# Extending QED to the Full Eight-component Vacuum Wavefunction in the Geometric Representation of Clifford Algebra

Peter Cameron

Abstract

Clifford algebra is the math language of quantum mechanics, known to most physicists in the matrix representations of Pauli and Dirac. Less familiar (but far more intuitive) is the original geometric intent of Clifford, the algebra of interactions of fundamental geometric objects - point, line, plane, and volume elements. In geometric representation, the 3D vacuum wavefunction is comprised of one scalar point, three vector line elements (orientational degrees of freedom), three bivector area elements, and one trivector volume element. Various combinations of the four fundamental constants that define the dimensionless electromagnetic coupling constant alpha (speed of light, permittivity of space, electric charge quantum and angular momentum quantum) permit assigning geometrically and topologically appropriate electric and magnetic flux quanta to the eight wavefunction components, increasing `dimensionality' of the model to the ten degrees of freedom of string theory. Time (quantum phase) emerges from wavefunction interactions, in the dimension-increasing property of Clifford algebra wedge products. Such a 6D Yang-Mills model is naturally gauge invariant, finite, confined, asymptotically free, background independent, and contains the four forces [1,2].

[1]https://www.researchgate.net/publication/335240613_Naturalness_begets_Naturalness_An_Emergent_Definition

[2]https://www.researchgate.net/publication/335976209_Naturalness_Revisited_Spacetime_Spacephase

## Extending QED to Interactions of the Full Eight-Component Vacuum Wavefunction of the Geometric Representation of Clifford Algebra

DPF annual meeting
https://indico.cern.ch/event/1034469/

Jul 14, 2021, 4:45 PM this talk
15m
Track L (Zoom)

talk | Beyond Standard M... | Beyond Standard Model

youtube link to dry run
https://www.youtube.com/watch?v=Q1bNkXmfUq8

- Clifford algebra in the geometric representation – vacuum wavefunction and geometric quantization
- wavefunction interactions – the geometric product
- the ‘geometric S-matrix’
- physical manifestation – coupling constant and electromagnetic quantization
- the ‘electromagnetic S-matrix’

## QED Model of Massless Neutrino Oscillation in the Geometric Representation of Clifford Algebra

Jul 14, 2021, 5:00 PM next talk
15m
Track L (Zoom)

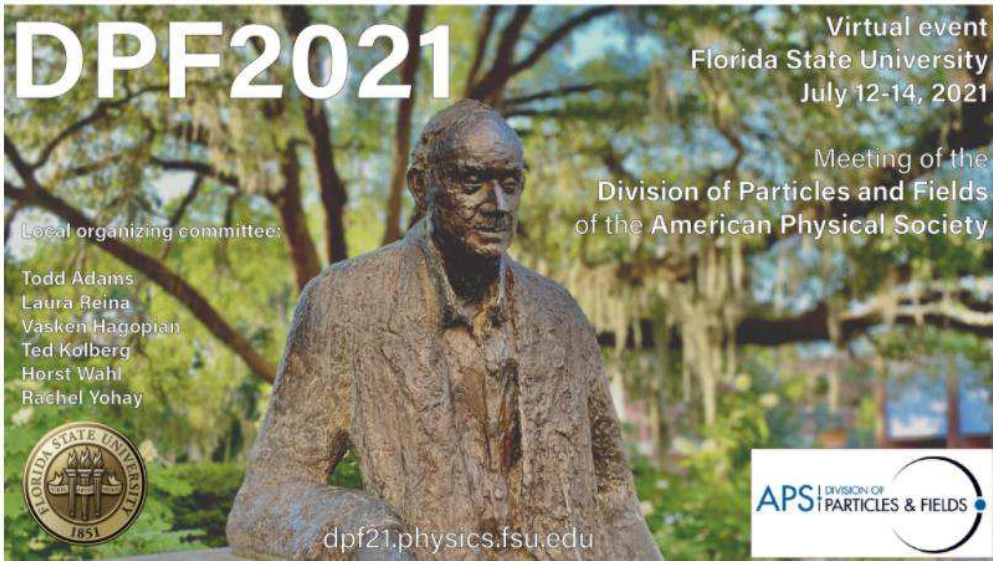
talk | Beyond Standard M... | Beyond Standard Model

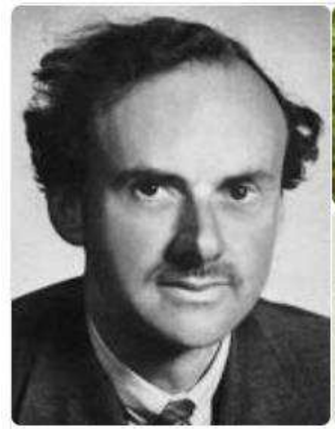
- quantized impedance networks of wavefunction interactions – the connection to physical reality
- examples – H atom, unstable particle spectrum, Planck length, cosmology, chiral anomaly,…
- massless neutrino oscillation and the **muon collider**

