GENERAL ATOMICS
AND AFFILIATED COMPANIES

Test of an Indirect Drive Fast Ignition Target Concept

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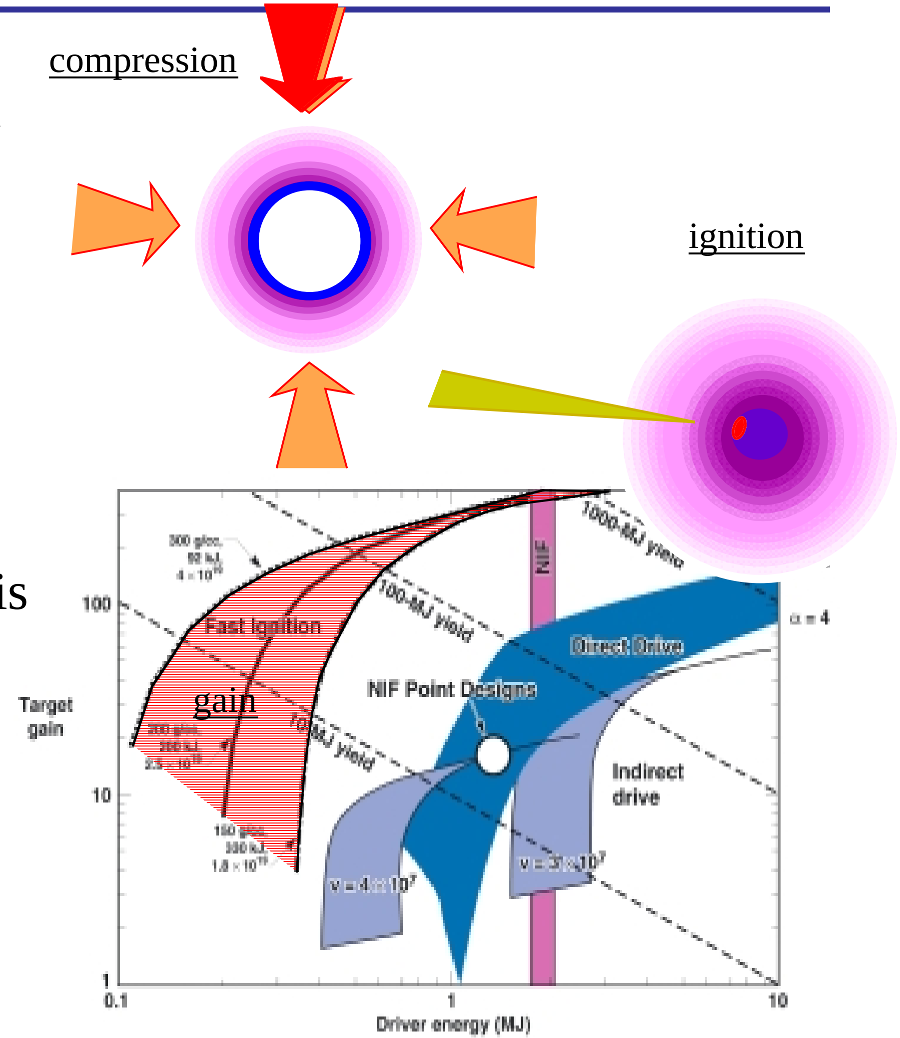
Abstract

- We compared implosion of an indirectly driven reentrant-cone shell target to Lasnex simulations.
- The target design is the hydrodynamic equivalent of a NIF cryo ignition target scaled down to be driven by Omega;
- A sequence of radiographs recorded each implosion; simulated radiographs were generated from the Lasnex calculation.
- These radiographs gave diameter, density, and symmetry as a function of time through the stagnation time.
- The simulations were in good agreement with the experiments with respect to the shell.
- Non-thermal gold m-line radiation from the hohlraum wall penetrated the shell wall, vaporized material off the reentrant cone surface, causing some high Z material to mix into the collapsed core.
- Substantial target redesign will be necessary to avoid this problem.

The Fast Ignition (FI) Inertial Fusion Energy (IFE) concept has the potential to improve the attractiveness of IFE reactors.

