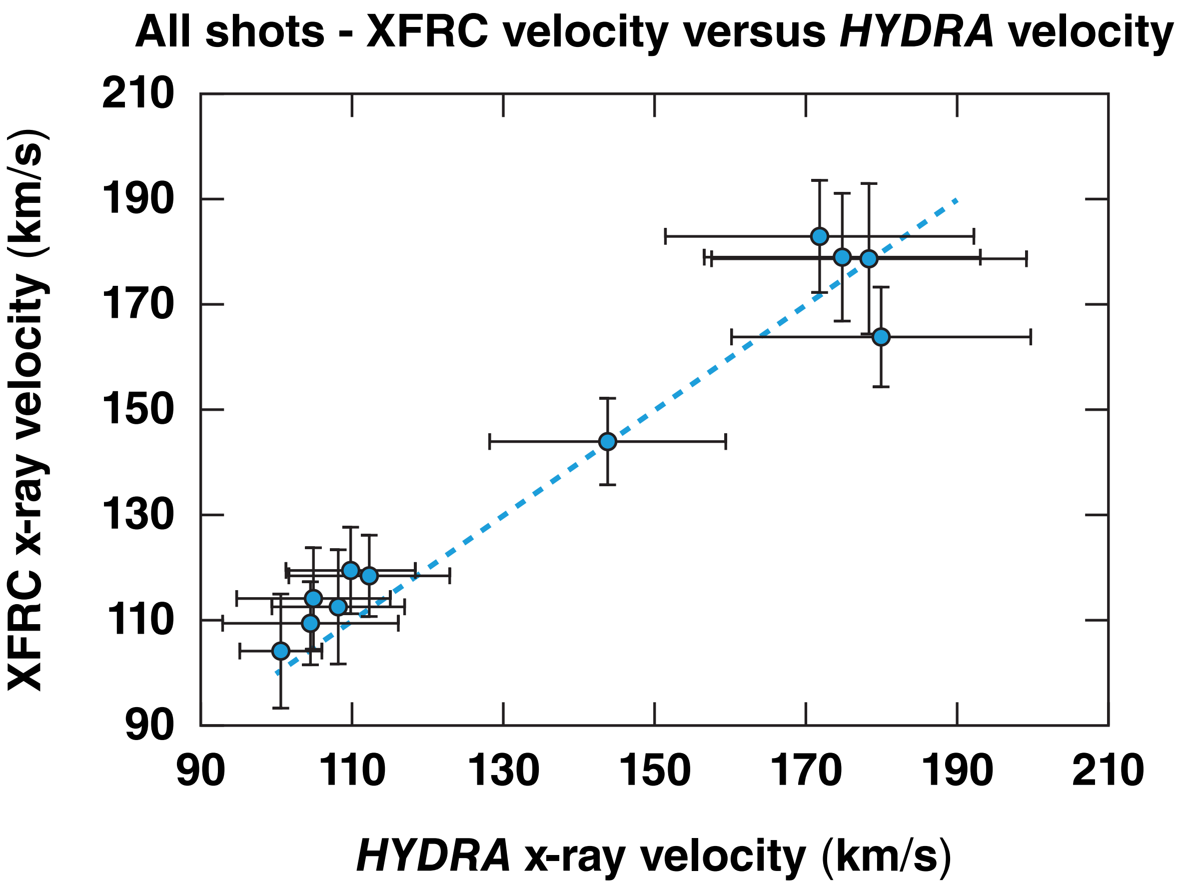
Experiments and Simulations of Laser-Driven Magnetized Liner Inertial Fusion



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Summary

2-D *HYDRA* simulations accurately model the implosion velocity at the center of the implosion region

- X-ray images of laser-driven cylindrical implosions were recorded along the radial direction without a preheat beam or applied magnetic field
- Two-dimensional *HYDRA* simulations of the experiment including measured beam pointing and 3-D ray tracing were performed
- Quantitative analysis of experimental and simulated x-ray images provide a measurement of implosion velocity and uniformity of implosion

Analysis technique will be applied to laser-driven, integrated MagLIF* shots (preheat beam, applied magnetic field) on OMEGA.

*MagLIF: magnetized liner inertial fusion
S. A. Slutz *et al*., Phys. Plasmas 17, 056303 (2010).

