London Journal of PHYSICS

Volume 2 No 2

The Structures of the Gauge Bosons after the Symmetry Breaking and the Experimental Data on the Elementary Particles

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October 27, 2025

Abstract

The properties of the gauge bosons built out of the two component spinors are outstandingly well in line with the experimental data on Cabibbo-Kobayashi-Maskawa (CKM) matrix elements, in terms of the relations between the values of the CKM matrix elements and predictions of the margins of error. The same can be said about the experimental data on the charged lepton decays and massive gauge boson decays. This kind of the structure of the gauge bosons also bring more clarity to the absence of the flavor - changing neutral currents (FCNC). The relation of the fermion masses to the Z boson structure is briefly discussed. The peculiarities of the values of the CKM matrix elements are also emphasized.

The interaction Lagrangian built on the basis of the two component spinors type of gauge bosons is scale invariant before the symmetry breaking. The conventional form of the two - point correlation function near the critical point can be obtained by two different methods using this Lagrangian, by applying the CFT approach and the theory of critical exponents approach. It is pointed out that this interaction Lagrange functions near Wilson's renormalization group flow fixed points.

1 Introduction

In the earlier works we have discussed the coupling constant - electroweak gauge boson mass relation

$$M_W/g \;=\; M_B/g' \tag{1}$$

which in a compact form leads to the Standard Model form of the W and Z bosons ([1], [2], [3]). One can observe that the approximate form of this type of relation between the mass and coupling constants holds for all known elementary particles including all quarks and leptons [3]. It has been emphasized that Eq.(1) can be considered as a simple form of the manifestation of the more general connection between the energy and the structural complexity of the quantum systems [3]. The drastic difference in the latent heat of fusion of the crystals tell us that atoms and molecules are not like flamboyant objects moving chaotically within quantum systems, they are more likely follow the certain pattern in their thermal motion: under extreme conditions the whole structure of this pattern breaks down, this phase transition induces the superconducting state in the case of metals [4]. 'Halogens' vs 'alkali metals' type of relations between the groups of the elementary particles has also been analyzed [5].

A closer look at the structure Z boson built out of the two component spinors reveals another mechanism for the fermion mass generation. This 'non - spinor' type of Z boson also brings more clarity to the absence of the FCNC. All the available experimental data on the values of the margins of error on the lepton decays, massive gauge boson decays and the CKM matrix elements tell us consistently about this type of structure of the massive gauge bosons.

Both Eq.(1) and scale invariance of the interaction Lagrangian based on the two component spinor type of the gauge bosons induce the conventional form of the two - point correlation function near the critical point.

2 Methods

A. The connection of the the spinor structure of the gauge bosons to the experimental data on the CKM matrix elements, lepton decays and massive gauge boson decays, a *Z* boson related fermion mass generation mechanism

We have discussed the possible two component spinor structure of the gauge bosons in [2]. The B boson has the form

$$B_\mu(x) \;=\; \Psi^\dagger(x)(i/g')\partial_\mu\Psi(x)/(\Psi^\dagger(x)\Psi(x)) \tag{2}$$

and the The triplet of the vector bosons $\mathbf{W}_\mu$ has the form

$$(W_l)_\mu(x) \;=\; \Psi^\dagger(x)\sigma_l(2i/g)\partial_\mu\Psi(x)/(\Psi^\dagger(x)\Psi(x)) \tag{3}$$

Here $\Psi(x)$ is the two component spinor :

$$\Psi(x) = \begin{pmatrix} \Psi_1(x) \\ \Psi_2(x) \end{pmatrix} \tag{4}$$

We can liken the formation of this type $\mathbf{W}$ boson and B boson with the Pauli matrices (spin 1/2) inside the structure to formation of the water droplets in the state of the vacuum and weightlessness. All the droplets will gain a spherical shape. The similar process occurs when after the symmetry breaking the gauge terms of the newly formed bosons are produced. Similarly, the original gauge terms related to the $\mathbf{W}$ boson and the B boson disappear after the symmetry breaking, the new gauge terms representing the photon, the Z boson and the charged W bosons emerge.

The 4 - vector property of Eq.(2) and Eq.(3) based bosons could be accommodated by the different sources: one can consider the first order infinitesimal transformations only and omit the contributions due to the spinor factors; the Lorentz transformed spinors still induce the same pattern of structure (situation similar to the'alkali metals' vs 'halogens' [5]).

