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Overview of NIC target assessment procedures, NIF ALE-AMR, and results for upcoming campaigns

A. Koniges, R. Anderson, N. Barton, R. Becker, D. Benson, D. Eder, A. Fisher, B. Gunney, O. Jones, T. Kaiser, O. Landen, B. Maddox, N. Masters, J. Milovich

July 9, 2008

Third International Workshop on High-Powered Laser Chamber Issues - Focus: Debris and Shrapnel
Livermore, CA, United States
June 2, 2008 through June 4, 2008

3rd International Workshop on High-Powered Laser Chamber Issues

Focus: Debris and Shrapnel

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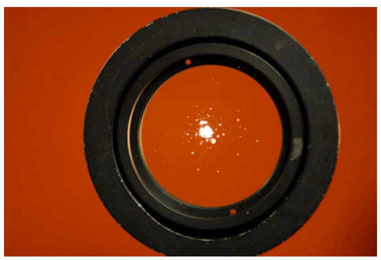
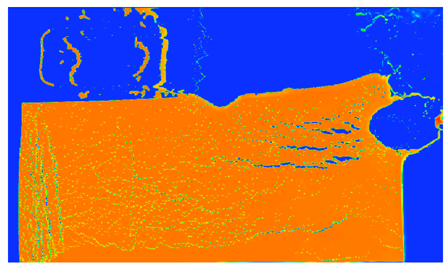
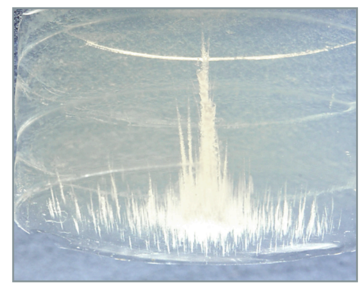
Overview of NIC target assessment procedures, NIF ALE-AMR, and results for upcoming campaigns







Alice Koniges

Contributors: R. Anderson, N. Barton, R. Becker, D. Benson, D. Eder, A. Fisher, B. Gunney, O. Jones, T. Kaiser, O. Landen, B. Maddox, N. Masters, J. Milovich

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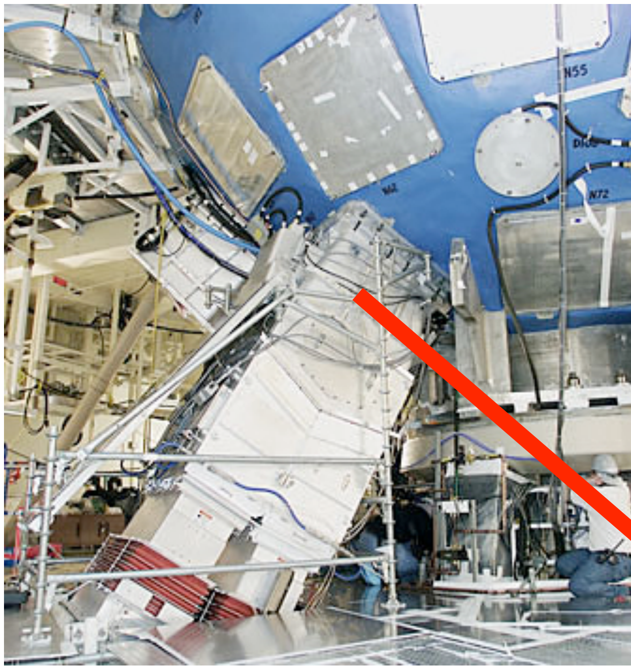
Outline

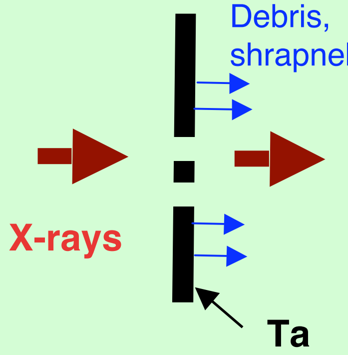
The National Ignition Campaign

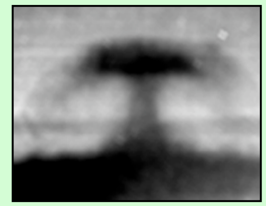
- Motivation
- NIF ALE-AMR Code
- Code Validation
- Target Analyses
  - Energetic campaign
    - Cooling rings
    - Dante shield
  - Keyhole target for shock timing campaign
  - Re-emit target for symmetry campaign

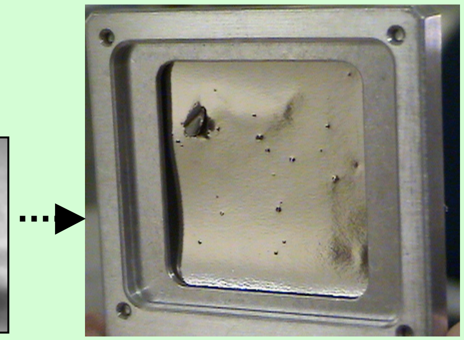
NIF targets must be designed to minimize damage to optics and diagnostics from target debris

The National Ignition Campaign

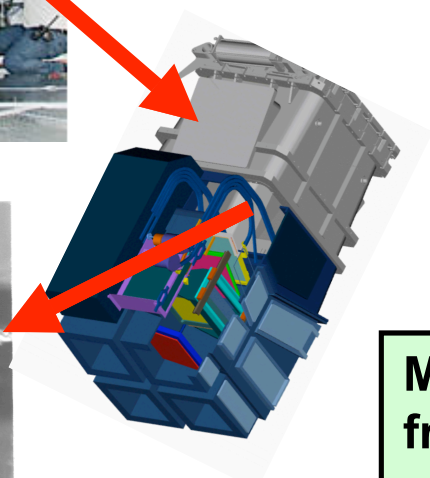


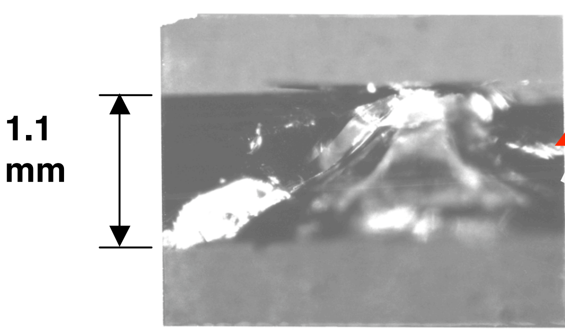






Damage prior to tilting



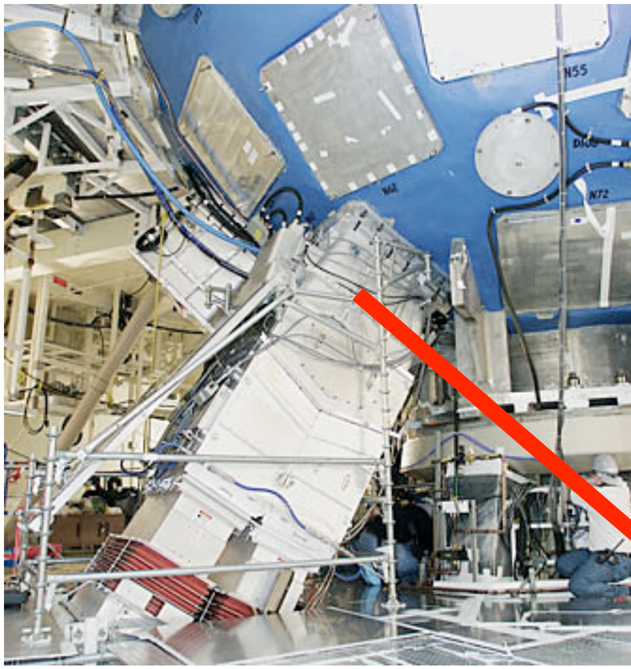


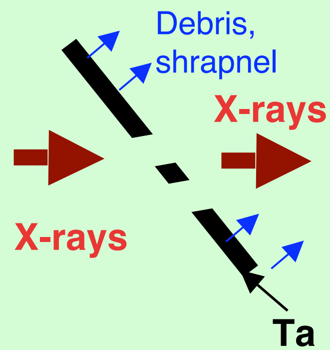
Damage to debris shields

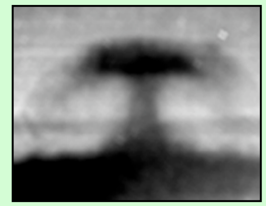
Mitigation of damage requires fragmentation model: size, velocity and direction must be predicted

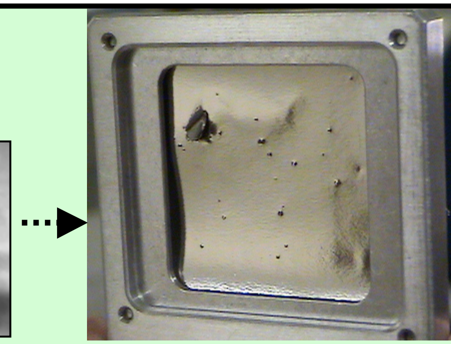
NIF targets must be designed to minimize damage to optics and diagnostics from target debris

