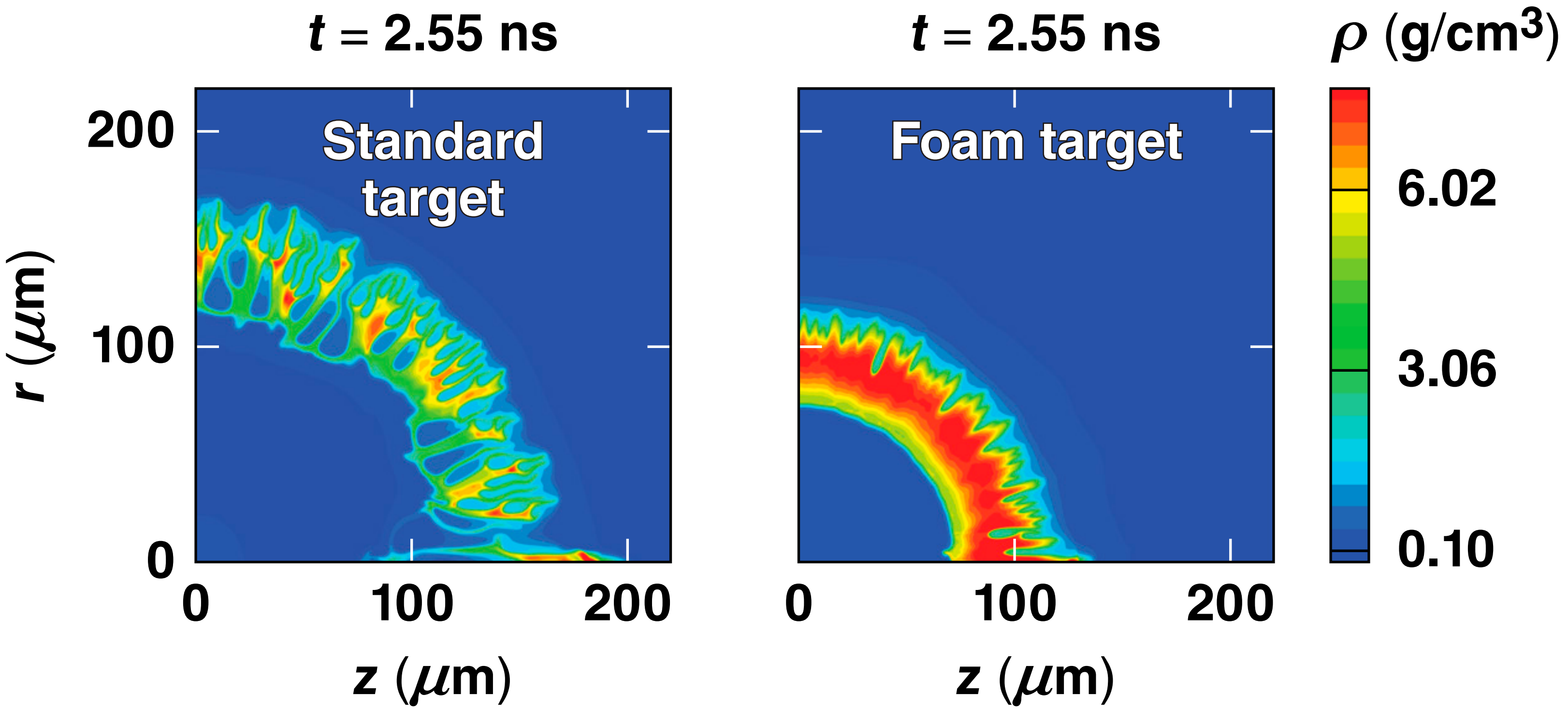
Mitigating Laser-Imprint Effects on Direct-Drive Implosions on OMEGA with Low-Density Foam Layers



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Summary

DRACO simulations* have indicated that a low-density foam layer can mitigate laser imprints in direct-drive inertial confinement fusion (ICF)

- A thin foam layer of above critical density has been proposed to mitigate laser-imprint effects in direct-drive implosions on OMEGA
- Two-dimensional *DRACO* simulations, with the state-of-the-art physics models, have been performed to examine this idea
- The simulation results indicate that a 40-μm-thick foam layer with density of $\rho \approx$ 40 mg/cm^3 can increase the neutron yield by a factor of 4 to 8 and recover the 1-D compression ρR

Planar experiments using a thin foam layer to mitigate laser imprints are currently being pursued on OMEGA.

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*S. X. Hu *et al.*, "Mitigating Laser-Imprint Effects in Direct-Drive Inertial-Confinement Fusion Implosions with an Above-Critical-Density Foam Layer," submitted to Physics of Plasmas.