If you simply put a 2 x 2 unit matrix inside the B boson structure, Eq.(2) and use the standard from of the definition of the Z boson,

$$Z \;=\; (gW_3 \;-\; g'B)/\sqrt{g^2 \;+\; (g')^2}$$

you will get a 'non -spinor' form of the Z boson. When you subtract $g'B)$ from gW_3 (with σ_3 Pauli matrix) the coupling constants drop out, only the right bottom element of the 2 x 2 matrix remains non - zero. As a result only the lower component of the two component spinor takes part in the formation of the Z boson. The fact that $\frac{1}{2}\sigma_3$ is the eigenstate for the spin $\frac{1}{2}$, makes it more likely that the Z boson has the semiclassical nature. Both the upper component and the lower component of the spinor participate in the formation of the charged W bosons and one can expect that they have more standing out quantum mechanical features than the Z boson has. The formation of the photons with the upper component of the spinor only is a more subtle question, it requires the equalness of the values of the coupling constants g and g'. The photon with this kind of feature would be similar to neutrinos regarding its masslessness. As we see this aspect of the current model holds another path leading to the zero mass of the photon [3]. Is not this 'non - spinor' feature of the photon the reason why the photons/electromagnetic waves are so well described by the equations of the classical electrodynamics (a polarization vector is a different degree of freedom of the photon)?

The experimental data on the Z boson, W boson lifetime and decay modes are well in line with this feature of the Z boson, with its semiclassical nature, in terms of the margins of error. The same is true about the tau lepton and muon decay modes. The experimental values for all the CKM matrix elements also exhibit similar patterns.

The experimental value for the W boson life time has almost three times bigger margin of error than the Z boson life time has [26]:

 DOI 10.69710/ljp.v2i2.16021

$$t_W = (3.158 \pm 0.064) \times 10^{-25} \text{ s}, \; t_Z = (2.6391 \pm 0.0024) \times 10^{-25} \text{ s}$$

The muon and τ lepton life time experimental values also have several times bigger margin of error than Z boson life time has [27], [28]:

$$t_\mu = (2.111 \pm 0.034) \times 10^{-6} \text{ s}, \; t_\tau = (2.80 \pm 0.20) \times 10^{-13} \text{ s}$$

The decay of these leptons occur through the coupling to the W bosons.

Similarly, the W boson decay mode, for example, into hadrons has four times bigger value for the margin of error than the analogous quantity for the Z boson has the margin of error [29], [30]:

W boson decay, hadrons, $(67.60 \pm 0.27)\%$,
Z boson decay, hadrons, $(69.9 \pm 0.06)\%$

As we see the W boson reveals itself in a more quantum mechanical form, in a more probabilistic form in the experiments than the Z boson does ([31], [32]).

The experimental data on the margins of error for the CKM matrix elements also reveal similar tendencies ([34], [35]). The matrix elements related to the change of quark generation, e.g., $V_{cd} = 0.22486 \pm 0.00067$, have several times bigger value for the margin of error than the matrix elements related to the flavor changing within the same quark generation have the margin of error, e.g., $V_{cs} = 0.97349 \pm 0.00016$. $V_{ts} = 0.04110 \pm 0.00078$ vs $V_{tb} = 0.999118 \pm 0.000033$ is also this kind of relation. One should expect the full mobilization of the two component spinor structure nature of the W boson for the transition from one generation to another generation of quarks. At the same time the Z boson with the 'non - spinor' structure (and photon) can not trigger processes with the flavor changing and therefore we have FCNC processes so dramatically suppressed. This feature of the Z boson brings more clarity to the origin of the Glashow-Iliopoulos-Maiani (GIM) mechanism ([35], [36]).

Patterns of the lepton and quark masses (except for the u quark and the d quark) are in a good agreement with the Eq.(1) of the current work [3]. From the other side this 'non - spinor' structure of the Z boson is also in a good agreement with the patterns of the lepton masses and the first generation of the quarks' masses. There could well be two competing tendencies in the quark mass generation: Eq.(1) based tendency and the Z boson based tendency[1]. As a result we get a 'strange' value for the mass of the strange quark: $m_s = 95MeV < m_\mu = 105.66MeV$ ([37], [38]). The full saturation state for these two tendencies are similar.The mass ratio for the τ lepton and muon is close in value to the ratio of the structural complexities for the top quark and the bottom quark.

