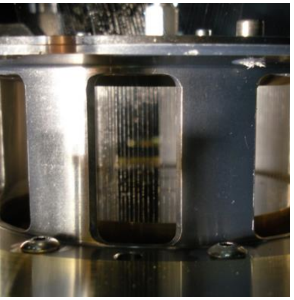

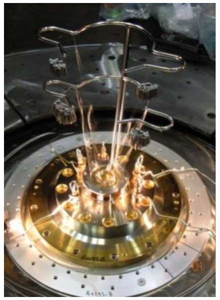

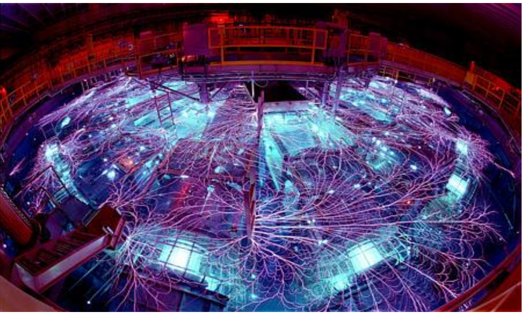

SAND2017-7310C

Differentiating Different Modeling Assumptions in Simulations of MagLIF* loads on the Z Generator

C.A. Jennings, M.R. Gomez, E.C. Harding P. F. Knapp, D. J. Ampleford, S.B. Hansen, M.R. Weis, M.E. Glinsky, K. Peterson

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

Sandia National Laboratories, Albuquerque, NM, USA

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Imperial College, London, UK

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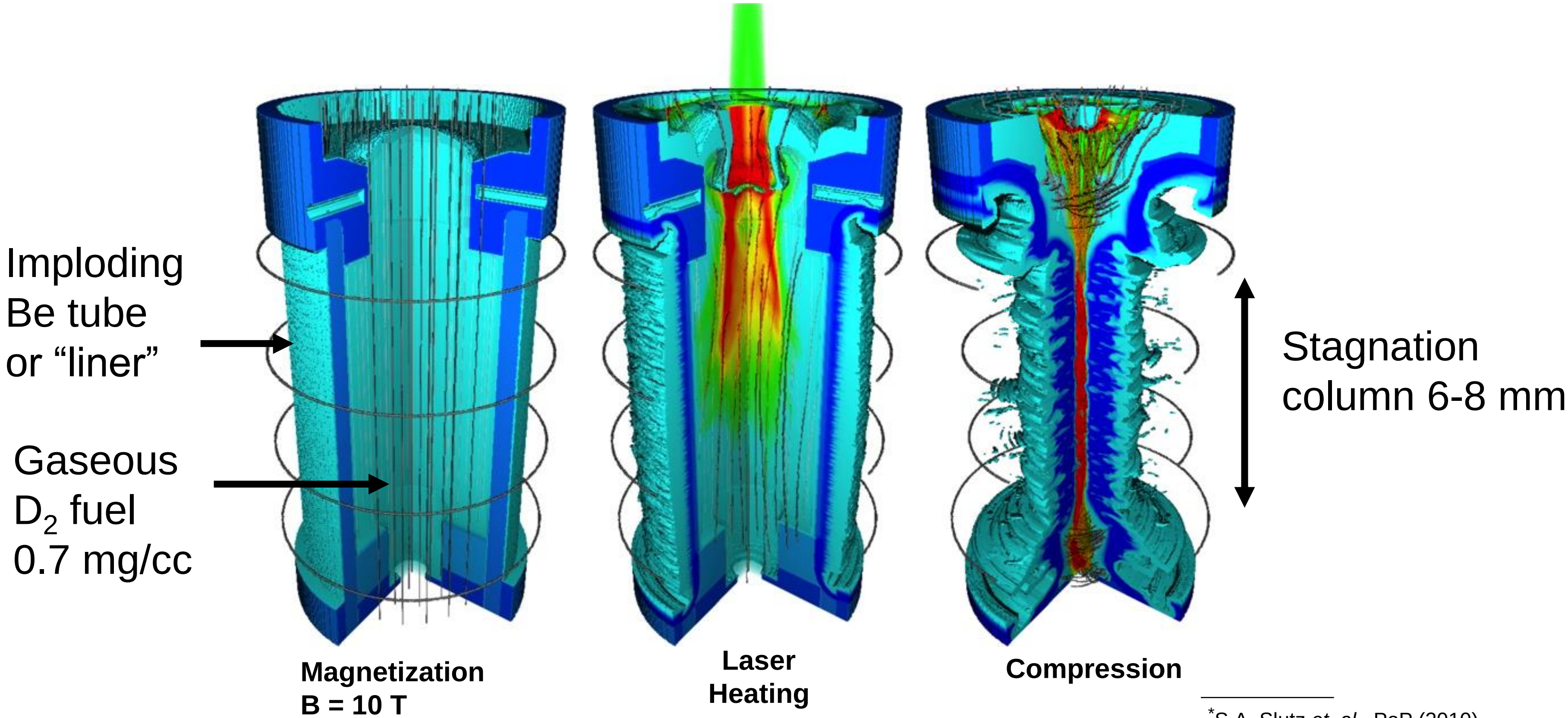
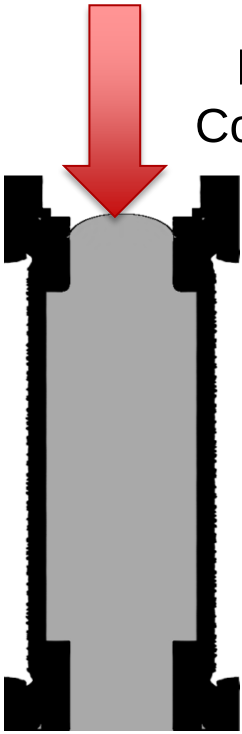
The Magnetized Liner Inertial Fusion (MagLIF) concept is being pursued on Z and has produced DD yields as high as 3 x 1012.*



*S.A. Slutz *et. al.*, PoP (2010)
S.A. Slutz and R. A. Vesey, PRL (2012)
M.R. Gomez *et. al.*, PRL (2014)
P.F. Schmit *et. al.*, PRL (2014)
A.B. Sefkow, *et. al.* ,PoP (2014)
M.R. Gomez, *et. al.*, PoP (2015)
S.B. Hansen, *et. al.* , PoP (2015)
R.D. McBride, *et. al.*, PoP (2016)

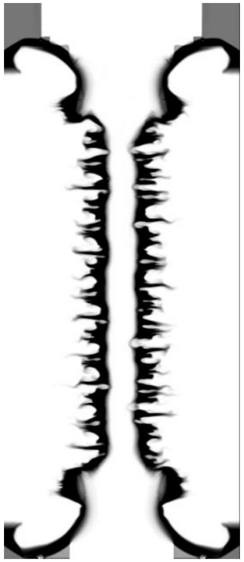
3 Main areas of concern: Laser Coupling, High Z Mix, Liner Instabilities

