Diagnostic Hole Closure Calculations for Z-Pinch-Driven Hohlraums on Z

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Abstract

Experiments on the Z accelerator are being developed to heat a hohlraum with x-rays from a z-pinch external to the hohlraum. The experiments produce radiation temperatures in excess of 100 eV and are useful in preparation for NIF [1]. A cylindrical hohlraum 4 mm in height and diameter, is placed atop a tungsten wire array CH foam target z-pinch. The wall temperature inside the hohlraum is measured by observing the radiation emitted through a 2 mm diameter hole. The hole closes over time due to the blow-off of hohlraum material. The changing effective hole area as a function of time effects the hohlraum temperature measurement. A 10 g/cc CH foam plug has been inserted into the hole in an attempt to keep the hole open longer. 2-D calculations with the RAGE radiation hydrodynamics code have been used to predict the diagnostic hole closure for these experiments. Results of the RAGE calculations with the measurements of radiation emission from the hole will lead to a measured wall and radiation temperature history for these experiments.

[1] T.W.L. Sanford, et al. this meeting.

Related Published Papers and Presentations at APS-DPP 99

Published Papers:

•**"Z-Pinch Generated X-Rays Demonstate Potential for Indirec-Drive ICF Experiments,"** T. W. L. Sanford, R. E. Olson, G. A. Chandler, M.S. Derzon, D. E. Hebron, R. J. Leeper, R. C. Mock, T. J. Nash, L. E. Ruggles, W. W. Simpson, K. W. Struve, R. A. Vesey , R. L. Bowers, and D. L. Peterson**,** to be published, ***Phys. Rev Lett***. (1999).

•**"Z-Pinch Generated X-Rays in Static-Wall-Hohlraum Geometry Demonstrate Potential for Indirect-Drive ICF Studies,"**T. W. L. Sanford, R. E. Olson, R. C. Mock, G. A. Chandler, D. E. Hebron, R. J. Leeper, T. J. Nash, L. E. Ruggles, W. W. Simpson, K. W. Struve, R. A. Vesey, R. L. Bowers, W. Matuska, D. L. Peterson, and R.R. Peterson, 1st Intl. Conf. Inertial Fusion Sci. and Appl. (Bordeaux, France, 1999).

•**"Characteristics of ICF Relevant Hohlraums Driven by X-Rays from a Z-pinch,"** T. W. L. Sanford, R. E. Olson, R. A. Vesey, G. A. Chandler , D. E. Hebron, R. C. Mock, R. J. Leeper, T. J. Nash, C.L. Ruiz, L. E. Ruggles, W. W. Simpson, R. L. Bowers, W. Matuska, D. L. Peterson, and R.R. Peterson **,** Target Fabrication Conference (November, 1999).

At this meeting:

•[FP1.20] "**Shaped Foam and ICF Pellet Implosions on Z,"** Tom Nash, Mark Derzon, Gordon Chandler, Ramon Leeper, Tom Mehlhorn, Dave Fehl, Joel Lash, Carlos Ruiz, Steve Slutz, Gary Cooper, Darrell Petersen, Richard Bowers, and Walter Matuska.

•[FP1.13] **"Instability Effects on Energy Flow in Z-Pinch Simulations,"** D. L. Peterson, R. L. Bowers, C. Deeney, M. Derzon, M. Douglas, and N. F. Roderick.

•[QO1.03] **"Dynamics of High-Temperature X-Ray Driven Hohlraums on Z,"** T. W. L. Sanford, R. E. Olson, G. A. Chandler, S. Dropinski, T. L. Gilliland, D. Jobe, D. E. Hebron, S. Lazier, R. J. Leeper, R. C. Mock, T. J. Nash, L. E. Ruggles, J. F. Seamen, W. W. Simpson, K. W. Struve, J. A. Torres, R. A. Vesey, R. L. Bowers, W. Matuska, D. L. Peterson, and R.R. Peterson.

Diagnostic Hole Closure is Critical to Measurement of Radiation Temperature in Z Hohlraums

- RAGE code predictions of hole closure.
- Plastic foam plugs or thin foils may help slow hole closure.
- Best guess radiation temperature calculation, based on observed radiated power is performed.
- Sensitivity of hole closure to radiation temperature is studied.
- Bound radiation temperature in 4x4 pinch driven hohlraums.

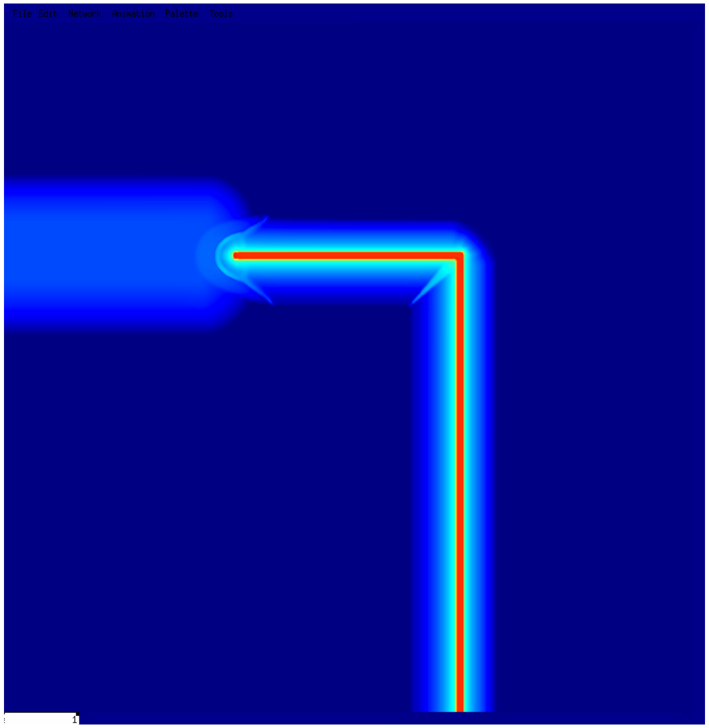
RAGE is a 1, 2, or 3-D AMR Radiation Hydrodynamics Computer Code Developed by SAIC and LANL

- Hydrodynamics with an Adaptive Mesh Refinement (AMR) method.
- Radiation Transport by Grey Diffusion
- Applied temperature and energy sources.
- Opacities and equations of state from SESAME or analytic models.
- Platforms: LANL Cray or ASCI.
- Post-Processing with POP

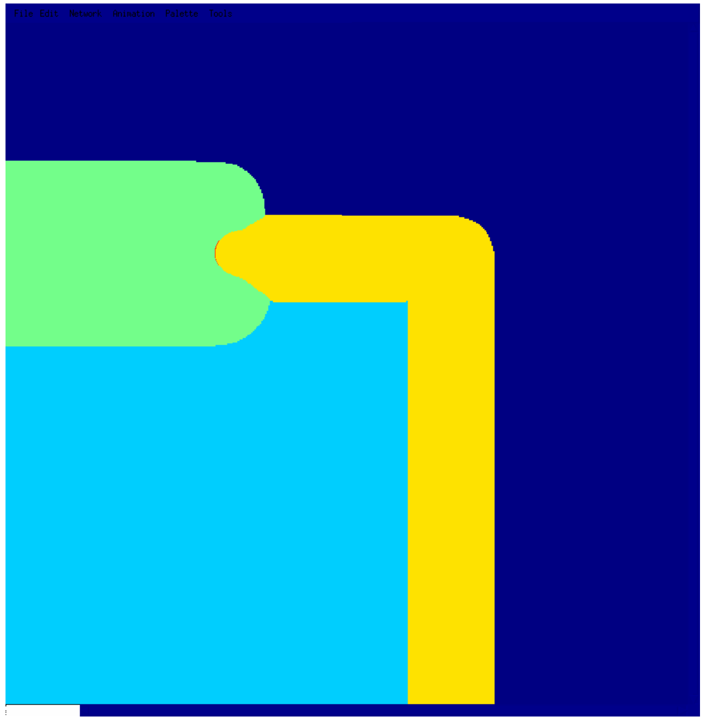
Foam and Glue Can Keep Gold from Blowing Into Hole

