The Mechanism of Nuclear Fusion

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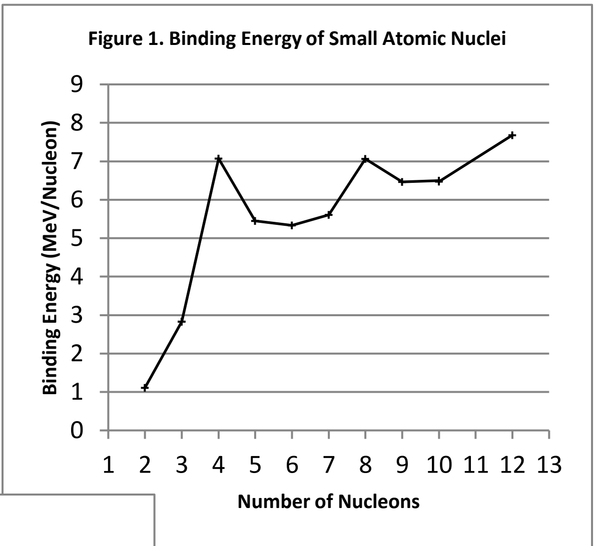
Abstract

Nuclear binding energy is the best measured property of the atomic nucleus, but no previous model of the nucleus has accurately explained the experimental data for small nuclei. Current models either get the general shape of the curve right but the magnitudes wrong, or get closer to the magnitudes but deviate from the shape of the curve. We derive a new model of the binding energies of atomic nuclei largely free of these defects. Plausible internal structures of protons and neutrons deduced from their known properties lead to a natural physical interpretation of the mass defect. The structures of quarks internal to the particles determine two types of binding energy. These combine with electromagnetic forces to duplicate the binding energy of 12 isotopes from deuterium through carbon with correlation 0.999. Average absolute difference between the model and experimental data is 1.43%, compared with the next closest model at 10.95%.

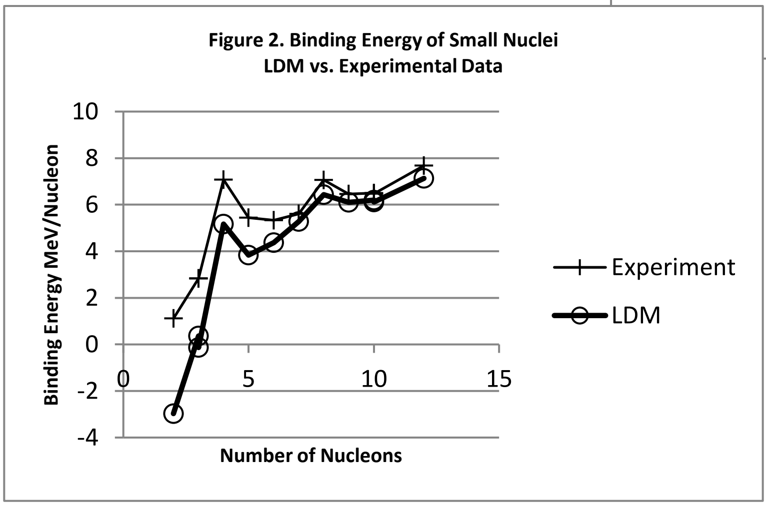
Keywords: The New Physics, nuclear structure, nuclear binding energy, nuclear physics, nuclear fusion

1. Introduction

The binding energies of all isotopes are well known, but they exhibit a puzzling property most marked in the smaller nuclei: one might expect that as nucleons are added to the nucleus, the amount of binding energy would increase monotonically with each additional nucleon. This is not the case: Figure 1 charts the experimental values for the binding energies of 12 isotopes, expressed as the amount of binding energy per nucleon. The values rise and then fall off, only to rise again. The cause of this variation has been the subject of extensive debate for decades.

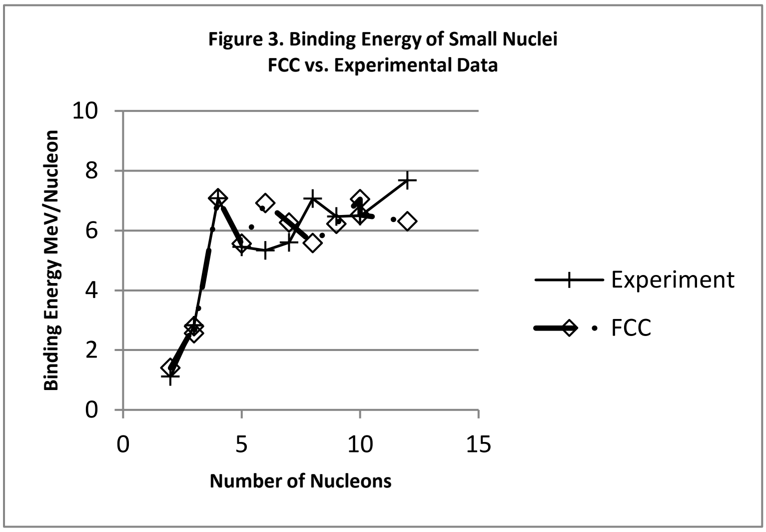


Three theories have tried to explain the shape of Figure 1 [1]. These are the Independent Particle Model (IPM), the Liquid Drop Model (LDM) and the Face Centered Cubic Lattice Model (FCC).



Mainstream nuclear theory *is* the Independent Particle Model, developed in the 1940's and formalized by Meyer & Jensen [2]. It attempts to explain Figure 1 by trying to explain the peaks. According to IPM these arise from the nucleons filling shells within the nucleus, similar to the filling of quantum shells by electrons. IPM can say nothing quantitative about binding energy, so it need not concern us further in this context.