Poor laser Coupling



High Z mix

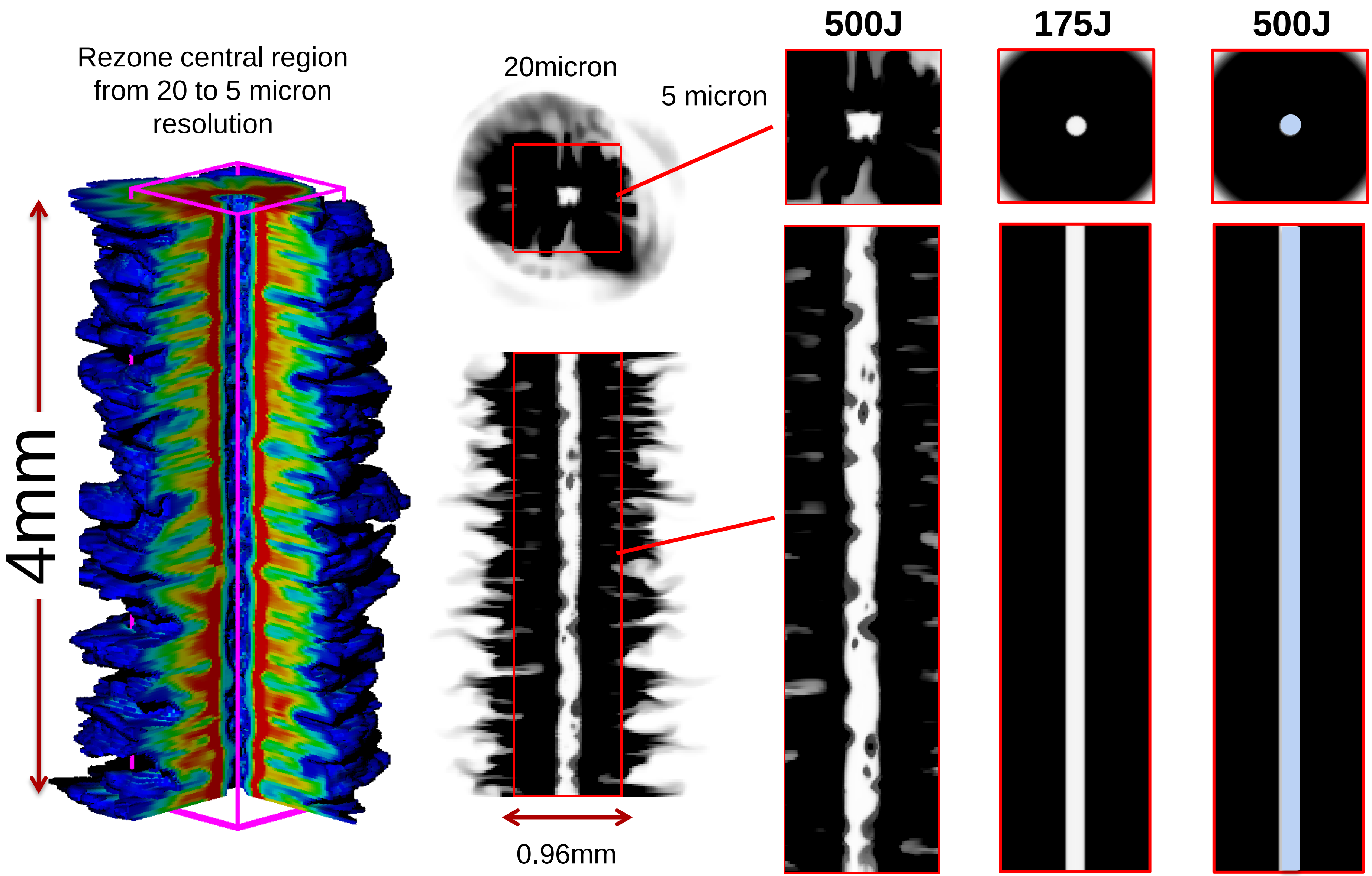
Implosion / stagnation instabilities



Contrast these 3 degradation mechanisms within the same model and start to compare some of the typical observables

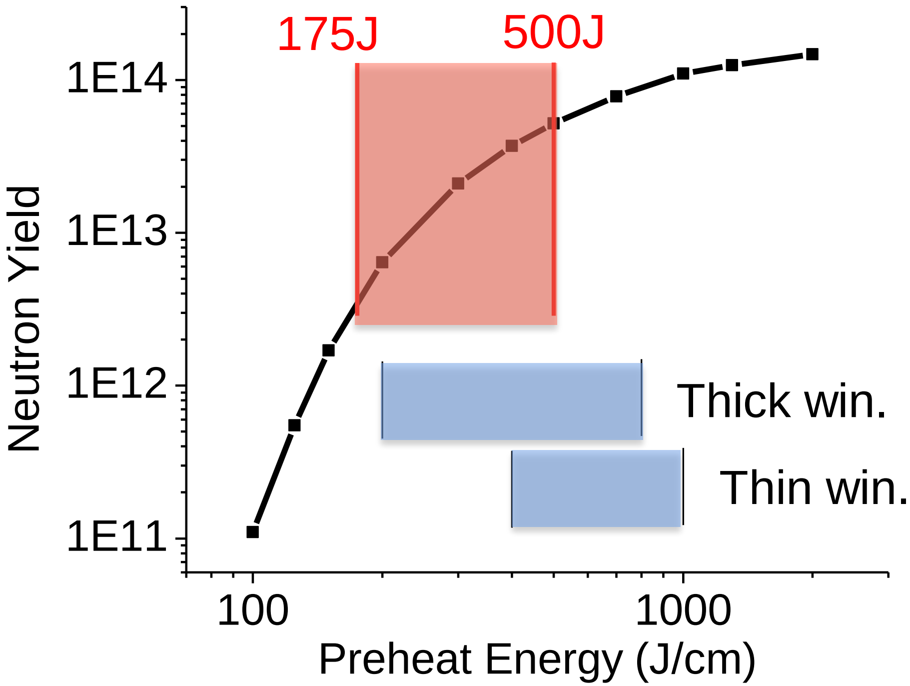
In reality it is likely all 3 are in play to some degree

For these comparisons we model a 4mm tall section, neglecting end losses using GORGON MHD Code



For ideal Maglif 1D implosion, this range of preheat energies has a significant effect on neutron yield

For an ideal 1D implosion 175J – 500J represents
> order of magnitude change in yield

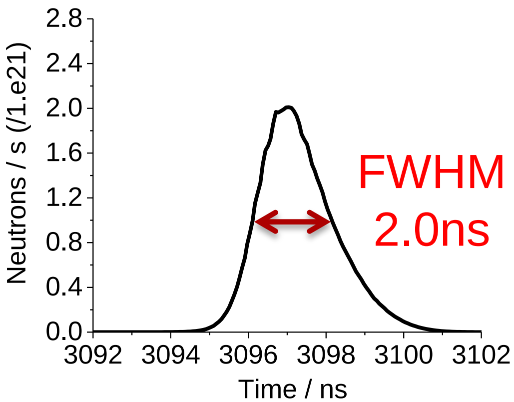


Range of uncertainty in laser energy deposited

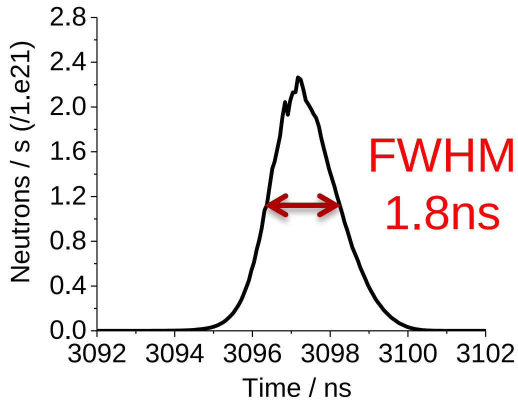
Comparable burn widths recovered for all 3 degradation mechanisms