The National Ignition Campaign









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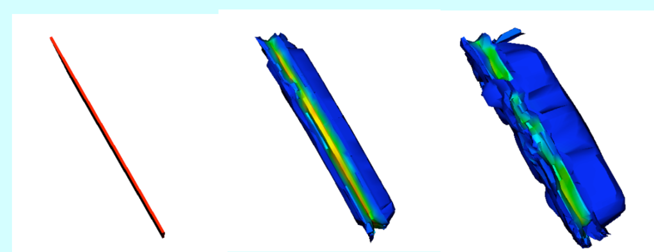
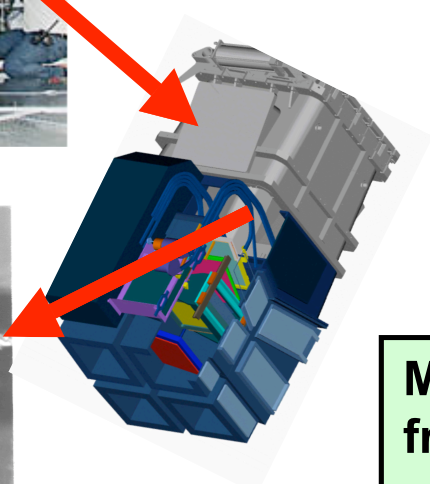
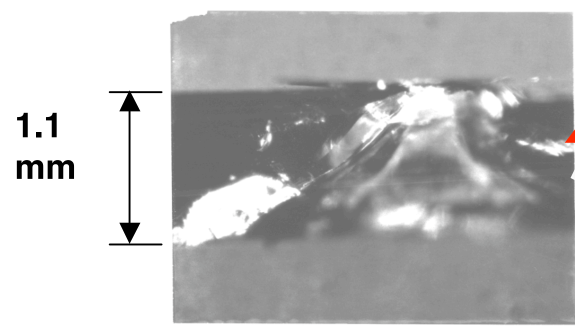


Time progression of 3D foil simulation (density isosurfaces) shows blow-off in normal direction





Damage to debris shields

Mitigation of damage requires fragmentation model: size, velocity and direction must be predicted

Calculations must include the entire target structure; focus is outside the hohlraum

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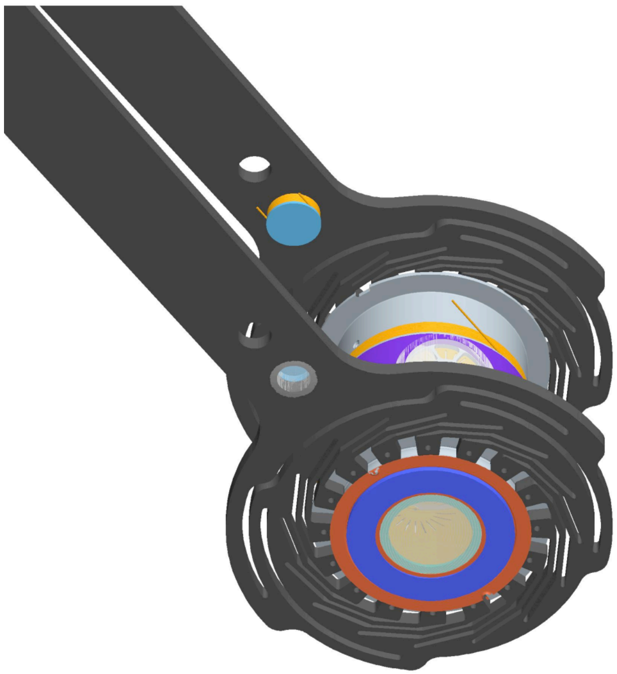
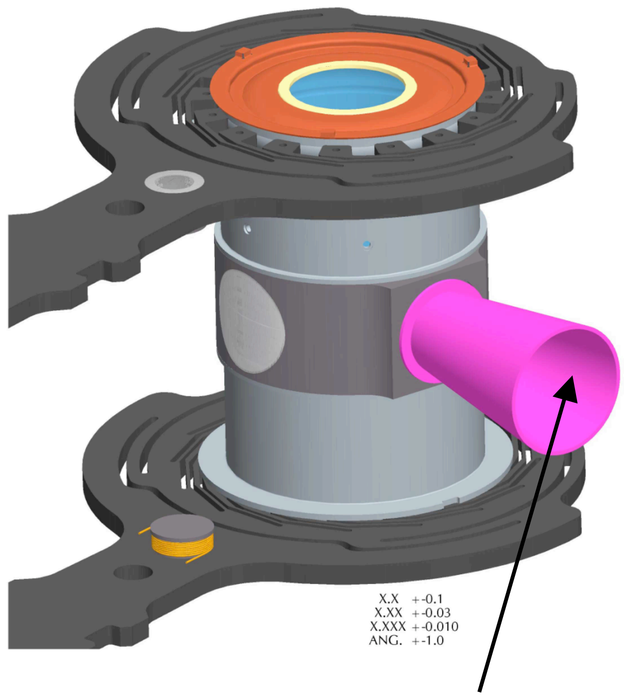
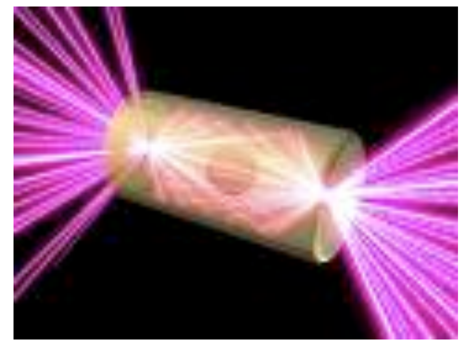
Sample NIF Targets



Generic Hohlraum with Cooling Rings



Outer Cone on Keyhole target



Contrast with traditional simulations that model physics inside hohlraum and capsule

New multiscale hydro/rad/materials code predicts fragmentation through temporal/spatial scales

NIC
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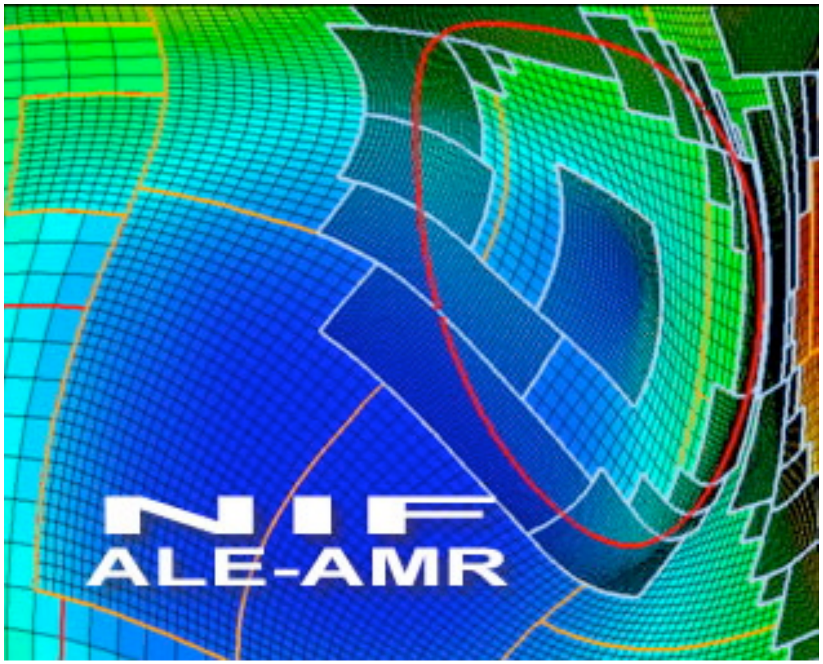
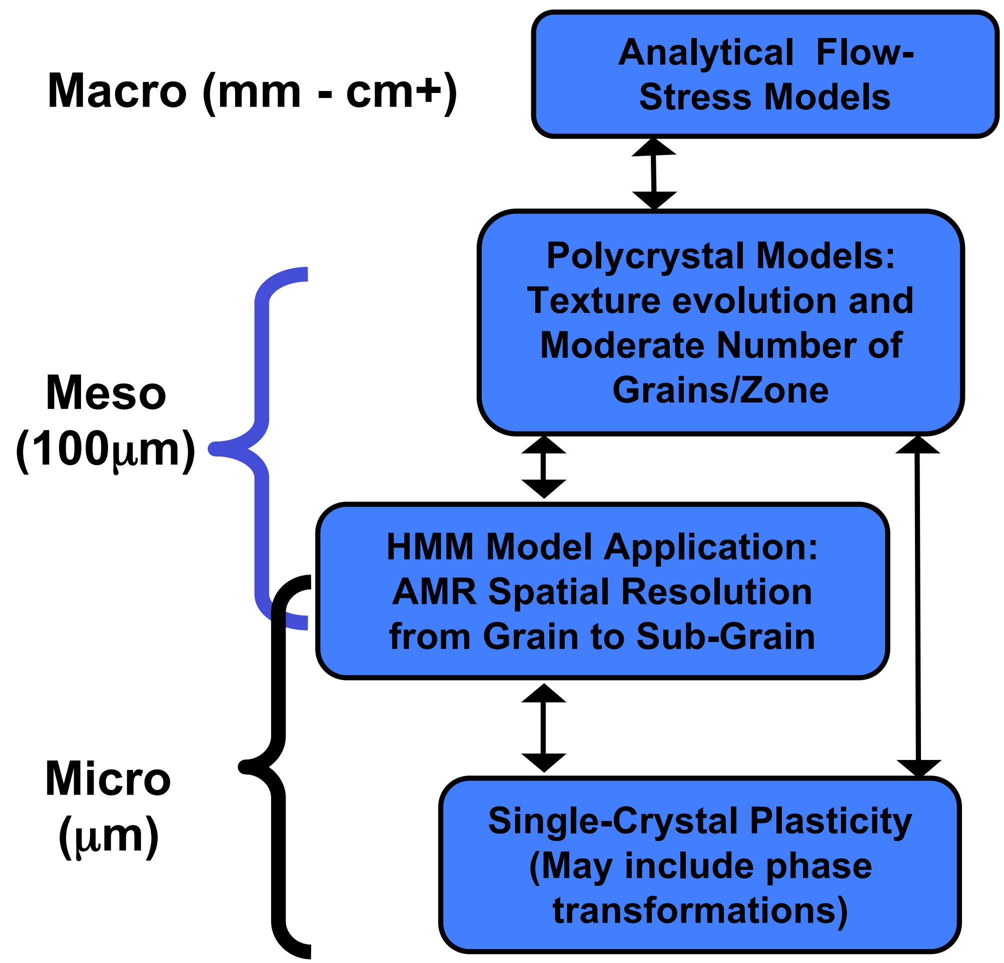


