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Improvements in Modeling Au Sphere Non-LTE X-ray Emission

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Abstract

We've previously reported* on experiments at the Omega laser at URLLE, in which 1.0 mm in diameter, Au coated, spheres, were illuminated at either 10^{14} W/ cm^2 (10 kJ / 3 ns) or at 10^{15} W/ cm^2 (30 kJ / 1 ns).

Spectral information on the 1 keV thermal x-rays, as well as the multi-keV M-band were obtained.

We compared a variety of non-LTE atomic physics packages to this data with varying degrees of success. In this paper we broaden the scope of the investigation, and compare the data to newer models:

1) An improved Detailed Configuration Accounting (DCA) method.

2) This model involves adjustments to the standard XSN non-LTE model which lead to a better match of coronal emission as calculated by XSN to that calculated by SCRAM, a more sophisticated stand-alone model.

We show some improvements in the agreement with Omega data when using either of these new approaches.

* E. Dewald, M. D. Rosen, et al Physics of Plasmas **15**, 072706 (2008).

Summary of new models' performance

1) Omega Au 1-D sphere NLTE output analysis:
   - Sub keV (~ thermal) emission:
     - Good match to data for both models.
   - M band:

     @ 1E15 / 1 ns
     - DCA M band ~ 2x too high
     - XSNLJS M band ~ 2x too low

     @ 1E14 / 3 ns
     - DCA M band ~ 3x too high
     - XSNLJS M band ~ OK

2) Implications for NIF point design 2-D hohlraum (vs. XSN):
   - Both of these newer models give a few % higher T_r .
   - This is consistent with their ~ 10% higher conversion efficiency in Omega Au spheres vs. XSN

We are testing 2 new non-LTE atomic models

1) DCA:
   - Detailed Configuration Accounting
   - PI is Howard Scott

2) XSNLJS:
   - A judicially chosen "set of knobs" that adjust various excitation rates within the context of our "standard" XSN average atom model.
   - These "knob settings" were chosen by Larry J. Suter in order to match the emissivity of Au at 0.2 n_{crit} for 1-3 keV as predicted by SCRAM, a very detailed atomic physics code due to S. Hansen et al.

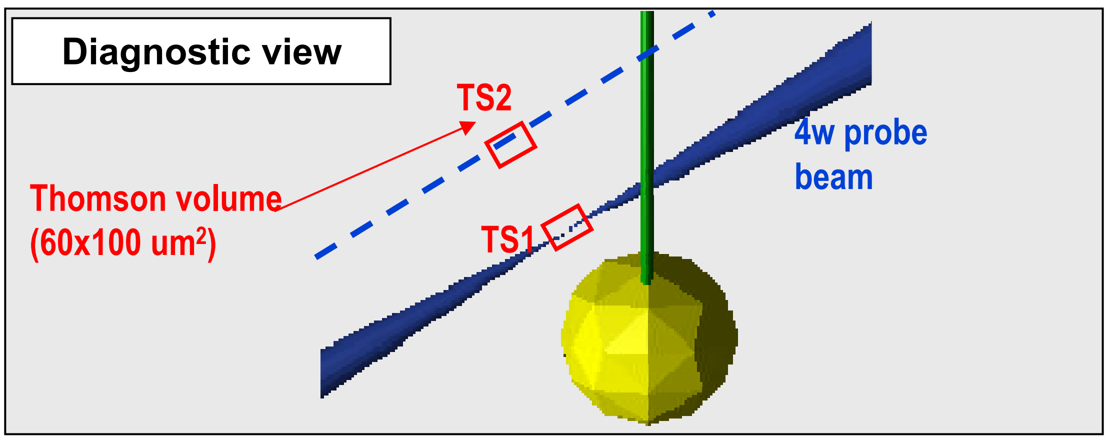
- Our previous studies were with standard XSN and with SCA.

Au Omega sphere allows for 1-D simulations and for comparison to data

$T_e(x,t)$ (via Thomson Scattering)

$E_{\text{Laser absorbed}}(t)$ (via the FABS diagnostic)

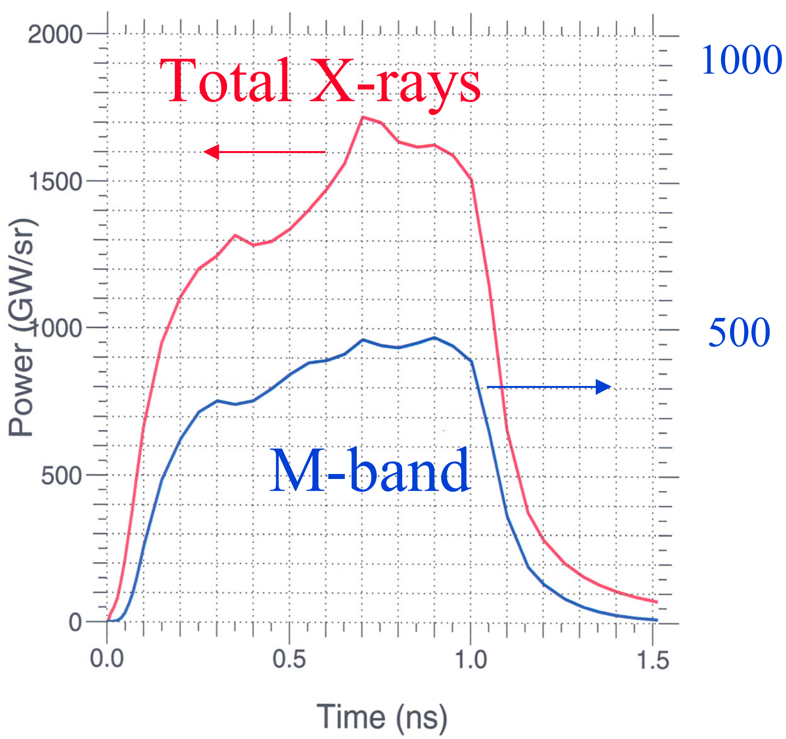
$E_{\text{x-ray}}(h\nu, x, t)$ (via Dante & other diagnostics)

