Effect of Surface Resolution on Ray-Tracing Optical Simulations

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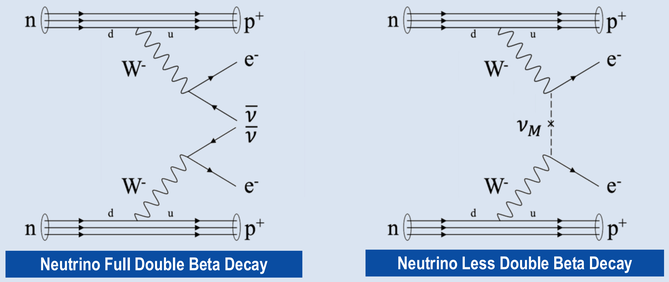
The nEXO Experiment

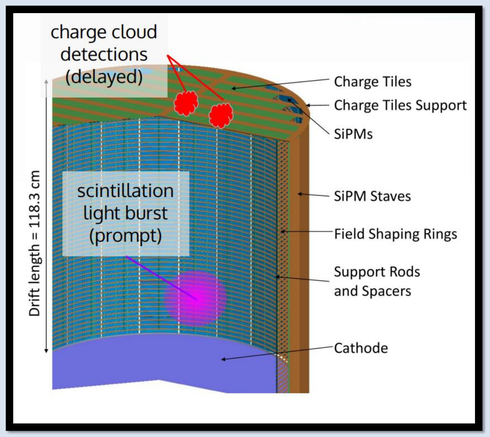
The nEXO collaboration will search for neutrinoless double beta decay in xenon-136. Using 5000 kg of liquid xenon enriched to 90% in the mass 136 isotope. If such a decay does occur, this Time Projection Chamber experiment could reveal whether neutrinos are their own antiparticles and inform about the absolute scale of neutrino mass, thus exploring physics beyond the standard model.



Neutrino Full Double Beta Decay

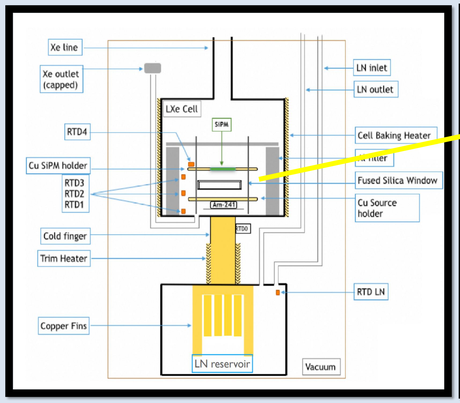
Neutrino Less Double Beta Decay

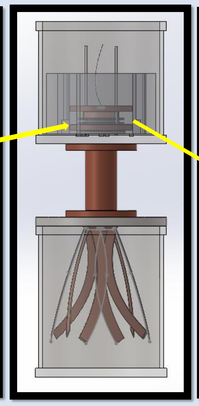
- Energy deposits in liquid xenon release scintillation light (~175 nm) and ionize the surrounding liquid, with (ionization) charge clouds drifting to the anode in an electric field.
- The combined light and charge readout improves energy resolution, spatial localization, and helps distinguish between α, β, and γ events.

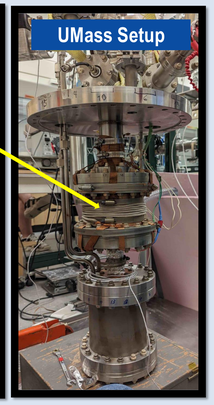


UMass Liquid Xenon Setup

A kg-scale LXe setup at UMass Amherst is operated to characterize the response of prototype SiPMs for nEXO and study VUV optics in LXe for different surfaces and reflector materials.



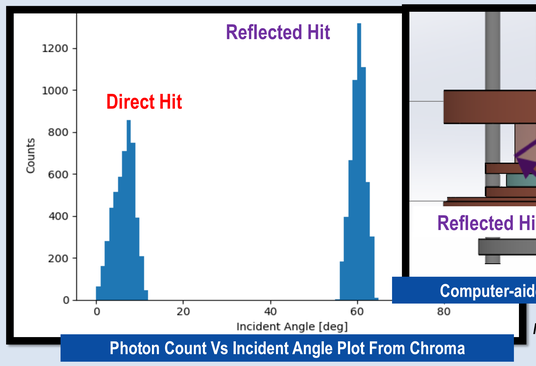




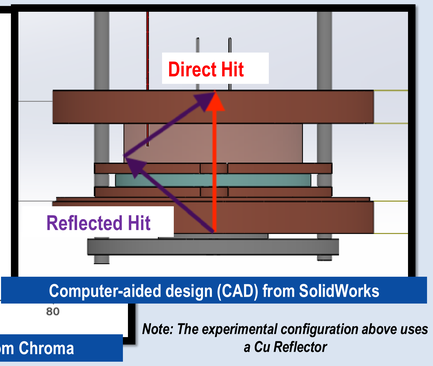
The Chroma Simulation Software

Chroma is a GPU-based ray-tracing optical simulation software used to study the photon transport efficiency (PTE) of scintillation light in the UMass LXe test cell in various geometrical and optical configurations.

