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A NIF 3-D high Mach number feature experiment

Presented to:

9th IWPCTM

Cambridge, UK

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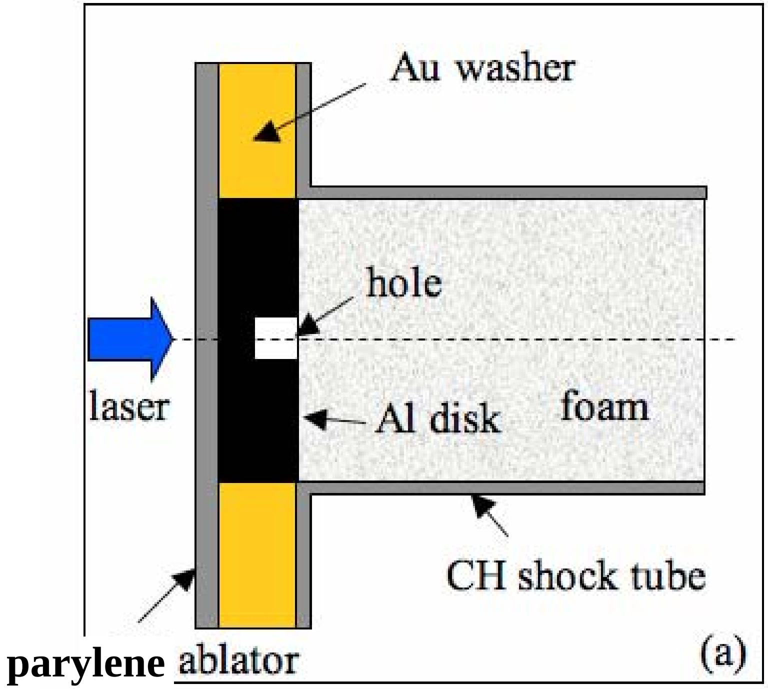
IWPCTM04. 1

The jet experiment demonstrated NIF capabilities and validated 3-D modeling of shock effects

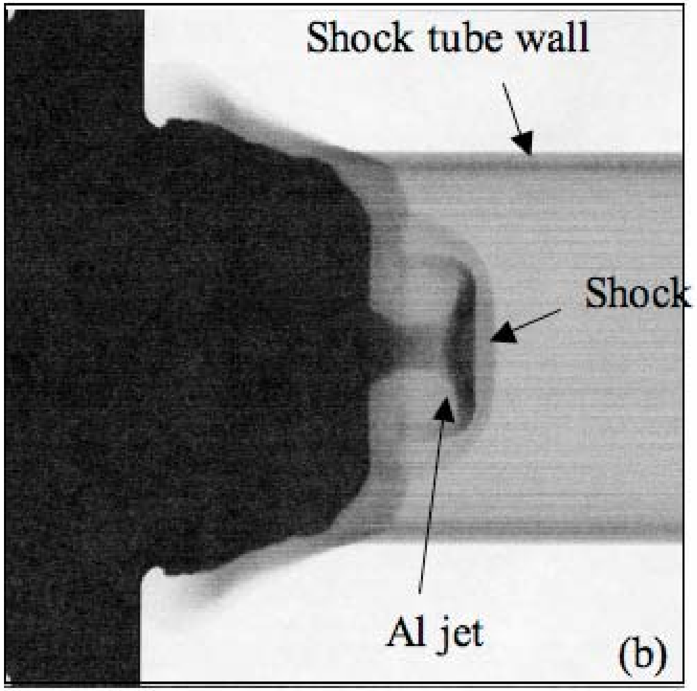
- Shock passage over a cylindrical void in an Al disk generated a jet into CRF foam
  - First hydrodynamics experiment driven by NIF, still in early stages of construction
  - 5.8 kJ direct drive from two beams in one quad; approximately uniform supergaussian spot from improved phase plates
  - Target 1: axisymmetric (2-D), cylinder axis normal to the disk surface
  - Target 2: explicitly 3-D, cylinder axis tilted 45º to disk surface
- Relevant to ICF and astrophysics
  - ICF shell features such as waist joints, fill tubes can result in jets of shell material into DT fuel
  - Astrophysical jets
- Similar experiments have been done on other facilities by several labs
  - Nova, Omega, Z; AWE, LLE, LANL, SNL
- Good images were obtained at two times from 2-D targets and two orthogonal views for 3-D targets; <u>reproducibility</u> <u>demonstrated</u>
- 2-D and 3-D HYDRA simulations are in good quantitative and qualitative agreement with data, with a few apparent discrepancies

A shock is driven through an Al disk with an embedded defect, resulting in a jet of Al into CRF foam

