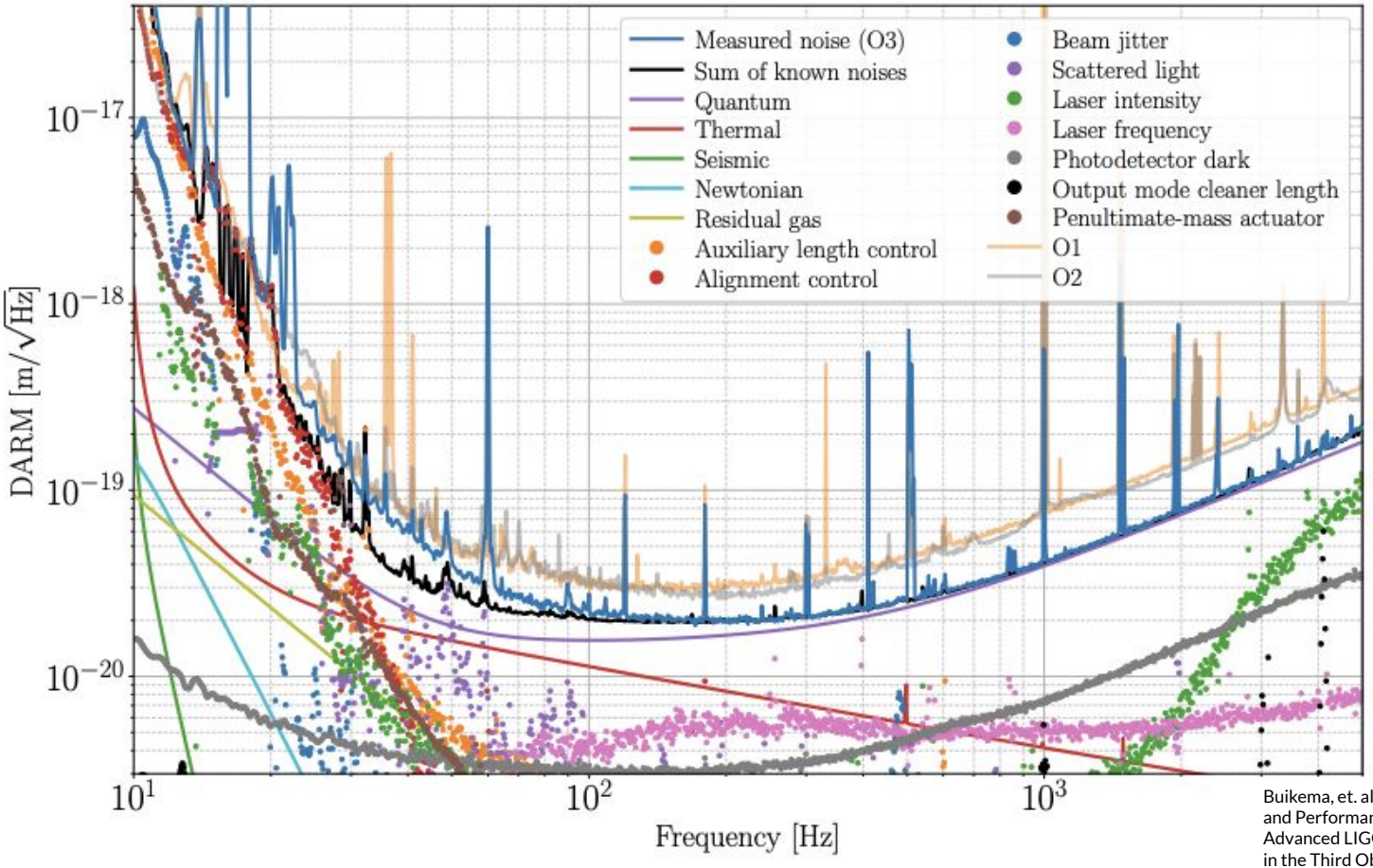
Developing spatially-tunable adaptive optics for LIGO

Celeste Virador, LIGO SURF 2023

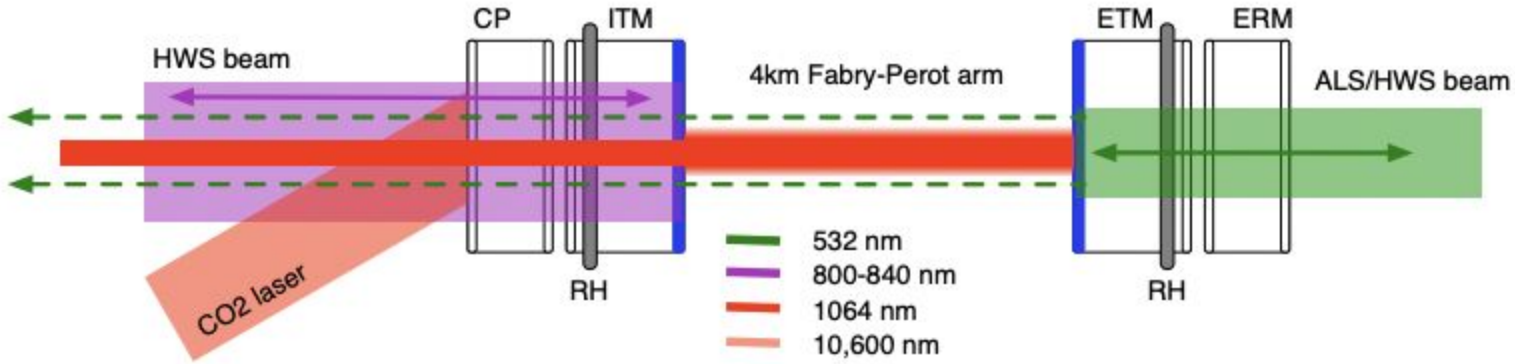
Mentors: Dr. Jon Richardson and Dr. Huy-Tuong Cao, UCR

LHO Noise Budget (O3)



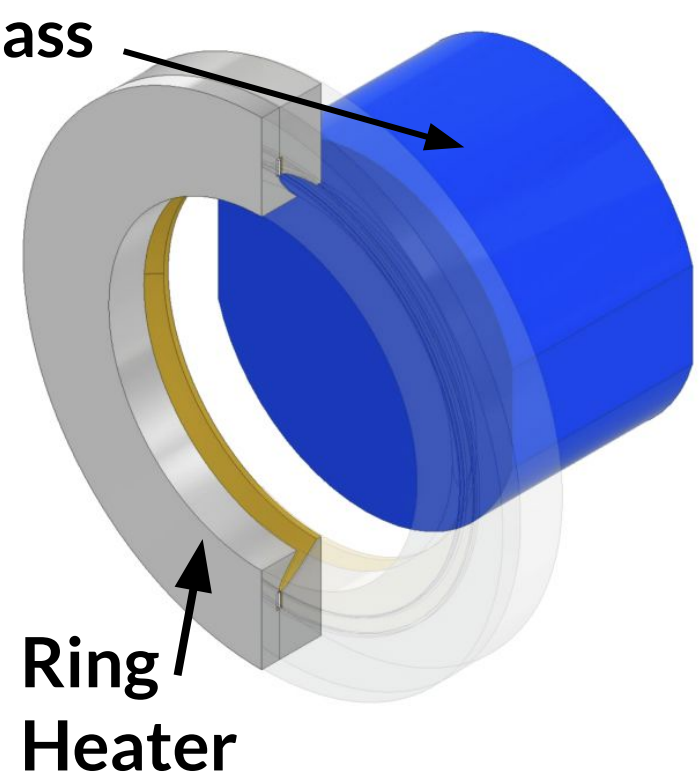
Buikema, et. al., Sensitivity and Performance of the Advanced LIGO Detectors in the Third Observing Run, 2020.

Thermal Compensation System (TCS)

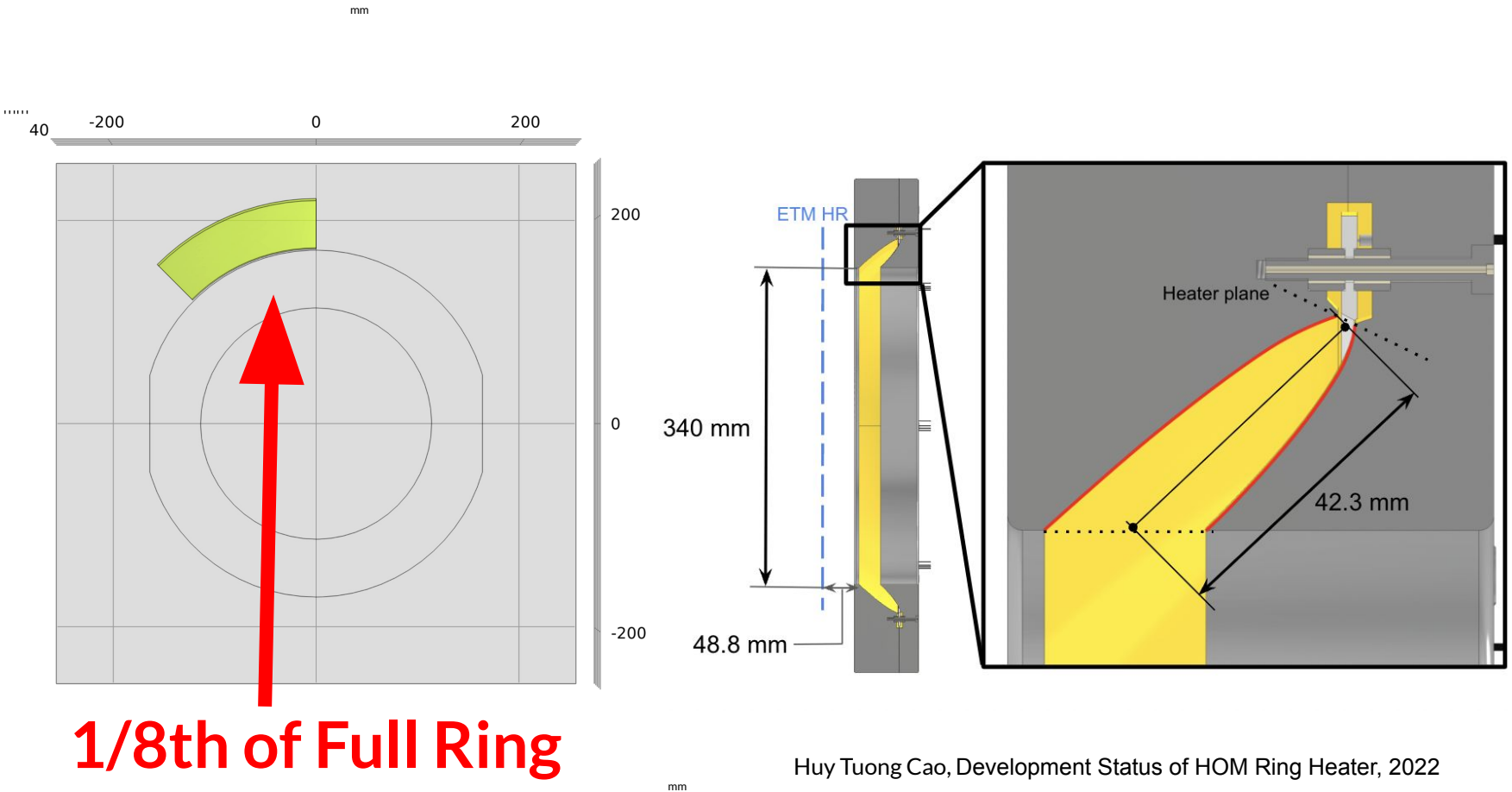


Brooks, Overview of Advanced LIGO Adaptive Optics, 2016.

FroSTI: **Fro**nt **S**urface **T**ype **I**rradiator

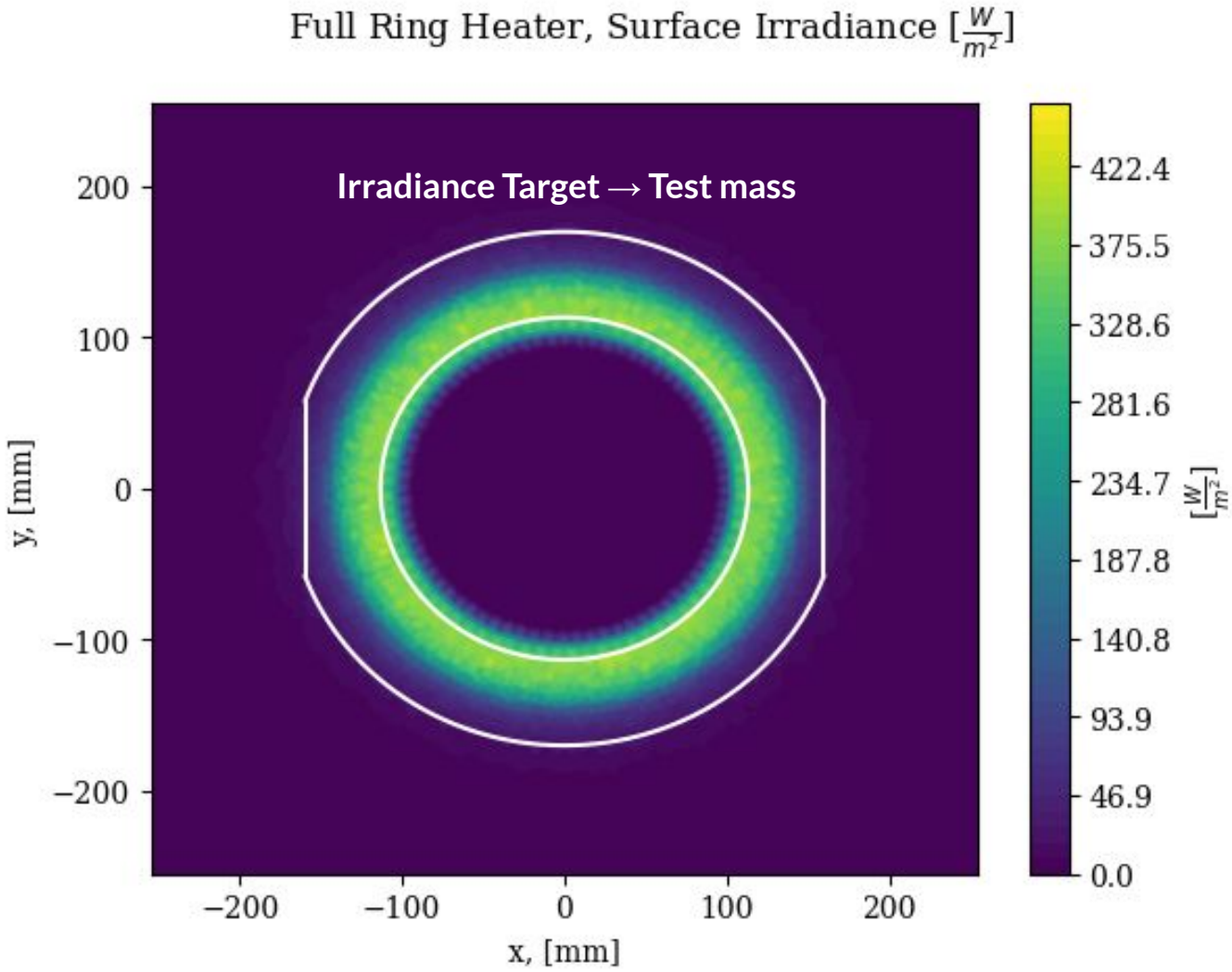


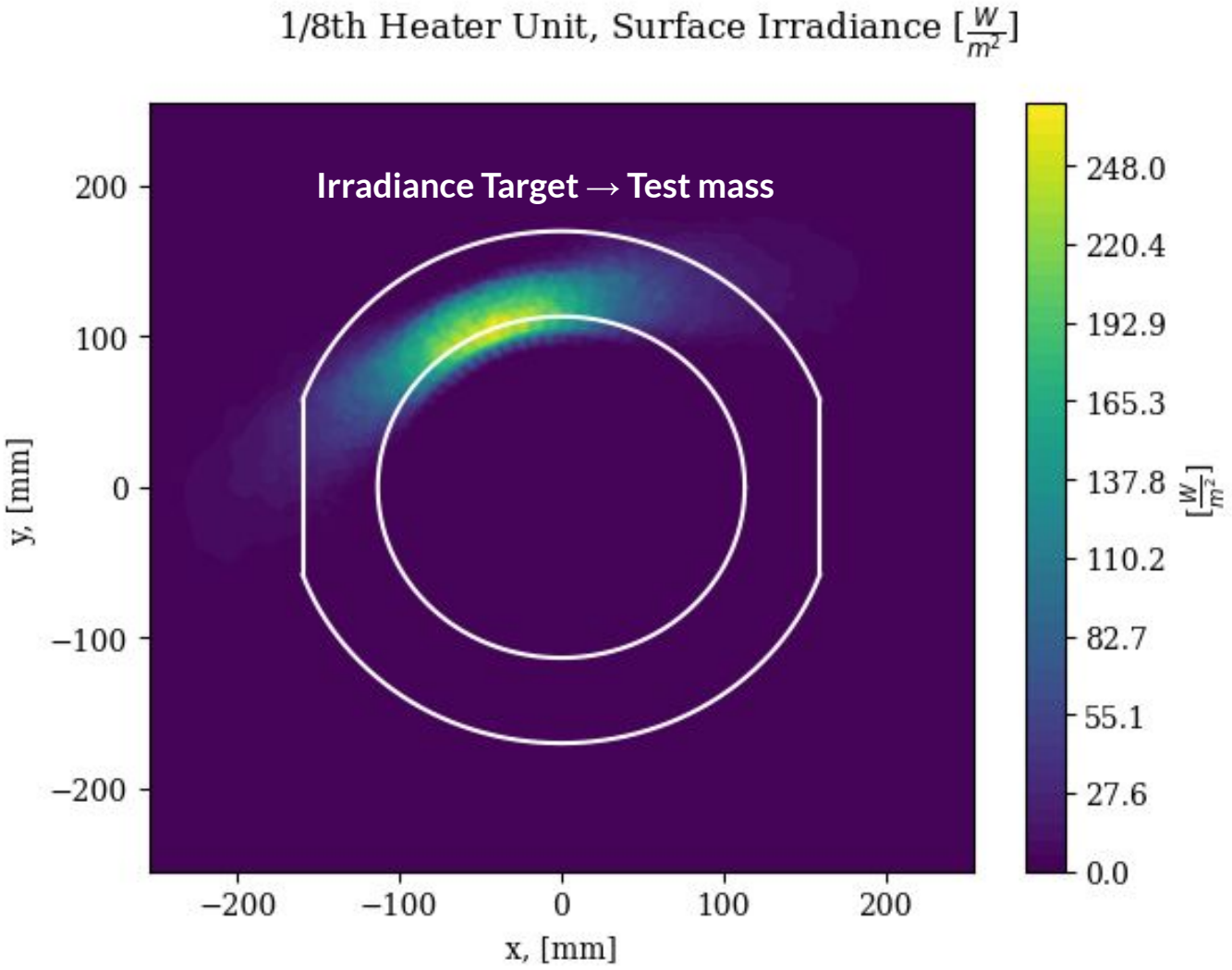
Jon Richardson, Active Wavefront Control for Megawatt Arm Power, 2022



