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328Post shot analysis of plasma conditions of Au Spheres illuminated by the URLLE Omega laser, as measured via Thomson scattering

M. D. Rosen, J. S. Ross, H. A. Scott, N. Landen, E. Dewald, D. Froula, M. May, K. Widmann

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Disclaimer

Post shot analysis of plasma conditions of Au Spheres illuminated by the URLLE Omega laser, as measured via Thomson scattering

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Lawrence Livermore National Laboratory

LLNL-PRES-xxxxxx

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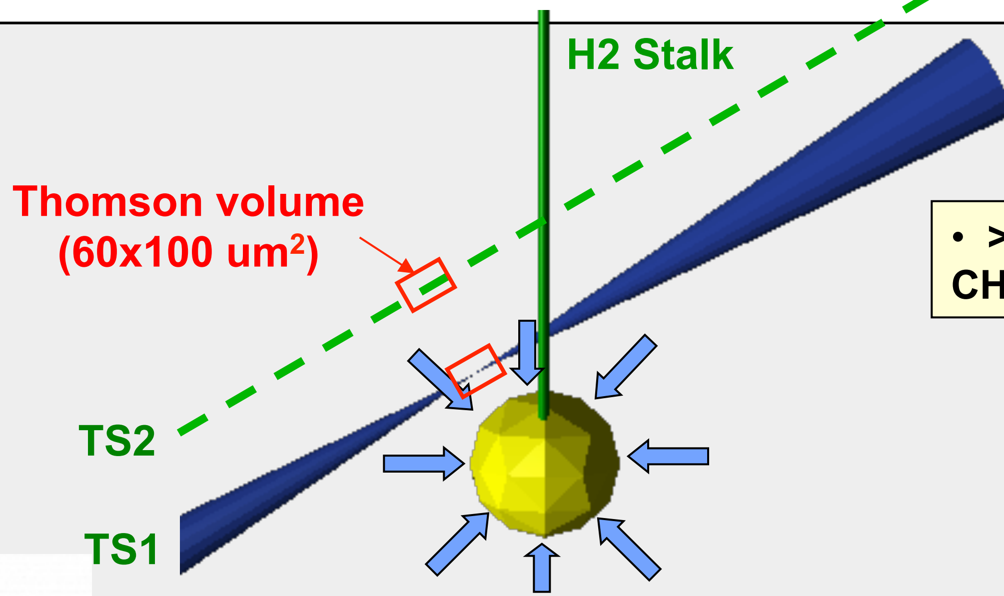
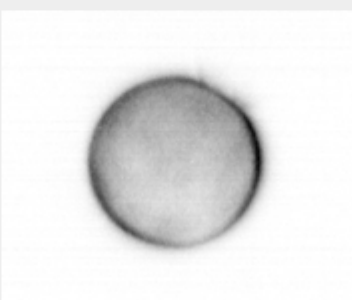
Abstract

- Recently there was a follow up to the 2006 campaign to illuminate 1 mm diameter gold spheres using the Omega laser at LLE.
- The 2013 campaign uses Thomson scattering to diagnose the plasma conditions as a function of time, at various radial positions in the coronal, laser heated, blow-off region.
- Laser irradiances were 1, 5, and 10 x 10^{14} W/cm^2, usually in a 1 ns pulse duration. Depleted uranium (DU) and Ag spheres were also tested.
- We compare the predictions of plasma conditions using various non-LTE computational models of atomic physics and electron transport (as implemented into the rad-hydro code Lasnex) to this data.
- The “high flux model (HFM)” (DCA atomic physics and non local transport) compares well for some of experiments, while an intermediate model that radiates a bit less total x-ray fluence than the HFM, does better on other experiments.

The 2013 Omega Sphere Campaign bolsters the 2006 x-ray data, with Thomson Scattering for plasma conditions



- > 5 um Au, DU, Ag coating on CH mandrels, 1 mm OD



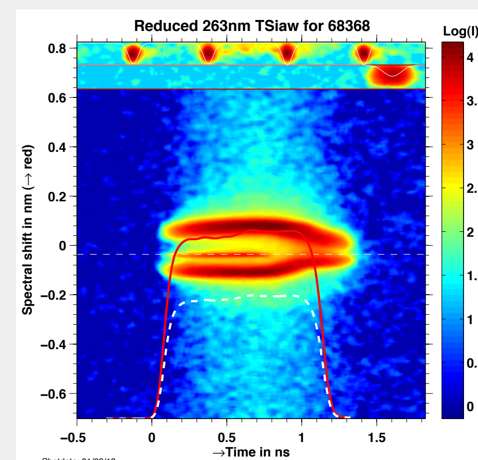
XRPHC Image 1E14

LASER DRIVE: 59 beams (+4w TS probe)

10^{14} W.cm^{-2} / 3 ns square, 180 J/beam

5×10^{14} W.cm^{-2} / 1 ns square, 250 J/beam

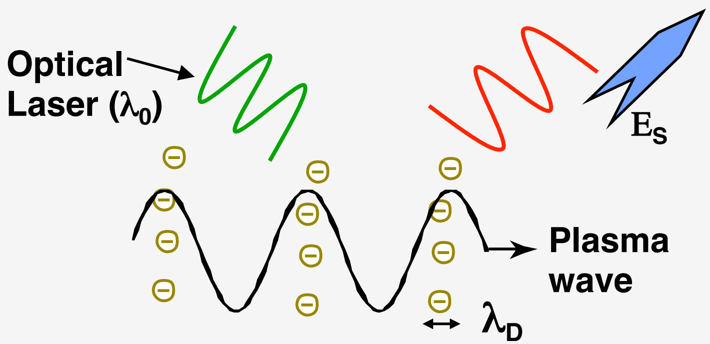
10^{15} W.cm^{-2} / 1 ns square, 500 J/beam



TS spectra vs time

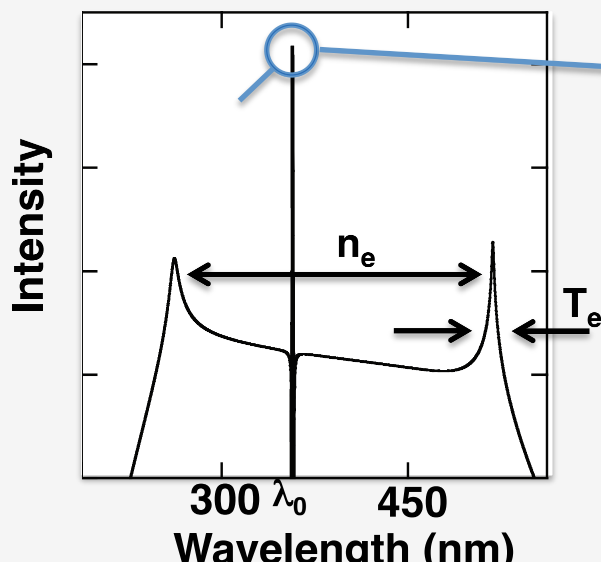
Thomson scattering (TS) provides a local measurement of the plasma conditions with high accuracy

Thomson scattering is the scattering of an electromagnetic wave by free electrons.

