Comparison of Implosion Velocities for Be, C, and CH Ablators Measured in Direct-Drive Implosions

D. T. Michel, V. N. Goncharov, I. V. Igumenshchev, P. B. Radha, S. X. Hu, and D. H. Froula

University of Rochester, Laboratory for Laser Energetics

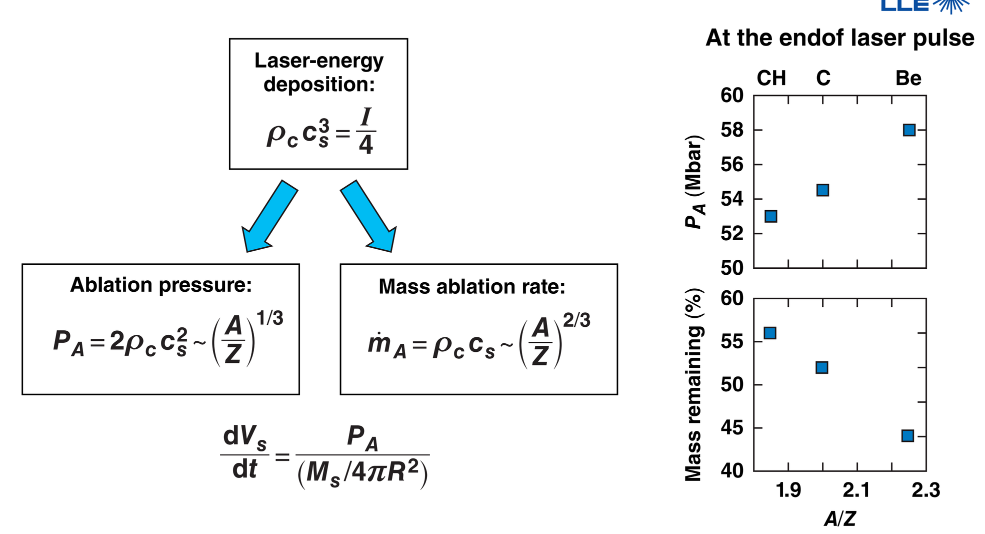
Summary

Increasing the ratio of the atomic mass to the atomic number (A/Z) of the ablator increases the velocity of direct-drive implosions

- Accurate measurements of the trajectory of imploding shells are made for different ablators
- The hydrodynamic efficiency is calculated to increase with A/Z
- A 20% increase in shell velocity was measured for Be ablators compared to C and CH ablators when maintaining a constant shell mass
- *LILAC* simulations that include CBET and nonlocal heat transport accurately reproduce the measurements

E22146

A simple model shows that increasing A/Z increases the mass ablation rate and the ablation pressure*



Increasing A/Z by changing the ablator from CH to Be is predicted to increase the implosion velocity.

E22148

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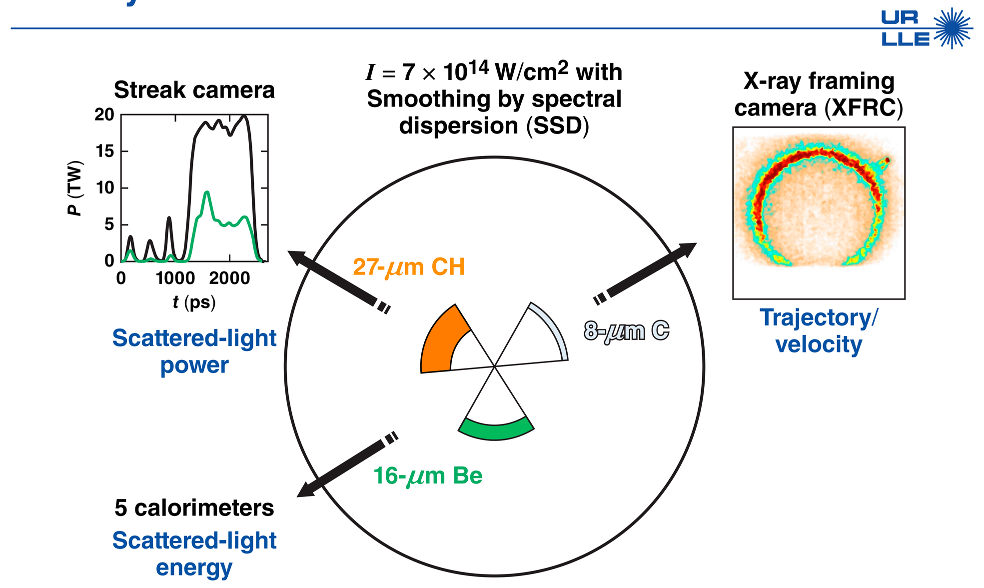

To determine the effect of A/Z on the target performance, the velocity must be accurately measured.

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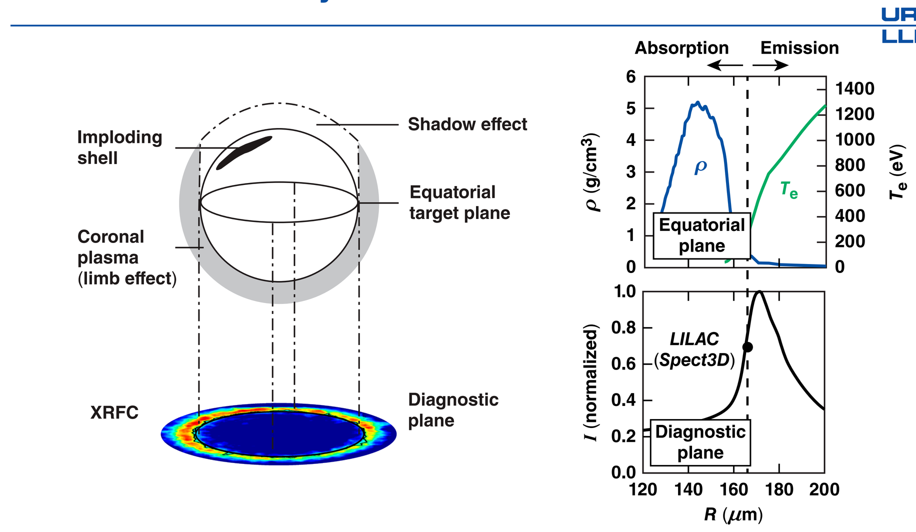
The steep gradient in the x-ray emission is created by the combination of the limb effect and the absorption of the coronal x-rays in the cold dense shell