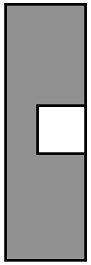
Shock-tube target package



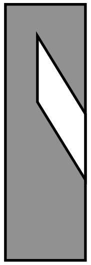
Simulated x-ray radiograph



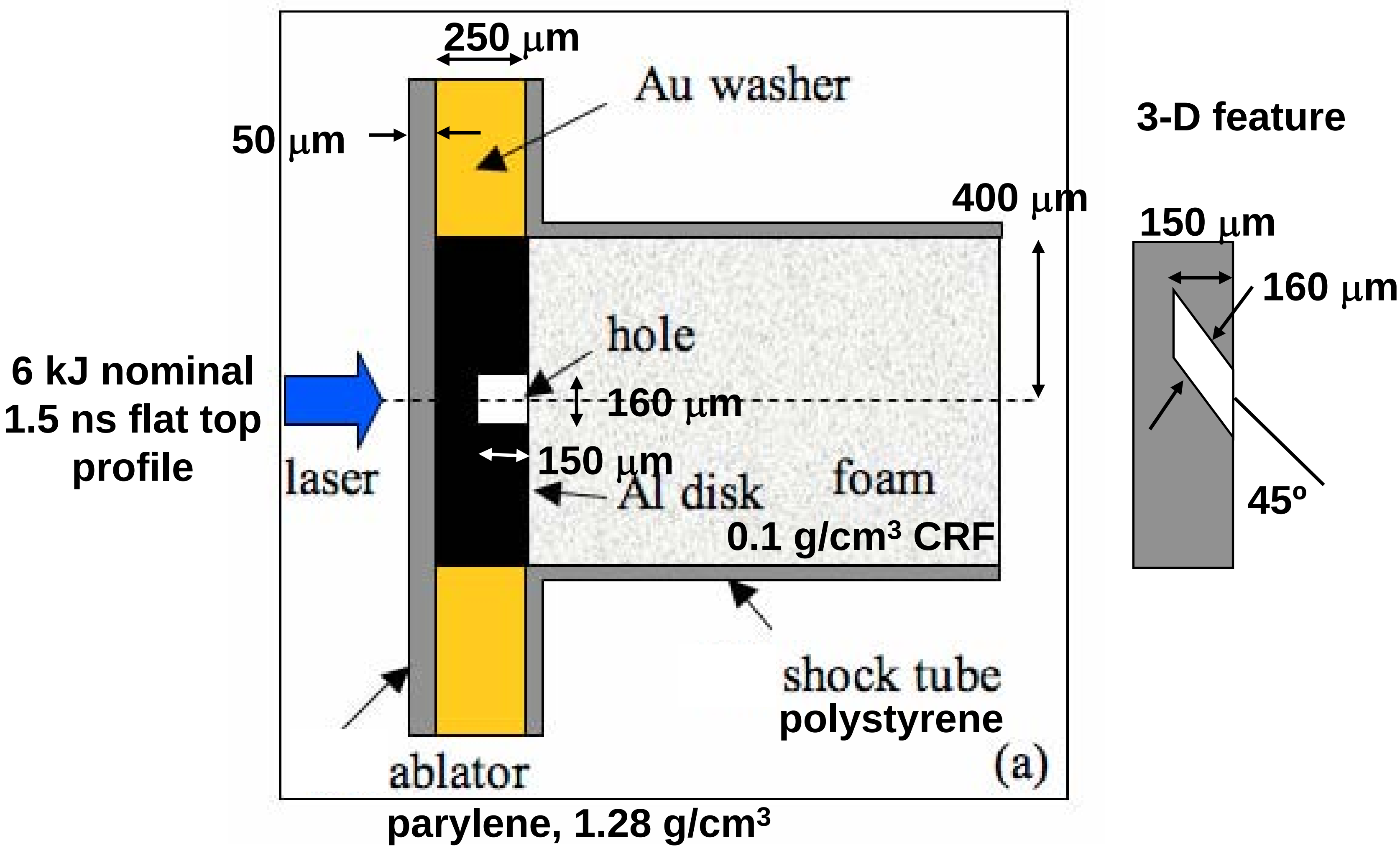
2-D target



3-D target

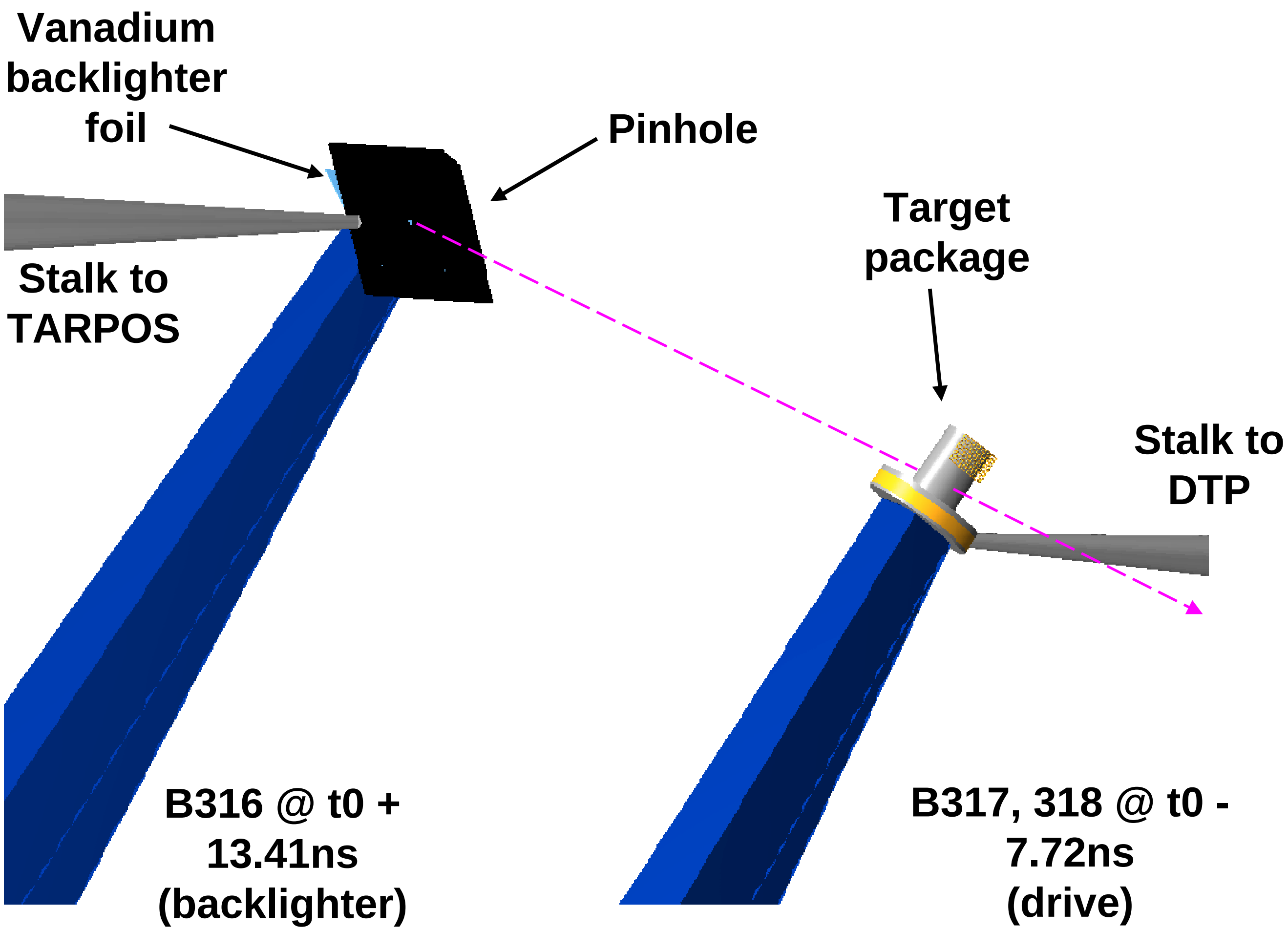


Target dimensions



IWPCTM04. 4

From the one available NIF quad, two beams drove the target and one the backlighter



- Backlighter delay (15 or 21.6 ns from start of drive to middle of backlighter pulse) was limited by laser constraints (on one quad)

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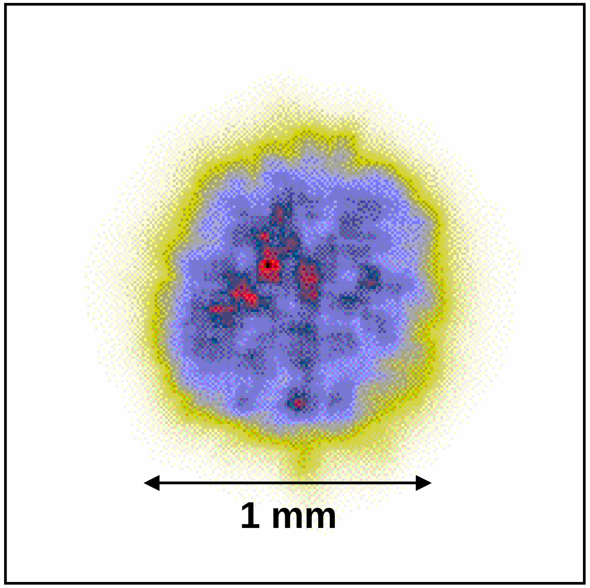
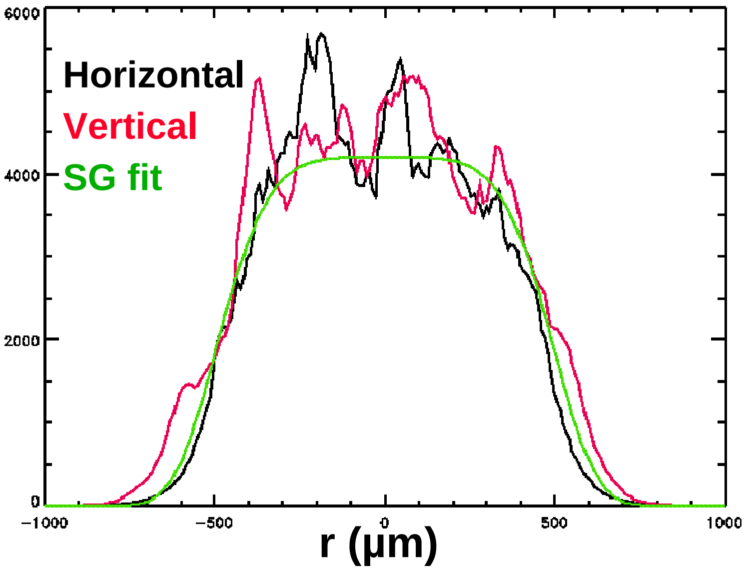
The full aperture phase plates provided a flat, approximately uniform spot profile

