J. Condensed Matter Nucl. Sci. 19 (2016) 46–55

Research Article

Off-mass-shell Particles and LENR

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Abstract

A recent and somewhat radical theoretical explanation for LENR is reviewed. It is based on variable mass theories of relativistic quantum mechanics that date back to the 1930s in works by Fock and Stueckelberg, and up to the present by many others. It explains a large number of observed anomalous effects in LENR by positing that nuclear rest-masses can vary in "nuclear active environments" in condensed matter settings. The varying masses modify the kinematic constraints of the nuclear reactions. It also offers a mechanism for enhancing electron screening and-or quantum tunneling rates, for allowing for resonant tunneling, and for modified radioactive decay rates by mass changes in the decaying isotopes.

Keywords: Horwitz-Piron, LENR, Nuclear anomalies, Stueckelberg, Variable mass

1. Introduction

There are a large number of experiments that cannot be explained easily or at all by conventional nuclear physics theory. These include most experiments from the LENR community along with a number of others concerning radioactive decay rates and other anomalous phenomena ([7,8] and references therein). Physicists have largely disengaged from this subject, although many study it secretly late at night, the problem being frustration over how these experimental results can possibly be true. If one reads enough of the experimental literature though, one begins to ask the mirror question - How can these experiments all be wrong? I found myself on this path and tried about a dozen ideas to explain and reconcile this dilemma over a number of years. Slowly, I felt cornered into the theory presented here, and in previous papers [7,8]. My conclusion was, and still is, that the only way the experiments can be explained is if the nuclear rest masses of particles are somehow varying in those "nuclear active environments" where the reactions are occurring. But how could that be? Aren't the rest masses fixed? Having been trained in theoretical particle physics, I knew that in relativistic quantum field theory, like the standard model of particle physics, the masses inside of Feynman diagrams – the "virtual particles" – can and do vary from their rest masses [50,49]. These particles are also called "off the mass shell" in the vernacular of particle physics for this reason. Actually, the standard model makes a very interesting prediction in this regard. It predicts that all interacting particles have some probability of being off the mass shell all of the time, even if the inter-particle interactions are very weak (just not exactly zero for all time).

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This conclusion follows from the fact that Feynman integrals, the building blocks of perturbative solutions to quantum fields, involve integrations over the masses of particles in loops and in the interior portions of the diagrams, and since all particles in our universe have been interacting with other particles since the beginning of time and will continue to interact, they are always at least slightly virtual. In order to explain LENR, quite large off-shell deviations are required, often in the MeV range. These have never been directly observed, or expected. Thus this must be viewed as a highly speculative idea. I've proposed this theory because I see no other way to explain the experiments of LENR. I want the reader to understand this, and that I am not claiming that mass variation is in any way proven. I shall make arguments in favor of it, but proving that nature works this way will depend on future experiments.

Off-mass-shell behavior is an inherently relativistic effect. Usually it's associated with hgih velocity motion. In ordinary matter at near to room temperature we expect that the velocities of the particles to be non-relativistic, since otherwise the matter would not be stable. The usual relativistic correction factor of $\gamma = 1/\sqrt{1-\mathbf{v^2}/c^2}$ can be safely set to 1. Nevertheless, we consider the possibility that the rest masses can deviate from their usual values in some special systems. Inside of a Feynman diagram, consider a virtual particle with a 4-momentum P^μ. The velocity of the virtual particle (if it is timelike) can be taken to be $|\mathbf{v}| = c\left|\overrightarrow{P}\right|/\sqrt{P^\mu P_\mu}$ (I use the time-like metric signature here $(+,-,-,-)$). So it is possible for a virtual particle to have a slow velocity, but still go off the mass shell, since all values for P^μ are integrated over in the Feynman integral. Even though the motions of all the massive particles in a solid might be non-relativistic, we must still use a relativistic theory to examine this off-shell behavior. The laws of physics in a local Lorentz frame are Lorentz covariant to a high degree of accuracy (if we ignore curvature of space-time locally and gravity effects). The non-relativistic limit of the laws of physics, resulting in Galilean invariance, is only an approximation to this. So we should use a Lorentz-covariant theory, like the standard model of particle physics or quantum electrodynamics (QED), to study this sort of phenomenon. The problem is that this is very hard to do. We would prefer to use a relativistic wave mechanical theory, like Schrödinger's non-relativistic equation, to describe it instead, But the standard relativistic versions of wave mechanics, like the Dirac equation, Klein–Gordon equation, Proca equation, Rarita–Schwinger equation, etc. are all unacceptable as many body quantum theories because either their energy is not bounded from below, or they have negative probability states, or both. The modern view among particle physicists is that only a quantum field theory description is possible, and a wave mechanical particle description does not exist. Due to the complexity of the perturbation theory for the standard model in a solid, there exists no rigorous bound on how far the virtual masses can wander off-shell. Thus we are venturing into terra incognita, but I feel that the experiments require us to pursue this theoretical possibility.

