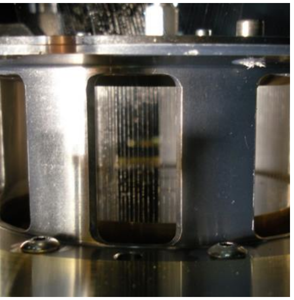

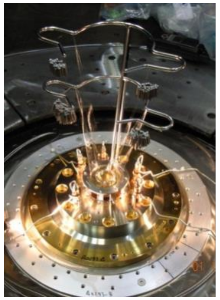

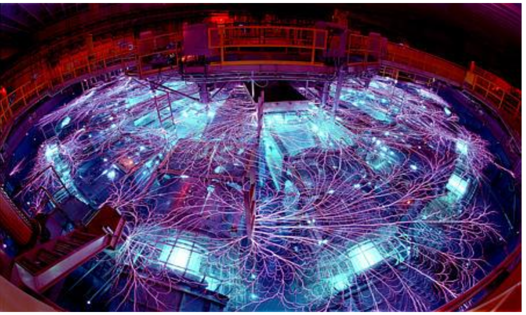

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SAND2016-1709C

Three Dimensional modeling of instability development in MagLIF loads on the Z Generator

C.A. Jennings, E.C. Harding M.R. Gomez, S.B. Hansen, T.J. Awe, R.D. McBride, M.R. Martin, K. Peterson, P. F. Knapp

Sandia National Laboratories, Albuquerque, NM, USA

J. Chittenden,
Imerial College, London, UK

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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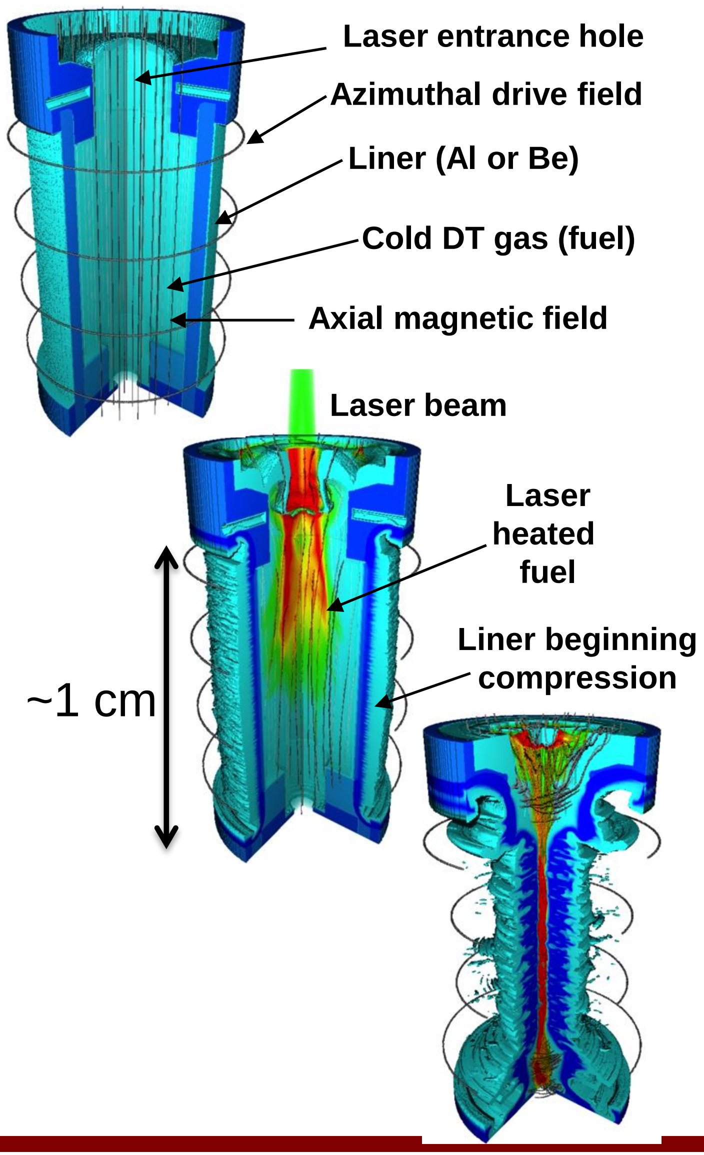
We are working toward the evaluation of a new Magnetized Liner Inertial Fusion (MagLIF)* concept



- An initial ~10 T axial magnetic field applied
- Laser preheat applied when inner surface starts to move
  - ~400J Pre-pulse to disassemble window followed by ~2kJ main pulse
  - Likely that poor coupling of laser energy is presently limiting performance (A. Sefkow APS 2014 invited)
- Implosion instabilities have the potential to disrupt fuel compression and confinement
  - Have been heavily diagnosed in stand alone experiments

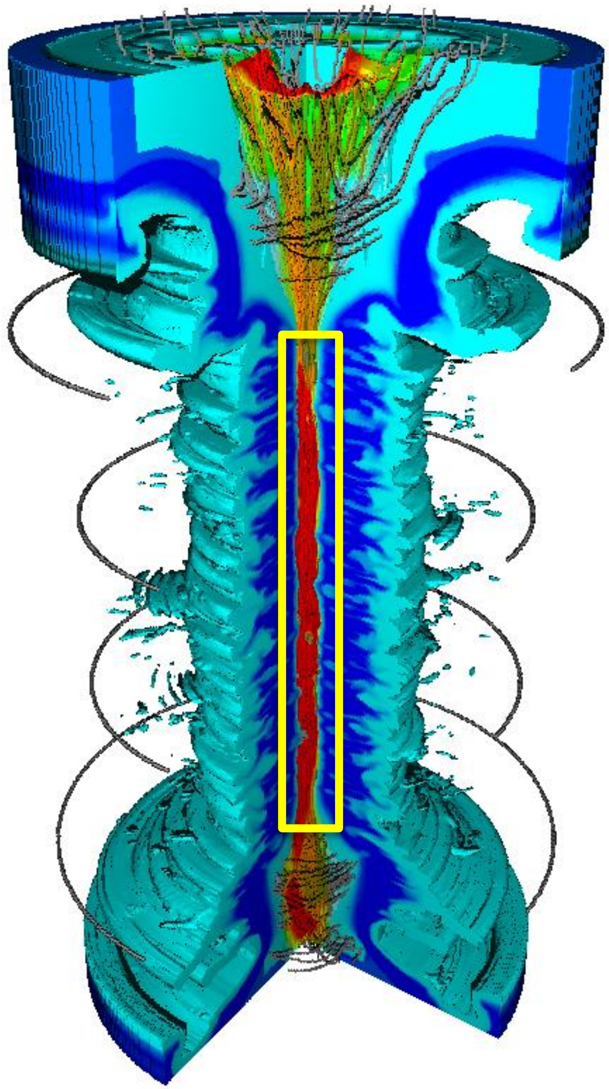
*S.A. Slutz *et al.*, Phys. Plasmas 17, 056303 (2010). S.A. Slutz and R.A. Vesey, Phys. Rev. Lett. (2012).