ALE-Arbitrary Lagrangian Eulerian

AMR-Adaptive Mesh Refinement

Hierarchical Material Model (HMM)



Major Improvements to NIF ALE-AMR have promoted it to our major design/evaulation tool

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- Full multimaterial capability (talk by Masters)
- Wide range of material failure models (talk by Fisher)
- Physics of radiation diffusion (talk by Gunney)
  - Single group now, multigroup in future
  - Add conduction heat transfer in future
- Laser ray trace on going (talk by Masters/Kaiser)

When intuition is not enough -- or graphic example of why we need simulations

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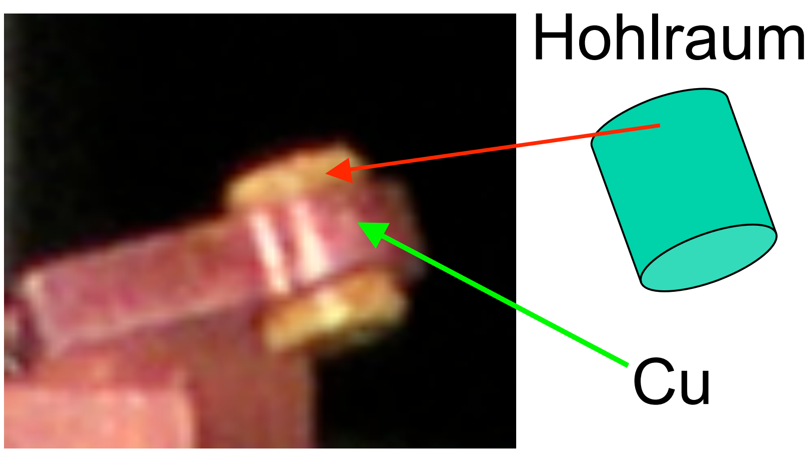

Hohlraum surrounded by
Cu notched cooling ring structure
rendered 10 debris shields
inoperable on Omega.

Simulations explain why this was not a good solution to debris problem.

Simulation explains that notched ring breaks into larger pieces instead of small spall planes/rings

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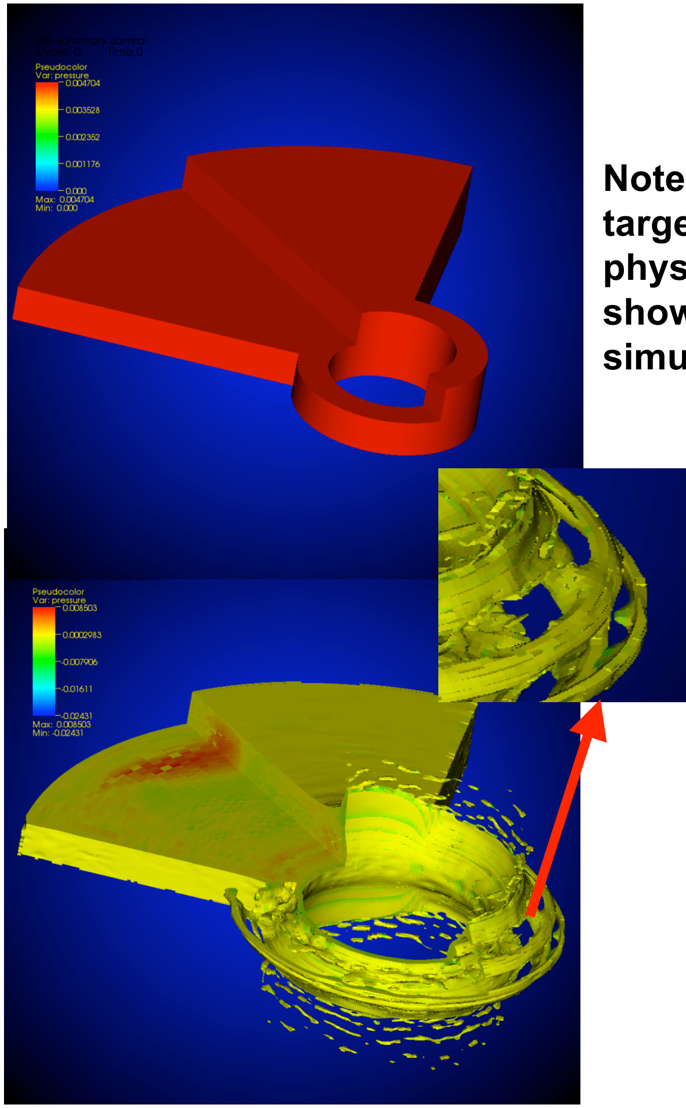
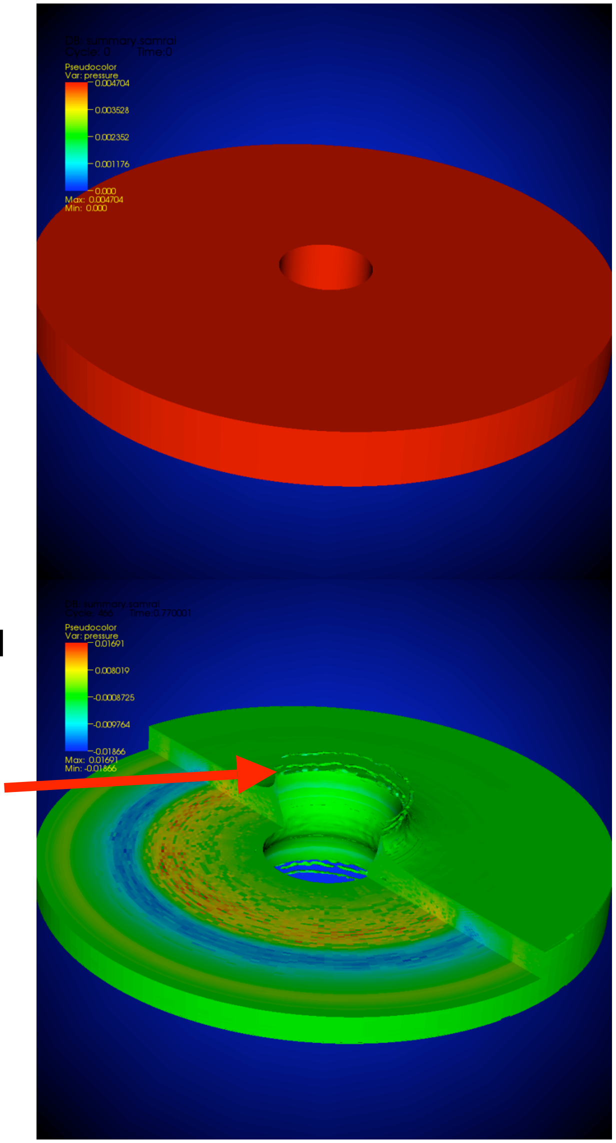


Note: "step" in target is not physical -- just to show interior of simulation.

FORMATION OF LARGE DAMAGING PIECES IN THIS REGION

FORMATION OF SMALL SPALL PLANES



New model for failure and fragmentation allows cracks and voids to form -- similar to CEA code

