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SNL Progress and Planning in Campaign 4

SNL Science Campaign Review Meeting
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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

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Reproducible x-ray sources drive high quality experiments.

FY07 Highlights

- Demonstrated Z-pinch dynamic hohlraum (ZPDH) reproducibility:
  < 15% in amplitude and ~5% in pulse-shape

- Demonstrated unique ZPDH capability:
  Opacity measurements at >150 eV (2.5x higher than previous)

- Collaborated with LANL to determine source accuracy and reproducibility requirements.

- Developing a 5-yr plan for high-quality SAT experiments on Z.

Outline

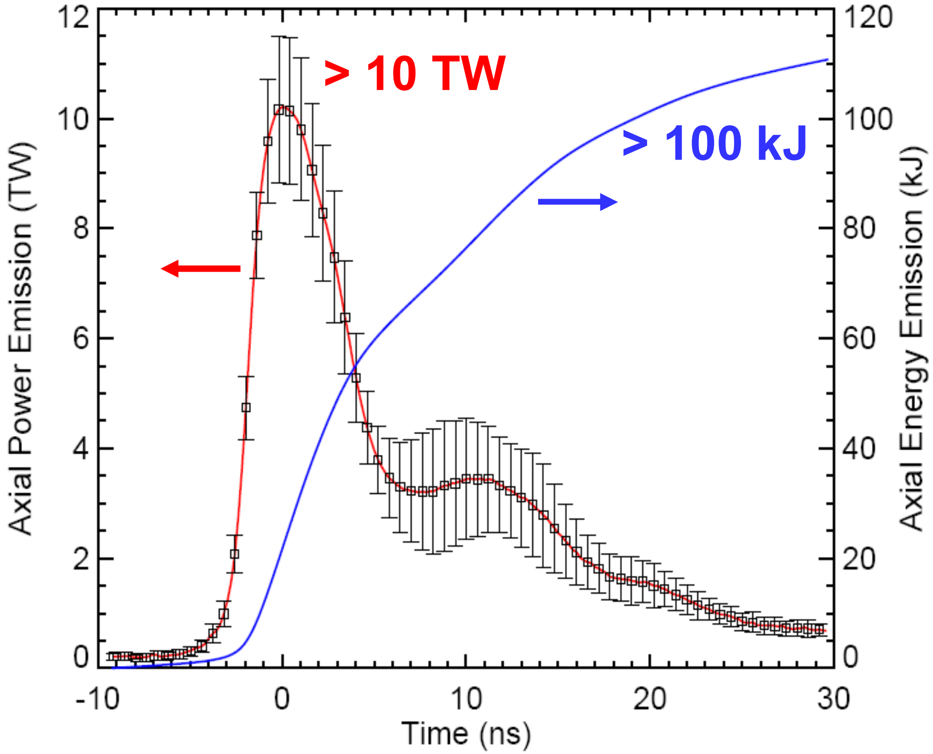
I. The Z-pinch Dynamic Hohlraum (ZPDH)
- Conceptual operation
- Reproducibility metrics

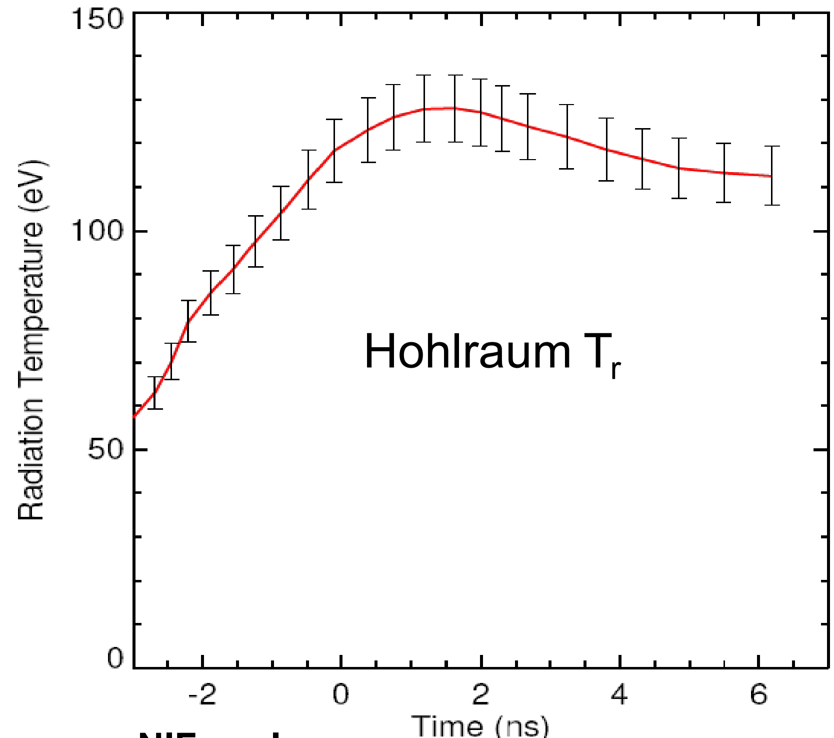
II. ZPDH Platform Development
- Fe opacity experiment

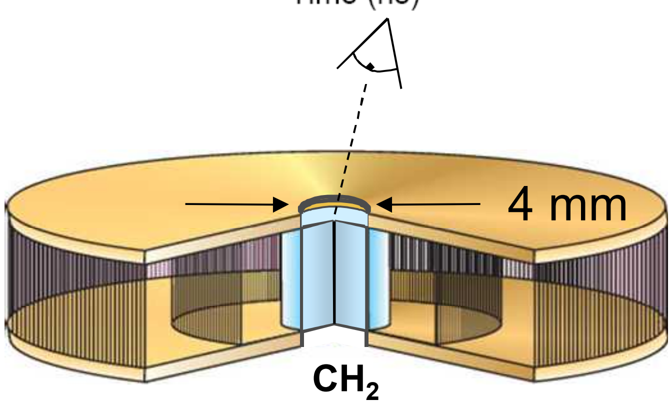
III. Future Development
- Accuracy and reproducibility criteria
- Total power characterization approach
- 5-yr plan

SNL C4 activities:
- accurately characterized and reproducible source
- proven capability in unique and relevant regimes

