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Lasnex Simulations of NIF Vacuum Hohlraum Experiments

APS – DPP 09

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

The radiation temperatures measured in the first NIF vacuum hohlraum experiments exceeded our expectations.

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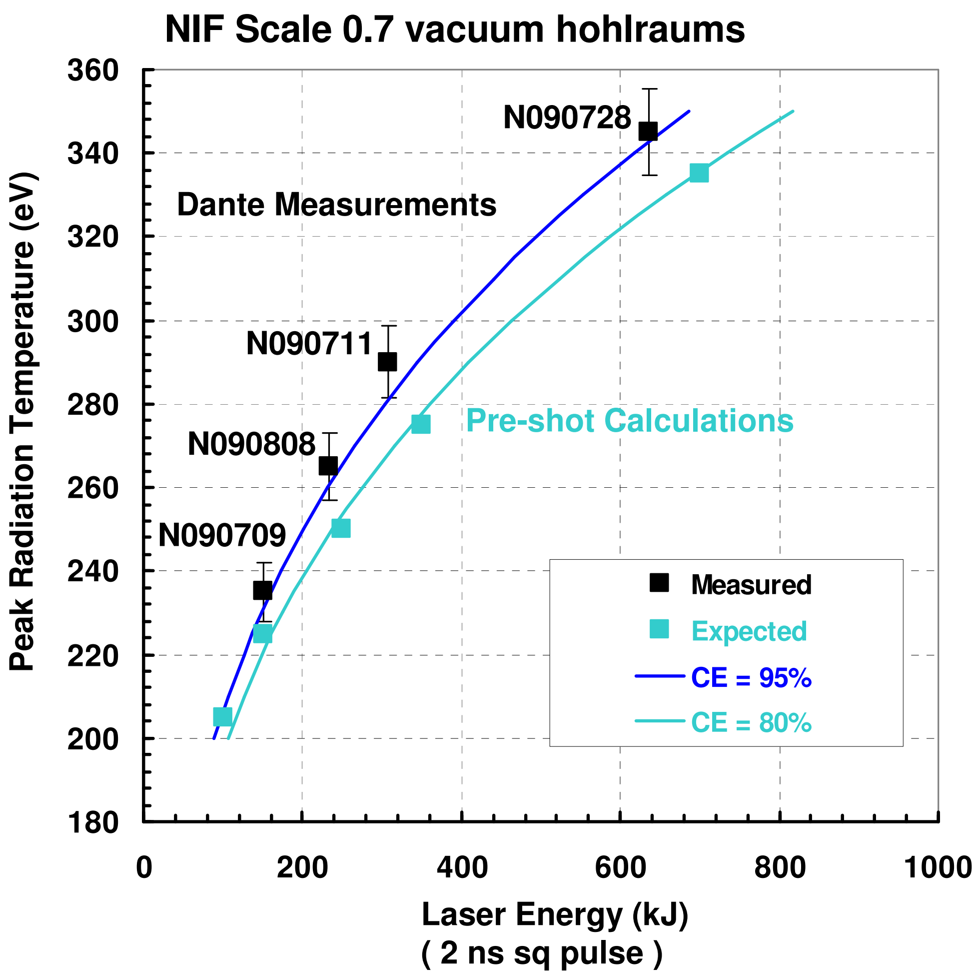

We are surprised by how large the difference is between our expectations and the results, and we are closely scrutinizing all aspects of the measurements and calculations.

A possible explanation is that the x-ray conversion efficiency is higher than we had anticipated. New Lasnex calculations employing variations in emissivity and heat conduction models can explain the Dante measurements.

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The first vacuum hohlraum experiments at NIF

