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The Near Vacuum Hohlraum Campaign at the NIF: A New Approach

S. Le Pape

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THE NEAR VACUUM HOHLRAUM CAMPAIGN AT THE NIF: A NEW APPROACH

American Physical Society
Division of Plasma Physic

Sebastien Le Pape

November 17, 2015

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This work depends upon the efforts of a large and dedicated team

LLNL

N. Meezan, L. Divol, L. Berzak Hopkins, A. Mackinnon, D. Turnbull, D. Ho, O. Jones, J. S. Ross, J. Milovich, S. Khan, P. Amendt, R. Benedetti, J. Biener, R. Bionta, D. Bradley, J. Caggiano, D.A. Callahan, D. Casey, P. Celliers, G. Collins, E. Dewald, T. Doeppner, M. Eckart, D. Fittinghof, S. Haan, A. Hamza, R. Hatarik, D. Hinkel, N. Izumi, B. Kozioziemski, T. Ma, A.G. MacPhee, J. McNaney, P. Michel, J. Moody, A. Pak, J.L. Peterson, J. Ralph, H. Robey, R. Rygg, V. Smalyuk, B. Spears, P. Sterne, D. Strozzi, R. Tommasini, R. Town, D. Turnbull, B. Yoxall, E. Storm, W. Hsing, O. Landen, J.L. Atherton, J. D. Lindl, M. J. Edwards

NIF operations, laser, target fabrication, cryogenic, and diagnostic teams

MIT

A. Zylstra, H. Rinderknecht, M. Rosenberg, M. Gatu-Johnson, J. Frenje, F. Seguin, C. Li, R. Petrasso

LANL

G. Grim, N. Guler, F. Merrill, A. Yi, G. Kyrala, J. Kline, R. Olson

GA

J. Kilkenny, D. Hoover, H. Huang, W. Requieron, A. Nikroo

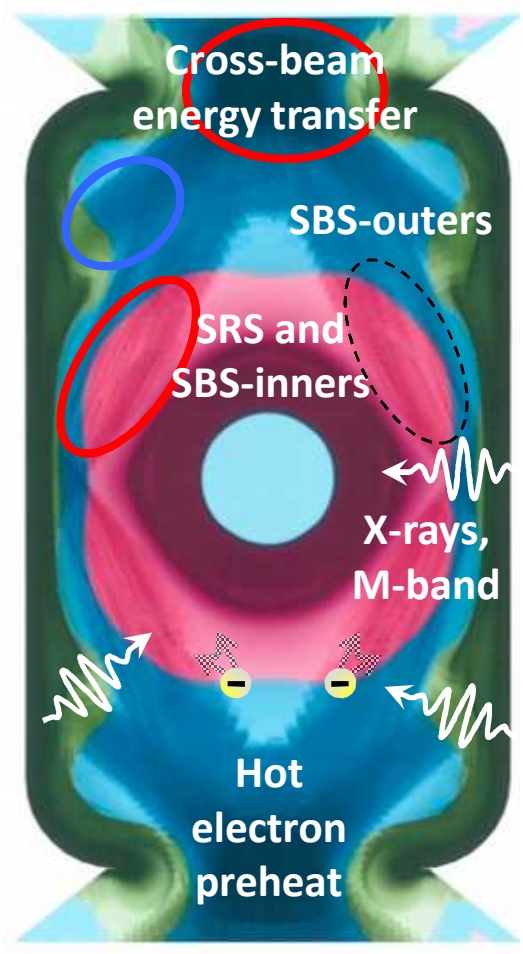
Diamond Materials GMBH, Germany

C. Wild, E. Werner

Outline

- Near Vacuum Hohlraum is a low Laser plasma interaction, high efficiency platform. Can it support a 3 shock ignition pulse for HDC?
- Symmetry in small case to capsule ratio target (CCR ~ 2.8, 3.1) is hard to control at 10x convergence.
- Symmetry in larger case to capsule ration (CCR~3.4) can be controlled at 20x convergence.
- Higher convergence (30x) @ CCR 3.4 is still challenging in AU NVH
- Exploring path to a no-coaster, low LPI platform : low gas fill (0.3), DU hohlraum @ CCR 3.4 @ 30x convergence.

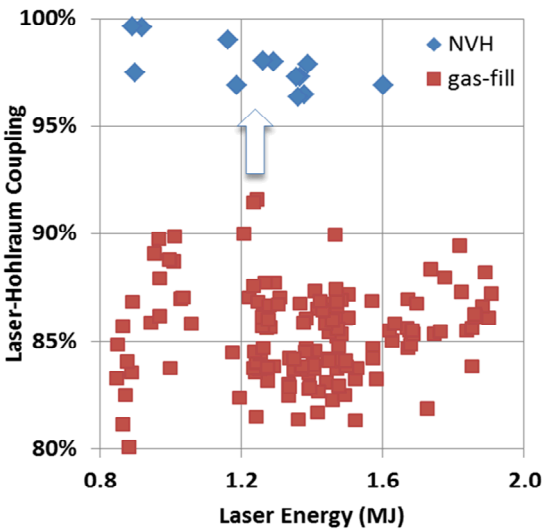
Why NVH?
Gas-filled hohlraum dynamics are complicated

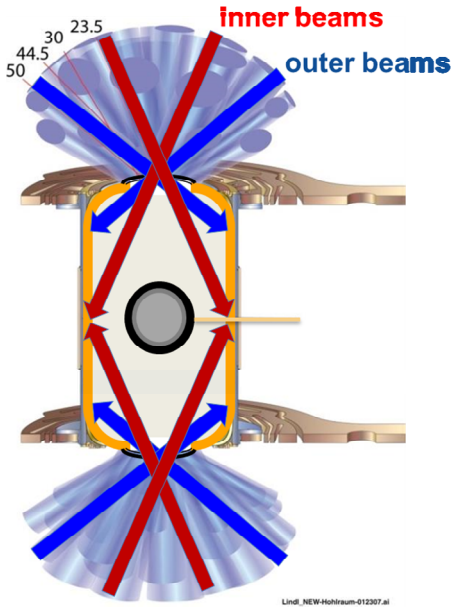


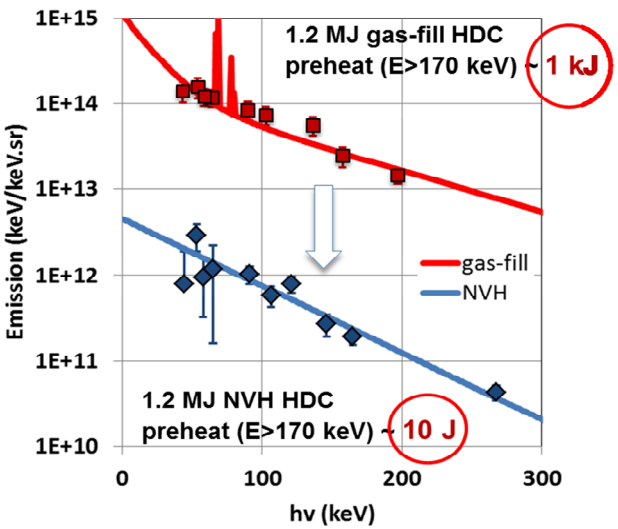
- Backscatter losses ~ 15% (~200kJ)
- Capsule drive is over-predicted~ 200kJ → drive degradation required for 2D HYDRA simulations to match experiment
- Suprathermal electron generation (0.5 - 2 kJ)
- Poor late-time inner beam propagation requires high inner beam power to achieve implosion symmetry
- Require cross-beam energy transfer (CBET) to control implosion symmetry → leads to time dependent asymmetries

Near-vacuum hohlraums (NVH) with High Density Carbon (HDC) capsules have reduced laser-plasma interactions (LPI) and improved coupling

- **NVH use a minimal hohlraum gas-fill density, no beam wavelength separation (Δλ = 0/0), minimal CBET, and direct cone-fraction tuning for symmetry control**







- **Reduced backscatter**
- **100x reduction in hot electrons**

A promising low LPI platform 30-40% more efficient relative to gas-filled hohlraums

Near-vacuum hohlraums (NVH) with High Density Carbon (HDC) capsules have reduced laser-plasma interactions (LPI) and improved coupling

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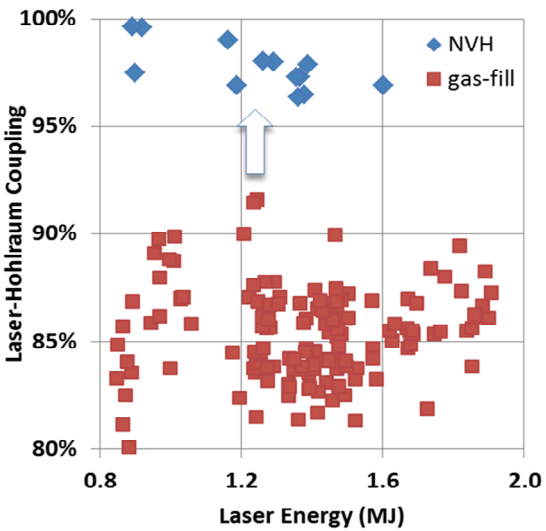
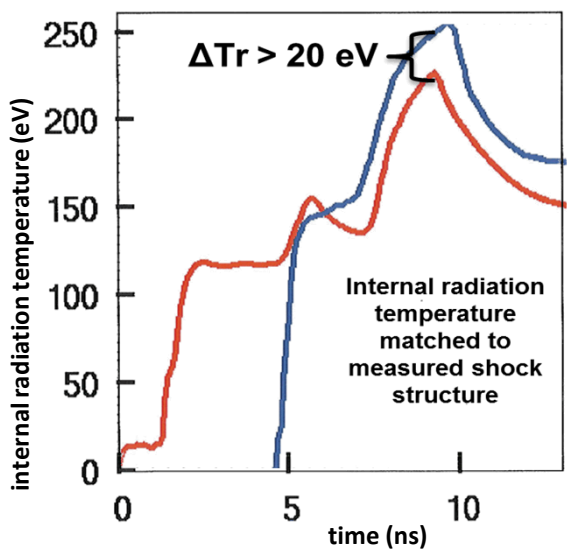
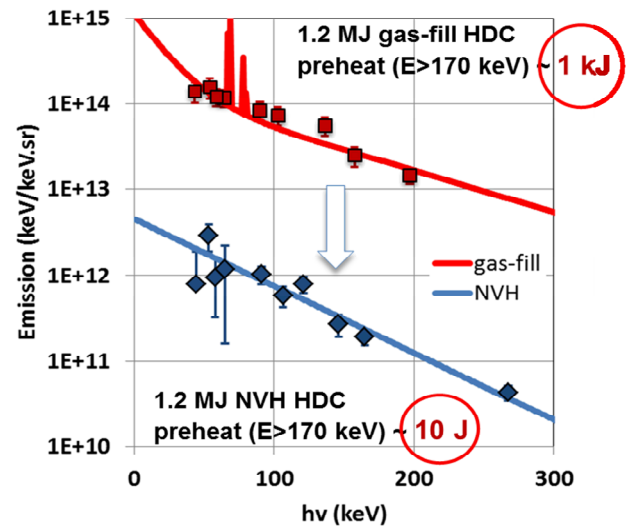


