

# 2020 QuarkNet Online Neutrino Workshop Notes

## Day 1

- 09:00 – 09:30 QuarkNet Account Registration – **What does this involve?**
- 09:30 – 09:50 Proposed by Pauli in 1930 to explain energy spread of particles in  $\beta$ -decay.  
No photon interactions observed with the electron in  $\beta$ -decay. Neutral particle must be a neutral, almost non-interacting, particle, later called an electron anti-neutrino ( $\bar{\nu}_e$ ).  
 $\beta$ -decay:  $n \rightarrow p^+ + e^- + \bar{\nu}_e$  ,  
Inverse  $\beta$ -decay:  $\bar{\nu}_e + p^+ \rightarrow n + e^+$  ,  
Decay mean lifetime ( $\tau$ ):  $N(t) = N_0 e^{-t/\tau}$
- 09:50 – 10:00 “What is the most likely number of throws necessary to produce a “1” on the top of a 6-sided die?”  
Get off-the-cuff responses.  
Make sure that participants have a Tally Sheet (emailed to them) for use.  
Describe Google Sheet for common data entry and Excel spreadsheet for individual use.
- 10:00 – 10:45 Conduct experiment or simulation.
- 10:45 – 11:00 Discuss why “One throw” is the answer to the initial question. Note that “six throws” is the weighted average value for a large number of repetitions.
- 11:00 – 11:45 Describe MINER  $\nu$  A hardware and ARACHNE software with neutrino to muon examples.
- 11:45 – 14:00 **LUNCH** (when convenient).  
Participants gather MINER  $\nu$  A data to determine muon lifetime and Michel electron energy.  
**Moderator available for consultation:  
11:45 – 12:30 and 13:30 – 14:00.**
- 14:00 – 14:30 Describe how to make and plot a histogram in Google sheets (and Excel if necessary). Note avoidance of first 500 microseconds in MINER  $\nu$  A data and how to cope with that. Compare measured muon mean lifetime with standard value.

14:30 – 14:45 Discuss Michel electron energy histogram and implications of that for neutrinos in muon decay. Note conservation of lepton family number.

14:45 – 15:45 “Neutrinos: Mystery and History” – Three options: (1) play recorded QW2 talk, (2) sue slides from QW2 talk with or without the script provided, (3) Moderator provides talk on neutrino history

15:45 – 16:00 Participants present and discuss reflections on day’s activities. Homework assignment

## **Day 2**

09:00 – 09:30 Greetings. Homework review. (Email to participants solutions to any homework problems.)

09:30 – 10:15 “How do we know that our cosmic ray detectors are detecting muons?” Gather and discuss off-the-cuff answers from participants.  
Engage in “Mean Lifetime Part 2: Cosmic Muons” activity.

10:15 – 10:30 Discuss activity results.

10:30 – 10:45 Break

10:45 – 11:00 Moderator present “What Heisenberg Knew” activity.

11:00 – 11:45 Participants engage in “What Heisenberg Knew” activity.

11:45 – 12:00 Discuss activity results.

12:00 – 13:00 **For 1.5-day Workshop:**  
Participants develop plans to implement in their classrooms activities or approaches derived from this workshop.  
**End of Workshop**  
**Note resources available on neutrinos.**