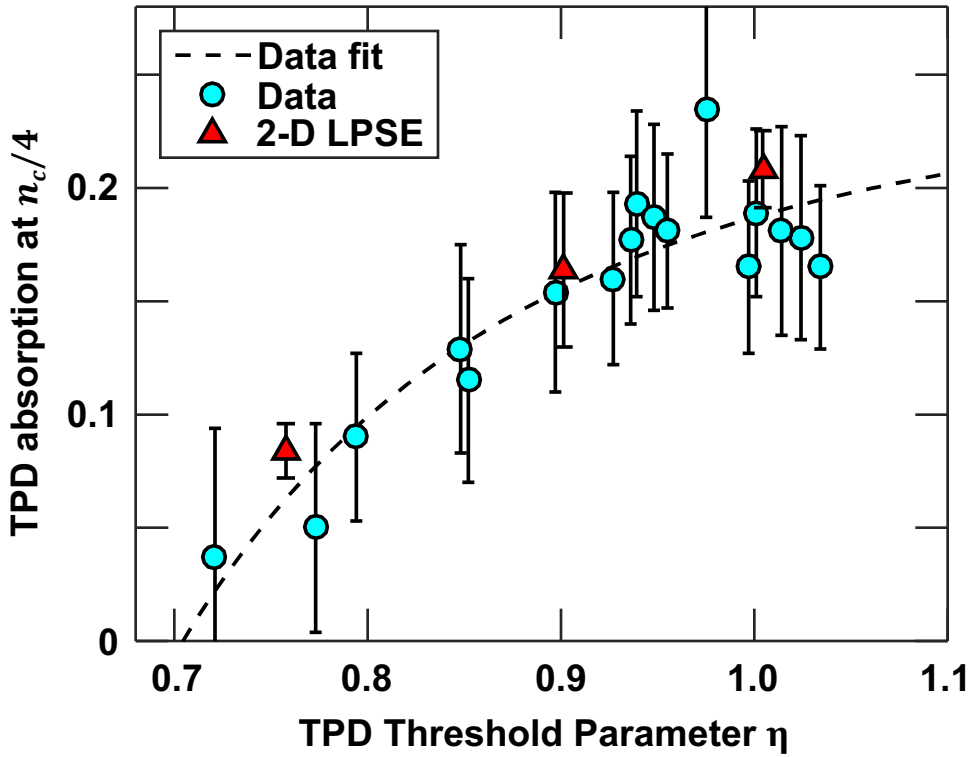
Anomalous Absorption by the Two-Plasmon-Decay Instability in Directly Driven Inertial Confinement Fusion Experiments



David Turnbull
University of Rochester
Laboratory for Laser Energetics

61st Annual Meeting of the
APS Division of Plasma Physics
Fort Lauderdale, FL
21-25 October 2019

Summary

The Two-Plasmon-Decay (TPD) instability is a strong laser absorption mechanism in OMEGA-scale directly driven implosions

UR LLE

- Discrepancies between predicted and observed scattered light correlate extremely well with multiple (additional) signatures of TPD
- Scattered light data were used to infer that ~15-20% absorption typically occurs when TPD is active
- 2-D LPSE simulations using a new pump depletion model agree well with the data**

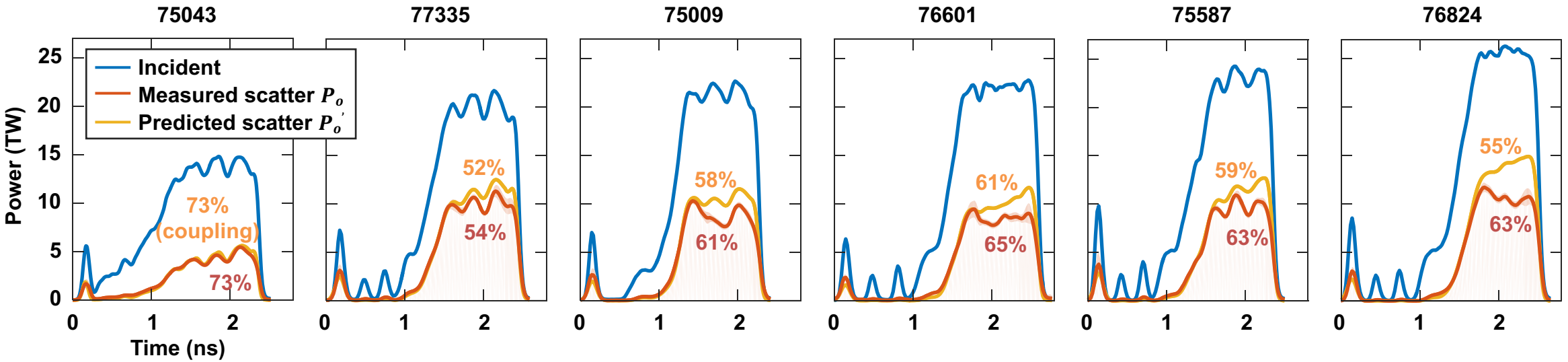
A model for TPD should be included in radiation-hydrodynamic simulations to improve their accuracy

