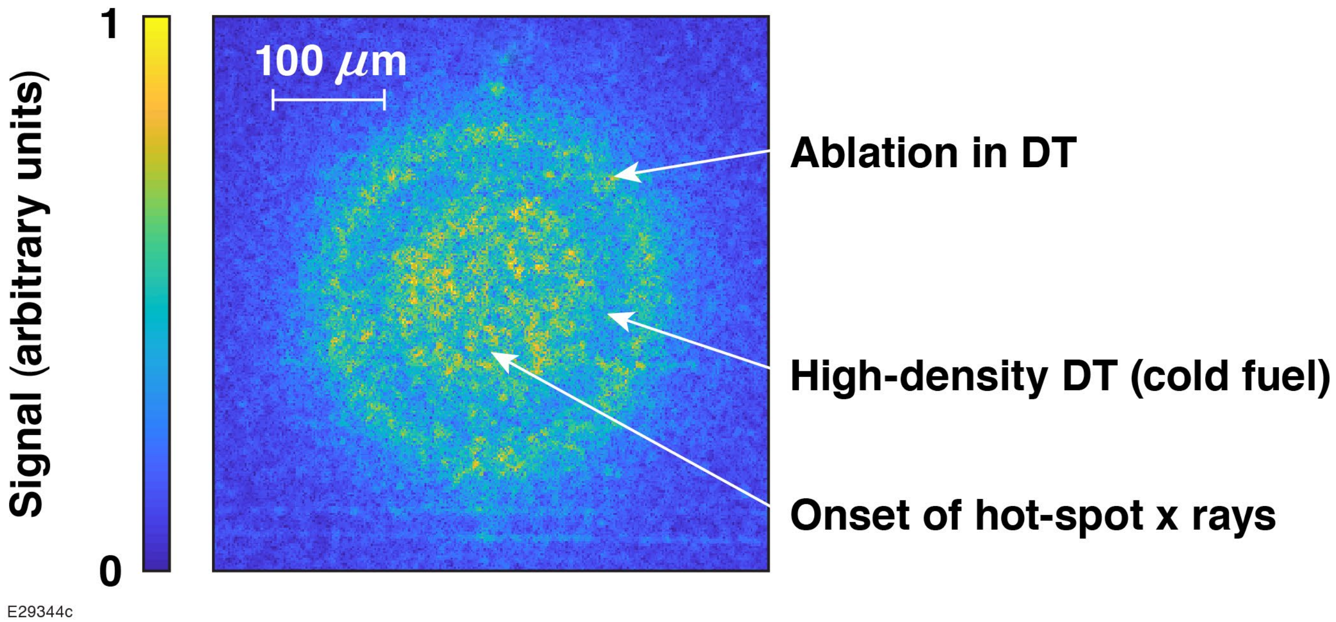
Anomalous X-Ray Emission at the Early Stages of Hot-Spot Formation in Deuterium–Tritium Cryogenic Implosions

Framed, soft x-ray self-emission from DT cryogenic implosion at CR ~ 3



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The onset of hot-spot x-ray emission in experiments is used to infer conditions at the start of deceleration

- The onset of the hot-spot x-ray self emission in experiments occurs when the ablation front is at a larger radius than calculated by models*
- Thicker shells [lower in-flight-aspect-ratio (IFAR)] and higher adiabats (α) reduce, but do not eliminate the discrepancy
- The image data suggests the dense fuel encounters instability growth and is decompressed at the start of deceleration beyond what is expected from nominal modeling with laser imprint

* R. C. Shah *et al.*, Phys. Rev. E 103, 023201 (2021).

Collaborators

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University of Rochester
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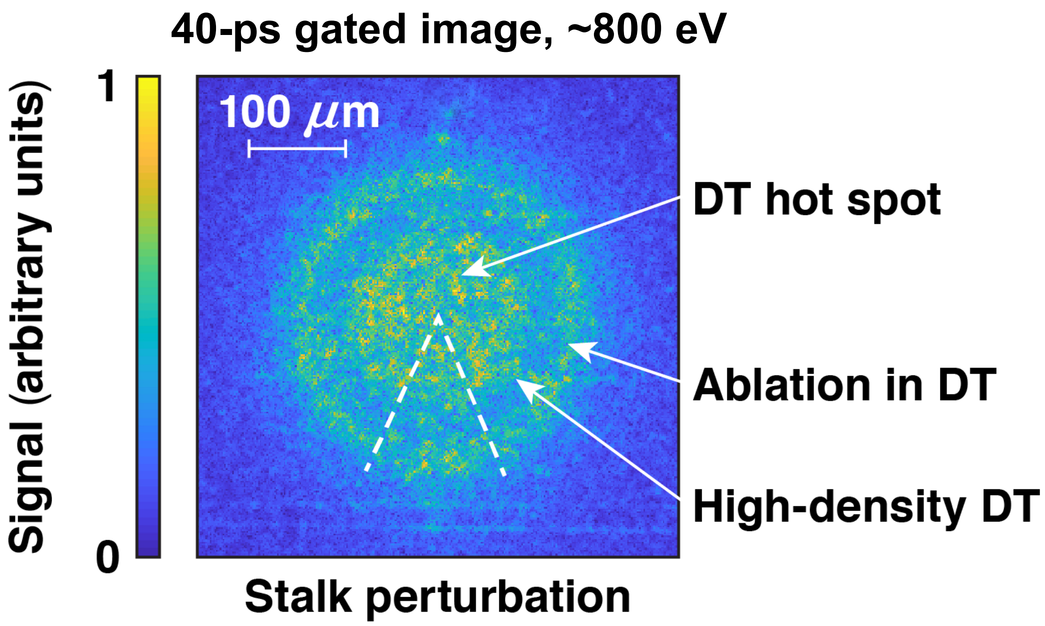
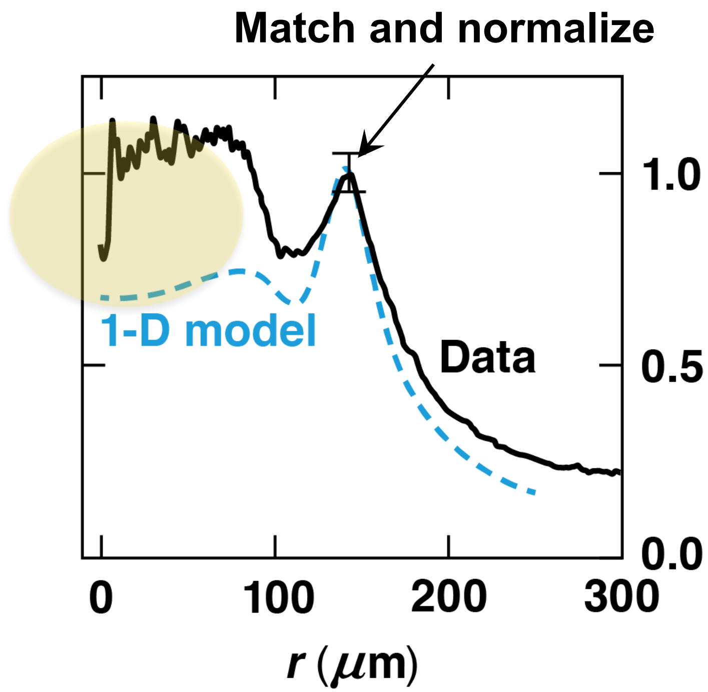
An observed discrepancy in the onset of hot-spot x-ray self-emission motivated its use to diagnose early-stage hot-spot formation





