Physics 142 Literature lab # 1
Introduction to reading scientific papers

Mission #1—"The quick overview"

Here is a selection of papers from Physical Review Letters describing what are (now) famous discoveries (or inventions).

Abachi et al. (D0 Collaboration) *Phys. Rev. Lett.* **74**, 2632 (1995), `https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.74.2632`

Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration) *Phys. Rev. Lett.* **116**, 061102 (2016), `https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.116.061102`

Binnig et al. *Phys. Rev. Lett.* **56**, 930 (1986), `https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.56.930`

Wu et al. *Phys. Rev. Lett.* **58**, 908 (1987), `https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.58.908`

For each paper,

a Identify the "In this letter"/"In this paper" sentence

b Using that sentence, with help from the title and abstract, summarize the main point of the paper in 1–2 sentences.

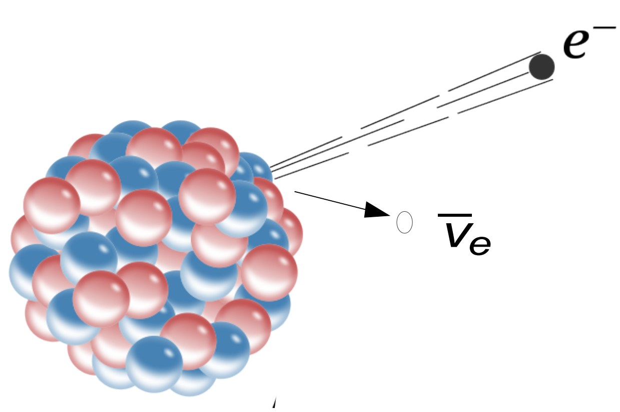
Mission #2—Going a little deeper

Let's go a bit deeper with the paper by Fukuda et al. entitled "Evidence for oscillation of atmospheric neutrinos.", `https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.81.1562`.

Before doing anything else, repeat mission 1 here (caveat: I couldn't find a solid "in this paper" sentence, but maybe a short paragraph? See what you think).

Background

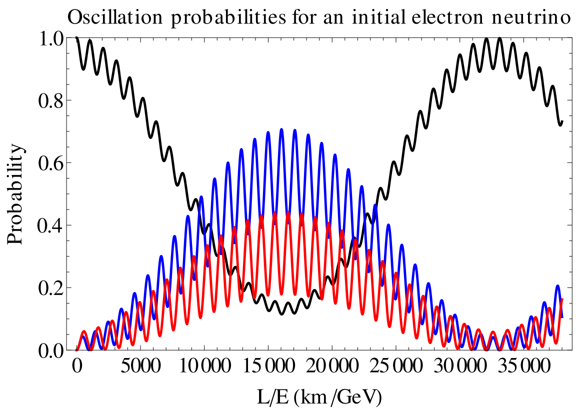
Neutrinos are a type of elementary particle. They were originally hypothesized in the context of nuclear beta decay. In beta decay, a neutron can decay into a proton and electron and neutrino; the neutrino could not be detected directly, but the process seemed to violate energy and momentum conservation unless an extra mystery particle (the neutrino) was included.

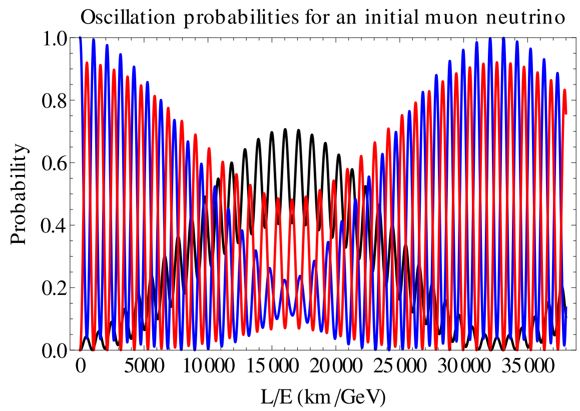


(adapted from `https://commons.wikimedia.org/w/index.php?curid=2859203`)

Neutrinos can be produced in nuclear reactions (both at reactors on earth and in the sun) as well as when cosmic rays strike atoms in the upper atmosphere. Lacking in charge, they interact only via the weak force and the (even weaker) gravitational force; as they interact so weakly with other stuff (trillions of them pass through you every second), they're quite hard to detect! Their symbol is the greek letter ν ("nu"), and they come in three flavors: the electron, muon, and tau neutrino.