DD Yield on all 3 cases is 4.6×10^{12}

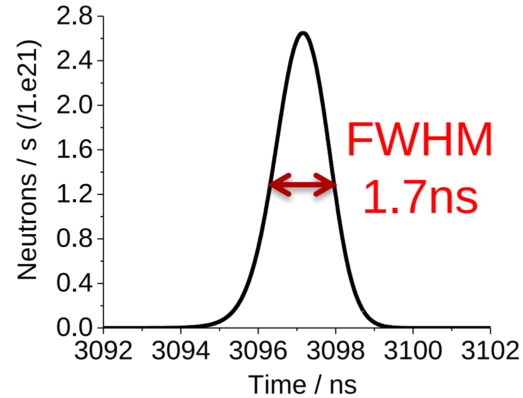
Low Preheat
Preheat: 175J



Be Mix
Preheat: 500J

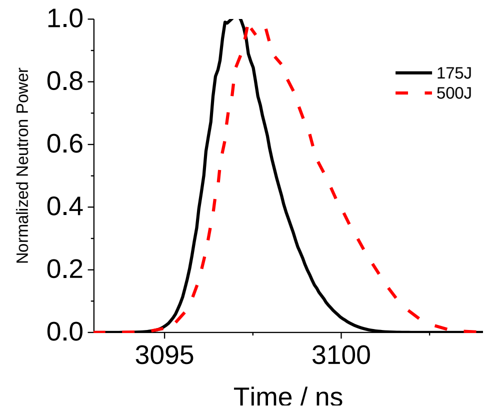


3D unstable
Preheat: 500J

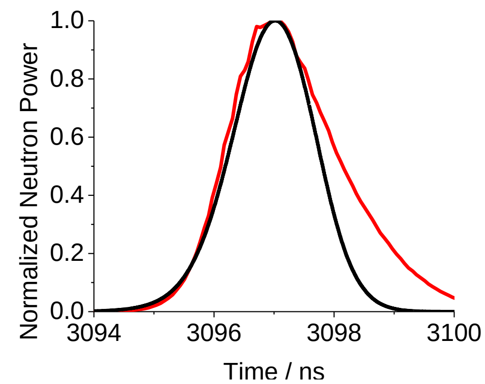


3D instabilities tend to truncate neutron pulse faster, low fuel energy tends to only light up late, for a short time.

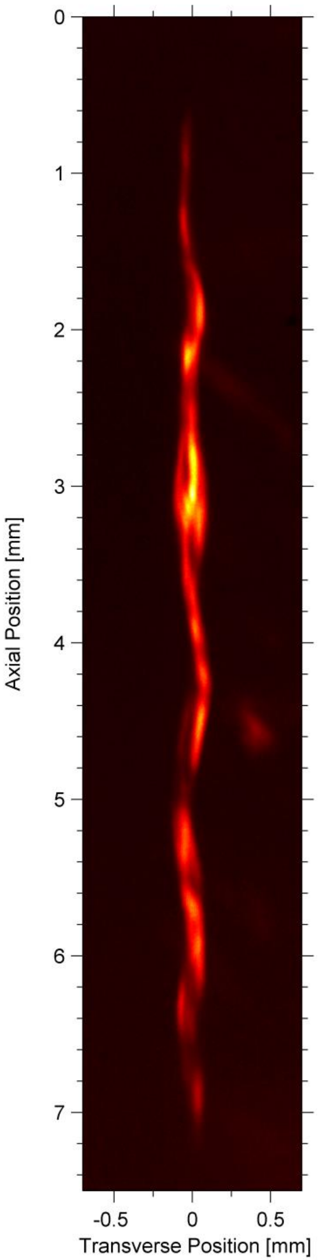
Normalized pulse 1D clean,
175J / 500J

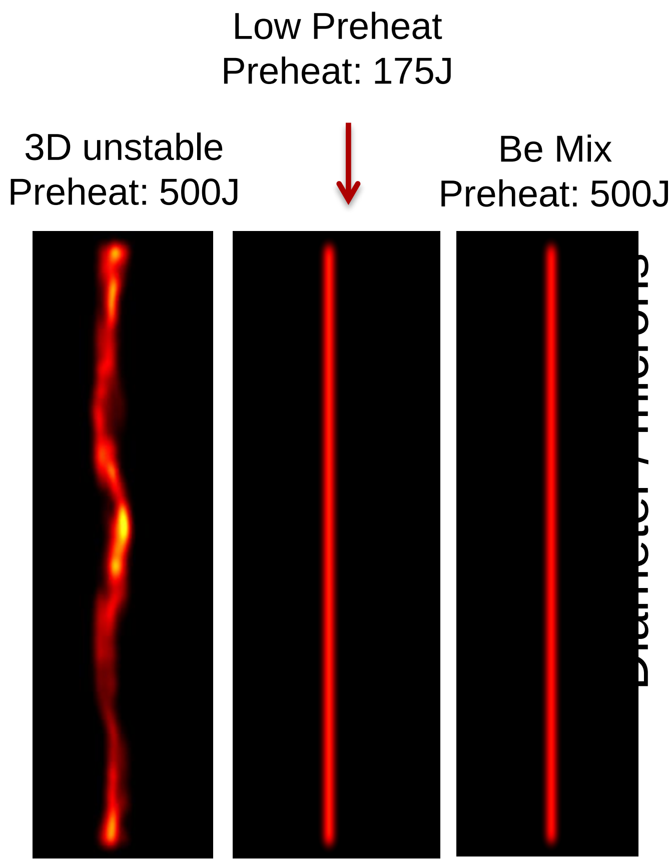


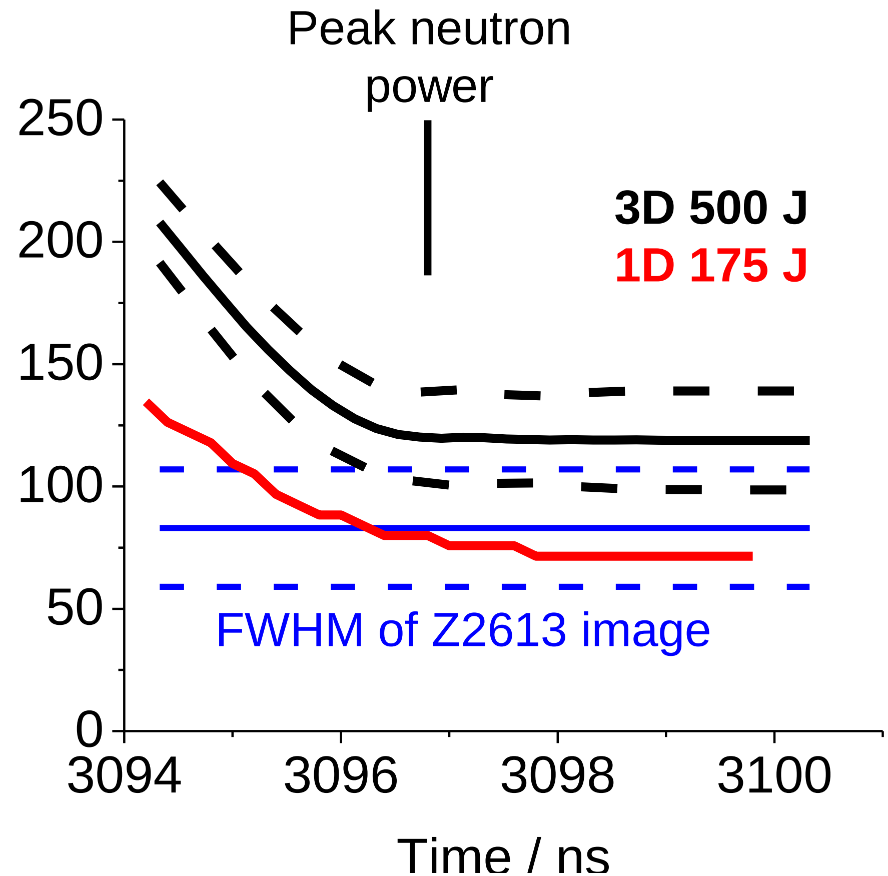
Normalized pulse shapes
Low preheat / 3d



Self emission imaging stagnation diameters are comparable between different degradation mechanisms

