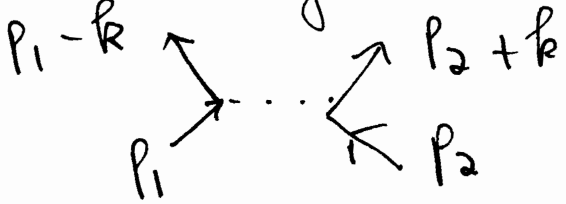
32(4): Application of m Theory to the Pion

Reference

https://opentextbc.ca/physicstextbook2/chapter/the-yukawa-particle-and-the-heisenberg-principle-revisited/

Yukawa in 1935 explained the short range of the force between a neutron and a proton by the creation and exchange of a pion, causing temporary violation of conservation of mass energy. The pion is not directly observable and is called a virtual particle. The process can be described by



i.e.

$$\underline{p}_1 + \underline{p}_2 = \underline{p}_1 + \underline{p}_2 - \underline{k} + \underline{k} \quad -(1)$$

$$= \underline{p}_3 + \underline{p}_4$$

where

$$\underline{p}_3 = \underline{p}_1 - \underline{k} \quad -(2)$$

$$\underline{p}_4 = \underline{p}_2 + \underline{k} \quad -(3)$$

The range of the force is limited by the fact that the pion can only exist for a short time allowed by the Heisenberg uncertainty principle in the standard model. Conservation of mass energy is violated for an amount of time:

$$t \sim \frac{h}{4\pi \Delta E} \quad -(4)$$

and no process can detect the violation.

The distance the pion travels is:

$$d \sim c\Delta t, \quad -(5)$$

2) So its lifetime is:

$$t \sim \frac{d}{c} \quad - (6)$$

if it travels close to the speed of light. If is $\sim 10^{-15}$ m then

$$t \sim 3.310 \times 10^{-24} \text{ s} \quad - (7)$$

and

$$E = \frac{\hbar}{4\pi \Delta t} = 1.610 \times 10^{-11} \text{ J} \quad - (8)$$

$$\sim 100 \text{ meV}$$

So the mass of the pion is:

$$m = \frac{E}{c^2} \quad - (9)$$

To many physicists this has always been an unsatisfactory procedure. It is entirely rejected by the ECE School of physics, because the HUP has been refuted in great detail in UFT175, now a classic.

The simplest way of describing the quantization of a wave particle is to use the de Broglie Einstein equations:

$$E = \gamma m c^2 = \hbar \omega \quad - (10)$$

$$\underline{p} = \gamma m \underline{v} = \hbar \underline{\kappa} \quad - (11)$$

In m theory, eq. (10) becomes:

$$E = \gamma m(r) m c^2 = \hbar \omega \quad - (12)$$

and this can be expressed as

$$E^2 = p^2 c^2 + m(r) m^2 c^4 = \hbar^2 \omega^2 \quad - (13)$$

3) If the particle is at rest then:

$$E = n(r)^{1/2} mc^2 = \hbar\omega \quad -(14)$$

$$= 2\pi\hbar f$$

$$= \frac{2\pi\hbar}{t}$$

so the Heisenberg principle is changed to:

$$Et = 2\pi\hbar \quad -(15)$$

i.e.

$$E = \frac{\hbar}{t} \quad -(16)$$

The distance travelled by the particle in time t is

$$d = ct \quad -(17)$$

so

$$t = \frac{d}{c} \quad -(18)$$

and

$$E = \frac{\hbar c}{d} = \frac{2\pi\hbar c}{d} \quad -(19)$$

Therefore its mass is:

$$\boxed{m = \frac{2\pi\hbar}{n(r)^{1/2} c d}} \quad -(20)$$

Comparing eqs. (14) and (20):

$$n(r)^{1/2} = \frac{2\pi\hbar}{mcd} \quad -(21)$$

So the mass of any particle is determined by the $n(r)^{1/2}$ function.

