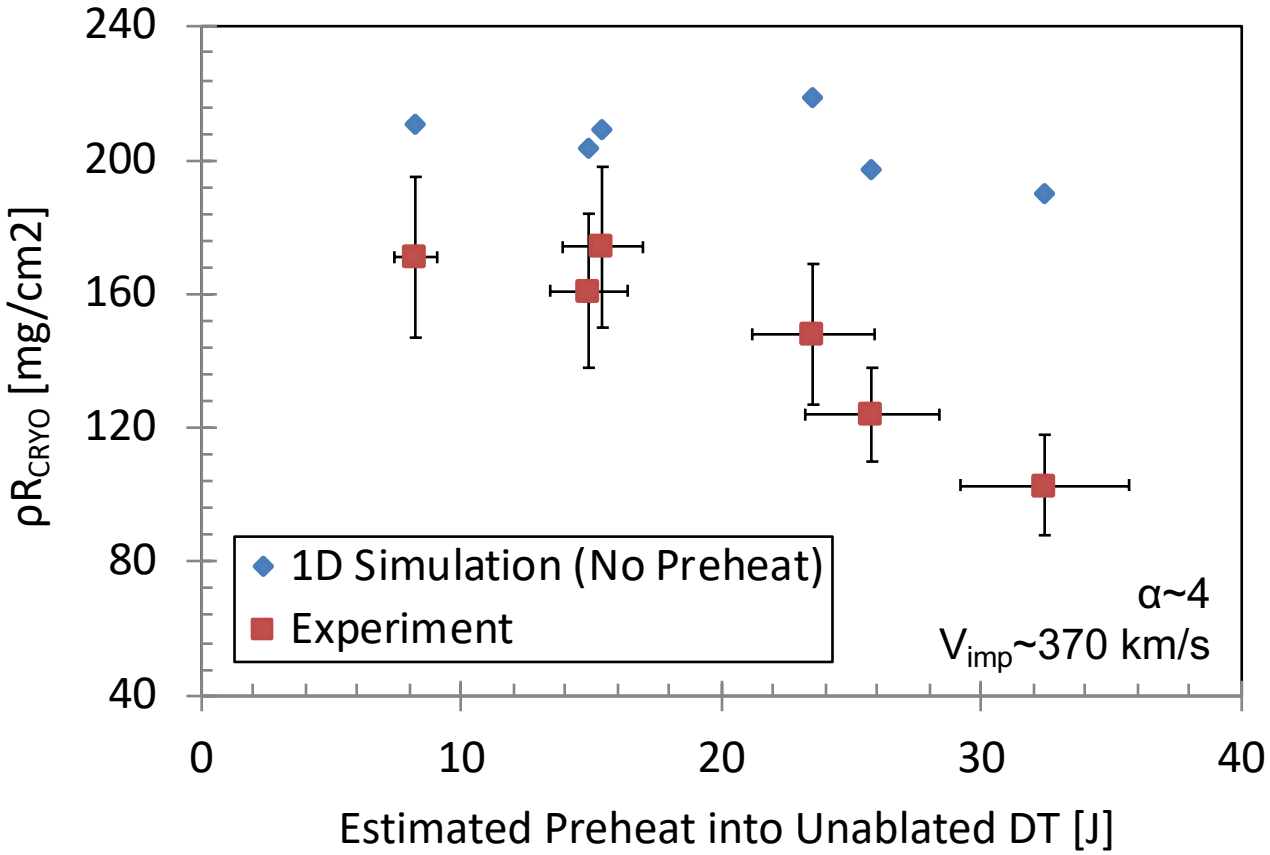
Implosion Designs Varying Hot-Electron Production for Direct-Drive Inertial Confinement Fusion Implosions on OMEGA



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Summary

Increased areal density in cryogenic implosions was observed as inferred preheat was reduced

- Increased hot electron production is expected when using smaller R_{beam}/R_{target} to reduce Cross-Beam Energy Transfer (CBET) and improve hydro-efficiency
  - Less laser energy lost leads to higher overlapped intensity at $n_c/4$ and thus more hot-electrons from two-plasmon decay (TPD)