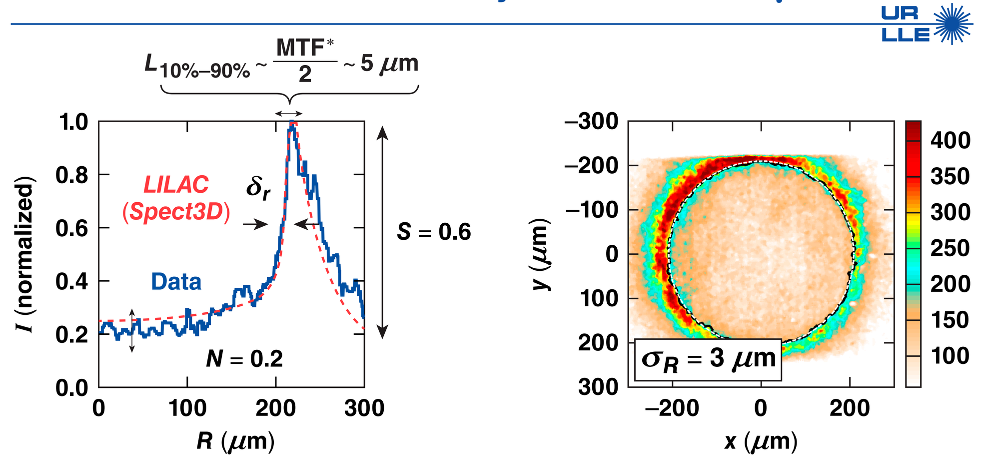


The diagnostic analysis has a very weak dependence on the modeling of the plasma conditions.

E22150

D. T. Michel et al., Rev. Sci. Instrum. 83, 10E530 (2012).

The position of the gradient in the XRFC images is measured with an accuracy better than 0.5 μm



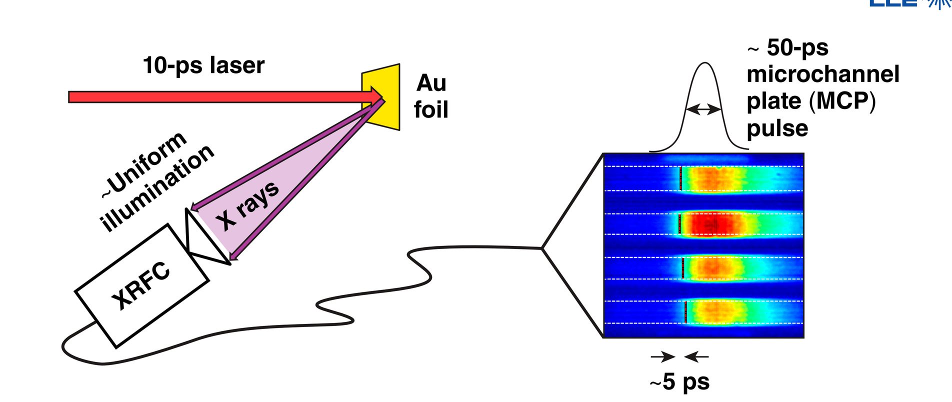
$\delta R = \left(\frac{MTF}{2}\right)\left(\frac{1}{S/N}\right) \sim 2$ μm $\quad R_{av} = \frac{1}{N_\theta}\sum_\theta R(\theta) = 195$ μm

$\delta R_{av} = \frac{\sigma_R}{\sqrt{N_\theta^{**}}} \sim \frac{\delta R}{10} < 0.5$ μm $\quad {}^{**}N_\theta = \frac{2\pi R}{MTF}$

E22151

*Modulation transfer function

The XRFC interstrip timing is known to within ~5 ps, allowing for a 4% accuracy in the 200-ps-averaged shell velocity

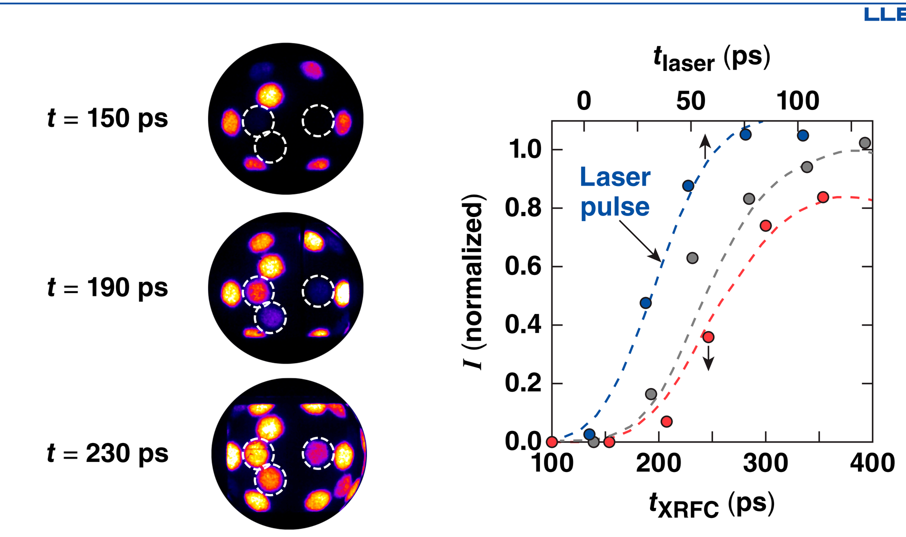


$\frac{\delta v}{v} = \frac{\delta(\Delta R)}{\Delta R} + \frac{\delta(\Delta t)}{\Delta t} = \frac{0.5\ \mu m}{40\ \mu m} + \frac{5\ ps}{200\ ps} \sim 4\%^{**}$

E22152

*Microchannel plate
**A 200 km/s shell velocity is assumed

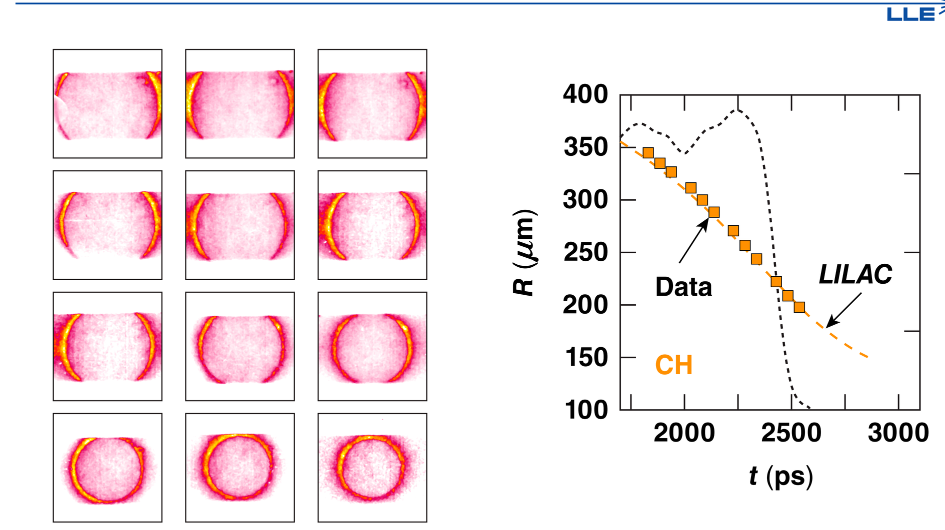
The absolute timing requires cross calibrating the XRFC with the pulse shape of the laser



The absolute timing has been measured on multiple absolute timing shots and an accuracy of ~ ±30 ps was inferred.

