SYNOPSIS

During my doctorate work, I have studied various aspects of neutrinos at extremely high energies ($> 10$ TeV), specifically with a view to unravelling possible hints of non-standard physics that might be embedded in such events. Neutrinos at energies greater than 10 TeV are produced in the extremely energetic cores and jets of astrophysical sources located either within our galaxy (e.g. pulsars, supernovae, etc.) or outside our galaxy (e.g. active galactic nuclei (AGN), gamma ray bursts (GRB), etc.). Thereafter, being extremely inert, they stream to the earth almost unperturbed, with only oscillation among the three flavours modifying their fluxes. Because the fluxes of the neutrinos produced at these energies are extremely low, detecting them at the earth requires detectors with very large volumes ($\sim$ Km$^3$). The IceCube (IC), built at the South Pole into the Antarctic ice bed, is a 1 Km$^3$ detector designed to detect and study such high energy neutrinos. My work has involved analysing the neutrino events that might be seen at IC, in the future, to understand a) the nature of the source producing these neutrinos, b) the nature of mixing among the three flavours as the neutrinos oscillate while propagating from the source to the earth, specifically looking at whether it is in keeping with standard physics or affected by small non-standard physical effects such as neutrino decay, violation of Lorentz invariance, etc., and c) novel signatures of the highest energy standard model process hitherto unseen, viz. the Glashow Resonance (GR),

$$\bar{\nu}_e + e^- \rightarrow W^-,$$

occurring when a $\bar{\nu}_e$ with energy of 6.3 PeV (in the lab frame) interacts with an electron within the IceCube resulting in the production of $W^-$ at resonance, which then decays promptly into hadrons and, to about one-sixth of the time, into leptons.

IceCube is capable of distinguishing between the three flavours of neutrinos, as they interact with the nuclei within the detector, by means of their event topologies: a) showers due to charged current interactions of the $\nu_e$ and, for incident energies less than a PeV, $\nu_\tau$, and, neutral current interactions of all the three flavours, b) muon-track events due to the charged current interactions of $\nu_\mu$, and finally c) signature topologies of the $\nu_\tau$ at energies above a PeV, such as the double bang, lollipop, etc. In my work with my supervisor and
other collaborators, we have shown that, as IceCube collects a significant number of events over the next five years, it will be possible, by comparing the fluxes of three flavours, to detect signatures of non-standard physics, if any, on the neutrino oscillation probabilities at these energies. By considering each of neutrino decay, Lorentz violation, existence of additional pseudo-Dirac neutrinos and quantum decoherence in turn, we have predicted the expected parameter space in each case that such high energy events will be sensitive to, and should therefore be able to rule out if the events are consistent with expectation from standard physics.

Finally, we have also discussed the possibility of seeing the GR in the IceCube. Specifically we have calculated the expected number of shower events around the GR energies, *i.e.* $\sim 6.3$ PeV as a function of the source spectrum and discuss the rare but tell-tale and completely background-free events seen when the resonantly produced W decays to leptons, rather than to hadrons. We have also shown how non-standard physical effects might modify the number of events otherwise expected around the GR energies.