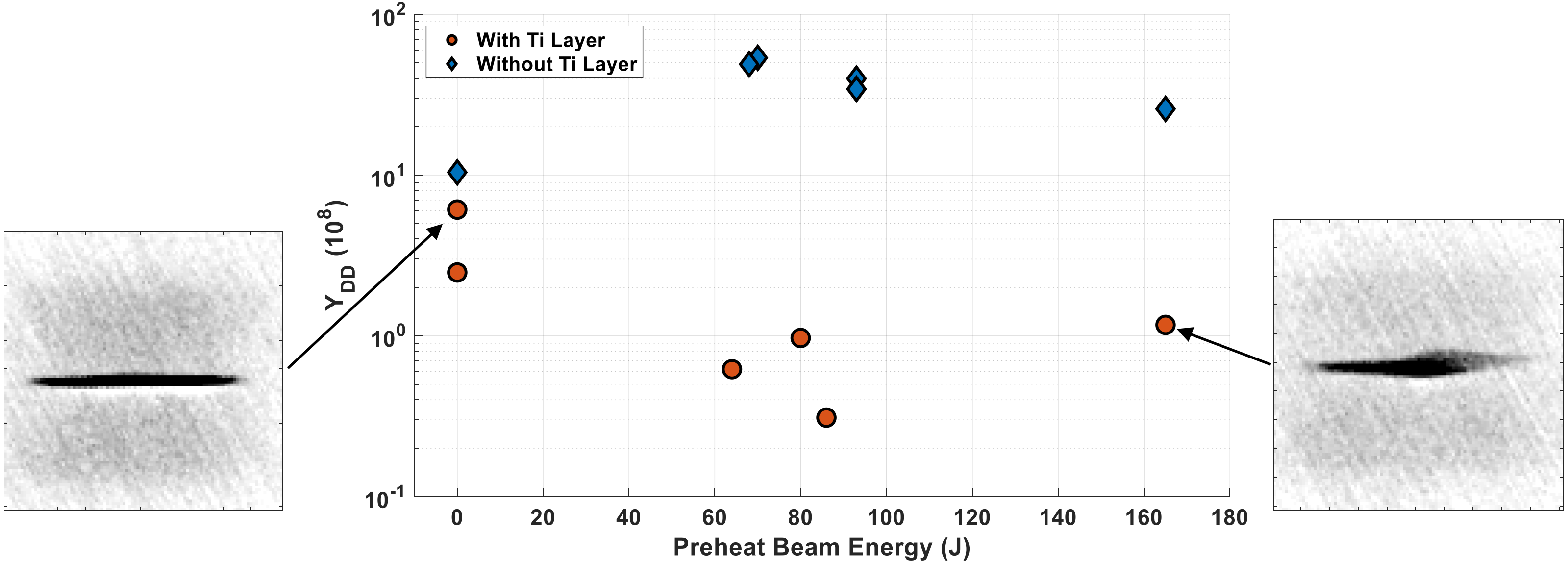
Measurements of Laser-Preheat–Induced Mix in Scaled Magnetized Liner Inertial Fusion (MagLIF) Implosions



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Experiments on the scaled MagLIF platform at OMEGA demonstrate the detrimental effects of mix at high preheat levels

- **Magnetized, preheated implosions saw significant yield gains, though gains decreased with additional preheat energy**

- **Experiments using a titanium tracer layer demonstrated mix was not from the preheat entrance**

- **Further experiments with a tracer layer on the inner wall of the cylinder showed significant mix, decreasing yield and implosion quality with the introduction of the preheat beam**

Collaborators

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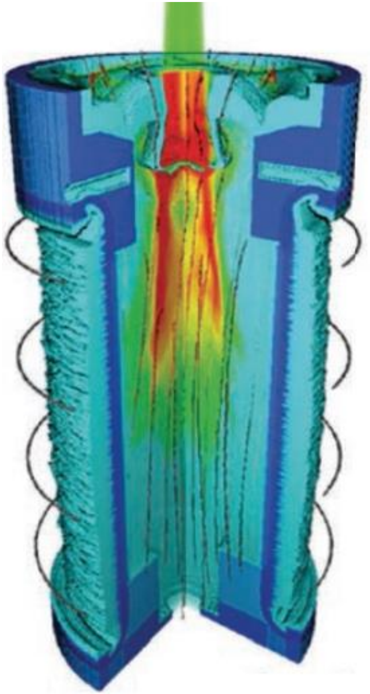
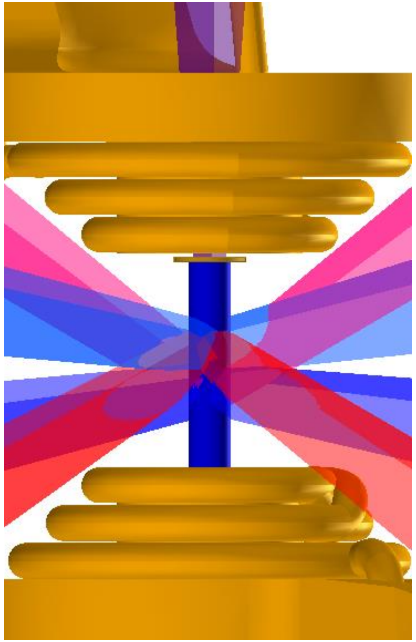
OMEGA can carry out magnetized, preheated, cylindrical compressions, allowing a scaled-down version of MagLIF*



OMEGA has 1/1000 the energy coupled to the target, scale linear dimensions by order of magnitude

MagLIF Design	Z (Sandia)	Laser Driven on OMEGA
Energy (MJ)	1	10^{-3}
Target Size OD (mm)	6	0.6
B_0 (T)	Up to 30	35+
T_0 (eV)	0 - 100	0 - 200
ρ (mg/cc)	0.7 to 1.0	0.7 to 1.8
BR (T-m)	0.4	0.02

Scaled Laser-Driven MagLIF



*D. H. Barnak *et al* Phys. Plasmas **24** 056310 (2017)

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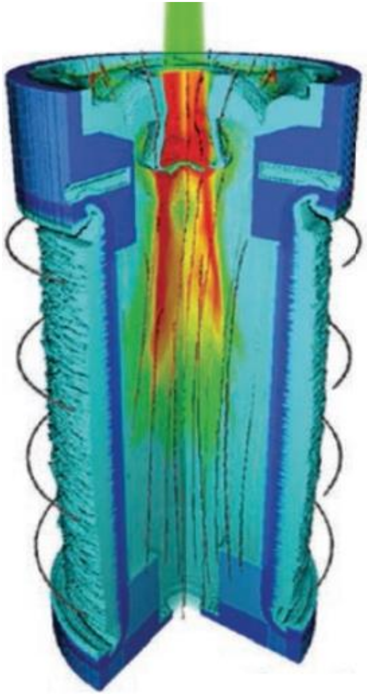
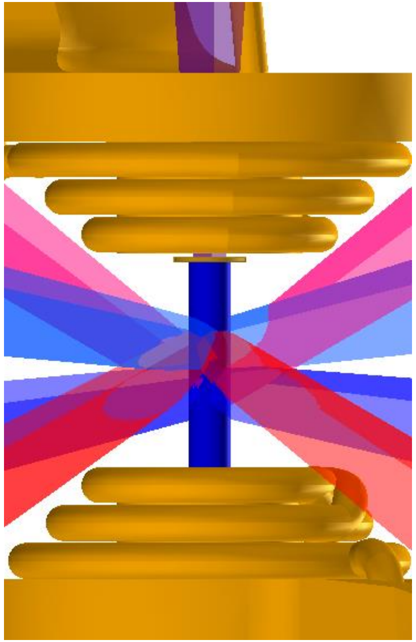


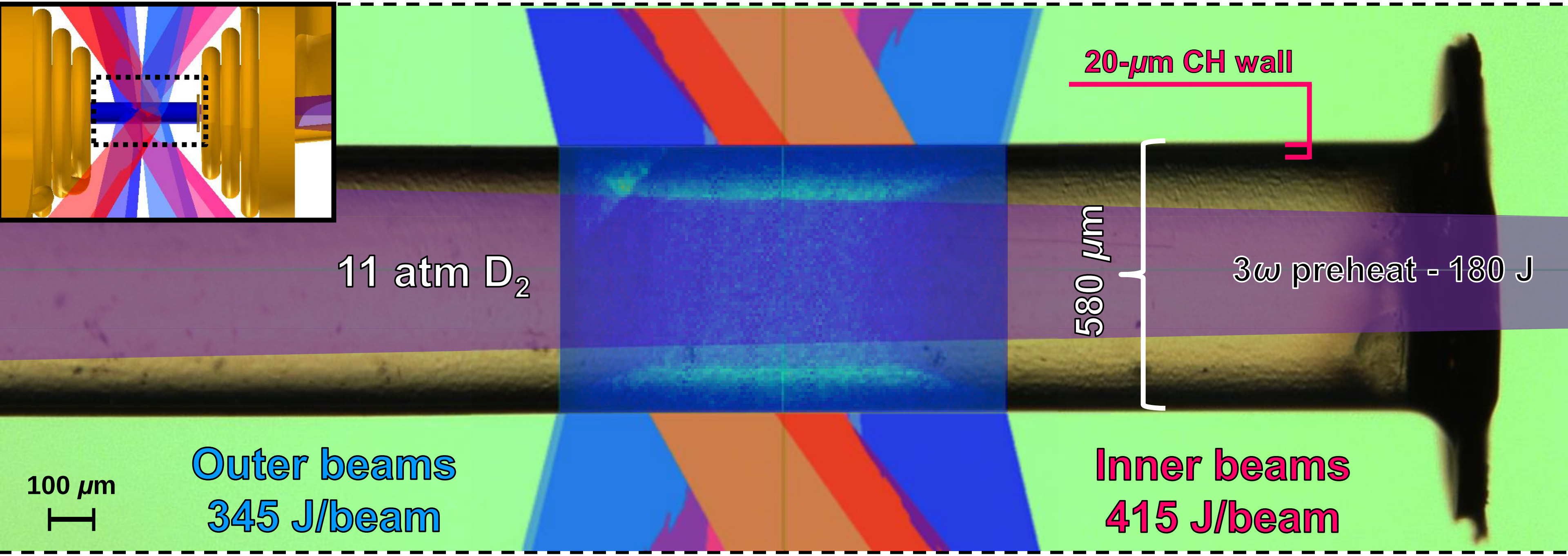
Change in dimensions causes some differences in spacing between important regions of mix, which are not scaled between facilities

