Anomalous Magnetic Moment of the Entangled Muon without QED/QCD

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ABSTRACT

The application of QED/QCD to the calculation of the muon's magnetic anomaly has not achieved the same level of precision as in the case of the electron's anomaly. This discrepancy has led many researchers to conjecture the existence of "new physics" capable of resolving the issue. In this work, we adopt a deterministic, non-local Bohm-like approach (dBBZ), as detailed in previous publications, analogously to the electron case, perform a structural analysis of the muon.
The muon's internal structure is examined via the (hybrid) Mz matrix method, in which the weak components are computed with high accuracy, reproducing the muon's mass while exactly embedding the electron's structure (and thus its charge and mass). Following the procedure already tested for the electron, we evaluate the anomalous moments of each orbital and impose entanglement through a calibrated normalization of the relevant parameters. The same "source parameter" used for the electron, providing a double check on its precise value, is adopted here for calculating the electrostatic potentials.
Magnetic-field effects are accounted for only on the masses carrying electric charge; however, in the overall energy balance of each orbital, the weak mass also plays an indirect yet essential role. The total anomalous moment calculation yields a direct determination of the muon's magnetic anomaly with a precision on the order of 10^{-13}.

1) INTRODUCTION

This work proceeds in parallel with the procedure used to determine the electron's magnetic anomaly, to which explicit reference is made for shared derivations and common calculations. For necessary background, the reader is referred to earlier publications.

This document is organized into the following phases:

Determination and analysis of the muon's hybrid orbital structure, with a 2–3-loop calculation of the weak coupling constant, consistent with the muon's mass and embedding the electron (which supplies its electric charge).

Energy balance for each orbital between the kinetic-plus-magnetic-energy condition and the pure-kinetic-energy condition. In this phase, only masses associated with charges generating magnetic fields are considered (as in the electron case), not weak masses.

Further specialization of the model to include the role of weak masses in the total orbital energy, calculation of entanglement between electrostatic and weak masses, and improved fitting based on the increased precision in the muon mass determination.

Determination of the anomalous momentum for each orbital (defined solely for the electrostatic masses), imposition of entanglement, and computation of normalization coefficients.

Calculation of the total anomalous orbital momentum and of the muon's magnetic anomaly.

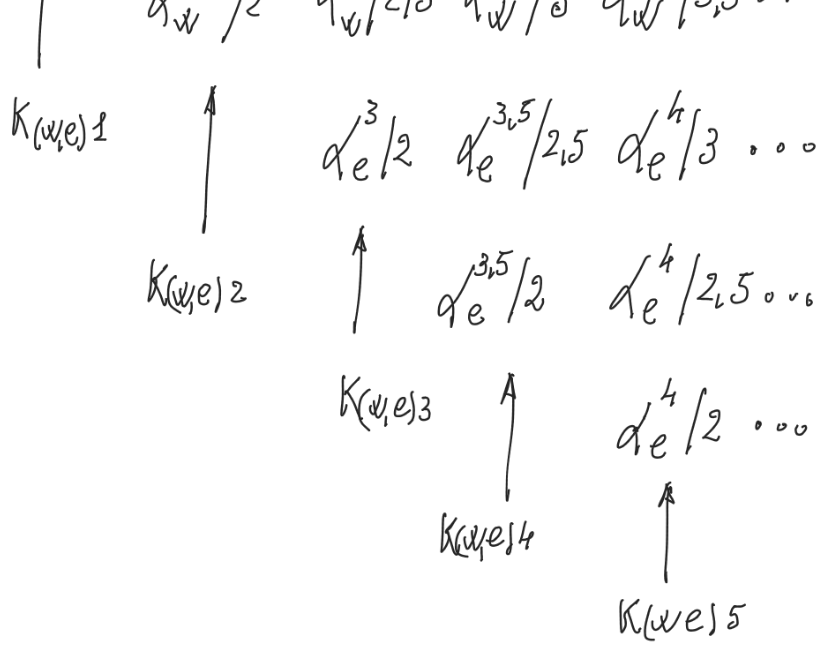
Each phase refines the model, orbital by orbital and overall, while enforcing conservation of total energy. Since orbitals are treated as closed systems, any modification of one orbital may alter other internal parameters, particularly the velocities of the associated masses and charges.

