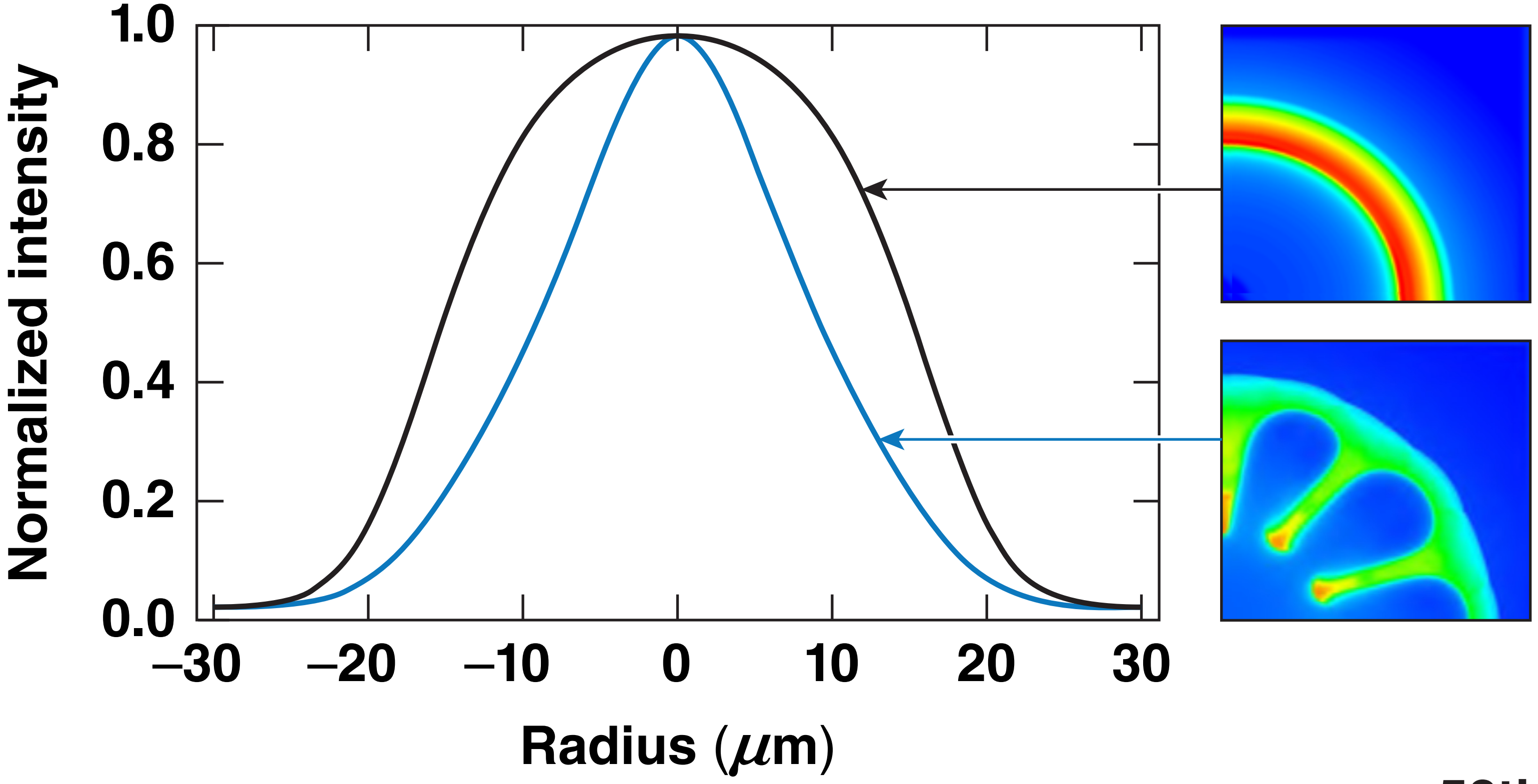
The 1-D Campaign on OMEGA: A Systematic Approach to Find the Path to Ignition

Core self-emission



58th Annual Meeting of the American Physical Society Division of Plasma Physics
San Jose, CA
31 October–4 November 2016

R. Betti
University of Rochester
Laboratory for Laser Energetics

Summary

The 1-D campaign on OMEGA uses systematic changes and looks for trends to improve physics understanding and find the optimal target design

- The 1-D campaign uses ON/OFF systematic changes in cryo implosions to understand the implosion behavior
- The 1-D campaign looks for 1-D trends in qualitative features of the experimental observables to elucidate the physics and assess the dimensionality of the implosion
- A short-term goal is to find the optimum 1-D performance at high adiabat (~7) using two-shock (single-picket) pulse shapes
- The ultimate goal is to find the optimum target design through an adiabat and velocity scan

TC13092

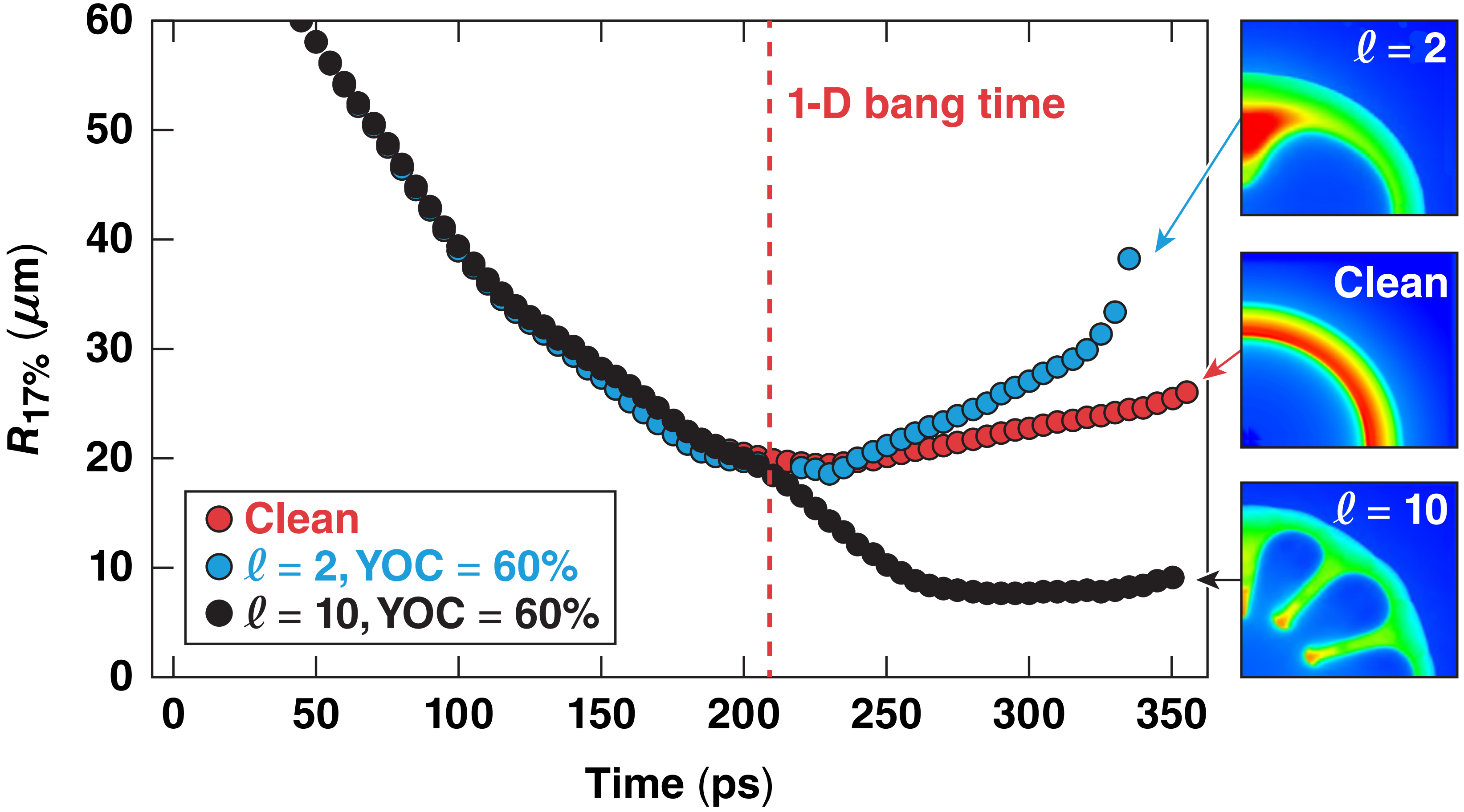
Collaborators

J. P. Knauer, A. V. Maximov, T. J. B. Collins, C. Stoeckl, A. Bose, J. Woo,
A. R. Christopherson, A. Shvydky, W. Theobald, J. A. Delettrez, F. J. Marshall,
P. B. Radha, S. P. Regan, E. M. Campbell, W. Shang, W. Seka, and S. X. Hu