MagLIF Design	Z (Sandia)	Laser Driven on OMEGA
Energy (MJ)	1	10^{-3}
Target Size OD (mm)	6	0.6
Distance from laser entrance (LEH) to implosion	0.5×OD	2×OD
Distance from LEH to bottom cushion	1.5×OD	30×OD
Size of preheat beam	0.18×OD	0.5×OD

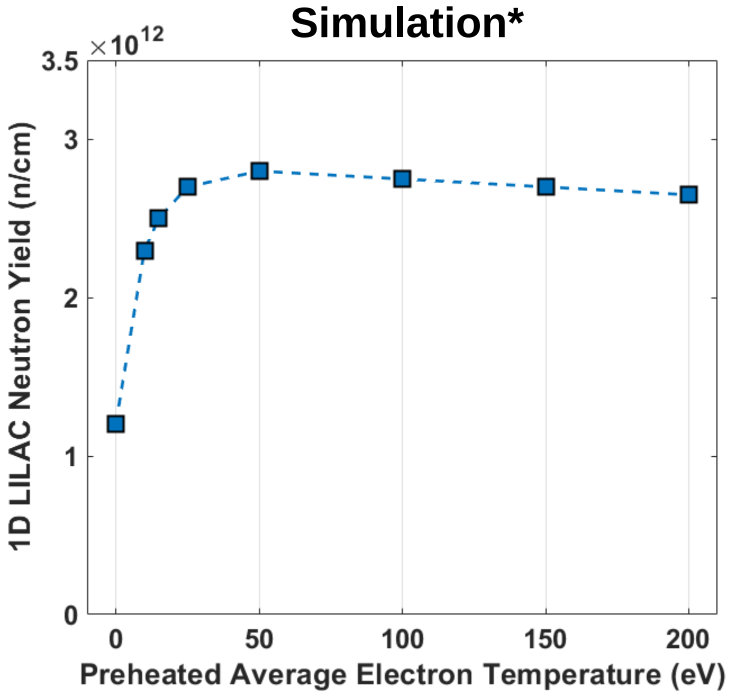
Scaled Laser-Driven MagLIF

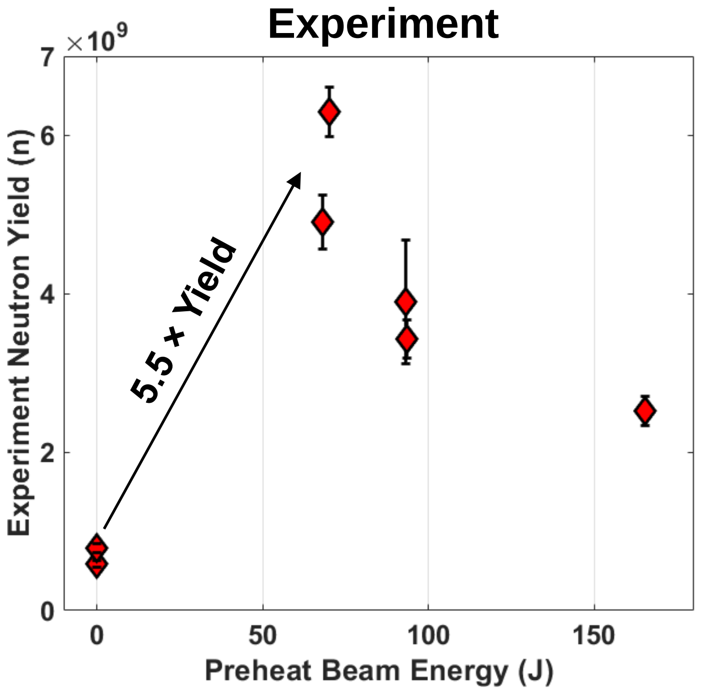


Forty OMEGA beams are tuned and spaced to evenly drive a cylindrical implosion using a 1.5-ns square pulse



Experiments demonstrated a quick drop off in yield enhancement at 27 T with higher preheat, contrary to simulations



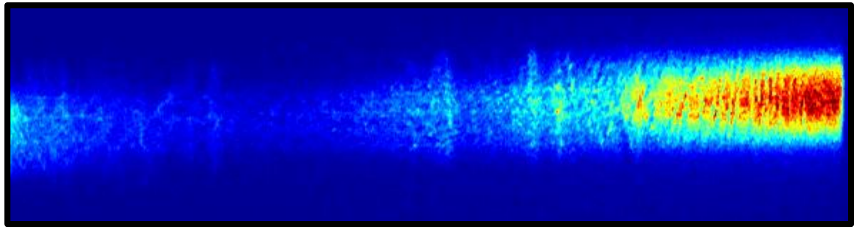


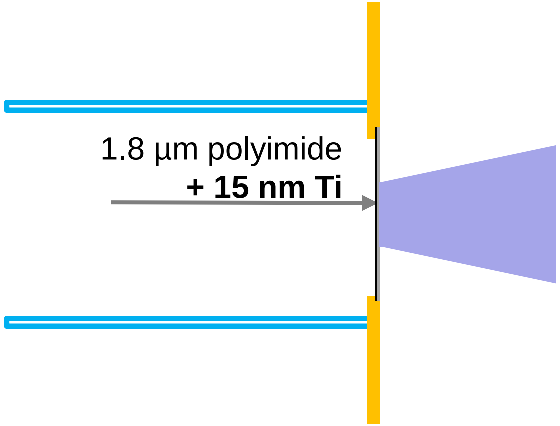
Simulations do not account for mix, which likely increases as preheat energy increases

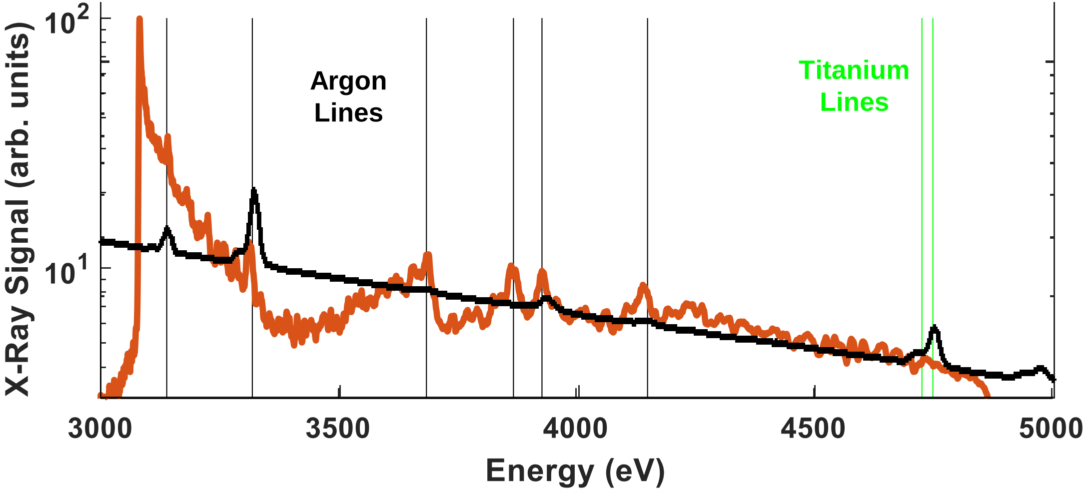
*D. Barnak *et al.*, Physics of Plasmas 24, 056310 (2017)

Experiments using a titanium layer on the preheat beam window indicated no significant mix from window blow-in

The detector should be able to measure a fraction of window dopant (< 1 picogram) entering the core





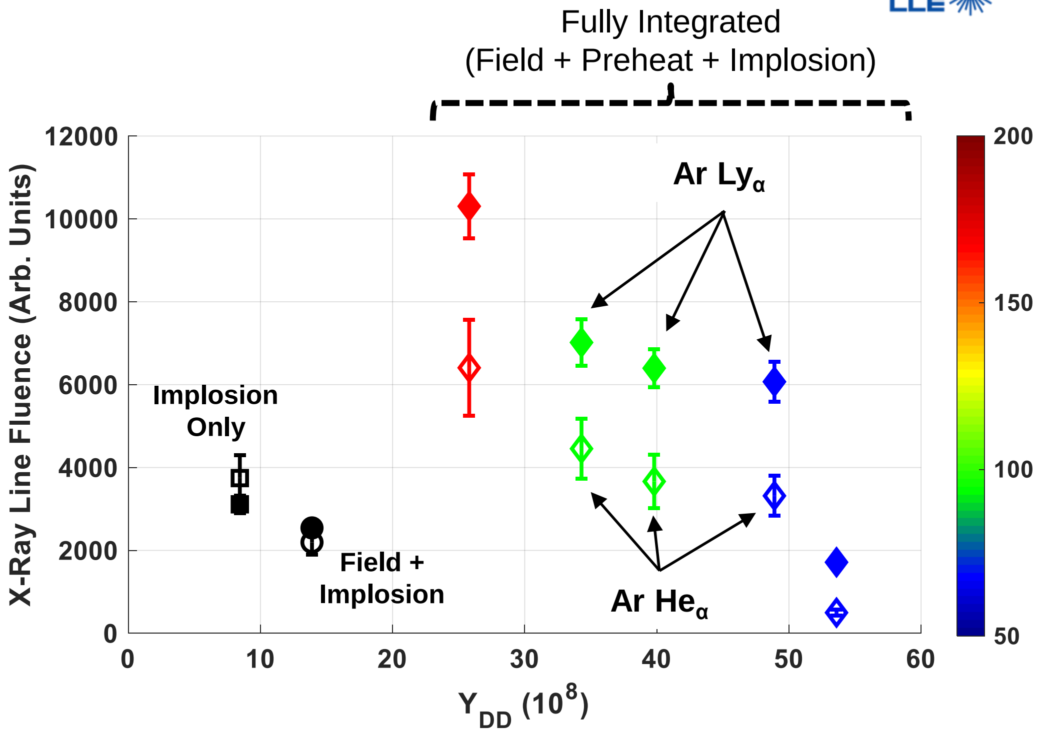


Spectrometers indicated no titanium emission from window mix, but there were unintended argon lines!