- To counteract this, hot electron production can be controlled by tailoring power levels of the main drive
  - Reducing hot electron preheat lead to increased areal density in cryogenic implosions

- In the future, will examine preheat sensitivity for 0.8x hydro-scale of highest performing OMEGA shot-to-date

Collaborators

D. Patel, M. J. Rosenberg, W. Theobald, C. Stoeckl, A. R. Christopherson, I. V. Igumenshchev, V. Gopalaswamy, S. P. Regan, C. Thomas, P. B. Radha, R. Betti, and V. N. Goncharov

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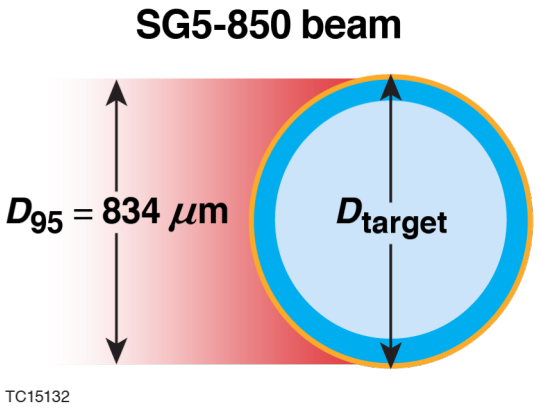
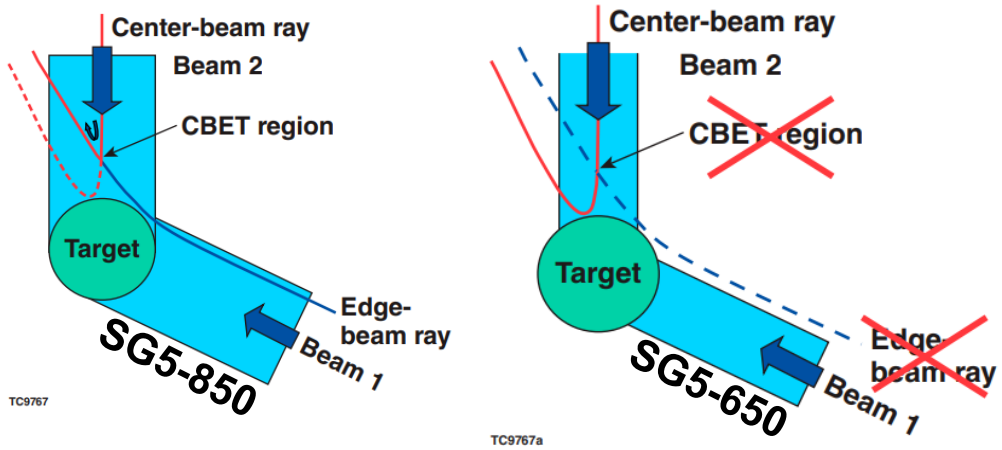
New SG5-650 phase plates* have been fielded on OMEGA to increase energy coupling relative to the SG5-850 phase plates



- Decreased D_{95}/D_{target} by ~20% (beam super-Gaussian order kept fixed)
- Less energy lost from refraction
- Less cross-beam energy transfer (CBET)