The International System of Units (SI) is employed, with constants consistent with CODATA 2022. Unless explicitly stated, the sign of electric charges is not considered. The spin value is always treated as a positive scalar.

2) MUON STRUCTURE

We describe the muon's structure via the (hybrid) Mz_μ matrix:

$$
\begin{array}{cccccccccc}
X & X & X & X & \alpha_w^{2}/4 & \alpha_w^{2{,}5}/4{,}5 & \alpha_w^{3}/5 & \alpha_w^{3{,}5}/5{,}5 & \alpha_w^{4}/6 & \ldots \\
 & X & X & X & \alpha_w^{2}/3{,}5 & \alpha_w^{2{,}5}/4 & \alpha_w^{3}/4{,}5 & \alpha_w^{3{,}5}/5 & \alpha_w^{4}/5{,}5 & \ldots \\
 & & X & \alpha_w^{1{,}5}/2{,}5 & \alpha_w^{2}/3 & \alpha_w^{2{,}5}/3{,}5 & \alpha_w^{3}/4 & \alpha_w^{3{,}5}/4{,}5 & \alpha_w^{4}/5 & \ldots \\
 & & & \alpha_w^{1{,}5}/2 & \alpha_w^{2}/2{,}5 & \alpha_w^{2{,}5}/3 & \alpha_w^{3}/3{,}5 & \alpha_w^{3{,}5}/4 & \alpha_w^{4}/4{,}5 & \ldots \\
 & & & \uparrow & & & & & & \\
 & & & K_{w0} & \alpha_e^{2}/2 & \alpha_e^{2{,}5}/2{,}5 & \alpha_e^{3}/3 & \alpha_e^{3{,}5}/3{,}5 & \alpha_e^{4}/4 & \ldots \\
 & & & & \uparrow & \alpha^{2{,}5}/2 & \alpha^{3}/2{,}5 & \alpha^{3{,}5}/3 & \alpha^{4}/3{,}5 & \ldots
\end{array}
$$



The hybrid orbitals (excluding the exclusively weak orbital K_{w0}) can be divided into electrostatic sub-orbitals K_i and weak sub-orbitals K_{wi}. This subdivision is justified by population inversion: weak levels, having greater mass, occupy regions closer to the center than the electrostatic levels of the same orbital.

Notice that the muon's structure fully contains the electron's structure without alteration, thereby preserving both its mass and charge.

We can list the sequences of sub-orbitals separately as follows:

Weak sub-orbitals	Electrostatic sub-orbitals
$K_{w0} = \left(\frac{1}{2} + \frac{1}{2,5}\right)\alpha_w^{1,5}$	—
$K_{w1} = \left(\frac{1}{2,5} + \frac{1}{3} + \frac{1}{3,5} + \frac{1}{4}\right)\alpha_w^2$	$K_1 = \left(\frac{1}{2}\right)\alpha_e^2$
$K_{w2} = \left(\frac{1}{2} + \frac{1}{3} + \frac{1}{3,5} + \frac{1}{4} + \frac{1}{4,5}\right)\alpha_w^{2,5}$	$K_2 = \left(\frac{1}{2,5}\right)\alpha_e^{2,5}$
$K_{w3} = \left(\frac{1}{2,5} + \frac{1}{3,5} + \frac{1}{4} + \frac{1}{4,5} + \frac{1}{5}\right)\alpha_w^3$	$K_3 = \left(\frac{1}{2} + \frac{1}{3}\right)\alpha_e^3$
$K_{w4} = \left(\frac{1}{3} + \frac{1}{4} + \frac{1}{4,5} + \frac{1}{5} + \frac{1}{5,5}\right)\alpha_w^{3,5}$	$K_4 = \left(\frac{1}{2} + \frac{1}{2,5} + \frac{1}{3,5}\right)\alpha_e^{3,5}$
$K_{w5} = \left(\frac{1}{3,5} + \frac{1}{4,5} + \frac{1}{5} + \frac{1}{5,5} + \frac{1}{6}\right)\alpha_w^4$	$K_5 = \left(\frac{1}{2} + \frac{1}{2,5} + \frac{1}{3} + \frac{1}{4}\right)\alpha_e^4$

. . . .

