Work on neutrino cross sections for the NOvA and MMBC experiments

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Cosmic Watch

Introduction

The **M**odern **M**odular **B**ubble **C**hamber (**MMBC**) looks to obtain better measurements of hydrogen neutrino cross section to help with the data collection and analysis of various experiments. The MMBC will be the first hydrogen bubble chamber to be built in more than 40 years and will reduce the uncertainty of hydrogen cross section. This will be beneficial to experiments like DUNE because hydrogen targets can provide increased sensitivity as opposed to heavier nuclear targets such as argon.

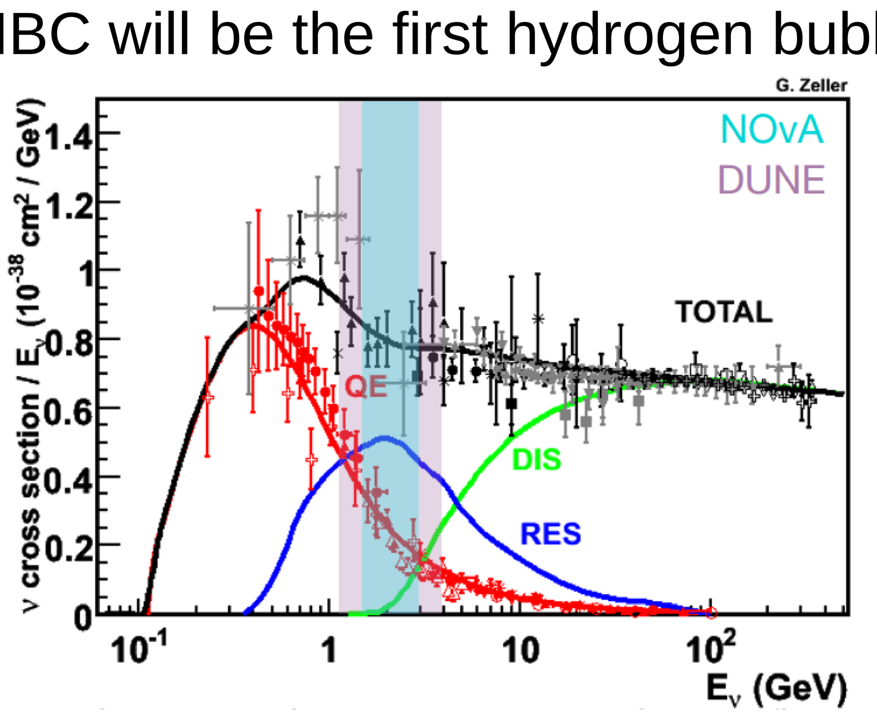

Figure 1. Graph of Neutrino Cross Section vs Energy depicting the range in which the NOvA experiment is operating, and DUNE will be operating.

Purpose

To build the MMBC, muon detectors are needed to observe the cosmic ray background and calibrate the bubble chamber detectors. The type of muon detector being built is called "Cosmic Watch". Cosmic Watch is a project designed by a group of physicist at MIT led by Spencer Axani.

