# Beta decay as a virtual particle interaction analogous to Hawking radiation

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**Abstract**

The existing theory of the weak interaction has some troublesome issues with conservation of energy and limited range. Beta decay theory would be more complete if there were a mechanism that places the electron or positron decay product farther from the proton or neutron so that they would not be immediately reabsorbed. This is readily accomplished by a Hawking radiation type interaction between a virtual electron-positron pair and a proton or neutron and this type of interaction readily accounts for each form of beta decay.

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## Introduction

Beta decay has always been problematic to physicists, as it cannot be accounted for within the scope of classical electromagnetic theory. That theory does not include a mechanism to account for nuclear decay and does not account for the fact that the beta particles have a continuum of energies. In a letter to some colleagues in 1930 Wolfgang Pauli speculated that an electrically neutral particle, which came to be known as the neutrino, could take away the remainder of the energy, thus adjusting for the energy continuum. The neutrino theory was soon formulated in much greater detail by Enrico Fermi.[1] This beta decay theory was grouped with a number of other mostly nuclear scale interactions into what was termed the weak force or weak interaction.

While the neutrino theory provided a mechanism accounting for the excess energy, it did not satisfactorily address why there was a continuum of energies in the first place. In an intuitively ideal scenario the beta particle would have a fixed amount of kinetic energy equal to or a fixed fraction of the total energy. Instead, the beta particles have a broad range of energies starting at the maximum, peaking somewhere near the middle and tailing off near zero. The energy difference between the maximum and any given beta particle is then carried by a neutrino or antineutrino. That explanation, however, does not explain why there is a continuum and additionally it does not satisfactorily address how and why the particles decay. In order to address the later problem, electroweak theory was developed whereby these weak interactions occurred due to the mediation of W and Z particles.

## W and Z Particle Theory

The difficulties with electroweak interaction theory begin with those particle's mass-energies. The $W^+$ and $W^-$ have a mass energy of 80,398 MeV and the Z is somewhat greater, but they are said to be emitted from quarks with substantially less mass-energy. In order to not violate the principle of conservation of energy the $W^+$ and $W^-$ must be

virtual. In other words they must exist for less time than is necessary for them to be measurable as quantified by Heisenberg's Uncertainty Principle. Even though free $W^+$ and $W^-$ particles are known to have very short half-lives that means that they can only exist for $1.3 \times 10^{-26}$ seconds in order to not violate Heisenberg's Uncertainty Principle as it applies to delectability. That gives a maximum range of motion of slightly over $3.8 \times 10^{-18}$ meters assuming a velocity of the speed of light.. If we compare that range to the charge radius of a proton per CODAT 2010 of $0.8775 \times 10^{-15}$ meters, the $W^+$ and $W^-$ Range is ~230 times smaller than the radius of a proton, and similarly smaller than a neutron. A $W^-$, for example, would decay well inside the proton in the vast majority of cases, so unless the electron has sufficient energy, equal to or greater than the total energy released by neutron decay of hundreds of keV, then it will be recaptured. Even if an electron were released at the surface of a proton, it would still need the same amount of energy to avoid being recaptured.

If the W particle is a virtual particle, however, how can it give up energy without once again violating the principle of conservation of energy? Furthermore, if a virtual W particle decays into a permanently stable particle such as an electron, conservation of energy has already been violated. The only way out of this conundrum is to presume the W and Z particles take some quasi-virtual state. The vast majority of the rest mass-energy must be in a virtual form to prevent the violation of the principle of conservation of energy, while a small amount of additional mass-energy must be non-virtual and be available to be contributed to the mass-energy of a stable particle along with its kinetic energy. The model of a single particle with a combination of virtual and stable energy is a highly questionable concept because of the violation of conservation of energy, and yet that is what the current electroweak theory asks us to believe. There is also still the question of why beta particles are emitted with a continuum of energies. Taken together there are enough questions about the current theory of beta decay that it makes sense to find additional mechanisms to fill in the gaps in the theory, if not replace it in its entirety.


**The Hawking Interaction**
Stephen Hawking came up with the idea that a vacuum fluctuation, a virtual particle-antiparticle pair, that comes into existence near a black hole can be partly absorbed by the black hole when one particle of the pair crosses the black hole event horizon leaving the other outside.[1] When that occurs the virtual particle pair cannot recombine and consequently the black hole loses energy as the now free particle leaves the vicinity of the black hole. Consequently a black hole radiates energy through a mechanism that became known as Hawking radiation.

We can similarly consider what happens when a vacuum fluctuation, consisting of a virtual electron-positron pair comes into existence near a neutron. A neutron is known to form when an electron is sufficiently energetic and gets very close to a proton. Similarly a free neutron decays into a proton and electron with an average half-life of ~10 minutes. For the purpose of determining the most simple possible neutron decay interaction it is then useful to think of a neutron being an electron collocated with a proton, neglecting for the moment quark decay mechanisms. Now if we have a virtual

electron-positron pair next to a neutron we can see that the virtual positron may annihilate with the electron part of the neutron. This is analogous to a virtual particle being absorbed by a black hole as it prevents recombination of the virtual particle pair. That leaves a free proton in place of the original neutron, with the once virtual electron becoming free at some distance from the proton. That distance is related to the virtual electron-positron wavelength, as is the newly freed electron's energy.