The difficulties with developing a relativistic wave mechanics can be understood very easily. Relativity theory says that space and time are coordinates in a 4-dimensional manifold, and that they mix linearly under Lorentz transformations. So space and time are the same in some sense. But in quantum mechanics, time is a c-number parameter that precisely orders the evolution of causal history and events and therefore commutes with all the operators of the Hilbert space of quantum states, whereas the positions of quantum particles become non-commuting operators. So in quantum mechanics. time is very different from position. These two different requirements on the time variable produce lots of problems for relativistic quantum mechanics. The time variable is overloaded. This problem was recognized early on in the development of quantum theory, and a solution was proposed in the 1930s independently by Fock and Stueckelberg [13,47,46]. We discuss these theories more below.

2. The Time–energy Uncertainty Relation and Variable Mass

Some physicists might ask the following question.

In a solid, where the velocity of the particles are non-relativistic, the energy of a particle is simply given by $E \approx mc^2$. *But we expect an energy-time uncertainty relation of the form* $\Delta E \Delta t \approx \hbar$, *and therefore (taking* $c = 1$*)*

$\Delta m \Delta t \approx \hbar$. If the particle is stable, so it is lifetime is infinite, then we can take Δt to be ∞ and consequently why is not $\Delta m \approx 0$, i.e. on the mass shell?

Therefore, they expect weakly interacting particles to be always on the mass shell. This argument is reinforced by the fact that most of the time when we measure a particle's mass in condensed matter it is on the mass shell. I believe that the experimental evidence in LENR suggests that in very rare and special nuclear active environments, the masses are varying unexpectedly, and so let's examine the theoretical basis for this Heisenberg uncertainty argument a bit deeper.

First of all, the Heisenberg uncertainty relation deals with the uncertainty for E, it says nothing about the expectation value $\langle E \rangle$

$$\Delta E = \sqrt{\left\langle (E - \langle E \rangle)^2 \right\rangle}. \tag{1}$$

Second of all, the Heisenberg uncertainty relation is an inequality, and so for energy and time it would be

$$\Delta E \Delta t \geq \hbar/2 \tag{2}$$

and therefore, if $\Delta t = \infty$ all we can say is that $\Delta E \geq 0$, which is not a very significant result.

Third, the origin of the Heisenberg uncertainty is the canonical quantization rule $[p, q] = -i\hbar$, but time t in conventional quantum mechanics is a c-number which commutes with all the operators in the Hilbert space of states. Therefore the commutator$[E, t] = 0$. So how could there be a time-energy uncertainty relation? This unresolved question has occupied many articles over the years, a partial list being [5,3,6,9,26,43,36].

Finally, there is no acceptable relativistic wave mechanical theory, and so we can't even define a Hamiltonian or position operators covariantly for a many-body system.

Consequently, I conclude that the Heisenberg uncertainty principle argument against variable masses in a condensed matter setting are not conclusive or even relevant. We expect the nuclear active environment to be a non-equilibrium mixed-state quantum open system with complex morphology, unknown catalytic processes, and possibly with external electromagnetic fields, and proton, deuteron, and electron currents flowing in the material. In other words, it is basically a perfect storm of complexity about which it is very difficult to say anything with rigor and confidence. One thing we can say for sure though, and that is that the energy–momentum tensor density is conserved, since this is a property of the standard model, or any other relativistic model we might consider. Consequently, even though the mass of a particular particle may change, this does not mean that energy is not conserved. Just as in the Feynman diagrams of relativistic perturbation theory where the particles are off shell, the total energy and momentum are always exactly conserved.

3. Fock–Stueckelberg Covariant Wave Mechanics

The idea of Fock and Stueckelberg was to add a second time variable and make the space five dimensional (for a single particle) [13,47,46]. Sometimes these are called historical-time or proper-time models. The theory was utilized by Feynman, Schwinger, and Nambu [11,41,34]. For example, Feynman used it to carry out his path integration approach to quantum mechanics for the Klein–Gordon equation [11]. This is the simplest example of a historical time theory.

