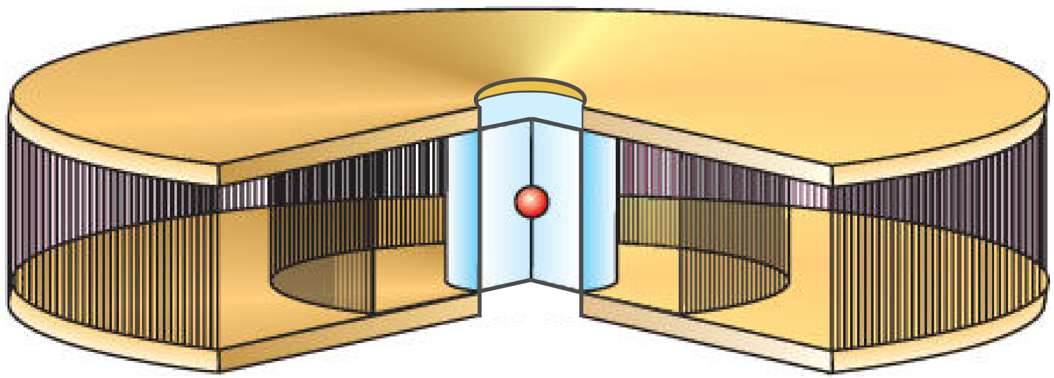
SAND2006-6731C

Performance Metrics of the Z-pinch Dynamic Hohlraum



APS-DPP, Tuesday, Oct. 31, 2006

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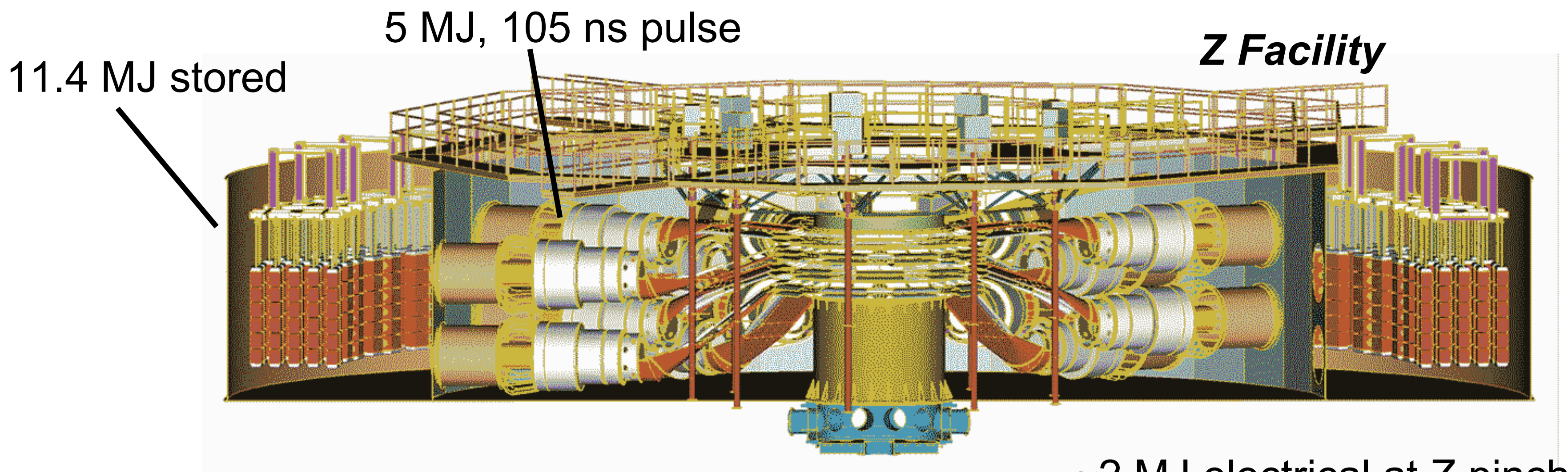
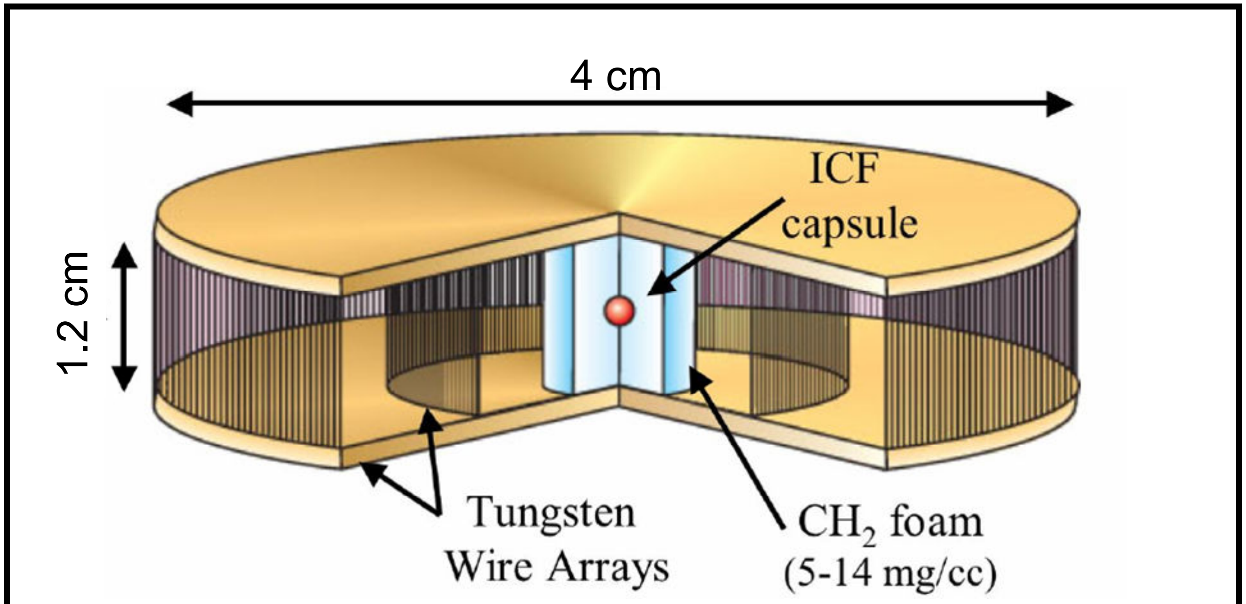
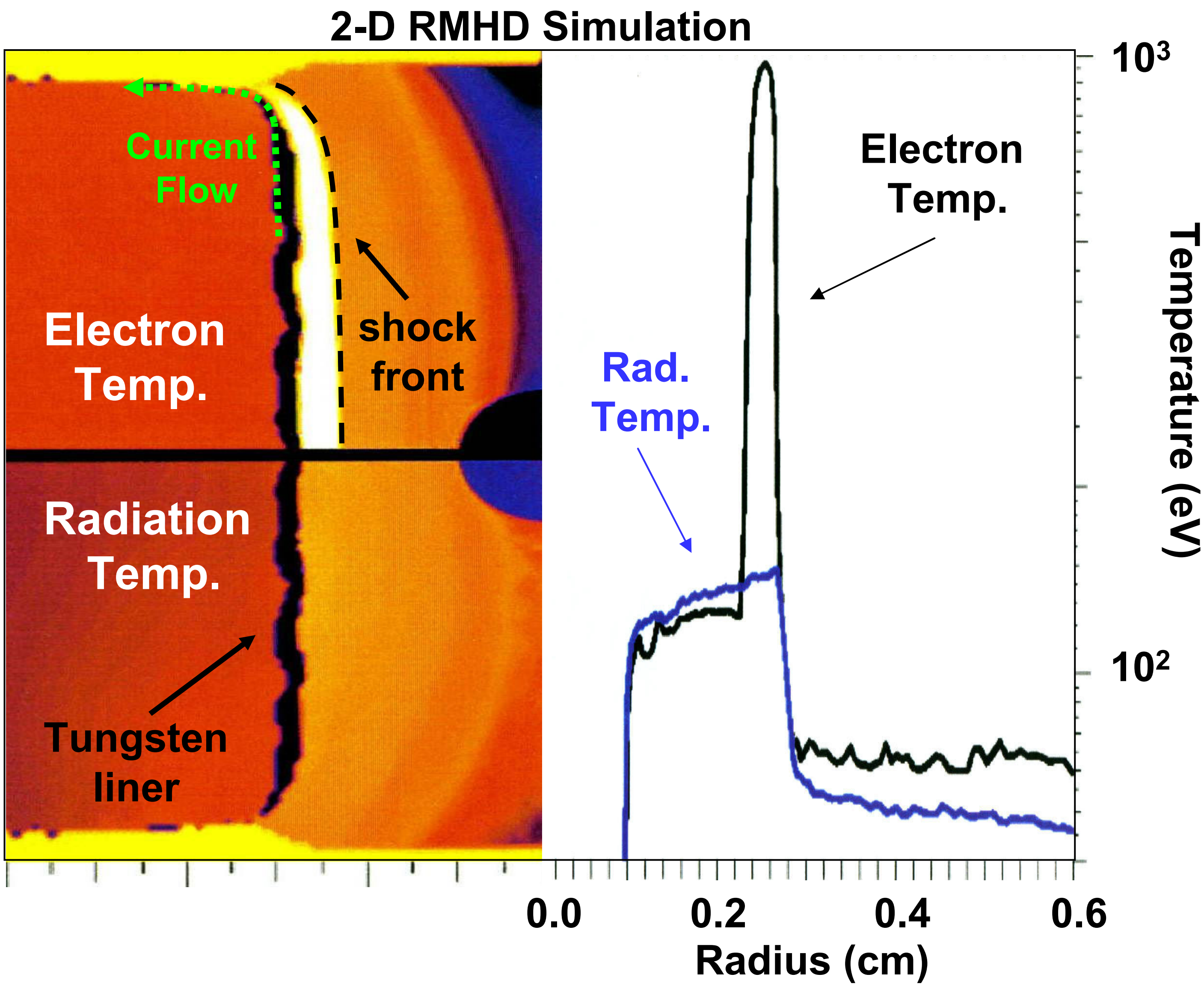
The Z-pinch dynamic hohlraum reaches internal temperatures >200 eV and peak axial power >10 TW.



