2020 QuarkNet Online
Neutrino Workshop Notes

Day 1

09:00 – 09:30   QuarkNet Account Registration and Account update

09:30 – 09:45   Story line:
The idea of neutrinos arose in connection with radioactive beta-decay ($n \rightarrow p^+ + e^- + \overline{\nu}_e$). One important characteristic of beta decay is the random nature of the decay and the mean lifetime (tau) used to characterize it, where the number of undecayed particles after time t = 0 is given by
$N(t) = N_0 e^{-t/\tau}$. To better understand the meaning of "mean lifetime" for radioactive particle, let us examine the following question:

09:45 – 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 or available online) for use.
Describe Google Sheet for common data entry and Excel spreadsheet for individual use.

10:00 – 10:45   Conduct experiment or simulation.

BREAK   (Take a break before 10:45 when convenient for you.)

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.
Note the connection to the QuarkNet Data Activity "Mean Lifetime Dice: part 1" and the connection between mean lifetime and half-life.

11:00 – 11:45   Describe MINER ν A hardware and ARACHNE software with neutrino to muon examples.
Note the connection to the QuarkNet Data Activity "Mean Lifetime Part3: MINERvA."

11:45 – 14:00	**LUNCH** (when convenient). Participants gather MINERνA 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 MINERνA data and how to cope with that. Compare measured muon mean lifetime with standard value. Note availability of Excel spreadsheet with all MINERvA electron values.
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. **For 2-day or 1.5-day Workshop:** Homework assignment
16:00 – 17:00	**For 1-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.**

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 presents "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.

12:00 – 12:15   **For 2-day workshop:**
                   "How do we use neutrinos to measure neutron momentum in a
                   nucleus?"
                   Neutrinos can be used as probes to study other particles.
                   Participants speculate.
                   Moderator presents MINERνA "Momentum Conservation"
                   activity and assigns data sets to participants.

12:15 – 14:15   **LUNCH** (when convenient).
                   Participants gather MINERνA data on muon and proton
                   momentum and energy values and determine target neutron
                   transverse momentum.
                   (Moderator sets time available for consultation, *e.g*. 12:15 –
                   12:45 and 13:45 – 14:15.)

                   Provide Google sheet or Excel spread sheet for data gathering
                   and calculations.

14:15 – 14:45   Discuss MINERνA "Momentum Conservation" activity results.
                   Note availability of documents with all MINERvA data and
                   reviews of various possible causes of nuclear motion.

14:45 – 15:15   Moderator presents information on current neutrino
                   experiments.

15:15 – 15:30   Complete QuarkNet Workshop Survey

15:30 – 16:30   **For 2-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.