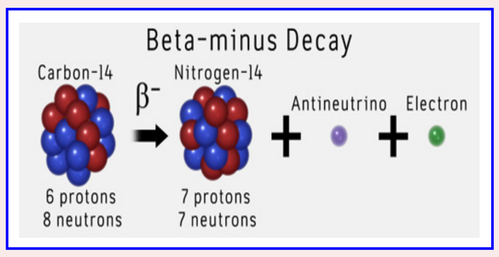
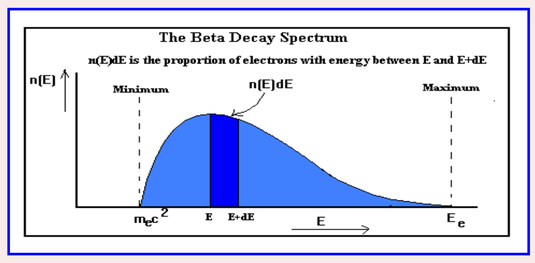
Neutrinos: A New Window to Our Universe

Sabya Sachi Chatterjee
sabya@iopb.res.in
(Research scholar at IOP)

Most abundant elementary particle in Nature

- Neutrinos are everywhere
- A key particle to understand our Universe





Niels Bohr

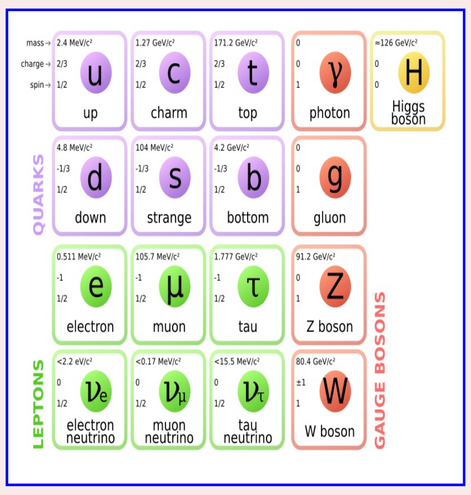
Niels Bohr: Energy is not conserved in Quantum domain.

The neutrino (name coined by Fermi) was postulated first by Wolfgang Pauli in 1930 to explain how beta decay could conserve energy, momentum, and angular momentum (spin).

Wolfgang Pauli

Basic Properties of Neutrinos

Charge	0
Mass	≈ 0
Spin	1/2 - Fermion
Types	(3: ν_e, ν_μ & ν_τ)
Family	Lepton
Interaction	Weak



Different sources of Neutrinos

Nuclear Reactors

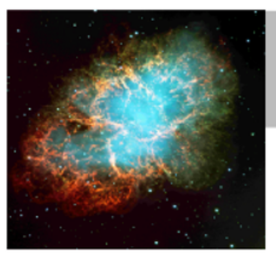
Detected (1956)
Cowan, Reines
Nobel Prize in 1995

Sun

Detected (1968)
Davis, Bahcall
Nobel Prize in 2002

Particle Accelerators

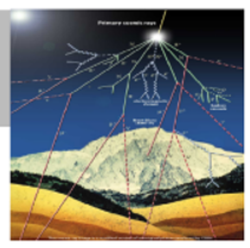
Detected (1962)
Brookhaven National Lab, Nobel Prize 1988



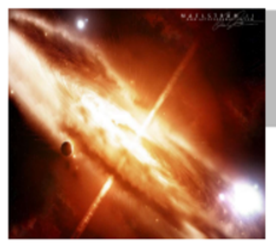
Supernovae (Stellar Collapse)

Detected in 1987 SA

Earth Atmosphere (Cosmic Rays)



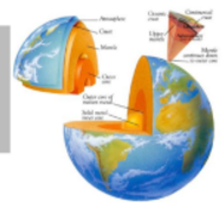
Detected (1965)
KGF in India



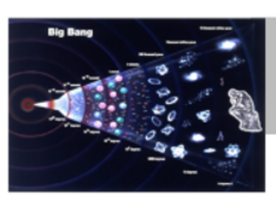
Astrophysical Accelerators

Recently IceCube detected 28 HE events

Earth Crust Natural Radioactivity



Detected (2000)