Collaborators

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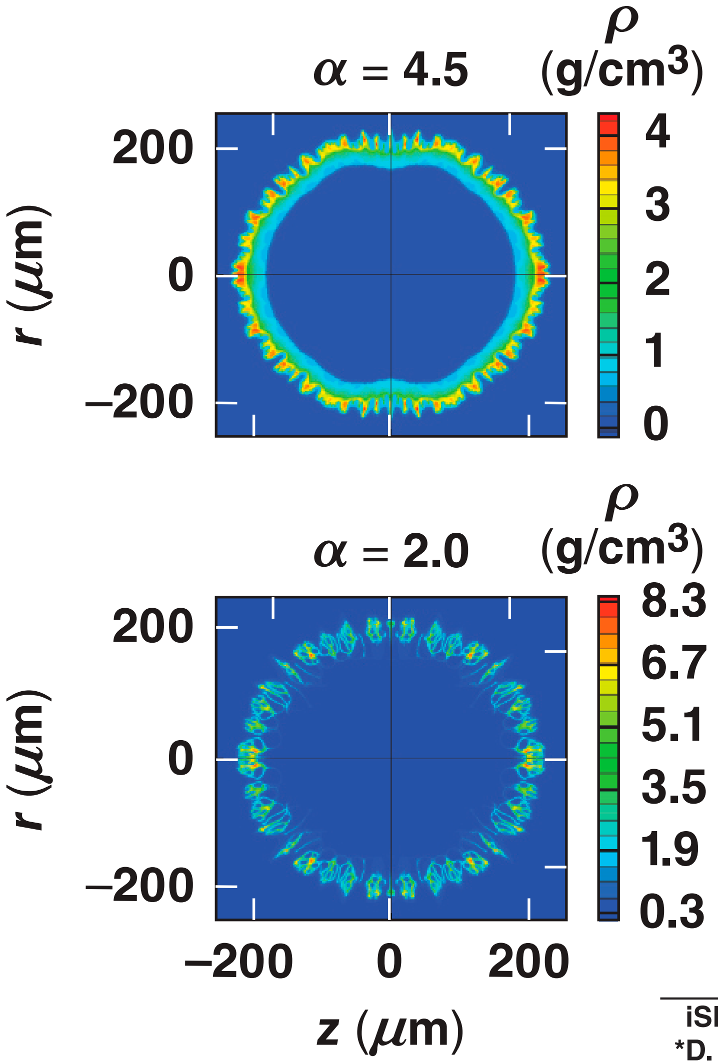
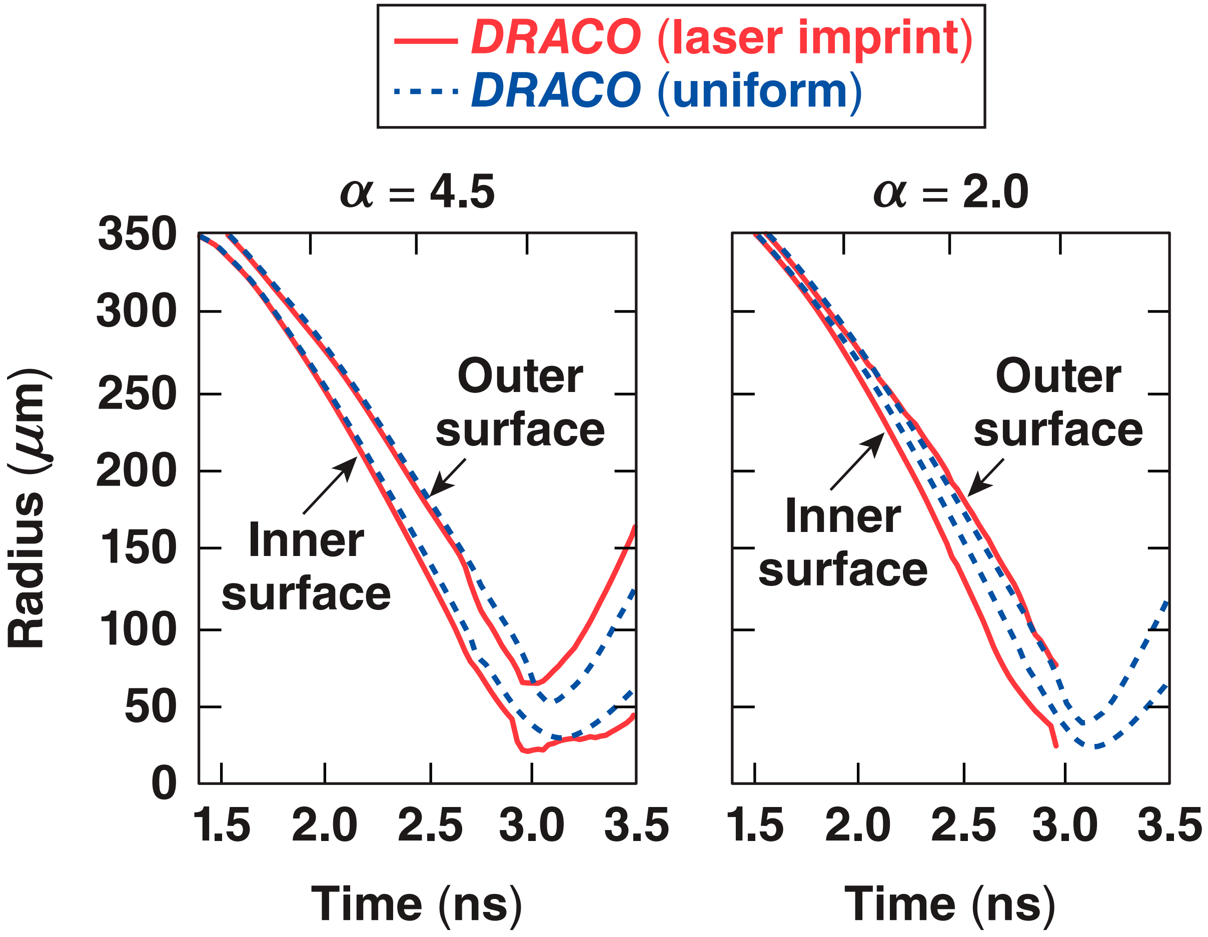
DRACO simulations with new physics models (iSNB,* CBET,** FPEOS†) predicted significant distortions for low-α implosions caused by laser imprint (up to mode $\ell = 200$)





TC12900a

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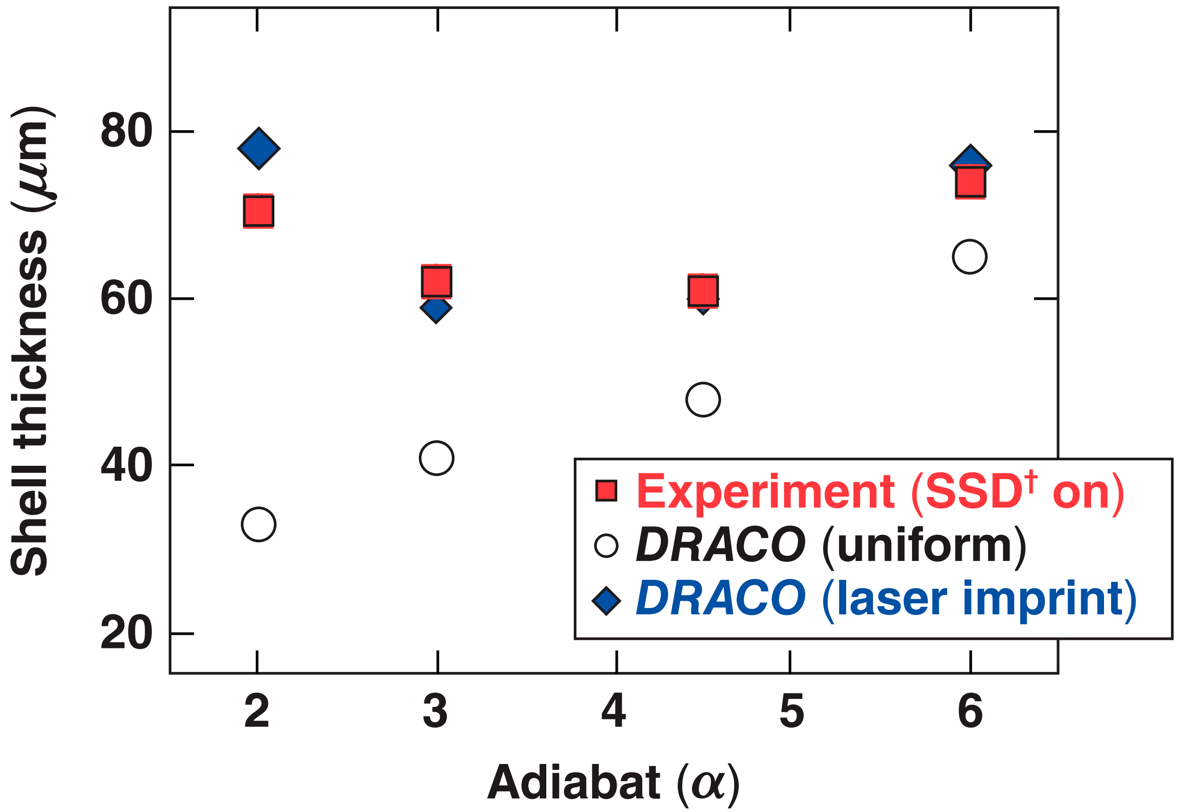
iSNB: improved Schurtz Nicolai-Busquet; CBET: cross-beam energy transfer; FPEOS: first-principles equation of state