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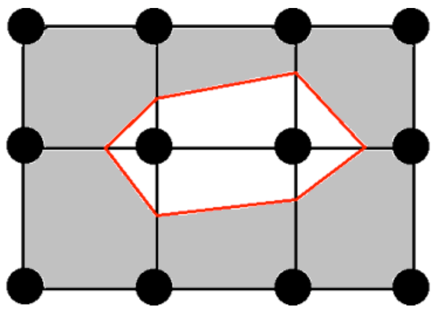
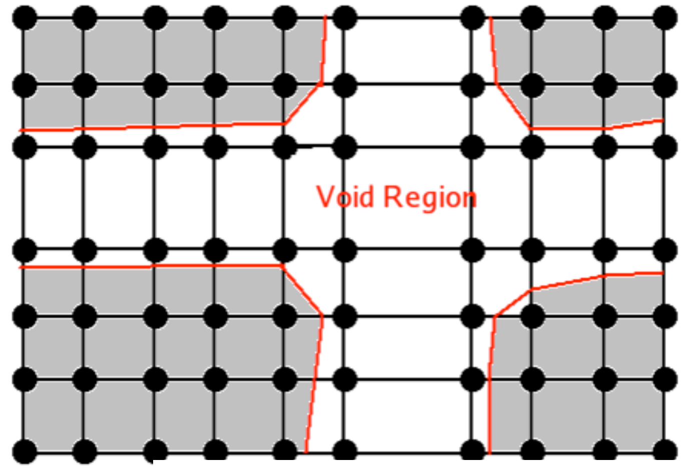
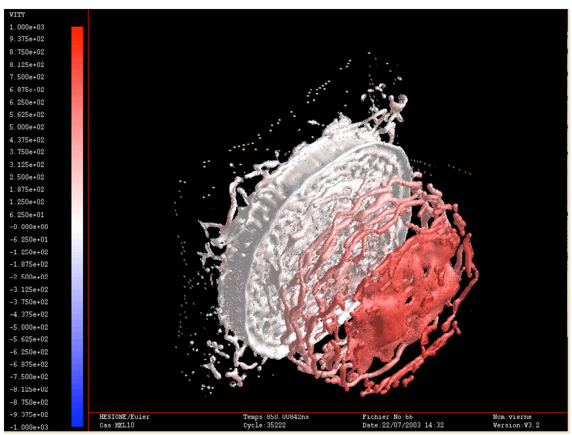
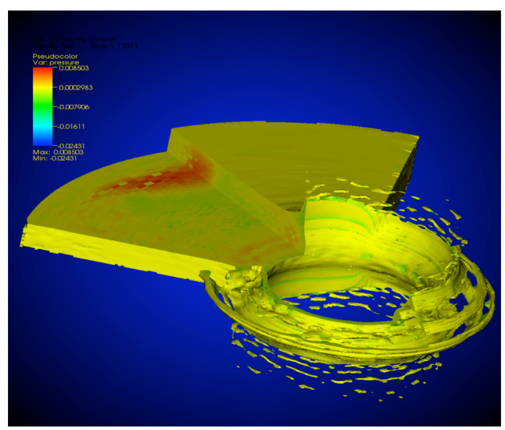
Volume fraction interface reconstruction allows voids to coalesce to form cracks

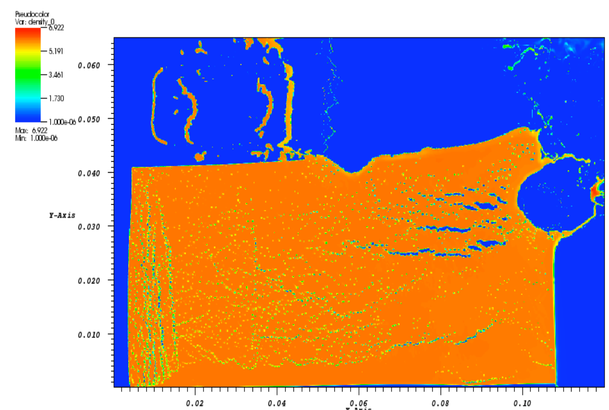


Cracks can grow large enough to span across cells allowing fragment formation









More info: Talks by Fisher and Masters

Validation studies include macroscopic and microscopic data collection and analysis

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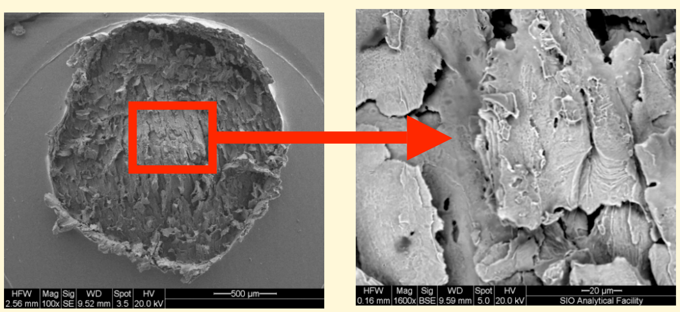
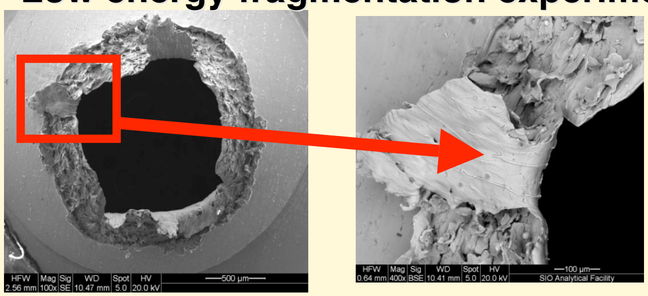
- Macroscale expanding ring problem (talk by Fisher)
- Dedicated fragment collection experiments on Janus Laser at LLNL (talk by Maddox)
- Dedicated experiments at CEA-LIL (several talks this workshop)

We have collected laser-spalled fragments of Va and Ta both on glass and in aerogel

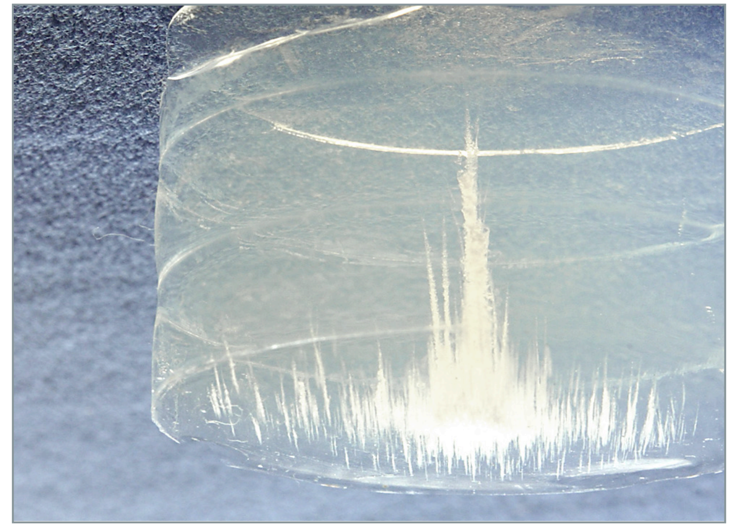
Since targets are small (~1 cm), size scale of targets is within a few orders of magnitude of the microstructure (grain sizes ~ 10 microns)

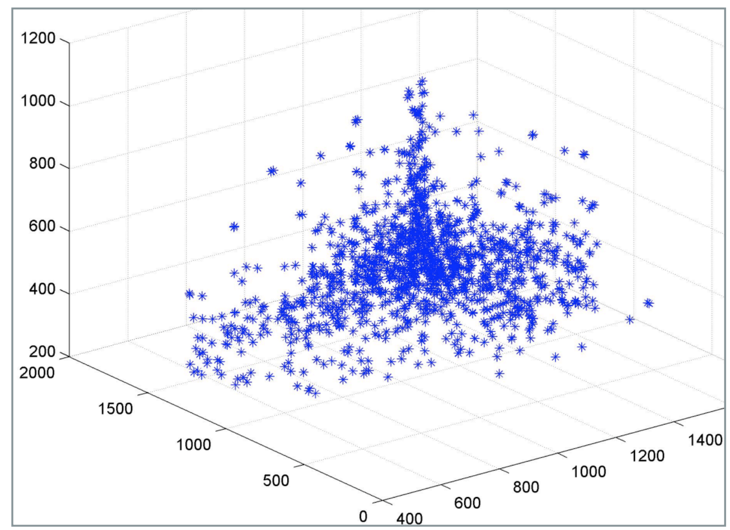


Low energy fragmentation experiment



High energy fragmentation experiment





Simulations shows spall off back plane that creates fragments for experimental validation

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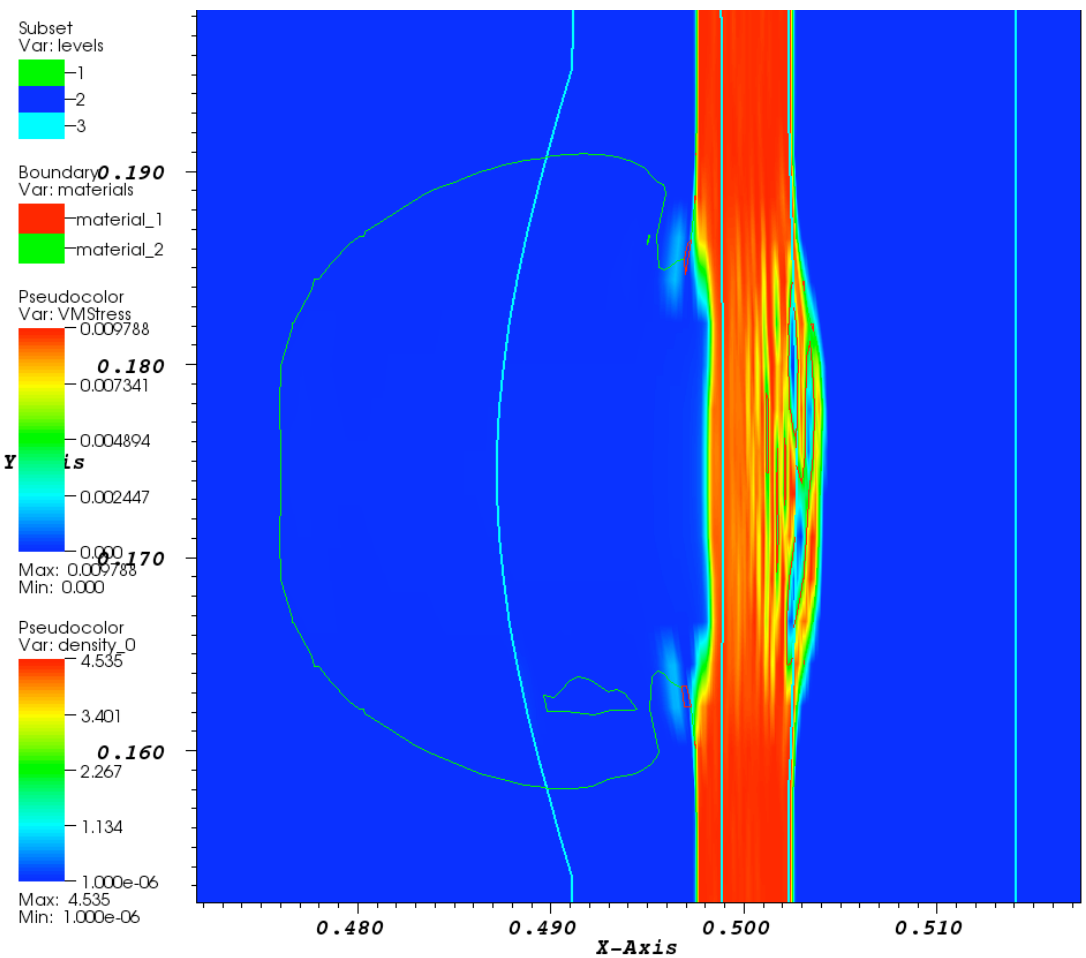