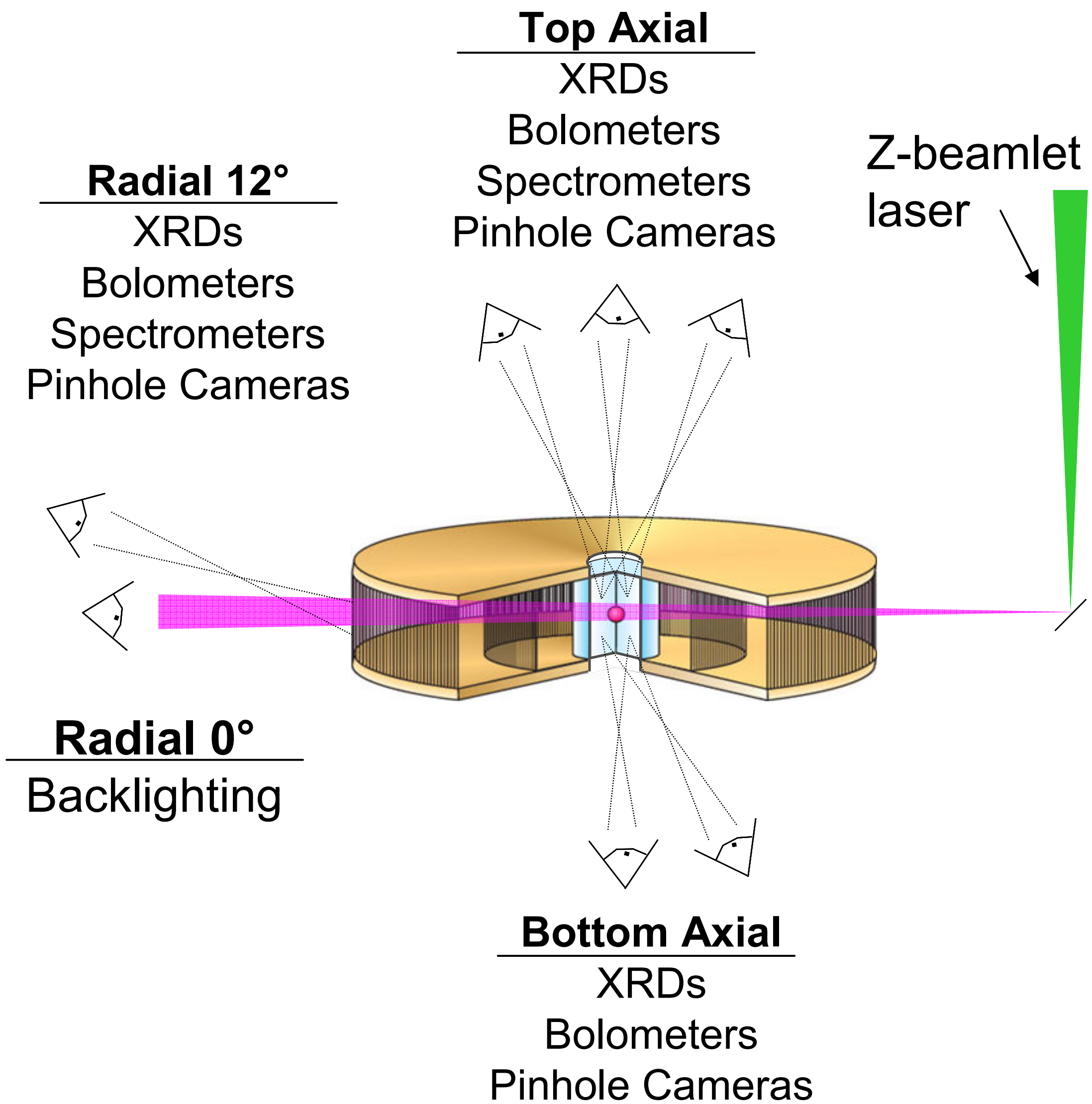


Total Radiated X-ray Energy	~ 0.8 MJ
Peak Axial Power	> 10 TW
Peak Internal Rad. Temp.	> 200 eV

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

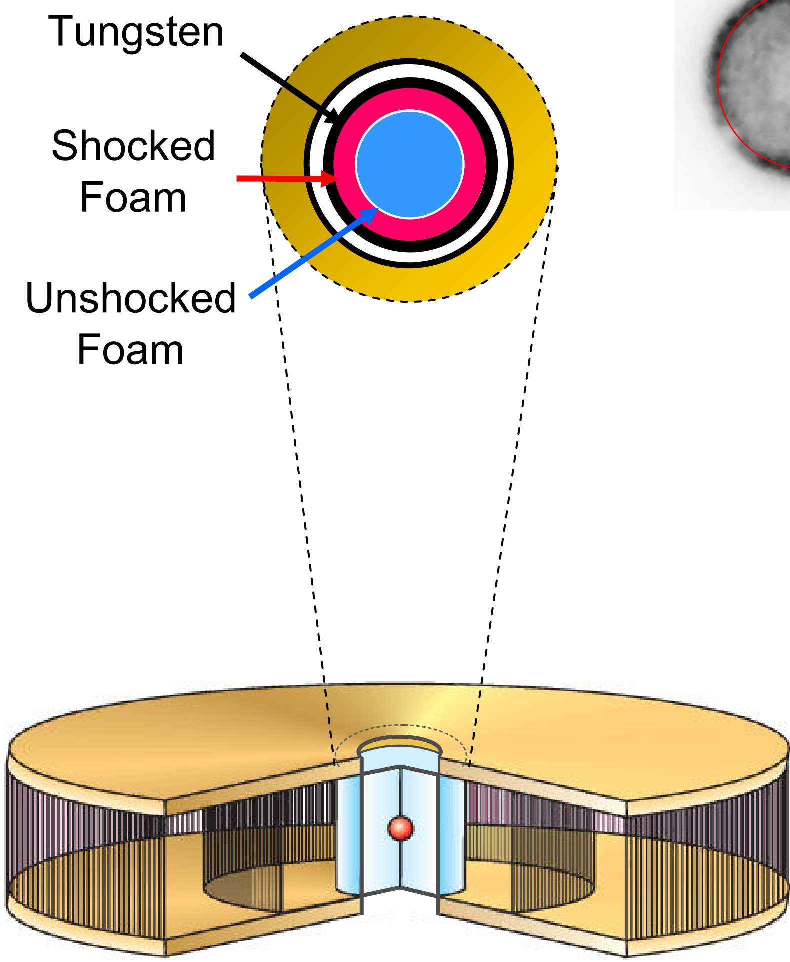


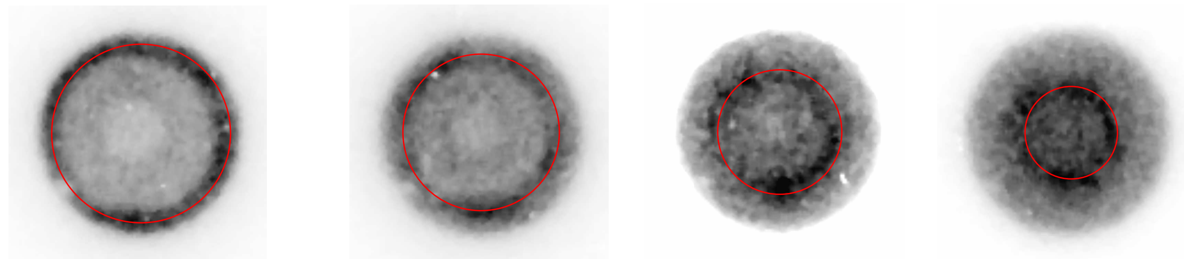
A number of diagnostics are used to measure conditions of the dynamic hohlraum.

