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A Classical Derivation of the Neutron Strong Force from Internally Confined Charge Structure

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Abstract

This work presents a first-principles derivation of neutron confinement and the strong nuclear force within the Vacuum Tension Interaction (VTI) framework, formulated entirely in a classical, deterministic setting. The neutron is modeled as a composite of discrete, electrically neutral quantum-charge (Qc) units, each generating an intrinsic inward Coulomb confinement pressure. By enforcing volumetric scaling and electrostatic equilibrium at the Qc level, a unique effective Qc radius is obtained. Two independent derivations, geometric partitioning of the neutron volume and saturation of Coulomb pressure at the universal vacuum tension limit c^4, converge on the same Qc length scale without the introduction of adjustable parameters. The Qc-level confinement force is then scaled geometrically to the neutron surface, yielding a neutron strong force, of order 10^5 newton, which is consistent with established confinement estimates. Neutron stability emerges as a direct consequence of pressure invariance across scales, with inward Coulomb forces exactly balanced by universal vacuum tension. The strong force is thus shown to arise deterministically from charge geometry and vacuum boundary conditions, without invoking Yukawa potentials, quantum chromodynamics, or phenomenological coupling constants.

Keywords: Neutron Strong Force, VTI Neutron model, Coulomb force unification, Plank stiffness factor, Sub-neutron charge quanta.

1. Introduction

The problem of neutron confinement and the origin of the strong interaction has been examined for several decades using a variety of theoretical approaches [1; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14]. Early models employed phenomenological potentials to account for nuclear binding, while later developments introduced quantum-field-based descriptions in which the strong interaction is mediated through effective exchange mechanisms. These frameworks have been successful in reproducing a wide range of experimental observations, including binding energies and scattering data, and form the basis of modern nuclear theory. At the same time, such approaches typically focus on effective interactions and numerical agreement, rather than on direct analytical derivations of confinement force and characteristic length scale from elementary physical principles. This has left open the question of whether aspects of neutron stability can be understood from a simpler, deterministic perspective. The present work is situated within this context and explores an alternative classical formulation aimed at addressing this question.

1.1 Background and Motivation

The neutron is a fundamental constituent of atomic nuclei, and its stability under strong confinement is a central issue in nuclear physics. While experimental properties such as neutron decay and nuclear binding energies are well established, theoretical descriptions of neutron confinement commonly rely on phenomenological or quantum-field-based models. These approaches successfully reproduce observed nuclear behavior; however, a direct analytical derivation of the neutron confinement force and of a specific neutron length scale emerging from elementary physical considerations is not typically provided.

This motivates examining whether key features of neutron stability and strong-force magnitude can be understood within a classical, deterministic framework based on electrostatics, geometry, and force balance.

The present work addresses this question by exploring neutron confinement through internal charge organization and pressure equilibrium, without invoking probabilistic field descriptions or externally imposed interaction ranges.

1.2. Limitations of Phenomenological Range-Based Models:

Many descriptions of the strong interaction employ effective, range-based models in which the short-range nature of the force is introduced phenomenologically. While such approaches reproduce experimental observables, the interaction range and force magnitude are not typically derived from elementary physical principles but are introduced as external or effective parameters. As a result, the origin of the neutron confinement scale and the magnitude of the confinement force are not addressed explicitly within these formulations.

1.3. Need for a Deterministic, Classical Perspective:

While quantum-field-based models are widely used to describe nuclear phenomena, simple analytical expressions for confinement force and characteristic length scale are not typically obtained within those formulations. A deterministic classical perspective allows these quantities to be examined through force balance, geometry, and pressure constraints. Classical electrostatics provides a well-defined interaction law that can be applied to internal confinement without probabilistic assumptions. Geometric scaling permits forces and pressures to be related across length scales without introducing phenomenological parameters. Within such a framework, mechanical equilibrium conditions underlying stability can be identified explicitly. This motivates an examination of neutron confinement using elementary physical principles. Accordingly, the present analysis is restricted to a classical and deterministic formulation.

1.4. Concept of Internal Structure in the Neutron

Experimental observations such as neutron decay and nuclear binding energies indicate that the neutron possesses an internal organization of energy rather than behaving as a strictly structureless point-like entity. Within a classical perspective, this suggests that confinement may arise from the collective behavior of internal constituents. Treating the neutron as a composite system allows internal forces and pressures to be meaningfully defined. Such an interpretation does not conflict with point-like behavior observed in high-energy scattering, but addresses confinement under stable conditions. An internal structure also provides a natural basis for relating neutron stability to force balance, geometric constraints, and the organization of sub-neutronic constituents under confinement. This view motivates the introduction of elementary charge-based units as building blocks of neutron structure. The present work adopts this interpretation to examine confinement and stability in a deterministic manner.