University of Rochester
Laboratory for Laser Energetics

The time history of the hot-spot radius $R_{17\%}$ monitors deviations from one-dimensional behavior

- Low modes (ℓ ~2) increase the hot-spot size
- Intermediate modes (ℓ ~10) decrease the size

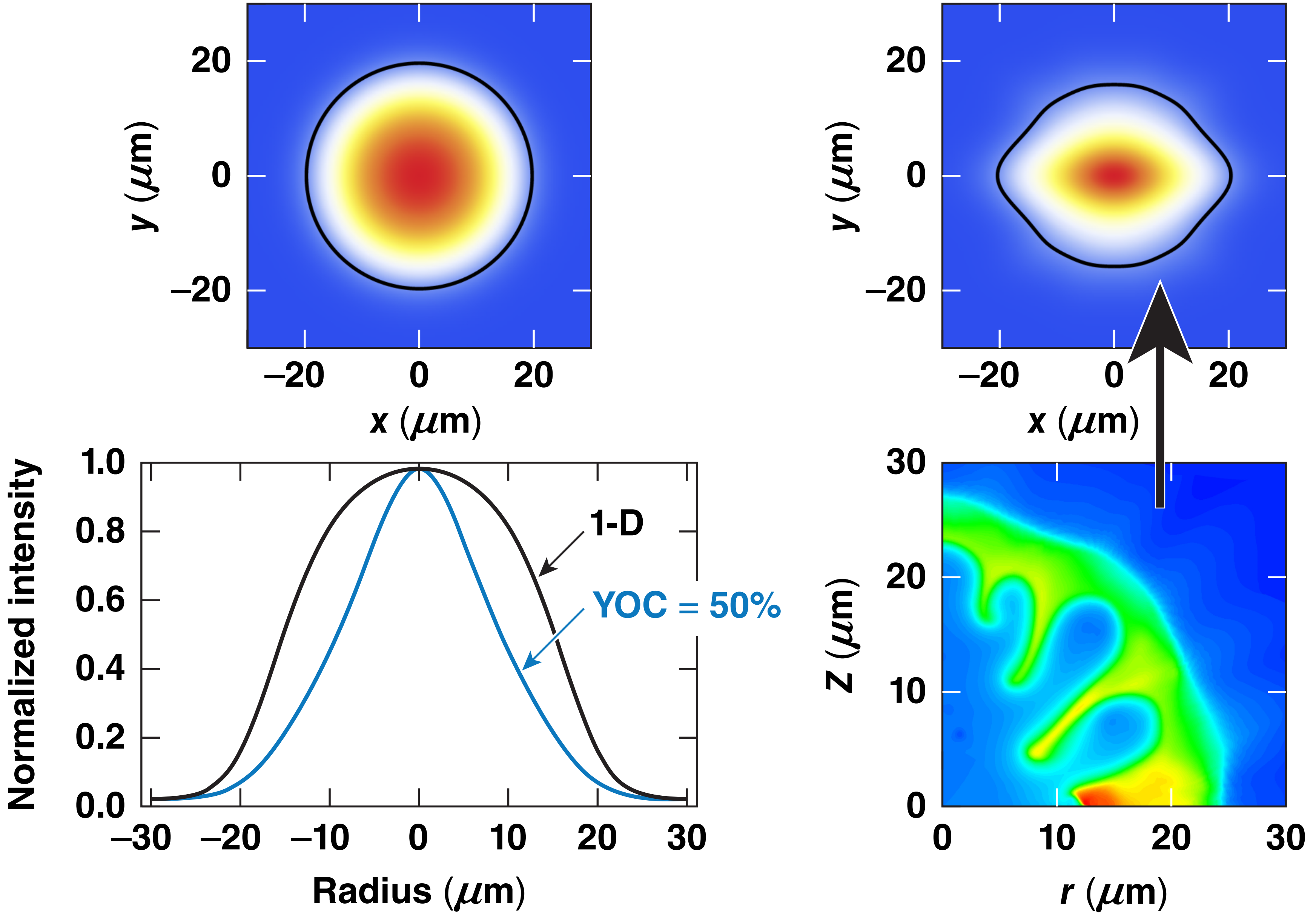


The time history of the hot-spot radius reveals what modes are dominant.

A. Bose *et al.*, UO5.00001, this conference.
YOC: yield over clean

TC13093

The shape of the hot-spot self-emission is another measure of the deviations from a one-dimensional implosion



Rayleigh-Taylor (RT) spikes from intermediate modes lead to a peaked self-emission profile.

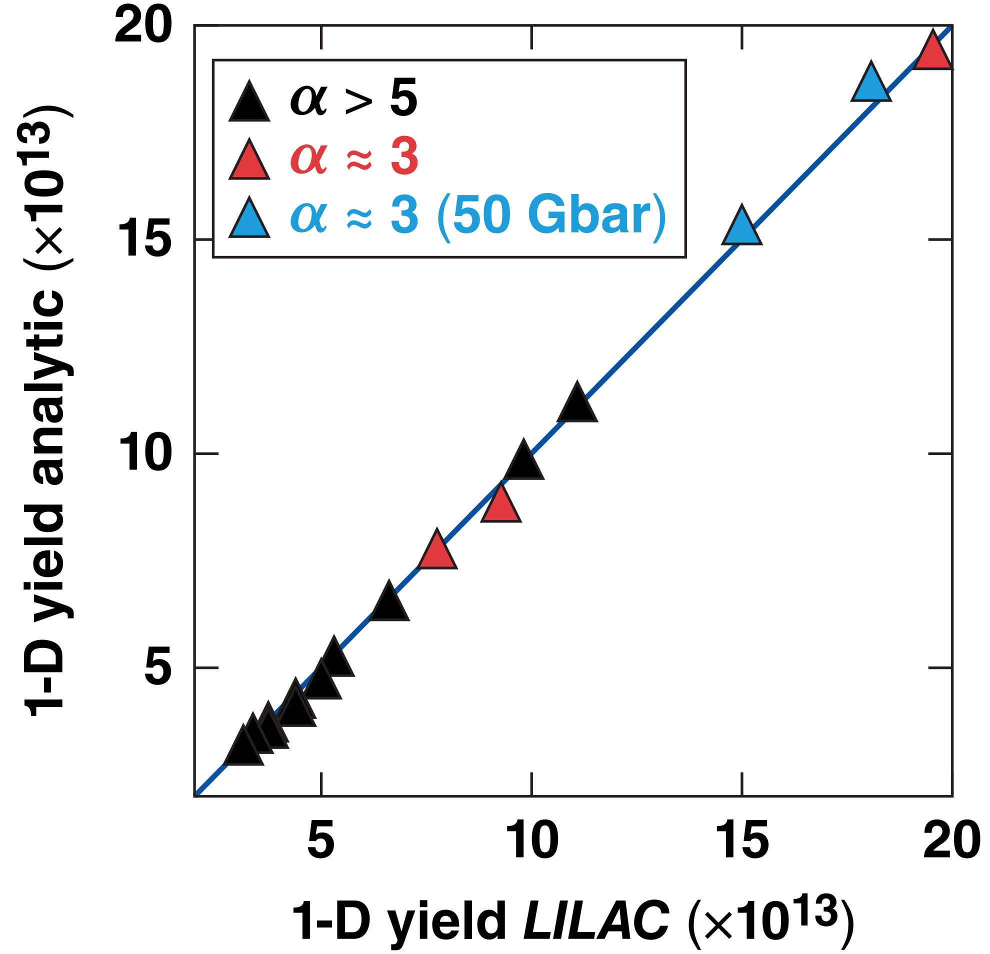
R. Nora, Lawrence Livermore National Laboratory, private communication (2013).

