X-ARAPUCA efficiency comparison for different Dichroic filters and 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

April 12, 2022

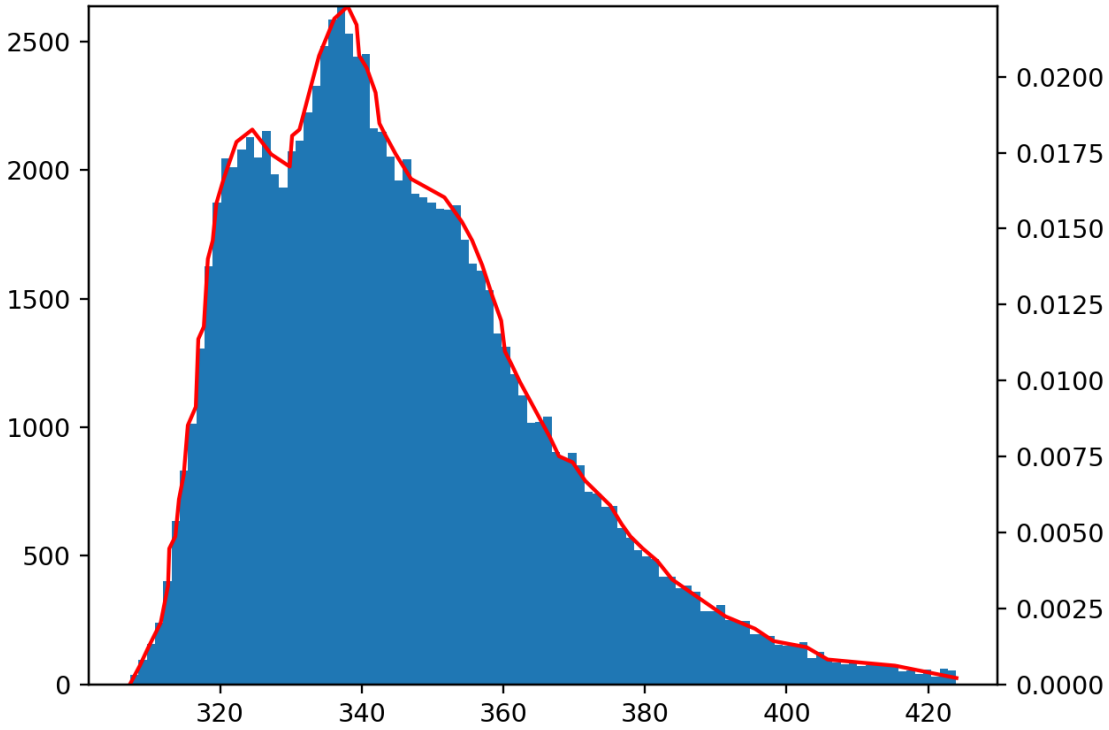
Updates of the group

- Found two bugs in the last run.
- Compared 3 different dichroic filters.
- We further studied the effects of dimples.

Simulation details

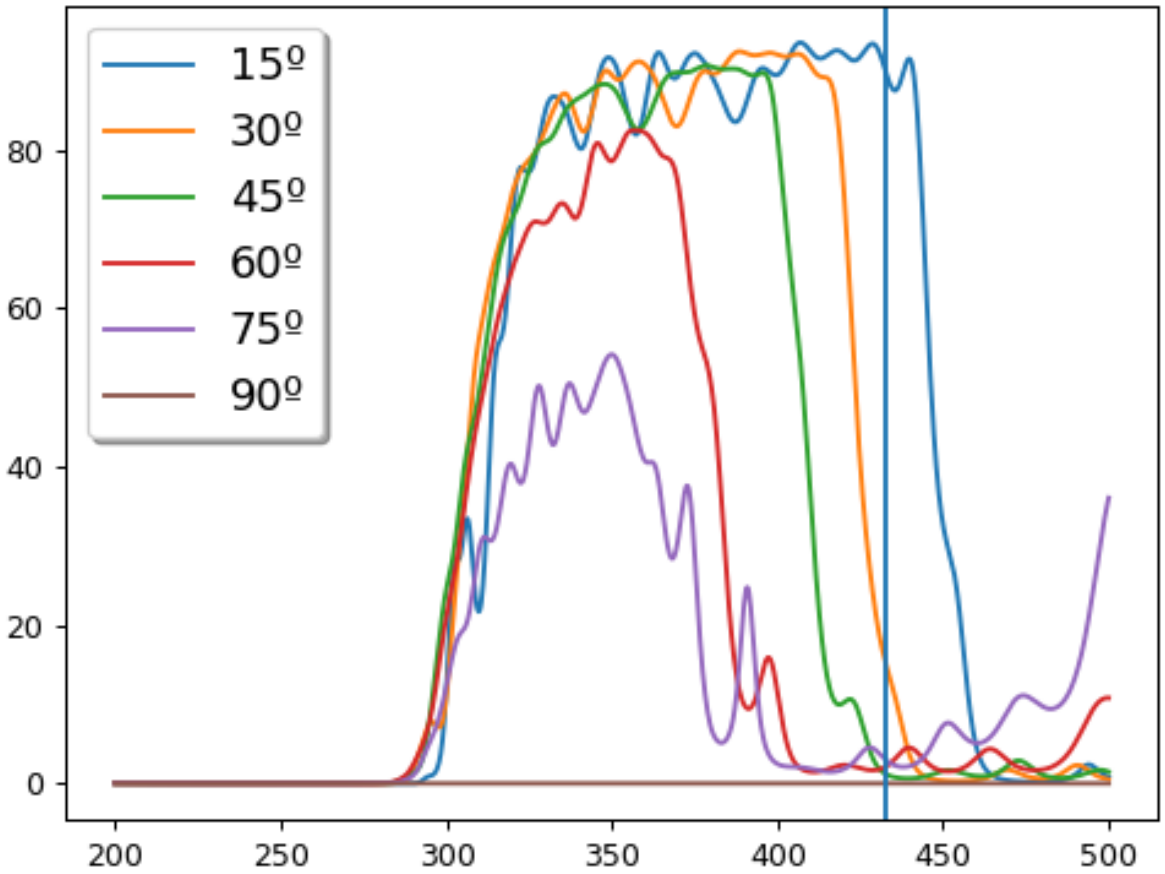
- The pTP layer absorbs and re-emits (by emission spectra) 47.5% of the photons in the direction of the dichroic filters.
- Dichroic filter transmittance and reflectance in accordance to experimental data (fitted).
- WSL absorbance and emission spectra by experimental data.
- Refraction index L. Ar. 1.228; WLS 1.58; critical angle - 53º.
- 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 (78mm x 93mm).
- Small distance WLS - SiPM: 0.1 mm.
- No interactions with L. Ar. inside the X-Arapuca.

pTP emission spectra and histogram of emitted photos in the simulation



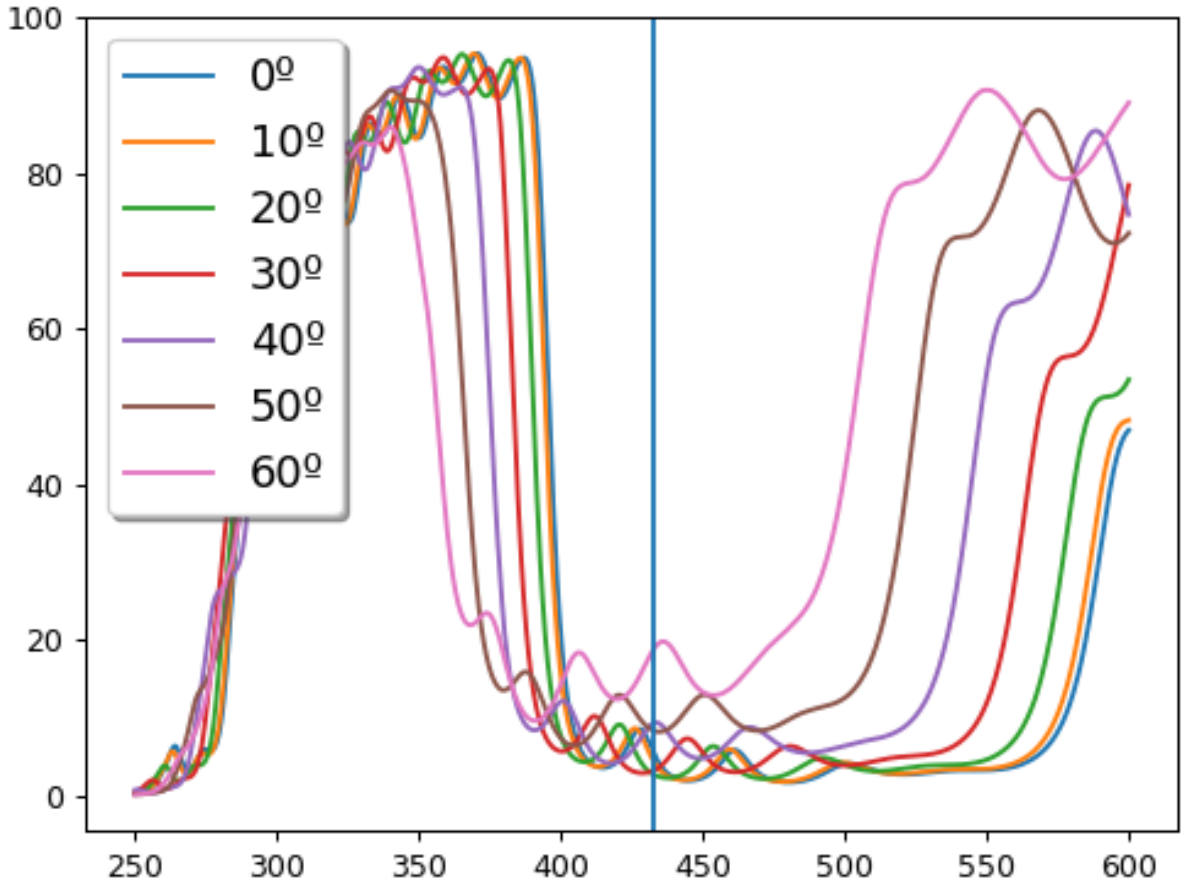
Source: P-Terphenyl deposited quartz plate calorimeter prototype. Akgun, U. 2008