Several areas ripe for collaboration particularly with regard to chamber relevant material models

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- Strength and failure models for target chamber materials at appropriate T and P must be located
- Typical filter and shield materials are
  - Ta, Be, Va, doped plastic, Pt, Au, Al
- Are there experiments we should be doing to improve these models?
- What materials are planned for LMJ?
- CEA-LLNL collaboration on both simulation models and results should be continued

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  - Re-emit target for symmetry campaign

A procedure to evaluate debris and shrapnel is in place with time required for assessments

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- Campaigns provide a sketch of all components within 1 meter of TCC ~6 months prior to when final specs are given to target fab
- Evaluate all three sources of debris depending on target and laser parameters, → calculate loss of transmission per shot
- Conduct initial assessment , → identifies components that could produce shrapnel that is not consistent with constraints
- Components are shields, pinholes, etc. that are far enough from TCC not to be vaporized but close enough to be melted/fragmented
- Stand-alone simulations of components are completed including unconverted light and hohlraum x-rays as source terms
    - Must account for full-range of proposed energies, i.e., truncated pulses
    - New designs are proposed as needed to mitigate damage

Energetic Campaign Summary

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- Energetic campaign is first use of cryogenic cooling rings
  - Rapidly expanding hohlraum pushes cooling ring causing ring to break apart
  - Cooling ring simulations have been completed in 2D and 3D for Si and Al
  - Component at risk is 1mm thick DDS
    - Adequate safety margin for Si is predicted
- Shielding is required for Dante, which measures energy in hohlraum
  - Calculations show Si ring provides adequate shielding

Time progression of cooling ring disintegration allows us to determine particle size/velocity

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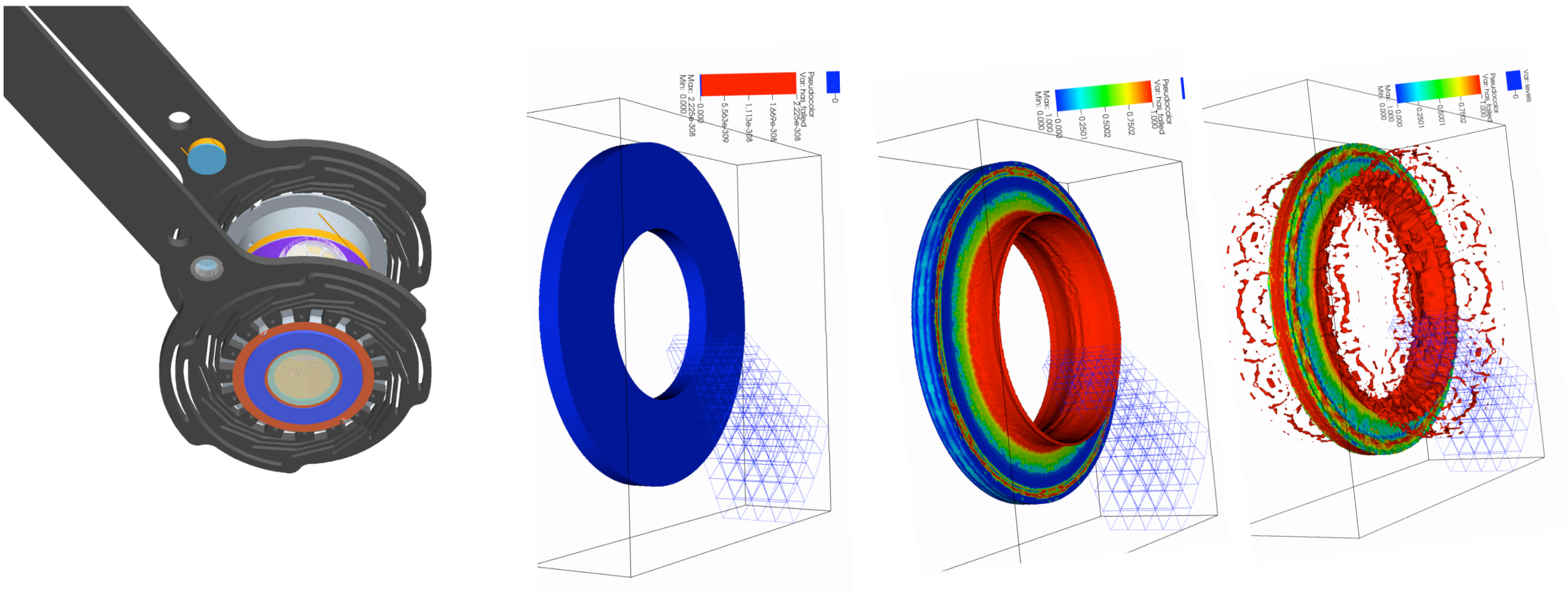

Studies of cooling rings use an icf code hohlraum simulation as an initial condition for the force on the cooling ring.

Simulations show that fragments from Si Cooling Rings have a greater safety margin than Al Rings

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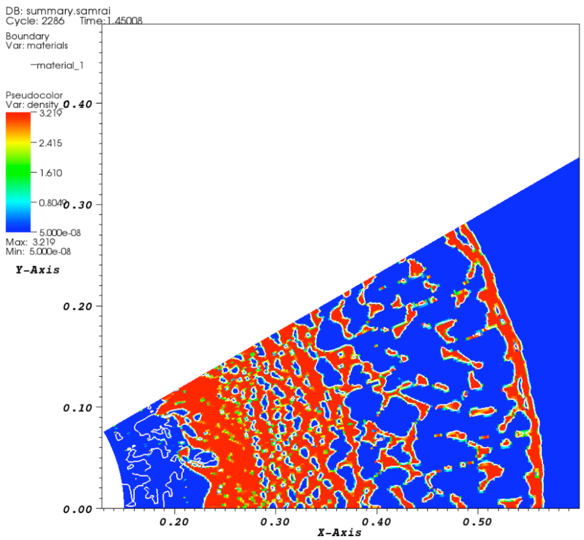
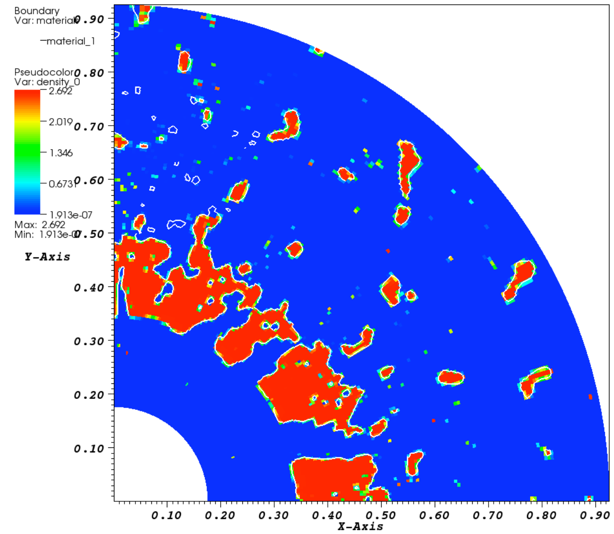
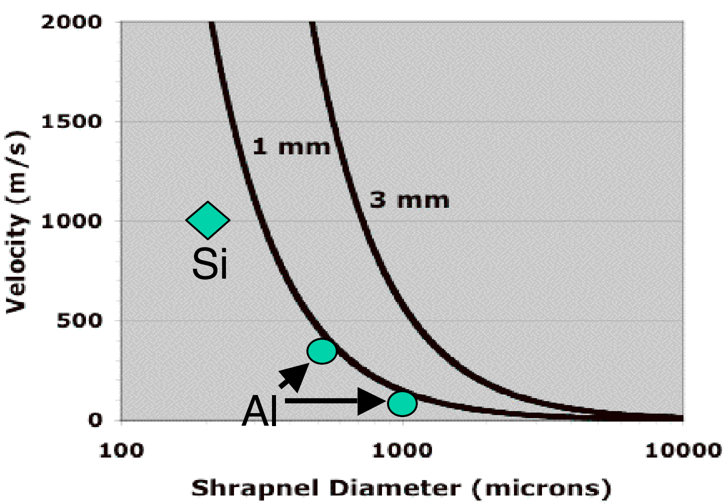


Si ring
t = 1.45 μs



Al ring
t = 14 μs



- Si breaks into relatively small similar sized fragments with velocities of ~1000 m/s
- Al breaks into a range of relatively large fragments with velocities 100 - 350 m/s
- Al fragments are closer to curve showing size/velocity to penetrate 1 mm thick DDS

Diagnostic design requires shielding -- where to place shields and what material won't damage?