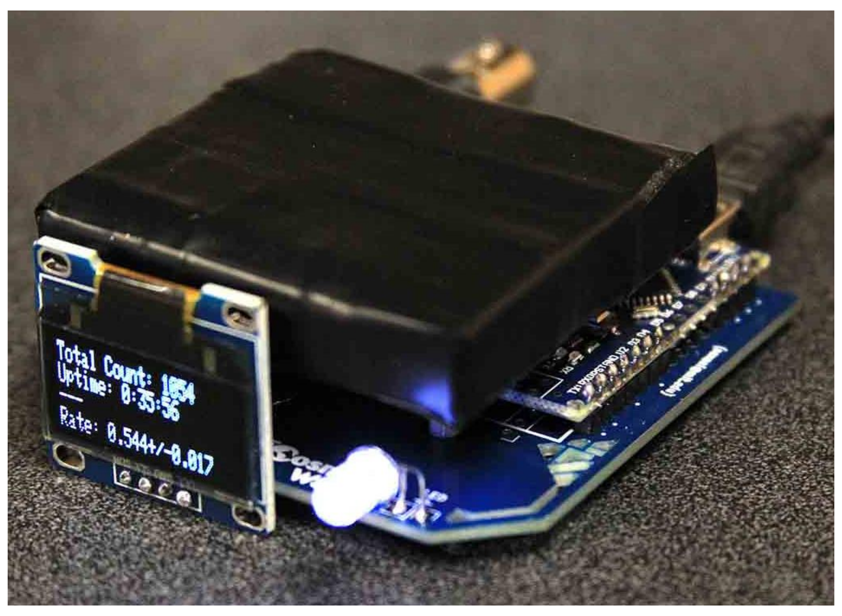

Figure 2. Completed Cosmic Watch example from Cosmic Watch team

Methods

The Cosmic Watch detects muons by using a plastic scintillator. Muons generated from cosmic rays reach the surface of the Earth regularly. When a muon reaches the detector, it excites electrons inside the scintillator. Excited electrons quickly go back to a de-excited state by releasing a photon. The photon is then detected by a silicon photomultiplier (SiPM). Building the Cosmic Watch is quite straightforward, an Arduino Nano is set up by uploading code to it. Then, the primary circuit boards (PCB) are populated. Finally, the plastic scintillator is put around the SiPM PCB and a reflective foil is wrapped around it. All the components are combined, and an aluminum case is added.

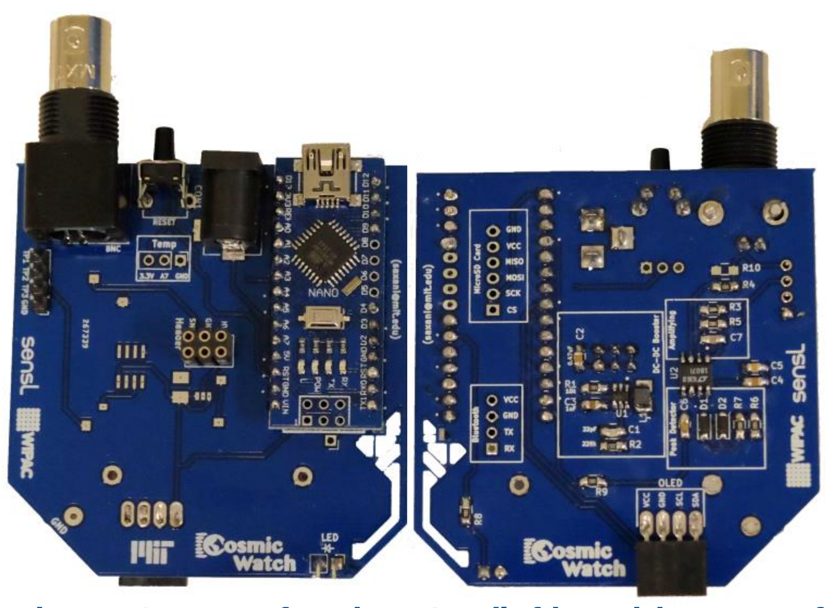

Figure 3. Top of Main PCB (left) and bottom of Main PCB (right) example from Cosmic Watch.

Results

The PCBs for the Cosmic Watch were populated and tested, working as expected. The SiPM and Plastic scintillator will be added soon when they are received.