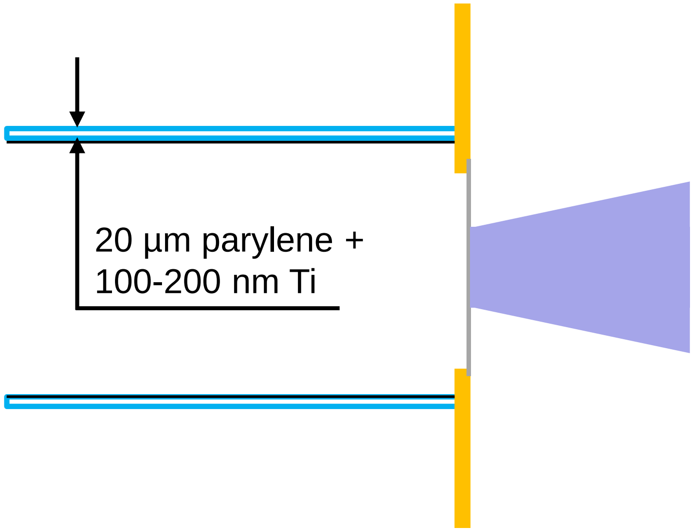
Argon diffuses into the parylene shell in the days prior to shot

Measuring significant quantities of Argon indicate large amounts of wall mix must be taking place, especially with the preheat beam

Caveat: Argon quantity could potentially vary shot to shot



A dedicated experiment used a thin titanium layer to determine whether wall mix was dominant



100-200 nm Ti was sputtered along the length of the interior of the cylinder

Opacity showed that the Ti distribution was present but non-uniform

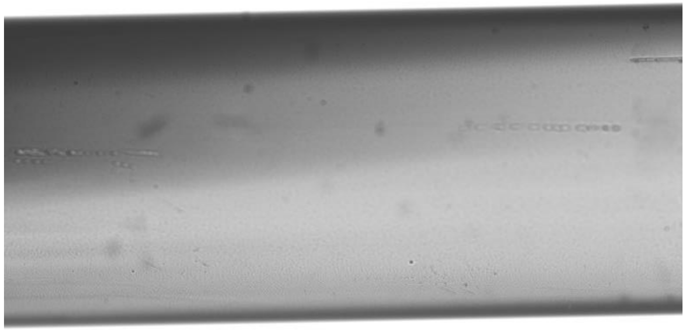
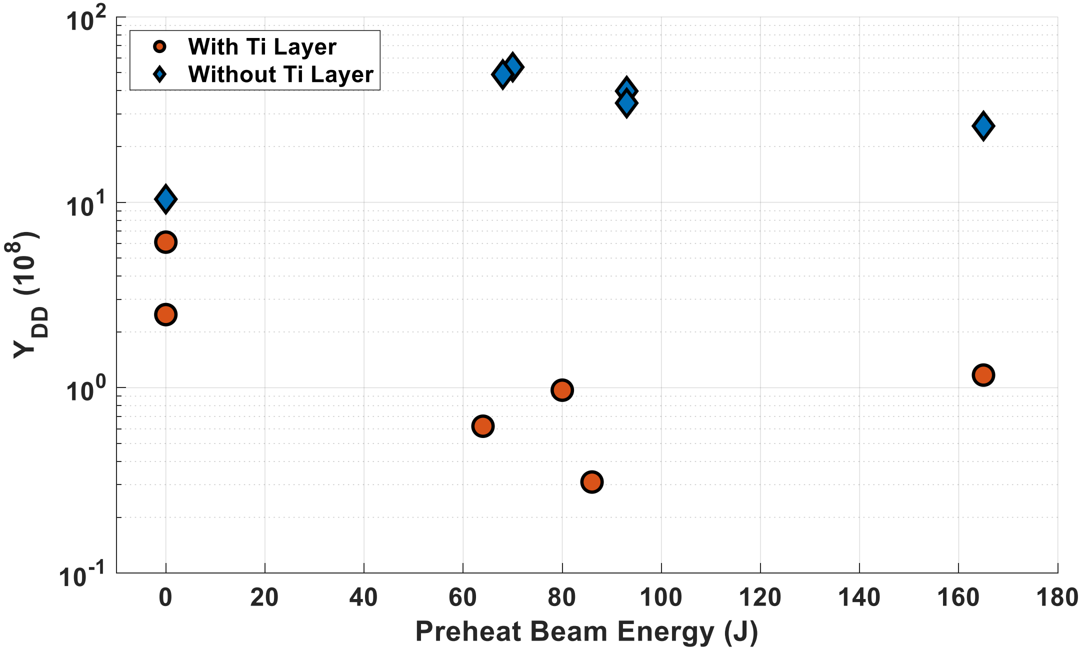


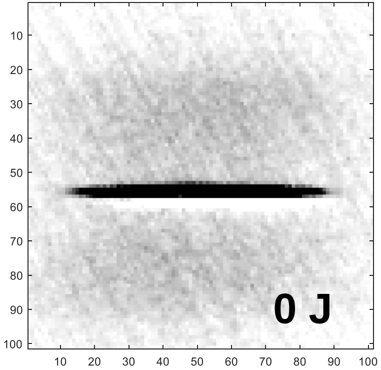
Image of cylindrical target ROI w/Ti

Yield degraded by a factor of 2 for baseline implosions, but degraded by nearly 2 orders of magnitude when preheat was introduced

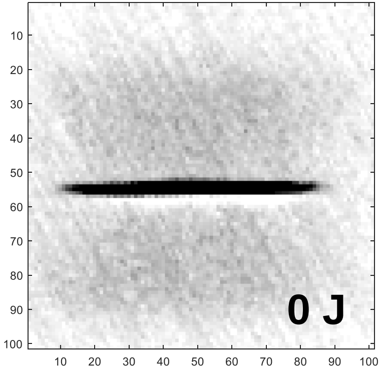


Yields indicate that some degree of wall mix occurs with just the implosion, but preheat causes far more mix of the inner wall material into the fuel

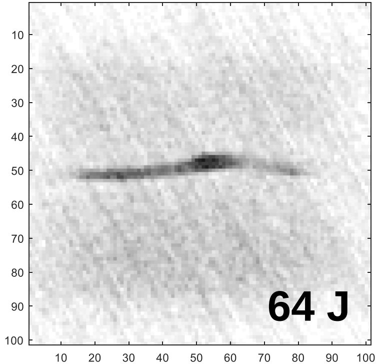
Pinhole cameras and a Fresnel Zone Plate tuned to Ti-He$_\alpha$ verified titanium mixed by preheat had a far more detrimental impact on the implosion

