DANTE vs. Witness Plate Radiation Temperature Comparison

(long version)

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http:/astro.swarthmore.edu/~cohen/presentations/trad_comparison_bkg.ppt

The question: DANTE sees a different proportion of hot spots, wall, low-albedo witness plate, and LEH/vacuum than does the witness plate. How do the radiation temperatures and spectra incident on DANTE and the witness plate compare? How does beam pointing affect the temperatures? How important is it to model these effects when analyzing hohlraum/halfraum data from OMEGA?

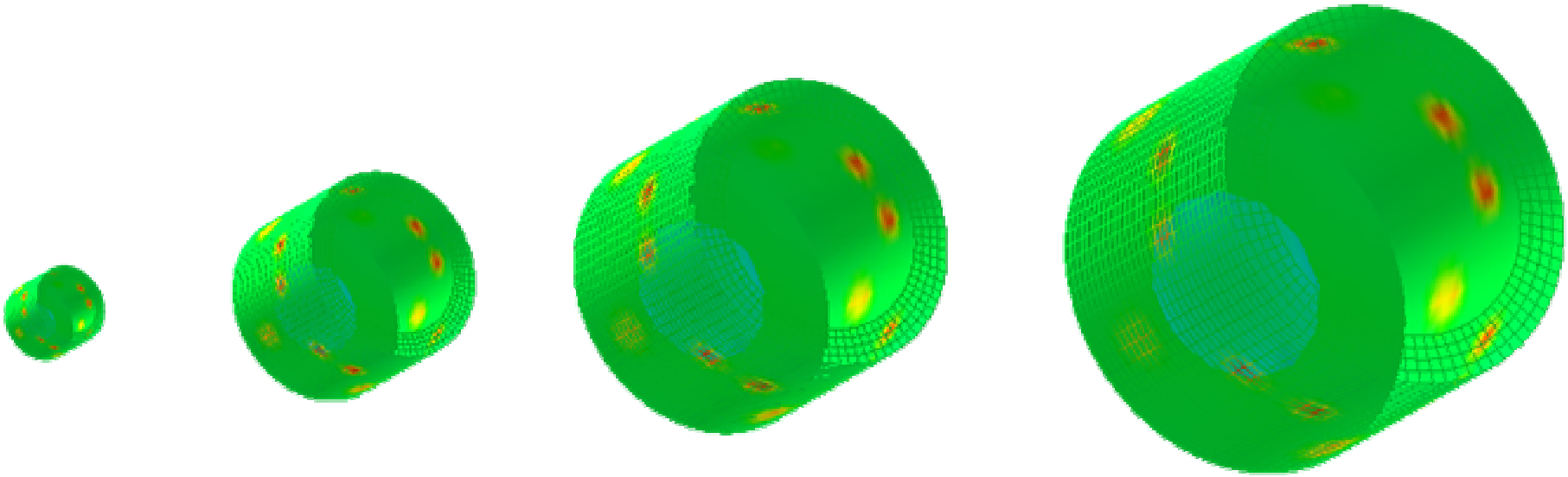


Figure 1: What Dante sees in a typical VisRad halfraum simulation, progressively zoomed in. Emission temperature is shown here.

To investigate this, we performed a series of viewfactor calculations using *VisRad*. We used a scale-1 halfraum on the P6-P7 axis (DANTE angle of 37.4 degrees), and made the following simplifying assumptions:

- No backlighter in the experiment
- The witness plate and the halfraum are both made of gold (maximum albedo = 0.7)
- The laser beam power is constant with a 1ns square pulse (475 J/beam for each of 15 beams).
- There is no "lip" on the halfraum (Figure 2)
- The 15 laser beams were pointed to make a single ring of laser hot spots around the halfraum.

Some of these simplifying assumptions are relaxed later.

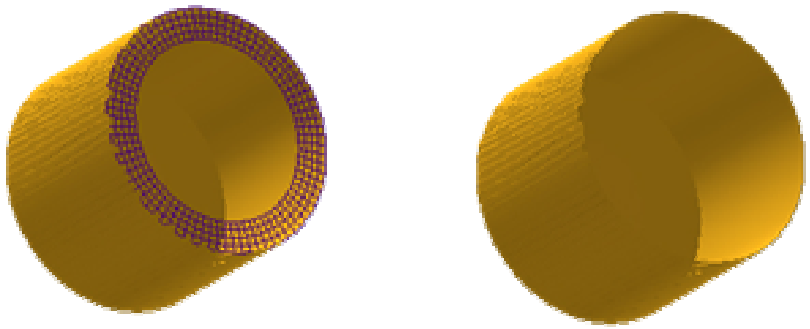


Fig. 2: Left: A typical halfraum with a (1/4) lip over the LEH. Right: A simplified halfraum with no lip. Some surfaces in the VisRad simulations are shown as 'mesh' so the viewer can see what's behind them.

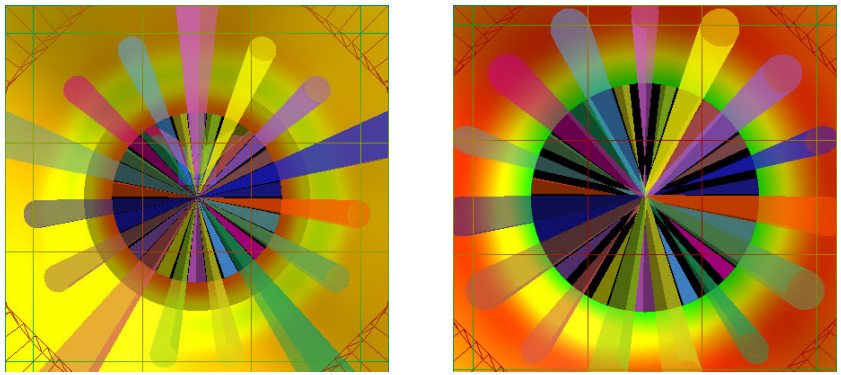
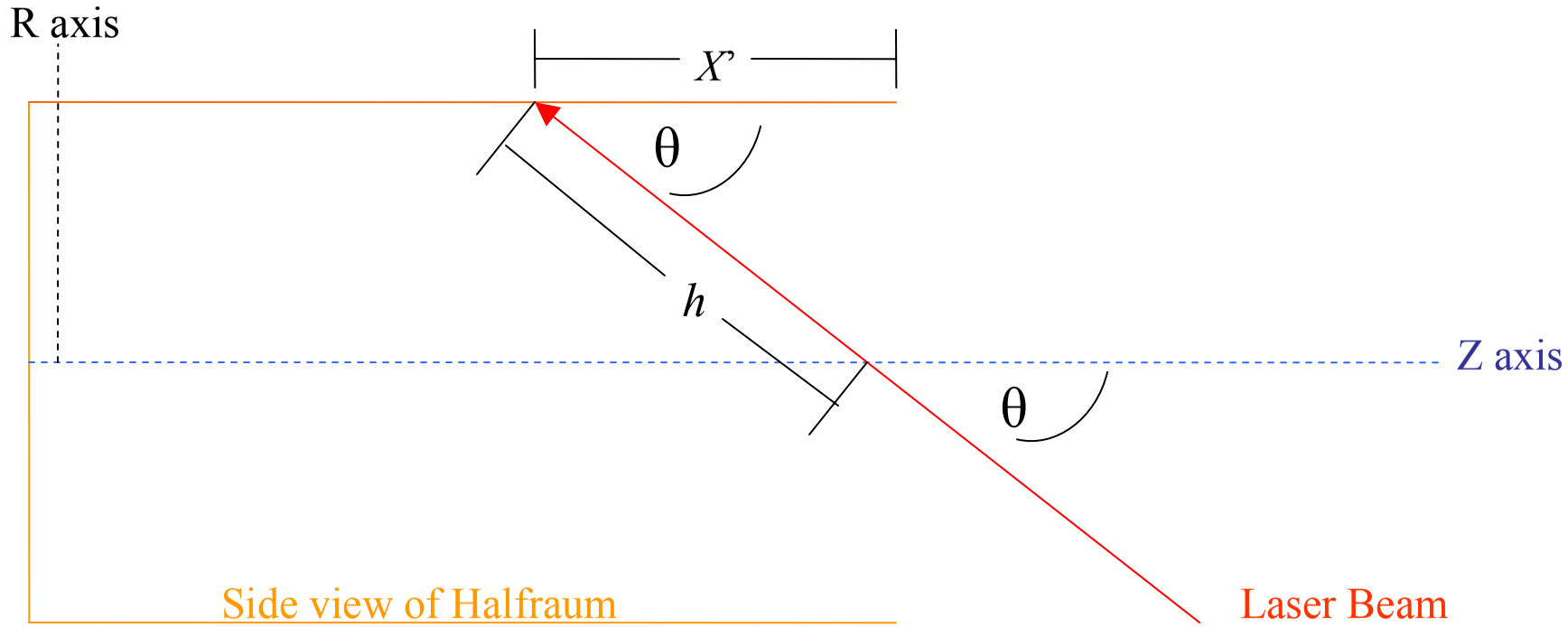


Fig. 3: view from center of witness plate, looking out the LEH. On the left, a more typical configuration with cone 2 and cone 3 beams pointed differently and an LEH lip included. On the right, the result of implementing the simplifying assumptions.

The specification of beam pointing and focusing



Key:

θ = polar angle

X' = the pointing distance into the halfraum

h = the focus offset distance

The main variable in this set of calculations is *X'*. We want to see how the DANTE and witness plate radiation temperatures and their incident spectra compare to each other as *X'* varies every 200 microns from 200 to 800.

To calculate *h*, choose a value for *X'*, Look up θ in *VisRad* and use the following relationship:

$h = X'/\cos(\theta)$ (assuming we want the focus on the z-axis at the LEH plane)

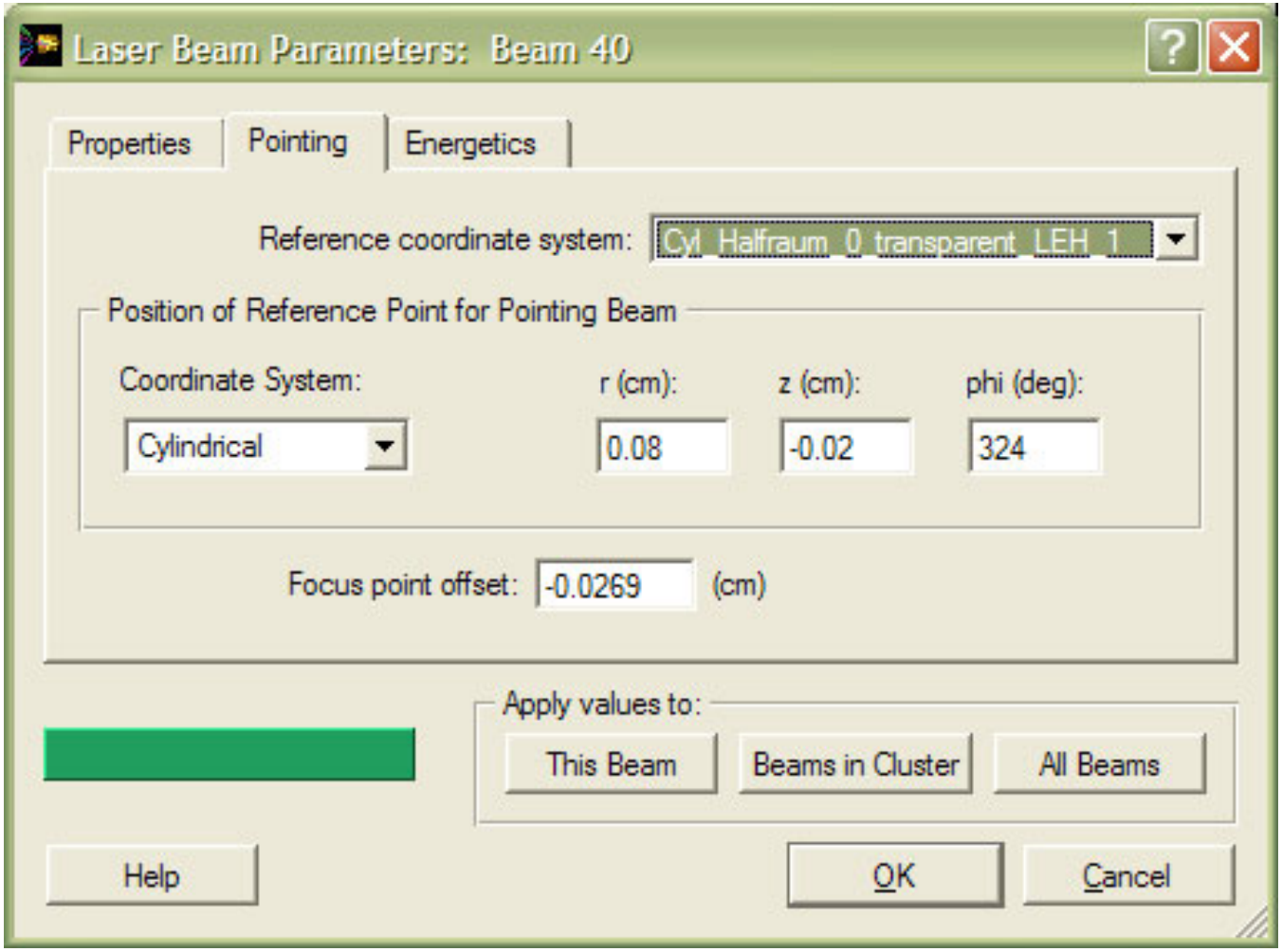


Figure 4: Pointing tab of the laser beam parameter dialogue box.

For our simulations, we found it most convenient to use a cylindrical coordinate system in the reference frame of the LEH plane of the halfraum (Figure 4)

To reposition a beam, you need to specify its r, z, phi, and focus offset values.

After determining the r, z, and focus off set values, you need to add 180° to the stated azimuthal (phi) value given in the port position menu to make the beam cross over the z axis before hitting the halfraum wall (Figures 5 and 6)

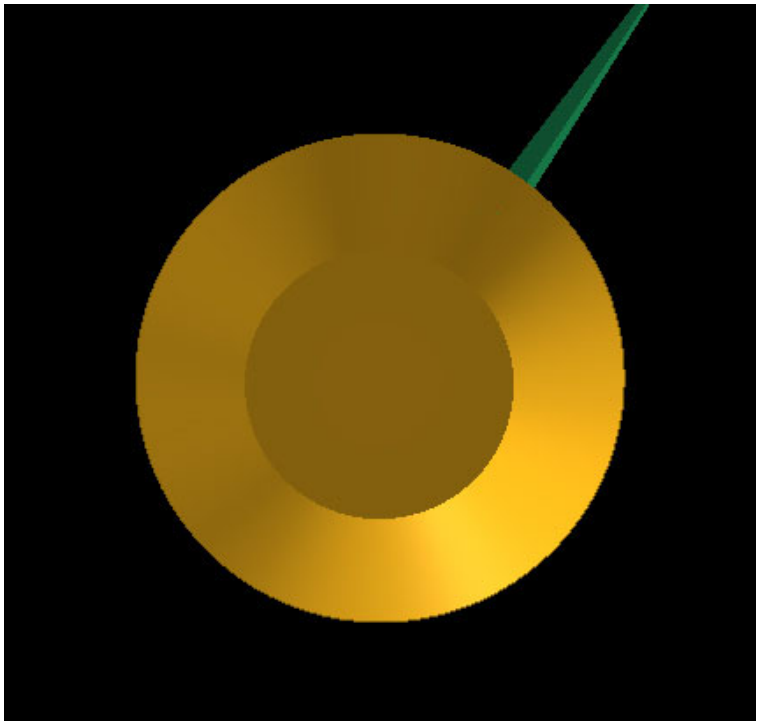


Figure 5: Beam position with beam's original azimuthal value.

