Neutrons magnetic Mass

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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 Proton (m_p). So the intrinsic spin (S=1/2h-bar) of the electron entails a magnetic moment because of charge (e). However, a magnetic moment of a charged particle can also be generated by a circular motion (due to spin) 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 binding energy. The change of neutrons magnetic moment (μ_n) during the decay process based on energy and spin and charge conservation should allow to calculate the restmass of the neutrino.
(KATRIN <1.1eV (2019) about 0.2eV (2021). Estimation from μ_n: 0.10(20)eV (2020)

Introduction

In short (using codata 2020): The fact that the charged particle (m_p) is lighter than the „neutral" one (m_n) about (m_n-m_p=1,29333235989MeV or m_n-m_p-m_e=0.**78233341**MeV or mn/mp=1.00137841931) remained mysterious up to now. The difference between the neutron mass (m_n) and proton (m_p) mass is an open question in Standard Model Physics [1]. Fact is, the neutron contains the mass of a neutrino about (0.2eV KATRIN 2019) while the proton does not!

As shown by Cottingham [1], the magnetic mass is determined by the spin averaged forward Compton scattering amplitude. However, the Cottingham formula [1] did not explain the size of the observed mass differences with such a high accuracy (m_{QED}=0,7(3)MeV) [1] needed to come up with neutrino restmass estimation.

In this paper we start with the magnetic moment definition based on Ampère's law. From Ampère's law pure neutral restmass without charge can not generate a magnetic moment. Thus the neutron mass must have an internal dynamic charge-action from a positive and negative parts (a least from quarks [1]) to come up with a magnetic moment and direction.

Elementary particles like electron, electron-neutrino and fundamental particles like proton, and neutron obey the wave-particle behaviour as nature's fundamental fact, shown by Compton-Einstein equation [2]:

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

Here Compton introduced the wavelength (λ=c/f) instead of frequency (f) as Einstein did concerning photons. The **Compton wavelength** [2] **(λ)** is a quantum mechanical **wave like parameter** of a massive quantum entity defined by mass (m) not zero, velocity of light (c), and Planck constant (h) based on Einsteins E=m*c^2.

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 (Compton scattering)." [3]

Remark:
Compton-Einstein: wave (λ) of a particle-mass (m)
Compton-Einstein: wave (λ) of a particle-radius (r_{GN}) [4]

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

Let us (instead of λ) introduce an equivalent **particle like parameter** r_{GN} [4] here by hypothesis, only to switch from wave picture into a particle picture. Assuming the particle ist not point-like (and quantised due to N) this allows to apply Ampère's Law (I*pi*r_{GN}^2).

Hint: $_G$ indicates a (missing) General Relativity theoretical fundament concerning the derivation of mass from theory [4] and $_N$ formally indicates an intrinsic Quantum Number which respects the quantisation of mass of elementary and fundamental particles from a GR point of view. [4]

The intrinsic spin (S=1/2*$\hbar$) due to r_{GN}-interpretation can be written:

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

If m increases from electron to proton thus r_{GN} must decrease respectively while spin remains invariant.

Magnetic Moments and Ampère's Law

In atomic physics, the Bohr magneton [5] μ_B=e*h/(4π*m) in [As*Js/kg] is a „natural unit" expressing the magnetic moment in Si-units [J/T=Am²] with (T=1kg/s/(A*s)) caused by either its spin-orbital or spin-angular momentum of a particle and mass (m). The Magnetic Moment (μ) [5] while using Ampère's law [5] and 1.3 then reads [3,4,5,6]:

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

in units [A*m²] = [J/T]

The Intrinsic Magnetic Moment [5] from textbook $\mu = 1/2\ g_s \cdot e \cdot (1/m) \cdot S$ depends on the Landé Factor gs, the charge (e=1.602176634E-19C), velocity of light (c=2.99792458E8m/s) and instead of particle parameter (r_{GN}) we had from Compton wavelength (λ). Or from textbook, using at first Rest-Mass (m) of the particle under investigation. Planck constant (h=6.62607015E-34Js) is needed if we use the intrinsic Spin (S) for basic discussion and calculation. (Thus 1.3 and 1.4 combined gives formula μ above [5]).

Important to mention:.
The two formulae (1.3 and 1.4) above show an important energy based effect: Magnetic Energie is equivalent to „Magnetic-Mass“, ie. Total Restmass.

