Simulation studies for WLS with dimples.

Márcio Adames
Francisco Ganacim
André Steklain

Federal University of Technology - Paraná
marcioadames@utfpr.edu.br
ganacim@utfpr.edu.br
steklain@utfpr.edu.br

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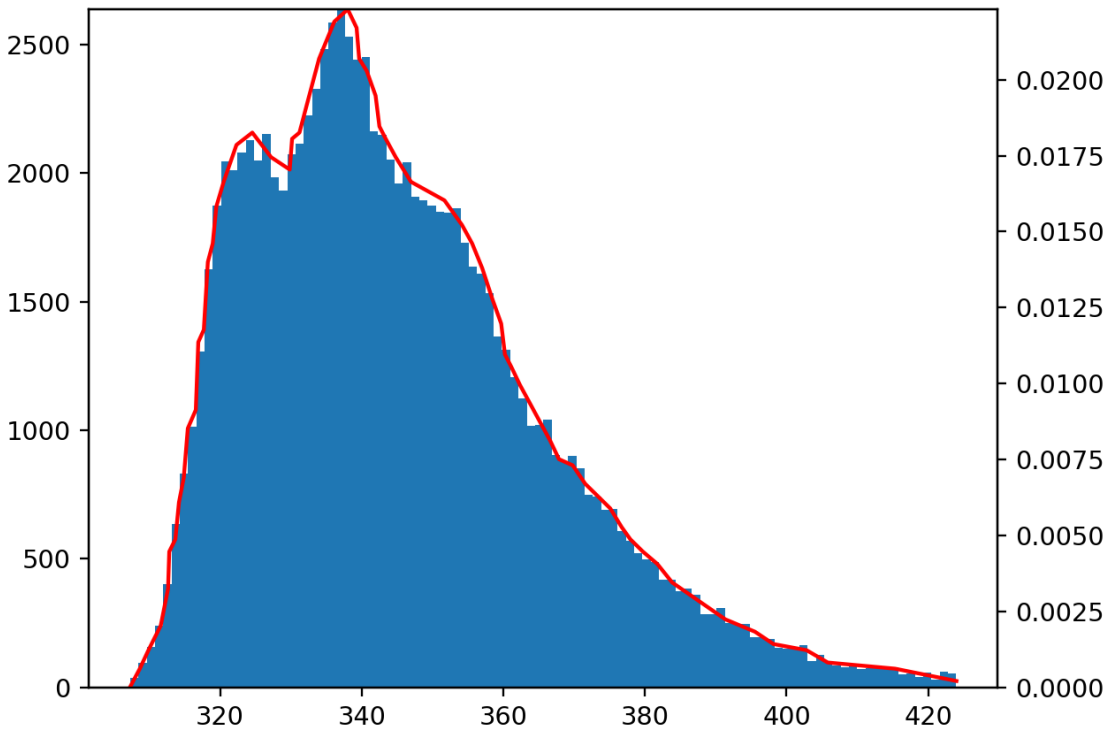
Updates of the group

- We corrected wls absorbance (with help of Carla).
- We added detailed Dichroic Filter Data (from Ana Machado).
- We improved our statistical analysis.

Simulation details

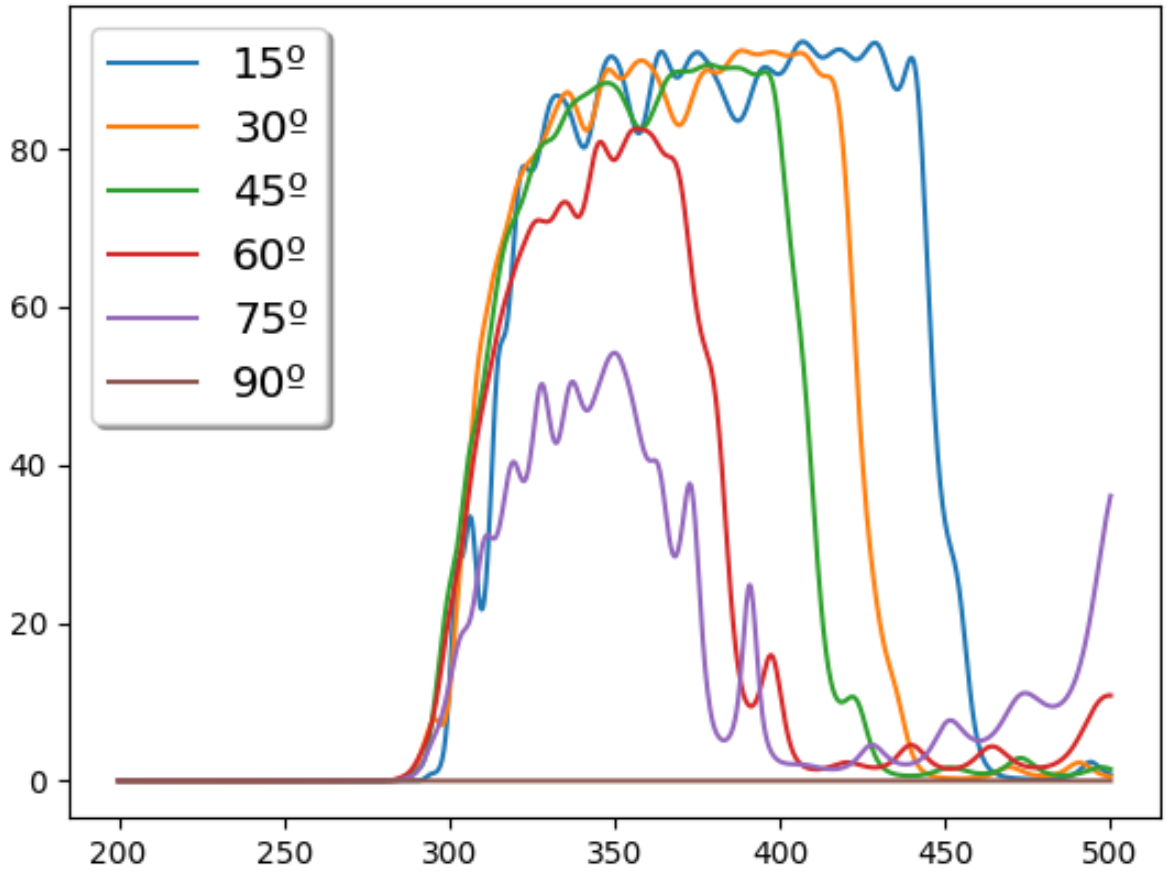
- The pTP layer absorbs and re-emits 47.5% (50% from isotropic emission and 95% efficiency) of the photons in the direction of the dichoic filters.
- Photons re-emitted from pTP by emission spectra.
- Dichroic filter transmittance and reflectance in accordance to experimental data (fitted).
- WSL absorbance and emission spectra added.
- WSL non ideality included as 1% chance that the photon "tunnels" through the walls at each reflection.
- Inner X-ARAPUCA walls 98% reflectivity (do not change wavelength).
- SiPM detection efficiency spectrum by Hamamatsu datasheet*.
- Supercell 6x1 (93mm x 78mm) and Megacell 6x6 (97mm x 97mm).

pTP emission spectra and histogram of emitted photos in the simulation

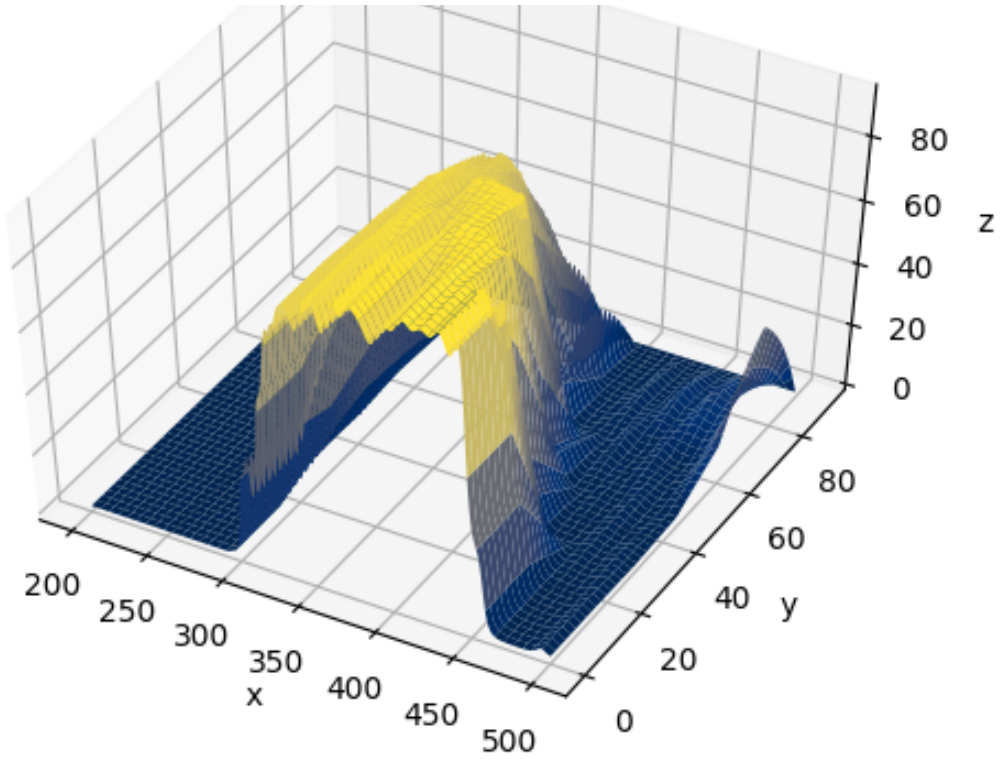


Source: P-Terphenyl deposited quartz plate calorimeter prototype. Akgun, U. 2008

Experimental data (Ana Machado) on the OPTO Dichroic Filters transmittance for incidence angles 15º, 30º, 45º, 60º, 75º,

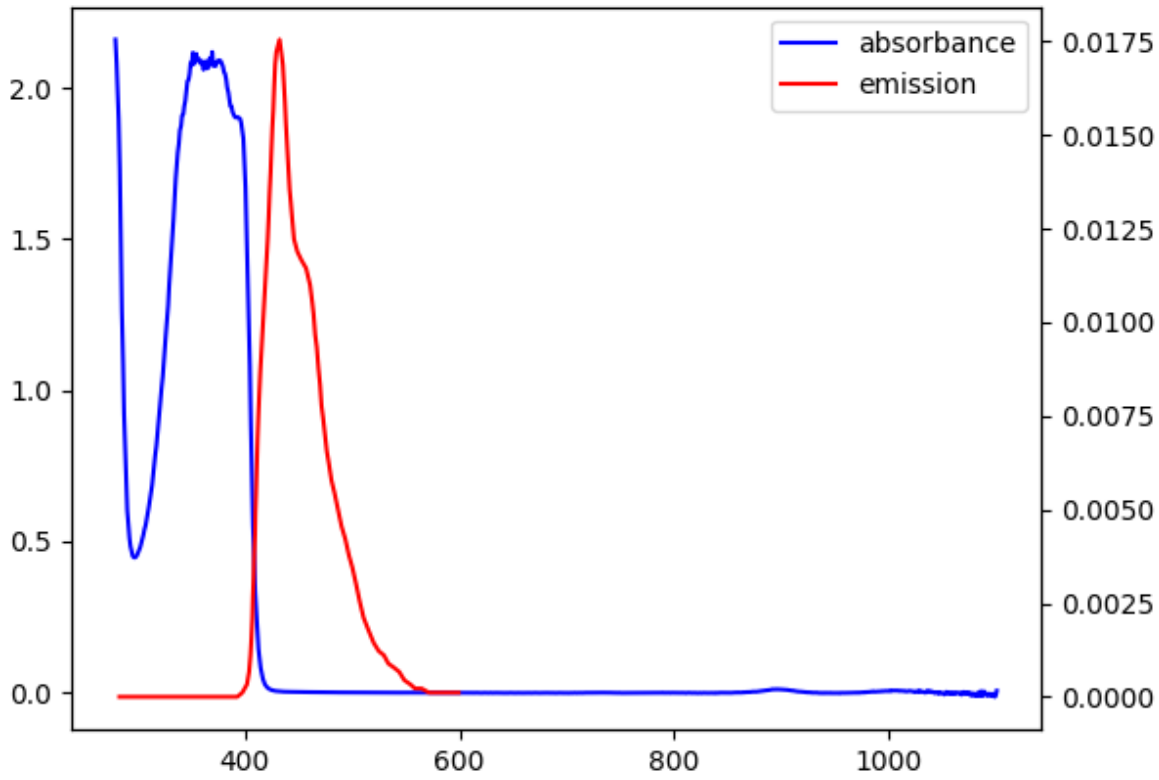


Interpolation of the transmittance



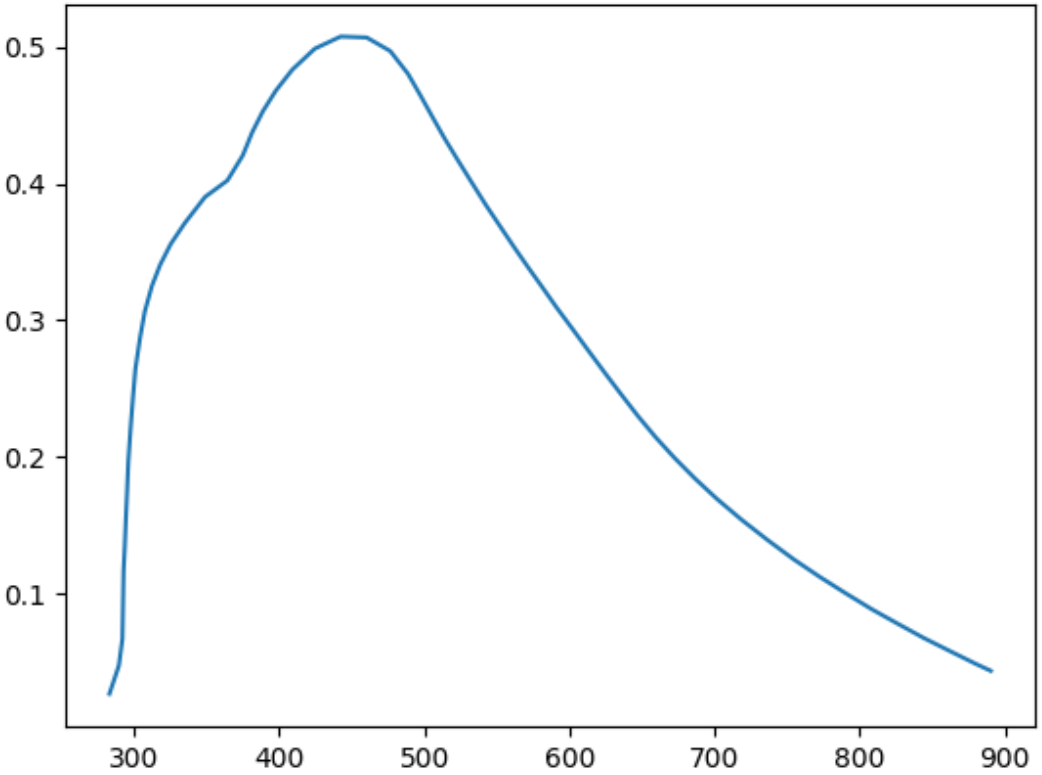
Approximation using Schlick's approximation adapted to real data on the right. Reflectance = 1 - transmittance.

Emission / Zeroed WSL absorbance



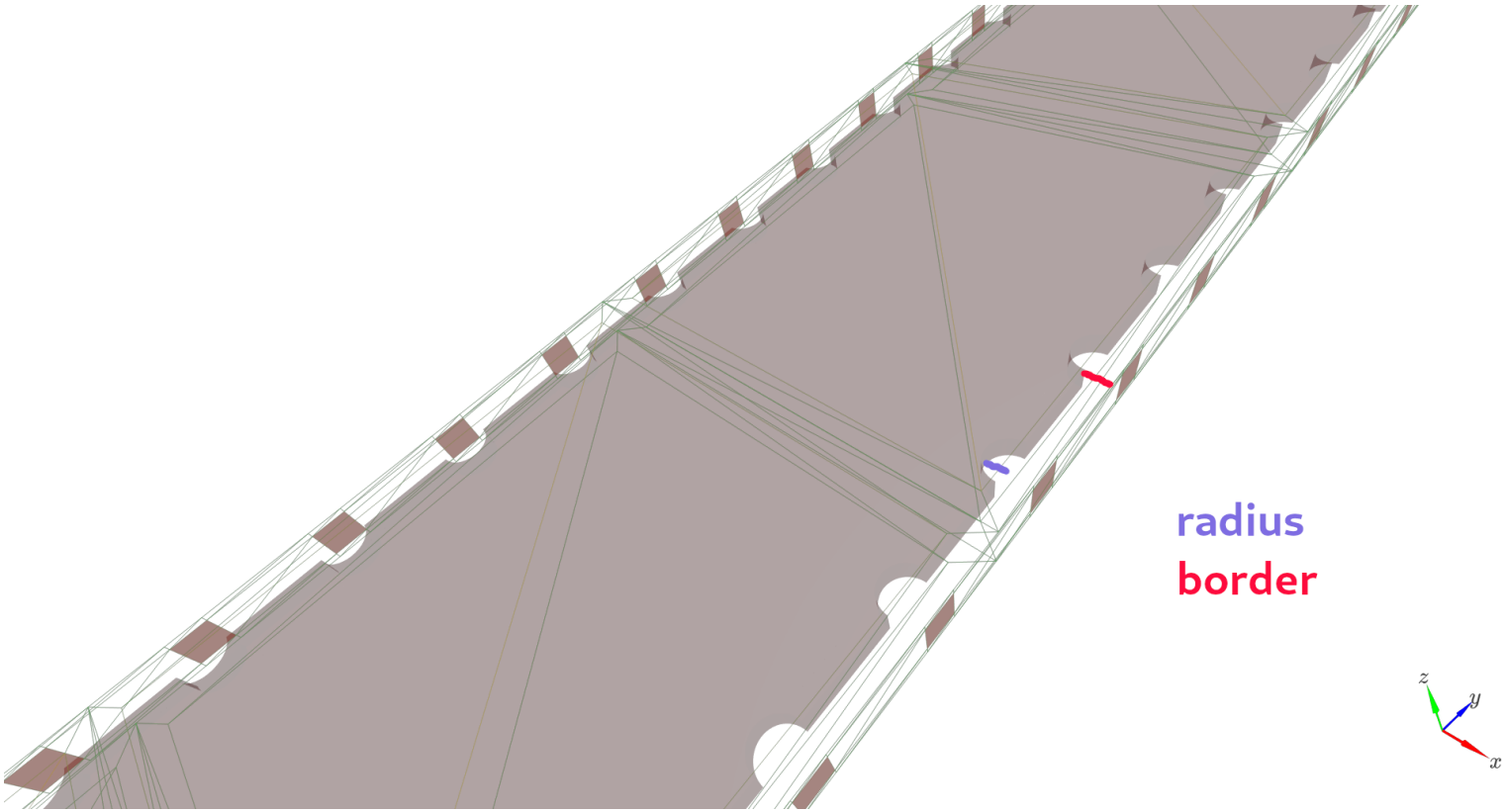
We determined $\epsilon c = A_0/l_0$ using the experimental data A_0 (assuming $l_0 = 4\text{mm}$) an reconstructed for any distance using Beer-Lambert Law $T = 10^{-A} = 10^{-\epsilon c l}$.

SiPM detection efficiency



Data from Hamamatsu S14160-6050HS (Datasheet).

X-ARAPUCAS Supercells with dimples. We use two parameters: cylinder radius and the distance of the WLS to the inner walls (exaggerated in the image)

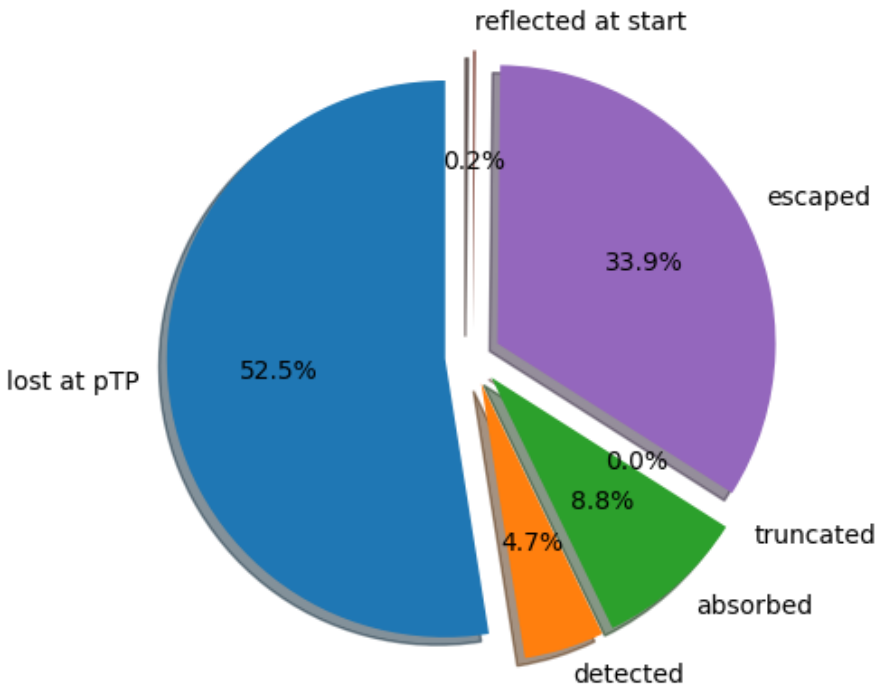


Supercell simulations results

		Dimple Radius *mm*					
		0	**0.5**	**1**	**1.5**	**2**	**3**
Border *mm*	**0.1**	4.6%	6.7%	7.0%	7.1%	7.0%	6.5%
	0.5	4.4%	5.9%	6.0%	6.1%	6.1%	5.7%
	1	4.2%	5.2%	5.3%	5.3%	5.3%	5.1%

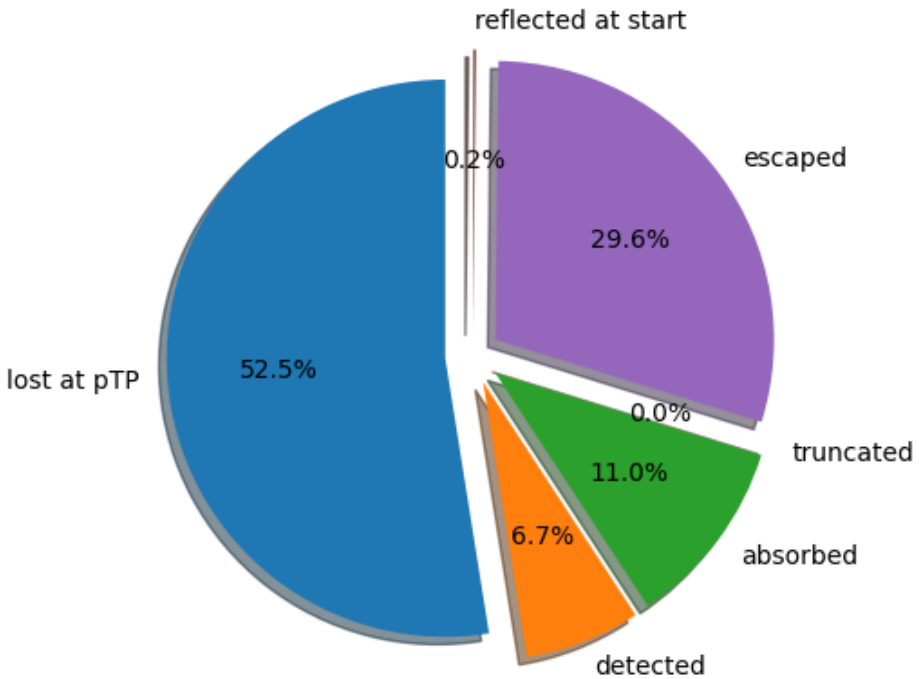
Table: Photon detection efficiency for different border sizes and dimple radius. The best result shows a relative increase (in comparison to the one without dimples and same border) in efficiency of about 50%.