Final Pinch Structure Measured with Time Integrated Self-emission

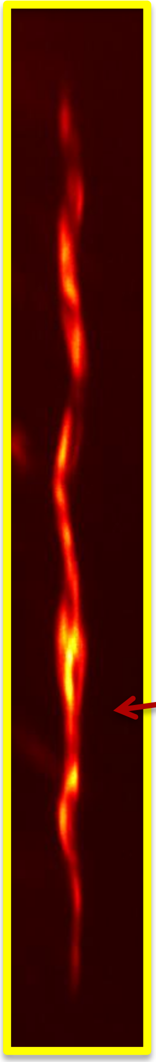
Integrated Experiments performed by
M. Gomez
P. Knapp
T. Awe

DD fuel
+
Laser Preheat
+
Applied Bz

Generated ~10^{12} neutrons



Z2613

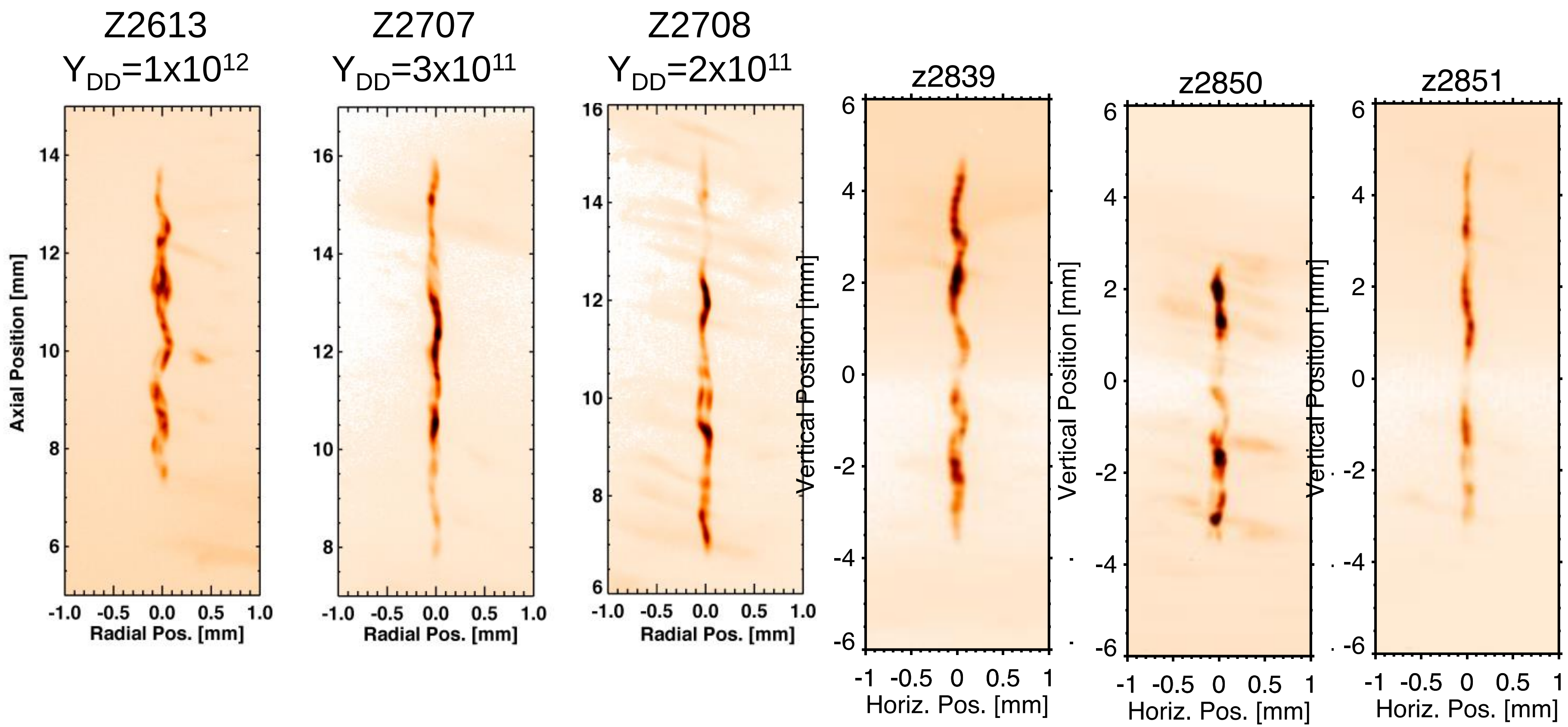


Eric Harding fielded a crystal imager, recording time integrated self emission from the assembled pinch.

Apparent helical structure

Axial variations in emission observed.

Stagnation structure is similar between multiple yield producing shots



The average, radial width is around 100 μm, which is approaching the diagnostic limit of 60 μm.

Questions to address:

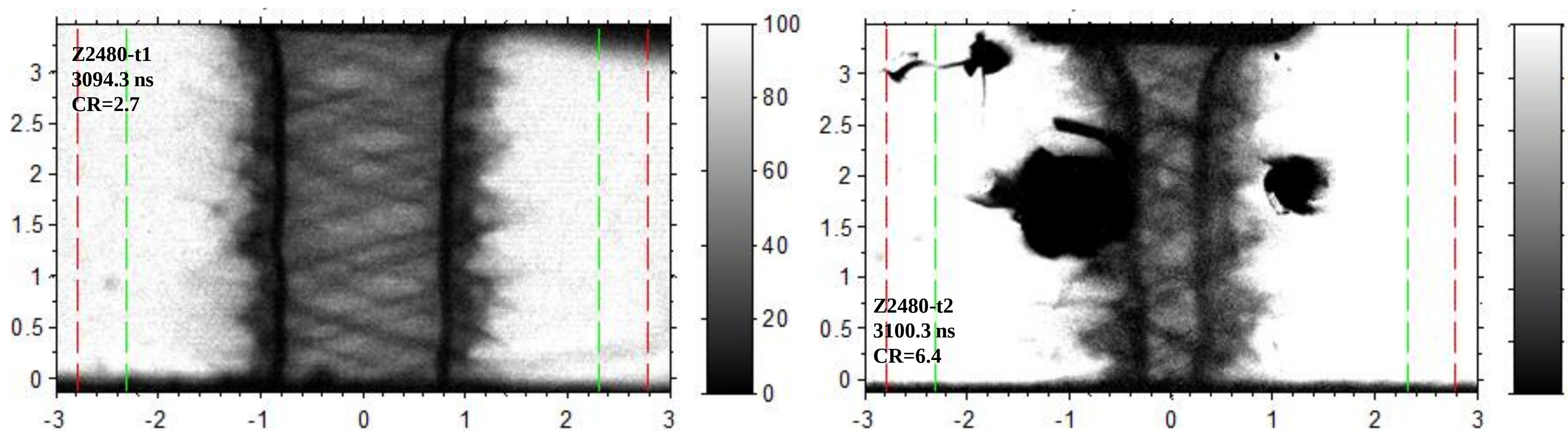
- What is the origin of structure seen in stagnation imaging ?
  - Liner reabsorption
  - Feed through of MRT implosion instabilities
  - Development of instabilities during deceleration on axis.

If structure results from feedthrough of MRT implosion instabilities:

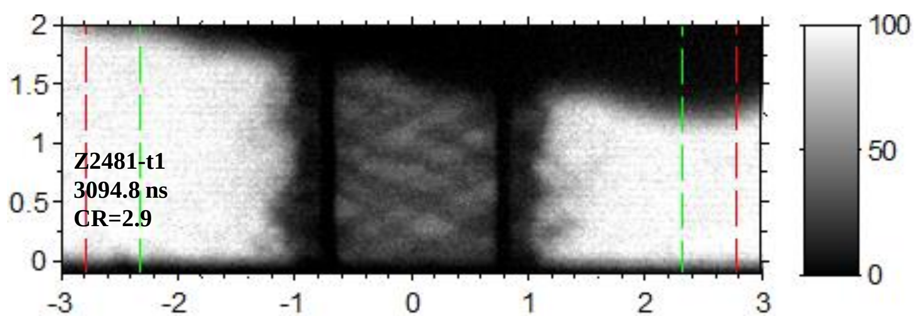
- To what extent can the development of this structure limit neutron yield ?
- How might we test if this is the case ?