- CH Foam + Glue
- 230.6 ns

Mass Density



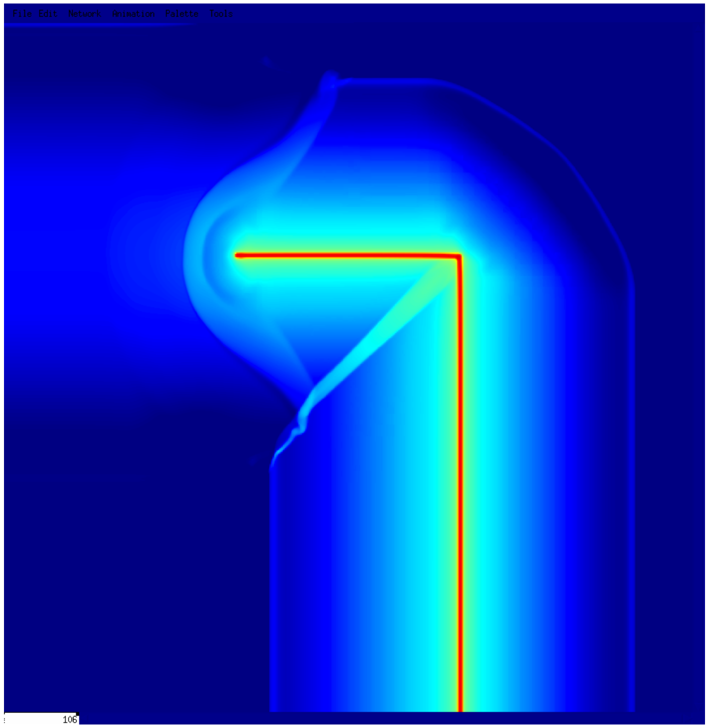
Materials



Foam and Glue Can Keep Gold from Blowing Into Hole

•CH Foam + Glue
•233.7 ns

Mass Density



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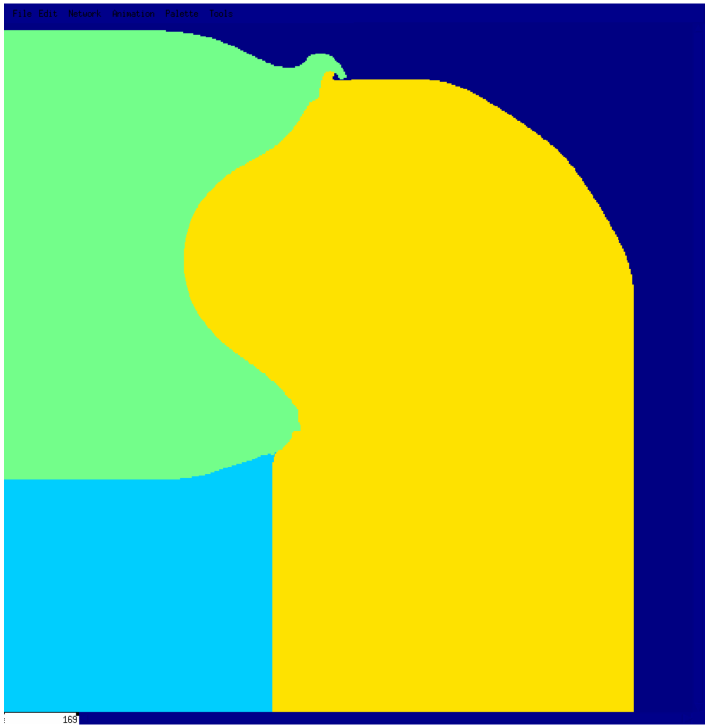
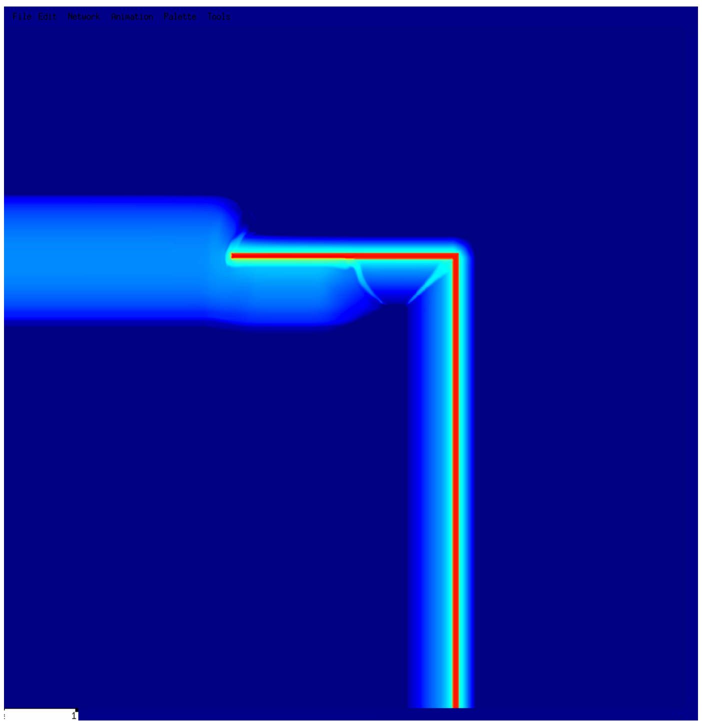