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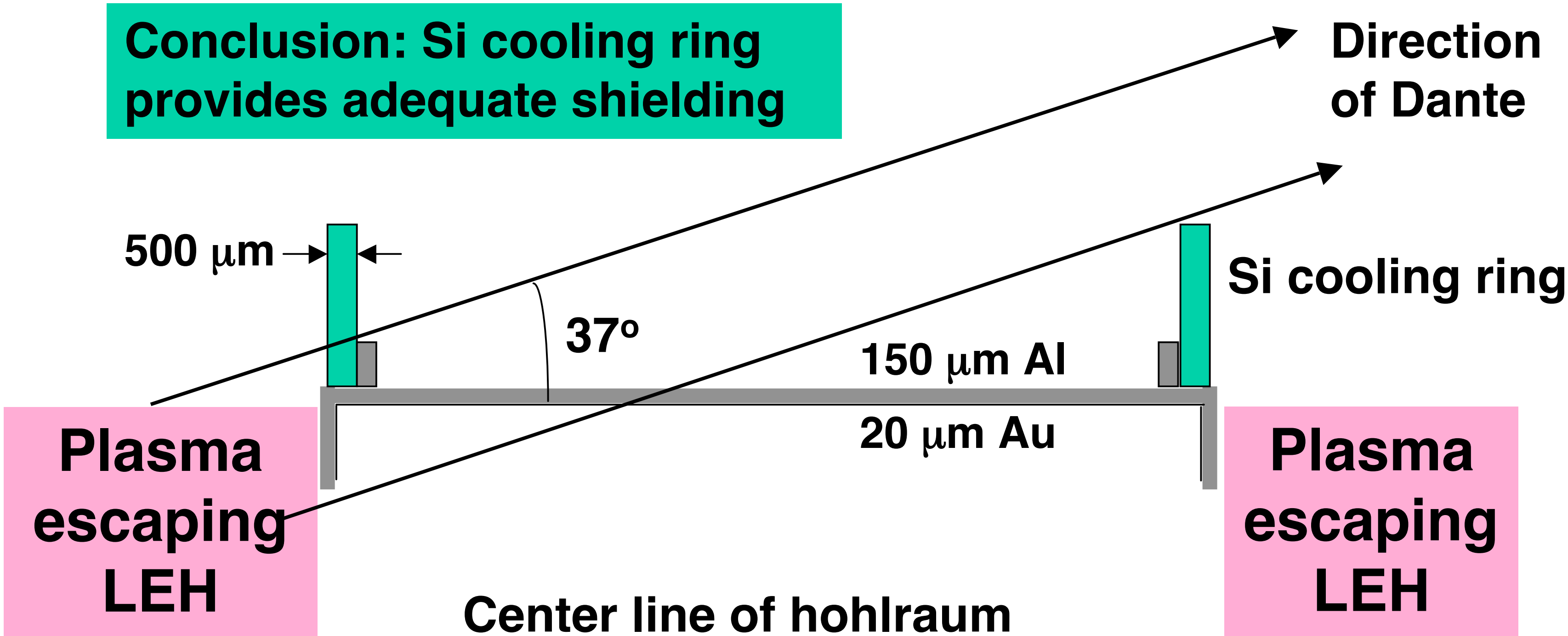
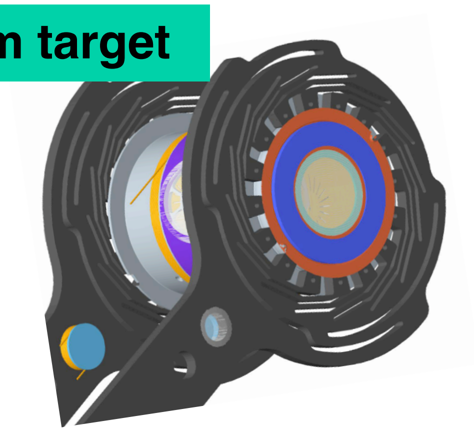
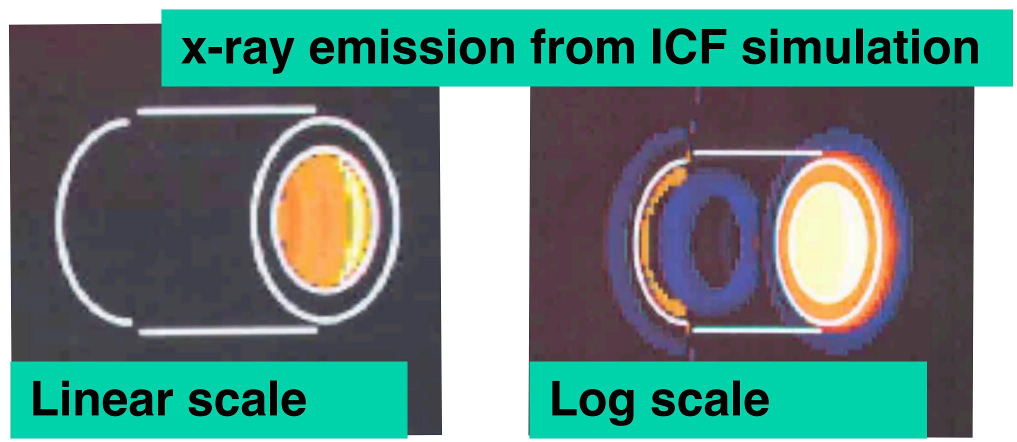
Conclusion: Si cooling ring provides adequate shielding



96 beam target





Keyhole target for shock timing campaign - Summary

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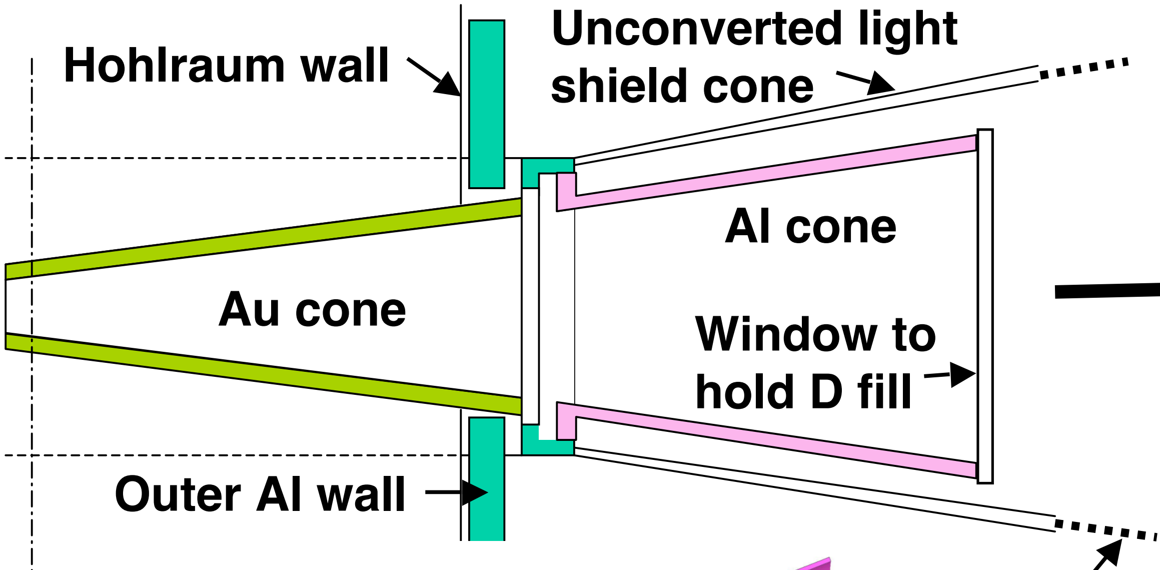
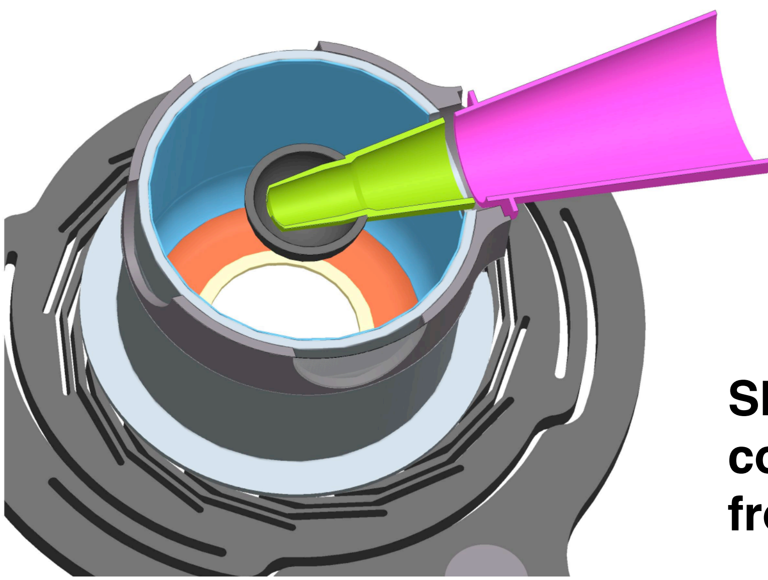
- Inner and outer cone creates window into hohlraum capsule
  - Material of outer cone determined (gold)
  - Inner cone vaporizes
  - Outer cone is launched with slow velocity
  - Shape charge plume created by inner cone is under investigation