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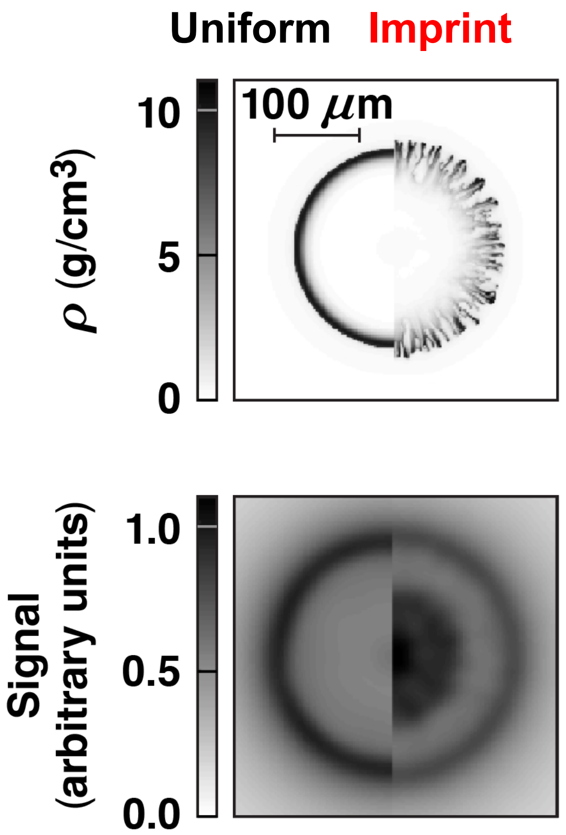
Imprint *can* cause early hot-spot emission

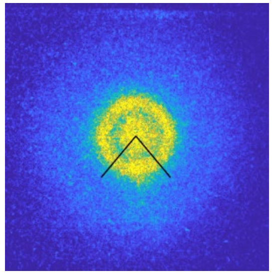
ASTER*

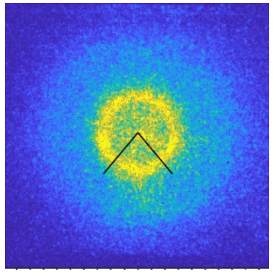
- α = 1.7, IFAR = 39
- 90% yield reduction due to imprint
- Mix is a small fraction of the enhancement in this simulation

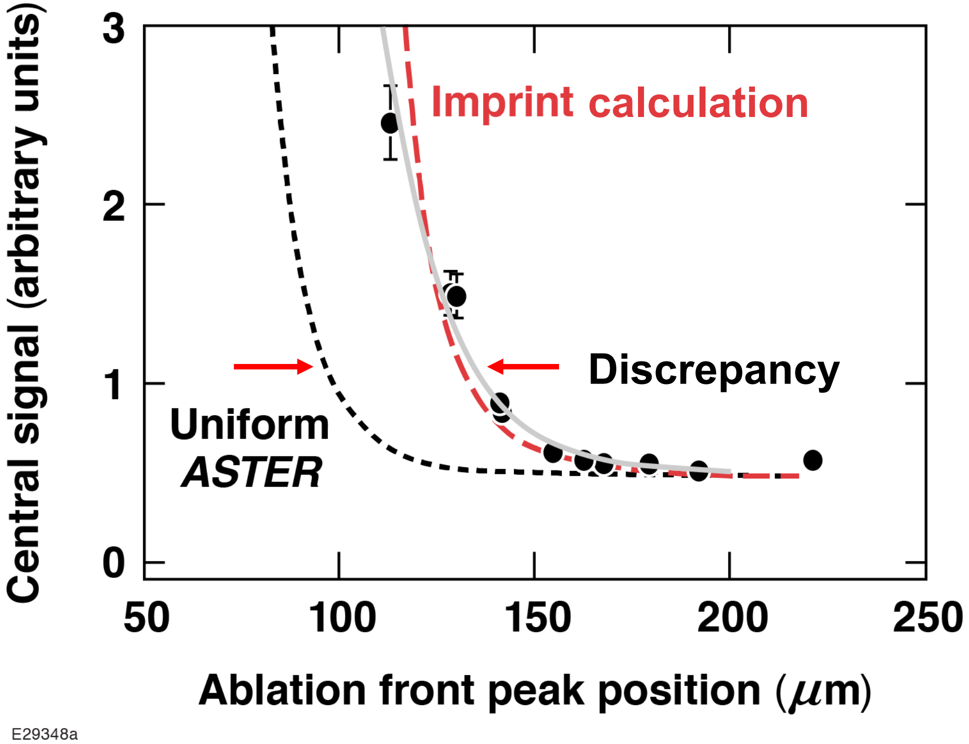


* I. V. Igumenshchev *et al.*, Phys. Plasmas 23, 052702 (2016),
I. V. Igumenshchev *et al.*, Phys. Rev. Lett. 123, 065001 (2019).

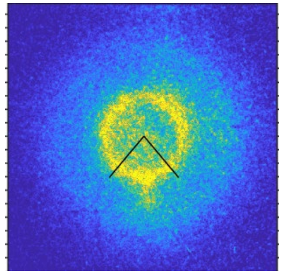
The onset is measured in experiments by using a sequence of framed images

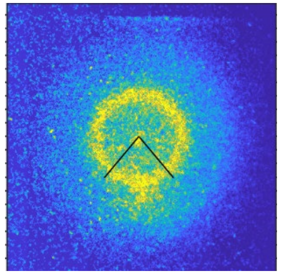






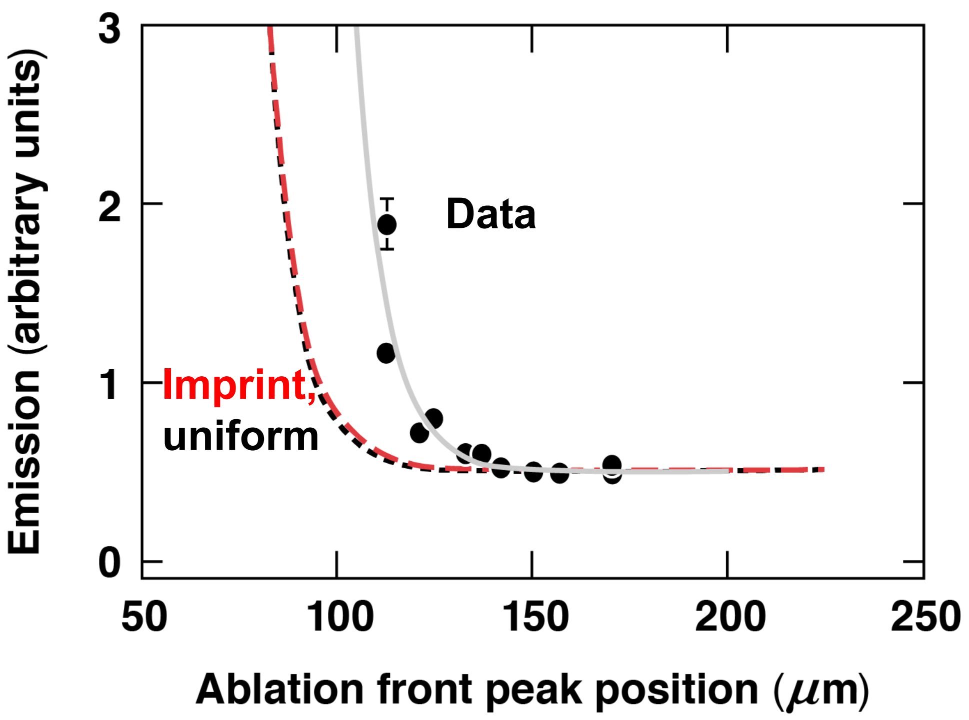
- When conditions are well defined by dominant role of imprint, there is good agreement between analysis and the 3-D imprint model