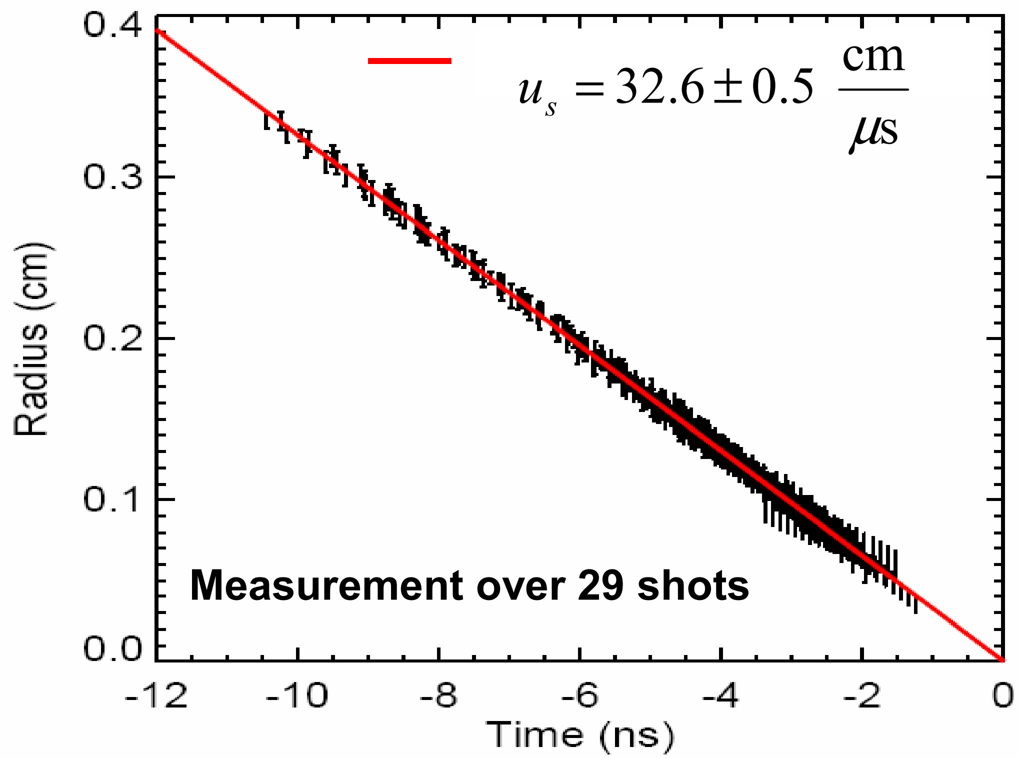


- **Z-pinch physics**
  - -Power / Energy
  - -Self-Emission Imaging
  - -Backlit Imaging
- **DH source formation**
  - -Si Emission Spectroscopy
  - -Self-Emission Imaging
- **DH hohlraum temperature**
  - -Power / Energy
  - -Axial Foil Heating
  - -Capsule Implosions (Y_n and Ar spectroscopy)
- **DH drive symmetry**
  - -Multi-view Ar Emission Spectroscopy
  - -Backlit Imaging

2-D images of the DH source shock provide information on the shock velocity and symmetry.

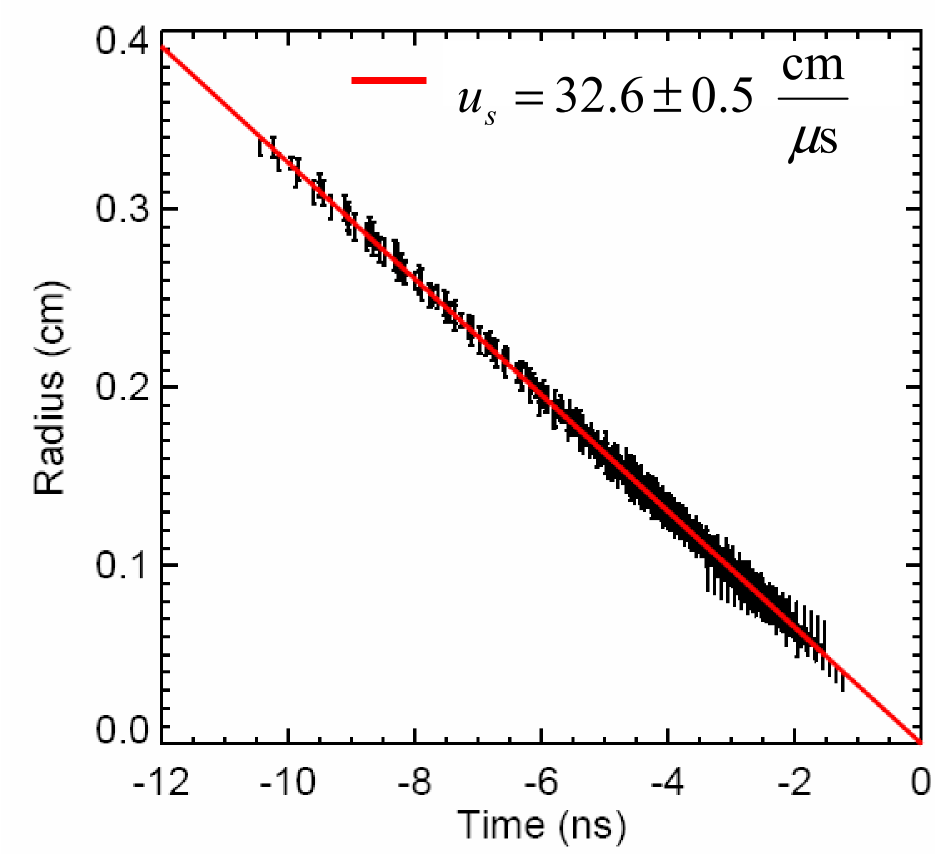






The DH source shock velocity is measured across 29 shots to be reproducible to ~ 1.5%.

Shock Measurements from 29 shots



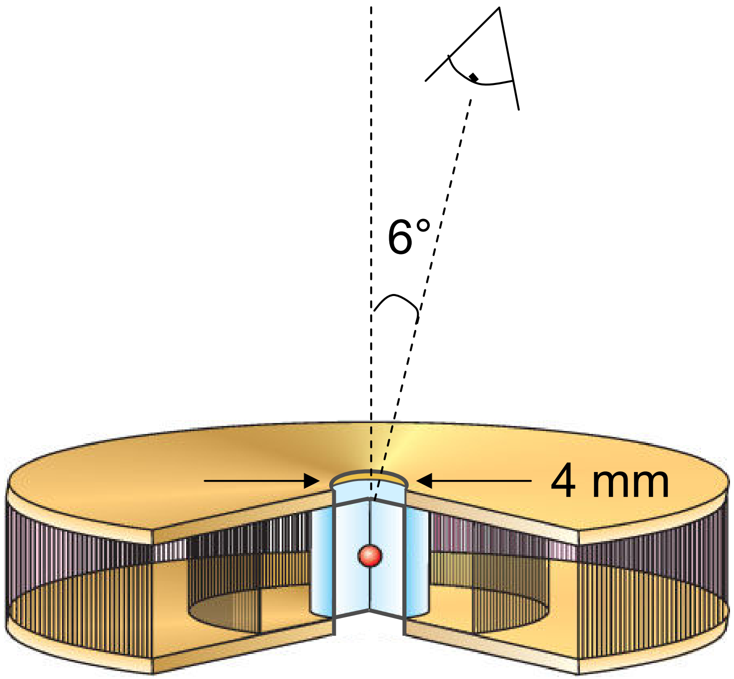
$$P_s = \frac{2u_s^2}{\rho_u(\gamma+1)} \xrightarrow{\text{Ideal Gas}} u_s \propto \sqrt{T_s \rho_s \rho_u}$$

$$\frac{du_s}{u_s} = \sqrt{\left(\frac{\partial T_s}{2T_s}\right)^2 + \left(\frac{\partial \rho_s}{2\rho_s}\right)^2 + \left(\frac{\partial \rho_u}{2\rho_u}\right)^2 + \left(\frac{\partial Inst.}{Inst.}\right)^2}$$