Tom Awe experiments imposed an axial magnetic field (~10T)

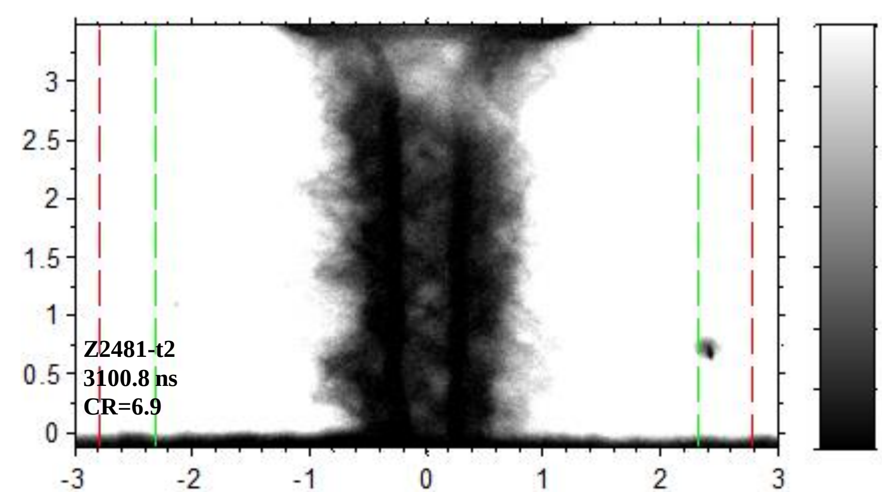
Helical structures were clearly observed to develop in the imploding liners



Z 2480 (7T applied Bz field)

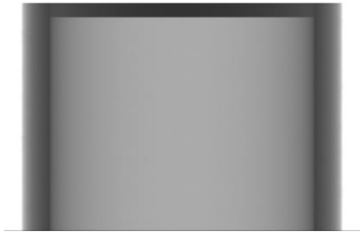


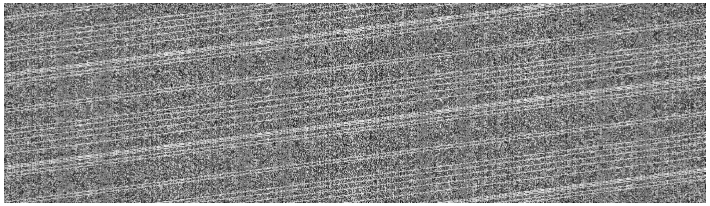
Z 2481 (10T applied Bz field)



We can impose helical perturbation as a small amplitude initial surface perturbation

Initial Conditions

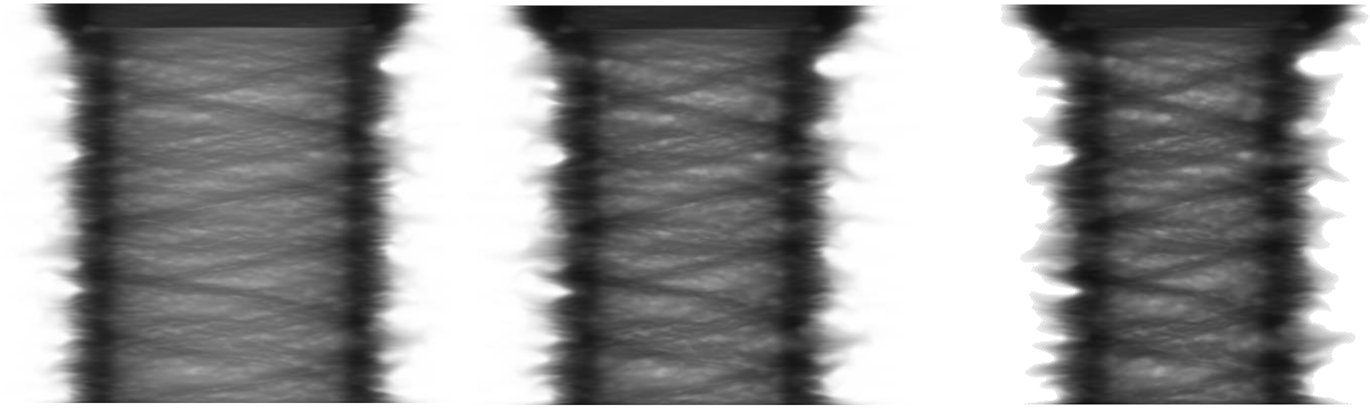




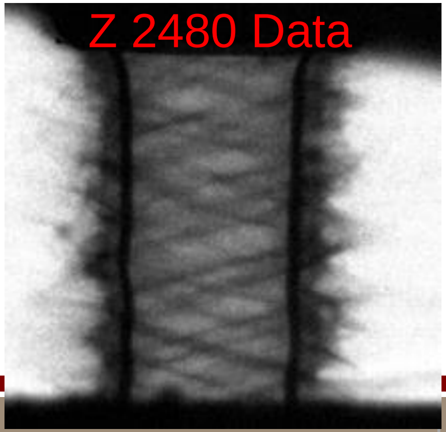
7.2 degree helix etched onto liner surface at 20 micron grid resolution

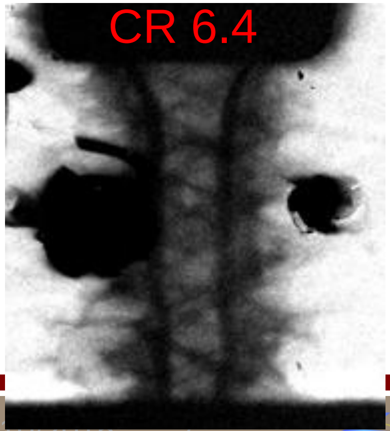
Density slice

Convergence of 6.4



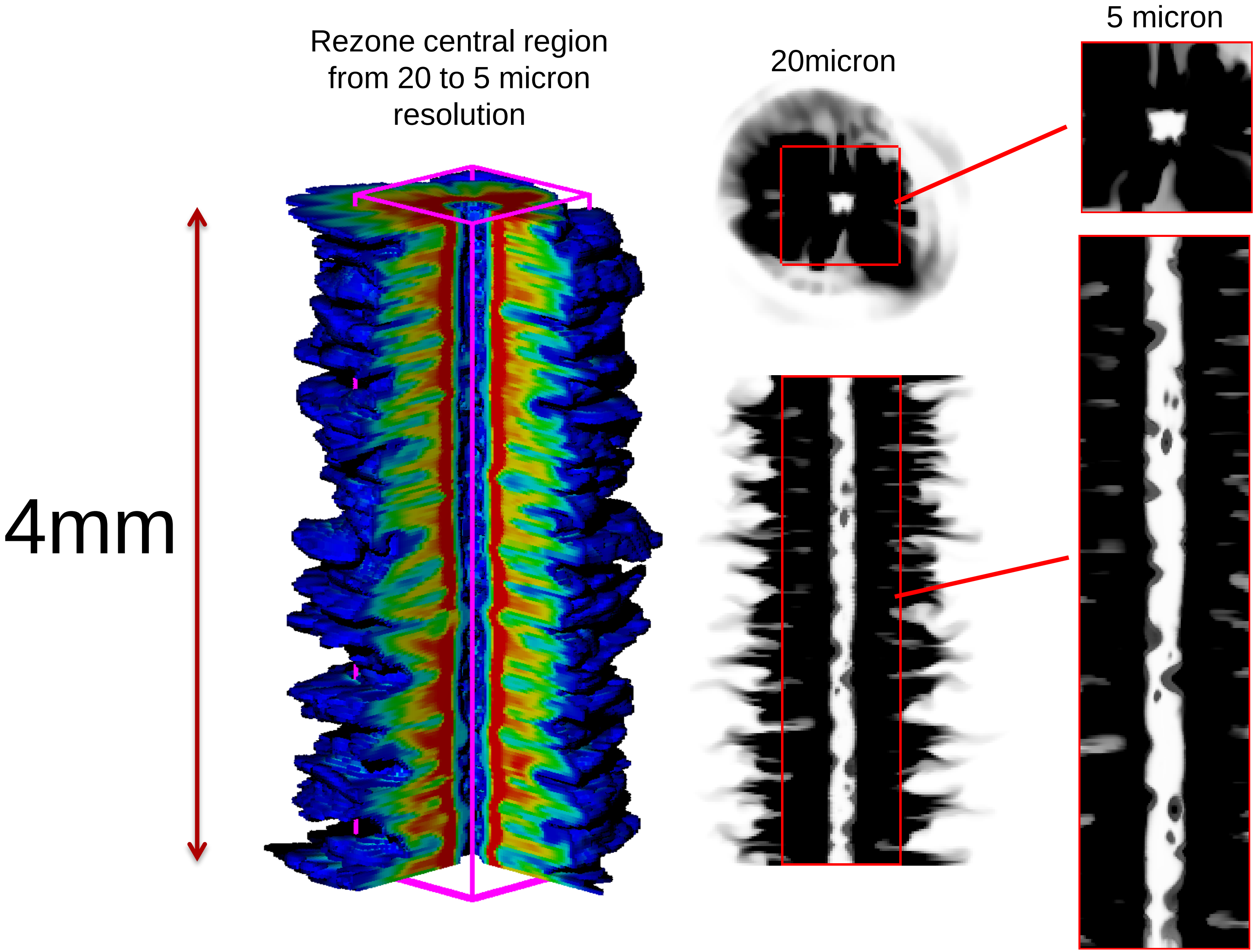
Simulated Radiographs





- Helical structure grows enough to be retained in radiographs during implosion.
- These calculations did not include initial 10T Bz field. It is not required for initial perturbation to persist

