Process Theology as a Lens for Bringing Quantum Physics into Focus

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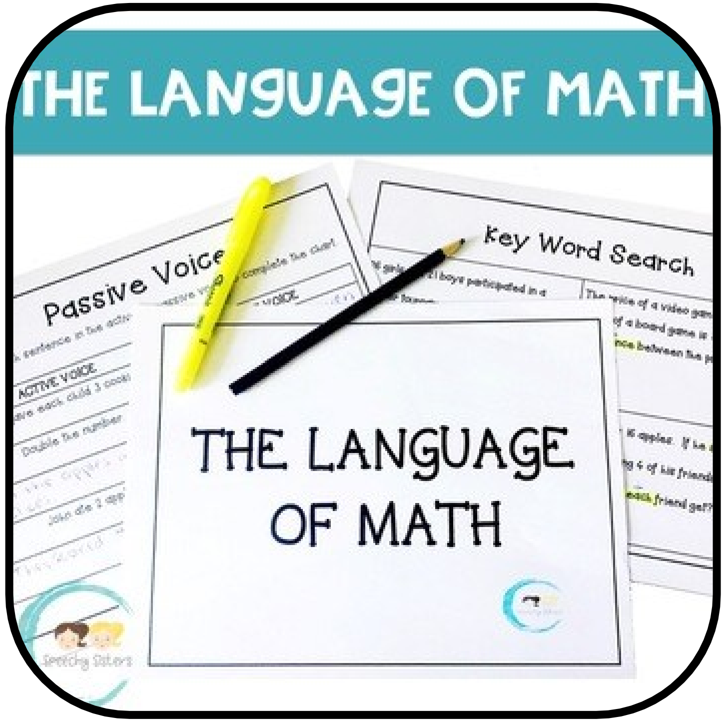
Lecture 2: The Standard Model → Detected Events (Actual occasions)

The Language Problem in Quantum Physics

Quantum Physics and Human Understanding

- The deepest and most accurate language of quantum physics is mathematics.
- But mastering the mathematics of quantum theory requires years of specialized study.
- Quantum physics challenges — or “destabilizes” — the classical picture of reality as fundamentally made of stable, independently existing things.
- Yet quantum physics does not naturally provide replacement conceptual language for ordinary human understanding.



The Result: We can calculate quantum reality with extraordinary precision, but struggle to describe it conceptually in everyday language.

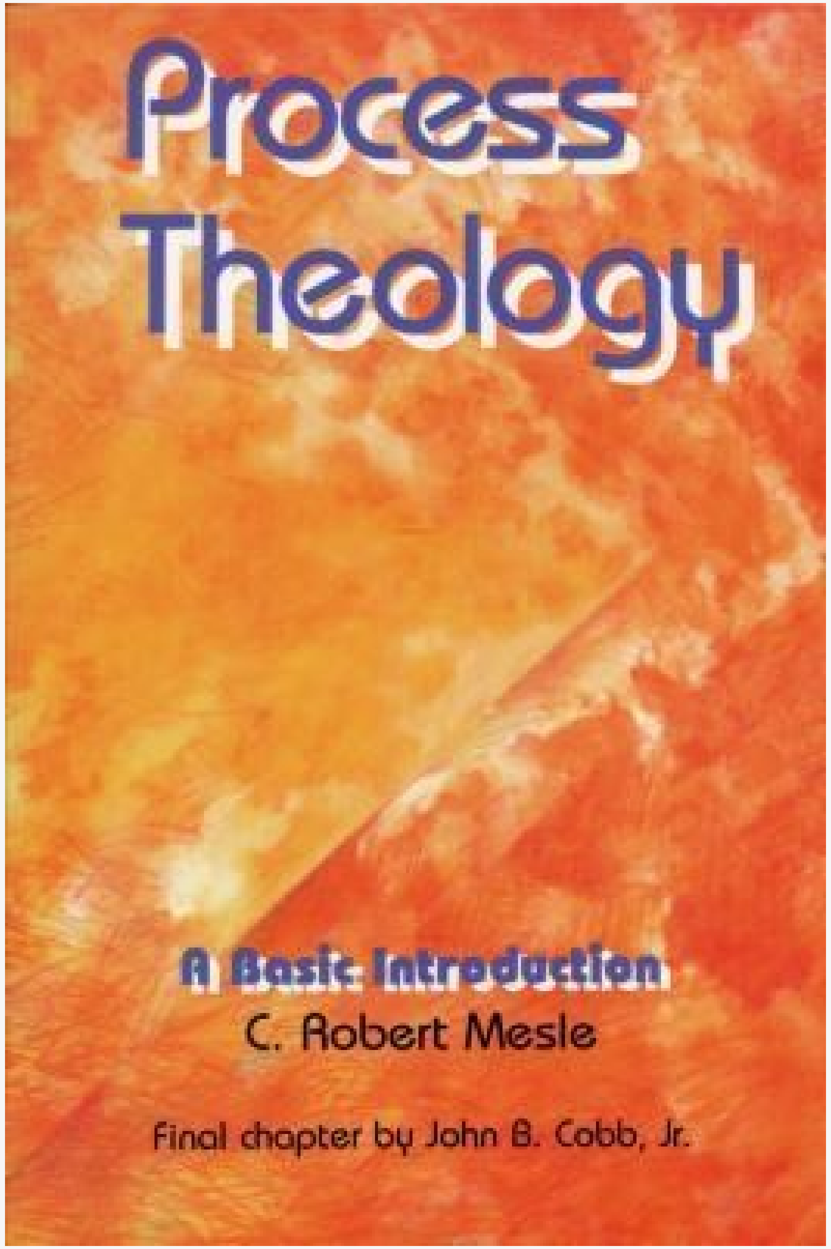
Why Process Theology Matters Here

Process Theology as a Conceptual Bridge

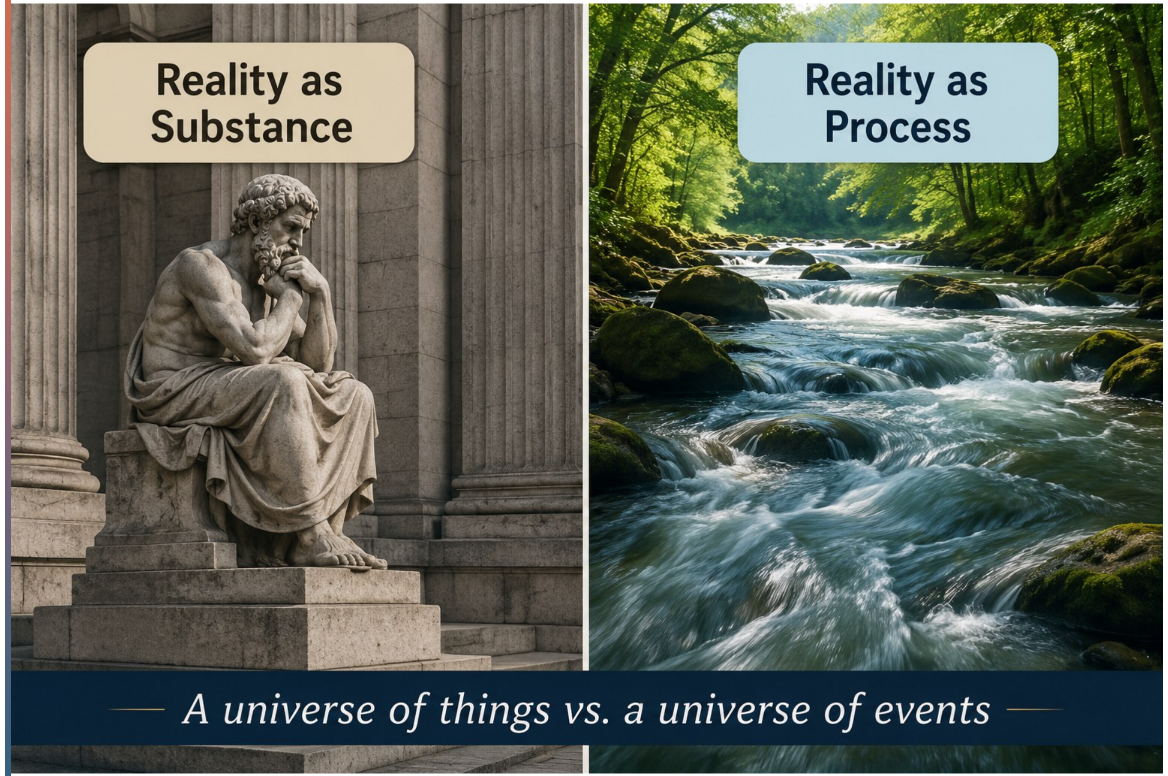
- Process Theology provides a highly developed vocabulary of:
  - events
  - relations
  - becoming
  - process
- This language is far more accessible to a lay audience than advanced quantum mathematics.
- Process Theology helps translate event-centered quantum thinking into concepts people can discuss, imagine, and reflect upon.
- In this lecture series, Process Theology is being used philosophically and pedagogically rather than as a literal description of reality.

Central Idea

Process Theology does not replace quantum mathematics. It provides conceptual language that helps make quantum thinking more understandable.



What Is Process Theology?



A Different Way of Understanding Reality

Traditional theology often emphasizes:

- Being over becoming
- Substance over event
- Permanence over change

Process Theology emphasizes:

- Becoming over being
- Events over substances
- Relationship over isolation
- Creativity over determinism

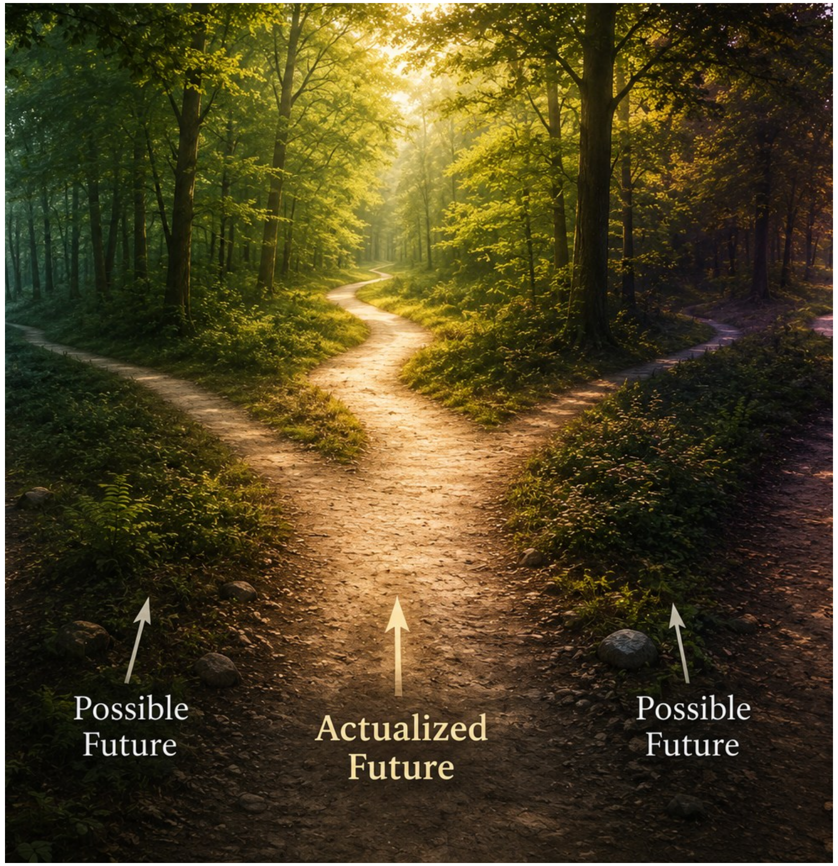
Key Insight

- Reality is not a collection of static things.
- Reality is an ongoing process of becoming.

Core Themes of Process Theology

Reality as Creative Becoming

- Reality consists of interconnected events.
- Every moment contributes something new.
- The future is partly open.
- Creativity is a fundamental feature of existence.
- God continuously offers new possibilities.



Process Theology in One Sentence

- The universe is a creative process unfolding within constraints.

Implications of Process Theology

A God Who Participates in History

Process Theology portrays God as:

- Experiencing the joys and sufferings of creation.
- Working through persuasion rather than coercion.
- Calling creation toward greater beauty, truth, and justice.
- Sharing in the world's ongoing becoming.

Implications

- Human choices matter.
- The future is not predetermined.
- New possibilities can emerge.

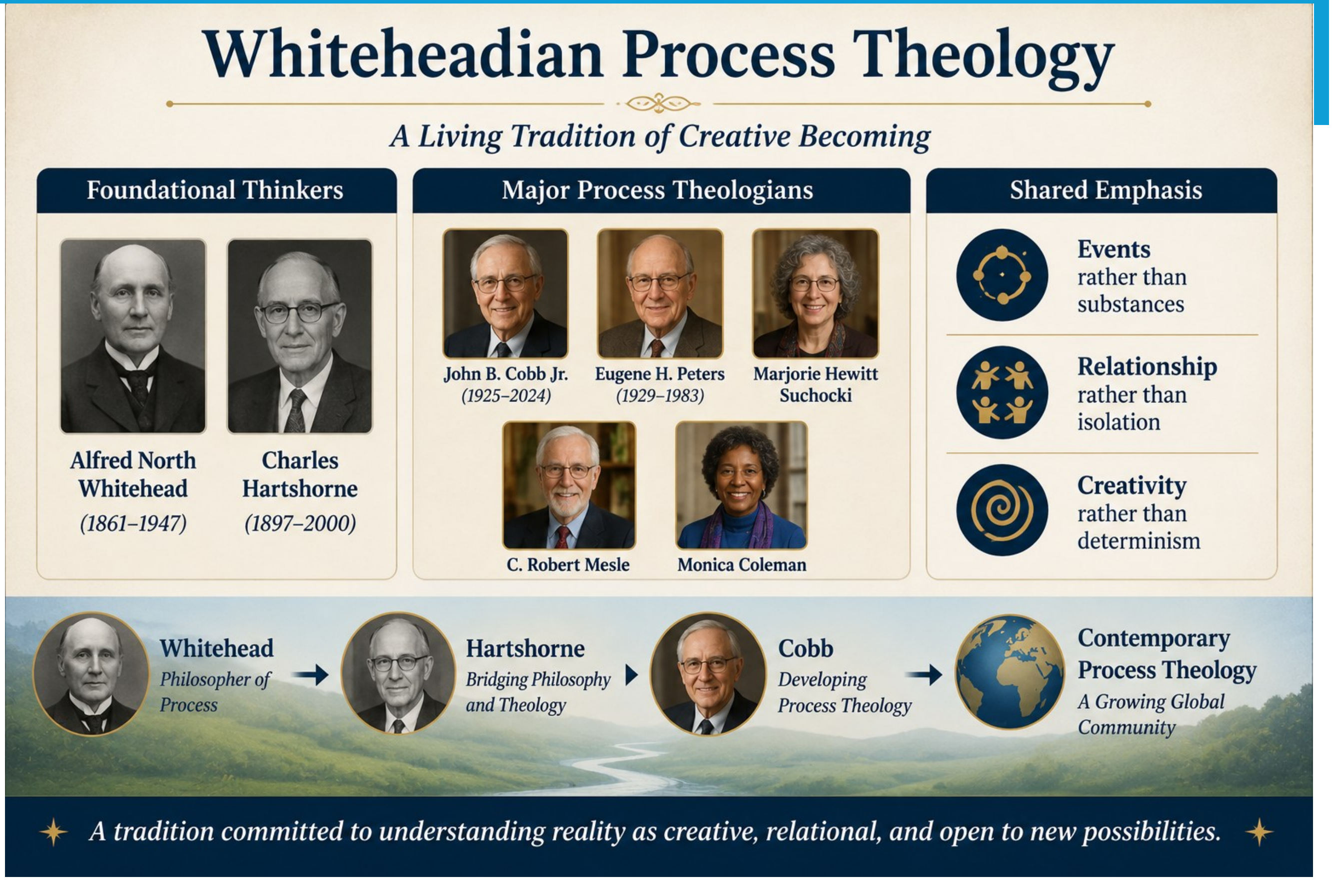
Creation as cooperative participation.

Key Process Thinkers

Whiteheadian Process Theology
Foundational Thinkers
- Alfred North Whitehead
- Charles Hartshorne

Major Process Theologians
- John B. Cobb Jr.
- Eugene H. Peters
- Marjorie Hewitt Suchocki
- C. Robert Mesle
- Monica Coleman

Shared Emphasis
- Events rather than substances
- Relationship rather than isolation
- Creativity rather than determinism



The Broader Family of Process Thought

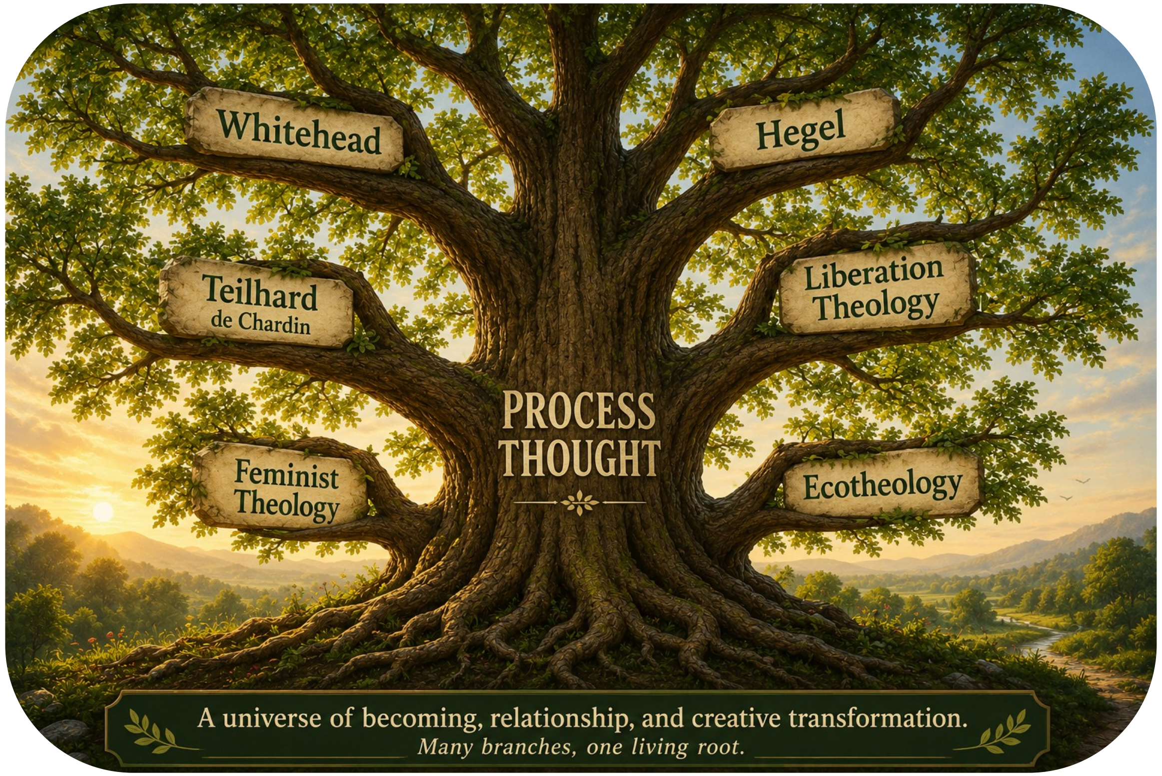
Beyond Whitehead

John Cobb suggested that "process theology" may include all theologies emphasizing:

