ENTANGLED ELECTRON FOR NEW QUANTUM MECHANICS PART 1

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ABSTRACT

This work advances the theoretical framework of the electron model introduced in a previous paper (viXra: 2411.0050 -Quantum Physics) , which describes the electron as composed of entangled mass elements . This model proposes an extension of the de Broglie-Bohm (dBB) paradigm , achieving compatibility with Special Relativity .
Explicit expressions for Z and ZC are derived , describing the sequence of orbitals and their associated masses , along with a detailed analysis of their physical significance .
An innovative interpretation of spin and magnetic moment is presented , viewing them as invariant properties across orbitals , despite variations in the associated parameters .
This perspective provides a potential explanation for the experimentally observed phenomenon of spatial spin separation from its particle .
Additionally , the Appendix includes applications of the MZ matrix—a conceptual tool integral to the proposed formalism—for estimating particle masses, specifically those of the muon and tauon, with notable accuracy.
This work represents the second part of a trilogy.
A forthcoming extension will focus on the characteristics of orbitals, with particular emphasis on the definition of attractive and repulsive potentials and the associated Hamiltonian, thereby completing the theoretical framework.

1-INTRODUCTION

The electron model described in the referenced document is formally defined through the distribution of mass elements on concentric s-type orbitals , alongside the associated distributions of spin and magnetic moment .
This conceptual framework provides a detailed perspective on the internal structure of the electron, with implications for its quantum mechanical properties.

The document is structured as follows:

Derivation of the expression Z :

This section introduces Z , which describes the sequence of s-type orbitals and their associated masses .
The derivation is based on the electrostatic work performed by an elementary charge moved from infinity to a distance corresponding to the reduced Compton wavelength by another elementary charge .

Derivation of the expression ZC:

The formulation of ZC extends Z by incorporating a corrective term , accounting for the magnetic mass .
This correction is derived from the velocity of the electric charge associated with each s-orbital .

Distribution of spin and magnetic moment : The spin and magnetic moment are distributed across the s-type orbitals , with their defining parameters allowed to vary .
This includes the conceptual exploration of the spatial separation between a particle and its spin , as observed experimentally .

Application of the MZ matrix : In the Appendix, the MZ matrix—a theoretical tool developed for deriving Z—is utilized for the estimation of the masses of certain leptons , specifically the muon and the tauon .

All constants used refer to CODATA 2022[a] .

The international system is adopted unless otherwise indicated .

2- GENESIS OF THE EXPRESSIONS Z AND ZC

The expressions of Z and later of ZC reported in the document viXra : 2411.0050 cited , are :

Z : $m_e = \hbar c \, \mathfrak{D} \sum_{i=1}^{n} k_i$

ZC : $m^{th} = m_e + \Delta m_e$

The elements of the relative expressions represent the succession of masses which, when summed, approximate the experimental mass of the electron with different precision .

We distinguish the quantities related to Z and ZC to avoid confusion .

Quantities relative to Z : m_i^z , $\lambda_i^{c,z}$, m_e , $\lambda_T^{c,z}$

the quotes c , z indicate respectively quantities calculated on the radius of the relative Compton regions , (which are always more extensive than the one calculated on the basis of the experimental mass) and obtained within the expression Z . m_e and λ_T^c they are total quantities .

Quantities related to ZC : m_i , λ_i^c , m^{th} , λ_T^c

with meanings similar to the previous cases : m^{th} and λ_T^c they are total quantities .

2.1) GENESIS OF Z :

Consider the work done by the electrostatic field to bring an elementary charge from ∞ to the distance λ_d (reduced Compton length relative to the experimental mass) with respect to an elementary charge of the same sign considered at rest and in the absence of other force fields . In an ideal experiment , express the work as the difference of the potential energies in the two given points :

1) $L_e = \Delta U_e = e^2/4\pi\varepsilon_0\lambda_c$; $U(\infty) = 0$

taking into account the absolute value of the electron charge and Le .

2) $e = \sqrt{4\pi\varepsilon_0\hbar c\alpha_e}$ with obvious meaning of the symbols .

for convenience : $A = \sqrt{\alpha}$ with : $1 > \alpha > 0$

where α is considered as an independent variable of which α_e is a particular value .

This assumption , which does not harm but rather expands the generality of what follows , may be useful in extending the proposed method to other elementary particles .