For these comparisons we model a 4mm tall section, neglecting end losses

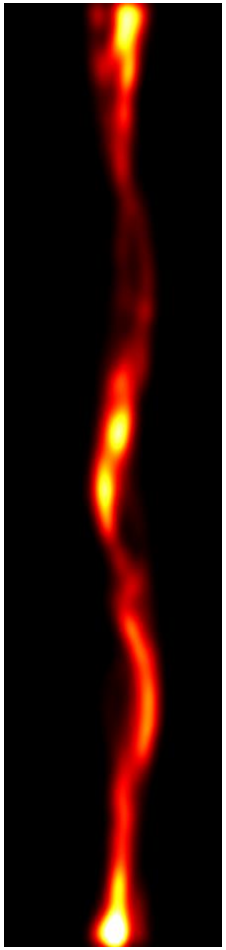


Implosion instabilities have the potential to degrade neutron yield

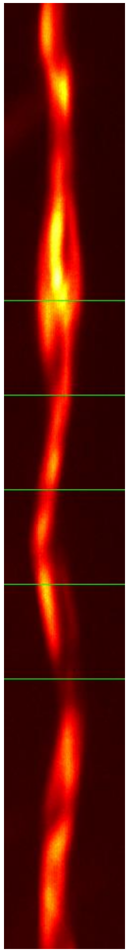
Density Profile at Peak Neutron Emission

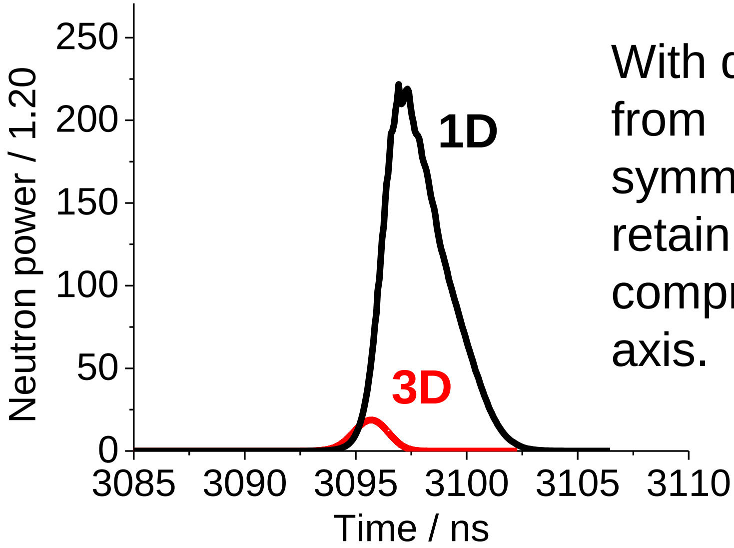
0.96mm

Synthetic Ar Image



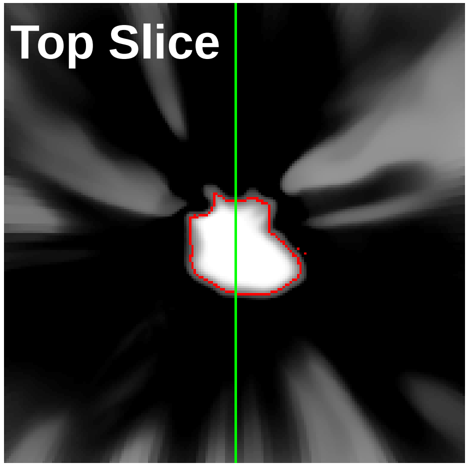
Z2613





With departures from cylindrical symmetry we retain only initial compression on axis.

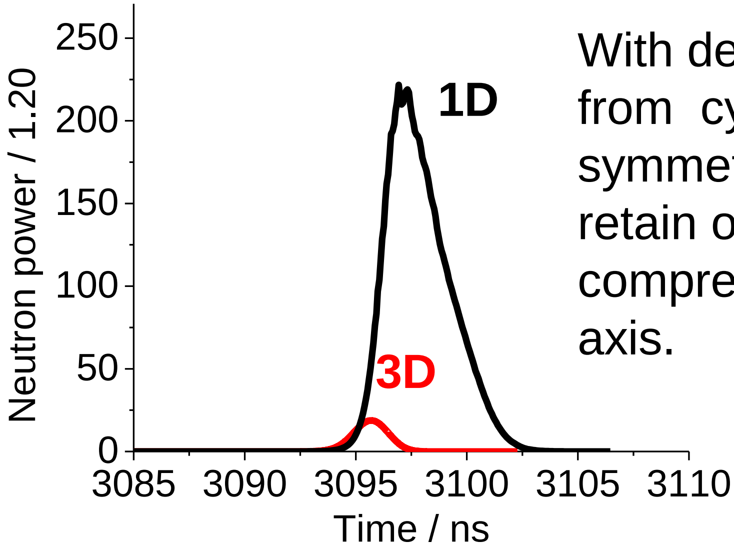
-0.6ns



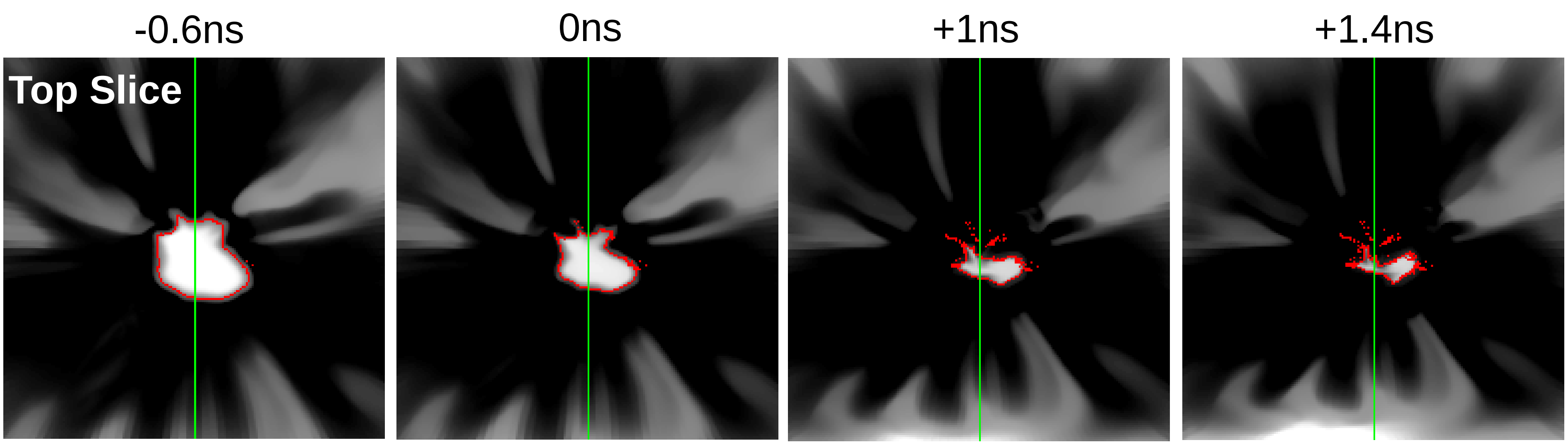
Azimuthal liner structure is not effectively decelerated against compressed fuel.

