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3 Dimensional Magneto-hydrodynamic modeling of liner implosions on the Z Generator

C.A. Jennings, R.D. McBride, D.B. Sinars, J. Chittenden,
S.A. Slutz, M.E. Cuneo, M.C. Herrmann,

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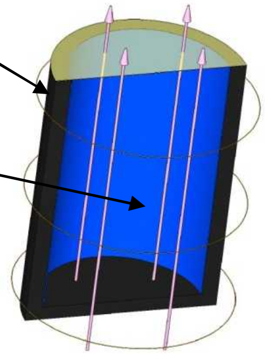
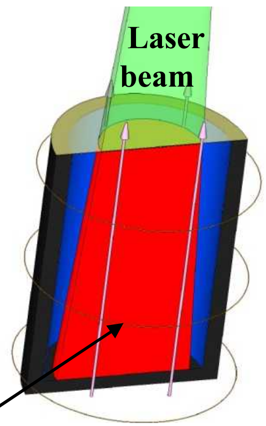
Magnetized Liner Inertial Fusion (MagLIF)* may be a promising path to high fusion yields on Z



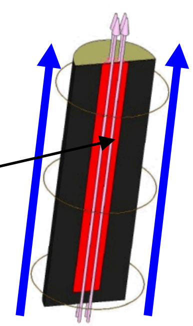
<u>Idea:</u> Directly drive solid liner containing fusion fuel

1. An axial magnetic field (B_z) is applied to inhibit thermal conduction and enhance alpha particle deposition



2. Z Beamlet preheats the fuel

Liner Integrity Critical!



3. The Z accelerator efficiently drives a z-pinch implosion

*S. A. Slutz *et al.*, Phys. Plasmas **17**, 056303 (2010).

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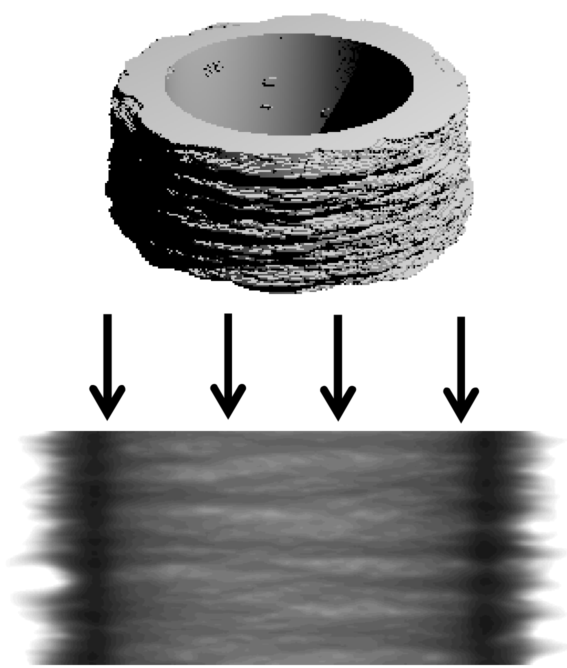
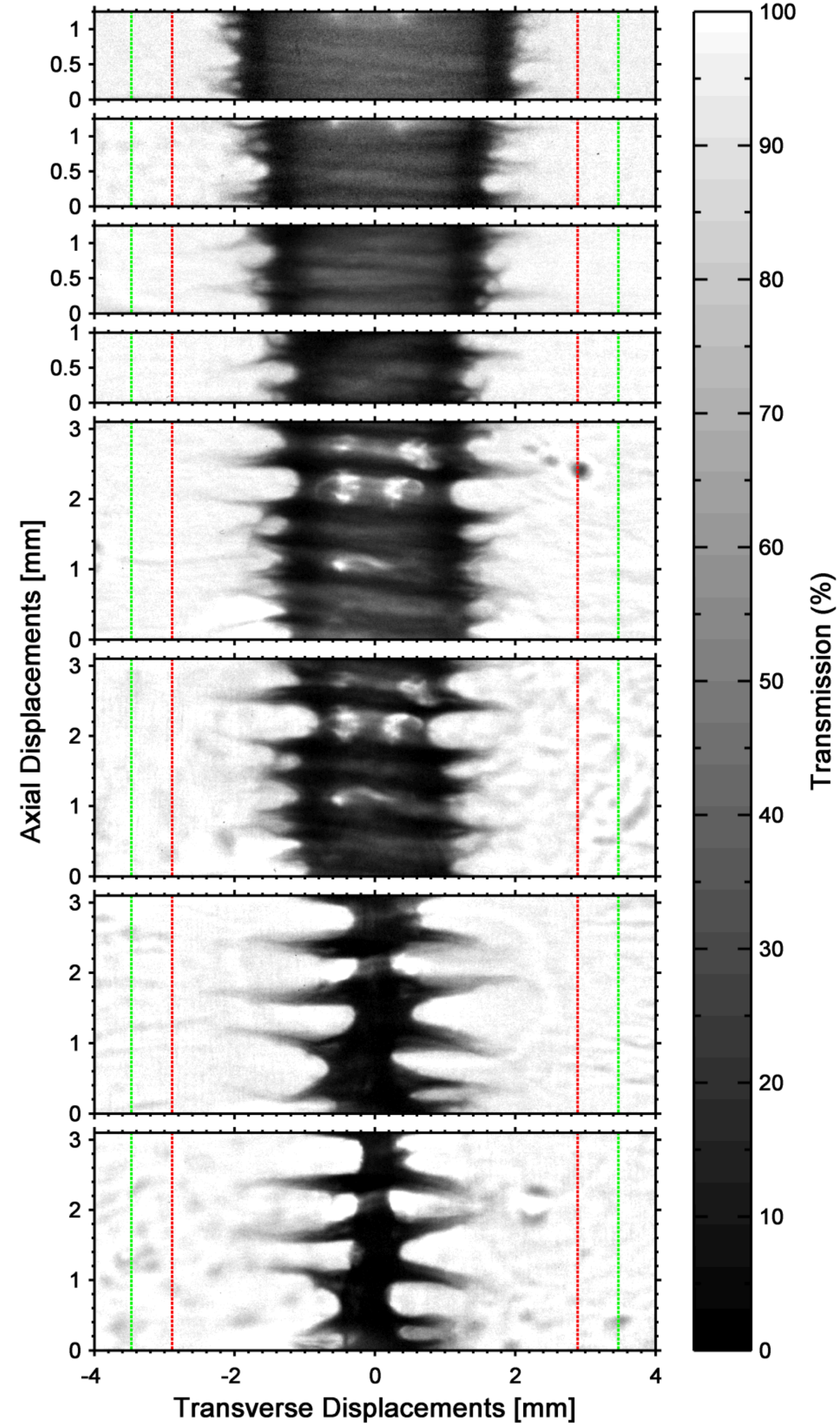
Liner Implosion

Experiments have been performed on the Z generator to study the evolution instabilities in Be liner implosions.