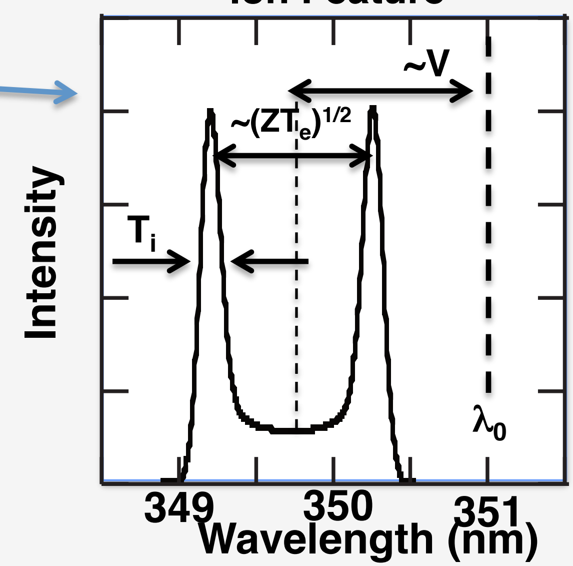


$$S(\mathrm{k},\omega)=\frac{2\pi}{k}\left|1-\frac{\chi_e}{\varepsilon}\right|^2 f_e\left(\frac{\omega}{k}\right)+\frac{2\pi Z}{k}\left|\frac{\chi_e}{\varepsilon}\right|^2 f_i\left(\frac{\omega}{k}\right)$$

Electron Feature



Ion Feature



xxxx

In 2006 we did ***not*** measure plasma conditions

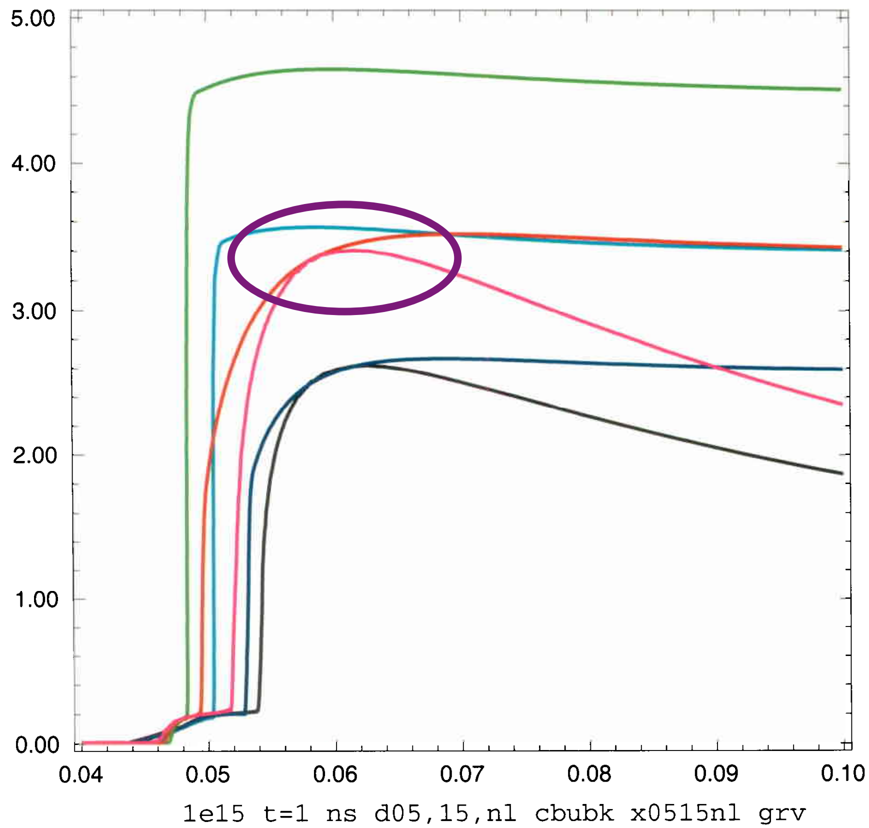
- 2006: Dante X-ray Emission: (no TS data used): Total, and M-band
- Irradiance: 1 x 10^{15} W/cm^2, 1 ns pulse & 1 x 10^{14} W/cm^2 , 3 ns pulse
- Elements: Au, DU, Cocktail
- Concluded: (via Lasnex modeling 1-D sphere, well resolved: 400 zones)
  - f = 0.15 (or eventually, non-local) needed
  - Spectral shape, and ~ M–band, better (but not perfect) with DCA
  - Did ***not*** discriminate between models (at the ~ 10% level) with respect to the total emission (Dante & absorption error bars…)
    - Eventually: HFM matched NIC empties, & later applied to gas filled
    - Recently: HFM matches IDXP, yet 0.85 multiplier needed for NIC

Measuring plasma conditions would discriminate between models

Te profiles at 1 ns for Au Sphere at 1 10^{15} W/cm^2

Te (keV) vs. radius at 1 ns

Te (keV)



Radius (cm)

XSN f=0.05

DCA f=0.05
XSN f=0.15
XSN non-local

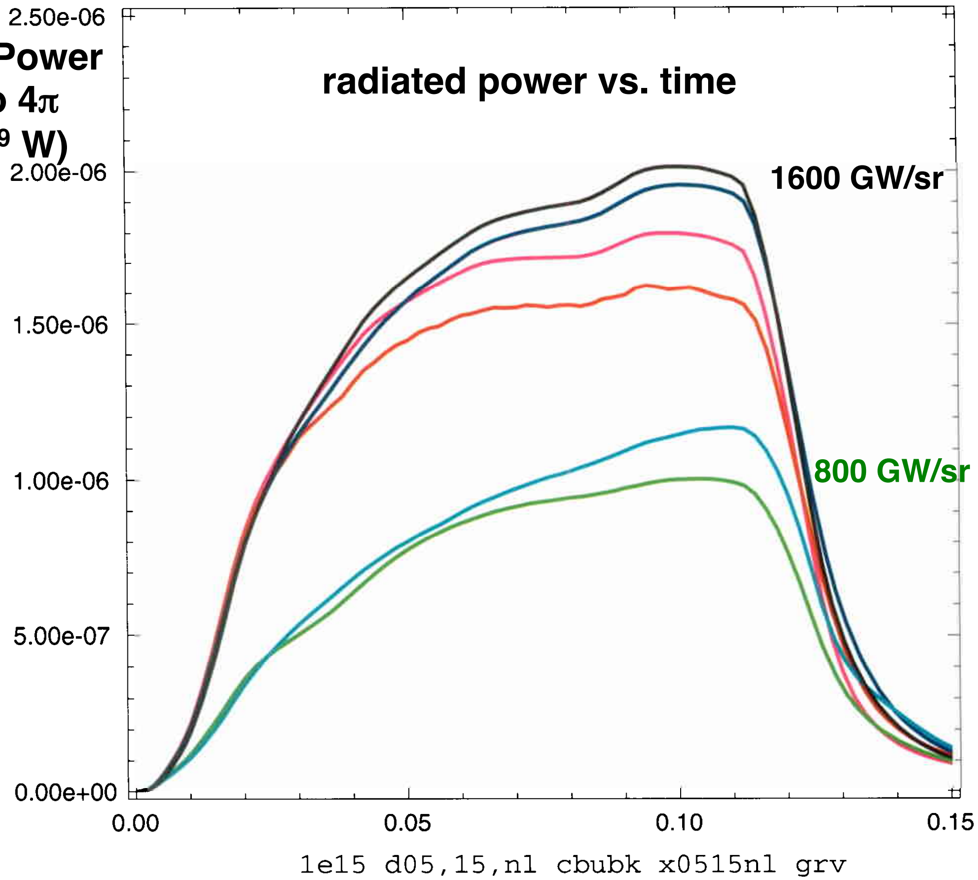
DCA f=0.15

DCA non-local ("HFM")

n.b.: Degeneracy of 3 intermediate models: Less radiated than the HFM, so it gets hotter

Radiation from 10^{15} W/cm^2 Au Sphere implies High Electron Thermal Flux

Total Power into 4π (10^{19} W)



Time (10^{-8} s)