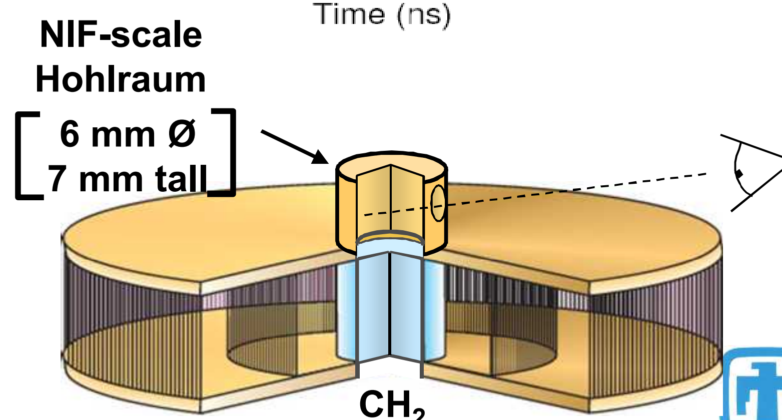
The ZPDH is the world's most energetic x-ray source



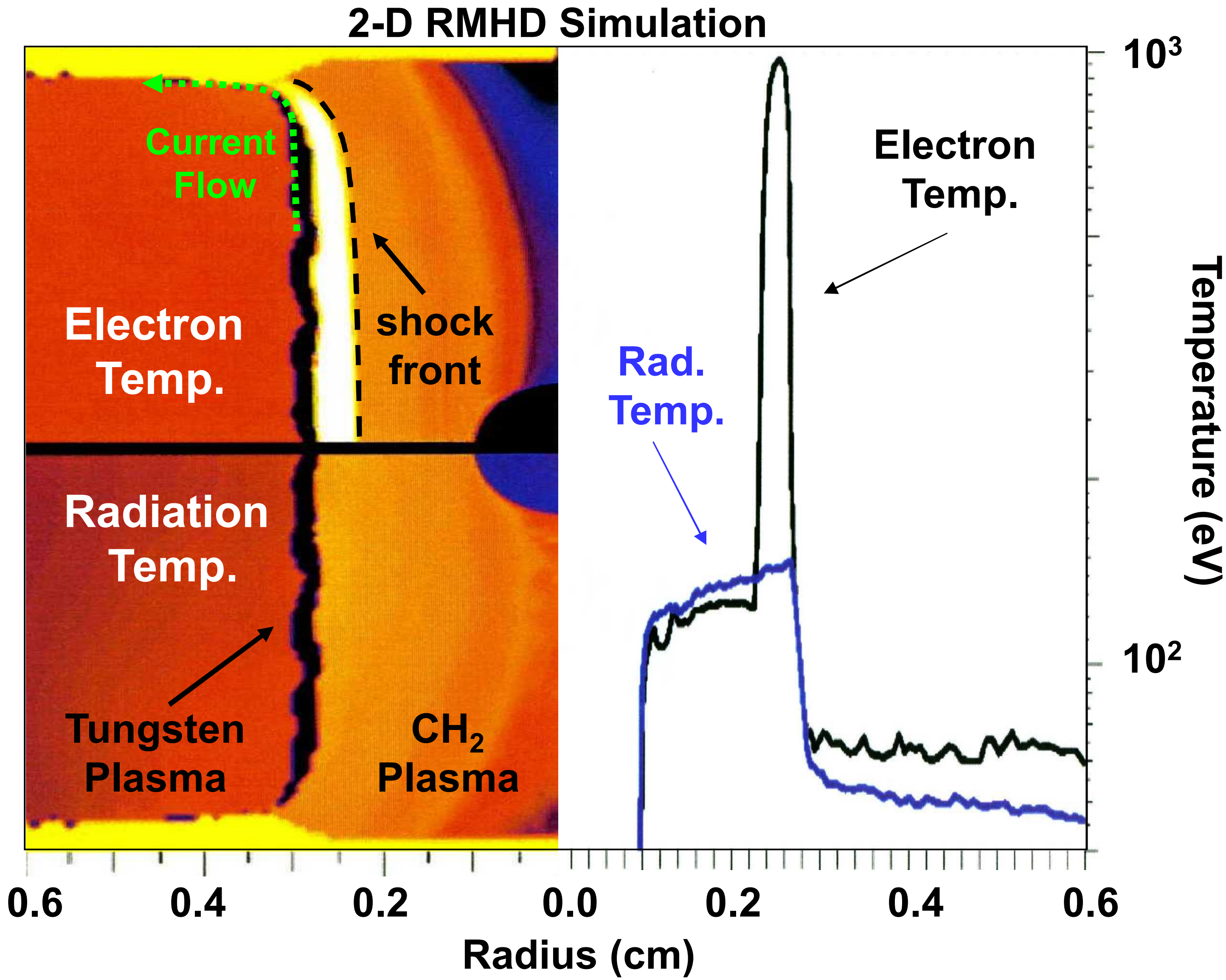




Tungsten Wire Arrays

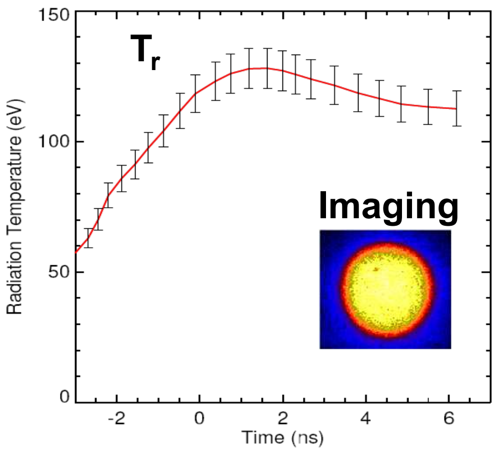


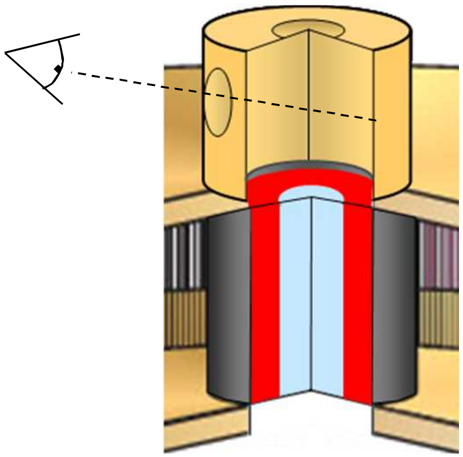
The dynamic hohlraum is formed by an imploding tungsten Z pinch, and heated by a strong radiating shock.