The Liquid Drop Model derives properties of the nucleus from analogy to a drop of liquid. The model has been refined over 80 years, resulting in a match to the experimental data shown in Figure 2. (Data for Figure 2 are conveniently supplied by the NVS program of [1], republished there from public databases.)



As you can see, LDM shows an uncanny ability to match the shape of the experimental data, but the absolute error is relatively large, with an average absolute deviation from the experimental points of 55.918%. Correlation is quite respectable at 0.981.

The Face Centered Cubic model was proposed by Cook in 1976 [3]. This model views the nucleons as bound in a face-centered-cubic lattice. The binding energies of the FCC model are shown plotted with the experimental data in Figure 3 (data again supplied by NVS [1].) FCC is a much better fit to the data than LDM, with average absolute deviation of 10.949%. Correlation however suffers, falling to 0.915.

2. **The New Physics**

The New Physics (TNP) arose from an attempt to understand the cause of gravitation [4, 5]. TNP observes that the natural size of each quantum level—the square of the integer quantum level times the radius of the first one—is a “home position” for the quantum level. When combined with the same quantum level of a second particle, they form a single quantum at the same level that naturally attempts to restore to its home position. Gravitation is the result of the cumulative restoring forces of the quantum levels merging between all the particles of both bodies. The inverse square law ensues.

The hypothesis of TNP is that when a particle is created, most of the energy in its creation goes into making a bubble in space, compressing the space outward that used to be where the particle now exists. This is analogous to placing a ball bearing into a block of foam. When a particle is created it pushes space back, cocking it like a spring. The restoring force of this spring is what has in previous models like the IPM and its derivatives been called the Strong Force. (If the idea of a bubble in space remains after due consideration incomprehensible, imagine instead a spherical balloon of very thin material.)

What, then, can we say about this bubble in space that we call a proton? For one thing we know it is mostly hollow. When a proton disintegrates in a collision with another particle, the only things that emerge are three quarks having together only 1% of the energy of the proton. Where does the other 99% of the formation energy of the proton go? TNP says it goes into creating the bubble in space, cocking the Strong Force spring.

With two up quarks and one down quark forming the interior of a proton, nothing else inside, and space pressing in with considerable force, it is reasonable to assume that the quarks form a bracing structure that keeps the bubble in space from collapsing. This begs us suspend our disbelief for one further moment, and acknowledge that if this much were an accurate model of reality, then either space must have something like surface tension (or a balloon is installed), otherwise space would collapse inward around the quark structure.

3. **Proton Structure**

Can we say anything at all about the shape of this bracing structure? There are a number of constraints that any answer must meet:

1. A free neutron (outside the nucleus) decays in 14.75 minutes into a proton, an electron, an anti-neutrino, and energy in the form of motion of these three particles.
2. The proton lives essentially forever, so must be highly stable.
3. The neutron must be demonstrably unstable compared to the proton.
4. The quarks that comprise protons and neutrons amount to only 1% of the mass of the particles they support.
5. A neutron is made up of two down quarks and one up quark.
6. A proton is made up of two up quarks and one down quark.
7. The down quark is about twice as massive as the up quark.
8. When a neutron decays, one down quark becomes an up quark. This transition leaves a total of 2 up quarks and one down quark: a proton.
9. The quark combinations must be fairly strong and self-bracing to stand the considerable pressure from the compressive spring that is the surrounding space.
10. There must be some reason why the neutron has a long life within the nucleus, but a short life as a free particle.

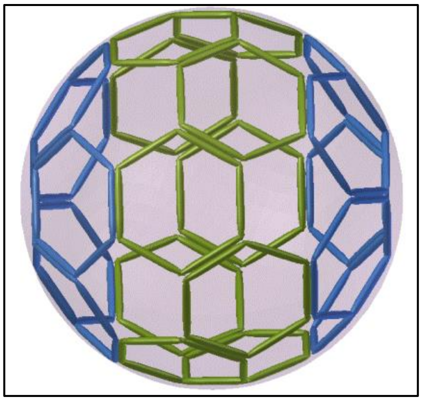


Figure 4. The New Physics model of the proton, showing the bubble in space, two up quarks, and a down quark.

And we must explain one more thing: the mass defect.

TNP would contend that when two particles are adjacent to each other in the nucleus, the pressure from the spring of space would force their bracing structures to touch. If we visualize a bubble with an internal bracing structure, the volume of the spherical cap that flattens when the bracing structures touch is the mass defect.

So our final constraint is this:

11. The spherical caps that are cut off when the bracing quarks of two particles are forced together must be equal to the binding energy of the resulting nucleus; said binding energy must also overcome any repulsive electromagnetic forces whilst being assisted by any attractive electromagnetic forces.

These constraints have led us to consider a variety of possible bracing structures. The best model we have found so far is the truncated icosahedron, also known as a buckyball, named after the famous geometrist Buckminster Fuller. The resulting model of the proton with its internal bracing quarks is shown in Figure 4, drawn to scale.

The bubble in space is represented by the semi-transparent sphere complete as you can see with “surface tension” (or if you insist, a “balloon”.) The up quarks are represented by two sets of 5 dark hexagons. The 10 light-coloured hexagons in the middle comprise the down quark. The down quark has twice the mass of a single up quark.

The truncated icosahedron is a very stable structure and hence a good candidate for bracing the proton bubble. More importantly as we shall see the spherical caps suggested by this model have volumes that, when lost, account with good accuracy for the observed mass defects.