Measured single beam intensity profile
1 mm full aperture phase plate



lineouts



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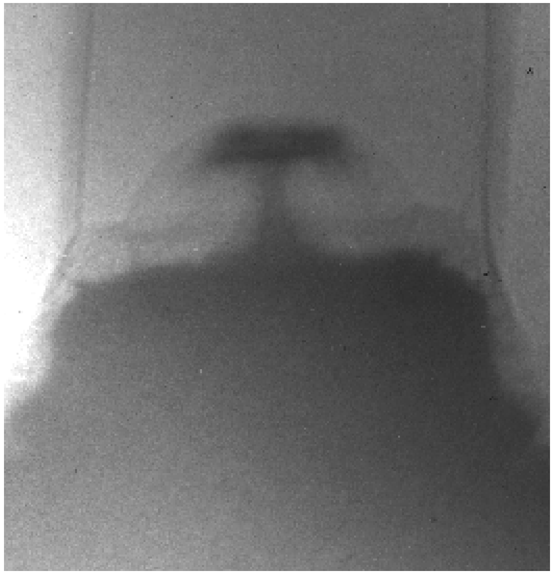
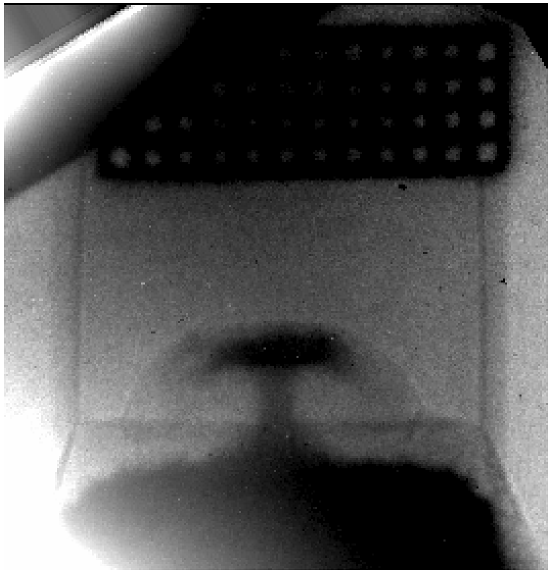
Late time data from axisymmetric targets was reproducible and matches simulations

040525-001



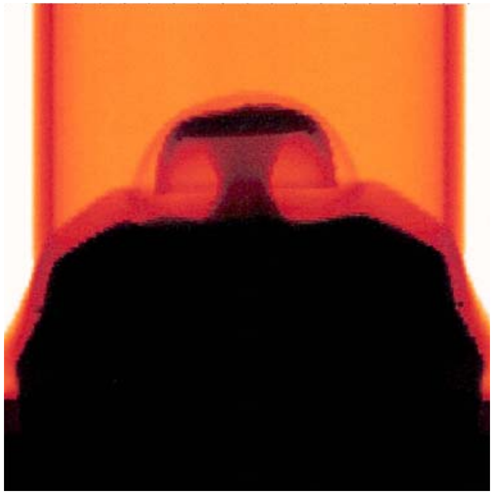
21.9 ns

040526-002



21.8 ns

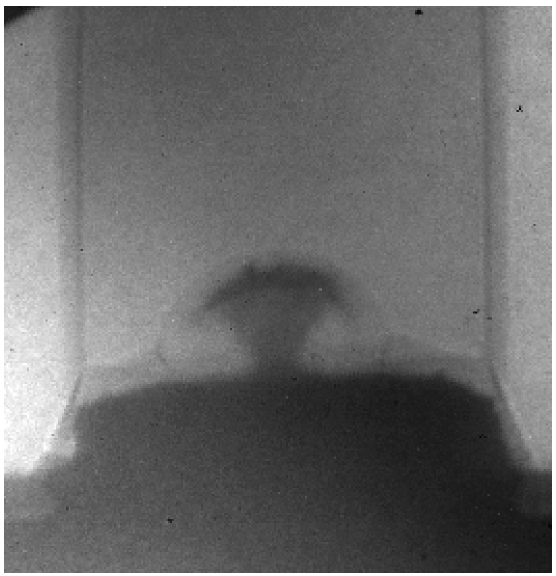
Simulated image
3-D, 21.6 ns



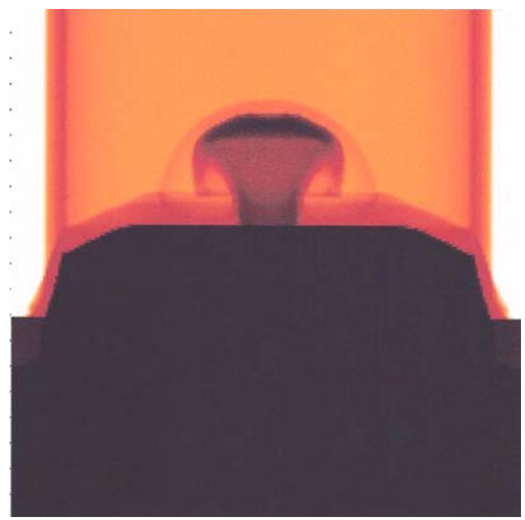
- **Simulations predict too much lag in the foam shock near the tube walls**

An early time image of a symmetric target also matches simulations

040527-001 16 ns



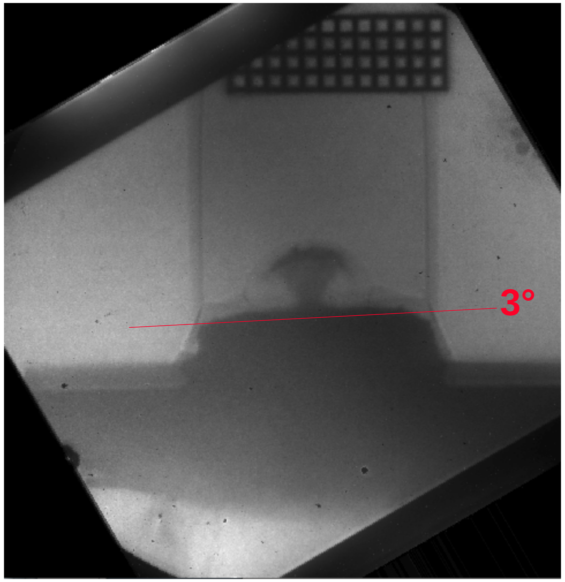
simulated image (2-D), 15 ns



simulated image (3-D), 15 ns

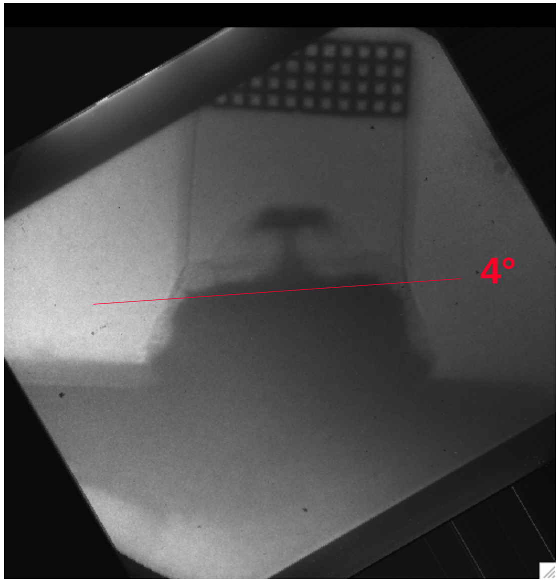
In all 2D jet images, the interface is tilted 2-4°