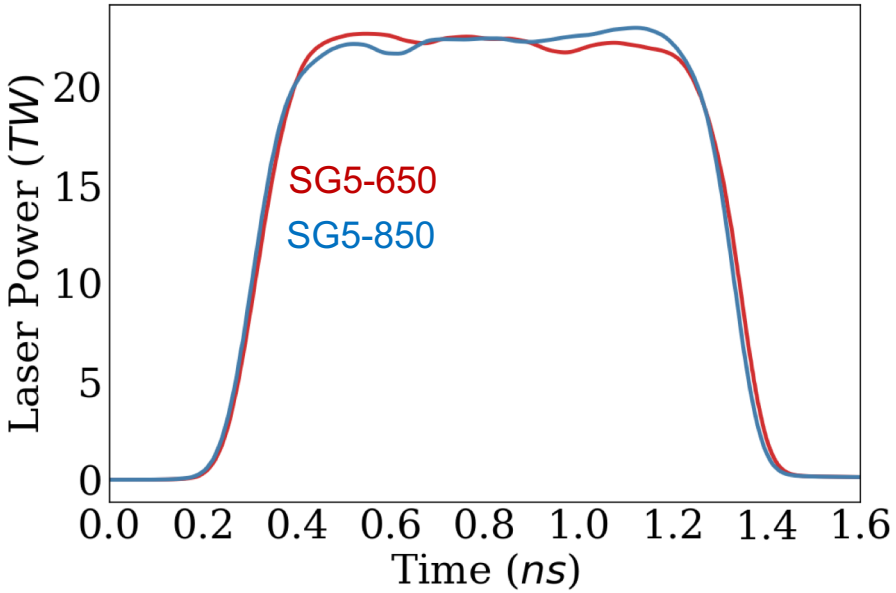


Predictions of enhanced laser-energy coupling by +10% was experimentally demonstrated**

* I. Igumenschev *et al.*, Physics of Plasmas 23, 052702 (2016
** W. Theobald *et al.*, JO7.00012, this conference.

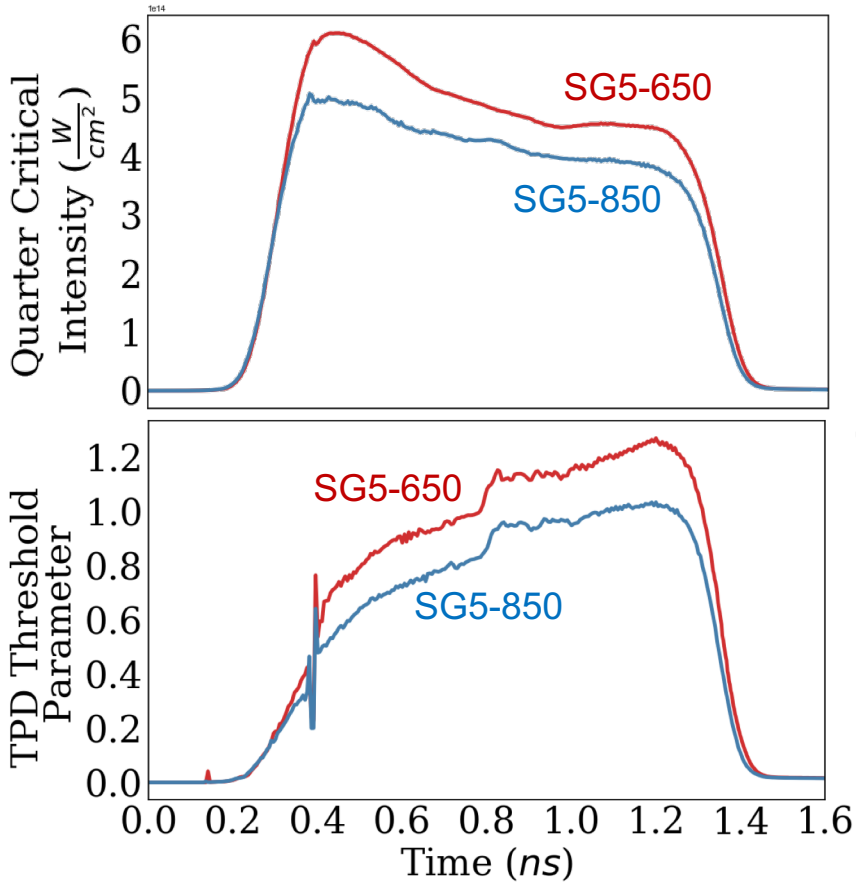
Less laser energy lost also leads to increased intensity at 0.25 n_c and therefore increased hot-electron generation from two-plasmon decay (TPD)

For the same square pulse incident on a reference target…



predict ~Δ25% quarter critical intensity…

…and ~Δ25% TPD threshold parameter.