6 keV Transmission Radiographs taken of imploding liners





GORGON 3D resistive MHD code used to study the development of implosion instabilities

<u>GORGON – 3D Resistive MHD</u>

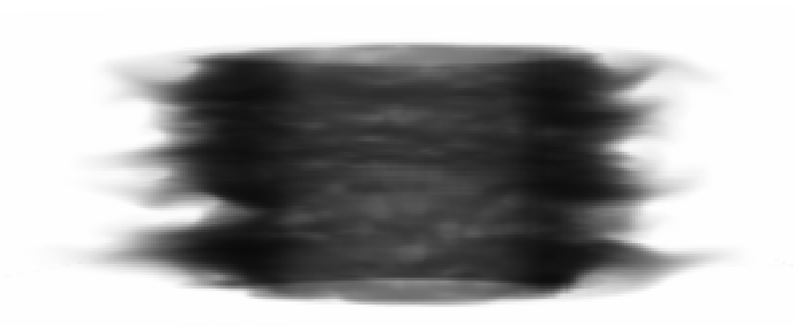
Fixed square grid finite volume hydrodynamics

Single fluid – separate electron and ion temperatures

Explicit electro-magnetic field solution (wave equation in vacuum / diffusion equation in plasma)

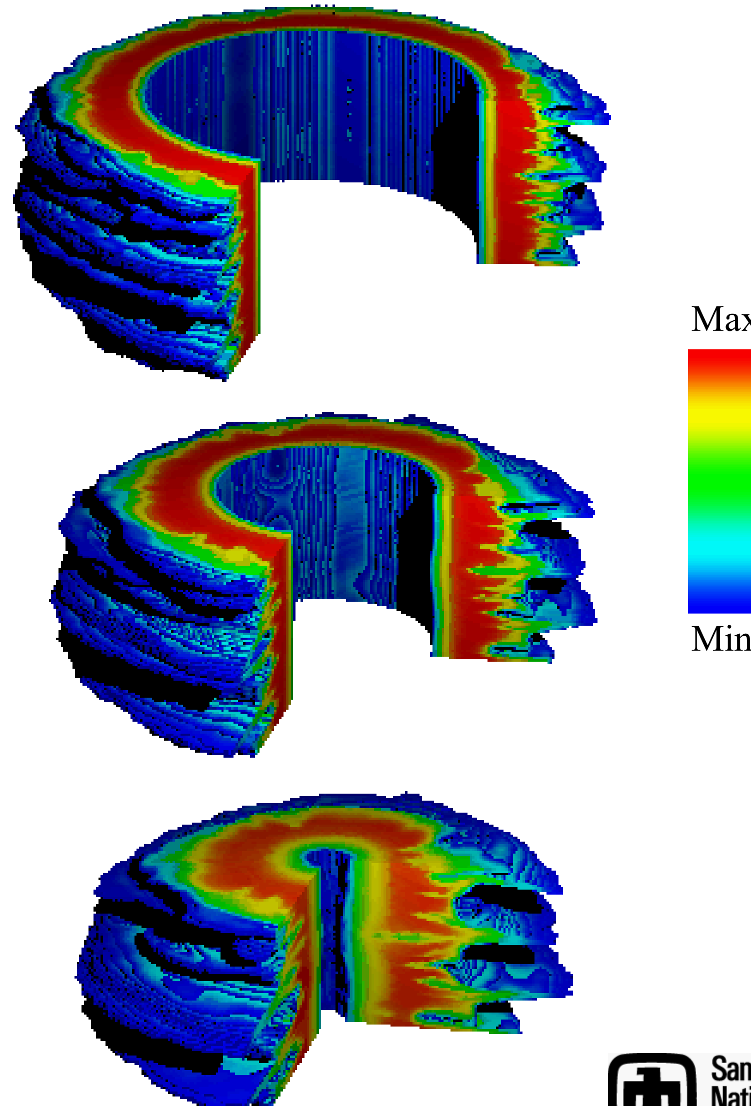
Van Leer Advection

Driven from measured generator current



Density used to construct synthetic radiographs for direct comparison with experimental measurements