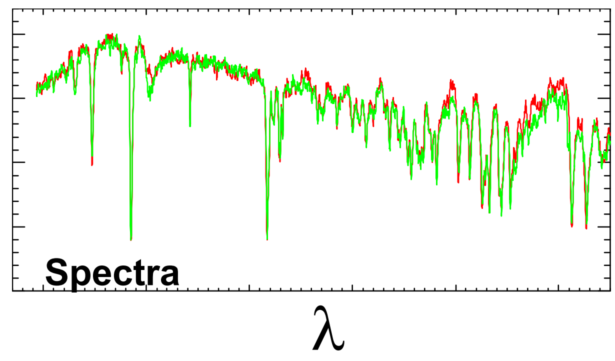
The ZPDH is a versatile x-ray source

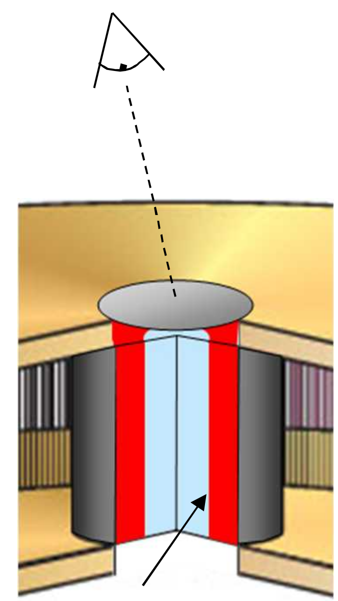
Hohlraums





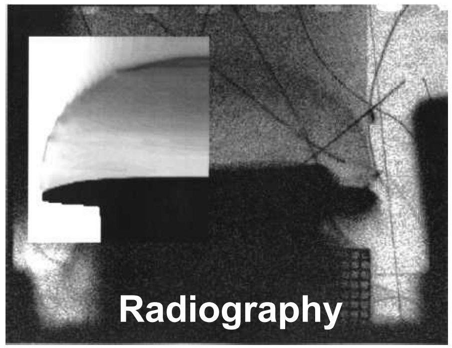
Planar Samples

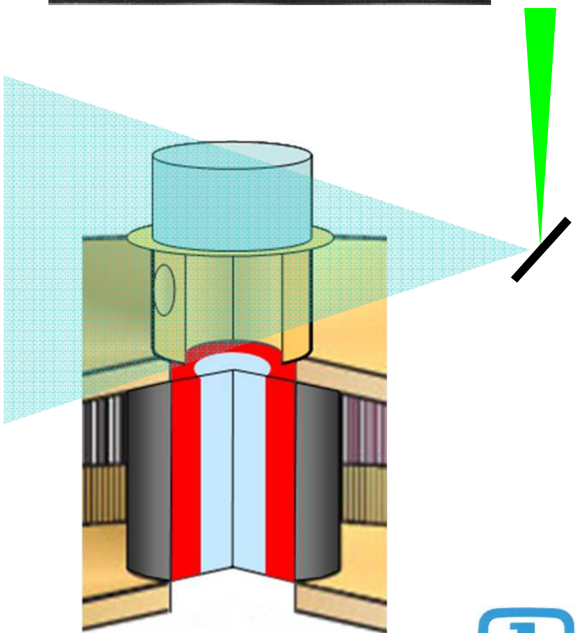




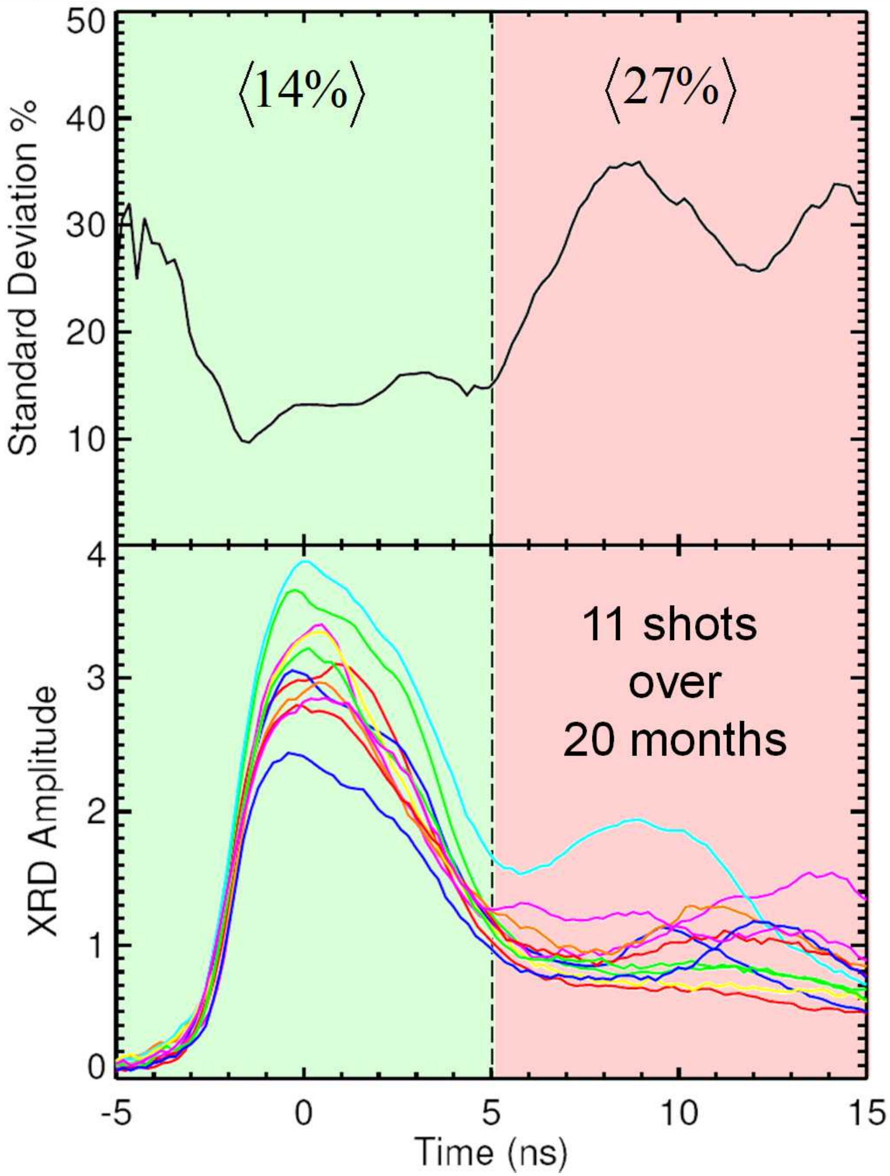
Internal T_r > 200 eV

Complex Packages

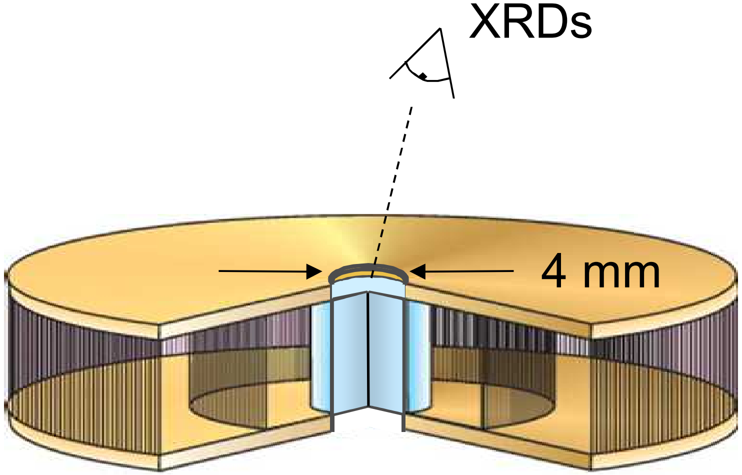




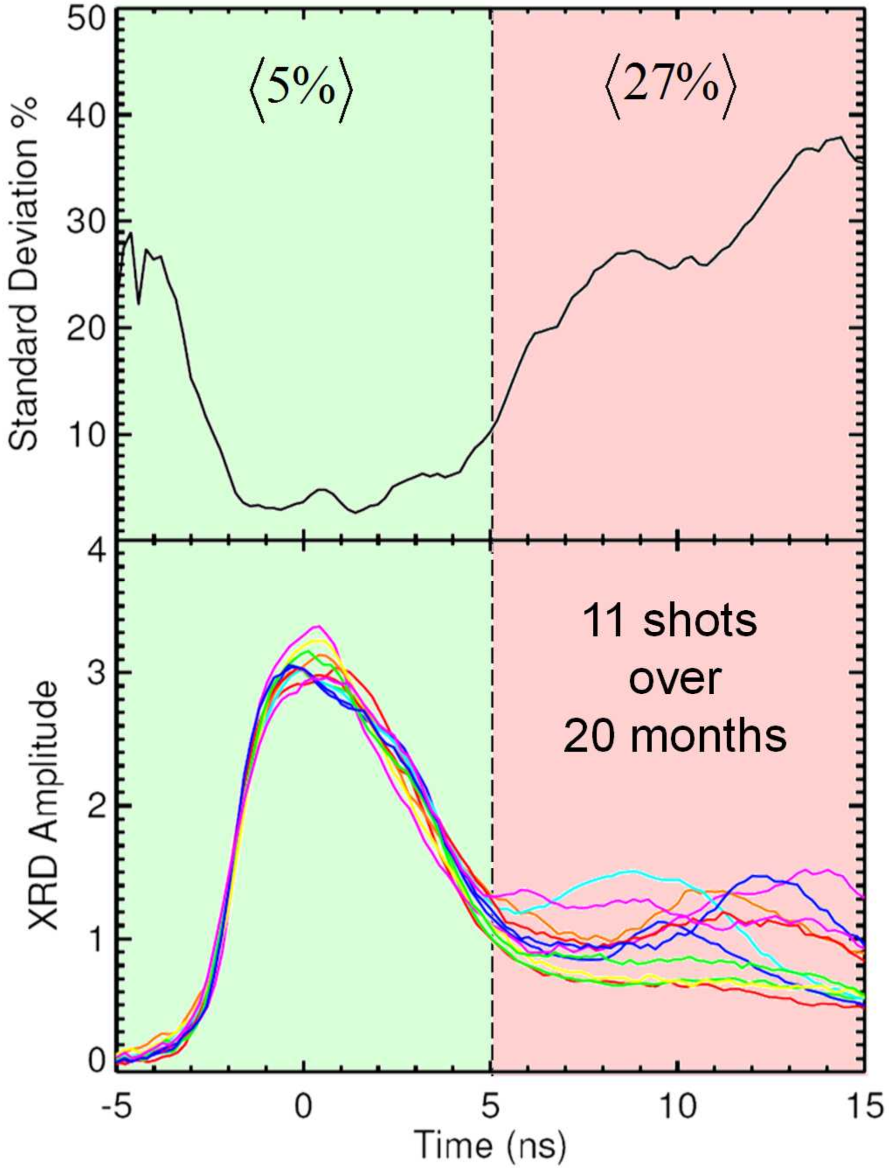
The DH power emission is reproducible to <15%.