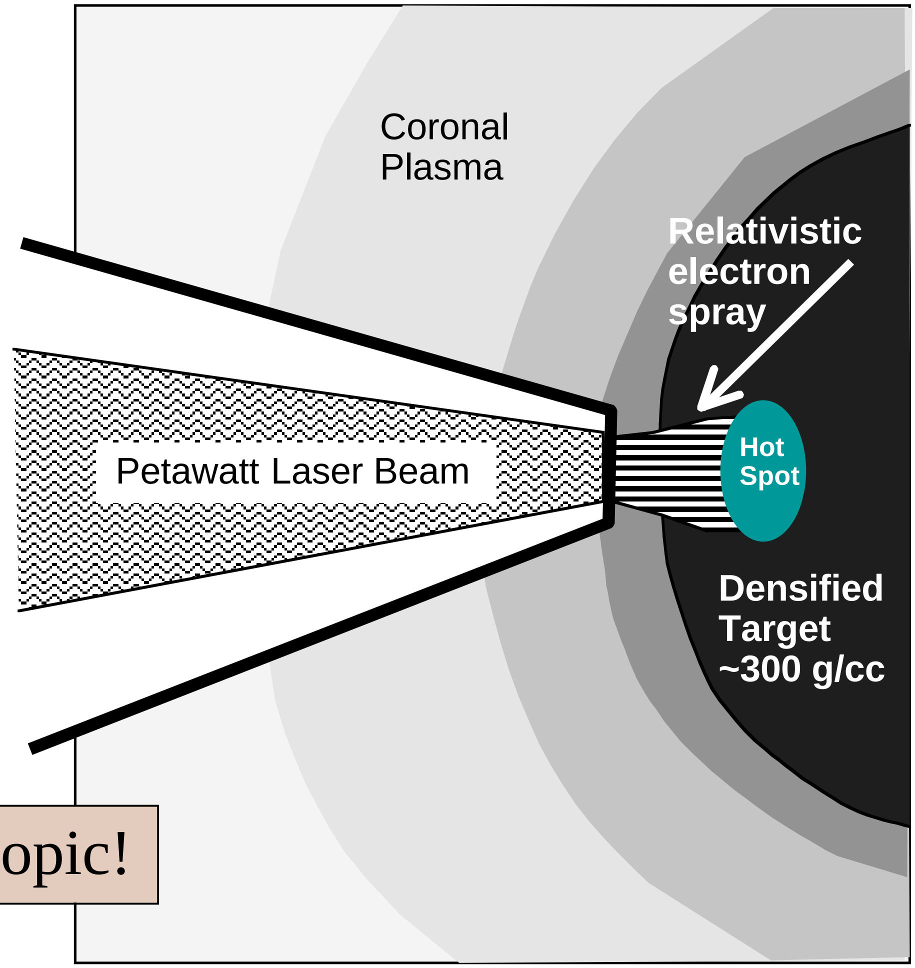
- FI ignites the dense core of separately compressed fuel pellets with a very intense laser pulse [Tabak94],
  - achieves much higher gain than is possible with the baseline central hot spot (CHS) approach [Rosen99]

- However, the target core (~200 g/cc) is hidden under a plasma corona that is opaque for densities higher than ~1 g/cc.



A FI IFE target must convert the ignitor pulse photons to a stream of charged particles

- Photons can be efficiently converted to electrons [Key98]
- Distance to the core can be minimized with reentrant cone
  - excludes blow-off from laser beam
  - gives controlled surface for photon<=> electron conversion



FI targets are extremely anisotropic!

Is a reentrant cone shell a feasible approach?

- **Questions for this study:**
  - —Can one assemble a usable core?
  - —Is the anisotropic implosion properly modeled with existing hydro models?