- Event over substance
- Becoming over being
- Change over permanence

Related Voices

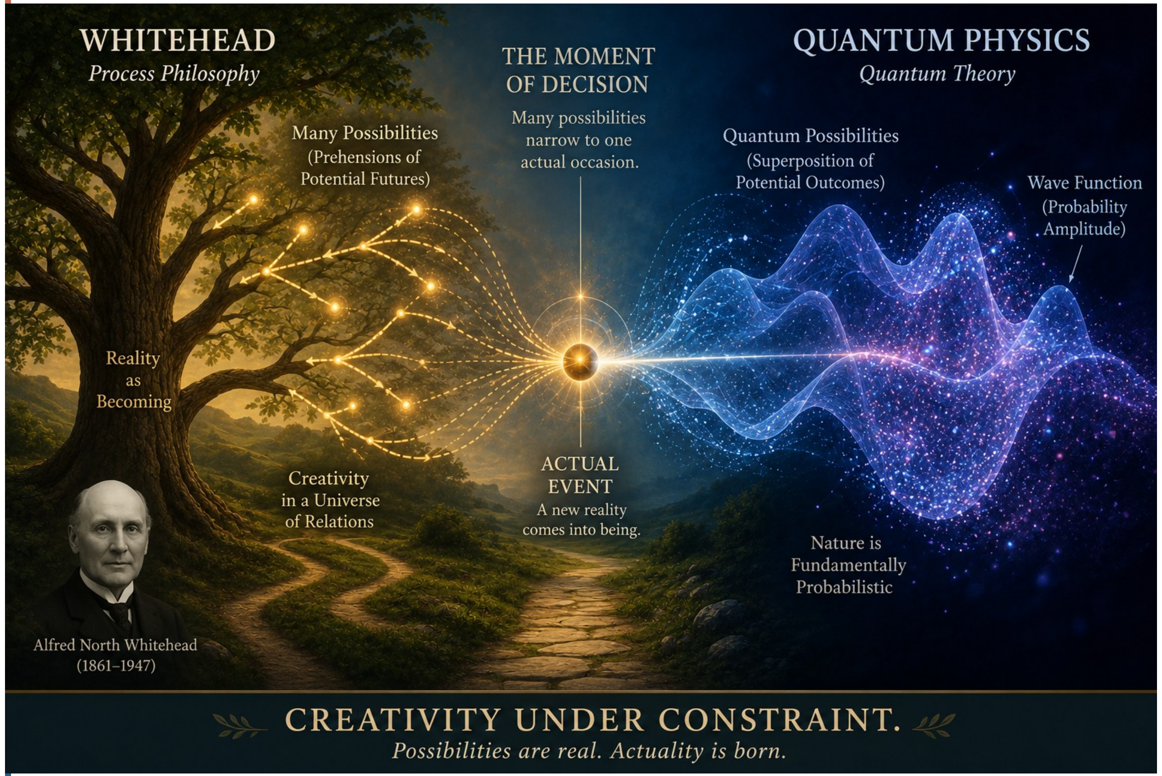
- G. W. F. Hegel
- Pierre Teilhard de Chardin
- Matthew Fox
- Richard Rohr
- Sallie McFague
- Rosemary Ruether
- Catherine Keller
- Henry Young



Shared Question

How does genuine novelty emerge in the universe?

From Process Theology to Quantum Physics



A Remarkable Convergence

Process Theology proposes:

- Reality is fundamentally event-like.
- The future contains real possibilities.
- Creativity is woven into existence.
- Novelty emerges continuously.

Modern Quantum Physics Suggests:

- Nature is built from quantum events.
- Multiple futures are physically possible.
- Outcomes are constrained but not predetermined.
- Reality unfolds through actualized possibilities.

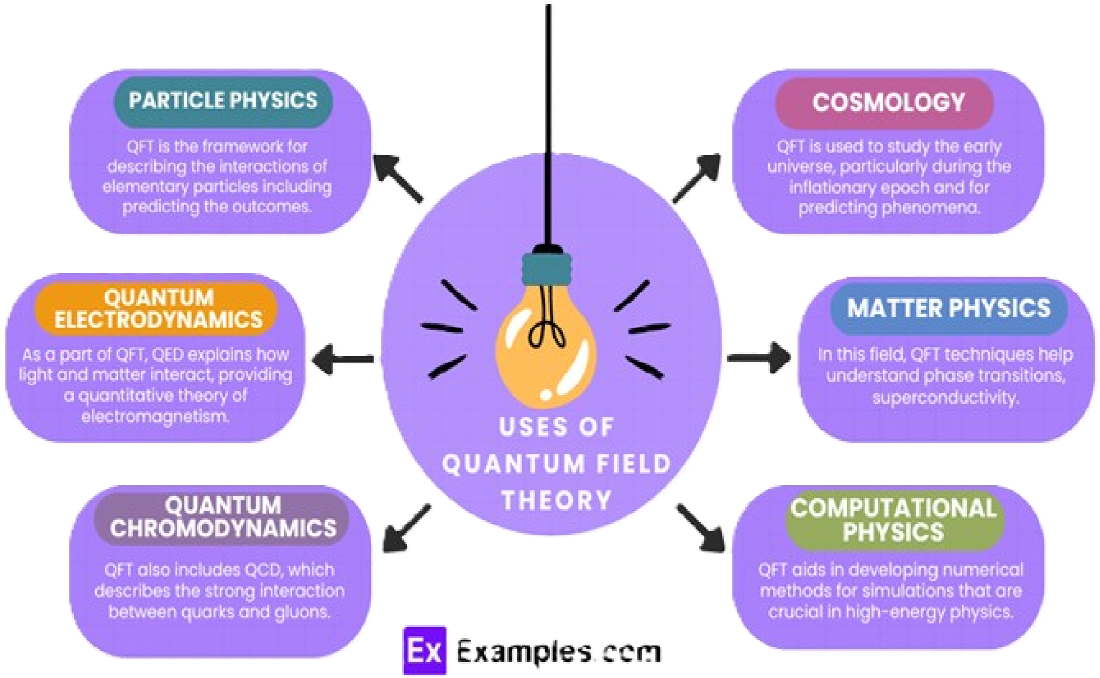
Central Question of This Lecture

- Can the language of Process Theology help us better understand the physical world revealed by quantum physics?

Quantum Physics as a Predictive Framework

Quantum Physics as an Instrumental Framework

- **The quantum state machine model is fundamentally predictive rather than ontological.**
- **Its purpose is to predict probability distributions of detection events.**
- **The mathematics predicts statistical patterns with extraordinary precision.**
- **But the theory does not specify a classical underlying cause for any individual event.**



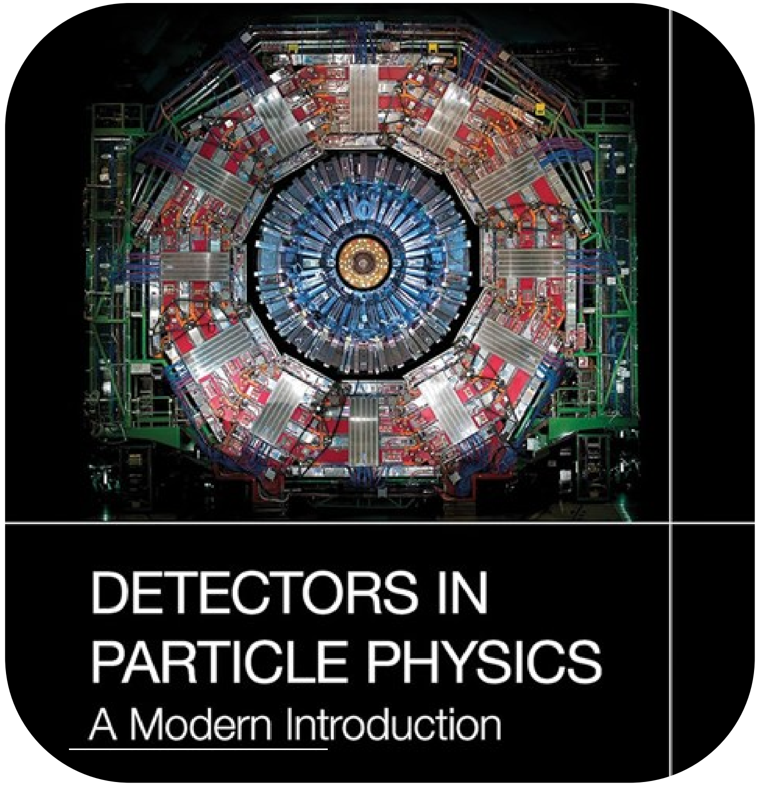
Instrumental View

Quantum theory is used here primarily as a predictive mathematical framework rather than a literal picture of underlying reality.

What Quantum Physics Actually Gives Us

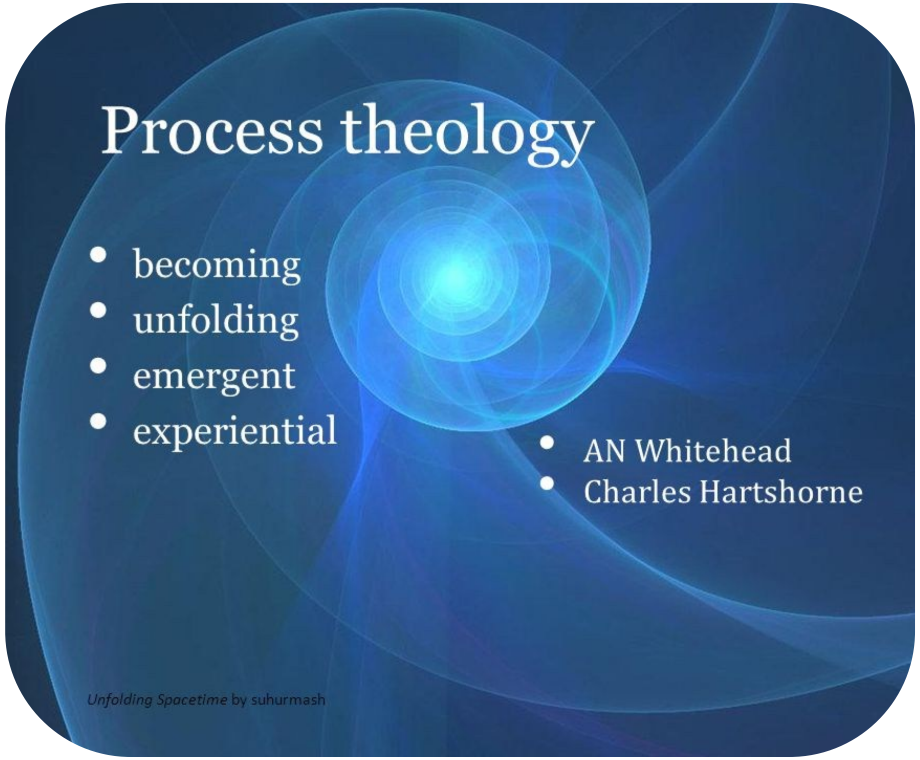
What Physics Directly Observes

- Quantum physics experimentally gives us:
    - flashes
    - clicks
    - ionizations
    - localized detector events
- Conceptual Structures Used in Quantum Theory:
    - Quantum fields
    - The Hamiltonian
    - Hilbert spaces
    - Probability amplitudes
    - Virtual particles



These mathematical structures need not be treated as literally existing physical objects.

Process Theology as an Interpretive Framework



Process Theology as an Instrumental Framework

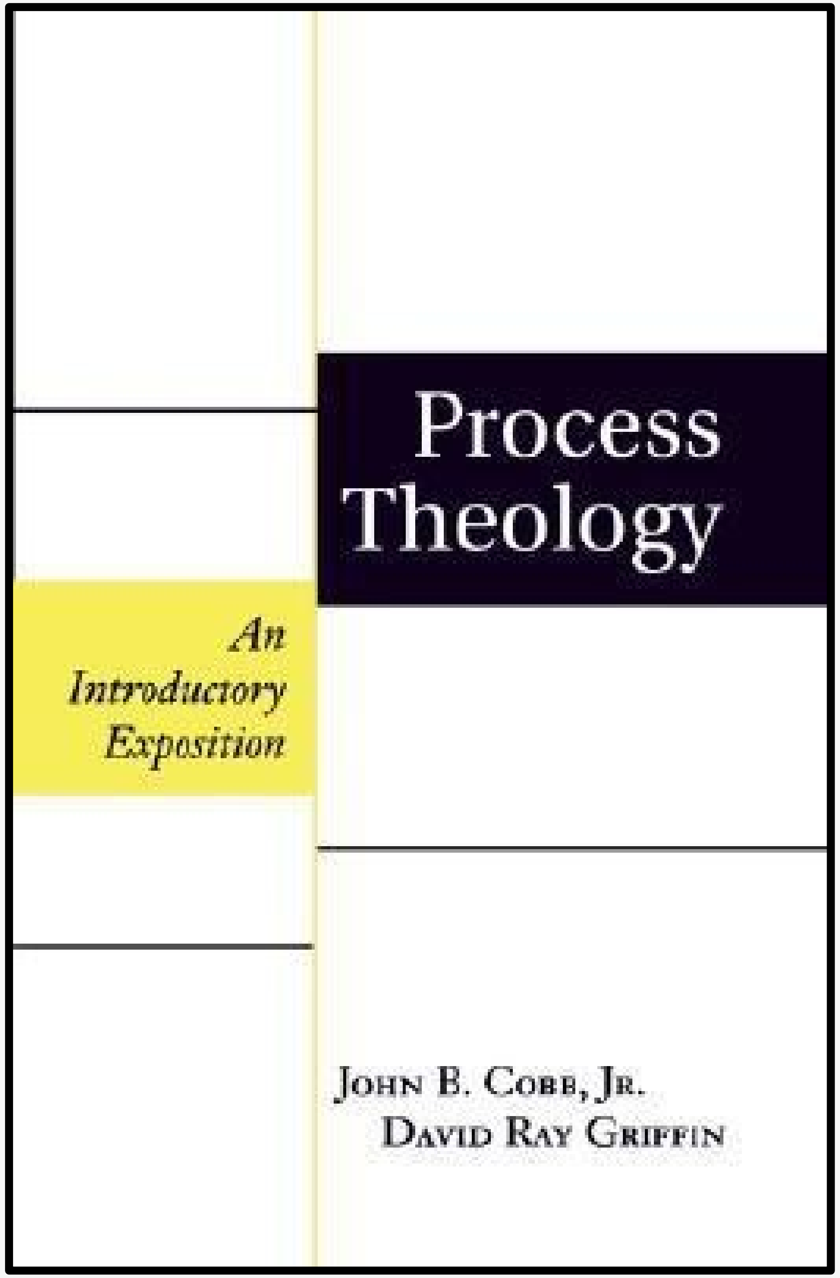
- **Process Theology provides conceptual language centered on:**
  - **events**
  - **relations**
  - **becoming**
  - **process**
- **It helps people think beyond classical substance-centered categories.**
- **It is being used philosophically and pedagogically rather than as a literal description of reality.**

Instrumental View: Process Theology is used here primarily as a conceptual interpretive framework rather than a literal picture of underlying reality.

The Conceptual Vocabulary of Process Theology

Conceptual Language in Process Theology

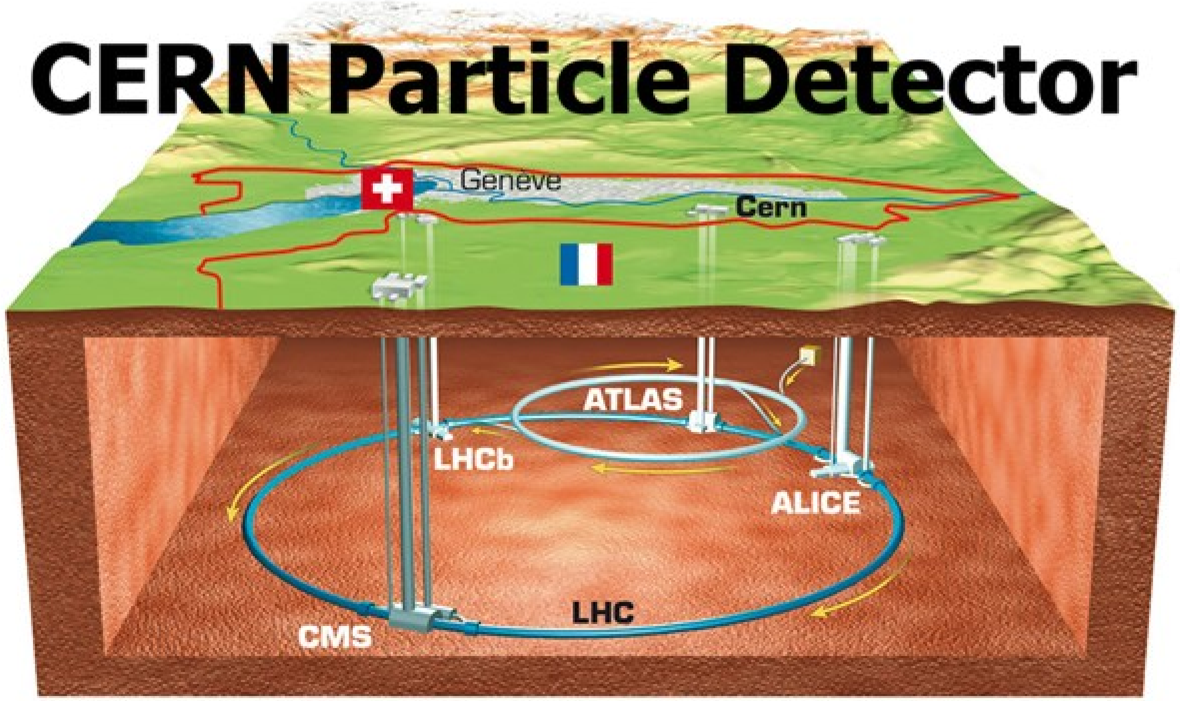
- Process Theology uses concepts such as:
  - Actual occasion
  - Primordial Nature of God
  - Superjective Nature of God
  - Consequent Nature of God
- These concepts are being used here as interpretive tools rather than scientifically established entities.
- These conceptual structures need not themselves be treated as literal descriptions of underlying reality.



What Do Physicists Actually Detect?

Quantum physics experimentally gives us:

- flashes
- clicks
- ionization tracks
- localized detector events
- quantized energy transfers



Important Point

- Physics does not directly observe tiny visible "particles" moving through space.
- What physics directly observes are localized detection events in measuring instruments.