- **Reduced backscatter**



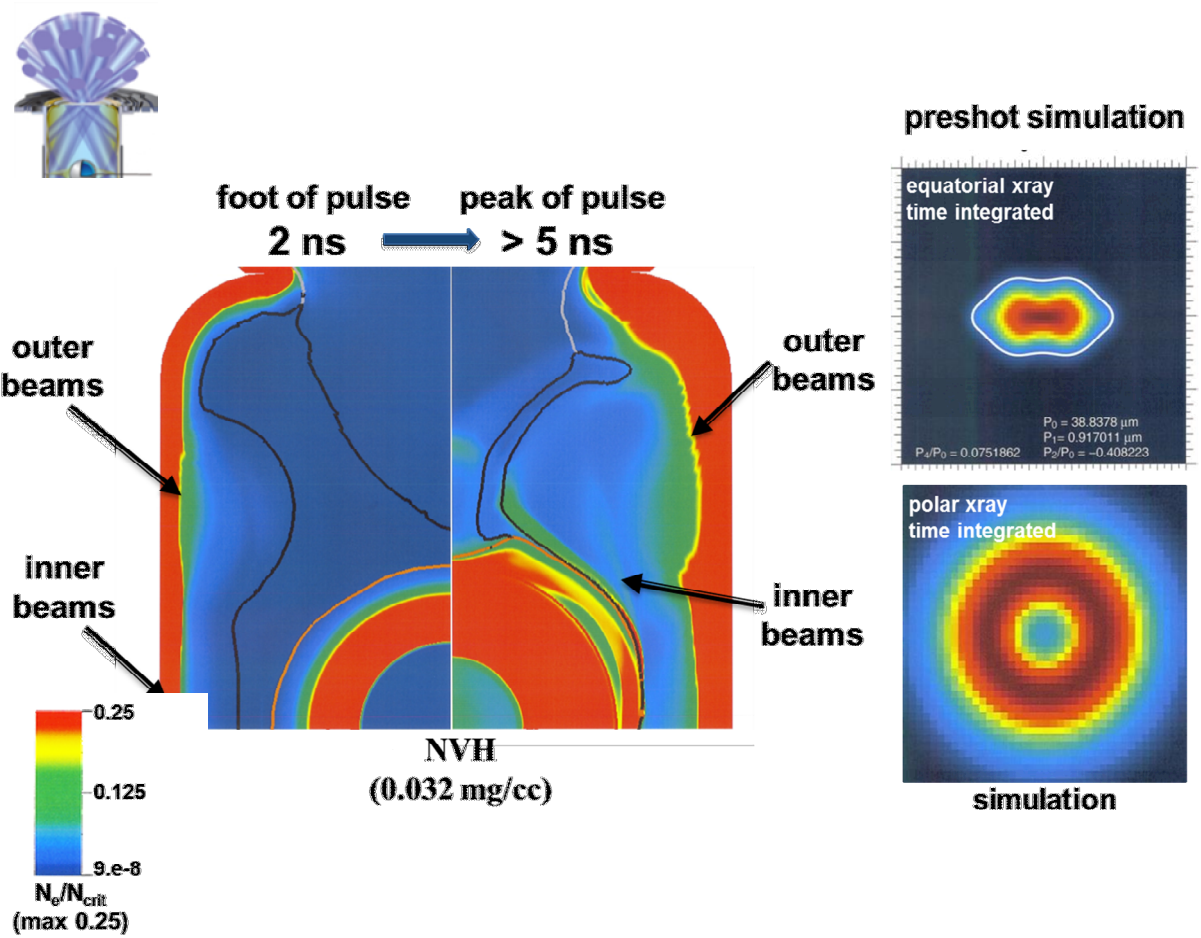
- **Minimal need for drive degradation to match simulations → increased Tr for same laser drive**

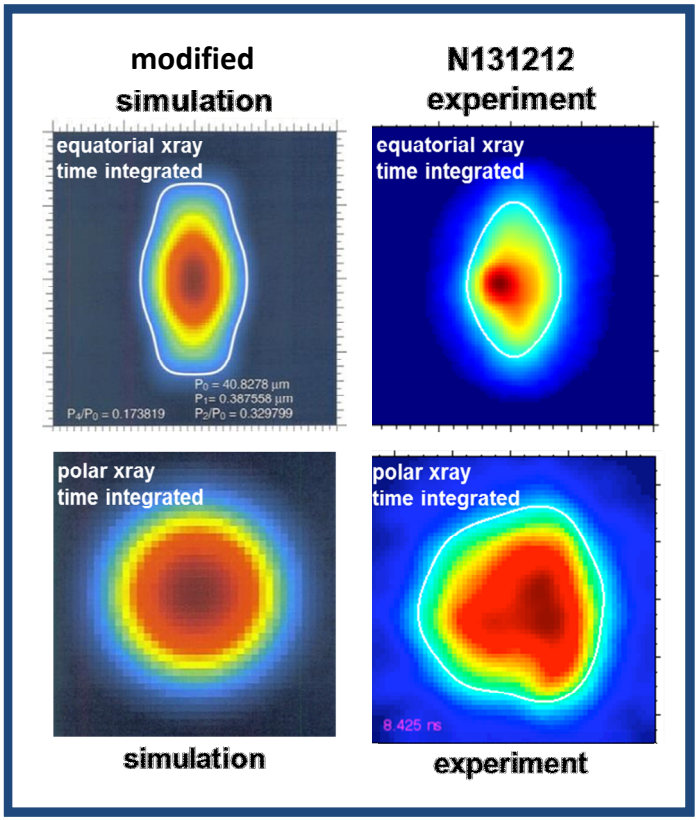


- **100x reduction in hot electrons**

A promising low LPI platform 30-40% more efficient relative to gas-filled hohlraums

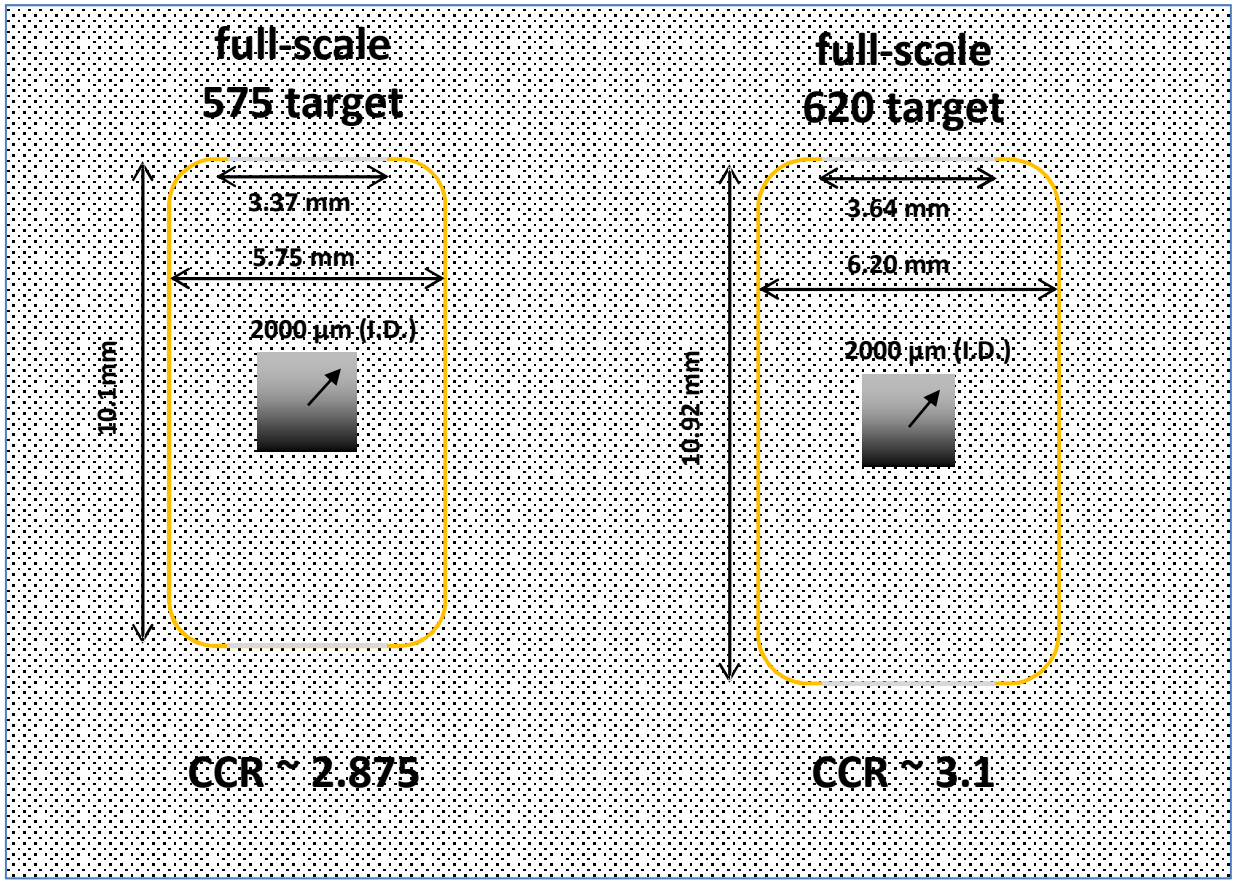
Nominal HYDRA simulations predict inner beams hindered by dense region formed between capsule and wall, but measured symmetry shows more waist drive than simulated