If in (1.3) the mass (m) increases so (r_{GN}) decreases because the spin remains constant. If in (1.4) (r_{GN}) decreases then the magnetic moment (μ) decreases.

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

Data from 2020

We „use“ r_G instead of r_{GN} now.

Of course the magnetic moment should be based on the quark model [1] on the level of the constituent quarks. The theoretical result is not completed. up to 2021[6].Thus our „simplified“ discussion is helpful as a common (Fermi) way while today using high accurate data from Codata 2020.

Free **Proton:**
Magnetic moment: μ_p **(**+1.41060679736(60)E-26J/T**)**
g_{sp} (5.5856946893(16)) defined relative to the proton mass
Restmass: m_p (**1.67**262192369(51)E-27kg)
- S-radius from (1.3): **r_{Gp}**(S)=(1.0515445516 7E-16m)
- µ-radius from (1.4): **r_{Gp}**(M)=(1.05154455167E-16m)

Free **Neutron:**
Magnetic moment: μ_n **(-**9.6623651(23)E-27J/T**)**
g_{snp} (3.82608545(90)) defined relative to the proton (not neutron) mass
Restmass: m_n (**1.67**492749804E-27kg)
- S-radius from (1.3): r_{Gn}(S)=**1.05**0097077 59E-16m
- µ-radius (1.4): r_{Gnp}(M)=**1.05**154455167eE-16m

Free **Electron**
Magnetic moment: μ_e **(-**9.2847647043(28)E-24J/T**)**
g_{se} (2.00231930436256(35)) defined relative to the electron mass
Restmass: m_e (9.1093837015(28)E-31kg)
- S-radius from (1.3): r_{Ge}(S)=1.9307963398E-13m
- µ-radius from (1.4): r_{Ge}(M)=1.9307963398E-13m

Why a „mismatch“ for the neutron due to Codata’s g_{snp}?

The electron and proton go confirm with this 1.4 while comparing the r_{Gx}(M) with r_{Gx}(S) (table 1). Not so for the neutron if we use g_{snp} =3.82608545(90) (gyromagnetic ratio from Codata). This g_{snp} here is related to the proton mass and not to the neutron mass as it should be if we want to apply 1.3 and 1.4 in general. For that discussion we have to re-define $g_{sn}=g_{snp}*m_n/m_p$=3.83135940. Then 1.4 works for the neutron assuming a „dominating" negative charge. (Neutrons charge (positive+negative) compensate while the resultant magnetic moments are not zero due to a more effective negative charge then the positive does.)

Overview: (2020-Codata (m), (μ), (g), from 1.3 r_{Gx}(S), from 1.4 r_{Gx}(M))

2020	Restmass (m) In kg	Magnetic Moment (μ) In J/T	Landé Factor (g)	rGx(S) in m rGx(M) in m
Electron mn/me	9.**10938370**15(28)E-31 1838.6836617	-9.**28476470**43(28)E-24	2.**00231930**436256 (35)	1.**93079633**98E-13 1.9307963398E-13
Muon	1.883531627(42)E-28	-4.49044830(10)E-26	2.0023318418(13)	9.3379715299E-16 9.3379715376E-16
Tauon	3.16754E-27	No value	No value	5.5526890611E-17
Proton Mp/me	1.**67262192**369(51)E-27	1.**41060679**736(60)E-26	5.**58569468**93(16)	**1.05**15445516E-16 **1.05**15445516E-16
Neutron mn/mp	1.**67492749**804(95)E-27 1.00137841931	-9.6623651(23)E-27	3.83135940 3.82608545(90)	**1.05**00970776E-16 **1.05**15445516E-16

Table 1 Magnetic Moments and magnetic Mass equivalent to restmass radius r_{GN} from Spin. (x now indicates e, p, n, np instead of se, sp, sn, snp)

