From Atoms to Higgs Boson
Voyages in Quasi-Spacetime

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Saskatoon, Canada welcomes you to attend the

11th edition of the International Conference on Isotopes (11 ICI) on June 19-23, 2022

Themes:
Production of isotopes
Extraction of isotopes and uranium mining
Radio-analytical chemistry
Isotopes in Cosmos and Astrophysics
Application of isotopes in soil and plant sciences
Radiochemistry and radiopharmaceuticals
Etc.

A short PR

Contents

- Introduction
- Space vs geometry
- Quasi realism
- Mathematical Spaces
- Mass
- When an Atom ?
- Bosons & Photons
- Higgs Boson
- Epilogue

A disclaimer

- We <u>do not </u>propose new theories

- We don't claim that we are smarter than our predecessors and genii of earlier and present times

- We ask simple, honest questions to examine the logical rigour, conceptual clarity, meaning of physical reality

Space vs Geometry

- *Our task is to learn the use of these words correctly – that is, unambiguously and consistently --   Niels Bohr*

- Geometry is <u>NOT</u> a synonym of space

- Geometry is used to describe the shape(s) of confined spaces.

- An empty space without any contents to define its boundaries has no geometry

Space vs Geometry

- Euclid of Alexandria (323-285 BCE ??) – Euclidean geometry

5 postulates ---- 5th Postulate of parallel lines

If a straight line falling on two straight lines makes the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles.[2]
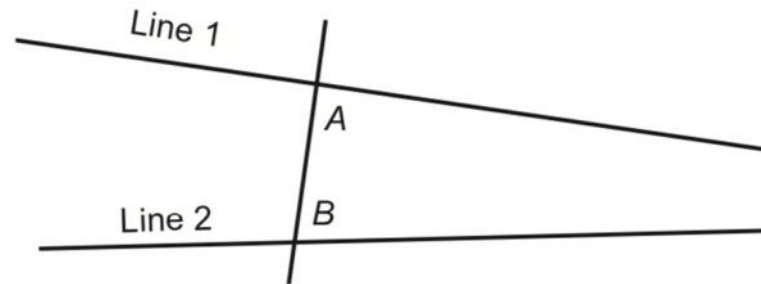

Figure 4.1 Non-parallel lines as defined in Euclid's fifth postulate of geometry.

Euclid's Postulates (From Wolfram Mathworld)

1. A straight line segment can be drawn joining any two points.

2. Any straight line segment can be extended indefinitely in a straight line.

3. Given any straight line segment, a circle can be drawn having the segment as radius and one endpoint as center.

4. All right angles are congruent.

5. If two lines are drawn which intersect a third in such a way that the sum of the inner angles on one side is less than two right angles, then the two lines inevitably must intersect each other on that side if extended far enough. This postulate is equivalent to what is known as the parallel postulate.

Non- Euclidean Geometry (not space)