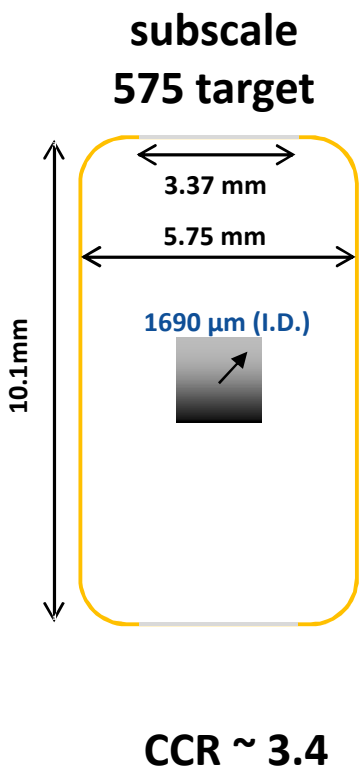




New region of hohlraum parameter space not originally predicted by nominal simulations

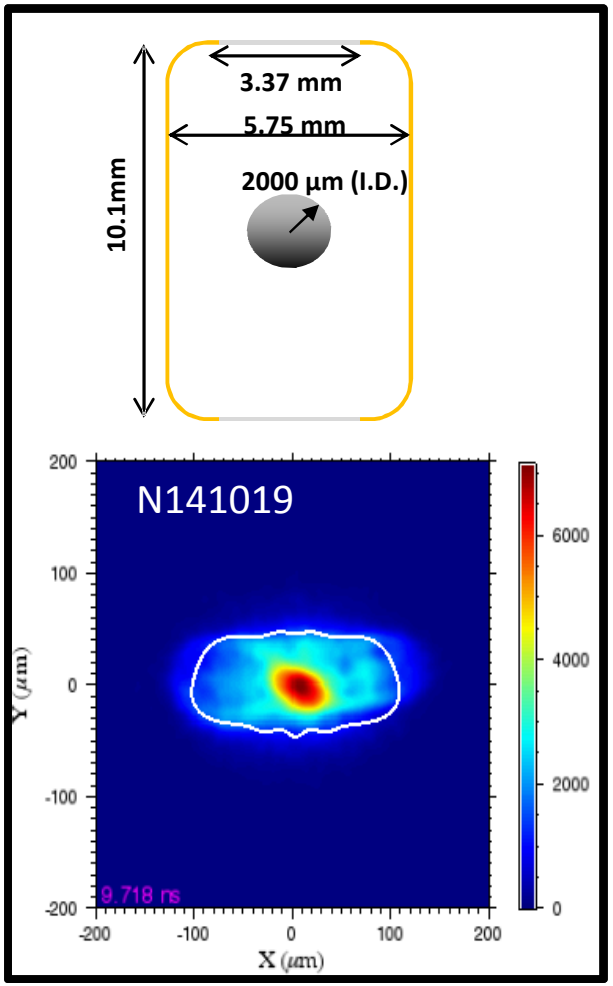
To study symmetry control, 2 hohlraum sizes and 2 capsule sizes have been simulated and experimentally explored

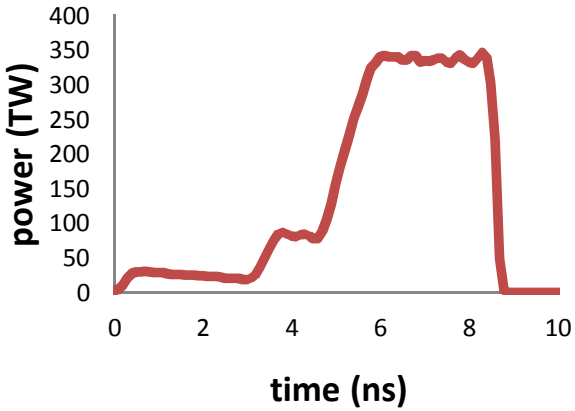




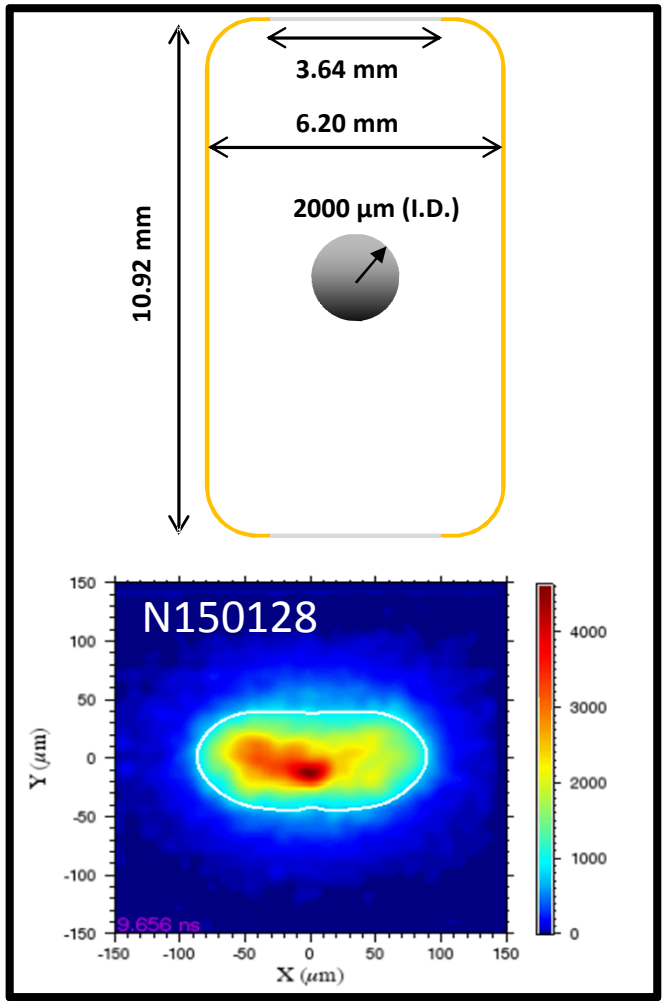
Varying target size allows exploration of pulse length & hohlraum performance

Keeping pulse shape and capsule the same, while increasing CCR improved symmetry



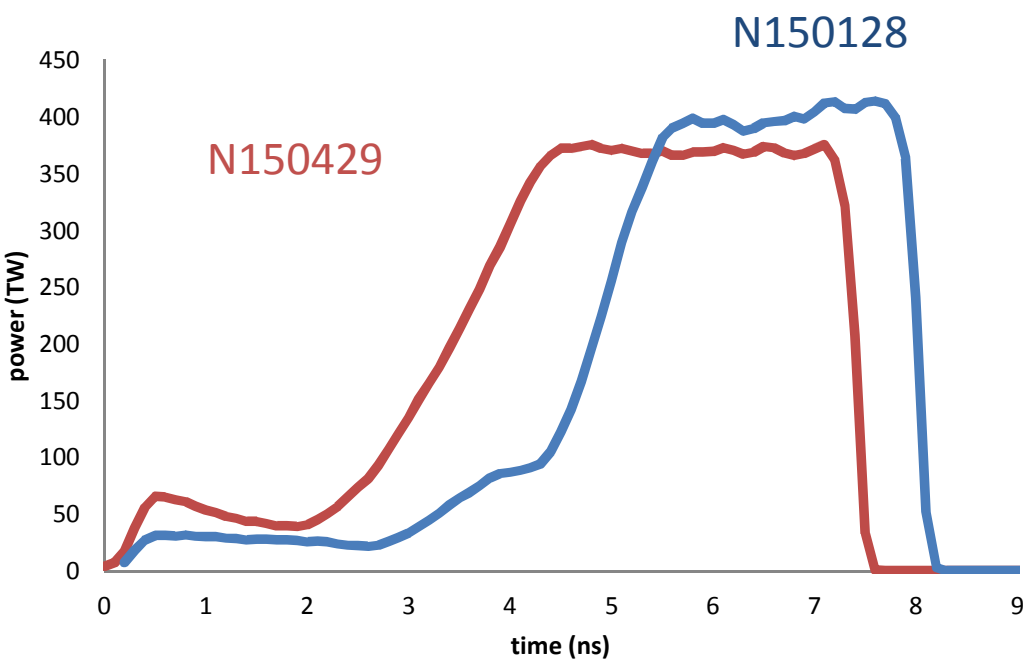


Equatorial X ray image at bang time

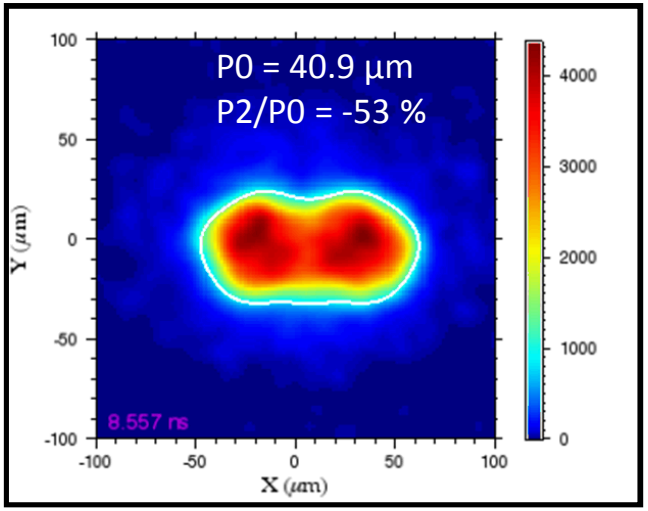


Pulse shape is too long to control symmetry in 620 hohlraum

Going into a high convergence DT, pulse shape was changed for a shorter 2 shocks pulse