Time

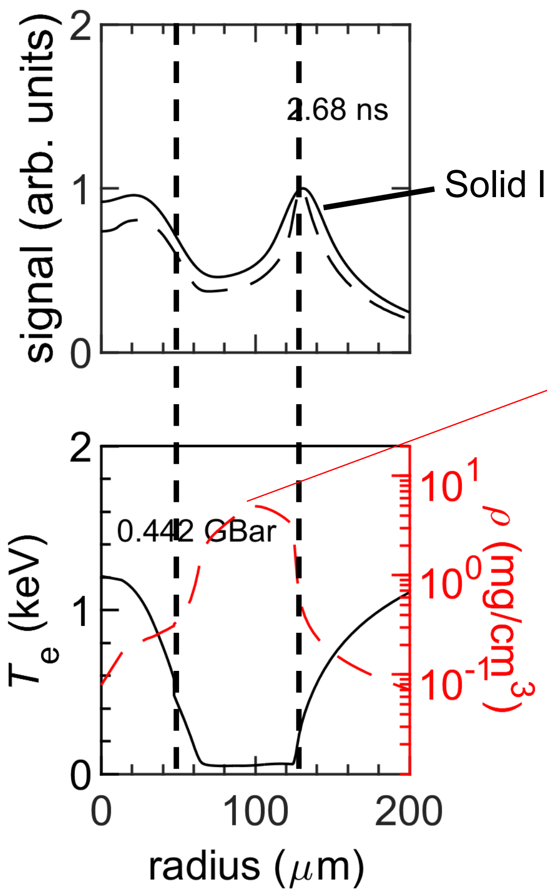
Imprint is not predicted to cause a discrepancy for a more-stable implosion, however a discrepancy (albeit smaller) still persists in the experiment



- α = 2.8; IFAR = 24.5
- experiments with lower IFARs and higher adiabats show discrepancy persists
- A similar observation is insensitivity of performance to imprint at higher adiabats*

* J. P. Knauer, NI02.00002, this conference (invited).

The cold DT region appears thicker* than in models

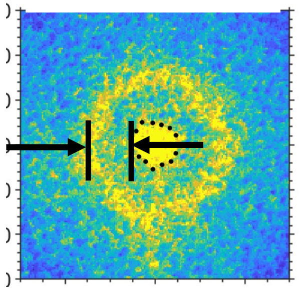


Solid line is with spatial blur

Dense fuel (thick layer and slow implosion are an advantage for this analysis)

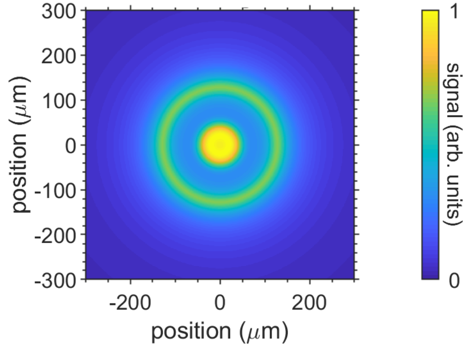
measured

"Thickness, *T*"



T=91.5±3.5 μm
(avg from two cameras)

1-D



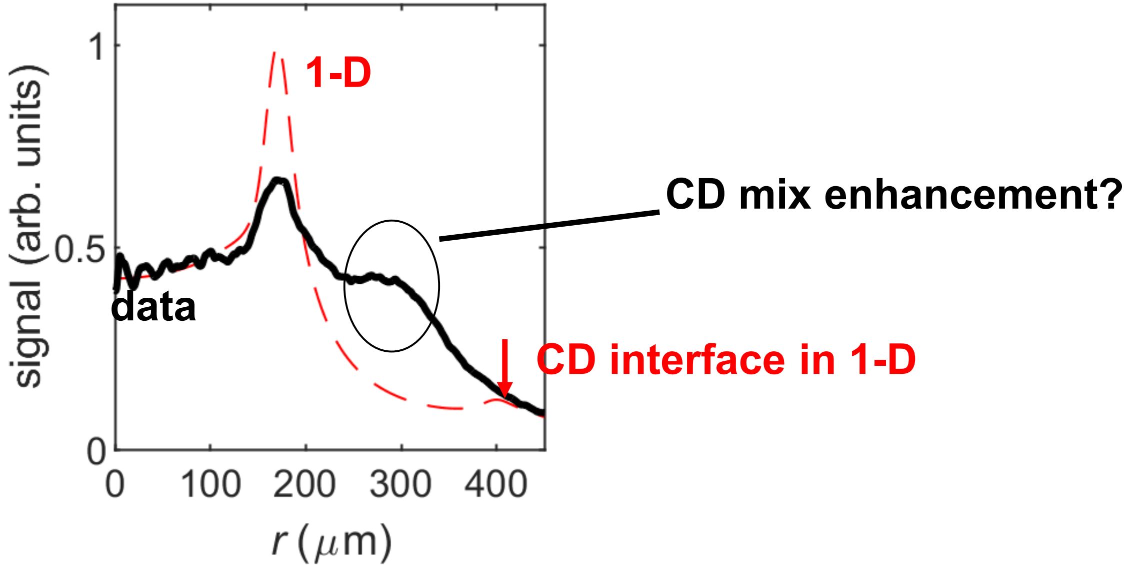
T = 74 μm

- $\alpha = 6$;$IFAR = 10$

* D. T. Michel *et al.*, Phys. Rev. E 95, 051202(R) (2017); J. Baltazar *et al.*, Bull. Am. Phys. Soc. 65, BO09.00006 (2020).