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Collaborators

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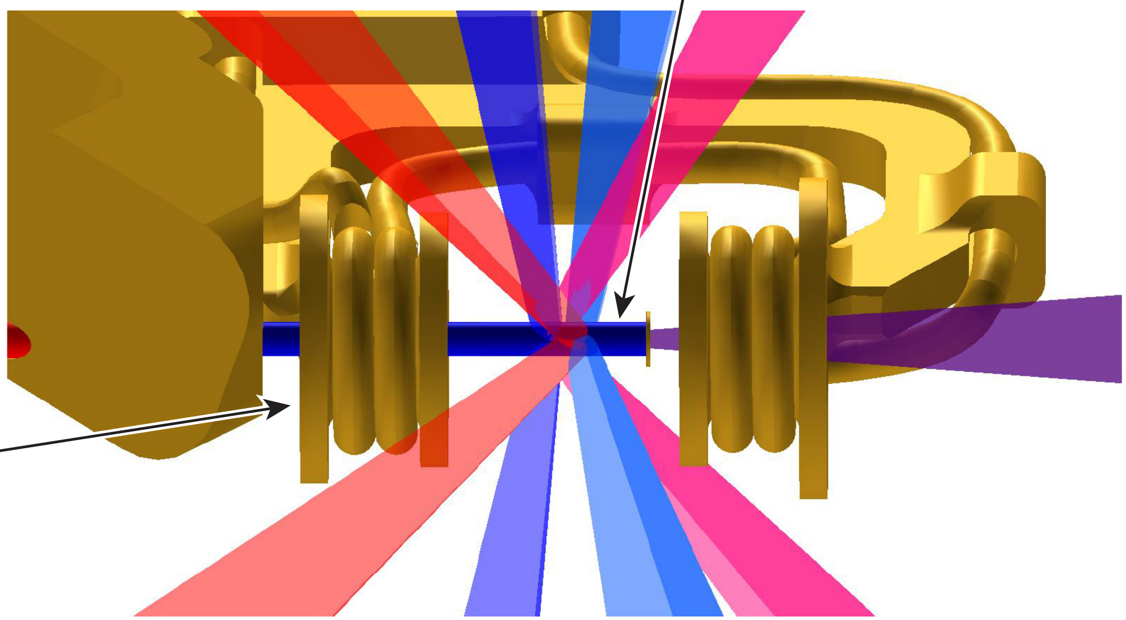
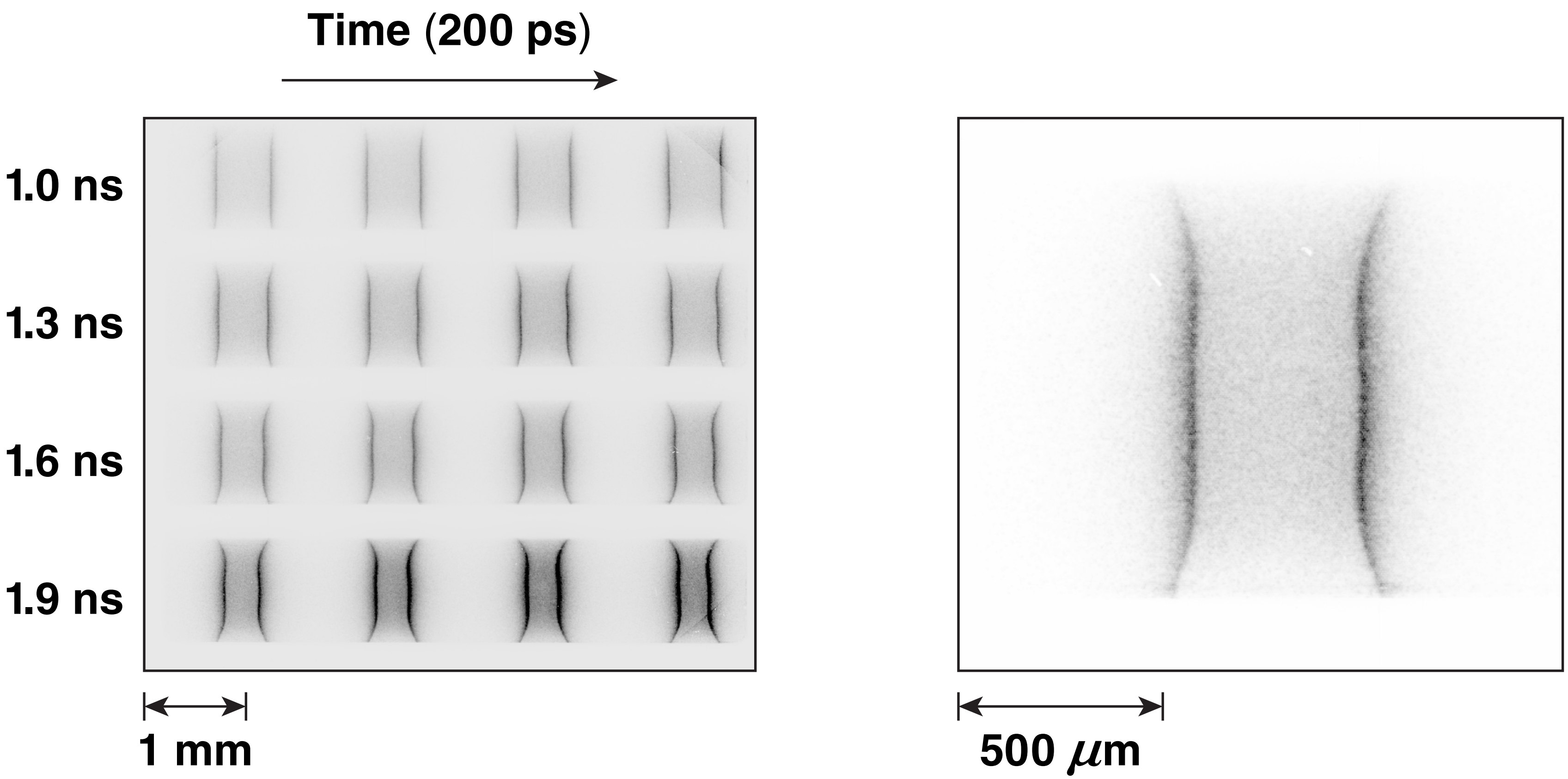
The goal is to diagnose integrated shots on OMEGA that use compression beams, a preheat beam, and axial magnetic fields