Equatorial X ray

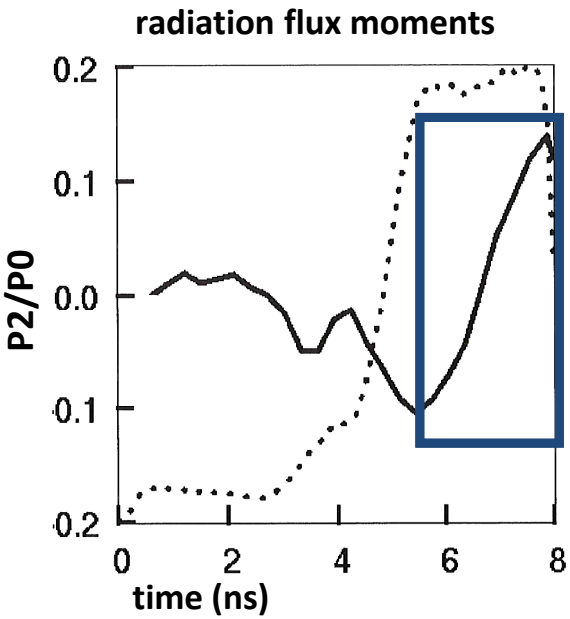


Experimental data

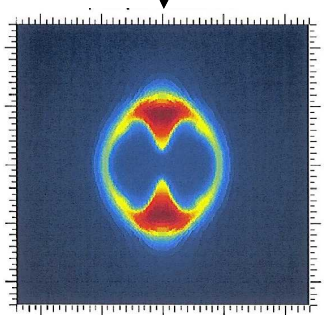
DT yield : 1.45 e15
Tion : 3.81 keV
DSR : 2.91
Bang time : 8.59 ns
Coupling @ 97.45 %

Yield is 1/6 of 1d clean, degradation from pre-shot simulation is due to shape

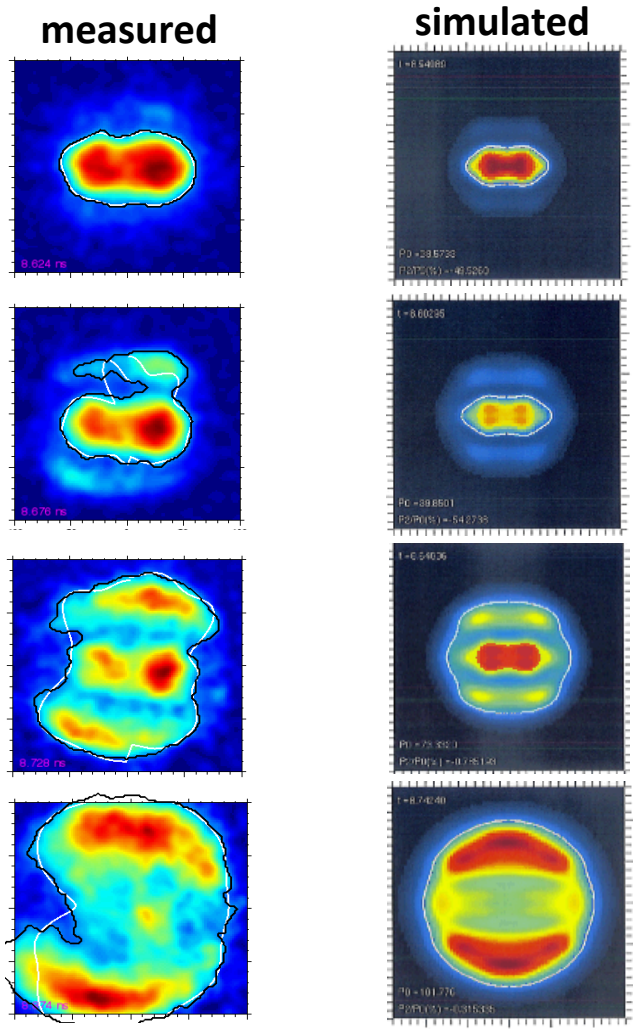
Ad Hoc hydra simulations indicates that polar jets are the reason of the shape degradation



Smooth P2 until late time results in round shell with dense polar features, complex xray emission



N150429
CCR ~ 3.1
time-resolved x-ray emission

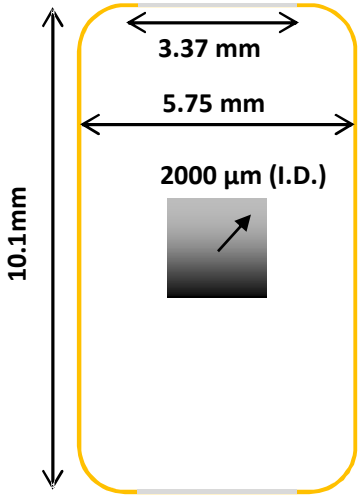


L. Berzak Hopkins U07.0008
On Nov. 19, 3:24 pm

CCR (2.8,3.1) is too small to control symmetry at high convergence

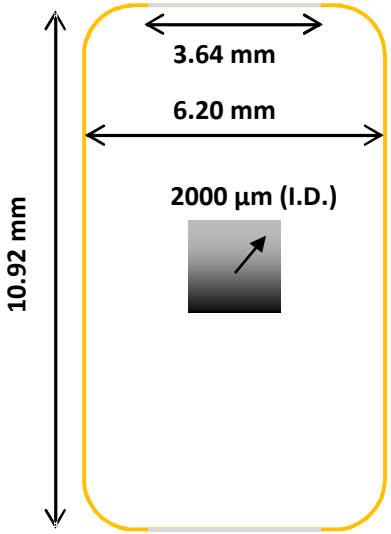
To study symmetry control, 2 hohlraum sizes and 2 capsule sizes have been simulated and experimentally explored

full-scale 575 target



CCR ~ 2.875

full-scale 620 target

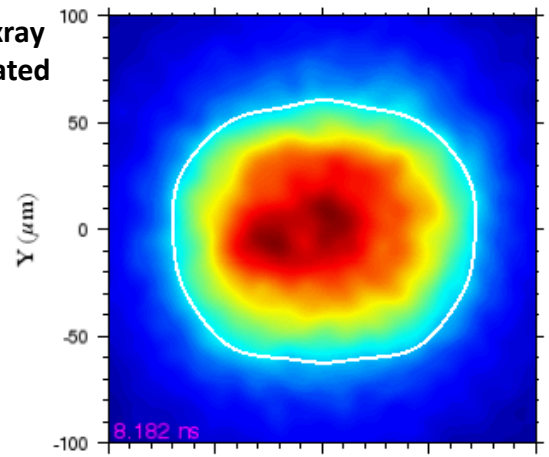


CCR ~ 3.1

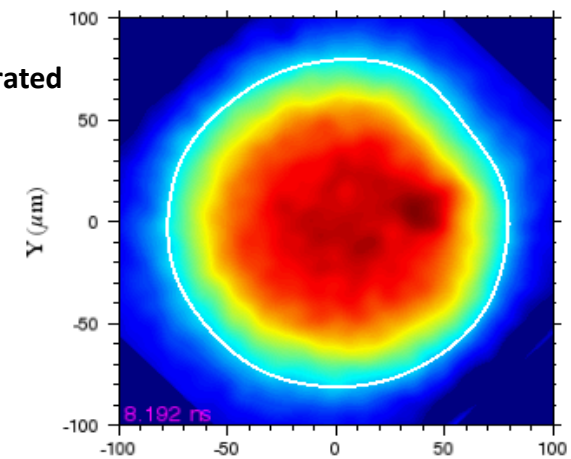
Varying target size allows exploration of pulse length & hohlraum performance

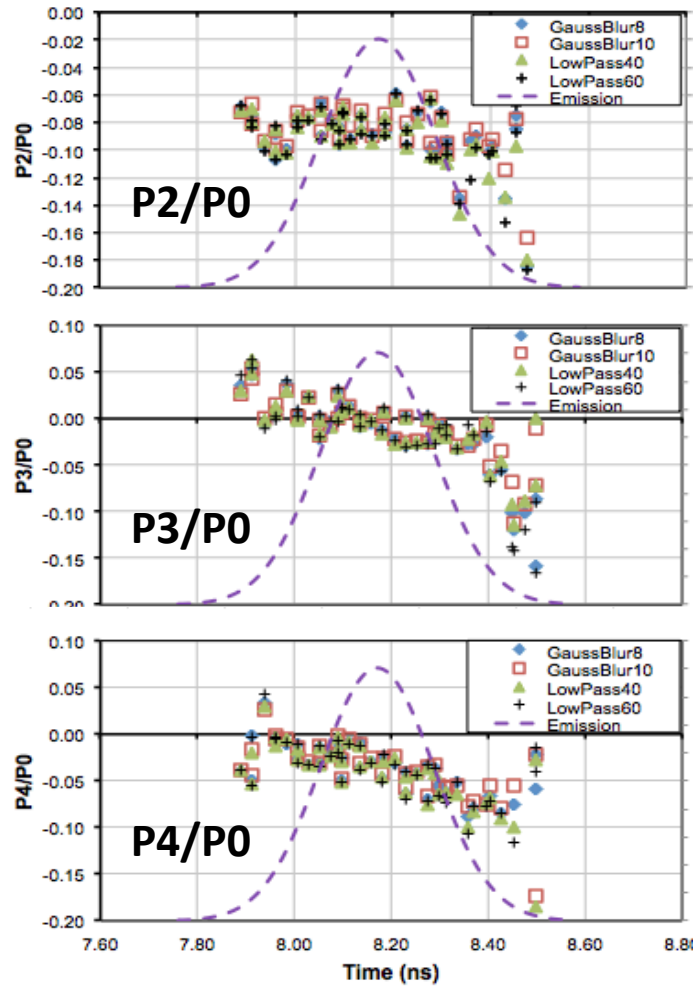
3 shock pulse shape @ 3.4 CCR drove a round implosion at 15x convergence

Equatorial xray time integrated



Polar xray time integrated





Equatorial xray moments time resolved

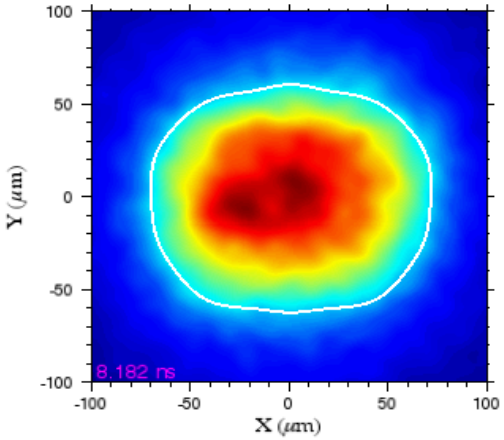
Can we stay round at higher convergence ?

