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Cartan's Supersymmetry and the Decay of $H^0(0+$, 125 GeV$)$ to $\gamma\gamma$, WW and ZZ

Sadataka FURUI*
Graduate School of Science and Engineering,
Teikyo University
E-mail: furui@umb.teikyo-u.ac.jp

Cartan's supersymmetry can be applied not only to electromagnetic interaction but also to weak interaction of leptons and quarks. We studied the decay of the possible higgs partner h^0(11GeV) to $\Upsilon(b\bar b)\gamma(\ell\bar\ell)$, and extended the model to study the decay branching ratios of Higgs boson H^0(125GeV) to $W\bar W, Z\bar Z$ and $\gamma\gamma$.
The ratio of the signal strength ratio $\frac{\sigma(H^0\to W\bar W)}{\sigma(H^0\to\gamma\gamma)} = \frac{0.87\pm 0.2}{1.58\pm 0.3}$ agrees with the ratio of the number of independent diagrams that Cartan's symmetry predicts $\frac{9}{16}$.
The extended Cartan's theory defines the amplitudes of penguin and tree diagrams of B^0 and $\bar B^0$ to $K^0 J/\Psi$, and explains the CP violation of $\bar B^0 \to J/\Psi \bar K^0_L$ as an effect of tree diagrams which is absent in $B^0 \to J/\Psi K^0_L$.

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*Speaker.

1. Introduction

Higgs boson $H^0(0^+$,125GeV) decays to $\gamma\gamma(\ell\bar\ell\ell\bar\ell)$, $W(\ell\bar\nu)\bar W(\bar\ell\nu)$ and $Z(\ell\bar\ell)\bar Z(\bar\ell\ell)$ with the ratio of the signal strength $\sigma(H^0\to xx) = B(H^0\to xx)_{exp}/B(H^0\to xx)_{SM}$, equals 1.58 ± 0.3 for $\gamma\gamma$, 0.87 ± 0.2 for $W\bar W$ and 1.11 ± 0.3 for $Z\bar Z$ [1, 2]. The process of $g\bar g\to Z\bar Z$ is expected to enhance the signal strength of $Z\bar Z$, and including this correction, the signal strength of $Z\bar Z$ reduces to 0.93 ± 0.3 [3].

Cartan's supersymmetry[4] fixes couplings of two types of fermions

$$\ell_L = \begin{pmatrix}\psi\\ \mathscr{C}\psi\end{pmatrix} \quad \text{and} \quad \bar\ell_L = (\mathscr{C}\phi,\phi).$$

where $\psi,\phi\in(C\bigotimes C\ell_{1,3})f$ are Clifford algebraic spinors. The components ψ are expressed as ξ_*, those of $\mathscr{C}\psi$ are expressed as ξ_{***}, those of ϕ and $\mathscr{C}\phi$ are expressed as ξ_{**}, ξ_0 and ξ_{1234}, where the number of indices are expresed by $*$. There are two types of vector fields $\vec E = (x_1,x_2,x_3,x_4)$ and $\vec E' = (x'_1,x'_2,x'_3,x'_4)$.

The transformation G_{23} changes interaction of leptons or quarks to that of particle-antiparticle interaction, and the transformation G_{12},G_{123},G_{13} and G_{132} contains the supersymmetric transformation[11, 12]. The Clifford algebra [9, 10] says that a combination of quaternions $\mathscr{H}\oplus\mathscr{H}\ell$, where ℓ is a new imaginary unit ($\ell^2=-1$) makes an octonion $\mathscr{O}$. A Dirac particle which is expressed by a pair of quaternions could form an octonion and has the triality symmetry, whose extra freedom can be attributed to the color degrees of freedom.

Assuming that the coupling of a Higgs bosons to two leptons and to two quarks are given by

$$-y_\ell^{ij}\mathscr{E}_i(\mathscr{L}_j\circ\mathscr{H}_d) = -y_\ell^{ij}H_d^0\bar\ell_{L_i}\ell_j \quad \text{and} \quad -y_b^{ij}\mathscr{D}_i(\mathscr{Q}_j\circ\mathscr{H}_d) = -y_b^{ij}\,v_d\,\bar b_i b_j,$$

and the coupling of a u quark to Higgs boson is given by[5]

$$y_u^{ij}\mathscr{U}_i(\mathscr{Q}_j\circ\mathscr{H}_d) = y_u^{ij}\,v_u\,\bar u_i u_j.$$

we can calculate decay branching ratios of the Higgs boson H^0(125GeV), that of the possible partner h^0(11GeV) and that of $B^0(\bar B^0)$ meson.

2. $H(0^+)\to VV$, $H(0^+)\to\gamma\gamma$ and $h(0^+)\to\Upsilon(b\bar b)\gamma(\ell\bar\ell)$

When we identify H^0 as 0^+ coupled states of $\psi\bar\psi$ and $\phi\bar\phi$, we find that the decay amplitudes of the 0^+ states to 4γ cancel with each other. Cartan's supersymmetry predicts 8 amplitudes of $\Psi=\psi\bar\psi$ into two $2\gamma(\ell\bar\ell)$ and 8 amplitudes of $\Phi=\phi\bar\phi$ into two $2\gamma(\ell\bar\ell)$, and altogether 16 diagrams.