E22153

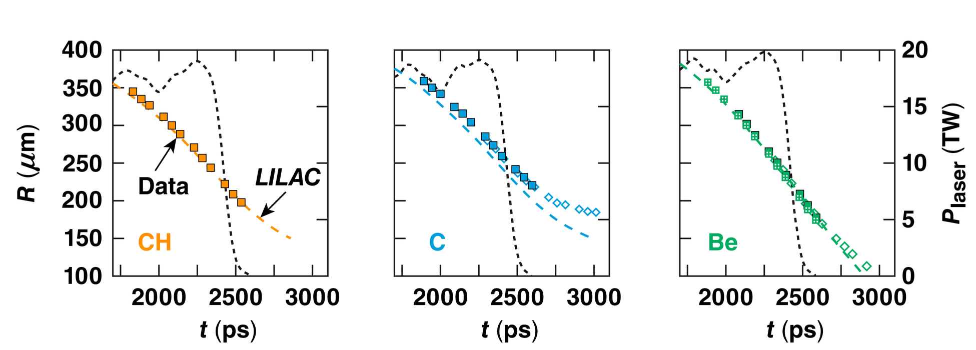
The XRFC was used to measure the trajectory of the imploding shell



To determine the effect of A/Z on the target performance, the velocity must accurately measured.

E22230

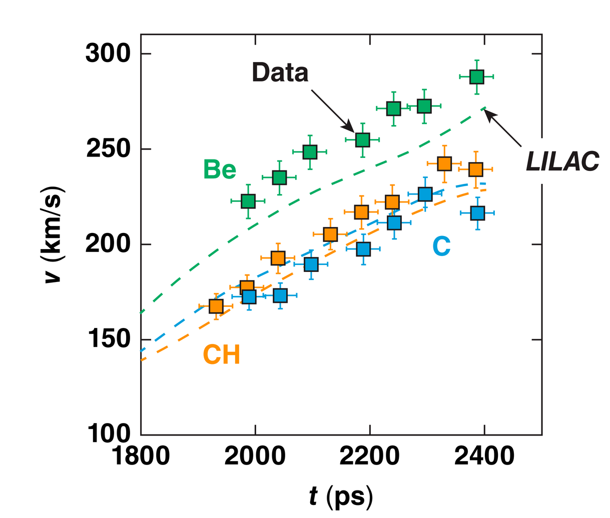
Accurate measurements of the shell trajectories were obtained for the three ablators



The good match between simulation and experiment indicate that transfer of the absorbed laser energy to the motion of the shell is well modeled.

E22155

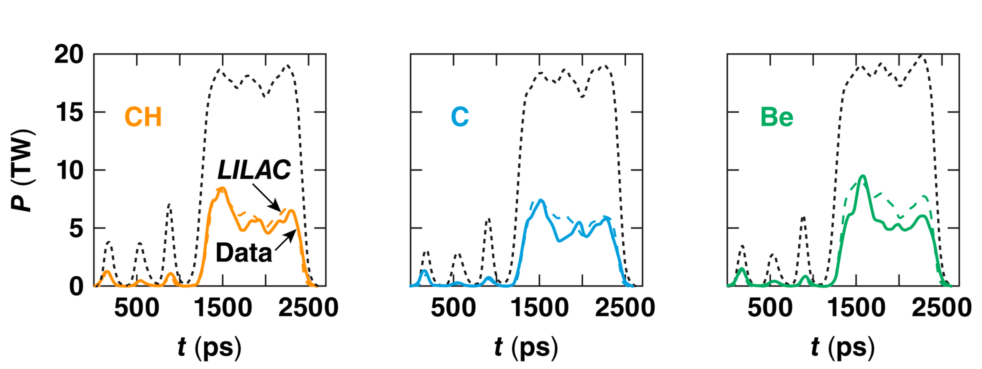
A 20% increase in the velocity of the shell is observed for Be compared to CH and C ablators



The increase in A/Z results in the increased shell acceleration could be caused by increased absorption or hydroefficiency.

E22149

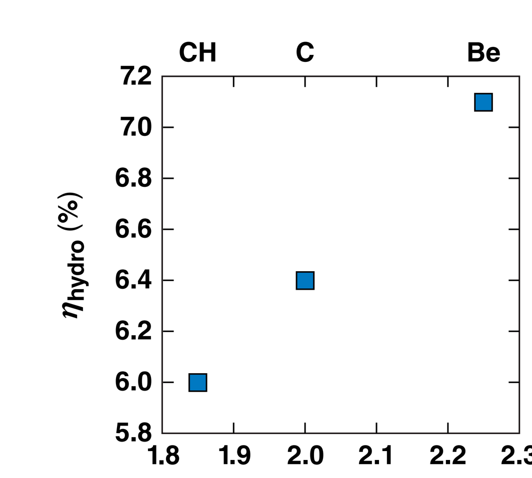
The absorption was the same for all three materials, suggesting increased hydroefficiency



Simulations that include CBET and nonlocal heat flux reproduce the amount of laser energy coupled to the plasma.

E22154

The hydrodynamic modeling shows that the increase in A/Z results in an increase in hydrodynamic efficiency



Simulations show that the hydrodynamic efficiency is increased by 18% in Be and 7% in C.