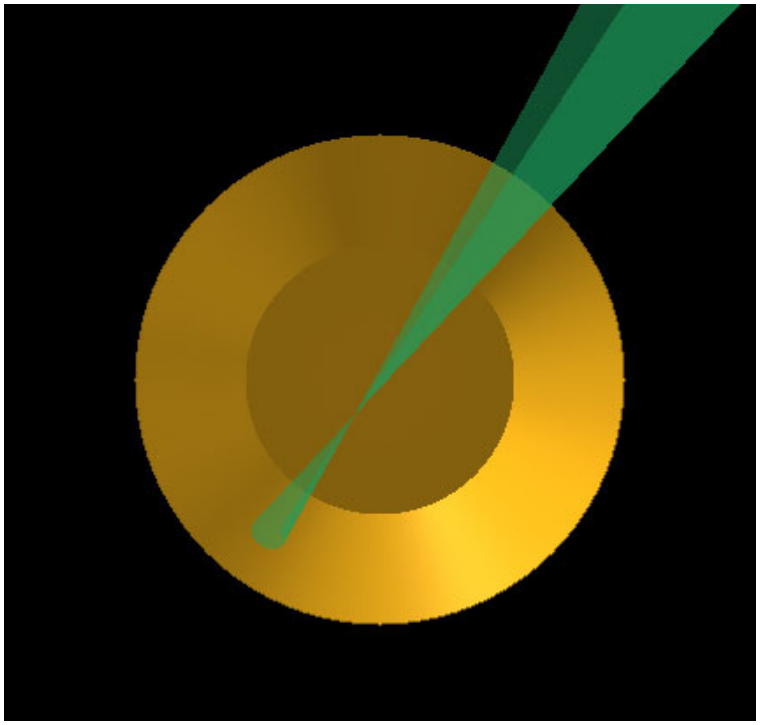
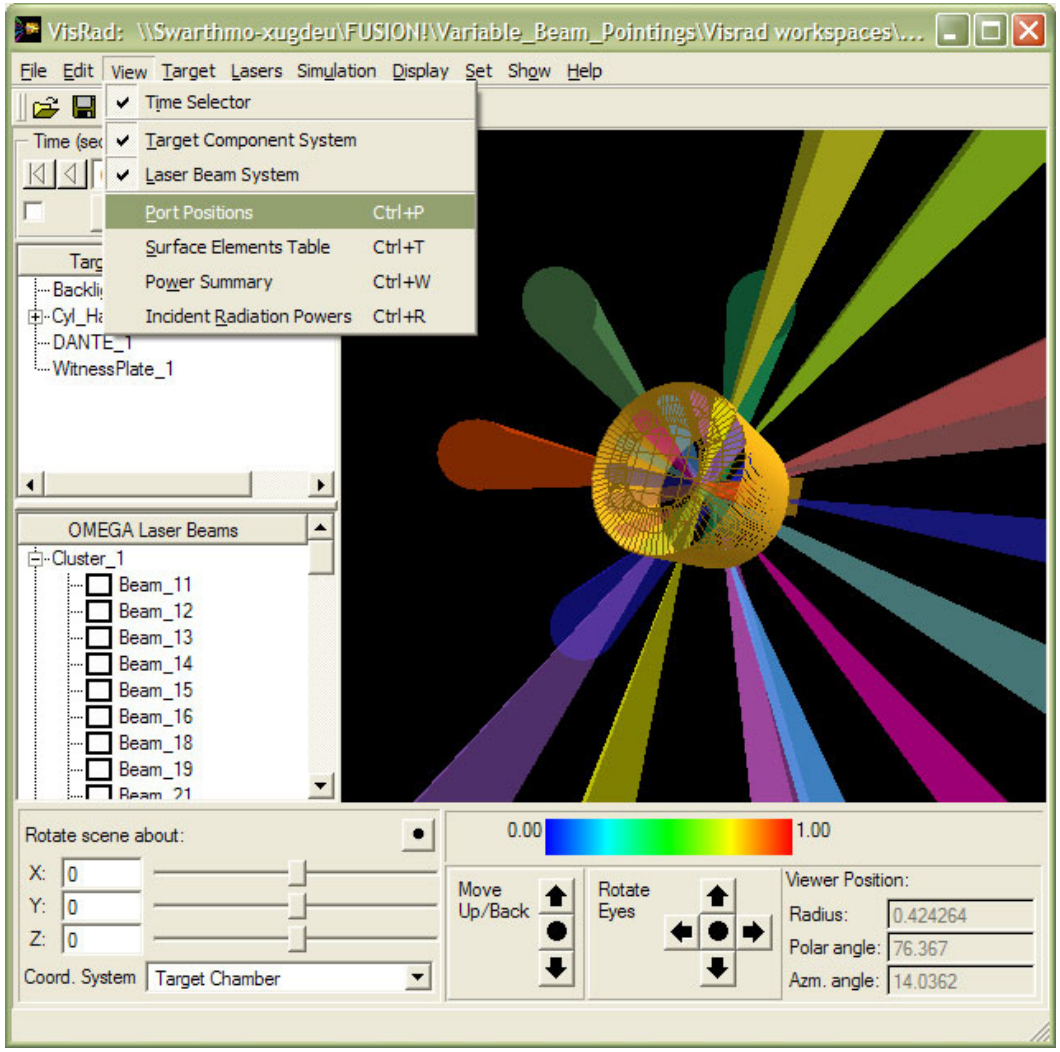


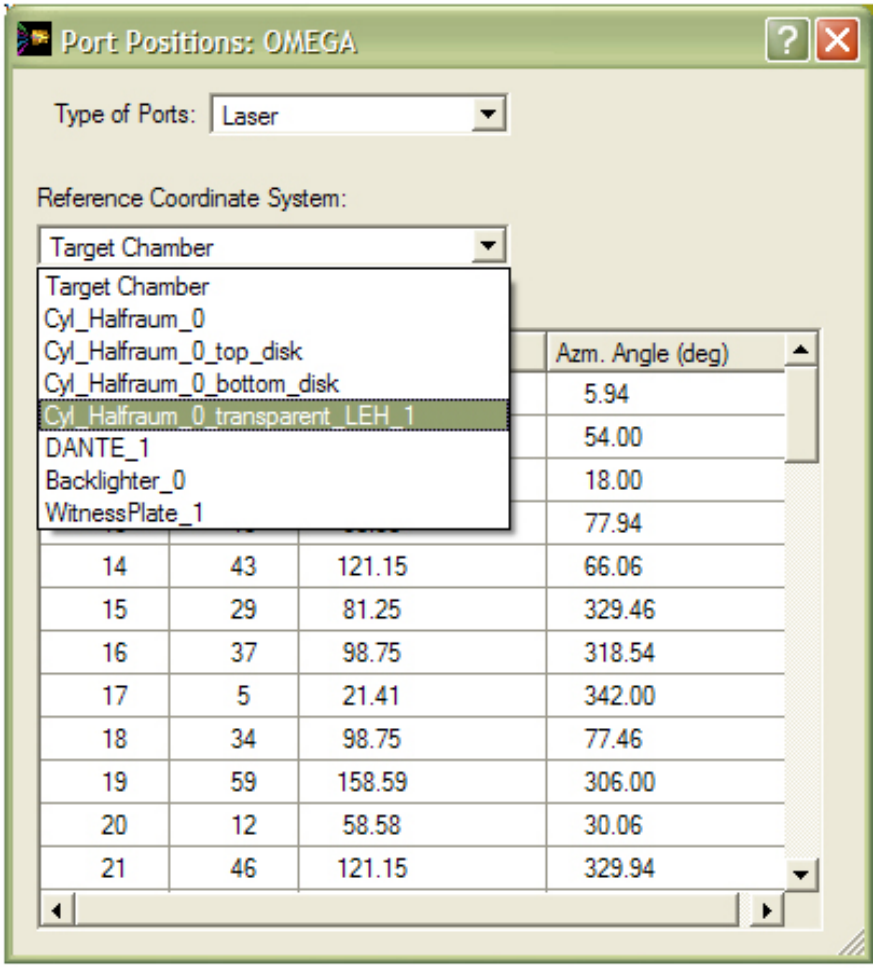
Figure 6: Beam position after adding 180° to the stated azimuthal value. Note that is crosses the z-axis. (z-axis is into the page)

To look up the polar angle (theta)

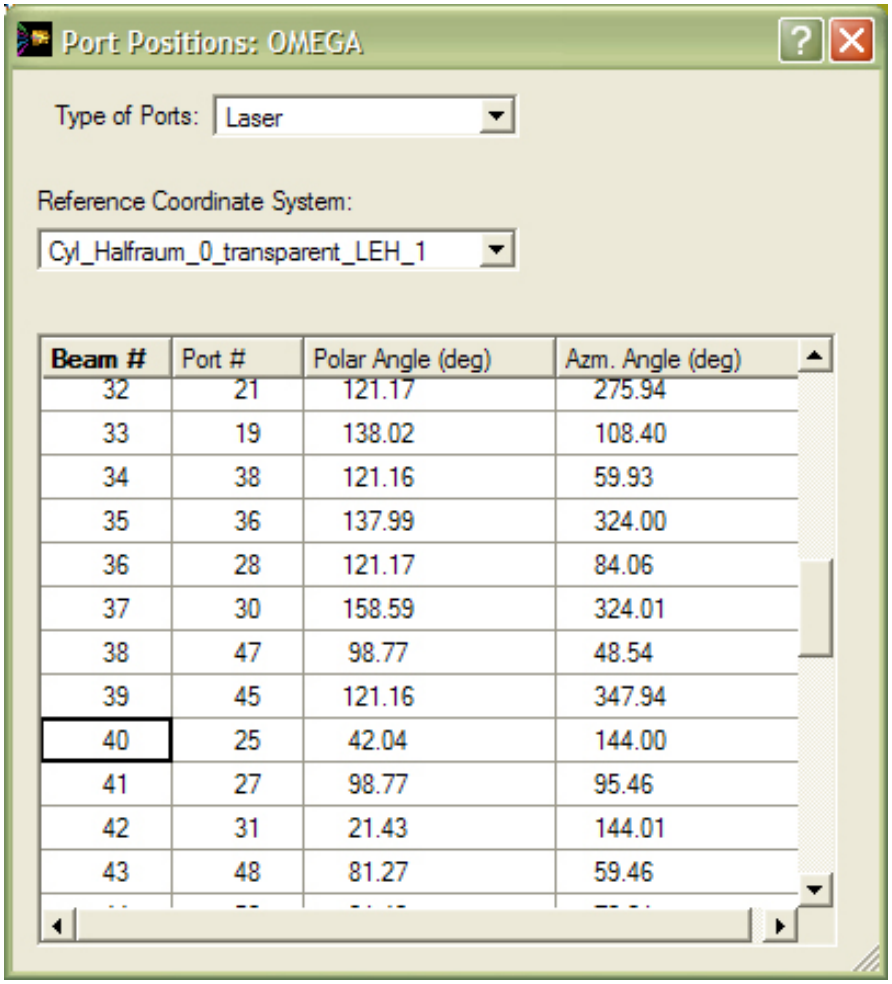
and the aziumthal angle (phi)



First, choose Port Positions from the View menu.



Second, make sure to change your Reference Coordinate System from Target Chamber to Cyl_Halfraum_0 or Cyl_Halfraum_0_transparent_LEH_1. (The Halfraum is oriented along the P6-P7 axis which is tilted with respect to the target chamber coordinate system.)



Beam #	Port #	Polar Angle (deg)	Azm. Angle (deg)
32	21	121.17	275.94
33	19	138.02	108.40
34	38	121.16	59.93
35	36	137.99	324.00
36	28	121.17	84.06
37	30	158.59	324.01
38	47	98.77	48.54
39	45	121.16	347.94
40	25	42.04	144.00
41	27	98.77	95.46
42	31	21.43	144.01
43	48	81.27	59.46

Third, find the number of the beam and read off the polar and azimiuthal angles.

Remember in the pointing menu:

θ = Polar Angle

ϕ = Azimuthal Angle

We found one problem with having the focus offset at the LEH plane for beam pointings 200 and 400 microns into the halfraum.

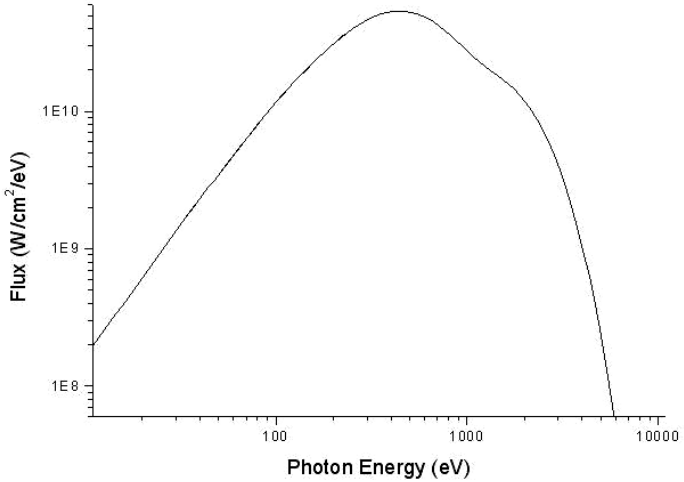


Figure 7: Witness Plate spectrum with focus offset on the LEH plane

A bump in the spectrum occurred at high energies (Figure 7) because the laser hot spot size was too small (Figure 8)

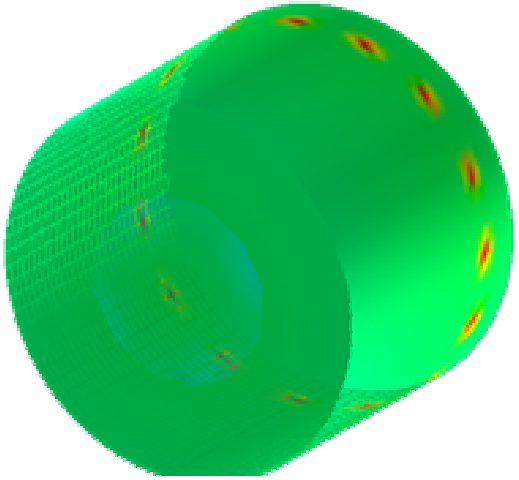


Figure 8

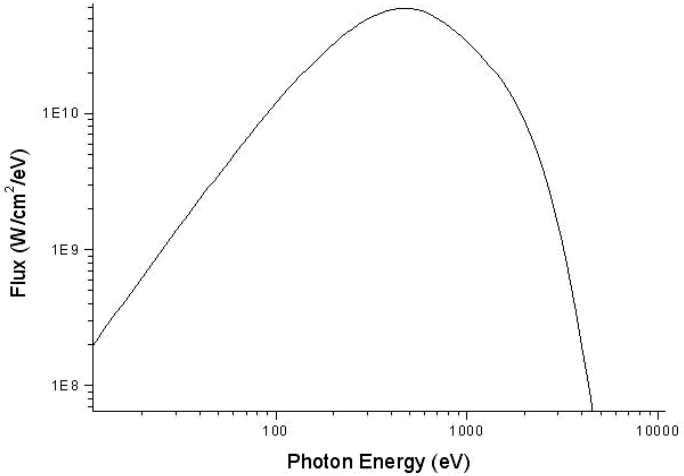


Figure 9: Witness Plate spectrum with focus off set 500 microns out of the LEH plane

By moving the focus offset to 500 microns outside the LEH plane, the hot spots became larger resulting in less energy in a given area (Figure 10), and a lower peak temperature, removing the bump in the spectrum (Figure 9).

The latest version of VisRad has a more realistic beam spot size, which will tend to make the hard spectral bump from the hot spot less severe.