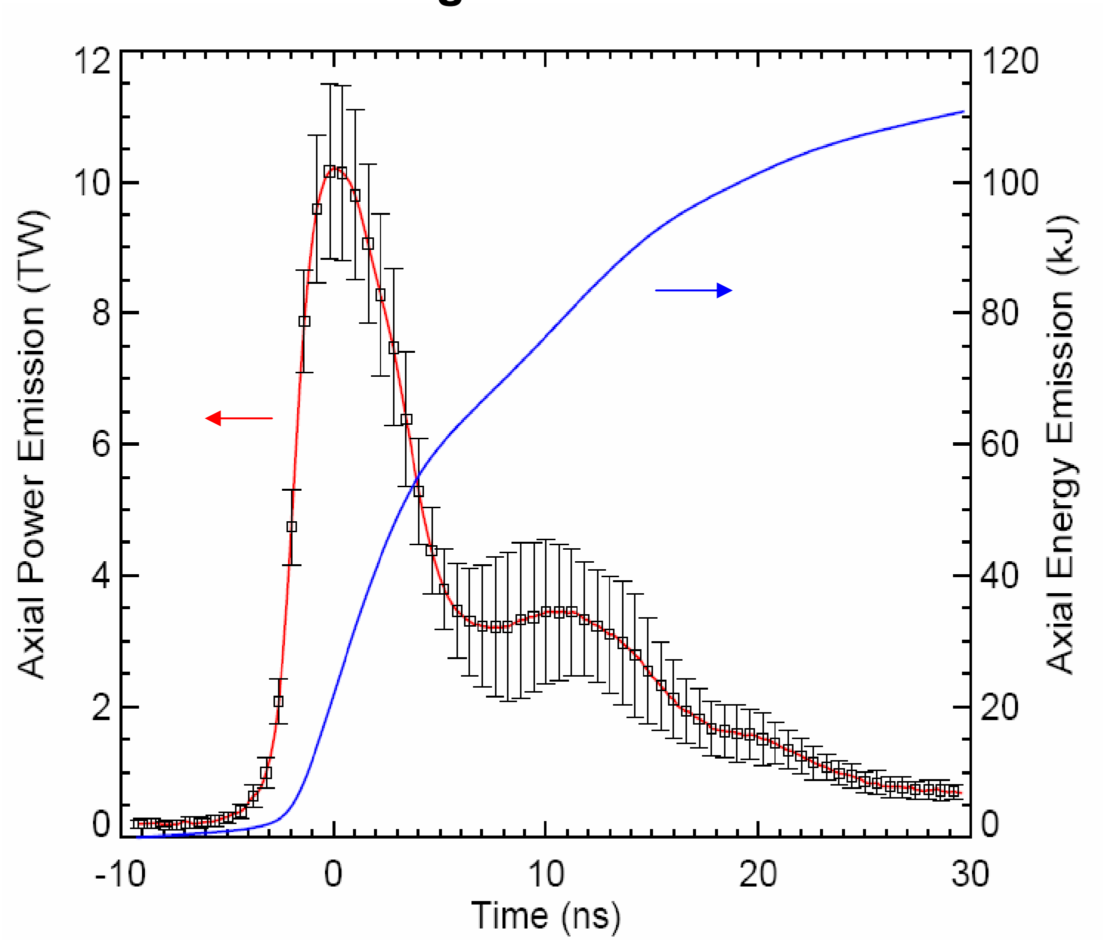
$$\rightarrow \quad \frac{dT_s}{T_s} < 2\frac{du_s}{u_s}$$

Source temperature is reproducible to < 3%

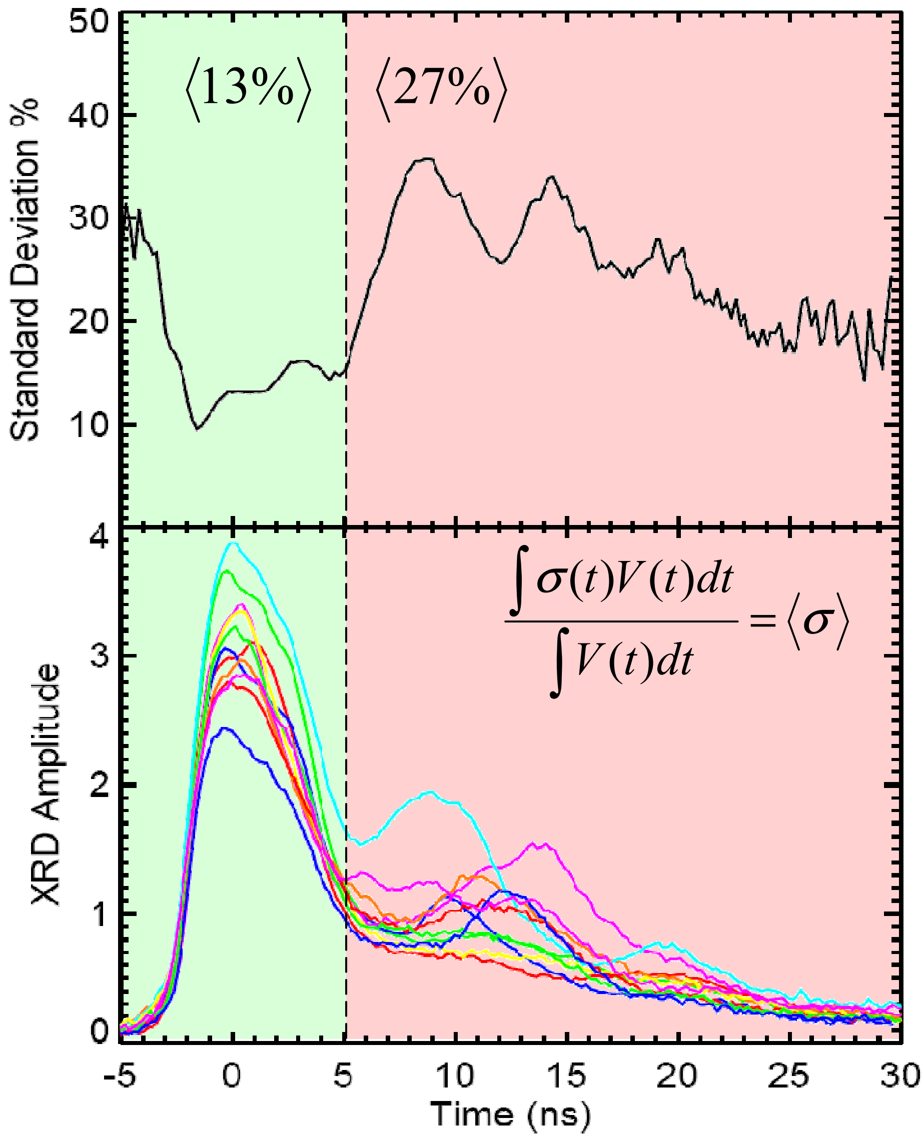
X-ray photodiodes (XRDs) and bolometers are used to measure the axial hohlraum emission.



Emission through a 4 mm diameter REH



Measured from 11 shots spanning 20 months, the DH power emission is reproducible to <13% up to 5 ns after peak.



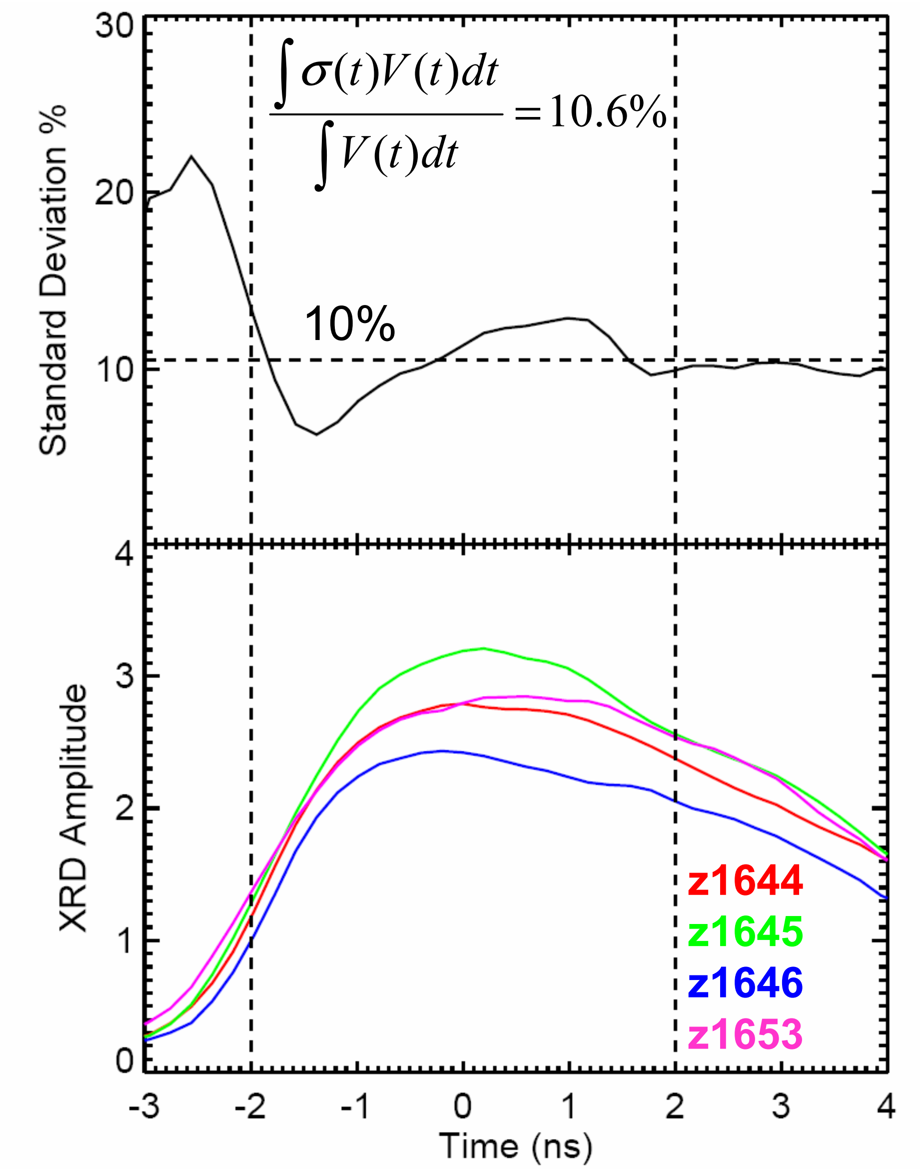
$$\frac{dV_{xrd}}{V_{xrd}} = \sqrt{\left(\frac{\partial P_{DH}}{P_{DH}}\right)^2 + \left(\frac{\partial Inst.}{Inst.}\right)^2} \quad \sim 13\%$$