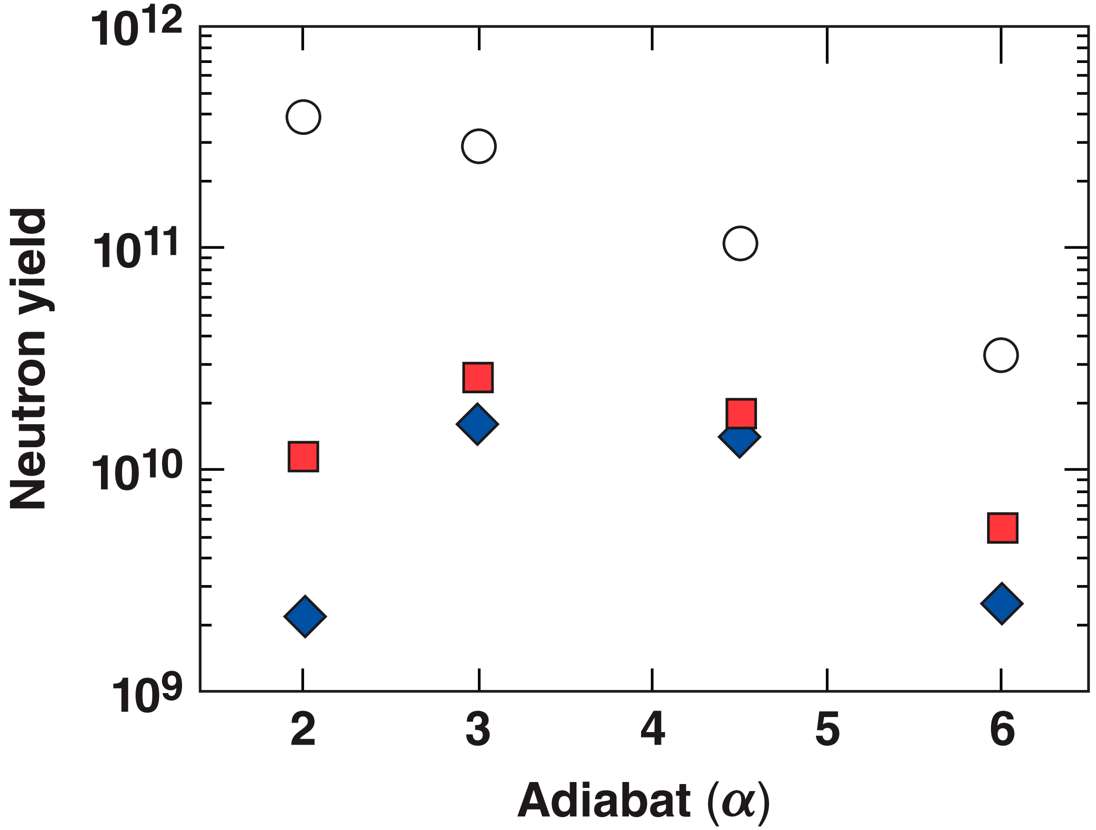
*D. Cao, G. Moses, and J. Delettrez, Phys. Plasmas 22, 082308 (2015)

**I. V. Igumenshchev *et al.*, Phys. Plasmas 17, 122708 (2010); J. A. Marozas and T. J. B. Collins, Bull. Am. Phys. Soc. 57, 344 (2012).

†S. X. Hu *et al.*, Phys. Rev. Lett. 104, 235003 (2010); Phys. Rev. B 84, 224109 (2011); Phys. Rev. E 92, 043104 (2015).

Both simulations* and experiments** have indicated that laser imprint is a major source of target performance degradation in low-adiabat implosions on OMEGA





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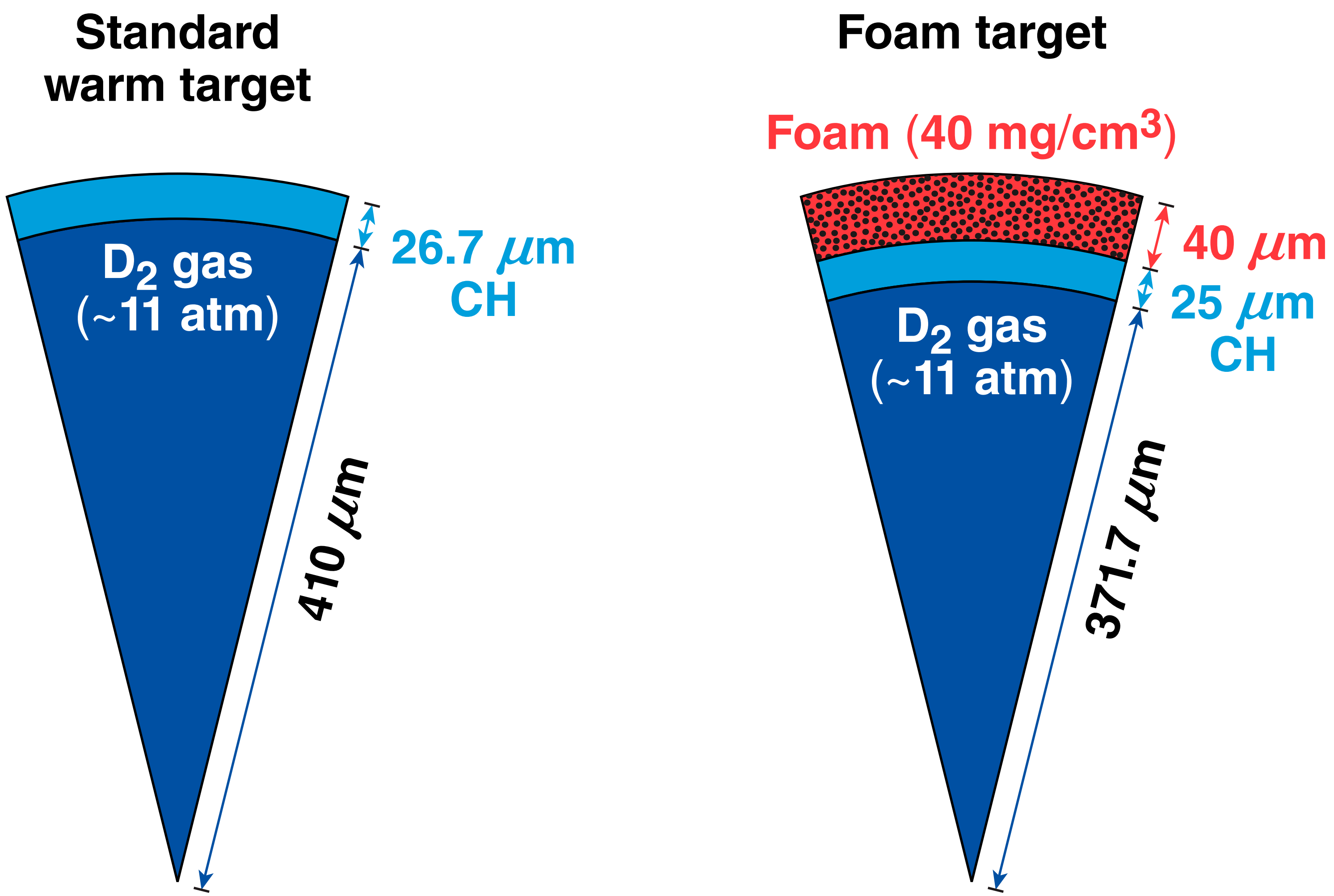
*S. X. Hu *et al.*, Phys. Plasmas 23, 102701 (2016).