E22156

Summary

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A simple model shows that increasing *A*/*Z* increases the mass ablation rate and the ablation pressure*

Laser-energy deposition:

$$\rho_c c_s^3 = \frac{I}{4}$$

Ablation pressure:

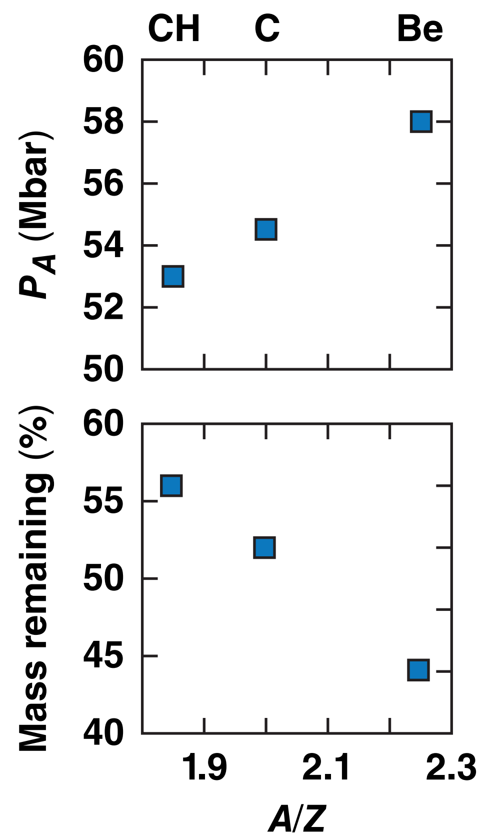
$$P_A = 2\rho_c c_s^2 \sim \left(\frac{A}{Z}\right)^{1/3}$$

Mass ablation rate:

$$\dot{m}_A = \rho_c c_s \sim \left(\frac{A}{Z}\right)^{2/3}$$

$$\frac{dV_s}{dt} = \frac{P_A}{(M_s/4\pi R^2)}$$

At the endof laser pulse



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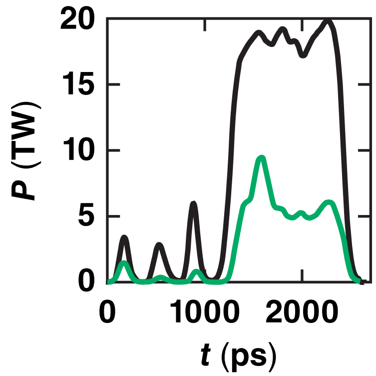
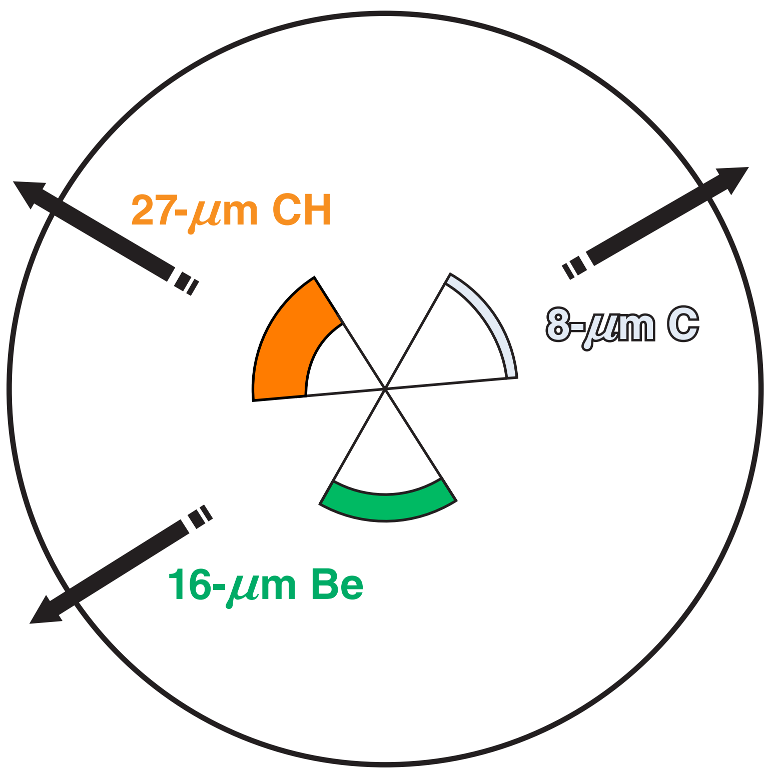
$I = 7 \times 10^{14}$ W/cm^2 with Smoothing by spectral dispersion (SSD)

Streak camera



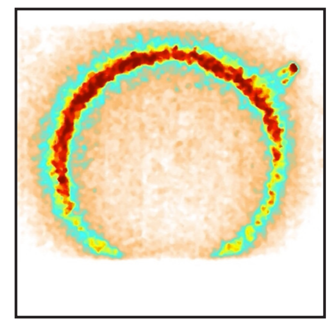
Scattered-light power



5 calorimeters

Scattered-light energy

X-ray framing camera (XFRC)



Trajectory/ velocity

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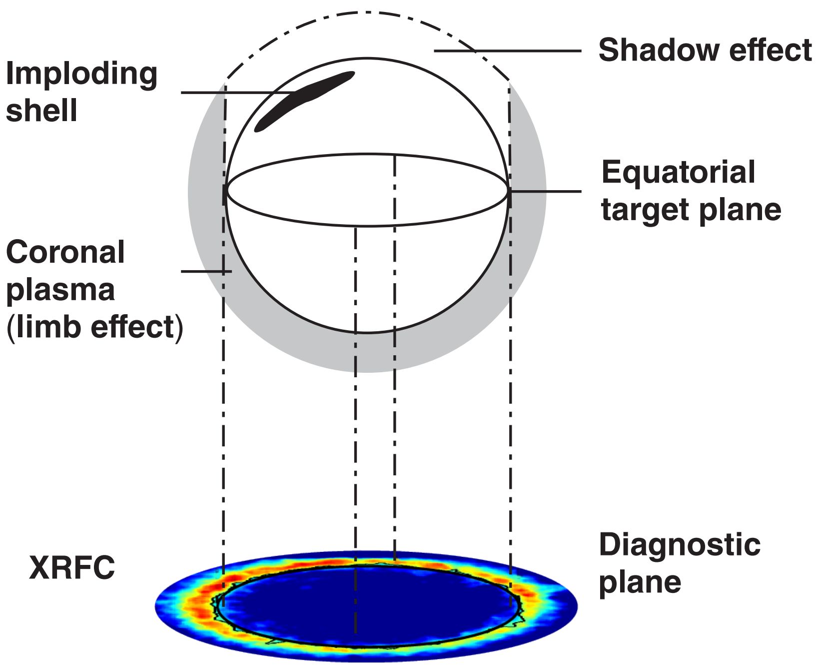

