

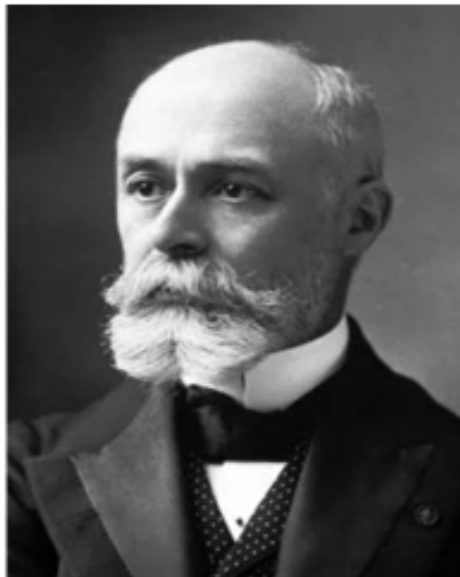


NEUTRINO : THE GHOST PARTICLE

By Alina Naqvi
M.Sc. (Physics) Student
University of Lucknow

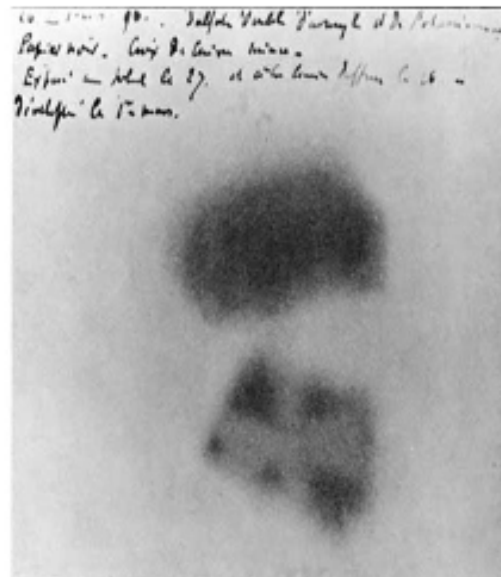
RADIOACTIVITY

- Accidentally discovered by Henri Becquerel in 1896
- Radioactivity (also called radioactive decay) is a spontaneous and random event happening inside the nucleus of an atom
- It is the process by which unstable nuclei becomes stable by emitting radiation or particles