Analysis has been applied to implosion-only shots (no preheat, no field).

*MIFEDS: magneto-inertial fusion electrical discharge system
G. Fiksel *et al*., Rev. Sci. Instrum. 86, 016105 (2015).

X-ray framing camera (XRFC) data are used to determine x-ray velocity and curvature of the shell from self-emission



X-ray velocity and shell implosion velocity are approximately equal.

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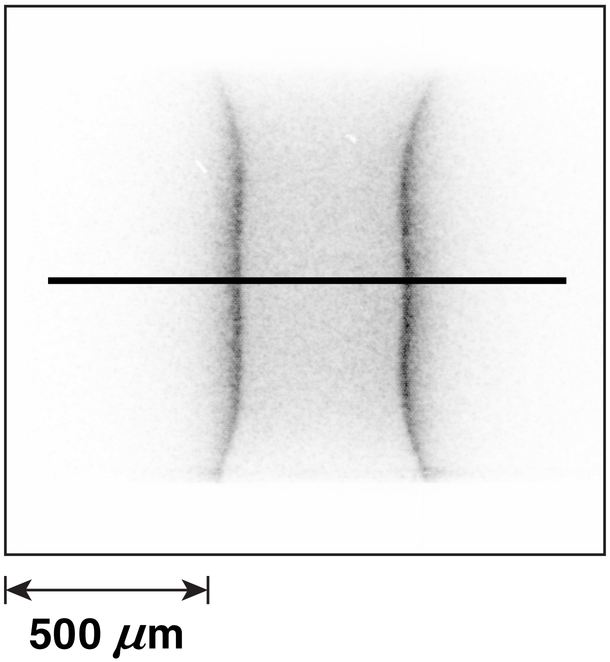
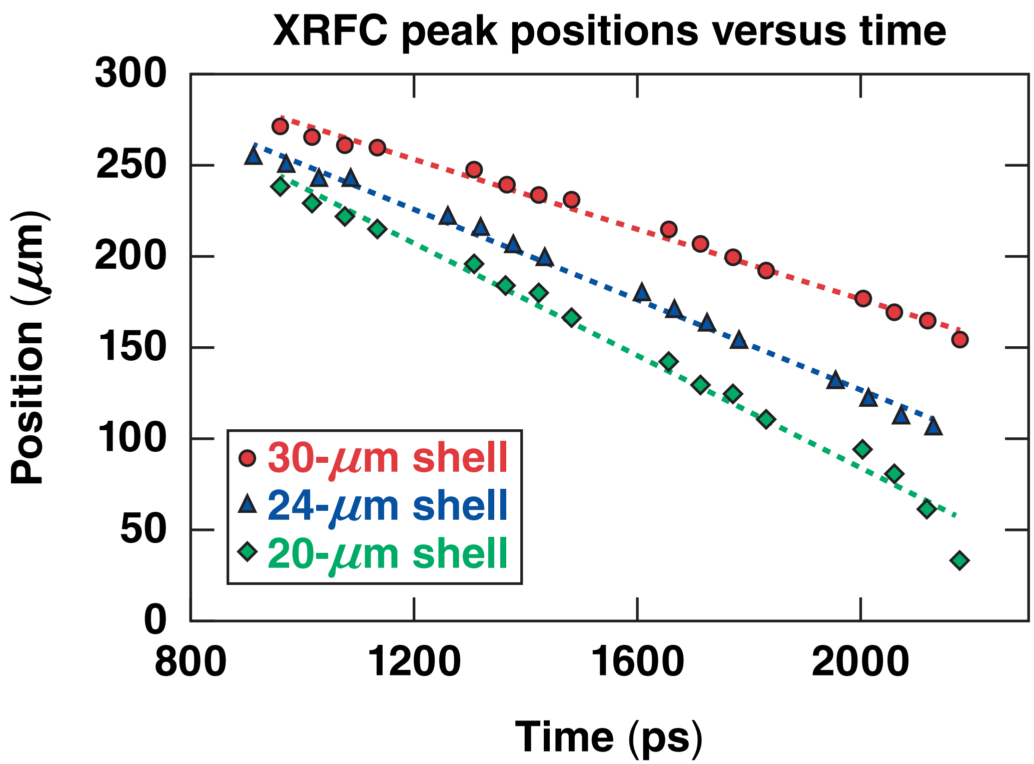
Implosion velocity is calculated from the slope of the best-fit line to the emission peak position versus time