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



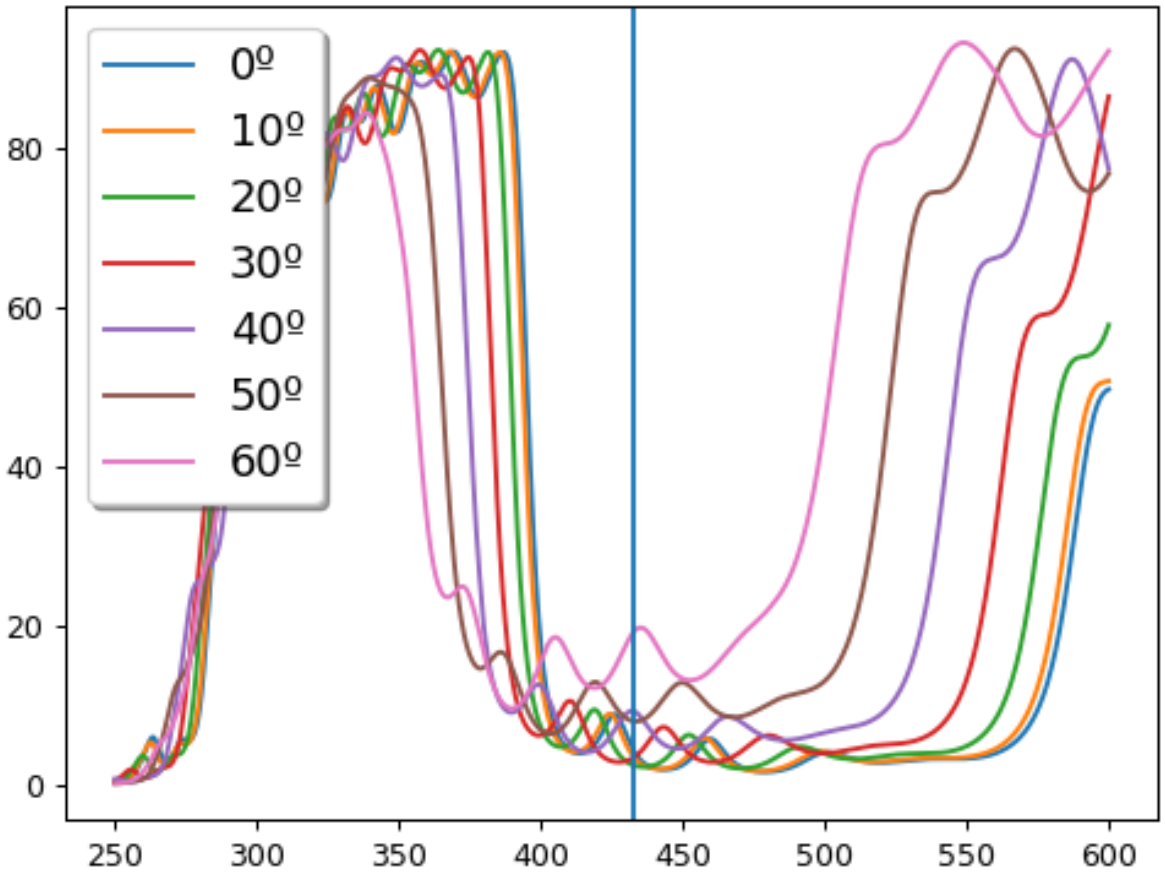
The blue vertical line shows peak WLS emission. 1mm thick. Optimized for 45º.

Experimental data on the ZAOT Dichroic Filters transmittance for incidence angles 0º, 10º, 20º, 30º, 40º, 50º, 60º, with reflective coating (CARLA CATTADORI)



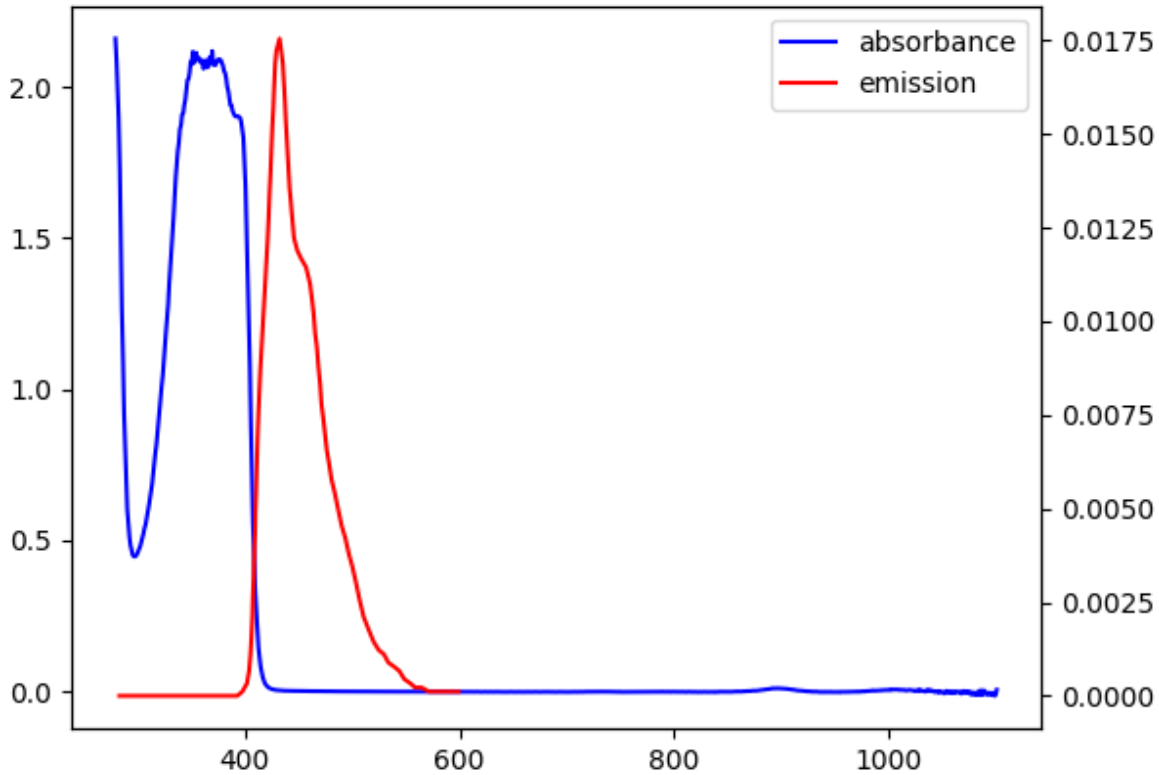
The blue vertical line shows peak WLS emission. 1mm thick. Optimized for low incidence angle.

Experimental data on the ZAOT Dichroic Filters transmittance for incidence angles 0º, 10º, 20º, 30º, 40º, 50º, 60º, without reflective coating (CARLA CATTADORI)



