Elementary Particles, Atomic Nuclei, and Strong Interactions:

The Application of the Geometry of Space-Time Structures at Extremely Small Spatial Scale

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Abstract

Based on the Geometry of Space-Time Structures founded by the author himself, this paper demonstrates the physical nature of the integration of time, space, matter at the extremely small spatial scale, and the natural essence of strong interactions between particles; proves that proton p^+ and electron e^- are the most fundamental particles of matter in the natural world; reveals the material structure and creative logic of neutrons and atomic nuclei; establish precise mathematical relationships between neutron and atomic nucleus structures and discrete space fractional dimensions; reveals various new quantum state structures of pep quantum pairs formed by adjacent protons in atomic nuclei and their relationships with natural number sets, etc.

Preface

The author of this paper devoted his entire life to the creation and improvement of the Geometry of Space-Time Structures, which can intuitively, concisely, and accurately describe and characterize the basic laws of motion and change in nature [1-5]. This paper is a partial application of the Geometry of Space-Time Structures at the extremely small space-time scale, mainly to demonstrate the most fundamental construction problems of natural space-time space and natural matter, i.e., the essential properties of electrons e^- and protons P^+ as elementary particles, the structures of neutrons, atomic nuclei and other instantaneous composite particles, and the strong interaction between elementary particles inside composite particles, etc.

1. Natural Space-Time Space and Its Geometric Characteristics at Extremely Small Scale [1,2,5]

The definition of natural space-time space [1-2] is the real space of nature, which is mathematically represented as a quasi-4-dimensional space consisting of a stationary 3D natural space and a quasi 1D time dimension, with coordinates in the form of (x, y, z, ict) or abbreviated as (r, ict). Time t passes unidirectionally at the speed of light c, and only acts on any point in the 3-dimensional natural space at the present moment (for the same observer). There is no independent time space, and the time dimension is "virtual".

The Geometry of Space-Time Structures is a motion geometry based on natural space-time space, which dynamically reveals and characterizes the motion change law of natural matter. The basic assumptions of the Geometry of the Space-Time Structures include [1,2,5]:

① Time, space, and matter are integrated forms of energy motion and they all have their own smallest quantization units， the speed of light is the largest and unchanged, the time quantum is exactly the light quantum, time is the main variable, and the structure, form, and motion state of any object in natural space-time are all existence forms of material energy. The existence forms of material energy are diverse and can be converted into each other while maintaining energy conservation.

② There is the relativistic momentum mass energy relationship for free particle states: $E^2 = (Pc)^2 + (m_0c^2)^2$, where E is the total energy of the free particle, P is the momentum of the particle, and m_0 is the stationary mass of the particle. This is precisely the invariance relationship of the momentum energy interval (distance) of free particles in the momentum energy coordinate system (P, iE/c) corresponding to the spacetime coordinate system (r, ict).

③ The points in natural space-time space, or any structure composed of points, are open sets containing certain physical properties, with sizes but no absolute lines or planes. Length, surface area, morphological structure and the spatial volume it encompasses, are all measures and expressions of material energy. In a broad sense, the distance S in quasi-4-dimensional natural space-time space is determined by the integral of the differential element dS as defined below

$$dS^2 = n_x^2dx^2 + n_y^2dy^2 + n_z^2dz^2 - c^2dt^2 = dr^2 - c^2dt^2 \qquad (1)$$

where, n (x, y, z) represents the generalized refractive index tensor of the spatial medium. When dt=0, equation (1) becomes the optical path differential of 3D natural space at equal time.

In a very small natural space-time, if the space is isotropic and near vacuum, n (x, y, z) =1, then the quasi-4-dimensional space-time coordinate system in the region is a uniform unit orthogonal coordinate system, the distance S between any two points (r_1, ict_1) and (r_2, ict_2) is simplified as,

$$S^2 = (r_2 - r_1)^2 - c^2(t_2 - t_1)^2 = \Delta r^2 - c^2\Delta t^2 \qquad (2)$$

If (r_1, ict_1) is the coordinate origin O (0,0), then equation (2) becomes a hyperbolic form.

At the microscopic scale of atoms and molecules, $\Delta r^2 \ll c^2\Delta t^2$, $\Delta r \approx 0$, $\Delta S^2 \approx -c^2\Delta t^2$, the photothermal effects are dominant, the positions of atoms and molecules cannot be precisely determined, exhibiting random fluctuations in 3D space.