Smaller shell thickness → higher velocity

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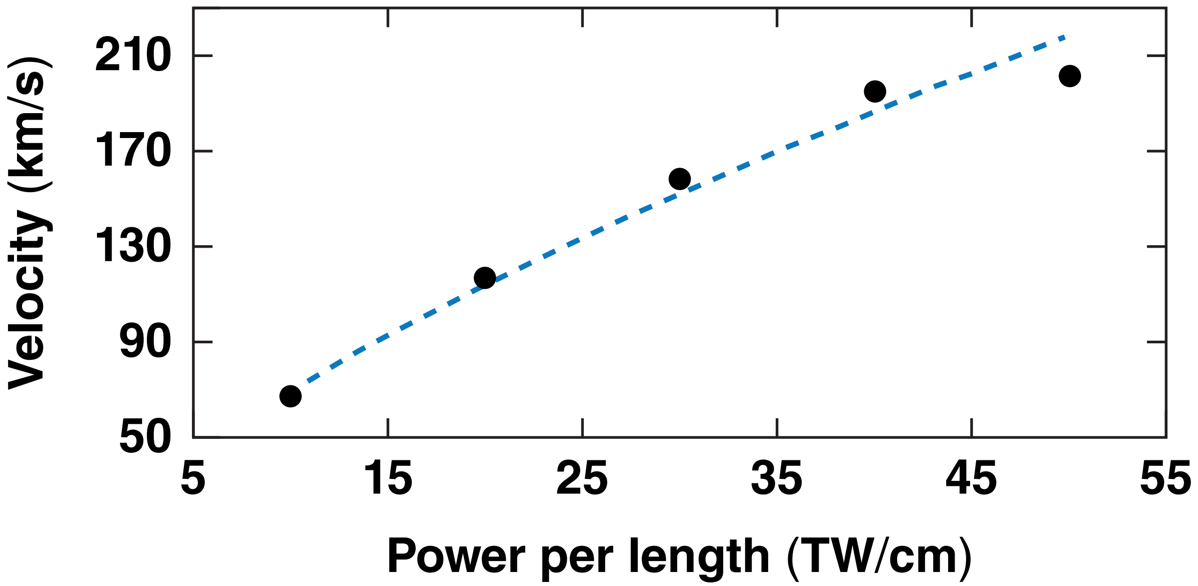
One dimensional *LILAC* with 2-D ray tracing requires the laser power to be reduced by a factor of 2 to match velocity because the angle of incidence is not taken into account

$v = 13.563 * P_L^{0.7107}$

- For shot 79499, v = 178.7 km/s, P_L = 77.68 TW/cm
- *LILAC* power law → P_L = 37.63 TW/cm, 48.45%

X-ray velocity versus P_L in *LILAC*



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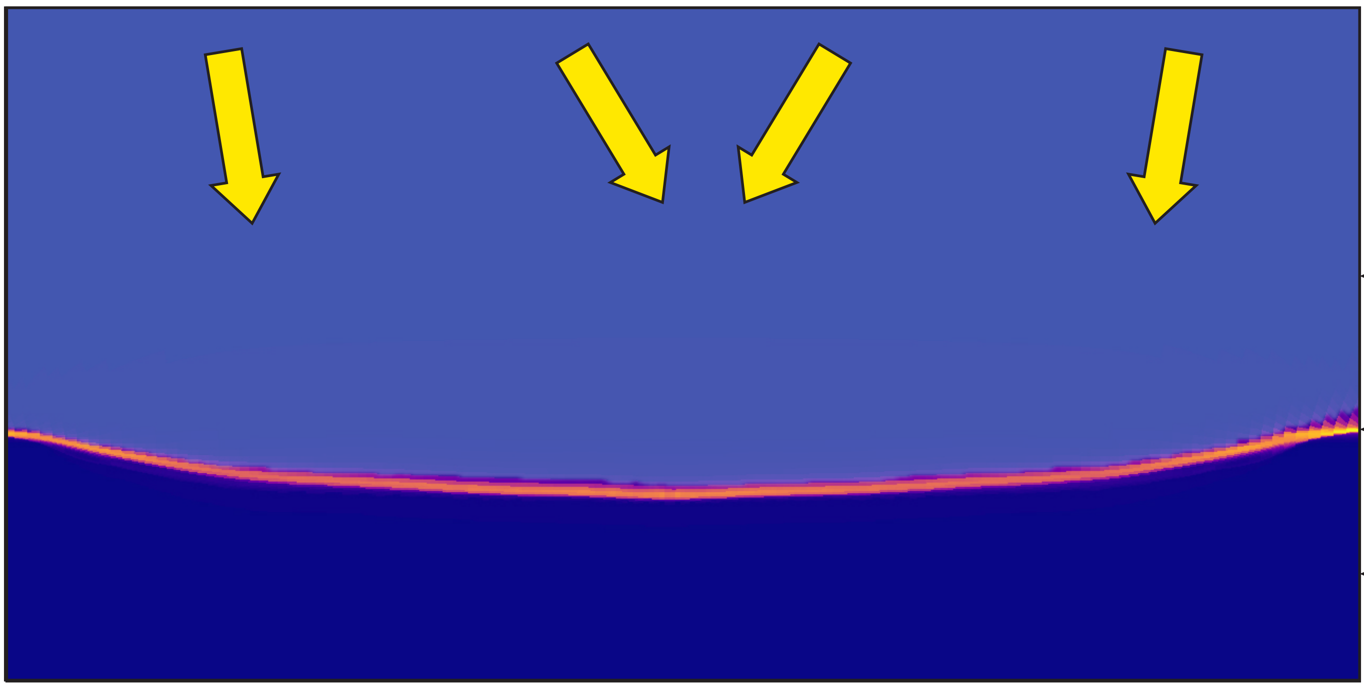
Measured beam pointing is used with 3-D ray tracing to simulate implosions in 2-D *HYDRA*



