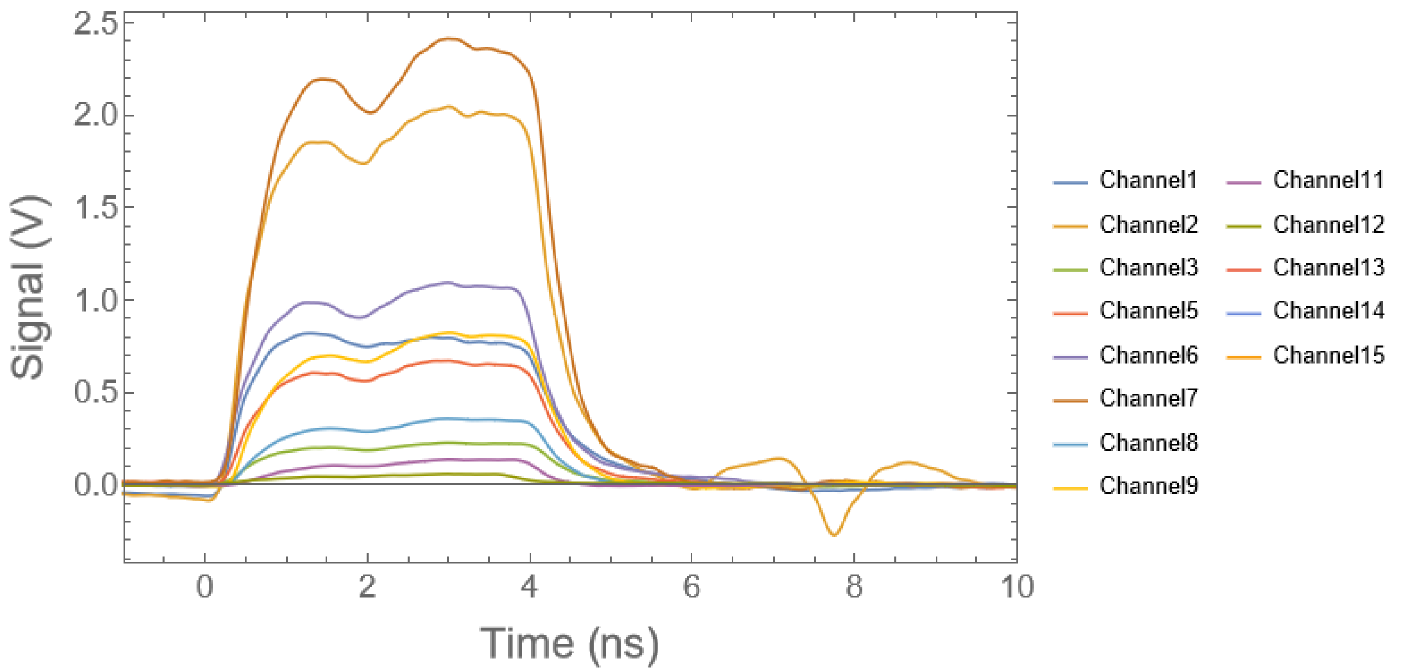
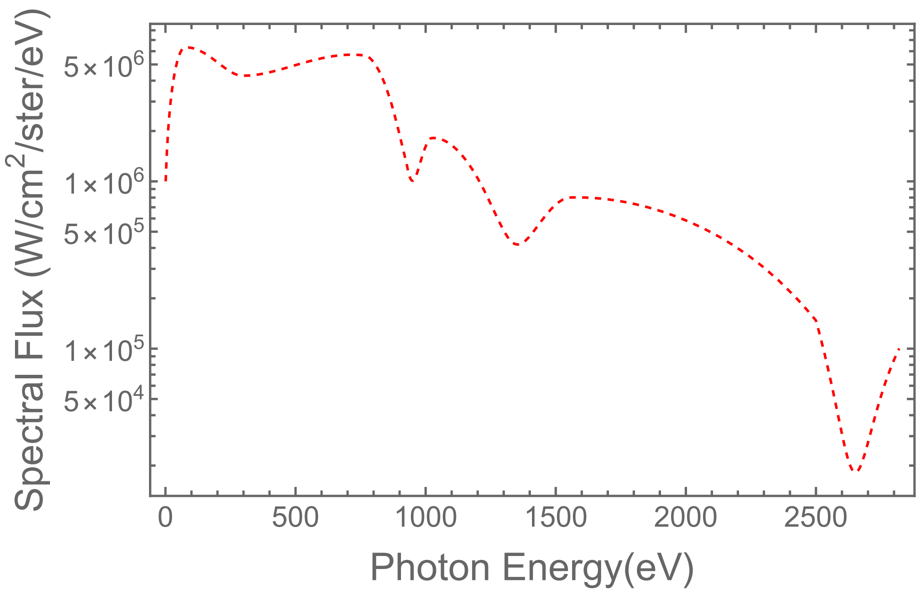
Determining X-ray conversion efficiency of direct drive implosions using Cubic Spline Unfolds of the Dante diagnostic



t = 1.0 ns



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A conversion efficiency from laser light to x-rays of ~5% is relatively independent of laser intensity for solid CH sphere ICF targets