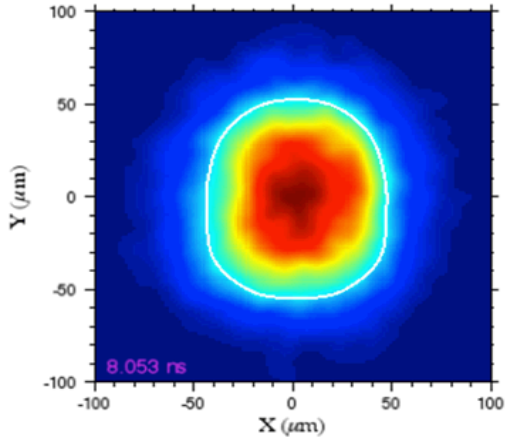
Lower capsule gas fill (8 to 1 mg/cc) increased the convergence from ~14x to ~ 20x

N140913 (14x)

N150107 (20x)

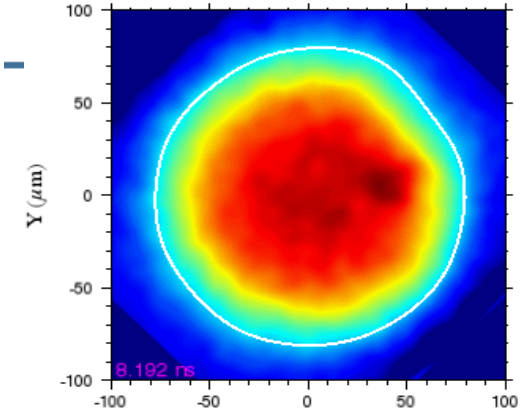
Equatorial
P_0 = 69 µm
P_2/P_0 = -8.3%

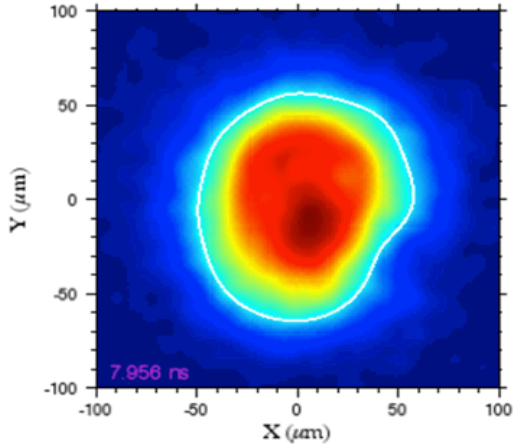




Equatorial
P_0 = 49 µm
P_2/P_0 = 11.4%

Polar
M_0 = 79 µm
M_2/M_0 < 2%

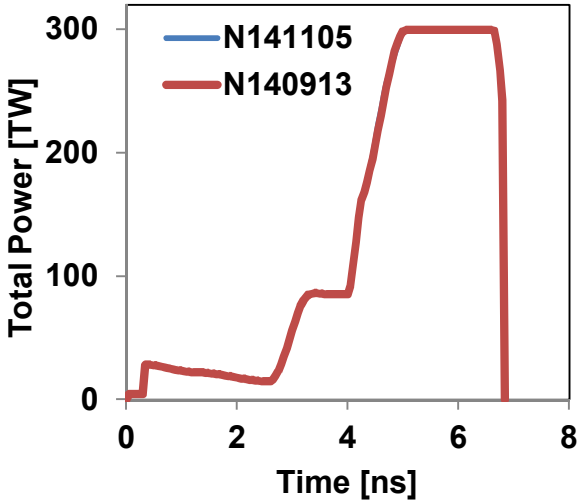


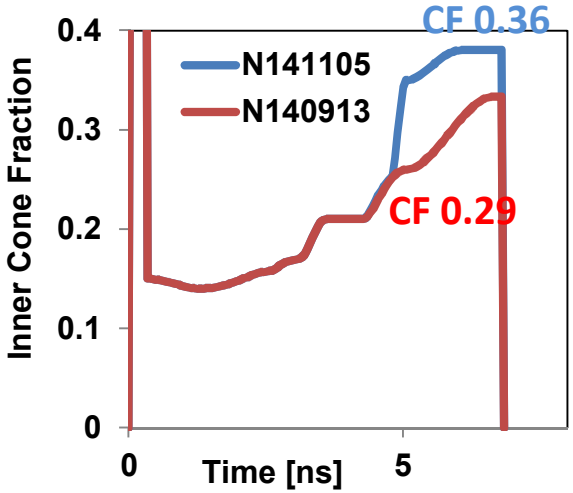


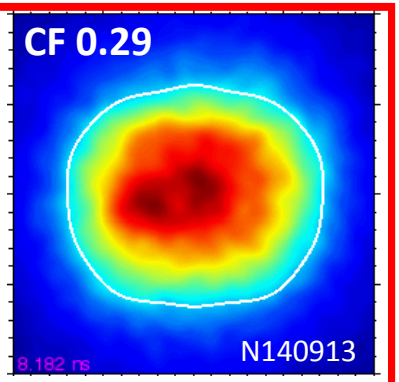
Polar
M_0 = 55 µm
M_2/M_0 = 8.6%

Convergence increased from ~14 to ~20 and hot spot remained round

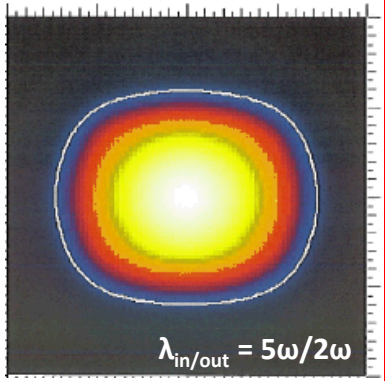
We have investigate the possibility of changing symmetry via cone fraction