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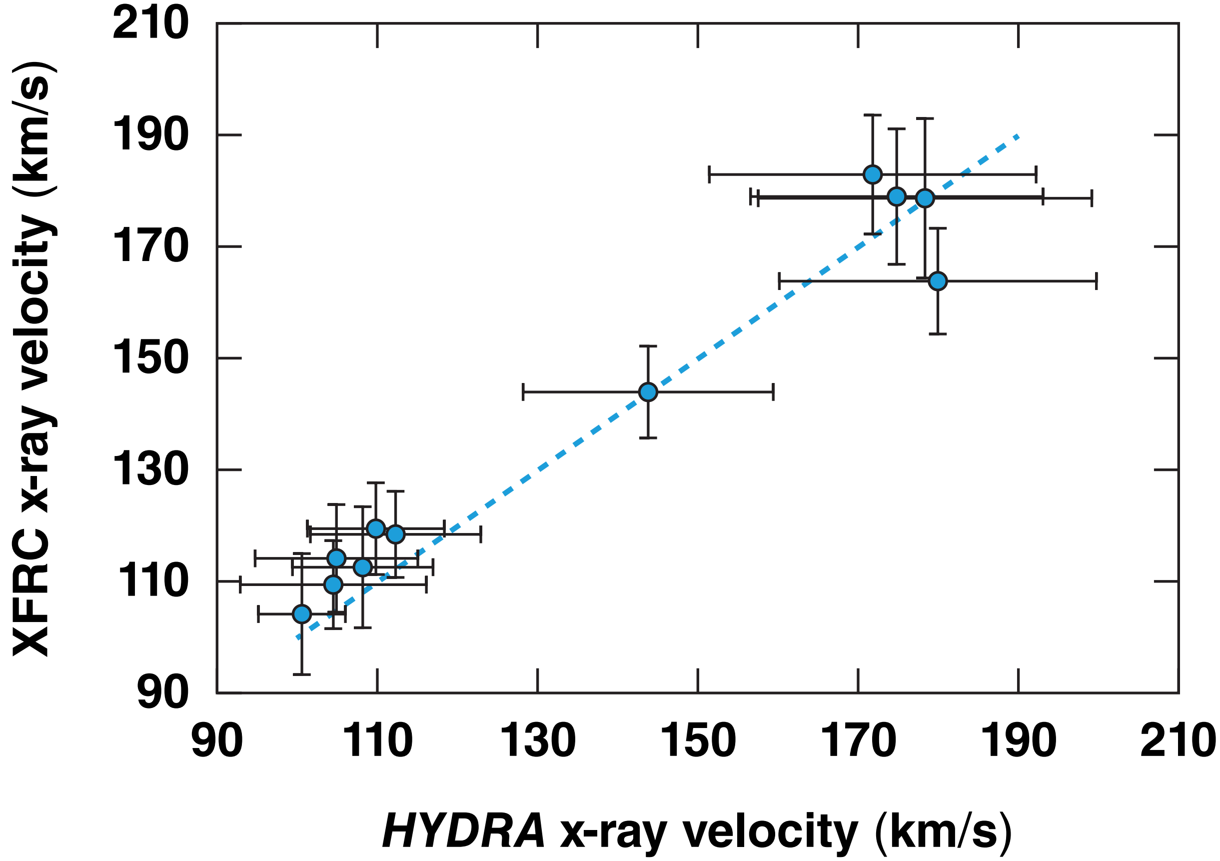
Velocity from *HYDRA* is consistent with velocity from XRFC