Supercell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 0



BLUE - do not enter the guide because of the pTP efficiency
BROWN - reflected at dichroic before entering
PURPLE - escaped through the dichroic filters
GREEN - absorbed by the inner walls or the SiPMs
GRAY - truncated (max reflections 100k),
ORANGE- detected at SiPMs

Supercell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 0.5



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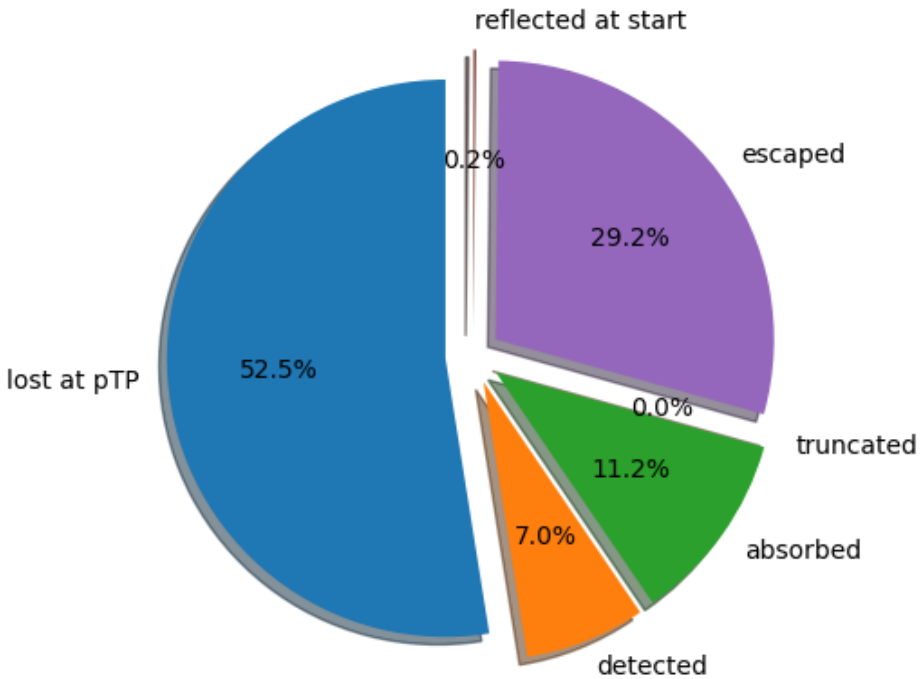
Supercell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 1



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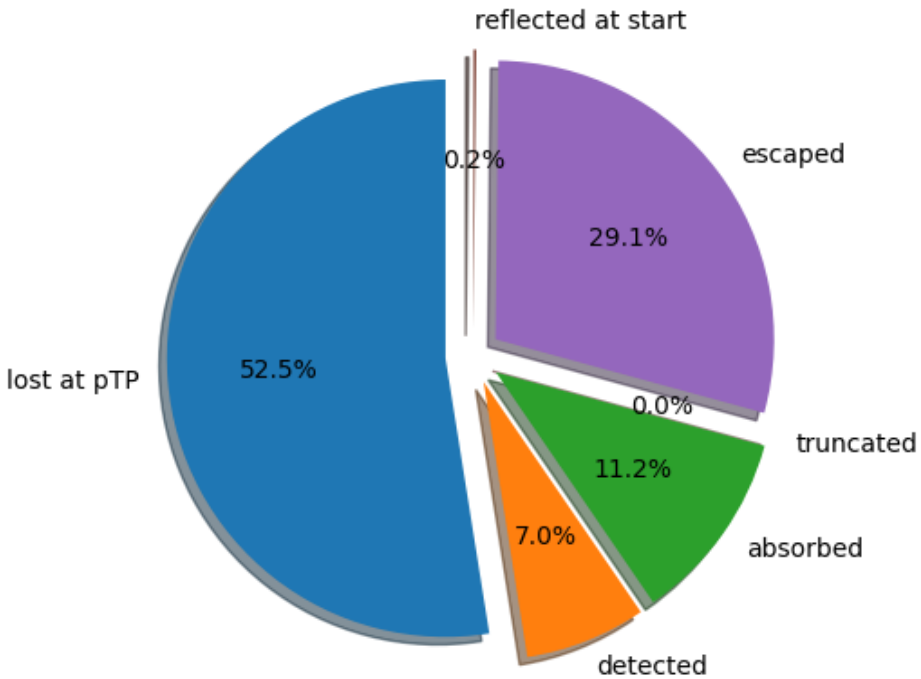
ORANGE- detected at SiPMs

Supercell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 1.5



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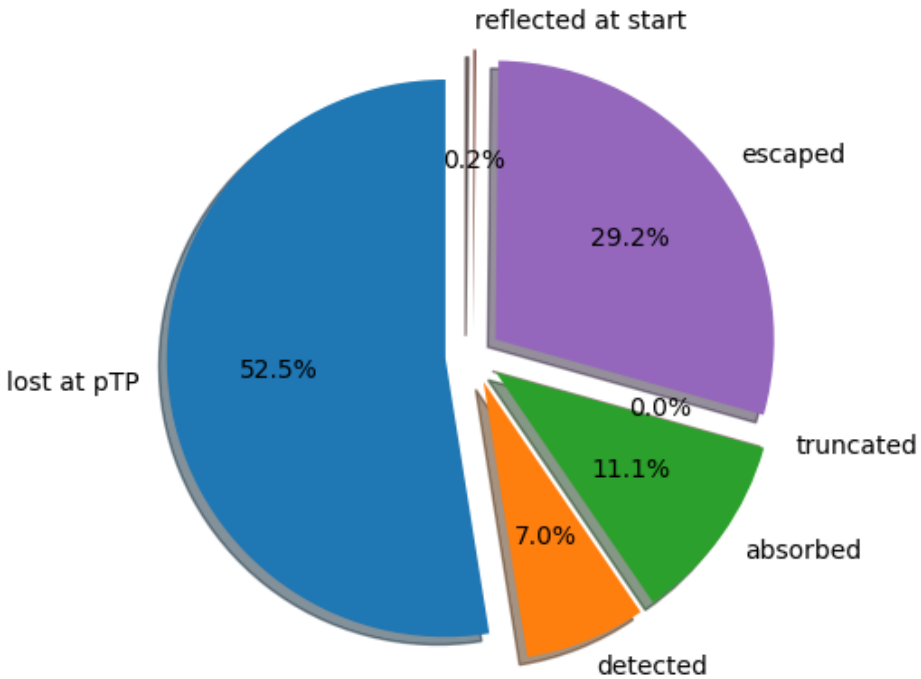
ORANGE- detected at SiPMs

Supercell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 2



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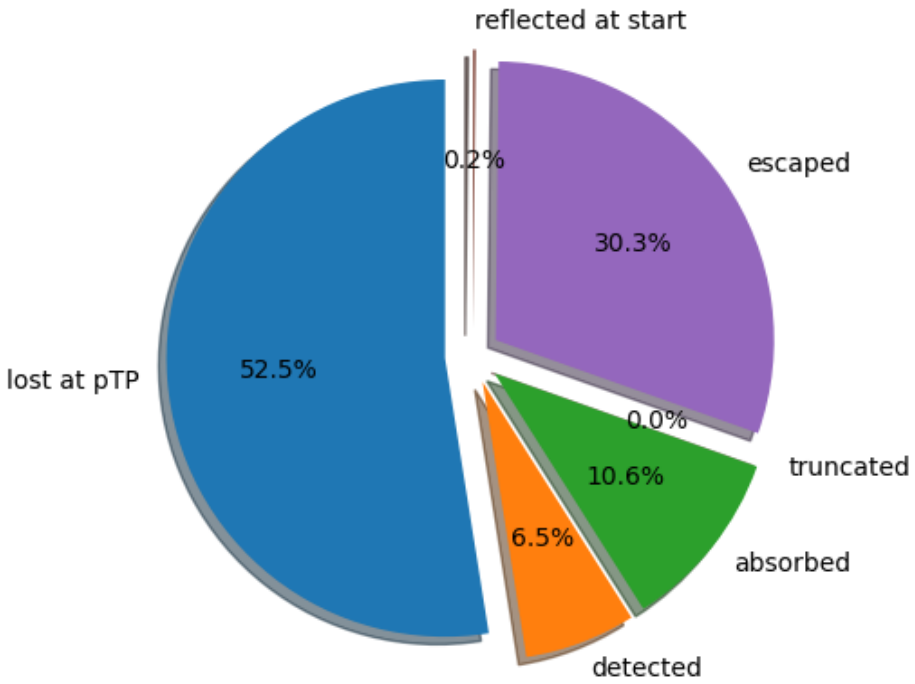
GREEN - absorbed by the inner walls or the SiPMs
GRAY - truncated (max reflections 100k),
ORANGE- detected at SiPMs

Supercell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 3



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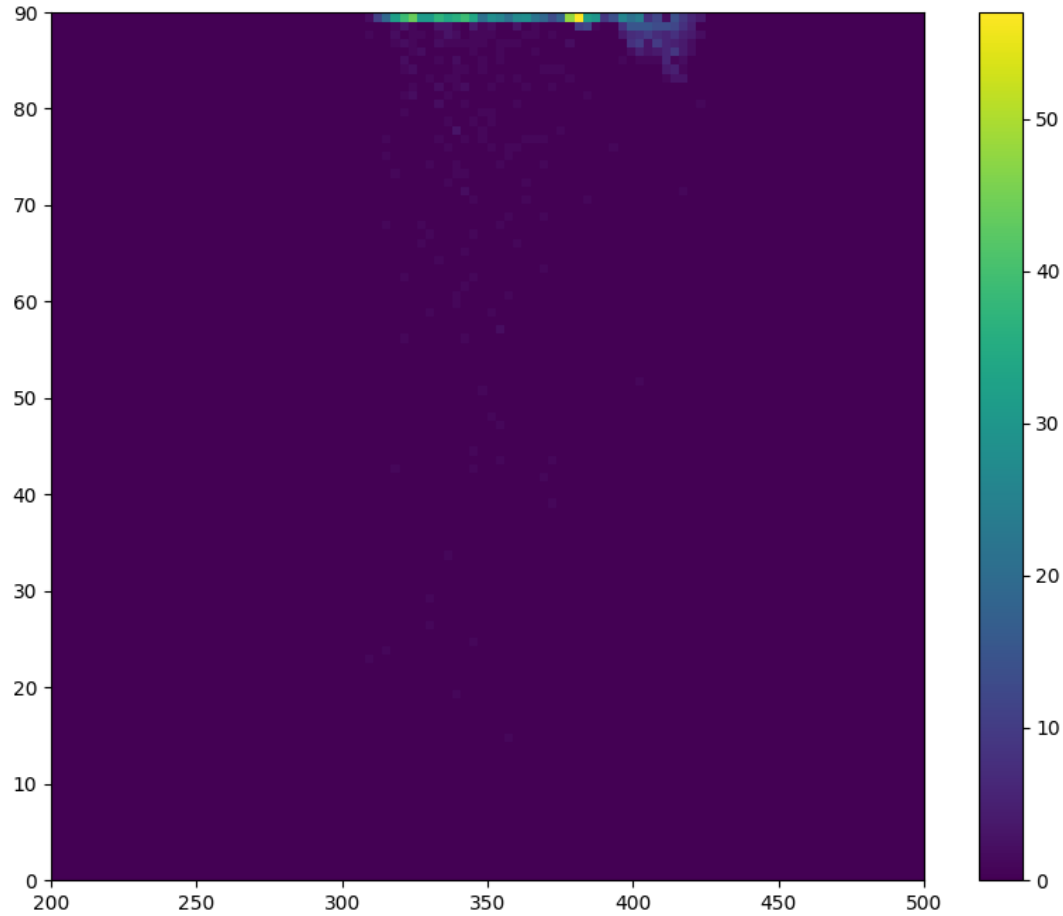
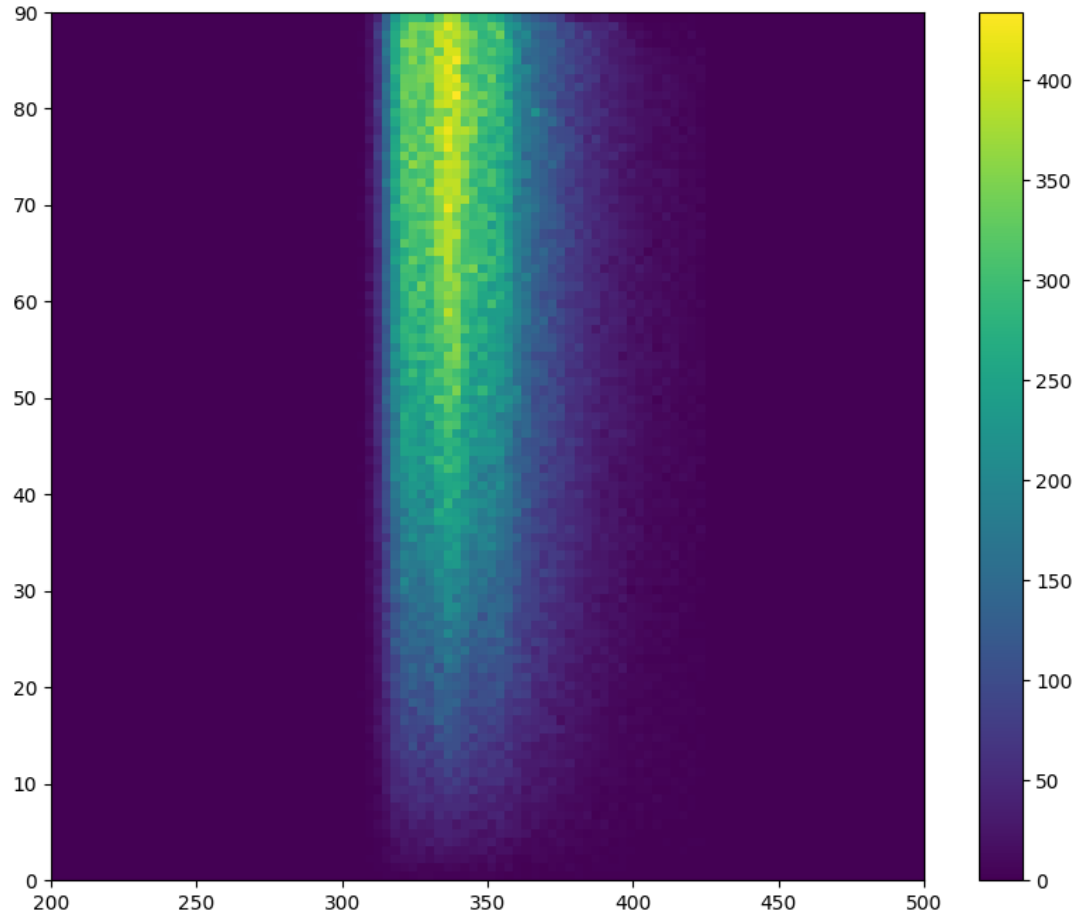
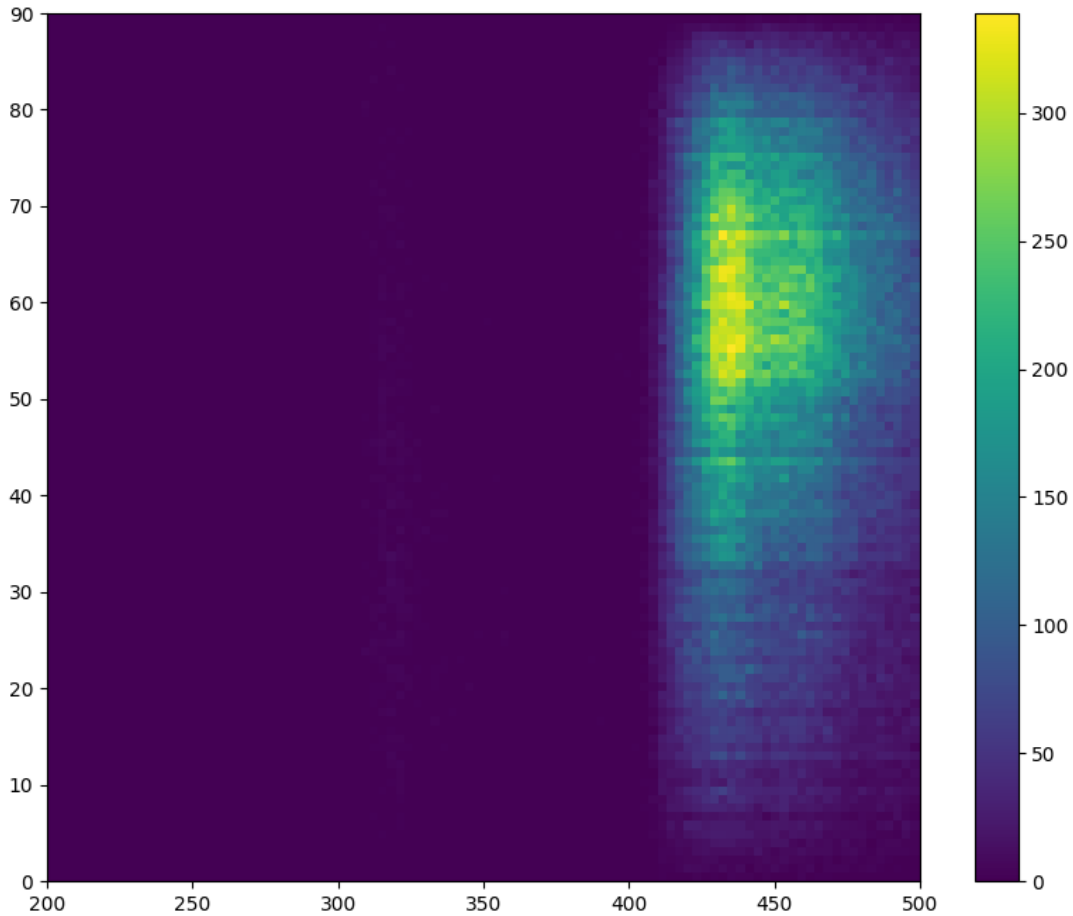
Supercell. Histogram of photons reflected at the dichroic filters coming from ptp (wavelength x incidence angle). Border = 0.1, Dimple Radius = 1.5



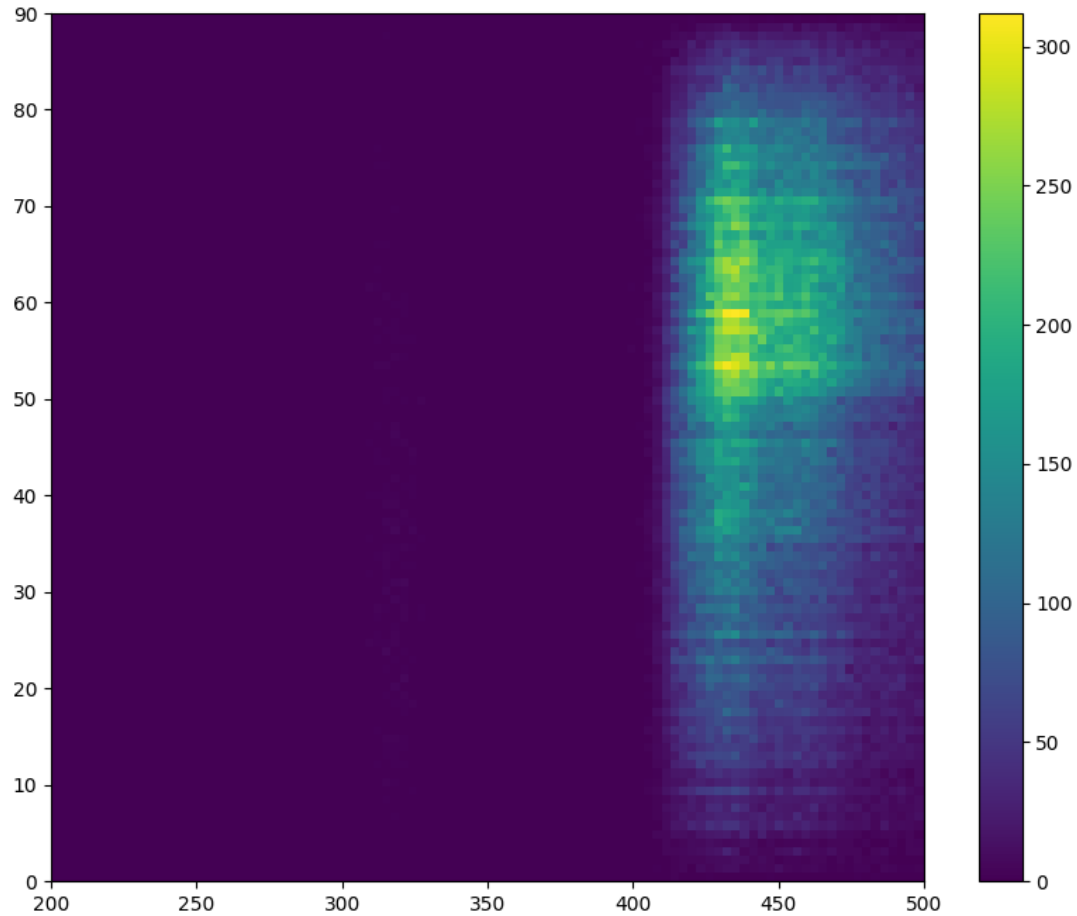
Supercell. Histogram of photons that actually enter the X-ARAPUCA (wavelength x incidence angle). Border = 0.1, Dimple Radius = 1.5



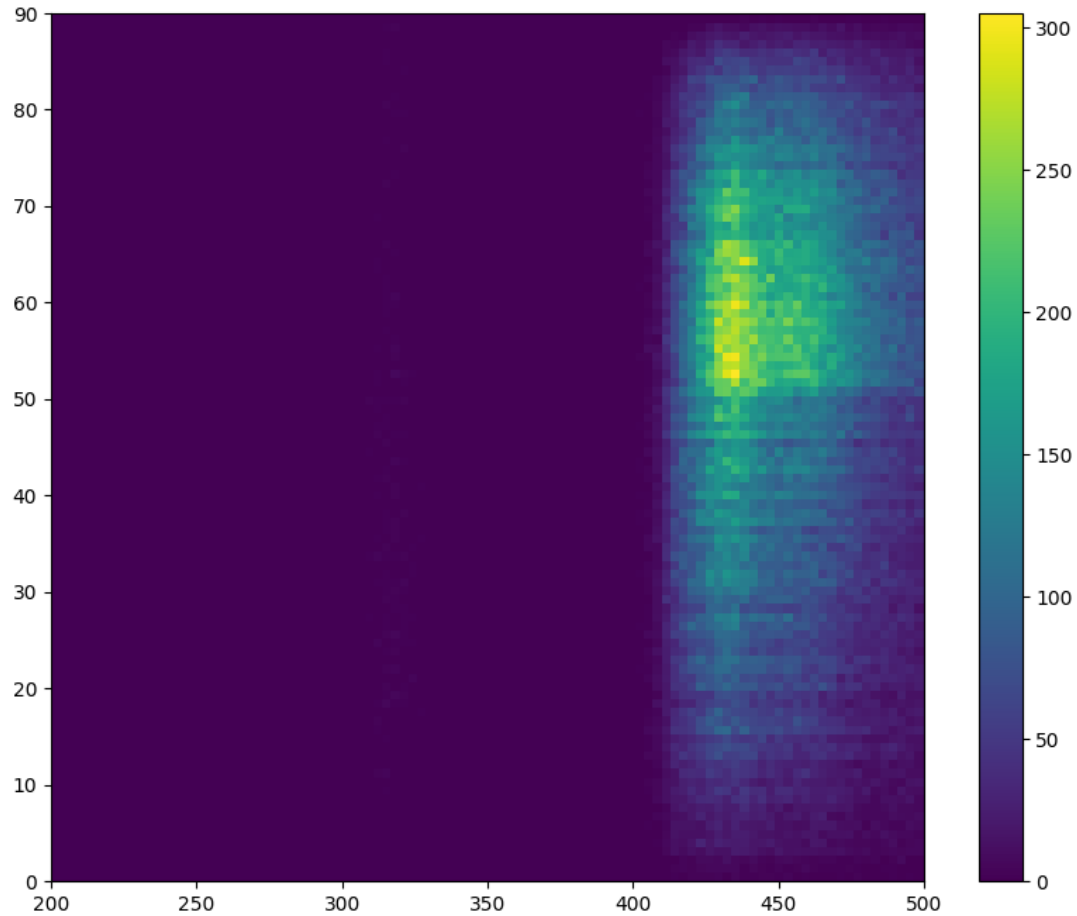
Supercell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 0



