Neutrino Nobel Prize overview

Slides provided by the University of Calgary,
Dept. of Physics and Astronomy,
Outreach Committee

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Canadian Association of Physicists
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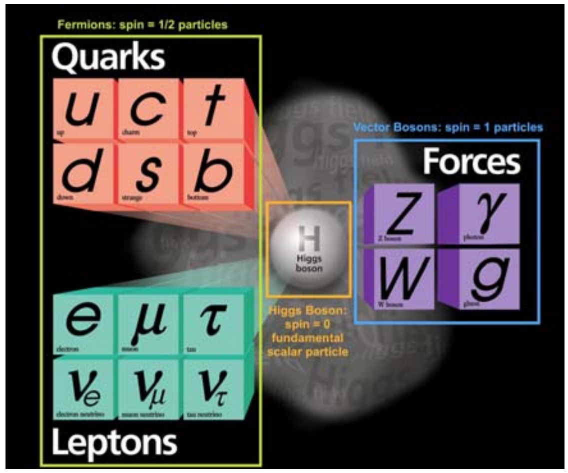
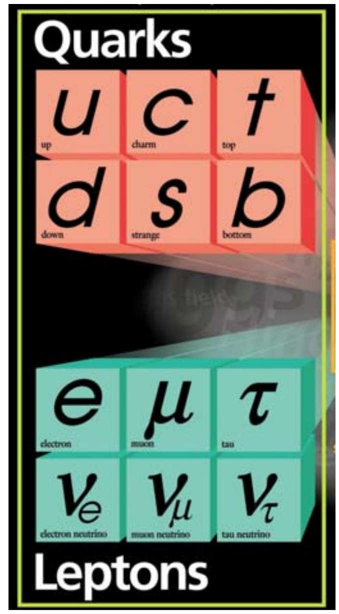
Neutrinos are fundamental particles



One of the fundamental building blocks of the universe.

Same family as electrons

- Spin ½
- Lepton
  - means light particle
- Most abundant particles with mass in the universe
- Trillions go through you every second, with no effect



Neutrinos are made in the centre of the sun, and pass through the sun without interacting at all! They are very weakly interacting.

‘neutrino’ = Little neutral one

- Beta decay
  - Observationally didn’t seem to conserve momentum or energy
- Proposed by Pauli in 1930
  - Carries momentum and energy
  - Fixed the momentum and energy problem, but couldn’t be detected!
- No electric charge
  - Pauli called it a ‘neutron’; Fermi changed the name to Italian ‘neutrino’ in 1934

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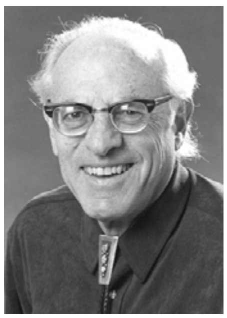
Wolfgang Pauli is on top, Enrico Fermi is on bottom. Neutrino means little neutral one in Italian.

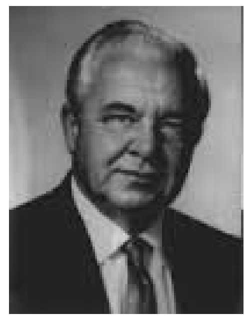
Reines and Cowan

- Finally detected neutrinos in 1953 at Hanford
- Reines won the Nobel Prize in 1995
- Cowan had died; Nobel can't be awarded posthumously.



Reines

Cowan



Reines on left, Cowan on right
Used the neutrino flux from the nuclear reactor to get enough neutrinos to detect.