We develop A in series of powers , in order to ensure contributions of the individual terms always positive and decreasing (this choice is due to the fact that the single terms are closely related to the massive terms , which by their nature are always positive) .
In addition , the decreasing terms create a more stable structure with the heavier parts close to the center and self-limiting) :

3) $A = c_1 A^2 + c_2 A^3 + c_3 A^4 + c_4 A^5 + \dots$ put : $c_i = a_i \sqrt{\lambda_c / l}$ so what :

4) $e = \sqrt{4\pi\varepsilon_0 \hbar c k_c / l} \cdot (a_1 A_e^2 + a_2 A_e^3 + a_3 A_e^4 + a_4 A_e^5 + \dots)$

Where returning to the particular case of the electron : $\alpha = \alpha_e$

By squaring the two terms of (4) and manipulating the resulting expression :(a)

5) $e^2/4\pi\varepsilon_0 = \hbar c (b_1 A_e^4 + 2b_2 A_e^5 + 3b_3 A_e^6 + 4b_4 A_e^7 + \dots) \cdot k_c / l$

Where the b_i can be obtained from a_i and in any case remain unknown .

$\sum_{i=1}^{n} K_i$ are term in parentheses and K_i the various elements that compose it .

Taking up (1) :

6) $U_e = e^2/4\pi\varepsilon_0 k_c = \hbar c \sum_{i=1}^{n} K_i / l$

Writing (6) in a more appropriate way :

7) $U_e = \frac{\hbar c}{l} [b_{1,1} \alpha_e^2 + (b_{2,1} + b_{2,2}) \alpha_e^{2,5} + (b_{3,1} + b_{3,2} + b_{3,3}) \alpha_e^3 + (b_{4,1} + b_{4,2} + b_{4,3} + b_{4,4}) \alpha_e^{3,5} + \dots]$

Taking into account that the total energy of the system consists only of the calculated electrostatic energy :

8) $m_e = \frac{U_e}{c^2} = \frac{\hbar c}{c^2 \cdot l} \cdot \sum_{i=1}^{n} K_i$ by posing : $D = 1/(l \cdot c^2)$ it can be shown that :(b)

9) $D = 1\ [s^2/m^3]$ get :

10) $m_e = \hbar c D \sum_{i=1}^{n} K_i$ which turns out to be (1)

The form of (7) has been chosen on the basis of the assumption of the presence of a "fine structure" of the elements K_i , in fact taking the generic K_i as a reference and considering (10) :

11) $m_i^2 = \hbar c K_i = \hbar c \alpha_e^J (b_{J,1} + b_{J,2} + \dots) = \hbar c \alpha_e^J \cdot b_{J,1} + \hbar c \alpha_e^J b_{J,2} + \dots$

Taking into account that : $k_c = \frac{\hbar}{mc}$ get :

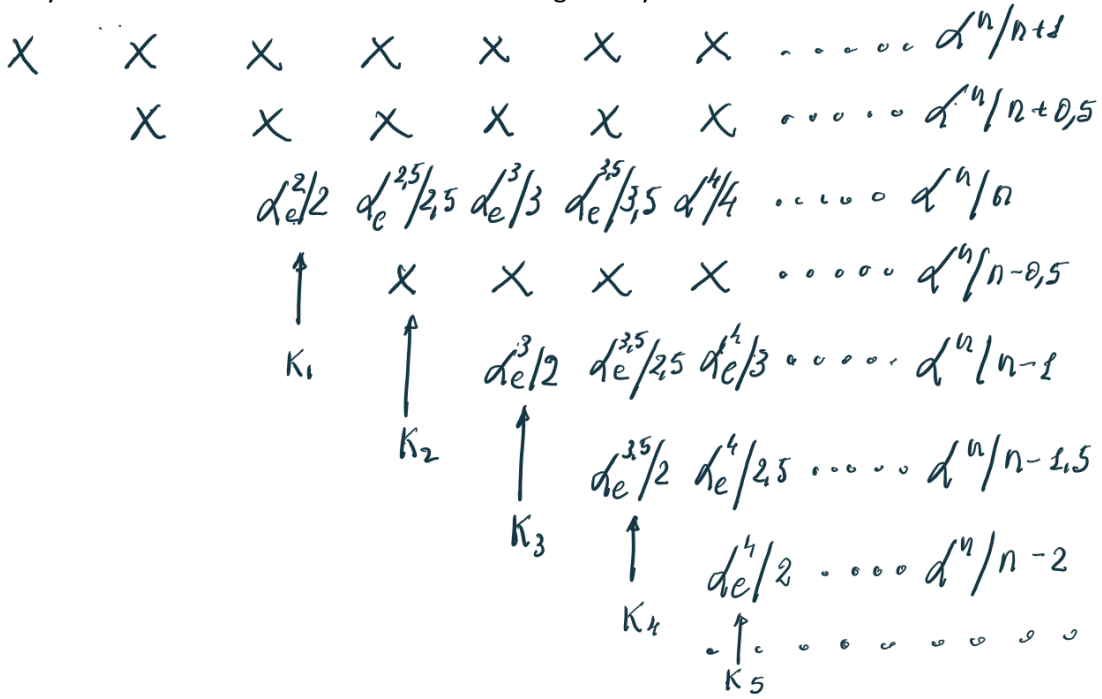
12) $k_{J,1}^c = \frac{1}{c^2 \alpha_e^J b_{J,1}}$; $k_{J,2}^c = \frac{1}{c^2 \alpha_e^J b_{J,2}}$; $\dots$ and by posing : $g_{J,i} = 1/b_{J,i}$

