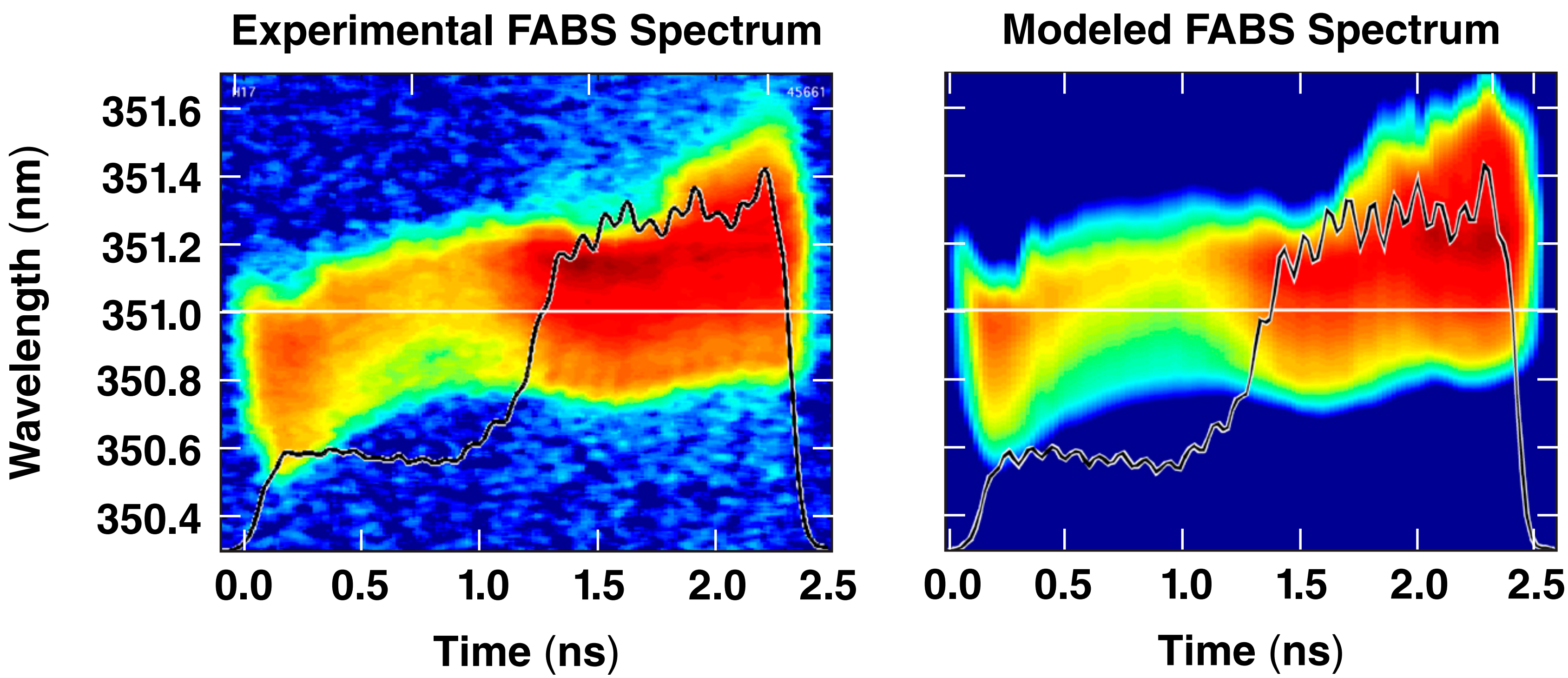
Time-Dependent Scattered-Laser-Light Spectroscopy in Direct-Drive Inertial Confinement Fusion Implosion Experiments



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Laboratory for Laser Energetics

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Absorption Conference
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Summary

Detailed analysis of scattered light spectra from implosions indicate that absorption is slightly less than predictions

- **Time-dependent scattered-laser-light spectra in the SBS range (351±1 nm) are modeled by a combination of hydrodynamic and ray-tracing codes.**
- **Analysis of the spectra indicates that after the initial plasma production the hydro-code over-predicts absorption by ~20%.**
- **Nonlinear LPI cross-beam power transfer via EM-seeded SBS may cause some laser power to "by-pass" the high absorption region.**
- **Precise knowledge of the absorption is important for implosion modeling and shock timing.**

Collaborators

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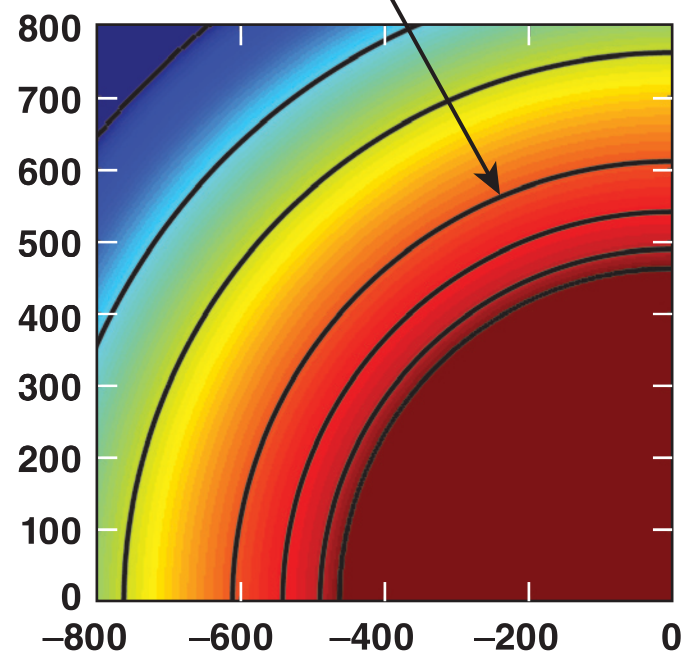
Time-dependent scattered-light spectra are modeled for OMEGA implosions

- *LILAC*: 1-D hydrodynamic code predicts time-dependent plasma profiles
  - using various electron-heat transport models: fixed flux-limited, Goncharov nonlocal model[1]

Plasma density contours



E15989a

[1] V. Goncharov *et al.*, Phys. Plasmas 13, 012702 (2006).

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UR LLE

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- ***SAGERAYS*: Ray traces 351-nm-drive laser light through plasma and calculates spectral shift along each path[2]**

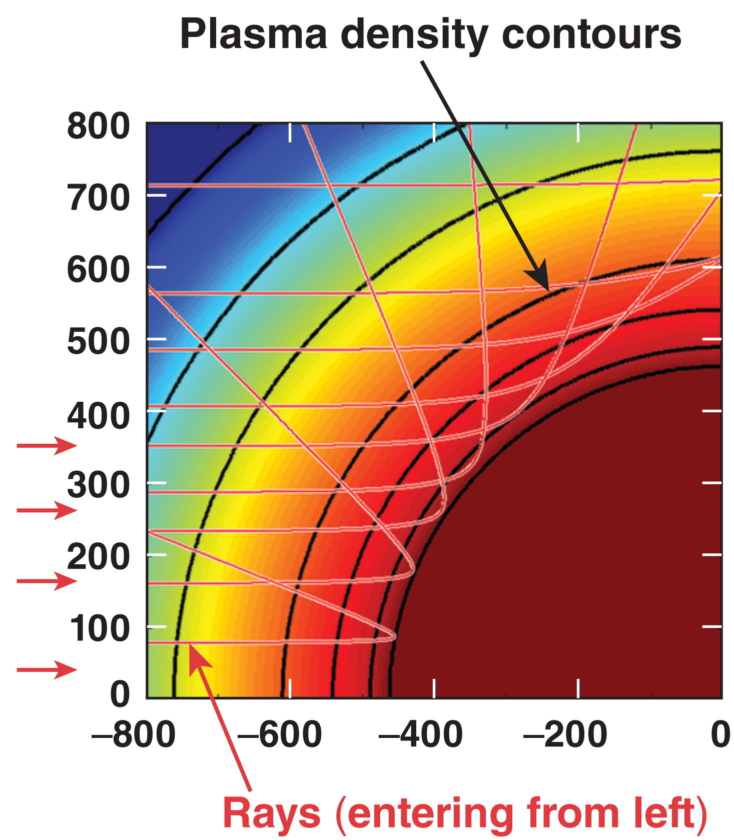
$$\Delta\omega = -\omega_0 \frac{\partial \tau_f}{\partial t} = +\frac{\omega_0}{2c} \int \left(1 - \frac{n_e}{n_c}\right)^{-1/2} \frac{\partial}{\partial t}\left(\frac{n_e}{n_c}\right) ds$$

τ_f = time of flight of light along ray

n_e = plasma density

n_c = plasma critical density

ω_0 = laser-light angular frequency



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[2]T. Dewandre, J. R. Albritton, and E. A. Williams, Phys. Fluids 24, 528 (1981).

