

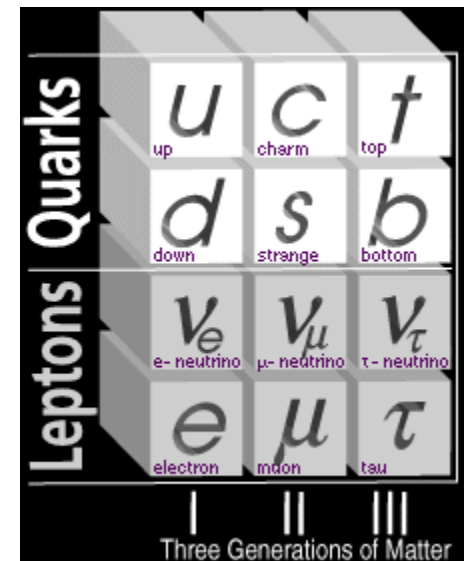
GEO-NEUTRINOS: NEUTRINOS FROM THE EARTH'S INTERIOR

Spencer Rosenfeld

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What is a neutrino?

- Neutrinos are fundamental particles with a very small mass (the actual mass is unknown).
- They only interact with the weak and gravitational forces. (i.e. colorless and no charge)
- Each charged lepton has a neutrino associated with it.

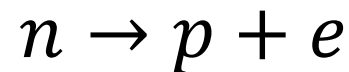


Evidence for neutrinos

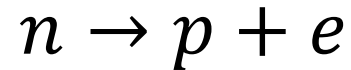
- Beta decay provides evidence for their existence.
- Beta decay is the decay of a neutron into a proton, an electron, and an anti-electron neutrino.



- Before the existence of neutrinos was known the equation looked like this:



Evidence for neutrinos



1. Energy wasn't conserved, when measured the electron always seemed to have less energy than it should have.
2. Momentum wasn't conserved. If the decay went to only two particles then they *had* to move in opposite directions, but this wasn't observed. The trajectories of the electron and proton could be at an angle.

Evidence for neutrinos

- Wolfgang Pauli predicted the existence of a small neutral particle to solve this problem.
- Later Enrico Fermi developed a theory of radioactive decay which explained the discrepancies in experimental results.
- Fermi coined the term neutrino which stands for “Little neutral one”.
- In 1968 the first neutrinos from the sun were detected.

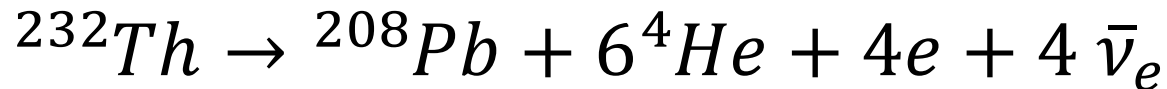
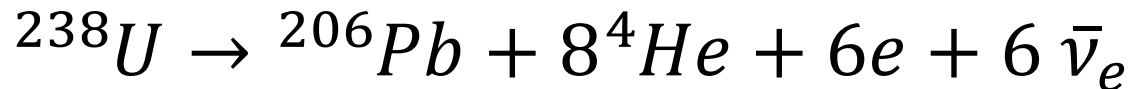
Solar Neutrinos

- Neutrinos are produced in the fusion processes of the sun.
- The primary fusion reaction in the sun is the pp-chain.
- The net reaction for this process is:
$$4p \rightarrow {}^2\text{He} + 2e^+ + 2\nu_e$$
- The positrons are necessary in this reaction to conserve charge.
- Lepton number conservation \Rightarrow regular neutrinos.
- Solar neutrinos aren't anti-neutrinos.

Geo neutrinos

- A geo neutrino is defined to be a neutrino that was created in the earth's interior.

- These are produced in radioactive decays.