Detection Events and "Actual Occasions"

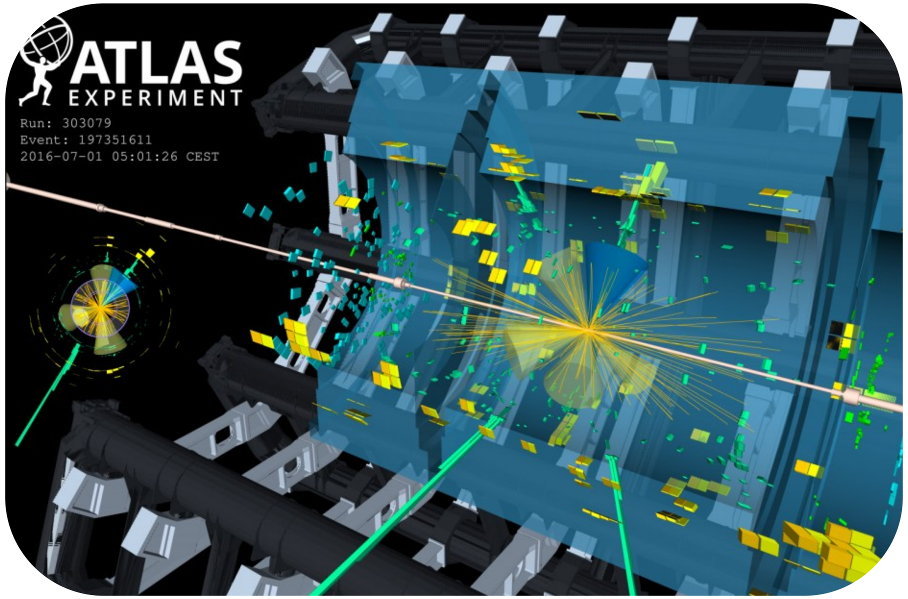
An Event-Centered Interpretation

In this lecture series, a particle-like detection event may be interpreted through the conceptual lens of an "actual occasion."

- **a localized event**
- **a momentary interaction**
- **a transfer of energy**
- **a quantized occurrence**

Important Boundary

- **A detector event is a physical observation.**
- **An actual occasion is part of a philosophical interpretive framework.**



Detection of the Higgs Boson by the ATLAS Detector at CERN

Why “Particle” Is Instrumental Language

The Operational Meaning of “Particle”

In practice, a “particle” means:

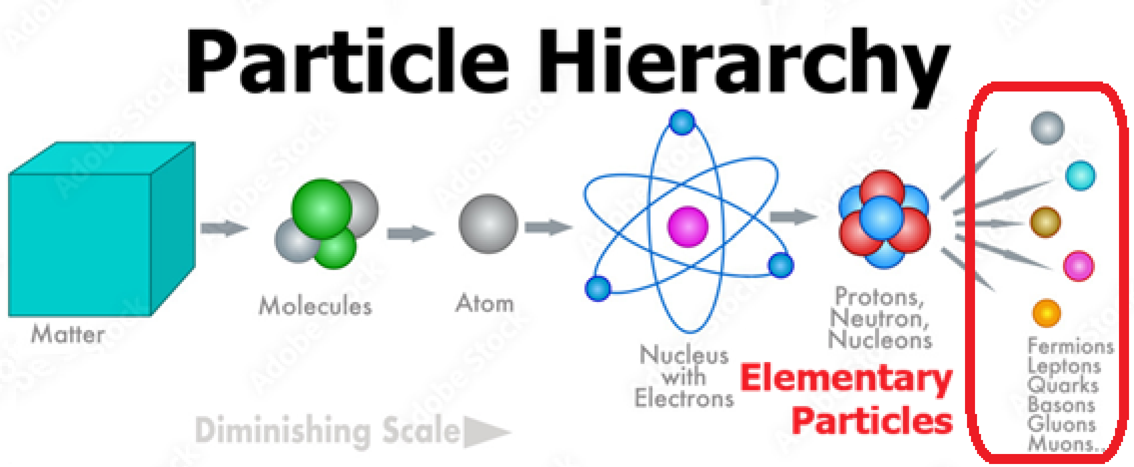
- a recurring pattern of quantized detection events with consistent measurable properties.

Physics predicts:

- where detections are likely to occur
- how much energy is transferred
- what measurable properties appear

But Physics Does NOT Directly Show

- tiny billiard-ball objects
- miniature planets orbiting nuclei
- classical objects moving along exact trajectories



Instrumental View

- **“Particle” is therefore being used operationally and instrumentally rather than necessarily as a literal tiny object.**

A particle-like detection may be interpreted as an event-centered “actual occasion”.

Quantized Energy Transfer

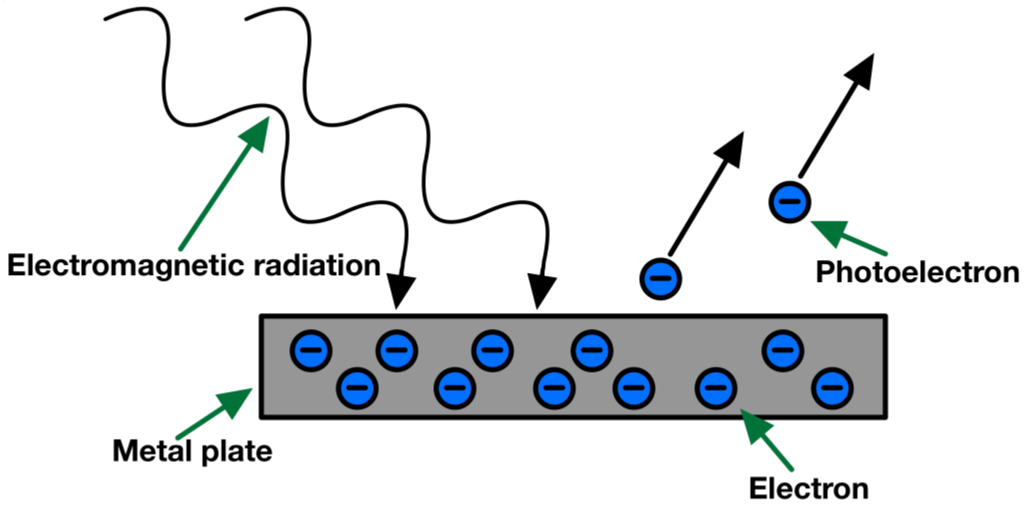
What Happens in a Detection Event?

A detector registers:

- a localized interaction
- involving a discrete transfer of energy
- The energy does not arrive continuously.
- It arrives in quantized packets associated with elementary particle types.

Examples

- an electron ionizes atoms in a detector
- a photon transfers energy to an electron
- a muon leaves a detectable track
- a neutrino occasionally triggers a weak interaction



Central Idea

Elementary particles are identified through characteristic patterns of quantized interaction.

How Are Elementary Particles Identified?

Three Key Properties

Elementary particles are primarily identified by:

- **mass**
- **electric charge**
- **spin**

These measurable properties allow physicists to distinguish one particle type from another.

Examples

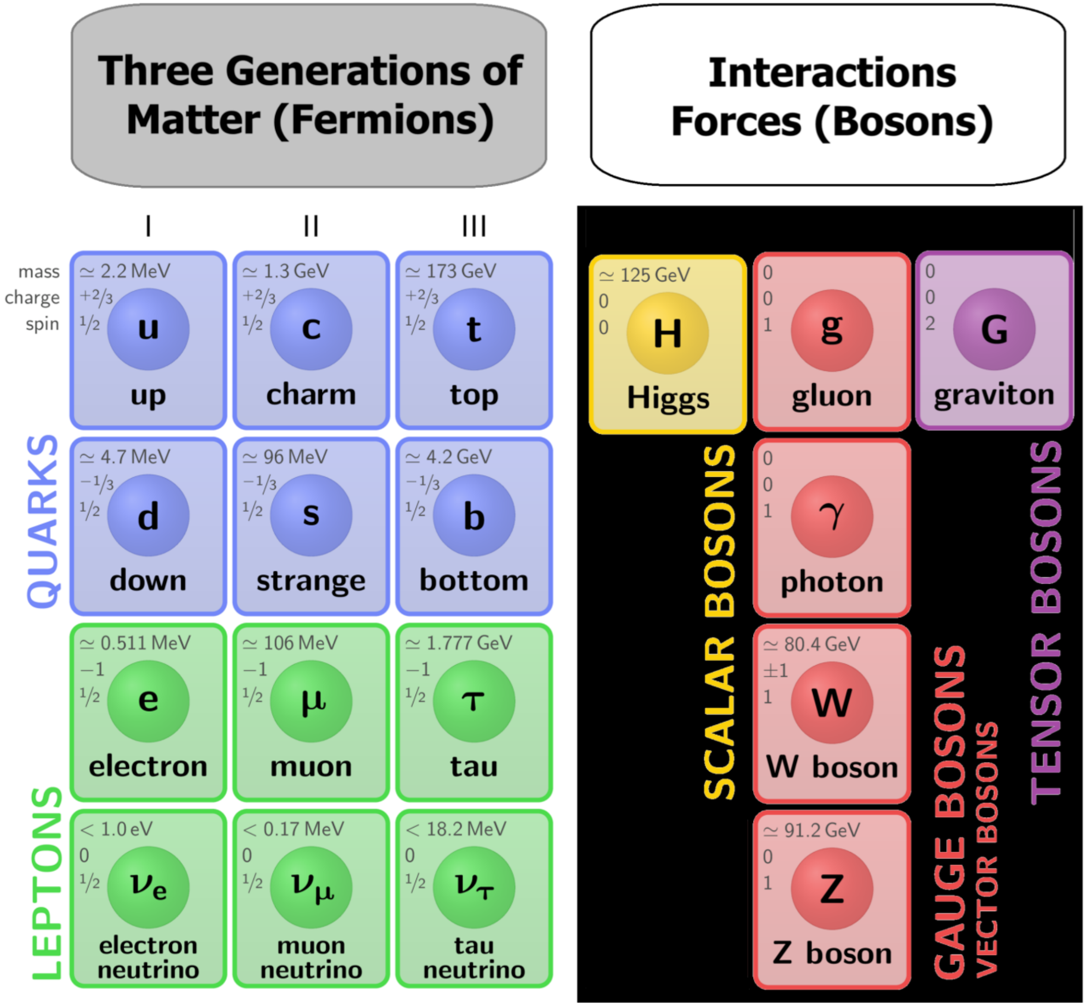
Electron:

- **0.511 MeV mass**
- **Negative charge**
- **spin 1/2**

Photon:

- **zero mass**
- **zero charge**
- **spin 1**

The Standard Model of Particle Physics



Important Note:

In modern physics, mass is treated as an intrinsic invariant property of a particle.

The Goal of
The Standard Model (SM)

What the Standard Model Attempts To Do

The Standard Model organizes the known elementary particles into a coherent mathematical framework.

It predicts:

- **interaction probabilities**
- **decay patterns**
- **conservation laws**
- **measurable detector outcomes**

In This Lecture

We will introduce a simplified "666" structure:

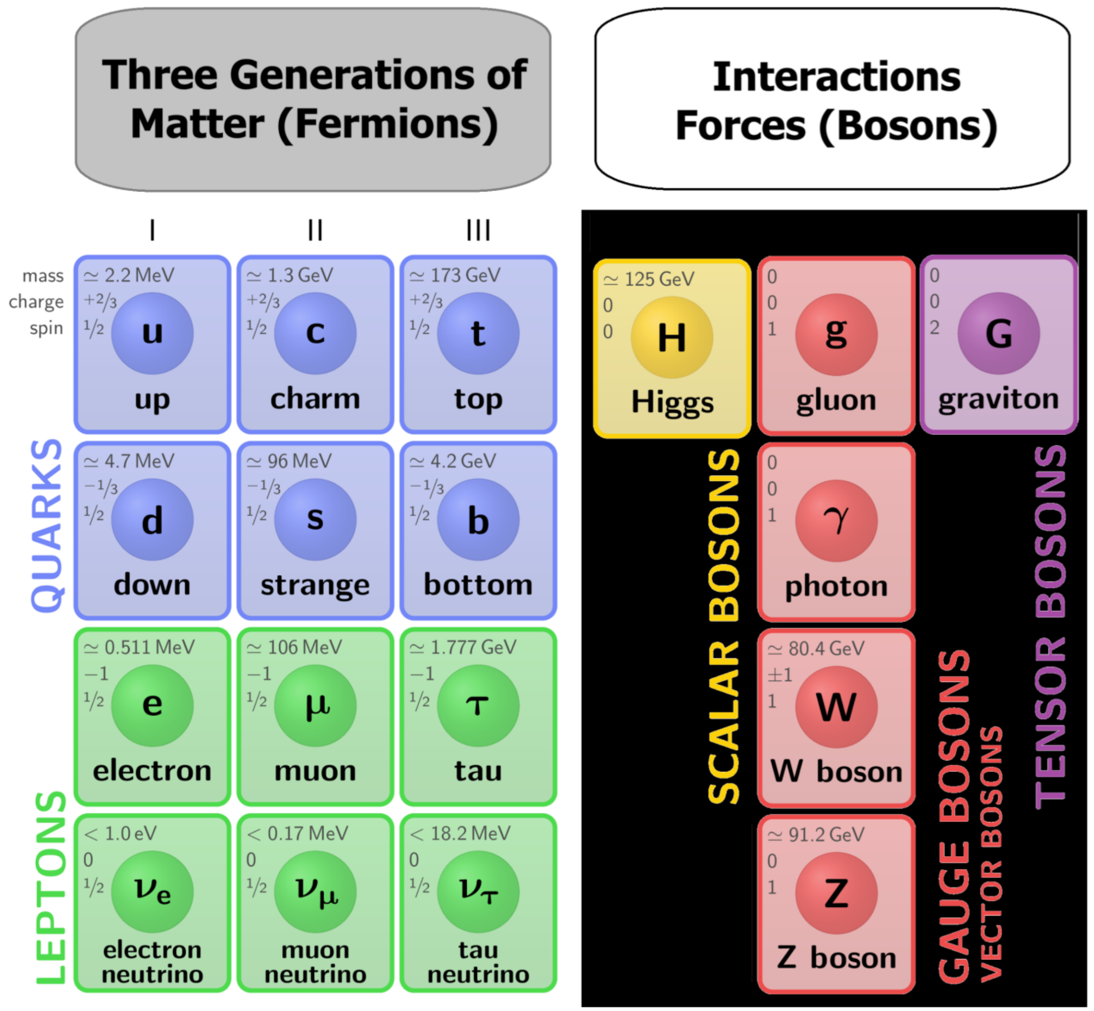
6 quarks
6 leptons
6 bosons

along with their associated anti-particles.

Important Simplification

This presentation intentionally simplifies some aspects of modern particle physics in order to build conceptual understanding before technical detail.

The Standard Model of Particle Physics

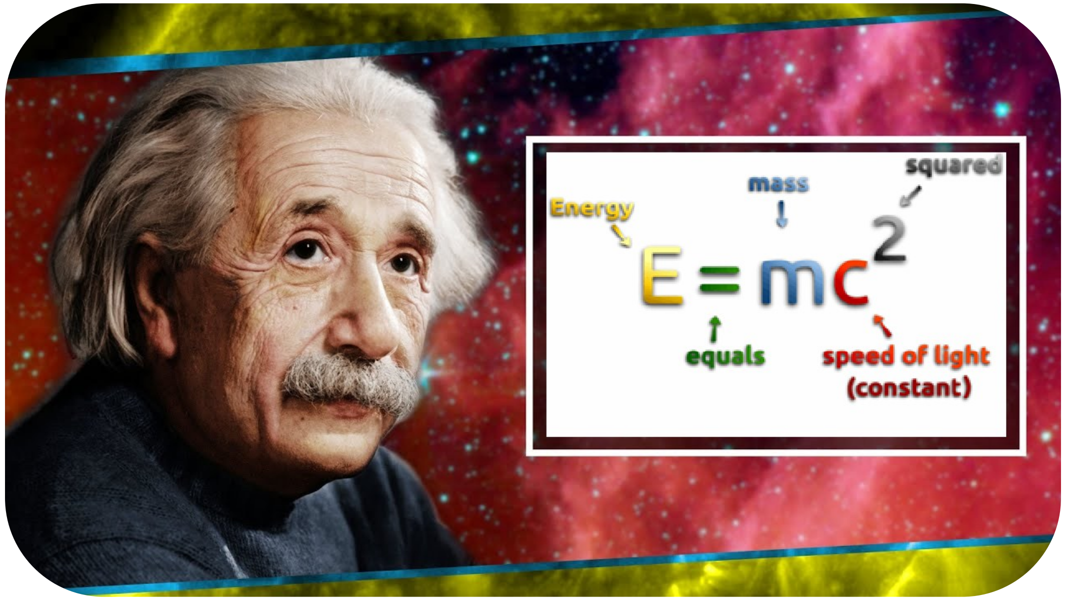


Einstein and Mass–Energy Equivalence

Einstein's Revolutionary Insight

$$E = mc^2$$

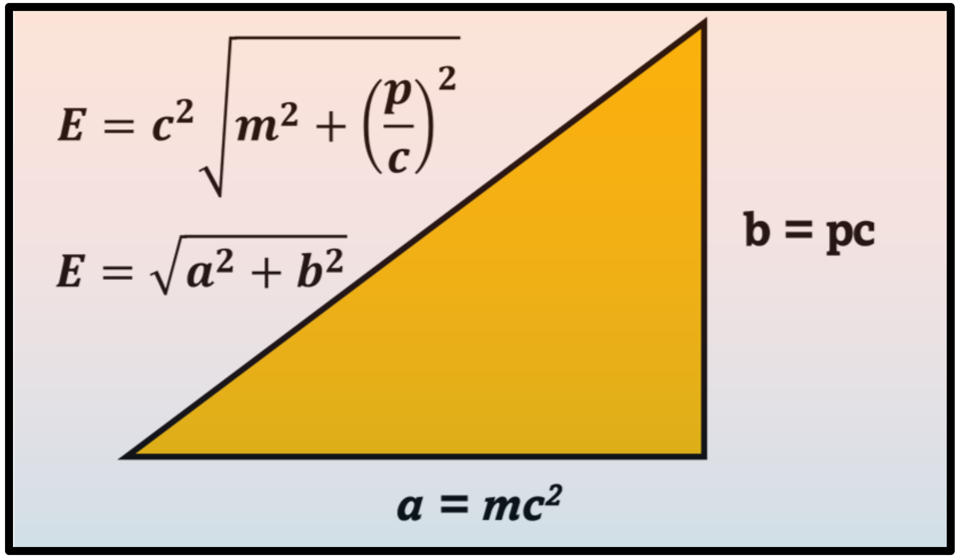
- Mass and energy are different forms of the same underlying physical quantity.
- A small amount of mass corresponds to an enormous amount of energy because c^2 is extremely large.
- In modern physics, the conserved quantity is total energy, not mass alone.



Important Idea

Mass is a concentrated form of energy.

Energy, Momentum, and Mass



Important Point

Even massless particles can carry energy and momentum.

The Relativistic Energy Equation

$$E = c^2\sqrt{m^2 + \left(\frac{p}{c}\right)^2}$$

Where:

- E= total energy
- m= invariant mass
- p= momentum
- c= speed of light

Two Important Cases

- If $p = 0$:
  - the particle is at rest
  - energy reduces to $E = mc^2$
- If $m = 0$:
  - the particle is massless
  - Energy reduces to E = pc

Why Particle Mass Is Listed in eV, MeV, and GeV

Mass Expressed as Energy

- Because mass and energy are equivalent, particle masses are commonly expressed using energy units.

Common units include:

- electron volts (eV)
- mega electron volts (MeV)
- giga electron volts (GeV)

Important Point

In particle physics, energy units are often more convenient than kilograms for describing elementary particles.

