# Updates from NuDot: Double-Beta Decay with Direction Reconstruction in Liquid Scintillator

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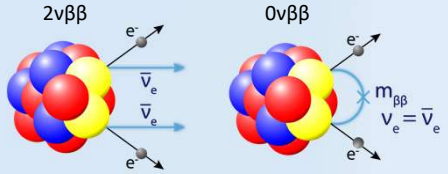
## Neutrinoless Double-Beta Decay

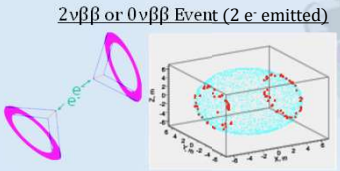
- 2νββ is the process in which two nucleons undergo β-decay simultaneously.
- If 0νββ is detected, the neutrino is Majorana, i.e. the neutrino is its own anti-particle.

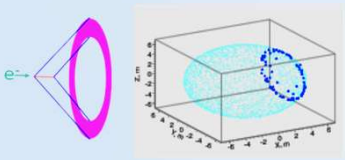


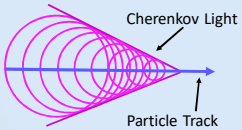

- The implications of detecting this process include Lepton number violation and a potential explanation of matter-antimatter asymmetry.

## NuDot Objectives

- $^1/_2$ -ton proof of concept liquid scintillator experiment.
- NuDot is a prototype for the use of fast-timing photodetectors to separate Cherenkov and scintillation light[1].
- Use Cherenkov light for event reconstruction to reduce background in future kiloton-scale liquid scintillator experiments.



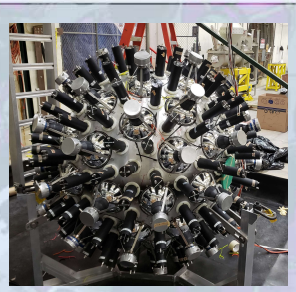

*Simulated hits with 100% quantum efficiency

## Calibration System

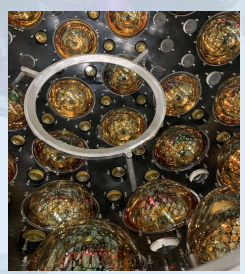
- Pointable $^{90}$Sr beta source
- Three remotely operated motors allow us to point the collimator at any region of the sphere.
- Installed in August of 2021.




## Move to TUNL



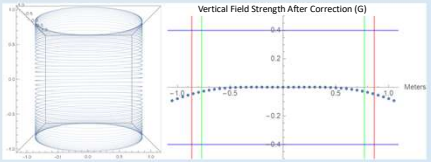
- NuDot is currently undergoing a move from the MIT Bates Research and Engineering Center to Triangle Universities Nuclear Laboratory (TUNL) at Duke University.



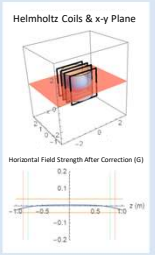
- Initial construction and early testing having been carried out at Bates, NuDot will be reassembled at TUNL to continue its surface operation phase.

## Magnetic Shielding

Vertical Coil Design




Horizontal Coil Design

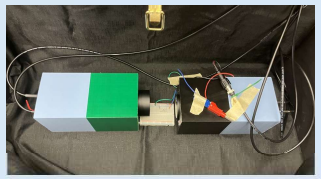



- The PMT's are sensitive to the Earth's Magnetic Field (EMF), reducing efficiency up to 30%[2].
- Goal is to reduce the surrounding magnetic field to 0.1 EMF, where the PMTs can operate at 99% efficiency.

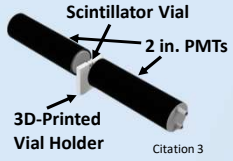
## Quantum-Dot Scintillator Testing

- QD scintillators would aid 0νββ detection in three ways:
  - Brighter scintillators for better energy resolution
  - Lower-wavelength scintillators to improve timing
  - Loading more double beta-decay isotopes
- Scintillators from private company BrightComsol


Left: Pure Toluene
Right: Toluene with 300 mg/L of $Cs_3Cu_2I_5$ particles



- Built a darkbox for testing and have undergone successful data collection with LED light pulses.




Citation 3

### References

[1]J. Gruszko et al. Detecting Cherenkov Light From 1-2 MeV Electrons in Linear Alkylbenzene (2019) [arXiv:1811.11144]
[2]Korga, George & Ranucci, G. & Smirnov, O. & Sotnikov, A.. (2000). Compensating the influence of the Earth's Magnetic Field on the Scintillator Detector Resolutions by PMTs Orientation. 10.15161/oar.it/1448986128.29.
[3]Graham, E.M., Gooding, D., Gruszko, J., Grant, C., Naranjo, B., & Winslow, L. (2019). Light yield of Perovskite nanocrystal-doped liquid scintillator. *Journal of Instrumentation, 14*, P11024 - P11024.
Certain images courtesy of other NuDot collaborators: Ravi Pitelka, Henry Nachman & Daniel Heimsoth.

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