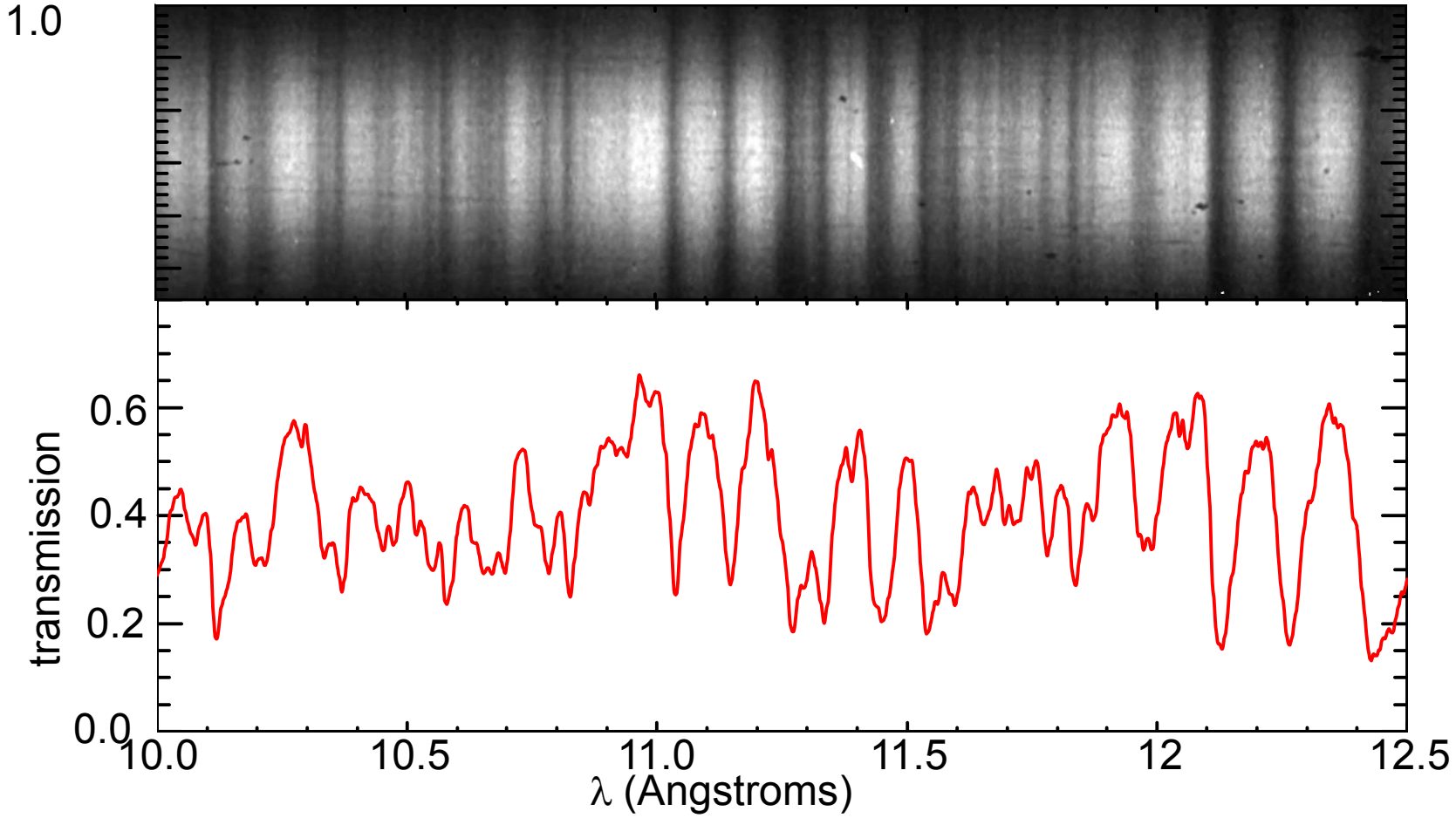
The Fe L-shell spectrum exhibits a wealth of line absorption features



- **Reproducing these features is a difficult test for any opacity model**

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