$$\frac{dV_{xrd}}{V_{xrd}} = \sqrt{\left(\frac{\partial P_{DH}}{P_{DH}}\right)^2 + \left(\frac{\partial Inst.}{Inst.}\right)^2} \quad \sim 15\%$$



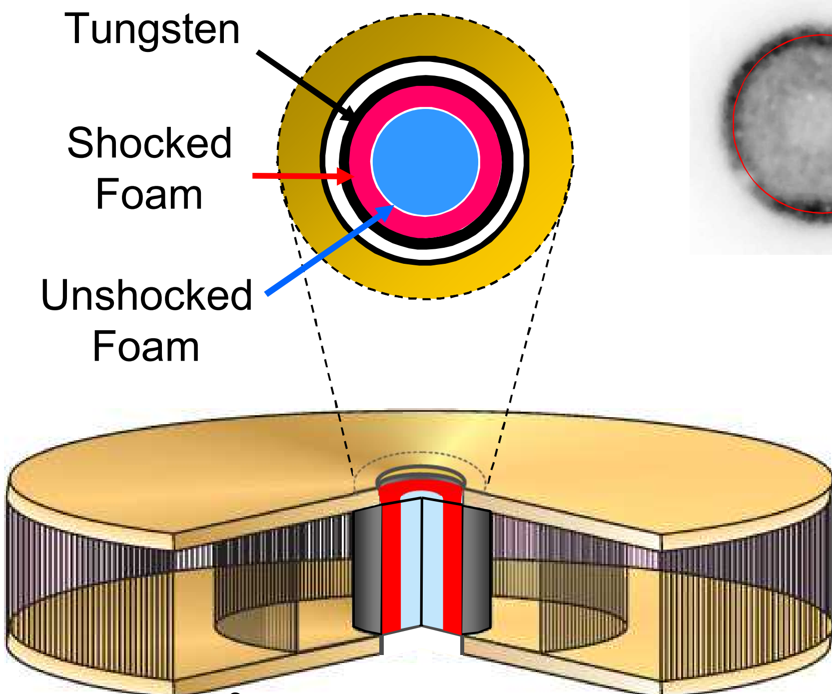
The DH power pulse-shape is reproducible to ~ 5%.



$$\frac{dV_{xrd}}{V_{xrd}} \approx \frac{\partial P_{DH}}{P_{DH}} \quad \sim 5\%$$

Pulse-shape reproducibility implies that only the ENERGY needs to be measured on each shot.

