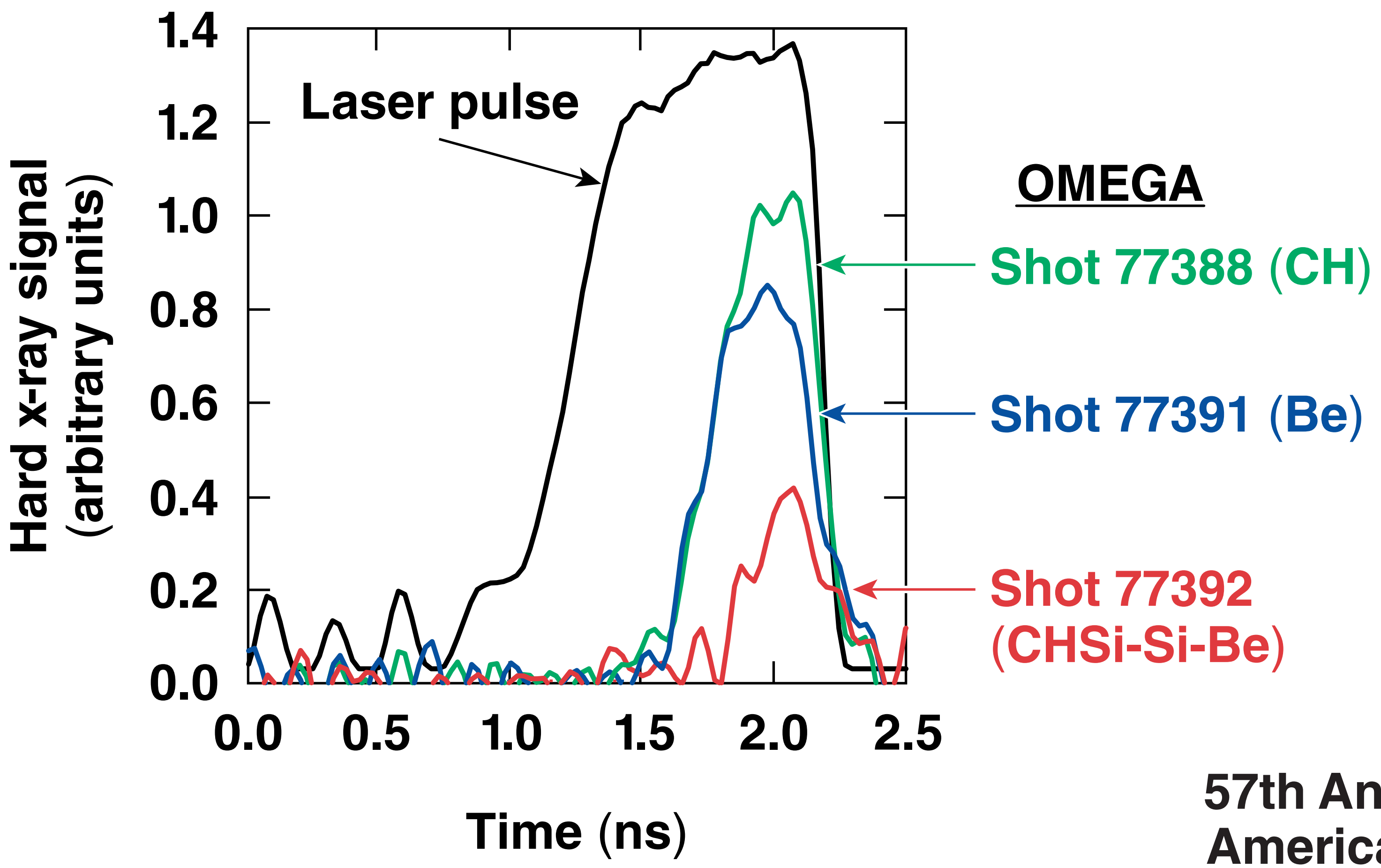
A Numerical Model for Two-Plasmon–Decay Hot-Electron Production and Mitigation in Direct-Drive Implosions



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Summary

*LPSE** simulations predict a strong reduction of hot electrons in multilayer ablator designs

UR LLE

- The hot electrons are assumed to be generated by the multibeam two-plasmon–decay (TPD) instability
- A reduction in hard x-ray production has been recently observed in experiments on the OMEGA laser using multilayer ablators
  - – the reduction is consistent with *LPSE* predictions
  - – this demonstrates the validity of the mitigation strategy
- Experiments will test this scheme at the National Ignition Facility (NIF) (for ignition conditions) in FY16

*Laser-plasma simulation environment (*LPSE*)
See A. A. Solodov *et al*., NO5.00007, this conference
and P. B. Radha *et al*., CI3.00004, this conference (invited).

TC12222a

Collaborators

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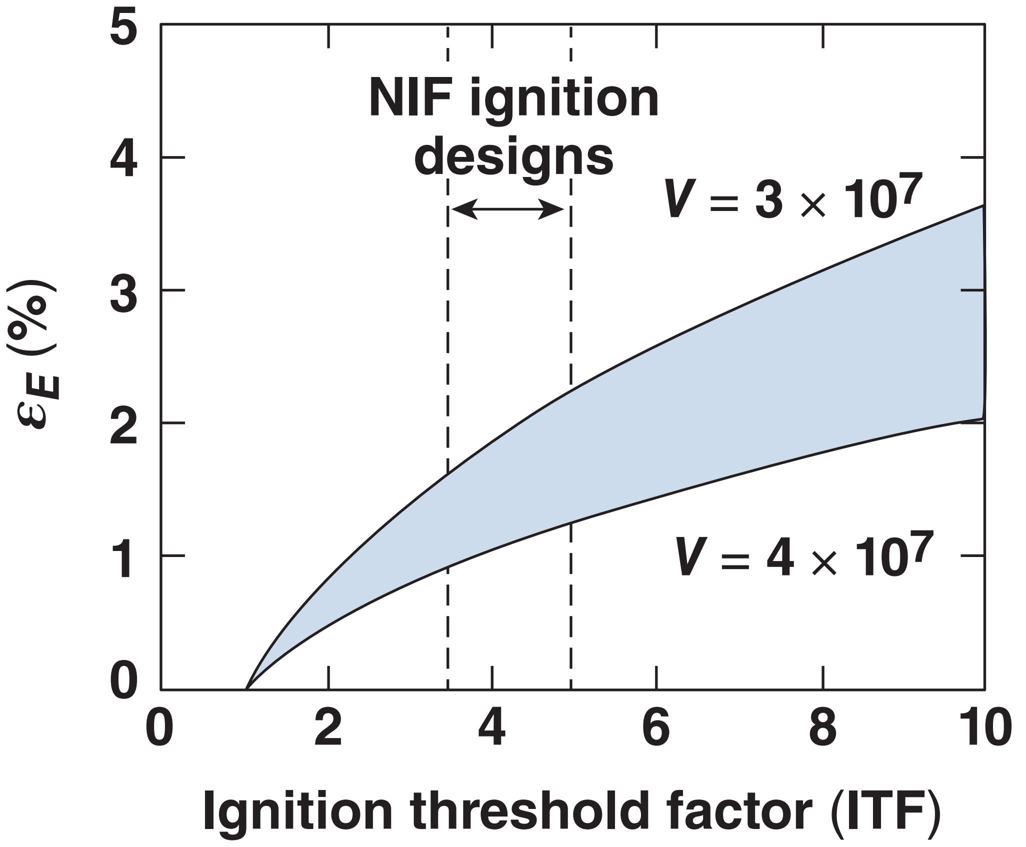
LPSE is designed to perform large-scale simulations of laser–plasma interactions (LPI's), where the 3-D geometry is essential