1.5. Vacuum Tension Interaction (VTI) Framework:

The Vacuum Tension Interaction (VTI) framework is introduced to describe confinement in terms of a balance between internal forces and a universal limiting pressure. Within this formulation, the vacuum is characterized by a maximum tension scale, denoted by c^4, which bounds the compressibility of confined systems. When internal confinement pressures approach this limit, mechanical equilibrium is established. This concept provides a natural boundary condition for stable structures at small length scales. In the context of the neutron, VTI allows internal Coulomb confinement to be related directly to an external pressure constraint. In this way, confinement and stability are treated as consequences of pressure balance rather than as single range-limited interactions. The framework serves as a classical basis for the derivations presented in this work.

1.6 A Quantum Charge Qc Unit:

The motivation for introducing sub-neutronic quantum-charge (Qc) units arises primarily from the observed properties of neutron beta decay. All free neutrons undergo decay into a proton, an electron, and an antineutrino, releasing a fixed and reproducible amount of energy. The appearance of a negatively charged electron and the simultaneous conversion of the neutron into a positively charged proton indicate that opposite electric charges must have been present within the neutron prior to decay. Since free electric charges do not remain bound without confinement, this observation suggests the existence of an internal charge-confining structure within the neutron. In this interpretation, Qc units represent internally confined charge–energy quanta within the neutron, rather than pre-existing free particles; the proton and electron emerge as distinct entities only upon decay. Further support for this interpretation comes from the fact that the proton mass differs from the neutron mass by the same characteristic energy quantum released in decay, indicating a well-defined internal energy partition rather than an arbitrary transformation. In addition, the existence of neutron–neutron and neutron–proton binding energies implies that neutrons participate in stable interactions that are difficult to reconcile with a strictly structureless point-particle description. Taken together, these observations motivate the introduction of confined electrically neutral charge units as a minimal internal structure capable of accounting for decay energetics, charge emergence, and binding behavior within a deterministic VTI framework conceptual model, as depicted Fig.1 and Fig. 2.

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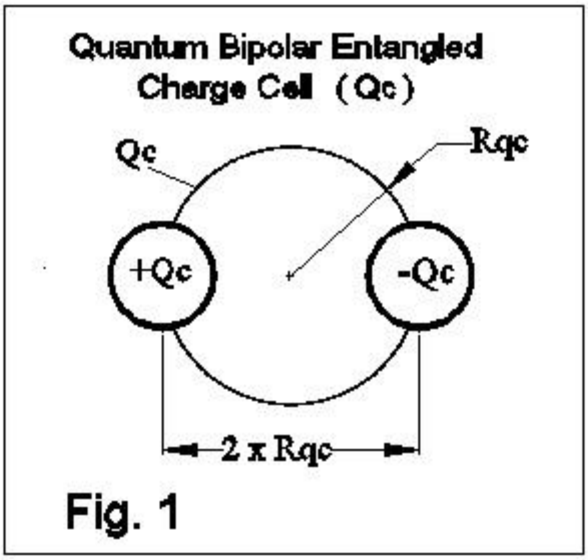

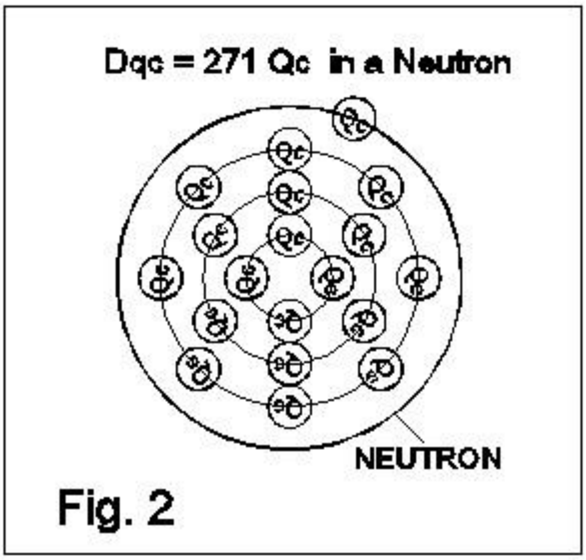

VTI: Conceptual Neutron Model

Fig. 1: A Qc charge quantum, composed of two oppositely charged components (+Qc) and (-Qc) each carrying a charge q, separated by a distance 2 x Rqc, where Rqc is the characteristic radius of the Qc unit.

