Neutron's basic Mass

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Research Article

Keywords: Partiale physics, Neutron, Neutrino, beta-decay

Posted Date: October 15th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-971432/v1

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Abstract:
In Quantum Physics the Spin of an elementary particle is defined to be an „intrinsic, inherent“ property. The same to the magnetic moment (μ) due to the spin of charged particles - like Electron (m_e) and Muon (m_u). So the intrinsic spin (S) of the electron entails a magnetic moment. However, a magnetic moment of a charged particle can also be generated by a circular motion of an electric charge (e), forming a current. Hence the „orbital motion of charge“ around a „mass-nucleus“ generates a magnetic moment by Ampère’s law. This concept leads to an alternative way calculating the neutrino mass (m_v) while discussing the beta decay of a neutron into fragments: proton, electron, neutrino and kinetic energy - now based on the change of magnetic moments during the process. This alternative calculation gives m_v = 0.10(20)eV.

Introduction

From Ampère’s law point of view pure restmass without charge can not generate a magnetic moment. Surprisingly the charge-less-neutron shows a magnetic moment on the contrary. Thus the neutron must have an internal dynamic (quark based) charge-action from a positive and negative part.

Elementary particles like electron and muon and fundamental particles like proton, and neutron (and neutrino) obey the wave-particle behaviour as nature’s fundamental fact. The „anyhow“ contradicting picture is a concept in todays quantum physics and at least a „completed“ one already shown by Einsteins famous equation (1):

1. $h \cdot c/\lambda = m \cdot c^2$

Here using the Compton wavelength (λ=c/f) instead of frequency (f).

The **Compton wavelength** (1) **(λ)** is a quantum mechanical **wave like parameter** of a massive quantum entity defined by mass (m) velocity of light (c) and Planck constant (h).

1.1 $\lambda = h/(m \cdot c)$

„The wavelength (λ) was introduced by Arthur Compton in his explanation of the scattering of photons by electrons (a process known as Compton scattering)." (2)

Let us (instead of lambda) introduce an equivalent **particle like parameter** r_{GN} by the following hypothesis only to switch from wave picture into a particle picture (3):

1.2 $\lambda = 4\pi \cdot r_{GN}$

Hint: $_G$ indicates a necessary still missing (General Relativity) (3) theoretical fundament concerning the derivation of mass from theory and $_N$ formally indicates an intrinsic Quantum Number which respects the quantisation of mass of elementary and fundamental particles.

So this r_{GN} is also related to the mass of the particle under investigation as well as the Compton wavelength does. So r_{GN} is nothing new from the Einstein-Compton point of view but there is a particle picture behind r_{GN} now.

The spin (S=1/2*h-bar) can be written (3):

1.3 $S = c \cdot m \cdot r_{GN}$

Magnetic Moments and Ampère's Law

In atomic physics, the Bohr magneton (4) μ_B=e*h/(4π*m) in [As*Js/kg] is a „natural unit" expressing the magnetic moment in Si-units [J/T] with (T=1kg/s/As) caused by either its spin-orbital or spin-angular momentum of fundamental particles. The Magnetic Moment (μ) (4) while using Ampère's law (4) reads (2,3,4,5): in units [A*m²] = [J/T]