- **Large laser intensities seem to decrease the conversion efficiency despite having higher peak x-ray power**
- **X-ray flux curves have the same functional shape but with higher power at higher laser intensities**
- **Conversion efficiency is independent of the time evolution of the coronal plasma for solid CH targets at low intensities, but varies at intensities ~10^{15} W/cm^2**

Collaborators

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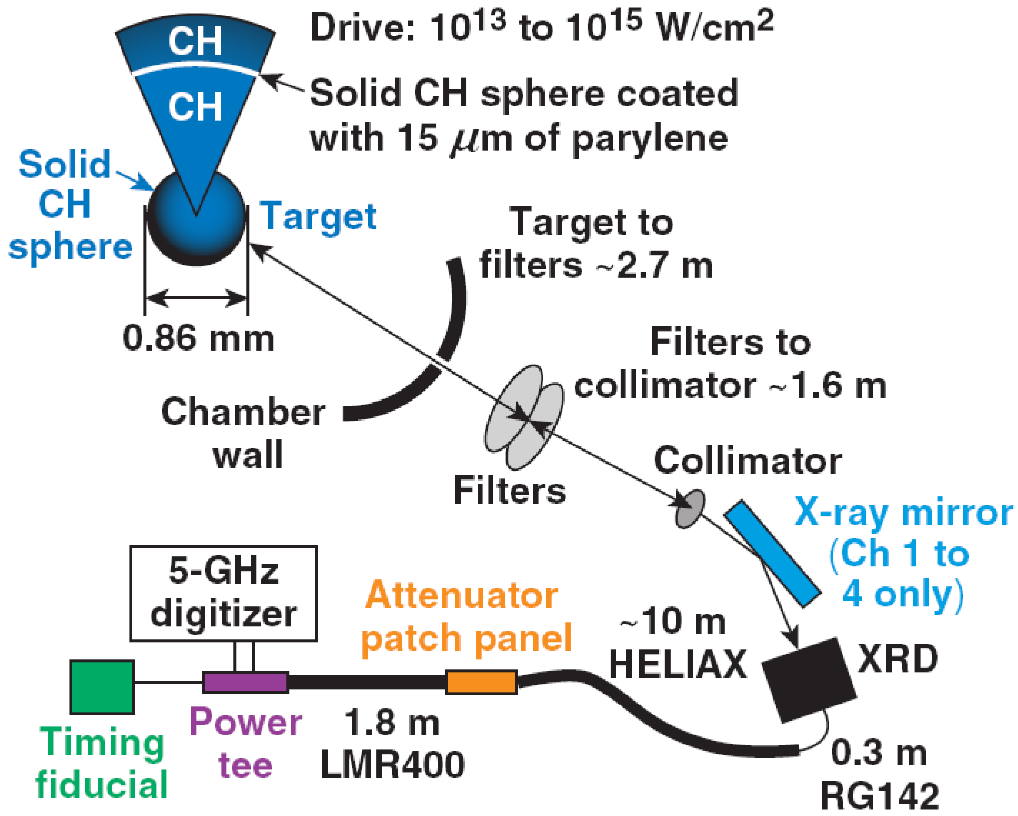
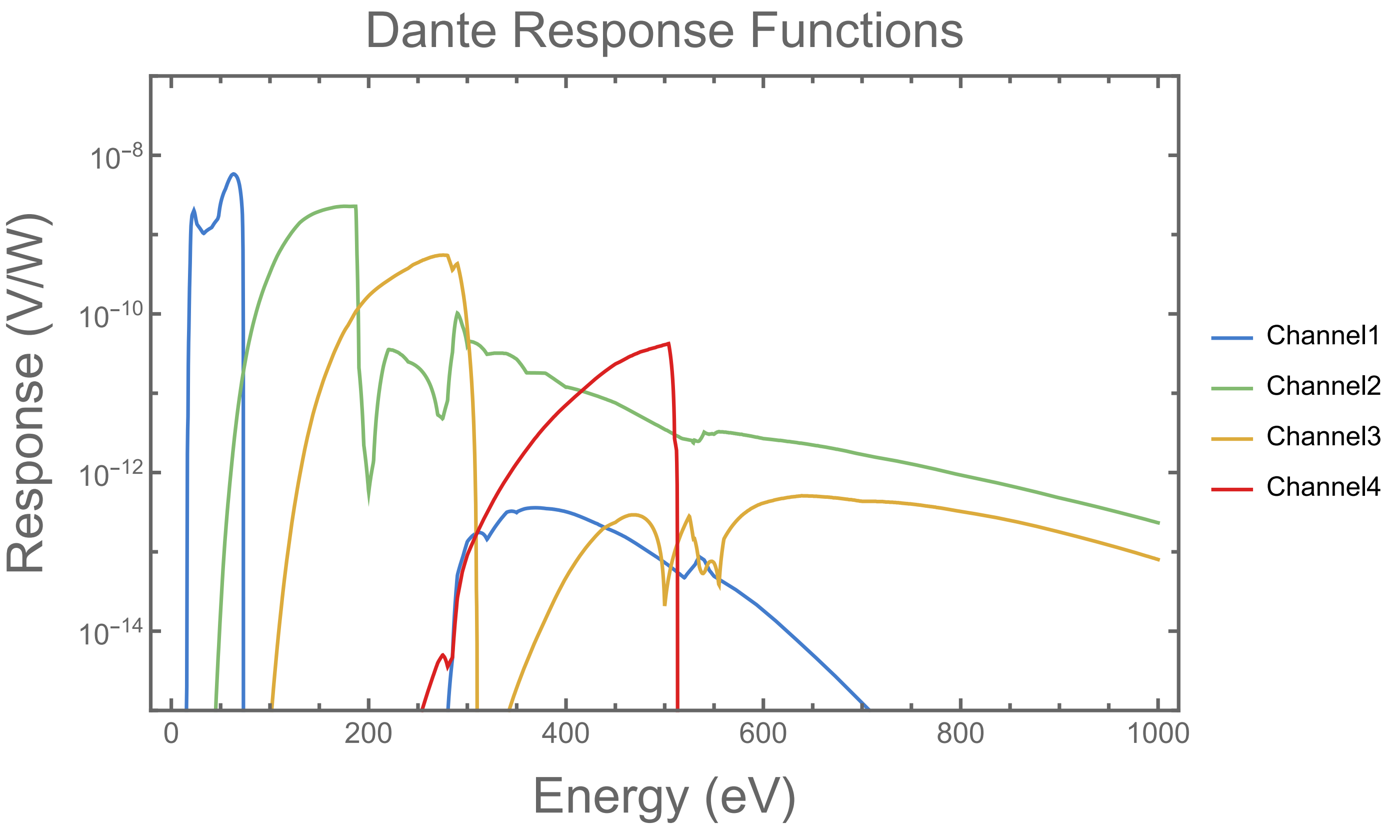
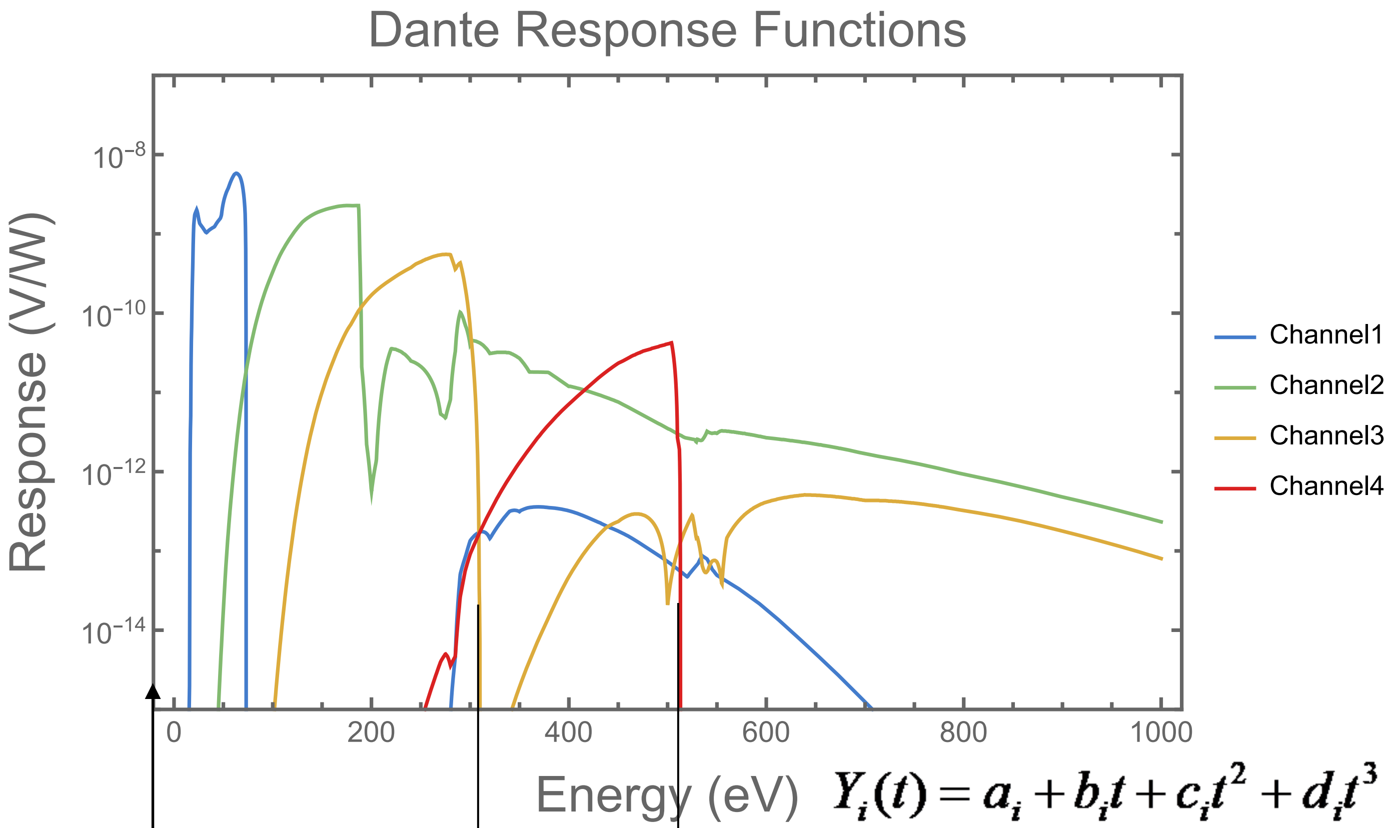
Solid sphere CH targets were illuminated at intensities of 10^{13} – 10^{15} W/cm^2 and broadband spectral flux was measured using 15 channels of the Dante diagnostic

