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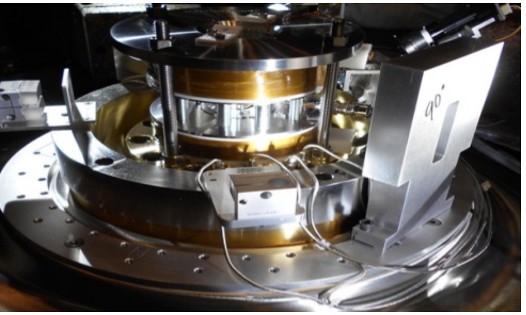

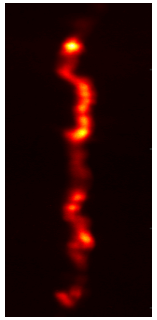

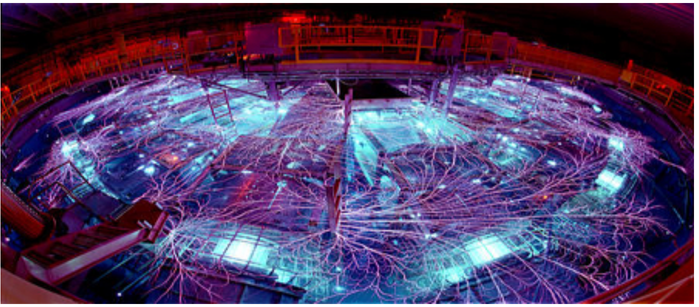

# Modifying MagLIF Stagnation Morphology by Changing Liner Initial Conditions

D.J. Ampleford, C.A. Jennings, M.R. Gomez, P.F. Knapp, E.C. Harding, K. Hahn, P.F. Schmitt, M. Weis, S.B. Hansen, D.C. Lamppa, T.J. Awe, K.J. Peterson, G.A. Rochau

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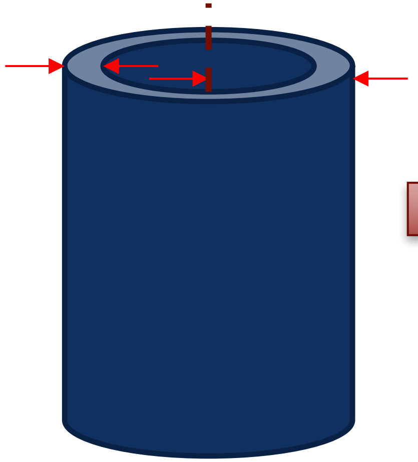
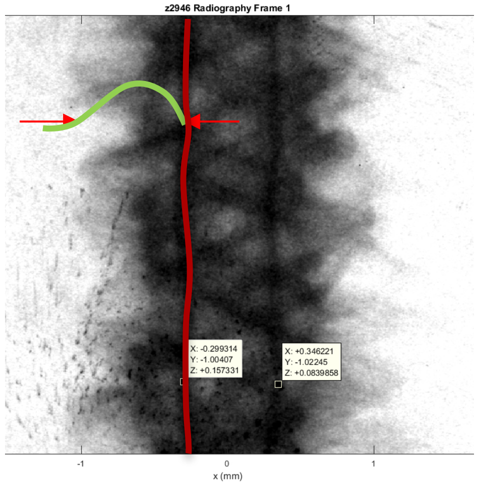
# How does liner initiation and initial liner geometry impact stagnation morphology and conditions?

- MagLIF exhibits non-uniformities at stagnation (helix and brightness)
- Postulated that this is caused by instabilities initiated on the outside of the liner
  - Instability theory indicates feedthrough should be inversely proportional to liner aspect ratio (outer liner radius/ liner thickness)
- Here we vary liner aspect ratio to explore feedthrough and also test dielectric coatings on full MagLIF shots to try to minimize seed of electro-thermal instabilities

