

# Neutron's basic Mass

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## Research Article

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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 ( $\mu$ ) due to the spin of charged particles - like Electron ( $m_e$ ) and Muon ( $m_\mu$ ). 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 ( $m_\nu$ ) 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  $m_\nu = 0.10(20)eV$ .

## Introduction

From Ampère's law point of view pure restmass without charge can not generate a magnetic moment. Thus the neutron must have an internal dynamic (quark based) charge-action from a positive and negative part to come up with a magnetic moment.

Elementary particles like electron fundamental particles like proton, and neutron (and neutrino) obey the wave-particle behaviour as nature's fundamental fact shown by Einsteins famous equation <sup>(1)</sup>:

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

Here using the Compton wavelength ( $\lambda=c/f$ ) instead of frequency (f).

The **Compton wavelength** <sup>(1)</sup> ( $\lambda$ ) is a quantum mechanical **wave like parameter** of a massive quantum entity defined by mass (m) velocity of light (c) and Planck constant (h).

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

„The wavelength ( $\lambda$ ) was introduced by Arthur Compton in his explanation of the scattering of photons by electrons (a process known as Compton scattering).“ <sup>(2)</sup>

Einstein: From wave to particle

Compton: From particle to wave

This paper: From wave to particle

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 <sup>(3)</sup>:

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

Hint: <sub>G</sub> indicates a necessary still missing (General Relativity) <sup>(3)</sup> theoretical fundament concerning the derivation of mass from theory and <sub>N</sub> 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 ( $S=1/2 \cdot \hbar$ ) can be written <sup>(3)</sup>:

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

### Magnetic Moments and Ampère's Law

In atomic physics, the Bohr magneton <sup>(4)</sup>  $\mu_B = e \cdot \hbar / (4\pi \cdot m)$  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 ( $\mu$ ) <sup>(4)</sup> while using Ampère's law <sup>(4)</sup> reads <sup>(2,3,4,5)</sup>: in units [A\*m<sup>2</sup>] = [J/T]

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

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

### Result:

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 ( $\mu$ ) 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.**

## 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  $\mu_p$ ) **remain the same during the beta decay process and specially after decay.**

This assumption simplifies the discussion in so far 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 <sup>(5)</sup>. Thus our simplified discussion is helpful for the moment as a first step of this common alternative way.

### Free Proton:

Magnetic moment:  $\mu_p$  (+1.41060679736(60)E-26J/T)

$g_{sp}=5.5856946893(16)$

Restmass:  $m_p$  (**1.67262192369**(51)E-27kg)

- S-radius (1.3):  $r_{Gp}(S)$  (1.05154455167E-16m)

-  $\mu$ -radius (1.4):  $r_{Gp}(M)$  (1.05154455167E-16m)

### Neutron:

Magnetic moment:  $\mu_n$  (-9.6623651(23)E-27J/T)

$g_{sp}=3.82608545(90)$

Restmass:  $m_n=1.67492749804E-27kg.$

- S-radius (1.3):  $r_{Gn}(S)=1.05009707759E-16m$

- Captured  $\mu$ -radius (1.4):  $r_{Gen}(M)=r_{Gpn}(M)=r_{Gn}(M)=1.05154455167eE-16m$

### Free Electron

Magnetic moment:  $\mu_e$  (-9.2847647043(28)E-24J/T)

$g_{sp}=2.00231930436256(35)$

Restmass:  $m_e=9.1093837015(28)E-31kg$

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

-  $\mu$ -radius (1.4):  $r_{Ge}(M)=1.9307963398E-13m$

**Electron and Proton data go confirm with formula 1.3 and 1.4 - not so the Neutron**

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 ( $r_{GN}(\text{neutrino})$ ) in accordance with Fermi's 1934 theory of beta decay.

Overview:

2020	Restmass (m) In kg	Magnetic Moment ( $\mu$ ) In J/T	Landé Factor (g)	$r_{G(S)}$ in m $r_{G(M)}$ 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 9.3379715376E-16
Tauon	3.16754E-27	No value	No value	5.5526890611E-17
Proton	1.67262192369(51)E-27	1.41060679736(60)E-26	5.5856946893(16)	1.0515445516E-16 1.0515445516E-16
Neutron	1.67492749804(95)E-27	-9.6623651(23)E-27	3.82608545(90)	1.0500970776E-16 1.0515445516E-16

Table 1 **Magnetic Moments and Neutrino's Mass.** The mass of the Neutron ( $m_n(S)$ ) is that of the experimental mass  $m_n=1.67492749804E-27$ kg. So we get from the Spin (1.3) the corresponding  $r_{GN}(S)=1.05009707759E-16$ m and from the magnetic moment  $r_{GN}(M)=1.50154455167E-16$ m from (1.4). Both are different. (Not so for proton and electron!)

## Conclusion:

In short:

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

- $m_n(M)=1.67262192386E-27$ kg from  $r_{GN}(M)$
- $m_p=1.67262192369(51)E-27$ kg from experiment or from  $r_{Gp}(S)$
- $m_n=1.67492749804(95)E-27$ kg from experiment or from  $r_{GN}(S)$

The change of magnetic moment 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 (fixed) magnetic moments and rest mass.

## Binding energy energy without neutrino before decay

$$m_n - m_n(M) - m_e = 782.333311 \text{ keV} = B_E$$

## Binding energy energy including anti-neutrino mass before decay

$$m_n - m_p - m_e = 782.333410 \text{ keV} = B_{Ev}$$

$$B_E - B_{Ev} = -m_p(S) + M_n(M) = -0.099 \text{ eV} = m_\nu$$

So  $m_\nu$  must be the restmass of the neutrino - of course its a positive mass!

$$m_\nu = m_n(M) - m_p = \mathbf{0.10(20)eV}$$

### Remark:

$g_{sn} = 3.82608545(90)$  and  $\mu_n = -9.6623651(23)E-27 J/T$  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.

Ampère's law combined with a particle-picture introducing  $r_G$  leads to a new way to calculate the non-magnetic-neutrino mass based on the change of magnetic moments during the beta-decay (short before decay).

### 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: 978-94-007-5297-9 Gerardo Delgado-Barrio, Piotr Piecuch, Verlag: Springer Netherlands
- (2) Compton scattering:  
[https://en.wikipedia.org/wiki/Compton\\_wavelength](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](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  $1/2 \hbar$ , 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)