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Discovery of Neutrinos

Malik Tischmann

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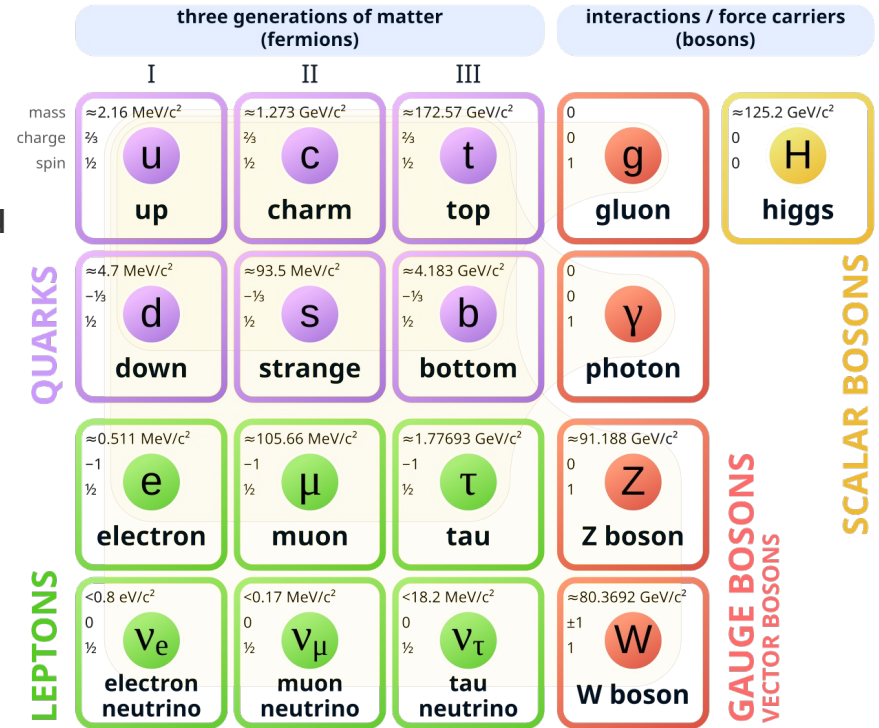
Contents

- 1 General informations
- 2 The beta decay problem
- 3 The nuclear bomb
- 4 Cowan-Reines (Hanford)
- 5 Cowan-Reines (Savannah River)
- 6 The second and third neutrino

What is a Neutrino?

- Elementary particle
- Comes in 3 flavors: electron, muon and tau
- Electrically neutral
- Very small mass
 - Exact values are unknown
- Interacts using the weak interaction

Standard Model of Elementary Particles

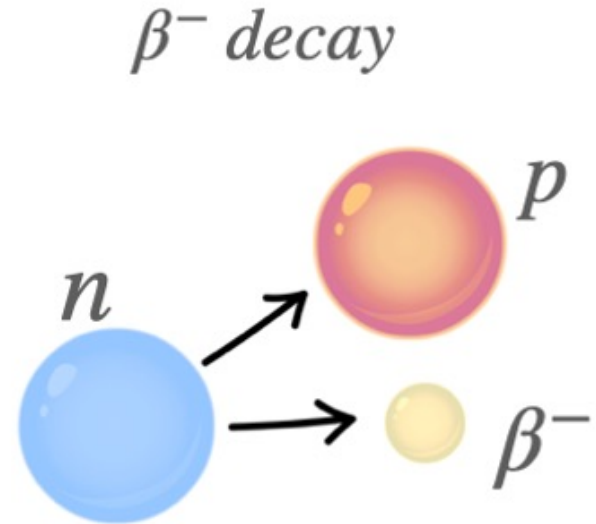


Origins of Neutrinos

- Radioactive decay
 - For example in stars
- Neutrinos pass through matter
 - Difficult to detect
- Nuclear reactions in nuclear reactors
 - Best source for experiments