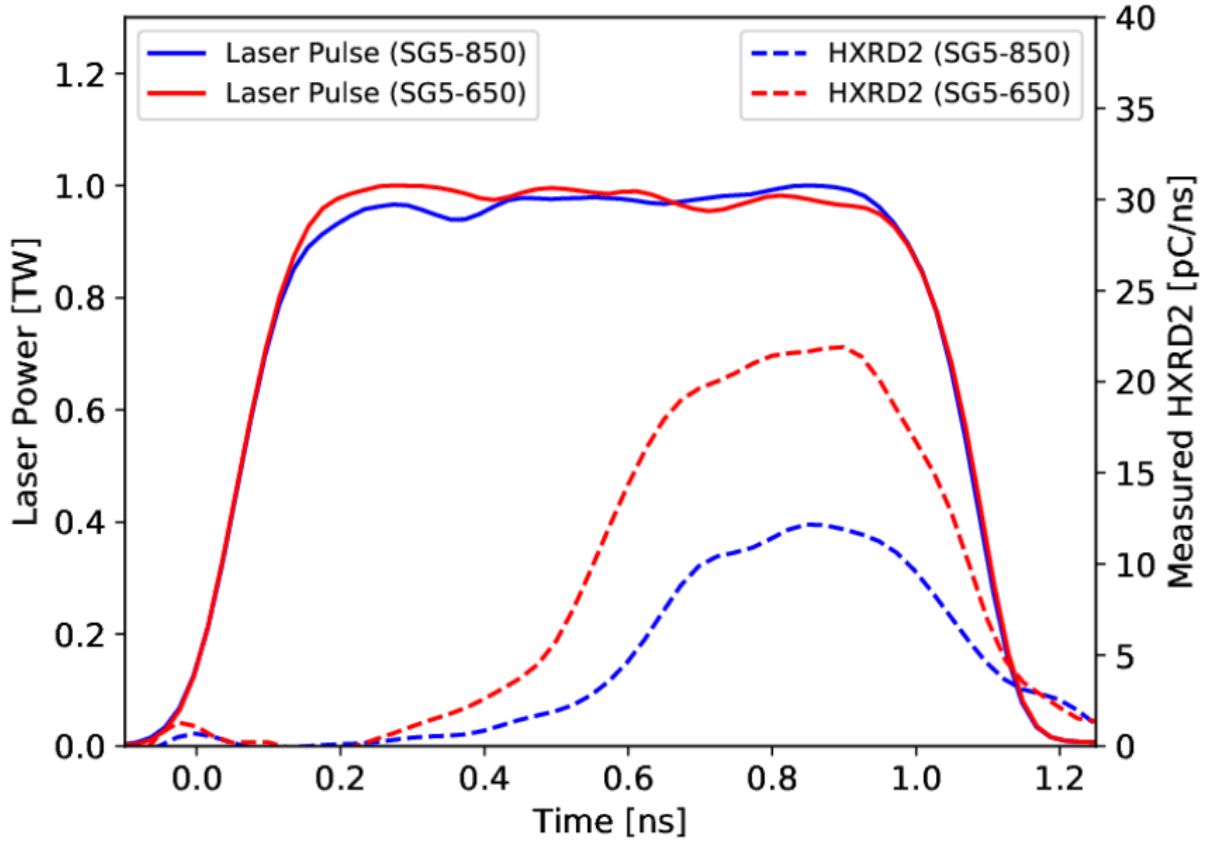


$$\text{TPD threshold parameter}^{*} = \frac{I_{n_c/4}\left(10^{14}\ W/cm^2\right) L_{n_c/4}(\mu m)}{233\ T_{n_c/4}\ (keV)}$$

* A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).