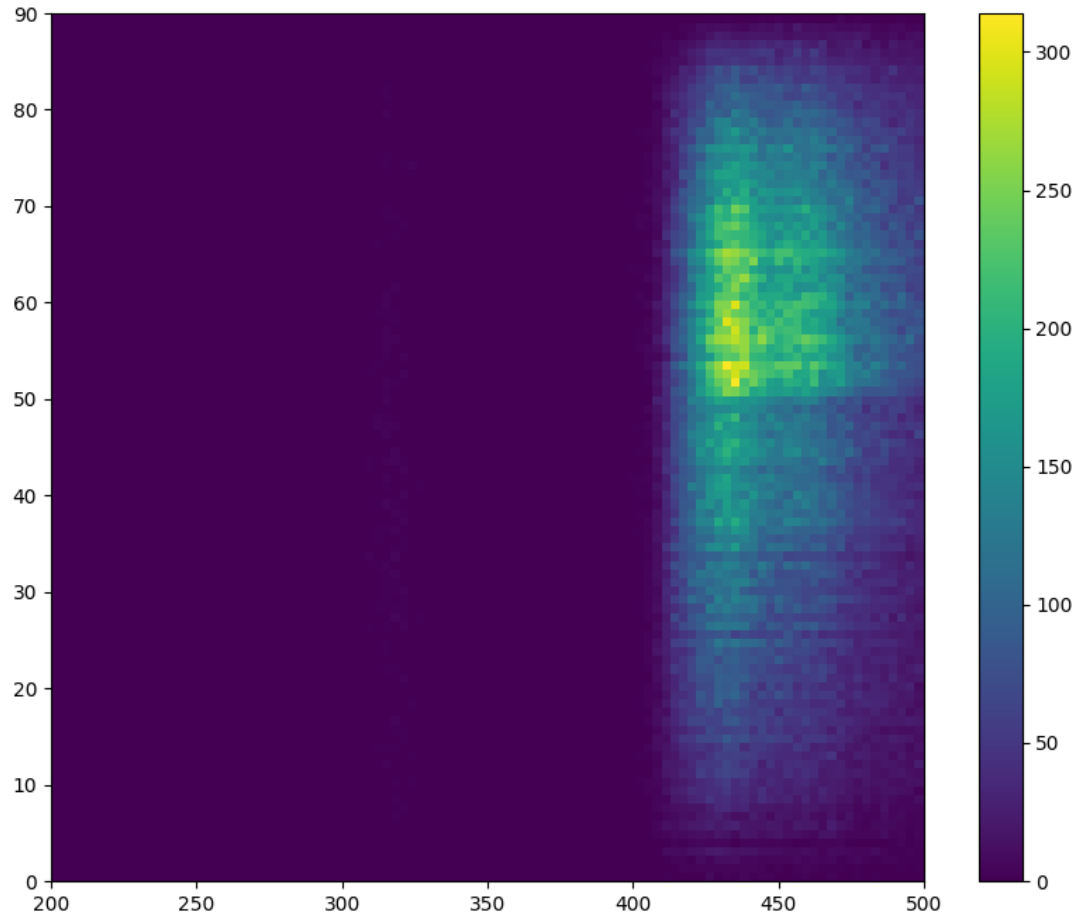
Supercell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 0.5



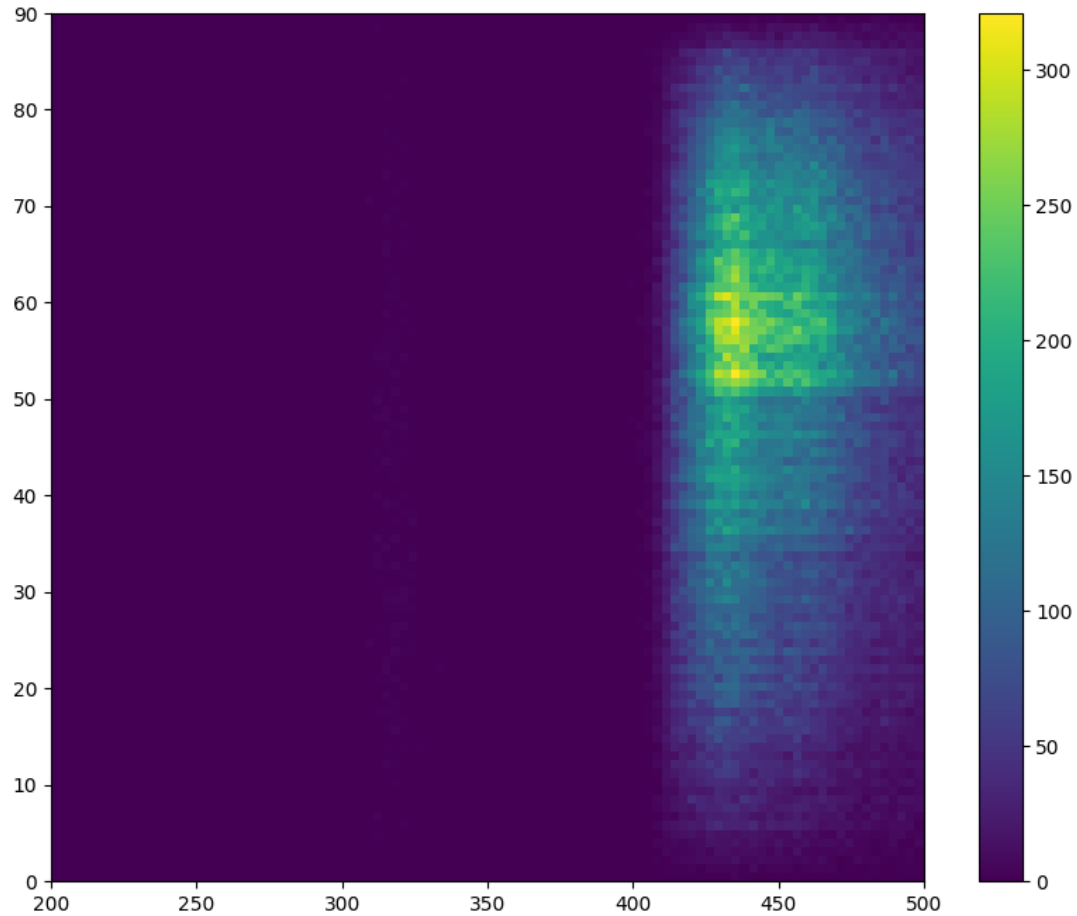
Supercell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 1



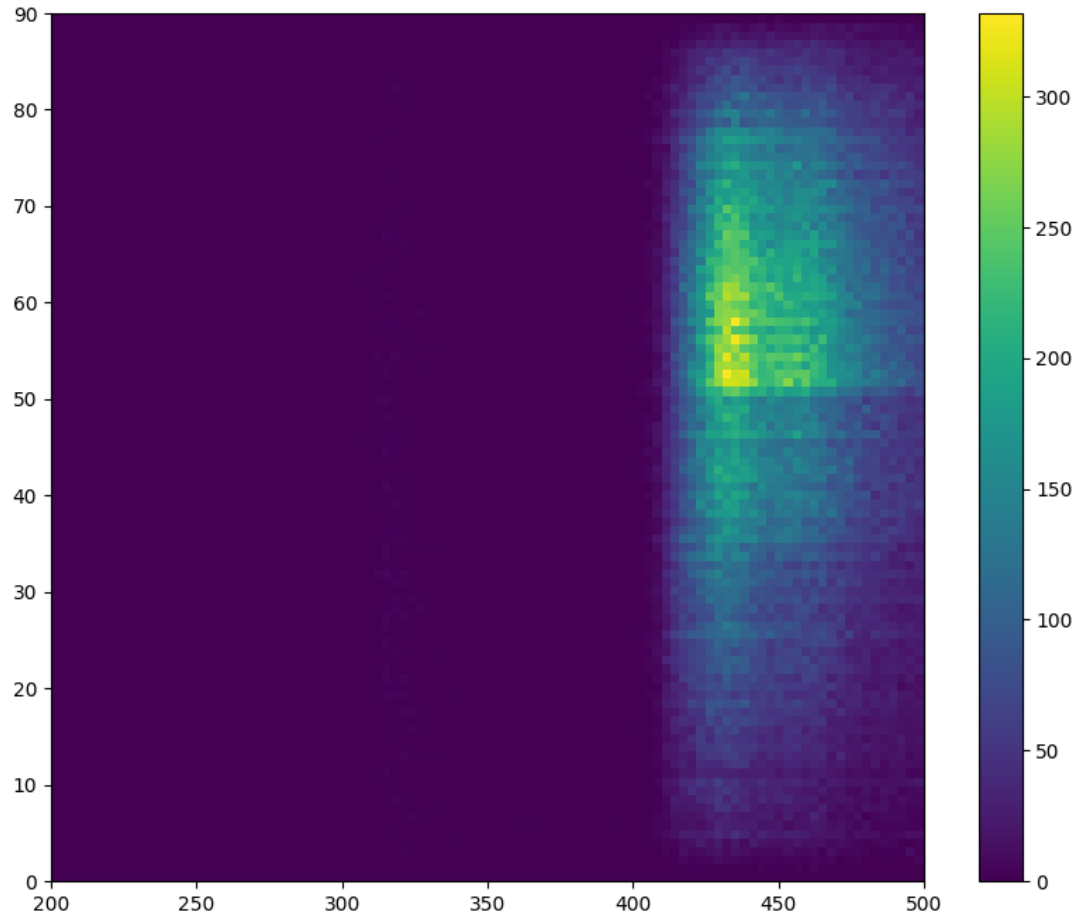
Supercell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 1.5



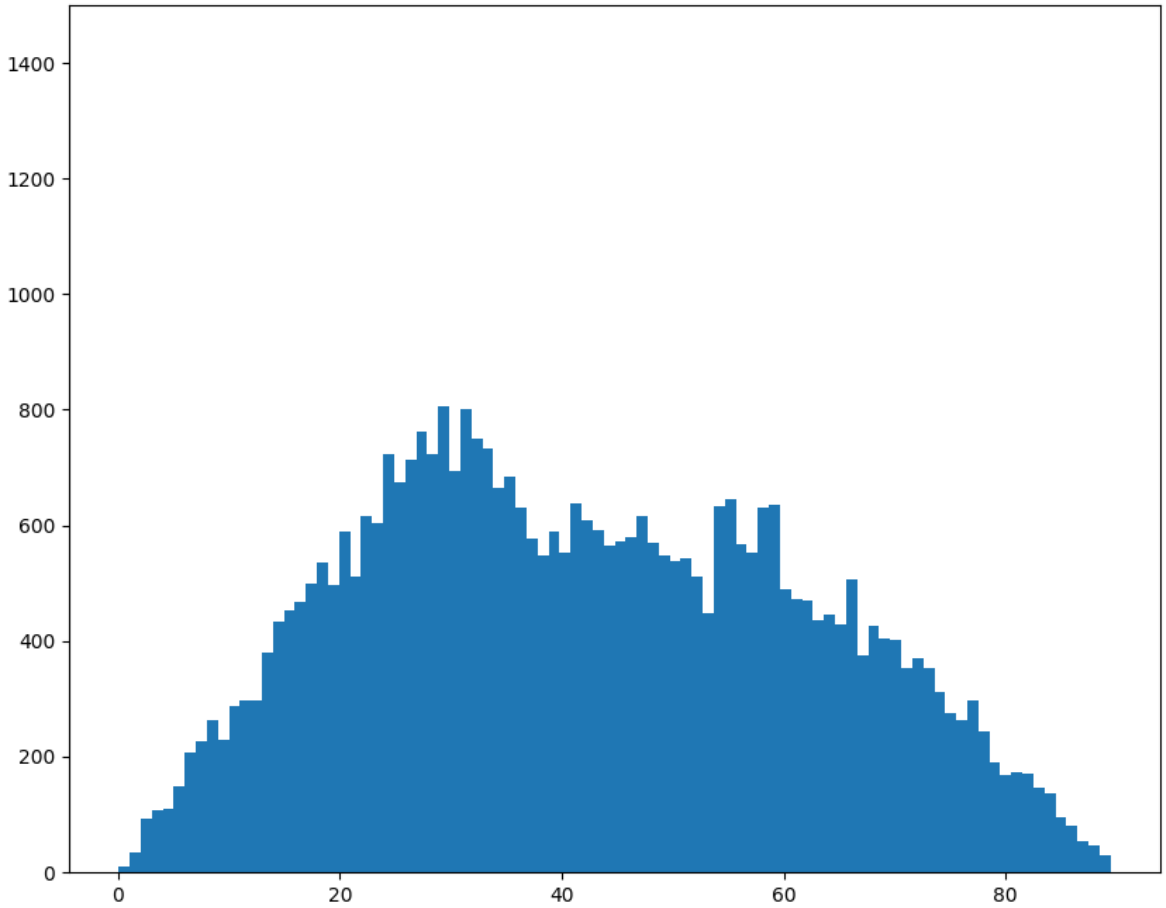
Supercell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 2



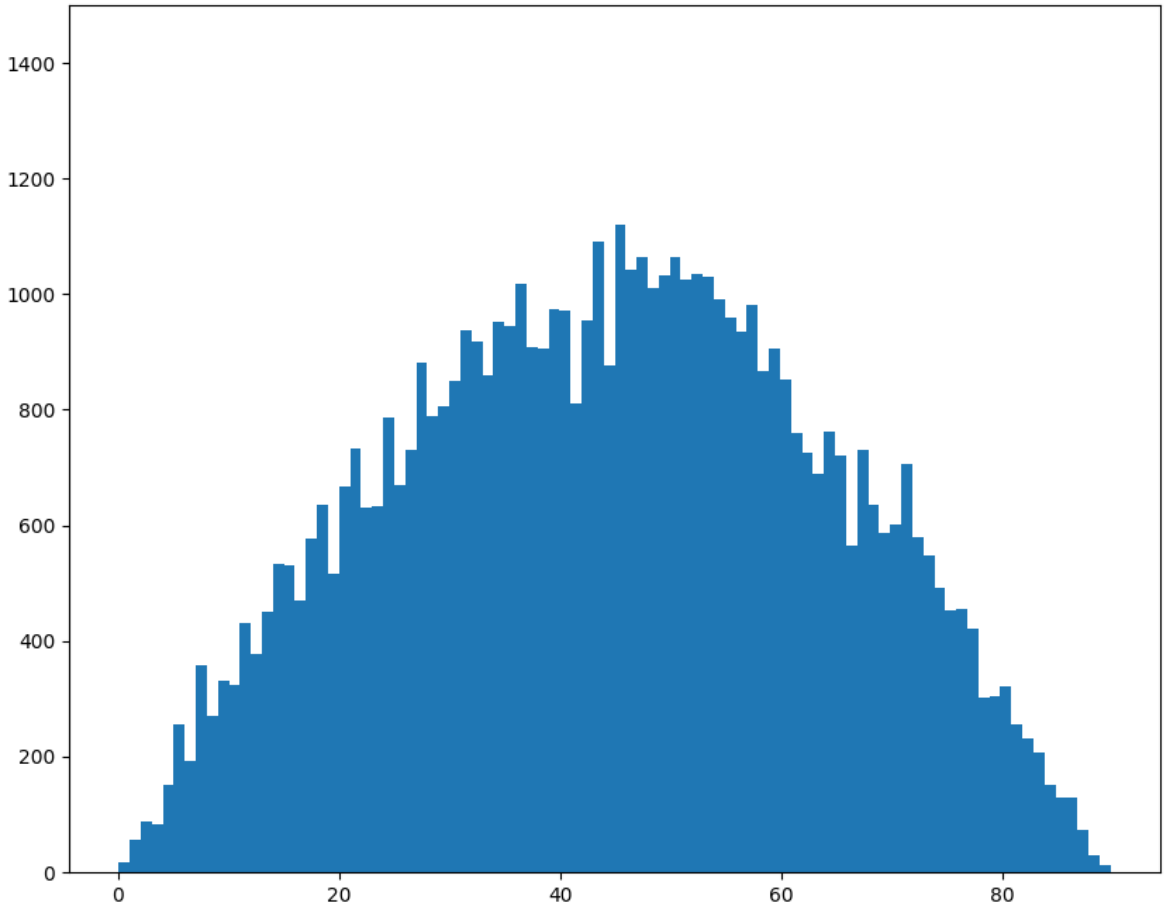
Supercell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 3



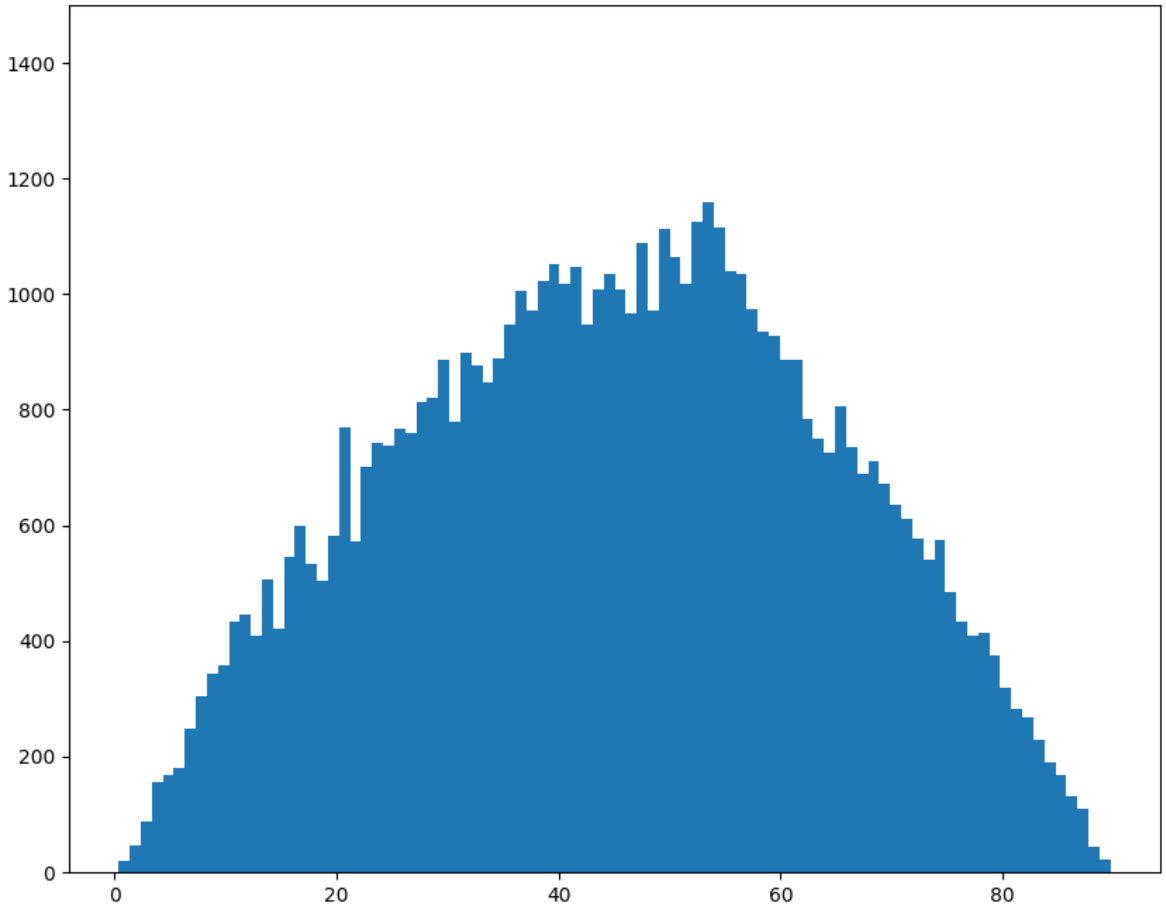
Supercell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 0



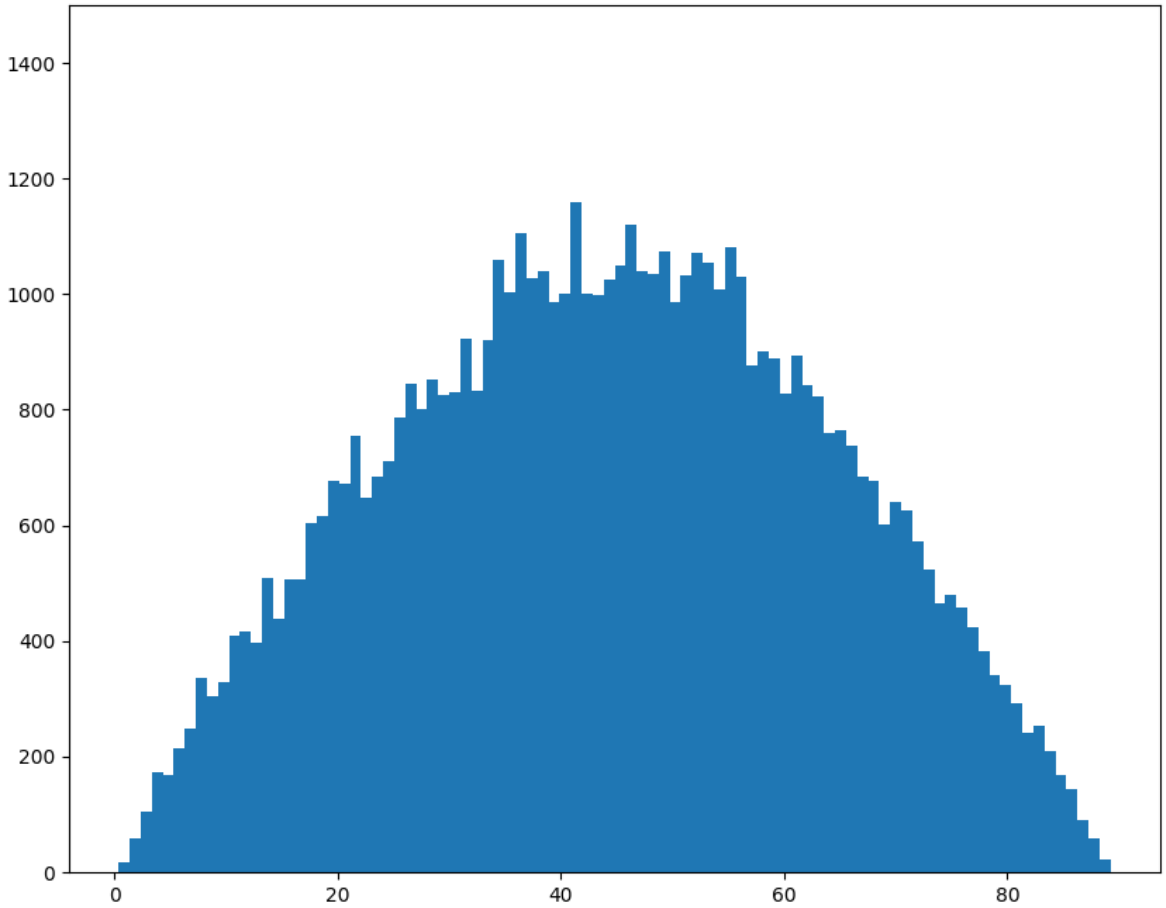
Supercell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 0.5



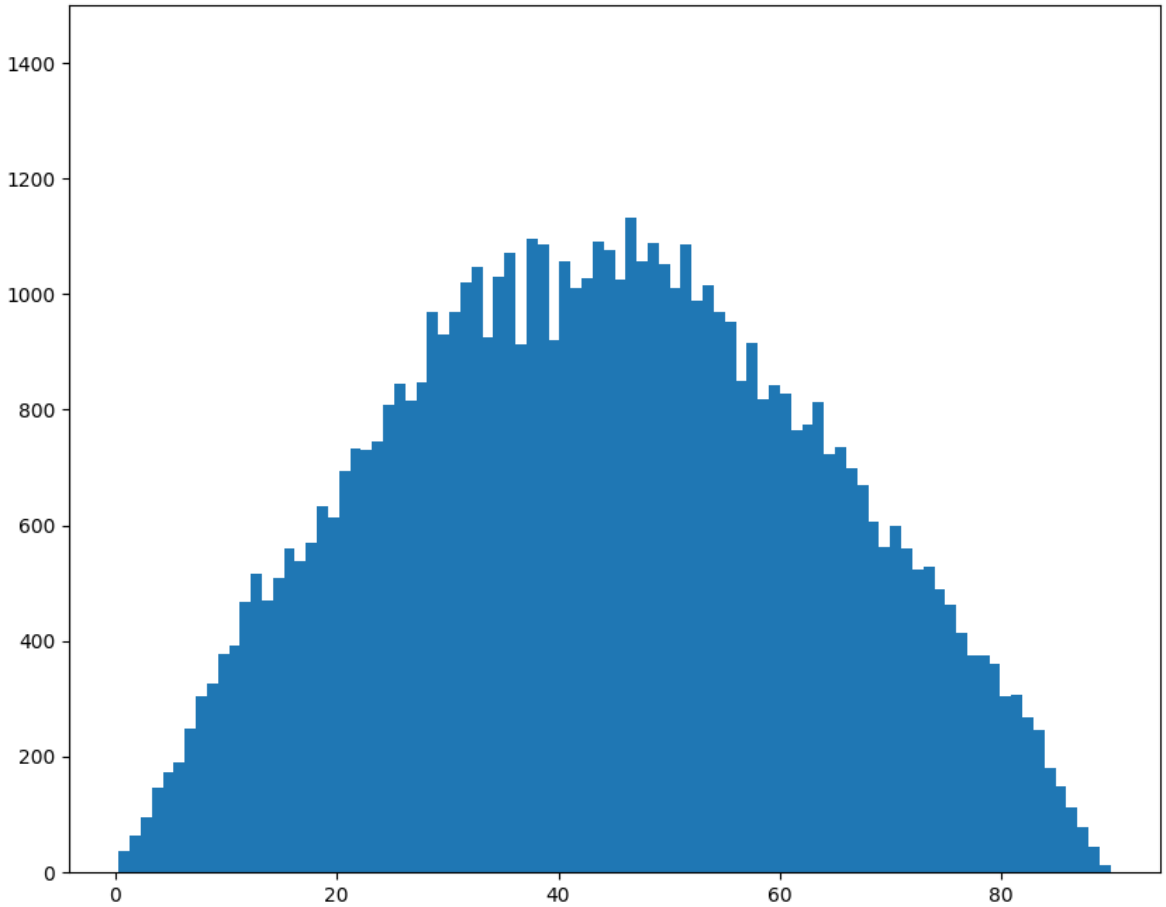
Supercell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 1