$$\frac{\partial Instr.}{Instr.} \triangleq$$ Shot-to-shot variability in instrument response

$\frac{\partial Instr.}{Instr.}$	5%	10%
$\frac{\partial P_{DH}}{P_{DH}}$	12%	8%

*Note: This analysis does not include XRD response function changes

Within a given series, the absolute DH power emission can be reproducible to ~ 10% up to 5 ns after peak.

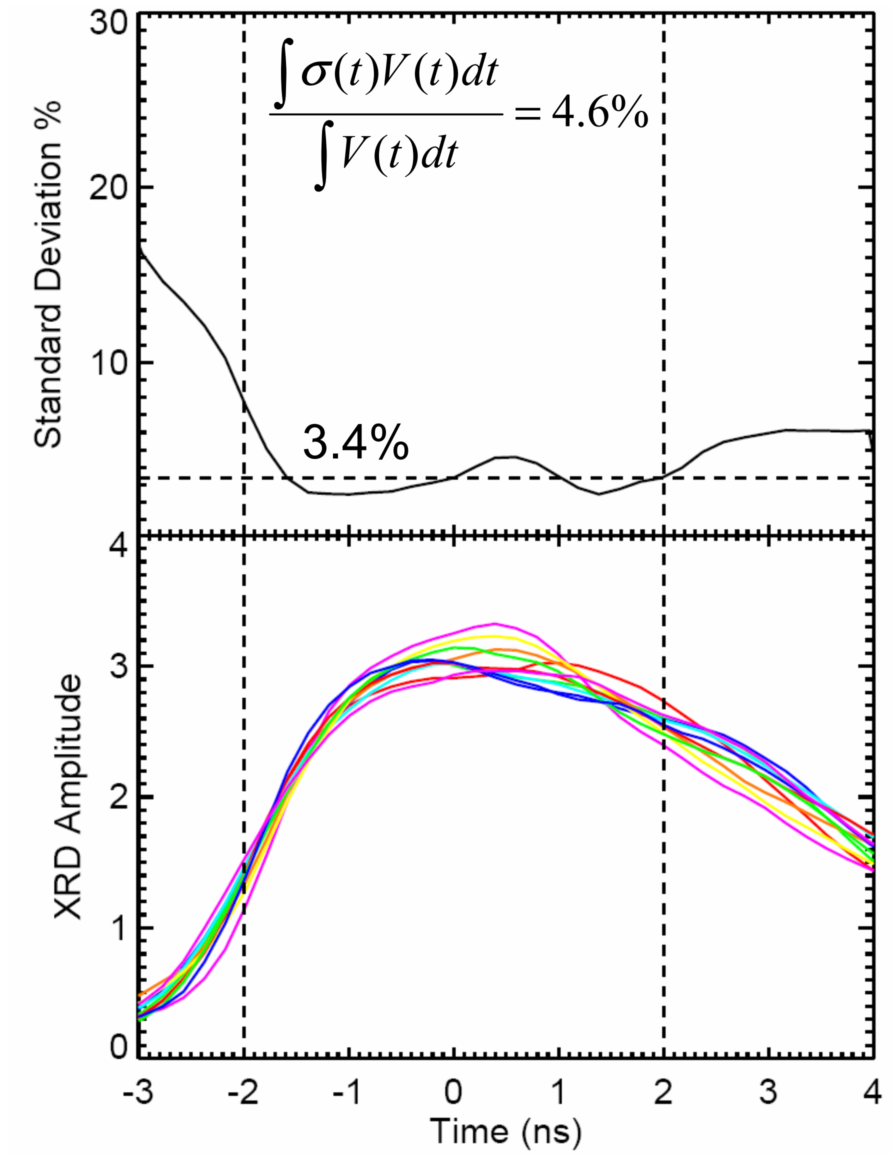


$$\frac{dV_{xrd}}{V_{xrd}} = \sqrt{\left(\frac{\partial P_{DH}}{P_{DH}}\right)^2 + \left(\frac{\partial Inst.}{Inst.}\right)^2} \sim 10\%$$

$\frac{\partial Instr.}{Instr.} \triangleq$ Shot-to-shot variability in instrument response

$\frac{\partial Instr.}{Instr.}$	5%	10%
$\frac{\partial P_{DH}}{P_{DH}}$	9%	< 1%

Measured from 11 shots spanning 20 months, the DH power pulse-shape is reproducible to < 4%.