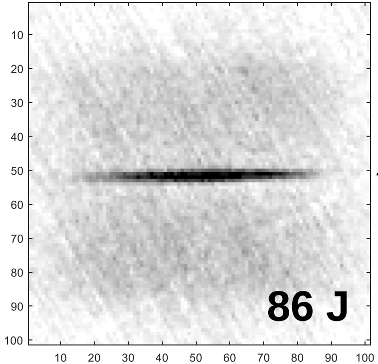


Implosion Only

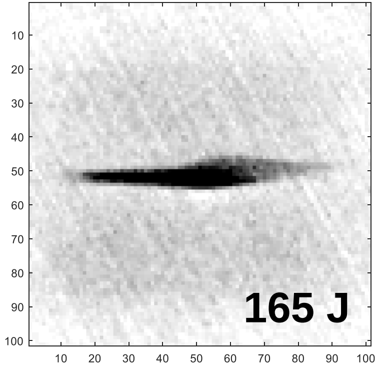


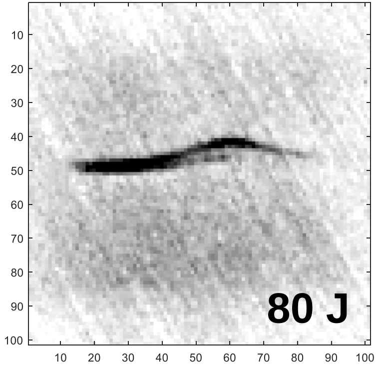
Implosion + Field





Preheat direction

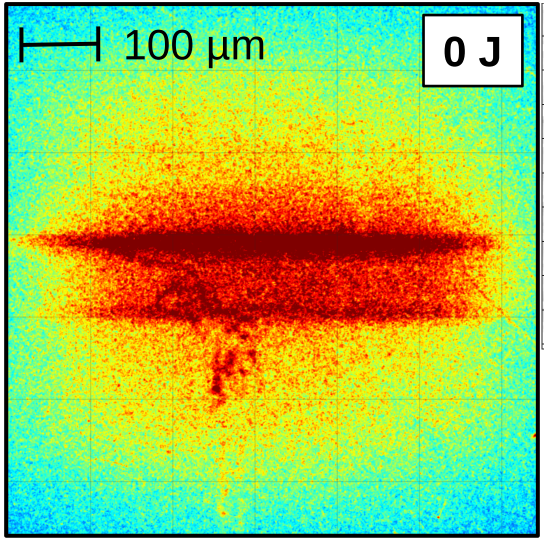


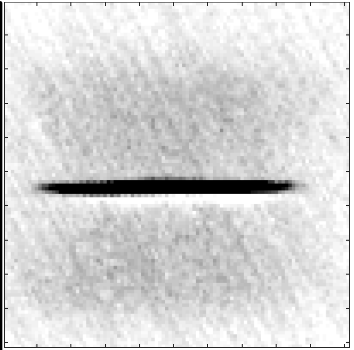


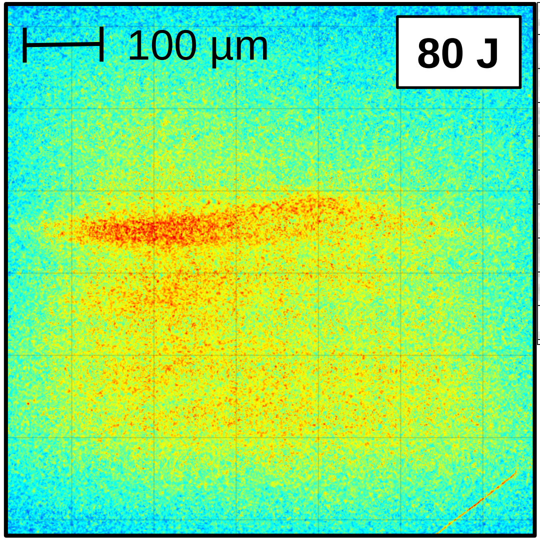
Shots with preheat showed significant disruption to convergence, especially on the side with the preheat beam

Following this talk, CO05.00011 by L. Leal will show Ti in fuel disrupts yield and convergence

Fresnel zone plate images confirm poor implosion quality with preheat and expansion of the titanium layer on the inner wall







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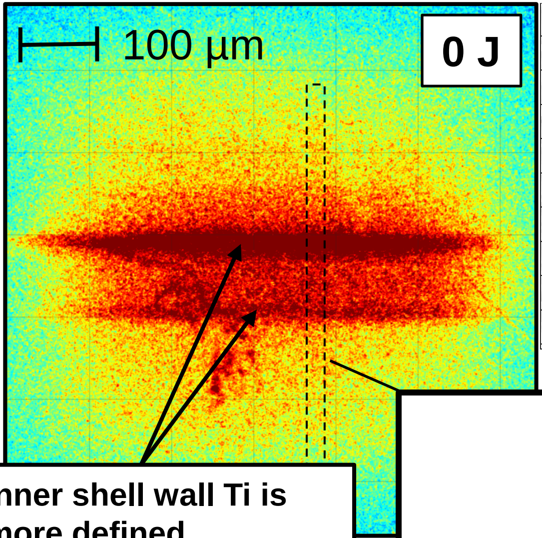

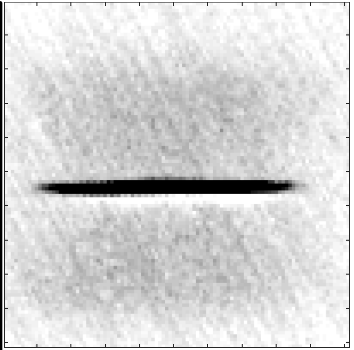

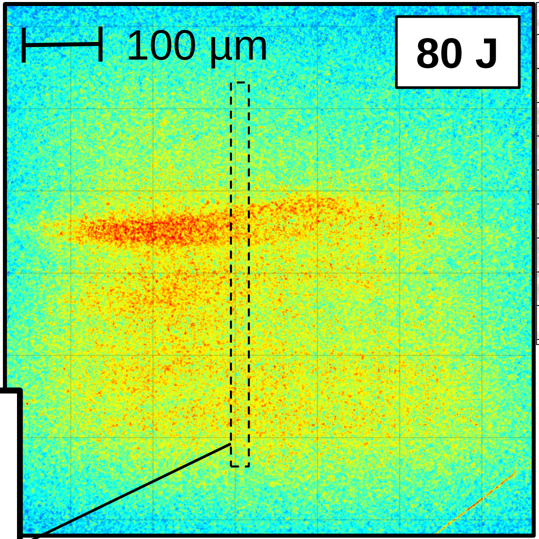

Inner shell wall Ti is more defined

Two sides are closer together indicating higher convergence

Ti quantity non-uniform between shots
Comparing relative values shows preheat shots “smeared” Ti signal

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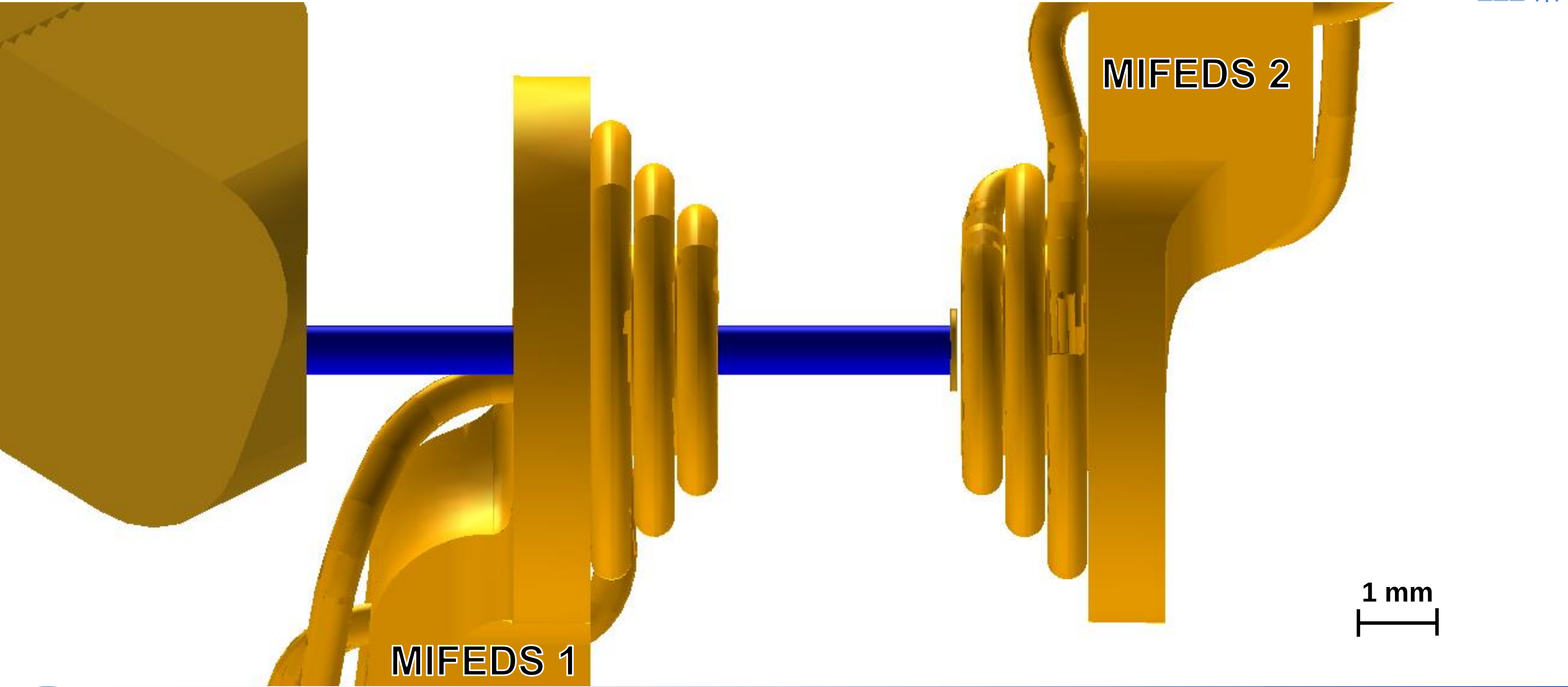
- **Further experiments with a tracer layer on the inner wall of the cylinder showed significant mix, decreasing yield and implosion quality with the introduction of the preheat beam**

Questions to:
jpeebles@lle.rochester.edu

Extra Slides

MIFEDS units trigger 1 μs prior to implosion, developing a 27–T magnetic field in the region of interest