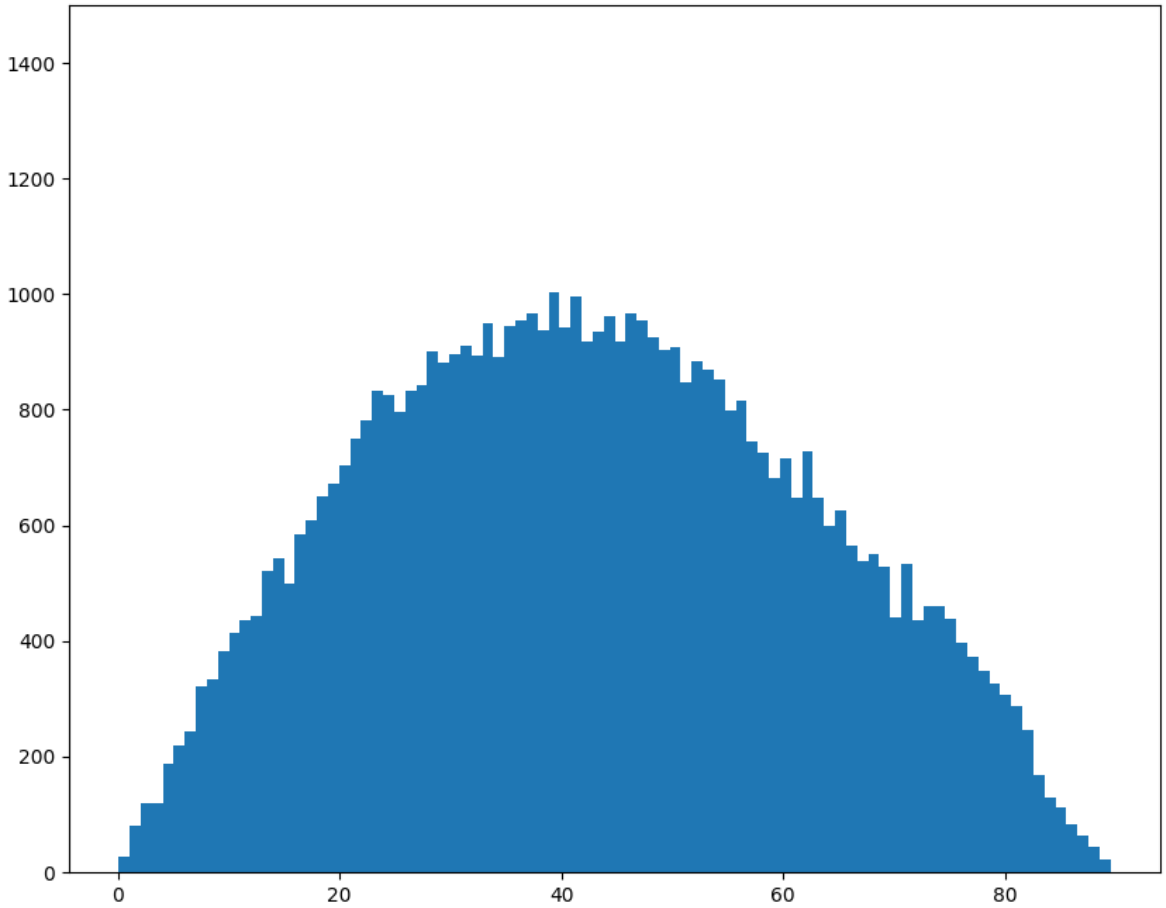
Supercell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 1.5



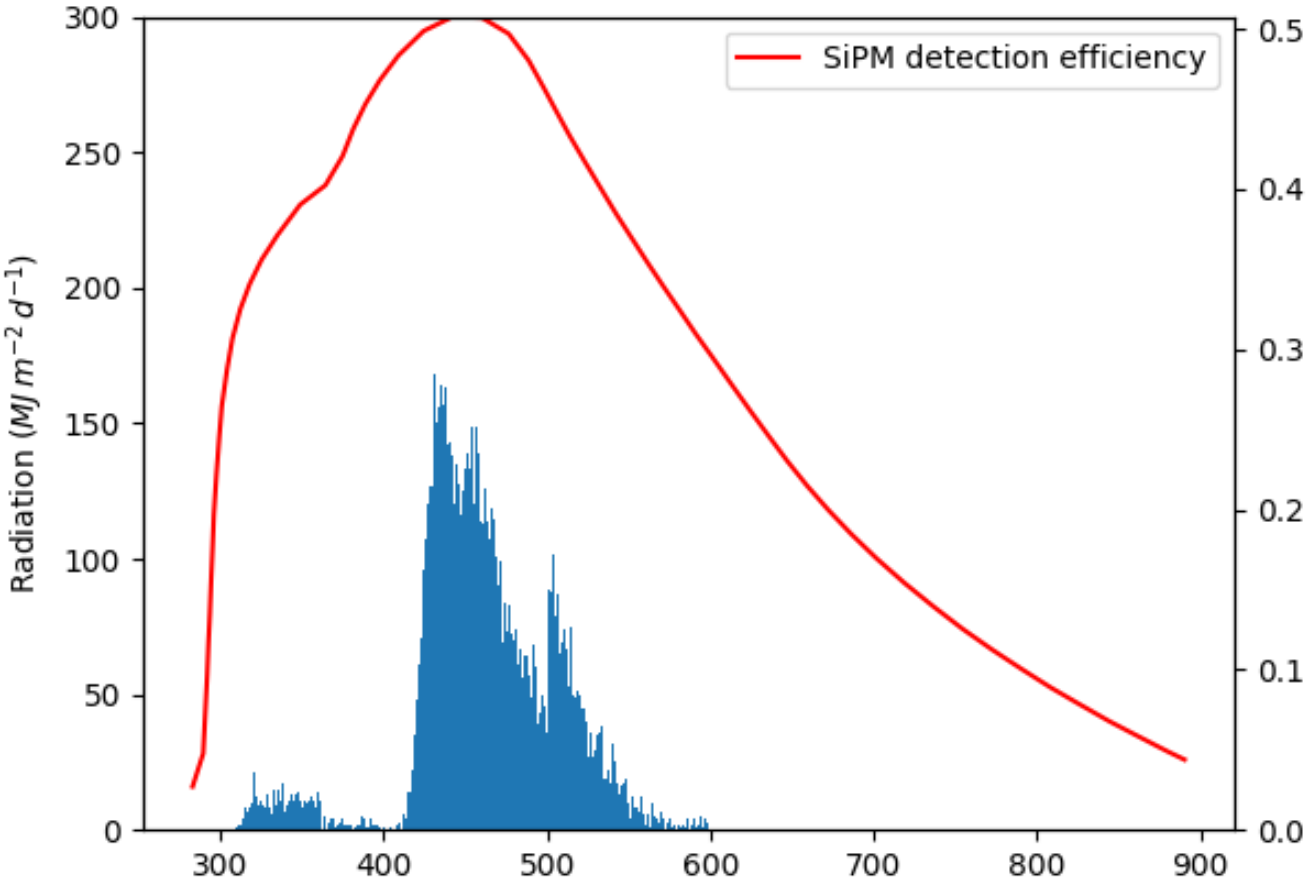
Supercell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 2



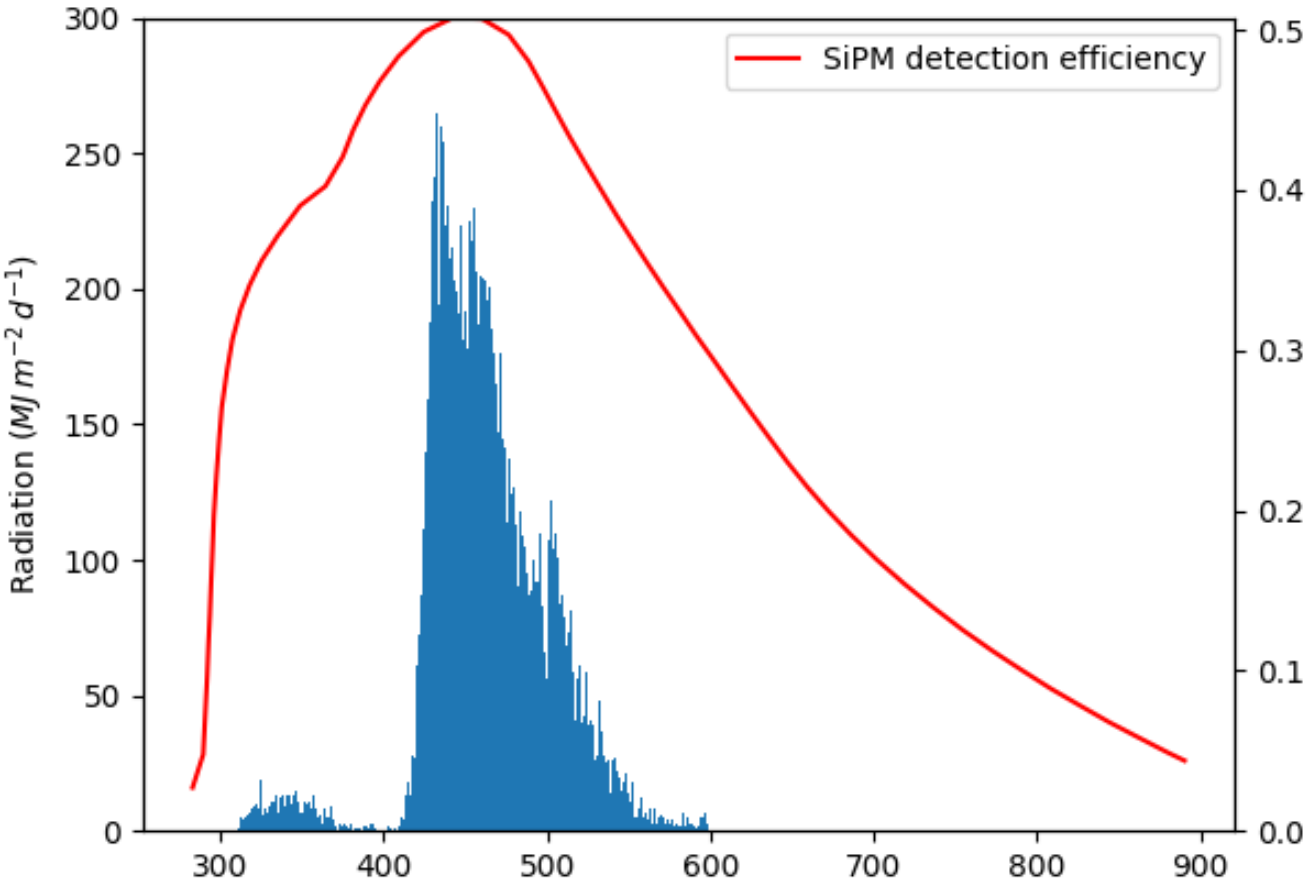
Supercell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 3



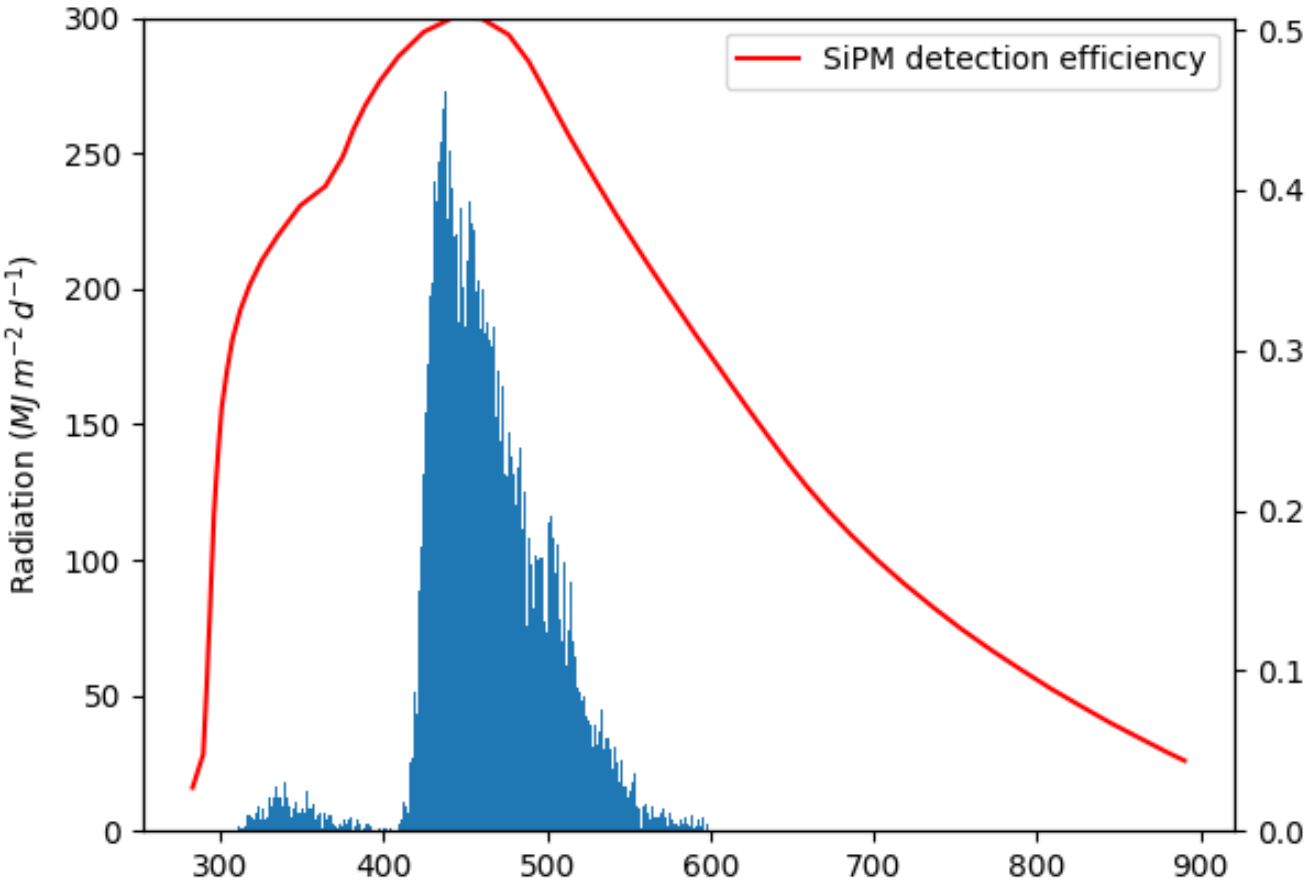
Supercell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 0



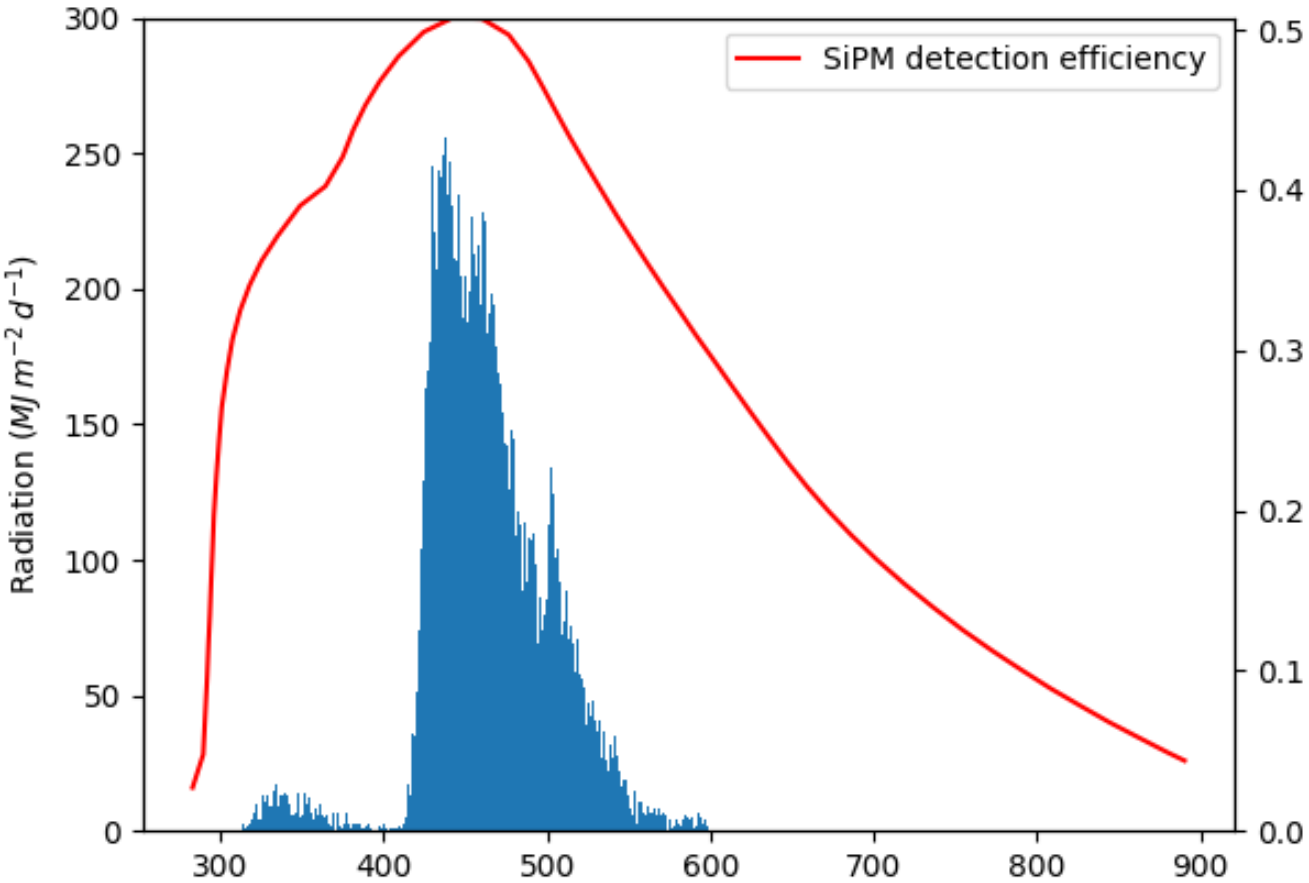
Supercell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 0.5



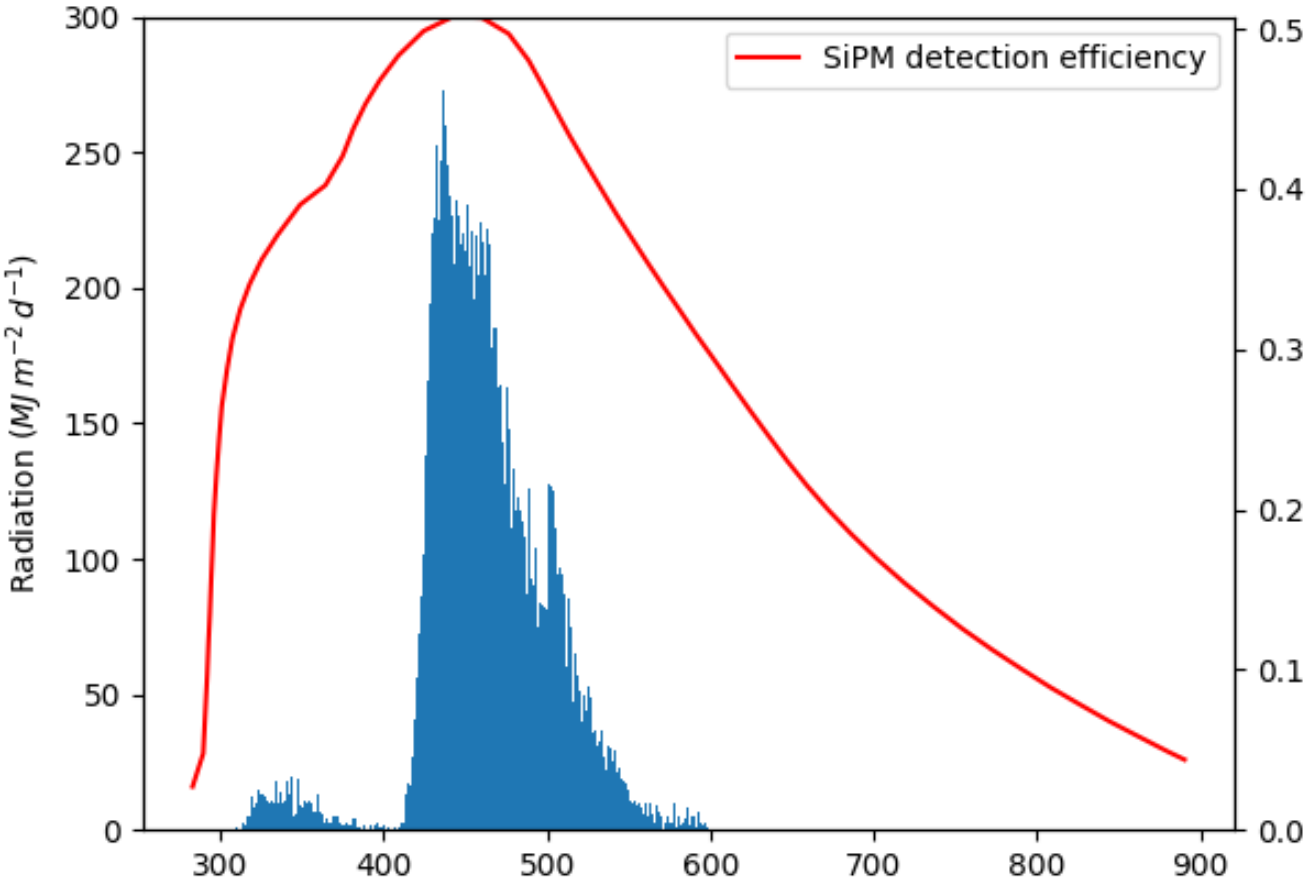
Supercell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 1



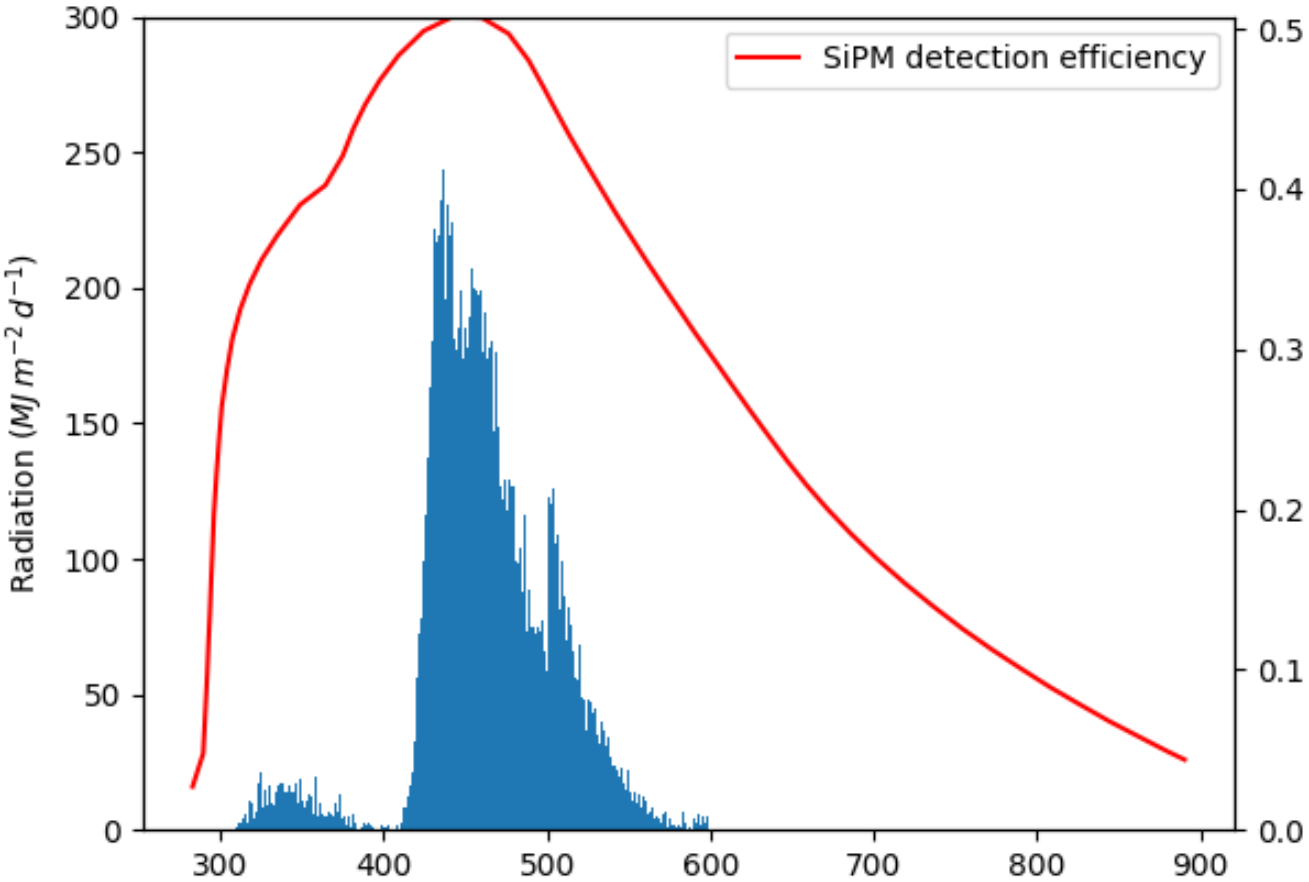
Supercell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 1.5