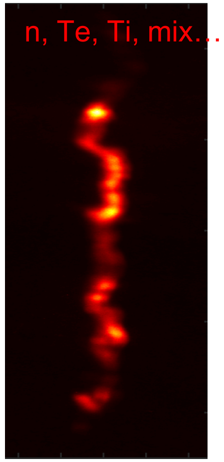
Initial liner configurations



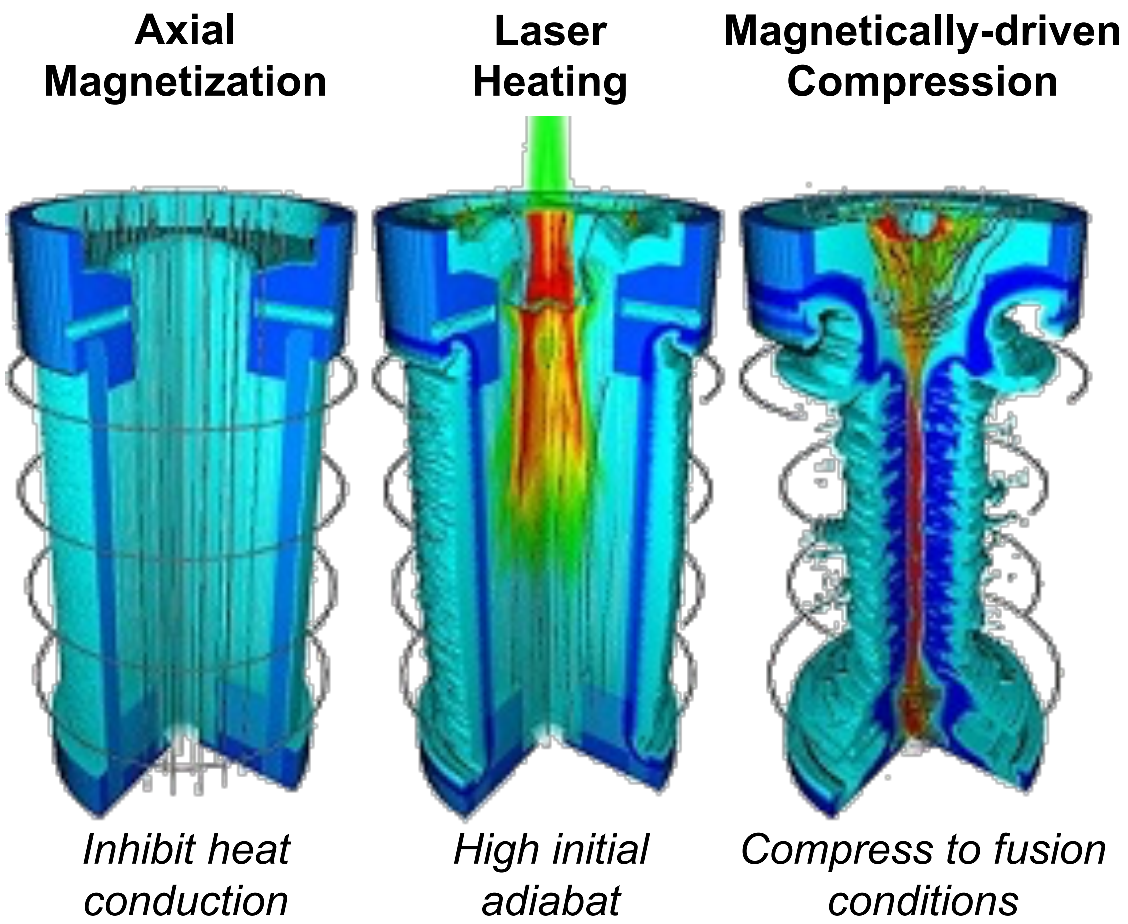
In-flight liner stability/density

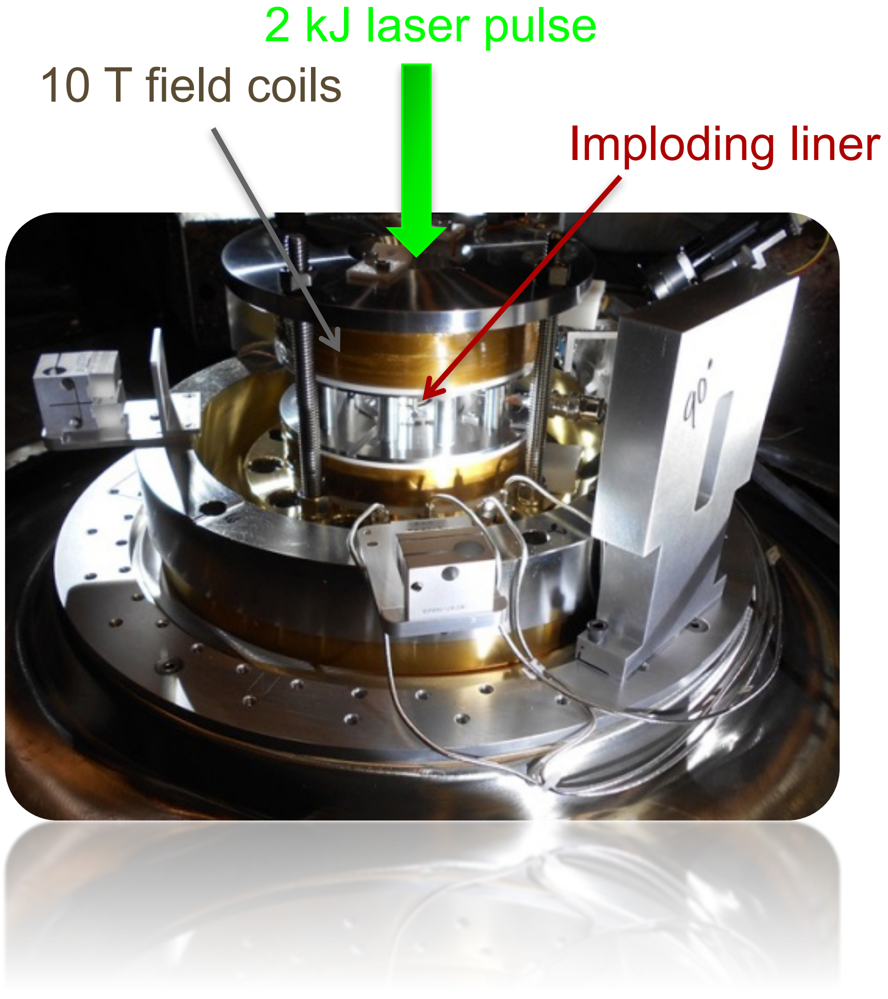



Stagnation structure/conditions



# MAGnetized Liner Inertial Fusion consists of imploding a pre-magnetized, pre-heated liner with the Z electrical pulse



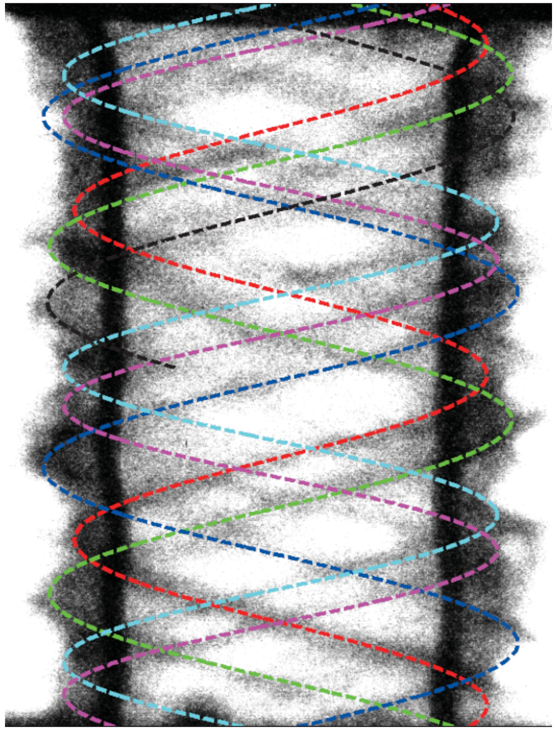

Dynamics from 3D MHD simulations, C.A. Jennings

Photograph of hardware from MagLIF experiment on Z

# Early MagLIF experiments indicated that these implosions are susceptible to helical instabilities during implosion and at stagnation

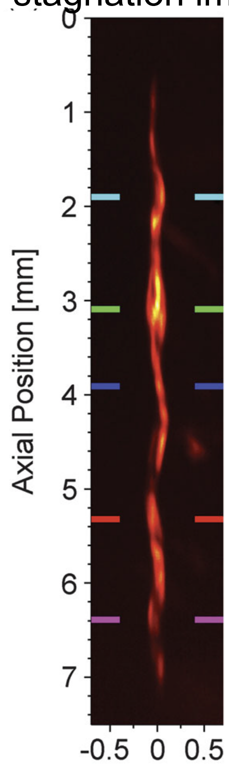
- Helical implosion structure
- Various hypotheses for cause

Early-time radiography
With axial B-field



Early-time Helical MRT structure

6/9 keV self-emission stagnation image




Helical structure at stagnation

- Helical mode
- Variations in brightness
- Bifurcation

Is there a connection between early-time helical outer structure and helical stagnation structure

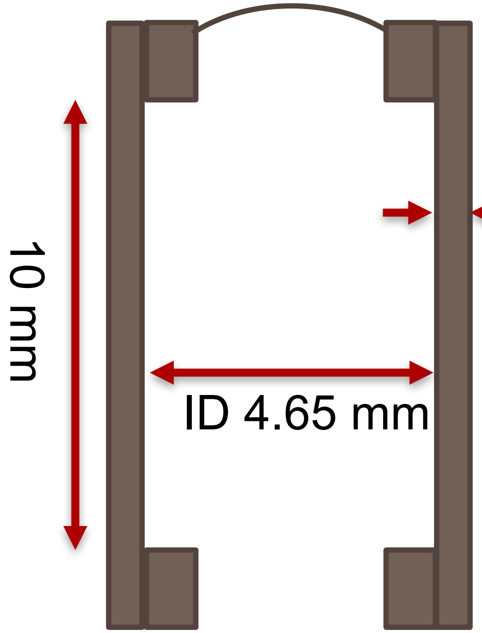
Is the final structure the result of MRT feedthrough?



T. J. Awe et al., Phys. Rev. Lett. 111, 235005 (2013). M. R. Gomez et al., Phys. Rev. Lett. 113, 155003 (2014).

# By varying the liner aspect ratio we aim to vary the feed-through of instabilities

Cross section:




| Liner Thickness | Outer Diameter | Aspect Ratio |
|---|---|---|
| 651 µm | 5.95 mm | 4.6 |
| 465 µm | 5.58 mm | 6 |
| 290 µm | 5.23 mm | 9 |

More robust to MRT feed through

**‘Standard’ MagLIF** (aspect ratio 6)

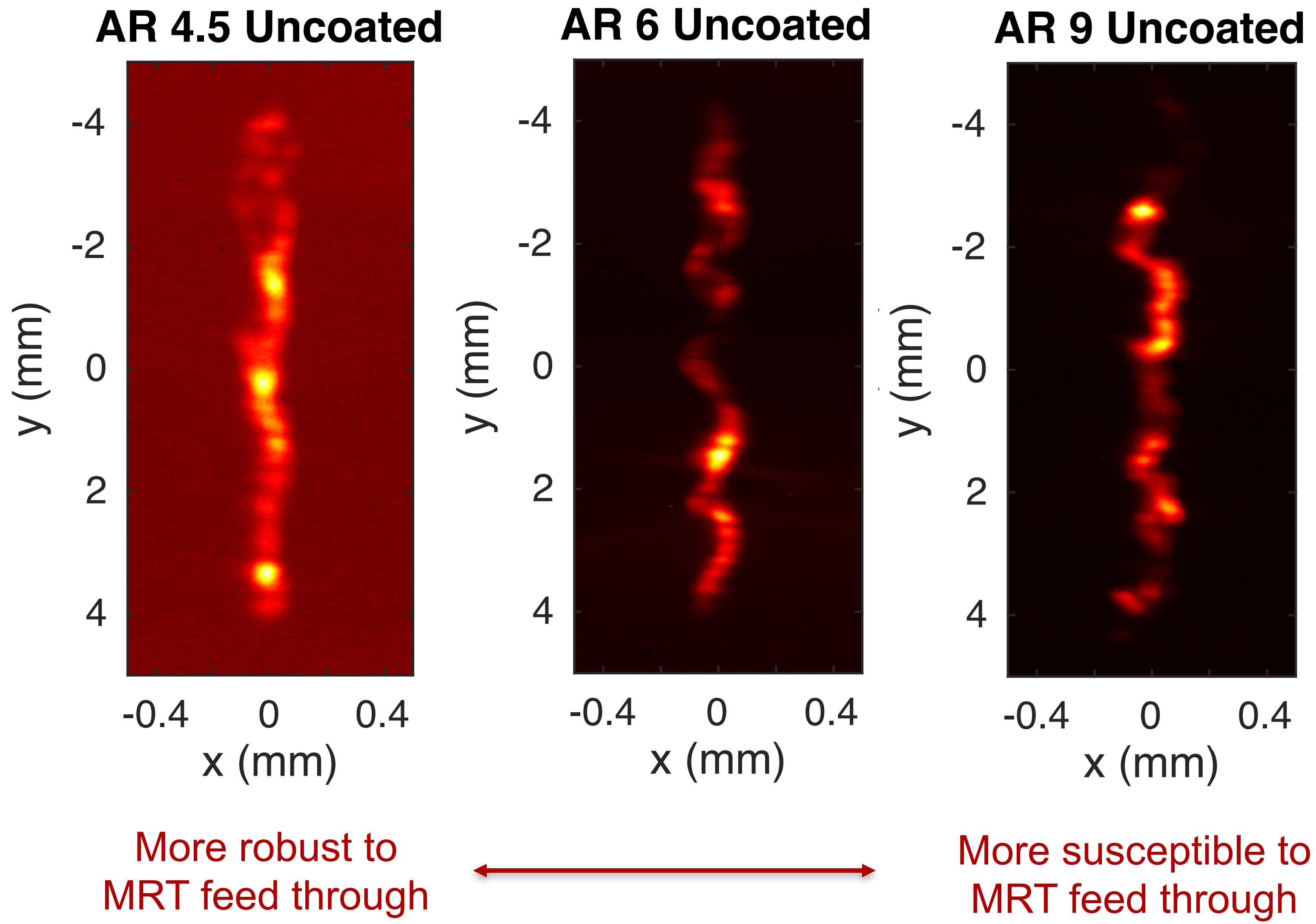
More susceptible to MRT feed through

Premagnetization, $B_z$ ~ 10 T
Incident laser energy ~ 0.4 kJ + 2.1 kJ
Deuterium fill density ~ 1 mg/cm$^3$