The usual Klein–Gordon equation is

$$(i\partial - A)^{\mu} (i\partial - A)_{\mu} \Psi = -M^2 \Psi, \tag{3}$$

where M is the particle's rest mass, and where A is the vector potential for an external classical electromagnetic field. The conserved current is $j_{\mu} = i\left[\phi^* \partial_{\mu} \phi - \phi \partial_{\mu} \phi^*\right]$, but j_0 takes on both positive and negative values, and so it cannot be taken to be a probability current. Moreover, a localizable Schrödinger type position operator cannot be defined for this equation in the sense of Newton and Wigner [35]. The idea is to add a second invariant time τ, and consider the modified Klein–Gordon equation

$$i\frac{\partial\varphi(x,\tau)}{\partial\tau} = \frac{1}{2}\left(i\partial - A\right)_{\mu}\left(i\partial - A\right)^{\mu}\varphi(x,\tau), \quad \text{where } x = \{x^0, x^1, x^2, x^3\}. \tag{4}$$

It is very similar to the time dependent Schrödinger equation, but with the "historical time" τ replacing the usual time variable t, and with the four coordinates of space-time x^{μ} replacing the usual three coordinates of space. Because of this, it is quite easy to formulate the path integral method for this system by following the same steps as used for the Schrödinger equation. Feynman points out that if A^{μ} does not depend on τ, then separable solutions exist so that $\varphi(x,\tau) = \Psi(x)\exp(i\frac{1}{2}M^2\tau)$ and ψ is the solution to the usual Klein-Gordon equation. Equations of this type were first studied by Fock and Stueckelberg. The path integral solution includes all paths in space-time connecting two space-time points and parametrized by τ, with no restrictions on the path, so that off-mass-shell paths are included in the path integral solutions. This reflects the fact that Feynman diagrams contain virtual particles which are not on the mass shell. Horwitz and Piron [19–23] extended the theory to multiple particles. This theory is no longer simply a reformulation of the standard quantum mechanics. It is now different, and in particular the off-shell behavior is much more prevalent. In the quantum version of this theory, the on-mass-shell state vectors are not complete in the whole quantum Hilbert space. Rather, off shell states are also required for completeness.

Another approach that has been taken is to develop a 5-dimensional generalization of QED, called pre-Maxwell theory, for which the Feynman diagram rules have been worked out and applied to various scattering processes [29,28].

So the assumption is that in the "nuclear active environments" of LENR, a variable mass theory such as one of these has become an effective theory for the solid state behavior. Perhaps this assumption can be derived from just the standard model of particle physics, exploiting its off-shell virtual particle qualities, but in the meantime we can take a phenomenological approach and try and deduce what experimental conditions seem to lead to off-shell behavior in LENR. More discussions along these lines were presented in [7,8].

4. Could the Standard Model of Particles Allow Large Virtual Mass Variations in Condensed Matter?

The standard model is believed by most physicists to describe all phenomenon observed in nature except for gravity [37,50]. Thus all of nuclear and condensed matter physics are believed to be derivable from the standard model. For example, the neutron–proton mass difference has recently been accurately calculated, and agrees with the measured value, by using lattice QCD plus QED [2].

The first question then is, are there any theorems that would rule out the possibility of large mass variations? The usual arguments based on the Heisenberg uncertainty relations, as we have seen above, are not conclusive on this point. There is the equivalence theorem in field theory which states that changing field variables will change off-shell Green's functions while leaving the S-matrix invariant [10,48]. But this does not prove that in condensed matter which is undergoing some arbitrary complex non-equilibrium process, that large excursions off the mass shell cannot occur and contribute significantly to the resulting probability amplitudes for different reactions. I have not found any theorem that rigorously limits off-shell mass excursions of this type in condensed matter that would be relevant.

In quantum electrodynamics, charged particles do not have a simple fixed mass due to the interaction with infrared photons as in [16,4,33] and references therein. Charged particles continually interact with massless infrared photons, and therefore cannot be assigned fixed masses. The charged particle surrounded by its cloud of infrared photons is called an infraparticle. This infrared problem poses an interesting and as yet unsolved challenge to QED and the standard model. When you consider these results in the framework of an interacting, non-equilibrium condensed matter system, it seems quite plausible that in some special circumstances a large mass variation for charged particles may be possible. Perhaps, in some approximation, the Fock–Stueckelberg models might describe such an interacting infraparticle.