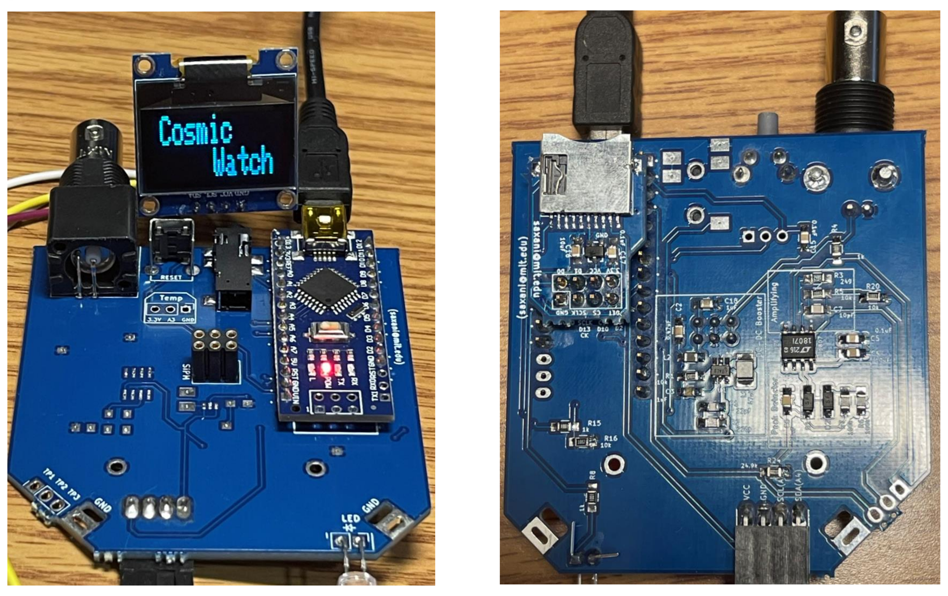

Figure 4. Constructed top (left) and bottom (left) of Cosmic Watch

GENIE Data Analysis

Introduction

An excellent way to study and better understand neutrino cross sections are simulations. For neutrino interactions, an event generator called "**G**enerates **E**vents for **N**eutrino **I**nteraction **E**xperiments" (**GENIE**) is utilized. GENIE is an international collaboration developed by the best neutrino interaction experts in the world. GENIE is made up of around 110,000 lines of code and gives scientist the opportunity to change custom model configurations (CMC) as they please.

Purpose

Finding accurate cross section models is important for improving current and future experiments. Simulation for neutrino cross sections helps to understand how neutrinos interact in different models and how these models differ from one another.

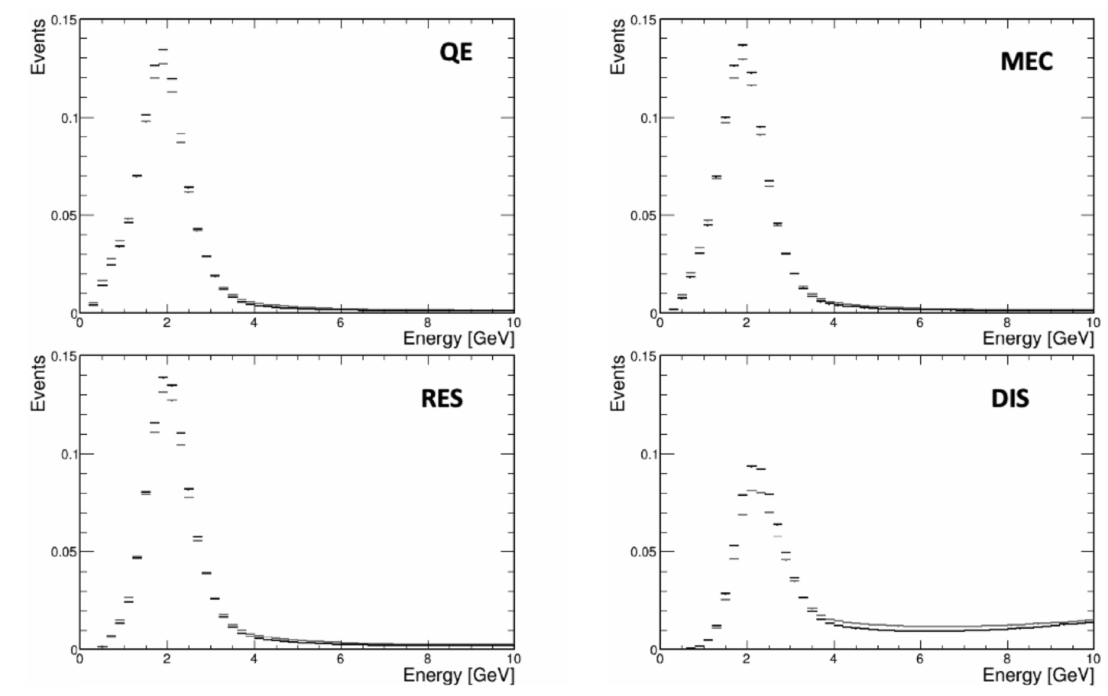

Figure 5. Graphs of Model Comparisons

Methods

To analyze the data obtained from GENIE, an object-oriented computer program called ROOT is used. ROOT was developed in C++ by CERN, and it is widely utilized for scientific analysis of large quantities of data. The data is stored in what is called a "TTree" where each parameter of the simulation is stored in a different "branch". The data is then plotted into histograms, displaying the number of events regarding a specific variable. These histograms are compared between different models to analyze how the configurations vary.