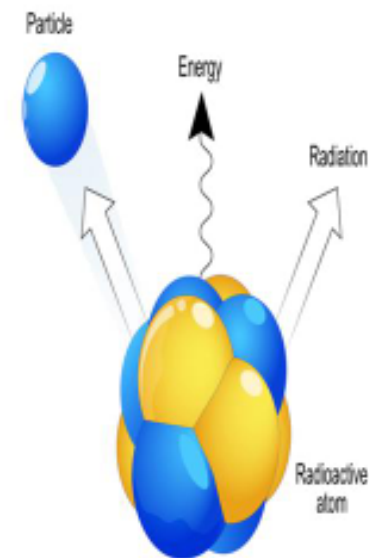
Henri Becquerel

<https://www.nobelprize.org/images/becquerel-12834-content-portal-mobile.jpg>



Images formed by Becquerel's uranium salts

<https://timeline.web.cern.ch/becquerel-discovers-radioactivity>

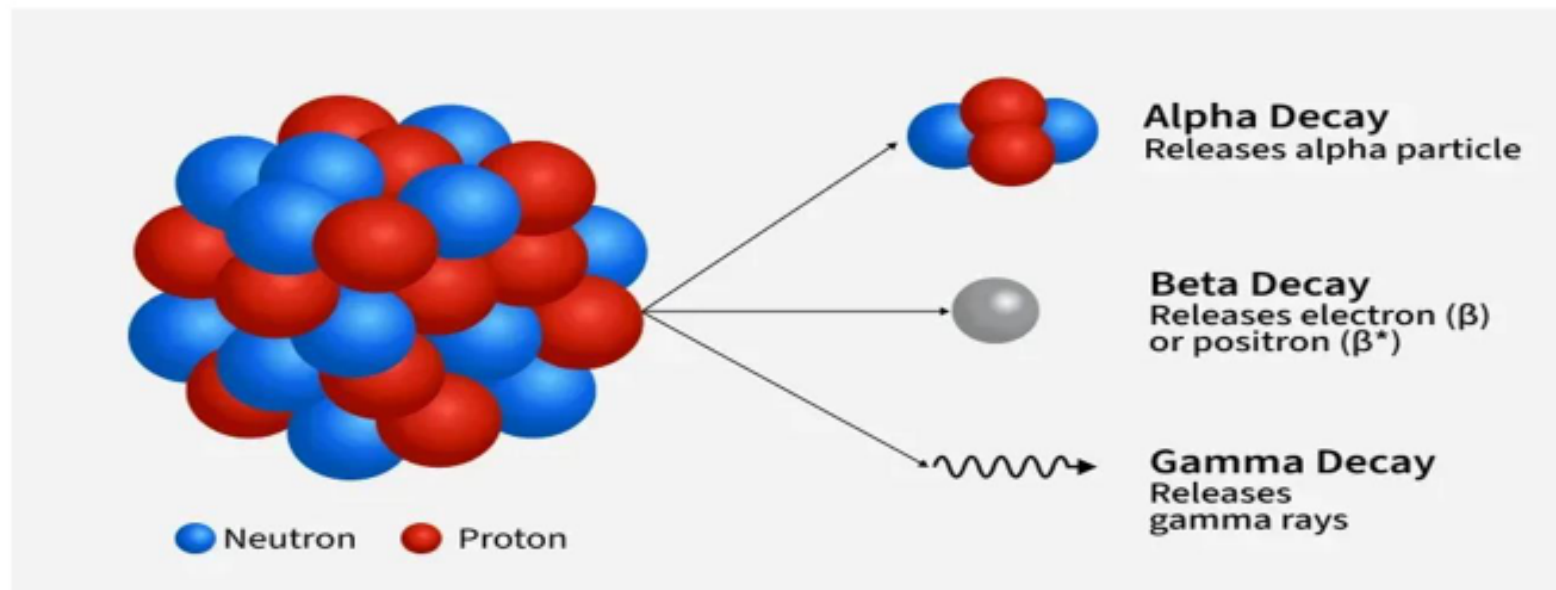


Radioactive decay

<https://www.cdc.gov/radiation-health/media/images/1427214056.jpg>

TYPES OF RADIOACTIVE DECAY

- Alpha Decay
- Beta Decay
- Gamma Decay

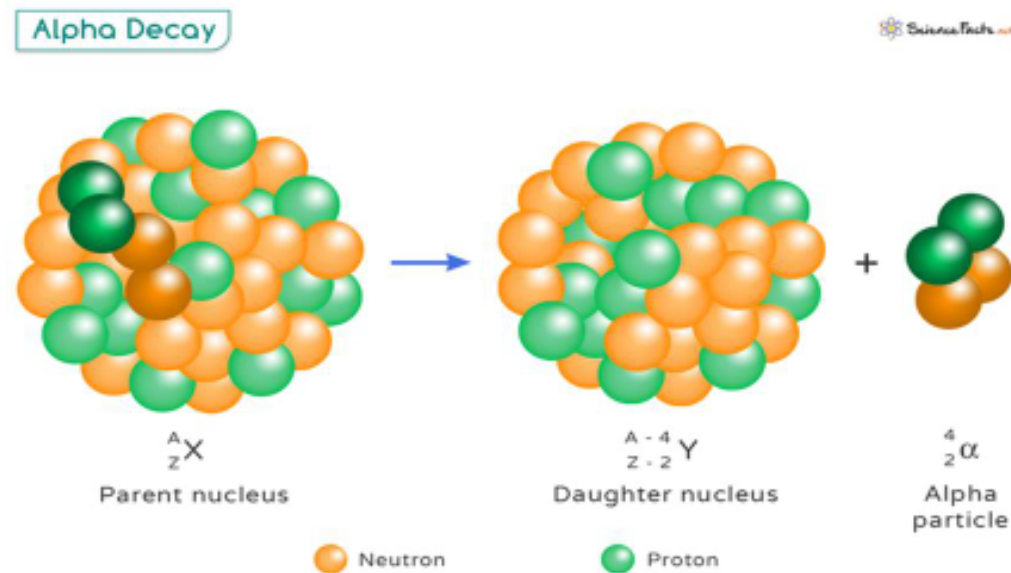
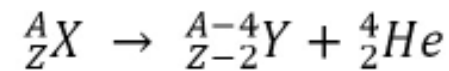


