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Highly-resolved 2D Perturbation Simulation Studies of NIF Ignition and Omega Double-shell Targets

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Disclaimer

Highly-resolved 2D Perturbation Simulation Studies of NIF Ignition and Omega double-shells targets*

Jose Milovich, Peter Amendt, Marty Marinak and Harry Robey

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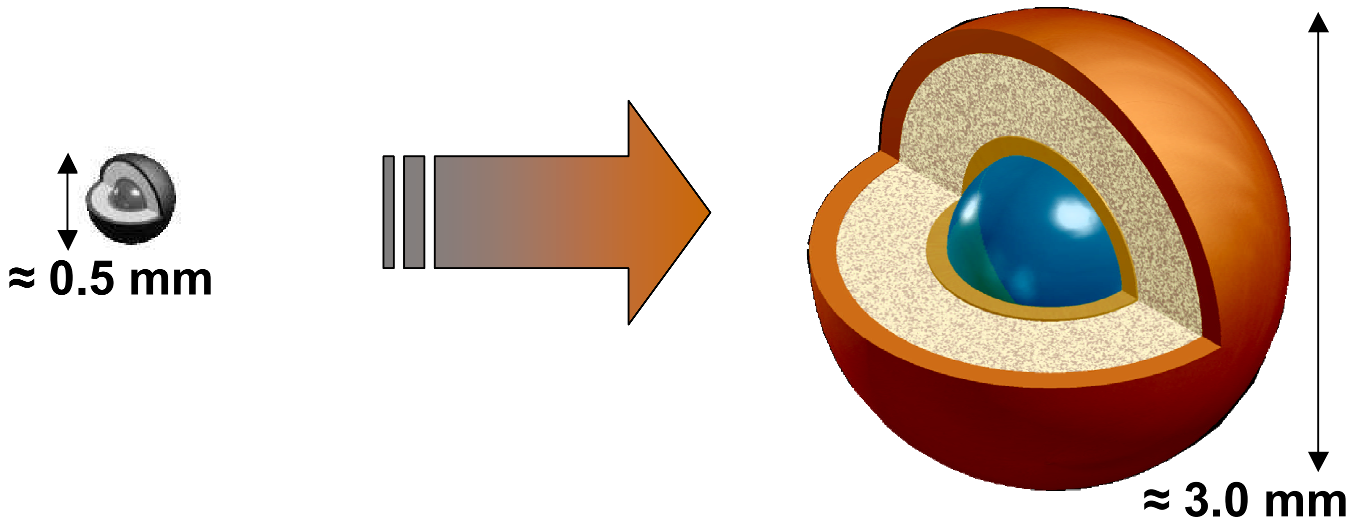
Omega ignition-like double-shell design

NIF ignition double-shell design



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Double-shell research at LLNL shows growing promise for demonstrating ignition in FY11

OUTLINE

Introduction

- complementary roles of double-shell/single-shell ignition on NIF

NIF ignition design

- why so stable?

Omega experiments

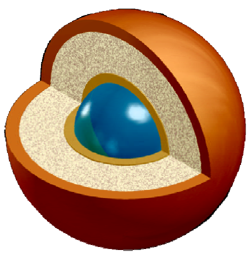
- Highly-resolved simulations of April, 2003 all-CH double-shell implosions

- Highly-resolved simulations of upcoming glass inner-shell double-shell implosions

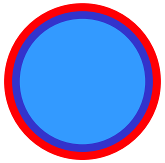
Summary

Double-shell ignition is complementary to cryogenic single-shell ignition effort at LLNL

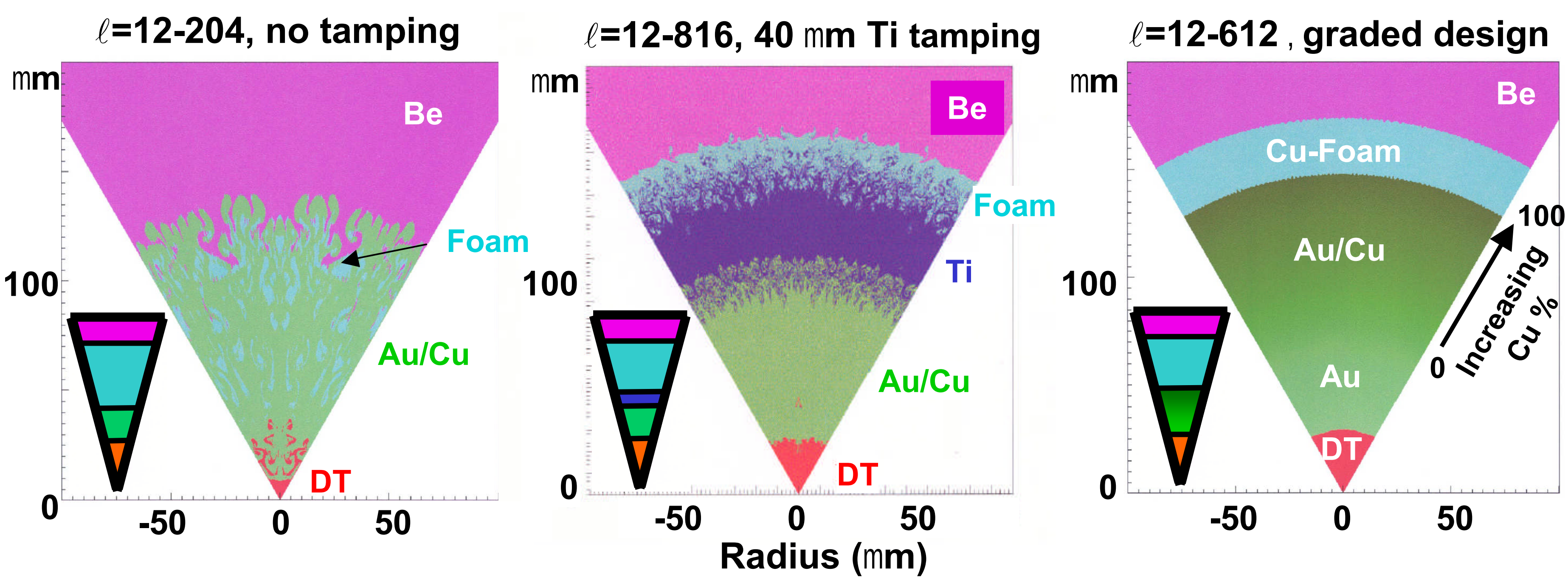
- D-shells will be fielded at room temperature
- D-shells utilize volume ignition (≈4 keV)
- D-shells are low gain
- D-shells use reverse-ramp pulse-shape
- D-shells have *in situ* high-Z pusher
- D-shells will be diffusion filled, i.e., no fill-tube required
- D-shells are sensitive to fuel-pusher mix