Keep inner diameter fixed to keep fuel volume and preheat fixed

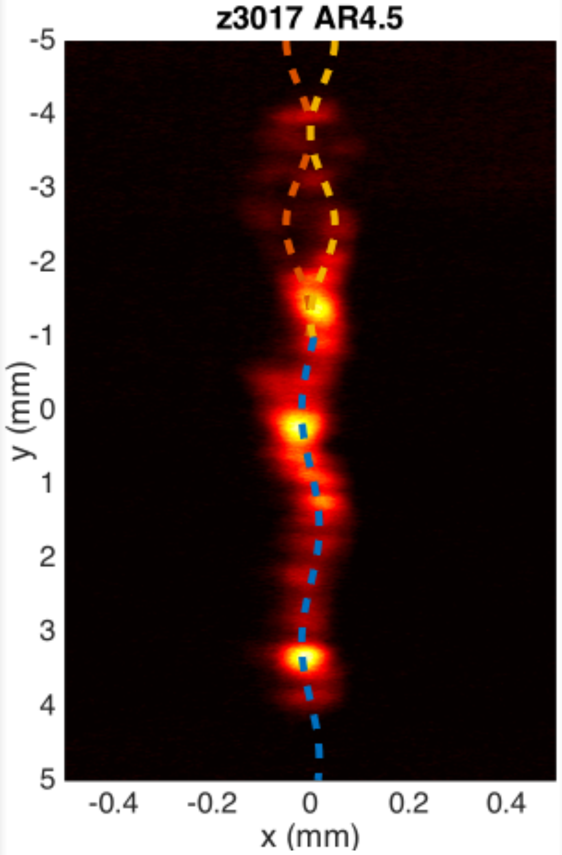
# Stagnation uniformity is inversely proportional to aspect ratio

- Data shown in spherical crystal imaging at 6+9 keV
  - Developed by E Harding
- Decreasing AR from typical AR 6 liner we showed improved stability & uniformity
- Increasing AR we showed a more unstable stagnation column



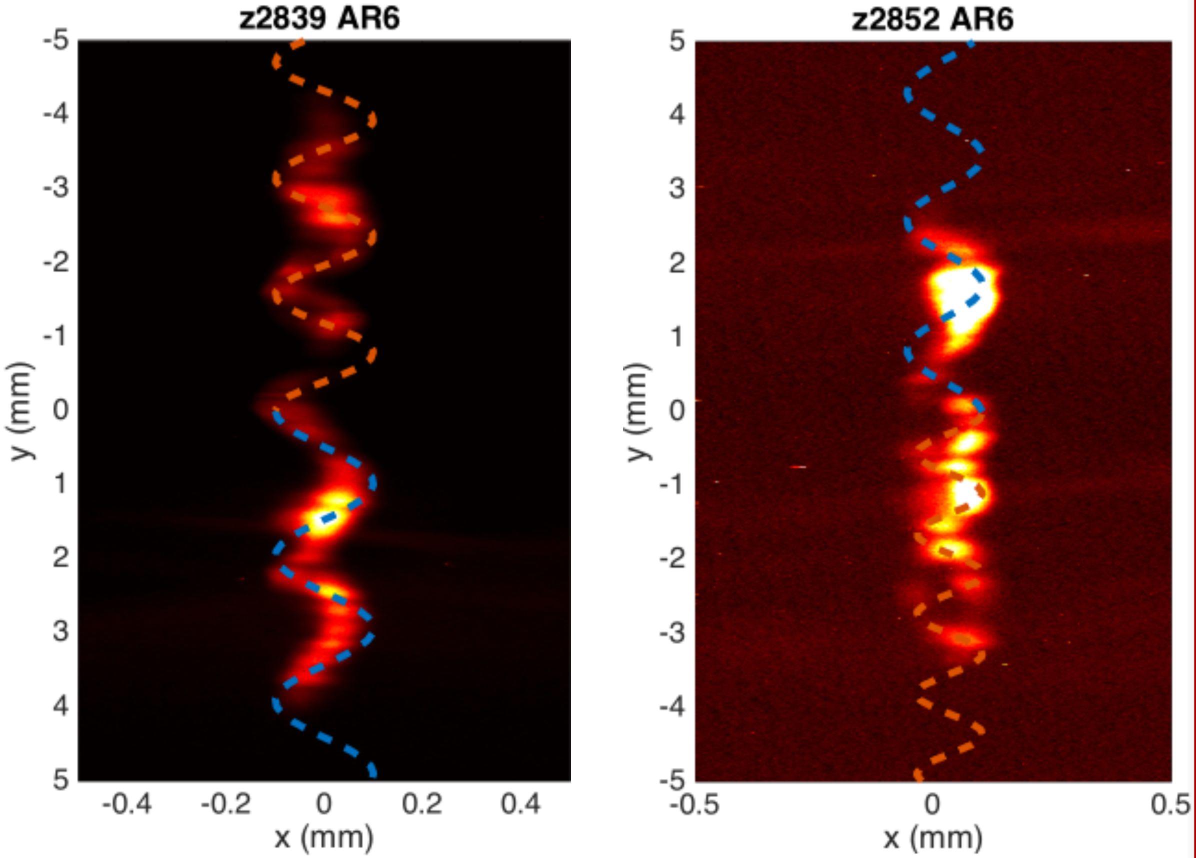
# Structures are significantly changed with different aspect ratios