**D. T. Michel, S. X. Hu *et al.*, Phys. Rev. E 95, 051202 (2017).

†SSD: smoothing by spectral dispersion

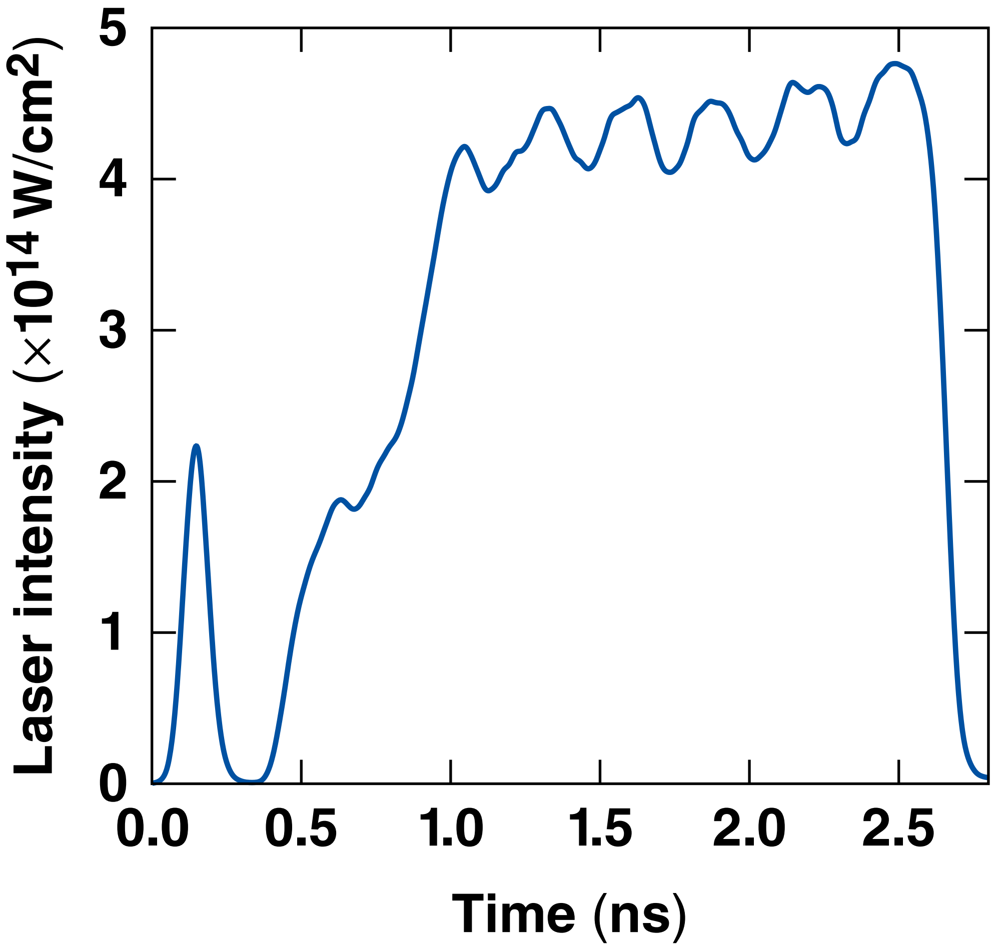
TC12903a

We have proposed to use a thin foam layer on top of a standard target to mitigate laser imprints in direct-drive ICF implosions



TC14268

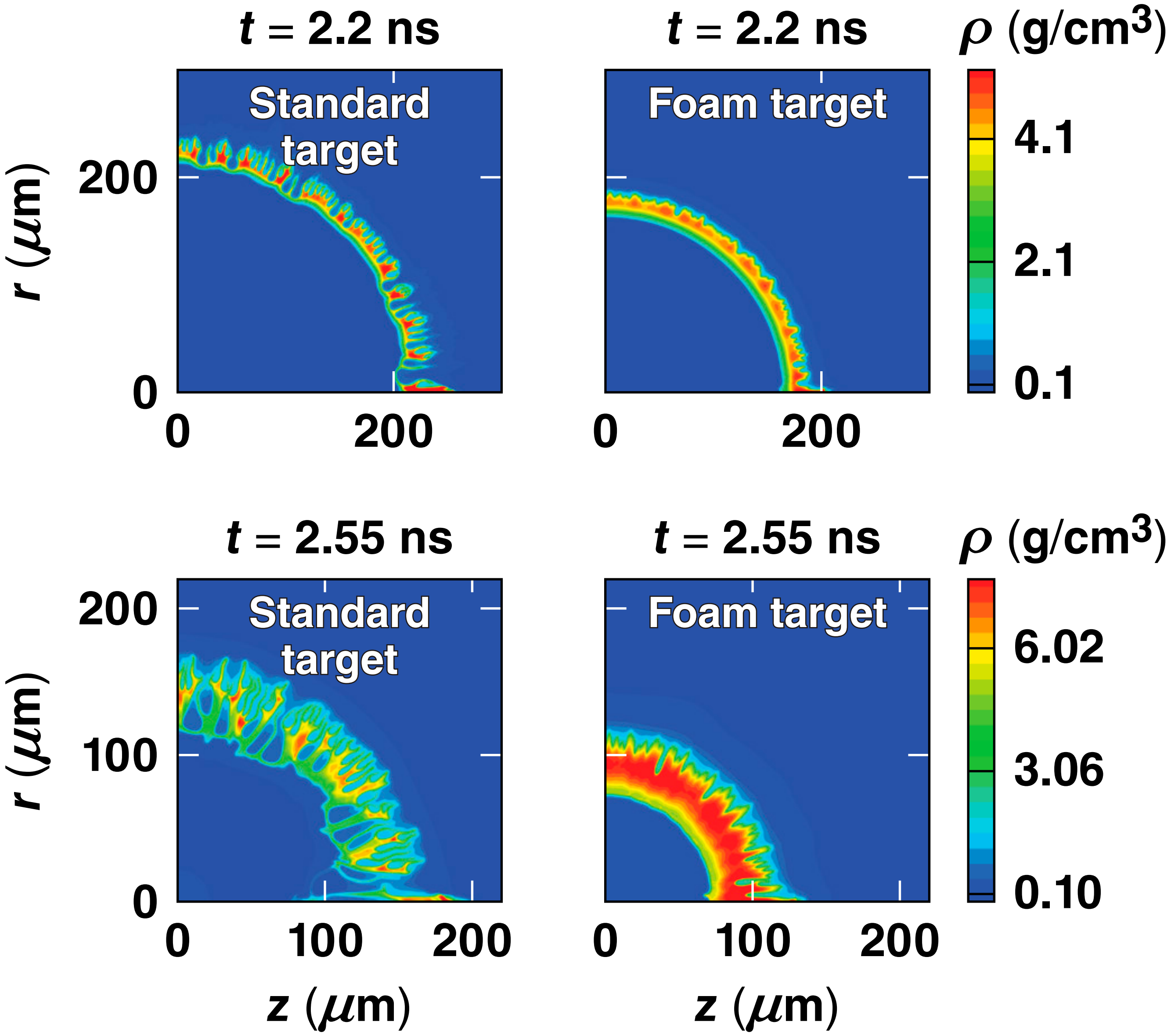
A single-picket pulse drives a mid-adiabat ($\alpha \approx 3$) implosion for these targets, which are simulated by *DRACO* with iSNB + CBET + FPEOS models