All shots - XFRC velocity versus *HYDRA* velocity



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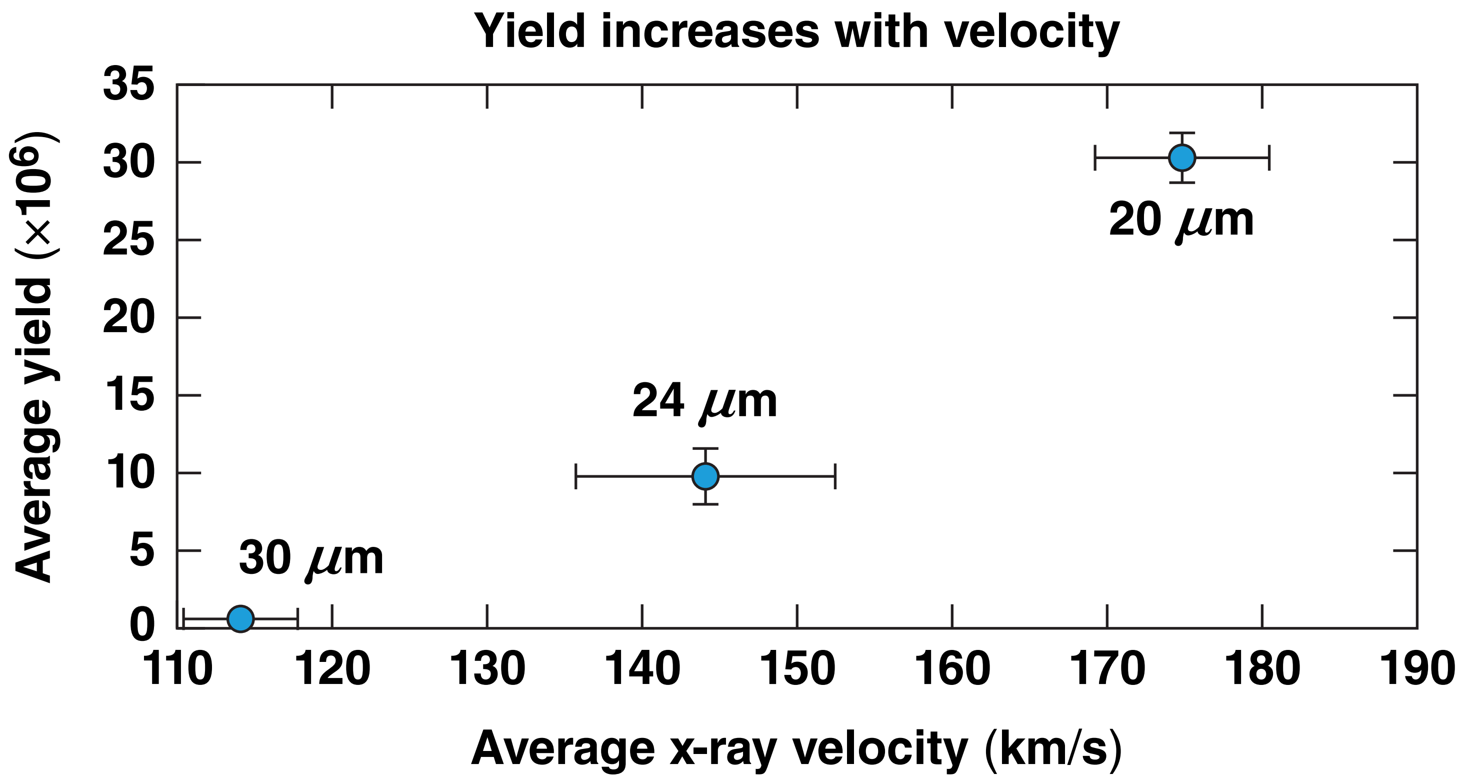
Higher average implosion velocity correlates with higher average neutron yield



