PocarLab NOTE
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Exploring Chroma Simulation Discrepancies: A Comparative Analysis of SolidWorks and Fusion360 Geometries

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Abstract

This report examines discrepancies in simulation results from 3D geometries created in SolidWorks and Fusion360. Despite using identical simulation parameters, variations were observed based on the software used and their settings. This report details the model creation, simulation setup, and execution workflow. Using 1,000,000 photons generated by the source, the comparative analysis highlights differences in numerical outcomes and graphical outputs, exploring potential reasons such as model creation and software-specific settings. The impact on experiment validity and reliability is discussed, leading to recommendations for eliminating these discrepancies. This investigation underscores the importance of understanding software-specific behaviours for accurate simulation outcomes.

1 Motivation

The motivation for this comparison test stems from the logistical and financial constraints associated with using SolidWorks in our lab. Currently, only one computer in the lab is equipped with a SolidWorks license, creating significant limitations for team members needing to generate 3D geometries for Chroma Simulations. Given the high cost of additional SolidWorks licenses, exploring a more economical alternative is essential. Fusion360, free for personal and student use, presents a viable option.

By adopting Fusion360, we could utilize multiple computers for 3D modeling, thereby increasing productivity and reducing costs. However, before making this transition, it is crucial to understand any potential differences in simulation outcomes when using geometries created in SolidWorks versus Fusion360. This report aims to highlight these differences to inform our decision on whether Fusion360 can serve as a suitable replacement for SolidWorks in our lab.

2 Component Comparison

In both the SolidWorks and Fusion360 geometries utilized for the Chroma Analysis, identical components were employed. It is important to note that these components share identical dimensions, material properties, surface properties, and all other relevant factors across both geometries. Figure 1 provides a comprehensive display of the geometry's dimensions, highlighting that the Source-SiPM distance remained consistent between the two models.

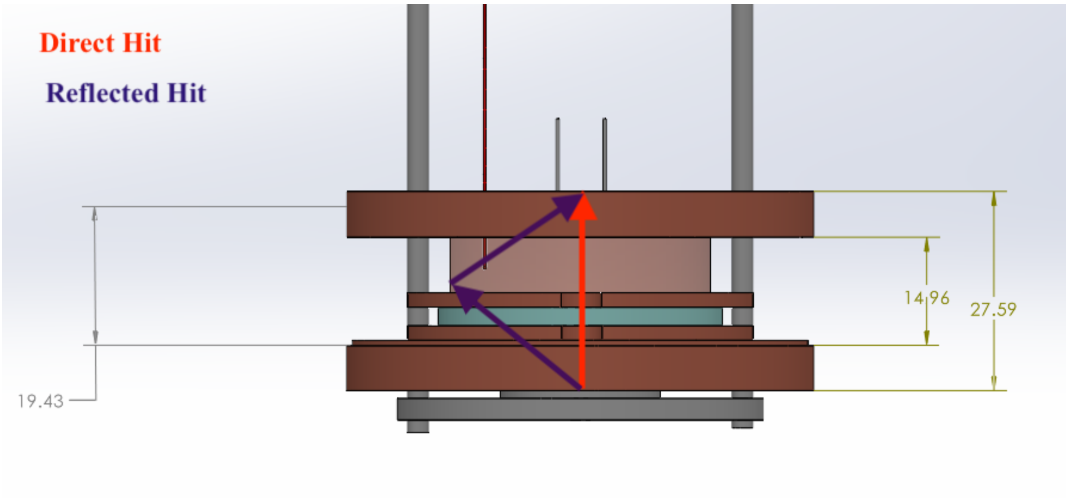

Figure 1: Geometry Schematic

The following are the Chroma-generated visual representations [1] of the geometry from SolidWorks and Fusion360 (Figure 2), along with the components used in this geometry:

1. the Source (red)
2. the Silica Window (blue)
3. the Copper Reflector (orange)
4. the SiPM (gray)

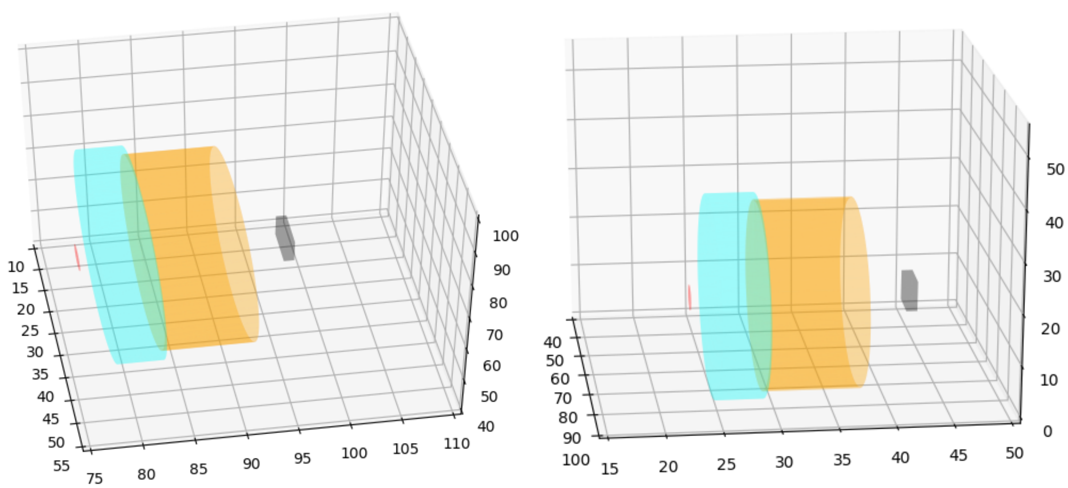

Figure 2: SolidWorks Visual Representation (left) and Fusion360 Geometry Visual Representation (right) generated using the Analysis Manager script

It is noteworthy that the two visual representations are on different x,y,z positions in Fig 2 and Fig 3. This is because geometries generated in different CAD software have different relative origins. However, the visual depiction of both geometries is indistinguishable, thereby confirming that any discrepancies observed in the simulation results are attributable to differences in the software utilized rather than inherent disparities in the components themselves.