To obtain the muon's theoretical mass, one must define the value of α_w , which, in first approximation, can be calculated via the 2–3-loop running equation of the SU(2) coupling at the length scale of the first weak orbital λ_{wo}.

We estimate, and then verify, a mass for the first weak orbital equal to approximately 80% of the muon's weak mass (total muon mass minus electron mass). From this mass, one computes the corresponding reduced Compton wavelength:

1) $$\lambda_{wo_T} = \hbar / \left(0{,}8 \cdot \left(m_\mu^{sp} - m_e^{sp} \right) \cdot c \right) \simeq 2{,}34584 \cdot 10^{-15} \ [m]$$

At that distance, we calculate the weak coupling constant via the 2-loop running formula and an approximate 3-loop extension. Temporarily adopting natural units:

Initial parameters[6] at the Z-boson mass: $MZ \simeq 91{,}1876$ [GeV]

$\alpha_e(mz) \simeq 0{,}00781543$ electromagnetic coupling constant at

$\hat{\sin}^2\theta(mz) \simeq 0{,}23121$ $\theta(mz)$ Weinberg angle at mZ

Other parameters appearing in the running formulas: $b_0 = 19/6$; $b_1 = 35/6$; $b_2 = 147/6$

We define the reference energy for running as:

2) $$Q_0 \simeq HC / \lambda_{wo_T} \simeq 0{,}0841179 \ [GeV] \quad ; \quad HC \simeq 0{,}197326804 \ [GeV \cdot Fm]$$

We determine the weak coupling at the reference mass mZ :

3) $$\alpha_w(mz) = \alpha_e(mz) / \hat{\sin}^2\theta(mz) \simeq 0{,}0338023$$

We compute the 2-loop running at energy Q_0[9] :

4) $$\frac{1}{\alpha_w(Q_0)_{2L}} = \frac{1}{\alpha_w(mz)} + \left(\frac{b_0}{2\pi} \right) \cdot \ln\left(\frac{mz}{Q_0} \right) + \left(\frac{b_1}{2\pi\, b_0} \right) \cdot \ln\left[1 + b_0 \cdot \left(\frac{\alpha_w(mz)}{2\pi} \right) \cdot \ln\left(\frac{mz}{Q_0} \right) \right]$$

We add an approximation for the 3-loop term:

5) $$\frac{1}{\alpha_W(Q_0)_{agg.}} = \left(\frac{\alpha_W(M_Z)}{(4\pi)^2}\right)\cdot\left(\frac{b_2}{b_0}\right)\cdot\left(\frac{b_0\cdot\alpha_W(M_Z)}{2\pi}\right)\cdot \ln\left(\frac{M_Z}{Q_0}\right)$$

From (3) and (5) we obtain:

6) $$\frac{1}{\alpha_W(Q_0)_{3L}} \simeq \frac{1}{\alpha_W(Q_0)_{2L}} + \frac{1}{\alpha_W(Q_0)_{agg.}}$$ and thus:

7) $$\alpha_W(Q_0)_{3L} = 1/\left(1/\alpha_W(Q_0)_{3L}\right) \simeq 0{,}030175856$$

Having determined $\alpha_{W0} \cong \alpha_W(Q_0)_{3L}$, we perform a detailed evaluation, considering that the muon mass calculation achieves an uncertainty comparable to that of the electron case (excluding the magnetic mass).