E15990b

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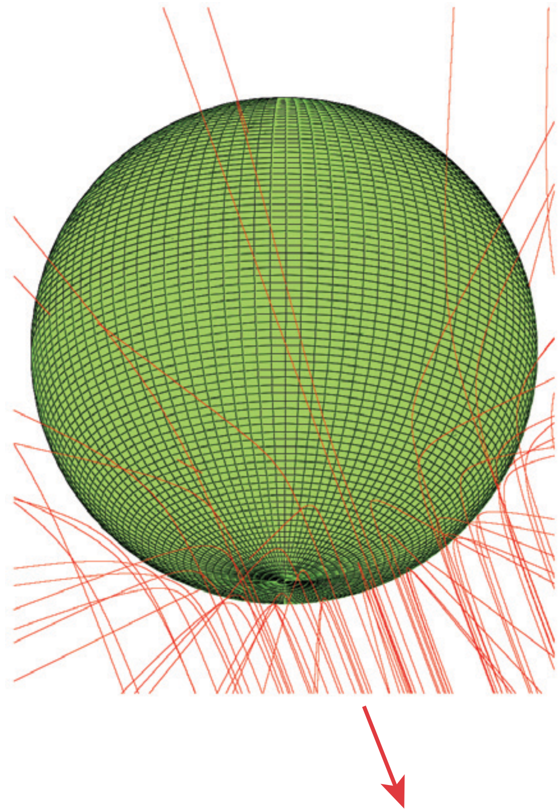
- MATLAB code calculates total spectrum collected by FABS from all 60 beams



Rays collected by FABS

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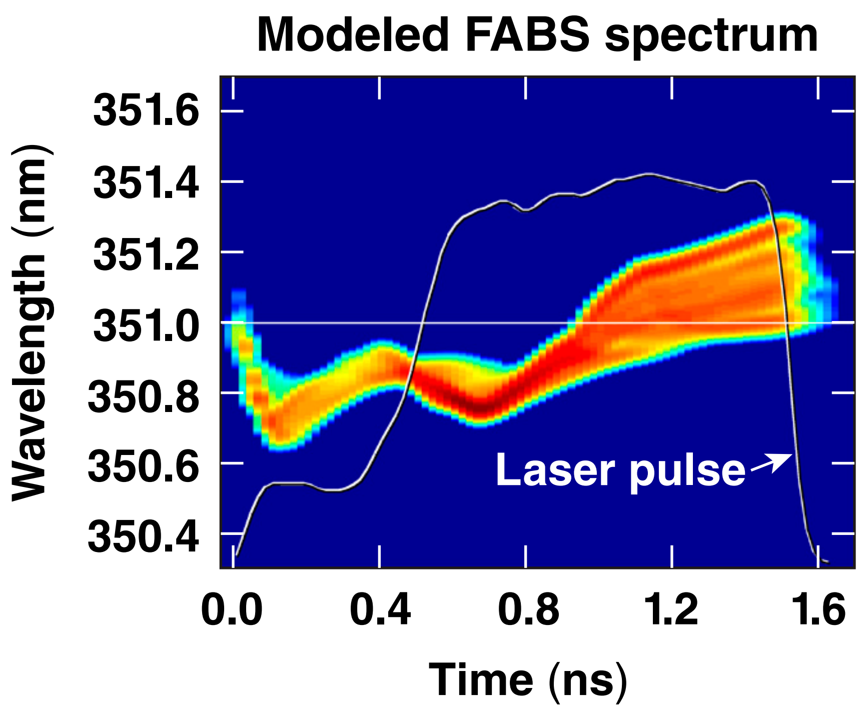
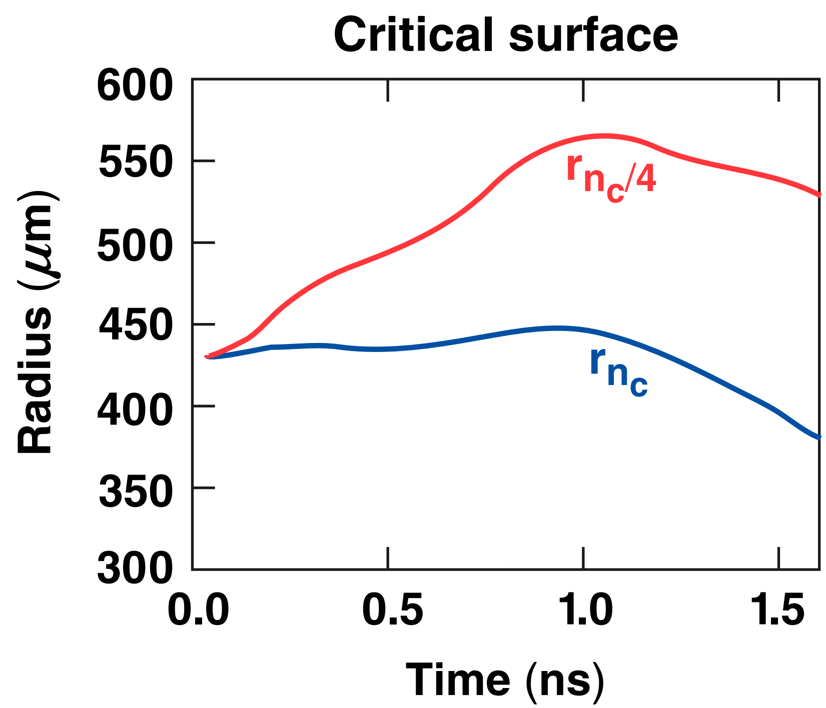
Modeled scattered-light spectra show a detailed structure with both blue- and red-shifted components