- Single-shells require cryogenic preparation
- Single-shells require hot-spot ignition (≈10 keV)
- Single-shells are high gain
- Single-shells require a 4 shock ramped pulse
- Single-shells have pre-formed low-Z pusher
- Fast-track single-shells require fill-tube at present
- Single-shells have like-material low-Z fuel and pusher



Stable double-shell design requires material science development and laboratory validation



Original, YoC ≈ 3%

Improved, YoC ≈ 90%

Current YoC ≈ 99+%

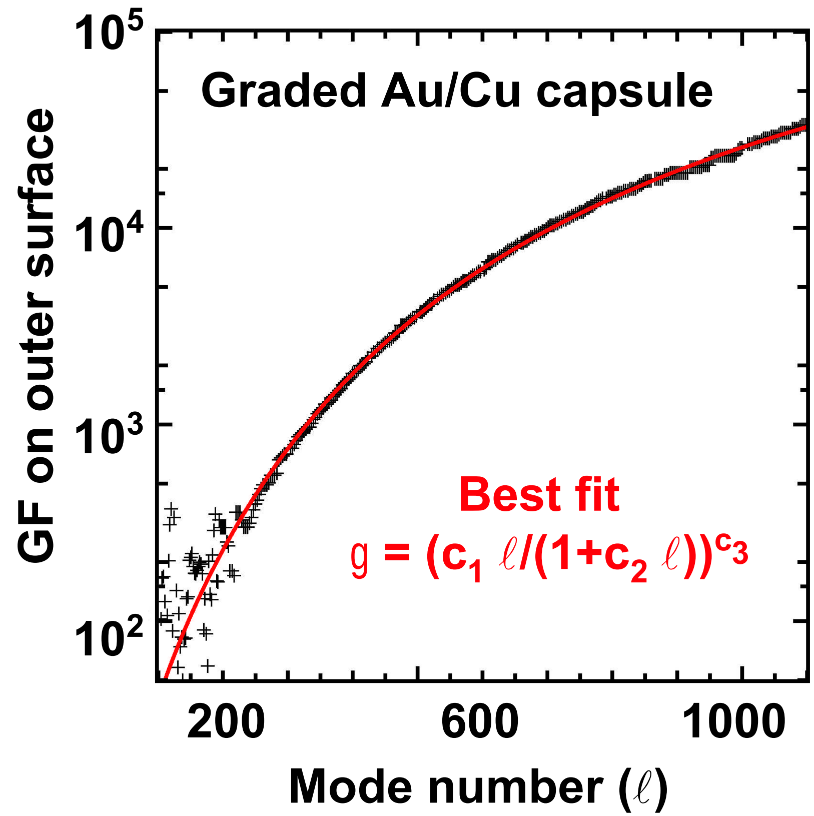
- A similar graded design with W/Cr also exhibits near 1D behavior with the advantage of added tensile strength

Single-mode GFs for the graded capsule show small mix-widths consistent with 2D modeling

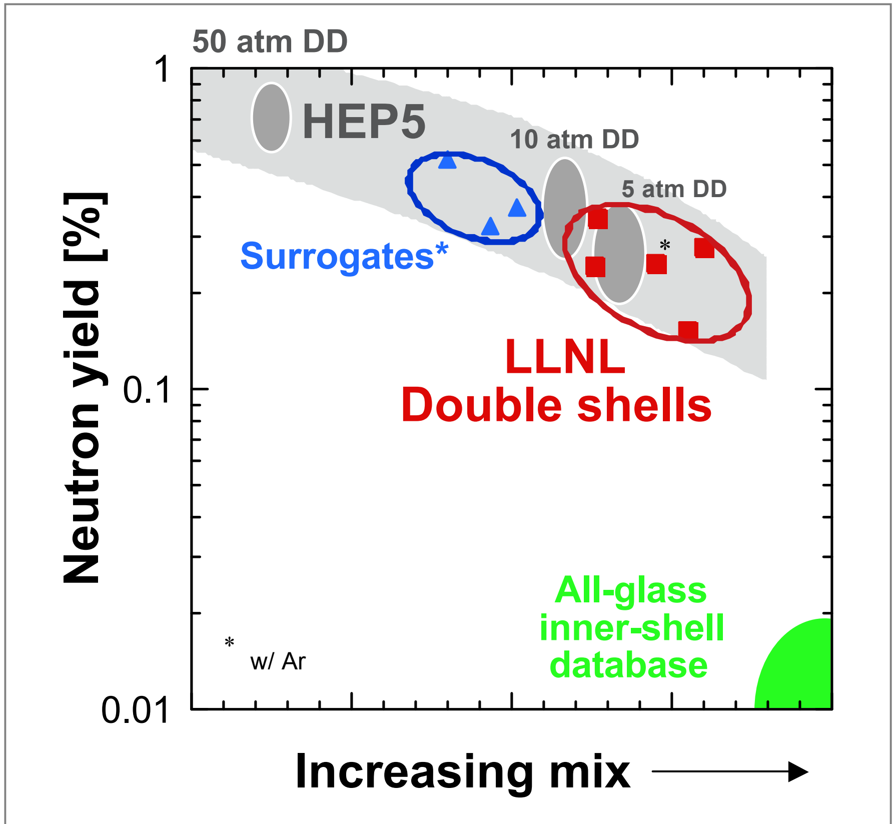
- Best fit for linear growth on outer surface of inner shell near outer surface deceleration onset (t = 10.95 ns)