- **Results:**

  👍 Target hydro is well modeled by standard codes

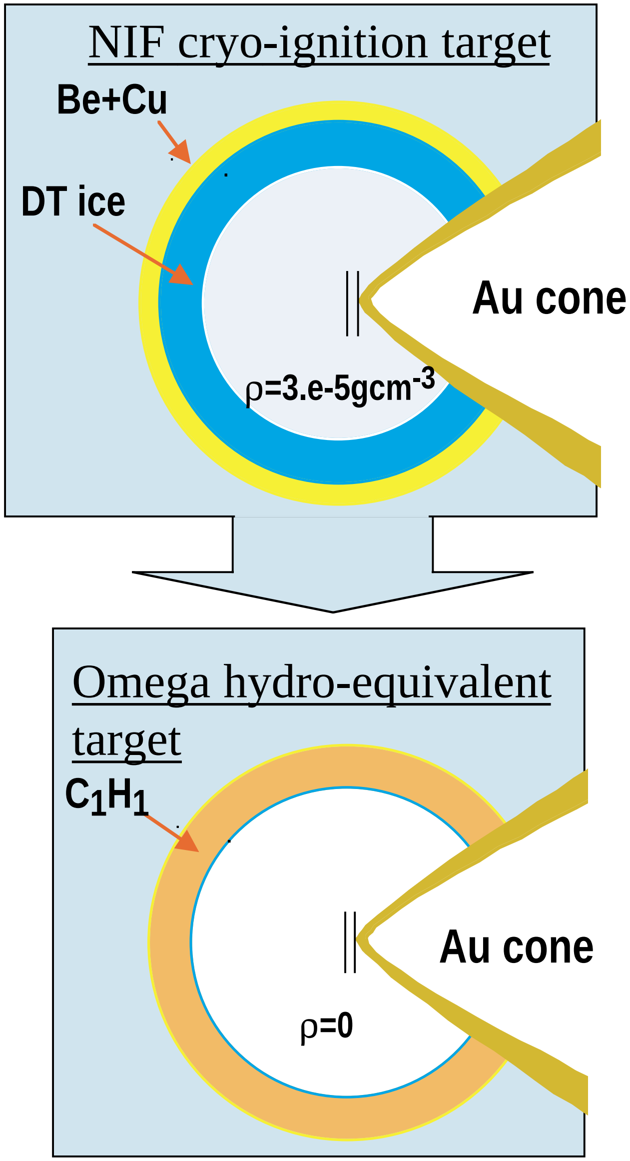
  👍 The fuel is assembled in a reasonably compact form.

  👎 Indirect drive x-rays generate Au vapor from the surface of the gold cone and that vapor is mixed in with the assembled fuel.

  ⇒ Minimizing that contamination source will require a substantial shine through barrier (for keV x-rays!), or use of direct drive.

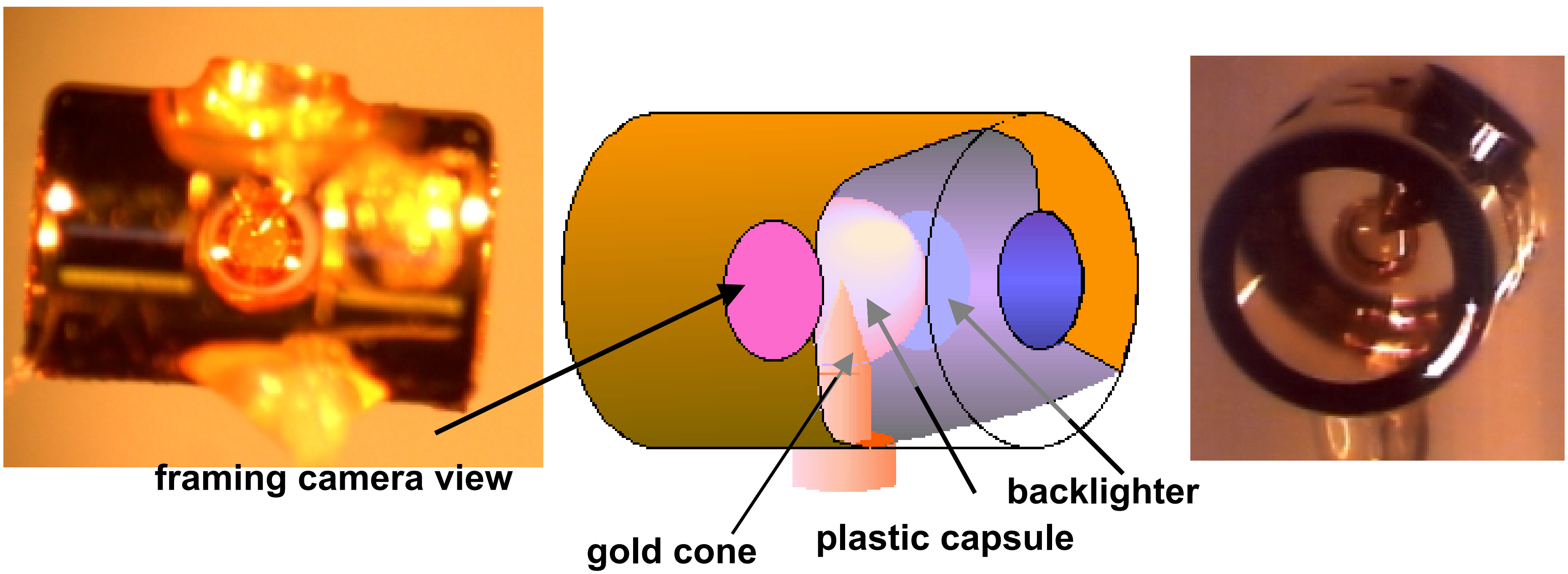
Experimental setup - Shell

- Target was scaled from the NIF ignition target and driven in a scale 1 hohlraum on Omega.
- Shell is 510 μm od with a 57 μm thick polymer wall.
- Cone is ~ 50 μm thick Au with a hyperboloidal tip (foci separation 40 μm) and a 35° half angle; the intersection of the asymptotes are 12 μm from the center of the shell.