Spikes of liner material can penetrate through fuel

- Reduces fuel compression (liner can decelerate against liner)
- Increases surface area to thermal losses.
- Mixes cold fuel and liner material into hot fuel.



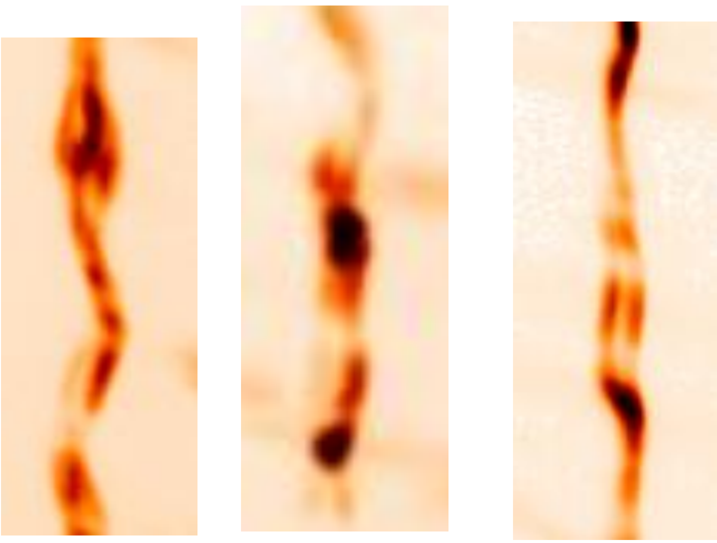
With departures from cylindrical symmetry we retain only initial compression on axis.



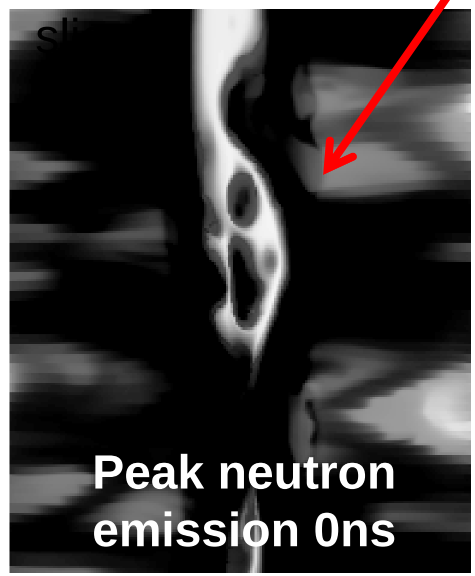
Penetration of Fuel Volume can results in bifurcation of emission structure

Fuel volume can be bisected creating bifurcated structures evident is some of the Ar imaging

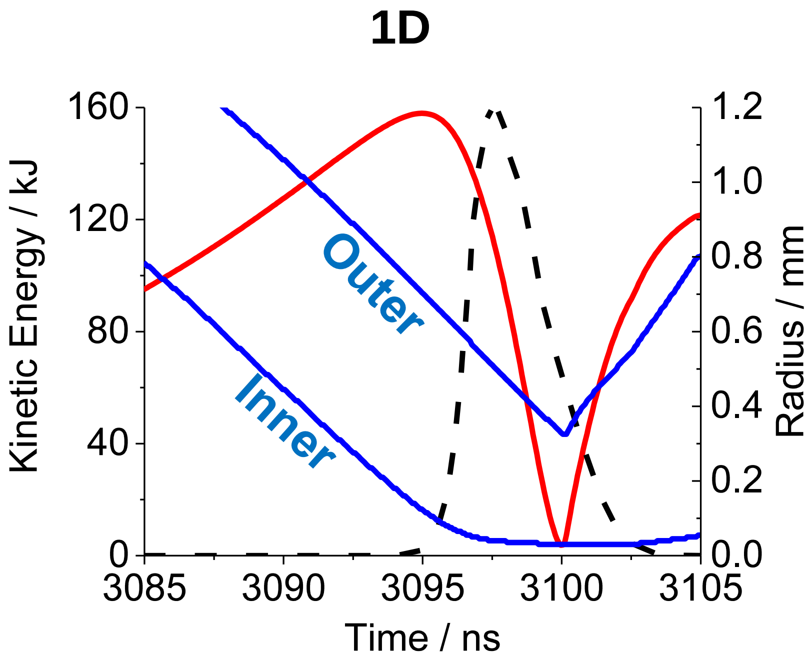
2613 / 2850 / 2708

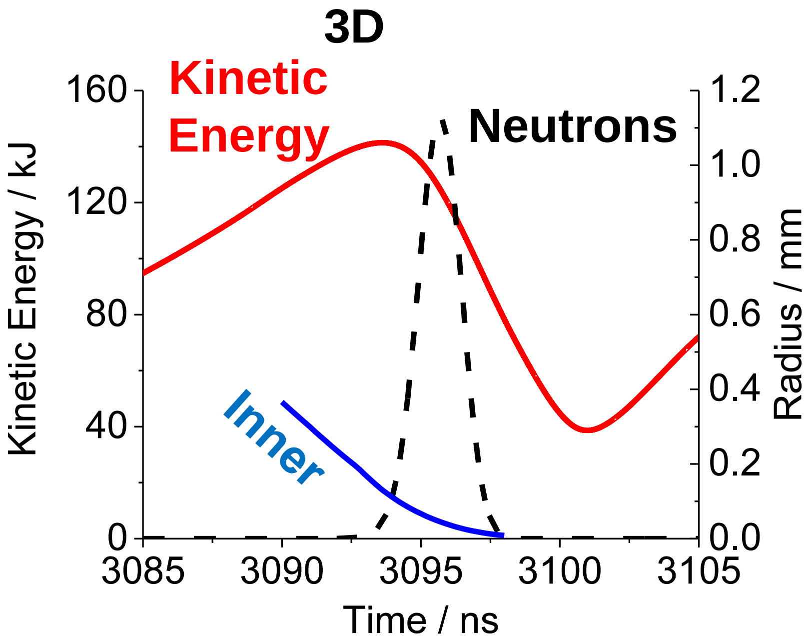


Side



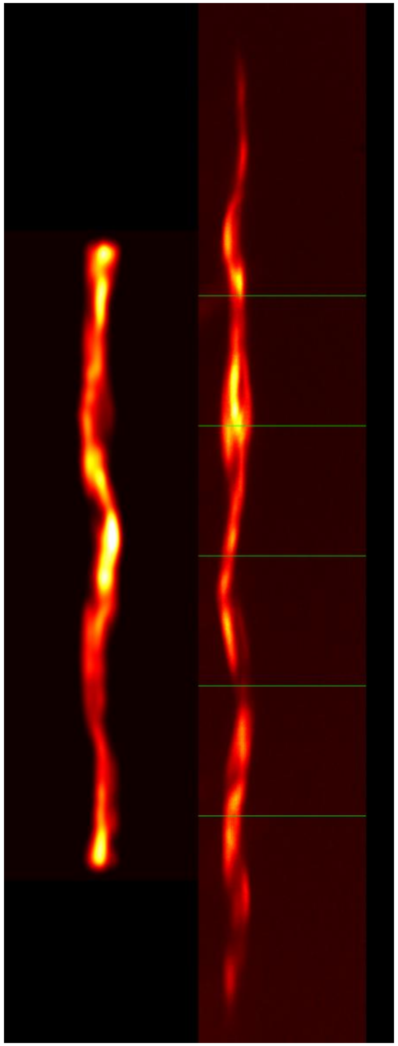
3D perturbed stagnation retains ~30% of peak liner kinetic energy