The images are suggestive of a shell break-up despite the insensitivity to imprint

Angle averaged self-emission profiles

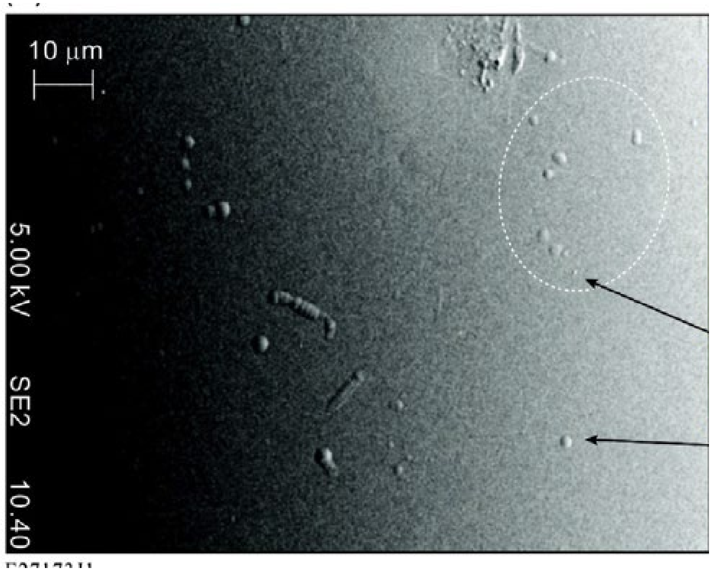


- **A few % CH mix could create enhanced emission**
- **The reduced limb is observed in the case of a highly imprinted implosion as a consequence of a broken shell**

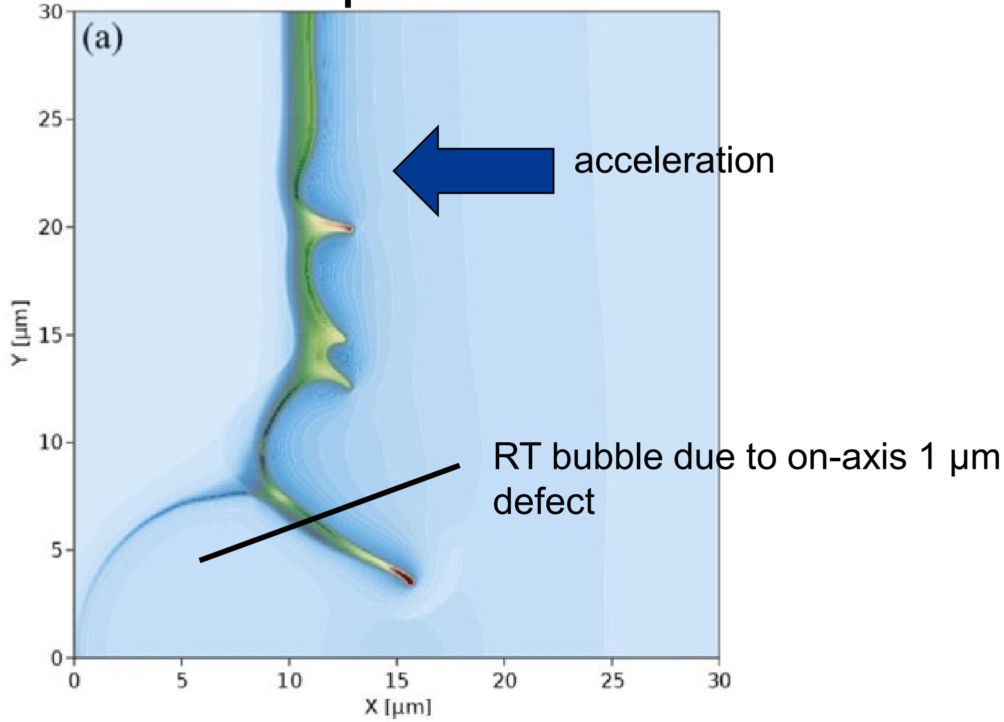
Collectively, the emission, width, and profile signatures suggest an unmodeled source of shell breakup and decompression

Ablator defects are emerging as a primary candidate for the observations

Electron micrograph of typical plastic ablator surface (there are 1000s)[*]



Calculated density profile after 90 µm advance of ablation front following interaction with 1 µm void in ablator[**]

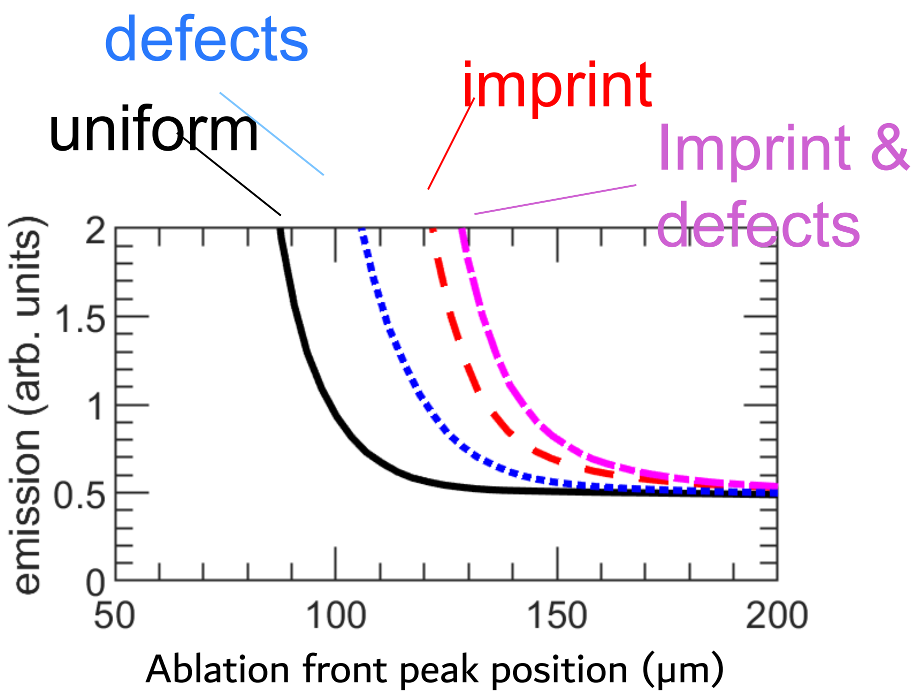


1000s of RT bubbles suggest a plausible means of breaking up the shell / mass injection[**]

[*]D. R. Harding et al. Matter and Radiation at Extremes 3 (2018) 312.
[**]S. C. Miller and V. N. Goncharov, Phys. Plasmas 29, 082701 (2022);
I.V. Igumenshchev et al. Phys. Plasmas 20, 082703 (2013);
B. M. Haines *et al.*, Phys. Plasmas 29, 042704 (2022).
T. J. Collins *et al.*, UO05.00001, this conference.