There are two different spherical caps suggested by the model. The PentaCap energy is the amount of energy that will be lost if a particle is forced adjacent to its neighbour’s bracing structure at a pentagonal quark face. Shortly we will find it is 1.76504E-13 Nm. It is proportional to the volume lost when the spherical cap over the pentagon is crushed.

HexaCap energy is the amount of energy that will be lost if the spherical cap over the hexagon is crushed when the particles come together. We will find it is 4.87596E-13 Nm. It is larger because the hexagon is larger than the pentagon. Below we will discuss the calculations which yield these constants.

Before diving deep into the numbers, let’s take a look at the TNP model for the neutron.

4. **Neutron Structure**

Neutrons have a couple of additional characteristics that must be taken into account when constructing their model. The fact that a free neutron disintegrates spontaneously in 14.75 seconds [7] means there is some sort of instability in its structure that is not present in the proton.

The other interesting property of the neutron is that it has a positive charge at its surface. This is clear from Figure 5 [8]. This means that a neutron and a proton will repel each other if they are touching. Not all of the negative charge of the neutron is developed at the line marked “RMS Radius”. We are working inside this radius, since the most recent work on the radius of the proton puts it at 0.841840 fm [6]. With the caps collapsing the particles touch at distances even closer than that, which we shall determine in Section 6. Below we will find a linear approximation to Coulomb charge as a function of distance in these close quarters.

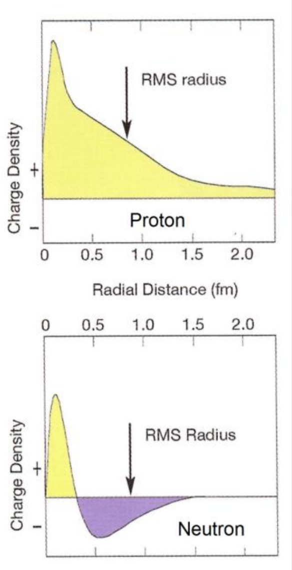


Figure 5. Proton and Neutron charge densities. RMS Radius here is the former accepted value of 8.768 x 10^{-16}.

The best model for the neutron we have devised so far that matches the criteria of Section 3 is shown in Figure 6. The two outer down quarks are shown in slightly different shades. The up quark is in the centre of the down quarks, corresponding with its 2/3 charge to the positive charge of Figure 5 (bottom, lighter shading.)

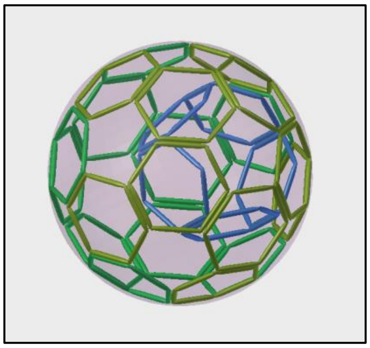


Figure 6. TNP model of the neutron, showing the bubble in space, two down quarks, and an up quark. The up quark here is shown as a circular loop of 6 hexagons.

The hypothesis is that with the up quark rattling about on the inside, the neutron eventually shakes itself apart and reforms as a proton.

5. **Results**

Figure 7 shows the results of applying the The New Physics model to the construction of some isotopes from deuterium through carbon. The TNP model is a surprisingly good fit to the experimental data. Details are in a Table in the Appendix.

The average absolute error and correlation coefficients for the three models are given in Table 1.

Model	Average Absolute Error	Correlation Coefficient
The New Physics	1.430%	0.99893
Face-Centered Cubic	10.950%	0.91500
Liquid Drop	55.918%	0.98057

Table 1. Error comparison of the three most accurate models of nuclear binding energy.

These results are sufficiently encouraging for us to explain how we derived them.

6. **Model construction**

We include the details of our model so the reader can reproduce and improve upon our results.

Please bear in mind that this is a first order model. Our approach is to start simply, then use the results as a proof of concept to support the effort of developing a more exacting model.

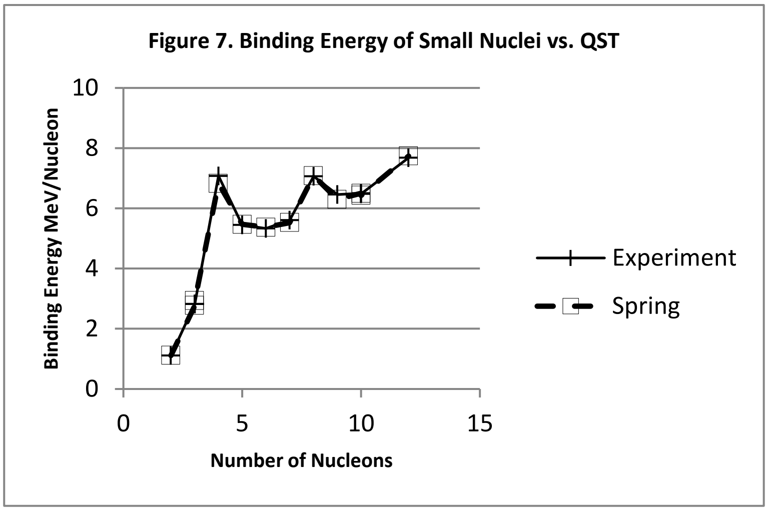


Figure 7. Binding Energy of Small Nuclei vs. QST

It is easier for us (and perhaps for nature) to build nuclei from protons and neutrons if they are both the same size. Perhaps later we shall learn something more precise, but until then this is a prediction of our first order model. With this assumption the only difference between the masses of the proton and the neutron is the more massive quarks in the neutron. If the down quark is exactly twice as massive as the up quark we have

where m_d is the mass of the down quark and m_u is the mass of the up quark. Furthermore

$$m_n - m_p = (2m_d + m_u) - (2m_u + m_d) \qquad (2)$$

where m_n and m_p are the masses of the neutron and the proton, respectively. Substituting (1) in (2), we see that

$$m_n - m_p = m_u \qquad (3)$$

Formation energy of the proton is 1.50328E-10 Nm and of the neutron is 1.50535E-10 Nm [7]. (Because the proton radius is only known to 6 significant digits [6] and lies at the root of our conclusions, even when our constants are known with greater accuracy we limit them to 6 digits.) This permits us to predict precisely the formation energies of the up and down quarks:

	Measurements [7]			Predictions
	Lower Bound	Average	Upper Bound	The New Physics
Up Quark Energy (Nm)	2.2E-13	3.99E-13	5.4E-13	2.07214E-13
Down Quark Energy (Nm)	5.4E-13	8.09E-13	9.4E-13	4.14429E-13

Table 2. Measurement ranges and the TNP predictions of quark formation energies.

The predictions by TNP are below the lower bounds of current measurements. Yet it is obviously difficult to measure quark formation energy accurately, as we can see from the broad range of current measurements in Table 2. Until we know more we will pursue this simple model, treating these meanwhile as two more predictions.

7. **Electrostatic Energy**

In order to compute the binding energy with some precision, we must take into account the electrostatic force between particles. We have found the electrostatic repulsion between protons and neutrons is typically about 5% to 10% of the binding energy (see Appendix.) The neutron has a positive charge at its surface because its neutral charge is not fully developed until well outside its radius (Figure 5.)

The repulsive electrostatic force is trying to separate the particles. This means the real binding energy is the observed binding energy plus the electrostatic energy that it must also overcome to keep the particles together.

Notice that in the region of the RMS the slope of the charge density is approximately linear. To aid a simpler computation of binding energies, we take advantage of this linearity and fit regression lines to the electrostatic charges for protons and neutrons as implied by Figure 5. The linear regression formula is:

$$q\,(d) = (md + \ b) * q_0 \qquad (4)$$

where m is the slope, b is the intersect, d is the distance from the centre of the particle in metres, and q_0 is the unit charge: 1.60218 x 10^{-19} Coulombs. We deduce Table 3 from Figure 5.

Particle	Slope, *m*	Intersect, *b*
Proton	$6.58735\ x\ 10^{14}$	0.22240
Neutron	$-8.32155\ x\ 10^{14}$	0.88625

Table 3. Coefficients of regression fit for charges near the RMS of protons and neutrons.

As we can see from Figure 5, Eq. (4) has discrete limits. When applied to the proton, Eq. (4) should not exceed the unit charge; using the coefficients in Table 3, beyond a distance of 1.17920E-15 m the proton has a unit charge. Similarly beyond a distance of 1.06375E-15 m the neutron has no charge.

The Coulomb force between two particles is given by

$$ {}_{C}\boldsymbol{F}(\boldsymbol{r}) = \frac{Cq_1q_2}{r^2}\,|\boldsymbol{r}| \tag{5}$$

where C is the Coulomb constant (8.98755E9 $\mathrm{Nm^2/C^2}$), q_i is the charge of particle i, r is the separation between them, and the unit vector between the particles is denoted by $|\boldsymbol{r}\,|$.

With q_i given by Eq. (4) within its limits, and noting that $d = r/2$, the equation for the Coulomb force between two particles denoted by subscripts 1 and 2 becomes

$$ {}_{C}\boldsymbol{F}(\boldsymbol{r}) = Cq_0^2\left(\frac{m_1m_2}{4} + \frac{b_1m_2+b_2m_1}{2r} + \frac{b_1b_2}{r^2}\right)|\boldsymbol{r}| \tag{6}$$

To determine the energy required to push the two particles together to separation s we integrate Eq. (6):

$$ {}_{C}E(s) = Cq_0^2\left(\int_s^\infty \frac{m_1m_2}{4}\,d\boldsymbol{r} + \int_s^\infty \frac{b_1m_2+b_2m_1}{2r}\,d\boldsymbol{r} + \int_s^\infty \frac{b_1b_2}{r^2}\,d\boldsymbol{r}\right) \tag{7}$$

$$ {}_{C}E(s) = Cq_0^2\left(\frac{m_1m_2r}{4}\bigg|_s^\infty + \frac{b_1m_2+b_2m_1}{2}\ln(|r|)\bigg|_s^\infty - \frac{b_1b_2}{r}\bigg|_s^\infty\right) \tag{8}$$

where here $|r|$ means absolute value of r.

8. **Magnetostatic Energy**

The measured proton magnetic moment is 1.41061E−24 J/T, whilst the neutron magnetic moment is −9.66236E−27 J/T. However the sum of these is not the deuterium magnetic dipole moment. To understand the TNP explanation as to why this might be so, we have only to look a bit more closely at our model of the neutron, Figure 6. Observe the up quark free to move about the interior.

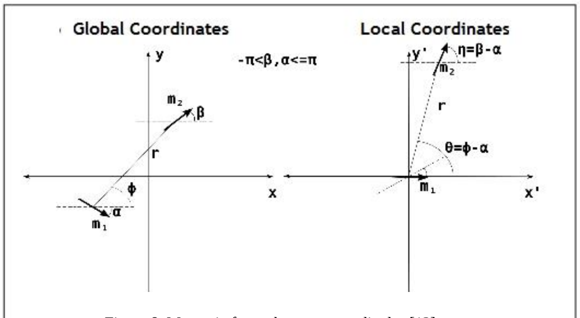


Figure 8. Magnetic forces between two dipoles [12].