Thin Plastic Foil Can Fill Hole and Push Any Gold Vapor out of Hole

- CH Foil
- 230.6 ns

Mass Density



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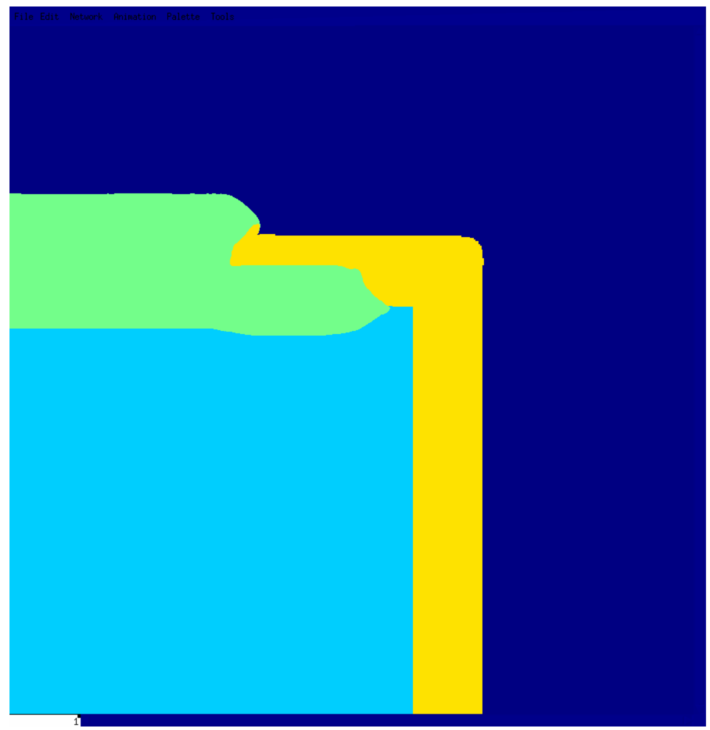
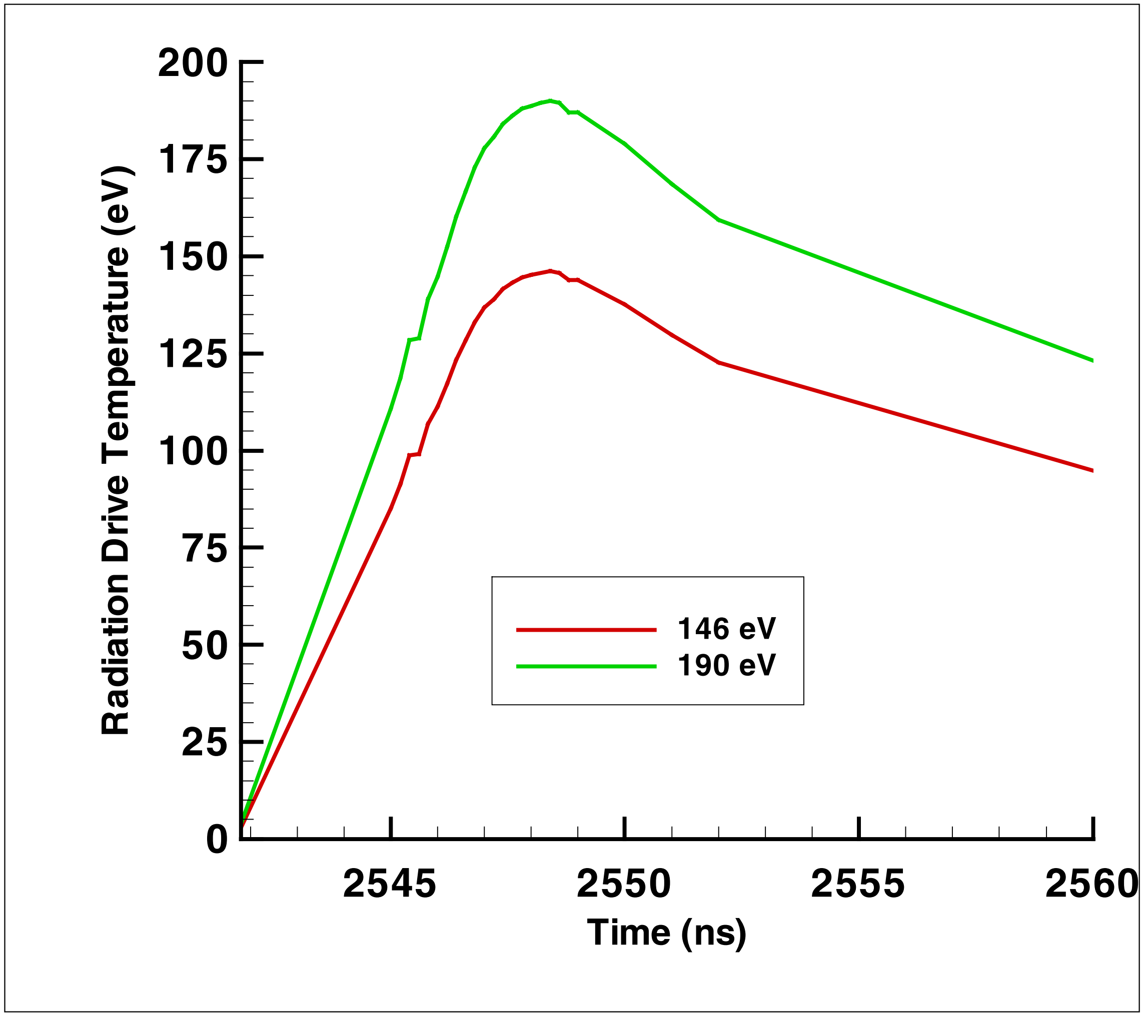
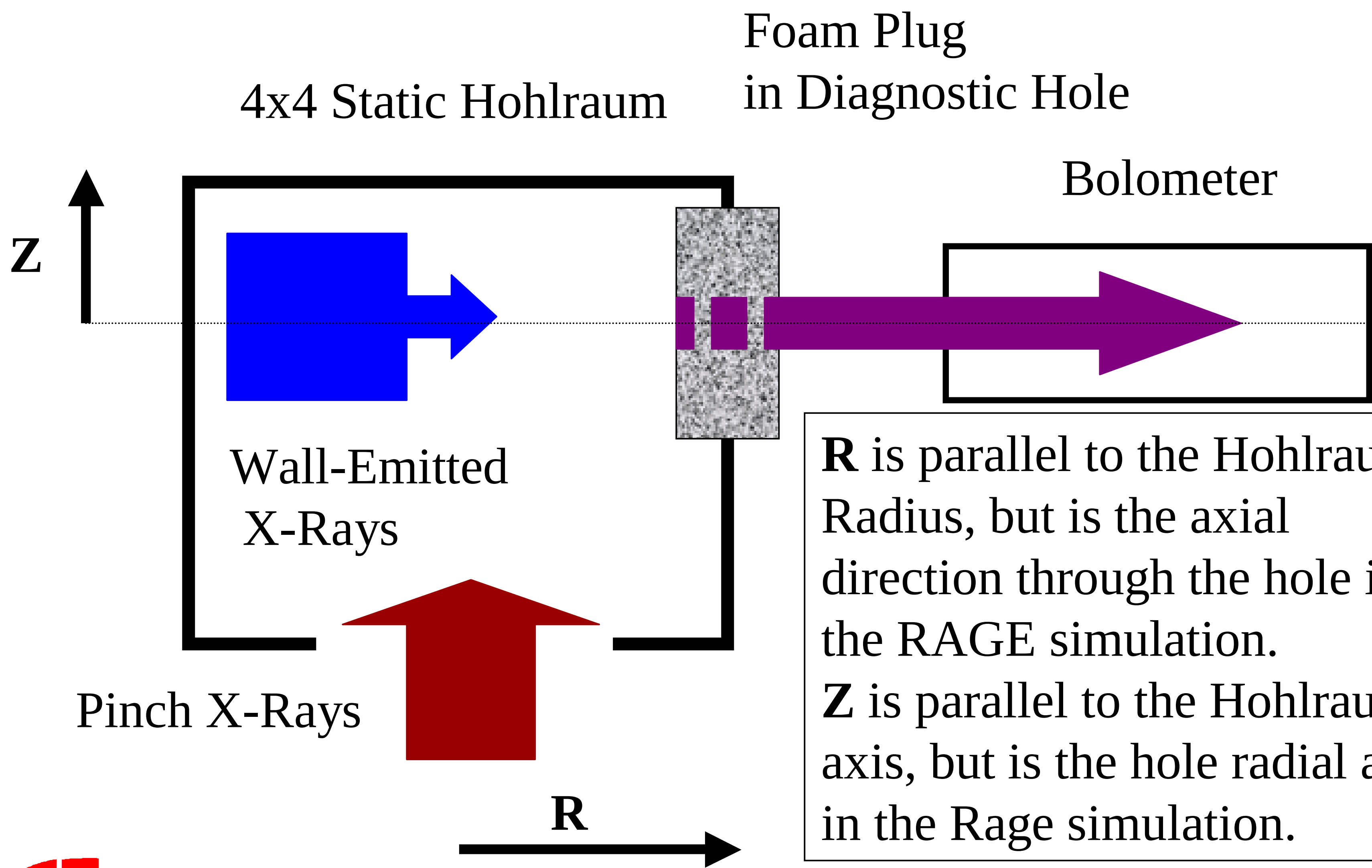


RAGE Target Simulations Performed for Two Drive Temperature Histories

- Radiation temperature was originally estimated from Bolometer measurements on shot Z442 by assume diagnostics hole radius of 1.4 mm.
- Observed radiation is from Wall, so must divide by albedo to get drive temperature.
- Original drive temperature peaks at 146 eV.
- Other diagnostics (shock break-out) suggest a peak drive temperature of 190 eV.
- Time is measured from Marx trigger.