Radioactive Decay

<https://www.geeksforgeeks.org/physics/types-of-radioactivity-alpha-beta-and-gamma-decay/>

Alpha Decay

Unstable heavy nuclei converts to stable nuclei by emitting an alpha particle

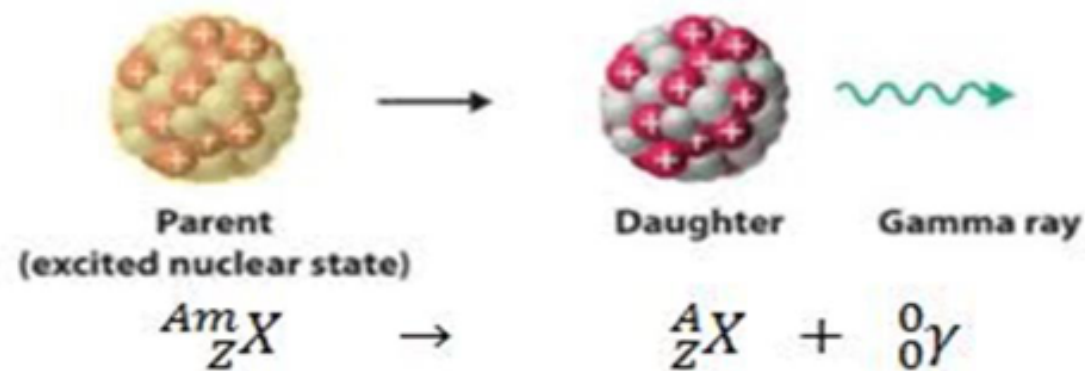
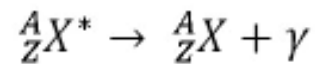


Alpha Decay

<https://www.sciencefacts.net/wp-content/uploads/2024/08/Alpha-Decay.jpg>

Gamma Decay

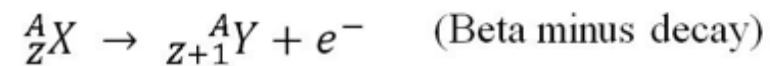
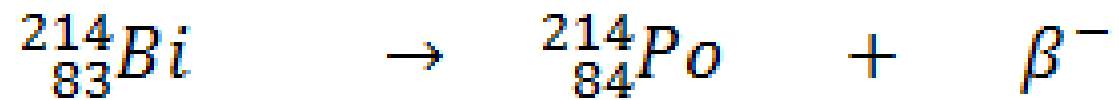
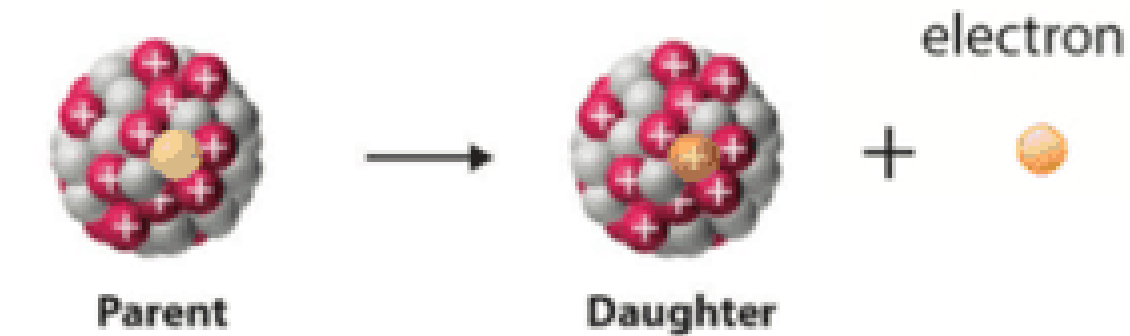
Excited atomic nucleus releases excess energy by emitting high-energy, short-wavelength photons (gamma rays) to reach a lower, more stable ground state