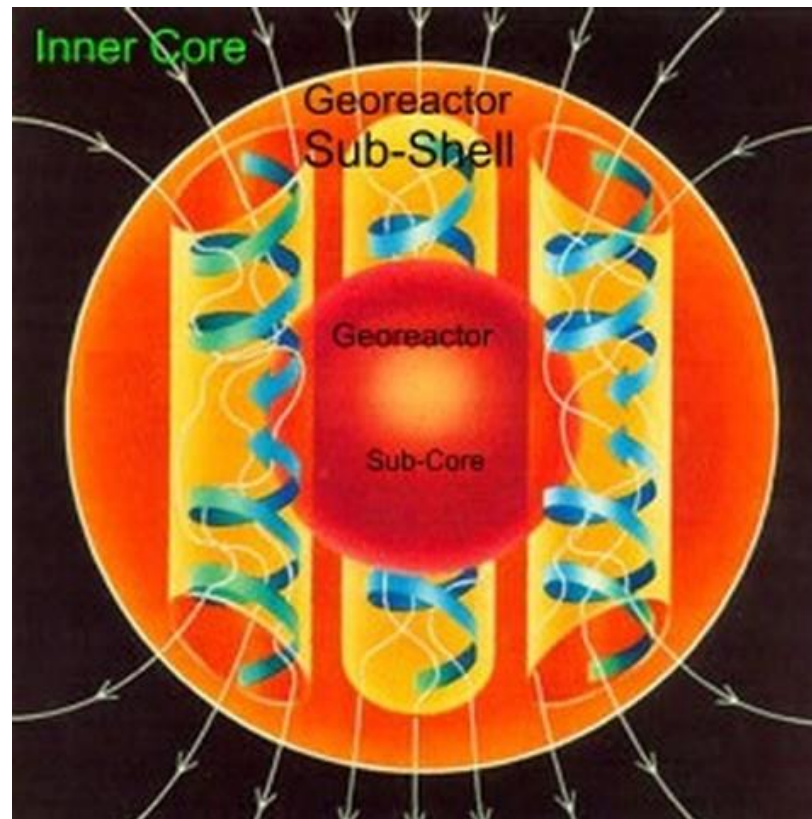
- Notice that these decays only produce anti-neutrinos. This allows us to differentiate between neutrinos produced in the earth and neutrinos produced in the sun.

Geological Importance

- The deepest direct measurements of the composition of the Earth's interior go no further than 12 km
- Considering that the earth has a radius of 6,378 km we have barely scratched the surface.
- Seismology can give us information about the density in the interior but not the composition.
- Neutrinos can give us direct information about the composition of the Earth's interior.

Nuclear Geo-reactor

- There is a geological theory that the Earth's core has a large scale fission reaction in its core.



Geo-neutrinos detected

- In March of 2010 the Borexino collaboration announced that they had detected geo neutrinos.
- Earlier another collaboration KamLAND reported that they had an excess of low energy neutrinos that were an *indication* of geo-neutrinos .
- KamLAND was unable to definitively detect geo-neutrinos because they had a too high of a background on their signal.

Geo-neutrinos detected

- Borexino was built to have as low a background as possible.
- The parts were specially made in radioactive clean rooms and the detector was built far away from artificial sources of neutrinos (nuclear reactors).
- The result is that Borexino has a background 100 times smaller than KamLAND.