A keyhole target will be used in one capsule campaign to measure shock timing





Shield (not shown) attached to cooling rings to block x rays from plasma escaping LEH

2D and 3D analysis of “keyhole” target used to design cone material and identify plume issue

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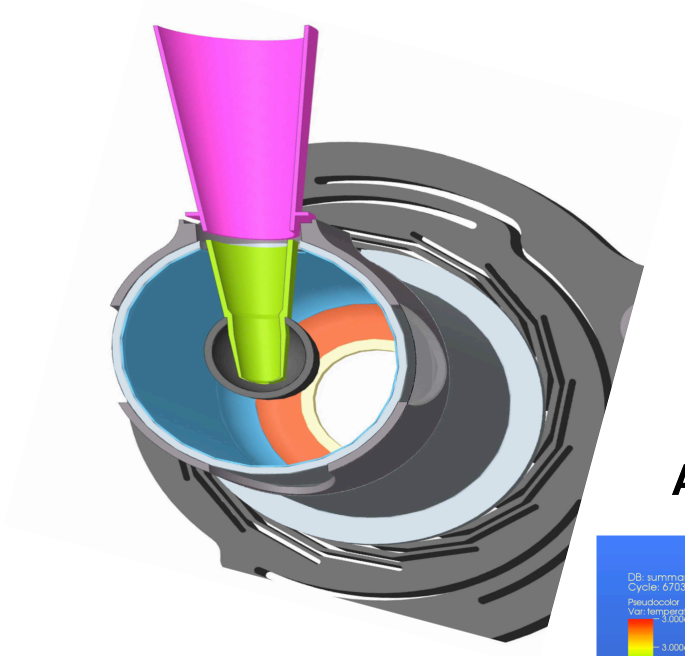
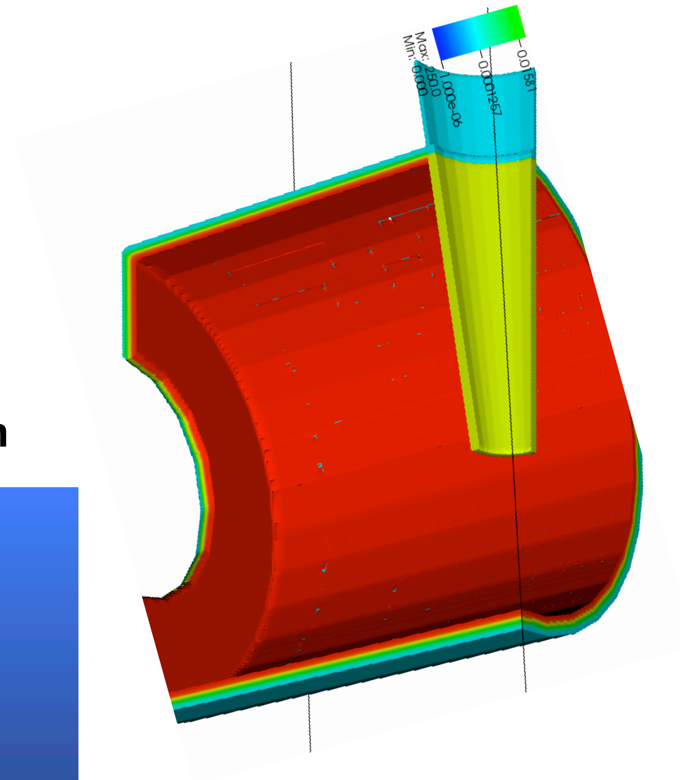
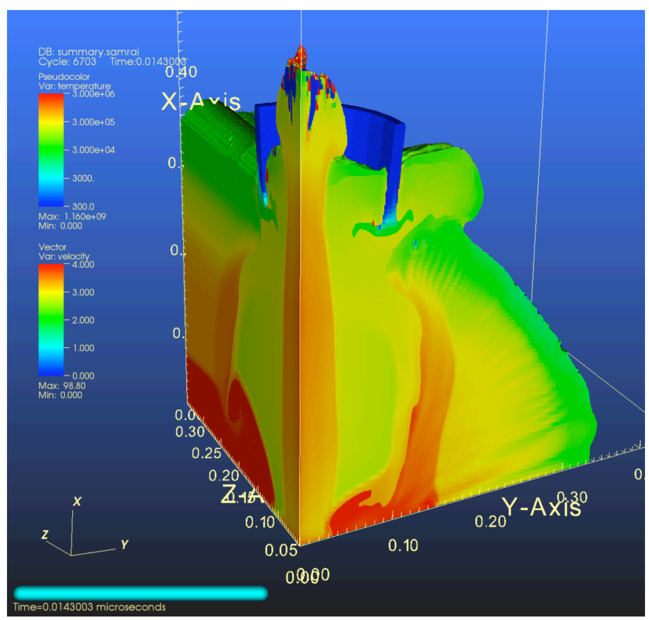
Preliminary Design Drawing



ALE-AMR Full 3D Geometry



ALE-AMR 3D Simulation



See Talk by Masters

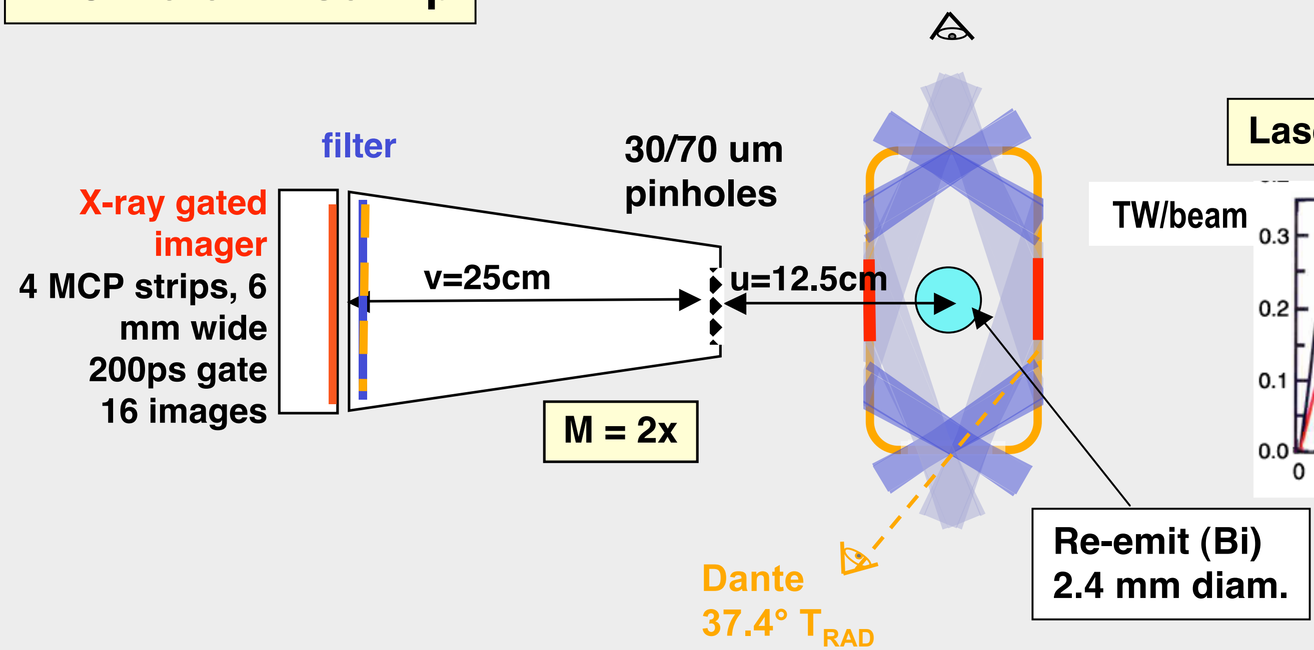
Re-emit target for symmetry campaign - Summary

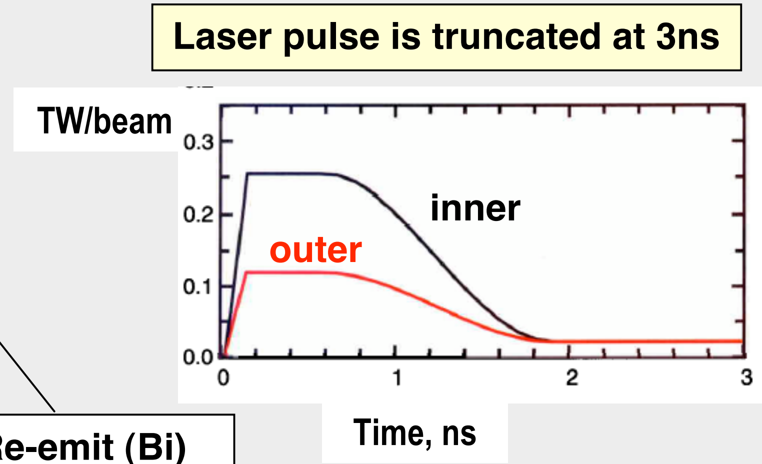
The National Ignition Campaign

- High-Z Bi capsule replaces low-Z Be (or CH) capsule in hohlraum
  - Capsule is imaged during the low energy foot of ignition pulse
  - Issues
    - Use of very thin (6 micron) Al filter behind Ta pinhole
    - Vaporization of hohlraum assembly for low laser energy (~50kJ) shots
  - Conclusions
    - Launch velocity depends on laser energy / x-ray loading
      - For re-emit energies, Ta is not launched at thin Al filter
      - For higher energy shots, Ta is launched at thicker filters
        - » Tilting of Ta pinhole arrays may be required
    - Hohlraum assembly with 150 micron Al outer layer vaporized
      - Current design with 500 micron Al requires further study