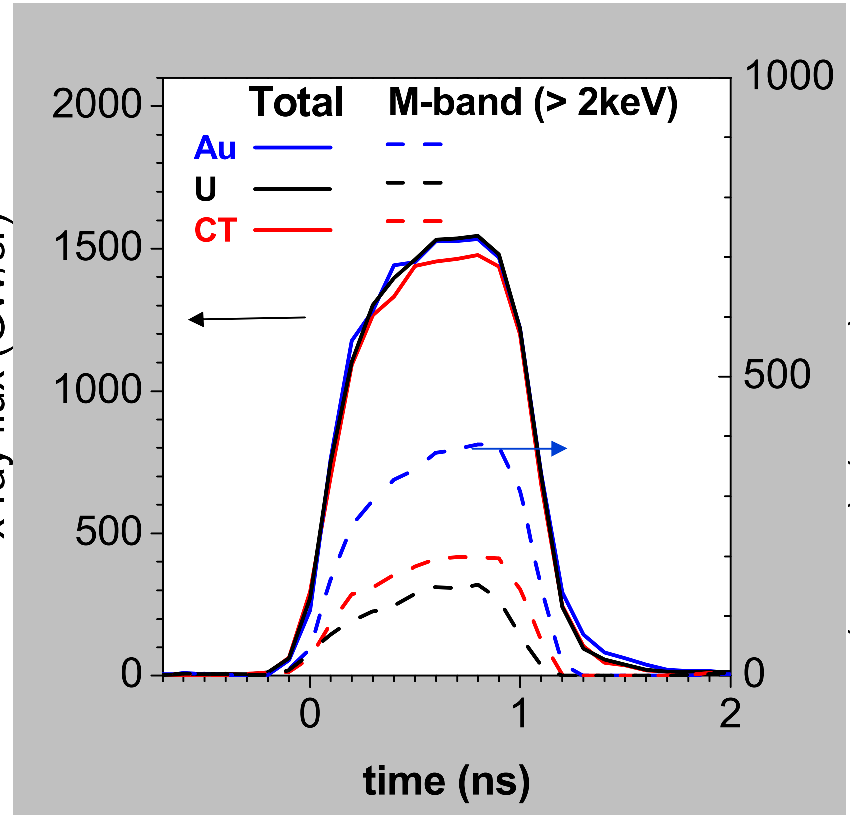


1-D simulations allow for 400-zone runs:

very well resolved conversion efficiency layer

"Typical" comparison of simulation with data (@ 10^{15} W/cm^2)





Au Simulation
30 KJ / 1 ns 10^{15} W/cm^2

Data

SCA M-band ~20% too high

DCA: comparison of simulation with data (@ 10^{15} W/cm^2) : M band is ~ 1.7x too high

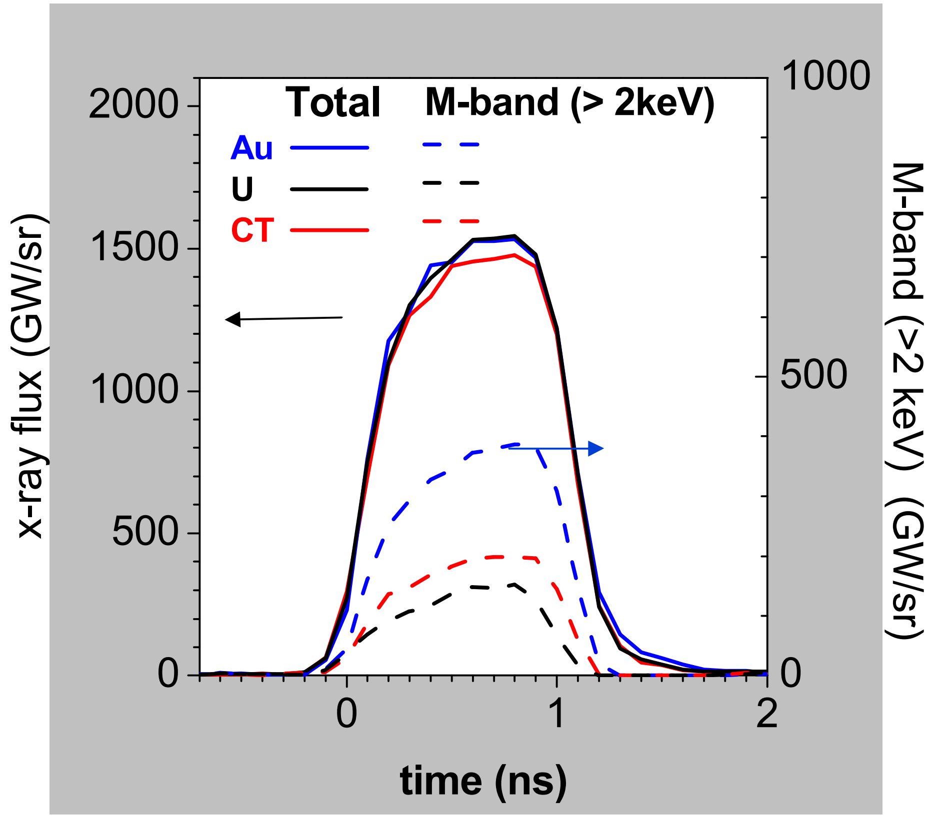
Total X-rays

1000

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

500

M-band



Au DCA Simulation

30 KJ / 1 ns 10^{15} W/cm^2

Data

XSNLJS: comparison of simulation with data (@ 10^{15} W/cm^2) : M band is ~ 0.6x too low