Lederman, Schwartz and Steinberger

- 1988 Nobel Prize in physics for the neutrino beam method and showing that there are two different neutrinos
- This Nobel prize, related to the second (muon) neutrino, was awarded seven years before the Nobel prize for the experimental work, done decades before, that detected the first (electron) neutrino


Lederman


Schwartz

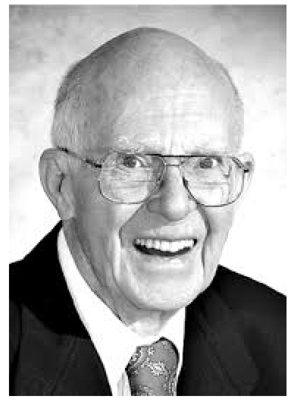

Steinberger

This neutrino goes with the muon, another fundamental particle that’s like a big electron. Lederman (left), Schwartz (centre) and Steinberger (right)

Koshiba and Davis (2002)

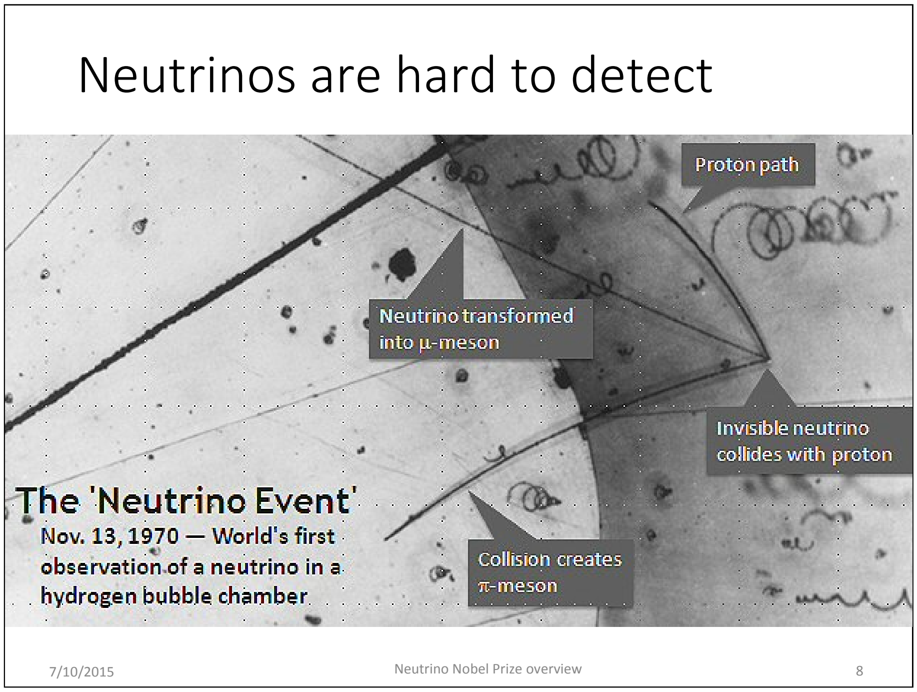
- Nobel Prize for the detection of cosmic neutrinos

Koshiba



Davis

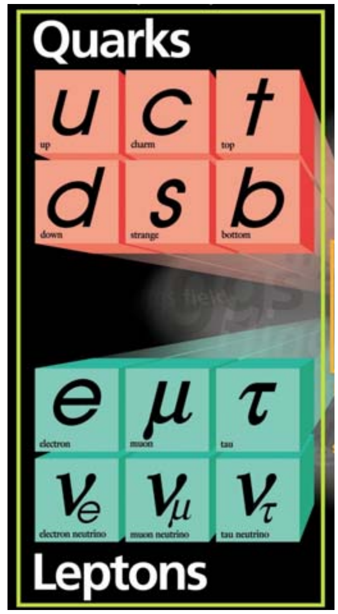
Cosmic neutrinos are useful for seeing nuclear interactions in space, it’s another window into the universe. Koshiba (left) and Davis (right)



Neutrino comes in from the bottom right corner and hits a proton in a chamber filled with hydrogen gas at the right pressure and temperature. It ran into a proton (the hydrogen) and made the proton shoot off along the proton path), the neutrino transformed into a mu-meson and created a pi meson. This was not the first observed neutrino, but the first of this type of observation.