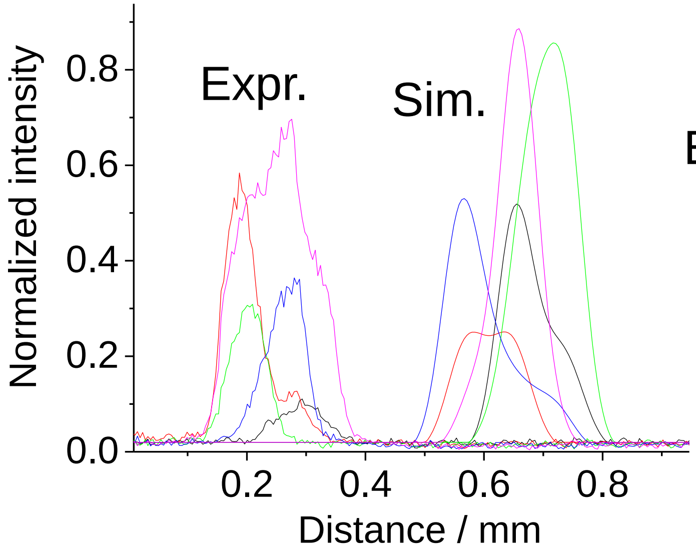




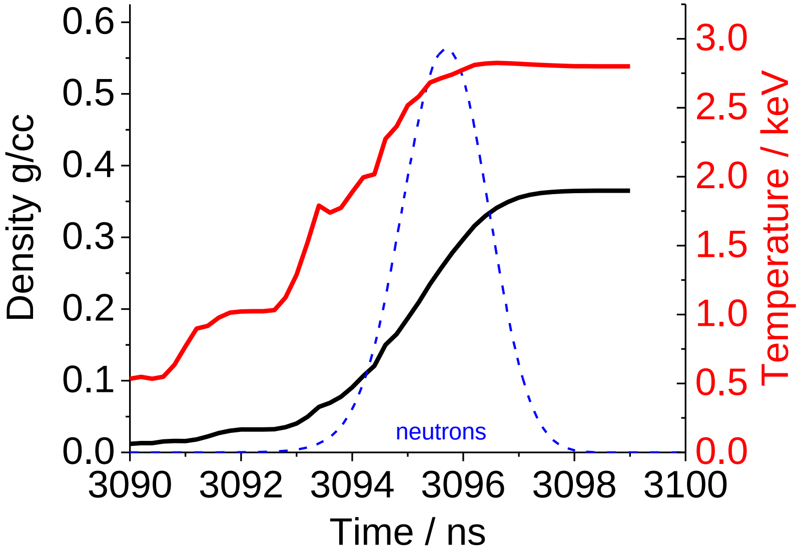
Minimum liner kinetic energy occurs after end of neutron pulse

Comparable Emission Widths obtained between experiment and Simulation





Emission image Widths

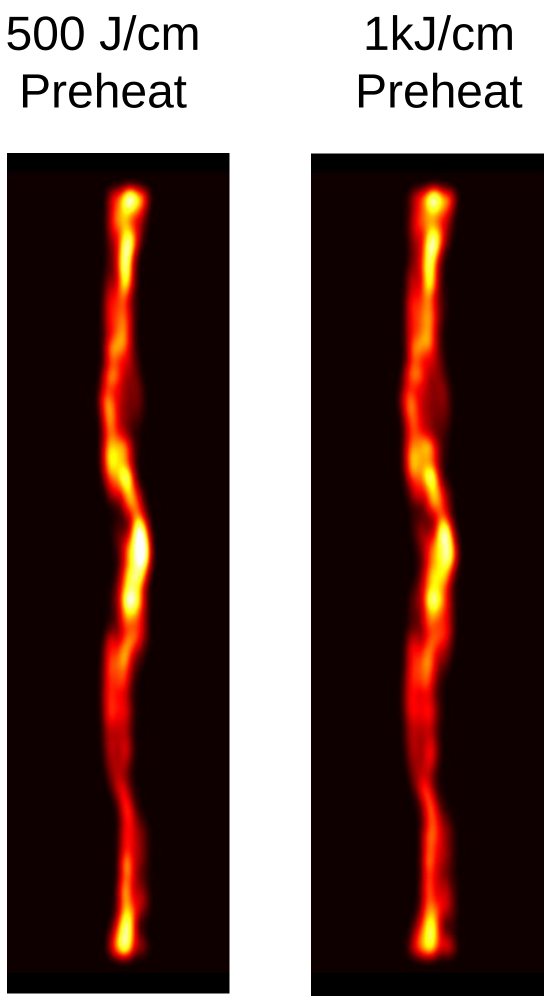


Time integrated temp. / density (emission weighted)

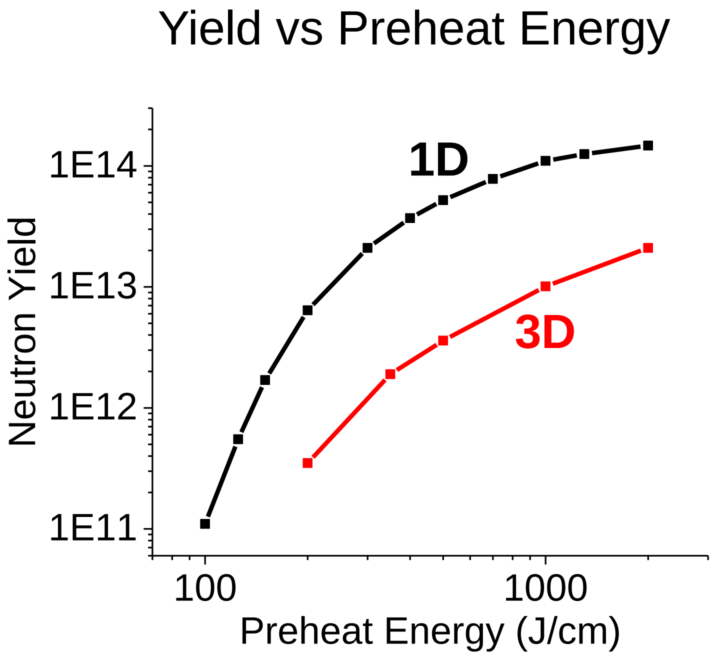
2.8keV g/cc

0.36 g/cc

Neutron yield still scales favorably with preheat energy.



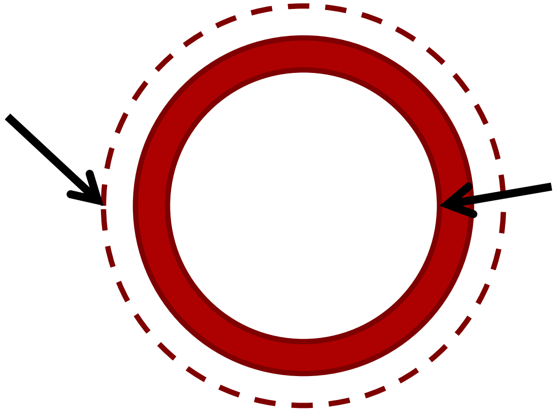
Negligible change in stagnation structure from increasing preheat energy



Yield still scales with increasing preheat energy, but magnitude lowered from 1D equivalent

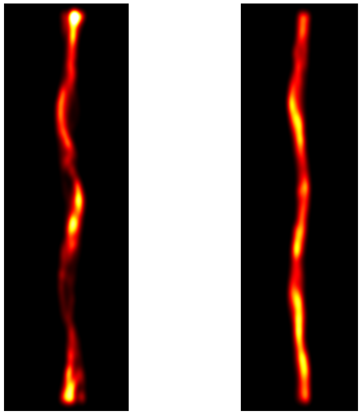
Increasing Liner Thickness (aspect ratio) decreases yield in 1D, but increases yield in a 3D perturbed system.