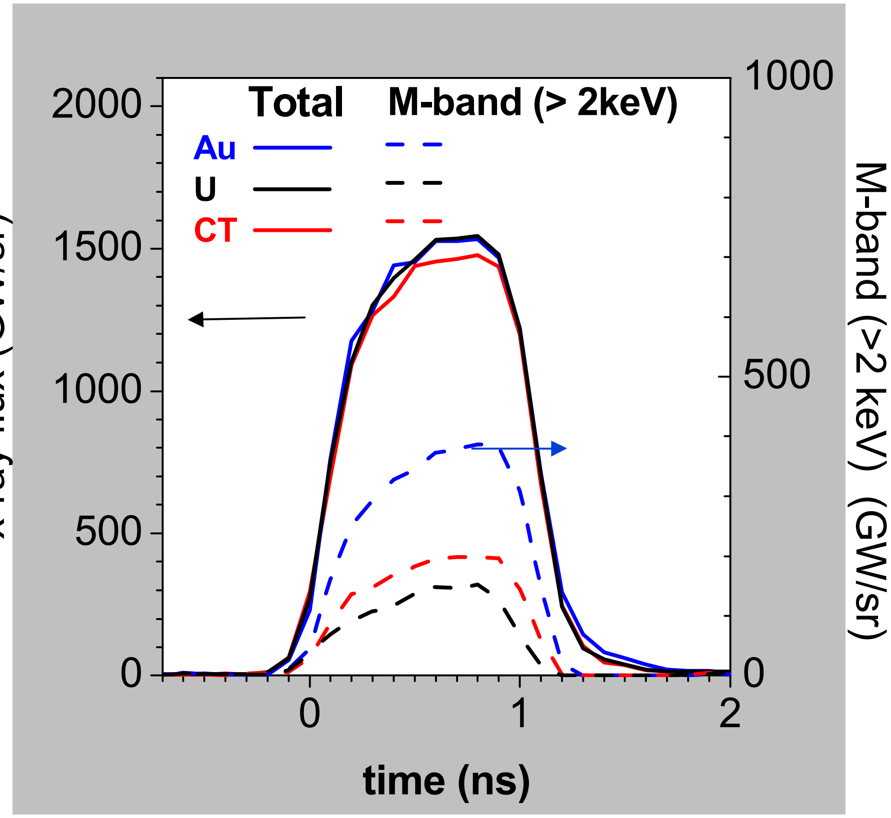
1000

Total X-rays

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

500

M-band

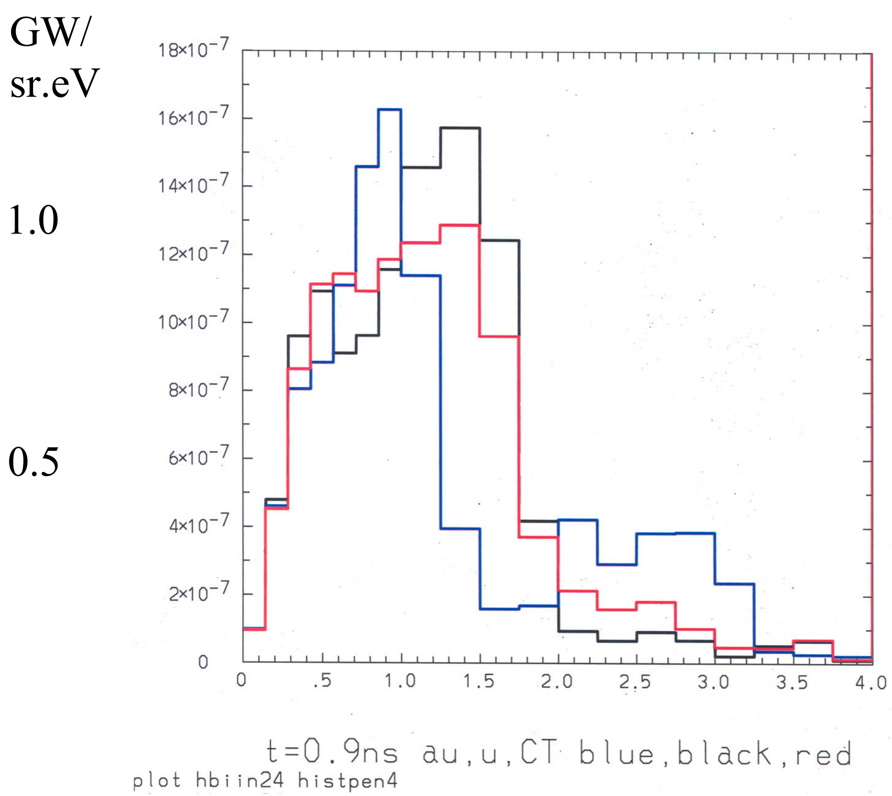


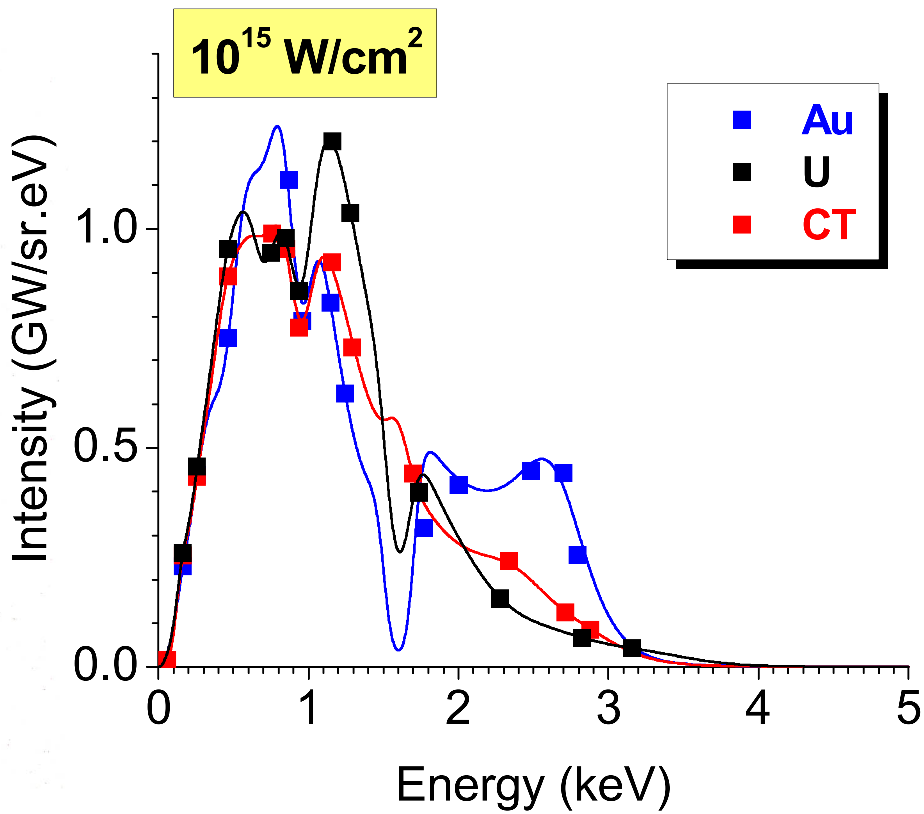
Au XSNLJS Simulation

30 KJ / 1 ns 10^{15} W/cm^2

Data

The general vanilla XSN spectral behavior vs. Target Material is modeled well (@ 10^{15} W/cm^2)