Borexino

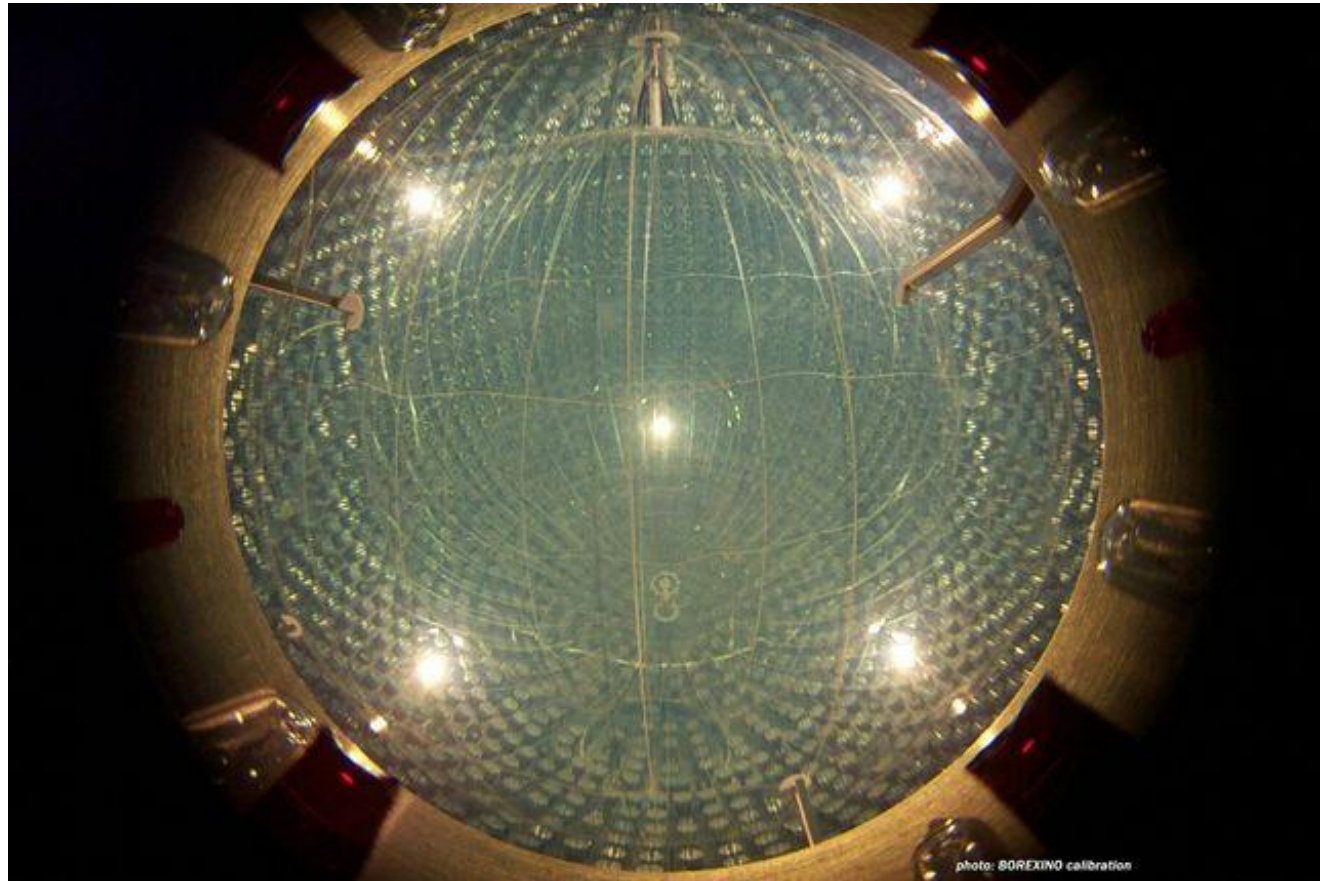
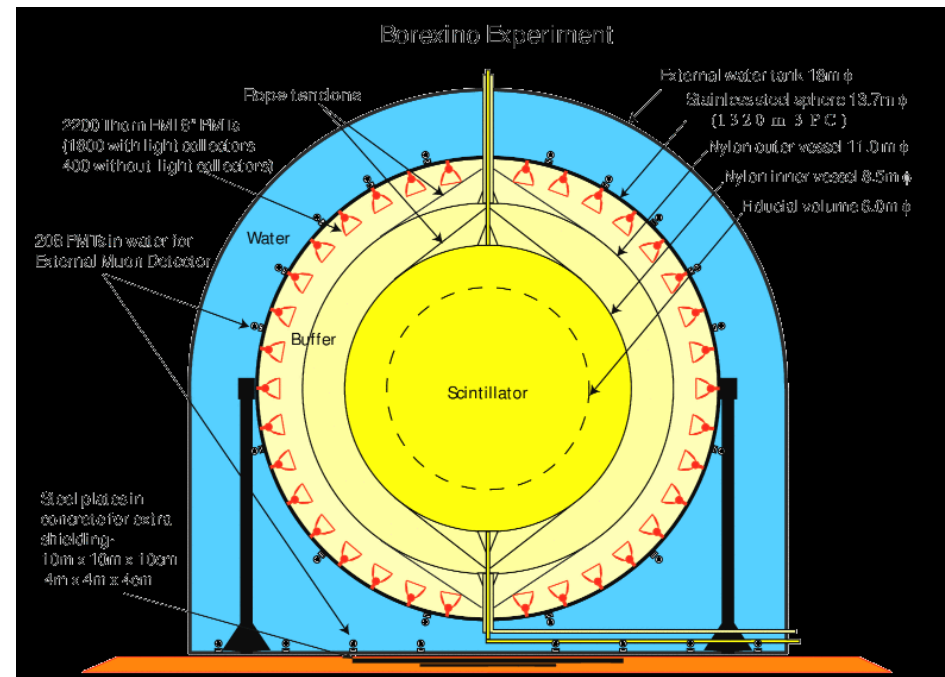


Figure-2: Borexino Detector

Neutrino Detection

- The neutrinos are detected in 300 tons of a doped hydrocarbon called pseudocumene $C_6H_3(CH_3)_3$.
- This liquid is surrounded by a stainless steel sphere with photomultiplier tubes on its interior.
- All of this is surrounded by 2400 tons of purified water which is in another steel container 18 m in diameter.

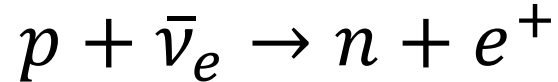


Neutrino Detection (Scintillator)

- The pseudocumene acts as a scintillator. Releasing light when the neutrinos pass through it. The neutrinos interact with the electrons in the pseudocumene through the weak force.
- Light is released in the process and then detected by the photomultipliers surrounding the scintillator.

Neutrino Detection (Inverse Beta Decay)

- Another avenue of neutrino detection is inverse beta decay.



- This can only be caused by anti-neutrinos due to the conservation of Lepton number.
- The positrons produced by this reaction quickly annihilate producing gamma rays characteristic of this reaction.

Summary and Conclusion

- Neutrinos are fundamental particles with a small mass and no charge.
- Geo neutrinos are neutrinos produced in the earth's interior by radioactive decay and fission.
- Geo neutrinos are a window into the Earth's interior allowing us to directly test theories about its composition.
- Geo neutrinos exist and have been detected by the Borexino collaboration at Gran Sasso National Lab.

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