* D. Turnbull *et al.*, in review (2019).
** See also talk by A. Maximov, Session G06 (LPI)

Collaborators

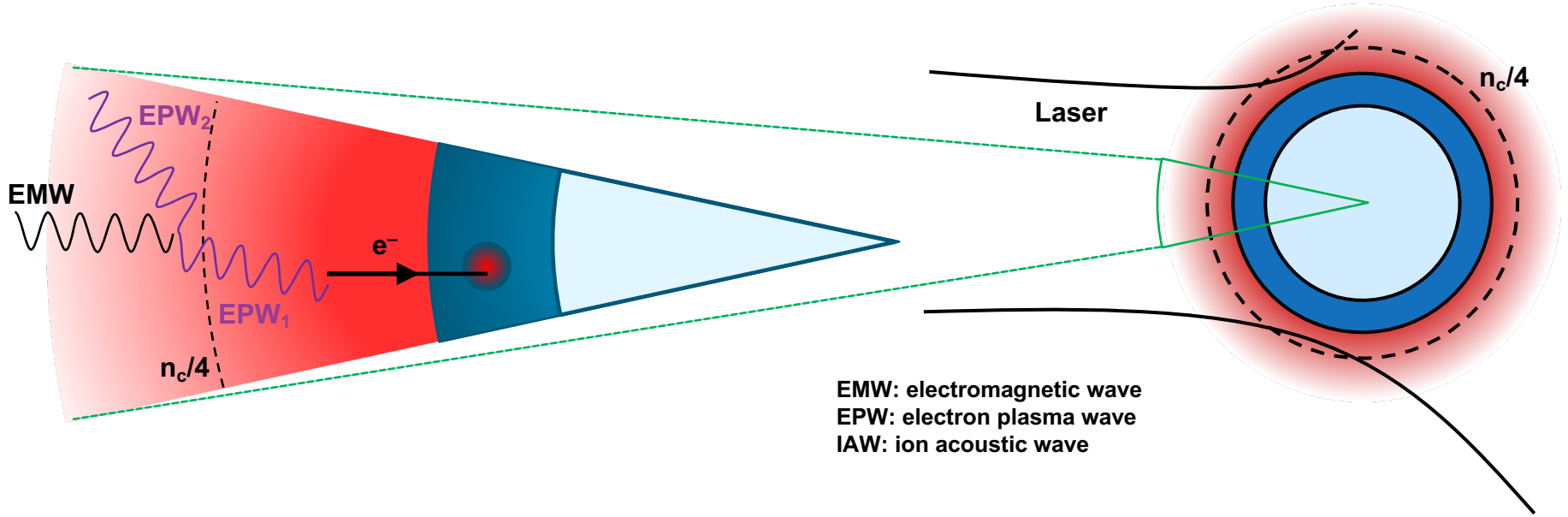
D. Cao, D. H. Edgell, R. K. Follett, D. H. Froula, V. N. Goncharov,
A. V. Maximov, J. P. Palastro, W. Seka, C. Stoeckl, and H. Wen
University of Rochester Laboratory for Laser Energetics

LILAC (with nonlocal & CBET models) predicts scattered light accurately for low peak power pulse shapes, but discrepancies appear at higher peak power



Features like the sometimes rapid onset and typically growing divergence during peak power were suggestive of a nonlinear, threshold process like TPD

Could the Two-Plasmon-Decay instability—typically only worried about for preheat—actually be a strong laser absorption mechanism?