Au, U, CT XSN (no Auger) Simulations

Data

30 KJ / 1 ns 10^{15} W/cm^2 at t= 0.9 ns

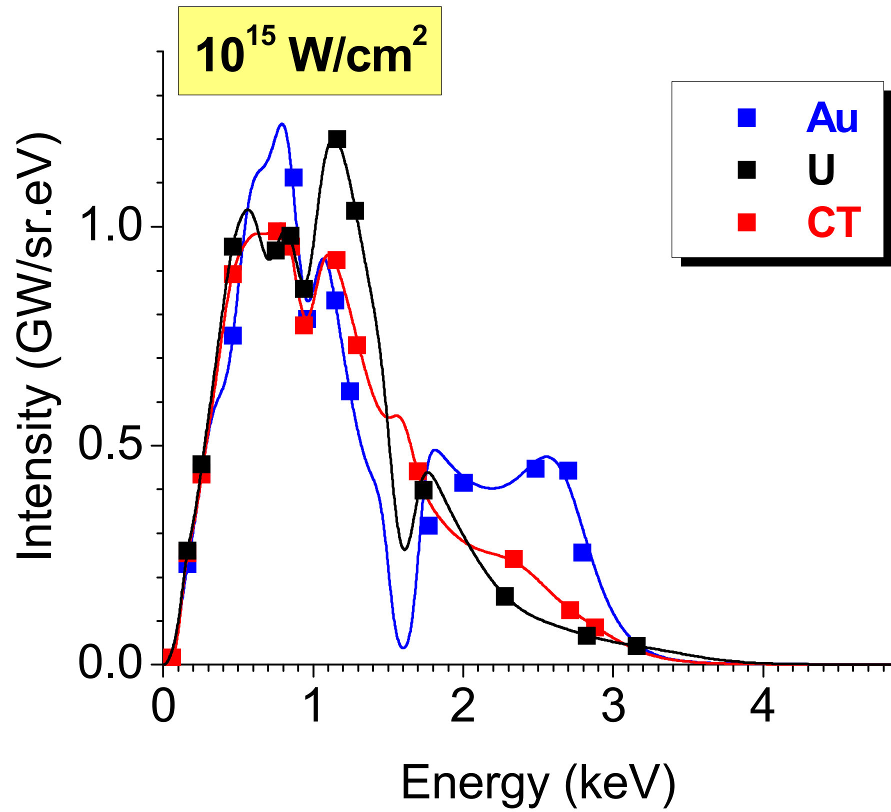
DCA has trouble with the spectral shape for Au (@ 10^{15} W/cm^2) : High M - band

GW/
sr.eV

1.0

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

0.5



Au, DCA Simulation

Data

30 KJ / 1 ns 10^{15} W/cm^2 at t= 0.9 ns

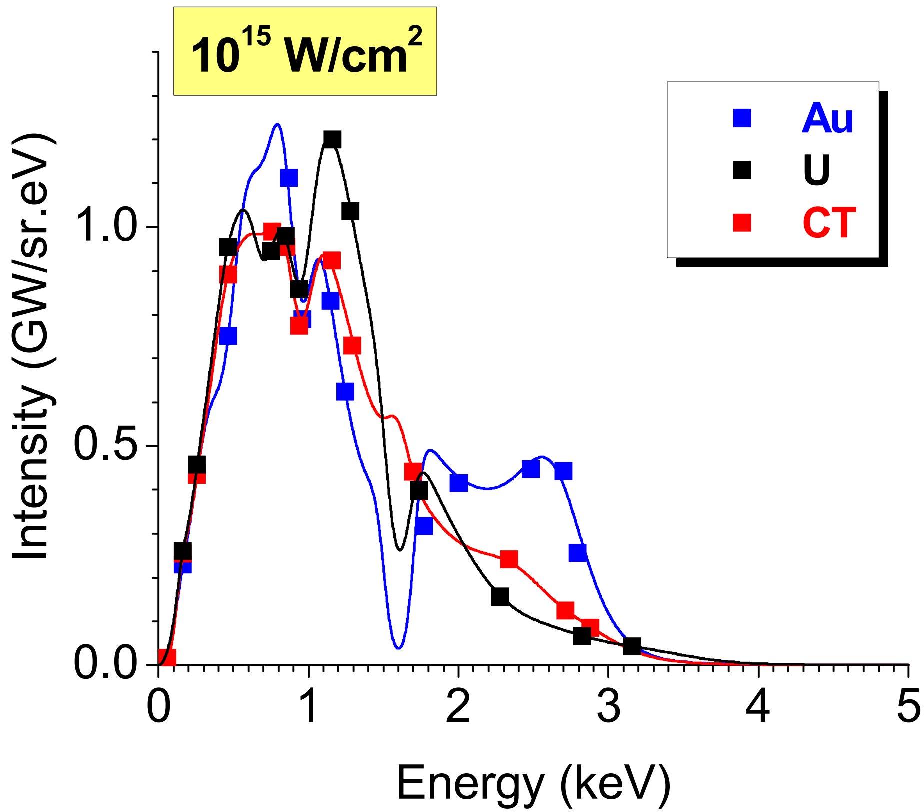
XSNLJS has trouble with Au spectral shape (@ 10^{15} W/cm^2) : High Sub keV & Low M - band