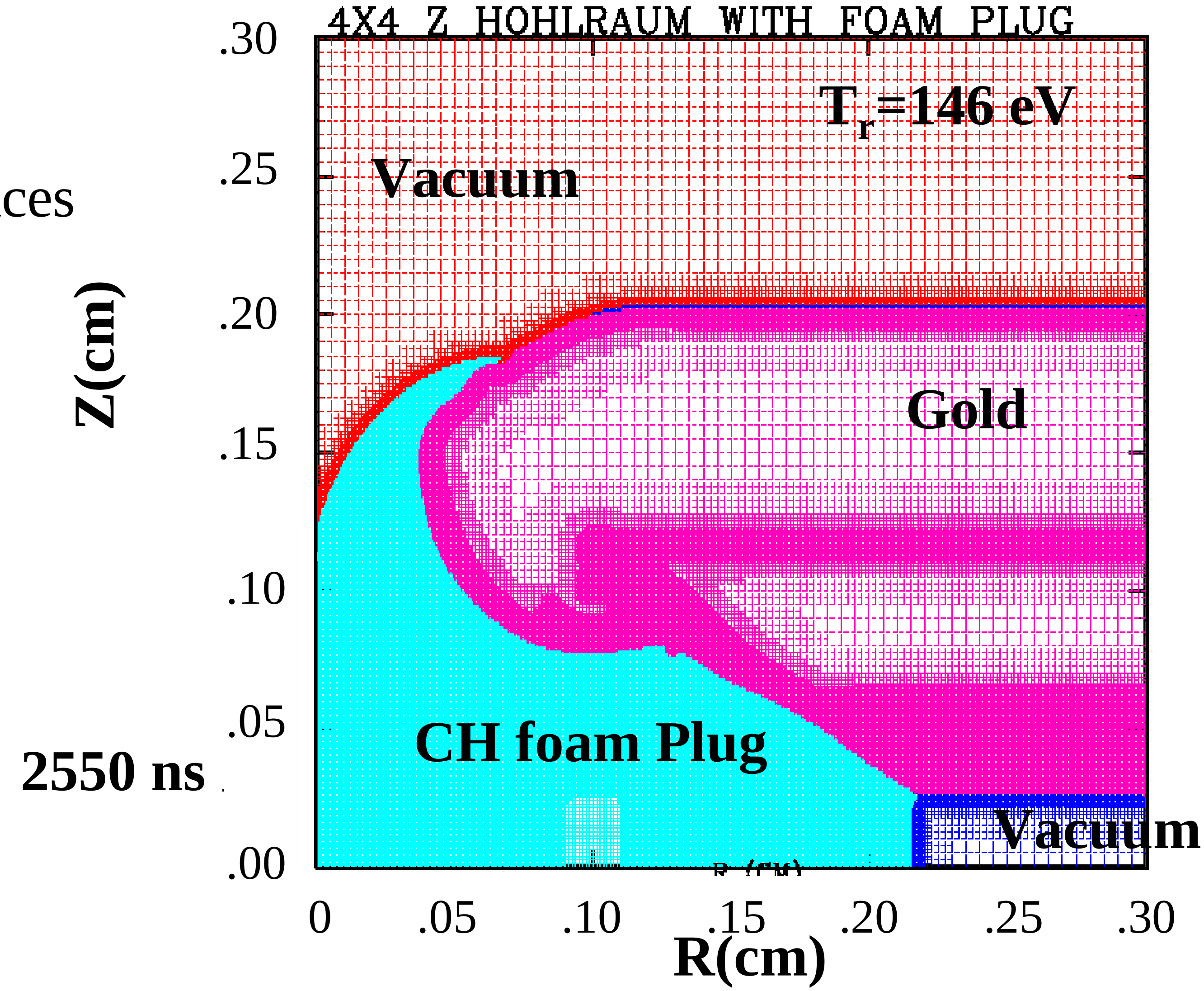
RAGE Target Simulations of Z Hohlraums



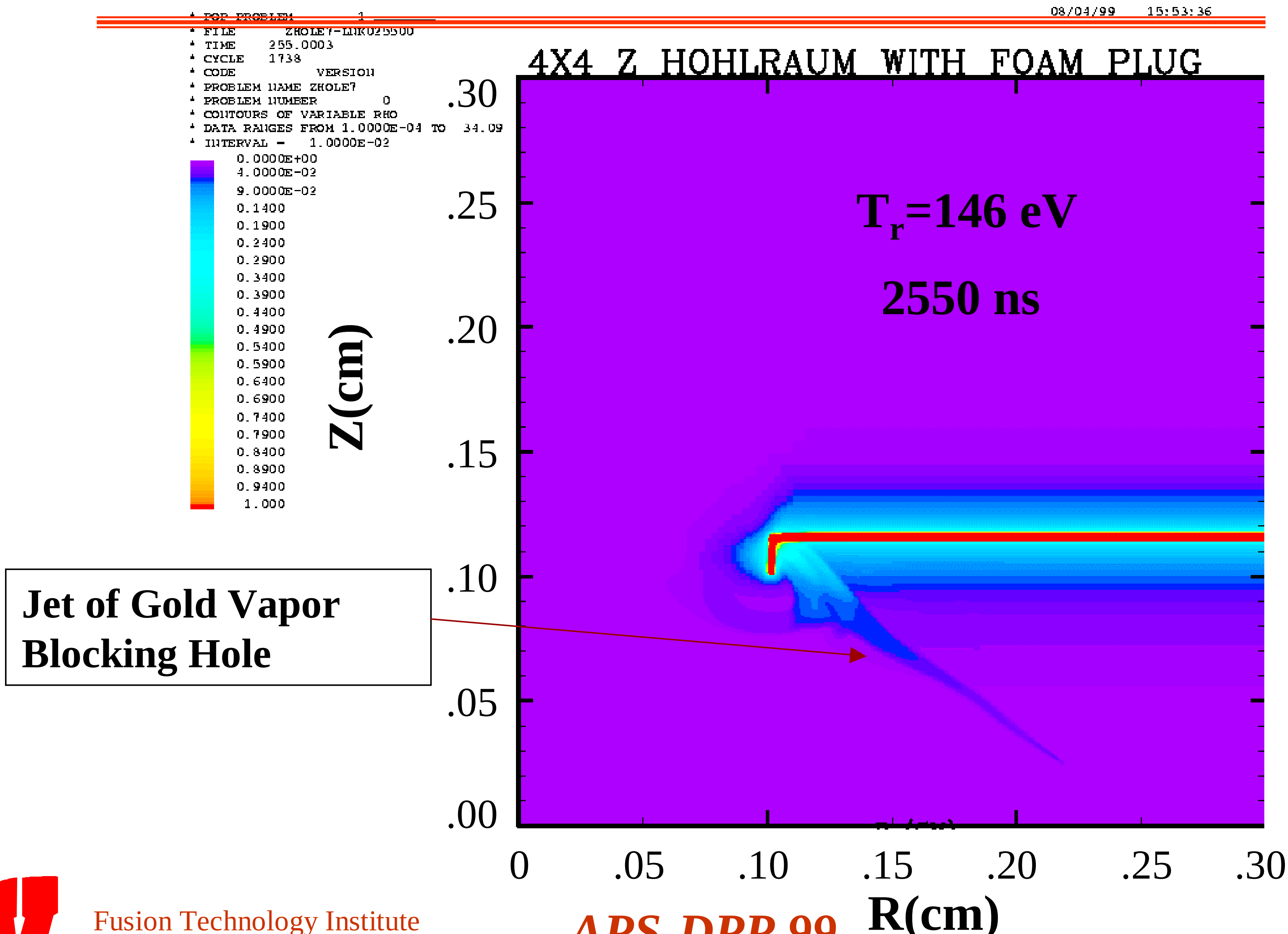
R is parallel to the Hohlraum Radius, but is the axial direction through the hole in the RAGE simulation.
Z is parallel to the Hohlraum axis, but is the hole radial axis in the Rage simulation.

Geometry Used RAGE Target Simulations

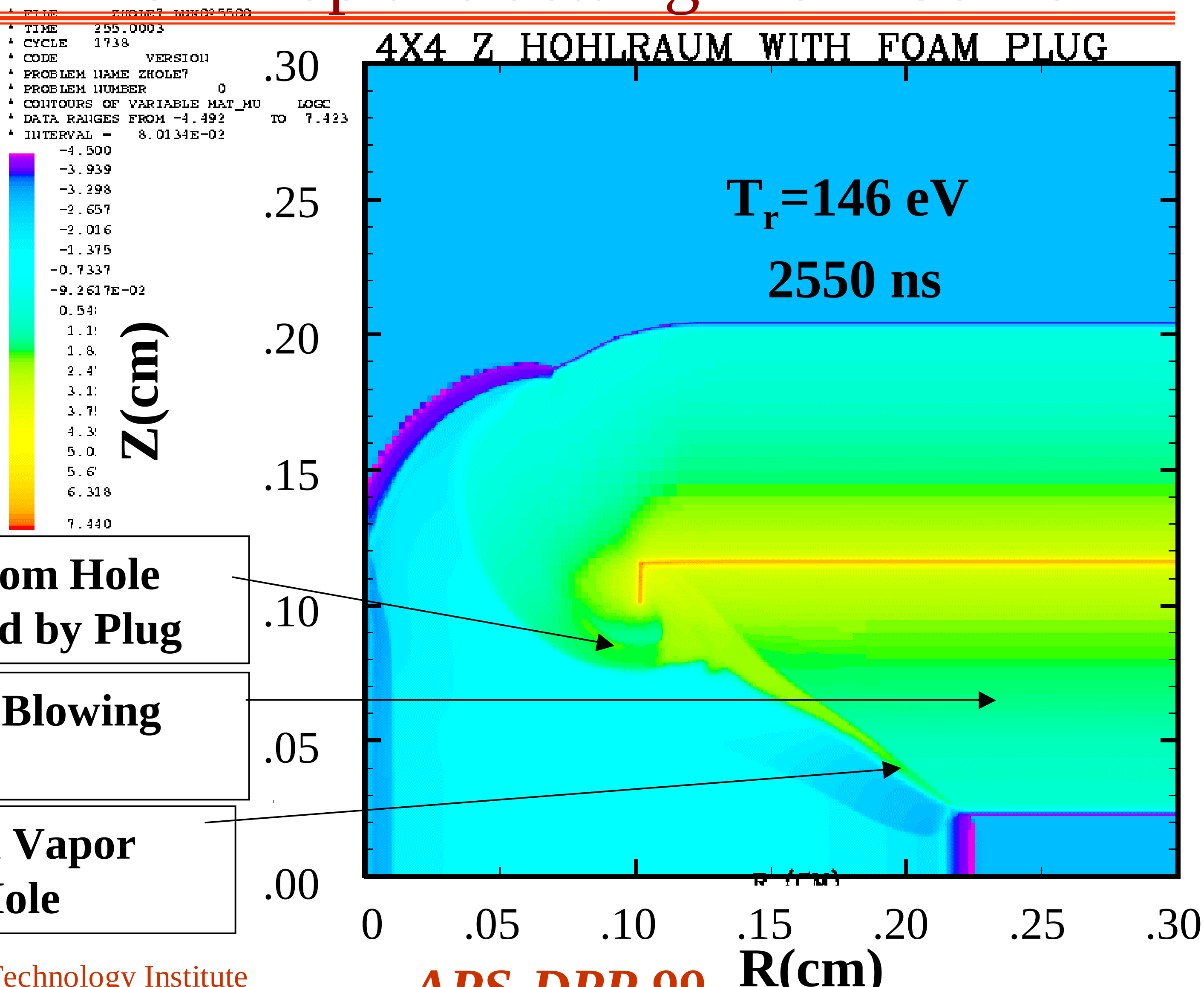
- RAGE mesh
- Much finer at material interfaces and density gradients.