3 flavours (types)

- Each flavour/type corresponds to another particle
  - Electron → Electron neutrino
  - Muon → Muon neutrino
  - Tau → Tau neutrino

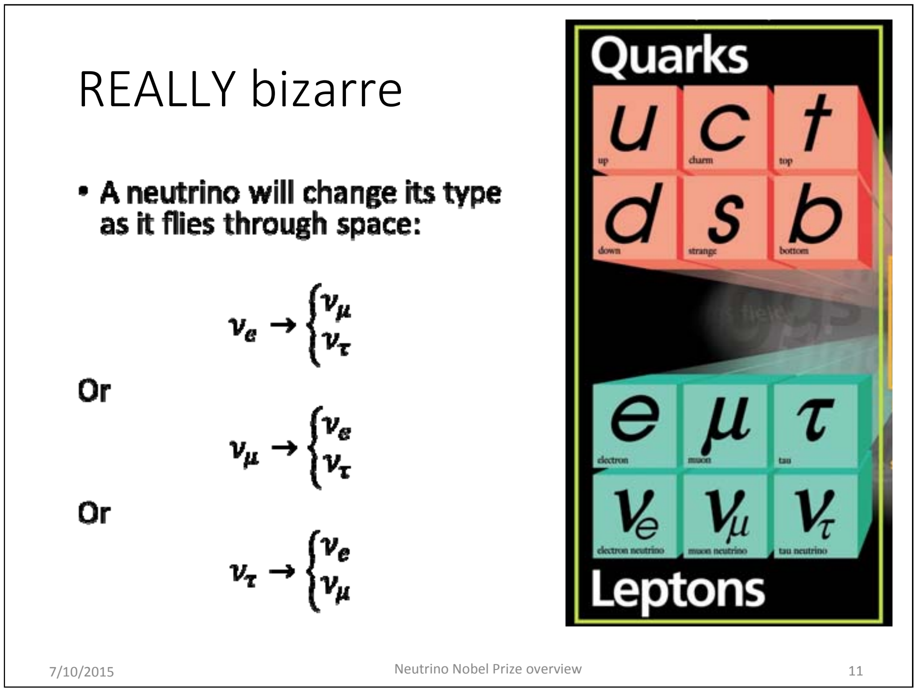


Particles come in groups, like on the periodic table.

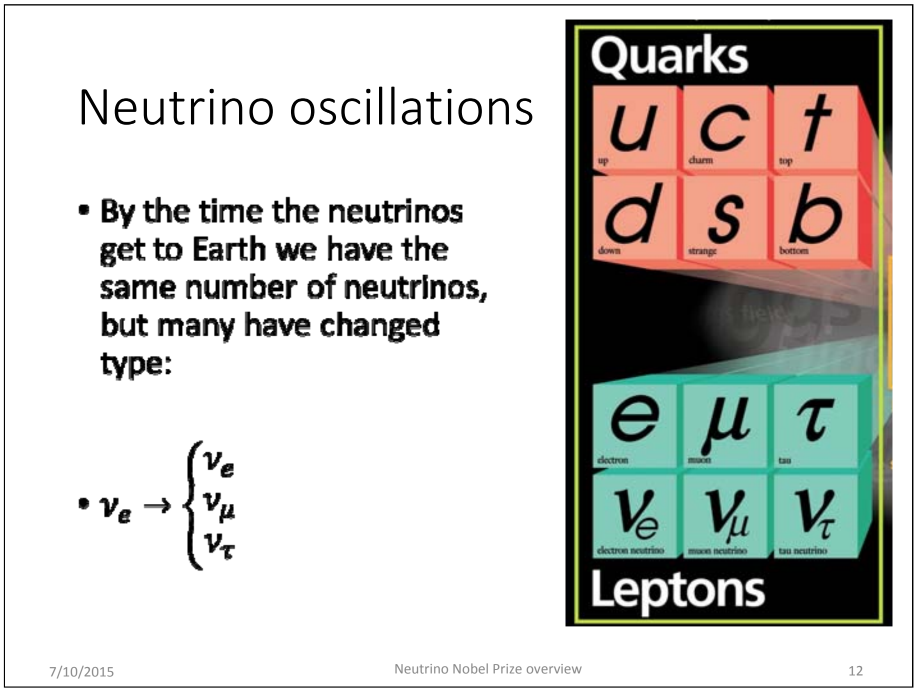
Fusion in the sun creates the solar neutrino problem