Fig.2: A neutron model composed of 271 Qc units, symmetrically arranged to produce a neutral, confined charge structure responsible for both neutron strong force and surface pressure Pn.

1.7. Central Hypothesis of the Present Work:

The present work is based on the hypothesis that neutron stability and confinement arise from a deterministic balance between internal electrostatic forces and a universal pressure limit. It is proposed that this balance operates at both the sub-neutronic and neutron scales, linking internal charge confinement to subneutronic stability. Within this framework, the neutron is viewed as a composite system whose internal structure governs the magnitude of the confinement force and the characteristic length scale. The same pressure constraint is taken to apply uniformly across scales, allowing force magnitudes to be related through geometric considerations. This hypothesis provides the basis for deriving the quantum-charge radius, the number of internal constituents, and the neutron confinement force using elementary physical principles.

1.8. Objectives of the Present Study

The objective of the present study is to examine whether neutron confinement and the magnitude of the strong force can be derived within a deterministic, classical framework. Specifically, the work aims to establish the effective quantum-charge radius using independent pressure-based and energy-based considerations. A further objective is to determine the number of quantum-charge units constituting the neutron through geometric scaling. The study also seeks to derive the neutron confinement force from pressure invariance across sub-neutronic and neutron scales. Throughout, the analysis is restricted to elementary electrostatics, geometry, and a universal pressure bound, without invoking phenomenological interaction ranges or probabilistic field descriptions.

1.9. Scope and Methodology:
The scope of the present work is limited to a deterministic, classical analysis of neutron confinement. The methodology is based on elementary electrostatics, geometric scaling, and force–pressure relations, with particular emphasis on pressure balance across sub-neutronic and neutron scales. Only experimentally established quantities such as neutron rest energy, decay energetics, and binding-energy constraints are used as physical inputs. No phenomenological interaction ranges, quantum chromodynamic formalisms, or probabilistic field descriptions are employed. The analysis proceeds analytically, with all key quantities derived through explicit scaling relations and equilibrium conditions.

1.10. Organization of the Paper:
The paper is organized as follows. The conceptual framework and physical assumptions are introduced in the initial sections. The derivation of the quantum-charge radius and the number of internal constituents is then presented using independent pressure-based and energy-based arguments. This is followed by the derivation of the neutron confinement force through geometric scaling and pressure balance. The results are subsequently discussed in terms of neutron stability and internal structure. The paper concludes with a summary of the main findings, limitations of the present approach, and possible directions for further study.

2. Main Framework:

2.1 Derivation of the Qc Number (Dqc) in the Neutron:
Having established the conceptual foundation of the Vacuum Tension Interpretation (VTI), we now develop its quantitative framework. The formulation rests on a set of interrelated physical quantities that together determine the internal structure of the neutron:

- Qc –Charge quanta having $\pm$q charges separated by 2 x Rqc
- Rqc- Radius of Qc quanta
- Dqc-Total number of Qc quanta within Neutron
- Total rest energy of the neutron, En
- Effective radius of the neutron, Rn
- Vacuum tension pressure, Ps
- Inward confinement pressure within the neutron, Pn
- Total number of charge-confinement units in the neutron, Dqc
- Energy associated with a single charge-confinement unit, Eqc
- Proton rest energy, Ep
- Neutron beta-decay energy, Ed
- Binding energy of deuterium, Eb
- Magnitude and spatial confinement of the neutron strong force, Fn

Together, these quantities demonstrate how VTI translates a charge-based framework into concrete, physically testable predictions.

2.2 Estimation of the Number of Qc Units (Dqc) from Beta Decay and Binding Energy

The quantization of the neutron's internal structure is inferred from its beta-decay process,

$$(En \rightarrow Ep + e^{-} + \bar{\nu}_e)$$

which is interpreted here as a manifestation of conserved internal charge-confinement structure and charge symmetry.

The mass–energy released during neutron beta decay is given by

$$Ed = En - Ep \approx 1.239 \text{ MeV} \quad (2.1)$$

where En and Ep denote the rest energies of the neutron and proton, respectively.

In addition to this decay energy, the neutron's internal energy budget must account for the experimentally measured binding energy of deuterium,

$$Eb \approx 2.224 \text{ MeV} \quad (2.2)$$

which reflects the residual confinement energy associated with neutron–proton coupling.