The values of the CKM matrix elements are approximately equal for the one quark generation change transitions: $V_{cd} \approx V_{us}$ (the transitions between the first and the second generations of quarks) and $V_{ts} \approx V_{cb}$ (the transitions between the second and the third generations of quarks). One would expect that the same relation must hold for the two generations change transitions, for the V_{td} vs V_{ub} relation. However, the $V_{td} = 0.00857 \pm 0.00019$ value is more than twice as big as the $V_{ub} = 0.00369 \pm 0.00011$ value. The two different tendencies of the fermion mass generation is the only opportunity currently available to shed some light to this difference of the values of the CKM matrix elements. As we have just told the u quark and the d quark gain their masses largely by the Z boson mechanism and the third generation of quarks gain their masses largely by the Eq.(1) based mechanism. Therefore the CKM matrix element V_{ub} identifies a transition between the Z boson mechanism wise massless quark and the massive quark, in some sense, while the CKM matrix element V_{td} determines a transition between two massive quarks, massive by the both fermion mass generation mechanisms. One wing of the u quark is neutrino like and this feature of it leads to the noticeably smaller value of the CKM matrix element V_{ub}. The margin of error for V_{ub} is almost twice smaller that the margin of error for V_{td} which also tells us about the stronger presence of the Z boson related mechanism for the u quark $\to$ b quark transition.

We have two approximate equality relations for the values of the CKM matrix elements for the one quark generation change transitions, in the meantime the values of the CKM matrix elements for the transitions between the first and the second generations of quarks are several times bigger than the corresponding values for the transitions between the second and the third generations of quarks. As we have told earlier, the influence of the Z boson related mechanism gradually wanes from generation to generation (of quarks).

[1] the Z boson related fermion mass generation mechanism is further discussed in method B

 DOI 10.69710/ljp.v2i2.16021

At the same time the stronger presence of this mechanism induces the higher transition rate just like in the V_{td} vs V_{ub} case discussed above. In other words, these relations of the CKM matrix elements also support the presence of the two mechanisms pattern for the quark mass generation process. Sometimes it is claimed that the charged weak current transitions are increasingly suppressed as the quark mass difference increases. The $V_{td} > V_{ub}$ relation does not support this notion, the quark mass difference is not among the crucial factors influencing the values of the CKM matrix elements. Yet all the available experimental data on the CKM matrix elements are in agreement with the Z boson related mechanism vs Eq.(1) based mechanism of the quark mass generation nature of the values of these matrix elements: the bigger the presence of the Z boson related mechanism, the stronger quark couplings to the charged W boson. The value of the CKM matrix element $V_{ts} = 0.04110 \pm 0.00078$ is slightly smaller than the value of the CKM matrix element $V_{cb} = 0.04182 \pm 0.00080$. We can interpret this slight difference of the values of the matrix elements the following way. The down quark type s quark is one generation earlier than the same type b quark. However this is the situation where Eq.(1) type influence becomes more powerful than the Z boson based mechanism for the generation of the quark masses ($m_t >> m_b$) and therefore $V_{ts} < V_{cb}$. The thorough analysis of the relations between the values of the CKM matrix elements certainly would be helpful for better understanding the pulses of the world of quarks.

B. The scale invariance of the interaction Lagrangian and the correlation functions

Eq.(2) and Eq.(3) bosons based interaction Lagrangian is scale invariant before the symmetry breaking, the interaction Lagrangian coupling constant and the coupling constant in the denominator of the boson structure cancel out each other. With no coupling constants around we may regard the boson - fermion structure of the interaction Lagrangian as a unit of two free particles and assume them as the scale invariant quantities, fields. The two - point correlation function for the scale invariant fields exhibit a typical form of the correlation function near the critical point ([39], [40]). For $x \to \lambda x$,

$$< \phi_1(x_1)\phi_2(x_2) >= \lambda^{\Delta_1+\Delta_2} < \phi_1(\lambda x_1)\phi_2(\lambda x_2) > \tag{5}$$

and

$$< \phi_1(x_1)\phi_2(x_2) >= \frac{d_{12}}{\mid x_1 - x_2 \mid^{\Delta_1+\Delta_2}} \tag{6}$$

Here d_{12} is a constant which can be taken as $d_{12} = 1$ for the case when $\Delta_1 = \Delta_2$. Otherwise $d_{12} = 0$.

Eq.(1) can be considered as a high energy limit of the coupling constant dependence on the energy scale:

$$g(E) = a + bE \tag{7}$$

Here a and b are energy - independent parameters. We have indicated the necessity of the equalness of the coupling constants g and g' for the 'non - spinor' structure of the photon in Method **A**. In order that these coupling constants draw level at the certain values of energy and other parameters, $g(E) \to a$ condition should be satisfied for that range of parameters. This implies $\beta(g(E)) = 0$ in the Callan - Symanzik equation. This in turn leads to the typical form for the two - point correlation function near the critical point [41].