Because the virtual electron-positron wavelength is large relative to the size of the proton, the electron is free and clear of the proton, and unlikely to be reabsorbed. Note that the virtual electron-positron pair wavelength at the pair production energy, 1.022 MeV, is $6.07 \times 10^{-13}$ meters, nearly 700 times the proton radius. It is not necessary for the virtual particle pair to be at the pair production energy, since as with Hawking radiation, the now free electron has the annihilated electron's rest mass-energy, plus what is left of the virtual energy, and energy released due to the decay. If the particle pair energy were only 0.01 MeV, then the wavelength would be $6 \times 10^{-11}$ meters, which is slightly greater than the Bohr radius of a hydrogen atom.

Such an interaction easily explains the beta energy continuum as the energy of the vacuum fluctuations participating in such an interaction covers a range of energies. The beta energy decay curve flattens out at ~750 keV in the upper range and reaches a maximum at nearly 300 keV energy.[3] When initiated by a Hawking interaction the beta energy is equal to or a function of the vacuum fluctuation energy, while the height of the curve at a given energy depends on the interaction probability. The neutrino theory is still the likeliest explanation accounting for the difference between the beta particle energy and the total energy of the interaction and conservation of momentum. If the beta particle energy is equal to the virtual particle pair energy, then if for example a virtual electron-positron pair has 400 keV of energy initially, the neutron decay product would be a 400 keV beta along with an antineutrino and a free proton.

The same type of Hawking interaction occurs when the neutron is within a nucleus. Beta decay generally occurs in cases where a nucleus has too many neutrons to be stable and is thus able to give up sufficient energy for a neutron to decay. This decay is still mediated by a virtual electron-positron pair, which appears out of the vacuum adjacent to the nucleus so that the virtual positron annihilates with the electron component of a neutron. This leaves a free electron at some distance from the nucleus with enough excess energy given to it by the nucleus that it becomes free of the atom and radiates outward.


**Electron Capture and Positron Emission**
Another common form of beta decay happens when a nucleus is unstable because it has an excess of protons. In this case a proton may capture an orbital electron turning the proton into a neutron. The nucleus provides the 600+ keV of energy a free electron needs to approach a proton, plus the additional energy of the decay products. The question has always been, how does an orbital electron gain many times its orbital energy so that the two can combine? The Hawking interaction provides a simple and elegant explanation for electron capture and overcomes that problem, as the positron from a virtual electron-

positron pair annihilates with an orbital electron depositing a now stable electron near the nucleus where it can be absorbed by a proton. A neutrino and one or more photons must still be emitted to balance the energy and momentum per the usual formulae. In the case of positron emission a virtual electron-positron is close enough to a proton in the nucleus so that the electron gets captured leaving the positron free. The nucleus provides the positron's energy allowing it to escape the atom.


**Virtual Proton-Antiproton Interactions**
These reactions can also be thought of as virtual proton-antiproton mediated interactions. If an antiproton from a proton-antiproton pair interacts with a neutron, then the part of the neutron that equates to a proton will be annihilated leaving behind a free electron and a new proton deposited off to the side. The energy of proton-antiproton pair at the pair production energy is 1.877 GeV, which equates to a wavelength of $0.33 \times 10^{-15}$ meters, roughly a third of the proton radius. The range of interaction for a proton-antiproton mediated interaction is much smaller than with the electron-positron mediated interaction, but it could be sufficient enough in some cases where the virtual proton-antiproton wavelength is longer or the energy of decay is greater so that the electron and proton do not recombine. The proton-antiproton mediated interaction accounts for a second mode of beta decay as is sometimes present. Note that current theories do not do a good job explaining two modes of decay either. In cases where virtual proton-antiproton interactions do not cause decay they make the nucleus appear to vibrate.


**Orbital Transitions**
Another long unanswered puzzle of atomic mechanics is how does an electron instantaneously jump from orbital to orbital? When electrons make theses jumps they appear not to accelerate or decelerate while moving at or near the speed of light. There is only a single photon emitted with energy equal to the difference in energy between orbits, when there would be many photons emitted if there where gradients of acceleration and deceleration. Of course orbital transitions are a lot like electron capture without the capture. Orbital electron transitions must also be mediated by virtual electron-positron pairs. The virtual positron annihilates with the orbital electron and the newly free electron appears in another orbital. A photon is emitted for the energy difference if it has moved to a lower energy orbital. It is possible for an electron to move to a higher orbital if a photon of the exact energy of the difference in orbital energies is absorbed.

Even more generally the appearance of electron orbits as probabilistic clouds is readily accounted for by the same Hawking interaction. At the quantum scale, when electrons move distances that are a similar size or smaller than the electron's Compton radius, they move due to virtual electron-positron mediated quantum jumps.

**Conclusion**

A Hawking interaction that is analogous to Hawking radiation yields a logical and intuitive mechanism explaining beta decay, electron capture, positron emission, and neutron decay. As with Hawking radiation, half of a virtual particle pair is captured allowing the other half to be freed. When this occurs adjacent to a nucleon, the virtual particle pair can either annihilate the electron component of a neutron or produce a neutron by combing an electron with a proton. This is a simpler and a more fundamentally intuitive way of explaining the quantum jumps across distances than the existing W and Z model without violating conservation of energy. Additionally it meets the requirements for explaining orbital motion and orbital transitions of electrons. It is also important to recognize that this interaction theory has essentially the same probability of being correct as Hawking's theory of radiation from a black hole.

More generally a virtual particle-antiparticle interaction provides a mechanical description of all movement at the quantum level, for all types of particles. At the same time it is fundamentally consistent with quantum electrodynamic theory such that it cannot be considered an independent force or interaction.

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[3] A.R.Young et al, The UCNA Experiment: Recent Progress, 6th International UCN Workshop, 5 July 2007, Saint Petersburg, Russia. http://cns.pnpi.spb.ru/6UCN/articles/Young.pdf