Au Omega Sphere 1 10^{15} W/cm^2 Post shot

DCA non-local ("HFM")
DCA f=0.15

XSN non-local
XSN f=0.15

DCA f=0.05
XSN f=0.05

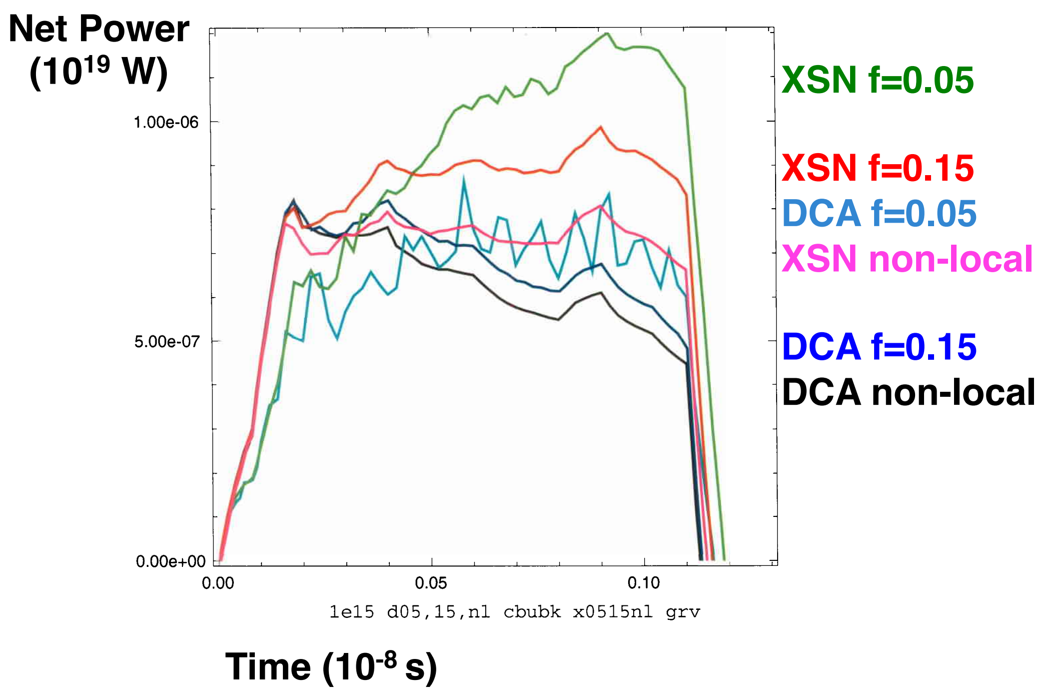
The 2006 Dante fluence of ~ 1550 GW/SR ruled out f = 0.05

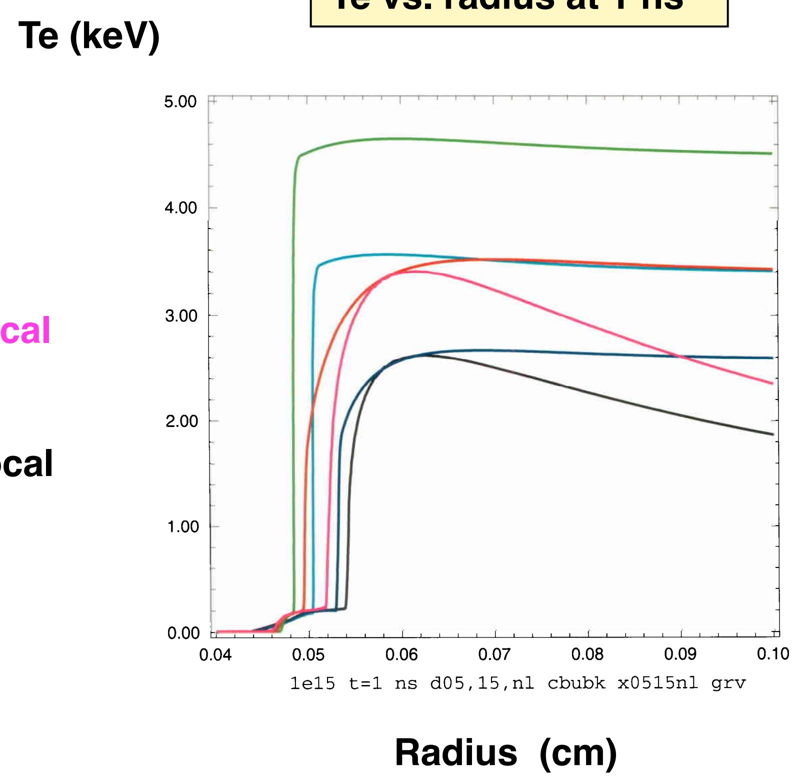
Net (= absorbed – radiated) Power Remaining in the Au Sphere determines Te

Au Omega Sphere 5 10^{14} W/cm^2 **Post shot**

Net Power Remaining vs. time

Te vs. radius at 1 ns





This "net power remaining" ~ correlates with T_e

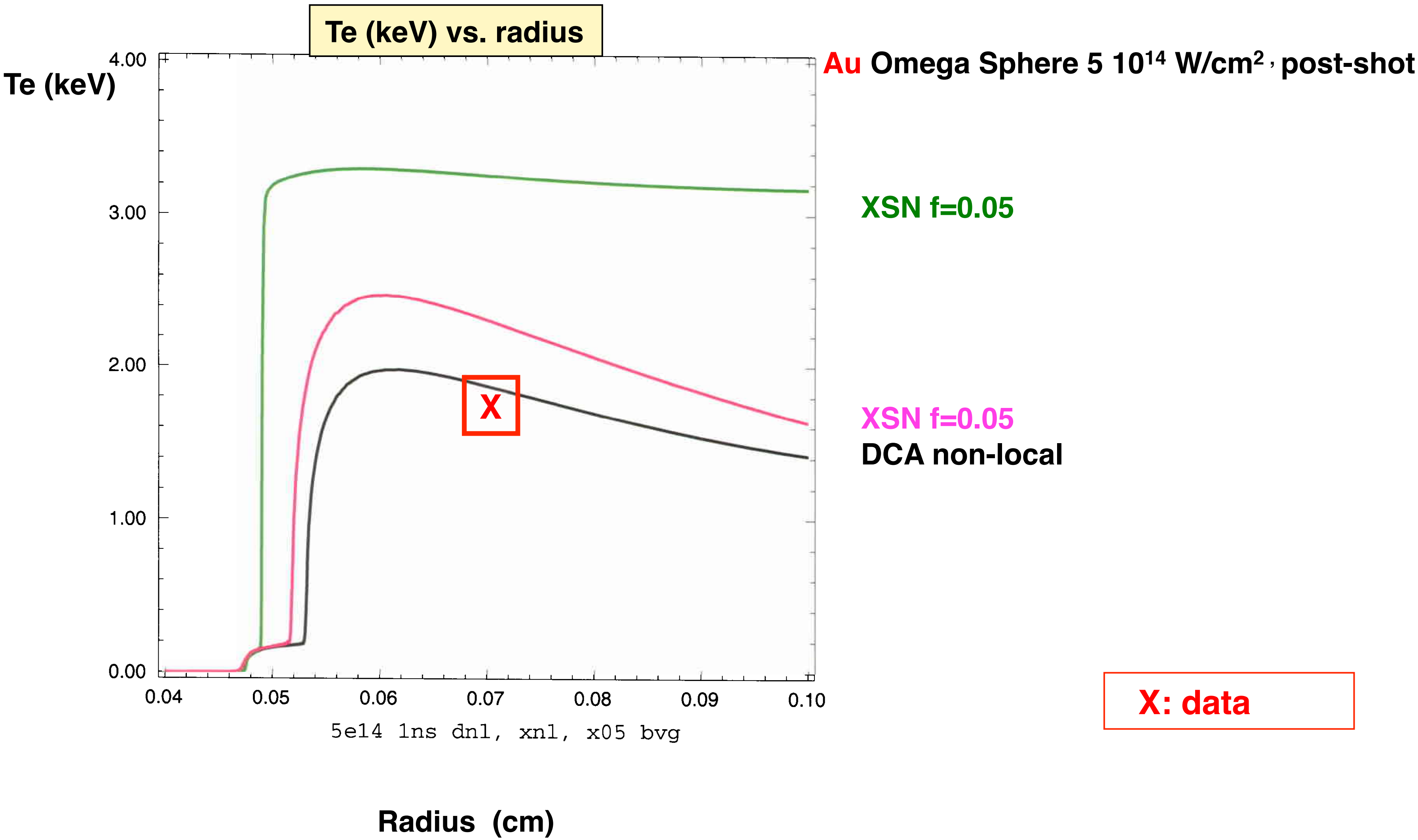
Summary of the analysis of the 2013 data

- **vs. Space:**
  - **mostly at r = + 200 μm from the R_0 = 500 μm sphere surface**
    - **DCA non-local (= "HFM") looks pretty good there for T_e, n_e**
- **vs. Time, Irradiance, & Elements**
  - **DCA non-local looks pretty good for T_e, n_e**
    - **Z_B (t) low vs data early in time, but OK later in time**
  - **Some of the (Z_BxT_e) data vs time is matched best by an intermediate model !**

More data with respect to spatial profiles, Z_B , & Dante analysis needed

Combining Thomson Scatter with Spectroscopy would be useful too !