Accordingly, the characteristic charge-confinement energy per Qc unit is defined as,

$$Eqc \approx Ed + Eb \approx 1.239 + 2.224 \approx 3.46 \text{ MeV} \quad (2.3)$$

Assuming that the neutron's total rest energy arises from an ensemble of identical charge-confinement units, the neutron energy may be written as,

$$En = Dqc \times Eqc \quad (2.4)$$

from which the total number of Qc units follows directly:

$$Dqc = \frac{En}{Eqc} = \frac{939.565}{3.46} \approx 271 \quad (2.5)$$

Each Qc unit is demonstrated to consist of two oppositely charged sub-components (±Qc), each carrying a charge magnitude equal to the elementary charge,

$$q = 1.602 \times 10^{-19} \text{ C} \quad (2.6)$$

This value corresponds to the fundamental electric charge experimentally established through electron emission and decay processes.

The independently obtained value Dqc≈271, derived here from beta-decay energetics and nuclear binding considerations, and later corroborated through vacuum-tension and pressure balance arguments, demonstrates internal consistency across multiple derivations. This convergence substantially strengthens the physical plausibility of the proposed charge-confinement structure of the neutron.

2.3 Derivation of the Effective Qc Radius (Rqc):

The neutron radius employed in this study is treated in two physically distinct but experimentally consistent regimes:

- An **effective radius (confined to ~ 0.8 free Neutron radius)** Rn≈1.0 fm, corresponding to maximum inward confinement force Fn;
- A **free Neutron radius** Ro ≈ 1.23 to 1.25 fm,

Both values lie well within the experimentally established neutron radius range of 0.8–1.24 fm reported in the literature. The confined radius is adopted here because the present analysis concerns **internal force balance and stability**, not scattering asymptotic.

2.4 Volumetric Scaling and Definition of the Qc Radius:

Assuming that the neutron consists of Dqc = 271,see Equation(5), identical charge-quantum (Qc) units uniformly confined within an effective neutron radius Rn≈1.0 fm, the characteristic linear dimension of each Qc unit follows directly from volumetric scaling:

$$R_{qc} = \frac{Rn}{(N_c)^{\frac{1}{3}}} \qquad (2.7)$$

substituting numerical values,

$$R_{qc} = \frac{1.0\,x10^{-15}}{(271)^{\frac{1}{3}}} \approx\ 0.155\,x10^{-15}\,m =\ 0.155\,fm \qquad (2.8)$$

This radius represents the **effective confinement scale** of an individual Qc unit within the neutron.

2.5 Internal Coulomb Confinement Force of a Qc Unit

We now evaluate the internal electrostatic confinement force acting within a single Qc unit. Treating the Qc as a charge-separated entity of characteristic diameter 2Rqc, the inward Coulomb force is given by the classical expression:

$$\mathrm{F_{qc}} = \frac{q^2}{\left(4 \times \pi \times \varepsilon_0 \times \left(2 \times R_{qc}\right)^2\right)} \qquad (2.9)$$

Where:

q =1.602×10^{-19} C is the elementary charge,

ε_0 =8.55×10^{-12} F/m is the vacuum permittivity,

Rqc = 0.155×10^{-15} m is the effective radius of a Qc cell,

Dqc = 271 is the number of Qc quanta units within the neutron

2.6 Qc Surface Pressure:

The force Fqc acts over the surface of the Qc cell [15]. The corresponding surface pressure is therefore:

$$\boldsymbol{Pqc} = \frac{\boldsymbol{Fqc}}{\boldsymbol{Aqc}} = \frac{\mathrm{Fq_c}}{4\ x\ \pi\ x(\ R_c)^2} \tag{2.10}$$

Substituting Equation (2.9) into Equation (2.10), we obtain:

$$\text{Pqc} = \frac{\boldsymbol{q^2}}{\mathbf{16} \times \boldsymbol{\pi} \times \boldsymbol{\varepsilon_0} \times (\ \boldsymbol{R_c})^2}\ \mathbf{x}\ \frac{1}{4\ x\ \pi\ x(\ R_c)^2} \approx \frac{\boldsymbol{q^2}}{64\ x\ \boldsymbol{\pi^2}\ \boldsymbol{x}\ \boldsymbol{\varepsilon_0}\ \boldsymbol{x}\ (\ \boldsymbol{R_c})^4} \tag{2.11}$$

This expression represents the **inward Coulomb pressure** acting within a single Qc unit.

