Upgrades to miniCHANDLER

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Abstract

In preparation for the assembly and deployment of the prototype antineutrino detector miniCHANDLER we are assembling 80 sets of photomultiplier tubes (PMT), polymethyl methacrylate (PMMA) light guides, and PMT bases. This is an involved, multi-step process that includes identifying the ideal adhesive, carefully gluing together the light guides and PMTs, and soldering wires to the PMT bases. We found that the PMMA light guides, a new addition to the prototype, increase light collection efficiency by between 40% and 50%, which will lead to an expected decrease in RMS of between 15% and 25%. This will increase the energy resolution of the detector. This increase in energy resolution combined with a new technique for matching gamma events will make reconstructing inverse beta decay events much easier.

1 Introduction

The Carbon Hydrogen Anti-Neutrino Detector with a Lithium Enhanced Raghavan optical lattice (CHANDLER) is a planned, portable anti-neutrino detector. It detects anti-neutrinos via a combination of plastic scintillating cubes and neutron detection sheets which are made of lithium-6 fluoride and silver activated zinc sulfide scintillator. The process by which CHANDLER detects anti-neutrinos is shown in Figure 1. The miniCHANDLER detector is a prototype for the full sized CHANDLER detector and is shown in Figure 2. It is made up of five 8x8 layers of scintillating cubes and weighs 80 kg. See [1] for more information about CHANDLER and miniCHANDLER.