GW/
sr.eV

1.0

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

0.5



Au, XSNLJS Simulation

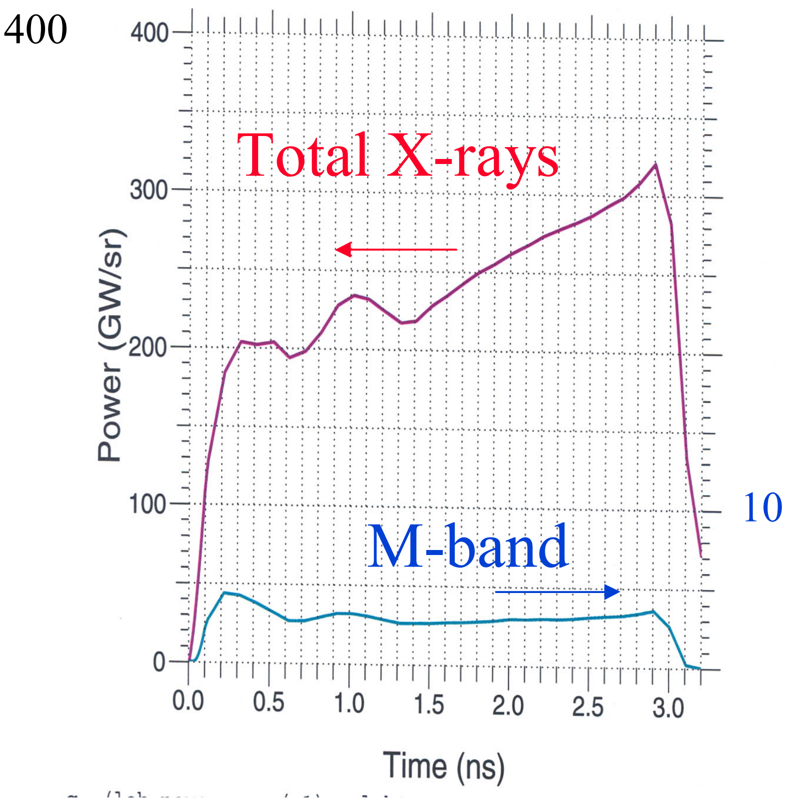
Data

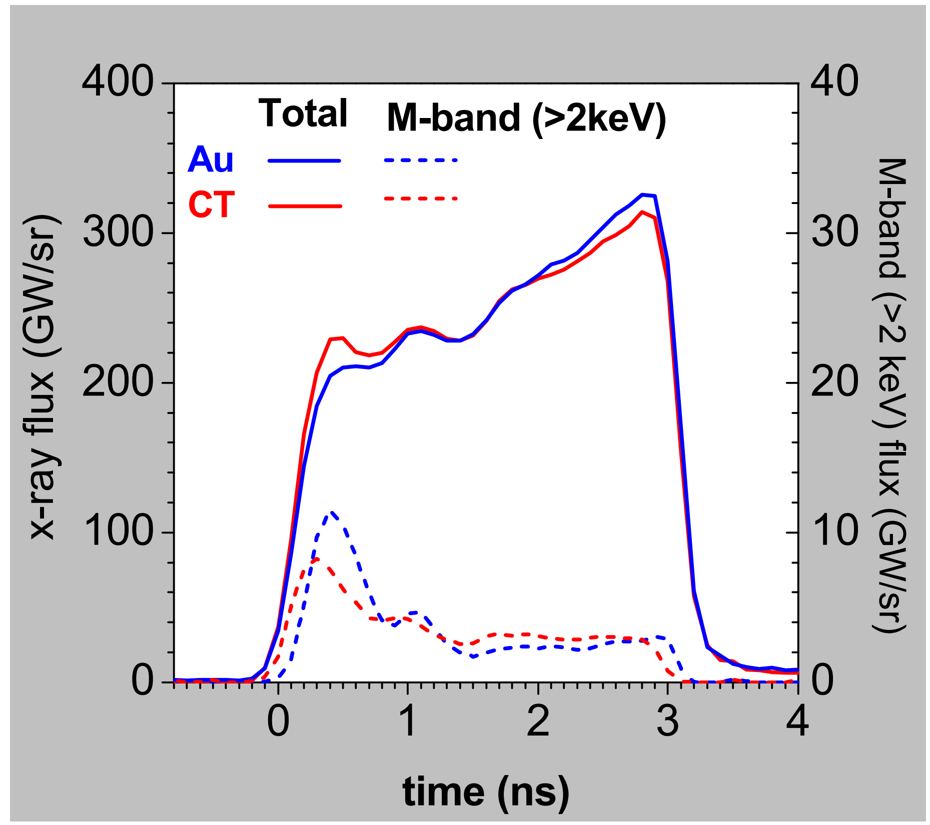
30 KJ / 1 ns 10^{15} W/cm^2 at t= 0.9 ns

Summary: 10^{15} W/cm^2

	Total	M-Band
Data (GW/Sr @ peak)	1600	400
Model (Type : Flux limit / Auger)		
XSN 0.15 / -	1600	300
XSNLJS 0.15 / +	1700	250
DCA 0.15 / +	1600	630

“Typical” vanilla XSN comparison of simulation with data□ (@ 10^{14} W/cm^2)





XSN Au Simulation

10 KJ / 3 ns 10^{14} W/cm^2

Data

XSN M-band ~ 2x too low early in the pulse

SCA M-band > 2x too high throughout the pulse

DCA0508 comparison of simulation with data (@ 10^{14} W/cm^2)- near perfection!