We can say for certain that the Fock–Stueckelberg type of models are compatible with the basic principles of relativity and quantum mechanics, and that they do allow for large mass variation. It is conceivable that in some special circumstances in a solid, the matter there might be better described by them rather than by the usual Schrödinger theory. What environmental conditions are required to bring about such a state of matter? I do not know, but the experiments of LENR shed some light on it. The nuclear active environments tend to occur near the metallic surface, in non-equilibrium situations, possibly in cracks or crevices, and in the presence of fluxes of deuterium, hydrogen, and electrons through the metal. External stimulation with electrical, optical, or other stimuli of the metal often helps, as do catalytic elements.

5. Enhanced Tunneling Rates Caused by Increased Electron Masses

In the Born–Oppenheimer approximation for molecules and solids, the size scale is determined by the inverse of the electron mass [7]. Therefore, an electron mass increase will reduce the inter-nuclear distance, and greatly enhance quantum tunneling and fusion rates. This is a form of electron screening. The enhancement of deuterium fusion in a D_2 molecule was rigorously quantified by Koonin and Nauenberger [27], where it was shown that a mass of ten electron masses was necessary to explain the reaction rates measured by Fleischmann and Pons, and a mass of five electron masses was needed to explain Jones' results. With simply a large electron mass, one cannot explain the discrepancy in the branching ratio, but with a simultaneous reduction in the deuterium mass, one can explain that as well, and in this case the electron mass increase factor can be much smaller than 10 since the resonant tunneling effect greatly enhances the fusion rate [7]. An electron mass increase factor of 5 is sufficient to explain the results of Jones, and this could be adequate, when combined with resonant tunneling, to explain the excess heat experiments that have been observed [7].

Another form of tunneling which might have been observed in some experiments is neutron transfer. In a test of the commercial E-Cat reactor [30] it was reported that the fuel consisting of powder containing nickel and lithium in their natural isotopic ratios, was modified by the reaction and that the ash consisted mainly of lithium-6, most of the lithium-7 having apparently lost a neutron, and the only isotope observed in the ash of nickel was nickel-62, the heaviest stable isotope. So apparently the neutrons from lithium-7 had been transferred to nickel isotopes. Neutron tunneling has been proposed as an explanation for this [15]. If electron masses were to increase in a molecule binding together lithium and nickel atoms, then the tunneling rate could increase by many orders of magnitude. Therefore, this neutron transfer mechanism seems quite plausible as a candidate for explaining these results provided that masses can vary in this way. I take this experimental result as quite tentative though.

6. Some Anomalous Nuclear Reactions that can be Interpreted as Allowed by Mass Variation

Most of the nuclear anomalies that have been observed in LENR experiments and elsewhere cannot be explained by conventional nuclear physics. I believe that they can all be interpreted as being enabled by variable mass behavior. So, here is a partial list of various effects and how they can be explained. I do not claim that these experimental claims are all correct. I do think that there is some non-zero probability in the Bayesian sense that any of these experiments might be true though, and since they are persistently reported in the literature I have tried to explain them.

(1) Deuterium fusion $\mathrm{d}+\mathrm{d} \to \alpha$. This reaction was studied in detail in [7]. It takes place between two neighboring deuterons in a palladium lattice. The electron mass must increase for at least one electron which is binding the two deuterium particles together, and the deuteron masses must subsequently decrease. When the two deuterons, imagined as continuously going off-shell in [7], reach a combined mass which is very close to the

mass of an alpha particle, a resonant tunneling effect can be expected to occur, and this gives the observed behavior of Pons and Fleischmann. Fusion is enabled by mass-tuned quantum tunneling in this picture, but only excess heat is produced.

(2) In the Widom–Larsen theory [51] it is argued that protons and "heavy" electrons can react to form a neutron and a neutrino $\mathrm{e} + \mathrm{p} \rightarrow \mathrm{n} + \nu_{\mathrm{e}}$ at near room temperatures, because the electron's rest mass has increased. The neutron activation caused by the presence of these neutrons then can produce nuclear reactions. The general variable mass theory contains this Widom–Larsen effect as a special case. We allow masses for all charged particles to decrease as well as increase, unlike Widom–Larsen, and this leads to many more reactions being possible.

