Quantum Impedance Matching to Gravitational Waves

Peter Cameron

Abstract

Standard practice takes spacetime characteristic impedance to be c^3/G ~ 10^35 kg/s, and assumes that it is scale invariant. However, it is easy to show that this value applies at the Planck length, and not necessarily at scales of interest to the experimentalist. Given that impedance matching governs amplitude and phase of energy/information transmission, quantization of wavefunction interaction impedances is of particular interest in design of storage ring gravitational wave detectors and sources.

Accelerator Research and Innovation for European Science and Society

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Quantum Impedance Matching to Gravitational Waves

Peter Cameron
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prepared for the ARIES workshop on Storage Ring Gravitational Wave Detectors and Sources

Outline

- how impedance matching was lost in quantum mechanics
- how mechanical impedances can be calculated from Mach's principle
- conversion to electrical, electron 'mass gap' impedance calculations
- historical perspective on impedance matching
- Hydrogen atom – Rosetta stone of atomic physics
- unstable particle spectrum
- gauge group of the electron
- chiral anomaly – precise calculation of pizero, eta, and etaprime branching ratios
- curvature of GR = phase shifts of flat space geometric Clifford algebra
- impedance matching to the Planck length (and beyond)
- impedance matching to boundary of the observable universe (and beyond)
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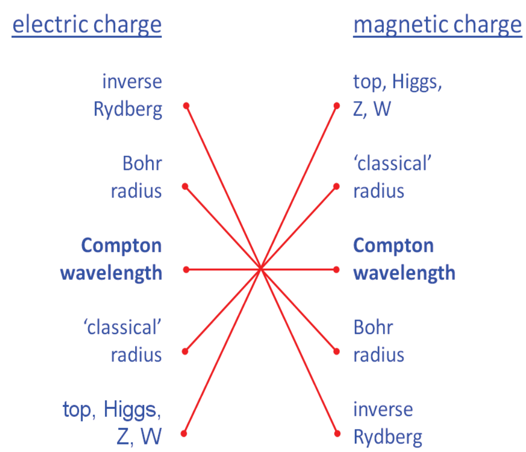
- summary and conclusions

impedance matching governs
amplitude and phase
of energy/information transmission

How Impedance matching was lost in QM

1. Topological inversion – units of mechanical impedance are [kg/s]. Intuitively one might expect that more [kg/s] would mean more mass flow. However more impedance means less flow. Thwarted Bjorken, Feynman,…
2. concept of ***exact*** impedance quantization did not exist until vonKlitzing et.al discovered QHE in 1980.
3. QHE was easy – scale invariant!
4. habit of setting fundamental constants to dimensionless unity h = c = G = Z = … = 1 let Z slip over the horizon.



Mismatches are Feynman's regularization parameters of QED.
Inclusion renders QED finite. This is what Bjorken discovered back in 1959, anticipated it would be a powerful tool, was led astray by the inversion of SI units.
Feynman had a student do a thesis on impedance matching to the maser.

Bjorken was perhaps not familiar with their work when writing his 1959 thesis[46]. In that thesis is an approach summarized[47] as "...an analogy between Feynman diagrams and electrical circuits, with Feynman parameters playing the role of *resistance*, external momenta as current sources, and coordinate differences as voltage drops. Some of that found its way into section 18.4 of..." the canonical text[48]. As presented there, the units of the Feynman parameter are [sec/kg], the units of mechanical *conductance*[5].

One of the black hole event horizon impedances is the 25812 ohm quantum Hall – scale invariant, topological, communicates phase only, can do no work.

J. Bjorken, "Experimental tests of Quantum electrodynamics and spectral representations of Green's functions in perturbation theory", Thesis, Stanford (1959) http://searchworks.stanford.edu/view/2001021

J. Bjorken, private communication (2014)

J. Bjorken, and S. Drell, *Relativistic Quantum Fields*, McGraw-Hill, section 18.4 (1965)

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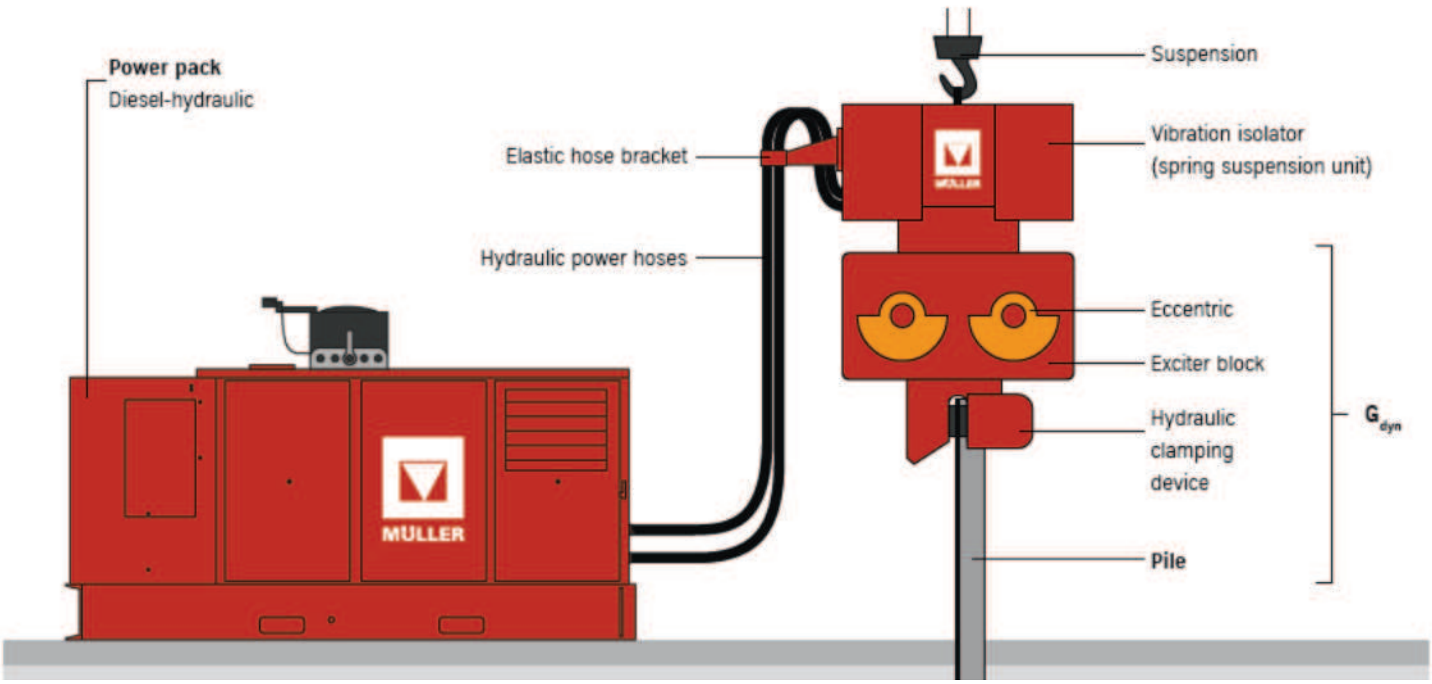

Synchronous counter-rotating eccentrics transform 2D rotation to 1D translations, are an analog to electron and positron spinors of Dirac equation counter-rotating in phase space.