Naturalness begets Naturalness: An Emergent Definition
Naturalness Revisited: not Spacetime, Spacephase

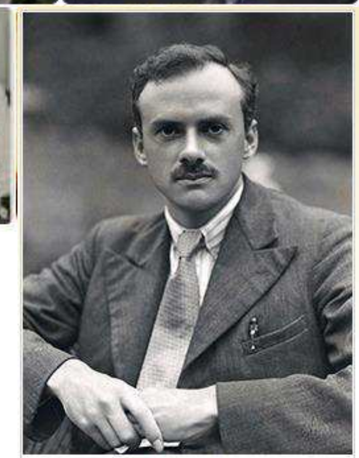
# Extending two component QED Dirac Spinors: Eight component vacuum wavefunctions in the **geometric** representation of Clifford algebra

Peter Cameron
Michigan/MIT/Brookhaven (retired)



FSU Emeritus
1969-1984


Paul A.M. Dirac

“Geometric Algebra is the universal language for mathematical physics”

Clifford’s intent was an algebra of geometric objects. He called it ‘Geometric Algebra’ (1878, DoD 1879)

GA lost the math war with vector algebra (true in 3D only) of Heaviside and Gibbs (~1900 )

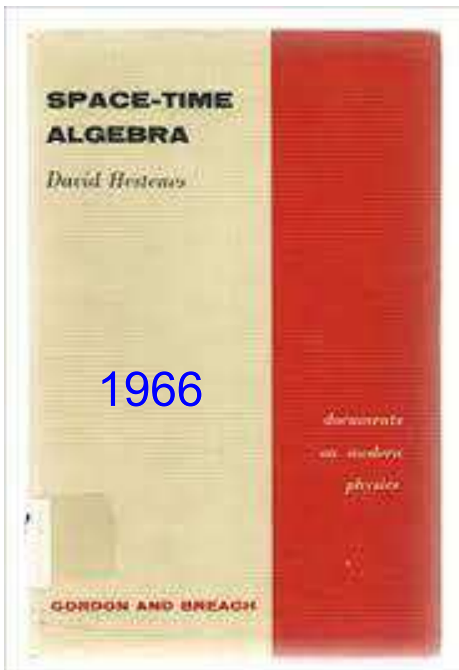
Absent GA, the natural language of GR, Einstein adopted the calculational artifice of ‘curved space’ (1917)

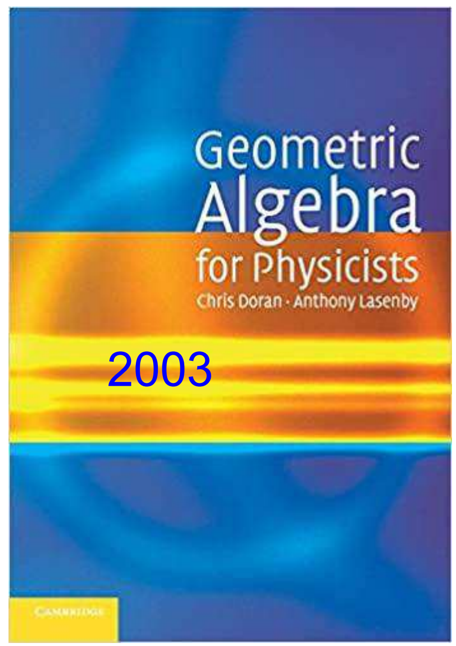
‘’ ‘’ ‘’ ‘’ ‘’ ‘’ QM, Dirac discovered the unintuitive matrix representation (1928)

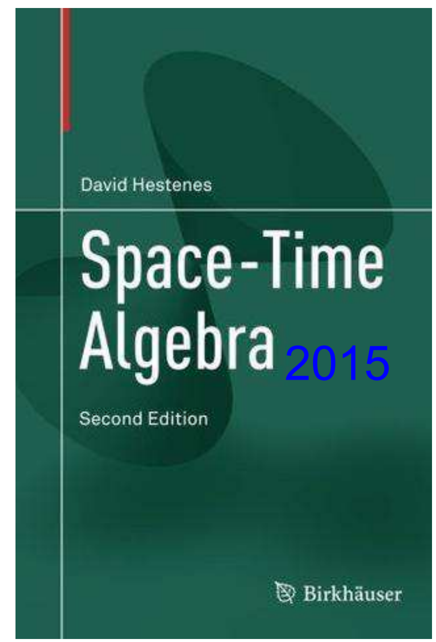
GA rediscovered and extended by Hestenes, Cambridge group, many others (1965 onwards)