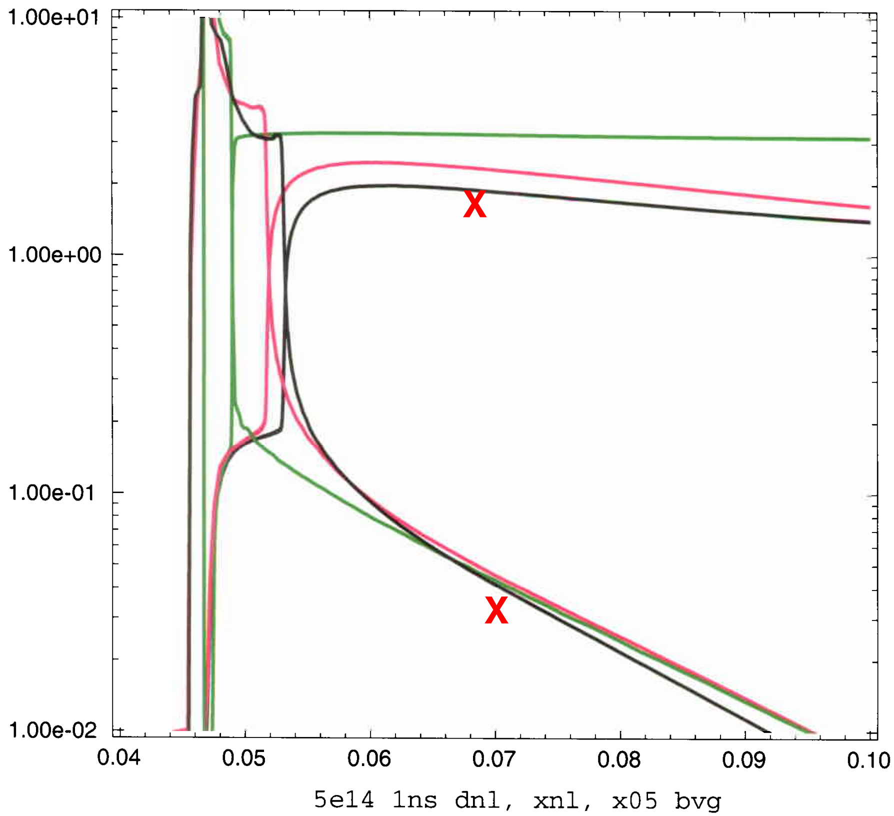
Te profiles at 1 ns for Au vs. Data at 5 10^{14} W/cm^2



Te and n/n$_c$ profiles at 1 ns for Au at 5 10^{14} W/cm^2

Te (keV) and n/n$_c$ vs. radius

Au Omega Sphere 5 10^{14} W/cm^2, post-shot



XSN f=0.05
XSN non-local
DCA non-local

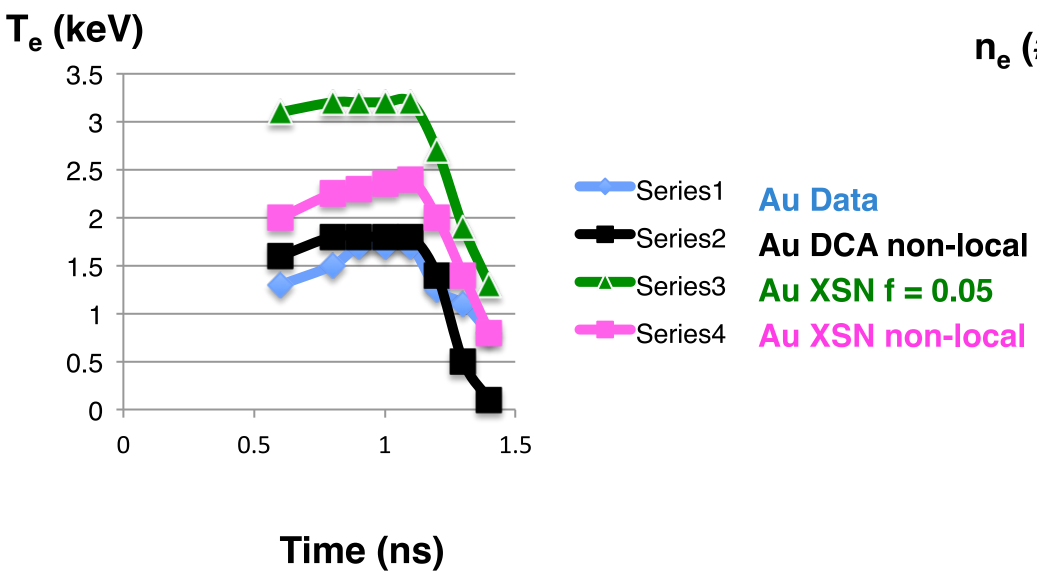
X: data

Radius (cm)

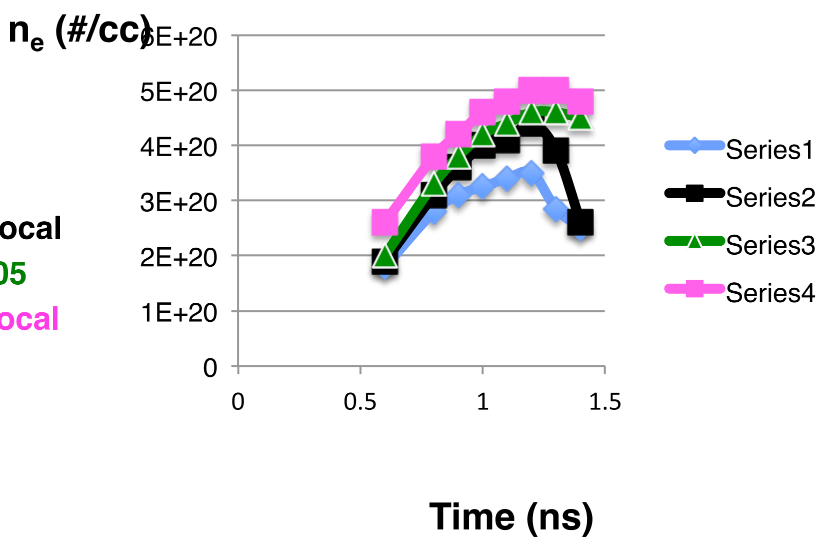
Time dependence of T_e, n_e, for Au at 5 10^{14} W/cm^2