We can increase liner thickness to mitigate the feedthrough of MRT implosion instabilities

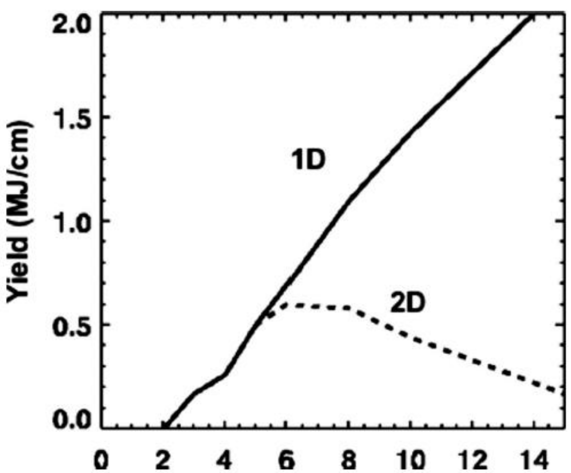


Maintaining the same inner surface radius to preserve the same preheat conditions

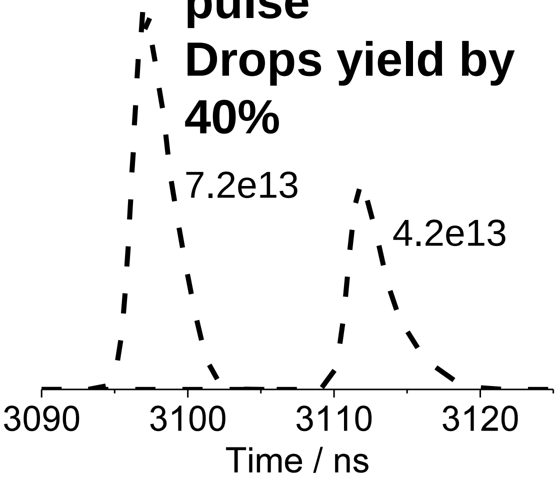
40% thicker



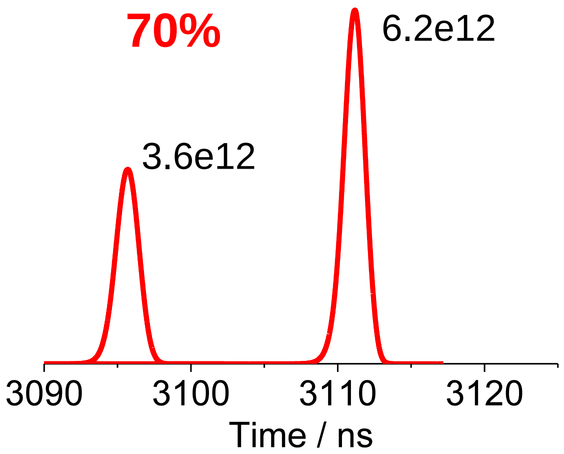
S. Slutz *et al*
Phys. Plasmas 17, 056303 (2010)