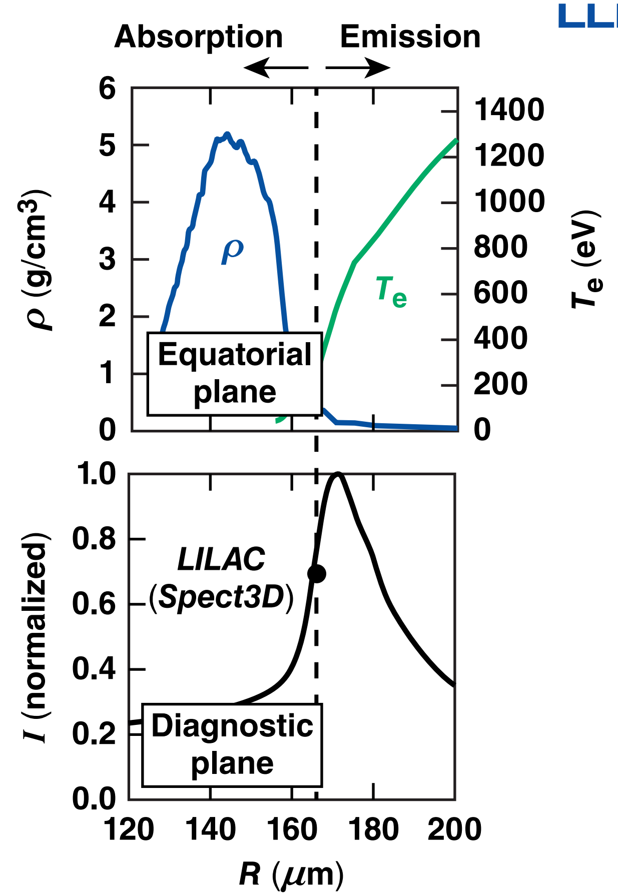

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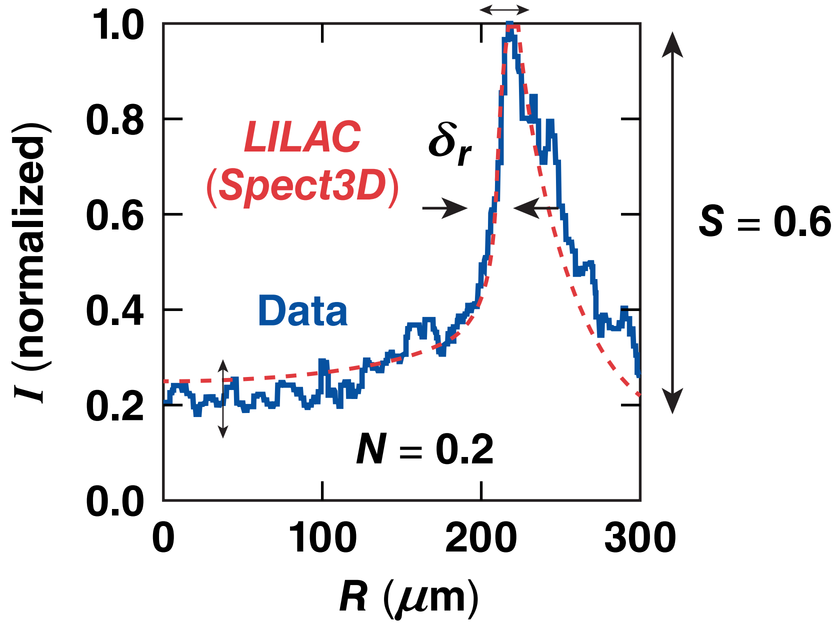

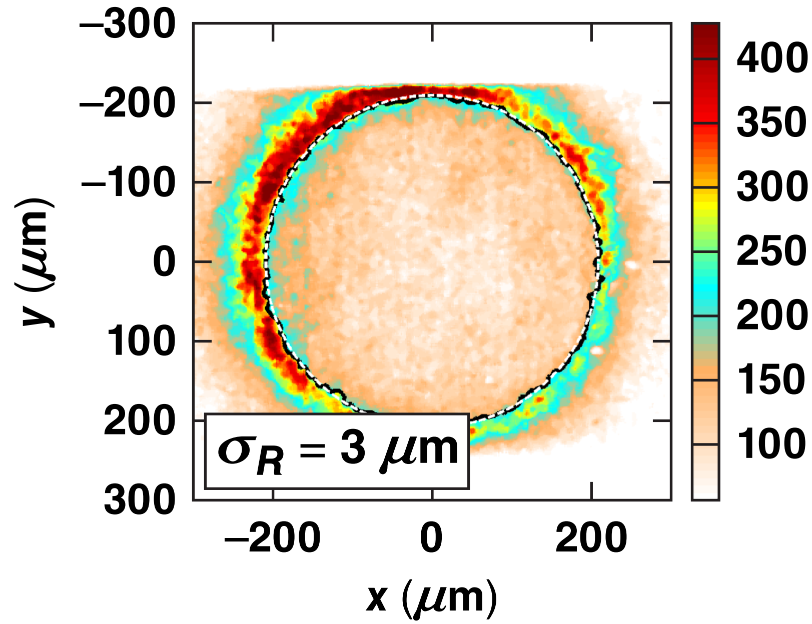

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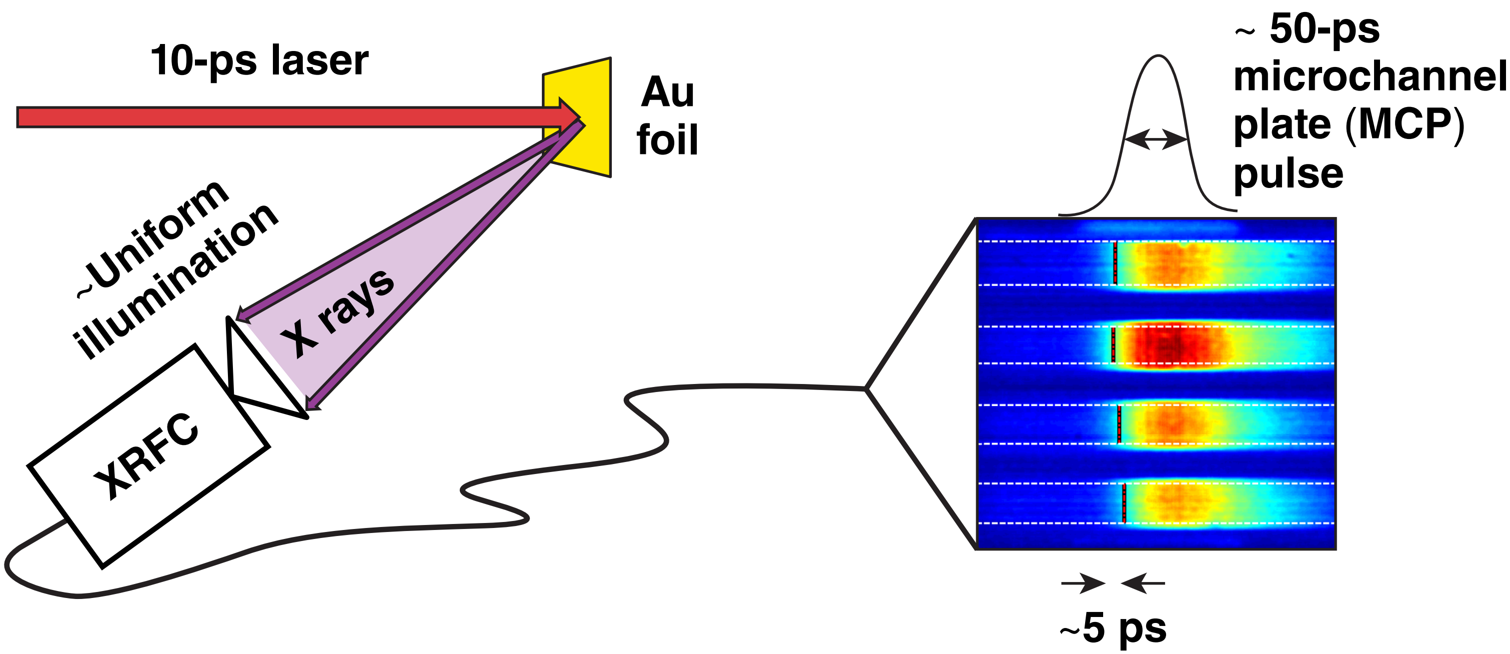