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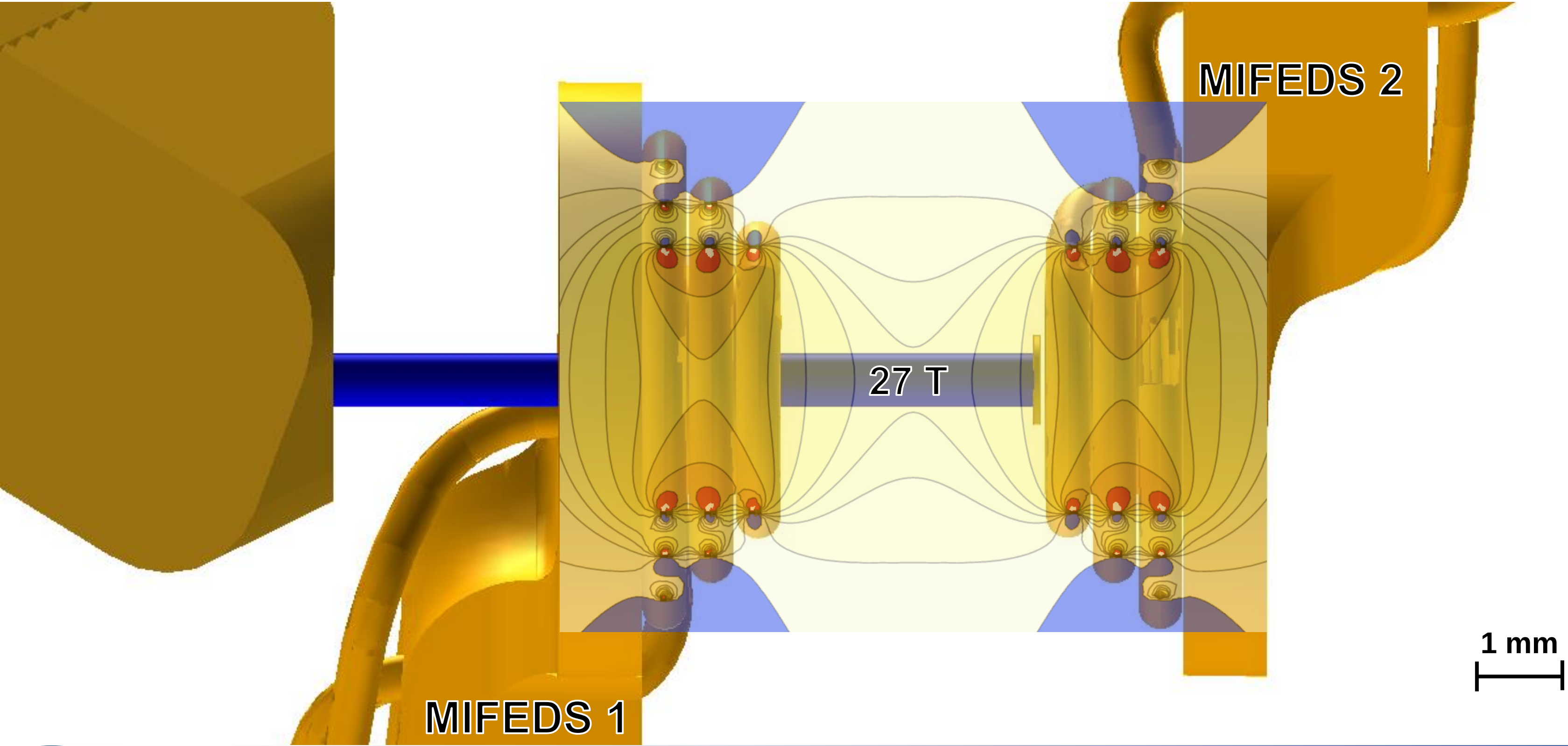
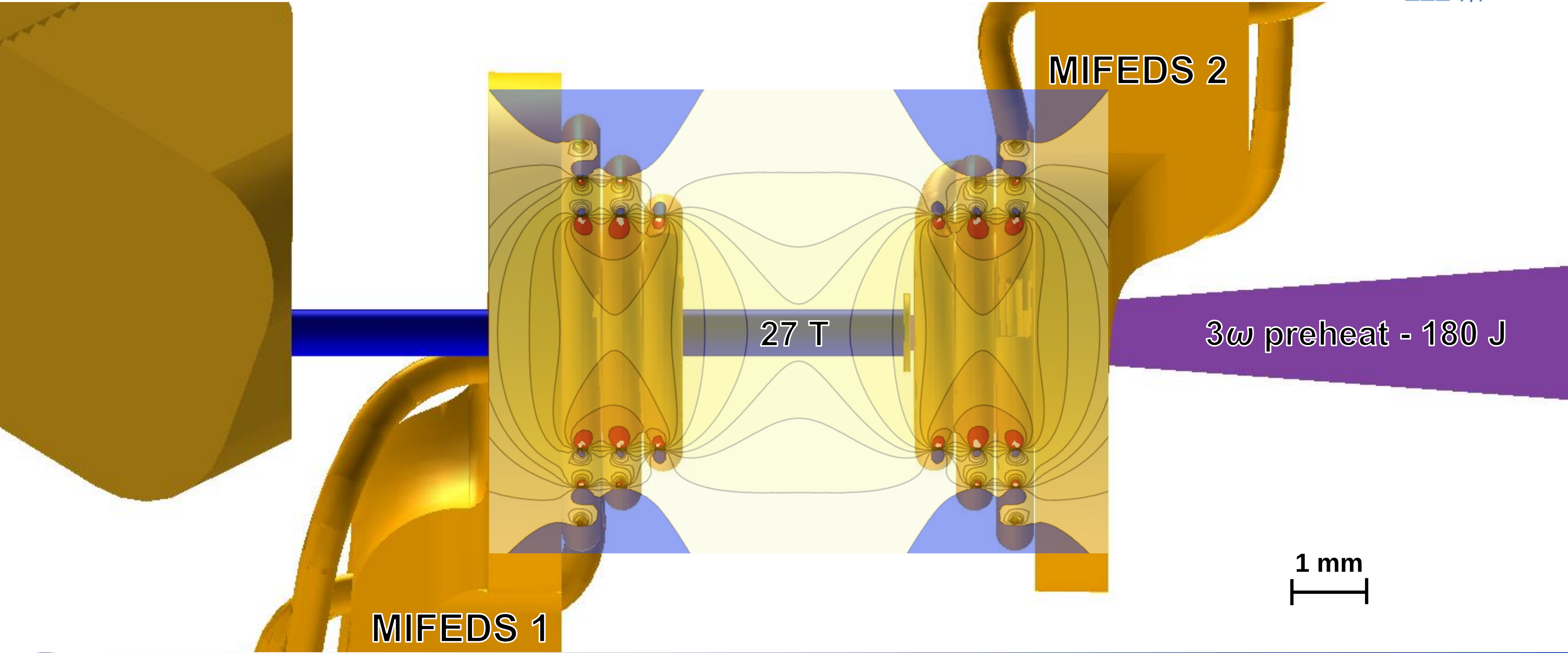


1 ns prior to implosion a specialized 3ω preheat beam fires down the axis of the fuel, heating it to 200 eV



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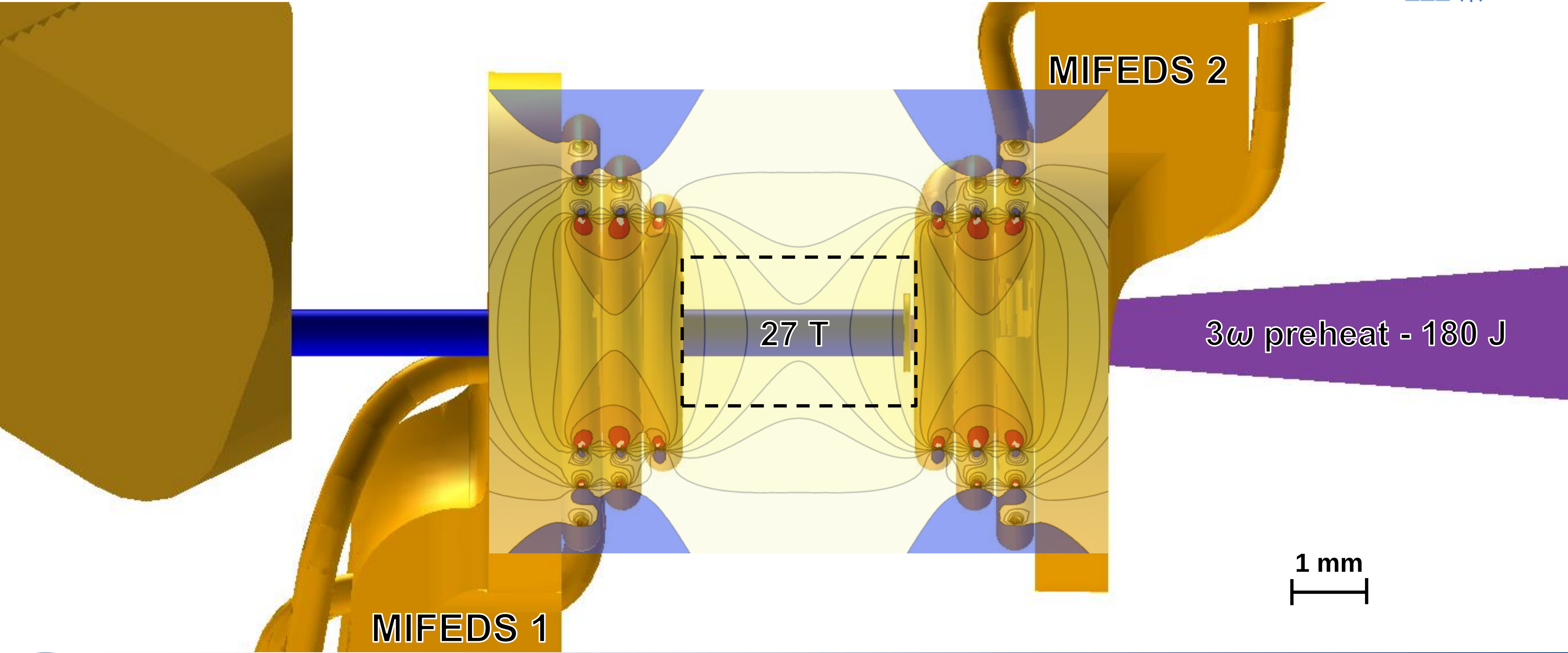