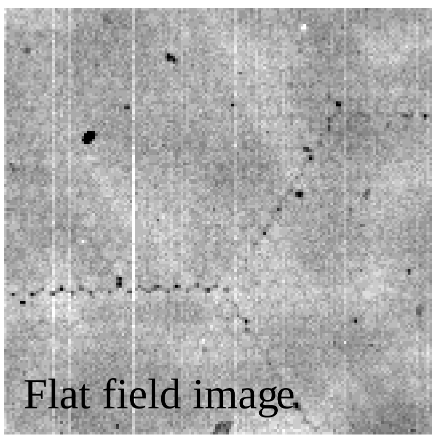
Experimental setup - Hohlraum

- Backlighter windows orthogonal to hohlraum and cone axes; Fe (6.7 keV) radiation.
- Gold cone stepped outside the shell to avoid the high angle laser beams and to avoid creating hot spots on the cone surface close to the shell.



Data needs processing

Corrected for
— Background pattern
— Camera streaks
— Light leak
— Non-uniform
illumination



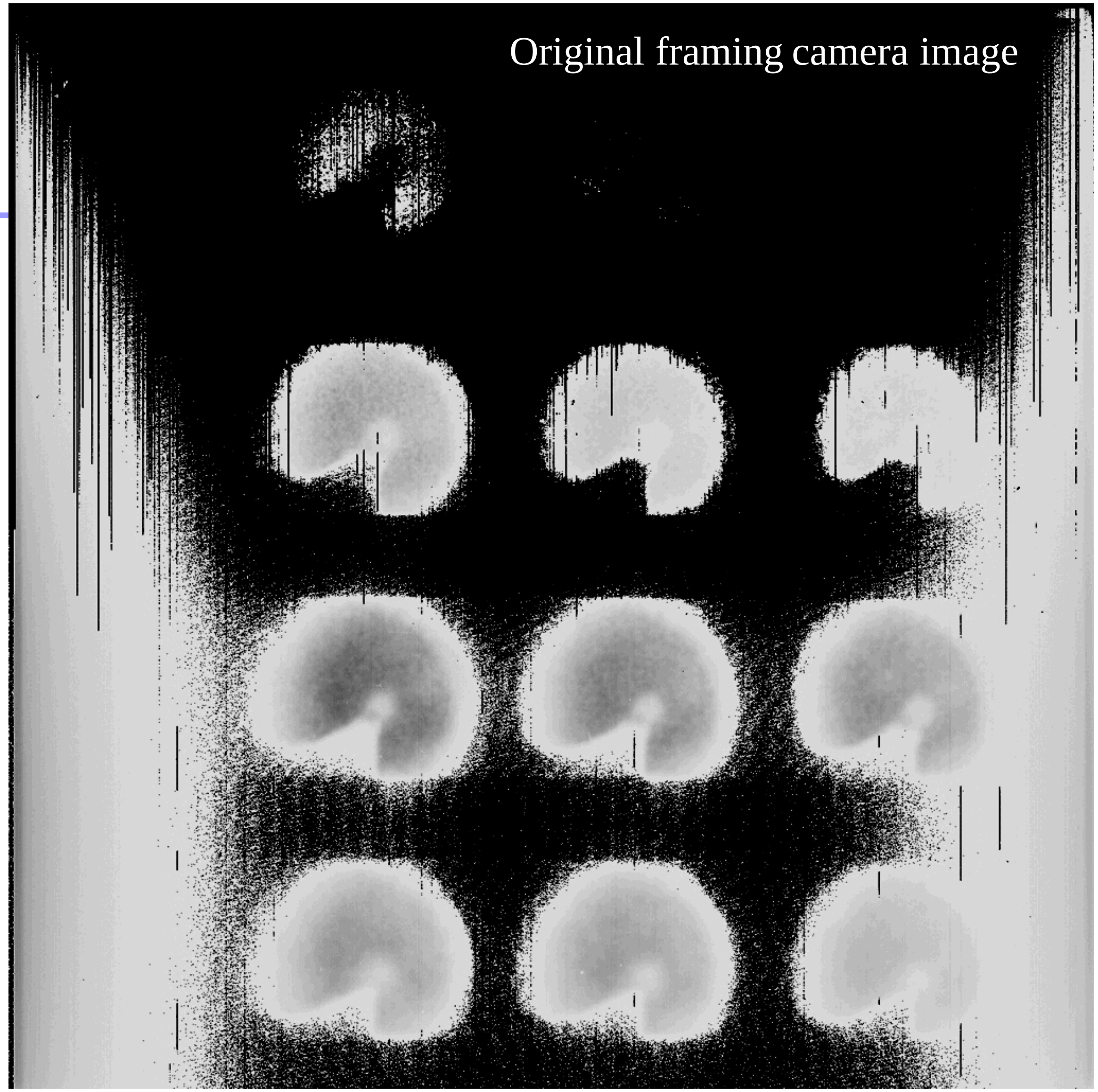
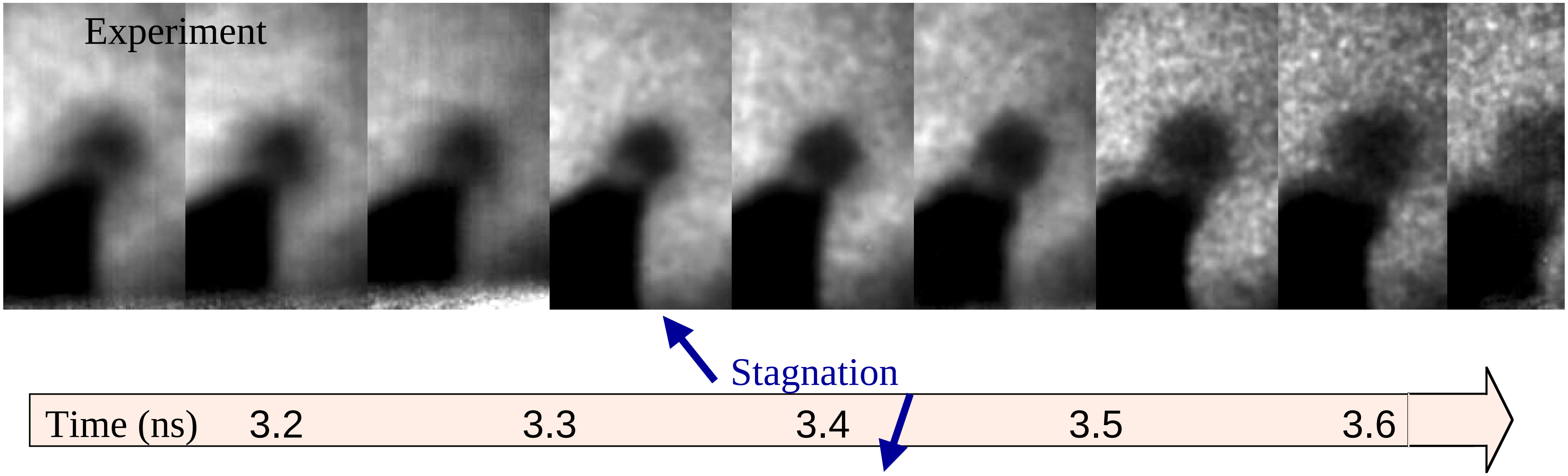
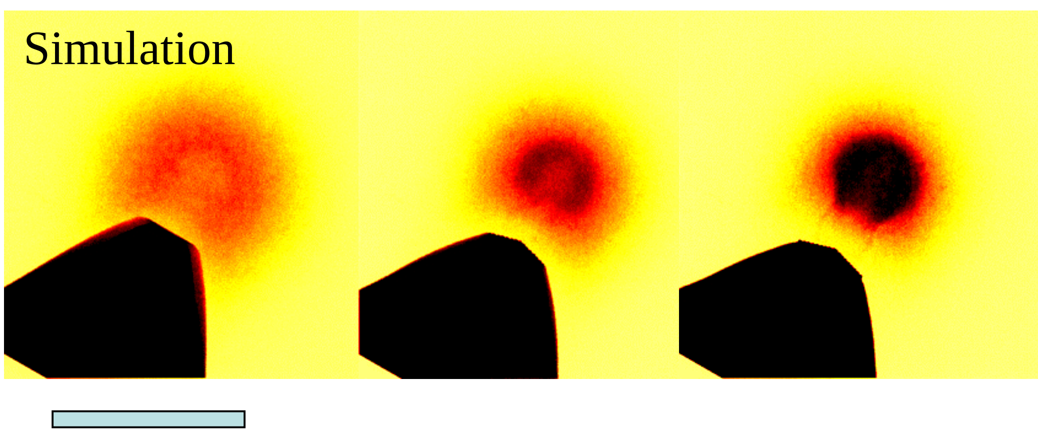


