Hunting for Neutrinos in Antarctica by **Prof Ryan Nichol**, on 26th November 2021

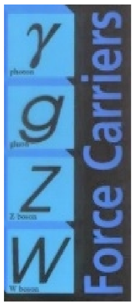
Prof Nichol, of UCL, introduced his talk with a graph with an origin at "1 metre" and going in steps of 10^3 down to 10^{-18} m (the size of quarks) and up to 10^{30} m (the size of the known universe). Atoms are at 10^{-15} m, humans at 1 m, the Sun is 10^{12} m away.

The Family of Particles

Quark 'u' is an up-quark, 'd' a down-quark;

Leptons 'ν_e' is an elecron neutrino, 'e' is an electron.

These four make up the atoms and molecules of ordinary matter.



'γ' is a Photon
'g' is a Gluon
'Z' and 'W' (all four are Bosons)

The four Forces are 'Strong' which hold atoms together; 'Gravity', 'Electromagnetic, and 'Weak'. The Weak force is responsible for decay processes and can turn a neutron into a proton, or a proton into a neutron, and enables the fusion processes keeping the Sun shining. It was believed that a Neutron, n, could undergo β-decay into a Proton, p, plus an Electron, e. In 1930 Pauli first proposed, later to be vindicated, that an extra particle must be produced: the Electron Neutrino, ν_e .

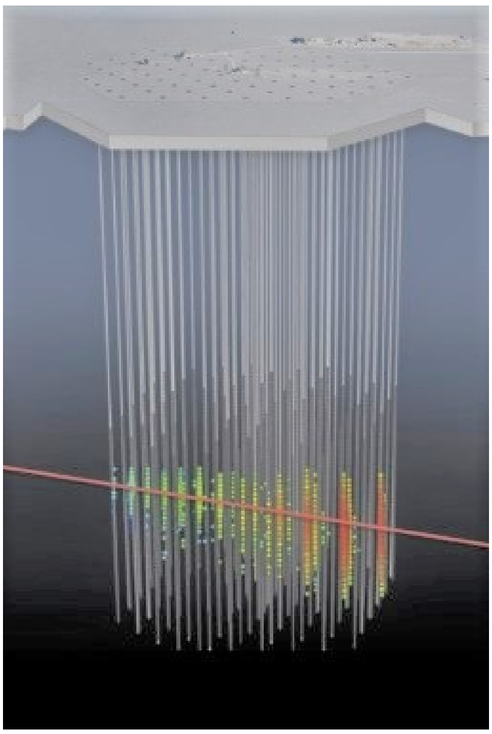
$n^0 \rightarrow p^+ + e^- + \nu^0_e$ their charge shown by ^{0}, $^+$ and $^-$.

Cosmic Rays were first detected in 1912 by Victor Hess. Using a balloon at up to 5km altitude, he showed that radioactivity increased with altitude rather than decreasing as expected. Radar equipment, being developed at Bawdsey Manor in the late 1930s, was also receptive to cosmic rays, leading to a paper by Blackett and a young Bernard Lovel (who did more work on them at Jodrell Bank before going on to other things). Cosmic Rays comprise high energy particles including neutrinos and gamma rays.

An application of cosmic ray measurements is to look for voids in large solids (eg a Pyramid) as there would be less absorption in the void.

Neutrinos, with no charge and little or no mass, only interact via the weak force. This is a rare event - neutrinos normally passing through what we regard as solid matter without any impediment. Most reaching Earth come from the Sun, but the entire universe contributes. There is a 25% chance you will stop one of them in your lifetime.

Prof Nichol said that to detect them you need: A lot of neutrinos: A huge detector.



Antarctica - here there is lots of Ice, some of it 4km thick. It is the coldest, driest, windiest place on Earth, but the only continent exclusively dedicated to scientific research with no indigenous (human) population.

A 1km cube of ice, 1.45km down, was chosen to act as the **IceCube** Neutrino Observatory. Between 2005 and 2010 hot water drills were used to made 86 holes into it from the surface.

In a high energy neutrino event an emitted particle can travel at a speed greater than the speed of light in ice, causing a flash of light (Cherenkov radiation), detectable with a photomultiplier tube. Each of the holes is equipped with a string of 60 Digital Optical Modules, each of these with a photomultiplier tube and a single-board computer to send data to a counter on the surface above the array.

The **ANITA** experiment uses a balloon with a detector launched into the naturally occurring antarctic circular wind system at altitude of 37km (120,000 ft). Here its horizon is

700km, with over 1 million km^2 of ice visible. It had 32-48 dual polarisation antennas, and differential GPS for positioning and orientation. As well as signals from the ice it could also receive ultra-high energy cosmic radiation directly or reflected from the ice surface – filters were fitted to select the wanted signals.

The first flight, in 2006, was centred to one side of the optimum position, and was terminated after 35 days having completed 3½ orbits, and recorded 8 million triggers.

Following design upgrades, ANITA II followed in 2008, ANITA III in 2008, and ANITA IV in 2014. The longest flight lasted 42 days. On the ANITA III flight an unexpected cosmic-ray-like event was seen, travelling upwards.

Each ANITA had solar panels to provide power and keep batteries charged. This, and almost continual solar heating (in the Antarctic summer) meant that it had to be kept cool – everything was painted white to reflect the sunshine – except the battery boxes which had half black/half white (artwork) treatments. ANITA was built as a lightweight openwork lattice structure, with enough strength to, more or less, survive a rough landing, with its scientific equipment intact.

There were several advantages to the use of a balloon. It provided a sufficiently stability at a convenient height; it gave continuous coverage while in orbit; and it was relatively cheap.

PUEO (Payload for Ultrahigh Energy Observations), a new balloon borne orbiter with improved electronics, allows work to continue with greater accuracy. It now has electronic filters which greatly improve the selectivity of the observations.

Prof Nichol closed by saying Neutrinos are interesting – but we still know almost nothing about them.