## Aspect Ratio 4.6



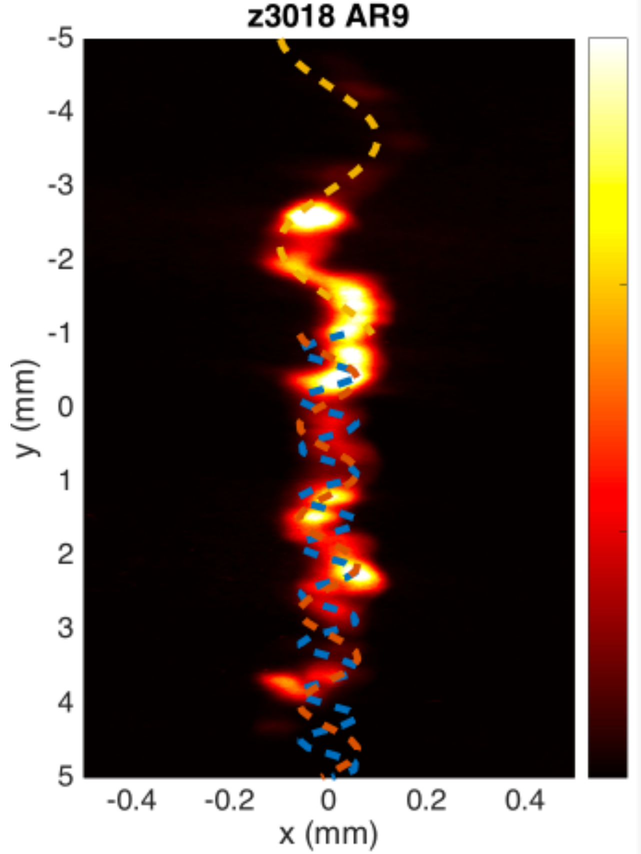

- Near continuous column
- Bifurcation near top

## Aspect Ratio 6



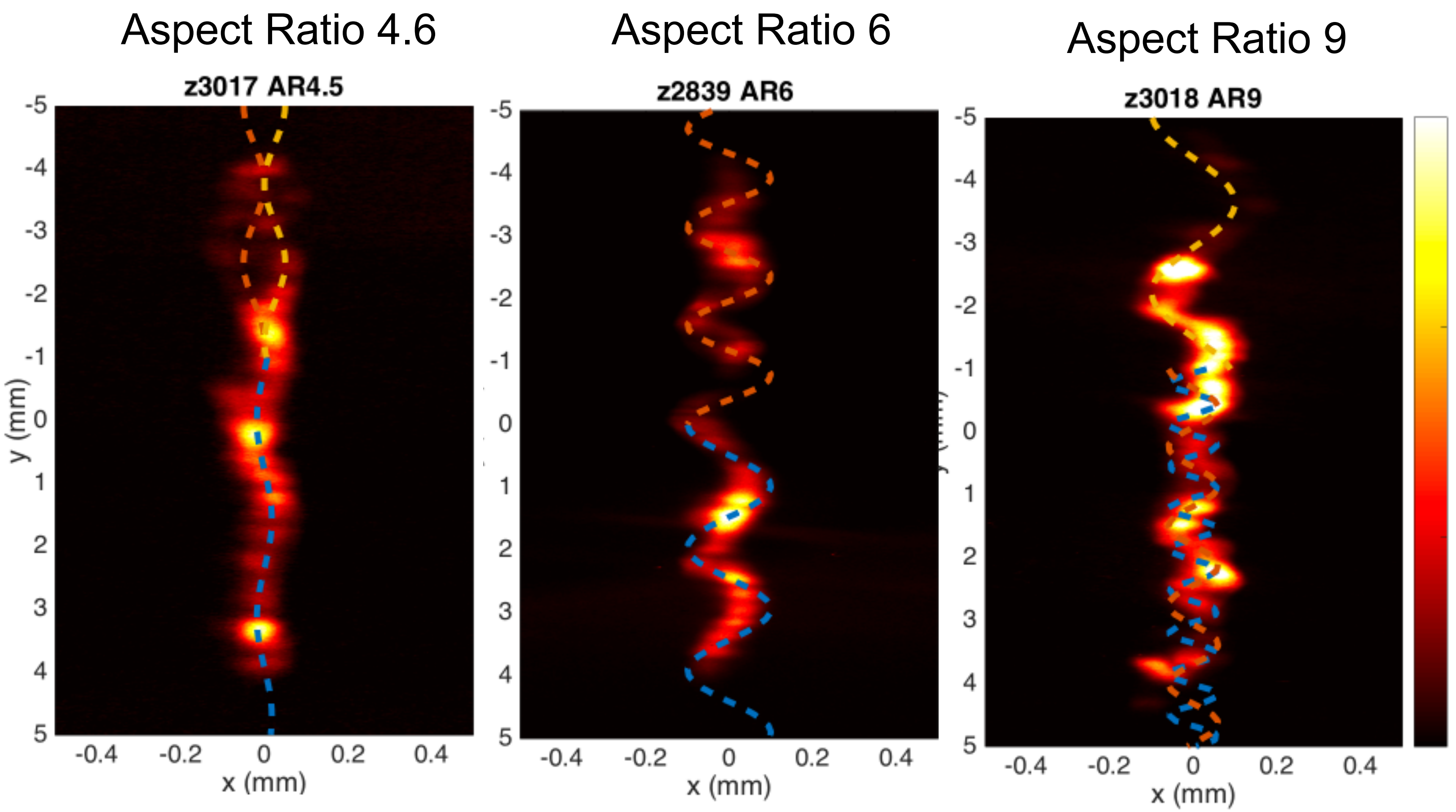

- Spotty structure
- Bifurcation on some shots

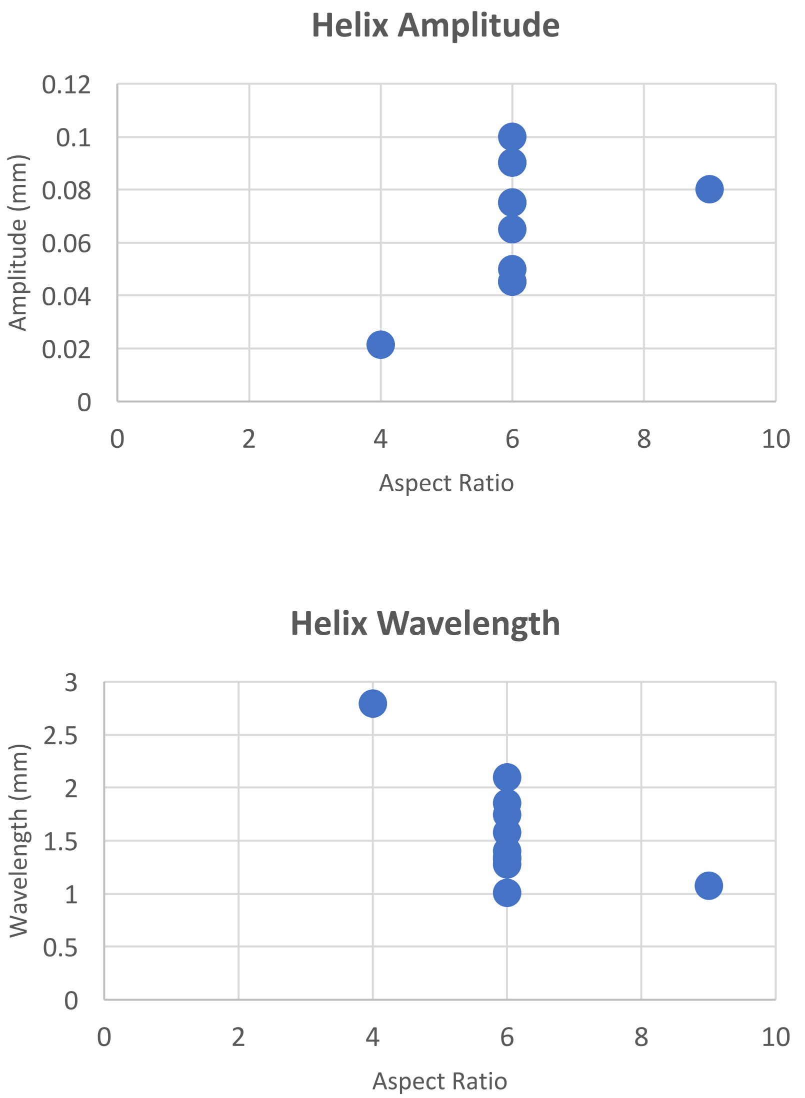
## Aspect Ratio 9




- Complicated structure
- Many overlapped modes
- Change in wavelength at top

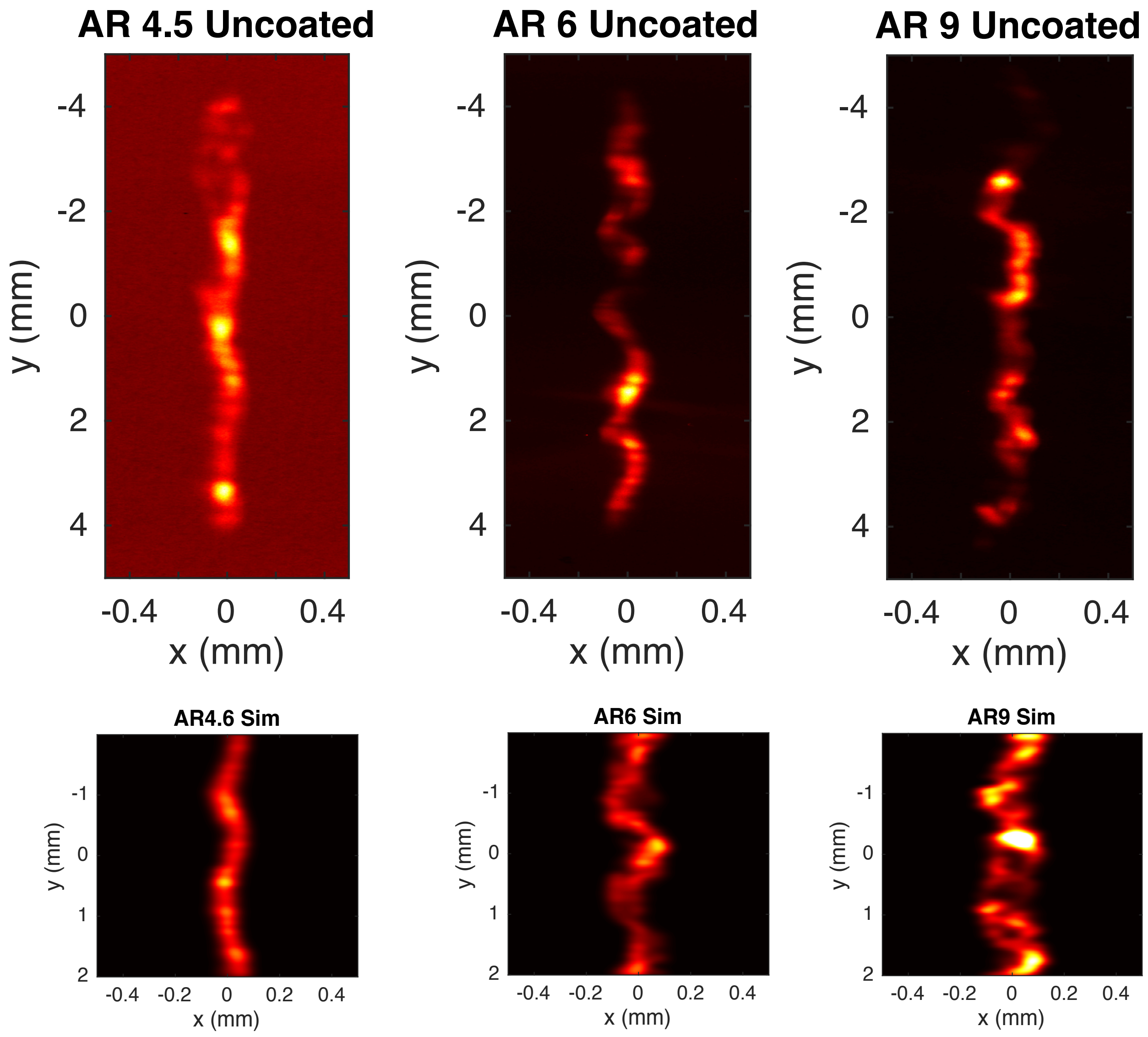
# Amplitude and frequency of helical structure increases with aspect ratio