Increased hot-electron generation with smaller focal spots was experimentally verified using the Hard X-ray Diagnostic (HXRD)*

- The HXRD measures 40+ keV bremsstrahlung from hot-electrons slowing down in plasma
- Higher HXRD signal in SG5-650 case indicates larger presence of hot-electrons

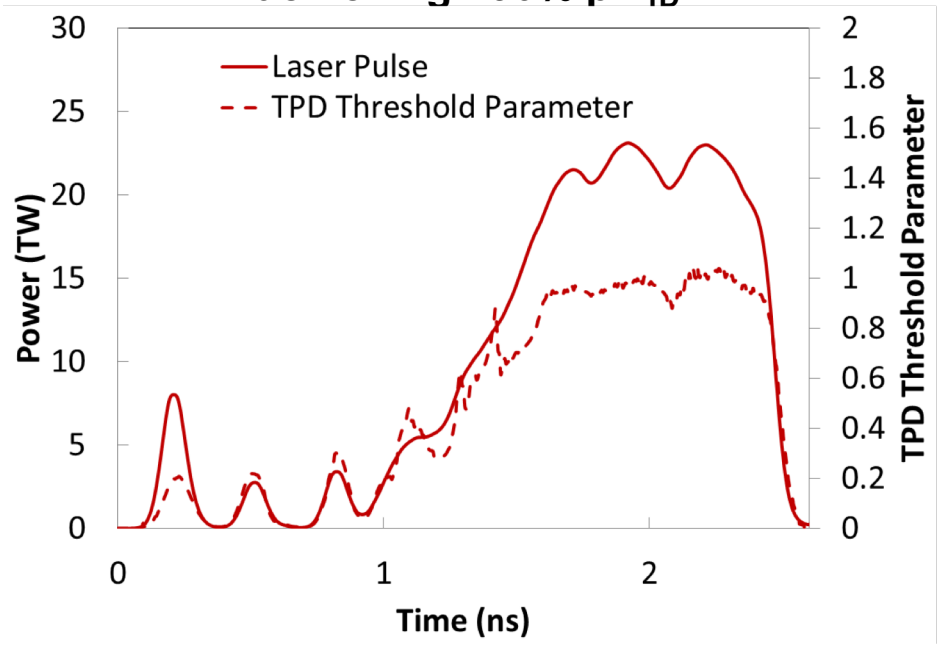


How can hot-electron production be kept to acceptable levels?

* C. Stoeckl *et al.*, Review of Scientific Instruments 72, 1197 (2001)

For new designs, hot electron production levels can be constrained based on previous SG5-850 performers

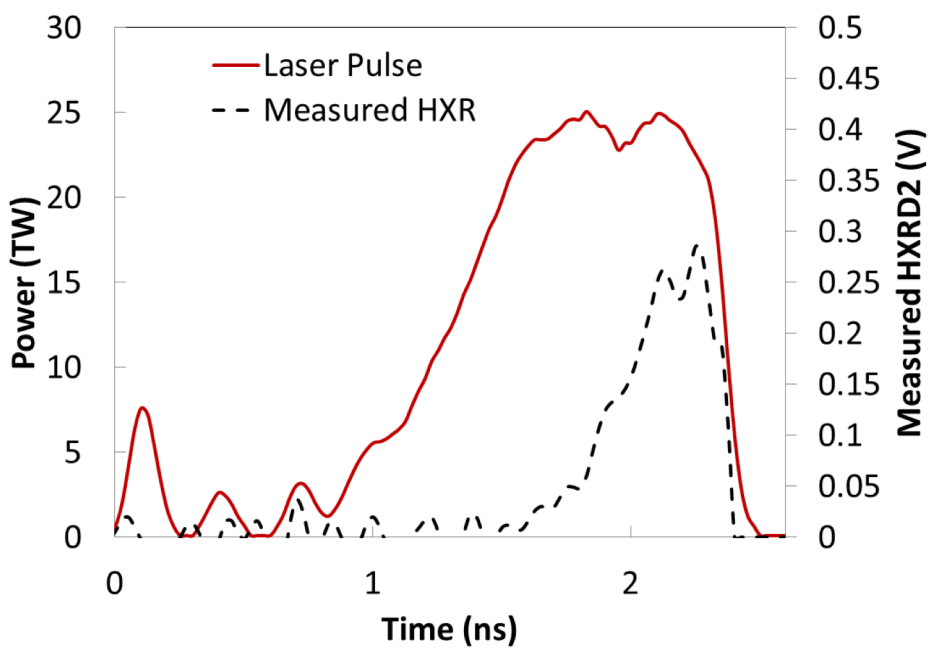
Previous SG5-850 design achieving ~90% ρR_{1D}*