Log Density



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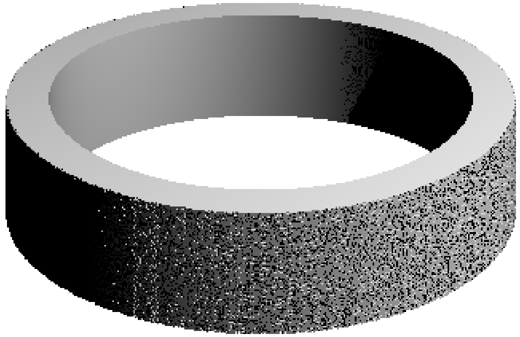
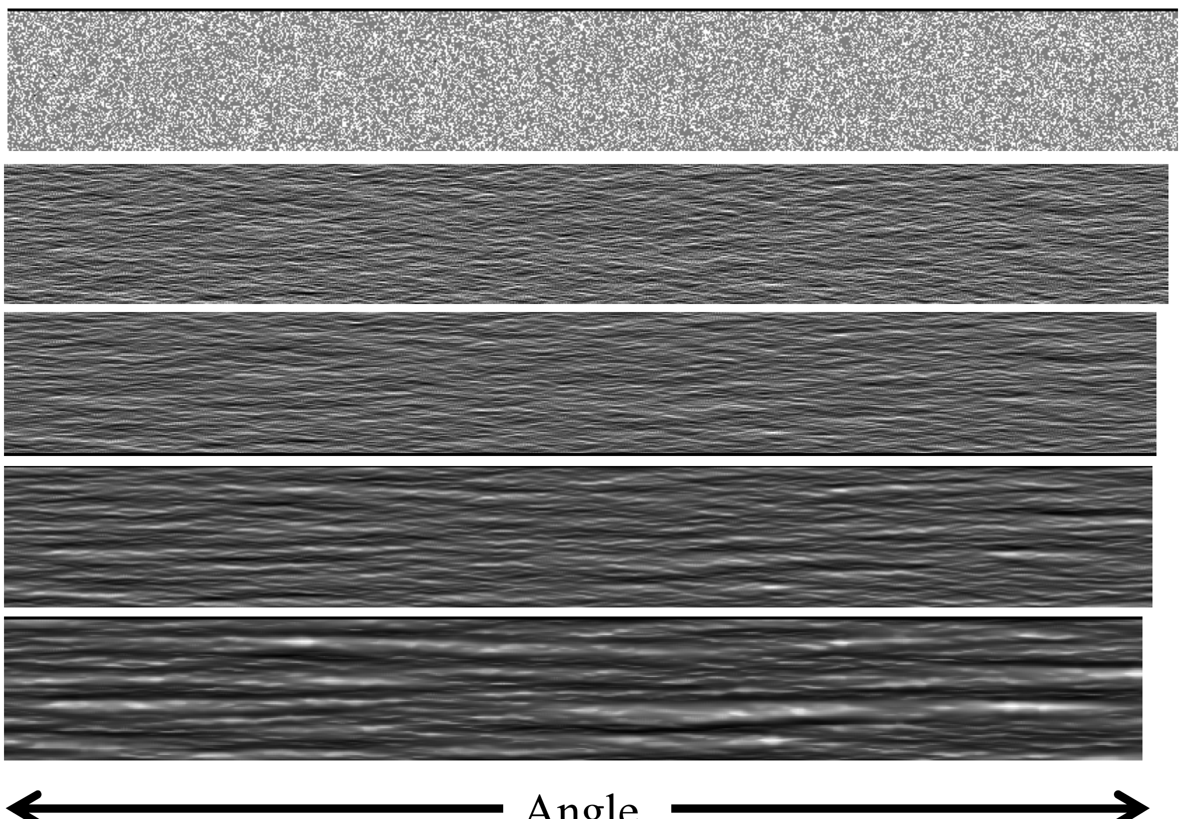
Calculations are initialized with a randomized 20 micron surface roughness

Liner radiograph unwrapped to study growth of surface structures



This initialization is not intended to study how different surface structures develop, and does not attempt to reproduce initial liner surface



Synthetic Radiographs

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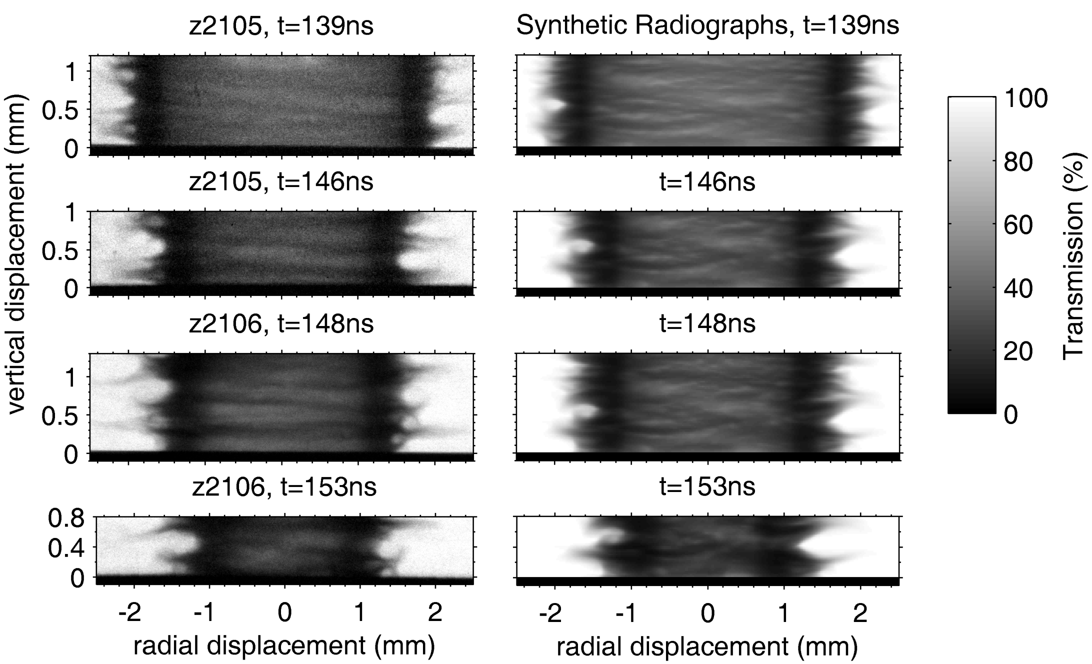
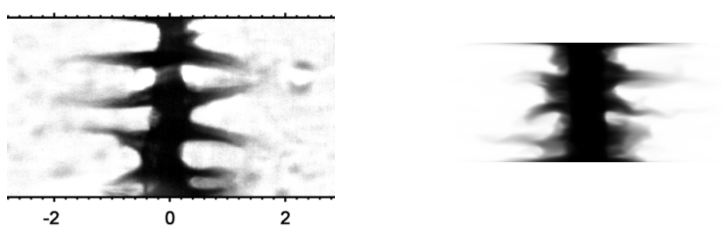
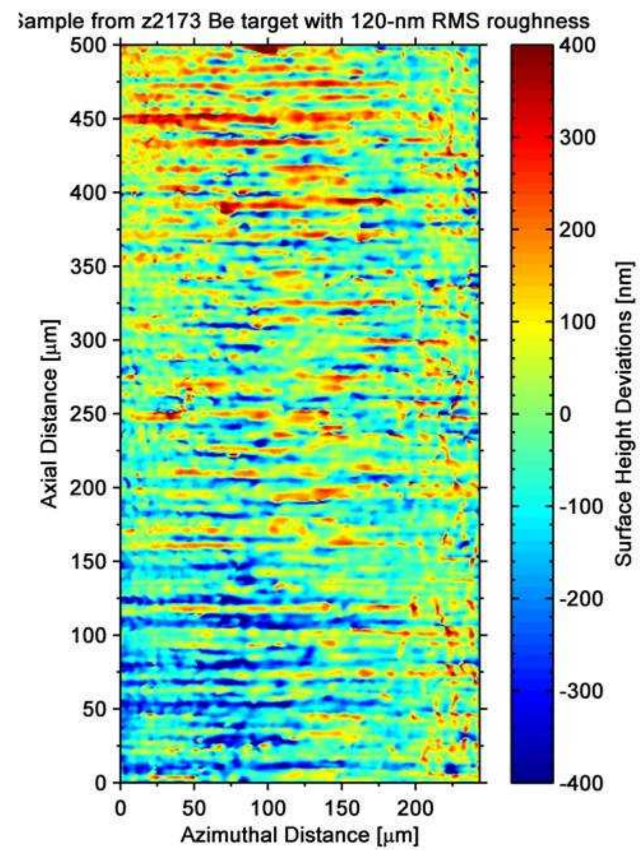
Reasonable early time agreement with measured radiographs, but late time discrepancies