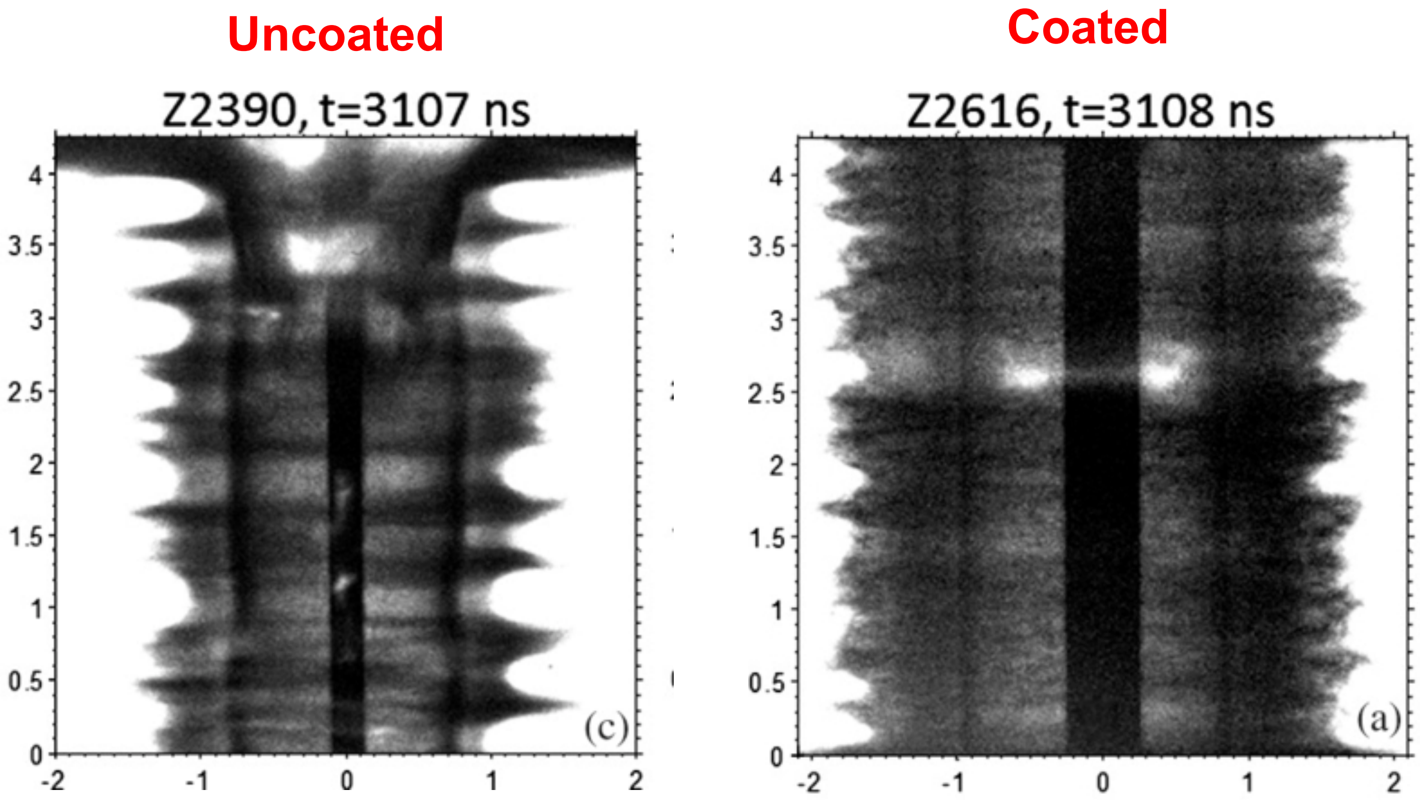
# We have shown promising predictions of stagnation stability under different initial conditions

- Shown are comparison of experimental and pre-shot simulated monochromatic images
- Full height simulations are underway to give more appropriate comparison
- Work continuing on comparison of plasma parameters

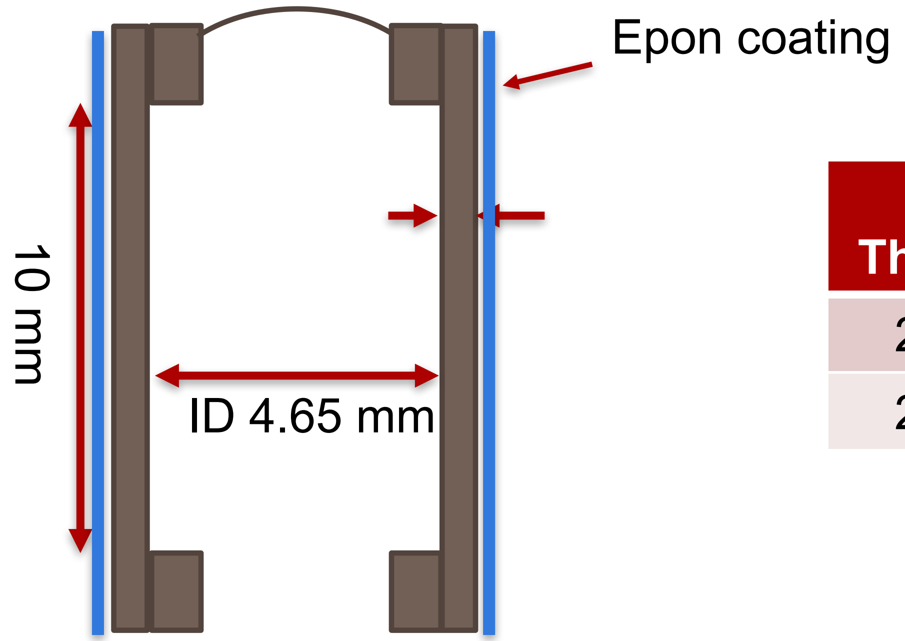


# Previous Z experiments have demonstrated that dielectric coatings can tamp early-time electro-thermal instability growth, and enhance implosion stability

- Experiments by T. Awe et al. have shown that imploding surface of liner is more stable if a thin dielectric coating is used on the outer surface of an aspect ratio 6 liner
- Experiments use a Pt tracer to identify inner surface of implosion



# We explored the stabilizing role of dielectric coatings on high aspect ratio liners



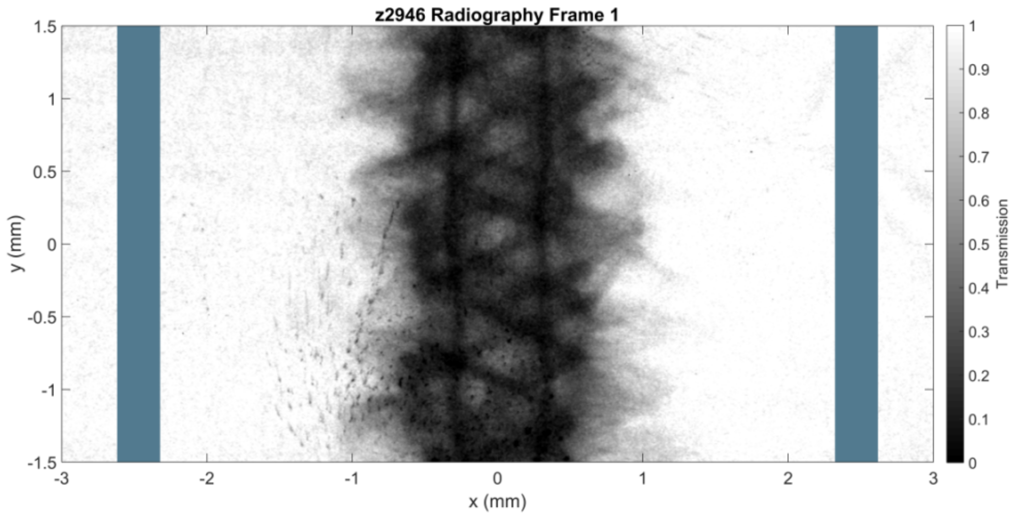

| Liner Thickness | Outer Diameter | Epon coating | Complete mass |
|---|---|---|---|
| 290 μm | 5.23 mm | 0 | 8.3 mg |
| 242 μm | 5.13 mm | 75 μm | 8.3 mg |