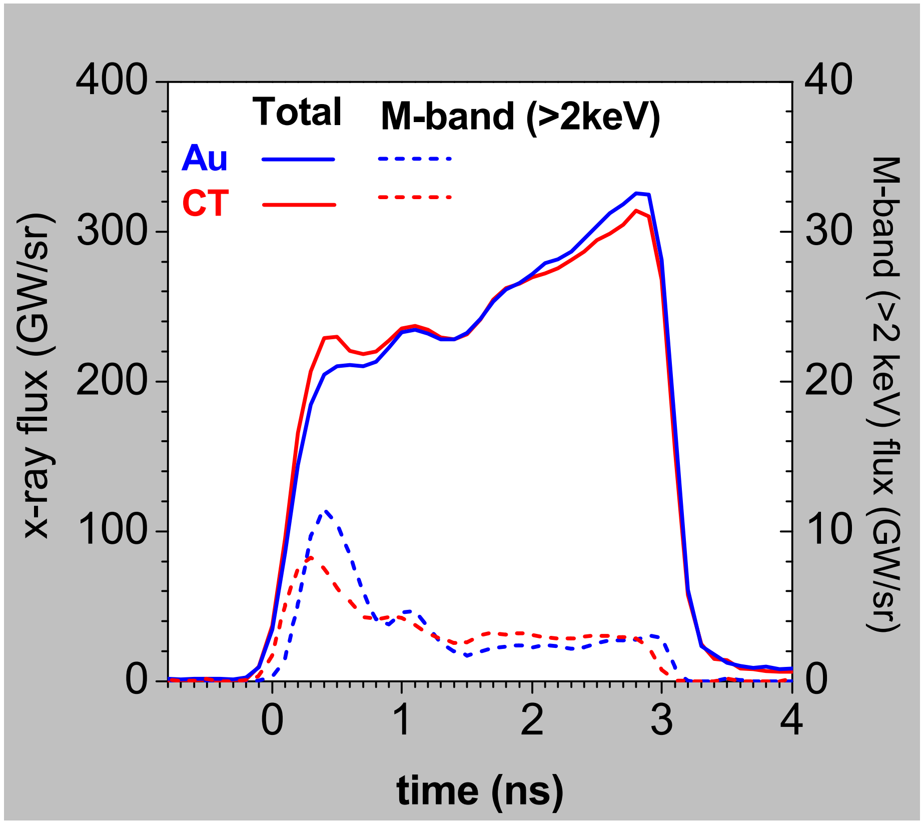
400

Total X-rays

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

M-band

10



Au Simulation DCA 0508

10 KJ / 3 ns 10^{14} W/cm^2

Data

DCA0908 comparison of simulation with data (@ 10^{14} W/cm^2)- now M band is 3x too high!

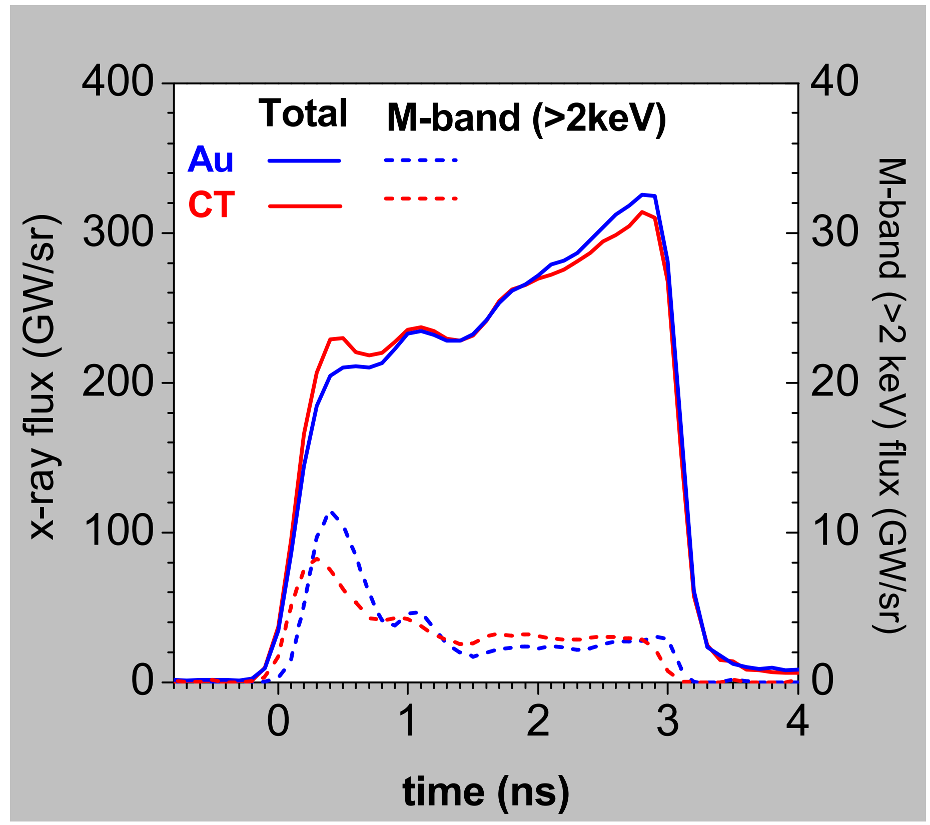
400

Total X-rays

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

10

M-band



Au Simulation DCA 0908

10 KJ / 3 ns 10^{14} W/cm^2

Data

UCRL-PRES-xxxxxx

XSNLJS comparison of simulation with data (@ 10^{14} W/cm^2)- ~ same as XSN!