- Hyperbolic Geometry
- Spherical Geometry etc…..
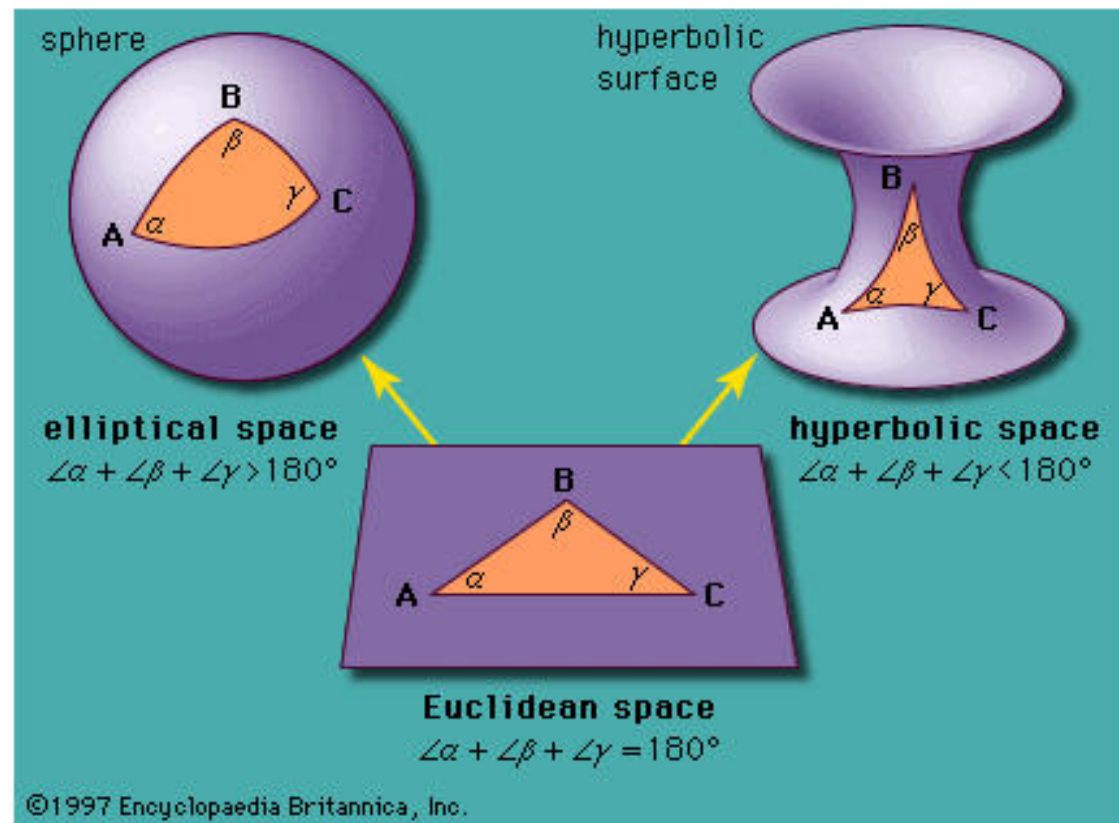
- As physicists, we are aware of the advantages of employing the best suited geometries to identify symmetries and conserved laws

  Ex: Central forces (spherical polar coordinates)

  Axial symmetry (cylindrical coordinates) etc.

The space has not changed. It is the geometry which is changed.

Quasi particle Approach

- Introduced in solid state physics

A microscopically complicated many body system is treated as if it consists of a fewer bodies in a mean field or even as free entities, but with an effective mass, much different from its nominal mass

Electrons ---- > Electron quasiparticles

- Phonons, Cooper pairs, Plasmons, Magnons etc...

Empiricism, Positivism, Realism and Quasirealism

Positivism is a philosophical theory stating that certain ("positive") knowledge is based on natural phenomena and their properties and relations.

Empiricism, in philosophy, the view that all concepts originate in experience

realism about a given object is the view that this object exists in reality independently of our conceptual scheme. In philosophical terms, these objects are ontologically independent of someone's conceptual scheme, perceptions, linguistic practices, beliefs, etc.

Quasirealism: A philosophical perspective on science that identifies otherwise clearly unphysical mathematical conveniences as having real existence in the physical world

Quasi Realism --- 4d space-time

- (x, y, z, ict)

- Unlike the spatial components, time is not an independent observable

- The multiplicative factor "c" is not linearly independent variable

$$c = \frac{|\delta r|}{\delta t} = \frac{|\delta r'|}{\delta t'}$$

Each observer should recalibrate their rulers and clocks to get the value "c" in their reference frame

- By the way, speed of light is constant in empty space.

- Empty space does not exist

Mathematical Spaces:

- A mathematical function of "n" <u>linearly independent</u> variables spans an "n" dimensional vector "space".

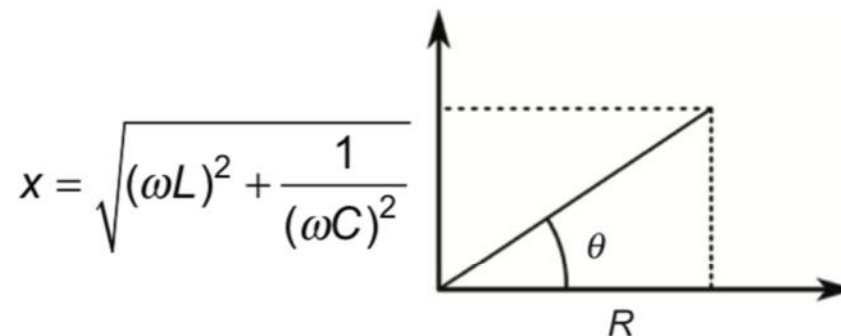- A simple example of mathematical non- physical space

$$x = \sqrt{(\omega L)^2 + \frac{1}{(\omega C)^2}}$$

Figure 4.2   Representation of resistance (R) and reactance (χ) of an electrical circuit as a complex variable two-dimensional plane. No one misinterprets this plane to be a physical space.