1.4 $\mu = 1/2\ g_s \cdot e \cdot c \cdot r_{GN}$

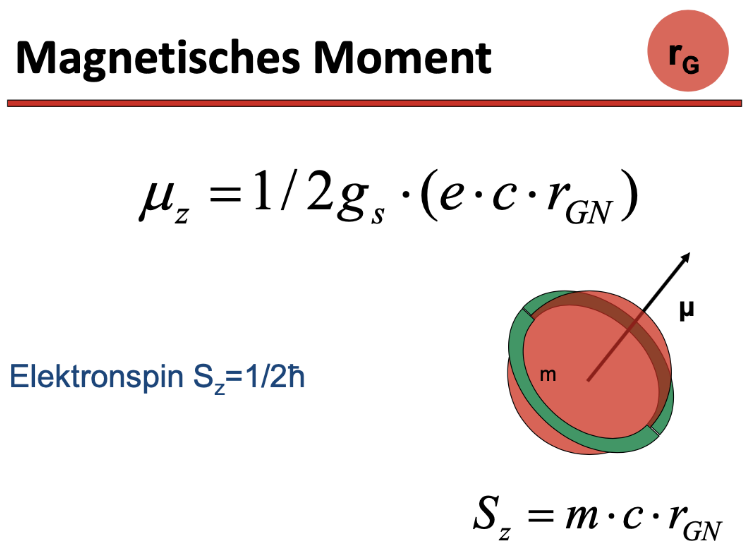

Figure 1 **The Magnetic Moment** (4) depends on the Landé Factor gs, the charge (e=1.602176634E-19C), velocity of light (c=2.99792458E8m/s) and particle parameter (r_{GN}) - instead of the Compton Wavelength (λ) or instead of the Rest-Mass (m). Planck constant (h=6.62607015E-34Js) is needed if we take the Bohr-magneton definition or use the Spin for basic discussion and calculation.

Result:

The magnetic moment (μ) formula (1.4, figure 1) due to the r_{GN}-value allows to assume an orbit of a charge (e) with velocity (c/2) due to a spin-mass-radius (g_s*r_{GN}) of a non point like particle coming up with a magnetic moment (μ) if we use Ampère's law. The two formulae above show an important energy based effect:

If in (1.3) the mass (m) increases (r_{GN}) decreases because the spin remains constant. If in (1.4) (r_{GN}) decreases then the magnetic moment (μ) decreases. This has to be respected within the beta-decay process.

Thus from the energy point of view if the magnetic moment decreases then mass-energy increases and vice versa to keep total energy constant.

My first private attempt to compare r_{GN} based magnetic moments with those given from codata is shown in table 1.

Landé Faktor g_i* r_{GNi}

.		cod1999	cod1999	calculation	cod1999
i	s	m_i [kg]	μ_i [Am^2]	g_i	g_i
1) Proton	1/2	1.67262158e-27	+1.410606633e-26	**5.585694660**	**5.585694675**
2) Neutron	1/2	1.67492716e-27	-9.6623640e-27	**-3.831627460**	**-3.826085450**
3) Muon	1/2	1.88353109e-28	-4.49044813e-26	**2.0023318320**	**2.0023318320**
4) Electron	1/2	9.10938188e-31	-9.28476362e-24	**2.002319305**	**2.0023193043737**

Table 1 **Landé Factor gs-numbers**, gi calculated from magnetic moment-experiment values (μ_i), while using r_{GNi} (from Spin formula 1.3, not shown here). Then compared with the alternative determined (g_i-Codata, last column) of four particles: electron and muon and proton and neutron. (r_{GN}-proton fits without using the quark-model! The neutron fails.)

Conclusion:

1. The Codata gi-results go confirm with the calculated gi-numbers when using the r_{GNi} concept for proton and electron.

2. The particle picture and Ampère's law are successful. There is a mismatch only concerning the neutron.

3. This r_{GN}-model based results excludes the point particle hypothesis for electron.

Remark:
Why a mismatch for the neutron?

The reason for the neutron mismatch is due to neutrons structure. The neutron is not a simple „union“ (2.00 -5.58=-3.58) of proton-particle-r_{GN}(p) with electron-particle-r_{GN}(e) building a neutron r_{GN}(n) (-3.82). This fails because the magnetic moments can not be combined in a simple additive way. However, we know that the neutron decays into a proton r_{GN}(p), electron r_{GN}(e) and neutrino (r_{GN}(neutrino)) in accordance with Fermi's 1934 theory of beta decay.

