TAP 533- 4: Positron, muon, neutrino

Practical advice:

This is just an outline. Your students will probably be much more forthcoming. They should be encouraged to put ideas into their own words rather than copy chunks from websites. (Some chunks are below.) It is good practice for them to fully reference their sources. It is possible that there is some conflict with different web sources; an example is given with the muon answers. Episode 534 gives the basic outline that all students should have.

Outline answers

What is a positron?

Anderson saw an example of anti-electrons, "positrons" in photographs of cosmic rays passing through a cloud chamber.

(Pictures are provided at the site below)

The discovery of the positron

http://www.physics.ubc.ca/~waltham/p400/presentation/asgeirsson.pdf [Accessed 14 October 2005]

Who discovered it?

A direct quote from Anderson's 1933 paper: -

"On August 2 1932 during the course of photographing cosmic-ray tracks produced in a vertical Wilson chamber (magnetic field 15,000 gauss) designed in the summer of 1930 by Prof R A Millikan and the writer the track shown in fig 1was obtained which seemed to be interpretable only on the basis of a particle carrying a positive charge but having the same mass of the same order of magnitude as that normally possessed by a free electron."

Anderson Carl D, The positive electron, Physical Review, Vol 43 pp 491-494 15 March 1933

http://www.hep.man.ac.uk/babarph/babarphysics/positron.html puts the discovery as 1933 but as Anderson's paper shows the observations were made in 1932

Who suggested it must exist?

"In the 1920's, Paul Adrien Maurice Dirac, a British physicist, developed a quantum-mechanical wave equation which was able to explain the origin of the electrons magnetic moment and spin. There was only one problem, the relativistic equation would only be satisfied if there were solutions for it which corresponded to negative energy states, and in the case of the electron, an electron with a positive charge."

The above is quote from: http://www.upei.ca/~phys221/mmh/

Another suitable source is: http://www.infoplease.com/ce6/sci/A0804257.html

"The existence of antiparticles for electrons was predicted in 1928 by P. A. M. Dirac's relativistic quantum theory of the electron. According to the theory both positive and negative values are possible for the total relativistic energy of a free electron. In 1932, Carl D.

Anderson, while studying cosmic rays discovered the predicted positron, the first known antiparticle."

Or

"Paul Dirac:

Relativity and antiparticles

Paul Dirac set himself the task of repairing the big problem with Schrödinger's wave theory: that it didn't agree with the theory of relativity. What he found in 1928 was totally unexpected. If relativity was included the theory necessarily predicted that every particle must have a 'mirror image' particle, exactly the same but opposite in all properties except mass. These pairs of particles could annihilate one another. This interpretation wasn't clear at first to Dirac, but it gradually became a second cornerstone of quantum physics. If particles can be created or destroyed they have to come in such pairs. Otherwise quantities like electric charge won't be conserved. Soon afterwards, in 1933, the creation of pairs of electrons and antielectrons was observed by Carl Anderson. By the way, as a bonus, Dirac's theory explained the existence of spin too."

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Anderson was given 1936 Nobel Prize for Physics for this discovery

What is a muon?

The muon is a lepton that decays to form an electron or positron. It carries a charge of the same size as that on an electron but is much more massive, more than 2000 times that of an electron

When was it discovered?

"The muon was discovered in 1937 by J. C. Street and E. C. Stevenson in a cloud chamber. The discovery was published in "New Evidence for the Existence of a Particle Intermediate Between the Proton and Electron", Phys. Rev. 52, 1003 (1937)."

http://hyperphysics.phy-astr.gsu.edu/hbase/particles/muonhist.html

However

"Muons were discovered 60 years ago, by Carl Anderson and Seth Neddermeyer at Caltech. Muons live for about 2.2 microseconds, and often survive to ground level, before changing into electrons and invisible neutrinos.

In 1947, ten years after the muon discovery, Cecil Powell's group at Bristol University discovered that the muons are produced by other particles - pions - which live for only a few hundredths of a microsecond. In this image, pions fly out from a collision in the streamer chamber."

http://www.cs.wisc.edu/~kaxiras/decay.html

But muons had been predicted by Yukaya:

Yukaya Hideka, On the Interaction of Elementary Particles 1, *Proceedings of the Physico-Mathematical Society of Japan* (3) 17, 48, pp 139-148 (1935). (Read 17 Nov 1934)

"It seems natural to modify the theory of Heisenberg and Fermi in the following way. The transition of a heavy particle from neutron state to proton state is not always accompanied by

the emission of light particles. The transition is sometimes taken up by another heavy particle".

Who said, 'Who ordered that?'

The muon was discovered accidentally in 1936-1937 in the hunt for a particle predicted by Yukaya. At the time it seemed to serve no purpose in particle physics. I I Rabi asked, "Who ordered that?", when he was told of it.

http://www.everything2.com/index.pl?node_id=92185&displaytype=printable&lastnode_id=92185

What is a neutrino?

"Three types of neutrinos are known; there is strong evidence that no additional neutrinos exist, unless their properties are unexpectedly very different from the known types. Each type or "flavour" of neutrino is related to a charged particle (which gives the corresponding neutrino its name). Hence, the "electron neutrino" is associated with the electron, and two other neutrinos are associated with heavier versions of the electron called the muon and the tau (elementary particles are frequently labelled with Greek letters, which confuses the layman)".

"Neutrinos are similar to the more familiar electron, with one crucial difference: neutrinos do not carry electric charge".

Who suggested it must exist?

"1931 - A hypothetical particle is predicted by the theorist Wolfgang Pauli. He based his prediction on the fact that energy and momentum did not appear to be conserved in certain radioactive decays. Pauli suggested that this missing energy might be carried off, unseen, by a neutral particle which was escaping detection.

1934 - Enrico Fermi develops a comprehensive theory of radioactive decays, including Pauli's hypothetical particle, which Fermi coins the neutrino (Italian: "little neutral one"). With inclusion of the neutrino, Fermi's theory accurately explains many experimentally observed results"

Who discovered it?

1959 - Discovery of a particle fitting the expected characteristics of the neutrino is announced by Clyde Cowan and Fred Reines.

Source for the above: http://www.ps.uci.edu/~superk/neutrino.html