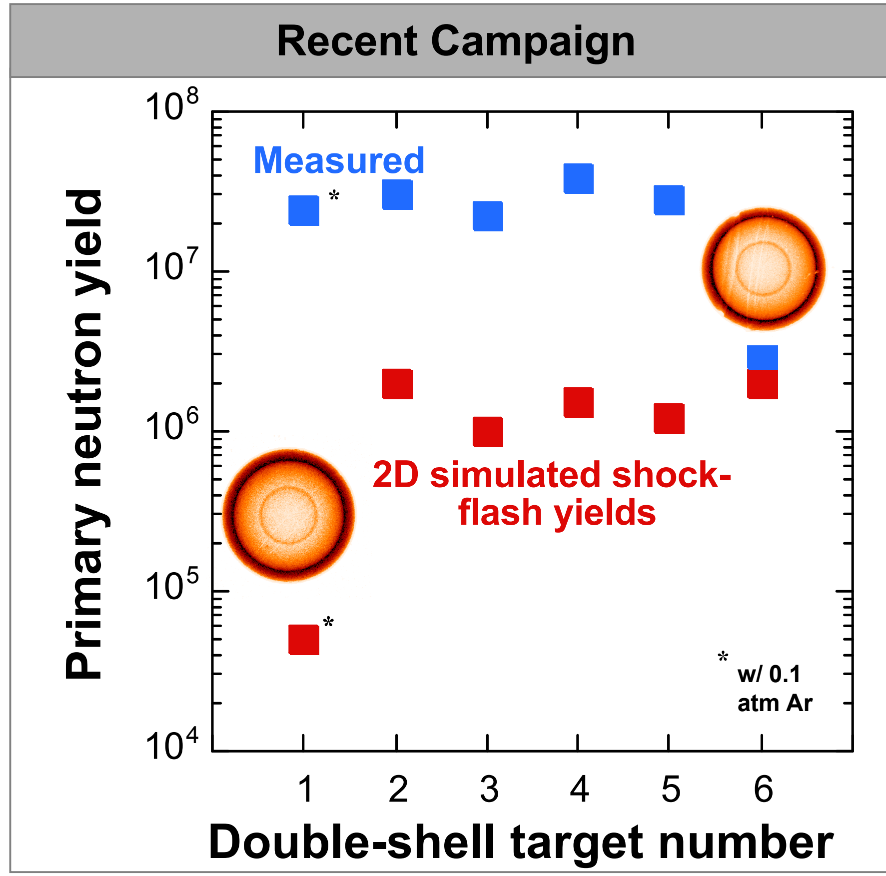
- Convolving these growth factors with the initial perturbation spectrum (RMS ≈ 3nm) gives following mix-widths:

	$S_\ell = 2R/\ell^2$ (Haan criteria)	0.1* l
ℓ=12-1100	0.14 mm	2.5 mm
ℓ=12-10^6	0.16 mm	15.5 mm



The April 2003 campaign on OMEGA advanced our confidence in double-shell ignition path

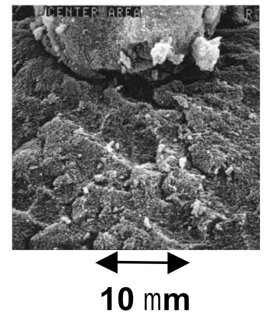




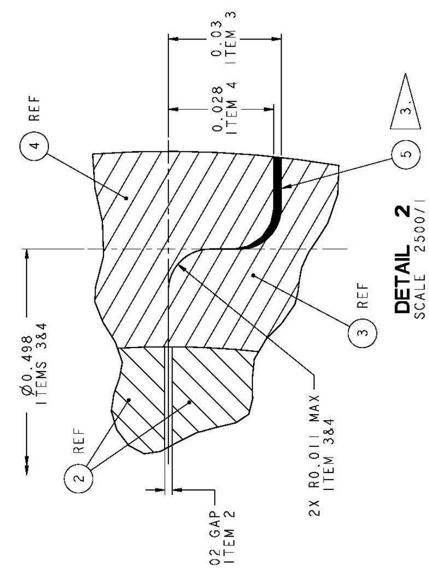
Consistently high compression neutron yields were observed at ignition-like convergences (> 30)

Several important candidates sources of yield degradation have been identified and studied

- **Foam surface roughness (≈ 5 μm)**
  - **Bulk porosity is ≈ 100 nm**



- **Outer-shell joint imprinting**
  - **Joint gap size**
  - **Glue opacity / density mismatch**
  - **Irregularities in the bonding**