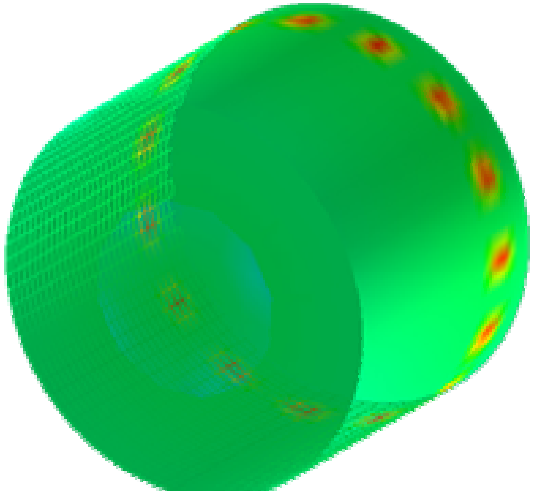
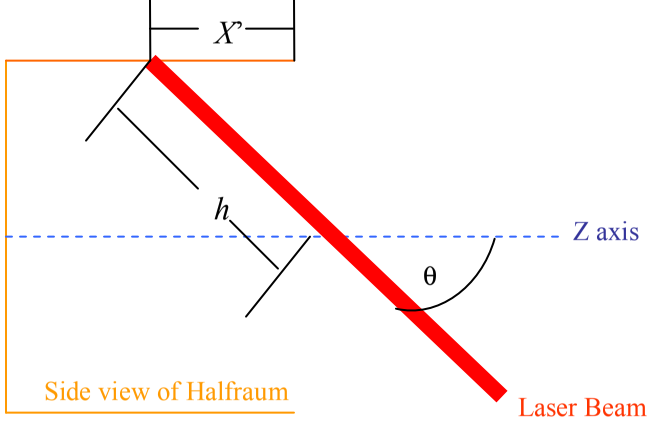


Figure 10

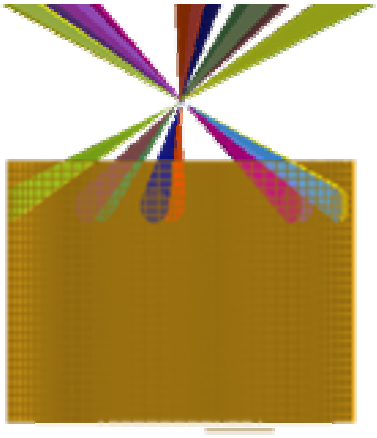
The size of the laser beam spot on the wall of the halfraum varied by pointing distance into the halfraum (X') and focus location.



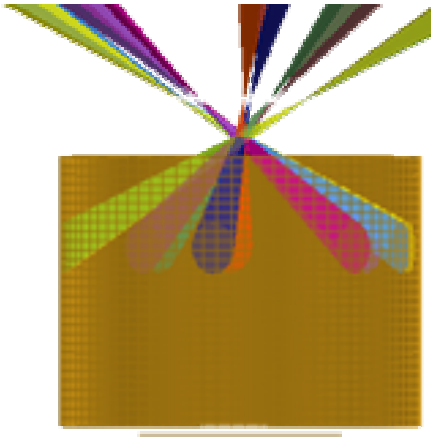
	Pointing (X')	Focus location	Distance to wall from focal point	Spot size (D)	Projected spot size (D-*wall*)
	200	-500			
Cone 2			769	165	246
Cone 3A			887	182	213
Cone 3B			890	183	213
	400	-500			
Cone 2			1039	205	306
Cone 3A			1273	240	280
Cone 3B			1280	241	281
	600	0			
Cone 2			808	171	255
Cone 3A			1161	223	261
Cone 3B			1170	225	262
	800	0			
Cone 2			1077	211	315
Cone 3A			1547	281	328
Cone 3B			1560	283	329

Positive numbers are into the halfraum from the LEH plane.
And all values are in microns.

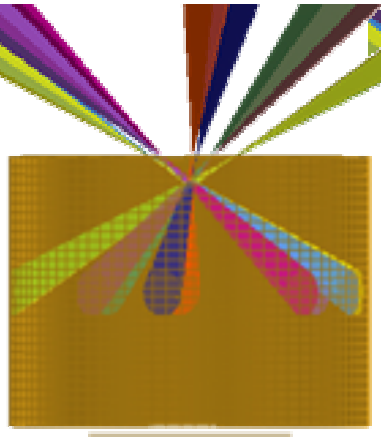
Summary of beam pointings for our simulations



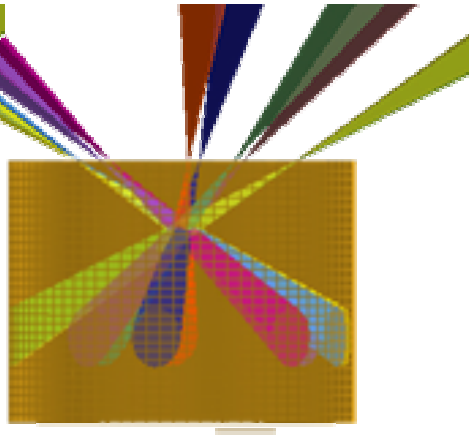
beam pointing = 200 µm into the halfraum, focus offset at 500 microns outside the plane of the LEH



beam pointing = 400 µm into the halfraum, focus offset at 500 microns outside the plane of the LEH



beam pointing = 600 µm into the halfraum, focus offset at the plane of the LEH



beam pointing = 800 µm into the halfraum, focus offset at the plane of the LEH

We ran eight simulations initially. The above four positions once with an albedo of 0.7 and an X-ray Conversion Efficiency (XCE) of 0.55 and again with an albedo of 0.5 and an XCE of 0.4

Our ultimate goal is to compare the radiation temperatures seen by the witness plate and DANTE.

A higher-order comparison involves the spectra incident on the two locations.

DANTE is much farther from the source in the experiment than is the witness plate, resulting in a spectrum much colder, or lower, than the spectrum of the witness plate (Figure 11). To make a meaningful comparison, we can boost up the spectrum seen by DANTE (Figure 12), according to the temperature that would be obtained if the observed radiation filled 2π steradians.

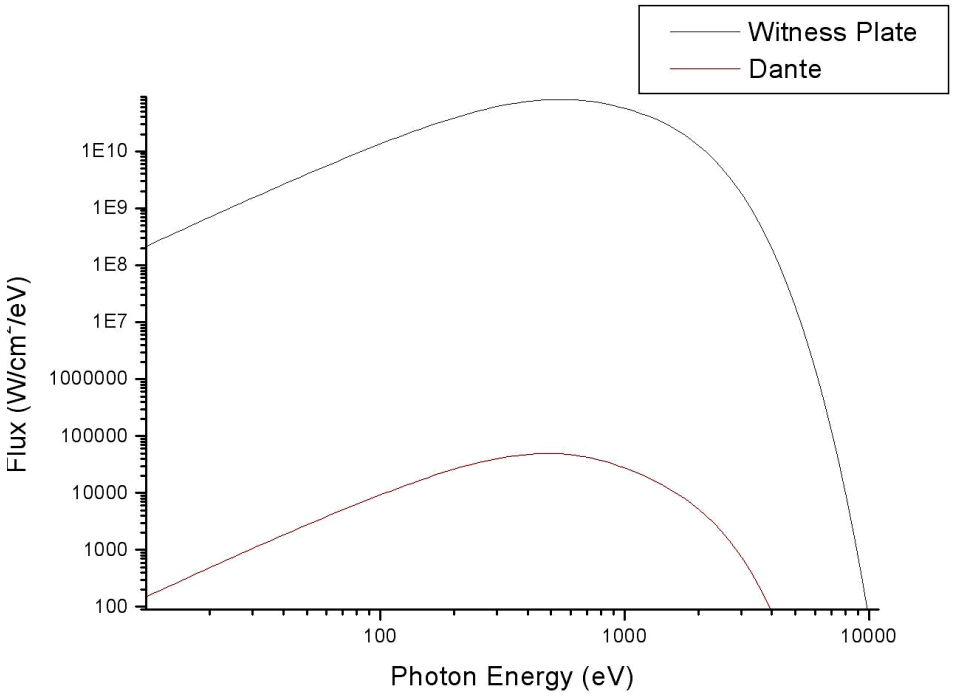


Figure 11

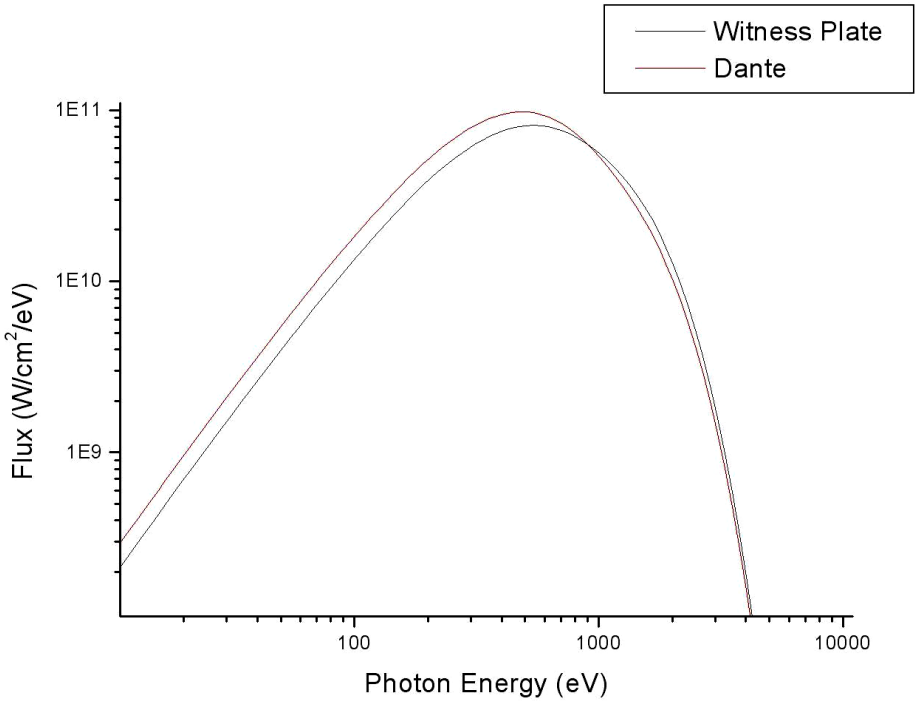


Figure 12

How do we know how much to boost the DANTE spectrum to compare it with the witness plate spectrum?

We want to have the DANTE spectrum represent the spectrum that DANTE would have seen if it was located just outside the LEH instead of 99.94 cm away form the LEH (Figure 13), but without the perspective inherent to having Dante physically at that location (Figure 14).

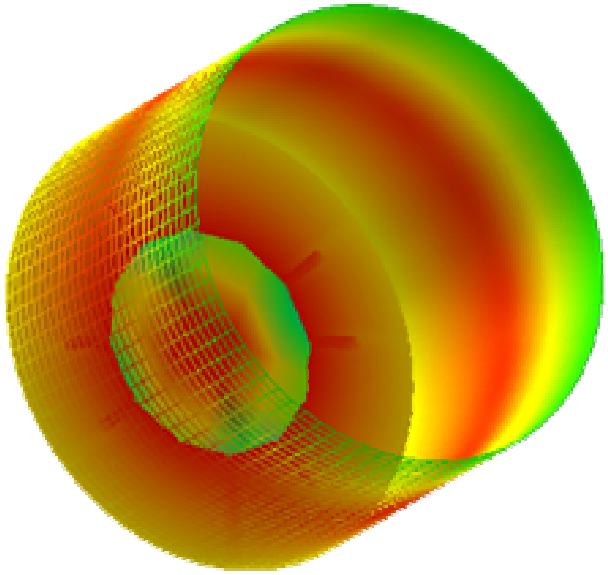


Figure 13: What DANTE sees from 99.94cm away but "zoomed in" without a perspective change. This is the view that actually corresponds to the calculation of the "DANTE temperature."

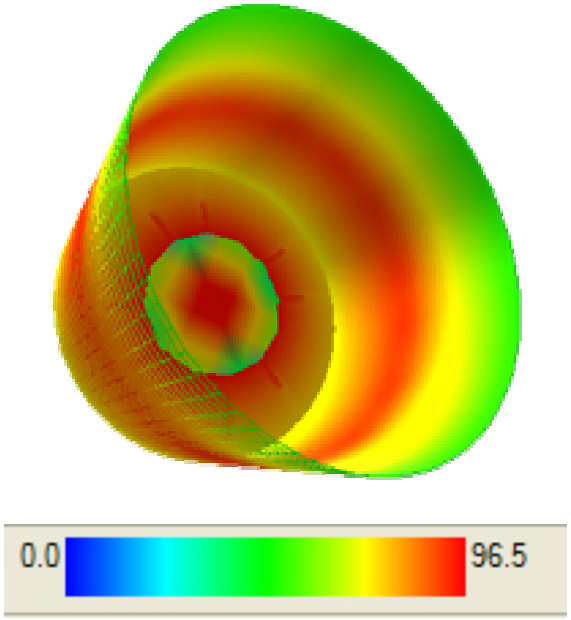


Figure 14: What DANTE would see with the perspective of being actually located outside the LEH.

Converting the *VisRad* DANTE spectrum to the DANTE spectrum at the LEH

Governing equation: Flux = $\int$Intensity * cos(θ) dΩ

In spherical coordinates:

$$\text{Flux} = \int_0^{2\pi} \int_0^{\pi/2} \text{Intensity}^* \cos(\theta)\sin(\theta)\, d\theta\, d\phi$$

Solving the integral using $\mu = \cos(\theta)$ gives us:

Flux = Intensity * Ω

To go from the spectrum from *VisRad* to a boosted up spectrum:

Flux (Dante at the LEH) = Flux (Dante from *VisRad*)* π /Solid Angle of the LEH

So our correction factor to convert the Dante spectrum from *VisRad* to the Dante spectrum at the LEH is

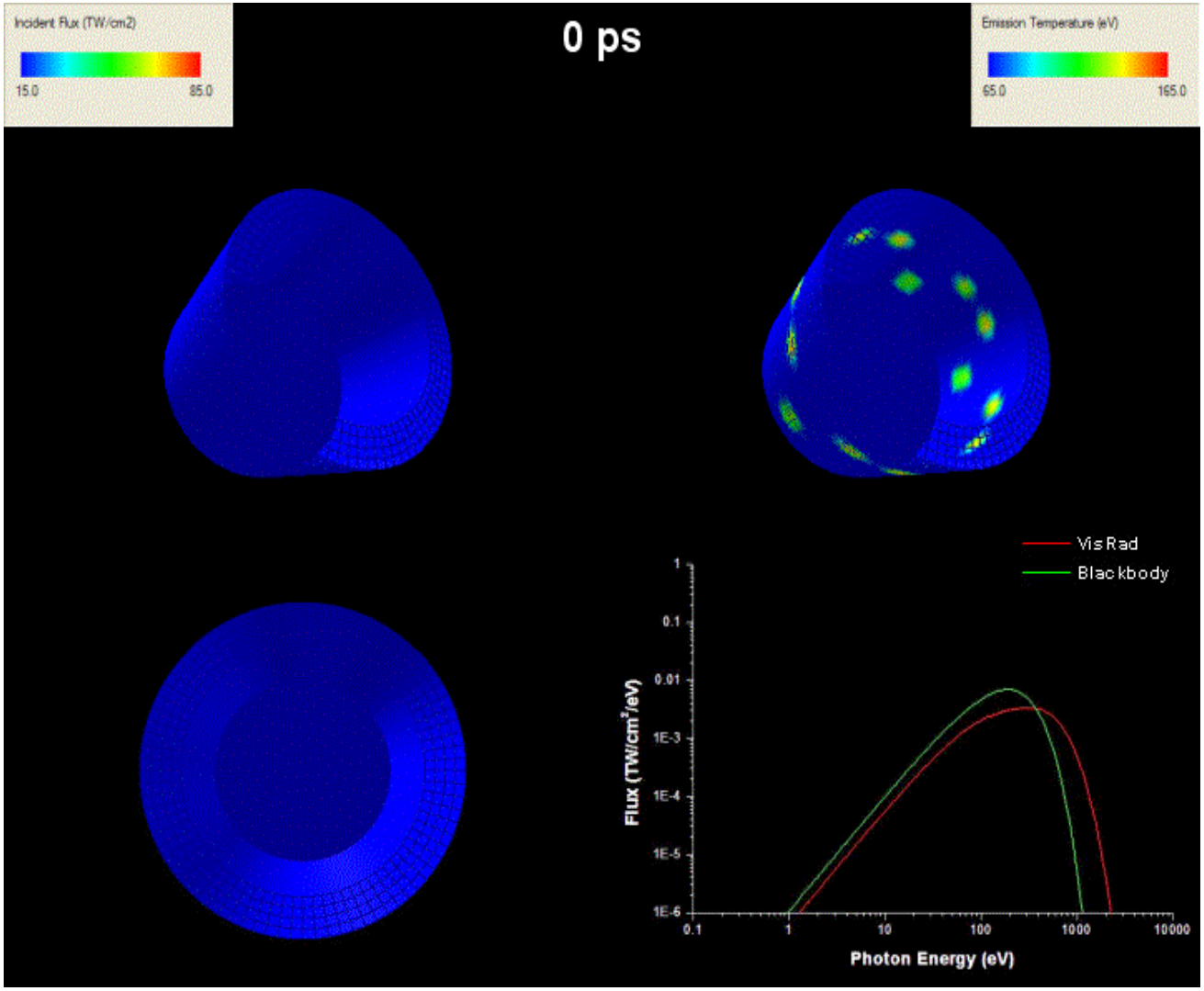
π/(Solid Angle of the LEH) = 1.962×10^6 (in our simulation, the DANTE surface is at 100 cm)

Note: A similar correction is made to the radiation temperature on DANTE calculated by *VisRad*. See http://astro.swarthmore.edu/~cohen/presentations/DANTE-convfac-VisRad.pdf for more details on these corrections.