At the extremely small particle scale, time, space, and matter tend to be integrated, the motion state of particles is completely matched with the effect of time， and the quasi-4-dimensional space-time space approximates Minkowski space, then $S^2 = r^2 - c^2t^2 = (ict_0)^2 = -c^2t_0^2$ and $P^2 - E^2/c^2 = (iE_0/c)^2 = -c^2m_0^2$ equations hold and dominate the space-time state of particles. In the equation, ict_0 and iE_0/c ($E_0 = m_0c^2$) are respectively the coordinates of the imaginary axis of the hyperbola vertex in the coordinate system (r, ict) and (P, iE/c). The equivalence of the distance relationship between the (r, ict) coordinate system and the corresponding (P, iE/c) coordinate system can be proved simply: for example, $(0, ict_0)$ and (r, ict) represent the static and other arbitrary state of the electron e^- respectively, v=r/t is the electron velocity, then there is, $r^2 - c^2t^2 = t^2(v^2 - c^2) = -c^2t_0^2$, $t^2m_e^2(v^2 - c^2)/t_0^2 = -c^2m_e^2$, due to $t = t_0/\sqrt{1 - v^2/c^2}$, so, $P^2 - E^2/c^2 = -c^2m_e^2$. Let $r_0 = ct_0$, where r_0 can be considered as the spatial scale of stable particles at static state. By measuring the space-time coordinates of a stable particle, its space-time hyperbola can be plotted, and the coordinate $(0, ict_0)$ of the hyperbola vertex can be estimated, then the spatial size of the particle at static state can be obtained. This actually gives an experimental way to find the size of a stable particle (e^-or p^+).

In the extremely small space-time space of $\Delta r \to 0$ and $\Delta t \to 0$, $\Delta S^2 \to 0$， time, space, and matter are integrated(this can be understood that in this limit small space-time, the energy change ΔE, mass change Δm, spatial size ΔV and corresponding time variable Δt of any particle have a definite correspondence with each other). The interaction between particles is close to zero distance, and its transmission speed is close to the light speed c, which belongs to the strong correlation relationship. Any composite particle is an independent space-time quantum (including instantaneous states), with compact and discrete properties. This establishes the simple geometric construction logic of any stable composite particle in the extremely small space-time: the unity of time, space, and matter within oneself; the composite particles are independent of each other and can produce zero-distance strong interactions; the elementary particles (construction units) inside a composite particle have the same status and indistinguishable identical equivalence from each other； the interaction between elementary particles is random, zero distance, close proximity, strong interaction; the internal structure morphology of the composite particles is determined by the number of elementary particles and the structural dimension D (fraction) [1,2].

The origin (0,0) of the coordinate system on the extreme small-scale is an empty state, the intersection point of any particle's hyperbola and imaginary axis is the static state of the particle (which can be considered as the initial state). Except for the stable proton P^+ and electron e^-, the space-time states of other particles, or points on the hyperbola, are all near the origin. The distance between any meaningful points in the coordinate system corresponds to the neighboring material interaction between the two points, that is, the static mass energy variation $\mathbf{c\Delta m_0^2}$ or the static scale variation $\mathbf{c\Delta t_0}$. So, the geometric points and curve shapes of the quasi-4-dimensional coordinate system on the extreme small-scale, only describe and characterize the energy levels of particles, the energy levels of arbitrary neighborhood interaction between particles, and the characteristic quantities of the space-time quanta of corresponding energy levels, but not the structural form or motion trajectory.

2. Strong Interaction, Elementary Particle Properties of Electron e^- and Proton P^+

The interactions between natural objects are scale dependent, with inertial gravity at the celestial scale, electromagnetic interaction at the atomic and molecular scale, and strong interaction at the particle and atomic nucleus scale.

The strong interaction between particles or within atomic nuclei is the interaction that causes a change of inertial mass, and is independent of charge and spin; its magnitude is the variation in mass energy, i.e. Δmc^2 . This indicates that at the scale of particles or atomic nuclei, the electromagnetic energy of charge is equivalent to inertial mass energy. The mass energy of positive or negative electron ($\text{i.e.}, m_e c^2$), is the electromagnetic energy of $\pm e$ charge. Therefore, the mutual conversion between electrons and gamma photons naturally exists, i.e. $(e^-, e^+) \rightleftharpoons (\gamma, \gamma)$. As long as the photon energy level $h\nu \geqslant m_e c^2$, it is possible to convert into positive and negative electron pairs; conversely, when positive and negative electrons meet, they annihilate and transform into gamma photons.This equivalence between electromagnetic energy and inertial mass energy also means that electromagnetic action and inertial mass gravity are essentially the same.

