Underground neutrino transit time

Eidolon Physicist, EidolonPhysicist@gmail.com

Abstract. The measurement of the transit time of a beam of neutrinos from CERN in Geneva, Switzerland to the Gran Sasso laboratory in Italy has recently been repeated. The new measurements confirm the neutrinos arrive (57.8 ± 7.8) ns faster than expected if the neutrinos had been travelling at the speed of light, bringing into question whether the observation of Special Relativity that nothing can travel faster than the speed of light is warranted. We show that it is indeed possible for the neutrinos to arrive early at Gran Sasso and not contradict Special Relativity. Extending our previous model of particle creation we show that a little time is gained for each large nucleus through which the neutrino passes. The sum of these gains accounts for the observed reduction in transit time. The amount of time gained depends more on the density of the material on the path than on specific atomic elements. The model predicts that should the matter be denser or the path longer, even more time will be gained.

PACS: 21.60.De; 21.10.Dr; 21.65.Cd; 91.10.Kg

1. Introduction

The OPERA project has recently reconfirmed the early arrival of neutrinos from the neutrino beam at CERN near Geneva, Switzerland to the detector at Gran Sasso east of Rome, Italy [1]. The distance from the source to the detector is known to be 731,278.0 ± 0.2 m. The results of the original measurements showed the early arrival of the neutrinos in Gran Sasso of ((57.8 ± 7.8 stat.)$^{+8.3}_{-5.9}$ (sys.)) ns. To eliminate possible systematic errors from using longer bursts of neutrinos, new measurements using four bunches of neutrinos in 3 ns bursts separated by 524 ns yielded (62.1 ± 3.7) ns, in agreement with the main results. This tends to confirm the original conclusion that the neutrinos are travelling faster than the speed of light in a vacuum.

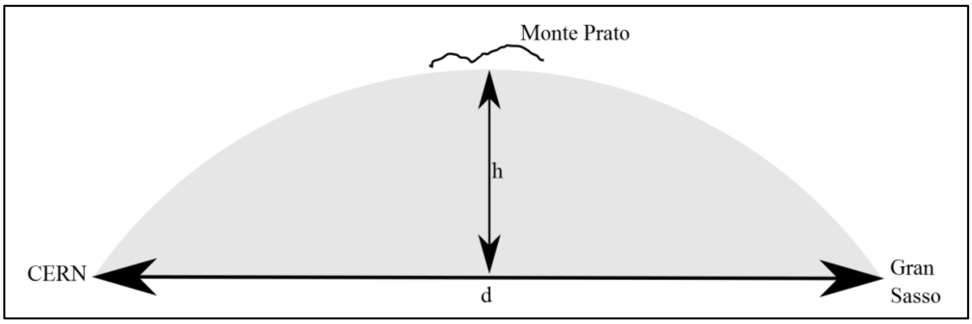


Figure 1. The CERN Neutrino to Gran Sasso experiment (CNGS). Depth from sea level is found using the formula for the height of a spherical cap of diameter d = 731,278, assuming the Earth has a mean radius at sea level of 6371 km. To the resulting value h = 10.5 km add 900 m halfway up the northern slope of Monte Prato for a total depth of about 11.4 km. Horizontal and vertical scales differ.

This has been interpreted to mean that the fundamental observation of the Michelson-Morley experiment—that the speed of light in empty space is constant and cannot be exceeded—has been somehow violated, thus undermining the fundamental basis of Special Relativity [2].

We can resolve this apparent contradiction by pointing out that the ground under the mountain between CERN and Gran Sasso is not a vacuum. Now we only need to show why a beam of neutrinos might travel more quickly through a mountain than they can through a vacuum.

It may seem at first glance that we have just made our problem even more difficult. To see that this is not true we only need to look carefully at the structure of the matter that makes up the mountain, and explore how this might affect the transit time of a neutrino.

In an analysis of the same data used in the OPERA experiment, Ferrari et. al. contend that the absence of Cherenkov radiation from the observed neutrinos refutes the notion that they may be travelling faster than light [3]. This argument derives from theoretical attributes of neutrinos travelling faster than light in a vacuum. Since we contend this is not precisely the case here, we believe this argument is not a refutation of the observed phenomenon.

2. The New Physics

In order to better understand the structure of the material underground, we appeal to the model put forth by The New Physics (TNP) regarding the nature of particles [4, 5]. TNP began as a model to explain one of the enduring unresolved problems in physics: what causes gravitation.

The creation of a particle engenders its quantum levels in the surrounding space. 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.

This model has been extended to yield a model of nuclear construction that is seven times better than the current best model explaining nuclear binding energy for small nuclei, with absolute error 1.43% and correlation 0.999 [5]. In order to achieve these results TNP considers how particles might be constructed based on what we know about the particles and their constituents.

2.1 Particle creation

At the core of TNP is the hypothesis that when a particle is created, it does not *replace* the space that used to be where the particle now resides; it *displaces* that space. The displaced space is compressed into the immediately surrounding “nuclear skin”. This displaced space exerts a Strong Force on the particle that holds it together. (In the Standard Model of particle physics this has been called the Residual Strong Force.)

In order to resolve the issues surrounding the binding energies of small nuclei, TNP suggests a fairly detailed view of the structure of protons and neutrons. Consider for example a proton. The two up quarks and one down quark that make up the proton together account for about 1% of the formation energy of the proton. No matter how many times we break them apart, we can find no other matter inside a proton. What happens to the other 99% of the energy?

TNP suggests it creates a bubble in space, pushing out and compressing the space into the nuclear skin. Figure 2 shows a diagram of a proton, with its two up quarks and its down quark illustrated schematically. This physical interpretation of particle creation helps $E = mc^2$ make a lot more sense.