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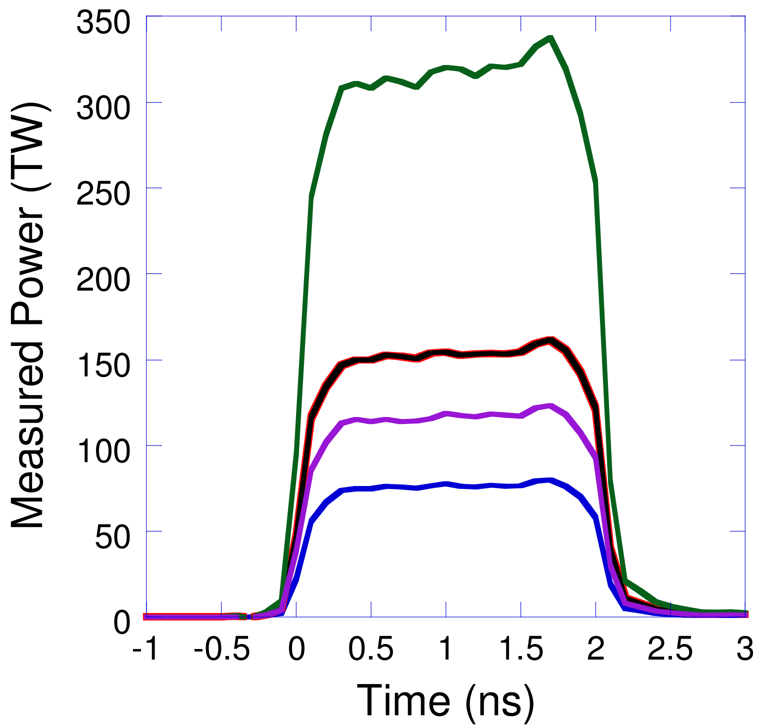
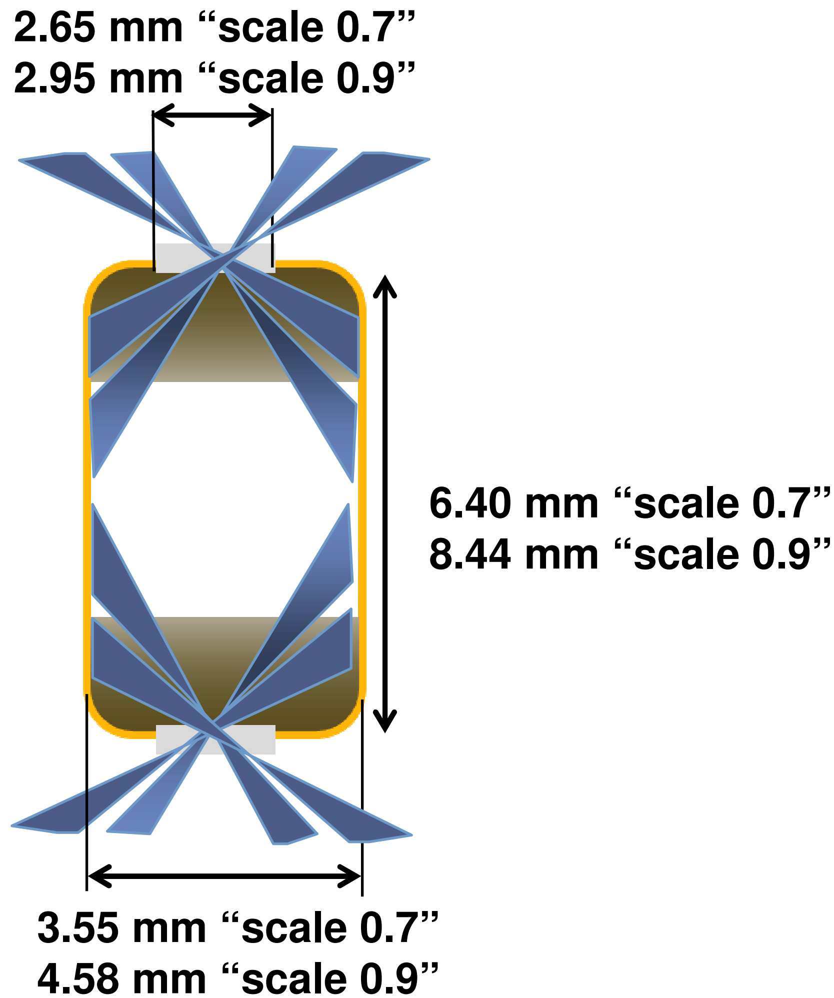
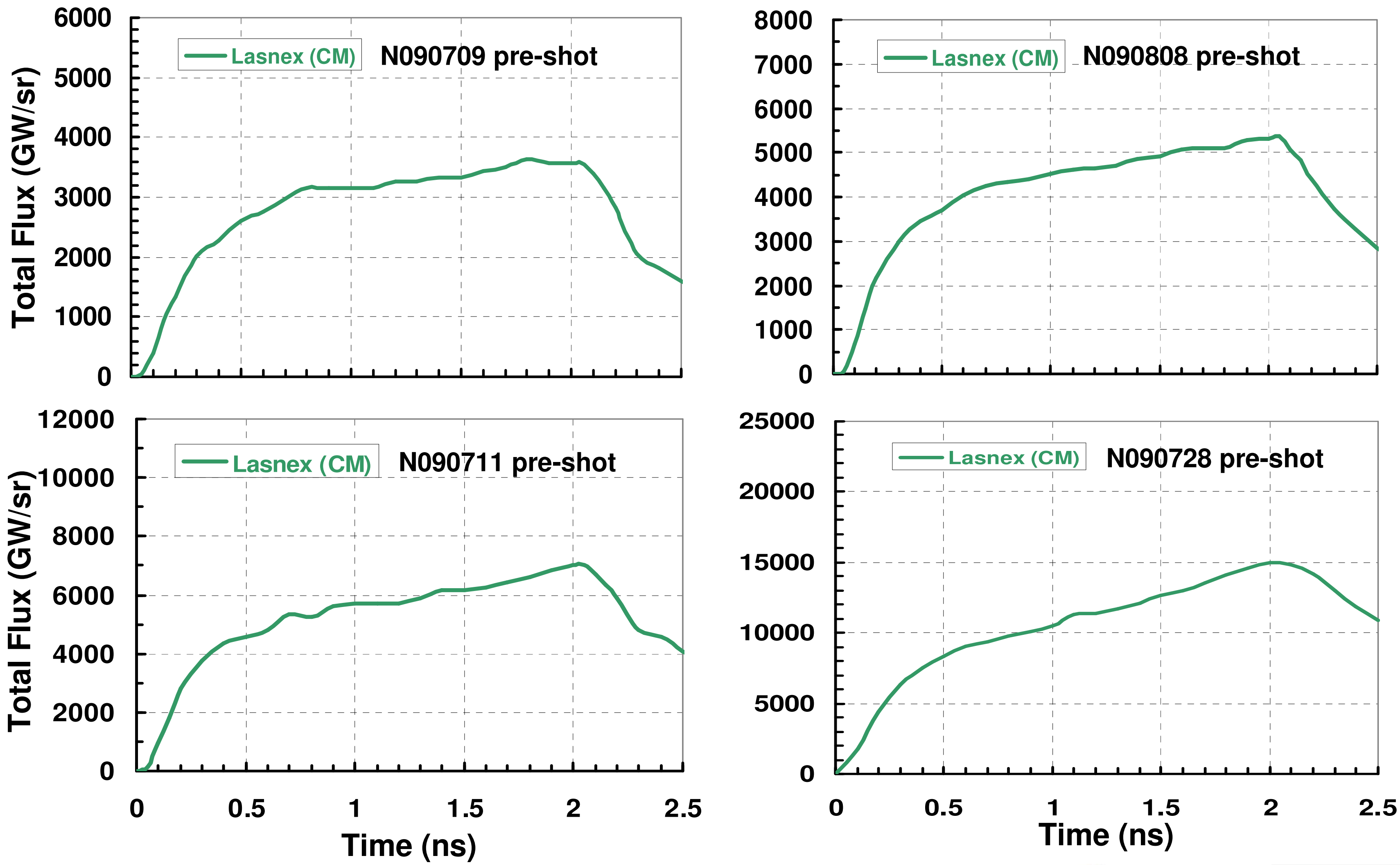
NIF shot number	# beams & energy	comments
Scale 0.7:		
N090709	96 beams, 150 kJ	Peak Tr, ~235 eV
N090711	88 beams, 308 kJ	Peak Tr~290 eV
N090713	88 beams, 306 kJ	Au:B liner; Peak Tr~290 eV
N090728	184 beams, 635 kJ	Peak Tr ~345 eV
N090808	96 beams, 233 kJ	Peak Tr ~ 265 eV
Scale 0.9:		
N090817	192 beams, 591 kJ	Peak Tr ~310 eV
N090828	192 beams, 588 kJ	cryogenic; Peak Tr ~ 310 eV