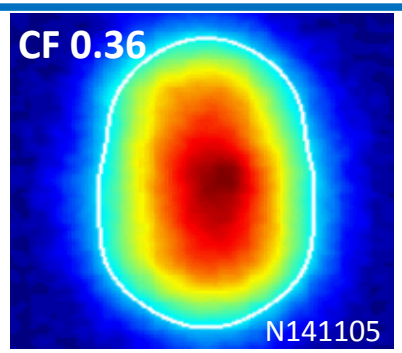




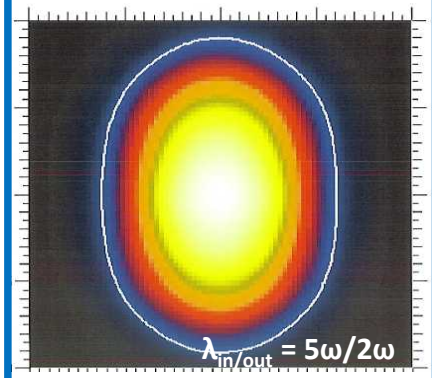
P0 = 68.9 µm
P2/P0 = -8.3 ± 1.9%



P0 = 66.8 µm
P2/P0 = -11.0%



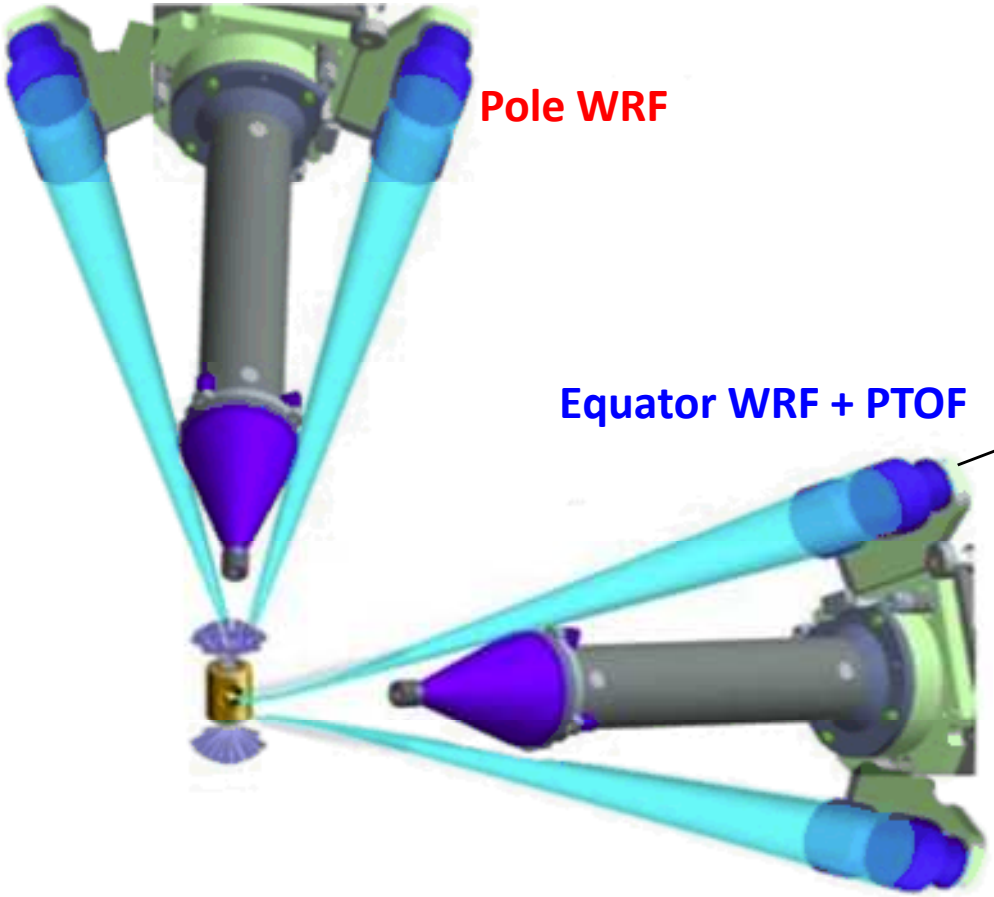
P0 = 64.7 ± 2.8 µm
P2/P0 = +34.5 ± 3.4%

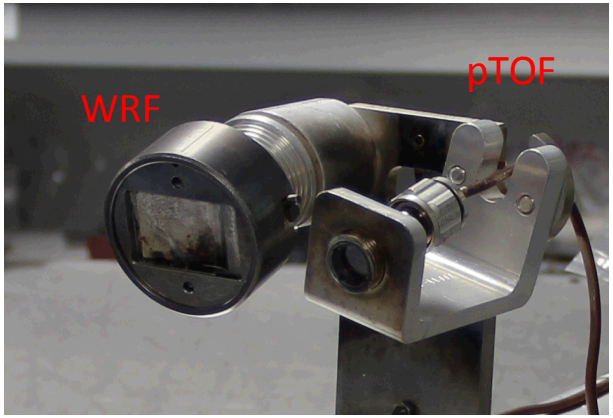


P0 = 65 µm
P2/P0 = +34%

Hot spot symmetry reacts to changes in cone fraction, we have a tool to tune symmetry

In addition of matching symmetry Dhe3 proton spectrum and bang time further constrain simulation



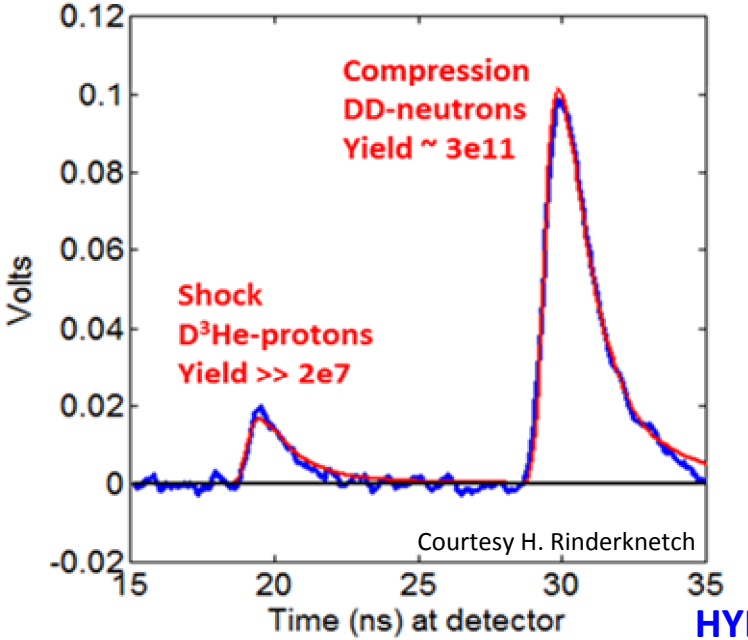


In collaboration with MIT

D + ^{3}He -> α + **p (14.7 MeV)**

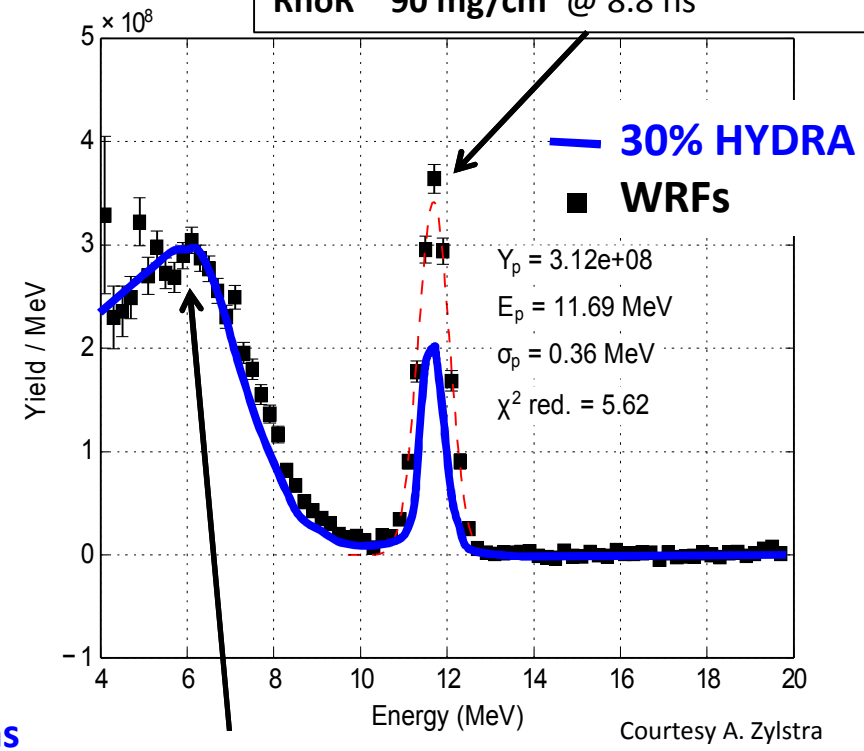
The low LPI environment of NVH allows us to measure for the first time shock flash and compression bang time in HDC implosion

Proton Time of Flight detector



		HYDRA
DD-n bang time:	9.74 ± 0.07 ns	9.6 ± 0.05 ns
D^3He-p bang time**:	8.82 ± 0.10 ns	8.84 ± 0.05 ns
(Compr – shock) ΔBT:	0.9 ± 0.1 ns	0.84 ± 0.08 ns

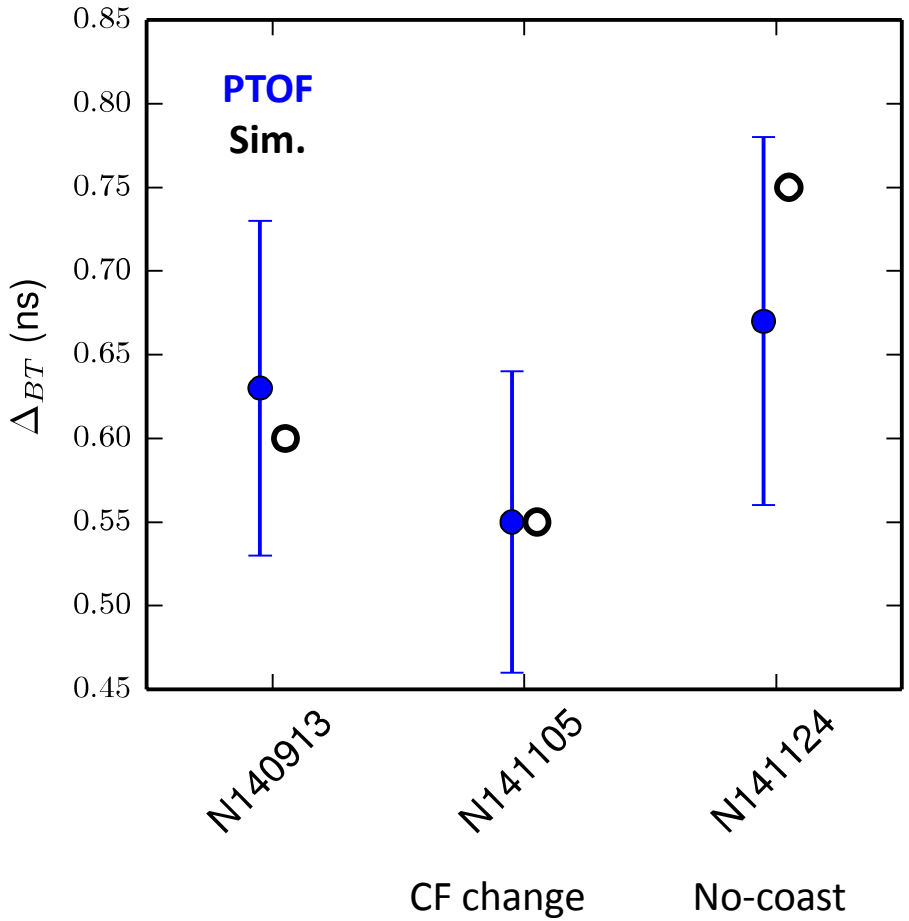
11.7 MeV Shock flash escaping protons :
RhoR ~ 90 mg/cm² @ 8.8 ns