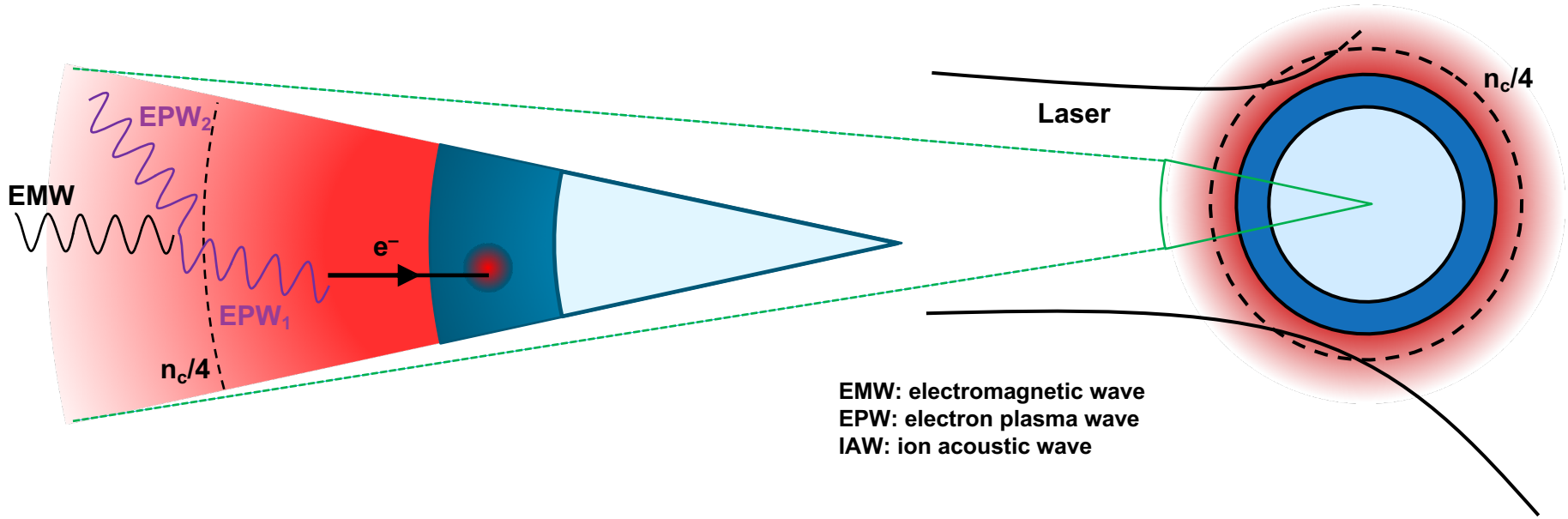


Incident light → Primary EPW's → Secondary EPW's → Landau damping / cavitation → Hot electrons (preheat)

Secondary EPW's → Collisional damping

Primary EPW's → IAW's

Could the Two-Plasmon-Decay instability—typically only worried about for preheat—actually be a strong laser absorption mechanism?

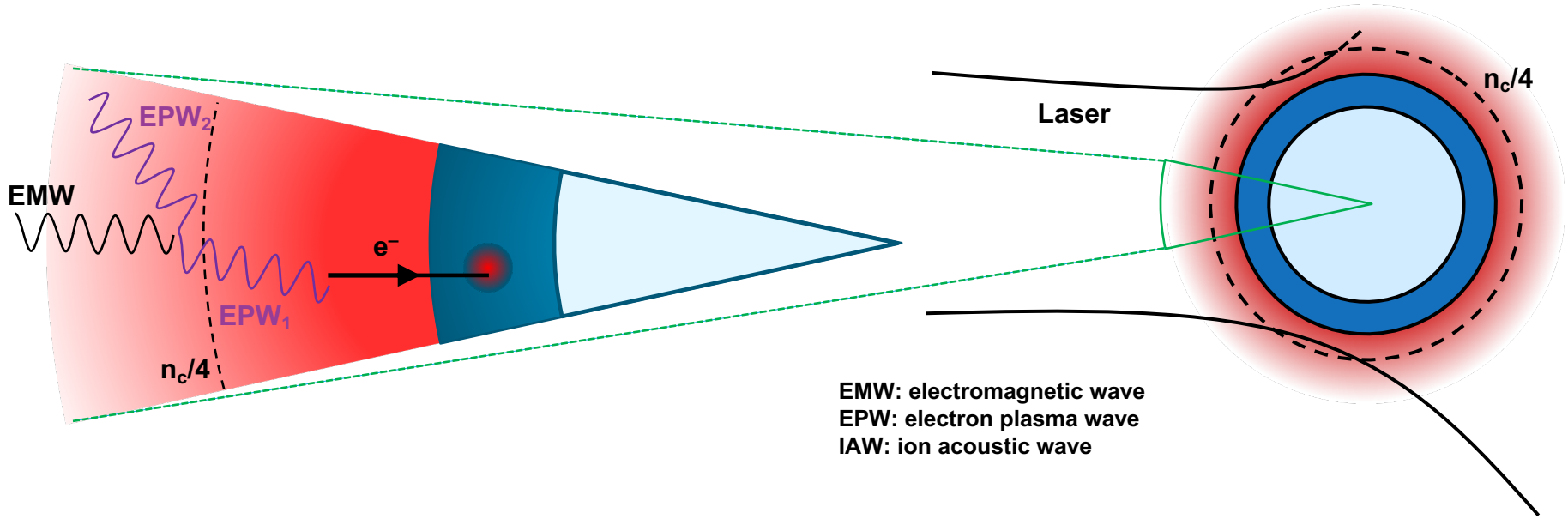


Incident light → Primary EPW's → Secondary EPW's → Landau damping / cavitation → Hot electrons (preheat)

Primary EPW's → IAW's → Collisional damping

Usually only worry about this piece…

Could the Two-Plasmon-Decay instability—typically only worried about for preheat—actually be a strong laser absorption mechanism?