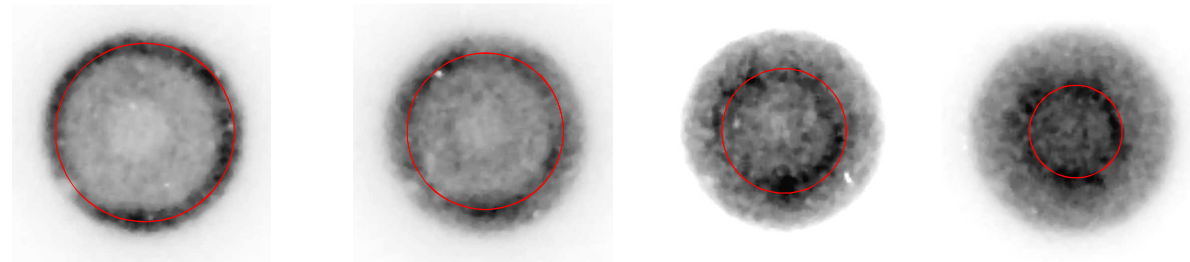
The axial emission reproducibility stems from the shock reproducibility.

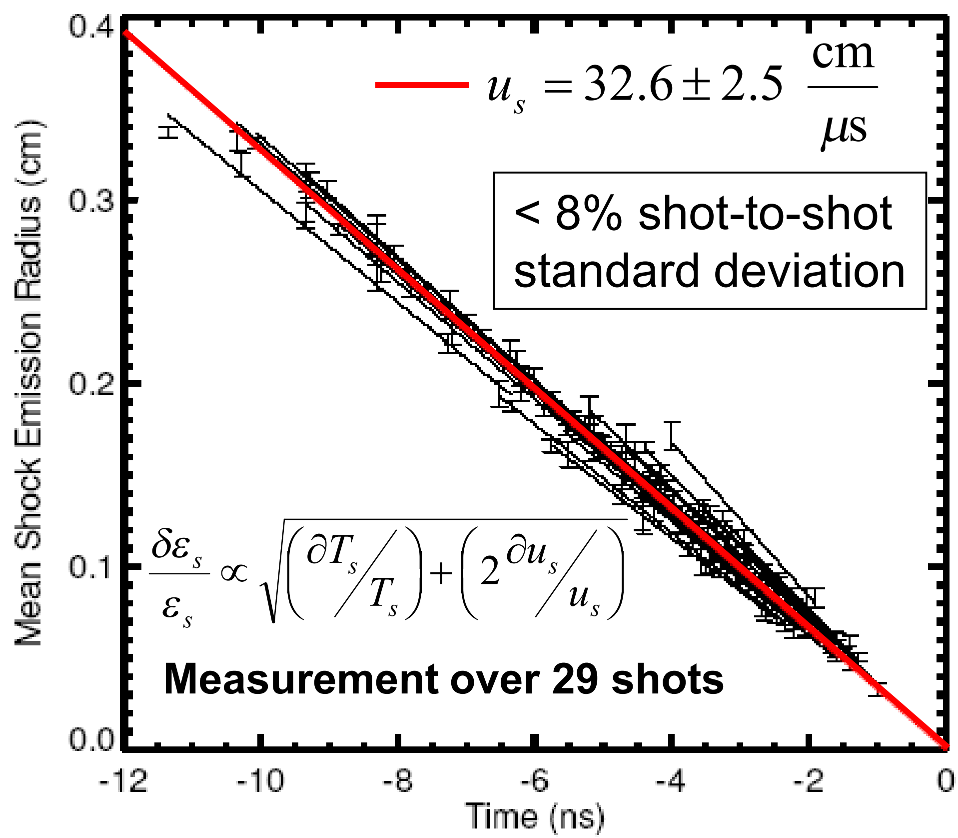


$$P_s \propto \frac{u_s^2}{\rho_u}\ ,\ P_s \propto \rho_s T_s\ ,\ \varepsilon_s \propto \rho_s^2$$

$$\longrightarrow\ \varepsilon_s \propto \underbrace{\left(\frac{\rho_s}{\rho_u}\right)}_{\text{constant}} T_s^{-1} u_s^2$$