- e.g., multibeam instabilities such as TPD,* stimulated Raman scattering (SRS),** and cross-beam energy transfer (CBET)†
- The *LPSE* TPD model
  - describes near $n_c/4$ only; hydro is prescribed by hydrocode (*LILAC*)
  - CBET is taken into account using a ray-trace model in the hydrocode
  - an established model of Langmuir wave (LW) turbulence is used to describe nonlinear saturation of TPD‡
  - a novel hybrid kinetic model describes nonlinear evolution and hot-electron production

*D. T. Michel *et al*., Phys. Rev. Lett. 109, 155007 (2012).
**P. Michel *et al*., Phys. Rev. Lett. 115, 055003 (2015).
†I. V. Igumenshchev *et al*., Phys. Plasmas 19, 056314 (2012).
‡D. F. DuBois, D. A. Russell, and H. A. Rose, Phys. Rev. Lett. 74, 3983 (1995).

TC12224a

Hot-electron production caused by the TPD instability must be controlled to prevent excessive fuel preheat



ε_E: maximum tolerable preheat as fraction of shell kinetic energy

OMEGA: E_k ~ 1.2 kJ, ε_E ~ 20 J

NIF: E_k ~ 60 to 100 kJ, ε_E ~ 0.8 to 1 kJ

Based on the results of $\alpha = 4$ implosions (ρR_{exp} > 90% of 1-D predictions without preheat), the estimated fuel preheat on OMEGA is below 10 J.

Laboratory for Laser Energetics LLE Review 130, 72, LLE Document No. DOE/NA/28302-1058 (2012).

Mid-Z layers are being investigated as a TPD mitigation strategy on both OMEGA and the NIF

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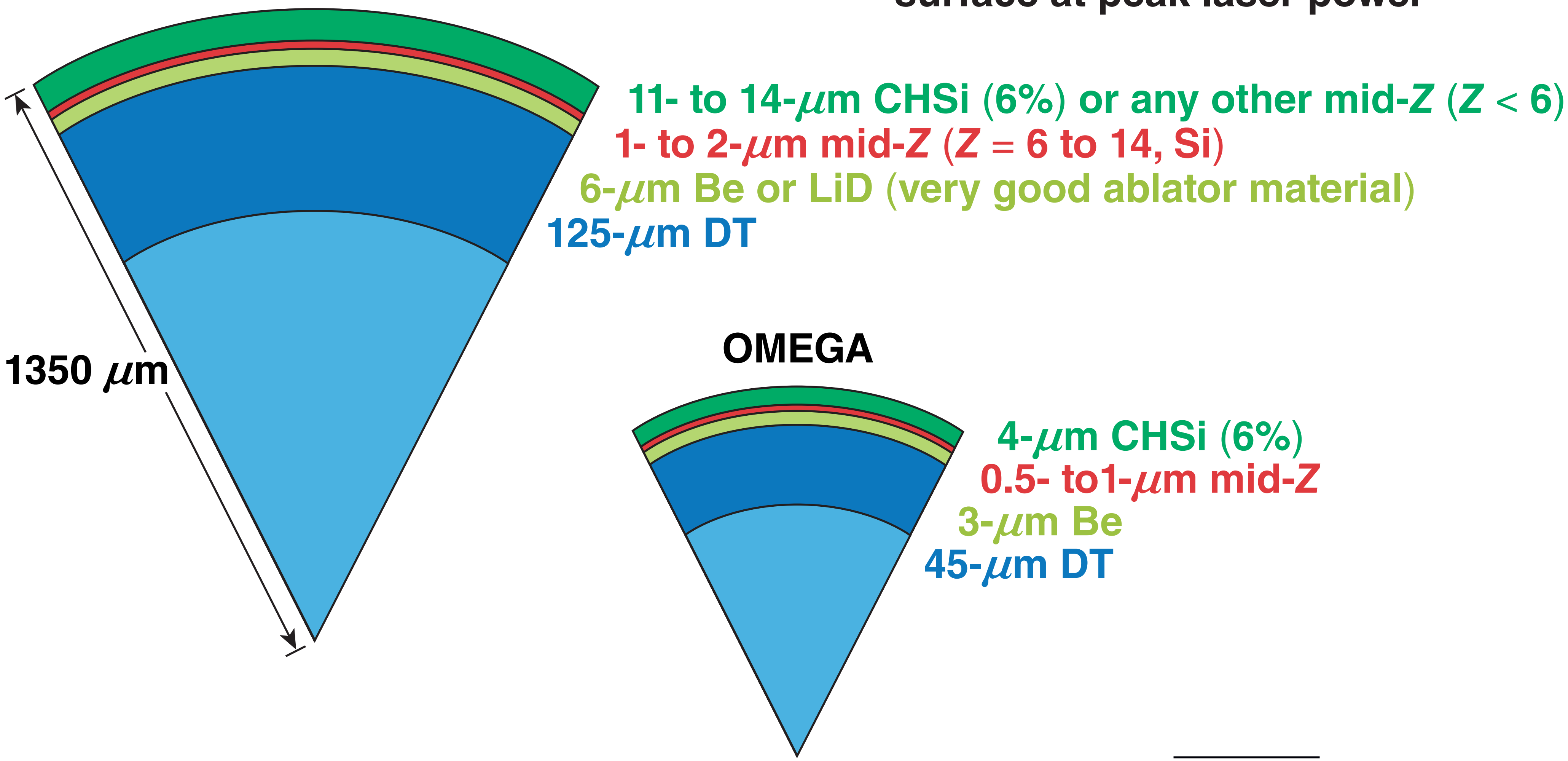
- The thin mid-*Z* layer (e.g., Si) is designed to reach the quarter-critical density surface at peak laser power