Mass Density Contours Show Jetting from Corner



Opacity Contours Show Blockage of Hole Due Blow-off From Top and Jetting From Corner

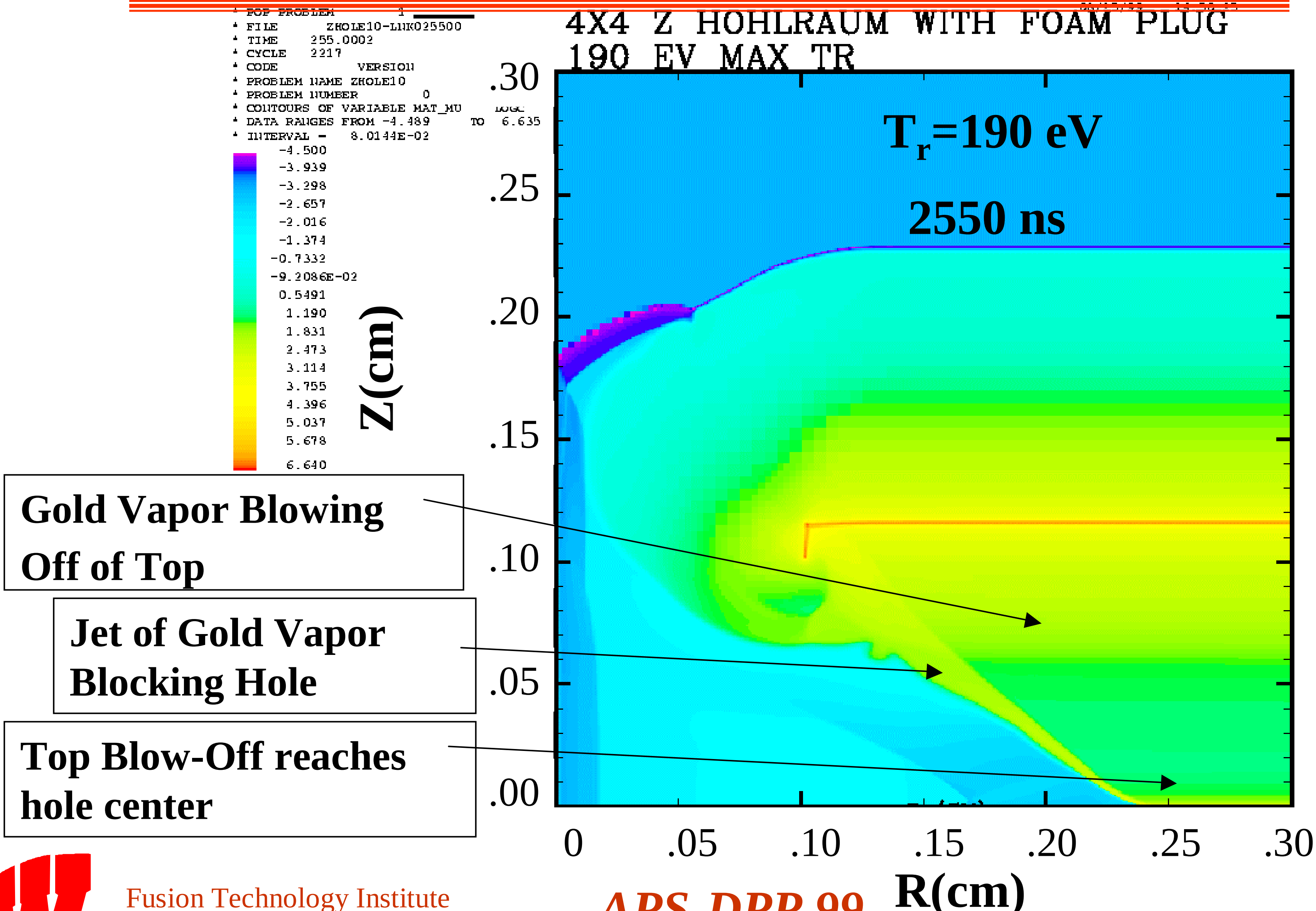


Blow-Off From Hole Edge Limited by Plug

Gold Vapor Blowing Off of Top

Jet of Gold Vapor Blocking Hole

High Drive Temperature Case Predicts Gold From Hohlraum Top Reaching Hole Center by 2550 ns



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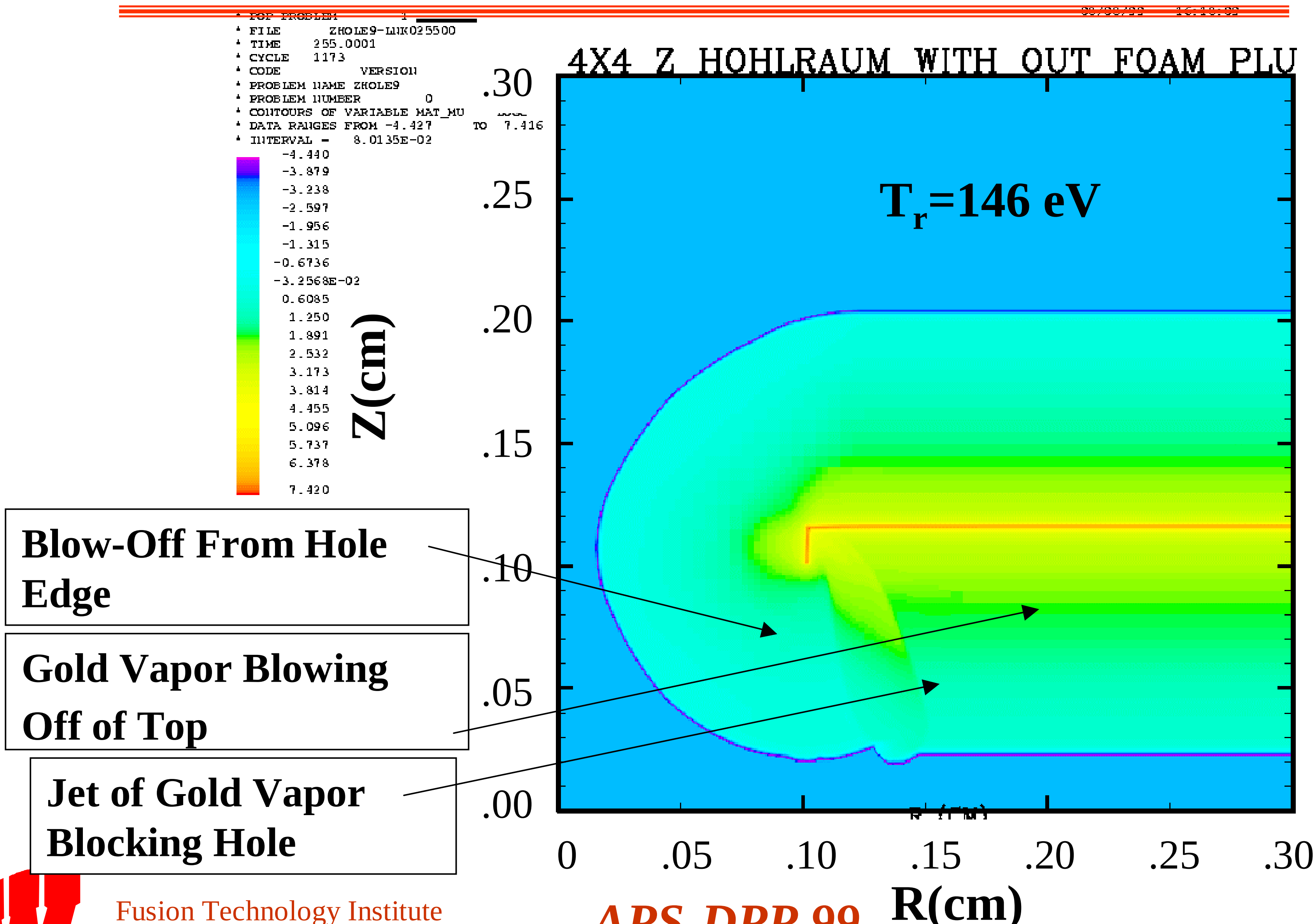
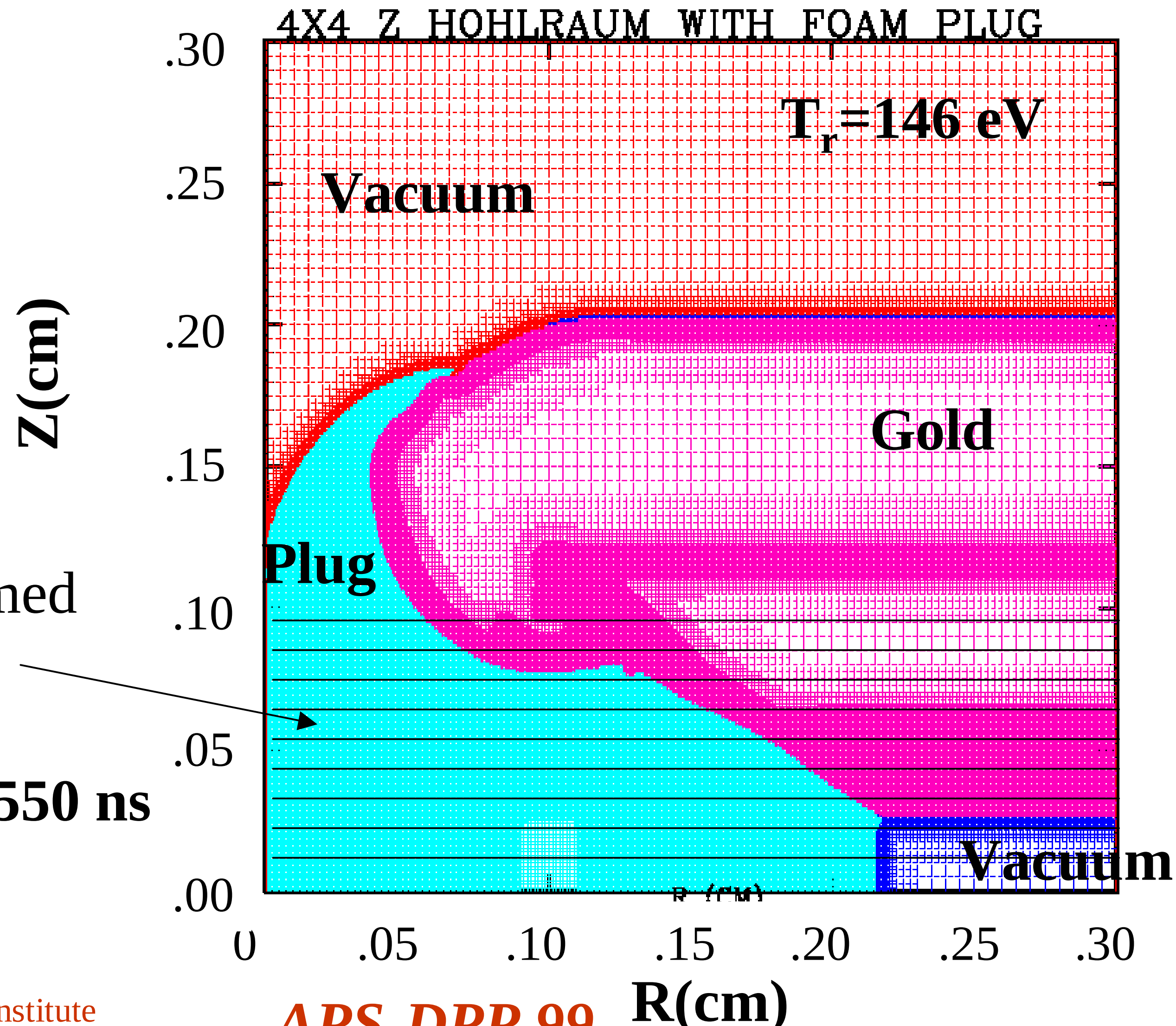
University of Wisconsin - Madison