- Gives off neutrinos
- Fewer neutrinos detected than theories about the sun predict

$$4{}_{1}^{1}H \rightarrow {}_{2}^{4}He + 2{}_{1}^{0}e^{+} + 2\upsilon$$



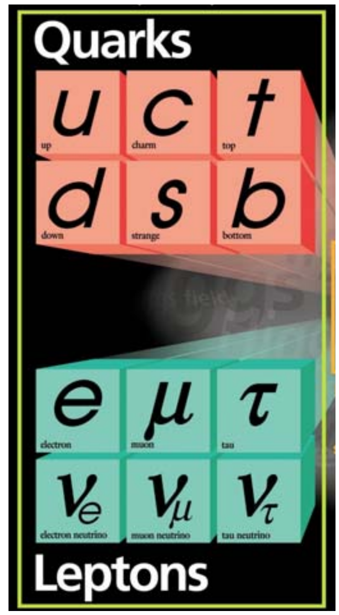
This is like an elk jumping and turning into a magpie and then into a tiger before it lands. The neutrino is the *only particle* that changes itself spontaneously back and forth among different types while far from other particles.



The number of neutrinos are conserved, but the specific types change, after the 8 minutes that it takes to get from the sun, they’re all mixed up.

Neutrino mass

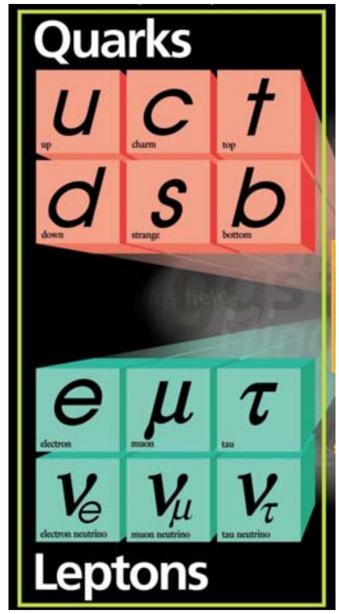
- Mass required to make the oscillations happen (proposed by Wolfenstein, Mikheyev and Smirnov)
- Can't directly measure the mass



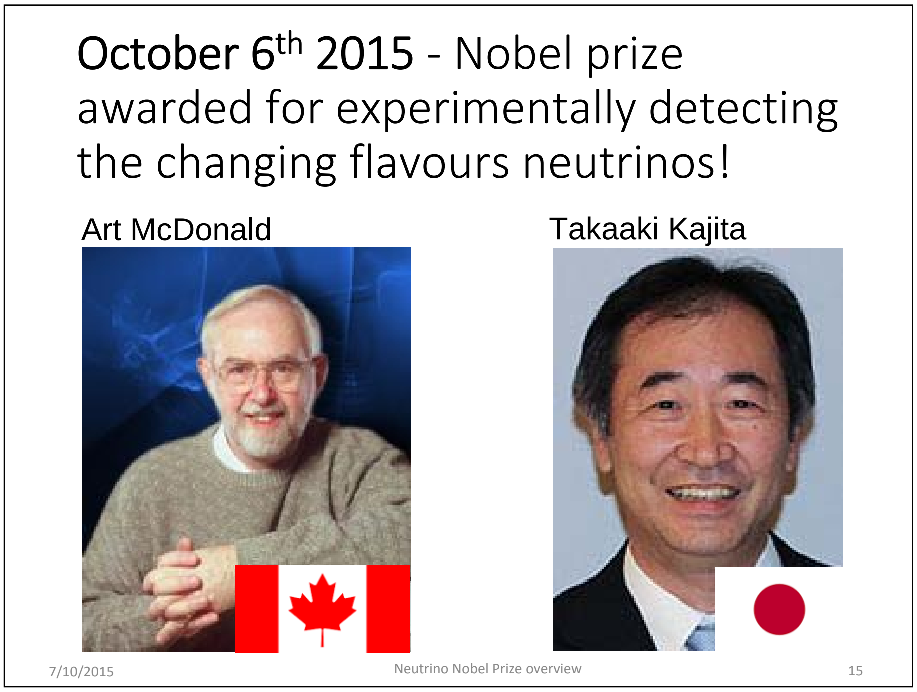
The $\nu_e \to \nu_\mu \to \nu_\tau \to \nu_e$ are called neutrino oscillations because the type of neutrino that it is oscillates back and forth. Quantum mechanics says that we need mass to make this happen.