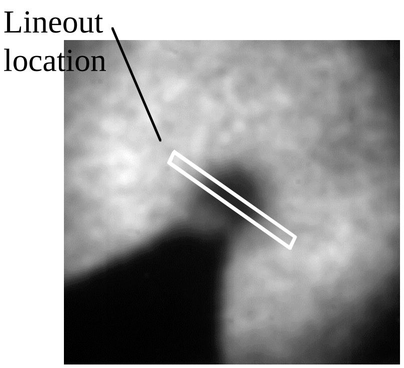
Image sequence shows symmetry and size



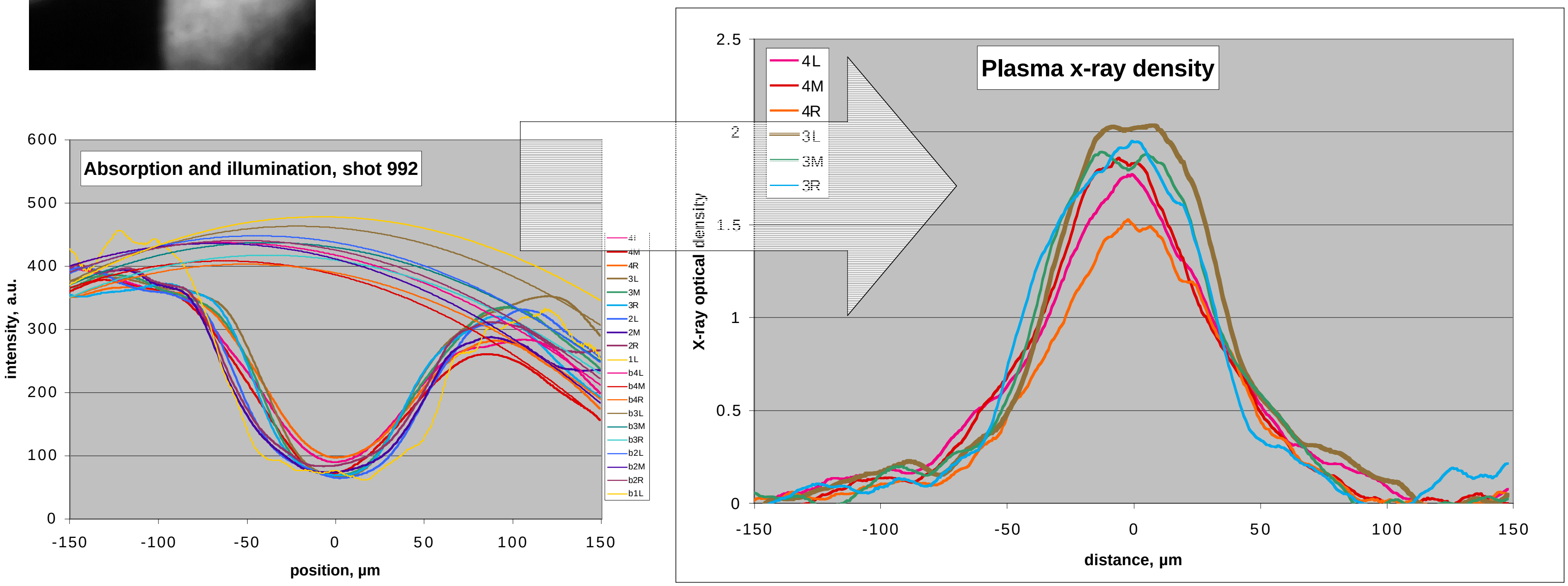


- Shell images are very similar to previously calculated simulation
- Cone images are initially too pointed, then blow apart