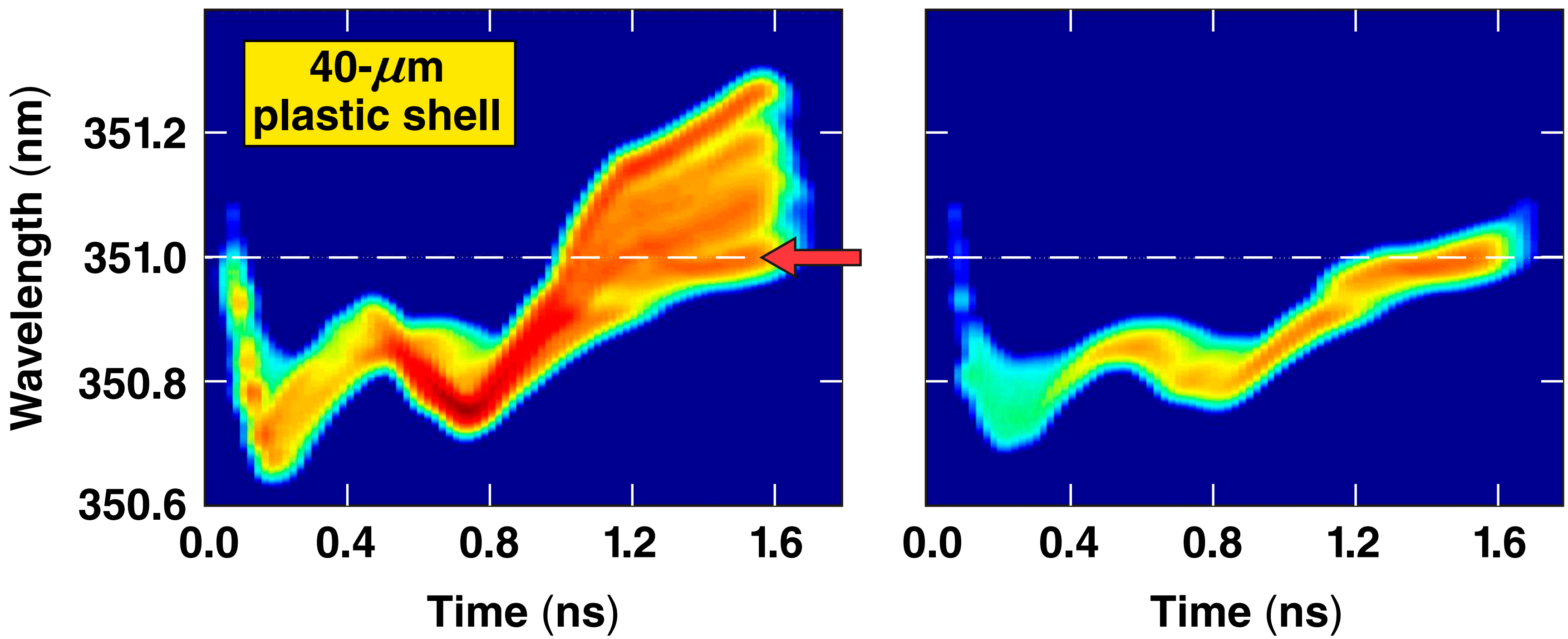


- Sharp initial blue shifts due to plasma production at laser pulse edges
- Red-shifted "fan-tail" due to compression of target

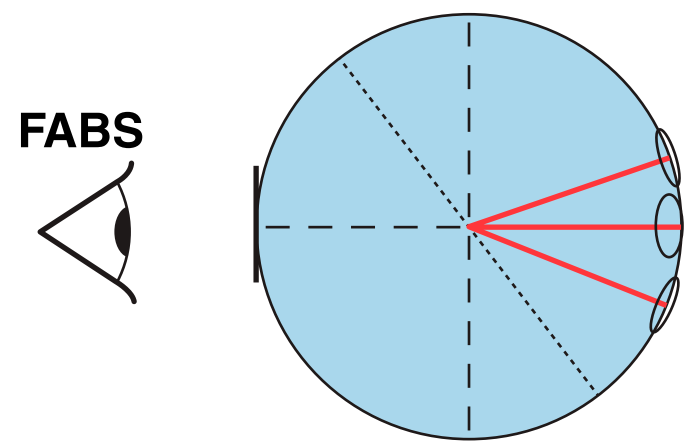
40-μm plastic shell

E16793

Fan-tail "fingers" come from groups of beams at similar angles with respect to the detector



Beams on the side farthest from the detector show the least shift



E16794

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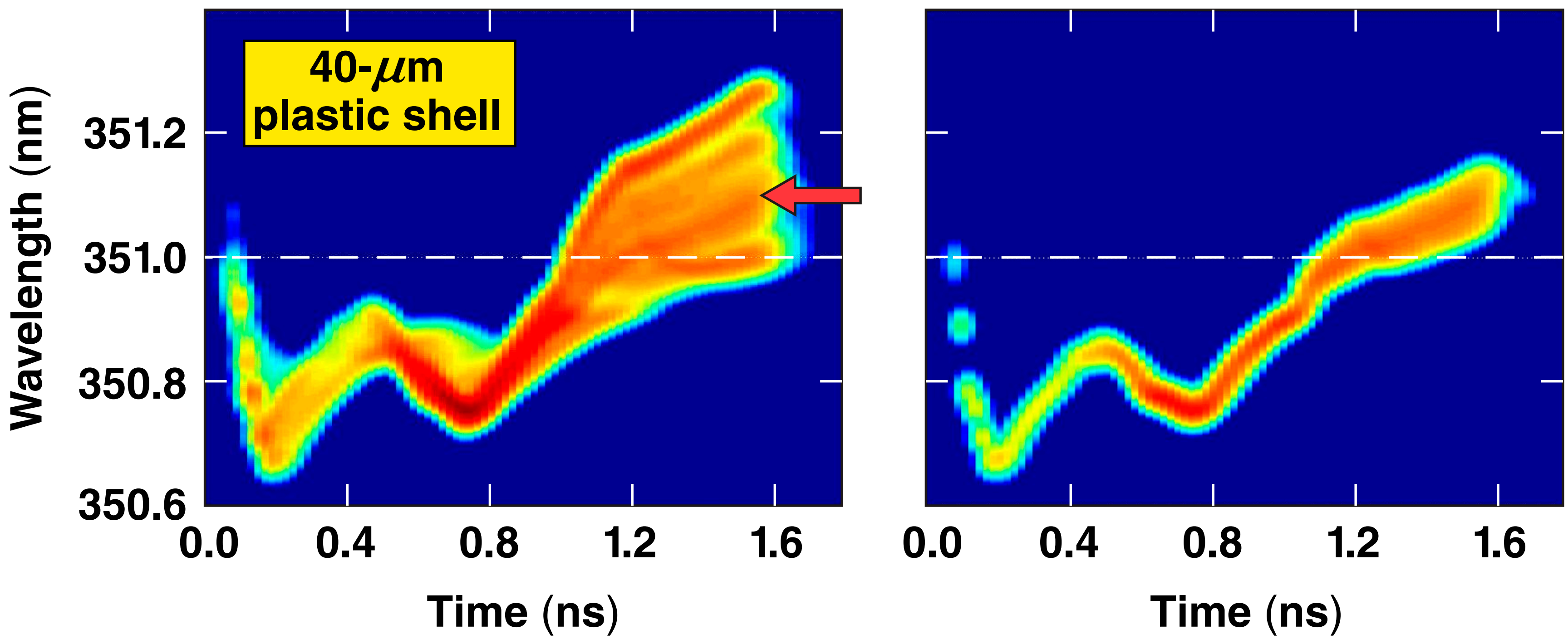
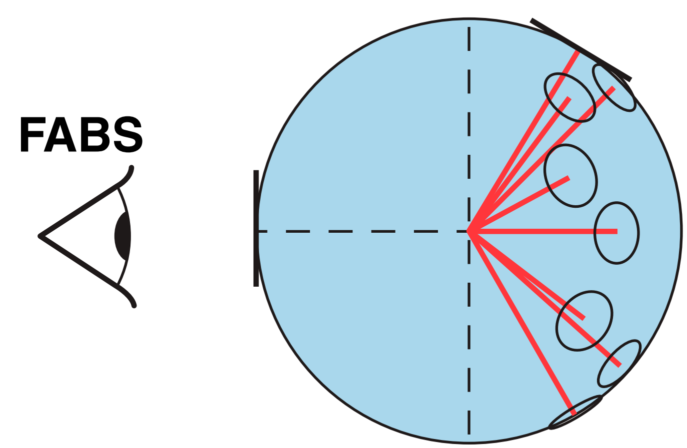