[1] The specific steps on how to use a CAD geometry to generate a Chroma simulation are detailed in the Chroma Onboarding Document (on the OneDrive)

3 Photon Transport Efficiency Comparison

In this report, Photon Transport Efficiency (PTE) is defined as the ratio of photons reaching the SiPM to the total photons emitted by the source. It is through differences in PTE that discrepancies between data generated from SolidWorks and Fusion360 geometries were discerned.

Through the Chroma Simulation, the following PTE values were obtained (Seed: 712003):

CAD Software	Resolution	PTE	PTE Uncertainty	Percentage Uncertainty
SolidWorks	Custom: Extra Fine	0.01336	0.00012	0.9%
Fusion360	Medium	0.01324	0.00011	0.9%

Table 1: SolidWorks & Fusion360 Resolution Settings and PTE Data

Here we can see that for every 1,000,000 photons generated by the source, the SiPM in the SolidWorks geometry would be hit with approximately 13360 photons, whereas the SiPM in the Fusion360 geometry would be hit with approximately 13240 photons. This is not a statistically significant difference as the SiPM in the SolidWorks geometry is hit by approximately 1.009 times (or about 0.9%) more photons as compared to that of the Fusion360 geometry, however, we expected the two outputs to be identical as they used the same geometry and all bulk material and surface properties were kept constant.

Presented below is a comparative analysis of the Incident Angle Distribution histograms for the SolidWorks-generated geometry (Figure 3) and the Fusion360-generated geometry (Figure 4). These histograms illustrate the angle at which photons strike the SiPM. The initial peak, spanning from 0 to 13 degrees, represents direct hits—photons emitted by the source that directly reach the SiPM without reflection by the Copper Reflector. The subsequent peak, ranging from 57-64 degrees, indicates reflected hits—photons emitted by the source and reflected by the Copper Reflector before reaching the SiPM.

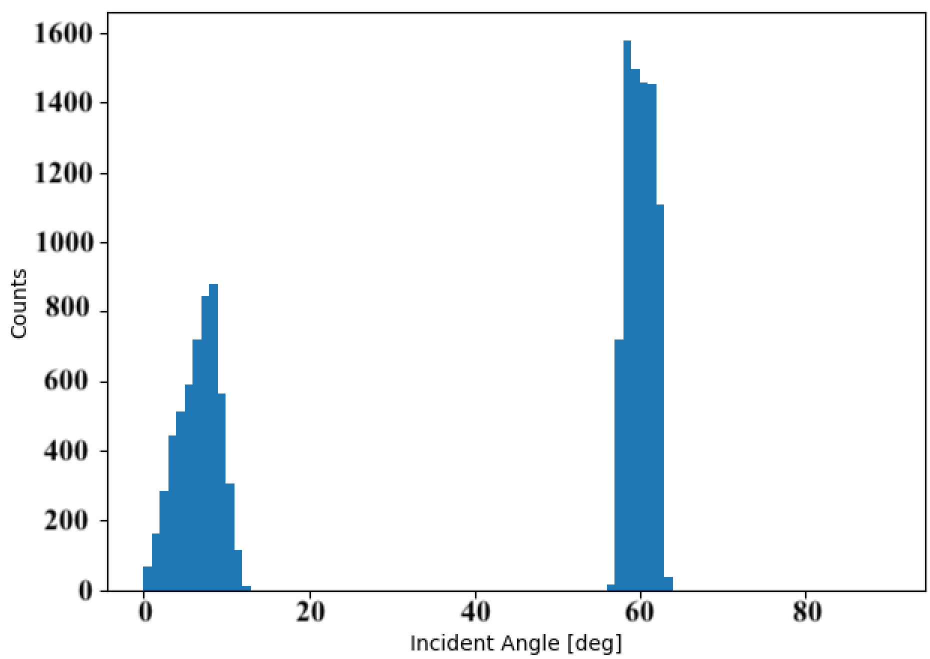

Figure 3: Solidworks (Custom: Fine Resolution) Incident Angle Distribution data which describes the angle at which the photons hit the SiPM. The first peak is the direct photon hit, and the second peak is the reflected photon hit