040527-001



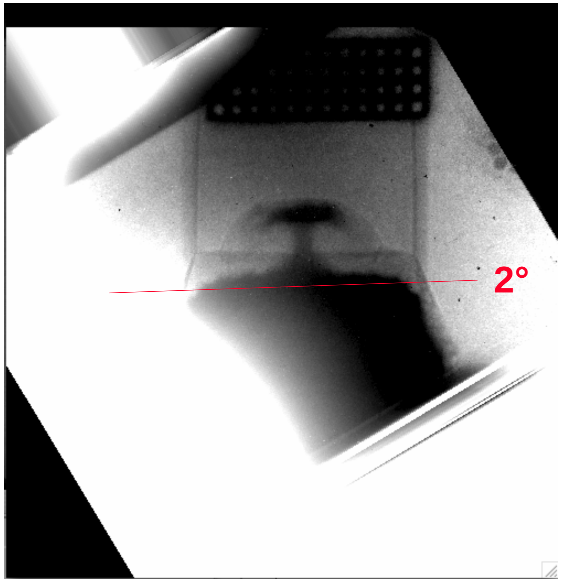
15 ns

040525-001



21.6 ns

040526-002

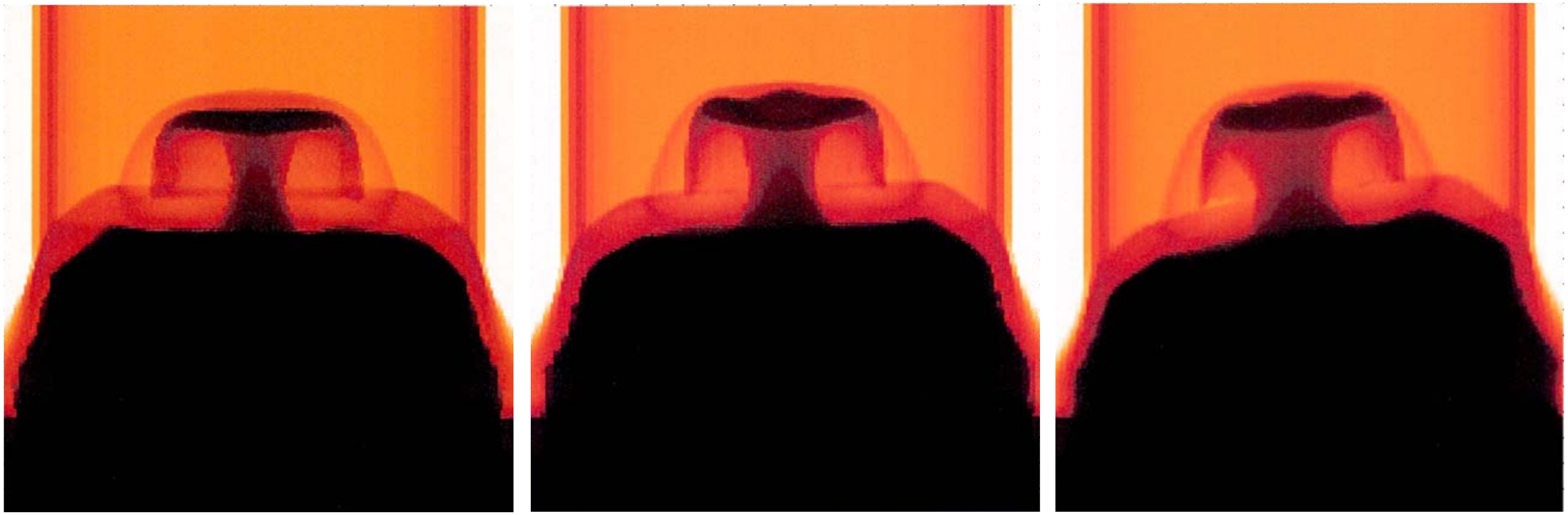


21.6 ns

Simulations of effects of beam offset indicate that ~100 μm offset would give the observed tilt

simulated images at 22 ns with offset beams

50 μm offset	100 μm offset	200 μm offset



1.7° tilt	3.9° tilt	9.8° tilt

- **Central bump for 100,200 μm appears to have been caused by an erroneous ALE control**

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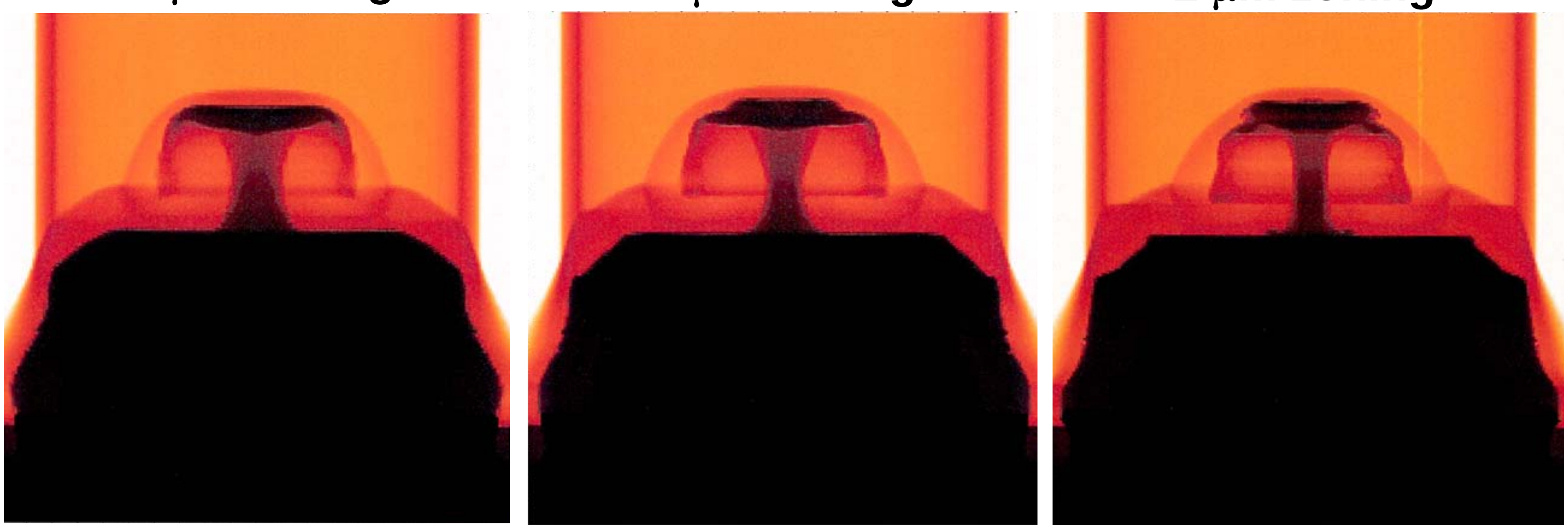
In 2-D, more structure is predicted for the head of the jet as resolution is increased