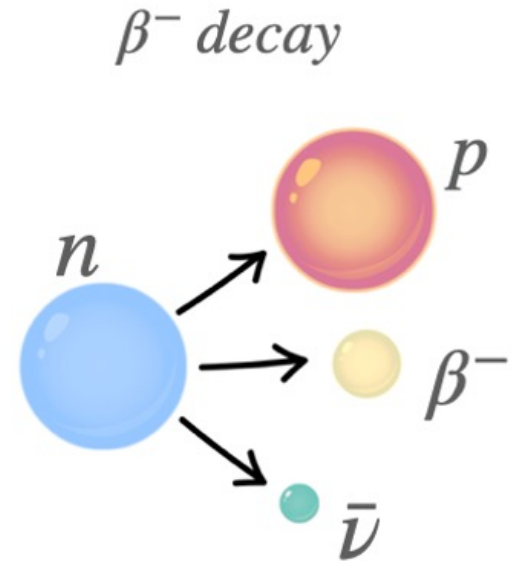
The beta decay

- Radioactive nucleus needed
- Emission of one electron
- the old nucleus transforms into a new, slightly lighter nucleus
- With all masses specified, the Energy of the new nucleus is fixed



The beta decay problem

- Emitted electrons in experiments vary in Energy
 - Energy conservation broken
- Wolfgang Pauli 1930: A new particle carries the missing energy
- It actually is a neutrino
 - In this case a antineutrino



Paulis hypothesis

- Electrically neutral particle
- Pauli called it the „Neutron“
- He was concerned because it had not been detected
- Fermi expands on Paulis theory, calls them „Neutrinos“
 - Also introduces the weak force

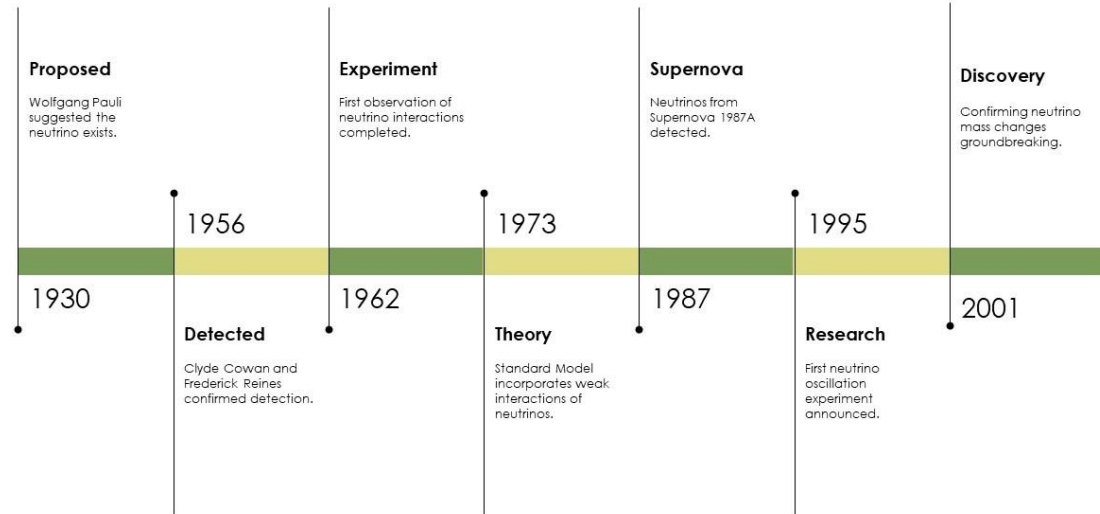
DEAR RADIOACTIVE LADIES AND GENTLEMEN, AS THE BEARER OF THESE LINES, FOR WHOM I PRAY THE FAVOR OF A HEARING WILL EXPLAIN IN MORE DETAIL, I HAVE... HIT UPON A DESPERATE REMEDY FOR RESCUING THE "ALTERNATION LAW".. THIS IS THE POSSIBILITY THAT THERE MIGHT EXIST IN THE NUCLEI ELECTRICALLY NEUTRAL PARTICLES, WHICH I CALL NEUTRONS.