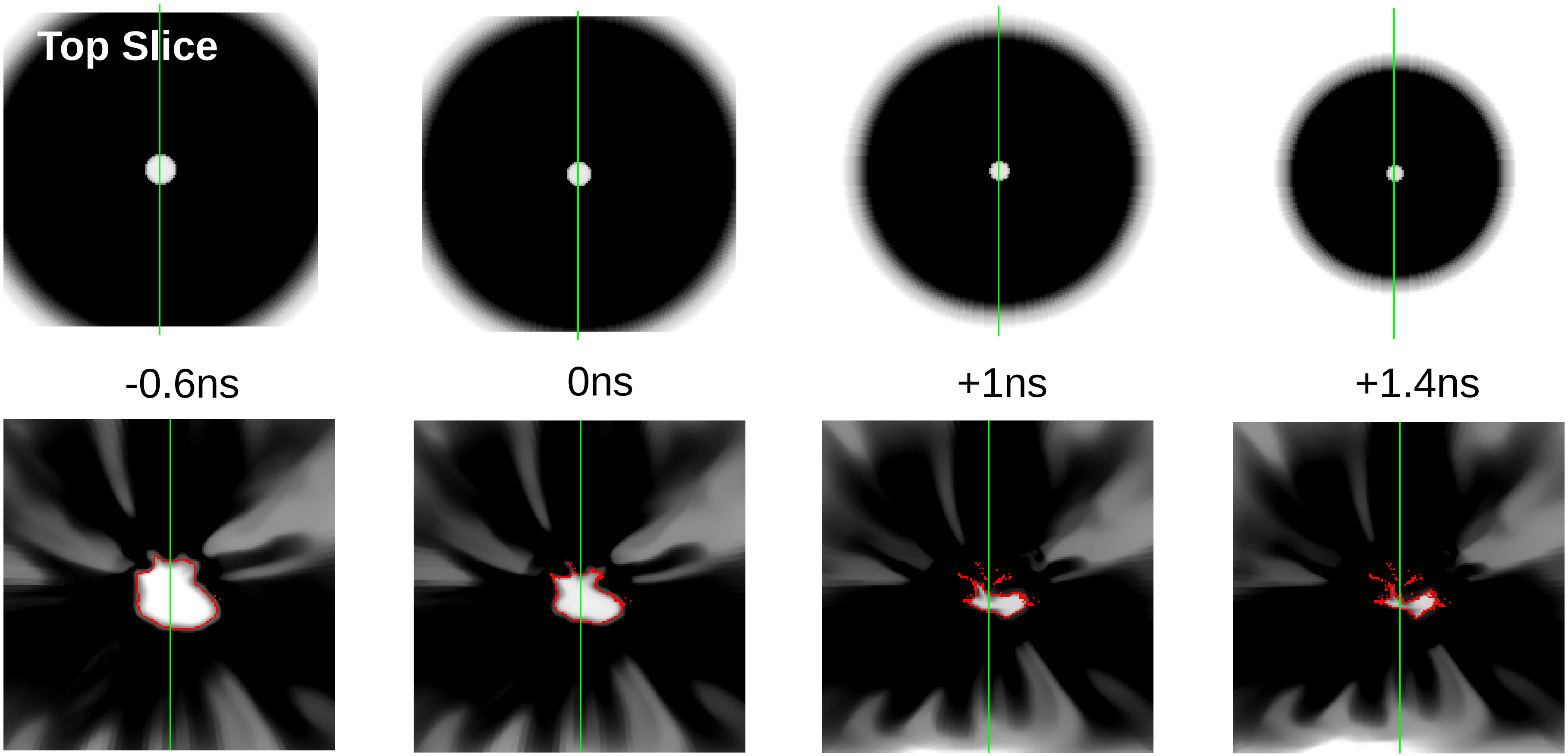






Mechanism for short burn width and narrow emission image significantly different between two extremes (low preheat / stable vs higher preheat unstable)