We compute the muon's theoretical mass, including all electrostatic and weak components:

8) $$m_\mu^{th} = \hbar e\left(\sum_{i=1}^{10} K_i + \sum_{i=1}^{10} K_{Wi} + K_{W0}^r\right)$$ with:

9) $$K_{W0}^r = K_{W0}/\sqrt{1-2K_{W0}^2}$$ (2) Insert relativistic correction term

By iterating the total mass calculation (via $M_{Z\mu}$) and imposing an allowed error:

10) $$err_{m\mu} \approx \frac{(m_\mu^{sp} - m_\mu^{th})}{m_\mu^{sp}} \simeq 2{,}88\cdot 10^{-5}$$ we obtain:

11) $$\alpha_W \simeq 0{,}030196393$$ (a)

Let us carry out a verification, adopting the (11) of the estimate of the first weak orbital .

Let's take the mass of the first weak orbital and divide it by the total weak mass :

12) $$K_{W0}^r / \sum_{i=0}^{10} K_{Wi} \simeq 0{,}800346$$ in accordance with the initial estimate .

3) ENERGY BALANCES

For the i-th orbital, the energy balances enable the matching (in total-energy terms) of a purely dynamical model with the next, more sophisticated model, thus improving performance.
We reuse the electron’s anomaly results to account for the muon’s electric charges.

Regarding the total electric charge, the electrostatic and magnetic fields of the electrostatic sub-orbitals (and their derivatives) are identical to those in the electron case; we refer to those previous results for brevity. (3) (4)

The source charge q_s is chosen via the partial electroweak unification parameter (within a permitted range) $\alpha_{ew} \simeq 0{,}0326\,286575$ enabling the expression of the source potential at distance r :

$$13)\quad U_{q_s} = \frac{q_s}{4\pi\varepsilon_0 r}$$

Taking into account, in the charge “seen” by the i-th orbital, the stationarity constraints (“Poincaré belt” problem), and applying Gauss’s theorem, the electrostatic energy on the orbital is:

$$14)\quad E_{\varepsilon_i} = U_{q_i} \cdot q_{ir} = \frac{q_s}{4\pi\varepsilon_0}\left(e - 2\sum_{k=1}^{i} q_k\right) \Big/ \left(\lambda m_i / m_q\right)$$

From (14) one derives the magnetic energy for the i-th orbital: (2)

$$15)\quad E_{B_i} = E_{\varepsilon_i} \cdot v_i^2 / 4\pi c^2$$

We then write the first energy balance between the purely dynamical model and the dynamical + electromagnetic model:

16) $$0,5\left(m_i v_{a_i}^2 + m_{w_i} v_{aw_i}^2\right) = 0,5\left(m_i v_{b_i}^2 + m_{w_i} v_{bw_i}^2\right) - E_{\epsilon_i} \cdot v_{b_i}^2 / 4\pi c^2$$

where the term : $v_{aw_i} = v_{bw_i}$ because the magnetic field does not affect the velocities of the weak masses, and the magnetic term : $E_{\epsilon_i} \cdot v_{b_i}^2 / 4\pi c^2$ contains no weak-mass velocities, as weak charges do not generate a magnetic field.

Thus (16) reduces to:

17) $$0,5\, m_i v_{a_i}^2 = 0,5\, m_i v_{b_i}^2 - E_{\epsilon_i} v_{b_i}^2 / 4\pi c^2$$

Equation (17) is exactly the same energy balance as in the electron case.

Because the electron's masses and orbitals are entangled (per previous work) (1) (3), we propose that, to advance beyond the prior model, one must impose entanglement between the electrostatic and weak masses for each orbital where both are present. The previously computed refinement parameter z also plays a role in defining this new model.

Finding how entanglement and refinement jointly affect the results is nontrivial. Therefore, we first present the definitive solution, validated by its results, then discuss alternative options whose outcomes proved inadequate or only partially adequate.

The chosen solution introduces an additional parameter z only in the new model and imposes the cited entanglement alongside the magnetic field. We write separately the expressions for the two models which, due to these considerations, can no longer reduce to (16) and (17), but must include weak-mass contributions.