Recently evidence has emerged that the electron is to an extraordinarily high degree spherical [6]: 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 a bubble in space and this explains why it is so perfectly spherical.

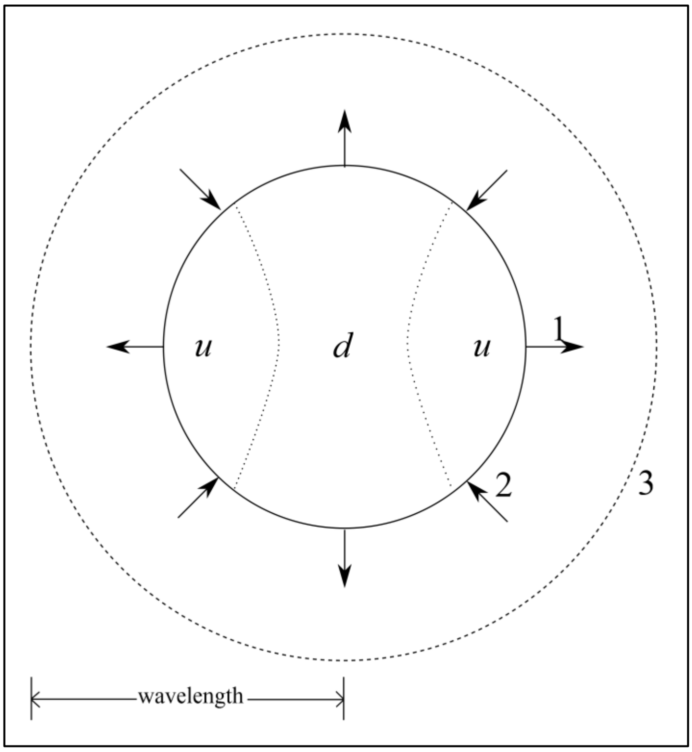


Figure 2. Proton schematic. The solid circle is the spherical proton, with *u*'s representing the up quarks and *d* representing the down quark. 1 is the pressure from the particle skin on space. 2 is the Strong Force holding the proton together. 3 is the nuclear skin. Note that the wavelength of the proton is the radius of the nuclear skin.

Quantum Mechanics suggests that a particle is either a particle or a wave depending on the mechanism used to observe it. The wavelength is given by $\lambda = ch/E$ where c is the speed of light in a vacuum, h is the Planck Constant, and E is the formation energy of the particle. TNP suggests that the wave phenomenon of a particle is just the compressed space it generates when it is created. In the TNP model the ch/E wavelength of the proton is the radius of the nuclear skin, 1.33E-15 m. [E-15 means times 10^{-15}, chosen to aid moving numbers from the article to calculating programs like Excel.] This is the same phenomenon whether the particle is a proton with supporting quark structure, or a photon (or neutrino) without a supporting structure. This important observation gives us an unambiguous way to visualize the wave-particle duality for all types of photons and particles.

Figure 2 is somewhat misleading because it shows the up and the down quarks schematically as filling the space, but we know they comprise only 1% of the formation energy. TNP models hypothesize that quarks form an interior bracing structure within the particle that holds the bubble open. For the proton a particular bracing structure has been chosen that solves the binding energy problem [5]. The result is shown in figure 3.

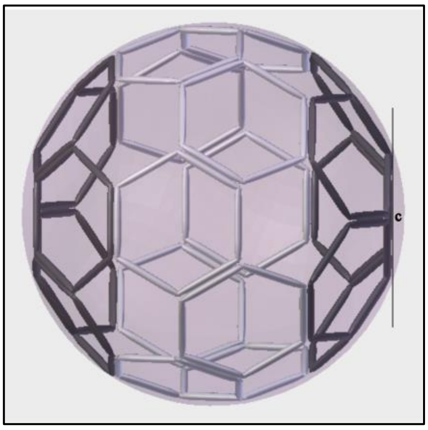


Figure 3. Proton, showing internal bracing structure of two up quarks and one down quark. The coloured sphere is the bubble in space. The black line separates the spherical cap, c: this is the mass defect lost when the proton adheres to another particle in the nucleus [5].

Why doesn't space collapse into the bracing structure? Either it has some sort of "surface tension", or there is an interior particle surface that prevents its entry. TNP has over time evolved to the latter viewpoint. This is motivated primarily by the observation in [5] that the binding energy per unit volume of the spherical cap cut off when the proton adheres to a neutron is larger than that required by the proton to create the sphere. As we see there is also a larger percentage of surface area per unit volume of a spherical cap than of the volume as a whole. This seems to indicate that something is being created at the surface that is more "expensive" in terms of creation energy than the creation of the volume itself.

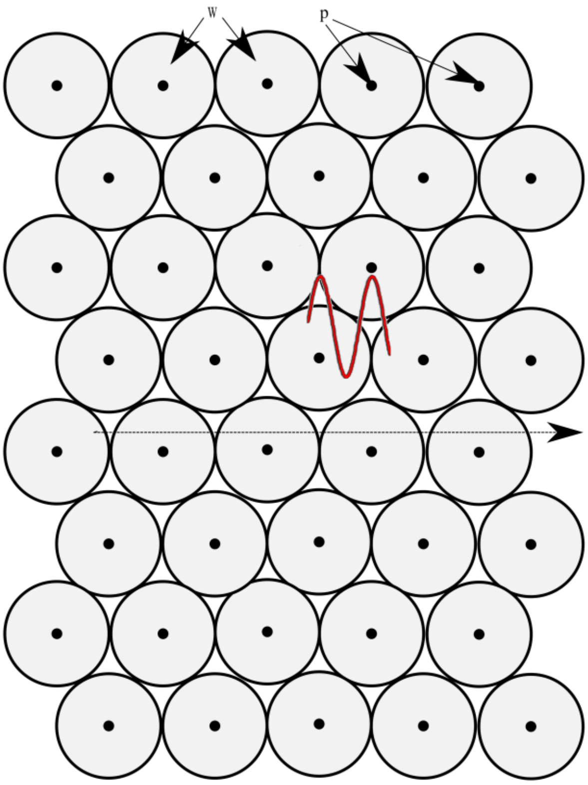


Figure 4. Propagation of beam of coherent light or neutrinos (not drawn to scale.) Letter p indicates photons or neutrinos and w the compressed space resulting from their creation: the particle's wave. Dashed line denotes direction of travel of the light or neutrino wave(s). Wavelength is depicted by sine wave fragment (centre right.)