Magnetic Moments and Neutrons Mass from Codata (2020).
The mass of the Neutron (including m_v neutrino) is that of the experimental mass m_n=1.67492749804E-27kg. So we get from the Spin (1.3) the r_{Gn}(S)=1.0500970776E-16m corresponding to the neutron restmass (m_n). From (1.4) the magnetic moment μ_n (g_n)=-9.6623651(23)E-27J/T based on the neutron mass we have the $r_{Gn}(M)=r_{Gn}(S)$=**1.05**0097077**59**E-16m corresponding to the magnetic mass $m_n(M)=m_n$ (including m_v neutrino). From (1.4) the same magnetic moment of neutron due to g_{np} $\mu_n(g_{np})$=-9.6623651(23)E-27J/T and Codata g_{np} based on proton mass m_p we have r_{Gnp}(M)=1.05**154455157**E-16m corresponding to the proton mass m_p. Thus r_{Gnp}(M)=1.05**154455157**E-16m*(m_p/m_n)=**1.05**0097077**48**E-16m=$r_{Gn}(M)<r_{Gn}(S)$.
r_{Gp}(S) =1.05**154455168**E-16m to be compared (difference due to m_v)

So r_{Gnp}(M) from 1.4 with 1.3 leads to mass m_{np}(M) (including the Neutrino m_v) > m_p (never including m_v) $m_{np}(M)-m_p$=S/c*{1/r_{Gnp}(M) - (1/r_{Gp}(S)} = 0.94eV (but not acceptable accuracy)

Remark on absolute accuracy limits

g_{np}=3.82608545(90) and μ_n=-9.6623651(23)E-27J/T error-limits giving the maximum absolut error-bars (+444.15 and - 443.95)eV while calculating the corresponding mass values from 1.4. From this we get the „mean relative error" (0.20)eV „estimation" while assuming gaussian shaped statistics as a rough estimation that mean values are the same without systematic influences assumed.

Conclusion:

The change of neutron magnetic moment during the beta-decay must have to do with the binding energy.

„**Magnetic Binding" Energy** from Codata restmass values:
m_n-(**m_p+**m_e)=**782333.41**eV=$B_{E\nu}$ (compared with 0.7(3) MeV from [1])

$B_{E\nu}$ =B_E+m_ν **„including" anti-neutrino restmass** reads:
B_E=m_n-(**m_p+**m_e+m_ν)=**782333.??**eV after decay

(Katrin <1.1eV Cosmological observations suggest that the mass of neutrinos could be 0.1 eV or lighter. [8])

However, the neutrino restmass speculation (0.10(20)eV is not possible reflecting accuracy limits from Codata 2020.

Beyond the SM:
The Spin (S), charge, velocity of light and energy all must be invariant during the process. Mass (m), radius (r_G), and magnetic moment (μ) must not be constant. This is true for electron and proton and neutron mass steps.

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

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

Notice: N formally respects quantisation of radius or mass respectively m(N) [4].

Remark:
Suppose the neutron changes magnetic moment and releases a proton (its mass and magnetic moment) and at the same time releases an electron keeping an anti-neutrino inside at the beginning of the process (me+mv > me). So the magnetic moment of the electron is smaller for that. The electron then releases an anti-neutrino getting its final mass and magnetic moment, statistically based. The neutrino has no charge, so has no magnetic moment after emission, so shows only restmass (m_ν). The kin. energies are from binding excess energy: m_n-m_p-(m_e+m_ν) as usual.

Literature

(1) J. Gasser, H. Leutwyler, A. Rusetsky On the mass difference between proton and neutron Physics Letters B Volume 814, 2021.
(https://www.sciencedirect.com/science/article/pii/S0370269321000277?via%3Dihub)

(2) 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

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

(4) Derivation of Radius (Particle restmass (r_{GN}) behaves like a wave!)
https://www.researchsquare.com/article/rs-524770/v3
Only if a GR-theory is able to derive r_{GN} *exclusively. Thus 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?“*

(5) Magneton
https://en.wikipedia.org/wiki/Bohr_magneton
Intrinsic Magnetic Moment
https://de.wikipedia.org/wiki/Land%C3%A9-Faktor
mu_s(xM) = g_s *q/(2m(xM))*S leads to
m(pM)=**1.67**262192370E-27kg Codata: m_p=**1.67**262192369(51)E-27kg
m(eM)=**9.10**938837015E-31kg Codata: m_e=**9.10**938837015(28)E-31kg
m(nM)=**1.67**492749804E-27kg Codata:m_n=**1.67**492749804(95)E-27kg

(6) 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.“

(7) 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)

(8) https://www.nature.com/articles/d41586-019-02786-z