Beams closer
to the side of
the detector
show greater shifts



E16794a

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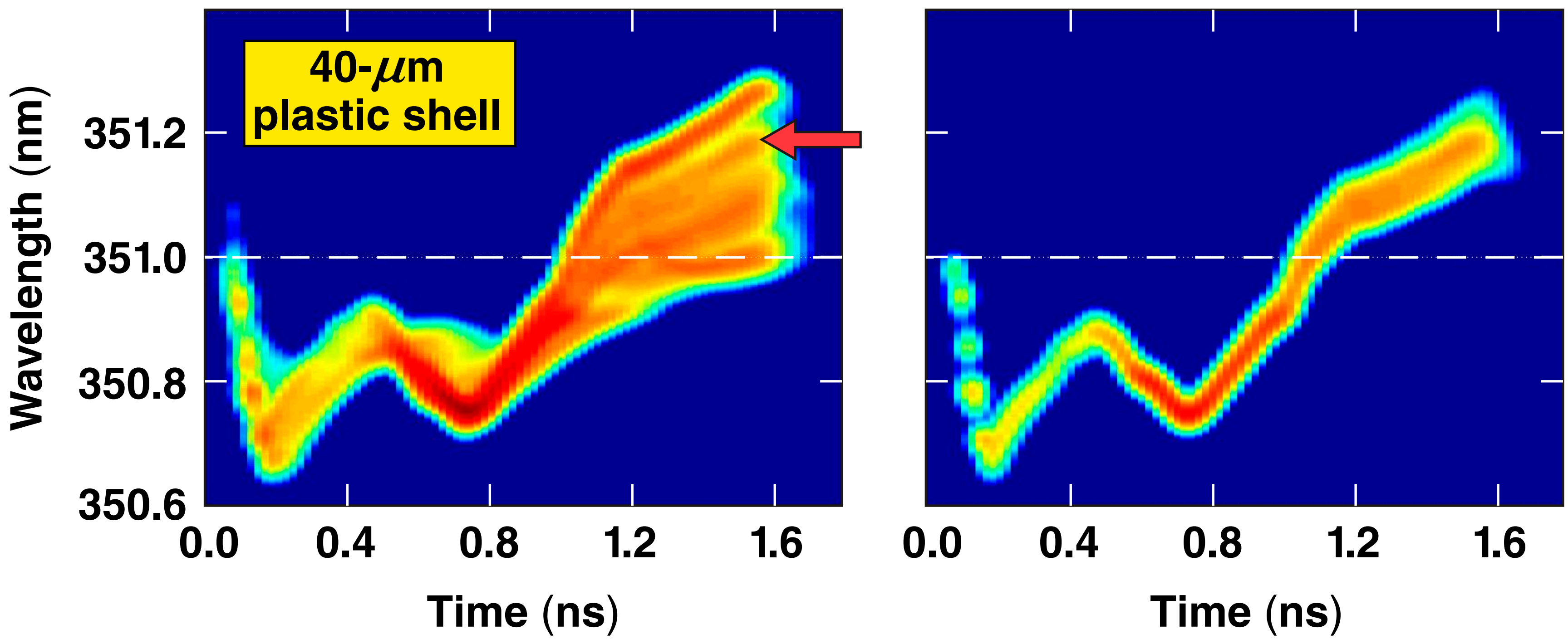
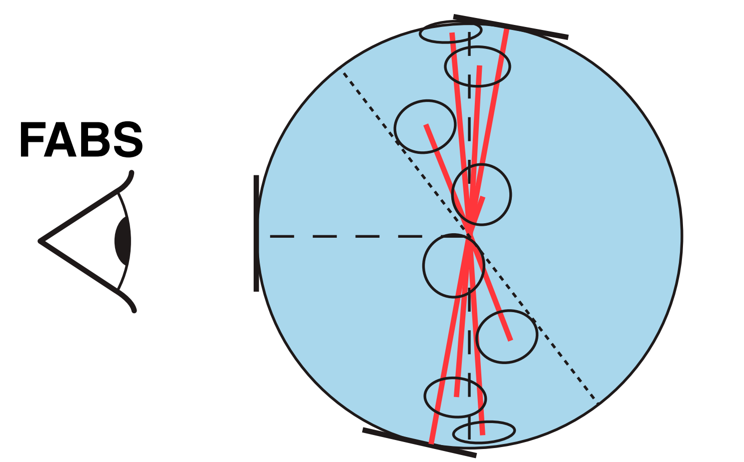


Beams closer to the side of the detector show greater shifts



E16794b

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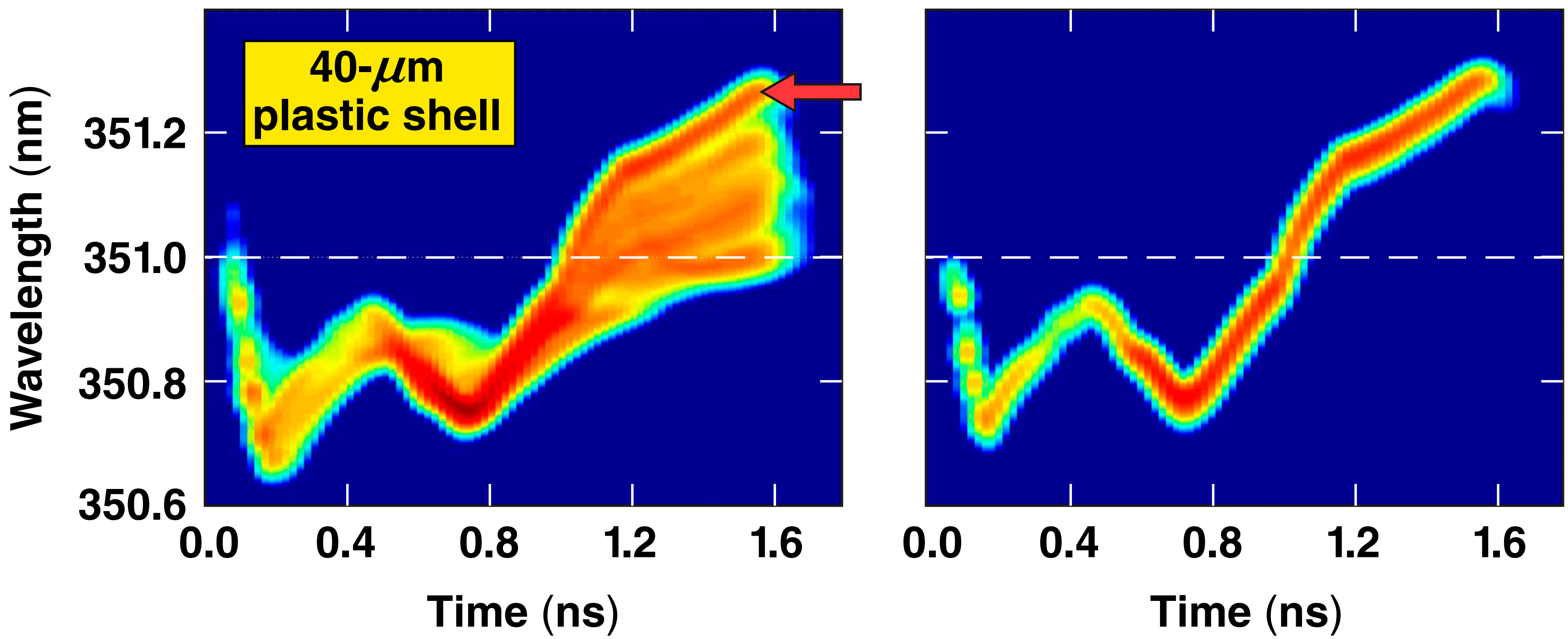
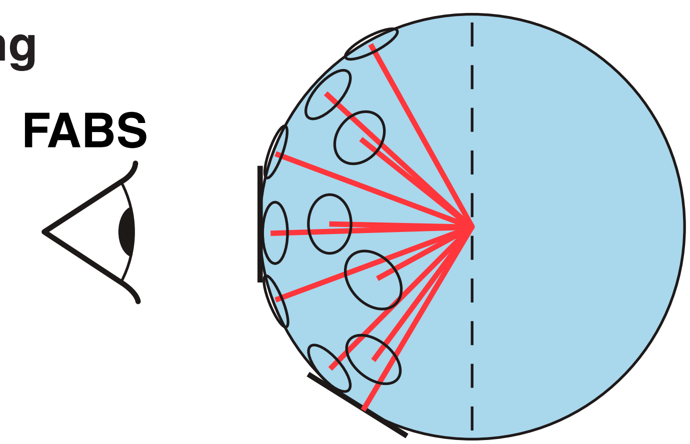