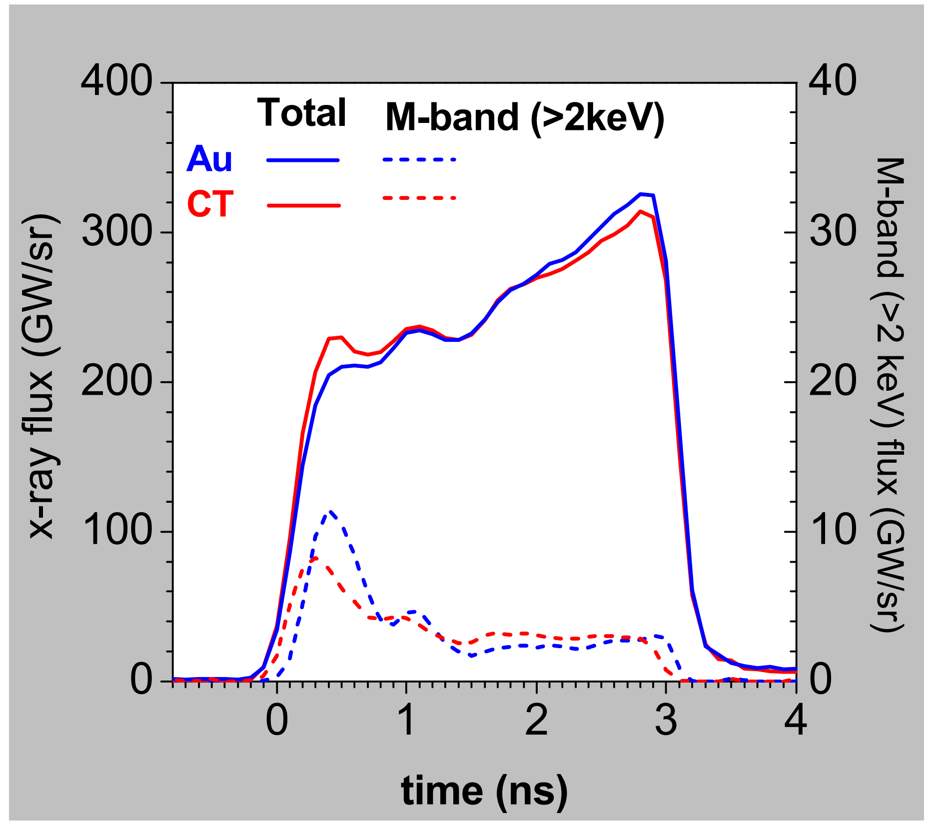
400

Total X-rays

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

M-band

10

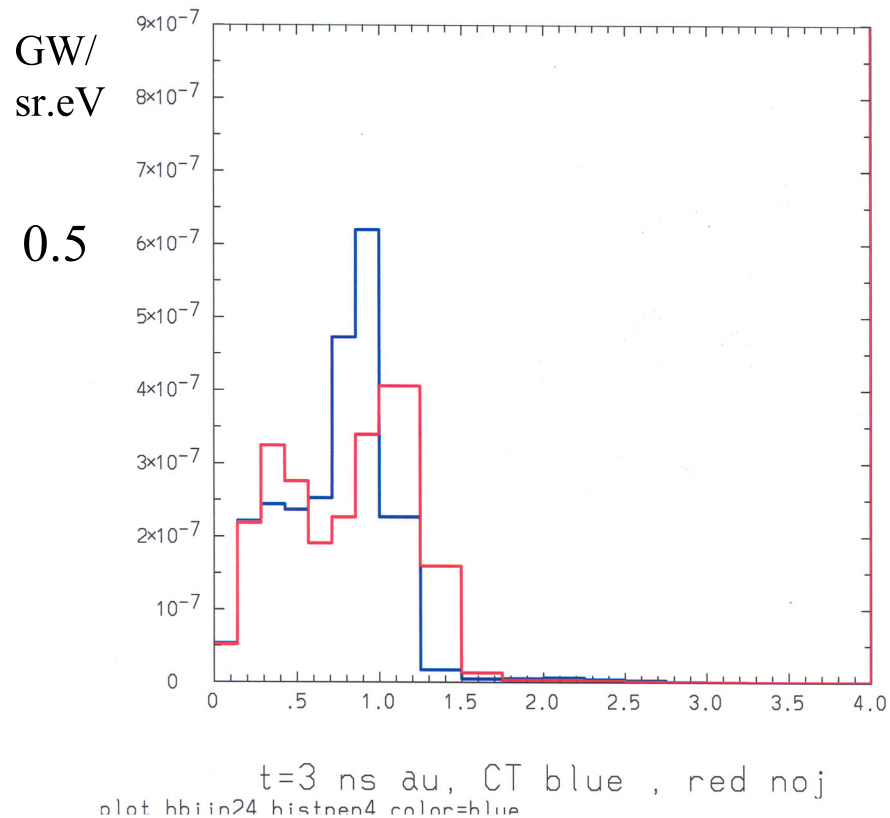


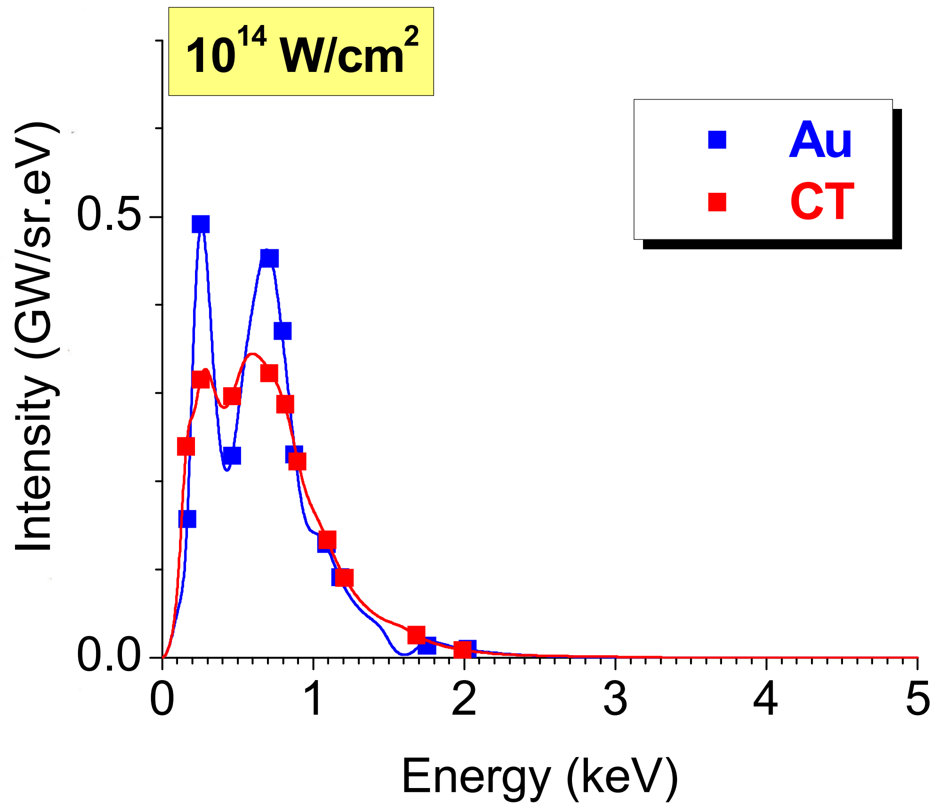
Au Simulation XSNLJS

10 KJ / 3 ns 10^{14} W/cm^2

Data

The general spectral behavior vs. Target Material is modeled well (@ 10^{14} W/cm^2)