Considering that: $v_{w_i}^2 = \frac{K_{w_i}}{K_i} \cdot v_i^2$

The pure dynamical term:

18) $$E_{i(d)} = 0,5\left(m_{w_i} \cdot v_{aw_i}^2 + m_i v_{a_i}^2\right) = 0,5\left(m_{w_i} \cdot \frac{K_{w_i}}{K_i} + m_i\right) v_{a_i}^2$$

Term including magnetic effects, entanglement, and refinement:

19) $$E_{i(ede)} = 0,5\left(F_{zw_i} \cdot m_{w_i} z_i \cdot \frac{K_{z_i}}{K_i} \cdot v_{c_i}^2 + F_{z_i} \cdot m_i \cdot v_{c_i}^2\right) - E_{\epsilon_i} \cdot v_{c_i}^2 / 4\pi c^2$$

The magnetic energy in (19) must be positive, being an additional energy term, so since the term E_{ϵ_i} is always negative, it must appear with a negative sign.

We clarify the presence of z_i and F_{z_i}, F_{zw_i} in the previous expression.

We consider the refinement parameter z : multiplying the weak coupling constant, it affects the various weak sub-orbitals depending on the exponent present in them. Therefore, we substitute : $m_{\psi_i} \rightarrow m_{\psi_i} \cdot z_i$ and : $K_{w_i} \rightarrow K_{w_i} \cdot z_i \equiv K_{z_i}$ Where:

$$z_1 = z^2;\ z_2 = z^{2,5};\ z_3 = z^3;\ z_4 = z^{3,5};\ z_5 = z^4;\ z_6 = z^{4,5};\ z_7 = z^5;\ z_8 = z^{5,5};\ z_9 = z^6;\ z_{10} = z^{6,5}$$

We then determine the normalization coefficients needed to impose entanglement between electrostatic and weak masses, considering only the terms K_i, K_{w_i}, since the constants $\hbar$, c cancel in the calculation. We adopt a common calculation method for quantities defined on each individual orbital:

$$20)\quad F_i = K_i / \sqrt{K_i^2 + K_{\psi_i}^2}\ ;\quad F_{\psi_i} = K_{w_i} / \sqrt{K_i^2 + K_{\psi_i}^2}$$

Recall that the z_i must also be inserted into (20); substituting : K_{z_i} a K_{w_i}, (20) becomes:

$$21)\quad F_{z_i} = K_i / \sqrt{K_i^2 + K_{z_i}^2}\ ;\quad F_{zw_i} = K_{z_i} / \sqrt{K_i^2 + K_{z_i}^2}$$

We can rewrite (21) accounting for the latest implementations:

$$22)\quad E_{i_{(ede)}} = 0,5\left(F_{zw_i} \cdot m_{\psi_i} \cdot z_i \cdot \frac{K_{z_i}}{K_i} + F_i \cdot m_i - E_{\epsilon_i} / 4\pi c^2\right) \cdot v_{c_i}^2$$

Equating (18) with (22):

$$23)\quad \left(m_{\psi_i} \cdot \frac{K_{\psi_i}}{K_i} + m_i\right) v_{a_i}^2 = \left(F_{zw_i} \cdot m_{\psi_i} \cdot z_i \cdot \frac{K_{z_i}}{K_i} + F_{z_i} \cdot m_i - E_{\epsilon_i} / 4\pi c^2\right) \cdot v_{c_i}^2$$

From (23) one calculates the velocity V_{c_i} for the last implemented model (ede):

$$24)\quad V_{c_i} = V_{a_i} \cdot \sqrt{\left(m_{w_i} \cdot \frac{K_{w_i}}{K_i} + m_i\right) \Big/ \left(F_{z w_i} \cdot m_{w_i} z_i \cdot \frac{K_{z_i}}{K_i} + F_{z_i} \cdot m_i - E_{z_i} / 4\pi c^2\right)}$$

Analogous to the transition from dynamical to electrodynamic model, we set:

25) $V_{c_i} = T_i \cdot V_{a_i}$ where the T_i are:

26) $T_1 \simeq 1{,}003430736$; $T_2 \simeq 1{,}003585736$; $T_3 \simeq 1{,}004318441$

$T_4 \simeq 1{,}005000075$; $T_5 \simeq 1{,}005683313$; $T_6 \simeq 1{,}006378695$; $T_7 \simeq 1{,}007082527$;

$T_8 \simeq 1{,}007790692$; $T_9 \simeq 1{,}008500930$; $T_{10} \simeq 1{,}009212254$.