A typical vibratory piledriver generates a sinusoidal inertial force of many tens or hundreds of tons, might be thought of as an `inertia wave generator'. Given equivalence of gravitational and inertial mass, it might also be called a gravitational wave generator.

The extent to which such a toy model might ultimately prove useful remains to be seen. For now it seems clear that it provides a simple mechanical shortcut to calculating quantized electromagnetic impedances, a tool of great phenomenological power.

this is important – impedance matching governs amplitude and phase of energy transmission

July 24, 1975

THE TWO BODY PROBLEM AND MACH'S PRINCIPLE

Peter Cameron

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submitted to Am.J.Phys 1975
referees: 'No new physics here'
Published 2011 as an appendix to the Electron Impedances paper (next slide)

The classical analysis of the two-body problem is frequently complicated by the introduction of a system of co-ordinates which is independent of either of the bodies. The validity of such an analysis rests upon the premise that the co-ordinate frame does not interact with the physical system via any known physical laws, and that one is therefore free to choose whatever reference frame seems most useful.

A strong epistemological argument might be advanced against this reasoning. If sufficently rigorous constraints are placed upon the spatial properties of the interacting bodies, the introduction of an independent observer will have a radical effect upon the form of the equations which describe the interaction, to the extent that strongly differing concepts might be developed regarding such fundamental things as space, time, and matter. Newton

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Apeiron, Vol. 17, No. 3, January 2010

Photon Impedance Match to a Single Free Electron

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It is not surprising that consideration of impedance matching the photon to the electron, or more specifically to the quantum of resistance at the length scale defined by the mass and angular momentum of the electron, has been long ignored in quantum electrodynamics. Conceptually the development of QED preceded the discovery of 'exact quantization' and the associated von Klitzing constant by many decades. Additionally, the relevance of the resistance quantum to photon interactions with a single free electron has only recently begun to be appreciated. In this note we offer a simple presentation of such an impedance match, briefly discuss the unexpected emergence of the fine structure constant from these simple first principles, and suggest how the procedure can be inverted to deliver a first principles calculation of the mass of the electron.

Apeiron, Vol. 18, No. 2, April 2011

Electron Impedances

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It is only recently, and particularly with the quantum Hall effect and the development of nanoelectronics, that impedances on the scale of molecules, atoms and single electrons have gained attention. In what follows the possibility that characteristic impedances might be defined for the photon and the single free electron is explored is some detail, the premise being that the concepts of electrical and mechanical impedances are relevant to the elementary particle. The scale invariant quantum Hall impedance is pivotal in this exploration, as is the two body problem and Mach's principle.

To understand the electron would be enough - Einstein

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Impedance History

1775 - 1915
early experimenters
DC, AC, bridges

1900 - 1945
commercial instruments
bridges, Q meter

1945 - 1965
coming of age
network analyzers

~ 1950
QED/QFT

1957
Jackson & Yovits
statistical

1959
Bjorken thesis
inverted analogy

1963
Feynman & Vernon
maser impedance

1965 - present
digital

1965
Bjorken & Drell
inverted analogy

1965
Feynman & Hibbs
1-D lattice match

1970
Landauer – 1D
quantum wire h/e^2

1975
two body problem
mechanical impedance

Mach's
principle

quantum

1980
von Klitzing – 2D
quantum Hall h/e^2

1985
von Klitzing
QHE Nobel

1988
van Wees
quantum wire h/e^2

1995
Goldman & Su
fractional QHE

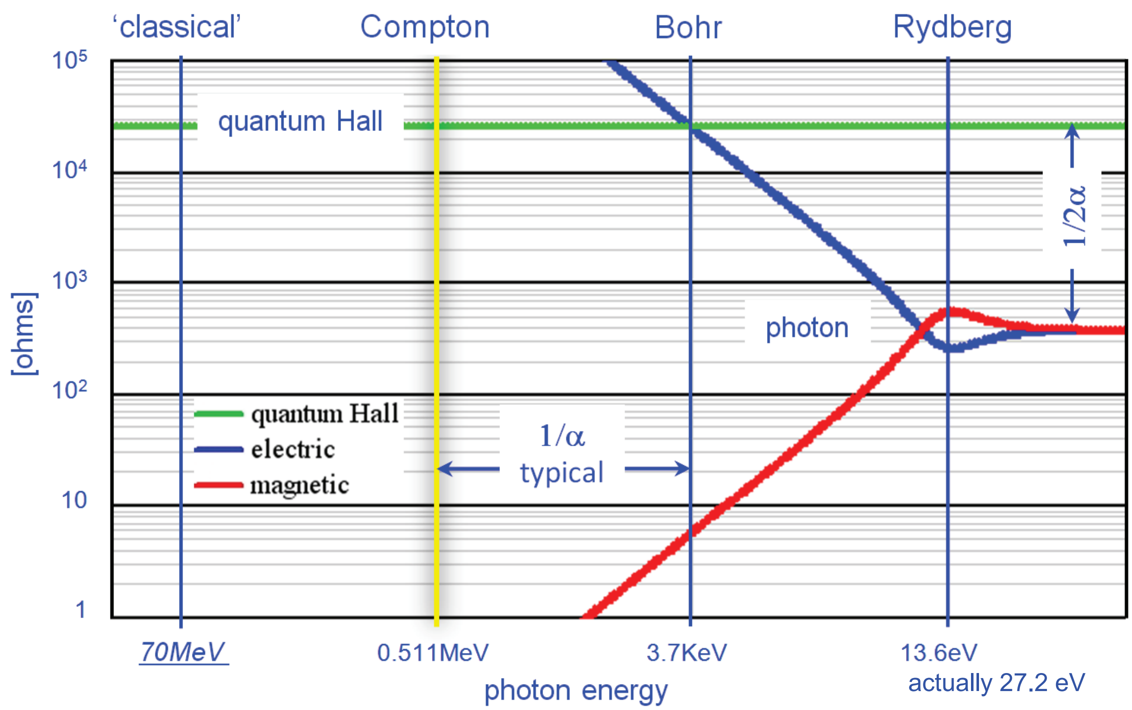
1998
Laughlin, Stoermer,
Tsui - fQHE Nobel

1980s - present
condensed matter at threshold

2011
electron impedances

SRGW2021

ionization of the Hydrogen atom (where is the proton?)