The NIF "scale 0.7" and "scale 0.9" vacuum hohlraum experiments used 2 ns sq laser pulse shapes.

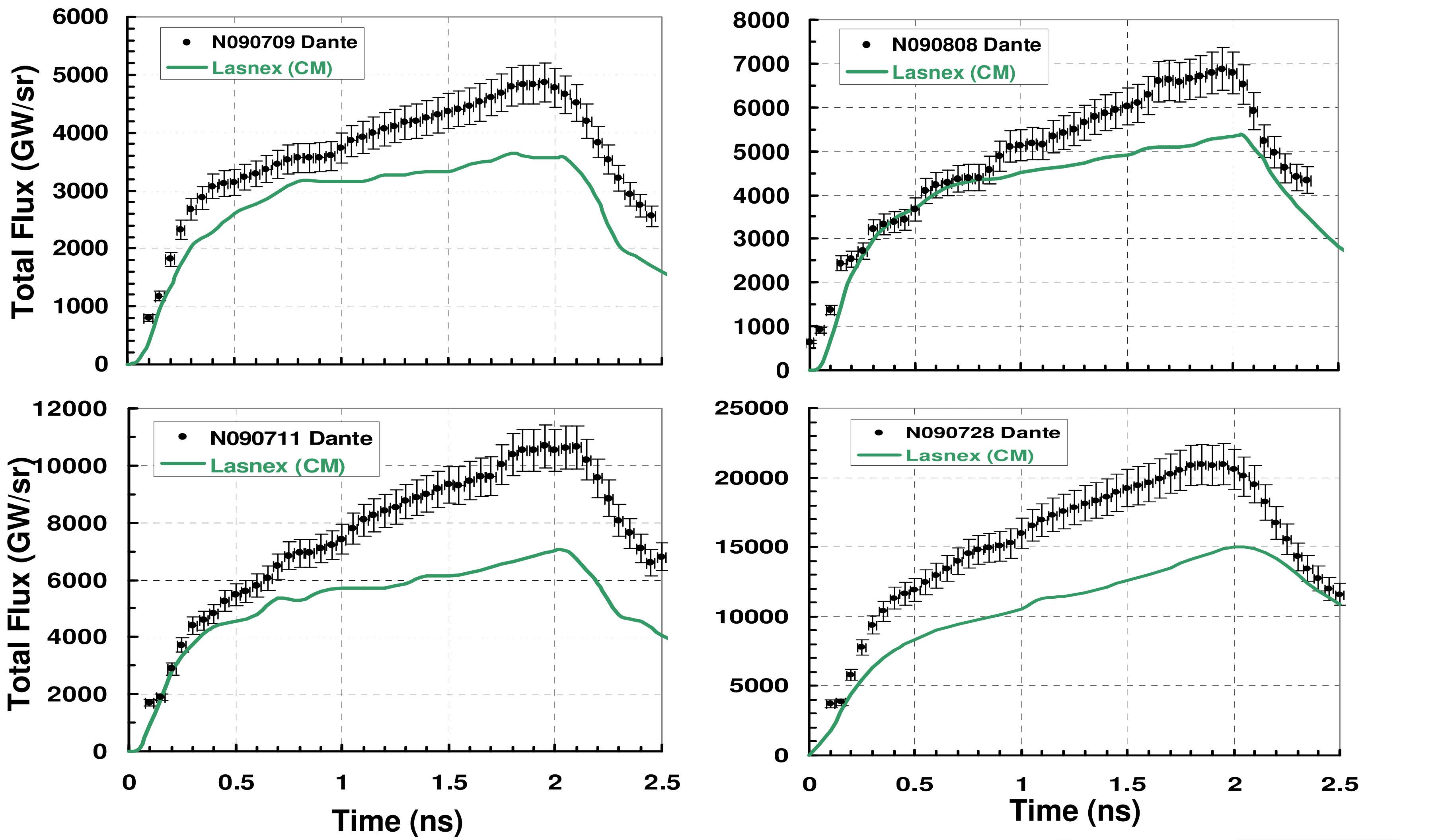




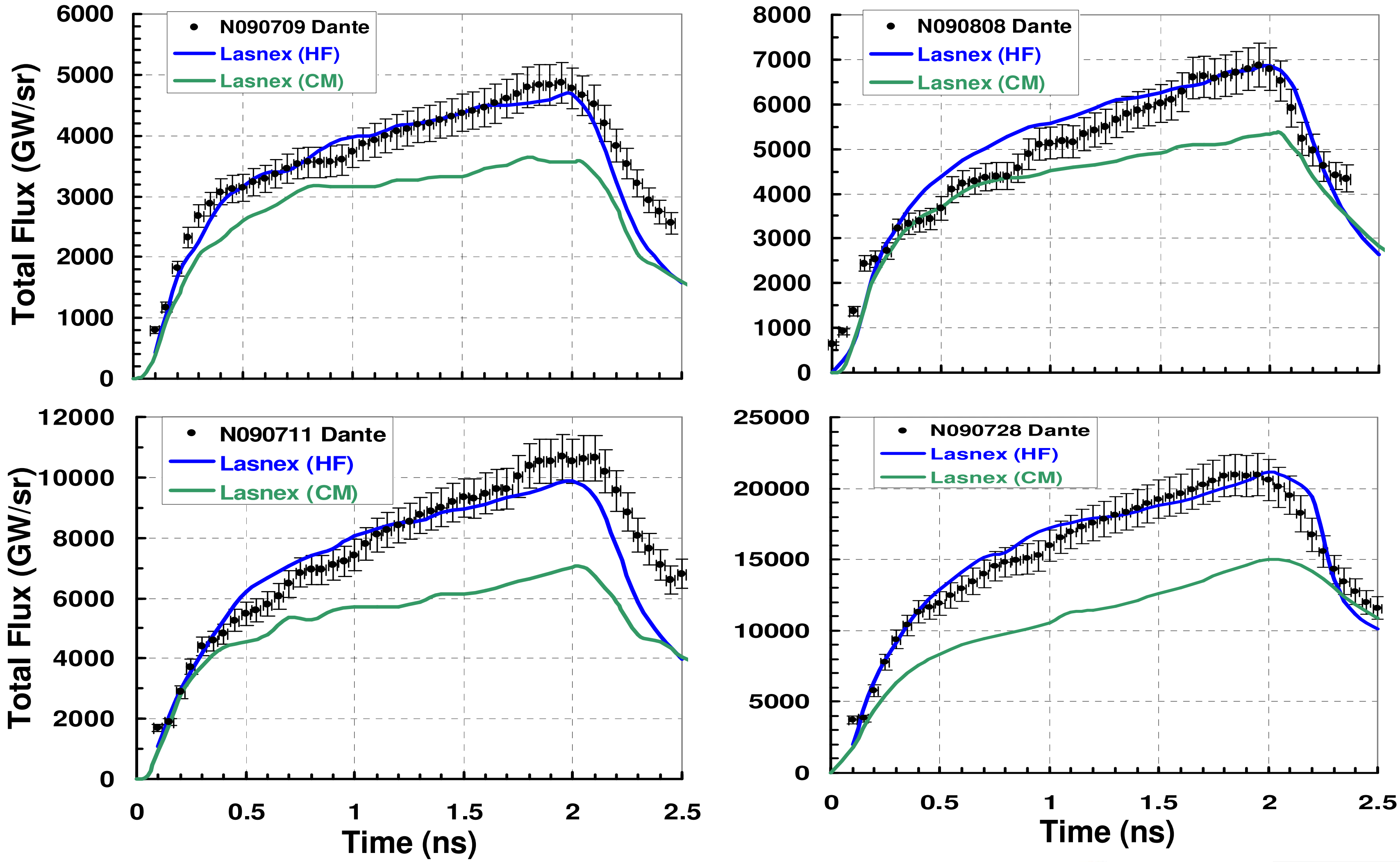
The pre-shot calculations employed a "configuration managed" (CM) Lasnex setup using default non-LTE XSN and flux limiter settings.