Gamma Decay

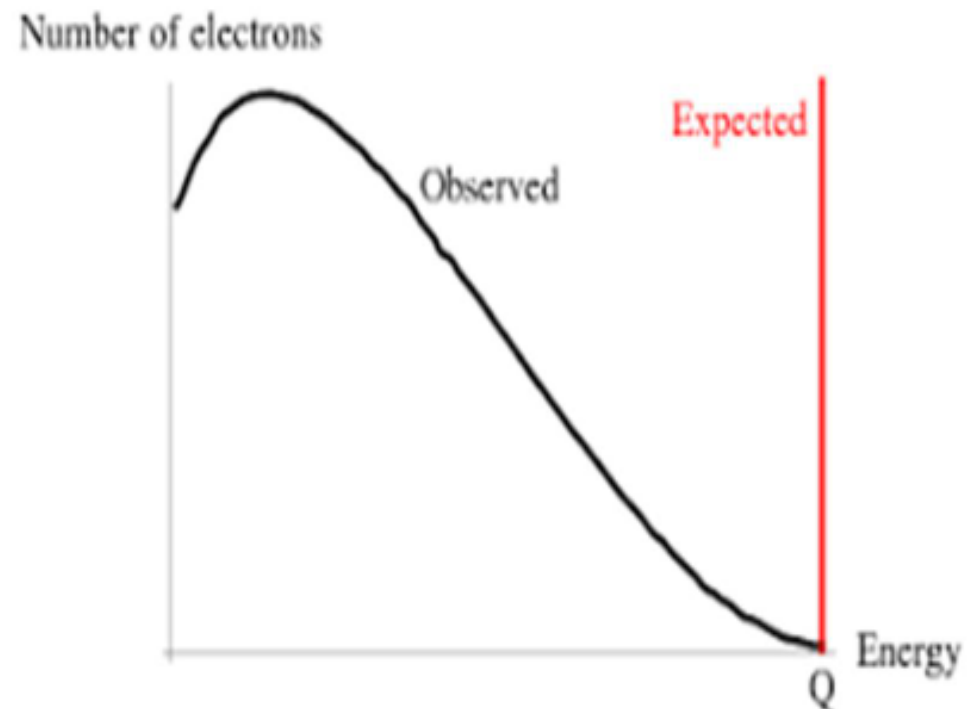
https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcTPbiZtHioZpCd6_CQBI1WjrWCgsYTtMXuEfg&sz

Beta Decay



BETA DECAY AND THE NEUTRINO HYPOTHESIS

- In the 20th century, it was considered that only two particles are emitted in the beta decay, namely, the daughter nucleus and the beta particle. For eg. $n \rightarrow p + e^-$
- However, experimentally we get the continuous energy spectrum instead of the line spectrum.
- This idea led to many discrepancies such as non-conservation of angular momentum and spin.



Energy spectrum of beta decay

<https://cds.cern.ch/record/2243592/files/mybeta.png>



Niels Bohr

<https://rinconeducativo.org/en/recursos-educativos/niels-bohr-contributed-understanding-atom-and-quantum-mechanics/>

During that time when big brains were brainstorming , Bohr even went to the length to say that energy does not remain conserved.

“The laws of physics as we know them are broken at the nuclear level.”

At the same time, Wolfgang Pauli had a different view

“The laws are fine, we're just missing a piece of the puzzle.”