- **Each channel of Dante looks at a specific photon energy band (i.e. channel 2 has peak response 150-180eV)**

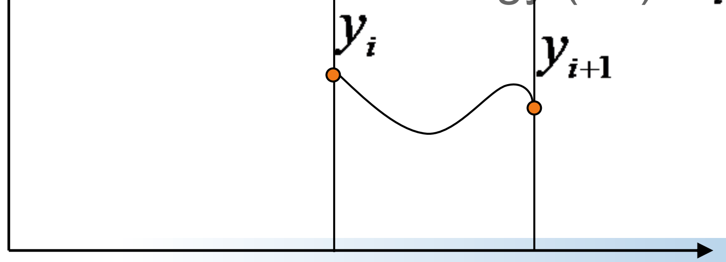




FIDUCIA*: Filtered X-ray Diode Unfold Using Cubic Interpolation Algorithm was used to unfold the voltage traces of Dante diodes into x-ray flux



$$Y_i(t) = a_i + b_i t + c_i t^2 + d_i t^3$$



$$t(E) = \frac{E - E_i}{E_{i+1} - E_i}$$

- Assume the flux is represented by a cubic function between the K-edges of each channel
- Each channel voltage can be represented by integrating over each cubic interval:

$$V_j = \int_0^\infty Y(t(E)) R_j(E) dE = \sum_i y \int_0^\infty [A(t) + TD_y^{-1} TD_{y'} B(t)] R_j(E) dE$$

- Solutions are found such that the spline is positive over the entire photon energy range and minimizes the differences between measured voltages
- FIDUCIA is available to download!
  - <pip install fiducia>
  - https://pypi.org/project/fiducia/

* Barnak D. H., et al. Rev. Sci. Instrum. 91(7): 073102 (2020)

FIDUCIA includes error analysis using a forward propagated Monte Carlo technique based upon matrix inversion

- The matrix of the cubic spline is modified with random samples within the error of the response functions
- The matrix is then inverted to obtain the distribution of matrix elements related to the solution space
- These distributions are then used to calculate the error in x-ray power and radiation temperature analytically

Obtained via MC

$$\sum_j M_{ij} V_j = y_i \quad \sigma_{y_i}^2 = \sum_i \left[(M_{ij} V_j)^2 \left[\left(\frac{\sigma_{M_{ij}}}{M_{ij}} \right)^2 + \left(\frac{\sigma_{V_j}}{V_j} \right)^2 \right] \right]$$

$$\sigma_{a_i} = \sigma_{y_i} \qquad \sigma_{b_i}^2 = \sigma_{D_i}^2 = \sum_j \left(TD_{y'}^{-1} TD_y \right)^2 \sigma_{y_j}^2$$

$$\sigma_{c_i}^2 = 3^2 \sigma_{y_{i+1}}^2 + 3^2 \sigma_{y_i}^2 + 2\sigma_{D_i}^2 + \sigma_{D_{i+1}}^2$$