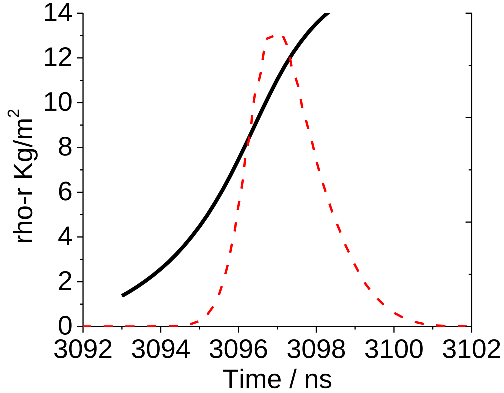
1D low preheat



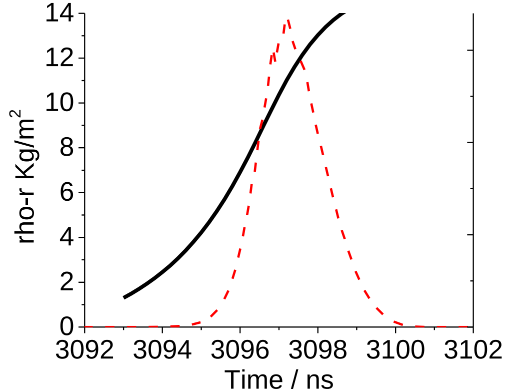
3D disruption

Liner rho-r a strong function of time through stagnation

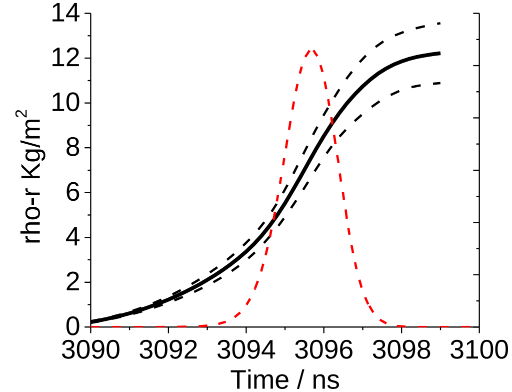
Low Preheat
Preheat: 175J



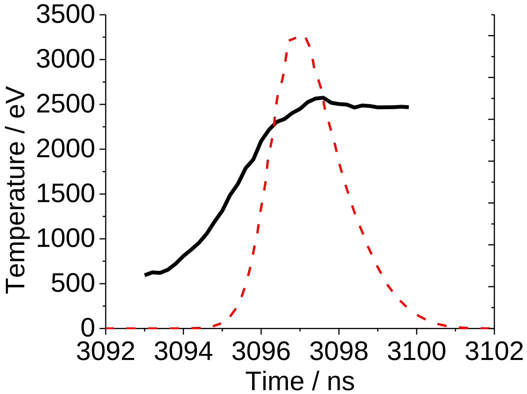
Be Mix
Preheat: 500J

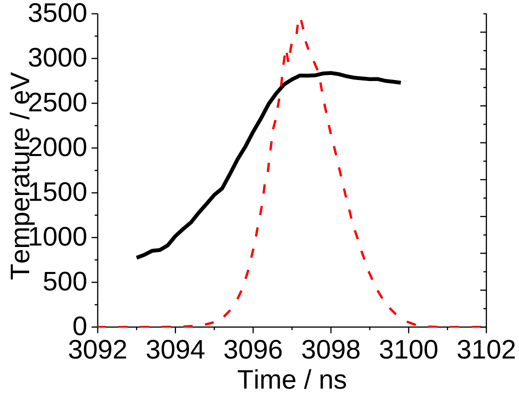


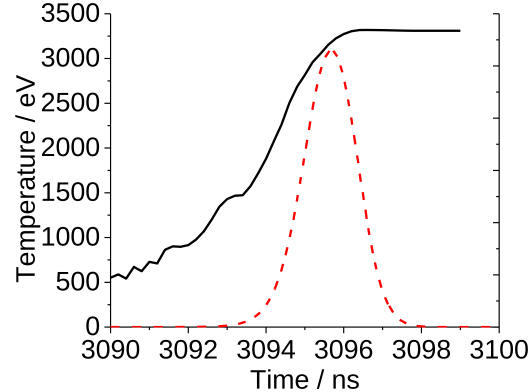
3D unstable
Preheat: 500J



Fuel Temperature

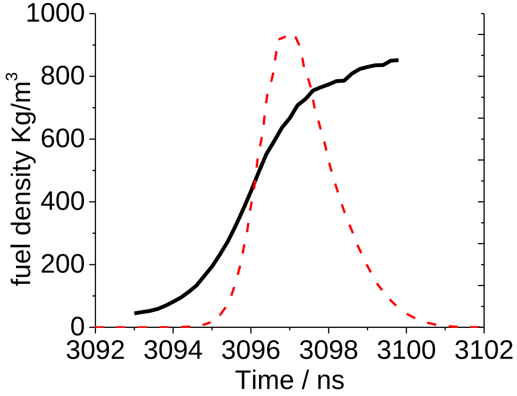


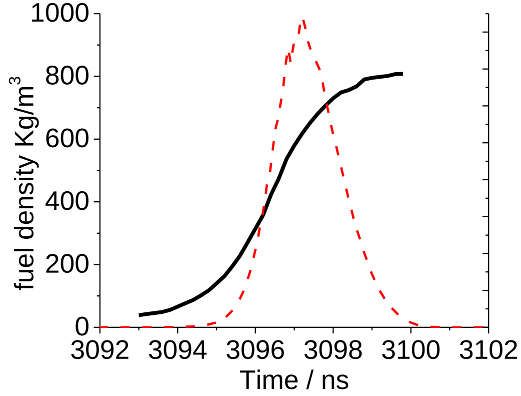


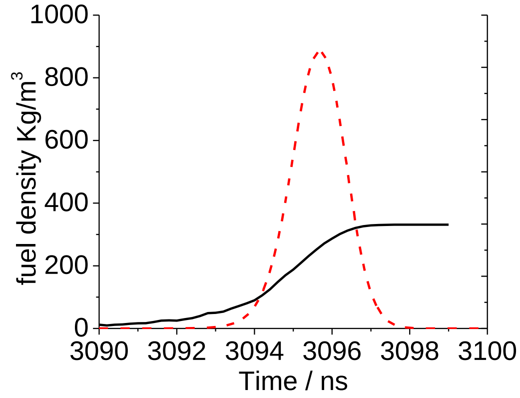


Emission weighted fuel density higher for high uniformity compressions

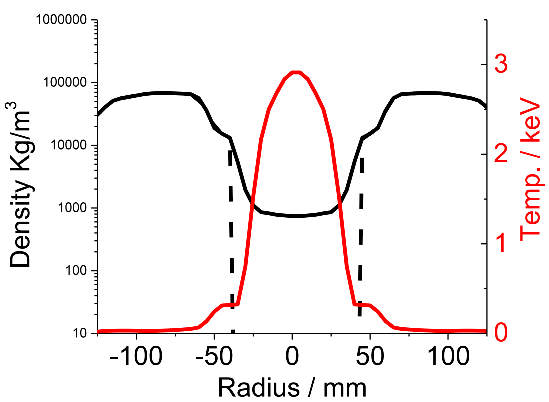
Low Preheat Preheat: 175J	Be Mix Preheat: 500J	3D unstable Preheat: 500J





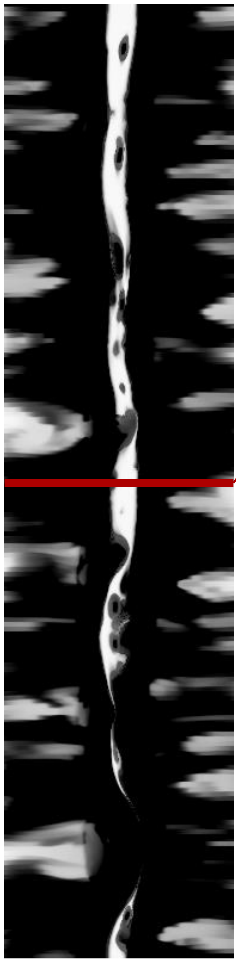


Lower fuel density as instabilities limit late time compression.

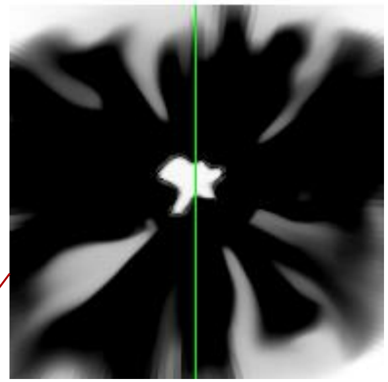


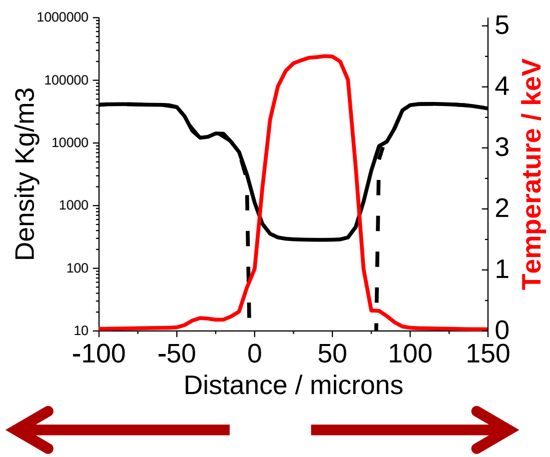
End losses will modify this, as will changes to the amount of cold / dense fuel that is retained against liner wall (influenced by preheat deposition profile)

Temperature and density gradients exist through stagnated fuel volume



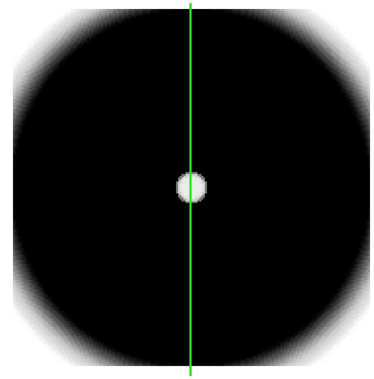
3D unstable
Preheat: 500J

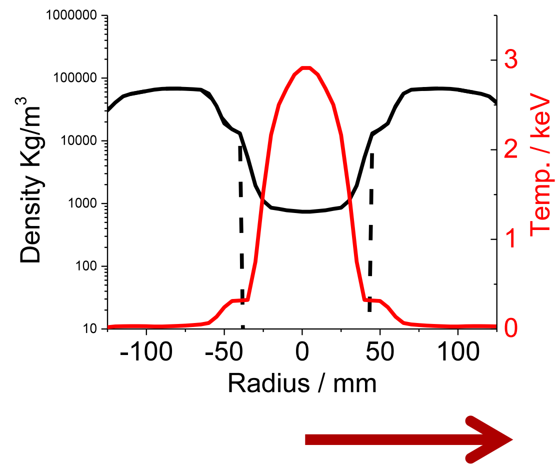




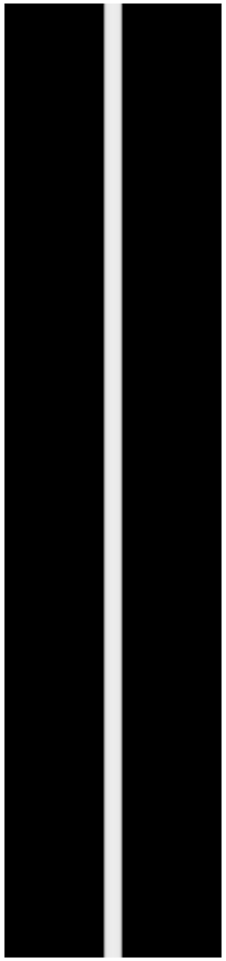
$\rho r = 0.88\ g/cm^2$ $\rho r = 0.61\ g/cm^2$