TC13094

A necessary condition for a one-dimensional implosion is that the neutron yield follows the 1-D formula based on stagnation properties

1-D yield-formula

$$Y_{an} = \left(\rho R_{g/cm^2}\right)^{0.56} \left(\frac{T_{keV}}{4.6}\right)^{4.7} \frac{M_{stag}^{mg}}{0.10} 10^{16}$$



This is a necessary but not sufficient condition for a one-dimensional implosion

$$Y_{exp} \approx Y_{an}$$

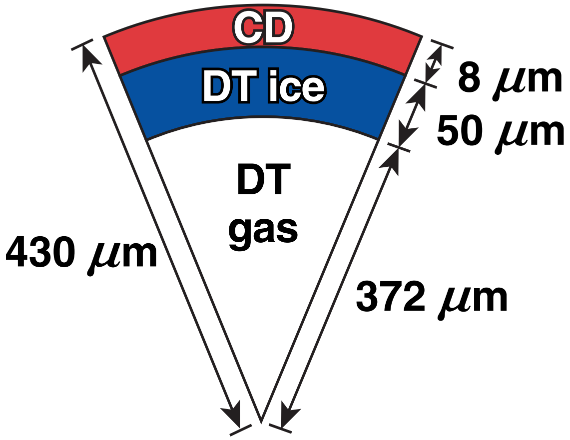
This is only true if our stagnation physics models are correct.

TC8777a

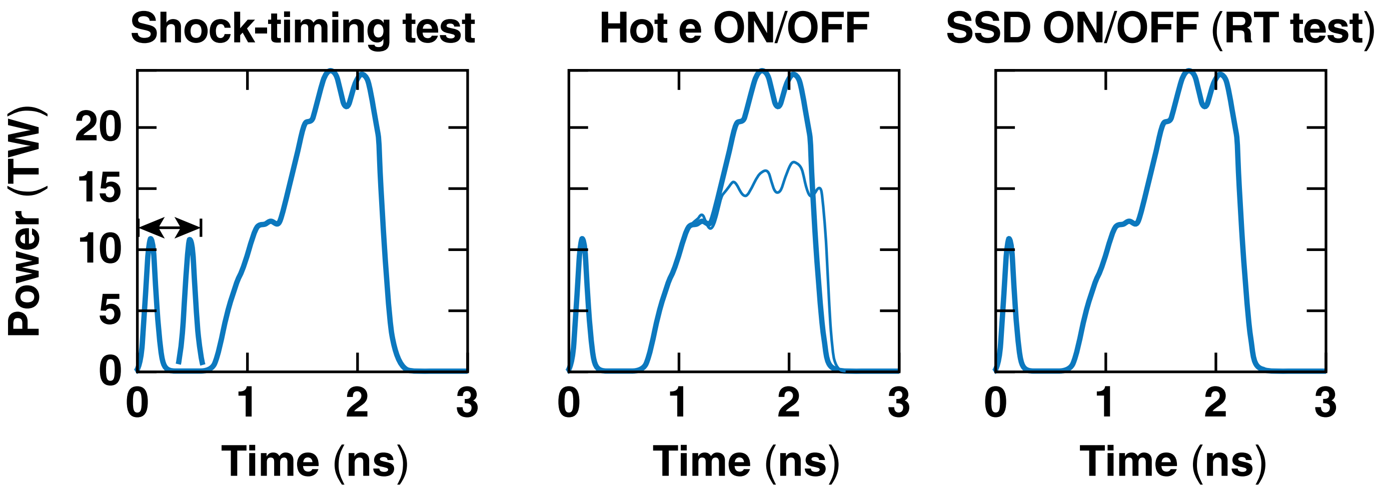
R. Betti *et al.*, Phys. Plasmas 17, 058102 (2010).

A typical cryogenic shot day of the 1-D campaign uses sets of systematic ON/OFF pairs of shots

OMEGA



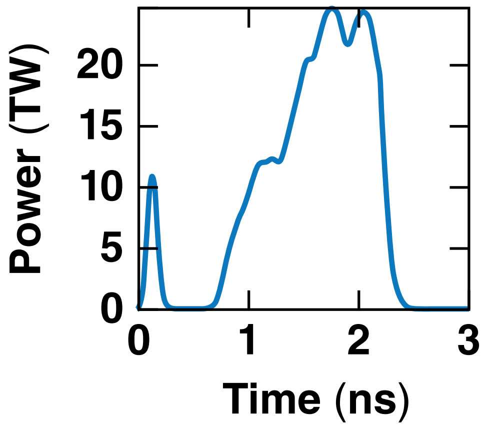
Change pulse shape


Shock-timing test

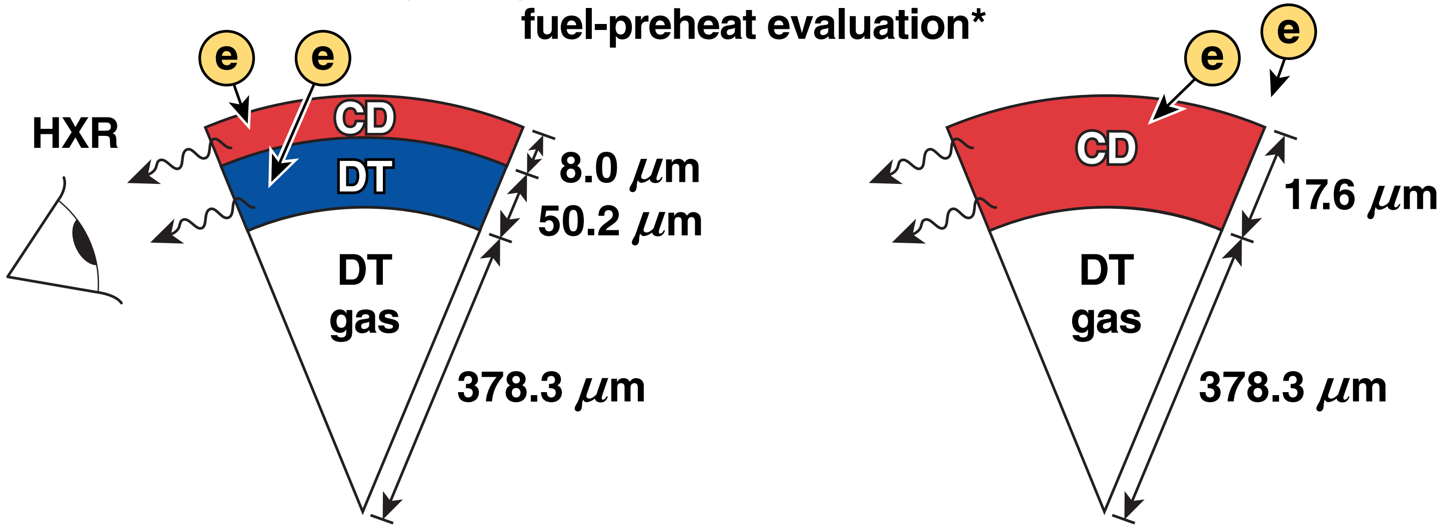
Hot e ON/OFF

SSD ON/OFF (RT test)