4) ENTANGLEMENT OF ORBITAL ANOMALOUS MOMENTS

Analogous to the electron's magnetic-anomaly case, we write the anomalous orbital moment of the i-th orbit solely in terms of the electrostatic-orbital components:

27) $L_i = m_i V_{c_i} \lambda_{w_i}$

We impose entanglement on the terms L_i by determining normalization coefficients. The sum of the entangled terms constitutes the total anomalous orbital moment L_T .

The parameters defining L_i: $m_i, V_{c_i}, \lambda_{w_i}$ themselves depend on K_i .

28) $m_i \simeq \hbar c K_i$; $V_{c_i} = c \cdot \sqrt{2 K_i T_i^2}$; $\lambda_{w_i} = 1 / (K_i \cdot c^2)$

The appropriate way to calculate normalization coefficients here is to use the squared probabilities of the individual orbital parameters , after a change of variables to make their probability distributions compatible.

Compute derivatives of (28) with respect to K_i :

$$29)\ d\omega_i/dK_i = \hbar c\ ;\ d(v_{a_i}T_i)/dK_i = cT_i/\sqrt{2K_i}\ ;\ d\lambda_{\omega_i}/dK_i = 1/(K_i^2 \cdot c^2)$$

Obtain the probabilities of the single parameters:

$$30)\ P_{\omega_i} = P(K_i)/(d\omega_i/dK_i) = P(K_i)/\hbar c$$

$$31)\ P_{v_{e_i}} = \overset{*}{P}(K_i)/(d(v_{a_i} \cdot T_i)/dK_i) = \overset{*}{P}(K_i) \cdot \sqrt{2K_i}/(c \cdot T_i)$$

$$32)\ P_{\lambda_{\omega_i}} = P(K_i)/(d\lambda_{\omega_i}/dK_i) = P(K_i) \cdot c^2 \cdot K_i^2$$

Determine the total probability squared for each i-th orbital:

$$33)\ P_{T_i}^2 = P_{\omega_i}^2 \cdot P_{v_{e_i}}^2 \cdot P_{\lambda_{\omega_i}}^2 = P^4(K_i) \cdot \overset{*}{P}{}^2(K_i) \cdot \frac{2 \cdot K_i \cdot c^4 K_i^4}{\hbar^2 c^2 \cdot c^2 T_i^2} = 2\, P^4(K_i) \cdot \overset{*}{P}{}^2(K_i) \cdot K_i^5/(T_i^2 \cdot \hbar^2)$$

We then sum the squares over all orbitals to obtain the normalization constants:

$$34)\ C_i = \sqrt{P_{T_i}^2 / \sum_{i=1}^{10} P_{T_i}^2} = \frac{\sqrt{2}\, P^2(K_i) \cdot \overset{*}{P}(K_i)/\hbar}{\sqrt{2}\, P^2(K_i) \cdot \overset{*}{P}(K_i)/\hbar} \cdot \sqrt{\frac{K_i^5}{T_i^2} \Big/ \sum_{i=1}^{10} \left(\frac{K_i^5}{T_i^2}\right)} = \left(\frac{K_i^{2.5}}{T_i}\right) \Big/ \sqrt{\sum_{i=1}^{10} (K_i^5/T_i^2)}$$

It is immediate to verify that : $\sum_{i=1}^{10} C_i^2 = 1$

5) DETERMINATION OF THE MUON MAGNETIC ANOMALY

With the modified velocities of the electrostatic masses obtained, we write the total anomalous orbital moment:

35) $L_T \simeq \sum_{i=1}^{10} c_i \cdot m_i \cdot v_{e_i} \cdot r_{cu_i} \simeq 7,725 \cdot 10^{-37} \, [J \cdot s]$

Recall the definition of the muon's anomalous magnetic moment:

36) $\mu_\mu^* \simeq \frac{e}{m_\mu} \cdot \frac{g_\mu - 2}{2} \cdot \hbar$ where:

37) $am_\mu = (g_\mu - 2)/2$ is defined as the muon's magnetic anomaly.