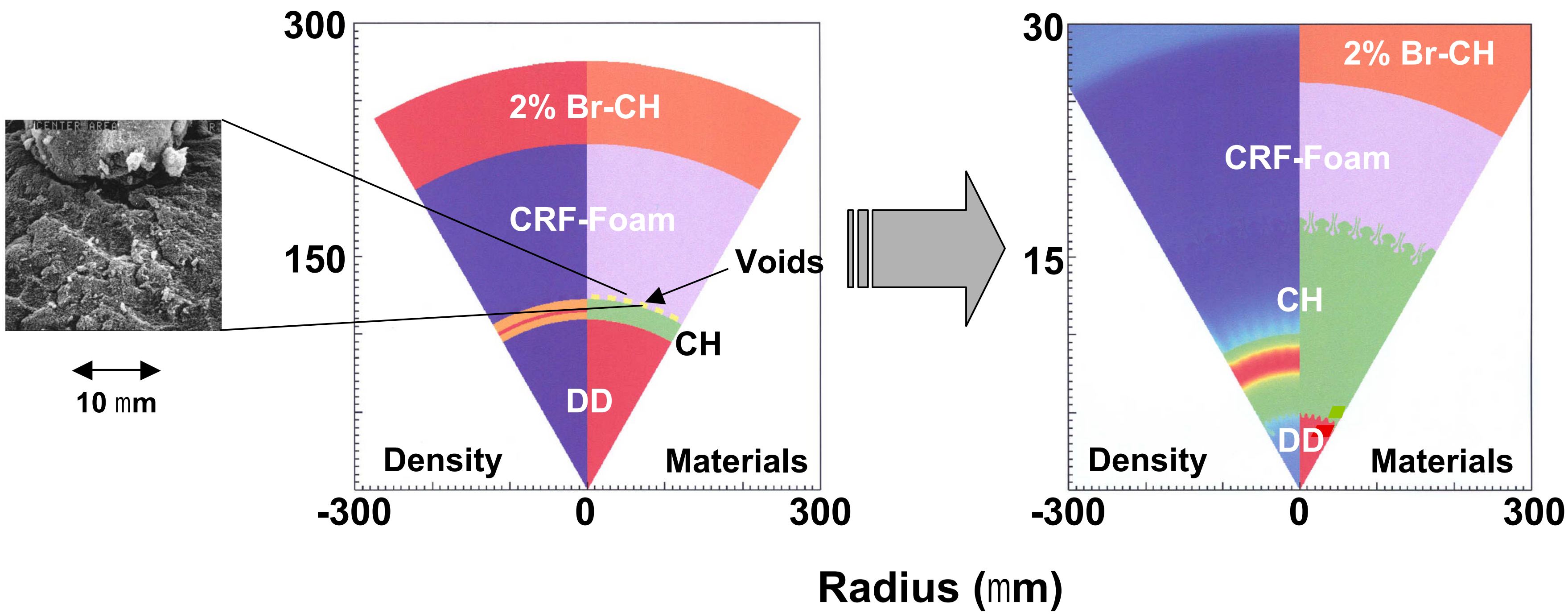
OMEGA

Simulation with foam voids for mimicking foam surface roughness shows minimal impact

YoC ≈ 92%

Initial Configuration

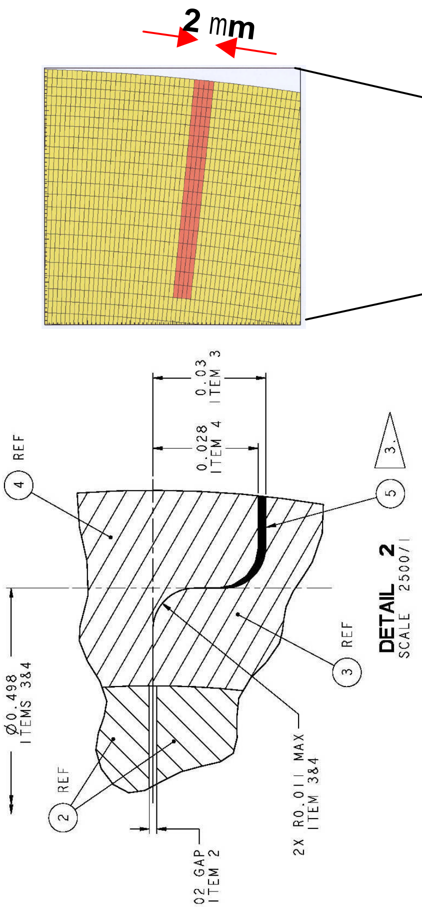
Peak neutron production



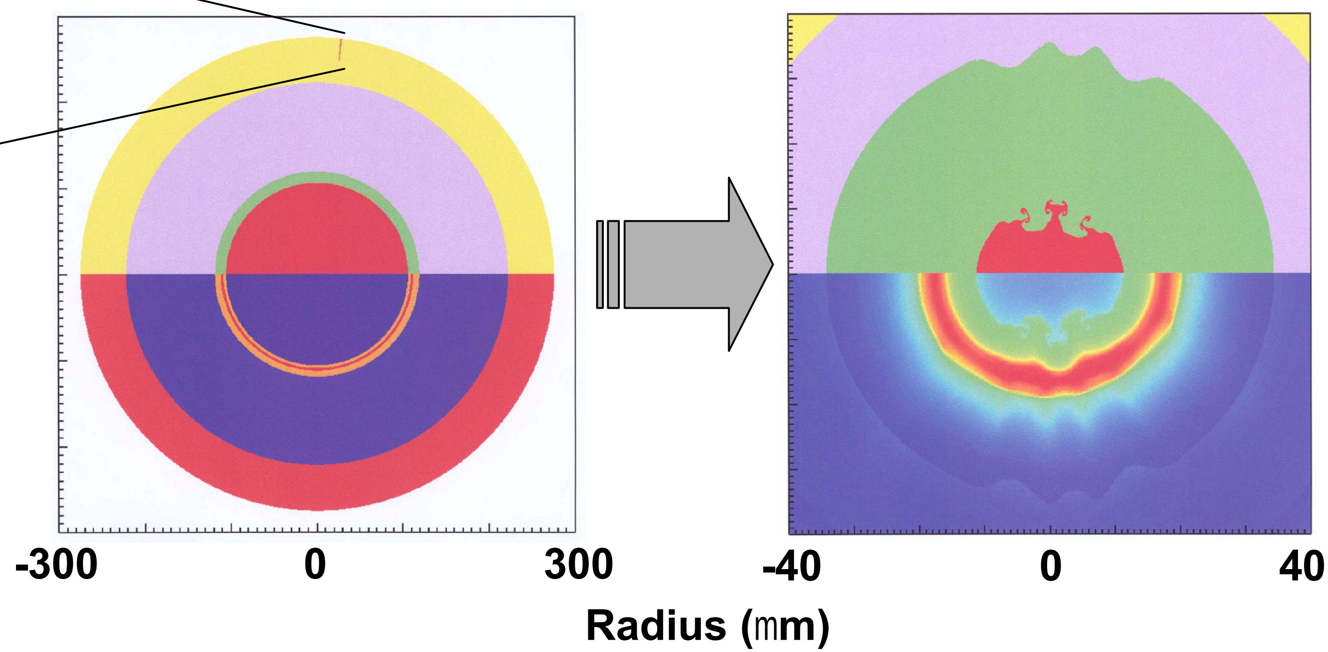
- Initial Setup: 10 mm in wavelength and 5 mm amplitude