Post shot Au Omega Sphere 5 10^{14} W/cm^2

T_e (keV) vs. time (ns), at r = +200 μm

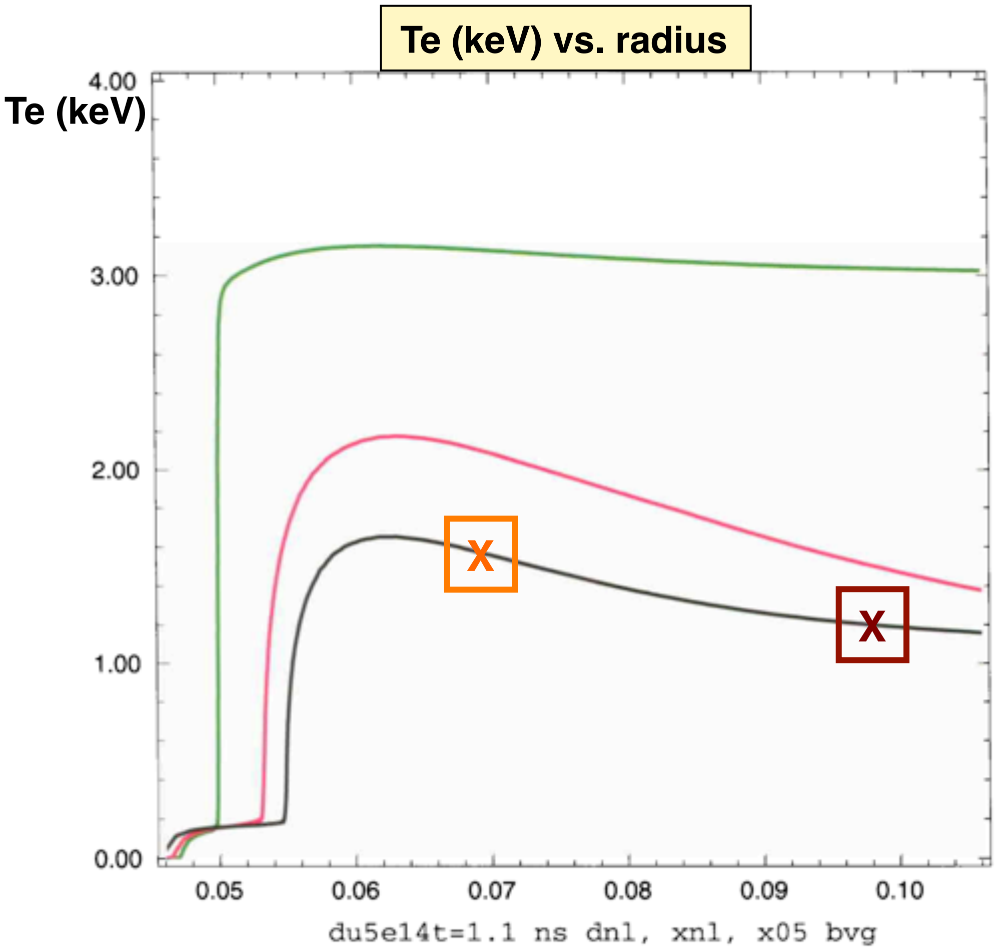


n_e (#/cc) vs. time (ns), at r = +200 μm



DCA non-local ("HFM") does a better job matching time behavior of T_e

Te profiles @ ~ 1 ns for DU vs. Data at 5 10^{14} W/cm^2



XSN f=0.05 solid

XSN non-local

DCA non-local

Radius (cm)

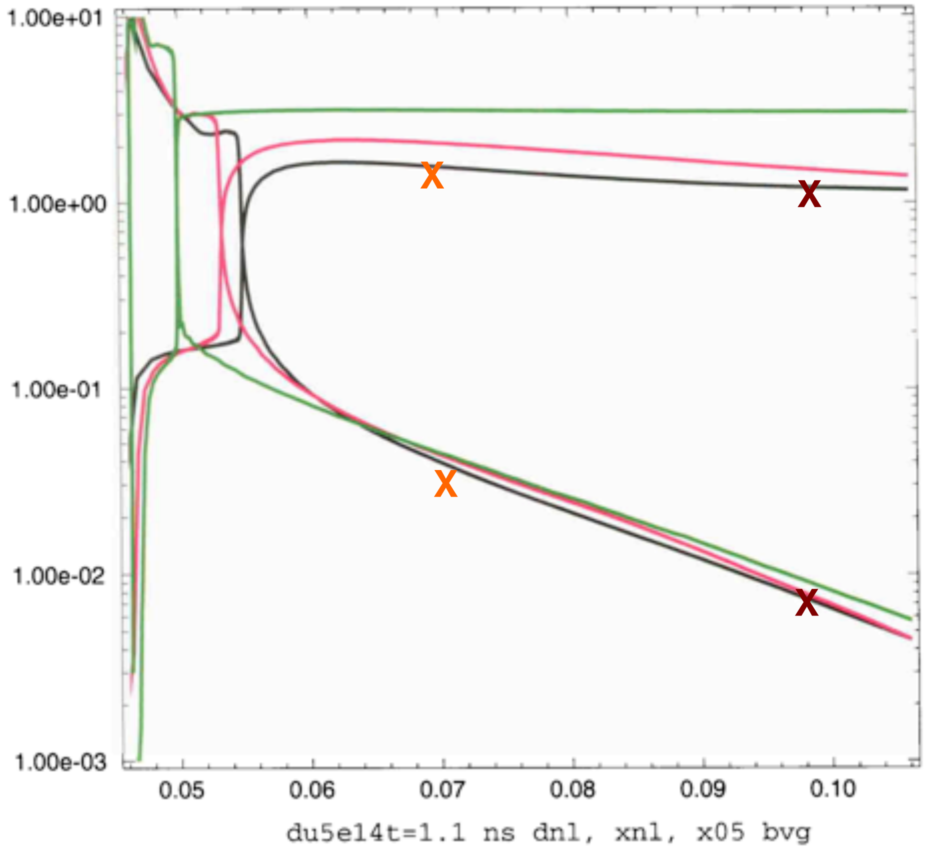
X: data (5/13)

X: data (10/13)

10/13 Omega Sphere 5 10^{14} W/cm^2
is based on 5/13 post -shot

Te and n/n_c profiles at ~ 1 ns for DU @ 5 10^{14} W/cm^2

Te (keV) and n/n_c vs. radius



Radius (cm)

XSN f=0.05

XSN non-local

DCA non-local

X: data (5/13)

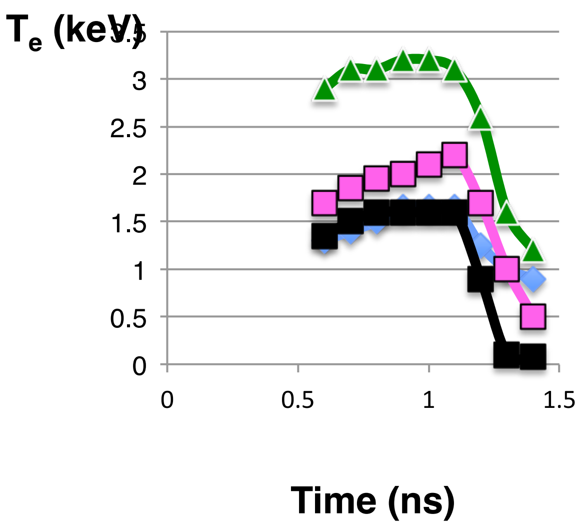
X: data (10/13)

10/13 Omega Sphere 5 10^{14} W/cm^2
is based on 5/13 post -shot

Time dependence of T_e, n_e, for DU at 5 10^{14} W/cm^2

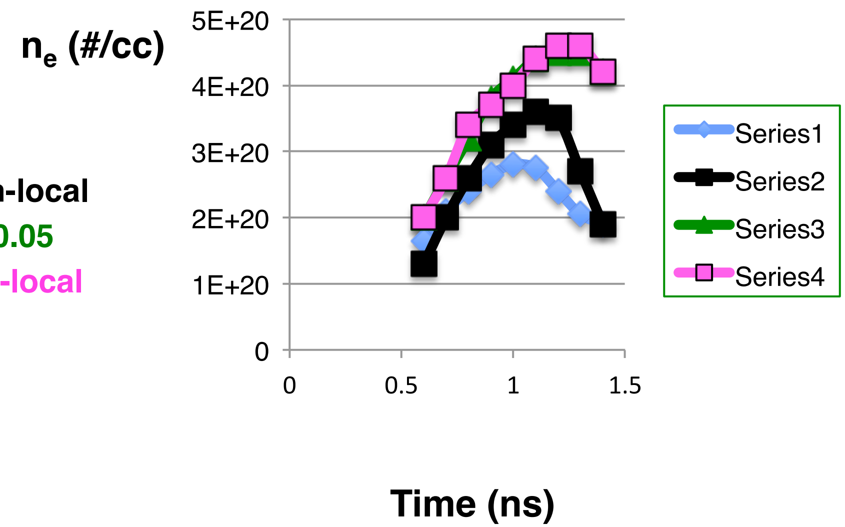
Post shot DU Omega Sphere 5 10^{14} W/cm^2