TNP explains the fact that the free neutron disintegrates in 14.75 seconds by pointing out that the up quark within might well oscillate internally until the structure destabilizes and shatters. Yet in the deuterium nucleus this does not occur. In Figure 9 we can see the up quark with its 2/3rds positive charge is repelled by the positive charge of the proton and is pinned against the far side of the neutron, opposite the binding point of attachment of the proton to the neutron.

This shift of the up quark also affects the magnetic moment of the bond. We can compute the effect. We see that the sum of the magnetic moments of the proton and the free neutron is 4.44371E-27 J/T, but that of deuterium is

4.32852E-27. Therefore the magnetic moment of the bound neutron must be −9.77755E-27 J/T to account for the difference. The up quark shift increases the neutron magnetic moment, so the sum is less, as observed.

We need a way to determine the magnetic repulsion between nucleons as they are added to the nucleus. We adopt a simplistic model that we can apply throughout the construction. Its lack of sophistication is compensated by clarity in the resulting first order model, which can be refined later.

The magnetic forces between two dipoles are illustrated in Figure 8 and given by [12]:

$$ {}_{r}\boldsymbol{F}\,(\boldsymbol{r},\alpha,\beta) = \frac{3\mu_0}{4\pi}\frac{m_1 m_2}{r^4}[2\cos(\phi-\alpha)\cos(\phi-\beta)-\sin\,(\phi-\beta)] \tag{9} $$

$$ {}_{\phi}\boldsymbol{F}\,(\boldsymbol{r},\alpha,\beta) = \frac{3\mu_0}{4\pi}\frac{m_1 m_2}{r^4}[\sin\,(2\phi-\alpha-\beta)] \tag{10} $$

where m_1 and m_2 are the magnetic dipoles, $\boldsymbol{r}$ is the vector distance from the first to the second dipole, and μ_0 is the permeability of space. μ_0 may be larger than normal in the vicinity of the nucleus, due to the compression of space in the region, but the effect is small and we shall ignore it for the moment. Assuming that the particles approach along the vector $\boldsymbol{r}$ so the angles stay constant, the energy involved in Eq.(9) is:

$$ {}_{r}E\,(r,\alpha,\beta) = \int_{s}^{\infty}\frac{3\mu_0}{4\pi}\frac{m_1 m_2}{r^4}[2\cos(\phi-\alpha)\cos(\phi-\beta)-\sin\,(\phi-\beta)] \tag{11} $$

$$ {}_{r}E\,(s,\alpha,\beta) = -\left[\frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^3}[2\cos(\phi-\alpha)\cos(\phi-\beta)-\sin\,(\phi-\beta)]\right]\Bigg|_{s}^{\infty} \tag{12} $$

where s is the separation between dipole centres. Similarly for Eq.(10) we have

$$ {}_{\phi}E\,(r,\alpha,\beta) = \int_{s}^{\infty}\frac{3\mu_0}{4\pi}\frac{m_1 m_2}{r^4}[\sin\,(2\phi-\alpha-\beta)] \tag{13} $$

$$ {}_{\phi}E\,(s,\alpha,\beta) = -\frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^3}[\sin\,(2\phi-\alpha-\beta)]\Big|_{s}^{\infty} \tag{14} $$

$$ {}_{M}E\,(s,\alpha,\beta) = {}_{r}E\,(s,\alpha,\beta) + {}_{\phi}E\,(s,\alpha,\beta) \tag{15} $$

Eq. (15) gives negative energies for net repulsive magnetic forces, and positive energies for net attractive magnetic forces.

9. **Calibration: Deuterium**

We model deuterium with a two 2 PentaCap bond, as illustrated in Figure 9. We explored using HexaCaps but did not obtain as good a fit to experimental data.

The length of the quark strut is given by the properties of the truncated icosahedron [9]:

$$ {}_{q}a = r_p/\left(\frac{1}{4}(58+18(5)^{0.5})^{0.5}\right) \tag{16} $$

where ${}_{q}a$ is the length of each quark strut and r_p is the radius of the proton. The distance from the centre of the proton to the pentagonal face is again by geometry

$$ {}_{p}d = {}_{q}a\left(\frac{1}{2}\left(\frac{1}{10}(125+41(5)^{0.5})\right)^{0.5}\right) + {}_{q}t/2 \tag{17} $$

where ${}_{q}t$ is the thickness of the quark strut; we assume the geometric plane bisects the strut so we add half its thickness. ${}_{q}t$ value will shortly be determined to be 4.12111E-17 m, yielding ${}_{p}d$ = 8.11290E-16 m.

The movement of the up quark shifts the centre of the charge of the neutron away from the proton. We assume by the geometry illustrated in Figure 7 that this shift moves the centre of the neutron's charge a further 25% of the radius of the proton. So the s in Eq. (8) and (15) we'll express as

$$s = 2_p d + 0.25_p d \tag{18}$$

which yields $s = 1.83304\text{E-}15$ m.