In modern physics

- Hilbert space of eigen states   (The isospin of Heisenberg is a subset of these wave functions)

- Phase space

- Complex spaces

- String theory (26 dimensions for Bosonic strings and 10 dimensions for Fermions)

  - 4d- spacetime does not meet this basic mathematical requirement

Mass

- Newton's definition: **F= ma**,

    At Newton's times, it was all mechanical and every thing was elastic

- Lorentz force recognizes non-mechanical forces and links to mechanical ones too..

- In particle physics, we make extensive use of Lorentz force through inertia to determine masses for stable and long-lived particles

-   $F = q [v \times B] = ma = m \omega^2 r$

Inertia as a measure of mass

- Limited applicability in particle physics

- Invariant mass

- More recently, a model parameter to fit cross section data

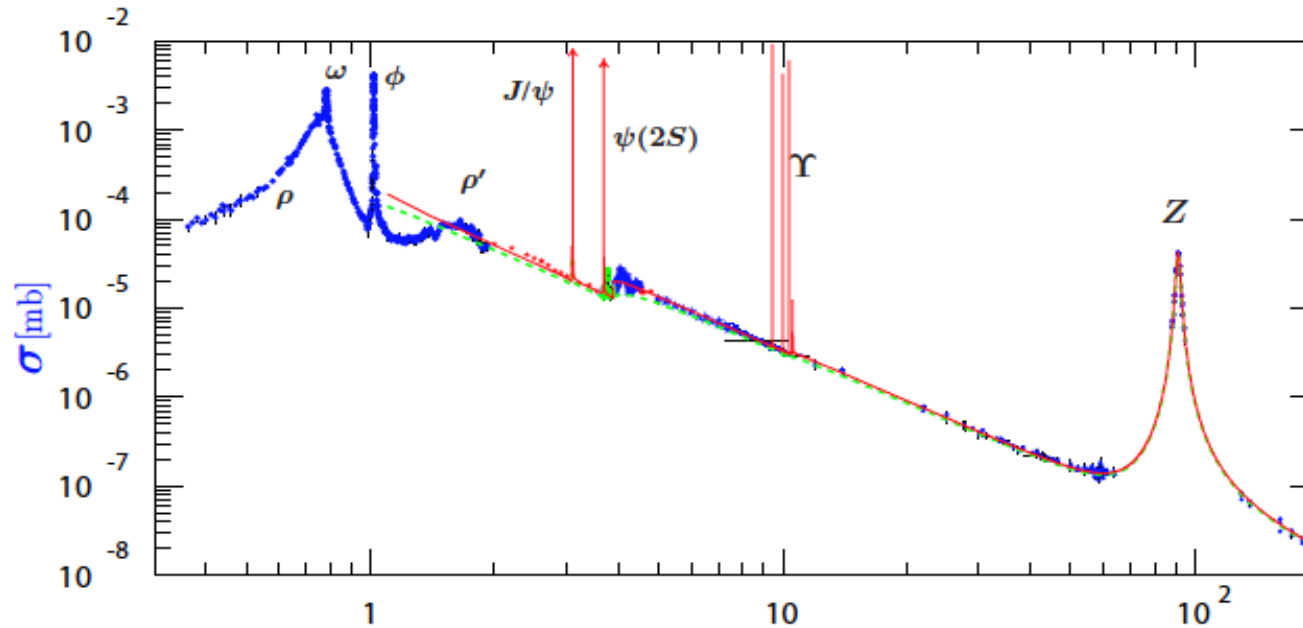# Electron-Positron Collisions: resonances and particles

Figure 5 - Particle and resonances appearing from electron-positron collisions.