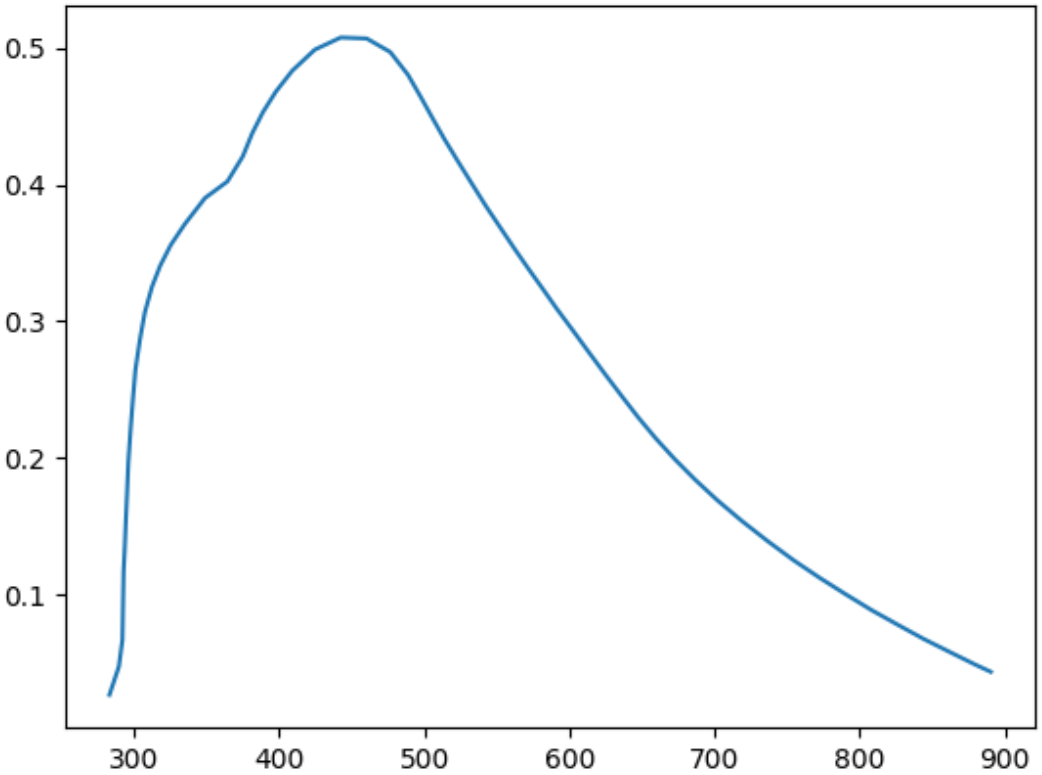
The blue vertical line shows peak WLS emission. 1mm thick. Optimized for low incidence angle.

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). Identical to S13360.

X-ARAPUCAS Supercells with dimples. The SiPMs are 0.1mm apart from the WLS. Dimples can have different radius. SiPMs can have thin laterals that absorb 80% os incoming photons.

See the following htmls in the folder
`dimp_dept_4.3_SiPM_thicn_0.html`
`dimp_dept_4.3_SiPM_thicn_1.4.html`

Supercell simulations results

		Dimple Radius *mm*						
		0	**0.5**	**1**	**1.5**	**2**	**3**	**4.3**
OPTO	*	6.3%	6.8%	7.1%	7.2%	7.1%	6.6%	5.6%
NO A.R.	**	4.2%	4.5%	4.8%	4.9%	4.8%	4.7%	5.1%
ZAOT	*	5.8%	6.3%	6.6%	6.6%	6.5%	6.0%	4.9%
NO A.R.	**	3.7%	4.1%	4.3%	4.4%	4.4%	4.2%	4.8%
ZAOT	*	5.8%	6.3%	6.6%	6.6%	6.5%	6.0%	4.9%
A.R.	**	3.7%	4.1%	4.3%	4.4%	4.4%	4.2%	4.8%

Table: * SiPM without thin laterals. ** SiPM with thin laterals.

The effects of dimples in the WLS

- Dimples make photons passing near a SiPM to exit the WLS.

The effects of dimples in the WLS

- Dimples make photons passing near a SiPM to exit the WLS.
- Dimples make photons exit the WLS farther away from the SiPM.

The effects of dimples in the WLS

- Dimples make photons passing near a SiPM to exit the WLS.
- Dimples make photons exit the WLS farther away from the SiPM.
- Dimple normals always have the "z component" equal zero.

The effects of dimples in the WLS

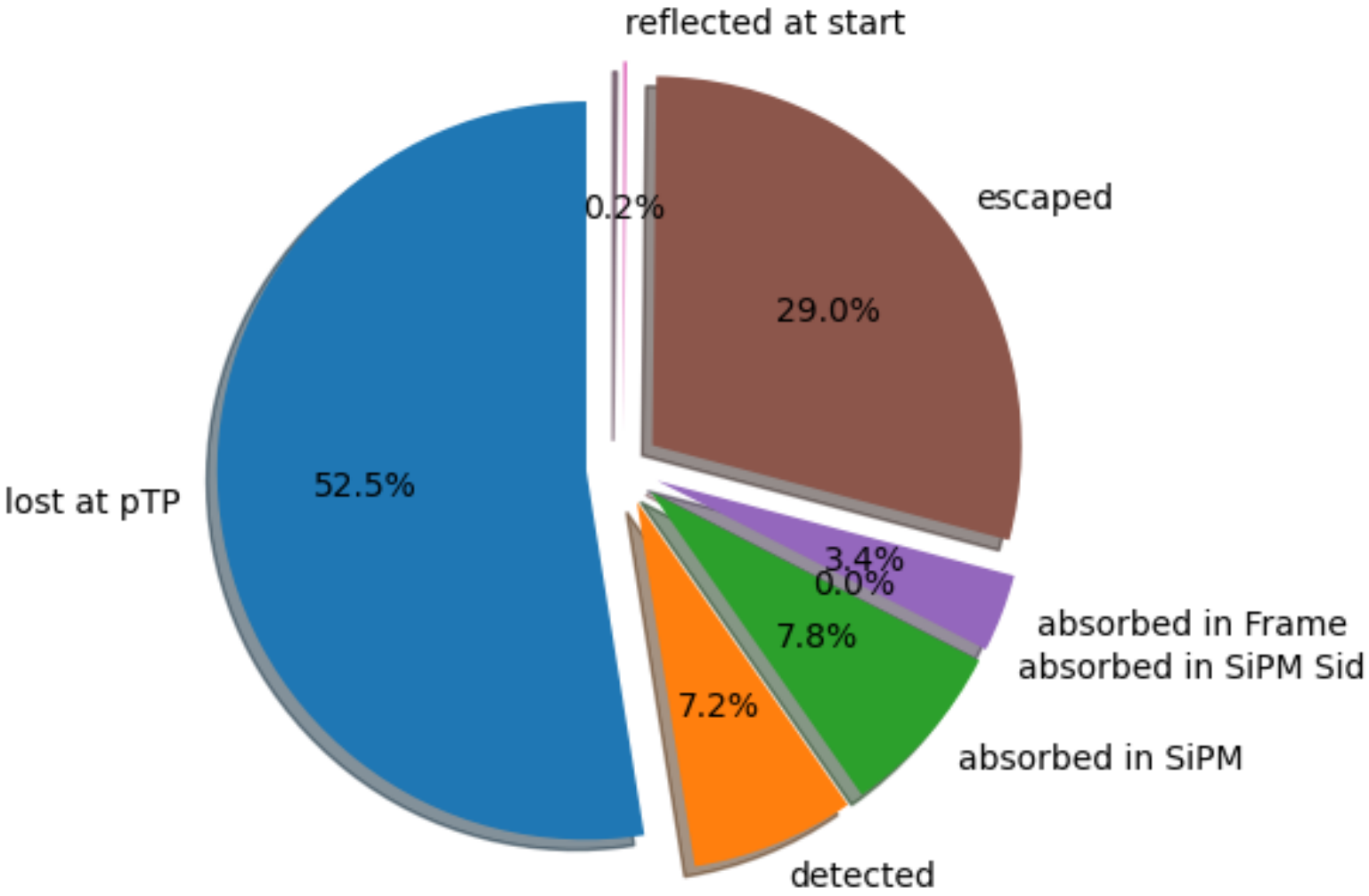
- Dimples make photons passing near a SiPM to exit the WLS.
- Dimples make photons exit the WLS farther away from the SiPM.
- Dimple normals always have the "z component" equal zero. So, when exiting through them, photon directions tend to increase in the z component.