- WOLFGANG PAULI -

Timeline of events

- Neutrinos almost entirely theoretically described
- Prediction of further Neutrino flavors
- Because Neutrinos pass through matter: No experimental detection

History of Neutrino Discovery

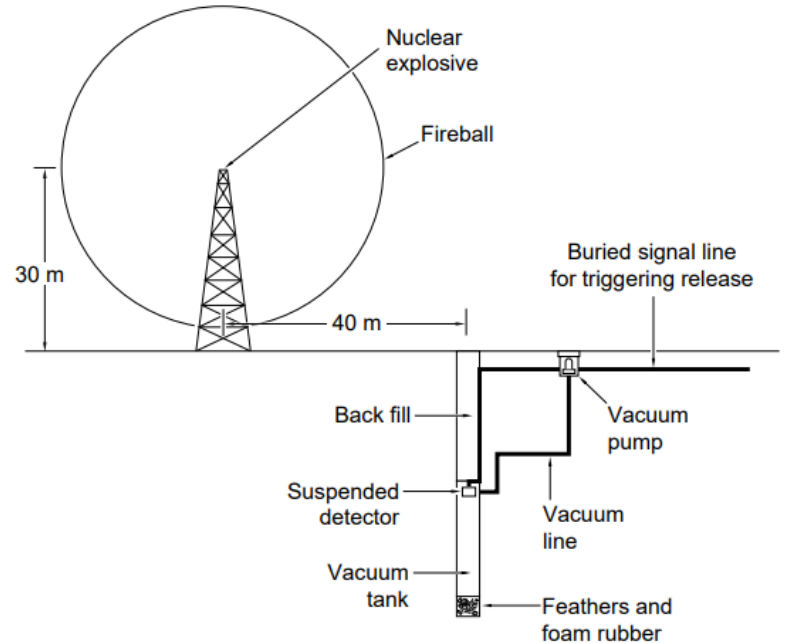


The Cowan-Reines Experiments

- Only way of detecting neutrinos is the inverse beta decay
- Rise of nuclear science (for example nuclear reactors)
 - Reliable source of Neutrinos
- Cowan and Reines at Los Alamos
 - They plan to use nuclear bombs as a neutrino source
 - No reliable detector yet

The nuclear bomb

- Reverse beta decay as the detection method
- When Neutrinos hit protons a neutron and positron are the result
- If positrons were detected there must have been neutrinos
- Giant detector was needed

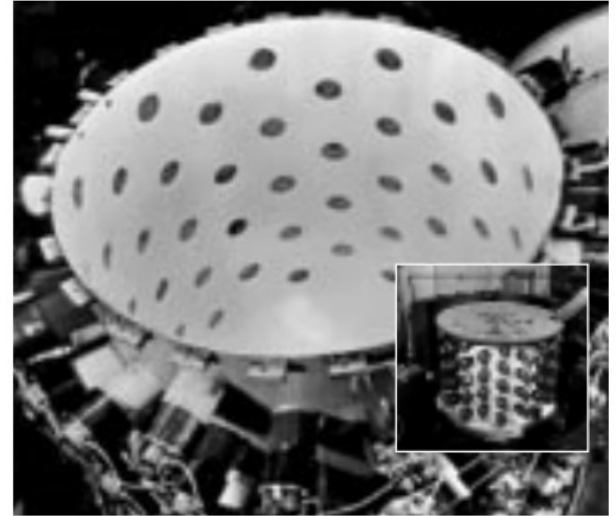


Change of plan

- Proposal of using a nuclear reactor as a neutrino source
- The explosion was a better source unless the background could be reduced at the reactor
- Solution: detecting both the positron and the neutron
- Neutron capture
- Detecting a „delayed coincidence“ to prove the existance of Neutrinos

The Hanford Experiment

- Over the next couple of months the detector was build
- Tested by detecting potassium in the human body
- Spring 1953: Setting up at the Hanford reactor
- Only probable detection of Neutrinos
- Interference from cosmic rays caused problems



The Savannah River Experiment

- Complete overhaul of the detector
- Now better protected from cosmic rays
- November 1955: Setup at the new and powerful Savannah River reactor
- Detector placed in basement, 11 meters of concrete protect the detector from neutrons

The neutrino detected!

- 900 hours of data over 5 months
- Many additional checks to ensure that actual neutrinos were detected
- Successful detection of multiple Neutrinos
- Telegram to Pauli on June 14 1956 officially confirming the Neutrion detection
- Follow-up experiments confirmed these results