Low Preheat
Preheat: 175J





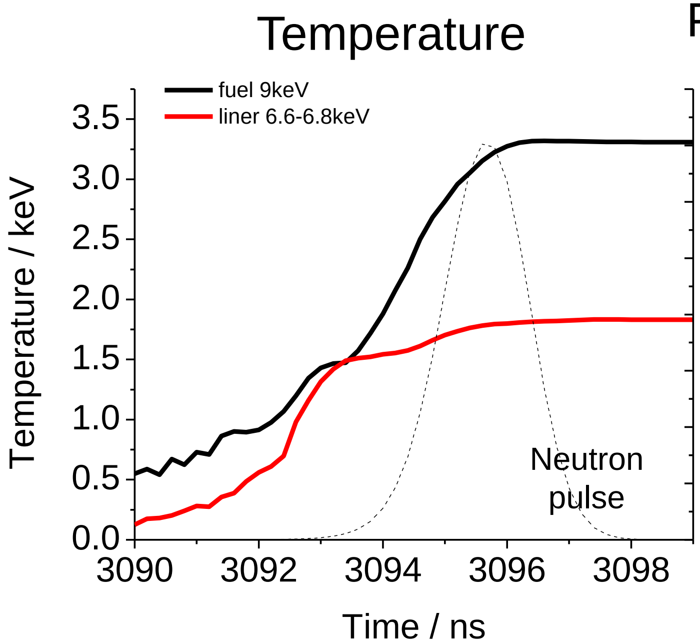
$\rho r = 1.33\ g/cm^2$

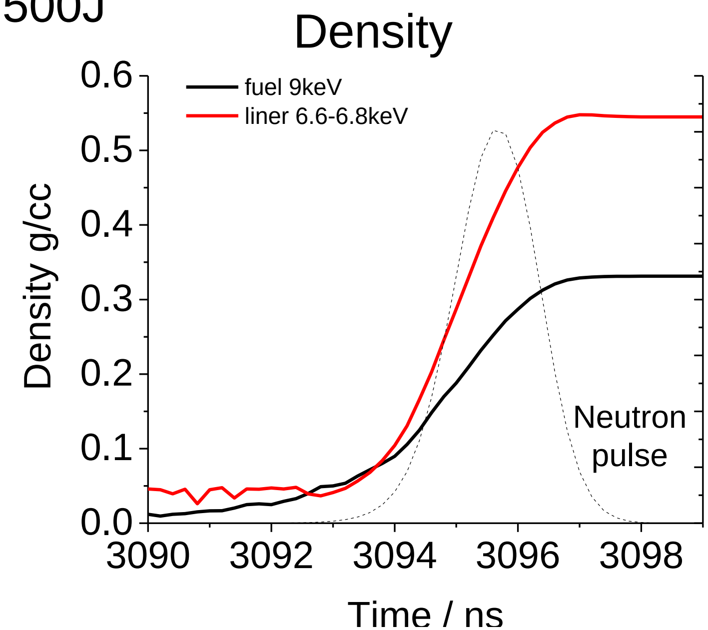


Time integrated emission quantities comparing fuel to Be iron contaminant

Iron impurity in Be liner is being used to diagnose stagnation conditions (Eric Harding Invited talk)

3D unstable
Preheat: 500J



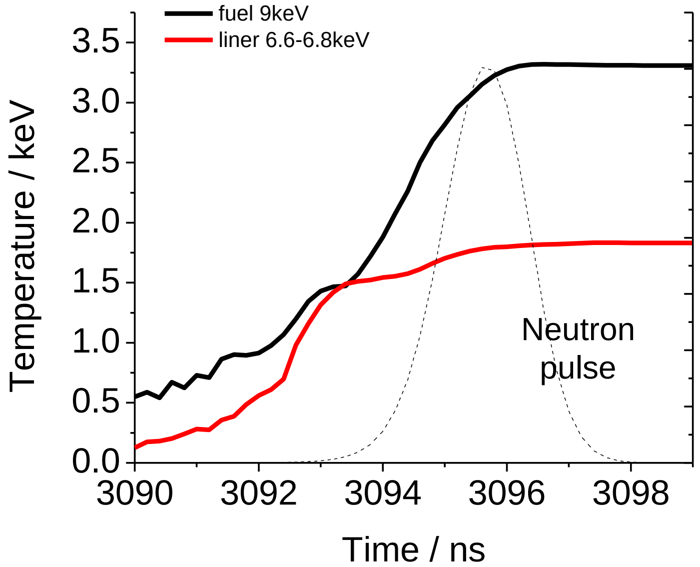


Fuel continuum weighted: **3.3keV**
Liner iron emission weighted: **1.8keV**

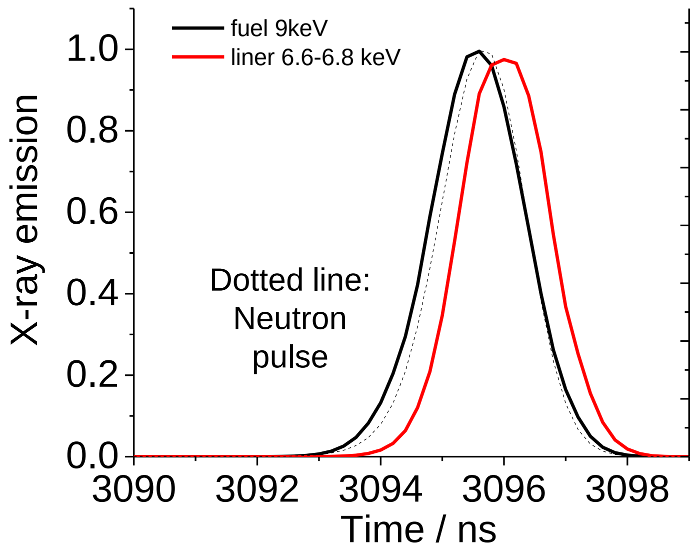
Fuel continuum weighted: **0.33 g/cc**
Liner iron emission weighted: **0.54 g/cc**

For clean fuel unstable liner stagnation, iron emission samples higher density lower temperature material

In this case, iron emission may be associated with later time disruption



For 1.7ns FWHM neutron pulse. Iron contaminant x-ray pulse delayed from fuel continuum x-ray pulse by ~0.5ns.
Fuel continuum emission is generally coincident with neutron pulse

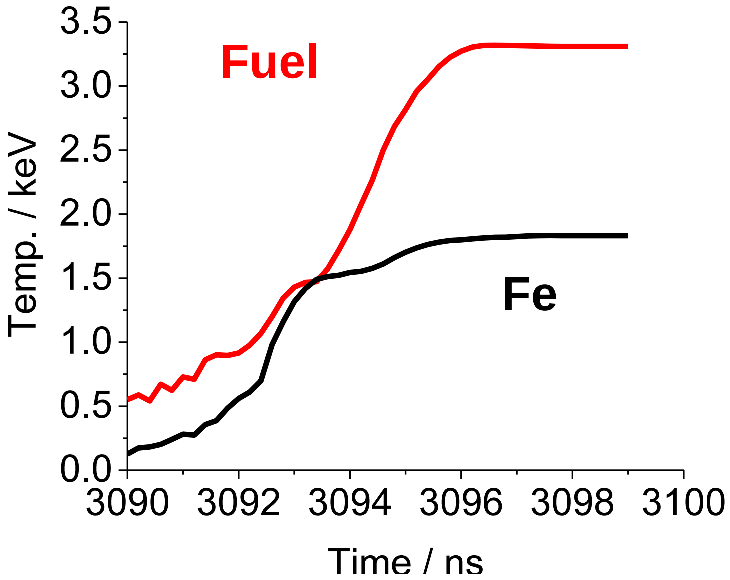


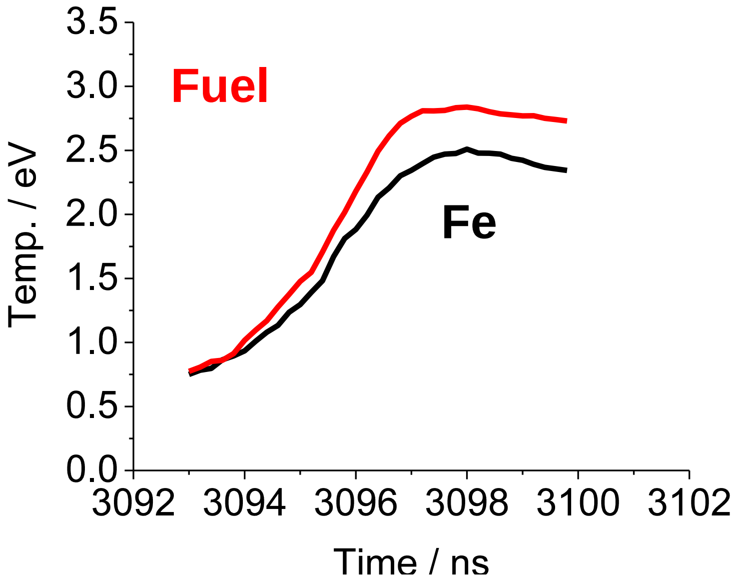
Normalized x-ray pulses from fuel continuum and iron liner contaminants