Fixed pulse shape



Change target (different payload, same ablator) fuel-preheat evaluation*

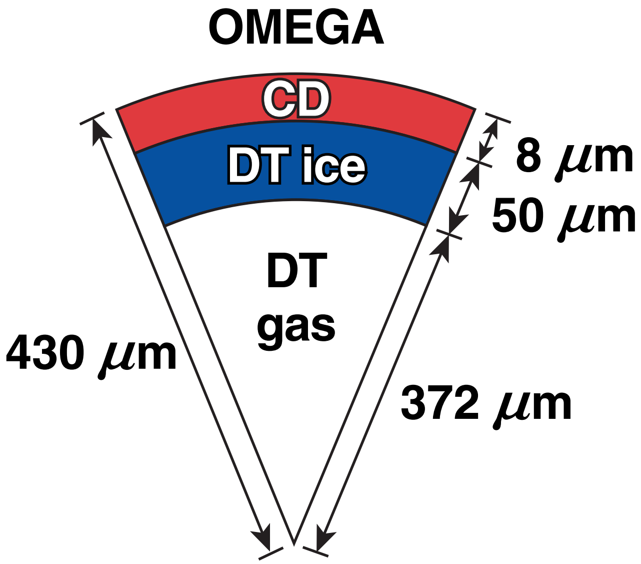


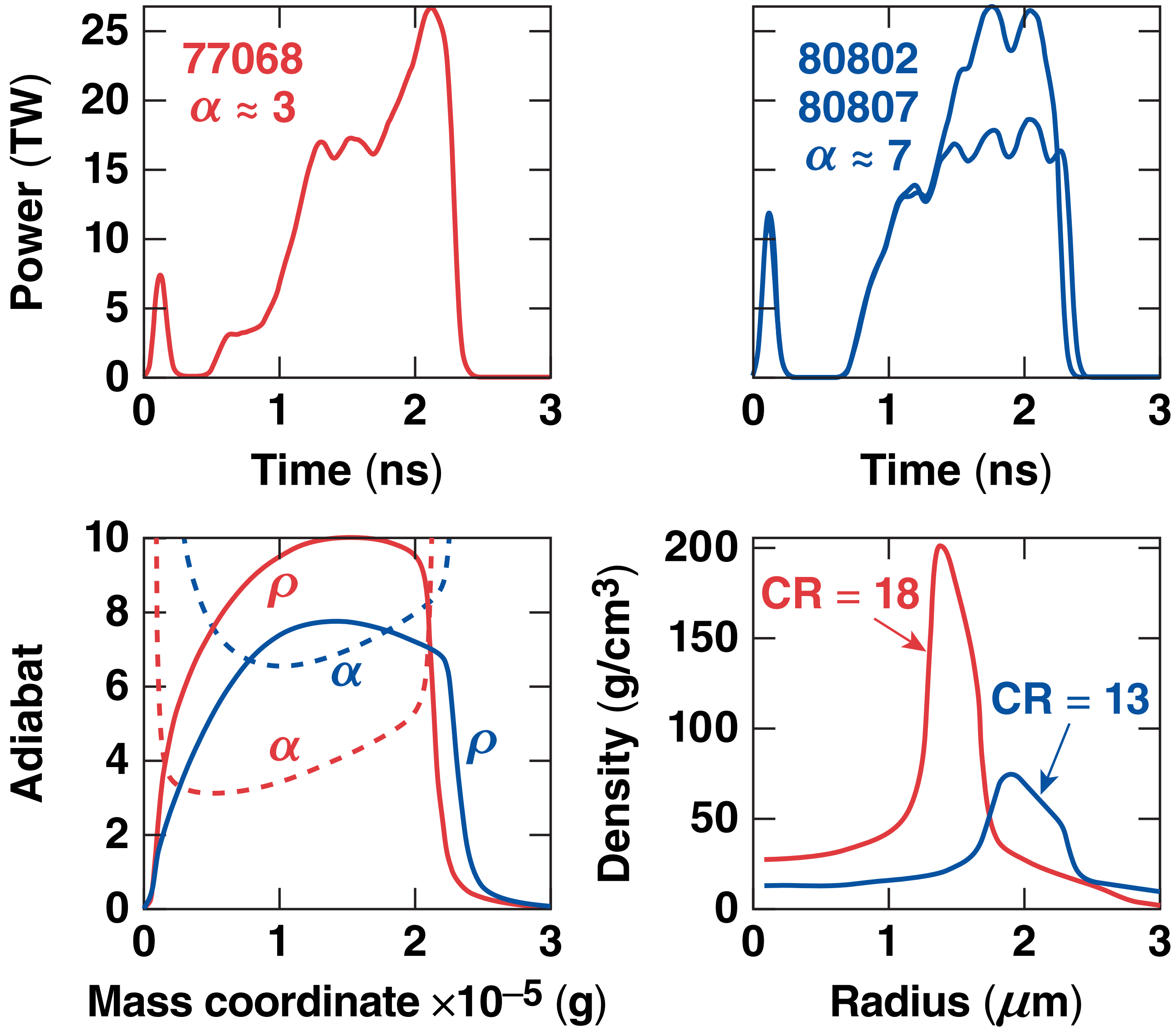
---

*A. R. Christopherson *et al*., NO5.00007, this conference.

TC13095

The first high-adiabat targets are designed for $\alpha \approx 7$ and compared to best performer* $\alpha \approx 3$



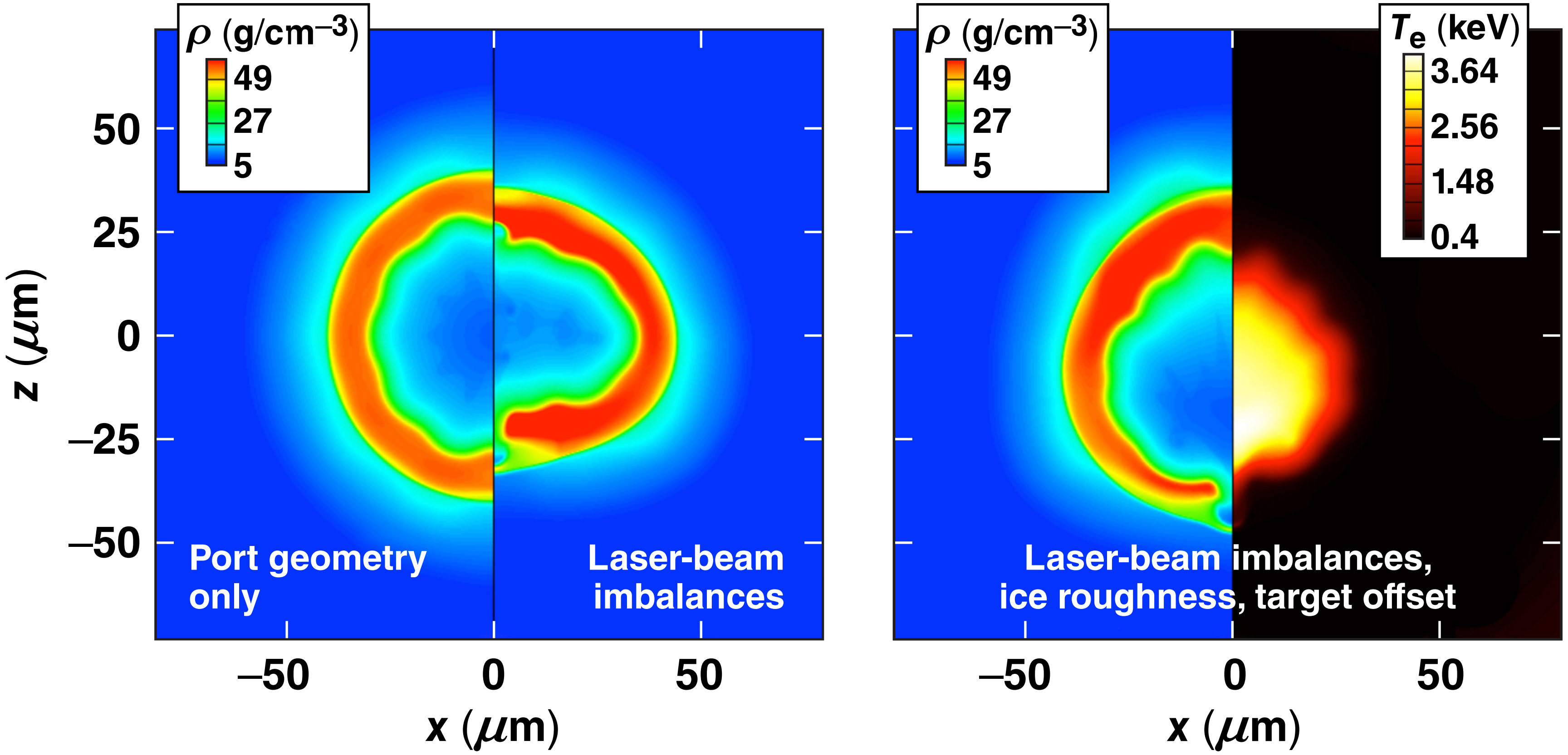


— 77068 ($\alpha \approx 3$) >50 Gbar
— 80802 ($\alpha \approx 7$)

---

* S. P. Regan *et al.*, Phys. Rev. Lett. 117, 025001 (2016); A. Bose *et al.*, Phys. Rev. E 94, 011201(R) (2016).