Level of disruption different at late times



Measured surface roughness is not random, but has some azimuthal correlation



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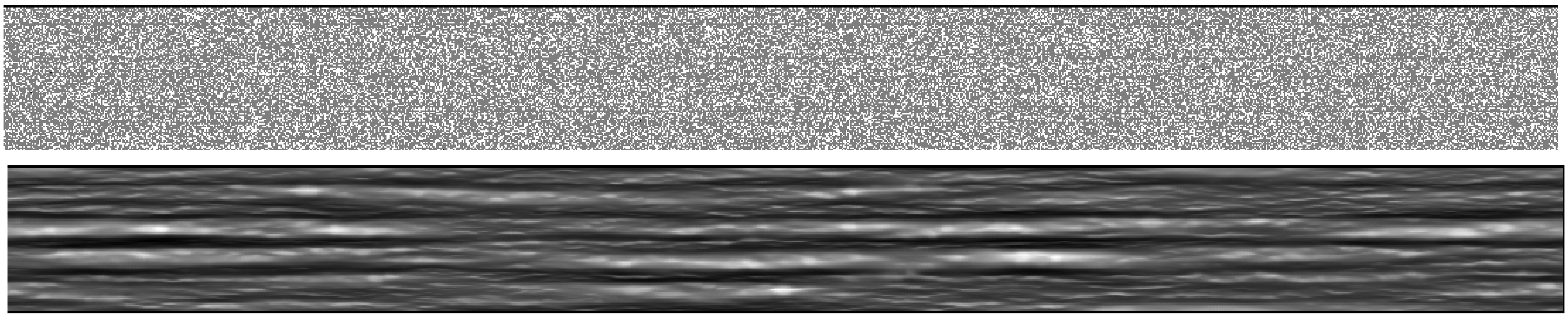
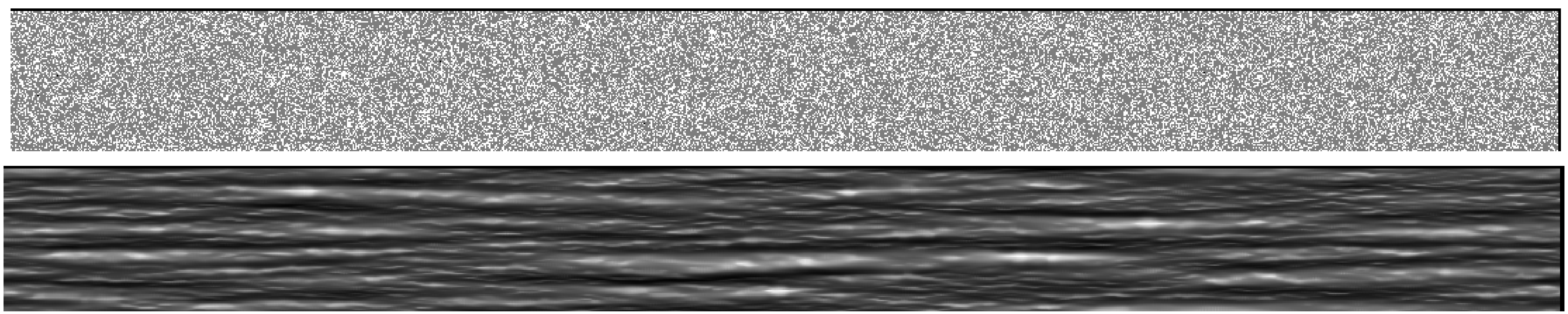
A small degree of azimuthal correlation is able to persist late in time