**Use aspect ratio 9 liner (most unstable) and compare this to a coated liner with the same mass**

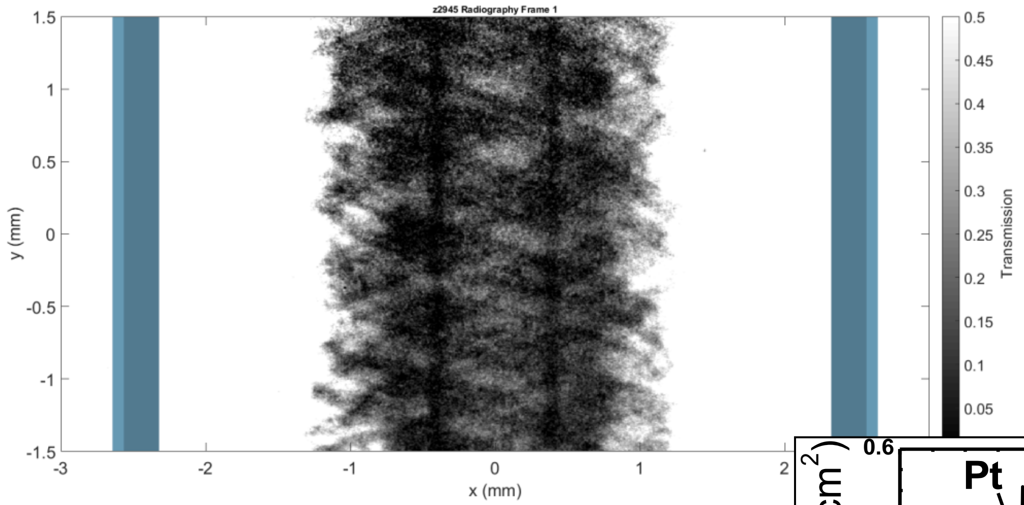
Keep inner diameter fixed to keep fuel volume and preheat fixed

# Consistent with previous aspect ratio 6 work, radiography demonstrates enhanced stability with coatings for aspect ratio 9 liners; mass profile is changed

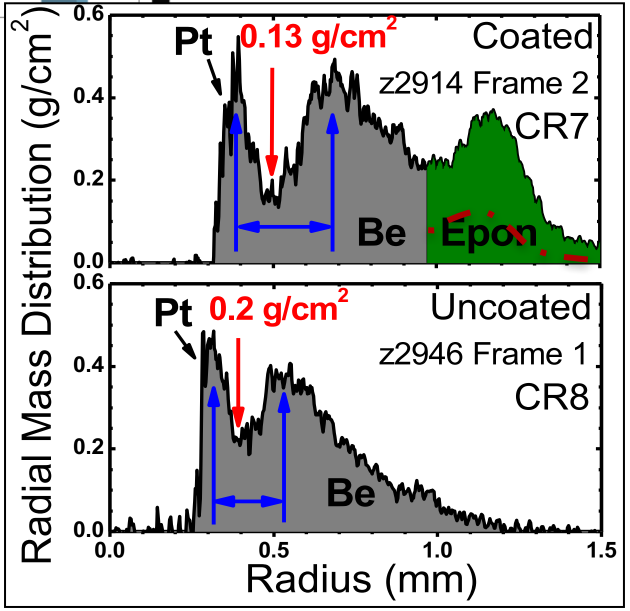
**Uncoated**




**Coated**

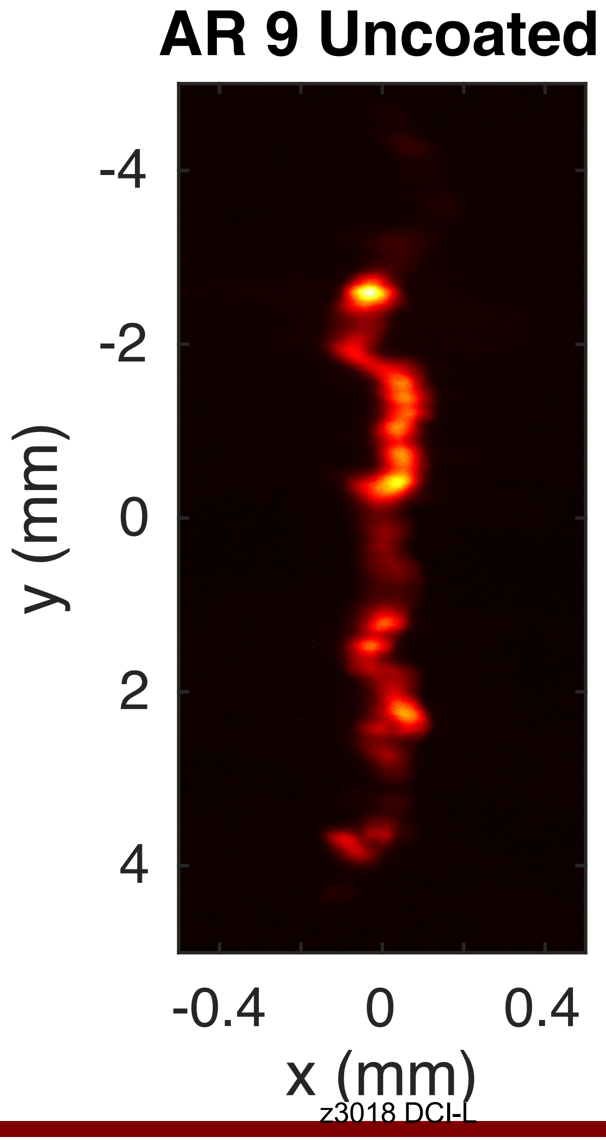


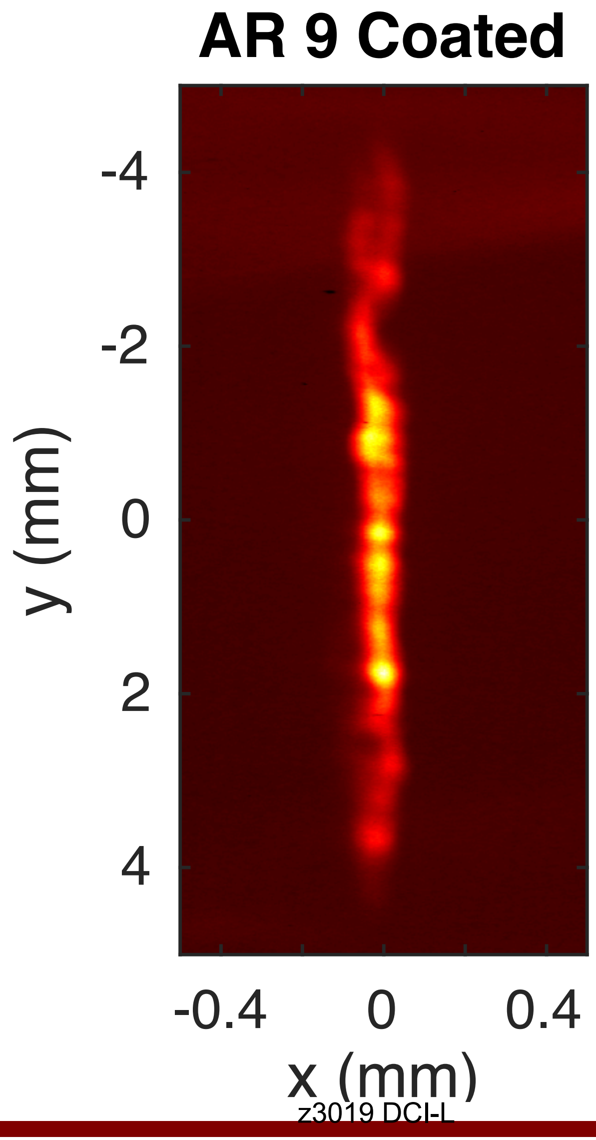

- Both coated and uncoated aspect ratio 9 liners show continuous, well defined implosion front to
- More uniform implosion front on coated
- Difference in mass distribution between two