The Dante measurements were 20-40% higher in peak flux than the pre-shot CM-Lasnex simulations had predicted.



The post-shot calculations employed a new "high flux" (HF) model with increased emissivity and electron heat conduction.



Calculations employing the “high flux” model can explain the Dante data for the 240 eV < Tr < 340 eV NIF vacuum hohlraums.

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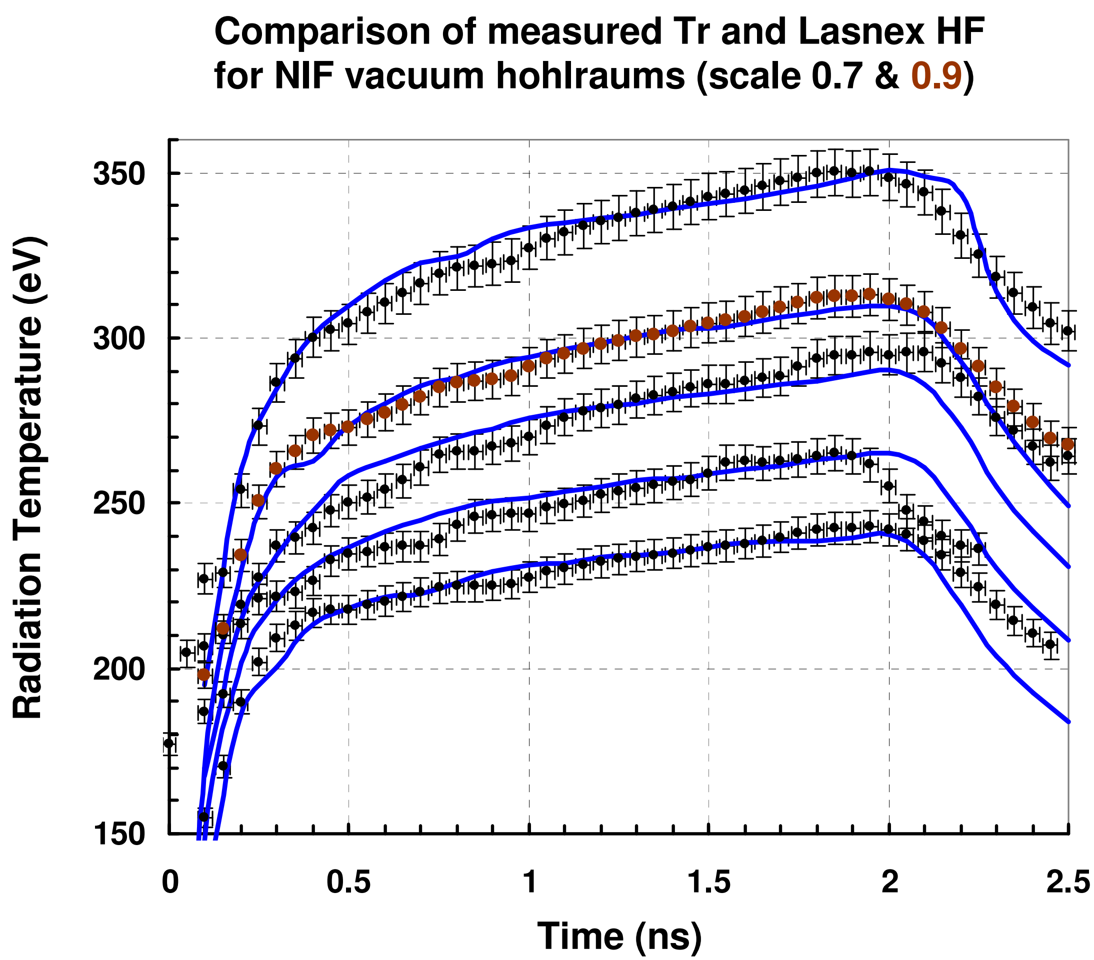

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The "high flux" Lasnex model was also applied in the scale-0.9 vacuum hohlraum post-shot calculations.