The effects of dimples in the WLS

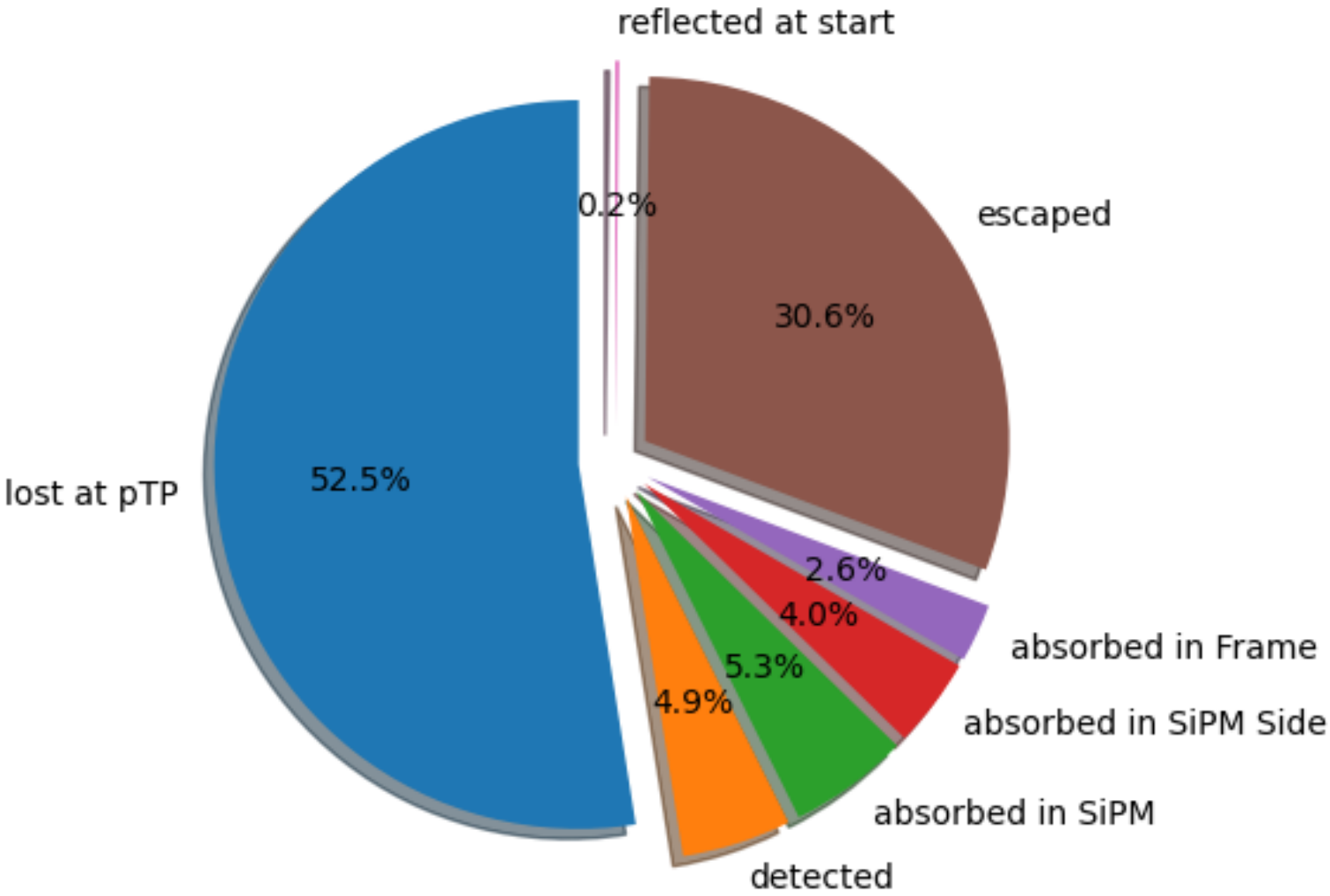
- Dimples make photons passing near a SiPM to exit the WLS.
- Dimples make photons exit the WLS farther away from the SiPM.
- Dimple normals always have the "z component" equal zero. So, when exiting through them, photon directions tend to increase in the z component.

`dimp_dept_3_SiPM_thicn_0.html`

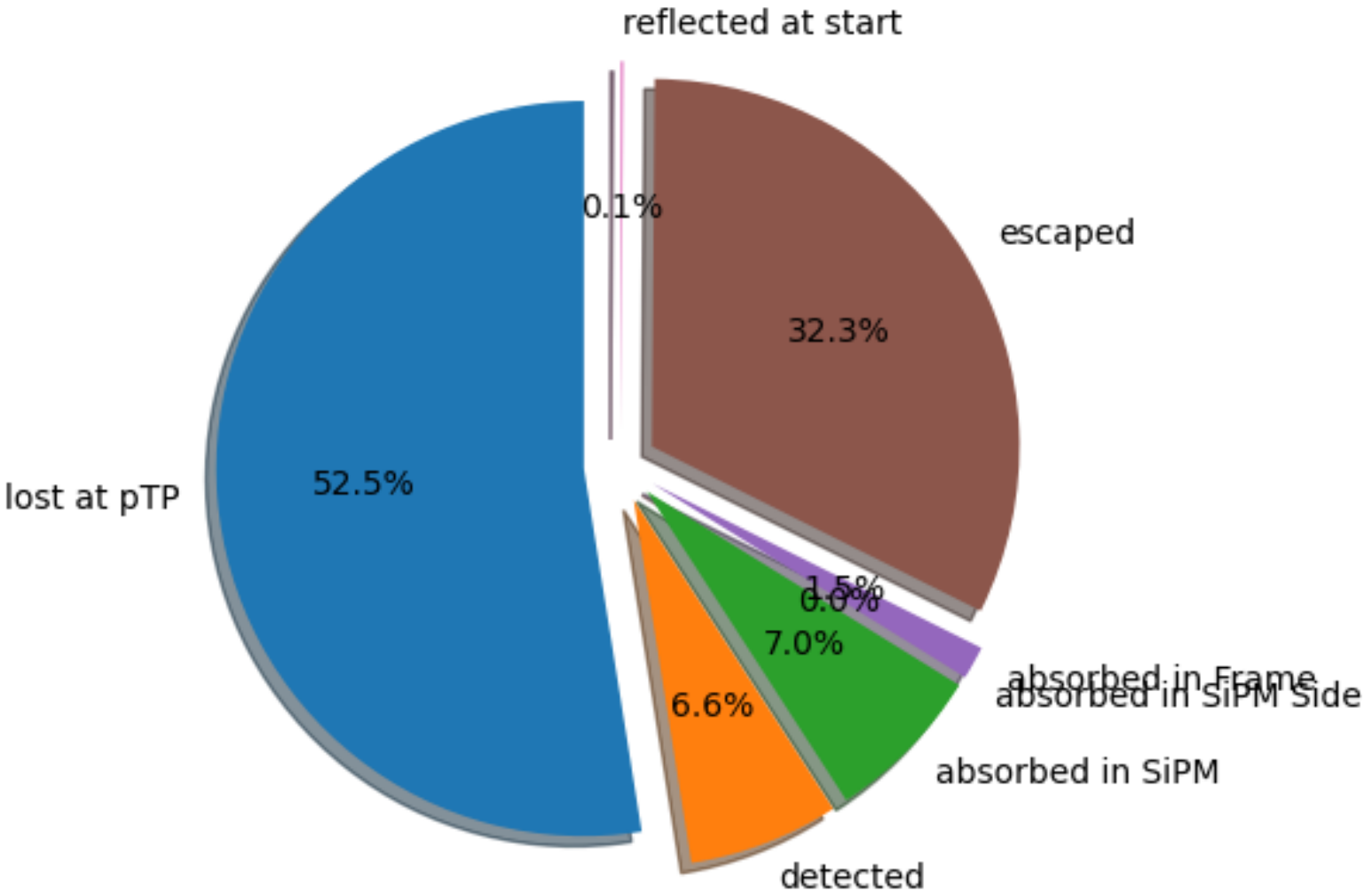
Supercell. Fraction of photons by end destination. OPTO NO A.R. Dimple Radius = 1.5. Without SiPM laterals.



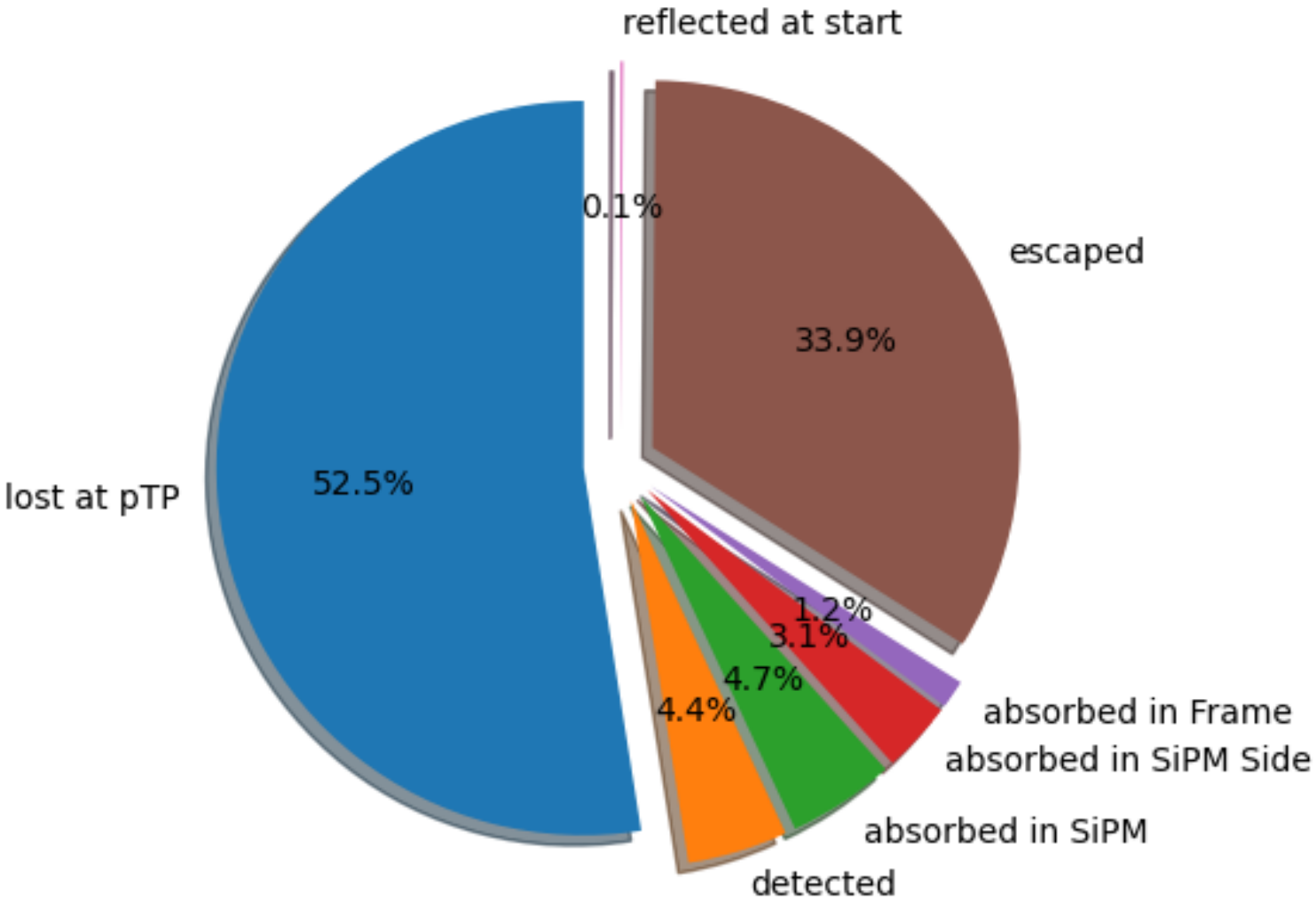
Supercell. Fraction of photons by end destination. OPTO NO A.R. Dimple Radius = 1.5. With SiPM laterals.