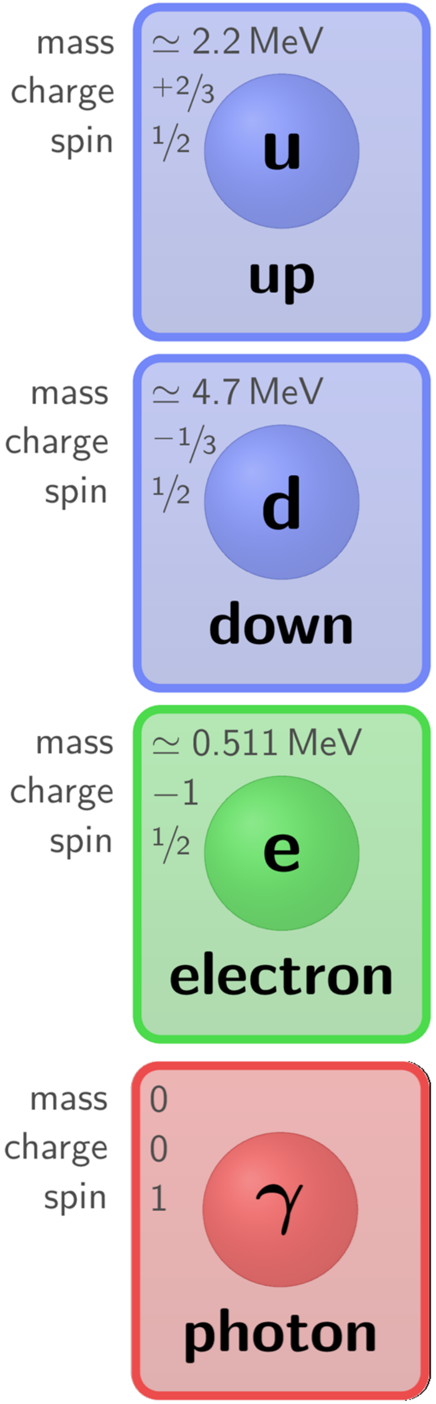
Examples:

Up Quark:
2.2 MeV

Down quark:
4.7 MeV

Electron:
0.511 MeV

Photon:
0 eV



Electric Charge

Electric Charge as an Identifying Property

Elementary particles may carry:

- positive charge
- negative charge
- or no charge at all

Charge determines how particles interact electromagnetically.

Examples

Electron:

charge = −1

Photon:

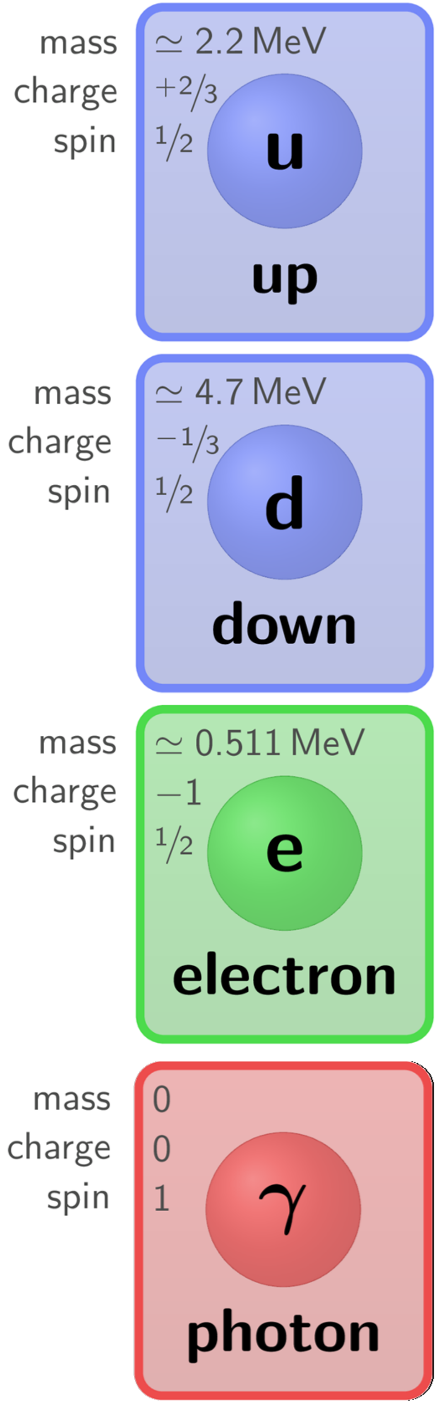
charge = 0

Quarks have fractional charges:

up quark = +2/3

down quark = −1/3

These combine to form the integer charges of protons and neutrons.



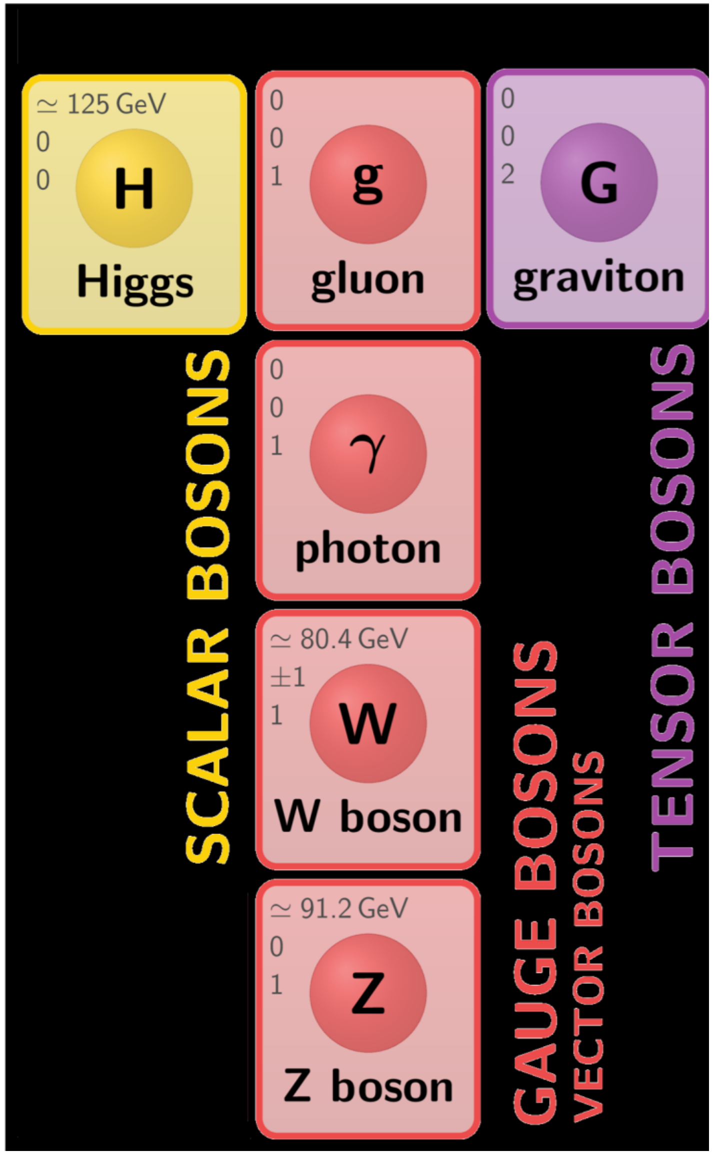
Spin and Rotational Symmetry

Spin Is a Quantum Property Related to Symmetry

- **Spin is not best understood as tiny objects physically spinning.**
- **Instead, spin describes how quantum states behave under rotation.**

Integer Spins (Bosons)

- **Spin 0:**
  - **Completely symmetric under rotation**
- Spin 1:
  - Symmetry somewhat like a globe: the overall pattern remains the same after a 360° rotation
- Spin 2:
  - Symmetry somewhat like a barbell:the overall pattern repeats after a 180° rotation



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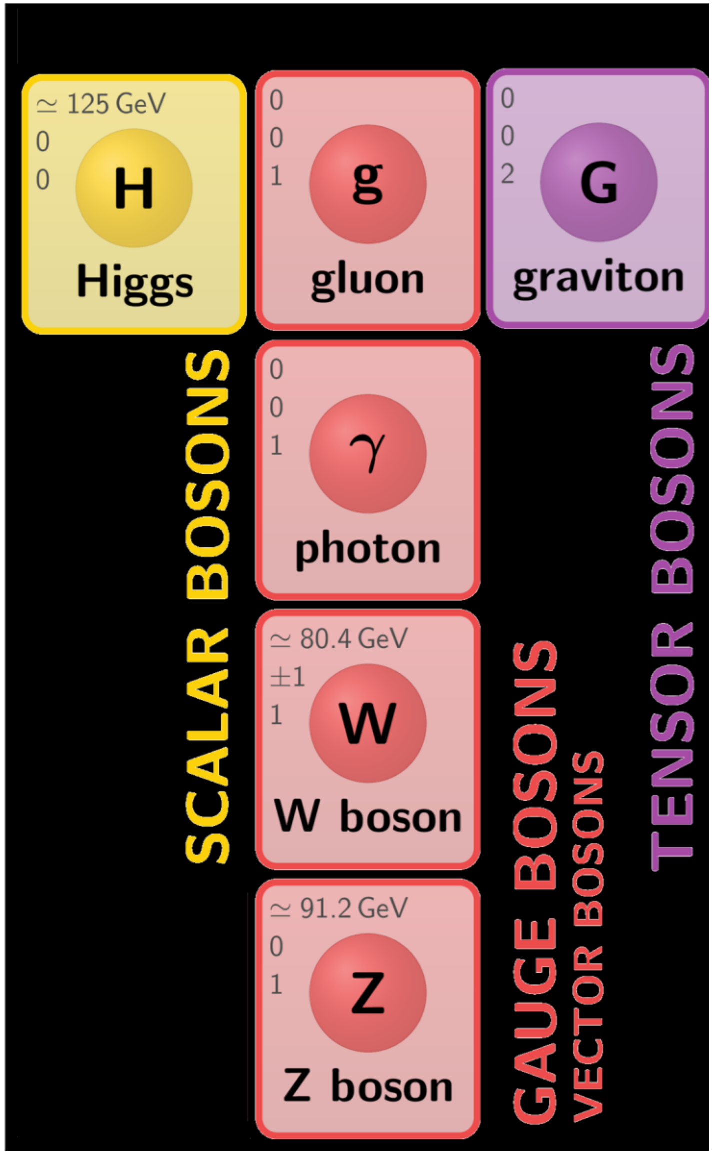

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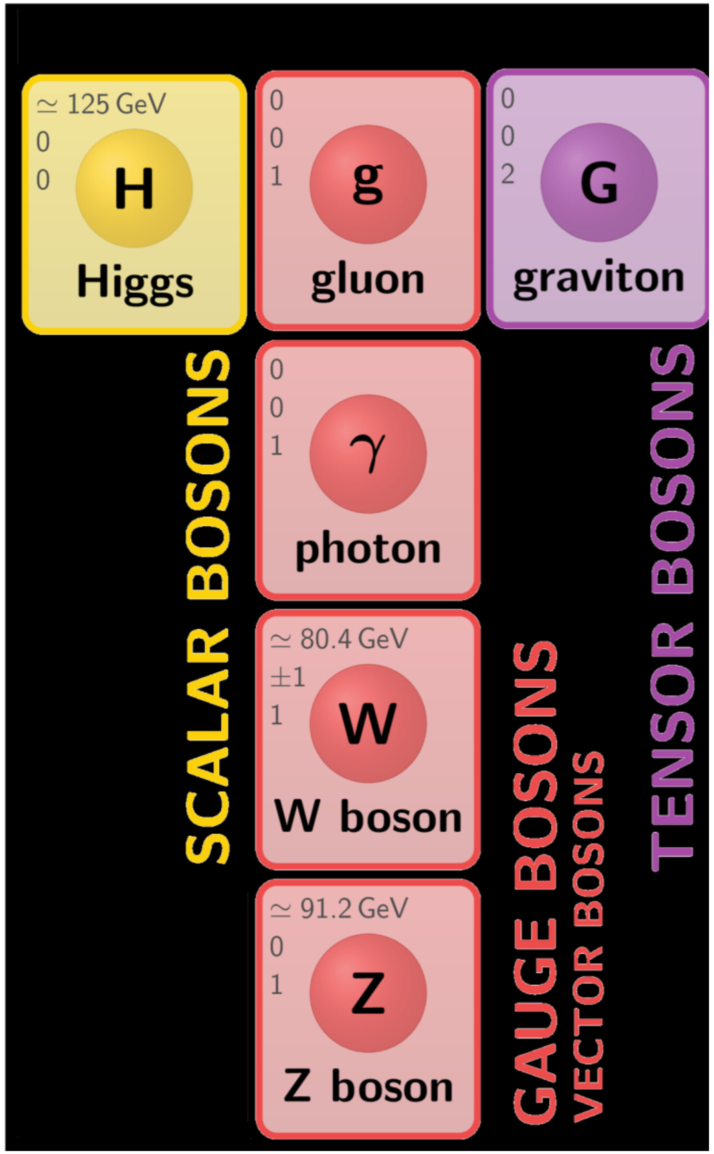

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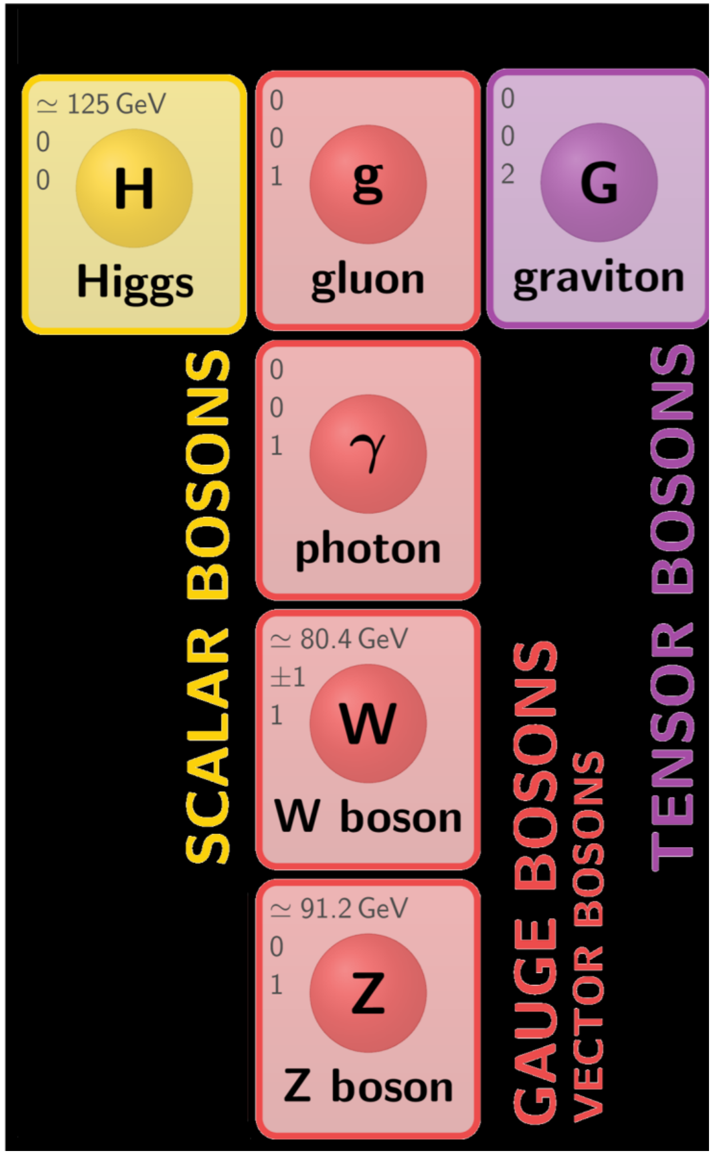
Examples

- **Higgs boson**
  → spin 0
- **Photon, Gluon, W^+ and Z:**
  → spin 1
- **Graviton (hypothetical)**
  → spin 2

Important Note: The full quantum mathematics of spin is more subtle and mathematically sophisticated.



Fermions and the 720° Rotation

Half-Integer Spin Has No Classical Analog

- **Fermions have half-integer spin:**
  - spin 1/2
  - spin 3/2
  - etc.

The electron, quarks, and neutrinos are all spin 1/2 particles.

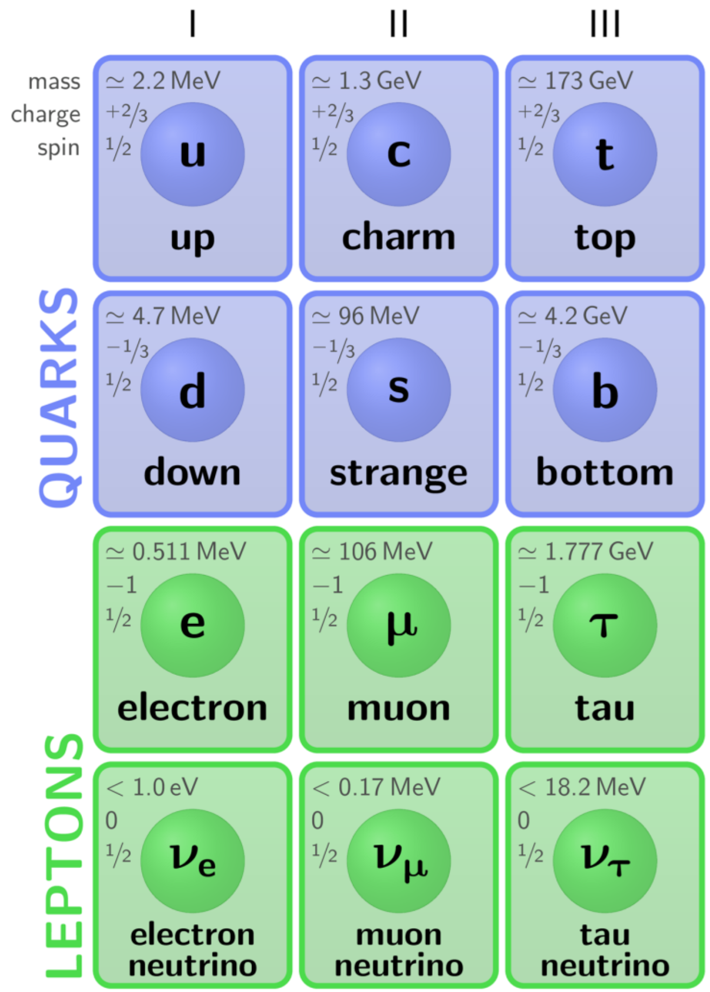
The Remarkable Property of Spin 1/2

- **A spin 1/2 particle:**
  - does NOT return to the same quantum state after a 360° rotation
  - requires a full 720° rotation to return to the same state

Important Point

Nothing like this exists in classical physics. This is one of the clearest examples of the fundamentally non-classical nature of quantum theory.

Three Generations of Matter (Fermions)



Fermions and Bosons

Two Major Classes of Elementary Particles

Particles are grouped according to their spin.