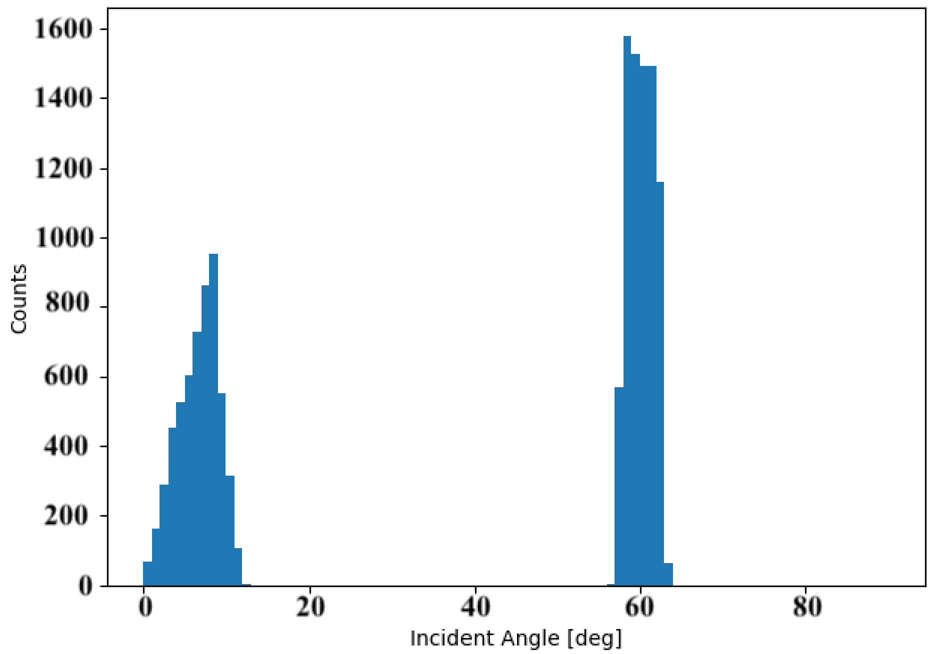

Figure 4: Fusion (Medium Resolution) Incident Angle Distribution data which describes the angle at which the photons hit the SiPM. The first peak is the direct photon hit, and the second peak is the reflected photon hit

Table 2 provides a breakdown of direct hit Photon Count per degree, offering insights into the disparities between data obtained from the SolidWorks and Fusion360 geometries.

Incident Angle	SolidWorks Photon Count	Fusion360 Photon Count
1	68	67
2	161	161
3	283	282
4	444	442
5	514	514
6	691	591
7	717	715
8	844	844
9	878	934
10	565	541
11	305	309
12	116	104
13	13	2
Total	5599	5506

Table 2: SolidWorks Vs Fusion360 Direct hit - Photon counts per incident angle. This table describes the direct photon hit peak which was shown in the histogram in Figures 3 and 4

After analyzing the data in Table 2 we observe that the direct hit data for the photon counts per incident angle is very similar, with only a few discrepancies that might be the result of the source and the SiPM's characteristic assigned by the 3D model software.

Table 3 provides a breakdown of reflected hit Photon Count per degree, offering insights into the disparities between data obtained from the SolidWorks and Fusion360 geometries.

Incident Angle	SolidWorks Photon Count	Fusion360 Photon Count
57	16	4
58	717	557
59	1579	1548
60	1494	1497
61	1456	1464
62	1453	1464
63	1109	1138
64	37	62
Total	7861	7734

Table 3: SolidWorks Vs Fusion360 Reflected hit - Photon counts per incident angle. This table describes the reflected photon hit peak which was shown in the histogram in Figures 3 and 4

After analyzing the data in Table 3 we observe that the reflected hit data for the photon counts per incident angle has a larger discrepancy, along with the differences in the direct hit data could be caused by a difference in resolution in the STL files generated by the 2 3D modelling software. This hypothesis is further supported by the observation that the reflected hit data has a larger discrepancy, as a difference in resolution would have a larger impact on the reflectivity of a curved surface.

A Two-Sample Unpaired T-Test [2] was conducted to evaluate the significance of the differences in data obtained from the SolidWorks and Fusion360 geometries. This analysis involved running Chroma Simulations using 15 randomly selected seeds for both geometries. For each seed, the simulation was performed separately for the SolidWorks and Fusion360 geometries. The resulting data was then subjected to the T-test to determine if the observed differences between the two sets of results were statistically significant.

[2] Website used for the T-Test: https://www.meta-calculator.com/t-test-calculator.php?panel-406-t-tests-input

The following was the data used:

Seed	SolidWorks_Cust_Fine PTE	Fusion360 (Medium) PTE
3591	0.01349	0.01338
8025	0.01340	0.01329
12043	0.01337	0.01329
2499	0.01366	0.01356
30393	0.01350	0.01343
5917	0.01325	0.01317
1322	0.01366	0.01355
10620	0.01320	0.01307
19143	0.01337	0.01324
20384	0.01336	0.01326
10583	0.01343	0.01333
4841	0.01337	0.01327
1632	0.01371	0.01357
7887	0.01338	0.01328
26490	0.01341	0.01334

Table 4: Comparison of PTEs obtained from 10^6-photon simulations of the nominally same geometry using SolidWorks and Fusion360 with settings found to give similar results. For reference, the error on these numbers is 0.00012 (you can verify this using the count numbers in the example summarized in Tables 2 and 3).

The two-tailed p-value was found to be 0.1112; because our p-value (0.1112) for the two sample unpaired t-test is more than the standard significance level of 0.05, we fail to reject the null hypothesis. The results are statistically insignificant when running simulations with 1,000,000 photons generated by the source. Therefore, both SolidWorks and Fusion360 can be used interchangeably to generate geometries for Chroma simulations, however, we should be mindful of their resolution settings and the number of photons being generated by the source. This conclusion is only valid if the SolidWorks geometry is generated using the Custom-Ext-Fine resolution setting, and the Fusion360 geometry is generated using the standard Medium preset, and the number of photons being simulated is 1,000,000.

To further understand how resolution affects the results of the Chroma simulation, we conducted other tests to see the degree to which a variation in the resolution would affect the PTE.