For us the important point is that there is no space inside the particle. Space has permittivity and permeability. Without these to resist the movement of a wave through the particle, it is reasonable to assume the wave would transit the particle instantly. This is the key to the solution of the neutrino transit time problem.

Looking at the proton wavelength in figure 2, it seems like the edge of the nuclear skin would be the minimum wave amplitude if the particle were the peak of the waveform. If this were true then λ would be ½ the required size, and the model would be incorrect. In figure 4 we show how a collection of photons or neutrinos would propagate. As you can see the distance between peaks of maximum energy is indeed λ due to the maximum possible packing arrangement between neutrinos.

2.2 Gravitation and inertia

One may well ask a couple of questions at this point. If particles are hollow, and have nothing inside, how can they have the properties of gravitational and inertial mass? Don't these properties require the particles to be, well, massive?

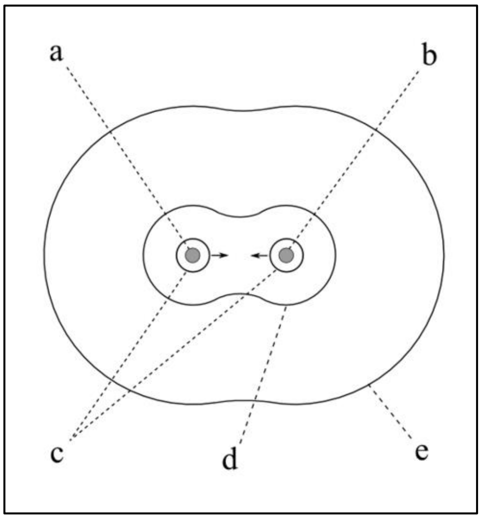


Figure 5. Gravitational mechanism. Two particles a and b with nuclear skins c (and no electrons) are drawn together by the contraction of their quantum levels trying to restore to their natural size j^2 r_1. Only quantum levels 1 (d) and 2 (e) are shown. Not drawn to scale.

As previously mentioned, gravitation is the result of the quantum levels of two particles merging. Each quantum level *j* of each particle has a natural radius, equal to j^2 times the radius of quantum level 1. When the quantum level *j* of the first particle merges with the quantum level *j* of the second particle, they become one quantum level *j*. This will want to return to its natural size of j^2 r_1. This contraction is, in fact, gravitation. Clearly, it does not require the particle to be "massive" as such, only to have engendered quantum levels when it was created. This is illustrated in figure 5 [1].

What about inertial mass? It requires force to accelerate a particle. If the particle is hollow, why is this?

According to the sophisticated Standard Model of particle physics, mass is conferred to particles by the Higgs Boson particle [7]. The TNP model is simpler. When the outer electrons of an atom are repelled by the outer electrons of a second atom, then the distance between the nucleus of the atoms and their quantum levels is put under pressure. We know from the preceding discussion that the quantum levels have a natural relationship to the nucleus, and it takes force to distort this relationship (Newton's Second Law.) Once constant velocity is achieved the distances are restored and no more force is required (Newton's First Law.) The moment while the force is being applied is illustrated in figure 6.

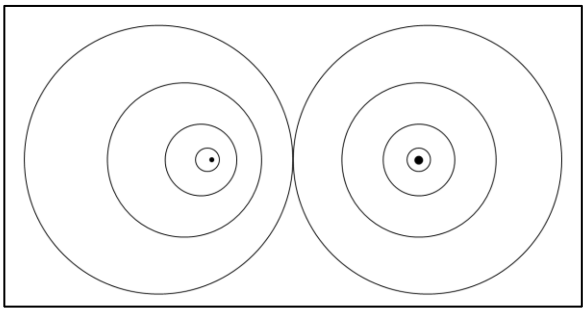


Figure 6. A larger atom pushes a smaller atom; both having electrons. The black dots in the centre are the nuclei. The relationship between the nuclei and their quantum levels is distorted, which is analogous to pushing on a spring: thus it requires force to move the atom. Not drawn to scale.

Now we can turn our attention to the earth and how a neutrino wave would be affected if the crust of the earth were made of atoms with particle bubbles.