Without Foam Plug, Blow-Off is More Uniform



Optical Depth Integrals Performed Parallel to Hole Axis



Integrals performed down hole axis

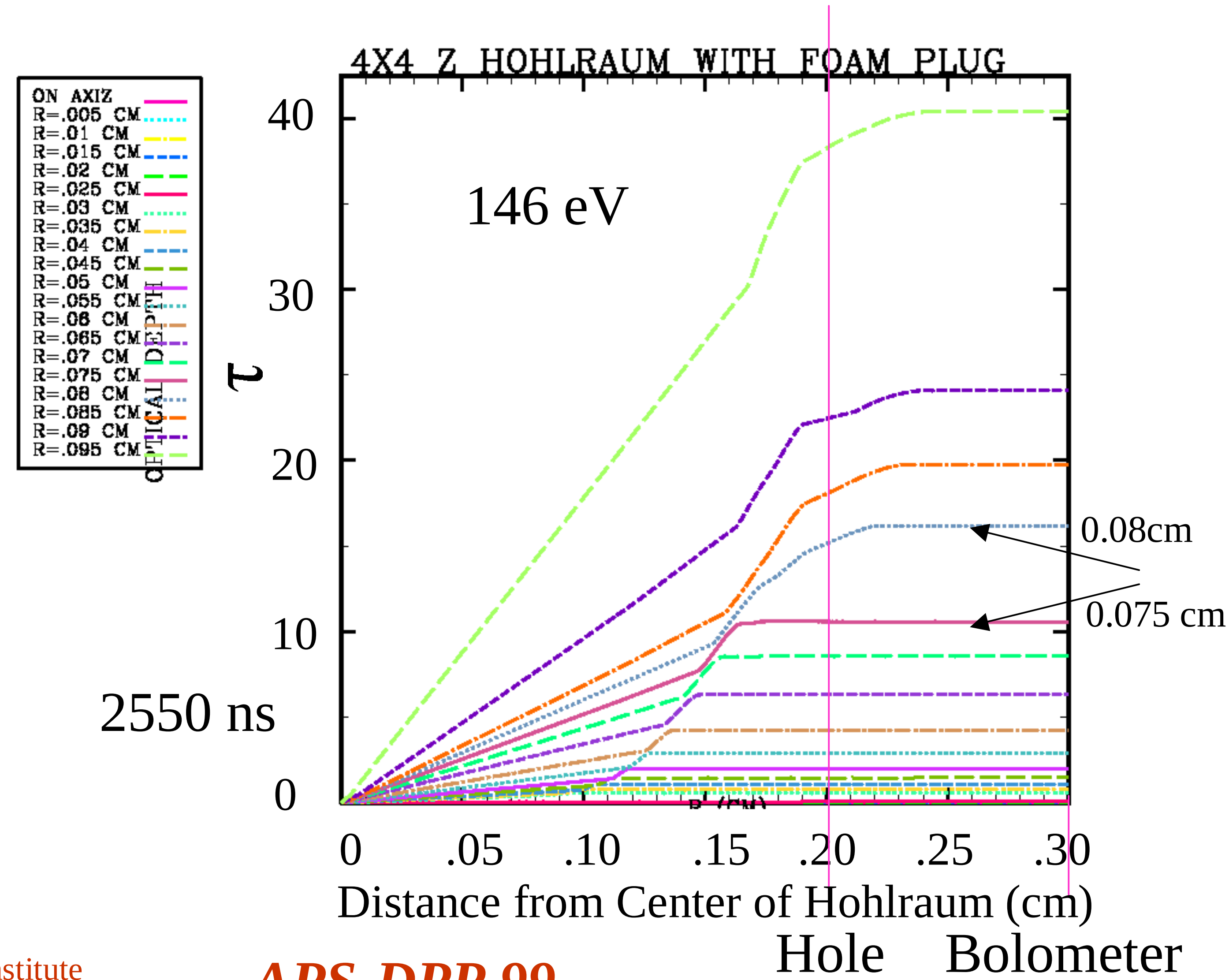
2550 ns

Integrated Optical Depths from Hole to Bolometer Give Closure from Hole Edge

Optical Depth

$$\tau = \int_{x_{hole}}^{x_{bolometer}} \left(\frac{1}{\lambda}\right) \partial x = 2/3$$

- Calculated along many parallel lines run from Hohlraum center to Bolometer
- Line that sees 2/3 jump in optical depth between hole and bolometer is edge of opening.
- Estimated hole radius is 0.775 cm.

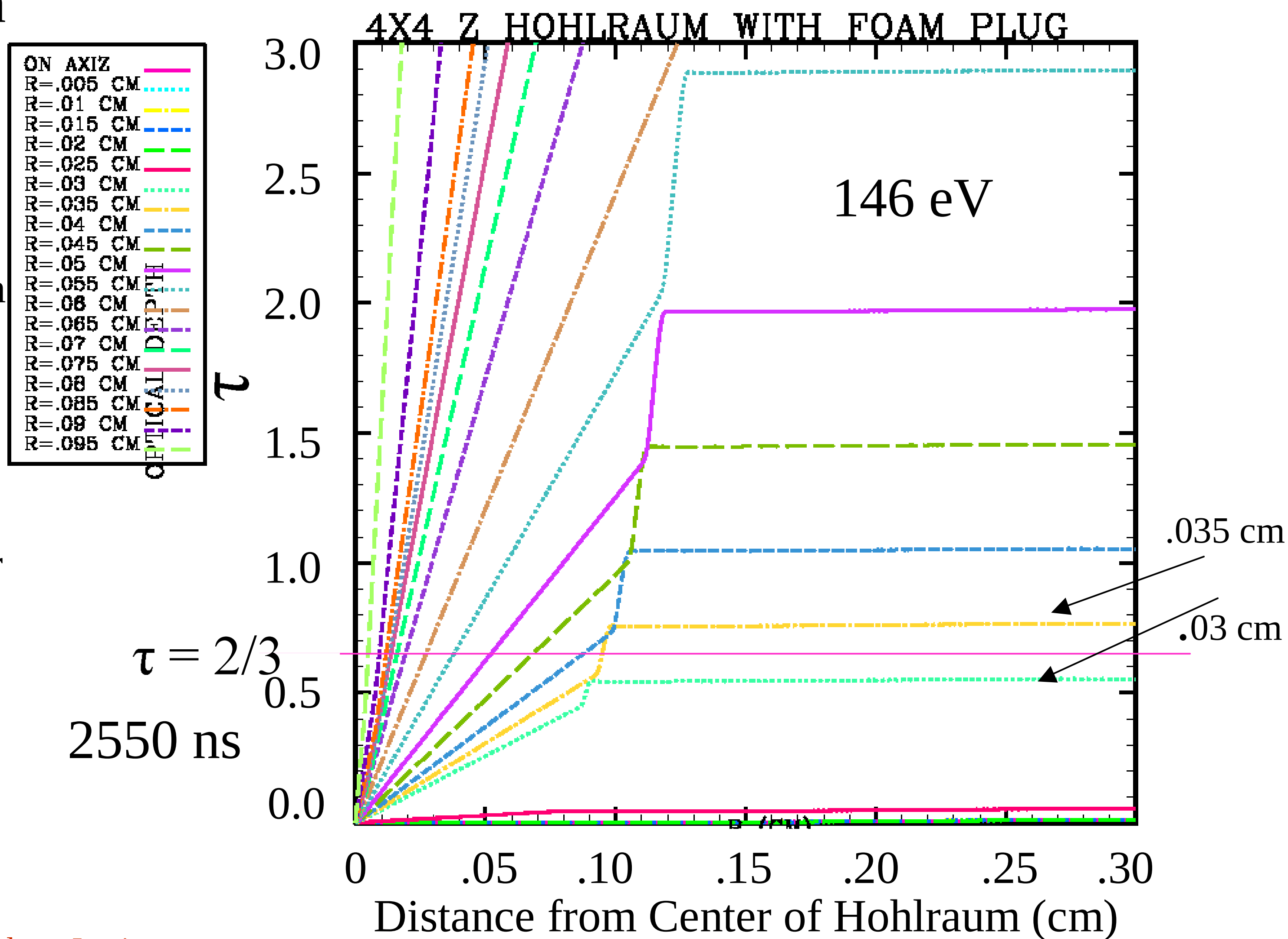


Integrated Optical Depths from Center of Hohlraum to Bolometer Give Closure from Top