Photon near-field impedance is not to be found in physics textbooks, curriculum, or journals.
What governs amplitude and phase of energy/information transmission in QED is absent from formal education of the physicist

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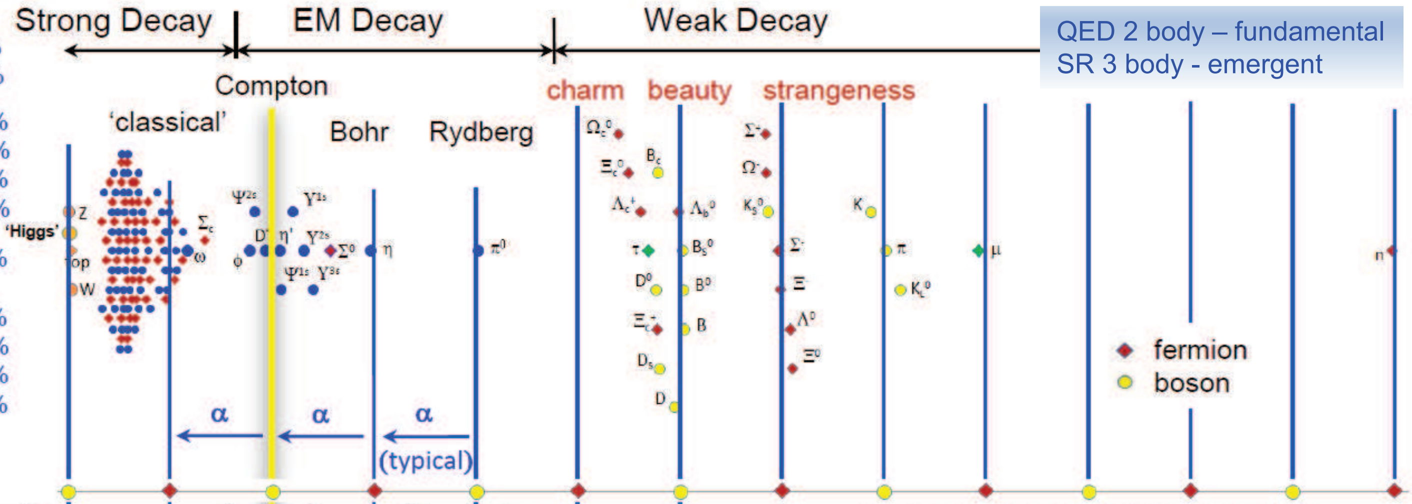
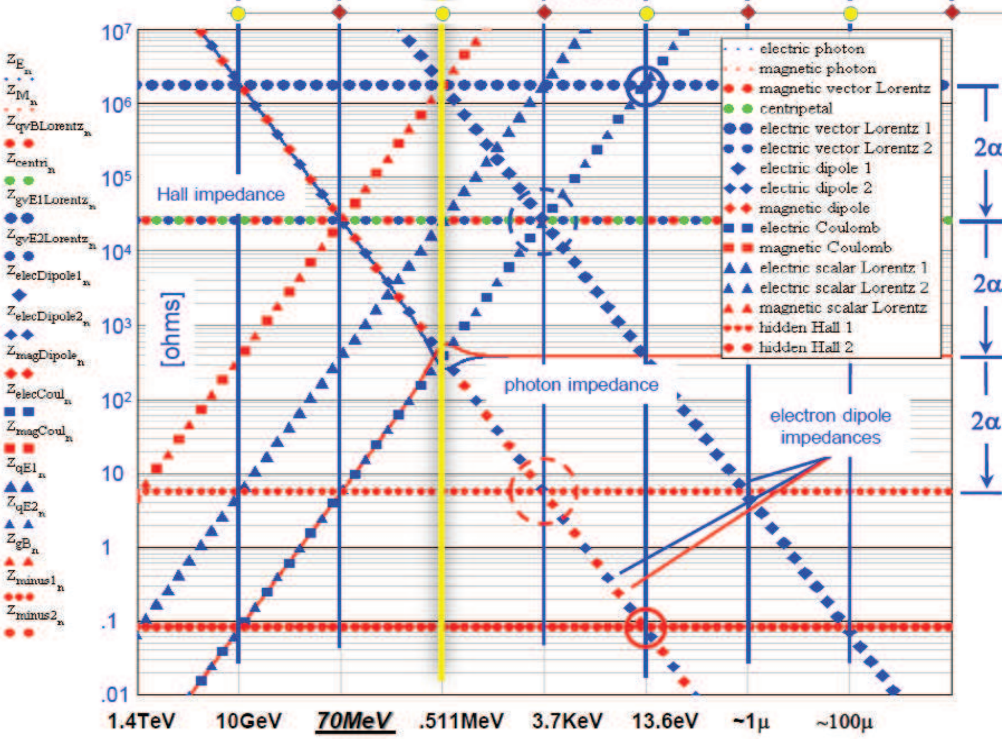
$\pi_0 \rightarrow 2\gamma$ 98.8%
$\pi_0 \rightarrow e^+e^-\gamma$ 1.2%

$\eta \rightarrow 2\gamma$ 39.3%
$\eta \rightarrow 3\pi^0$ 32.6%
$\eta \rightarrow \pi^+\pi^-\pi^0$ 22.7%
$\eta \rightarrow \pi^+\pi^-\gamma$ 4.6%

$\eta' \rightarrow \pi^+\pi^-\eta$ 39.3%
$\eta' \rightarrow \rho^0\gamma$
incl. $\pi^+\pi^-\gamma$ 29.3%
$\eta' \rightarrow \pi^0\pi^0\eta$ 21.6%
$\eta' \rightarrow \omega\gamma$ 2.8%
$\eta' \rightarrow \gamma\gamma$ 2.2%