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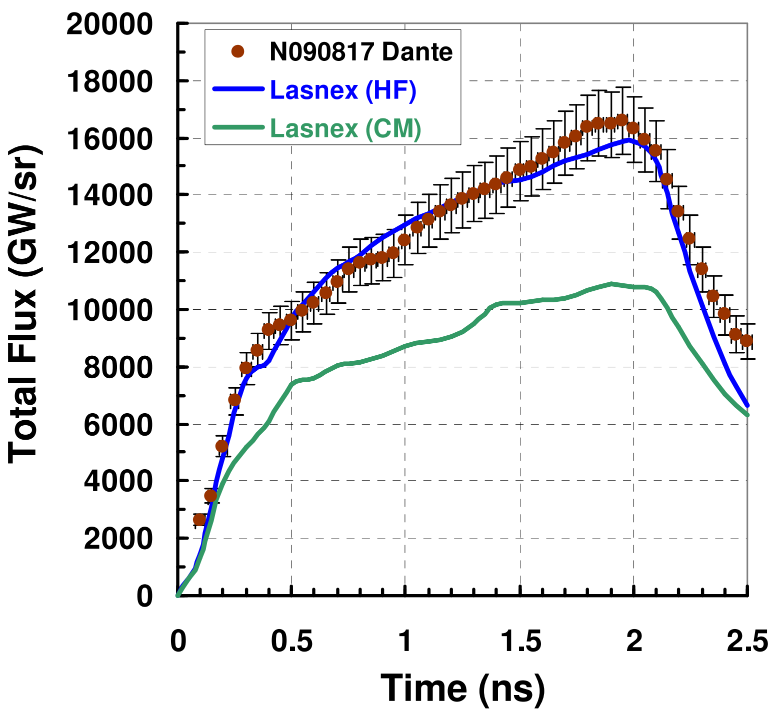
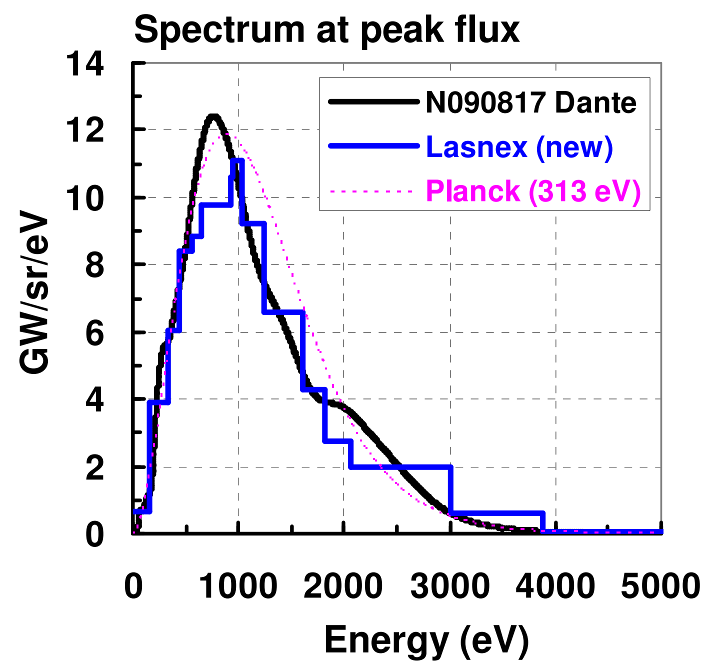
This calculation uses the "0.9 scale" hohlraum (4.58mm id, 8.44mm L, 2.95mm LEH), with 2 ns sq, 4 quads in 23.5 deg cones, 4 quads in 30 deg cones, 8 quads in 44.5 deg cones, and 8 quads in 50 deg cones.

Beams pointing and spot elliptical radii are:

r=0.98mm z=2.42 mm, 631 m x 882 m for 23.5 deg beams; r=0.5mm z=2.84 mm, 590 m x 824 m for 30 deg beams; r=0mm z=4.4mm, 367 m x 635 m for 44.5 deg beams, and r=0mm z=4.24mm, 343 m x 593 m for 50 deg beams.

Dante unfold uses SNL code, includes cable compensation.





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An examination of the N090817 "CM" and "HF" calculations shows that:

Enhancements in emissivity and election heat conduction in the HF model lead to reduced energy in the coronal plasma.