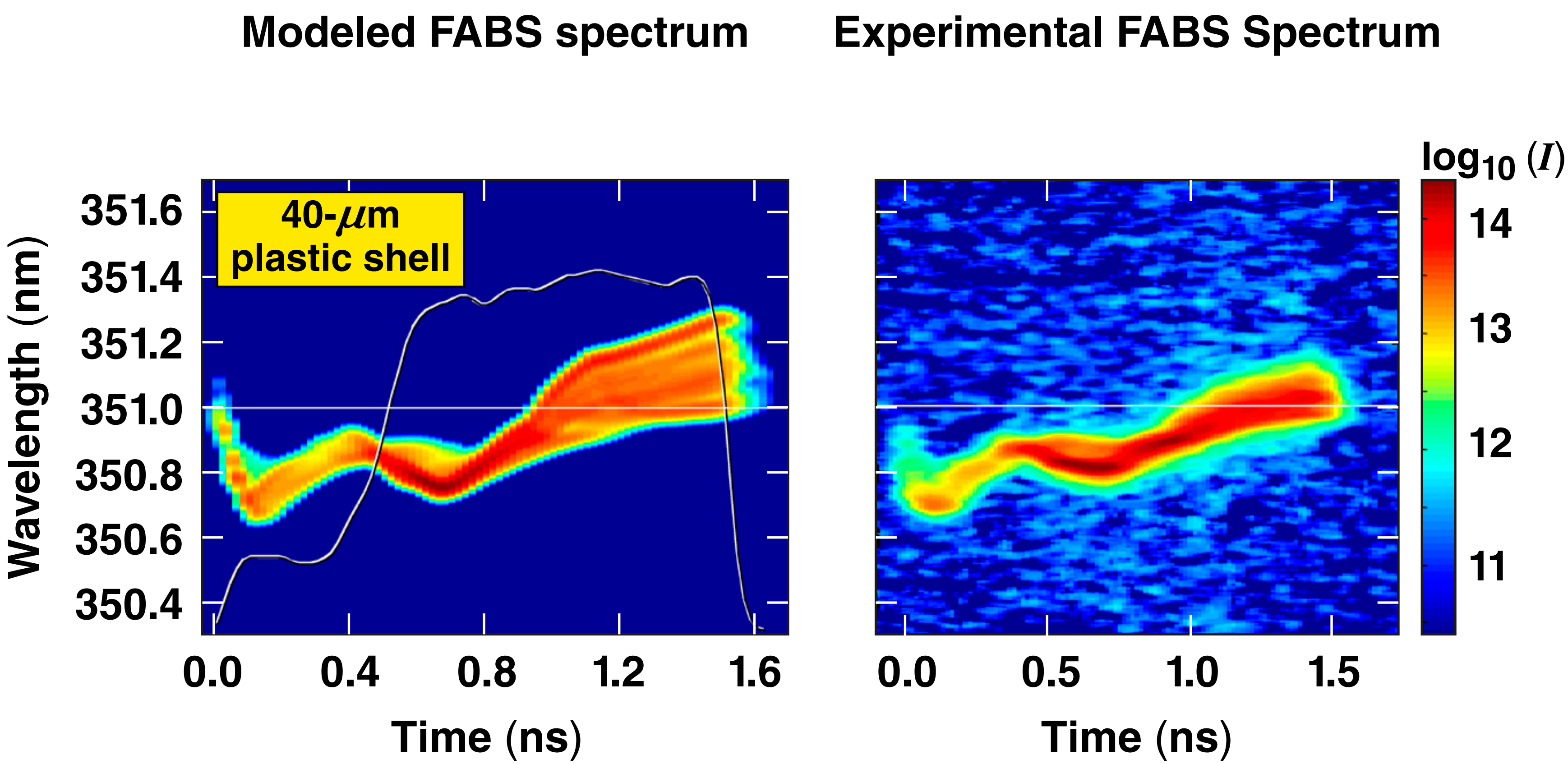
- The rays that form this finger have turning points closest to the critical surface

Beams on the side closest to the detector all show similar large shifts



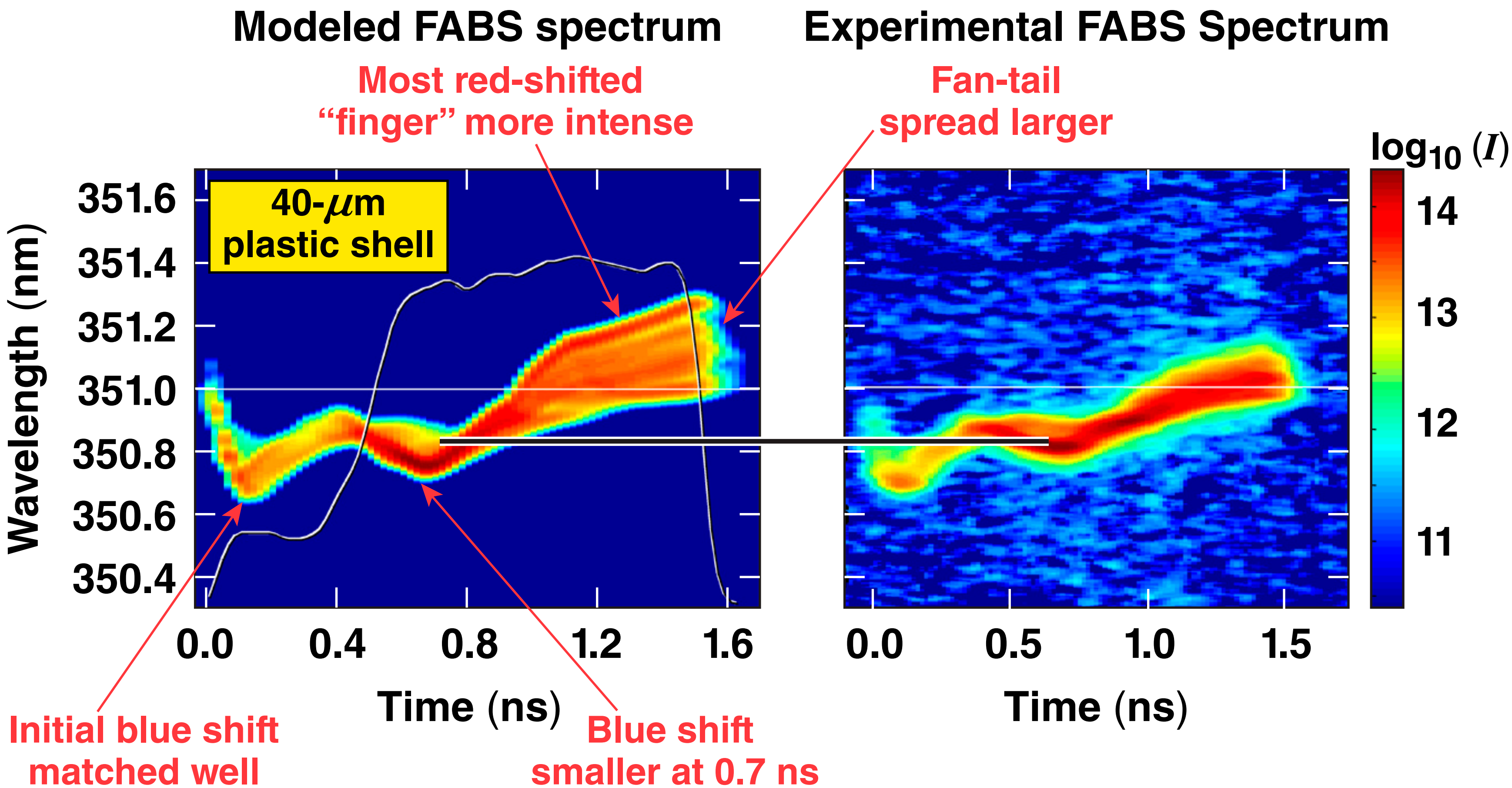
E16794c

Modeled spectra show all the basic structures visible in the experimental spectra but differ in some details