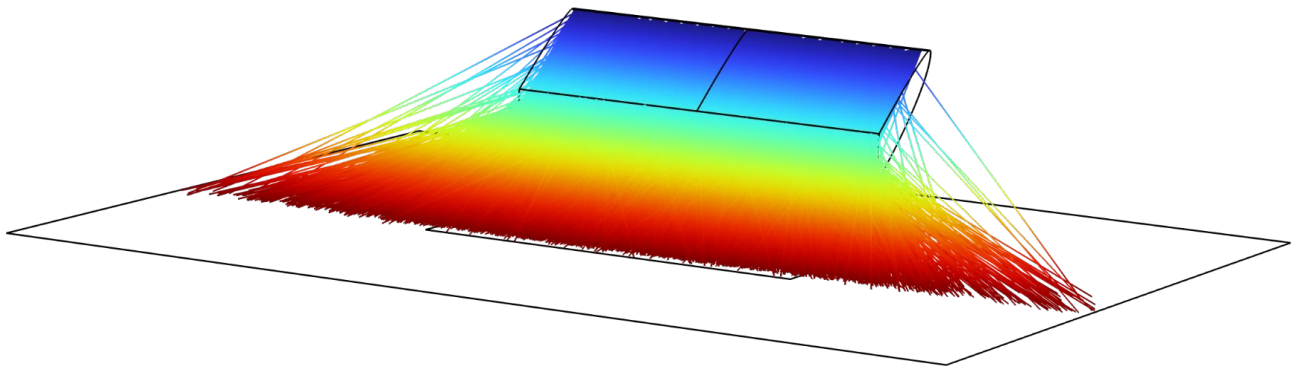
1/8th of Full Ring Heater

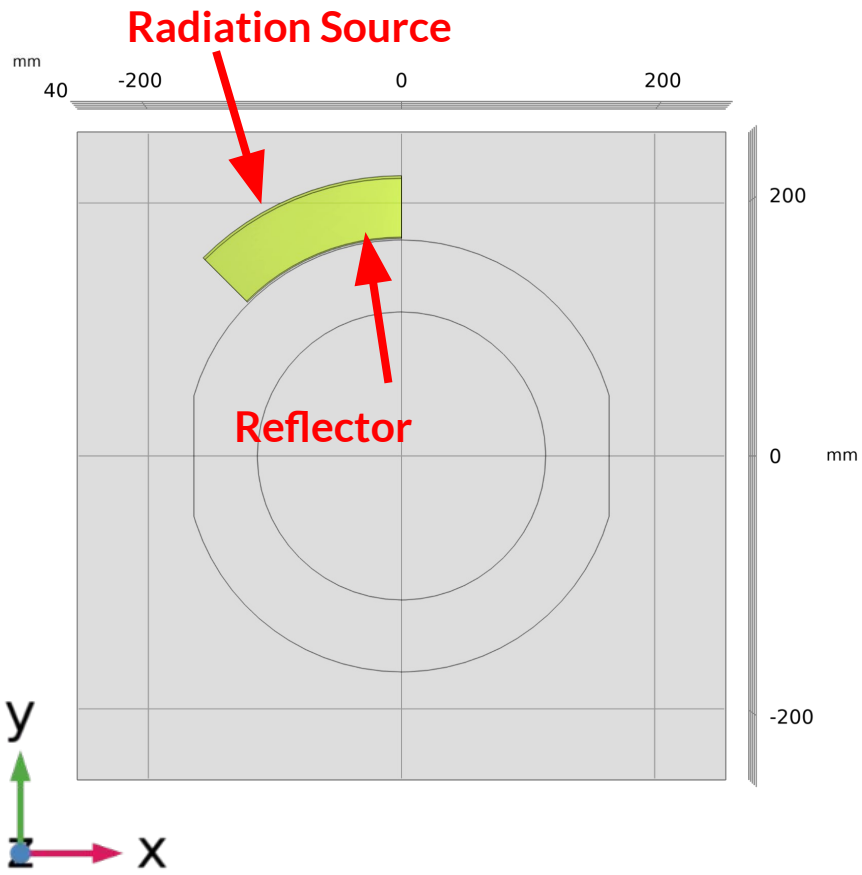
Huy Tuong Cao, Development Status of HOM Ring Heater, 2022

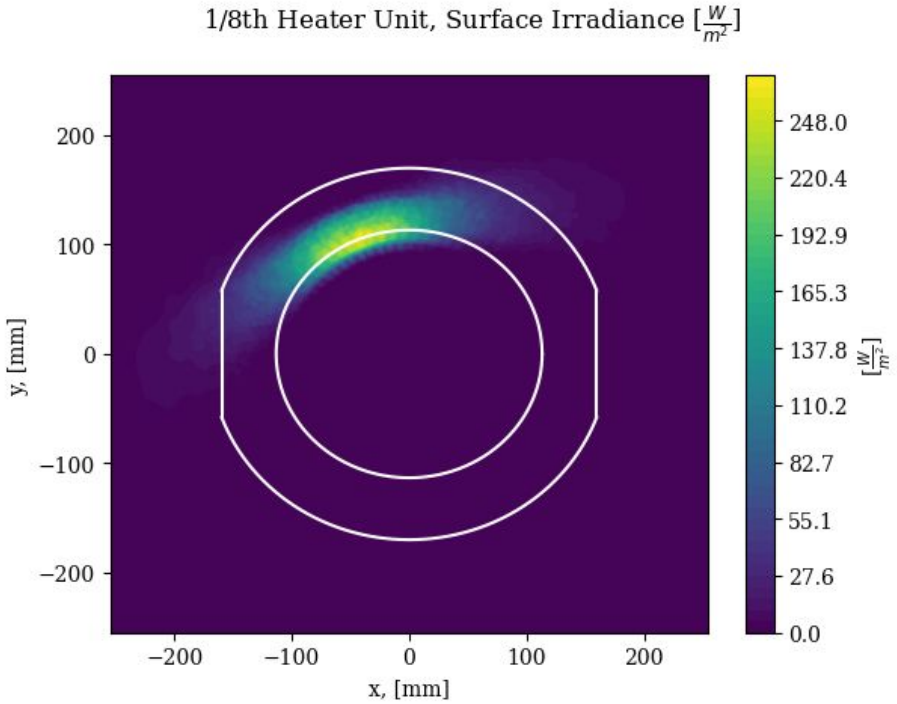

Full Ring Heater, Surface Irradiance [$\frac{W}{m^2}$]
Irradiance Target → Test mass
200
100
0
−100
−200
y, [mm]
−200
−100
0
100
200
x, [mm]
422.4
375.5
328.6
281.6
234.7
187.8
140.8
93.9
46.9
0.0
[$\frac{W}{m^2}$]


1/8th Heater Unit, Surface Irradiance [$\frac{W}{m^2}$]
Irradiance Target → Test mass
200
100
0
−100
−200
y, [mm]
−200
−100
0
100
200
x, [mm]
248.0
220.4
192.9
165.3
137.8
110.2
82.7
55.1
27.6
0.0
[$\frac{W}{m^2}$]

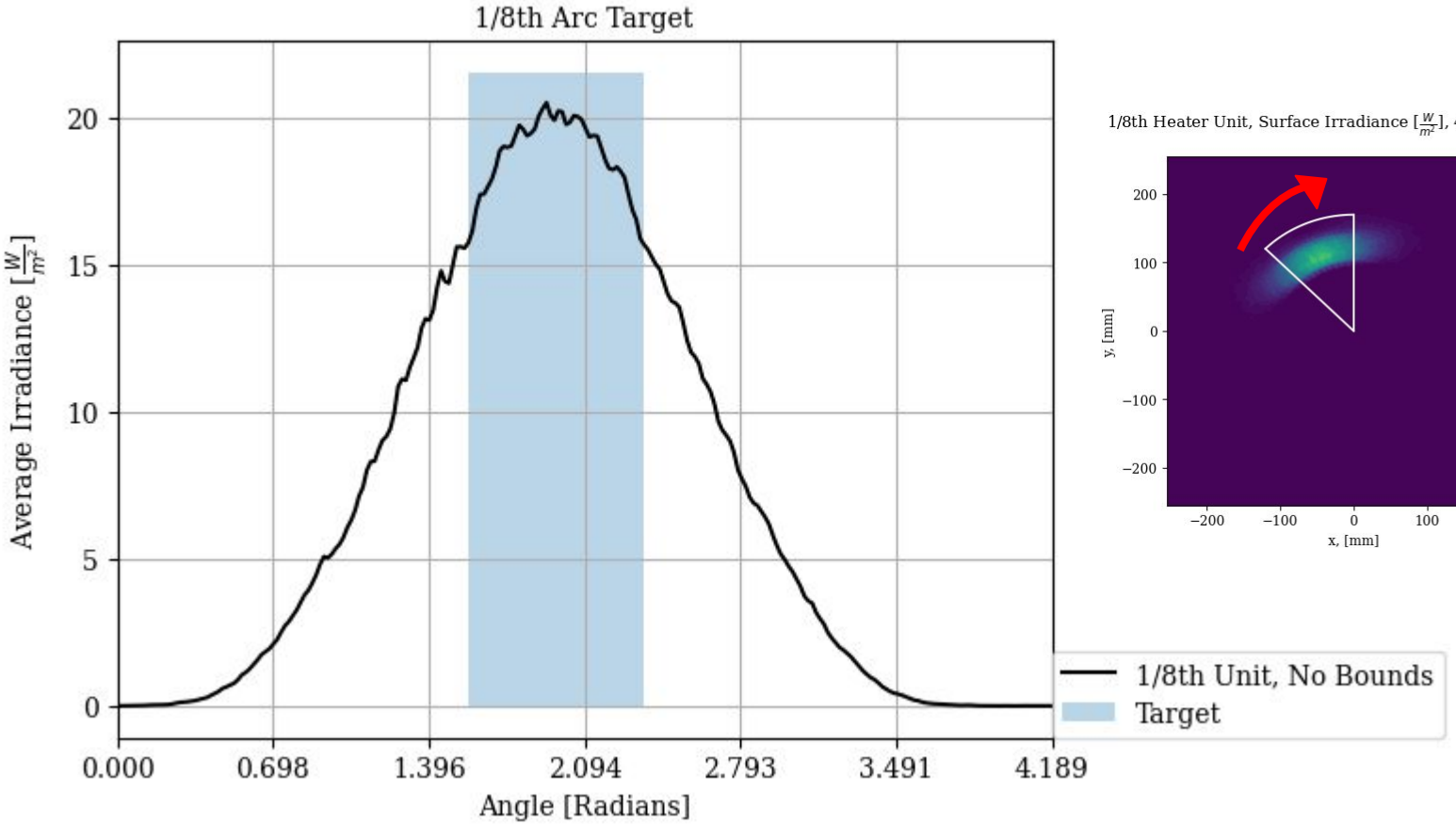
COMSOL



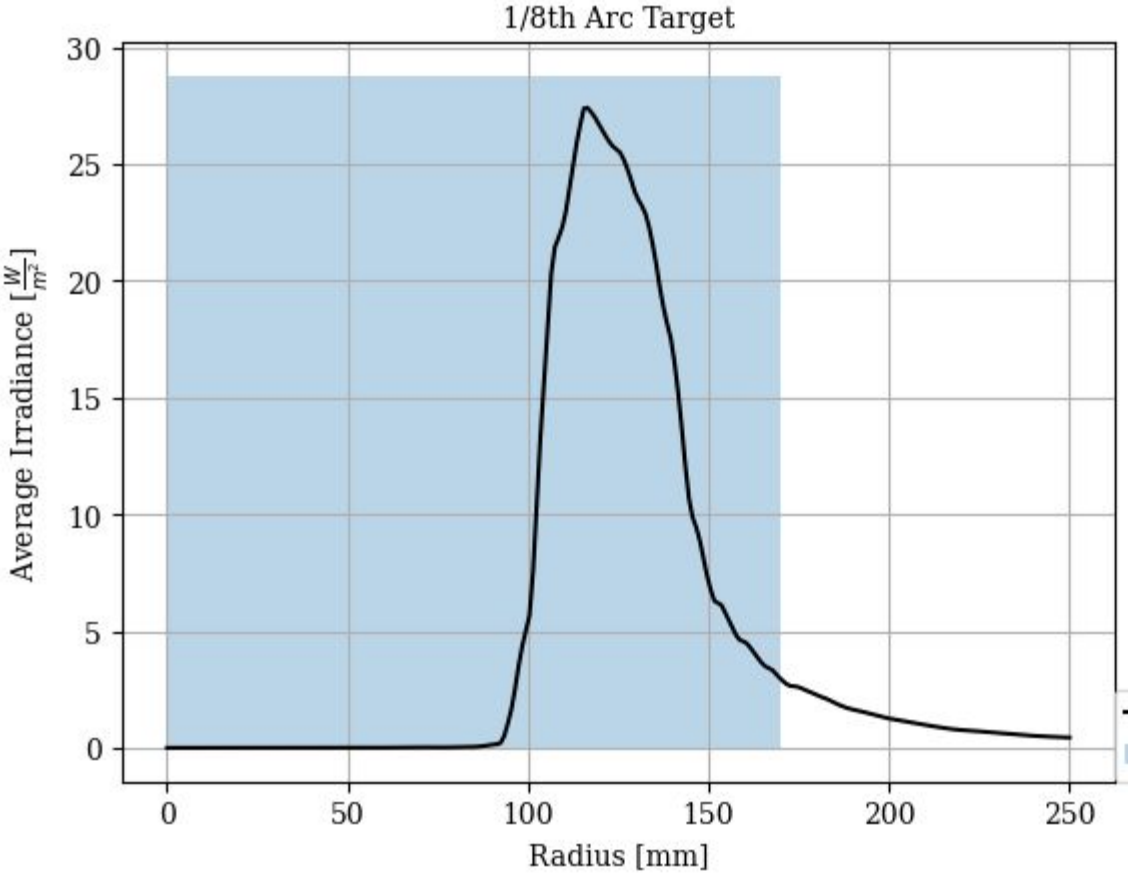

Radiation Source
Reflector
mm
40
-200
0
200
200
0
mm
-200
y
x

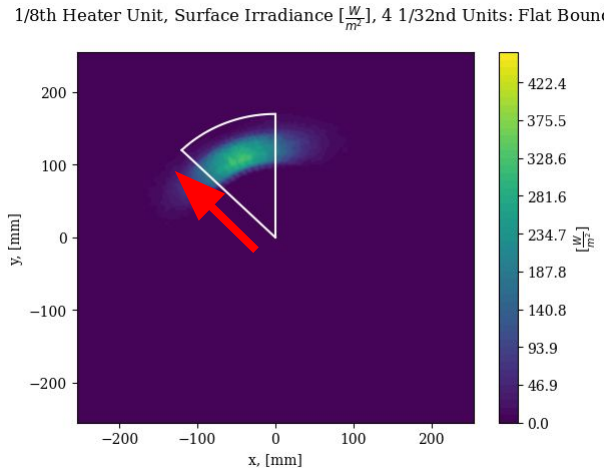

1/8th Heater Unit, Surface Irradiance [$\frac{W}{m^2}$]
y, [mm]
x, [mm]
200
100
0
−100
−200
−200
−100
0
100
200
248.0
220.4
192.9
165.3
137.8
110.2
82.7
55.1
27.6
0.0
[$\frac{W}{m^2}$]