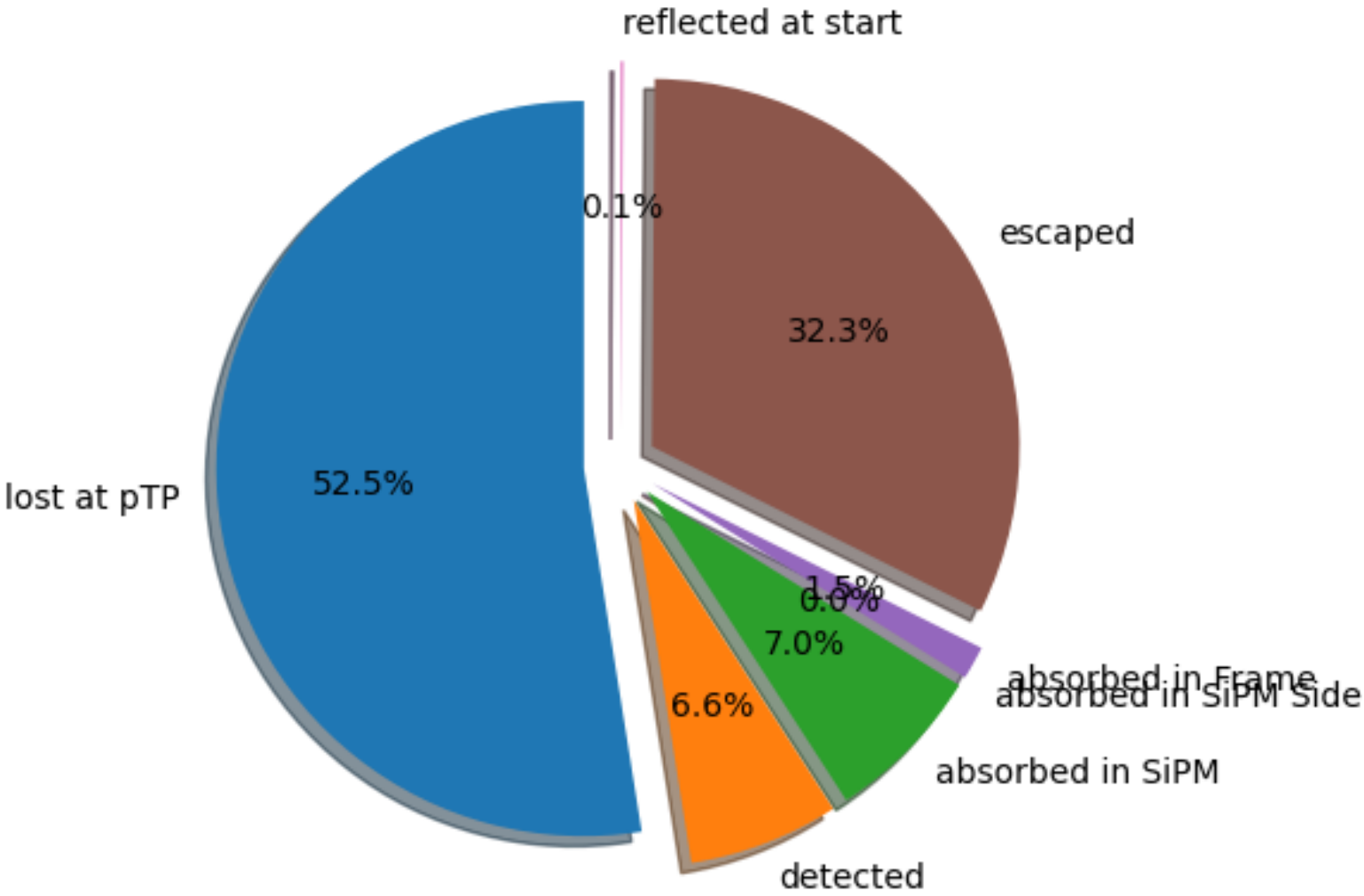
Supercell. Fraction of photons by end destination. ZAOT A.R. Dimple Radius = 1.5. Without SiPM laterals.



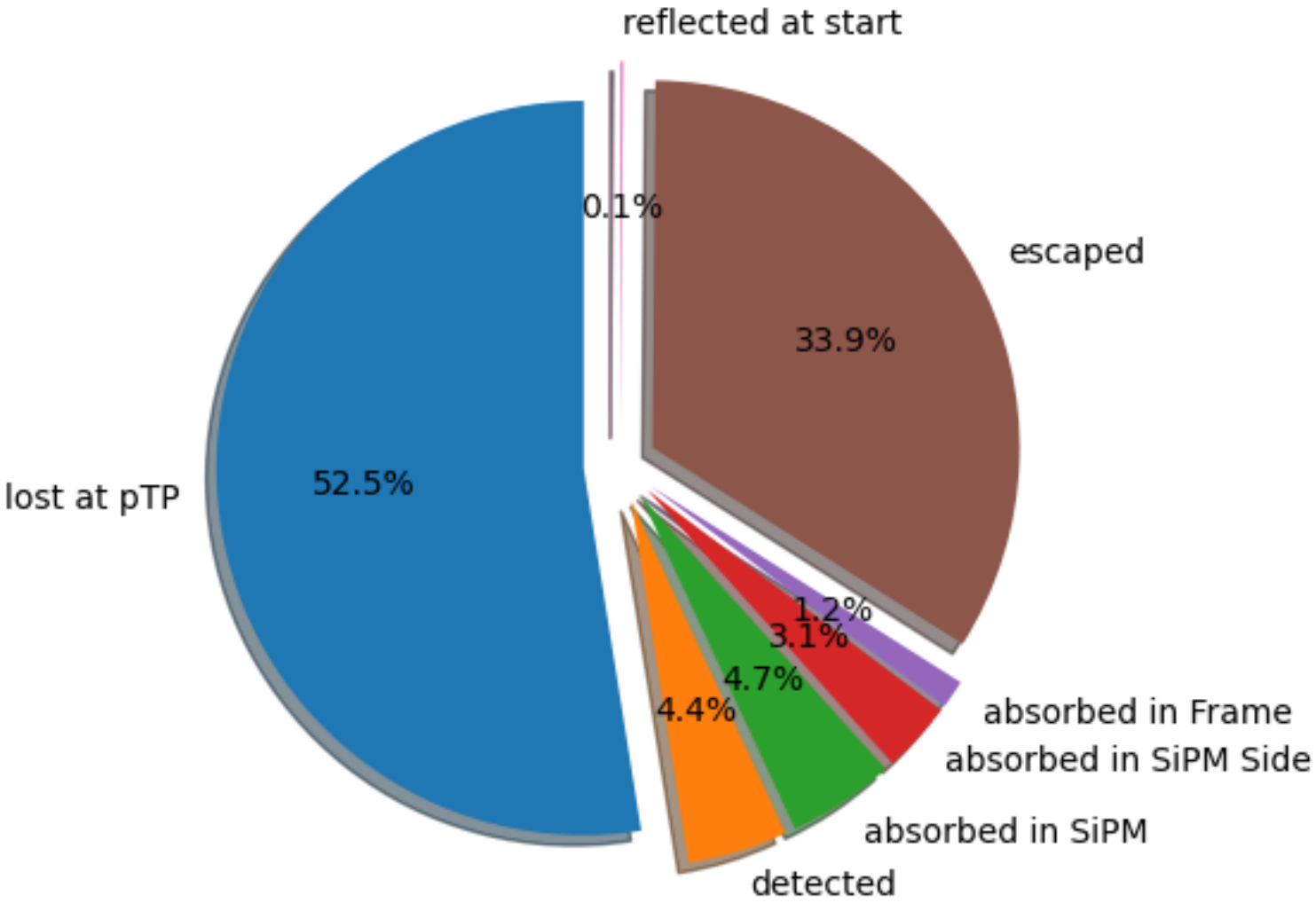
Supercell. Fraction of photons by end destination. ZAOT A.R. Dimple Radius = 1.5. With SiPM laterals.