Fermions

- half-integer spin
- matter particles
- obey Fermi–Dirac statistics

Examples:

- quarks
- electrons
- neutrinos

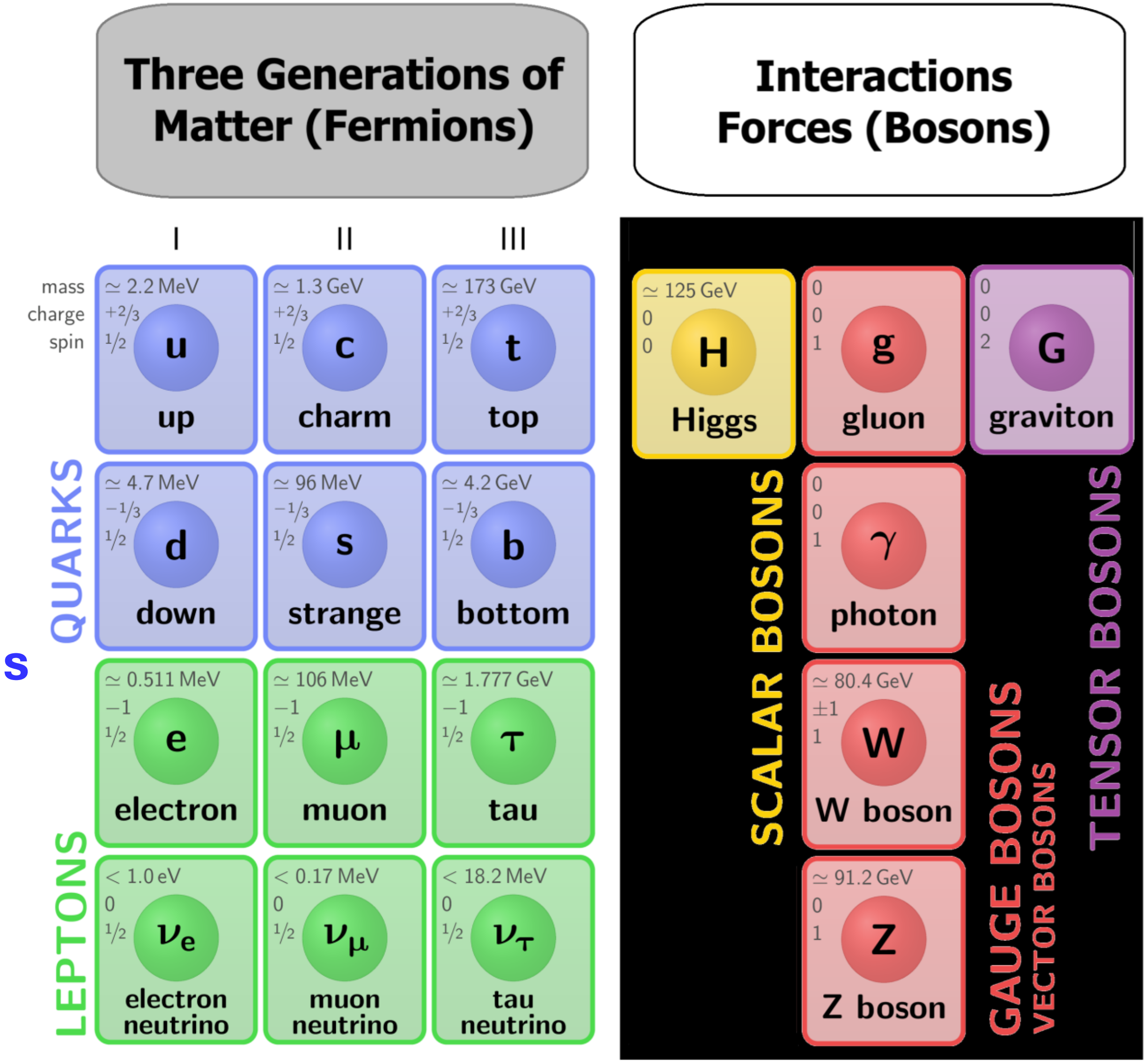
Bosons

- integer spin
- force-mediating particles
- obey Bose–Einstein statistics

Examples:

- photons
- gluons
- Higgs bosons

The Standard Model of Particle Physics



Important Idea: Fermions build matter. Bosons mediate interactions.

Spin Orientation

All elementary particles with nonzero spin possess spin orientation states.

For spin-1/2 fermions, these are commonly described as:

- **spin up**
- **spin down**

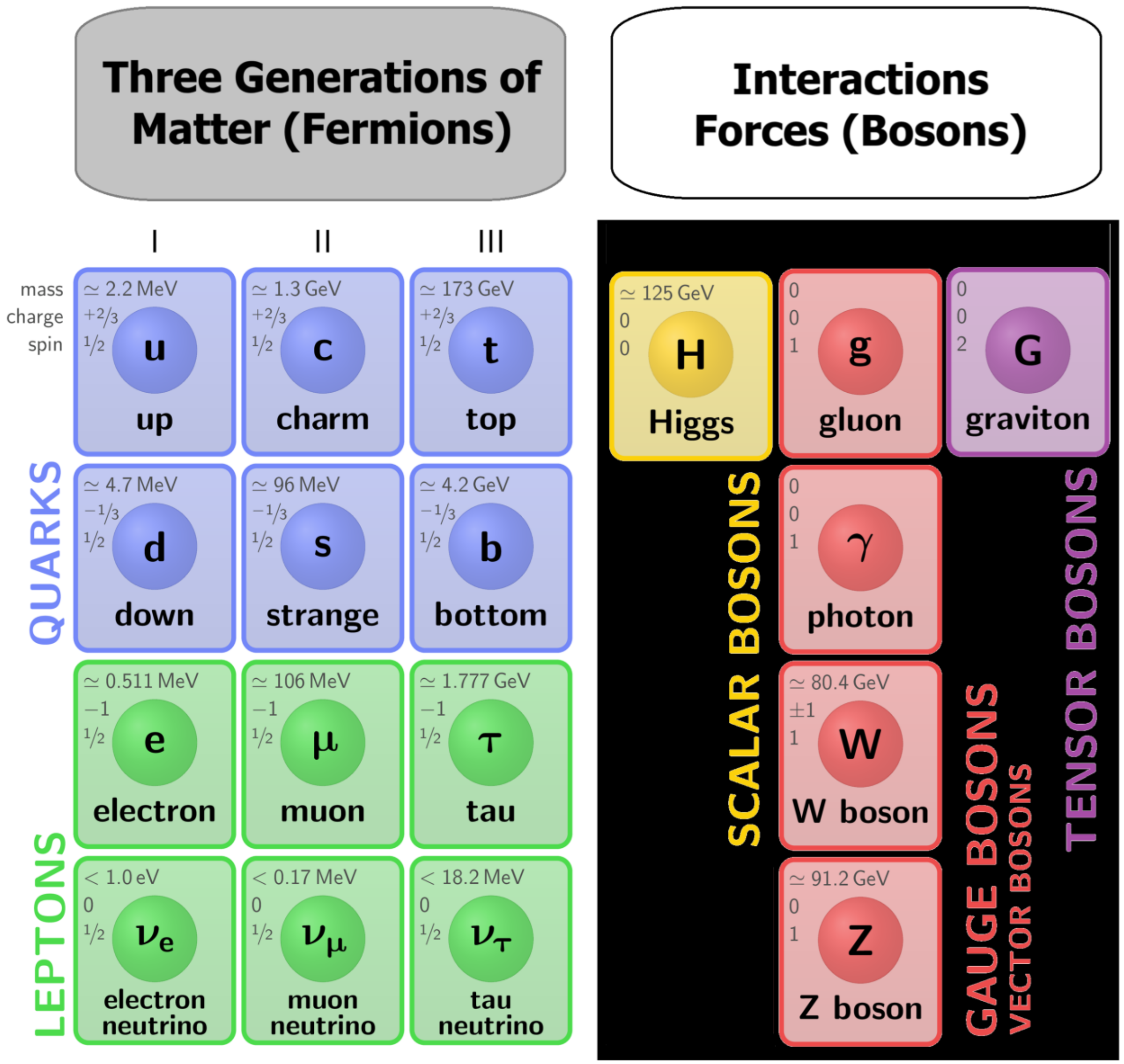
This is important in:

- **atomic structure**
- **magnetism**
- **the Pauli exclusion principle**

Bosons also possess spin projection states:

- **often labeled with positive and negative**
- **values depending on the particle and context.**

The Standard Model of Particle Physics



Chirality

Chirality ("Handedness")

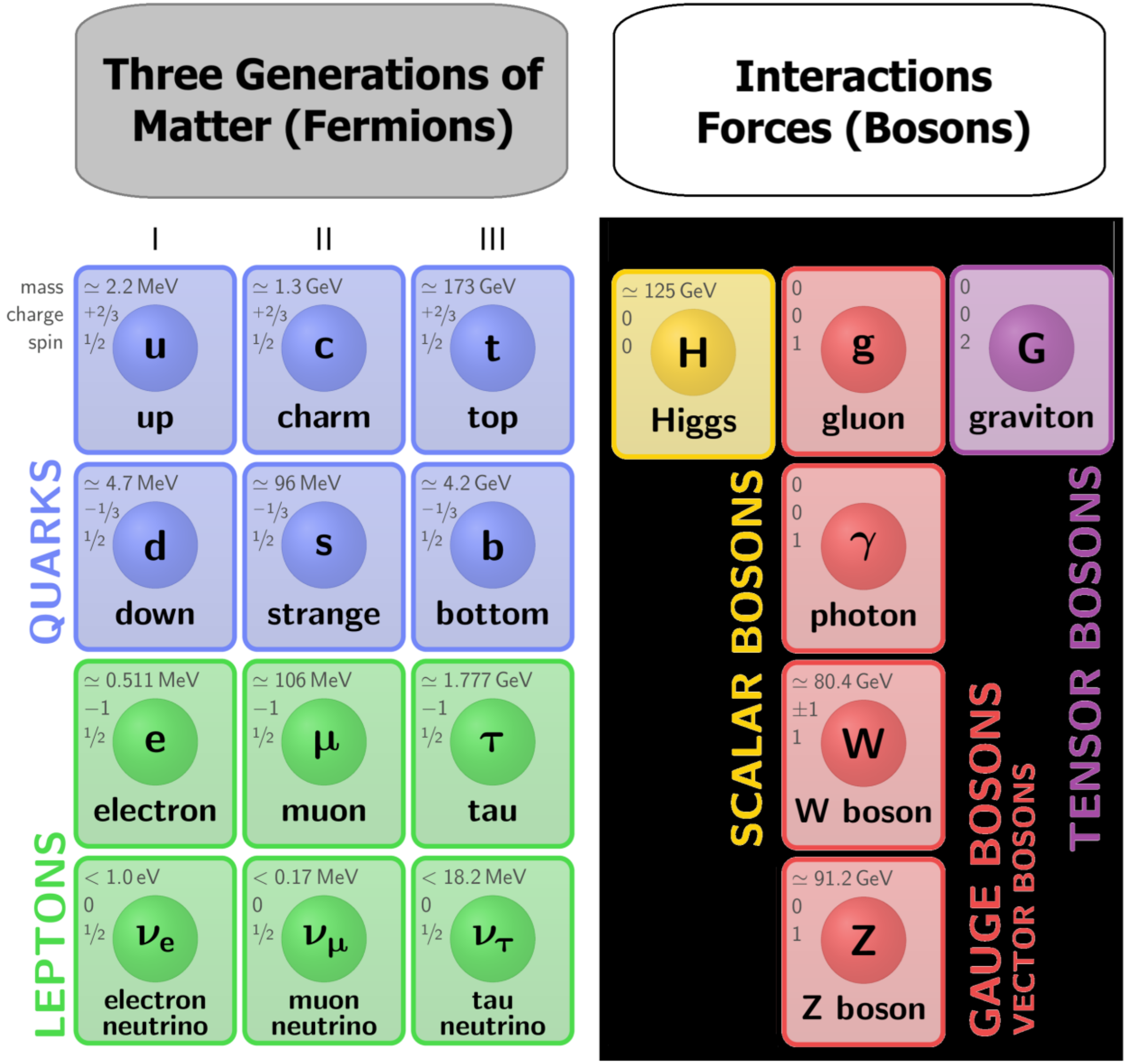
- Quantum physics also distinguishes between left-handed and right-handed quarks and leptons:
  - left-handed
  - right-handed
- This deeper quantum property is called chirality.

Important Point

Spin orientation and chirality are related ideas, but they are NOT the same thing.

- Chirality is important in weak-force interactions, where left-handed and right-handed fermions react differently.

The Standard Model of Particle Physics



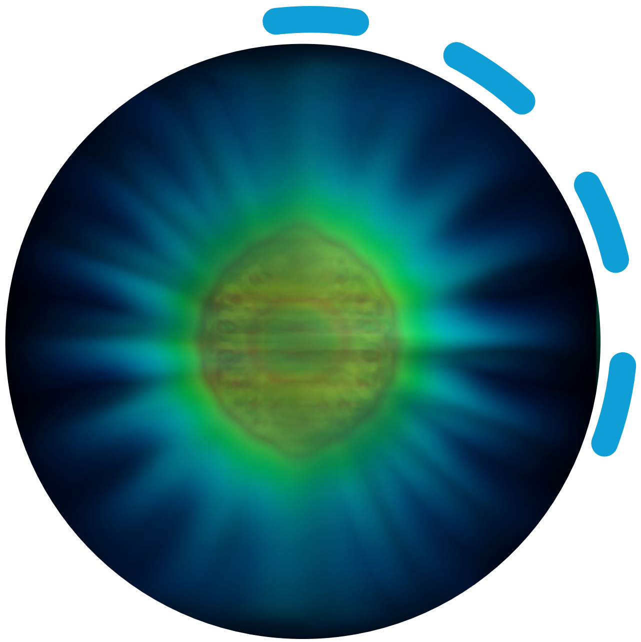
The Photon: Easy to Detect

The photon is the elementary particle associated with electromagnetic radiation:

- visible light
- radio waves
- microwaves
- X-rays
- gamma rays

Important Idea

A photon is best understood as a quantized packet of electromagnetic energy.



Experimental visualization associated with a single-photon electromagnetic interaction process near a nanoparticle surface.

Image credit: Benjamin Yuen, University of Birmingham (2024) "New theory reveals the shape of a single photon"

Key Properties of the Photon

- mass = 0
- charge = 0
- spin = 1

Why the Photon Matters

Photons:

- mediate the electromagnetic force
- are among the easiest elementary particles to detect directly
- Every act of seeing depends on photons interacting with matter.

Photon Detection Events

Photons are detected through localized energy-transfer events.

Examples include:

- vision
- cameras
- solar cells
- the photoelectric effect
- photon particle detectors

Quantized Interaction

- A photon transfers energy in discrete amounts.
- It does NOT arrive as a continuously spread-out classical wave.

Example:

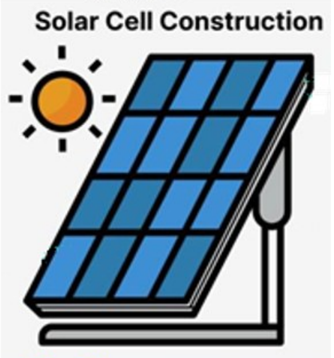
The Photoelectric Effect

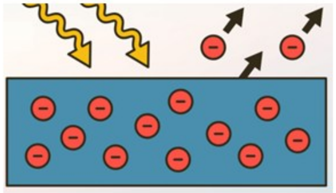
- A photon transfers energy to an electron
- the electron absorbs the energy
- the electron is ejected
- the detector registers an event

What we directly observe is:

- a localized interaction
- a quantized energy transfer
- a detector event

—not a tiny visible particle traveling through space.






Hey Crazies.
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Intro
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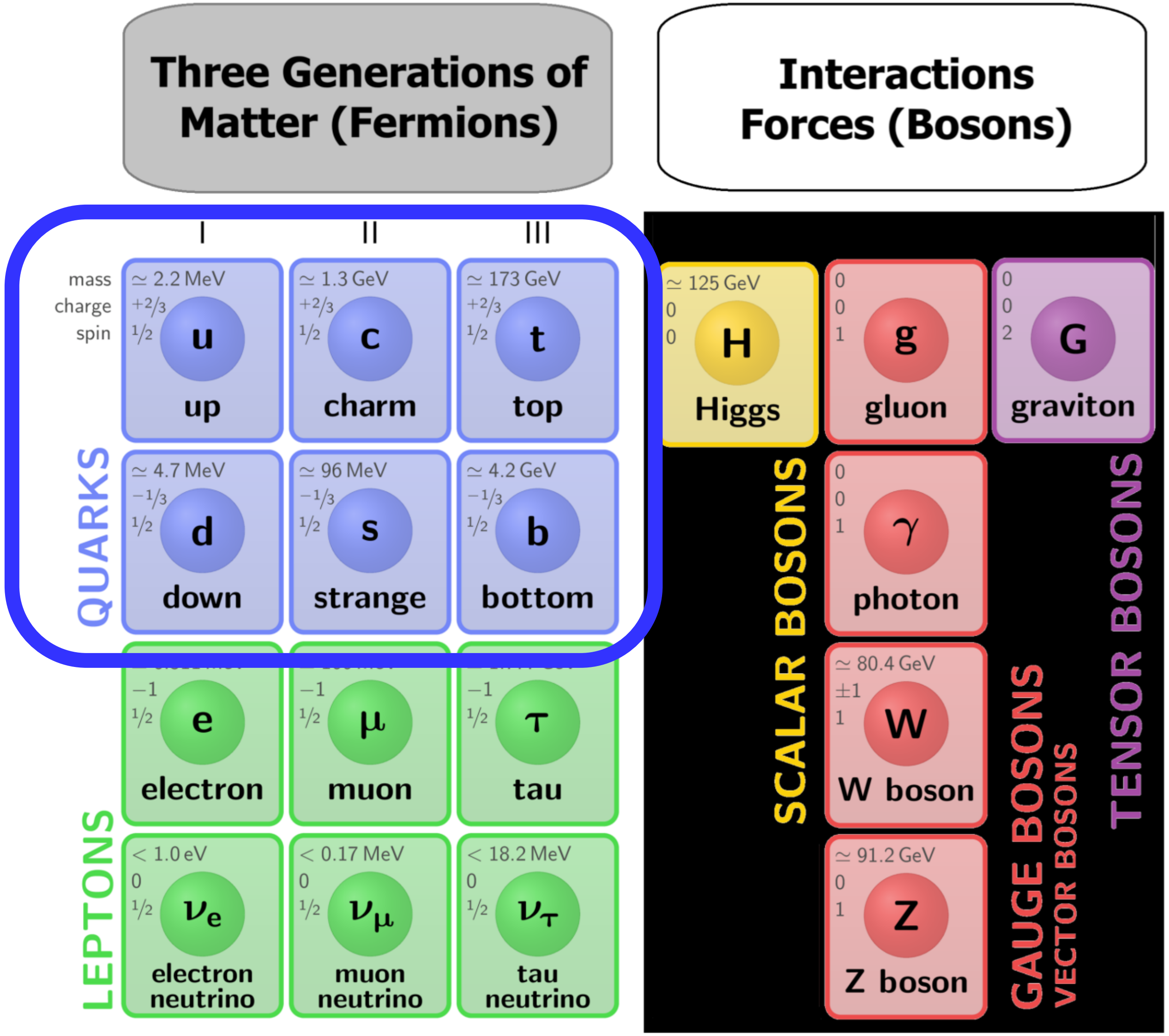
Energy Packets Determined by Their Particle-Like Detection