Simulated backlit images at 22 ns, 2-D

8 μm zoning **4 μm zoning** **2 μm zoning**

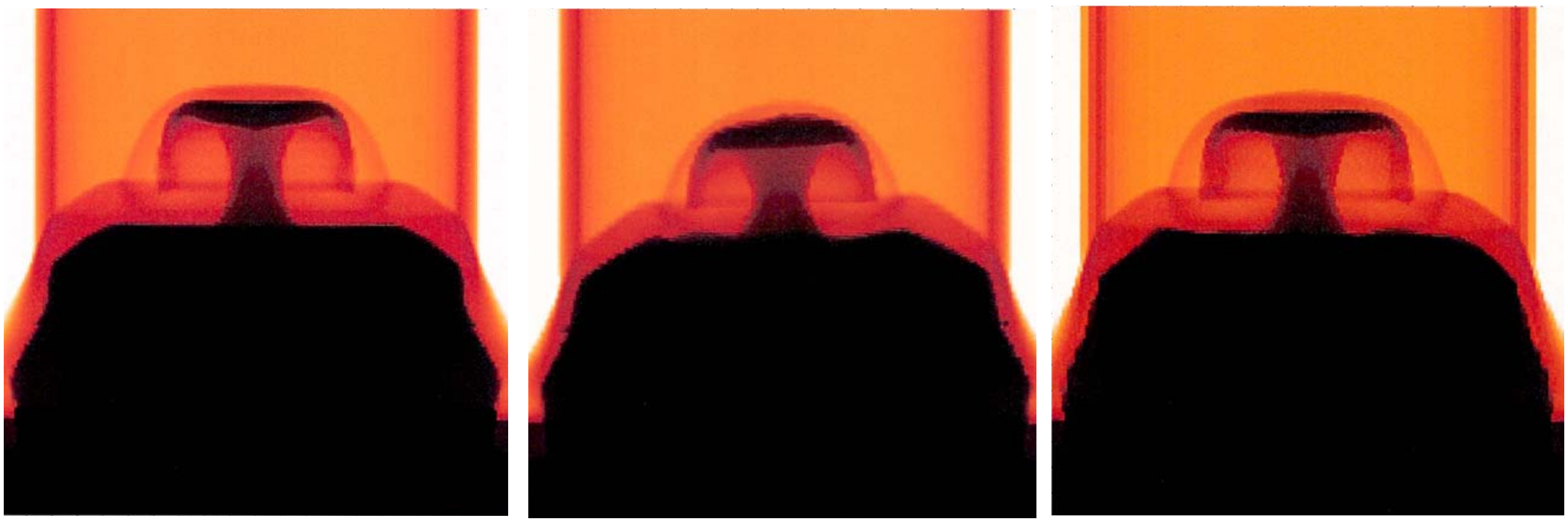


- **Most of our 2-D simulations employ 4 μm zoning; 3-D - 8 μm (one 4 μm run)**
- **Jet shows more structure but not substantial changes with increasing resolution**
  - **Courser resolution actually may fit the jet head structure better**
- **The width of the stem appears to decrease with finer resolution**

2-D, 3-D polar, and 3-D Cartesian zoning give small differences in jet structure

Simulated backlit images at 21.6 ns

2-D (8 μm resolution) | **3-D polar mesh measured 2-D laser spot** | **3-D Cartesian (50 μm offset spot)**



- **Both 3-D simulations use the measured single beam laser spot profile, which breaks axial symmetry**

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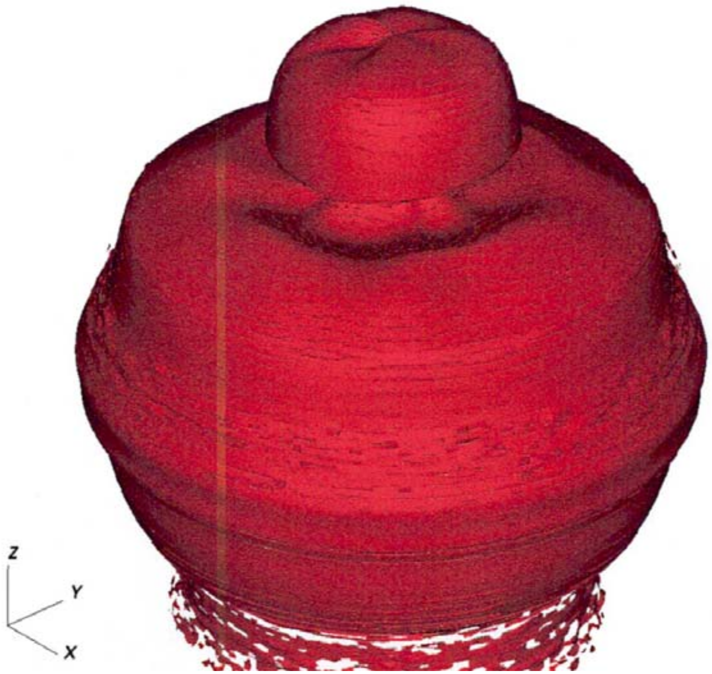
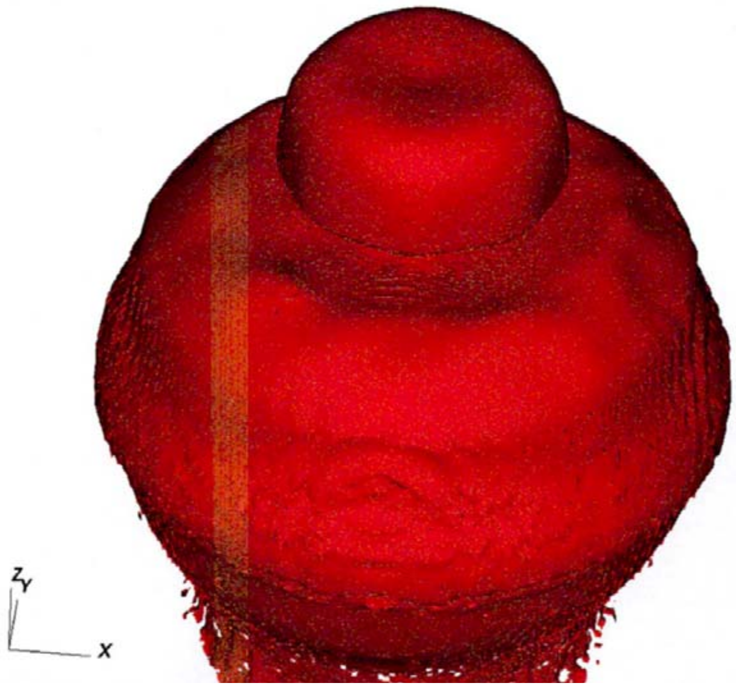
Cartesian and polar meshes both introduce artifacts, but of different types

Al region boundary, axisymmetric target, 21.6 ns

Polar mesh (r-φ-z)



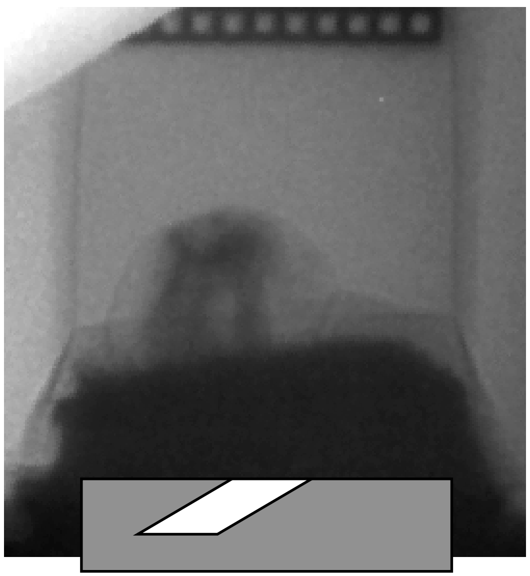
Cartesian mesh (x-y-z)