Laser-imprint was simulated up to a maximum mode of $\ell = 200$.

TC14269

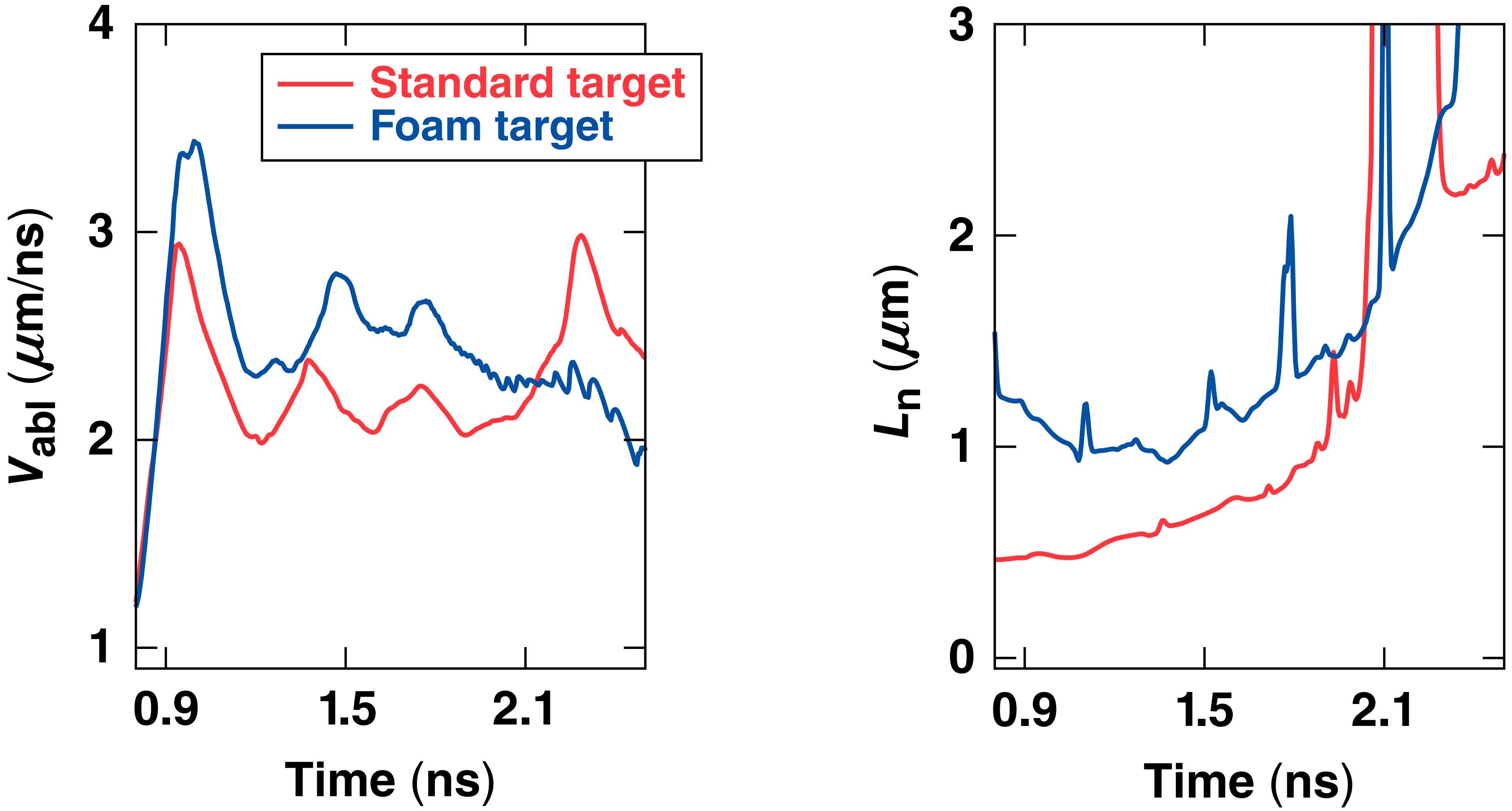
Laser-imprint–induced modulation growth has been examined for two targets during the acceleration phase