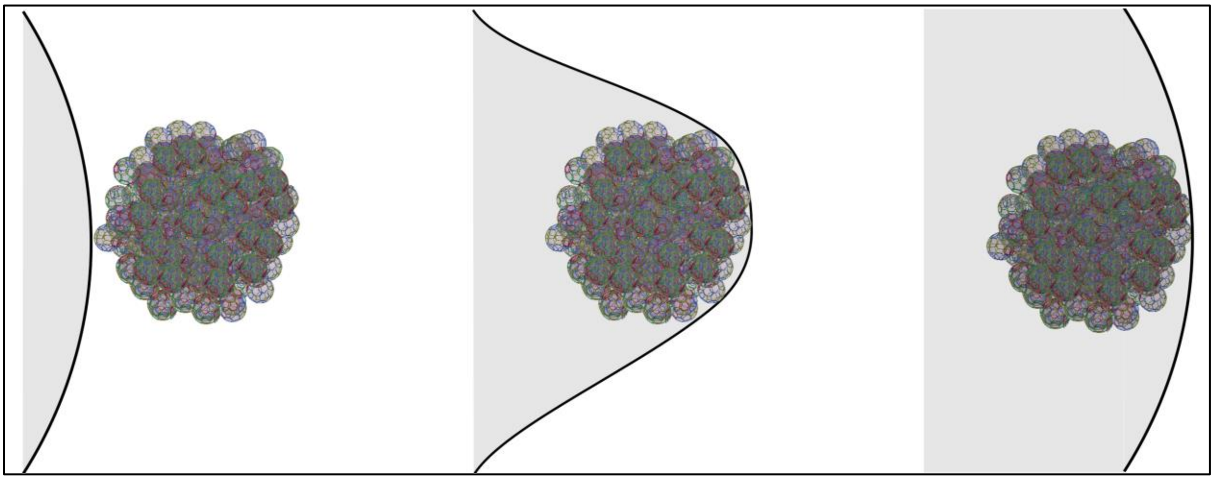
3. Light speed particle-wave passing through a solid

There are at least two types of particles. Larger particles like protons and neutrons seem to require a bracing structure on the interior of the particle skin. The smaller (lower formation energy) particles like photons and neutrinos do not to require an internal bracing structure when created as a bubble in space with a particle skin. We observe that these smaller particles are capable of passing through empty space at the speed of light, governed by the equation

$$c = \frac{1}{(\mu_0 \epsilon_0)^{0.5}} \quad (1)$$

where c is the speed of light in empty space, μ_0 is the permittivity of empty space, and ϵ_0 is the permeability of empty space. The key to understanding what is happening to the neutrino is that within the bubble in space that is the proton, there is no permittivity or resistance to the passage of a wave, so it traverses the interior of the proton *instantly*. This is a simple conclusion from the hypothesis that has otherwise served TNP well, that when a particle is created it forms a bubble in space.

Figure 7. The wave of a photon is shown passing from left to right through a nucleus in three panels. Not drawn to scale. If this had been drawn to scale the wavefront would have no visible curvature because it is so much larger than the nucleus. In the leftmost panel the wavefront is just encountering the nucleus. In the centre panel the wavefront has found no resistance to passage through the nucleus and appears immediately on the other side. In the final pattern the waveform is restored because any distortion away from the natural wavelength λ will meet with resistance. Because the nucleus is composed of an assembly of tightly packed bubbles in space, it has almost no internal resistance (permittivity or permeability) to the passage of the wave, so no measurable time passes as the wave transitions from the position in the left panel to the position in the right panel.



As bizarre as this suggestion may at first appear, it proves extremely instructive as we shall see. It is wise at this point (and always for that matter) to remember that this is only a model of reality, not reality itself, which might have behaviour completely different. Nonetheless we find this model informative, so please bear with us for a moment longer.

In developing this first order model we ignore any effect of the quark bracing structure on the wave, and we assume that neutrons behave the same way that protons behave in this regard. Another effect we are ignoring is the retarding effect on the neutrino of passing through the nuclear skin, which we think should have larger permittivity than a vacuum, due to the compression of space within the skin. These effects should be small but a more accurate model would include them.

Although this model is not extremely precise, we can still gain insight by considering its implications. We would like to understand how many nuclei might be exerting the effects of figure 7 on a neutrino wave at one time. The precise formation energy of the neutrino is not known; luckily the following discussion is not critically dependent on this precise number. Like the OPERA experiment we assume maximum neutrino formation energy of 2 eV which yields wavelength 6.20E-7 m by the equation in figure 2. Based on formation energy per unit volume from [5] of 7.24E-34 N/m^2 we have neutrino particle volume 4.43E-54 m^3, giving radius of 1.02E-18 m. It is clear from this that we could never draw figure 4 to scale spanning 11 orders of magnitude from 10^{-18} m for the radius of the particle to 10^{-7} m for the radius of the wavelength.

It is useful to grasp the physical reality of the situation. We have neutrinos with particle radius of 1.02E-18 m, protons of radius 0.84E-15 m, molecules of radius 3.4E-10 m, and a neutrino wave for each neutrino particle which has radius 6.20E-7 m. Taking for example the primary component of granite, Silicon Dioxide, each neutrino wave at any one time encloses 3.43E10 molecules if we use Kepler's Conjecture for densest packing [8] and a molecular radius of 1.73E-10 m.

The leading hemispherical surface area of the neutrino wave is 2.41E-12 m^2 since the wave's radius is the wavelength, 6.20E-7 m. If we treat this as a 2 dimensional circle, we can use the best packing density of small circles within a large circle: 90.7% [9]. The cross-sectional area of the molecule of radius 1.73E-10 m is 9.37E-20 m^2. Multiplying the packing density of 90.7% times the hemispherical surface area of the neutrino wave and dividing by the cross-sectional area of the molecule gives us at least 2.34E7 molecules on the leading surface of the neutrino wave. But at any one time the wavefront is not in contact with the nuclei of each of these molecules. For reasons considered later we ignore the Oxygen nuclei for the moment. To estimate the number of Si nuclei experiencing the effects of figure 7 at one time, we divide the diameter of the Si nucleus (5.95E-15 m) by the diameter of the molecule (3.45E-10 m) which gives a fraction of 1.72E-5. Multiplying this times the number of molecules on the leading surface of the neutrino wave we find that the wave is at any one point in time in contact with 403 of the nuclei. This appears to be a large enough number to propel the entire neutrino wave forward in the manner indicated by figure 7.