…doesn't necessarily account for all the laser power

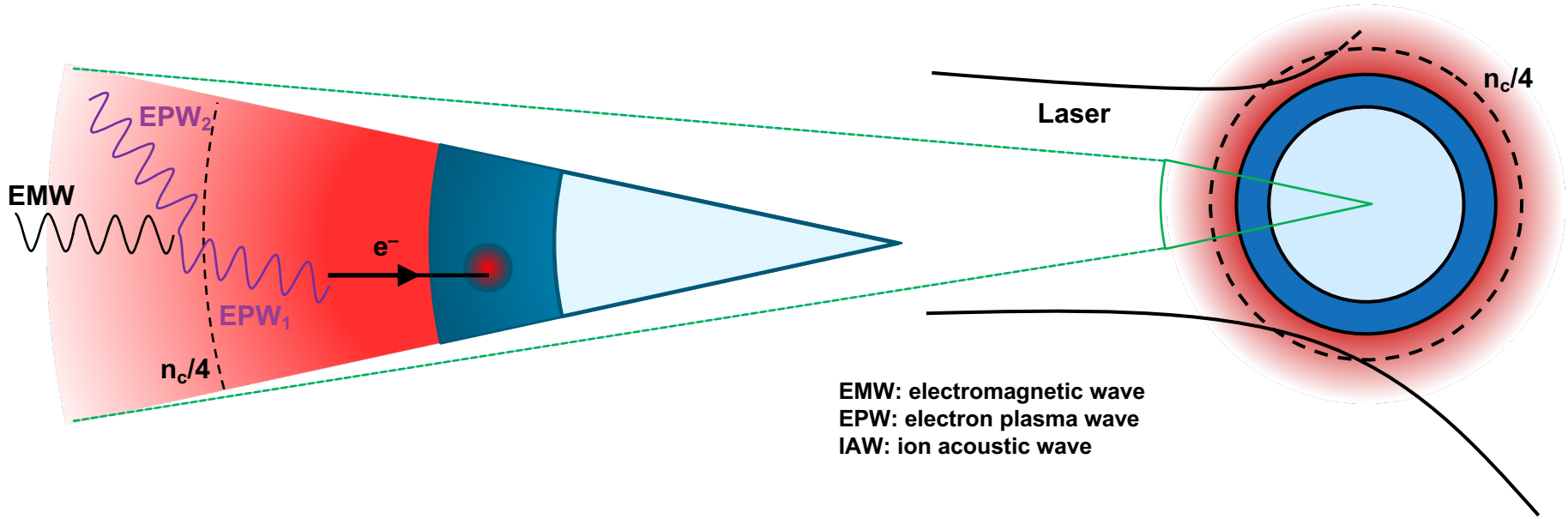
Incident light → Primary EPW's → Secondary EPW's / IAW's

Secondary EPW's → Landau damping / cavitation, Collisional damping

Landau damping / cavitation → Hot electrons (preheat)

Usually only worry about this piece…

Could the Two-Plasmon-Decay instability—typically only worried about for preheat—actually be a strong laser absorption mechanism?



…doesn't necessarily account for all the laser power

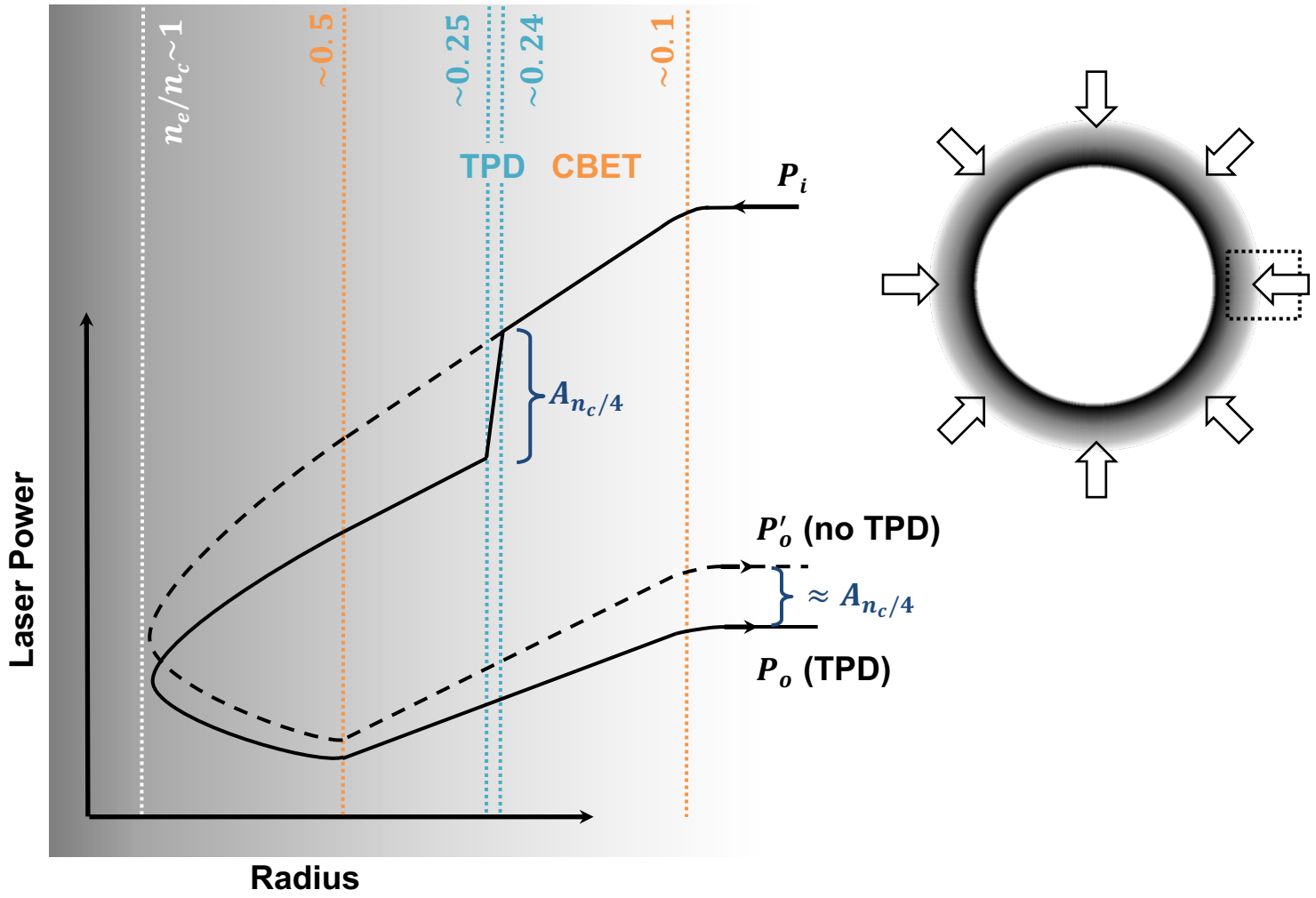
Incident light → Primary EPW's → Secondary EPW's / IAW's

