Generalized Quantum Impedances: A Model for the Unstable Particles

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The discovery of exact impedance quantization in the quantum Hall effect was greatly facilitated by scale invariance. Both follow from the application of the Lorentz force to a two dimensional ballistic current carrier. This letter speculates upon the possibility that quantum impedances may be generalized, defined not just for the Lorentz force, but rather for all forces, resulting in a precisely structured network of scale dependent and scale invariant impedances. If the concept of generalized quantum impedances correctly describes the physical world, then in quantum physics such impedances govern how energy is transmitted and reflected, how the hydrogen atom is ionized by a 13.6eV photon, or why the π_0 branching ratio is what it is. An impedance model of the electron is presented, and explored as a model for the unstable particles as well.

INTRODUCTION

One might divide the quantum impedances into two categories. The first would have but one member, the only massless particle that has been experimentally observed - the stable photon. The second category would contain all the massive particles, stable and unstable.

In the **first category**, the photon impedance is divided into the scale invariant far-field impedance of the coupled electric and magnetic flux quanta and the scale dependent near-field impedances of the decoupled electric and magnetic flux quanta. They decouple in the near field in the process of delivering their energy to the electric and magnetic impedances of the electron [1].

The photon far field impedance is defined in terms of the ratio of the magnetic permeability to the electric permittivity as [2]

$$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \simeq 376.73\Omega$$

The photon impedance is strictly electromagnetic. Unlike the massive particles, the photon has no mechanical impedance. Both far and near field dipole impedances [3] of a 511KeV photon are plotted in figure 1. Also plotted is the quantum Hall impedance. The $\frac{1}{2\alpha}$ ratio of the electron impedance to the far field photon impedance is a prominent feature of the figure.

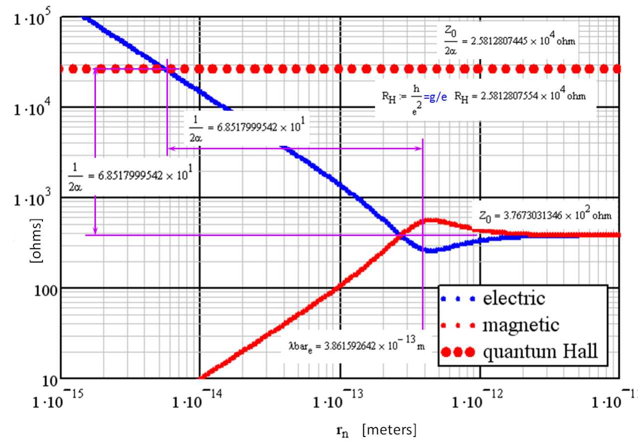

FIG. 1. photon and electron impedances

In the **second category**, that of the massive particles, the obvious place to begin is the electron. In the literature the quantum impedances of the electron comprise both the one-dimensional Landauer impedance [4–7] and the two-dimensional quantum Hall impedance [8, 9].

The scale invariance of these quantized impedances is perhaps easier to understand in the **two dimensional case**. The electron wave packet overlaps and coheres with itself as it executes circular cyclotron motion in the presence of an applied magnetic field. The cyclotron frequency varies inversely with the radius of the orbit. Taking the orbit to be in some sense a ring, the inductance of a ring varies directly with the radius. The product of frequency and inductance is then the scale invariant impedance. In classical electromagnetism inductance is a geometric property of material bodies. A current has no inductance. The existence of quantum impedances suggests that the properties of inductance and capacitance are somehow encoded in the wave function.