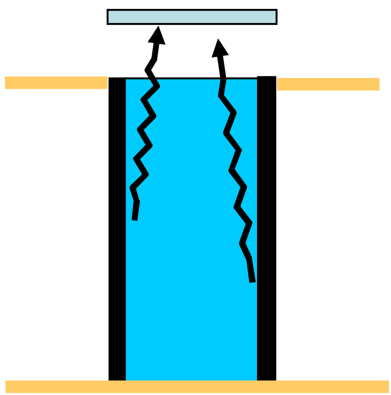
Framing Pinhole Camera Images



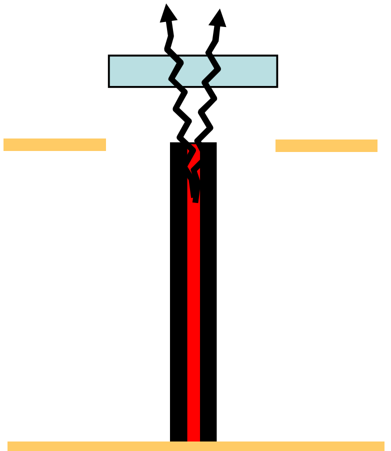


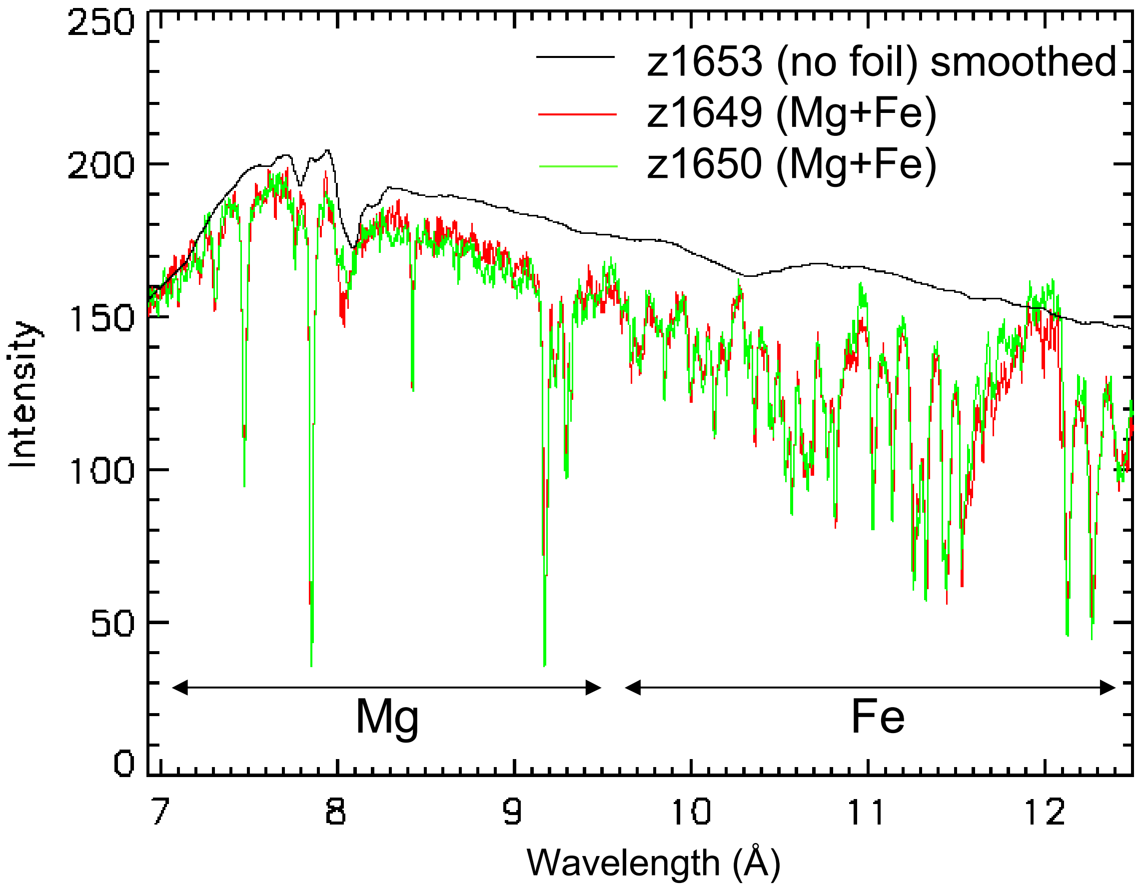
The energy and reproducibility of the ZPDH is exploited to measure high temperature opacity.

Foil is heated during the DH implosion



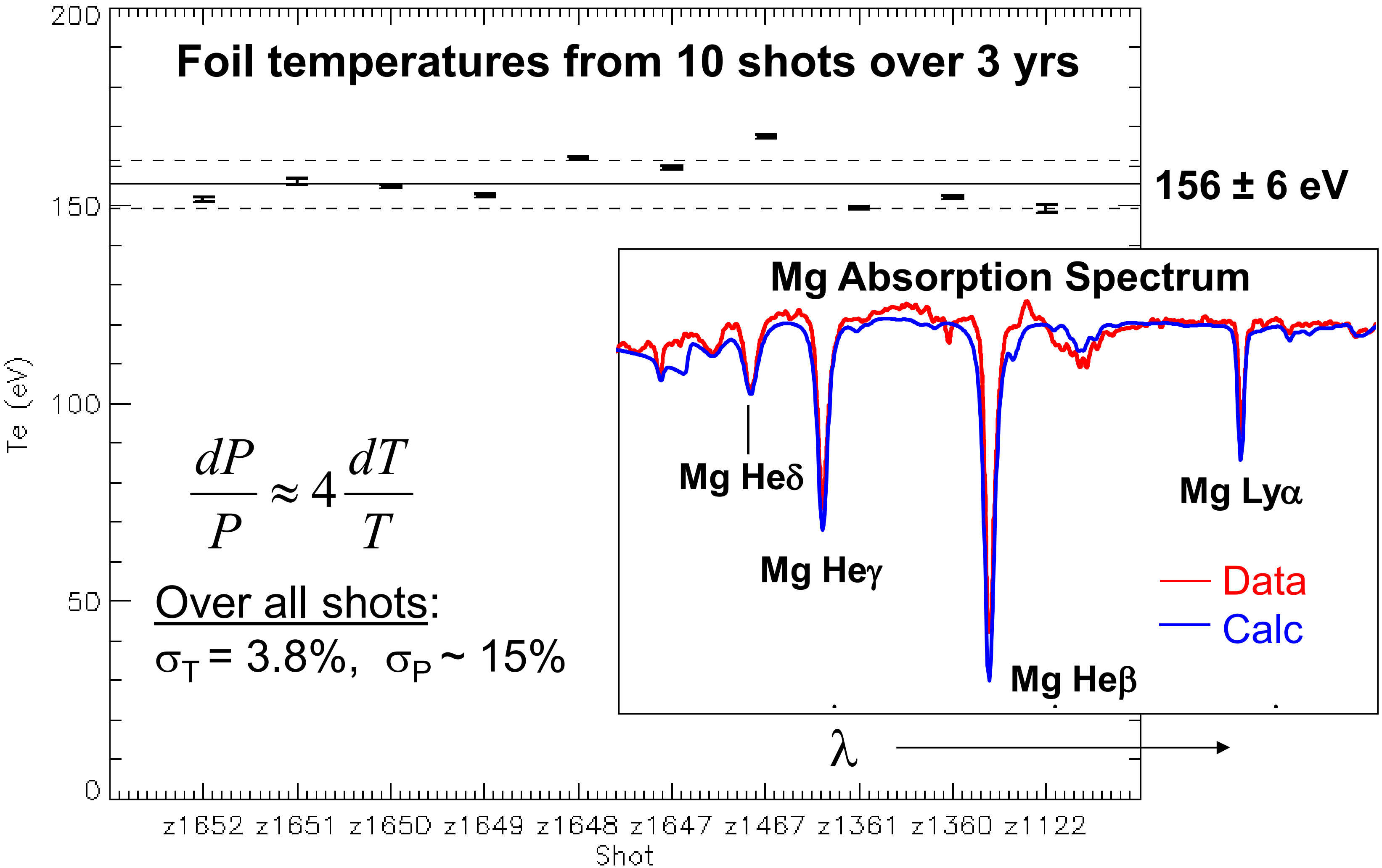
Foil is backlit at stagnation





- Measurement requires source reproducibility in power (heating) and spectrum (backlighting).

Sample electron temperatures are reproducible to < 4%.