The measured binding energy, which is the sum of the mass defect combined with the Coulomb and magnetic forces, is

$${}_{obs}E = {}_D E_{2H} + {}_C E_{2H} + {}_M E_{2H} \tag{19}$$

where ${}_D E_{2H}$ is the energy of the mass defect, ${}_M E_{2H}$ is the magnetic energy for ^{2}H which from Eq.(15) is an attractive force of 4.42592E-15 Nm, and ${}_C E_{2H}$ is the Coulomb energy from Eq. (8), which computes as −1.01600E−15 Nm. The observed deuterium binding energy is well-documented at 3.56419E-13 Nm [1, NVS]. So the actual pentagonal cap binding energy is 1.76504E-13 Nm: the result of solving Eq.(19) for ${}_D E_{2H}$ and dividing the result by 2 (since there are two PentaCaps in the bond, with each one getting half the mass defect.)

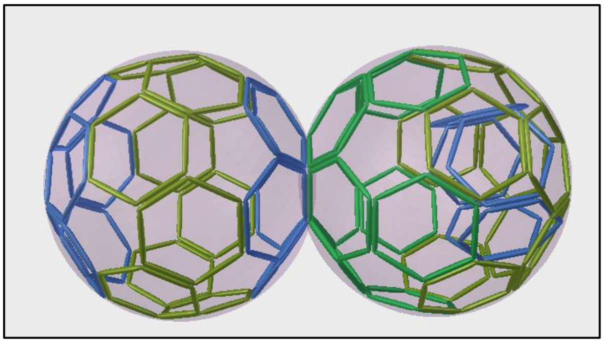


Figure 9. In the deuterium nucleus the internal up quark is pinned to the side of the neutron opposite the bond to the proton. Note the pentagonal spherical cap cut from each particle at the bond: the binding energy or mass defect.

We compute the volumes of the proton and the neutron based on the assumption they are spheres. (The assumption they are spheres is supported by recent evidence that the electron is to an extraordinarily high degree spherical [11]: if the electron were as large as the solar system it would be exactly spherical to the width of a human hair. TNP claims the electron is also a bubble in space: the only way to get something to be perfectly spherical.)

We now have a model of the deuterium binding energy that is an exact solution of Eq. (19).

The proton radius of 8.41840E-16 m [6] creates a spherical volume of 2.49906E-45 m^3. It is useful when determining the volume of the PentaCap to know the formula for the volume of a spherical cap [10]:

$${}_C V = \frac{1}{3}\pi h^2 (3r_p - h) \tag{20}$$

where h is the height of the spherical cap.

Our model tells us there is an interior quark framework. We have to account for this somehow. Our method is to assume the quark struts have a thickness. We reason that surely if they exist, they must have some thickness. Therefore we adjust the height of the spherical cap to account for this thickness so that our model yields the best match to measurement data. The result of this process is to adopt a quark strut thickness of 4.12111E-17 m and adjust the height of the PentaCap accordingly. This gives a PentaCap volume at 2.43846E-48 m^3. Therefore the binding energy lost per unit volume is 7.23834E34 Nm/m^3.

The distance to the hexagonal face from the centre of the proton can be computed from the geometry of the truncated icosahedron [9]:

$${}_h d = {}_q a \left(\frac{1}{2} \left(\frac{3}{2} (7 + 3(5)^{0.5}) \right)^{0.5} \right) + {}_q t/2 \tag{21}$$

Using Eqs. (20) and (21) gives us a volume for the HexaCap of 6.73630E-48 m^3. With our calibrated binding energy per unit volume of 7.23834E-34 Nm/m^3 we have the HexaCap energy of 4.87596×10^{-13} Nm.

10. **Nuclear models**

Armed with Eqs. (8) and (15) and our PentaCap and HexaCap binding energies, we can evaluate Eq. (19) for other nuclei, creating the Table in the Appendix and Figure 7.

To describe the bonds between the particles, it will help to have a way to refer to specific PentaCaps and HexaCaps. This is not because we think we have selected the only proper caps, but rather to enable the work to be reproduced and refined.

Figure 10 shows a way to label the caps looking at the "front" of the proton. The first numeral is the level of the cap, starting at level 1. The second numeral is the number of the cap on that level, starting at 1. The front of the particle with p11 in the centre (and closest to the reader, as though the reader were looking down on a ball) is chosen as the darker side on the neutron, and as the side where the initial bond is made on the proton. The first bond is arbitrarily chosen to be on the lowest numbered cap that matches the geometry of the nucleus. Figure 10 also shows the back of the proton but looking at it from the front, with the front half of the quark structure cut away so the rear caps are visible. The cap p81 is furthest from the reader, as though the reader were looking down into a cup. The numbering scheme extends smoothly from the front onto the back side with h51 on the back adjacent to h41 on the front.

We can label neutron caps the same way because in this model, the outer two down quarks of the neutron have the same geometry as the two up quarks plus the down quark of the proton.

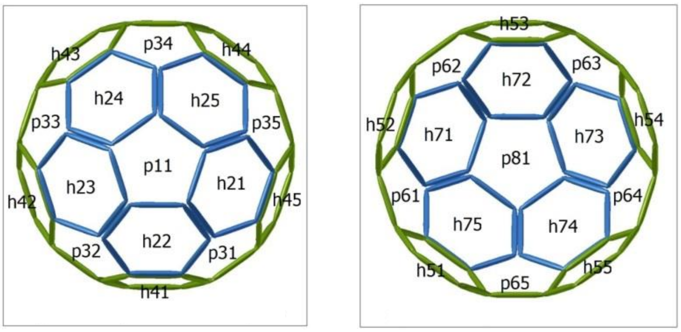


Figure 10. Cap numbering scheme.

In addition to this convention we will call the first proton added to the nucleus P1 and the first neutron N1. Looking for example at deuterium (Figure 9) we see a bond of P1p11-N1p11.

The Appendix lists the bond details for each of the nuclei illustrated in Figure 7.