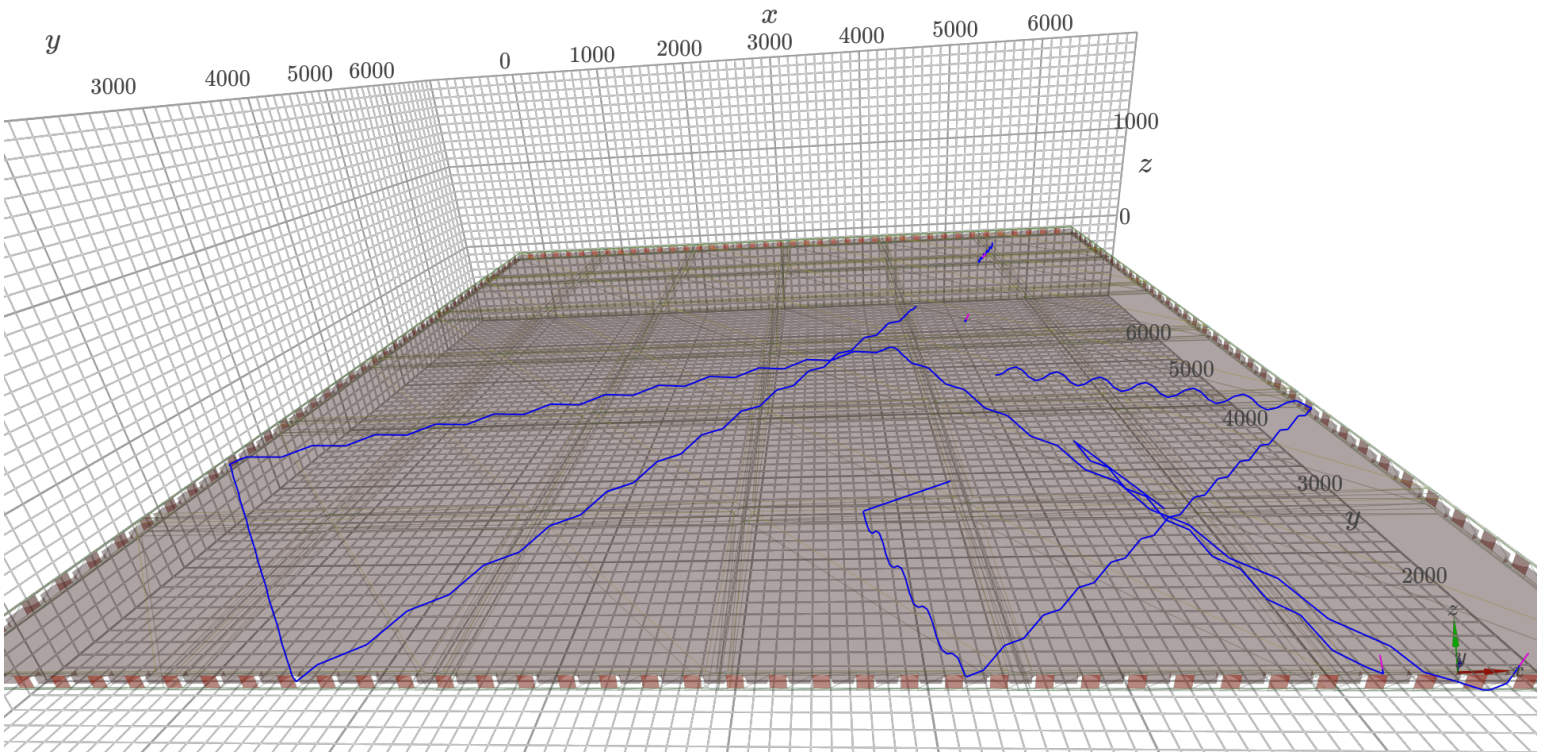
Supercell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 2



Supercell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 3



X-ARAPUCAS Megacells with dimples. We use two parameters: cylinder radius and the distance of the WLS to the inner walls)

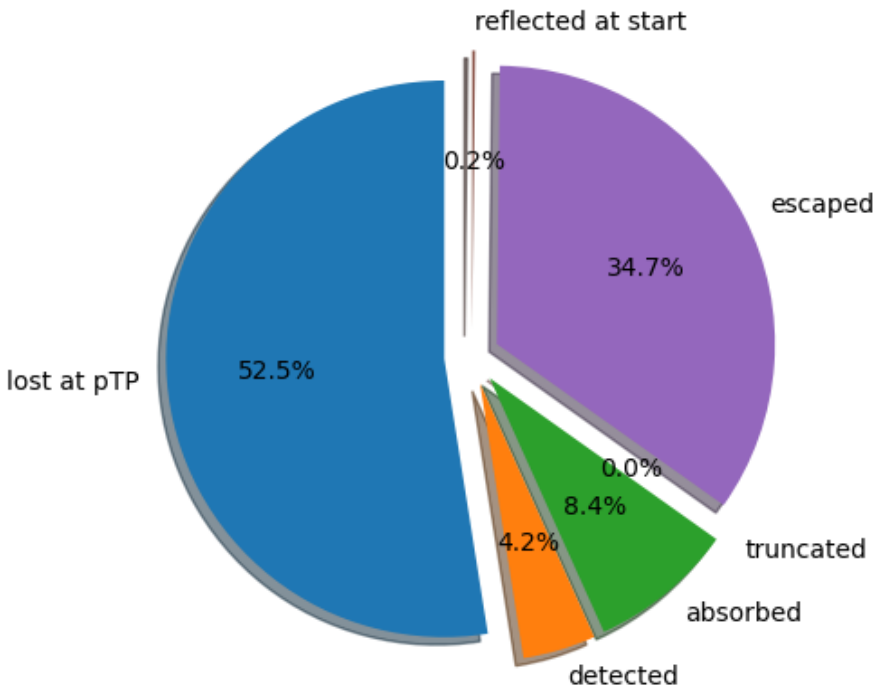


Megacell simulations results

		Dimple Radius *mm*					
		0	**0.5**	**1**	**1.5**	**2**	**3**
Border *mm*	**0.1**	4.2%	5.5%	5.4%	5.3%	5.2%	4.8%
	0.5	4.2%	5.3%	5.2%	5.1%	5.0%	4.6%
	1	4.0%	5.0%	5.0%	4.8%	4.7%	4.3%

Table: Photon detection efficiency for different border sizes and dimple radius. The best result shows a relative increase (in comparison to the one without dimples and same border) in efficiency of 50%.

Megacell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 0



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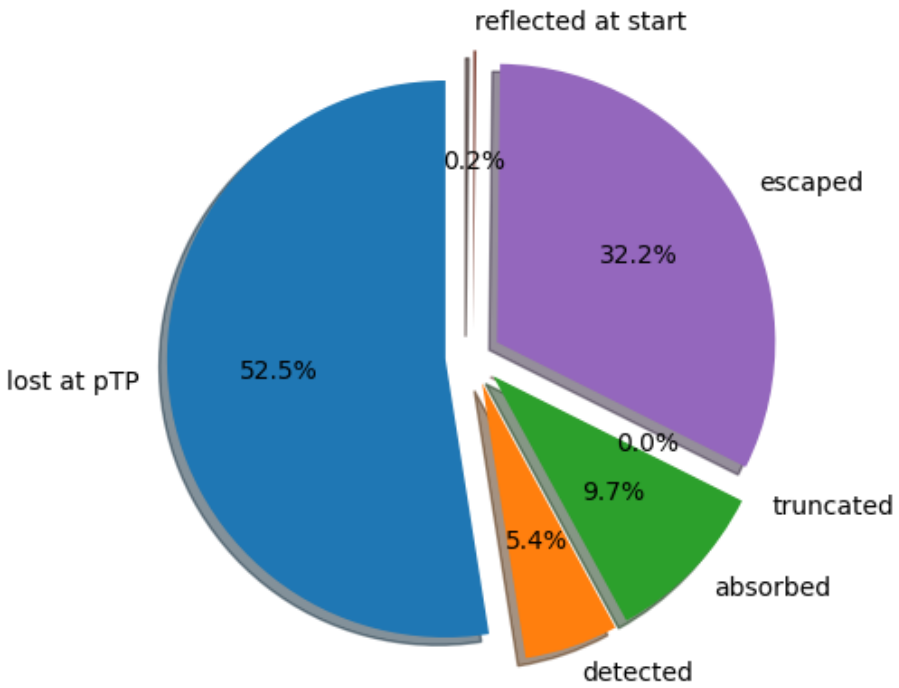
GREEN - absorbed by the inner walls or the SiPMs
GRAY - truncated (max reflections 100k),
ORANGE- detected at SiPMs

Megacell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 0.5



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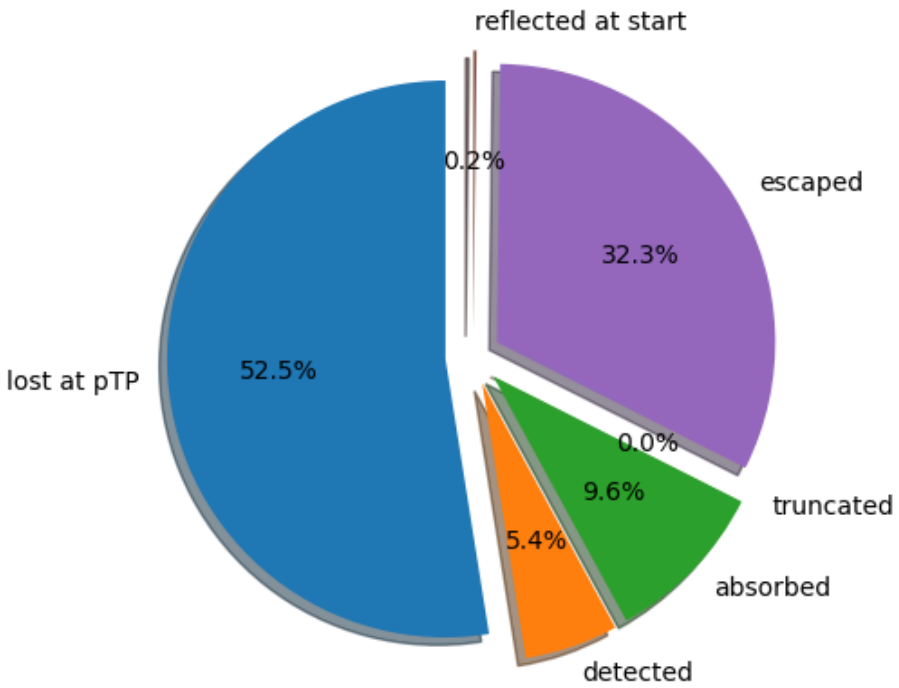
GRAY - truncated (max reflections 100k),
ORANGE- detected at SiPMs

Megacell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 1



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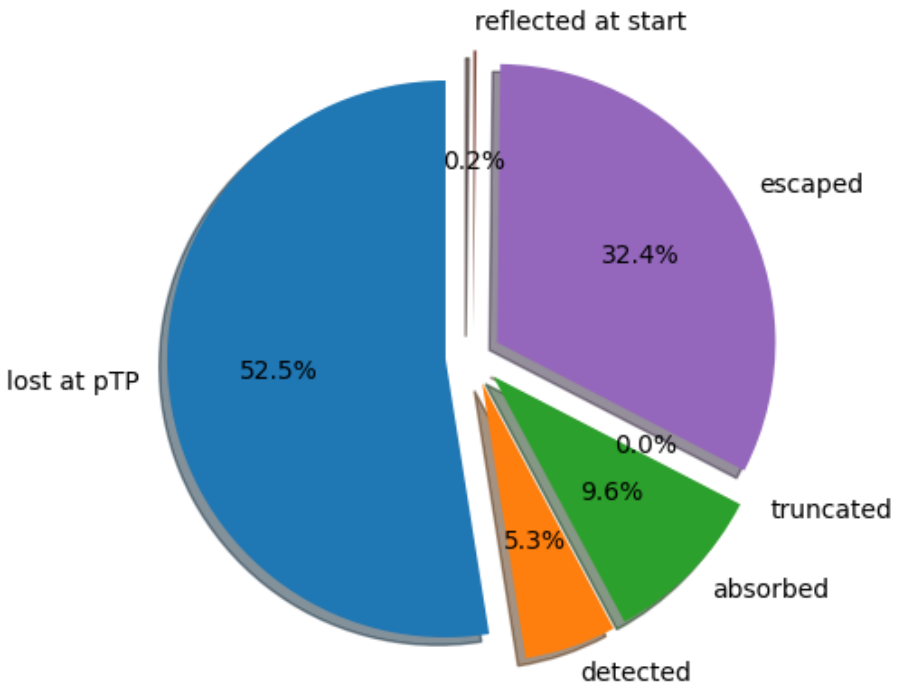
ORANGE- detected at SiPMs

Megacell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 1.5



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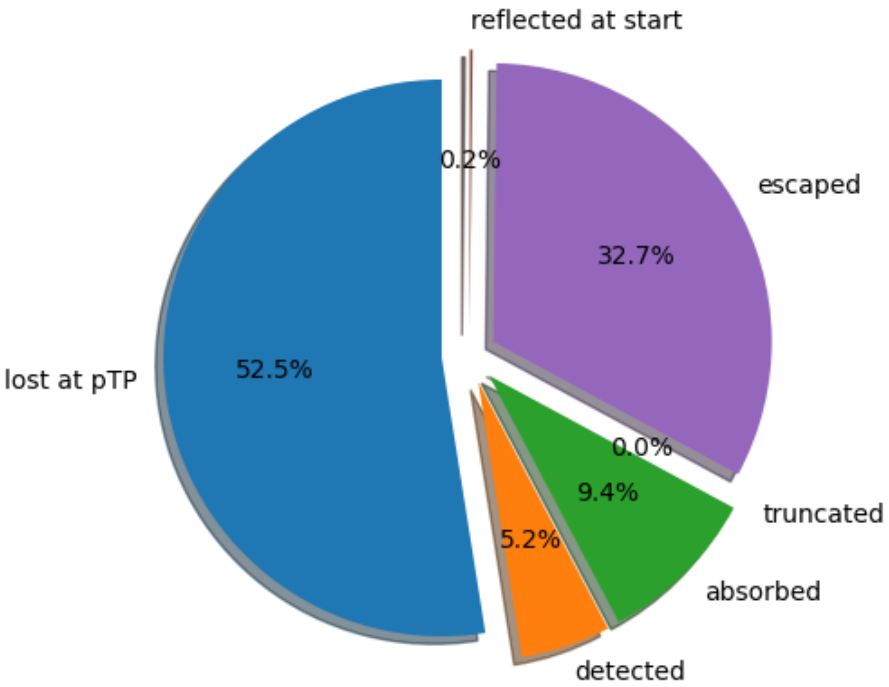
Megacell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 2



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PURPLE - escaped through the dichroic filters
GREEN - absorbed by the inner walls or the SiPMs
GRAY - truncated (max reflections 100k),
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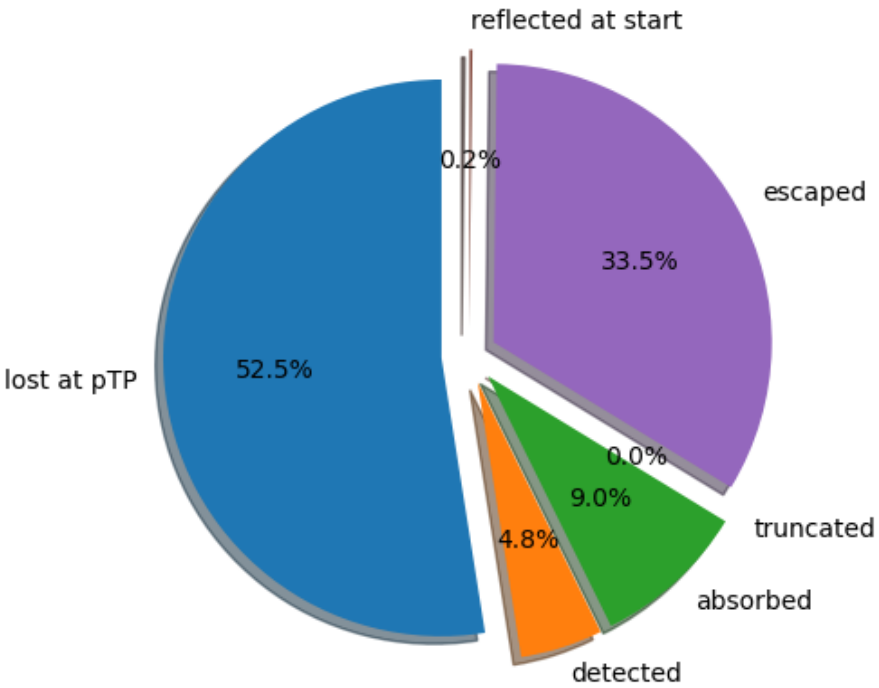
Megacell. Fraction of photons by end destination. Border = 0.1, Dimple Radius = 3



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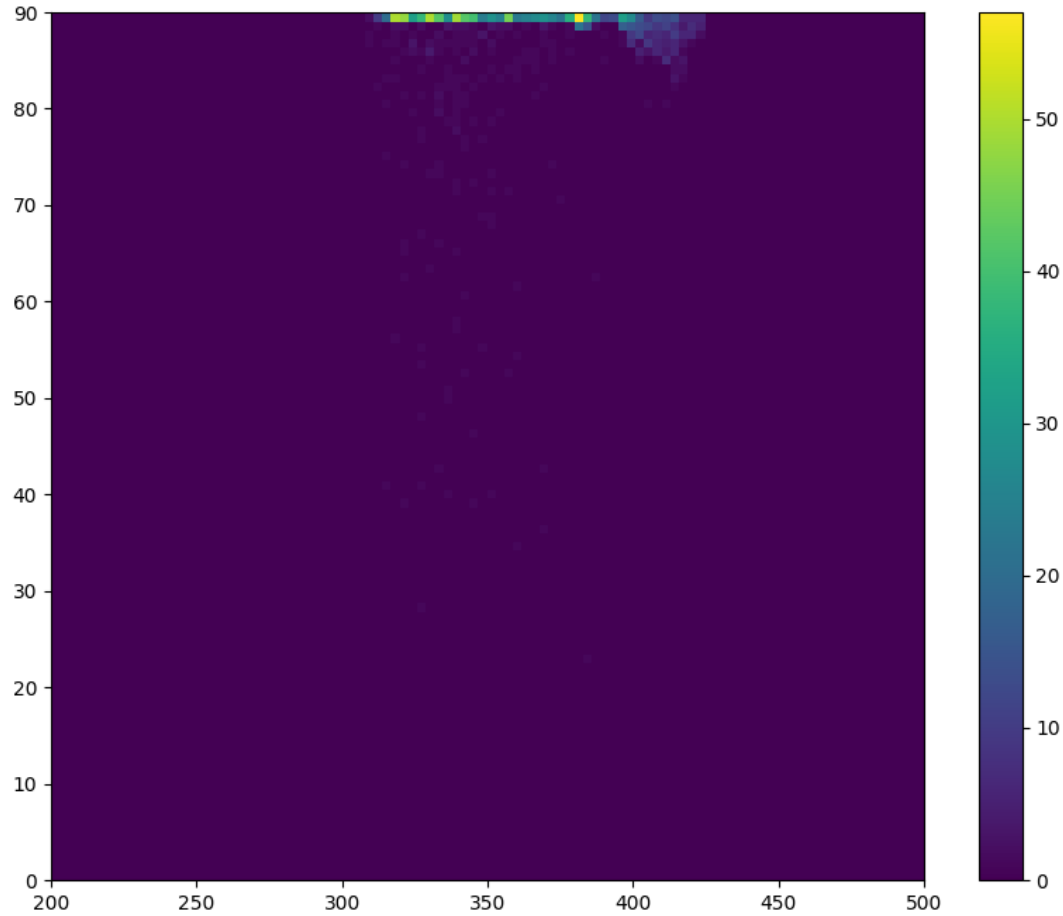
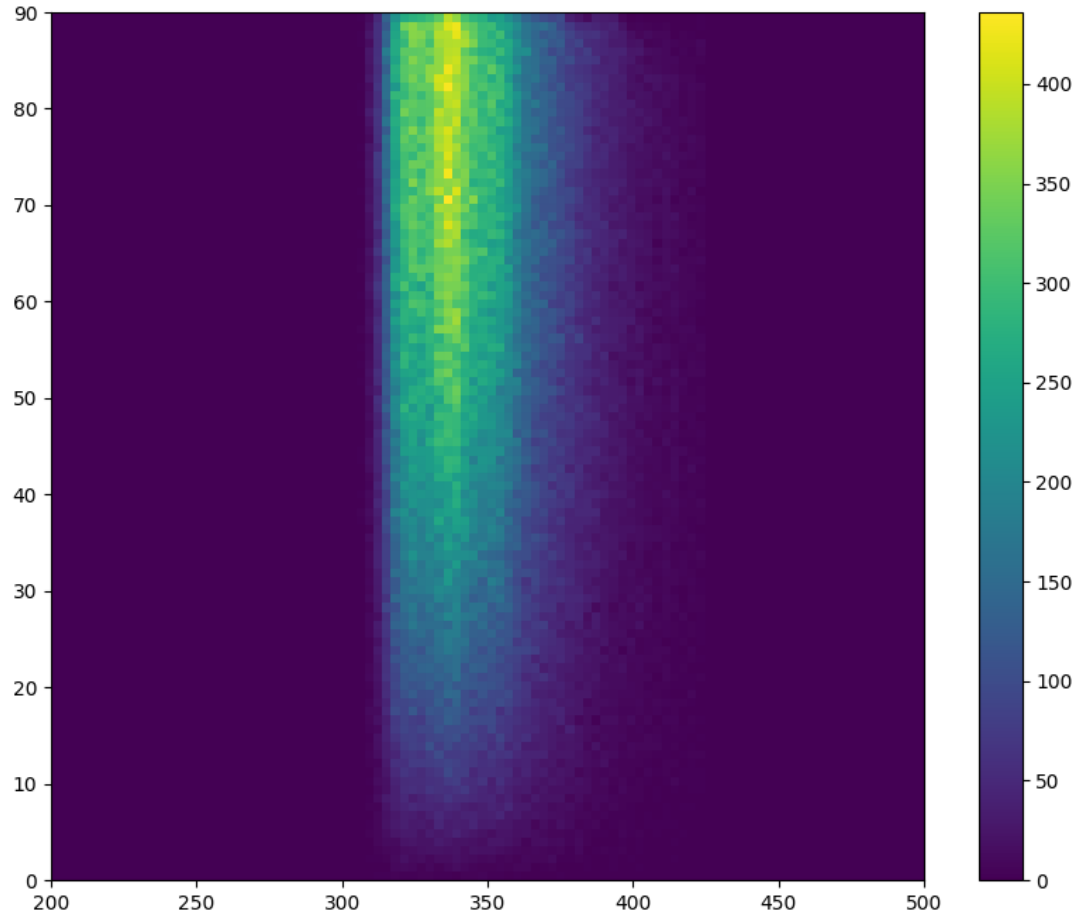
ORANGE- detected at SiPMs

