Response to Referee's Report on SciPost Submission: "Generating the Electro-Weak Scale by Vector-like Quark Condensation"

We would like to thank the referee for thoroughly reviewing our manuscript and for the useful comments and questions which helped us to create an improved version. Below we list our responses to each of the comments and summarize the changes we have made in the revised manuscript.

1. *"Firstly - is it essential that the new vector like fermion carries QCD color for the model to break electroweak symmetry and be phenomenologically viable? Any uncolored massive fermion having a Yukawa coupling to the scalar sector should induce (perturbatively) a Coleman Weinberg potential for the scalars that could trigger dynamical electroweak symmetry breaking. "*

   Answer: It has been shown that dynamical electroweak symmetry breaking by a Coleman Weinberg mechanism in the Standard Model is parametrically not viable. The addition of new fermions to the particle spectrum would further destabilize the Coleman Weinberg potential, since contrary to bosons, fermions contribute negatively to the effective potential (see also [1, 2]).

2. *"Also, from the presentation, it would seem that an uncolored massive fermion would acquire a large condensate perturbatively as shown in Eq 8. Even if the quadratically divergent contribution to the condensate is subtracted away, a log divergent part would remain, which grows as fermion mass cubed. This is a very similar scaling behavior for the condensate with fermion mass to that suggested in Eq 16. The role that QCD is playing in the mechanism should be clarified. If the model with an uncolored vector like fermion would also be viable, this needs to be clearly stated in the introduction and section 4. "*

   Answer: We thank the referee for the important question. Studies of weakly coupled theories, like for example QED [3], have shown that below a critical value of the coupling there is no dynamical chiral symmetry breaking, hence, no generation of a condensate. Therefore, QCD is the only possible gauge force within the standard model which qualifies to trigger dynamical chiral symmetry breaking. To emphasize this we added a footnote on page 3: "Studies of weakly coupled theories like e.g. quantum electrodynamics [3] showed that there is a critical coupling below which there is no dynamical chiral symmetry breaking, hence, no condensate being generated."

   Eq. (8) in our manuscript demonstrates why the standard definition of a chiral condensate in Eq. (5) cannot be applied to massive cases. This is done by explicitly showing the divergences that appear if the dynamical mass function $M(p^2)$ includes a term proportional to the explicit mass. We describe a method to cure this issue which first removes the term that is linear in the explicit mass (see Eqs. (9,10)) and afterwards evaluates the integral as shown in Eq. (12). Our method therefore removes not only the quadratically divergent part of Eq. (8) but also the logarithmically divergent part. For clarification, we added the following sentence before Eq. (12) : "As $\tilde{M}(p^2)$, by definition, does not depend linearly on m_μ, none of the divergences shown in Eq. (8) emerge and we can safely evaluate the integral on the right side of Eq. (5) with $M(p^2)$ replaced by $\tilde{M}(p^2)$."

So, in short: uncolored (weakly coupled) fermions do not acquire condensates. We have also cross-checked this explicitly. Therefore, the role of strongly coupled (in the IR) QCD is essential for the mechanism to work.

3. *"Secondly, to what extent could the results for the condensate in figure 4 be applied to the bottom and top quarks of the standard model? This should at least be commented on, to enable comparison with results for these condensates obtained using different methods. "*

   Answer: We appreciate the referee's suggestion and have added the following sentence to page 9 of our updated manuscript: " The shown results can be applied to quarks of the SM as well. For example, for a bottom quark we obtain $\langle\overline{\psi}\psi\rangle_{\text{inv}} \approx (4.12\text{ GeV})^3$. This agrees within a factor two with earlier work [4] which however calculated a slightly different quantity (see discussion before Eq. (14))."

We thank the referee again for the useful questions and remarks and hope that the revised version is now acceptable for publication in SciPost Physics.

Sincerely,

The Authors

References

[1] S. R. Coleman and E. J. Weinberg, "Radiative Corrections as the Origin of Spontaneous Symmetry Breaking," *Phys. Rev. D* **7** (1973) 1888–1910.

[2] K. A. Meissner and H. Nicolai, "Conformal Symmetry and the Standard Model," *Phys. Lett. B* **648** (2007) 312–317, `arXiv:hep-th/0612165`.

[3] A. Kızılersü, T. Sizer, M. R. Pennington, A. G. Williams, and R. Williams, "Dynamical mass generation in unquenched QED using the Dyson-Schwinger equations," *Phys. Rev. D* **91** no. 6, (2015) 065015, `arXiv:1409.5979 [hep-ph]`.

[4] L.-f. Chen, Z. Bai, F. Gao, and Y.-x. Liu, "New insight on the quark condensate beyond the chiral limit," *Phys. Rev. D* **104** no. 9, (2021) 094041, `arXiv:2105.14317 [hep-ph]`.