13) $k_{J,1}^c = \frac{g_{J,1}}{c^2 \alpha_e^J}$; $k_{J,2}^c = \frac{g_{J,2}}{c^2 \alpha_e^J}$; $\dots$

Choosing parameter values $g_{J,i}$ with increasing pitch $p = 0,5$, we have regular sequences for each K_i of the kind : $2 - 2,5 - 3 - 3,5 - \dots$ which indicate a sequence of regularly

spaced wavelengths a that constitute the "fine structure" mentioned .

A synthesis of the structure of the electron is given by the matrix MZ :



The MZ shows , scrolling through the columns , the composition of the K_i in terms of the fine structure of its elements , moreover with the terms X are indicated the rows and therefore the missing terms to have a complete regularity of the structure that is reflected on the particularities of (1) if written in full .

Such a matrix, formally a triangular matrix , should be considered a tool with greater generality , useful for constructing other leptons , also taking into account that in these cases α it may be different from α_e and that some missing elements may appear .

Some examples are given in the Appendix , in particular for muon and tauon .

a) mathematical manipulations are justified by assumption of the fine structures presence to be highlighted

b) assuming that : $D \simeq 1/(l \cdot c^2)\ [s^2/m^3]$ then :

14) $L = 1/(D \cdot c^2) \simeq 1,112650056 \cdot 10^{-17}\ [m]$

Consider the : $m_e = \hbar / c \cdot \lambda_T^{c,2}$ we can rewrite it :

15) $m_e = \hbar c K_T / (K_T c^2 \lambda_T^{c,2})$

Calculating K_T :

16) $K_T = \sum_{i=1}^{10} K_i \simeq 2,881312793 4 \cdot 10^{-5}$ so that :

17) $K_T \cdot \lambda_T^{c,2} \simeq 1,112650056 \cdot 10^{-17}\ [m] \simeq L$ so that substituting in (15) we have :

18) $m_e = \hbar c K_T / (c^2 L)$ and being : $c^2 \cdot L = 1\ [m^3/s^2]$ we have :

19) $m_e = \hbar c D K_T$ and : $D = 1/(c^2 L) = 1\ [s^2/m^3]$

2.2) GENESIS OF ZC :

The proposed electron model provides a structure composed of concentric s-type orbitals with distribution of relative masses described by the expression Z .

From the individual masses one can calculate the distances from the center of each orbital , these distances and the relative wave functions are entangled as shown in viXra: 2411.0050-Quantum Physics .

Each s orbital can be interpreted in different ways that allow the evaluations of the case :

A) de Broglie wave , associated with the relative mass , which travels in a stationary manner , one of the maximum circumferences, relative to the spherical surface of the highest mass density, among those of the orbital in question .

All the infinite circles that can be traveled are equivalent for the proposed ends .

B) mass density , distributed in the orbital according to the function that derives from the square of the normalized wave function (this meaning accepts Bohm's interpretation which is therefore different from that of Copenhagen even if formally they coincide) .

Choosing mode A in order to calculate the corrective part relating to the expression Z and therefore the genesis of the expression ZC which leads to a more exact calculation of the theoretical total mass than that calculated with the expression Z .

For each orbital s , we assume that the associated mass mi , has a rotational motion (deterministically defined in the Bohmian approach) with tangential velocity vi , on one of the possible circumferences , around the center of mass of the electron and that the

Lorentz transformations of the R.R. are applicable to this motion. .

So for each mi :

20) $m_{i,v_i} \simeq m_{i,0} / \sqrt{1 - \frac{v_i^2}{c^2}}$ Developing in Taylor series :

21) $1/\sqrt{1 - \frac{v_i^2}{c^2}} \simeq 1 + \frac{1}{2}\frac{v_i^2}{c^2} = 1 + \gamma_i$ and therefore :

22) $m_{i,v_i} \simeq m_{i,0}\left(1 + \frac{1}{2}\frac{v_i^2}{c^2}\right) = m_{i,0} + m_{i,0}\gamma_i$

we determine the generic γ_i :

The difference in energy intrinsic to a given mass and its kinetic energy , vary in a similar way to the variation of the reference orbital .