QED 2 body – fundamental
SR 3 body - emergent





- Horizontal axis in both plots is logarithmic
- Length scales are the same for both plots, and they are properly aligned
- Upper plot shows particle lifetimes multiplied by the speed of light, the coherence lengths (adapted from The Power of Alpha by Malcolm MacGregor)
- Plot at left is electron impedances, details at http://redshift.vif.com/JournalFiles/V18NO2PDF/V18N2CAM.pdf
- Alpha-spaced coherence lengths of η', η, and π_0 are at conjunctions of mode impedances, can couple to the photon for fast EM decay
- Location of π_0 at boundary of EM and weak decays is suggestive of the chiral anomaly
- Weak decays are mismatched to the photon
- Alpha-spaced coherence length alternation of fermions/bosons in weak decays appears to be related to parity violation and electroweak enhancement of charm/tau coherence lengths
- *Clustering of superheavies* (top, Higgs, Z, W) at the 10GeV coherence length *is tantalizing*
- Impedance junctions at the classical radius are related to mass quantization and MacGregor's ***70MeV*** 'platform state'
- See also http://vixra.org/author/peter_cameron

	electric charge e *scalar*	elec dipole moment 1 d_{E1} *vector*	elec dipole moment 2 d_{E2} *vector*	mag flux quantum ϕ_B *vector*	elec flux quantum 1 ϕ_{E1} *bivector*	elec flux quantum 2 ϕ_{E2} *bivector*	magnetic moment μ_{Bohr} *bivector*	magnetic charge g *trivector*
e	ee ■ *scalar*	ed_{E1}	ed_{E2} *vector*	$e\phi_B$ ●	$e\phi_{E1}$ ▲	$e\phi_{E2}$ ▲ *bivector*	$e\mu_B$	eg *trivector*
d_{E1}	$d_{E1}e$	$d_{E1}d_{E1}$ ◆	$d_{E1}d_{E2}$	$d_{E1}\phi_B$	$d_{E1}\phi_{E1}$	$d_{E1}\phi_{E2}$	$d_{E1}\mu_B$	$d_{E1}g$
d_{E2}	$d_{E2}e$	$d_{E2}d_{E1}$	$d_{E2}d_{E2}$ ◆	$d_{E2}\phi_B$	$d_{E2}\phi_{E1}$	$d_{E2}\phi_{E2}$	$d_{E2}\mu_B$	$d_{E2}g$
ϕ_B	$\phi_B e$ ● *vector*	$\phi_B d_{E1}$	$\phi_B d_{E2}$ *scalar + bivector*	$\phi_B\phi_B$	$\phi_B\phi_{E1}$ γ	$\phi_B\phi_{E2}$ *vector + trivector*	$\phi_B\mu_B$	$\phi_B g$ ▲ *bv + qv*
ϕ_{E1}	$\phi_{E1}e$ ▲	$\phi_{E1}d_{E1}$	$\phi_{E1}d_{E2}$	$\phi_{E1}\phi_B$ γ	$\phi_{E1}\phi_{E1}$	$\phi_{E1}\phi_{E2}$	$\phi_{E1}\mu_B$	$\phi_{E1}g$ ●
ϕ_{E2}	$\phi_{E2}e$ ▲	$\phi_{E2}d_{E1}$	$\phi_{E2}d_{E2}$	$\phi_{E2}\phi_B$	$\phi_{E2}\phi_{E1}$	$\phi_{E2}\phi_{E2}$	$\phi_{E2}\mu_B$	$\phi_{E2}g$ ●
μ_B	$\mu_B e$ *bivector*	$\mu_B d_{E1}$	$\mu_B d_{E2}$ *vector + trivector*	$\mu_B\phi_B$	$\mu_B\phi_{E1}$	$\mu_B\phi_{E2}$ *scalar + quadvector*	$\mu_B\mu_B$ ◆	$\mu_B g$ *vector + pv*
g	ge *trivector*	gd_{E1}	gd_{E2} *bivector + quadvector*	$g\phi_B$ ▲	$g\phi_{E1}$ ●	$g\phi_{E2}$ ● *vector + pentavector*	$g\mu_B$	gg ■ *scalar + sv*

S-matrix of Dirac's QED, extended to the full eight-component vacuum wavefunction in the geometric representation of Clifford algebra (more familiar to physicists in the matrix representations of Pauli and Dirac) Symbols (triangle, diamond,…) correspond to previous slide.

spin 2 ‘graviton’ and spin 0 Higgs are both manifested in the S-matrix 6D entangled scalar + pseudoscalar

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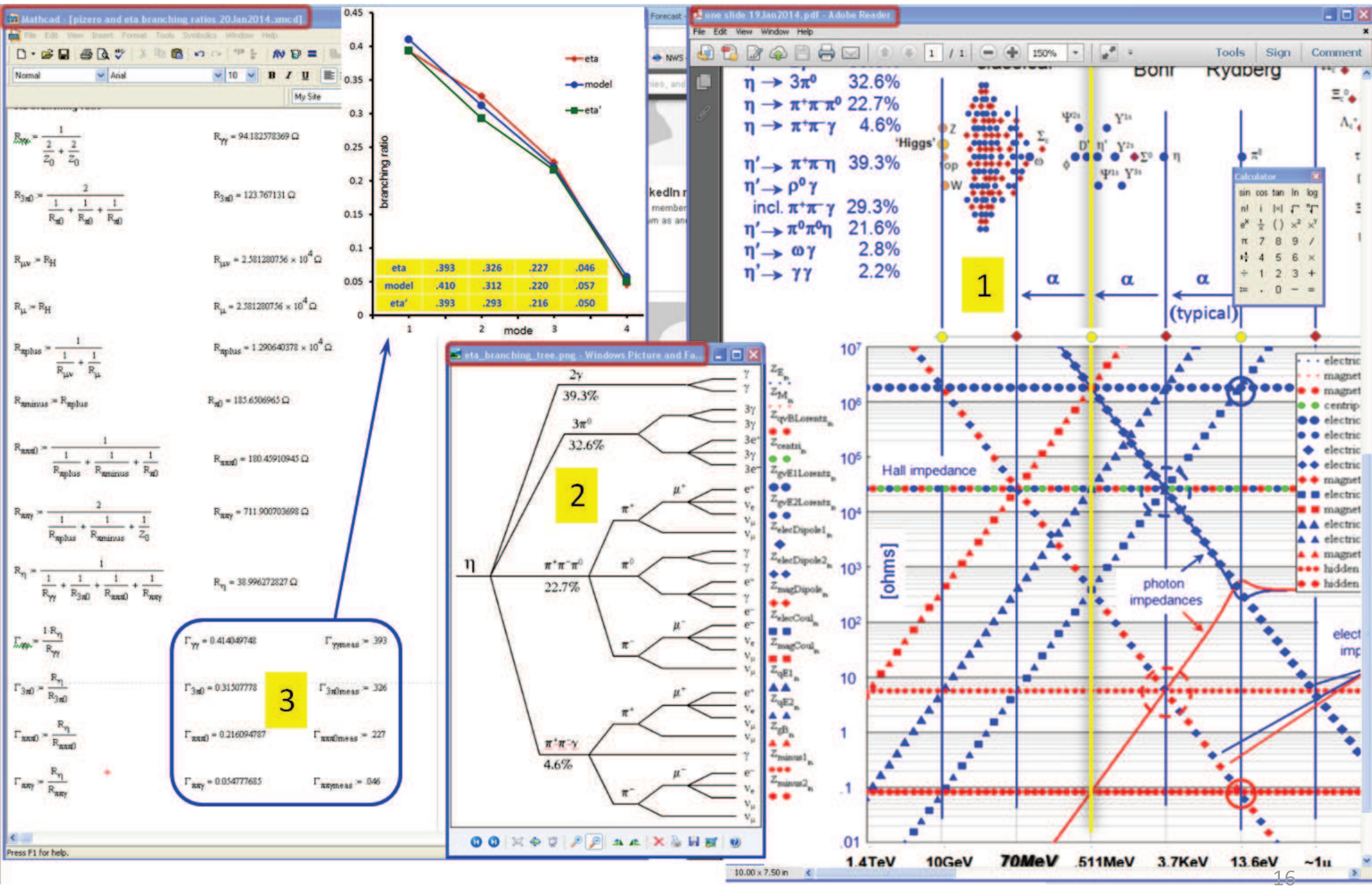
BSM example 2 – chiral anomaly – precise pizero, eta, and eta' branching ratios in powers of α