ρ, ω, ϕ : No knowledge of masses of constituent quarks;
J/Ψ and **Y** :   quark masses are ½ of the resonance energy
Z- boson is a particle despite its large width
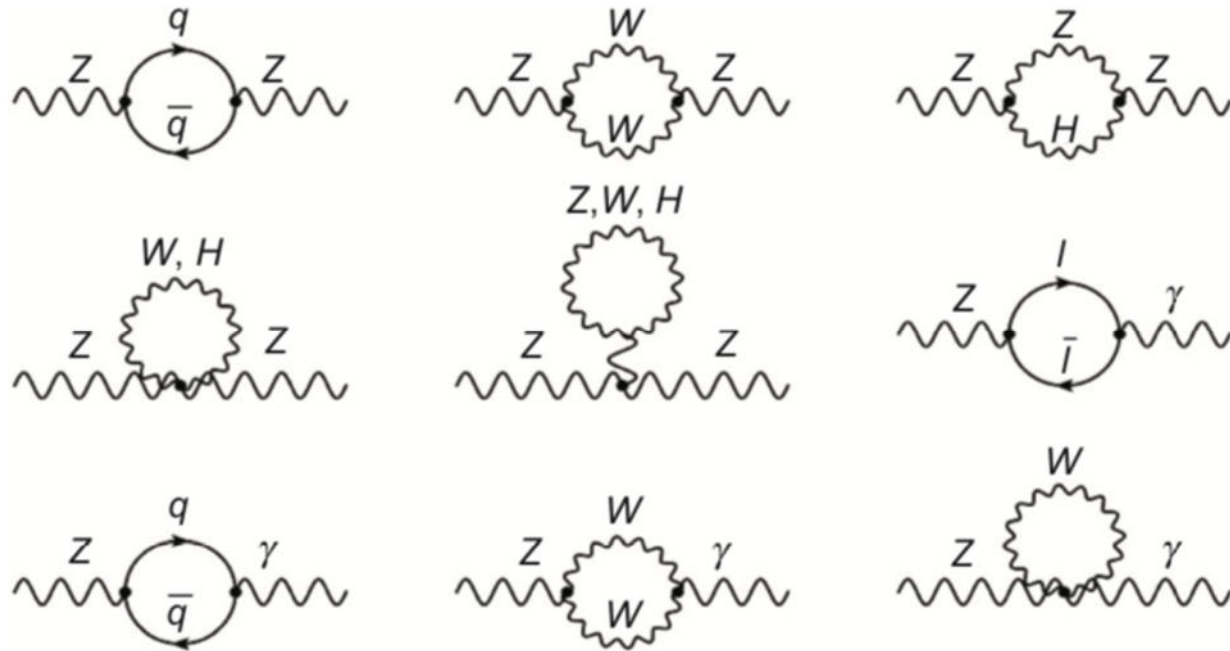
Speaking of Z-boson:

- Mass : 91.1876 ± 0.0021 (PDG)

- Width: 2.4952 ± 0.0023 (PDG) $\tau \sim 10^{-25}$ s.

Why this particle, solely designed to mediate weak interactions, is in such a hurry to end its life in strong interaction life times ?

$|Z\rangle = 0.88 |W_3\rangle + 0.52 |B\rangle$
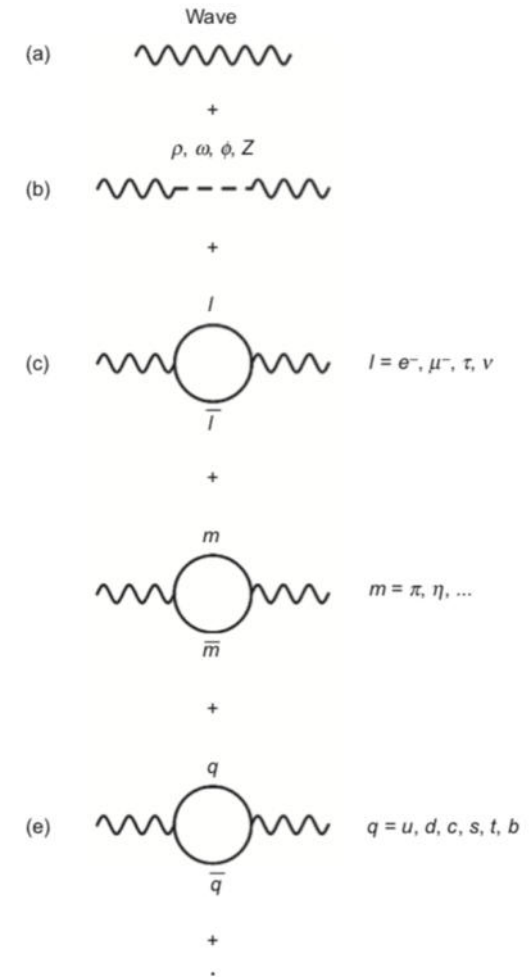
$|Photon\rangle = 0.88 |B\rangle - 0.52 |W_3\rangle$