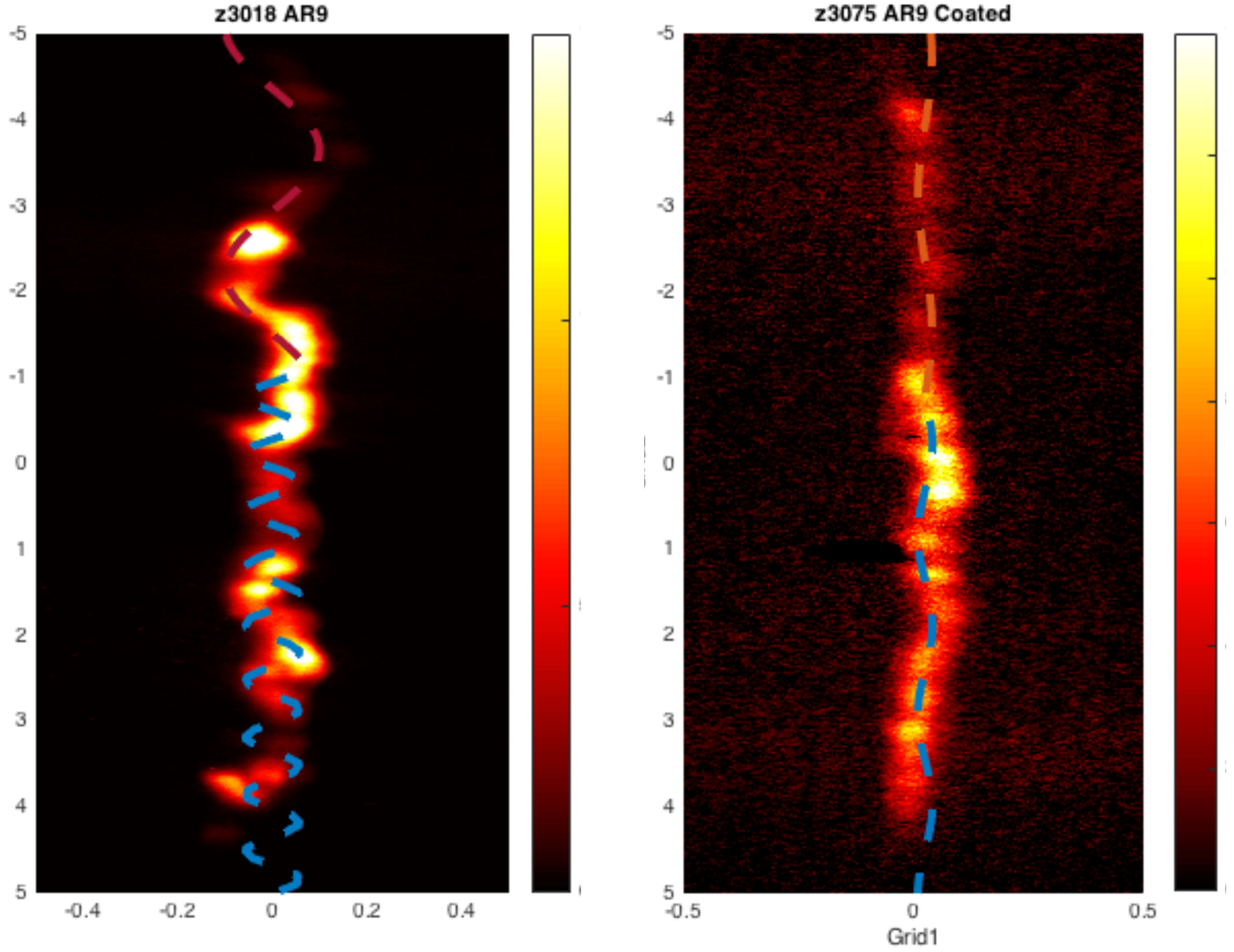
# At stagnation, find that coated liners can significantly aid stability

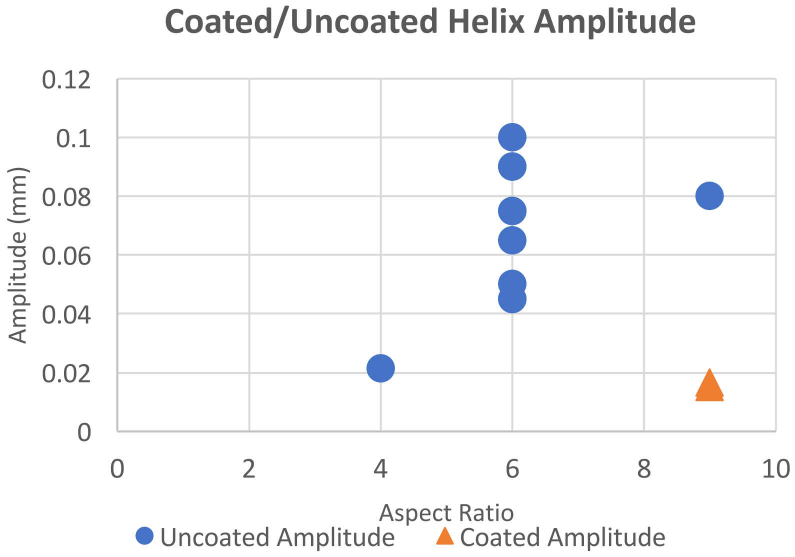
- Uncoated AR 9 was least stable/uniform implosion
- With coating, AR 9 can provide much more uniform column
- For AR 9, coating does not diminish yield
  - If anything enhanced from 2.2e12 to 3.0e12
  - AR 6 showed lower yield with coating (Gomez APS-DPP 2016)
- DT yield and spectrum indicate magnetization as good as most uncoated stagnations

