Measurement of the mass hierarchy.

The recent evidence for neutrino mass and oscillations constitutes the first proof of physics beyond the Standard Model (SM) of particle physics. However, its nature remains, at present, completely unknown, with very many possibilities and open questions. The quest for this new physics is closely linked to an unknown in the neutrino sector that is the hierarchy of neutrino masses. Neutrino masses can either follow the standard ($m_3>m_1$) or inverted hiearchy ($m_1>m_3$). The knowledge of the mass hierarchy has a great impact on the development of new theoretical models, as it is able to discriminates between classes of models and consequently the focus of our search for new physics beyond the Standard Model.

T2K, a long baseline neutrino experiment in Japan, has the potential to address the mass hierarchy problem in the coming years. After Summer 2013 T2K will have an increased beam power, and aim to run with both muon neutrino and anti-neutrino beams. The work to be performed in the thesis involves both the analysis of muon into electron neutrinos with a neutrino beam, muon into electron anti-neutrinos with an anti-neutrino beam, and the fit of the observed results to extract the mass hierarchy.

In conclusion, this thesis will provide the first results on one of the main unknowns of particle physics, that is the neutrino mass hierarchy.

Measurement of neutrino cross sections at the near detector ND280

The measurement of (anti)neutrino cross sections is essential to understand the interaction of neutrinos with the nucleus, and is especially vital in order to understand the signal and background channels in the measurement of the mass hierarchy and *CP* violation. We can make this measurement at T2K itself, a long baseline neutrino experiment in Japan, by exploiting its near detector, ND280. It is a multi-purpose detector suitable for both its primary aim that is the characterization of the neutrino beam before oscillation, but also the (anti)neutrino cross section measurements due to its high segmentation. In order to measure the mass hierarchy and *CP* violation, T2K will also run with an anti-neutrino beam. The anti-neutrino cross section is even less less known than the neutrino cross-section. This project will concentrate in both measuring the neutrino CC1π cross-section in particular aiming to understand the discrepancy in the current results from the different experiments, like MiniBooNE and NOMAD and also performing the first measurement of the muon anti-neutrino CC1π cross section at energies below 1 GeV, with the first data from the anti-neutrino running. These mesurements will be crucial for both T2K and future long baselines oscillation measurements.

In conclusion, this thesis aims to solve the puzzle of the neutrino cross section values, and to make a first measurement of the low energy anti-neutrino cross section. These measurements are all vital for neutrino mass-hierarchy and oscillation measurements.

Study of Sterile Neutrinos

The possible existence of one or more sterile neutrinos that do not couple to the electroweak current, but do mix with the active flavors has been discussed extensively in the literature. The existence of sterile neutrinos would provide new degrees of freedom that could help clarify certain outstanding theoretical problems, e.g. the neutrino mass spectrum. The coupling between sterile neutrinos and the active neutrinos would likely involve the existence of another mass eigenstate. Experimental observations show that the total flux of active neutrinos from the Sun agrees with expectations from solar models, thereby limiting the potential coupling of the first or second neutrino-mass eigenstates to a sterile neutrino. Additionally, the dominant mixing for muon neutrinos, that we use in a long baseline neutrino experiment like T2K, is into tau neutrinos. However, the current experimental results do not exclude a subdominant admixure with sterile neutrinos. The thesis will involve the measurement of the muon neutrino mixing at T2K, in particular analysing neutral current events at Super-Kamiokande, that is events with a π^0 in the final state, and the interpretation of the results in the context of several sterile neutrino theoretical models.

In conclusion, this thesis aims to address the sterile neutrino measurement, either discovering or setting the best workdwide limits on the sterile neutrino model parameters.

The other available projects will be added ASAP.

Last update, Francesca Di Lodovico Jan 4th 2013.