# EP Physics ch#1

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Q. What exactly is a meson? why is it significant? what are its properties? How is it produced?

Q. What is the Dirac Sea?

# 1.5 Neutrinos



(1930-1962)

- It's 1930 problems have arison with nuclear beta decay.

- In beta decay, a radioactive nucleus A is transformed into a slightly lighter nucleus B, with electron emission.

$$A \longrightarrow B + e^-$$

[nuc A] [nuc B]

- Conservation of charge requires B carry one more unit of positive charge than A.

- Thus the daughter nucleus (B) lies one position further along periodic table.

- But the underlying process is that

(neutron → proton/ electron
conversion protons electrons
emission

- Two-body decay ($A \to B + C$)

outgoing energies are kinematically determined, in the center-of-mass frame.

- Specifically if parent nucleus ($A$) is at rest, so that $\beta$ and $e$ come out with equal and opposite momenta. Then cons of energy dictates that energy

$$E = \left( \frac{M_A^2 - M_B^2 + M_e^2}{2M_A} \right) c^2$$

- $E$ is fixed once 3 masses are specified.
- Experimentally the electrons vary considerably in energy.
- This conservation of energy equation is only specific to a certain beta decay process

since electron energy varies.

- "How does the problem of conservation of energy in process is missing energy.

1.) Throw it out.

or

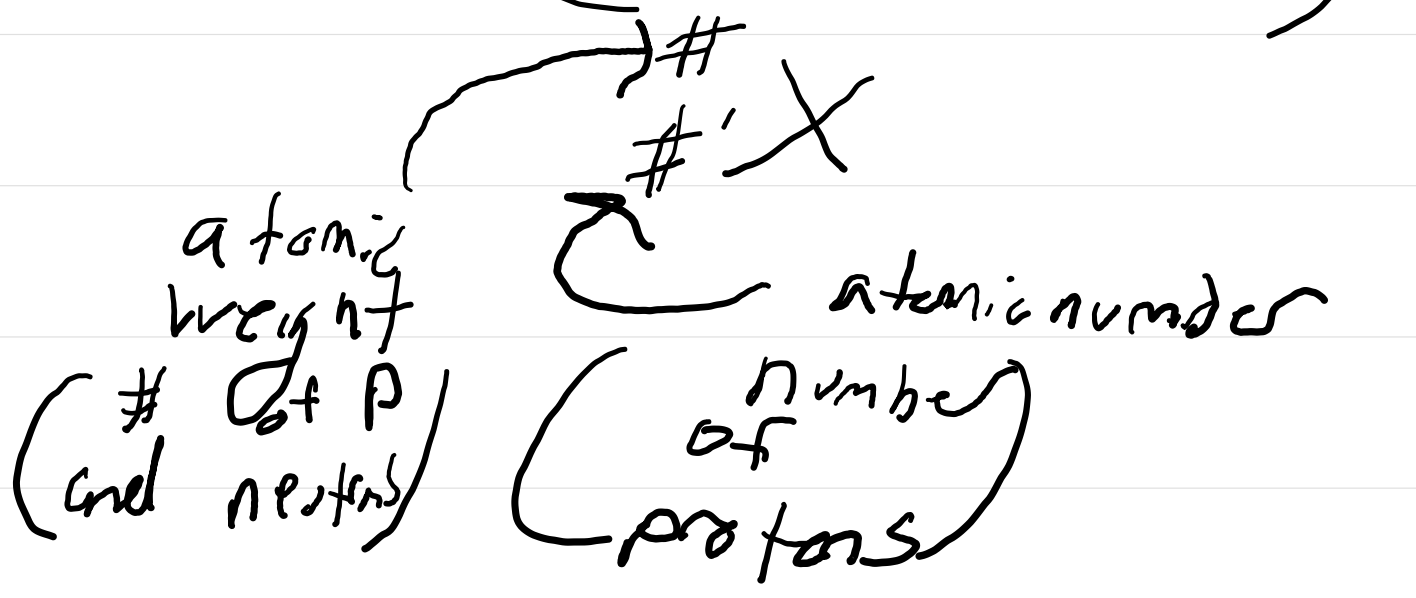
2.) "there is another particle emission in Beta decay process."

- This new particle could fill the missing energy, but it also must be electrically neutral

to conserve charge.
(explains why it leaves no tracks)
very light particle

- Side note:

CX.) ($^{40}_{20}Ca \rightarrow {}^{40}_{19}K$)




- This new particle is the neutrino, antineutrino.

$n \rightarrow p^+ + e^- + \bar{\nu}$

(Beta-Decay process) (antineutrino)

$\pi \rightarrow \mu + \nu$

(pions decays into muon + neutrino)

- $\mu \rightarrow e + 2\nu$

(electron + 2 neutrinos)

- neutrinos interact extraordinarily weak with matter.

- $\bar{\nu} + p^+ \rightarrow n + e^+$

(Inverse Beta decay process.)

- Here is a rule of what reactions will and won't work.

## Lepton number:

- $L = +1$ to the electron, muon and neutrino.

- $L = -1$ to the positron,

Positive muon, and the antiparticles.

- All other particle are given Lepton number of zero.

## Law of Cons of Lept number:

- Sum of leptons numbers must be same before/after reactions.

- Lepton numbers give

Allowed reactions and describe distinguishing of neutrinos and antineutrinos.

ex) (Pion Decays)

- $\pi^- \rightarrow \mu^- + \bar{\nu}$
- $\pi^+ \rightarrow \mu^+ + \nu$

(muon decays)

- $\mu^- \rightarrow e^- + \nu + \bar{\nu}$
- $\mu^+ \rightarrow e^+ + \nu + \bar{\nu}$

:) Lepton number is what distinguishes neutrinos and antineutrinos.

- Lepton number is $+1$ for neutrino and $-1$ for antineutrino.

This can be experimentally determinable.

- Q. what is helicity, how is related to particle trajectory?

- $\mu^- \not\to e^- + \gamma$

(never observed but it's still theoretically consistent)

- Q. *whatever is not expressly forbidden is mandatory?

- Are different kinds of neutrinos → are associated with ($\nu_e$) or with muons ($\nu_\mu$)

- <u>Muon number</u>: $L_\mu = +1$ to $\mu^-$ and $\nu_\mu$

  $L_\mu = -1$ to $\mu^+$ and $\bar{\nu}_\mu$

- <u>electron number</u>:

  $L_e = +1$ to $e^-$ and $\nu_e$

  $L_e = -1$ to $e^+$ and $\bar{\nu}_e$

- Redefine conservation of lepton number → Into conservation of muon number and electron number.

- Neutron Beta decay:

$$n \rightarrow p^+ + e^- + \bar{\nu}_e$$

- Pion decays:

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

$\pi^+ \rightarrow \mu^+ + \nu_\mu$

## muon decays:

- $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$
- $\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$

ex) 29 instances of

- $\bar{\nu}_\mu + p^+ \rightarrow \mu^+ + n$
- $\bar{\nu}_\mu + p^+ \rightarrow e^+ + n$

(one kind of neutrino)

- neutrinos are very light, they do have mass.

- neutrino oscillation is a phenomenon when neutrinos of one type convert to neutrinos of other types and so on and so forth.

- lepton family is characterized by their decomposed

particles.

- Mesons and baryons are called hadrons.

- Lepton finally don't interact with strong force and 1/2 spin integer.