For an example of a model of a nucleus consider the alpha particle, ^4He.

The alpha particle holds a special place in nuclear structure theory. Alpha radiation is one of the primary forms of radiation which occurs when—according to TNP—the strong force of the compressive space surrounding the nucleus can no longer hold the nucleus together. The fact that the alpha particle seems to be bound together as a unit more tightly than other combinations of particles is also reflected in the branch of nuclear structure theory that surmises that atomic nuclei are constructed of clumps of alpha particles [1]. Our findings place us firmly in this camp.

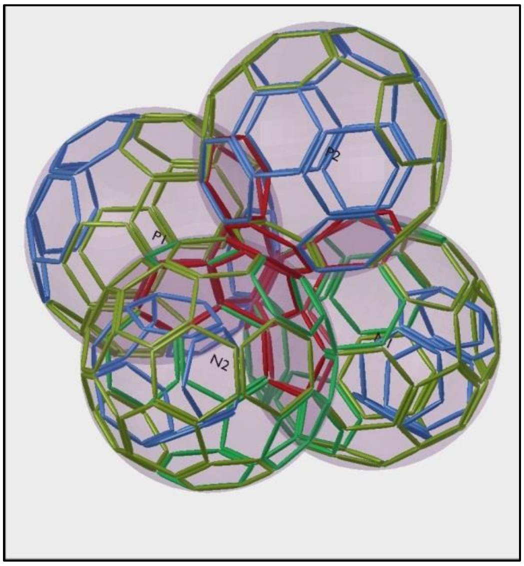


Figure 11. ^4He, the alpha particle.

All this circumstantial evidence is supported by our model of ^4He which has a large number of busted caps.

Three HexaCaps are broken by their proximity in the centre of the cluster of the first three particles. Their spherical caps interfere with each other, so they flatten when the particles bond. A fourth HexaCap that belongs to P2 sits on top of them and does not break because once these are flattened there is room for the fourth cap. P2 has three HexaCaps at the right locations to bond with three PentaCaps on the other three particles.

A number of factors influence how we construct these models. We look at all the various combinations of HexaCaps and PentaCaps and discover those that yield matches to the data. Then we consider more closely those that are feasible to build. As a general principle we assume that nature will strive for a spherical configuration. In TNP this is encouraged by the nuclear skin or "quantum level 0" as we call it. The nuclear skin is a layer around the nucleus of increased density [1, p135]. TNP explains this as the compressed space within a quantum level 0 that immediately surrounds the particles injected into space [5]. Its thickness is about 0.4 fm in ^{1}H but 2.3 to 2.4 fm in larger nuclei; its shape is less well understood. The TNP model asserts it is the restoration to home position by quantum level zero as the particles join that overcomes electromagnetic repulsion and engenders the momentum that busts the caps. We assume the nuclear skin will at least tend to be spherical if not actually attaining a spherical shape. It is not always possible to construct a sphere with just a few nucleons or alpha particles.

In addition calculations of the repulsive electrostatic forces by Eq. (8) show that protons repel protons with greater force than they do neutrons. The dual PentaCap proton-proton electrostatic energy is -1.20764E-13 Nm whilst the proton-neutron energy is −1.01600-15 Nm, with the negative signs indicating repulsion. This is a difference of more than a factor of 100, which we think will incline protons to bond to neutrons before protons, all other things being equal. Using the same logic the neutron-neutron dual PentaCap electrostatic repulsion is another factor of 10 weaker at −1.02557E-16 Nm, so a neutron is more likely to bond with a neutron than with a proton. Note that for HexaCap bonds the numbers are higher because there is less distance between centres.

Magnetic effects are more difficult to understand. We use Eq. (15) to compute the final binding energy, but are less certain how influential magnetic effects might be in determining the shape of the nucleus, and how they combine as nucleons are added. These are important areas for further investigation.

Does the bond between up and down quark structures have attraction? Are down quark bonds repulsive? Do particular caps have affinity for others? We don't have enough data to answer these questions yet.

^{5}He has the same number of bonds as ^{4}He: the third neutron is just resting against the other particles. It is not hard to understand this is not a stable isotope.

In ^{6}Li N3 bonds to P1 with two PentaCaps and P3 bonds to N3 with a PentaCap-HexaCap bond.

In ^{7}Li neutron N3 HexaCap bonds to N1, P3 PentaCap bonds to N2, and N4 has PentaCap bonds with both N2 and P3.

^{8}Be is our first cluster of alpha particles, with N4 of the second alpha particle binding to both N1 and P1 using PentaCaps.

^{9}Be is just like ^{8}Be but with an extra neutron N5 resting un-bonded on the surface. This is an unstable isotope.

For ^{10}Be and ^{10}B N5 bonds to the alpha cluster via P3 using 2 HexaCaps. In ^{10}Be N5 bonds to N6 with PentaCaps. In ^{10}B P5 bonds to N5 using a PentaCap-HexaCap bond.

^{12}C is a cluster of three alpha particles with the third bonded with HexaCaps to both of the other alpha particles. There is a rough fit of those bonds between N5 and N3/N2. There may be another geometry that makes a fit with smaller gaps, but we have not discovered it yet.

11. **Implications**

The model of particle physics put forth here is certainly a radical departure from conventional thinking. It has numerous far-reaching implications, a few of which we should touch upon before closing.

For example if the particles in our lives are mostly hollow, where is the inertial mass? According to The New Physics, particles are heavy because of the cumulative restoring forces of their merged quantum levels. But why are they hard to accelerate?