The Homestake experiment in the 1960's measured neutrinos arriving from the sun. The detector was located deep underground in the Homestake mine in South Dakota to shield it from cosmic rays, and it was only sensitive to electron neutrinos. Surprisingly, the flux of electron neutrinos was roughly 1/3 as large as expected. This was a big mystery (the "solar neutrino problem") which was eventually resolved with the concept of neutrino oscillations. This is a quantum mechanical effect, but in practice, what happens is that if you start with, say, an electron neutrino and then measure it at a later time, it has a finite probability of having turned into one of the other flavors of neutrino(!). Two examples of neutrino oscillations are given below, from wikipedia/Wolfram Demonstration Project written by Balázs Meszéna.[1][2]





The horizontal axis shows propagation distance *divided* by the neutrino's kinetic energy—you can think of this as being proportional to *time* in the neutrino's rest frame.[3] On the vertical axis, the probability of finding a particular flavor, with black representing the electron neutrino, blue the muon neutrino, and red the tau neutrino.

Neutrinos were initially assumed to be massless (which would mean they are obligated, in Einstein's special relativity, to travel at the speed of light). However, the theory introduced to explain neutrino oscillations relies on the three types of neutrinos having different (though very small) masses—thanks to neutrino oscillation measurements, we now know the differences between the squares of the three neutrino masses, but their absolute masses are not known—experiments have placed an upper bound that is more than 450,000 times smaller than the mass of the electron.

The Super-Kamiokande experiment described in Fukuda et al. was able to look at neutrino oscillations in the neutrinos formed in the upper atmosphere. As with Homestake, they use a large underground detector, but they are able to detect (and distinguish) electron and muon neutrinos. The neutrinos formed above the detector travel a short distance and have less time to oscillate than the ones formed on the opposite side of the earth. They were able to use this to show that the muon neutrinos oscillate not, primarily, to become electron neutrinos, but rather into some third type of neutrino (to which their detector was not sensitive, but which might be the tau neutrino).

[1] `https://commons.wikimedia.org/w/index.php?curid=116905713`

[2] `https://commons.wikimedia.org/w/index.php?curid=116905737`

[3] The neutrinos are traveling close to the speed of light, so the time in the lab frame is $\approx L/c$. The time in the neutrino's frame is thus $\approx L/\gamma c$, and we will see soon that the relativistic energy of a particle is γmc^2.

Remainder of the mission...

1. *Paper structure* See if you can break up the paper into Abstract, Introduction, Experimental methods, Results, Discussion, and Conclusions. You don't need to actually read everything to do this—you might start by glancing at the first sentence in each paragraph.

2. *Handling unfamiliar terms.* Let's focus on the abstract and introduction. Make a list of terms or phrases that are unfamiliar here.

   (a) With your partner/group members, select *six* terms that you think are most relevant/ important to your overall comprehension. [Important: you're only allowed six in this exercise, so make them count!]

   (b) Write definitions of these words based on how they're used in the paper. Your definitions may be somewhat sketchy at this point (e.g. neutrino—a particle that can be produced in the upper atmosphere by cosmic rays).

   (c) Once you've done this, select three terms that you are allowed to look up for real. Again, make them count. Then, use the internet to find/ compose definitions of your three selected terms (wikipedia could be helpful, and see the further reading below).

   (d) Try reading the abstract and introduction again.

Further reading about neutrino oscillations. (These are both commentaries, not original research).

1. Robert Garisto, "Neutrinos have mass," *Phys. Rev. Focus* **2**, 10 (1998) `https://physics.aps.org/story/v2/st10`

2. Phillip Ball, "Nobel prize—Neutrinos oscillate," *Physics* **8**, 97 (2015) `https://physics.aps.org/articles/v8/97`

Here is a video tour of the Super-Kamiokande detector: `https://www.youtube.com/watch?v=cs02i8TIphs`