## Division Algebras - add, subtract, multiply, **divide**

- division is essential for invertibility (… topology, singularities, dark matter, T-duality, …)
- there exist only four division algebras – real, complex, quaternion, and octonion ⟵ Hurwitz theorem
- these are Clifford algebras, more familiar in Pauli and Dirac matrix representations
  - Pauli matrices are basis vectors of 3D space in GA
  - Dirac matrices “ “ “ “ 4D spacetime
- eight-component 3D Pauli algebra is minimally and maximally complete
- the ‘natural’ vacuum wavefunction of quantum mechanics – the same at all scales




http://geocalc.clas.asu.edu/pdf/SpacetimePhysics.pdf

# Outline

- "… be bold and explicit in making **claims**…" Hestenes STA 2nd ed.
- the theoretical minimum – three assumptions
- Clifford algebra in the geometric representation – vacuum wavefunction
- wavefunction interactions – the geometric product
- the 'geometric S-matrix'
- physical manifestation – coupling constant
- the 'electromagnetic S-matrix'
- origin of inertial mass

- The next talk – massless neutrino oscillations

Abstract ID : **21**

# Extending QED to Interactions of the Full Eight-Component Vacuum Wavefunction of the Geometric Representation of Clifford Algebra

Clifford algebra is the math language of quantum mechanics, known to most physicists in the matrix representations of Pauli and Dirac. Less familiar (but far more intuitive) is the original geometric intent of Clifford, the algebra of interactions of fundamental geometric objects - point, line, plane, and volume elements. In geometric representation, the 3D vacuum wavefunction is comprised of one scalar point, three vector line elements (orientational degrees of freedom), three bivector area elements, and one trivector volume element. Various combinations of the four fundamental constants that define the dimensionless electromagnetic coupling constant alpha (speed of light, permittivity of space, electric charge quantum and angular momentum quantum) permit assigning geometrically and topologically appropriate electric and magnetic flux quanta to the eight wavefunction components, increasing 'dimensionality' of the model to the ten degrees of freedom of string theory. Time (quantum phase) emerges from wavefunction interactions, in the dimension-increasing property of Clifford algebra wedge products. Such a 6D Yang-Mills model is naturally gauge invariant, finite, confined, asymptotically free, background independent, and contains the four forces [1,2].

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… unstable particle lifetimes, branching ratio calculations, dark matter, dark energy, big bang/bounce, inflation, *quantum interpretations*…

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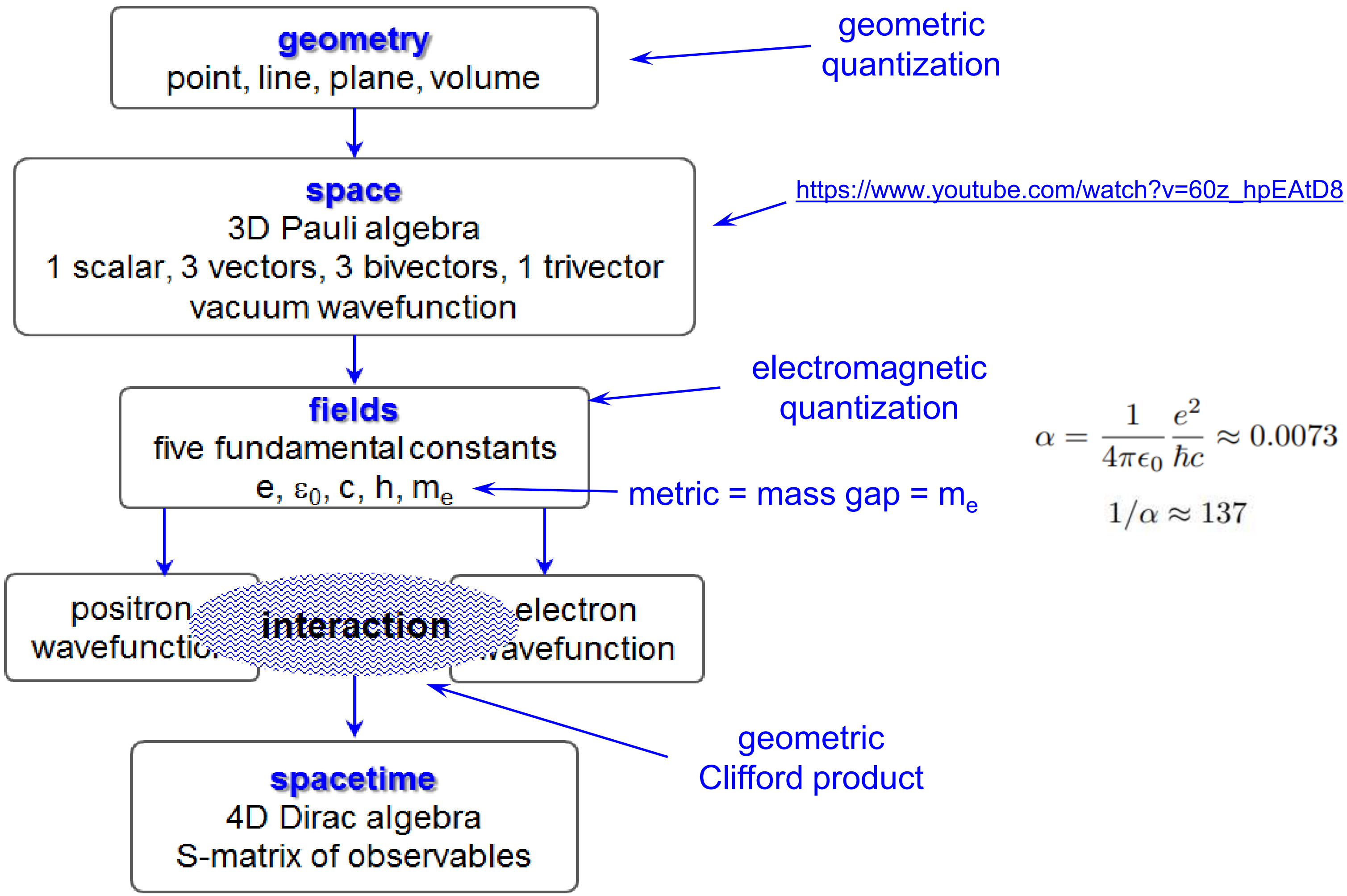
# The Theoretical Minimum