Results from our initial simulations

During the course of a shot, the XCE and albedo change, driven by changes in the wall temperature: Here is a simulation of a specific OMEGA shot (15 beams, 1 ns square pulse into a scale-1 halfraum)

Dante view; T_{rad}



Dante view; T_{emis}

On-axis view, T_{rad}

Incident spectrum (and BB equivalent) onto witness plate

For these simulations, we do not use a time-dependent model of the albedo and XCE, rather we take two representative values: high (albedo = 0.7, XCE = 0.55) indicative of late times, and low (albedo = 0.5; XCE = 0.4) indicative of early times.

Later, we add a third, intermediate, combination (albedo = 0.5, XCE = 0.55).

The results of a simulation done with the beams pointed 600 μm into the halfraum with the focus offset at the plane of the LEH, an albedo of 0.7 and an XCE of 0.55. Note that the witness plate (Figure 15) sees more hot spots than DANTE (Figure 16), but it also sees the relatively cold LEH.

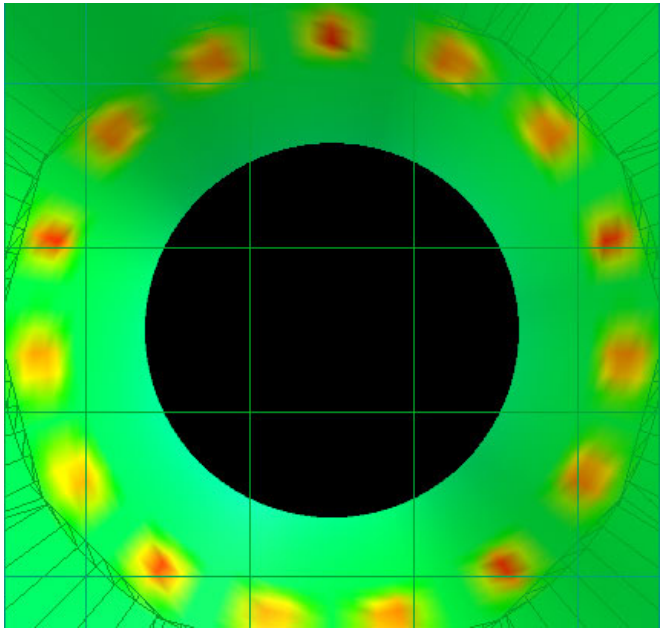


Figure 15

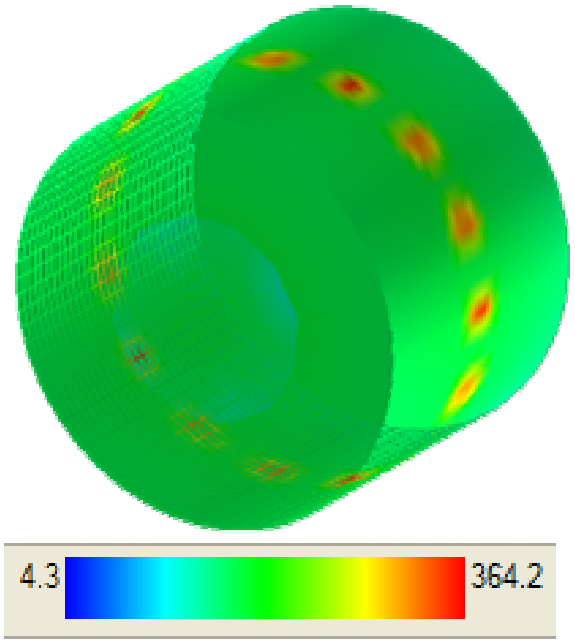
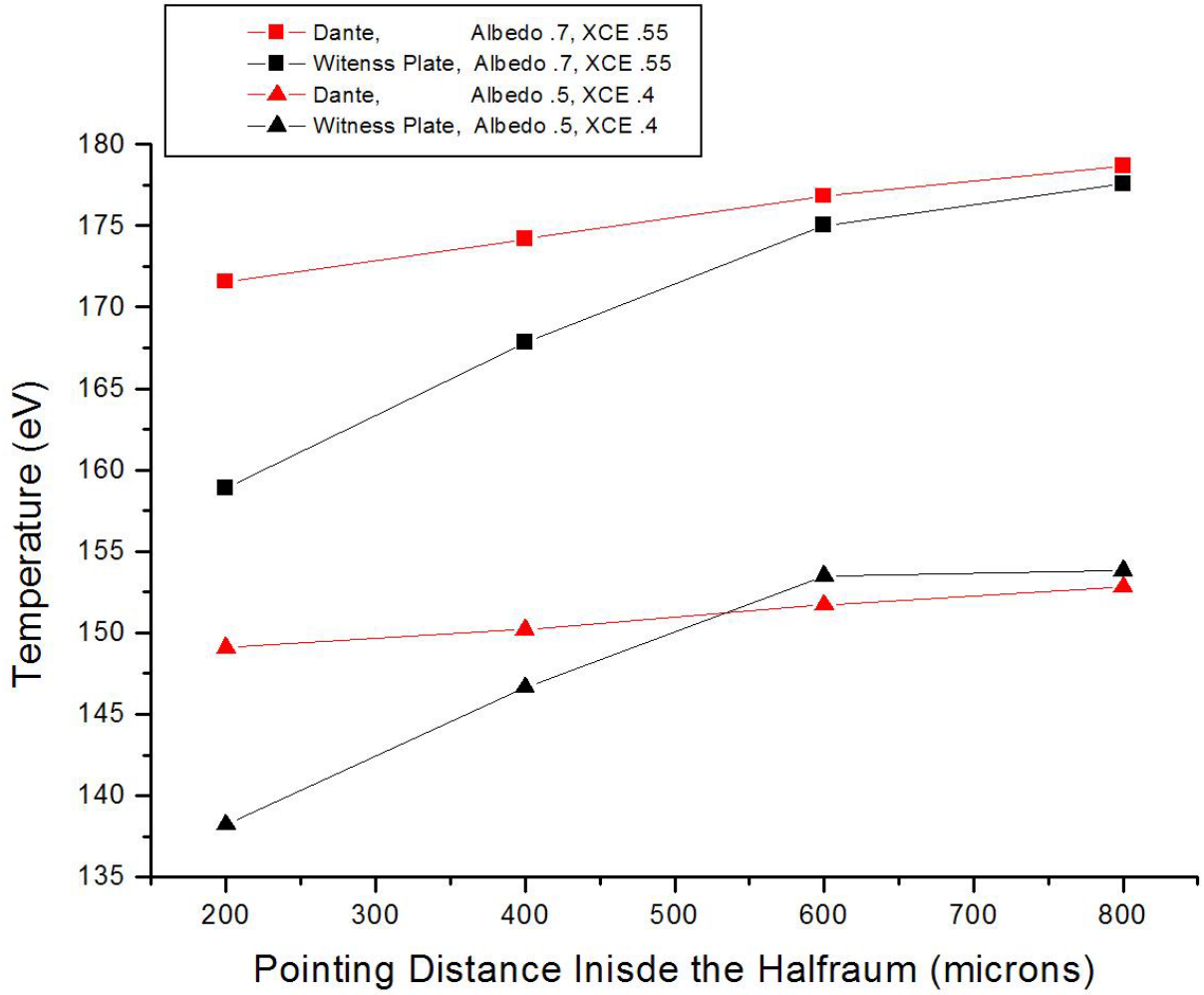


Figure 16

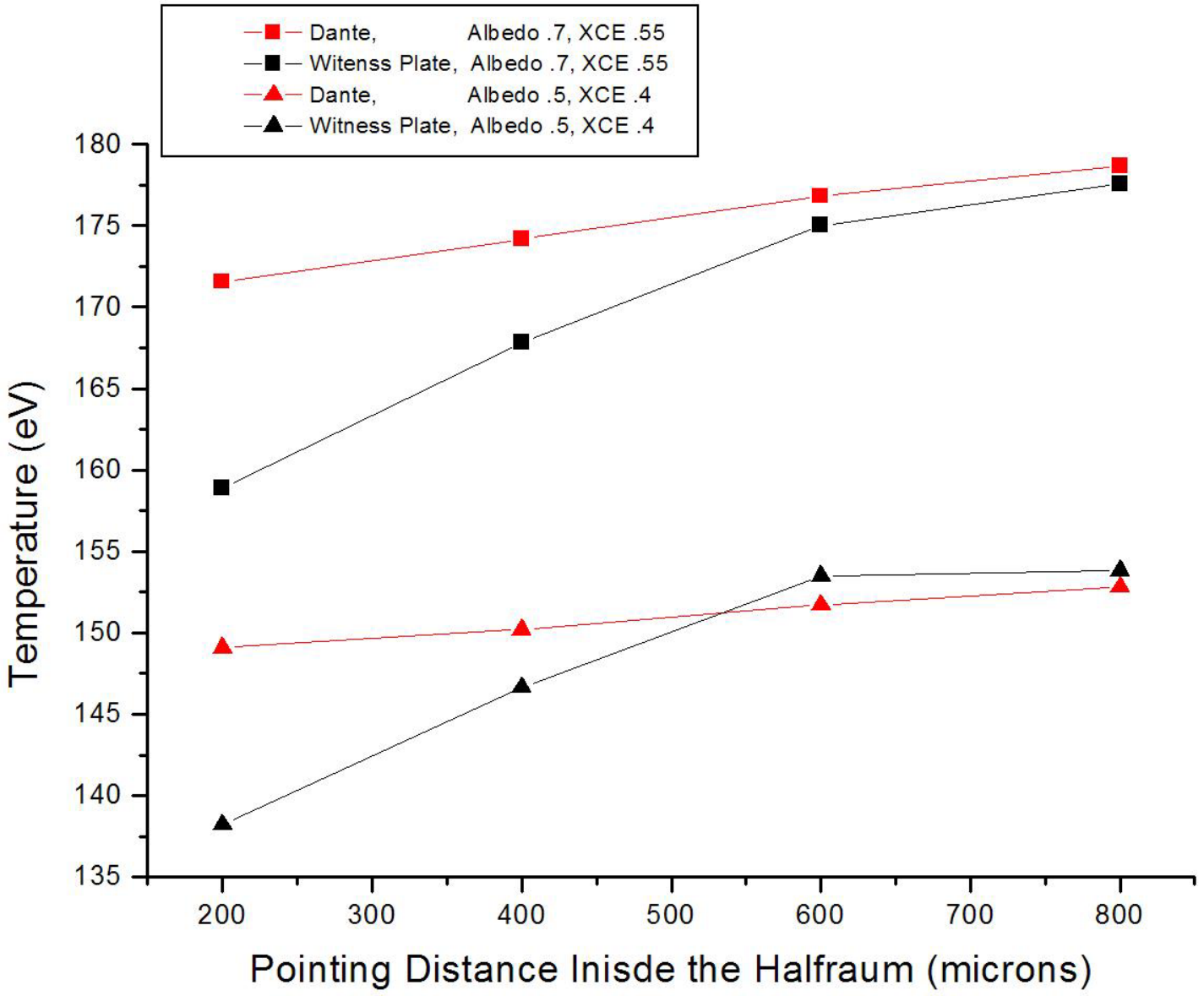
We would like to quantify this by post-processing these simulations in order to make a *histogram* of solid angle vs. temperature (future work).

Incident radiation temperatures changed due to the beam pointing and also due to the albedo and XCE



The data at the 600 and 800 micron pointing positions are done with a focus offset at the LEH plane. The data points at the 200 and 400 micron pointing positions are done with a focus offset of 500 microns outside the LEH plane.

The witness plate radiation temperature is higher than the DANTE temperature only for relatively deep pointings and low albedo, XCE

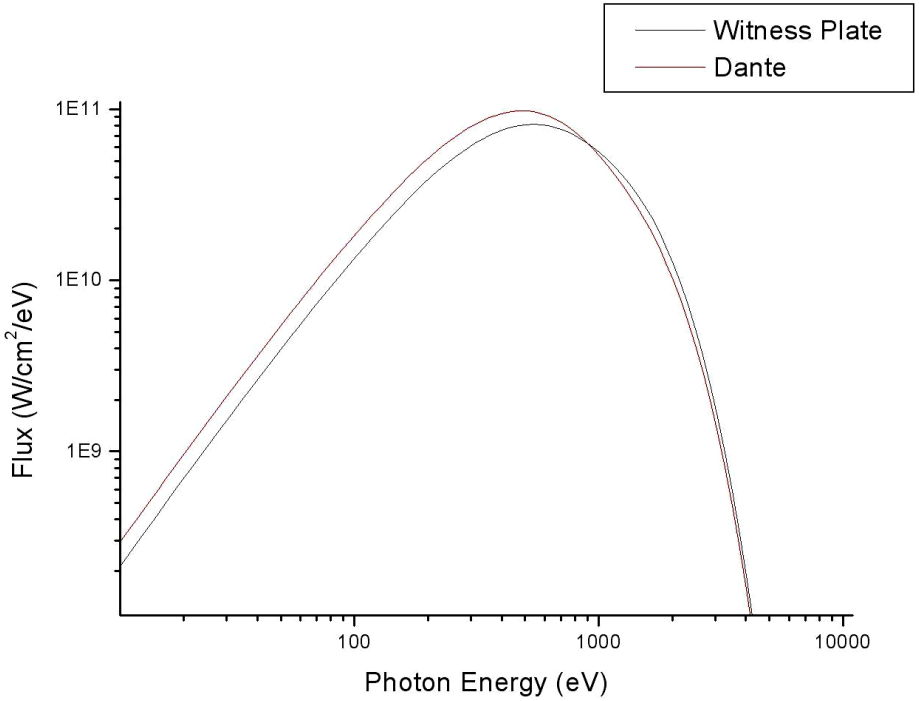


Simulation Results Summary

Pointing distance into the Halfraum	Focus offset	Albedo	XCE	VisRad reported DANTE temp (eV)	Actual DANTE temp (eV) VisRad temp*37.457	Witness plate temp (eV)	T_{DANTE}/T_{WP}
200	0	0.7	0.55	4.6	171.6	158.1	1.09
200	-500	0.7	0.55	4.6	171.6	158.9	1.08
200	-500	0.5	0.4	4.0	149.1	138.2	1.08
400	0	0.7	0.55	4.7	174.2	167.8	1.04
400	-500	0.7	0.55	4.7	174.2	167.8	1.04
400	-500	0.5	0.4	4.0	150.2	146.7	1.02
600	0	0.7	0.55	4.7	176.8	175.0	1.01
600	0	0.5	0.4	4.1	151.7	153.5	0.99
600	-500	0.7	0.55	4.7	176.8	175.0	1.01
800	0	0.7	0.55	4.8	178.7	177.6	1.01
800	0	0.5	0.4	4.1	152.8	153.8	0.99
(Distances measured in microns with the LEH Plane=0 microns. Into the Halfraum represents positive distances)							

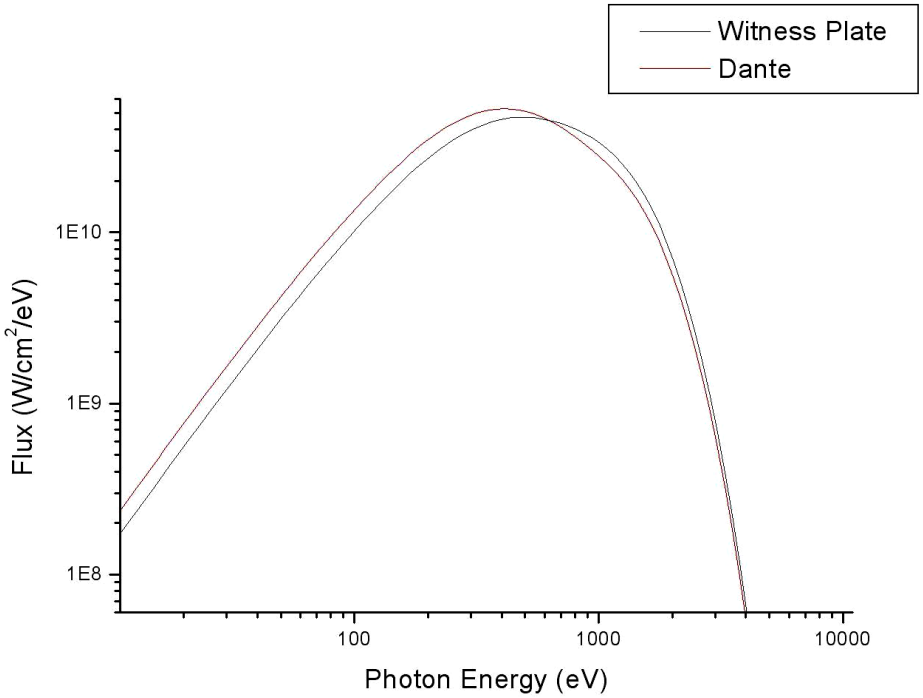
When we apply the spectral conversion factor to the DANTE spectrum and plot in along with the witness plate spectrum, it does not appear as if the area under the two curves is exactly equal.

