The Origin of the Experimental Weinberg Angle

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Abstract: Here, within the non-perturbative Scale-Symmetric Theory (SST), we derived the Paschos-Wolfenstein (PW) relationship. The derivation shows the true origin of the experimental Weinberg angle. We also showed that the PW ratio leads to the CP-violation sector in the PMNS matrix.

1. Introduction

The Paschos-Wolfenstein (PW) relationship/ratio R^- for an isoscalar target (i.e. the isospin is T = 0, i.e. there is equal number of neutrons and protons) is [1]

$$R^- = (\sigma^{\nu N}{}_{NC} - \sigma^{\nu(anti)N}{}_{NC}) / (\sigma^{\nu N}{}_{CC} - \sigma^{\nu(anti)N}{}_{CC}) =$$

$$= 1/2 - \sin^2\Theta_w = 1/2 - s_w{}^2 , \qquad (1)$$

where $\sigma^{\nu N}{}_{NC}$ and $\sigma^{\nu N}{}_{CC}$ are the deep inelastic neutrino-nucleon cross sections for neutral-current (NC) and charged-current (CC) interactions while $\sigma^{\nu(anti)N}{}_{NC}$ and $\sigma^{\nu(anti)N}{}_{CC}$, due to the opposite internal helicity of the muon-antineutrinos and nucleons [2], are the elastic cross sections as it is showed in this paper. The Θ_W is the experimental Weinberg angle.

The orthodox electroweak (EW) theory leads to following formula for the weak mixing angle

$$s_w{}^2 = 1 - (W^{\pm} / Z)^2 = 0.22301(27) , \qquad (2)$$

where $W^{\pm}$ = 80.379(12) GeV and Z = 91.1876(21) GeV [3] are the orthodox bosons carrying the weak interactions. Emphasize that at this time, there is no generally accepted theory that explains why the experimental value is so and not different.

Here the very simple derivation of the PW ratio on base of the Scale-Symmetric Theory (SST) [2] shows the true origin of the $s_W{}^2$.

SST leads to the atom-like structure of baryons [2]. There are three main parts in nucleons: the spin-1/2 torus/electric-charge X^+ which has left-handed internal helicity (L) and positive electric charge (E_+) so the signature is LE_+, the spin-0 central condensate Y responsible for the weak interactions which is composed of the Einstein-spacetime (ES) components i.e. of the spin-1 neutrino-antineutrino pairs, and the relativistic pion W (it is not the $W^\pm$ boson).

On the other hand, the muon-neutrinos have also the left-handed internal helicity (L) and negative weak charge (W_-) so the signature is LW_- (see Table 6 in [2]). Two whirls with antiparallel spins on the same straight line and with the same internal helicity attract each other. Moreover, the opposite electric charge and weak charge cause that there is additional attraction. It leads to conclusion that the muon-neutrinos are scattered on the X^+ and such scattering is the deep inelastic scattering because pions are produced inside the torus. According to SST, the muon-antineutrinos have the signature RW_+ so they are repulsed by X^+. It leads to conclusion that there is the elastic scattering on X^+. To conserve the spin and electric charge of the torus X^+, the muon-antineutrinos produce pairs of the spin-1 pairs – it can be the two spin-1 bare electron-positron pairs $(e^+e^-)_{bare}$ or two spin-1 neutrino-antineutrino pairs, for example, $\nu_\mu\nu_{\mu,anti}$ plus $\nu_e\nu_{e,anti}$ – such an object of four neutrinos is perfectly neutral (see Table 6 in [2]).

First the scattered neutrino produces the charged pions $\pi^{+,-} \rightarrow \pi^o + \Delta\pi^\pm$ or the bare pairs $(e^+e^-)_{bare}$ and next such neutrino is scattered on electron/positron in $\Delta\pi^\pm = 4.5936(5)$ [3] or on electron/positron in $(e^+e^-)_{bare} = 1.020814$ MeV [2].