Writing the two energies for an i-th orbital :

23) $m_i^2 c^2 \simeq \hbar c^3 \sum_{i=1}^{n} K_i$

24) $\frac{1}{2} m_i^2 v_i^2 \simeq \frac{1}{2} \hbar c v_i^2 \sum_{i=1}^{n} K_i$

Comparing (23) and (24) respectively between two adjacent orbitals S_i , S_{i+1}:

25) $\frac{m_{i+1}^2 c^2}{m_i^2 c^2} = \frac{\frac{1}{2} m_{i+1}^2 v_{i+1}^2}{\frac{1}{2} m_i^2 v_i^2} = \frac{K_{i+1}}{K_i}$

From (25) we can be deduced that the energies of the various orbitals are correlated through a particular "quantum jump" function of K_i and K_{i+1}

The correlation between the energies belonging to the same orbital cannot depend on but must depend on the K_i of the same orbital .

For this reason , we assume that , for an i-th orbital the ratio between kinetic energy and relative intrinsic energy are correlated as follows :

26) $\frac{\frac{1}{2} m_i^2 v_i^2}{m_i^2 \cdot c^2} = K_i = \gamma_i$

With this assumption it is possible to calculate the velocity and kinetic energy for each orbital. In particular , it is possible to calculate the maximum velocity among those of all orbitals :

27) $\sqrt{}_{max} = c\sqrt{2K_{max}} = c\sqrt{2dk^2/2} = c\,dk \simeq 2{,}18 \cdot 10^6$ [m/sec]

Therefore , being in a high but not relativistic velocity regime , classical physics can be applied .

Considering the relationship between magnetic field and electric field , in scalar terms , for a charge associated with a mass moving at velocity vi , in the Gaussian c.g.s. system :

28) $\beta_i = \frac{\epsilon_i \sqrt{i}}{c}$ which is applied to the i-th orbital :

The densities of electrical and magnetic energy are written :

29) $W_{\epsilon_i} = \frac{\epsilon_i^2}{8\pi}$; $W_{\beta_i} = \frac{\beta_i^2}{8\pi}$

Their ratio is as follows :

30) $W_{\beta i}/W_{\epsilon_i} = \beta_i^2/\epsilon_i^2$

Considering the relations between the Gaussian CGS system and the international system , we have :

31) $W_{\beta i}/W_{\epsilon_i}(c.g.s.) = \frac{1}{4\pi} W_{\beta_i}/W_{\epsilon_i}(S.I.)$

This is due to the fact that in the Gaussian CGS system β does not include the term 4π while in the international system magnetic permeability appears : $\mu_0 = 4\pi 10^{-7}$

In the international system , the ratio of energy densities is : (c)

32) $W_{\beta i}/W_{\epsilon_i}(S.I.) = \frac{\sqrt{}^2}{c^2}$ so that the ratio of the energy densities written in C.G.S.

corresponds to :

33) $W_{\beta_i}/W_{\epsilon_i}(c.g.s.) = \frac{\sqrt{}_i^2}{4\pi c^2}$ (S.I.)

Integrating the energy densities (in SI) on the volume Vi of the i-th orbital , we obtain :

34) $\int_V W_{\beta_i}\,dV \Big/ \int_V W_{\epsilon_i}\,dV = E_{\beta_i}/E_{\epsilon_i} = \frac{\sqrt{}_i^2}{4\pi c^2}$

Considering the mass-energy equivalence :

35) $m_{\beta_i} = m_{\epsilon_i} \cdot \frac{\sqrt{}_i^2}{4\pi c^2}$ which, considering (26) , becomes :

36) $m_{\beta_i} = m_{\epsilon_i} \cdot K_i/2\pi$

The mass m_{ϵ_i} is the mass of the charged particle on the i-th orbital : $m_{\epsilon_i} \equiv m_i^*$, so it m_{β_i}

turns out to be an increase in this mass due to the density of magnetic energy on the i-th orbital .

For this reason we can write :

37) $\Delta m_i \equiv m_{Bi} = m_i^z \cdot K_i/2\pi = \hbar c K_i^2/2\pi$

Whereby :

38) $m_i = m_i^z + \Delta m_i = \hbar c K_i + \hbar c K_i^2/2\pi = \hbar c K_i(1+K_i/2\pi)$

And then the expression of the corrected mass ZC :

39) $m^{th} = \sum_{i=1}^{n} m_i = \hbar c \sum_{i=1}^{n} K_i(1+K_i/2\pi)$

c) In the SI system we have (in scalar terms) :

40) $\beta = \frac{\sqrt{\epsilon}}{c^2}$ with the energy densities of the magnetic and electric fields :

41) $W_B = B^2/2\mu_0 \; ; \; W_\epsilon = \epsilon_0 \epsilon^2/2$ their ratio is :

42) $W_B/W_\epsilon = B^2/(\epsilon^2 \epsilon_0 \mu_0)$ consider (40) we have :

43) $W_B/W_\epsilon = \frac{\sqrt{}^2 \epsilon^2}{c^4} / (\epsilon^2 \epsilon_0 \mu_0) = \frac{\sqrt{}^2}{c^2}$

3- SPIN AND MAGNETIC MOMENT

In this context , the anomaly of the magnetic moment of the electron is not considered .