E16795

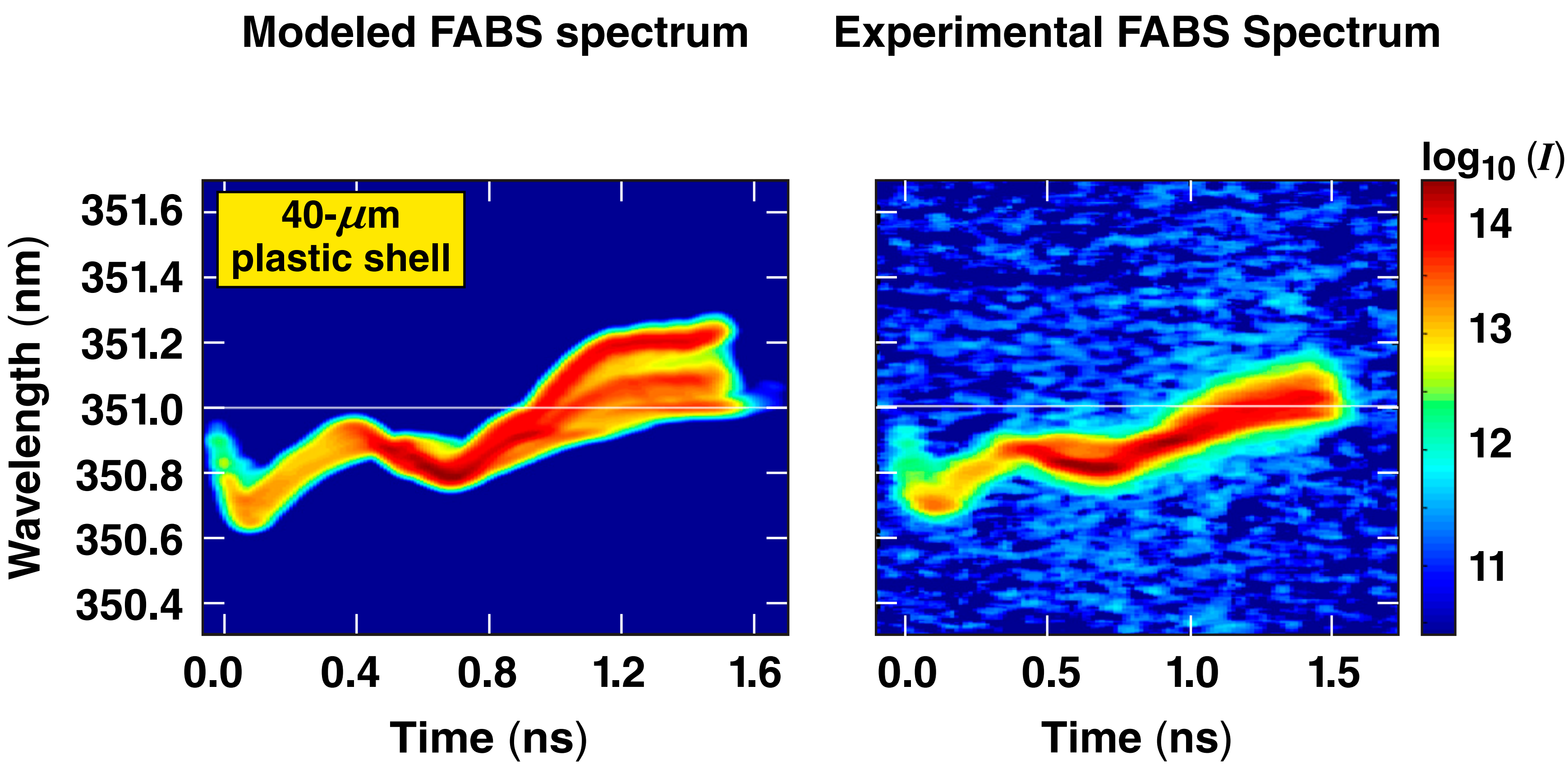
Modeled spectra show all the basic structures visible in the experimental spectra but differ in some details



The observed differences are consistent with less power absorbed into the target than predicted, but is 20% reduced absorption sufficient to reconcile differences?

E16795a

Modeling with a pulse scaled to give the experimentally observed absorption does not significantly improve the spectral shift predictions



Reduced absorption is likely concentrated in the beams best coupled to target ablation surface.

E16799

EM-seeded SBS cross-beam power transfer may be the cause of the "missing" absorption

UR LLE

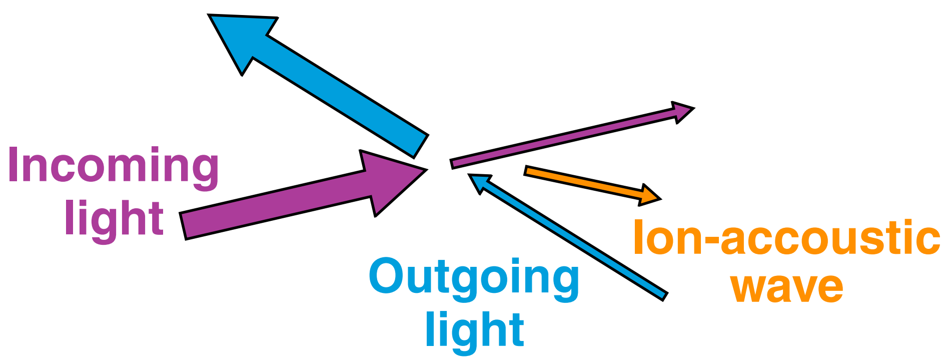
- Ion acoustic wave (IAW) transfers energy from a "pump" EM wave to a "seed" EM wave

$$\omega_{\text{pump}} = \omega_{\text{seed}} + \omega_{\text{IAW}}$$

$$\vec{k}_{\text{pump}} = \vec{k}_{\text{seed}} + \vec{k}_{\text{IAW}}$$

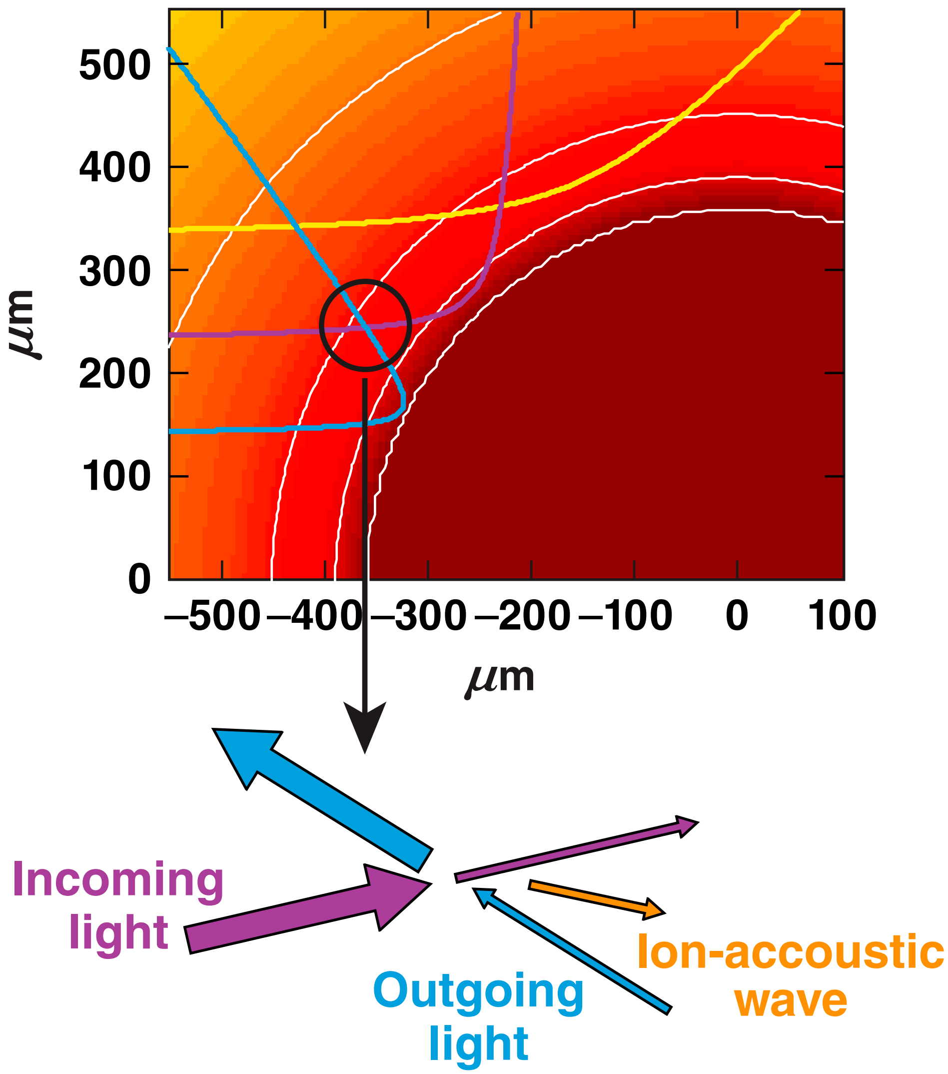
$$0 = \pm c_s |k| + \vec{v}_f \cdot \vec{k} - \omega$$

Observed shifts of the order of angstroms needed to satisfy this dispersion relation.