The Higgs boson can be regarded as a scalar of $\langle\psi,\mathscr{C}\psi\rangle$ or $\langle\phi,\mathscr{C}\phi\rangle$. A pair of $\langle\psi,\mathscr{C}\psi\rangle$ and $\langle\phi,\mathscr{C}\phi\rangle$ can decay into a pair of $l\bar\nu$ and $\bar l\nu$, by exchanging two vector particles X, which contains 9 diagrams. The leptons or quarks that X connects are $\psi\phi$ or $\mathscr{C}\psi\mathscr{C}\phi$.

Experimentally the ratio of the signal strength, i.e. branching ratio normalized to the standard model value $\sigma(H^0\to xx) = B(H^0\to xx)_{exp}/B(H^0\to xx)_{SM}$, of $W\bar W$ channel and $\gamma\gamma$ channel $\dfrac{\sigma(H^0\to W\bar W)}{\sigma(H^0\to\gamma\gamma)}$ is $\dfrac{0.87\pm0.2}{1.58\pm0.3}$, agrees with the ratio of the number of independent diagrams $\dfrac{9}{16}$ derived from Cartan's supersymmetric theory of spinors. We expect the signal strength of $Z\bar Z$ agrees with that of $W\bar W$ after reduction of $g\bar g$ effects[15].

Assuming that the Higgs partner h^0 is a 0^+ and a pair of $\psi\mathscr{C}\psi$ and $\phi\mathscr{C}\phi$ decay into $\gamma(\ell\bar{\ell})$ and $\Upsilon(b\bar{b})$ via exchange of vector particles x_2, we calculated the decay of $\chi_b(3P, 10.5157\mathrm{GeV})$ meson discovered by LHCb detector at CERN, to $\Upsilon(b\bar{b})\gamma(\ell\bar{\ell})$[14]. The leptons or quarks that x_2 connects are $\psi\mathscr{C}\psi$ or $\phi\mathscr{C}\phi$.

Figure 1: Typical diagram of $H^0 \to WW \to \ell\bar{\ell}\ell\bar{\ell}$ and $h^0 \to \Upsilon\gamma(\ell\bar{\ell})$

3. Decay of $B^0(0^-) \to K_L^0 J/\Psi$ v.s. $\bar{B}^0(0^-) \to \bar{K}_L^0 J/\Psi$

In Cartan's theory, the electromagnetic interaction of leptons and quarks is expressed as ${}^t\psi\mathscr{C}x_i\psi$. In the case of coupling of leptons and quarks with W, we extend the coupling ${}^t\phi\mathscr{C}X\psi$ to ${}^t\phi\mathscr{C}X(1-\gamma_5)\psi$, where $X = x_i$ or $x_i{}'$ is the degenerate vector particle, and unify the interactions in the form

$$ {}^t\phi\mathscr{C}\bar{x_i}\psi + {}^t\phi\mathscr{C}\overline{x_i{}'}\mathscr{C}\psi $$

where $\bar{x_i}$ implies appropriate x_i or $(-\gamma_5 x_i)$ dependent on i[16]. We apply to the B^0 decay to $K^0 + J/\Psi$ penguin diagrams and tree diagrams and compare with experiments[7]. We observed $\gamma_5\gamma_5$ type penguin diagrams yield $\bar{K}^0$ with small components and suppresses CP even $\bar{B}^0$ tagged events.

Figure 2: Typical diagrams of $\bar{B}^0 \to \bar{K}^0 J/\Psi$ decay, penguin diagram γ_5 type (left) and 1 1 type(right)[16]. In the $\gamma_5\gamma_5$ type, $b = \xi_{234}$ is a small component, and corresponding B^0 decay $\bar{b} = \xi_{14}$ is a large component.

Figure 3: Typical diagrams of $B^0 \to K^0 J/\Psi$ decay, tree diagram 1 1 type(left), and γ_5 type(right). In the γ_5 type, $\bar{s} = \xi_{1234}$ is a small component, and in the corresponding $\bar{B}^0$ decay $s = \xi_4$ is a large component.

4. Discussion and Conclusion

The decay of a Higgs boson to $\ell\bar{\ell}\ell\bar{\ell}$ and $\ell\bar{\nu},\bar{\ell}\nu$ can be well described by the model based on Cartan's supersymmetry[15]. The number of decay diagrams of H^0 to $W\bar{W}, Z\bar{Z}$ and $\gamma\gamma$ is 9, 9 and 16 respectively. The ratio of the signal strength agrees with the ratio of the number of independent decay diagrams.

The preference of $B_s(0^+) \to D_s^*(0^+)\mu^-$ rather than $B_s(0^+) \to B_s(0^-)\pi$ is expected to be due to the fact that b quark does not belong to the triality sector of μ^-, in which (s,c) quarks belong, and the decay via $D_s^*(0^+)$ after the transition of b to c of weak decay, which is blind to the triality, becomes more favored than the strong decay.

The origin of the discrepancy between the raw asymmetry of events of *CP* even final states in $B^0 \to J/\Psi K^0(\bar{B}^0 \to J/\Psi\bar{K}^0)$, and the best fit projection in Δt of B^0 tagged events and $\bar{B}^0$ tagged events[8] is expected to be due to effects of γ_5 type interaction of tree diagrams in the large Δt region, where *CP* asymmetry in Cartan's algebra plays an essential role[13, 16].

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