## Three assumptions – geometry, fields, and ‘mass gap’




$$\alpha = \frac{1}{4\pi\epsilon_0}\frac{e^2}{\hbar c} \approx 0.0073$$

$$1/\alpha \approx 137$$

**no free parameters**

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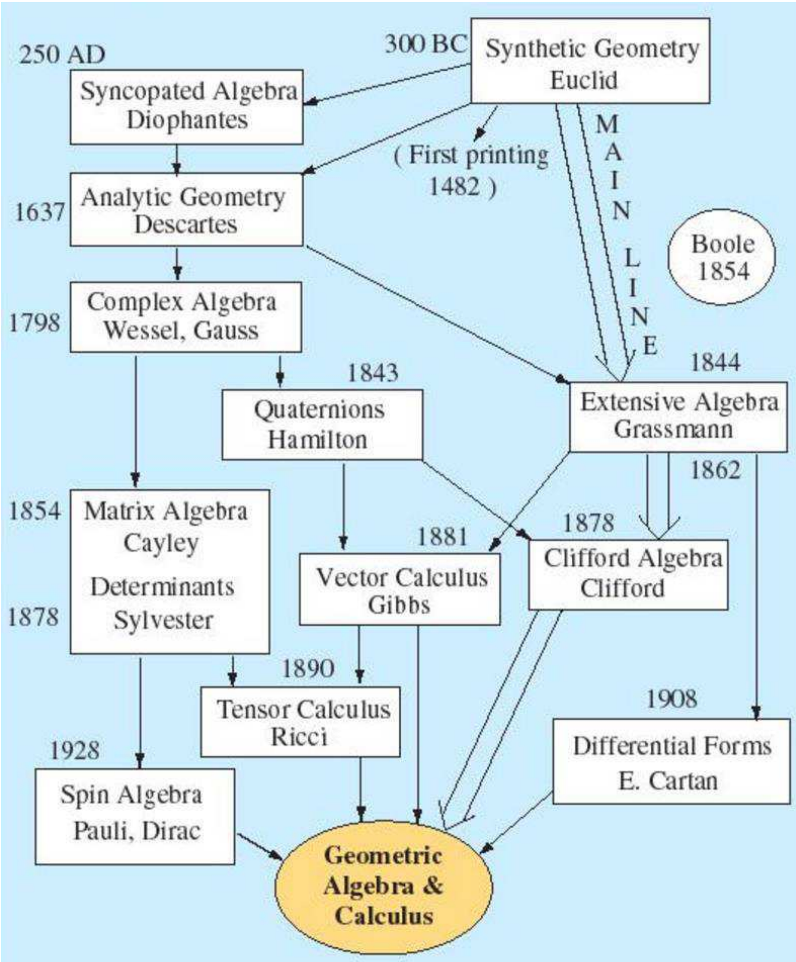
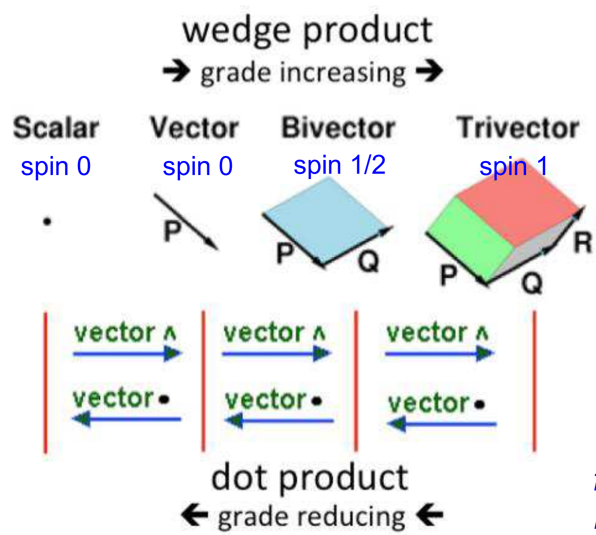
“Geometric Algebra is the universal language for mathematical physics”