Just as photons are the medium of electromagnetic interactions between atoms or molecules, electrons $\mathbf{e}^-$ are the medium of strong interactions between protons p^+ in atomic nuclei, any neighboring protons in the nucleus form a strongly attractive $p^+e^-p^+$ structural unit by exchanging a electron. A neutron is a composite particle of a proton p^+ and an electron $\mathbf{e}^-$, with a static mass greater than the sum of p^+ and $\mathbf{e}^-$, so it is impossible for neutrons with higher energy levels than protons to exist in the nucleus. There are only protons p^+ and electrons $\mathbf{e}^-$ in the nucleus, and there is the ($\mathbf{p^+e^-p^+}$) attractive structure between nucleons. Therefore, there is no spin or energy non-conservation problem in the β decay of the nucleus, and the mass energy of the nucleus also changes before and after β decay, so β decay is a strong interaction process [1,2]. Therefore, electromagnetic interaction, strong interaction, and the so-called "weak interaction" are essentially unified.

Geometrically, the interaction between two objects is characterized by changes of their geometric states (energy states, including their own energy fields). Compared to the free state of a single isolated object, when there is a two-object situation, the superposition and coincidence of the energy states of the two objects represents the attractive effect, while the separation and change of the energy states of the objects without superposition and coincidence represents repulsive effect. So, in the sense of geometry or matter energy, all the interactions in nature are completely unified. Particle and antiparticle, with completely antisymmetric states, can completely overlap and cancel each other, and generate a self-annihilation phase transition, in which the original form of the particles disappears, and the energy is completely converted into two-photon [1,2,5].

The definition of the elementary particle is the smallest and most stable quantum of matter that constitutes the natural world, and its inherent physical properties, mass, charge, spin, are all the smallest and most basic quantum units of corresponding physical properties. The only elementary particles are protons and electrons, the quantum units of mass are m_p and m_e, the quantum units of charge are e^+ and e^-, and the spin quantum unit is $\hbar$. The charge has mass, and the electron is a pure charge quantum unit. The proton is the most fundamental mass quantum unit with a single charge. In addition, the charge of a proton cannot be separated from the proton, it is inherent to a proton. There are no elementary particles with zero charge, because if elementary particles have only mass properties, in the extremely small spacetime space of $\Delta r \to 0$, $\Delta t \to 0$, they cannot overlap and coincide at zero distance with exactly the same state structure, and form strong interactions by exchanging material energy. It is only possible with positive and negative charges.

The nucleus is a inertia center with positive charge, since particles and antiparticles will annihilate when they meet, so the nucleus must be a $(p^+e^-p^+)$ combination structure of p+ protons with e− electrons as the bonding exchange medium. The instantaneous states of relatively light composite particles, such as μ muons, π mesons, K mesons, etc., are all composed of $\mathbf{e^-}$ and $\mathbf{e^+}$ with the combination structure forms such as $(\mathbf{e^-e^+e^-})$, $(\mathbf{e^+e^-e^+})$, or $\sum(e^-, e^+)$, $e^{\mp}\sum(e^-, e^+)$[2].

Thus, p^+ protons and e^- electrons, as the elementary particles that construct nature, are perfectly selected by nature. Only with yin and yang can there be endless changes, and only with incomplete anti-symmetry can there be no annihilation. There are no independent and stable positrons $e^+$and negative protons p^-in nature, they are by definition not true elementary particles, but rather like inverted ghosts that flash in the phase transition of particle energy states.