Secondary EPW's → Landau damping / cavitation; Collisional damping

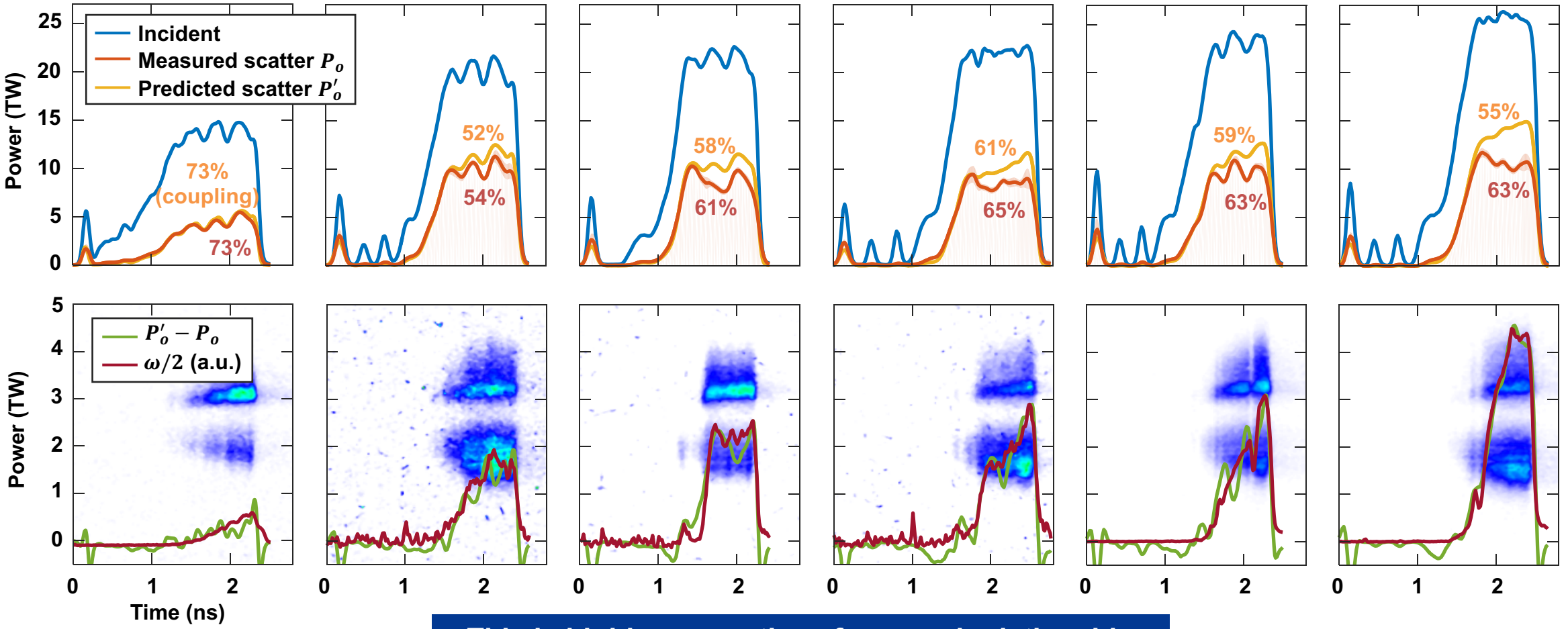
Landau damping / cavitation → Hot electrons (preheat)

Usually only worry about this piece…

The basic hypothesis is that the reduction of scattered light is a nearly direct signature of absorption due to TPD