Eq.(2) and Eq.(3) based interaction Lagrangian does not lose any of its components as a result of the symmetry breaking/shift in the symmetry, it just gets redistributed as the interaction Lagrangian for the newly emerging particles.The original gauge boson terms which are not scale invariant (with the coupling constants in the denominators of the boson wave functions) disappear after the symmetry breaking. This means that the scale invariance implies the conservation of the structural complexity which is natural to expect.

A similar situation must be the case for the second order phase transitions in liquids and alloys. The system, the interactions in the system, holds the scale invariance in a hidden form when it is not near the critical point. Near the critical point this feature of the system becomes explicit. The mathematical congruence of the scale invariance in the thermodynamic systems to the scale invariance of the electroweak interaction Lagrangian might stem from important physics behind this phenomenon.

What would be the scenario for the Z boson related fermion mass generation process? The second order phase transitions are gradual processes. The isospin 'down' fermions become aware of the Z boson and the photon formation process. We have already discussed the signs of the correlations of the different levels of matter, of the different types of spins earlier [5]. We can liken this 'awareness' process of the fermions to the formation of the crystals around the nucleation sites. Here the Z bosons play the role of the nucleation centers. The interaction Lagrangian with the Z boson and photon is no longer scale invariant and the masses of the particles could well be the manifestation of this change of the interaction Lagrangian[2]. As we see nature is as vibrant and multifaceted at its bottom, at its base, as it is around us in everyday life. This base does not consist of the rigid mathematical objects, rigid geometrical forms according to ancient Greek philosophy or the products of the one step condensation processes that some modern theories put forward. Nevertheless the firm knowledge of this foundation can certainly be helpful for having better rapport with nature.

3 Discussions and Conclusions

The Z boson built out of the two component spinors appears to have a 'non - spinor' structure and it must be a semiclassical nature. On the other hand, the charged W boson built this way must exhibit more prominent quantum features. It turns out that all the available experimental data on the elementary particle are remarkably well in line with these predicted features of the massive gauge bosons. All the processes with participation of the W boson have several times bigger margins of error than processes involving the Z boson. The knowledge of this property of the gauge bosons (including the photon) could be helpful in improving the quantum computing technology too. The relations between the CKM matrix elements are also analyzed in this context. It is indicated that there two mechanisms of the quark mass generation: Z boson related mechanism and Eq.(1) based mechanism. It is concluded that the stronger the presence of the Z boson related mechanism the bigger the value of the CKM matrix element.

The standard two - point correlation function near the critical point is obtained in two ways in the framework of the currently discussed model: the interaction Lagrangian is scale invariant which allows application of the techniques of CFT; by using the coupling constant - mass relation within this model. The connection between the scale invariance and the conservation of the structural complexity of the different physical systems is also briefly discussed.

4 Acknowledgements

The author would like to thank Sadiyar Rahimov, director of the Institute for the Physical Problems, Baku State University, for the several helpful discussions of the critical exponents and the renormalization procedures in quantum field theory.

5 Copyright Notice

6 References

1. F. Mamedov, *hep-ph/0606255*

2. F. A. Mamedov, $SU(2)_L \times SU(2)_R$ symmetry of the fermions and the vector bosons, the fermionic origin of the local gauge transformations, the visible traces of the flickering nature of the early stages of the universe's formation, *AJP Fizika C, 2023*

[2] It is worth noting that the mass related quantities also have the scale invariance feature: the curvature scalar in the equations of general relativity also has a certain form of the scale invariance

3. F.A. Mamedov, The connection between the energy and structural complexity of the matter, structural complexity origin of the electroweak boson masses as well as metabolism in living organisms, *AJP Fizika E, 2024*

4. Fizuli Mamedov, Structural complexity of the materials and superconductivity: how fundamental is the mechanism inducing this phenomenon of nature, *AJP Fizika E, 2025*

5. F. A. Mamedov, A possible mass - structural complexity connection for the elementary particles, Wilson's renormalization group fixed points in the realm of the structural complexity analysis, *AJP Fizika E, 2025*

6. S. L. Glashow, Partial Symmetries of Weak Interactions, *Nuclear Physics* **22** (1961), 579

7. S. Weinberg, A Model of Leptons, *Physical Review Letters*, **19**, 1264

8. A. Salam, *Svartholm, N, Proceedings of the Eighth Nobel Symposium, Almqvist & Wiksell, Stockholm* (1968)

9. S. Eidelman et al., *Phys. Lett. B* **592**, 1 (2004)

10. R. W. Brown, K. L. Kowalski, and S. J. Brodsky. Classical radiation zeros in gauge theory amplitudes. *Phys. Rev. D, 28:624, 1983.*