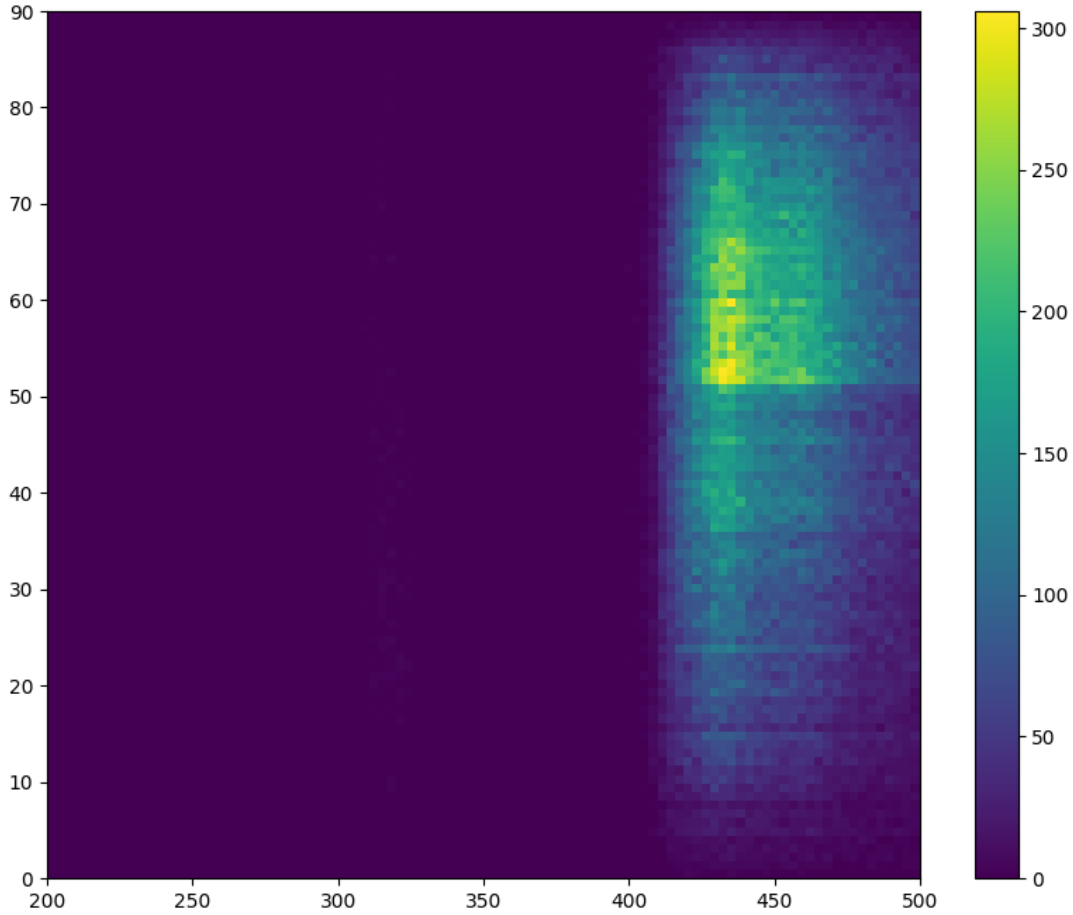
Supercell. Fraction of photons by end destination. ZAOT NO A.R. Dimple Radius = 1.5. Without SiPM laterals.



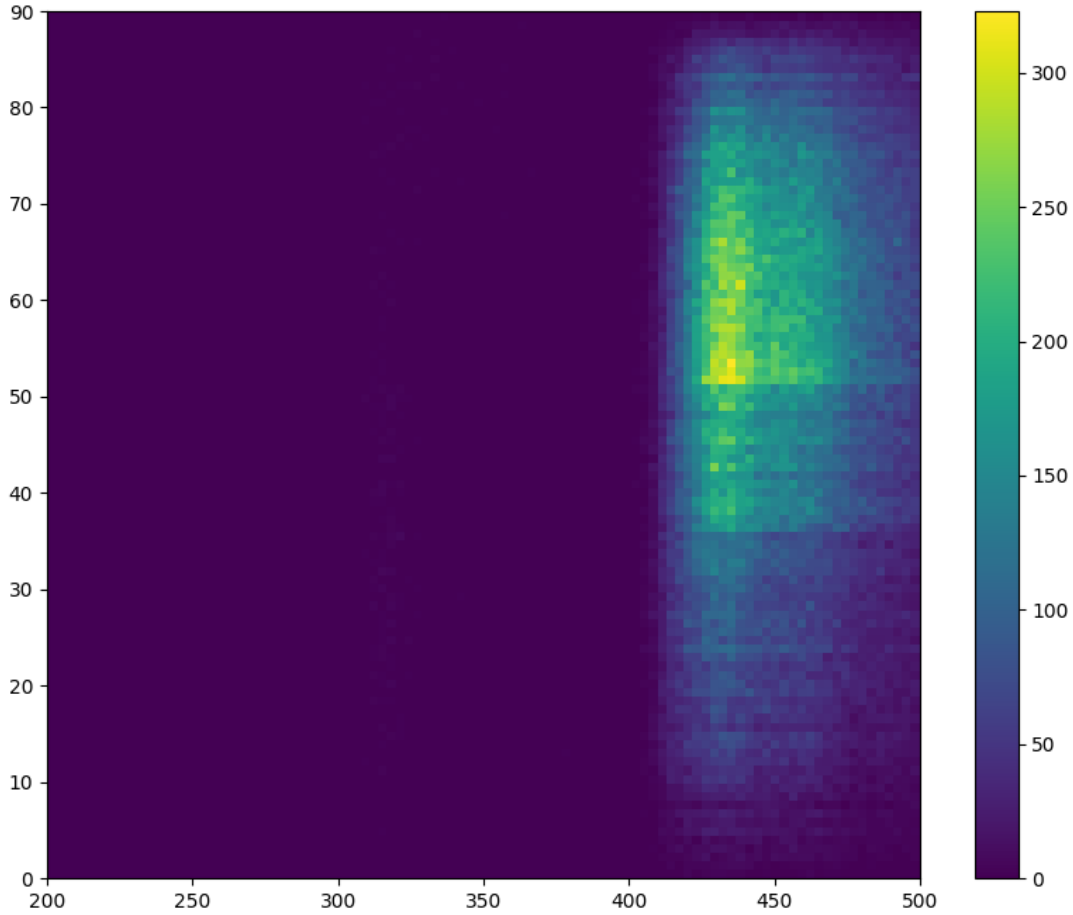
Supercell. Fraction of photons by end destination. ZAOT NO A.R. Dimple Radius = 1.5. With SiPM laterals.



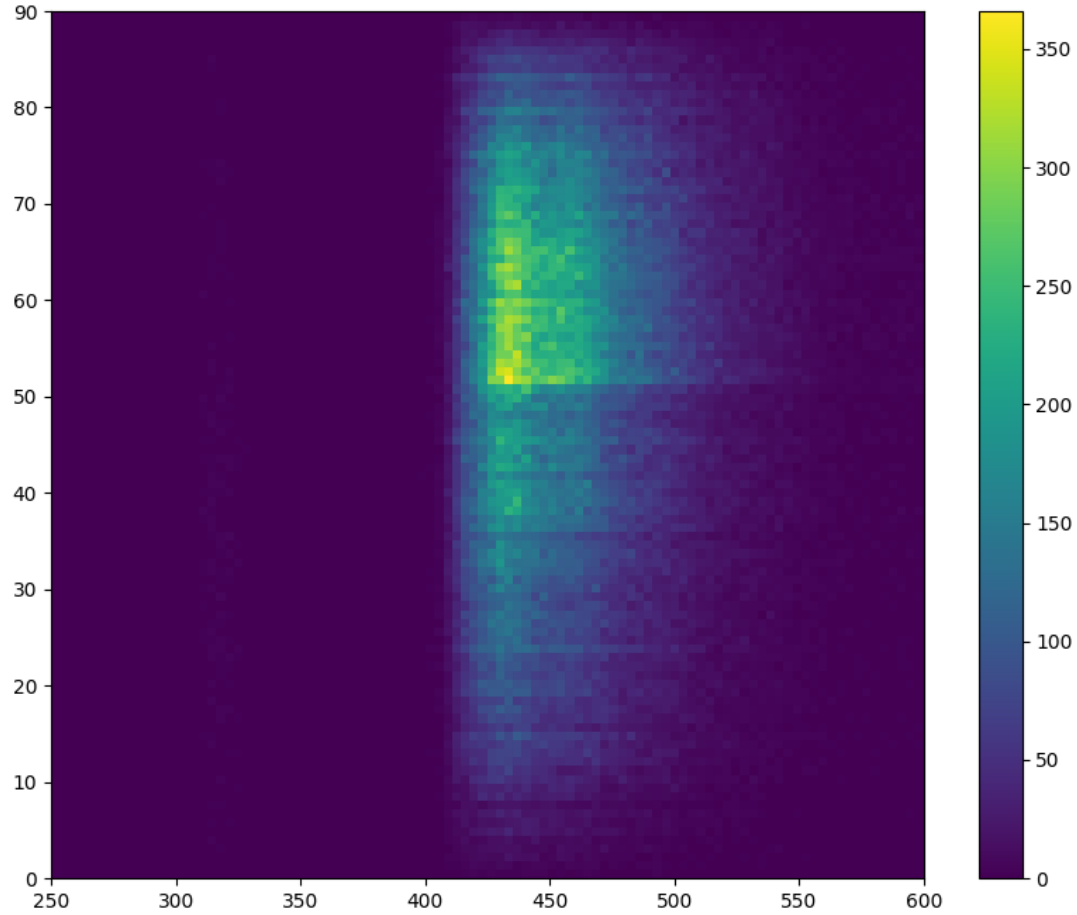
Supercell. Histogram of photons escaped through dichroic filters (wl x inc. angle). OPTO NO A.R. Dimple Radius = 1.5. Without SiPM laterals.



