論文の内容の要旨

Development of Neutron-Tagging Techniques and Application to Atmospheric Neutrino Oscillation Analysis in Super-Kamiokande
(スーパーカミオカンデにおける中性子検出手法の開発と大気ニュートリノ振動解析への適用)

アーヴィントリスタンジェームズ

Neutrino oscillation theory is now well established. The neutrino mixing angles and mass-squared splittings have been precisely measured, by a variety of experiments. However our understanding of this field is still not complete - the neutrino mass hierarchy and CP violating phase continue to elude us.

Sensitivity to neutrino mass hierarchy in the water Cherenkov detector Super-Kamiokande is dependent on its ability to distinguish anti-neutrino and neutrino interactions. This is inherently a difficult task in water Cherenkov detectors, but one possible method is through the detection of neutrons. In a typical charged-current anti-neutrino interaction, $\bar{\nu}_e + p \rightarrow n + e^+$, a neutron is ejected, however this is not true of the corresponding neutrino interaction. In water, these neutrons then thermalize and are captured by hydrogen. A 2.2 MeV γ-ray is emitted, which can be used to tag the neutrons, and thus infer that the preceding interaction was that of an anti-neutrino.

This thesis describes the development of neutron tagging methods and application to the Super-Kamiokande atmospheric neutrino sample. This information is then used to help distinguish between neutrino and anti-neutrino interactions, thus increasing our sensitivity to the neutrino mass hierarchy. A neutron-tagging efficiency of 20.5% is achieved, with a background of 1.8% per atmospheric neutrino event. Enriched neutrino and anti-neutrino samples are constructed, improving the sensitivity of the detector to neutrino mass hierarchy by $\Delta\chi^2 = 0.06$. Three-flavour neutrino oscillation analysis is performed using all data from SK-I to IV (4581.5 days). The normal hierarchy is favoured, with a significance of $\Delta\chi^2(\text{NH-IH}) = -0.9$.