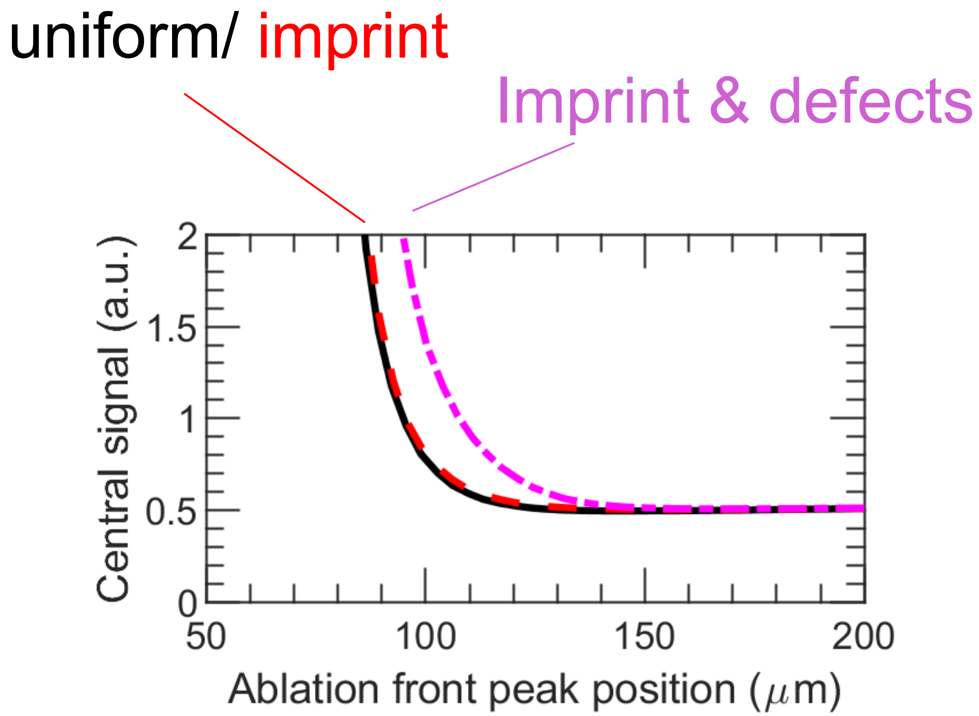
Including ablator defects provides a qualitative agreement with the trends observed for the emission advance

low adiabat



imprint dominated

mid adiabat



defect dominated

The onset of hot-spot x-ray emission in experiments is used to infer conditions at the start of deceleration

- The onset of the hot-spot self emission in experiments occurs when the ablation front is at a larger radius than calculated by models*
- From most recent data, thicker shells [lower in-flight-aspect-ratio (IFAR)] and higher adiabats (α) reduce, but do not eliminate the discrepancy
- The image data suggests the dense fuel encounters instability growth and is decompressed at the start of deceleration beyond what is expected from nominal modeling with laser imprint

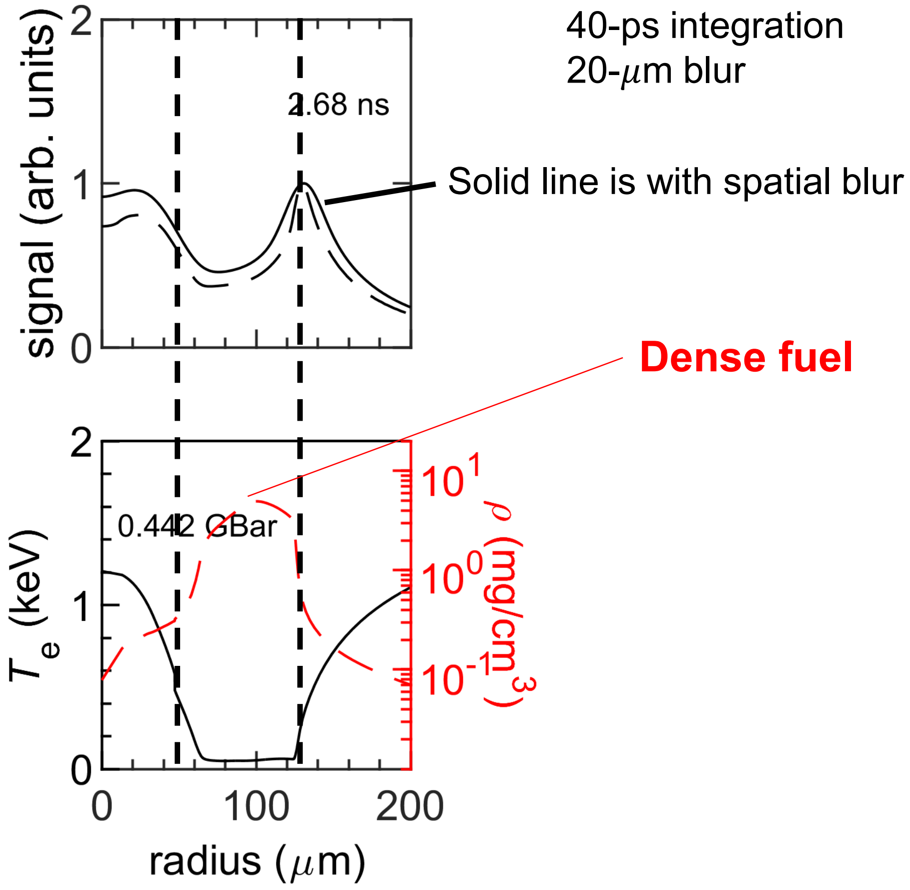
* R. C. Shah *et al.*, Phys. Rev. E 103, 023201 (2021).

Backup

A thickness analysis* suggests decompression of the DT

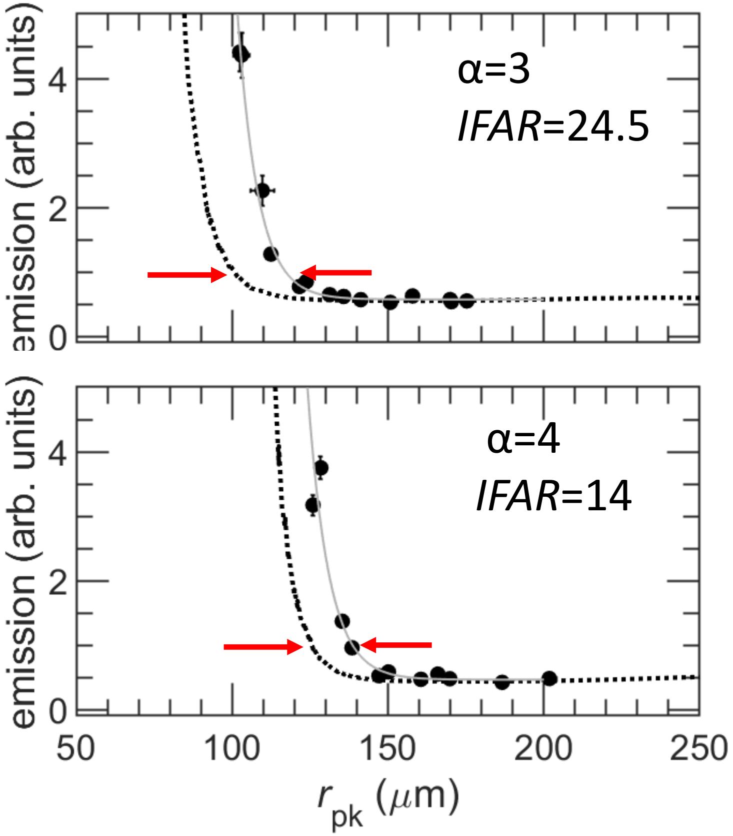
Dense fuel "thickness" =
Ablation radius – Hot-Spot periphery