More and more massive virtual fermions/tori produced in ES, have smaller and smaller sizes so lower and lower cross sections. Mass of torus is inversely proportional to its squared radius whereas cross section is directly proportional to squared radius so cross section is inversely proportional to mass of torus

$$\sigma^{\nu N} \sim 1 / \Delta\pi^\pm \sim 1 / (e^+e^-)_{bare} \,. \qquad (3)$$

We showed here also that $1/R^-$ leads to the SST invariant for the CP-violation sector in the SST PMNS matrix: 3.6018 [4].

2. Derivation of the Paschos-Wolfenstein ratio

In the simplest deep inelastic NC scattering of the muon-neutrinos on the torus X^+ is

$$\nu_\mu + p \rightarrow \nu_\mu + p + \pi^+ + \pi^- \,. \qquad (4)$$

There are two charged pions so we have

$$\sigma^{\nu N}{}_{NC} \rightarrow 1 / (2\Delta\pi^\pm) \,. \qquad (5)$$

In the simplest elastic NC scattering of the muon-antineutrinos on the torus X^+ is

$$\nu_{\mu,anti} + p \rightarrow \nu_{\mu,anti} + p \,, \qquad (6)$$

so $\sigma^{\nu(anti)N}{}_{NC}$ we can neglect.

From (4) – (6) we have

$$\sigma^{\nu N}{}_{NC} - \sigma^{\nu(anti)N}{}_{NC} \rightarrow 1 / (2\Delta\pi^\pm) \,. \qquad (7)$$

The muon is produced from selected particles from the two quadrupoles (the electron quadrupole and neutrino quadrupole). In the simplest deep inelastic CC scattering of the muon-neutrinos on the torus X^+ is

$$\nu_\mu + n + 2(e^+e^-)_{bare} + (\nu_\mu\nu_{\mu,anti} + \nu_e\nu_{e,anti}) \rightarrow \mu^- + (\Sigma^+ \rightarrow n + \pi^+) + \gamma + \nu \,. \qquad (8)$$

There is one charged pion and $2(e^+e^-)_{bare}$ on the left side so we have

$$\sigma^{\nu N}{}_{CC} \rightarrow 1 / [\Delta\pi^\pm - 2(e^+e^-)_{bare}] \,. \qquad (9)$$

In the simplest elastic CC scattering of the muon-antineutrinos on the condensate X^+ is

$$\nu_{\mu,anti} + n \rightarrow \nu_{\mu,anti} + n \,, \qquad (10)$$

so $\sigma^{\nu(anti)N}{}_{CC}$ we can neglect.

For the CC scattering from (8) – (10) we have

$$\sigma^{\nu N}{}_{CC} - \sigma^{\nu(anti)N}{}_{CC} \rightarrow 1 / [\Delta\pi^\pm - 2(e^+e^-)_{bare}]. \qquad (11)$$

From (1), (7) and (11) we have

$$R^- = [\Delta\pi^\pm - 2(e^+e^-)_{bare}] / (2\Delta\pi^\pm) = 1/2 - (e^+e^-)_{bare} / \Delta\pi^\pm = 1 / 3.6000 =$$

$$= 1/2 - s_w^2 \,. \qquad (12)$$

From (12) follows that $R^- = 1 / 3.6000$ and that $s_w^2 = (e^+e^-)_{bare} / \Delta\pi^\pm = 0.22223(3)$.

3. The origin of the Weinberg angle

In Paragraph **2** we showed that the derivation of the PW ratio leads to the origin s_w^2 – it is the ratio of two characteristic masses i.e. of the mass of the bare electron-positron pair to the mass distance between the charged and neutral pion. But what is the direct origin of the Weinberg angle Θ_W? We should carry out a deeper analysis.

The SST shows that in the CKM and PMNS matrices, the mixing angles are ratios of masses characteristic for the atom-like structure of nucleons [4], [5], [6].