(3) Oppenheimer–Phillips processes whereby a deuteron gives up a neutron to a metal nucleus through quantum tunneling. This effect has been advocated by Passell [38]. Enhanced electron screening is required for the cross sections of these reactions to be large enough to account for observed effects. Increased electron mass would provide such a mechanism.

(4) Neutron transfer involving two deuterons $\mathrm{d} + \mathrm{d} \rightarrow \mathrm{p} + \mathrm{t}$. This reaction would be made possible by an increased electron mass which would increase the electron's screening ability, along with possibly a variation in the deuteron mass to allow for resonant tunneling of the neutron when the summed mass of the two deuterons were to equal the sum of the on-shell masses of the proton and tritium. This reaction could help explain why there is much more tritium observed in Fleischmann–Pons type experiments than neutrons [45].

(5) The 'Reifenschweiler effect' [40] is the observation that the beta-decay rate of tritium (half-life 12.5 years) is reduced reversibly by about 25–30% when the isotope is adsorbed into 15 nm titanium-clusters in a temperature window between 160–275°C. Remarkably at 360°C the original radioactivity reappears. First discovered circa 1960/1962 at Philips Research, Eindhoven. The reported decay rate reduction can be explained if the tritium mass and consequently the kinematic phase space for the decay were reduced [8]. Since the Q for tritium decay is about 18.6 keV, if the mass of the tritium drops by this amount, its decay rate would go to zero.

(6) Other radioactive decay effects that might indicate mass variation [8]. Radioactive isotopes implanted into metals at low temperature $\sim$12 K show variations of decay rates in some cases, which could be due to enhanced electron screening, which in turn could be due to mass variation [31,32,14]. These results have not been completely reproducible so far, and the theory proposed based on conventional electron screening has been criticized. It is another controversial LENR phenomena .

(7) Time varying radioactive decay rates may indicate mass variation [8]. Experiments show decay rates varying with time for a number of isotopes. Frequency analysis has shown annual, diurnal, and approximate monthly variations [12]. Once again, these results are controversial. It has been suggested that solar neutrinos might be the cause of this decay-rate variation.

(8) With varying particle masses, transmutations can in theory at least occur in a number of ways in nuclear active environments. Enhanced electron screening caused by electron mass increases can modify alpha decays, beta decays, and electron capture rates. Mass changes of nuclei can change reaction rates or make reactions possible which would normally be forbidden. Resonant fusion of hydrogen or deuterium with other nuclei, resonant fusion of alpha particles and other nuclei, and even fission of heavier nuclei might occur after a mass change. Also, there is the possibility of neutron creation and subsequent capture as in the Widom–Larsen theory, or neutron stripping or hopping reactions, leading to many possible transmutations. In short a world of possibilities exist, and a managerie of transmutations have already been observed experimentally in LENR [44,45]. The number of transmutations observed in LENR are so large, that many scientists have concluded

that it is proof that the experiments must be wrong. But maybe not, given the multitude of processes made possible by variable masses.

More details may be found in [7,8].

7. Suggestions for Experiments to Test the Variable Mass Idea

If radioactive nuclei are placed into the nuclear active environments, their decay rates should change if their masses change, and this might be observable by monitoring the real-time radiation during an experiment. Probably gas loading experiments would be the easiest ones to monitor in this way, and some imaging capability would be desirable because the nuclear active environments tend to be very localized on the surface of the metal. Tritium is an excellent candidate to serve as a tracer element to reveal mass variations of hydrogen isotopes. Tritium can be added to deuterium or hydrogen in LENR experiments. The tritium in the nuclear active volumes should experience a mass change like deuterium if the variable mass theory is correct. This should be detectable as a change in the tritium decay rate in those zones while they remain in a nuclear active state. Other radioactive isotopes might be tried as well. A replication of the Reifenschweiler experiments would be very desirable too.

8. Implications for other Theories of LENR

The possibility of variable mass does not rule out any of the other prevalent theories of LENR, but actually can provide a mechanism for them to be valid. For example, the Widom-Larsen effect is enabled by the type of variable mass behavior we are contemplating here. Also, the collective interaction of the lattice with the nucleus as proposed by Hagelstein [17,18], Preparata [39], and Schwinger [42] could be understood as mediated by mass variation over an extended time leading up to the nuclear reaction. The lattice could slowly take up or give up energy to the nuclear environment as the masses of some of its particles changed prior to a nuclear reaction. There are a number of theories which rely on the existence of small atoms which can be understood if electrons can increase their mass. A theory due to Kim proposes a Bose–Einstein mechanism [25], and the existence of such a state of matter might be enabled by resonant tunneling as in [7] where deuterium resonant tunneling was enabled by mass reduction of the deuterium particles.