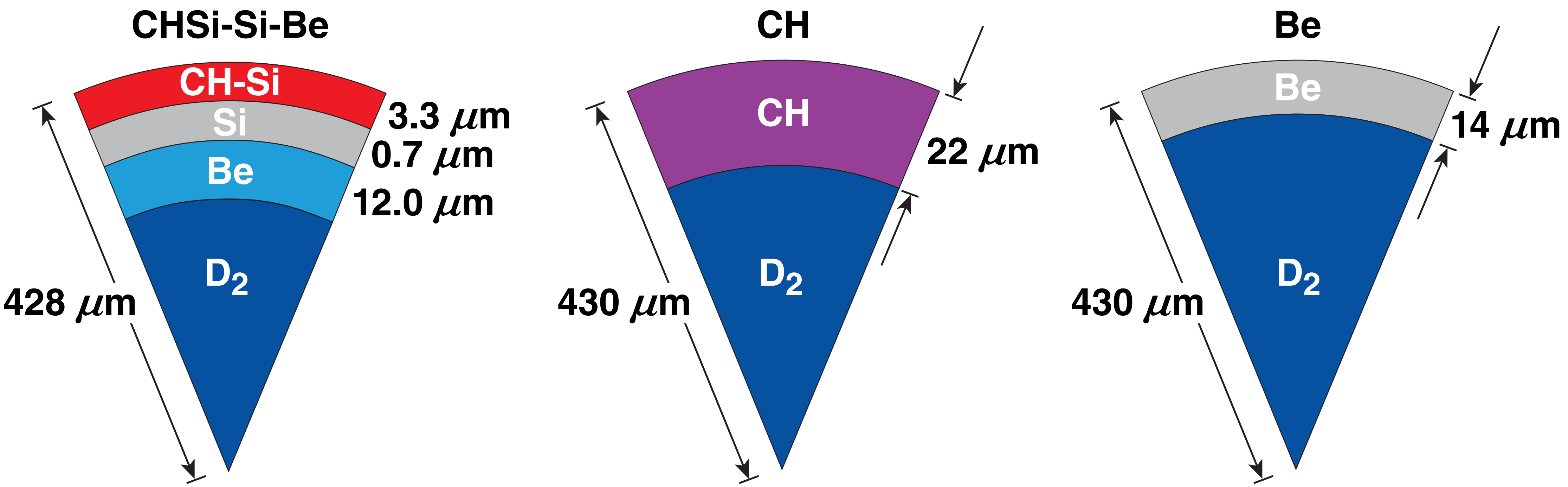
TC10544g

V. N. Goncharov *et al*., Phys. Plasmas 21, 056315 (2014).

Three spherical implosions experiments were simulated to obtain the hydrodynamic variables as a function of time

UR LLE

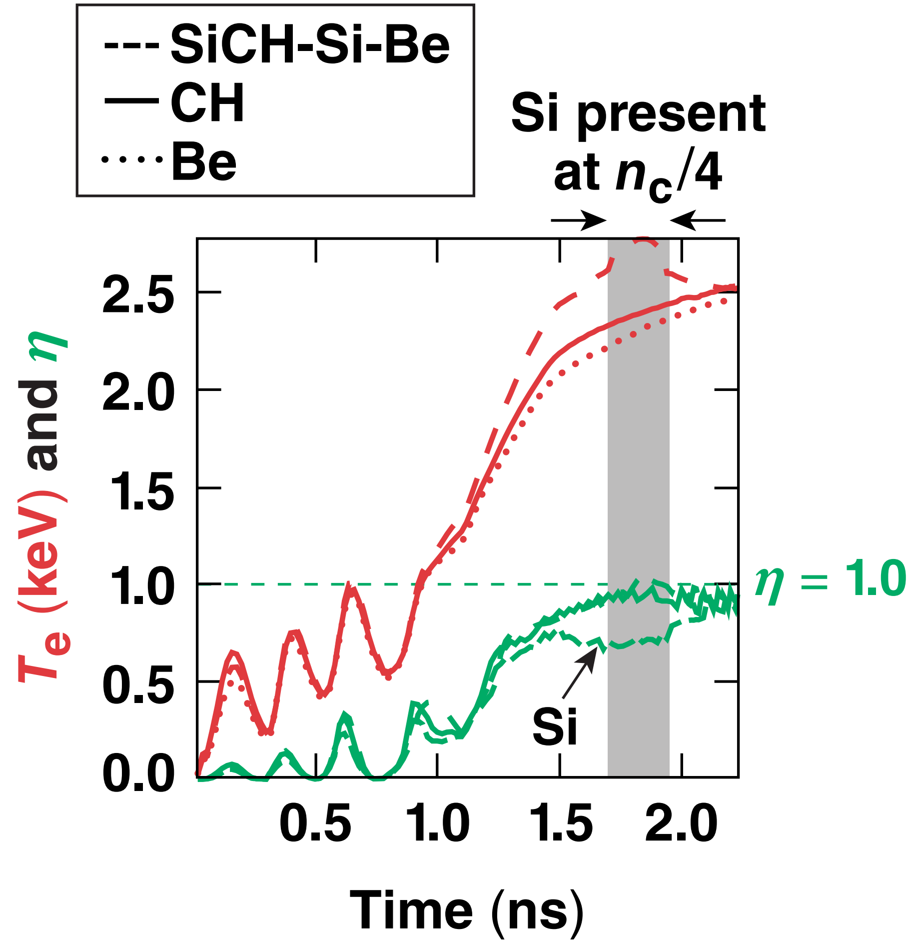
- 1-D *LILAC* (with CBET, no TPD)
- The coronal temperature is predicted to increase in the Be-Si-CHSi target