η ~ 1 (design constraint)

When shot on ambient targets

Measured hard X-ray produced

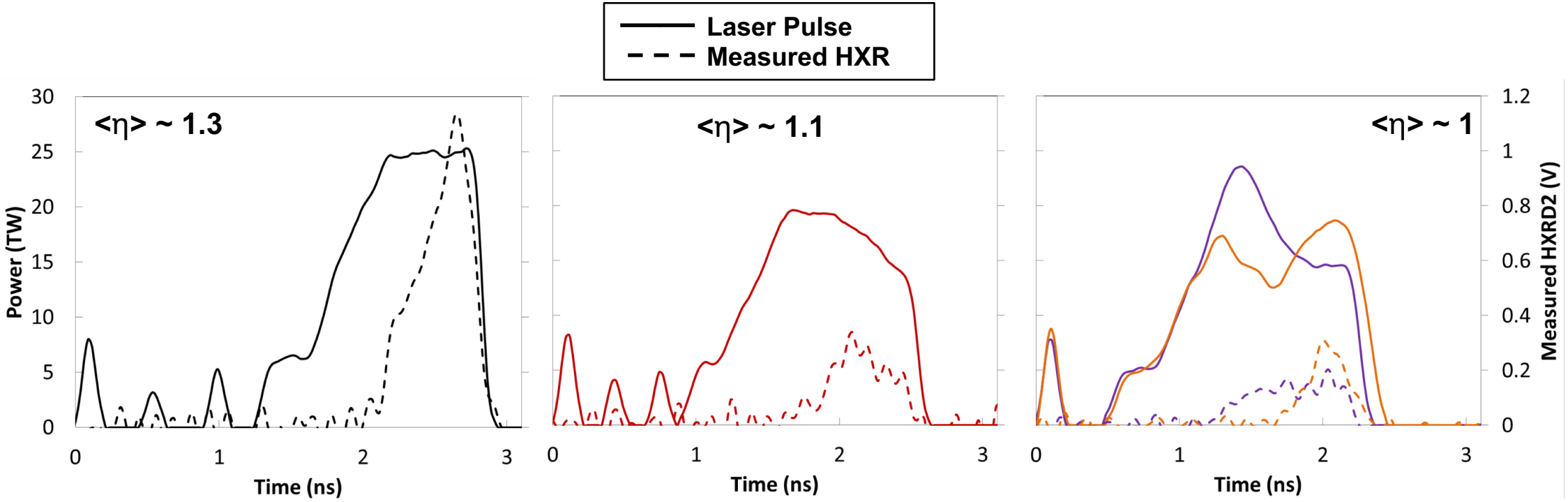


Integrated HXR signal ~ 300pC (experimental constraint)

* S. Regan *et al.*, PRL 117, 025001 (2016).

Variety of SG5-650 pulse candidates for cryogenic targets were tested on ambient targets to verify hot-electron production levels