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Not all are in agreement that Einstein whole-heartedly endorsed curved space interpretations. He expressed this quite clearly in politically correct private communication:

“It is wrong to think that `geometrization' is something essential. It is only a kind of crutch for finding of numerical laws. Whether one links `geometrical' intuitions with a theory is a ... private matter.“

Riemann's curvature tensor preceded general relativity by six decades. Absent Clifford's geometric interpretation, Einstein's adoption of Riemann's formalism led inevitably to dominance of curved space interpretations.

However, the equivalence of at Minkowski spacetime gauge theory gravity with curved space general relativity was introduced by the Cambridge group and Professor Hestenes, and elaborated upon by them over the course of following decades. In that context, impedance quantization offers immediate possibilities for quantizing gravity at the Planck length.

Of importance in general relativity is not geometrization, but rather the equivalence of gravitational and inertial mass, the equivalence principle.

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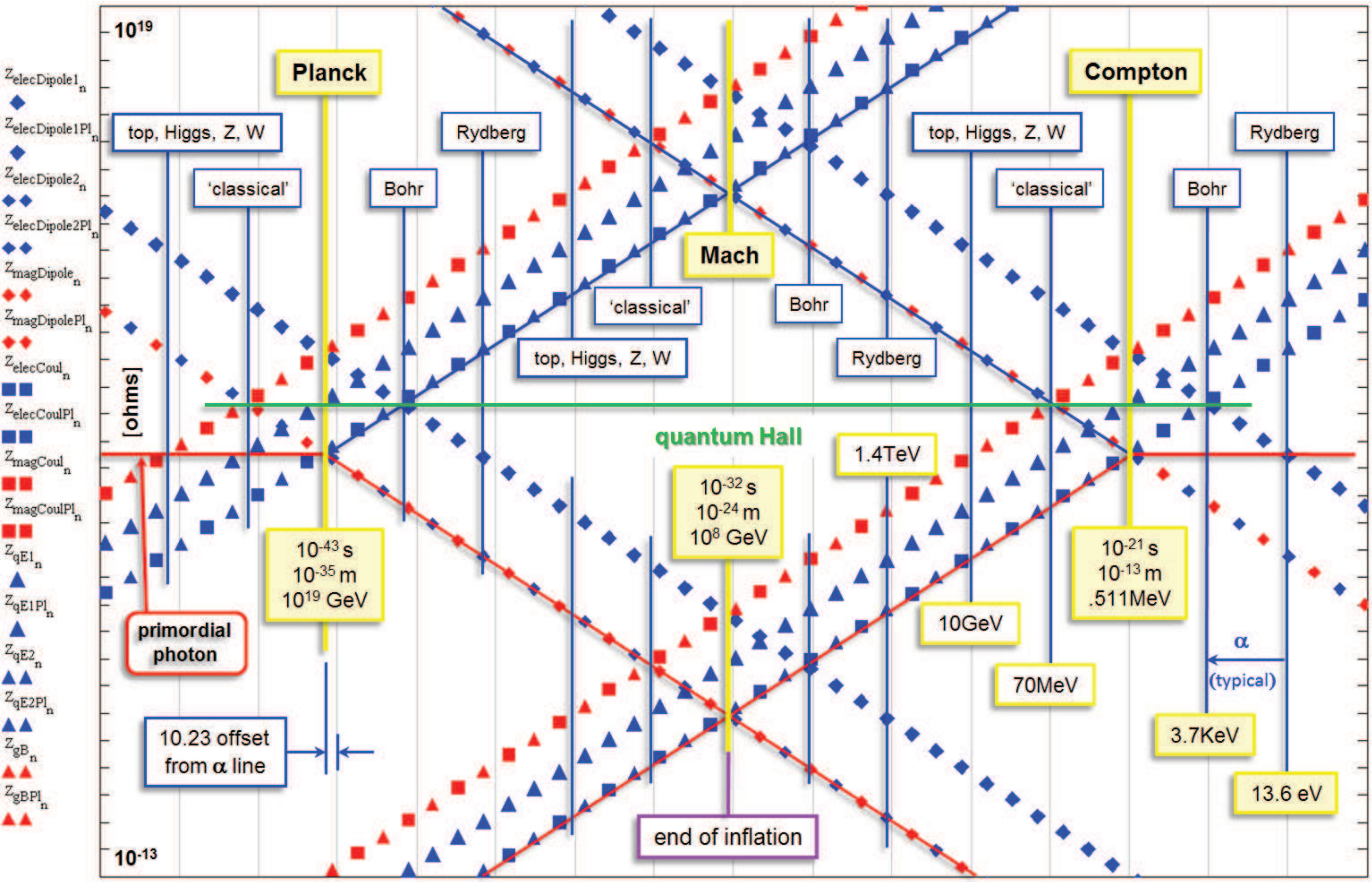
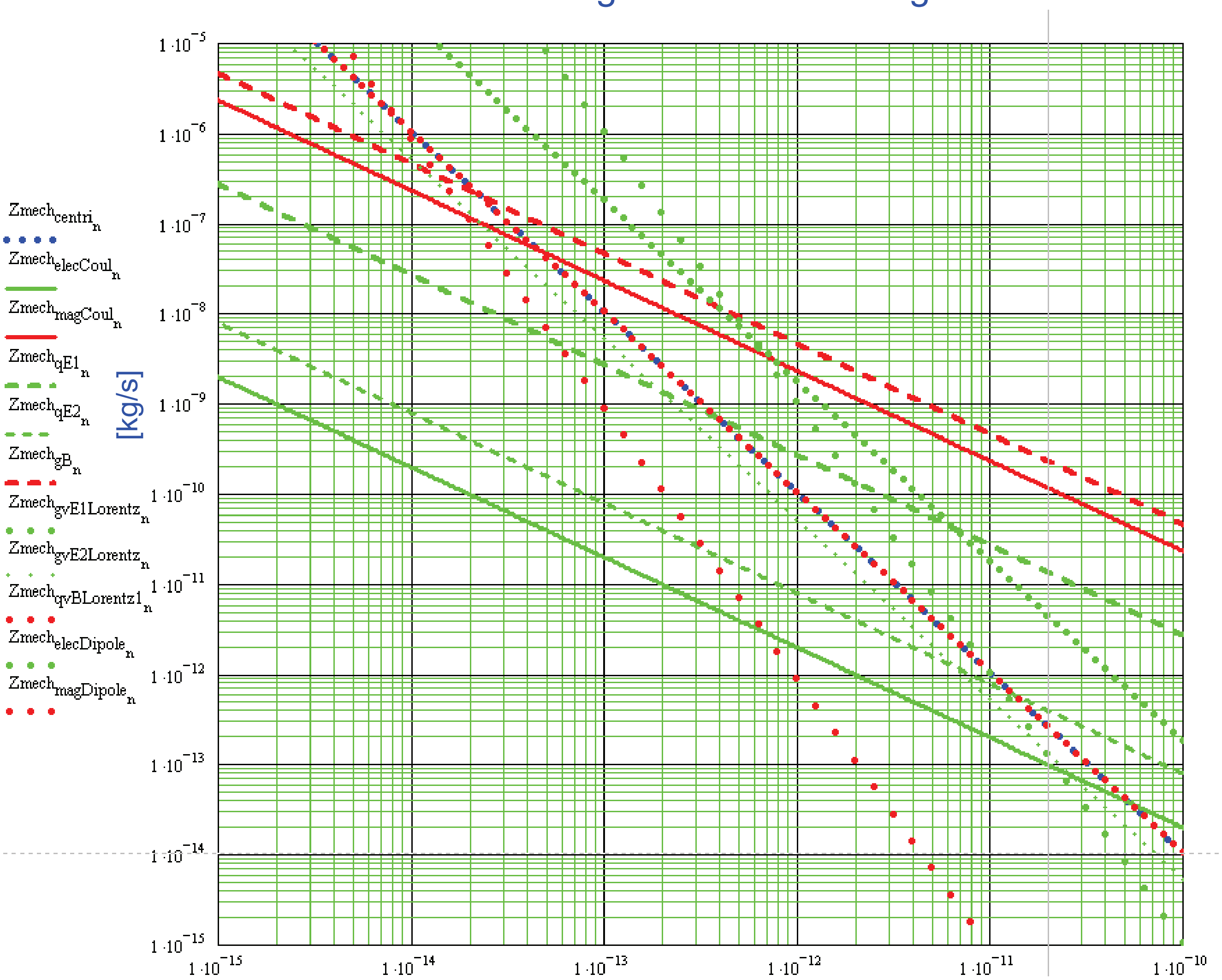
BSM example 3 – origin of mass, gravitation, inflation, chirality, baryon asymmetry,…