Lineouts are used to quantify plasma evolution

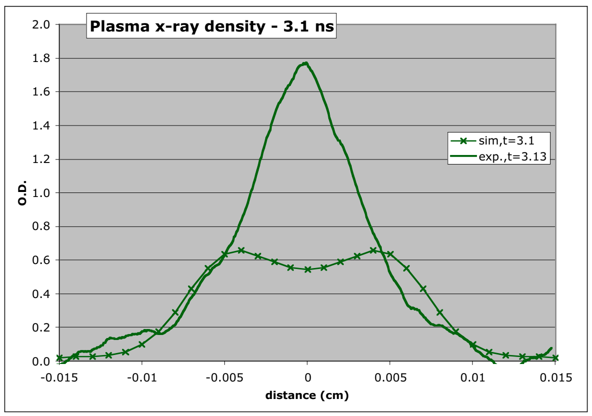


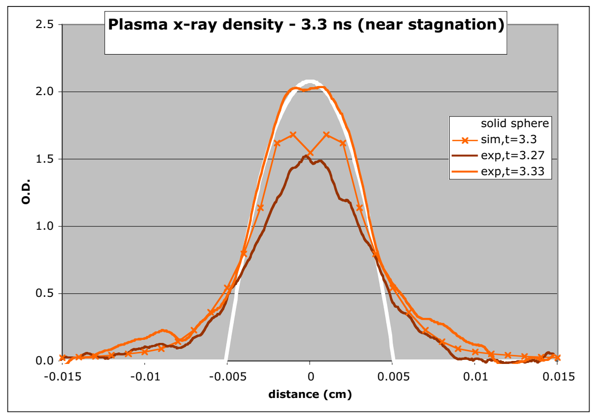
- Background descibed w/ parabola fit at edges away from shell obscuration
- Dark count estimated from unexposed regions of image
- Profiles smoothed w/ 30 µm boxcar average

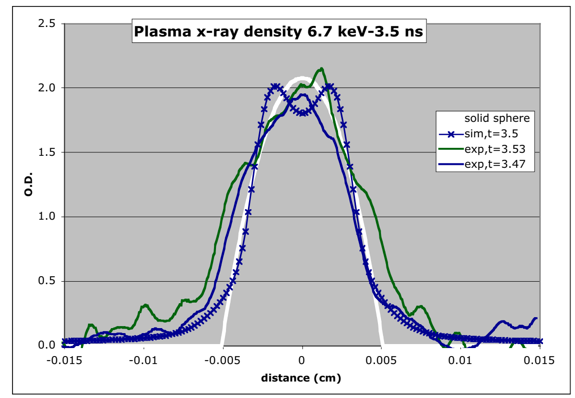


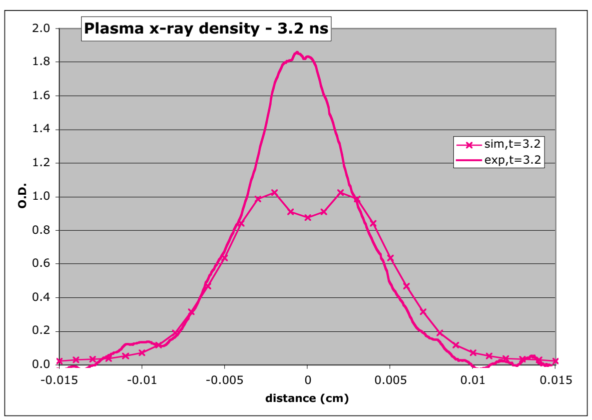
Experimental profiles don't match simulations

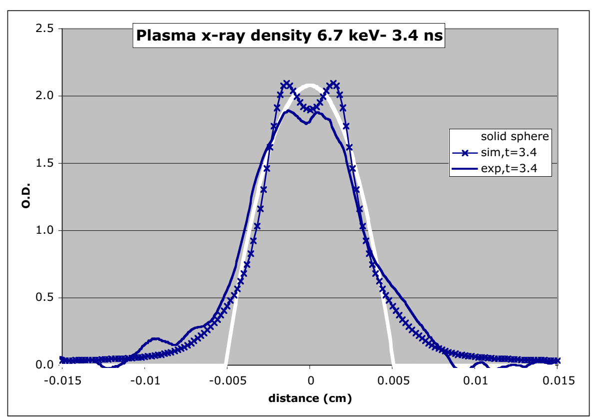
- Pre-stagnation, profiles have strong central absorption
  - fwhm and maximum density don't change much
- Stagnation profile like homogenous sphere