3. The Structure and Energy Levels of Neutrons and Nuclides, and Calculation of The Nucleon Binding Energy [1,2]

3.1 The relevant relationships determined in the Geometry of Space-Time Structure [1-4]

① The integrated relationship of space, time, and matter. Time and space are all objective forms of matter, and the ordered variables and places for representing energy and objects. At the extremely small fm scale, experimental observations or manifestations of the size of space and time must be based on physical particles; the extremely small quanta of space and time that can be perceived correspond to specific material quantities(quanta); Δr, Δt, Δm, and ΔE reflect the same physical property, all being energy quantum states, so there must be, $\Delta E = \Delta mc^2 \sim h/\Delta t = hc/\Delta r$ and $\Delta r = c\Delta t \sim h/\Delta mc$, this is precisely the strong interaction energy level, and the instantaneous change quantum states are characterized by the electron's inertial mass m_e, Planck's constant h, and the speed of light c as the characteristic measurement constants. The stable small spatial limit scale that humans can truly observe is 10^{-10}m, the particle state and structure at the 10^{-15}m limit small spatial scale can only be "speculated"; and the speed of changes in particle state and structure is almost synchronized with time (the speed of light), their shapes are no longer determinate or important. Therefore, "topological logic" becomes meaningful.

② Each particle is an open-set quantum dot in discrete space, with a size and compact convergence; in discrete space, different particles have different energy levels, but share the same material properties; therefore, the interaction between any two high-energy limit small particles must be a direct contact, zero-distance, and adjacent strong material interaction, and either they will merge into one new particle, or they will recombine and decompose into multiple new particles. The strong interaction between elementary particles within composite particles is also like this, except that the elementary particles themselves cannot be further decomposed.

③ Stable composite particles, except neutrons, are primarily nuclides ${}^{A}_{Z}X$. Within the atomic nucleus, neighboring protons randomly pair and form instantaneous $p^+e^-p^+$ quanta by exchanging high-energy electrons, and then form a tightly bound and strongly attractive structure of the nucleus. The protons within the nucleus have equal status, are completely equivalent, and cannot be distinguished from one another. This strongly correlated structure of protons is a dynamic, boundary-less, holographic equivalent structure (can be referred to as a dynamic fully symmetric structure), any single pep quantum pair of nuclides has same energy level unit, i.e., m_ec^2. Due to the random nearest-neighbor equivalent commutativity of pep quantum pairs, the quantum units within the nucleus, primarily pep quantum pairs, inevitably possess angular momentum quanta—spin quanta, which also have the same energy level unit m_ec^2. In comparison, the spin energy levels of particles can be neglected. The inertial mass of protons and the high-energy spin of discrete quanta are necessary conditions for maintaining a stable and tightly bound structure.

④ The generation of atomic nuclei is a process of the 0→1 creation of natural space-time and the natural world; in terms of mathematical logic, it is the 0→1 creation from the arithmetic algebraic point set to the minimum geometric space structure, and it is the "natural transition" from the unordered combination of algebraic point sets to multidimensional ordered geometric structures, where the state quantity transitions from arithmetic statistical operations to exponential (based on the natural constant e) and matrix operations. The 0→1 creation of the spatiotemporal structure of each atomic nucleus, in which the form and process are uncertain, but energy is conserved. For each atomic nucleus ${}^{A}_{Z}X$, the number of protons A, positive charges Z, or electrons A-Z are fixed, and the binding energy and the fractional dimension D of the random combination structure of neighboring pep quantum pairs are fixed. According to the rule of the integration of space, time and matter, the structural dimension D of the atomic nucleus and the nucleon binding energy ε are completely determined by A and Z(and due to the pep pair relationship of a structure unit, A≈ 2Z+). Similarly, the nucleon binding energy ε and the structural fractional dimension D must have a one-to-one correspondence, and the relationship is ,

$$\varepsilon = \frac{1}{2} e^{D} \varepsilon_{pep} = -\frac{1}{2} e^{D} (2+\Delta_J)\, m_ec^2 \qquad (3)$$

where, e^D is the number of nearest neighbors for each proton p in the atomic nucleus structure, i.e., the pep quantum pair number, m_ec^2 is the electronic matter energy, Δ_J is the spin quantum number for each pep pair, and $\varepsilon_{pep}=-(2+\Delta_J)m_ec^2$ is the energy level of each pep quantum pair (which is exactly 1/2 of the energy level of ${}^{2}_{1}H$, approximately $-2.176m_ec^2$=-1.112 Mev). When A ≤20, $\Delta_J \approx 0.176$; when A is sufficiently large, the number of nearest neighbors of a proton no longer changes with the increase of A and Z, and the nucleon structure inside the nucleus tends to be stable, then, $\Delta_J \rightarrow 0$.

⑤ Constructing fractal factor for the fractional dimension D within a unit sphere; the relationship between the structural dimension D=3 and the regular icosahedron.