4 PTE Vs Resolution

To investigate the impact of resolution settings on the PTE, an additional geometry, SolidWorks_Coarse was created using SolidWorks. This geometry mirrors the configuration of the SolidWorks geometry depicted in Figure 1. However, during the saving process of the STL files, the resolution setting was adjusted to the "coarse" preset. Conversely, the SolidWorks geometry represented in Figure 1 was saved with a custom resolution, designated as SolidWorks_Cust_Ext_Fine for this section [3].

A comparison between these two geometries enables an assessment of whether the resolution of the generated STL files influences the PTE of the Chroma Simulation.

[3] it should be noted that SolidWorks_Cust_Ext_Fine is completely identical, even in resolution, to the one in Figure 1

The following were the resolution settings used to generate STL files for SolidWorks_Cust_Ext_Fine and SolidWorks_Coarse:

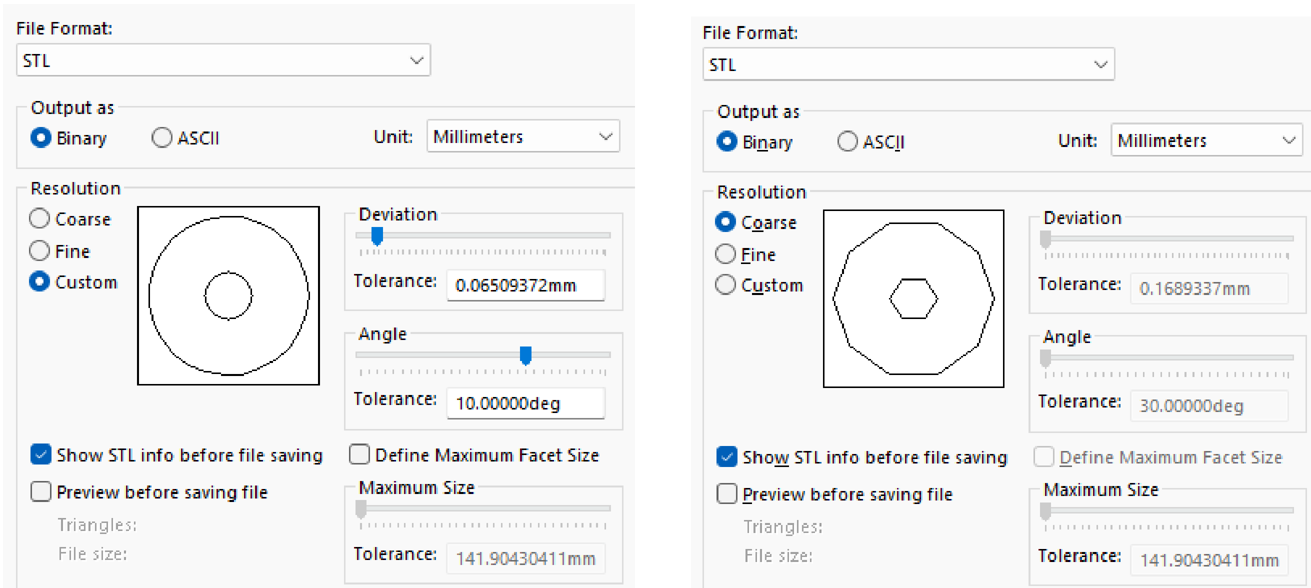

Figure 5: STL file import settings for SolidWorks_Cust_Ext_Fine (left) and SolidWorks_Coarse (right).

The Deviation Slider adjusts the "Deviation Tolerance", which controls whole-part tessellation. Lower numbers generate files with greater whole-part accuracy. The Angle Slider adjusts the "Angle Tolerance", which controls small-detail tessellation. Lower numbers generate files with greater small-detail accuracy, but those files take longer to generate. The Maximum Facet Size specifies the facet's maximum length (triangle). The Maximum Size slider adjusts the maximum size Tolerance of the facet. Through the Chroma Simulation, the following PTE values were obtained (Seed: 712003):

CAD Software	Resolution	PTE	Absolute Uncertainty	Percentage Uncertainty
SolidWorks	Custom: Extra Fine	0.01336	0.000116	0.87%
SolidWorks	Coarse	0.01268	0.000113	0.89%

Table 5: SolidWorks (Custom:Fine) & SolidWorks (Coarse) Resolution Settings and PTE Data

Here we can see that for every 1,000,000 photons generated by the source, the SiPM in the SolidWorks_Cust_Ext_Fine geometry would be hit with 13360 photons, whereas the SiPM in the SolidWorks_Coarse geometry would be hit with 12680 photons. This is a significant difference as the SiPM in the SolidWorks_Cust_Ext_Fine geometry is hit by approximately 1.053 times (or about 5.3%) more photons as compared to that of the SolidWorks_Coarse geometry.

Presented herein is the side-by-side comparison of the Incident Angle Distribution histogram for the SolidWorks_Cust_Ext_Fine (Figure 6) and the SolidWorks_Coarse geometry (Figure 7), accompanied by Table 6 and Table 7 illustrating the Photon Count per degree for the two geometries.