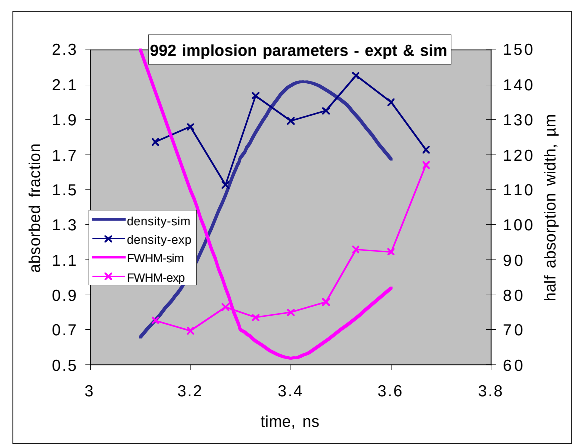






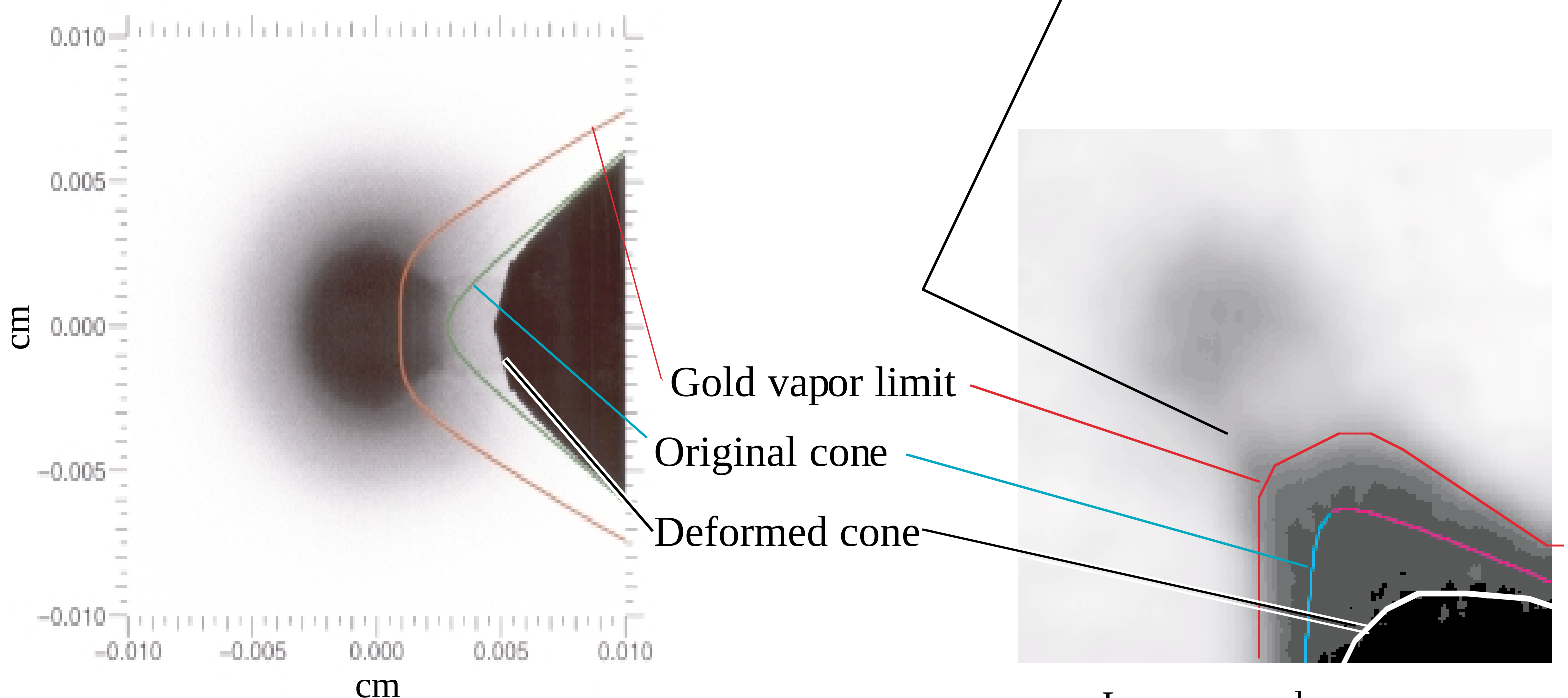






Gold getting into central cavity

- Simulation shows gold vapor coming off - dense gold vapor should be R-T stable against CH vapor
- Radiograph shows filament leaking into shell



Detailed calculation done w/o Au vapor

Log grey scale

Target has to be designed to protect cone surface

- Penetrating radiation comes from non-thermal m-line radiation
- Not easily avoided - all cocktail elements have similar lines →
- How does problem scale in going to ignition scale?
  - Hohlraum intensity larger
  - Thicker shell wall absorbs better (abs length(2 keV) ~100 µm for C, Be)

<u>Cocktail Elements m-lines</u>

41Nb ~2.7 keV(L)
57La ~1 keV
60Nd ~1.5 keV
64Gd ~1.5 keV
73Ta ~2 keV
74W ~ 2 keV
79Au ~2.5 keV
82Pb ~ 2.8 keV
83Bi ~ 3 keV
92U ~ 4 keV

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