The new data from 2020

We „use“ r_G instead of r_{GN} now and assume that the spin based proton-r_{Gp}(S) radius (1.3) is not (much) affected during the process of beta decay - thus mass, radius and magnetic moment of the proton (**m_p, r_{Gp} and μ_p) remain the same during the beta decay process and specially after decay.**

This assumption simplifies the discussion in so fare as we do **not need** the deeper going quark model to be taken into account concerning the proton's fit! During the decay process we must accept the proton and electron preparation is completed before releasing.

Of course the magnetic moment should be based on the quark model on the level of the constituent quarks. The result is almost identical to the measured values but theoretically not completed [5]. Thus our simplified discussion is helpful for the moment as a first step of this common alternative way.

Free **Proton:**
Magnetic moment: **μ_p (+**1.41060679<u>36</u>(60)E-26J/T**)**
Restmass: m_p (**1.67**262192<u>369</u>(51)E-27kg)

- Free particle mass-radius (1.3):
  r_{Gp}(S) (1.05154455<u>167</u>E-16m)
- and μ-radius (1.4):
  r_{Gp}(M) (1.05154455<u>167</u>E-16m)

No difference in the radius from Spin and magnetic moment for proton is a theoretical and experimental fact!

Not so for the neutron. We have a dramatical change of the magnetic moment: μ_n =-9.6623..E-27J/T=(μ_{en}+ μ_{pn}) assuming a „captured“ electron and proton compared with a free electrons μ_e (-9.2846..E-24J/T) and free protons μ_p (+1.4106..E-26J/T) after the decay - not forgetting the neutrino.

The neutron magnetic moment exists because of the „inner“ neutron(quark) interaction before beta day. The proton(quark)-electron interaction appears when using the inverse beta-decay result. The captured electron gets a significant smaller circular radius during the process by interaction of two different charge values, thus reducing the μ_e-value to come up with neutrons μ_n-value, now made from neutrons quarks.

Neutron:
Restmass: m_n=**1.67**492749804E-27kg.

- S-radius (1.3):
  r_{Gn}(S)=**1.05**0097077 59E-16m
- Captured radius (1.4):
  r_{Gen}(M)=r_{Gpn}(M)=rG$_n$(M)=**1.05**154455167eE-16m

Free **Electron**
Restmass: m_e=9.1093837015(28)E-31kg

- S-radius (1.3):
  r_{Ge}(S)=1.9307963398E-13m
- μ-radius (1.4):
  r_{Ge}(M)=1.9307963398E-13m

Here is the explanation why m_ν can be derived from Ampère’s law:

2020	Restmass (m) In kg	Magnetic Moment (μ) In J/T	Landé Factor (g)	rG(S) in m rG(M) in m
Electron	9.1093837015(28)E-31	-9.2847647043(28)E-24	2.00231930436256 (35)	1.9307963398E-13 1.9307963398E-13
Muon	1.883531627(42)E-28	-4.49044830(10)E-26	2.0023318418(13)	9.3379715299E-16 9.3379715**376**E-16
Tauon	3.16754E-27	No value	No value	5.5526890611E-17
Proton	**1.67**262192369(51)E-27	1.41060679736(60)E-26	5.5856946893(16)	**1.05**15445516E-16 **1.05**15445516E-16
Neutron	**1.67**492749804(95)E-27	-9.6623651(23)E-27	3.82608545(90)	**1.05**00970776E-16 **1.05**15445516E-16

Table 2 **Magnetic Moments and Neutrino’s Mass.** The mass of the Neutron (m_n(S)) is that of the experimental mass m_n=1.67492749804E-27kg. So we get from the Spin (1.3)

the corresponding $r_{Gn}(S)$=1.050097077<u>59</u>E-16m and from the magnetic moment $r_{Gn}(M)$=1.50**1544551**<u>**67**</u>E-16m from (1.4). Both are different. (Not so for proton and electron!)

As we can see the $r_{Gn}(M)$=1.50**1544551**<u>**67**</u>E-16m result from the Magnetic Moment Formula (1.4) is much different compared with the value $r_{Gn}(S)$=1.050097077<u>59</u>E-16m result from the Spin Formula (1.3).

