Search for High-Energy Neutrinos
Associated with Long Gamma Ray Bursts using the IceCube Detector

Lionel Brayeur

A century ago, it was discovered that charged particles coming from space were interacting in our atmosphere. These particles were called cosmic rays and since then scientists have tried to identify the sources of these cosmic rays. At the highest energies, the sources of the so-called Ultra High Energy Cosmic Rays (UHECRs) are believed to be located outside our Galaxy.

Since the most powerful objects known are Gamma Ray Bursts (GRBs) in which the energy of a supernova is released in just a few seconds, they represent an interesting candidate as sources of the UHECRs. Such an association implies the presence of protons inside the GRBs. This is compatible with the hypothesis that these cataclysmic events would result from the collapse of massive stars.

Following this scenario, the accelerated protons should interact with the ambient energetic photons (light) to produce, among other paticles, high-energy neutrinos. Since neutrinos are electrically neutral and interact only very weakly, they directly point back to their source and can reach the Earth unhindered. This is the reason why the century-long search for the sources of cosmic rays could be answered by using neutrino detectors like IceCube, a cubic kilometer neutrino detector located at the South Pole.

The analysis developed in the current thesis focuses on the detection of muon neutrinos associated with long duration GRBs (longer than 2 s). After the development of a new event selection, a study of statistical methods was performed in order to define the most suitable method to search for neutrinos from long GRBs. The newly designed statistical method allowed to improve the sensitivity of the analysis with respect to previous analyses while extending the search time around the GRB to one hour.

Unfortunately, no significant signal events in correlation with GRBs have been observed. This allowed to set upper-limits on the neutrino flux from GRBs. These limits rule out the neutron escape model (Ahlers et al.) and constrain the proton escape model (Waxman-Bahcall) as well as the so-called H-star precursor model (Razzaque et al.) of neutrino production in GRBs. Furthermore, constraints on the neutrino emission prior to the observed γ-rays as a function of time have been set for the first time.