TC14271

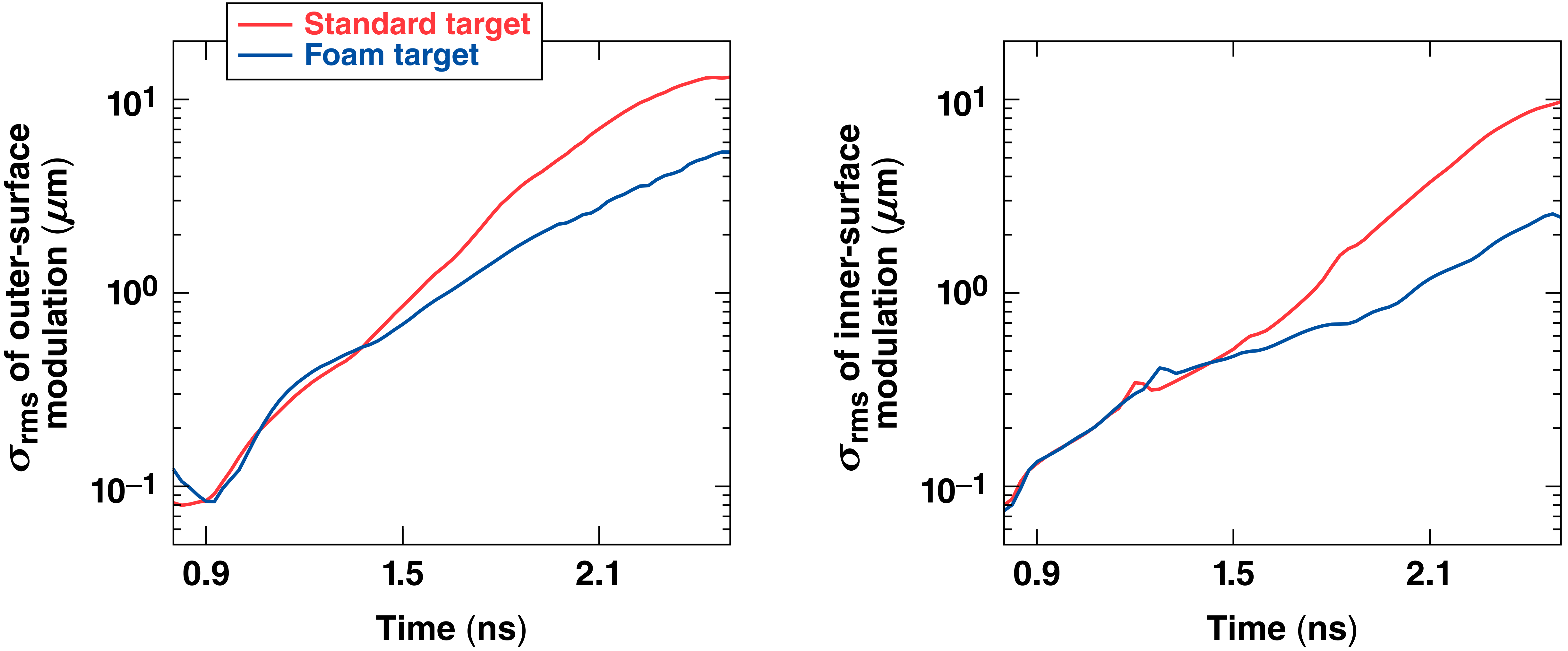
The foam layer can increase the ablation velocity and density scale length at the ablation front, which both help to reduce the imprint-induced Rayleigh–Taylor (RT) growth