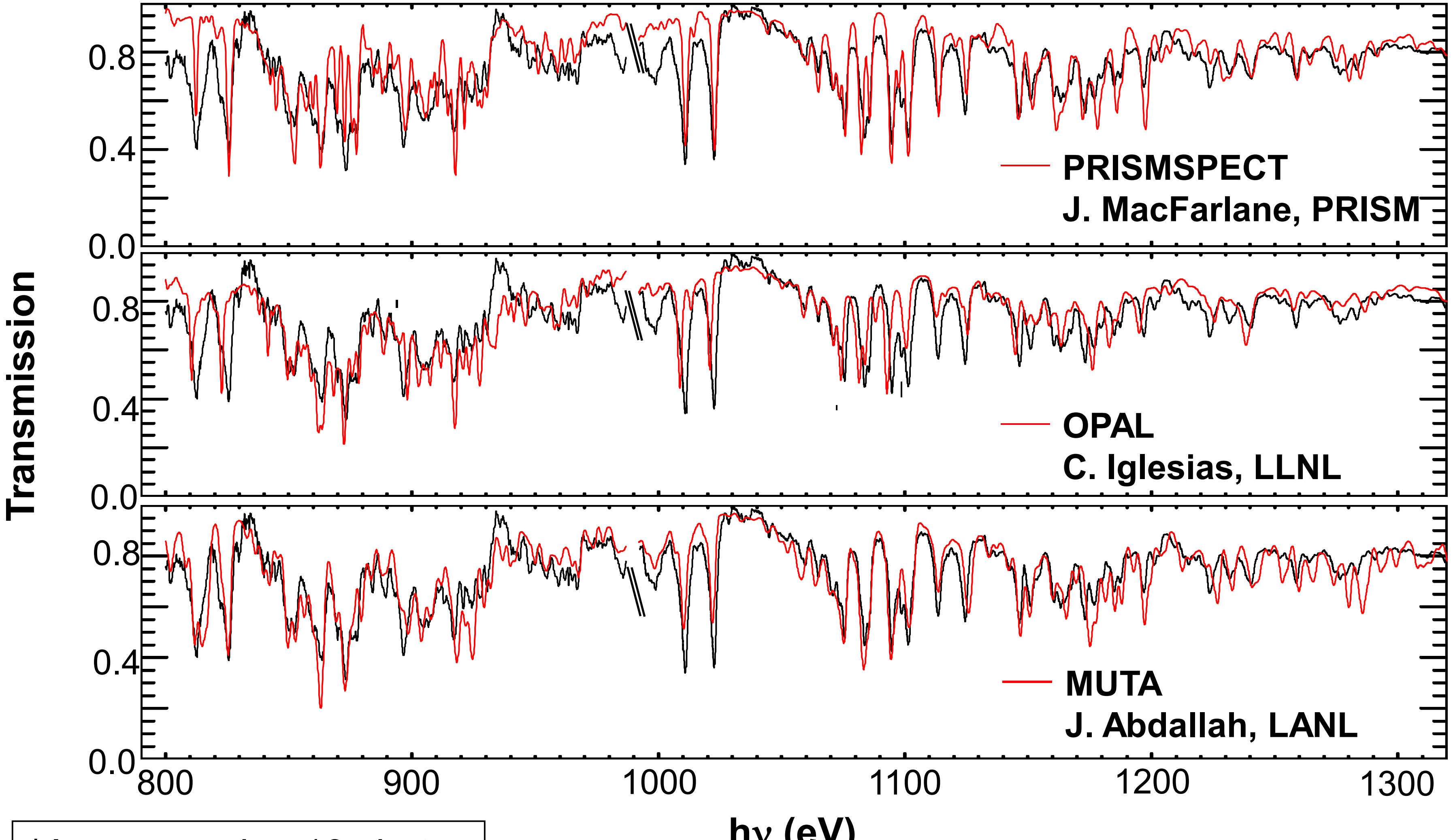
$$\frac{dP}{P} \approx 4\frac{dT}{T}$$

Over all shots:

$\sigma_T = 3.8\%, \ \sigma_P \sim 15\%$

2.5x higher T_e than any previous opacity measurement

The measured Fe transmission compares well with models from LANL, LLNL, and PRISM.



*Average using 10 shots
*Standard deviation < 3%

C4 SAT source requirements on performance, precision, and reproducibility*

Source requirements as applied to SAT experiments

	1st year (FY09)	3rd year (FY11)
Peak Drive Power (TW)	~ 11	≥ 13.5
Drive Energy (kJ) total (up to 5 ns after peak)	~ 110 (60)	≥ 135 (75)
Accuracy in Measured Power	~± 25%	< ± 25%
Shot-to-shot Power Reproducibility	≤ ± 20%	< ± 15%
Shot-to-shot Pulse Shape Reproducibility	< ± 10%	< ± 5%

- These requirements will evolve with the SAT experiment designs.

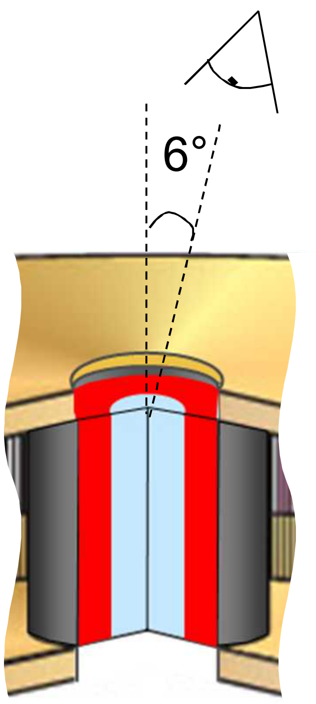
*Satisfied joint LANL / SNL milestone due 6/07

Axial power will be interpreted from end-on secondary hohlraum temperature measurements.

Previous Method

$$P_d = \frac{\pi}{\Omega} \frac{1}{\cos(6°)} P_{xrd}$$

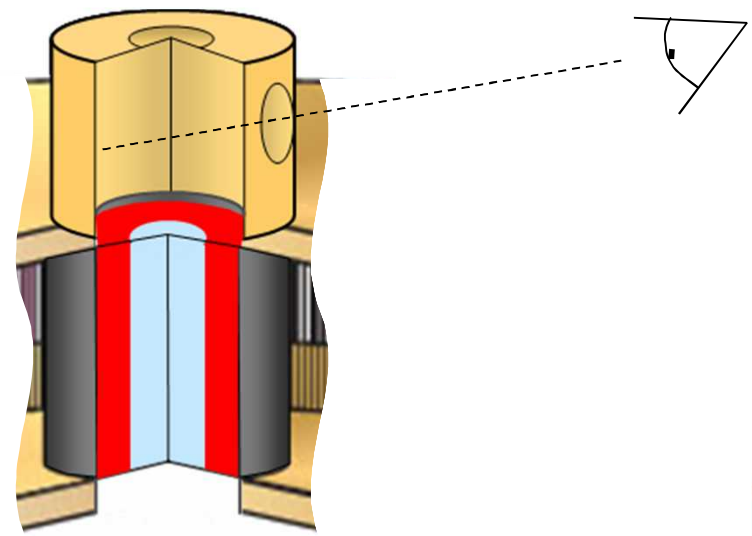
- Only measure one angle
- Assume a Lambertian distribution
- Diagnostics difficult to keep calibrated