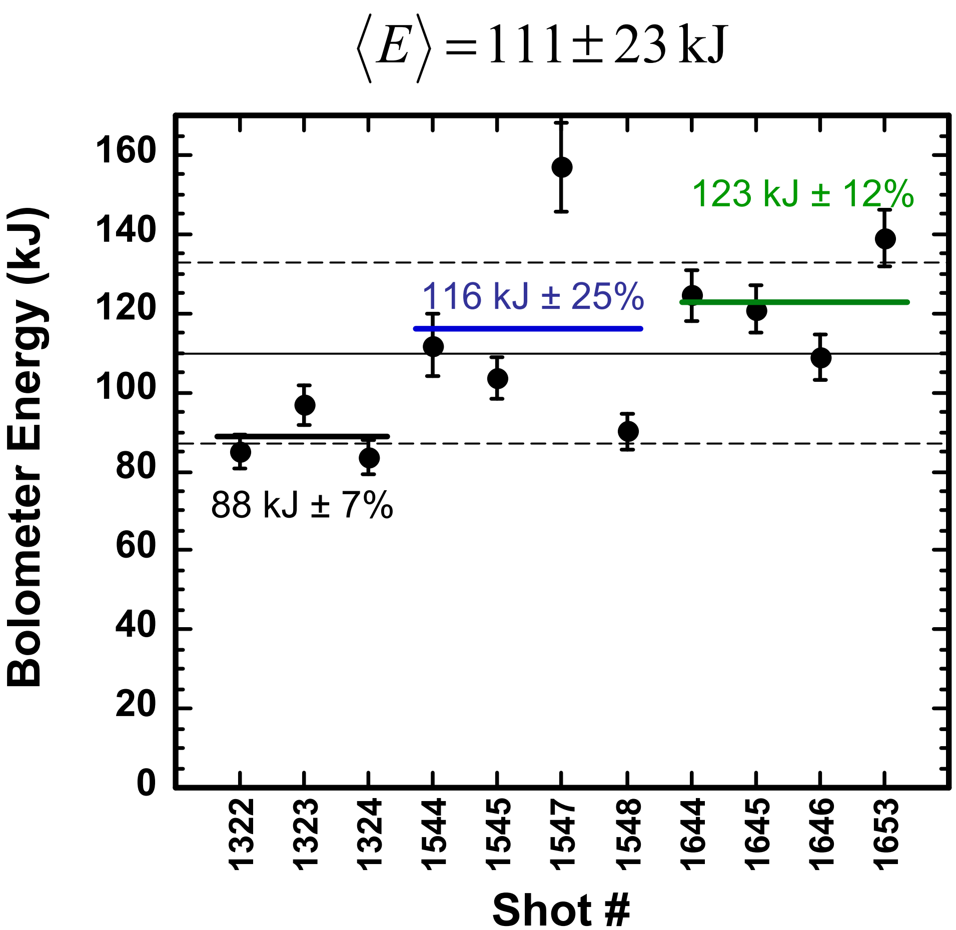


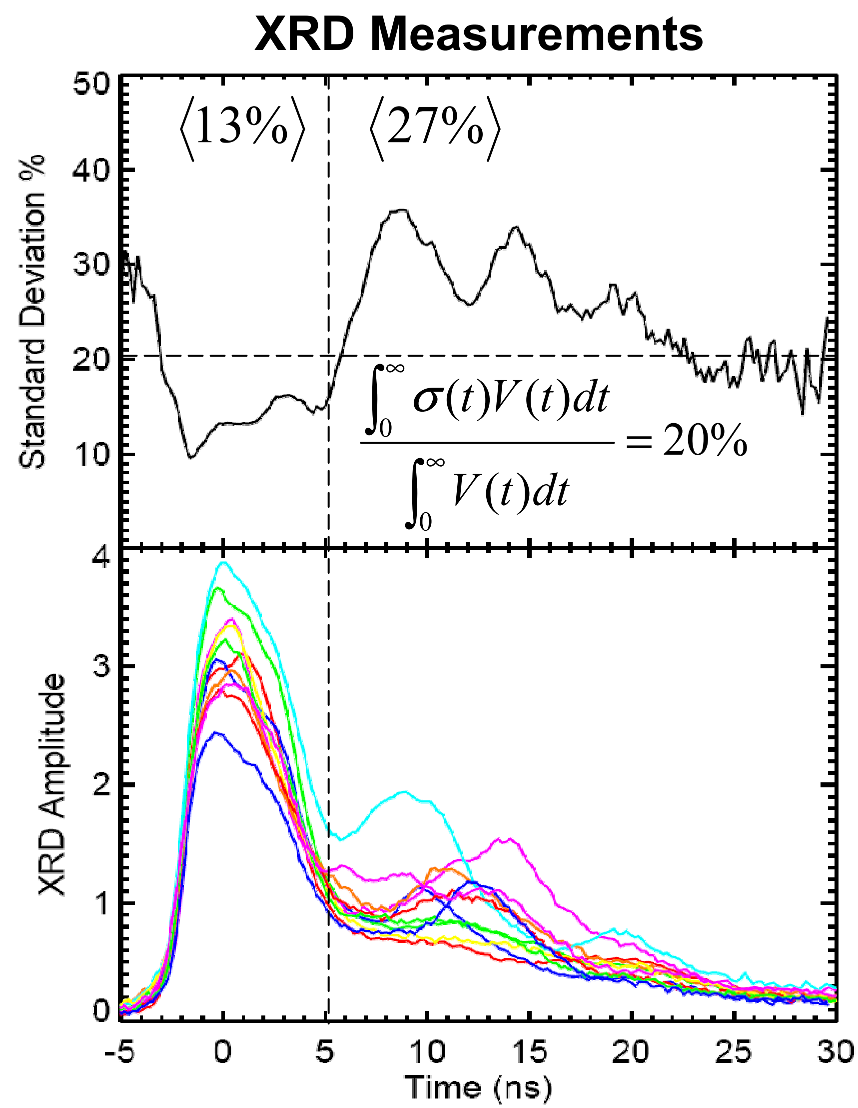
$$\frac{dV_{xrd}}{V_{xrd}} = \sqrt{\left(\frac{\partial P'_{DH}}{P'_{DH}}\right)^2 + \left(\frac{\partial Inst.}{Inst.}\right)^2} \quad \sim 4\%$$

$$\frac{\partial Instr.}{Instr.} \triangleq$$ Shot-to-shot variability in instrument response

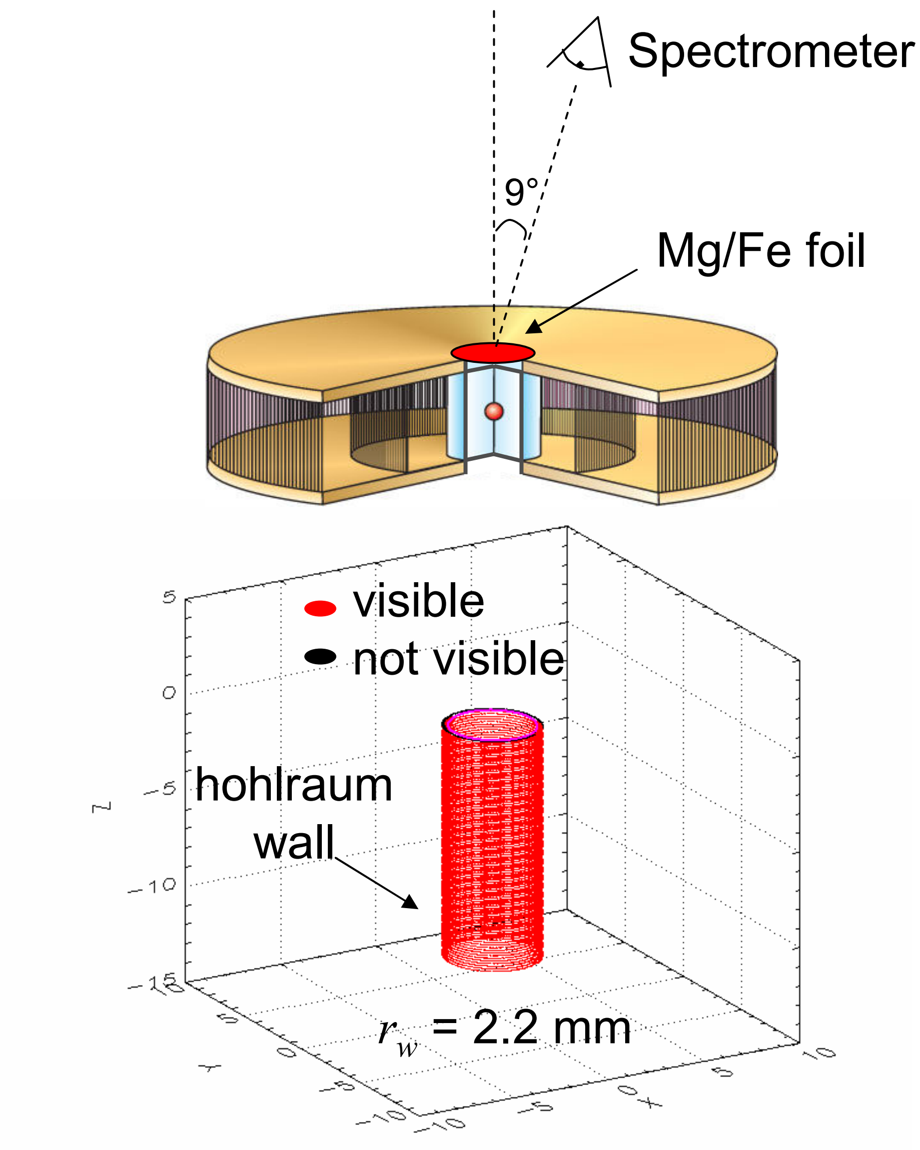
$\frac{\partial Instr.}{Instr.}$	2%	4%
$\frac{\partial P'_{DH}}{P'_{DH}}$	3%	< 1%

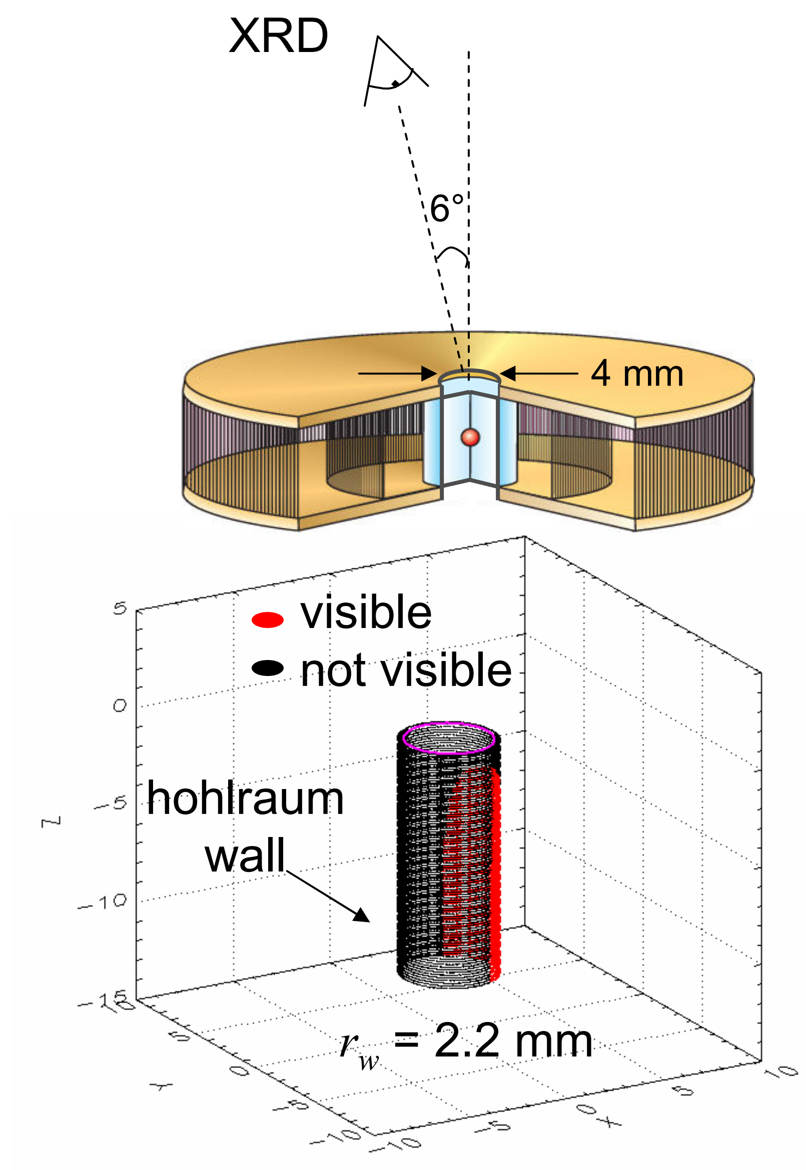
Due to late-time power variability, the total axial energy emission is reproducible to ±20%, but can be <13% within a given series.