Shown here are the spectra for simulations run with the beams pointed 600 microns into the halfraum.



X-ray Conversion Efficiency = .55, Albedo = .7

T_{DANTE}=176.73 $T_{\text{Witness Plate}}$=175.02



X-ray Conversion Efficiency = .4, Albedo = .5

T_{DANTE}=151.75 $T_{\text{Witness Plate}}$=153.50

Questions: Could our correction factors be wrong?

What is the ration of the areas under these curves?

Where do we go from here?

•Quantitatively sum up the area under the two curves in figures and to confirm the area underneath the DANTE spectrum does not equal the area under the witness plate curve.

•Perform a new simulation with a “lip” on the halfraum (Figure 17).

•Perform a new simulation where the albedo of the witness plate is lower than the albedo of the halfraum.

•Create a histogram of solid angle versus temperature.

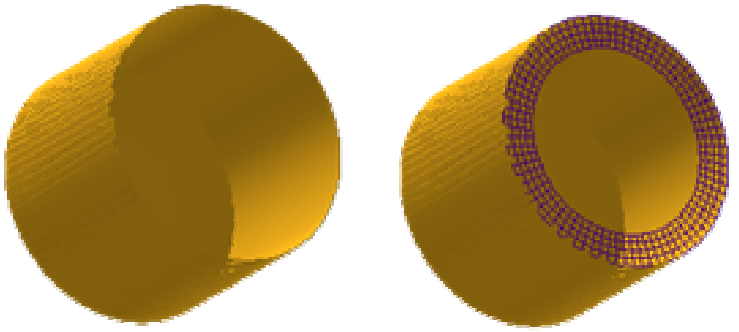
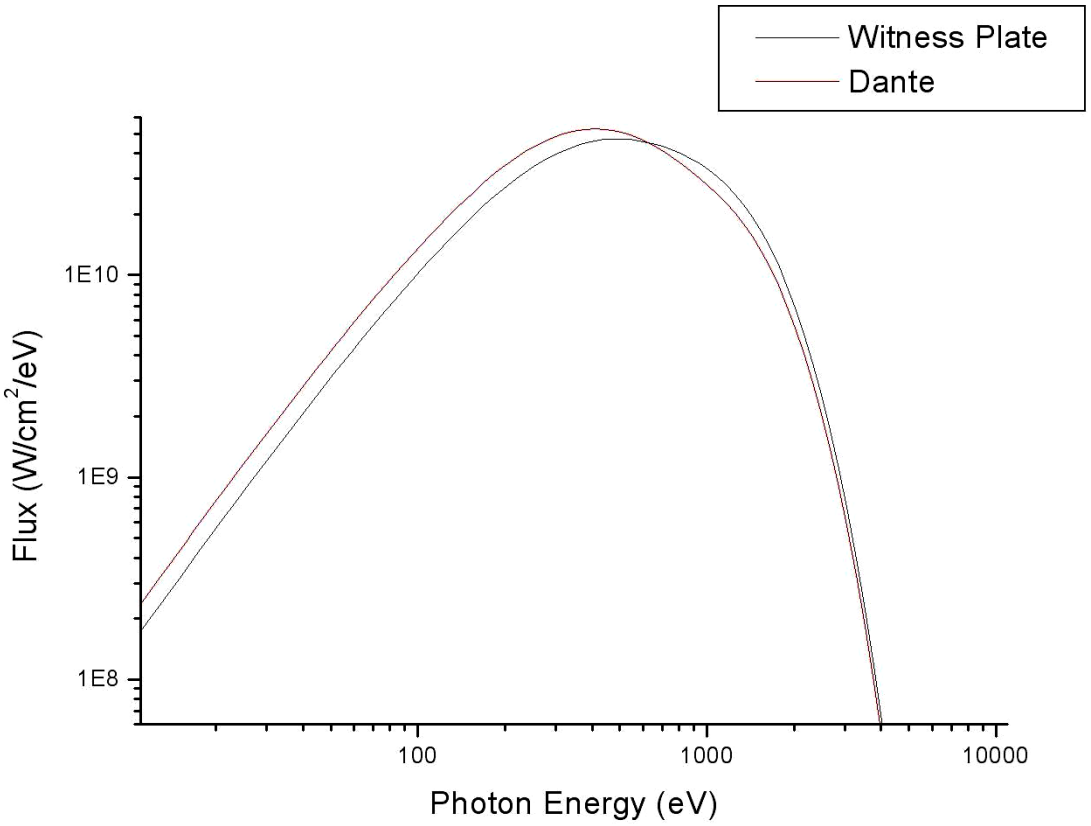


Figure 17

Now we've done some of the "next" tasks

The area under the spectral curves checks out: We compared the ratio of f_{wp}/f_{dante} to $(T_{wp}/T_{dante})^4$ and found good agreement (see next slide). Log plots can be misleading.

But, by the same token, the spectral energy distributions are different, even when the overall radiation temperatures are the same.

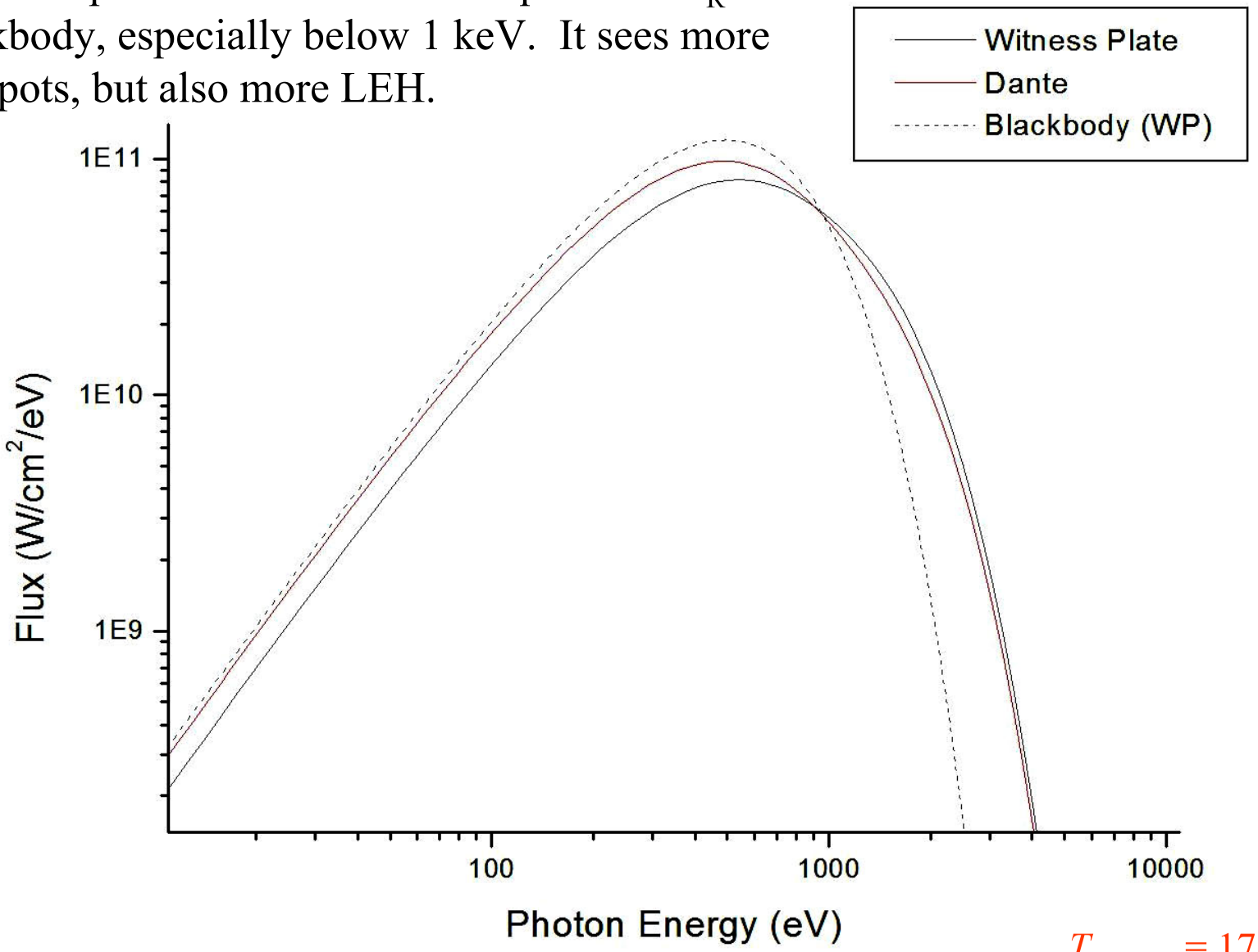


DANTE sees more soft emission, while the witness plate spectrum is harder.

Here is the comparison of area under the curve (flux) to temperature

Pointing distance into the halfraum	Albedo	XCE	DANTE temp (eV)	Witness plate temp (eV)	Dante flux (W/cm2)	Witness plate flux (W/cm2)	Ratio of DANTE temp to witness plate temp	Temp ratio to the fourth power	Ratio of DANTE flux to witness plate flux
200	0.70	0.55	171.6	158.9	9.8E+14	7.2E+14	1.08	1.36	1.36
400	0.70	0.55	174.2	167.8	1.0E+15	9.0E+14	1.04	1.16	1.16
600	0.70	0.55	176.8	175.0	1.1E+15	1.1E+15	1.01	1.04	1.04
800	0.70	0.55	178.7	177.6	1.2E+15	1.1E+15	1.01	1.03	1.02
200	0.50	0.40	149.1	138.2	5.6E+14	4.1E+14	1.08	1.35	1.35
400	0.50	0.40	150.2	146.7	5.8E+14	5.2E+14	1.02	1.10	1.11
600	0.50	0.40	151.7	153.5	6.0E+14	6.3E+14	0.99	0.95	0.96
800	0.50	0.40	152.8	155.7	6.2E+14	6.7E+14	0.98	0.93	0.93
(Distances measured in microns with the LEH Plane= 0 microns. Into the Halfraum represents positive distances)									

The witness plate spectrum is harder than the DANTE spectrum as well as the equivalent T_R blackbody, especially below 1 keV. It sees more hot spots, but also more LEH.



T_{DANTE} = 176.7 eV

T_{WP} = 175.0 eV

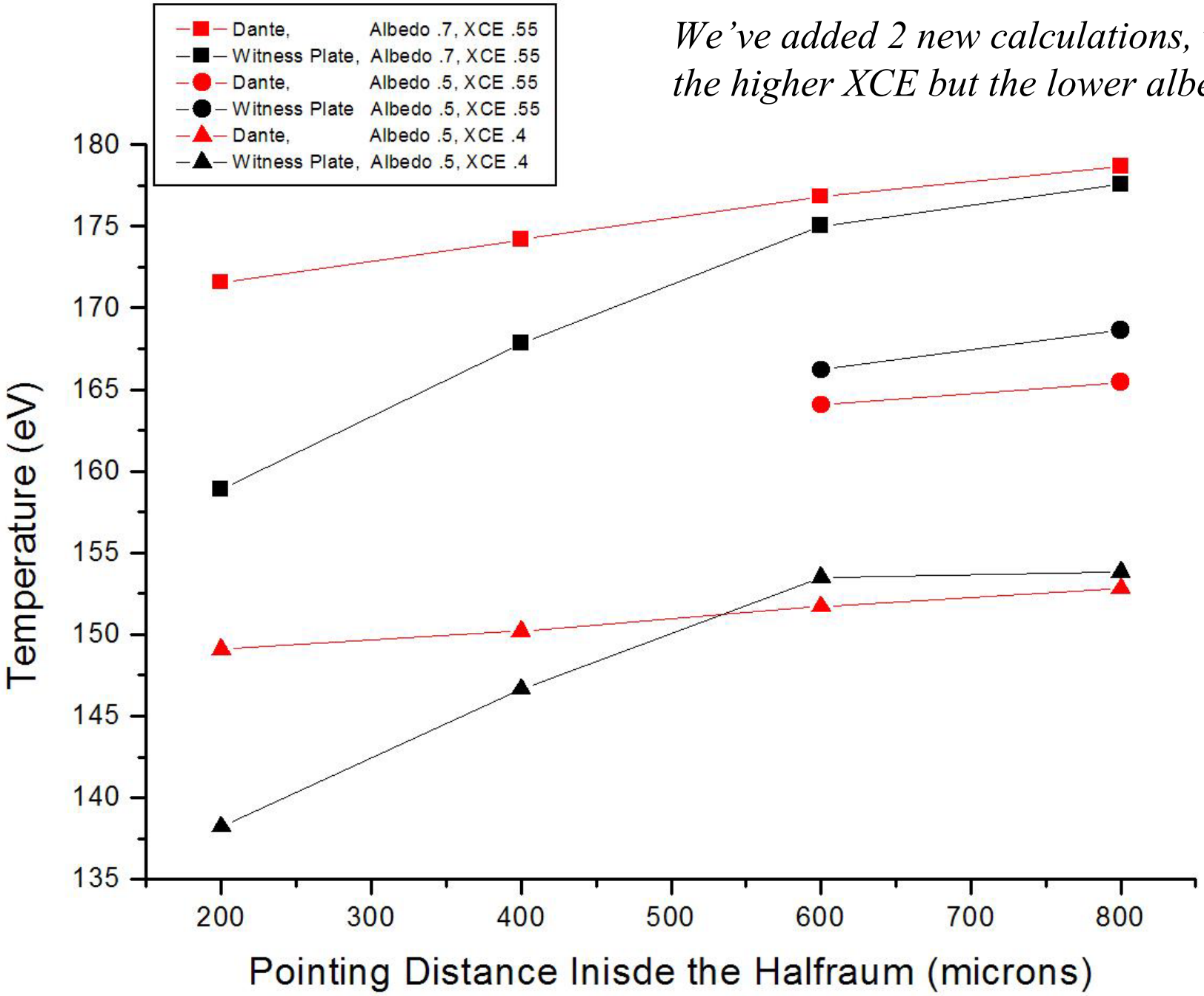
Question: is it the decrease in albedo or in the XCE that makes $T_{wp} > T_{DANTE}$ for deep pointings?