Joints appear to have a significant influence on double-shell performance

YoC ≈ 71%

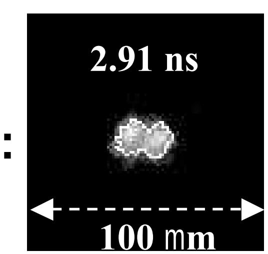


Initial configuration | **Peak neutron production**



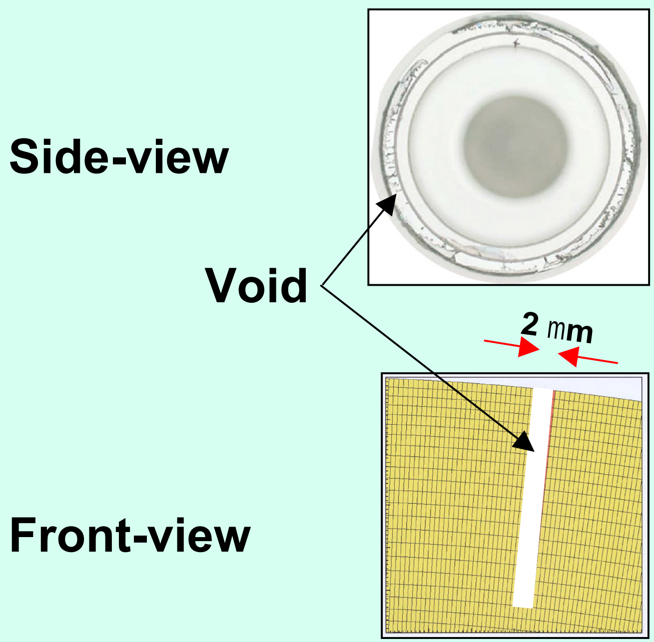
- Hint of core splitting shows some agreement

Data:



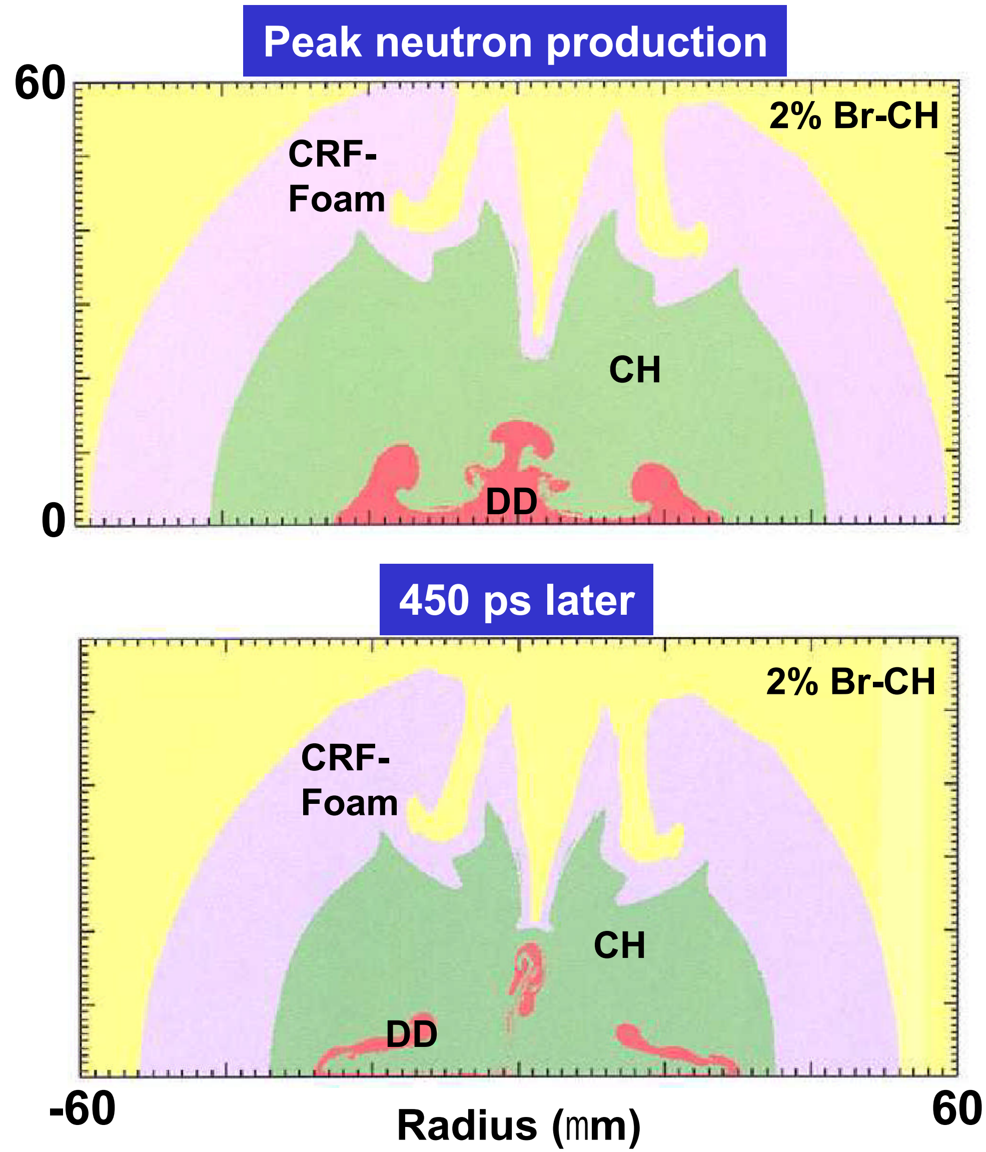
Simulations suggest a large impact from an empty joint