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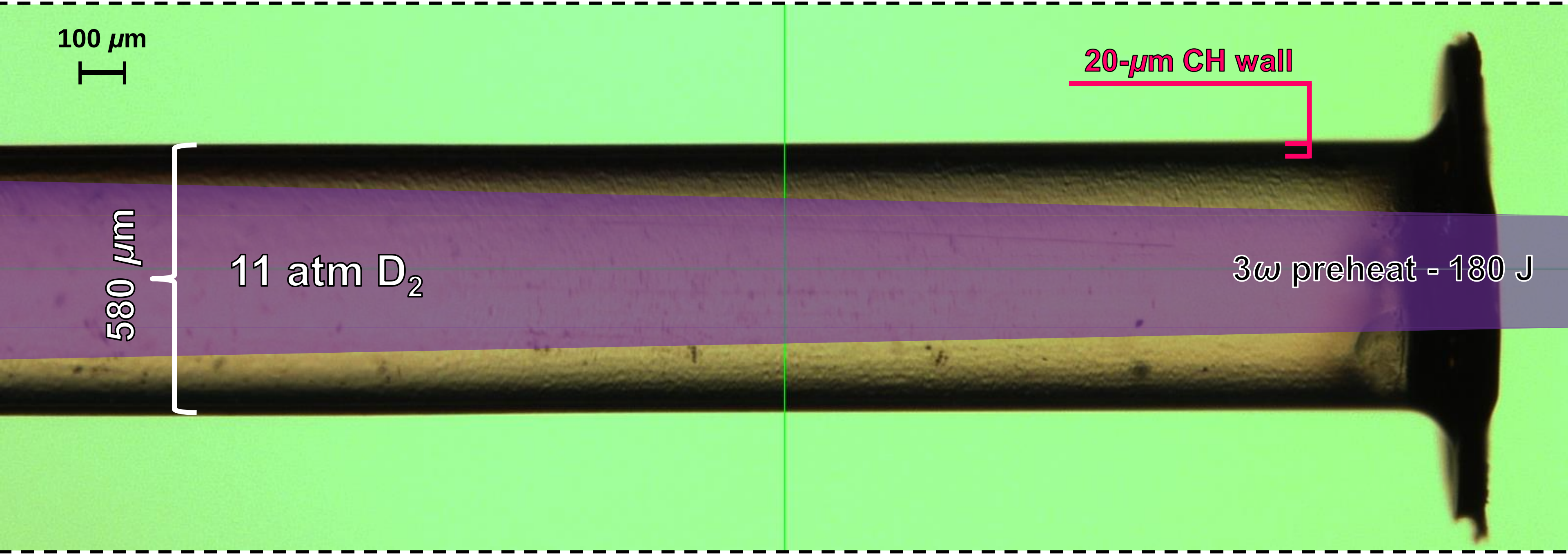

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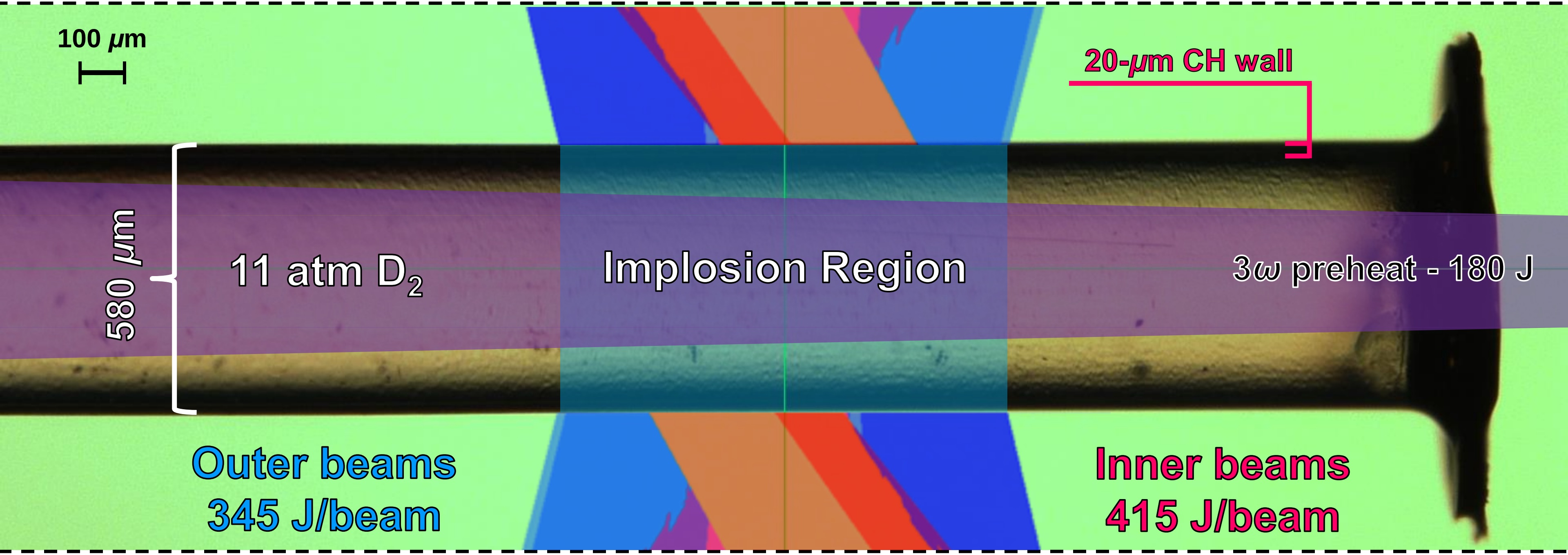