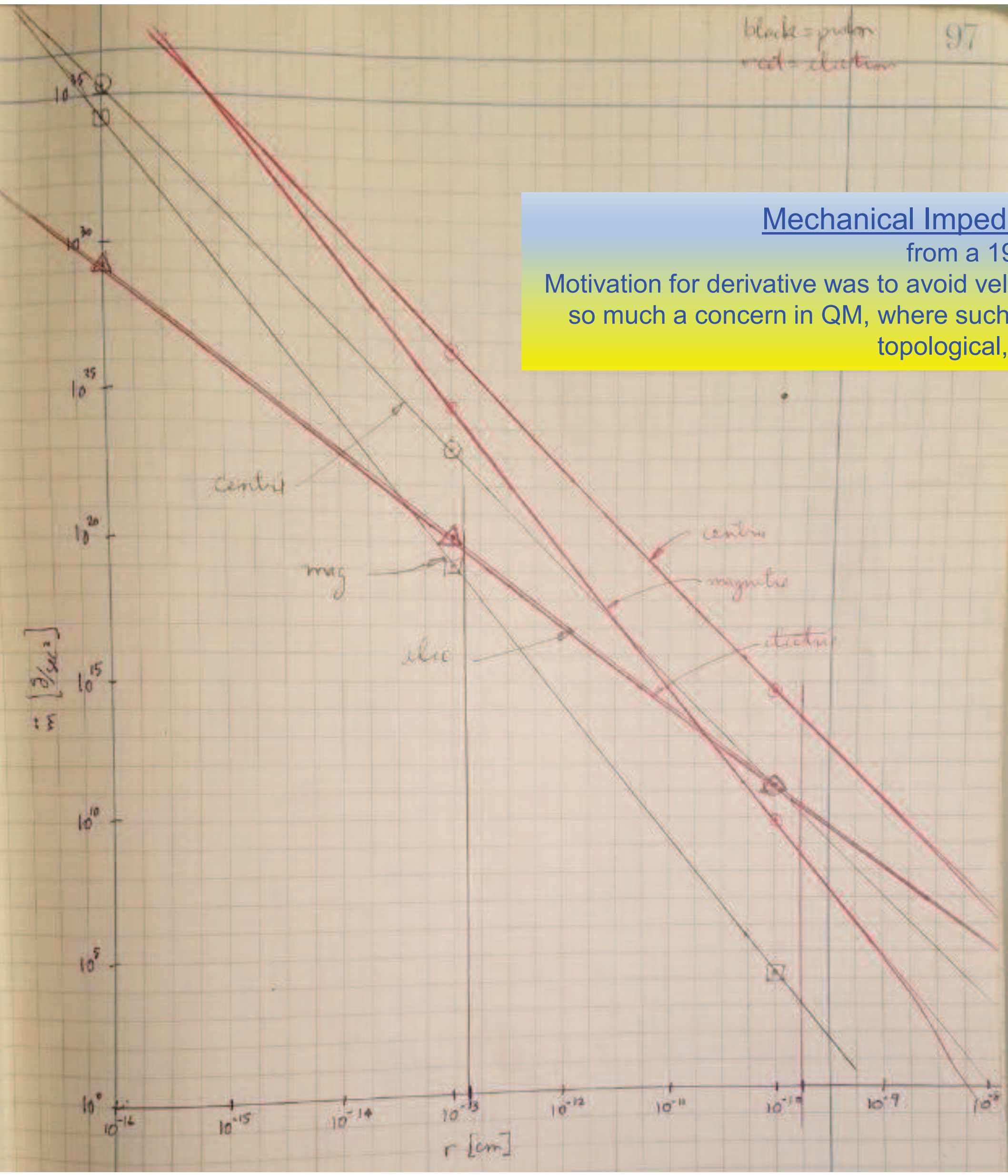


Mechanical Impedances

all rise at shorter length scales

LIGO - 10^{35} kg/s is at Planck length





Mechanical Impedance Time Derivatives

from a 1982 notebook

Motivation for derivative was to avoid velocity-dependent dissipative impedances. Not so much a concern in QM, where such impedances are not dissipative, but rather topological, scale invariant.