4. Computing the time gain

We don’t know what material is under the mountains between CERN and Gran Sasso. So we shall approach the problem from two directions. In the first case we shall consider the consequences of assuming the path to be filled with various single elements. This way we can determine if some elements work and others don’t. In next section we shall make some guesses about the composition of the crust of the earth under the mountains.

4.1. Elements producing the time gain

For an example atomic element we’ll start with Aluminium, which has the same density as the upper crust of the earth, 2.72 g/cm^3 [10]. If the smallest nuclei and the nuclear skin are excluded, an approximate formula for the diameter of the nucleus with A nucleons is given by [11, p.138]

$$r_A = 0.98\text{E} - 15\ (\text{A}^{1/3}) \tag{2}$$

For Aluminium (symbol Al) with 27 nucleons r_A is 2.94E-15 m, and assuming a mass of the neutron of 1.685E-24 g, we compute an atomic mass of 4.55E-23 g. We double the radius to get the nuclear diameter and divide it by the speed of light (299,792,488 m/s) to get a time gained per Al nucleus of 1.96E-23 s.

We do not know the precise distance between nuclei of the Aluminium atoms on our hypothetical path, but we know we want the density to be 2.72 g/cm^3. We can solve for the required nuclear separation as follows. We can postulate the radius of the atom to be the measured atomic radius of 1.43 Å [12]. The volume of the atom is given by the formula for a sphere of the postulated radius, giving 1.23E-29 m^3. The best packing of spheres into a cube is given by Kepler’s Conjecture to be $\pi/\sqrt{18}$ or 0.74 of the cubic volume to be occupied by spherical volumes. Dividing 0.74 m^3 by the volume of the atoms gives us the number of atoms in a cubic meter, in this case 6.01E28 atoms. Multiplying this by the atomic mass gives us the density of 2.72 g/cm^3. We take the cube root of the number of atoms in a cubic meter to get the number of atoms in a meter, or 3.92E9 atoms. Multiplying this by the distance gives us the number of Aluminium atoms between CERN and Gran Sasso: 2.86E15 atoms.

Multiplying the time gained per nucleus by the number of atoms on the 732 km path gives us 56.2 ns. We don’t think it a coincidence that this is close to the measured time gain of (57.8 ± 7.8) ns.

Al naturally has our suspected density of the path, but other elements of course have other atomic radii and densities. After setting the nominal atomic radius for an element to its measured atomic radius as a starting point, we use the goal seeking tool in Excel to find the nuclei separation that gives the required density of 2.72 g/cm^3 for the element. Whenever we do this, we find the resulting time gain is 56.2 ns.

This leaves us with the question: is the required nuclei separation realistic?

In Chart 1 we show the required nuclei separation for the most common isotope of each of the 70 elements (excluding noble gases) from Sodium (A = 23) through Polonium (A = 209). In all these cases the density was targeted to 2.72 g/cm^3, and the resulting time gain was found to be 56.2 ns.

In Chart 1 the required nuclei separation needed for this to be true for each of the elements is compared to some measured data on those elements. We would not expect the computed separation to be feasible if it were smaller than the smallest observed radius for the element. Of the 70 elements examined, this is true for only for Sodium and Potassium. Four other elements would return slightly smaller time gains if separated at their minimum (covalent) radii, but the gains are well within measurement uncertainty in OPERA.

In general we conclude that the amount of time gained by the neutrino in this idealized scenario is just about right no matter what element is involved on the path, as long as the density is near that of the upper crust of the earth. Only two elements need be excluded because the required density would be less than the covalent radius. We conclude the time gain observed is not critically dependent on the composition of elements on the path. This is encouraging, but not very realistic. It is unlikely that there is only one element on the path from CERN to Gran Sasso. Let's look more closely at what might really be the composition of the path under the Alps.