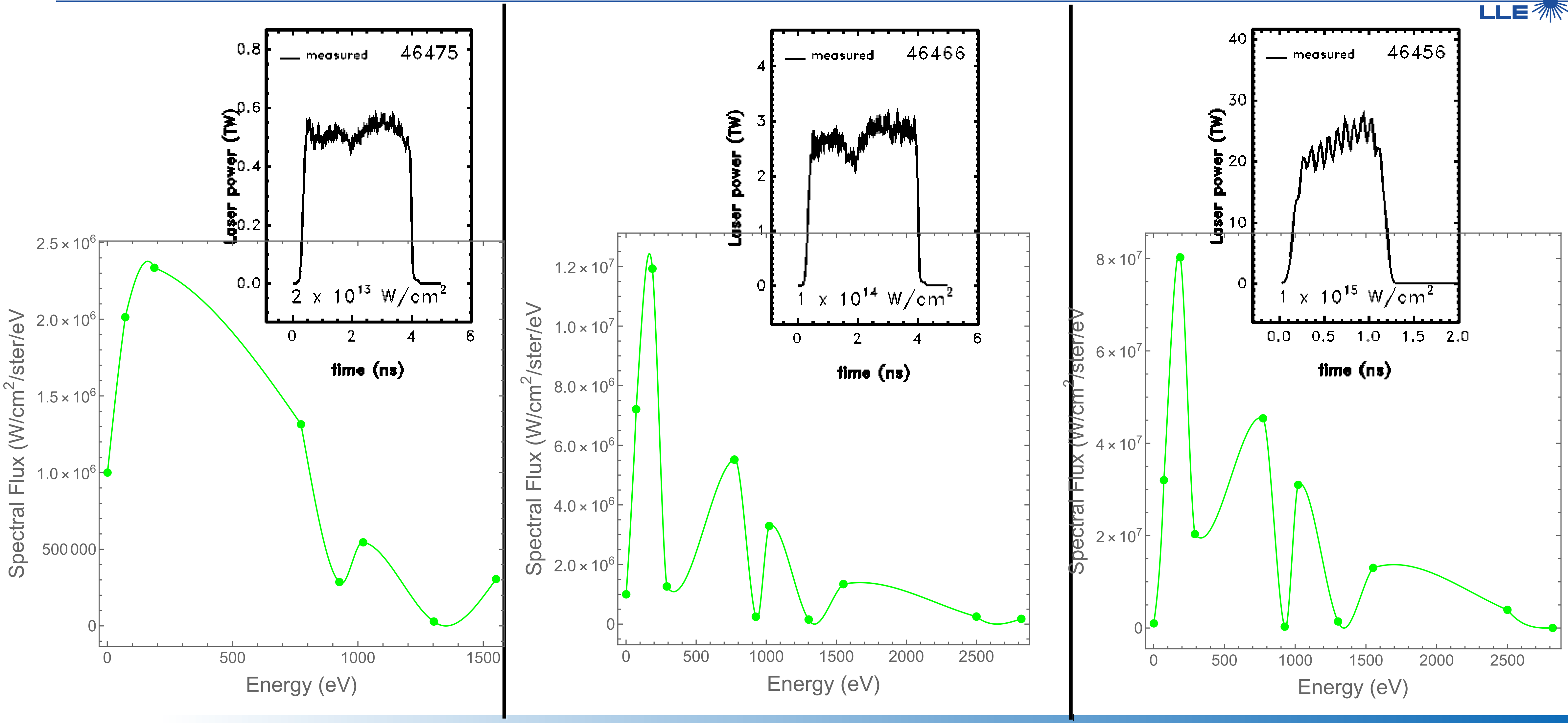
$$\sigma_{d_i}^2 = 2^2 \sigma_{y_i}^2 + 2^2 \sigma_{y_{i+1}}^2 + \sigma_{D_i}^2 + \sigma_{D_{i+1}}^2$$

Analytical error calculation of radiated x-ray power

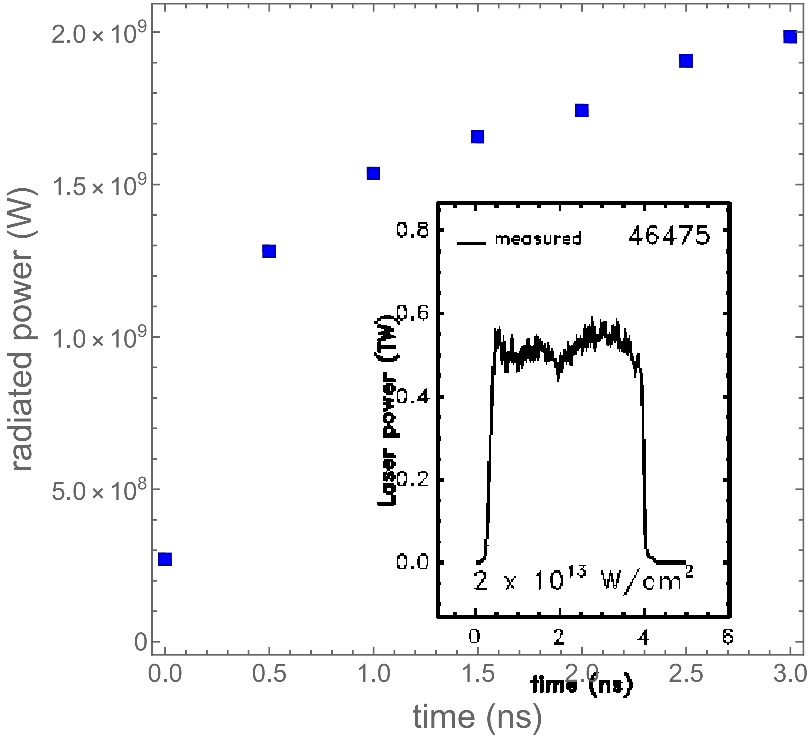
$$P = \sum_i P_i = \sum_i (E_{i+1} - E_i) \int_0^1 a_i + b_i t + c_i t^2 + d_i t^3 dt = \sum_i (E_{i+1} - E_i) * \left(a_i + \frac{b_i}{2} + \frac{c_i}{3} + \frac{d_i}{4} \right)$$