The Standard Model of Particle Physics

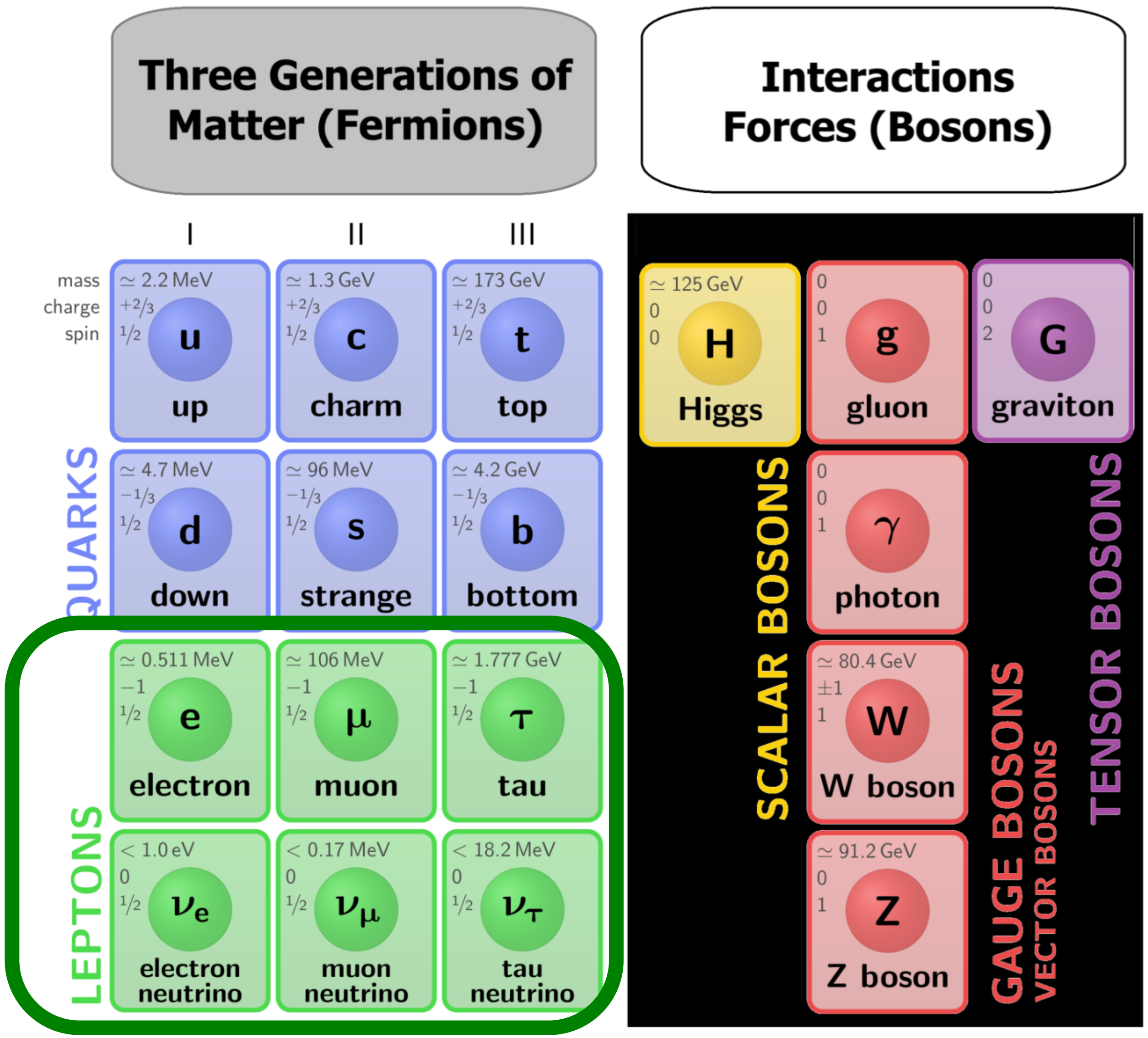


The Standard Model includes:

- **6 Quarks**

Energy Packets Determined by Their Particle-Like Detection

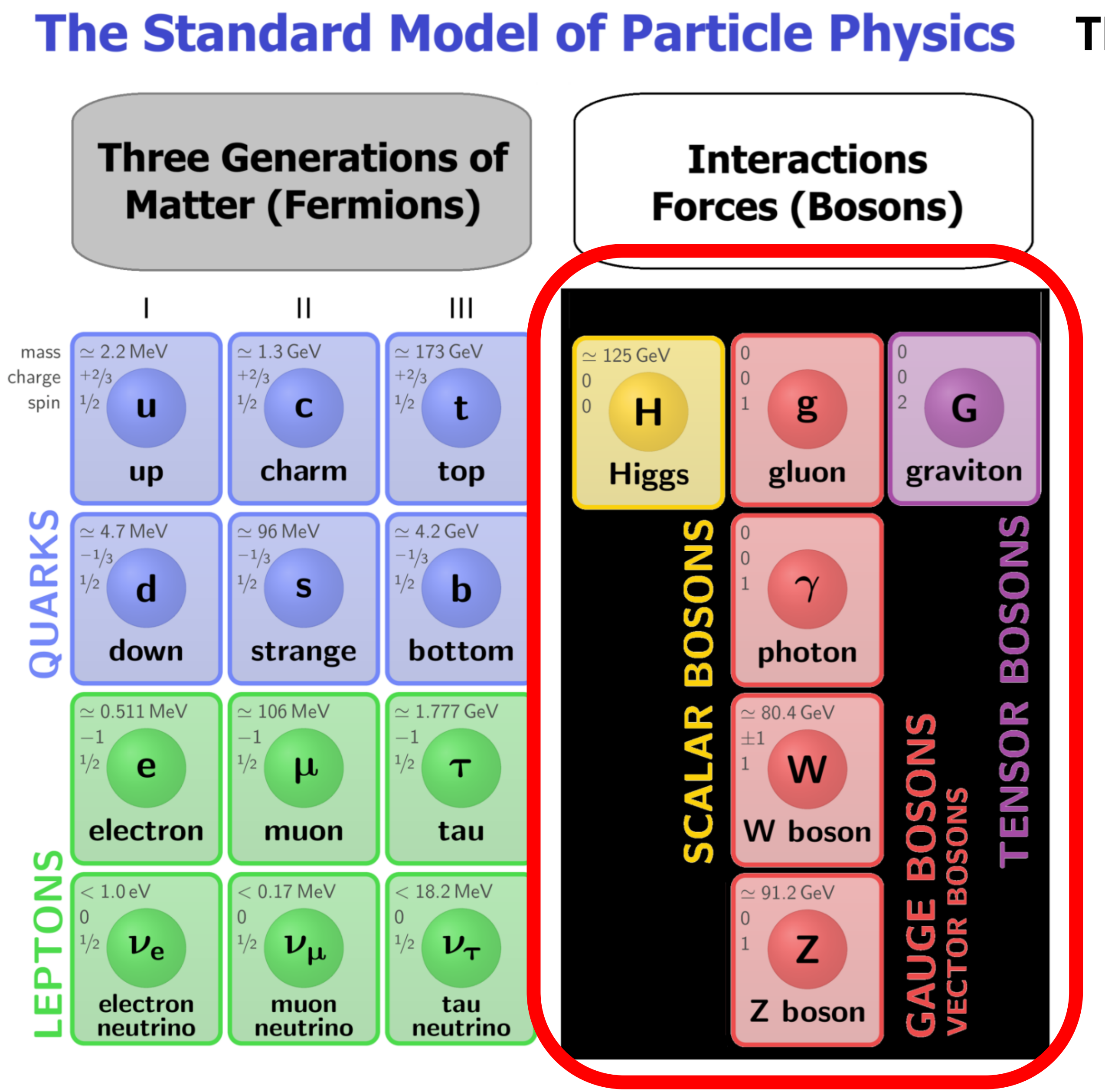
The Standard Model of Particle Physics



The Standard Model includes:

- 6 Quarks
- 6 Leptons

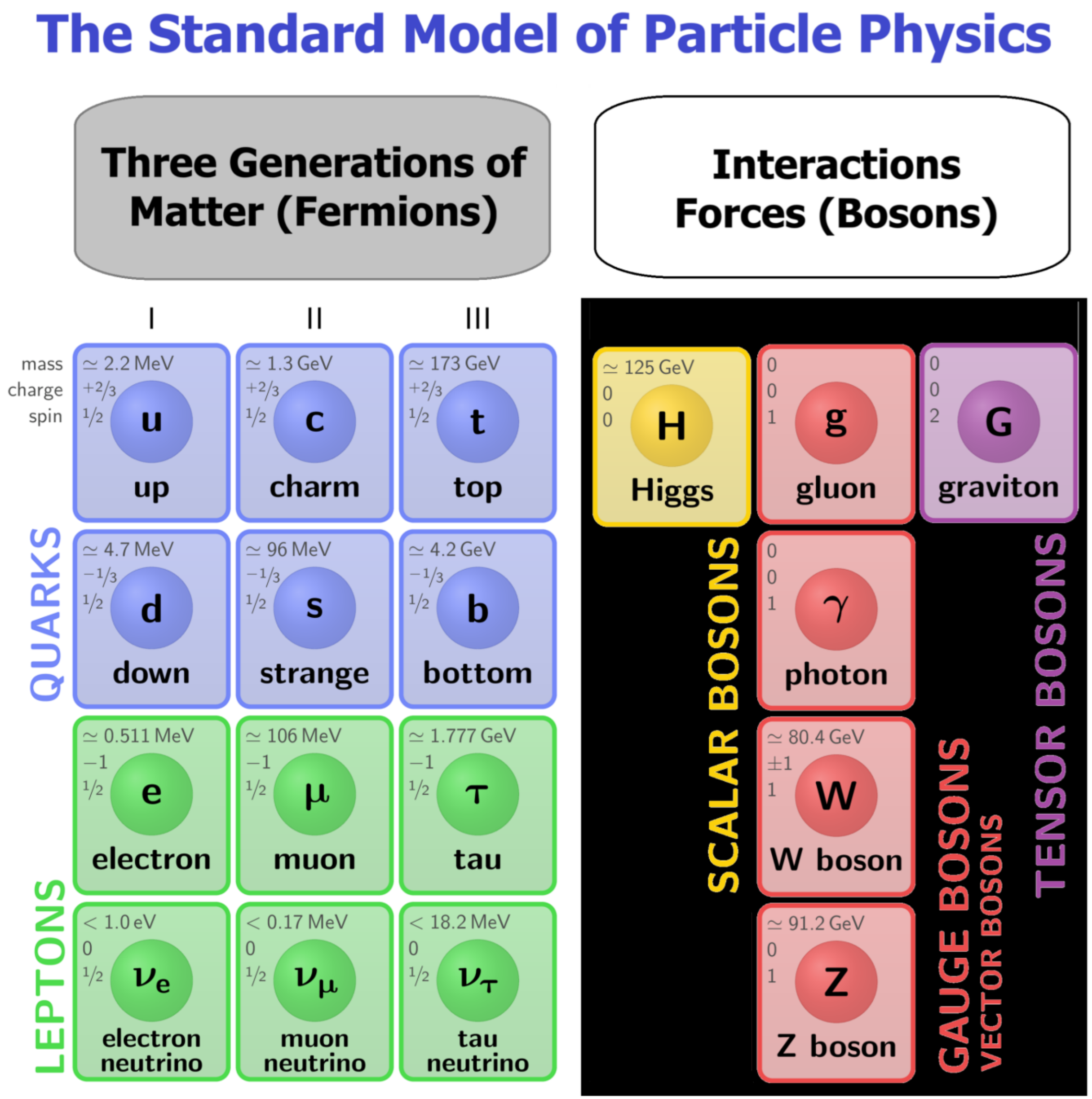
Energy Packets Determined by Their Particle-Like Detection



The Standard Model includes:

- 6 Quarks
- 6 Leptons
- 6 Bosons *(graviton is hypothetical)*

Energy Packets Determined by Their Particle-Like Detection



The Standard Model includes:

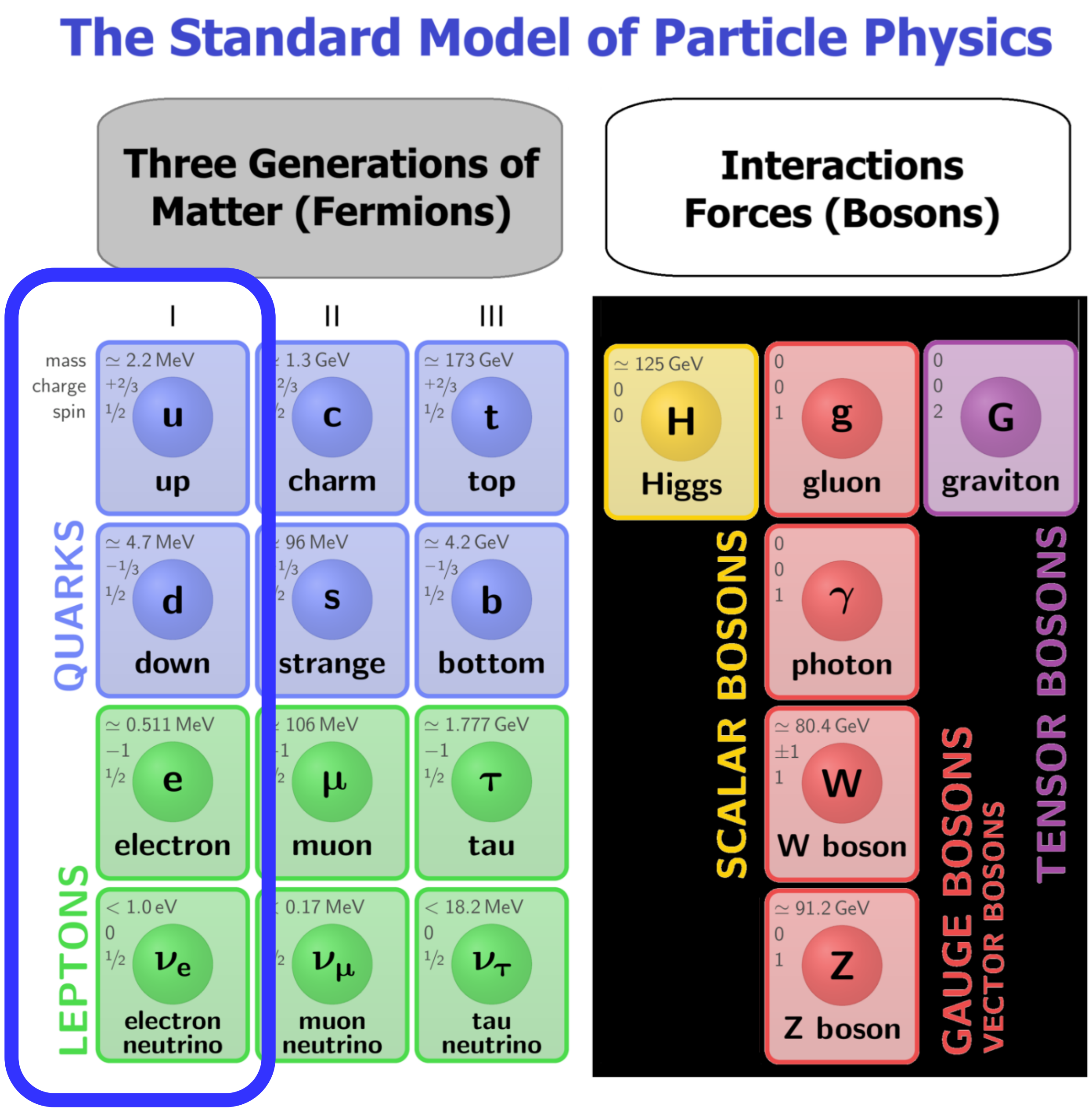
- 6 Quarks
- 6 Leptons
- 6 Bosons *(graviton is hypothetical)*

For simplicity, we list one representative particle of each type.

- Fermions (matter-like):
  - Quarks and leptons
  - Each has a distinct antiparticle
- Bosons (interaction-related):
  - Higgs, Photon, gluon, W, Z, Graviton
  - Most are their own antiparticles
  - Exception: W^+ has a distinct W^-

These Energy packets are not observed as objects—we observe them as discrete detection events with specific energy, charge, and spin.

Energy Packets Determined by Their Particle-Like Detection

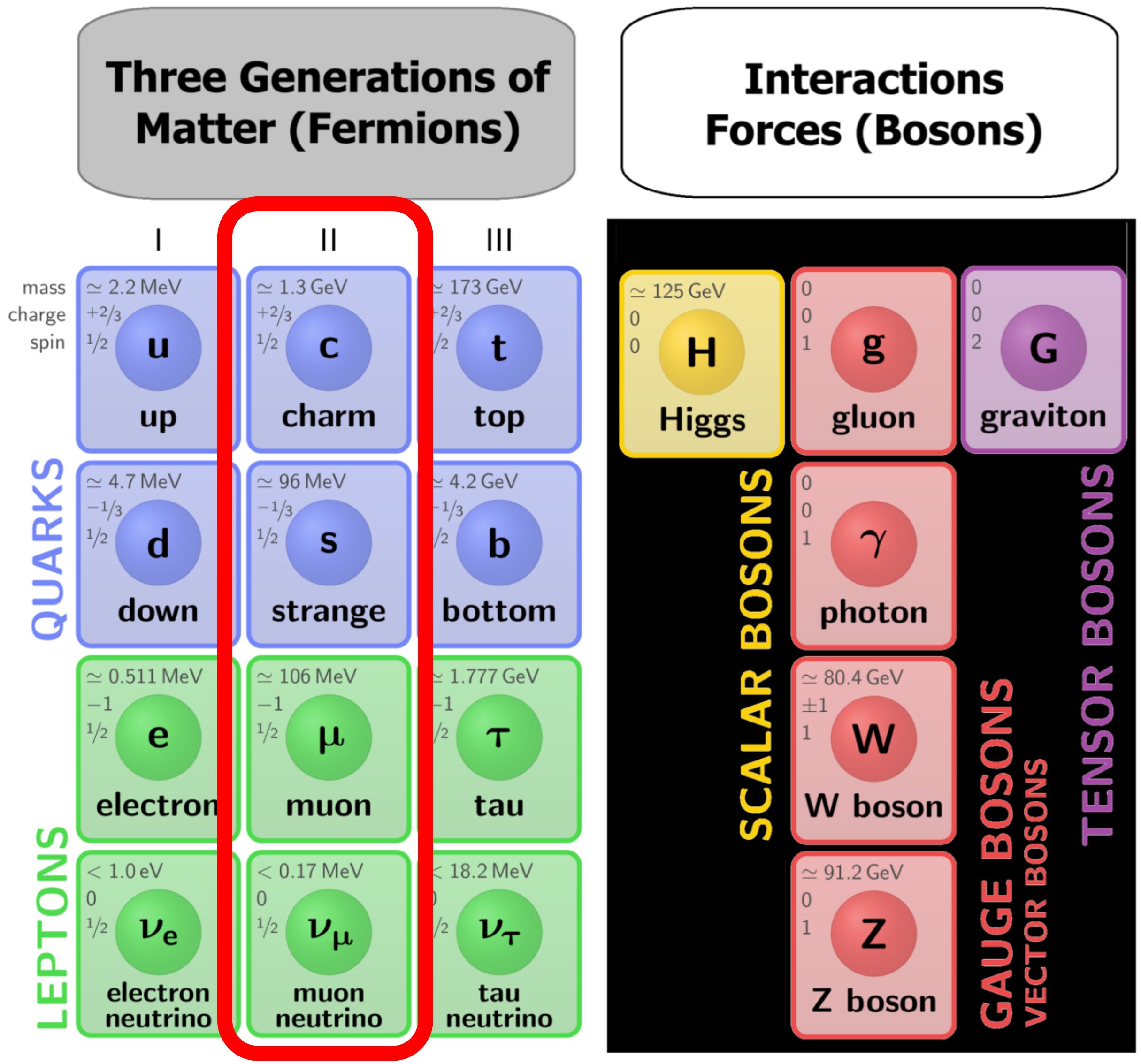


The Fermions come in three generations:

- Light weight

Energy Packets Determined by Their Particle-Like Detection

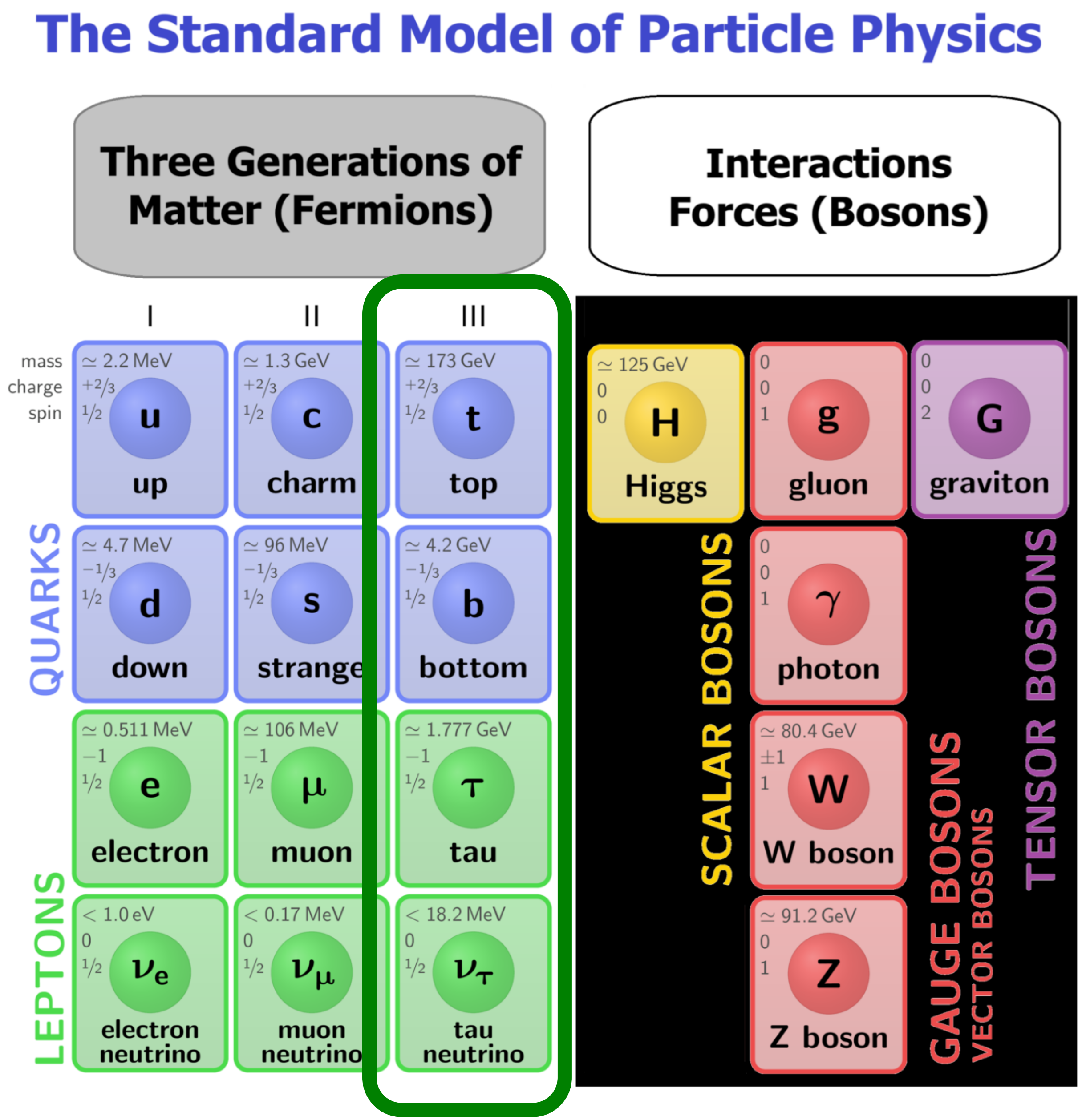
The Standard Model of Particle Physics



The Fermions come in three generations:

- Light weight
- Middle weight

Energy Packets Determined by Their Particle-Like Detection

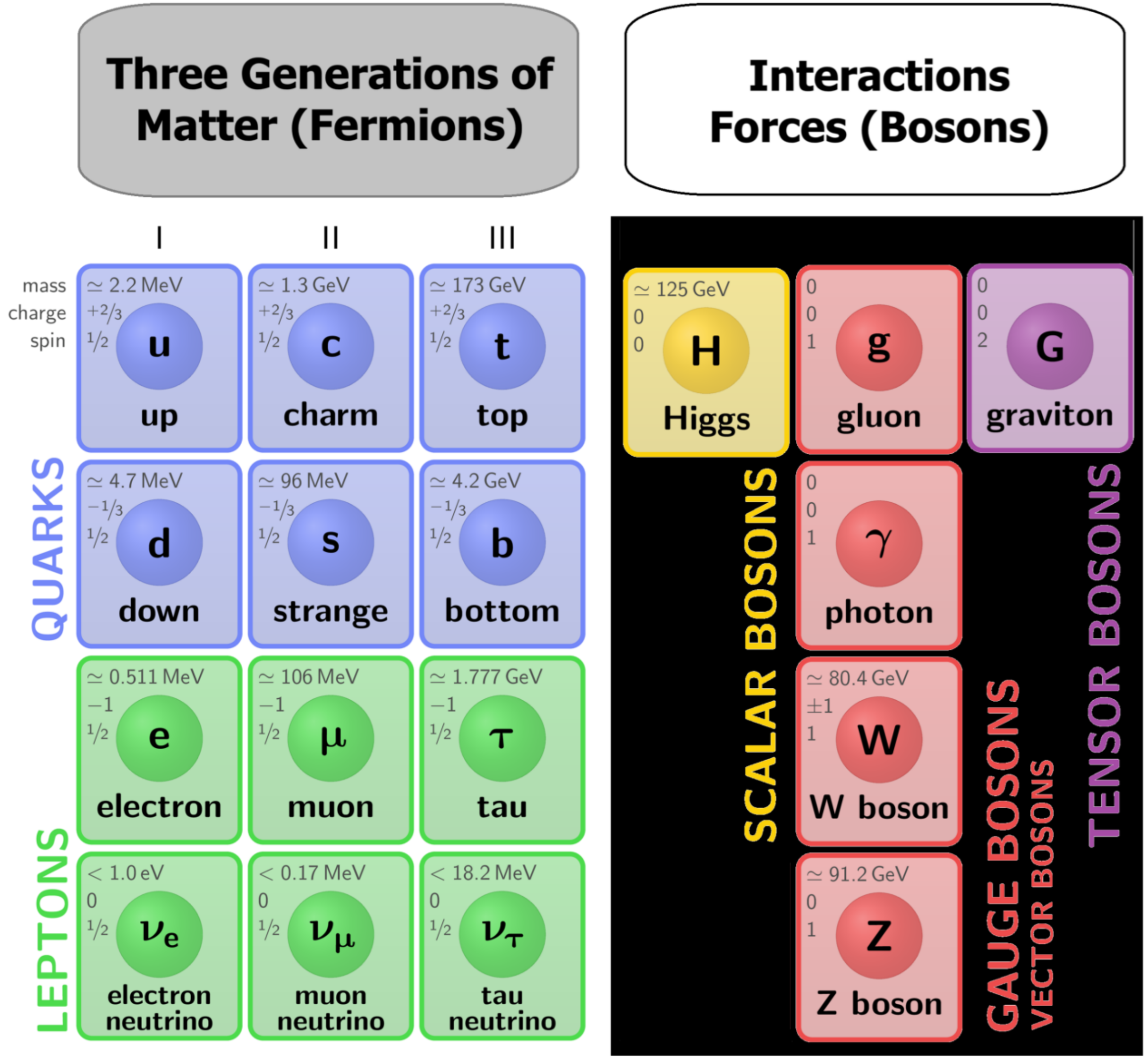


The Fermions come in three generations:

- Light weight
- Middle weight
- Heavy weight

Energy Packets Determined by Their Particle-Like Detection

The Standard Model of Particle Physics



The Fermions come in three generations:

- Light weight
- Middle weight
- Heavy weight

Only the light weight and the neutrinos are stable.

- The middle and heavy weight decay rapidly

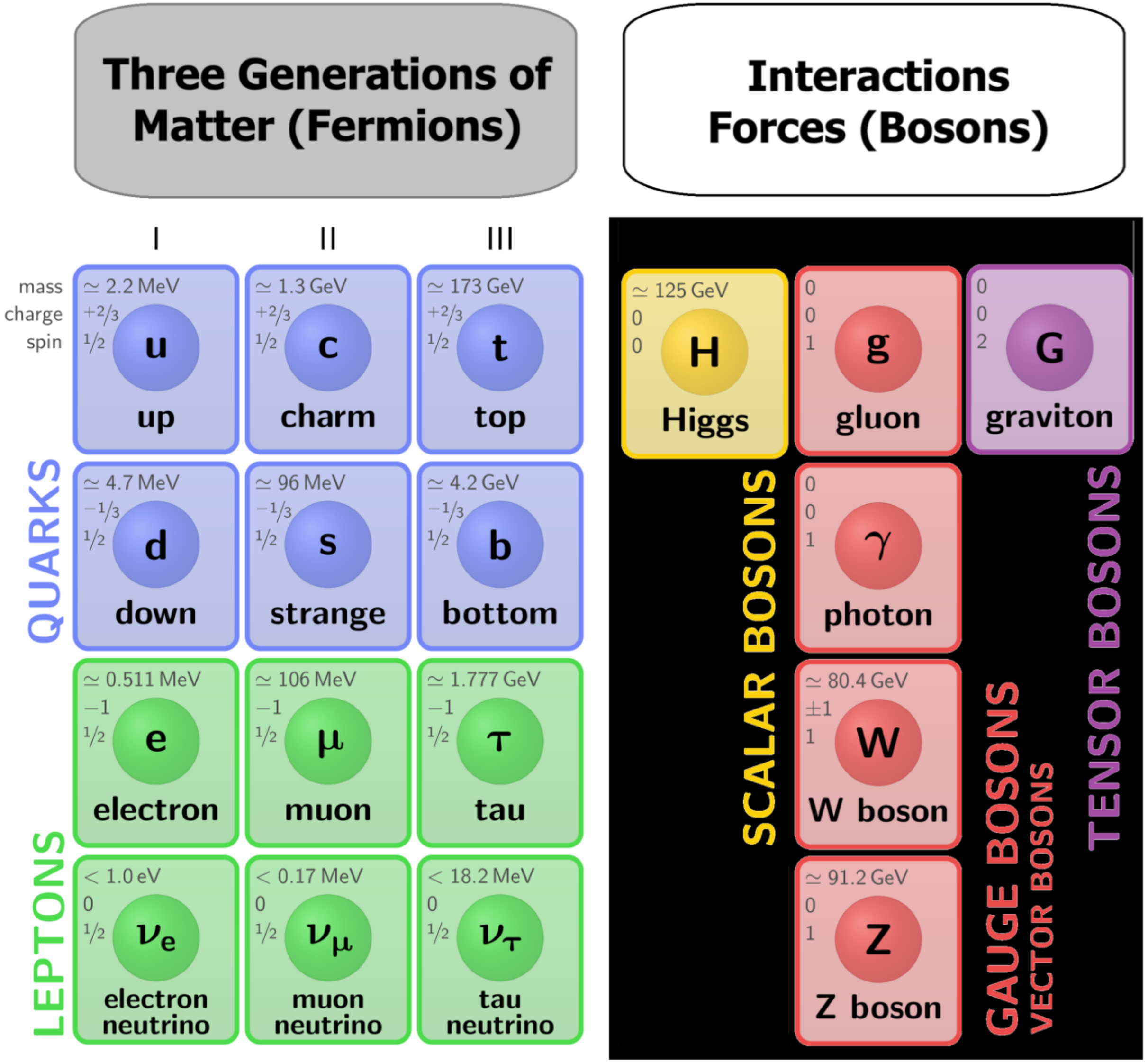
Our entire periodic table of chemistry is made up of only three fermions:

- Up Quark
- Down Quark
- Electron

Neutrinos are everywhere but do not interact with much of anything and therefore we don’t experience them in everyday life.

Energy Packets Determined by Their Particle-Like Detection

The Standard Model of Particle Physics



What Do We Mean by "Particle"?

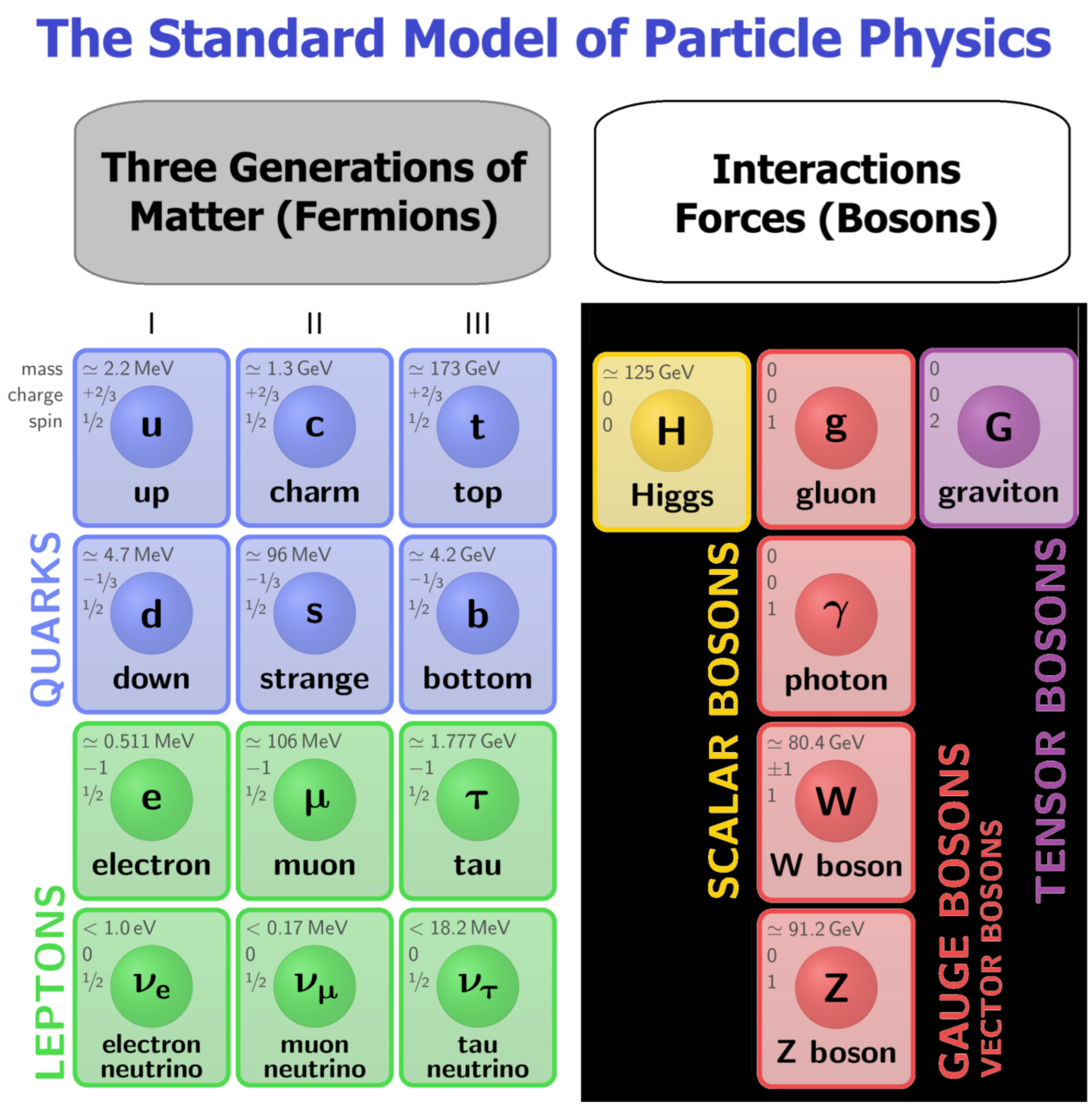
Different Words for the Same Thing

What we call particles in physics are described in different ways:

- "Wavicles" (Strassler)
- "Wave packets" (common physics language)
- "Energy packets" (used in this presentation)
- Quantum States

These are different ways of talking about the same mathematical model.

Energy Packets Determined by Their Particle-Like Detection



What Do We Mean by “Particle”?

What the model actually does:

The model predicts the probability that a detector will register a particle-like event, with specific properties such as:

- Energy
- Charge
- Spin

A “particle” is best understood as **a discrete detection event with specific properties**, not a little object moving through space.

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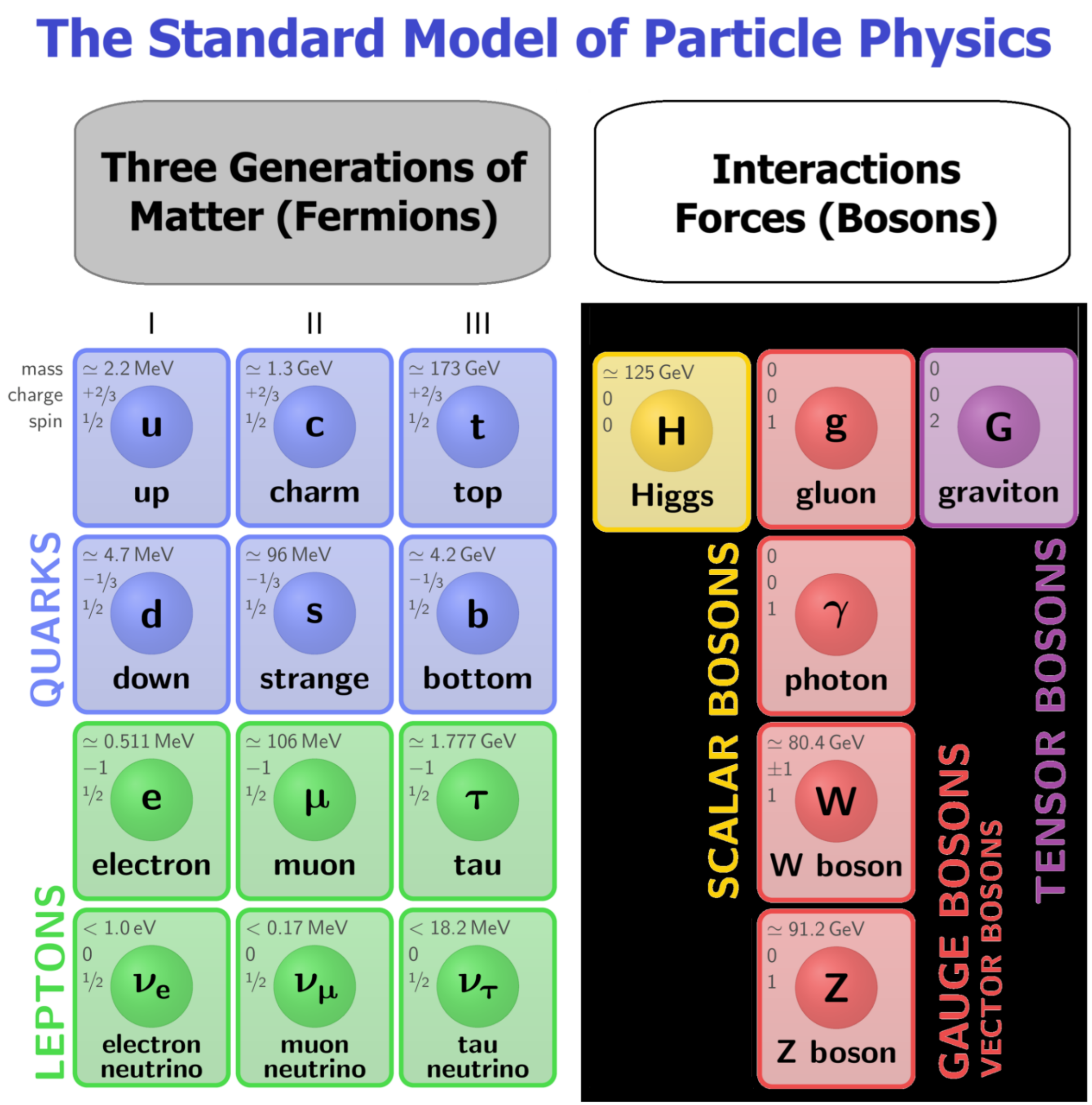
Energy Packets Determined by Their Particle-Like Detection



What Do We Mean by "Particle"?