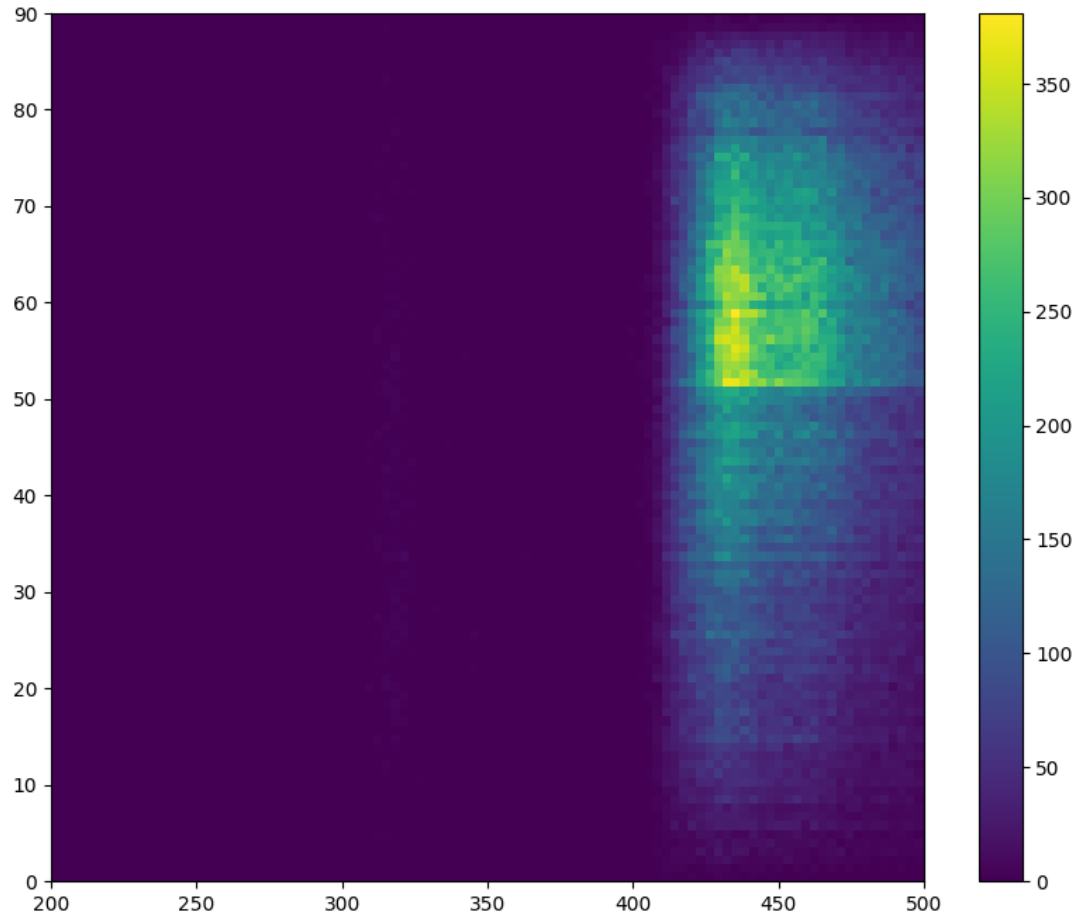
Megacell. Histogram of photons reflected at the dichroic filters coming from ptp (wavelength x incidence angle). Border = 0.1, Dimple Radius = 0.5



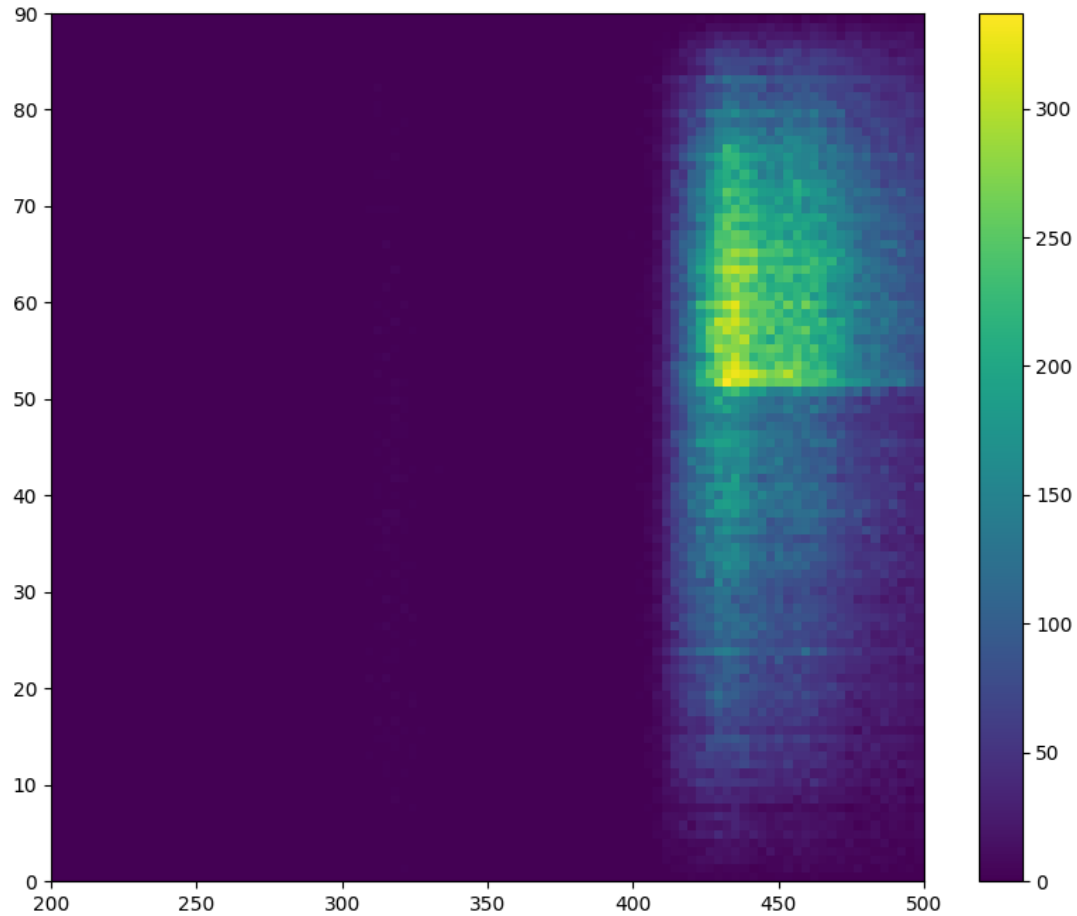
Megacell. Histogram of photons that actually enter the X-ARAPUCA (wavelength x incidence angle). Border = 0.1, Dimple Radius = 0.5



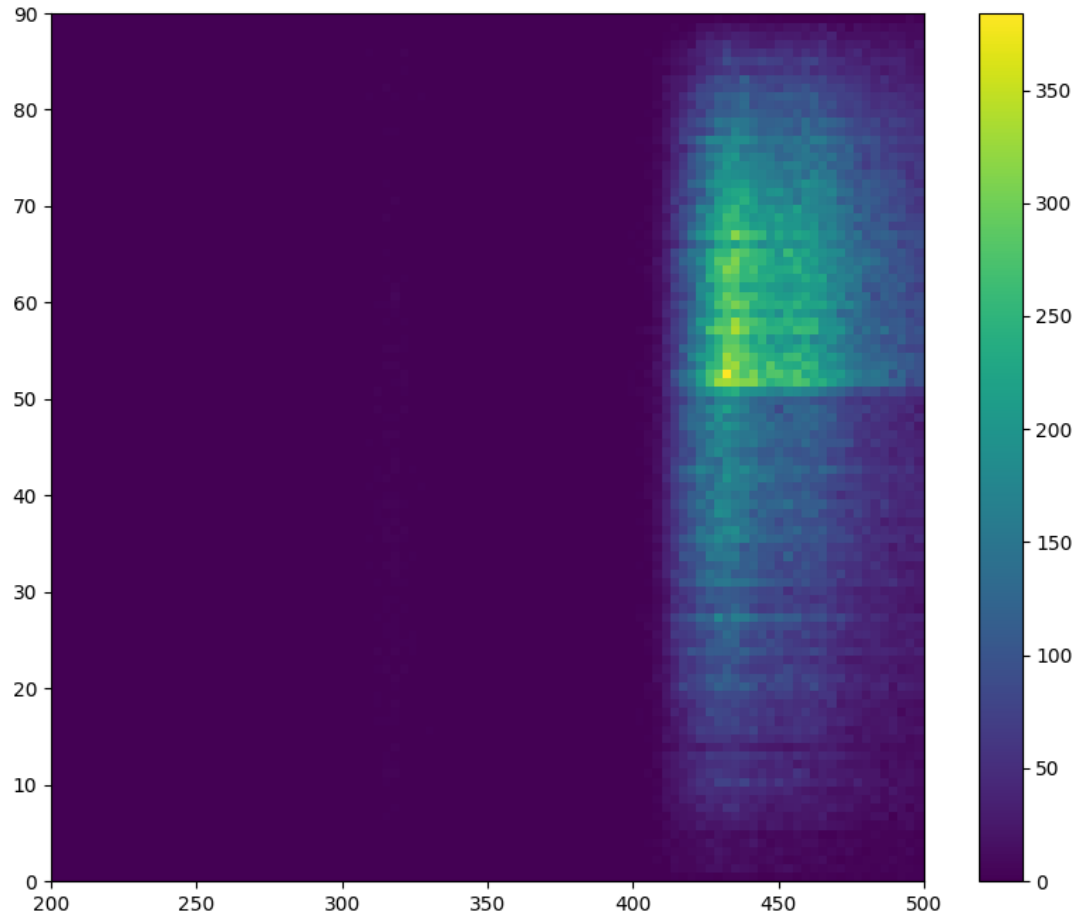
Megacell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 0



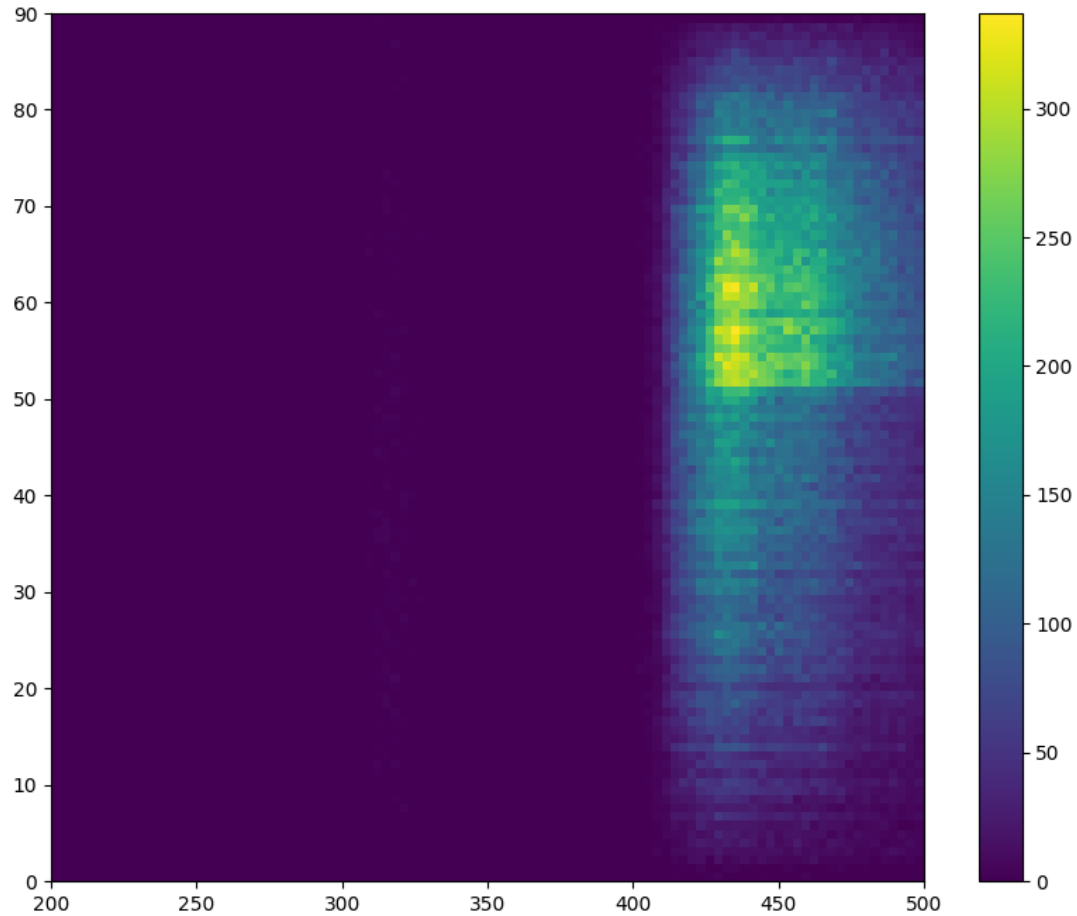
Megacell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 0.5



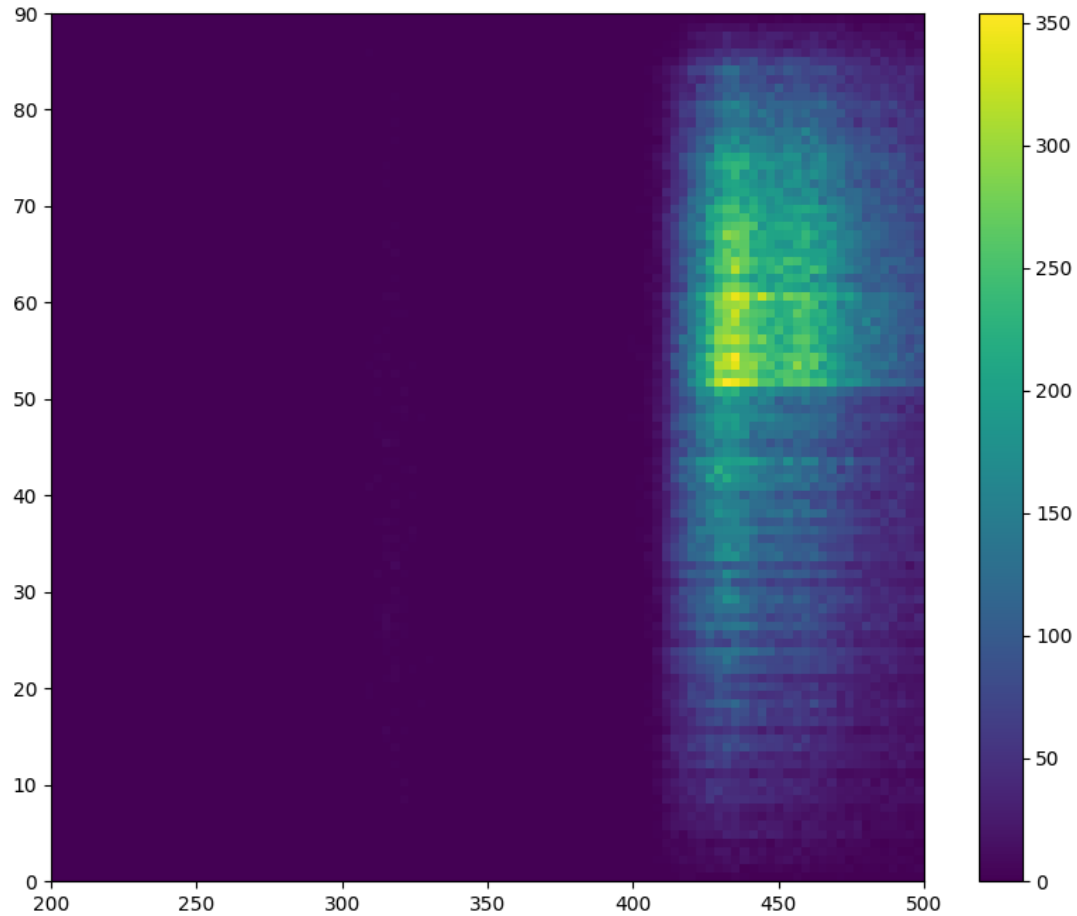
Megacell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 1



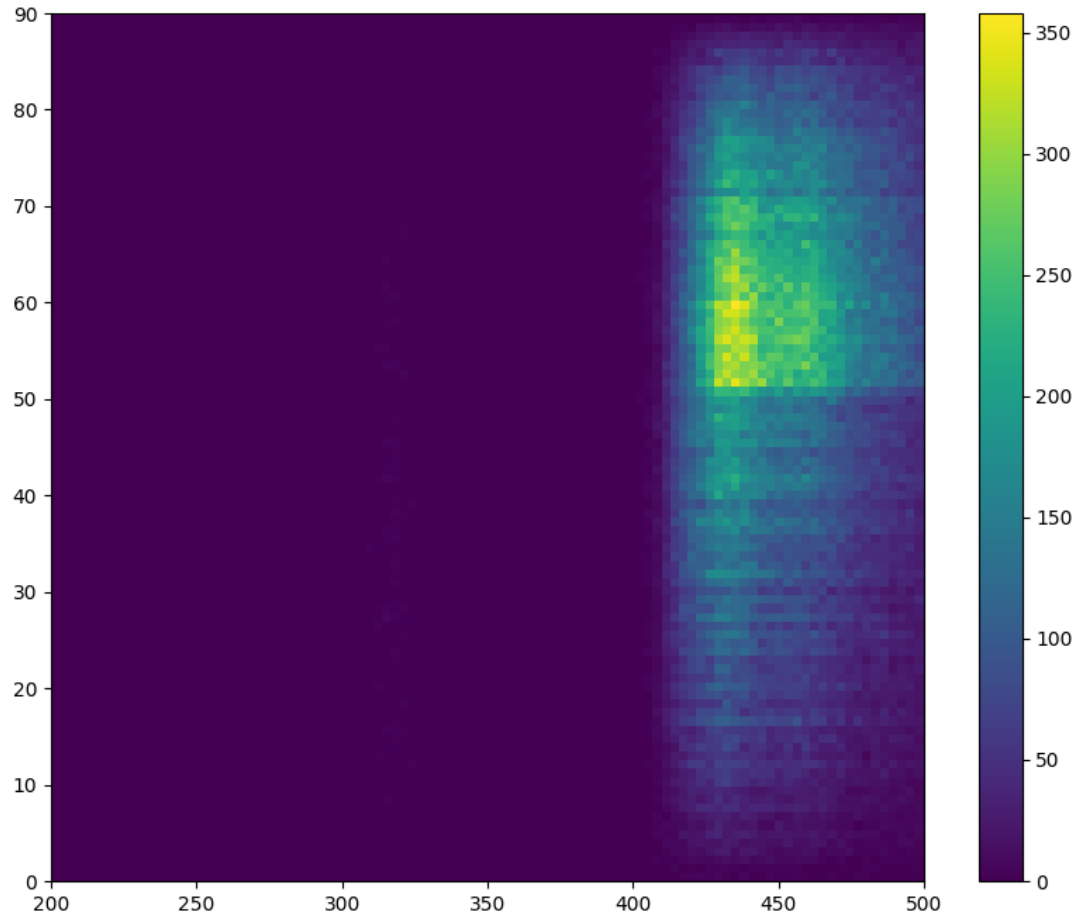
Megacell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 1.5



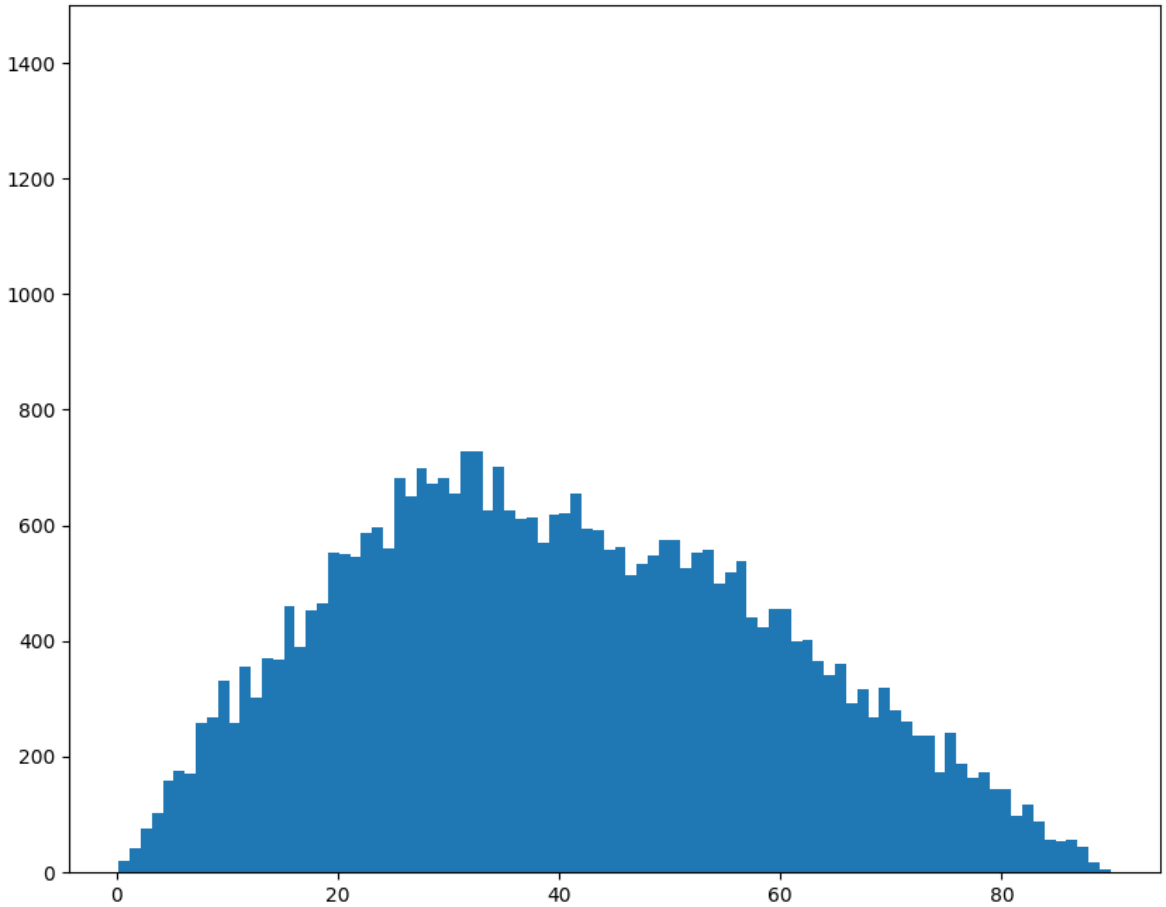
Megacell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 2



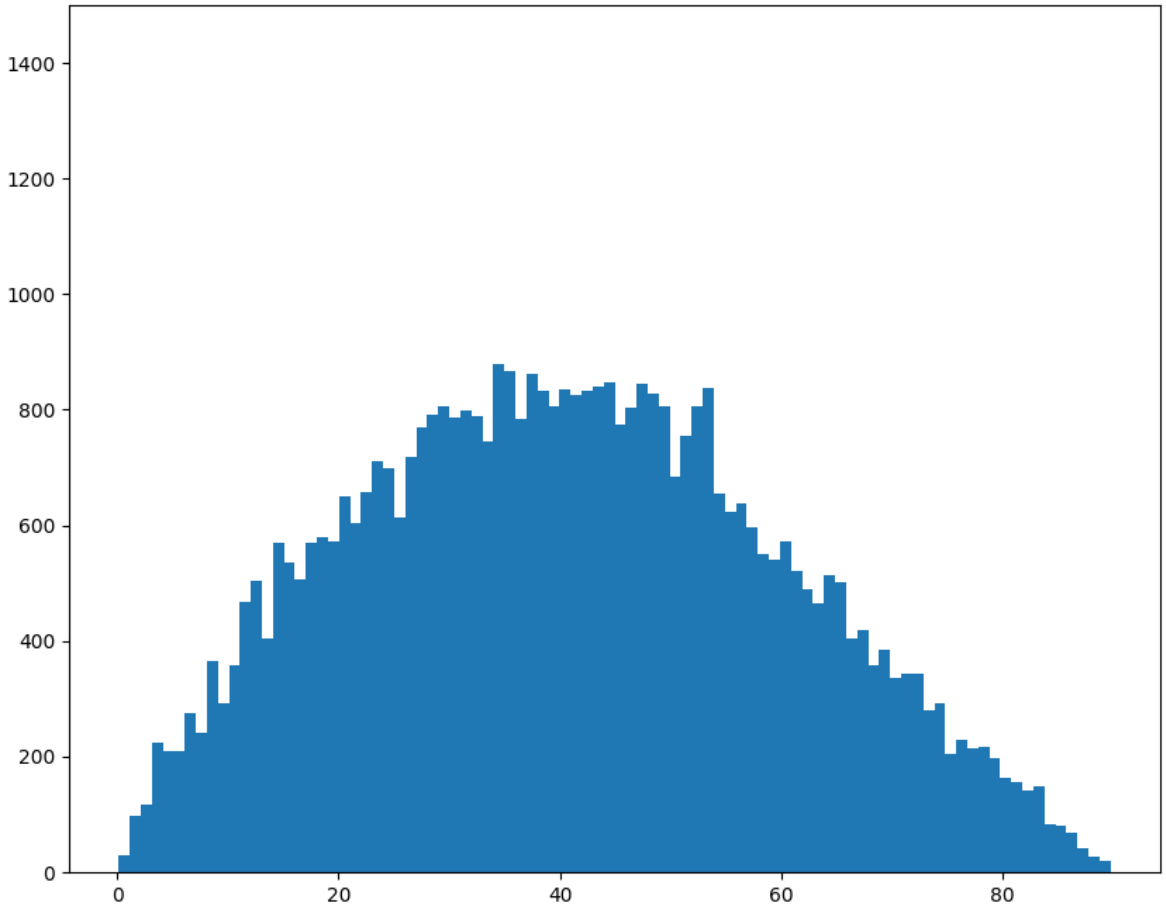
Megacell. Histogram of photons escaped through dichroic filters coming from inside the X-ARAPUCA (wl x inc. angle). Border = 0.1, Dimple Radius = 3