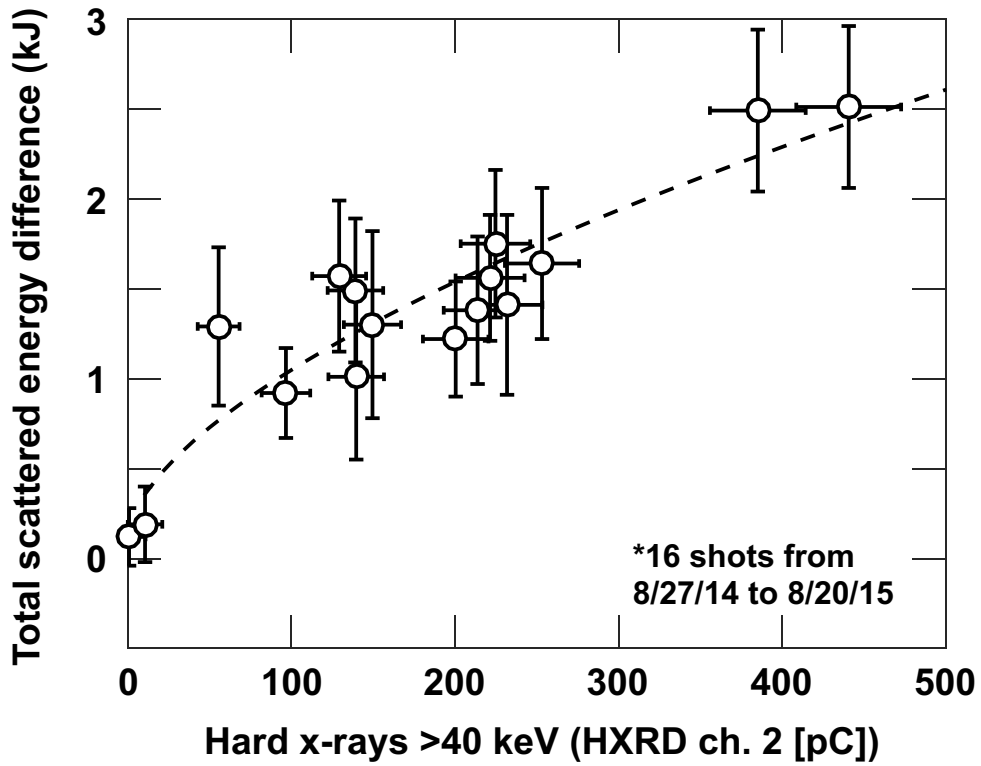


The scattered light discrepancy was found to correlate extremely well with the time history of TPD (as inferred from half-harmonic ω/2 emission)



This is highly suggestive of a causal relationship

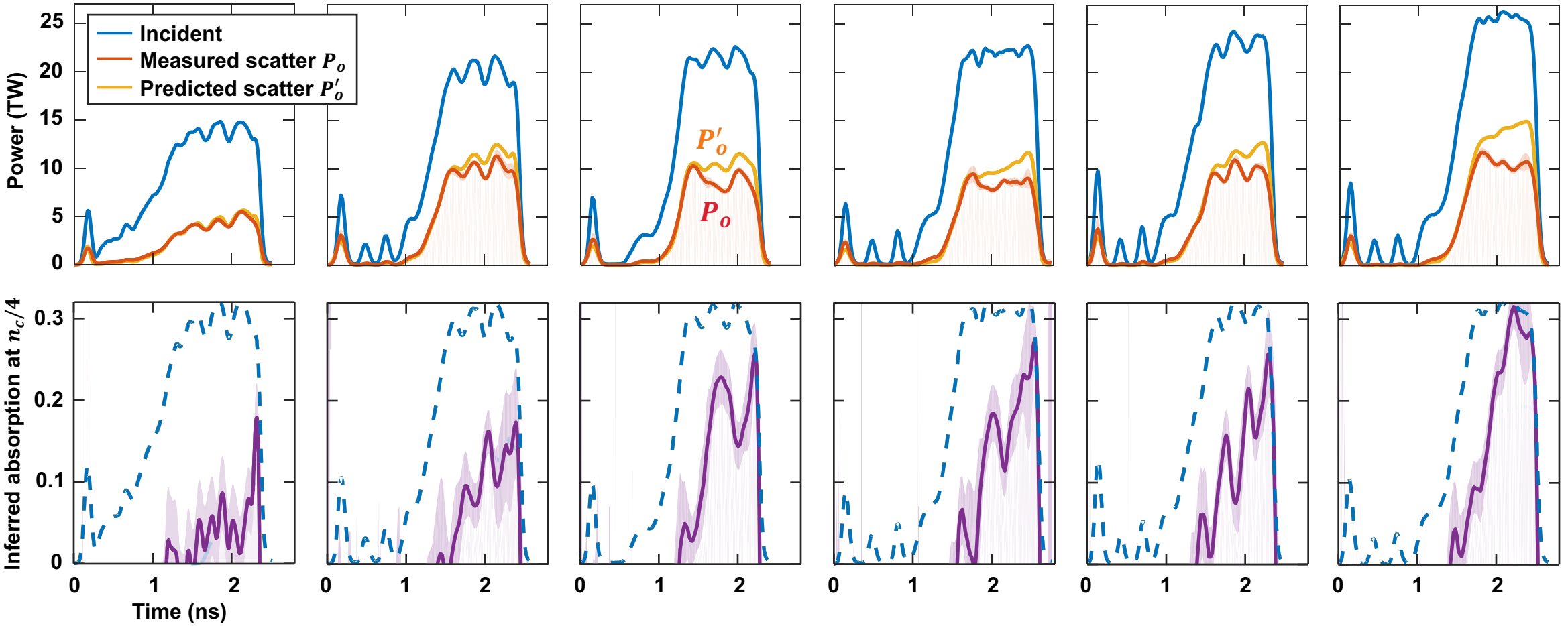
The FABS* TPD spectrometer is not maintained as absolutely calibrated, but the integrated scattered power difference also correlates well with hard x-rays