11. F. Mamedov, Radiation zeros in weak boson production processes at hadron colliders, *hep- ph/0107326*

12. C. A. Reynolds, B. Serin, and L. B. Nesbitt, The Isotope Effect in Superconductivity. I. Mercury, *https://doi.org/10.1103/PhysRev.84.691*

13. Leggett, Anthony J. (2022), Quantum liquids: Bose condensation and Cooper pairing in condensed-matter systems , *Oxford: Oxford University Press. ISBN* 9780192856944 *https://doi.org/10.1103/PhysRev.84.691*

14. Binding energy per nucleon, *http://barwinski.net/isotopes*

15. Krassimira Marinova, Istvan Angeli, Nuclear Charge Radii, International Atomic Agency,International Atomic Agency, *https://www-nds.iaea.org/radii*

16. Table of Isotopic Masses and Natural Abundances,
https://www.chem.ualberta.ca/ massspec/atomic_ mass_ abund.pdf

17. Size of helium nucleus measured more precisely than ever before,
https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-82143.html

18. J. E. Hirsch, BCS theory of superconductivity: it is time to question its validity, *Phys. Scr. 80 (2009)* 035702

19. Salucci, P. ; Burkert, A., Dark Matter Scaling Relations, *arXiv:astro-ph/0004397*

20. Collaboration, CMS (2019). "Evidence for light-by-light scattering and searches for axion-like particles in ultraperipheral PbPb collisions at $\sqrt{s_{NN}}$ $\sqrt{s_{NN}}$ = 5.02 TeV". Phys. Lett. B. 797: 134826. arXiv:1810.04602. doi:10.1016/j.physletb.2019.134826. S2CID 201698459

21. Sam Walters, How Eintstein Got His Field Equations,
arxiv.org/abs/1608.05752

22. M. E. Peskin, D. V. Schroeder, An Introduction to Quantum Field Theory, *Addison - Wesley Publishing Company, 1995.*

23. Fizuli Mamedov, Radiation amplitude zeros condition and the structural complexity of the quantum systems, the fundamental nature of the conservation of the structural complexity, *AJP Fizika E, 2025*

24. Fizuli Mamedov, Scaling properties of the Dirac matrices, the gravitational field and consistently life like transformation law behavior aspect of the Dirac matrices. Dirac matrices and dark matter, *AJP Fizika E, 2024*

25. Gell-Mann, M.; Low, F. E. (1954). "Quantum Electrodynamics at Small Distances", *Physical Review. 95 (5): 1300–1312*

26. https://arxiv.org/pdf/2203.11056

27. https://technotes.bnl.gov/PDF/publicationId=224196

28. https://www.slac.stanford.edu/pubs/slacreports/reports14/slac-r-292.pdf

29. https://www.hep.ucl.ac.uk/ jpc/all/ulthesis/node45.htmlpath

30. https://pdg.lbl.gov/2018/listings/rpp2018-list-z-boson.pdf

31. Thales Augusto Barbosa Pinto Silva, David Gelbwaser-Klimovsky, Fundamental constraints on quantum fluctuations: Conservation laws, reality, and no-signaling, *quant-ph/arXiv:2502.12905*

32. Charles Francis, A Model of Classical and Quantum Measurement,
arxiv.org/pdf/physics/9909047

33. Einstein, A., B. Podolsky, and N. Rosen, 1935, Can quantum-mechanical description of physical reality be considered complete?,
Physical Review, 47: 777 780

34. Giulia Ricciardi, Determination of the CKM matrix elements $| V_{xb} |$, *arXiv:1305.2844v2*

35. Vernon D. Barger, Roger J. N. Phillips, Collider Physics, *Addison- Wesley Publishing Company*, 1997.

36. The GIM Mechanism: origin, predictions and recent uses, Luciano Maiani, *hep-ph ¿ arXiv:1303.6154*

37. https://pdg.lbl.gov/2011/listings/rpp2011-list-muon.pdf

38. https://pdglive.lbl.gov/DataBlock.action?node=Q123SM

39. Joshua D. Qualls, Lectures on Conformal Field Theory,
arXiv:1511.04074v2 [hep-th]

40. David Simmons-Duffin, TASI Lectures on the Conformal Bootstrap,
arXiv:1602.07982v1 [hep-th]

41. S. Weinberg, Critical phenomena for field theorists, *lectures given at the International School of Subnuclear Physics (1976)*, Ettore Majorana Center for Scientific Culture, Erice, Italy