The integration of the concept of spin and magnetic moment in a distributed model of the electron is limited to considering the scalar properties without considering the vector properties that remain unchanged with respect to the standard approach .

Traditionally , spin is considered as a intrinsic momentum of particles considered as point and without internal structure .

Considering these particles , in particular the electron , as complex systems , spatially distributed with a given structure , allows us to consider spin differently .

The scalar value of the spin of the electron is $\hbar/2$ (considered in an absolute sense) .

We can therefore write :

44) $\hbar/2 = mc\lambda_c/2$

and with regard to each spherical surface deriving from the i-th orbital :[a]

45) $\hbar/2 = m_i c \lambda_i^c/2$

From (45) it can be seen that the spin is a constant that crosses all the orbitals while varying the parameters that define it , unlike the orbital moment which is characteristic for the orbital itself considered .

This distribution of spin on spatially structured orbitals allows the possibility of explaining spin-particle separation experiments carried out .[6]

A weak measurement of the position of inner orbitals , which indicate the position of the majority of the mass and charge of the electron , can be made at the same time as a weak measurement of spin on outermost orbitals that are at a distance from the former .

A spatial distribution of the spin of a particle has also been advanced by other authors .[3][4][5]

The magnetic moment is defined in scalar terms :

46) $\mu = e \cdot \hbar/2m$

The relative vector has the opposite direction for negative charges and the same direction as the spin vector for positive charges .

Given the possibility of dividing the mass of the electron into the elements of partial mass m_i , the need arises to implement (46) for each i-th orbital as follows :

47) $\mu_i = q_i \hbar/2 m_i^2$ and to maintain the same ratio : $\rho = e/m$ valid for all orbital qi must have the same law of distributions between the orbitals of the mi less than the constant ρ .

48) $q_i = \rho \hbar c K_i$ [Coulomb]

a) Applying to the spin (and to the magnetic moment which is closely related) , a deterministic collocation (following Bohm's approach) , as a vector orthogonal to one of the infinite planes where the maximum circumferences mentioned lie , then on average this vector will be zero , until , during a measurement of the relative magnetic moment , it will

be "forced" to assume a precise orientation .

4- CONCLUSIONS

In continuity with the previous document , the formal aspects outlining the genesis of the Z and ZC expressions have been developed. These expressions accurately approximate the experimental mass of the electron as the sum of entangled mass elements .

A new characterization of spin and magnetic moment has been provided , wherein their distribution among orbitals explains the experimentally observed spatial separation between the particle and its spin .

In the Appendix , a specific extension of the MZ matrix has been applied to approximate the masses of the muon and tauon , using an innovative technique based on mixed orbitals .

These results strengthen the validity of the proposed model and establish a foundation for future theoretical developments .

The third part of this work , currently under development , will focus on the properties of orbitals , thereby completing the broader framework of this novel approach to quantum mechanics .

APPENDIX

The formal calculations relating to the masses of muon and tauon are carried out through the application of the matrix MZ , whose orbitals are determined by the fine structure constant α_e or by the electroweak coupling constant α_w .

Matrices are triangular with a main diagonal formed by elements of the type : $\alpha^n/2$.

The sum of the elements of each individual column form the relative K_i that determine the reference orbitals .

The sum of all the columns forms K_i that produces , minus the constants $\hbar, c$, the mass of the particle in question .

To determine the constant α_w we use the following correlations :

49) $e = \sqrt{4\pi\alpha_e} \simeq 0,302822$ with natural constants ($\hbar = c = 1$)