Results

The Data was successfully plotted and more than 100 graphs for analysis were obtained from 6 different models and millions of events. It was observed that the models behaved as expected with more in-depth analysis to follow soon.

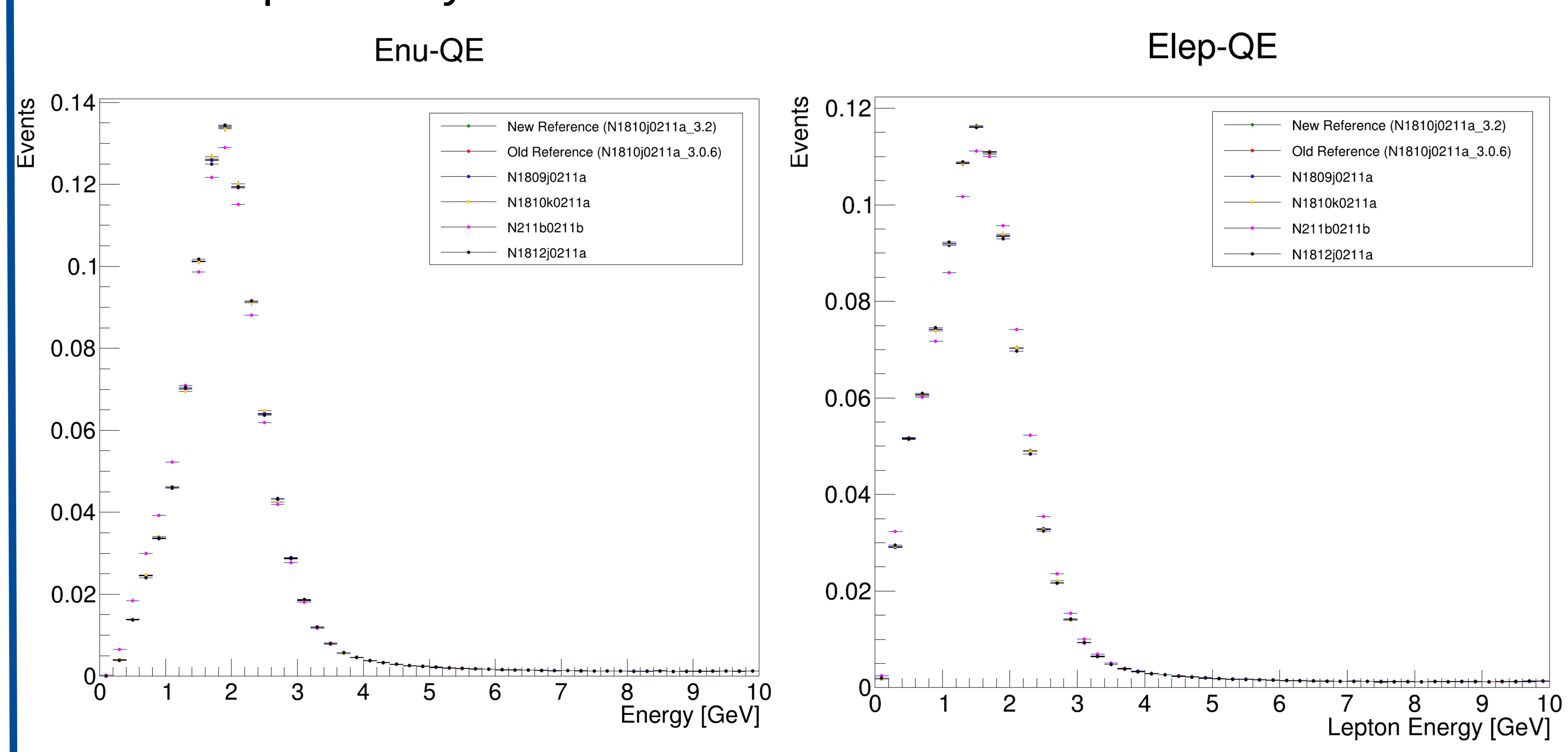

Figure 6. Graph of Energy of Neutrinos (left) and Energy of the Lepton (right) in a Quasi Elastic interaction comparing different CMC using GENIE v3.2.

Acknowledgments:

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