This further bolsters the case for a causal relationship

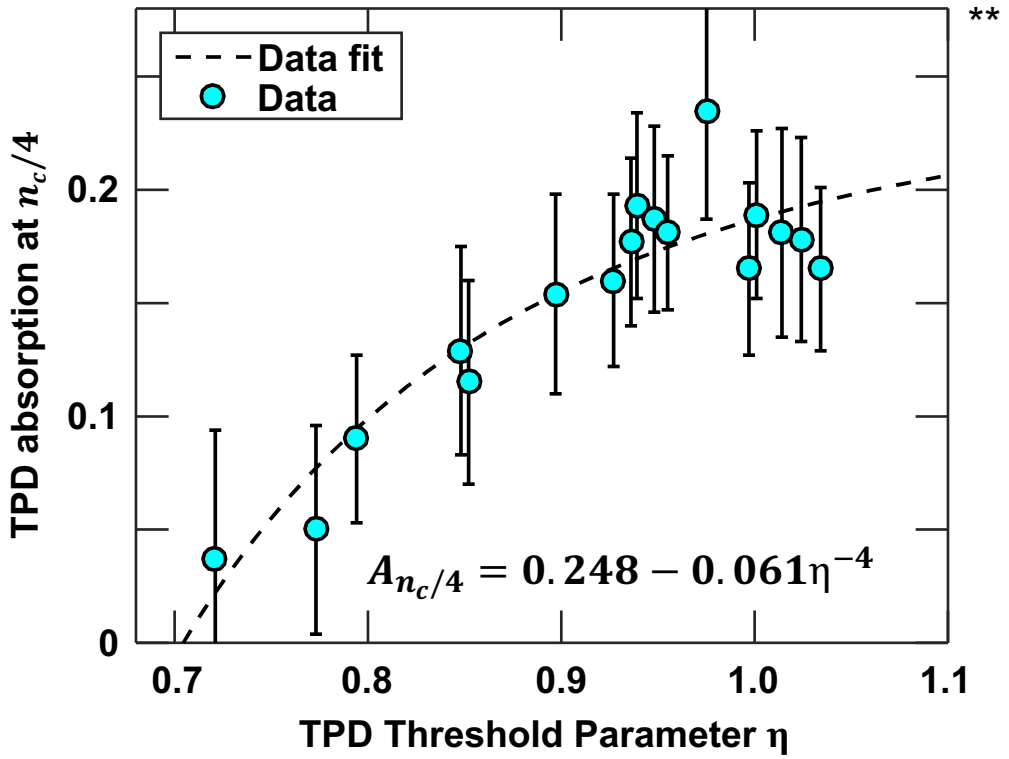
* Full aperture backscatter

Transmission past $n_c/4$ (and therefore absorption) can be directly inferred from the ratio of measured to predicted scattered light: $1 - A_{n_c/4} = T_{n_c/4} \approx P_o/P'_o$



Up to ~30% absorption of the light reaching quarter-critical is possible—a significant sink for laser power

It would be more useful to be able to predict TPD using code parameters, and TPD has been previously shown to scale reliably with $\eta = I_{14}L/(233T_e)$*



