

Neutron Beta Decay Energy Decomposition and Its Possible Relation to Proton–Neutron Interaction in Deuteron Binding Energy

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Abstract:

The present work examines nuclear binding from a charge-based perspective by starting from neutron beta decay as an experimentally accessible energy scale. A simple symmetric energy structure is considered, leading to an intrinsic component (~ 1.239 MeV) and a residual component (~ 0.99 MeV). The sum of these two independently obtained quantities closely matches the experimentally observed deuteron binding energy (~ 2.22 MeV), without direct fitting.

The residual energy is found to be of the same order as the electrostatic interaction energy between charges at nuclear distances (~ 1 fm). When expressed in terms of force, it corresponds to a magnitude ($\sim 10^2$ newton) comparable to the repulsion between protons at similar separations.

This agreement between independently obtained energy and force magnitudes suggests the existence of a characteristic interaction scale at the neutron boundary. However, no definitive claim is made. The observation is presented as an open question, inviting further investigation into whether this correspondence reflects a deeper physical connection or a numerical coincidence.

Keywords: Neutron beta decay; Deuteron binding; Coulomb energy scale; Charge structure; Interaction energy; Proton repulsion

1. INTRODUCTION:

The problem of nuclear binding and the origin of interaction scales at femtometer dimensions has been a central topic in nuclear physics for several decades [1–4]. While modern approaches based on quantum chromodynamics successfully describe nucleon interactions through quark and gluon dynamics, the resulting formulations are often complex and rely on effective parameters when applied to low-energy nuclear systems [5–7]. This leaves open the possibility of exploring alternative interpretations that emphasize simpler physical quantities such as charge, energy, and spatial scale.

In recent work, VTI model [13,14], neutron confinement and interaction scales, were examined within a charge-based framework involving internally confined Q_c units, including a hydrogenic representation of charge structure. [15] These studies demonstrated that characteristic nuclear-scale interaction

magnitudes can emerge from charge confinement and geometric considerations without invoking additional interaction terms. The present work builds upon these developments, focusing specifically on the energy structure associated with neutron beta decay.

One of the most fundamental and experimentally accessible processes in nuclear physics is neutron beta decay. In this process, a neutron transforms into a proton, electron, and antineutrino, releasing a characteristic energy that reflects internal charge reconfiguration [8–10]. This decay provides a direct window into the energy scale associated with charge separation at nuclear dimensions.

In the present work, neutron beta decay is used as a starting point to construct a charge-based interpretation of nuclear binding. A symmetric charge-energy structure is considered, motivated by the Qc framework, leading to the emergence of a residual energy component (~ 0.99 MeV) in addition to the intrinsic beta decay scale (~ 1.239 MeV). Remarkably, the sum of these independently obtained components closely reproduces the experimentally observed binding energy of the deuteron (~ 2.22 MeV) [11]. Furthermore, the residual energy scale (~ 1 MeV) is found to be comparable to the Coulomb interaction energy between unit charges at nuclear length scales (~ 1 fm), given by classical electrostatic considerations [12]. When expressed in terms of force, this corresponds to magnitudes of order 10^2 newton, consistent with the electrostatic repulsion between protons at similar separations.

These observations suggest the possibility of a characteristic interaction scale emerging from charge-based considerations at the neutron boundary. However, no definitive claim is made in this work. Instead, the analysis is presented as an exploratory framework aimed at identifying numerical and structural correspondences that may warrant further investigation.

The central question addressed in this study is therefore:

whether the ~ 1 MeV energy scale emerging from neutron beta decay decomposition is intrinsically related to proton–neutron interaction in deuteron binding, or whether the observed agreement is coincidental.

2. Main Framework:

2.1 Motivation and Approach

The present work is motivated by earlier studies of neutron structure based on internally confined Qc units, in which the fundamental constituents are treated as pairs of equal and opposite charges arranged in a hydrogenic configuration. Such a symmetric charge structure naturally suggests that the associated energy components may also be comparable in magnitude.

This observation raises a simple question: whether the energy associated with one charge component, as reflected in neutron beta decay, can provide a meaningful reference scale for understanding nuclear binding.

To explore this possibility, the analysis adopts a direct and observational approach, starting from neutron beta decay as an experimentally accessible process. This decay provides a measurable energy scale associated with internal charge separation.

The objective is to examine whether this energy scale, together with a residual component emerging from the decomposition, can be related to nuclear binding, and in particular to the binding energy of the deuteron.

2.2 Energy Scale from Beta Decay

The neutron undergoes beta decay:



This process reflects the release of internal energy associated with charge separation. The characteristic energy scale is taken as:

$$E_{\beta} = 1.239 \text{ MeV} \quad (2)$$

Within the present framework, this energy is interpreted as the energy associated with the release of one charge component ($-Q_c$) from the confined structure.

2.3 Symmetric Qc Energy Structure

Assuming that the internal structure consists of symmetric charge components, the energies associated with the positive and negative components are taken to be equal:

$$E_{+Q_c} = E_{-Q_c} = E_{\beta} \quad (3)$$

The total intrinsic energy of a Qc unit is therefore:

$$E_{Q_c} = 2E_{\beta} = 2 \times 1.239 = 2.478 \text{ MeV} \quad (4)$$

2.4 Emergence of Residual Energy

The total structural energy is considered as:

$$E_{total} = E_{\beta} + E_{d=} + 1.239 + 2.22 = 3.46 \text{ MeV} \quad (5)$$

Where E_d is Deuteron Binding Energy

This may be decomposed into intrinsic and residual components:

$$E_{total} = E_{Q_c} + E_{res} \quad (6)$$

Substituting:

$$3.46 = 2.478 + E_{res} \quad (7)$$

$$E_{res} = 0.99 \approx 1.0 MeV \quad (8)$$

The experimentally observed deuteron binding energy (2.22 MeV) is not equal to the total internal energy scale derived within the present framework (~3.46 MeV). However, the decomposition of this internal energy naturally yields components (~1.239 MeV and ~0.99 MeV) whose sum closely matches the binding energy.