The software allows to specify several optical parameters such as the refractive indices of components, the absorption and scattering length of LXe, the LXe scintillation wavelength (~175 nm), and the diffusive versus specular reflectivity of surfaces



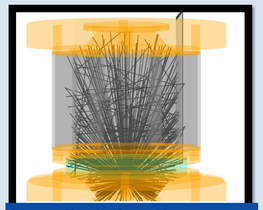
Photon Count Vs Incident Angle Plot From Chroma



Computer-aided design (CAD) from SolidWorks

Note: The experimental configuration above uses a Cu Reflector

Photon Transport Efficiency (PTE)

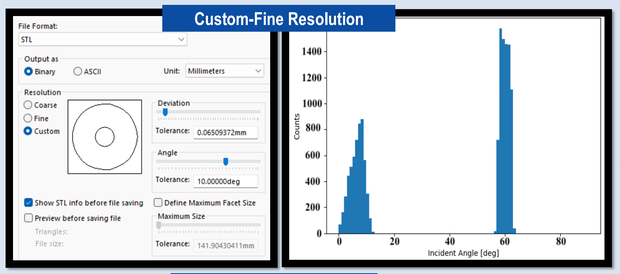


Photon Tracks from Chroma

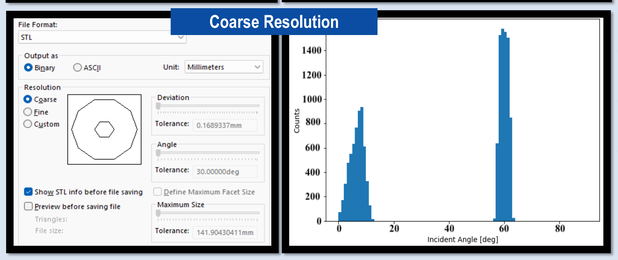
Photon Transport Efficiency is defined as the ratio of photons reaching the SiPM *(n)* to the total photons emitted by the source *(p)*.

$$\frac{n}{p} = \mathrm{PTE}$$

Surface Resolution affects PTE



- CAD Software:
  - SolidWorks
- Resolution Setting:
  - Custom-Fine
- PTE:
  - 0.0134 ± 0.0001

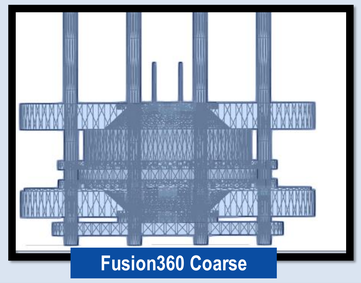


- *CAD Software:*
  - SolidWorks
- *Resolution Setting:*
  - Coarse
- *PTE:*
  - 0.0127 ± 0.0001

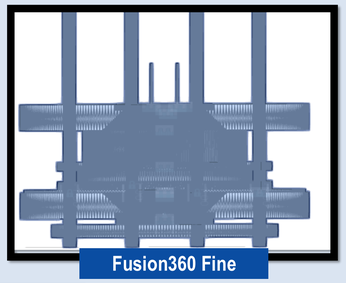
Note: All parameters other than the surface resolution were kept constant

Factors Affecting Surface Tessellation

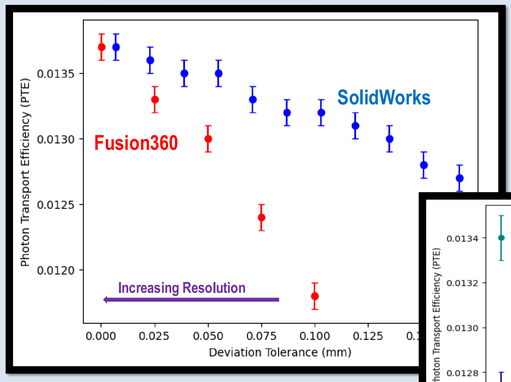
Tessellation defines the subdivision of surfaces into triangles. Increasing the resolution adds greater detail in digital simulations by using more triangles for finer, smoother representations, which gives us a closer approximation of the actual experimental setup.



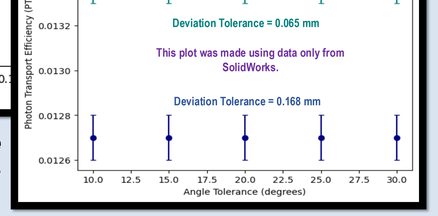
Fusion360 Coarse



Fusion360 Fine



In both SolidWorks and Fusion360, we found that the *Deviation Tolerance parameter* significantly impacts the tessellation and, in turn, the PTE in Chroma simulations.



Conversely, we observed that the *Angle Tolerance parameter* has negligible effect. This is shown in the plots below.

Conclusion

We studied the effect of different surface resolution settings in CAD models produced with SolidWorks and Fusion360, respectively. 3D model files using the standard settings of these two packages yielded statistically significant differences in the results of ray-tracing optical simulations using the Chroma software. Via a study of the PTE of the UMass LXe setup, we propose using the SolidWorks Fine resolution settings with the Fusion360 Medium resolution setting to yield comparable results.

References

- nEXO collaboration: G. Gallina et al. Performance of novel VUV-sensitive Silicon Photo-Multipliers for nEXO Eur. Phys. J. C 82:1125 (2022) https://link.springer.com/article/10.1140/epjc/s10052-022-11072-8
- nEXO collaboration: G. Adhikari et al. nEXO: Neutrinoless double beta decay search beyond 10^28 year half-life sensitivity J. Phys. G 49, 015104 (2022); https://iopscience.iop.org/article/10.1088/1361-6471/ac3631
- Solidworks.: https://my.solidworks.com/try-solidworks
- Fusion360.: https://www.autodesk.com/products/fusion-360

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