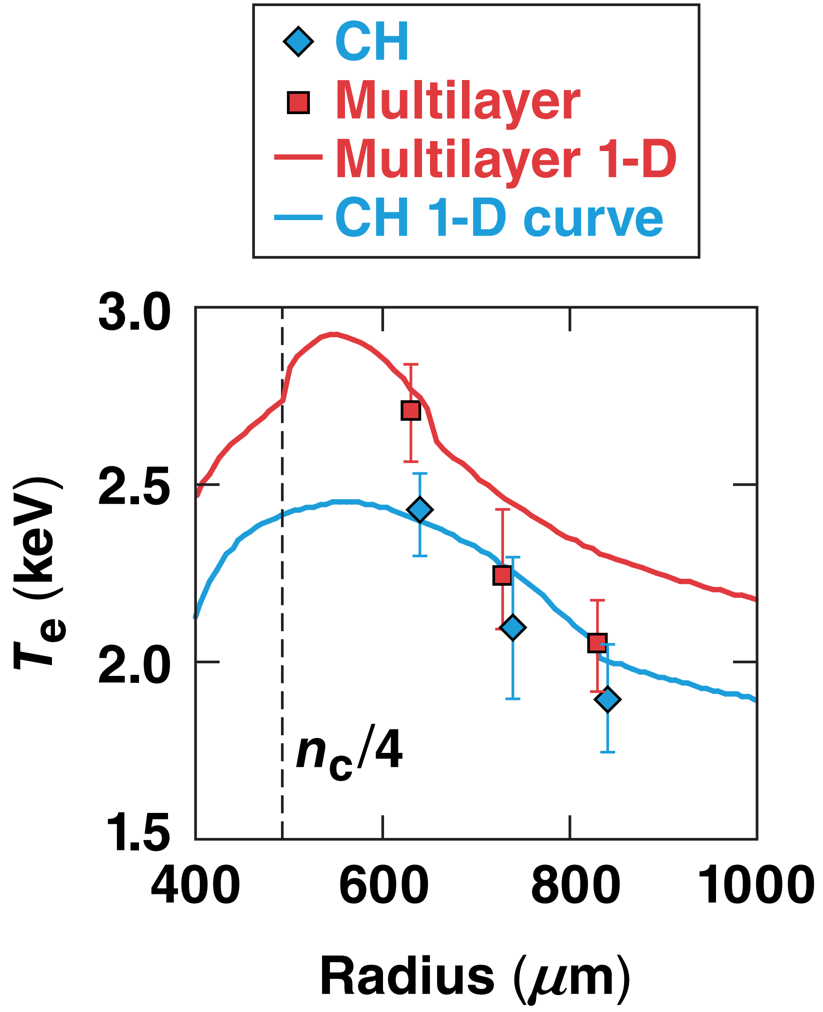


TC12162b

Based on *LILAC* predictions, the Be-Si-CHSi target is anticipated to excite the least TPD hot electrons

- The "strength" of TPD should depend on the quantity $\frac{IL_n}{T_e}$
- The linear threshold parameter for a single beam is $\eta = \frac{I_{14} L_{n,\mu m}}{230\, T_{e,\mathrm{keV}}}$*
- IL/T_e varies little during the main pulse because temperature increases compensate for the scale length



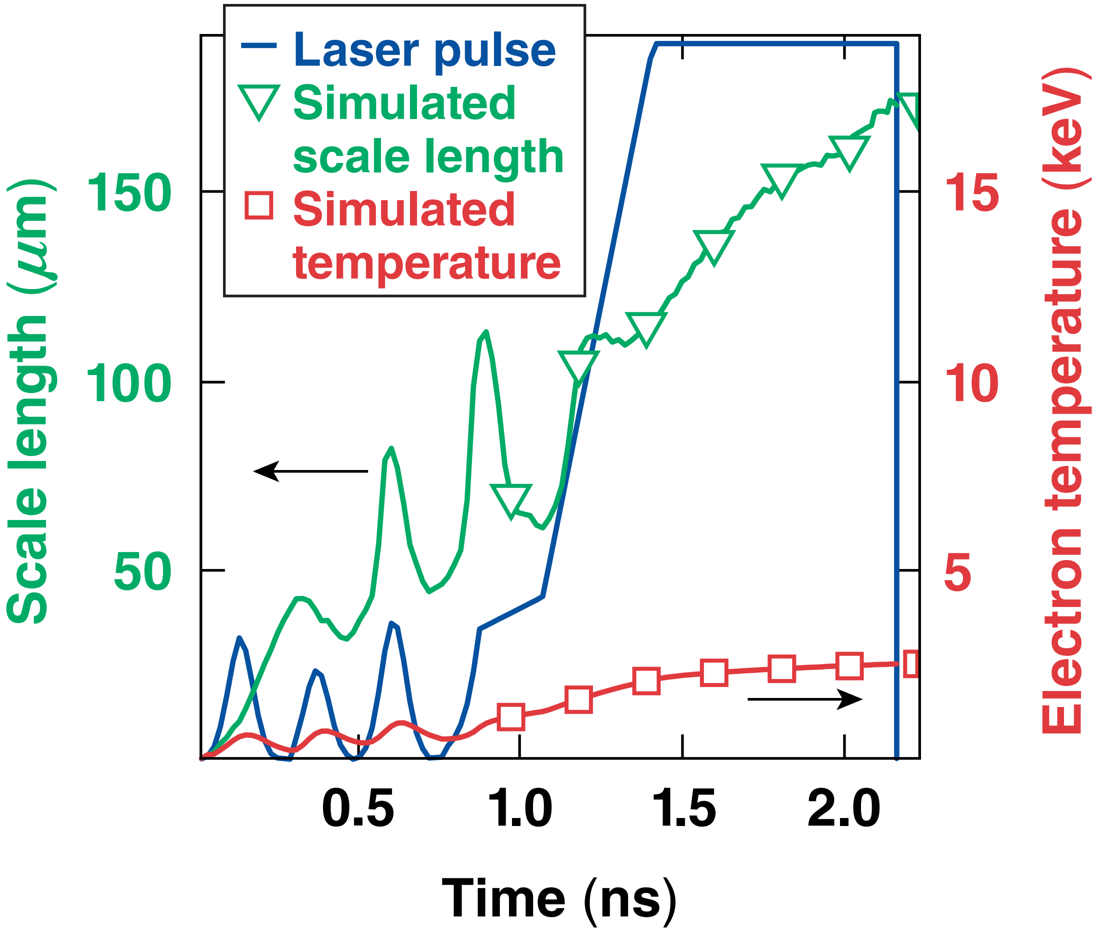


*A. Simon *et al*., Phys. Fluids 26, 3107 (1983); D. H. Froula *et al*., NO5.00001, this conference.