Angular Distribution of Average Irradiance: Normalized by Deposited Power

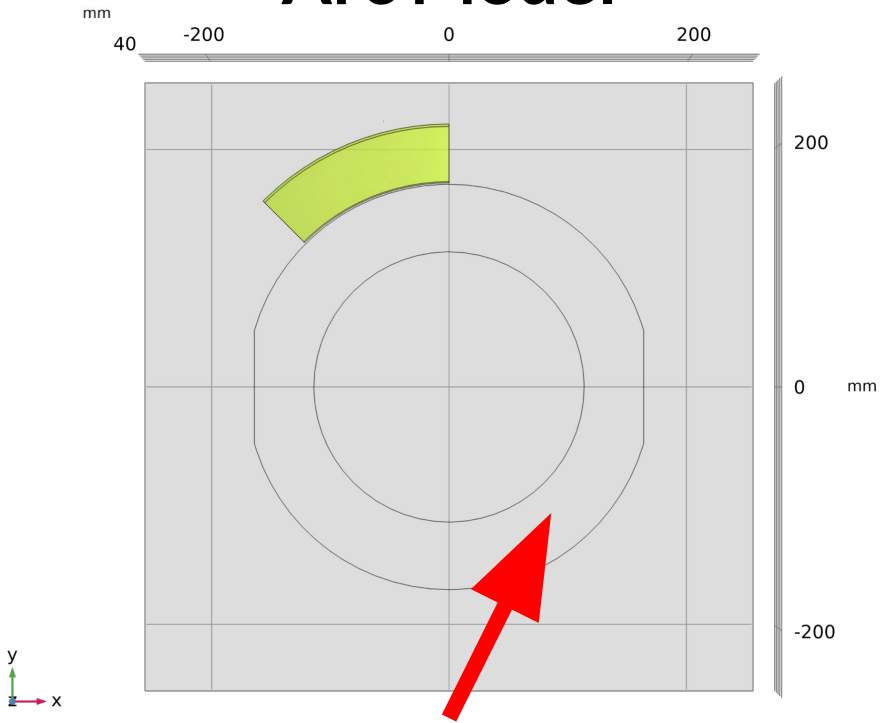


Radial Distribution of Average Irradiance: Normalized by Deposited Power



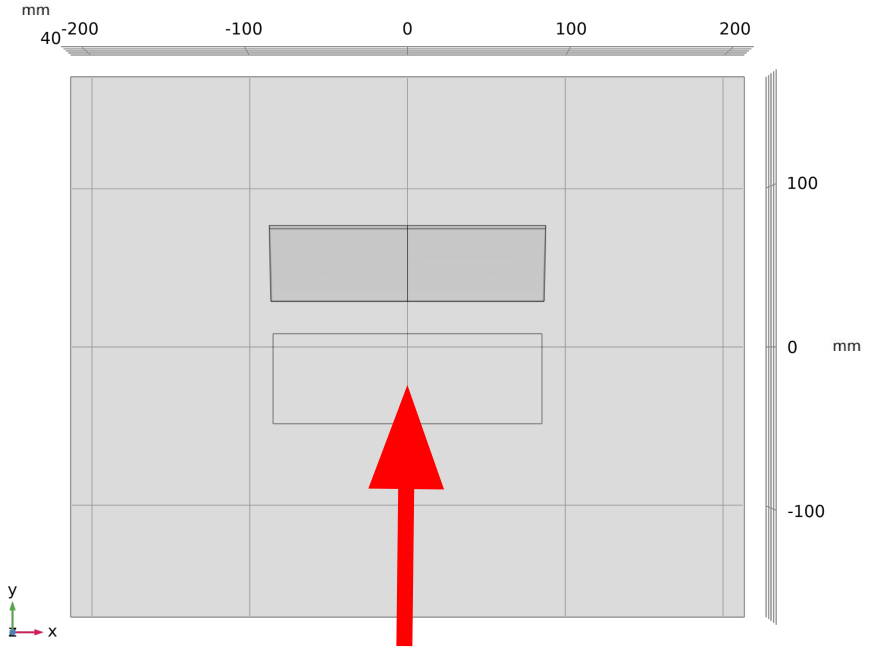


Arc Model



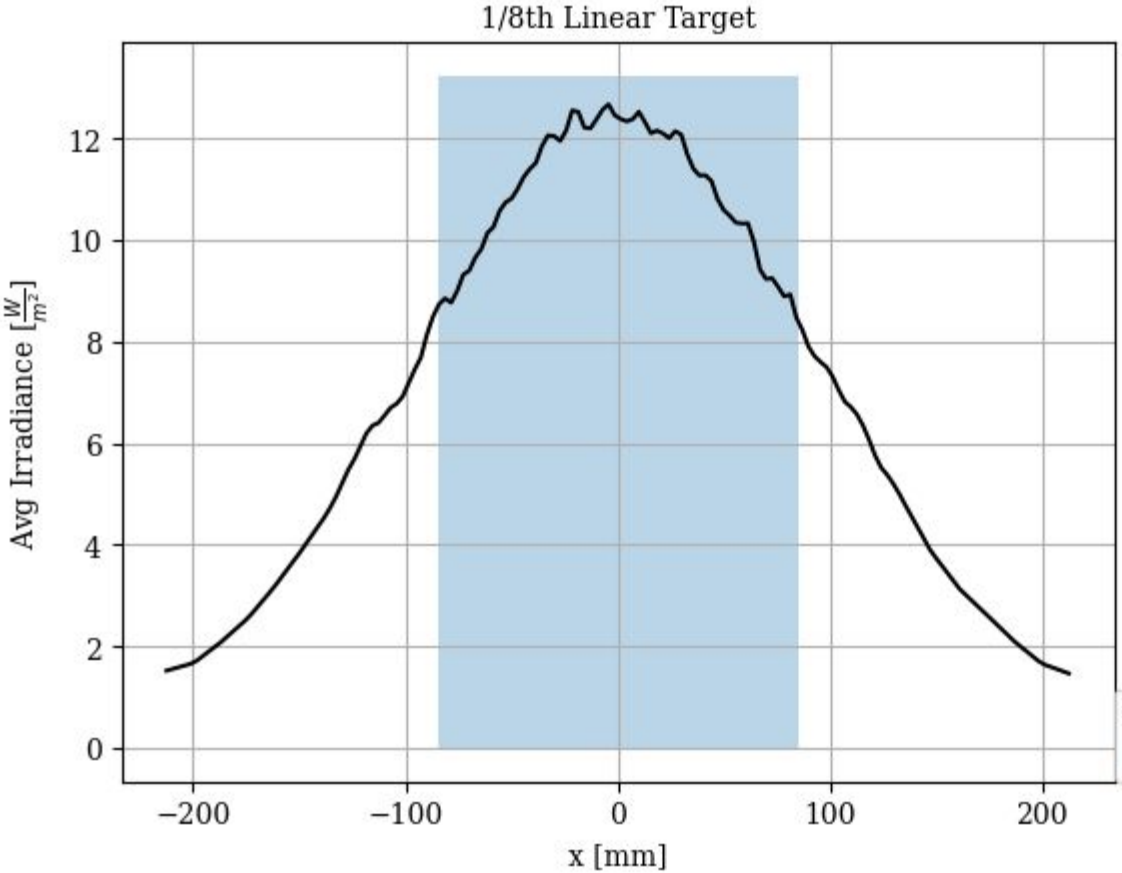
Test Mass/Target

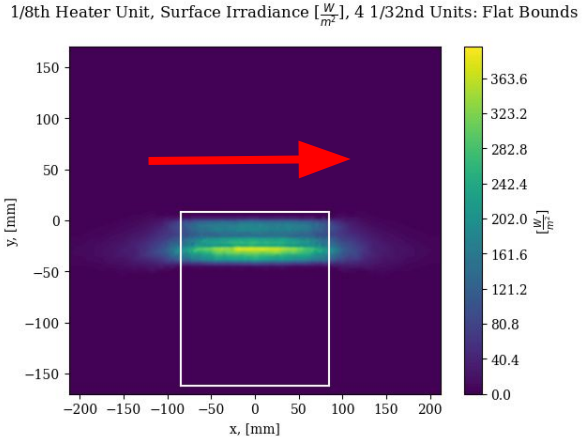
Straight Line Model



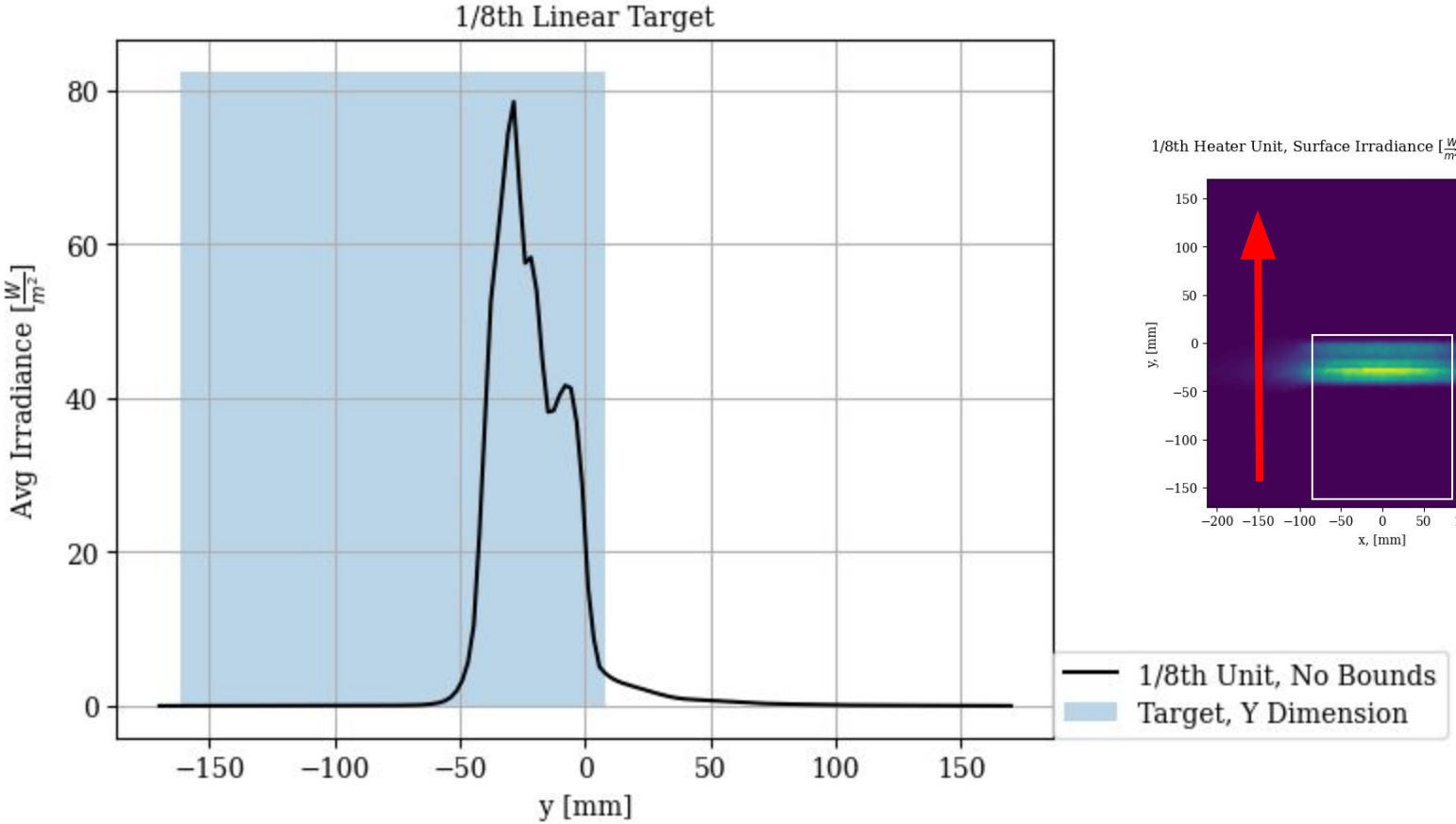
Test Mass/Target

Horizontal Distribution of Average Irradiance: Normalized by Deposited Power



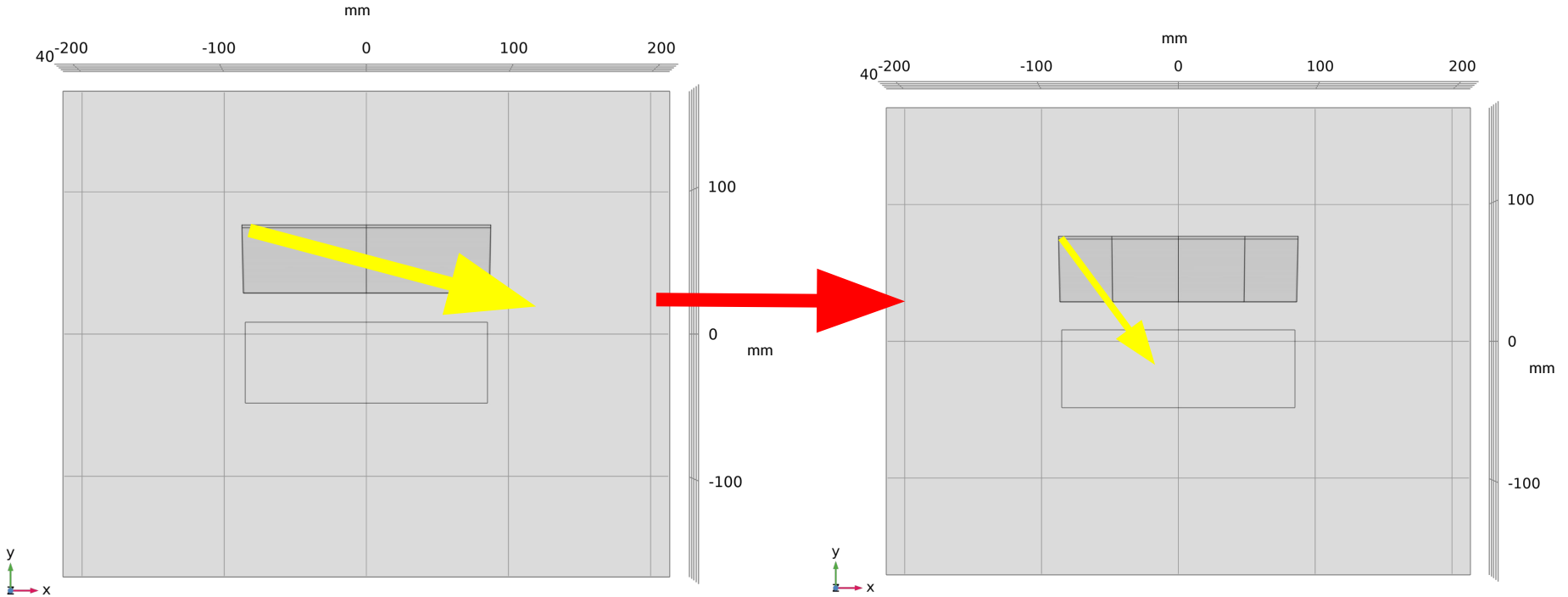


Vertical Distribution of Average Irradiance: Normalized by Deposited Power

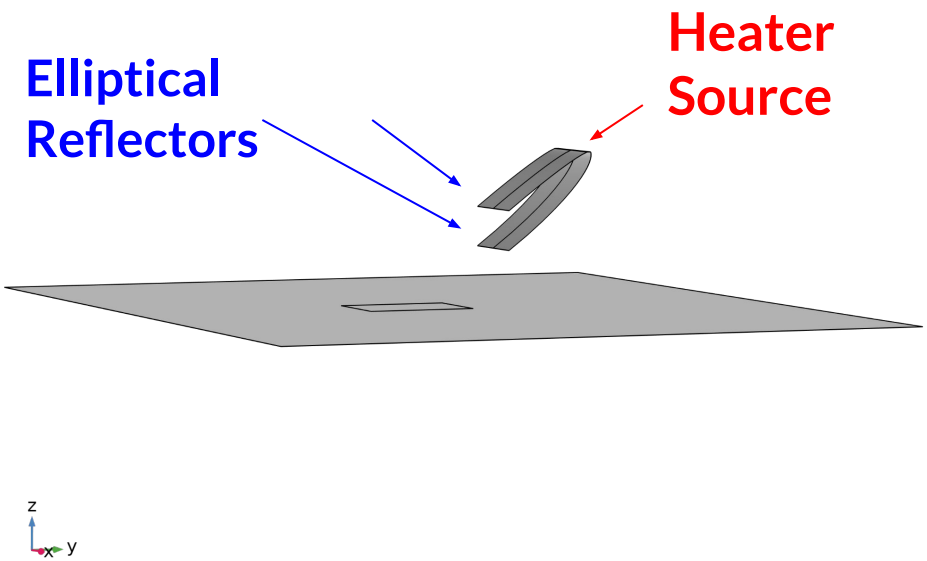


1/8th Model

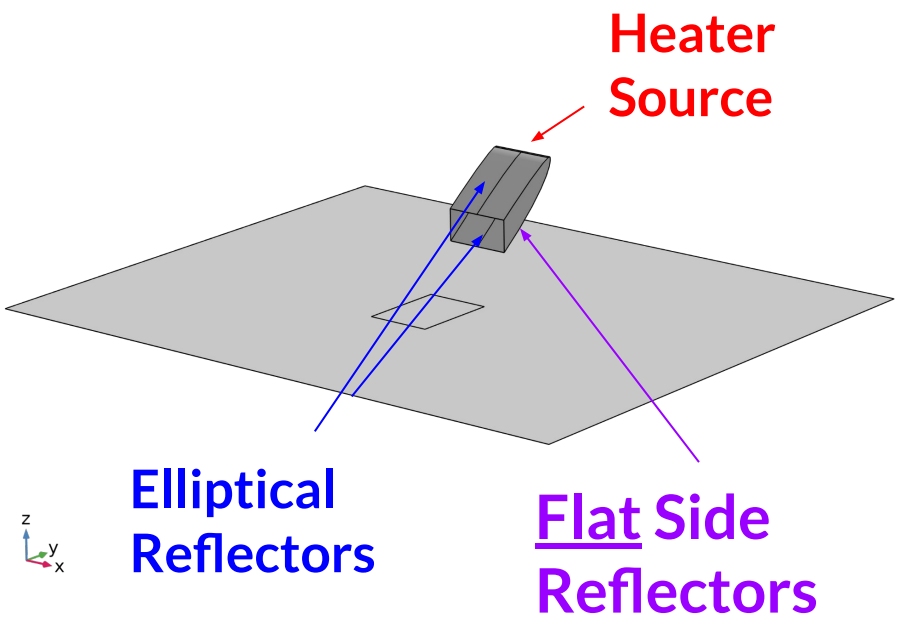
4 1/32nd Models

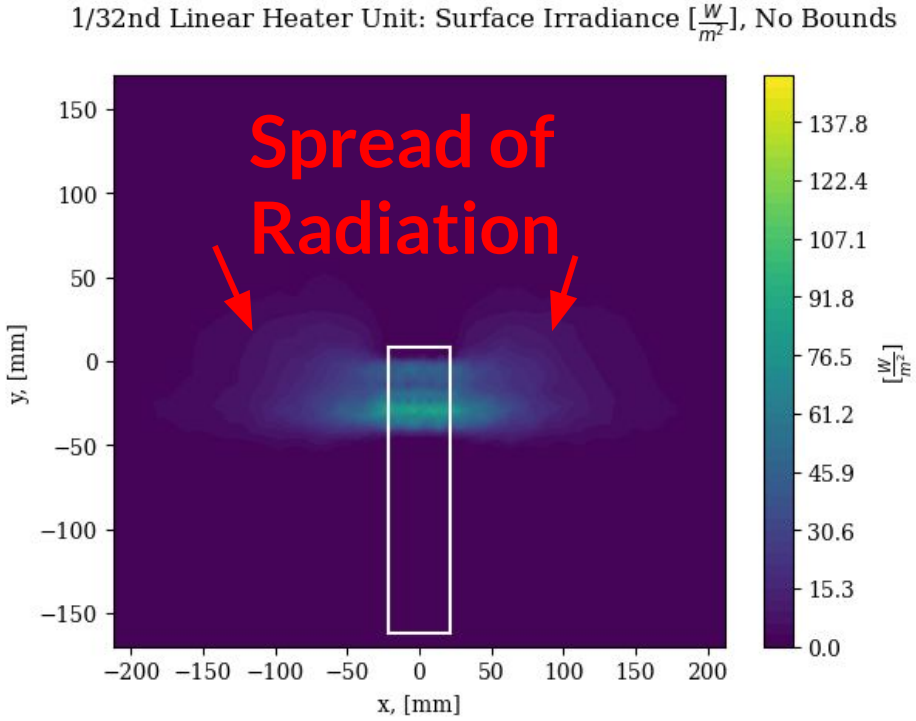


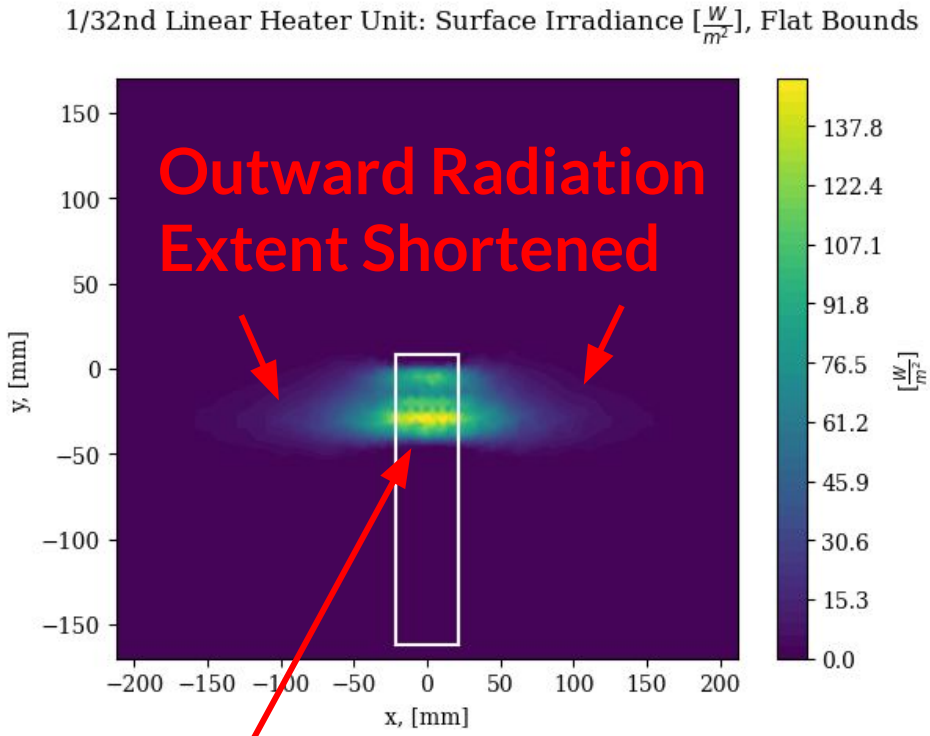
1/32nd Unit: Unbounded



1/32nd Unit: Flat Bounds

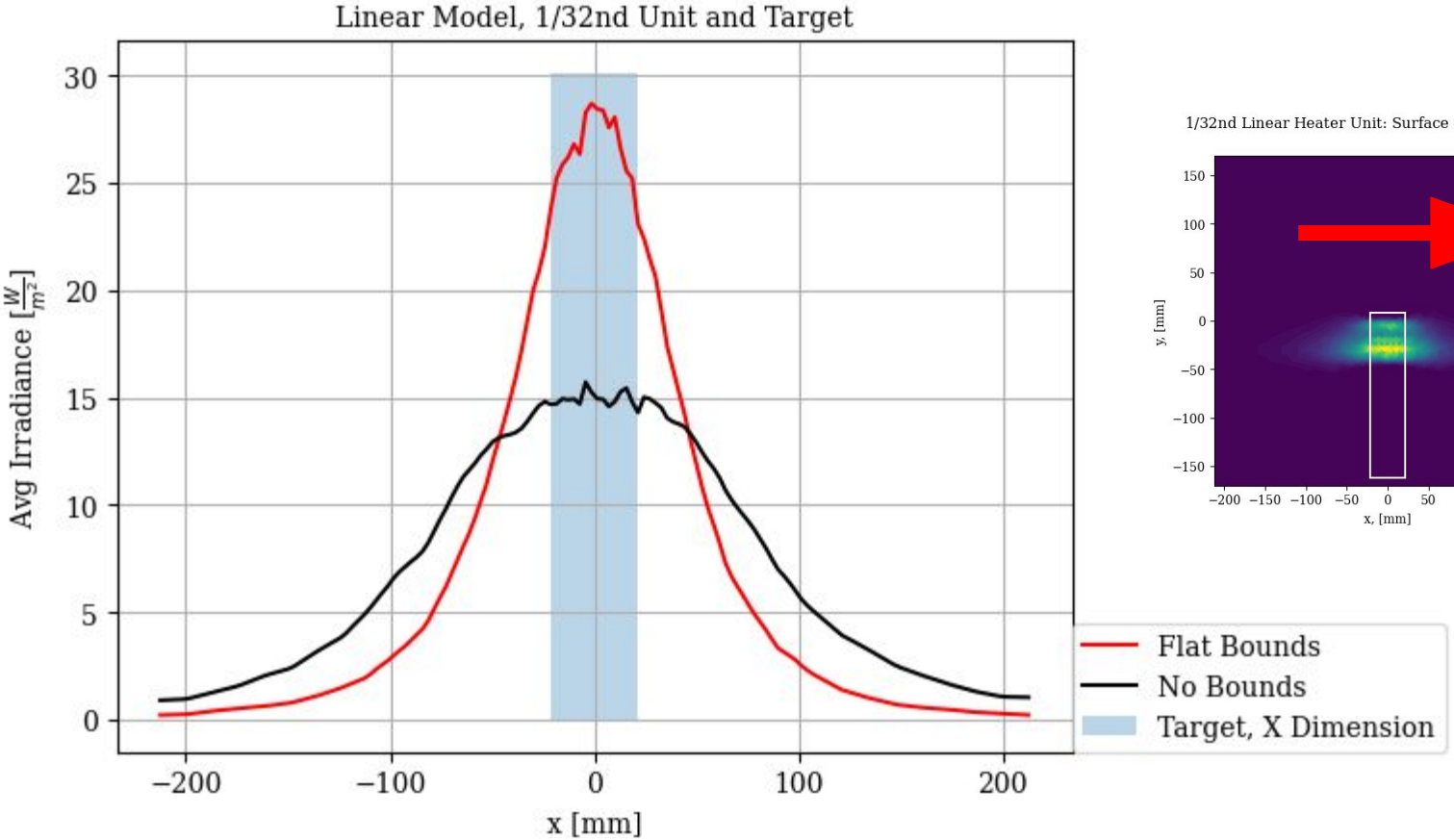




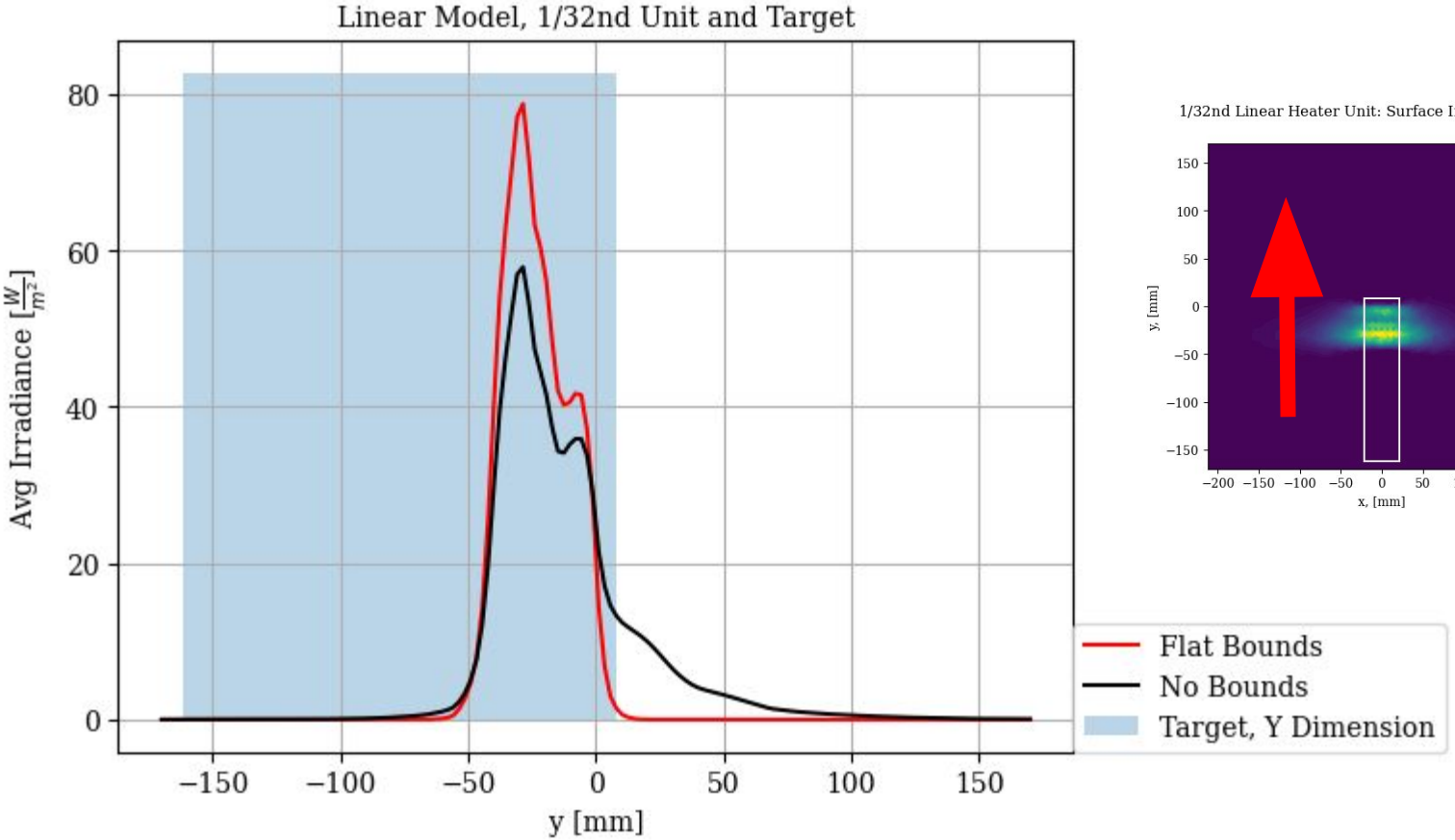


Higher Intensity Level within Target

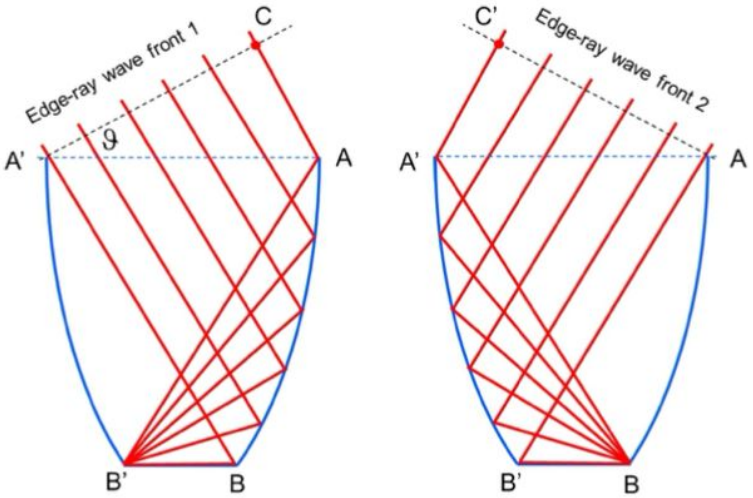
Horizontal Distribution of Average Irradiance: Normalized by Deposited Power



Vertical Distribution of Average Irradiance: Normalized by Deposited Power



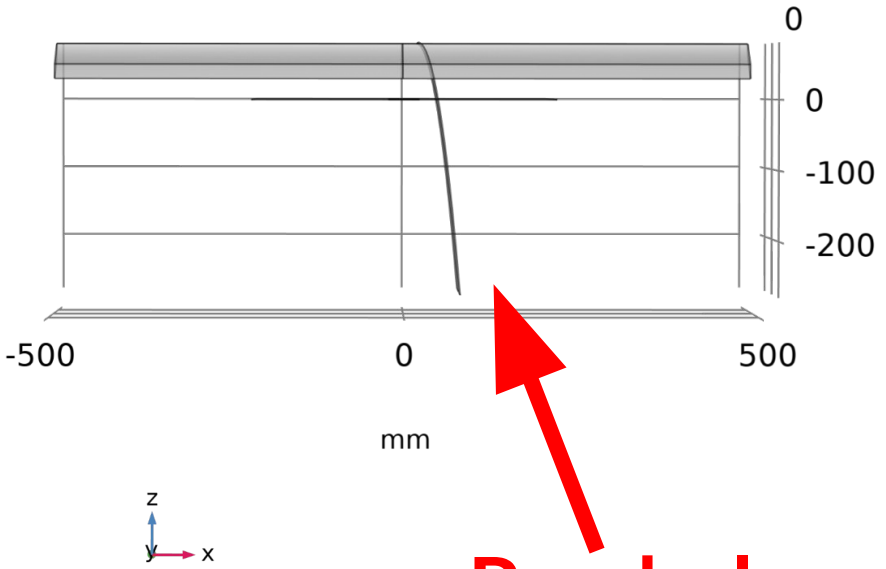
Designing New Edge Coverings



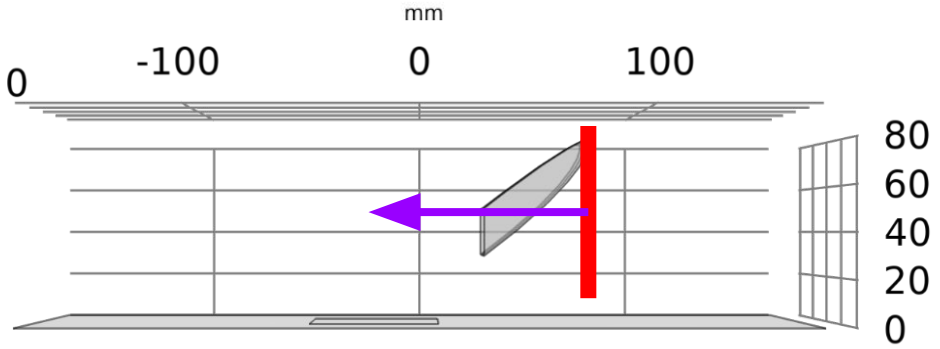
Winston, Jiang, and Ricketts,
Nonimaging Optics: A Tutorial, 2018.

