Toward a complete understanding of neutrino-nucleus interactions with the T2K near detectors

PhD 2019-2022

PHENIICS doctoral school – Université Paris-Saclay

LLR-Ecole Polytechnique Neutrino team:

M. Buizza Avanzini (Staff - PhD proponent)
A. Coffani (PhD student)
S. Dolan (post doc)
O. Drapier (Staff)
S. El Hedri (post doc)
M. Gonin (Staff - team leader)
Q. Huang (PhD student)
T. Mueller (Staff)
P. Paganini (Staff)
O. Volcy (PhD student)

The correct description of neutrino-nucleus interactions is a key point for the precise measurement of neutrino (ν) oscillations at long baseline (LB) experiments, such as T2K and NOVA.
T2K is a LB neutrino oscillation experiment located in Japan. Its main goal is the precise measurement of the (muon) electron neutrino and antineutrino (dis-)appearance. T2K is measuring the ν oscillation parameters with increasing precision and is providing first indications about neutrino Mass Hierarchy (MH) and CP violation phase (δ_{CP}) in the ν sector. The excellent results reported by T2K have motivated a second phase of the experiment, T2K-II, that will start in 2021 for 5 years and aims at establishing δ_{CP} violation at 3σ level.

The Charged Current Quasi Elastic (CCQE) ν interaction is the dominant interaction at the T2K flux energy (~600MeV), thus it is the main signal exploited in T2K for oscillation measurement. At higher energies, neutrino can interact *via* Charged Current interaction with resonant production (CCRES) or Charged Current Deep Inelastic Scattering (CCDIS). CCRES and CCDIS are particularly important for both the present NOvA and, in particular, the future DUNE experiments, where the neutrino energy spectrum reaches 5 GeV.
Precise knowledge of neutrino interactions is a critical input for the study of neutrino oscillation, not only in T2K but also in future experiments (DUNE, Hyper-Kamiokande) aiming at precise determination of MH and δ_{CP}. Correct modelling of neutrino-nucleus interaction is needed to avoid biases on the measurement of the oscillation parameters and to correctly estimate their uncertainties.
Moreover, the study of the ν-nucleus interaction is an interesting topic by itself. Indeed, in the last few years, the discrepancy between recent experimental results and theoretical predictions, in particular in CCQE-like channel, has revolutionized our approach to neutrino interaction, triggering rich theoretical studies and motivating the design and setup of new dedicated experiments for neutrino cross section measurements.

The T2K collaboration is presently playing a leading role also in this field. Indeed, the three T2K near detectors (INGRID, ND280, and WAGASCI), located at different off axis with respect to the beam direction, offer a unique opportunity to study interactions of neutrinos from the same beam but with different spectra and thus providing to the community a very large set of experimental data and measurements (~ 15 publications until now).

THE TEAMS

The LLR group is strongly involved in T2K and its upgrade (T2K-II) as well as in the Super-Kamiokande experiment. In particular, people working on T2K and T2K-II are: M. Buizza

Avanzini, S. Dolan, O. Drapier, M. Gonin, T. Mueller and O. Volcy.
In the context of the proposed thesis, two members of the LLR group are currently leading the T2K cross section working groups. The group is also involved in the development of the readout electronics for the upgrade of ND280. These aspects will guarantee full support and guidance to the PhD student.

In addition, the LLR group works in a strong collaboration with Japanese groups (University of Tokyo, IPMU (WPI), University of Tokyo). Depending on the candidate profile and interest, the student could spend a significant fraction of his time at the Tokyo University, profiting of the exciting and stimulating environments of both French and Japanese Institutions.

THESIS PROJECT

The ambitious project we are proposing aims at simultaneously measure the cross sections of neutrino for CCQE-like interactions on Oxygen and Carbon by exploiting data from the three T2K near detectors. The combined measurement from the different detectors, that properly takes into account the flux correlation, will allow to reduce the systematic error related to the flux, currently one of the most important. While a particular care will be dedicated to appropriate treatment of detector related systematics, the proposed analysis represents the first step towards a nuPRISM approach [arXiv:1412.3086].
LLR members will guide the PhD candidate towards the novel cross-section extraction methods. Developed in the T2K collaboration with a strong participation from LLR members, these techniques aim at minimising the bias from the input simulations and thereby maximising the usefulness and longevity of the result to the community.
The proposed measurement will represent the final and comprehensive study of CCQE interactions at T2K near detectors, thus ensuring a major visibility to the PhD candidate. She/He will be encouraged to present the results in international relevant conferences, so as to offer her/him the rare opportunity to work side-by-side with experimentalists and theoreticians, in an international community that is growing up around this major topic of neutrino physics.

Depending on the advancement of the analysis, the PhD student could also participate in the development of the reconstruction algorithms for the ND280 upgrade, thus preparing the new exciting era of T2K-II cross section measurements.

Contacts

Margherita Buizza Avanzini: buizza@in2p3.fr
http://llr.in2p3.fr/-physique-des-neutrinos-