

Lesson Plan for Teaching Particle Physics/Preparing for Soudan Underground Lab

Field Trip

Target: H.S. Physics

History:

In 1931 theorist Wolfgang Pauli noticed that the experiments he had been performing on beta decay (neutron into an electron and proton) were losing energy. To keep with known physics Pauli theorized that there was an unseen neutral particle, which was able to escape without detection. In 1933 Enrico Fermi took equations and experimental data from radioactive decays and devised a comprehensive theory that included Pauli's particle, which Fermi later called neutrino or "little neutral one." When Fermi included the particle into the theory, it then explained many experimentally observed results. In 1956 Clyde Cowan and Fred Reines discovered a particle that fit the expected characteristics of the neutrino, this neutrino is associated with a formation of an electron. 1962 scientists find that the neutrino that is created with a muon does not act in the same way as a neutrino that is created in juncture with an electron. Thus a new neutrino was discovered.

Materials:

- The four videos that were sent in the "video" CD (or folder).
- Textbook (note: your textbooks may be out dated. If so look to text revisions on the last page.)
- Some way to play the videos on the CD (requires Windows Media Player)
- An understanding of the videos is recommended for you to explain the videos to your students

Objectives/Outcomes

The objective of this lesson is: 1) to give your students a basic understanding of particle physics 2) to educate them on what is happening in the field today and what implications it will have on their lives in the future and 3) to get students to appreciate the time and effort that is needed to find these particles. This lesson can also be a great way to show your students the different types of careers in physics.

Day One

- Show your students a picture of a universe. A good spiral universe can be found at <http://www.spaceref.com/tools/vi.html?id=2&cat=galaxies&imgs=smallimage>.
- Ask them, "How many stars do you think would be in this galaxy?"
- Looking for trillions
- Continue asking them about our sun and how big it is to the rest of the solar system.
- The sun contains 99.89% of the solar systems mass.
- The sun has a mass of 1.989×10^{30} kg. The mass of the sun is almost the mass of the solar system.
- Then one galaxy has an observed mass of 1.989×10^{42} kg.

- But this is only between 1 and 5 % of the mass that is needed to allow the galaxy to move in the fashion that it does.
- Therefore the amount of mass that physics are looking for is 1.96911×10^{44} Kg in each galaxy.
- The purpose of this information is to give an idea of the large quantities involved.

Day Two

- Today we are going to talk about elementary particles (write “elementary particles” on the board).
 - What are elementary particles? You may have gone over this in a previous class, but it is still good review.
 - Encourage the students to give the desired response, “Something that is made up of nothing else, and are the building blocks of all matter.”
 - Ok what are some of the elementary particles that are out there?
 - You should get quarks, and electrons. It is very doubtful you’ll get a student that knows what leptons are?
 - Explain leptons; what an Electron, Muon, and Tau particles are.
 - Neutrinos are the sister particle to each of these and are also found in the lepton family, and every particle has its antimatter twin!
 - Make a table on the board that looks like this →
 - There are many different ways in which a neutrino is created, solar, cosmic, Big Bang.
 - Show Beta decay and muon decay videos. Take time to describe what is happening in each video.
 - If your book has information regarding neutrinos have the students turn there. If the book says that the neutrino has no mass, explain that MINOS and two other experiments have shown this to be incorrect, they do have tiny masses.
 - Take this time to explain about Wolfgang Pauli and how he came to hypothesize neutrinos must exist or Beta decay violates the conservation of energy and momentum laws.
 - Ask the students; “How could this be?”, “How could something that has mass be undetectable?”
 - It would have to have no charge, very little spin, and be VERY small indeed
 - Ask then; “What do you think it would take to see this thing?”
- Encourage them to say something along the lines of “a bunch of things” then go further in depth.
- When a muon neutrino “hits” an atom’s nucleus it creates a muon, which is like a big fat electron, about 200 times the mass of an electron with a negative charge. As the muon passes through the detector it causes electron excitation in the iron atoms in the detector. As the electrons return to the ground state they release energy as a photon of light, which is channeled to electronics and the computer by way of the scintillator strips.

The diagram is titled "Standard Model" and is divided into two main sections: "QUARKS" and "LEPTONS".

QUARKS: A 2x3 grid of particles. The top row contains Up (u), Charm (c), and Top (t). The bottom row contains Down (d), Strange (s), and Bottom (b). Each particle is represented by a small colored sphere.

LEPTONS: A 2x3 grid of particles. The top row contains Electron (e), Muon (μ), and Tau (τ). The bottom row contains Electron Neutrino (ν_e), Muon Neutrino (ν_μ), and Tau Neutrino (ν_τ). Each particle is represented by a small colored sphere.

At the bottom of the diagram, the three columns are labeled "1", "2", and "3", with the text "Generations of Matter" underneath.

Day Three

- Perform a quick review about what happened the day before remind them that they ended with a lack of mass in the universe.
- Show fourth clip of oscillation
- Explain that scientists cannot measure the mass of neutrinos directly but they need to detect if it can change flavors over time.
- Tell them how a neutrino is expected to change from a muon to a tau neutrino in 2.5 millisecond trip from Fermilab to the Far Detector at Soudan. If this happens they must have mass!
- Review superposition of waves of the same frequency, same amplitude, both constructive and destructive interference.
- Review DeBroglie matter, or matter probability waves.
- Ask what happens when two waves of different frequency mix. Look for sometimes constructive, sometimes destructive interference, but never zero amplitude. This is a good analogy to what must happen in neutrino oscillation. A neutrino of indeterminate mass, or two masses mixed each having a unique probability wave, will oscillate. This instant a muon neutrino (constructive) a moment later an electron neutrino (destructive) and so on.
- *Remaining time:* go to computer lab and have students perform research on the sites listed in this lesson plan.
- If you are not going on the field trip I encourage you to send your students to the Soudan mine page and look at some of the pictures that they have down there.
- If you are going to the mine I still encourage them to look at the site for it will give them a better what is happening when they are down there.

Student Modifications:

You know your students; if the class is more geared to hands on learning then please make full use out of the videos that have been provided. You may choose to use one day or all days of this lesson plan. If the class learns better from you just putting the material on the board then emphasize the mechanics behind the collisions and imitations. A mixture of both of these techniques should help to better convey the desired message. Again I say you know your class, please use what is best for your students.

Resources:

Some of the sites that I used are as follows:

<http://www.soudan.umn.edu> (Soudan Lab Website)

<http://www-numi.fnal.gov/>

<http://www.ps.uci.edu/~superk/neutrino.html>

<http://particleadventure.org/>

<http://hyperphysics.phy-astr.gsu.edu/hbase/HFrame.html>

Teacher Notes

I encourage you to look at these web sites because something is changing every day in the neutrino world. Also you may find information that would be more useful for your class than what has been provided to you.

Application to Life

Everyday physics is going deeper and deeper into finding more about how observed things work; almost every day another discovery is made that will impact your lives. Because your students are the next generation they will see things that scientists can't even fathom. The next generation will build off of our information, which can bring a change to the world that we live in and maybe even others.