Optical Depth

$$\tau = \int_{x_{center}}^{x_{bolometer}} \left(\frac{1}{\lambda}\right) \partial x = \frac{2}{3}$$

- Calculated along many parallel lines run from Hohlraum center to Bolometer
- Line that sees 2/3 optical depth from center to bolometer is edge of blow-off from top.
- Estimated top blow-off is .1-.0325 = .0675 cm.



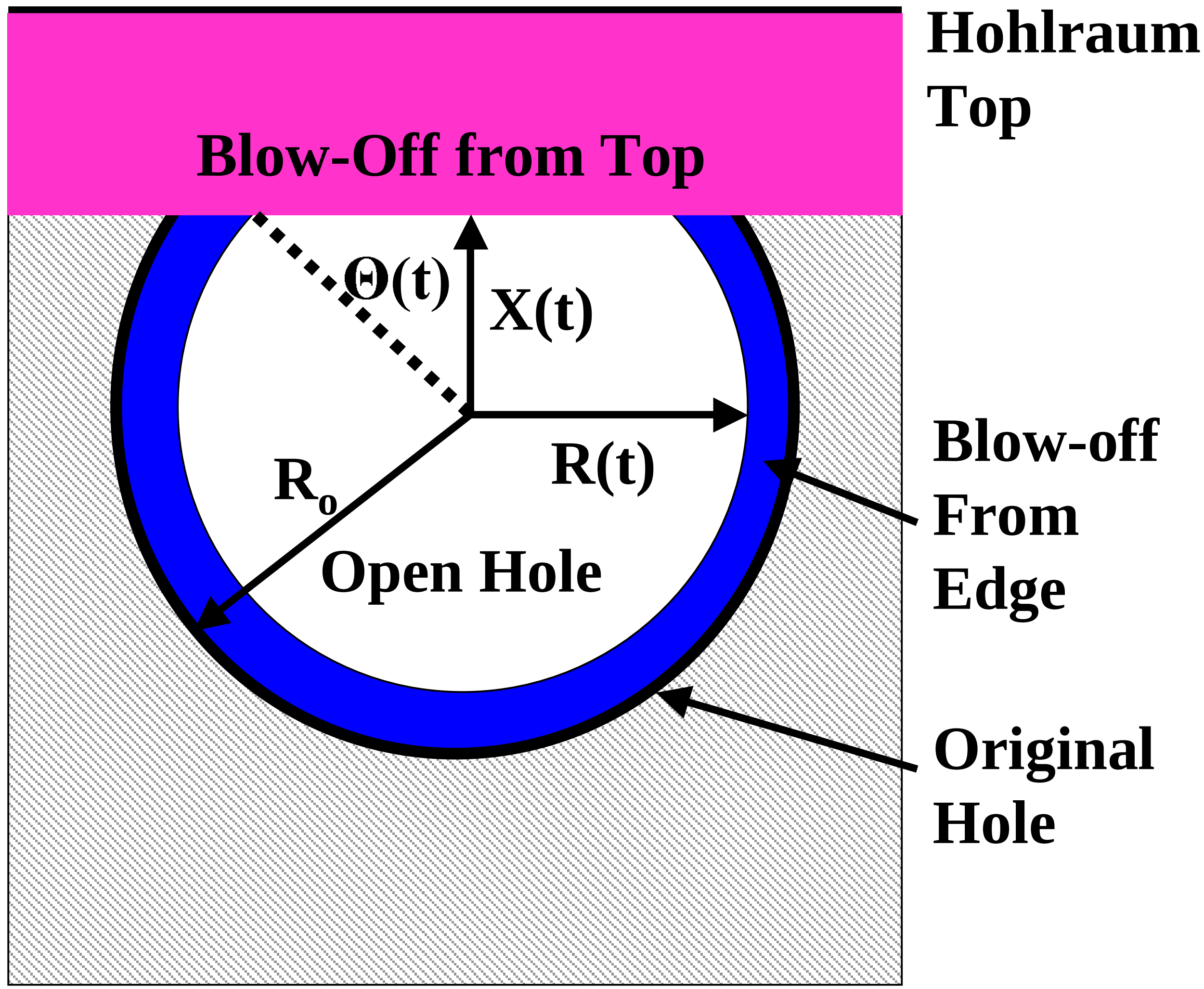
Diagnostics Hole Closure is Due to Gold Blow-off from Edge of Hole and Top of Hohlraum

$$\Theta(t) = \cos^{-1}\left(\frac{X(t)}{R(t)}\right)$$

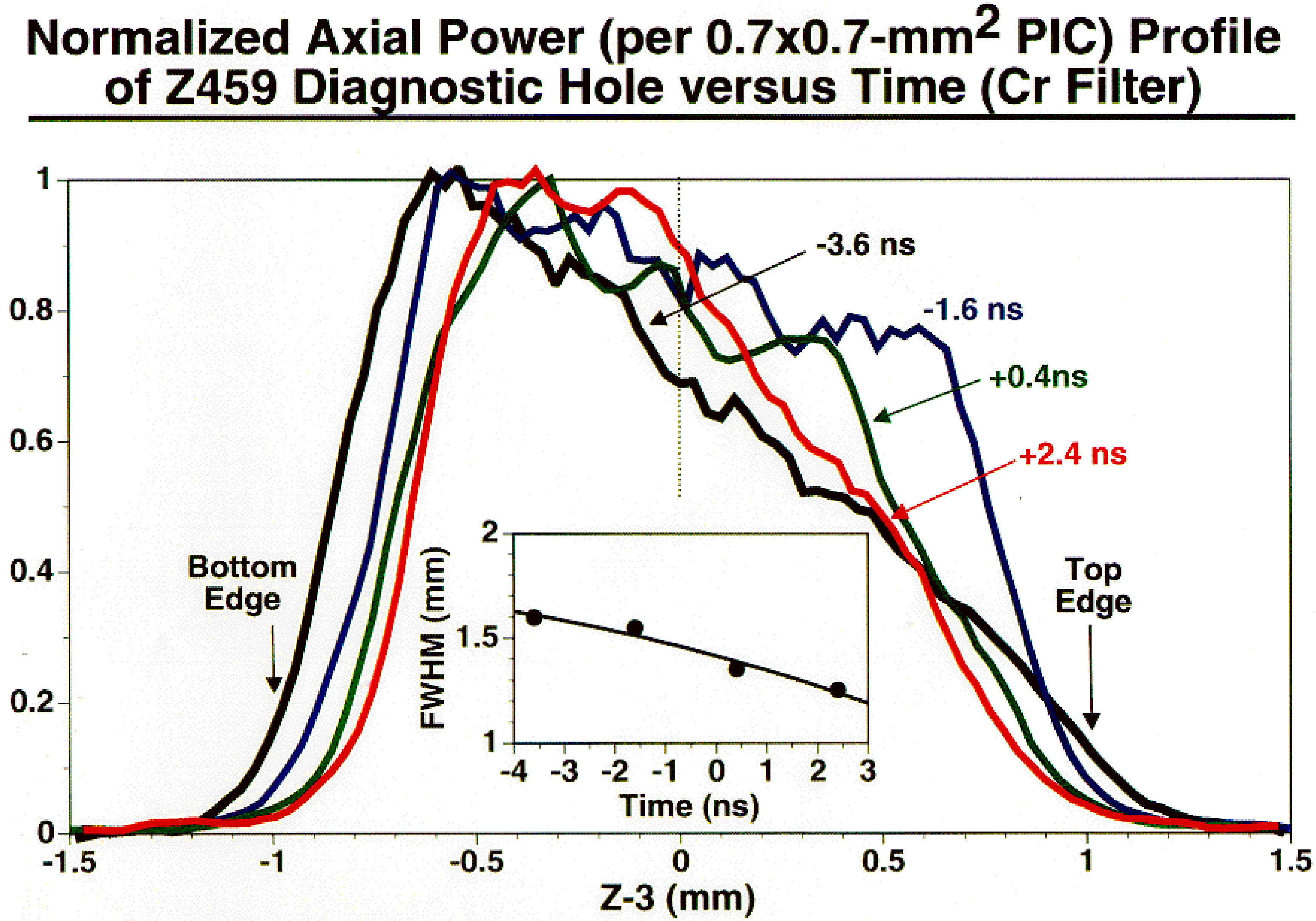
$$\textit{Total Open Area} = A(t)$$
$$= \begin{bmatrix} (\pi - \Theta(t)) + \\ (\sin(\Theta(t))\cos(\Theta(t))) \end{bmatrix} R^2(t)$$