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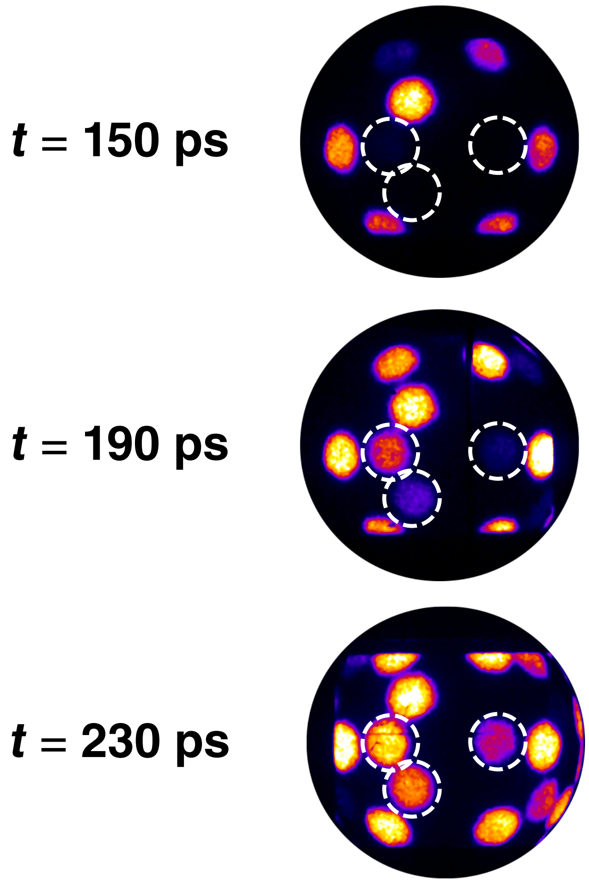

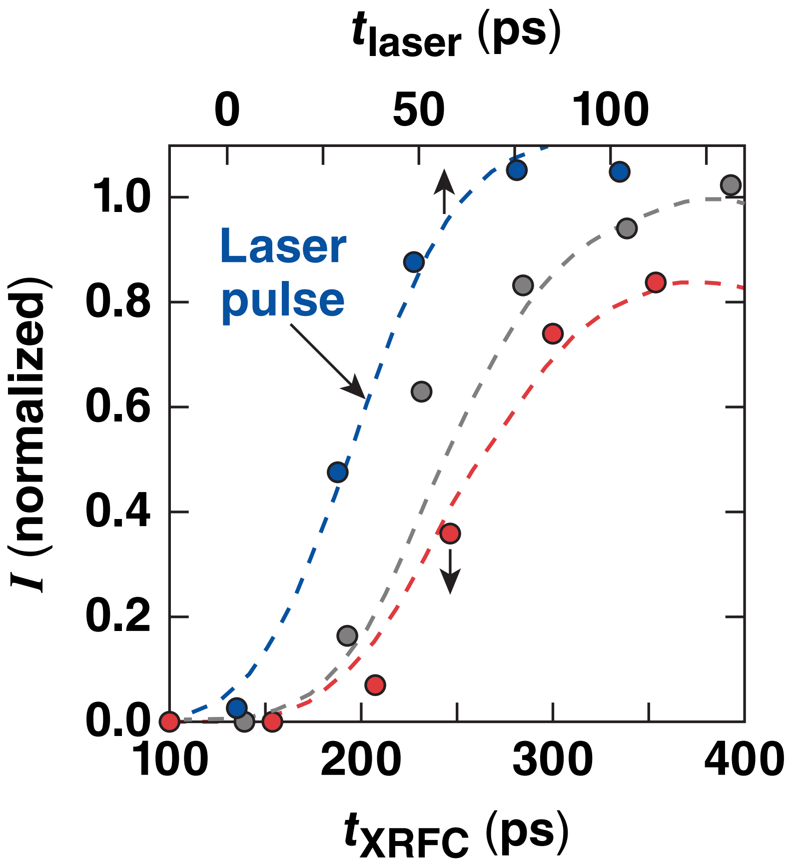

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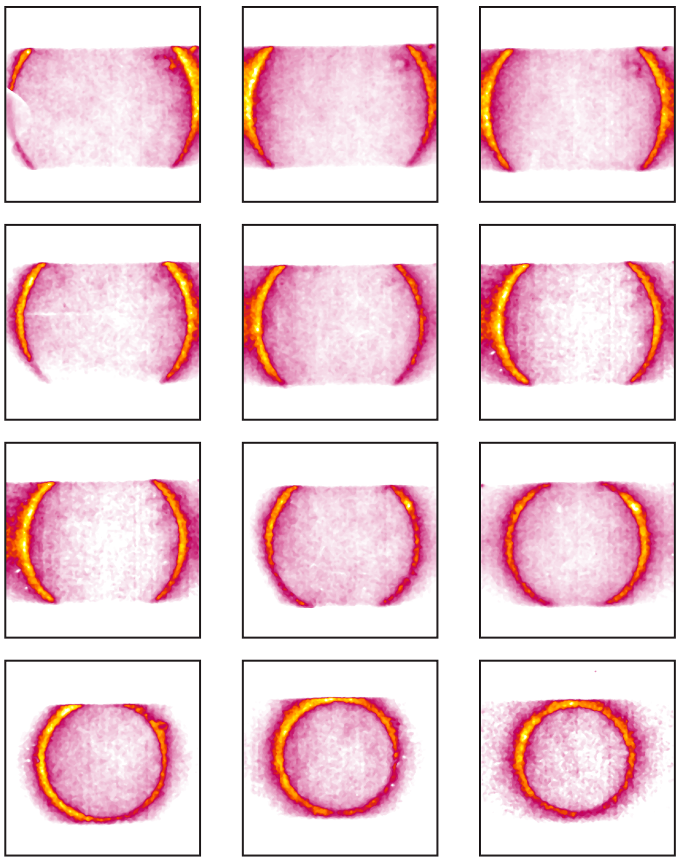