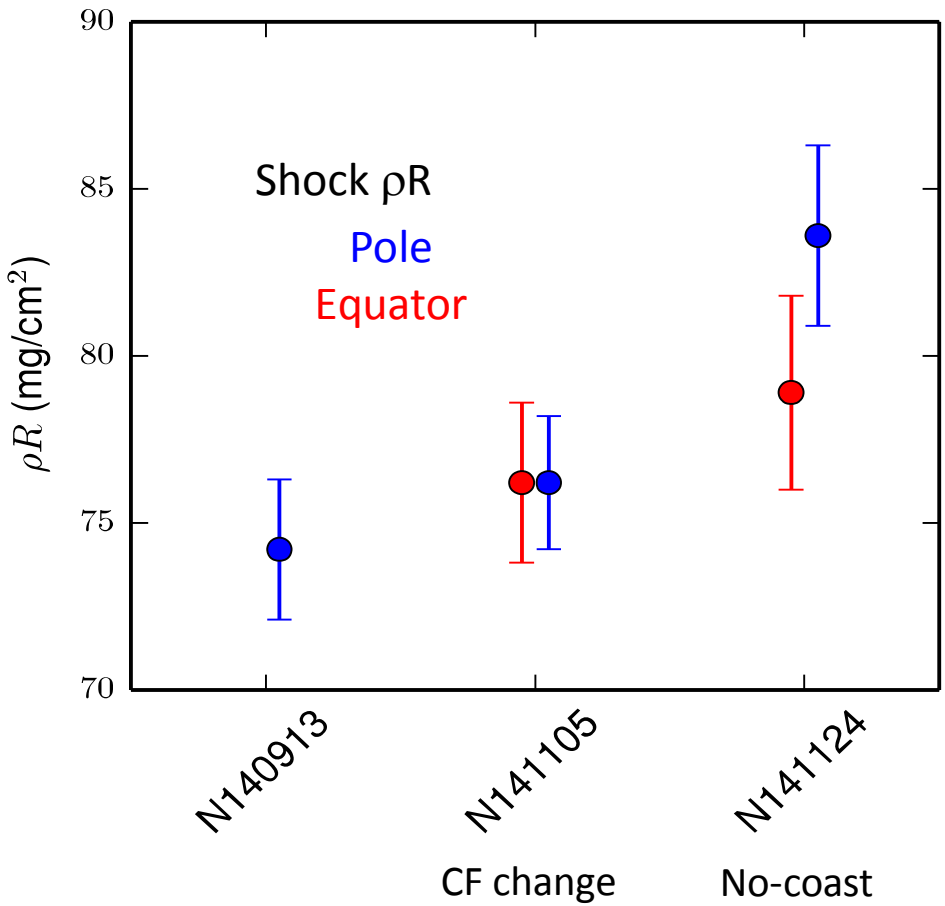


5.9 MeV Compression bang escaping protons :
RhoR ~ 270 mg/cm² at 9.7 ns

Bang times and rho*r are well match by HYDRA ad hoc simulations.

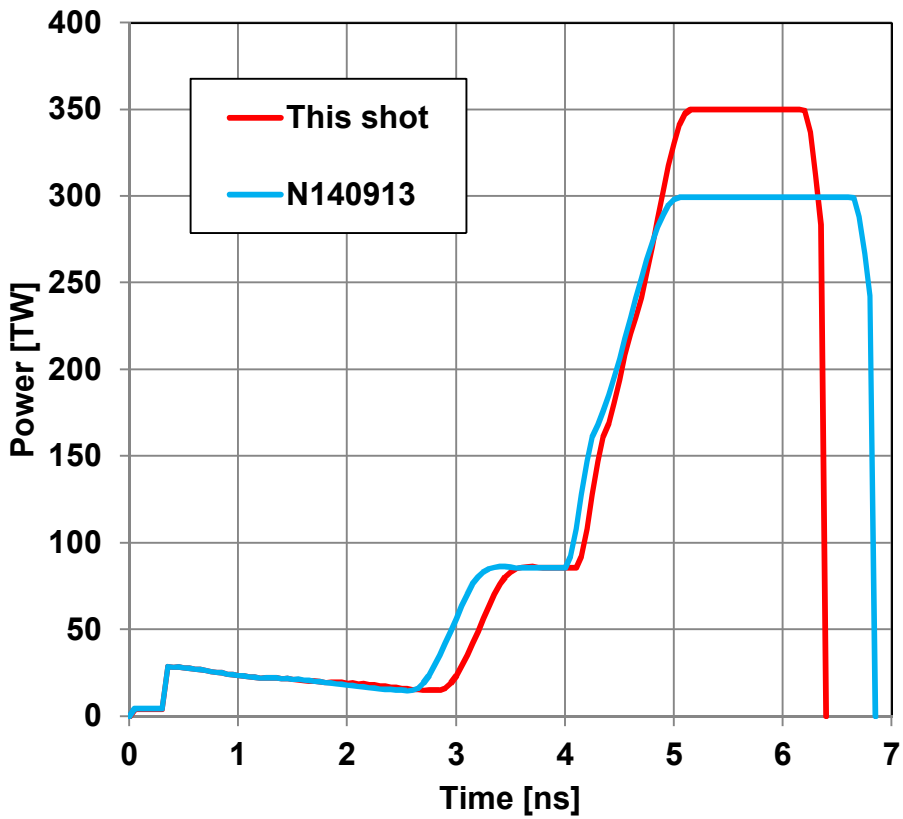
These diagnostic were used on subscale shots



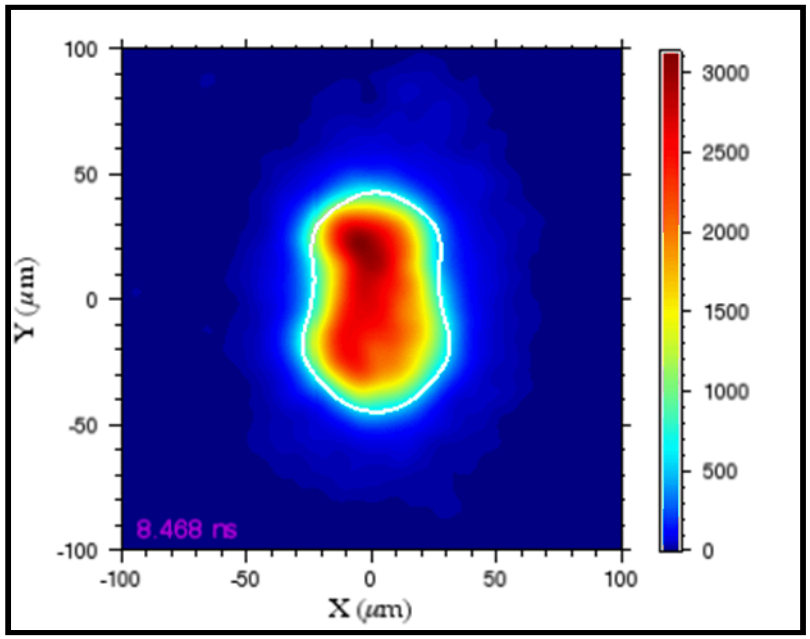


Good understanding of the subscale platform @ 20x convergence

A DT layered shot was done to test symmetry at high convergence (30x) @ CCR3.4 with a 3 shock pulse shape.



X ray equatorial image



P0 = 30.8 μm

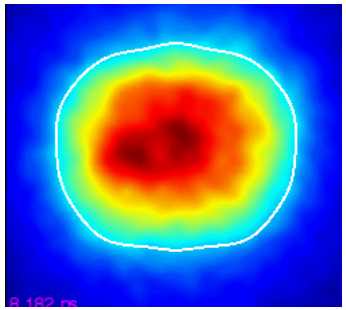
P2/P0 = 40 %

Symmetry is still challenging but YOC improved with larger CCR, YOC is 1/3

Helium gas, DU walls, and higher power/shorter laser pulses each improve P_2 symmetry

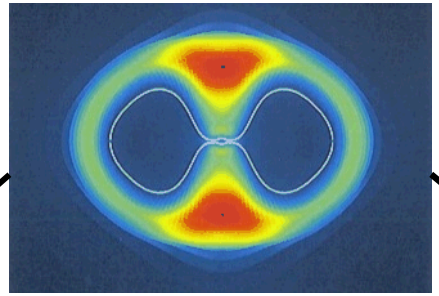
Meezan UO7.00012
Thusday, 19th, 4:12 pm

Symcap emission at bang time



Add 0.3 mg/cm³ helium

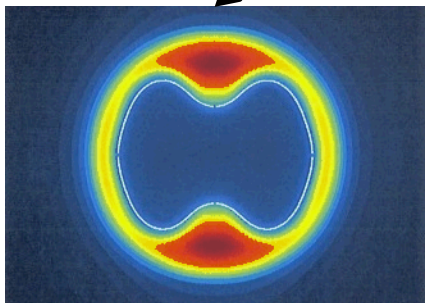
DT implosion density at bang time



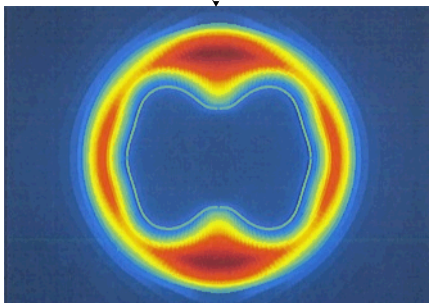
300 TW, gold vacuum

Change wall to DU

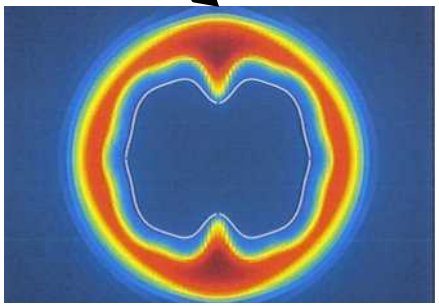
Change wall to DU and increase power to 350 TW