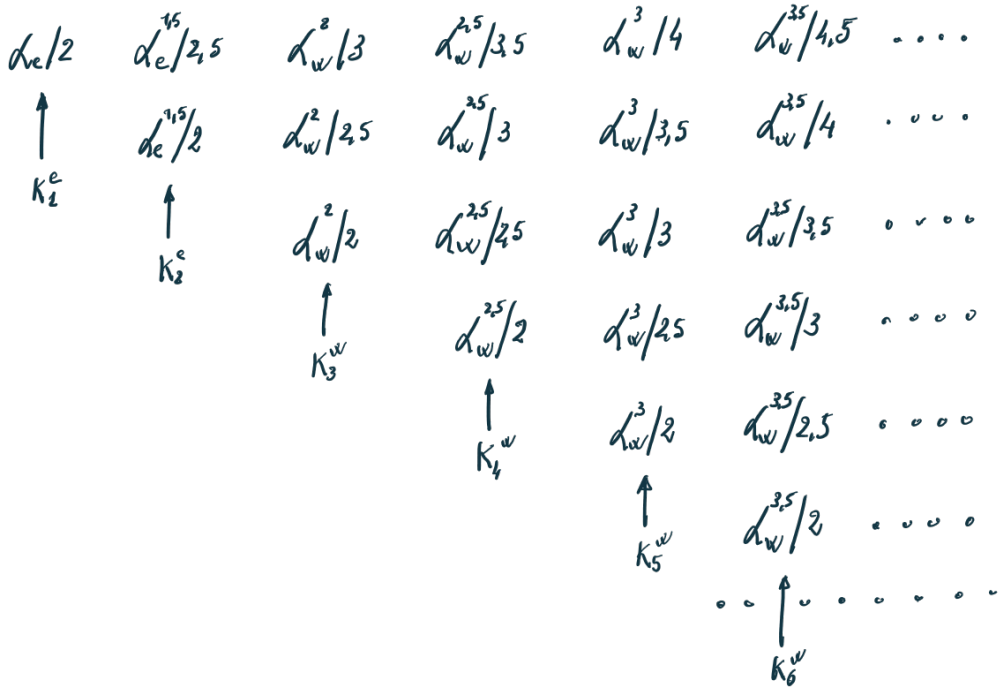
50) $g_w = e/\sqrt{\sin\theta_w} \simeq 0,649$ with g_w electroweak charge and θ_w Weinberg angle

51) $\alpha_w = g_w^2/4\pi \simeq 0,032736$

The technique of forming a generic matrix , requires a filling in the lower orbitals that is greater as the mass of the particle under consideration and a filling of the upper orbitals until their contribution to the total mass becomes negligible .

Further constraints imposed may refine and modify the proposed structure .

Matrix related to the muon MZ_μ :



Continuing up to K_9^w we get a good agreement with the experimental mass of the muon .

52) $m_\mu^{th} = \hbar c \sum_{i=1}^{9} K_i \simeq 1,86579 \cdot 10^{-28}$ [kg m]

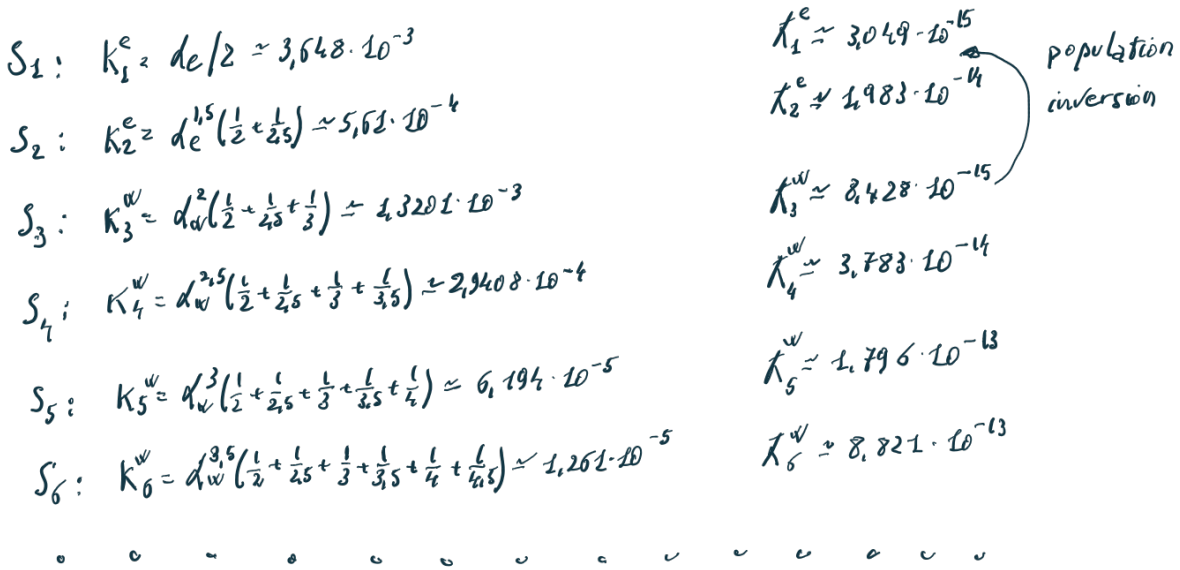
Since the experimental mass : $m_\mu^{sp} \simeq 1,883531 \cdot 10^{-28}$ [kg m]

The relative error can be calculated :