In the $0 \rightarrow 1$ creation process of atomic nuclei, the shape is uncertain, but the fractional dimension D is determined. Geometrically speaking, the $0 \rightarrow 1$ creation of the space-time structure of an atomic nucleus is the creation of a structural unit with a fractional dimension D. Each fractional dimension D corresponds to a fractal structure and a fractal factor. The fractal factor is defined as the fractal unit at the lowest level within the fractal structure of dimension D. Fractal factors of the same dimension D are divided into two types: centrosymmetric and non-centrosymmetric. It can be assumed that the pep quantum pair formed by two neighboring protons is a line connecting a point on the surface of a unit sphere to the center of the sphere (i.e.,unit radius line). The N_J neighboring pep quantum pairs of a proton can be regarded as the lines connecting N_J arbitrarily distributed points on the sphere to the sphere's center o (of course, a centrosymmetric distribution can be chosen). This combination of unit radius lines in the unit sphere is the centrosymmetric fractal factor of the fractional dimension D, and $N_J = e^D$， $D = \ln N_J$. For example, the lines connecting o1, o2, and o3 in Figure 1 represent the three pep neighboring quantum pairs of point o. The fractal factor is the geometric representation of the fractional dimension D. For a complete 3D space unit, D=3, and N_J=20.0855. If a unit radius line in the unit sphere corresponding to a pep quantum pair represents a triangular pyramid, then the regular icosahedron is an ideal fractal factor for a compact space structure with dimension D=3.

⑥ Unit sphere solid angle, Gauss Bonnet theorem [9], and their relationship with spatial structure dimension D.

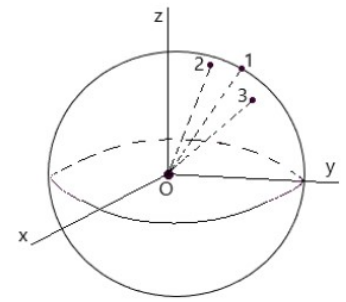

Figure 1 单位球，球心O和球面上点1,2,3连接成三棱锥立体角
Unit sphere, a solid angle of the triangular pyramid formed by the center O and points 1, 2, and 3 on the sphere

As shown in Figure 1, three points 1, 2, and 3 on a unit sphere can form a spherical triangle Δ 123, the line connecting them to the center o of the sphere forms a triangular pyramid with o as its vertex, and corresponds to a solid angle Ω with the center o of the sphere as its vertex. There is,

$$\Omega = \iint_s d\Omega = \iint_{\Delta 123} \frac{dS}{R^2} = \iint_{\Delta 123} \kappa^2 \, dS = \iint_{\Delta 123} dS = S_{\Delta 123} = \angle 1 + \angle 2 + \angle 3 - \pi \quad (4)$$

Where, R is the radius of the surface, κ=1/R is the curvature of the surface, and the unit sphere's R and κ are both 1, the final step uses the Spherical Excess Formula. The solid angle corresponding to the entire sphere is 4π. The Gauss-Bonnet theorem gives the relationship between the Gaussian curvature K on any closed smooth surface S and the Euler Characteristic χ (s) and genus g of the surface S, that is, $\oiint K\,dS = 2\pi\chi(s) = 4\pi(1-g)$. For the $0 \rightarrow 1$ creation of the space-time structure at the scale of $\Delta r \rightarrow 0$ and $\Delta t \rightarrow 0$, the compact convex surface g=0, the surface shape is not important or topologically equivalent, and can be a unit sphere, the principal curvature κ and Gaussian curvature $K = \kappa^2$ are both 1, then $\oiint K\,dS = \oiint dS = 4\pi$. The surface integral of Gaussian curvature is the solid angle Ω of surface S. In compact discrete spaces, surface calculus is meaningless, Gauss-Bonnet theorem is not applicable to analyzing the strong interaction structure of atomic nuclei in extreme small space. The solid angle dΩ is essentially the sin θ * d θ * d φ of the polar coordinate system (r, θ, φ), and is a continuous 2D variable. The continuously differentiable solid angle cannot be used to characterize the structure and fractional dimension of strongly interacting space-time with discreteness, but it can describe the electronic space-time state within composite particles.