- Design Basis: Compound Parabolic Concentrator

Parabolic Surface, Extruded Through Heater Unit

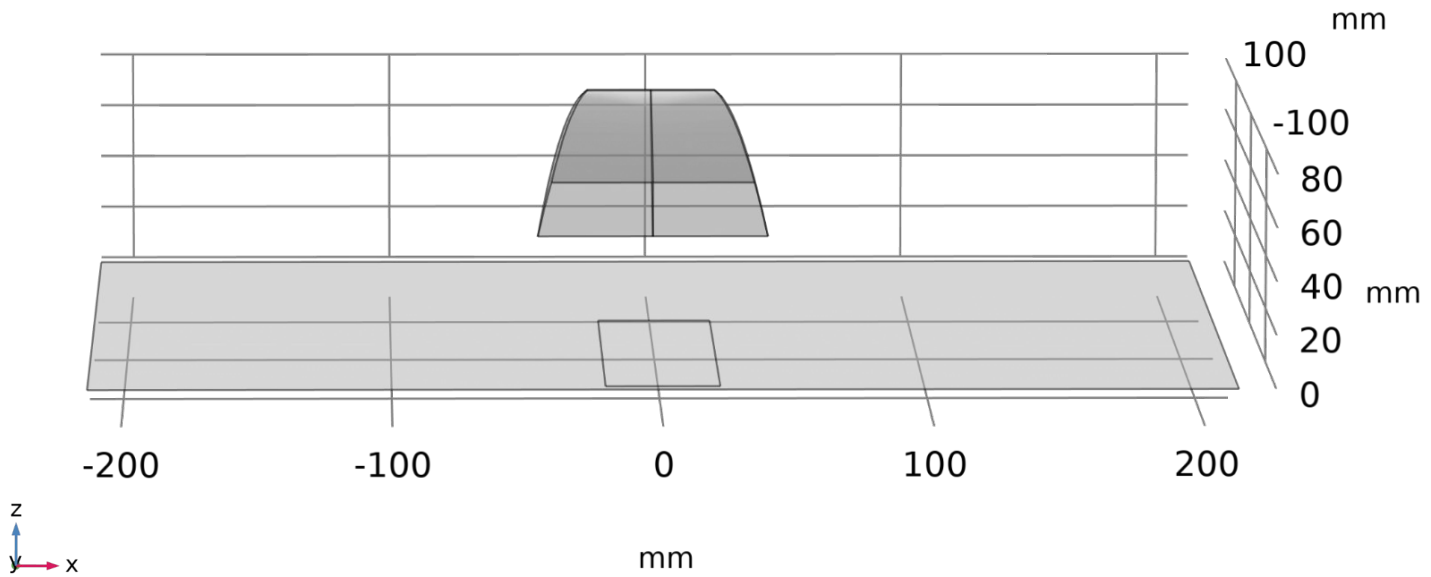


Parabola

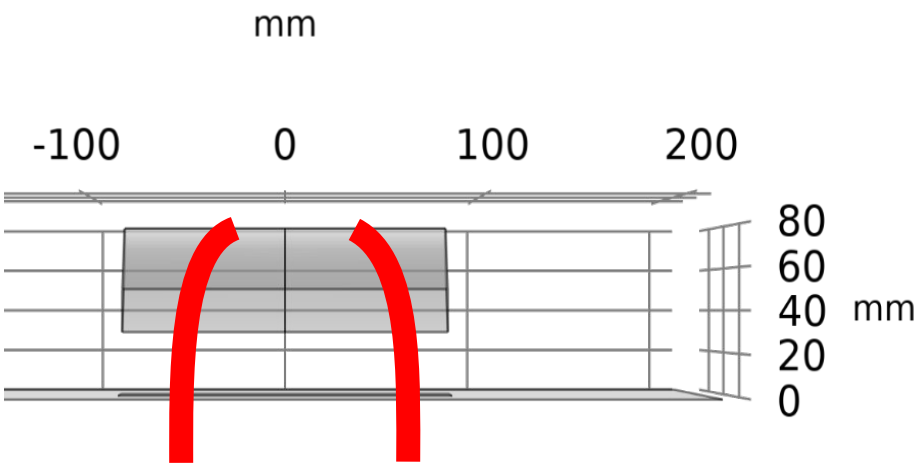


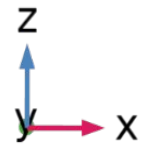
Extruded through Heater Unit

Resulting Heater

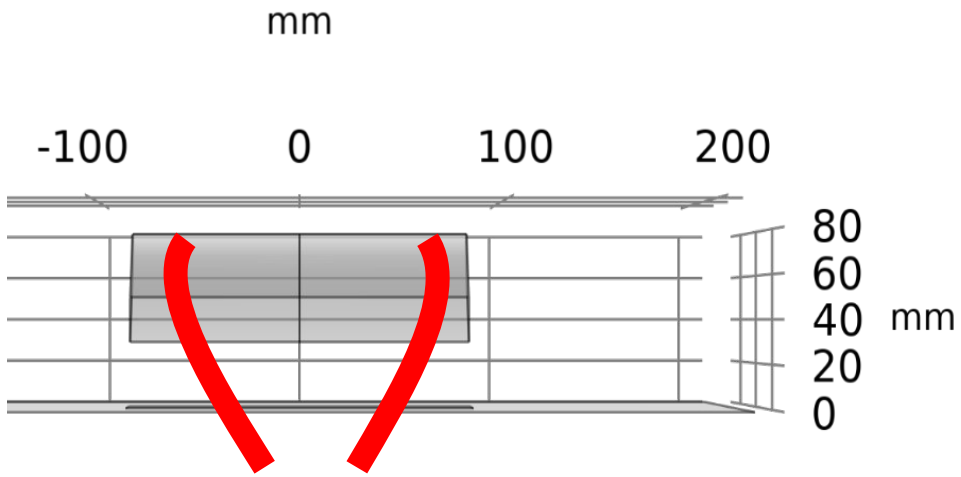


Model 1

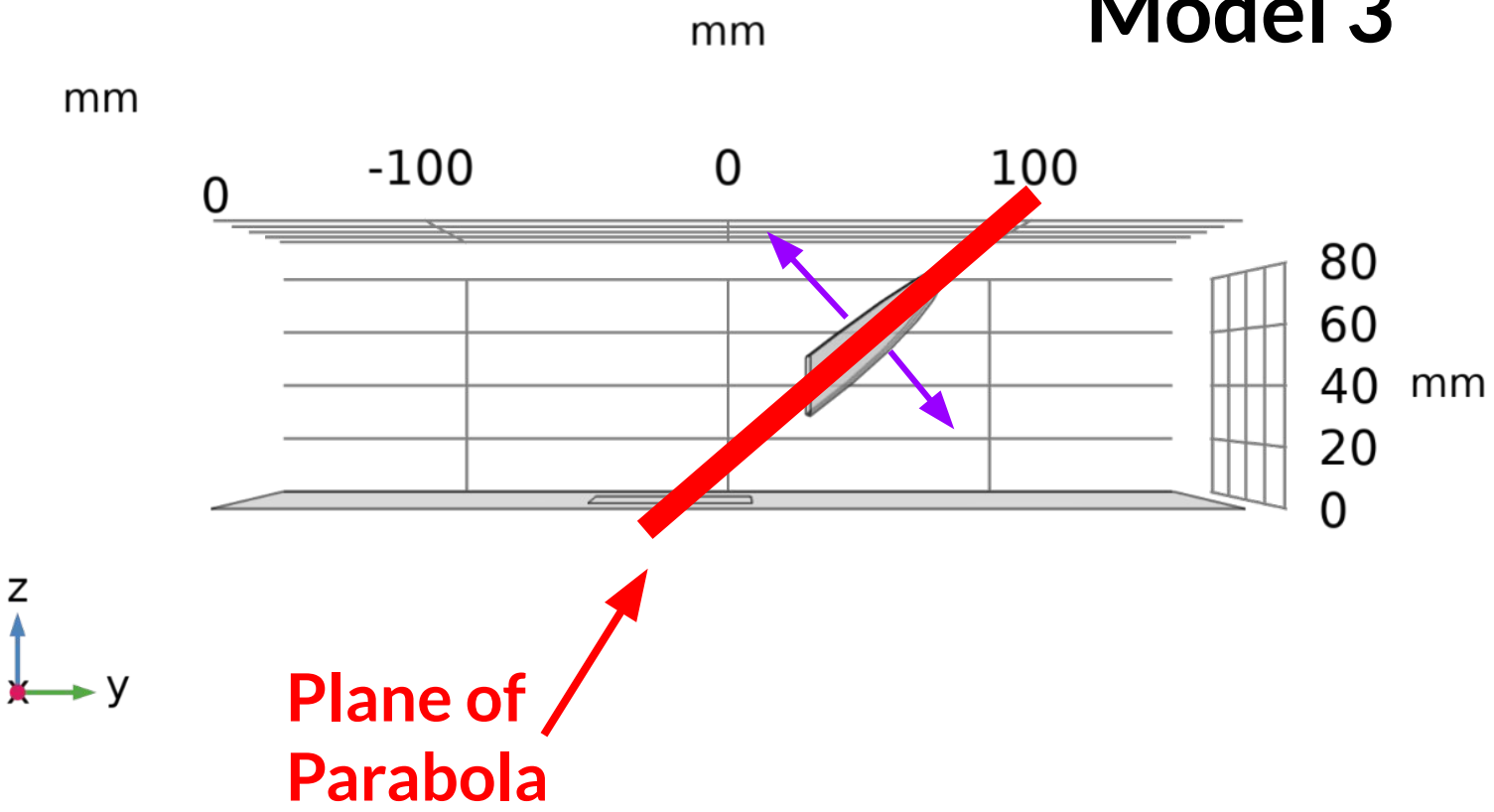




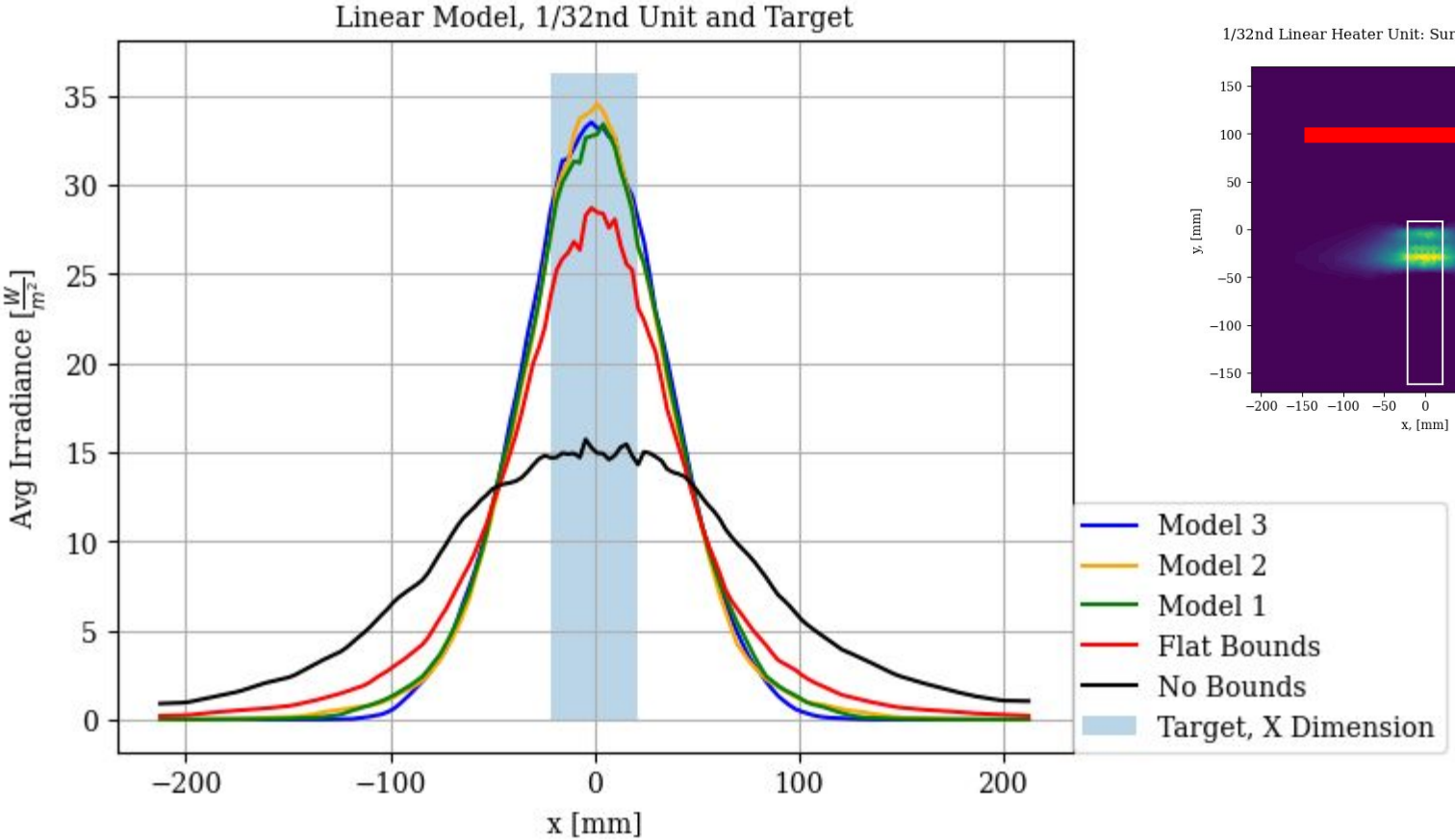
Model 2



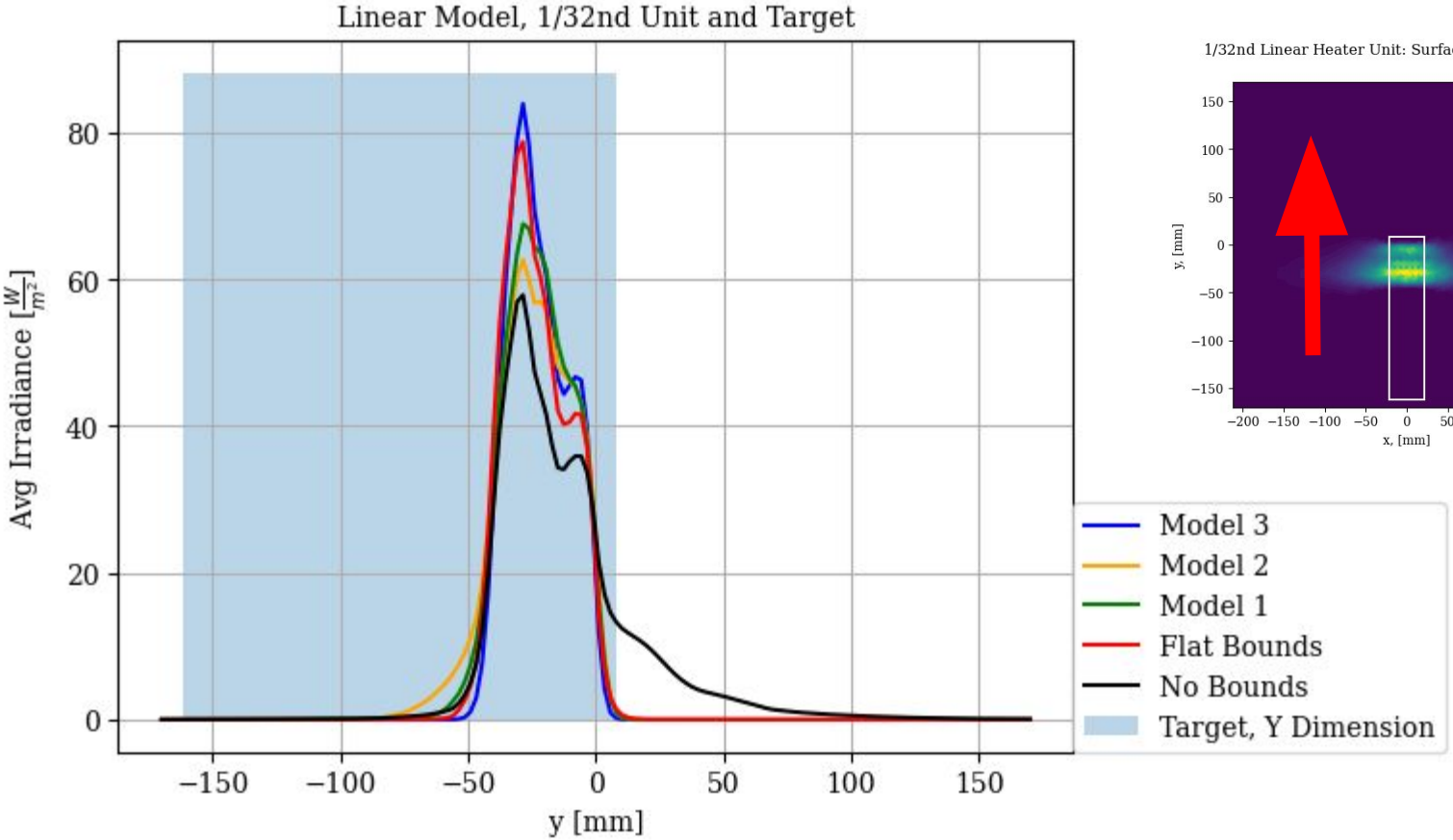
Model 3

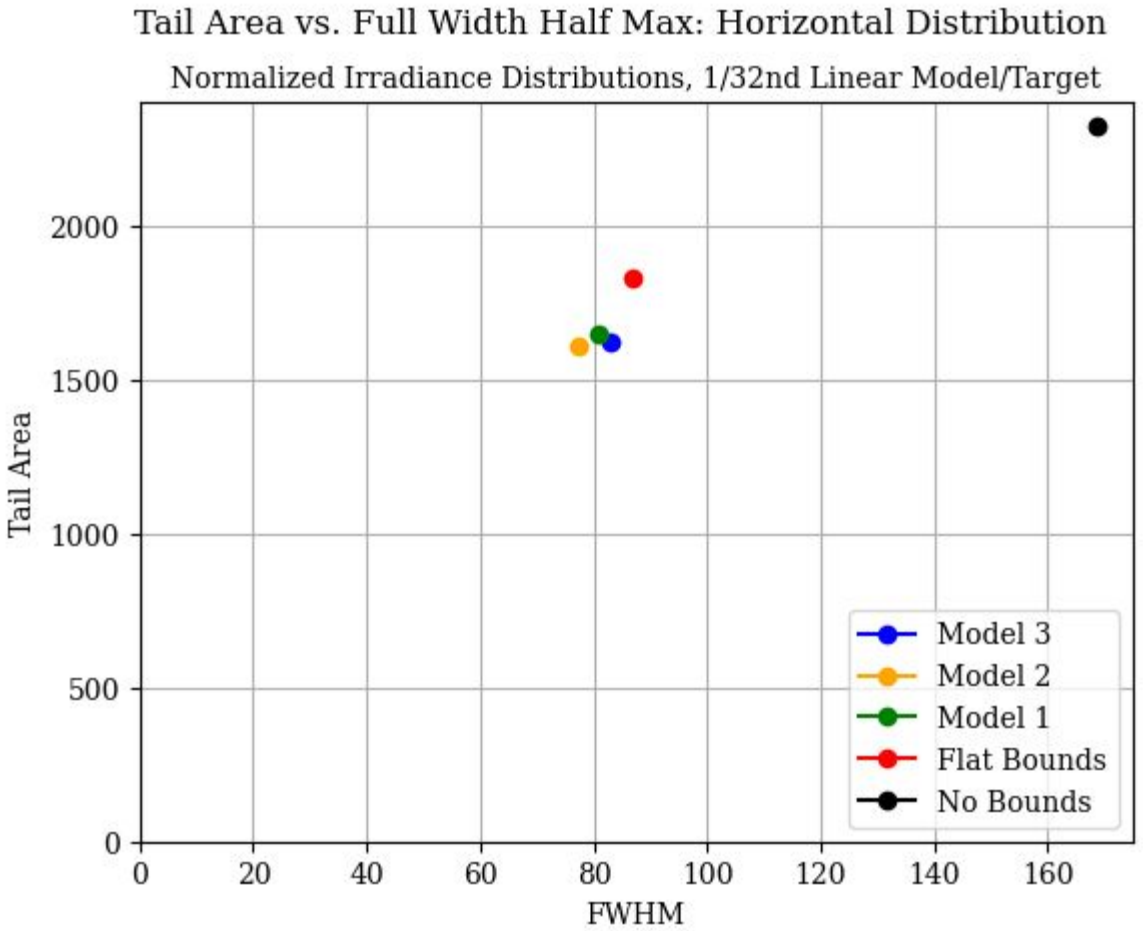