2-D post-shot simulations including low-mode perturbations show little degradation from low modes



Bang time, 2.55 ns

Offset = 10.5 μm
σ_{rms}, ice = 0.65 μm
5.3% power imbalance
8-μm mispointing
5-ps mistiming

- Simulations including beam mistiming, mispointing, and 5.3% power imbalance, with measured ice roughness and target offset, show a reduction in yield of 17% from the clean yield
- Even when the power imbalance is doubled to 10%, the yield degradation is just 26%

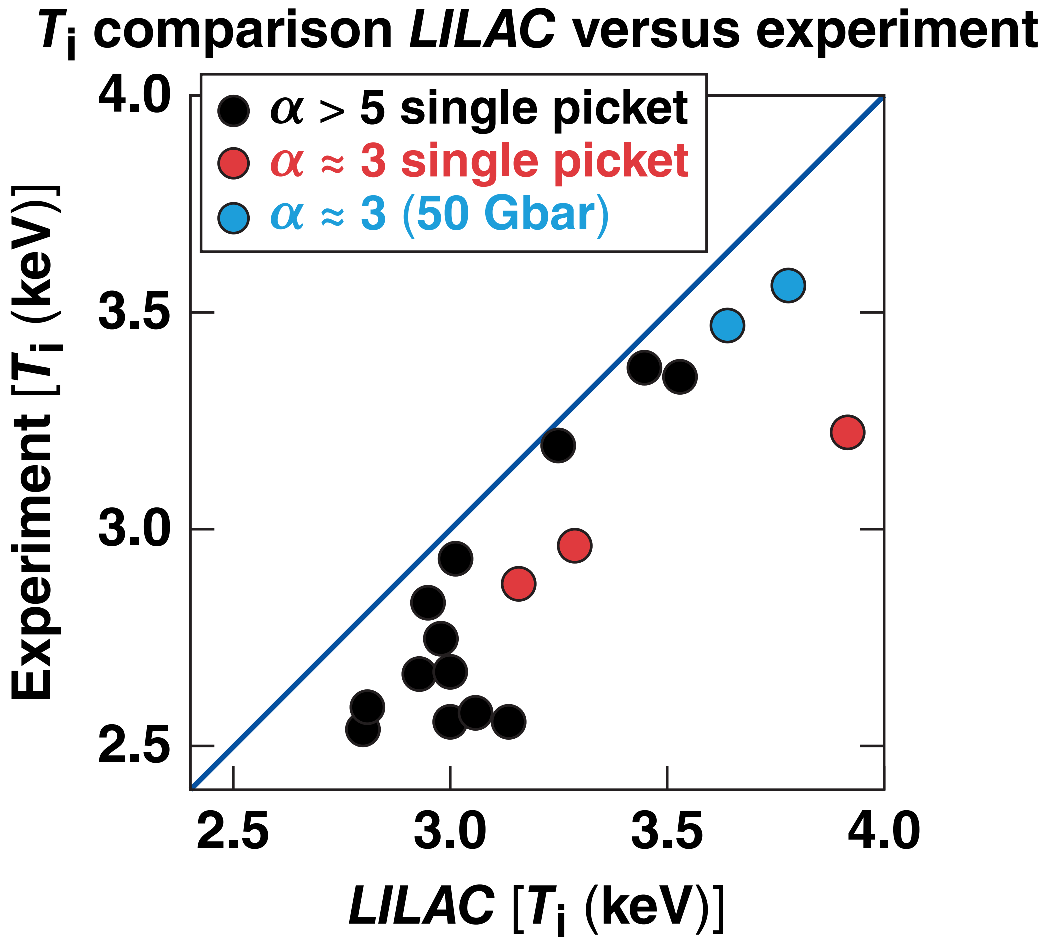
Multidimensional simulations are used to assist our strategy and help the interpretation of the results, but are not used to reach final conclusions.

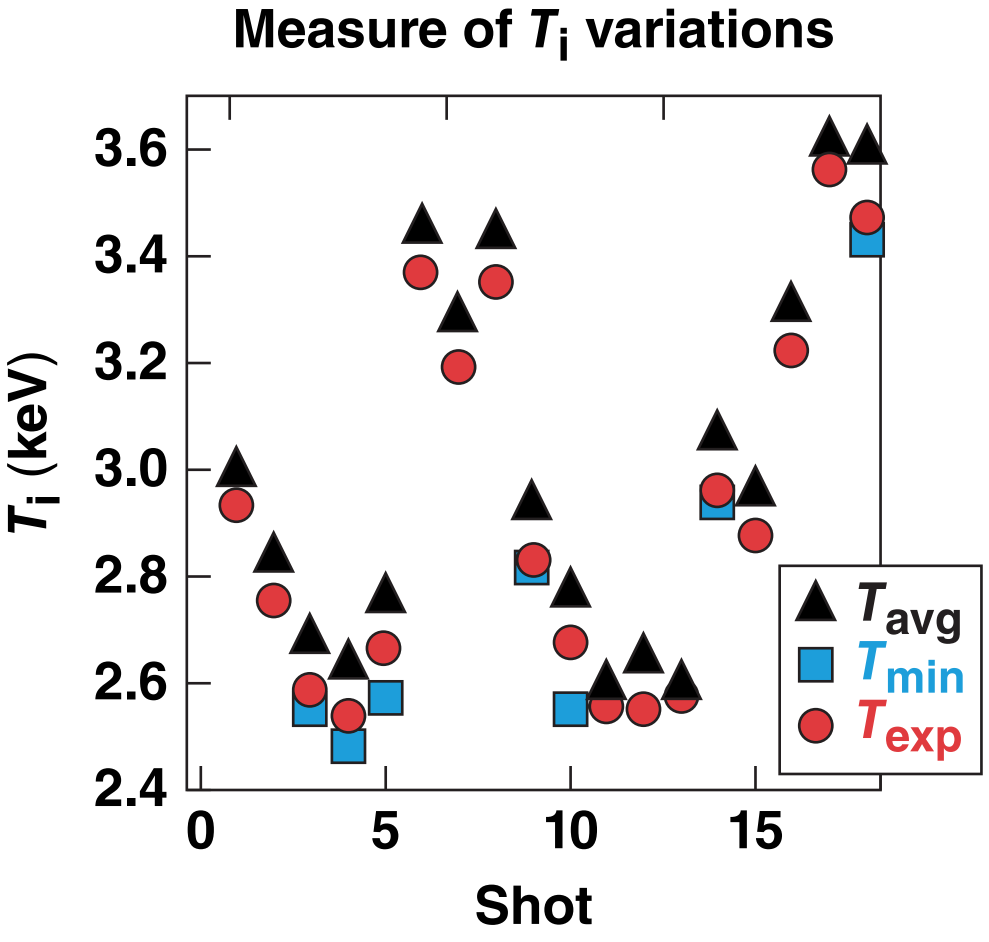
T. J. B. Collins *et al*., PO5.00009, this conference.

TC13097

The ion temperature is below the predictions of the 1-D code

$$T_{\text{exp}} = \text{Max}\left[T_{\text{min}}, \left\langle \frac{T_{\text{min}}}{T_{\text{avg}}} \right\rangle T_{\text{avg}}\right]$$