Mass of leptons

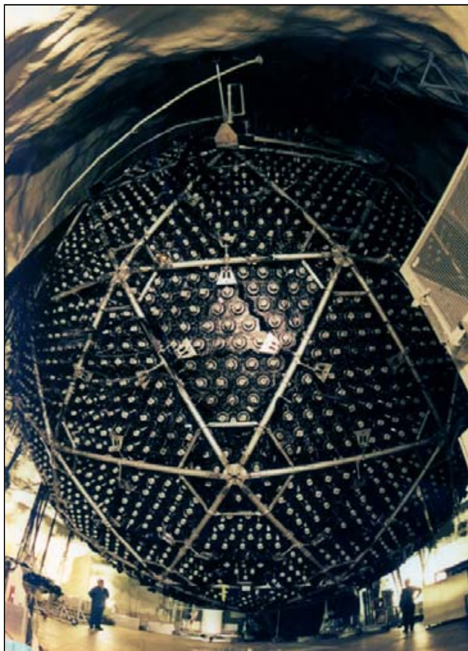
- Mass of an electron (m_{e-}) = 1800x smaller than the mass of a proton
- Muon is ~200 x m_{e-}
- Tau is ~3500 x m_{e-} (bigger than a proton)
- Neutrinos? Smaller than the electron mass, but how big? Open question!



Electrons are much lighter than muons. Tau weighs even more. The electron neutrino is known to be very much lighter than an electron, but no one knows exactly how much.



Art McDonald and Kajita have been able to experimentally show that the neutrinos change types (flavours) using brilliant research and a huge international team based in Canada and Japan. They could detect the electron neutrinos and the total of all three neutrino types (flavours).



Sudbury Neutrino Observatory (SNO)