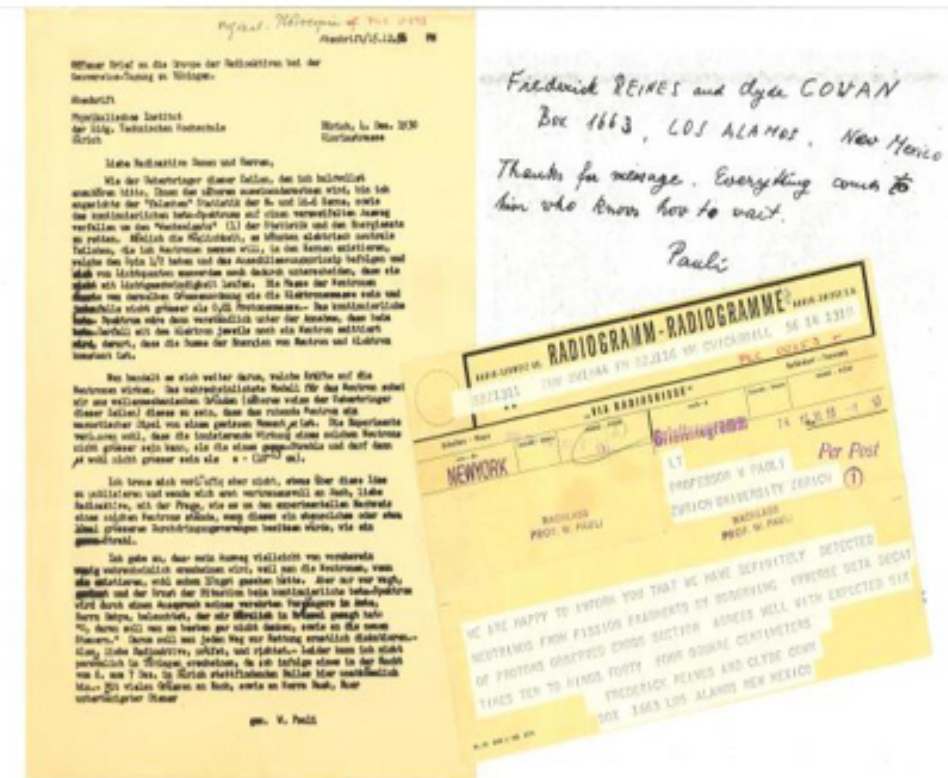


Wolfgang Pauli

<https://upload.wikimedia.org/wikipedia/commons/4/43/Pauli.jpg>

PAULI'S NEUTRINO HYPOTHESIS

- To explain the beta decay spectrum, Wolfgang Pauli in 1930, wrote a letter to a conference in Germany, in which he proposed that a neutral, spin $\frac{1}{2}$, massless particle called 'neutron' is produced in the beta decay i.e. it is a 3 body decay.
- It got renamed as 'neutrino' by Enrico Fermi

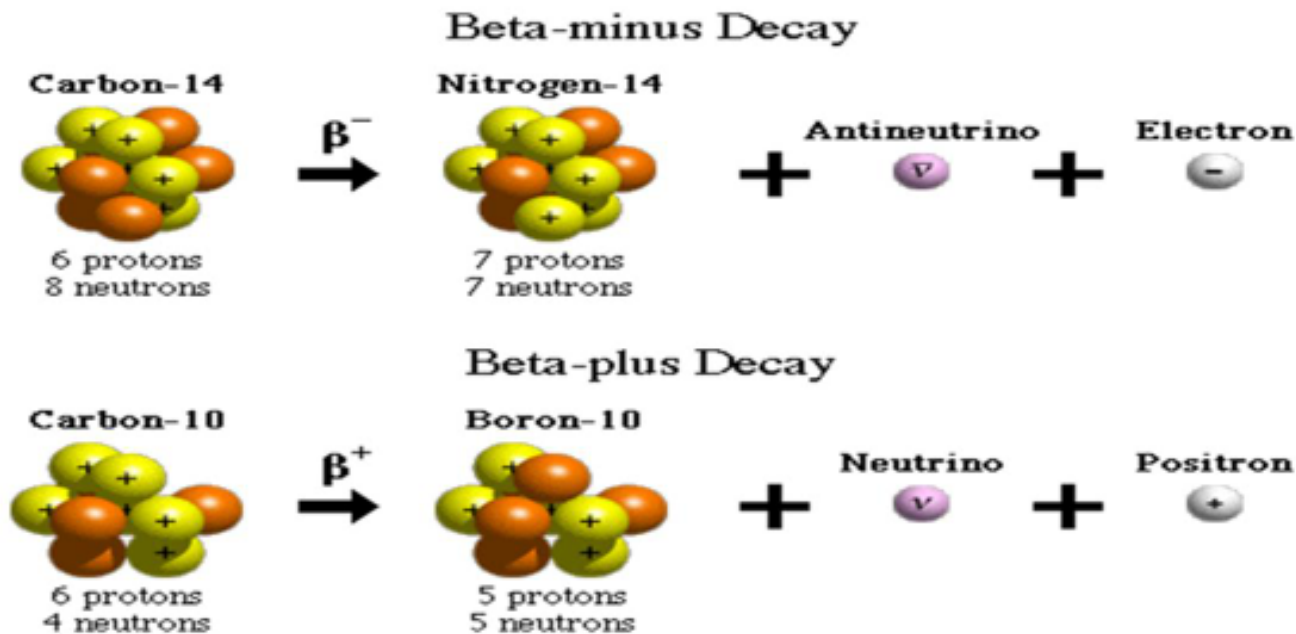
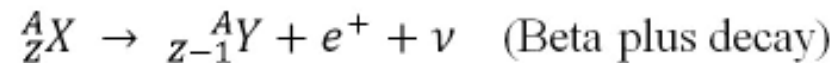
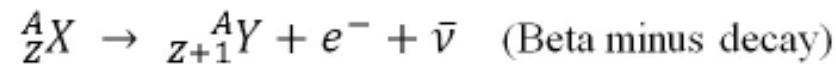