3.2 The structure, energy level, and lifetime of the neutron

The neutron is composed of a proton and a high-energy electron, and its energy level is higher than that of a proton by $\Delta\mathcal{E} = m_n\text{-}m_p\text{=}1.2933\text{Mev}/c^2\text{=}2.531m_e$. The neutron and ${}^4_2H_e$ are the most important composite particles. The high energy level $\Delta\mathcal{E}$ and decay period τ of the neutron are important space-time matter parameters. The structural relationship between neutrons, protons, and electrons, as shown in Figure 2, the mass centers and the positive and negative charge centers of protons and electrons completely coincide, resulting in the disappearance of their electronegativity and zero charge, the electron is constrained by a centrally symmetric high-energy potential barrier, while the proton is wrapped around the center of the space-time structure.

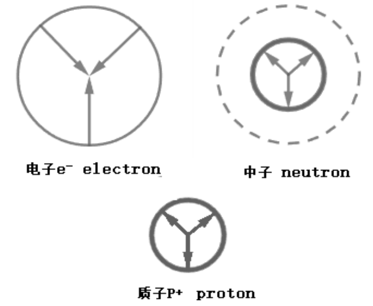

Figure 2 电子e⁻、质子P+、中子n的结构示意图
Schematic diagrams of the structures of electron e+, proton P+, and neutron n .

At a high energy level of $+2.531\ m_e c^2$, the neutron n is destined to have a short lifespan, with an experimental result of 877.75 seconds in 2021 [7]. In 2022, Yixing D.Z. from China discovered that the neutron decay period τ can be obtained entirely using physical constants according to the following formula [12], with a calculated result of 879 seconds:

$$\tau = \frac{\pi h}{(m_n\text{-}m_p)\,c^2}\,\frac{m_p}{m_e}\sqrt{\frac{e^2}{4\pi\varepsilon_0 G m_p m_e}} = \frac{h}{(m_n\text{-}m_p)\,c^2}\,\frac{\pi e}{m_e}\sqrt{\frac{1}{4\pi\varepsilon_0 G}}\sqrt{\frac{m_p}{m_e}} \qquad (5)$$

Such a simple and elegant formula is in line with the theoretical logic of expressing natural laws intuitively and concisely in the Geometry of Space-Time Structures. The equation simply unifies the so-called four natural forces into one algebraic formula. The neutron decay period is obviously inversely proportional to its high energy level, directly proportional to the charge mass ratio of a electron (because the electron with high-speed moving is strongly influenced by the positive charge of the proton; including π and a dimensionless correction), and the square root of the mass ratio ($\sqrt{m_p/m_e}$) contributed by the secondary effect of universal gravity .

The interaction between the proton and the electron in a neutron is a strong matter interaction, because of the integration of material properties such as charge, mass, and space, it can be concluded that the high energy level of $+2.531\ m_e c^2$ of a neutron is entirely contributed by high-speed moving electron. According to the previous sections ⑤and⑥, the electronic space-time structure state set of a neutron is equivalent to a unit sphere, with one sphericity as one electronic state unit, so the number of motion states of the electron is exactly the solid angle of the unit sphere, which is 4 π . Therefore, the degree of freedom D (i.e. space-time structure dimension) of the electron is $D=\ln 4\pi=2.531$, which means that the material energy of the electron in a neutron is $+2.531m_e c^2$, including motion energy $1.531m_e c^2$.

3.3 The structures and the nucleon binding energy of nuclides

The nucleons inside the atomic nucleus are all protons p^+, and neighboring protons are strongly attracted to each other by exchanging high-energy electrons e^-, forming a multidimensional dynamic fully symmetrical structure with ($p^+e^-p^+$) as the basic repeating structural unit, as shown in Figure 3 [2]. Protons in atomic nuclei cannot be distinguished from each other, and there is no distinction between inside and outside. This nucleon space-time structure, constructed by the zero distance neighboring strong interaction of protons with equal positions, is a compact fractal structure with a structural

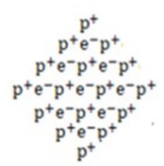

Figure 3 核内多维度$p^+e^-p^+$链示意图
Schematic diagram of multidimensional $p^+e^-p^+$ chains within the nucleus

dimension D of fraction.