For NIC we will use an un-mirrored gated imager filtered for 1 keV with 200 ps resolution

NIC Re-emit set-up





- We perform measurements at 900 eV and 1200 eV to crosscheck inferred total flux asymmetry
- Filters (rather than mirrors) simplify diagnostic construction, characterization and provide higher flux onto detector

Concern of damage to camera by shrapnel from piinhole arrays for 96-beam symmetry campaigns

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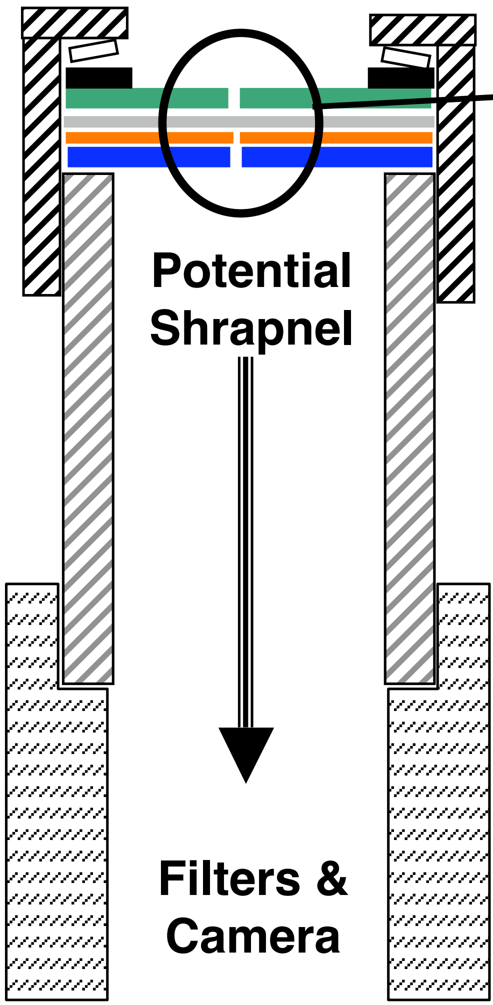
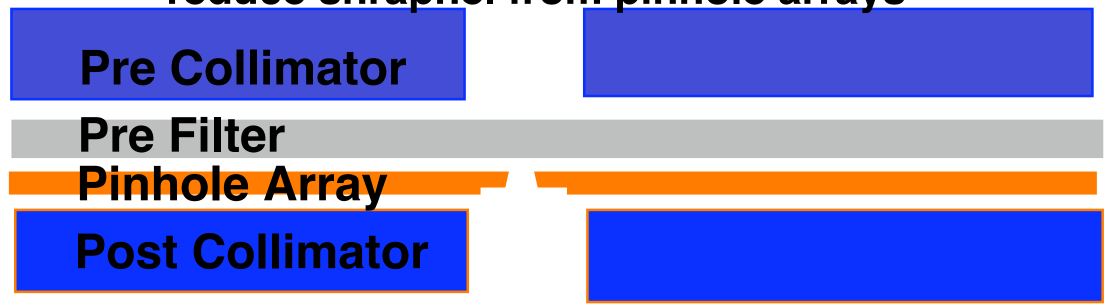
Pinhole Pack Cross Section

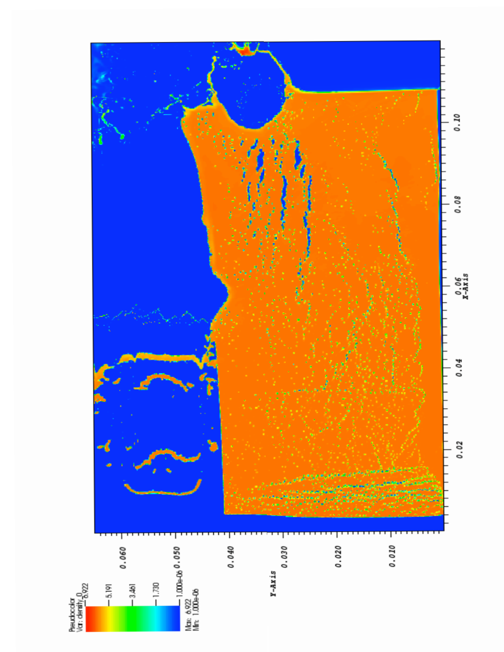


Collimators are used in snouts to reduce shrapnel from pinhole arrays



For close placement, shrapnel (molten & solid) from snout structure must be studied

See talk by Fisher.



For the lowest energy (33 kJ) shots planned in energetic campaign thin hohlraum vaporizes

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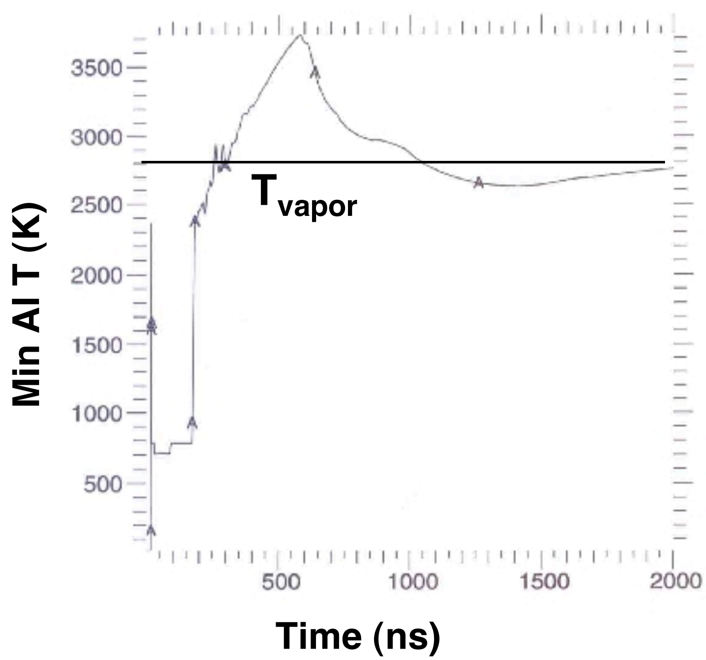
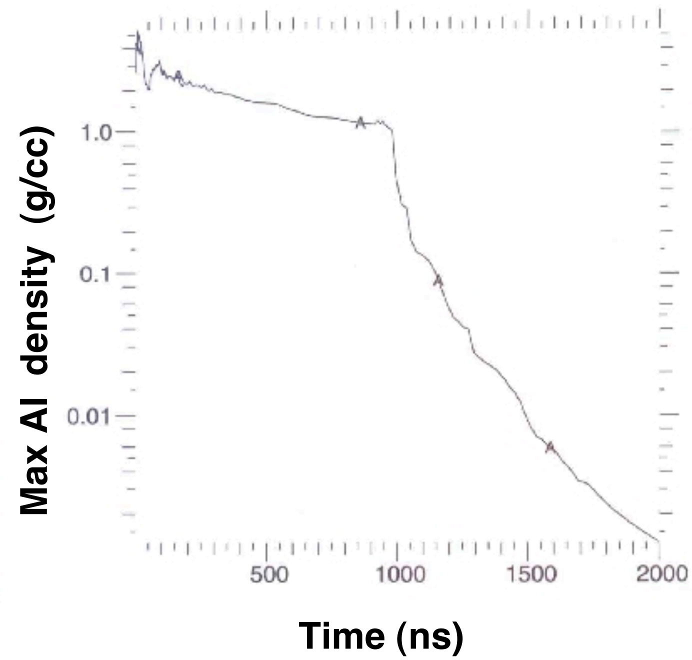
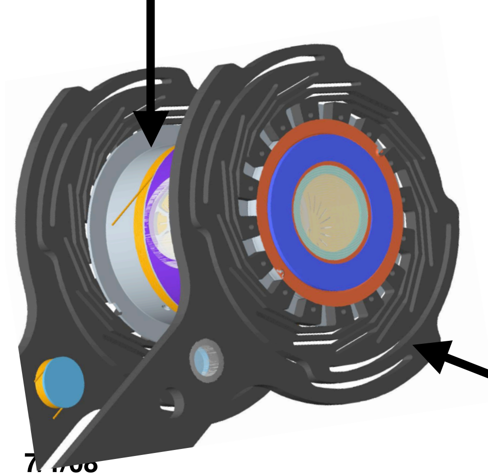
New designs with thicker Al coating require further study (2D)

NIF hohlraums have an outer Al shell and the high Z layer is inside this shell





Outer hohlraum wall is 150 μm of Al



Calculations of "300 eV" 96-beam energetic campaign hohlraum truncated at 6 ns (33 kJ) indicate Al vaporizes

Si cooling ring (not vaporized but will fragment)

Conclusions

The National Ignition Campaign

- We have designed a new multiscale multiphysics code that is used to determine the late-time behavior of NIF targets
  - Code uses an adaptive moving mesh and is unique in its ability to model the physics of fragmentation in this environment
  - Code development, still in progress, includes latest techniques, additional physics, and studies aimed at future many-core innovative architectures
- Each NIF configuration is analyzed and design changes are made to minimize debris and shrapnel damage
- Target analysis for upcoming campaigns is presented
  - Energetic campaign
    - Cooling rings
    - Dante shield
  - Keyhole target for shock timing campaign
  - Re-emit target for symmetry campaign