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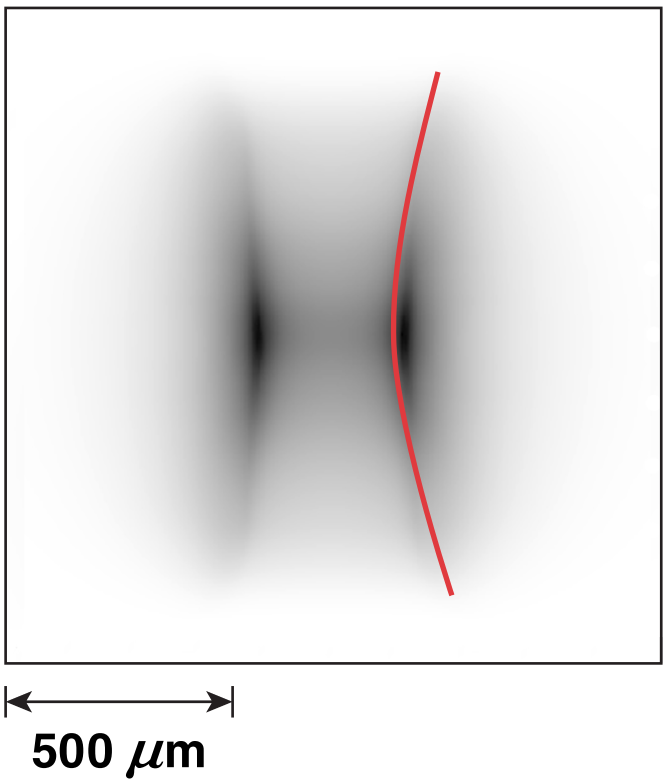
The radius of curvature of x-ray emission is calculated to determine flatness

- Curvature can be defined as $\kappa(z) = |r''(z)| / [1 + r'(z)^2]^{3/2}$



- An example from a 2-D *HYDRA* simulation

Change in curvature over time determines uniformity of implosion velocity.

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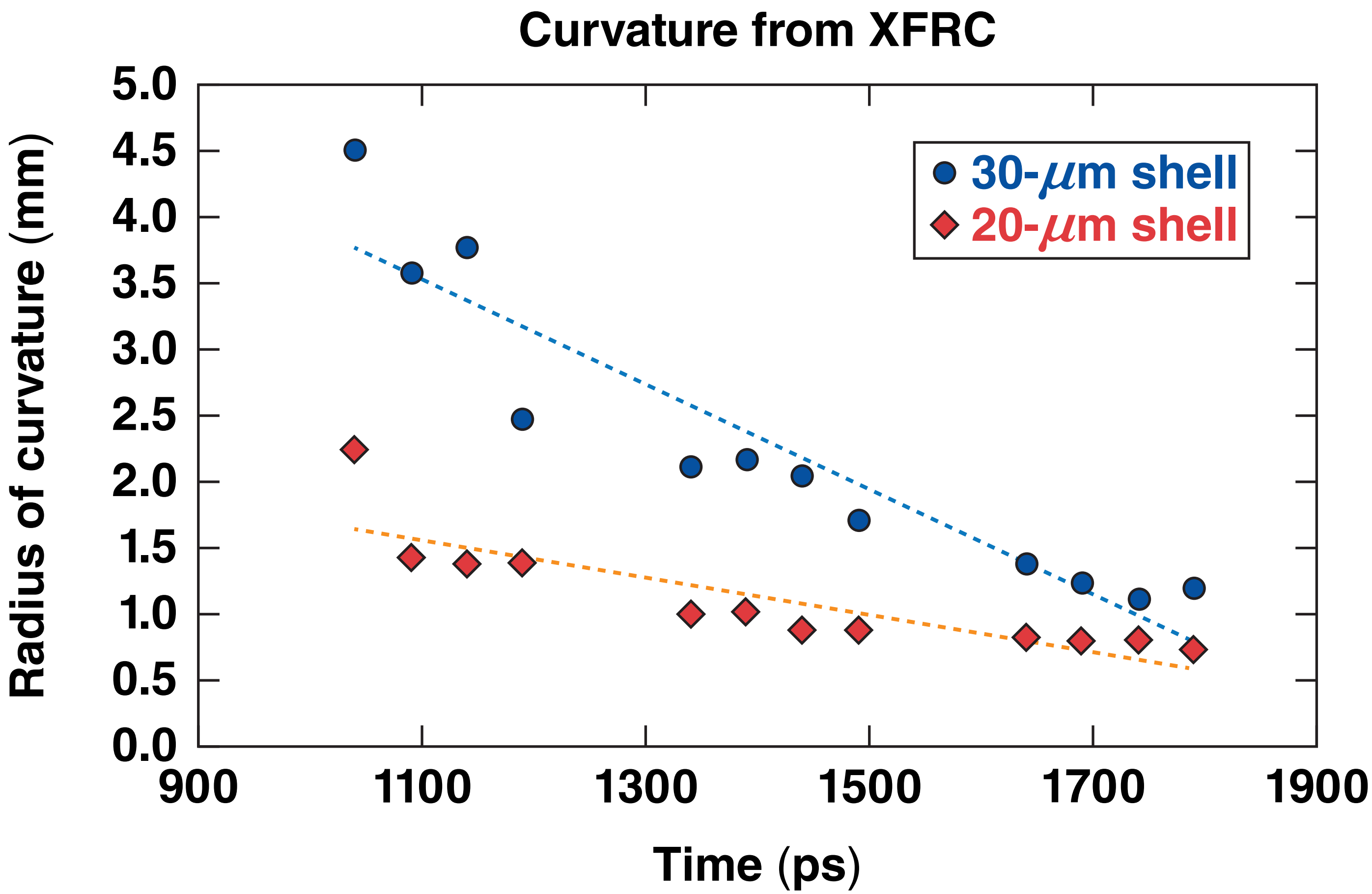
Thinner shells show smaller radius of curvature, but slower change in radius of curvature over time