In short:
From Spin (1.3) mass or from Magnetic Moment (1.4) m(M) we have:

- $m_n(M)$= **1.67**2621923<u>86</u>E-27kg from $r_{Gn}(M)$
- m_p =**1.67**2621923<u>69</u>(51)E-27kg from experiment or from $r_{Gp}(S)$
- m_n =**1.67**4927498<u>04</u>(95)E-27kg from experiment or from $r_{Gn}(S)$

The change of magnetic moment(s) of the neutron during the decay process into those of the fragments must have to do with the release of binding energy and emission of the neutrino, proton, and electron and their (possibly varying individual) kinetic energies combined with their own (fixt) magnetic moments and rest mass.

Binding energy energy without neutrino before decay
m_n-**m_n(M)**-m_e=**782.333<u>311</u>**keV=B_E

Binding energy energy inlcuding anti-neutrino mass before decay
m_n-**m_p**-m_e=**782.333<u>410</u>**keV=$B_{E\nu}$

BE-BEv=-mp(S)+Mn(M)=-0.099eV=m_ν
So m_ν must be the restmass of the neutrino - of course its a positive mass!

m_n=**1.67**4927498<u>04</u>E-27kg>m_n(M)=**1.67**2621923<u>87</u>E-27kg
m_n(M)=**1.67**2621923<u>87</u>E-27kg>m_p =**1.67**2621923<u>69</u>E-27kg.

m_n(M)-m_p=0.<u>10</u>(20)eV

Remark:
g_{sn}=3.826085<u>45</u>(90) and μ_n=-9.66236<u>51</u>(23)E-27J/T error-limits giving the maximum absolut error-bars (+444.15 and - 443.95)eV. From this we get the „mean error“ (0.20)eV while assuming the absolute error is gaussian shape.

Notice:

Ampère’s law combined with a particle-picture leads to a new way to calculate the non-magnetic-neutrino mass based on the change of magnetic moments during the beta-decay (and before and after). But the accuracy of the experimental values need to be increased significantly concerning the neutron data.

Literature

(1) The Dirac Electron: Spin, Zitterbewegung, the Compton Wavelength, and the Kinetic Foundation of Rest Mass, Herausgeber: Kiyoshi Nishikawa, Jean Maruani, Erkki J. Brändas, Print ISBN: 978-94-007-5296-2 or ISBN: 978-94-007-5297-9Gerardo Delgado-Barrio, Piotr Piecuch, Verlag: Springer Netherlands

(2) Compton scattering:
https://en.wikipedia.org/wiki/Compton_wavelength

(3) Derivation of Radius
https://www.researchsquare.com/article/rs-524770/v3

Only if a theory is able to derive r_{GN} *exclusively by theory we will have a theoretical answer for the open question: „Why does the Compton Wavelength exist from a theoretical point of view already proved by Compton scattering experiment?“*

(4) Magneton
https://en.wikipedia.org/wiki/Bohr_magneton

(5) Constituent quarks and magnetic moment
https://de.wikipedia.org/wiki/Proton

Große Deutsche Enzyklopädie
„Damit ein Elementarteilchen ein intrinsisches magnetisches Moment hat, muss es sowohl Spin als auch elektrische Ladung haben. Das Neutron hat einen Spin von 1/2 ħ, aber keine Nettoladung. Die Existenz des magnetischen Moments des Neutrons war rätselhaft und widersetzte sich einer korrekten Erklärung, bis in den 1960er Jahren das Quarkmodell für Partikel entwickelt wurde. Das Neutron besteht aus drei Quarks, und die magnetischen Momente dieser Elementarteilchen verbinden sich, um dem Neutron sein magnetisches Moment zu verleihen.“

(6) More accuracy
Double-trap measurement of the proton magnetic moment at 0.3 parts per billion precision Schneider et al., Science 358, 1081–1084 (2017)