TC12164b

Each target is simulated by *LPSE* to quantify the expected hot-electron production using the *LILAC* hydrocode

- The simulations take advantage of the separation between hydro and LPI time scales
- The duration of the implosion is broken up into several runs chosen to sample the main pulse (markers)
- The hydrodynamic variables are "frozen" over the duration of the *LPSE* simulation

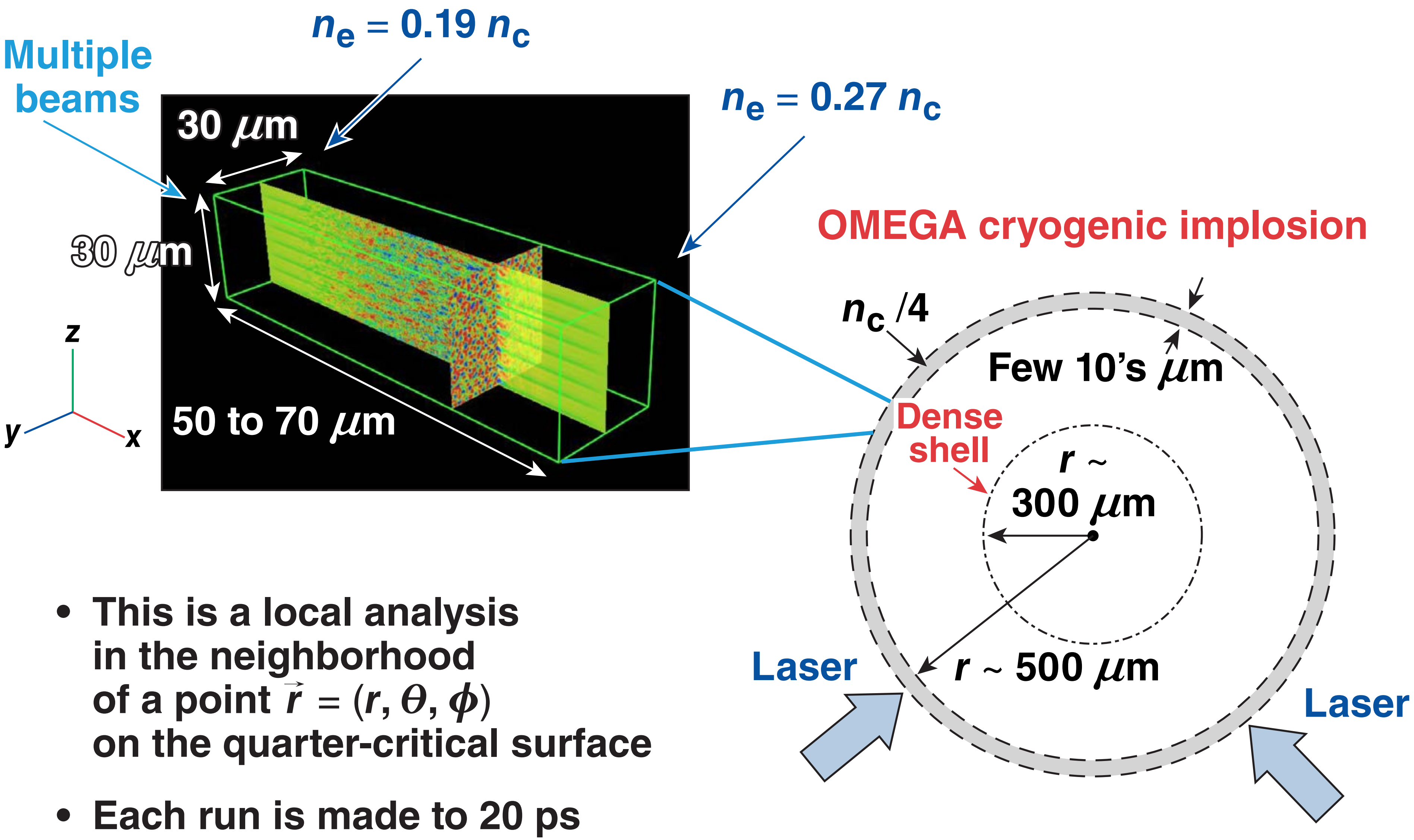


- For each simulated time, six different locations near the $n_c/4$ surface were computed [using a distributed polarization rotator (DPR) model]

TC12165b

Each simulation is carried out in a 3-D simulation box that is typically ~100 × 100 × 200 λ_0^3 in volume