Within the SST atom-like model, for neutrino with the typical energy inside nucleon ($m_{LL}/2 = 67.54441$ MeV [2]) interacting with $\Delta\pi^\pm = 4.5936(5)$ MeV [3] when it is produced by the three main parts inside nucleon (the torus with a mass of $X \approx 318.3$ MeV, the relativistic pion with a mean mass of $W_{mean} \approx 212.2$ MeV, and the central ES condensate with a mass of $Y \approx 424.1$ MeV [2]), we have

$$\Theta_W = (X + W_{mean} + Y - \Delta\pi^\pm) / (m_{LL}/2) = 28.1305^o \,, \qquad (13)$$

so the Weinberg angle Θ_W we interpret as a ratio of the characteristic masses. It leads to

$$s_w^2 = 0.22229 \,. \qquad (14)$$

The same value have the V_{12} and V_{21} elements in the CKM matrix $V_{12}=V_{21}= 1 / (1 + g)$, where $g = (X + Y) / W_{mean}$ i.e. $V_{12} = V_{21} = (X + W_{mean} + Y) / W_{mean} = 0.22229$ [4]. This means that the Weinberg angle is indirectly associated with the CKM matrix.

We can see that in the SST both the Θ_W and s_w^2 are ratios of the SST characteristic masses – the same concerns the mixing angles and the elements in the CKM and PMNS matrices.

On the other hand, when we apply the SST quark model, $g = m_b/m_c$ [MeV/MeV] = 4190/1267, we obtain $s_w^2 = 0.2322$ which is close to the Standard-Model value $\hat{s}_Z^2 = 0.23122(3)$ for 91.2 GeV [3]. Emphasize that in the Standard Model there is the scale dependence of the weak mixing angle defined in the $\overline{MS}$ scheme (see Fig.10.2 in [3]). The minimum of the curve $\sin^2\Theta_W(\mu) = f(\mu)$ corresponds to $\mu = M_W$.

There is as well the second interpretation of the Weinberg angle. Assume that the resting mass $H^+ + (e^+e^-)_{bare} = 728.4609$ MeV (it is mass of the core of baryons interacting with the bare electron-positron pair) [2] transforms in a relativistic mass in such a way that its resting mass is equal to mass of the neutral pion $\pi^o = 134.9770(5)$ MeV [3]:

$$m_{rel} / m_o = [H^+ + (e^+e^-)_{bare}] / \pi^o = (1 - v_{tor}^2 / c^2)^{-1/2} = c / v_{pol} , \qquad (15)$$

where v_{tor} is the toroidal speed of the relativistic mass while v_{pol} is the poloidal one.

The torus X has internal helicity so it has both toroidal and poloidal mean speeds. All matter is produced from the ES components so for them is

$$v_{tor}^2 + v_{pol}^2 = c^2 . \qquad (16)$$

From (15) and (16) follows that we can interpret the Weinberg angle as the ratio of the calculated squared toroidal and poloidal speeds

$$\Theta_w [^o] = v_{tor}^2 / v_{pol}^2 = 28.1268 . \qquad (17)$$

Such angle leads to $s_w^2 = 0.22224$. It is consistent with both the SST result 0.22223(3) and SLD result 0.222228(54).

4. Summary

Presented here derivation leads to the true origin of the experimental s_w^2 – it is the ratio of mass of the bare electron-positron pair to mass distance between the charged and neutral pion. We obtained $s_w^2 = 0.22223(3)$. Most important are the internal helicities of neutrinos and nucleons and their respectively weak charges and electric charges described within SST [2].

We can see that the $1/R^- = 3.6000$ is very close to value of the SST invariant for the CP-violation sector in the SST PMNS matrix 3.6018 (see Fig.7 in [4]). The SST invariant leads to $s_w^2 = 0.22236$.

Both SST results are consistent with the SLD result $s_w^2 = 0.22228(54)$ [3].

Here we showed that we can interpret the Weinberg angle Θ_w as both the ratio of the characteristic masses in the atom-like structure of nucleons (formula (13)) or the ratio of the squared toroidal and poloidal speeds of the neutral pion with characteristic relativistic mass (formula (17)). The SST mean value of the Weinberg angle that follows from the two ratios is 28.13^o – it leads to $s_w^2 = 0.2223$.

It is just a coincidence that the orthodox value (see formula (2)) is close to the two values received in this paper. There is not a dependence of s_w^2 on squared masses of the $W^{\pm}$ and Z bosons and such bosons are the composite particles [7]. Notice that both SST values are lower than the lower limit resulting from the orthodox formula.

References

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