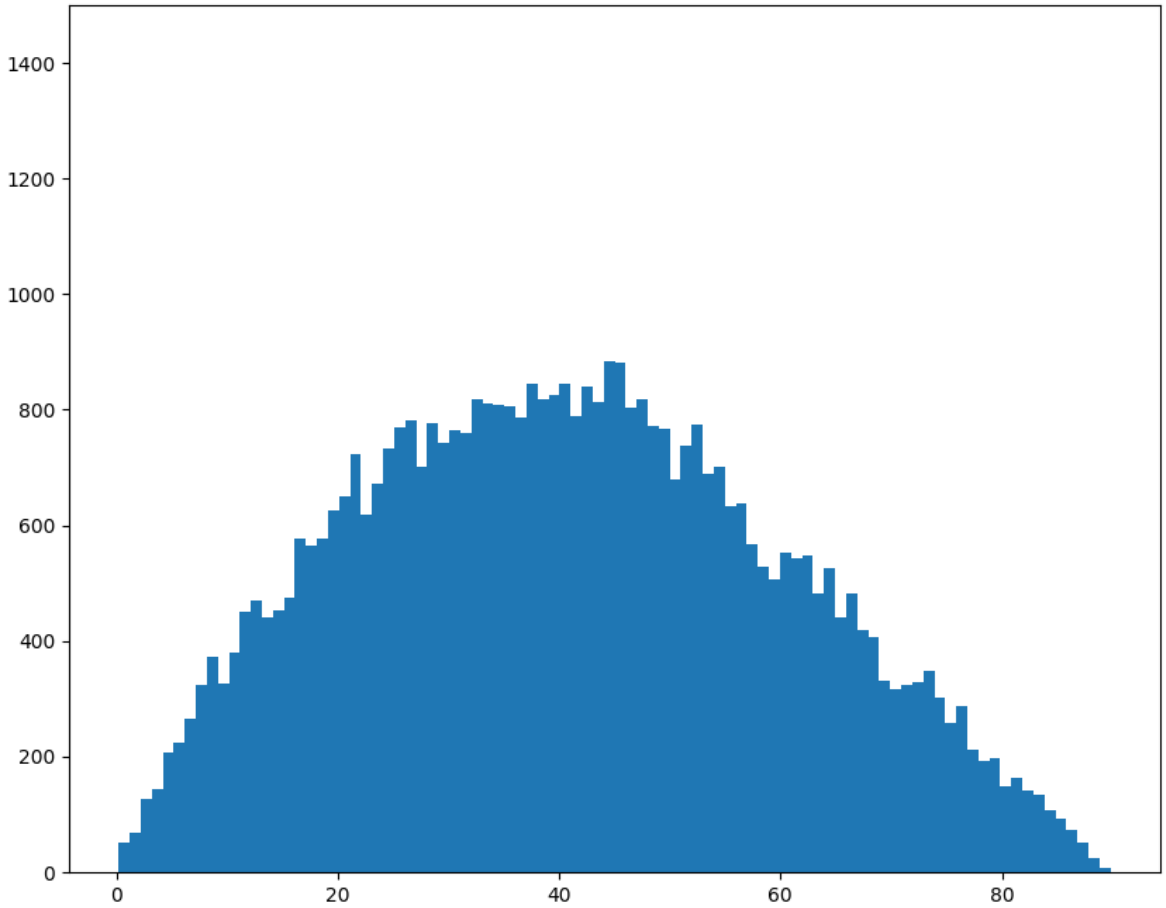
Megacell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 0



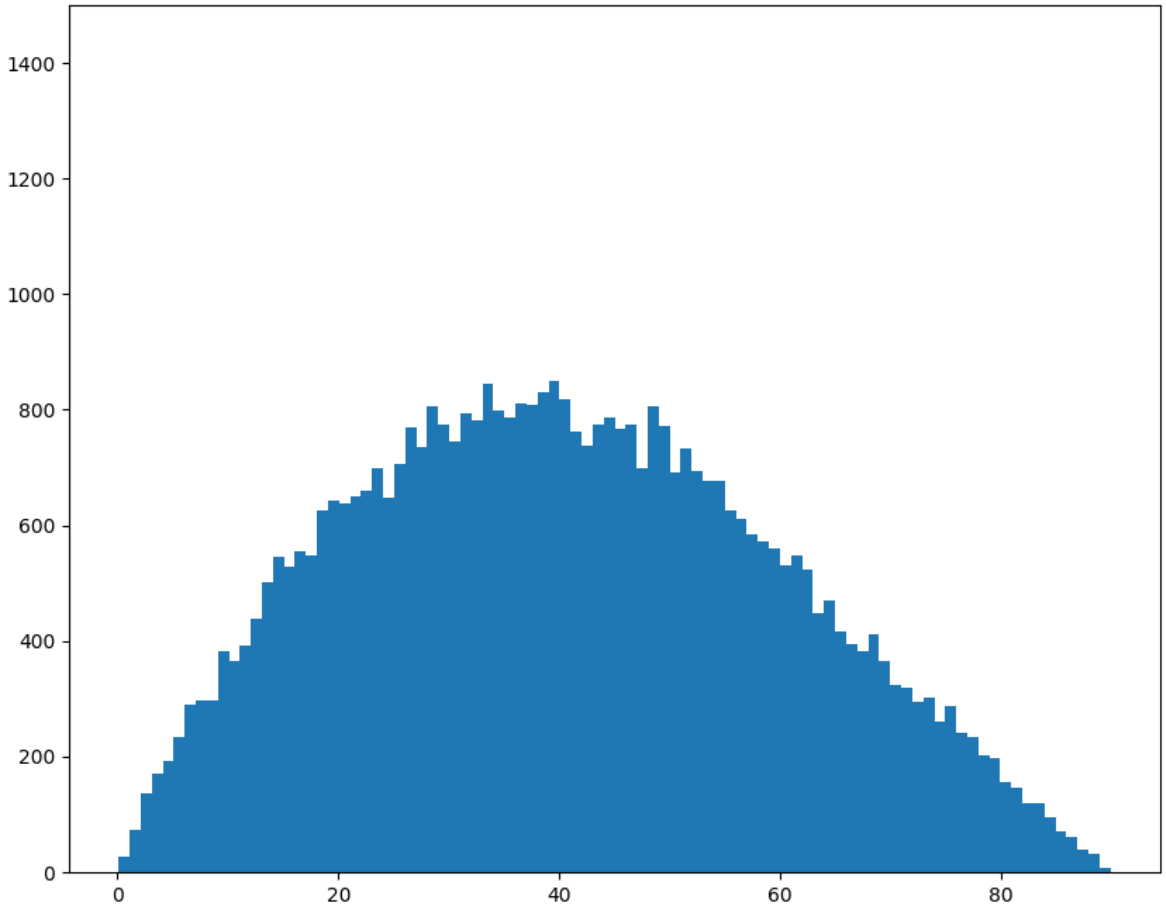
Megacell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 0.5



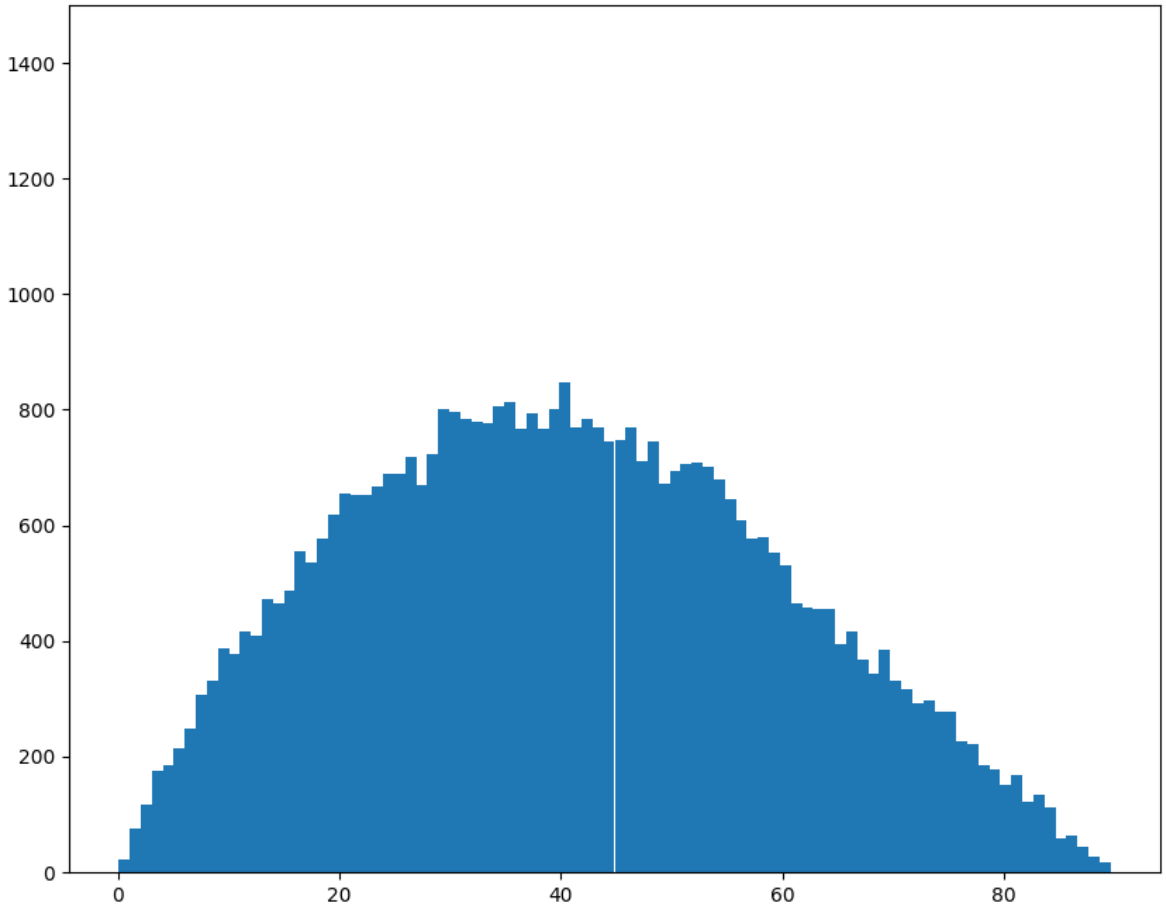
Megacell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 1



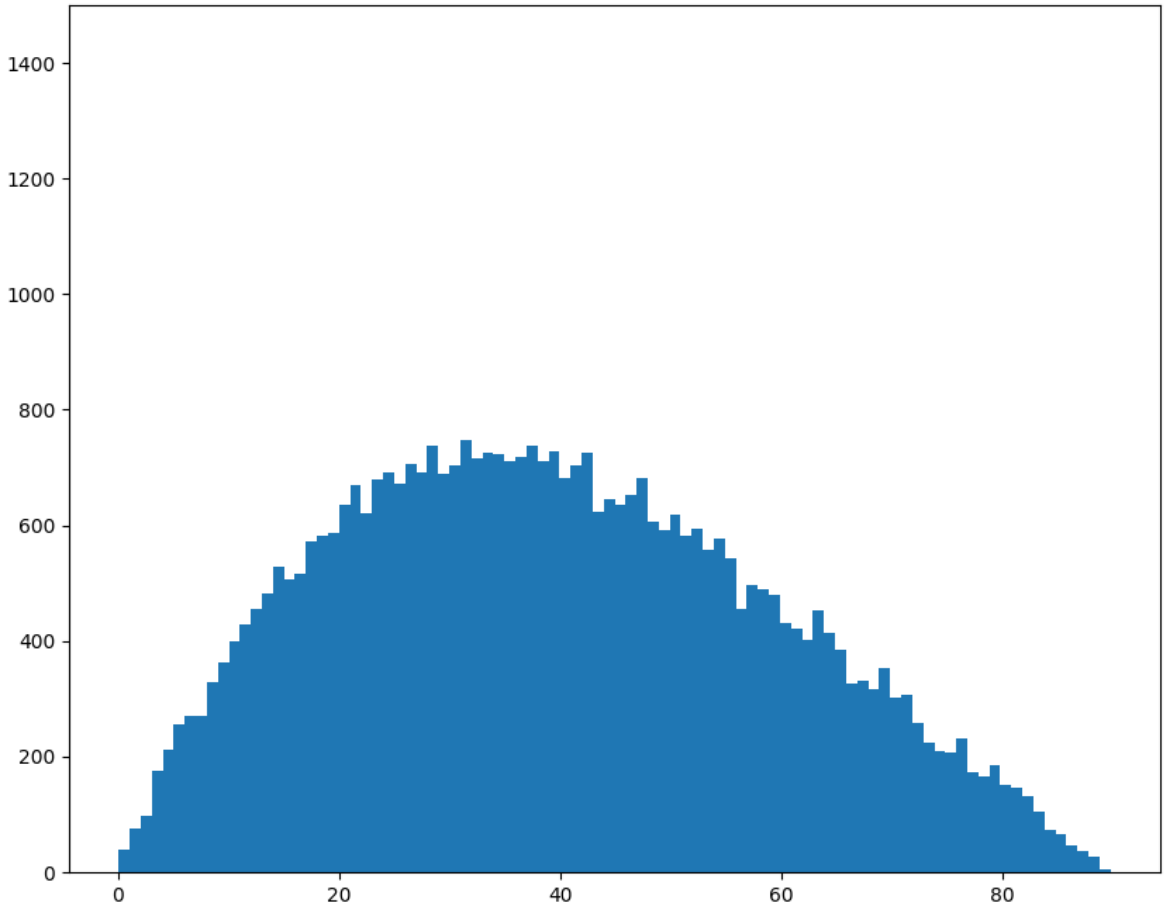
Megacell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 1.5



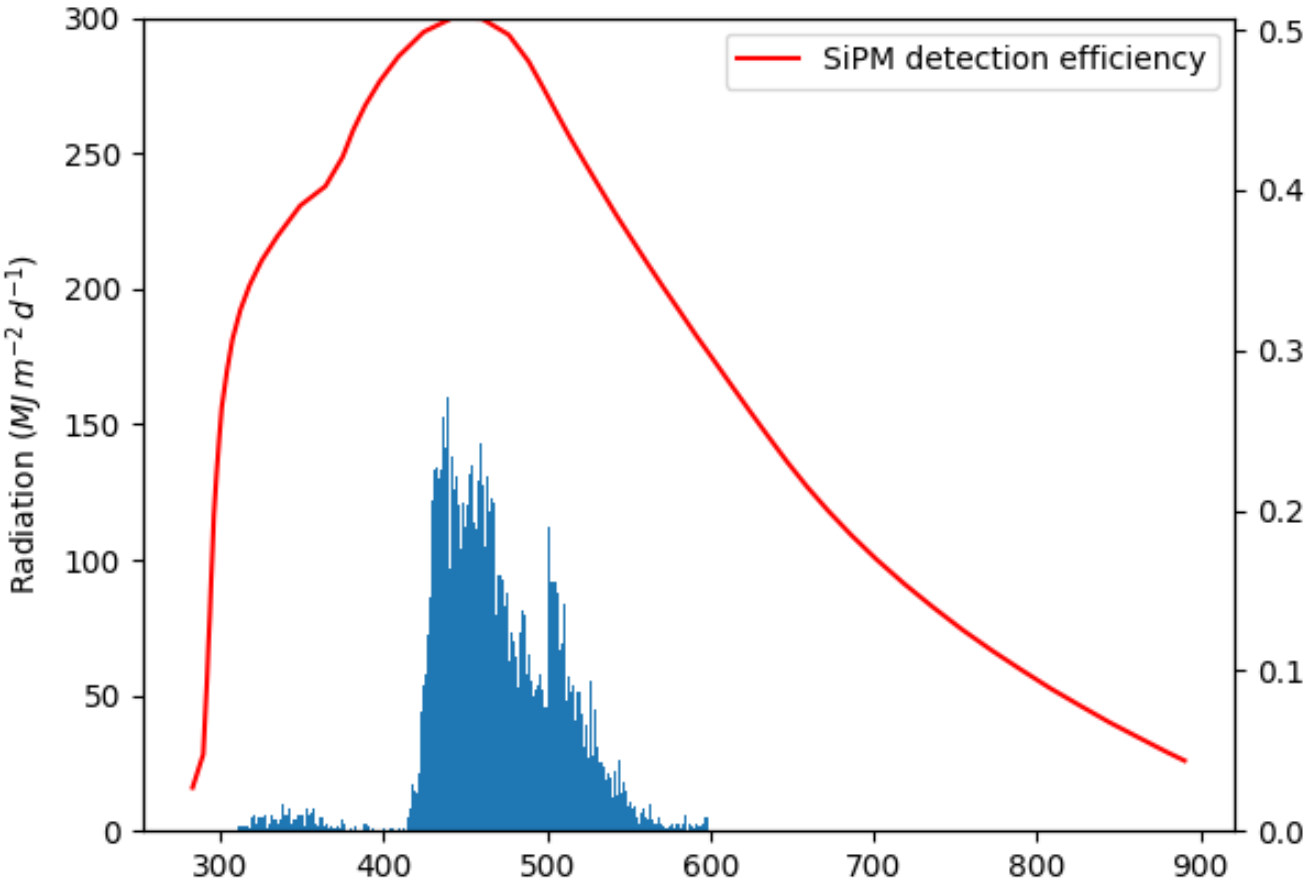
Megacell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 2



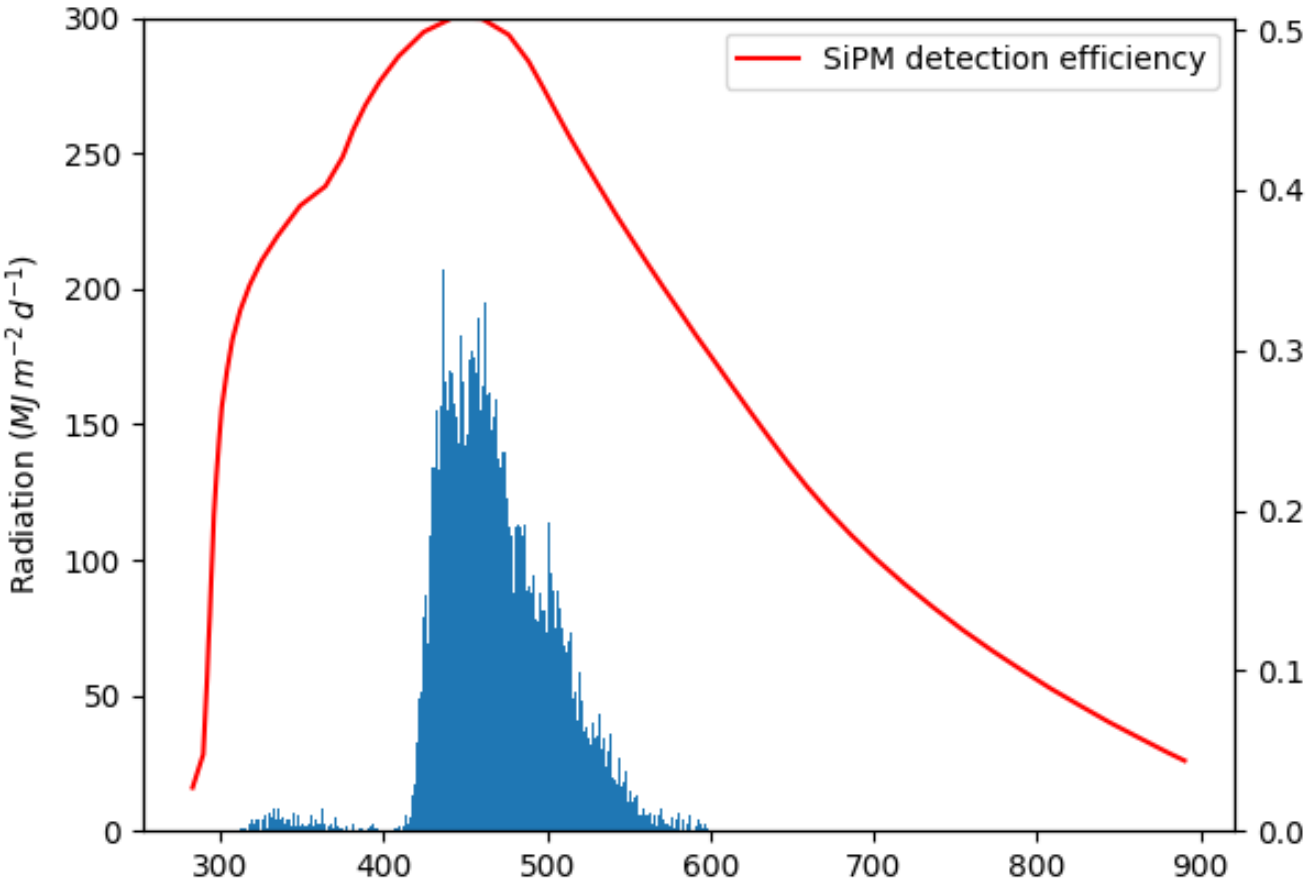
Megacell. Histogram of detected photons at the SiPMs by incidence angle. Border = 0.1, Dimple Radius = 3



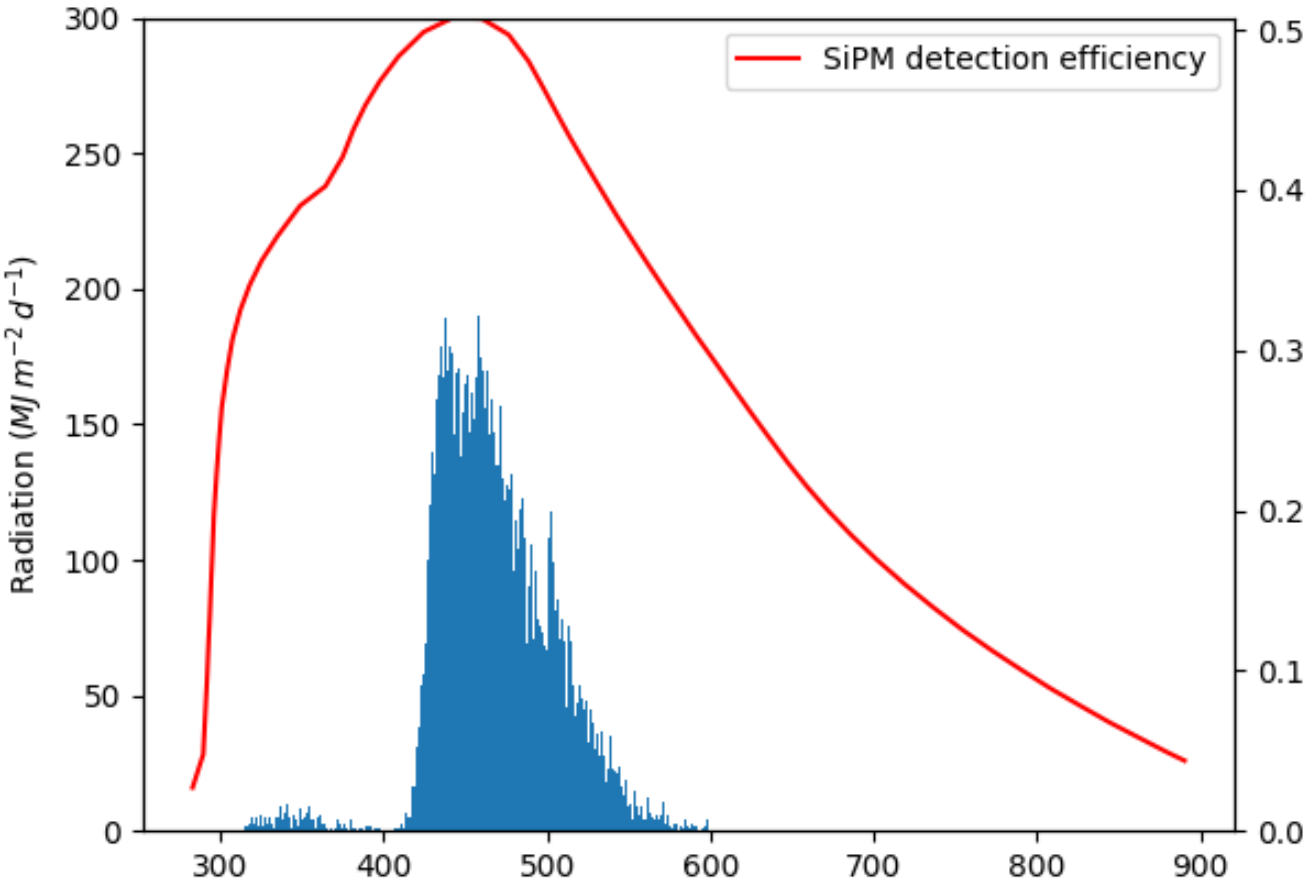
Megacell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 0