Similar reasoning applies to scale invariance in the **one dimensional case**. However, visualizing the self-coherence is more difficult, as the front of the wave packet never overlaps the rear. Despite this fundamental topological difference, they are numerically identical:

$$Z_H = \frac{h}{e^2} \simeq 25\,812.8\Omega$$

This definition of both the one and two dimensional quantized electron impedances explictly contains only electric charge and angular momentum, in the form of Planck's constant. It is in some sense an electromechanical impedance of the electron. It provides one of the es-

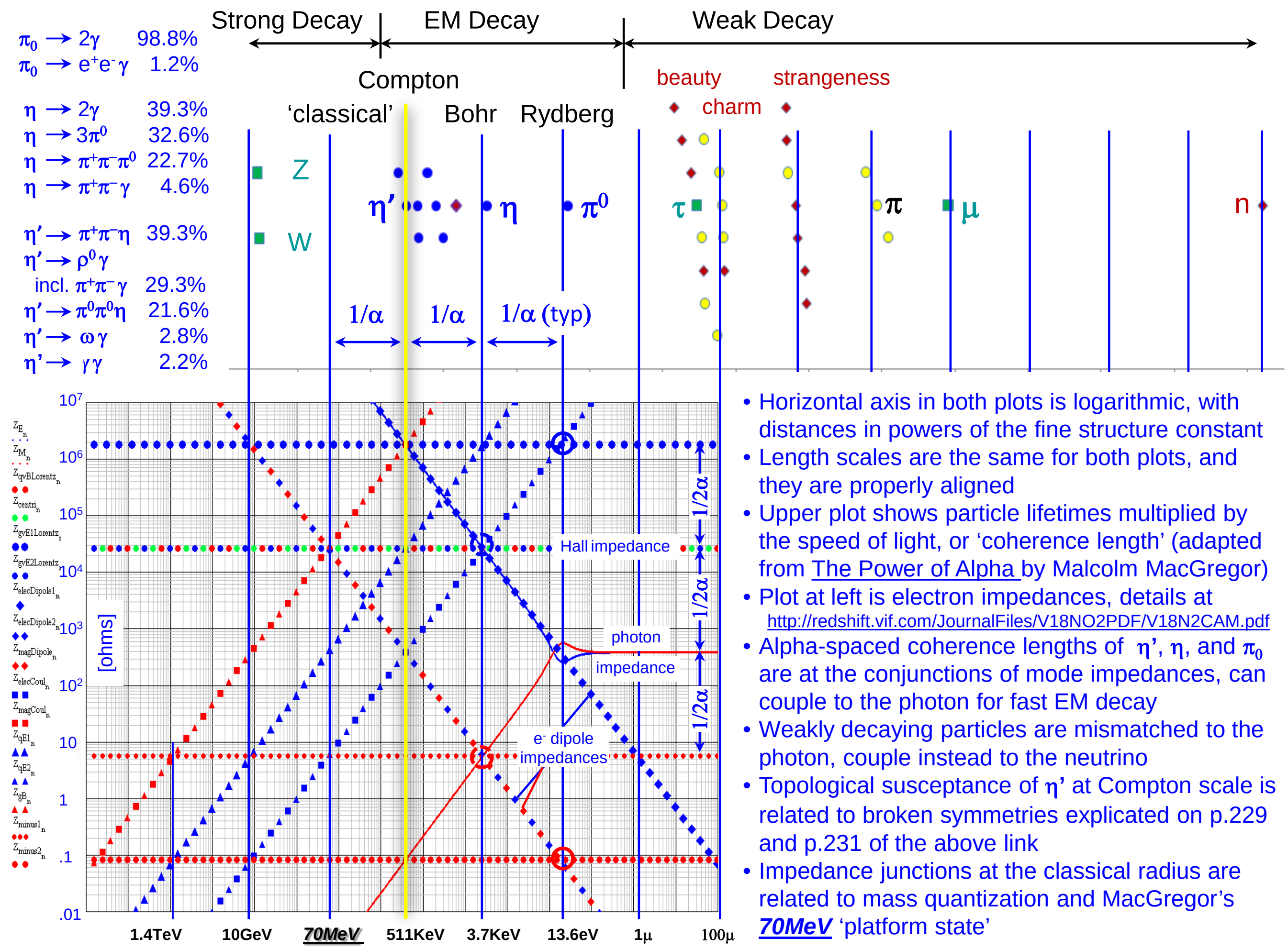

FIG. 2. A composite of photon impedance and a variety of electron impedances (lower), four fundamental lengths (upper), and the coherence lengths (upper) of the 36 unstable particles with lifetimes greater than the 10^{-21} second Compton period of the electron. Missing from this plot are the longitudinal dipole-dipole and longitudinal and transverse charge-dipole impedances.

sential keys to understanding how to calculate electromechanical and magnetomechanical quantum impedances for all forces.