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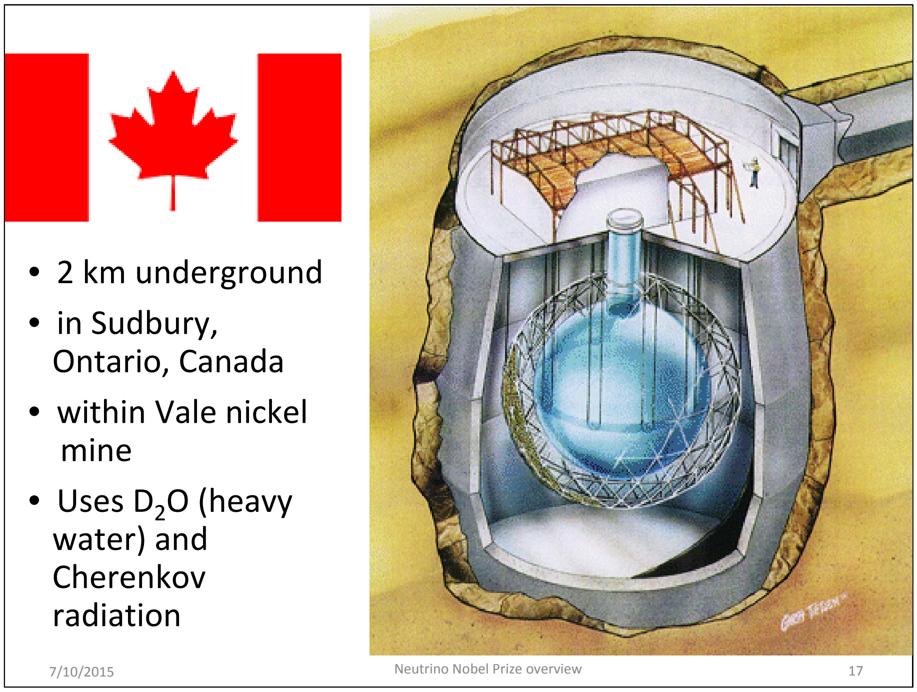
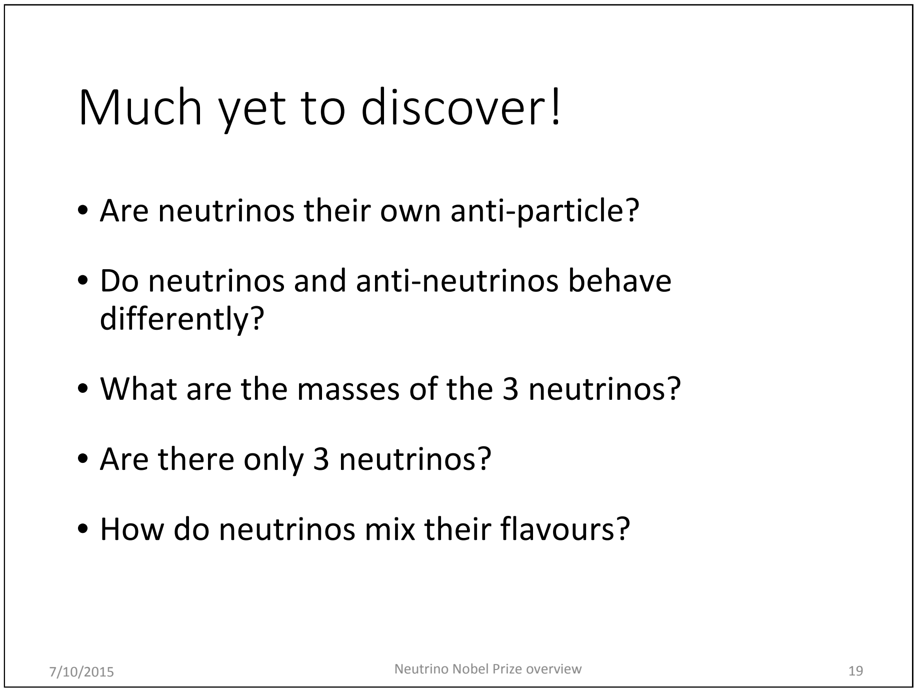
An actual picture of the SNO lab deep underground.



Heavy water (D_2O) is one of the ways of detecting neutrinos. The neutrinos cause nuclear processes to happen that can be detected. It needs to be deep underground to shield the detector from cosmic rays.

D_2O made by Atomic Energy of Canada Limited (now CANDU Inc. and Canada Nuclear Labs)

The Canadian nuclear power industry lent the needed D_2O to SNO labs.



Science is a constant evolving process, there are more Nobel prize level questions left to be answered by Canadians engaged in fundamental science research!

Some resources on neutrinos

- Overview:
  - http://www.nu.to.infn.it/
  - http://www.nobelprize.org/nobel_prizes/physics/laureates/2015/
  - http://hyperphysics.phy-astr.gsu.edu/hbase/particles/neutrino.html#c1

- The solar neutrino problem:
  - http://www.sns.ias.edu/~jnb/

- SNO:
  - https://www.snolab.ca/
  - http://hyperphysics.phy-astr.gsu.edu/hbase/particles/sno.html

- Super-Kamiokande:
  - http://www.ps.uci.edu/~superk/sk-info.html
  - http://www-sk.icrr.u-tokyo.ac.jp/sk/index-e.html

- IceCube (south pole observatory):
  - https://icecube.wisc.edu/info/neutrinos