What the model does NOT do:

The model does not tell us:

- what is "really happening" between detections
- that particles are tiny objects traveling through space
- what physically causes an individual detection event

Bottom line: A "particle" is best understood as a discrete detection event with specific properties.

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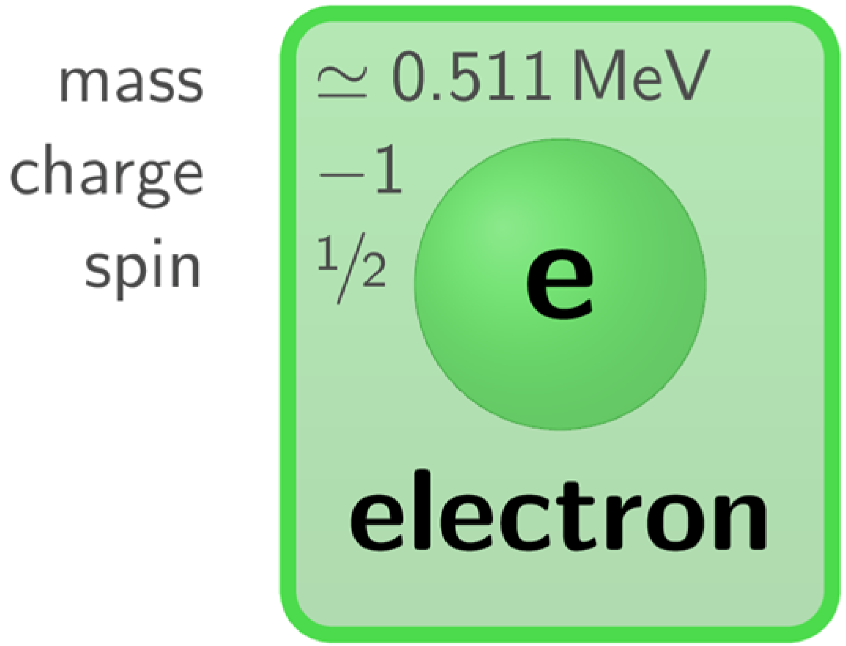


The Electron: Properties and What They Mean

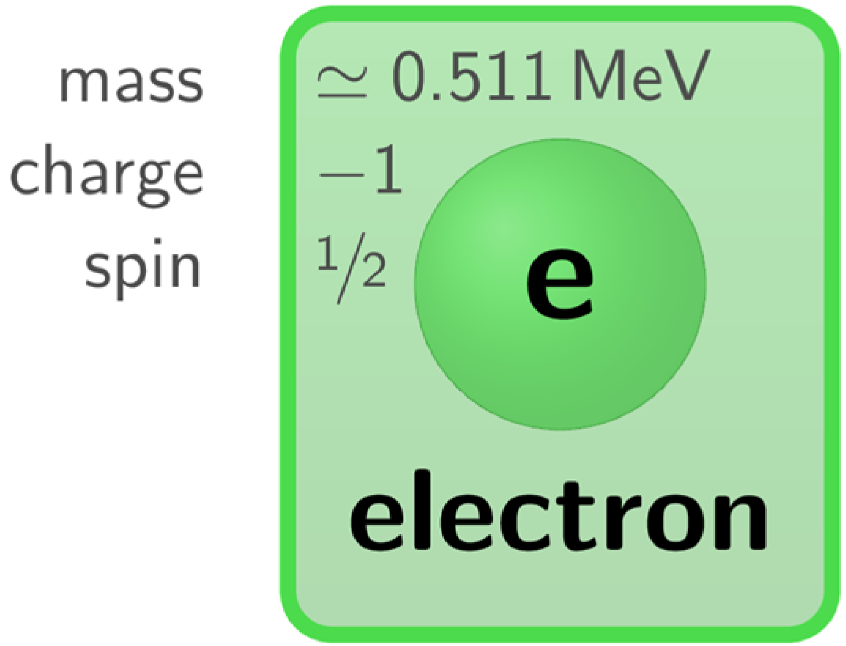
The electron is a lepton with specific measurable properties:

Mass: 0.511 MeV

Mass is expressed in energy units because mass and energy are related ($E = mc^2$)

Charge: −1

Charge determines how the electron interacts with electromagnetic fields



The Electron:
Properties and What They Mean

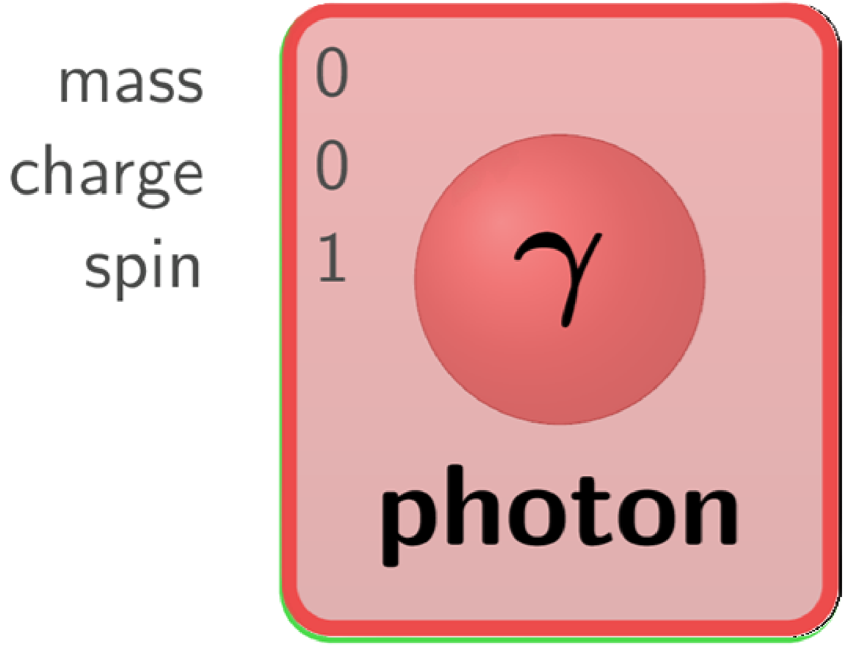
The electron is a lepton with specific measurable properties:

Spin: 1/2

Spin is a quantum property related to angular momentum. It does not mean the electron is physically spinning

Why only multiples of 1/2?

Spin comes from the mathematical structure of the model, which allows only discrete values. Fermions have half-integer spin (1/2, 3/2, ...), while bosons have integer spin (0, 1, 2, ...).



The Photon: Properties and What They Mean

The photon is a boson with specific measurable properties:

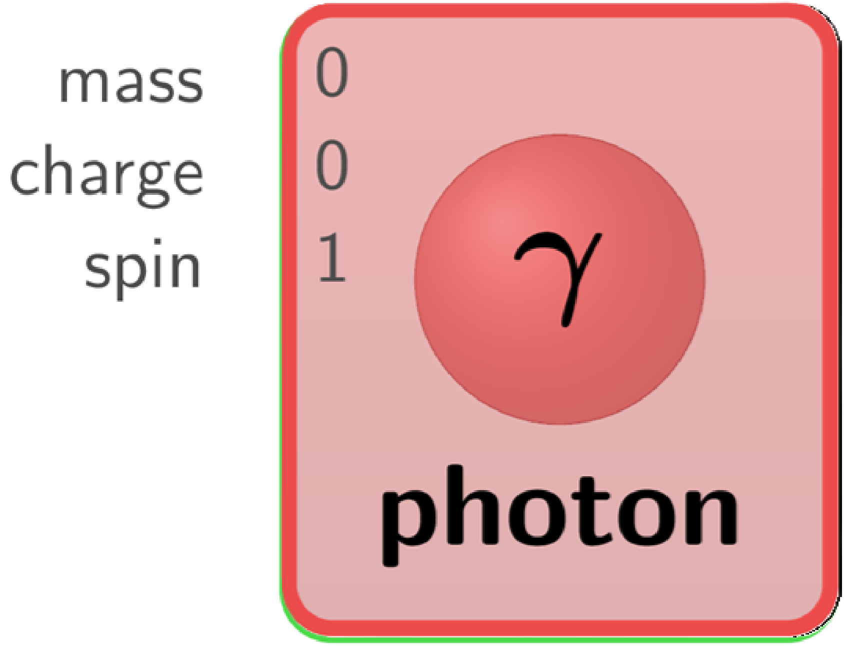
The photon is associated with electromagnetic interactions:

Mass: 0

Photons always move at the speed of light

Charge: 0

Photons do not respond to electric charge.



The Photon: Properties and What They Mean

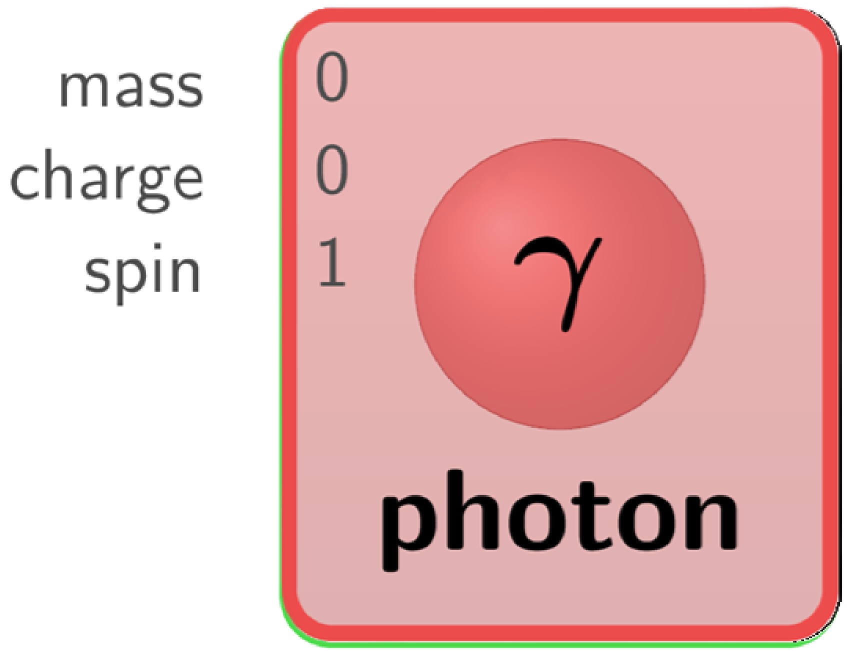
The photon is a boson with specific measurable properties:

Energy: variable

Depends on the situation (e.g., color of light)

Spin: 1

A quantum form of angular momentum (not literal spinning)



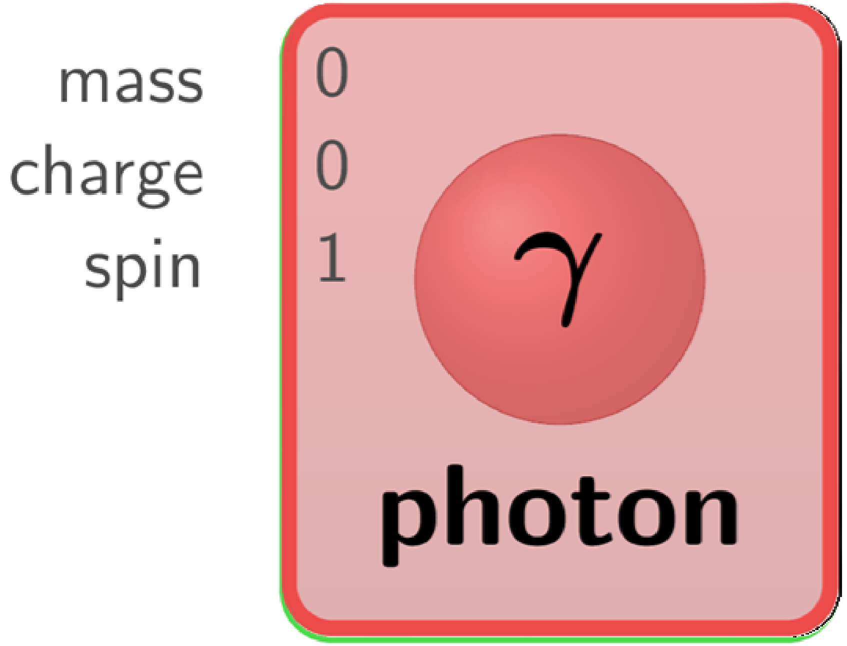
The Photon:
Properties and What They Mean

The photon is a boson with specific measurable properties:

Spin: 1

Why integer spin?

Photons are bosons, and bosons always have integer spin—this follows from the same mathematical structure that limits all spin values.



The Photon:
Properties and What They Mean

The photon is a boson with specific measurable properties:

Polarization (linked to chirality language):

Photons have two possible states:

- **Left-handed**
- **Right-handed**

This is somewhat similar to chirality language in fermions and is called polarization.

Bottom line: A photon is a discrete detection event carrying energy and other properties.

What Have We Learned?
From Particles to Detection Events

Central Ideas from This Lecture

- The Standard Model predicts measurable detector events with extraordinary precision.
- Elementary particles are identified through measurable properties such as:
    - mass
    - charge
    - spin
- Physics directly observes:
    - flashes
    - clicks
    - ionizations
    - quantized energy transfers

—not tiny visible classical objects.

"Particle" language is therefore operational and instrumental.

Important Shift

Quantum physics moves us away from:

- substance-centered thinking

toward:

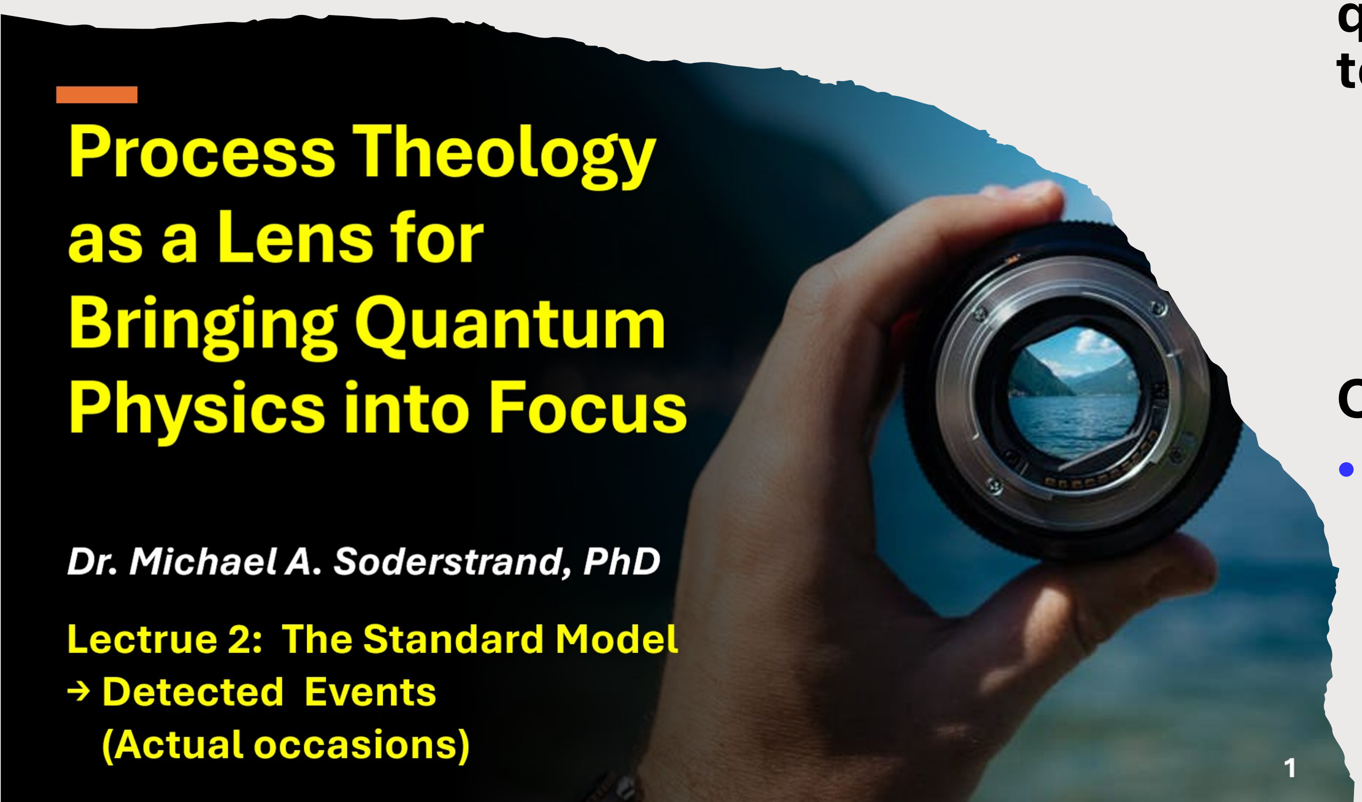
- event-centered thinking.

"Actual occasions" are the events of Process Theology

"Particle-like detections" are the events of Quantum Physics

Process Theology as a Conceptual Lens

Process Theology as an Interpretive Framework



Why Use Process Theology Here?

Process Theology provides conceptual language centered on:

- events
- relations
- becoming
- process

This language helps translate difficult quantum concepts into forms accessible to ordinary human understanding.

- detector events are physical observations
- "actual occasions" are philosophical interpretations

Central Idea

- The language of "actual occasions" provides one possible way of thinking about localized quantum detection events.

The Astonishing Success of Modern Physics

The Standard Model Works

- The Standard Model has predicted experimental results with extraordinary precision.
- ts mathematical structure successfully predicts:
  - particle interactions
  - decay patterns
  - scattering probabilities
  - conservation laws
  - detector events

with accuracy unmatched anywhere else in science.

Symmetry and Conservation

Modern physics discovered a profound connection:

Symmetry → Conservation Laws

Through the work of Emmy Noether, physicists learned that:

- symmetry in time relates to conservation of energy
- symmetry in space relates to conservation of momentum
- rotational symmetry relates to conservation of angular momentum

Important Idea: The mathematics of physics is not arbitrary. It reflects deep structural regularities in nature.

From Particles to Equations → Structured Possibility

Earlier atomic models eventually failed because they did not fully explain:

- stability
- symmetry
- conservation
- quantum behavior

The Standard Model appears fundamentally different.

Its mathematical structure:

- unifies interactions
- encodes symmetry principles
- predicts experimental outcomes with extraordinary accuracy

The 18 elementary particle types of this lecture series may represent something close to a complete set of fundamental quantum interaction structures.

Next Major Question

- If reality is fundamentally event-centered...
- then what structures constrain the possible events?

Lecture 3 Will Explore:

probability amplitudes, Hilbert spaces, Hamiltonian, structured possibility, Primordial Nature


"That's all Folks!"
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