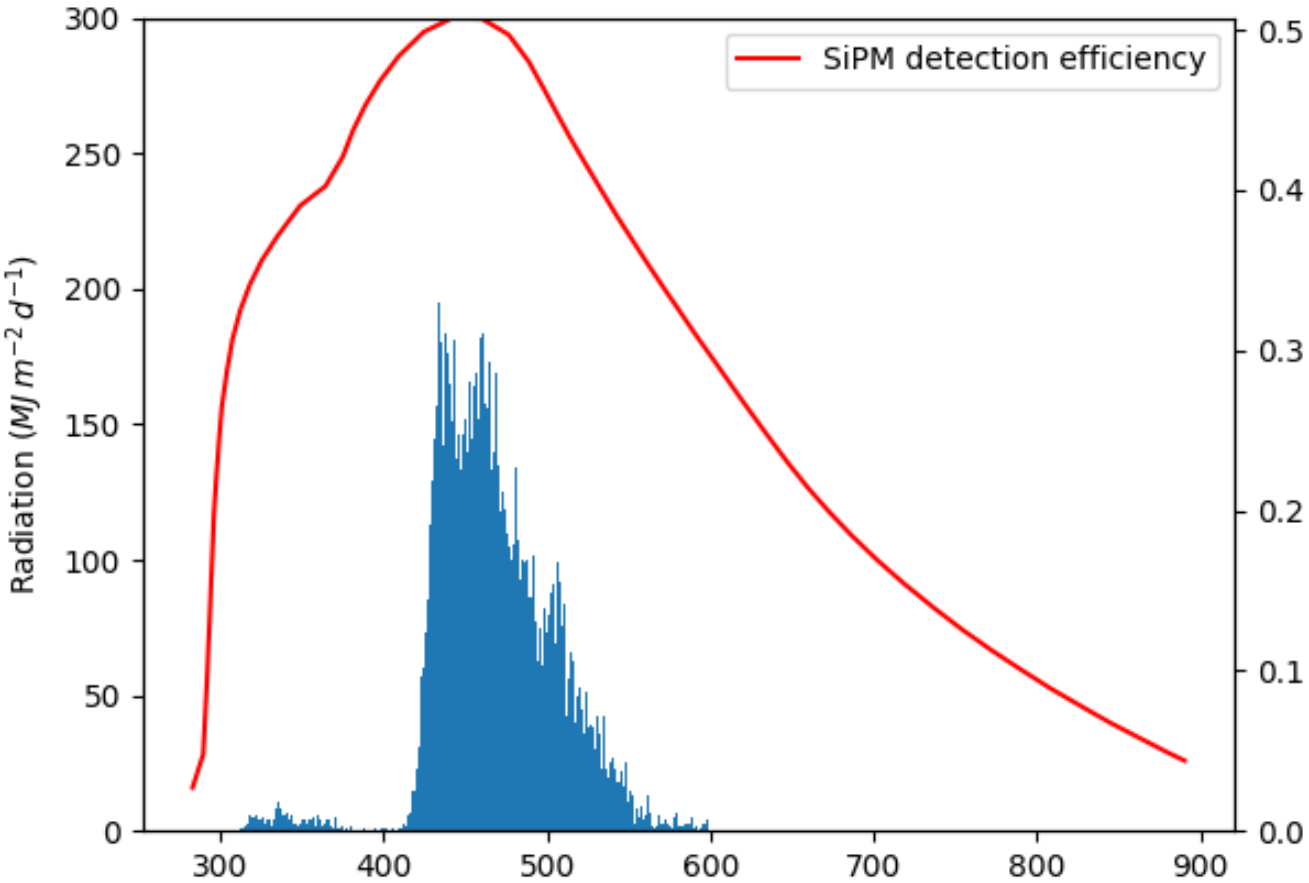
Megacell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 0.5



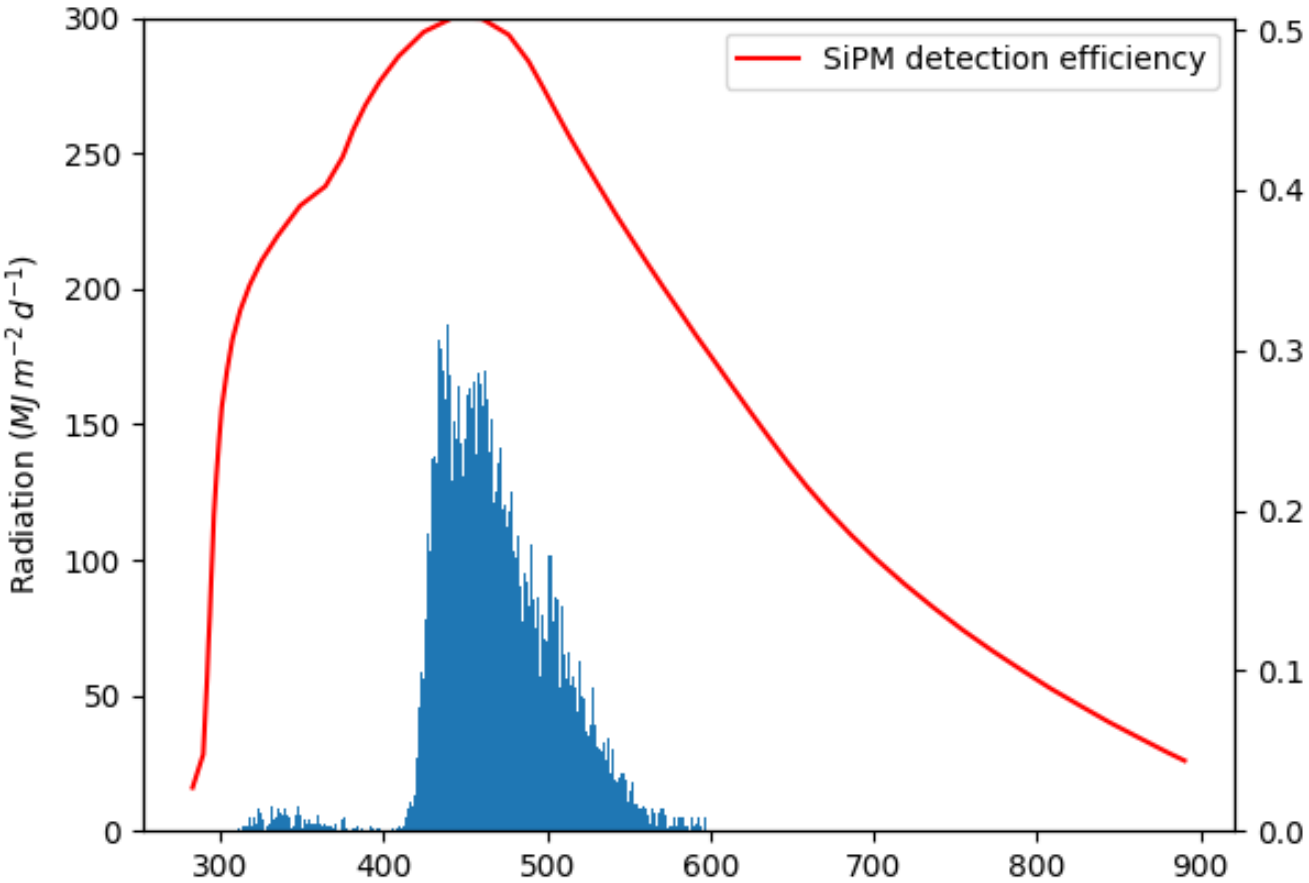
Megacell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 1



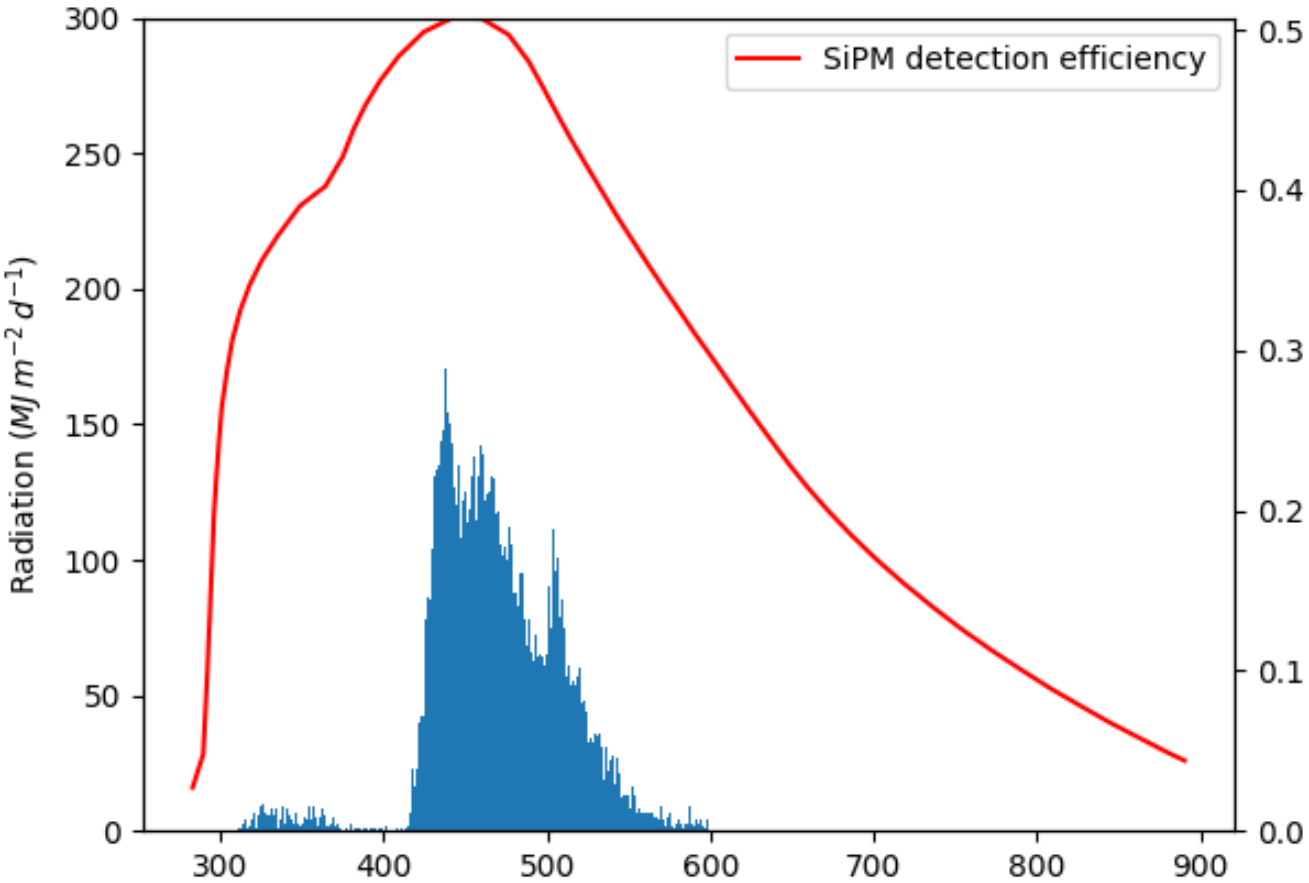
Megacell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 1.5



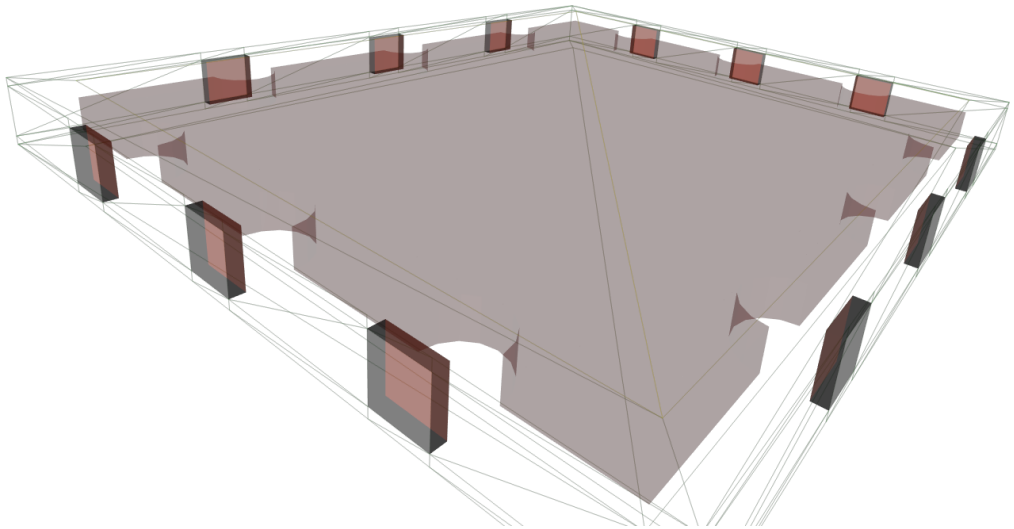
Megacell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 2



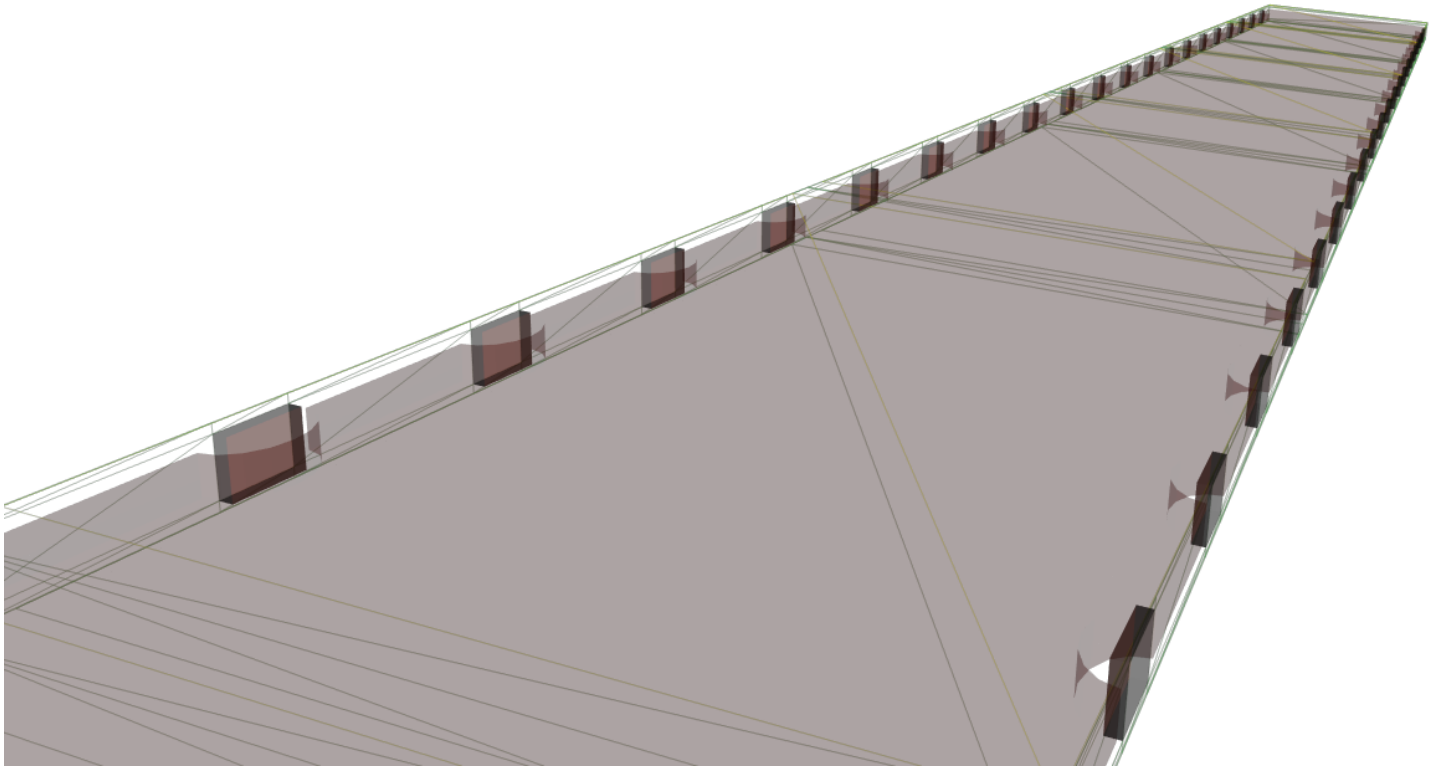
Megacell. Histogram of detected photons at the SiPMs by wavelength. Border = 0.1, Dimple Radius = 3



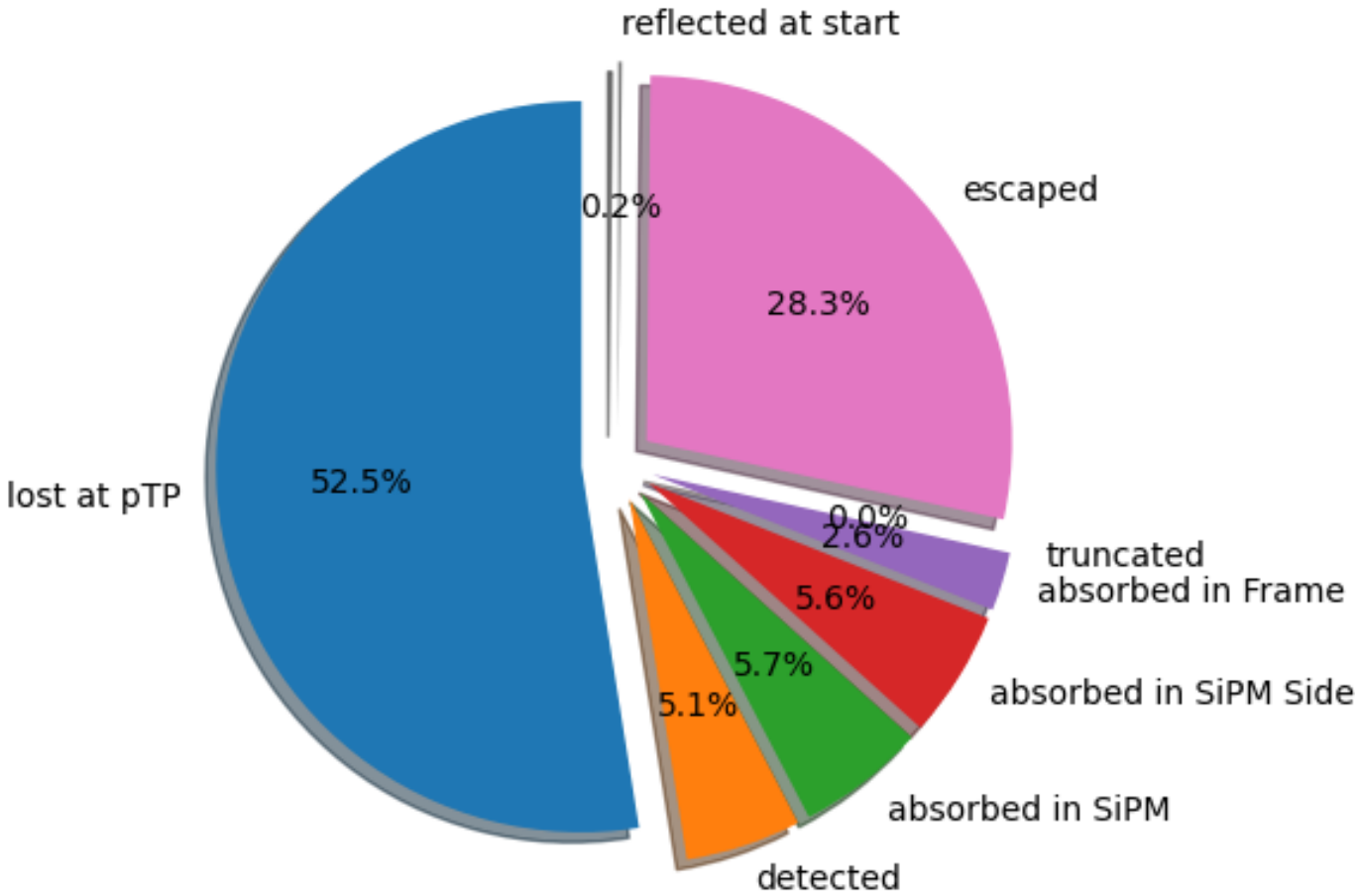
Exagerated X-ARAPUCAS with dimples and SiPMs with thin sides. Thin sides are simulated to absorb 80% of incomming photons and reflect the rest.



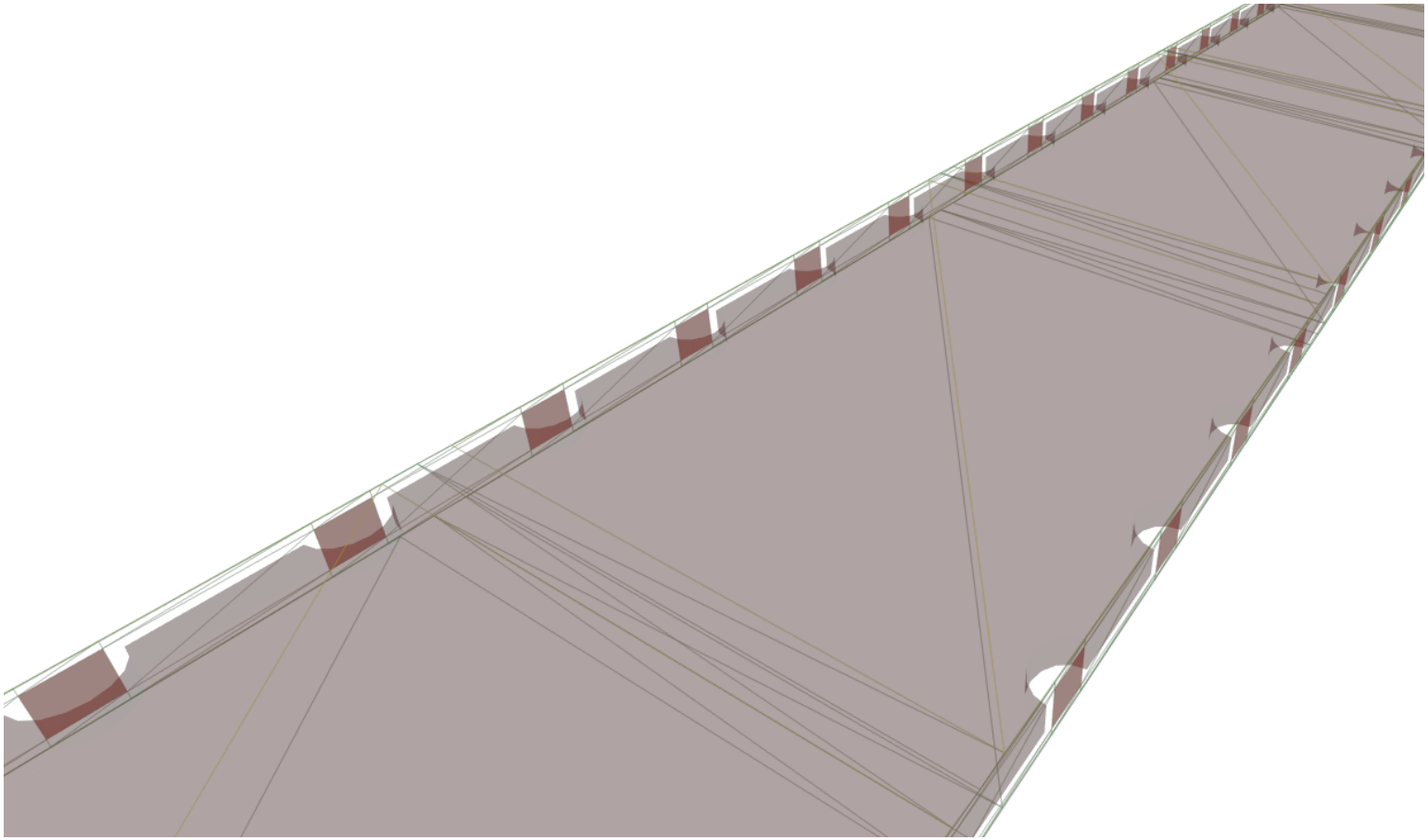
X-ARAPUCAS Supercells with dimples and SiPMs with thin sides. Dimples with radius 4.3mm and thin sides of 1.4mm.



Pie chart for X-ARAPUCAS Supercells with dimples and SiPMs with thin sides. Dimples with radius 4.3mm and thin sides of 1.4mm.



X-ARAPUCAS Supercells with dimples and SiPMs with thin sides. Dimples with radius 4.3mm, without thin sides.



Pie chart for X-ARAPUCAS Supercells with dimples and SiPMs with thin sides. Dimples with radius 4.3mm, without thin sides.