T_e (keV) vs. time (ns), at r = +200 μm



Series1 DU Data
Series2 DU DCA non-local
Series3 DU XSN f = 0.05
Series4 Du XSN non-local

n_e (#/cc) vs. time (ns), at r = +200 μm

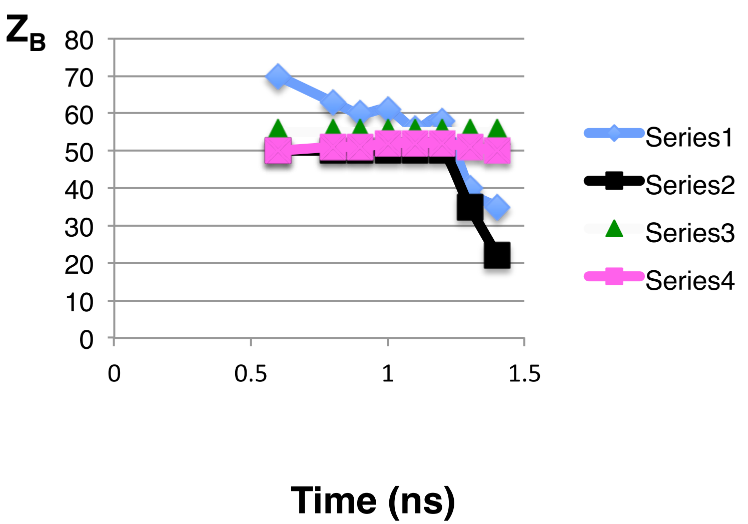


DCA non-local ("HFM") does a better job matching time behavior of T_e

Time dependence of Z_B, at 5 10^{14} W/cm^2 Au & DU

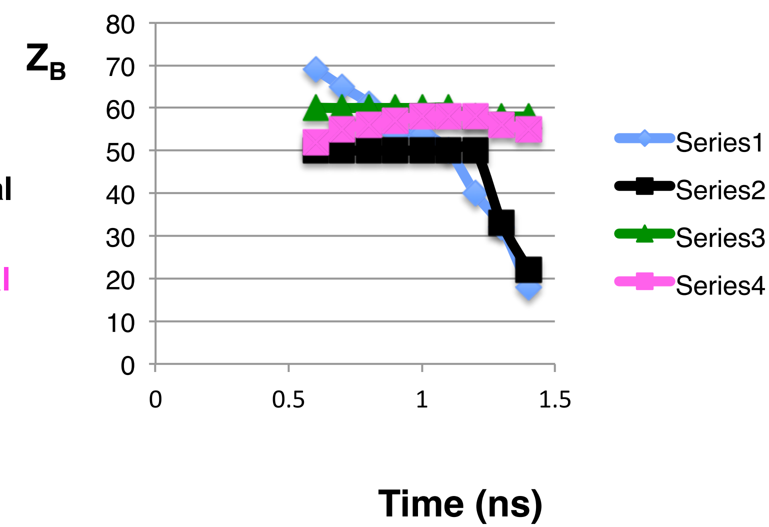
Post shot   Omega Sphere 5 10^{14} W/cm^2

Au Z_B vs. time (ns), at r = +200 μm



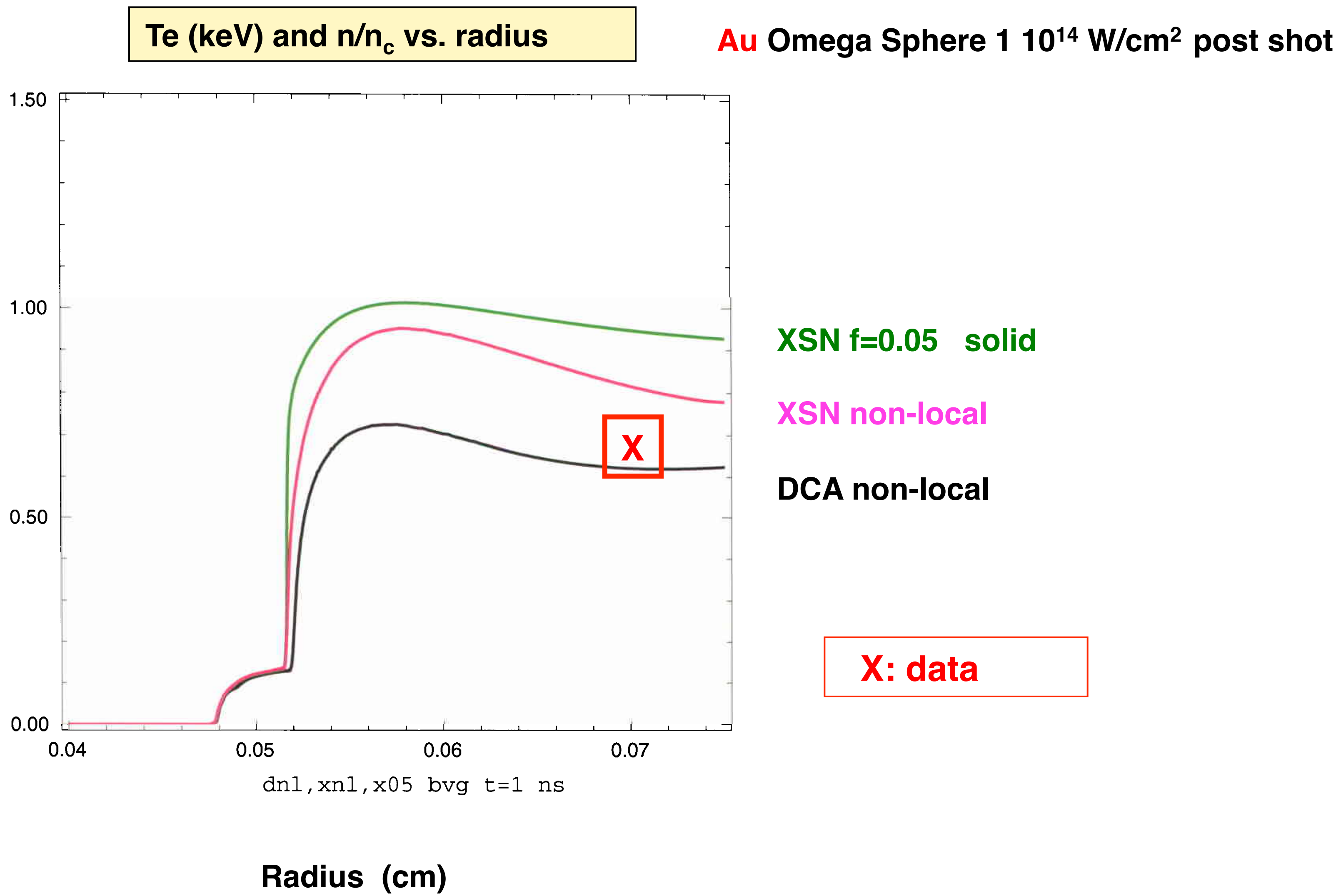
Data
DCA non-local
XSN f = 0.05
XSN non-local