Future Method

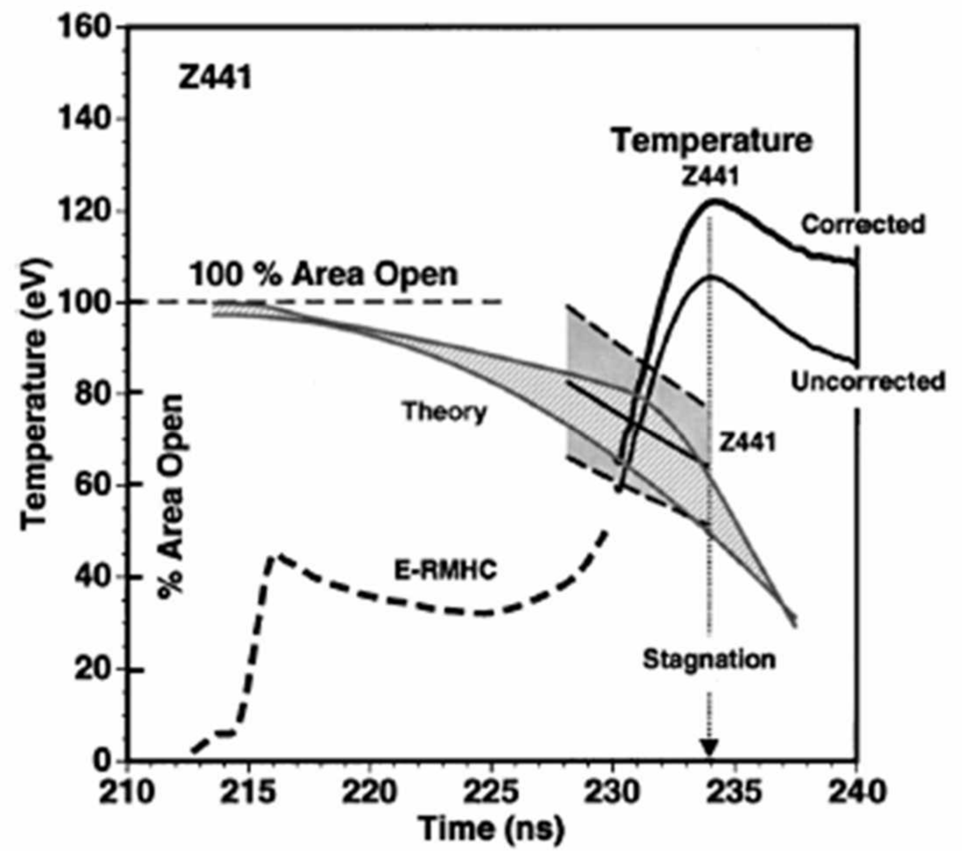
$$P_d = \sigma_{SB} T_r^4 \left[(1 - \alpha_w) A_w + A_h \right]$$

- Hohlraum integrates over all angles
- No assumption on angular distribution
- Common diagnostics w/ other campaigns
- requires hole closure measurement
- requires albedo calculation

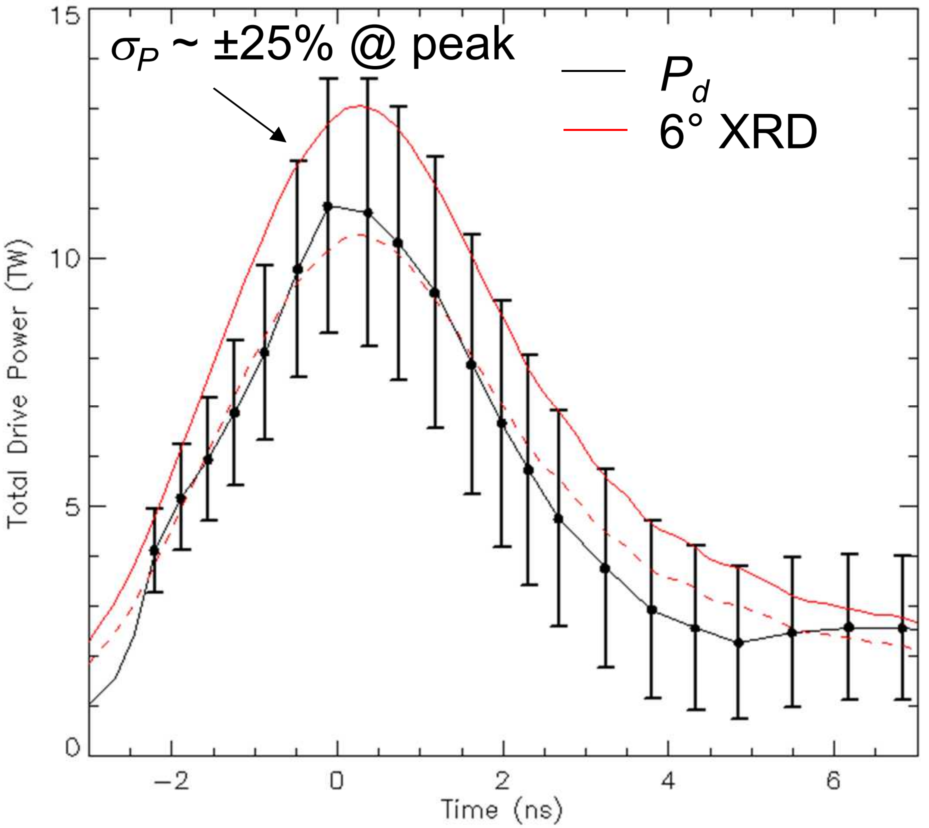


The hohlraum method gives the same pulse-shape as the XRD measurement but with lower amplitude.

DH driven NIF-scale (6 mm x 7 mm) halfraum measurement*



$$P_d = \sigma_{SB} T_r^4 \left[(1-\alpha_w) A_w + A_h \right]$$



*T.W. Sanford et al., Phys. Plasmas **7**, 4669 (2000).

The 5-year plan for C4 experiments on ZR