In the 3D space sense, the four protons and two electrons in ${}^{4}_{2}H_e$ can be randomly combined into two $p^+e^-p^+$ pairs, and four protons are fully enveloped by the space-time structure of electrons, densely packed into a highly symmetric regular tetrahedron structure where each proton and electron is completely equivalent. When A>4, any four neighboring nucleons in the atomic nucleus have this regular tetrahedron structure relationship; the newly added proton can tightly stack with any of the three neighboring protons (regular triangle) in nucleus A to form a new regular tetrahedron structure; therefore, when A>4, each proton represents one polyhedral vertex and one regular tetrahedron unit. In this way, the 3D space structure of large nuclides is related to the fractal factor structure and corresponding characteristics of regular icosahedra described in section ⑤ above. But it should be noted that the dense packing in 3D space is rigid, with a fixed and integer number of neighbors, while the space-time structure of atomic nuclei is a spatiotemporal topological structure that maintains A, Z, and volume (physical energy) unchanged. Obviously, when A is an even number or a multiple of 4, the nuclide is more stable.

The volume of a regular icosahedron is 18.51 times that of a regular tetrahedron with the same side length. If a regular icosahedron represents a fractal factor of center symmetry with a dimension of D=3, and the 20 regular pyramids with its center O as the vertex represent 20 protons in the nucleus, then the proton at the center O has a maximum of 20 neighboring protons. According to the topological invariance of matter energy, for the same size, with a regular tetrahedron as the structural unit (representing one proton), the proton at the center O can only have a maximum of 18.51 nearest neighbor protons. This means that there exists a multi-level self similarity relationship within the atomic nucleus of Big A, characterized by a maximum of 18. A ≤ 20, when A=4, only one regular tetrahedron unit is formed, then each proton added after A>4 can represent one regular tetrahedron unit. For atomic nuclei with A ≥ 56, there exists a third–level correlation with a combination of approximately 20 (I)+18 (II)+18 (III): each proton in the first level is directly strongly correlated with no more than 16 neighboring protons (level I); At the same time, these 16 neighboring protons (level I) have the same correlation with other level II protons, which is a secondary correction for level I strong correlation (approximately 1/18-1/20); there is a similar relationship between level II protons and level III protons (which may also be level I protons), which is a secondary after secondary correction to the strong correlation of level I (approximately $1/18^2$-$1/20^2$). So, the binding energy of ${}^{56}_{26}F_e$ is the highest. Combining fully symmetrical topological structures with regular tetrahedron as a unit, the maximum structural dimension D is ln18.51 ≈ 2.92. Due to the stronger repulsion between positive charges in nuclides with larger A values, the D value of nuclides is less than 2.9. This proton dynamic equal position neighbor correlation relationship, also exists in the brain nervous system.

The structure of atomic nucleus ${}^{2}_{1}H$ is a pep quantum pair state. There are two equivalent states p_1ep_2 and p_2ep_1 of the pep quantum pair in the structure of ${}^{2}_{1}H$. As shown in the left figure of Figure 4, two tightly bound protons can occupy any equivalent state inside their circumscribed sphere. The volume of the circumscribed sphere is four times of the pep pair, that means ${}^{2}_{1}H$ has four equivalent states including p1ep2 and p2ep1, each state exchanges one electron, four equivalent states contribute $-4\,m_ec^2$ to the binding energy; In addition, it should include as many as possible angular spin quantum states of odd combinations of the same kind quantum (the sum of the quantum numbers of an even number of angular spin quanta is 0), that is, ${}^{2}_{1}H$ should includes possible

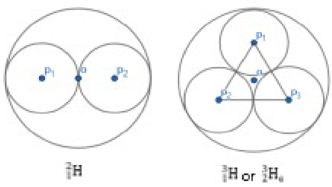

Figure 4 ${}^{2}_{1}H$, ${}^{3}_{1}H$ or ${}^{3}_{2}H_e$ 核子时空示意
Spacetime diagram of ${}^{2}_{1}H$, ${}^{3}_{1}H$ or ${}^{3}_{2}H_e$

angular spin quantum states composed of at least 3 and 5 units, contributing -2 × (1/3!+1/5!) $m_e c^2$=-2 × 0.175 $m_e c^2$. Therefore, the total binding energy of ^2_1H is approximately -4.35 $m_e c^2$, and the binding energy of one proton is approximately -2.175$m_e c^2$; the conventional value is approximately -2.176$m_e c^2$. This is also the binding energy of one pep quantum pair in the nuclide structure, the average value for one proton is of -1.088 $m_e c^2$ (excluding ^2_1H). The volume ratio of a regular icosahedron to a regular tetrahedron is 18.51, and the equivalent ratio of the number of pyramids (pep) for the two structures is 20.0855/18.51=1.085.