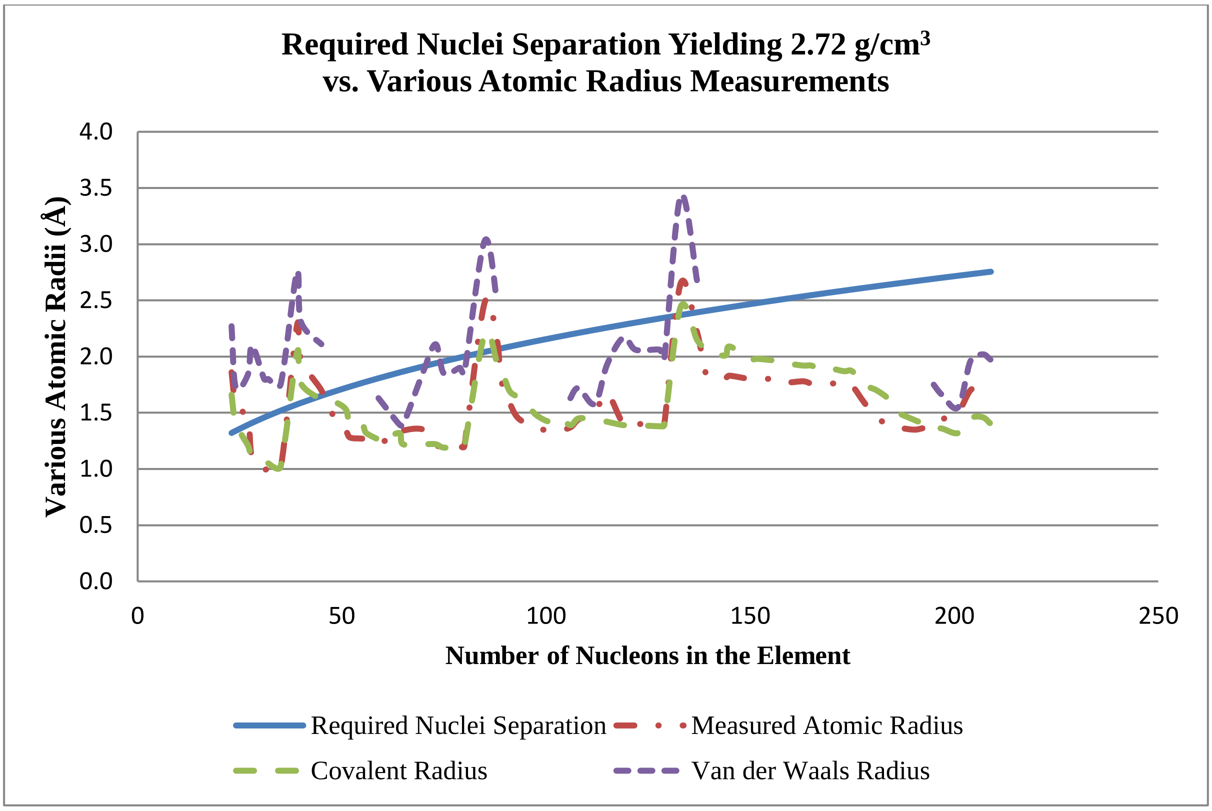


Chart 1. The nuclei separation required of a pure mountain of 70 elements, each considered in isolation, if the density were that of the crust of the earth and the time gained were that of the CNGS experiment. These are compared to other measurements of nuclei separation.

4.2. Characteristics of the earth's crust

One mountain whose density has been studied extensively is Schiehallion in Scotland [14]. Densities of various parts of the mountain, its subsurface and surrounds have been examined closely. When densities of the mountain's various constituent formations are averaged, they yield a nominal density of 2.73 g/cm^3. More dense formations do exist in the surrounding countryside, however. Furthermore the detailed geological density survey only goes to a depth of 1200 m, whereas neutrino is passing at a maximum depth about 11.4 km below the Alps (figure 1.) Even though Scotland is not the Alps, and the depths differ, the results are still encouragingly close to our previous density assumption.

The upper crust of the earth extends some 20 km beneath the surface, so it seems safe to continue to use its average density of 2.72 g/cm^3 [10] as the density of the material under the mountain. It turns out this is the average density of common granite, which we shall take as a representative material for our neutrinos to traverse.

Granite is composed of a number of compounds. Table 1 shows a worldwide average chemical composition of granite, by weight:

Table 1. Composition of worldwide average granite by weight.
Based on 2485 analyses [15].

Molecule	Percentage of Granite (%)	Density (g/cm^3)
SiO_2	72.04	2.65
Al_2O_3	14.42	4.03
K_2O	4.12	2.35
Na_2O	3.69	2.27
CaO	1.82	3.35
FeO	1.68	5.75
Fe_2O_3	1.22	5.24
MgO	0.71	3.58
TiO_2	0.30	4.23
P_2O_5	0.12	2.39
MnO	0.05	5.37

Using the weighted density of each of these compounds, the composite density would be 2.93 g/cm^3. This is higher than the average density of granite which is 2.7 g/cm^3. To attain the average density we have to assume the granite is only packed on average with 92.7% efficiency, which dilutes it to the target density of 2.72 g/cm^3.

4.3. Time gained by a molecule

Now that we know the density of each component, we can compute the number of molecules our neutrino beam will encounter between CERN and Gran Sasso. Let's take SiO_2 as our example; we will treat each component of granite with the same method.

The density of SiO_2 is 2.648 g/cm^3, but diluted by to 92.72% it is 2.45 g/cm^3. With an atomic number of 60, we multiply by the mass of the neutron (above) to get the atomic mass of 1.01E-22 g. Then we can divide this into the diluted density to get 2.43E22 molecules/cm^3. Taking the cube root and multiplying by 100 gives us 2.90E9 molecules per meter. Now we multiply times the distance between CERN and Gran Sasso to get 2.12E15 molecules in the path.

The nuclear diameter for Si is 5.95 E-15 m from Eq. (2). For O we derive an average diameter 3.42E-15 m in a moment. Dividing by the speed of light and accounting for two O atoms per molecule we have time gained per molecule of 4.26E-23 s. The total time gain is therefore 9.03E-8 s, were all the molecules on the path SiO_2. But this molecule is only 72.0% of the composition of granite so the real contribution from SiO_2 is 6.51E-8 s. (We intentionally ignore the case where the Oxygen atoms are aligned with the Silicon atom perpendicular to the path of the neutrinos. This would presumably result in a slightly lesser time gain but the additional accuracy will not prove helpful.)

Adding up all the contributions from the components of granite listed in Table 1 gives a total time gain of 1.08E-7 s, or 108 ns, where we wanted to see something between 50 – 60 ns.

We can abandon the entire model at this point, or we can appeal to our TNP model to rescue us. If it is a good model of the physical world, then we might be able to use it to help us understand what we have missed.