We show that (36) is equivalent to:

38) $\mu_\mu^{th} \simeq \frac{e}{m_\mu} \cdot (L_T + h)/2\pi$ hence:

39) $\frac{(g_\mu - 2)}{2} \cdot h = L_T + h$ and it follows immediately:

40) $am_\mu^{th} = (L_T + h)/h \simeq 1,001165920609$

We can compute the relative error:

41) $err_\mu \simeq (am_\mu^{sp} - am_\mu^{th}) / am_\mu^{sp} \simeq 5,884 \cdot 10^{-13}$

a) We extracted the weak coupling constant value α_W via a 3-loop perturbative evolution (approximate) up to the necessary scale. Although the perturbative regime may be contaminated by non-perturbative effects, we conservatively adopt a 1% uncertainty margin on the coupling , also accounting for the adjustment of this constant in α_w to reproduce the muon mass with precision comparable to that in the electron case. This choice ensures internal consistency and stability of the results within the required accuracy.

6) DISCUSSION AND FURTHER STUDIES

All calculations were performed with custom-developed software, enabling simulations of various scenarios to evaluate the impact of different approaches on partial and final results. We report the most relevant cases, comparing the magnetic anomaly, the relative error, and the velocity increase in the first mixed orbital (the most significant) between the proposed model and the previous energy-balance model for the same case. The models considered are:

AB – Model without entanglement and without refinement :

$$am_{\mu} \simeq 1{,}001636 \; ; \; err_{\mu} \simeq 2{,}346 \cdot 10^{-6} \; ; \; T_1 \simeq 1{,}0041$$

A – Model without refinement :

$$am_{\mu} \simeq 1{,}00643 \; ; \; err_{\mu} \simeq 1{,}642 \cdot 10^{-6} \; ; \; T_1 \simeq 1{,}00201$$

B – Model without entanglement :

$$am_{\mu} \simeq 1{,}0011652 \; ; \; err_{\mu} \simeq 7{,}051 \cdot 10^{-7} \; ; \; T_1 \simeq 1{,}00282$$

C – Model without electric charge :

$$am_{\mu} \simeq 1{,}0011659 \; ; \; err_{\mu} \simeq -1{,}767 \cdot 10^{-9} \; ; \; T_1 = 1{,}0034322$$

D – Proposed model :

$$am_{\mu} \simeq 1{,}00116592060 9 \; ; \; err_{\mu} \simeq 5{,}8 \cdot 10^{-13} \; ; \; T_1 \simeq 1{,}003430736$$

From the first three, we observe that the absence of entanglement, refinement, or both leads to a decrease in velocities T_1 , whereas their presence causes an increase , consistent with the hypothesis that weak masses (generally faster) “drag” the electrostatic masses.

From model C, we see that the absence of charge, and thus of magnetic field, allows velocities T_1 to increase, in line with the hypothesis of a “braking” function of the magnetic field on electrostatic masses.

Model D achieves the necessary balance of these effects, producing a system consistent with experimental results.

We consider an additional in-depth study of refinement, particularly concerning the modulation of the coupling constant via parameter z.

The z parameter acquires a structural role, affecting not only mass and velocity modulation but also entanglement itself. Here, its numerical value must be precise, even if applied equally to all weak sub-orbitals.

We analyze the weak sub-orbitals in detail to calculate, via the previously used running formulas, the ratio between each individual weak coupling constant and its weighted value across all orbitals, accounting for the 1% running-formula uncertainty.