All targets shot were 870-μm OD with 27-μm CH shells, vacuum fill



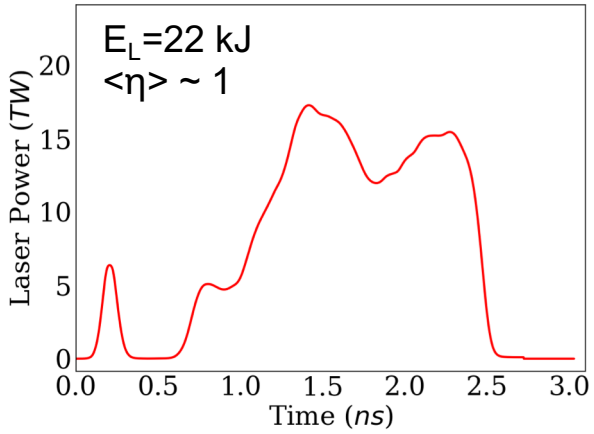
Integrated HXRD2 = 751 pC

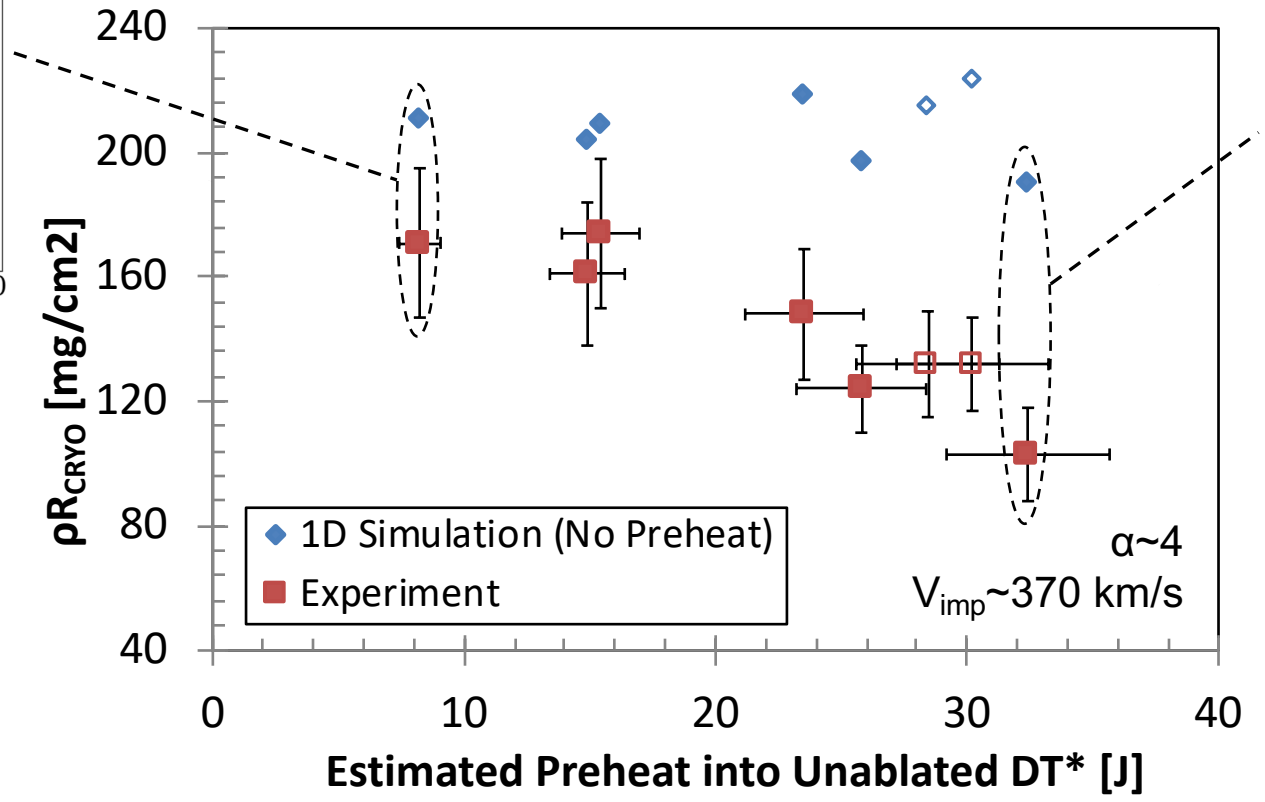
(Goal is <300 pC from previous SG5-850 performers)

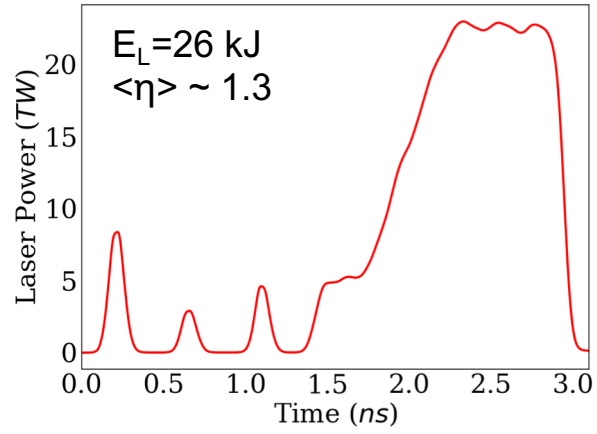
Integrated HXRD2 = 241 pC

Integrated HXRD2 = 185 pC
158 pC

Pulse designs from study led to ~30% higher areal density on cryogenic shots compared to their high preheat counterparts, while having 24% less DT mass