EM-seeded SBS cross-beam power transfer may be the cause of the "missing" absorption

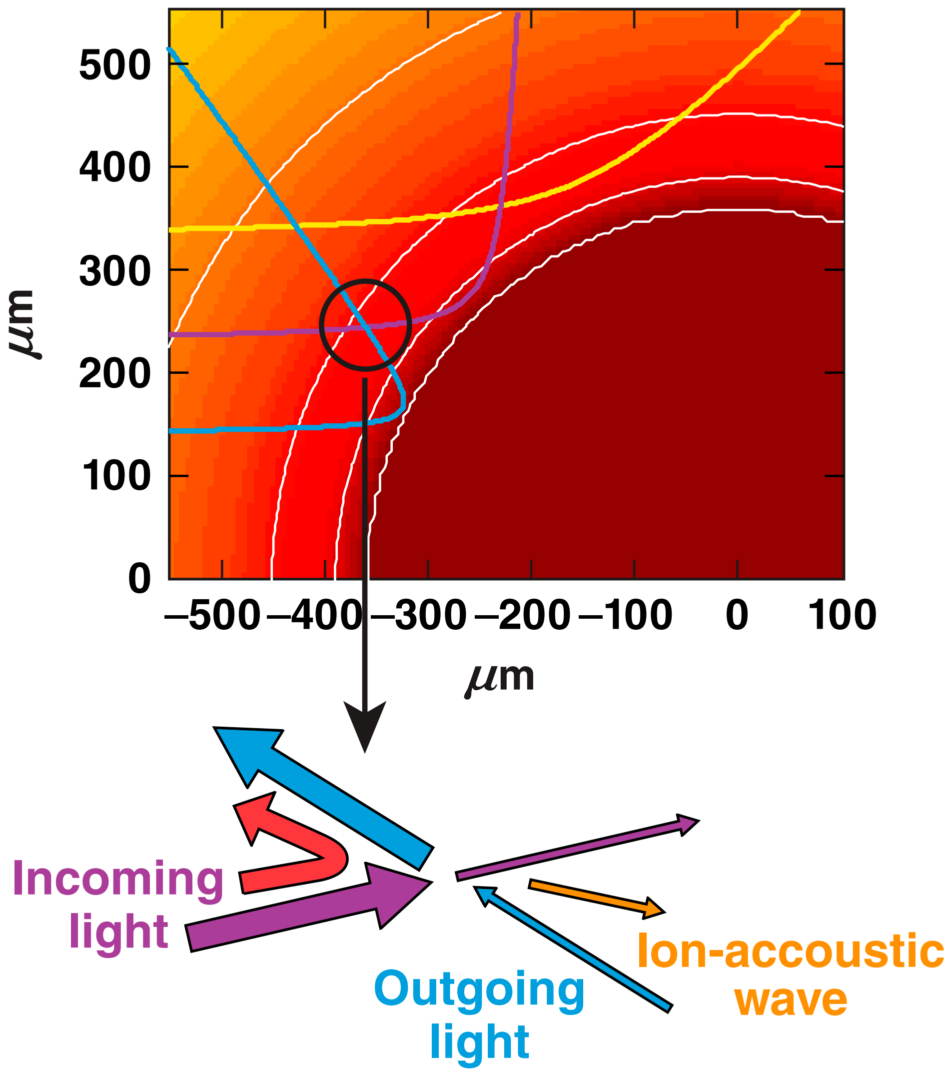
- Ion-acoustic wave (IAW) transfers energy from a "pump" EM wave to a "seed" EM wave
- Light entering the plasma can transfer energy to crossing light that is leaving the plasma



E16801

EM-seeded SBS cross-beam power transfer may be the cause of the "missing" absorption

- Ion-acoustic wave (IAW) transfers energy from a "pump" EM wave to a "seed" EM wave
- Light entering the plasma can transfer energy to crossing light that is leaving the plasma
- The result is that some laser pulse energy "bypasses" the absorption region, reducing the total absorbed power

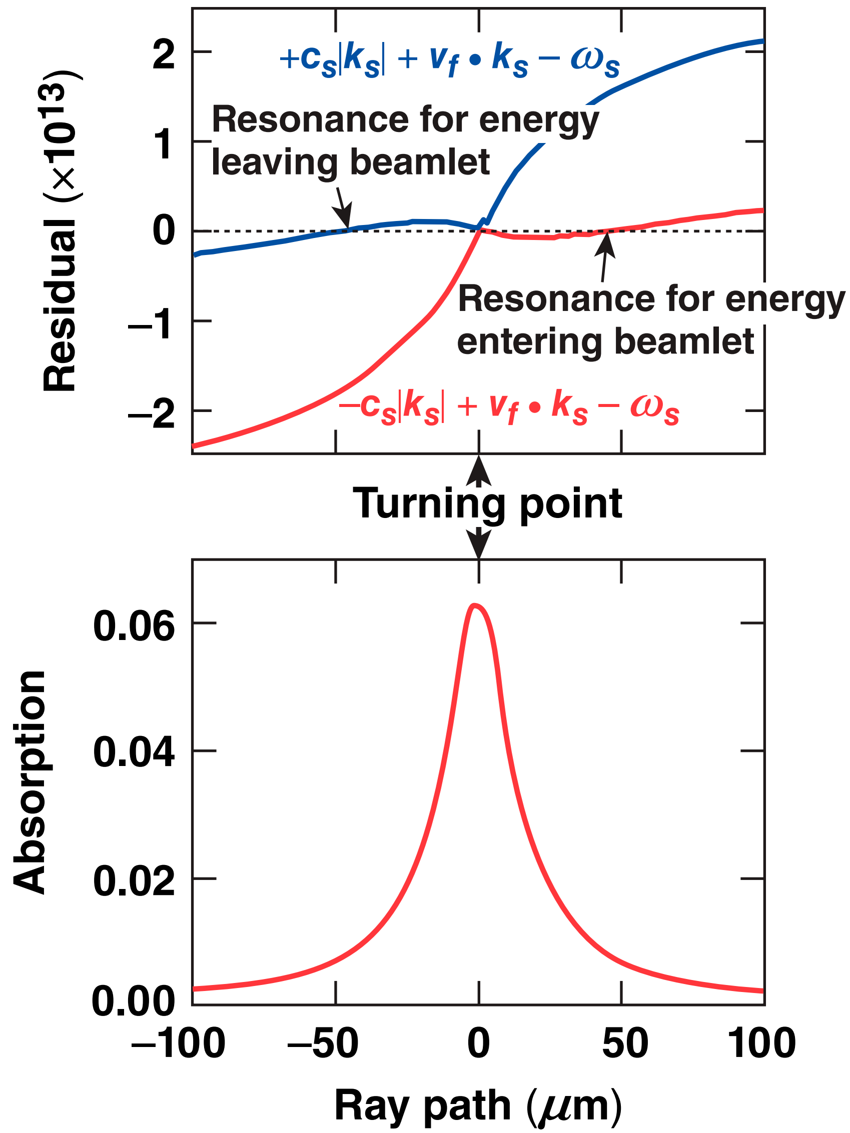


E16801a

Calculation of the resonance positions for EM-seeded SBS supports this speculation