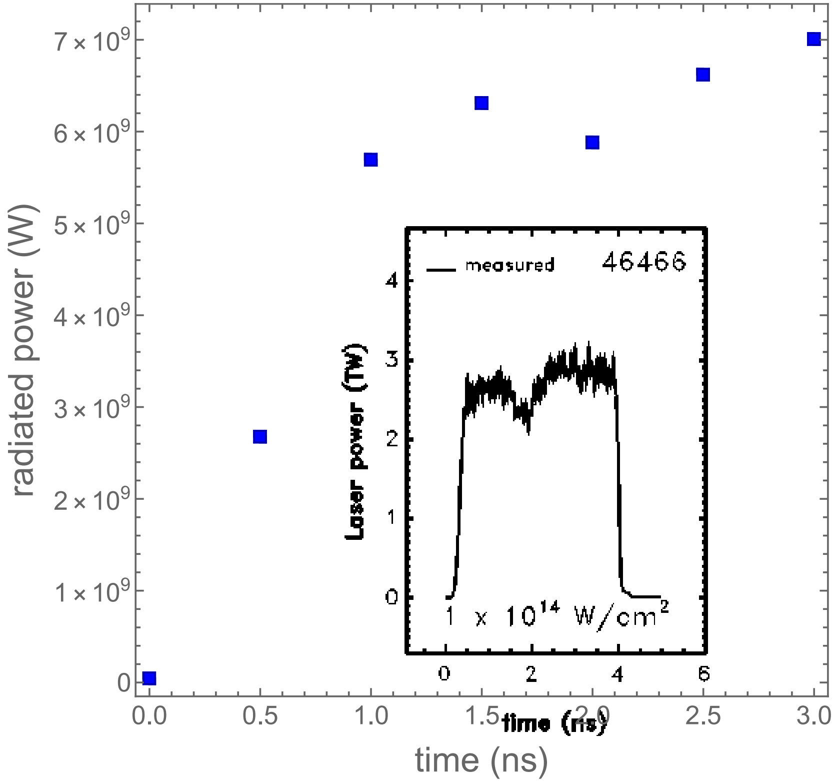
$$\sigma_{P_i}^2 = (E_{i+1} - E_i)^2 * \left(\sigma_{a_i}^2 + \frac{\sigma_{b_i}^2}{2^2} + \frac{\sigma_{c_i}^2}{3^2} + \frac{\sigma_{d_i}^2}{4^2} \right)$$

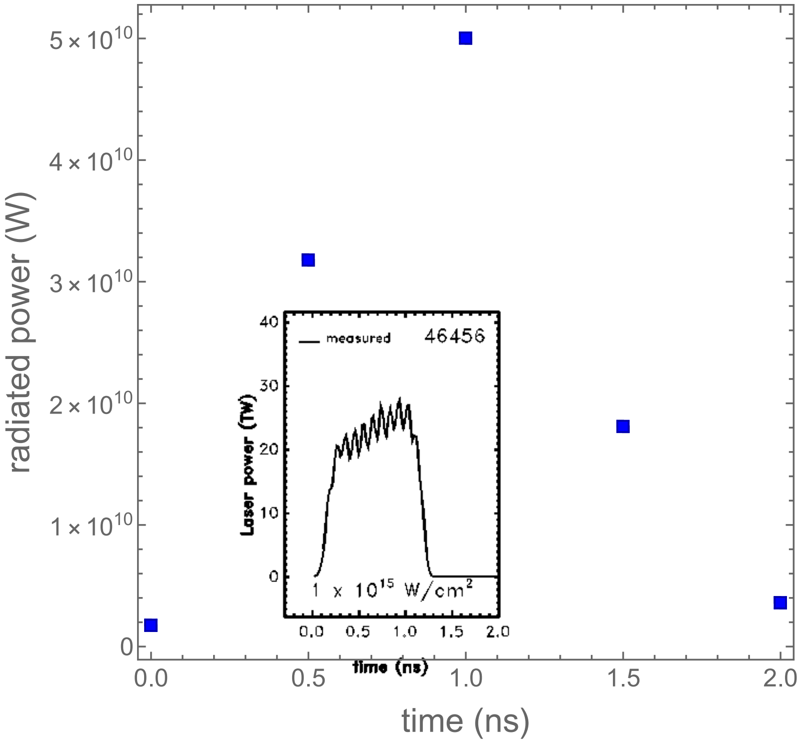
X-ray flux unfolds for 3 different intensities for t = tpulse/2