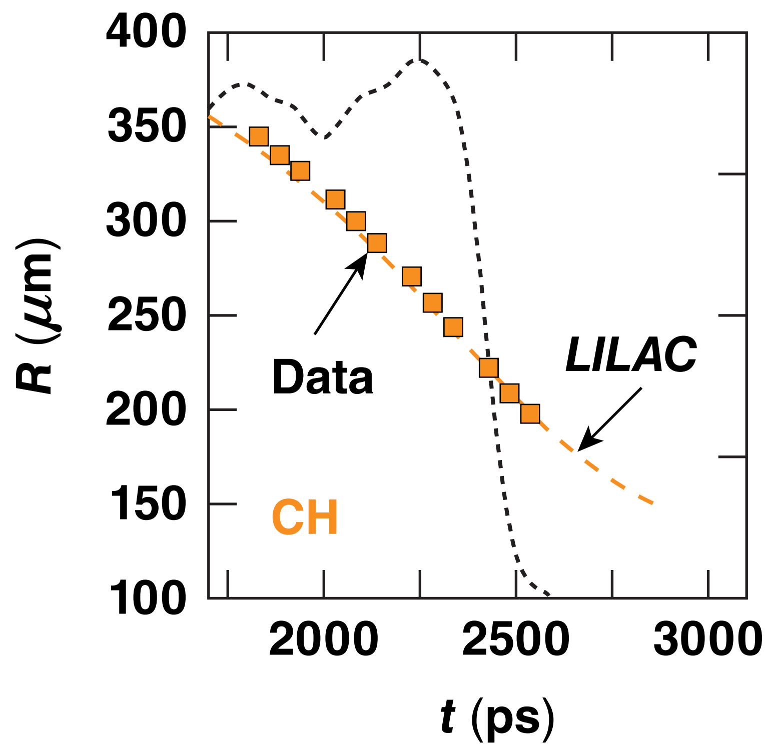

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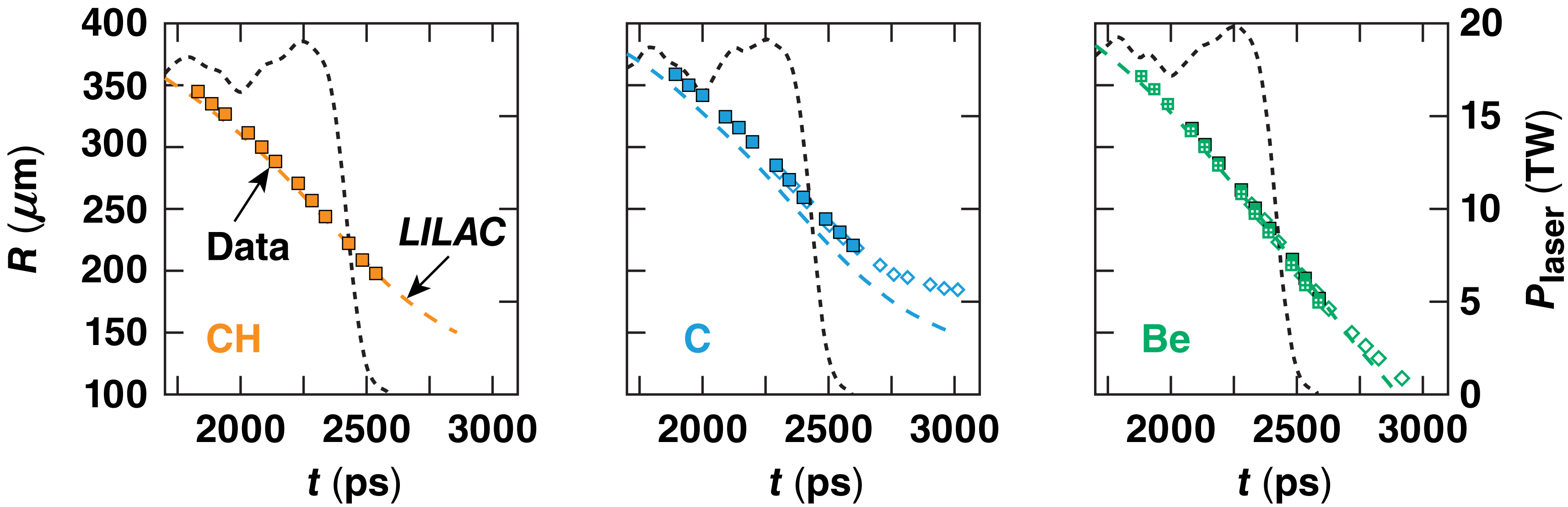