Fleeting Avatars of Z-boson

What is photon anyways?

❖ A classical wave

❖ A virtual

vector meson

Gauge boson

lepton-antilepton pair

meson-antimeson pair

quark-antiquark pair

Etc.

Wave

(a)

+

ρ, ω, ϕ, Z

(b)

+

l

(c) $l = e^-, \mu^-, \tau, \nu$

$\bar{l}$

+

m

$m = \pi, \eta, \ldots$

$\bar{m}$

+

q

(e) $q = u, d, c, s, t, b$

$\bar{q}$

+

.

None of the other physical Gauge bosons are elementary either

$$W^{\pm} = \frac{1}{\sqrt{2}}\left[W^1 \pm W^2\right]$$

The physical W$^+$, W$^-$ are not pure single configurations. The mathematical W^1 W^2 are not charge eigen states.

- Physical gluons are not elementary. Elementary gluons are not Physical.

$(r\bar{b} + b\bar{r})/\sqrt{2}$

$(r\bar{g} + g\bar{r})/\sqrt{2}$

$(g\bar{b} + b\bar{g})/\sqrt{2}$

$(r\bar{r} - b\bar{b})/\sqrt{2}$

$-i(r\bar{b} - b\bar{r})/\sqrt{2}$

$-i(r\bar{g} - g\bar{r})/\sqrt{2}$

$-i(-g\bar{b} + b\bar{g})/\sqrt{2}$

$(r\bar{r} + b\bar{b} - 2g\bar{g})/\sqrt{6}$
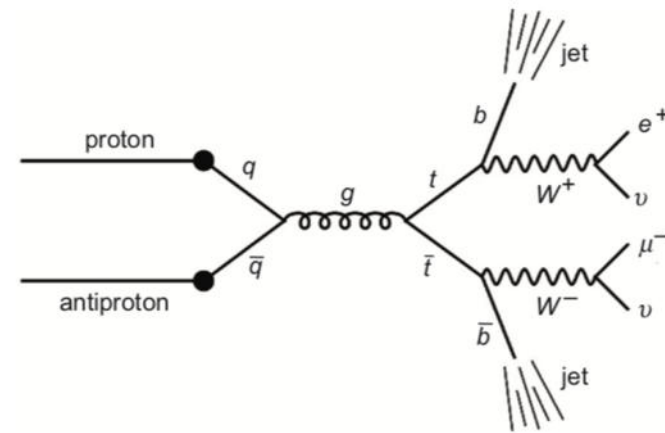
Turning to top quark:

- Production -

Figure 5.4 Illustration of the production of top quarks in a proton–antiproton collision.