Now consider the energy equation (13):

$$E - m(r)^{1/2} mc^2 = \frac{p^2c^2}{E + m(r)^{1/2} mc^2} \quad -(22)$$

So

$$E = \frac{p^2c^2}{E + m(r)^{1/2} mc^2} + m(r)^{1/2} mc^2 \quad -(23)$$

This equation can be used to describe the loss of a meson from a proton:

$$\underline{p} \rightarrow \underline{p} - \underline{k} \quad -(24)$$

So

$$E = \frac{c^2}{E + m(r)^{1/2} mc^2} (\underline{p} - \underline{k}) \cdot (\underline{p} - \underline{k}) + m(r)^{1/2} mc^2 \quad -(25)$$

and in the SU(2) basis:

$$E = \underline{\sigma} \cdot (\underline{p} - \underline{k}) \frac{c^2}{E + m(r)^{1/2} mc^2} \underline{\sigma} \cdot (\underline{p} - \underline{k}) + m(r)^{1/2} mc^2 \quad -(26)$$

Eq. (26) quantizes with:

$$\underline{p}\,\phi = -i\hbar \underline{\nabla} \phi \quad -(27)$$

to give energy levels of E:

$$E\phi = \underline{\sigma} \cdot (-i\hbar \underline{\nabla} - \underline{k}) \left(\frac{c^2}{E + m(r)^{1/2} mc^2} \right) \underline{\sigma} \cdot (-i\hbar \underline{\nabla} - \underline{k})\,\phi + m(r)^{1/2} mc^2 \phi \quad -(28)$$

The hamiltonian is:

$$H = E + U \quad -(29)$$

where U is the potential energy equivalent to the force between proton and neutron.

) Therefore the complete minimal prescription is:

$$E \rightarrow E + U \quad - (29)$$

and

$$\underline{p} \rightarrow \underline{p} - \underline{k} \quad - (30)$$

Therefore eq. (28) becomes:

$$(H - U)\phi = \underline{\sigma} \cdot \left(-i\hbar \underline{\nabla} - \underline{k}\right)\left(\frac{c^2}{E + m(r)^{1/2} mc^2}\right)\underline{\sigma} \cdot \left(-i\hbar \nabla - \underline{k}\right)\phi$$
$$+ m(r)^{1/2} mc^2 \phi \quad - (31)$$

For a slow moving particle

$$E \sim m(r)^{1/2} mc^2 \quad - (32)$$

so:

$$H\phi = -\frac{\hbar^2 \nabla^2}{2m(r)^{1/2} m}\phi + U\phi + m(r)^{1/2} mc^2 \phi + \dots \quad - (33)$$
$$= E\phi$$

Now consider:

$$H_0 \phi := \left(H - m(r)^{1/2} mc^2\right)\phi \quad - (34)$$
$$= \left(-\frac{\hbar^2 \nabla^2}{2m(r)^{1/2} m} + U\right)\phi$$

The expectation values are energy levels:

$$E = \langle H_0 \rangle = \int \phi^* \left(-\frac{\hbar^2 \nabla^2}{2m(r)^{1/2} m}\right)\phi \, d\tau + \int \phi^* U \phi \, d\tau \quad - (35)$$

3) These energy levels give a mass spectrum, and the pion masses.

Finally the potential energy U is evaluated from the n force:

$$F = -\frac{\partial n(r)}{\partial r}\frac{n^{1/2}(r)}{2n(r) - r\frac{dn(r)}{dr}} E \quad -(36)$$

where

$$E^2 = p^2c^2 + n(r)m^2c^4 \quad -(37)$$

and

$$F = -\frac{\partial U}{\partial r} \quad -(38)$$

For a slow moving particle:

$$E = n^{1/2}(r)mc^2 \quad -(39)$$

so

$$F = -\frac{\partial n(r)}{\partial r}\frac{n(r)mc^2}{2n(r) - r\frac{dn(r)}{dr}} \quad -(40)$$

Assuming that

$$r\frac{dn(r)}{dr} \ll 2n(r) \quad -(41)$$

then

$$F = -\frac{\partial n(r)}{\partial r}\frac{mc^2}{2} \quad -(42)$$

and

$$U = \frac{1}{2}n(r)mc^2 \quad -(43)$$

Therefore in this approximation the energy eigenvalue

se:

$$E = \langle H_0 \rangle = -\frac{\hbar^2}{2m}\int \phi^* \nabla^2 \left(\frac{\phi}{m(r)^{1/2}} \right) d\tau + \int \phi^* U \phi \, d\tau \quad -(44)$$

There are many more terms that can be considered in Eq. (31), as in previous UFT papers. The mass becomes is:

$$m = \frac{\langle H_0 \rangle}{c^2} \quad -(45)$$

Summary

In considering the interaction of a proton and a neutron, the meson momentum $\underline{k}$ is considered to play the role of the vector potential $\underline{A}$ in electromagnetic interactions. There is no need to postulate a virtual particle. The Feynman diagram is replaced by a minimal prescription:

$$E \rightarrow E + U \quad -(46)$$

$$\underline{p} \rightarrow \underline{p} - \underline{k} \quad -(47)$$