The 2002 Oersted Medal
was awarded to David Hestenes
by the American Physical Society for
“Reforming the mathematical
language of physics”




*dynamic susy!*
*fermions to bosons*
*bosons to fermions*

Given two vector bosons W and Z, the product WZ changes grades. In the product WZ = W·Z + W∧Z, two grade 1 vector bosons transform to grade 0 scalar boson and grade 2 bivector fermion WZ = Higgs + top

Taken together, the four superheavies comprise a minimally complete
2D Clifford algebra – one scalar, two vectors, and one bivector

sum mode $m_Z + m_W = m_{top}$ *no Higgs here?*
difference mode $m_Z - m_W = m_{bottomonium}$

# the geometric S-matrix

| | scalar | vector | vector | vector | bivector | bivector | bivector | trivector |
|---|---|---|---|---|---|---|---|---|
| scalar | scalar | vector | vector | vector | bivector | bivector | bivector | trivector |
| vector | vector | | | | | | | |
| vector | vector | | scalar + bivector | | | vector + trivector | | bivector + quadvector |
| vector | vector | | | | | | | |
| bivector | bivector | | | | | | | |
| bivector | bivector | | vector + trivector | | | scalar + quadvector | | vector + pentavector |
| bivector | bivector | | | | | | | |
| trivector | trivector | | bivector + quadvector | | | vector + pentavector | | scalar + sextavector |

*'geometric quantization'*

blue background = even dimensions = eigenmodes ~ flavor
yellow background = odd dimensions = transition modes ~ color

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$$\alpha = \frac{1}{4\pi\epsilon_0}\frac{e^2}{\hbar c} \approx 0.0073$$

$$1/\alpha \approx 137$$

## physical manifestation – coupling constant

| | | |
|---|---|---|
| electric charge | | $e := 1.602176487 \cdot 10^{-19} \cdot \mathrm{coul}$ |
| magnetic charge | $g := \frac{h}{e}$ | $g = 4.1356673326 \times 10^{-15}\, \mathrm{tesla} \cdot \mathrm{m}^2$ |
| magnetic flux quantum | $\Phi_B := \frac{h}{e}$ | $\Phi_B = 4.1356673326 \times 10^{-15}\, \mathrm{tesla} \cdot \mathrm{m}^2$ |
| large electric flux quantum (photon) | $\Phi_{E1} := \frac{h \cdot c}{e}$ | $\Phi_{E1} = 1.2398418751 \times 10^{0}\, \mathrm{mvolt} \cdot \mathrm{mm}$ |
| small electric flux quantum (electron) | $\Phi_{E2} := \frac{e}{\varepsilon_0}$ | $\Phi_{E2} = 1.809512651 \times 10^{-2}\, \mathrm{volt} \cdot \mu\mathrm{m}$ |
| Bohr magneton | $\mu_B := \frac{e \cdot \lambda\mathrm{bar}_e \cdot c}{2}$ | $\mu_B = 9.2740091365 \times 10^{-24}\, \frac{\mathrm{joule}}{\mathrm{tesla}}$ |
| large EDM | $d_{\mathrm{Bohr1}} := \frac{g \cdot \mathrm{hbar}}{\mu_0 \cdot m_e \cdot c^2}$ | $d_{\mathrm{Bohr1}} = 4.2391764 \times 10^{-30}\, \mathrm{mcoul}$ |
| small EDM | $d_{\mathrm{Bohr2}} := e \cdot \lambda\mathrm{bar}_e$ | $d_{\mathrm{Bohr2}} = 6.1869529329 \times 10^{-32}\, \mathrm{mcoul}$ |