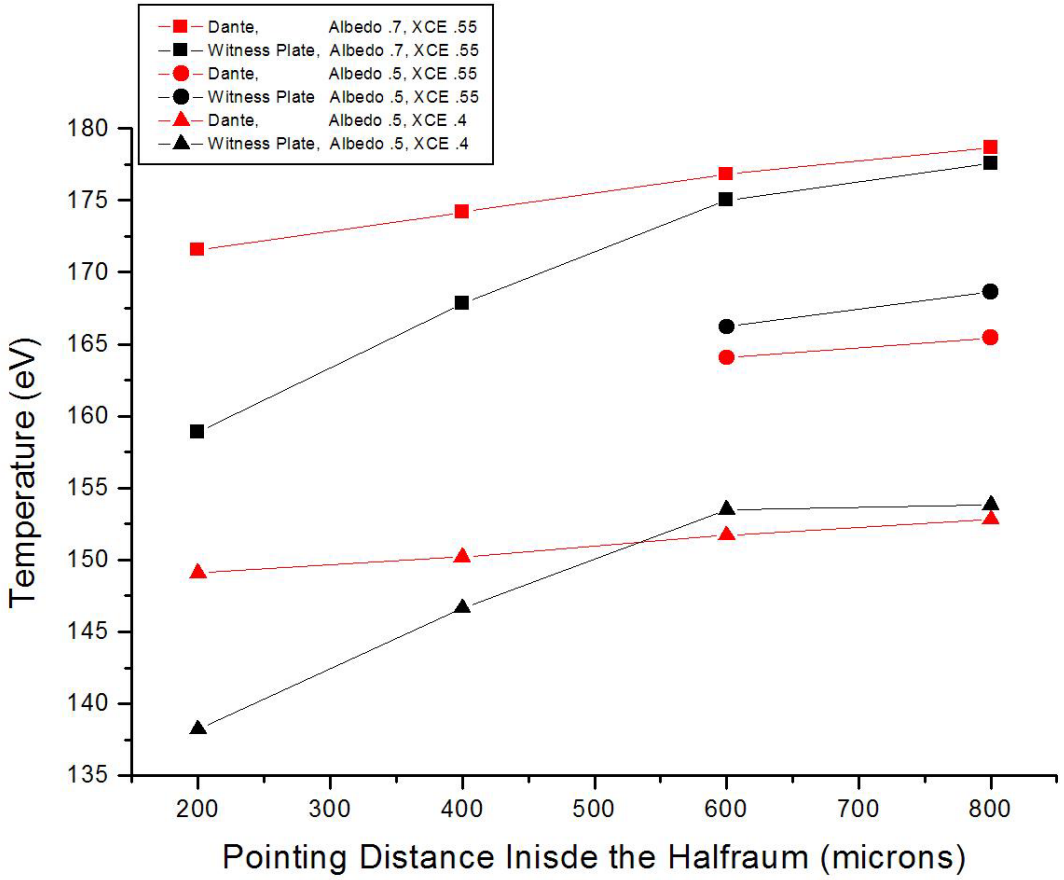
And for that matter, which effect dominates the overall lowering of the temperatures?

Question: how much difference does the low-albedo witness plate make?

What about the lip on the halfraum? (If we were to relax some of our simplifying assumptions and make the simulations more realistic.)

We've added 2 new calculations, with the higher XCE but the lower albedo





It appears to be the albedo-lowering that allows $T_{wp} > T_{DANTE}$

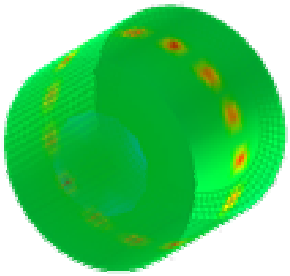
It makes sense that the XCE wouldn't do it, because that just scales the energy deposition

But the lower albedo also lowers the overall temperature a lot

Maybe the effect of the lower albedo on boosting the relative temperature of the witness plate is that the lower albedo essentially makes for colder walls. The hot spots are therefore more important, relatively, and the witness plate view must be more dominated by hotspots than is the DANTE view.

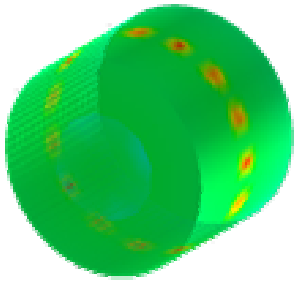
The next slides show comparisons between lip and no-lip halfraums and between low- and high-albedo witness plates

600 Microns Beam Pointing, Halfraum and WP Albedo 0.7



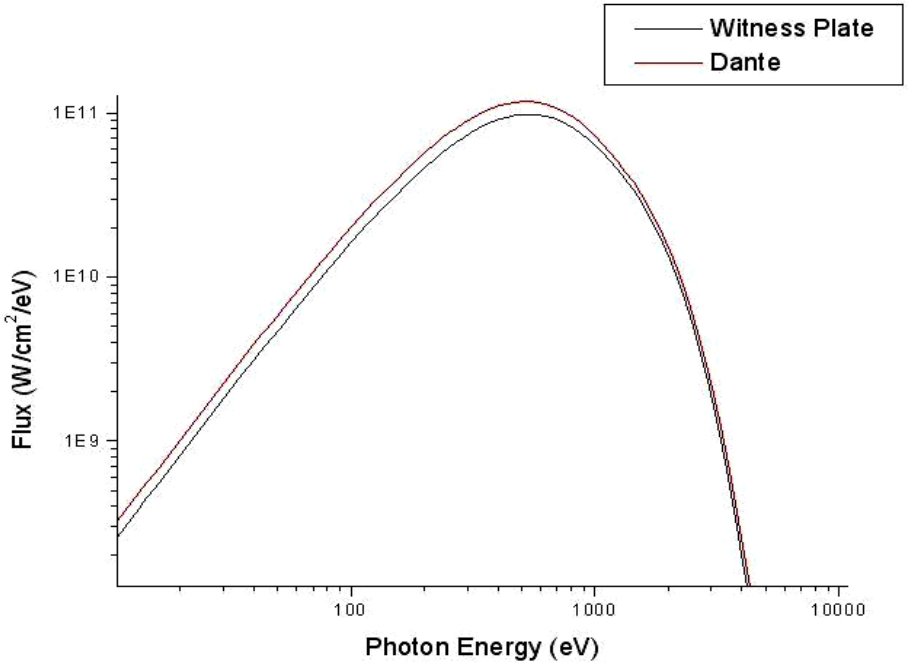
Lip:

LEH Radius = 600 μm

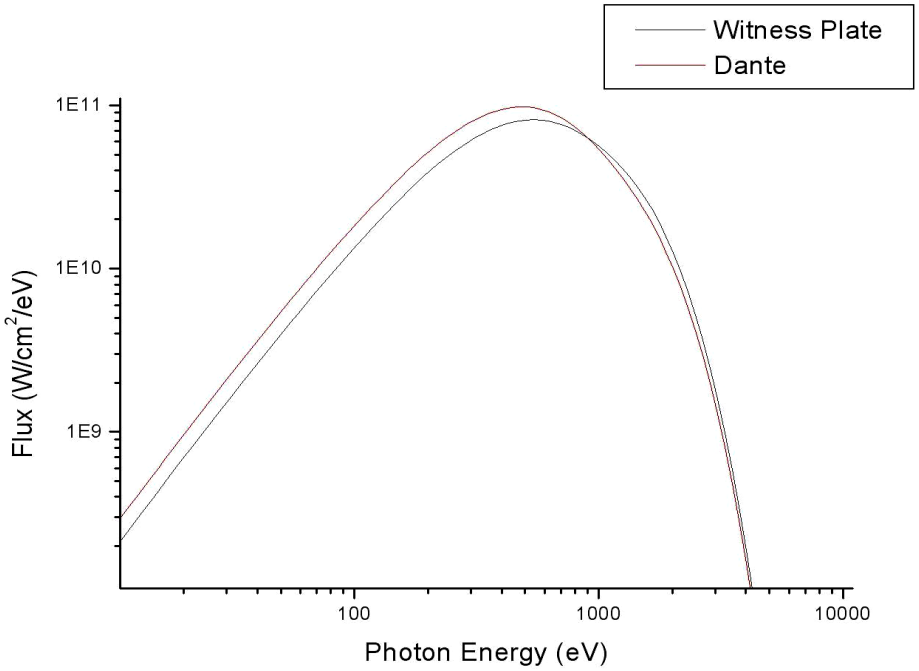


No Lip:

LEH Radius = 800 μm

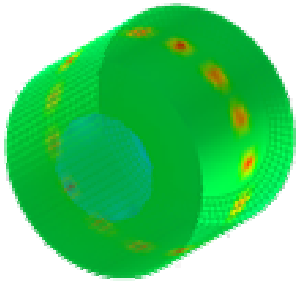


	Area Under the Curve (W/cm^^2)	Radiation Temerpature (eV)
Witness Plate	1.21E+15	180.98
Dante	1.42E+15	188.28

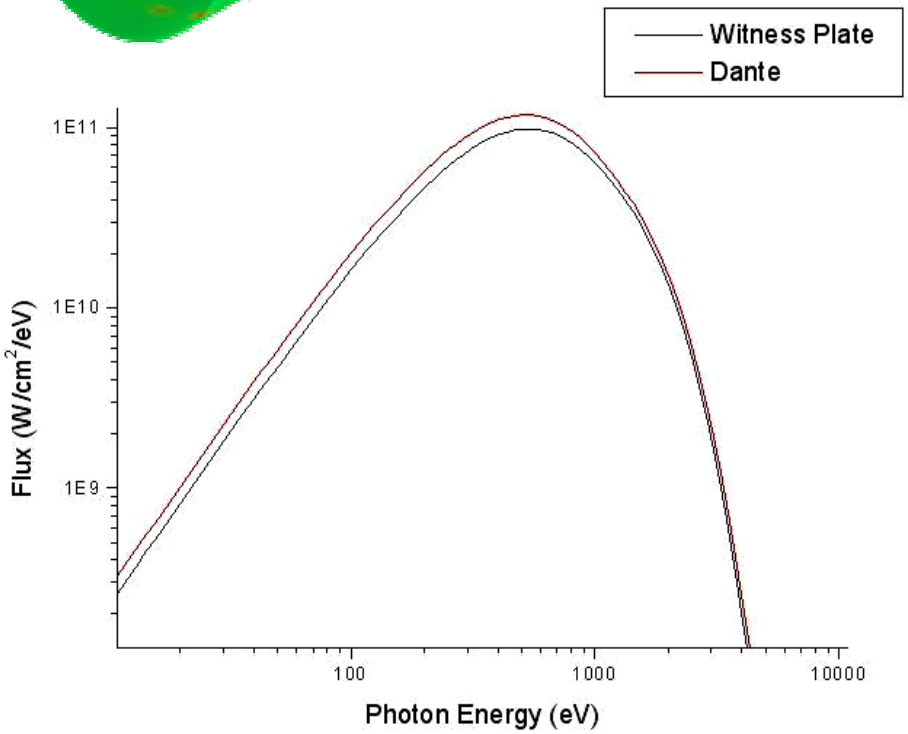


	Area Under the Curve (W/cm^^2)	Radiation Temerpature (eV)
Witness Plate	1.06E+15	175.01
Dante	1.10E+15	176.72

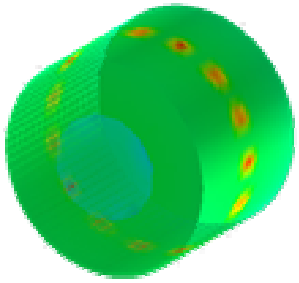
600 Microns Beam Pointing, Halfraum Albedo 0.7, WP Albedo 0.3



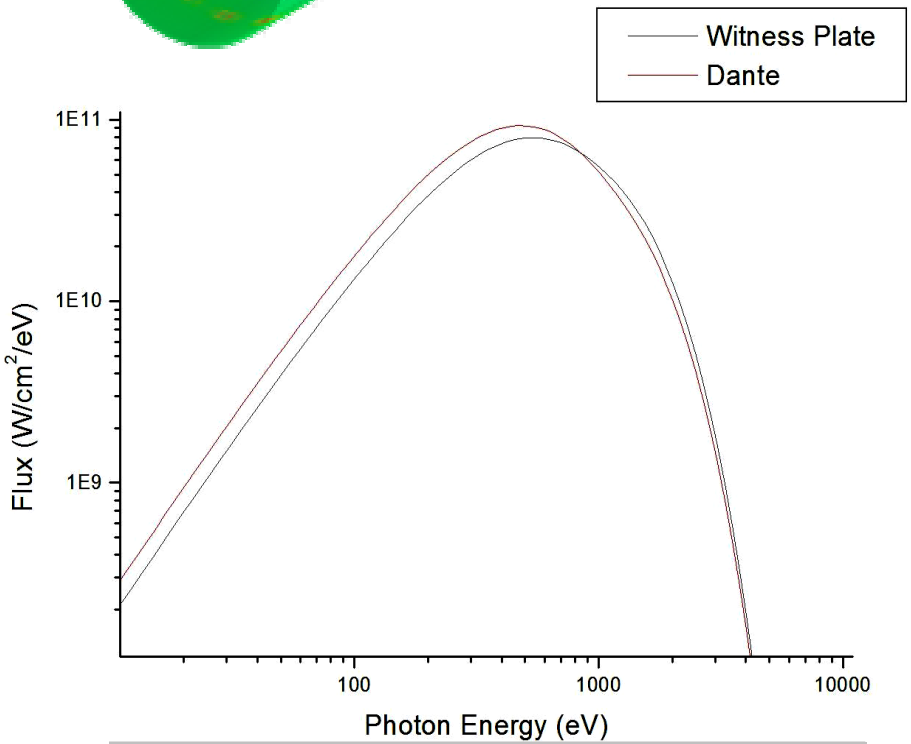
LEH Radius = 600 μm



	Area Under the Curve (W/cm^^2)	Radiation Temerpature (eV)
Witness Plate	1.19E+15	179.9
Dante	1.38E+15	187.11

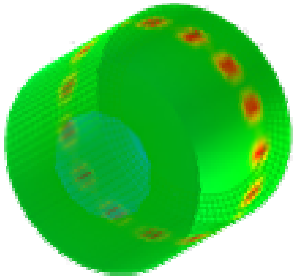


LEH Radius = 800 μm

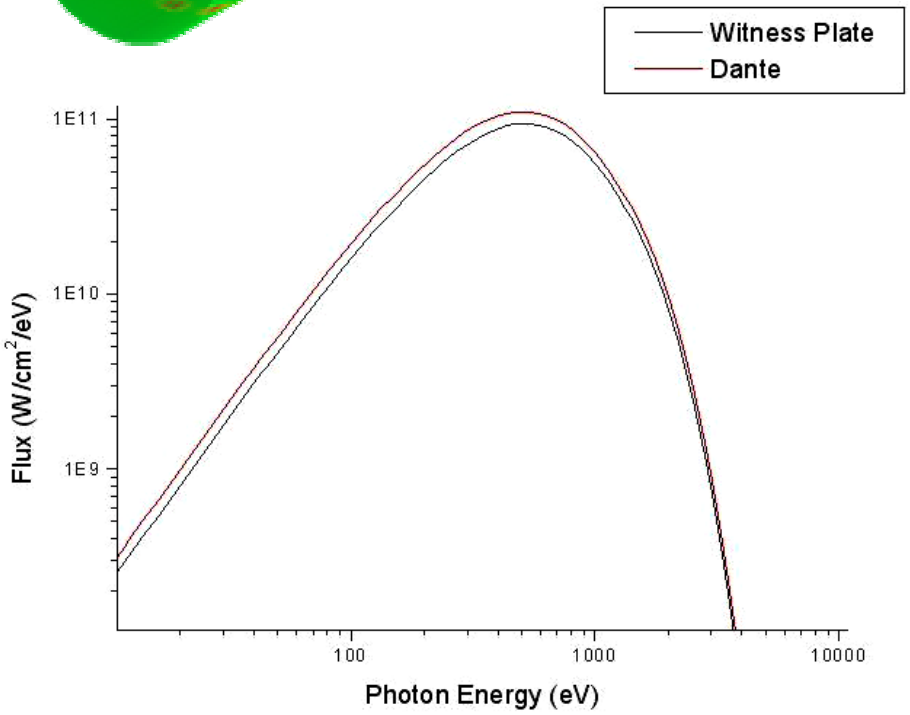


	Area Under the Curve (W/cm^^2)	Radiation Temerpature (eV)
Witness Plate	1.04E+15	174.25
Dante	1.06E+15	174.95

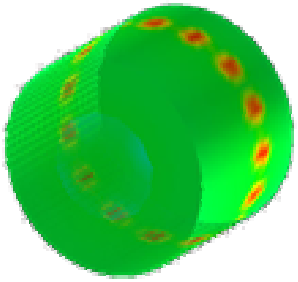
400 Microns Beam Pointing, Halfraum and WP Albedo 0.7