Cosmic Bigbang

Nuclear reactions in Sun and other massive Stars: a big source of extraterrestrial neutrinos

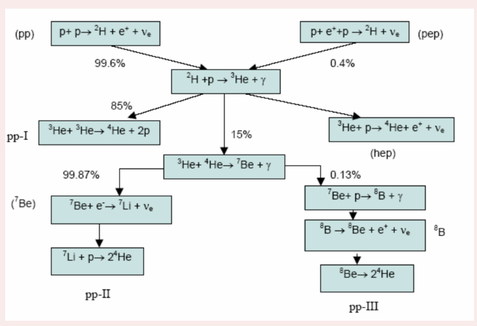


Fig1. pp-chain reactions in Sun

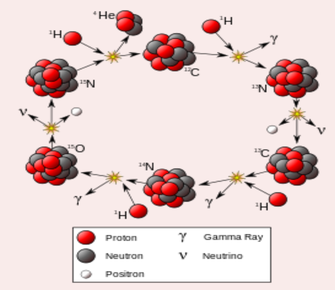


Fig2. CNO cycle in massive Stars like Neutron Star, White dwarf.

Neutrino fluxes

- Each second, 100 billion Solar neutrinos passing through the tip of our finger !
- Very weakly interacting particle; we do not see or feel them.

Mass of neutrino, $m_\nu \approx 0.00001 \times$ mass of electron .

Detection of neutrinos

Neutrinos are chargeless, difficult to detect.

⋆ In 1942 Wang Ganchang first proposed the use of beta-capture to experimentally detect neutrinos. In 1956, the first experiment which confirmed the detection of neutrino via the inverse beta decay ($\bar{\nu}_\mathbf{e} + \mathbf{p} \rightarrow \mathbf{n} + \mathbf{e}^+$) is known as Cowan–Reines neutrino experiment.

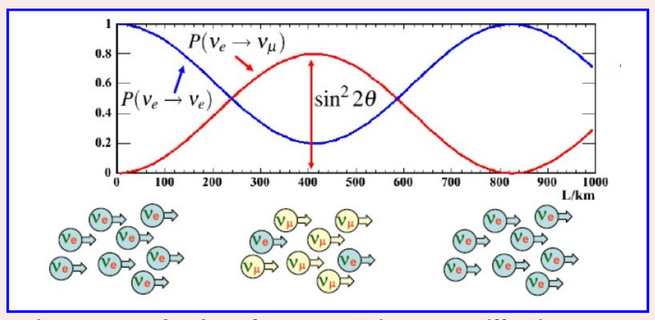
Clyde Cowan conducting the neutrino experiment c. 1956.

This result was rewarded with the 1995 Nobel Prize to Frederick Reines.

Neutrino Oscillation

- In the late 1960s, Ray Davis's and John N. Bahcall's Homestake Experiment was the first to measure the flux of neutrinos from the Sun and detected a deficit. This is known as "Solar neutrino puzzle".
- In 1968, Pontecorvo proposed that if neutrinos have mass, they can change their flavour while propagating from one place to another.

Two flavour neutrino Oscillation:



⋆ The most convincing proof of solar neutrino oscillation came in 2001 from Sudbury Neutrino Observatory (SNO) in Canada. The total number of events agreed quite well with the theoretical model. This led to the solution of long existing solar neutrino puzzle.

Raymond Davis Jr. and Masatoshi Koshiba

In 2002, Ray Davis and Masatoshi Koshiba won part of the Nobel Prize in Physics for pioneering work that found the number of solar neutrinos was around one third of the number predicted by the standard solar model.

Presented in DAE-IOP Science outreach program on 1st Feb, 2015 at IOPB.