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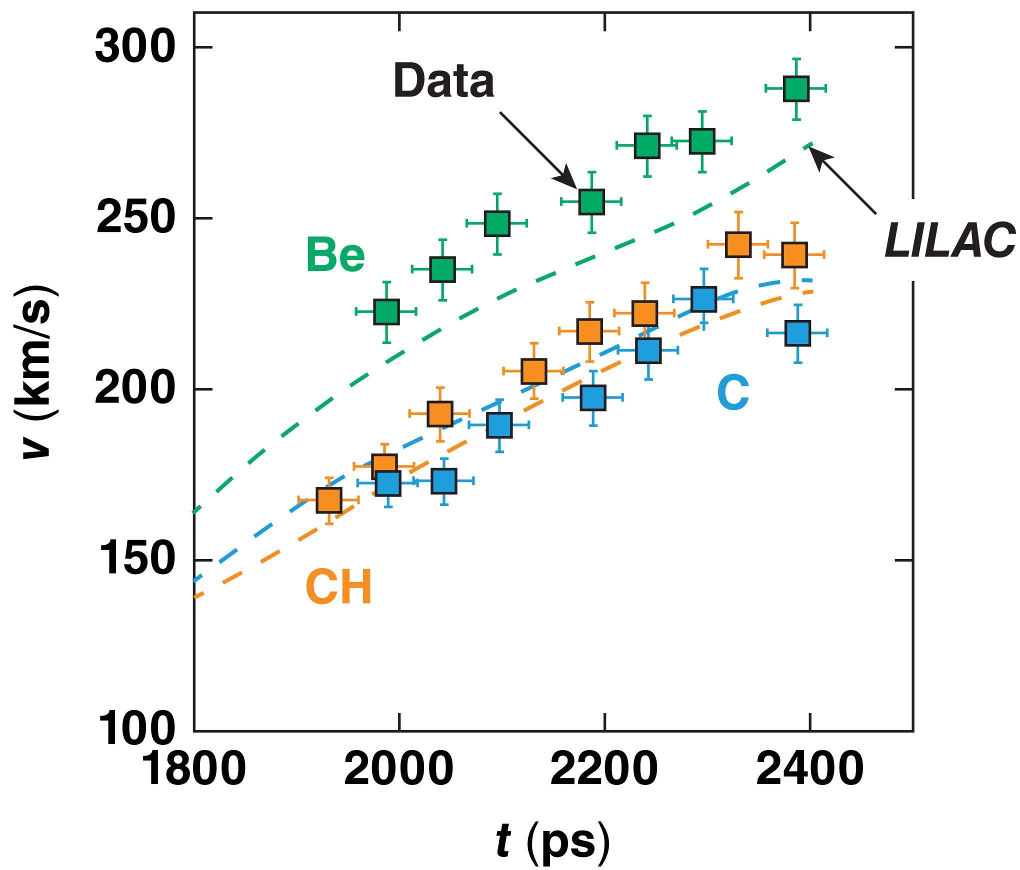

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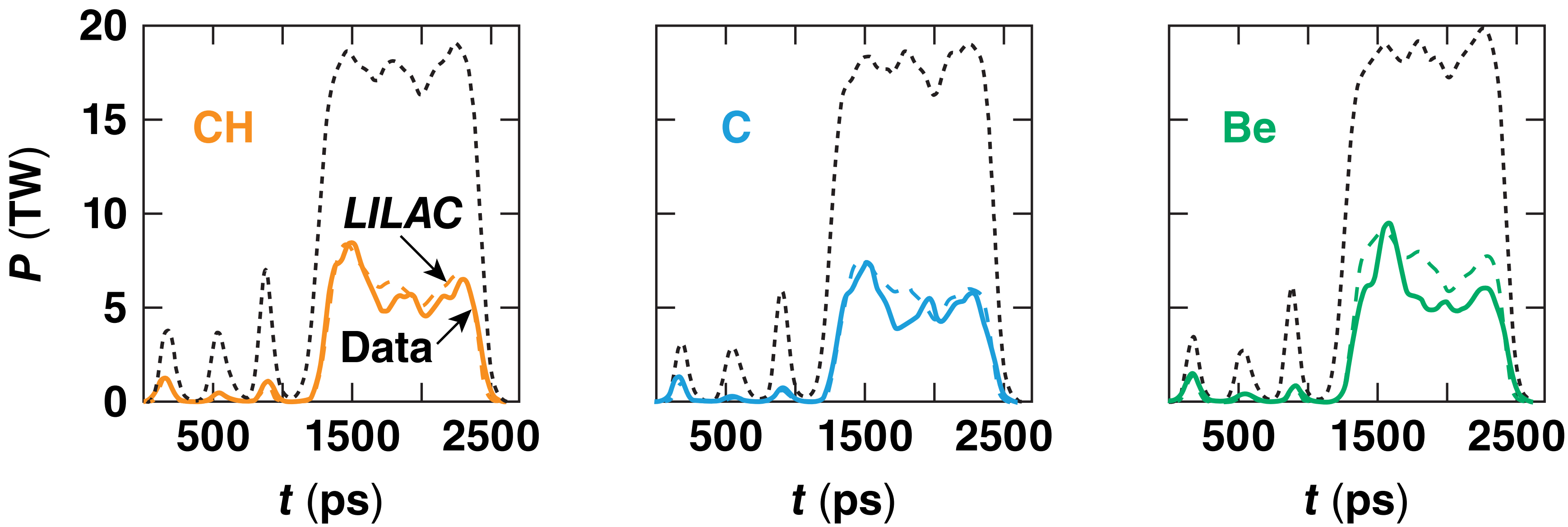

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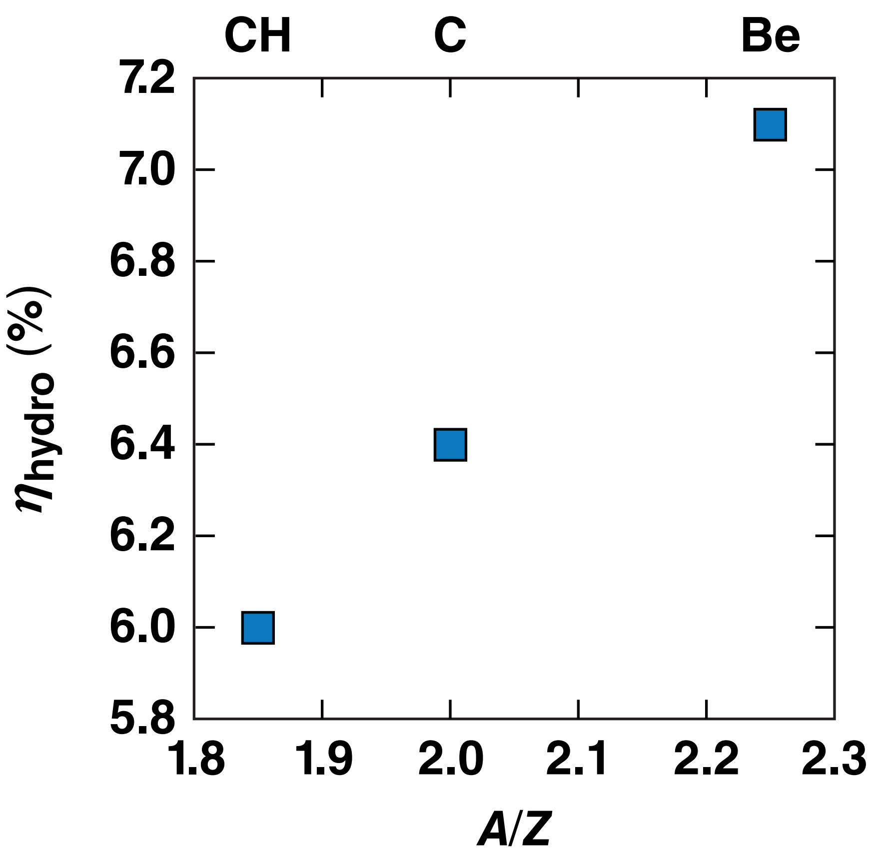

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