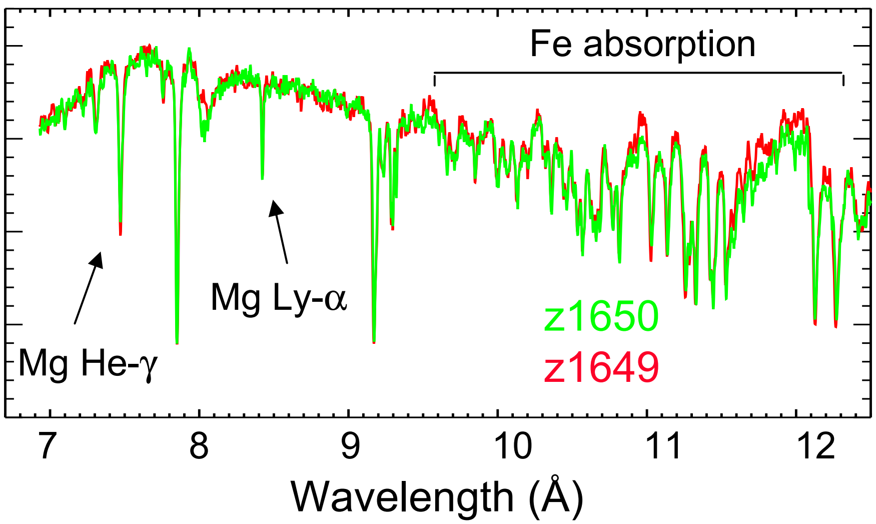
Mg/Fe witness foils on the upper REH provide a more local measure of the DH environment.



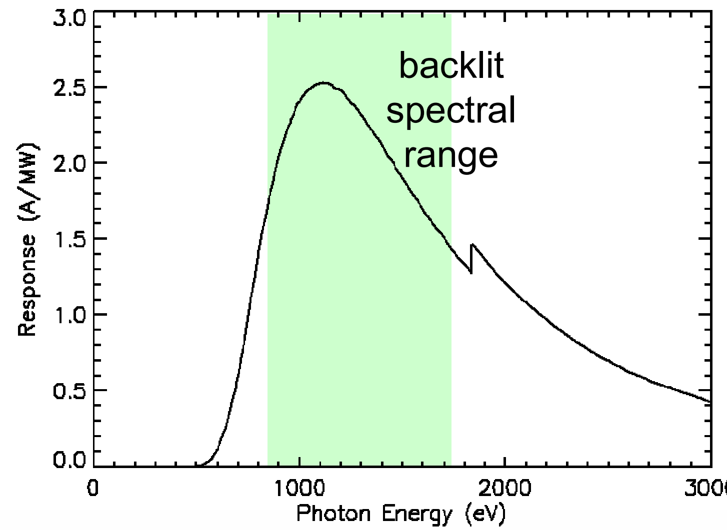


Mg/Fe witness foils are heated by the rising DH thermal emission and backlit by the stagnation peak.

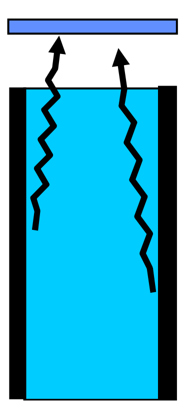
Time-Integrated Backlit Absorption Spectra