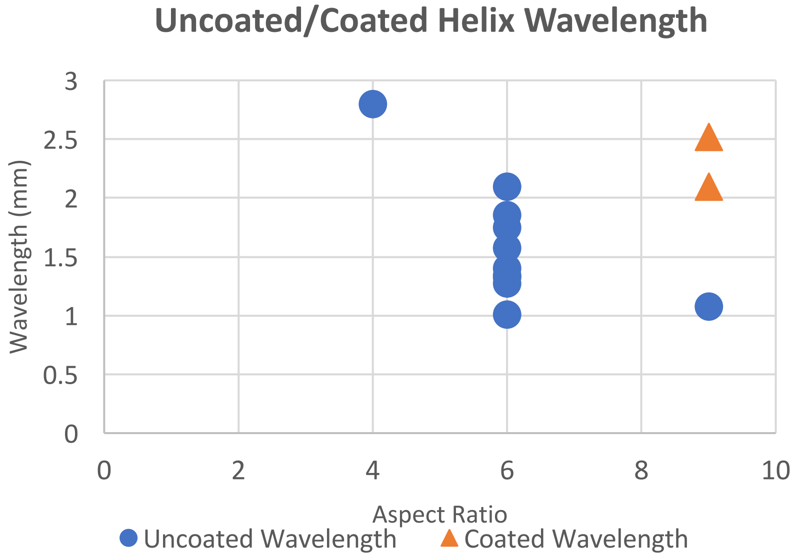


# Coating has significant impact on frequency and amplitude of helix



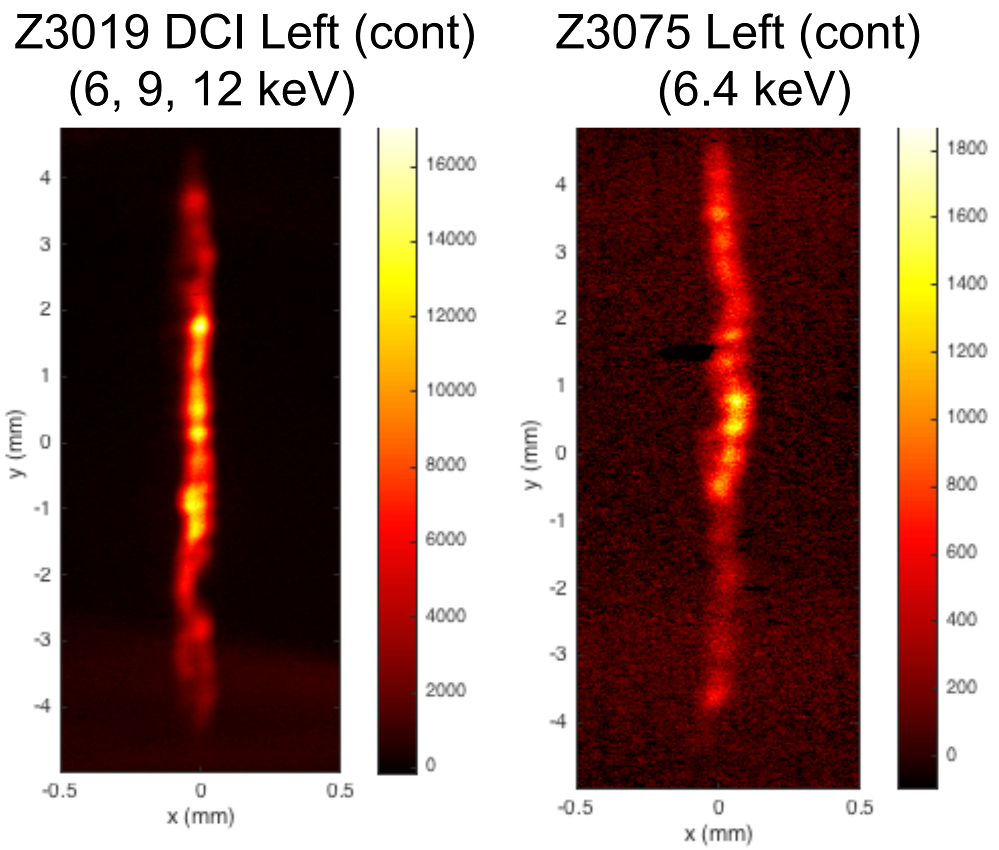



# Initial indications are that coated AR 9 liners shows promising reproducibility

- Both experiments with coated aspect ratio 9 liners showed quasi-uniform column and good yield and magnetization
  - Some changes is structure as shown by continuum images
  - Yields reproduce well

| | 3019 | 3075 | Variation |
|---|---|---|---|
| DD | 3.0e12 | 2.6e12 | -13% |
| DT | 4.8e10 | 4.1e10 | -15% |
| DD/DT | 62.5 | 63.4 | 1.4% |
| $T_e$(cont.) | 3.0 | 3.3 | +10% |

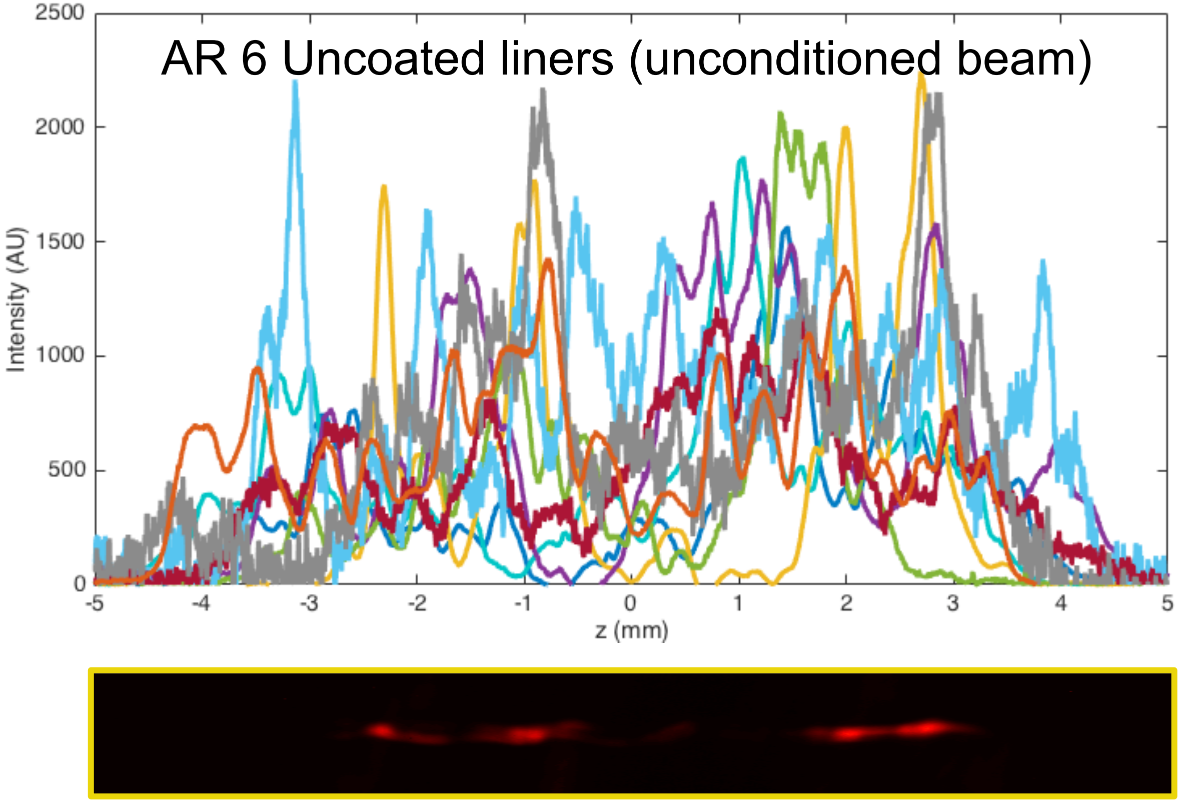


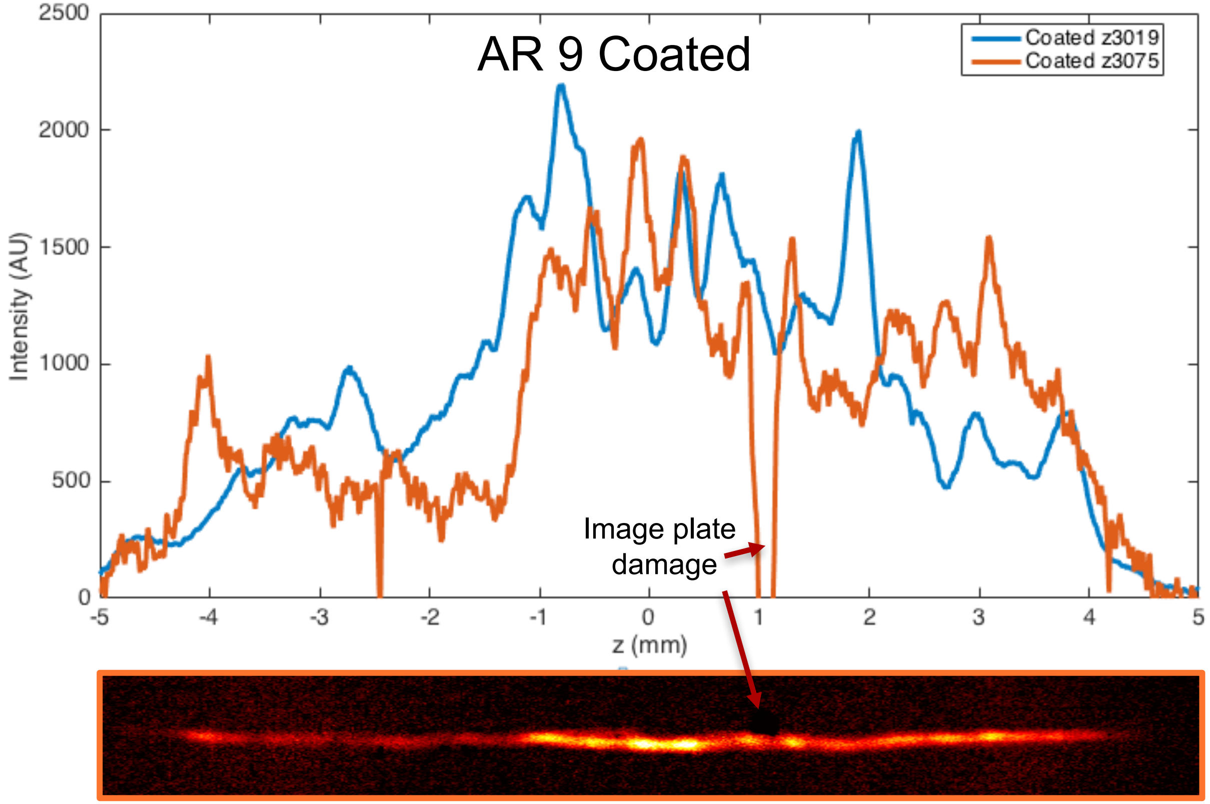
# X-ray intensity is significantly less axially-varying with coating

- Axial structure in typical uncoated AR6 shows significant variation
- Often emission series of bright spots rather than column

- Coated AR 9 exhibit significantly more uniform structures
- Coated AR 6 show similar (Gomez APS 2016)

Axial lineouts through central emission region



# Summary

- Liner stagnation structures change significantly with aspect ratios
  - Consistent with instability feed through
- Coatings significantly aid stability and uniformity
  - Promising for a good uniformity MagLIF platform

# Future directions

- Continue to quantify differences in stagnation structures
- Look at differences in stagnation conditions
- Diagnose evolution of stagnation with time resolved imaging
- Continue to study reproducibility of coated liner stagnations