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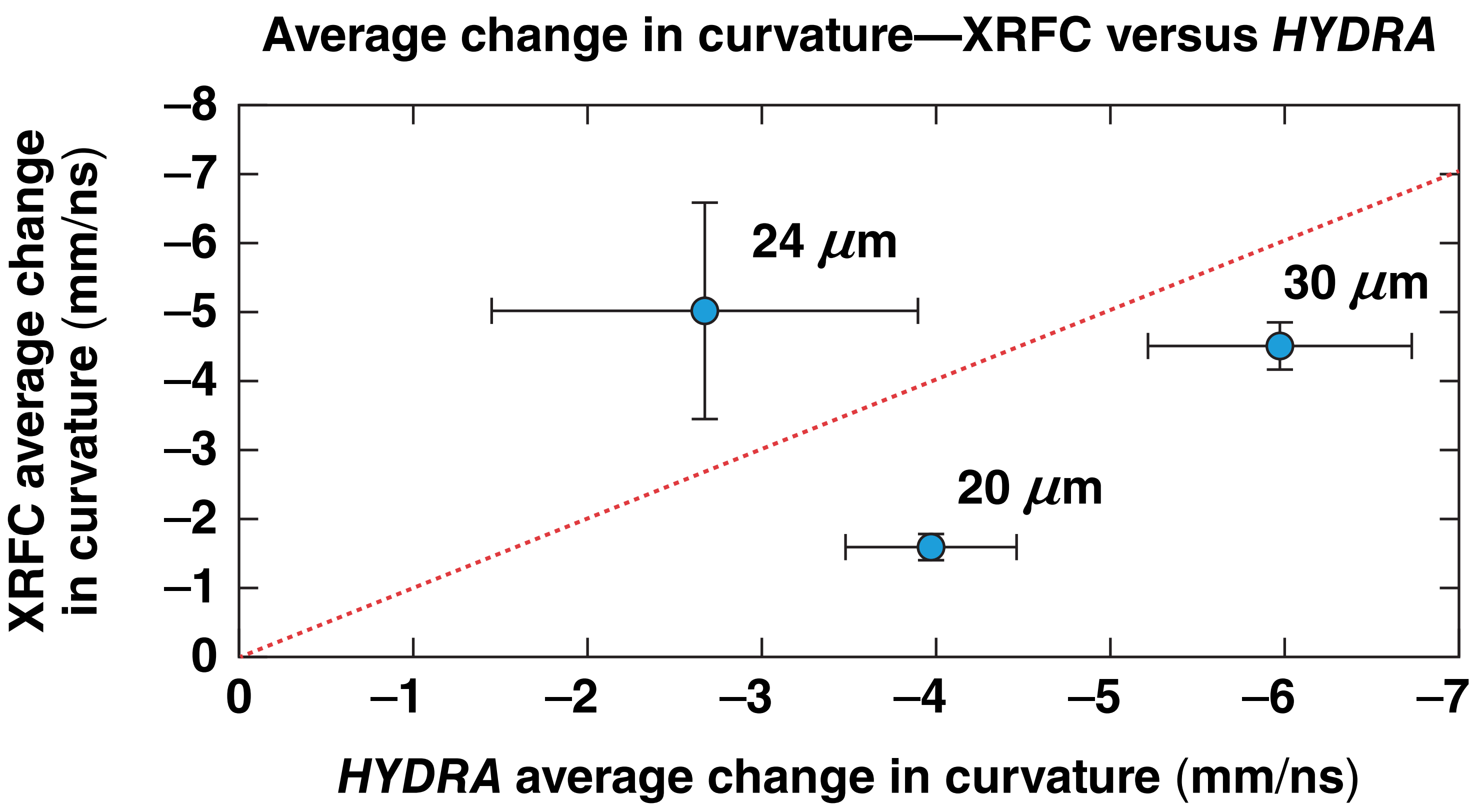
Shot-averaged curvature results from *HYDRA* are not consistent with XRFC data



CBET* may be altering energy in outer beams resulting in this discrepancy.

*CBET: cross-beam energy transfer
J. F. Myatt *et al*., Phys. Plasmas 24, 056308 (2017).

Discrepancies between simulations and experiment allude to physical processes that should be considered for future simulation and experimental design

1-D *LILAC*	2-D *HYDRA*
Model center of implosion	Model shape of implosion
Measure implosion velocity	Measure implosion velocity and curvature
Use laser power reduced by 50%	Use experimental laser power and beam pointing
No axial losses, no angle of incidence	Outer regions modeled inaccurately, current hypothesis is CBET

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Summary/Conclusions

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