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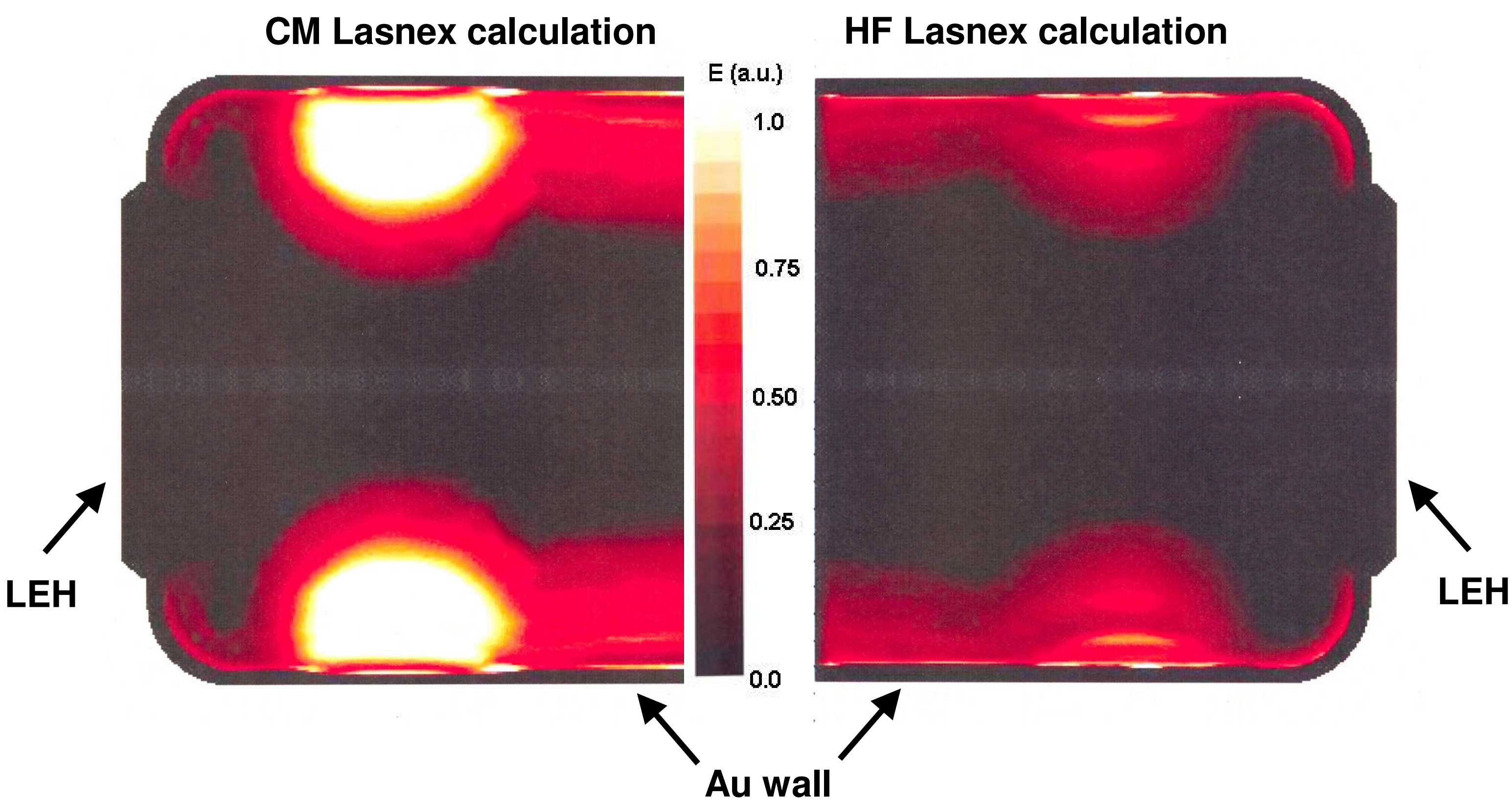
CM and HF Lasnex calculations of NIF shot N090817, energy contours at t = 1.0 ns.



Enhancements in emissivity and election heat conduction in the HF model lead to reduced energy in the coronal plasma and, hence, increased hohlraum x-ray conversion efficiency.

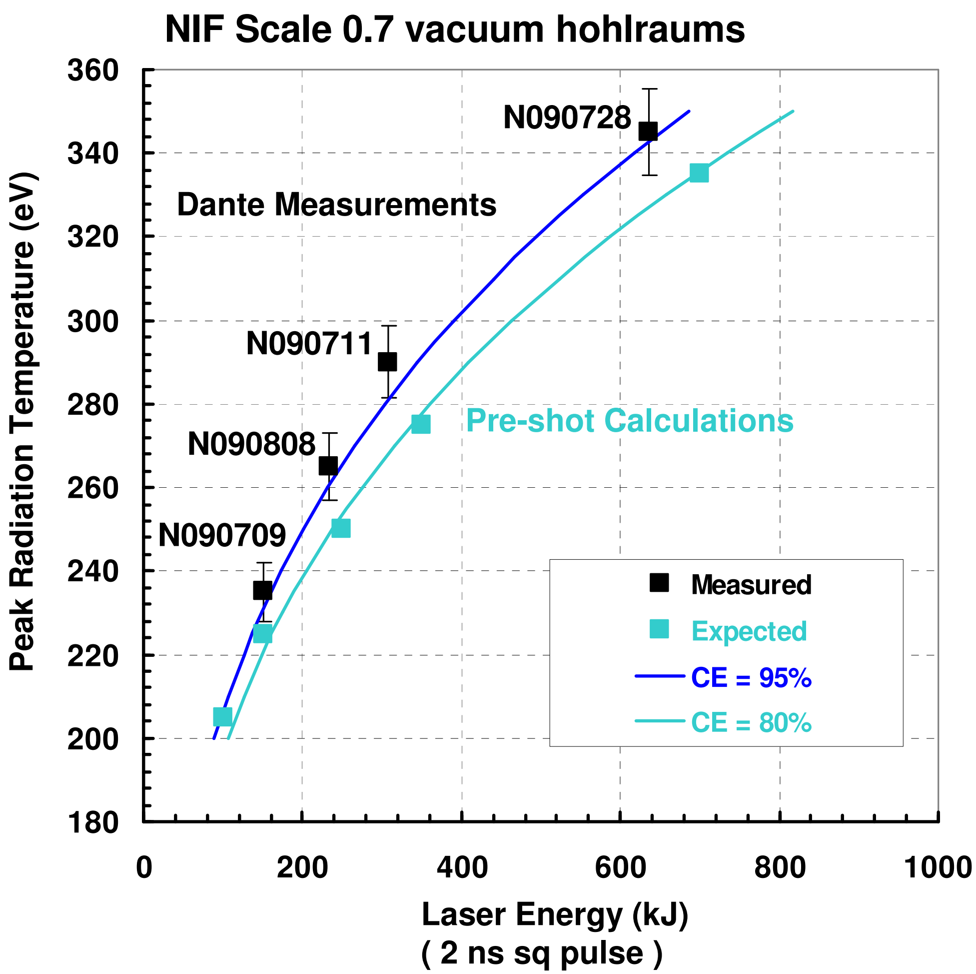
We've know for some time that emissivity models that produce more radiation per cc than the Lasnex default model will increase the efficiency of the hohlraum. Higher emissivity results in a smaller fraction of the laser energy being stored in the corona which means more energy is available for radiation production. The effect of the larger emissivity becomes more pronounced at larger scale sizes due to the larger volume to surface-area ratio. Independent, detailed NLTE estimates have indicated that the Lasnex default NLTE model underestimates the emissivity of the corona. So we're not surprised to measure higher x-ray fluxes than with our "configuration managed" model. We are surprised by how large the difference is and we are closely scrutinizing it.