20 % random number generator bias correlation at 6 random heights

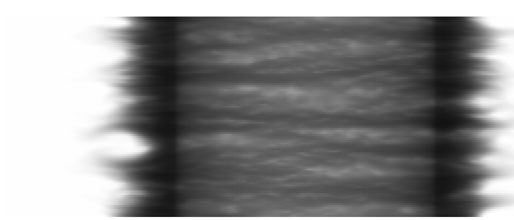


3110ns

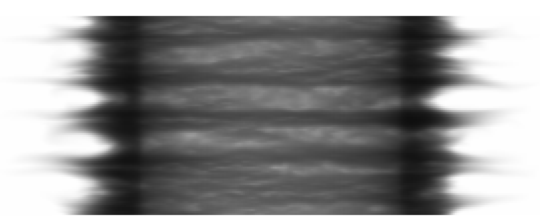
No Correlation



No correlation

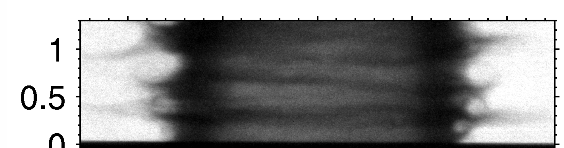


Correlation



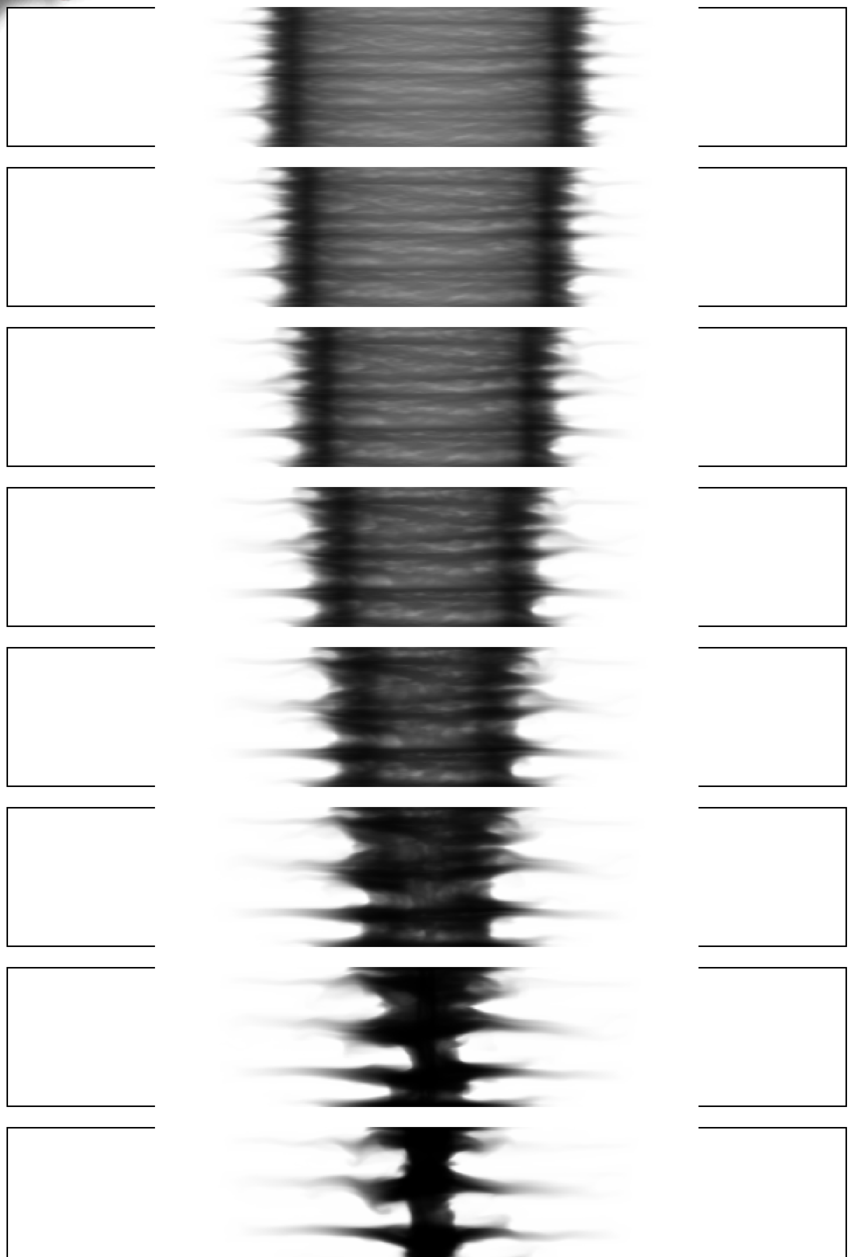
Experiment

z2106, t=148ns

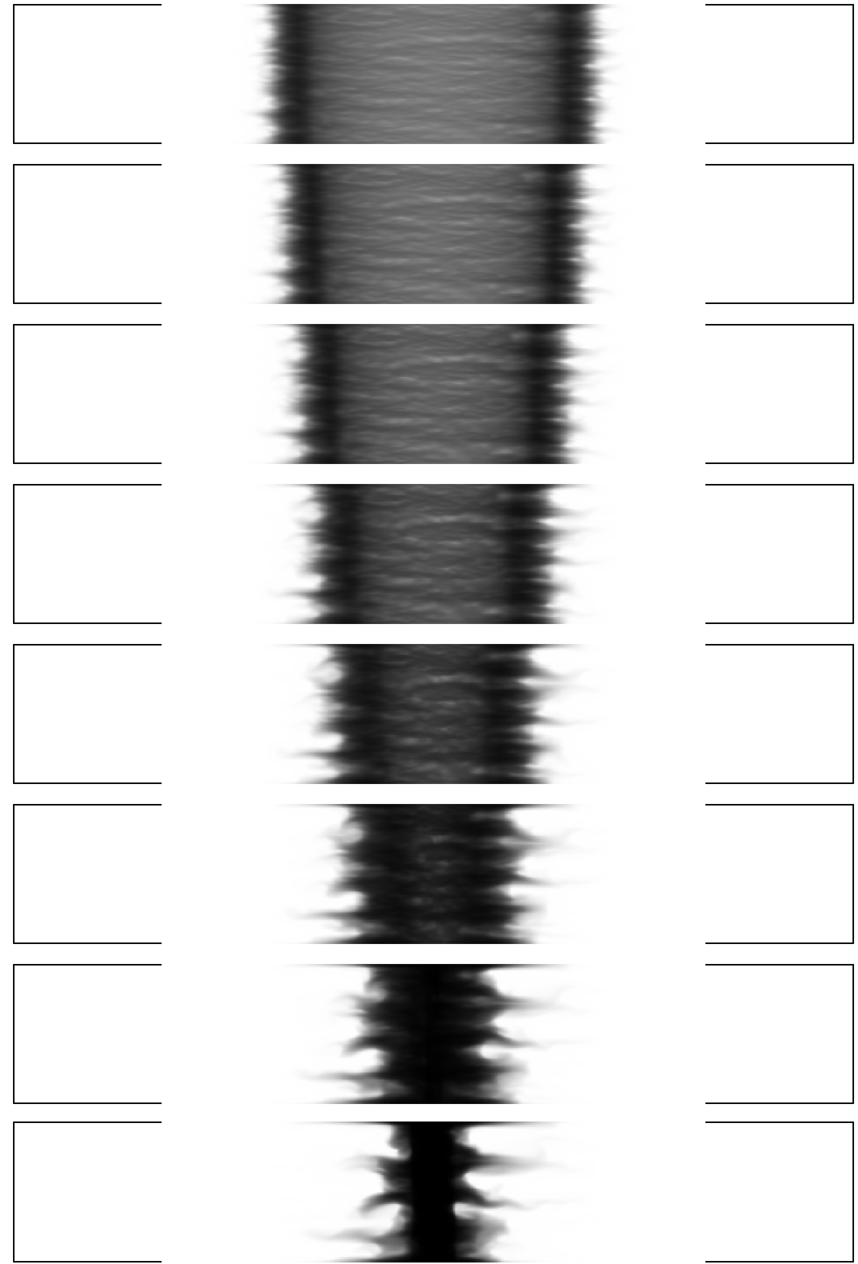


Effect of correlation more evident later in time

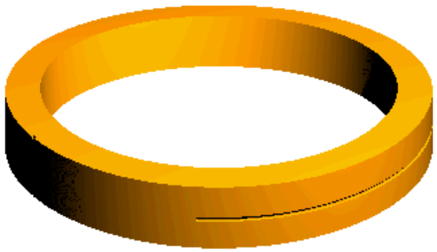
Azimuthal Correlate pert.