$P_{\text{dynamic}} \sim \rho\, v^2$
$P_{\text{hot spot}} \sim P_{\text{dynamic}}^{\,5/3}$

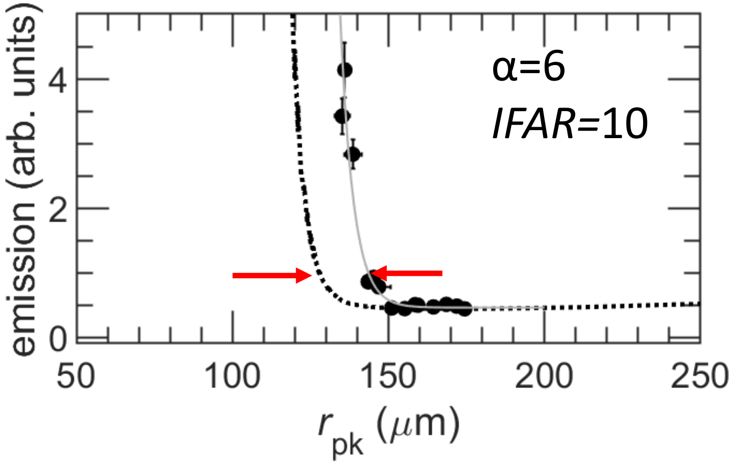


* D. T. Michel *et al.*, Phys. Rev. E 95, 051202(R) (2017); J. Baltazar *et al.*, Bull. Am. Phys. Soc. 65, BO09.00006 (2020).

