Semi-Dirac Fermion and Fundamental Particles

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Why in News?

Physicists from Columbia University and Pennsylvania State University discovered a unique particle known as the **semi-Dirac fermion**.

- This finding not only offers fresh insights into the properties of **fundamental particles** but also holds potential implications for **quantum physics.**

What is a Semi-Dirac Fermion?

- **About:** A semi-Dirac fermion is a particle that has **mass when moving in one direction but not in a perpendicular direction,** which is a unique behavior. It was discovered in the crystalline material **zirconium silicon sulphide (ZrSiS).**
- **Dirac Fermions vs. Semi-Dirac Fermions:**
    - **Dirac Fermions**: Have mass and are distinct from their anti-particles.
    - **Semi-Dirac Fermions**: Have mass along certain directional axes and can behave differently under various conditions. This unique mass behavior is due to their **interaction with electric and magnetic forces in specific materials.**
- **Quasiparticles:** The semi-Dirac fermion is a **quasiparticle,** meaning it behaves like a single particle under specific conditions but is made up of multiple energy packets or particles (similar to protons).

What are Fundamental Particles?

- **About:** Fundamental particles, or elementary particles, make up atoms and lack internal structure.
    - The Standard Model of particle physics explains **17 fundamental particles, divided into fermions and bosons,** which are the building blocks of matter and energy, excluding gravity.

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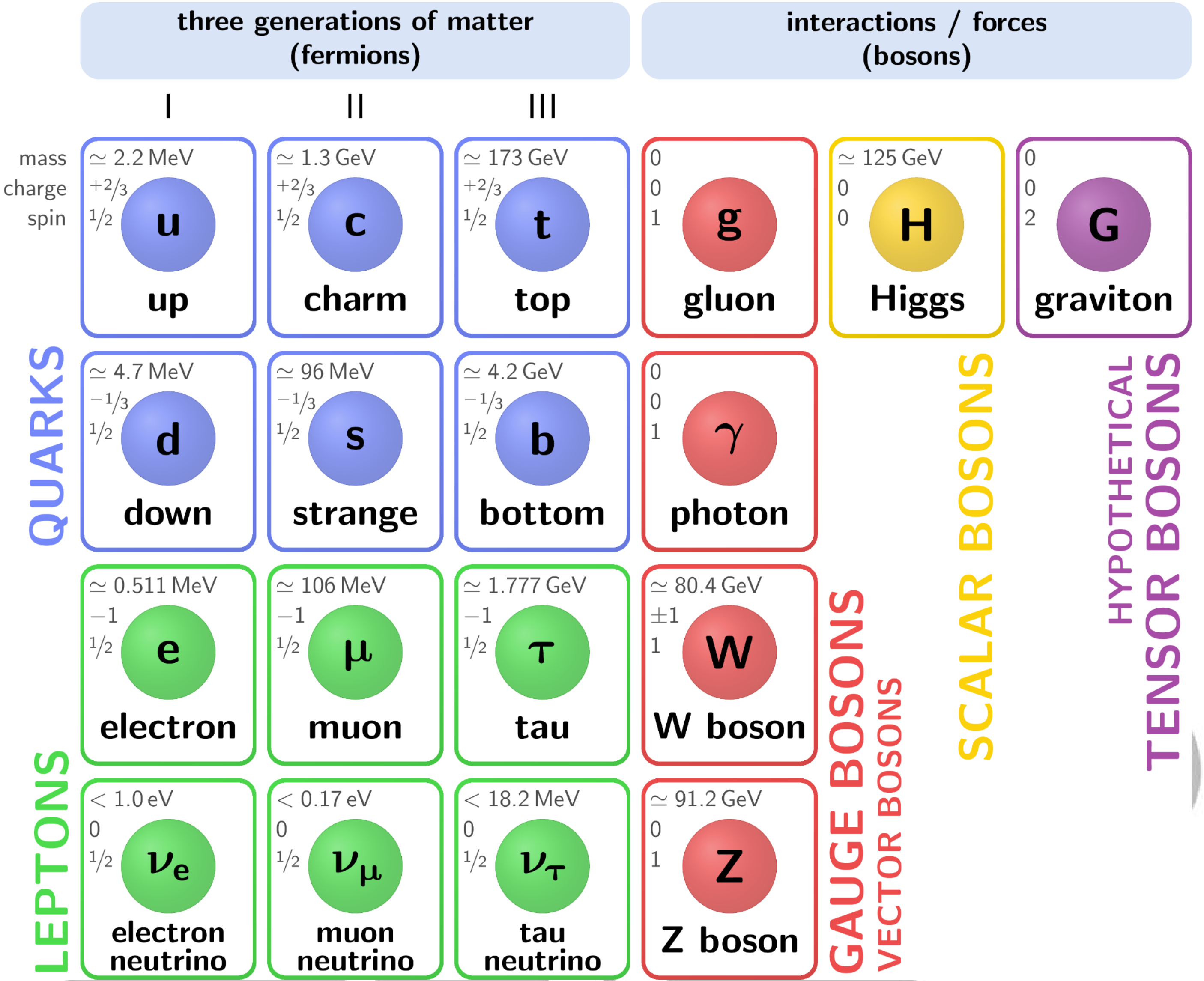
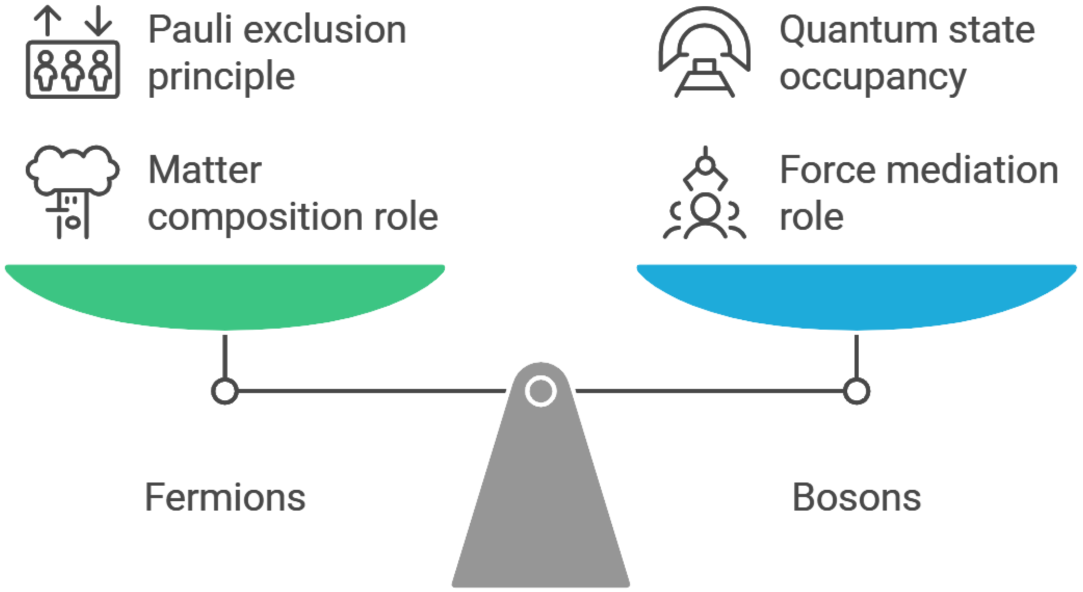