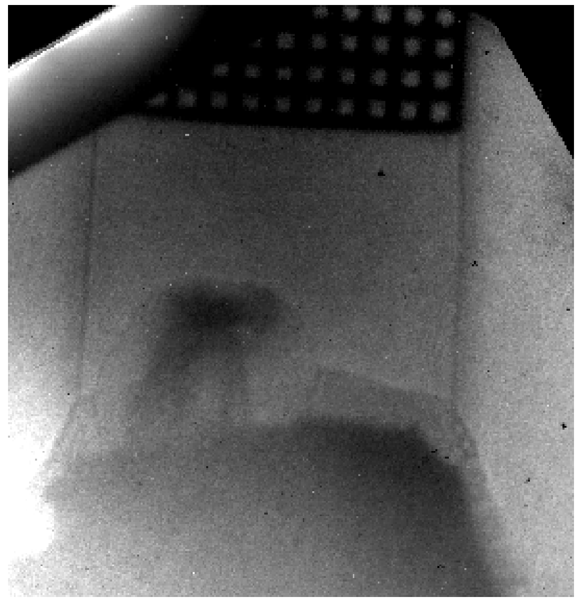
- **The Cartesian mesh gives a jet which is slightly broader along the mesh directions**
- **The polar mesh has trouble accommodating flow through the axis**

Late time structure of 3-D targets is reproducible; some differences from simulations

040526-001
21.7 ns



040528-003
22.2 ns

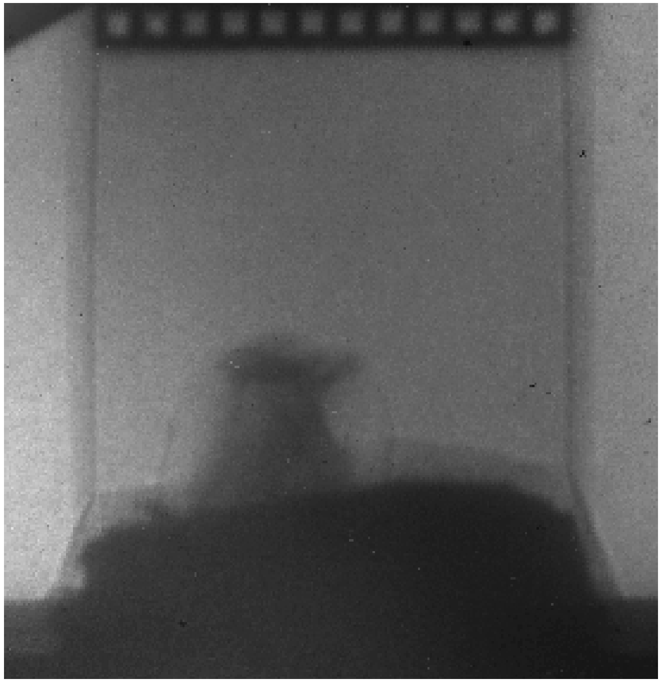


Simulated image
21.6 ns

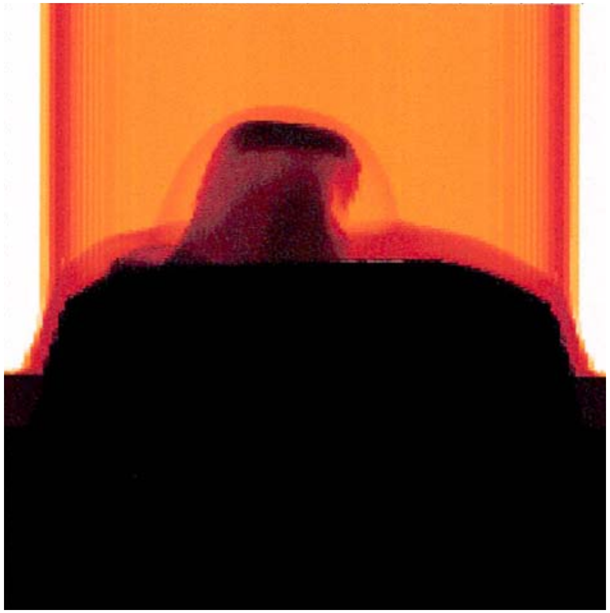
View looking normal to plane of hole tilt

Early time data has also been obtained for the 3-D target

040527 15.7 ns



Simulated image
15 ns



View looking normal to plane of hole tilt

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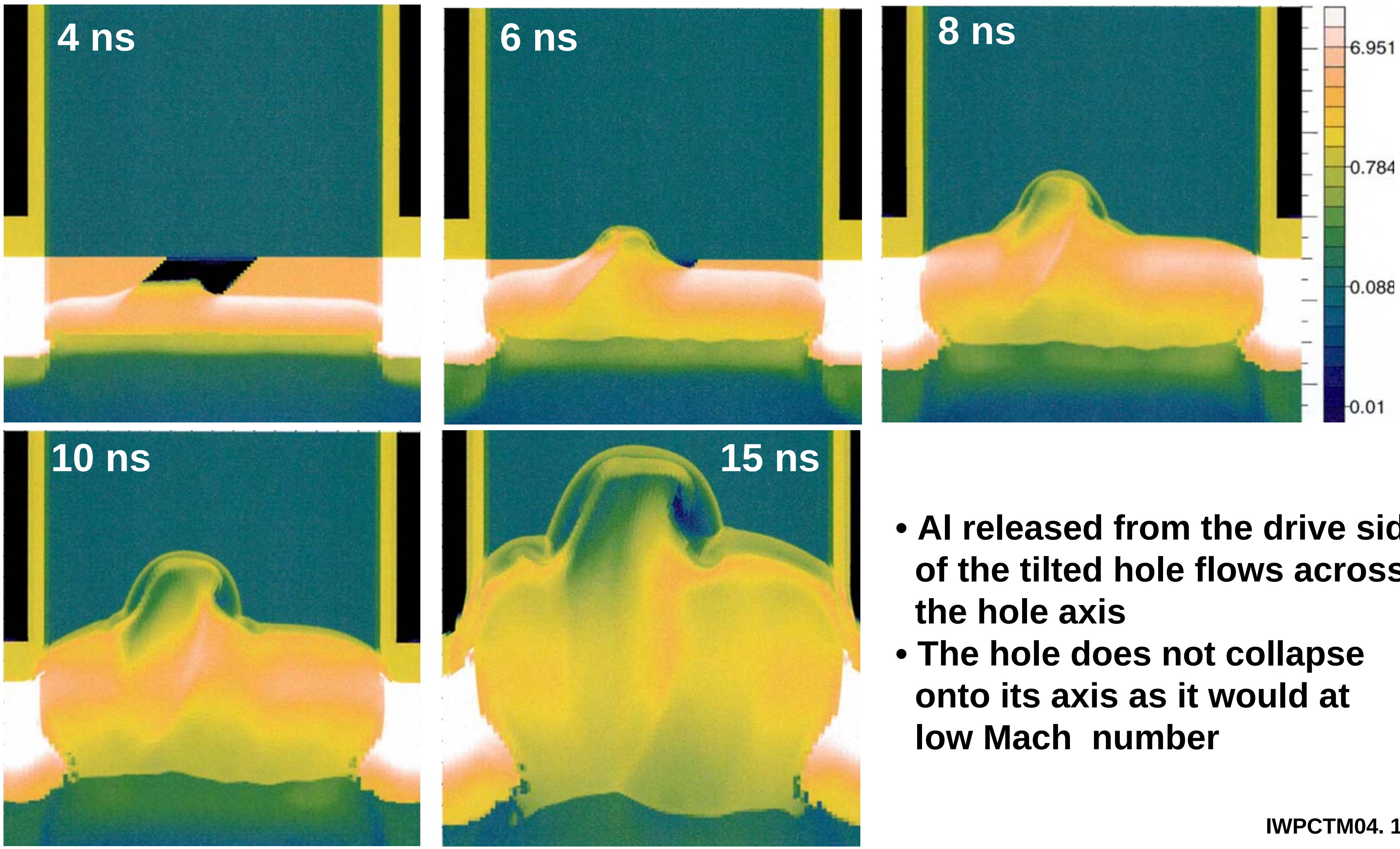
The 3-D jet is tilted to the opposite side of normal from the hole