THE 13.6eV PHOTON

The aim here is to see what insight into the hydrogen atom may be gained by exploring the role of quantum impedances in the transfer of energy from a 13.6eV photon to an electron.

In figure 2 the far field photon is the red line entering the impedance plot from the right at 377 ohms. The wavelength of the 13.6eV photon is the inverse Rydberg. At that scale the magnetic and electric flux quanta decouple. The electric flux quantum is well matched to the larger of the two electric dipole impedances, as seen in the figure, where the electric dipole impedance is represented by large blue diamonds. There is no corresponding magnetic dipole impedance, a broken symmetry. The magnetic flux quantum flies free, comparatively unimpeded.

As the head of the **electric flux quantum** wavepacket arrives at the Bohr radius the packet is still feeding increasing energy in from out beyond the Rydberg. From figure 2 it can be seen that at the Bohr radius there is a conjunction (upper dashed circle) of the electron dipole impedance with the scale invariant electric and magnetic vector Lorentz impedances, the scale invariant centripetal impedance, and the scale dependent electric Coulomb and scalar Lorentz impedances. The details of the couplings between the modes associated with the impedances (phases, coupling mechanisms,...) remain to be investigated. At the outset it is tempting to say that one knows the outcome (the H atom is ionized) and can work backwards from there.

But where is the proton in this plot?

The **magnetic flux quantum**, unlike the electric flux quantum, arrives at the Bohr radius without benefit of a continuous impedance match from the scale of the Rydberg, but presumably still phase-coherent. The excitation of the Bohr magneton (small red diamonds) at the Bohr radius is more of a shock excitation, more broadband. It should be noted that there is at least one scale invariant magnetic impedance present at the five ohm conjunction (lower dashed circle) of the magnetic flux quantum with the magnetic and the second of the two electric dipole impedances. Detailed calculations [1] suggest that the measured quantum Hall impedance is not just an electric impedance, but rather the sum of the scale invariant electric *and* magnetic impedances.

The main point here is that the impedance model seems to have some sort of 'Bohr correspondence', suggesting that the model has some credibility in the context of the Hydrogen atom. The impedance plot was generated with the electron in mind. It was only after the plot was generated that the photon was added. The Bohr correspondence was a nice serendipitous surprise.

PARTICLE LIFETIMES

The precise ordering of unstable particle lifetimes in powers of the fine structure constant [10–12] is arguably the most unappreciated and potentially useful organization of experimental data in the entire world of physics. Multiplying the lifetimes by the speed of light places them on the light cone, on the boundary between locality and non-locality, defining the coherence length of the unstable particles. It also makes clear their relation to the impedance plot. That some strong correlation exists between coherence lengths and conjunctions of the mode impedances can be seen from the figure.

It is helpful to think of the impedances as a network. A very complicated network. From this perspective a particle physics experiment is a big network analyzer, and the measurements are transfer function measurements.

Instead of a 13.6eV photon, suppose one looks at the interaction of a very high energy photon, several TeV, with this network. The multi-TeV photon successively shock excites the corresponding mode or modes of each of the impedances it encounters. The eigenmodes are dissipationless, coherent, quantum, and coupled. The network rings like a very pure and convoluted bell.

In the extreme short distance/high energy regime at the leftmost of the impedance plot the electric and magnetic impedances diverge, and the eigenmodes cannot couple to the photon. To the extent that the impedance model is in concordance with QED, one might suppose that the high energy impedance mismatch to the photon is a natural cutoff of the perturbation expansion, that the 'ultraviolet catastrophe' is absent. Similar reasoning applies in the long wavelength limit. The infrared divergences are cut off by the impedance mismatches.