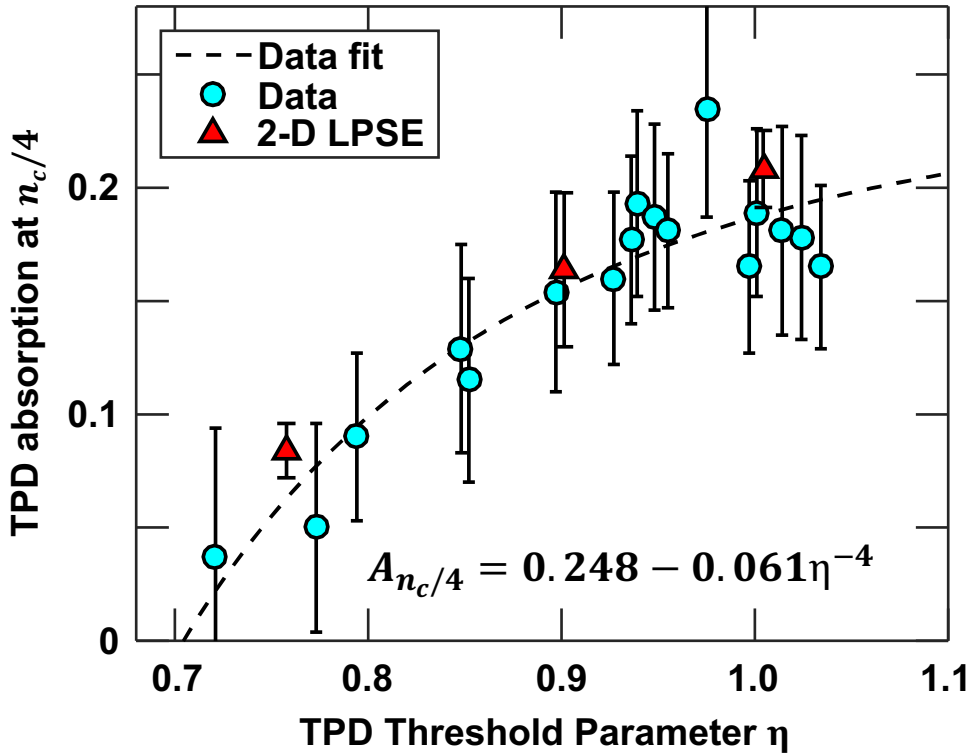
**

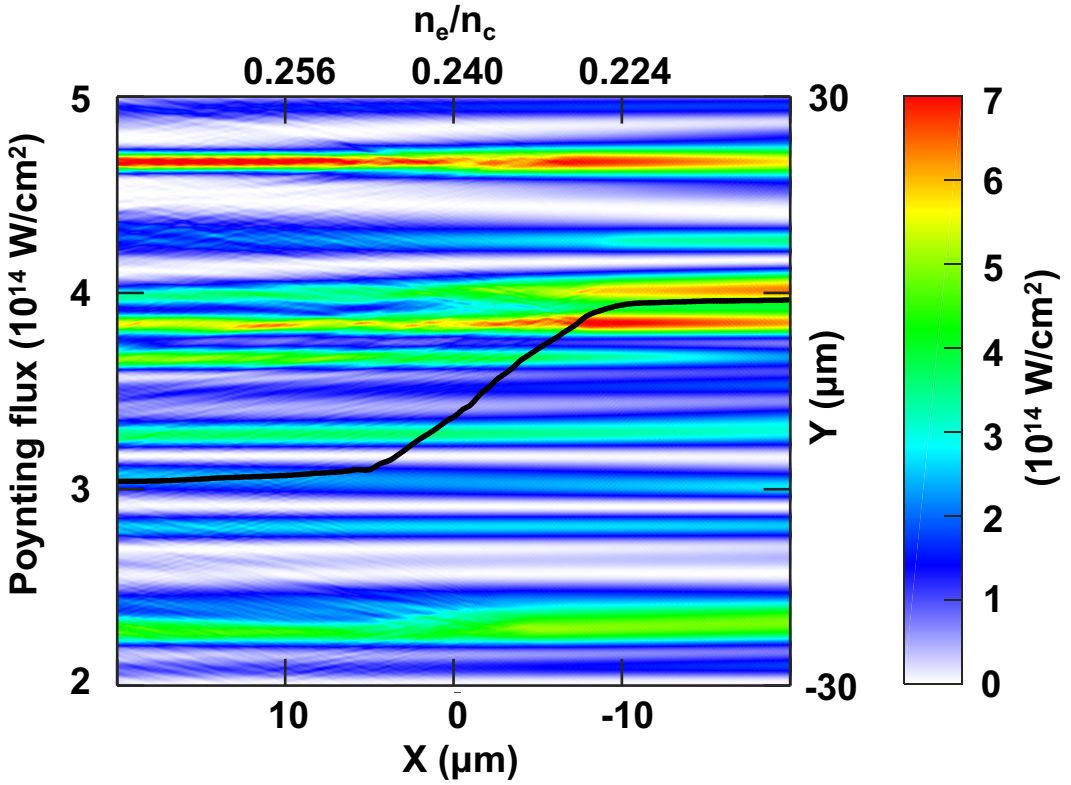
**average absorption over the duration of the TPD activity compared to average η extracted from LILAC simulations over a comparable duration, for a series of shots

There is a clear trend, suggesting TPD activity (and associated laser absorption) can be predicted inline in simulations

* A. Simon *et al.*, Phys. Fluids 26, 3107 (1983);
C. Stoeckl *et al.*, Phys. Rev. Lett. 90, 235002 (2003);
W. Seka *et al.*, Phys. Plasmas 16, 052701 (2009);
D.T. Michel *et al.*, Phys. Plasmas 20, 055703 (2013);
J. Delettrez *et al.*, Phys. Plasmas 26, 062705 (2019).

LPSE simulations using a new pump depletion model validate the empirical trend*





This scaling will be the basis for a reduced model that will be added to the radiation-hydrodynamic simulations

* See also talk by A. Maximov, Session G06 (LPI)

Summary/Conclusions

The Two-Plasmon-Decay (TPD) instability is a strong laser absorption mechanism in OMEGA-scale directly driven implosions

UR LLE

- Discrepancies between predicted and observed scattered light correlate extremely well with multiple (additional) signatures of TPD
- Scattered light data were used to infer that ~15-20% absorption at $n_c/4$ typically occurs when TPD is active
- 2-D LPSE simulations using a new pump depletion model agree well with the data**

A model for TPD should be included in radiation-hydrodynamic simulations to improve their accuracy

* D. Turnbull *et al.*, in review (2019).
** See also talk by A. Maximov, Session G06 (LPI)

Using the inferred scaling to predict absorption yields good agreement with the data in most cases