The second neutrino

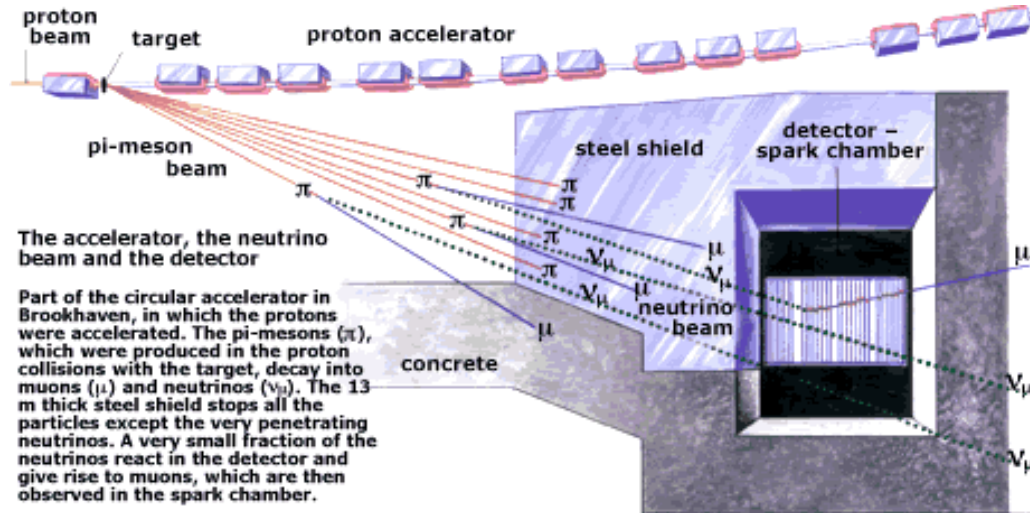
- After the discovery of the first neutrino, people were eager to discover the other flavors
- A team around Melvin Schwartz generated a proton beam of 15 GeV in 1962
- This beam hit a beryllium target, generating pions
- The pions quickly decayed into muons and neutrinos

The second neutrino

- This beam then passed through a 13.5m thick steel wall
- Mainly neutrinos left
- Spark chamber to detect the neutrinos
- A few low-energy muons also reach this point
- Several months of experimental runs

The muon neutrino

- Out of 113 events 51 were Neutrinos
- No further interactions, meaning the neutrinos were not electron neutrinos



The accelerator, the neutrino beam and the detector

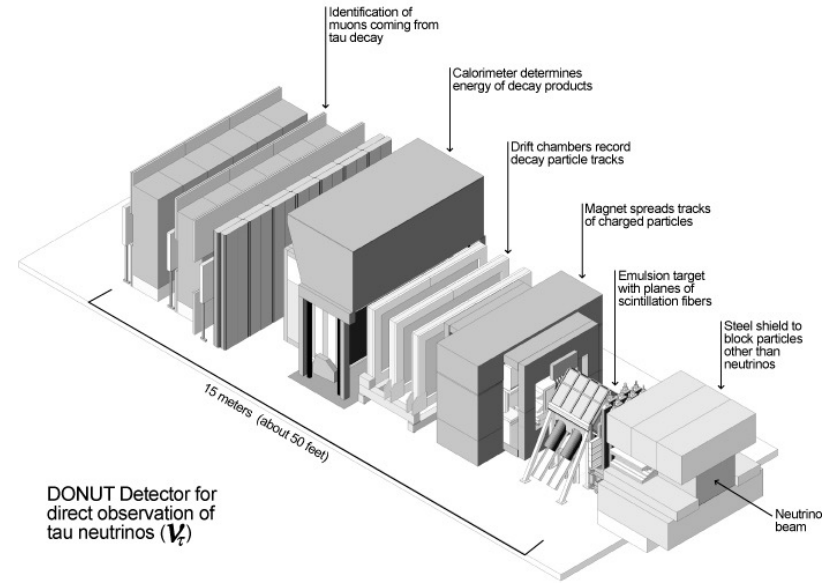
Part of the circular accelerator in Brookhaven, in which the protons were accelerated. The pi-mesons (π), which were produced in the proton collisions with the target, decay into muons (μ) and neutrinos (ν_μ). The 13 m thick steel shield stops all the particles except the very penetrating neutrinos. A very small fraction of the neutrinos react in the detector and give rise to muons, which are then observed in the spark chamber.

Based on a drawing in Scientific American, March 1963.

The third neutrino

- Tau Neutrino, least studied particle
- First detection in July 2000
- DONUT experiment from Fermilab
- Proton beam used to get neutrino beam
- Neutrino beam passes through sheets of nuclear emulsion
- Charged particles created by neutrinos create visible tracks

DONUT Detector



Sources

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