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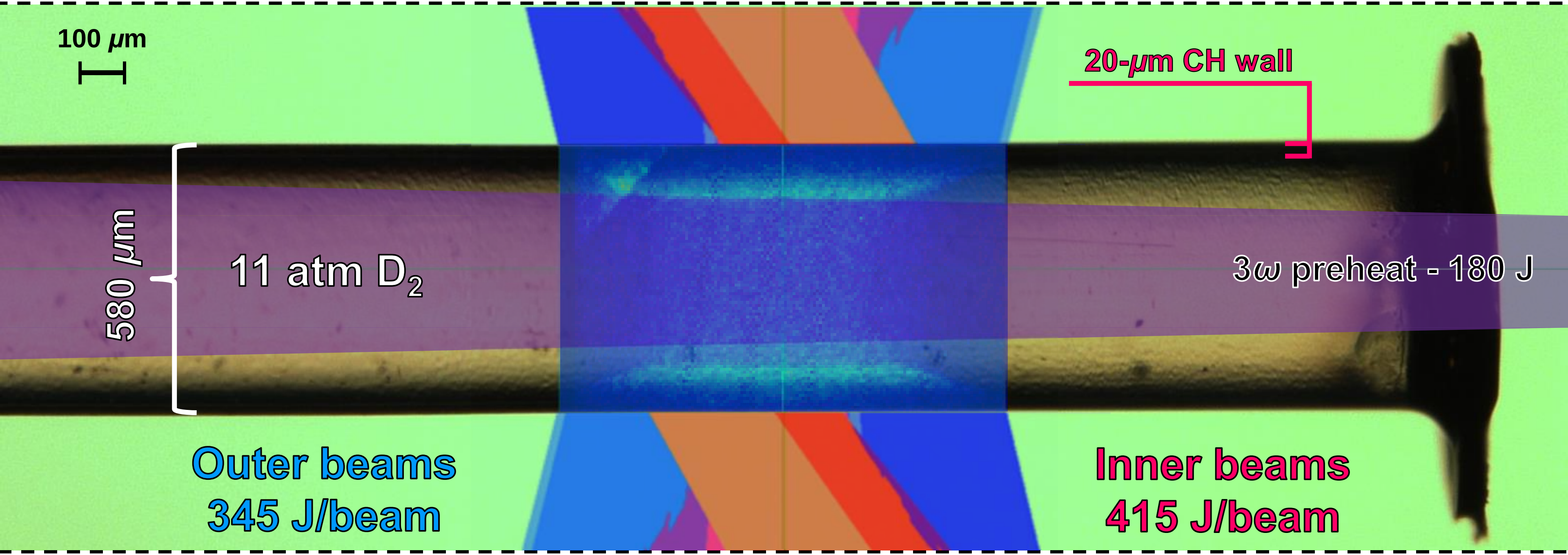
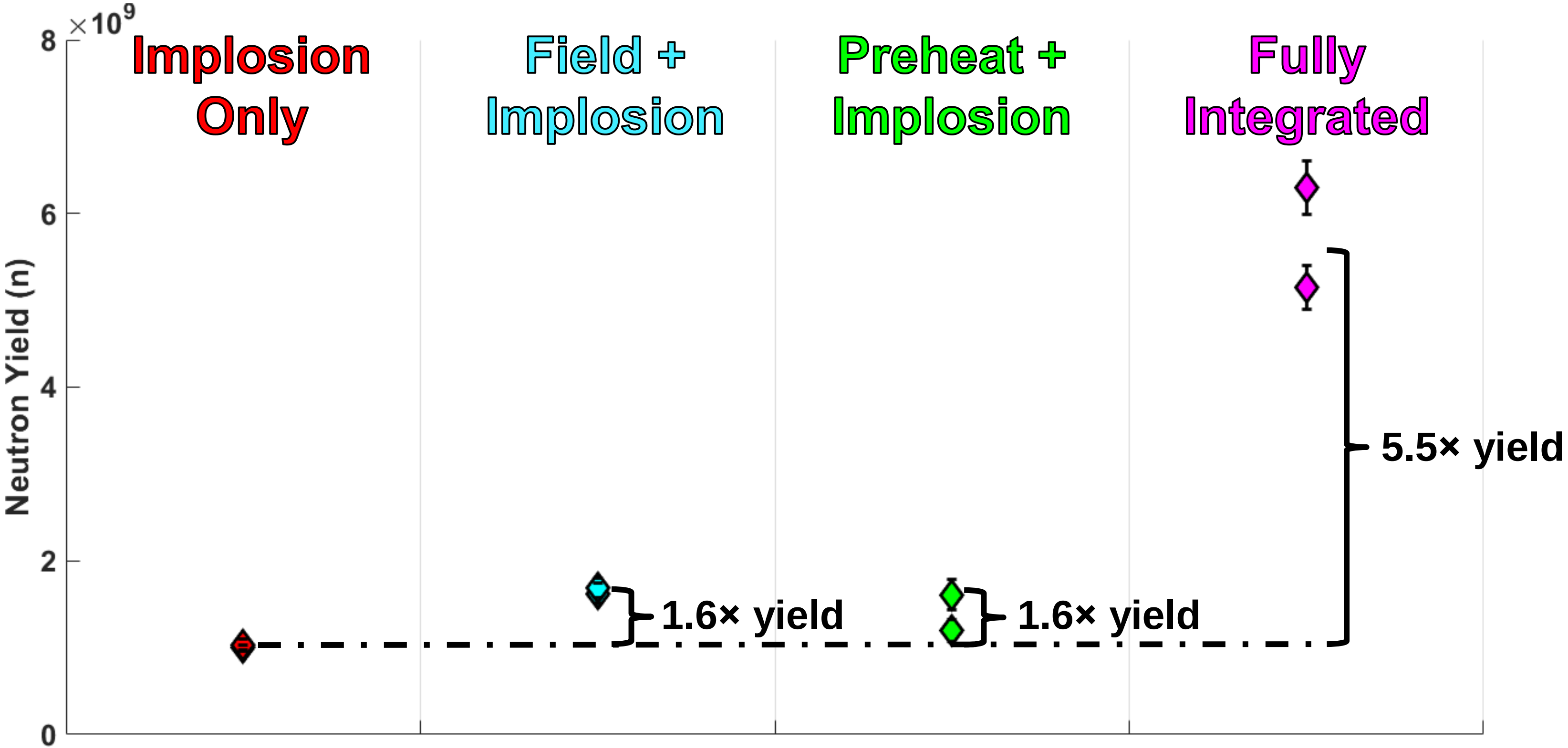
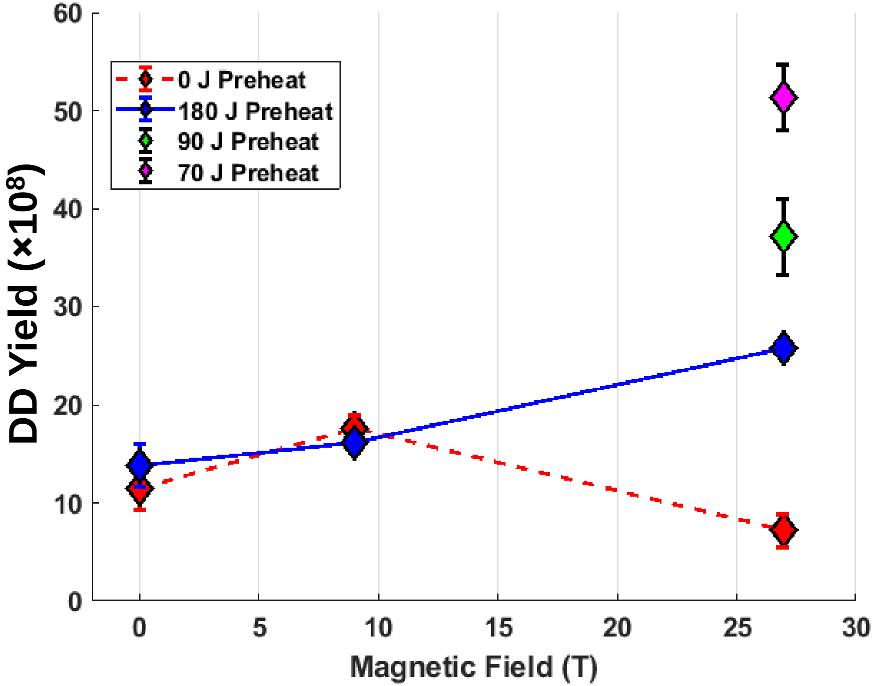
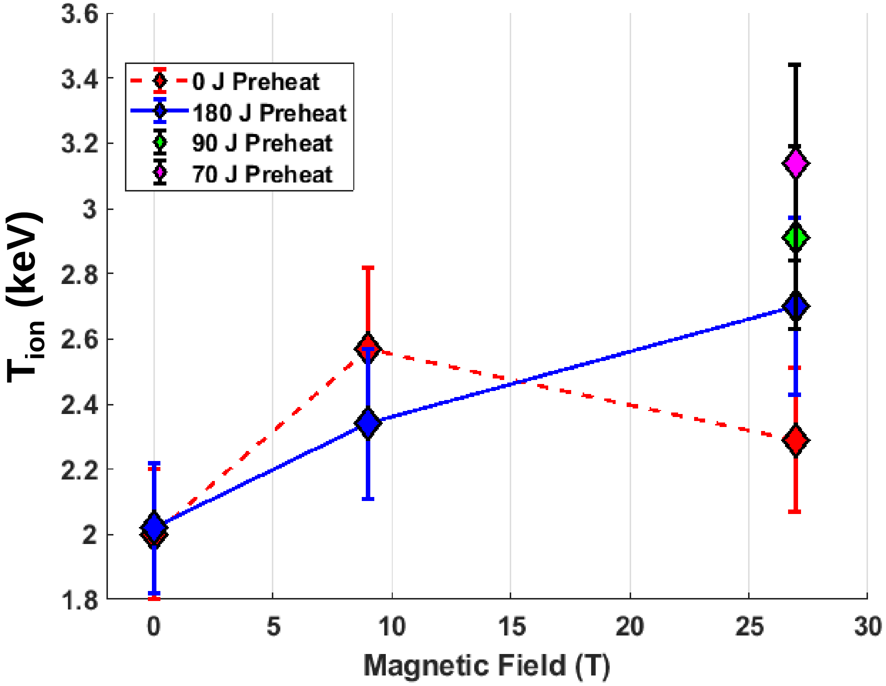


Fully integrated shots provide far more yield enhancement than field and preheat alone

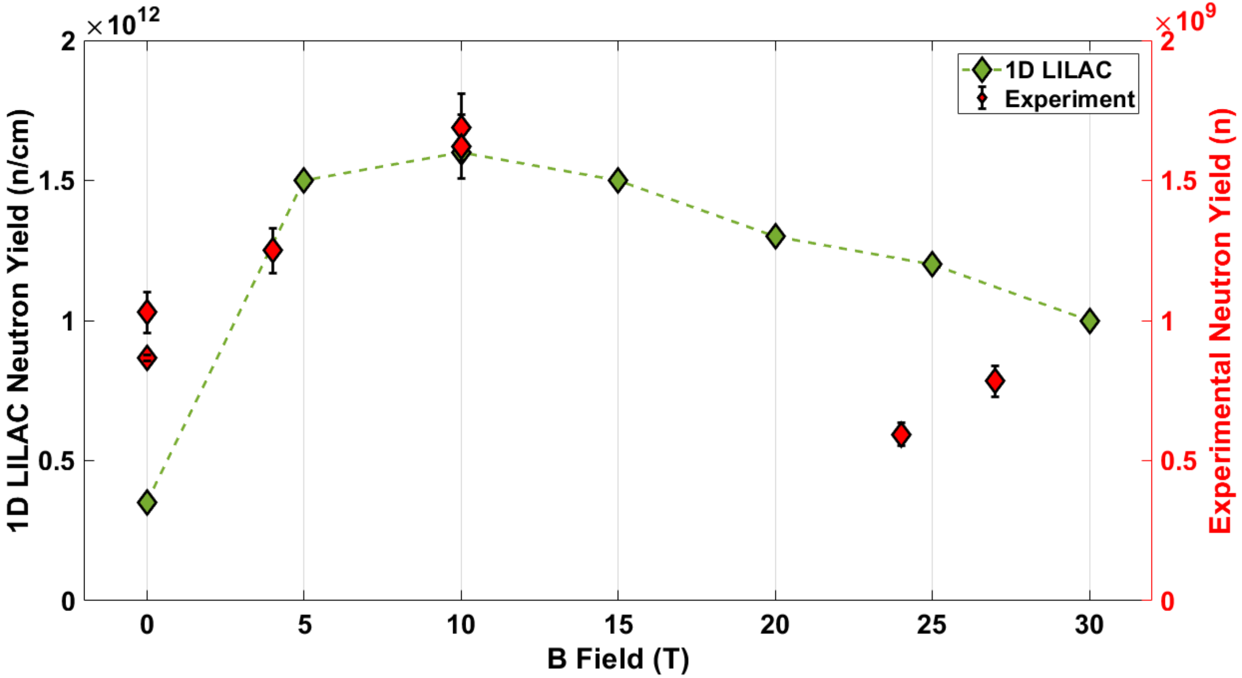


Neutron averaged ion temperatures show the same trends as neutron yields





Yield enhancement due to magnetization without preheat drops off at higher fields, possibility of β^{-1} approaching 1