2.7 Identification with Vacuum Tension:

Within the Vacuum Tension Interaction (VTI) framework [16:17], neutron stability requires that the internal Coulomb pressure of each Qc unit saturates at the universal vacuum tension scale [15]:

Pqc=c^4

Equating this condition with Equation (2.11) yields:

$$Rqc^4 \approx \frac{\boldsymbol{q^2}}{64\ x\ \boldsymbol{\pi^2}\ \boldsymbol{x}\ \boldsymbol{\varepsilon_0}\ \boldsymbol{x}\ (\ \mathbf{c})^4} \tag{2.12}$$

Solving for Rqc:

$$Rqc \approx \left(\frac{(\mathbf{1.602\ x\ 10^{-19}})^2}{\left(\mathbf{64} \times \boldsymbol{\pi^2} \times \mathbf{8.55}\ \boldsymbol{x}\ \mathbf{10^{-12}} \times (\ \mathbf{3\ x\ 10^8})^4\ \right)}\right)^{1/4} \approx 0.1545\ x\ 10^{-15} m \tag{2.13}$$

2.8 Consistency Check:

Equations (2.8) and (2.13) yield **numerically identical values** for the Qc radius:

Rqc≈0.155 fm

This agreement is non-trivial. The same length scale emerges independently from:

1. **Geometric (volumetric) partitioning** of neutron structure, and
2. **Force–pressure equilibrium** between Coulomb confinement and vacuum tension.

This convergence provides strong internal consistency for the Qc model and confirms that the adopted Qc radius is **not an adjustable parameter**, but a **derived physical scale**.

2.9 Derivation of the Strong Force Fqc and Surface Pressure Pqc at the Qc Level:

Within the **Vacuum Tension Interaction (VTI)** framework (see Figs. 1–2), the neutron is modeled as a composite structure formed from neutral quantum-charge (Qc) units. Each Qc unit consists of oppositely charged subcomponents whose mutual electrostatic interaction generates an intrinsic inward confinement force. The macroscopic neutron confinement force is therefore not introduced phenomenologically, but arises from the **geometrically scaled contribution of these Qc-level forces**.

A key feature of VTI is that the inward pressure responsible for neutron stability originates fundamentally at the **Qc scale itself**. The confinement pressure is not purely collective in origin; rather, it is an intrinsic property of each Qc unit that propagates upward through geometric packing to define the neutron's global force balance.

2.10 Qc-Level Confinement Force

Using the effective Qc radius derived earlier, the Coulomb confinement force within a single Qc unit is given by the classical electrostatic expression:

$$Fqc = \frac{q^2}{\left(4 \times \pi \times \varepsilon_o \times (2 \times R_{qc})^2\right)} \qquad (2.14)$$

Substituting numerical values,in Equation (2.14) yields:

$$Fqc = \frac{(1.602 \text{ x } 10^{-19})^2}{\left(4 \times \pi \times 8.55 \, x \, 10^{-12} \times (2 \times 0.155 \text{ x} 10^{-15})^2\right)} \approx 2.42 \times 10^3 N \qquad (2.15)$$

This force represents the **elementary inward confinement force** acting within each Qc unit.

2.11 Derivation of the Neutron Strong Force Fn:

Within the **Vacuum Tension Interaction (VTI)** framework, the inward strong force acting at the neutron scale arises directly from the pressure generated by its internal quantum-charge (Qc) units. The neutron is treated as a confined system in which the internal pressure is inherited from the Qc-level Coulomb confinement.

As established earlier, the surface pressure within each Qc unit saturates at the universal vacuum tension scale. Accordingly, the confinement pressure inside the neutron is given by

$$Pn \approx Pqc \approx c^4 \qquad (2.16)$$

2.12 Scaling of Force from Qc to Neutron Radius

This equality expresses the central VTI demonstrates that **pressure equilibrium is scale-invariant**, extending from the Qc level to the neutron as a whole.

Pressure is defined as force per unit area. Equating the pressure at the neutron surface to that at the Qc surface yields:

$$\frac{Fn}{An} = \frac{Fqc}{Aqc} \Rightarrow Fn = \left(\frac{An}{Aqc}\right) x \, Fqc \qquad (2.17)$$

Since area scales as radius squared:

$$Fn = \left(\frac{Rn}{Rqc}\right)^2 x \, Fqc \qquad (2.18)$$

This expression provides a **purely geometric scaling law**, linking the neutron-scale strong force to the elementary Qc confinement force.