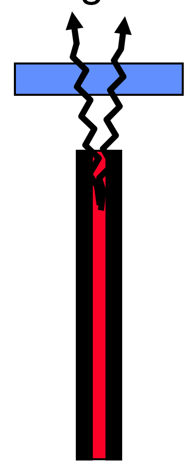
Be-parylene XRD response

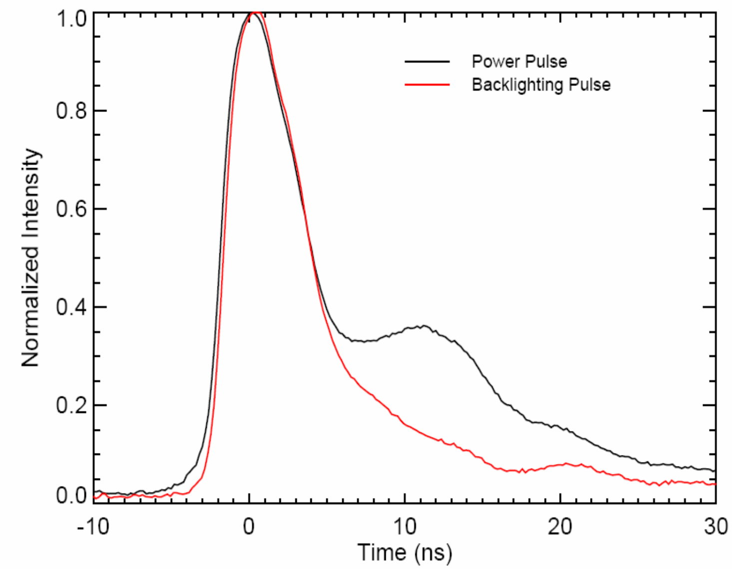


Foil is heated during the DH implosion

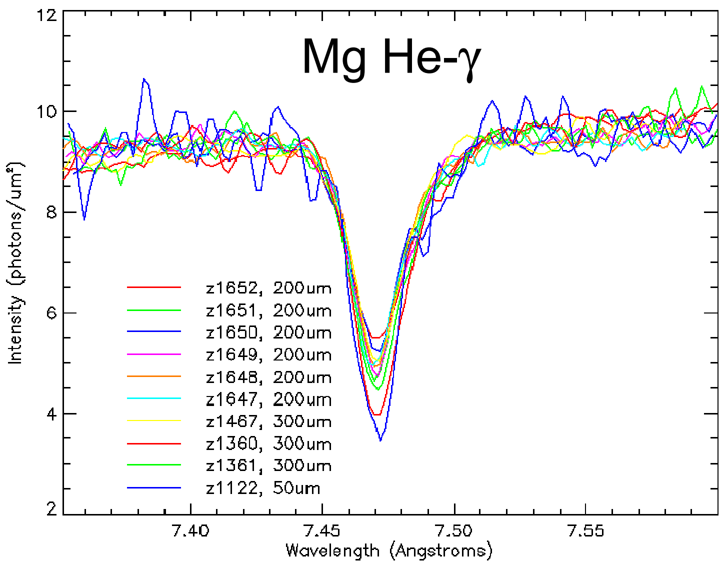


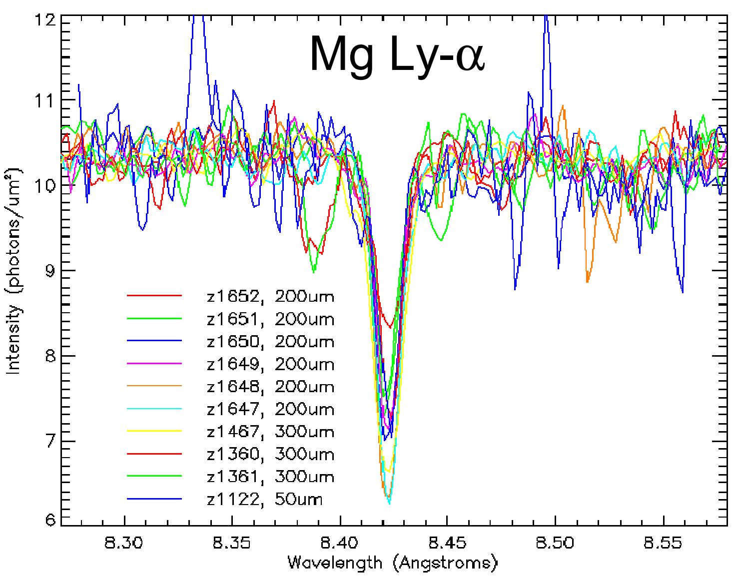
Foil is backlit at stagnation





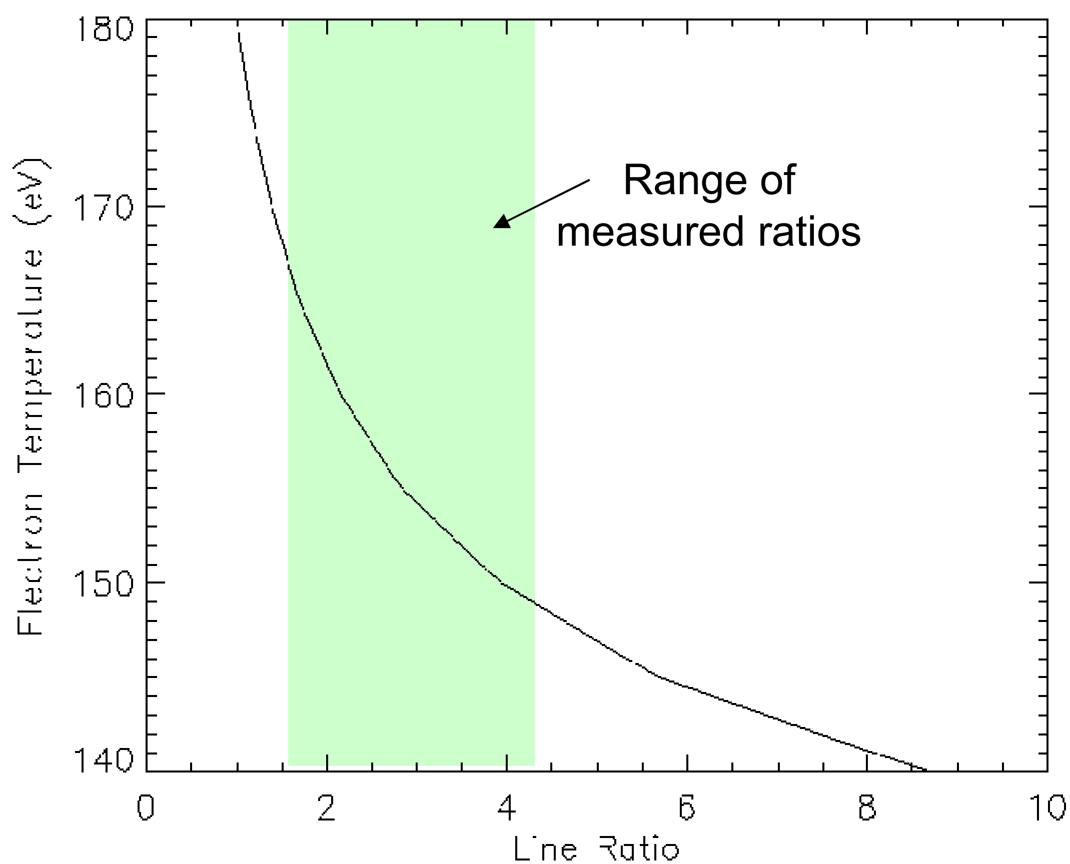
The ratio of the Mg He-γ to Ly-α absorption lines provides a measure of the sample temperature.



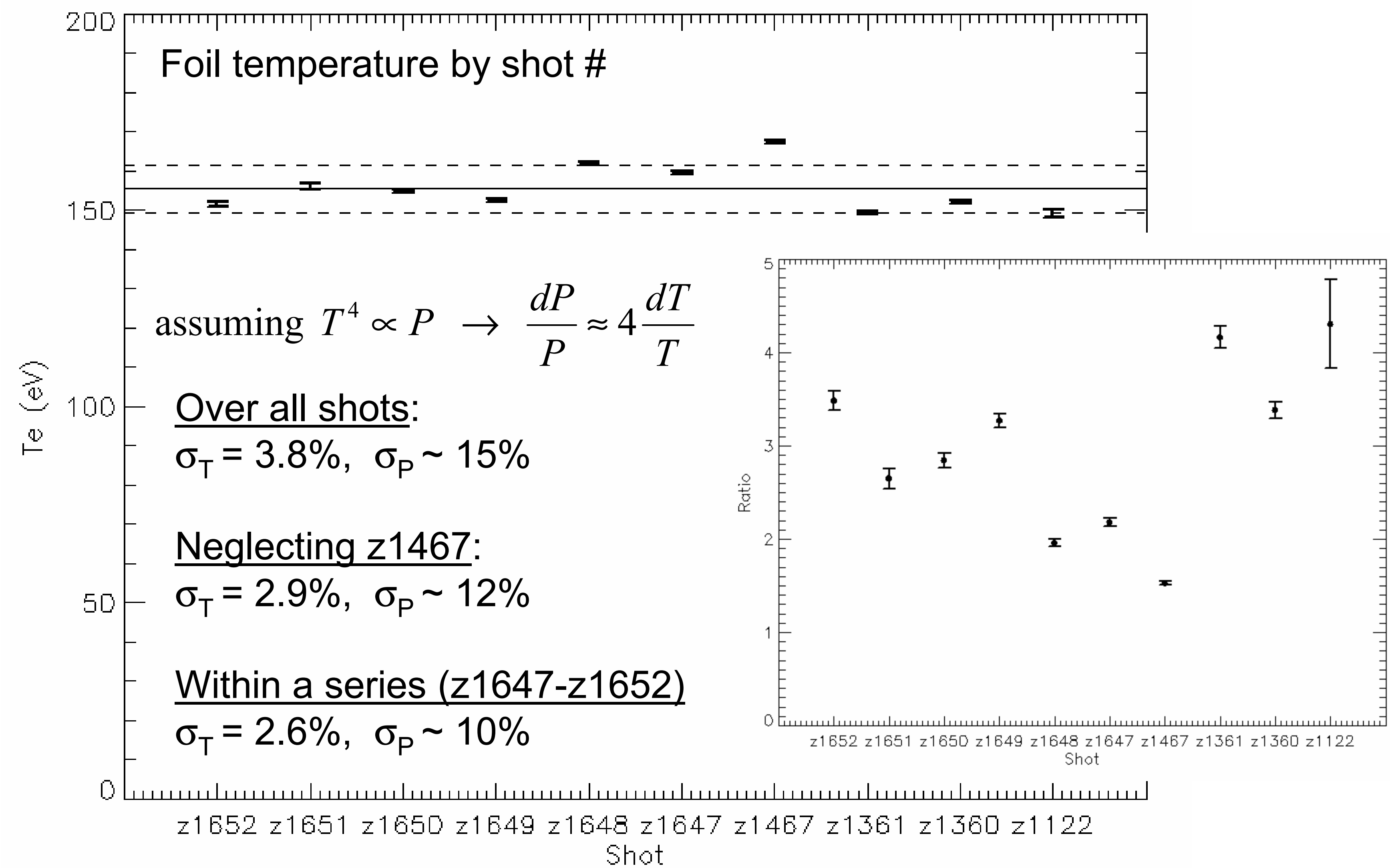


PrismSpect Calculation

ρ = 0.05 g/cc, ρr = 1.053e-4 g/cm^2



Measured line ratios from 10 shots spanning ~3 years indicate sample temperatures that are reproducible to < 4%.



assuming $T^4 \propto P \rightarrow \frac{dP}{P} \approx 4\frac{dT}{T}$

Over all shots:
σ_T = 3.8%, σ_P ~ 15%

Neglecting z1467:
σ_T = 2.9%, σ_P ~ 12%

Within a series (z1647-z1652)
σ_T = 2.6%, σ_P ~ 10%

Summary

- The Z-pinch Dynamic Hohlraum (DH) is formed by an imploding tungsten liner and heated by a strong radiating shock.
- The measured source shock velocity is reproducible to ±1.5%, which indicates a shock temperature reproducibility of ~< 3%.
- XRD measurements indicate an axial x-ray power emission that is reproducible to < ±13% up to 5 ns after the peak emission, but show a power variability of ±27% for times > 5ns after peak.
- XRD measurements indicate an axial x-ray power *pulse-shape* that is reproducible to < ±4% up to 5 ns after the peak emission.
- Bolometer measurements show a ±20% variability in the total axial emitted energy, which is consistent with the time-integrated variability of the XRD power measurements. This high degree of variability is caused by inconsistency in the late-time (> 5 ns after peak) emission from the REH. Within a shot series (back-to-back experiments), the total emitted energy can vary by < ±13%.
- Absorption spectra of Mg/Fe foils placed at the DH REH show sample temperature variations of < ±4%, which is consistent with the XRD measured power variation of ±13% up to 5 ns after peak emission.