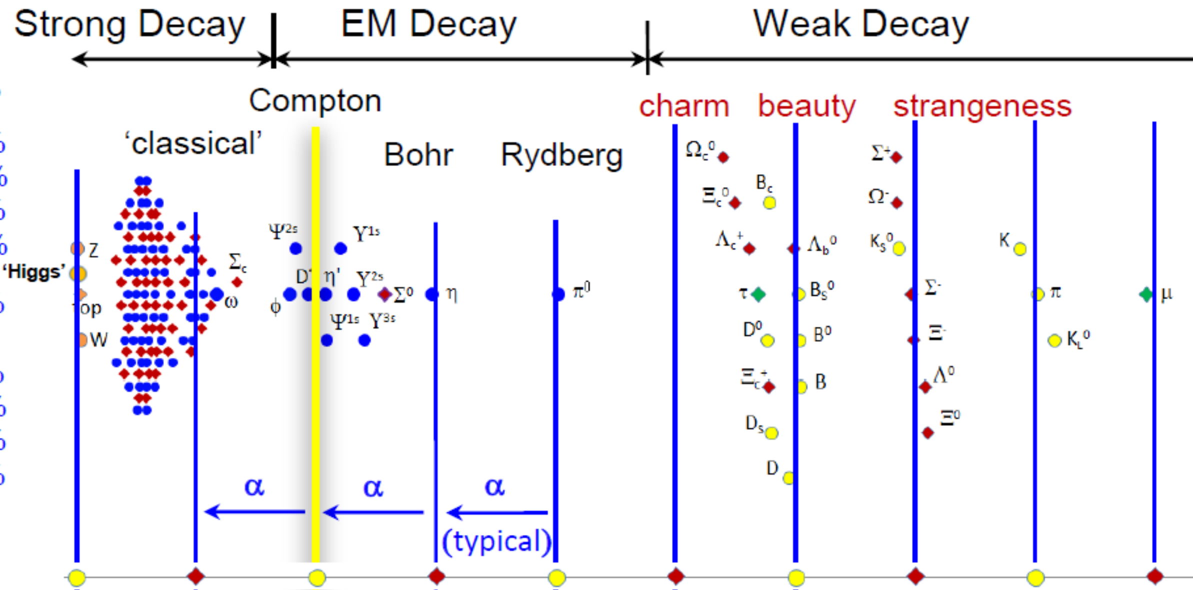
| | electric charge<br>$e$<br>*scalar* | elec dipole moment 1<br>$d_{E1}$<br>*vector* | elec dipole moment 2<br>$d_{E2}$<br>*vector* | mag flux quantum<br>$\phi_B$<br>*vector* | elec flux quantum 1<br>$\phi_{E1}$<br>*bivector* | elec flux quantum 2<br>$\phi_{E2}$<br>*bivector* | magnetic moment<br>$\mu_{Bohr}$<br>*bivector* | magnetic charge<br>$g$<br>*trivector* |
|---|---|---|---|---|---|---|---|---|
| $e$ | $ee$<br>*scalar* | $ed_{E1}$ | $ed_{E2}$<br>*vector* | $e\phi_B$ | $e\phi_{E1}$ | $e\phi_{E2}$<br>*bivector* | $e\mu_B$ | $eg$<br>*trivector* |
| $d_{E1}$ | $d_{E1}e$ | $d_{E1}d_{E1}$ | $d_{E1}d_{E2}$ | $d_{E1}\phi_B$ | $d_{E1}\phi_{E1}$ | $d_{E1}\phi_{E2}$ | $d_{E1}\mu_B$ | $d_{E1}g$ |
| $d_{E2}$ | $d_{E2}e$ | $d_{E2}d_{E1}$ | $d_{E2}d_{E2}$ | $d_{E2}\phi_B$ | $d_{E2}\phi_{E1}$ | $d_{E2}\phi_{E2}$ | $d_{E2}\mu_B$ | $d_{E2}g$ |
| $\phi_B$ | $\phi_B e$<br>*vector* | $\phi_B d_{E1}$ | $\phi_B d_{E2}$<br>*scalar + bivector* | $\phi_B\phi_B$ | $\phi_B\phi_{E1}$<br>$\gamma$ | $\phi_B\phi_{E2}$<br>*vector + trivector* | $\phi_B\mu_B$ | $\phi_B g$<br>*bv + qv* |
| $\phi_{E1}$ | $\phi_{E1}e$ | $\phi_{E1}d_{E1}$ | $\phi_{E1}d_{E2}$ | $\phi_{E1}\phi_B$<br>$\gamma$ | $\phi_{E1}\phi_{E1}$ | $\phi_{E1}\phi_{E2}$ | $\phi_{E1}\mu_B$ | $\phi_{E1}g$ |
| $\phi_{E2}$ | $\phi_{E2}e$ | $\phi_{E2}d_{E1}$ | $\phi_{E2}d_{E2}$ | $\phi_{E2}\phi_B$ | $\phi_{E2}\phi_{E1}$ | $\phi_{E2}\phi_{E2}$ | $\phi_{E2}\mu_B$ | $\phi_{E2}g$ |
| $\mu_B$ | $\mu_B e$<br>*bivector* | $\mu_B d_{E1}$ | $\mu_B d_{E2}$<br>*vector + trivector* | $\mu_B\phi_B$ | $\mu_B\phi_{E1}$ | $\mu_B\phi_{E2}$<br>*scalar + quadvector* | $\mu_B\mu_B$ | $\mu_B g$<br>*vector + pv* |
| $g$ | $ge$<br>*trivector* | $gd_{E1}$ | $gd_{E2}$<br>*bivector + quadvector* | $g\phi_B$ | $g\phi_{E1}$ | $g\phi_{E2}$<br>*vector + pentavector* | $g\mu_B$ | $gg$<br>*scalar + sv* |