UR LLE

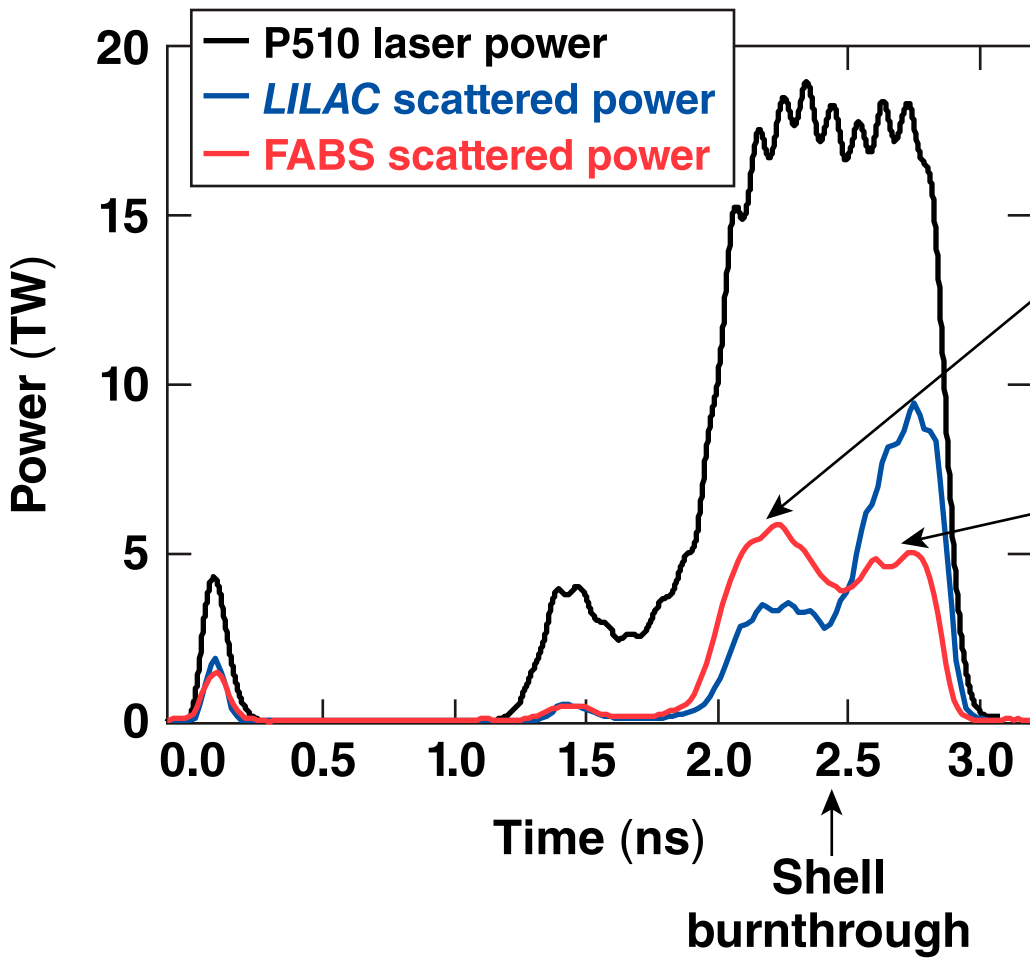
- Follow a single beamlet (ω_1, k_1) and calculate (ω_2, k_2) of the beamlets crossing its path at each point
- Zero crossings of the dispersion relation residual show where energy exchange can occur
- Energy can bypass the highest absorption region near the turning point



E16802

Burnthrough

After shell burnthrough, modeling overpredicts the light scattered from D_2 in cryogenic targets



More scattered light is seen experimentally than predicted (Reduced absorption already discussed)

Less scattered light is seen experimentally than predicted

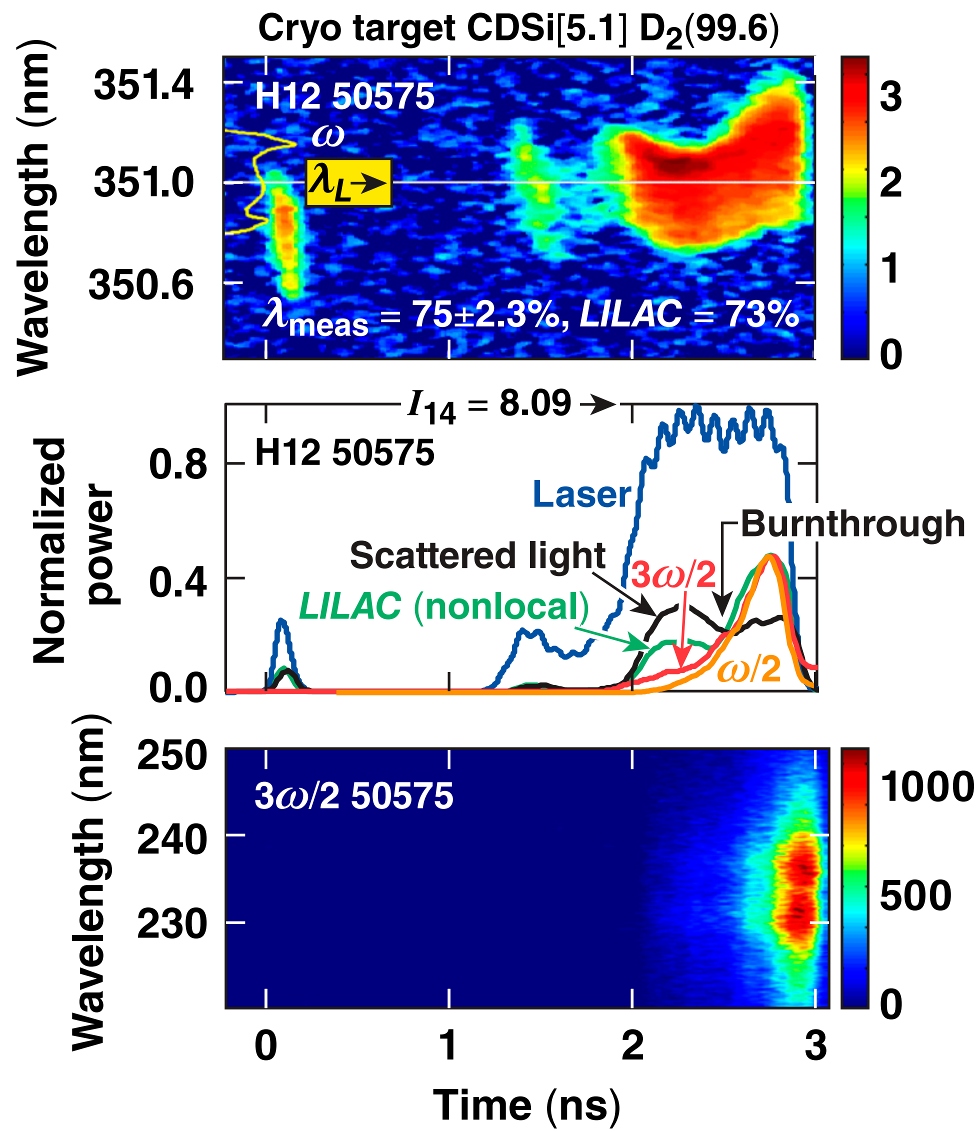
Either absorption underpredicted in D_2 OR power is lost through another pathway

There is no evidence that nonlinear behavior, which would affect absorption, changes significantly

E16804

The "missing" scattered light may be explained as energy lost through the two-plasmon decay (TPD)

- There is a sudden increase in emission at the $3\omega/2$ and $\omega/2$ at burnthrough.
- TPD is believed responsible for this emission.
- Absorption after burnthrough may still be anomalously low by ~20%.



E16807

Summary/Conclusions

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