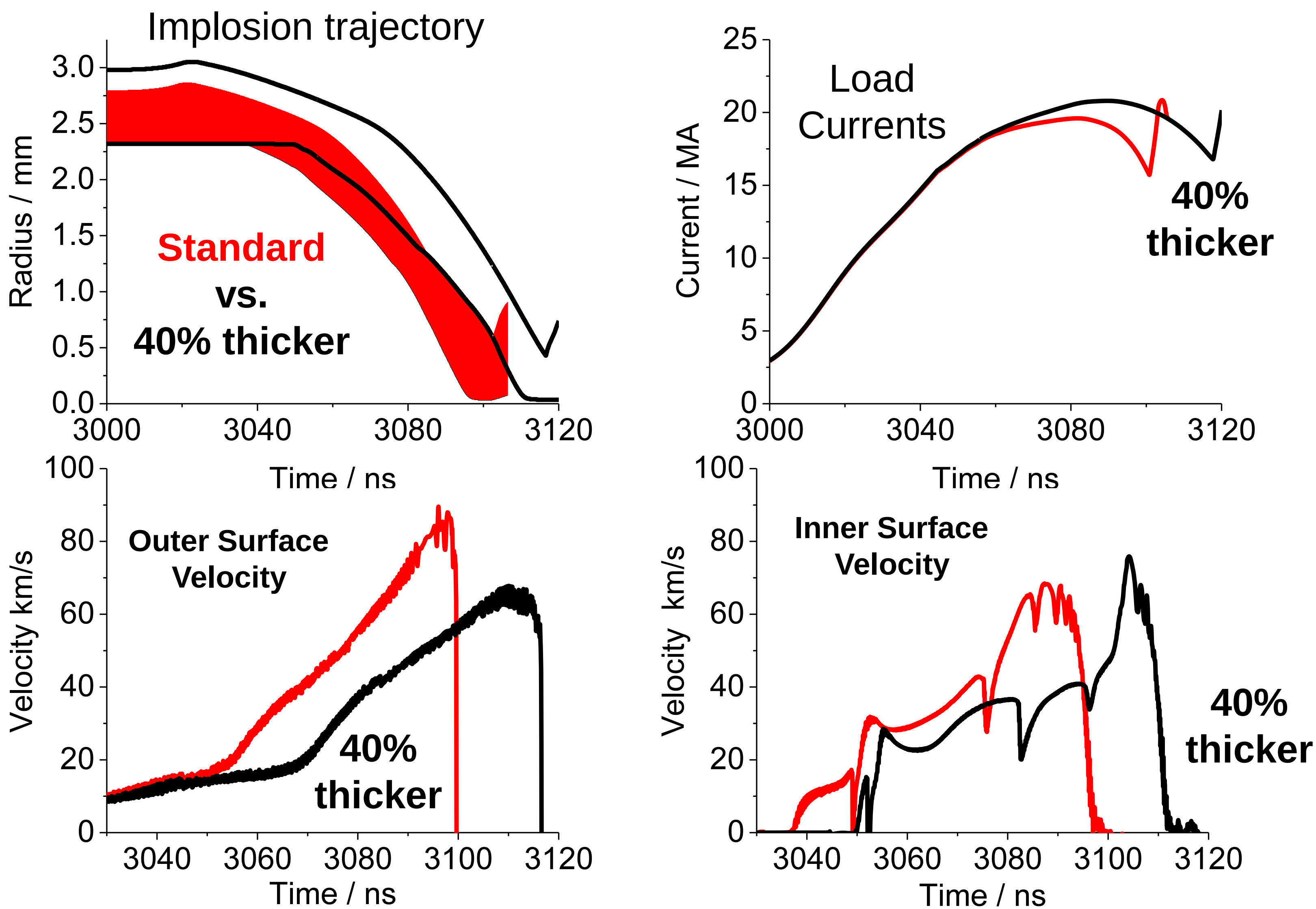
1D – neutron pulse
Drops yield by 40%



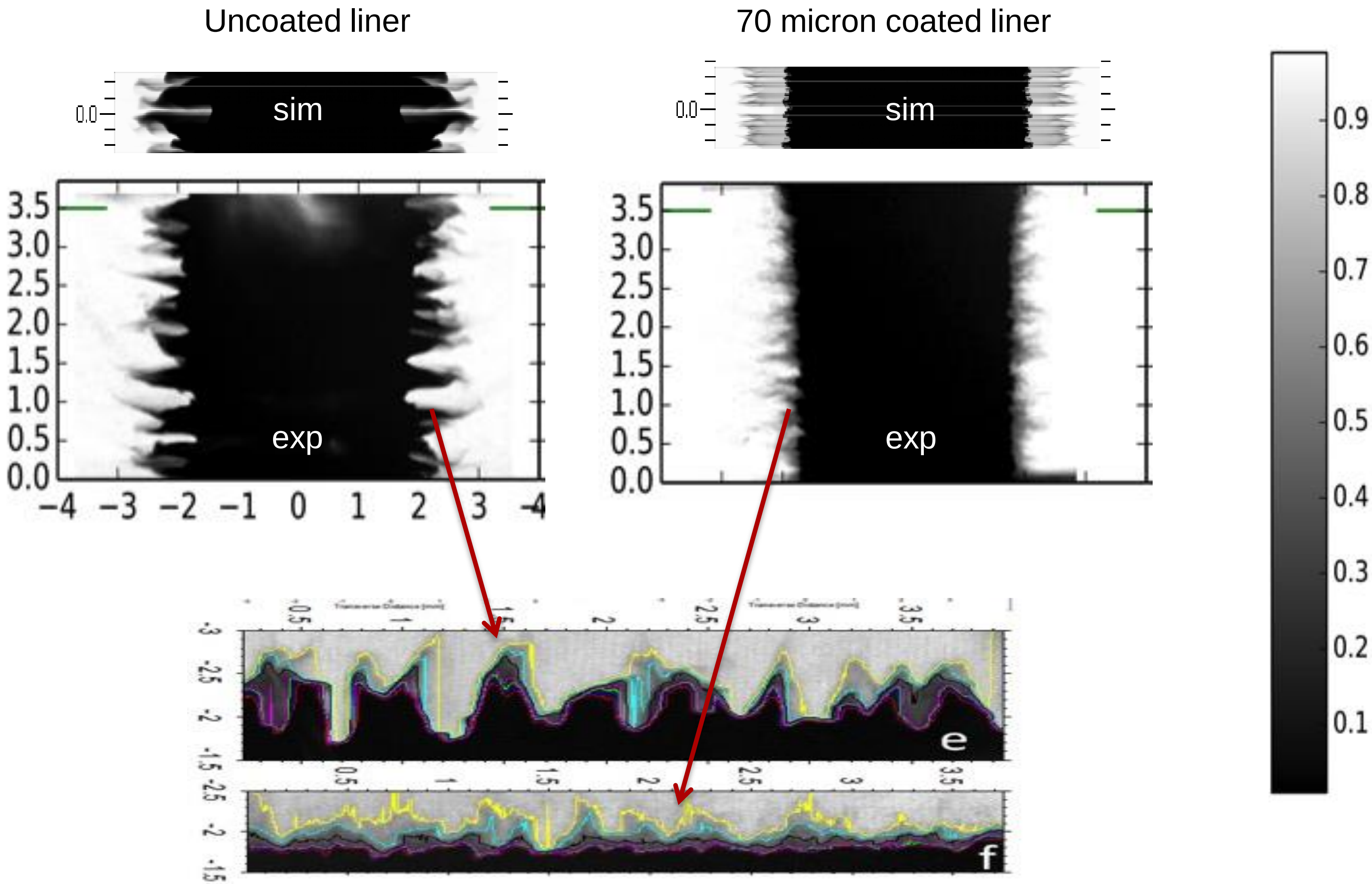
3D – neutron pulse
Increase yield by 70%



Modest increases in liner thickness are not necessarily detrimental to inner surface implosion velocity at stagnation



Options are available to potentially reduce MRT instability Development (K. Peterson Inv. Talk)



T. J. Awe & K. J. Peterson, et. al., *submitted PRL* (2015).

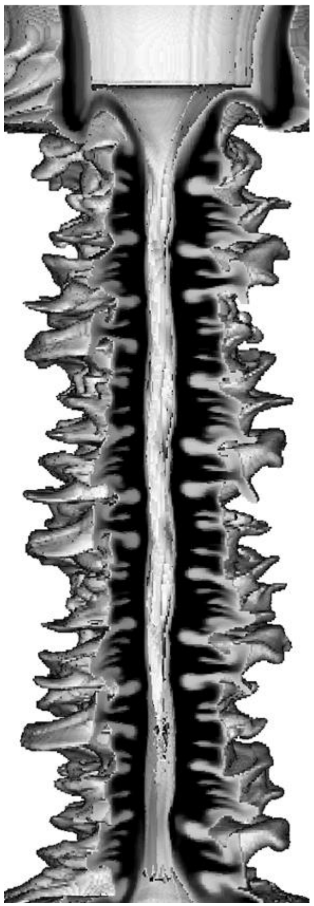
Summary:

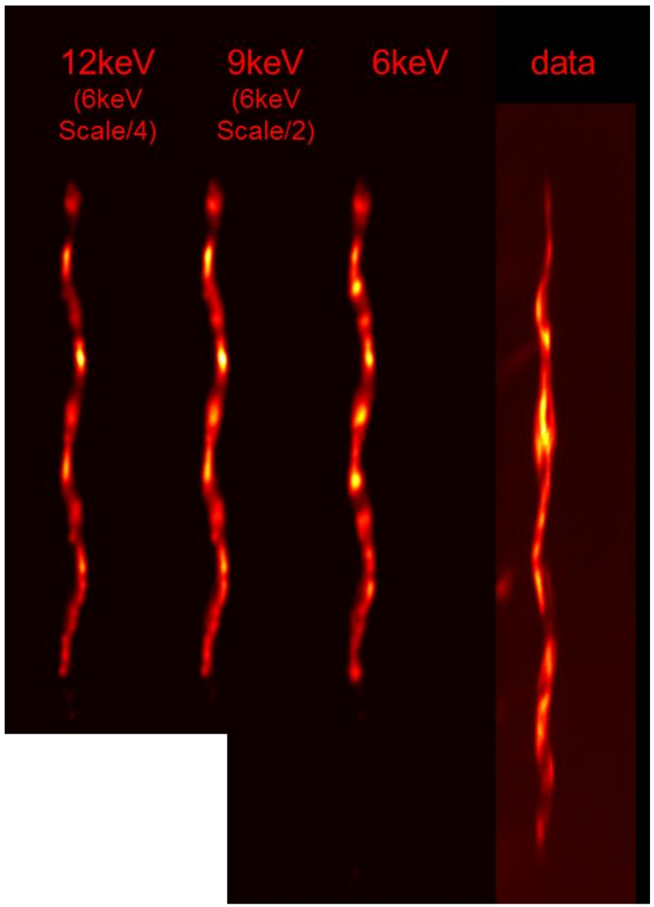
- Azimuthally asymmetric implosion instabilities have the potential to degrade neutron yield.
- If this is the result of MRT instabilities fed through from the outside of the liner then aspect ratio variations may be able to identify / mitigate some of this.
  - If structure is the result of deceleration instabilities this may be harder to discern
- We have potential options to inhibit or reduce instability growth (dielectric coatings)

Backup

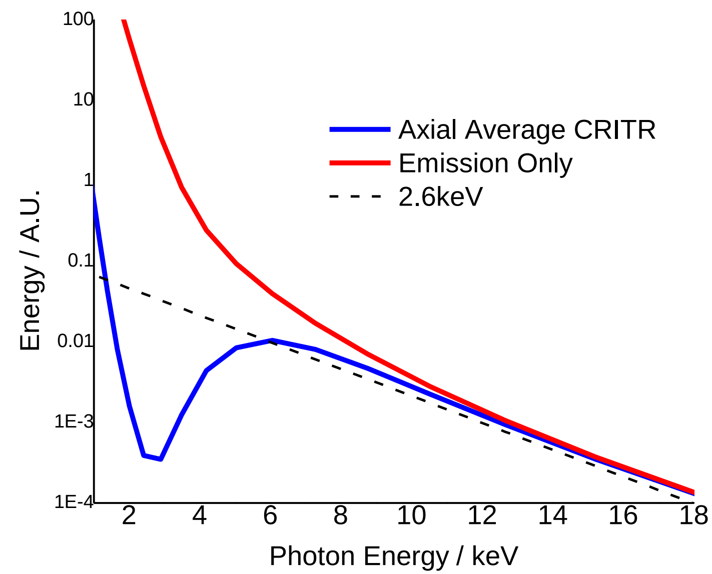
Synthetic Crystal Imaging Reconstructed from Simulation Output

Some axial structure results from reabsorption from liner structure, but some represents emission variations





Eric Harding's photometric calculations of this instrument, indicates sensitivity is comparable at 6 and 9keV



Contrasting stagnation imaging from different liner surface perturbations

- These are 4mm height, no end loss.
- Random initial surface perturbation is more detrimental to performance than long wavelength helix.
- Finite azimuthal structure wrecks compression and confinement and appears to produce axial structure more consistent with stagnation imaging