To this end we extended the work of [5] to look at the Oxygen atom. We find it has 44 Hexagonal caps and 28 Pentagonal caps, which give a mass defect (including electrostatic repulsion and magnetostatic attraction) that is 1.68% less than the observed mass defect. This improves the average absolute error of the TNP model of nuclear binding energy from Deuterium through Carbon plus Oxygen to 1.33%. A view from three dimensions of one physical model of the Oxygen atom with the required mass defect is shown in figure 8; it has an average radius of 3.42E-15 m:

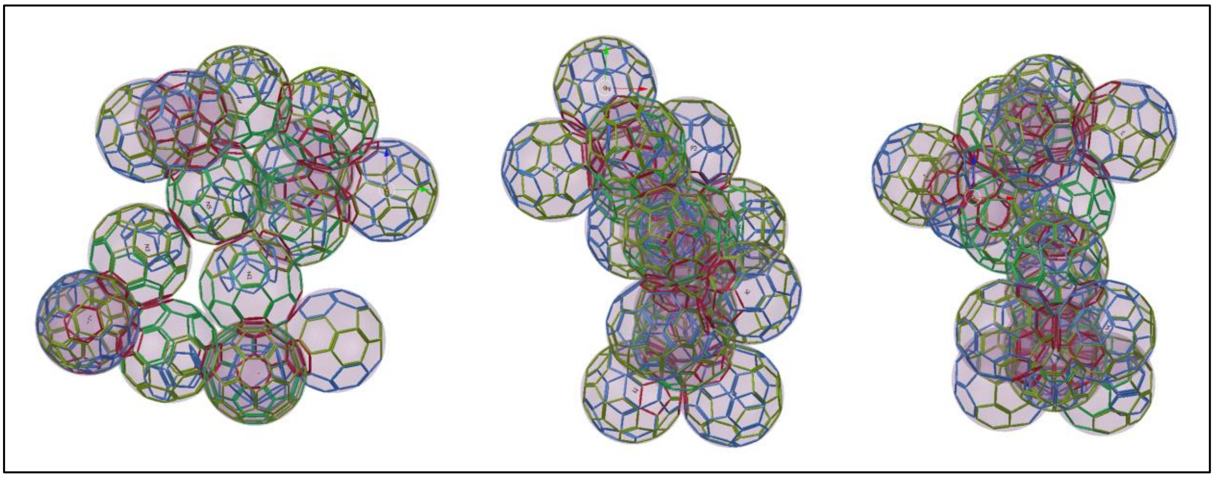


Figure 8. X, Y, and Z-axis views of a possible model of the Oxygen nucleus with binding energy within 1.68% of measurement. The darker hexagonal and pentagonal caps are those that are broken during nuclear fusion, resulting in the mass defect.

The striking thing about figure 8 is the asymmetric nature of the nucleus, a characteristic of the small atoms. It may be possible to create a model of Oxygen that has the proper mass defect and is more spherical in shape, but how to do this is not immediately obvious. One problem is that TNP shows that nuclei are constructed of alpha particles bound together, a conjecture (based on measurements) advanced previously by others [11, 13]. This means clusters of four nucleons are possibly roughly spherical but when bound together they do not in small numbers form a sphere. For example if you simply take two spheres and put them next to each other, the resulting composite structure is not a sphere; it looks more like a solid number "8". (An alternative shape for the alpha particle has all four nucleons in a plane, which seems to yield the most magnetically stable configuration although it has other issues. Even with this shape for alpha particles, the problem with combining small numbers of them (greater than two) into a sphere remains.)

The second problem is that when the alpha particles bind together, to yield the empirical mass defect a certain number of spherical caps of a certain type need to be consumed by the particles' quark structures touching each other; this constrains how the particles can be joined. For example to make Oxygen by adding an alpha particle to a Carbon nucleus, we need to consume 4 additional Hexagonal caps when putting the new alpha particle on the existing structure, yielding the correct mass defect to within 1.68%. This constrains the positions that will work; figure 8 is one such model.

So although we would like to have spherical nuclei because we think the nuclear skin would attain a symmetrical shape if it could, as noted in [5] this is not always possible. The hypothesis here is that this has an impact on the ability of the Oxygen nucleus to assist the neutrino to gain time under the mountain.

Leveraging our model we now ask the question, how much does Oxygen assist the neutrino to gain time? Given a target time gain of 57.8 ns, we find that if Oxygen nuclei only contributed the equivalent of 11.4% of their diameter to the neutrino wave's time gain, we would get the desired target time gain between CERN and Gran Sasso. The model therefore suggests irregularly shaped small nuclei do not have the same effect as larger, more spherical nuclei on the transit time of the neutrino. We acknowledge this may be difficult to verify.

We have to allow that there are other explanations that might permit Oxygen to participate more fully, but Silicon less than fully. The slightly non-spherical nature of even larger nuclei or the somewhat non-isotropic internal construction of the nuclei might either of them detract from the time gain. Perhaps the full time gain is only obtained at the thickest portion of the nuclei, being attenuated at the front and the back of the nuclei relative to the direction of travel of the wave. We have to admit we do not understand which of these many models is the most accurate. Nonetheless the amazing coincidence of the computed time gain with the observed time gain cannot be ignored. Hopefully over time a more accurate model of the factors at play will emerge.

5. Predictions

Other features of the model may be easier to verify experimentally. Perhaps the most counter-intuitive prediction our model makes is this: if density of the material transited remains constant, the amount of time gained by the neutrinos should increase linearly with distance. Gran Sasso is about 732 km from CERN. If instead it were twice as far or 1,464 km distant, and the underground density remained consistent with the current path, then we would expect a gain of 115.6 ns instead of the 57.8 ns observed at Gran Sasso.

Density plays a role as well. Suppose the entire 732 km path from CERN to Gran Sasso were made of pure Lead. Our model states that in this case we should see a gain in time of 90.8 ns. The gain in time is not linear with the density: because density relates to atoms per unit volume and the neutrinos take a linear path through the volume, time gained varies roughly with the cube root of the ratio of the densities.

Looking at this another way, recall that the assumed density of 2.72 g/cm^3 that we made initially resulted in a time gain of 56.2 ns. If instead of fixing the density, we fix the time gain at 57.8 ns and solve for density, we get a density of 2.98 g/cm^3. This is at the lower end of the range suggested for the lower crust of the earth [10]. It is also the maximum density of granite from Table 1. We know that in part the Alps were formed by elements of the lower crust of the African tectonic plate thrusting up against the Eurasian plate [18]. Therefore this prediction that the density of the neutrino path is greater than average for the upper crust of the earth cannot yet be readily dismissed. Actually the possibility of using neutrino beams to chart the geology of planetary interiors is enticing.

