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Using GPUs to Design a Water Cherenkov Detector for a Neutrinoless Double Beta Decay Search in nEXO

nEXO? 0νββ?? 🤔

nEXO is a proposed **neutrinoless double beta decay (0$\nu\beta\beta$) experiment** in ^{136}Xe [1].

0νββ is a **lepton number violating process.** An observation of such a process is an observation of **new physics from beyond the Standard Model.**

Cosmogenic Backgrounds

High-energy cosmogenic muons from the upper atmosphere travel deep underground and **induce backgrounds to experiments searching for rare events**, e.g. 0νββ.

The Outer Detector

nEXO's Outer Detector (OD), is being developed in part to **account for cosmogenic backgrounds by tagging the Cherenkov light of nearby muons** [2] as they pass through a cylindrical water tank.

This study was conducted to determine the **optimal placement of photosensors (PMTs) to tag cosmogenic muons by their Cherenkov emission.**

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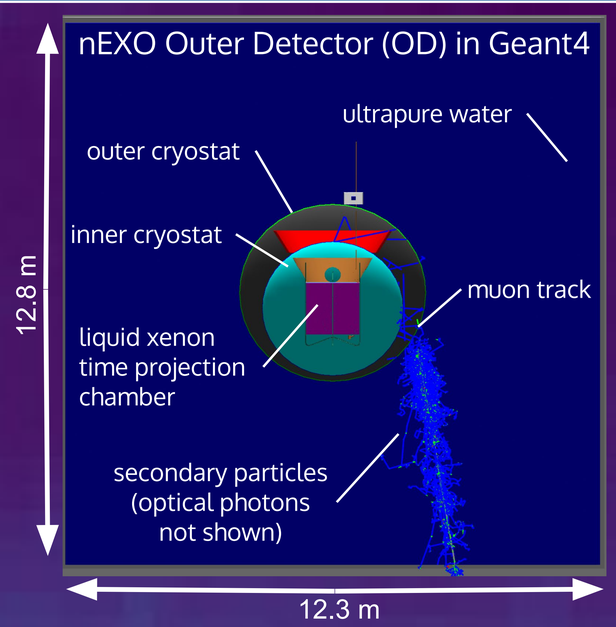
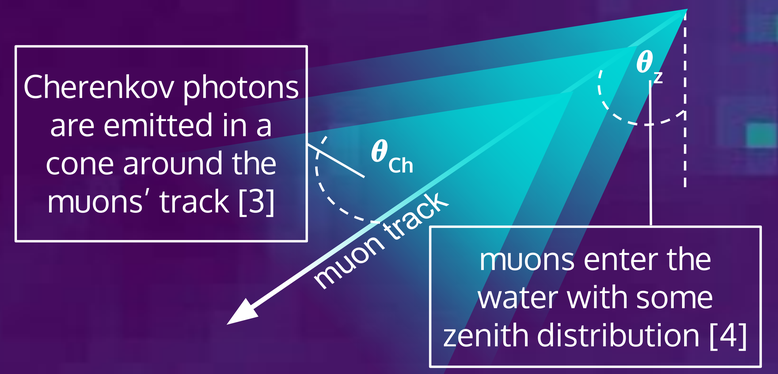
1 Study Background Production with Conventional CPU-based Monte Carlo



CPU-based methods are computationally expensive (slow) for studying high energy particles while ray tracing many photons. GPU-based ray tracing is at least ~100x faster.

2 Break the Relevant Physics out of the Problem



3 Build the Physics into a GPU-based Ray-Tracing Program (Chroma) and Simulate the Photon Hit Patterns

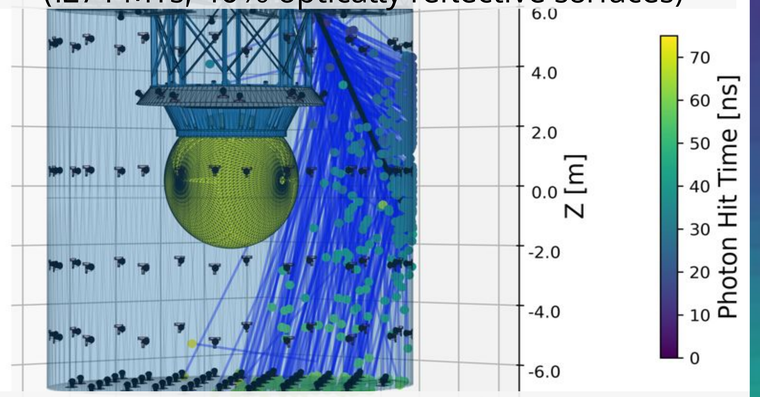
Component Name	OD Cylinder Wall	OD Floor	Outer Cryostat	OD Ceiling
% of incident light	52.9	39.7	6.8	0.6

The background of this poster is a **Cherenkov light map** of muons on the OD's cylindrical wall, unrolled.

4 Place PMTs in the Outer Detector According to the Light Map & Evaluate Muon Tag Efficiency

tag condition: 10 photons/PMT, 5 PMT coincidence within 25 ns

Example non-uniform PMT configuration
(127 PMTs, 40% optically reflective surfaces)



The **muon tagging efficiency** of the above PMT configuration is **84.4 ± 0.7 %.**
A uniform PMT distribution yields: **76.9 ± 0.8 %.**

References

1. "nEXO: neutrinoless double…", J.Phys.G., 49.1 (2021): 015104
2. "PMT Response Simulation and…", L. Retty, CAP 2022 P#39
3. "Chroma Simulations of… ", E. Klemets, CAP 2022
4. "Cosmogenic Muon Background…", R. Ross, CAP 2022 P#40

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