2.5 Physical Meaning of Residual Energy

The residual energy is interpreted as an interaction barrier (or boundary stabilization energy) associated with the internal charge structure.

It represents the energy required to:

- counteract internal electrostatic opposition
- maintain stable confinement at the nuclear boundary

2.6 Relation to Nuclear Length Scale

At nuclear dimensions, the electrostatic interaction between unit charges is given by:

$$E_C = \frac{e^2}{4\pi \epsilon_0 R} \quad (9)$$

For a characteristic free nuclear radius:

$$R \sim 1.23 fm \quad (10)$$

the corresponding energy scale becomes:

$$E_C \sim 1.17 MeV \quad (11)$$

This is of the same order as:

$$E_{res} \sim 1.0 MeV \quad (12)$$

2.7 Observational Remark

The independently obtained residual energy (~0.99 MeV) closely matches the characteristic Coulomb energy at nuclear length scales.

Whether this agreement represents a deeper structural relationship or a numerical coincidence is left as an open question.

2.8 Extension to Deuteron Binding

Where E_d is taken as the characteristic energy corresponding to the deuteron binding scale.

$$E_d = 2.22 MeV \quad (13)$$

Within the present framework, the binding energy may be expressed as:

$$E_d \sim E_{beta} + E_{res} \tag{14}$$

Substituting:

$$2.22 \sim 1.239 + 1.0 \tag{15}$$

2.9 Interpretation of Binding

This suggests that the binding energy consists of two contributions:

$$E_{binding} = E_{intrinsic} + E_{boundary} \tag{16}$$

where:

- $E_{intrinsic}$ corresponds to the fundamental charge – associated energy
- $E_{boundary}$ corresponds to the interaction barrier energy

2.10 Conceptual Picture

The binding process may be understood as a balance of opposing tendencies:

$$E_{confinement} \sim E_{repulsion} \tag{17}$$

The residual energy (~1.0 MeV) represents the equilibrium scale of this balance at the neutron boundary.

2.11 Scope and Focus

Force and pressure scales corresponding to this energy framework have been discussed in earlier work. The present analysis focuses specifically on the emergence of energy structure from beta decay and its relation to nuclear binding.

2.12 Final Relation

$$E_{total} = 2 \times E_{beta} + E_{boundary} \tag{18}$$

$$E_b \approx 1 \text{ MeV} \tag{19}$$

Force Interpretation

Converting boundary energy into equivalent force:

Converting in N force yields

$$Fb = \frac{E_{bj}}{R_0} \quad (20)$$

Where R_0 is Neutron free Radius = 1.23fm

$$Fb = \frac{1.0 \times 1.6 \times 10^{-13}}{1.23 \times 10^{-15}} \approx 130 \text{ N} \quad (21)$$

Proton Boundary (Electrostatic) Force (F_p)

Where R_0 is Neutron free Radius (separation) = 1.23 fm

$$F_p = \frac{e^2}{4\pi \epsilon_0 R^2} \quad (22)$$

$$F_p = \frac{e^2}{4\pi \epsilon_0 * R_0^2} = \frac{(1.6 \times 10^{-19})^2}{4 \pi \epsilon_0 (1.23 \times 10^{-15})^2} \approx 152 \text{ N} \quad (23)$$

At the nominal neutron boundary radius $R_0=1.23$ fm, the Coulomb repulsive force between unit charges is estimated to be approximately 152 newton, which exceeds the confinement force scale (~130 newton). Since the Coulomb force decreases with increasing separation ($\propto 1/R^2$), a slightly larger effective separation leads to a reduction in repulsion, allowing consistency with the confinement condition.

Observation

The independently obtained residual energy (~1.0 MeV) closely matches the characteristic Coulomb energy at nuclear length scales (see Eq. (8) and Eq. (12)). The corresponding force estimates (see Eq. (21) and Eq. (22)), evaluated at a common radius (~1.2 fm), are also of the same order (~ 10^2 newton). Whether this agreement reflects a deeper structural relationship or a numerical coincidence remains an open question.

3. CONCLUSIONS:

The present work adopts an observationally grounded approach by beginning with neutron beta decay as a measurable energy source associated with internal charge separation. From this, a symmetric charge-energy structure is considered, leading to an intrinsic energy component (~1.239 MeV) and an independently emerging residual term (~0.99 MeV).

A key observation is that the sum of these two components closely reproduces the experimentally known deuteron binding energy

$$E_d \approx 1.239 + 0.99 \approx 2.22 \text{ MeV}$$

without direct fitting to the binding energy itself.

The residual energy (~ 0.99 MeV), obtained independently, is found to be of the same order as the electrostatic interaction energy at nuclear length scales (~ 1 fm). When expressed as an equivalent force, it yields a value ($\sim 10^2$ newton) that is also consistent with the Coulomb repulsive force between protons at similar distances.

This convergence of independently derived quantities—energy decomposition, Coulomb scale, and force magnitude—suggests the existence of a characteristic interaction scale at the neutron boundary.

However, no definitive claim is made at this stage. The observed correspondence may represent either:

- a fundamental structural connection between internal charge configuration and nuclear binding, or
- a numerical coincidence arising from similar underlying scales

This ambiguity motivates further investigation.

The present framework therefore highlights a simple but potentially significant question:

Is the ~ 1 MeV energy scale emerging from beta decay decomposition intrinsically related to nuclear binding and electrostatic interaction at femtometer dimensions?

The answer to this question remains open and may require deeper theoretical and experimental examination.

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