2.13 Numerical Evaluation:

Using the derived and experimentally consistent values:
Rn = 1.0 x 10^{-15} m
Rqc = 0.155x 10^{-15} m
Fqc = 2.42 x 10^{3} N
we obtain:

$$Fn = \left(\frac{1.0 \, x \, 10^{-15}}{0.155 \, x \, 10^{-15}}\right)^2 x \, 2.42 \, x \, 10^3 \approx 1.01 \, x \, 10^5 \text{ N} \qquad (2.19)$$

2.14 Interpretation and Physical Significance

The derived value of the neutron strong force,
$Fn \approx 10^5$ newton, is consistent with established theoretical estimates for neutron-scale confinement. Importantly, this force is **not postulated**, but emerges deterministically from:

- Coulomb confinement at the Qc level,
- geometric scaling of surface areas, and
- saturation of pressure at the universal vacuum tension limit.

Since Fn/An ≈ c^4, the neutron interior operates precisely at the **Planck vacuum tension interactive (VTI) boundary**. This confirms that neutron cohesion is governed by an exact mechanical equilibrium between discrete internal charge forces and a universal vacuum boundary condition, rather than by an externally imposed short-range force law.

3. Conclusions:

3.1 Central Physical Principle:

The present work is founded on a single physical principle**:** both the Qc-level confinement and the neutron-level strong force are governed by a common pressure balance fixed by the universal limit $\mathbf{c^4}$. This pressure bound defines the mechanical stability of confined charge systems and constitutes the basis of the Vacuum Tension Interaction (VTI) framework.

3.2 Determination of Rqc and Dqc:

The analysis establishes the effective quantum-charge radius as Rqc≈0.155 fm through two independent considerations. One is obtained by requiring pressure equilibrium at the Qc surface, at which the Coulomb confinement pressure reaches the universal limit c^4. The other arises from an independent energy-based derivation, in which the neutron rest energy (En) is partitioned using experimentally observed beta-decay energetics together (Eqc)with nuclear binding-energy constraints. The agreement of these two independent methods confirms that the Qc radius is a physically determined scale rather than an adjustable parameter. Once this characteristic radius is fixed, the number of Qc units contained within the neutron follows directly from geometric scaling with the neutron radius, yielding Dqc≈271. This result supports the conclusion that neutron structure is necessarily composite, consisting of a finite number of Qc constituents rather than a structureless point-like entity.

3.3 Force Balance from Qc Scale to Neutron Scale:

The analysis indicates that the neutron reaches maximum confinement at an effective radius of approximately 1.0 fm. At this radius, the inward confinement force attains its maximum value while remaining bounded by the universal pressure limit c^4. Because the pressure at the Qc surface and at the neutron boundary is governed by the same limiting value, the neutron confinement force follows deterministically from geometric scaling of surface areas. Equating the pressure at the Qc level to that at the neutron surface yields a neutron strong force of order Fn $\approx 10^5$ newton very much within acceptable limits. This scale lies within the experimentally accepted neutron radius range and therefore represents the physically relevant configuration for evaluating neutron stability and strong-force magnitude. For larger radii, the confinement force decreases, whereas further compression below this scale is restricted by the pressure bound c^4.

3.4 Neutron Radius and Maximum Confinement:

The analysis indicates that the neutron reaches maximum confinement at an effective radius of approximately 1.0 fm. At this radius, the inward confinement force attains its maximum value while remaining consistent with the universal pressure bound c^4. This scale lies within the experimentally accepted neutron radius range and therefore represents the physically relevant configuration for evaluating neutron stability and strong-force magnitude. For larger radii, the confinement force decreases, whereas further compression below this scale is restricted by the pressure limit c^4.

3.5 Scope of the Present Work:

The analysis has been intentionally restricted to a classical and deterministic framework. Quantum chromodynamics, Yukawa-type force ranges, and probabilistic field descriptions have not been employed. The results therefore do not seek to replace existing quantum treatments, but to demonstrate that essential features of neutron confinement can be obtained from elementary electrostatics, geometry, and a universal pressure limit. In this sense, the present approach may offer a complementary classical foundation that could inform or motivate further investigations within quantum and semi-classical frameworks.

3.6 Concluding Remarks:

The results show that neutron stability can be understood as a consequence of exact mechanical equilibrium between internal Coulomb confinement and a universal vacuum pressure bound. The same limit governs both Qc-scale and neutron-scale forces, providing a coherent and internally consistent classical picture. This pressure-based formulation offers a simple foundation for further analytical studies of confinement and nuclear-scale forces within the VTI framework.

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