$$\gamma = 0.94 \times \sqrt{\frac{kg}{1 + kL_n}} - 1.5 \times kV_{abl}$$



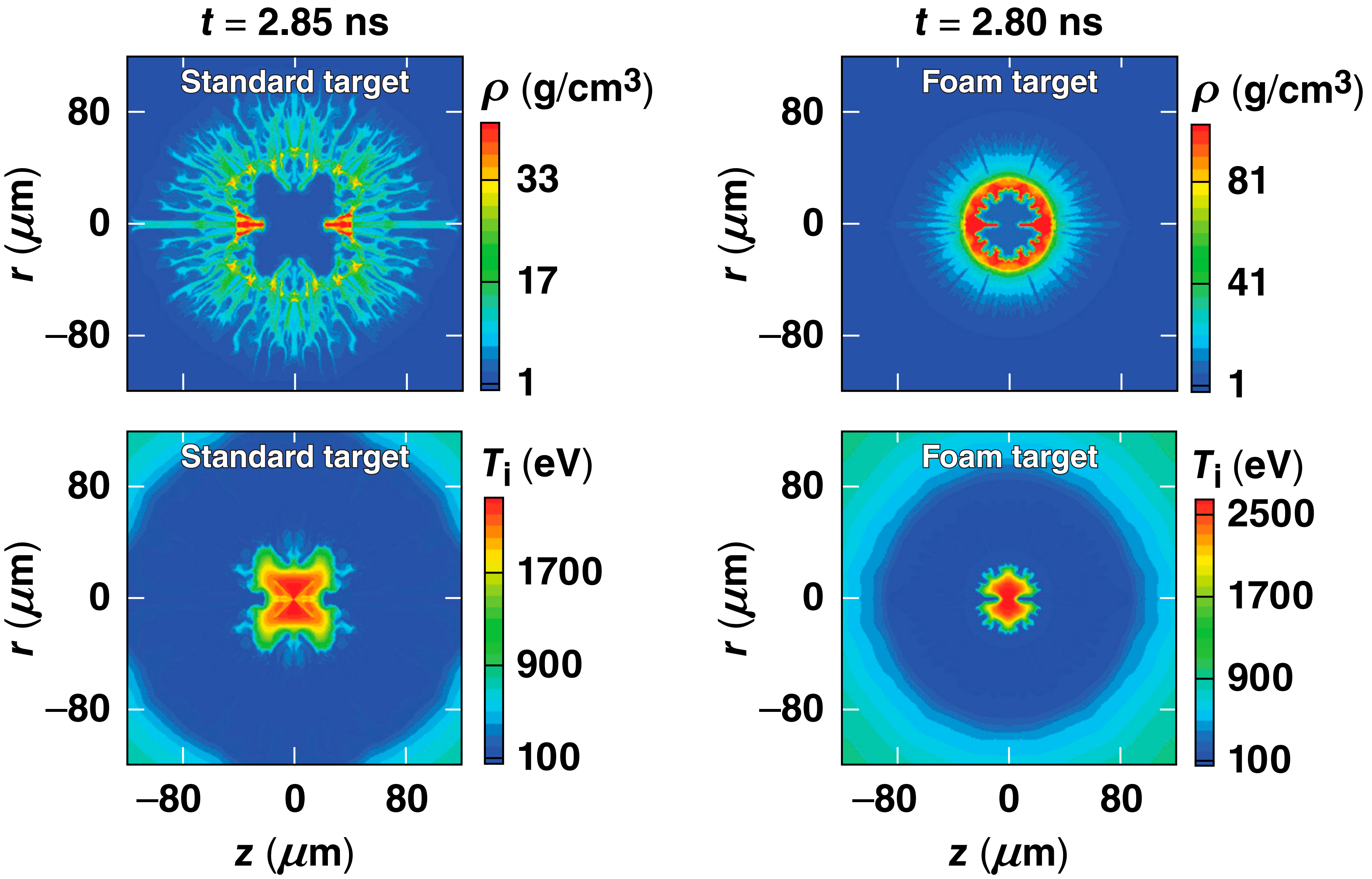
TC14273

The simulations show a smaller outer-/inner-surface growth for the foam target



TC14274

At peak neutron production, the foam target gives a much better performance



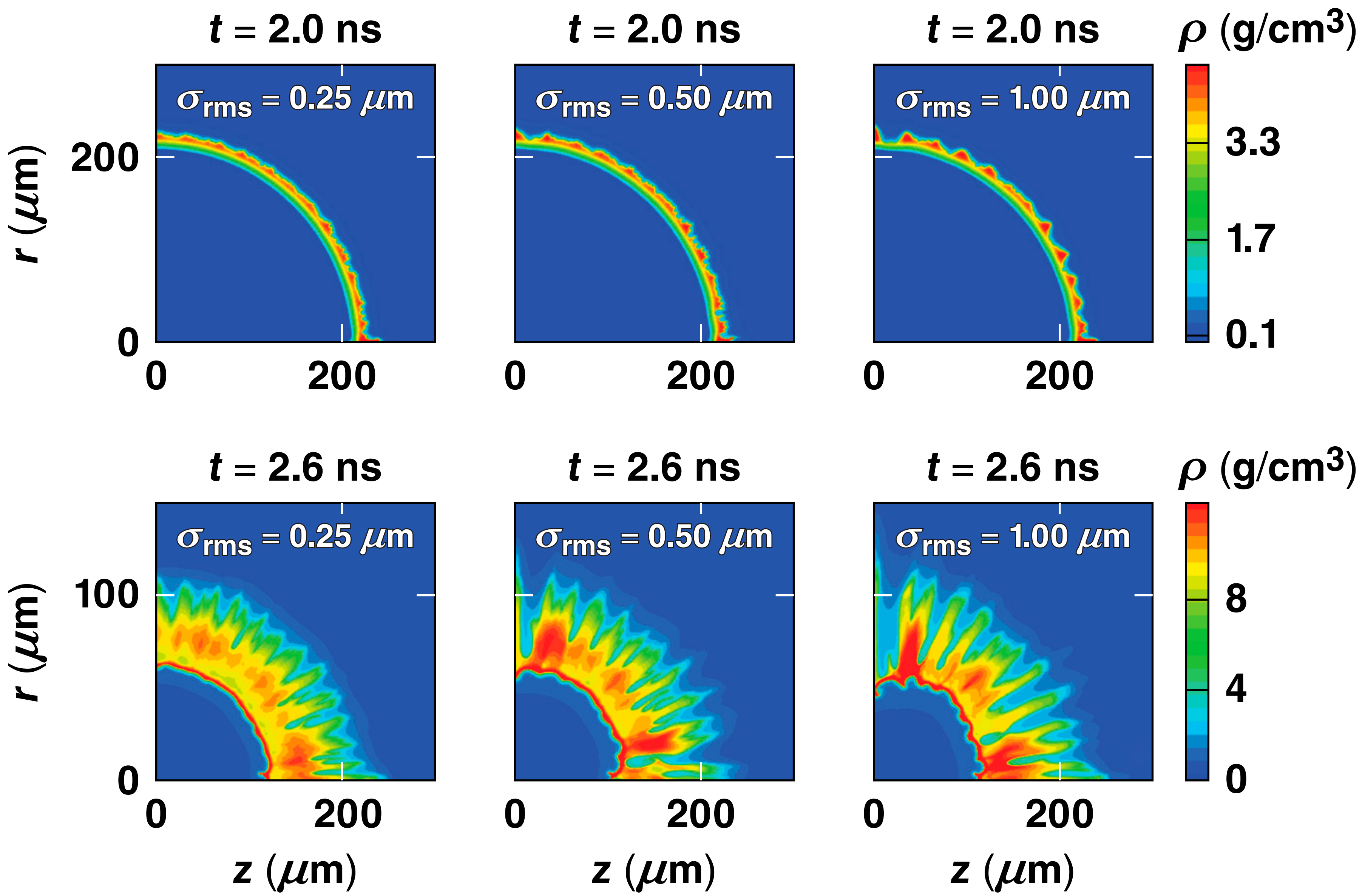
TC14276

Comparison of the implosion performance between two types of targets has indicated the mitigation of laser imprints by the foam target

	Standard target	Foam target
ρR (mg/cm^2)	112	230
$\langle T_\mathrm{i} \rangle$ (keV)	1.74	2.06
DD yield	5.2×10^9	3.9×10^{10}

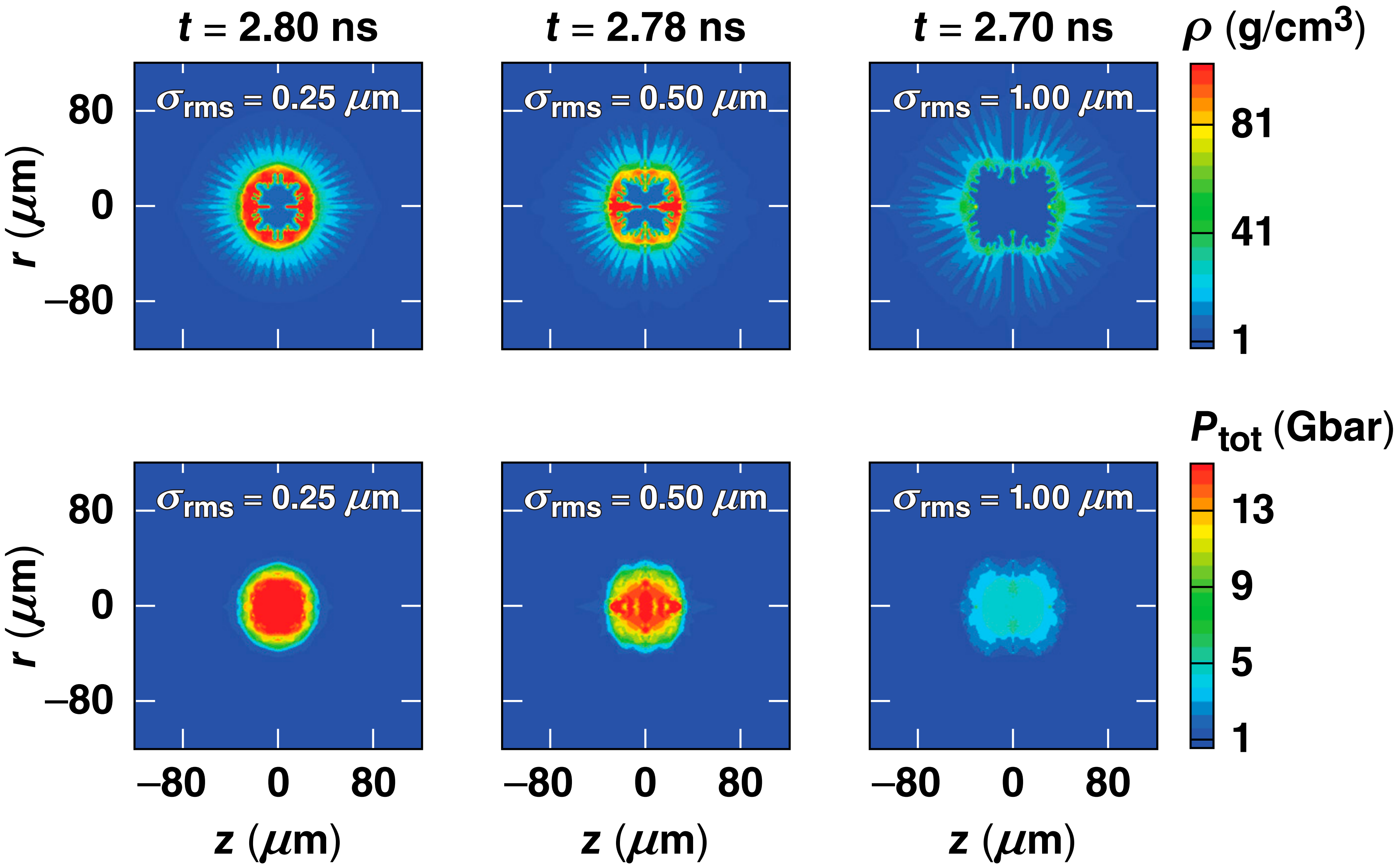
A factor of 7 to 8 enhancement in yield is obtained with the foam target!