The quantum levels of a particle begin creation at the moment of its insertion into space. We assume that they propagate into space at the speed of light. This means every particle that has been here for a while has a very large number of quantum levels by now. When a particle is accelerated, it is unlikely that all of its quantum levels accelerate at the same time. Therefore acceleration of a particle is a distortion of the particle's distance from its quantum levels. Just as the quantum level wants to restore to its home position (gravitation), so it also resists deformation from the home position (inertia).

To create General Relativity Einstein had to assume that gravitational mass and inertial mass are the same thing. The New Physics shows that they have the same source: the tendency of every quantum level to restore to its home position [4].

One more implication of TNP should be mentioned. Dark matter has been transforming into dark energy over time as the universe has evolved. In our earlier work we put forth the conjecture that TNP permits dark matter to be composed of neutron matter [5], something not permitted by the Standard Model of particle physics.

A collection of neutrons in a black hole would eventually amass enough gravitational force to crush the neutron shown in Figure 6. This would leave no gravitational mass (quantum levels); only the formation energy would remain, trapped at the centre of the black hole. As the black holes of the universe gather more mass, more neutrons will be crushed and more dark energy will be formed. The resultant loss of gravitational mass then accounts for the observed accelerating expansion of the universe [14].

12. **Conclusions**

We have presented a The New Physics model of the structure of the nucleus, and have shown how to build models of several of the small nuclei. The constructions are more than 7 times better match to known data than the next closest model of binding energy.

The TNP model is in the same family as its predecessor the FCC model: both are crystalline structures. The FCC model is a regular structure, but the TNP model derives its improved accuracy from constructing each nucleus as demanded by the observed binding energy. As this work is extended we may see some of the FCC regularities emerge, such as FCC's alternating layers of protons and neutrons. One of the most impressive attributes of the FCC model is its replication of the properties of the IPM. We have as yet made no attempt to draw this correlation with the TNP models.

TNP is a simple, unified view of physics incorporating the strong nuclear force, light, and gravitation. By TNP the mechanism of gravitation is the quantum levels of particles restoring to their natural size; this is the first satisfactory explanation of the cause of gravitation since Newton posed the question. Inertia is the same restoring force reacting to the acceleration of the particle. The accuracy of the TNP model of the nucleus lends important credibility to these conclusions. With such a promising start further efforts to refine this alternative model of physics should continue to reveal new insights into the way the universe is constructed.

At CERN in Switzerland considerable effort is currently underway to discover the Higgs Boson predicted by the Standard Model of particle physics. TNP would say it is certainly possible for such a large particle to be created because the size of a particle is only limited by the amount of energy focused to create it. However unless additional bracing structures beyond the quark structures proposed here are discovered, it is unlikely such a large particle would last very long before collapsing. Nonetheless if the Higgs Boson is found it will likely be considered as "proof" of the Standard Model and it may be difficult to get much interest in alternative models. On the other hand if the elusive particle is not found then a promising alternative such as The New Physics will have to fill the resulting void.

13. **References**

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14. **Appendix**

Detailed results of the New Physics model of the nucleus:

Atom	P	N	Penta-Caps	Hexa-Caps	Bonds	Electro-Static Energy	Magneto-Static Energy	Spring Theory	Measure-ment	% Err
^{2}H	1	1	2	0	P1p11 - N1p11	-1.01600E-15	4.42592E-15	3.56419E-13	3.56419E-13	0.00%
^{3}H	1	2	2	2	P1p11 - N1p11 P1h41 - N2h21	-2.35659E-15	7.20862E-15	1.33305E-12	1.35897E-12	-1.91%
^{3}He	2	1	3	2	P1p11 - N1p31 N1p34 - P2h21h45	-9.54685E-14	-1.00028E-15	1.40824E-12	1.35894E-12	3.63%
^{4}He	2	2	9	6	P1p11 - N1p11 P1h21-N1h21-N2h45 P1p31-P2h41 P1p35-N2p35 N2p31-P2h45 N2p35-N1p31 N1p35-P2h45	-1.45993E-13	8.37836E-15	4.37650E-12	4.53352E-12	-3.46%
^{5}He	2	3	9	6	same as 4He	-1.49575E-13	1.39438E-14	4.37849E-12	4.36449E-12	0.32%
^{6}Li	3	3	12	7	same as 4He 1p32-N3p31 N3p81-P3h21	-3.73600E-13	5.73487E-15	5.16336E-12	5.12601E-12	0.73%
^{7}Li	3	4	15	8	same as 4He N3h21-N1h53 N4p11-P3p31 N4p11-N2p62 P3p11-N2p61	-3.59934E-13	8.51757E-15	6.19692E-12	6.28438E-12	-1.39%
^{8}Be	4	4	22	12	same as 2 sets of 4He N4p61-N1p32 N4p62-P1p32	-6.81418E-13	2.39653E-14	9.07680E-12	9.05230E-12	0.27%
^{9}Be	4	5	22	12	same as 8Be	-6.85729E-13	2.95307E-14	9.07806E-12	9.31906E-12	-2.59%
^{10}Be	4	6	24	14	same as 8Be	-6.88091E-13	3.50962E-14	1.04095E-11	1.04105E-11	-0.01%
^{10}B	5	5	23	15	same as 8Be P3h73-N5h21 N5p81-P5h21	-1.09787E-12	2.68873E-14	1.03026E-11	1.03743E-11	-0.69%
^{12}C	6	6	31	22	same as 3 sets of 4He N5h71-N2h71 N5h74-N3h72	-1.37286E-12	4.79307E-14	1.48738E-11	1.47660E-11	0.73%