The discrepancy does not monotonically follow further increases in stability



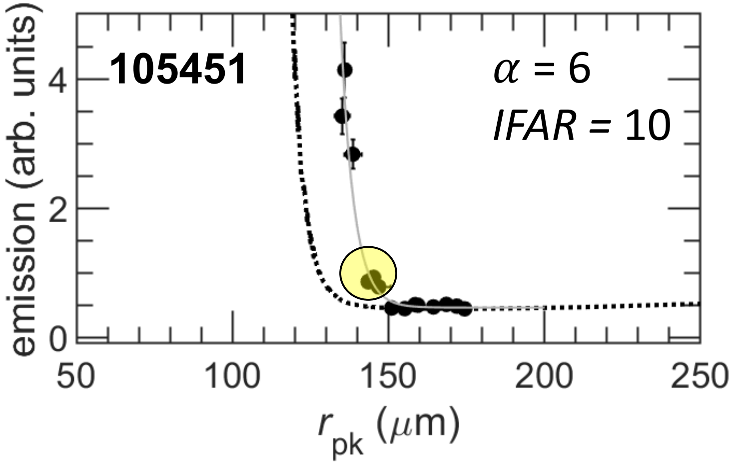
Higher inner and outer adiabat

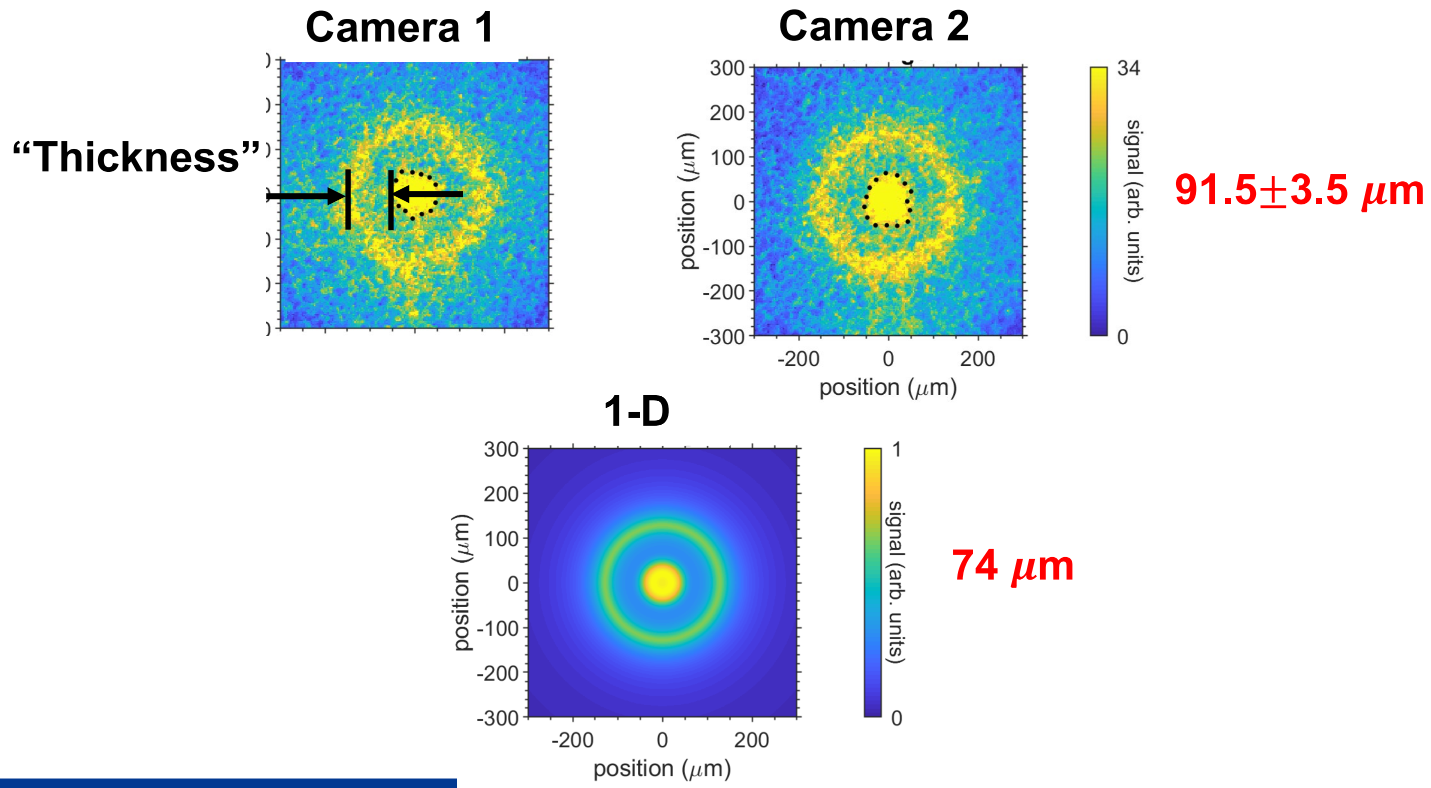


Target thickness

A thickness analysis suggests decompression of the DT

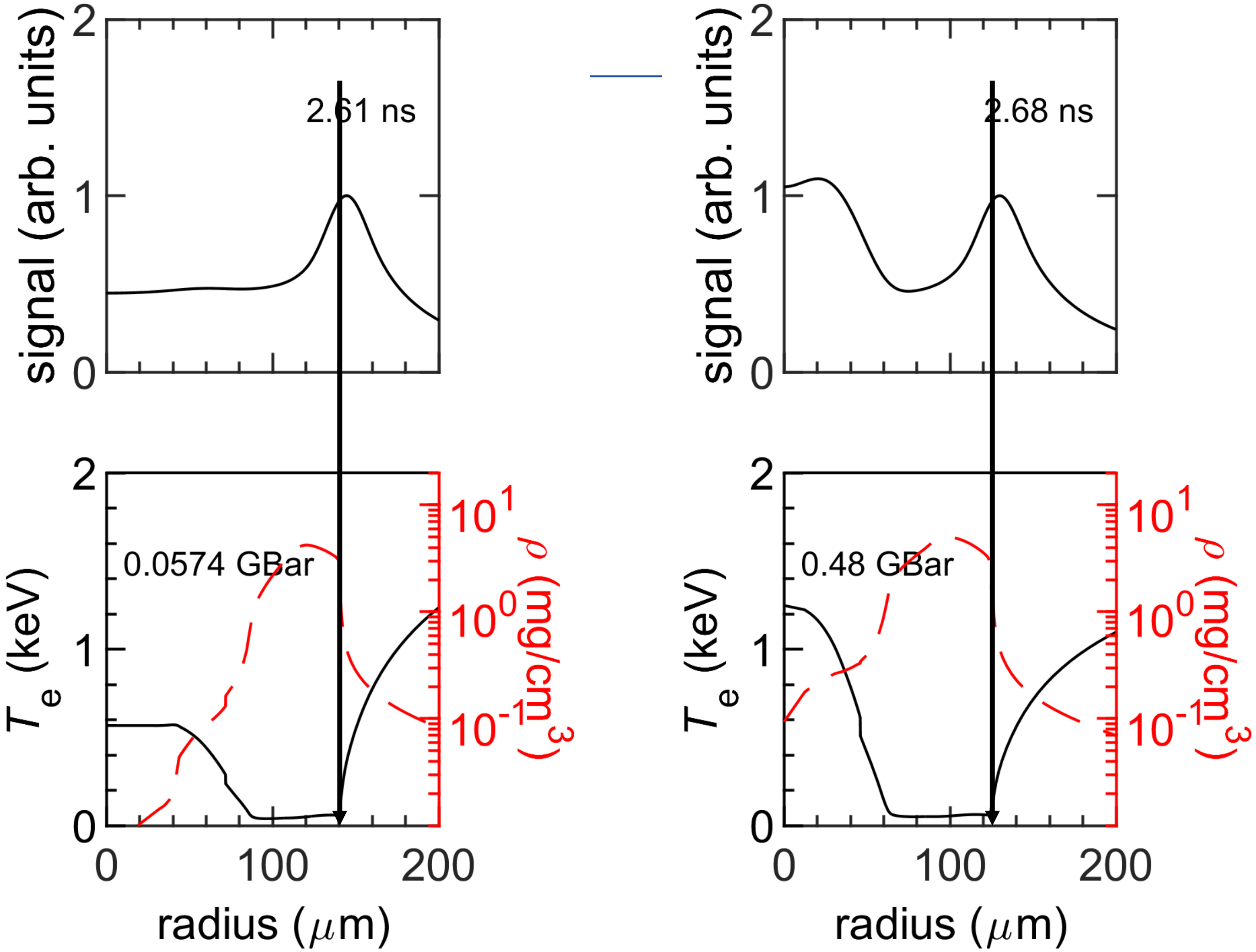
Dense fuel "thickness" =
Ablation radius – Hot-Spot periphery





Nonlinear growth of ablator defects* will be tested by varying the initial ablator thickness so as to change the initial defect number.

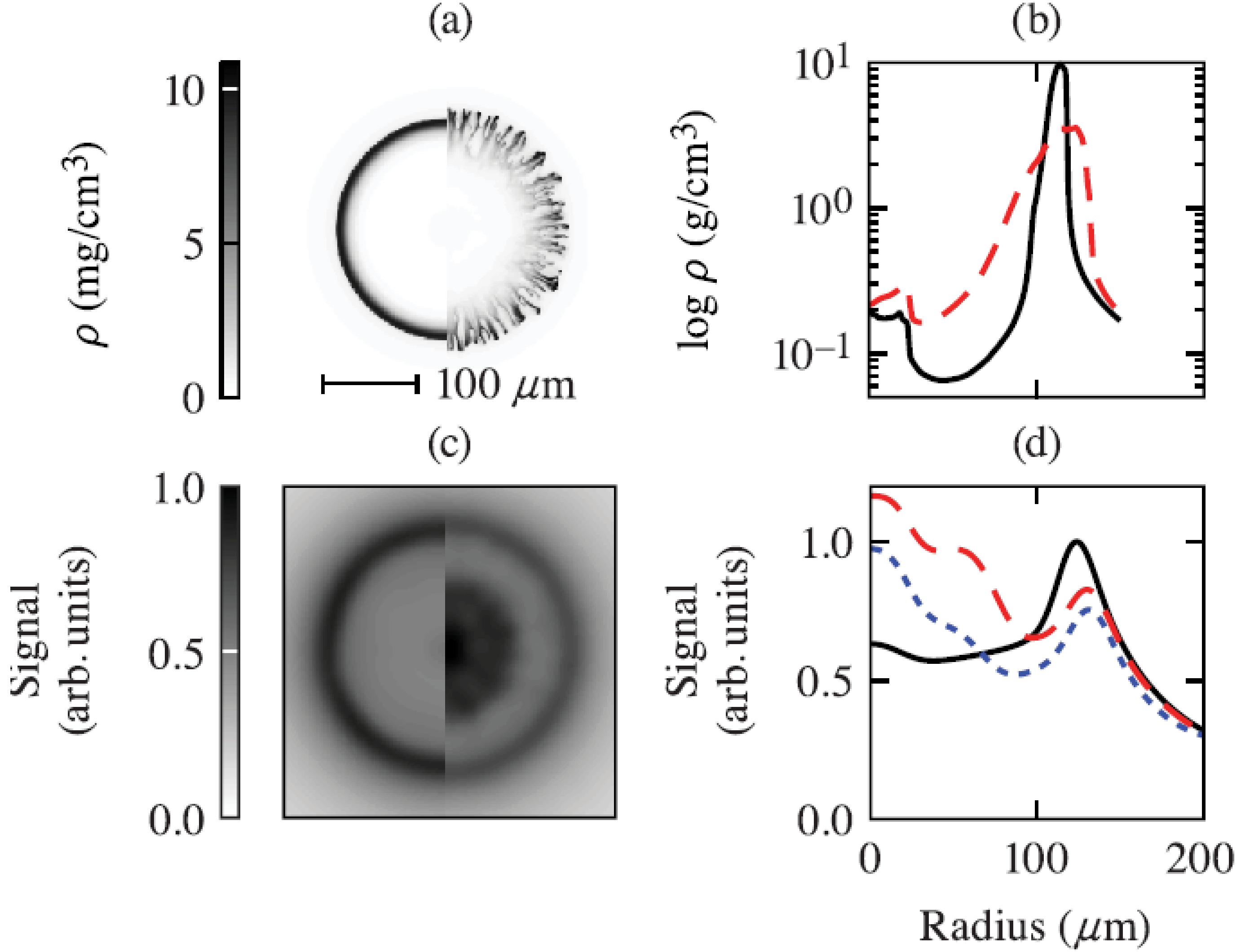
T. J. Collins *et al.*, UO05.00001, this conference.
S. C. Miller and V. N. Goncharov, Phys. Plasmas 29, 082701 (2022).
B. M. Haines *et al.*, Phys. Plasmas 29, 042704 (2022).