UR LLE

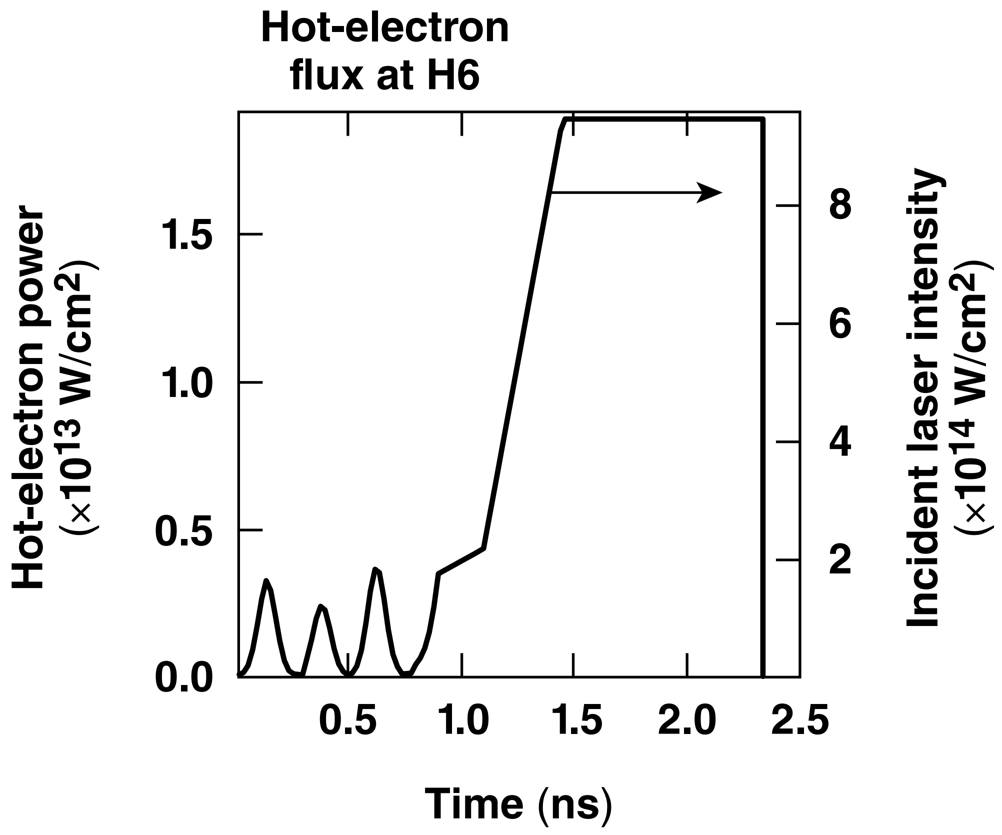


- This is a local analysis in the neighborhood of a point $\vec{r} = (r, \theta, \phi)$ on the quarter-critical surface
- Each run is made to 20 ps

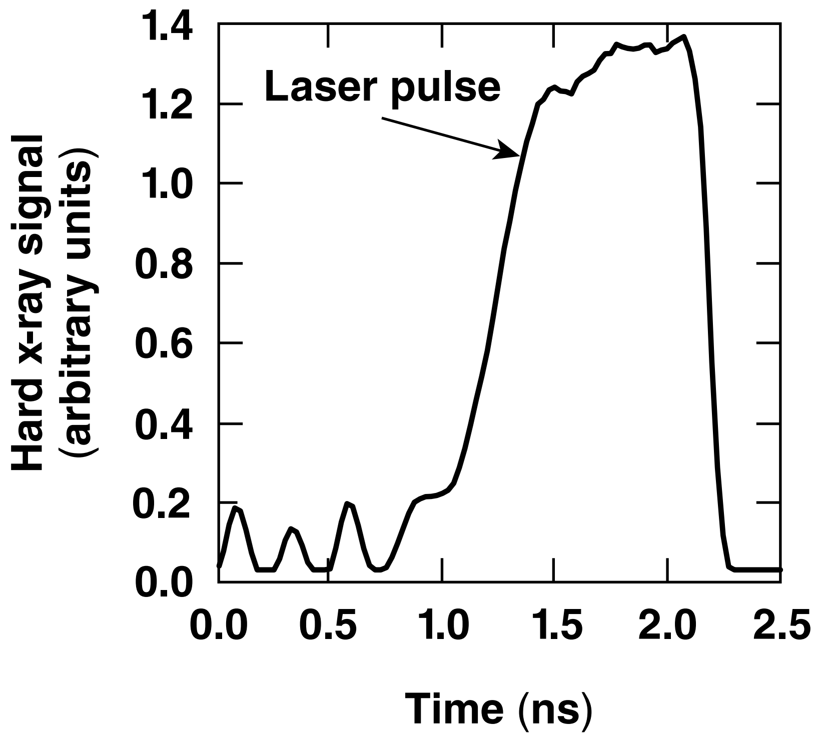
TC11243d

LPSE simulations predict a strong reduction of TPD hot electrons in the Be-Si-CHSi design