Au, CT XSN Simulations

Data

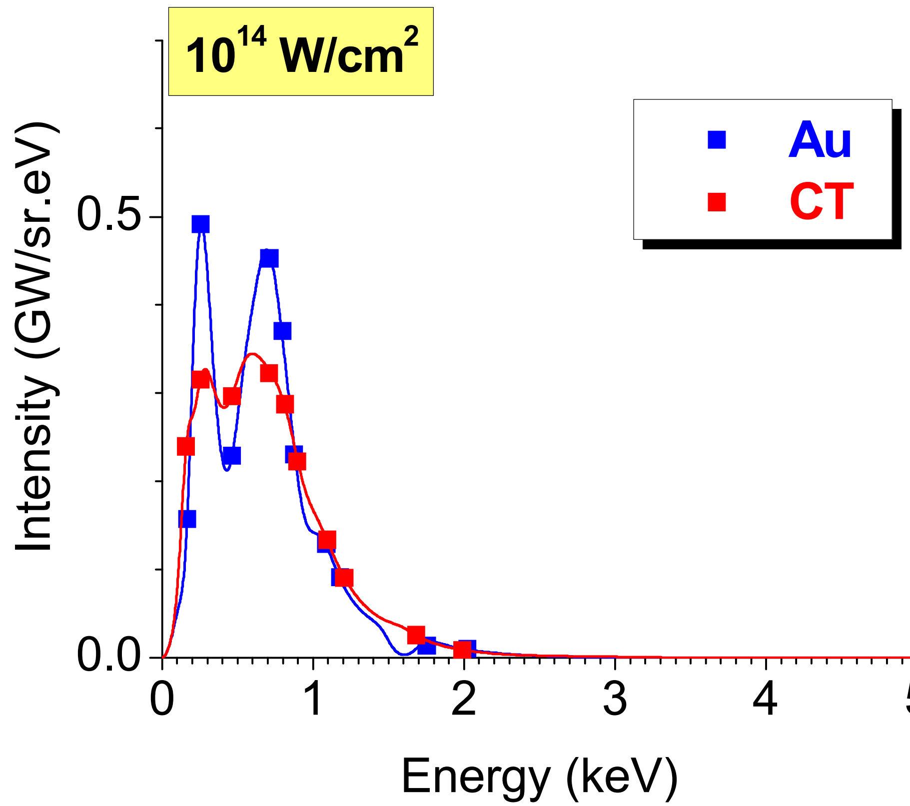
10 KJ / 3 ns 10^{14} W/cm^2 at t= 2.9 ns

The Au sub keV spectral shape is modeled especially well by DCA(@ 10^{14} W/cm^2)

GW/
sr.eV

0.5

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.



Au, DCA Simulation

Data

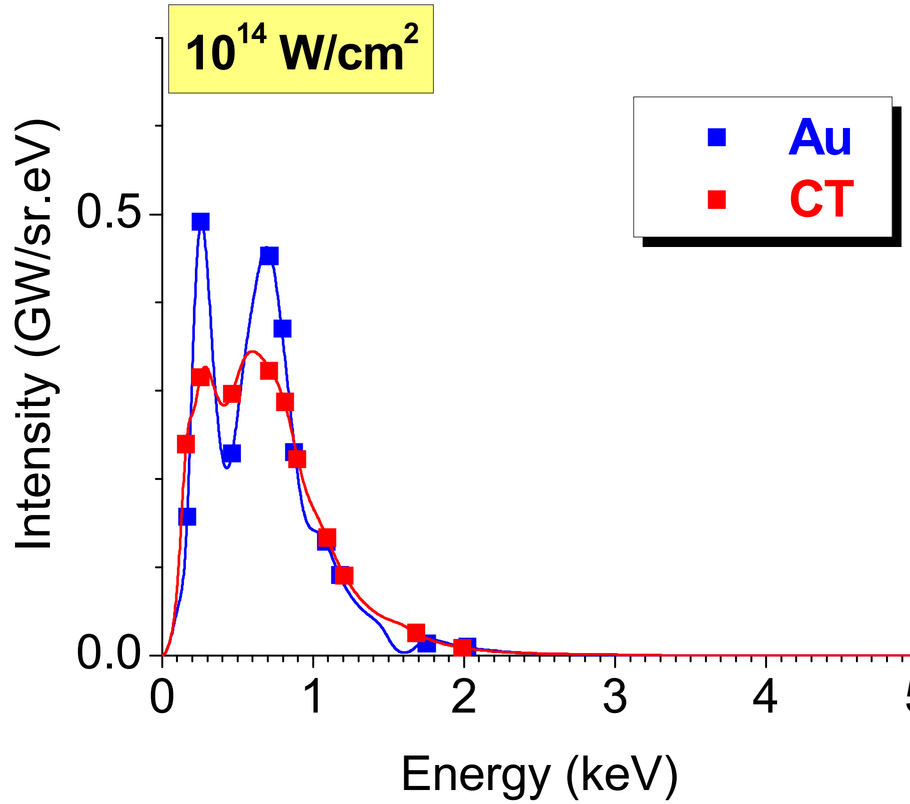
10 KJ / 3 ns 10^{14} W/cm^2 at t= 2.9 ns

The Au spectral behavior is modeled ~ OK by XSNLJS (@ 10^{14} W/cm^2)

GW/
sr.eV

0.5

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.



Au, XSNLJS Simulation

Data

10 KJ / 3 ns 10^{14} W/cm^2 at t= 2.9 ns

Summary: 10^{14} W/cm^2

	Total	M-Band
Data (GW/Sr @ peak)	300	3
Model (Type : Flux limit / Auger)		
XSN 0.15 / -	300	2
XSNLJS 0.15 / +	300	4
DCA 0.15 / +	300	12

NIF 2-D hohlraum point design sensitivites

- XSN: Auger / Di-electronic effects:
  - Lowers Z-bar in Au corona by ~ 10%.
  - Lowers Te in Au corona by ~ 10%.
  - Raises Tr in hohlraum by ~ 5 eV or “Dante signal” by 7%

- DCA, XSNLJS:
  - Rise in Tr consistent with their higher conversion efficiency as seen in the Omega Au Sphere simulations
  - Running laser Power @ 0.9x can ~ reproduce Tr as seen in XSN

NIF 2-D hohlraum point design sensitivites

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

- **XSN: dotted line**
- **XSNLJS**
  - **Upper: full power**
  - **Lower: 90% power**
- **DCA**
  - **Upper: full power**
  - **Lower: 90% power**

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