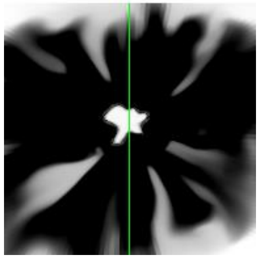
For Be mix uniform stagnation iron emission and fuel continuum still sample different temperatures due to temperature density gradients

For detailed discussion see S.B. Hansen, *et. al.* , PoP (2015)

Time integrated emission weighted temperatures

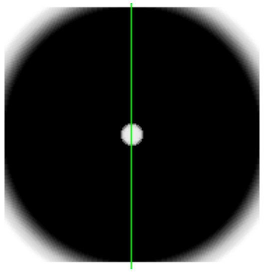






Penetration of iron carrying Be into cold fuel

Iron emission from fuel mix weighted to colder / denser edge of fuel



Summary:

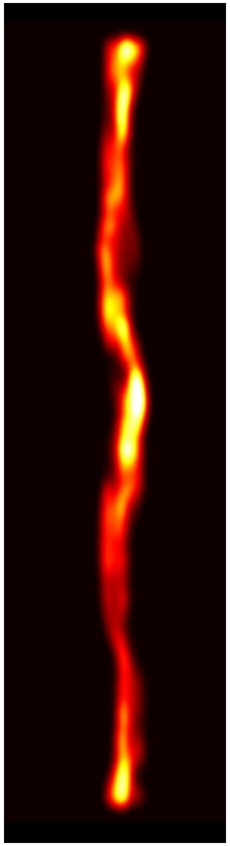
It's likely that some combination of reduced preheat / mix and instabilities are at play.

- Different mechanisms degrading Maglif performance can result in similar observables.
- Improved measurements, with targeted experiments will help is better balance the combination of mechanisms used in our calculations.
- Better determining dominant problems will determine directions taken to make progress

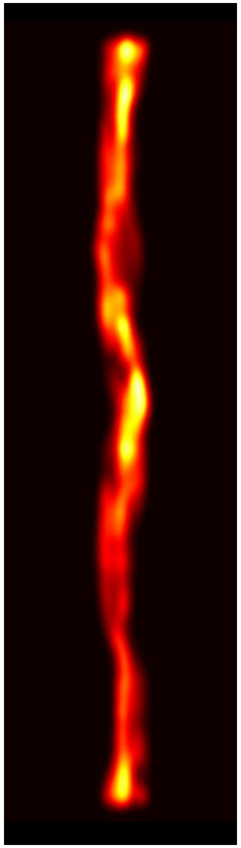
Backup

Neutron yield still scales favorably with preheat energy.

500 J/cm Preheat

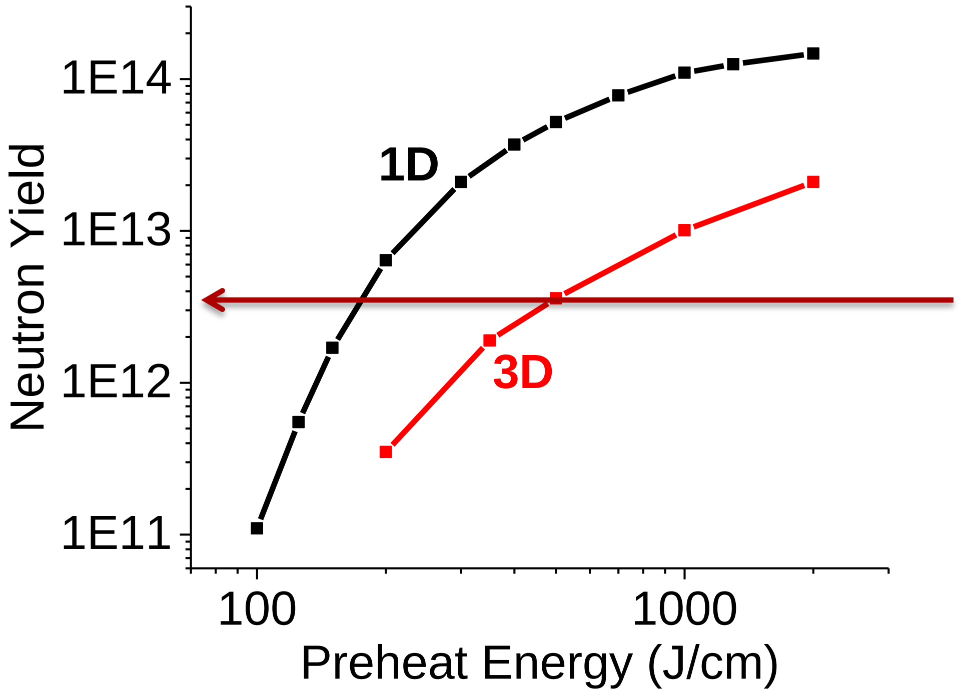


1kJ/cm Preheat



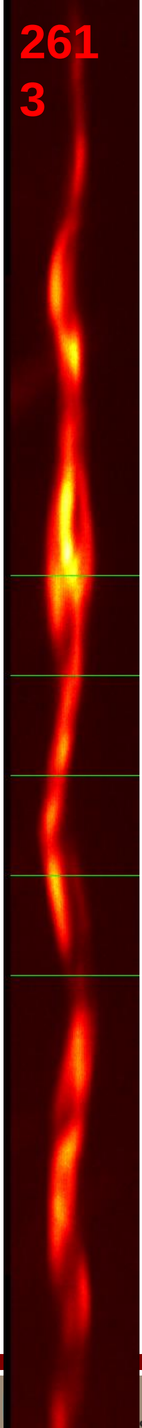
Negligible change in stagnation structure from increasing preheat energy

Yield vs Preheat Energy

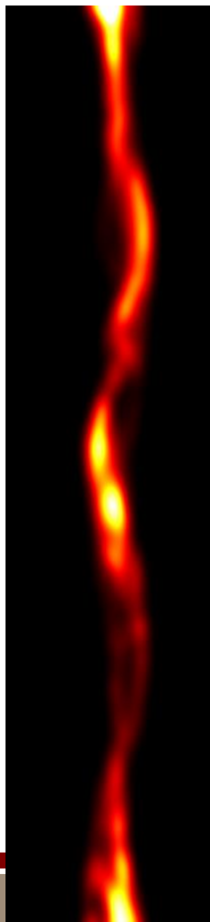


Yield still scales with increasing preheat energy, but magnitude lowered from 1D equivalent

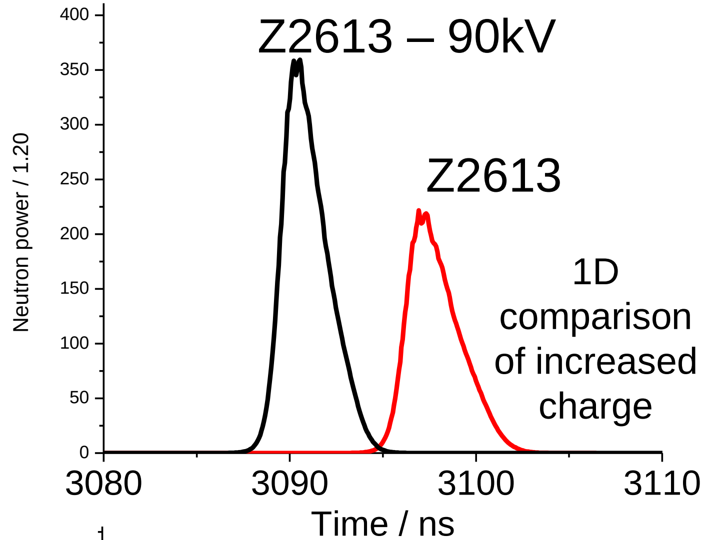
If implosion instabilities are significantly degrading yield then driving faster implosions at higher charge voltage may not help, and driving slower implosions may not hurt.