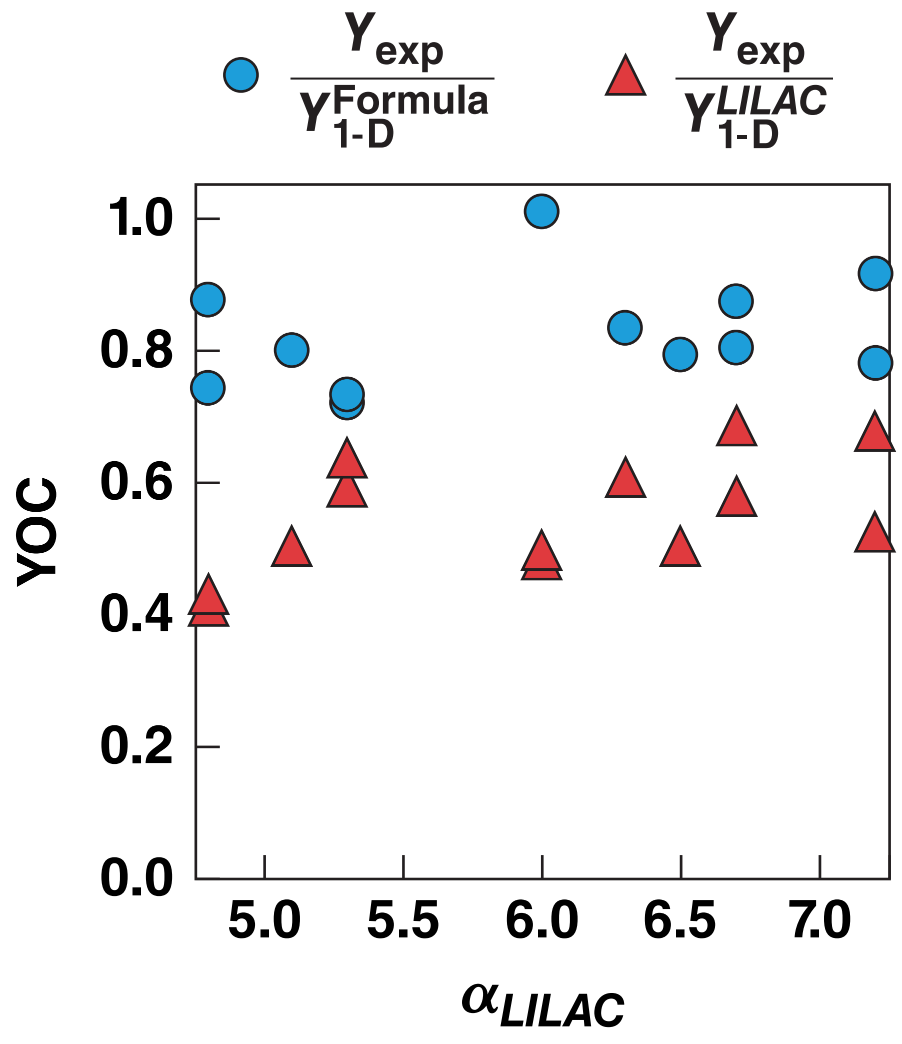


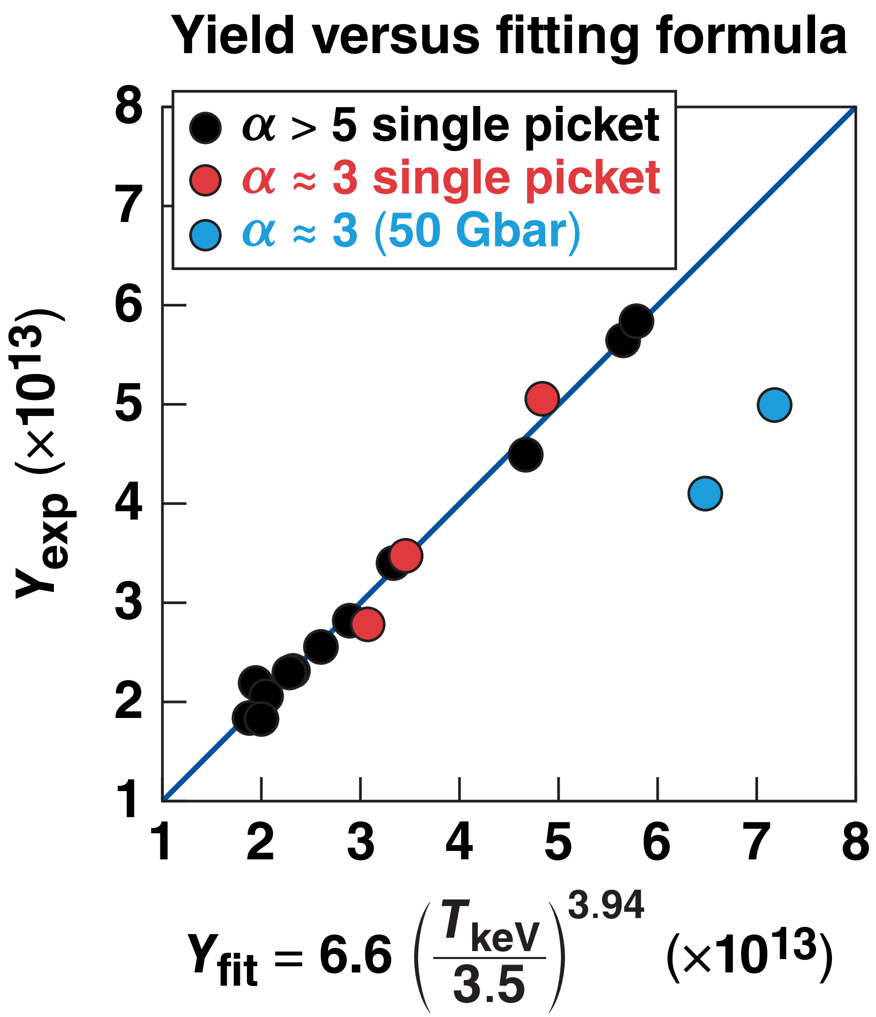


These shots exhibit small T_i variations among detectors.

TC13201

For high-adiabat shots, the measured yield closely follows a T^4 power law



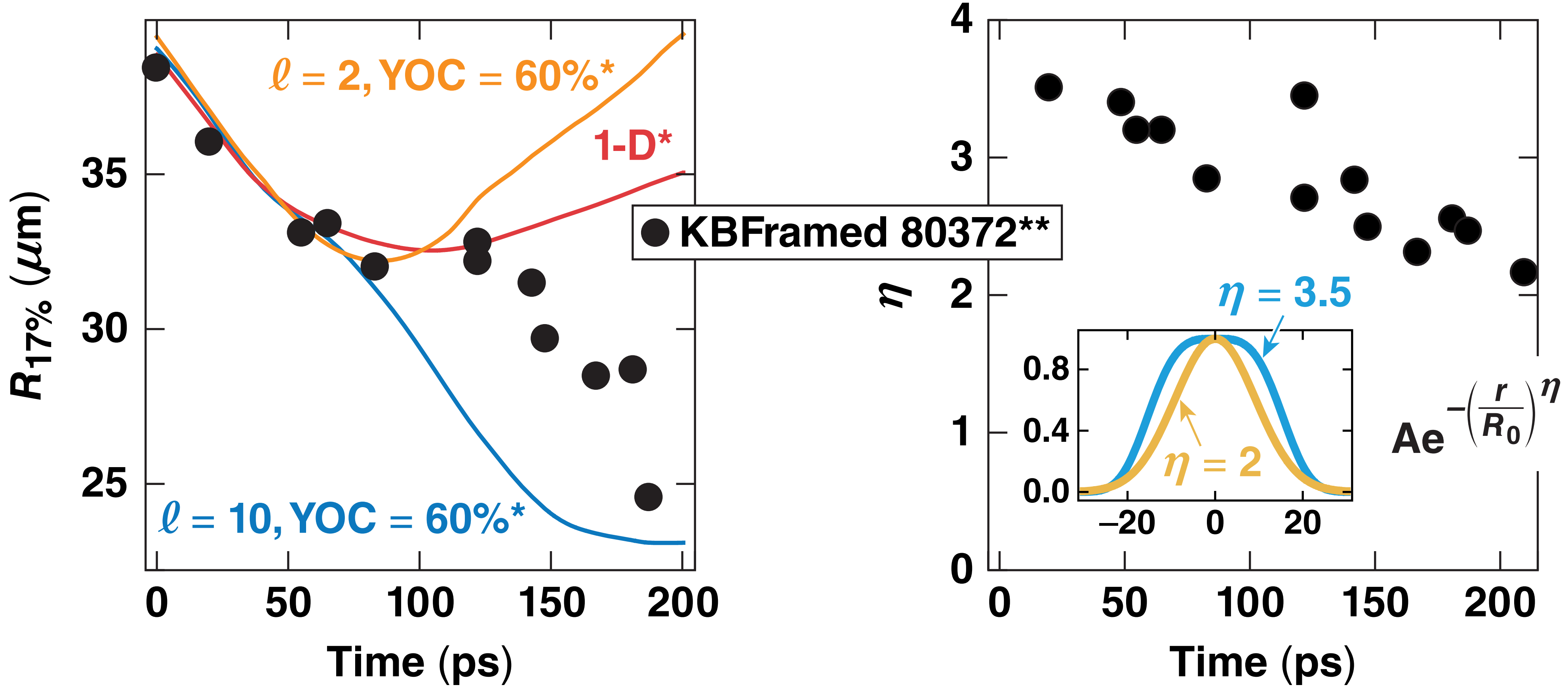


$$Y_{fit} = 6.6\left(\frac{T_{keV}}{3.5}\right)^{3.94} (\times 10^{13})$$

The 50-Gbar shots do not follow the T^4 power law; *LILAC* fit of the yield is $T^{4.7}$.

TC13202

Preliminary analysis of the hot-spot framed images indicate the presence of RT spikes from mid-ℓ modes after stagnation



The size of the self-emission becomes smaller after stagnation

The self-emission profile becomes peaked with time

This analysis will make it possible to generate a multidimensional picture of the hot-spot dynamics (error bars are large → look at trends).

---

*A. Bose *et al.*, UO5.00001, this conference.