Letter written by Pauli (on left) to the conference and the letter written by Reines and Cowan to Pauli after the detection of neutrino (on right)

Neutrino was first detected in 1956 by Cowan and Reines, almost after 3 decades of its prediction!

Beta Decay

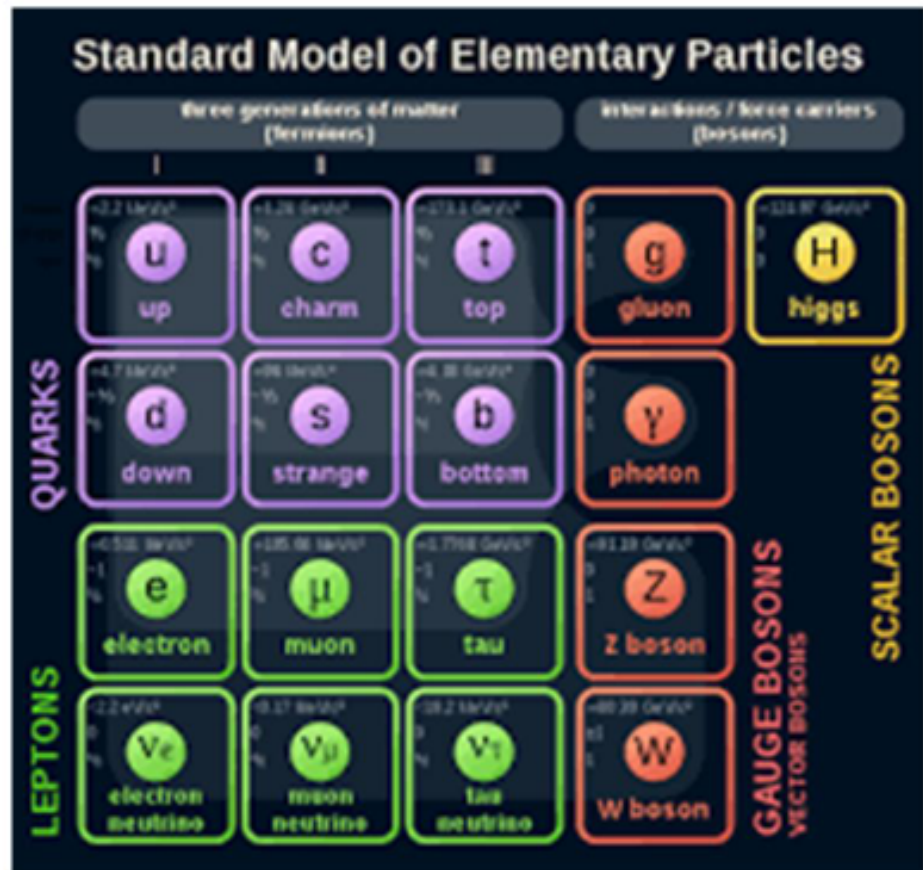
Unstable nuclei changes to stable nuclei by emitting a beta particle (electron or positron) accompanied by anti-neutrino or neutrino