53) $err_\mu = \dfrac{(m_\mu^{sp} - m_\mu^{th})}{m_\mu^{sp}} \simeq 9,419 \cdot 10^{-3}$

We report the values of the K_i and the relative wavelengths $\lambda_i^{e,e}$ for each orbital ,

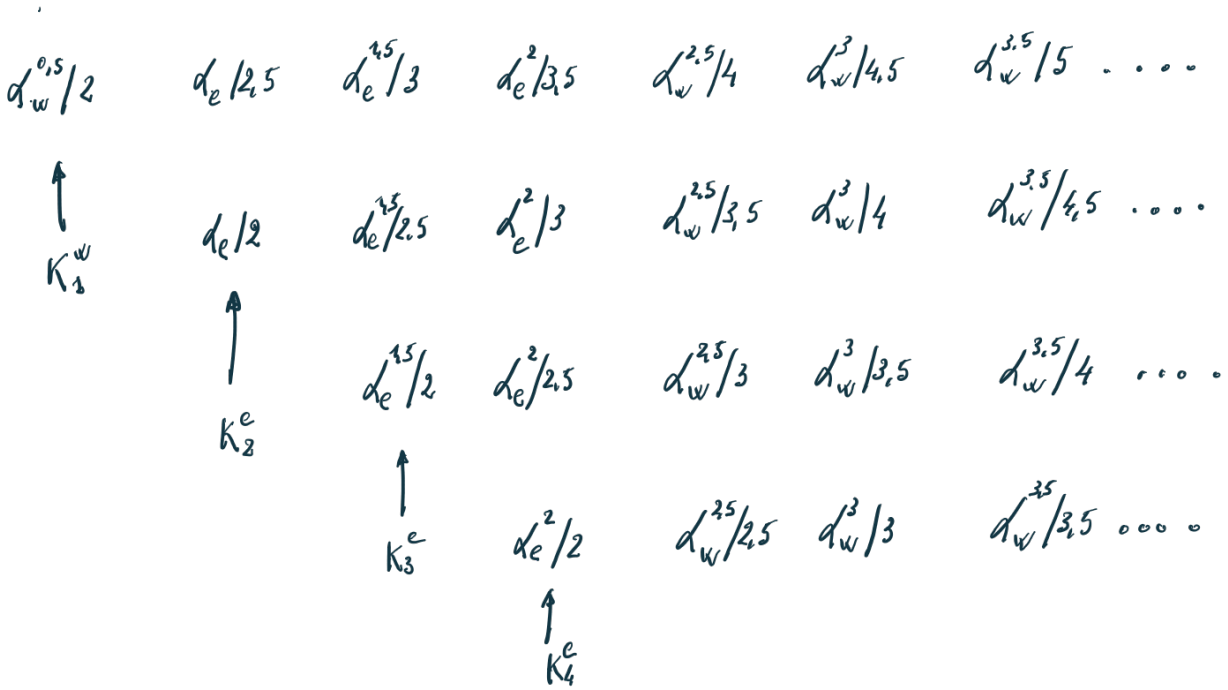
returning to the SI system :

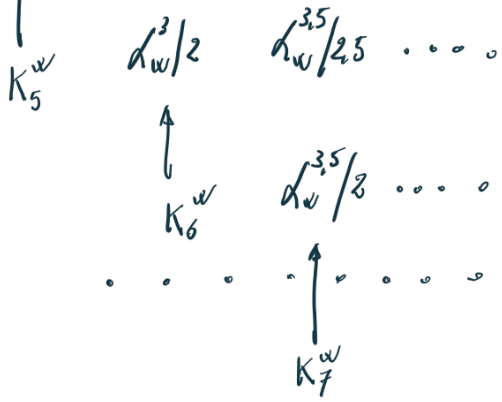


At the expense of the orbitals S_2, S_3 there is an anomaly that I call "population inversion" which consists in the fact that the orbital S_3 being small in size compared to S_2 changes its place with the latter .

This rearrangement , not present in the electron , can be a contributing fator to the decay of the muon .

Tauon matrix MZ_τ:





I repeat the same procedure used in the muon' s case :

$S_1: K_1^w = \alpha_w^{0,5}/2 \simeq 9,043 \cdot 10^{-2}$ $\quad K_1^w \simeq 1,230 \cdot 10^{-16}$

$S_2: K_2^e = \alpha_e \left(\frac{1}{2} + \frac{1}{2,5}\right) \simeq 6,567 \cdot 10^{-3}$ $\quad K_2^e \simeq 1,694 \cdot 10^{-15}$

$S_3: K_3^e = \alpha_e^{1,5} \left(\frac{1}{2} + \frac{1}{2,5} + \frac{1}{3}\right) \simeq 7,688 \cdot 10^{-4}$ $\quad K_3^e \simeq 1,447 \cdot 10^{-14}$