DU Z_B vs. time (ns), at r = +200 μm



DCA non-local does a better job matching time behavior of Z_B

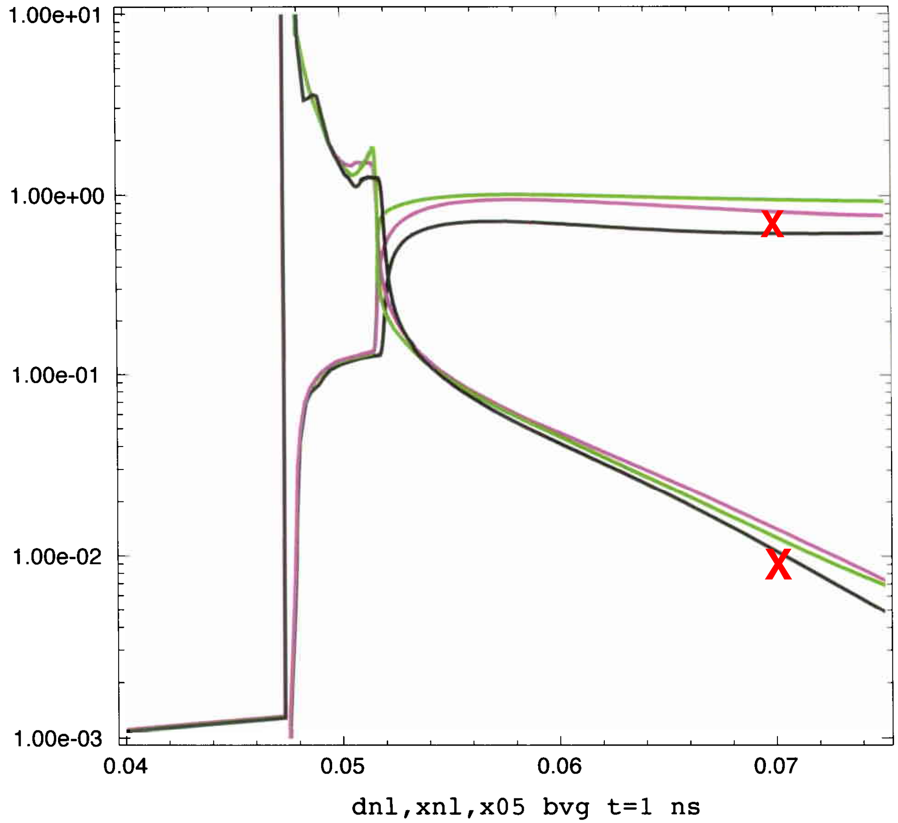
Te profile at 1 ns vs data for Au at 1 10^{14} W/cm^2



Te and n/n_c profiles at 1 ns vs data for Au at 1 10^{14} W/cm^2

Te (keV) and n/n_c vs. radius

Au Omega Sphere 1 10^{14} W/cm^2 ***post shot***



XSN f=0.05 solid
XSN non-local
DCA non-local

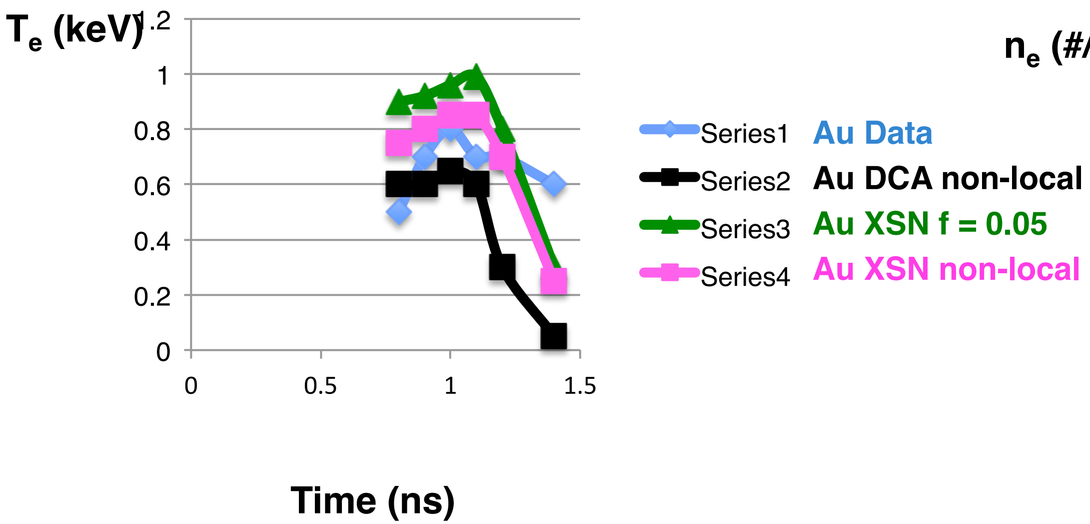
X: data

Radius (cm)

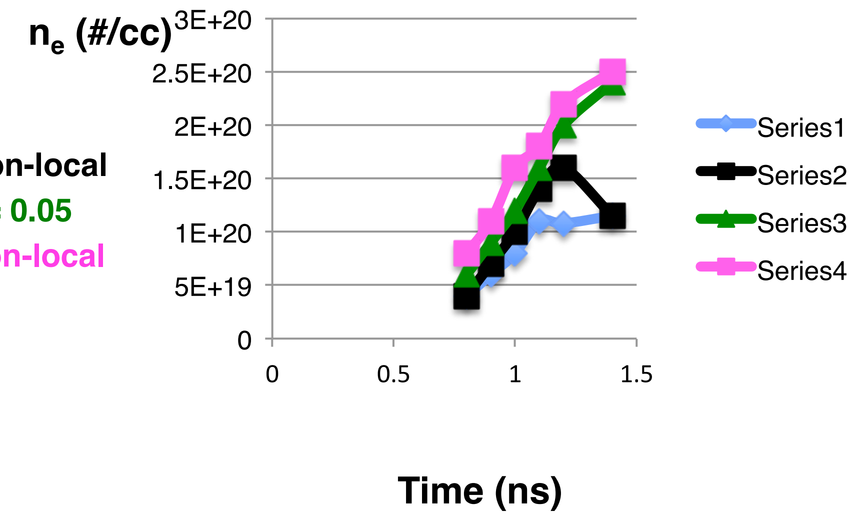
Time dependence of T_e, n_e, for Au at 1 10^{14} W/cm^2

Post shot **Au Omega Sphere 1 10^{14} W/cm^2**

T_e (keV) vs. time (ns), at r = +200 μm



n_e (#/cc) vs. time (ns), at r = +200 μm



DCA non-local does ~ better job matching time behavior of T_e and n_e

Some Z_B x Te data support an intermediate model

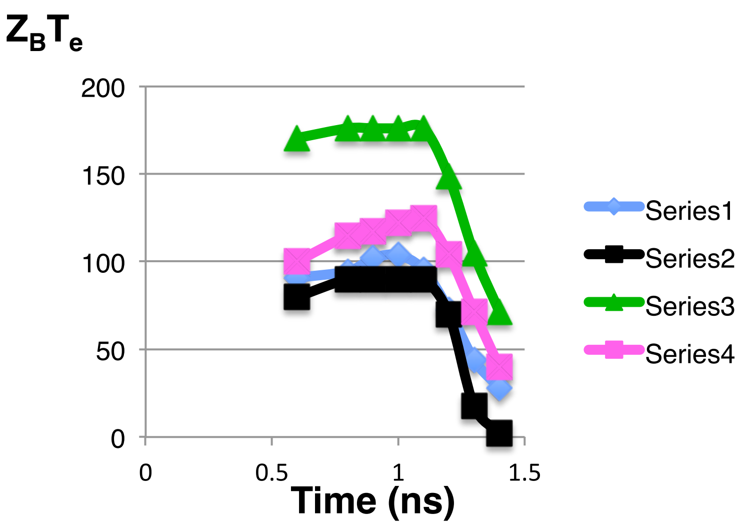
- There is much more data available for the Z_B x Te product
  - from the ion feature of the TS spectrum
- More Irradiances and spatial positions available
- Nearer the Au or DU surface the intermediate model does better
  - eg XSN non-local – but really, *any* model that radiates a bit less than the HFM will be a bit hotter
- At the highest Au irradiance (1 x 10^{15} W/cm^2) the intermediate model does better

Accurate total Dante emission data will an important model constraint

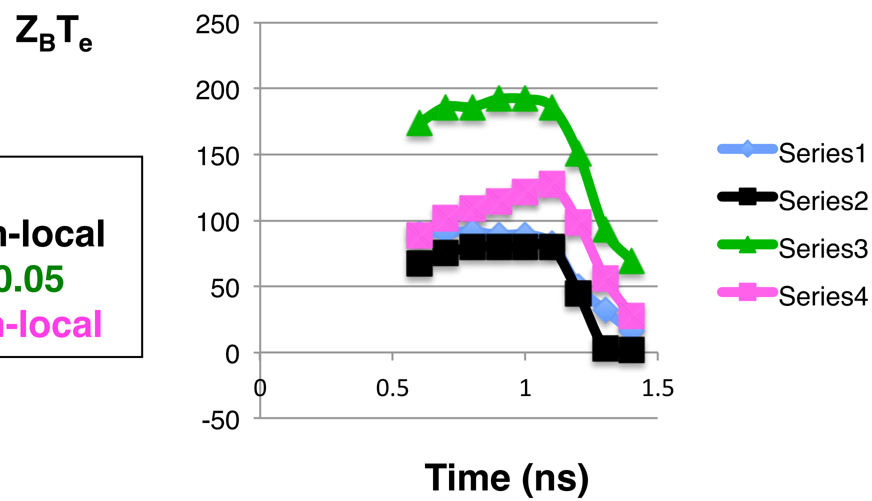
Time dependence of Z_B x T_e, at 5 10^{14} W/cm^2: Au & DU at r= + 200 μm