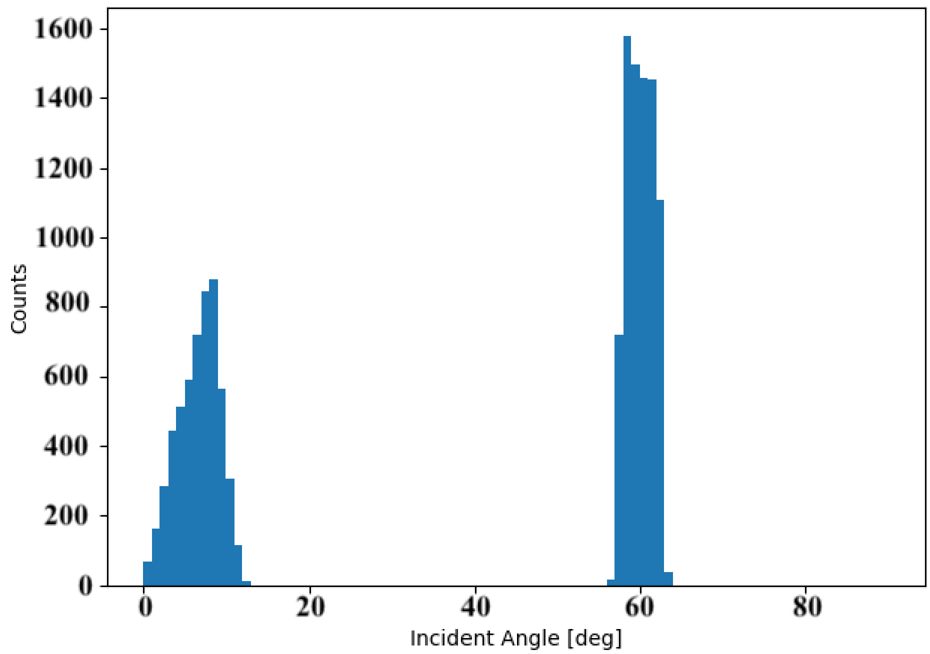

Figure 6: SolidWorks_Cust_Ext_Fine Incident Angle Distribution data which describes the angle at which the photons hit the SiPM. The first peak is the direct photon hit, and the second peak is the reflected photon hit

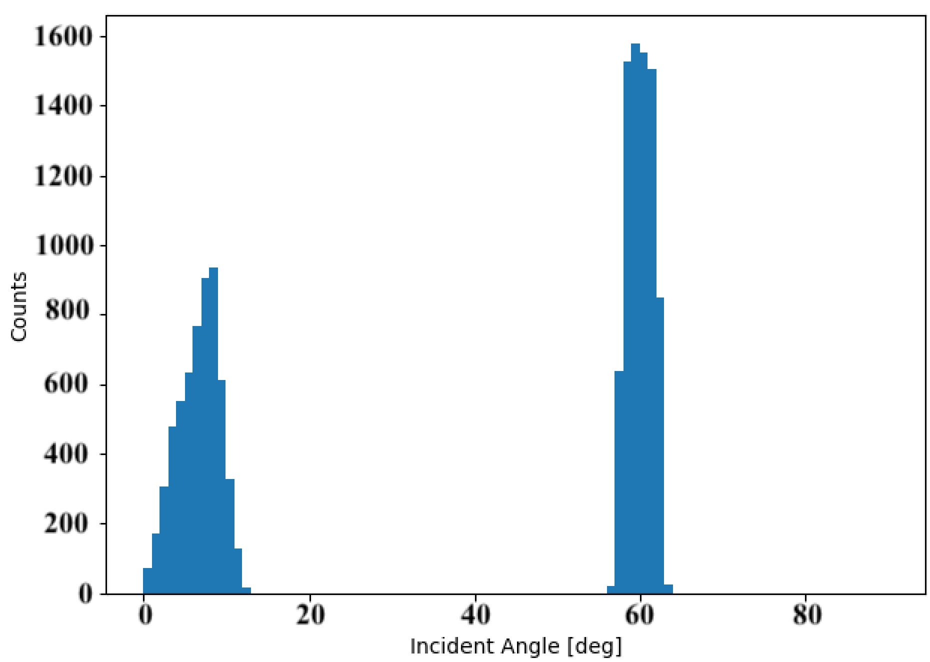

Figure 7: SolidWorks_Coarse Incident Angle Distribution data which describes the angle at which the photons hit the SiPM. The first peak is the direct photon hit, and the second peak is the reflected photon hi

Incident Angle	SolidWorks_Cust_Fine Photon Count	SolidWorks_Coarse Photon Count
1	68	68
2	161	160
3	283	283
4	444	444
5	514	514
6	591	591
7	717	717
8	844	845
9	878	873
10	565	572
11	305	305
12	116	119
13	13	15
Total	5499	5506

Table 6: SolidWorks_Cust_Ext_Fine Vs SolidWorks_Coarse: Direct hit - Photon counts per incident angle. This table describes the direct photon hit peak which was shown in the histogram in Figures 6 and 7

Incident Angle	SolidWorks_Cust_Fine Photon Count	SolidWorks_Coarse Photon Count
57	16	20
58	717	594
59	1579	1423
60	1494	1474
61	1456	1447
62	1453	1403
63	1109	794
64	37	23
Total	7861	7178

Table 7: SolidWorks_Cust_Ext_Fine Vs SolidWorks_Coarse: Reflected hit - Photon counts per incident angle. This table describes the reflected photon hit peak which was shown in the histogram in Figures 6 and 7

After analysing the data from Table 6 and Table 7 we observe that the direct hit photon counts are very similar, the largest discrepancies are observed when comparing the reflected angle data. This aligns with the PTE analysis above as the SolidWorks_Cust_Ext_Fine geometry has a larger photon count for every reflected angle in comparison to the SolidWorks_Coarse geometry.

The same was observed when we analysed the PTE data using a Fusion360 geometry of 3 varying resolution settings, namely: Low, Medium, and High.