Note: Each jet carries a fractional charge

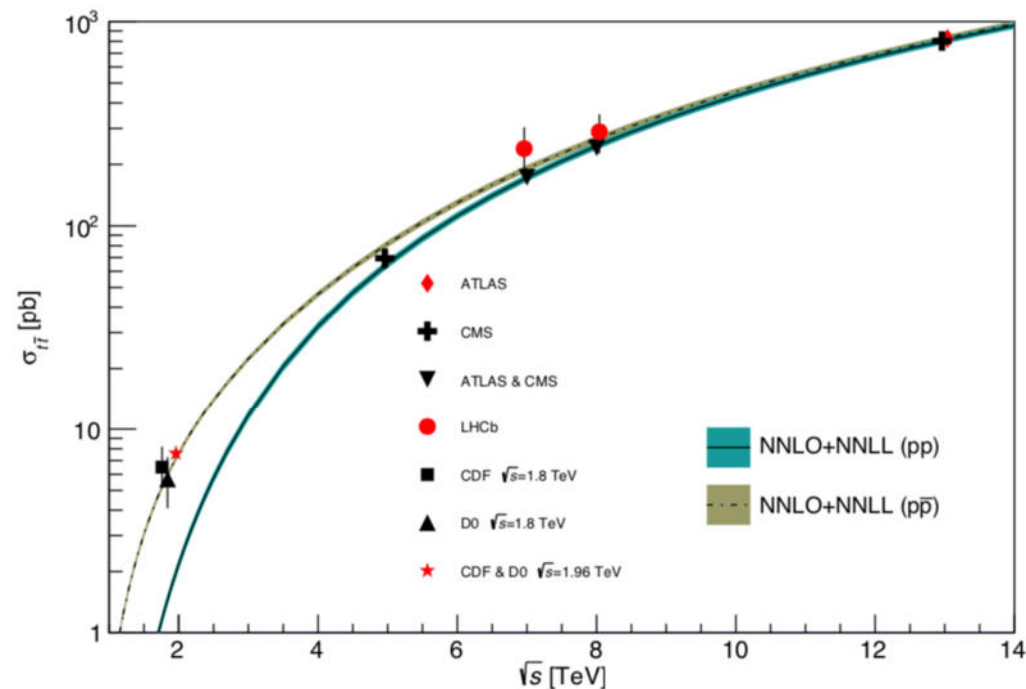# Top quark Mass Estimate (a far cry from a direct measurement)

Figure 67.1: Measured and predicted $t\bar{t}$ production cross sections from Tevatron energies in $p\bar{p}$ collisions to LHC energies in pp collisions. Tevatron data points at $\sqrt{s} = 1.8$ TeV are from Refs.

Experimental data deduced from a mass of 172.5 and model using the same value agrees with data.
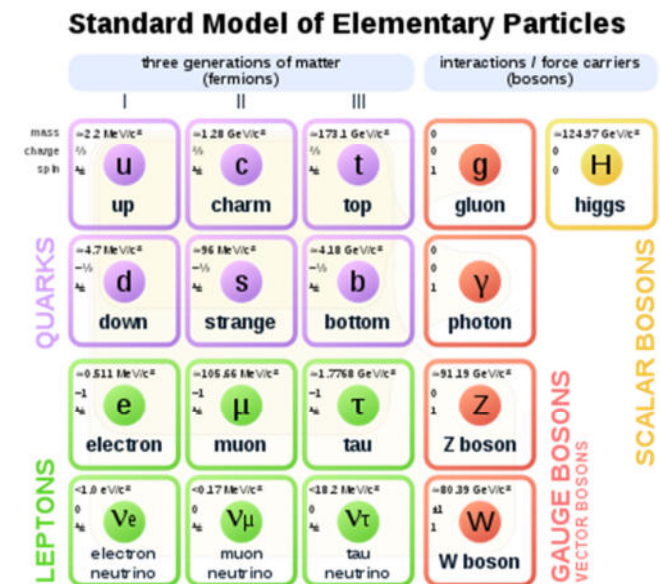
Virtual particles

- The virtual particles' masses are not constrained to nominal masses.
- The virtual particles can also have properties not permitted to real ones (longitudinal photons and photons of non-zero mass)

Generations of quarks and leptons

Table 8.1   Quark and lepton generations

	Generation			Electric Charge[14]
	I	II	III	
Quarks	u up	c charm	t top	2/3
	d down	s strange	b bottom	−1/3
Leptons	ν_e e-neutrino	ν_μ μ-neutrino	ν_τ τ-neutrino	0
	$e-$ electron	$\mu-$ muon	$\tau-$ tau	−1

Present-day picture

- Left handed doublets

$$\binom{u}{d}_L \quad \binom{c}{s}_L \quad \binom{t}{b}_L \quad \text{and} \quad \binom{\nu_e}{e}_L \quad \binom{\nu_\mu}{\mu}_L \quad \binom{\nu_\tau}{\tau}_L \quad I=1/2$$

- Right handed singlets :

$$u_R \quad d_R \quad c_R \quad s_R \quad \tau_R \quad b_R$$

- Right handed charged leptons

$$e_R \quad \mu_R \quad \tau_{R,}$$

- No right handed neutrinos

CKM mixing Matrix

$$\begin{bmatrix} d' \\ s' \\ b' \end{bmatrix} = \begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix} \begin{bmatrix} d \\ s \\ b \end{bmatrix}.$$

Physical

Mathematical

Physical quarks are not elementary !!