Post shot Omega Sphere 5 10^{14} W/cm^2

Au Z_BT_e vs. time (ns), at r = +200 μm



DU Z_BT_e vs. time (ns), at r = +200 μm



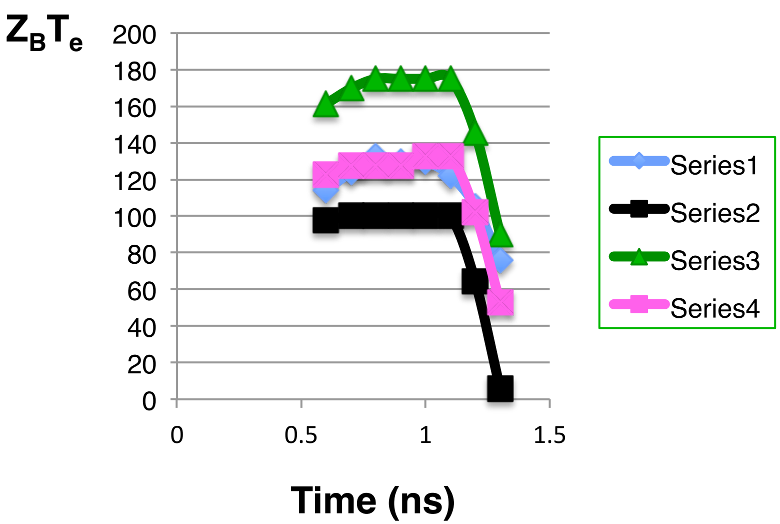
Data
DCA non-local
XSN f = 0.05
XSN non-local

DCA non-local does a better job matching time behavior of Z_BT_e at r=+200 μm

Time dependence of $Z_B \times T_e$, at 5 10^{14} W/cm^2: Au & DU at r= + 100 μm

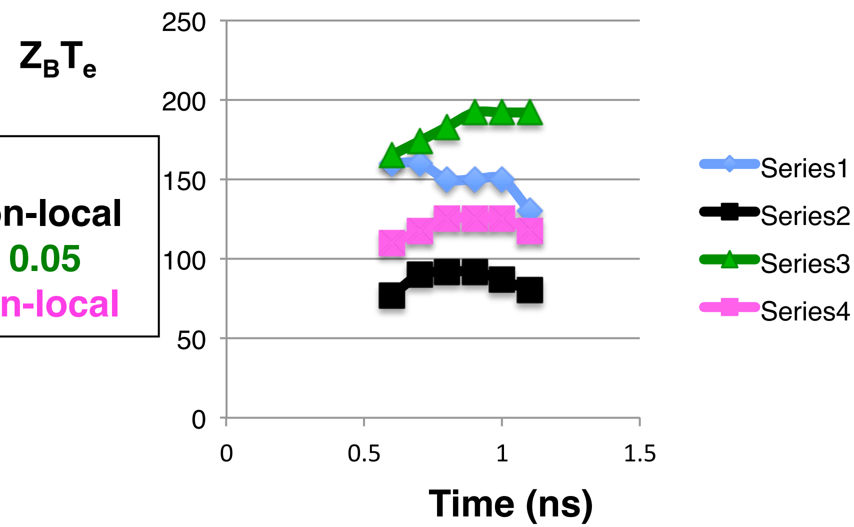
Post shot Omega Sphere 5 10^{14} W/cm^2

Au $Z_B T_e$ vs. time (ns), at r = +100 μm



Data
DCA non-local
XSN f = 0.05
XSN non-local

DU $Z_B T_e$ vs. time (ns), at r = +100 μm

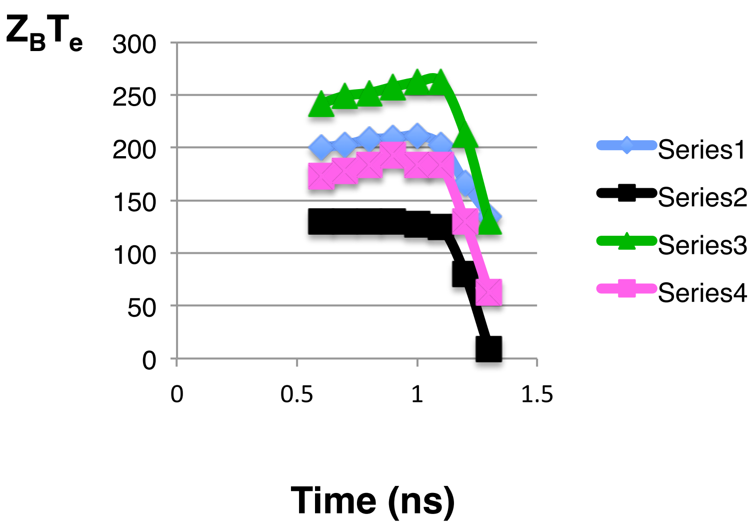


Intermediate model does better job matching time behavior of $Z_B T_e$ at r=+100 μm

Time dependence of $Z_B \times T_e$, at 1 10^{15} W/cm^2 Au: at r= + 100 μm and at + 200 μm

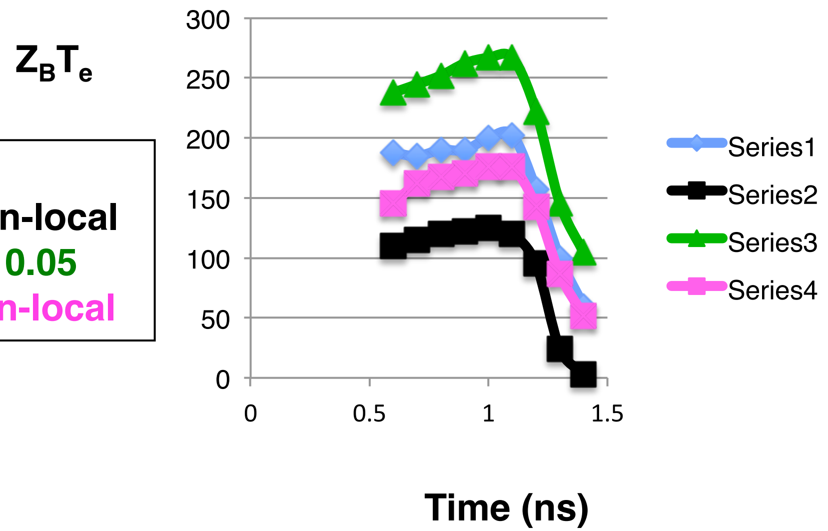
Post shot   Omega Sphere 1 10^{15} W/cm^2

Au $Z_B T_e$ vs. time (ns), at r = +100 μm



Data
DCA non-local
XSN f = 0.05
XSN non-local

Au $Z_B T_e$ vs. time (ns), at r = +200 μm



Intermediate model does a better job matching time behavior of $Z_B T_e$ at r = +100 μm & +200 μm

We await the 2013 version of Dante analysis to help clarify this

Summary of the analysis of the 2013 data

- vs. Space:
  - mostly at r = + 200 μm from the R_0 = 500 μm sphere surface
    - DCA non-local looks pretty good there for T_e, n_e
- vs. Time, & Irradiances
  - DCA non-local looks pretty good for T_e, n_e
    - Z_B (t) low vs data early in time, OK late in time
  - Some of the ($Z_B x T_e$) data vs time is matched best by an intermediate model !

More data with respect to spatial profiles, Z_B , & Dante would be useful

Combining Thomson Scatter with Spectroscopy would be useful too !

Back-ups

Analysis with Te data error bars