Just the same, one has to confront the question of where the energy goes. The photon imparted several TeV to the network. Is it reflected back out through the network as a consequence of the exponentially increasing mismatch to the photon at ever smaller spatial scale? Conservation of energy requires that, one way or another, this energy comes back out.

Electromagnetic decays appear to be the most straightforward route out of the network for the energy in excited eigenmodes. The α-spaced coherence lengths of the π_0, η, and η' are at the conjunctions of mode impedances, and can couple to the photon for fast electromagnetic decay. Their branching ratios are shown in the upper left corner of the figure.

The coherence length of the π_0 is the inverse Rydberg. Just as the 13.6eV photon coupled to the electric dipole impedance at that length scale, the dipole mode of the π_0 couples equally well to the photon.

However in the case of the π_0, additional modes are excited at the Rydberg scale, a magnetic mode junction at a tenth of an ohm (indicated by the lower solid circle) and an electric mode at a couple megohms (upper solid circle). They are mismatched to the Landauer/Hall electron impedance by that factor of $\frac{1}{2\alpha}$, resulting in suppression of the $e^+e^-\gamma$ decay relative to 2γ.

A simple impedance matching calculation of the π_0 branching ratio agrees with the the measured experimental value at better than three parts per thousand. The result of that calculation can be used in the calculation of the η branching ratio within two percent on each the four decays shown in the figure, though with the proviso that unexplained factors of two previously introduced [1] intrude here as well. Presumably one could use the π_0 and η results to calculate the η' branching ratio, though the complexity grows formidably as one goes deeper into the decay chains. Numerically, the relative values of the η and η' branching ratios shown in the figure are remarkably similar. This suggests that the impedance structure resulting in the η ratios is well replicated in the η'.

Weak decays are not so straightforward. That they are slower than electromagnetic decays follows from their mismatch to the photon. The energy cannot get out of the network so easily via that route. One might conjecture that the weak force is not really a force, just an impedance mismatch. The roles (if any) of the W and the Z in this scheme are not yet clear.

The rather precise ordering of coherence lengths in powers of the fine structure constant makes the displacement of the beauty family and the tau away from the line between the Rydberg and the charm family quite remarkable. It raises the question of how this displacement towards *greater* coherence length might be calculated in terms of electroweak interference.

What have not yet been addressed are the longitudinal dipole-dipole and longitudinal and transverse charge-dipole impedances. These impedances will likely prove to be of interest in understanding weak decays.

Strong decays are yet more obscure. The biggest problem might be that QCD doesn't play well with high energy spin physics [13–15].

The approach presented here views the unstable particles as excited states of the electron impedances. The model takes the electron Compton wavelength as a fundamental length. In the case of the electromagnetic and weak decays the coherence lengths are greater than the Compton wavelength. For strong decays this is not the case. This implies that the short-lived resonance excitations cannot be coherent over the entire electron.

In the impedance model weak and electromagnetic decays are coherent, the coherence manifesting in α-spacing of coherence lengths. Strong decays are incoherent.

THE 70MeV MASS QUANTUM

There is a comprehensive phenomenology of the particle mass spectrum [10–12] based upon the 70MeV platform state. It will be interesting to see the extent to which the impedance model and that phenomenology agree.

In the model the mass of the electron is calculated at the limit of experimental accuracy (though one might argue that the mass is given by defining the Compton radius to be a fundamental length), the mass of the muon at one part in one thousand, the pion at two parts in ten thousand, the kaon at one part in one hundred, and the nucleon at seven parts in one hundred thousand [16, 17]. All, including the 70MeV mass quantum, follow directly from electric and magnetic flux quantization.

CONCLUSION

The question of fundamental importance is not whether the model presented here is a good model. The question is whether the concept of generalized quantum impedances is scientifically correct, and also whether it is a useful concept with practical applications.

So far nothing in the impedance model appears to be in disagreement with either the small sample of experimental data to which it has been applied, or with the Standard Model. As in the case of the 70MeV mass phenomenology, it will be interesting to see if the model can be more deeply connected with both theory and data.

An immediate task list would calculate the longitudinal impedances, electron spin cross sections, and proton spin cross sections. Not necessarily in that order.

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