The structures of ^3_1H and $^3_2H_e$ are almost identical. As shown in the right figure of Figure 4, the circumscribed sphere of the tightly bound three protons are $(1+2\sqrt{3}/3)^3 * 1/3$ times their volume, and the triangle composed of every 3 adjacent protons, including 3 pep equivalent states (contributing -3$m_e c^2$), and one definite angular spin quantum state (-1$m_e c^2$), and possible indefinite angular spin quantum states (-0.175 $m_e c^2$). So the total binding energy of ^3_1H or $^3_2H_e$ is approximately $-4.175 * (1+2\sqrt{3}/3)^3 * 1/3\, m_e c^2 \approx$ -13.92 $m_e c^2$, then the binding energy of one proton is about -13.92$m_e c^2$/3= -4.64$m_e c^2$.The conventional values of ^3_1H and $^3_2H_e$ are -4.58$m_e c^2$ and -4.59$m_e c^2$, respectively. (When A>2, the nucleon binding energy should be calculated based on the mass of a proton and an electron, and its conventional formula should be: $\varepsilon=[M-Am_p-Am_e]c^2/A$, where M is the mass of the corresponding atom of the nuclide.)

Helium $^4_2H_e$, similar to a highly symmetrical regular tetrahedron structure, has a nucleon binding energy of approximately 12 * 1.088 ≈ 13.06 , (2 * 6=3 * 4). The conventional value is about 13.14.

When $A \leq 20$, the binding energy can be calculated using (3), which is the product of the number C_p (i.e., e^D) of the pep quantum pairs of one proton, multiplied by 1.088,i.e., 1.088$e^D m_e c^2$. The A protons of nuclide ^A_ZX can form many polyhedrons with A vertices, take the weighted average of the nearest neighbors of each vertex of all these polyhedrons as C_p, and the formula is:

$$C_p=e^D = \sum_i \sum_j (A_{ij} m_{ij}) / \sum_i \sum_j m_{ij} \qquad (6)$$

where, A_{ij} and m_{ij} are respectively the number of neighbors and the number of vertices with the same number of neighbors of the jth vertex in the i-th combination of A vertex convex polyhedron structures [1].

If A > 56, the number of nearest neighbors of protons, reaches its maximum value and no longer increases with the increase of Z and A values, but the repulsive effect of the increased ΔZ positive charge on protons becomes apparent and increases uniformly with the element number Z value. κ is used to represent the positive constant of the binding energy decreasing linearly with Z, so the binding energy ε of large Z nuclide should be,

$$\varepsilon = - e^D m_e c^2 + \kappa Z \qquad (7)$$

A≥200, the structural dimension D of non artificially synthesized nuclides tends to e, i.e., $D \rightarrow e$, then the nucleon binding energy ε tends to $- e^e m_e c^2 = -7.74$mev.

Traditional physics theory suggests that strong attraction occurs between nucleons through the exchange of π mesons (energy levels>130 Mev), which have energy levels much higher than the highest level of strong interaction between nucleons in nuclides, which is 8 Mev, and there are no stable π particles present, which is clearly incorrect.

4. **Summary and Discussion**

This paper mainly using the Geometry of Space-Time Structures established by the author, demonstrates the construction logic of natural matter at the extremely small space-time scale, focusing on the elementary particle properties of protons and electrons, the strong interaction between particles, and the space-time structure of atomic nuclei.

In this paper, we demonstrate that the size of elementary particle can be determined by the vertex ict_0 of its hyperbola in the space-time coordinate system (r, ict), i.e., using the relationship $r^2 - c^2t^2 = t^2(v^2 - c^2) =- c^2t_0^2 =- r_0^2$, let r_0, as the spatial size of protons p^+ or electrons e^-. The key point of the experiment is to determine at least one precise space-time coordinate value (r, ict). When the particle velocity v approaches the speed of light c, the coordinates (r, ict) are independent of observers. The velocity v (entering the cloud chamber, obtained from momentum) of proton p^+ can be measured using methods such as cloud chamber. The moment Δt_1 of primary collision reaction of the proton in the cloud chamber can be approximated as the time point of the proton in the (r, ict) coordinate system, i.e. t $\approx \Delta t_1$, the corresponding $r = vt \approx v\Delta t_1$, then we can obtain, $r_0 = ct_0 \approx \Delta t_1\sqrt{c^2 - v^2} = c\Delta t_1/\gamma$.

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