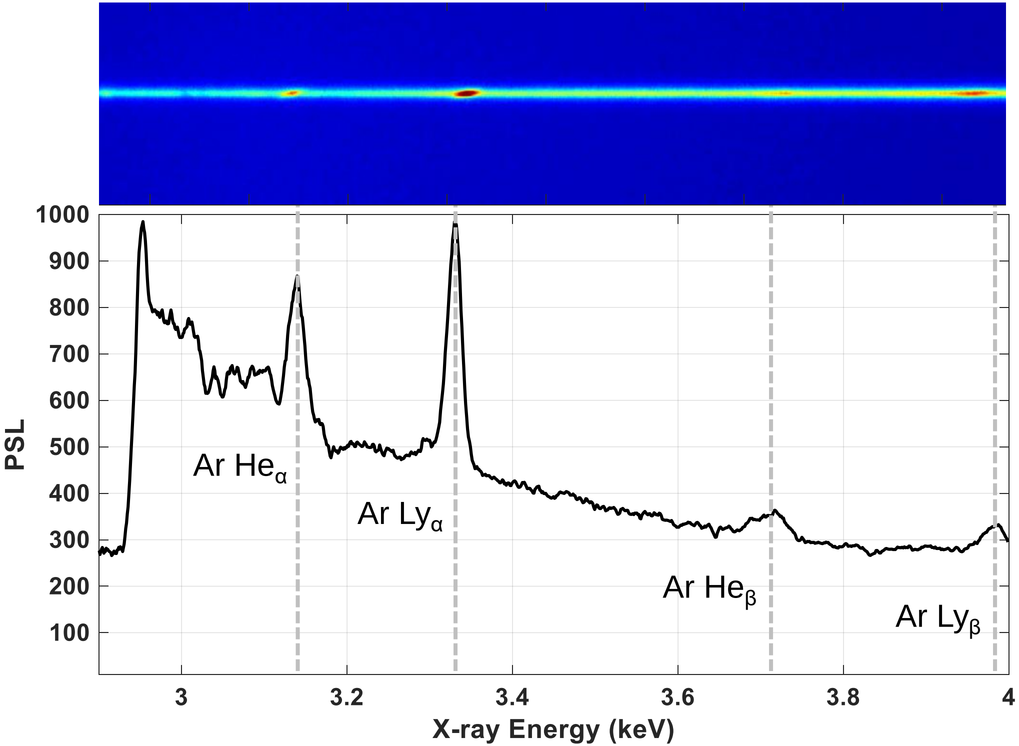
Simulations qualitatively match experimental results.
Laser energy goes toward compressing field instead of fuel at higher fields without preheat.

Spectrometers indicated no titanium emission from window mix, but there were unintended argon lines!

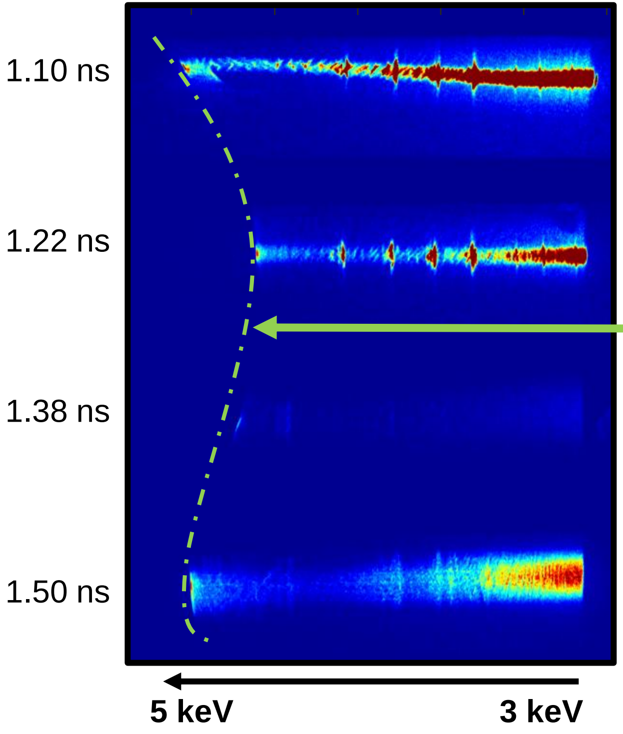
Argon diffuses into the parylene shell in the days prior to shot

~~A time integrated spectrometer (XRS) captured Ar Ly$_\alpha$ and He$_\alpha$ in more detail, can be used to get a rough estimate of mix and temperature from the wall~~

Caveat: Argon quantity could potentially vary shot to shot



Experiments using a titanium layer on the preheat beam window indicated no significant mix from window blow-in



Multi-spectrometer (MSPEC) is a time-resolved, 1D spatially resolved spectrometer

Damage to the crystal potentially ruined the calibrated dispersion

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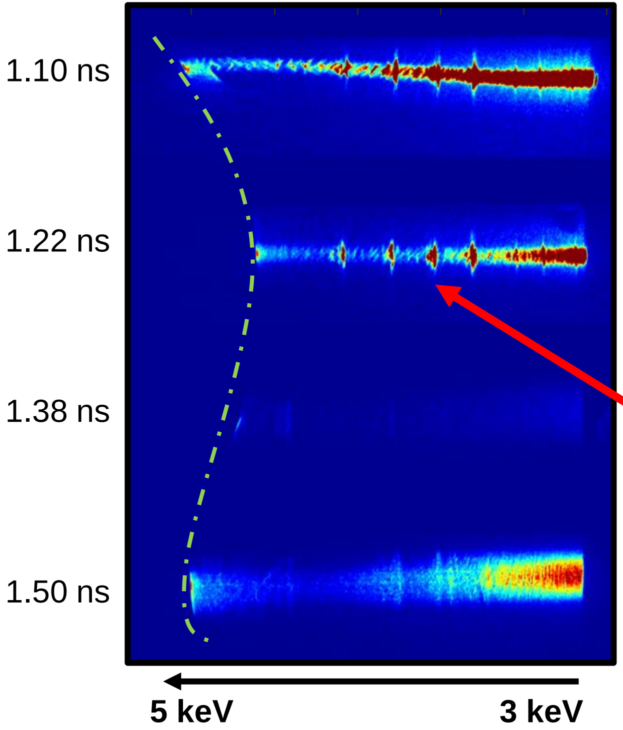

Multi-spectrometer (MSPEC) is a time-resolved, 1D spatially resolved spectrometer

Damage to the crystal potentially ruined the calibrated dispersion

Inadvertent signal from a glass backlighter gave clear lines used to recalibrate

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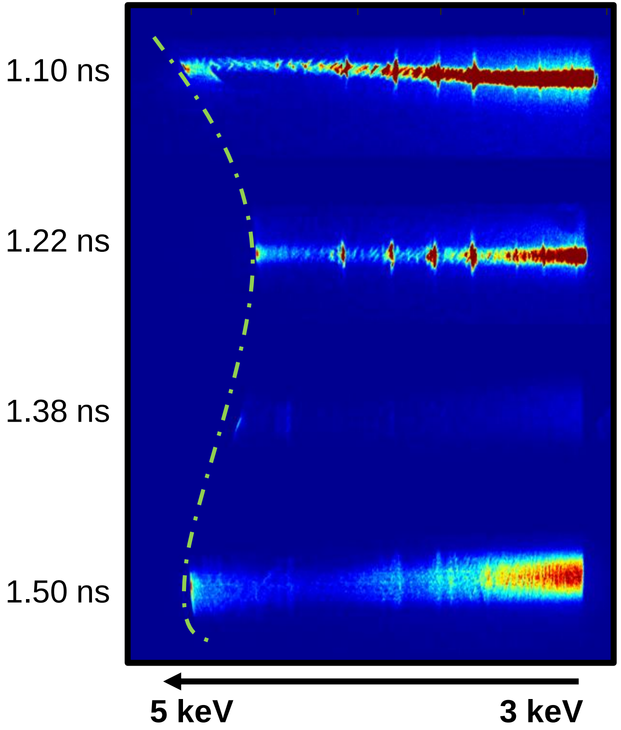

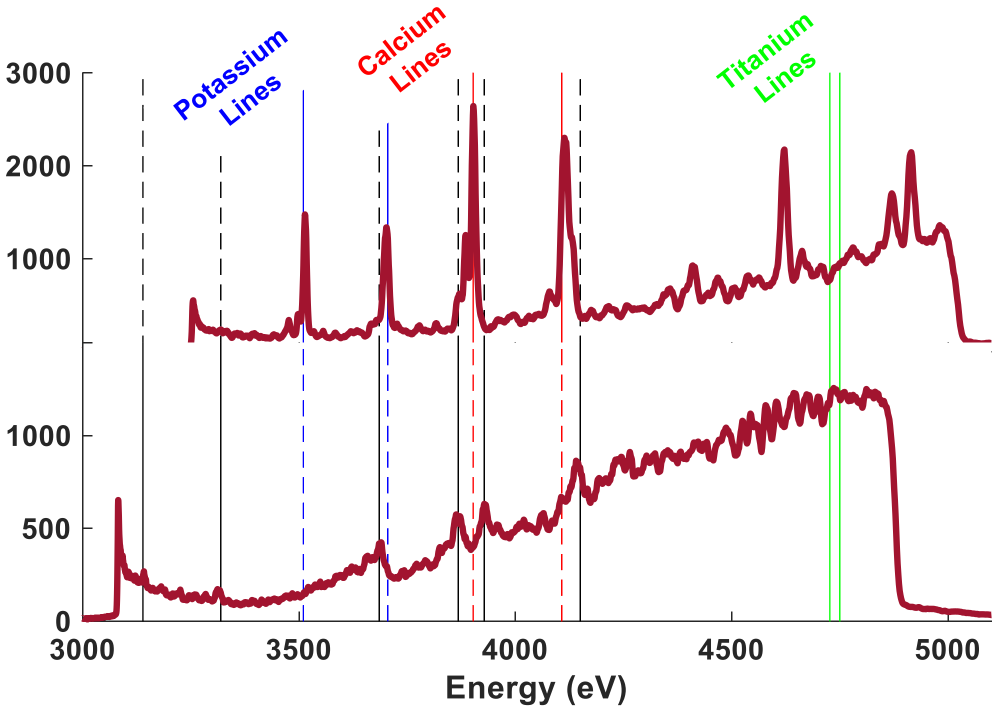

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