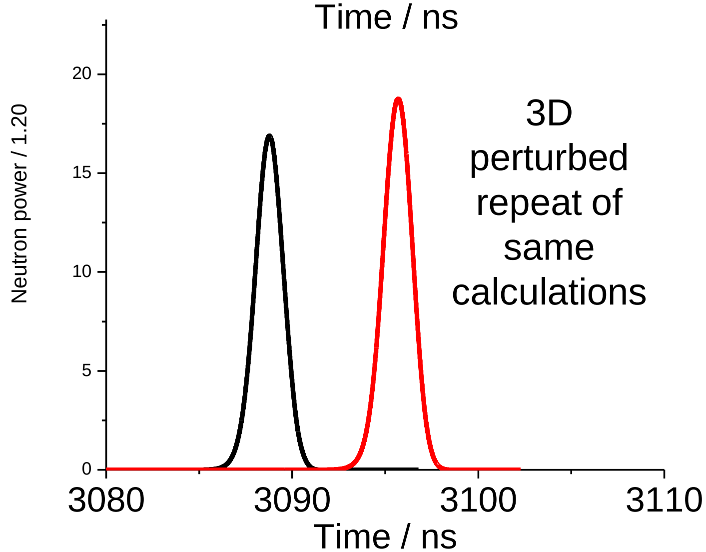


Perturbed Calculation Z2613

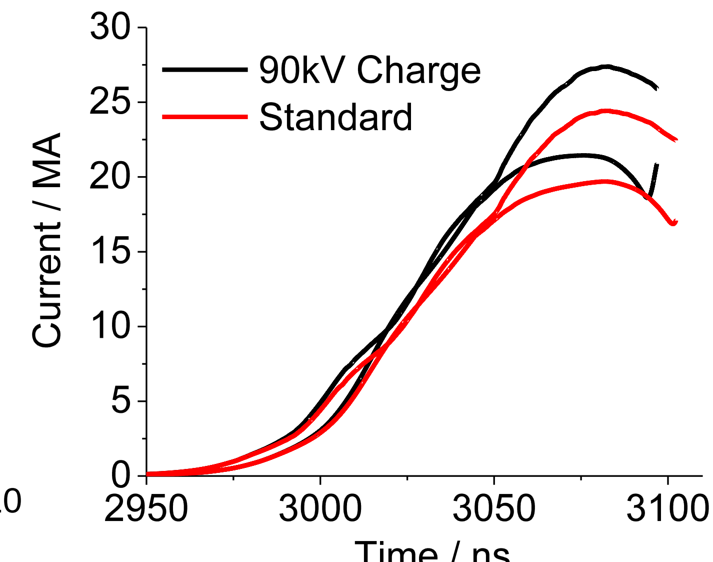


Neutron Pulses



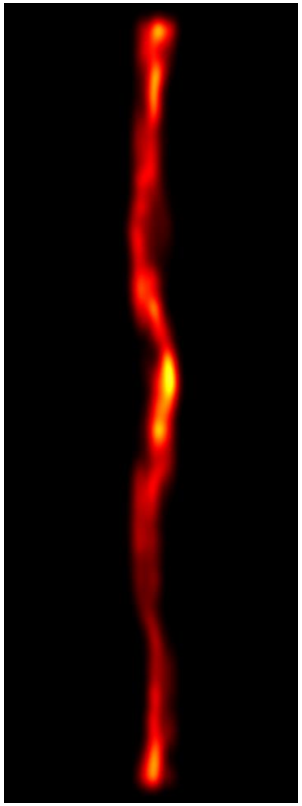


If performance gains rely on pushing the same liner harder, we might want to be cautious, as that's not going to help if implosion instabilities are limiting performance – will need to redefine liner.



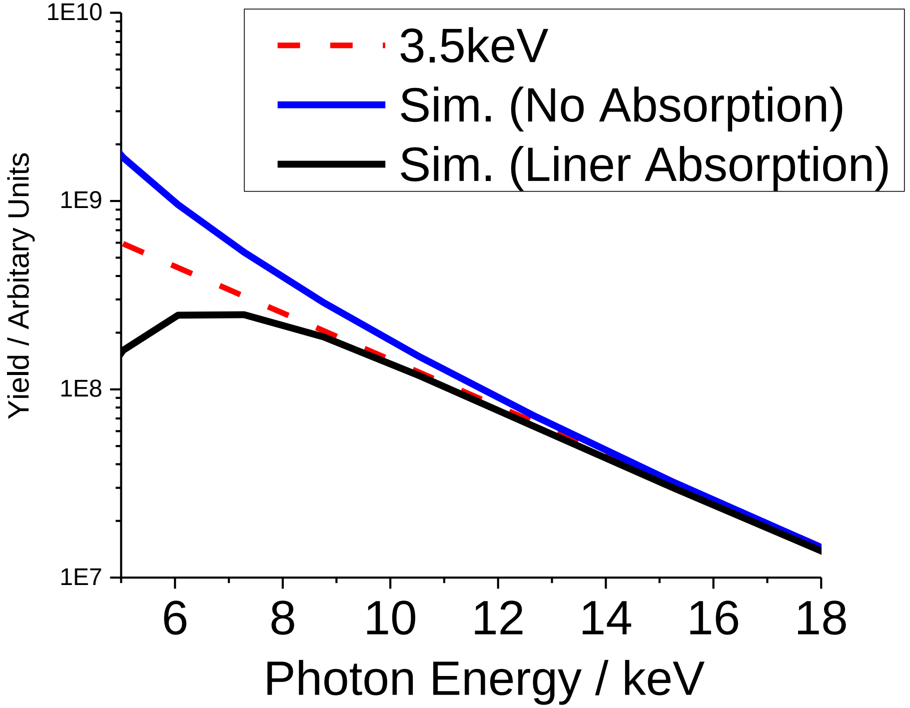
Continuum spectra reconstructed from stagnation simulation

For unstable stagnation with moderate preheat energy (500J) producing low 10^{12} neutrons



Time and spatially integrated continuum spectra.

For this calculation the time integrated burn averaged ion temperature was 3.5keV

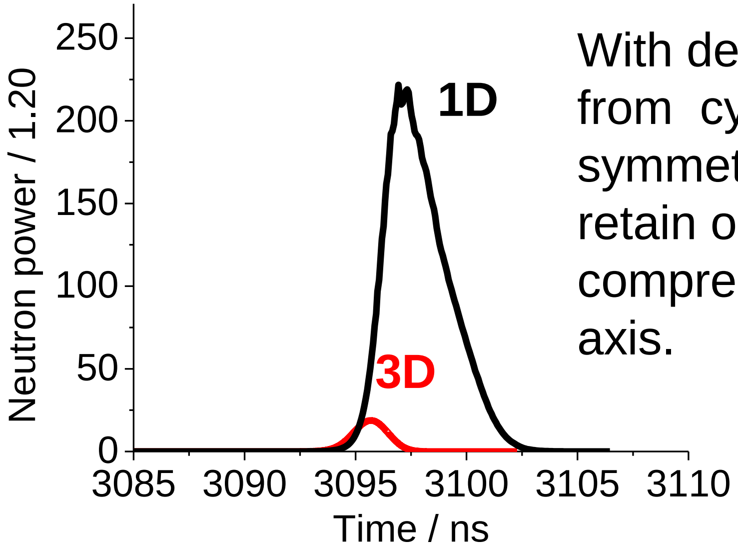


Black line – spectra including liner reabsorption
Blue line – neglect liner reabsorption
Red line – 3.5 keV continuum slope

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.