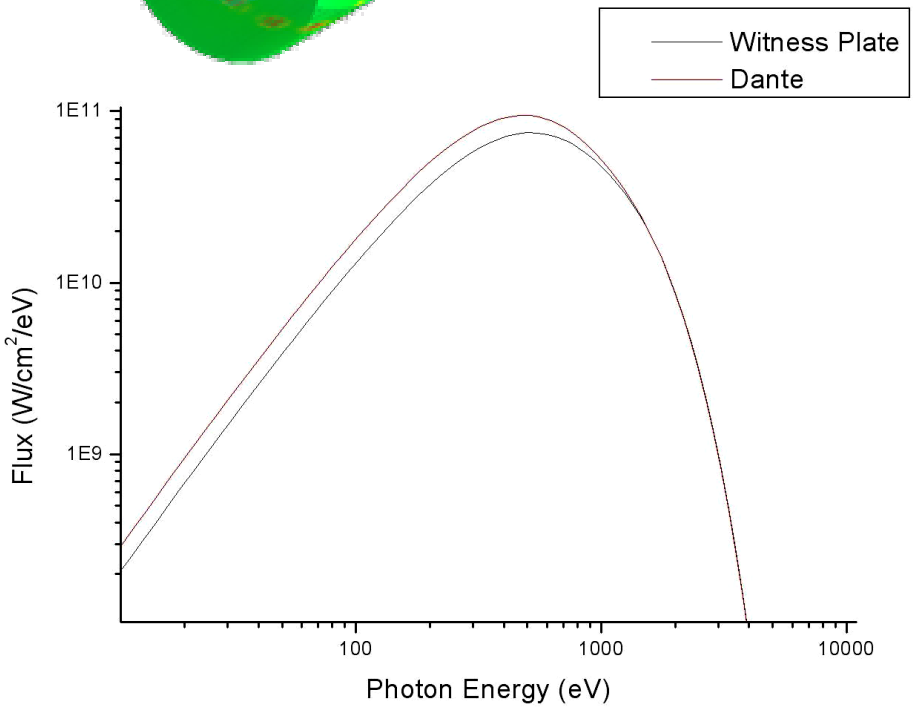
LEH Radius = 600 μm



	Area Under the Curve (W/cm^^2)	Radiation Temerpature (eV)
Witness Plate	1.07E+15	175.46
Dante	1.26E+15	182.94905

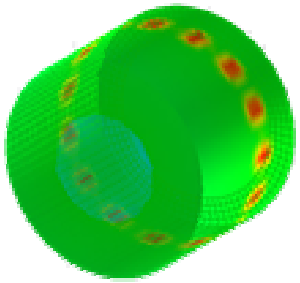


LEH Radius = 800 μm

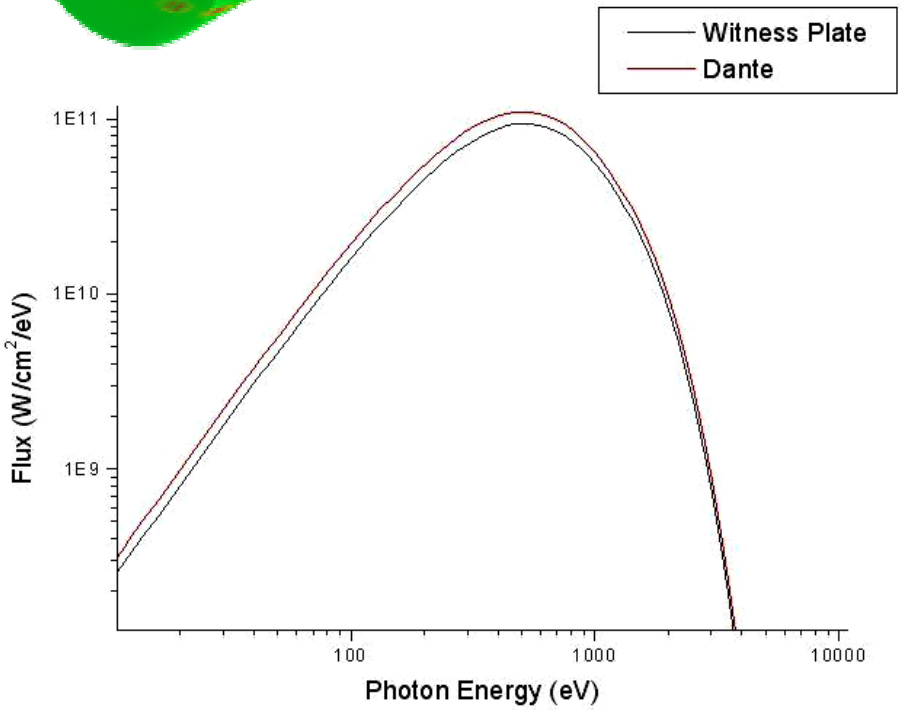


	Area Under the Curve (W/cm^^2)	Radiation Temerpature (eV)
Witness Plate	8.98E+14	167.8407
Dante	1.04E+15	174.2799

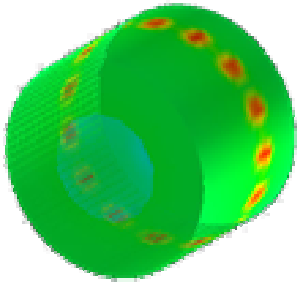
400 Microns Beam Pointing, Halfraum Albedo 0.7, WP Albedo 0.3



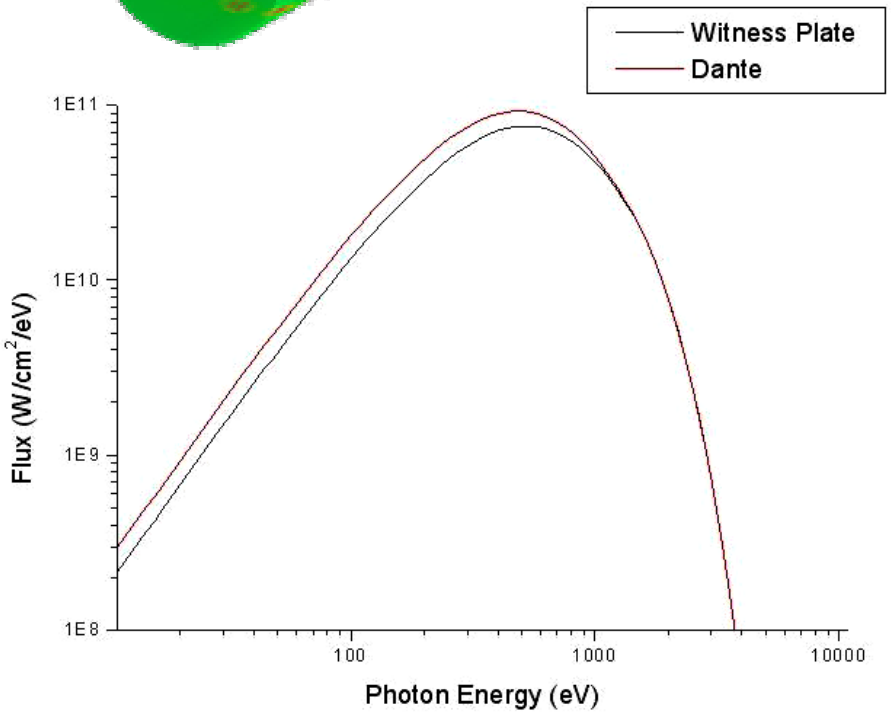
LEH Radius = 600 μm



	Area Under the Curve (W/cm^^2)	Radiation Temerpature (eV)
Witness Plate	1.05E+15	174.42
Dante	1.23E+15	181.8203



LEH Radius = 800 μm



	Area Under the Curve (W/cm^^2)	Radiation Temerpature (eV)
Witness Plate	8.83E+14	167.12
Dante	1.01E+15	172.7442

At 600 microns, the lip helps DANTE relative to the witness plate, but at 400 microns, it helps them both equally.

The lower albedo witness plate hardly makes a difference, and that difference doesn't favor the witness plate itself over DANTE. (Well, for the no-lip case, the witness plate is favored somewhat, but we're talking about 1 eV here.)

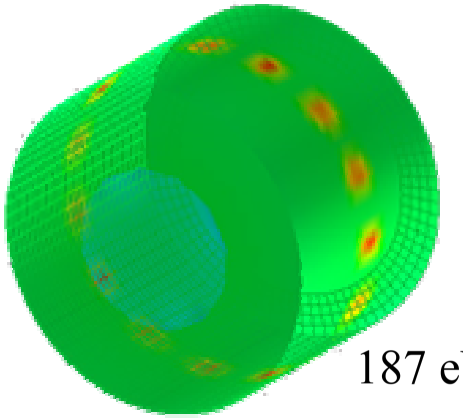
Now compare the views from the two locations: different pointings and also lip vs. no lip. Can we understand the trends?

With LEH lip

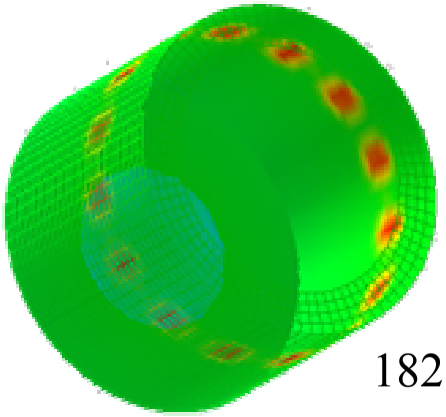
600 micron pointing

400 micron pointing

Dante View

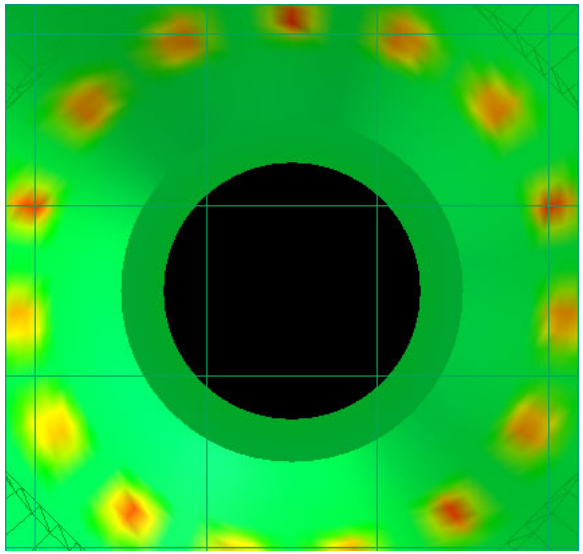


187 eV

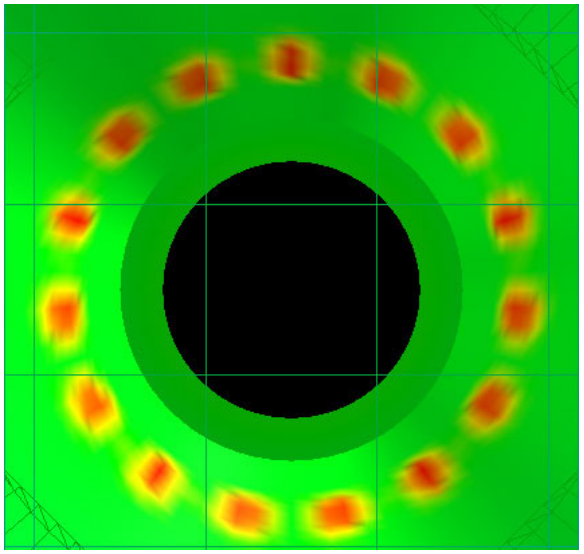


182 eV

180 eV



174eV



Witness Plate View

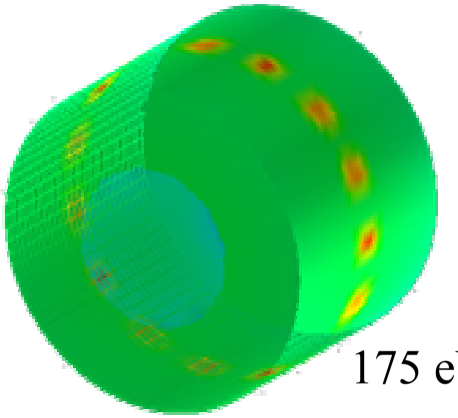
TW/cm^^2

Without LEH lip

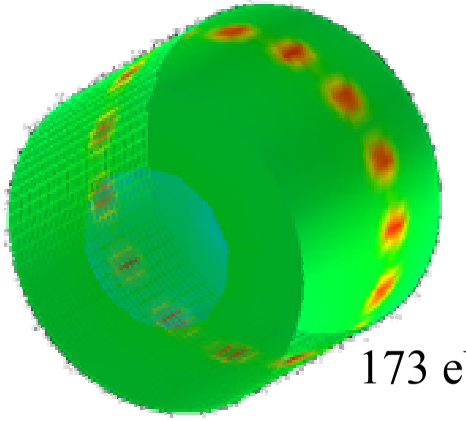
600 micron pointing

400 micron pointing

Dante View



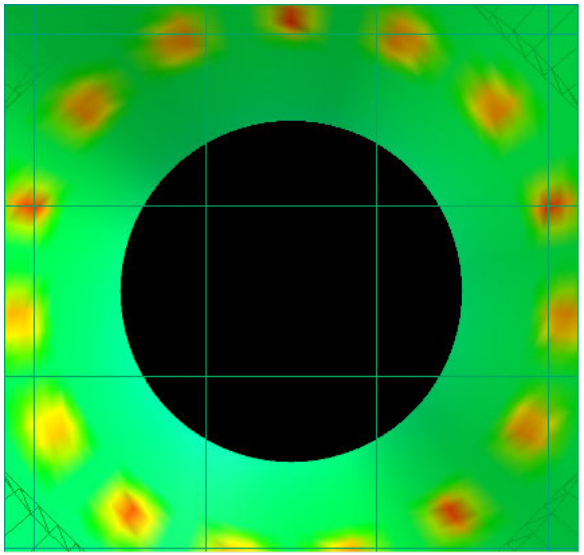
175 eV



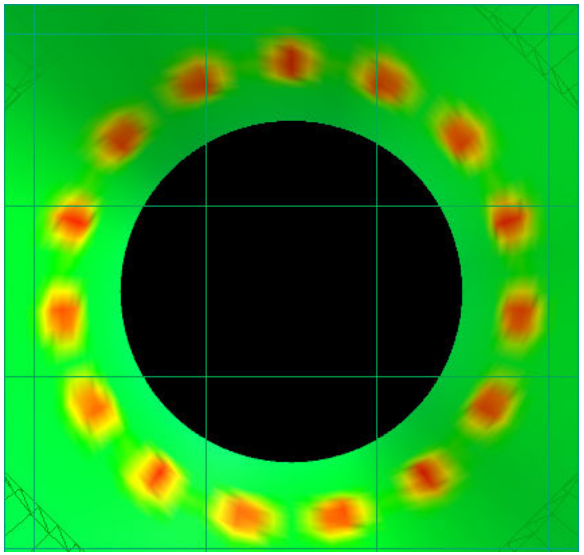
173 eV

Witness Plate View

174 eV



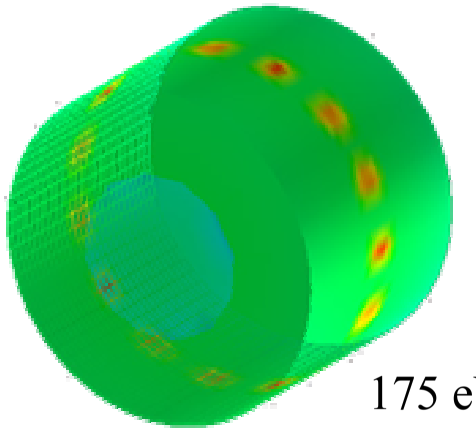
167 eV



600 micron pointing

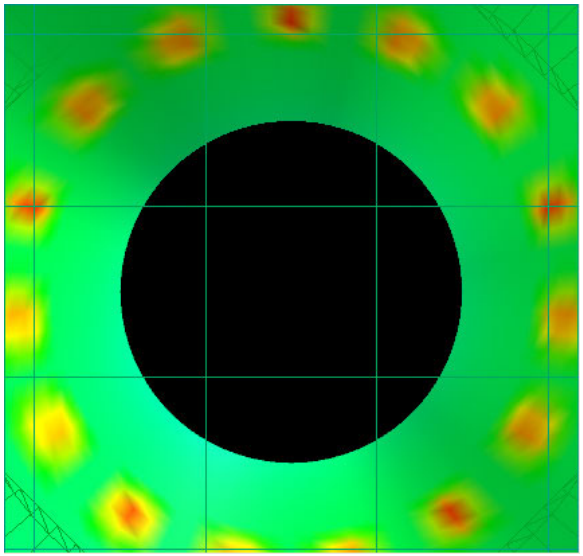
TW/cm^2

Dante View



175 eV

174 eV



Witness Plate View

The witness plate view (bottom) has the harder spectrum: these two views in this simulation have nearly identical T_Rs. The witness plate view sees more hot spots, and also has a completely cold object in its field of view. The net effect is to reduce the soft emission (LEH replacing wall) while enhancing the hard emission (more spots).