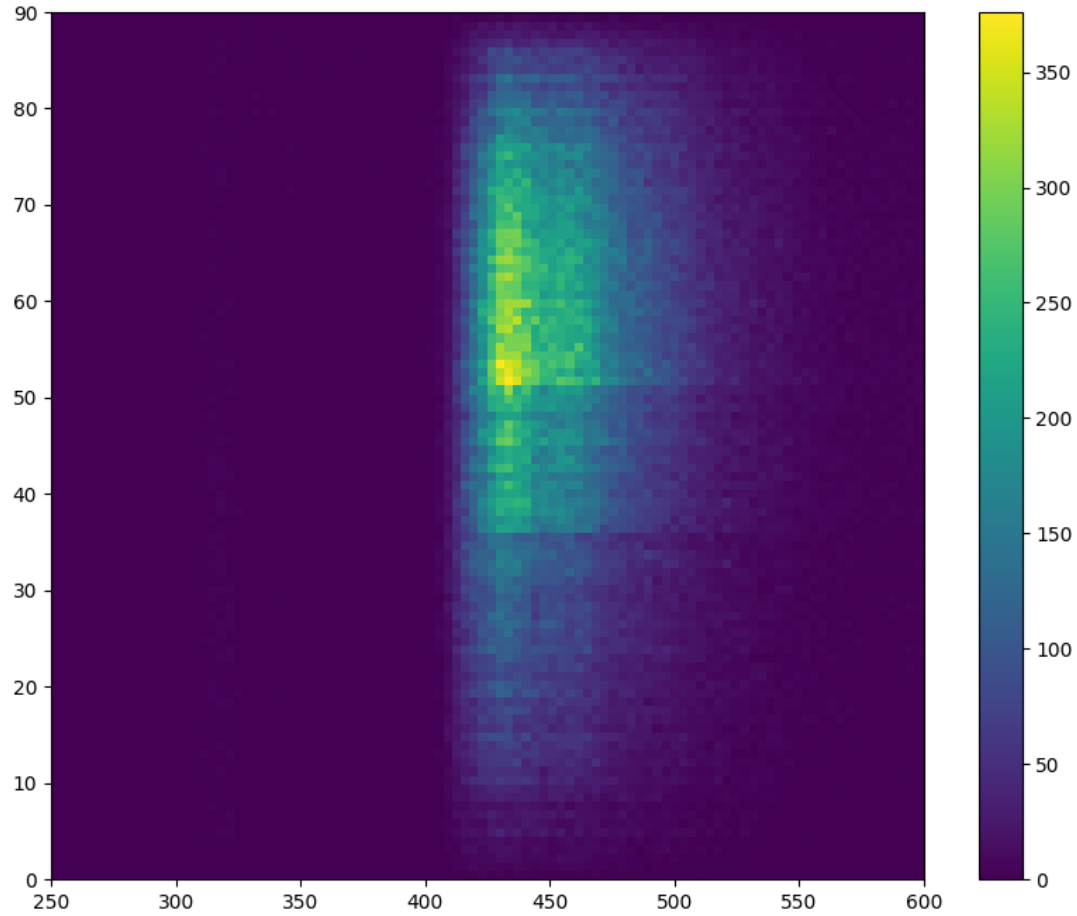
Supercell. Histogram of photons escaped through dichroic filters (wl x inc. angle). OPTO NO A.R. Dimple Radius = 1.5. With SiPM laterals.



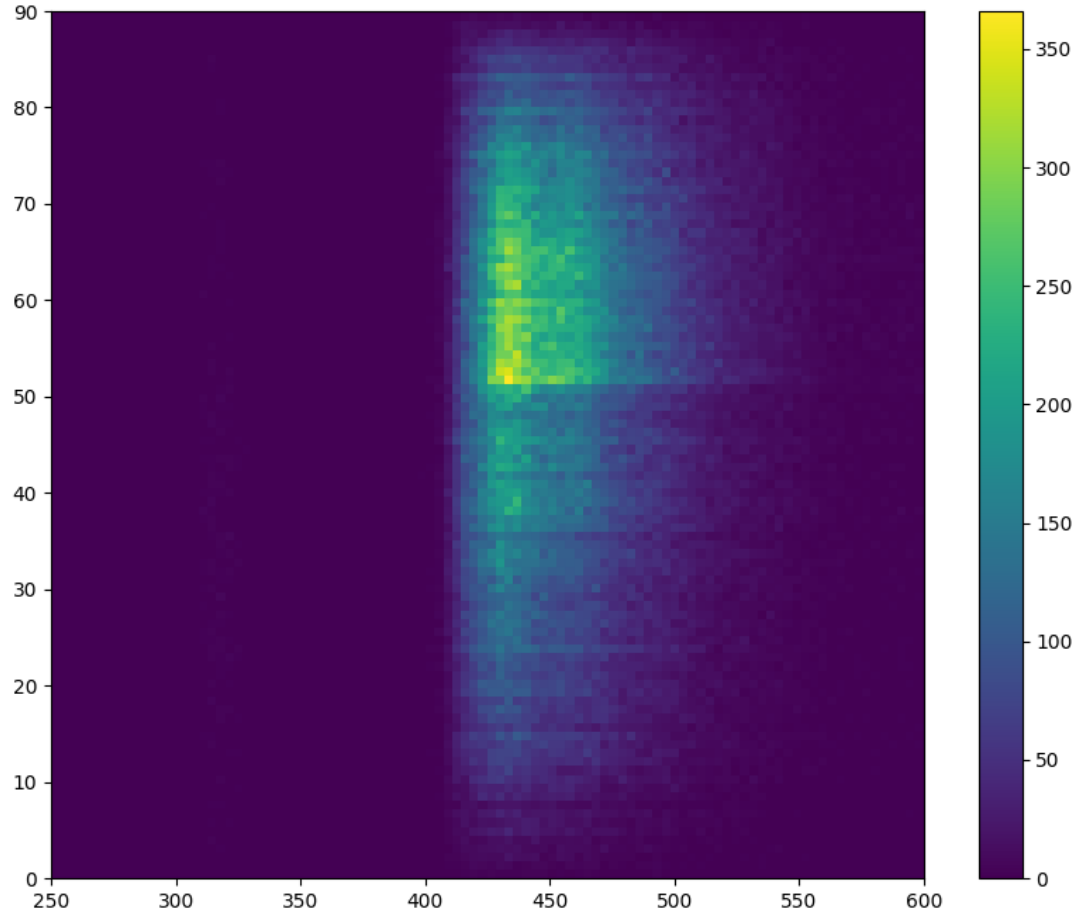
Supercell. Histogram of photons escaped through dichroic filters (wl x inc. angle). ZAOT A.R. Dimple Radius = 1.5. Without SiPM laterals.



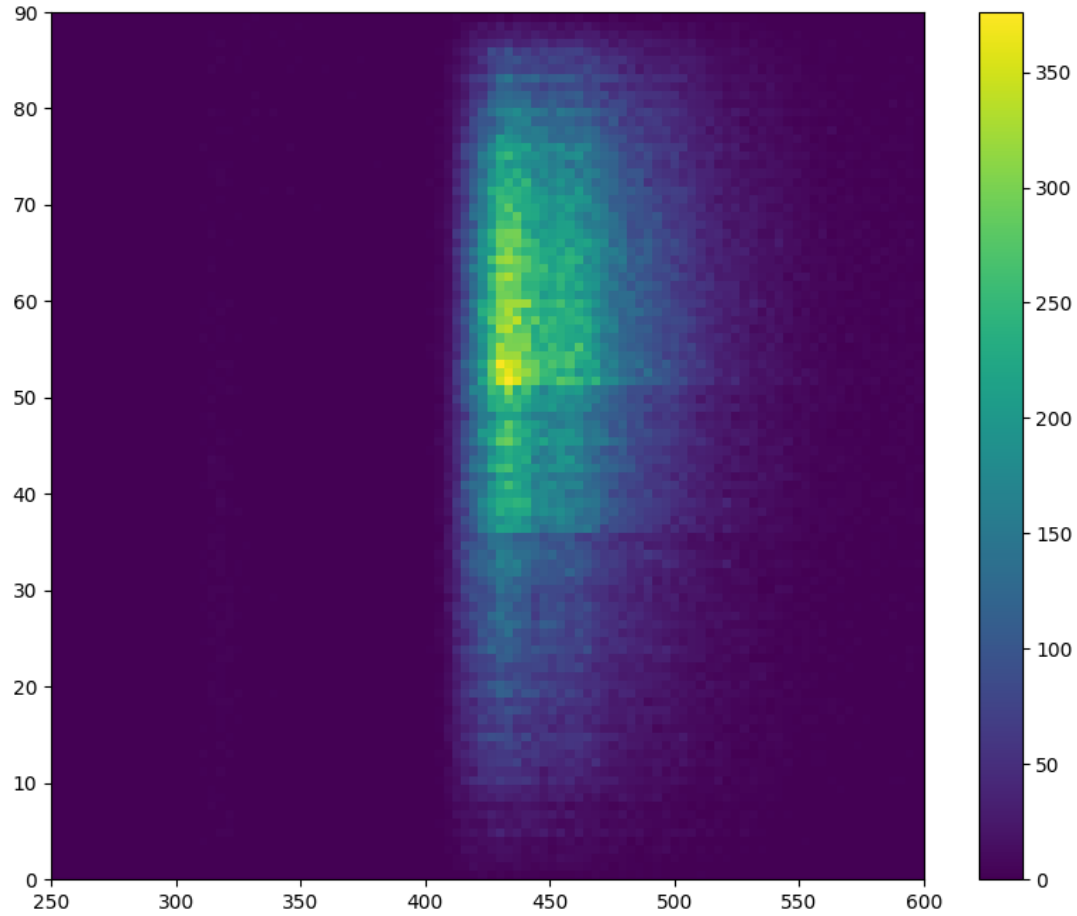
Supercell. Histogram of photons escaped through dichroic filters (wl x inc. angle). ZAOT A.R. Dimple Radius = 1.5. With SiPM laterals.