Example of Beta Decay

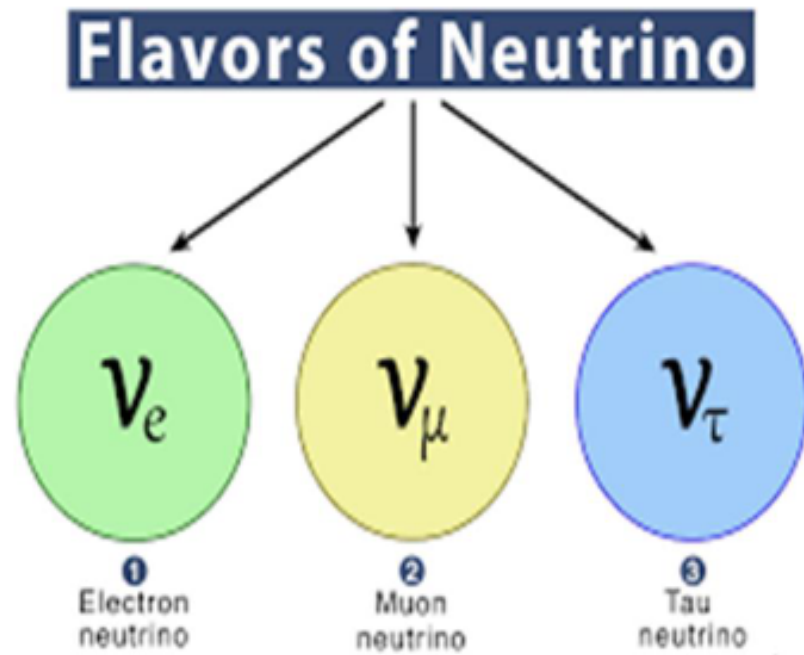
NEUTRINOS AND THE STANDARD MODEL OF PARTICLE PHYSICS

- Standard Model of particle physics classifies all the elementary particles and explains 3 of the 4 fundamental forces namely, strong force, weak force and electromagnetic force.
- Under the Standard Model, elementary particles are classified as quarks and leptons, which come in three generations.



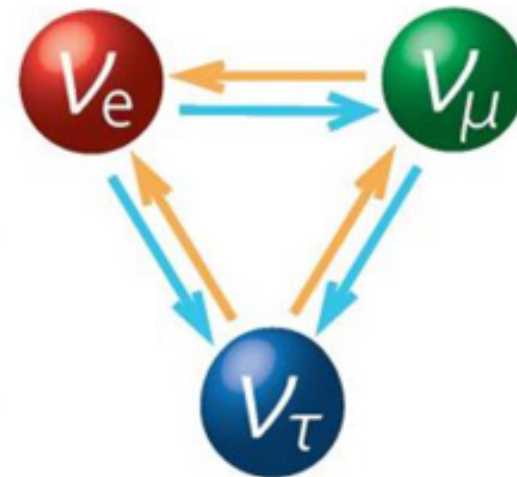
<https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcRXmjMuC5Hl4LpyfkQJswlIFMqHg1M6E-rw&s>

- Neutrinos are classified as leptons and exist in three flavors, electron neutrino (ν_e), muon neutrino (ν_μ) and tau neutrino (ν_τ)
- They are considered massless under the Standard Model
- All active neutrinos are left handed whereas anti-neutrinos are right handed



NEUTRINO OSCILLATIONS

- Neutrinos can change flavor over time i.e. one neutrino flavor can change into another neutrino flavor as they travel known as ‘neutrino oscillation’
- Neutrino Oscillations prove that neutrinos are not massless, because a massless particle does not have a concept of time, if a neutrino is converting to another type of neutrino as a function of distance then it must be time dependent and if it knows time then it is not massless as predicted by the Standard Model



https://wp.lancs.ac.uk/dune/files/2016/10/Neutrino-flavors_web-300x254.jpg

Need new theories Beyond Standard Model !

OPEN QUESTIONS IN NEUTRINO PHYSICS

- What is the absolute mass of the neutrino?
- Are there sterile neutrinos?
- Are neutrinos Dirac or Majorana particles?

THANK YOU