Primary, specific conclusions

The DANTE radiation temperature tends to be higher than the witness plate's, especially when the pointing is small. (i.e. the beams are relatively near the LEH.) This difference can be as big as ~15eV.

The main exception is with low albedo and deep pointing. Then the witness plate radiation temperature can actually be somewhat higher than DANTE's.

The witness plate incident spectrum is always harder than the DANTE spectrum

The LEH lip makes both temperatures higher, but the DANTE temperature gains more than the witness plate temperature (typically 10 eV vs 5 eV).

Witness plate albedo has little effect on the overall results (~1 eV).

General conclusions

Assuming $T_{dante}=T_{wp}$ is a pretty good approximation when the beam pointing position is deeper than ~500μm, but the spectral energy distributions differ significantly.

But if accuracy and precision are desired, or the spectral energy distribution of the incident radiation is needed, modeling is necessary

Primary, specific conclusions

The DANTE radiation temperature tends to be higher than the witness plate's, especially when the pointing is small. (i.e. the beams are relatively near the LEH.) This difference can be big (~15eV).

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General conclusions

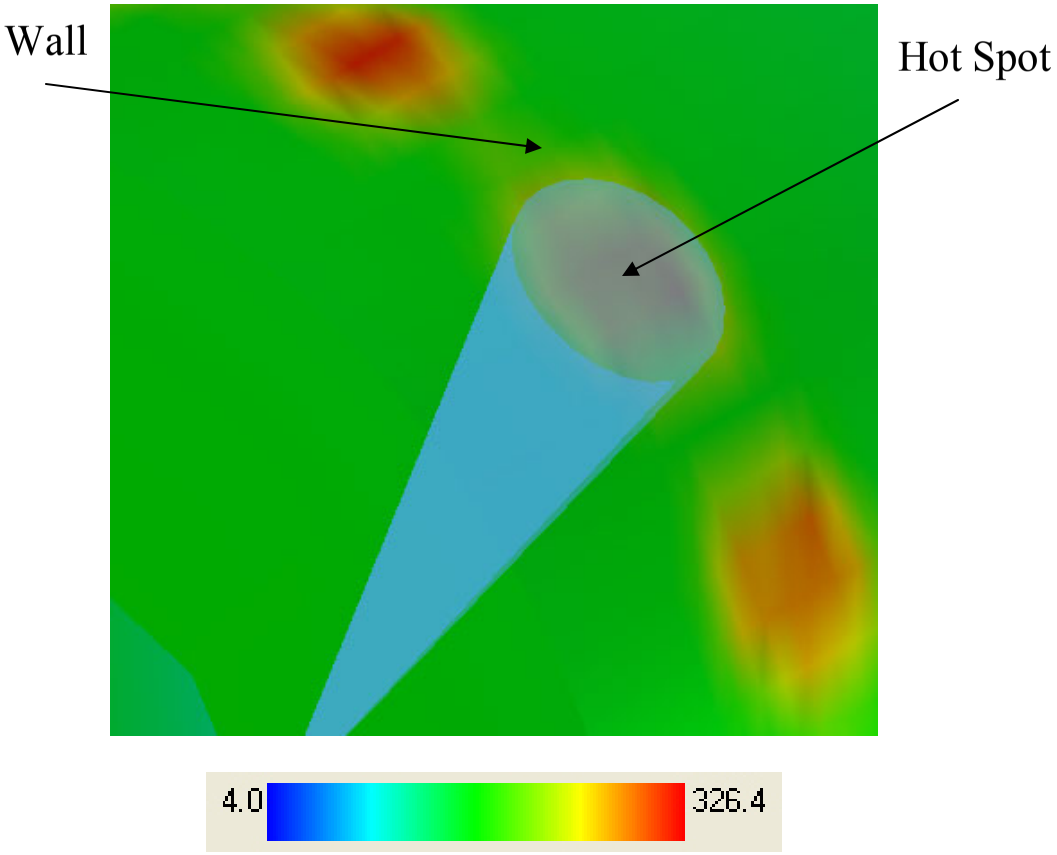
Assuming $T_{dante}=T_{wp}$ is a pretty good approximation when the beam pointing position is deeper than ~500μm, but even then, the spectral energy distributions differ significantly.

But if accuracy and precision are desired, or the spectral energy distribution of the incident radiation is needed, modeling is necessary.

Supplemental Slides

The following slides show a comparison of wall re-emission temperatures for different albedo cases

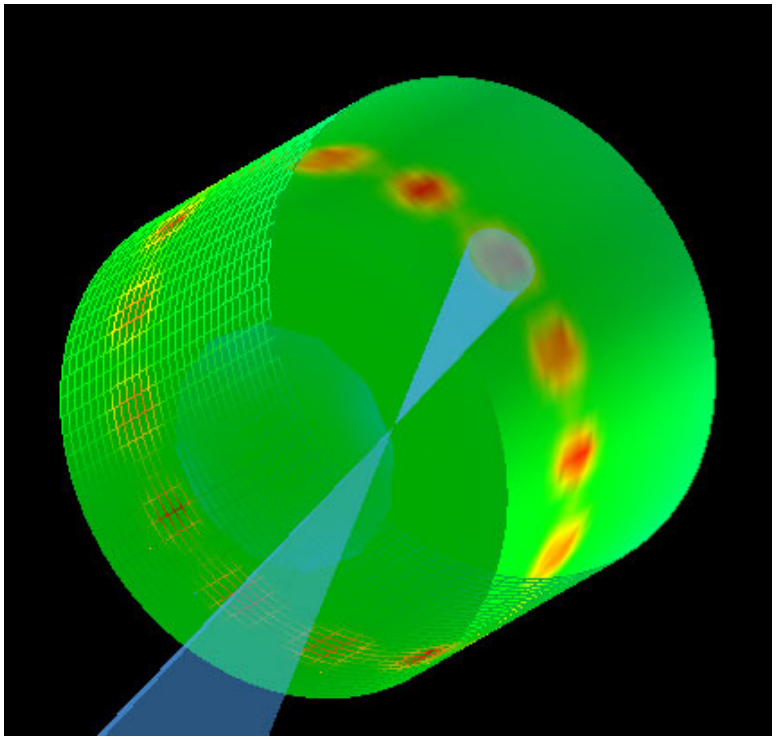
800 micron pointing with albedo = .7 and xce = .55



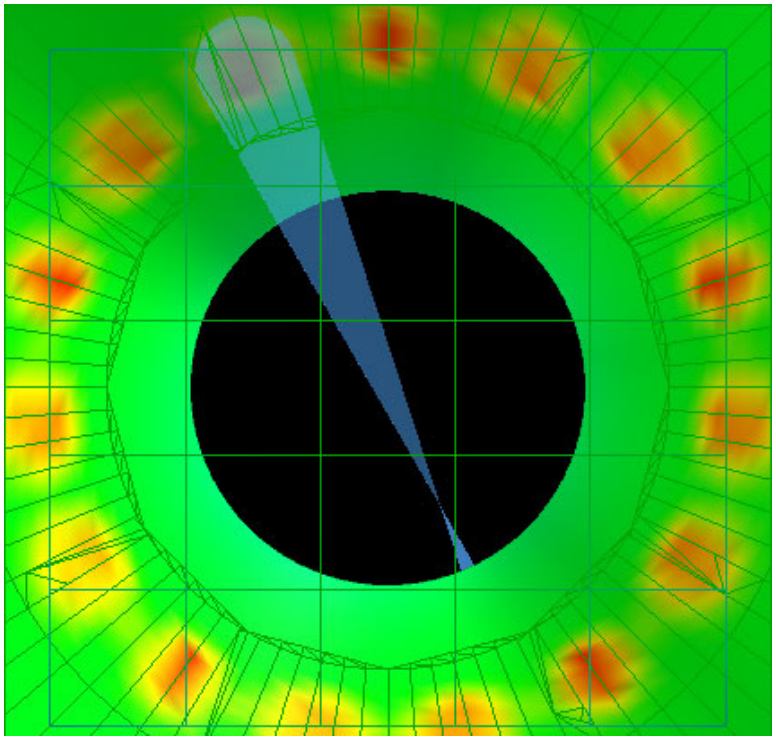
Emission Temperature Wall = 160.85 eV

Emission Temperature Hot Spot = 274.34 eV

800 micron pointing with albedo = .7 and xce = .55

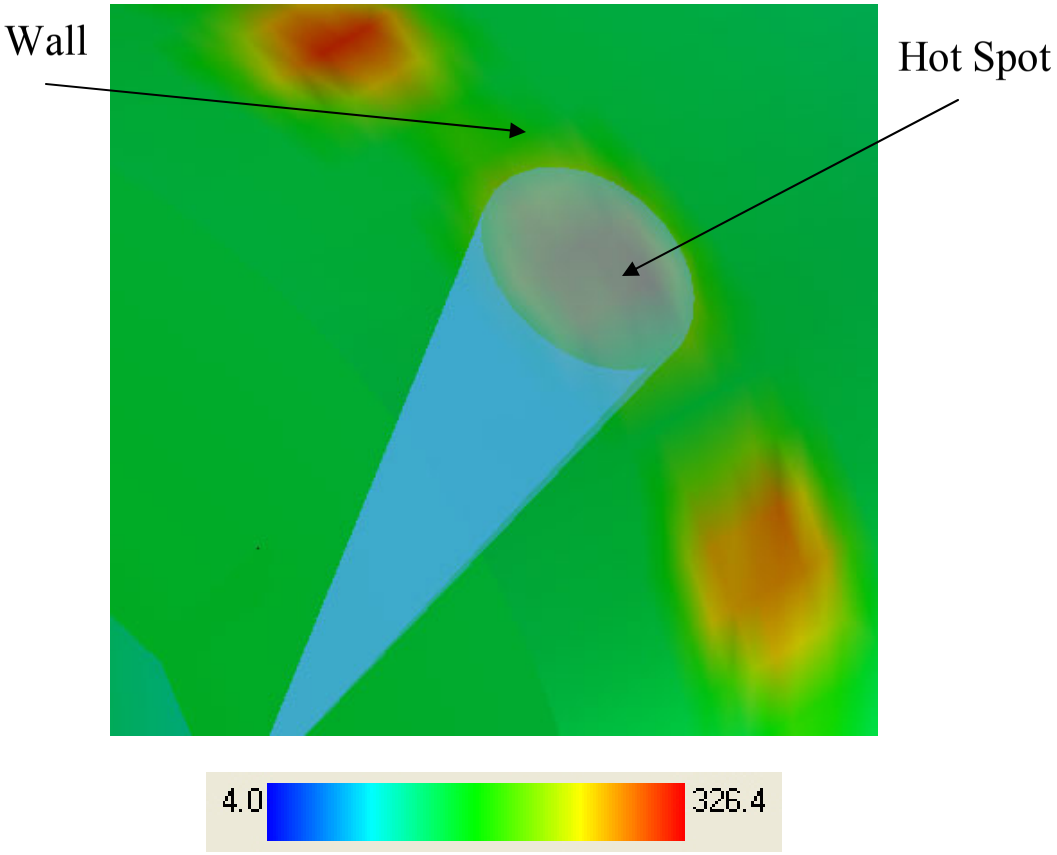


Dante View



Witness Plate View

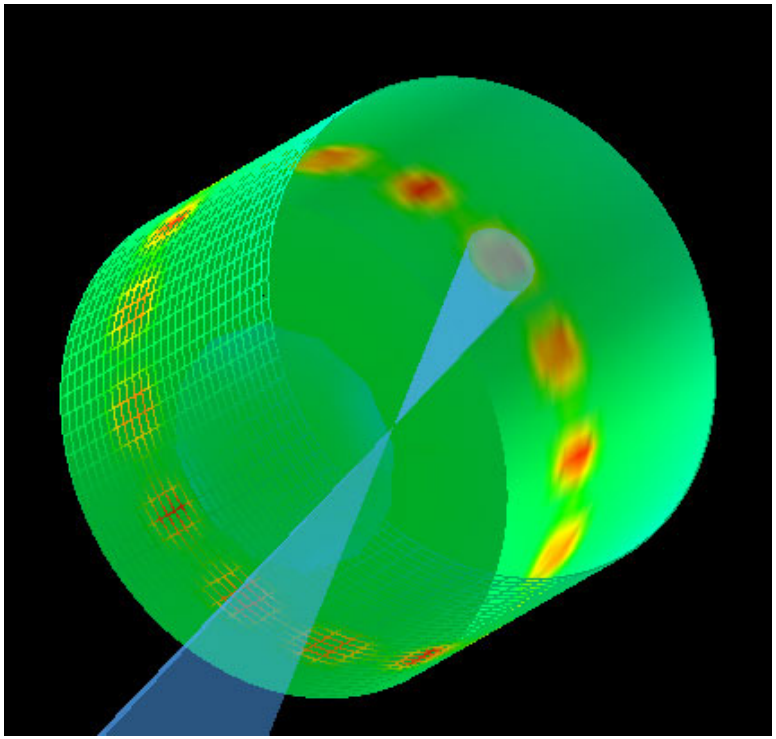
800 micron pointing with albedo = .5 and xce = .55



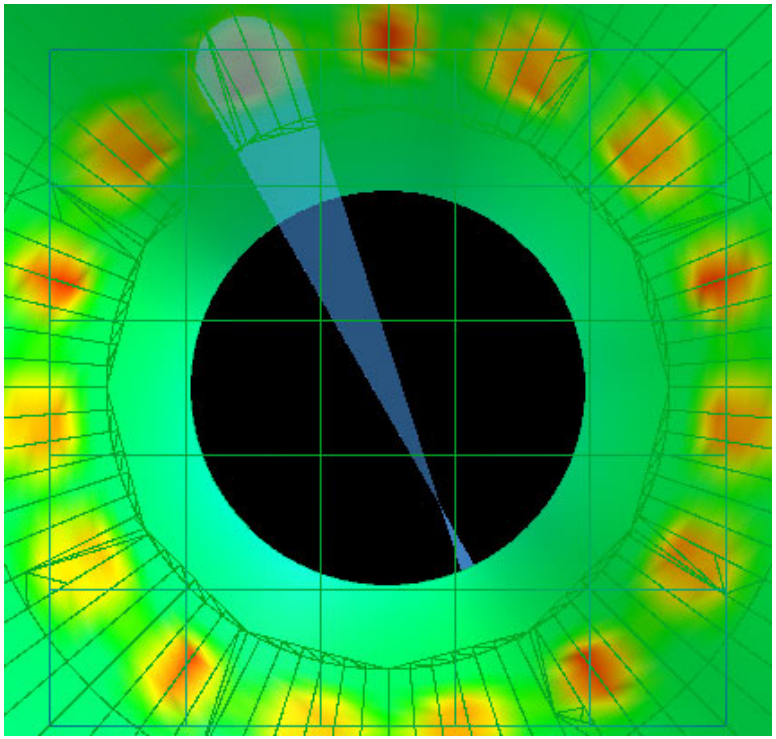
Emission Temperature Wall = 138.05 eV

Emission Temperature Hot Spot = 270.53 eV

800 micron pointing with albedo = .5 and xce = .55



Dante View



Witness Plate View

Summary

Pointing (microns)	Albedo	XCE	Emis. Temperature- Wall (eV)	Emis.Temperature- Hot Spot (eV)
800	0.7	0.55	160.85	274.34
800	0.5	0.55	138.05	270.53

The albedo decreased to 0.718 its original value,
and T_{wall}^4 decreased to 0.543 its original value.