300 TW, Au 0.3 mg/cm³ helium



300 TW, DU vacuum

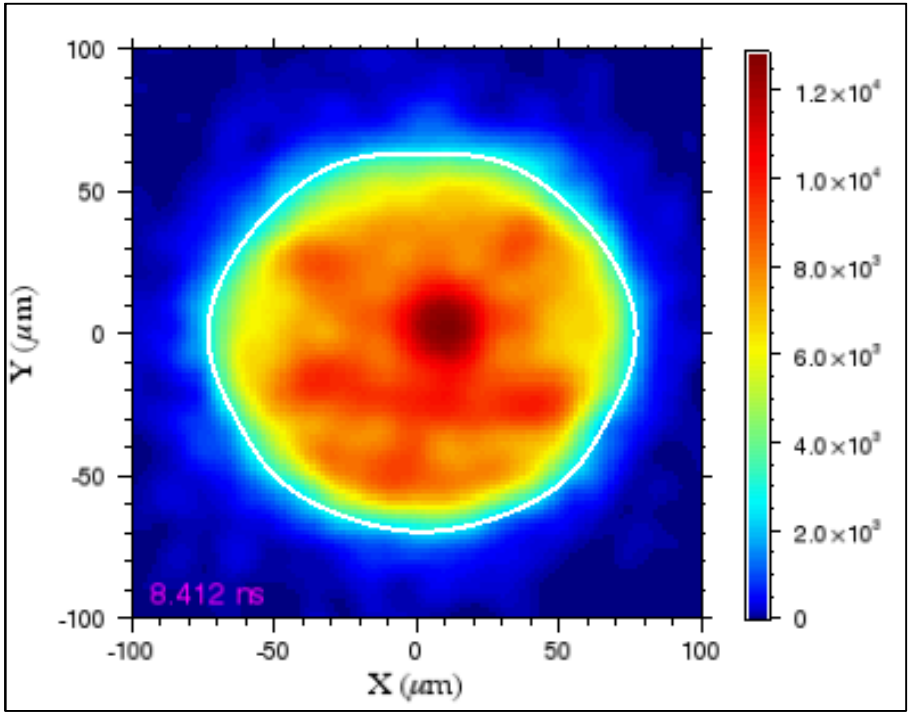


350 TW, DU vacuum

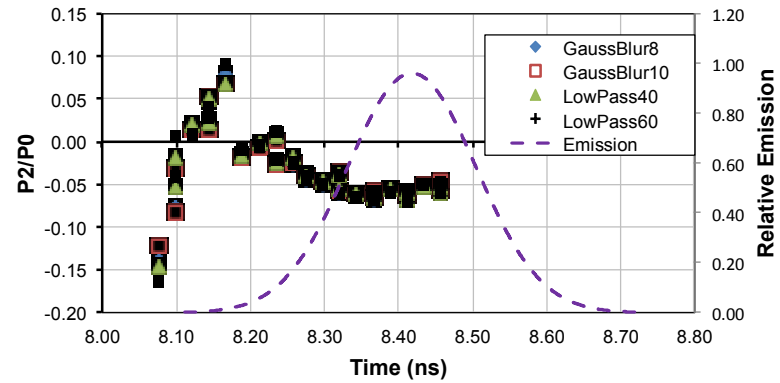
We plan to experimentally test these hohlraum changes in the first 6 months of this FY

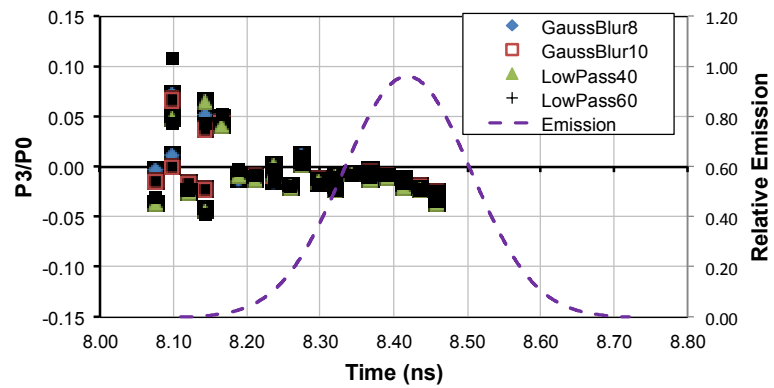
First DU symcap with 0.3 mg/cc Helium @ 350 TW resulted in a round implosion with small mode 2-3 swngs

X ray equatorial image



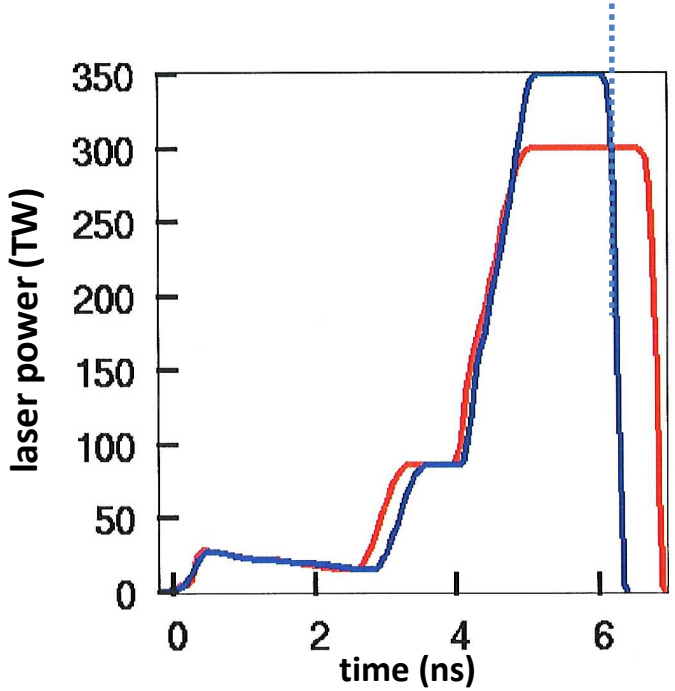
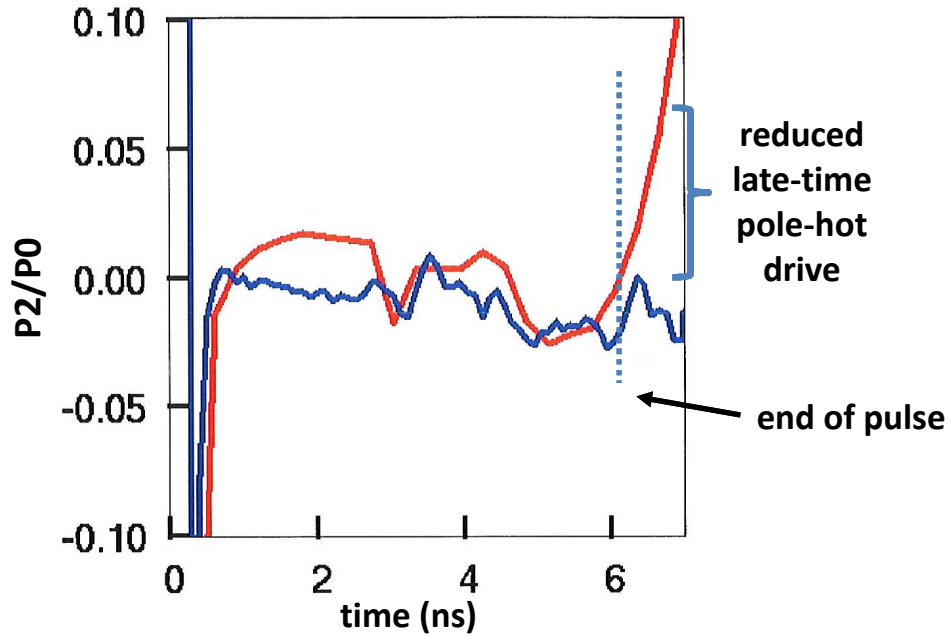
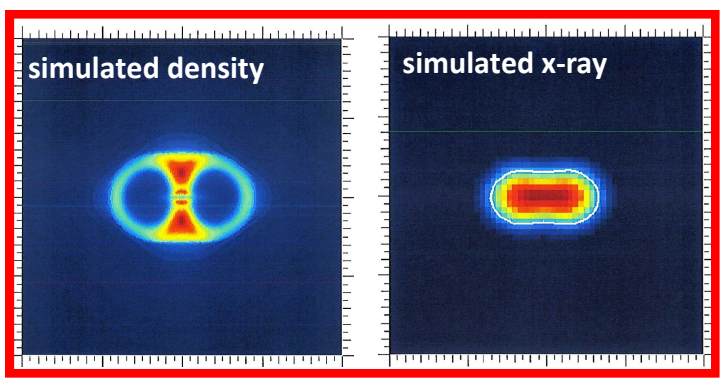
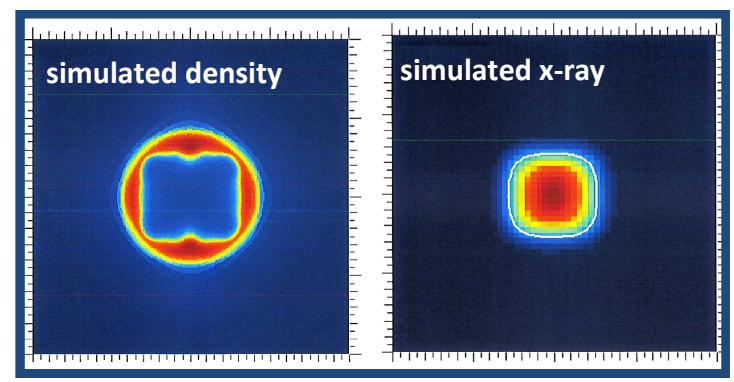
P0 = 70 µm
P2/P0 = -3.7 %





HDC will use this platform for the rest of the campaign

Conclusion

- Near Vacuum Hohlraum is a low Laser plasma interaction, high efficiency platform. Can it support a 3 shock ignition pulse for HDC?
- Symmetry in small case to capsule ratio target (CCR ~ 2.8, 3.1) is hard to control at 10x convergence.
- Symmetry in larger case to capsule ration (CCR~3.4) can be controlled at 20x convergence.
- Higher convergence (30x) @ CCR 3.4 is still challenging in AU NVH
- Exploring path to a no-coaster, low LPI platform : low gas fill (0.3), DU hohlraum @ CCR 3.4 @ 30x convergence.

Alternate solution to improved symmetry control: Higher power and shorter peak → maintain velocity, minimize late-time pole-hot feature