9. Choices for Physics

As I see it, physics should re-engage in a serious way with this subject. Here are the choices facing mainstream physics: (1) Dismiss the experimental claims and the entire field of LENR (more than 1500 international research papers); (2) Do nothing, but wait and see what happens next; (3) Continue to try and explain the claims with existing theories after 24 years of failed effort; or (4) Develop a new theory, based on relativistic quantum mechanics, that modifies existing theory and explains the experiments. Obviously I prefer the fourth choice.

Much of modern physics has separated from close laboratory experimental feedback. Fields like quantum gravity, string theory, interpretations of quantum mechanics, emergent theories of gravity, etc. are examples. Here, with LENR, we have a large discrepancy between theory and experiment which may require a fundamental modification of our theories for nuclear physics and condensed matter, and we also have lots of laboratory feedback to aid us.

If off-mass-shell quantum mechanics is needed in order to understand LENR results, then our understanding of quantum mechanics will be affected at a fundamental level. The standard on-shell wave equations would have to be considered then as approximations to more general off-shell theories. The standard relativistic wave equations (Klein–Gordon, Dirac, Proca, etc.) all have problems with a localized position operator, or negative energies, or negative probabilities. Thus, modern physics regards quantum fields as preeminent over wave mechanics. But a resurgence of the Fock–Stueckelberg theories could change this, and make wave mechanics prominent once again. The practical implications if LENR is real are obviously potentially enormous. Only the re-engagement of the physics community will allow the full promise of this technology to be realized. The downside monetary risk of coming up dry seems insignificant compared to the potential benefits both to mankind and to fundamental physics. What gambler would not take this bet? Even if all the experiments in LENR turn out to be wrong, physics could still benefit if by examining this issue we can learn to engineer the control of rest masses. This would then open doors to finding new ways to make LENR devices and provide a powerful tool in chemistry and condensed matter physics.

10. Conclusion

We have listed here some of the anomalous LENR reactions which have not been explained by conventional nuclear physics. If nuclear rest masses can vary in special nuclear active environments, then all of these reactions can be allowed with the right mass variation.

After surveying the literature on mass variation in relativistic physics, the historical time models pioneered by Fock and Stueckelberg are prominent. The modern refinements of this theory especially by Horwitz and co-workers stand out as the most likely candidate theories around which to construct a model for LENR. The task before us is to try and quantify what physical effects cause a nuclear active environment to come into existence.

The theories for mass variation are not yet complete. In particular, we do not have a theory which interpolates between theories in which the rest mass is quite freely variable, like for instance pre-Maxwell theory, and ones that have fixed mass, like conventional QED or the standard model applied to few particle systems. I have in mind a new phenomenological parameter that would depend on position inside a material and control how easy or hard it is for particles to drift off the mass shell. In ordinary matter or in vacuum, this parameter would make deviation from standard rest masses exceedingly small, but in the nuclear active environments it would allow significant deviation of mass from the expected value.

Many of the objections to LENR experimental claims in the past were based on the fact that neutrons and tritium were not observed in experiments involving deuterated palladium in the proper amounts, energies, and ratios as deuterium fusion would require [1,24]. If masses of electrons and deuterons can vary, then this not a valid justification for rejecting these results out of hand. So, if one is to rule out a theory like this one, the change in the ratios of tritium to neutrons or their energies cannot be used to dismiss experiments. Rather, they might be viewed as experimental evidence in support of variable masses.

Much of modern physics has separated from close laboratory experimental feedback. Fields like quantum gravity, string theory, interpretations of quantum mechanics, emergent theories of gravity, etc. are examples. Here, with LENR and related anomalies, we have a large discrepancy which may be resolved by a fundamental modification of our theories for nuclear physics and condensed matter, and we also have lots of laboratory feedback to aid us. It seems that physicists ought to re-examine this subject in the light of these new developments, and determine with certainty whether or not the nuclear anomalies are real.

Acknowledgments

I would like to thank Larry Horwitz, Martin Land, Peter Hagelstein, David Nagel, David Katinsky, David Kidwell, Michael McKubre, and Tom Grimshaw for valuable conversations and correspondence, and Antonio LaGatta and TSEM for their hospitality as hosts for ICCF19.

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