The following was the result (Seed: 712003):

CAD Software	Resolution	PTE	Absolute Uncertainty	Percentage Uncertainty
Fusion360	Low	0.01324	0.000115	0.87%
Fusion360	Medium	0.01353	0.000116	0.86%
Fusion360	High	0.01366	0.000117	0.85%

Table 8: Fusion360 (Low), Fusion360 (Medium), and Fusion360 (High) Resolution Settings and PTE Data

This observation helps us conclude that the finer the resolution, the higher the photon count for the reflected hit photon counts. Furthermore, we can conclude that the resolution of the STL generated has a direct impact on the PTE. In the following section, we dive into tessellation and it's affect on resolution, and the factors that affect the tessellation of a geometry.

5 Surface Tessellation and Factors Affecting Tessellation

The tessellation of a 3D geometry refers to the process of subdividing its surface into smaller triangles. This subdivision helps in accurately representing the shape and details of the geometry in digital simulations. The higher the tessellation, the greater the number of triangles that constitute the surface. As a result, the resolution of the geometry becomes finer, capturing more intricate details and smoother surfaces. This increased detail can improve the accuracy and precision of simulations and renderings, as the geometry more closely approximates the ideal geometry designed in the CAD software. This is especially relevant for smooth round geometries, which apply to the Teflon and Copper reflectors. The finer the geometry, the higher the tessellation. As we saw from the Fusion360 data above, as the resolution increased from Low to High, we saw a steady increase in the PTE. The following figures help better demonstrate the difference in tessellation of the geometries:

Fusion360 Low PTE: 0.01324 ± 0.000115

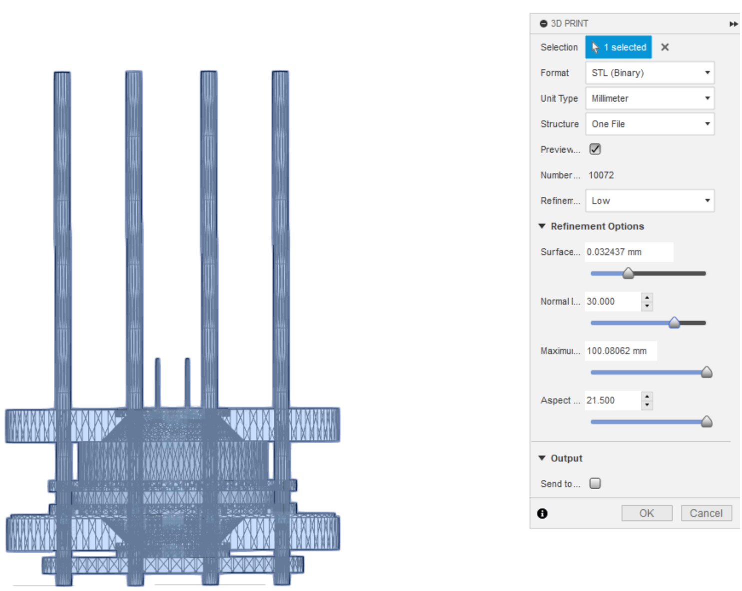

Figure 8: Fusion360 Low Tessellation

Fusion360 Medium PTE: 0.013535 ± 0.000116

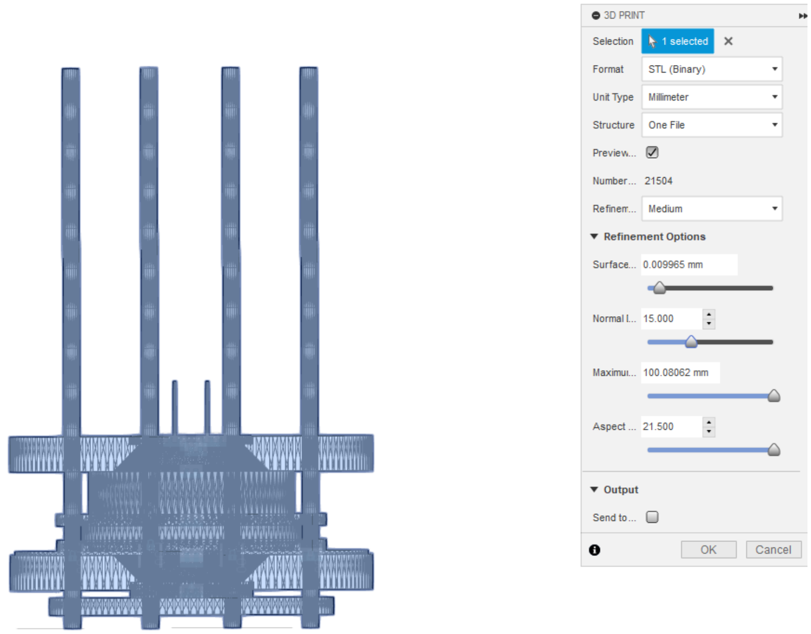

Figure 9: Fusion360 Med Tessellation

Fusion360 High PTE: 0.013664 ± 0.000117

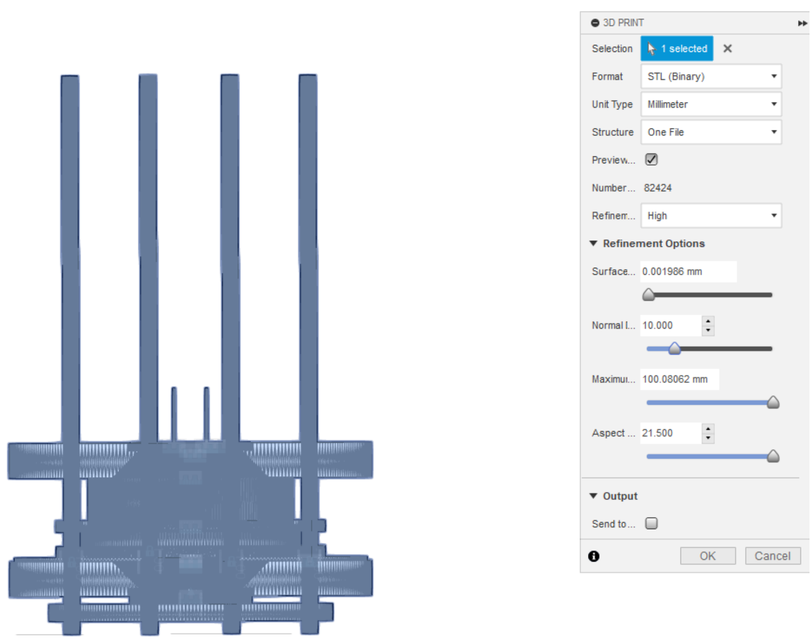

Figure 10: Fusion360 High Tessellation

5.1 Factors That Affect Tessellation

5.1.1 SolidWorks

While using SolidWorks, we observed that between the two parameters: Deviation Tolerance and Angle Tolerance. It was the Deviation Tolerance factor that significantly impacted the tessellation of the geometry and, consequently, the Photon Transport Efficiency (PTE). In comparison, the Angle Tolerance had a negligible effect on the PTE results.

To further understand the extent to which Deviation Tolerance affects the PTE, we kept all other factors constant and simulated varying Deviation Tolerance values, subsequently analyzing their PTE results. This approach allowed us to isolate the influence of Deviation Tolerance and assess its direct impact on the simulation outcomes. The following was the result:

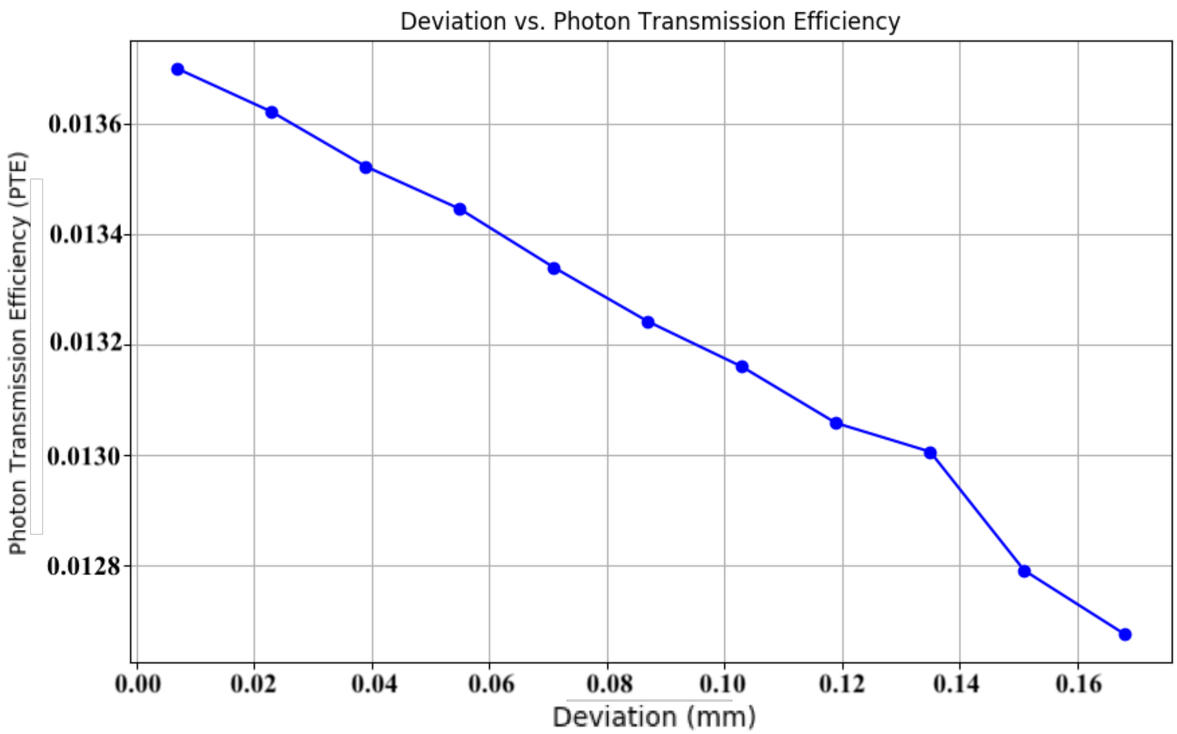

Figure 11: SolidWorks Deviation Tolerance Vs PTE graph

5.1.2 Fusion360

While using Fusion360, similar to SolidWorks, we observed that between the two parameters—Surface Deviation and Normal Deviation—it was the Surface Deviation factor that significantly impacted the tessellation of the geometry and, consequently, the Photon Transport Efficiency (PTE). In comparison, the Normal Deviation had a negligible effect on the PTE results.

To further understand the extent to which Surface Deviation affects the PTE, we kept all other factors constant and simulated varying Surface Deviation values, subsequently analyzing their PTE results. This approach allowed us to isolate the influence of Surface Deviation and assess its direct impact on the simulation outcomes.