6. Conclusion

The New Physics previously presented a unified formula for the relationship between light, gravitation, and the nuclear strong force. It also provided simple models for the mechanism of gravitation, the equivalence of energy and mass, the mechanism of mass as evidenced by inertia, and the nature of the mass defect. Here it explains why neutrinos gain time on the vacuum speed of light when traversing underground.

In Quantum Mechanics it is Heisenberg's Uncertainty Principle that lies at the basis of the view that an event is either a particle or a wave depending on how it is measured, but not both at the same time. Recently this view has been questioned by empirical evidence to the contrary [17]. The TNP model supports the experimental result. In TNP the particle is a bubble in space and the wave is the resulting surrounding compressed space. Both particle and wave exist simultaneously and do not depend on the observational mechanism.

We have found that as long as the density of the material is consistent with that of the upper crust of the earth (about 2.72 g/cm^3), it does not matter which elements are on the path of the neutrinos: nearly all elements of the periodic table from Sodium through Polonium yield a time gain on the path from CERN to Gran Sasso of 56.2 ns, matching the observed value of (57.8 ± 7.8) ns. The separations of the nuclei that yield the target density are in most cases consistent with experimental data on atomic radii. A more accurate match to the data results if the density under the mountains averages 2.98 g/cm^3, possibly consistent with the geology of the region.

The model also makes the unexpected prediction that twice as long a path through the same density of earth will yield twice the time gain of the CNGS data. Similarly a denser material will yield an increase in time as well. Both of these predictions are experimentally verifiable.

The TNP model also retains the observations leading to Special Relativity, namely that in empty space the speed of light is a constant. It relies instead on the fact that the matter under the mountain is not empty space, but rather is made up of particles that push space aside and in so doing, create the opportunity for the neutrino wave to make a very large number of very tiny gains on the speed of light in empty space.

The entire TNP model provides a significantly simpler model of physics than the much more sophisticated model of Quantum Mechanics, but is too new to have attempted to explain all of the many observations that QM has been able to explain over the past century. More than one model can be developed to explain a set of phenomena. The best model is the simplest one that explains the widest set of observed phenomena. It must also be possible to use the model to enhance our understanding of the physical world, including making new predictions that can be verified experimentally. Eventually as our knowledge of the physical world matures, new models are put forth that explain new results and make new predictions. The place of TNP in this evolution is currently unknown, but it is off to a promising start.

Acknowledgements

Thanks to Thor Prohaska for his helpful comments on early drafts of this paper.

References

1. Migliozzi P, et. al., Measurement of the neutrino velocity with the OPERA detector in the CNGS beam, arXiv:1109.4897v2, 17 Nov 2011.
2. Einstein A, Zur Electrodynamik bewegter Körper, Annalen der Physik, **322** (10):891-921.
3. Ferrarri A, et. al., A search for the analogue to Cherenkov radiation by high energy neutrinos at superluminal speeds in Icarus, arXiv:1110.3763v2, 22 Oct 2011.

4. Physicist, E., The Mechanism of Quantum Gravity, https://NewPhysics.Academy, (accessed 22-02-28).
5. Physicist, E. The Mechanism of Nuclear Fusion, https://NewPhysics.Academy, (accessed 22-02-28).
6. Hudson J J, Kara D M, Smallman I J, Sauer B E, Tarbutt M R and Hinds E A, "Improved measurement of the shape of the electron", *Nature*, 2011; **473** (7348): 493 DOI:10.1038/nature10104.
7. Anderson P, "Plasmons, gauge invariance and mass." In: *Physical Review*. **130**, 1963, p. 439–442.
8. Hopkins A B., Stillinger F H, and Torquato S, Densest local sphere-packing diversity. II. Application to three dimensions, Physical Review E **83**, 011304 (2011).
9. Steinhaus H, *Mathematical Snapshots, 3rd ed.* New York: Dover, 1999, p. 202.
10. Looking Inside the Earth, Australian Museum Online, http://australianmuseum.net.au/Looking-inside-the-Earth/, Retrieved 18-12-2011.
11. Cook N D, *Models of the Atomic Nucleus*, Springer, The Netherlands, 2006.
12. Slater J C, Atomic Radii in Crystals, 1964 *Journal of Chemical Physics* **41** (10): 3199–3205. Bibcode 1964JChPh..41.3199S. doi:10.1063/1.1725697.
13. MacGregor M H, *Il Nuovo Cimento* A **36**, 113, 1976.
14. Smallwood J R, Maskelyne's 1774 Schiehallion experiment revisited, 2007 *Scottish Journal of Geology*, **43**, p 15-31; doi: 10.1144/sjg43010015.
15. Blatt H and Tracy R J, *Petrology* (2nd ed.). New York: Freeman, 1967, p. 66. ISBN 0-7167-2438-3.
16. Pohl R, et. al., The size of the proton, *Nature* 2010, **466**, 8, doi:10.1038/nature09250.
17. Kocsis, et al., Observing the Average Trajectories of Single Photons in a Two-Slit Interferometer, *Science* 3 June 2011: 1170-1173.DOI:10.1126/science.1202218
18. Stampfli G M and Borel G D. "The TRANSMED Transects in Space and Time: Constraints on the Paleotectonic Evolution of the Mediterranean Domain". In Cavazza W, Roure F, Spakman W, Stampfli GM, Ziegler P. *The TRANSMED Atlas: the Mediterranean Region from Crust to Mantle*. Springer Verlag, 2004. ISBN 3540221816.