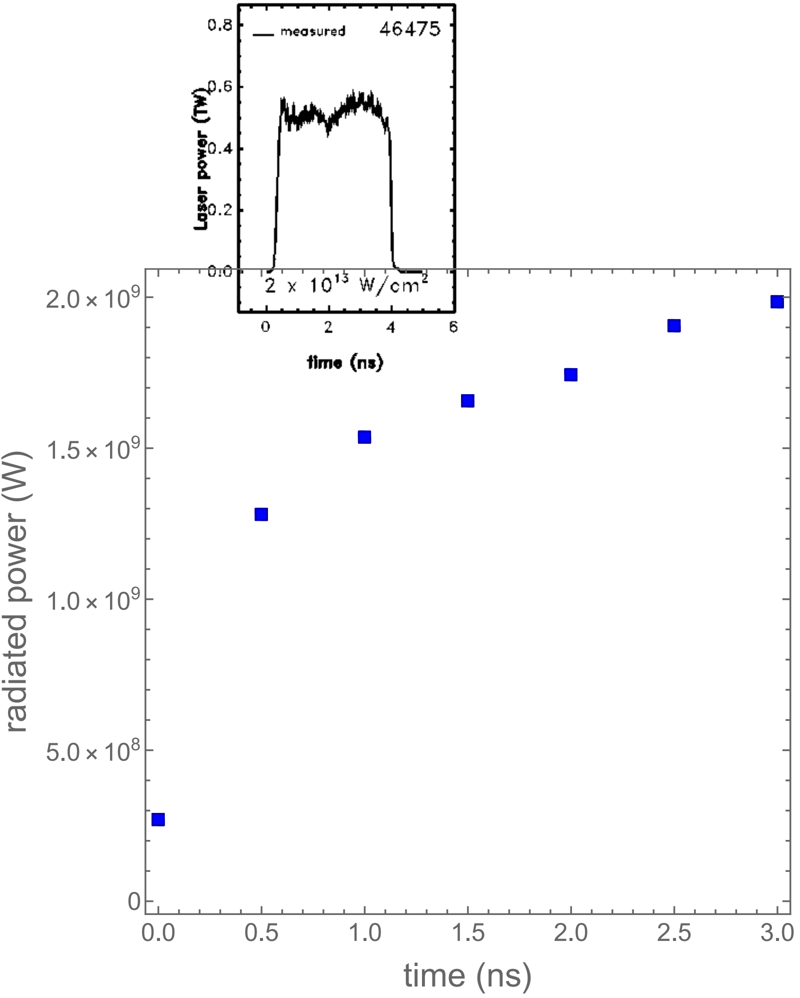
Radiated power during the main pulse is constant at low intensities and peaked at higher intensity