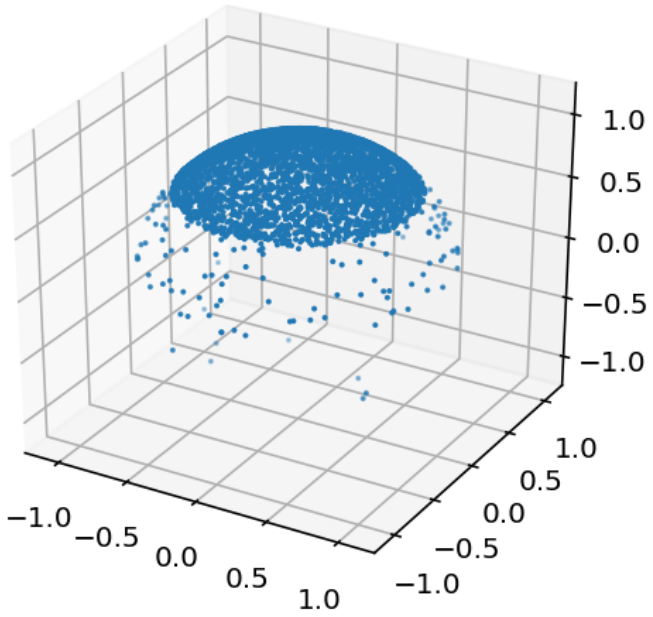
Supercell. Histogram of photons escaped through dichroic filters (wl x inc. angle). ZAOT NO A.R. Dimple Radius = 1.5. Without SiPM laterals.

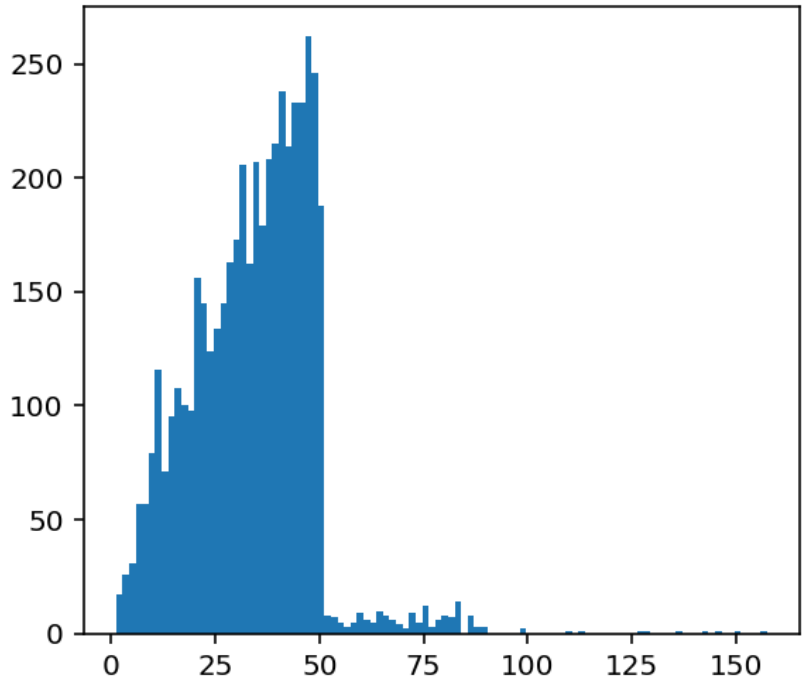


Supercell. Histogram of photons escaped through dichroic filters (wl x inc. angle). ZAOT NO A.R. Dimple Radius = 1.5. With SiPM laterals.

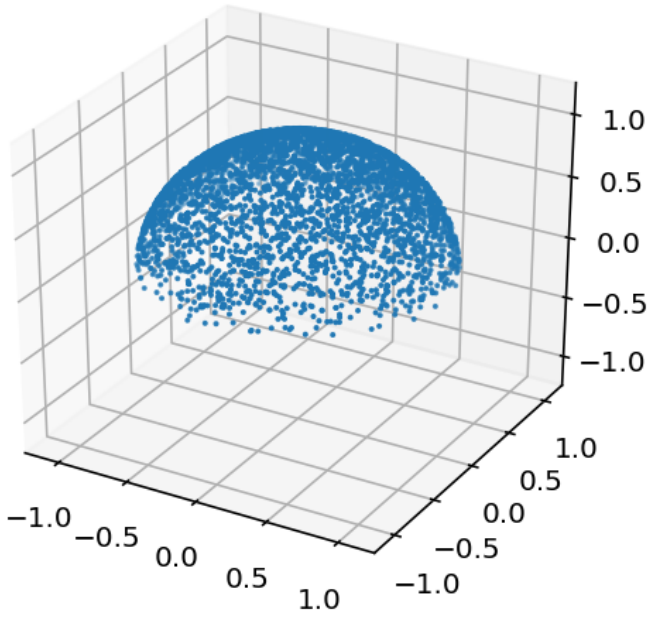


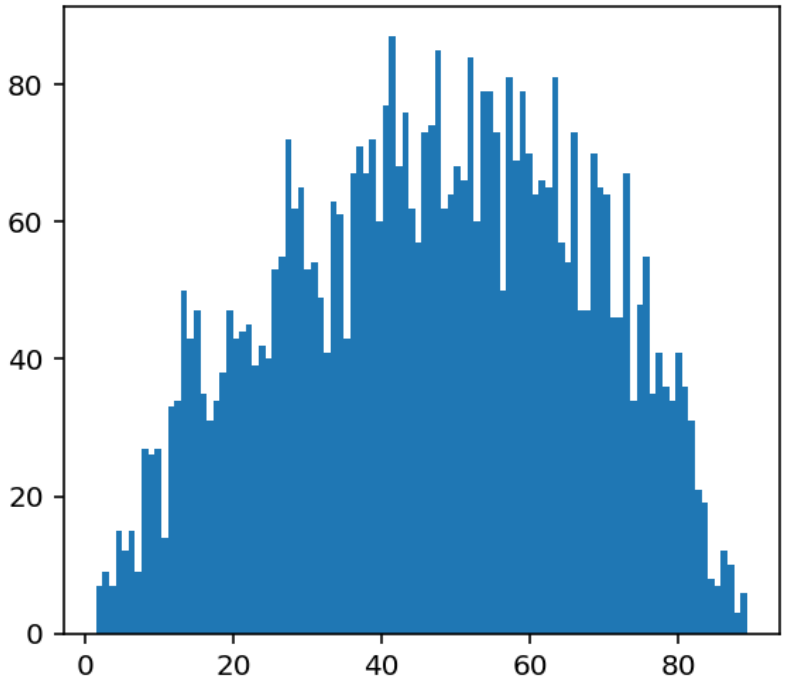
Last but one photon directions for photons escaped through dichroic filters. (before leaving the WLS)





Photon directions when escaping, for photons escaped through dichroic filters. (after refraction)





Conclusions

Our simulations indicate that

- Dimples might increase the efficiency of the Supercell in up to 15%. Smaller ones might be recommendable.

Conclusions

Our simulations indicate that

- Dimples might increase the efficiency of the Supercell in up to 15%. Smaller ones might be recommendable.
- SiPMs should be as close to the WLS as possible.

Conclusions

Our simulations indicate that

- Dimples might increase the efficiency of the Supercell in up to 15%. Smaller ones might be recommendable.
- SiPMs should be as close to the WLS as possible.
- Many photons escape the dichroic filters with high incidence angle.

Conclusions

Our simulations indicate that

- Dimples might increase the efficiency of the Supercell in up to 15%. Smaller ones might be recommendable.
- SiPMs should be as close to the WLS as possible.
- Many photons escape the dichroic filters with high incidence angle.

Conclusions

Our simulations indicate that

- Dimples might increase the efficiency of the Supercell in up to 15%. Smaller ones might be recommendable.
- SiPMs should be as close to the WLS as possible.
- Many photons escape the dichroic filters with high incidence angle.
- Our naive proposal. Click here.