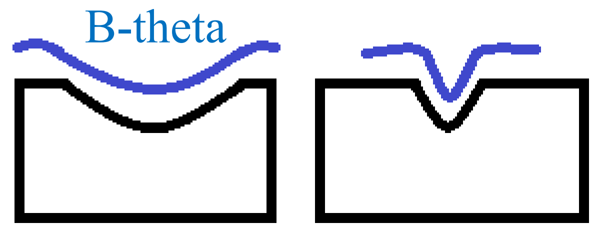


random pert.

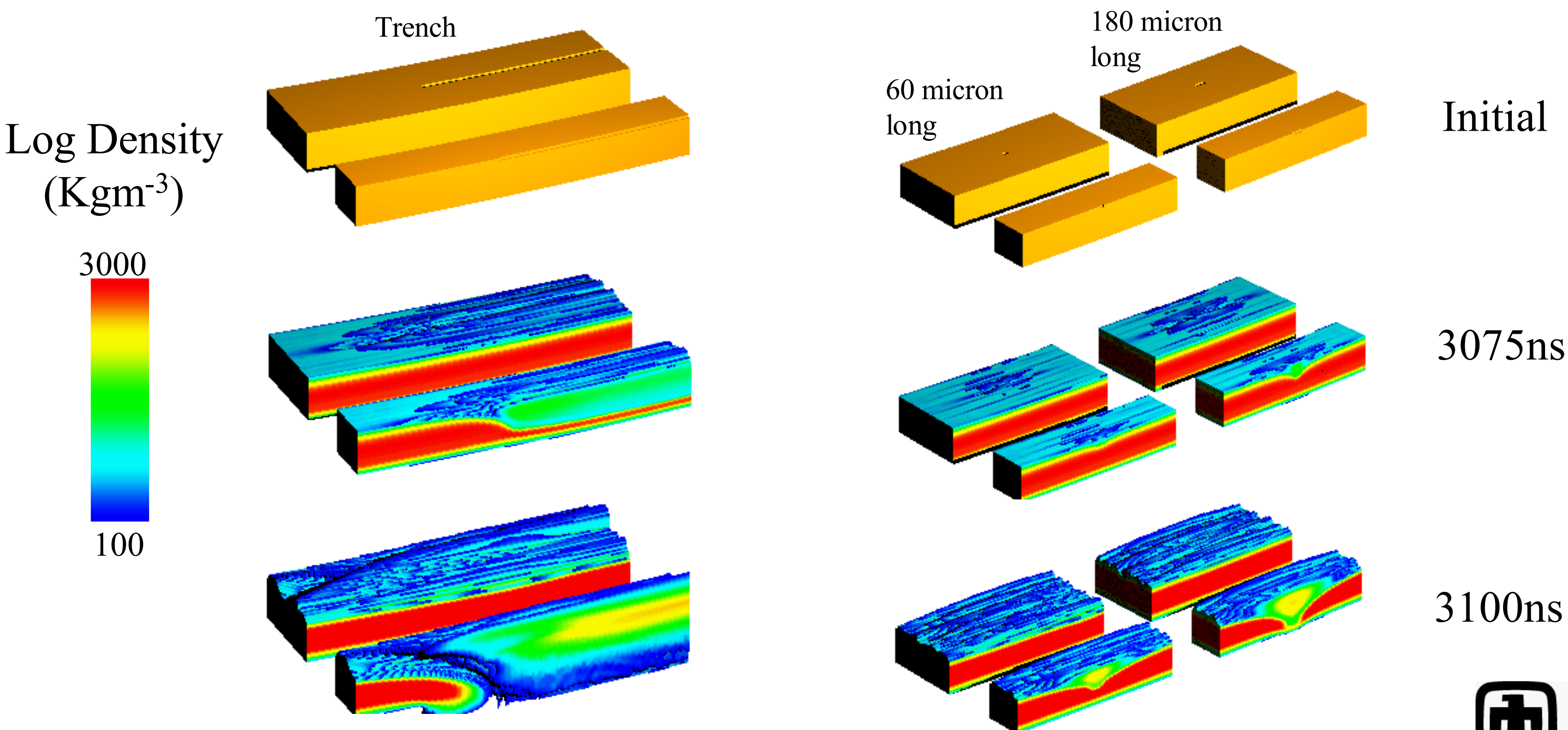


The degree of azimuthal correlation of an instability affects how much it can penetrate and disrupt an imploding shell





Field line tension will not allow us to simply drill a hole through the liner



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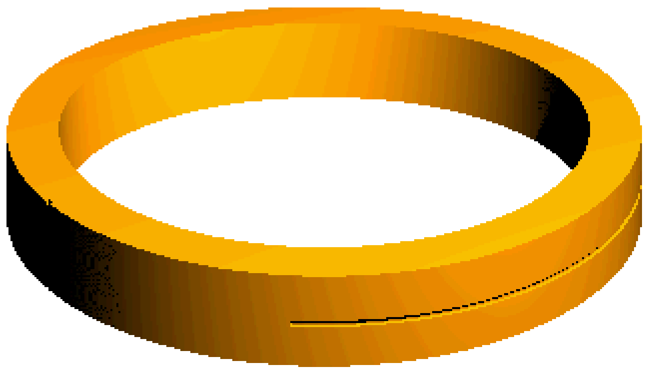
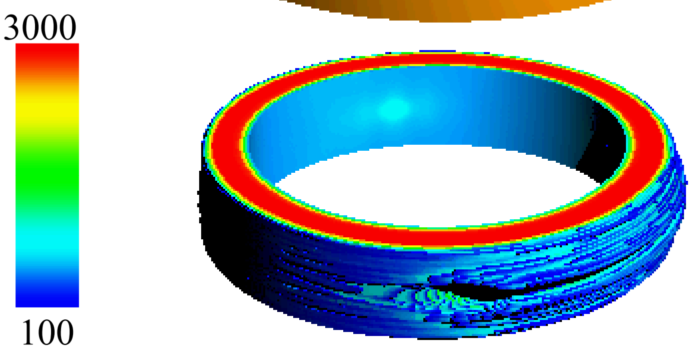
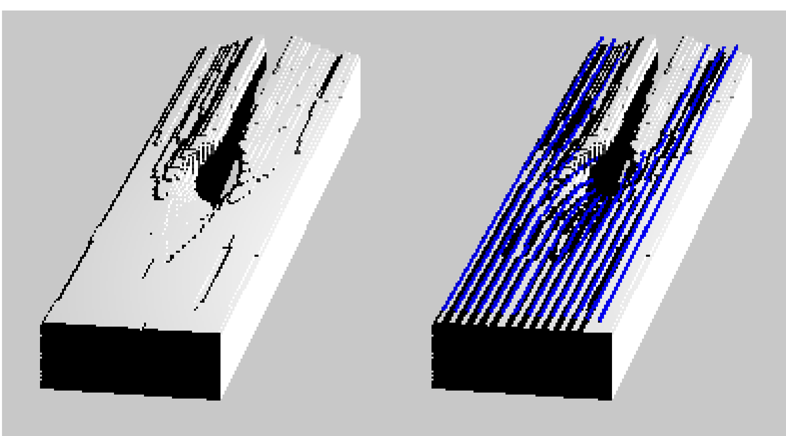
To propagate the instability azimuthally, an instability has to plough its way though a lot of dense material