LPSE simulation



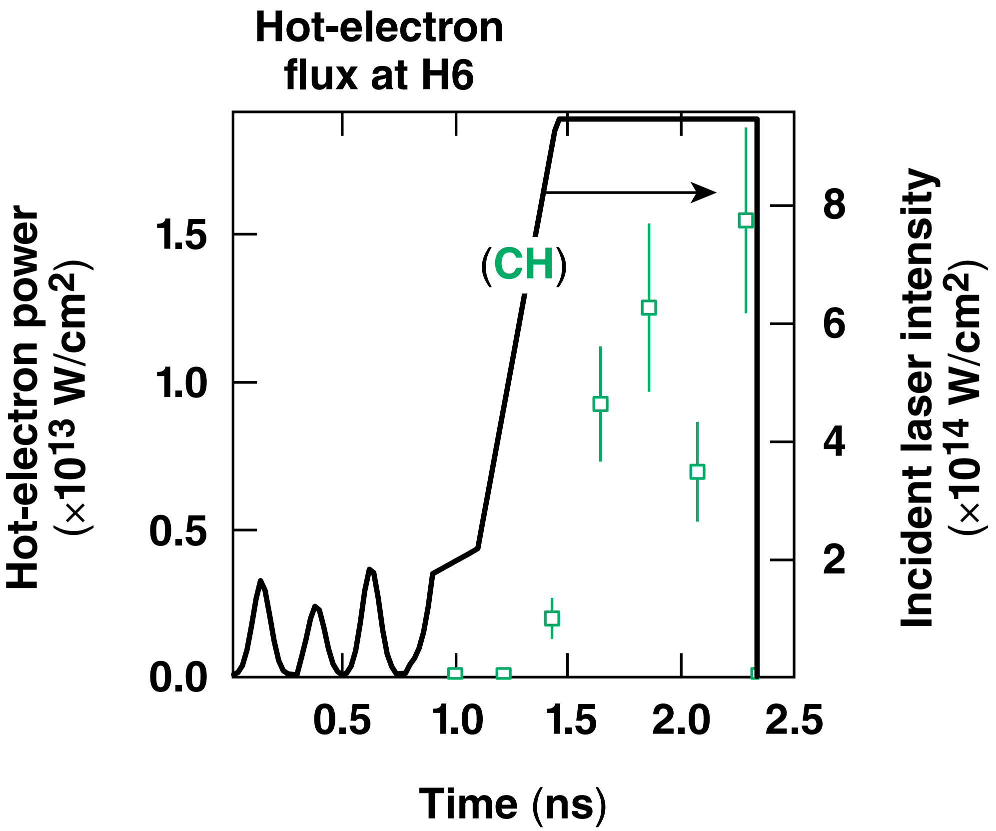
OMEGA experiment



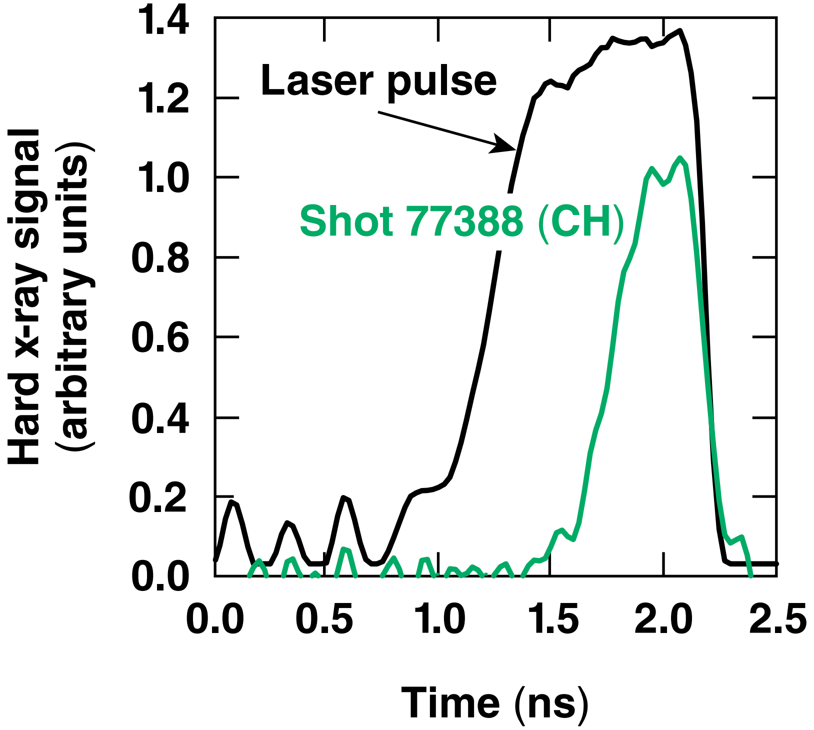
TC12168e

LPSE simulations predict a strong reduction of TPD hot electrons in the Be-Si-CHSi design

LPSE simulation



OMEGA experiment

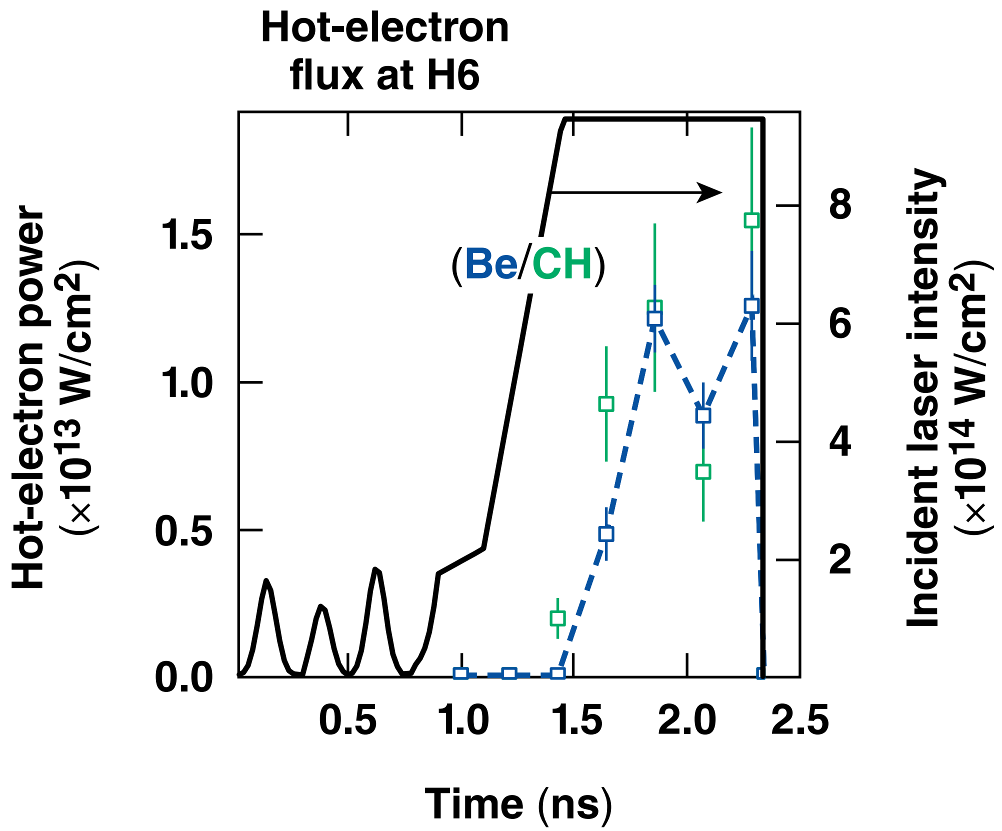


TC12168f

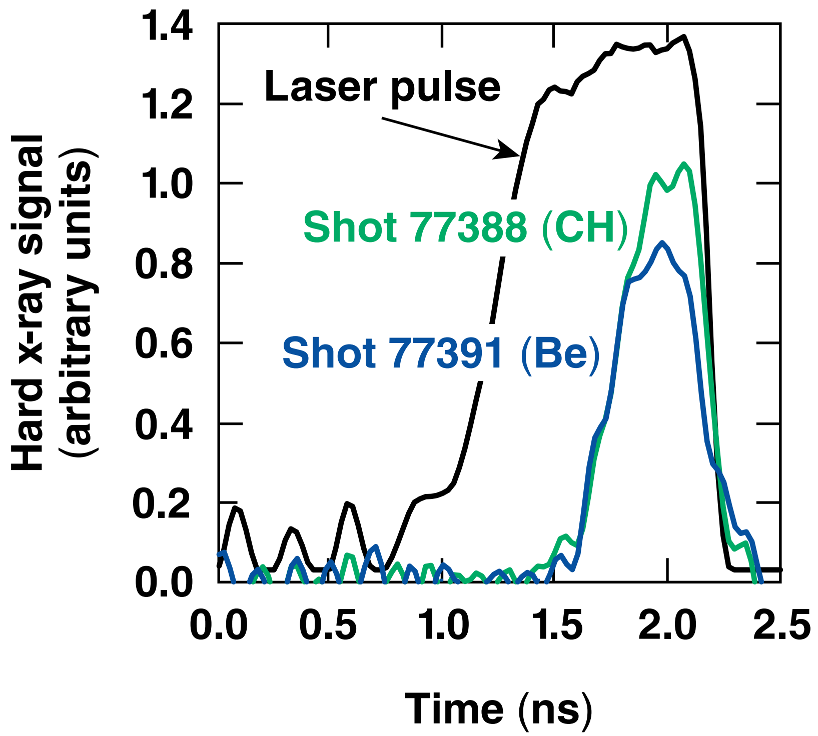
LPSE simulations predict a strong reduction of TPD hot electrons in the Be-Si-CHSi design