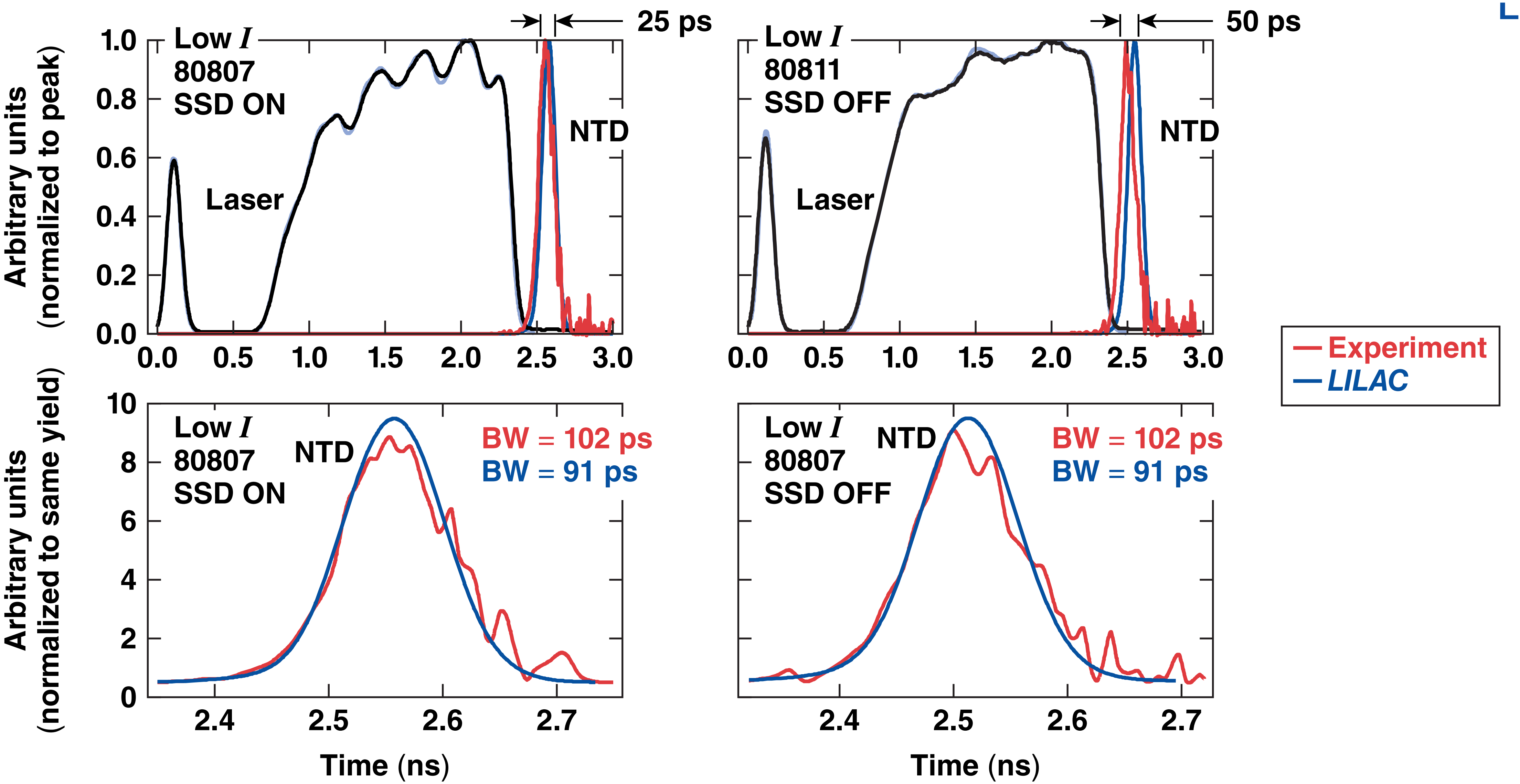
**F. J. Marshall, Laboratory for Laser Energetics, private communication (2016).

Summary/Conclusions

The 1-D-campaign on OMEGA uses systematic changes and looks for trends to improve physics understanding and find the optimal target design

- The 1-D campaign uses ON/OFF systematic changes in cryo implosions to understand the implosion behavior
- The 1-D campaign looks for 1-D trends in qualitative features of the experimental observables to elucidate the physics and assess the dimensionality of the implosion
- A short-term goal is to find the optimum 1-D performance at high adiabat (~7) using two-shock (single-picket) pulse shapes
- The ultimate goal is to find the optimum target design through an adiabat and velocity scan

No clear signatures of imprinting are observed, indicating stable implosions to short wavelengths



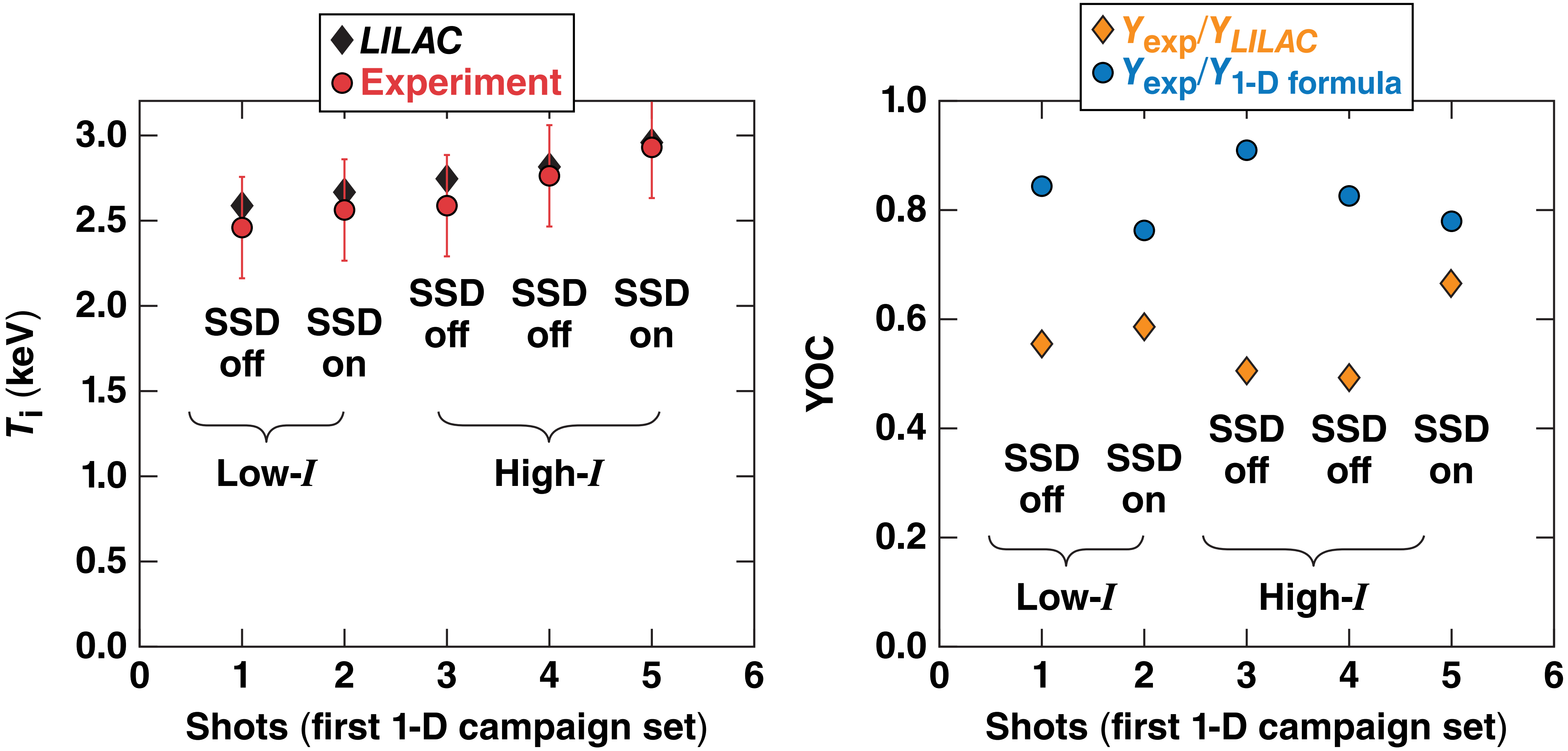
In warm targets, SSD OFF leads to earlier bang times and wider burn histories.*

TC13098

---

*S. X. Hu *et al*., Phys. Plasmas 23, 102701 (2016).