**L. Suter et al., Bull. Am. Phys. Soc. 53, 89 (2008).*

During the past couple years, we've suspected that the Lasnex default electron flux limiter of 0.05 will lead to an underestimate of the heat conduction losses from the Au coronal plasma. The new model uses an electron flux limiter of 0.15, which has been shown to produce a better match to Dante in Au sphere x-ray conversion efficiency measurements (at Omega)**. The higher heat conduction results in increased energy in the wall, reduced coronal plasma temperature, and a net increase in the hohlraum x-ray conversion efficiency.

***E. L. Dewald et al., Phys. Plasmas 15, 072706 (2008).*

Our hypothesis is that the high fluxes measured in the NIF vacuum hohlraums are due to high x-ray conversion efficiency.



This hypothesis can be illustrated via a simple hohlraum power balance formula:

$$\eta P_L \sim \sigma T^4 [A_w (1-\alpha) + A_{LEH}]$$

P_L, laser power
A_w, wall area
A_{LEH}, area of laser entrance holes
η, x-ray conversion efficiency
α, wall albedo:
$\alpha = 1 - F / T^4$
$F = 0.34 (1+4p)^{0.5} T^{3.35} / t^{0.41}$
$T(t) = T_o t^p$

Conclusion:

The radiation temperatures measured in the first NIF vacuum hohlraum experiments exceeded our expectations.

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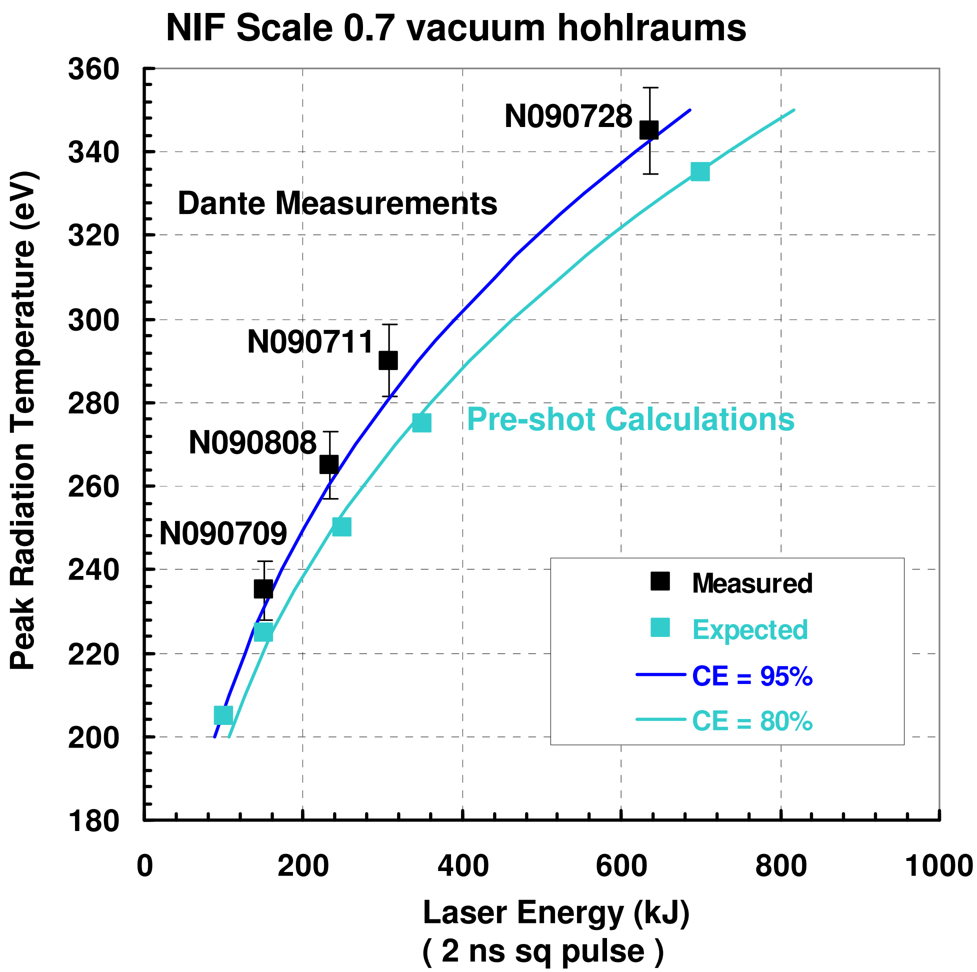

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