Neutrinos -- Pontecarvo Maki Nakagawa Sakata

$$\begin{bmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{bmatrix} = \begin{bmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{bmatrix} \begin{bmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{bmatrix}$$

Physical

Mathematical

Physical Neutrinos are not elementary either !!

- Basic physical entities are not elementary

- Fundamental mathematical entities are not physical

Higgs Boson:

- Detected in the decay mode of 2-photons, while photons do not interact with it (though a photon is about 30% Z- boson)

- Given the mass of a particle, it will tell us the interaction strength and vice versa.

  Eg: Proton is 1836 times heavier than electron

  Proton interaction with Higgs is 1836 times that of electron

  Mass of a fermion $\propto$ Coupling with Higgs

  Mass of a boson $\propto$ square of its coupling with Higgs

  Couplings in Isospin space (a complex mathematical space)

CONCLUSION(s)

- There is <u>NOTHING</u> physically fundamental or elementary any more in particle physics according to present-day models

- Not all is lost…. Indeed, we have an EXCELLENT news for the 20th -21st Century particle physicists

We found the Rosetta stone of Democritus !!

- They are:

  proton, neutron and electron

  They are indivisible

  proton and neutron transform from one to the other but they do not totally disappear

- If particle physicists are looking for reductionism, they already found in proton, neutron and electron

- If they want to study higher and higher energies to see what can be found: Nature told them they are looking at **Piñatas**

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- #6

- #6

Everything should be as simple as it can be, but not simpler –
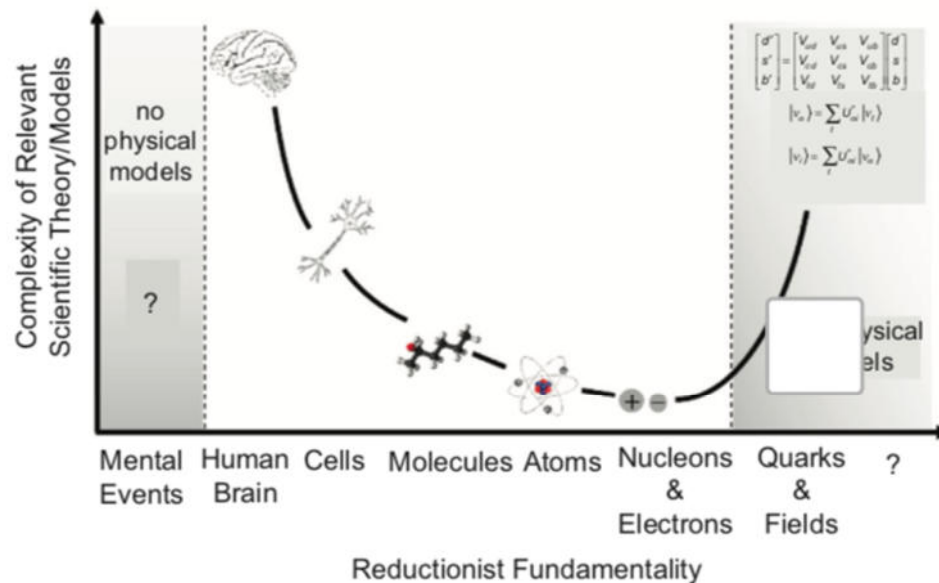
attributed to Einstein

Figure E.1 The hierarchy of physical reductionism compared to the complexity of corresponding scientific models. The trend toward simplification appears to be violated when we reach the sub-nuclear level of quarks, neutrinos, and quantum fields. This may be a clue that we have reached the bottom.

- *Science is a beautiful gift to humanity - we should not distort it*

---- A.P. J. Abdul Kalam (1931- 2015)

Aerospace scientist, ISRO, DRDO Administrator

President of India

- Thank You / Merci

- 有難うございました