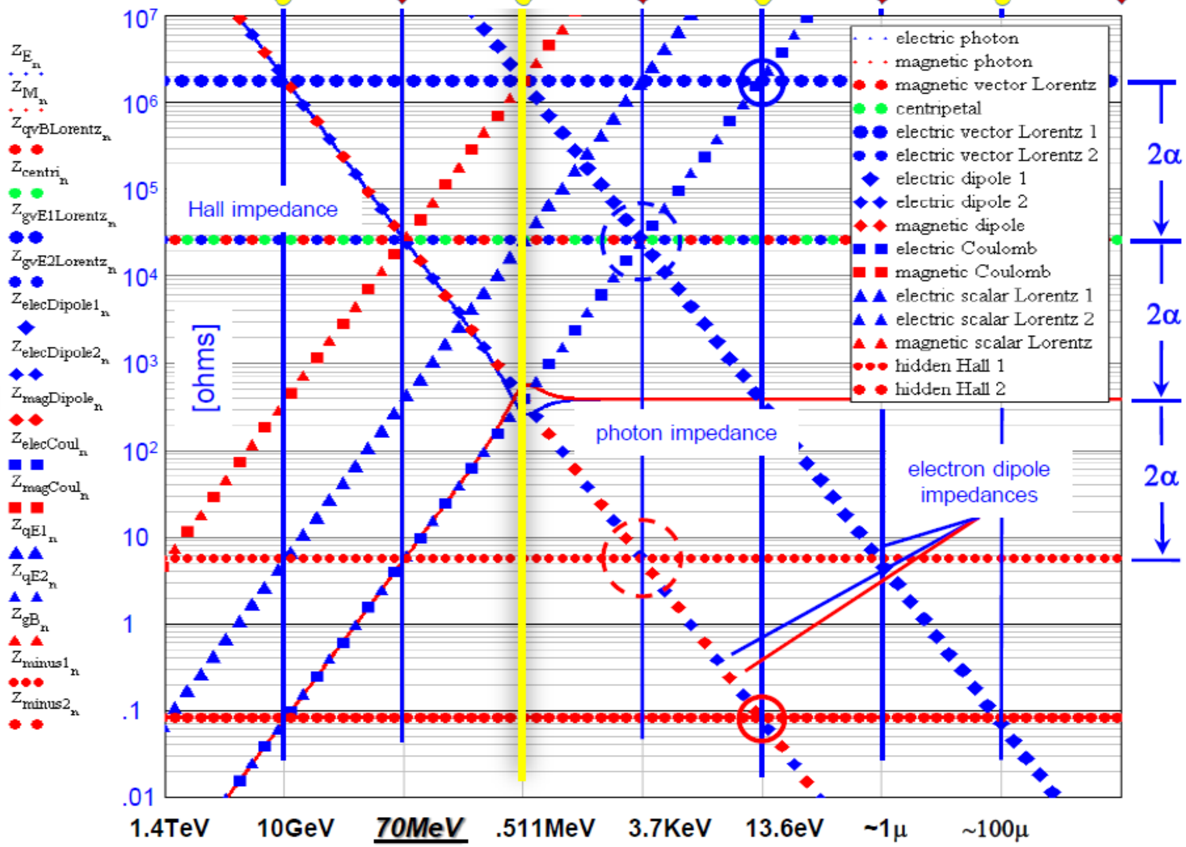
S-matrix of Dirac's QED, extended to the full eight-component vacuum wavefunction in the geometric representation of Clifford algebra. Symbols (triangle, diamond,…) correspond to following slides.

QED 2 body – fundamental
SR 3 body – emergent

.511 MeV ‘mass gap’ requires massless ν oscillation.
No match at Bohr radius

| | | |
|---|---|---|
| $\pi_0 \to 2\gamma$ | | 98.8% |
| $\pi_0 \to e^+e^-\gamma$ | | 1.2% |
| $\eta \to 2\gamma$ | | 39.3% |
| $\eta \to 3\pi^0$ | | 32.6% |
| $\eta \to \pi^+\pi^-\pi^0$ | | 22.7% |
| $\eta \to \pi^+\pi^-\gamma$ | | 4.6% |
| $\eta' \to \pi^+\pi^-\eta$ | | 39.3% |
| $\eta' \to \rho^0\gamma$ | | |
| incl. $\pi^+\pi^-\gamma$ | | 29.3% |
| $\eta' \to \pi^0\pi^0\eta$ | | 21.6% |
| $\eta' \to \omega\gamma$ | | 2.8% |
| $\eta' \to \gamma\gamma$ | | 2.2% |




- 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 $\pi_0$ are at conjunctions of mode impedances, can couple to the photon for fast EM decay
- Location of $\pi_0$ 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