the density must be augmented due to decompression (bubble advance)

some may in part be due to spike growth pushing the ablation front to larger radii (i.e. meaning we are accessing later times in the simulation)

reduced limb due to break up



- the limb (red-dashed) is not broader than the 1-D (solid-black)
- The peak density is lower but the ablated density is likely the same
- The ridges must modify the temperature gradients and thereby reduce the emission

Mode 1 does not modify this emission curve

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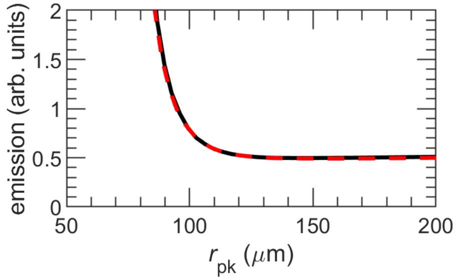
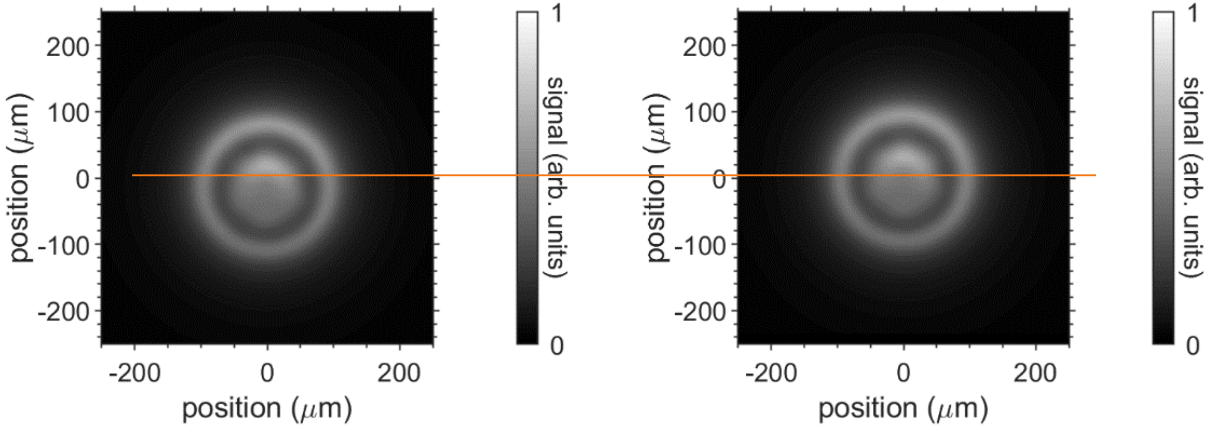
Mode 1- orthogonal view



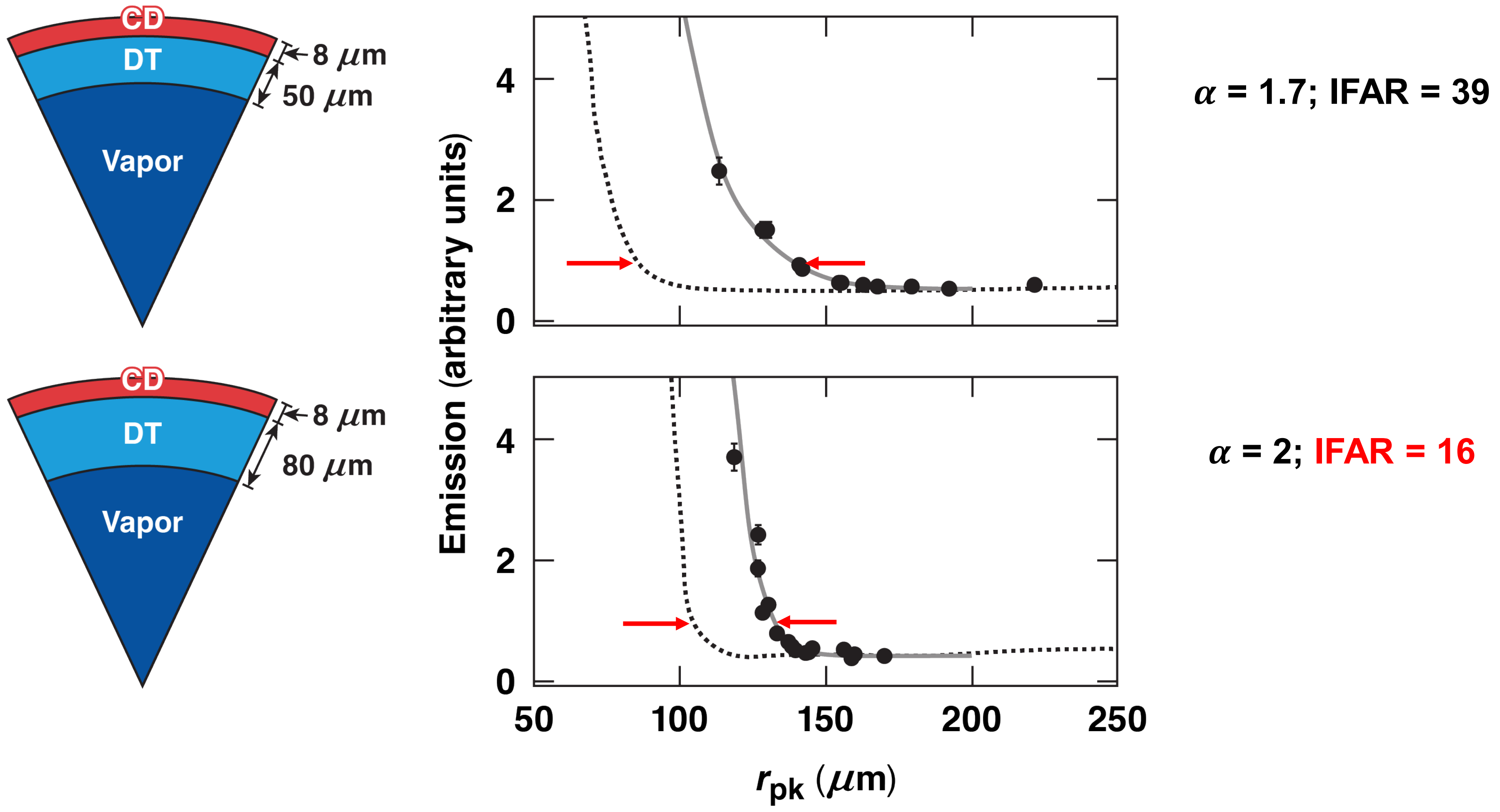
ASTER O/P

Re-center O/P



The limb peak was used to re-determine a center prior to analysis, procedure like that used with data

The discrepancy is reduced but not eliminated with a thicker, more protective target



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