- Pre-shot radiograph shows evidence of voids in joint



- Simulations with a completely 2 μm empty join yields large degradation in yield

- YoC ≈ 7 %

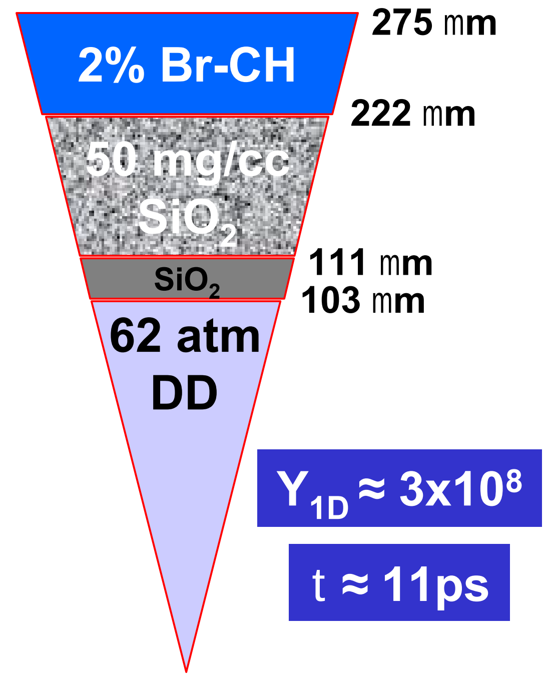


A glass-foam design will be fielded for the March '05 double-shell implosions

- Glass foam should reduce instability on outer surface of inner shell, i.e., smaller Atwood number since like-material

- 50 mg/cc glass aerogels with small pore size (≈100 nm) exist and are machinable

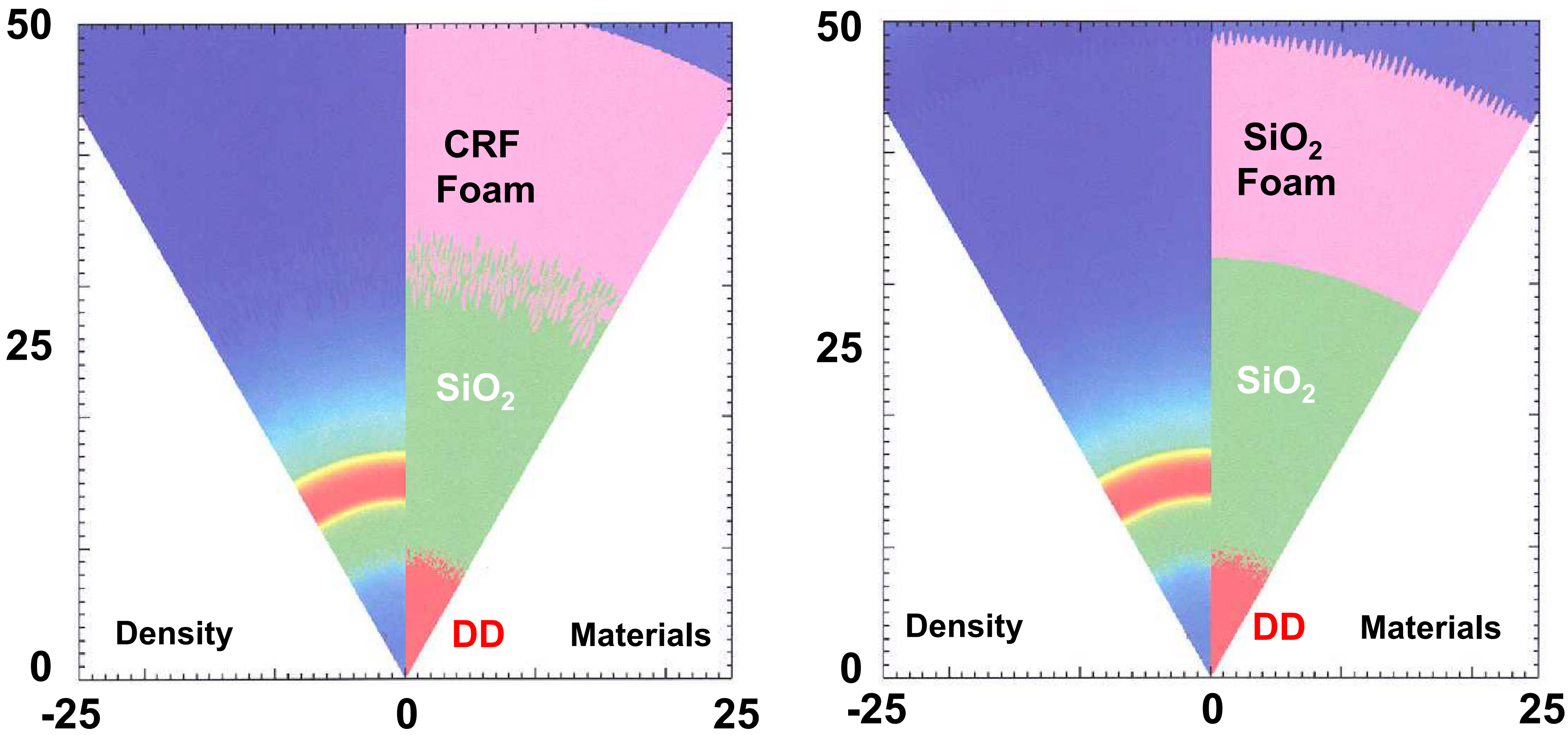
- Preheat absorption outside inner shell will help mitigate M-band strength and asymmetry (transverse smoothing by conduction)