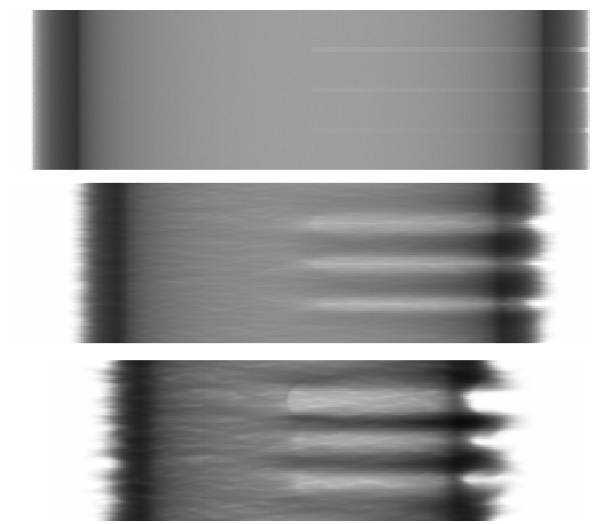






The ability of established features to propagate azimuthally is quite limited, so gain azimuthal extent and disrupt the shell requires the amalgamation of adjacent features. So trouble develops if initial conditions correlated them to start with.

Synthetic Radiographs



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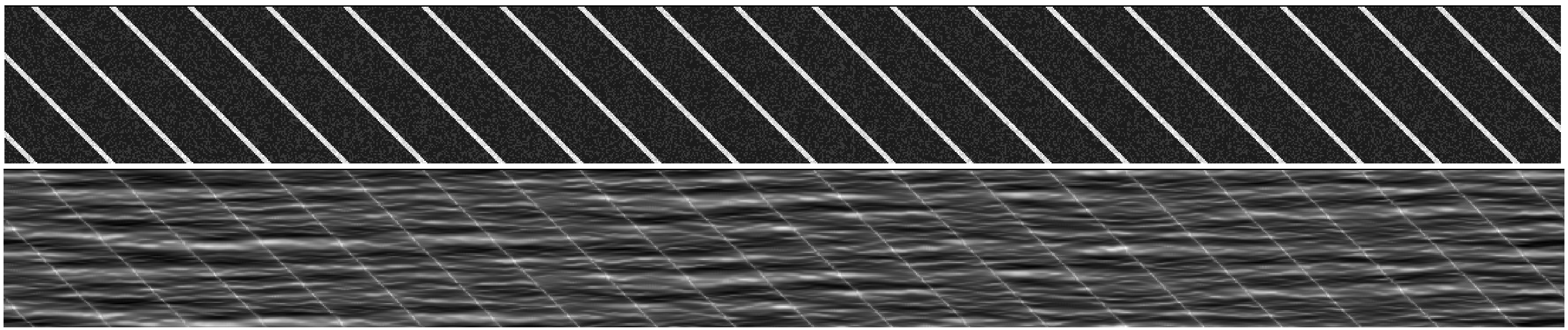
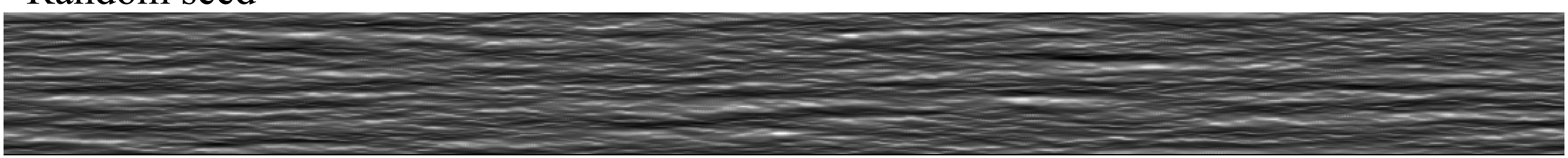
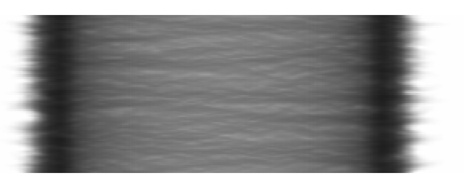
Reorientation the perturbation away from azimuthal prevents it from growing

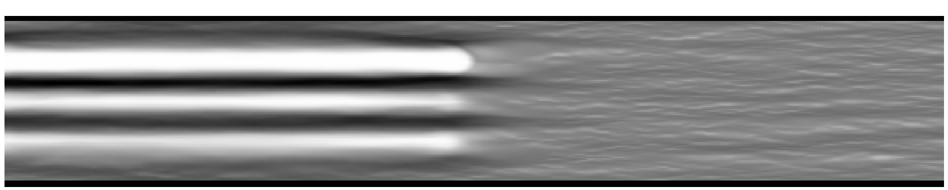
3095ns   Periodic boundary conditions in Z to study helical perturbation growth