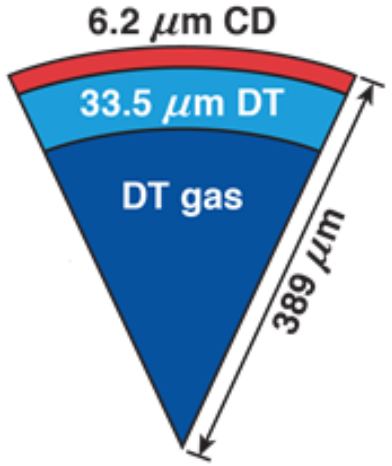




* A. Christopherson *et al.*, NO5.00011, this conference.

A shot day in late November will correlate hot-electron production to performance for smaller scales (i.e. hydro-scale of best performing shot-to-date)

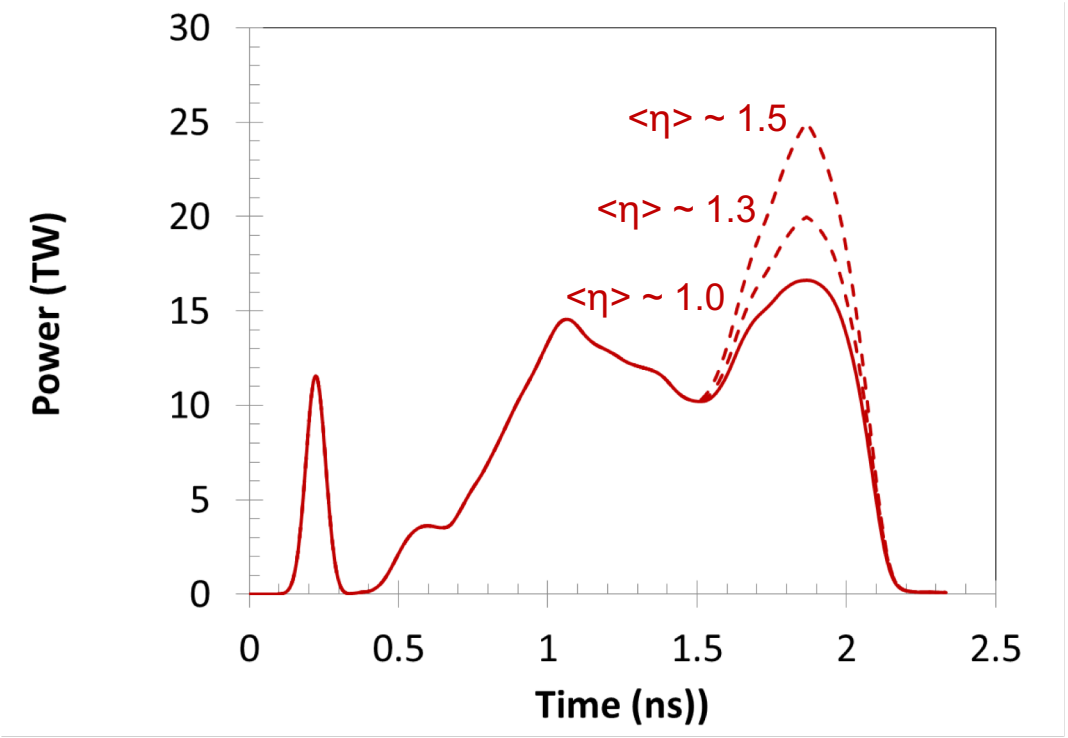
0.8x Hydro-scale of Shot 90288



v_{imp} = 479 km/s
E_L = 15.4 kJ
α = 4.7
IFAR = 28

Hot-electron/intensity scan

– intensity can increase by $(1/0.8)^2 \sim 1.6\times$



IFAR: in-flight aspect ratio

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