density cuts in plane of tilt



- **Al released from the drive side of the tilted hole flows across the hole axis**
- **The hole does not collapse onto its axis as it would at low Mach number**

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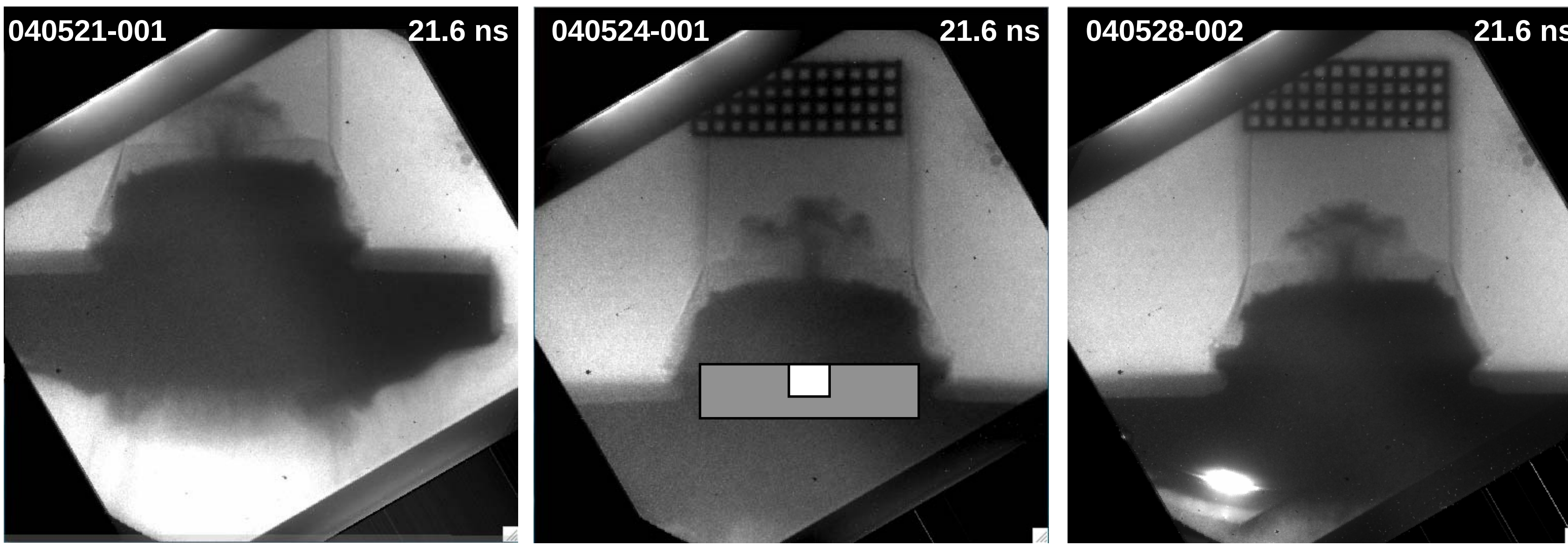
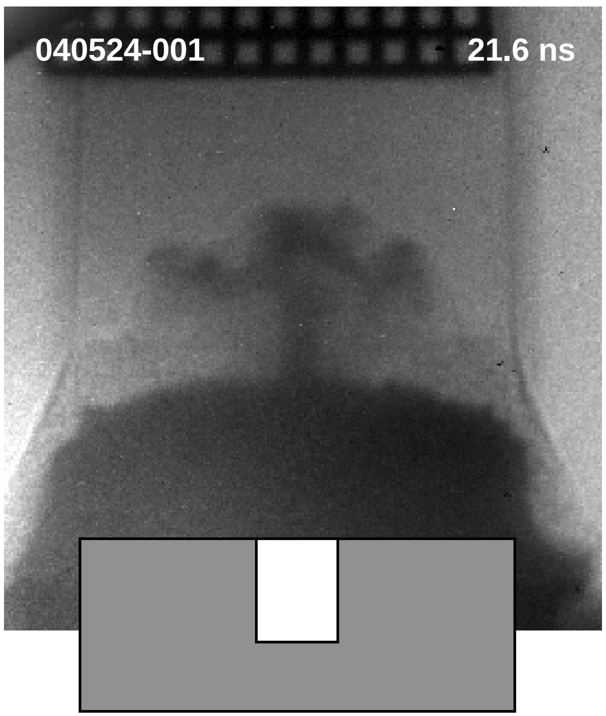
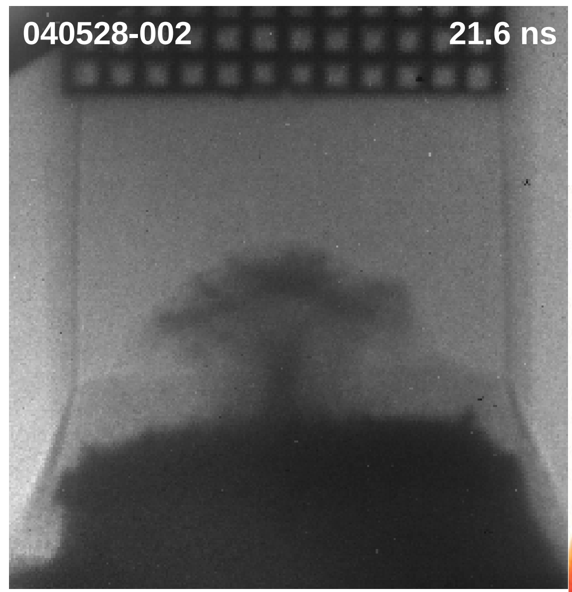
Some variation was seen among images of the 3-D target viewed in the tilt plane



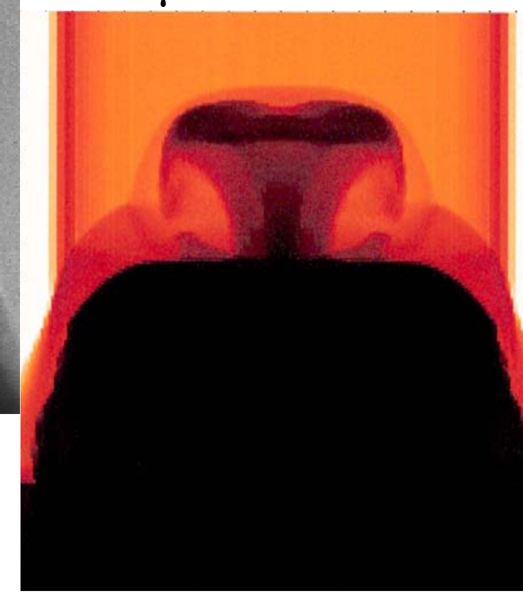
View looking along plane of hole tilt
No early time data was taken for this view