Effects of the foam-surface/thickness modulation on the laser-imprint mitigation was investigated



TC14278

At peak neutron production, the foam modulation level of $\sigma_{\text{rms}} \leq 0.5\ \mu\text{m}$ still gives much better target performance than the standard-target case



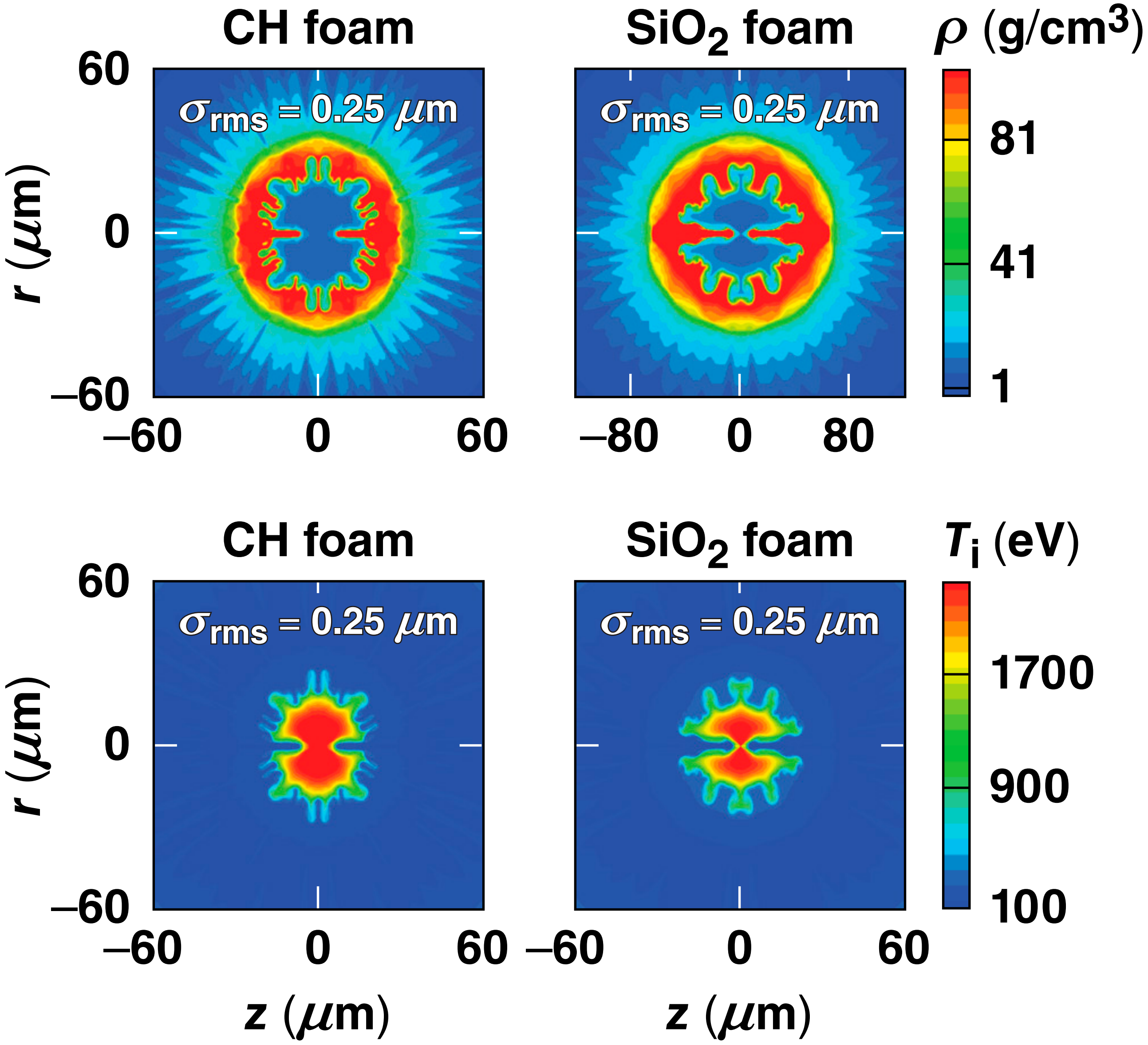
TC14280

DRACO simulations have indicated that a foam target with a surface modulation of $\sigma_{\mathrm{rms}} \le 0.5\ \mu\mathrm{m}$ can increase the neutron yield by a factor of 4 to 8

	Standard target	Foam target ($\sigma_{\mathrm{rms}} = 0.0\ \mu\mathrm{m}$)	Foam target ($\sigma_{\mathrm{rms}} = 0.25\ \mu\mathrm{m}$)	Foam target ($\sigma_{\mathrm{rms}} = 0.5\ \mu\mathrm{m}$)	Foam target ($\sigma_{\mathrm{rms}} = 1.0\ \mu\mathrm{m}$)
ρR (mg/cm^2)	112	230	246	183	127
$\langle T_{\mathrm{i}} \rangle$ (keV)	1.74	2.06	2.08	2.00	1.94
DD yield	5.2×10^9	3.9×10^{10}	3.99×10^{10}	2.1×10^{10}	8.3×10^9

A factor of 4 to 8 enhancement in yield and ~80% of 1-D ρR can be obtained with a foam target of $\sigma_{\mathrm{rms}} \le 0.5\ \mu\mathrm{m}$!

DRACO simulations also indicated that different low-/mid-Z foam materials can be used to mitigate laser imprints



Similar target performance has been seen for both CH foam and SiO$_2$ foam targets.

TC14283

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