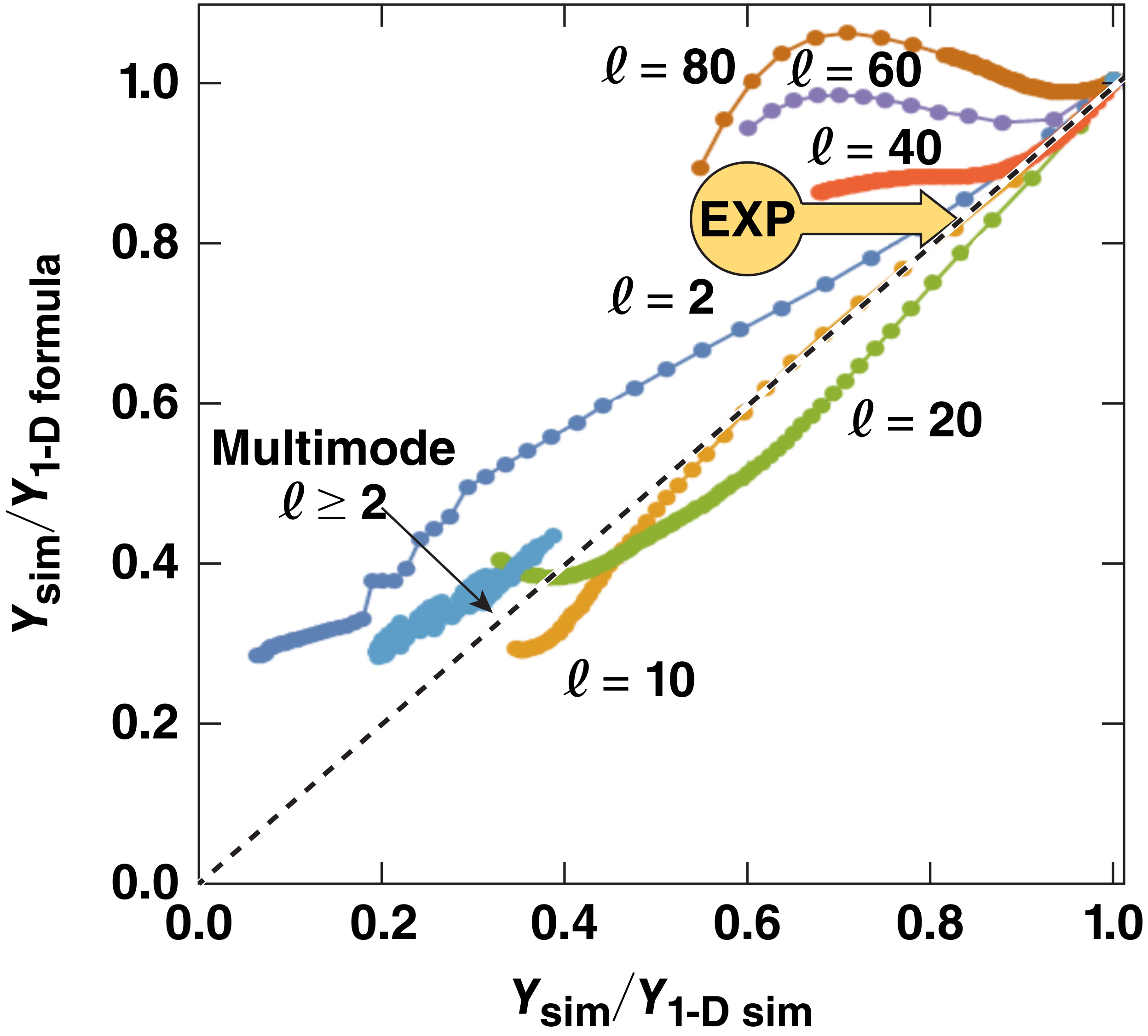
The measured yield is about 60% of the *LILAC* yield and ~85% of the 1-D yield formula based on measured *T* and *ρR*



The measured T_i is slightly lower than *LILAC* T_i and explains ~1/2 of the discrepancy; early indication of a 1-D-code over-prediction of 1-D yield.

TC13099

A comparison between YOC's from *LILAC* and the 1-D formula gives preliminary indications of the 1-D code over-estimating the 1-D yield

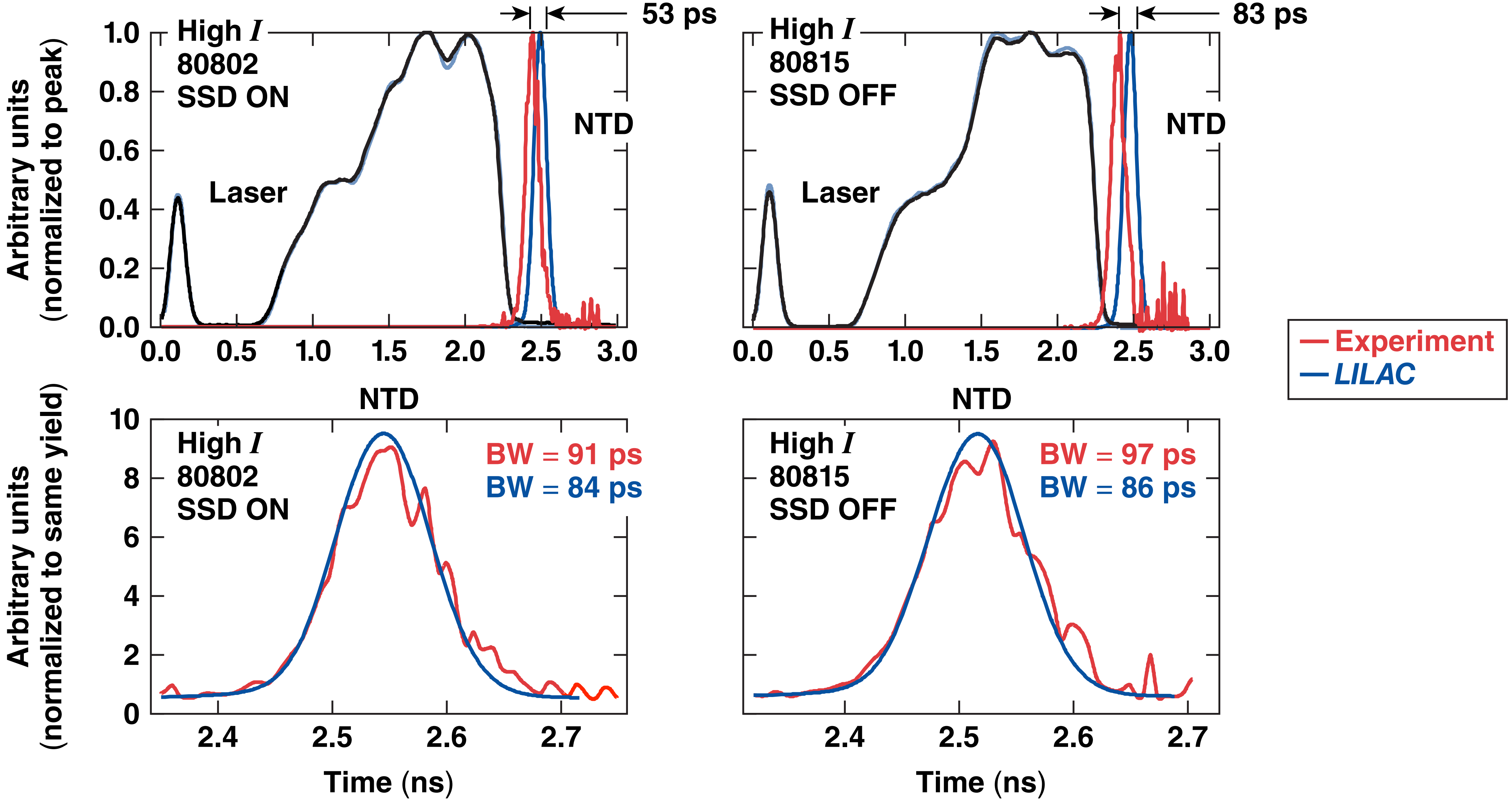


- Differences between *LILAC* YOC and 1-D formula can be reconciled using high-mode distortion
- SSD-ON/OFF experiments indicate implosions stable to high modes
- Possible explanation is that *LILAC* overpredicts the 1-D yield

The yield formula also provides a lower bound for the 1-D yield in implosions degraded by nonuniformities.

TC13100

Similar trends are observed for higher intensity shots (but larger bang-time differences)



TC13101