three potentials – $1/r$, $1/r^2$, and $1/r^3$ - are shown here for proton and electron

	GRAV	Inertial	Centrip	Elec Mono	Mag Mono	Mag Dip	Lorentz	[illegible]
$\ddot m$, $\dot m$	$G\frac{m^2}{r^2}$	$m\ddot r$ $\dot m\dot r$ $\ddot m r$	$m\omega^2 r$ $= m\dot r^2/r$ $= h^2/mr^3$	$\frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2}$	$\frac{\mu_0}{4\pi}\frac{g^2}{r^2}$	$\frac{\mu_0}{4\pi}\frac{\mu^2}{r^3}$	$eB\frac{h}{mr}$ $\dot e B r$	
G	0	Gm^2/r^3 (F/r)	$\frac{2}{3}\frac{h^2}{mr^4}$ $(\frac{2}{3}F/r)$	$\left[\frac{1}{4\pi\epsilon_0 G}\right]^{1/2}\ddot e$	$\left[\frac{\mu_0}{4\pi G}\right]^{1/2}\ddot g$			
I	$\frac{Gm^3}{hr}$ $F/\dot r$	0	$\frac{h^2}{mr^4}$	$\frac{1}{4\pi\epsilon_0}\frac{e^2}{r^3}$	$\frac{\mu_0}{4\pi}\frac{g^2}{r^3}$	$\frac{\mu_0}{4\pi}\frac{\mu^2}{r^4}$	$eB\frac{h}{mr^2}$	
C	$-\frac{1}{3}\frac{h}{r^2}$	$\frac{h}{r^2}$	0	$2\left[h^2/mr^4 - \frac{h}{r^2}\frac{\dot e}{e} + m\left(\frac{\dot e^2}{e^2}+\frac{\ddot e}{e}\right)\right]$		$\frac{2m}{\mu^2}(\dot\mu^2+\mu\ddot\mu)$	$eB = \frac{h}{r^2}$	
E	$\left[\frac{1}{4\pi\epsilon_0 G}\right]^{1/2}\dot e$	$\frac{e^2 m}{4\pi\epsilon_0 h r}$	$2m\frac{\dot e}{e}-\frac{h}{r^2}$	0	$e^2=\epsilon_0\mu_0 g^2$	$e^2\ \epsilon_0\mu_0\mu^2/r$		
mm	$\left[\frac{\mu_0}{4\pi G}\right]^{1/2}\dot g$	$\frac{\mu_0 g^2 m}{4\pi h r}$		$e^2=\epsilon_0\mu_0 g^2$	0	$g^2=\frac{\mu^2}{r}$		
mD	$\left[\frac{\mu_0}{4\pi G r}\right]^{1/2}\dot\mu - \frac{h}{2r}$	$\frac{\mu_0\mu^2 m}{4\pi h r^2}$	$-2m\frac{\dot\mu}{\mu}$	$e^2=\epsilon_0\mu_0\mu^2/r$	$g^2=\frac{\mu^2}{r}$	0		
L		eB	$eB=\frac{h}{r^2}$	$hB\left(\frac{e\dot r-\dot e r}{e^2}\right)$		$\frac{h}{\mu}\left(\frac{r^2\dot e-2er\dot r}{r^4}\right)$	0	$-\frac{2kTh}{mr^3}$
T							$\frac{2kT}{r}$	0

matrix used (in part) for previous slide
upper right of main diagnonal is impedances
lower left is impedance time derivatives

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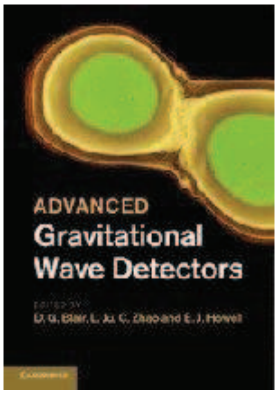


3.3 Key concepts in gravitational wave detection (page 50)

There are four key concepts that must be addressed in building detectors for any type of wave. **The first** is the fundamental issue of designing a detector with the best possible **impedance matching** to the wave: this determines the amount of energy that the detector receives…

"Spacetime has a characteristic impedance $c^3/G \sim 10^{35}$ kg/s"

In electromagnetic units this is ~ 10^{25} ohms!!! photon = 377 ohms

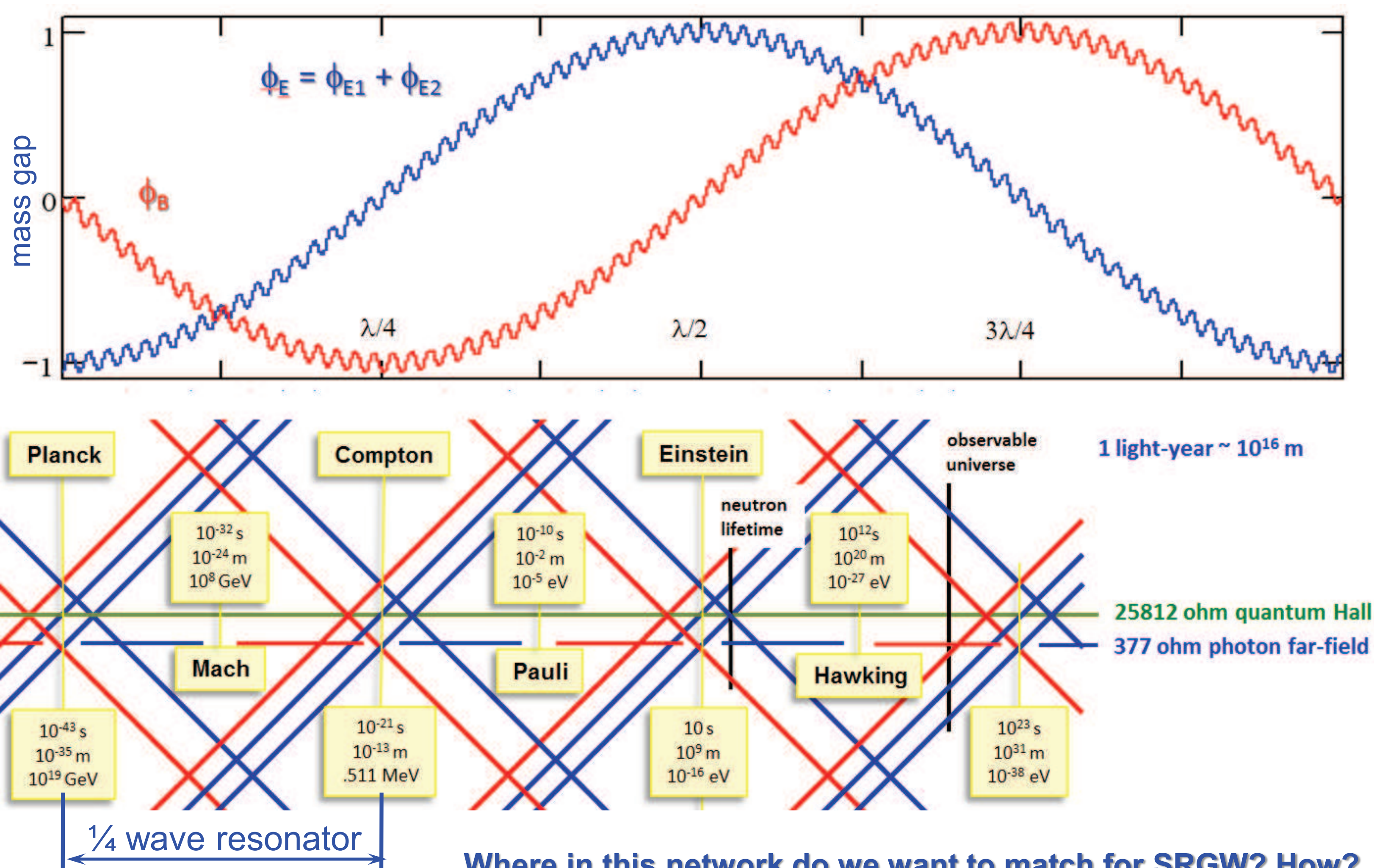
There exist two (or more?) varieties of impedances - geometric and topological:

- scale invariant? then topological (quantum Hall, Aharonov-Bohm, centrifugal, chiral,…) *acausal*
  rotation gauge fields – resulting motion is perpendicular to applied force
  cannot do work - communicates phase only, not a single measurement observable
  cannot be shielded, channels of both local and non-local entanglement, EPR,…
- scale dependent? then geometric (Coulomb, dipole, scalar Lorentz,…) *causal*
  translation gauge fields – communicates amplitude and phase
  can be shielded, local entanglement only

$c^3/G \sim 10^{35}$ kg/s is dimensionally scale invariant – far field? need near

All rest mass particles have mechanical impedances.
Mass is quantized in QM. Therefore impedances are quantized.
This property has been **lost in QED**
$Z_{mech} = Z_{EM}$ x (line charge density)^2 *string theory*

mismatch attenuated Hawking photon (‘graviton’ is entire 8-component wavefunction)



Where in this network do we want to match for SRGW? How?

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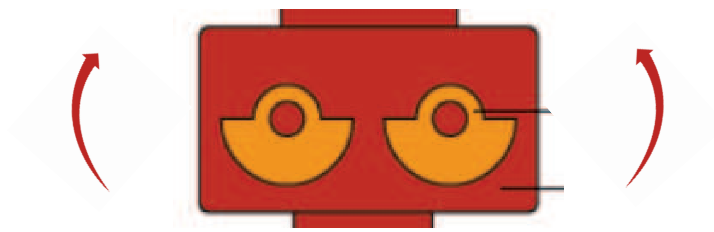
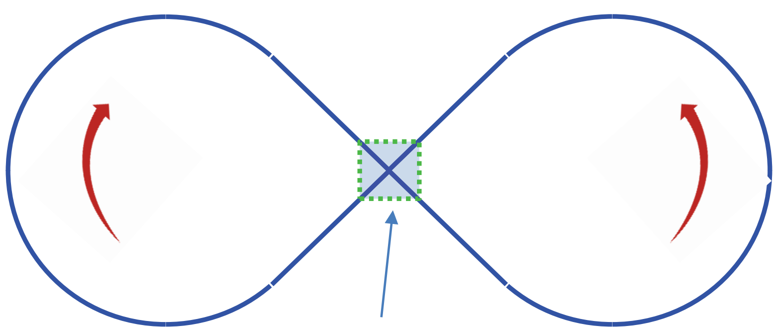
speculation on a machine design

- satisfy four primary considerations
  - impedance match G-wave to beam
  - impedance match beam signal to pickup
  - null/difference measurement - 'dark port'
  - employ a 'parametric process'



- need to understand graviton
  - equivalence principle says gravitational = inertial
    - for moon orbiting earth gravitational potential is 1/r whereas centrifugal is $1/r^2$
    geometric ≠ topological: this is subtle and seems to be pivotal in quantum gravity.
  - S-matrix (slide 16) geometric product of two 'dark' spin 1 magnetic charge trivectors yields spin 0 scalar entangled with spin 2 six DoF object (3 space and 3 relative phase)
  - we take scalar to be Higgs and entangled spin 2 pseudoscalar to be graviton.
  - graviton mode is indicated by red squares in the impedance network plots.



does there exist a gravitational wave difference mode in this topologically twisted storage ring configuration analog of the piledriver of slide 5?

Outline

- how impedance matching was lost in quantum mechanics
- how mechanical impedances can be calculated from Mach's principle
- conversion to electrical, electron 'mass gap' impedance calculations
- historical perspective on impedance matching
- Hydrogen atom – Rosetta stone of atomic physics
- unstable particle spectrum
- gauge group of the electron
- chiral anomaly – precise calculation of pizero, eta, and etaprime branching ratios
- curvature of GR = phase shifts of flat space geometric Clifford algebra
- impedance matching to the Planck length (and beyond)
- impedance matching to boundary of the observable universe (and beyond)
- speculation on a machine design
- *summary and conclusions*

impedance matching governs
amplitude and phase
of energy/information transmission

Summary and Conclusions – very preliminary

- in gauge theory gravity space is inert, vacuum wavefunction has no energy (is this true?)
  - curvature of GR = relative phase shifts of GTG (not single measurement observable)
- LIGO – $c^3/G = 10^{35}$ kg/s is at Planck length
  - not relevant to SRGW? to LIGO? relevant to axion searches?
- equivalence principle – equality of inertial and gravitational masses
  - centrifugal potential is $1/r^2$, topological
  - gravitational is $1/r$, geometric
  - Hawking graviton phase evolution very slow – almost topological
- graviton and Higgs are both manifested in the S-matrix 6D pseudoscalar
- understanding impedance quantization opens new possibilities for SRGW
  - longitudinal impedance ($F/\delta v$) of 7 TeV proton is ~10^6 kg/s = 10^{18} ohms???
  - want high relativistic γ for high longitudinal impedance – work with electrons?
  - antimatter falls up?,… want a difference signal measurement
- and similarly for possibly augmenting muon collider lifetime enhancement at low energy.

*The open question in my opinion is whether giving further attention to **quantum** impedance matching might increase the possibility of more robust next generation machine designs.*