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- origin of inertial mass

- The next talk – massless neutrino oscillations

| ‘classical’ | Compton | Bohr |
|---|---|---|

## ‘classical’

$$d_{Bohr1}\cdot E_1 = 7.0025246458\times 10^{1}\ \mathrm{MeV}$$

$$\frac{g}{\mu_0}\cdot B\cdot \lambda bar_e = 7.0025246458\times 10^{1}\ \mathrm{MeV}$$

$$\pi\cdot\varepsilon_0\lambda bar_e^{\,3}\cdot E_1^{\,2} = 7.0025246458\times 10^{1}\ \mathrm{MeV}$$

$$\pi\ \lambda bar_e^{\,3}\sqrt{\frac{\varepsilon_0}{\mu_0}}\,E_1\cdot B = 7.0025246458\times 10^{1}\ \mathrm{MeV}$$

$$\frac{\pi\ \lambda bar_e^{\,3}}{\mu_0}\cdot B^2 = 7.0025246458\times 10^{1}\ \mathrm{MeV}$$

## Compton

$$2\mu_B\cdot B = 1.02199782\times 10^{0}\ \mathrm{MeV}$$

$$d_{Bohr1}\cdot E_2 = 1.02199782\times 10^{0}\ \mathrm{MeV}$$

$$d_{Bohr2}\cdot E_1 = 1.02199782\times 10^{0}\ \mathrm{MeV}$$

$$e\cdot E_1\cdot\lambda bar_e = 1.02199782\times 10^{0}\ \mathrm{MeV}$$

$$\pi\cdot\varepsilon_0\lambda bar_e^{\,3}\cdot E_1\cdot E_2 = 1.02199782\times 10^{0}\ \mathrm{MeV}$$

$$\pi\ \lambda bar_e^{\,3}\sqrt{\frac{\varepsilon_0}{\mu_0}}\,E_2\cdot B = 1.02199782\times 10^{0}\ \mathrm{MeV}$$

## Bohr

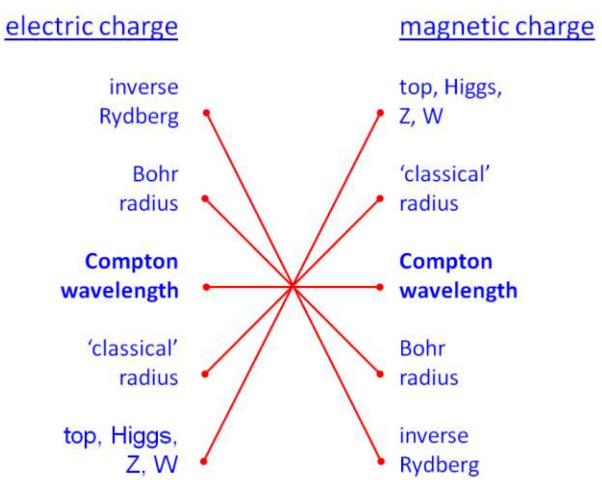
$$d_{Bohr2}\cdot E_2 = 1.4915756772\times 10^{1}\ \mathrm{KeV}$$

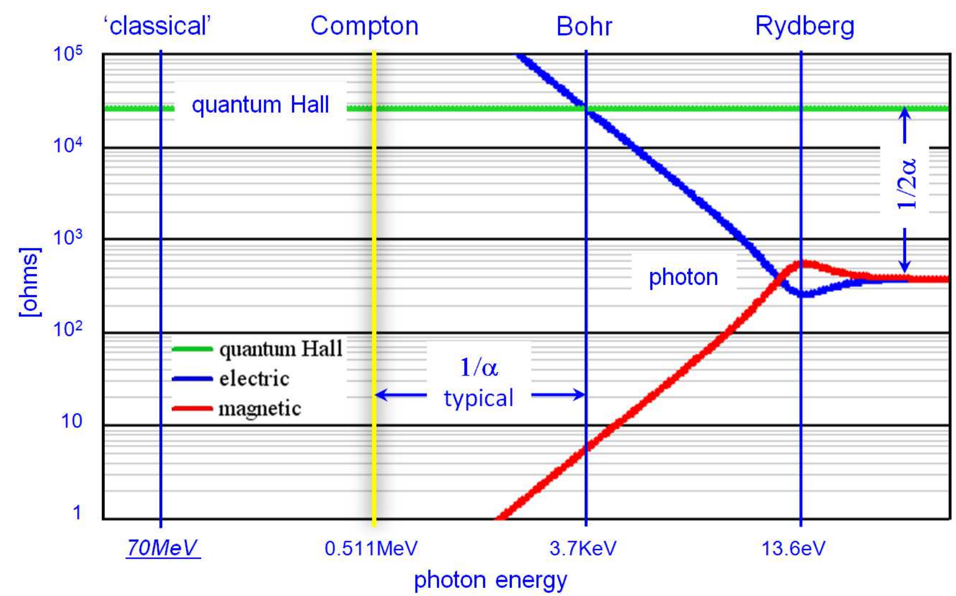
$$e\cdot E_2\cdot\lambda bar_e = 1.4915756772\times 10^{1}\ \mathrm{KeV}$$

$$\pi\cdot\varepsilon_0\lambda bar_e^{\,3}\cdot E_2^{\,2} = 1.4915756772\times 10^{1}\ \mathrm{KeV}$$

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

## topological inversion



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