The following was the result:

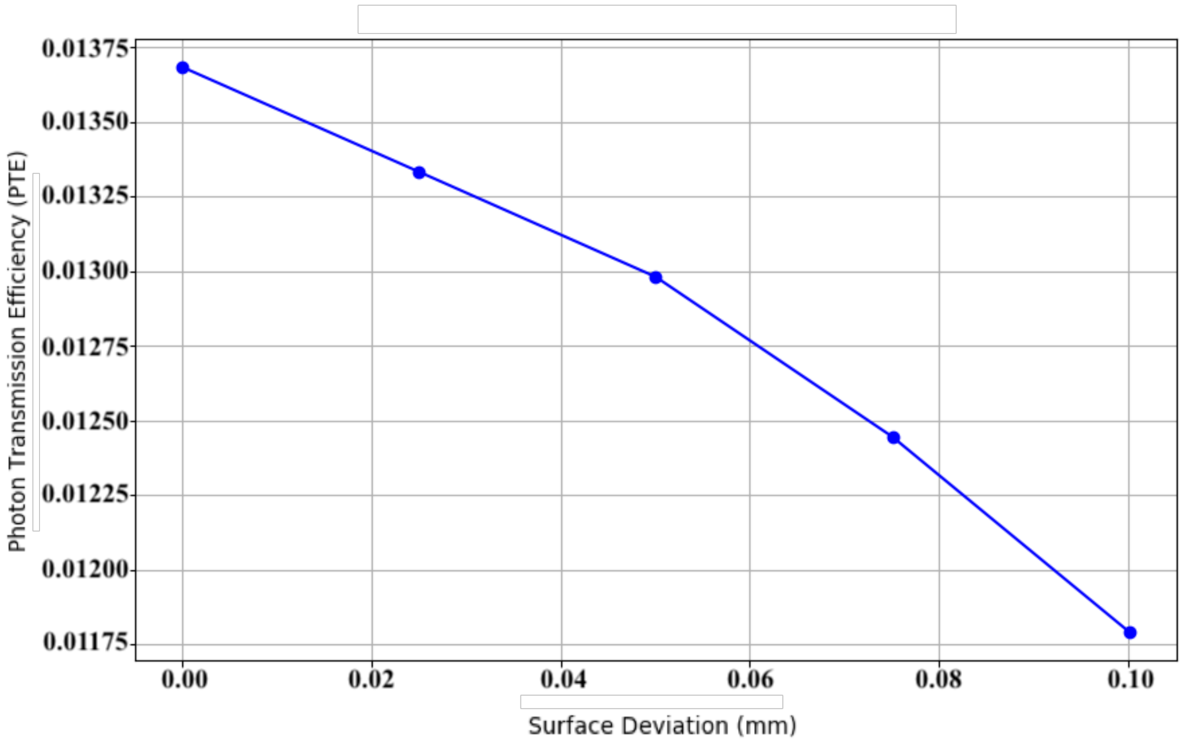

Figure 12: Fusion360 Surface Deviation Vs PTE graph

6 Precautions when importing CAD models into Chroma

Upon examining the five geometries (SolidWorks_Cust_Ext_Fine, SolidWorks_Coarse, and Fusion360 Low, Medium, and High), it became evident that discrepancies in the PTE for identical geometries stemmed from variations in the resolution of the generated STL files. To mitigate such issues in future simulations, it is imperative to ascertain the resolution settings employed for the SolidWorks_Cust_Ext_Fine geometry, which align with those utilized in prior analyses, and apply these settings consistently in Fusion360. In essence, we can use SolidWorks and Fusion360 interchangeably, as long as we use the Custom-Ext-Fine resolution settings for SolidWorks, and use the Medium preset for Fusion360.

Standardizing resolution settings across both software platforms would ensure uniform results for geometries generated using either tool. This approach not only facilitates broader participation within the lab, as Fusion360 is more accessible but also enhances the reproducibility and reliability of simulation outcomes.

7 Conclusion

In conclusion, our investigation into simulation disparities between SolidWorks and Fusion360 geometries revealed that the discrepancies in Photon Transport Efficiency (PTE) were statistically insignificant.

Through comparative analysis, we established that differences in PTE were attributed to the resolution of the STL files generated by each software. Specifically, our findings underscored a direct correlation between resolution and PTE, as evidenced by the disparity in photon counts between SolidWorks geometries with varying resolution settings (shown in section 4).

To address these discrepancies in future simulations, we recommend standardizing resolution settings across both SolidWorks and Fusion360 platforms. Specifically to match the "Deviation Tolerance" and the "Angle Tolerance" of the STLs when generating them from SolidWorks (as shown in section 4). This proactive measure not only ensures uniformity in simulation outcomes but also enhances accessibility and reliability, thereby facilitating broader participation within the lab. Therefore, we can use SolidWorks (Cust-Ext-Fine) and Fusion360 (Medium) interchangeably for generating geometries can still yield reliable and usable results.

8 References

8.1 Chroma

The simulation data for this report was acquired using Chroma V0 (the version used in PocarLab until June 2024).

8.2 SolidWorks

This report used the 2021 version of SolidWorks, under it's education license.
For more information, visit The SolidWorks Website.

8.3 Fusion360

This report used the Autodesk Fusion360 for personal use.
For more information, visit The Fusion360 Website.

8.4 The Chroma Onboarding Document

Before running chroma simulations and to better understand this document please go through the Chroma Onboarding Document. The Chroma Onboarding Document along with the Chroma Output Analysis is essential to understand the working of the Chroma Software and details what different functions do. It can be found on the Pocar OneDrive:
PocarLab-021 Repository/Reports-Presentations-Theses/Reports