The details of the jet structure of the 3-D target viewed in the tilt plane differ from simulations





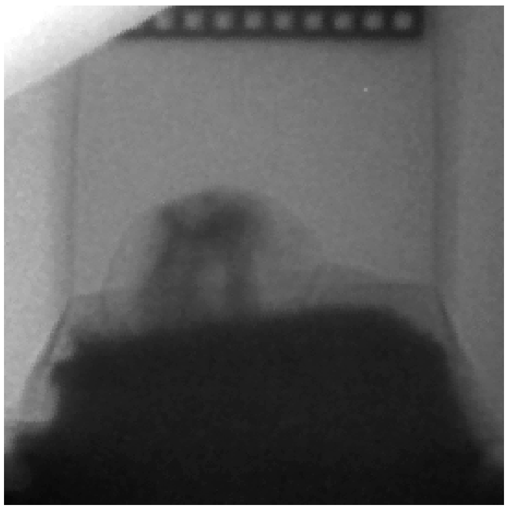
Simulated image
21.6 ns
8 μm resolution

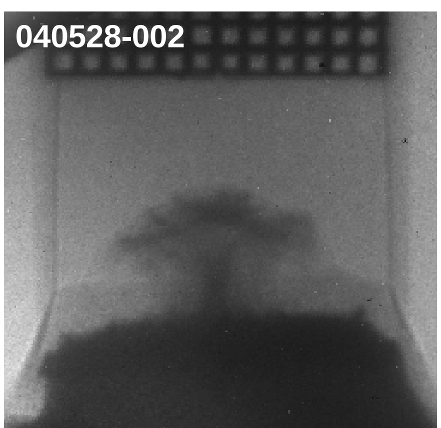


View looking along plane of hole tilt

Simulated images show qualitative changes between 8 μm and 4 μm zoning

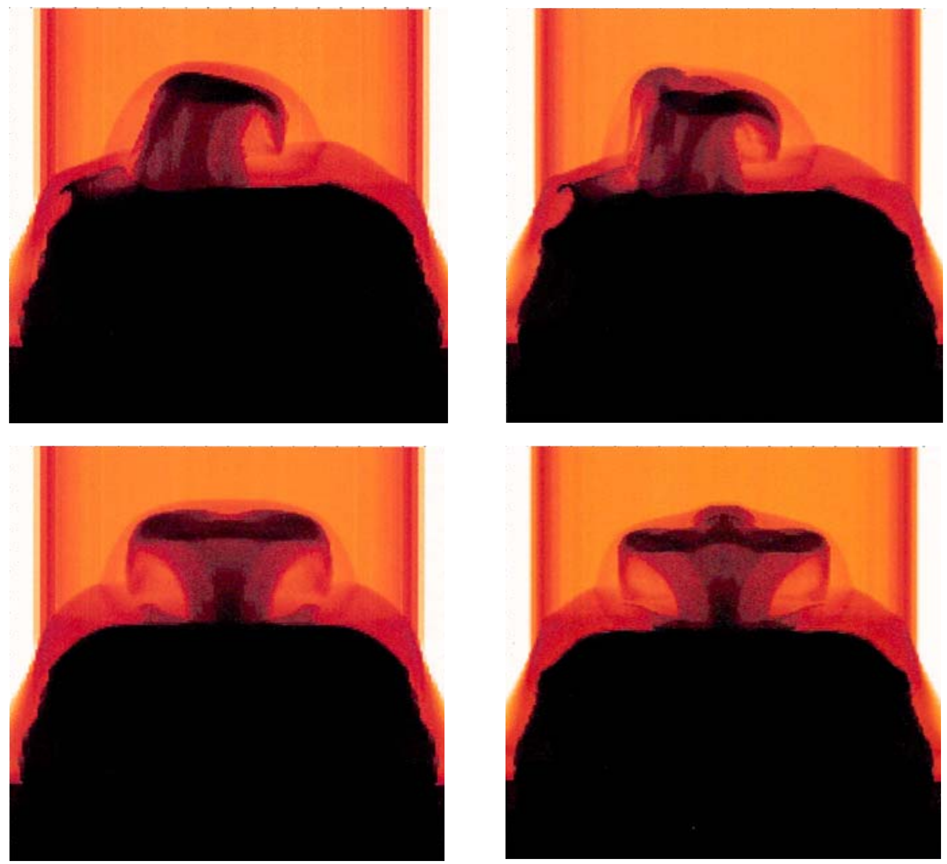
040526-001





Simulated images, 21.6 ns

8 μm zoning **4 μm zoning**



view ⊥ to tilt

view || to tilt

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Most dimensions of the axisymmetric jets are matched well by simulations

time	feature	Data 1	Data 2	simulation	Difference (sim-data avg)
15 ns	pedestal	274 μm		286 μm	14 μm
	Foam shock	316 μm		327 μm	11 μm
	Jet head	490 μm		481 μm	-9 μm
	Foam head	514 μm		501 μm	-13 μm
	Head width	298 μm		240 μm	-58 μm
	Bow width	454 μm		353 μm	-101 μm
21 ns	pedestal	442 μm	420 μm	456 μm	25 μm
	Foam shock	541 μm	490 μm	530 μm	15 μm
	Jet head	694 μm	670 μm	688 μm	6 μm
	Foam head		680 μm	724 μm	44 μm
	Head width	255 μm	275 μm	328 μm	63 μm
	Bow width	571 μm	570 μm	462 μm	-108 μm

- It is not clear where the experimental head width was measured
- Simulations use the nominal 6 kJ, while shots average ~5800 J

IWPCTM04. 20

Dimensions of the 3-D jets are also fit well by the simulations

time	feature	Data 1	Data 2	Data 3	simulation	Difference (sim-data avg)
15 ns	pedestal	255 μm			283 μm	28 μm
asymm	Foam shock	320 μm			340 μm	20 μm
	Jet head	510 μm			513 μm	3 μm
	Head width	250 μm			216 μm	-34 μm
	Bow width	379 μm			403 μm	24 μm
21 ns	pedestal	417 μm	432 μm		467 μm	43 μm
asymm	Foam shock	495 μm	545 μm		568 μm	48 μm
	Jet head	703 μm	746 μm		739 μm	15 μm
	Head width	236 μm	274 μm		279 μm	24 μm
	Bow width	492 μm	442 μm		498 μm	31 μm
21 ns	pedestal	435 μm	464 μm	432 μm	471 μm	28 μm
symm	Foam shock	500 μm	550 μm	520 μm	561 μm	38 μm
	Jet head	738 μm	722 μm	742 μm	737 μm	3 μm
	Head width	416 μm	482 μm	440 μm	440 μm	-6 μm
	Bow width	584 μm		592 μm	585 μm	-3 μm

The jet experiment demonstrated NIF capabilities and validated 3-D modeling of shock effects

- Shock passage over a cylindrical void in an Al disk generated a jet into CRF foam
  - First hydrodynamics experiment driven by NIF, still in early stages of construction
  - 5.8 kJ direct drive from two beams in one quad; approximately uniform supergaussian spot from improved phase plates
  - Target 1: axisymmetric (2-D), cylinder axis normal to the disk surface
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