Effective Radius

$$R_{eff}(t) = \sqrt{A(t)/\pi}$$

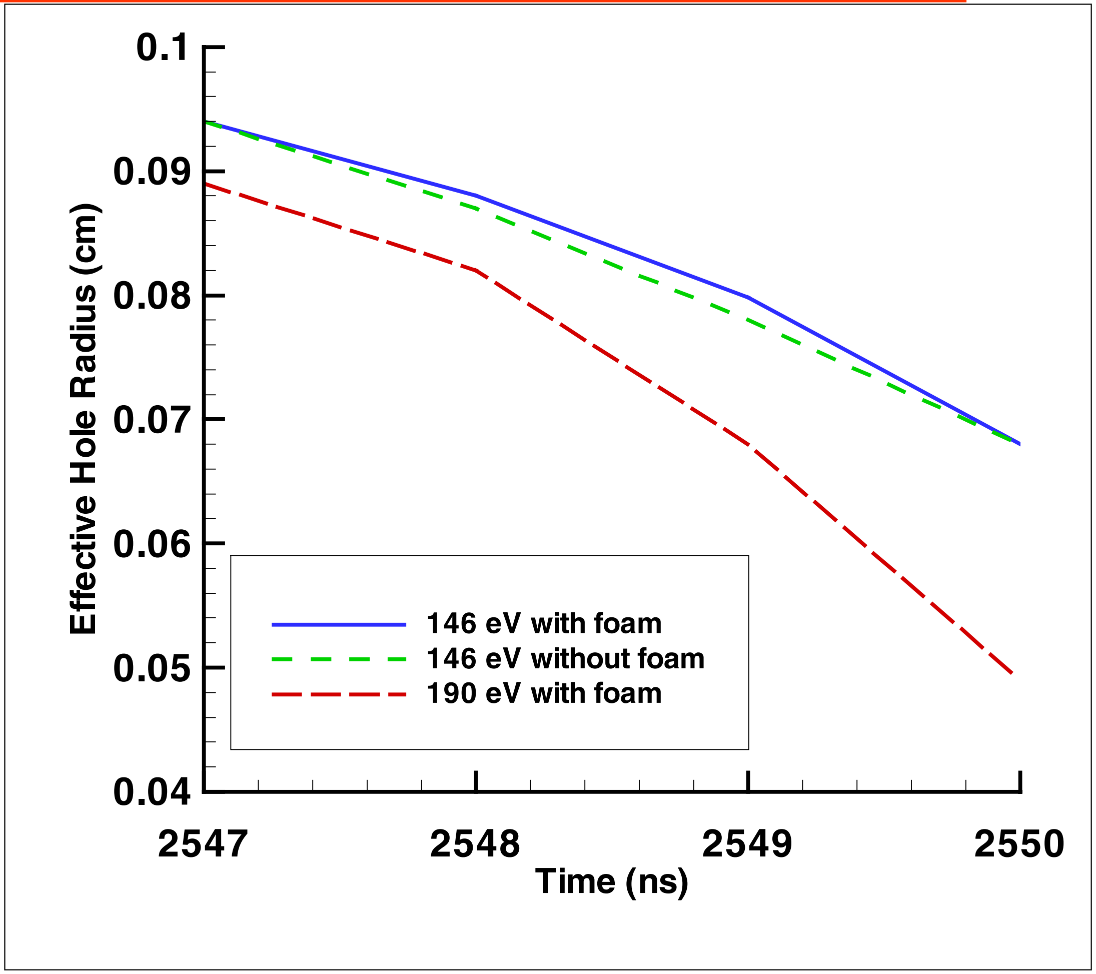


Images from Z Experiments Confirm Important of Gold Blow-off from Top of Hohlraum.



Foam Plug has Little Effect on 146 eV Hohlraum Diagnostics Hole

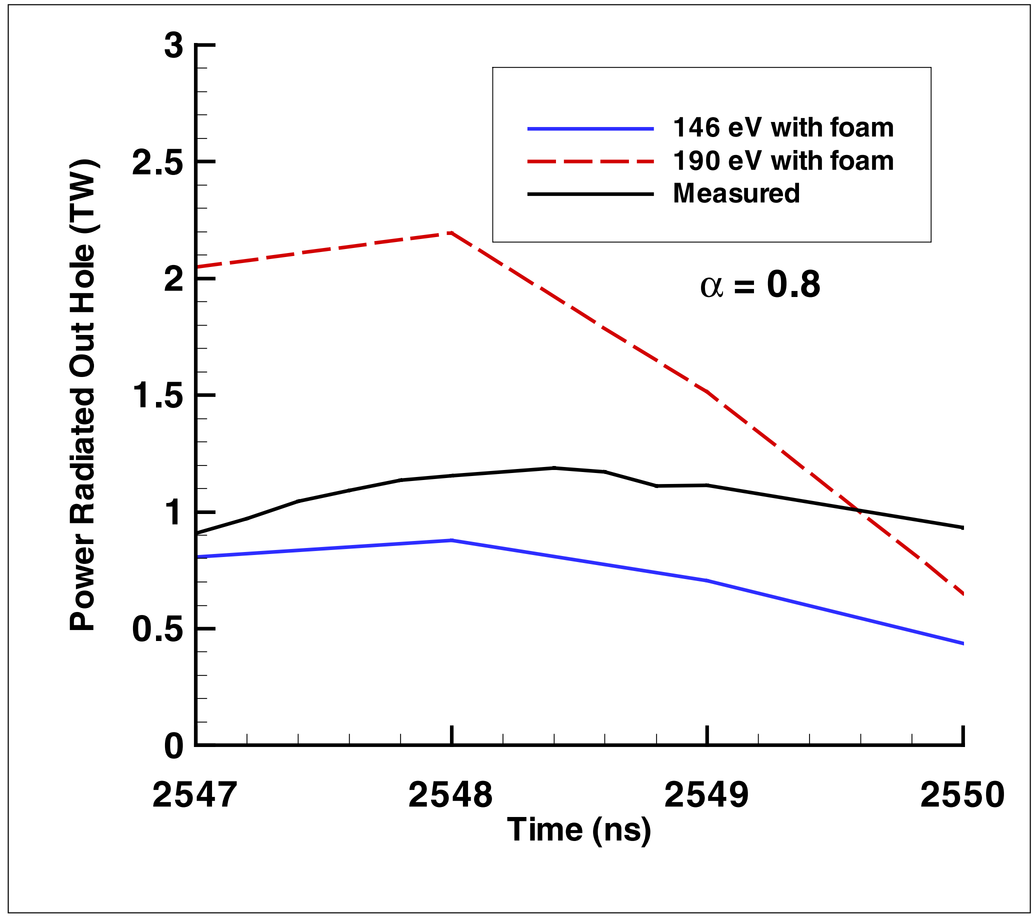
- For a peak radiation drive temperature of 146 eV, the effective hole radius is the same with and without a foam plug.
- Hole closure is much more pronounced for a 190 eV drive temperature, with a foam plug



Closure is Calculations Indicate a Holhraum Temperature Greater than 146 eV, But Less than 190 eV

$$I = A(t)\alpha\sigma T_r^4$$

- RAGE calculations of hole area for 146 eV drive temperature predict a radiated power below the measured values.
- RAGE calculations at 190 eV over-predict radiated power, except late in time.
- Drive temperature must be somewhere in between 146 and 190 eV.
- Need to try more drive histories.



Radiation Temperature in Shot Z442 is Between 146 eV and 190 eV

- Foam plugs do not effect hole closure in a major way.
- Jetting of gold from corner in hohlraum is an important cause of hole closure.
- Vapor from top of hohlraum is also important because hole is very close to top.
- Hole closure is very sensitive to drive temperature, which some what reduces sensitivity of radiated power to drive temperature.
- Peak drive temperature on shot Z442 is between 146 eV and 190 eV.

Additional Calculations are Needed and More Experiments Are Planned

- More RAGE calculations are needed:
  - —Calculations by Bowers predict a pre-pulse on the radiation pulse.
  - —Try more radiation histories between 148 and 190 eV.
  - —3-D simulations of hole closure.
  - —Other methods of measuring hole size.
  - —Study 7x6 hohlraums.
- Other Experiments:
  - —Spectrometer to measure temperature from spectrum.
  - —Rounded corners would reduce jetting and hole closure.
  - —Hohlraums driven by two zpinches.