- **Fermions and Bosons:**
  - **Fermions:** These particles make up matter and follow the [Pauli Exclusion Principle](no two fermions can occupy the same quantum state), which helps them maintain their form and not collapse.
    - They have odd half-integer spins (angular momentum) (1/2, 3/2, and 5/2).
    - They include **protons, neutrons, electrons, neutrinos, and quarks.** These are the basic building blocks of everything around us.
    - Fermions can be further classified as **Dirac or Majorana fermions.**
      - **Dirac fermions** are fermions that **may or may not have mass** but are always different from their **anti-particles (particles with opposite charge and properties).**
      - **Majorana fermions** are fermions that are also their own antiparticles.
  - **Bosons:** Bosons are responsible for **transmitting forces between particles.** Unlike fermions, bosons do not follow the **Pauli exclusion principle**, can exist in **large numbers in the same quantum state,** as observed in phenomena like **superfluidity** and leading to the formation of a **Bose-Einstein Condensate (bosonic atoms are cooled to near absolute zero).**
    - Bosons include **photons, gluons, and Higgs boson**, all of which act as force carriers. They have whole number spins (0, 1, 2, etc.).
    - Bosons are divided into two categories as gauge bosons and scalar bosons.
      - **Gauge bosons (spin of 1),** such as photons, gluons, carry fundamental forces like electromagnetic, strong, and weak nuclear forces.
      - **Scalar bosons,** with a spin of 0, include the **Higgs boson,** which is

responsible for giving particles mass.

- **Applications:** Fundamental particles have various applications, including in **medical imaging, nuclear energy** (**neutrons in fission**).
  - They also play a key role in **quantum computing,** particle therapy for **cancer treatment,** and electronics, where electrons power devices like **transistors and semiconductors.**
  - These particles are central to advancing both practical technologies and fundamental physics research.



Comparing Roles and Properties of Fundamental Particles

UPSC Civil Services Examination, Previous Year Questions (PYQ)

Q1. The terms 'Event Horizon', 'Singularity', 'String Theory' and 'Standard Model' are sometimes seen in the news in the context of (2017)

(a) Observation and understanding of the Universe
(b) Study of the solar and the lunar eclipses
(c) Placing satellites in the orbit of the Earth
(d) Origin and evolution of living organisms on the Earth

Ans: (a)

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