- CH and Be targets produce similar hot-electron fluxes

LPSE simulation



OMEGA experiment

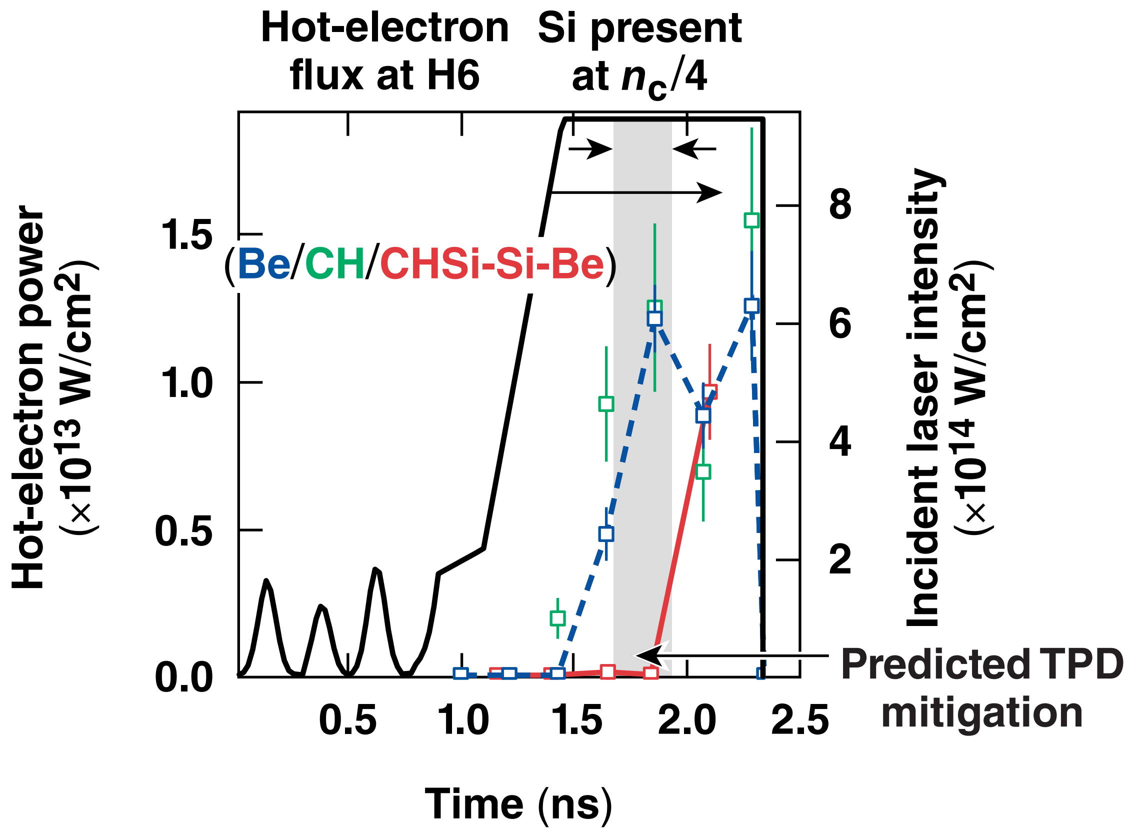


TC12168g

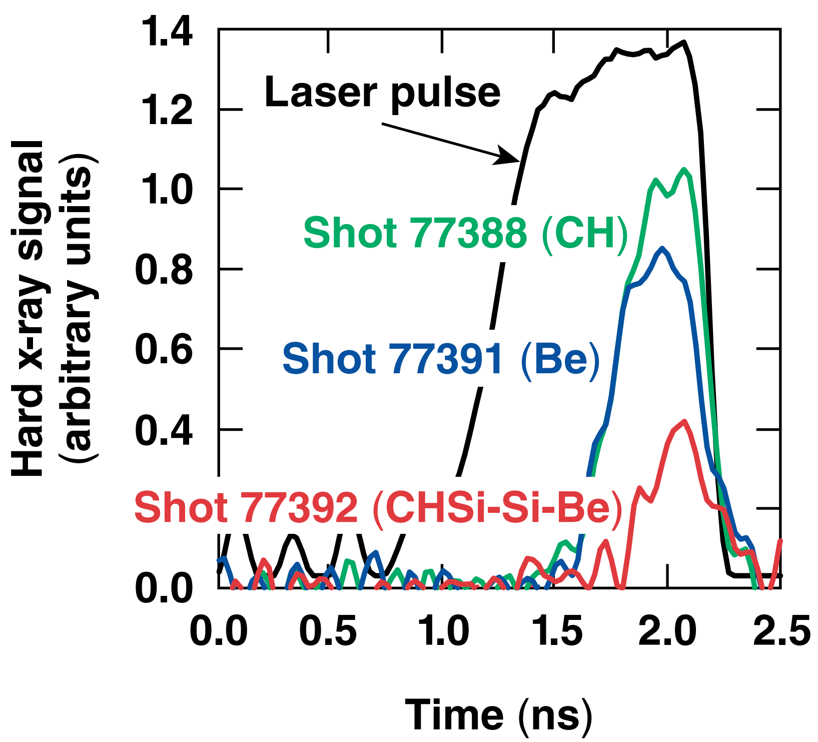
LPSE simulations predict a strong reduction of TPD hot electrons in the Be-Si-CHSi design

- The multilayer target produces hot electrons only when Si leaves the $n_c/4$ region

LPSE simulation



OMEGA experiment



The simulations are remarkably consistent with the experiment.

TC12168h

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