Horizontal Distribution of Average Irradiance: Normalized by Deposited Power



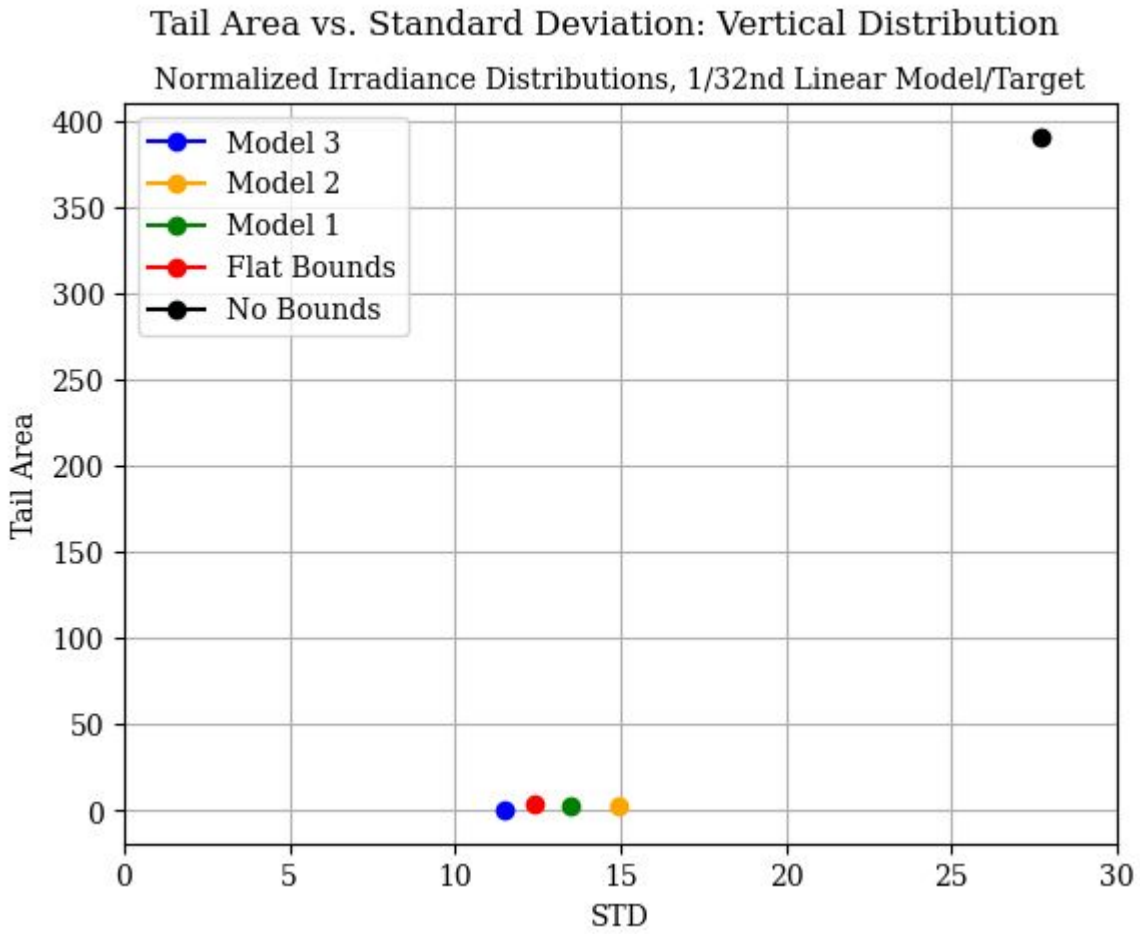
Vertical Distribution of Average Irradiance: Normalized by Deposited Power





Notice:

- **Separation of No Bounds Point from other points**
- **FWHM/Tail Area Value for Model 2**

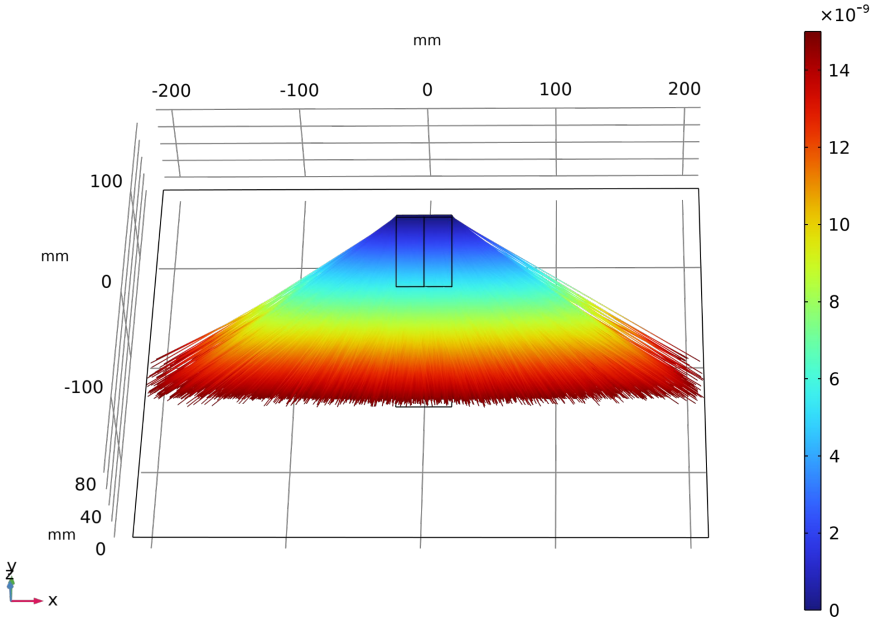


Notice:

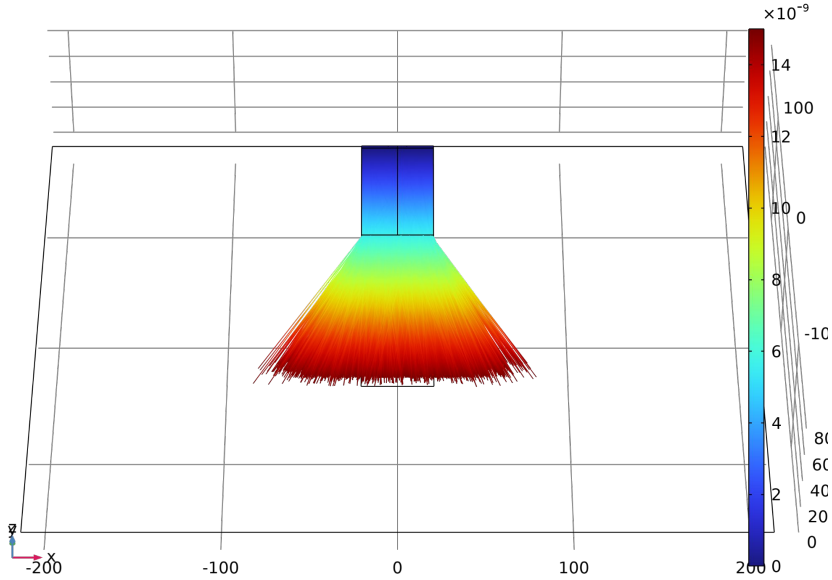
- **STD/Tail Area value of Model 3**

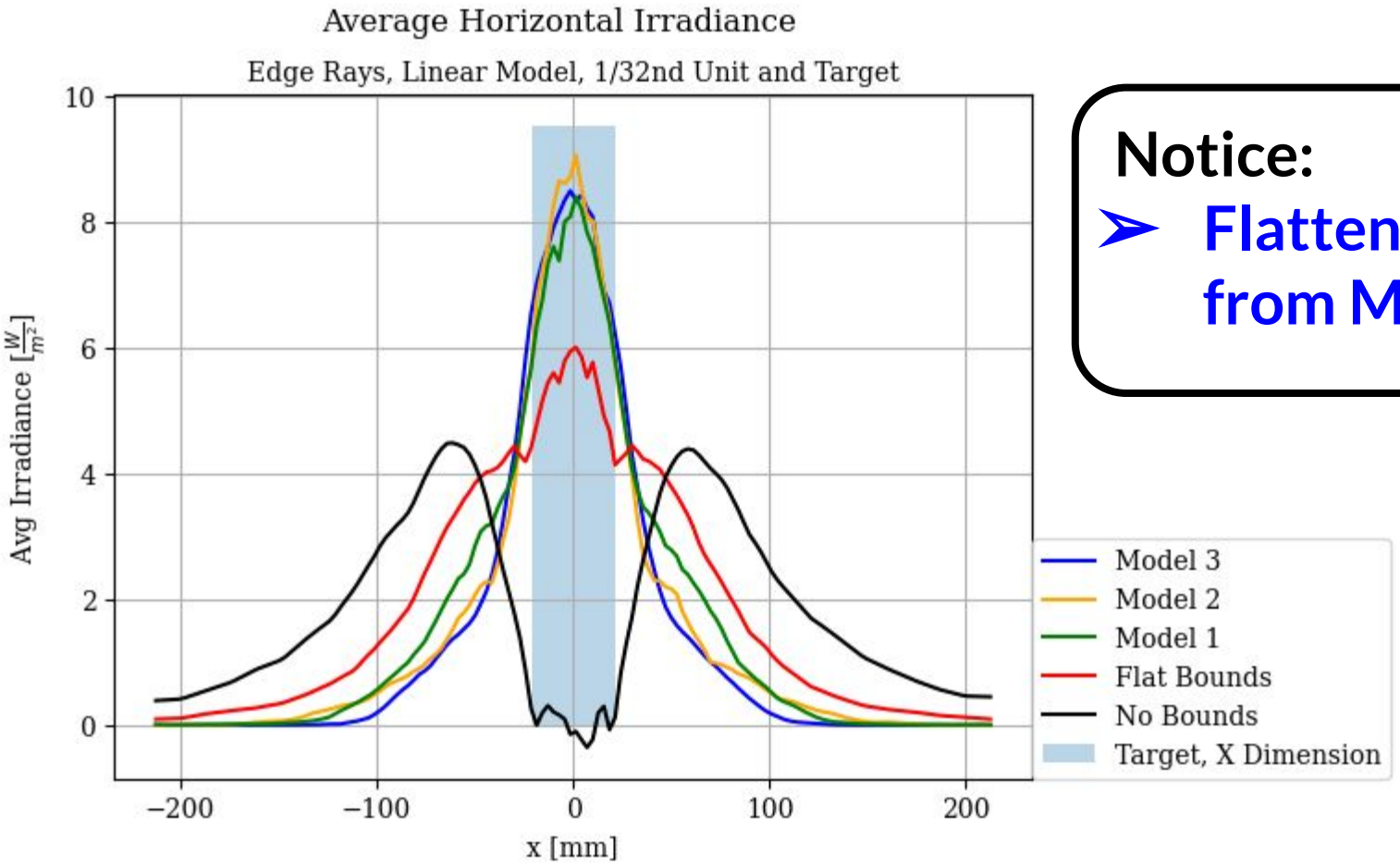
Confirming Effects of Edge Surfaces

No Bounds



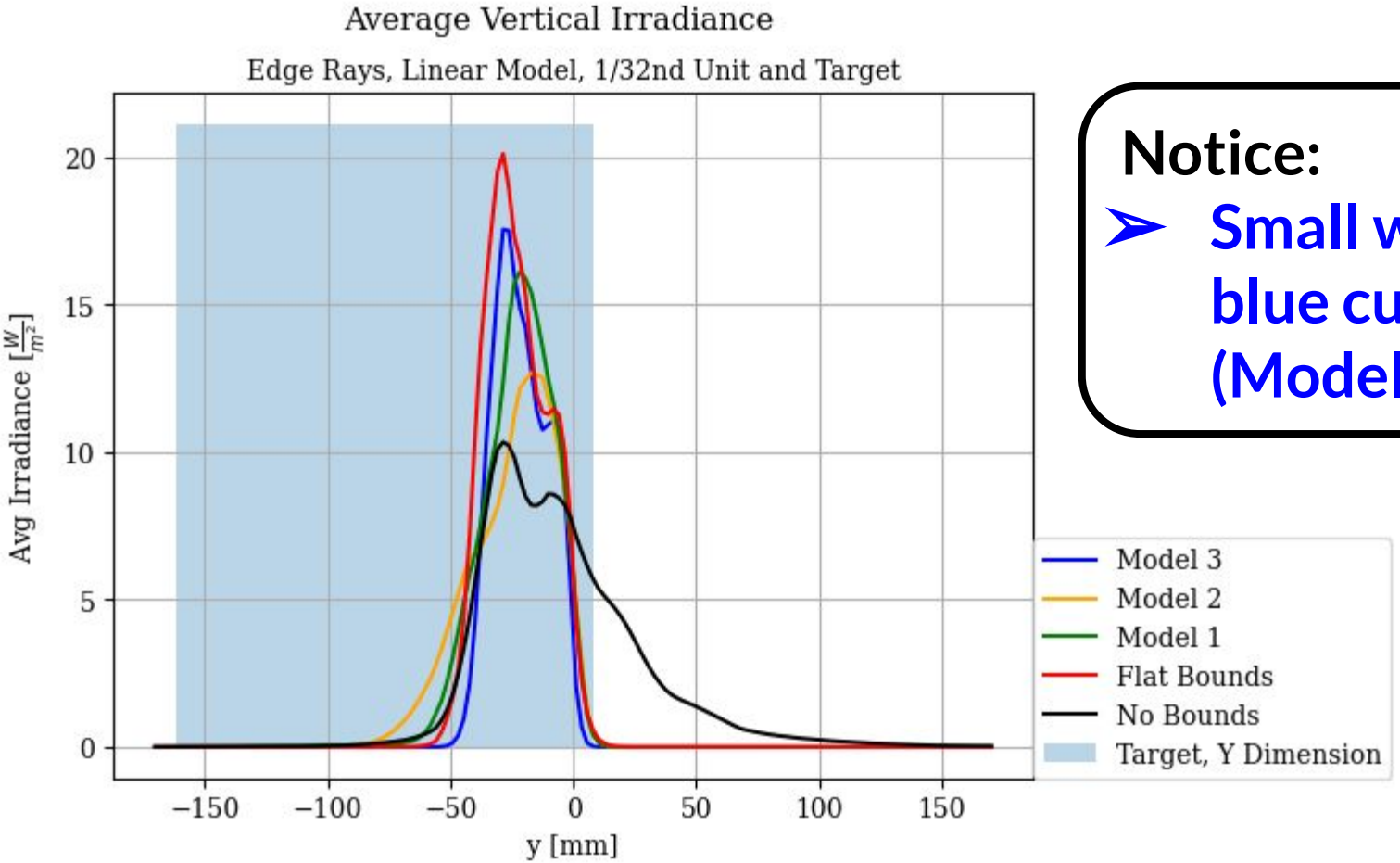
Absorptive Bounds





Notice:

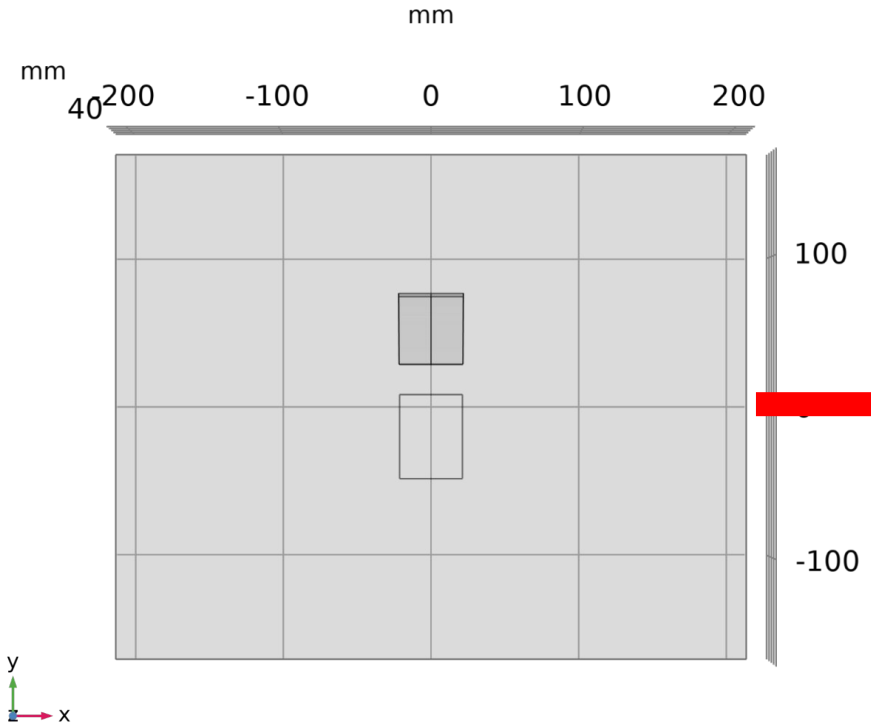
➢ **Flattened Tails from Model 3**



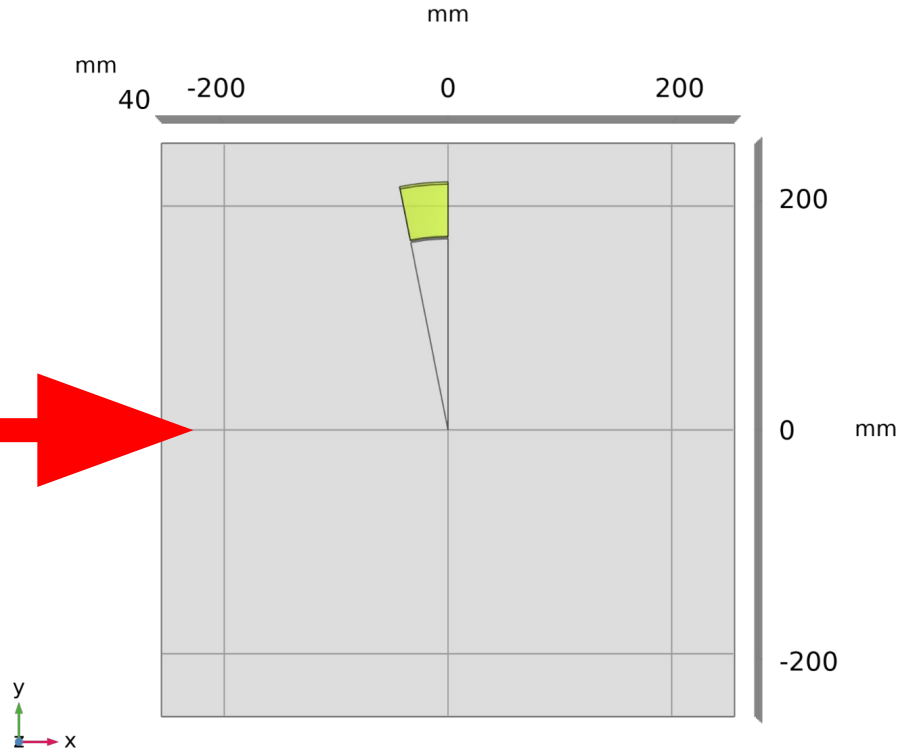
Notice:

➢ **Small width of blue curve (Model 3)**

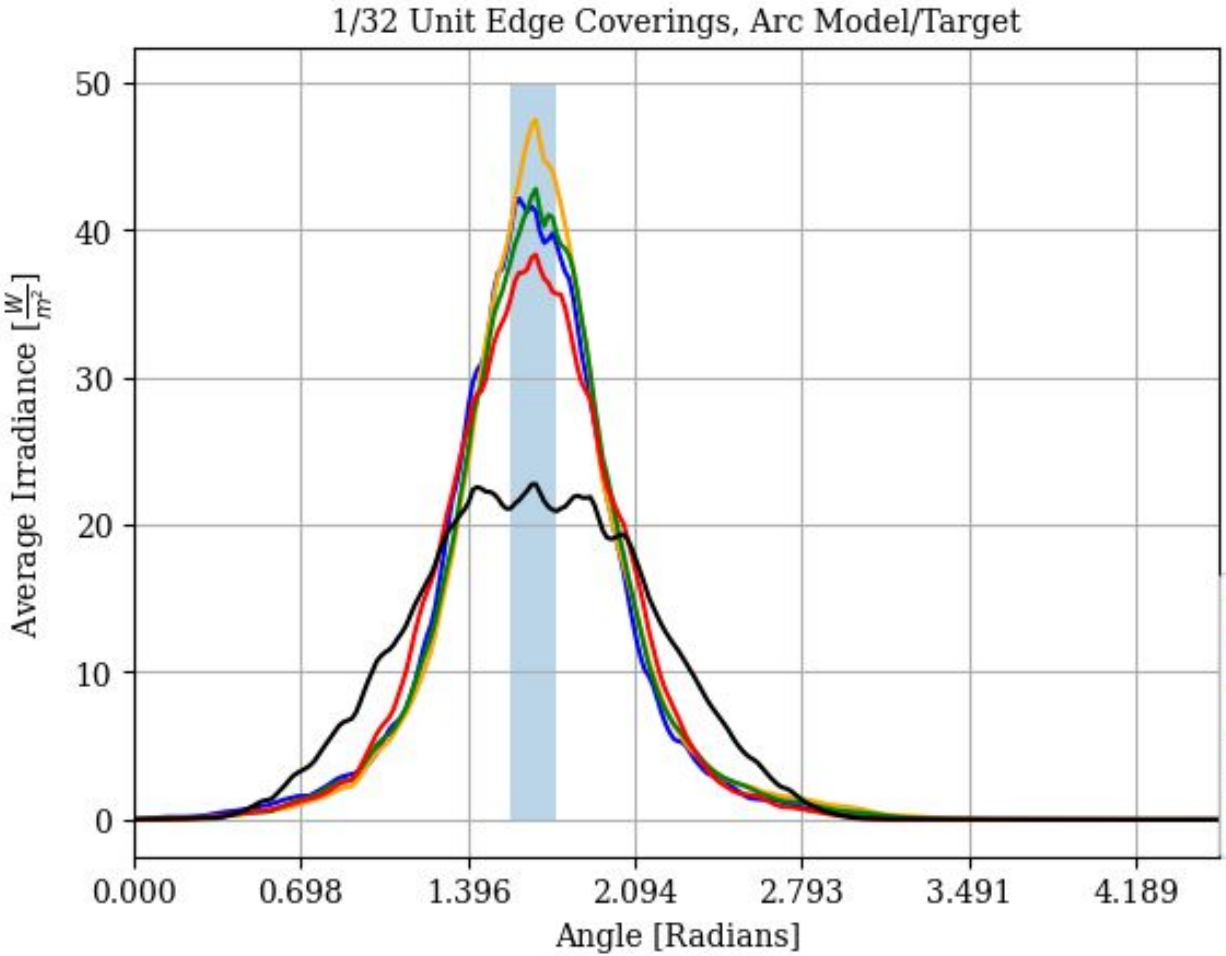
Straight Line Model

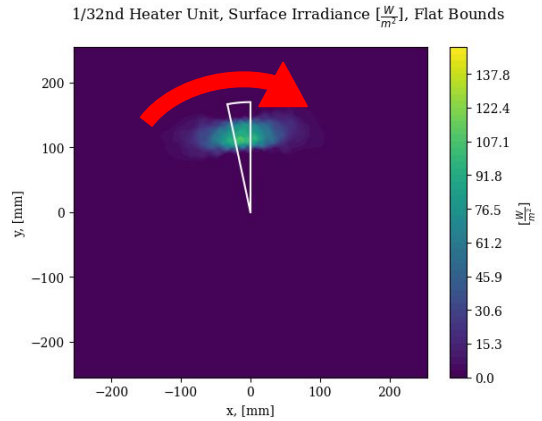


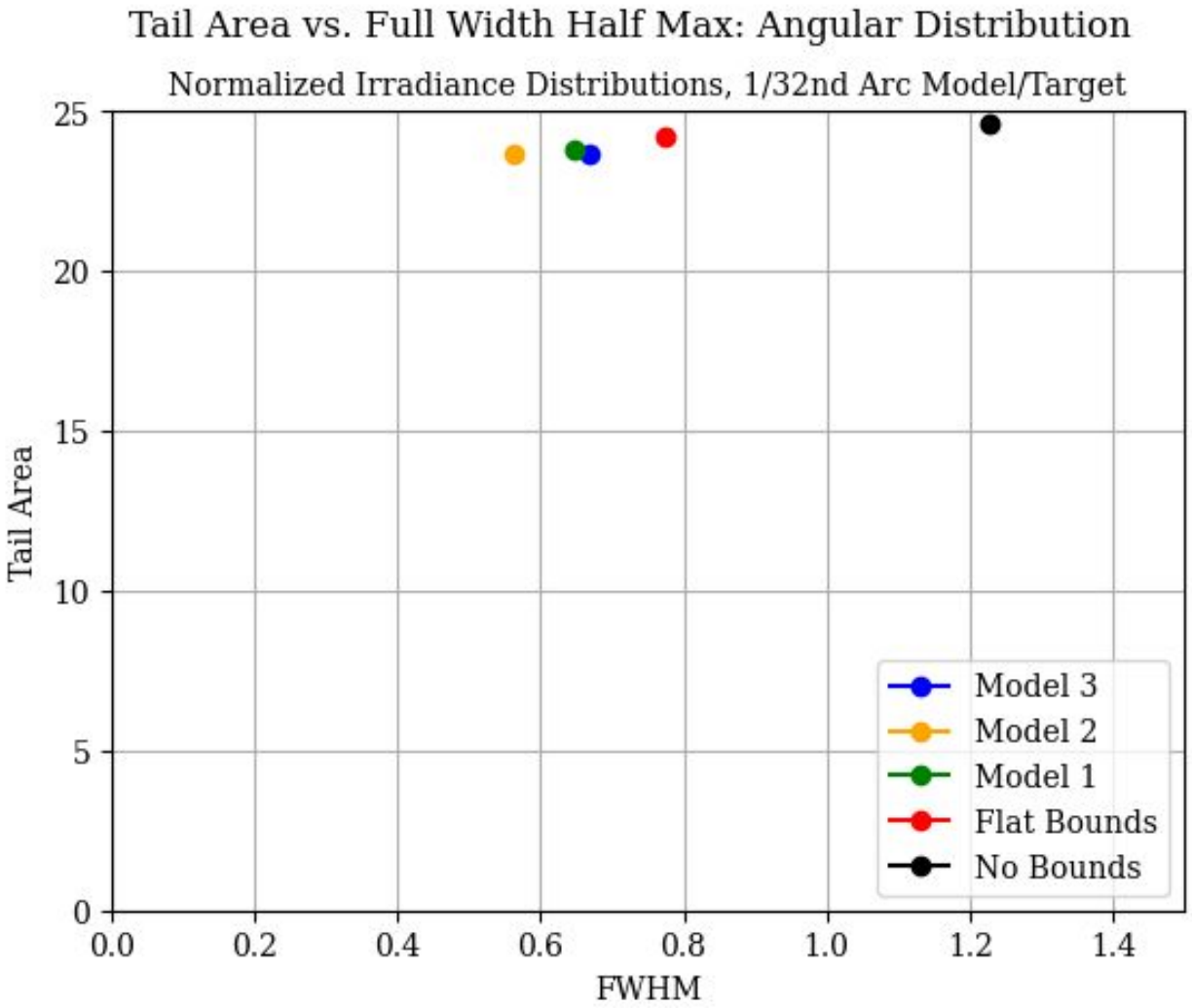
Arc Model



Angular Distribution of Average Irradiance: Normalized by Deposited Power



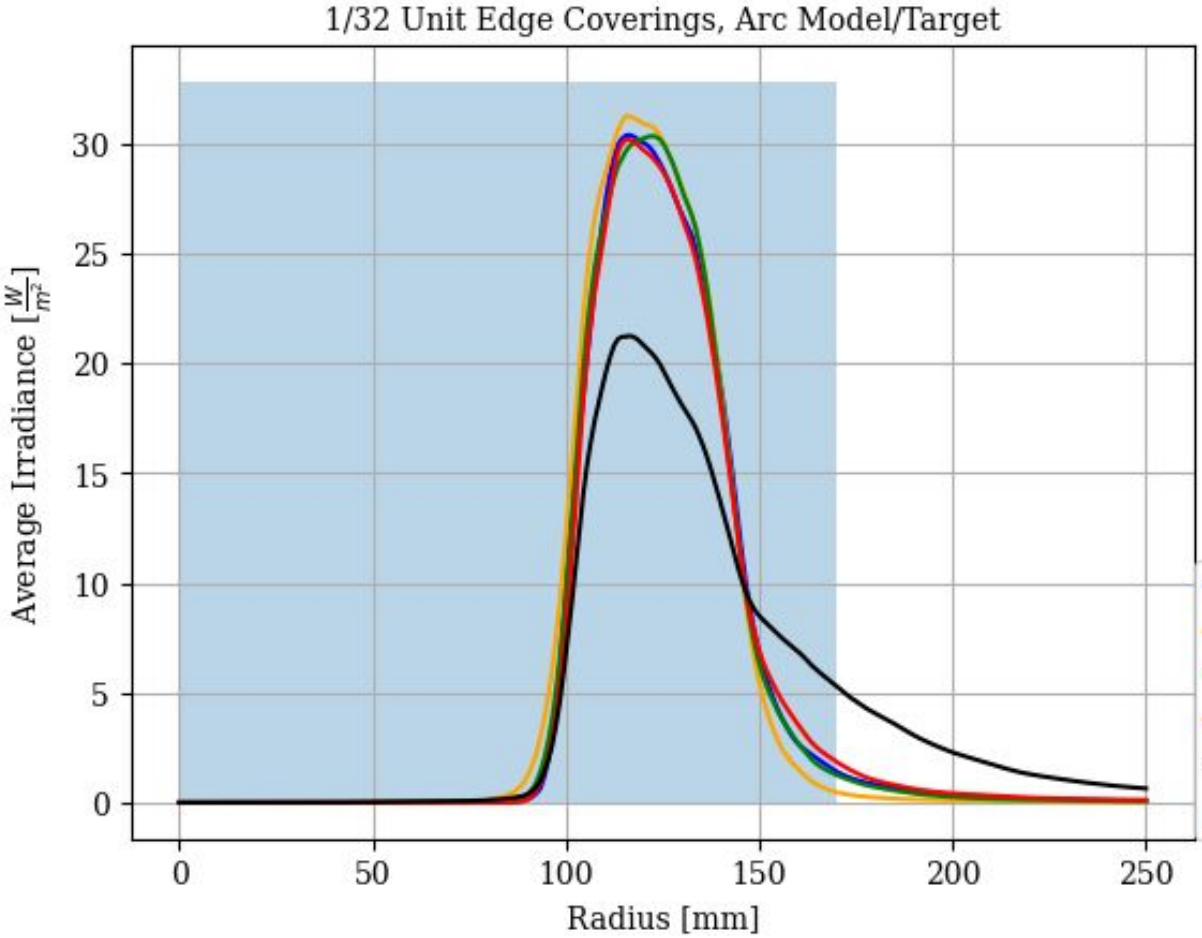


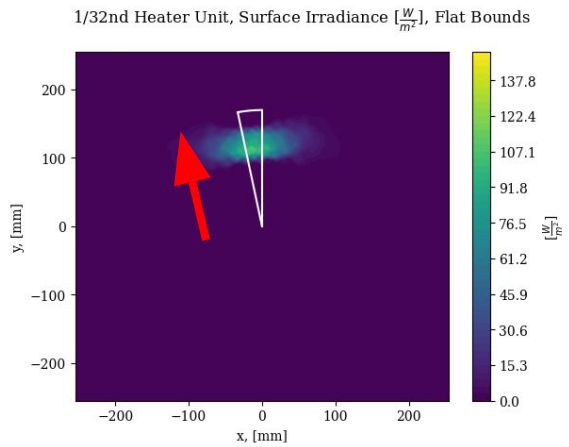


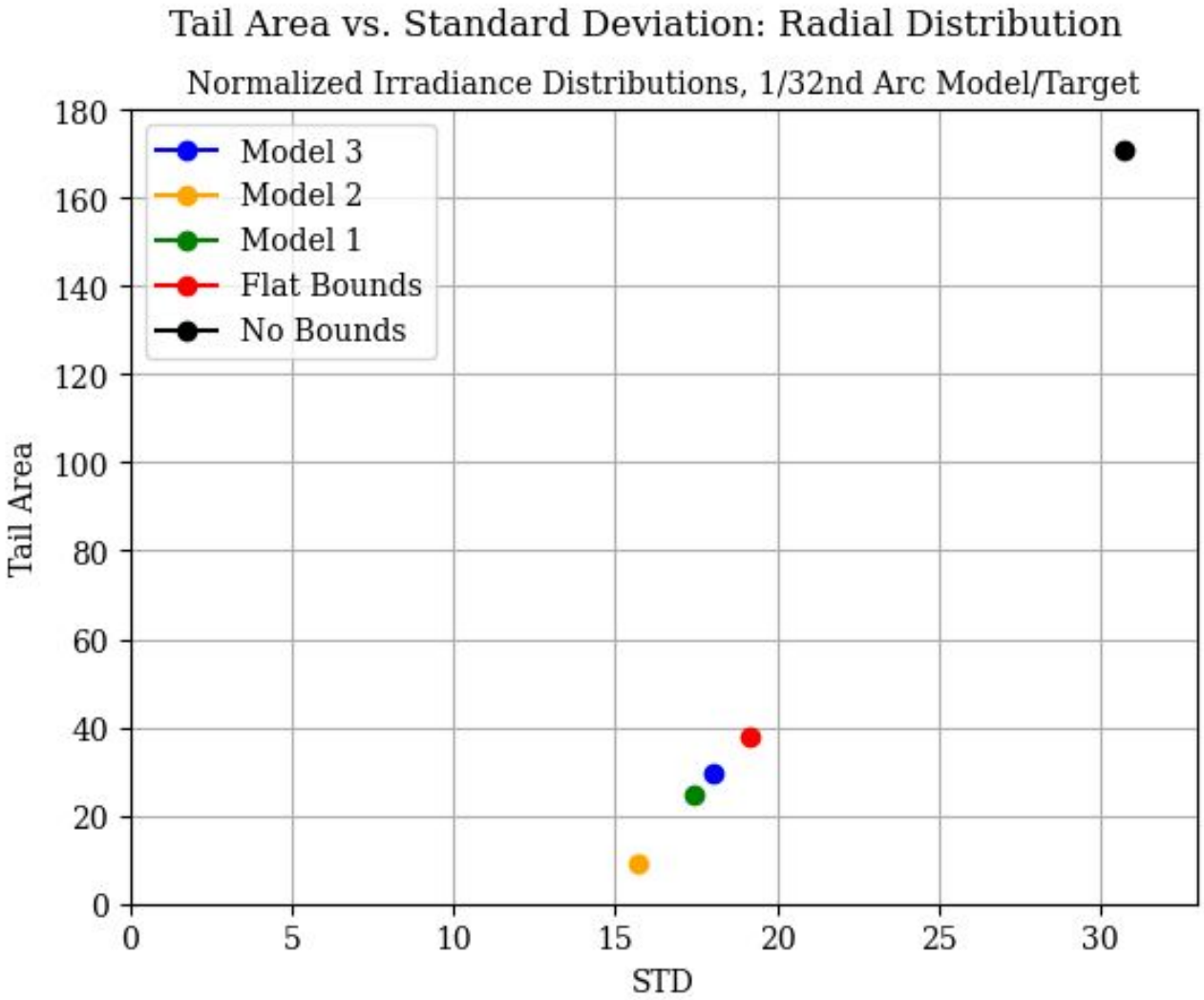
Notice:

- **Low FWHM/Tail Area value for Model 2**

Radial Distribution of Average Irradiance: Normalized by Deposited Power



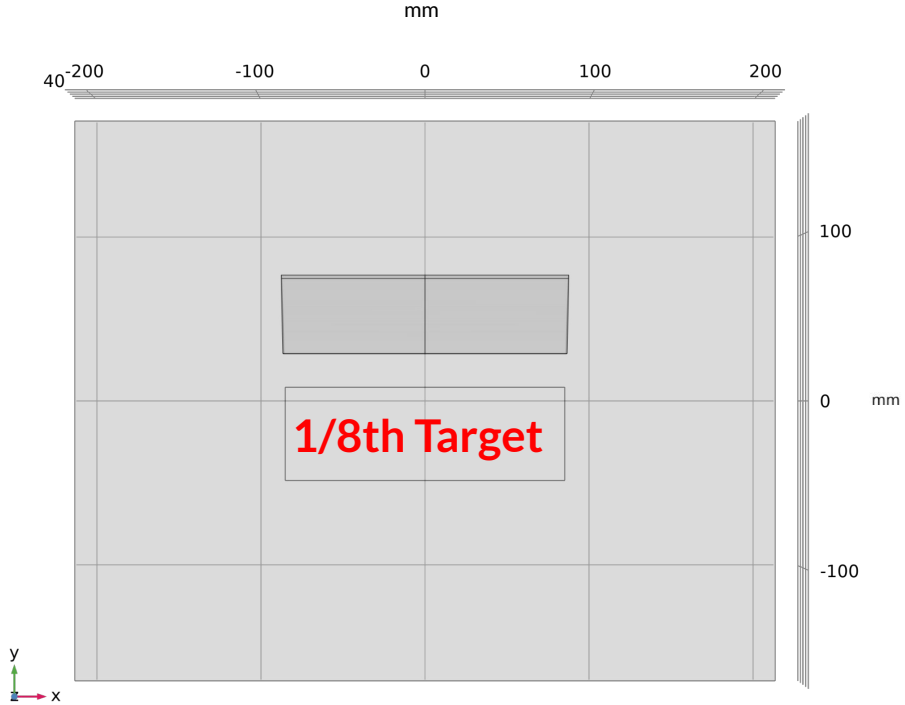




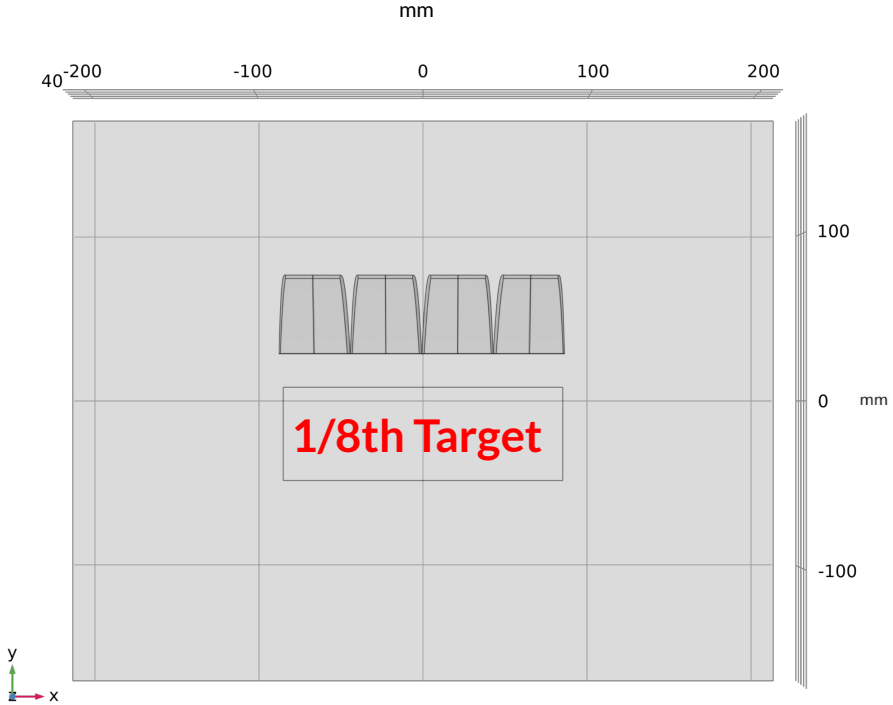
Notice:

- **Low Tail Area and STD for Model 2**

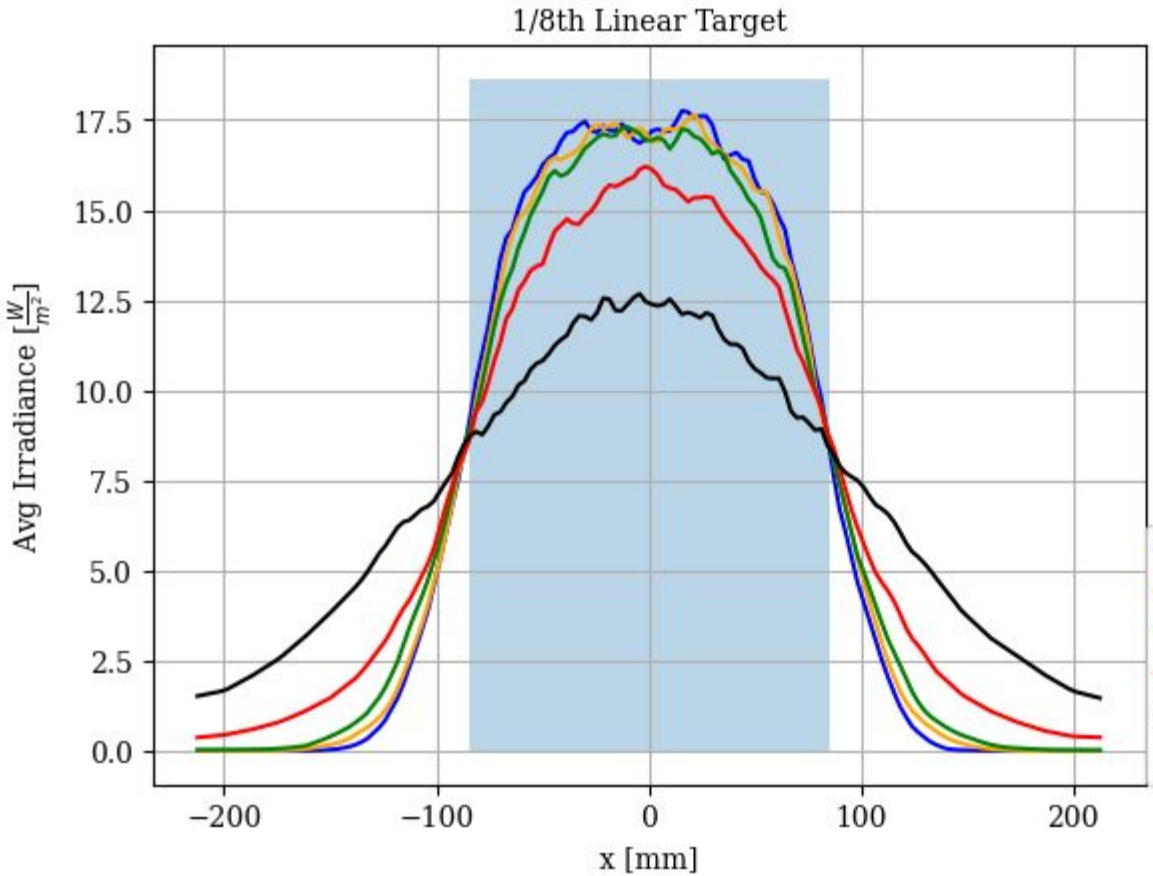
1/8th Straight Line Heater Unit

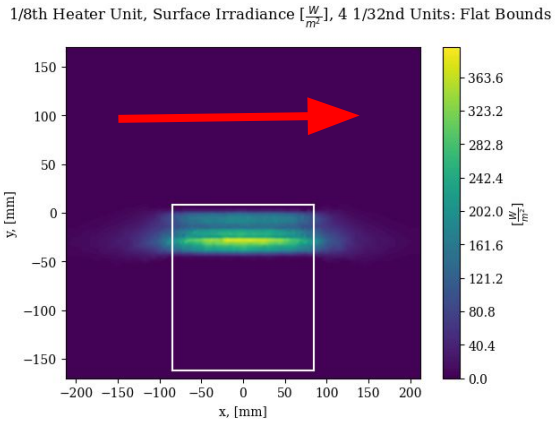


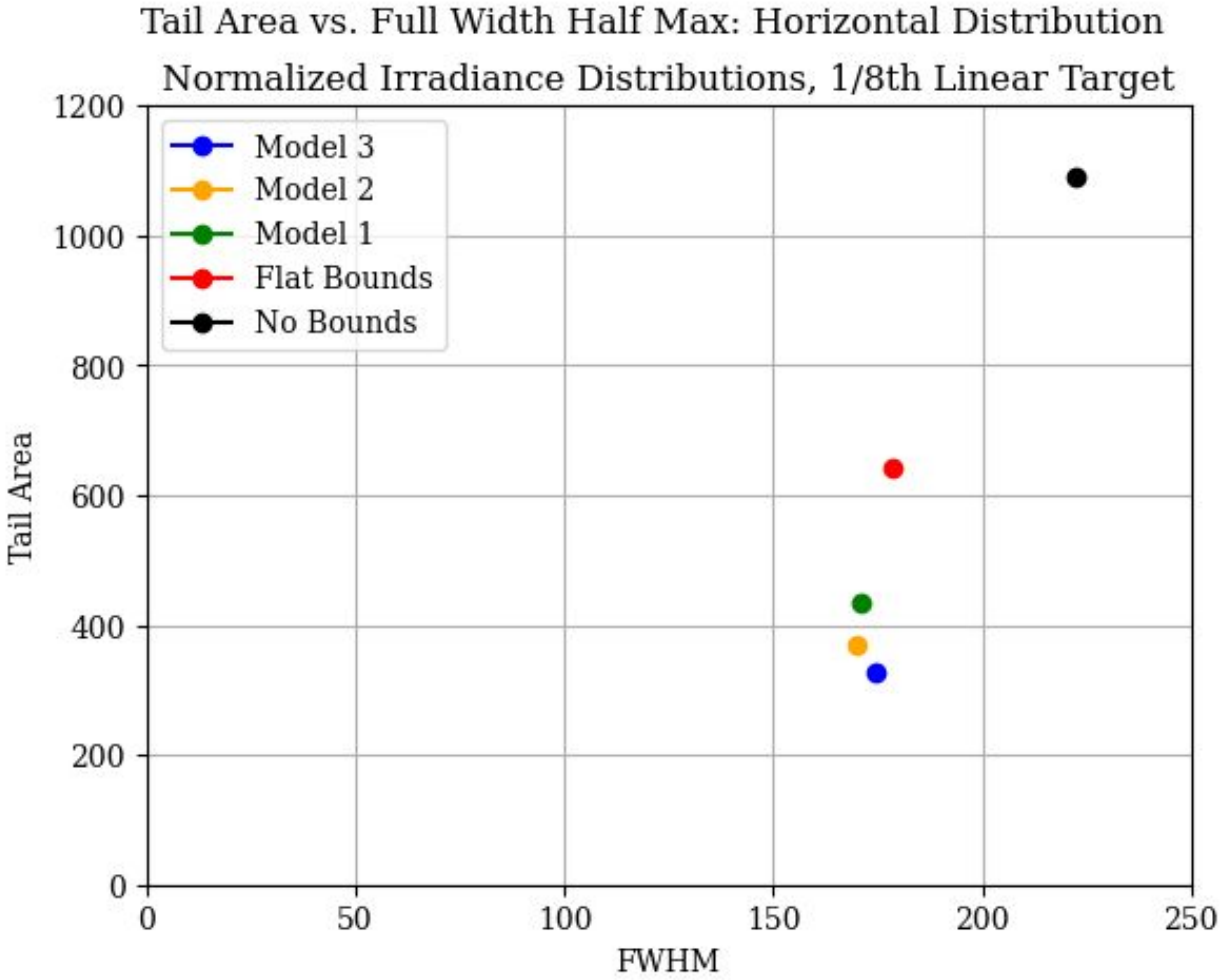
4 1/32nd Straight Line Heater Units



Horizontal Distribution of Average Irradiance: Normalized by Deposited Power



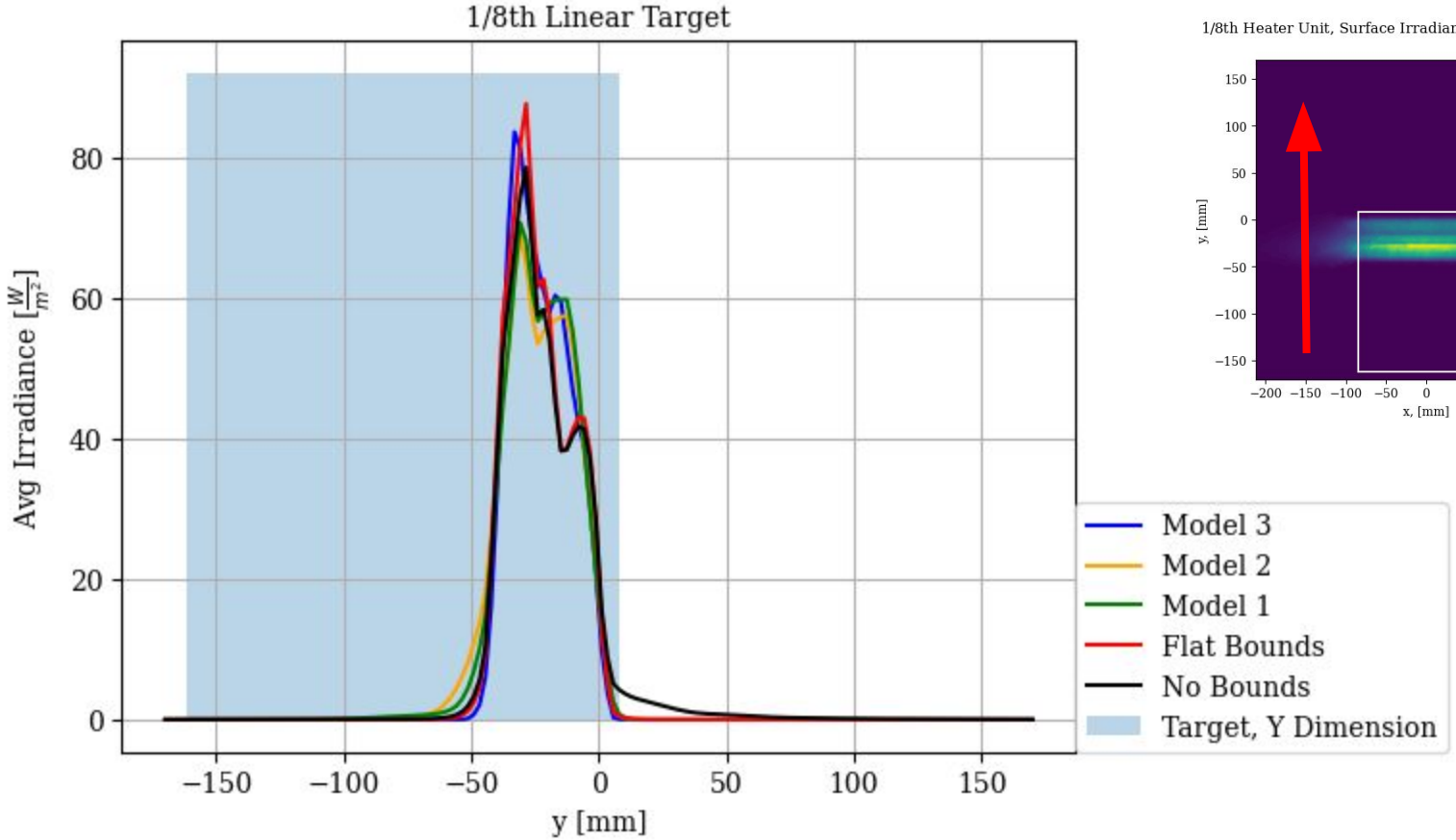


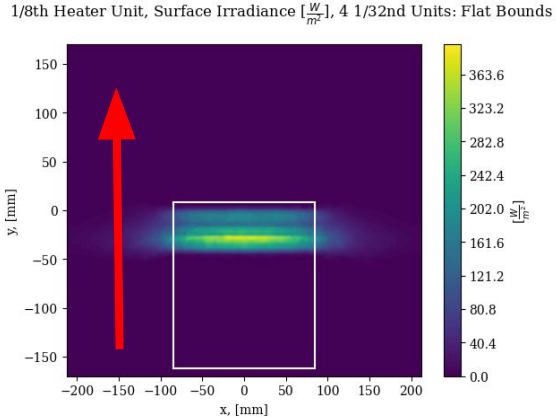


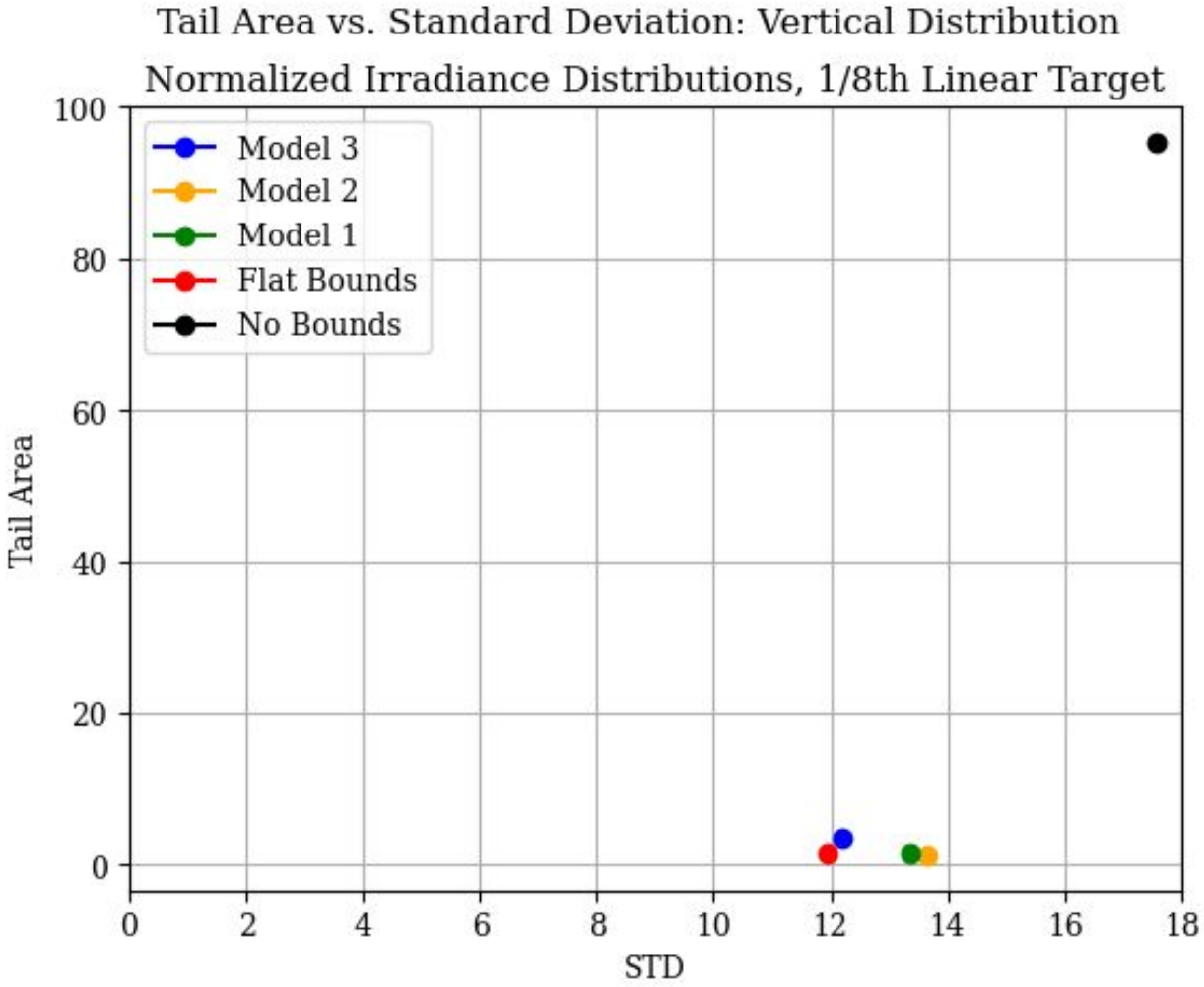
Notice:

- **Low Tail Area and FWHM value for Model 3**

Vertical Distribution of Average Irradiance: Normalized by Deposited Power



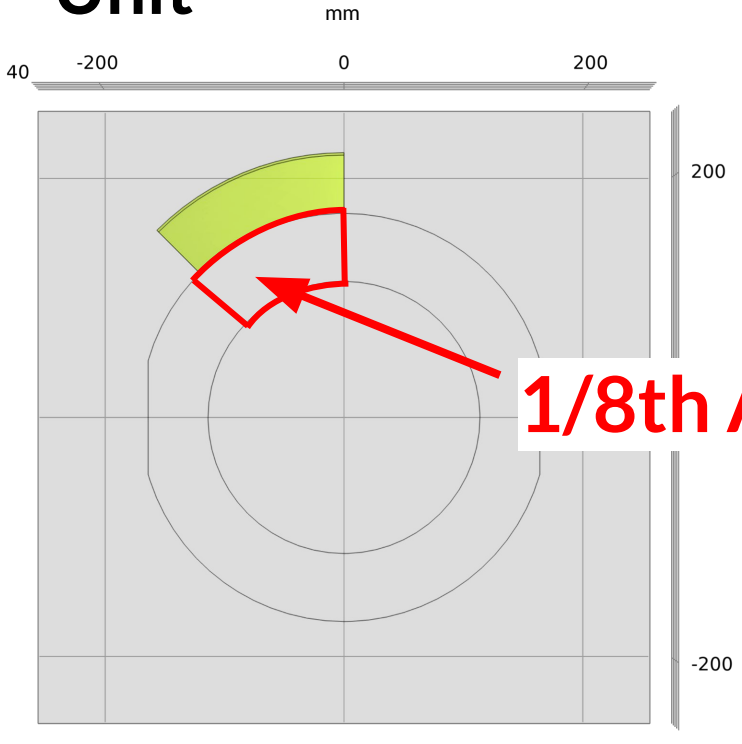




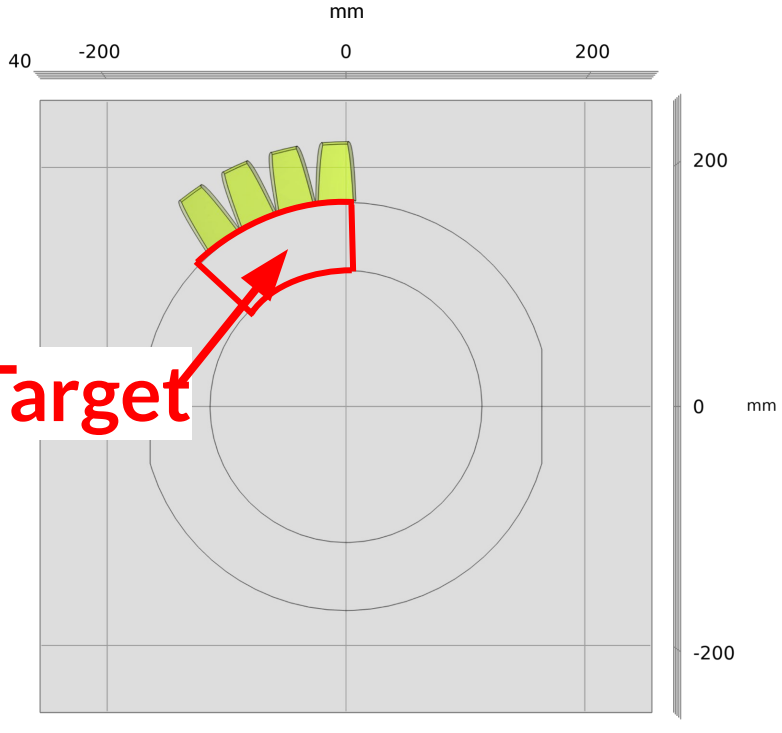
Notice:

- **Low Tail Area and FWHM value for Flat Bounds**

1/8th Arc Heater Unit

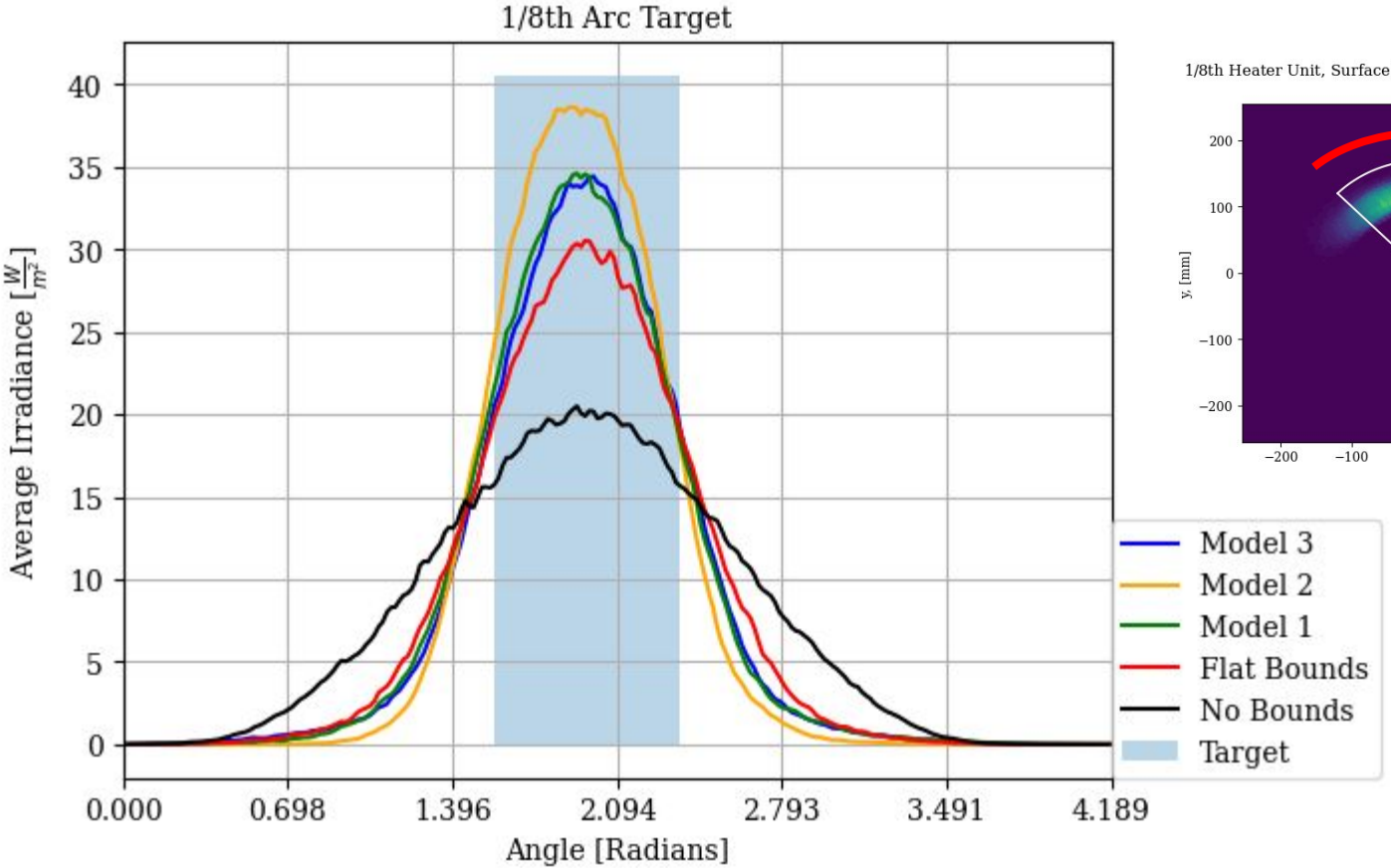


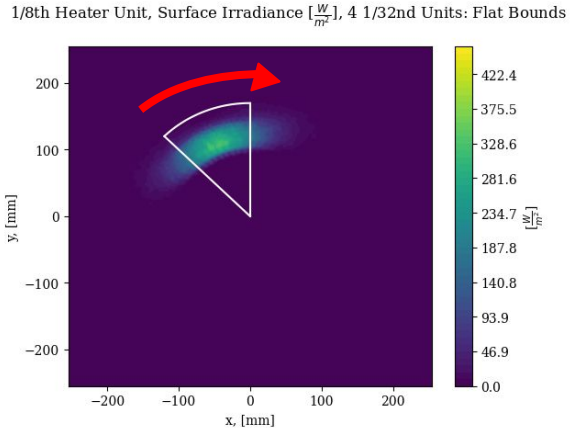
4 1/32nd Arc Heater Units

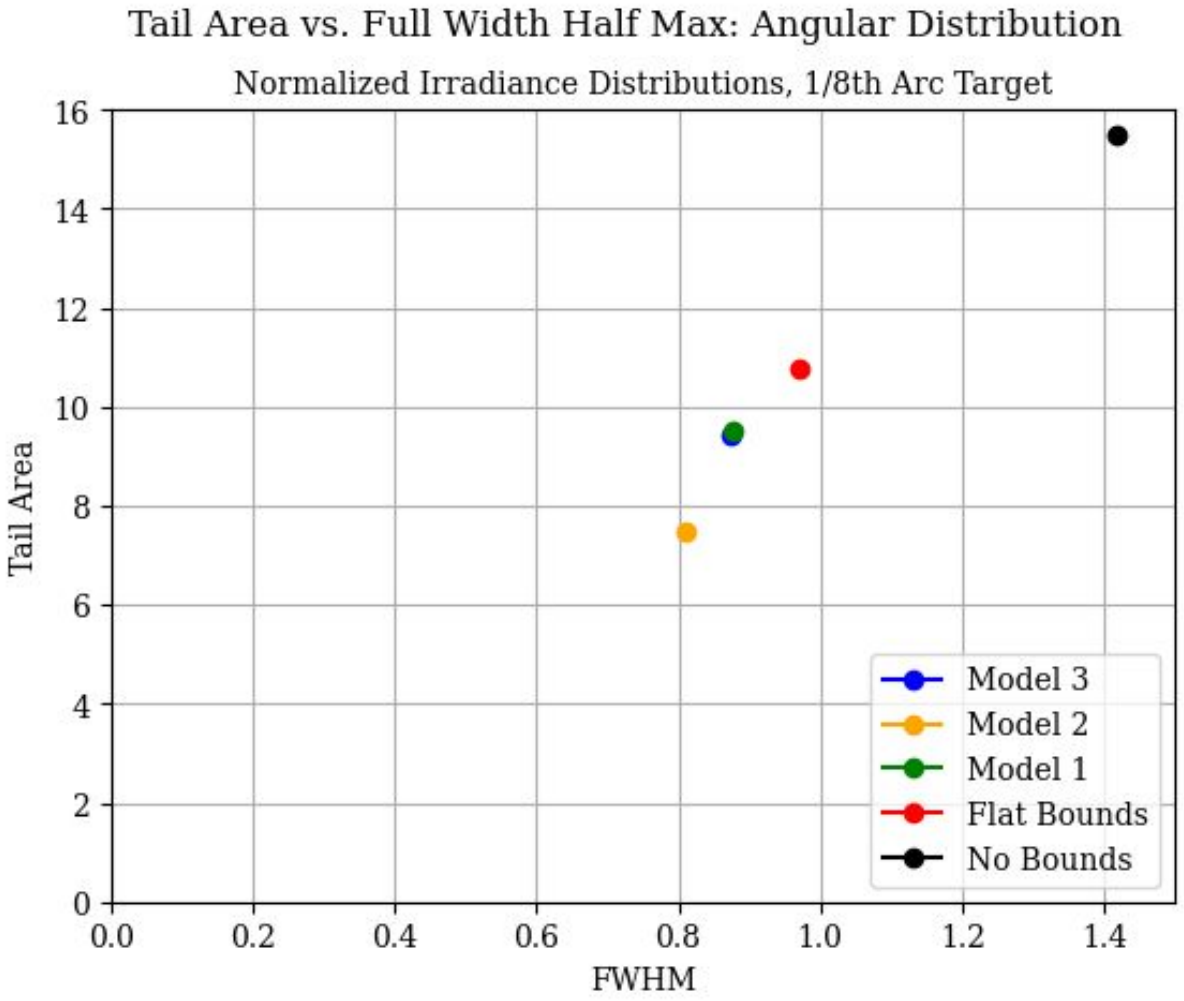


1/8th Arc Target

Angular Distribution of Average Irradiance: Normalized by Deposited Power



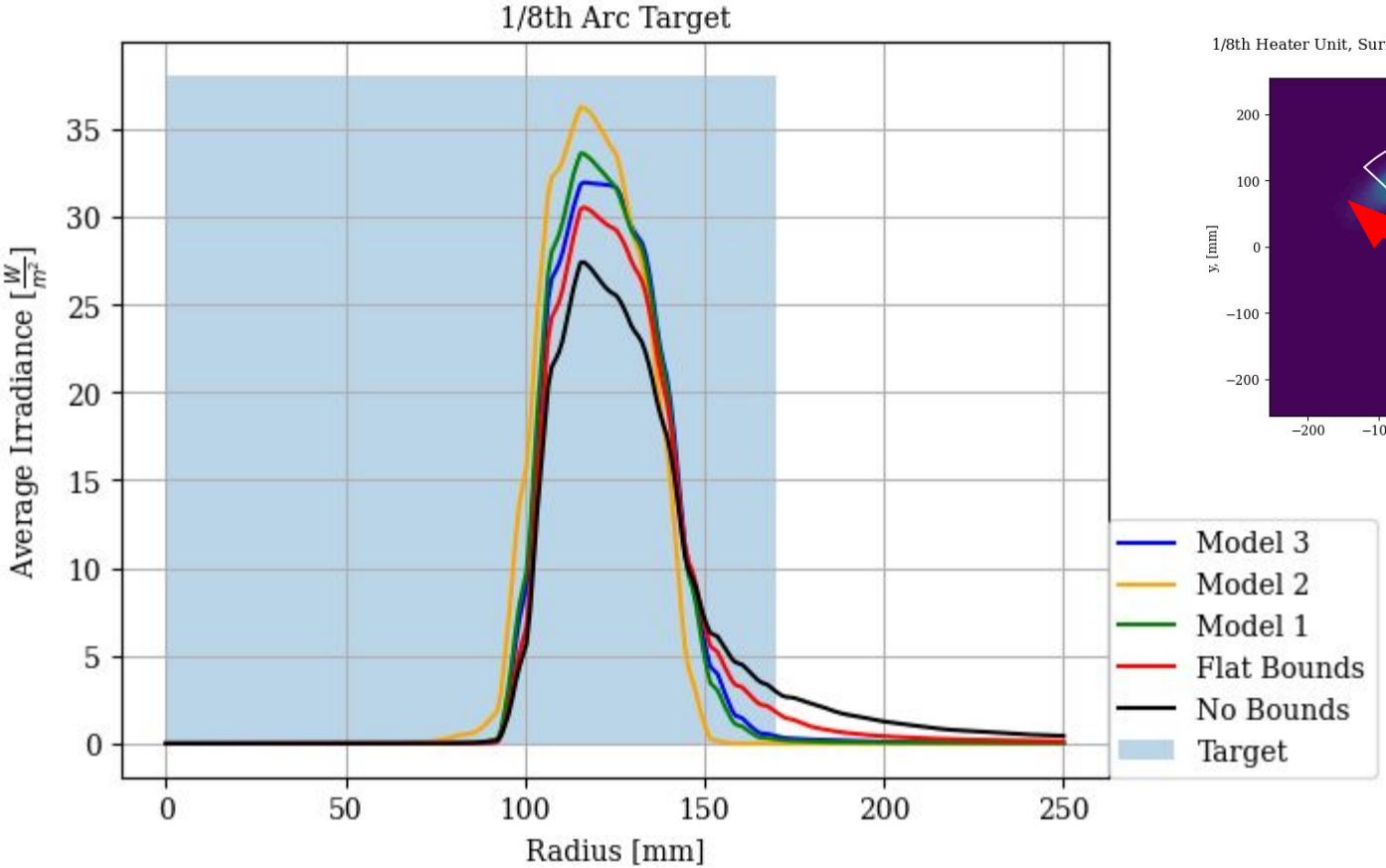


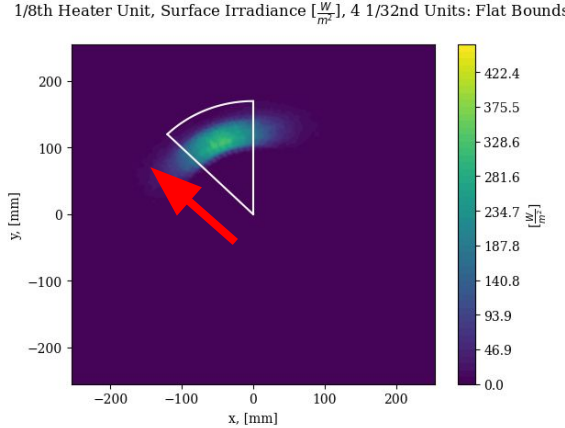


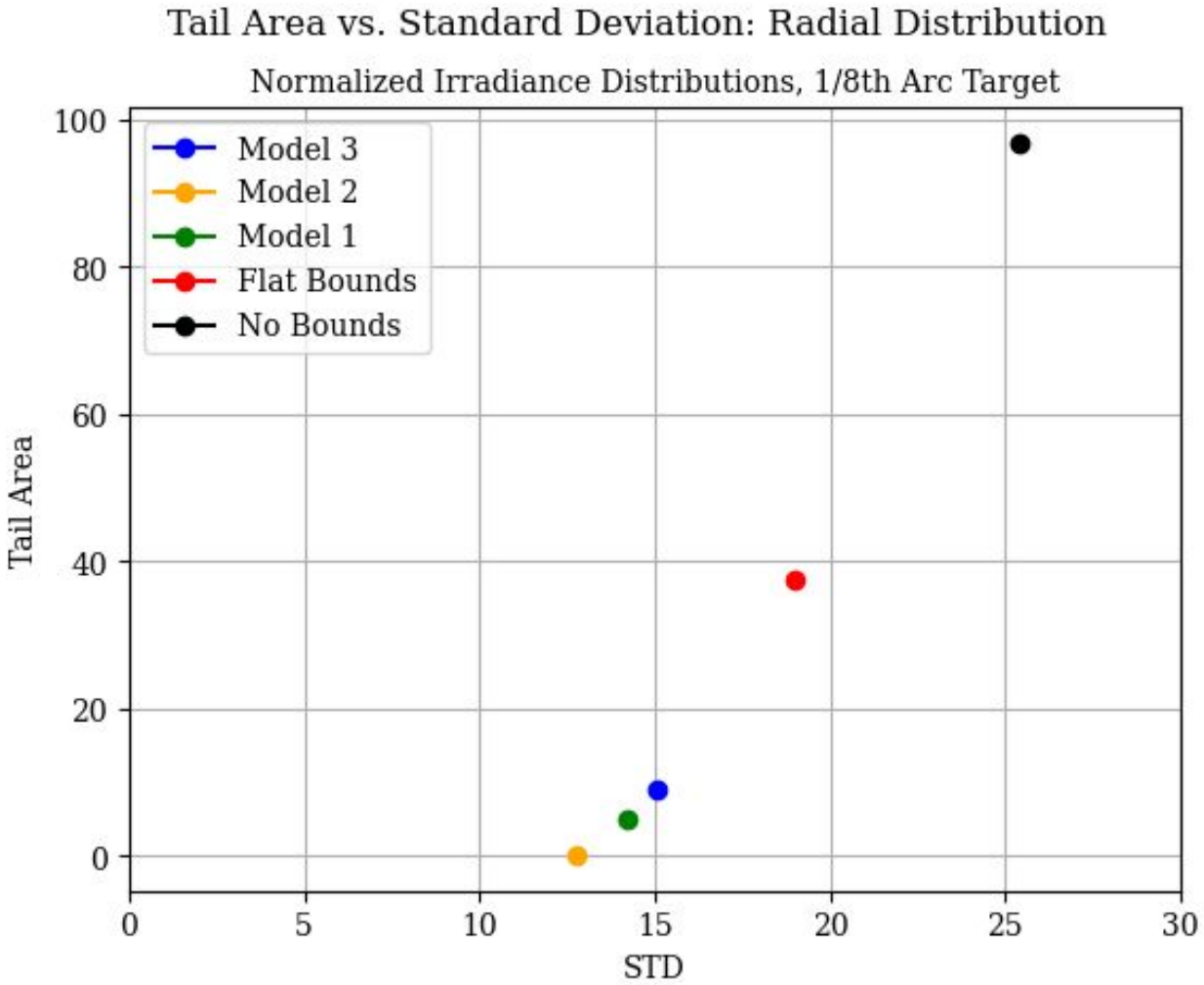
Notice:

- **Low FWHM/Tail Area of Model 2**

Radial Distribution of Average Irradiance: Normalized by Deposited Power



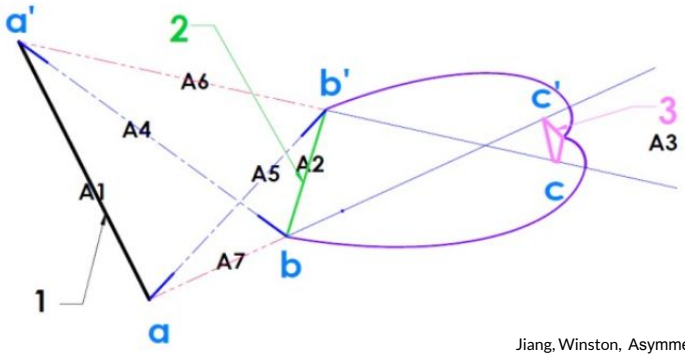




Notice:

- **Low STD/Tail Area for Model 2**

Next Steps



Jiang, Winston, Asymmetric design for Compound Elliptical Concentrators (CEC) and its geometric flux implications, 2015

- Further exploration of parabolic edge coverings on arc models
- Elliptical Concentrator Design → Elliptical Side Reflectors
- Generalized Surfaces

Conclusion

- Characterized the spread of radiation from both arc and linear heater units
- Identified capability of flat reflective boundaries to improve confinement of radiation in angular dimension
- Explored the design and optimization of parabolic edge surfaces
- Identified capability of parabolic surfaces to improve radiation confinement for both 1/32nd heater units and 1/8th heater units in the linear and angular dimensions

Acknowledgements

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