OMEGA

Like-material foams substantially reduce the inner-shell outer-surface perturbation growth

Time: Peak neutron production



Radius (mm)

CRF Foam

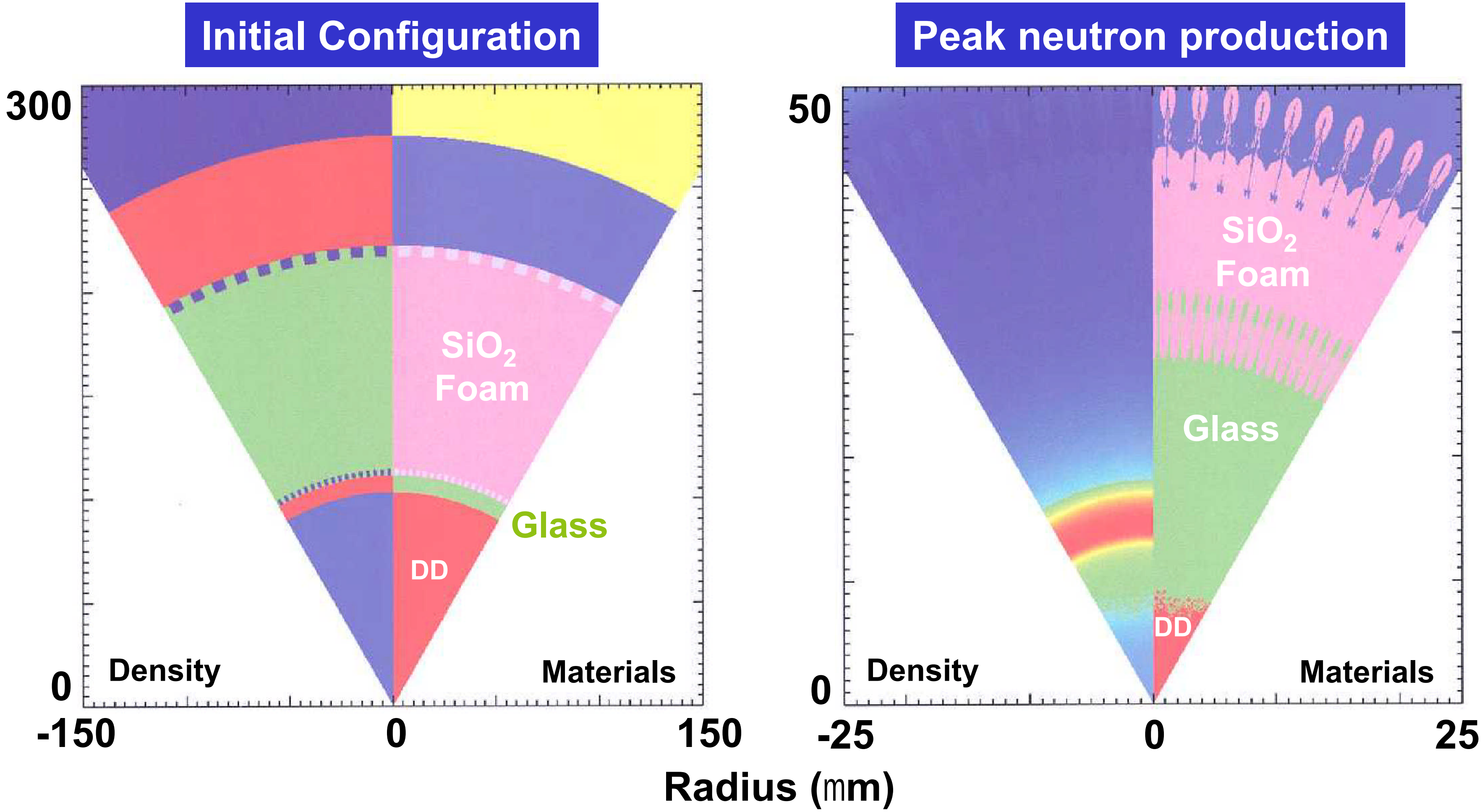
Glass Foam

OMEGA

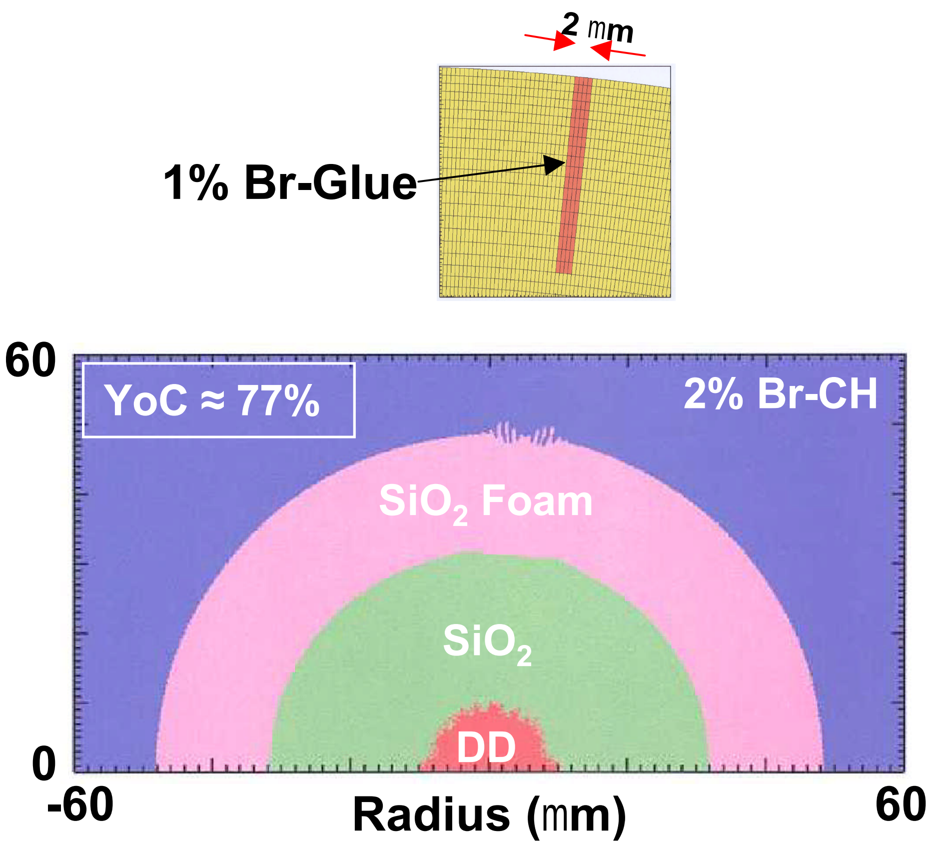
Simulated foam gouges on both surfaces and shell surface perturbations show intact implosion

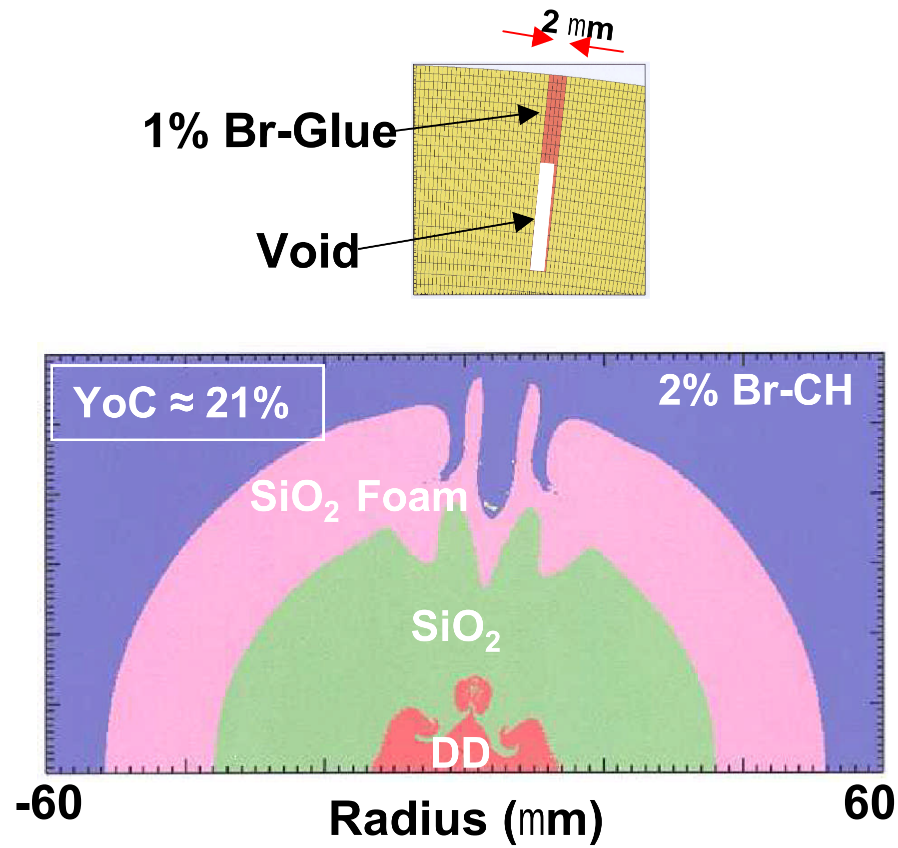
- **Surface roughness (ℓ = 12 – 408) + foam gouging**

YoC ≈ 85%



2D simulations of the outer shell joint indicate the need for careful design and manufacturing



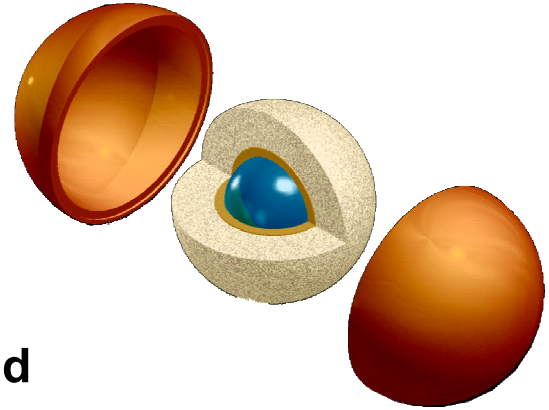


- The presence of voids greatly affects the yield performance
- The March ’05 shots will use a 20x smaller (100 nm) joint gap with density-matched glue

SUMMARY

Progress in simulation and experiment enhances prospects for NIF double-shell ignition in FY11

- **Simulation studies have identified a stable double-shell ignition design based on graded density shells and metallic foams**
- **Recent double-shell implosion experiments on Omega have shown unprecedented performance**
- **Identification of possible failure mechanisms have motivated new and improved double shell designs,**
  - **e.g. like-material outer surface of inner shell and foam**
  - **Greatly reduced gap size**
  - **Density-matched glue**



Progress in double-shell research has inspired many exciting material science advances on the path to ignition