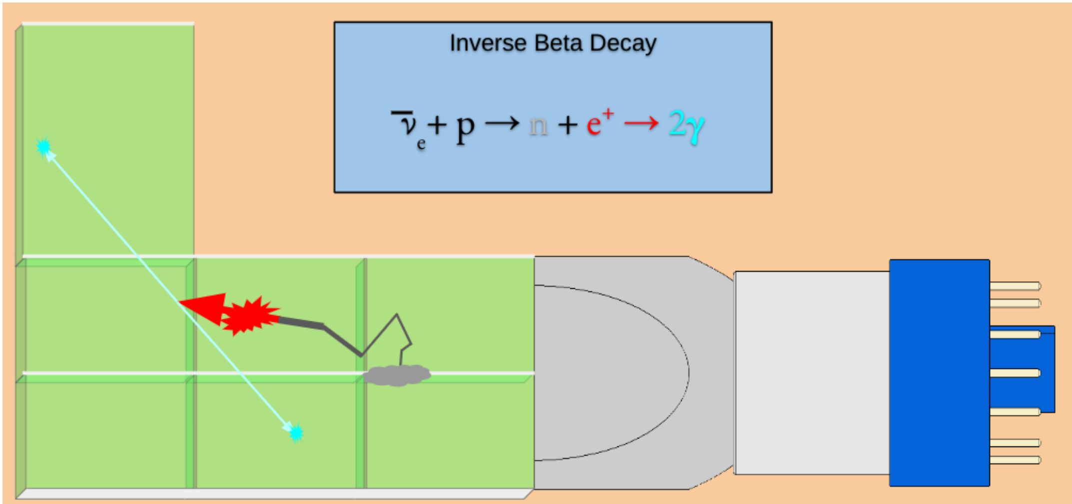

Figure 1: This figure shows inverse beta decay as it occurs in CHANDLER

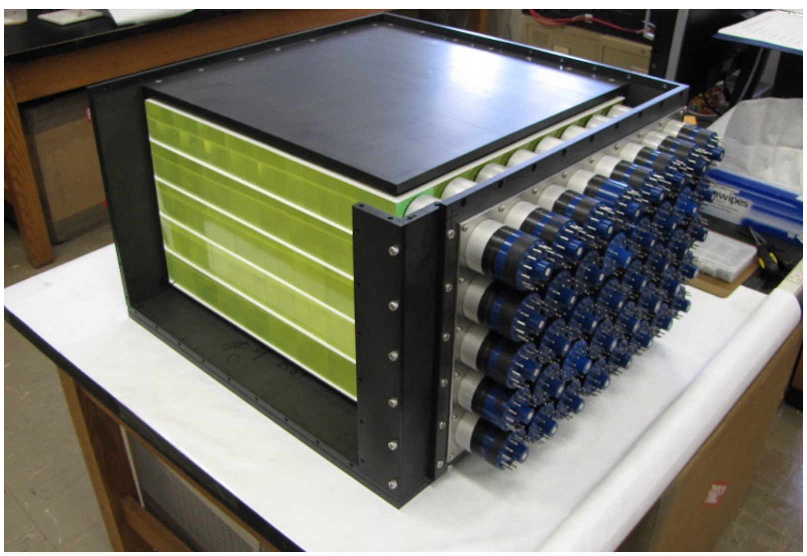

Figure 2: An image of miniCHANDLER

2 Planned Upgrades

There are multiple planned upgrades for miniCHANDLER that will improve it over it's 2017 version. First is the inclusion of PMMA light guides, as shown in Figure 3. These light guides will be glued to the faces of multiplier tubes in order to collect more light from the detector. Testing has shown an increase in light collection of between 40 and 50 percent which results in a much improved energy resolution for the detector.

Figure 3: The new light guides planned for use in miniCHANDLER.

Another upgrade is the use of new PMTs. The previously used Amperex XP2202B PMTs will be replaced by Hamamatsu R6231-100 PMTs, see Figure 4. The Hamamatsu PMTs 80% better resolution than the Amperex PMTs. They also have less tube-to-tube variation in resolution. The final planned hardware upgrade involves the PMT bases. The new "All-In-One" base design would provide high voltage to the PMTs and also immediately digitize the signal without the need for a separate digitizer. Due to ongoing global supply chain issues, this upgrade can not currently be implemented.

Figure 4: A picture of a Hamamatsu R6231-100 PMT.

3 Gamma Matching

In order to reconstruct events, we need to be able to identify gamma pairs resulting from positron annihilation inside the detector. Previously this was done using the back to back angle method (B2B) which is shown in Figure 5. With this method, two candidate gamma events are selected, and the angle between the cubes they were detected in is found, centered on the cube where the positron annihilated. If the angle is greater than or equal to 90^o, the pair is accepted. The new method, called the corner method, instead draws lines between every corner of one gamma candidate cube to the matching corner on the other cube. If any of these lines intersect the cube where the positron annihilated, the pair is accepted. We are able to do this because if any line formed by any pair of points chosen from each cube intersects a given cube, at least one of the corner to corner lines also intersects that cube. The corner method is depicted in Figure 5. A major benefit of the corner method is that it rules out some gamma pairs that are accepted by B2B, as shown in Figure 6.

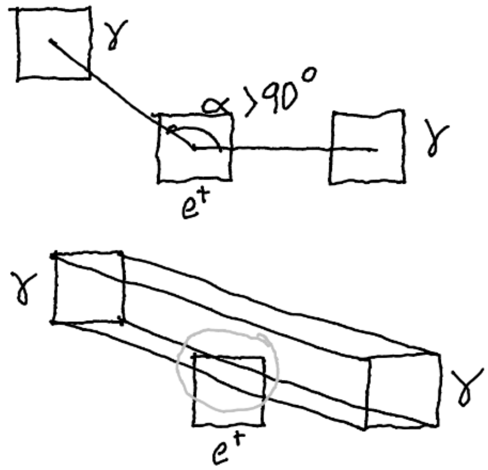

Figure 5: On the top: A 2D representation of B2B
On the bottom: A 2D representation of the corner method

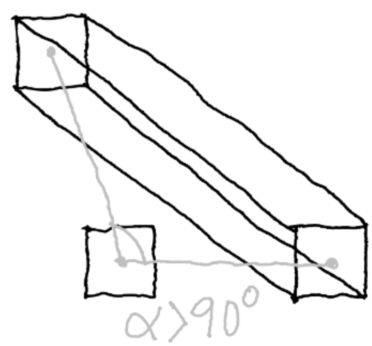

Figure 6: One example of a case where B2B accepts an impossible pair that the corner method rejects

4 Conclusion

The increased effectiveness of miniCHANDLER due to these upgrades will allow us to better reconstruct events where both gammas are detected. By learning more about these events, we hope to learn enough about the process to also reconstruct events where only one gamma is detected, as well as reconstruct events where the gammas compton scatter multiple times in the detector. The increase in detector resolution will contribute a lot to this effort, while the changes to our cuts will help discard erroneous events.

5 Acknowledgements

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References

[1] Alireza Haghighat, Patrick Huber, Shengchao Li, Jonathan M. Link, Camillo Mariani, Jaewon Park, and Tulasi Subedi. Observation of reactor antineutrinos with a rapidly deployable surface-level detector. *Physical Review Applied*, 13(3), mar 2020.