Random seed







Stark contrast to disruption from an azimuthal groove

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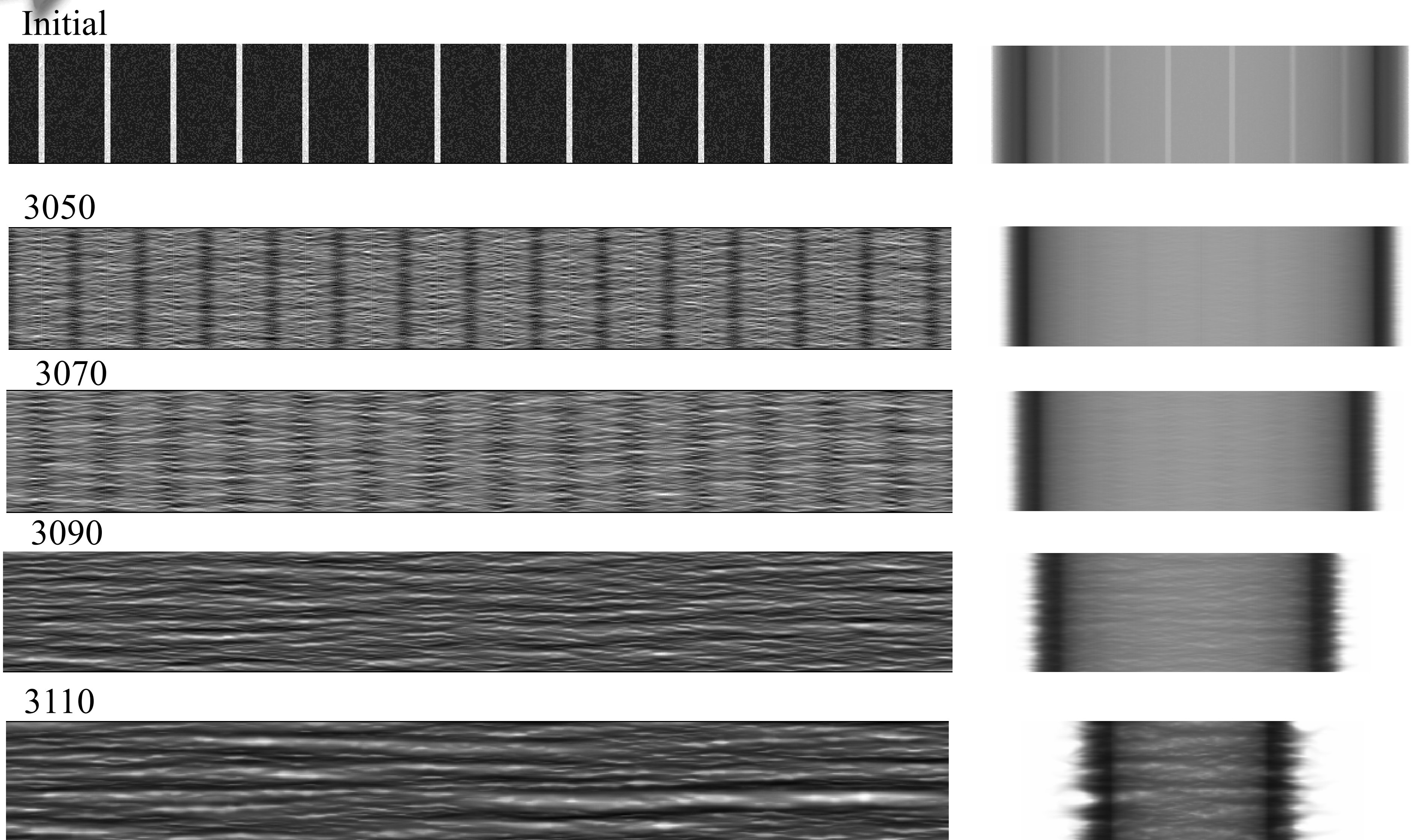
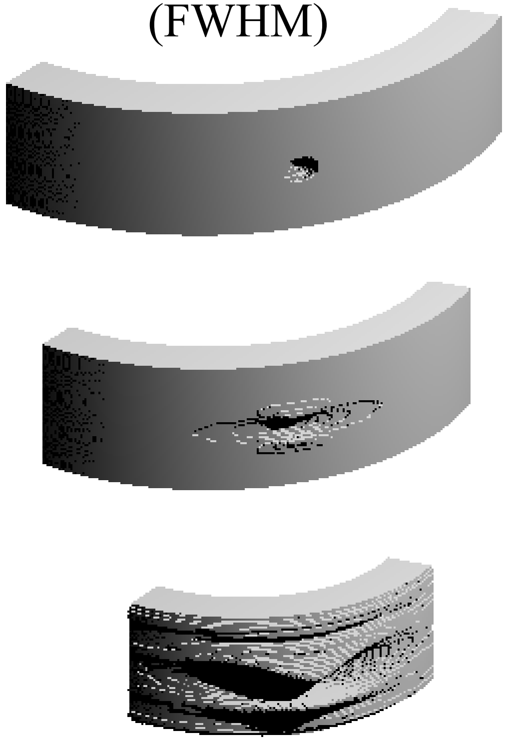
Vertical features do not grow at all



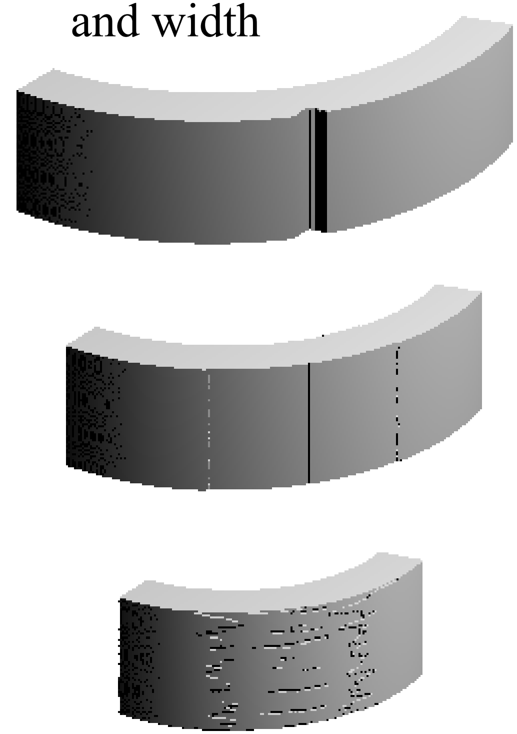
Initial 80 micron deep groove

For a given perturbation, a vertical groove is actually preferable to surface hole of same width and depth

~100 micron hole (FWHM)



Groove of same depth and width



Conclusions

<u>If</u> surface perturbations are seeding late time instabilities then:

- To disrupt an imploding shell a perturbation needs some azimuthal extent.
- Perturbations grow and correlate quite slowly in the azimuth
- Real damage can be done if the initial seed perturbation has any azimuthal correlation
- If an infinitley smooth liner is an unrealistic ideal, then there are surface structures we can pick to leave behind that are better than others