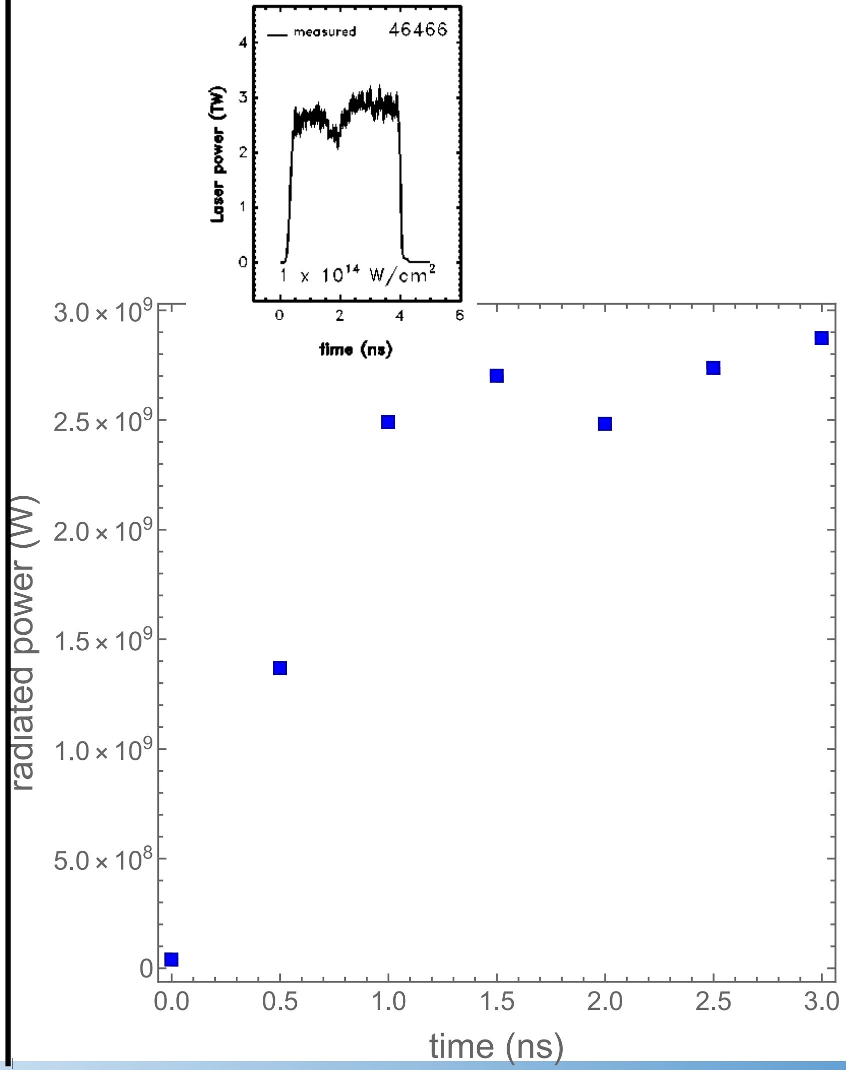


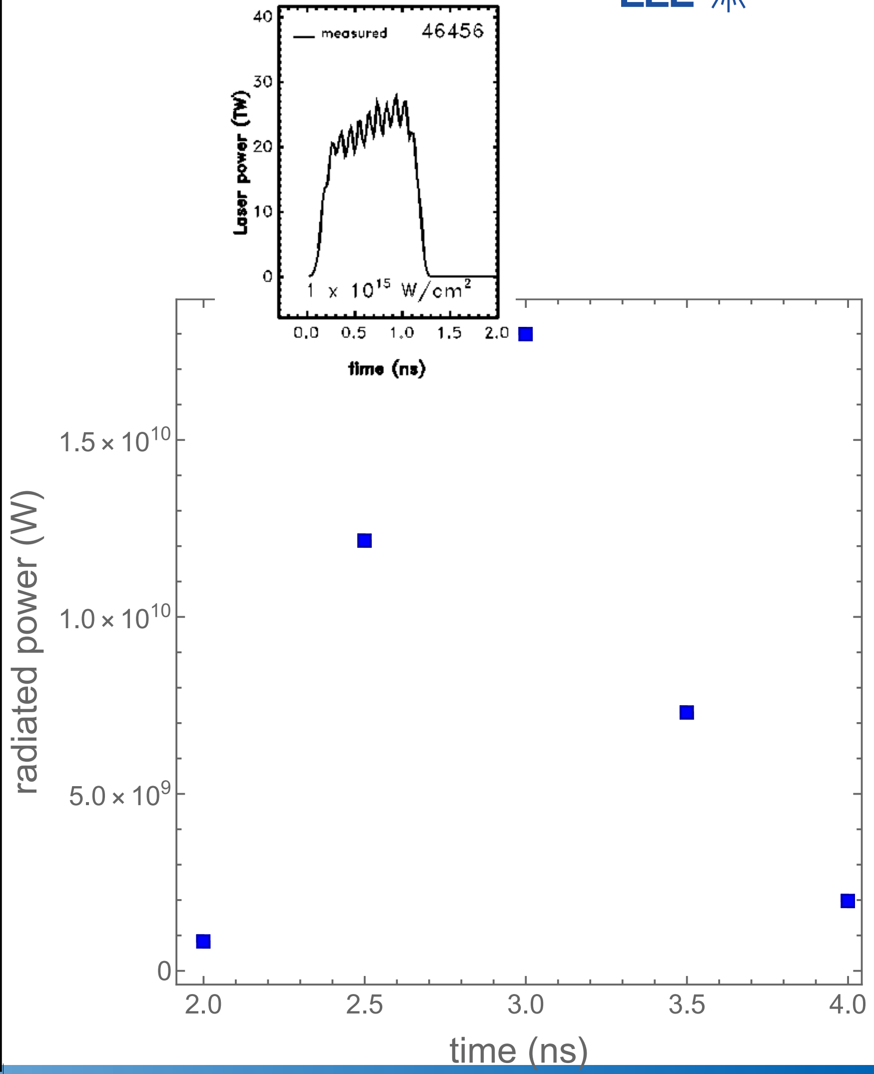




Carbon K-shell emissions for 3 different intensities (1-500eV)

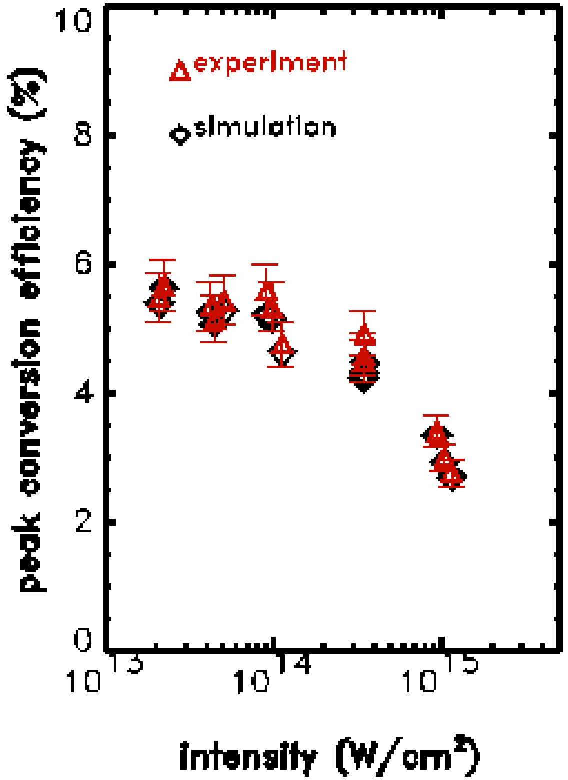






Conversion efficiency is higher at lower intensities; more x-ray production per Joule at lower intensity

- Peak x-ray power is higher for high intensity pulses
- More x-ray energy per Joule of laser energy is radiated by the ablated sphere at lower intensity



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