$S_4: K_4^e = \alpha_e^2 \left(\frac{1}{2} + \frac{1}{2,5} + \frac{1}{3} + \frac{1}{3,5}\right) \simeq 8,089 \cdot 10^{-5}$ $\quad K_4^e \simeq 1,875 \cdot 10^{-13}$ population inversion

$S_5: K_5^w = \alpha_w^{2,5} \left(\frac{1}{2} + \frac{1}{2,5} + \frac{1}{3} + \frac{1}{3,5} + \frac{1}{4}\right) \simeq 3,424 \cdot 10^{-4}$ $\quad K_5^w \simeq 3,248 \cdot 10^{-14}$

$S_6: K_6^w = \alpha_w^3 \left(\frac{1}{2} + \frac{1}{2,5} + \frac{1}{3} + \frac{1}{3,5} + \frac{1}{4} + \frac{1}{4,5}\right) \simeq 6,973 \cdot 10^{-5}$ $\quad K_6^w \simeq 1,595 \cdot 10^{-13}$

$S_7: K_7^w = \alpha_w^{3,5} \left(\frac{1}{2} + \frac{1}{2,5} + \frac{1}{3} + \frac{1}{3,5} + \frac{1}{4} + \frac{1}{4,5} + \frac{1}{5}\right) \simeq 1,387 \cdot 10^{-5}$ $\quad K_7^w \simeq 8,016 \cdot 10^{-13}$

Also in the case of the tauon we have the structural anomaly with population inversion and similar arguments explicit for the muon are valid .

Continuing up to K_9^w , we have a good approximation of the theoretical mass to the experimental mass :

54) $m_\tau^{th} = \hbar c \sum_{i=1}^{9} K_i \simeq 3,1073 \cdot 10^{-27}\ [Kgm]$

The experimental mass is : $m_\tau^{SP} \simeq 3,1675 \cdot 10^{-27}\ [Kgm]$ therefore the relative error is :

55) $err_\tau = \frac{(m_\tau^{SP} - m_\tau^{th})}{m_\tau^{SP}} \simeq 1,9 \cdot 10^{-2}$

In both cases , corrective expressions were not applied , as in the case of the electron .

REFERENCES

1) Zamboni L. (2024). A New Paradigm for Quantum Mechanics . viXra 2411.0050 - Quantum Physics .

2) CODATA Recomended Value of the Fundamental Physical constants : 2022. Retrieved from: http://physics.nist.gov/constants

3)Hodge W.B., Migirditch S.V., Kerr W.C.(2014) . Electron spin and probability current density in quantum mechanics . American Journal of Physics .

4) Liping Zou et al. (2020) . Position and spin in relativistic quantum mechanics . Physical Review A .

5) Sebens C.T. (2019) . How Electron Spin . Studies in History and Philosophy of Modern Physics .

6) Tobias D. et al. (2014) . Observation of a Quantum Cheshire Cat in a matter-wave interferometer experiment . Nature Comunication .

7) Bohm, D.(1952). A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variable. I & II. Physical Review, 85(2), 166-193.

8) Dirac, P.A.M. (1981). Principles of Quantum Mechanics. Oxford University Press.

9) Sakurai, J.J. (1994). Advanced Quantum Mechanics. Pearson.

10) Greiner, W. (1990). Quantum Mechanics: An Introduction. Springer.

11) Bjorken, J.D., & Drell, S.D.(1964). Relativistic Quantum Mechanics. McGraw-Hill.

12) Jackson , J.D. Classical Electrodynamics . Wiley , 1998 .

13) Tanabashi , M. , et al. (Particle Data Group) . Review of Particle Physics . Physical Review D , 98(3), 030001 , 2018 .

14) Quigg , C . (2013) . Gauge Theories of the Strong , Weak , and Electromagnetic Interactions . Princeton University Press . ISBN : 978-0691150823

15) Cottingham W.N., Greenwood D.A. (2007). An Introduction to the Standard Model of Particle Physics . Cambridge University Press . ISBN : 978-0521852494

16) Scroedinger, E. (1935). Discussion of Probability Relations Between Separated Systems. Proceedings of the Cambridge Philosophical Society, 31, 555-563.

17) Hiley, B.J., & Peat, F.D. (1991). Quantum Implications: Essays in Honour of David Bohm. Routledge .

18) Holland, P.R. (1993) . The Quantum Theory of Motion : An Account of the de Broglie-

Bohm Causal Interpretation of Quantum Mechanics . Cambridge University Press.

19) Cushing, J.T., Fine, A., & Goldstein, S. (1996). Bohomian Mechanics and Quantum Theory: An Appraisal. Springer.