By performing these calculations, we determine, for each sub-orbital, the specific weak coupling constants as functions of their respective distances, αw_i, which replace αw.
We compute extrema due to the 1% error:

42) $\alpha w_{i(min)} = \alpha w_i \, (1-0{,}01) \quad ; \quad \alpha w_{i(max)} = \alpha w_i \, (1+0{,}01)$

We then determine the minimum and maximum values of the relative $K w_i$ and their sums, via application of $M z_\mu$:

43) $$\overline{\alpha w}(min) = \sum_{i=1}^{10} \frac{K w_i(min)}{K w T(min)} \cdot \alpha w_i(min) \simeq 0{,}0297093$$

44) $$\overline{\alpha w}(max) = \sum_{i=1}^{10} \frac{K w_i(max)}{K w T(max)} \cdot \alpha w_i(max) \simeq 0{,}0303075$$

Thus we obtain reference minima and maxima of a weak coupling constant $\overline{\alpha w}$ weighted across the orbitals.
We note that αw lies between $\overline{\alpha w}(min)$ and $\overline{\alpha w}(max)$.

We determine the deviation, as a ratio from these reference values, of the coupling constants for each orbital , calculated via their running, thus providing greater detail than a simple substitution of αw with $\overline{\alpha w}$. We compute the maximum amplitude of these ratios as a function of the extrema from the 1% running error:

45) $$ZZ_i(min) = \frac{\alpha w_i(min)}{\overline{\alpha w}(max)} \quad ; \quad ZZ_i(max) = \frac{\alpha w_i(max)}{\overline{\alpha w}(min)}$$

We report the results as reference intervals:

46) $ZZ1 = 0{,}97 \div 1\,;\; ZZ2 = 0{,}95 \div 0{,}975\,;\; ZZ3 = 0{,}916 \div 0{,}9527\,;\; ZZ4 = 0{,}9 \div 0{,}927\,;$
$ZZ5 = 0{,}87 \div 0{,}904\,;\; ZZ6 = 0{,}85 \div 0{,}882\,;\; ZZ7 = 0{,}828 \div 0{,}861\,;$
$ZZ8 = 0{,}809 \div 0{,}841\,;\; ZZ9 = 0{,}791 \div 0{,}822\,;\; ZZ10 = 0{,}773 \div 0{,}804$

By substituting Z_i with values within these reference intervals for ZZ_i, we obtain a relative error on the magnetic anomaly of: $err_\mu \simeq 1{,}29 \cdot 10^{-13}$

The chosen values based on (46) are:

47) $ZZ1 = 0{,}99859034\,;\; ZZ2 = 0{,}9686\,;\; ZZ3 = 0{,}94\,;\; ZZ4 = 0{,}92\,;\; ZZ5 = 0{,}90$
$ZZ6 = 0{,}88\,;\; ZZ7 = 0{,}86\,;\; ZZ8 = 0{,}84\,;\; ZZ9 = 0{,}82\,;\; ZZ10 = 0{,}80$

We observe that only the first 2–3 hybrid orbitals significantly influence the determination of the magnetic anomaly at the considered precision level.

7) CONCLUSIONS

The determination of the muon’s magnetic anomaly fits seamlessly within the modeling framework developed for the electron’s anomaly. Both systems share not only the same procedural method but also the same source-parameter value, analogous structure, and the electron’s charge and mass, whether free or embedded in the muon.

The muon’s hybrid nature required additional effort to describe its structure and to establish energy balances for each orbital, due to the necessary entanglement of weak masses in the muon’s overall dynamics.

This integrated structure, accounting for kinetic, electromagnetic, entanglement of electrostatic and weak masses, and entanglement of anomalous orbital moments, can be termed the Hybrid Entangled Electro-Dynamic Model (H.E.E.D.M.).

A detailed analysis of the weak sub-orbitals, aimed at characterizing the peculiarities of the weak coupling constant in each, allowed us to assign a physical meaning and numeric value to the refinement parameter z , essential for result convergence.

The methodology has no connection with QED or QCD techniques, thus overcoming the latter's computational difficulties and assigning clear physical meaning to the quantities and parameters within the deterministic, non-local dBBZ framework, which treats the muon as a distributed entangled structure, just as for the electron.

We have calculated the muon's magnetic anomaly with a relative error on the order of 10^{-13} whereas current theoretical methods reach a relative error of about 2.5×10^{-9}.

These results, together with those for the electron, may provide a solid foundation for a deterministic, non-local, and more physically meaningful reinterpretation of the quantum world.

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